Consortium for Small-Scale Modelling

A Description of the
Nonhydrostatic Regional COSMO-Model

Part VII :
User's Guide

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COSMO V5.4 **February 2016**

DWD MeteoSwiss www.cosmo-model.org UGM HNMS

ARPA–SIM IMGW AGeoBw

www.cosmo-model.org

Printed at Deutscher Wetterdienst, P.O. Box 100465, 63004 Offenbach, Germany

Contents

Section 1

Overview on the Model System

1.1 General Remarks

The *COSMO-Model* is a nonhydrostatic limited-area atmospheric prediction model. It has been designed for both operational numerical weather prediction (NWP) and various scientific applications on the meso-β and meso-γ scale. The COSMO-Model is based on the primitive thermo-hydrodynamical equations describing compressible flow in a moist atmosphere. The model equations are formulated in rotated geographical coordinates and a generalized terrain following height coordinate. A variety of physical processes are taken into account by parameterization schemes.

Besides the forecast model itself, a number of additional components such as data assimilation, interpolation of boundary conditions from a driving host model, and postprocessing utilities are required to run the model in NWP-mode, climate mode or for case studies. The purpose of the *Description of the Nonhydrostatic Regional COSMO-Model* is to provide a comprehensive documentation of all components of the system and to inform the user about code access and how to install, compile, configure and run the model.

The basic version of the COSMO-Model (formerly known as *Lokal Modell (LM)*) has been developed at the *Deutscher Wetterdienst* (DWD). The COSMO-Model and the triangular mesh global gridpoint model GME form – together with the corresponding data assimilation schemes – the NWP-system at DWD, which is run operationally since end of 1999. The subsequent developments related to the model have been organized within COSMO, the *Consortium for Small-Scale Modeling*. COSMO aims at the improvement, maintenance and operational application of a non-hydrostatic limited-area modeling system, which is now consequently called the COSMO-Model. The meteorological services participating to COSMO at present are listed in Table 1.1.

For more information about COSMO, we refer to the web-site at `www.cosmo-model.org`.

The COSMO-Model is available free of charge for scientific and educational purposes, especially for cooperational projects with COSMO members. However, all users are required to sign an agreement with a COSMO national meteorological service and to respect certain conditions and restrictions on code usage. For questions concerning the request and the agreement, please contact the chairman of the COSMO Steering Committee. In the case of a planned operational or commercial use of the COSMO-Model package, special regulations

Table 1.1: COSMO: Participating Meteorological Services

DWD	Deutscher Wetterdienst, Offenbach, Germany
MeteoSwiss	Meteo-Schweiz, Zürich, Switzerland
USAM	Ufficio Generale Spazio Aero e Meteorologia, Roma, Italy
HNMS	Hellenic National Meteorological Service, Athens, Greece
IMGW	Institute of Meteorology and Water Management, Warsaw, Poland
ARPA-SIMC	Agenzia Regionale per la Protezione Ambientale dell Emilia-Romagna Servizio Idro Meteo Clima Bologna, Italy
ARPA-Piemonte	Agenzia Regionale per la Protezione Ambientale, Piemonte, Italy
CIRA	Centro Italiano Ricerche Aerospaziali, Italy
ZGeoBW	Zentrum für Geoinformationswesen der Bundeswehr, Euskirchen, Germany
NMA	National Meteorological Administration, Bukarest, Romania
RosHydroMet	Hydrometeorological Centre of Russia, Moscow, Russia

will apply.

The further development of the modeling system within COSMO is organized in Working Groups which cover the main research and development activities: data assimilation, numerical aspects, upper air physical aspects, soil and surface physics aspects, interpretation and applications, verification and case studies, reference version and implementation and predictability and ensemble methods. In 2005, the COSMO Steering Committee decided to define *Priority Projects* with the goal to focus the scientific activities of the COSMO community on some few key issues and support the permanent improvement of the model. For contacting the Working Group Coordinators or members of the Working Groups or Priority Projects, please refer to the COSMO web-site.

The COSMO meteorological services are not equipped to provide extensive support to external users of the model. If technical problems occur with the installation of the model system or with basic questions how to run the model, questions could be directed via email to `cosmo-support@cosmo-model.org`. If further problems occur, please contact the members of an appropriate Working Group. We try to assist you as well as possible.

The authors of this document recognize that typographical and other errors as well as discrepancies in the code and deficiencies regarding the completeness may be present, and your assistance in correcting them is appreciated. All comments and suggestions for improvement or corrections of the documentation and the model code are welcome and may be directed to the authors.

1.2 Basic Model Design and Features

The nonhydrostatic fully compressible COSMO-Model has been developed to meet high-resolution regional forecast requirements of weather services and to provide a flexible tool for various scientific applications on a broad range of spatial scales. When starting with the development of the COSMO-Model, many NWP-models operated on hydrostatic scales of motion with grid spacings down to about 10 km and thus lacked the spatial resolution required to explicitly capture small-scale severe weather events. The COSMO-Model has been designed for meso-β and meso-γ scales where nonhydrostatic effects begin to play an essential role in the evolution of atmospheric flows.

By employing 1 to 3 km grid spacing for operational forecasts over a large domain, it is expected that deep moist convection and the associated feedback mechanisms to the larger scales of motion can be explicitly resolved. Meso-γ scale NWP-models thus have the principle potential to overcome the shortcomings resulting from the application of parameterized convection in current coarse-grid hydrostatic models. In addition, the impact of topography on the organization of penetrative convection by, e.g. channeling effects, is represented much more realistically in high resolution nonhydrostatic forecast models.

In the beginning, the operational application of the model within COSMO were mainly on the meso-β scale using a grid spacing of 7 km. The key issue was an accurate numerical prediction of near-surface weather conditions, focusing on clouds, fog, frontal precipitation, and orographically and thermally forced local wind systems. Since April 2007, a meso-γ scale version is running operationally at DWD by employing a grid spacing of 2.8 km. Applications with similar resolutions are now run by most COSMO partners. We expect that this will allow for a direct simulation of severe weather events triggered by deep moist convection, such as supercell thunderstorms, intense mesoscale convective complexes, prefrontal squall-line storms and heavy snowfall from wintertime mesocyclones.

The requirements for the data assimilation system for the operational COSMO-Model are mainly determined by the very high resolution of the model and by the task to employ it also for nowcasting purposes in the future. Hence, detailed high-resolution analyses have to be able to be produced frequently and quickly, and this requires a thorough use of asynoptic and high-frequency observations such as aircraft data and remote sensing data. Since both 3-dimensional and 4-dimensional variational methods tend to be less appropriate for this purpose, a scheme based on the observation nudging technique has been chosen for data assimilation.

Besides the operational application, the COSMO-Model provides a nonhydrostatic modeling framework for various scientific and technical purposes. Examples are applications of the model to large-eddy simulations, cloud resolving simulations, studies on orographic flow systems and storm dynamics, development and validation of large-scale parameterization schemes by fine-scale modeling, and tests of computational strategies and numerical techniques. For these types of studies, the model should be applicable to both real data cases and artificial cases using idealized test data. Moreover, the model has been adapted by other communities for applications in climate mode (CCLM) and / or running an online coupled module for aerosols and reactive trace gases (ART).

Such a wide range of applications imposes a number of requirements for the physical, numerical and technical design of the model. The main design requirements are:

(i) use of nonhydrostatic, compressible dynamical equations to avoid restrictions on the spatial scales and the domain size, and application of an efficient numerical method of solution;

(ii) provision of a comprehensive physics package to cover adequately the spatial scales of application, and provision of high-resolution data sets for all external parameters required by the parameterization schemes;

(iii) flexible choice of initial and boundary conditions to accommodate both real data cases and idealized initial states, and use of a mesh-refinement technique to focus on regions of interest and to handle multi-scale phenomena;

(iv) use of a high-resolution analysis method capable of assimilating high-frequency asynoptic data and remote sensing data;

(v) use of pure Fortran constructs to render the code portable among a variety of computer systems, and application of the standard MPI-software for message passing on distributed memory machines to accommodate broad classes of parallel computers.

The development of the COSMO-Model was organized along these basic guidelines. However, not all of the requirements are fully implemented, and development work and further improvement is an ongoing task. The main features and characteristics of the present release are summarized below.

Dynamics

- **Model Equations** – Nonhydrostatic, full compressible hydro-thermodynamical equations in advection form. Subtraction of a hydrostatic base state at rest.
- **Prognostic Variables** – Horizontal and vertical Cartesian wind components, pressure perturbation, temperature, specific humidity, cloud water content. Optionally: cloud ice content, turbulent kinetic energy, specific water content of rain, snow and graupel.
- **Diagnostic Variables** – Total air density, precipitation fluxes of rain and snow.
- **Coordinate System** – Generalized terrain-following height coordinate with rotated geographical coordinates and user defined grid stretching in the vertical. Options for (i) base-state pressure based height coordinate, (ii) Gal-Chen height coordinate and (iii) exponential height coordinate (SLEVE) according to Schaer et al. (2002).

Numerics

- **Grid Structure** – Arakawa C-grid, Lorenz vertical grid staggering.
- **Spatial Discretization** – Second-order finite differences. For the two time-level scheme also 1st and 3rd to 6th order horizontal advection (default: 5th order). Option for explicit higher order vertical advection.
- **Time Integration** – Two time-level 2nd and 3rd order Runge-Kutta split-explicit scheme after Wicker and Skamarock (2002) and a TVD-variant (Total Variation Diminishing) of a 3rd order Runge-Kutta split-explicit scheme. Option for a second-order leapfrog HE-VI (horizontally explicit, vertically implicit) time-split integration scheme, including extensions proposed by Skamarock and Klemp (1992). Option for a three time-level 3-d semi-implicit scheme (Thomas et al. (2000)) based on the leapfrog scheme.

- **Numerical Smoothing** – 4th-order linear horizontal diffusion with option for a monotonic version including an orographic limiter. Rayleigh damping in upper layers. 2-d divergence damping and off-centering in the vertical in split time steps.

Initial and Boundary Conditions

- **Initial Conditions** – Interpolated initial data from various coarse-grid driving models (GME, ECMWF, COSMO-Model) or from the continuous data assimilation stream (see below). Option for user-specified idealized initial fields.
- **Lateral Boundary Conditions** – 1-way nesting by Davies-type lateral boundary formulation. Data from several coarse-grid models can be processed (GME, IFS, COSMO-Model). Option for periodic boundary conditions.
- **Top Boundary Conditions** – Options for rigid lid condition and Rayleigh damping layer.
- **Initialization** – Digital-filter initialization of unbalanced initial states (Lynch et al. (1997)) with options for adiabatic and diabatic initialization.

Physical Parameterizations

- **Subgrid-Scale Turbulence** – Prognostic turbulent kinetic energy closure at level 2.5 including effects from subgrid-scale condensation and from thermal circulations. Option for a diagnostic second order K-closure of hierarchy level 2 for vertical turbulent fluxes. Preliminary option for calculation of horizontal turbulent diffusion in terrain following coordinates (3D Turbulence).
- **Surface Layer Parameterization** – A Surface layer scheme (based on turbulent kinetic energy) including a laminar-turbulent roughness layer. Option for a stability-dependent drag-law formulation of momentum, heat and moisture fluxes according to similarity theory (Louis (1979)).
- **Grid-Scale Clouds and Precipitation** – Cloud water condensation and evaporation by saturation adjustment. Precipitation formation by a bulk microphysics parameterization including water vapour, cloud water, cloud ice, rain and snow with 3D transport for the precipitating phases. Option for a new bulk scheme including graupel. Option for a simpler column equilibrium scheme.
- **Subgrid-Scale Clouds** – Subgrid-scale cloudiness is interpreted by an empirical function depending on relative humidity and height. A corresponding cloud water content is also interpreted. Option for a statistical subgrid-scale cloud diagnostic for turbulence.
- **Moist Convection** – Tiedtke (1989) mass-flux convection scheme with equilibrium closure based on moisture convergence. Option for the Kain-Fritsch (Kain and Fritsch (1993)) convection scheme with non-equilibrium CAPE-type closure.
- **Shallow Convection** – Reduced Tiedtke scheme for shallow convection only.
- **Radiation** – δ two-stream radiation scheme after Ritter and Geleyn (1992) short and longwave fluxes (employing eight spectral intervals); full cloud-radiation feedback.
- **Soil Model** – Multi-layer version of the former two-layer soil model after Jacobsen and Heise (1982) based on the direct numerical solution of the heat conduction equation. Snow and interception storage are included. Option for the (old) two-layer soil model employing the extended force-restore method still included.
- **Fresh-Water Lake Parameterization** – Two-layer bulk model after Mironov (2008) to predict the vertical temperature structure and mixing conditions in fresh-water lakes of various depths.
- **Sea-Ice Scheme** – Parameterization of thermodynamic processes (without rheology) after Mironov and B. (2004). The scheme basically computes the energy balance at the ices surface, using one layer of sea ice.

- **Terrain and Surface Data** – All external parameters of the model are available at various resolutions for a pre-defined region covering Europe. For other regions or grid-spacings, the external parameter file can be generated by a preprocessor program using high-resolution global data sets.

Data Assimilation

- **Basic Method** – Continuous four-dimensional data assimilation based on observation nudging (Schraff (1996), Schraff (1997)), with lateral spreading of upper-air observation increments along horizontal surfaces. Explicit balancing by a hydrostatic temperature correction for surface pressure updates, a geostrophic wind correction, and a hydrostatic upper-air pressure correction.
- **Assimilated Atmospheric Observations** – Radiosonde (wind, temperature, humidity), aircraft (wind, temperature), wind profiler (wind), and surface-level data (SYNOP, SHIP, BUOY: pressure, wind, humidity). Optionally RASS (temperature), radar VAD wind, and ground-based GPS (integrated water vapour) data. Surface-level temperature is used for the soil moisture analysis only.
- **Radar derived rain rates** – Assimilation of near surface rain rates based on latent heat nudging (Stephan et al. (2008)). It locally adjusts the three-dimensional thermodynamical field of the model in such a way that the modelled precipitation rates should resemble the observed ones.
- **Surface and Soil Fields** – Additional two-dimensional intermittent analysis:
  - **Soil Moisture Analysis** – Daily adjustment of soil moisture by a variational method (Hess (2001)) in order to improve 2-m temperature forecasts; use of a Kalman-Filter-like background weighting.
  - **Sea Surface Temperature Analysis** – Daily Cressman-type correction, and blending with global analysis. Use of external sea ice cover analysis.
  - **Snow Depth Analysis** – 6-hourly analysis by weighted averaging of snow depth observations, and use of snowfall data and predicted snow depth.

Code and Parallelization

- **Code Structure** – Modular code structure using standard Fortran constructs.
- **Parallelization** – The parallelization is done by horizontal domain decomposition using a soft-coded gridline halo (2 lines for Leapfrog, 3 for the Runge-Kutta scheme). The *Message Passing Interface* software (MPI) is used for message passing on distributed memory machines.
- **Compilation of the Code** – The compilation of all programs is performed by a Unix shell script invoking the Unix *make* command. All dependencies of the routines are automatically taken into account by the script.
- **Portability** – The model can be easily ported to various platforms; current applications are on conventional scalar machines (UNIX workstations, LINUX and Windows-NT PCs), on vector computers (NEC SX series) and MPP machines (CRAY, IBM, SGI and others).
- **Model Geometry** – 3-d, 2-d and 1-d model configurations. Metrical terms can be adjusted to represent tangential Cartesian geometry with constant or zero Coriolis parameter.

1.3 Organization of the Documentation

For the documentation of the model we follow closely the *European Standards for Writing and Documenting Exchangeable Fortran 90-Code*. These standards provide a framework for the use of Fortran-90 in European meteorological organizations and weather services and thereby

Table 1.2: COSMO Documentation: A Description of the Nonhydrostatic Regional COSMO-Model

Part I:	Dynamics and Numerics
Part II:	Physical Parameterization
Part III:	Data Assimilation
Part IV:	Implementation Documentation
Part V:	Preprocessing: Initial and Boundary Data for the COSMO-Model
Part VI:	Postprocessing
Part VII:	User's Guide

facilitate the exchange of code between these centres. According to these standards, the model documentation is split into two categories: external documentation (outside the code) and internal documentation (inside the code). The model provides extensive documentation within the codes of the subroutines. This is in form of procedure headers, section comments and other comments. The external documentation is split into seven parts, which are listed in Table 1.2.

Parts I - III form the scientific documentation, which provides information about the theoretical and numerical formulation of the model, the parameterization of physical processes and the four-dimensional data assimilation. The scientific documentation is independent of (i.e. does not refer to) the code itself. Part IV will describe the particular implementation of the methods and algorithms as presented in Parts I - III, including information on the basic code design and on the strategy for parallelization using the MPI library for message passing on distributed memory machines (not available yet). The generation of initial and boundary conditions from coarse grid driving models is described in Part V. This part is a description of the interpolation procedures and algorithms used (not yet complete) as well as a User's Guide for the interpolation program INT2LM. Available postprocessing utilities will be described (in the future) in Part VI. Finally, the User's Guide of the COSMO-Model provides information on code access and how to install, compile, configure and run the model. The User's Guide contains also a detailed description of various control parameters in the model input file (in NAMELIST format) which allow for a flexible model set-up for various applications. All parts of the documentation are available at the COSMO web-site (`http://www.cosmo-model.org/content/model/documentation/core/default.htm`).

Section 2

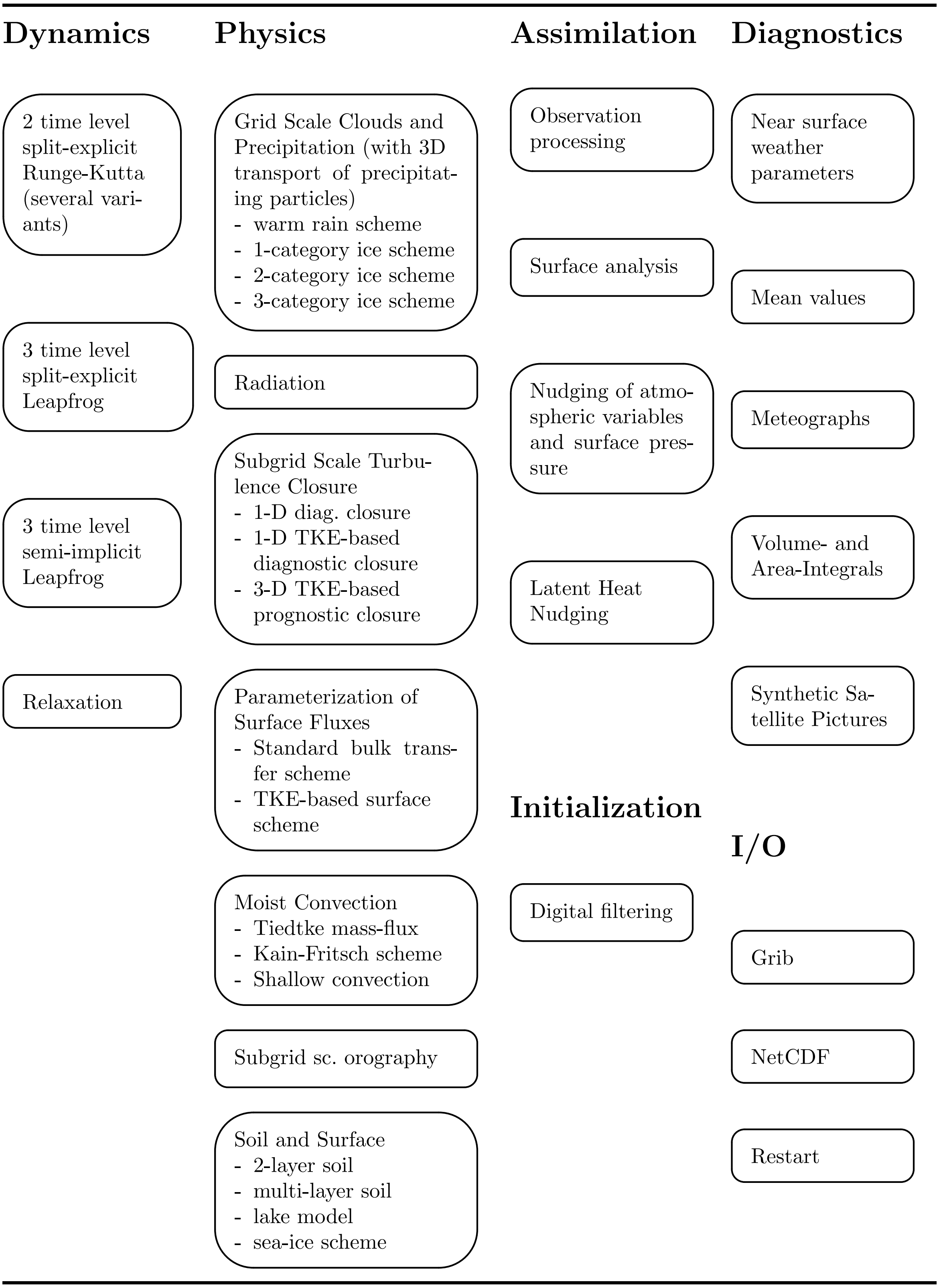
Introduction

The usage of the program package for the COSMO-Model is a rather complex task, both, for the experienced and even more for the non-experienced user. This User's Guide serves in a first instance as a complete reference for all the different `NAMELIST` groups and variables, with which the execution of the model can be controlled. It also includes a description on how to install the package and gives additional necessary information, e.g. on the Grib format used for I/O.

Knowing the meaning of all `NAMELIST`-variables normally is not enough to find the way through the possible configurations of the model. Therefore, a description would be desirable that explains how the variables can be put together to give a meaningful setup, or which variable settings contradict each other or simply are not possible. We apologize, that such a description is not yet available, but it will be developed in the future. It will explain, how the different components of the model (see Fig. 2.1) can be selected and which configurations are possible.

Up to then, Part VII of the model documentation is organized as follows. First, an overview on the model formulation and the data assimilation is given. In Section 4, the installation of the package is explained. The necessary input files of the model are listed in Section 6 and Section 5.1 gives a short description of the GRIB code used for input and output of the meteorological fields. Section 7 then is the complete reference for all `NAMELIST` variables. Sections 8.1 and 8.2 finally describe the ASCII output of the COSMO-Model, and Section 8.4 provides information on the output model fields.

Figure 2.1: Schematic view of the different COSMO-Model components



Section 3

Model Formulation and Data Assimilation

3.1 Basic State and Coordinate-System

The COSMO-Model is based on the primitive hydro-thermodynamical equations describing compressible nonhydrostatic flow in a moist atmosphere without any scale approximations. A basic state is subtracted from the equations to reduce numerical errors associated with the calculation of the pressure gradient force in case of sloping coordinate surfaces. The basic state represents a time-independent dry atmosphere at rest which is prescribed to be horizontally homogeneous, vertically stratified and in hydrostatic balance.

By introducing the basic state, the thermodynamic variables temperature (T), pressure (p) and density (ρ) can be formally written as the sum of a height dependent reference value and a space and time dependent deviation:

$$T = T_0(z) + T', \qquad p = p_0(z) + p', \qquad \rho = \rho_0(z) + \rho' \, , \tag{3.1}$$

where $T_0(z)$, $p_0(z)$ and $\rho_0(z)$ are related by the hydrostatic equation

$$\frac{\partial p_0}{\partial z} = -g\rho_0 = -\frac{gp_0}{R_d T_0} \tag{3.2}$$

and the equation of state, $p_0 = \rho_0 R_d T_0$. R_d is the gas constant of dry air. The vertical profile $T_0(z)$ of temperature can be specified arbitrary since we do not linearize the model equations with respect to the reference state.

In the first implementation of the COSMO-Model we prescribed a constant rate β for the temperature increase with the logarithm of pressure (as proposed by Dudhia (1993)), $\partial T_0 / \partial \ln p_0 = \beta$. The integration of the hydrostatic equation (3.2) with the boundary values $p_{SL} = p_0\,(z=0)$ and $T_{SL} = T_0\,(z=0)$ for the pressure and temperature at mean sea level $z = 0$ then yields the vertical profiles of the reference state:

$$p_0(z) \quad = \quad \begin{cases} p_{SL} \exp\left\{ -\frac{T_{SL}}{\beta} \left(1 - \sqrt{1 - \frac{2\beta g z}{R_d T_{SL}^2}} \right) \right\} & \text{if } \beta \neq 0 \\ p_{SL} \exp\left\{ -\frac{gz}{R_d T_{SL}} \right\} & \text{if } \beta = 0 \end{cases}$$

$$T_0(z) \quad = \quad T_{SL}\sqrt{1-\frac{2\beta g z}{R_d T_{SL}^2}}. \tag{3.3}$$

For the three parameters p_{SL}, T_{SL} and β, which define the basic state, we use the default values p_{SL} = 1000hPa, T_{SL} = 288.15K and β = 42K. The variable names in the programs are `p0sl` (p_{SL}), `t0sl` (T_{SL}) and `dt0lp` (β), resp. This basic state is still available in the COSMO-Model and can be chosen as *Reference Atmosphere 1* (`irefatm=1`).

Since COSMO-Model 4.5, a new alternative reference atmosphere has been implemented, which can be chosen as *Reference Atmosphere 2* (`irefatm=2`). This reference atmosphere is based on the temperature profile

$$T_0(z) = T_{00} + \delta_T \cdot \exp(-z/h_{scal}), \tag{3.4}$$

with default values of T_{00} = 213.15K, δ_T = 75K and h_{scal} = 10km. In the model code, $T_{00} = T_{SL} - \delta_T$ = `t0sl - delta_t`. Thus, the reference atmosphere approaches an isothermal profile in the stratosphere, whereas the existing reference profile has an increasingly negative vertical temperature gradient in the stratosphere. The vertical extent of the model domain is no longer limited with the new reference atmosphere.

The new reference atmosphere needs two additional parameters δ_T (model variable `delta_t`) and h_{scal} (model variable `h_scal`). Default values are `delta_t=75.0` and `h_scal=10000.0`, resp.

The model equations are formulated with respect to a rotated lat/lon-grid with coordinates (λ, φ). The rotated coordinate system results from the geographical (λ_g, φ_g) coordinates by tilting the north pole (see Part I of the Documentation, *Dynamics and Numerics*). In the vertical, we use a generalized terrain-following height coordinate ζ, where any unique function of geometrical height can be used for transformation. Since ζ doesn't depend on time, the $(\lambda, \varphi, \zeta)$-system represents a non-deformable coordinate system, where surfaces of constant ζ are fixed in space - in contrast to the pressure based coordinate system of most hydrostatic models, where the surfaces of constant vertical coordinate move in space with changing surface pressure.

The transformation of the model equations from the orthogonal (λ, φ, z)-system to the non-orthogonal terrain-following $(\lambda, \varphi, \zeta)$-system is given by the three elements of the inverse Jacobian matrix $\mathcal{J}^z$,

$$J_\lambda \equiv J_{13}^z = \left(\frac{\partial z}{\partial \lambda}\right)_\zeta, \quad J_\varphi \equiv J_{23}^z = \left(\frac{\partial z}{\partial \varphi}\right)_\zeta, \quad J_\zeta \equiv J_{33}^z = \frac{\partial z}{\partial \zeta} = -\sqrt{G}. \tag{3.5}$$

The terrain-following ζ-system of the COSMO-Model is defined to be left-handed, i.e. the value of the ζ-coordinate increases with decreasing height z from the top of the model to the surface. Thus, J_ζ is always negative and equal to the negative absolute value ($\sqrt{G} = |\det(\mathcal{J}^z)|$) of the determinant of the inverse Jacobi matrix.

3.2 Differential Form of Thermodynamic Equations

By transforming the primitive hydro-thermodynamical equations to the $(\lambda, \varphi, \zeta)$ coordinate-system and subtracting the basic state, we achieve the following set of prognostic model equations for the three components u, v and w of the wind vector, the perturbation pressure p', the temperature T and the humidity variables q.

$$\begin{aligned}
\frac{\partial u}{\partial t} + \mathbf{v}\cdot\nabla u - \frac{uv}{a}\tan\varphi - fv &= -\frac{1}{\rho a\cos\varphi}\left(\frac{\partial p'}{\partial\lambda} + \frac{J_\lambda}{\sqrt{G}}\frac{\partial p'}{\partial\zeta}\right) + M_u \\
\frac{\partial v}{\partial t} + \mathbf{v}\cdot\nabla v + \frac{u^2}{a}\tan\varphi + fu &= -\frac{1}{\rho a}\left(\frac{\partial p'}{\partial\varphi} + \frac{J_\varphi}{\sqrt{G}}\frac{\partial p'}{\partial\zeta}\right) + M_v \\
\frac{\partial w}{\partial t} + \mathbf{v}\cdot\nabla w &= \frac{1}{\rho\sqrt{G}}\frac{\partial p'}{\partial\zeta} + B + M_w \\
\frac{\partial p'}{\partial t} + \mathbf{v}\cdot\nabla p' - g\rho_0 w &= -(c_{pd}/c_{vd})pD \\
\frac{\partial T}{\partial t} + \mathbf{v}\cdot\nabla T &= -\frac{p}{\rho c_{vd}}D + Q_T \\
\frac{\partial q^v}{\partial t} + \mathbf{v}\cdot\nabla q^v &= -(S^l + S^f) + M_{q^v} \\
\frac{\partial q^{l,f}}{\partial t} + \mathbf{v}\cdot\nabla q^{l,f} + \frac{1}{\rho\sqrt{G}}\frac{\partial P_{l,f}}{\partial\zeta} &= S^{l,f} + M_{q^{l,f}}
\end{aligned} \tag{3.6}$$

Here, the continuity equation has been replaced by an equation for p'. In Eqs. (3.6) a is the radius of the earth, c_{pd} and c_{vd} are the specific heat of dry air at constant pressure and constant volume, g is the gravity acceleration, f is the Coriolis parameter, R_v and R_d are the gas constants for water vapour and dry air. ρ is the density of moist air which is calculated as a diagnostic variable from the equation of state:

$$\rho = p\{R_d(1 + (R_v/R_d - 1)q^v - q^l - q^f)T\}^{-1}\,. \tag{3.7}$$

q^v is the specific humidity, q^l represents the specific water content of a category of liquid water (cloud or rain water) and q^f represents the specific water content of a category of frozen water (cloud ice, snow or graupel). The corresponding precipitation fluxes are denoted by P_l and P_f.

The terms M_ψ denote contributions from subgrid-scale processes as, e.g. turbulence and convection and Q_T summarizes the diabatic heating rate due to this processes. The various sources and sinks in the equations for the humidity variables due to microphysical processes of cloud and precipitation formation are denoted by S^l and S^f. The calculation of all these terms related to subgrid-scale processes is done by physical parameterization schemes. An overview of the schemes used in the COSMO-Model is given in Section 3.5.

The term B in the equation for the vertical velocity is the buoyant acceleration given by

$$B = g\frac{\rho_0}{\rho}\left\{\frac{T - T_0}{T} - \frac{p'\,T_0}{p_0\,T} + \left(\frac{R_v}{R_d} - 1\right)q^v - q^l - q^f\right\}. \tag{3.8}$$

The advection operator in terrain-following coordinates is defined as

$$\mathbf{v}\cdot\nabla = \frac{1}{a\,\cos\varphi}\left(u\frac{\partial}{\partial\lambda} + v\cos\varphi\frac{\partial}{\partial\varphi}\right) + \dot{\zeta}\frac{\partial}{\partial\zeta},$$

where $\dot{\zeta}$ is the contra-variant vertical velocity in the ζ-system:

$$\dot{\zeta} = \frac{1}{\sqrt{G}} \left(\frac{J_\lambda}{a \cos\varphi} u + \frac{J_\varphi}{a} v - w \right) .$$

D is the three-dimensional wind divergence which is calculated from

$$D = \frac{1}{a\cos\varphi} \left\{ \frac{\partial u}{\partial \lambda} + \frac{J_\lambda}{\sqrt{G}} \frac{\partial u}{\partial \zeta} + \frac{\partial}{\partial \varphi} (v \cos\varphi) + \cos\varphi \frac{J_\varphi}{\sqrt{G}} \frac{\partial v}{\partial \zeta} \right\} - \frac{1}{\sqrt{G}} \frac{\partial w}{\partial \zeta} .$$

In deriving the prognostic equation for the perturbation pressure from the continuity equation, a source term due to diabatic heating has been neglected. For most meteorological applications, this source term is much smaller than the forcing by divergence. This approximation is also used in many other nonhydrostatic simulation models.

3.3 Horizontal and Vertical Grid Structure

The model equations (3.6) are solved numerically using the traditional finite difference method. In this technique, spatial differential operators are simply replaced by suitable finite difference operators. The time integration is also by discrete stepping using a fixed timestep Δt.

The terrain-following coordinate system with the generalized vertical coordinate ζ allows to map the irregular grid associated with the terrain-following system in physical space onto a rectangular and regular computational grid. Thus, constant increments

$\Delta\lambda$: grid-spacing in longitudinal direction,
$\Delta\varphi$: grid-spacing in latitudinal direction,
$\Delta\zeta$: grid-spacing in ζ-direction ($\Delta\zeta = 1$),

of the independent variables are used to set up the computational grid. To simplify the notation, we set the vertical grid-spacing equal to one (see below). The discrete computational $(\lambda, \varphi, \zeta)$-space is then represented by a finite number of grid points (i, j, k), where i corresponds to the λ-direction, j to the φ-direction and k to the ζ-direction. The position of the grid points in the computational space is defined by

$$\begin{aligned} \lambda_i &= \lambda_0 + (i-1)\,\Delta\lambda\,, & i &= 1, \cdots, N_\lambda \\ \varphi_j &= \varphi_0 + (j-1)\Delta\varphi, & j &= 1, \cdots, N_\varphi \\ \zeta_k &= k\,, & k &= 1, \cdots, N_\zeta\,. \end{aligned} \tag{3.9}$$

N_λ denotes the number of grid points in λ-direction, N_φ the number of points in the φ-direction and N_ζ the number of points in the ζ-direction. λ_0 and φ_0 define the south-western corner of the model domain with respect to the rotated geographical coordinates (λ, φ). Thus, $i = 1$ and $i = N_\lambda$ correspond, respectively, to the western and the eastern boundaries of the domain. Accordingly, the southern and the northern borderlines are given by $j = 1$ and $j = N_\varphi$. The corresponding variables in the programs are `dlon` ($\Delta\lambda$), `dlat` ($\Delta\varphi$), `startlon_tot` (λ_0), `startlat_tot` (φ_0), `ie_tot` (N_λ), `je_tot` (N_φ) and `ke_tot` (N_ζ).

Every grid point (i, j, k) represents the centre of an elementary rectangular grid volume with side lengths $\Delta\lambda$, $\Delta\varphi$ and $\Delta\zeta$. The grid-box faces are located halfway between the grid points in the corresponding directions, i.e. at $\lambda_{i\pm1/2}$, $\varphi_{j\pm1/2}$ and $\zeta_{k\pm1/2}$.

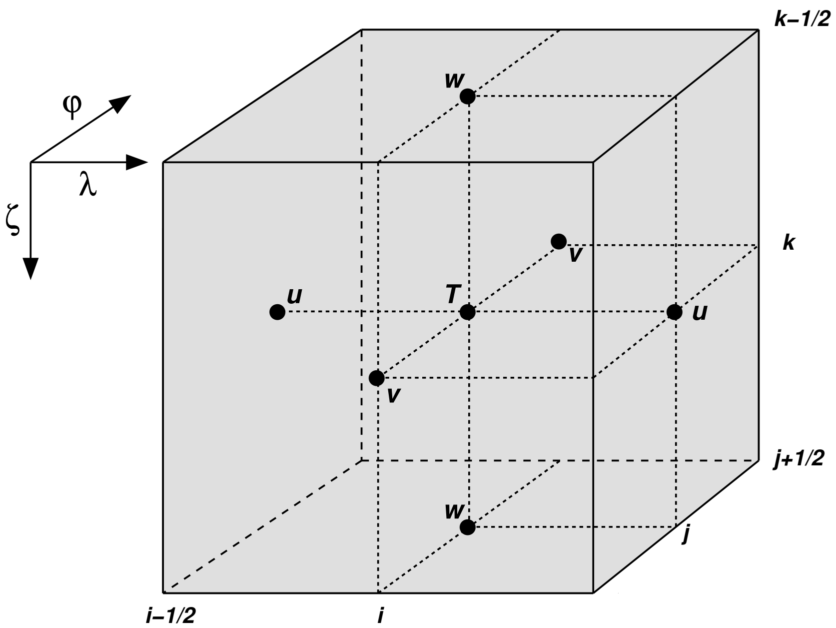


Figure 3.1: A grid box volume $\Delta V = \Delta\zeta \, \Delta\lambda \, \Delta\varphi$ showing the Arakawa-C/Lorenz staggering of the dependent model variables.

The model variables are staggered on an Arakawa-C/Lorenz grid with scalars (temperature, pressure and humidity variables) defined at the centre of a grid box and the normal velocity components defined on the corresponding box faces (see Figure 3.1). For a given grid spacing, this staggering allows for a more accurate representation of differential operators than in the A-grid, where all variables are defined at the same point. In general, we use second order centered finite difference operators, i.e. the numerical discretization error is reduced by a factor of four when we increase the resolution by a factor of two. For a detailed description of the numerical operators see Part I of the Documentation, *Dynamics and Numerics*.

The grid-box faces in vertical direction are usually referred to as the half levels. These interfacial levels separate the model layers from each other. The model layers labeled by integers k are also denoted as main levels. Thus, for a model configuration with N_ζ layers we have $N_\zeta + 1$ half levels. The top boundary of the model domain is defined to be the half level ($\zeta = 1/2$) above the uppermost model layer ($\zeta = 1$). At the lower boundary, the ζ-coordinate surface becomes conformal to the terrain height. The half level ($\zeta = N_\zeta + 1/2$) below the first model layer above the ground ($\zeta = N_\zeta$) defines the lower boundary of the model.

The discrete formulation of the model equations is independent on a specific choice for the vertical coordinate. This is achieved by a two-step transformation procedure: First we apply a transformation to a specific terrain-following system, where in principle any unique function of geometrical height z can be used. In the first implementation of the COSMO-Model, either a generalized sigma-type coordinate η based on base-state pressure (`ivctype=1`) or a generalized Gal-Chen coordinate μ based on height (`ivctype=2`) could be chosen. Later, two variants of the *Smooth LEvel VErtical coordinate* (SLEVE) have been added (`ivctype=3/4`).

In a second step this vertical coordinate is mapped onto the computational coordinate ζ with discrete coordinate values $\zeta_k = k$ and an equidistant grid spacing of $\Delta\zeta = 1$. The latter mapping is by a table which relates specific values of the terrain-following coordinate η or

μ to the $N_\zeta + 1$ values of the half-level values $\zeta_{k+1/2}$. In this way a user-defined vertical grid-stretching can be easily applied. Details on the set-up of the vertical grid are provided in Part I of the Documentation, *Dynamics and Numerics*.

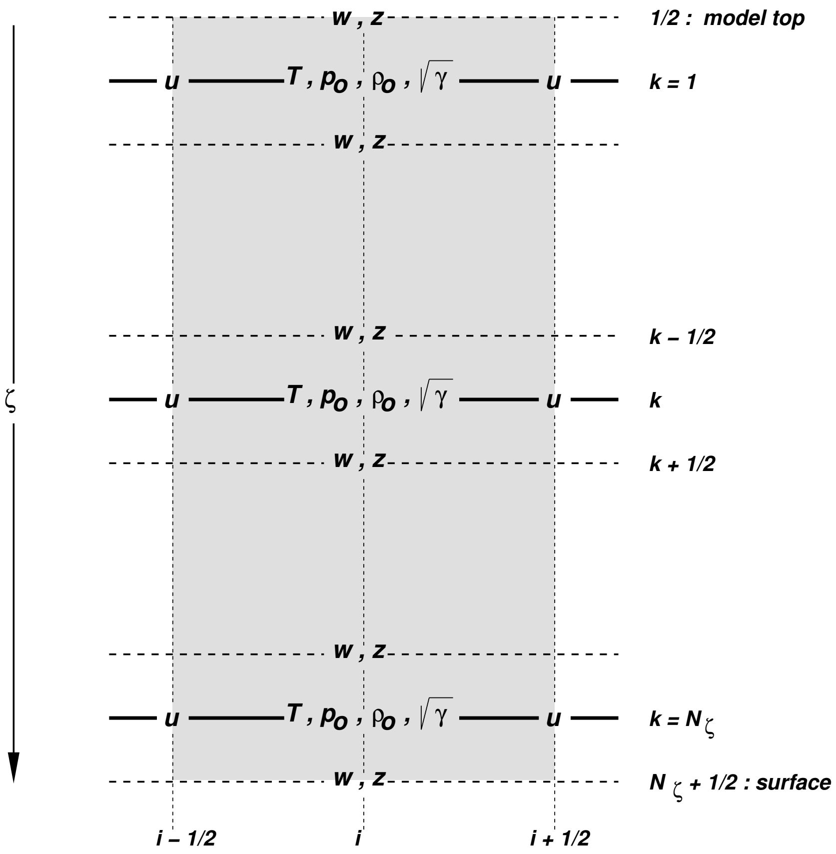


Figure 3.2: Vertical staggering of variables and metric terms in a grid box column with N_ζ layers. Dashed lines are the model half levels separating the main levels (full lines).

To render the model code independent on η or μ, all metric terms involving the three components (3.5) of the Jacobi-matrix are evaluated numerically on the computational grid. These terms are rewritten in the form

$$\sqrt{G} = \frac{1}{g\rho_0}\sqrt{\gamma}\,, \qquad \frac{J_\lambda}{\sqrt{G}} = -\frac{1}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \lambda}\,, \qquad \frac{J_\varphi}{\sqrt{G}} = -\frac{1}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \varphi}\,, \tag{3.10}$$

where $\sqrt{\gamma} \equiv \partial p_0/\partial\zeta$ denotes the change of base-state pressure with ζ. In discretized form we have

$$\begin{aligned} \sqrt{\gamma}_k &= (\Delta p_0)_k = (p_0)_{k+1/2} - (p_0)_{k-1/2}\,, \\ (p_0)_k &= \frac{1}{2}\{(p_0)_{k+1/2} + (p_0)_{k-1/2}\}\,. \end{aligned} \tag{3.11}$$

for $\sqrt{\gamma}$ and the base-state pressure p_0 on model main levels. Additionally, the height of model half levels $z_{k+1/2}$ resulting from the coordinate transformation is stored as a 3-D array `HHL`.

The base-state density on main levels then results from the discretized hydrostatic relation

$$(\rho_0)_k = \frac{1}{g} \frac{\sqrt{\gamma}_k}{z_{k-1/2} - z_{k+1/2}}$$

and the main level base-state temperature results from the equation of state. Fig. 3.2 illustrates the vertical staggering of model variables as well as base state variables and metric terms used in the discretization.

In order to implement boundary conditions and to apply the domain decomposition strategy for code parallelization in a convenient way, the horizontal extent of the computational domain is chosen to be smaller than the total domain size. The lateral physical boundaries are positioned with a spatial offset from the outer boundaries to the interior. This offset is

$$\begin{array}{ll} N_{\text{off}}\Delta\lambda - \Delta\lambda/4 & \text{in } \lambda\text{-direction and} \\ N_{\text{off}}\Delta\varphi - \Delta\varphi/4 & \text{in } \varphi\text{-direction,} \end{array}$$

where N_{off} (`nboundlines` as program variable) denotes the number of grid intervals used to define the position of the physical boundaries. By default, N_{off} is set to 2 (larger but not smaller numbers for N_{off} may be specified by the user).

All grid points interior to the physical boundary constitute the computational (or model interior) domain, where the model equations are integrated numerically. These are points with subscripts (i, j) running from $i = N_{\text{off}}+1, \cdots, N_\lambda - N_{\text{off}}$ and $j = N_{\text{off}}+1, \cdots, N_\varphi - N_{\text{off}}$. The extra points outside the interior domain constitute the computational boundaries. At these points, all model variables are defined and set to specified boundary values, but no dynamical computations are done. For $N_{\text{off}} = 2$, we have two extra lines of grid points adjacent to each physical boundary (see Fig. 3.3).

3.4 Numerical Integration

Because the governing nonhydrostatic equations describe a compressible model atmosphere, meteorologically unimportant sound waves are also part of the solution. As acoustic waves are very fast, their presence severely limits the time step of explicit time integration schemes. In order to improve the numerical efficiency, the prognostic equations are separated into terms which are directly related to acoustic and gravity wave modes and into terms which refer to comparatively slowly varying modes of motion. This mode-splitting can formally be written in the symbolic form

$$\frac{\partial \psi}{\partial t} = s_\psi + f_\psi \, , \tag{3.12}$$

where ψ denotes a prognostic model variable, f_ψ the forcing terms due to the slow modes and s_ψ the source terms related to the acoustic and gravity wave modes. s_ψ is made up of the pressure gradient terms in the momentum equations, the temperature and pressure contributions to the buoyancy term in the w-equation and the divergence term in the pressure and the temperature equation. The subset of equations containing the s_ψ-terms is then integrated with a special numerical scheme. The COSMO-Model provides four different integration methods.

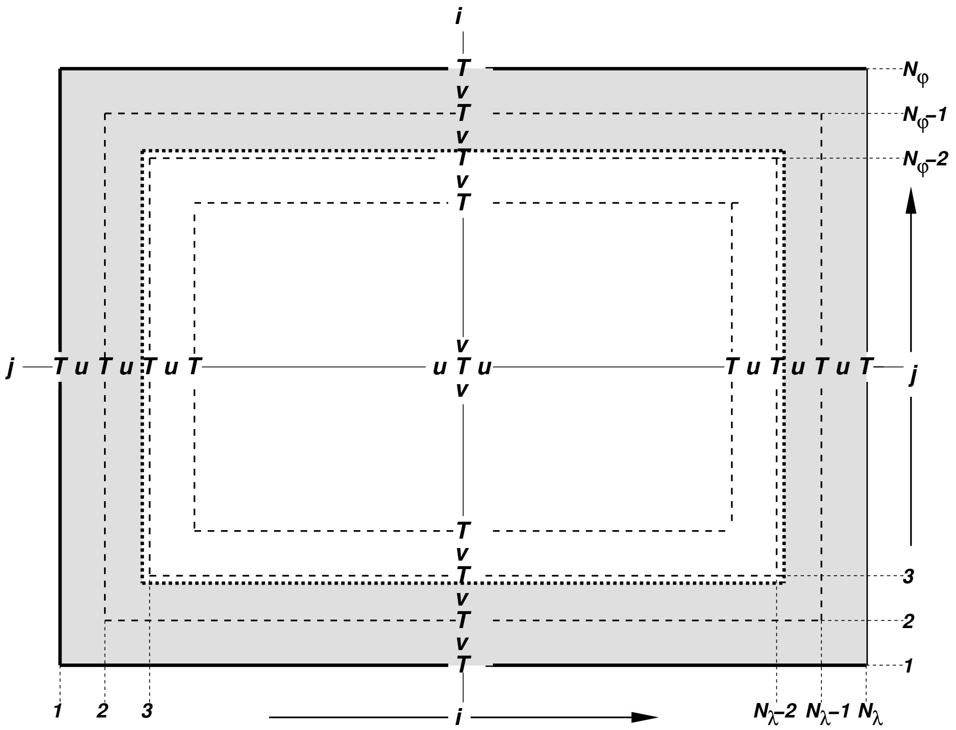


Figure 3.3: Horizontal model domain for $N_\lambda \times N_\varphi$ grid points and an offset of $N_{\text{off}} = 2$ for the position of the physical boundaries (dotted). The computational boundaries are shaded; the integration is done for variables in the interior computational domain ($i = 3, \cdots, N_\lambda - 2$ and $j = 3, \cdots, N_\varphi - 2$).

3.4.1 Runge-Kutta: 2-timelevel HE-VI Integration

Basic Namelist settings: `l2tls=.TRUE.;` `lsemi_imp=.FALSE.;` `irunge_kutta=1/2`
This scheme (with `irunge_kutta=1`) is used for the COSMO-DE and COSMO-EU.

This scheme has been implemented into the COSMO-Model as an alternative to the former default, the Leapfrog scheme, and can be combined with a forward-backward scheme for integrating the high-frequency modes of the elastic equations. The first (`irunge_kutta=1`) variant is the normal 3rd-order Runge-Kutta scheme used by Wicker and Skamarock (2002) whereas the second one is a total variation diminishing (TVD) variant of 3rd-order (Liu et al. (1994)) (`irunge_kutta=2`).

Different horizontal advection upwind or centered-differences schemes of 3rd- to 6th-order can be used – the operators are formulated in advection form. The vertical advection is normally treated in an implicit way using a Crank-Nicolson scheme and centered-differences in space. Most slow tendencies such as vertical diffusion, thermal/solar heating, parameterized convection and coriolis force are computed only once using values of the prognostic variables at time step n. These tendencies are fixed during the individual Runge-Kutta steps and contribute to the total slow-mode tendencies which are integrated in several small time steps together with the fast-mode tendencies in a time-splitting sense. In contradiction to this, the whole 3D-advection is computed in each Runge-Kutta step.

3.4.2 Leapfrog: 3-timelevel HE-VI Integration

Basic Namelist settings: `l2tls=.FALSE.; lsemi_imp=.FALSE.`

This method is a variant of the Klemp and Wilhelmson (1978) scheme which is based on a Leapfrog integration for the slow modes from time level $n-1$ to time level $n+1$ using an integration interval of $2\Delta t$. The slow mode tendencies are evaluated at time level n for horizontal advection using standard second order centered differences and at time level $n-1$ for most physical forcings. Vertical advection and vertical diffusion are calculated by a quasi-implicit scheme. The integration step is then subdivided into a number N_s of small time steps $\Delta\tau_s$ according to $2\Delta t = N_s \Delta\tau$ and the prognostic equations (3.12) are stepped forward according to

$$\psi^{\nu+1} = \psi^{\nu} + s_{\psi}^{\nu}\Delta\tau + f_{\psi}^{n}\Delta\tau\,. \tag{3.13}$$

Figure 3.4 illustrates the basic idea of the time-splitting scheme. In the integration of (3.13), sound waves are treated explicitly for horizontal directions using the forward-backward method while implicitly for the vertical direction (HE-VI). Thus, the small time step $\Delta\tau$ is limited by the CFL stability criterion for horizontal but not for vertical sound wave propagation. This makes the HE-VI scheme numerically very efficient for large grid aspect ratios, i.e. $\Delta x/\Delta z \gg 1$, which are typically used in meso-β and meso-γ applications.

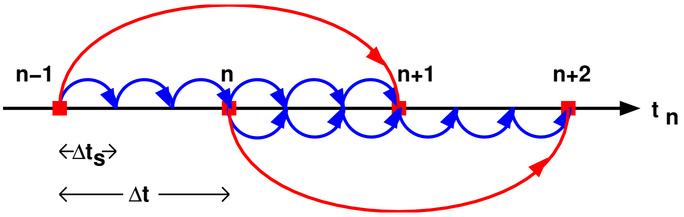


Figure 3.4: The time splitting algorithm

An additional 3-D divergence damping as well as a slight time off-centering in the vertical implicit formulation is applied to damp acoustic modes. On the big time step, the Asselin time filter and a 4th order horizontal diffusion are used for numerical smoothing. While this 3-timelevel HE-VI integration was the default time scheme of the COSMO-Model in the beginning, it has now been replaced by the 2-timelevel Runge-Kutta schemes..

3.4.3 Leapfrog: 3-timelevel Semi-Implicit Integration

Basic Namelist settings: `l2tls=.FALSE.; lsemi_imp=.TRUE.`

Because the HE-VI scheme integrates the horizontal momentum equations explicitly, steep orography may provoke instabilities in small-scale applications. Full 3D semi-implicit schemes can avoid such stability problems by treating all pressure gradient and divergence terms implicitly both vertically and horizontally (HI-VI-scheme) - thus, a small time step is not used. Moreover, 3D semi-implicit schemes have the potential to become more cost-effective than split-explicit schemes at higher resolution where the grid aspect ratio is more isotropic and where the number of small time steps increases with the sound speed Courant number for low Mach number flows.

The derivation of the scheme is based on the 3-timelevel Leapfrog integration and uses the time-tendency formulation to minimize cancellation errors. An elliptic equation for the pressure perturbation tendency

$$\mathcal{L}\left(\delta_\tau(p') = q_p\right.$$

is obtained by forming the divergence of the momentum equations and eliminating the buoyancy terms. However, the use of a nonorthogonal curvilinear coordinate system results in an elliptic operator $\mathcal{L}$ containing cross-derivative terms with variable coefficients. A minimal residual Krylov iterative solver (GMRES) was thus chosen to solve for the perturbation pressure tendency. We found the convergence criterion proposed by Skamarock et al. (1997) to be both sufficient and a robust predictor of when the RMS divergence of the flow has stabilized. An efficient line-Jacobi relaxation preconditioner was developed having the property that the number of Krylov solver iterations grows slowly as the convergence parameter ε_c decreases. Once the solution for the pressure tencendy is known, the other variables are updated by back-substitution.

3.5 Physical Parameterizations

Some parts of the physics package of the COSMO-Model are adapted from the former operational hydrostatic model DM. Others have been widely rewritten or were replaced by new developments. This section gives a short overview on the parameterization schemes used. A detailed description is given in Part II of the Documentation, *Physical Parameterizations*.

3.5.1 Radiation

Basic Namelist settings: `lphys=.TRUE.; lrad=.TRUE.; hincrad=1.0`

To calculate the heating rate due to radiation we employ the parameterization scheme of Ritter and Geleyn (1992). This scheme is based on a δ-two-stream version of the general equation for radiative transfer and considers three shortwave (solar) and five longwave (thermal) spectral intervals. Clouds, aerosol, water vapour and other gaseous tracers are treated as optically active constituents of the atmosphere, which modify the radiative fluxes by absorption, emission and scattering.

As an extension to the original scheme, a new treatment of the optical properties of ice particles has been introduced which allows a direct cloud-radiative feedback with the predicted ice water content when using the cloud ice scheme for the parameterization of cloud and precipitation.

Numerically, the parameterization scheme is very cost-intensive. Thus, it is called only at hourly intervals during an operational forecast on the meso-β scale. The resulting short- and longwave heating rates are then stored and remain fixed for the following time interval. In case of high resolution simulations, the calling frequency of the radiation scheme can be increased to allow for a better representation of the interaction with the cloud field. The radiation can also be computed on a coarser grid to save computation time.

3.5.2 Grid-scale Precipitation

Basic Namelist settings: `lphys=.TRUE.; lgsp=.TRUE.`

The basic parameterization scheme for the formation of grid-scale clouds and precipitation is an adapted version of the DM-scheme. It is based on a Kessler-type bulk formulation and uses a specific grouping of various cloud and precipitation particles into broad categories of water substance. The particles in these categories interact by various microphysical processes which in turn have feedbacks with the overall thermodynamics. Microphysical processes are parameterized by corresponding mass transfer rates between the categories and are formulated in terms of the mixing ratios as the dependent model variables.

Besides water vapour in the gaseous phase three categories of water are considered by the default scheme:

- *cloud water* is in the form of small suspended liquid-phase drops. Cloud droplets are smaller than about 50 μm in radius and thus have no appreciable terminal fall speed relative to the airflow.
- *rain water* is in the form of liquid-phase spherical drops which are large enough to have a non-negligible fall velocity. An exponential Marshall-Palmer size-distribution is assumed for the raindrops and a drop terminal velocity depending only on drop diameter is prescribed.
- *Snow* is made up of large rimed ice particles and rimed aggregates which are treated as thin plates with a specific size-mass relation. Particles in this category have a non-negligible terminal velocity which is prescribed to depend only on particle size. An exponential Gunn-Marshall size-distribution is assumed.

The budget equation for the specific water contents q of the various categories (water vapour q^v, cloud water q^c, cloud ice q^i and graupel q^g, depending on the scheme used) take advective and turbulent transport into account and contain source and sink terms due to the microphysical processes of cloud and precipitation formation. For rain water q^r and snow q^s, only advective transport is considered. The following mass-transfer rates are considered by the scheme:

(a) condensation and evaporation of cloud water,

(b) the initial formation of rainwater by autoconversion and of snow by nucleation from the cloud water phase,

(c) the subsequent growth of the precipitation phases rain and snow by accretion, riming, deposition and shedding,

(d) evaporation of rainwater and sublimation of snow in subcloud layers and

(e) melting of snow to form rain and freezing of rain to form snow.

The impact of the vertical motion of rain and snow relative to the airflow due to the sedimentation of particles with their terminal velocities is also taken into account by the vertical divergence of the corresponding precipitation fluxes P_r and P_s. Figure 3.5 illustrates the microphysical processes considered by this parameterization scheme.

In contrast to the former diagnostic precipitation scheme with its assumption of column equilibrium for the precipitating particles, we now solve the complete prognostic equations

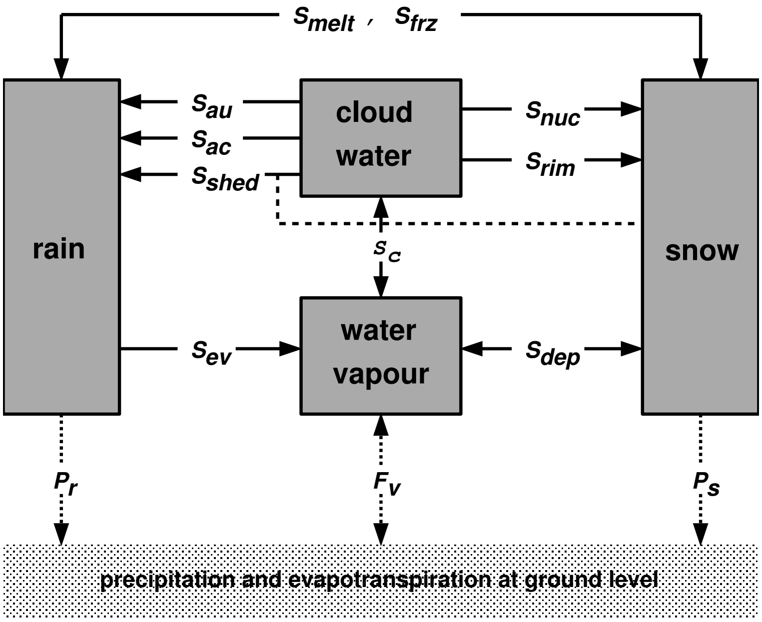


Figure 3.5: Hydrological cycle in the COSMO-Model cloud and precipitation scheme

for rain q^r and and snow q^s This approach is therefore applicable to the meso-γ and smaller scales.

These options are available for the microphysics parameterization scheme:

(a) `itype_gscp=1`: A *warm rain scheme* which is similar to the original Kessler (1969) scheme; all ice-phase processes are ignored.

(b) `itype_gscp=2`: The basic scheme described above.

(c) `itype_gscp=3`: An extension of the basic scheme which includes cloud ice as an additional prognostic variable (*cloud ice scheme*). The scheme allows for an explicit representation of ice clouds and a more complete simulation of precipitation formation in mixed phase clouds. This scheme is used in the COSMO-EU.

(d) `itype_gscp=4`: A graupel-scheme (in addition to cloud-ice) has been implemented recently. It allows for an explicit simulation of deep convective clouds. This is available only as a prognostic scheme. This scheme is used in the COSMO-DE.

The use of `itype_gscp=1/2` is not recommended for real cases. They are only used in idealized test cases.

3.5.3 Moist Convection

Basic Namelist settings: `lphys=.TRUE.; lconv=.TRUE.`

For model applications on the meso-α and meso-β scales down to grid spacings of 5-10 km, cumulus convection is a subgrid-scale process which requires a parameterized representation. And even on the meso-γ scale it turned out, that a parameterization of shallow convection still is necessary. The COSMO-Model offers three options:

(a) Mass flux Tiedtke scheme
Basic Namelist settings: `itype_conv=0`
The mass flux scheme of Tiedtke (1989), which is used in coarser grid applications (above 3 km), has been implemented for the meso-α and meso-β scale. This parameterization discriminates three types of moist convection: *shallow convection*, *penetrative convection* and *midlevel convection*, which are treated by different closure conditions. Both shallow and penetrative convection have their roots in the atmospheric boundary layer but they differ in vertical extent. Midlevel convection, on the other hand, has its roots not in the boundary layer but originates at levels within the free atmosphere.

As a closure condition, the Tiedtke scheme requires a formulation of the vertical mass flux at the convective cloud base in terms of the grid-scale variables. For shallow and penetrative convection, it is assumed that this mass flux is proportional to the vertically integrated moisture convergence between the surface and the cloud base. In case of midlevel convection, the mass flux is simply set proportional to the grid-scale vertical velocity.

Given the mass flux at cloud base, the vertical redistribution of heat, moisture and momentum as well as the formation of precipitation is then calculated by integrating a simple stationary cloud model for both updrafts and downdrafts. This finally allows to compute the convective tendencies, i.e. the feedback of the subgrid vertical circulation onto the resolved flow. The downdrafts are assumed to originate at the level of free sinking. As an additional closure condition, the downdraft mass flux in this level is set proportional to the updraft mass flux at cloud base via a coefficient γ_d, which is a disposable parameter. In the present version of the scheme γ_d is set to a constant value of 0.3. In subsaturated regions below cloud base, the precipitation in the downdrafts may evaporate with a parameterized rate. Depending on the temperature of the lowest model layer, the precipitation is interpreted as convective snow or rain.

The parameterization scheme is numerically very expensive. Thus, a timestep number increment can be specified for which the convection scheme is called. The convective tendencies are then stored and remain fixed for the following time steps.

(b) A scheme for shallow convection
Basic Namelist settings: `itype_conv=3`
This scheme has been extracted from the Tiedtke scheme and can be used for the *convection permitting* scales. It is applied for the COSMO-DE.

Fractional Cloud Cover

In the parameterization schemes for grid-scale clouds and precipitation the condensation rate for cloud water is based on saturation equilibrium with respect to water. Consequently, a grid element is either fully filled with clouds at water saturation where $q^c > 0$ (relative humidity $= 100\%$) or it is cloud free at water subsaturation where $q^c = 0$ (relative humidity $< 100\%$). The area fraction of a grid element covered with grid-scale clouds is thus a bivalued parameter which is either 1 or 0.

However, with respect to the calculation of radiative transfer but also for weather interpretation in postprocessing routines, it is useful to define a fractional cloud cover also for those grid boxes where the relative humidity is less than 100% and no grid-scale cloud water exists. The calculation of the fractional cloud cover σ_c in each model layer is calculated based on a traditional scheme which has been used in the former operational hydrostatic models

EM/DM. σ_c is determined by an empirical function depending on the relative humidity, the height of the model layer and the convective activity. In addition to the EM/DM scheme, the contribution of convection to σ_c is assumed to depend on the vertical extent of the convection cell by prescribing a heuristic function. Also, a check for temperature inversions at the convective cloud tops is done to take anvils by an increase of σ_c in case of inversions into account.

3.5.4 Vertical Turbulent Diffusion

Basic Namelist settings: `lphys=.TRUE.; ltur=.TRUE.`

For vertical turbulent diffusion, several schemes are available:

a) 1-D diagnostic closure:
Basic Namelist settings: `itype_turb=1; l3dturb=.FALSE.`
In the original EM/DM scheme, the vertical diffusion due to turbulent transport in the atmosphere is parameterized by a second-order closure scheme at hierarchy level 2.0 (Mellor and Yamada (1974); Müller (1981)). This results in a diagnostic closure where the turbulent diffusion coefficients are calculated in terms of the stability of the thermal stratification and the vertical wind shear. The impact of subgrid-scale effects on the heat and moisture fluxes due to condensation and evaporation of cloud water is not taken into account.

b) 1-D TKE based diagnostic closure:
Basic Namelist settings: `itype_turb=3; l3dturb=.FALSE.`
For the COSMO-Model, a new scheme has been developed, which is based on a prognostic equation for turbulent kinetic energy (TKE), that is a level 2.5 closure scheme. The new scheme includes the transition of turbulence which contributes mainly to the fluxes (diffusive turbulence) to very small scale (dissipative) turbulence by the action of small scale roughness elements, and the handling of non-local vertical diffusion due to the boundary layer scale turbulence. Most important seems to be the introduction of a parameterization of the pressure transport term in the TKE-equation, that accounts for TKE-production by subgrid thermal circulations. The whole scheme is formulated in conservative thermodynamic variables together with a statistical cloud scheme according to Sommeria and Deardorff (1977) in order to consider subgrid-scale condensation effects.

c) 3-D closure:
Basic Namelist settings: `itype_turb=5/7; l3dturb=.TRUE.`
The parameterization of subgrid-scale turbulent processes, also called a subgrid-scale (SGS) model, is of particular meaning for highly resolved LES-like model simulations. For resolutions reaching to the kilometer-scale, a more adequate turbulence parameterization scheme should be used. For both versions described above, there is the possibility to use a 3-D closure scheme. Up to now, this has been implemented into the COSMO-Model only for testing purposes.

COSMO-EU and COSMO-DE use the 1-D TKE based closure scheme.

3.5.5 Parameterization of Surface Fluxes

Basic Namelist settings: `lphys=.TRUE.; ltur=.TRUE.`

Mesoscale numerical modelling is often very sensitive to surface fluxes of momentum, heat and moisture. These fluxes provide a coupling between the atmospheric part of the model and the soil model. For both closure schemes described in Sec. 3.5.4, a special surface layer scheme can be applied.

a) A bulk-transfer scheme:
Basic Namelist settings: `itype_tran=1`
For the 1-D diagnostic turbulence scheme, a stability and roughness-length dependent surface flux formulation based on Louis (1979) is implemented.

b) A TKE-based surface transfer scheme:
Basic Namelist settings: `itype_tran=2`
In context with the TKE-scheme, a revised and consistent formulation for the transport through the surface layer should be used. This surface scheme extends the TKE-equation to the constant flux layer and introduces an additional laminar layer just above the surface. This makes it possible to discriminate between the values of the model variables at the rigid surface (e.g. radiative surface temperatures) and values at the roughness height z_0 (lower boundary of the turbulent atmosphere). The Charnock formula to estimate the surface fluxes over sea is also reformulated using TKE.

COSMO-EU and COSMO-DE use the TKE based surface transfer scheme.

3.5.6 A subgrid-scale orography scheme

Basic Namelist settings: `lphys=.TRUE.; lsso=.TRUE.`

3.5.7 Soil Processes

Basic Namelist settings: `lphys=.TRUE.; lsoil=.TRUE.`

The calculation of the surface fluxes requires the knowledge of the temperature and the specific humidity at the ground. The task of the soil model is to predict these quantities by the simultaneous solution of a separate set of equations which describes various thermal and hydrological processes within the soil. If vegetation is considered explicitly, additional exchange processes between plants, ground and air have to be taken into account.

a) The soil model TERRA:
Basic Namelist settings: `lmulti_layer=.FALSE.`
For land surfaces, the soil model TERRA provides the surface temperature and the specific humidity at the ground. The ground temperature is calculated by the equation of heat conduction which is solved in an optimized two-layer model using the extended force-restore method (Jacobsen and Heise (1982)). The soil water content is predicted for two or three layers by the Richards equation. Evaporation from bare land surfaces

as well as transpiration by plants are derived as functions of the water content, and - only for transpiration - of radiation and ambient temperature.

Most parameters of the soil model (heat capacity, water storage capacity, etc.) strongly depend on soil texture. Five different types are distinguished: sand, sandy loam, loam, loamy clay and clay. Three special soil types are considered additionally: ice, rock and peat. Hydrological processes in the ground are not considered for ice and rock. Potential evaporation, however, is assumed to occur over ice, where the soil water content remains unchanged.

In the default configuration the thicknesses of the upper and lower thermal layers are taken to be 9 cm and 32 cm, respectively, and two layers of 10 cm and 90 cm depth are used for the hydrological calculations. Below these soil layers climatological values for temperature and soil moisture are prescribed. The soil model is run for all gridpoints with a land fraction larger or equal than 50%. All other gridpoints are treated as sea points with an initial surface temperature which remains constant throughout a model run. For operational applications, the sea surface temperature is provided by an external analysis scheme.

b) The multi-layer soil model TERRA_ML:
Basic Namelist settings: `lmulti_layer=.TRUE.`
Recently, the multi-layer version (TERRA_ML) of the soil model has been implemented in the COSMO-Model as an option. The main differences of this version in comparison to the older version (TERRA) are:

- The EFR-method for the temperature prediction is replaced by a direct solution of the heat conduction equation.
- The effect of freezing/melting of soil water/ice is included.
- The process of snow melting is changed.
- A time dependent snow albedo is introduced.

The multi-layer concept avoids the dependence of layer thicknesses on the soil type. Additionally it avoids the use of different layer structures for the thermal and the hydrological sections of the model.

c) The lake model FLake:
Basic Namelist settings: `lsoil=.TRUE.; llake=.TRUE.`
FLake (Fresh-water Lake), is a lake model (parameterisation scheme) capable of predicting the surface temperature in lakes of various depth on the time scales from a few hours to many years (see `http://lakemodel.net` for references and other information about FLake). It is based on a two-layer parametric representation (assumed shape) of the evolving temperature profile and on the integral budgets of heat and kinetic energy for the layers in question. The same concept is used to describe the temperature structure of the ice cover. An entrainment equation is used to compute the depth of a convectively-mixed layer, and a relaxation-type equation is used to compute the wind-mixed layer depth in stable and neutral stratification. Both mixing regimes are treated with due regard for the volumetric character of solar radiation heating. Simple thermodynamic arguments are invoked to develop the evolution equation for the ice thickness. The result is a computationally efficient bulk model that incorporates much of the essential physics. Importantly, FLake does not require re-tuning, i.e. empirical

constants and parameters of FLake should not be re-evaluated when the model is applied to a particular lake. There are, of course, lake-specific external parameters, such as depth to the bottom and optical properties of water, but these are not part of the model physics.

Using the integral approach, the problem of solving partial differential equations (in depth and time) for the temperature and turbulence quantities is reduced to solving ordinary differential equations for the time-dependent quantities that specify the temperature profile. FLake carries the equations for the mean temperature of the water column, for the mixed-layer temperature and its depth, for the temperature at the lake bottom, and for the shape factor with respect to the temperature profile in the lake thermocline (a stably stratified layer between the bottom of the mixed layer and the lake bottom). In case the lake is cover by ice, additional equations are carried for the ice depth and for the ice-surface temperature. The lake-surface temperature, i.e. the quantity that communicates information between the lake and the atmosphere, is equal to either the mixed-layer temperature or, in case the lake in question is covered by ice, to the ice-surface temperature. In the present configuration (a recommended choice), the heat flux through the lake water-bottom sediment interface is set to zero and a layer of snow over the lake ice is not considered explicitly. The effect of snow above the ice is accounted for parametrically through changes in the surface albedo with respect to solar radiation. Optionally, the bottom-sediment module and the snow module can be switched on. Then, additional equations are carried for the snow-surface temperature (temperature at the air-snow interface), for the snow depth, for the temperature at the bottom of the upper layer of bottom sediments penetrated by the thermal wave, and for the depth of that layer. Surface fluxes of momentum and of sensible and latent heat are computed with the operational COSMO-model surface-layer parameterization scheme. Optionally, a new surface-layer scheme can be used that accounts for specific features of the surface air layer over lakes.

In order to be used within the COSMO model (or within any other NWP or climate model), FLake requires a number of two-dimensional external-parameter fields. These are, first of all, the fields of lake fraction (area fraction of a given numerical-model grid box covered by lake water that must be compatible with the land-sea mask used) and of lake depth. Other external parameters, e.g. optical characteristics of the lake water, are assigned their default values offered by FLake. Since no tile approach is used in the COSMO model, i.e. each COSMO-model grid box is characterised by a single land-cover type, only the grid boxes with the lake fraction in excess of 0.5 are treated as lakes. Each lake is characterised by its mean depth. Deep lakes are currently treated with the *false bottom*. That is, an artificial lake bottom is set at a depth of 50 m. The use of such expedient is justified since, strictly speaking, FLake is not suitable for deep lakes (because of the assumption that the thermocline extends down to the lake bottom). However, as the deep abyssal zones typically experience no appreciable temperature changes, using the false bottom produces satisfactory results. A Global Land Cover Characterization (GLCC) data set (`http://edcdaac.usgs.gov/glcc`) with 30 arc sec resolution, that is about 1 km at the equator, is used to generate the lake-fraction filed. The filed of lake depth is generated on the basis of a data set (developed at DWD) that contains mean depths of a number of European lakes and of major lakes of the other parts of the world. Notice that, unless tile approach is used to compute the surface fluxes, only the lake-depth external parameter filed is actually required to use FLake within the COSMO model. Setting the lake depth to its actual value for the COSO-model grid boxes with the lake fraction in excess of 0.5, and to a negative value, say $-1m$, otherwise, unambiguously specifies the grid-boxes for which the lake-surface temperature should be computed.

d) A sea-ice scheme:
Basic Namelist settings: `lsoil=.TRUE., lseaice=.TRUE.`
The presence of sea ice on the oceans surface has a significant impact on the air-sea interactions. Compared to an open water surface the sea ice completely changes the surface characteristics in terms of albedo and roughness, and therefore substantially changes the surface radiative balance and the turbulent exchange of momentum, heat and moisture between air and sea. In order to deal with these processes the COSMO model includes a sea ice scheme (Mironov (2008)).

COSMO-EU and COSMO-DE use the multi-layer soil model and the FLake-Model. The sea-ice scheme is only used in COSMO-EU.

3.6 Data Assimilation

Basic Namelist setting: `luseobs=.TRUE.`

The requirements for the data assimilation system for the operational model are mainly determined by the very high resolution of the model and by the task to employ it also for very short-range forecasting. Hence, detailed high-resolution analyses of the atmosphere have to be able to be produced frequently, and this requires a thorough use of asynoptic and high-frequency observations such as aircraft data and remote sensing data. Note that the synoptic scales are largely determined by the lateral boundary conditions provided by the driving model, and the main purpose of the assimilation scheme is to analyze the meso scales.

By design, 3-dimensional analysis methods tend to be less appropriate for this purpose. They do not allow to account for the exact observation time of asynoptic data, and they make it necessary to neglect most of the high-frequent data unless the analysis scheme is applied very frequently at significant computational costs. Moreover, the geostrophic approximation, a key ingredient of some of these schemes as used e.g. for the GME, is of limited validity on the meso scale. Therefore, 4-dimensional methods offer potential advantages since they include the model dynamics in the assimilation process directly. However, the 4-dimensional variational (4DVAR) method has been too expensive in the past for operational application considering the small amount of time available to produce the analyses and forecasts.

a) Observation Nudging —— Basic Namelist setting: `lnudge=.TRUE.`

Therefore, a scheme based on the observation nudging technique has been developed to define the atmospheric fields. It is based on an experimental nudging assimilation scheme which had been developed for the former hydrostatic model DM and its Swiss version SM (Schraff (1996); Schraff (1997)) and which compared favorably with the at that time operational Optimum Interpolation analysis of DM in a number of test cases. The scheme for COSMO has then been adapted to the nonhydrostatic modelling framework and runs on distributed memory machines using domain decomposition.

Nudging or Newtonian relaxation consists of relaxing the prognostic model variables towards prescribed values within a predetermined time window (see e.g. Davies and

Turner (1977); Stauffer and Seaman (1990)). In the present scheme, nudging is performed towards direct observations which is more appropriate for high-resolution applications than nudging towards 3-dimensional analyses (Stauffer and Seaman (1994)). A relaxation term is introduced into the model equations, and the tendency for a prognostic variable $\psi(\mathbf{x}, t)$ is given by

$$\frac{\partial}{\partial t}\psi(\mathbf{x},t) \quad = \quad F(\boldsymbol{\psi},\mathbf{x},t) \quad + \quad G_\psi \cdot \sum_{k_{(obs)}} W_k \cdot [\psi_k - \psi(\mathbf{x}_k,t)] \tag{3.14}$$

F denotes the model dynamics and physical parameterizations, ψ_k the value of the k^{th} observation influencing the grid point $\mathbf{x}$ at time t, $\mathbf{x}_k$ the observation location, G_ψ the constant so-called nudging coefficient, and W_k an observation-dependent weight which usually varies between 0 and 1. Neglecting the dynamics and physics and assuming a single observation with a constant weight W_k equal 1, the model value at the observation location relaxes exponentially towards the observed value with an e-folding decay rate of $1/G_\psi$ corresponding to about half an hour. The observational information is provided to the nudging scheme in the form of NetCDF observation input files which are described in Section 6.4.

In practical applications, the nudging term usually remains smaller than the largest term of the dynamics so that the dynamic balance of the model is not strongly disturbed. The coupling between the mass and wind field innovations is primarily induced implicitly by the model dynamics. If the assimilation process is successful the model fields will be close to dynamic balance at the beginning of the forecast, and an initialization step is not required.

b) Latent Heat Nudging —— Basic Namelist setting: `llhn=.TRUE.`

Radar-derived precipitation rates can be assimilated by an extra Latent Heat Nudging scheme (Stephan et al. (2008)). It computes additional temperature and humidity increments at each model column independently from each other. It is tuned and should be used only for convection-permitting model configurations (with horizontal mesh widths of $\leq 3\,\text{km}$). The observation input is gridded precipitation rates read in the form of extra Grib files. Further Grib files can be read optionally, containing a blacklist, and radar beam height maps utilised for bright band detection.

c) Analysis of surface and soil fields, outside COSMO code

In addition to the nudging-type assimilation schemes for the atmosphere, a set of 2-dimensional intermittent analysis schemes can be applied for some of the surface and soil fields in a full data assimilation cycle for the COSMO model. This comprises of a variational soil moisture analysis (Hess (2001)), a snow analysis, and a sea surface temperature (SST) analysis (including an analysis of sea ice cover). These analysis schemes are not integrated into the COSMO code, but are programs on their own. Therefore, they are not covered by this User's Guide, even though a scientific description or outline of them is included in the COSMO Documentation Part III on data assimilation.

d) Diagnostic surface analyses —— Basic Namelist setting: `lsurfa=.TRUE.`

In contrast, the data assimilation code of the COSMO model includes a module with a Cressman-type successive correction analysis scheme, which can be used to compute a set of other 2-dimensional surface-level analyses. This set comprises of a 2-m temperature, 2-m relative humidity, 10-m wind speed, and surface precipitation analysis.

While the precipitation analysis is purely based on rain gauge (surface synoptic) data, the other analyses use the corresponding model field as a first guess purely to help defining the small-scale details that are not resolved by the surface observations. All these analyses are used only for diagnostic purposes. As an exception, the daytime 2-m temperature and optionally 2-m humidity analyses are used in the variational soil moisture analysis.

Section 4

Installation of the COSMO-Model

This chapter explains the steps necessary to compile and run the model. Section 4.1 lists the external libraries that are necessary to run different components of the model and what can be done, if these libraries are not available. The next sections give detailed informations on how to prepare, compile, link and run the COSMO-Model.

4.1 External Libraries for the COSMO-Model

For some components, the COSMO-Model uses external libraries. Usage of most of these libraries can be controlled by conditional compilation. To handle this, the C preprocessor (cpp) must be called. Most Fortran compilers activate the C preprocessor for files ending with a capital `F` in the suffix: `.F` or `.F90`. The COSMO-Model does not use capital letters in the suffix, therefore a special compiler option has to be set, to activate this preprocessor. Take a look to the manual of your compiler to find out about this option.

4.1.1 `libgrib1.a`:

The original implementation of INT2LM and the COSMO-Model used GRIB (Grided Binary), Version 1, as standard format. Coding and decoding of GRIB1 records can be done with the DWD GRIB1 library, the **`libgrib1.a`**. This library also contains C-routines to write data to and read it from disk. The Grib library is available from DWD and is provided together with the source code for the COSMO-Model. A short guide for the installation is included in the tar-file of the Grib library.

With GRIB1, DWD used a Grib file format, where all records are starting and ending with additional bytes, the so-called *controlwords*. To process these controlwords properly, you have to set the environment variable

```
export LIBDWD_FORCE_CONTROLWORDS=1
```

Usage of the DWD GRIB1 library can be controlled by conditional compilation and setting the macro `GRIBDWD`. If this macro is not set during compilation, the parts of the source code that do use `libgrib1.a` calls are not compiled and the library will not be linked to the binary.

4.1.2 `libgrib_api.a, libgrib_api_f90.a:`

Since Version 4.28 another grib library can be used to read grib data. This is the `grib_api` (Application Programmer's Interface) from ECMWF. With this library it is possible to read and write also GRIB2 data (i.e. GRIB, Version 2). To use grib_api properly, two sets of definition files are necessary for running the programs: one contains all original definitions from ECMWF (`definitions`), the other set is compiled and maintained by DWD and must be used for the INT2LM and the COSMO-Model (`definitions.edzw`). Also, some special sample files are needed by both programs.

The grib_api source code is available from the ECMWF web pages `http://www.ecmwf.int`. Both sets of definition files and the necessary samples, which have to correspond to the grib_api version used, are distributed together with the INT2LM by DWD. For INT2LM and the COSMO-Model, grib_api Version 1.11.0 or higher is required to read GRIB2 data. For writing GRIB2 data, grib_api Version 1.13.1 is required.

Please read more on grib_api and its usage in the Section on *Data Formats for I/O* in the COSMO-Model User Guide.

Usage of the grib_api library can be controlled by conditional compilation and setting the macro `GRIBAPI`. If this macro is not set during compilation, the parts of the source code that do use grib_api calls are not compiled and the library will not be linked to the binary.

4.1.3 `libnetcdf.a:`

Since Version 3.18, input and output of data can also be done in the NetCDF format (Network Common Data Format). Using NetCDF requires an external library `libnetcdf.a`. The source code of this library can be downloaded from `http://www.unidata.ucar.edu` .

Usage of the NetCDF library can be controlled by conditional compilation and setting the macro `NETCDF`. If this macro is not set during compilation, the parts of the source code that do use NetCDF calls are not compiled and the library will not be linked to the binary.

NOTE:
The usage of NetCDF can only be avoided, if also the Nudging is switched off. If Nudging (the data assimilation) shall be used, a NetCDF library has to be available, because the observation processing is done via NetCDF.

4.1.4 `libmisc.a:`

Before Version 4.24 of the COSMO-Model, a library `libmisc.a` was needed for special applications in the data assimilation (the nudging). Since version 4.24 this library is not necessary any more.

4.1.5 `libcsobank.a`, `libsupplement.a`:

Before COSMO-Model 4.25 and INT2LM 2.1

The COSMO-Model and INT2LM use a tool for parallel asynchronous I/O from or to files or a data base system (only for Grib). The routines for that tool are grouped together in a module `mpe_io.f90`. In the VCS of DWD, `mpe_io.f90` is provided as an external module, hence it is not in the source code of the model library. `mpe_io.f90` uses the two libraries `libcsobank.a` and `libsupplement.a`.

For users outside DWD, `mpe_io.f90` has been included in the source code of the COSMO-Model and also in the INT2LM. To satisfy the calls from `mpe_io` to the data base system, an additional file `dummy_db.f90` is provided.

- NEW:
  Since COSMO-Model Version 4.25 and INT2LM Version 2.1, `mpe_io.f90` has been replaced by a modified version `mpe_io2.f90`, which does not support the database access any more. Therefore the usage of these external libraries is now obsolete.

4.1.6 `libRTTOVxx.a`:

Since Version 3.7 the COSMO-Model contains an interface to the RTTOV7-library (Radiative Transfer Model). This interface has been developed at the DLR Institute for Atmospheric Physics in Oberpfaffenhofen. Together with the RTTOV7-library it is possible to compute *synthetic* satellite images (brightness temperatures and radiances) derived from model variables for Meteosat5-7 and Meteosat Second Generation.

Since Version 4.18, also the use of newer RTTOV-libraries (namely RTTOV9) is possible.

The RTTOV model has been developed by UKMO et.al. in the framework of the ESA NWP-SAF. To use any version of the RTTOV model, a license is necessary. For getting this license, please contact `nwpsaf@metoffice.gov.uk`.

Usage of the RTTOV libraries can be controlled by conditional compilation and setting one of the macros `RTTOV7`, `RTTOV9` or `RTTOV10`. Note that RTTOV7 has been modified at DWD to be used in parallel programs. For the usage or RTTOV9 (and also RTTOV10), a special interface `mo_rttov_ifc.f90` is necessary, which can also be obtained from DWD.

If the license (and hence the RTTOV libraries) is not available, the corresponding macros must not be set. The computation of the synthetic satellite images is not possible then.

4.2 Preparing the Code

You have got a tar-file `cosmo_yymmdd_x.y`, where `yymmdd` describes the date in the form "Year-Month-Day" and `x.y` gives the version number. By de-taring, a directory is created with the following contents:

`DOCS`	Contains a short documentation of the changes in version `x`.
`edid`	Script to edit files in `src` and store them in `work`.
`Fopts`	Definition of the compiler options and also directories of libraries.
`LOCAL`	Contains several examples of `Fopts`-files for different computers.
`Makefile`	For compiling and linking the programs.
`RUNSCRIPTS`	Several examples of scripts (`run_cosmo_xx` or `run_ideal_xx`) to set the Namelist values for a configuration xx or for idealized test cases and start the program.
`src`	Subdirectory for the source code.
`obj`	Subdirectory where the object files are written.
`ObjDependencies`	Definition of the dependencies between the different source files.
`Objfiles`	Definition of the object files.
`work`	Subdirectory for intermediate files.

The directories `./obj` and `./work` are empty and can therefore get lost by the tar-process. If so, you have to create them again. In `edid` you have to adapt the pathnames if you want to work with it.

4.3 Compiling and Linking

Before compiling and linking the program you should check and, if necessary, adapt the `KIND`-type parameter `wp` in the module `kind_parameters.f90`. This parameter can either be set to `sp` (for single precision) or to `dp` for double precision (default).

You have to choose the options for compiling the code in `Fopts`. See the User Guide of your computer system for necessary and/or desired options. In particular you have to set the macros to select external libraries. Since COSMO-Model Version 5.1 you definitely have to set the macro `-D__COSMO__`! Before linking check that all necessary external libraries (see 4.1) are available.

All other input variables for the program can be determined before running the program with the `NAMELIST`-input (see Chapter 7).

The COSMO-Model is parallelized for distributed memory parallel computers using the domain decomposition technique and explicit message passing with the Message Passing Interface (MPI). Thus it can run on parallel platforms but also on sequential platforms where MPI is not available. For this purpose an additional module `dummy_mpi.f90`, together with a file `mpif.h`, are provided in the directory `LOCAL`. Place these files in the `src`-directory before compiling and linking. Then you can only create `sequential` binaries (see below).

You can invoke a `make`-run by typing `make` *entry*. The following *entries* are available. Note that the special *entry* has to correspond to the settings of the macros. `seq` or `par` correspond to the sequential or parallel mode, resp.

`pur[par|seq]` A pure binary without nudging and synthetic satellite images. `-DNUDGING`, `-DRTTOVx` and `-DNETCDF` must not be set.

`all[par|seq]` A full binary with nudging and synthetic satellite images, if `-DNUDGING`, `-DNETCDF` and `-DRTTOVx` are set.

`nud[par|seq]` A binary with nudging but without synthetic satellite images. `-DNUDGING` and `-DNETCDF` must be set and `-DRTTOVx` must not be set.

`sat[par|seq]` A binary without nudging but with synthetic satellite images. `-DNUDGING` must not be set and `-DRTTOVx` must be set.

More *entries* can be added on your own.

4.4 Running the Code

To run the code, several ASCII-files `INPUT_***` have to be provided that contain values for the `NAMELIST` variables. The form of these `INPUT_***` files is described in Chapters 6 and 7. They are created by the provided run-scripts.

The run-scripts also contain the command to invoke the binary, which you have to adapt. While a sequential binary usually can be invoked just by typing `<name_of_binary>`, a parallel binary must be invoked by a special tool. Often this tool is `mpirun`, but also other tools are possible. See the manual for your system on how to invoke the binary created in the last step.

Section 5

Data Formats for I/O

All input and output fields of the COSMO-Model and the preprocessor program providing interpolated initial and boundary conditions can be stored in GRIB or in NetCDF format. Restart files are always written in pure binary format. The basic namelist settings to control the format are `yform_read=`*string* and `yform_write=`*string*, where *string* can be either `'grb1'` or `'ncdf'` for reading and writing. Since the implementation of `grib_api` (see below), *string* can also be `'apix'` for reading and `'api1'`, `'api2'` for writing. The same values are possible for corresponding namelist variables in the INT2LM.

The next sections explain the GRIB (Edition 1 and 2) and NetCDF format in more detail, but without claiming to be a full reference hand book. Therefore we refer also to the original documentation of these formats. The last section 5.2 of this chapter will highlight some practical differences between GRIB1 and GRIB2 and their consequences for running INT2LM and the COSMO-Model.

5.1 The GRIB Binary Data Format

GRIB is designed for the international exchange of processed data in the form of grid-point values expressed in binary form. The GRIB-code is part of the FM-system of binary codes of the World Meteorological Organization (WMO). For coding details, see the *Manual on Codes, International Codes, Volume 1.2* of WMO (WMO Publication No. 306). In this section, we describe only the basic features of the GRIB code which are relevant for the I/O of the COSMO-system.

Each GRIB-coded record (analysis or forecast field) consists of a continuous bit-stream which is made up of a sequence of octets (1 octet = 8 bits). The representation of data by means of series of bits is independent of any particular machine representation. The COSMO-Model can read and write two flavors of GRIB, namely Edition 1 and Edition 2. Note that Edition 2 is fully implemented only since INT2LM 2.02 and COSMO-Model 5.03.

To deal with GRIB2, the application programmers interface, `grib_api`, from ECMWF has been implemented into INT2LM and the COSMO-Model. The approach, how data is coded to / decoded from GRIB messages is different than in the DWD GRIB1 library. While the GRIB1 library provides interfaces to code / decode the full GRIB message in one step, the `grib_api` uses a *key / value* approach to write or read single meta data. Each meta datum, called a key, has a special name. Values for the keys can be read or written by special `grib_api` commands. Please refer to the `grib_api` manual for further information.

5.1.1 GRIB Edition 1

For Edition 1, GRIB means ”gridded binary”. The octets of a GRIB 1 message are grouped in sections (see Table 5.1), where the length of the record and the length of the sections are expressed in octets. Section 0 has a fixed length of 8 octets and Section 5 has a fixed length of 4 octets. Sections 1, 2, 3 and 4 have a variable length which is included in the first three octets of each section.

Code Structure

Table 5.1: *Form of GRIB1-code*

Section number	**Name**	**Contents**
0	Indicator Section	”GRIB”; length of record; GRIB edition number
1	Product Definition Section	Length of section; identification of the coded analysis/forecast field
2	Grid Description Section (optional)	Length of section; grid geometry, as necessary
3	Bit-map Section (optional)	Length of section; the bit per grid-point, placed in suitable sequence
4	Binary Data Section	Length of section; data values
5	End Section	7777

Octets are numbered 1, 2, 3, etc., starting at the beginning of each section. Bit positions within octets are referred to as bit 1 to 8, where bit 1 is the most significant bit and bit 8 is the least significant bit, as in big endian UNIX computers. Thus, an octet with only bit 8 set to 1 would have the integer value 1.

Indicator and End Section

The Indicator Section has a fixed length of 8 octets. The first four octets shall always be character coded in a human readable form as ”GRIB” (according to the CCITT International Alphabet No. 5). The remainder of the section shall contain the length of the entire GRIB-record (including the Indicator Section) expressed in binary form over the left-most 3 octets (i.e. 24 bits in octet 5-7), followed by the GRIB edition number (here: 1), in binary, in the remaining octet 8. Note that the length of GRIB1 records therefore is limited to a value of $2^{24} - 1 = 16777215$ bytes! The End Section has a fixed length of 4 octets. These octets are character coded as ”7777” according to the International Alphabet No. 5.

Thus, the beginning and the end of a GRIB-record can be identified by the character coded words "GRIB" and "7777". All other octets included in the code represent data in binary form. Each input or output array defined on the rotated lat/lon grid of the COSMO-model (e.g the surface pressure or the temperature at a specified model level) is coded as a GRIB-record. Various records can be combined in a single GRIB-file.

Product Definition Section

The Product Definition Section (PDS) contains the necessary information to identify the binary coded field contained in the GRIB1-record. The most important octet in this section is the indicator of the meteorological parameter. The indicator relates a specific meteorological element to an integer number. This indicator number is also referred to as *GRIB-number* or *element-number* and is defined in a separate code table. More than one indicator code tables may be used in GRIB1-code. Thus, one can have the same element-number but different code table numbers for various fields. Every I/O-field of the COSMO-Model is uniquelly mapped to a pair of numbers *(element number, code table)*. These numbers are coded in the COSMO module `src_setup_vartab.f90`.

The program `grbin1` of the supplementary GRIB1-library `libgrib1` can be used to decode GRIB1 binary code. Besides the decoded data set, this program does also retrieve the contents of the octets of the PDS in an integer array `ipds`. To illustrate the structure of the PDS, Table 5.6 shows the contents of the product definition section of a binary coded output array, the total cloud cover (CLCT). The GRIB1-record for this field is valid for 28.10.1998 00 UTC + 11 h and was created at 28.10.1998 7.04 UTC by a forecast of the COSMO-Model.

Octet 4 (ipds(2)) assigns a table number to the parameter indicator number given in octet 9. Besides the official WMO table 2, we use some additional local tables, 201 to 205. A full list of variables defined by these tables is available from DWD.

Octet 6 (ipds(4)) indicates the generating process identification number which is allocated by the originating centre. The process numbers used for the COSMO applications at DWD are shown in Table 5.2. At DWD this number is strongly connected to the data base system, because it also specifies the different application and whether it is a forecast or an analysis.

Table 5.2: *Process identification numbers*

process id-number; ipds(4)	**Comment**
131	Analyses from data assimilation cycle for former model domain
132	Forecasts and initialized analyses for former model domain
134	Analyses from data assimilation cycle for COSMO_EU
135	Forecasts and initialized analyses for COSMO_EU
137	Analyses from data assimilation cycle for COSMO_DE
138	Forecasts and initialized analyses for COSMO_DE

The level or layer for which the data are included in the GRIB1-record is coded in octets 10 - 12 (ipds(8) - ipds(9)), where octet 10 indicates the type of level and octets 11 and 12 indicate the value of this level. Table 5.3 shows the level types used for the COSMO-Model. For reserved values, or if not defined, octets 11 and 12 shall contain zero.

Table 5.3: *Types of fixed levels or layers used by the COSMO-Model*

level type ipds(8)	**Meaning**	**ipds(9)**	**ipds(10)**
1	Ground or water surface	0	0
2	Cloud base level	0	0
3	Level of cloud tops	0	0
4	Level of $0°C$ isotherm	0	0
8	Top of atmosphere	0	0
100	Pressure (isobaric) level	0	Pressure in hPa
102	Mean sea level	0	0
103	Specified height above mean sea level	0	Height in m
105	Specified height level above ground	0	Height in m
109	Hybrid level (half levels)	0	Level number (k)
110	Hybrid layer (main level) between two hybrid levels	Level number of top (k)	Level number of bottom (k+1)
111	Depth below land surface	0	Depth in cm
112	Layer between two depths below land surface	Depth of upper surface in cm	Depth of lower surface in cm

Most 3-D variables are defined on terrain-following main levels. In GRIB1, these main levels are coded as level-type 110: hybrid layers between two adjacent hybrid levels - which are the half levels in the COSMO-Model, i.e. the layer interfaces. In this case, octet 11 contains the level index of the upper half level and octet 12 contains the level index of the lower half level. Only few variables (as the vertical velocity or the height of the half levels) are coded as level type 109: hybrid levels, i.e. the model half levels. In this case, octet 11 contains zero and octet 12 contains the level index of the model half level. Pressure levels (ipds(8) = 100) and height levels (ipds(8) = 105) are used when the interpolation from model to specified p- or z-surfaces is switched on for model output.

Octets 13-17 contain the reference time of the data: the start of a forecast, the time for which an analysis is valid or the start of an averaging or accumulation period. The year of the century is coded in octet 13 and the century (100 years) in octet 25. For a reference time within the year 2000, octet 13 will contain the integer value 100 and octet 25 will contain the integer value 20.

The time or time interval for which the data are valid with respect to the reference time is coded in octets 18-21 (ipds(16)-ipds(19)). Octets 19 and 20 contain two periods of time, P1 and P2. The units of the values of P1 and P2 are defined in octet 18. Normally, we use hours as the time unit, but other values may be more appropriate for special applications of the model as the maximum integer number in an octet is 256. Thus, for long-term climate runs or short-term cloud simulations, other time units must be chosen. In the COSMO-DE we use *quarter of an hour* or *half an hour* for writing special variables more often than hourly. Note that the corresponding values for the unit of time (13 and 14) have only been lately adopted by WMO as official numbers. The WMO code-table for the unit of time in P1 and P2 is given in Table 5.4.

Table 5.4: *Code table for unit of time*

ipds(16)	**Meaning**	**ipds(16)**	**Meaning**	**ipds(16)**	**Meaning**
0	Minute	5	Decade	11	6 hours
1	Hour	6	Normal	12	12 hours
2	Day	7	Century	13	Quarter of an hour
3	Month	8-9	Reserved	254	Half an hour
4	Year	10	3 hours	254	Second

The meaning of the time period P1 in octet 19 (ipds(17)) and of the time period P2 in octet 20 (ipds(18)) - given in the units coded in octet 18 - depends on the time-range indicator, which is contained in octet 21 (ipds(19)). The WMO code-table allows for a large number of indicators including averages and accumulation over a number of forecasts and analyses. For the COSMO-system, we use only a few standard indicators as shown in Table 5.5.

Table 5.5: *Time range indicators used by the COSMO-Model*

`ipds(19)`	**Meaning**
0	Forecast product valid for reference time + P1 (if $P1 > 0$) or uninitialized analysis product valid for reference time ($P1 = 0$)
1	initialized analysis product valid for reference time ($P1 = 0$)
2	Product with a valid time ranging between reference time + P1 and reference time + P2
3	Average from reference time + P1 to reference time + P2
4	Accumulation from reference time + P1 to reference time + P2; product valid for reference time + P2

Table 5.6: ***Contents of the Product Definition Section***

array ipds(i)	**Octet number**	**Contents of PDS**	
		Value	**Remarks**
1	1-3	54	Length of the PDS (in octets)
2	4	2	Version number of the GRIB1 indicator table (see Table 5.6)
3	5	78	Identification of originating/generating centre (DWD has WMO number 78)
4	6	132	Generating process identification number (allocated by originating centre, see Table 5.2)
5	7	255	Number of grid used - from catalogue defined by the originating centre. Octet 7 set to 255 indicates a non-cataloged grid, in which case the grid is defined in the grid description section.
6	8	128	Block-flag; the value 128 indicates that the grid description section is included.
7	9	71	Indicator of parameter (element number) from GRIB1-table in ipds(2).
8	10	1	Indicator of type of level, see Table 5.3
9-10	11-12	0	Value of level (height, pressure, etc.) for which the data are included (see Table 5.3)
11	13	98	Year (start time of forecast; analysis time)
12	14	10	Month (start time of forecast; analysis time)
13	15	28	Day (start time of forecast; analysis time)
14	16	0	Hour (start time of forecast; analysis time)
15	17	0	Minute (start time of forecast; analysis time)
16	18	1	Indicator of unit of time range (see Table 5.4)
17	19	11	P1 - period of time (number of time units);
			time units given by octet 18 (ipds(16))
18	20	0	P2 - period of time (number of time units);
			time units given by octet 18 (ipds(16))
19	21	0	time range indicator (see Table 5.5)
20	22-23	0	Number of forecasts included in average, when octet 21 (ipds(19)) indicates an average or accumulation of forecasts (or analyses); otherwise set to zero.
21	24	0	Number of forecasts missing from averages or accumulations.
22	25	20	Century of reference time of data given by octets 13- 17
23	26	255	Sub-centre identification, national use
24	27-28	0	Units decimal scale factor (D)
25-36	29-40	0	Reserved: need not to be present
37	41	254	Octets 41-54 are reserved for the originating centre. The integer value 254 indicates that additional data follow. We use this part as follows:
38	42	0	not used
39	43-45	0	not used
40	46	0	not used
41	47	0	Additional indicator for a GRIB1 element number
42	48	98	Year of production of GRIB1-record
43	49	98	Month of production of GRIB1-record
44	50	11	Day of production of GRIB1-record
45	51	2	Hour of production of GRIB1-record
46	52	0	Minute of production of GRIB1-record
47	53-54	1	Version number, currently 1

Grid Description Section

Section 2 of a GRIB1-record, the grid description section GDS, contains all information about the geometry of the grid on which the data are defined. For all input and output files of the model, this section is coded completely for every field contained in the file. The program `grbin1` of the supplementary GRIB1-library `libgrib1` retrieves the contents of the GDS in an integer array `igds`.

The contents of the grid description section of a COSMO-EU GRIB1-record is illustrated in Table 5.7 for the model domain used operationally at DWD. The octets corresponding to the integer array `igds` are numbered relative to this section.

Bit-map Section

This section is optional, and provides the possibility to include only some grid points of the grid defined in the Grid Description Section. The bit-map is a sequence of bits with a bit-to-grid point correspondence, ordered as defined in the grid definition.

DWD uses bit-maps to send only those data from the global model ICON (or the older model GME) to the national weather services running the COSMO-Model, that are needed for the corresponding domain.

Binary Data Section

This section contains all values of the defined grid, usually in a packed format. At DWD typically 16 bits are used to store a packed value.

Table 5.7: ***C*ontents of the Grid Description Section**

array igds(i)	**Octet number**	**Contents of GDS**	
		Value	**Meaning**
1	1-3	250	Length of GDS (in octets) including the vertical coordinate parameters. (here for $ke = 40$ layers, i.e. $ke + 1 = 41$ half levels)
2	4	52	NV: Number of vertical coordinate parameters (four base state parameters + $(ke + 1)$ values of the vertical coordinates of the half levels + evtl. other parameters)
3	5	43	PV: Location (octet number) of the list of vertical coordinate parameters
4	6	10	Data representation type according to WMO code-table 6; '10' assigns a rotated latitude/longitude grid
5	7-8	665	Number of gridpoints in 'zonal' direction
6	9-10	657	Number of gridpoints in 'meridional' direction
7	11-13	-18000	Rotated latitude of the first gridpoint in millidegrees
8	14-16	-20000	Rotated longitude of the first gridpoint in millidegrees
9	17	0	Resolution flag according to WMO code-table 7; '0' means that the grid spacing is not given
10	18-20	23500	Rotated latitude of the last gridpoint in millidegrees
11	21-23	21000	Rotated longitude of the last gridpoint in millidegrees
12	24-25	0	Longitudinal direction increment (grid spacing in λ-direction, not given)
13	26-27	0	Meridional direction increment (grid spacing in ϕ-direction, not given)
14	28	64	Scanning mode flag according to WMO code-table 8 '64' means that points scan in +i and +j direction and adjacent points in i-direction are consecutive
15-19	29-32	0	Reserved (set to zero)
20	33-35	-40000	Geographical latitude of rotated southern pole in millidegrees
21	36-38	10000	Geographical longitude of rotated southern pole in millidegrees
22	39-42	0	Angle of rotation
26-65	43-202	.....	List of vertical coordinate parameters, each packed on 4 octets (length = 4 x NV octets). first the three parameters defining the base state: `igds(26)=p0sl`, `igds(27)=t0sl`, `igds(28)=dt0lp`; then the parameter `igds(29)=vcflat` of the hybrid coordinate system; and finally the $ke + 1$ values of the vertical coordinate $\eta(k)$ of the model half levels for $k = 1, \ldots, ke + 1$ in `igds(30)`,..., `igds(65)`.

5.1.2 GRIB Edition 2

Due to some weaknesses and limitations of GRIB1 (see the limited size of GRIB1 messages) a new Edition 2 has been developed. This new edition has been approved already in November 2001, but it is only now that several weather centers start to adopt and use it. DWD started to use GRIB Edition 2 for all operational products in June 2014.

For Edition 2, GRIB means "General Regularly distributed Information in Binary Form". The octets of a GRIB 2 message are also grouped in sections, where the length of the record and the length of the sections are expressed in octets, as it is done in Edition 1.

Because GRIB Edition 2 (also called GRIB2) is much more complex than Edition 1, we cannot describe it here in the same details. We refer to additional introductory reading in `http://www.wmo.int/pages/prog/www/WMOCodes/Guides/GRIB/GRIB2_062006.pdf`. Additional information can also be found on a special page on the COSMO web-site. This page contains descriptions of the templates and code tables used in the COSMO-Model. Please see `http://www.cosmo-model.org/content/model/documentation/grib/default.htm`.

The following short documentation should serve as a rapid introduction to GRIB2. We start with a number of remarkable differences to GRIB1 and will then describe the single sections briefly.

Differences between the two GRIB Editions

The structure of GRIB2 is more modular than Edition 1. It enables the representation of new products and provides an easy way for expansion and additions by extensively using *code tables* and *templates*. In this way the definition of parameters or attributes are separated in functionality so that items related to time, purpose or production method are independent. This makes maintenance easier when descriptions of new products or new parameters are required.

GRIB2 permits the coding of ensemble data, probability and percentile forecasts, forecast error fields, satellite image data, radar data, the analysis and forecast of accumulated and averaged parameters and offers enhanced capability to describe fields involving multiple time periods. Also it supports more compression schemes, for example JPEG2000 and PNG.

Templates and Table Driven Code

A template is a standard list of descriptive information, which also includes some coded values. While the *product definition section* in GRIB1 only was one unique standard template, the *product definition section* in GRIB2 contains a coded value for the *product definition template number*. Possible values for this template number are described in *Code Table 4.0* and include for example

0: Analysis or forecast at a horizontal level or in a horizontal layer at a point in time.

1: Individual ensemble forecast, control and perturbed, at a horizontal level or in a horizontal layer at a point in time.

8: Average, accumulation, extreme values or other statistically processed values at a horizontal level or in a horizontal layer in a continuous or non-continuous interval.

This demonstrates how new products or different representations can be added by defining new templates and adding new elements to the set of tables in the official Manual without changing existing definitions.

Representation of products

While products in GRIB1 were mainly specified by two numbers, the *table* and the *element number*, GRIB2 requires to specify a triple of numbers: the *discipline*, the *category* and the *parameter number*. Here are the specifications for some temperature products:

Table 5.8: ***G*RIB 1/2 Specifications of Temperature Products**

Product	**GRIB1**		**GRIB2**			
	Element	Table	Discipline	Category	Parameter	Product Definition Template Number
`T`	11	2	0	0	0	0
`TMIN_2M`	16	2	0	0	0	8

Both products shown are temperatures, the first one is the usual temperature without any specialities, so it uses the *product definition template number* 0. The second one is the minimum temperature two meters above ground. This is a statistically processed product, so the *product definition template number* to use is 8. Note that for this product, `TMIN_2M`, additional coded values have to be specified. The first one of the list below is only contained in the *product definition template number* 8.

- type of statistical processing = 3: specifies the minimum;
- type of first fixed surface = 103: specifies a height level above ground;
- scale vactor of first fixed surface = 0;
- scaled value of first fixed surface = 2: specifies the 2 meter.

Code Structure

Also a GRIB2 message consists of a number of octets. Again there are sections at the beginning, which describe the data contained in the message. These sections contain pointers towards elements in predefined and internationally agreed tables (stored in the official WMO Manual on Codes). By reading and decoding these sections, the following part of the message containing the data (the data section) can be understood. The characteristics (name, unit, etc.) of the parameters to be transmitted must already be defined in the tables of the WMO Manual on Codes. The *pointers* in the description sections are in fact numbers, which correspond to entries in the GRIB code tables of the WMO Manual.

The layout of a GRIB2 message is shown in Table 5.9. The GRIB2 indicator, grid definition, bit-map, data, and end sections map directly to their counterparts in GRIB1, although their contents in GRIB2 are somewhat different than in GRIB1. However, the GRIB2 identification, product definition, and data representation sections all map into the GRIB1 product definition section, and the GRIB2 sections contain substantially more information than in GRIB1. The GRIB2 local use section is not present in GRIB1.

Table 5.9: *Form of GRIB2-code*

Section number	Name	Contents
0	Indicator Section	"GRIB"; discipline; edition number; length of record
1	Identification Section	Length of section; section number; characteristics that apply to all processed data in the GRIB message
2	Local Use Section	Length of section; section number; items for local use by originating center
3	Grid Description Section	Length of section; section number; grid surface and geometry of data values within the surface
4	Product Definition Section	Length of section; section number; description of the nature of the data
5	Data Representation Section	Length of section; section number; description of how the data values are represented
6	Bit-Map Section	Length of section; section number; indication of presence or absence of data at each grid point, as applicable
7	Data Section	Length of section; section number; data values
8	End Section	7777

Indicator Section

Section 0 is a short section, which identifies the start of the GRIB2 message in a human readable form. It already contains the first product identifying value, the *discipline*, and specifies the Edition Number of GRIB used to encode the message. The total length of the message is coded in octets 9-16. Having 8 octets available for the length, a message can now have up to $2^{64} - 1 = 1.84 \cdot 10^{19}$ bytes (= octets).

To illustrate the usage of keys (in `grib_api`) and code tables (in GRIB2), Table 5.10 shows the contents of the Indicator Section for the 2 meter minimum temperature `TMIN_2M` for COSMO-EU. Besides the identifier `GRIB` it contains the number of the discipline, the edition number and the total length of the GRIB message. The key names are the names, by which `grib_api` identifies the corresponding GRIB meta data. For the *discipline* also Code Table 0.0 is shown, which contains the different disciplines defined up to now.

Note that from this section you can only identify that it is a meteorological product coded in GRIB2, and that the length of the total message is 874052 octets. The 2 meter minimum temperature cannot be identified here.

Identification Section

The identification section contains characteristics that apply to all processed data in the GRIB message. These characteristics identify the originating centre and sub-centre, indi-

Table 5.10: ***C*ontents of the Indicator Section**

Octet	**Key Name**	**Contents**	
		Value	**Comments**
1-4	`identifier`	GRIB	coded according to the International Alphabet No. 5
5-6	-	MISSING	Reserved
7	`discipline`	0	Discipline according to GRIB master table number Code Table 0.0: 0 Meteorological products 1 Hydrological products 2 Land surface products 3 Space products 4-9 Reserved 10 Oceanic products 11-191 Reserved 192-254 Reserved for local use 255 Missing
8	`editionNumber`	2	GRIB edition number
9-16	`totalLength`	874052	Total length of GRIB message in octets (incl. Section 0)

cate the GRIB master table and local table versions used, and give the reference time, the production status, and the type of processed data contained in this GRIB message.

Local Use Section

The purpose of the local use section is just what the section name implies: information for local use by the originating / generating center. The originating / generating center can put anything it desires in this Section.

The COSMO community agreed that all applications will employ a local use section and that all different sections are coordinated between the partners. The following sections are already defined. The number refers to the *local definition number* of the section:

250: basic section layout defined by COSMO

252: DWD: used for ensemble system incl. postprocessing

253: DWD: used for ensemble system

254: DWD: used for deterministic system

Grid Definition Section

The purpose of the grid definition section is to define the grid surface and geometry of the data values within the surface for the data contained in the next occurrence of the data section. Already GRIB1 contained the concept of templates in the grid description section and it is again used here. Use of a template means there are very few values common to all grid definition sections possible in GRIB2. Rather, the number of the *grid definition template* used is encoded. The values that must follow are those required by that particular grid definition template.

For the COSMO-Model we use the grid definition template 1, which defines a rotated latitude / longitude grid. This template is rather similar to the GRIB1 template. The most significant change is, that the number of vertical coordinate parameters (NV) has been moved to the product definition section for GRIB2.

Product Definition Section

The purpose of the product definition section is to describe the nature of the data contained in the next occurrence of the data section. The generic content of this section is rather short, containing the number of coordinate values after the template and the *product definition template number*. Depending on this number, more information on the data is given.

A new feature in this section, which is used by the COSMO-Model, is the new vertical coordinate type, coded with value 150, the *generalized vertical coordinate*. If the algorithm to compute the vertical levels for a model is too complicated, it is now possible to specify the vertical grid as a three-dimensional field. For the COSMO-Model, this 3D field is the `HHL`, a field that specifies the height of the half levels. All atmospheric fields that are defined on these half levels (or the corresponding full levels, which are the arithmetic mean of the half levels) have to code the level type as 150. This new level type contains only 6 vertical coordinate parameters describing the generalized vertical coordinate.

As a consequence the meta data describing the reference atmosphere and the vertical grid used cannot be coded in GRIB2 any more. Of course coding these values within the vertical coordinates in GRIB1 already was a mis-use of GRIB1. How this is handled in the COSMO-Model when using GRIB2 is explained in detail in Sect. 5.2.3.

Data Representation Section

The purpose of the data representation section is to describe how the data values are represented in the next occurrence of the data section. Again, there are only few coded values (e.g. number of data points) together with the data representation template number. This number specifies the template to use, which could for example be *grid point data - simple packing* or *spherical harmonics data - complex packing*.

New to GRIB2 is the possibility to use some special packing (JPEG 2000 or PNG) or even IEEE floating point data.

Bit-Map Section

The purpose of the bit-map section is to indicate the presence or absence of data at each of the grid points, as applicable, in the next occurrence of the data section. Whether a bit-map is present or not is set in octet 6 of this section:

0: A bit-map applies to this product and is specified in this section.

1-253: A bit-map pre-determined by the originating/generating center applies to this product and is not specified in this section.

254: A bit-map defined previously in the same "GRIB" message applies to this product.

255: A bit-map does not apply to this product.

If present, the bit-map follows as a series of contiguous bits, ordered as defined in the grid description section (Section 3). A bit is set to 1, if a data value is present and it is set to 0, if it is not present.

Data Section

The data section contains the data value themselves in a format described in the data representation template in Section 5.

End Section

The end section serves to identify the end of the GRIB2 message in a human readable form: "7777"

5.2 Practical Consequences when using GRIB Edition 2

5.2.1 Vertical Coordinate and Reference Atmosphere Parameters

To put up the vertical grid, INT2LM and the COSMO-Model need to know the vertical coordinate parameters `vcoord` and a coordinate value `vcflat`, where the vertical levels change from terrain-following to flat z-levels. If the SLEVE (smooth level vertical) coordinate is used, additional parameters are necessary, to compute the filtering for splitting the orography: `nfltvc`, `svc1` and `svc2`. Which type of vertical coordinate is used is coded in the value `ivctype`. We refer to all these values as the *vertical coordinate parameters*. The following table summarizes the vertical coordinate parameters:

`ivctype`	Type of the vertical coordinate (values ≥ 100 indicate the new reference atmosphere) 1: Pressure based hybrid coordinate η 2: Height based hybrid coordinate μ 3: Height based hybrid SLEVE coordinate μ_s 4: Variant of the SLEVE coordinate μ_s
`ke`	Number of vertical levels
`vcflat`	Coordinate value where system changes back to z-levels
`svc1, svc2, nfltvc`	decay rates and number of filtering steps for splitting the orography for the SLEVE coordinate
`vcoord`	list of the vertical parameters

For computing the reference atmosphere, also some special parameters are necessary, namely the reference pressure and temperature on sea level, `p0sl` and `t0sl`. For the COSMO-Model there are two different types of reference atmospheres, coded with `irefatm=1` or `irefatm=2`. Depending on the type, additional values are necessary: For `irefatm=1`, a constant rate for the temperature increase with the logarithm of pressure is prescribed, which is `dt0lp` $= \partial T_0 / \partial \ln p_0$. For `irefatm=2`, a temperature difference between sea level and the stratosphere, `delta_t`, and a scale height `h_scal`, have to be specified. These values are the *reference atmosphere parameters*. The following table summarizes the reference atmosphere parameters:

`p0sl, t0sl`	Reference pressure and temperature on sea-level
`dt0lp`	d (t0) / d (ln p0) ("old" reference atmosphere)
`delta_t`	temperature difference between sea level and stratosphere ("new" reference atmosphere)
`h_scal`	scale height ("new" reference atmosphere)

All these values can be specified via namelist variables in the INT2LM. INT2LM then computes the vertical grid and the reference pressure p_0 on that grid, i.e. the three-dimensional variables `HHL` and `P0`. When using GRIB1 or NetCDF, the vertical coordinate and the reference atmosphere parameters are encoded in the meta data of the initial and boundary fields for the COSMO-Model. The atmospheric pressure variable passed to the COSMO-Model as initial field is not the full pressure `P`, but only the pressure deviation `PP`, because it suffers less from a precision loss due to GRIB packing.

The COSMO-Model reads the values for these parameters from the meta data and therefore is able to re-compute the fields `HHL` and `P0` in the same way as the INT2LM does. But coding the reference atmosphere parameters and the additional vertical coordinate parameter `vcflat` in the GRIB1 meta data for the *vertical coordinates* is a violation of the GRIB1 standard.

5.2.2 GRIB2 and the generalized vertical coordinate

The GRIB1 standard referred to the vertical coordinate parameters always as *pairs of coordinates* a_k, b_k, where for example the pressure on level k is given by a simple formula $p_{ijk} = a_k + b_k \cdot p_{sij}$, where p_{sij} is the surface pressure at a special horizontal grid point ij.

Not all type of vertical grids, which are possible in the COSMO-Model, can be computed by such an easy formula. Therefore we introduced a new *type of vertical level* for GRIB2, which has been accepted by WMO. This new type of vertical level is specified as *generalized vertical coordinate* and has the value 150 in GRIB2.

To define the generalized vertical coordinate, some additional meta data have to be specified:

- Number of vertical levels (`nlev`): This corresponds to the number of half levels `ke+1`
- Number of vertical grid used (`numberOfVGridUsed`): This corresponds to `ivctype`
- A universally unique identifier for the vertical grid (`uuidOfVGrid`): This is a special identifier, which should ensure that INT2LM and the COSMO-Model always use the same grid. As hexadecimal value it takes 16 bytes (or octets).

These meta data (the names in brackets are the grib_api keys) are encoded in the list of coordinate values.

NOTE:
Not all COSMO vertical coordinate parameters and reference atmosphere parameters can be coded in GRIB2 anymore! This has consequences for INT2LM, the COSMO-Model and eventually also for post-processing programs.

5.2.3 New method for the vertical coordinate parameters

Main purpose of the vertical coordinate parameters is the computation of the three-dimensional grid for the COSMO-Model. When using GRIB2, not all coordinate parameters are available in the COSMO-Model. Therefore the 3D-field `HHL` is written to the laf-file with the initial fields. This is done from INT2LM and also from the COSMO-Model itself, if it is running in analysis mode. This field is written with a grib-packing to 24 bits, which gives a higher precision than the packing to 16 bits, which is used for most other fields. The COSMO-Model then does not need to recompute the grid.

But there are some other tasks, mainly in the data assimilation, that require the knowledge of the height of the levels above mean-sea level or a reference pressure profile on these heights. The height of the levels above mean-sea level is exactly the information, the vertical coordinate parameters `vccoord` are giving. Therefore we code these values in the meta data for the `HHL`-file, which is defined on half levels. For such variables, the meta data for the *second fixed surface* usually are not set and we can use them to code the vertical coordinate parameters `vcoord`. The value for the vertical coordinate parameter of level k is coded in the `scaleFactorOfSecondFixedSurface` and the `scaledValueOfSecondFixedSurface` of the corresponding level of `HHL`.

The coordinate value, where the system changes back to z-levels (`vcflat`), is not available in GRIB2 anymore. In case of `ivctype=2`, it can be reconstructed from the values of `HHL`.

For `ivctype=3/4`, this is not possible. Only an approximation can be computed by using the method from `ivctype=2`. For `ivctype=1`, the pressure based coordinate parameters, this is not possible at all. Therefore, the use of `ivctype=1` is deprecated when using GRIB2.

Also the additional parameters, which are necessary to compute the filtering for the SLEVE coordinate (`svc1, svc2, nfltvc`), are not available in GRIB2. But they are only needed for the computation of `HHL`, which is not necessary in the COSMO-Model, when reading the `HHL` from the laf-file.

5.2.4 New method for the reference atmosphere parameters

The information about the reference atmosphere parameters is necessary for the COSMO-Model, if it has to process the pressure deviation `PP` as input field. Because then it has to compute the reference pressure `P0` to get the full pressure `P`. The pressure deviation has been chosen as the transfer parameter between the INT2LM and the COSMO-Model and also between the assimilation cycle and the forecast, when using GRIB1, because it minimizes the loss in precision, when using the GRIB packing.

For GRIB2, we are now transfering the full pressure field, but with a higher precision, using 24 bits for GRIB packing (same as for `HHL`). Nevertheless, the COSMO-Model still needs the reference atmosphere parameters to compute `P0` and `PP`, because the prognostic variable used in the COSMO-Model is `PP`. But the reference atmosphere parameters that are used in the COSMO-Model, are in most cases independent of the ones used in the INT2LM! Therefore, new namelist variables have been introduced for the reference atmosphere parameters in the COSMO-Model (in group `/LMGRID/`).

The only restriction is, that the new reference atmosphere (`irefatm=2`) has to be chosen, if the model height is higher than 27000 meters. `irefatm=1` will not work then.

5.2.5 The UUID and a special HHL-file for INT2LM

The universally unique identifier (UUID) is a speciality about the new generalized vertical coordinate in GRIB2. It serves as an identifier for a certain vertical grid and is used to check, that all three-dimensional variables are using the same grid. Only the INT2LM, which computes the `HHL`, can set a valid UUID.

All atmospheric (3D) variables computed by INT2LM get the same UUID as the `HHL`-field. The COSMO-Model then ensures that an atmospheric variable really belongs to the vertical grid specified by `HHL` by comparing the UUIDs of both fields.

This is controlled by the INT2LM namelist variable `lnewVGrid`.

`lnewVGrid = .TRUE.`
Then a new vertical grid `HHL` is computed using the vertical coordinate parameters from namelist input and a new UUID is set for this field. If this variable is always set to `.TRUE.`, every run will have a new UUID. This is only possible, if INT2LM computes both, the initial and the boundary values for a COSMO forecast.

`lnewVGrid = .FALSE.`
Then the vertical grid is read from an extra file, specified by the namelist variable `ylm_hhl`

and the UUID from this `HHL`-field is taken for further use. We recommend to produce such a special `HHL`-file for INT2LM. It can be extracted out of the laf-file, for example, and can then be used again for the next runs. This is absolutely necessary when running a data assimilation cycle, because the `HHL`-file then is used from the COSMO assimilation run, while all atmospheric variables for initial or boundary values are produced by the INT2LM, but have to have the same UUIDs than the `HHL`-file from the COSMO run.

5.3 The NetCDF Data Format

netCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF of the COSMO-Model is self explaining, i.e. no additional tables are needed. The contents of an output file can be listed with the program `ncdump` which installs automatically along with the netCDF library. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The freely available source can be obtained as a compressed tar-file or a zip-file from Unidata or from other mirror sites.

`http://www.unidata.ucar.edu/packages/netcdf/index.html`.

Information on the F90 implementation can also be obtained from

`http://www.unidata.ucar.edu/packages/netcdf/f90/index.htm`.

In the current implementation of netCDF I/O data are in 32bit accuracy. For GRIB format, an additional packing can be done (usually using 16 bit accuracy). But this packing will lose information.

NetCDF I/O can be turned on via the `yform_read` and the `yform_write` parameters in the namelist `IOCTL`. The parameters can be chosen independently, e.g. it is also possible to have GRIB as input and netCDF as output format and vice versa.

Name	Type	Definition / Purpose / Comments	Default
`yform_read`	`CHAR`	Format of input data `'grb1'` = GRIB formatted input `'ncdf'` = netCDF formatted input	`'grb1'`
`yform_write`	`CHAR`	Format of output data `'grb1'` = GRIB formatted output `'ncdf'` = netCDF formatted output	`'grb1'`

5.3.1 CF Conventions

The basic conventions for netCDF Output in COSMO are the Climate and Forecast (CF) conventions. These define standards on the naming and structuring of the netCDF output.

The latest description of the CF conventions can be found on the Lawrence Livermore WEB page `http://cf-pcmdi.llnl.gov/`.

The values for `units` and `standard_name` have fixed values and are defined by the CF conventions. Values for `long_name` and the name of the parameter field can be freely chosen by the user. The `long_name` is often used by graphic programs in creating the legend of figures. The `_FillValue` attribute holds the value set for missing data. The name of the parameter is used to extract a certain field from the output file.

5.3.2 Namelist Input

The netCDF I/O can be controlled via the Namelist `IOCTL`. In addition to the parameters `yform_read` and the `yform_write` described above global attributes can be defined to describe the model simulation.

`yncglob_institution`	CHAR	originating center name	'-'
`yncglob_title`	CHAR	title string for the output	'-'
`yncglob_source`	CHAR	program name and version	'-'
`yncglob_contact`	CHAR	identification of the project of the simulation	'-'
`yncglob_project_id`	CHAR	identification of the experiment of the simulation	'-'
`yncglob_experiment_id`	CHAR	contact e.g. email address	'-'
`yncglob_references`	CHAR	URL, report etc.	'-'
`ncglob_realization`	INT	number of the realisation of the experiment	1

The "`yncglob_...`" parameters are written into the netCDF output as global attributes (see example header output below).

5.3.3 netCDF Header Section

The following is a typical content of the header section of a netCDF formatted output file. Such a listing can be produced by using the `ncdump` command

`ncdump -h lffd1979010200.nc`.

The dimensions of the variables are written in the C language order, i.e. the last coordinate comes first (Example: `float T(time, level, rlat, rlon)` in C reads `float T(rlon, rlat, level, time)` in F90).

```
netcdf lffd1979010200 {
dimensions:
        rlon = 101 ;
        rlat = 107 ;
        srlon = 101 ;
        srlat = 107 ;
        level = 20 ;
        level1 = 21 ;
        height_2m = 1 ;
        height_10m = 1 ;
        soil = 9 ;
        soil1 = 10 ;
        time = UNLIMITED ; // (1 currently)
        bnds = 2 ;
variables:
        char rotated_pole ;
                rotated_pole:long_name = "coordinates of the rotated North Pole" ;
                rotated_pole:grid_mapping_name = "rotated_latitude_longitude" ;
                rotated_pole:grid_north_pole_latitude = 32.5f ;
```

```
                rotated_pole:grid_north_pole_longitude = -170.f ;
        float rlon(rlon) ;
                rlon:standard_name = "grid_longitude" ;
                rlon:long_name = "rotated longitude" ;
                rlon:units = "degrees" ;
        float rlat(rlat) ;
                rlat:standard_name = "grid_latitude" ;
                rlat:long_name = "rotated latitude" ;
                rlat:units = "degrees" ;
        float srlon(srlon) ;
                srlon:standard_name = "grid_longitude" ;
                srlon:long_name = "staggered rotated longitude" ;
                srlon:units = "degrees" ;
        float srlat(srlat) ;
                srlat:standard_name = "grid_latitude" ;
                srlat:long_name = "staggered rotated latitude" ;
                srlat:units = "degrees" ;
        float lon(rlat, rlon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
        float lat(rlat, rlon) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
        float slonu(rlat, srlon) ;
                slonu:standard_name = "longitude" ;
                slonu:long_name = "staggered U-wind longitude" ;
                slonu:units = "degrees_east" ;
        float slatu(rlat, srlon) ;
                slatu:standard_name = "latitude" ;
                slatu:long_name = "staggered U-wind latitude" ;
                slatu:units = "degrees_north" ;
        float slonv(srlat, rlon) ;
                slonv:standard_name = "longitude" ;
                slonv:long_name = "staggered V-wind longitude" ;
                slonv:units = "degrees_east" ;
        float slatv(srlat, rlon) ;
                slatv:standard_name = "latitude" ;
                slatv:long_name = "staggered V-wind latitude" ;
                slatv:units = "degrees_north" ;
        float vcoord(level1) ;
                vcoord:long_name = "terrain following coordinate" ;
                vcoord:units = "Pa" ;
                vcoord:p0sl = 100000. ;
                vcoord:t0sl = 288.15 ;
                vcoord:dt0lp = 42. ;
                vcoord:vcflat = 0.22 ;
        float height_2m(height_2m) ;
                height_2m:standard_name = "height" ;
                height_2m:long_name = "height above the surface" ;
                height_2m:units = "m" ;
                height_2m:positive = "up" ;
        float height_10m(height_10m) ;
                height_10m:standard_name = "height" ;
                height_10m:long_name = "height above the surface" ;
                height_10m:units = "m" ;
                height_10m:positive = "up" ;
        float soil1(soil1) ;
                soil1:standard_name = "depth" ;
                soil1:long_name = "depth of soil layers" ;
                soil1:units = "m" ;
                soil1:positive = "down" ;
                soil1:bounds = "soil1_bnds" ;
        float soil1_bnds(soil1, sbnds) ;
                soil1_bnds:long_name = "boundaries of soil layers" ;
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "time" ;
                time:units = "seconds since 1979-01-01 00:00:00" ;
                time:calendar = "proleptic_gregorian" ;
                time:bounds = "time_bnds" ;
        double time_bnds(time, tbnds) ;
                time_bnds:long_name = "time bounds" ;
                time_bnds:units = "seconds since 1979-01-01 00:00:00" ;
        float P(time, level, rlat, rlon) ;
                P:standard_name = "air_pressure" ;
                P:long_name = "pressure" ;
                P:units = "Pa" ;
                P:grid_mapping = "rotated_pole" ;
                P:coordinates = "lon lat" ;
        float PS(time, rlat, rlon) ;
                PS:standard_name = "surface_air_pressure" ;
                PS:long_name = "surface pressure" ;
                PS:units = "Pa" ;
                PS:grid_mapping = "rotated_pole" ;
                PS:coordinates = "lon lat" ;
        float T(time, level, rlat, rlon) ;
                T:standard_name = "air_temperature" ;
                T:long_name = "temperature" ;
                T:units = "K" ;
                T:grid_mapping = "rotated_pole" ;
                T:coordinates = "lon lat" ;
        float U(time, level, rlat, srlon) ;
                U:standard_name = "grid_eastward_wind" ;
```

```
                U:long_name = "U-component of wind" ;
                U:units = "m s-1" ;
                U:grid_mapping = "rotated_pole" ;
                U:coordinates = "slonu slatu" ;
        float V(time, level, srlat, rlon) ;
                V:standard_name = "grid_northward_wind" ;
                V:long_name = "V-component of wind" ;
                V:units = "m s-1" ;
                V:grid_mapping = "rotated_pole" ;
                V:coordinates = "slonv slatv" ;
        float TOT_PREC(time, rlat, rlon) ;
                TOT_PREC:standard_name = "precipitation_amount" ;
                TOT_PREC:long_name = "total precipitation amount" ;
                TOT_PREC:units = "kg m-2" ;
                TOT_PREC:grid_mapping = "rotated_pole" ;
                TOT_PREC:coordinates = "lon lat" ;
                TOT_PREC:cell_methods = "time: sum" ;
        float ASOB_S(time, rlat, rlon) ;
                ASOB_S:standard_name = "surface_net_downward_shortwave_flux" ;
                ASOB_S:long_name = "surface net downward shortwave radiation" ;
                ASOB_S:units = "W m-2" ;
                ASOB_S:grid_mapping = "rotated_pole" ;
                ASOB_S:coordinates = "lon lat" ;
                ASOB_S:cell_methods = "time: mean" ;
        float VMAX_10M(time, height_10m, rlat, rlon) ;
                VMAX_10M:standard_name = "wind_speed" ;
                VMAX_10M:long_name = "maximum 10m wind speed" ;
                VMAX_10M:units = "m s-1" ;
                VMAX_10M:grid_mapping = "rotated_pole" ;
                VMAX_10M:coordinates = "lon lat" ;
                VMAX_10M:cell_methods = "time: maximum" ;

// global attributes:
                :title = "Simulation in the EU project ENSEMBLES" ;
                :institution = "GKSS" ;
                :source = "CCLM4" ;
                :project_id = "ENSEMBLES" ;
                :experiment_id = "ERA40@50km" ;
                :realization = 1 ;
                :Conventions = "CF-1.0" ;
                :conventionsURL = "http://www.unidata.ucar.edu/packages/netcdf/conventions.html" ;
                :contact = "John.Somebody@somewhere.de" ;
                :references = "http://www.ensembles-eu.org" ;
                :creation_date = "2005-09-16 20:50:38" ;
}
```

The header is divided in three parts :

1. Dimensions

netCDF dimension	COSMO dimension	Description
rlon	ie	number of grid points in rotated longitudinal direction (mass points)
rlat	je	number of grid points in rotated latitudinal direction (mass points)
srlon	ie	number of grid points in rotated longitudinal direction (flux points)
srlat	je	number of grid points in rotated latitudinal direction (flux points)
level	ke	number of vertical full levels
level1	ke1	number of vertical half levels
height_2m	–	= 1 (single atmosphere level)
height_10m	–	= 1 (single atmosphere level)
soil	ke_soil	number of soil layers
soil1	ke_soil1	number of soil layers +1
bnds	–	=2 (bounds of variables soil_bounds and time_bounds)
time	–	=1 (dimension for time series)

The *time* dimension is different from the other dimensions since it is declared as "unlimited". This makes it possible to cat together several output files and construct time series and animations.

2. Variables

   Variables can be divided in two categories: coordinate variables and the meteorological quantities. Coordinate variables have the same name as their dimension. All variables are in 32bit (i.e. float) except of *time* which is in 64bit (i.e. double) and *rotated_pole* which is defined as a character variable.

3. Global attributes

   The global attributes contain general information about the data. The attributes `conventions`, `conventionsURL`, and `creation_date` are set within the model itself. The other global attributes can be set by the user via namelist `IOCTL` (see above).

5.3.4 Useful Post-Processing Utilities

- *ncdump (Freeware)* Shows information about the contents of a netCDF file. This program is part of the netCDF standard software package.
- *ncview (freeware)* Visual browser for netCDF. `http://meteora.ucsd.edu/ pierce/ncview_home_page.html`
- *NCO (freeware)* Software package including several programs to manipulate netCDF data. `http://nco.sourceforge.net/`
- *CDO (freeware)* Software package including several programs to manipulate grib and netCDF data. This is the successor of the PINGO package at the German Climate Research Centre (DKRZ). `http://www.mpimet.mpg.de/∼cdo`
- *Others* An extensive listing of software that uses netCDF is available from `http://www.unidata.ucar.edu/packages/netcdf/software.html`

Section 6

Input Files for the COSMO-Model

The COSMO-Model requires several input files.

- ASCII-files, called `INPUT_***` (see below for the exact filenames), that contain the namelist variables. The form of these files is described in Section 6.1. The namelist groups, the variables, their meanings and possible values are described in Chapter 7.
- GRIB-Code or NetCDF files for the initial and boundary values. These files are described in Section 6.2 and in Section 6.3, respectively.
- NetCDF observation input files (or alternatively an AOF file) which contain the observational information for data assimilation (nudging) and for producing a NetCDF feedobs file. The purpose of the feedobs file (see first remarks in Section 8) is to serve as input to a LETKF analysis scheme or to verification tools. The NetCDF observation input files, including a blacklist file, are described in Section 6.4.

6.1 File for Namelist Input

The COSMO-Model uses `NAMELIST`-input to specify runtime parameters. The parameters are splitted into several groups, which are distributed to the components. Table 6.1 lists the components, the groups and the corresponding `INPUT_***` files.

The last group of component Input / Output (`GRIBOUT`) can occur several times. Every group can determine a different list of variables for output and also different output steps.

The program provides default values for all parameters. To change a default value, an appropriate `NAMELIST` statement has to appear in the corresponding ASCII-file `INPUT_***`. The form of a `NAMELIST` statement depends on the specific platform you are using but is always similar to the following (refer to the Language Reference Manual of your system):

1. The ampersand (`&`) character, followed immediately by the name of the namelist group.
2. A sequence of zero or more

   `parameter=value,`

   statements.

Table 6.1: `NAMELIST`-groups and `INPUT_***` files

Component	Description	Group	INPUT file
Setup	specifying the domain and the size of the grid parameters for the model run parameters for tuning variables	/LMGRID/ /RUNCTL/ /TUNING/	INPUT_ORG
Dynamics	parameters for the adiabatic model	/DYNCTL/	INPUT_DYN
Physics	parameters for the diabatic model	/PHYCTL/	INPUT_PHY
Diagnostics	parameters for the diagnostic calculations parameters for the satellite images	/DIACTL/ /SATCTL/	INPUT_DIA
Assimilation	controlling the data assimilation	/NUDGING/	INPUT_ASS
Additionals	parameters for the initialization parameters for controlling the EPS mode	/INICTL/ /EPSCTL/	INPUT_INI INPUT_EPS
Input / Output	controlling the I/O parameters for using DWD's database system controlling the grib input controlling the grib output	/IOCTL/ /DATABASE/ /GRIBIN/ /GRIBOUT/	INPUT_IO

3. `/` to terminate the `NAMELIST` group.

Example:
In the following example new values are set for the parameters in the Namelist group `lmgrid`:

```
&lmgrid
  startlon_tot=-10.4,    startlat_tot=-3.025,
  pollat=32.5,           pollon=-170.0,
  dlon=0.025,            dlat=0.025,
  ie_tot=72,             je_tot=92,
/
```

For a complete reference of all `NAMELIST` parameters see Chapter 7.

6.2 Conventions for File Names

The initial and boundary fields needed for the model are provided either in Grib or in NetCDF format. Also for the output files, one can choose between Grib or NetCDF. Restart files are written in binary format with full precision. There is one file for the initial fields and also for every set of boundary fields. The following conventions apply for the filenames.

A file name for the COSMO-Model or the INT2LM has the general form

`yheader // ydate // yextension` (for Grib files),

or

`yheader // ydate // yextension // '.nc'` (for NetCDF files),

where `yheader`, `ydate` and `yextension` have the following meaning:

`yheader`: File header (3 characters, only for ICON 4 characters)

- first character: specifies the model
  - `ig`: ICON (global model)
  - `g`: GME (global model)
  - `l`: COSMO-Model
  - `e`: ECMWF model IFS (Integrated Forecast System)
  - `c`: A general (global) climate model
- second character (for ICON: third character):
  - `a`: analysis file (uninitialized)
  - `i`: analysis file (initialized)
  - `b`: boundary file
  - `f`: forecast files
  - `r`: restart files
- third character (for ICON fourth character): specifies the region covered by the data
  - `f`: full model domain
  - `s`: subdomain

`ydate`: There are two forms of specifying the date, either with the full date or relative to the start date:

- In the name of analysis files (second character in the header `a` or `i`) the full date is specified: `ydate` = `'yyyymmddhh'` with `yyyy`: year; `mm`: month; `dd`: day; `hh`: hour.

  Example:

`laf1992072100`	COSMO-Model, uninitialized analysis for full model domain from July, 21st, 1992.

Since COSMO-Model Version 4.24, the initial date can be specified with 14 digits, where the last digits represent minutes and seconds. If the namelist variable `ydate_ini` is specified with 14 digits, also for the filenames 14 digits are used.

- In forecast, boundary or restart files, `ydate` consists of a single character (the time unit of forecast range, `ytunit`), followed by a string.

  `ydate` = `ytunit // '`*string*`'`

  Depending on `ytunit`, the string has the following meaning:

  `t:` timestep mode: forecast range given in timesteps

  `f:` forecast mode: the forecast range is given in the form `ddhhmmss`, where `dd`: day, `hh`: hour, `mm`: minute, `ss`: second

  `c:` climate mode: the forecast range is given in the form `yyydddhh`, where `yyy`: year, `ddd`: day of the year, `hh`: hour

  `d:` day mode: the full date is given in the form `'yyyymmddhh'`, where `yyyy`: year; `mm`: month; `dd`: day; `hh`: hour

`yextension` (1 character, optional): Extension, e.g. data interpolated from model to pressure levels.

Examples:

`lbff00050000`	COSMO-Model, file with boundary values for hour 5
`lfff01233000`	COSMO-Model, forecast at day 1, 23 hours and 30 minutes.
`lrff01000000`	COSMO-Model, restart file for day 1.

6.3 Initial and Boundary Data

To start a forecast, the files containing the initial and boundary data have to provide all meteorological fields necessary for running the model. It is checked whether all fields are present, otherwise the run will be aborted. Which fields are needed, depends on the settings of special Namelist switches. All possible initial fields required are listed below.

Initial fields required for the COSMO-Model in all cases:

`hsurf`	geopotential of the earth's surface
`gz0`	roughness length
`fr_land`	part of land in the grid cell
`soiltyp`	soil type of the land
`plcov`	degree of plant covering
`lai`	leave area index
`rootdp`	root depth
`u`	zonal wind speed
`v`	meridional wind speed
`w`	vertical wind speed
`pp`	deviation from reference pressure
`t`	temperature
`t_snow`	temperature of snow surface
`t_s`	temperature at the boundary soil-atmosphere
`qv`	specific water vapor content
`qc`	specific cloud water content
`qv_s`	specific water vapor content at the surface
`w_i`	water content of interception water
`w_snow`	water content of snow
`vio3`	vertical integrated ozone content
`hmo3`	ozone maximum

Initial fields required for multi-layer soil model:

`t_so`	soil temperature on the different layers
`w_so`	soil moisture of the different layers
`rho_snow`	density of snow
`freshsnw`	weighting function indicating 'freshness' of snow

Initial fields required for 2-layer soil model:

`t_m`	temperature between upper and medium soil layer
`t_cl`	temperature between medium and lower soil layer
`w_g1`	water content of the upper soil layer
`w_g2`	water content of the medium soil layer
`w_g3`	water content of the lower soil layer
`w_cl`	climatological water content of the lowest soil layer

Initial field required for cloud-ice, rain, snow and graupel if appropriate `NAMELIST` parameters are set):

`qi`	specific cloud ice content
`qr`	specific rain content
`qs`	specific snow content
`qg`	specific graupel content

Next, all possible fields necessary for the boundary files are listed. This again depends on Namelist switches. All boundary fields are provided for the full forecast domain.

Boundary fields required for the COSMO-Model:

`u_bd`	zonal wind speed
`v_bd`	meridional wind speed
`pp_bd`	deviation from reference pressure
`t_bd`	temperature
`t_snow_bd`	temperature of snow surface
`qv_bd`	specific water vapor content
`qc_bd`	specific cloud water content
`qv_s_bd`	specific water vapor content on the surface
`w_snow_bd`	water content of snow

Boundary fields required for 2-layer soil model:

`t_s_bd`	temperature at the boundary soil-atmosphere
`t_m_bd`	temperature between upper and medium soil layer
`w_g1_bd`	water content of the upper soil layer
`w_g2_bd`	water content of the medium soil layer
`w_g3_bd`	water content of the lower soil layer

For the multi-layer soil model, no boundary fields are necessary. If the model should run with cloud-ice, also the following field is needed.

Boundary field required for cloud-ice, rain and snow if appropriate `NAMELIST` parameters are set):

`qi`	specific cloud ice content
`qr`	specific rain content
`qs`	specific snow content

If the `NAMELIST` parameter `LGEN` is set to `.TRUE.` (see 7.2), the input of initial and boundary data is skipped and artificial data are generated instead in the routines `gen_ini_data` and `gen_bound_data`. Note that these routines have to be edited and modified by the user to generate appropriate conditions for the case under consideration.

6.4 Observation Input Files

This section describes the format of the **NetCDF file observation input** to the COSMO model and what has to be done, if these files are used as input to the nudging-type assimilation scheme inside COSMO, or to writing (NetCDF or ASCII (i. e. YUVERIF)) feedobs files for verification purposes, or to perform surface analyses based on observations (e. g. of 2-m temperature). The observation input described here currently relates to conventional observations only, and it does not describe the (gribbed) input for the latent heat nudging.

An alternative observation input for the conventional observations is given by the '**AOF**' file. Here, a single binary file has to be read, of which the format is described in a separate documentation (available from `christoph.schraff@dwd.de`). The AOF interface is not fully supported any more in the sense that it does not include new features introduced in the data assimilation part after COSMO V4_17 . In particular, writing NetCDF feedobs files is not working completely.

The choice between the two formats of observation input is made by setting the value for the namelist parameter 'itype_obfile' of COSMO. A value of 1 indicates AOF file input and a value of 2 NetCDF files input.

In the following items, general properties of the **NetCDF file observation input** are described:

- **Required files and file names :**

  The NetCDF observation input files have fixed file names which are given in the following sub-sections and begin with 'cdfin_'. For the observation file type 'SYNOP' for instance, the file name would be 'cdfin_synop'. For each observation file type, it is possible to have several input files, with suffix '.2', '.3', etc. for the file names (the suffix '.1' is not used). An additional suffix '.nc' is optional. Thus, for a second file for SYNOP data, the file name 'cdfin_synop.2.nc' would be possible.

  The existence of any of the NetCDF observation input files is optional. If there are no observations available of a certain type then the corresponding NetCDF file should be missing in the input directory. Any file with a corresponding file name must have the correct format (as described further below), and files with zero length are not allowed.

  In addition, a blacklist file with fixed name 'blklsttmp' containing a blacklist and a whitelist is read by COSMO. The existence of this file is mandatory (if itype_obfile = 2 and any of the namelist parameters 'lnudge', 'lverif', or 'lsurfa' is true).

  All these input files must reside in the directory given by the namelist parameter 'ycdfdir'.

- **Content of the NetCDF observation input files :**

  The NetCDF observation input files 'cdfin_'* are usually created by direct conversion of BUFR files (using the 'bufrx2netcdf' program). This means that they contain the same variables as the input BUFR files. Hence, if possible, all BUFR reports in a file should use exactly the same template in order to allow for a complete conversion into NetCDF. 'bufrx2netcdf' will only convert those observation reports in a BUFR file which have exactly the same template as the first report converted, and it will neglect the other reports. Therefore, if the BUFR reports do not have an identical template, several calls of 'bufrx2netcdf' (using the '-x' option to skip the previous reports with other templates) to a BUFR file are necessary to create several NetCDF files for the same observation file type. A BUFR file without any observations will result in a file 'cdfin_'* with zero length. Such a file must be deleted before starting running COSMO.

COSMO expects the NetCDF files to contain specific variables. Some of the variables are mandatory while others are optional. This implies that the BUFR file prior to conversion into NetCDF must also contain these variables (at least the mandatory ones). Any BUFR files lacking these variables or containing the quantities in a different form with e.g. different variable names must first be converted into a BUFR file according to the specifications below prior to conversion into NetCDF.

The descriptions of the templates below applies to the NetCDF input files. However, the templates, in particular of BUFR Section 3, are based upon those of the BUFR files. Therefore, reference is made to descriptions of BUFR templates where available by WMO, and additional common sequence BUFR descriptors are included in the description even though they are absent in the NetCDF file. The specified variable types (int / float / char) relate only to the NetCDF file after conversion from BUFR.

- From **BUFR Section 1**, the following elements are **mandatory** for all observation types (i.e. COSMO will abort, if any of these are absent in the NetCDF file):

descriptor	type	variable name (NetCDF file)	meaning
	int	edition_number	BUFR edition number (usually = 4)
C-11	int	section1_centre	originating / generating data centre
C-12	int	section1_subcentre	e.g. processing centre for GPS reports
	int	section1_update_sequence_nr	upd. seq. number (station correction)
C-13	int	section1_data_category	WMO data category
C-13	int	section1_int_data_sub_category	internatl. (WMO) data sub category
	int	section1_date	year-month-day [YYYYMMDD]
	int	section1_time	hour-minute-second [HHMMSS]

The identifiers C-* denote BUFR-CREX Common Code Tables which are detailed in: http://www.wmo.int/pages/prog/www/WMOCodes/TDCFtables.html#TDCFtables, link 'Common Code Tables to Binary and Alphanumeric Codes'.

Observational reports which have missing values for 'section1_data_category' or for 'section1_int_data_sub_category' will be rejected. This also applies to GPS reports if 'section1_centre' or 'section1_subcentre' have missing values.

- From **BUFR Section 2**, the following elements are **optional**. This means that they are read and stored internally for all observation types, but it is not mandatory that they exist or contain non-missing values (i. e. COSMO will not abort, if they do not exist):

descriptor	type	variable name (in NetCDF file)	meaning
	int	section2_ikz	DWD-internal data base ID
	int	section2_decoding_date	year-month-day [YYYYMMDD]
	int	section2_decoding_time	hour-minute-second [HHMMSS]

- From **BUFR Section 3**, the variables read and used mandatorily or optionally are detailed in the following sub-sections for the different observation file types. The variable names in the NetCDF files equal the BUFR mnemonics for these variables.

The 'ifxy' attribute for any variable in the NetCDF file is equal to the BUFR descriptor for that variable. These BUFR descriptors are described in http://www.wmo.int/pages/prog/www/WMOCodes/TDCFtables.html#TDCFtables, link 'BUFR/CREX Table B - Classification of elements' , and on the same page, the link 'Code and Flag Tables associated with BUFR/CREX Table B' provides the details of the code tables.

Observational reports are rejected unless they contain appropriate non-missing values for observation time (year, month, day, hour, minute), location (latitude, longitude), and for some observation types station altitude and some form of station identity.

Note that for some observation file types, the (BUFR and the) NetCDF files produced at DWD contain an additional variable for each (or most) of the existing variables of section 3. This variable contains a quality flag related to the value of the original variable. The variable name of this quality flag variable is equal to the name of the original variable plus a suffix 'Q'. However, all the quality flag variables of this type are obsolete, i.e. they are never needed, never used or read by COSMO, they always contain missing values only, and therefore they are never described hereafter.

In the following sub-sections of this section, the sequences of variables (templates) related to BUFR Section 3 are detailed for the different observation types. In the last sub-section, the blacklist file is described.

6.4.1 Templates for observation types for which Table-Driven Code Forms (TDCF) defined by WMO exist

The BUFR templates, which the NetCDF files described in this sub-section are based on, are described at
http://www.wmo.int/pages/prog/www/WMOCodes/TemplateExamples.html.

- **SYNOP, SYNOP MOBIL, and SHIP**

File names:	for fixed land stations	(SYNOP)	:	'cdfin_synop'
	for mobile land stations	(SYNOP MOBIL)	:	'cdfin_synop_mob'
	for sea stations	(SHIP)	:	'cdfin_ship'.

The templates for observation type SYNOP and for SYNOP MOBIL follow the WMO common sequence descriptors '**TM 3 07 080**' resp. '**TM 3 07 090**'. These sequences, and also the use of the variables in COSMO, are identical to each other except for the report header (common sequences '3 01 090' esp. '3 01 092'). The template for SHIP follows the WMO common sequence descriptor '**TM 3 08 009**'.

Caution: The use of observation file type 'SYNOP MOBIL' in COSMO has not been tested yet due to a lack of testing opportunity because of a lack of data of this type. Its use is at the user's own risk. However, as the template is almost the same as for fixed land SYNOP, errors are unlikely. If errors occur, they should be reported to the author.

For all the 3 observation (file) types, the table below lists all the variables which are used by COSMO, plus some of the other variables, but it does not detail the variables for those common sequences which contain only variables that are not used by COSMO. For convenience, the table is split into a report header and three report body parts.

The use of the variables (first column of table) is defined as follows:

’need’: COSMO asks stringently for this variable and will abort if variable is absent (but will not abort if values are equal to ’missing value’)

’opt’: variable exists and is read/used (but COSMO will not abort if it does not exist); ’used’ means here that it is e. g. written to the feedobs file, but it does not imply active use in the data assimilation

’+’: variable exists but is not read by COSMO

’−’: descriptor (a BUFR common sequence, or a BUFR data description operator) exists only in the BUFR file, not in the NetCDF file

’(−)’: descriptor itself exists only in the BUFR file, not in the NetCDF file; however the descriptor indicates a common sequence of variables, which *are* present in the NetCDF file, but which are not used by COSMO and hence are not detailed here

The existence (2^{nd} column ’L’ for land stations, 3^{rd} column ’S’ for SHIP sea stations) of the variables or descriptors for the different observation (file) types according to the above mentioned BUFR common sequence descriptors is defined as follows:

’+’ : exists (for both types of land stations resp. for sea stations)

’f’ : exists for fixed land stations, but not for mobile land stations

’m’ : exists for mobile land stations, but not for fixed land stations

’ ’ : does not exist

use	L	S	WMO descriptor	type	mnemonics	meaning
−	f		3 01 090			Fixed surface station ID, time, horiz. + vertical coordinates
−	m		3 01 092			Mobile surface station ID, time, horiz. + vertical coordinates
−		+	3 01 093			Ship ID, movement, date / time, horiz. + vertical coordinates
−		+	3 01 036			Ship ID, movement, time, lat/lon
need	m	+	0 01 011	char*9	YDDDD	Ship or mobile land sta. identifier
+		+	0 01 012	int	MDS	Platform motion direction
+		+	0 01 013	int	NVS	Platform motion speed
+	m		0 01 003	int	MA	WMO region number
−	f		3 01 004			Surface station identification
need	f		0 01 001	int	MII	WMO block number
need	f		0 01 002	int	NIII	WMO station number
opt	f		0 01 015	char*20	YSOSN	Station or site name
need	+	+	0 02 001	int	NIX	Type of station
−	+		3 01 011			Year, month and day
need	+	+	0 04 001	int	MJJJ	Year
need	+	+	0 04 002	int	MMM	Month
need	+	+	0 04 003	int	MYY	Day
−	+		3 01 012			Hour, minute
need	+	+	0 04 004	int	MGG	Hour
need	+	+	0 04 005	int	NGG	Minute
−	+		3 01 021			Latitude and Longitude
need	+		0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	+		0 06 001	float	MLOH	Longitude (high accuracy) [deg.]

use	L	S	WMO descriptor	type	mnemonics	meaning
need		+	0 05 002	float	MLALA	Latitude (coarse accuracy) [deg.]
need		+	0 06 002	float	MLOLO	Longitude (coarse accur.) [deg.]
need	+	+	0 07 030	float	MHOSNN	Height of station above MSL (1)
need	+	+	0 07 031	float	MHOBNN	Height of barometer a. MSL (1)
opt	m		0 33 024	int	MSEQM	Station elevation quality mark
–	+		3 02 031			**Pressure** data
–	+	+	3 02 001			Pressure group
need	+	+	0 10 004	float	MPPP	Pressure
opt	+	+	0 10 051	float	MPPPP	Pressure reduced to MSL
opt	+	+	0 10 061	float	NPPP	3-hour pressure change
+	+	+	0 10 063	int	NA	Characteristic of press. tendency
+	+		0 10 062	float	NP24	24-hour pressure change
opt	+		0 07 004	float	MPN	Pressure (standard level)
opt	+		0 10 009	int	NHHHN	Geopotential height [gpm] of the standard level
–	+		3 02 035			Basic synoptic 'instanteous' data
–		+	3 02 054			SHIP 'instanteous' data
–	+		3 02 032			**Temperature + humidity** data
–		+	3 02 052			
opt	+	+	0 07 032	float	MHOSEN	Height of sensor above local ground / marine deck platform (for temp. + humidity meas.)
opt		+	0 07 033	float	MHAWAS	Height of sensor above water surface (temp. + hum. meas.)
need	+	+	0 12 101	float	MTDBT	Temperature / dry-bulb temperat.
+		+	0 02 039	int	MMOWTM	Method of wet-bulb temp. meas.
+		+	0 12 102	float	MTFNH	Wet-bulb temperature
need	+	+	0 12 103	float	MTDNH	Dew-point temperature
opt	+	+	0 13 003	int	MUUU	Relative humidity [%]
–	+		3 02 033			**Visibility** data
–		+	3 02 053			
+	+	+	0 07 032	float	MHOSEN0	Height of sensor a. ground (vis.)
opt		+	0 07 033	float	MHAWAS0	Height of sensor above water surface (for visibility)
opt	+	+	0 20 001	float	MVV	Horizontal visibility
–	+	+	3 02 034			**Precipitation** past 24 hours
+	+	+	0 07 032	float	MHOSEN1	Height of sensor a. gr. (precip.)
opt	+	+	0 13 023	float	MRR24	Total precipitation past 24 hours
–	+	+	3 02 004			**Cloud** data
opt	+	+	0 20 010	int	MN	Cloud cover (total) [%]
opt	+	+	0 08 002	int	MVTSU	Vertical significance
opt	+	+	0 20 011	int	MNH	Cloud amount (of low or middle clouds)
opt	+	+	0 20 013	float	NH	Cloud base height above surface
opt	+	+	0 20 012	int	MCC	Cloud type (low clouds C_L)
opt	+	+	0 20 012	int	MCC0	Cloud type (middle clouds C_M)
opt	+	+	0 20 012	int	MCC1	Cloud type (high clouds C_H)
opt	+	+	0 31 001	int	MDREP	Delayed descriptor replication
–	+	+	3 02 005			Individual cloud layers of masses

use	L	S	WMO descriptor	type	mnemonics	meaning
opt	+	+	0 08 002	int *n	MVTSU0	Vertical significance (2)
opt	+	+	0 20 011	int *n	MNH0	Cloud amount (2)
opt	+	+	0 20 012	int *n	MCC2	Cloud type (C) (2)
opt	+	+	0 20 013	float*n	NH0	Height of base of cloud (2)
(−)	+		3 02 036			Cloud with bases below station level
(−)	+		3 02 047			Direction of cloud drift
(−)	+		3 02 048			Direction and elevation of cloud
−	+		3 02 037			State of ground, snow depth, ground minimum temperature
opt	+		0 20 062	int	ME	State of ground (w. or w/o snow)
opt	+		0 13 013	float	NSSS	Total snow depth
+	+		0 12 113	float	MTGTGH	Ground min. temperat. past 12 hrs
(−)		+	3 02 055			Icing and ice
(−)		+	3 02 057			SHIP marine data
(−)		+	3 02 056			Sea surface temperature, depth
(−)		+	3 02 021			Waves
(−)		+	3 02 024			Wind waves
(−)		+	3 02 023			Swell waves
−	+		3 02 043			Basic synoptic 'period' data
−		+	3 02 060			SHIP 'period' data
−	+	+	3 02 038			**Present and past weather**
opt	+	+	0 20 003	int	NWW	Present weather
opt	+	+	0 04 024	int	MGGTP	Time period in hours
opt	+	+	0 20 004	int	MW1	Past weather 1
opt	+	+	0 20 005	int	MW2	Past weather 2
(−)	+		3 02 039			Sunshine data
−	+	+	3 02 040			**Precipitation** measurement
+	+	+	0 07 032	float	MHOSEN3	Height of sensor above ground / marine deck platform (precip.)
−	+	+	1 02 002			Replicate next 2 descript. twice
opt	+	+	0 04 024	int *2	MGGTP1	Time period in hours
opt	+	+	0 13 011	float*2	MRRR	Total precipitation / total water equivalent of snow
−	+		3 02 041			**Extreme temperature** data
−		+	3 02 058			
+	+	+	0 07 032	float	MHOSEN4	Height of sensor above ground / marine deck platf. (temper.)
opt		+	0 07 033	float	MHAWAS2	Height of sensor above water surface (for temperature)
opt	+		0 04 024	int	MGGTP2	Start of time period in hours
opt		+	0 04 024	int	MGGTP1	
opt	+		0 04 024	int	MGGTP3	End of time period in hours
opt		+	0 04 024	int	MGGTP2	
opt	+	+	0 12 111	float	MTXTXH	Maximum temperature over period specified
opt	+		0 04 024	int	MGGTP4	Start of time period in hours
opt		+	0 04 024	int	MGGTP3	
opt	+		0 04 024	int	MGGTP5	End of time period in hours
opt		+	0 04 024	int	MGGTP4	

use	L	S	WMO descriptor	type	mnemonics	meaning
opt	+	+	0 12 112	float	MTNTNH	Minimum temperature over period specified
−	+		3 02 042			**Wind** data
−		+	3 02 059			
+	+	+	0 07 032	float	MHOSEN5	Height of sensor a. ground/deck
opt		+	0 07 033	float	MHAWAS2	Height of sensor a. water surface
+	+	+	0 02 002	int	NIW	Type of instrumentation for wind measurement
opt	+	+	0 08 021	int	MTISI	Time significance (= 2 (time averaged))
opt	+	+	0 04 025	int	NGGTP	Time period (-10 min, or since a significant wind change)
need	+	+	0 11 001	int	NDNDN	Wind direction
need	+	+	0 11 002	float	NFNFN	Wind speed
+	+	+	0 08 021	int	MTISI0	Time significance (missing value)
−	+	+	1 03 002			Replicate next 3 descript. twice
opt	+	+	0 04 025	int *2	NGGTP0	Time period in minutes
+	+	+	0 11 043	int *2	NMWGD	Maximum wind gust direction
opt	+	+	0 11 041	float*2	NFXGU	Maximum wind gust speed
(−)	+		3 02 044			Evaporation data
(−)	+		3 02 045			Radiation data
(−)	+		3 02 046			Temperature change data

Table notes:

(1) Only one of the variables 'MHOBNN' and 'MHOSNN' is strictly needed to exist. 'MHOBNN' is preferred to exist (and to be used if both variables exist and have non-missing values) because it should provide the precise height of the barometer for the pressure measurement, which is the observation with the most critical dependency on sensor (or 'station') height.

(2) The use of '*n' in the variable type definition means that this variable has an additional dimension, i. e. several values may be present in one report. If the corresponding replication factors 'MEDRE' or 'MDREP' are zero for all reports in the NetCDF file, then the corresponding multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.

- **TEMP, TEMP MOBIL, and TEMP SHIP**

File names:	for fixed land stations	(TEMP)	:	'cdfin_temp'
	for mobile land stations	(TEMP MOBIL)	:	'cdfin_temp'
	for sea stations	(TEMP SHIP)	:	'cdfin_tempship'.

The template given by the common sequence descriptor '**TM 3 09 052**' is used for the observation types TEMP (fixed land stations), TEMP MOBIL (mobile land stations), as well as TEMP SHIP (sea stations). The table below lists all the variables of this template and their use in COSMO.

The use of the variables (first column of table) is defined as follows:

'need': COSMO asks stringently for this variable and will abort if variable is absent (but will not abort if values are equal to 'missing value')

'opt': variable exists and is read/used (but COSMO will not abort if it does not exist); 'used' means here that it is e. g. written to the feedobs file, but it does not imply active use in the data assimilation

'+': variable exists but is not read by COSMO

'−': descriptor (a BUFR common sequence, or a BUFR data description operator) exists only in the BUFR file, not in the NetCDF file

use	WMO descriptor	type	mnemonics	meaning
−	3 01 111			Identific. of launch site + instumentation
−	3 01 001			Station identification
need	0 01 001	int	MII	WMO block number (1)
need	0 01 002	int	NIII	WMO station number (1)
need	0 01 011	char*9	YDDDD	Ship or mobile land station identifier (1)
need	0 02 011	int	NRARA	Radiosonde type
opt	0 02 013	int	NSR	Solar and infrared radiation correction
opt	0 02 014	int	NSASA	Tracking technique / status of system
opt	0 02 003	int	NA4	Type of measuring equipment
−	3 01 113			Date / time of launch
opt	0 08 021	int	MTISI	Time significance (= 18 (launch time))
−	3 01 011			Year, month and day
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
−	3 01 013			Hour, minute, second
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
+	0 04 006	int	MSEC	Second
−	3 01 114			Horiz. + vert. coord. of launch site
−	3 01 021			Latitude and Longitude
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [degree]
need	0 07 030	float	MHOSNN	Height of station above MSL (2)
need	0 07 031	float	MHOBNN	Height of barometer above MSL (2)
opt	0 07 007	int	MH	Height of release of sonde above MSL
opt	0 33 024	int	MSEQM	Station elevation quality mark
−	3 02 049			**Cloud** info reported with vert. soundings
opt	0 08 002	int	MVTSU	Vertical significance
opt	0 20 011	int	MNH	Cloud amount (of low or middle clouds)
opt	0 20 013	float	NH	Cloud base height above surface
opt	0 20 012	int	MCC	Cloud type (low clouds C_L)
opt	0 20 012	int	MCC0	Cloud type (middle clouds C_M)
opt	0 20 012	int	MCC1	Cloud type (high clouds C_H)
+	0 22 043	float	MTN00	Sea / water temperature
need	0 31 002	int	MEDRE	Extended delayed descriptor replicat. fac.
−	3 03 054			**Temperature**, **dewpoint** + **wind** data

use	WMO descriptor	type	mnemonics	meaning
				at a pressure level with sonde position
opt	0 04 086	int *n	NLTPD	Time displacement since launch time [s]
need	0 08 042	int *n	MEVSS	Extended vertical sounding significance
need	0 07 004	float*n	MPN	Pressure (vertical location) [Pa]
need	0 10 009	int *n	NHHHN	Geopotential height [gpm]
opt	0 05 015	float*n	MLADH	Latitude displacement since launch site
opt	0 06 015	float*n	MLODH	Longitude displacement since launch site
need	0 12 101	float*n	MTDBT	Temperature / dry-bulb temperature
need	0 12 103	float*n	MTDNH	Dew-point temperature
need	0 11 001	int *n	NDNDN	Wind direction [degree true]
need	0 11 002	float*n	NFNFN	Wind speed [m/s]
+	0 31 001	int	MDREP	Delayed descriptor replication factor
–	3 03 051			**Wind shear** data at a pressure level
+	0 04 086	int *n	NLTPD0	Time displacement since launch time [s]
+	0 08 042	int *n	MEVSS0	Extended vertical sounding significance
+	0 07 004	float*n	MPN0	Pressure (vertical location) [Pa]
+	0 05 015	float*n	MLADH0	Latitude displacement since launch site
+	0 06 015	float*n	MLODH0	Longitude displacement since launch site
+	0 11 061	float*n	NVBVB	Absolute wind shear in 1 km layer below
+	0 11 062	float*n	NVAVA	Absolute wind shear in 1 km layer above [m/s]

Table notes:

(1) Only either the pair of variables 'MII' and 'NIII' or the single variable 'YDDDD' is strictly needed to exist. If both exist and have non-missing values for a certain report, then the values of the pair 'MII' and 'NIII' are used.

(2) Only one of the variables 'MHOBNN' and 'MHOSNN' is strictly needed to exist. For radiosondes, 'MHOBNN' is found to be the pressure at the site where the ground check and calibration is done, whereas 'MHOSNN' coincides with the 'surface level' of the sounding. Therefore, for the three TEMP types and unlike for other observation types, 'MHOSNN' is preferred to exist (and be used if both variables have non-missing values).

(*n) '*n' in the variable type definition means that this variable has an additional dimension, used here for the vertical levels, and hence, several values may be present in one report. If the corresponding replication factors 'MEDRE' or 'MDREP' are zero for all reports in the NetCDF file, then the corresponding multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.

- **PILOT either with height or pressure as vertical coordinate**

File names:	for PILOT with height as vertical coordinate	:	'cdfin_pilot'
	for PILOT with pressure as vertical coordinate	:	'cdfin_pilot_p'.

Irrespective of the vertical coordinate used, the templates for PILOT (from fixed land stations), PILOT MOBIL (from mobile land stations), as well as PILOT SHIP (from sea stations) are identical. The common sequence descriptors '**TM 3 09 050**' and '**TM 3 09 051**' are used for PILOTs with pressure resp. height as vertical coordintate. These templates are identical to each other except for the vertical coordinate. '**TM 3 09 050**' contains pressure but lacks height as a variable, whereas for '**TM 3 09 051**', the variable pressure does not exist, and the vertical level is expressed as height.

COSMO is coded such that from the file 'cdfin_pilot_p', in addition to the mandatory pressure variable, the height variable can also be read as an optional variable, and from 'cdfin_pilot', in addtion to the mandatory height variable, the pressure variable is also read if present. This would allow for using PILOT reports which contain both pressure levels and height levels. *However, since the current version of 'bufrx2netcdf' is not able to produce such 'mixed' PILOT NetCDF files, this has never been tested.*

The table below, split into two parts, lists all the variables and their use in COSMO. The use of the variables (first column of the header table; columns 'Z' and 'P' of the body table for PILOT with height resp. pressure as vertical coordinate) is defined as follows:

'need':	COSMO asks stringently for this variable and will abort if variable is absent (but will not abort if values are equal to 'missing value')
'opt':	variable exists and is read/used (but COSMO will not abort if it does not exist); 'used' means here that it is e. g. written to the feedobs file, but it does not imply active use in the data assimilation
'(opt)':	variable does not exist in the template; if it does exist nevertheless then it is read and used by COSMO
'+':	variable exists but is not read by COSMO
'−':	descriptor (for a BUFR common sequence) exists only in the BUFR file, not in the NetCDF file
' ':	variable does not exist at all

'Z', 'P'	WMO descriptor	type	mnemonics	meaning
−	3 01 110			Identific. of launch site + instumentation
−	3 01 001			Station identification
need	0 01 001	int	MII	WMO block number (1)
need	0 01 002	int	NIII	WMO station number (1)
need	0 01 011	char*9	YDDDD	Ship or mobile land station identifier (1)
need	0 02 011	int	NRARA	Radiosonde type
opt	0 02 014	int	NSASA	Tracking technique / status of system
opt	0 02 003	int	NA4	Type of measuring equipment
−	3 01 113			Date / time of launch
opt	0 08 021	int	MTISI	Time significance (= 18 (launch time))
−	3 01 011			Year, month and day
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
−	3 01 013			Hour, minute, second
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
+	0 04 006	int	MSEC	Second
−	3 01 114			Horiz. + vert. coord. of launch site
−	3 01 021			Latitude and Longitude
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [degree]

’Z’, ’P’	WMO descriptor	type	mnemonics	meaning
need	0 07 030	float	MHOSNN	Height of station above MSL (2)
need	0 07 031	float	MHOBNN	Height of barometer above MSL (2)
opt	0 07 007	int	MH	Height of release of sonde above MSL
opt	0 33 024	int	MSEQM	Station elevation quality mark

’Z’	’P’	WMO descr.	type	mnemonics	meaning
need	need	0 31 002	int	MEDRE	Extended delayed descriptor replicat.
	–	3 03 050			**Wind** data at a pressure level
–		3 03 052			**Wind** data at a height level
opt	opt	0 04 086	int *n	NLTPD	Time displacem. since launch time [s]
need	need	0 08 042	int *n	MEVSS	Extend. vertic. sounding significance
(opt)	need	0 07 004	float*n	MPN	Pressure (vertical location) [Pa]
need	(opt)	0 07 009	int *n	NHHH	Geopotential height [gpm]
opt	opt	0 05 015	float*n	MLADH	Latitude displacem. since launch site
opt	opt	0 06 015	float*n	MLODH	Longitude displace. since launch site
need	need	0 11 001	int *n	NDNDN	Wind direction [degree true]
need	need	0 11 002	float*n	NFNFN	Wind speed [m/s]
+	+	0 31 001	int	MDREP	Delayed descriptor replication factor
	–	3 03 051			**Wind shear** data at a pressure level
–		3 03 053			**Wind shear** data at a height level
+	+	0 04 086	int *n	NLTPD0	Time displacem. since launch time [s]
+	+	0 08 042	int *n	MEVSS0	Extend. vertic. sounding significance
	+	0 07 004	float*n	MPN0	Pressure (vertical location) [Pa]
+		0 07 009	int *n	NHHH0	Geopotential height [gpm]
+	+	0 05 015	float*n	MLADH0	Latitude displacem. since launch site
+	+	0 06 015	float*n	MLODH0	Longitude displace. since launch site
+	+	0 11 061	float*n	NVBVB	Absolute shear in 1 km layer below
+	+	0 11 062	float*n	NVAVA	Absolute shear in 1 km layer above [m/s]

Table notes:

(1) Only either the pair of variables ’MII’ and ’NIII’ or the single variable ’YDDDD’ is strictly needed to exist. If both exist and have non-missing values for a certain report, then the values of the pair ’MII’ and ’NIII’ are used.

(2) Only one of the variables ’MHOBNN’ and ’MHOSNN’ is strictly needed to exist. If both exist and have non-missing values for a certain report, then the values of ’MHOBNN’ are used.

(*n) ’*n’ in the variable type definition means that this variable has an additional dimension, used here for the vertical levels, and hence, several values may be present in one report. If the corresponding replication factors ’MEDRE’ or ’MDREP’ are zero for all reports in the NetCDF file, then the corresponding multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.

6.4.2 Observation types with templates proposed or approved by WMO

The BUFR templates, which the NetCDF files described in this sub-section are based on, are described in (the lower part of)
http://www.wmo.int/pages/prog/www/WMOCodes/TemplateExamples.html
respectively for GPS zenith total delay and water vapour data at
http://egvap.dmi.dk/support/formats/egvap_bufr_v10.pdf .

- **BUOY**

  File name: 'cdfin_buoy'.

  The template follows the proposed WMO descriptor '**TM 3 08 008**'. The table below lists all the variables which are used by COSMO, plus only a subset of the variables that are not used by COSMO. For convenience, the table is split into a report header and a report body part.

  The use of the variables is defined as follows:

'need':	COSMO asks stringently for this variable and will abort if variable is absent (but will not abort if values are equal to 'missing value')
'opt':	variable exists and is read/used (but COSMO will not abort if it does not exist); 'used' means here that it is e. g. written to the feedobs file, but it does not imply active use in the data assimilation
'+':	variable exists but is not read by COSMO
'−':	descriptor (for a BUFR common sequence) exists only in the BUFR file, not in the NetCDF file

use	WMO descriptor	type	mnemonics	meaning
need	0 01 005	int	MABNN	Buoy / platform identifier
need	0 02 001	int	NIX	Type of station
+	0 02 036	int	NBOTY	Buoy type
opt	0 02 149	int	MTODB	Type of data buoy
−	3 01 011			Year, month and day
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
−	3 01 012			Hour, minute
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
+	0 08 021	int	MTISI	Time significance (= 26 (time of last known position))
−	3 01 011			Year, month and day
−	3 01 012			Hour, minute
−	3 01 021			Latitude and Longitude
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [degree]
need	0 07 030	float	MHOSNN	Height of station above MSL (1)
+	0 01 012	int	MDS	Platform drift direction
+	0 01 014	float	MDSDS	Platform drift speed

use	WMO descriptor	type	mnemonics	meaning
opt	0 33 023	int	MQOBL	Quality of buoy location
–	3 02 021			Waves
–	3 06 004			Depths / salinities / temperatures
+	0 31 001	int	MDREP	Delayed descriptor replication factor
+	0 07 062	float*n	NZNZN	Depth below sea / water surface (2)
+	0 22 043	float*n	MTN00	Sea / water temperature (2)
+	0 22 062	float*n	MSNSN	Salinity (2)
–	3 06 005			Depths / directions / speeds of currents
–	3 02 001			Pressure and pressure change
need	0 07 031	float	MHOBNN	Height of barometer above MSL (1)
need	0 10 004	float	MPPP	**Pressure**
opt	0 10 051	float	MPPPP	Pressure reduced to MSL
opt	0 10 061	float	NPPP	3-hour pressure change
+	0 10 063	int	NA	Characteristic of pressure tendency
opt	0 07 032	float	MHOSEN	Height of sensor above marine deck platform (for temperature and humidity measurements)
+	0 07 033	float	MHAWAS	Height of sensor above water surface (for temperature and humidity)
need	0 12 101	float	MTDBT	**Temperature** / dry-bulb temperature
need	0 12 103	float	MTDNH	**Dew-point** temperature
opt	0 13 003	int	MUUU	Relative humidity [%]
+	0 07 032	float	MHOSEN0	Height of sensor above marine deck platform (for wind measurement)
+	0 07 033	float	MHAWAS0	Height of sensor above w. surf. (wind)
+	0 08 082	int	NACH2V	Artificial correction of sensor height to another value
+	0 07 033	float	MHAWAS1	Height of sensor above w. surf. (wind)
opt	0 08 021	int	MTISI1	Time significance (= 2 (time averaged))
opt	0 04 025	int	NGGTP	Time period in minutes
need	0 11 001	int	NDNDN	**Wind** direction
need	0 11 002	float	NFNFN	**Wind** speed
opt	0 04 025	int	NGGTP0	Time period in minutes
opt	0 11 041	float	NFXGU	Maximum wind gust speed
opt	0 04 024	int	MGGTP	Time period in hours
opt	0 13 011	float	MRRR	Total precipitation [kg/m2]

Table notes:

(1) Only one of the variables 'MHOBNN' and 'MHOSNN' are needed to exist. Preferred to exist is 'MHOBNN' (and to be used if both variables exist and have non-missing values) because it should provide the precise height of the barometer for the pressure measurement, which is the observation with the most critical dependency on sensor (or 'station') height.

(2) '*n' in the variable type definition means that this variable has an additional dimension, i. e. several values may be present in one report. If the corresponding replication factor 'MDREP' is zero for all reports in the NetCDF file, then these multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.

- **GPS (GNSS) zenith total delay and water vapour**

  File name: 'cdfin_gps_zenith'.

  GPS or GNSS (Global Navigation Satellite System: GPS, GLONASS, + GALILEI) reports on zenith total (path) delay (ZTD) are obtained via GTS from the UK Met Office as BUFR reports in a template which has been approved by WMO and has the (Table D) descriptor '**TM 3 07 022**'. These reports can be directly converted into NetCDF. The following table describes this template, and a description can also be found at : http://egvap.dmi.dk/support/formats/egvap_bufr_v10.pdf .

  The formats consist of the descriptors in the following table where

'need' :	COSMO asks stringently for this variable (and will abort if variable is absent)
'opt' :	variable exists and is read/used (but COSMO will not abort if it does not exist)
'+' :	variable exists but is not read by COSMO

GPS	descript.	type	mnemonics	meaning
need	0 01 015	char*20	YSOSN	Station or site name
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [deg.]
need	0 07 001	int	MHP	Height of station [m]
+	0 08 021	int	MTISI	Time significance
need	0 04 025	int	NGGTP	Time period or displacement [min]
need	0 10 004	float	MPPP	Pressure [Pa]
need	0 12 001	float	MTN	Temperature / dry bulb temperature [K]
need	0 13 003	int	MUUU	Relative humidity [%]
need	0 33 038	int	NQFGD	Quality flags for ground-based GNSS data
+	0 08 022	int	MTOTN	Total number (accumulation / average)
+	0 02 020	int *n	MSACL	Satellite classification
+	0 01 050	int *n	MPTID	Platform transmitter ID number
+	0 05 021	float*n	MDA	Bearing or azimuth [degree_true]
need	0 07 021	float*n	MDE	Elevation [degree]
need	0 15 031	float*n	NADES	**Atmospheric path delay** in sat. signal [m]
need	0 15 032	float*n	NEERR	Estimated error in atmospheric path delay [m]
+	0 08 060	int	MSSMS	Sample scanning mode significance
+	0 15 033	float	NDPDL	Diff. in path delays for Limb views [m]
+	0 15 034	float	NEEPDD	Estimated error in path delay difference [m]
+	0 08 060	int	MSSMS0	Sample scanning mode significance
+	0 15 033	float	NDPDL0	Diff. in path delays for Limb views [m]
+	0 15 034	float	NEEPDD0	Estimated error in path delay difference [m]
need	0 15 035	float	NCZWV	Component of zenith path delay due to water vapour [m]
need	0 13 016	float	NWLN	**Precipitable water** [kg/m**2]
+	0 15 011	float	MLIED	LOG_10 of integrated electron density [log(1/m**2)]

  Table note: '*n' in the variable type definition means that this variable has an additional dimension. Currently, this is set to a fixed value of 25.

- **single-level AMDAR**

  File name: ’cdfin_amdar’.

  The template follows the proposed WMO descriptor **’TM 3 11 010’** and is described in the table below. The use of the variables is defined as follows:

  ’need’ : COSMO asks stringently for this variable (and will abort if variable is absent)
  ’opt’ : variable exists and is read/used (but COSMO will not abort if it does not exist)
  ’+’ : variable exists but is not read by COSMO
  ’(+)’ : descriptor exists only in the BUFR file, not in the NetCDF file

use	WMO descriptor	type	mnemonics	meaning
+	0 31 021		MADDF	Associated field significance (1)
–	3 11 005			Standard AMDAR report
need	0 01 008	char*8	YAIRN	Aircraft identification
+	0 01 023	int	NOSNO	Observation sequence number
–	3 01 021			Latitude and Longitude
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [degree]
–	3 01 011			Year, month and day
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
–	3 01 013			Hour, minute and second
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
+	0 04 006	int	MSEC	Second
need	0 07 010	int	NFLEV	Flight level (2)
opt	0 08 009	int	NDEPF	Detailed phase of flight (3)
need	0 11 001	int	NDNDN	**Wind** direction
need	0 11 002	float	NFNFN	**Wind** speed
opt	0 11 031	int	MB	Degree of turbulence
opt	0 11 036	float	NMDEWX	Derived equivalent vertical gust speed
need	0 12 101	float	MTDBT	**Temperature** / dry-bulb T
+	0 33 025	int	MAIV	ACARS interpolated values
need	0 08 004	int	MPHAI	Phase of flight
need	0 02 064	int	MQARA	Wind quality/roll angle
opt	0 13 003	int	MUUU	Relative **humidity**
need	0 12 103	float	MTDNH	Dew-point temperature
opt	0 13 002	float	MMIXR	Mixing ratio
–	1 02 000			Delayed replication of 2 descriptors
+	0 31 001	int	MDREP	Delayed descriptor replication factor
+	0 11 075	float*n	MMPI	Mean turbulent intensity (EDR) (4)
+	0 11 076	float*n	MPTI	Peak turbulent intensity (EDR) (4)
+	0 11 037	int	MTUIN	Turbulence index (EDR)
+	0 11 039	int	NTIED	Extended time of occur. of peak EDR
+	0 11 077	int	NRED	EDR reporting interval
+	0 20 042	int	NAICE	Ice/no ice
+	0 20 043	float	NPLWC	Peak liquid water content
+	0 20 044	float	NALWC	Average liquid water content
+	0 20 045	int	NSLD	Supercooled water droplet conditions

Table notes:

(1) Variable 'MADDF' does not exist in the WMO descriptor 'TM 3 11 010', but is added at DWD by the decoding software.

(2) Flight level is defined relative to the ICAO standard sea level pressure and is readily converted to static air pressure using standard formulae (i. e. using the ICAO standard atmosphere). Hence, flight level is *not* the geometrical height.

(Once converted, the original resolution (either 100ft or 10ft) in the BUFR report is lost, hence it is desirable to disseminate the element in the received form.)

(3) This phase of flight table is expanded to indicate wind quality from roll angle (or roll and pitch combined) and also to indicate the method of ascent and descent observation interval selection either by time or pressure increments.

(4) The use of '*n' in the variable type definition means that this variable has an additional dimension, i. e. several values may be present in one report. If the corresponding replication factor 'MDREP' is zero for all reports in the NetCDF file, then the variables 'MMPI' and 'MPTI' do *not* exist in the NetCDF file.

- **multi-level AMDAR**

File name: 'cdfin_amdar_ml'.

Caution: The use of this observation file type in COSMO has not been tested thoroughly yet, mainly due to a lack of data of this type (at least over Europe). The use of it is at the user's own risk.

The template follows the proposed WMO descriptor '**TM 3 11 009**' and is described in the table below, which is split into two parts for convenience. There is also a proposed descriptor '**TM 3 11 008**' for aircraft profiles *without* latitude and longitude reported at each level. (Descriptor 'TM 3 11 008' equals 'TM 3 11 009' except that '3 11 007' is replaced by '3 11 006', which in turn is the same as '3 11 007' except that '3 01 021' is missing.) The use of the various variables is defined as follows:

'need' : COSMO asks stringently for this variable (and will abort if variable is absent)
'opt' : variable exists and is read/used (but COSMO will not abort if it does not exist)
'+' : variable exists but is not read by COSMO
'(+)' : descriptor exists only in the BUFR file, not in the NetCDF file

use	WMO descriptor	type	mnemonics	meaning
opt	0 01 033	int	MMIOGC	Identific. of orig./ generat. centre (1)
+	0 01 034	int	MMIOGS	Identific. of orig./ gen. sub-centre (1)
+	0 01 023	int	NOSNO	Observation sequence number (1)
need	0 01 008	char*8	YAIRN	Aircraft identification
−	3 01 011			Year, month and day
need	0 04 001	int	MJJJ	Year
need	0 04 002	int	MMM	Month
need	0 04 003	int	MYY	Day
−	3 01 013			Hour, minute and second
need	0 04 004	int	MGG	Hour
need	0 04 005	int	NGG	Minute
+	0 04 006	int	MSEC	Second

use	WMO descriptor	type	mnemonics	meaning
–	3 01 021			Latitude and Longitude
need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	0 06 001	float	MLOH	Longitude (high accuracy) [degree]
need	0 08 004	int	MPHAI	Phase of flight
–	1 01 000			Delayed replication of 1 descriptor
need	0 31 001	int	MDREP	Delayed descriptor replication factor
–	3 11 007			Aircraft ascent / descent profile data for 1 level with lat. / lon. indicated
need	0 07 010	int *n	NFLEV	Flight level (2, 3)
–	3 01 021			Latitude and Longitude
opt	0 05 001	float*n	MLAH0	Latitude (high accuracy) [degree] (3)
opt	0 06 001	float*n	MLOH0	Longitude (high accuracy) [degree] (3)
need	0 11 001	int *n	NDNDN	**Wind** direction (3)
need	0 11 002	float*n	NFNFN	**Wind** speed (3)
need	0 02 064	int *n	MQARA	Wind quality/roll angle (3)
need	0 12 101	float*n	MTDBT	**Temperature** / dry-bulb temperature (3)
need	0 12 103	float*n	MTDNH	**Dew-point** temperature (3)
+	0 13 002	float*n	MMIXR	Mixing ratio (1, 3)

Table notes:

(1) The Variables 'MMIOGC', 'MMIOGS', 'NOSNO', and 'MMIXR' do not exist in the WMO BUFR descriptor 'TM 311009', but are added at DWD by the data base decoding software.

(2) Flight level is defined relative to the ICAO standard sea level pressure and is readily converted to static air pressure using standard formulae (i. e. using the ICAO standard atmosphere). Hence, flight level is *not* the geometrical height.

(Once converted, the original resolution (either 100ft or 10ft) in the BUFR report is lost, hence it is desirable to disseminate the element in the received form.)

(3) The use of '*n' in the variable type definition means that this variable has an additional dimension, here for vertical levels. If the corresponding replication factor 'MDREP' is zero for all reports in the NetCDF file, then these multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.

6.4.3 Observation types without templates proposed by WMO

- **ACARS**

File names: 'cdfin_acars', 'cdfin_acars_uk', resp. 'cdfin_acars_us'.

As a standard way implemented at DWD, ACARS can be read by COSMO in 2 different ways:

1. A file type ('cdfin_acars_us') with BUFR obtained via GTS from ARINC Center 56 (USA, denoted as '_us' in the table below) plus another file type ('cdfin_acars_uk') with BUFR obtained via GTS from UK Met Office and Canada (denoted as '_uk'), or
2. A single file type ('cdfin_acars') in a unified format (defined by DWD) which contains the reports from the two other files (denoted as 'unif.').

The formats consist of the descriptors in the following table where

'need':	COSMO asks stringently for this variable (and will abort if variable is absent)
'opt':	variable exists and is read/used (but COSMO will not abort if it does not exist)
'+':	variable exists but is not read by COSMO
'−':	variable does not exist in this format

unif.	_uk	_us	descript.	type	mnemonics	meaning
opt	−	−	0 01 033	int	MMIOGC	Identific. of orig./ generat. centre
+	−	−	0 01 034	int	MMIOGS	Identific. of orig./ gen. sub-centre
need	need	need	0 01 008	char*8	YAIRN	Aircraft identification
−	+	+	0 01 006	char*8	YXXNN	Aircraft identification
+	−	−	0 01 023	int	NOSNO	Observation sequence number
−	−	opt	0 02 001	int	NIX	Type of station
−	−	+	0 02 002	int	NIW	Instrument type for wind measure.
−	+	−	0 02 061	int	NS1	Aircraft navigational system
need	need	need	0 05 001	float	MLAH	Latitude (high accuracy) [degree]
need	need	need	0 06 001	float	MLOH	Longitude (high accuracy) [deg.]
need	need	need	0 04 001	int	MJJJ	Year
need	need	need	0 04 002	int	MMM	Month
need	need	need	0 04 003	int	MYY	Day
need	need	need	0 04 004	int	MGG	Hour
need	need	need	0 04 005	int	NGG	Minute
+	−	+	0 04 006	int	MSEC	Second
−	need	−	0 07 002	float	MHHH	Height or altit. (vert. level) (1, 2)
need	−	opt	0 07 004	float	MPN	Pressure (vertical level) (1)
−	+	−	0 07 007	int	MH	Height
need	−	−	0 07 010	int	NFLEV	Flight level (1, 2)
−	−	need	0 10 070	int	MIAA	Indicated aircraft altitude (1, 2)
opt	−	−	0 08 009	int	NDEPF	Detailed phase of flight (3)
need	need	need	0 11 001	int	NDNDN	**Wind** direction
need	need	need	0 11 002	float	NFNFN	**Wind** speed
opt	opt	−	0 11 031	int	MB	Degree of turbulence
−	+	−	0 11 032	float	MHBT	Height of base of turbulence
−	+	−	0 11 033	float	MHTT	Height of top of turbulence
opt	opt	−	0 11 036	float	NMDEWX	Derived equiv. vertical gust speed
−	need	need	0 12 001	float	MTN	**Temperature** / dry-bulb T (4)
need	−	−	0 12 101	float	MTDBT	Temperature / dry-bulb T (4)
+	−	+	0 33 025	int	MAIV	ACARS interpolated values
need	need	need	0 08 004	int	MPHAI	Phase of flight
need	need	need	0 02 064	int	MQARA	Wind quality/roll angle
opt	−	opt	0 13 003	int	MUUU	Relative **humidity**
opt	−	−	0 12 103	float	MTDNH	Dew-point temperature
opt	opt	opt	0 13 002	float	MMIXR	Mixing ratio
−	+	−	0 11 076	float	MPTI	Peak turbulent intensity (EDR)
+	+	−	0 20 041	int	MAICI	Airframe icing
opt	opt	opt	0 02 005	float	MPOTO	Precision of temperature observ.

unif.	_uk	_us	descript.	type	mnemonics	meaning
+	+	+	0 02 062	int	NADRS	Type of aircraft data relay system
+	−	+	0 02 070	int	NOSLL	Original specif. of latit. / longit.
+	−	+	0 02 065	char*5	YAGRS	ACARS ground receiving system
opt	−	opt	0 33 026	int	MMRQ	Mixing ratio quality
−	−	+	0 04 015	int	NGGTI	Time increment
−	−	+	0 04 032	int	NGGTM	Duration rel. to following value
−	−	+	0 11 235	int	011235	unknown descriptor

Table notes:

(1) For the definition of the vertical level, it is in fact only required that at least one of the variables 'NFLEV', 'MIAA', 'NHHH', or 'MPN' exists in (any of) the NetCDF file(s) but it does not really matter which one(s). (And in order to use a report, the corresponding vertical level must not be a missing value.)

(2) Flight level is defined relative to the ICAO standard sea level pressure and is readily converted to static air pressure using standard formulae (i. e. using the ICAO standard atmosphere). Hence, flight level is *not* the geometrical height. In the above file types, the variables 'MIAA' and 'NHHH' also denote the same type of flight level as variable 'NFLEV' and are therefore not geometrical height either. (Once converted, the original resolution (either 100ft or 10ft) in the BUFR report is lost, hence it is desirable to disseminate the element in the received form.)

(3) This phase of flight table is expanded to indicate wind quality from roll angle (or roll and pitch combined) and also to indicate the method of ascent and descent observation interval selection either by time or pressure increments.

(4) For temperature, it is in fact only required that at least one of the variables 'MTDBT' or 'MTN' exists in (any of) the NetCDF file(s), but it does not really matter which one.

The unified ACARS format ('unif.') produced at DWD (file type 'cdfin_acars') contains additionally the following variables which do not occur in either of the ACARS formats ('_uk' and '_us') obtained via GTS (except for variable 'MPTI'), but which are part of the AMDAR template proposed by WMO:

unif.	descript.	type	mnemonics	meaning
−	1 02 000			Delayed replication of 2 descriptors
+	0 31 001	int	MDREP	Delayed descriptor replication factor
+	0 11 075	float*n	MMPI	Mean turbulent intensity (EDR) (1)
+	0 11 076	float*n	MPTI	Peak turbulent intensity (EDR) (1)
+	0 11 037	int	MTUIN	Turbulence index (EDR)
+	0 11 039	int	NTIED	Extended time of occurrence of peak EDR
+	0 11 077	int	NRED	EDR reporting interval
+	0 20 042	int	NAICE	Ice/no ice
+	0 20 043	float	NPLWC	Peak liquid water content
+	0 20 044	float	NALWC	Average liquid water content
+	0 20 045	int	NSLD	Supercooled water droplet conditions

Table note:

(1) The use of '*n' in the variable type definition means that this variable has an

additional dimension, i. e. several values may be present in one report. If the corresponding replication factor 'MDREP' is zero for all reports in the NetCDF file, then the variables 'MMPI' and 'MPTI' do *not* exist in the NetCDF file.

- **Wind Profiler, RASS temperature profiler, Radar VAD wind profiles**

  File names: 'cdfin_wprof', 'cdfin_rass', resp. 'cdfin_radar_vad'.

  Wind Profiler reports ('WP'), Radio Acoustic Sounding System temperature profile reports ('RASS'), and Radar Velocity Azimuth Display wind profile reports ('VAD') are usually obtained as BUFR reports with a variety of templates. At DWD, BUFR reports with a unified template for each of the 3 data types are produced from the original reports for subsequent conversion into NetCDF. These unified templates are described below.

  The formats consist of the descriptors in the following table where

'need':	COSMO asks stringently for this variable (and will abort if variable is absent)
'opt':	variable exists and is read/used (but COSMO will not abort if it does not exist)
'+':	variable exists but is not read by COSMO
'−':	variable does not exist in this format

WP	RASS	VAD	descript.	type	mnemonics	meaning
opt	opt	opt	0 01 033	int	MMIOGC	Identif. of orig./ generat. centre
+	+	+	0 01 034	int	MMIOGS	Identif. of orig./ gen. sub-centre
need	need	need	0 01 001	int	MII	WMO block number
need	need	need	0 01 002	int	NIII	WMO station number
+	+	−	0 02 001	int	NIX	Type of station
need	need	need	0 04 001	int	MJJJ	Year
need	need	need	0 04 002	int	MMM	Month
need	need	need	0 04 003	int	MYY	Day
need	need	need	0 04 004	int	MGG	Hour
need	need	need	0 04 005	int	NGG	Minute
need	need	need	0 05 002	float	MLALA	Latitude (coarse accuracy) [deg.]
need	need	need	0 06 002	float	MLOLO	Longitude (coarse accur.) [deg.]
need	need	need	0 07 001	int	MHP	Height of station [m]
opt	opt	−	0 10 018	char*5	YSSOSN	Short station or site name
opt	opt	opt	0 02 003	int	NA4	Type of measur. equipment used
opt	opt	−	0 25 021	int	MWCE	Wind computation enhancement
opt	opt	−	0 08 021	int	MTISI	Time significance
opt	−	−	0 04 026	int	MSETP	Time period or displacement [s]
need	need	need	0 31 001	int	MDREP	Delayed descript. replic. factor
opt	−	opt	0 33 002	int *n	MQINZ	Quality information
need	need	need	0 07 007	int *n	MH	Height [m]
need	−	need	0 11 001	int *n	NDNDN	**Wind** direction [degree]
need	−	need	0 11 002	float*n	NFNFN	**Wind** speed [m/s]
−	need	−	0 12 007	float*n	MTVIR	**Virtual temperature** [K]
opt	opt	opt	0 11 006	float*n	MWMPS	W-component [m/s]

WP	RASS	VAD	descript.	type	mnemonics	meaning
opt	opt	–	0 21 030	int *n	NSINOR	Signal to noise ratio [db]
opt	opt	–	0 25 034	int *n	NWPQ	NOAA WP quality ctrl. results
opt	–	opt	0 11 050	float*n	NSTDFF	Stand. deviat. wind speed [m/s]
+	–	–	0 11 051	float*n	NSTDVF	Std. vertical wind speed [m/s]

Table notes:

- If YSSOSN is present, then MII and NIII are not strictly mandatory.
- '*n' in the variable type definition means that this variable has an additional dimension, here for vertical levels. If the corresponding replication factor 'MDREP' is zero for all reports in the NetCDF file, then these multi-dimensional variables do *not* need to exist (and probably will not exist) in the NetCDF file.
- Not all variables are listed here, that are present in some of the templates, but are not read and used by COSMO.
- Some of the variables that are used (but not needed) e.g. in the wind profiler file but are not present e.g. in the VAD file, could be added to the VAD file in the future and used without changing the COSMO code.

6.4.4 The blacklist file

The blacklist file contains both a blacklist and whitelist. The blacklist contains the stations with the variables and vertical ranges that are known to have a bad quality statistically. Observations of that variables and in that vertical ranges are then excluded permanently from active use in the assimilation. The whitelist contains all stations related to certain observation types, which are known to issue observations of good quality.

The difference in concept between the blacklist and the whitelist becomes important when a new station sends observations of a certain type via GTS and these data have unknown quality. These observations will be excluded from active use only if a whitelist exists for that observation type. Whitelists are useful for types where there are not too many stations and the risk that a new station will deliver data of minor quality is considered rather high. This often applies to remote sensing observation types.

A station (related to a certain observation type) can appear both on the whitelist and (several times) on the blacklist. The whitelist activates the station as a whole, and in the blacklist, certain vertical ranges for certain variables can be excluded then from active use.

The blacklist file is a formatted ASCII file and has a format as follow:

Format of Blacklist :

The first line is fixed, and the following lines are the entries in the blacklist, with following 10 columns:

1: station identity ('.' as wildcard allowed)

2: observation type (1: surface-level, 2: aircraft, 4: buoy, 5: TEMP, 6: PILOT)

3,4: lower / upper limit (pressure in [hPa]) of blacklisted vertical range for geopotential

5,6: blacklisted vertical range for (horizontal) wind

7,8: blacklisted vertical range for temperature

9,10: blacklisted vertical range for humidity

```
2IIIIIIII T P.G.U P.G.O P.W.U P.W.O P.T.U P.T.O P.D.U P.D.O
 01295    1  1100     0     0     0     0     0     0     0
 0210     1  1100     0     0     0     0     0     0     0
 9Z4Y48JP 2     0     0     0     0  1100     0     0     0
 ABX.     2     0     0  1100     0     0     0     0     0
 ABX..    2     0     0  1100     0     0     0     0     0
 ABX...   2     0     0  1100     0     0     0     0     0
 ABX....  2     0     0  1100     0     0     0     0     0
 17912    4  1100     0     0     0     0     0     0     0
 21523    4     0     0  1100     0     0     0     0     0
 07137    5  1100     0  1100     0  1100     0     0     0
 10437    5   300     0  1100     0     0     0     0     0
 10828    5  1100     0  1100     0     0     0     0     0
 10204    6     0     0   500     0     0     0     0     0
 10266    6     0     0   200     0  1100     0     0     0
 10384    6     0     0  1100   850     0     0     0     0
```

Immediately after the last line of the blacklist, the whitelist follows.

Standard format of Whitelist

```
    WHITELIST
03019       6    132
10135       6    132
10266       6    132
10394       6    132
47912       6    134
47945       6    134
72246       6    136
74341       6    136
10169       6    137
10204       6    137
10384       6    137
```

Alternative format of Whitelist

```
WHITELIST   6   132
03019      6    132
10135      6    132
10266      6    132
10394      6    132
WHITELIST   6   133
WHITELIST   6   134
47912      6    134
47945      6    134
WHITELIST   6   136
72246      6    136
74341      6    136
WHITELIST   6   137
10169      6    137
10204      6    137
10384      6    137
```

In the standard format, the first line is fixed, and the following lines are the entries in the whitelist, with the following 3 columns:

1: station identity
2: observation type (currently only 6: PILOT , which includes profilers)
3: observation code type (132: European wind profiler,
    133: European RASS / SODAR,
    134: Japan. wind profiler / RASS,
    136: US wind profiler / RASS,
    137: Radar VAD wind profiles)

The standard format assumes a whitelist exactly for those observation code types for which there are entries on whitelist. In the blacklist file used at DWD currently, no RASS profiler station is on the whitelist, which implies that COSMO will assume that no whitelist exists for RASS. Hence, all RASS reports would be used actively unless they are on the blacklist. This is indeed the case, i. e. the temperature profiles from all the known RASS stations are put on the blacklist, see e. g. station `10266` in the example above.

There is an alternative format for the whitelist which can be used (but is not yet as thoroughly tested). A line containing '`WHITELIST`' and observation type and code type precedes the whitelist for each code type, even if the whitelist for that code type is empty. Only this alternative format allows to use empty whitelists, and the above example in this alternative format is also shown above.

Section 7

Namelist Input for COSMO-Modell

The execution of the COSMO-Model is controlled by 14 `NAMELIST`-groups:

- `LMGRID` – specifying the domain and the size of the grid
- `RUNCTL` – parameters for the model run
- `DYNCTL` – parameters for the adiabatic model
- `PHYCTL` – parameters for the diabatic model
- `TUNING` – parameters for tuning dynamics and physics
- `DIACTL` – parameters for the diagnostic calculations
- `SATCTL` – parameters for the satellite images
- `NUDGING` – controlling the data assimilation
- `INICTL` – parameters for the initialization of model variables
- `EPSCTL` – controlling the ensemble prediction mode
- `IOCTL` – controlling the environment
- `DATABASE` – specification of database job
- `GRIBIN` – controlling the grib input
- `GRIBOUT` – controlling the grib output

These `NAMELIST`-groups have to appear in the corresponding `INPUT_*` files. See Tab. 6.1 for the distribution of the `NAMELIST`-groups to the `INPUT_*` files. The `INPUT_*` files have to be in the directory, from where the model is started. Every group is read in a special subroutine called `input_`*groupname*. This subroutine also sets default values for all parameters and checks most parameters that have been changed for correctness and consistency.

The `NAMELIST` variables can be specified by the user in the run-script for the model, which then creates the `INPUT_*` files. An excerpt of this run script is shown in Figure 7.1 for the forecast part and in Figure 7.2 for the nudging part.

```
#################################################
# cat together the INPUT*-files
#################################################

cat > INPUT_ORG << end_input_org
 &LMGRID
  startlat_tot  = -20.0, startlon_tot  = -18.0,
  pollat=40.0,        pollon=-170.0,
  dlat=0.0625,        dlon=0.0625,
  ie_tot=665,         je_tot=657,        ke_tot=40,
 /
 &RUNCTL
  hstart = 0.0,   hstop  = 48.0,    dt      = 40.0,    ydate_ini='2008021500',
  nprocx = 8,  nprocy = 8,   nprocio = 0,
  lphys      = .TRUE.,   luse_rttov    = .TRUE.,  luseobs = .FALSE., leps = .FALSE.,
  idbg_level = 2,
 /
 &TUNING
  clc_diag  =  0.75, pat_len   = 500.0, rlam_heat =   1.0, rlam_mom  =   0.0,
  rat_lam   =  1.0,  rat_can   =   1.0, rat_sea   =  20.0, c_lnd     =   2.0,
  c_soil    =  1.0,  c_sea     =   1.5, z0m_dia   =   0.2, crsmin    = 150.0,
  rat_sea   = 20.0,  wichfakt  =   0.0, qc0       =   0.0,
 /
end_input_org

cat > INPUT_IO  << end_input_io
 &IOCTL
  lgen=.FALSE., lasync_io=.FALSE., ngribout=1, yform_write='grb1',
 /
 &DATABASE
 /
 &GRIBIN
  hincbound=1.0,
  lchkini=.TRUE., lchkbd =.TRUE., lbdana=.FALSE.,
  lana_qi=.TRUE., llb_qi=.TRUE., lana_rho_snow=.TRUE., lana_qr_qs=.FALSE.,
  ydirini='/gtmp/routfor/dat/initial/',
  ydirbd='/gtmp/routfor/dat/boundaries/',
 /
 &GRIBOUT
  hcomb=0.0,48.0,1.0,
  lanalysis=.FALSE., lcheck=.TRUE., l_p_filter=.TRUE., l_z_filter=.TRUE.,
  lwrite_const=.TRUE.,
  yvarml='U         ','V         ','W         ','T         ','QV        ','QC        ',
         'QI        ','QR        ','QS        ',
         'P         ','PS        ','T_SNOW    ','T_SO      ','W_SO      ','W_SNOW    ',
         'QV_S      ','W_I       ','RAIN_GSP  ','SNOW_GSP  ','RAIN_CON  ','SNOW_CON  ',
         'U_10M     ','V_10M     ','T_2M      ','TD_2M     ','TMIN_2M   ','TMAX_2M   ',
         'VMAX_10M  ','TCM       ','TCH       ','CLCT      ','CLCL      ','T_G       ',
         'TQC       ','TQI       ','TQV       ','TKE       ', W_CL      ','T_CL      ',
         'FRESHSNW  ','RHO_SNOW  ','W_ICE     ','H_SNOW    ',
  yvarzl='default', yvarpl='default', yvarsl='default',
  ydir='/gtmp/routfor/dat/output/',
 /
end_input_io

cat > INPUT_DYN << end_input_dyn
 &DYNCTL
  betasw=0.4, epsass=0.15, hd_corr_q=0.5, hd_corr_t=0.75,
  hd_dhmax=250., itype_hdiff=2, lcond=.TRUE., lspubc=.TRUE., itype_lbcqx=1,
 /
end_input_dyn

cat > INPUT_PHY << end_input_phy
 &PHYCTL
    lgsp =.TRUE.,  lprogprec=.TRUE., ltrans_prec=.TRUE., itype_gscp=3,
    lrad =.TRUE.,  nradcoarse=1, lradf_avg=.FALSE.  hincrad=1.0, lforest=.TRUE.,
    ltur =.TRUE.,  lexpcor=.TRUE., ltmpcor=.FALSE., lprfcor=.FALSE., lnonloc=.FALSE.,
                   lcpfluc=.FALSE.,
                   ninctura=1,   itype_turb=3, imode_turb=1, itype_tran=2, imode_tran=1,
                   itype_wcld=2, icldm_rad =4, icldm_turb=2, icldm_tran=0, itype_synd=2,
    lsoil=.TRUE.,  itype_evsl=2, itype_trvg=2,
                   lmulti_layer=.TRUE., lmelt=.TRUE., lmelt_var=.TRUE.,
                   ke_soil = 7,
                   czml_soil = 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58,
    lconv=.TRUE.,  itype_conv=0, lcape=.FALSE.,
    lsso =.TRUE.,
 /
end_input_phy

cat > INPUT_DIA << end_input_dia
 &DIACTL
  n0meanval=0, nincmeanval=1,
  lgplong=.TRUE., lgpshort=.FALSE., lgpspec=.FALSE.,  n0gp=0, hincgp=1.0,
  stationlist_tot= 0, 0, 50.050,  8.600, 'Frankfurt-Flughafen',
                   0, 0, 52.220, 14.135, 'Lindenberg_Obs',
                   0, 0, 47.800, 10.900, 'Hohenpeissenberg',
 /
end_input_dia
```

Figure 7.1: Excerpt of run script from the COSMO-Model to create `INPUT_*` files

The following sections serve as a complete reference to all namelist variables used in the COSMO-Model. There is a section for every namelist group. Within the sections the descriptions of the variables is organized in subgroups, if the variables can be separated into different scopes. For example in the physics group `PHYCTL` there is a subgroup for every parameterization. All variables are displayed in tables, showing the name of the variable, their numerical type in the model, the definition including some comments and the default value.

A problem that less experienced COSMO users often face, is to find out, which namelist variables they have to adapt, if they want to change e.g. the domain or the resolution of their application. Therefore we introduced an additional 5th column to the tables, which should indicate the dependency of a variable on a special category. The following categories have been defined up to now:

M: Mode of simulation (NWP, CLM, ITC, ART)

R: Region

dx: Horizontal resolution

dz: Vertical resolution

dt: Time step

BC: Boundary conditions

P: Performance

If you want to change for example your horizontal resolution, you should check for which variables a dependency on dx is listed in the tables below.

7.1 LMGRID — Model Domain and Reference Atmosphere

The namelist group `LMGRID` contains parameters that specify

- the lat-lon coordinates of the pole of the rotated grid,
- the position of the model domain within the rotated grid,
- the size and resolution of the model grid.
- and parameters for the reference atmosphere (since COSMO-Model Version 5.1)

The specifications of the parameters for this group are included in the file `INPUT_ORG`.

Domain size and model grid

Name	Type	Definition / Purpose / Comments	Default	Depend.
`pollat`	`REAL`	Geographical latitude of the rotated north pole (in degrees, north > 0); for a non-rotated lat-lon grid set `pollat = 90.`	32.5	R
`pollon`	`REAL`	Geographical longitude of the rotated north pole (in degrees, east > 0); for a non-rotated lat-lon grid set `pollon = -180`.	-170.0	R
`polgam`	`REAL`	Angle between the north poles of two rotated grids (in degrees, east > 0); necessary for transformation from one rotated grid to another rotated grid	0.0	R
`dlat`	`REAL`	'Meridional' (rotated lat-direction) grid spacing (in degrees).	0.008	dx
`dlon`	`REAL`	'Zonal' (rotated lon-direction) grid spacing (in degrees).	0.008	dx
`startlat_tot`	`REAL`	Latitude of the lower left scalar grid point of the total domain (in degrees, north > 0, rotated coordinates).	-7.972	R
`startlon_tot`	`REAL`	Longitude of the lower left scalar grid point of the total domain (in degrees, east > 0, rotated coordinates).	-1.252	R
`ie_tot`	`INT`	Number of gridpoints of the total domain in 'west-east' direction of the rotated coordinates.	51	dx,R
`je_tot`	`INT`	Number of gridpoints of the total domain in 'south-north' direction of the rotated coordinates.	51	dx,R
`ke_tot`	`INT`	Number of gridpoints of the total domain in vertical direction (i.e. number of layers or main-levels; there are `ke_tot+1` half-levels).	20	dz

The specifications for the model domain and the grid size are compared to the values from the headers of the data files (the Grid Description Section (GDS) of the Grib files or the headers of NetCDF files) for the initial and boundary fields. If they do not correspond, the program will print an error message and abort.

Variables for the reference atmosphere

Since Version 5.1, there are also namelist variables to specify the reference atmosphere parameters, because these parameters cannot be written to the GRIB2 meta data any more.

When using GRIB1 or NetCDF, these parameters are specified in INT2LM and are written to the meta data of all atmospheric fields. The pressure field exchanged between INT2LM and the COSMO-Model or within a COSMO-Model assimilation cycle is the pressure deviation `PP`, because this field suffers less from the precision loss due to GRIB packing than the full pressure `P`. When the COSMO-Model reads the atmospheric fields, including `PP`, it gets the values for the reference atmosphere from the meta data, constructs the reference pressure field `P0` and then computes the full pressure `P`.

When using GRIB2, not the pressure deviation, but the full pressure field `P` is exchanged between INT2LM and the COSMO-Model or within a COSMO-Model assimilation cycle. This is done using a packing to 24 bits (while most other fields are packed to 16 bits). This gives a high enough precision for the values of the full pressure. Internally, the COSMO-Model is working with the pressure deviation as a prognostic variable, therefore it has to compute the reference pressure field `P0`, and for that has to know the reference atmosphere parameters. Therefore we introduced the following namelist variables; their names and meanings are identical to the corresponding namelist variables in the INT2LM.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`irefatm`	`INT`	type of reference atmosphere 1: The reference atmosphere is based on a constant rate β for the temperature increase with the logarithm of pressure: $\partial T_0 / \partial \ln p_0 = \beta$. 2: The reference atmosphere is based on a temperature profile $t_0(z) = (t_{0sl} - \Delta t) + \Delta t \cdot \exp\left(\frac{-z}{h_{scal}}\right)$, where $z =$ `hhl(k)` is the height of a model grid point. If this option is used, the values for $\Delta t =$ `delta_t` and $h_{scal} =$ `h_scal` have also to be set.	2	dz
`p0sl`	`REAL`	constant reference pressure on sea-level	10000.0	
`t0sl`	`REAL`	constant reference temperature on sea-level	288.15	
`dt0lp`	`REAL`	d (t0) / d (ln p0)	42.0	
`delta_t`	`REAL`	temperature difference between sea level and stratosphere (for `irefatm=2`)	75.0	
`h_scal`	`REAL`	scale height (for `irefatm=2`)	10000.0	

Note that the reference atmosphere used in INT2LM and the one used in the COSMO-Model need not be the same, when the full pressure `P` is exchanged. The only dependency is: If the top of the atmosphere is above 27 km and INT2LM is using `irefatm=2`, then also the COSMO-Model has to use `irefatm=2`.

7.2 RUNCTL — Parameters for the Model Run

The namelist group RUNCTL contains the parameters that control the basic configuration of a model run. The specifications for the parameters in RUNCTL are included in the file INPUT_ORG.

The namelist parameters of this group are described in the subsections

- initial time, forecast range, time step and calendar used,
- basic control parameters,
- parameters related to artificial initial and boundary conditions,
- parameters for parallel and sequential execution,
- parameters for diagnostic min/max model output and
- parameters for debug purposes

Initial time, forecast range, time step and calendar used

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ydate_ini`	CHAR	Initial date and time of the forecast. Since Version 4.24 there are two different formats: • `ydate_ini = 'yyyymmddhh'`, or • `ydate_ini = 'yyyymmddhhmise'`. where yyyy = year, mm = month, dd = day, hh = hour, mi = minutes and se = seconds. If the date is specified in the old format (still the default), all file names are also treated as usual. If the date is given with minutes and seconds, then all relevant files are also written with minutes and seconds in the file names. This will be necessary, if a sub-hourly analysis cycle will be used.	' '	
`ydate_bd`	CHAR	Start date and time of the forecast from which the boundary fields are used, specified by year-month-day-hour. (`'yyyymmddhh'`) as above. `ydate_bd` can be set different than `ydate_ini`, when the forecast, which produced the boundary files, started earlier than `ydate_ini`, for example, if forecasts from 00 UTC are used to drive a COSMO-Model forecast starting at 06 UTC. Note that `ydate_bd` always has to be older than `ydate_ini`! *If omitted,* `ydate_bd` *is set to* `ydate_ini`.	' '	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ydate_end`	`CHAR`	End date for the whole forecast. This is needed for climate simulations, where the forecast can be splitted into several runs on a computer and hstop only indicates the stop of a single run. The format is as above, i.e. either `'yyyymmddhh'` or `'yyyymmddhhmise'`. If omitted, `ydate_end` is not set and the end of the whole forecast is specified by `hstop` or `nstop`, resp.	`' '`	
`lyear_360`	`LOG`	To use a climatological year with 360 days. Eliminated: replaced by itype_calendar in Version 4.4		BC
`itype_calendar`	`INT`	To specify, which calendar is used during the forecast (introduced in Version 4.4): 0: gregorian calendar 1: every year has 360 days 2: every year has 365 days	0	BC
`hstart`	`REAL`	Number of the first hour relative to the initial time given by `ydate_ini`. For a regular forecast, `hstart = 0.0`. If `hstart > 0.0`, the model is in restart mode and it requires restart data (for Leapfrog from 2 consecutive time levels; for Runge-Kutta only from 1 time level) to resume a forecast run.	0.0	
`hstop`	`REAL`	Duration of the forecast in hours.	0.0	
`nstop`	`INT`	Number of time steps to be performed; determines the forecast range (`nstop*dt`) relative to the initial time. *can be specified alternatively to* `hstop`.	0	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`dt`	`REAL`	Time step (in seconds); `dt` refers to the large time step size Δt associated with the Leapfrog or Runge-Kutta time integration of the slow modes. Since vertical advection and diffusion is calculated implicitly, the large time step can be determined from the linear stability criterion for horizontal advection $$\Delta t \leq \frac{\Delta s}{\sqrt{2}\, v_{max}} \, ,$$ where Δs is the minimum grid spacing in physical space and v_{max} is the maximum absolute horizontal velocity during the forecast. For operational purposes, v_{max} is estimated as a high jet-stream velocity of about 120 m/s. The number N_s of small time steps $\Delta\tau$ per Leapfrog time intervall ($2\Delta t = N_s \Delta\tau$) is calculated automatically inside the program using the CFL stability criterion for horizontal acoustic wave propagation to estimate $\Delta\tau$. With the above value for v_{max}, we get 7 small steps per Leapfrog intervall (or 4 steps per Eulerian forward time step in the Runge-Kutta scheme). *Note: Both too small values ($N_s < 3$) and too large values ($N_s > 20$) for the number of small steps may have a detrimental impact to the solution.*	10.0	dx

Basic control parameters

The basic control parameters allow to switch on and off main features and/or packages of the model system.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`lphys`	`LOG`	Main switch to include physical parameterizations. If .FALSE., the corresponding Namelist input from `PHYCTL` (see Section 7.4) is skipped and no physical parameterizations will be computed – except cloud condensation and evaporation by saturation adjustment. To supress this process, set `lcond = .FALSE.` in input group `DYNCTL` (see Section 7.3).	`.TRUE.`	
`ldiagnos`	`LOG`	Main switch to include diagnostic calculations. If this switch is set to `.TRUE.`, the variables in the group `DIACTL` should also be set (see Section 7.6)	`.FALSE.`	
`ldfi`	`LOG`	Main switch to run a model initialization by using the digital filtering technique. If this switch is set to `.TRUE.`, the variables in the group `INICTL` should also be set (see Section 7.8)	`.FALSE.`	IC

Name	Type	Definition / Purpose / Comments	Default	Depend.
`luseobs`	`LOG`	Main switch to use observations during the model run (for data assimilation purposes). To perform a free model forecast, `luseobs` is set to `.FALSE.` If this switch is set to `.TRUE.`, the variables in the group `NUDGING` should also be set (see Section 7.9)	`.FALSE.`	M
`leps`	`LOG`	Main Switch to run the model in ensemble mode. Setting this switch has the effect that special GRIB meta data are set and / or processed during I/O. If `lsppt` is also set, special actions are taken during the stochastic perturbation of physics tendencies (SPPT). If this switch is set to `.TRUE.`, the variables in the group `EPSCTL` should also be set (see Section 7.10)	`.FALSE.`	M
`lsppt`	`LOG`	Main Switch to run stochastic perturbation of physics tendencies (SPPT). If it is activated, related namelist variables are read from the namelist group `/EPSCTL/`.	`.FALSE.`	
`luse_rttov`	`LOG`	Main switch to compute synthetic satellite images. If this switch is set to `.TRUE.`, the variables in the group `SATCTL` should also be set (see Section 7.7)	`.FALSE.`	
`luse_radarfwo`	`LOG`	To activate the radar forward operator.	`.FALSE.`	
`lroutine`	`LOG`	To indicate an operational run (if `.TRUE.`. This variable is used to set GRIB2 meta data.	`.FALSE.`	
`l_cosmo_art`	`LOG`	Main switch to compute the *Aerosol and Reactive Tracer* module. The COSMO-Model has to be compiled with `-DCOSMOART` to activate this module in the source code of the COSMO-Model. The source code of the ART module itself can be obtained from the *Karlsruhe Institute of Technology*.	`.FALSE.`	M
`l_pollen`	`LOG`	Main switch to compute the *Pollen* module. The COSMO-Model has to be compiled with `-DPOLLEN` to activate this module in the source code of the COSMO-Model. The source code of the Pollen module itself can be obtained from the *Karlsruhe Institute of Technology*.	`.FALSE.`	M
`llm`	`LOG`	Running with zero vertical velocity as lower boundary condition in the fast_waves solver.	`.FALSE.`	

Parameters related to artificial initial and boundary conditions

The following parameters are only in effect if the control parameter `lartif_data` is set to `.TRUE.`. This parameter controls the basic type of the simulation: if it is set to `.TRUE.`,a run with artificial (or *idealized*) initial and boundary data is performed. If it is set to `.FALSE.`, a real-case simulation with initial and boundary data coming from a coarse-grid driving model or from an assimilation run is done.

If `lartif_data=.TRUE.` is chosen, there are parameters to control the type of lateral boundary conditions (relaxation, periodic, open) and to include/exclude metrical terms. Also, in this case another namelist `ARTIFCTL` will be read from the file `INPUT_IDEAL` and the namelist `GRIBIN` from file `INPUT_IO` has no effect and will be skipped. `ARTIFCTL` offers parameters for a wide variety of choices to configure idealized runs, such as definition of orography (idealized hills or pre user-provided ASCII files), specification of atmospheric and soil profiles for intitial and boundary conditions, and artificial convection triggers (*warm bubbles*, soil *hot spots*).

Name	Type	Definition / Purpose / Comments	Default	Depend.
`lartif_data`	`LOG`	If `.TRUE.`, the model runs with user-defined initial and boundary data. All Namelist input from `GRIBIN` is skipped and the corresponding parameters are not in effect. A Namelist group /ARTIFCTL/ has to be defined instead. If `.FALSE.`, the model expects initial and boundary data in Grib or NetCDF format. Control parameters for these files are contained in Namelist input group `GRIBIN`. (`lartif_data` has been renamed (named `lgen` before) and moved from group `GRIBIN` to `RUNCTL` in Version 4.8.)	`.FALSE.`	M
`l2dim`	`LOG`	Run a 2-dimensional model version. *To run the model in 2-d mode, the number of gridpoints in south-north direction must be set to* `je_tot = 5`.	`.FALSE.`	M
`lperi`	`LOG`	Eliminated in Version 4.17 and replaced by `lperi_x` and `lperi_y` (see below).	-	
`lperi_x`	`LOG`	Use periodic lateral boundary conditions in x-direction.	`.FALSE.`	
`lperi_y`	`LOG`	Use periodic lateral boundary conditions in y-direction.	`.FALSE.`	
`lcori`	`LOG`	moved to group /DYNCTL/ in Version 4.8		
`lmetr`	`LOG`	moved to group /DYNCTL/ in Version 4.8		
`lradlbc`	`LOG`	moved to group /DYNCTL/ in Version 4.8		

Also, a 1-dimensional set-up can be realized by setting the number of gridpoints in west-east direction to `ie_tot = 5` and choosing periodic lateral boundary conditions. Depending on the problem at hand, however, some additional modification of the dynamics code might be neccessary (e.g. to include a constant pressure gradient in terms of a geostrophic wind).

Note:
To generate artificial initial and boundary conditions for idealized model runs, the routines `gen_ini_data` (to specify initial data) and `gen_bound_data` (to specify boundary data) contained in the source file `src_artifdata.f90` are used. The configuration of such idealized model runs can be done with the help of a large number of namelist parameters in the namelist `ARTIFCTL` in the file `INPUT_IDEAL`, which offers a wide variety of choices for orography, atmosphere and soil profiles for initial and boundary conditions and convection triggers. However, there is no unique way for this specification as it depends on the problem to be considered, and therefore it is possible to extend `src_artifdata.f90` according to special needs.

The documentation of the namelist group `ARTIFCTL` would go beyond the scope of this User Guide, therefore an extra document will be provided for running idealized cases.

Parameters for parallel and sequential execution

This section contains parameters for the decomposition (parallelization) of the model domain and for generating additional information about timings for the different parts of the model run. Furthermore, the type of communication can be specified (see parameters `ldatatypes`, `ncomm_type`). How the different types of communications perform surely depends on the computer used. Therefore it would require some testing to find the optimal settings.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`nprocx`	`INT`	Number of processors in the x-direction of the grid.	1	P
`nprocy`	`INT`	Number of processors in the y-direction of the grid.	1	P
`nprocio`	`INT`	Number of processors for GRIB I/O.	0	P
`num_asynio_comm`	`INT`	To choose the number of asynchronous I/O communicators for NetCDF. With several communicators it is possible to parallelize the output over the files to be written (the `GRIBOUT` namelists), so that several output files can be written simultaneously.	0	P
`num_iope_percomm`	`INT`	To choose the number of asynchronous I/O processes per communicator for NetCDF I/O. With several processes per communicator it is possible to do a parallel writing of single files. This is only possible, if the parallel NetCDF library is available and the code has been compiled with the preprocessor directive `-DPNETCDF`.	0	P

Name	Type	Definition / Purpose / Comments	Default	Depend.
`nboundlines`	INT	Number of boundary lines at each side of a subdomain; specifies the size of the halo around each subdomain, where variables are updated by neighboring processors. Along `nboundlines` at the lateral boundaries of the total domain, the variables are set to boundary data from the driving host model. A minimum of 2 boundlines is required for the Leapfrog dynamical core. And a minimum of 3 boundlines is required for the Runge-Kutta dynamical core.	2	
`ltime_proc`	LOG	Eliminated; replaced by `itype_timing` in Version 4.4		
`ltime_mean`	LOG	Eliminated; replaced by `itype_timing` in Version 4.4		
`itype_timing`	INT	To specify, how a timing of the program should be done: 1: output hourly timings per task 2: output timings per task, summed up over all hours 3: output hourly mean values for all tasks 4: output mean values for all tasks, sum over all hours	4	
`lreproduce`	LOG	Ensures the computation of reproducible results in parallel mode.	`.FALSE.`	M
`lreorder`	LOG	If .TRUE., the numbering of the MPI-processes can be reordered for the cartesian MPI-communicator. This might give some performance benefits, depending on the computer platform used.	`.FALSE.`	P
`ldatatypes`	LOG	Switch to choose between an explicit buffering (`.FALSE.`) or an implicit buffering (`.TRUE.`) using MPI-datatypes for the boundary exchange. Setting `ldatatypes=.TRUE.` might give some performance benefits, depending on the computer platform used.	`.FALSE.`	P
`ltime_barrier`	LOG	If `.TRUE.`, some more barriers are called during the model run, to separate communications from computations in a very clean way. But without these barriers, the model will run faster.	`.TRUE.`	P

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ncomm_type`	`INT`	To choose a certain type of communication: 1: immediate send, blocking receive and wait on the sender side 2: immediate receive, blocking send and wait on the receiver side 3: using `MPI_SENDRECV`	1	

Parameters for diagnostic min/max model output

Name	Type	Definition / Purpose / Comments	Default	Depend.
`hincmxt`	`REAL`	Interval in hours for the period of validity of minimum and maximum values of the 2m-temperature (`TMIN_2M and TMAX_2M`), i.e. every `hincmxt` hours the corresponding arrays are reset to default values.	6.0	
`hincmxu`	`REAL`	Interval in hours for the period of validity of minimum and maximum values of the 10-m wind gusts (`VMAX_10M`), i.e. every `hincmxu` hours the corresponding array is reset to default values.	1.0	

Control parameters for debug purposes

Additional informations on the status of the model run can be obtained by increasing the debug level. However, this reduces the efficiency of the model run and blow up the standard ascii output enormously. Therefore these options are recommended to be used by model developers and/or in case of problems with the execution of a model run.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`idbg_level`	`INT`	Selects the verbosity of ASCII output during a model run. The higher the value, the more debug output is written to standard output. To switch on/off debug output for special components, the additional flags `ldebug_xxx` have to be set to `.TRUE. / .FALSE.`	2	
`ldump_ascii`	`LOG`	To save the ASCII-Files written during the run of the model to disk in every time step. This may cause a performance slow down on some machines and can be switched off. Then the files are only saved at the end of the run.	`.TRUE.`	
`lprintdeb_all`	`LOG`	In most cases, only the processor with ID = 0 will write the debug output. Setting the variable `lprintdeb_all=.TRUE.`, all processors will print the debug output.	`.FALSE.`	
`ldebug_dyn`	`LOG`	To switch on/off the debug output for the dynamics.	`.FALSE.`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ldebug_gsp`	`LOG`	To switch on/off the debug output for the microphysics.	`.FALSE.`	
`ldebug_rad`	`LOG`	To switch on/off the debug output for the radiation.	`.FALSE.`	
`ldebug_tur`	`LOG`	To switch on/off the debug output for the turbulence.	`.FALSE.`	
`ldebug_con`	`LOG`	To switch on/off the debug output for the convection.	`.FALSE.`	
`ldebug_soi`	`LOG`	To switch on/off the debug output for the soil processes.	`.FALSE.`	
`ldebug_io`	`LOG`	To switch on/off the debug output the input and output.	`.FALSE.`	
`ldebug_mpe`	`LOG`	To switch on/off the debug output for the asynchronous I/O module `mpe_io2.f90` (introduced in Version 4.27).	`.FALSE.`	
`ldebug_dia`	`LOG`	To switch on/off the debug output for the diagnostics.	`.FALSE.`	
`ldebug_ass`	`LOG`	To switch on/off the debug output for the assimilation.	`.FALSE.`	
`ldebug_lhn`	`LOG`	To switch on/off the debug output for the latent heat nudging.	`.FALSE.`	
`ldebug_art`	`LOG`	To switch on/off the debug output for the ART module (introduced in Version 4.9).	`.FALSE.`	
`linit_fields`	`LOG`	To switch on/off initialization of local variables (introduced in Version 4.9).	`.FALSE.`	

7.3 `DYNCTL` — Parameters for the Adiabatic Model

The namelist group `DYNCTL` contains control parameters for the numerical methods used to solve the thermo-hydro-dynamic model equations (the adiabatic part of the COSMO-Model) and to specify the boundary conditions and the numerical filtering for the COSMO solution, in particular close to the boundaries. The specifications for the parameters in `DYNCTL` are included in the file `INPUT_DYN`.

The namelist parameters of this group are described in the subsections

- main switches for the time integration,
- parameters for the semi-implicit time-integration scheme,
- parameters for the Runge-Kutta scheme,
- parameters for the lateral boundary conditions,
- horizontal diffusion,
- lower and upper boundary condition,
- additional numerical filters and
- spectral Nudging

Main switches for the time integration:

The main switch for the dynamics in the COSMO-Model is `l2tls`. Several options for the choice of numerical schemes are available with one of the schemes only. The more recent developments are implemented for the Runge-Kutta scheme (`l2tls=.TRUE.`) only.

In the first years of the COSMO-Model, the Leapfrog scheme was the only available dynamical core (`l2tls = .FALSE.`). But development for a 2 timelevel Runge-Kutta scheme started early. First, this scheme has been developed for very high resolutions below 4-5 km. But later it has been adapted also to the coarser resolutions. Now all applications can be run using the Runge-Kutta scheme and the Leapfrog scheme will no longer be supported.

Name	Type	Definition / Purpose / Comments	Default
`l2tls`	`LOG`	The default time-integration scheme is a 2 time-level Runge-Kutta scheme with time-split treatment of acoustic and gravity waves (`l2tls = .TRUE.`). Alternatively, a 3 time-level Leapfrog time-split scheme may be used (`l2tls = .FALSE.`).	`.TRUE.`
`lcpp_dycore`	`LOG`	This switch would activate the new code for the Runge-Kutta dynamical core, based on C++ template meta programming. But this code is not yet delivered for public use, since it is still under evaluation.	`.FALSE.`

Name	Type	Definition / Purpose / Comments	Default
`l_euler_dynamics`	`LOG`	This variable allows to switch off/on the Euler dynamical core, i.e. advection, pressure gradient, divergence and buoyancy-terms for the u,v,w,T and p-equation. It does not affect tracers or the Coriolis force, i.e. even if it is set to `.FALSE.`, tracer advection and diffusion can take place and (if `lcori=.TRUE.`) Coriolis force can act. However, for the Leapfrog or semi-implicit dynamical core, the vertical advection of the dynamical variables is still active, even if `l_euler_dynamics=.FALSE.`.	`.TRUE.`
`lsemi_imp`	`LOG`	Instead of the standard Leapfrog time-split scheme, a Leapfrog scheme with semi-implicit treatment of acoustic and gravity waves may be used. This option works only with (`l2tls = .FALSE.`). *Caution: the semi-implicit scheme is not yet fully evaluated.*	`.FALSE.`
`lcond`	`LOG`	To include (`.TRUE.`) or exclude (`.FALSE.`) cloud water condensation and evaporation during the forecast.	`.TRUE.`
`lcori`	`LOG`	Run with Coriolis force (has been moved from group `/RUNCTL/` to here in Version 4.8.	`.TRUE.`
`lmetr`	`LOG`	Run with metric terms. If .FALSE., the spherical geometry of the grid is neglected and the Coriolis force is assumed to be constant on the model domain (f-plane approximation). (has been moved from group `/RUNCTL/` to here in Version 4.8.	`.TRUE.`
`lcori_deep`	`LOG`	To take coriolis terms ($\cos(\varphi)$) into account.	`.FALSE.`
`ladv_deep`	`LOG`	To use all metric advective terms.	`.FALSE.`

Parameters for the semi-implicit time-integration scheme:

Name	Type	Definition / Purpose / Comments	Default
`ikrylow_si`	`INT`	Dimension of Krylow space for elliptic solver (GMRES).	20
`iprint_si`	`INT`	Selects output of print statistics of the elliptical solver. $>$ 1: Print statistics in file `YUSOLVER`. $=$ 0: No statistics are printed. $<$ 0: Print statistics on the screen.	0
`maxit_si`	`INT`	Maximum number of iterations for elliptic solver.	200
`eps_si`	`REAL`	Precision limit for the convergence of the solution from the elliptic solver.	10^{-8}

Parameters for the Runge-Kutta scheme:

Name	Type	Definition / Purpose / Comments	Default
`irunge_kutta`	INT	Parameter to select a special Runge-Kutta scheme: 0: This option has been eliminated in Version 4.23 The dynamical core `src_2timelevel.f90`, associated with this option, has been removed from the code. 1: Use the dynamical core for the Runge-Kutta scheme from module `src_runge_kutta.f90`. 2: use the TVD-RK scheme (total variation diminishing)	1
`irk_order`	INT	Order of the Runge-Kutta scheme. Can be in the range from 1-3. The value 3 is recommended.	3
`iadv_order`	INT	Order of the horizontal advection scheme.	3
`ieva_order`	INT	Order of the explicit vertical advection scheme.	3
`itheta_adv`	INT	Option for using potential temperature as advected variable in the Runge-Kutta scheme: 0: Use $T\prime$ (perturbation temperature) for advection 1: Use $\theta\prime$ (perturbation potential temperature) 2: Use θ (full potential temperature)	0
`ltadv_limiter`	LOG	Switch to use a limiter for temperature advection (only for `itheta_adv = 2`)	.FALSE.
`intcr_max`	INT	Maximal integer courant number in courant-number independent advection	1
`lva_impl_dyn`	LOG	has been eliminated in Version 4.15. and replaced by `y_vert_adv_dyn` Switch to run with implicit vertical advection in the Runge-Kutta-scheme (.TRUE.) or not.	.TRUE.
`y_vert_adv_dyn`	CHAR	Choose an implicit vertical advection scheme for the dynamical variables u,v,w, T' and p' in the Runge-Kutta-scheme. This switch replaces and extends the old switch `lva_impl_dyn`. The following options can now be chosen: 'expl' explicit vertical advection, called in every RK substep. See also `ieva_order`. (corresponds to `lva_impl_dyn=.FALSE.`) 'impl2' 2nd order implicit vertical advection, called in every RK substep. (corresponds to `lva_impl_dyn=.TRUE.`) 'impl3' 3rd order implicit vertical advection, called at the end of the RK scheme	'impl2'

Name	Type	Definition / Purpose / Comments	Default
`itype_fast_waves`	`INT`	Parameter to select the treatment of fast waves: 1: Old scheme (from module `fast_waves_rk.f90`). 2: New scheme (from module `fast_waves_sc.f90`) with – proper weightings for all vertical discretizations, – divergence operator in strong conservation form, – (optionally) isotropic (fully 3D) divergence damping, – (optionally) Mahrer (1984) discretization. This is the new default (from Version 4.27 on).	2
`lhor_pgrad_Mahrer`	`LOG`	(Only for `itype_fast_waves=2`) The horizontal pressure gradient (i.e. in the u- and v-equations) is either calculated in the terrain-following system (`.FALSE.`) or by interpolation of p' to a horizontal plane (Mahrer (1984) MWR) (`.TRUE.`). (See also Baldauf (2013))	`.FALSE.`
`divdamp_slope`	`REAL`	(Only for `itype_fast_waves=2`) exceed the theoretical slope stability criterion of the divergence damping	`20.0`
`l_3D_div_damping`	`LOG`	(Only for `itype_fast_waves=2`) The artificial divergence damping either acts only on the u- and v-equation (`.FALSE.`) or in a fully isotropic 3D manner (`.TRUE.`). The latter version is more time consuming (and less tested until now). (See also Baldauf (2013) and Baldauf (2014))	`.FALSE.`

Name	Type	Definition / Purpose / Comments	Default
`itype_bbc_w`	`INT`	Option for choosing bottom boundary condition for vertical wind: (before Version 4.12 this switch was named `itype_lbc_w`). For `itype_fast_waves=1`, allowed values are in the range 0-5: 0/1: Runge-Kutta like method following `iadv_order` 2/3: Second-order centered differences 4/5: Fourth-order centered differences 0/2/4: Quadratic extrapolation of horizontal wind to surface 1/3/5: No extrapolation of horizontal wind to surface For `itype_fast_waves=2`, the settings 102, 104, 112, 114, 122 and 124 are possible. The meaning of the three digits `1ed` are: 1 To make the value bigger than 100, to indicate the settings for `itype_fast_waves=2`. e=0 No extrapolation of u and v to the bottom e=1 Linear extrapolation of u and v to the bottom e=2 Quadratic extrapolation of u and v to the bottom d=2 Centered differences of 2nd order to discretize dh/dx and dh/dy d=4 Centered differences of 4th order to discretize dh/dx and dh/dy	`114`
`ldiabf_lh`	`LOG`	Include diabatic forcing due to latent heat in the Runge-Kutta scheme.	`.TRUE.`
`lsl_adv_qx`	`LOG`	has been eliminated in Version 4.18. This is now set by the new parameter `y_scalar_advect`. (Switch to use semi-Lagrangian advection of the moisture variables in the Runge-Kutta-scheme (`.TRUE.`) or not.)	`---`
`yef_adv_qx`	`CHAR`	has been eliminated in Version 4.18. This is now set by the new parameter `y_scalar_advect`. (type of Euler-forward advection of the moisture variables (= `'vanLeer', 'PPM', 'Bott_2' 'Bott_4'`))	`---`

Name	Type	Definition / Purpose / Comments	Default
`y_scalar_advect`	`CHAR`	String to specify the special horizontal advection type (only) for the Runge-Kutta dynamical core. This parameter replaces the 2 former parameters `yef_adv_qx` and `lsl_adv_qx`. The following table shows the possible settings of `y_scalar_advect` and how the old settings can be replaced (only for options that were also available before): `'SL3_MF'` SL-Advection with tricubic interpolation, multiplicative filling-option (`lsl_adv_qx=.TRUE.`, `yef_adv_qx='---'`) `'SL3_SC'` SL-Advection with simple clipping. `'SL3_SFD'` SL-Advection with tricubic interpolation, selective filling diffusion-option `'Bott2', 'Bott4'` Bott 2nd / 4th order finite-volume scheme (`lsl_adv_qx=.FALSE.`, `yef_adv_qx='Bott_x'`) `'Bott2_XYZYX', 'Bott4_XYZYX'` the same with modified sequence of Strang splitting. `'Bott2_Strang', 'Bott4_Strang'` Bott 2nd / 4th order finite-volume scheme with Strang splitting ('z-y-2x-y-z') `'Bott2_Strang_B', 'Bott4_Strang_B'` the same, but only works in the lowest `k_offset` levels of the atmosphere. `k_offset` is hardcoded with 5. `'vanLeer'` vanLeer type advection (`lsl_adv_qx=.FALSE.`, `yef_adv_qx='vanLeer'`) `'vanLeer_Strang'` vanLeer type advection with Strang splitting `'PPM'` PPM type advection (`lsl_adv_qx=.FALSE.`, `yef_adv_qx='PPM'`) `'PPM_Strang'` PPM type advection with Strang splitting `'MPDATA'` not yet available, work at MeteoCH `'NONE'` no tracer advection takes place NOTE: these strings are now case-insensitive (e.g. 'sl3_mF' or 'SL3_Mf' are both recognized).	`'BOTT2_STRANG'`

Parameters for the lateral boundary conditions:

Name	Type	Definition / Purpose / Comments	Default
`lw_freeslip`	LOG	Free-slip lateral boundary conditions are used for `w` by default in case of non-periodic Davies-type lateral boundaries. Otherwise, `w` must be specified along the boundaries. *It is recommended to use free-slip lateral boundary conditions for real-data simulations.*	`.TRUE.`
`lexpl_lbc`	LOG	eliminated in 5.1!: Now only the explicit formulation of the lateral boundary relaxation is possible. Chooses an explicit formulation of the lateral boundary relaxation.	`.TRUE.`
`crltau`	REAL	has been renamed in 5.1 to `crltau_inv`! To set the time factor for the explicit formulation of lateral boundary relaxation: $\tau_r = \texttt{crltau} \cdot \Delta t$.	`1.0`
`crltau_inv`	REAL	NOTE: Former name was `crltau` and the meaning really is `crltau_inv` = 1/`crltau`. Factor for relaxation time: $1/\tau_r = \texttt{crltau\_inv} \cdot 1/dt$. The advantage of this replacement lies in the fact, that `crltau_inv=0` completely switches off the relaxation (this was not possible before).	`1.0`
`rlwidth`	REAL	If `lexpl_lbc = .TRUE.`, this parameter specifies the width of the relaxation layer in meters. It should be 10 to 15 times the grid mesh size in meters, but should not exceed 0.25 times the full domain size.	`85000.0`
`itype_outflow_qrsg`	INT	To choose the type of relaxation treatment for `qr, qs, qg`. (before Version 4.9 this switch was named `itype_lbcqx`). 1: `qr, qs, qg` are treated with the same lateral boundary relaxation as the other variables 2: no relaxation of `qr, qs, qg` is done at outflow boundary points	`1`
`itype_lbc_qrsg`	INT	To choose the type of lateral boundary treatment for `qr, qs, qg`, i.e., which values are used at the boundary zone. 1: A zero-gradient condition is used for `qr, qs, qg` 2: `qr, qs, qg` are set to 0.0 at the boundary zone 3: No presetting is done in the whole the boundary zone (must not be chosen for Leapfrog applications).	`1`
`lradlbc`	LOG	To run with radiative lateral boundary conditions (if `.TRUE.`), or with Davies conditions (if `.FALSE.`). (In Version 4.5 this switch has been moved from the group `RUNCTL` to `DYNCTL`).	`.FALSE.`

Name	Type	Definition / Purpose / Comments	Default
`relax_fac`	`REAL`	reduction factor for strength of lateral boundary relaxation (only if radiative lateral boundary conditions are used). (Switch has been introduced in Version 4.5).	`0.01`

Horizontal diffusion:

Name	Type	Definition / Purpose / Comments	Default
`lhordiff`	`LOG`	Main switch to include horizontal diffusion.	`.TRUE.`
`itype_hdiff`	`INT`	Parameter to select a scheme for horizontal diffusion. 1: Regular 4th-order linear scheme 2: Monotonic 4th-order linear scheme with orographic limiter	`2`
`lhdiff_mask`	`LOG`	has been eliminated in Version 4.12 and has been replaced by reduction factors for the interior and the boundary zone (see below).	-
`l_diff_Smag`	`LOG`	to switch on/off the Smagorinsky diffusion.	`.TRUE.`
`hd_corr_u`	`REAL`	eliminated in 4.12; replaced by `hd_corr_u_[in,bd]`	
`hd_corr_u_bd`	`REAL`	Reduction factor for the horizontal diffusion flux for u, v and w in the boundary zone of the domain.	`0.25`
`hd_corr_u_in`	`REAL`	Reduction factor for the horizontal diffusion flux for u, v and w in the interior zone of the domain.	`0.25`
`hd_corr_t`	`REAL`	eliminated in 4.12; replaced by `hd_corr_t_[in,bd]` Also, there are separate factors now for t and pp.	
`hd_corr_t_bd`	`REAL`	Reduction factor for the horizontal diffusion flux for t in the boundary zone of the domain.	`0.0`
`hd_corr_t_in`	`REAL`	Reduction factor for the horizontal diffusion flux for t in the interior zone of the domain.	`0.0`
`hd_corr_p_bd`	`REAL`	Reduction factor for the horizontal diffusion flux for pp in the boundary zone of the domain.	`0.0`
`hd_corr_p_in`	`REAL`	Reduction factor for the horizontal diffusion flux for pp in the interior zone of the domain.	`0.0`
`hd_corr_q`	`REAL`	eliminated in 4.12; replaced by `hd_corr_q_[in,bd]`	
`hd_corr_q_[in,bd]`	`REAL`	Renamed in 4.26 to `hd_corr_trcr_[in,bd]`	
`hd_corr_trcr_bd`	`REAL`	Reduction factor for the horizontal diffusion flux for tracers in the boundary zone of the domain.	`0.0`
`hd_corr_trcr_in`	`REAL`	Reduction factor for the horizontal diffusion flux for tracers in the interior zone of the domain.	`0.0`
`hd_dhmax`	`REAL`	Threshold value for the maximum height difference (m) between adjacent gridpoints in the orographic flux limiter. With increasing height difference, the diffusive fluxes are gradually decreased to become zero at `hd_dhmax`. Active only for `itype_hdiff = 2`. *Caution: The parameter* `hd_dhmax` *should be adjusted when changing the grid spacing.*	`250.0`

Name	Type	Definition / Purpose / Comments	Default
`l_diff_cold_pools`	`LOG`	Use targeted diffusion for cold pools. It should avoid unrealistic undershootings in the temperature field near the bottom, if the value of a grid point is more than `thresh_cold_pool` degrees Kelvin less than the average value of the surrounding.	`.TRUE.`
`thresh_cold_pool`	`REAL`	Threshold for targeted diffusion for cold pools. Reasonable values are `thresh_cold_pool` $\in [5.0, 20.0]$.	`10.0`

Lower and upper boundary condition:

Name	Type	Definition / Purpose / Comments	Default
`lspubc`	`LOG`	Option to use a sponge layer with Rayleigh damping in the upper levels of the model domain. If `lspubc =.FALSE.`, a rigid lid upper boundary condition is used.	`.TRUE.`
`itype_spubc`	`INT`	To choose the type of Rayleigh damping in the upper levels. 1: chooses the damping against boundary fields; 2: chooses the damping against filtered forecast fields (can be chosen, if the boundary data is only available on frames. 3: New sponge layer near upper model boundary (according to Klemp et al.)	`1`
`nfi_spubc2`	`INT`	Number of applications of smoother for the determination of the large scale field used in the Rayleigh damping with `itype_spubc=2`	`10`
`lrubc`	`LOG`	Option to use a radiative upper boundary condition. *Not yet implemented.*	`.FALSE.`
`rdheight`	`REAL`	The bottom height (m) from which the Rayleigh sponge layer extends to the top of the model domain. A cosine damping profile with maximum damping at the top and zero damping at `rdheight` is assumed.	`11000.0`
`nrdtau`	`INT`	`nrdtau*dt` is the e-folding time for damping at the model top. Larger values of `nrdtau` result in weaker damping.	`5`
`ldyn_bbc`	`LOG`	To choose a dynamical bottom boundary condition.	`.FALSE.`

Additional numerical filters:

Name	Type	Definition / Purpose / Comments	Default
`epsass`	`REAL`	Value of the filter coefficient ε in the Asselin time-filter to damp the computational mode in the 3 time-level Leapfrog scheme (used only for `l2tls=.FALSE.`). *Caution: both too small* ($\varepsilon < 0.01$) *and too large values* ($\varepsilon > 0.25$) *may cause instabilities.*	`0.15`
`alphaass`	`REAL`	Weight for Williams 2009 modification to the Asselin time-filter ($0.5 <$ `alphaass` ≤ 1).	`1.0`
`betasw`	`REAL`	Value of the β-parameter used for time-weighting of the future values in the vertically implicit treatment of acoustic (sound) waves. $\beta = 0$ gives a time-centred average with no damping, $\beta = 1$ results in a fully implicit vertical scheme with strong damping of acoustic and gravity wave modes. *Slight positive off-centering is recommended to damp vertically propagating sound waves.*	`0.40`
`betagw`	`REAL`	Same as `betasw`, but used for gravity waves.	`0.40`
`beta2sw`	`REAL`	Same as `betasw`, but used in the p^*, T^* dynamics for sound waves.	`0.40`
`beta2gw`	`REAL`	Same as `betagw`, but used in the p^*, T^* dynamics for gravity waves.	`0.40`
`xkd`	`REAL`	Coefficient for divergence damping	`0.1`

Spectral Nudging

Name	Type	Definition / Purpose / Comments	Default
`lspecnudge`	`LOG`	to switch on/off spectral nudging	`.FALSE.`
`yvarsn`	`CHAR`	list of fields for spectral nudging (must be a subset of `yvarbd`	`U, V`
`pp_sn`	`REAL`	lowest pressure level for spectral nudging	`850.0`
`alpha_sn`	`REAL`	amplification factor for spectral nudging	`0.05`
`isc_sn`	`INT`	spectral nudging in i-direction	2
`jsc_sn`	`INT`	spectral nudging in j-direction	2
`nincsn`	`INT`	to define a time increment for calling the Spectral Nudging	1

Note: The spectral nudging has nothing to do with the Nudging, used as assimilation scheme in the COSMO-Model.

7.4 PHYCTL — Parameters for the Diabatic Model

The namelist group `PHYCTL` contains parameters controlling the physical parameterizations. All parameters are only active if the parameter `lphys` in Namelist `/RUNCTL/` is set to `.TRUE.` in order to enable physical parameterizations. There is one main switch for each physical process to turn on/off this process and to activate additional parameters and sub-options for the corresponding parameterisation. The specifications for the parameters in `/PHYCTL/` are included in the file `INPUT_PHY`.

The namelist parameters of this group are described in the subsections

- Grid-Scale Precipitation,
- Radiation,
- Moist Convection,
- Vertical turbulent diffusion,
- Surface layer fluxes,
- Soil Processes
- Subgrid Scale Orography

The switch to activate single column model runs is necessary in several schemes, therefore it is not assigned to a special group:

Name	Type	Definition / Purpose / Comments	Default
`lscm`	`LOG`	Main switch to run the single column model. Note, that up to the single column model is not fully implemented in the COSMO-Model.	`.FALSE.`

Grid-Scale Precipitation

These parameters control the parameterization of grid scale precipitation. Note that the sub-grid scale precipitation is controlled by the convection parameterization.

Name	Type	Definition / Purpose / Comments	Default
lgsp	LOG	Main switch for including grid scale precipitation. If .TRUE., the model is run with a grid-scale precipitation scheme which computes the effects of precipitation formation on temperature and the prognostic moisture variables in the atmosphere (water vapour, cloud water, optionally cloud ice, rain, snow and graupel) as well as the precipitation fluxes of grid-scale rain and snow at the ground.	.TRUE.
itype_gscp	INT	Control parameter to select a specific scheme for grid scale parameterization: 1: Kessler-type warm rain parameterization scheme without ice-phase processes. 2: Kessler-type bulk formulation using cloud water, rain and snow. 3: Extension of the basic scheme with cloud water and cloud ice. 4: Graupel scheme with prognostic cloud water, cloud ice, and graupel.	3
lgsp_first	LOG	Switch to run grid scale precipitation at the beginning of time loop. Usually it is computed after the dynamics at the end of the time loop. This is only implemented for the new COSMO-ICON physics, where it can have performance benefits to run the whole parameterizations in one block.	.FALSE.
lsuper_coolw	LOG	Switch to activate effects of supercooled liquid water in the microphysics (only activated for graupel and cloudice scheme).	.TRUE.
lprogprec	LOG	This switch has been eliminated in Version 4.23. All simulations are now done with prognostic precipitation.	—
ltrans_prec	LOG	This switch has been eliminated in Version 4.23. All simulations are now done with prognostic precipitation.	—
ldiniprec	LOG	To switch on a diagnostic initialization of rain and snow, in case that no initial data are given.	.FALSE.

Up to COSMO-Model Version 3.6 the parameter `itype_gscp` was used to switch on/off a prognostic treatment of rain and snow, but only for the 2-timelevel Runge-Kutta scheme (for `irunge_kutta = 0`). Now only the specific kind of parameterization scheme can be chosen with `itype_gscp` and there are two additional parameters to control the prognostic precipitation.

Radiation

The following parameters control the Ritter-Geleyn radiation parameterization scheme of the COSMO-Model. Here, among others, the frequency of the calculation, the surface albedo, the background aerosols and the greenhouse gas concentration scenario can be specified.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`lrad`	`LOG`	Main switch for including radiation. If `.TRUE.`, the model is run with the radiation scheme which computes heating rates in the atmosphere (solar and thermal) and the energy balance (solar and thermal) at the ground. To save computing time, the radiation scheme will be called at certain time intervalls defined by `nincrad` or `hincrad`. Between two consecutive calls of the scheme, the radiative heating rates are kept constant.	`.TRUE.`	
`nincrad`	`INT`	Interval (in time steps) between two calls of the radiation scheme.	`360`	P,dt
`hincrad`	`REAL`	As `nincrad`, but time interval in hours. In general, an interval of 0.5 – 1 hour yields sufficient accuracy. *Can be specified alternatively to* `nincrad`.	`0.0`	P,dt
`icldm_rad`	`INT`	Parameter to select the mode of cloud representation (i.e. cloud cover, and cloud water and ice content) as input to the radiation parameterization. 0: No clouds are considered. 1: Only grid-scale clouds are considered. 2: Grid- and sub-grid scale water clouds are considered; cloud cover and water content are calculated according to a relative-humidity criterion (`itype_wcld = 1`) or a statistical closure (`itype_wcld = 2`). 3: Grid- and sub-grid scale (including convective) water and ice clouds are considered; cloud cover, water content and ice content are calculated according to the diagnosis based on a relative humidity scheme. (But note that also cloud ice is considered here!) 4: (at the moment) same as 3.	`4`	
`lforest`	`LOG`	Switch to choose the external parameter fields modifying the snow albedo of evergreen and deciduous forest. (itype_alb has to be chosen accordingly) Recommended: .TRUE.	`.FALSE.`	R
`nradcoarse`	`INT`	If `nradcoarse` > `1`, the radiation is computed on a coarser grid to save computation time. `nradcoarse` grid points in every horizontal dimension are combined. Maximal possible value is `nboundlines`.	`1`	P

Name	Type	Definition / Purpose / Comments	Default	Depend.
`lradf_avg`	`LOG`	To average the radiative forcings when running on a coarser grid (`nradcoarse` $>$ `1`). ???	`.FALSE.`	dx
`lradtopo`	`LOG`	To use topographic corrections for the radiation. (needs additional fields from int2lm).	`.FALSE.`	
`nhori`	`INT`	Number of sectors for the horizont used by the topographic corrections for the radiation.	`24`	P
`ico2_rad`	`INT`	Parameter to choose a special CO_2-concentration scenario: 0: constant CO_2-concentration of 360 ppm (default for weather prediction) 1: A1B scenario, only CO_2 is considered 2: A1B scenario, effective CO_2 is considered (i.e. $CO_2 + CH_4 + N_2O$ 3: B1 scenario, only CO_2 is considered 4: B1 scenario, effective CO_2 is considered (i.e. $CO_2 + CH_4 + N_2O$ 5: 6: 7: Scenario RCP2.6 8: Scenario RCP4.5 9: Scenario RCP6 10: Scenario RCP8.5	`0`	
`lco2_stab`	`LOG`	Option, to perform simulations with stabilized GHG forcings.	`.FALSE.`	
`iy_co2_stab`	`LOG`	(Only in effect, if `lco2_stab = .TRUE.`) To define the year, when GHG stabilization begins.	`2001`	
`lemiss`	`LOG`	Option, to use an external surface emissivity map (if set to `.TRUE.`). If `lemiss` is `.FALSE.` (default), a constant surface emissivity is assumed.	`.FALSE.`	
`itype_aerosol`	`INT`	Switch to choose the type of aerosol map. 1: Tanre. (As it was up to Version 4.10 in the model.) Constant aerosol distributions are given for rural, urban, desert areas and the sea. 2: Tegen. A monthly aerosol climatology is used for sulfate drops, total dust, organic, black carbon and sea salt	`1`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`itype_albedo`	`INT`	Switch to choose the type of solar surface albedo. This parameter has been introduced in Version 4.23. 1: surface albedo is a function of soiltype (method up to now and still default) 2: surface albedo is determined as a weighted mean value of two external fields for dry and for saturated soil. As a weighting factor the relative soil moisture saturation for the top soil layer is used. 3: A background albedo is prescribed by external fields, which give average values for every month. The actual surface albedo is determined by a linear interpolation between two monthly values, depending on the day. This is done in INT2LM. 4: The vegetation albedo is modified by forest fraction. Note, that for this type, also `lforest` has to be set to `.TRUE.`	`1`	

Moist Convection

These parameters specify the convection parameterization used. In particular at resolutions below 3 km the deep convection parameterization should be switched off, since this process is mainly a grid scale process for such high horizontal resolutions.

Name	Type	Definition / Purpose / Comments	Default
`lconv`	LOG	Main switch for including subgrid-scale convection. If `.TRUE.`, the model is run with a moist convection parameterization, which computes the effect of moist convection on temperature, water vapour and horizontal wind in the atmosphere, and the precipitation rates of rain and snow at the ground. To save computing time, the convection scheme may not be called every time step, but at certain intervals defined by `nincconv`. Between two consecutive calls of the scheme, the convective tendencies and precipitation fluxes are kept constant.	`.FALSE.`
`ltiedtke`	LOG	Eliminated; replaced by itype_conv in Version 4.4	
`lkainfri`	LOG	Eliminated; replaced by itype_conv in Version 4.4	
`lshallow`	LOG	Eliminated; replaced by itype_conv in Version 4.4	
`itype_conv`	INT	To specify the type of convection parameterization 0: Tiedtke scheme 1: This option has been eliminated 2: This option has been eliminated 3: Shallow convection based on Tiedtke scheme	0
`nincconv`	INT	Interval (in time steps) between two calls of the convection scheme.	4
`lconf_avg`	LOG	Switch to apply a horizontal smoothing of the convective forcings (moisture convergence, surface moisture flux and vertical velocity) prior to calling the convection scheme.	`.TRUE.`
`lcape`	LOG	Enables a CAPE-type closure within the Tiedtke convection scheme (not fully tested yet).	`.FALSE.`
`lctke`	LOG	Enables a turbulent kinetic energy closure within the Tiedtke scheme (not fully tested yet).	`.FALSE.`
`lconv_inst`	LOG	Switch to write instantaneous (`.TRUE.`) or aggregate (`.FALSE.`) values of `top_con` and `bas_con` to model output.	`.FALSE.`

Vertical turbulent diffusion

There is one main switch to include turbulent diffusive fluxes, `ltur`, which activates both the parameterization of turbulent diffusion in the atmosphere and of surface-layer fluxes. A further selection of schemes can be done by the `itype_turb` and `itype_tran` parameters.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ltur`	`LOG`	Main switch for including turbulent diffusion. If `.TRUE.`, the model is run with a turbulence parameterization which calculates the transport coefficients for momentum (K_m) and heat (K_h, also applied for water substance) in the atmosphere and the transfer coefficients at the ground (surface-layer). Over water, also the roughness length z_0 is computed. To save computing time, the exchange coefficients in the atmosphere may not be computed every time step, but at certain time intervals defined by `nincture`.	`.TRUE.`	
`ninctura`	`INT`	Increment in time steps for recalculating the transport coefficients K_m and K_h for vertical diffusion (`itype_turb = 1`) and for recalculating the stability functions S_m and S_h in case `itype_turb = 3` which are used to diagnose K_m and K_h from the predicted TKE. *Note: When running with the Leapfrog time-integration,* `ninctura` *should be an odd number to avoid using the same time family all the time.*	`1`	dt
`itype_turb`	`INT`	Parameter to select the vertical turbulent diffusion parameterization. 1: Default diagnostic scheme. 2: Not used. 3: Prognostic TKE-based scheme, which includes effects from subgrid-scale condensation/evaporation. 4: Not used. 5/7: If a threedimensional turbulence scheme will be used.	`3`	dx
`l3dturb`	`LOG`	Switch to choose a 3D turbulence scheme (for (`itype_turb = 5/7`).	`.FALSE.`	dx
`l3dturb_metr`	`LOG`	To switch on/off the use of metric terms in the 3D turbulence.	`.FALSE.`	
`lprog_tke`	`LOG`	Switch to choose a prognostic treatment of TKE (for (`itype_turb = 5/7`).	`.FALSE.`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`imode_turb`	`INT`	Mode of turbulent vertical diffusion parametrization in case of `itype_turb = 3`. 0: Standard implicit treatment of the vertical diffusion in the solver for slow processes (`slow_tendencies.f90`). 1: As option `0`, but using Neumann boundary conditions for heat and moisture transport at the lower boundary (specified fluxes) instead of Dirichlet boundary conditions (specified values). 2: Explicit treatment of the vertical diffusion by calculating a process-splitted (explicit) tendency. 3: Implicit treatment of the vertical diffusion by calculating a process-splitted (implicit) tendency.	`0`	dt
`icldm_turb`	`INT`	Mode of cloud representation to take into account subgrid-scale condensation within the turbulence parameterization in case of `itype_turb = 3`. Options '0', '1' and '2' as for `icldm_rad`, i.e. 0: No clouds are considered. 1: Only grid-scale clouds are considered. 2: Grid- and sub-grid scale water clouds are considered; cloud cover and water content are calculated according to a relative-humidity criterion (`itype_wcld = 1`) or a statistical closure (`itype_wcld = 2`).	`2`	
`lexpcor`	`LOG`	Explicit corrections of the implicitly calculated turbulent heat and moisture fluxes due to effects from subgrid-scale condensation (only if `itype_turb=3`). *Should be set to* `.TRUE.` *to allow for a consistent treatment of diffusion coefficients and fluxes.*	`.FALSE.`	
`ltmpcor`	`LOG`	Consideration of thermal TKE-source in enthalpy budget (only if `itype_turb=3`).	`.FALSE.`	
`lnonloc`	`LOG`	Nonlocal calculation of vertical gradients used for turbulent diffusion (only if `itype_turb=3`).	`.FALSE.`	
`lcpfluc`	`LOG`	Consideration of fluctuations of the heat capacity of air (only if `itype_turb=3`).	`.FALSE.`	
`lturhor`	`LOG`	Switch to include horizontal turbulent diffusion. It has been eliminated in Version 4.10 and replaced by `limpltkediff`.	`.FALSE.`	
`limpltkediff`	`LOG`	Switch to include horizontal turbulent diffusion. Implemented in Version 4.10.	`.TRUE.`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ltkesso`	`LOG`	Switch, to calculate SSO-wake turbulence production for TKE. Implemented in Version 4.10.	`.FALSE.`	
`ltkecon`	`LOG`	Switch to consider convective buoyancy production for TKE. Implemented in Version 4.20.	`.FALSE.`	
`itype_sher`	`INT`	Type of shear production for TKE. Implemented in Version 4.10. 1: Only vertical shear. 2: Full isotropic 3D-shear. 3: Vertical shear and separated horizontal 2D-shear mode.	`1`	

Surface layer fluxes

These parameters control the calculation of the turbulent fluxes of latent and sensible heat.

Name	Type	Definition / Purpose / Comments	Default
`itype_tran`	`INT`	Main prameter to select a specific surface-layer parameterization. 1: Standard Louis-type scheme. 2: New TKE-based scheme including a laminar sub-layer.	2
`lfreeslip_sfc`	`LOG`	This functionality has been moved to the group `ARTIFCTL` in Version 4.17, but with a new name `lnosurffluxes_[m,h]`. (To switch on/off the surface momentum fluxes even if a turbulence scheme is used.)	`---`
		The following parameters apply only for the new surface layer scheme, i.e. only in case of `itype_tran = 2`.	
`imode_tran`	`INT`	Type of surface-atmosphere transfer. 1: Based on diagnostic TKE in the surface layer. 2: Based on prognostic TKE in the surface layer.	1
`itype_wcld`	`INT`	Type of cloud water diagnosis. 1: Diagnosis based on a relative humidity scheme. 2: Diagnosis based on a statistical scheme.	2
`icldm_tran`	`INT`	Mode of cloud representation to take into account subgrid-scale condensation within the new surface layer parameterization `itype_tran = 2`. Options '0', '1' and '2' as for `icldm_turb`, i.e. 0: No clouds are considered. 1: Only grid-scale clouds are considered. 2: Grid- and sub-grid scale water clouds are considered; cloud cover and water content are calculated according to a relative-humidity criterion (`itype_wcld = 1`) or a statistical closure (`itype_wcld = 2`).	0
`itype_synd`	`INT`	Type of diagnosis of synoptic station values. 1: Interpolation of screen-level (2-m, 10-m) values using traditional similarity theory. 2: Interpolation of screen-level (2-m, 10-m) values based on profile relations used in the new surface-layer scheme.	1
`lprfcor`	`LOG`	Using the profile values of the lowest main level instead of the mean value of the lowest layer for surface flux calculations. *Not tested, should be set to* `.FALSE.`	`.FALSE.`

Soil Processes

These parameters control the parameterization of soil and vegetation processes. Mainly the configurations of the soil and vegetation model TERRA, of the lake model FLake and of the snow model are specified. The optimal configuration depends on the region investigated.

Note:
Additional external parameter fields are required by some of the methods used as additional input fields (e.g. for FLake). They can be provided using an appropriate version of `INT2LM`.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`lsoil`	`LOG`	Main switch to include soil processes by running a soil model.	`.TRUE.`	M
`lseaice`	`LOG`	Main switch to activate the sea ice scheme at gridpoints covered by ice. **Note: This requires the temperature and the height of the sea-ice in the initial conditions**. These have to be provided by INT2LM from a driving model or from the assimilation cycle.	`.TRUE.`	R
`llake`	`LOG`	Main switch to include lake processes by running the lake model FLake. **This requires the lake fraction and lake depth in the initial conditions**. These have to be provided by INT2LM or from the data assimilation cycle.	`.FALSE.`	dx,R
`lmulti_layer`	`LOG`	Switch to run the new multi-layer soil model `TERRA_ML`. If `lmulti_layer = .FALSE`, the standard soil model `TERRA` based on the two-layer EFR-method is used.	`.TRUE.`	
`lmulti_snow`	`LOG`	Switch to run the multi-layer snow model. If `lmulti_snow = .FALSE`, the standard snow model within `TERRA_ML` is used. Introduced in Version 4.11. Remaining problems in COSMO.	`.FALSE.`	R
`nlgw`	`INT`	Only for `lmulti_layer = .FALSE.`: Number of prognostic soil water levels in the standard soil model `TERRA`, At present only `nlgw = 2` and `nlgw = 3` are implemented. *Caution: the number of soil water levels must be identical to the number of levels provided in the initial and boundary conditions.* Removed in 5.0.	2	
`lmelt`	`LOG`	Switch to include melting processes within the soil when running the multi-layer soil model `TERRA_ML`. Recommended .TRUE. Removed in 5.0.	`.FALSE.`	R
`lmelt_var`	`LOG`	Sub-option for the `lmelt` parameter. IF `lmelt_var = .TRUE`, the soil freezing temperature is treated to be dependent on the water content, otherwise a constant freezing temperature is used. Recommended .TRUE. Removed in 5.0.	`.FALSE.`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`ke_soil`	INT	Number of active soil layers in the new multi-layer soil model `TERRA_ML`. The total number of layers is `ke_soil + 1`.	7	
`lstomata`	LOG	Switch to use a minimum stomata resistance map for plants Introduced in Version 4.11.. If .FALSE. the standard value for mid latitudes is used. Addtional external parameter field RSMIN required.	`.FALSE.`	R
`ke_snow`	INT	Number of layers in the multi-layer snow model Introduced in Version 4.11.	2	
`czml_soil(:)`	REAL	Array to specify the main levels of the `ke_soil + 1` soil layers (in meters). The default specification is / 0.005, 0.02, 0.06, 0.18, 0.54, 1.62, 4.86, 14.58 / *The maximum number of soil layers is limited to 20.*	see left	
`itype_trvg`	INT	Parameter to select the type of parameterization for transpiration by vegetation. Recommended is 2. Removed in 5.0. 1: Bucket version. 2: BATS version.	2	
`itype_evsl`	INT	Parameter to select the type of parameterization for evaporation of bare soil. Recommended is 2. Removed in 5.0. 1: Bucket version. 2: BATS version.	2	
`itype_root`	INT	Parameter to select the type of root distribution Introduced in Version 4.11. Recommended is 1. 1: Uniform (Default) 2: Exponential (Arora & Boer, 2003)	1	
`itype_heatcond`	INT	Parameter to select the type of soil heat conductivity Introduced in Version 4.11. 1: Use average soil moisture 2: Take into account soil moisture/soil ice In NWP 1 is used due to soil moisture analysis.	1	
`czbot_w_so`	REAL	to specify depth of bottom of last hydrological active soil layer	2.5	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`itype_hydbound`	INT	Parameter to select the type of hydraulic lower boundary Introduced in Version 4.11. 1: Allow for drainage but not diffusion 2: Rigid lid: not yet implemented 3: Ground water with drainage and diffusion	1	

Subgrid Scale Orography

These parameters control the parameterization of the effect of unresolved orography on the resolved scales of motion. The main effect is an additional surface drag over mountains.

Note:
Additional external parameter fields describing the subgrid scale orography are needed as input fields. They can be provided using an appropriate version of `INT2LM`.

Name	Type	Definition / Purpose / Comments	Default
`lsso`	LOG	Main switch to include subgrid scale orography processes	.TRUE.
`nincsso`	INT	Interval (in time steps) between two calls of the SSO scheme.	5

7.5 TUNING — Parameters for tuning dynamics and physics

The namelist group `TUNING` contains parameters that can be used to tune special components and packages of the parameterizations and dynamics. This namelist group is intended to be used mainly by the EXPERTS. The parameters can be used to adapt the behaviour of the model to special regions, applications and resolutions. The specifications for the parameters in `TUNING` are included in the file `INPUT_ORG`.

In the following table some limitations and ranges for meaningful values of the different parameters are given in the form: values $\in [0, 1)$ where $[,]$ stands for *including* and $(,)$ for *excluding* a value.

Name	Type	Definition / Purpose / Comments	Default	Depend.
`tkesmot`	`REAL`	Time smoothing factor for TKE to reduce the time variability of the diffusion coefficient. Formel ???. Should be chosen as small as possible. (`tkesmot` $\in [0, 2]$)	`0.15`	???
`wichfakt`	`REAL`	Vertical smoothing factor for explicit vertical diffusion coefficients. (`wichfakt` $\in (0, 0.5]$)	`0.0`	dt
`securi`	`REAL`	Security factor for maximal diffusion coefficients for explicit vertical diffusion. (`securi` $\in (0, 1]$)	`0.85`	dz
`tkhmin`	`REAL`	Minimal diffusion coefficients for heat active in stable BL conditions. (`tkhmin` $\in [0, 2]$)	`0.4`	dz,R
`tkmmin`	`REAL`	Minimal diffusion coefficients for momentum active in stable BL conditions. (`tkmmin` $\in [0, 2]$)	`0.4`	dz,R
`z0m_dia`	`REAL`	Typical roughness length for a Synop station, which is used for the interpolation of screen-level values of the 10-m wind (instead of using the actual roughness length at the gridpoint) and T_{2M}. (`z0m_dia` $\in [0.001, 10]$). Modifies the T_2M calculation.	`0.2`	
`rat_lam`	`REAL`	Ratio of laminar boundary layer thickness for water wapour and sensible heat. Higher values allow to ... the Bowen ratio. (`rat_lam` $\in [0.1, 10]$)	`1.0`	
`rat_can`	`REAL`	Scaling factor for the calculation of the canopy height affecting the diagnostics of T_{2M} (`rat_can` $\in [0, 10]$). Removed in 5.0.	`1.0`	
`rat_sea`	`REAL`	Scaling factor for `rlam_heat` (for scalars) over sea. (`rat_sea` $\in [1, 100]$).	`20.0`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`pat_len`	`REAL`	Length scale (m) of sub-scale surface patterns over land. (`pat_len` $\in [0, 10000]$). Removed in 5.0.	`500.0`	dx
`tur_len`	`REAL`	Maximal turbulent length scale (m). (`tur_len` $\in [0, 10000]$)	`500.0`	
`c_lnd`	`REAL`	Surface-area index of gridpoints over land (excluding leaf-area index) used in ???. (`c_lnd` $\in [1, 10]$). Formula: ???.	`2.0`	
`c_sea`	`REAL`	Surface-area index of gridpoints over sea used in ???. (`c_sea` $\in [1, 10]$). Formula: ???.	`1.5`	
`c_soil`	`REAL`	Surface-area index of the evaporating fraction of gridpoints over land used in ???. (`c_soil` $\in [0, c\_lnd]$). Formula ???.	`1.0`	
`e_surf`	`REAL`	Exponent to get the effective surface area used in ??? (Why needed additionally to c_{xxx}). (`e_surf` $\in [0.1, 10]$).	`1.5`	
`rlam_heat`	`REAL`	Scaling factor for the thickness of the laminar boundary layer for heat. Formula: ???. (`rlam_heat` $\in [0.1, 10]$)	`1.0`	
`rlam_mom`	`REAL`	Scaling factor for the thickness of the laminar boundary layer for momentum. Formula: ???. (`rlam_mom` $\in [0, 1]$)	`0.0`	
`a_heat`	`REAL`	Factor for turbulent heat transport. (`a_heat` $\in [0.01, 100]$) Removed in 5.0.	`0.74`	
`a_mom`	`REAL`	Factor for turbulent momentum transport. (`a_mom` $\in [0.01, 100]$) Removed in 5.0.	`0.92`	
`a_hshr`	`REAL`	Length scale factor for separate horizontal shear production of TKE. Introduced in Version 4.10.	`0.2`	
`a_stab`	`REAL`	Length scale factor for the stability correction. Introduced in Version 4.10.	`0.0`	
`d_heat`	`REAL`	Factor for turbulent heat dissipation. (`d_heat` $\in [0.01, 100]$). Removed in 5.0.	`10.1`	
`d_mom`	`REAL`	Factor for turbulent momentum dissipation. (`d_mom` $\in [0.01, 100]$). Removed in 5.0.	`16.6`	
`c_diff`	`REAL`	Factor for turbulent diffusion of TKE. (`c_diff` $\in [0, 10]$).	`0.2`	
`clc_diag`	`REAL`	Cloud cover at saturation in statistical cloud diagnostic. (`clc_diag` $\in (0, 1)$)	`0.5`	
`q_crit`	`REAL`	Critical value for normalized over-saturation. (`q_crit` $\in [1, 10]$)	`4.0`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`crsmin`	`REAL`	Minimum value of stomatal resistance (used by the BATS approach for vegetation transpiration, `itype_trvg=2`). (`crsmin` $\in [50, 200]$)	`150.0`	
`qc0`	`REAL`	Cloud water threshold for autoconversion.	`0.0`	
`qi0`	`REAL`	Cloud ice threshold for autoconversion.	`0.0`	
`entr_sc`	`REAL`	Mean entrainment rate for shallow convection. Introduced in Version 4.5.	`0.0003`	
`thick_sc`	`REAL`	limit for convective clouds to be ”shallow” (in Pa). Recommended values for `thick_sc`: `thick_sc` $\in [10000.0, 45000.0]$ Introduced in Version 4.18.	`25000.0`	
`mu_rain`	`REAL`	Shape parameter of the rain drop size distribution. Reasonable values are: `mu_rain` $\in [0.0, 5.0]$. Introduced in Version 4.5. ATTENTION: In Version 4.21 the default value has been changed from 0.5 to 0.0!	`0.0`	
`rain_n0_factor`	`REAL`	To reduce the evaporation of rain drops. Reasonable values are: `rain_n0_factor` $\in [0.0, 1.0]$. Introduced in Version 4.14.	`1.0`	
`cloud_num`	`REAL`	Cloud droplet number concentration.	`5.0 E+08`	
`v0snow`	`REAL`	Factor in the terminal velocity for snow. This was a local variable in the subroutines `hydci_pp` and `hydci_pp_gr` before, but had different values. To reproduce the results from the former version, the following values have to be set: `itype_gscp = 3` and LF: 15.0 `itype_gscp = 3` and RK: 25.0 `itype_gscp = 4` and RK: 20.0 Introduced in Version 4.14.	`25.0`	
`gkdrag`	`REAL`	Scaling factor for gravity wave drag in SSO scheme. Reasonable values are: `gkdrag` $\in [0.0, 1.0]$. With a value of 1, the gravity wave drag in the SSO scheme is switched on. When reducing the value, the strength of the gravity wave drag is reduced. With a value of 0, the gravity wave drag in the SSO scheme is switched off.	`0.075`	

Name	Type	Definition / Purpose / Comments	Default	Depend.
`gkwake`	`REAL`	Scaling factor for low-level flow blocking in SSO scheme. Reasonable values are: `gkwake` $\in [0.0, 1.0]$. With a value of 1, the low-level flow blocking in the SSO scheme is switched on. When reducing the value, the strength of the low-level flow blocking is reduced. With a value of 0, the low-level flow blocking in the SSO scheme is switched off.	`0.5`	

7.6 `DIACTL` — Parameters for Diagnostic Output

`DIACTL` contains parameters to generate gridpoint and control ASCII output. These parameters are only in effect if the main switch `ldiagnos` in `RUNCTL` is set to `.TRUE.`. In this case, some additional time integrated fields – `TDIV_HUM` (vertically integrated divergence of specific humidity) and `AEVAP_S` (surface moisture flux) – are also calculated to allow for a mass-budget calculation based on GRIB-output. Currently, the following ASCII output can be generated:

- Grid point output (meteographs) in a specific form;
  results are written to files `M_`*stationname* (see Section 8.1.1).
- Control output for a quick-look monitoring of the model run;
  results are written to files `YUPRMASS` (for mass variables) and `YUPRHUMI` (for humidity variables), resp. (see Section 8.1.4 and 8.1.5).

Note: Up to model version 3.4, two addtional forms of ASCII output could be generated: Diagnostics for various subdomains and differences between predicted and and boundary fields. Since these diagnostics can be easily calculated from GRIB-output, they will no longer be retained.

Parameters for control ouput

For control output, a number of variables are computed and written to the ASCII files `YUPRMASS` (for mass variables) and `YUPRHUMI` (for humidity variables). These variables are domain averages of quantities like surface pressure, surface pressure tendency, kinetic energy, dry static energy, moist static energy, cloud water content, absolute vertical velocity at certain levels, precipitation rates and accumulated precipitation, and domain maxima of absolute horizontal and vertical velocity. This allows for a quick-look control of the model run.

Name	Type	Definition / Purpose / Comments	Default
`n0meanval`	`INT`	Number of time step for the first call of control output. If `n0meanval > nstop`, no control output will be computed.	0
`nincmeanval`	`INT`	Interval (in time steps) between two calls of the control calculations.	10

Ouput for COSMO Testsuite

Name	Type	Definition / Purpose / Comments	Default
`ltestsuite`	`LOG`	To activate additional ASCII output, which is used and evaluated when running the COSMO Technical Testsuite.	`.FALSE.`

Control parameters for grid point output

Only one type of grid point output can be chosen, either the short meteographs (`lgpshort = .TRUE.`), the long grid point output (`lgplong = .TRUE.`) or the special grid point output for the physics (`lgpspec = .TRUE.`). The parameter `nmaxgp` (=100 per default) in the module `src_gridpoints.f90` gives the maximum number of gridpoints for which calculations can be done. For every grid point, the output is stored for all time steps to a file `M_`*stationname*, where *stationname* is a name that can be specified by namelist input. If no name is specified, the geographical coordinates are used instead.

Name	Type	Definition / Purpose / Comments	Default
`n0gp`	`INT`	Time step of the first grid point calculation. *Alternatively:*	`0`
`h0gp`	`REAL`	Same as `n0gp`, but time in hours.	`0.0`
`nincgp`	`INT`	Time interval (in time steps) between two calls for grid point output. *Alternatively:*	undefined
`hincgp`	`REAL`	Same as `nincgp`, but time in hours.	`0.0`
`station-list_tot(:)`	`TYPE`	The list of stations for grid point output can be specified with a derived type declaration. The components of the type are: - `igp (INT)`: i-index - `jgp (INT)`: j-index - `rlatgp_tot (REAL)`: geographical latitude - `rlongp_tot (REAL)`: geographical longitude - `ystation_name (CHAR)`: name of the station	undefined
`lgpshort`	`LOG`	Calculate and print a short form of grid point output (1 line/step).	`.FALSE.`
`lgplong`	`LOG`	Calculate and print a long form of grid point output (about 1 page/step).	`.FALSE.`
`lgpspec`	`LOG`	Calculate and print a special form of grid point output for physics diagnostics.	`.FALSE.`

Computation of special diagnostics

Since Version 4.8 it is possible to choose different variants for special diagnostic computations:

Name	Type	Definition / Purpose / Comments	Default
`itype_diag_t2m`	INT	To specify the method for computing the 2m temperature 1: Computation with an exponential canopy profile, but with a diagnostic Prandtl layer interpolation even for scalars, using an adopted canopy layer resistance. 2: Computation with exponential canopy profile	1
`itype_diag_gusts`	INT	To specify the method for computing the maximal wind gusts 1: Dynamical gust derived from lowest model layer 2: Dynamical gust derived from 30 m 3: Dynamical gust derived after Brasseur 4: Similar to 1, but here the gust factor depends weakly on the mean wind speed at 10 meters.	1

Computation of surface and volume integrals

Since Version 3.23, the COSMO-Model offers the possibility to calculate volume integrals of arbitrary fields over an arbitrary cuboid defined in the numerical (i.e. terrain-following) grid. Also surface integrals of arbitrary vector fields ('fluxes') over the surface of this cuboid can be computed. With the following set of namelist variables, the cuboid can be defined (in terms of grid point indices of the total domain) and these integrations can be switched on/off.

Name	Type	Definition / Purpose / Comments	Default
`imin_integ`	INT	Starting i-index of the cuboid.	`1 + nboundlines`
`l_integrals`	LOG	To switch on/off the computation of integrals.	`.FALSE.`
`imax_integ`	INT	Ending i-index of the cuboid.	`ie_tot - nboundlines`
`jmin_integ`	INT	Starting j-index of the cuboid.	`1 + nboundlines`
`jmax_integ`	INT	Ending j-index of the cuboid.	`je_tot - nboundlines`
`kmin_integ`	INT	Starting k-index of the cuboid	`1`
`kmax_integ`	INT	Ending k-index of the cuboid	`ke_tot`

7.7 `SATCTL` — Controlling the Synthetic Satellite Images

In August 2003 a project was started between DWD and the DLR Institute for Atmospheric Physics which aimed at the generation of synthetic satellite images within the COSMO-Model. The RTTOV (Radiative Transfer model for TIROS Operational Vertical sounder) model, Version 7, is used to compute radiances for satellite infrared or microwave nadir scanning radiometers from an atmospheric profile of temperature, variable gas concentrations, and cloud and surface properties. In Version 4.18, also the use of RTTOV, Version 9, has been implemented and since Version 4.26, also RTTOV, Version 10, can be used.

The different RTTOV-libraries are included in the COSMO-Model by conditional compilation. Depending on which implementation is used, the corresponding macro has to be set when compiling the COSMO-Model (for example with -DRTTOV7):

`'RTTOV7'` to use the RTTOV7 library.
Note that the COSMO-Model does not use the official RTTOV7 library, but a modified one, which takes care of using this library within parallel programs. It also contains some optimizations for vector processors.

`'RTTOV9'` to use the RTTOV9 library.

`'RTTOV10'` to use the RTTOV10 library.

To use RTTOV9 or RTTOV10, another module, developed at DWD, is necessary as interface to this library: `mo_rttov_ifc.f90`. This module is available from DWD.

The RTTOV model can compute radiances and brightness temperatures of several instruments, which are located on diverse satellites. The implementation provided in the COSMO-Model only can compute the values for the following two instruments and channels specified in Table 7.23.

For every channel the following 4 products can be computed:

- cloudy brightness temperature
- clear-sky brightness temperature
- cloudy radiance
- clear-sky radiance

Note that the values for METEOSAT satellites can be computed, but be aware of the location of these satellites. Only MSG 2 is located such that it is useful for Europe.

Table 7.23: Instruments and channels for use in the COSMO-Model

Sensor	Satellite	Channel	Central Wavelength
MVIRI	METEOSAT [7]	1	WV6.4
MVIRI	METEOSAT [7]	2	IR11.5
SEVIRI	MSG [1-2]	4	IR3.9
SEVIRI	MSG [1-2]	5	WV6.2
SEVIRI	MSG [1-2]	6	WV7.3
SEVIRI	MSG [1-2]	7	IR8.7
SEVIRI	MSG [1-2]	8	IR9.7
SEVIRI	MSG [1-2]	9	IR10.8
SEVIRI	MSG [1-2]	10	IR12.1
SEVIRI	MSG [1-2]	11	IR13.4

Two fields have been implemented into the COSMO-Model to take care of the output of the synthetic satellite images. These fields can be specified by the shortnames

`'SYNME7'`	output of the products for MVIRI, METEOSAT7,
`'SYNMSG'`	output of the products for SEVIRI, MSG1 or MSG2.

Although special channel and products can be chosen via Namelist, the implementation is such that all channels and all products of a special instrument are computed.

Computation of the SynSat products can be controlled by the following namelist parameters:

Name	Type	Definition / Purpose / Comments	Default
`itype_rttov`	`INT`	To specify, which RTTOV Version shall be used. Possible values: 7,9.	7
`num_sensors`	`INT`	Number of sensors used during the calculation.	`0`
`lcon_clw`	`LOG`	To specify whether convective liquid water shall be used in the computations	`.FALSE.`
`lsynsat`	`LOG`	To activate computation of synthetic satellite images (default behaviour from former versions before 4.26).	`.FALSE.`
`lobsrad`	`LOG`	To activate satellite observation processing. This can only be done, if the model is compiled with -DRTTOV10!	`.FALSE.`
`lread_ct`	`LOG`	To read NWCSAF SEVIRI cloud type	`.FALSE.`
`yclouddir`	`CHAR`	Directory of cloud data.	`' '`
`linterp`	`LOG`	Do an interpolation of p, t and q to half levels.	`.TRUE.`

Name	Type	Definition / Purpose / Comments	Default
`sat_input_01`	`TYPE`	Structure to specify characteristics for first instrument and to specify the products that shall be generated.	
	`CHAR`	Name of the satellite	`all 'y'`
	`INT`	Satellite identification	`0`
	`CHAR`	Name of the sensor	`all 'y'`
	`INT`	Number of channels used	`0`
	`LOG`	To generate clear sky radiance	`.FALSE.`
	`LOG`	To generate cloudy sky radiance	`.FALSE.`
	`LOG`	To generate clear sky brightness temperature	`.FALSE.`
	`LOG`	To generate cloudy sky brightness temperature	`.FALSE.`
`sat_input_02`	`TYPE`	Structure to specify characteristics for second instrument and to specify the products that shall be generated (same as above).	
`nchan_input_01`	`INT`	input channel list for first sensor	all `0`
`nchan_input_02`	`INT`	input channel list for second sensor	all `0`
`emiss_input_01`	`REAL`	To read emissivities for all channels of first instrument	all `0.0`
`emiss_input_02`	`REAL`	To read emissivities for all channels of second instrument	all `0.0`
		The following parameters apply only for the RTTOV9	
`sat_long_01`	`REAL`	Position of first satellite (longitude)	`-999.0`
`sat_long_02`	`REAL`	Position of second satellite (longitude)	`-999.0`
`extrp_type`	`INT`	Type of extrapolation above highest model level • 0: constant • 1: linear • 2: extrapolate towards a climatological value	`0`
`iceshape`	`INT`	To specify, whether ice particles are • 1: hexagonal • 2: or ice aggregates	`1`

Name	Type	Definition / Purpose / Comments	Default
`iwc2effdiam`	INT	Type of conversion of ice water content to effective diameter of ice particles • 1: Ou and Liou, 1995, Atmos. Res., 35, 127-138. • 2: Wyser et al. (see McFarquhar et al. (2003)) • 3: Boudala et al., 2002, Int. J. Climatol., 22, 1267-1284. • 4: McFarquhar et al. (2003) NOTE: Only scheme 4 has been tested extensively!	4

7.8 INICTL — Parameters for the Model Initialization

The namelist group `INICTL` contains control parameters for the digital filter initialization (DFI). These parameters are only in effect if the main switch `ldfi` in `/RUNCTL/` is set to `.TRUE.`. The specifications for the parameters in `/INICTL/` are included in the file `INPUT_DYN`. The DFI is relevant for NWP applications.

When the COSMO-Model starts with interpolated data from a coarse grid driving model – GME, IFS or the COSMO-Model itself – the initial data may contain unbalanced information for the mass and wind field. This may give rise to spurious high-frequency oscillations of high amplitude during the first hours of integration (dynamical adaptation). In this case the initial data can be modified by an initialization procedure in order to filter the unbalanced gravity and sound wave components to a realistic level. For this purpose, the DFI scheme has been implemented. By default, the initialization consists of a 1-hour adiabatic backward integration followed by a 1-hour diabatic forward integration of the model. Other settings can be chosen by the below namelist parameters.

Name	Type	Definition / Purpose / Comments	Default
`ndfi`	INT	Indicator for kind of filtering. 0: No filtering is done. 1: Foreward-stage filtering (launching) using a diabatic foreward integration. 2: Two-stage filtering using an adiabatic backward integration followed by a diabatic foreward integration.	0
`nfilt`	INT	Indicator for method of filtering. 1: Dolph-Chebyshev filter is used. *(no other filter is implemented)*	1
`tspan`	REAL	Time-span (in seconds) for the adiabatic and diabatic stages of the initialization. *Caution: The time-span has to be less or equal to the time, the first boundary data set is provided!*	3600.0
`dtbak`	REAL	Time-step (s) for the backcast filtering stage. *It is recommended to set* `dtbak = dt`.	90.0
`dtfwd`	REAL	Time-step (s) for the forecast filtering stage. *It is recommended to set* `dtfwd = dt`.	90.0
`taus`	REAL	Cuttoff time period (in seconds) of the filter. High-frequency components with periods less than `taus` are filtered. *It is recommended to set* `taus` *to a value smaller or equal to* `tspan`.	3600.0

Name	Type	Definition / Purpose / Comments	Default
`itype_dfi_qx`	`INT`	Treatment of moisture variables during the digital filtering initialization (active only for `ndfi`=1): 0: All moisture variables are filtered in the forward stage. 1: `QV` is filtered, other variables are initialized with instantaneous values valid at **`nhalf`** step of forward stage 2: `QV` is filtered but corrected to maintain saturated points at **`nhalf`** step of forward stage, other variables are initialized with instantaneous values valid at **`nhalf`** step of forward stage.	0
`itype_dfi_soil`	`INT`	Treatment of soil variables during the digital filtering initialization (active only for `ndfi`=1): 0: All soil variables are derived from the average of values at the initial and final step of forward stage. 1: All soil variables are initialized with instantaneous values valid at **`nhalf`** step of forward stage.	0

The recommended settings that were tested at the Italian Met Service are:

- `itype_dfi_qx` = 2
- `itype_dfi_soil` = 1

7.9 NUDGING — Controlling the Data Assimilation

The `NAMELIST` group '`/NUDGING/`' is required and read only if the compile option '`-DNUDGING`' is used for the production of the COSMO binary and if the namelist parameter `luseobs` in `/RUNCTL/` is set to `.TRUE.`.

`/NUDGING/` contains the variables that control all the processes which require meteorological observations, except for the use of satellite radiances in order to produce synthethic satellite images (see `NAMELIST` group '`/SATCTL/`'). Figure 7.2 shows an example for it as an excerpt of the script that is used to run the COSMO-Model.

Note that the whole of the namelist group '`/NUDGING/`' has no effect at all as long as the `NAMELIST` variable '`luseobs`' of `NAMELIST` group '`/RUNCTL/`' is set to `.FALSE.`. This means that if a free model forecast is to be performed solely, it is sufficient to set `luseobs=.FALSE.`, and the group '`/NUDGING/`' does not have to be concerned with.

At present, there a four main processes requiring observations:

- data assimilation based on the nudging technique for atmospheric variables
- verification, which means here simply the writing of a NetCDF feedobs file (see first comments in Section 8) and / or a verification observation file VOF (see Section 8.2.7) for the purpose of observation input for the LETKF analysis scheme or input for verification tools
- latent heat nudging (LHN) for the assimilation of radar-derived surface precipitation rates
- production of 2-dimensional (2D) surface-level analyses based on (synoptic) observations; these analyses can be used for validation purposes or as input for the variational soil moisture analysis (SMA).

It is possible to perform any combination of these four processes, and the first group of `NAMELIST` variables in '`NUDGING`' decides which of them will be performed.

Switches on the main processes:

Name	Type	Definition / Purpose / Comments	Default
`lnudge`	`LOG`	On−off switch for nudging	`.FALSE.`
`lverif`	`LOG`	On−off switch for verification (i.e. for writing a VOF or NetCDF feedobs file, see `mveripr`)	`.FALSE.`
`llhn`	`LOG`	On−off switch for latent heat nudging (LHN)	`.FALSE.`
`lsurfa`	`LOG`	On−off switch for deriving 2D analyses from observations	`.FALSE.`

```
cat > INPUT_ASS << end_input_ass
 &NUDGING
  lnudge  =.TRUE.,
  hnudgsta= 0.0,  hnudgend = 7.0,  tconbox = 180.0,
  lverif  =.TRUE., lverpas = .TRUE., mveripr = 3,
  llhn    =.TRUE., llhnverif=.TRUE., lhn_wweight=.TRUE., rqrsgmax= 0.4,
  radar_in='./',
  ycdfdir ='./', itype_obfile = 2,
  hversta = 0.001, hverend = 3.0,
  nwtyp   = 7,
  niwtyp  = 1,4,2,1,1,3,1,
  iwtyp   = 0,-132,-133,-136,-137,1,4,2,9,-823,-830,-930,12,
  kwtyp   = 1,1,1,1,2,2,2,2,1,
  khumbal = 100,
  mruntyp = 2,
  ntpscor = 1,  ptpstop=400.0,  luvgcor=.TRUE.,  mpsgcor = 1,
  ltipol  =.TRUE.,  tipolmx = 3.0,  wtukrsa = 3.0,  wtukrse = 1.0,
  ltipsu  =.TRUE.,  tipmxsu = 1.0,  wtuksua = 1.5,  wtuksue = 0.5,
                                    wtukara = 1.5,  wtukare = 0.5,
  msprpar = 1,  msprpsu = 0,
  gnudg   = 0.0006, 0.0012, 0.0006, 0.0006,
  gnudgsu = 0.0006, 0.0012, 0.0000, 0.0006,
  gnudgar = 0.0006, 0.0000, 0.0006, 0.0000,
  gnudggp = 0.0003,
  vcorls  = .333 , .333 , .04  , .04  ,  vcutof  = 0.75, 0.75, 1.0 , 1.0 ,
  vcorlsu = .013 , .013 , .002 ,.00001,  vcutosu = 0.75, 0.75, 4.0 ,0.001,
  vcsnisu = 2500., 2500., 9.   , 9.   ,
                                         rhvfac  = 1.0 , 0.0 , 0.83, 0.83,
  rhinfl  =    0.,   70.,    0.,    0.,  rhtfac  = 1.3 , 1.43, 1.3 , 1.3 ,
  rhiflsu =   70.,   70.,  100.,   70.,  rhtfsu  = 1.0 , 1.43, 1.0 , 1.0 ,
  fnondiv = 0.8  ,   cnondiv = 0.1    ,  cutofr  = 3.5 , 3.5 , 3.5 , 3.5 ,
  tnondiv = 1.1  ,                       cutofsu = 2.0 , 3.5 , 2.0 , 2.0 ,
  topobs  =  849., 1099.,  799.,  699.,
  botmod  = 1099., 1099., 1099.,  899.,
  lscadj  =.TRUE.,.TRUE.,.TRUE.,.FALSE.,
  dtqc    =  720.,                       qcvf    = 5.0 , 1.0 ,10.0 , 1.0 ,
  qcc     =    0.,  500.,    0.,   .0,
  qccsu   =   12.,  500.,   12.,   .7,
  mqcorr92= 2,
  lsynop  =.TRUE.,
  laircf  =.TRUE.,
  ldribu  =.TRUE.,
  ltemp   =.TRUE.,
  lpilot  =.TRUE.,
  lsatem  =.FALSE.,
  lscatt  =.TRUE., lcd122 =.TRUE., lcd123 =.TRUE.,
  lgps    =.TRUE.,
  igpscen = 30,23,26,24,29,33,34,37,32,0,21,35,25,
  lcd132  =.TRUE., lcd133=.TRUE., lcd137=.TRUE.,
  maxmlo  = 800,  maxsgo = 6000,  maxuso = 5000,  maxgpo = 7000 , nolbc = 5,
  altopsu =  100., 5000., 5000., 5000.,  thairh  = 20.,
  exnlat  = 90.,  exslat =-90.,  exwlon = -180.,  exelon = 180.,
  lsurfa  =.TRUE.,
  lt2m    =.TRUE.,  ht2a = 0.,  ht2i = 1.,
  lrh2m   =.TRUE.,  hh2a = 0.,  hh2i = 1.,
  lff10m  =.TRUE.,  hffa = 0.,  hffi = 1.,
  lprecp  =.FALSE., hprc = 0.,  raintp = 12.,
  lpraof  =.FALSE.,  lprodr =.TRUE.,  ldiasa =.TRUE.,
  ionl    = 255,   jonl = 271,     ionl2 = 255,    jonl2 = 271,
 /
end_input_ass
```

Figure 7.2: Excerpt of run script for COSMO-Model to create the INPUT_ASS file related to the NAMELIST group 'NUDGING'.

General variables controlling the nudging:

Name	Type	Definition / Purpose / Comments	Default
`nudgsta`	`INT`	start of nudging period in [timesteps]	`0`
`nudgend`	`INT`	end of nudging period in [timesteps]	`0`
or:			
`hnudgsta`	`REAL`	start of nudging period in [hours]	`0.0`
`hnudgend`	`REAL`	end of nudging period in [hours] (relative to initial time of model run)	`0.0`
`tconbox`	`REAL`	time box in [s] for which analysis increments are computed once and then held constant (`dt` : model timestep)	`3*dt`
`nwtyp`	`INT`	if > 1 then compute net weighted observation increments (i.e. preliminary analysis increments $\overline{\Delta\psi}^m$ in Section 3.2 of Part III) for 'nwtyp' different 'sets of observing systems' separately	`1`
`niwtyp(20)`	`INT`	for each of the 'nwtyp' 'sets of observing systems': number of observation and/or code types which belong to and define that set of observing systems (for obs./code types, see below: 'use of observation and code types') (nwtyp = number of non-zero elements in 'niwtyp')	`1,0,0,`...
`iwtyp (50)`	`INT`	for each of the 'nwtyp' 'sets of observing systems': observation types (as positive values) and/or code types (as negative values by setting: 'minus code type') which define successively one set after the other; '0' denotes: all the remaining observation and code types that are not specified to belong to another set of observing systems (number of non-zero elements in 'iwtyp' = sum over values in array 'niwtyp' minus 1)	`0,0,0,`...
`kwtyp (22)`	`INT`	mode of weighting W for multiple observations k, specified for each 'set of obseration systems' m: $= 1 \;\rightarrow\; c_{w(m)} = 0$ $= 2 \;\rightarrow\; c_{w(m)} = 1$ with $W_k^m = \frac{w_{k_m}^2 + c_{w(m)}\, w_{k_m}}{\sum_{k'_m} w_{k'_m} + c_{w(m)}}$ (number of non-zero elements in 'kwtyp' = 1 if (nwtyp == 1) = nwtyp+2 if (nwtyp >= 2) → in this case, the - the first 'nwtyp' entries are used for the 'nwtyp' specified sets of observing systems - the 'nwtyp+1'th entry is used combine the net obs. increments from these sets for the final analysis increment, and - the 'nwtyp+2'th entry is for surface pressure)	`1,1,1,`...

General variables controlling the verification without influence on the nudging:

Name	Type	Definition / Purpose / Comments	Default
`nversta`	`INT`	start of verification period in [timesteps]	`0`
`nverend`	`INT`	end of verification period in [timesteps]	`0`
or:			
`hversta`	`REAL`	start of verification period in [hours]	`0.0`
`hverend`	`REAL`	end of verification period in [hours]	`0.0`
`mveripr`	`INT`	type of verification/observation file(s) written = 0 : no file written, equivalent to 'lverif=.false.' = 1 : NetCDF (feedobs/feedback) file for EnKF or verif. = 2 : ASCII file VOF (YUVERIF) = 3 : both NetCDF feedobs and ASCII VOF files	`3`
`mruntyp`	`INT`	type of current model run used for increments written to the (NetCDF feedobs and/or ASCII VOF) verification files = -1 : no increments written to VOF = 2 : increments from current assimilation run = 40 : increments from current forecast run	`-1`
`lverpas`	`LOG`	on−off switch for writing also passive reports to the verification file(s)	`.TRUE.`

Corrections to balance the analysis increments:

Name	Type	Definition / Purpose / Comments	Default
		temperature correction : density – pressure balancing	
`ntpscor`	INT	switch for hydrostatic temperature correction (to balance the "surface" pressure analysis increments Δp_{k_s} such that the implied upper-level pressure increments Δp decrease with increasing height according to the functions given below and become zero for $p < p_{top}$) $= 0:$ no hydrostatic temperature correction $= 1: \ \frac{\Delta p}{\Delta p_{k_s}} = \eta^2 \, e^{(1-\eta^3)/8} \quad , \ \eta = \frac{p - p_{top}}{p_{k_s} - p_{top}} \ , \ p \geq p_{top}$ $= 2: \ \frac{\Delta p}{\Delta p_{k_s}} = \frac{1}{2} \, \eta \cdot (1+\eta) \cdot \frac{p}{p_{k_s}} \quad , \ \eta = \frac{p - p_{top}}{p_{k_s} - p_{top}} \ , \ p \geq p_{top}$	1
`ptpstop`	REAL	upper boundary p_{top} of temperature correction in [hPa]	`400.0`
		geostrophic wind correction : wind – mass field balancing	
`luvgcor`	LOG	on–off switch for geostrophic wind correction	`.TRUE.`
`qgeo`	REAL	fraction of the full geostrophic wind increments that is added to the model wind fields at 1000 hPa	`0.3`
`qgeotop`	REAL	fraction of the full geostrophic wind increments that is added to the model wind fields at level '`ptpstop`' (in between, this fraction is linearly interpolated)	`0.5`
		geostrophic pressure correction : wind – mass field balancing	
`mpsgcor`	INT	switch for geostrophic pressure correction $= 0:$ no pressure correction $= 1:$ correction balacing wind increments from scatterometer $= 2:$ corr. balacing scatterometer + in-situ 10-m wind increm.	1
`qgeops`	REAL	fraction of the full geostrophic pressure increments that is added to the pressure field at the lowest model level	`0.9`
		humidity – temperature balancing	
`khumbal`	INT	radius (in [number of mesh widths]) of the area around a convectively precipitating grid point, in which specific humidity instead of relative humidity is preserved when temperature is nudged. Special cases: $=$ -1 : relative humidity preserved everywhere $\geq$ 99 : specific humidity preserved everywhere $\geq$ 100 : specific humidity preserved additionally for increments from hydrostatic temperature correction	`100`

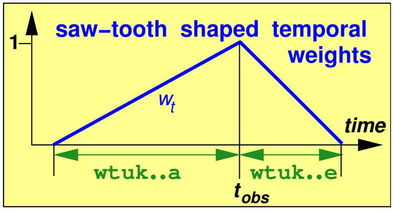
Several of the subsequent blocks of descriptions of `NAMELIST` parameters contain variables which are arrays of 4 elements. These always relate to the following physical quantities:

1: horizontal wind $(u\,,\,v)$
2: 'surface' pressure p_s ; this relates to station pressure observations and to pressure (observation and analysis) increments at the lowest model level
3: temperature T
4: humidity f

Nudging coefficients:

Name	Type	Definition / Purpose / Comments	Default
`gnudg(4)`	`REAL`	nudging coefficients in [1/s] for radiosonde data	$6 \cdot 10^{-4}$, $1.2 \cdot 10^{-3}$, $6 \cdot 10^{-4}$, $6 \cdot 10^{-4}$
`gnudgar(4)`	`REAL`	nudging coefficients in [1/s] for aircraft data	$6 \cdot 10^{-4}$, 0. , $6 \cdot 10^{-4}$, 0.
`gnudgar(4)`	`REAL`	nudging coefficients in [1/s] for MODE-S data	$6 \cdot 10^{-4}$, 0. , $6 \cdot 10^{-4}$, 0.
`gnudgsu(4)`	`REAL`	nudging coefficients in [1/s] for surface-level data	$6 \cdot 10^{-4}$, $1.2 \cdot 10^{-3}$, 0. , $6 \cdot 10^{-4}$
`gnudggp`	`REAL`	nudging coefficient in [1/s] for GPS-derived IWV	0.

Temporal weights:

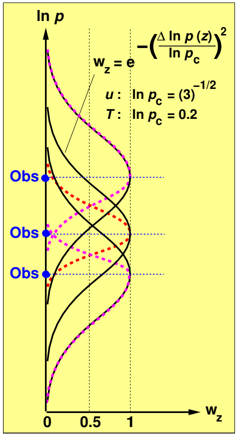
Name	Type	Definition / Purpose / Comments	Default
		linear temporal interpolation :	
`ltipol`	`LOG`	linear interpolation in time between pairs of collocated upper-air reports (one report in the past and one in the future) from the same station which are less than `tipolmx` hours apart from each other ==> at most 2 reports per station used at each timestep	`.TRUE.`
`ltipsu`	`LOG`	linear interpolation in time of pairs of surface-level reports less than `tipmxsu` hours apart from each other	`.TRUE.`
`tipolmx`	`REAL`	max. time span (in [hours]) between 2 upper-air reports to allow for temporal linear interpolation	`1.0`
`tipmxsu`	`REAL`	max. time span (in [hours]) between 2 surface-level reports to allow for temporal linear interpolation	`1.0`
		temporal weights for single reports: temporal radii of influence relative to observation time t_{obs}, if reports from the same station are assimilated independently from each other using saw-tooth shaped temporal weights: 	
`wtukrsa`	`REAL`	radius towards the past for radiosonde data	`3.0`
`wtukrse`	`REAL`	radius towards the future for radiosonde data	`1.0`
`wtukara`	`REAL`	radius towards the past for aircraft data	`1.5`
`wtukare`	`REAL`	radius towards the future for aircraft data	`0.5`
`wtuksua`	`REAL`	radius towards the past for surface-level data	`1.5`
`wtuksue`	`REAL`	radius towards the future for surface-level data	`0.5`

Spatial weights, basic mode of spreading:

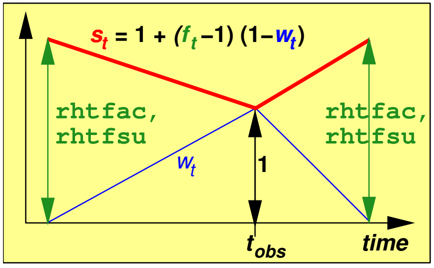
Name	Type	Definition / Purpose / Comments	Default
`msprpar`	`INT`	switch specifying the surfaces along which upper-air observation increments are (primarily) spread = 0: spreading along model levels ==> vertical weights depend approximately on differences in log-pressure (exactly on differences in scaled height) between the point P_{OI} , for which the observation increment is valid, and the target level at the horizontal location of the observation = 1: spreading along horizontal surfaces ==> vertical weights depend approximately on log-pressure differences between point P_{OI} and the target grid point = 2: spreading along isentropic surfaces ==> vertical weights depend on potential temperature differences between point P_{OI} and the target grid point	1
`msprpsu`	`INT`	switch specifying the surface along which surface-level observation increments are (primarily) spread = 0: spreading along model levels = 1: spreading along horizontal surfaces = 2: spreading along isentropic surfaces (for `msprpsu`, point P_{OI} is always a grid point at the lowest full model level)	0

A "target grid point" is any model grid point for which the analysis increments and hence the influence (or weight) of any observation is to be computed.

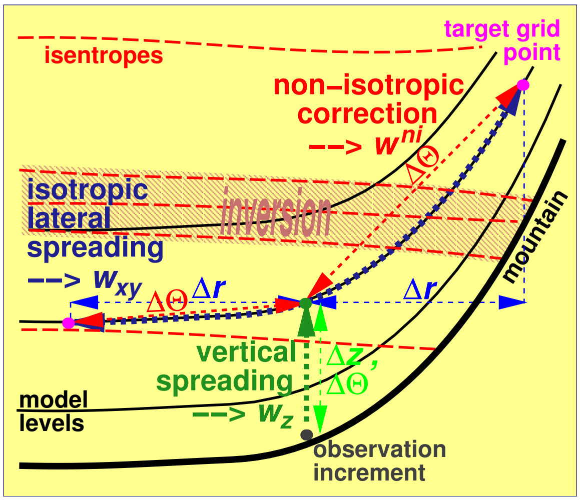
Vertical weights:

Name	Type	Definition / Purpose / Comments	Default
		vertical weights for upper-air observations :	
`vcorls(4)`	`REAL`	square of the vertical correlation scale i.e. square of Gaussian vertical “radius” of influence - in log-pressure differences , if (`msprpar` ≤ 1) - in potential temperature Θ diff. , if (`msprpar` $= 2$) (reasonable values in latter case: 275., 275., 33., 33.)	0.333 , 0.333 , 0.04 , 0.04
`vcutof(4)`	`REAL`	cut-off for Gaussian vertical correlation function w_z such that $w_z = e^{-\frac{\ln^2(p_{cut}/p_{obs})}{\texttt{vcorls}}} \doteq e^{-\texttt{vcutof}}$ (p_{cut} : resulting cut-off pressure) (if (`msprpar` $= 2$) , $\ln(p)$ is replaced by Θ)	0.75 , 0.75 , 1.0 , 1.0
`lsvcorl`	`LOG`	for aircraft observations only: decrease of the vertical correlation scales as given by `vcorls` such that the resulting correlation functions (dotted lines) are adjusted individually for each observation and take the value of 0.5 halfway between the present observation and nearest observation above resp. below if they are (nearly) colocated in the horizontal and are reported by the same aircraft 	`.TRUE.`
		vertical weights for surface-level observations :	
`vcorlsu(4)`	`REAL`	square of the vertical correlation scale i.e. square of Gaussian vertical “radius” of influence - in log-pressure differences , if (`msprpar` ≤ 1) (i.e. default e-folding decay height for T, f $\approx$ 300 m) - in potential temperature Θ diff. , if (`msprpar` $= 2$) (reasonable values: 11.1, 11.1, 1.33, 1.33)	0.013 , 0.013 , 0.002 , 0.002
`vcutosu(4)`	`REAL`	cut-off for Gaussian vertical correlation function w_z such that $w_z = e^{-\frac{\ln^2(p_{cut}/p_{obs})}{\texttt{vcorlsu}}} \doteq e^{-\texttt{vcutosu}}$ (p_{cut} : resulting cut-off pressure) (if (`msprpar` $= 2$) , $\ln(p)$ is replaced by Θ)	0.75 , 0.75 , 4.0 , 4.0
`vpblsu(4)`	`REAL`	Gaussian vertical “radius” of influence in potential temperature differences between the observation increment point P_{OI} and the target model level at the horizontal observation location (—> this defines an additional Gaussian weight that makes the total vertical weight depend on the near-surface stability even if (`msprpar` $= 1$))	99.0 , 99.0 , 99.0 , 99.0

Horizontal weights for upper-air observations:

<table>
<tr><th>Name</th><th>Type</th><th>Definition / Purpose / Comments</th><th>Default</th></tr>
<tr><td></td><td></td><td>isotropic horizontal correlation function w_{xy} :
($w_{xy} = (1 + \Delta r/s) \cdot e^{-\Delta r/s}$ for scalar model variables)</td><td></td></tr>
<tr><td><code>rhinfl(4)</code></td><td><code>REAL</code></td><td>constant part s_c of the correlation scale s
$s = (s_c + f_v \cdot s_v) \cdot s_t$
$= (s_c + f_v \cdot s_v) \cdot (1 + (f_t - 1) \cdot (1 - w_t))$</td><td>0.0 ,
70.0 ,
0.0 ,
0.0</td></tr>
<tr><td><code>rhvfac(4)</code></td><td><code>REAL</code></td><td>multiplication factor f_v to the vertically varying part s_v of the correlation scale s .
s_v is given in [km] as a function of pressure p ([hPa]) :
<table>
<tr><th>p</th><th>1000</th><th>850</th><th>700</th><th>500</th><th>400</th><th>300</th><th>250</th><th>200</th><th>150</th><th>50</th></tr>
<tr><td>$s_v^{(u,v)}$</td><td>70</td><td>80</td><td>90</td><td>100</td><td>100</td><td>110</td><td>115</td><td>120</td><td>125</td><td>125</td></tr>
<tr><td>s_v^T , s_v^f</td><td>70</td><td>80</td><td>90</td><td>100</td><td>100</td><td>100</td><td>100</td><td>110</td><td>120</td><td>120</td></tr>
</table></td><td>1.0 ,
0.0 ,
0.83 ,
0.83</td></tr>
<tr><td><code>rhtfac(4)</code></td><td><code>REAL</code></td><td>temporal factor f_t scaling the correlation scale s
at the beginning and the end of the nudging period for an individual observation relative to s valid at the observation time

 </td><td>1.3 ,
1.43 ,
1.3 ,
1.3</td></tr>
<tr><td><code>rhfgps</code></td><td><code>REAL</code></td><td>additional scaling factor f_{GPS} to the horizontal correlation scale s which is applied only for humidity profiles derived from GPS IWV ($s_{GPS} = f_{GPS} \cdot s$)</td><td>0.45</td></tr>
<tr><td><code>cutofr(4)</code></td><td><code>REAL</code></td><td>cut-off (in [multiples of correlation scales s])
of the horizontal correlation function w_{xy}</td><td>3.5 ,
3.5 ,
3.5 ,
3.5</td></tr>
<tr><td></td><td></td><td>non-isotropic correction w^{ni} to isotropic function w_{xy} :</td><td></td></tr>
<tr><td><code>vcsni(4)</code></td><td><code>REAL</code></td><td>square of Gaussian “radius” of influence
- in potential temperature Θ diff. , if (<code>msprpar</code> ≤ 1)
- in log-pressure differences , if (<code>msprpar</code> $= 2$)
between the target grid point and the point at the horizontal observation location on the surface along which observation increments are spread laterally (see figure for <code>vcsnisu</code> below)</td><td>2500. ,
2500. ,
2500. ,
2500.</td></tr>
</table>

Horizontal weights for surface-level observations:

Name	Type	Definition / Purpose / Comments	Default
		isotropic horizontal correlation function w_{xy}: ($w_{xy} = (1 + \Delta r/s) \cdot e^{-\Delta r/s}$ for scalar model variables)	
`rhiflsu(4)`	`REAL`	constant part s_c of the correlation scale s (in [km]) $s = s_c \cdot s_t = s_c \cdot (1 + (f_t - 1) \cdot (1 - w_t))$ (w_t : temporal weight)	70.0 , 70.0 , 100.0 , 70.0
`rhtfsu(4)`	`REAL`	temporal factor f_t scaling the correlation scale s at the beginning and the end of the nudging period for an individual observation relative to s valid at the observation time (see figure for `rhtfac` above)	1.0 , 1.43 , 1.0 , 1.0
`cutofsu(4)`	`REAL`	cut-off (in [multiples of correlation scales s]) of the horizontal correlation function w_{xy}	2.0 , 3.5 , 2.0 , 2.0
		non-isotropic correction w^{ni} to isotropic function w_{xy}:	
`vcsnisu(4)`	`REAL`	square of Gaussian 'radius' of influence - in potential temperature differences i.e. $w^{ni} = e^{-\frac{(\Delta\Theta)^2}{\texttt{vcsnisu}}}$ if ($\texttt{msprpsu} \leq 1$) - in log-pressure differences , if ($\texttt{msprpsu} = 2$) between the target grid point and the point at the horizontal observation location on the surface along which observation increments are spread laterally  spreading of surface-level observation increments along model levels ($\texttt{msprpsu} = 0$)	2500. , 2500. , 9. , 9.
`rhfpsdd`	`REAL`	for scaling horizontal correlation scale for surface pressure data	1.0

Geometry for lateral spreading of horizontal wind:

<table>
<tr><th>Name</th><th>Type</th><th>Definition / Purpose / Comments</th><th>Default</th></tr>
<tr><td></td><td></td><td>2-dimensional wind correlation functions:
correlation functions for longitudinal and transverse wind components $w_{xy}^{LL} = e^{-\Delta r/s}$,
$w_{xy}^{LT} = w_{xy}^{TL} = 0$, $w_{xy}^{TT} = e^{-\Delta r/s} - \gamma_n \cdot (\Delta r/s) \cdot e^{-\Delta r/s}$</td><td></td></tr>
<tr><td><code>cnondiv</code></td><td><code>REAL</code></td><td>constant part γ_c of the non-divergence correction factor γ_n
$\gamma_n = (\gamma_c + f_v \cdot \gamma_v) \cdot \gamma_t$
$= (\gamma_c + f_v \cdot \gamma_v) \cdot (1 + (f_t - 1) \cdot (1 - w_t))$</td><td><code>0.1</code></td></tr>
<tr><td><code>fnondiv</code></td><td><code>REAL</code></td><td>multiplication factor f_v to the vertically varying part γ_v of the non-divergence correction factor γ_n ;
γ_v is given as a function of pressure p ([hPa]) :
<table>
<tr><td>p</td><td>1000</td><td>850</td><td>700</td><td>500</td><td>400</td><td>300</td><td>250</td><td>200</td><td>150</td><td>50</td></tr>
<tr><td>γ_v</td><td>0.4</td><td>0.5</td><td>0.5</td><td>0.5</td><td>0.5</td><td>0.6</td><td>0.65</td><td>0.7</td><td>0.75</td><td>0.75</td></tr>
</table></td><td><code>0.8</code></td></tr>
<tr><td><code>tnondiv</code></td><td><code>REAL</code></td><td>temporal factor f_t scaling the correction factor γ_n at the beginning and the end of the nudging period for an individual observation relative to γ_n valid at the observation time (analogous to <code>rhtfac</code> above)</td><td><code>1.1</code></td></tr>
</table>

Observation increments from multi-level reports:

Name	Type	Definition / Purpose / Comments	Default
		computation of observation increments at model levels:	
`lscadj(4)`	`LOG`	vertical scale adjustment (by vertical averaging the observed profile over each model layer) instead of vertical interpolation as a method to convey the observational information to the model levels	`.TRUE.` , `.TRUE.` , `.TRUE.` , `.FALSE.`
		use of observation increments:	
`topobs(4)`	`REAL`	at pressure $p <$ `topobs` (in [hPa]) , only observation increments at model levels are used, i.e. increments at observation levels are not used (`topobs` is fixed at 1099., if `msprpar` $= 0$)	`849.` , `1099.` , `799.` , `699.`
`botmod(4)`	`REAL`	at pressure $p >$ `botmod` (in [hPa]) , only observation increments at observation levels are used, i.e. increments at model levels are not computed (`botmod` is fixed at 1099., if `msprpar` $= 0$) (`botmod` $\geq$ `topobs` must be satisfied)	`1099.` , `1099.` , `1099.` , `899.`

Observation increments from surface-level reports:

Name	Type	Definition / Purpose / Comments	Default
`loiqv2m`	`LOG`	`TRUE`: 2-m humidity observation increments as differences of specific humidity instead of relative humidity	`.FALSE.`
`lqfqv2m`	`LOG`	`TRUE`: quality weight factor for 2-m humidity observations dependent on 2-m temperature observation increments	`.FALSE.`

Threshold quality control:

<table>
<tr><th>Name</th><th>Type</th><th>Definition / Purpose / Comments</th><th>Default</th></tr>
<tr><td>dtqc</td><td>REAL</td><td>timestep (in [s]) for the threshold quality control (QC)
(in addition, QC is applied to an observation when it is used for the first time)</td><td>720.0</td></tr>
<tr><td></td><td></td><td>QC thresholds ψ^{thr} for upper-air data</td><td></td></tr>
<tr><td>qcc(4)</td><td>REAL</td><td>constant part ψ_c^{thr} of the thresholds ψ^{thr} at observation time
$\psi^{thr} = (\psi_c^{thr} + f_v \cdot \psi_v^{thr})$
units for ψ_c^{thr}: wind v: [m/s], “surface” pressure: [hPa], temperature T: [K], relative humidity: [ ]</td><td>0.0,
500.0,
0.0,
0.7</td></tr>
<tr><td>qcvf(4)</td><td>REAL</td><td>multiplication factor f_v to the vertically varying part ψ_v^{thr} of the QC thresholds ψ^{thr};
the 2^{nd} element relates to height / thickness checks for multi-level temperature rather than to “surf.” pressure;
ψ_v^{thr} is given as a function of pressure p ([hPa]) for radiosonde ($v_{v_{RS}}^{thr}$, $T_{v_{RS}}^{thr}$) and aircraft ($v_{v_{air}}^{thr}$, $T_{v_{air}}^{thr}$) wind and temperature:
<table>
<tr><th>p</th><th>1000</th><th>850</th><th>700</th><th>500</th><th>400</th><th>300</th><th>250</th><th>200</th><th>150</th><th>100</th><th>50</th></tr>
<tr><td>$v_{v_{RS}}^{thr}$</td><td>2.3</td><td>2.3</td><td>2.5</td><td>3.0</td><td>3.5</td><td>3.7</td><td>3.5</td><td>3.5</td><td>3.4</td><td>3.3</td><td>3.2</td></tr>
<tr><td>$v_{v_{air}}^{thr}$</td><td>2.5</td><td>2.5</td><td>3.0</td><td>3.5</td><td>4.0</td><td>4.0</td><td>4.0</td><td>4.0</td><td>4.0</td><td>4.0</td><td></td></tr>
<tr><td>$T_{v_{RS}}^{thr}$</td><td>1.2</td><td>1.0</td><td>.7</td><td>.4</td><td>.4</td><td>.5</td><td>.5</td><td>.6</td><td>.7</td><td>.8</td><td>.9</td></tr>
<tr><td>$T_{v_{air}}^{thr}$</td><td>1.2</td><td>1.0</td><td>.7</td><td>.5</td><td>.5</td><td>.6</td><td>.6</td><td>.7</td><td>.8</td><td>.9</td><td></td></tr>
</table>
ψ_v^{thr} for humidity (4^{th} element) is given as a function of observation error, background error and stability.
(for height / thickness thresholds, see Scientific Documentation Part III)</td><td>5.0,
1.0,
10.0,
0.0</td></tr>
<tr><td>qccsu(4)</td><td>REAL</td><td>QC thresholds ψ^{thr} at observation time for surface-level data
(units for as for qcc)</td><td>12.0,
500.0,
12.0,
0.7</td></tr>
<tr><td></td><td></td><td>QC thresholds ψ^{thr} for GPS IWV data</td><td></td></tr>
<tr><td>qcciq</td><td>REAL</td><td>constant part of the thresholds at observation time (in [mm])</td><td>1.0</td></tr>
<tr><td>qcsiq</td><td>REAL</td><td>fraction of the IWV of the saturated model temperature profile, which is added to the QC threshold</td><td>0.15</td></tr>
</table>

Quality weights for observations:

Name	Type	Definition / Purpose / Comments	Default

`doromx (4)`	`REAL`	cut-off and Gaussian "radius" in [m] for reduction factor ϵ_z which is part of quality weight ϵ for surface-level observations:
		$\lvert f_D \Delta z \rvert \leq$ `doromx` : $\epsilon_z = e^{-\left(\frac{f_D \cdot \Delta z}{\texttt{doromx}}\right)^2}$ (for p_s only)
		$\lvert f_D \Delta z \rvert \leq$ `doromx` : $\epsilon_z = 1$ (for the other variables)
		$\lvert f_D \Delta z \rvert >$ `doromx` : $\epsilon_z = 0$ (applied to all variables)
		where $\Delta z = z_{obs} - z_{mod}$: difference (in [m]) between station height z_{obs} and model orography z_{mod} (for p_s : z_{mod} = height of lowest model level)
		and $f_D = 4$ for p_s if $\Delta z < 0$ (i.e. if extrapolating)
		$f_D = 1$ otherwise
		—> surface-level data are neglected if $\lvert f_D \Delta z \rvert >$ `doromx` !
			`100.0 ,`
			`150.0 ,`
			`150.0 ,`
			`150.0`

`qcfpst`	`REAL`	maximum enhancement factor of the (quality) weight for surface pressure observations due to observed 3-hourly surface pressure tendency $\partial_t \, p_s$ (`qcfpst` is applied if $\lvert \partial_t \, p_s \rvert \geq 25\,\text{hPa}$; the enhancement decreases linearly with decreasing $\lvert \partial_t \, p_s \rvert$ to 1 for $\lvert \partial_t \, p_s \rvert \leq 3\,\text{hPa}$)	`1.5`

Use of observations and reports:

Name	Type	Definition / Purpose / Comments	Default

`altopsu (4)`	`REAL`	surface-level observations above height `altopsu` (in [m]) are neglected;
		if `altopsu` = 0. , all surface-level observations assigned to land grid points are neglected
			`100. ,`
			`5000. ,`
			`5000. ,`
			`5000.`

`thairh`	`REAL`	for contructing multi-level reports ('piecewise profiles') from single-level aircraft reports : maximum horizontal distance in [km] between the resulting multi-level report and the original location of any single-level report included in this multi-level report	`20.`
`lgpsbias`	`LOG`	This switch has been eliminated in Version 5.4. seasonal daytime-dependent bias correction applied to GPS-derived IWV (integrated water vapour) data	`.FALSE.`
`mqcorr92`	`INT`	switch for bias correction for Vaisala RS92 radiosonde humidity = 0 : no correction for humidity = 1 : correction of solar radiation bias only = 2 : correction of total bias (incl. nighttime bias)	`0`
`nolbc`	`INT`	number of grid rows at the lateral boundaries of the COSMO-Model domain where all reports are neglected	`5`
		observation area : all reports outside of it are neglected	
`obnlat`	`REAL`	latitude of northern boundary of observation area ([deg.])	`90.`
`obslat`	`REAL`	latitude of southern boundary of observation area ([deg.])	`-90.`

Name	Type	Definition / Purpose / Comments	Default
`obwlon`	`REAL`	longitude of western boundary of observation area ([deg.])	-180.
`obelon`	`REAL`	longitude of eastern boundary of observation area ([deg.])	180.

Use of observation types and code types:

Name	Type	Definition / Purpose / Comments	Default
		exclusion area: reports inside of it are neglected if their observation or code type is set to `.FALSE.`	
`exnlat`	`REAL`	latitude of northern boundary of exclusion area ([deg.])	90.
`exslat`	`REAL`	latitude of southern boundary of exclusion area ([deg.])	-90.
`exwlon`	`REAL`	longitude of western boundary of exclusion area ([deg.])	-180.
`exelon`	`REAL`	longitude of eastern boundary of exclusion area ([deg.])	180.
		observation type: reports inside the exclusion area are set passive if their type is set to `.FALSE.`	
`lsynop`	`LOG`	observation type SYNOP	`.TRUE.`
`laircf`	`LOG`	observation type AIREP (aircraft)	`.TRUE.`
`lsatob`	`LOG`	observation type SATOB	`.FALSE.`
`ldribu`	`LOG`	observation type DRIBU (drifting buoy)	`.TRUE.`
`ltemp`	`LOG`	observation type TEMP	`.TRUE.`
`lpilot`	`LOG`	observation type PILOT	`.TRUE.`
`lsatem`	`LOG`	observation type SATEM	`.FALSE.`
`lgps`	`LOG`	observation type GPS	`.FALSE.`
`lscatt`	`LOG`	observation type SCATT (scatterometer)	`.TRUE.`
		code type: reports inside the exclusion area are set passive if their code type is set to `.FALSE.`	
`lcd011`	`LOG`	SYNOP code 11 (manual land)	`.TRUE.`
`lcd014`	`LOG`	SYNOP code 14 (autom. land)	`.TRUE.`
`lcd021`	`LOG`	SYNOP code 21 (manual ship)	`.TRUE.`
`lcd022`	`LOG`	SYNOP code 22 (abbrev. ship)	`.TRUE.`
`lcd023`	`LOG`	SYNOP code 23 (reduced ship)	`.TRUE.`
`lcd024`	`LOG`	SYNOP code 24 (autom. ship)	`.TRUE.`
`lcd140`	`LOG`	SYNOP code 140 (METAR)	`.TRUE.`

Use of observation types and code types (continued):

Name	Type	Definition / Purpose / Comments	Default
		code type (continued): reports inside the exclusion area are set passive if their code type is set to `.FALSE.`	
`lcd041`	`LOG`	AIREP code 41 (CODAR)	`.TRUE.`
`lcd141`	`LOG`	AIREP code 141 (AIREP)	`.TRUE.`
`lcd241`	`LOG`	AIREP code 241 (constant level balloon)	`.TRUE.`
`lcd144`	`LOG`	AIREP code 144 (AMDAR)	`.TRUE.`
`lcd146`	`LOG`	AIREP code 146 (MODE-S)	`.TRUE.`
`lcd244`	`LOG`	AIREP code 244 (ACAR)	`.TRUE.`
`lcd088`	`LOG`	SATOB code 88 (SATOB)	`.TRUE.`
`lcd188`	`LOG`	SATOB code 188 (SST)	`.TRUE.`
`lcd063`	`LOG`	DRIBU code 63 (bathy sphere)	`.TRUE.`
`lcd064`	`LOG`	DRIBU code 64 (TESAC)	`.TRUE.`
`lcd165`	`LOG`	DRIBU code 165 (drifting buoy)	`.TRUE.`
`lcd035`	`LOG`	TEMP code 35 (land radiosonde)	`.TRUE.`
`lcd036`	`LOG`	TEMP code 36 (ship radiosonde)	`.TRUE.`
`lcd037`	`LOG`	TEMP code 37 (mobile radiosonde)	`.TRUE.`
`lcd135`	`LOG`	TEMP code 135 (drop sonde)	`.TRUE.`
`lcd039`	`LOG`	TEMP code 39 (land rocket)	`.TRUE.`
`lcd040`	`LOG`	TEMP code 40 (ship rocket)	`.TRUE.`
`lcd032`	`LOG`	PILOT code 32 (land PILOT)	`.TRUE.`
`lcd033`	`LOG`	PILOT code 33 (ship PILOT)	`.TRUE.`
`lcd038`	`LOG`	PILOT code 38 (mobile PILOT)	`.TRUE.`
`lcd132`	`LOG`	PILOT code 132 (European wind profiler)	`.TRUE.`
`lcd133`	`LOG`	PILOT code 133 (European SODAR / RASS)	`.TRUE.`
`lcd136`	`LOG`	PILOT code 136 (US wind profiler / RASS)	`.FALSE.`
`lcd137`	`LOG`	PILOT code 137 (radar VAD)	`.FALSE.`
`lcd122`	`LOG`	SCATT code 122 (OSCAT)	`.TRUE.`
`lcd123`	`LOG`	SCATT code 123 (ASCAT)	`.TRUE.`
`lcd096`	`LOG`	GPS code 96 (ground-based GPS) ; this code type is used only for GPS data read from a special ASCII file in COST-716 format	`.TRUE.`
`igpscen (20)`	`INT`	array of processing centres of GPS reports used actively: - the order of centres determines the preference in the redundancy check; '-1' means no active centre - the numbers N_p indicating the processing centres are given in the WMO Common Code Table C-12 for BUFR/CREX data (WMO descriptor '0 01 034') - the code types for GPS data (if read from NetCDF files) are set to '$X + N_p$' where X=800 or X=900 ; these code type have to be used e.g. for setting '`iwtyp`'	`-1,-1,` ...

The previous blocks of `NAMELIST` variables (except for the verification block) determine the meteorologically relevant contents of the nudging scheme, i.e. they determine the direct (explicit) influence of the various observations on the model fields. Once the values for these variables have been set in a (quasi-)operational environment, they usually do not need to be adjusted according to the (day-to-day) variation of the observational supply except when the observation system changes so dramatically that it modifies the fundamental behaviour of the system.

This is in some contrast to the following block of `NAMELIST` variables, and in particular to the first 4 variables. They determine the size of the run-time arrays which contain the observations and observation increments. They should be large enough to accommodate all these data, but at the same time, they must not be too large because these arrays contribute to the processor memory required. Thus, if the number of available observations (e.g. aircraft data) increases significantly, it may occur that the arrays are filled up completely, and some of the good data have to be neglected. In such a case, the program does not stop or crash, but it will issue messages with the label `CAUTION` both to standard output and additional ASCII output files. This is decribed in sections 8.2.6 and above all 8.2.5. The messages also provide information on which of the `NAMELIST` variables need to be increased in order to allow the use of all the good data.

Observation dependent array sizes:

Name	Type	Definition / Purpose / Comments	Default
		size of internal arrays to store observations or increments	
		maximum number of reports (or stations) which are actively used at the same timestep in the total model domain	
`maxmlo`	`INT`	maximum number of multi-level reports	300
`maxsgo`	`INT`	maximum number of surface-level reports	3000
`maxuso`	`INT`	maximum number of upper-air single-level reports	900
`maxgpo`	`INT`	maximum number of ground-based GPS reports	3000
		Note: - `maxmlo` + `maxsgo` = maximum number of surface pressure reports - `maxmlo`, `maxsgo`, and `maxgpo` also scale the size of the arrays which contain all the multi-level, single-level (upper-air and surface level) resp. GPS reports on the local sub-domain (on distributed-memory computers) which have to be stored at a certain timestep to be used then or later on	
`maxmlv`	`INT`	maximum number of observation levels in multi-level reports	100
`mxfrep`	`INT`	maximum number of reports in NetCDF feedobs file	−1
`mxfobs`	`INT`	maximum number of observations in NetCDF feedobs file	−1
		Note: if `mxfrep`, `mxfobs` ≤ 0 then reasonable values are computed dynamically from `maxmlo`, `hverend` etc.	

Directory and file names related to nudging:

Name	Type	Definition / Purpose / Comments	Default
`itype_obfile`	`INT`	This switch has been eliminated in Version 5.4. Only NetCDF files are possible now, AOF files are no more supported.	—
`yaofpath`	`CHAR`	This switch has been eliminated in Version 5.4.	—
`ycdfdir`	`CHAR *70`	directory, where NetCDF observation input files and the blacklist file reside	`'./'`
`yfofdir`	`CHAR *250`	directory for output NetCDF `fof` file	`'./'`

Diagnostic output:

Name	Type	Definition / Purpose / Comments	Default
`lprodr`	`LOG`	diagnostic print about observation data record ODR on file `YUOBSDR` (see section 8.2.2)	`.TRUE.`
`ionl` `jonl`	`INT` `INT`	} grid point coordinates for control output on file `YUPRINT` (see section 8.2.8)	167 103
`ionl2` `jonl2`	`INT` `INT`	} grid point coordinates for further control output on file `YUPRINT` (see section 8.2.8)	167 103
		All these switches have been eliminated in Version 5.4.	
`lpraof`	`LOG`	diagnostic print of analysis observation file AOF on file `YUAOFEX` (see section 8.2.1)	`.FALSE.`
`dinlat`	`REAL`	latitude of northern boundary of diagnostic print area ([deg.])	0.
`dislat`	`REAL`	latitude of southern boundary of diagnostic print area ([deg.])	0.
`diwlon`	`REAL`	longitude of western boundary of diagnostic print area ([deg.])	0.
`dielon`	`REAL`	longitude of eastern boundary of diagnostic print area ([deg.])	0.
`noctrq`	`INT`	observation or code type of reports to be printed; if (`noctrq` = 9) then print all report (types)	9

The following variables and are relevant only if '`lsurfa = .TRUE.`'.

2-dimensional analyses derived from observations:

Name	Type	Definition / Purpose / Comments	Default
		2-m temperature analyses	
`lt2m`	LOG	2-m temperature field is analysed (if true)	.FALSE.
`ht2a`	REAL	time (in [hours]) of first 2-m temperature analysis relative to initial time of model run	999.
`ht2i`	REAL	time increment (in [hours]) between successive 2-m temperature analyses	999.
		2-m relative humidity analyses	
`lrh2m`	LOG	2-m relative humidity field is analysed	.FALSE.
`hh2a`	REAL	time (in [hours]) of first 2-m relative humidity analysis relative to initial time of model run	999.
`hh2i`	REAL	time increment (in [hours]) between successive 2-m relative humidity analyses	999.
		10-m wind analyses	
`lff10m`	LOG	10-m wind speed is analysed	.FALSE.
`hffa`	REAL	time (in [hours]) of first 10-m wind analysis relative to initial time of model run	999.
`hffi`	REAL	time increment (in [hours]) between successive 10-m wind analyses	999.
		precipitation analyses	
`lprecp`	LOG	precipitation is analysed	.FALSE.
`hprc`	REAL	time (in [hours]) of analysis of precipitation sum relative to initial time of model run	999.
`raintp`	REAL	time period (in [hours]) over which precipitation is summed up	12.
`ldiasa`	LOG	diagnostics on 2-dimensional surface analyses on file `YUSURF` (see section 8.2.10)	.FALSE.

The remaining variables in this section are related to the latent heat nudging and are relevant only if '`llhn = .TRUE.`'.

Some basic variables on the LHN and its diagnosis:

Name	Type	Definition / Purpose / Comments	Default
		Basic on−off switches	
`llhnverif`	`LOG`	switch for verification (skill scores against radar obs, written to file `YULHN`)	`.FALSE.`
`lhn_diag`	`LOG`	switch for enhanced detailed diagnostic output (written to file `YULHN`)	`.TRUE.`
		LHN period (relative to the initial time of the model run)	
`nlhn_start`	`INT`	start of latent heat nudging (LHN) period in [timesteps]	`0`
`nlhn_end`	`INT`	end of latent heat nudging (LHN) period in [timesteps]	`0`
or:			
`hlhn_start`	`REAL`	start of latent heat nudging (LHN) period in [hours]	`0.0`
`hlhn_end`	`REAL`	end of latent heat nudging (LHN) period in [hours]	`0.0`
		verification period	
`nlhnverif_start`	`INT`	start of period of verification of LHN in [timesteps]	`0`
`nlhnverif_end`	`INT`	end of period of verification of LHN in [timesteps]	`0`
or:			
`hlhnverif_start`	`REAL`	start of period of verification of LHN in [hours]	`0.0`
`hlhnverif_end`	`REAL`	end of period of verification of LHN in [hours]	`0.0`
		(relative to the initial time of the model run)	

Variables controlling the LHN algorithm itself:

Name	Type	Definition / Purpose / Comments	Default
		'reference precipitation'	
`lhn_qrs`	LOG	use of the vertically averaged precipitation flux as 'reference precipitation' (i.e. this is used as the model quantity (instead of model surface precip) to compare with the observed precip rate)	.TRUE.
`rqrsgmax`	REAL	threshold in terms of fraction of the maximum of the precipitation flux in a model column which defines the uppermost model level used to compute the vertically averaged precip flux (which is then deployed as 'reference precipitation')	0.0
		'grid point search'	
`lhn_search`	LOG	search for an appropriate nearby model heating profile ('grid point search', applied to those grid points where the observed and modelled rain rates differ strongly)	.TRUE.
`fac_lhn_search`	REAL	threshold of the ratio of observed and simulated rain rate above which the 'grid point search' is performed	5.0
`rlhn_search`	INT	max. radius (in [number of grid pts.]) for 'grid point search'	10
		scaling factors of the latent heating profile	
`fac_lhn_up`	REAL	upper limit α_{max} } of the factor α which scales	2.0
`fac_lhn_down`	REAL	lower limit α_{min} } the model latent heating profile (the difference betw. the scaled and the original latent heating profile is the LHN temperature increment)	0.5
`lhn_logscale`	LOG	use of logarithmic scaling factors : $\alpha \rightarrow (1 + \log(\alpha))$ (so as to unbias the absolute size of positive and negative LHN increments ; this also scales α_{max} and α_{min})	.TRUE.
		limits, restrictions, reduced weighting of LHN increments	
`lhn_limit`	LOG	absolute limits for LHN temperature increments	.TRUE.
`abs_lhn_lim`	REAL	upper limit (in [K/s]) for the absolute value of the LHN temperature increments (applied if `lhn_limit`)	50./3600.
`lhn_incloud`	LOG	restriction of LHN increments to cloudy layers only	.TRUE.
`kbot_lhn`	INT	index of lowest } model level at which	ke_tot
`ktop_lhn`	INT	index of uppermost } LHN increments are applied	1
`ktop_temp`	REAL	temperature of uppermost model level at which LHN increments are applied (as alternative to `ktop_lhn`)	-999.9
`lhn_wweight`	LOG	additional weighting of LHN increments; weight decreases with increasing mean horizontal wind speed (if $> 20\,\mathrm{m/s}$)	.FALSE.
`lhn_coef`	REAL	overall scaling factor (≤ 1) for the LHN temperature increments (i.e. a kind of nudging coefficient)	1.0
`lhn_hum_adj`	LOG	application of humidity adjustment (along with the temperature increments)	.TRUE.

Observation and file input for LHN:

Name	Type	Definition / Purpose / Comments	Default
		spatial filtering	
`lhn_filt`	LOG	vertical filtering of LHN temperature increments	.TRUE.
`lhn_relax`	LOG	horizontal filtering, both of the – (observed and simulated) precipitation fields (input) – LHN temperature increments (output)	.TRUE.
`nlhn_relax`	INT	number of iterations of (2-grid-point scale) horiz. filtering	2
		thresholds and weighting of observation input	
`thres_lhn`	REAL	threshold (in [mm/s]) below which the rain rate is considered to be zero in many aspects within the LHN scheme	0.1/3600.
`rad_wobs_lhn`	REAL	maximum range from radar site with full observation weight (in [km])	100.
`lhn_spqual`	LOG	use of a spatial quality function of the input rain rates	.FALSE.
		observation and auxilliary file input	
`nradar`	INT	maximum number of radar stations in obs input data	33
`lhn_dt_obs`	REAL	time step of the observation input data (in [minutes])	5.0
`noobs_date (36)`	CHAR *12	dates without radar data (as [YYYYMMDDHHTT], where YYYY = year, MM = month, DD = day, HH = hour, TT = minute)	' '
`lhn_black`	LOG	use of a blacklist for radar data (this requires an additional Grib file, see `blacklist`)	.TRUE.
`lhn_bright`	LOG	bright band detection (and rejection of flagged data) (this requires radar beam height maps)	.TRUE.
`lhn_height`	LOG	use of radar beam height maps (this requires an additional Grib file, see `height_file`)	.TRUE.

Name	Type	Definition / Purpose / Comments	Default
		directory and file names	
`radar_in`	CHAR *100	directory in which the radar data files reside (incl. blacklist & beam height map files)	'.'
`blacklist_file`	CHAR *100	file name of blacklist for radar data	'blacklist_dx.grib1'
`height_file`	CHAR *100	file name of radar beam height maps	'height_dx.grib1'

7.10 `EPSCTL` — Controlling the Ensemble Prediction Mode

The namelist group `/EPSCTL/` contains control parameters for the ensemble prediction mode (EPS), e.g. to define the number of members, variations in input- and boundary data and variations in other namelist parameters to generate ensemble perturbations. The specifications for the parameters in `/EPSCTL/` are included in the file `INPUT_EPS`.

Since Version 5.1 there are two more sets of variables in this namelist group, related to the stochastic perturbation of physics tendencies (SPPT) and the generation of random fields for SPPT.

The namelist parameters of this group are described in the subsections

- basic control parameters and
- parameters for changing input fields
- stochastic perturbation of physics tendencies (SPPT)
- generation of random fields for SPPT

Basic control parameters:

Name	Type	Definition / Purpose / Comments	Default
`iepsmem`	`INT`	ID of the member in the ensemble (ID ≥ 0) As a local solution for Grib 1, `iepsmem` is coded in product definition section 52 (`ipds(52)`).	`-1`
`iepstot`	`INT`	Total number of ensemble members (≥ 0) As a local solution for Grib 1, `iepstot` is coded in product definition section 51 (`ipds(51)`).	`-1`
`iepstyp`	`INT`	ID of the ensemble generation type (ID ≥ 0) As a local solution for Grib 1, `iepstyp` is coded in product definition section 50 (`ipds(50)`).	`-1`

Parameters for changing input fields:

Name	Type	Definition / Purpose / Comments	Default
`fac_plcov`	`REAL`	Modification factor for `PLCOV`	`1.0`
`rmin_plcov`	`REAL`	Lower limit for values of `PLCOV`	`0.0`
`rmax_plcov`	`REAL`	Upper limit for values of `PLCOV`	`1.0`
`fac_lai`	`REAL`	Modification factor for `LAI`	`1.0`
`rmin_lai`	`REAL`	Lower limit for values of `LAI`	`0.0`
`rmax_lai`	`REAL`	Upper limit for values of `LAI`	`8.0`
`fac_rootdp`	`REAL`	Modification factor for `ROOTDP`	`1.0`
`rmin_rootdp`	`REAL`	Lower limit for values of `ROOTDP`	`0.0`
`rmax_rootdp`	`REAL`	Upper limit for values of `ROOTDP`	`2.0`

Parameters for the stochastic perturbation of physics tendencies

The following variables are only in effect, if the namelist variable `lsppt` in group `/RUNCTL/` is set to `.TRUE.`.

Name	Type	Definition / Purpose / Comments	Default
`itype_qxpert_rn`	`INT`	Defines, which hydrometeor tendencies are perturbed: 0: `qv` only. 1: `qv, qc, qi`. 2: `qv, qc, qi, qr, qs, qg`.	0
`itype_qxlim_rn`	`INT`	Type of reduction/removal of the perturbation in case of negative (for `qv, qx`) or supersaturated (`qv`) values 0: No limitation of perturbed tendencies. 1: If new `qv` values are negative or super-saturated then tt T- and tt qv-tendencies are not perturbed; if new `qc, qi, qr, qs, qg`-values are negative then the corresponding tendencies are not perturbed.	0

Generation of random fields for SPPT

The following variables are only in effect, if the namelist variable `lsppt` in group `/RUNCTL/` is set to `.TRUE.`.

Name	Type	Definition / Purpose / Comments	Default
`lhorint_rn`	`LOG`	`.TRUE.` The random numbers (as defined on a random number horizontal coarse grid) are horizontally bi-linearly interpolated to the COSMO-Model grid. `.FALSE.` The model grid points contained in the same random number coarse grid box have the same random number value.	`.TRUE.`
`ltimeint_rn`	`LOG`	`.TRUE.` The 3-D fields of random numbers (available at *random number time steps*) are interpolated linearly in time. `.FALSE.` The random numbers remain constant in time until the next random number time step.	`.TRUE.`
`lgauss_rn`	`LOG`	`.TRUE.` Use a gaussian distribution of random numbers. `.FALSE.` Use a uniform distribution of random numbers.	`.TRUE.`
`itype_vtaper_rn`	`INT`	Type of tapering near surface and in stratosphere: 0: No vertical tapering. 1: Prescribed tapering near surface and in stratosphere. 2: Prescribed tapering only in stratosphere. 3: Tapering according to namelist variable `vtaper_rn`.	1
`imode_rn`	`INT`	0: Use only one stream of random numbers (for each pattern) for all random number time steps; the same offset of the coarse grid relative to the lower left corner of the COSMO grid is then used for all random number time steps (for a given pattern). 1: Use a new stream of random numbers for every random number time step; this renders the 3-D random number fields valid for a given time reproducible even if produced by successive model runs, and enables temporal correlations in DA cycles across analysis steps; the offset of the coarse grid relative to the lower left corner of the COSMO grid is then different for each random number time step.	1

Name	Type	Definition / Purpose / Comments	Default
npattern_rn	INT	Number of random number patterns with different (4-D) correlation scales used for SPPT (must be ≤ 5).	1

For the following namelist parameters, **npattern_rn** values have to be specified:

Name	Type	Definition / Purpose / Comments	Default
hinc_rn	REAL	Random number time step (in [hrs]), i.e. hour increment for drawing a new 3-D field of random numbers; if **imode_rn** > 0, 24 hours must be divisible by **hinc_rn**; and if both **hinc_rn** and **ninc_rn** are given valid values (> 0) then the value of **hinc_rn** is used.	6.0
ninc_rn	INT	Random number time step (in [model timestep] units), i.e. timestep increment for drawing a new 3-D field of random numbers.	-1
nseed_rn	INT	External part of seed for random number generation.	0
nseed_rn2	INT	Only for **imode_rn**=1: External part of seed to generate 3-D random number fields valid for times later than the initial time of the model run.	0
dlat_rn	REAL	Random number coarse grid point distance in meridional direction (in [degrees]).	2.5
dlon_rn	REAL	Random number coarse grid point distance in zonal direction (in [degrees]).	2.5
stdv_rn	REAL	Standard deviation of the Gaussian distribution of random numbers.	0.5
range_rn	REAL	Upper limit imposed to absolute value of random numbers (the condition is: SUM(**range_rn2**) < 1 (sum over **npattern_rn**), otherwise the perturbations may change the sign of physics tendencies, which may easily lead to instabilities).	**stdv_rn_d** $\cdot 2$

For the following namelist parameter, **ke** values have to be specified (number of vertical model layers):

Name	Type	Definition / Purpose / Comments	Default
rvtaper_rn	REAL	Only for **itype_vaper_rn** $= 3$: Externally specified function (by values ≤ 1 for each model layer from top down) for vertical tapering of the random number.	-

7.11 IOCTL — Controlling the Grib I/O

The namelist group /IOCTL/ contains some general parameters to control the Grib or NetCDF IO of a model run. It is the *top level* configuration namelist group for I/O. The specifications for the parameters in /IOCTL/ are included in the file INPUT_IO.

The namelist parameters of this group are described in the subsections

- basic control parameters,
- writing (and reading) Restart-Files,
- additional specifications for NetCDF-IO,
- reading and writing "Ready-Files",
- controlling the Soil Moisture Analysis,

Basic control parameters:

There are two options for prescribing initial and boundary conditions. If `lartif_data` (former name was `lgen`; the new switch now is in namelist group /RUNCTL/) is set to .TRUE., a run with user-defined artifical initial and boundary data is performed. Another namelist group /ARTIFCTL/ has to be specified in that case. But the default is a real-case model run with initial and boundary data coming from a coarse-grid driving model (initial data can also be generated by a continuous data assimilation using the nudging technique).

Name	Type	Definition / Purpose / Comments	Default
lgen	LOG	Eliminated in 4.8. Has been renamed to `lartif_data` and moved to group /RUNCTL/.	
lasync_io	LOG	If .TRUE., the model runs with extra processors for asynchronous IO.	.FALSE.
lprefetch_io	LOG	Enables reading of boundary files ahead of time, i.e. when the forthcoming I/O operation will be reading a GRIB file, then this can be done simultaneously with the preceding compute steps. Prefetching can only be enabled with true asynchronous I/O (`lasync_io=.TRUE.`).	.FALSE.
itype_gather	INT	To choose the type of gathering output fields: 1: (default) gather the fields by an extra communication per level 2: gather fields by one communication for `nproc` levels (with MPI_ALLTOALLV)	1
ngribout	INT	To specify how many NAMELIST-groups /GRIBOUT/ are contained for the model run.	1
nvers	INT	The version number of a model run for documenting purposes. `nvers` is coded in the PDS of GRIB output files and is the only parameter to distinguish GRIB output files for the same case but coming from different model versions.	1

Name	Type	Definition / Purpose / Comments	Default
`ncenter`	INT	To specify the WMO-identification of generating center.	78
`nsubcenter`	INT	To specify the WMO-identification of the originating subcenter (to set GRIB2 metadata).	255
`nlocaldefnr`	INT	To specify the local definition number for GRIB local sections. The default value of -1 means, that no local section is present.	-1
`yform_read`	CHAR	Specifies the format of input files. The following formats are implemented: `'grb1'` read GRIB1 data with DWD's GRIB library. `'apix'` read GRIB (1/2) data with ECMWF's grib_api. `'ncdf'` read NetCDF data.	`'grb1'`
`yform_write`	CHAR	In Version 4.18 this parameter has been moved to the group `/GRIBOUT/`. This gives the possibility, that it can be specified for every output group. (Specifies the format of output files (can be `'grb1'` or `'ncdf'`)	`'grb1'`
`ymode_read`	CHAR	Specifies the mode how files are opened for reading.	`'r  '`
`ymode_write`	CHAR	Specifies the mode how files are opened for writing.	`'w  '`
`num_gribtabs`	INT	Specifies the number of different GRIB tables used in COSMO-Model variable table.	6
`lst_gribtabs(:)`	LOG	Identifications of the different GRIB tables. Current table used are: 2, 201, 202, 203, 204, 205	see left
`lbdclim`	LOG	If .TRUE., use additional boundary fields that are needed for long term simulations.	`.FALSE.`
`lbdsst`	LOG	If .TRUE., use an additional boundary field to update the Sea Surface Temperature during NWP simulations	`.FALSE.`
`ldwd_grib_use`	LOG	If .TRUE., special DWD Grib settings are used	`.TRUE.`
`l_ke_in_gds`	LOG	If .TRUE., write number of vertical levels as a vertical coordinate parameter to the GDS grib section	`.TRUE.`

Writing (and reading) Restart-Files:

Name	Type	Definition / Purpose / Comments	Default
`nhour_restart`	INT	Triplet to specify start, stop and increment for writing restart files. Specifications are in full forecast hours.	`12, 0, 12`
`ydir_restart`	CHAR	Eliminated in 5.1; replaced by `ydir_restart_in` and `ydir_restart_out`	`''`
`ydir_restart_in`	CHAR	Directory for reading restart files.	`''`
`ydir_restart_out`	CHAR	Directory for writing restart files.	`''`
`ytunit_restart`	CHAR	Time unit to specify the file name for restart files.	`'f'`

Additional specifications for NetCDF-IO:

The Network Common Data Format (`NetCDF`) is designed to identify the data contained in a file in a unique way. Hereto the necessary informations need to be written into the file.

`yncglob_institution`	CHAR		`'-'`
`yncglob_title`	CHAR		`'-'`
`yncglob_source`	CHAR		`'-'`
`yncglob_contact`	CHAR		`'-'`
`yncglob_project_id`	CHAR		`'-'`
`yncglob_experiment_id`	CHAR		`'-'`
`yncglob_references`	CHAR		`'-'`
`ncglob_realization`	INT		1

Reading and writing "Ready-Files":

In an operational environment, the COSMO-Model can also be run in parallel with the interpolation program which generates lateral boundary conditions from the corresponding coarse-grid model run. In this case, the interpolation program writes so-called *ready-files*, which simply indicate that a lateral boundary file for a certain forecast time has been successfully and completely written. During program execution, the model checks for the existence of these files in certain time intervals – and in this way waits until the required lateral boundary data-set is available for the next READ-operation on the corresponding input file. In a similar way, the COSMO-Model writes ready files for each output file that has been successfully written. This allows to run postprocessing utilities in parallel to the model execution.

`ytrans_in`	CHAR	Directory path for reading ready-files.	' '
`ytrans_out`	CHAR	Directory path for writing ready-files.	' '
`nincwait`	INT	Seconds to wait until the next read attempt for a lateral boundary file if the corresponding ready file is not available.	0
`nmaxwait`	INT	Maximum seconds to wait until abort if the ready file for the next lateral boundary file is not available.	0

Controlling the Soil Moisture Analysis:

`nsma_stat`	INT	Status for soil moisture analysis. `nsma_stat` is coded in the PDS of the grib-ed fields for soil moisture content (in the "local use area"). 0: this is a "normal" soil moisture field. 20: this is a field derived by soil moisture analysis.	0

7.12 DATABASE — Specification of Database Job

This Namelist group has been eliminated in Version 4.25, since the direct writing to the database system has never been used!

Instead of using the file-based GRIB-IO, there is also a capability to read and write GRIB-files directly from a database system. However, this option works only if you work within the DWD IT-environment, which provides a very special but not portable interface `csodaban` to a commercial database system. To use this option, you should be familiar with the DWD database interface and the structure of the database system.

All users outside DWD have to work with file-based IO. Most Namelist input parameters from `DATABASE` are not relevant in this case – except `nout_sockets` and `nin_sockets` which both have to be set to 0 (default) in order to enable file-based IO.

Name	Type	Definition / Purpose / Comments	Default
`yinit_order`	CHAR	String to initialize the data-base interface program `csodaban` for GRIB-IO, including specifications to write GRIB output to the data base system.	'ak=nix'
`yana_tab`	CHAR	Specifications to retrieve initial data from the data base system.	'*****'
`ybd_tab`	CHAR	Specifications to retrieve boundary data from the data base system.	'*****'
`nout_sockets`	INT	Number of sockets for database output per PE (0 means File-IO).	0
`nin_sockets`	INT	Number of sockets for database input per PE (0 means File-IO; has to be ≤ 1).	0
`iretry`	INT	Number of seconds to retry on database failure.	0
`ibackup_size`	INT	Size of incore backup space (in bytes) by a database failure.	-1
`ybackup_dir`	CHAR	Directory path for outcore backup.	'.'
`idbg_level`	INT	Debug level for `mpe_io`.	0

7.13 GRIBIN — Controlling the Grib Input

The namelist group /GRIBIN/ contains parameters related to the input of initial and boundary files, which are an analysis file for the initialization of the model fields (containing also the *constant* parameter fields such as orography, soil type etc.), and boundary data files for certain equidistant boundary update time steps.

Note that the namelist group /GRIBIN/ applies to all possible input data formats (GRIB, NetCDF), not only to GRIB data. The specifications for the parameters in /GRIBIN/ are included in the file INPUT_IO.

Each namelist parameters of the list is described in one of the sections:

- control parameters for initial data,
- control parameters for boundary data and
- additional parameters for continuous data assimilation

Control parameters for initial data

Name	Type	Definition / Purpose / Comments	Default
ydirini	CHAR	Directory path of the initial data file – interpolated data from a driving model or analysis from a continuous COSMO-Model data assimilation.	' '
lchkini	LOG	Checking the initial data for min/max values.	.FALSE.
yvarini(:)	CHAR	has been eliminated in Version 4.12.	
lana_qi	LOG	If .TRUE., use the cloud-ice field contained in the initial data file as initial condition for cloud-ice; otherwise, initial conditions for cloud-ice are set in the model.	.FALSE.
lana_qr_qs	LOG	If .TRUE., values for rain and snow are read from the initial conditions. Otherwise, values are set in the model.	.FALSE.
lana_qg	LOG	If .TRUE., values for the graupel scheme are provided in the initial data;	.FALSE.
lana_rho_snow	LOG	If .TRUE., values for the density of snow are provided in the initial data;	.FALSE.
nlgw_ini	INT	Number of prognostic soil water levels in initial data. This parameter is only used for the "old" soil model.	2

Control parameters for boundary data

Name	Type	Definition / Purpose / Comments	Default
`hincbound`	`REAL`	Interval in hours between two consecutive sets of boundary data (boundary update frequency). Within this time interval, boundary values are interpolated linearly in time. Only multiples of `0.25` are possible.	`1.0`
`ydirbd`	`CHAR`	Directory path of the boundary data files.	`' '`
`lchkbd`	`LOG`	Checking the boundary data for min/max values.	`.FALSE.`
`yvarbd`	`CHAR`	has been eliminated in Version 4.12.	
`llb_qi`	`LOG`	If `.TRUE.`, take cloud-ice values contained in the lateral boundary data as boundary condition for cloud ice; otherwise, cloud ice boundary conditions are set in the model.	`.FALSE.`
`llb_qr_qs`	`LOG`	If `.TRUE.`, take rain and snow values contained in the lateral boundary data as boundary condition.	`.FALSE.`
`llb_qg`	`LOG`	If `.TRUE.`, take graupel values contained in the lateral boundary data as boundary condition.	`.FALSE.`
`lbdana`	`LOG`	If `.TRUE.`, use analysis data as lateral boundary conditions.	`.FALSE.`
`ytunitbd`	`CHAR`	Time unit indicator in the boundary data file name (see Section 6.2). `t` : forecast range given in timesteps `f` : the forecast range is given in the form `ddhhmmss` (where `dd`: day, `hh`: hour, `mm`: minute, `ss`: second) `c` : the forecast range is given in the form `yyydddhh` (`yyy`: year, `ddd`: day of the year, `hh`: hour) `d` : the forecast range is given in the form `yyyymmddhh` or (optionally) `yyyymmddhhmise` (can only be used, if hincbound is given in full hours) (Use `'d'` for COSMO-CLM)	`'f'`
`nlgw_bd`	`INT`	Number of prognostic soil water levels in boundary data. This parameter is only used for the “old” soil model.	2
`lbd_frame`	`LOG`	Normally, the boundary data are defined on the full 3-D model domain. IF `lbd_frame = .TRUE.`, it is assumed that the boundary data are only defined on a lateral frame (e.g. when using boundary data obtained from ECMWF/IFS).	`.FALSE.`
`npstrframe`	`INT`	Number of grid-point rows and colums where lateral boundary data are defined when using the `lbd_frame` option.	8

Name	Type	Definition / Purpose / Comments	Default
`ilevbotnoframe`	`INT`	Number of vertical layer which separates frame and no-frame boundary data. For layers extending from the top of the model domain to `ilevbotnoframe`, the boundary data are defined for the full horizontal domain (this enables the application of a Rayleigh damping layer near the model top), and for layers from `ilevbotnoframe` to the lowest layer, the boundary data are defined on a frame.	0

Additional parameters for continuous data assimilation

Name	Type	Definition / Purpose / Comments	Default
`newbc`	`INT`	Number of times that boundary update is analysis after 1 hour.	360
`newbcdt`	`INT`	Time step increment of boundary update from analysis.	' '
`hnewbcdt`	`REAL`	Hour increment of boundary update from analysis.	0.0
`nincboufac`	`INT`	Factor to `nincbound` when new boundary update is analysis.	2
`lan_t_s`	`LOG`	Selection of analysed (tri=0) sea surface temperature.	`.FALSE.`
`lan_t_so0`	`LOG`	Selection of analysed (tri=0) sea surface temperature (for the multi-layer soil model.	`.FALSE.`
`lan_t_snow`	`LOG`	Selection of analysed snow temperature.	`.FALSE.`
`lan_t_cl`	`LOG`	Selection of analysed climatological soil temperature.	`.FALSE.`
`lan_w_snow`	`LOG`	Selection of analysed water content of snow.	`.FALSE.`
`lan_w_i`	`LOG`	Selection of analysed interception water.	`.FALSE.`
`lan_w_so`	`LOG`	Selection of analysed or external soil moisture.	`.FALSE.`
`lan_w_cl`	`LOG`	Selection of analysed climatological soil water content.	`.FALSE.`
`lan_vio3`	`LOG`	Selection of analysed vertical integrated ozone.	`.FALSE.`
`lan_hmo3`	`LOG`	Selection of analysed ozone maximum.	`.FALSE.`
`lan_plcov`	`LOG`	Selection of analysed plant cover.	`.FALSE.`
`lan_lai`	`LOG`	Selection of analysed leaf area index.	`.FALSE.`
`lan_rootdp`	`LOG`	Selection of analysed root depth.	`.FALSE.`
`lan_rho_snow`	`LOG`	Selection of analysed density of snow.	`.FALSE.`

The control of the parameters `lan_xxx` is as follows:
`.TRUE.`: Fields are used from external analyses or from an interpolated coarse grid field.
`.FALSE.`: Fields are used from the continous data assimilation of the COSMO-Model.

7.14 GRIBOUT — Controlling the Grib Output

How to use the `NAMELIST` group `gribout` is explained in Section 8.4 in detail.

Basic parameters for controlling the output:

Name	Type	Definition / Purpose / Comments	Default
`ydir`	CHAR	Directory of the output file.	' '
`yvarml(:)`	CHAR	List of model variables for output	
`yvarpl(:)`	CHAR	List of variables for pressure levels	
`plev(:)`	REAL	Pressure levels	
`yvarzl(:)`	CHAR	List of variables for z-levels	
`zlev(:)`	REAL	Z-levels	
`yvarsl(:)`	CHAR	List of satellite channels for output	
`ngrib(:)`	INT	List of output steps given in time steps	99999
`ncomb(:)`	INT	Triplets for building ngrib	99999
`hgrib(:)`	REAL	List of output steps given in hours	0.0
`hcomb(:)`	REAL	Triplets for building ngrib	0.0

Controlling the output domain and time unit indicator:

`ytunit`	CHAR	Time unit indicator in the output data file name (see Section 6.2).	'f'
`ydomain`	CHAR	Domain type (full or sub) indicator in the output data file name (see Section 6.2).	'f'
`slon`	REAL	Left longitude for a subdomain	`startlon_tot`
`slat`	REAL	Bottom latitude for a subdomain	`startlat_tot`
`elon`	REAL	Right longitude for a subdomain	`endlon_tot`
`elat`	REAL	Upper latitude for a subdomain	`endlat_tot`

Additional parameters for controlling the output:

Name	Type	Definition / Purpose / Comments	Default
ysystem	CHAR	This switch has been eliminated in Version 4.28 File, database or ecfs.	
ydbtype	CHAR	This switch has been eliminated in Version 4.28 Type of the database.	
yform_write	CHAR	Specifies the format of output files 'grb1' write GRIB1 data with DWD's GRIB library. 'api1' write GRIB 1 data with grib_api. 'api2' write GRIB 2 data with grib_api. 'ncdf' write NetCDF data.	'grb1'
nprocess_ini	INT	Generating process identification for initial data.	-999999
nprocess_bd	INT	Generating process identification for boundary data.	-999999
n_num	INT	This switch has been eliminated in Version 4.28 Counter for nests.	
nrbit	INT	Number of bits per value for grib packing. Usually, 16 bits give sufficient accuracy.	16
nunit_of_time	INT	Indicates the *Unit of Time* for Grib Code	1
lcheck	LOG	Checking the output data for min/max values.	.TRUE.
lanalysis	LOG	If .TRUE., analysis output files are written when the model runs in nudging mode.	.FALSE.
lwrite_const	LOG	If .TRUE., constant fields are written as grib output at initial time.	.TRUE.
luvmasspoint	LOG	Enables interpolation of horizontal winds to mass grid points for output.	.FALSE.
loutput_q_densities	LOG	Determines the output units of the hydrometeor contents "QC", "QR", etc. If .FALSE., these are output as mass specific quantities (kg/kg), which is the model internal convention. If .TRUE., mass densities (kg/m^3) are output instead. In case of using the two-moment microphysical scheme, the units of the number contents "QNCLOUD", "QNRAIN", etc. (1/kg or 1/m^3) are chosen analogously.	.FALSE.
l_p_filter	LOG	Logical switch, if .TRUE., the fields on pressure levels are digitaly filtered to remove small-scale noise	.FALSE.
l_z_filter	LOG	Logical switch, if .TRUE., the fields on height levels are digitaly filtered to remove small-scale noise.	.FALSE.
itype_vertint	INT	To specify the type of the vertical interpolation used to interpolate values to p- and / or z-level. 1: Cubic tension splines (previous method) 2: Linear interpolation (new in Version 4.17)	1

Name	Type	Definition / Purpose / Comments	Default
`l_fi_ps_smooth`	`LOG`	This switch has been renamed (see below), because what really is smoothed here is the mean sea level pressure!	`---`
`l_fi_pmsl_smooth`	`LOG`	Logical switch, if `.TRUE.`, additional smoothing is done for mean sea-level pressure and geopotential in mountainous areas.	`.FALSE.`
`l_fi_filter`	`LOG`	Logical switch to filter the geopotential `FI` independent of the settings of `l_p_filter`.	`.FALSE.`
`l_pmsl_filter`	`LOG`	Logical switch to filter the mean sea level pressure `PMSL` independent of the settings of `l_p_filter` and / or `l_z_filter`	`.TRUE.`
`ysuffix`	`CHAR`	To add an optional suffix to the file names.	`' '`

Section 8

Model Output

The COSMO-Model provides three kinds of output:

- The model fields resulting from the model integration can be written in GRIB or in NetCDF output; more information on this can be found in Section 8.4.
- For a quick monitoring and diagnostic output, several ASCII files are written. These are described in Sections 8.1 and 8.2.
- For data assimilation or verification purposes, a special NetCDF '*feedobs*' file (sometimes also (mis)called '*feedback*' file) can be written. Section 8.3 provides some information on it. A comprehensive description of the format of '*feedback*' files (which are extended '*feedobs*' files) is given in an extra documentation *Feedback File Definition*, which can also be found on the COSMO web site (`www.cosmo-model.org`).

8.1 ASCII Output for the Forecast Model

For a quick forecast monitoring the model writes various control output to ASCII files. These files are:

- `YUSPECIF`: `NAMELIST`-parameters
- `YUCHKDAT`: Checking the input/output data from GRIB / NetCDF
- `YUPRMASS`: Protocolling the forecast with selected mean values for mass variables
- `YUPRHUMI`: Protocolling the forecast with selected mean values for humidity variables
- `YUDEBUG`: More detailed information for debugging purposes
- `YUTIMING`: Timings for the different parts of the forecast

In addition, output for meteographs (grid point output) can also be done. For every selected grid point a file `M_`*stationname* is written.

8.1.1 `M_`*stationname* — Grid point output

The files `M_`*stationname* provide a monitoring of model variables at single grid points. There is a short form (`NAMELIST`-variable `lgpshort = .TRUE.`) or a long form (`lgplong = .TRUE.`). Only one of these two forms can be chosen. If none of the two variables is set to `.TRUE.`, the meteograph files are not printed.

The number of grid points considered are limited because of memory reasons. Up to `nmaxgp` grid points can be chosen. The parameter `nmaxgp` is contained in `data_runcontrol.f90` (`nmaxgp = 100`). If more grid points should be considered, this parameter has to be changed and the program has to be recompiled.

With `n0gp` and `nincgp`, the first output and the interval of outputs in time steps can be controlled (alternatively `h0gp` and `hincgp` for specifying these values in hours).

Figure 8.1 shows an example of a file `M_`*stationname* with the short form of the grid point output. This short form contains the following information for every grid point:

A header specifying the initial date of the forecast and the i- and j-indices of the model domain, the model orography (m), the fraction of land (%) within the grid cell, the geographical latitude (φ) and the geographical longitude (λ). For every time step, the following quantities are listed in one line:

`HH`	date
`PS`	surface pressure reduced to sea-level
`DF10M`	wind direction (°) and speed (kn, where $1\,m/s \approx 2\,kn$) at 10m above surface
`DF500M`	wind direction (°) and speed (kn) at 500m above surface
`DF850`	wind direction (°) and speed (kn) at 850 hPa
`DF700`	wind direction (°) and speed (kn) at 700 hPa
`DF500`	wind direction (°) and speed (kn) at 500 hPa
`TG`	surface temperature (°C)
`T2M`	temperature (°C) 2m above surface
`TD2M`	dew point (°C) 2m above surface
`T30M`	temperature (°C) 30m above surface
`T850`	temperature (°C) at 850 hPa
`T700`	temperature (°C) at 700 hPa
`T500`	temperature (°C) at 500 hPa
`HML`	cloud cover (high, medium, low) (range $0 \dots 8$)
`=`	ground fog (range $0 \dots 8$)
`HBAS`	base height of convective cloud above msl
`HTOP`	top height of convective cloud above msl
`RR`	rain (grid scale and convection)
`RS`	snow (grid scale and convection)
`WS`	water content of snow

Figure 8.2 shows an example of a file `M_`*stationname* with the long form of the grid point output. This long form contains the following information for every grid point:

`HSURF`	height of model orography (in m)
`FR_LAND`	land fraction (%)
`LAT`	geographical latitude (in °) of the grid point

```
          *** Model: LM  ***          Start of the forecast: SUN 17.02.2008  18 UTC
          Short meteograph of the LM at selected grid points

     Meaning of the parameters:
       HH:       forecast hour                                 (hours)
       PS:       mean sea level pressure                         (hpa)
       DF10M:    wind direction and speed at 10m      (degree/knots)
       DF500M:   wind direction and speed at 950 hPa  (degree/knots)
       DF850:    wind direction and speed at 850 hPa  (degree/knots)
       DF700     wind direction and speed at 700 hPa  (degree/knots)
       DF500     wind direction and speed at 500 hPa  (degree/knots)

       TG:       ground temperature                                (C)
       T2M:      temperature at 2m                                 (C)
       TD2M:     dew point temperature at 2m                       (C)
       T30M:     temperature at ~ 30m (lowest level)               (C)
       T850:     temperature at 850 hpa                            (C)
       T700:     temperature at 700 hpa                            (C)
       T500:     temperature at 500 hpa                            (C)

       HML:      cloud cover (high, medium, low)                (0..8)
        = :      ground fog                                     (0..8)
       HBAS:     base height of con. cloud above msl             (hpa)
       HTOP      top  height of con. cloud above msl             (hpa)
       RR:       rain amount (grid scale and convective)          (mm)
       RS:       snow amount (grid scale and convective)          (mm)
       WS:       water content of snow                             (m)



GRID POINT:        Frankfurt-Flughafen     I:    23    J:    70
Initial Date:      SUN 17.02.2008  18 UTC
    HSURF   ( m ):   111.208
    FR_LAND ( % ):   100.000
    LAT     (dgr):    50.055
    LON     (dgr):     8.637
    SOIL TYPE    : sandy loam     4

    HH   PMSL    DF10M  DF500M   DF850   DF700   DF500   TG    T2M    TD2M  T30M  T850  T700   T500 HML =  HBAS HTOP  RR    RS     WS
     h   hpa   dgr m/s dgr m/s  dgr m/s dgr m/s dgr m/s              degree centrigrade         octas     10*m        mm          m

  18.0 1039.60 234/  1 271/  4 342/  5 344/  7 343/ 13  -0.5   1.2  -9.6   2.7   0.3  -7.1 -21.9 000 0    0    0 0.00  0.00  0.000
  19.0 1039.67 244/  1 271/  4 332/  6 341/  7 348/ 14  -1.0  -0.5  -8.9   2.5   0.3  -7.0 -22.0 100 0    0    0 0.00  0.00  0.000
  20.0 1039.35 241/  2 276/  4 332/  6 338/  8 349/ 14  -1.4  -1.1  -8.3   0.8   0.1  -6.6 -21.8 100 0    0    0 0.00  0.00  0.000
  21.0 1039.12 237/  2 280/  4 327/  6 346/  9 349/ 15  -2.0  -1.8  -7.6  -0.5   0.1  -6.5 -22.0 100 0    0    0 0.00  0.00  0.000
```

Figure 8.1: Example file `M_`*stationname* with short grid point output.

```
GRID POINT:        Frankfurt-Flughafen     I:     23     J:     70
Initial Date:      SUN 17.02.2008  18 UTC
    HSURF   ( m ):   111.208
    FR_LAND ( % ):   100.000
    LAT     (dgr):    50.055
    LON     (dgr):     8.637
    FC    (1E4/s):     1.119
    SOIL TYPE    : sandy loam     4

      Actual date:           SUN 17.02.2008  18 UTC +  0.0     (time step:      0)
    PS(hpa): 1025.3    DPSDT(hpa/h):   -4.2

  K   Pmain    T       QV      QC      QI REL_HUM     CLC   CLC_CON       U       V   SPEED     HML
       hPa   Grd C     g/kg       mg/kg        %      %       %               m/s           m

  1   34.19 -76.61   0.004   0.000   0.000   15.01    0.00    0.00   42.73   -1.29   42.75  22184.5
  2   51.27 -78.10   0.004   0.000   0.000   25.42    0.00    0.00   30.44  -13.05   33.12  19807.4
  3   69.20 -74.72   0.004   0.000   0.000   20.32    0.00    0.00   22.42  -14.96   26.95  18062.0
  4   88.30 -73.62   0.004   0.000   0.000   21.87    0.00    0.00   13.30  -14.65   19.79  16634.0
 ..........
 37 1010.77   3.46   1.696   0.000   0.000   35.13    0.00    0.00    1.73    1.37    2.21    226.7
 38 1016.66   3.24   1.722   0.000   0.000   36.43    0.00    0.00    1.33    0.99    1.66    179.6
 39 1020.97   2.95   1.740   0.000   0.000   37.73    0.00    0.00    1.06    0.76    1.30    145.4
 40 1024.03   2.71   1.759   0.000   0.000   38.93    0.00    0.00    0.85    0.60    1.04    121.2

  K   Phalf      W        TKVM      TKVH    HHL
       hPa     cm/s           m**2/s         m

  1   19.91     0.000                     23588.5
  2   42.73    -0.741     1.000     1.000  20780.5
  3   60.24    -1.355     1.000     1.000  18834.3
  4   78.75    -1.979     1.000     1.000  17289.8
 ..........
 38 1013.71     0.338     1.000     1.000    199.7
 39 1018.82     0.269     1.000     1.000    159.6
 40 1022.50     0.186     1.000     1.000    131.1
 41 1025.29     0.168                         111.2

   Surface variables:        TCM     :      0.00000
               ( m/s )       TCH     :      0.00000
               (  m  )       Z0      :      0.75001
               ( w/m2)       SHFL    :      0.007                ( N/m2)       UMFL    :      0.000
                             LHFL    :     -0.002                ( N/m2)       VMFL    :      0.001
               ( g/kg)       QV_S    :      2.125
               (kg/m2)       RUNOFF_S:      0.000
                             RUNOFF_G:      0.000
   Plants:                   LAI     :      1.060      Ozone:                 VIO3    :      0.078
                             PLCOV   :      0.670                             HMO3    :   5477.051
                             ROOTDP  :      0.120

   Soil temperatures         T_SNOW  :     -0.460      Soil moistures/Snow    W_SNOW  :      0.000
               (dgr C)       T_S     :     -0.460               (mm H2O)      W_I     :      0.000
                             T_G     :     -0.460                             FRESHSNW:      1.000
                                                                (kg/m3)       RHO_SNOW:     50.000
                                                                (m)           H_SNOW  :      0.000
                             T_SO( 0):     -0.460
                             T_SO( 1):     -0.460      W_SO( 1):      1.338 W_SO_ICE( 1):     0.234
                             T_SO( 2):     -0.181      W_SO( 2):      2.710 W_SO_ICE( 2):     0.000
                             T_SO( 3):      0.545      W_SO( 3):      8.211 W_SO_ICE( 3):     0.000
                             T_SO( 4):      0.678      W_SO( 4):     25.668 W_SO_ICE( 4):     0.000
                             T_SO( 5):      2.592      W_SO( 5):     26.953 W_SO_ICE( 5):     0.000
                             T_SO( 6):      5.600      W_SO( 6):    353.938 W_SO_ICE( 6):     0.000
                             T_SO( 7):      8.717      W_SO( 7):   1061.812 W_SO_ICE( 7):     0.000
                             T_SO( 8):      9.795      W_SO( 8):   3185.500 W_SO_ICE( 8):     0.000

   Temperatures              T2M     :      1.191        Winds                U10M    :      0.832
               (dgr C)       TD2M    :     -9.592               ( m/s )       V10M    :      0.584
                             TMIN2M  :      1.191                             VBMAX10M:      1.206
                             TMAX2M  :      1.191

   Solar radiation           SOBT    :      0.000        Thermal radiation    THBT    :   -232.998
               (w/m**2)      SOBS    :      0.000               (w/m**2)      THBS    :   -104.491
   Photosynt. active Rad.    PABS    :      0.000        Surface albedo (%)   ALB     :     17.108

   Precipitation        rates     and    amount                Cloud Cover
                        (mm/d)            (mm)                     (%)
         RAIN_GSP:      0.000            0.000                CLCH    :      4.701
         SNOW_GSP:      0.000            0.000                CLCM    :      0.000
         RAIN_CON:      0.000            0.000                CLCL    :      0.000
         SNOW_CON:      0.000            0.000                CLCT    :      4.701
         TOTAL:         0.000            0.000
```

Figure 8.2: Example file M_*stationname* with long grid point output.

`LON`	geographical longitude (in °) of the grid point
`FC`	Coriolisparameter (in $10^{-4} s^{-1}$)
`SOIL TYPE`	type of the soil (keys 0-9)
`PS`	unreduced surface pressure (in hPa)
`DPSDT`	tendency of surface pressure (in hPa/h)

For all main levels `k=1,...,ke_tot` the following parameters are printed:

`Pmain`	pressure (in hPa) of the main levels
`T`	temperature (in °C)
`QV`	specific water vapor content (in g/kg)
`QC`	specific cloud water content (in g/kg)
`QI`	specific cloud ice content (in g/kg)
`REL_HUM`	relative humidity (in %)
`CLC`	cover with grid scale clouds (in %)
`CLC_CON`	cover with convective clouds (in %)
`U`	zonal wind component (in m/s)
`V`	meridional wind component (in m/s)
`SPEED`	wind speed (in m/s)
`HML`	height of model main levels (in m)

For the half levels the following parameters are printed:

`Phalf`	pressure (in hPa) of the half levels
`W`	vertical velocity
`TKVM`	turbulent diffusion coefficients for momentum
`TKVH`	turbulent diffusion coefficients for heat and moisture
`HHL`	height of model half levels (in m)

In addition the values of several near surface and soil parameters are printed.

8.1.2 `YUSPECIF` — `NAMELIST`-parameters

`YUSPECIF` contains all `NAMELIST`-variables, their default and their actual values. At the end of this file, the vertical coordinate parameters `sigma(k)` and the values of the reference atmosphere are printed. `YUSPECIF` is always written.

8.1.3 `YUCHKDAT` — Checking the Grib input/output data

`YUCHKDAT` contains information about fields that are read from or written to GRIB files. For every field the maximum value, the minimum value (together with the corresponding indices) and the mean value are written. This output can be controlled with the `NAMELIST`-parameters

- `lchkini` (in `gribin`): check the initial data
- `lchkbd` (in `gribin`): check the boundary data
- `lcheck` (in `gribout`): check the output data

If none of these variables is set to `.TRUE.`, `YUCHKDAT` is not written.

8.1.4 `YUPRMASS` — Protocolling the forecast with mass variables

`YUPRMASS` contains meanvalues of model variables related to mass and deviations from initial mean values. First, the initial values of the following variables are written:

- area mean value of the surface pressure (in hPa) for the total model domain without boundary zone.
- volume mean values of dry static, moist static and kinetic energy (in J/kg).

In the next lines, the following values are written:

`ntstep`	actual time step.
`Real`	elapsed time since the last line was printed.
`dpsdt`	area mean value of the tendency of the surface pressure. (This is a good measure for the noise in the model.)
`ps`	area mean value of the surface pressure.
`dse`	deviation of the volume mean value of dry static energy from the initial value.
`mse`	deviation of the volume mean value of moist static energy from the initial value.
`ke`	deviation of the volume mean value of kinetic energy from the initial value.
`vamx`	maximum of the horizontal velocity.
`wamx`	maximum of the absolute vertical velocity.
`waxxx`	area mean values of the absolute vertical velocity for three model layers in about 850, 500 and 300 hPa.

The file `YUPRMASS` is always written. With the `NAMELIST`-parameters `n0meanval` and `nincmeanval` of `/diactl/` the first output and the interval of the outputs in time steps can be controlled. With `ldump_ascii = .TRUE. / .FALSE.`, the flushing of `YUPRMASS` to disk in every time step can be switched on/off.

An example of `YUPRMASS` is shown in Figure 8.3.

8.1.5 `YUPRHUMI` — Protocolling the forecast with humidity variables

`YUPRHUMI` contains meanvalues of model variables related to humidity and rain rates. First, the initial values of the humidity variables are written.

In the next lines, the following values are written:

`ntstep`	actual time step.
`Real`	elapsed time since the last line was printed.
`qc`	area mean value of cloud water.
`qi`	area mean value of cloud ice.
`qr`	area mean value of rain.
`qs`	area mean value of snow.
`qg`	area mean value of graupel.
`prrs`	precipitation rate for grid scale rain.
`prss`	precipitation rate for grid scale snow.
`prrk`	precipitation rate for convective rain

```
    Experiment: LM      Number:      1   SUN 17.02.2008  18 UTC +   0 H  (SUN 17.02.2008  18 UTC)     19.02.2008   15.21.47
    Elapsed time for providing initial and boundary values:     REAL (S):      1.12

    Initial mean values for nstart = 0 for several variables:
    surface pressure (hPa)  dry static energy (J/kg)  moist static energy (J/kg)   kinetic energy (J/kg)
           967.278                313977.93                314962.08                   207.08

    Experiment: LM      Number:      1   SUN 17.02.2008  18 UTC +   0 H  (SUN 17.02.2008  18 UTC)     19.02.2008   15.21.47
ntstep   Real      dpsdt     ps         dse       mse       ke       vamx       wamx     wa850     wa500     wa300
           s        Pa/s     hPa        J/kg      J/kg      J/kg      m/s        m/s      cm/s      cm/s      cm/s
                     E-2                E+3       E+3

   0     3.680    22.809   967.195    -0.005     0.002    -0.621    47.647     0.800     3.231     3.940     5.151
   1     1.200    25.425   967.324     0.001     0.012    -0.924    47.693     0.801     3.763     5.798     7.087
   2     0.360    17.142   967.265     0.000     0.014    -1.220    47.724     0.810     3.782     4.657     5.440
   3     0.370    14.223   967.289     0.003     0.020    -1.463    47.749     0.828     3.946     4.945     5.979
   4     1.250    11.841   967.284     0.005     0.023    -1.679    47.769     0.845     4.025     4.739     5.595
   5     0.370    12.827   967.289     0.006     0.027    -1.872    47.784     0.860     4.151     4.887     5.730
   6     0.360    11.485   967.299     0.008     0.030    -2.044    47.797     0.869     4.216     4.806     5.588
   7     0.360    11.888   967.294     0.009     0.032    -2.202    47.807     0.874     4.292     4.855     5.617
   8     1.260    10.977   967.303     0.010     0.035    -2.338    47.817     0.877     4.342     4.819     5.595
   9     0.400    11.277   967.297     0.011     0.038    -2.464    47.826     0.880     4.388     4.814     5.567
  10     0.360    10.802   967.301     0.013     0.040    -2.573    47.834     0.883     4.415     4.815     5.583
  11     1.270    10.548   967.297     0.014     0.042    -2.671    47.842     0.883     4.432     4.814     5.563
  12     0.360    10.328   967.298     0.015     0.045    -2.755    47.850     0.883     4.444     4.823     5.581
  13     0.360    10.335   967.295     0.016     0.047    -2.828    47.859     0.881     4.448     4.822     5.574
  14     0.360     9.545   967.294     0.017     0.049    -2.889    47.868     0.885     4.453     4.836     5.592
  15     1.260     8.093   967.291     0.019     0.051    -2.937    47.879     0.917     4.455     4.844     5.586
  16     0.360     8.277   967.288     0.020     0.053    -2.975    47.894     0.946     4.460     4.859     5.597
  17     0.360     8.472   967.284     0.021     0.055    -3.002    47.910     0.975     4.465     4.877     5.600
  18     0.360     8.484   967.281     0.022     0.057    -3.020    47.917     1.002     4.471     4.898     5.617
  19     1.360     8.104   967.277     0.024     0.060    -3.031    47.921     1.029     4.478     4.918     5.641
  20     0.360     7.968   967.272     0.025     0.062    -3.035    47.926     1.056     4.485     4.935     5.661
  21     0.370     8.029   967.267     0.026     0.064    -3.032    47.933     1.084     4.494     4.957     5.680
  22     1.250     7.658   967.262     0.027     0.065    -3.025    47.941     1.111     4.504     4.981     5.696
  23     0.370     7.442   967.257     0.028     0.067    -3.013    47.948     1.138     4.513     5.003     5.708
  24     0.360     7.288   967.252     0.029     0.069    -2.997    47.955     1.164     4.522     5.027     5.716
  25     0.360     7.210   967.246     0.030     0.071    -2.977    47.963     1.189     4.532     5.054     5.728
  26     1.260     6.887   967.240     0.031     0.072    -2.953    47.971     1.212     4.541     5.080     5.744
  27     0.370     6.880   967.233     0.032     0.074    -2.926    47.980     1.233     4.550     5.104     5.768
  28     0.360     6.796   967.226     0.033     0.076    -2.894    47.990     1.249     4.559     5.125     5.792
  29     0.390     6.489   967.220     0.034     0.077    -2.854    47.997     1.264     4.566     5.144     5.809
  30     1.280     5.797   967.214     0.035     0.079    -2.807    48.001     1.275     4.574     5.159     5.811
  31     0.360     5.203   967.208     0.036     0.080    -2.750    48.005     1.285     4.582     5.169     5.804
  32     0.360     4.570   967.200     0.037     0.082    -2.686    48.017     1.291     4.587     5.177     5.803
  33     1.290     4.018   967.190     0.037     0.083    -2.615    48.033     1.296     4.593     5.185     5.813
  34     0.360     3.653   967.180     0.038     0.084    -2.539    48.045     1.300     4.598     5.191     5.828
```

Figure 8.3: Example file `YUPRMASS`

```
    Experiment: LM      Number:      1   SUN 17.02.2008  18 UTC +   0 H  (SUN 17.02.2008  18 UTC)     19.02.2008   15.21.47
    Elapsed time for providing initial and boundary values:     REAL (S):      1.12

    Initial mean values for nstart =
    cloud water  cloud ice     rain        snow       graupel      (all: g/kg)
        0.000       0.000       0.000       0.000       0.000
    Experiment: LM      Number:      1   SUN 17.02.2008  18 UTC +   0 H  (SUN 17.02.2008  18 UTC)     19.02.2008   15.21.47
ntstep     qc        qi        qr        qs        qg       prrs      prss      prrk      prsk      rrn       rsn
                            kg/kg (1E-5)                                   mm/D                               mm

   0     0.000     0.085     0.000     0.386     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   1     0.000     0.076     0.000     0.385     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   2     0.000     0.072     0.000     0.383     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   3     0.000     0.069     0.000     0.382     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   4     0.000     0.067     0.000     0.380     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   5     0.000     0.065     0.000     0.379     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   6     0.000     0.064     0.000     0.377     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   7     0.000     0.062     0.000     0.376     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   8     0.000     0.061     0.000     0.374     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   9     0.000     0.060     0.000     0.373     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  10     0.000     0.059     0.000     0.371     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  11     0.000     0.059     0.000     0.370     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  12     0.000     0.058     0.000     0.369     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  13     0.000     0.057     0.000     0.367     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  14     0.000     0.057     0.000     0.366     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  15     0.000     0.056     0.000     0.365     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  16     0.000     0.056     0.000     0.364     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  17     0.000     0.055     0.000     0.362     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  18     0.000     0.055     0.000     0.361     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  19     0.000     0.055     0.000     0.360     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  20     0.000     0.054     0.000     0.359     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  21     0.000     0.054     0.000     0.358     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  22     0.000     0.054     0.000     0.357     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  23     0.000     0.054     0.000     0.357     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  24     0.000     0.054     0.000     0.356     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  25     0.000     0.054     0.000     0.355     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  26     0.000     0.054     0.000     0.354     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  27     0.000     0.054     0.000     0.353     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  28     0.000     0.054     0.000     0.353     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  29     0.000     0.054     0.000     0.352     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  30     0.000     0.054     0.000     0.352     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  31     0.000     0.054     0.000     0.351     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  32     0.000     0.054     0.000     0.350     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  33     0.000     0.054     0.000     0.350     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  34     0.000     0.054     0.000     0.349     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  35     0.000     0.054     0.000     0.349     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  36     0.000     0.054     0.000     0.348     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Figure 8.4: Example file `YUPRHUMI`

`prsk`	precipitation rate for convective snow.
`rrn`	sum of precipitation (rain) since start of the forecast.
`rsn`	sum of precipitation (snow) since start of the forecast.

The file `YUPRHUMI` is always written. With the `NAMELIST`-parameters `n0meanval` and `nincmeanval` of `/diactl/` the first output and the interval of the outputs in time steps can be controlled. With `ldump_ascii = .TRUE. / .FALSE.`, the flushing of `YUPRHUMI` to disk in every time step can be switched on/off.

An example of `YUPRHUMI` is shown in Figure 8.4.

8.2 ASCII Output Related to the Use of Observations

The ASCII output described in this section is produced only if the compile option `-DNUDGING` is used for the production of the COSMO binary, and the `NAMELIST` variable `luseobs` is set to `.TRUE.`. For some of the files, additional prerequisites exist. The ASCII files provide a helpful tool for a quick monitoring and diagnosis of the tasks related to the use of observations, such as data assimilation, input for verification, and production of 2-dimensional analyses based on observations. These files are:

- `YUAOFEX`: Nudging, observation input AOF
- `YUOBSDR`: Nudging, list of active and passive reports
- `YUREJCT`: Nudging, list of rejected reports
- `YUQUCTL`: Nudging, list of data rejected by quality control
- `YUSTATS`: Nudging, statistics on observation processing
- `YUCAUTN`: Nudging, warning messages indicating insufficient array sizes
- `YUVERIF`: Nudging, verification file VOF
- `YUPRINT`: Nudging, other, various aspects
- `YUSURF` : 2-D surface analyses
- `YULHN` : Latent Heat Nudging (description not yet available)

Note that the `NAMELIST`-parameters related to the tasks which use observations are also written to file `YUSPECIF`. This has already been described in Section 8.1. Furthermore, the file `YUTIMING` is also extended with parts that consider the nudging (or production of the `YUVERIF` and / or NetCDF feedobs files) and the latent heat nudging.

8.2.1 `YUAOFEX` — Nudging: Observation Input AOF

File `YUAOFEX` is written only if the observations for the nudging scheme are read from an 'AOF' file (see variable '`itype_obfile`' in `NAMELIST` '`NUDGING`') and if `NAMELIST` variable '`lpraof`' is set to '`.TRUE.`'. `YUAOFEX` then prints the complete observations that are read from the AOF file. In this case, the AOF file contains all the observations (except for the GPS data) that made available to the COSMO Model either for the purpose of nudging, verification, or production of two-dimensional surface analyses. Figure 8.5 shows an example of a file `YUAOFEX` which includes an aircraft report, a SYNOP report, and the beginning of a TEMP report. For each report, the first four lines contain the 19 items of the report header:

1	length of record for whole report	
2	length of preliminary array	
3 - 5	missing (length of next record; record number; analysis box number)	
6 / 7	observation type / code type (see Figure 8.12)	
8	station latitude,	in [degree * 100 + 9000]
9	station longitude,	in [degree * 100 + 18000]

10 date of observation, in [yyyymmdd] (yyyy=year; mm=month; dd=day)
11 / 12 synoptic / exact time of observation, in [hh ' '] (hh=hour; ' ' = minutes)
13 , 14 station identity (for characters 1 - 4 resp. 5 - 8, ASCII allocating sequence)
15 data base key
16 station altitude, in [m + 1000]
17 / 18 station characteristics / instrument specifications
19 flags on latitude/longitude/date/time/altitude

Further details related to these elements are given in the AOF documentation in appendix A of Documentation Part IV (Implementation Guide).

In file `YUAOFEX`, the header is repeated in octal numbers. Then each observation level of the report body is also given first in digital numbers and then in octal numbers. For each observation type used currently, the first elements are pressure (in [0.1 hPa], or geopotential [m]), wind direction ([°]), wind speed ([m/s]), and temperature ([0.1 K]). For TEMP radiosonde reports, this is followed by dew point ([0.1 K]), height ([m+1000]), and two flag words. For PILOT and aircraft reports, the same applies except that there is no value for dew point. For SYNOP reports, dew point is followed by pressure tendency ([0.1 hPa / 3 h]), sea surface temperature ([0.1 K]), the weather group word and general cloud group word, a pressure level code flag and two further flag words, and optional groups.

```
****************************************************** A O F    R E P O R T *****
0         27           4  2147483647  2147483647  2147483647
           2         144       14425       18863    20020109
        1100        1158    88773930    88773930  2147483647
  2147483647     1032192          22           0
          33           4 17777777777 17777777777 17777777777
           2         220       34131       44657   114275615
        2114        2206   522512452   522512452 17777777777
 17777777777     3740000          26           0
0       2381         212          40        2140  2147483647
           0           0
        4515         324          50        4134 17777777777
           0           0
****************************************************** A O F    R E P O R T *****
0         35           4  2147483647  2147483647  2147483647
           1          11       13552       18867    20020109
        1200        1200   103651382   109580320       16166
        1169          65          32           0
          43           4 17777777777 17777777777 17777777777
           1          13       32360       44663   114275615
        2260        2260   613314066   642010040       37446
        2221         101          40           0
0      10160         999           0        2692        2678
         502  2147483647   131073280   133757695          64
           0           0         256         127           0

       23660        1747           0        5204        5166
         766 17777777777   764002400   776175377         100
           0           0         400         177           0

****************************************************** A O F    R E P O R T *****
0        332           4  2147483647  2147483647  2147483647
           5          35       14057       19038    20020109
        1200        1200   103553716   117968928          56
        1450         768         127           0
         514           4 17777777777 17777777777 17777777777
           5          43       33351       45136   114275615
        2260        2260   613015264   702010040          70
        2652        1400         177           0
0       9830         150           1        2679        2676
        1453      507904           0
       23146         226           1        5167        5164
        2655     1740000           0
................................................................................
```

Figure 8.5: Example file `YUAOFEX`.

8.2.2 `YUOBSDR` — Nudging: Active and Passive Reports

File `YUOBSDR` lists the active reports. It is written only if the `NAMELIST` parameter '`lprodr`' is set to '`.TRUE.`'. The passive reports are also listed if '`lverif=.TRUE.`' and '`lverpas=.TRUE.`'. The criteria to distinguish between passive and fully rejected (i.e. omitted) reports are given in Figure 8.13. In addition, a message is also written if a report or a single observation level within a multi-level report is redundant.

The first three lines in Figure 8.6 relate to redundant surface-level reports. At first, the station identity and code type (see Figure 8.12) of the redundant report are given. This is followed by a list of properties of the (resulting) active report, consisting of the (rotated) wind components, temperature, relative humidity, pressure, station identity, code type, longitude, latitude, order index, station correction flag, replacement indicator, and report time (relative to the initial time of the model run). The replacement indicator is organized in the same

```
 --> REDUNDANT: 60571      35  / ACTIVE:    -1.3   -1.6  290.2 0.39******** 60571      35 -2.3 31.5 1 F   0  2.0
 --> REDUNDANT: 11520      14  / ACTIVE:     2.1   -2.2  273.4 0.91  98300. 11520      11 14.5 50.0 2 T   0  0.0
 --> REDUNDANT: 11520      35  / ACTIVE:     1.0   -2.9  274.0 0.91******** 11520      35 14.5 50.0 1 F  32  2.3
 11520     Z: ACT/REJ: P/ZERR/Z:  39900.  40000.******   9.8*******  6970.
 11520     T: ACT/REJ: P/T/FLAG:  39900.  40000.******   0.4 0 0
 11520     Q: ACT/REJ: P/Q/FLAG:  39900.  40000.******   0.2 0 0
TEMP  11520        0.9  -2.8 274.0 0.90***************  302***** 1.2 0.40*****    0(335,322)  14.44  50.02  35 5  2.25
TEMP  11520     P  0.9  -2.8 274.0 0.90***************  302***** 1.2 0.40*****    0(335,322)  14.44  50.02  35 5  2.25
SYNOP 11520     P  2.1  -2.2 273.4 0.91  983.00   303.  303***** 1.0 0.10  7.5    1(335,322)  14.44  50.02  11 1  0.00
SYNOP 11520        2.1  -2.2 273.4 0.91  983.00   303.  303***** 1.0 0.10  7.5    1(335,322)  14.44  50.02  11 1  0.00
SYNOP 11520        2.1  -2.2 273.6 0.92  983.70   303.  303***** 1.0 0.10  7.5    1(335,322)  14.44  50.02  11 1  1.00
SYNOP 11520        1.2  -2.8 274.0 0.90  984.40   303.  303***** 1.0 0.10  7.5    1(335,322)  14.44  50.02  11 1  2.00
TEMP  11520        OBS/CODE TYPE: 5  35  STA/MOD HEIGHT: 302  301  LON= 14.44 LAT= 50.02  G.P.=(335,322)  HOUR=  2.3
     u      v     t    rh      p      z  v-err t-er rh-er z-er lev
    0.9   -2.8  274.0 0.90   985.0   302.***************   4.3  64
    2.8   -6.4************   958.0*******  2.1*************** 128
**************  271.0 1.00   945.0************  1.1 0.10***** 256
    1.2   -7.9  269.9 1.00   925.0   803.  2.2  1.1 0.10  4.3  32
   -2.0   -9.8  266.3 0.93   850.0  1468.  2.4  1.0 0.10  4.4  32
   -3.3   -8.4************   800.0*******  2.4***************  32
   -4.7   -7.7************   765.0*******  2.5*************** 128
**************  258.5 0.90   738.0************  0.8 0.10***** 256
**************  259.9 0.89   732.0************  0.8 0.10***** 256
   -5.4  -10.7  257.3 0.59   700.0  2956.  2.5  0.7 0.10  5.2  32
  -10.0  -11.2************   600.0*******  2.9***************  32
**************  247.3 0.25   568.0************  0.5 0.10***** 256
  -14.3  -19.3  241.4 0.14   500.0  5410.  3.4  0.4 0.15  8.4  32
**************  240.9 0.09   473.0************  0.4 0.15***** 256
**************  241.1 0.11   469.0************  0.4 0.15***** 256
  -17.8  -29.0  233.4 0.12   400.0  6970.  3.5  0.4 0.15  9.8  33
**************  226.3 0.20   344.0************  0.5 0.20***** 256
  -13.6  -22.1  222.9 0.09   300.0  8880.  3.7  0.5 0.20 10.7  32
  -14.7  -23.9  218.3 0.06   259.0*******  3.5  0.5**********   2
  -13.6  -22.1  218.3 0.05   250.0 10060.  3.5  0.5***** 11.8  32
  -12.1  -24.1************   206.0*******  3.5*************** 128
  -12.1  -24.1  217.9 0.02   200.0 11480.  3.5  0.6***** 13.2  32
**************  219.6 0.01   155.0************  0.7********** 256
   -7.3  -11.9  218.6 0.01   150.0 13320.  3.4  0.7***** 15.2  32
   -0.3  -11.0  215.6 0.01   100.0*******  3.3  0.8********** 384
   -2.4  -11.8  214.3 0.01    70.0 18140.  3.2  0.8***** 19.5   8
   -3.6   -3.4  214.1 0.01    50.0 20250.  3.2  0.9***** 22.5   8
   -0.6   -1.9  212.4 0.01    30.0 23430.  3.3  0.9***** 25.0   8
    2.9    0.7  212.1 0.01    20.0 25940.  3.6  1.0***** 32.0   8
   11.0   -0.3  220.6 0.01    10.0*******  4.5  1.2********** 128
PILOT 10266        OBS/CODE TYPE: 6 132  STA/MOD HEIGHT:  57   56  LON= 11.84 LAT= 53.31  G.P.=(306,374)  HOUR=  0.5
     u      v     t    rh      p      z  v-err t-er rh-er z-er lev
   -1.1   -2.5************   958.9   525.  2.1***************   0
   -0.8   -2.3************   941.6   669.  2.1***************   0
   -1.0   -2.1************   924.5   814.  2.2***************   0
   -0.6   -2.5************   907.9   958.  2.2***************   0
    0.8   -3.4************   891.4  1103.  2.3***************   0
PILOT 10266     P  OBS/CODE TYPE: 6 133  STA/MOD HEIGHT:  57   56  LON= 11.84 LAT= 53.31  G.P.=(306,374)  HOUR=  0.5
     u      v     t    rh      p      z  v-err t-er rh-er z-er lev
**************  270.4*****   956.9   542.********************   0
**************  269.7*****   940.4   679.********************   0
**************  269.0*****   924.3   816.********************   0
**************  269.1*****   908.3   954.********************   0
**************  270.3*****   892.8  1091.********************   0
SYNOP Q671         0.7  -1.9 272.6 1.00********   750.  750***** 1.0 0.10*****    1(284,295)   9.48  48.38  14 1  2.00
SYNOP 07497     P -1.0   0.2 278.5 0.52  917.90   868.  868******************* -781(253,252)   6.76  45.61  11 1  2.00
SYNOP 02868     P  5.1   7.4 262.0 0.92 1002.60     0.  488*******************  156(417,596)  29.14  66.16  14 1  2.00
SYNOP 02876        4.3   5.5 271.1 0.80 1003.40     5.    5  3.6 1.0 0.10  7.4    2(396,571)  25.39  65.00  14 1  2.00
SYNOP 63108        6.0  -3.0 280.0 0.94 1017.50     0.    0  3.6 1.0 0.10 14.5    0(223,497)   1.70  60.79  24 1  2.00
SYNOP DBFC         2.0  -2.2 273.9 0.73 1024.30     0.    0  3.6 1.0 0.10 14.5    0(320,402)  13.39  55.00  21 1  2.00
DRIBU 63551      ********************** 1014.50     0.    0************** 14.5    0(230,605)   0.84  67.53 165 4  0.00
DRIBU 64071       -0.5  -5.0 265.3 1.00********     0.    0  5.4 1.0**********    0(171,632)  -9.25  68.46 165 4  2.00
Scatt 004          4.7   0.5*******************     0.    0  7.0**************    0(227,395)   3.36  54.46 123 9  1.63
Scatt 004          4.3  -0.1*******************     0.    0  7.0**************    0(235,395)   4.23  54.48 123 9  1.63
```

Figure 8.6: Example file `YUOBSDR`, first part.

way as the finite observation error indicator of the VOF (see section 8.2.7). It reveals which observations of the active report have been missing and were replaced by data from the rejected report. Rejected multi-level reports are written to file `YUOBSDR` in a format very similar to that for the active reports (see below).

The next three lines inform about an observation level being redundant within a multi-level report. Pressure level, observation error, and observed value for height resp. quality flags for other variables are provided both from the active and the redundant level.

The following information is given for each (active or passive) single-level report (stars ' *** ' always indicate missing values):

- observation type , and station identity
- status indicator: ' ': active, '`P`': passive, '`M`': used as part of a multi-level report
- zonal and meridional wind components u , v [m/s]
- temperature T [K] , and relative humidity rh [ ]
- pressure level p [hPa]
- height z at observation level [m] , and station height [m]
- observation errors assigned to wind, temperature, humidity, and height data
- station altitude minus height of model orography
- coordinates of the grid point to which the report is assigned
- longitude and latitude [°]
- code type , and observation type (see Figure 8.12)
- reported observation time [h] relative to the initial model time

```
AIREP EU5331    M  0.4  -5.1 265.5 0.66  840.38  1550.*****  2.5 1.0 0.10**********(313,297)  12.27  48.50 244 2  2.51
AIREP EU5331    M  0.2  -4.1 266.5 0.62  848.67  1470.*****  2.5 1.0 0.10**********(313,297)  12.25  48.47 244 2  2.51
AIREP EU5331    M -0.1  -3.1 267.0 0.63  858.08  1380.*****  2.5 1.0 0.10**********(313,297)  12.23  48.45 244 2  2.51
AIREP EU5331    M  0.7  -3.5 268.0 0.56  869.69  1270.*****  2.5 1.0 0.10**********(313,296)  12.21  48.43 244 2  2.53
AIREP EU5331       0.1  -2.6 268.5 0.65  882.51  1150.*****  2.5 1.0 0.10**********(312,296)  12.15  48.41 244 2  2.53
AIREP EU5331    P  1.1  -4.5 268.8 0.50  879.29  1180.*****  2.5 1.0 0.10**********(312,296)  12.18  48.42 244 2  2.53
AIREP EU5331    P  0.2  -2.1 268.8 0.63  882.51  1150.*****  2.5 1.0 0.10**********(312,296)  12.12  48.40 244 2  2.54
AIREP EU5331    M  0.3  -2.6 269.0 0.62  881.43  1160.*****  2.5 1.0 0.10**********(311,296)  12.10  48.40 244 2  2.54
AIREP EU5331    M  0.6  -3.5 269.3 0.58  882.51  1150.*****  2.5 1.0 0.10**********(311,295)  12.06  48.38 244 2  2.54
AIREP EU5331    P  0.2  -3.1 269.3 0.55  882.51  1150.*****  2.5 1.0 0.10**********(311,295)  12.03  48.38 244 2  2.56
AIREP EU5331    M -0.1  -3.1 269.5 0.54  882.51  1150.*****  2.5 1.0 0.10**********(310,295)  12.01  48.37 244 2  2.56
AIREP EU5331    M -0.4  -2.6 270.0 0.52  890.05  1080.*****  2.5 1.1 0.10**********(310,295)  11.98  48.37 244 2  2.56
AIREP EU5331    M -0.6  -2.5 270.8 0.53  902.01   970.*****  2.5 1.1 0.10**********(310,295)  11.95  48.37 244 2  2.58
AIREP EU5331    M -0.3  -2.1 270.8 0.62  913.00   870.*****  2.5 1.1 0.10**********(310,295)  11.93  48.37 244 2  2.58
AIREP EU5331    M -0.5  -2.5 272.5 0.58  922.98   780.*****  2.5 1.1 0.10**********(309,295)  11.91  48.37 244 2  2.58
AIREP EU5331    M -0.4  -2.6 272.8 0.60  930.81   710.*****  2.5 1.1 0.10**********(309,295)  11.89  48.37 244 2  2.60
AIREP EU5331    M -0.3  -2.6 273.2 0.56  938.69   640.*****  2.5 1.1 0.10**********(309,295)  11.87  48.37 244 2  2.60
AIREP EU5331    M -0.1  -2.6 273.3 0.58  946.62   570.*****  2.5 1.1 0.10**********(309,295)  11.86  48.37 244 2  2.60
AIREP EU5331    M  0.2  -1.5 273.8 0.59  955.75   490.*****  2.5 1.1 0.10**********(309,295)  11.85  48.37 244 2  2.61
AIREP EU5331    M  0.3  -0.4 274.3 0.60  963.80   420.*****  2.5 1.2 0.10**********(308,295)  11.82  48.36 244 2  2.61
AIREP EU5331       OBS/CODE TYPE: 2 244  STA/MOD HEIGHT:****  443  LON= 11.82 LAT= 48.36  G.P.=(308,295)  HOUR=  2.6
     u      v     t    rh      p      z  v-err t-er rh-er z-er lev
    0.3   -0.4  274.3 0.60   963.8   420.  2.5  1.2 0.10***** 384
    0.2   -1.5  273.8 0.59   955.8   490.  2.5  1.1 0.10***** 384
   -0.1   -2.6  273.3 0.58   946.6   570.  2.5  1.1 0.10***** 384
   -0.3   -2.6  273.2 0.56   938.7   640.  2.5  1.1 0.10***** 384
   -0.4   -2.6  272.8 0.60   930.8   710.  2.5  1.1 0.10***** 384
   -0.5   -2.5  272.5 0.58   923.0   780.  2.5  1.1 0.10***** 384
   -0.3   -2.1  270.8 0.62   913.0   870.  2.5  1.1 0.10***** 384
   -0.6   -2.5  270.8 0.53   902.0   970.  2.5  1.1 0.10***** 384
   -0.4   -2.6  270.0 0.52   890.1  1080.  2.5  1.1 0.10***** 384
   -0.1   -3.1  269.5 0.54   882.5  1150.  2.5  1.0 0.10***** 384
AIREP EU5331       OBS/CODE TYPE: 2 244  STA/MOD HEIGHT:****  481  LON= 12.06 LAT= 48.38  G.P.=(311,295)  HOUR=  2.5
     u      v     t    rh      p      z  v-err t-er rh-er z-er lev
    0.6   -3.5  269.3 0.58   882.5  1150.  2.5  1.0 0.10***** 384
    0.3   -2.6  269.0 0.62   881.4  1160.  2.5  1.0 0.10***** 384
    0.7   -3.5  268.0 0.56   869.7  1270.  2.5  1.0 0.10***** 384
   -0.1   -3.1  267.0 0.63   858.1  1380.  2.5  1.0 0.10***** 384
    0.2   -4.1  266.5 0.62   848.7  1470.  2.5  1.0 0.10***** 384
    0.4   -5.1  265.5 0.66   840.4  1550.  2.5  1.0 0.10***** 384
GPS   COMO-METO P  6.5  42.1******************* 2286.0  247  1.4     0.00       -46(279,253)   9.09  45.80 80012  0.50
GPS   COMO-METO P  6.4  41.2******************* 2285.1  247  1.7     0.00       -46(279,253)   9.09  45.80 80012  0.75
GPS   COMO-ROB_ P****************************** 2279.8  247  1.7    *****       -46(279,253)   9.09  45.80 83712  0.50
GPS   COMO-ROB_ P****************************** 2278.1  247  1.8    *****       -46(279,253)   9.09  45.80 83712  0.75
GPS   COMO-ASI_ P****************************** 2272.6  247  2.4    *****       -46(279,253)   9.09  45.80 82112  0.50
GPS   COMO-ASI_ P****************************** 2261.2  247  2.6    *****       -46(279,253)   9.09  45.80 82112  0.75
GPS   COMO-SGN_ P****************************** 2275.0  247  2.2    *****       -46(279,253)   9.09  45.80 82912  0.50
GPS   COMO-SGN_  ****************************** 2273.4  247  2.5    *****       -46(279,253)   9.09  45.80 82912  0.75
GPS   COMO-SGN1 P****************************** 2274.3  247  2.3    *****       -46(279,253)   9.09  45.80 92912  0.50
GPS   COMO-SGN1 P****************************** 2272.6  247  2.6    *****       -46(279,253)   9.09  45.80 92912  0.75
GPS   COMO-BKG_  ****************************** 2273.6  247  1.0    *****       -46(279,253)   9.09  45.80 83012  0.50
```

Figure 8.7: Example file `YUOBSDR`, second part.

Figure 8.6 provides examples of a TEMP radiosonde, a wind profiler, and a RASS multi-level report. For multi-level reports, a self-explanatory header line is followed by lines each providing the following information for one observation level: horizontal wind components, temperature, relative humidity, pressure, height, observation errors for wind, temperature, humidity, and height, and level identity. The latter is a bit pattern as specified for the VOF (see section 8.2.7). Figure 8.6 also includes examples for drifting buoy, scatterometer wind, Synop ship, and Synop surface land reports. Two of the latter reports are set passive since all their observations are passive due to large differences between observation level and model orography.

Figure 8.7 shows an example of an descending aircraft before landing. The process of deriving a multi-level report from the original single-level reports is interrupted at a level where the aircraft had to stay on hold before it was allowed for the final landing. As a result, two instead of one multi-level reports are created, and at the holding altitude (of 882 hPa), several single-level reports remain, all of which except for one are set passive due to redundancy.

Figure 8.7 is completed by examples of ground-based GPS reports. Compared to other single-level reports, the values for wind are replaced here by integrated water vapour and zenith wet delay values (in [mm]), height by zenith total delay (ZTD, in [mm]), and the observation errors by the ZTD error and the bias correction (in [mm]). All reports shown here are from one station (COMO), but the raw data have been processed by different processing centres in order to obtain ZTD. In such cases, all except for one report have to be set to passive due to redundancy according to the preference given by `NAMELIST` parameter '`igpscen`'. In the example, the reports processed by '`BKG`' for observation time `0.5` and by '`SGN`' for time `0.75` are active.

8.2.3 `YUREJCT` — Nudging: Rejected Reports

`YUREJCT` (see Figure 8.8) lists the station identities of the rejected (or passive) reports and indicates the reasons for their rejection. For instance, the station height and its difference to the model orography is provided if this difference is so large that every observed quantity from that report is excluded from use. Most of the messages are self-explanatory.

The '`FLIGHT TRACK`' messages all deliver station identity, observation time (relative to the model initial time), and pressure of observation level. They are complemented by position confidences (in [%]) with original resp. reversed sign for longitude (if the line includes "`LON SIGN`") or position confidences for the foreward resp. backward trajectory of the report sequence.

The '`BLACKLISTED`' messages indicate in general rejection of certain parts rather than complete reports. Observation types '`OBTYP`' are as specified in Figure 8.12, and the 4 pairs of numbers at the end of the lines indicate the lower and upper limit in [hPa] of the blacklisted vertical range for height (geopotential) or pressure, wind, temperature, resp. humidity.

The last 12 lines in Figure 8.8 relate to single observed quantities or to single observation levels of multi-level reports. The lapse rate and wind shear messages deliver station identity, observation time, threshold value, actual value (in [K] resp. [m/s]), and the pressure range of the rejected levels. By default (see `NAMELIST` parameter '`maxmlv`'), a maximum of 100 observation levels are allowed in a multi-level report (see second but last message).

```
 STATION 04339      : OBS. LOCATION OUT OF DOMAIN   -22.0   70.5 ,    2.0 HRS
 STATION 004        : OBS. LOCATION OUT OF DOMAIN    10.5   70.8 ,   -0.1 HRS
 STATION EU0324     : OBSERVATION TOO OLD:   âˆ’0.6 [FORECAST HRS]
 STATION 11142      : HEIGHT  647. DIFF. TO MODEL  937. TOO LARGE,     0.0 HRS
 STATION 11916      : HEIGHT 2007. DIFF. TO MODEL 1294. TOO LARGE,     0.0 HRS
 STATION 01455      : HEIGHT  255. DIFF. TO MODEL  410. TOO LARGE,     0.0 HRS
 STATION LCAR-METO  : HEIGHT   16. DIFF. TO MODEL  172. TOO LARGE,     1.0 HRS
 STATION ARDE-LPT_  : HEIGHT 1497. DIFF. TO MODEL 2033. TOO LARGE,     1.0 HRS
 STATION ASDE09     : SEA OBS. IS LOCATED OVER (MODEL) LAND AT    10.0   53.0 ,    1.6 HRS
STATION ASDE09     : NO SURFACE-LEVEL REPORT DERIVED FROM TEMP / PILOT
 STATION DBBI       : SEA OBS. IS LOCATED OVER (MODEL) LAND AT     8.5   53.5 ,    0.0 HRS
 STATION 61933      : STA HEIGHT FLAGGED,    -0.5 HRS
 STATION 62934      : STA HEIGHT FLAGGED,     1.3 HRS
STATION 11164      : NO SURFACE-LEVEL REPORT DERIVED FROM TEMP / PILOT
 STATION 06620     CODE TYPE 132 NOT ON WHITELIST,    0.0 HRS
 STATION 07145     CODE TYPE 137 NOT ON WHITELIST,    0.5 HRS
 FLIGHT TRACK THINNING  EU4611   ,  3.73,  393.: (TOO) CLOSE TO OBS. TIME  3.72
 FLIGHT TRACK THINNING  EU4611   ,  3.80,  330.: (TOO) CLOSE TO OBS. TIME  3.77
 FLIGHT TRACK THINNING  EU4611   ,  3.83,  330.: (TOO) CLOSE TO OBS. TIME  3.77
 FLIGHT TRACK CHECK  EU6363   , 0.80  216.: HORIZONTAL CONFIDENCES:  83.9  57.9
 FLIGHT TRACK CHECK  EU3311   ,-0.07  344.: HORIZONTAL CONFIDENCES: 101.0  58.5
 FLIGHT TRACK CHECK  EU1234   , 3.52  238.: HORIZONTAL CONFIDENCES:  59.2 101.0
 EXAGGERATED HORIZONTAL COLOCATION EU0350   :  28 REPORTS FROM  1.68 TO  3.70
 FLIGHT TRACK CHECK  LHEU0456 , 4.80  780.: HORIZONTAL CONFIDENCES:  19.0   0.0
 FLIGHT TRACK CHECK  EU3268   , 2.70  376.: VERTICAL CONFIDENCES:  59.0  81.2
 FLIGHT TRACK CHECK  EU9145   , 3.88  290.: LON SIGN, FOREWARD CONFIDENCE:  54  89
 FLIGHT TRACK CHECK  EU8969   , 1.61  376.: LON SIGN, FOREWARD CONFIDENCE:  29  89

 STA 62023     OBTYP 1 BLACKLISTED (Z,V,T,Q):    0   0 1100   0    0   0    0   0
 STA 16115     OBTYP 1 BLACKLISTED (Z,V,T,Q): 1100   0    0   0    0   0    0   0
 STA EU8742    OBTYP 2 BLACKLISTED (Z,V,T,Q):    0   0    0   0 1100   0    0   0
 STA KLM791    OBTYP 2 BLACKLISTED (Z,V,T,Q):    0   0 1100   0    0   0    0   0
 STA RCH7440   OBTYP 2 BLACKLISTED (Z,V,T,Q):    0   0 1100   0 1100   0    0   0
 STA 62337     OBTYP 5 BLACKLISTED (Z,V,T,Q):   30   0 1100   0   30   0    0   0
 STA 34247     OBTYP 5 BLACKLISTED (Z,V,T,Q):  150   0    0   0  150   0    0   0
 STA 22522     OBTYP 5 BLACKLISTED (Z,V,T,Q): 1100   0    0   0 1100   0    0   0
 STA 08007     OBTYP 6 BLACKLISTED (Z,V,T,Q):    0   0 1100 900    0   0    0   0
 STA 08007     OBTYP 6 BLACKLISTED (Z,V,T,Q):    0   0  600   0    0   0    0   0
 STA 10678     OBTYP 6 BLACKLISTED (Z,V,T,Q):    0   0  200   0 1100   0    0   0

 PRECIPITATION AMOUNT EXCEEDS LIMIT âˆ’    DATUM REJECTED.  STID=08226    RR=914.0 TR=12.
 PRECIPITATION AMOUNT EXCEEDS LIMIT âˆ’    DATUM REJECTED.  STID=07649    RR= 18.0 TR= 1.
03507    : Fog with precip.: weather:127 ,vis.:   300 ,flags:  0  0
10488    : Fog with precip.: weather: 51 ,vis.:   200 ,flags:  0  0
10544    : Fog with precip.: weather: 77 ,vis.:   300 ,flags:  0  0
 LAPSE RATE  EU8943   ,  0.8: THRESHOLD , VALUE: -0.5 -0.69 , P:  332. -  331.
 LAPSE RATE  22550    ,  2.5: THRESHOLD , VALUE: -1.5 -2.10 , P:  565. -  549.
 WIND SPEED SHEAR  03920    ,  3.0: THRESH, VALUE: 42.6  44.0 , P:  250. âˆ’  200.
 WIND SPEED SHEAR  03496    ,  3.0: THRESH, VALUE: 39.9  50.0 , P:  400. âˆ’  300.
 SINGLE LEV REP  06458     : PRESSURE TENDENCY:  4506 ,  FLAG:   0
 SINGLE LEV REP 07600     : NO ACCEPTED DATA IN REPORT
 MULTI LEV REP  03501     :   130th LEVEL, BUT ODR SIZE IS   100
```

Figure 8.8: Example file `YUREJCT`.

8.2.4 `YUQUCTL` — Nudging: Data Rejected by Quality Control

`YUQUCTL` (see Figure 8.9) lists the data which are rejected by the quality control at the observation time. Note that as the quality control procedures are applied to each observation several times during the individual assimilation time window, the messages do not imply automatically that all of these observations are never used. It only means that these data are rejected at least at the individual observation time itself, when the checks give the best estimation about the data quality, and when the nudging weights would be largest.

The entries for each line denote the type of rejection. The entries '`uv`', '`uv-10m`', '`T`', '`T-2m`', '`RH`', and '`RH-2m`' indicate that an upper-air resp. surface-level wind, temperature, resp. humidity observation is rejected by the individual threshold quality control. The same applies to the entries '`p-TEMP`' and '`ps`' for pressure, except that '`p-TEMP`' refers to a single pressure datum at the lowest model level as derived from radiosonde geopotential data. The entry '`IWV`' relates to an integrated water vapour value (in [mm]), which is derived from a ground-based GPS report (and possibly bias-corrected), and which is either rejected by the threshold quality control or is smaller than an absolute minimum threshold value (2 mm). For each entry, the following properties are given: station identity, code type (see Figure 8.12), observation time (relative to the model initial time, in [h]), pressure (in [hPa]) at the observation level, latitude and longitude (in [°]), threshold value for the difference, observed value, model value, and in some cases the difference between observed and model value. For wind, both the zonal and meridional value components are given, complemented

```
List of Observations Rejected by the Threshold Quality Control at the Observation Time
======================================================================================
                                                                                        Obs.
     Station ID Code Time Pressure Lat. Lon. Thresh. Var: Obs /Model  Var: Obs /Model  Diff Op.

uv    : 08019     137  0.0  893.9  43.5  -6.3 10.4 : u     5.5   -7.1 , v   -2.3    2.3  13.5
V-mult: 08019     137  0.0  915.8  43.5  -6.3        p-top: 367.6
T -2m : 62144      24  0.0 1000.1  53.4   1.7 12.0 : T    250.7  287.4  -36.6
uv-10m: 06012      14  0.0  995.7  62.3  -6.3 12.0 : u     2.9  -11.3 , v   -1.2  -10.0  16.7
RH    : EU6564    244  0.0  815.9  48.2  12.2  0.45: RH    0.46   0.96
RH    : EU6564    244  0.1  857.0  48.3  12.1  0.44: RH    0.48   0.95
RH    : EU6564    244  0.1  883.6  48.3  12.0  0.44: RH    0.46   0.94
RH    : EU6564    244  0.1  846.6  48.3  12.1  0.44: RH    0.48   0.96
RH    : EU6564    244  0.1  838.3  48.3  12.1  0.47: RH    0.50   0.97
q-mult: EU6564    244  0.1  846.6  48.3  12.1        p-top: 815.9
T-mult: EU9734    144  0.1  959.5  50.2  14.3        p-top: 729.9
T-mult: EU9734    144  0.2  694.2  50.3  14.1        p-top: 578.7
T-mult: EU9734    144  0.2  555.9  50.3  13.8        p-top: 483.4
T-mult: EU9734    144  0.3  465.6  50.2  13.5        p-top: 406.5
uv    : RCH7440   141  0.3  206.5  60.0 -20.3 16.1 : u    21.8   18.0 , v    7.8   13.8   7.1
T     : RCH7440   141  0.3  206.5  60.0 -20.3  6.9 : T    233.1  223.4
uv    : EU5261    244  0.7  507.1  51.2  11.6 14.0 : u    19.8   18.7 , v   15.6   14.3   1.7
T     : EU5261    244  0.7  507.1  51.2  11.6  5.1 : T    267.0  260.8
dz    : EU5261    244  0.6  984.7  51.4  12.2  26.1  p-top: 750.6  : dz   45.9, dT-mean   5.8
uv    : EU0350    244  0.7  197.0  50.1   8.6 16.1 : u   -15.9  -12.7 , v  -18.2  -37.0  19.1
T     : EU0350    244  0.7  197.0  50.1   8.6  7.1 : T    221.7  213.6
uv    : RCH8125   141  0.8  196.8  57.5 -17.6 16.1 : u    21.7   23.5 , v   15.7   12.8   3.4
T     : RCH8125   141  0.8  196.8  57.5 -17.6  7.1 : T    229.1  218.8
ps-scc: SKEC       24  1.0  994.6  56.1  16.6  3.3 : ps  994.6  998.5 , bias|w2:  -0.1   8.5
z-mult: 40179      35  1.5 1000.0  32.0  34.8        p-top:  50.0
RH    : 60571      35  1.8  604.0  31.5  -2.2  0.58: RH    0.02   0.66
RH    : 60571      35  1.8  500.0  31.5  -2.2  0.56: RH    0.11   0.86
RH    : 60571      35  1.8  485.0  31.5  -2.2  0.56: RH    0.10   0.82
IWV-sc: 60571      35  1.8  371.0  31.5  -2.2  5.2 :IWV    5.6   11.7 , bias|w2:   0.0   0.0
uv    : 16080      35  1.9   10.0  45.4   9.3 22.7 : u    19.4   -3.9 , v    1.5    3.6  23.5
T     : 16080      35  1.9   10.0  45.4   9.3 12.1 : T    226.9  211.1
z-mult: 17609      32  2.0  977.6  34.9  33.6        p-top: 783.1
z-mult: 17600      32  2.0  977.7  34.7  32.5        p-top: 844.1
ps    : 16080      35  2.0  985.0  45.4   9.3  5.0 : ps  985.0  990.0
ps-scc: 16080      35  2.0  985.0  45.4   9.3  5.5 : ps  985.0  987.0 , bias|w2:  -3.0  17.5
IWV   : TRYN-NGAA 834  2.2 ******  61.4  12.4  2.82:IWV    6.87   9.73
IWV   : NYKO-NGAA 834  2.2 ******  55.9  11.7  3.47:IWV    4.98   8.60
IWV   : OSV2-NGAA 834  2.2 ******  60.2  17.2  3.05:IWV    5.24   9.08
IWV-sc: NYKO-NGAA 834  2.2 ******  55.9  11.7  3.9 :IWV    5.0    8.6 , bias|w2:  -1.6   2.7
IWV-sc: TRYN-NGAA 834  2.2 ******  61.4  12.4  3.0 :IWV    6.9    9.8 , bias|w2:  -0.7   1.2
RH-2m : 01415      35  2.4 1012.0  58.9   5.7  0.70: RH    0.05   0.80  -0.76
RH    : 01415      35  2.4  560.0  58.9   5.7  0.51: RH    0.22   0.76
q-mult: EU5331    244  2.4  618.0  48.9  12.5        p-top: 538.0
q-mult: EU5331    244  2.5  707.3  48.7  12.4        p-top: 639.2
z-mult: 17220      35  2.5 1000.0  38.4  27.2        p-top:  50.0
z     : 17220      35  2.5   10.0  38.4  27.2 312.1 (p-top:  10.0)    : z              324.2
RH    : 60571      35  3.0  500.0  31.5  -2.2  0.56: RH    0.11   0.88
IWV-sc: 60571      35  3.0  400.0  31.5  -2.2  5.2 :IWV    5.1   12.0 , bias|w2:   0.0   0.0
p-TEMP: 02527      35  3.0  948.4  57.7  12.5  5.0 : ps  948.4  955.0
ps    : 02527      11  3.0  953.0  57.7  12.5  5.0 : ps  953.0  959.5
ps    : 02527      35  3.0  953.0  57.7  12.5  5.0 : ps  953.0  959.6
z-mult: 02527      35  3.0  953.0  57.7  12.5        p-top: 500.0
T     : 26038      35  3.0  250.0  59.4  24.6  5.0 : T    207.1  212.4
T     : 26038      35  3.0  245.0  59.4  24.6  5.1 : T    206.7  212.5
T-mult: 26038      35  3.0  250.0  59.4  24.6        p-top: 150.0
dz    : 26038      35  3.0  250.0  59.4  24.6  96.9  p-top: 100.0  : dz -119.9, dT-mean  -4.5
ps-scc: 14427      11  3.0 1011.8  43.8  15.2  3.4 : ps 1011.8 1015.3 , bias|w2:   0.1  12.0
ps-scc: 16584      14  3.0 1011.9  41.1  16.8  3.6 : ps 1011.9 1008.3 , bias|w2:  -0.3   9.3
```

Figure 8.9: Example file `YUQUCTL`.

by the absolute value of the difference vector (in [m/s]). For relative humidity (in [ ]), the temperature values (in [K]) are also provided if the humidity observation is rejected only due to the rejection of the corresponding temperature observation. The same applies to aircraft temperature, if it is rejected due to the rejection of the wind observations, and vice versa.

The entry '`ps-scc`' usually denotes a (surface) pressure report which after passing the individual threshold quality control is rejected by the spatial consistency check. However, if the entry follows immediately the entry '`ps`' for the same report (e.g. report '`16080`' in Figure 8.9), it implies that the spatial consistency check accepts the observation by cancelling the rejection suggested by the individual threshold quality control. The '`ps-scc`' lines are always complemented with the value for the bias correction applied to the model value used in the check, and with the total weight of the observations used to determine this bias. The same as for '`ps-scc`' applies to entry '`IWV-sc`', if it is related to a ground-based GPS observation. '`IWV-sc`' can also occur for a radiosonde report – in this case, this means that the whole humidity profile report is rejected.

In the case of the entry '`z`', the height observation increment as derived hydrostatically from multi-level temperature increments (and possibly a surface pressure increment) exceeds the threshold at the given pressure level. This implies that all temperature, humidity, and geopotential data from that level up to the top level '`p-top`' of the multi-level profile are set passive. Similarly, the entry '`dz`' means that these types of data are rejected due to the hydrostatic thickness check between the given pressure level and the pressure level '`p-top`' which in this case does not coincide with the top level of the report in general. The specification of the threshold and the thickness increment is complemented here by the mean temperature increment '`dT-mean`' corresponding to the thickness increment within the given vertical range.

Finally, the entries '`V-mult`', '`T-mult`', '`q-mult`', and '`z-mult`' indicate that the corresponding observations are set passive in the given pressure range due to the multi-level check. While rejection of temperature implies rejection of humidity, rejection of height does not imply rejection of temperature here.

8.2.5 `YUCAUTN` — Nudging: Warning Messages on Insufficient Array Sizes

The size of arrays which are used to store non-gridded observational information are a function of several `NAMELIST` parameters. This means that the values of these `NAMELIST` parameters determine the size of these arrays. If the values are too small, there are various places in the program, where such arrays may fail to accommodate all the available data. In such a case, the program will not crash or stop, but it will simply omit the surplus data and issue warning messages which always contain the label '`CAUTION`'. This allows to '*grep*' for it (yet there may be also other types of messages containing the word '`CAUTION`'). Messages on short array sizes related to individual observational reports are written to the files `YUREJCT` (see section 8.2.3), `YUPRINT` (section 8.2.8), and / or to the standard output. The messages on `YUPRINT` are written by one processing unit and often take into account only one sub-domain on distributed-memory machines. In contrast, the whole model domain is considered by the messages on `YUREJCT` and the standard output. In addition, there are summary '`CAUTION`' messages related to insufficient array size occurring in any of the sub-domains written to the files `YUSTATS` (section 8.2.6) and `YUCAUTN`.

In an operational setting, it is important that the model does not crash due to insufficient

```
CAUTION !!!!! t=    0: 1923 LOCAL SINGLE-LEVEL OBS. BEYOND maxsgl  5573
   ==>  INCREASE NAMELIST VARIABLE maxsgo BY AT LEAST  1381
CAUTION !!!!! t=    0:   88 LOC MULTI-LEV. AIRCRAFT REPORTS BEYOND ARRAY SIZE
CAUTION !!!!! t=    0:  203 LOCAL MULTI-LEVEL OBS. BEYOND maxmll   244
   ==>  INCREASE NAMELIST VARIABLE maxmlo BY AT LEAST   292
CAUTION !!!!! t=    0:  980 LOCAL GPS (IWV) OBS. BEYOND maxgpl  3344
   ==>  INCREASE NAMELIST VARIABLE maxgpo BY AT LEAST   587
...
CAUTION !!!!! t=   90: 2617 UPPER-AIR SINGLE-LEVEL OBS. INCR., ARRAY SIZE  2500
   ==>  INCREASE NAMELIST VARIABLE maxuso BY AT LEAST   117
CAUTION !!!!! t=  162: 4372 SURFACE PRESSURE OBS. INCREMENTS, ARRAY SIZE  4350
   ==>  INCREASE NAMELIST VARIABLE maxsgo BY AT LEAST    22
CAUTION !!!!! t=  270: 1374 MULTI-LEVEL STATIONS OF OBS. INCR., ARRAY SIZE  1351
   ==>  INCREASE NAMELIST VARIABLE maxmlo, maxgpo OR maxtvo BY AT LEAST    23
...
CAUTION !!!!! t=  252: 2452 IWV INCREMENTS FOR HUMIDITY CHECK, ARRAY SIZE  2350
   ==>  INCREASE NAMELIST VARIABLE maxmlo OR maxgpo BY AT LEAST   102
...
CAUTION !!!!! total number of reports  35088 > FOF size max_rep = 25056
   ==>  INCREASE SUM OF NAMELIST VARIABLES maxmlo + maxsgo + 2*maxgpo + 2*maxtvo
        BY AT LEAST   3344 FOR NetCDF FEEDOBS FILE fof_*
...
```

Figure 8.10: Example file `YUCAUTN`.

array size. Otherwise, any simple increase from one day to the next of the number of observations that are input to the data assimilation scheme could potentially cause a crash of the operational suite. Omitting the (presumably rather small number of) surplus observations will usually lead only to a minor degradation of the analysis, if at all. On the other hand, it should be made sure that the data assimilation does not run for weeks or months with too small array sizes.

The file '`YUCAUTN`' serves this purpose. It is not created at all, except if one of the following two events occurs. Either there is an insufficient array size related to observational information, or an observation with unknown observation type has been read. Thus, if the file `YUCAUTN` is produced by the COSMO model, this implies that action needs to be taken to ensure an optimal use of the data in subsequent data assimilation cylces. (At DWD, e-mails are sent automatically to responsible persons if the file `YUCAUTN` is created in the operational suite or even in an experiment by the experimentation system NUMEX.)

If an unknown observation type is found, the reason has to be investigated. The event may indicate that there is a problem with the observation data base or with a pre-processing step before the data are read by the COSMO model. If an array size is too small, the value(s) of some `NAMELIST` parameter(s) have to be increased appropriately (this requires testing that there is enough memory available on the processors of the computer). File `YUCAUTN` also provides recommendations on how much to increase the value of which `NAMELIST` parameter. Even though the recommended increase is often sufficient to obtain appropriate array sizes everywhere, this is not always the case, particularly in situations where several arrays are too small for several reasons and the surplus data add to each other. Note that similar types of messages and recommendations are also given in file `YUSTATS` (see Section 8.2.6).

Figure 8.10 shows excerpts of an example file. Each message contains the model timestep (after '`t=`'), at which the message was issued. While in a real `YUCAUTN` file, the messages are ordered according to the timestep, they have been ordered thematically in the example shown here for convenience.

The first group of 4 messages relates to the observation reports themselves. After reading, the observations to be used at a certain timestep or later on are stored in arrays called 'observation data record' (ODR). The ODR is a local array, i.e. at each local node on a distributed-memory computing platform, only the data related to the respective model sub-domain are stored. The size of the ODR arrays depends on the `NAMELIST` parameters '`maxsgo`' for single-level reports, '`maxmlo`' for multi-level reports, and '`maxgpo`' for GPS ZTD (or IWV) reports. The second message in Figure 8.10 simply means that the ODR size for multi-level reports is too small in order to accommodate all multi-level aircraft reports which could have been created from the input single-level reports. In this case, the aircraft reports do not have to be omitted (unless '`maxsgo`' is also too small), but they are assimilated as single-level reports rather than multi-level reports as preferred.

The second group of 3 messages relates to the arrays containing the observation increments from the total model domain used at a certain timestep. There are four types of sets of increments in the scheme and hence four types of families of arrays in the code: multi-level, upper-air single-level, surface-level, and surface pressure increments. The length of the respective arrays correspond to the number of stations (in case of temporal linear interpolation) or reports (otherwise) with active observation increments (or reports to be written to the `YUVERIF` or NetCDF feedobs files). These lengths are given by the `NAMELIST` parameters '$\texttt{maxmlo} + \texttt{maxgpo}/2 + 1$' for multi-level, '`maxuso`' for upper-air single-level, '`maxsgo`' for surface level, and '$\texttt{maxsgo} + \texttt{maxmlo}$' for surface pressure increment arrays. Note that e.g. from the GPS ZTD observations, profiles of humidity increments are derived. Therefore, the size of the multi-level increment arrays also depends on '`maxgpo`'.

The next message relates to an array that is used purely for the spatial consistency quality check for integrated water vapour (IWV) derived from GPS ZTD and from radiosonde humidity profile data. The final message in Figure 8.10 indicates that there is insufficient space in the NetCDF feedobs file to write all the observations onto that file.

8.2.6 `YUSTATS` — Nudging: Statistics on Observation Processing

`YUSTATS` provides statistics on the processed observations and on the analysis increments accumulated over time. It consists of several parts.

In the first part (Figure 8.11), the domain-averged analysis increments integrated over time since the beginning of the model integration are provided once every hour (the last hour is written almost at the end of the file). For the 3-dimensional variables wind speed '`|v|`', wind direction, temperature '`T`', pressure '`p`', geopotential '`FI`', specific water vapour content '`qv`', and specific cloud water content '`qc`', this information is given for each vertical model level separately, and this results in vertical profiles of the domain averaged analysis increments. Note that the time integrated values are obtained by updating them with the analysis increments from the nudging (without the latent heat nudging) at each model timestep, i.e. it is the sum over the nudging increments from every timestep. This can be very different from the difference 'analysis minus first guess', if 'first guess' is e.g. a 3-hour free forecast. The reason is that the model dynamics and physics can react to the changes of the model state from the nudging by producing modfied dynamics and physics tendencies in the subsequent timestep(s).

The second part of `YUSTATS` (Figure 8.12) shows the number of processed, active, passive, and rejected reports for each observation type and code type. The meaning of the type numbers is also specified. The third part (Figure 8.13) first mentions the conditions for a report to be set passive rather than rejected. In contrast to rejected reports, passive reports are processed further for being written to the VOF file `YUVERIF` and / or the NetCDF feedobs file for verification purposes (if `NAMELIST` variable '`lverpas`' is set to '`.TRUE.`'). The subsequent '`REPORT EVENTS`' table declares the reasons in a statistical sense (rather than for each individual report), why a certain number of the reports of a certain code type is set passive or rejected. Further report events relate mainly to the processing of aircraft reports. The '`DATA EVENTS`' tables in the forth part (Figure 8.14) provide similar statistical information on the reasons for rejecting parts of reports, i.e. either complete observation levels or single observations.

The fifth part (Figure 8.15) finally delivers the hourly maximum total number of stations (in case of temporal linear interpolation) or reports (otherwise) with active observation increments. There are four types of sets of increments in the scheme and hence four types of families of arrays in the code: multi-level, upper-air single-level, surface-level, and surface pressure increments. The length of the corresponding arrays, listed in the table as '`array bounds`', are a function of `NAMELIST` parameters: '`maxmlo`+`maxgpo/2`+`1`' for multi-level, '`maxuso`' for upper-air single-level, '`maxsgo`' for surface level, and '`maxsgo`+`maxmlo`' for surface pressure increment reports.

If the array lengths which depend on the selected values of these `NAMELIST` parameters are not sufficiently large, there are various places in the program, where arrays may fail to accommodate all the available data. The program will not crash or stop in such a case, but it will simply omit the surplus data and issue warning messages which always contain the label '`CAUTION`'. For more information on this concept, see Section 8.2.5. As already mentioned there, summary messages are also written to `YUSTATS`. As shown in Figure 8.16, there are two types of messages. The first one relates to the arrays which store internally the observation

```
1     Diagnostics on time-integrated analysis increments
      2009022409 + 2 h: horizontal mean of  2-hourly sums of analysis increments
                        TQV [g/m2]    TQC [mg/m2]       Dry Static Energy [J/kg]
                       -389.070       7539.854               0.003 (volumn mean)
      level p0(k)    |v|    wind dir    T        p        FI      qv       qc
            hPa      m/s       deg      K       hPa     m2/s2    g/kg    mg/kg
       1    30.00   -0.174   -14.29    0.728     0.13    211.7    0.000    0.000
       2    50.18   -0.074   -73.22    1.228     0.08     88.7    0.000    0.000
       3    70.87   -0.025  -124.75   -0.064     0.04     32.7    0.000    0.000
       4    92.35    0.241   -46.38   -0.176     0.06     41.5    0.000    0.000
       5   114.84    0.150    -5.74    0.186     0.07     41.1    0.000    0.000
       6   138.49    0.096     8.00    0.267     0.06     28.1    0.000    0.000
       7   163.43    0.247    -5.58    0.695     0.01      3.9    0.000    0.000
       8   189.73    0.377   -23.58    0.051    -0.04    -13.5    0.000    0.000
       9   217.42    0.302     7.52   -0.379    -0.02     -6.9    0.000    0.000
      10   246.48    0.227   -10.69   -0.273     0.02      4.5    0.000    0.000
      11   276.87    0.144    -8.65   -0.221     0.06     12.4   -0.001    0.000
      12   308.52    0.109    -6.54   -0.232     0.10     19.8   -0.002    0.002
...
      29   867.95   -0.017    37.67    0.046     0.18     16.2   -0.067    4.879
      30   890.50   -0.021    44.06    0.045     0.18     15.9   -0.084    7.029
      31   910.85   -0.021    38.69    0.109     0.18     15.5   -0.122    3.819
      32   928.96   -0.031    69.08    0.146     0.18     14.9   -0.109    1.592
      33   944.79   -0.092    76.08    0.138     0.17     14.3   -0.101    0.094
      34   958.36   -0.207    50.72    0.138     0.17     13.9   -0.083   -0.338
      35   969.73   -0.301    20.85    0.175     0.16     13.5   -0.075   -0.007
      36   979.00   -0.339    -1.08    0.216     0.16     13.0   -0.069    0.544
      37   986.31   -0.353   -19.18    0.249     0.15     12.6   -0.070    0.494
      38   991.87   -0.366   -37.67    0.255     0.15     12.2   -0.088    0.447
      39   995.93   -0.375   -51.05    0.251     0.15     12.0   -0.092    0.369
      40   998.82   -0.377   -63.93    0.251     0.10      8.0    0.095   -0.121
```

Figure 8.11: Example file `YUSTATS`, first part (incomplete).

```
1
0 ---DISTRIBUTION OF PROCESSED/ACTIVE/PASSIVE/REJECTED REPORTS FOR ASSIMILATION
0                                           processed   active  passive rejected
0
0 --- total number of reports                   59556    38808    14041    11437
      reports with unknown obs/code type            0        0        0        0
0 --- observation type 1    SYNOP               16011    11860     1025     4959
      code type  11      SYNOP Manual Land       5955     4951      457     1025
      code type  14      SYNOP Automatic Land    9430     6418      537     3830
      code type  21      SHIP                     126       90        6       30
      code type  22      SHIP Abbreviated           0        0        0        0
      code type  23      SHIP Reduced SHRED         0        0        0        0
      code type  24      SHIP Automatic           500      401       25       74
      code type 140      METAR                      0        0        0        0
0 --- observation type 2    AIREP               11716    10214      926      576
      code type  41      CODAR                      0        0        0        0
      code type 141      AIREP Aircraft           386      178        9      199
      code type 144      AMDAR                   4721     4167      321      233
      code type 244      ACARS                   6609     5869      596      144
      code type 241      COLBA Const Lev Ball       0        0        0        0
0 --- observation type 3    SATOB                   0        0        0        0
0 --- observation type 4    DRIBU                 778      138        0      640
      code type  63      BATHY                      0        0        0        0
      code type 165      DRIBU Drifting Buoy      778      138        0      640
0 --- observation type 5    TEMP                  549      114        1      434
      code type  35      TEMP Land                531      111        0      420
      code type  36      TEMP SHIP                 18        3        1       14
      code type  37      TEMP Mobile                0        0        0        0
      code type  39      ROCOB Land                 0        0        0        0
      code type  40      ROCOB SHIP                 0        0        0        0
      code type 135      TEMP DROP                  0        0        0        0
0 --- observation type 6    PILOT                1389      601      740      262
      code type  32      PILOT Land                25        2        3       20
      code type  33      PILOT SHIP                 0        0        0        0
      code type  38      PILOT Mobile               0        0        0        0
      code type 132      Wind Profiler (Eur)      235      107      128        0
      code type 133      RASS / SODAR  (Eur)       40        4       36        0
      code type 136      Wind Prof/RASS (US)        0        0        0        0
      code type 137      RADAR VAD Wind Prof.    1089      488      573      242
0 --- observation type 7    SATEM                   0        0        0        0
0 --- observation type 9    Scatterometer        1322     1145        0      177
      code type 123      ASCAT scatterometer     1322     1145        0      177
      code type 122      QuickScat scatterom.       0        0        0        0
0 --- observation type12    GPS                 27791    14736    11349     4389
      code type 800      GPS by METO             4270     2127     2097      347
      code type 900      GPS by MET_                0        0        0        0
      code type 821      GPS by ASI_              939      152      727      162
      code type 823      GPS by GFZ_                0        0        0        0
      code type 824      GPS by GOP_              352      153      199       46
      code type 924      GPS by GOPE                0        0        0        0
      code type 825      GPS by IEEC                0        0        0        0
      code type 826      GPS by LPT_              802      406      188      308
      code type 926      GPS by LPTR             1800      722      607      833
      code type 829      GPS by SGN_             3581     2483      906      519
      code type 929      GPS by SGN1             3335      600     2567      377
      code type 830      GPS by BKG_              564      548        4      143
      code type 930      GPS by BKGH                0        0        0        0
      code type 832      GPS by ROB_                0        0        0        0
      code type 833      GPS by KNMI             1122      683      439      228
      code type 933      GPS by KNM1              621      376      245      106
      code type 834      GPS by NGAA             4602     4094      400      184
      code type 934      GPS by NGA_                0        0        0        0
      code type 835      GPS by IGE_             2424     1228      917      579
      code type 837      GPS by ROB_             3379     1164     2053      557
      code type 899      GPS by XXX_                0        0        0        0
0
  --- Notes on the table above:
      "Rejected"/"passive" means that the whole report is rejected /set passive.
      Partly rejected and partly passive reports are labeled "active".
      A report can be labeled "active" even if part of its data is black listed.
```

Figure 8.12: Example file `YUSTATS`, second part.

```
      Reports may only be rejected or set passive for reasons given by report
        events 1 - 13 , except for events 3 and 5 (on station altitude) for
        TEMPs and PILOTs. Hence, the number of these events must equal the
        number of rejected and passive reports.
      In the verification mode (i.e if data are written to the VOF), reports are
        rejected in case of report events 1 - 3, 8 - 13, and event 4 if the re-
        port is outside the model domain. Otherwise the reports are set passive,
        except that already passive reports are also rejected if they do not
        contain any data or if they are redundant and a subset of an active
        report.
        Without verification, reports are always rejected for events 1 to 13.
0
1 *** REPORT EVENTS DEFINITIONS (THEIR ORDER MATCHES THE ORDER OF THE CHECKS):
         1 = DATA BASE FLAG ON LOCATION / TIME / ALTITUDE HIGH
         2 = OBSERVATION TIME OUT OF RANGE (TOO OLD) (OR TIME MISSING)
         3 = STATION ALTITUDE MISSING
         4 = STATION LOCATION OUT OF DOMAIN OR OUT OF USER-SPECIFIED AREA
         5 = DISTANCE "MODEL OROGRAPHY - STATION ALTITUDE" TOO LARGE
         6 = BLACKLISTED SHIP
         7 = OBSERVATION OR CODE TYPE EXCLUDED IN AREA AROUND STATION LOCATION
         8 = REPORT NUMBER EXCEEDING SIZE OF ODR (==> ADJUST NAMELIST !!!)
         9 = NO ACCEPTED DATA IN REPORT
        10 = PRESSURE TOO SMALL ( < 9 HPA), OR MISSING WITH AIRCRAFT REPORT
        11 = REDUNDANCY BETWEEN 2 MULTI-LEVEL, OR 2 SINGLE-LEVEL REPORTS
        12 = FLIGHT TRACK SUSPICIOUS, OR EXAGGERATED COLOCATION
        13 = THINNING OF DENSE AIRCRAFT FLIGHT TRACK
        14 = SURFACE LEVEL FROM MULTI-LEVEL REP. REDUNDANT AGAINST OTHER REPORT
        15 = ONE MULTI-LEVEL REPORT MADE FROM SINGLE-LEVEL REPORTS
        16 = SINGLE-LEVEL REPORT PUT IN MULTI-LEVEL REPORT AND SET PASSIVE
        17 = MULTI-LEVEL REPORT NOT BUILT DUE TO ODR SIZE LIMIT: ADJUST NAMELIST
0
     events        1  2   3    4   5  6    7  8    9 10   11  12   13 14  15   16 17
   ------
0 *SYNOP
SYNOP Manual Land  0  0   0  496 329  0    0508   54  0  125   0    0  0   0    0  0
SYNOP Automatic L  0  0   0   81 415  0    0*** 2439  0   77   0    0  0   0    0  0
SHIP               0  0   0   30   6  0    0  0    0  0    0   0    0  0   0    0  0
...
SHIP Automatic     0  0   0   15   7  0    0  0   59  0   18   0    0  0   0    0  0
0 *AIREP
CODAR              0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
AIREP Aircraft     0  0   0  199   0  0    0  0    4  0    3   0    2  0   0    0  0
AMDAR              0  0   0  233  67  0    0  0    0  0  185   0   69  0 342 2359 38
ACARS              0  0   0  144  50  0    0  0    3  0  109  40  394  0 148 1632 87
COLBA Const Lev B  0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
0 *SATOB
SATOB              0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
High-res VIS Wind  0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
AMV                0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
SST as DRIBU       0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
0 *DRIBU
BATHY              0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
DRIBU Drifting Bu 18  0   0  399   0  0    0  0  223  0    0   0    0  0   0    0  0
0 *TEMP
TEMP Land          0  0   0  116   0  0    0  0   71  0    7   0    0139   0  226  0
TEMP SHIP          0  0  18    4   2  0    0  0    3  0    0   0    0  0   0    6  0
...
0 *PILOT
PILOT Land         0  0   0   12   0  0    0  0    5  0    4   0    0  0   0    2  0
PILOT SHIP         0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
PILOT Mobile       0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
Wind Profiler (Eu  0  0   0    0   7  0    0  0   87  0   41   0    0  0   0    0  0
RASS / SODAR  (Eu  0  0   0    0   0  0    0  0   36  0    0   0    0  0   0    0  0
Wind Prof/RASS (U  0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
RADAR VAD Wind Pr  0  0   0    0  96  0    0214  584  0   17   0    0  0   0    0  0
0 *SATEM
...
0 *Scatterometer
ASCAT scatteromet  0  0   0  177   0  0    0  0    0  0    0   0    0  0   0    0  0
QuickScat scatter  0  0   0    0   0  0    0  0    0  0    0   0    0  0   0    0  0
0 *GPS
GPS by METO        0  0   0   46  92  0    0301    0  0 2005   0    0  0   0    0  0
...
GPS by LPT_        0  0   0   36 144  0    0116   28  0  188   0    0  0   0    0  0
GPS by LPTR        0  0   0    0 400  0    0425   71  0  607   0    0  0   0    0  0
GPS by BKG_        0  0   0    0  12  0    0133    0  0    4   0    0  0   0    0  0
...
```

Figure 8.13: Example file `YUSTATS`, third part (incomplete).

reports themselves from the local sub-domain, and the second one to arrays containing the observation increments from the total model domain that are used at a certain timestep. Both types of events, the relation to certain `NAMELIST` parameters, and considerations on the recommendations on how much to increase the values of these parameters are already decribed in detail in Section 8.2.5.

```
1 *** DATA EVENTS DEFINITIONS (LEVEL EVENTS APPLY TO MULTI-LEVEL DATA ONLY,
                               THE ORDER OF ALL EVENTS MATCHES THE ORDER OF
                               THE CHECKS EXCEPT FOR EVENT 8
         1 = LEVEL REJECTED: NUMBER OF LEVELS EXCEEDING ODR SIZE
         2 = LEVEL REJECTED: PRESSURE (PILOT: PRESSURE AND HEIGHT) MISSING
         3 = LEVEL REJECTED: PRESSURE (PILOT: HEIGHT) FLAGGED
         4 = LEVEL REJECTED: TOO MANY SURFACE LEVELS
         5 = LEVEL REJECTED: PILOT HEIGHT LEVEL OUTSIDE RANGE OF MODEL LEVELS
         6 = LEVEL REJECTED: PRESSURE < 9 HPA, OR LEVEL BELOW STATION HEIGHT
         7 = LEVEL REJECTED: SIGNIFICANT LEVEL ABOVE A SPECIFIED LIMIT
         8 = LEVEL REJECTED: REDUNDANT LEVEL IN REPORT  (NOT ACTIVE YET)
         9 = PRESSURE (TEMP: HEIGHT): MISSING
        10 = PRESSURE (TEMP: HEIGHT): FLAGGED
        11 = PRESSURE: BAD REPORTING PRACTICE
        12 = PRESSURE: HEIGHT DISTANCE TO OROGRAPHY OR STATION HEIGHT TOO LARGE
        13 = PRESSURE TENDENCY: FLAGGED, OR ABSOLUTE VALUE > 40 HPA/3H
        14 = TEMPERATURE: MISSING (TEMP: AT SIGNIFICANT TEMPERATURE LEVELS ONLY)
        15 = TEMPERATURE: FLAGGED
        16 = TEMPERATURE: < -90 C,  OR  > +60 C  (P < 700HPA: > +20 C , ETC)
        17 = TEMPERATURE AT 2M: HEIGHT OR HEIGHT DISTANCE TO OROGRAPHY TOO LARGE
        18 = TEMPERATURE (TEMP ONLY): LAPSE RATE TOO LARGE
0
    events         1  2  3 4  5   6    7  8    9  10 11  12 13   14 15 16   17 18
   ------
0 *SYNOP
SYNOP Manual Lan   0  0  0 0  0   0    0  0  129  20  2 257  0   36  0  0  200  0
SYNOP Automatic    0  0  0 0  0   0    0  0 4303  13  0 111  0 2569  0  0  119  0
SHIP               0  0  0 0  0   0    0  0    1   4  0   0  0    0  0  0    0  0
...
TEMP Land         38  1  0 0  0 216 3402  0 4212  77  0   0  0  519 93  0    0 18
...
GPS by LPTR        0  0  0 0  0   0    0  0 1038   0  0   0  0 1038  0  0    0  0
...
...
1 *** DATA EVENTS DEFINITIONS (CONTINUED):
        19 = HUMIDITY: MISSING (TEMP: AT SIGNIFICANT LEVELS BELOW 300 HPA LEVEL)
        20 = HUMIDITY: FLAGGED
        21 = HUMIDITY: DEWPOINT < -150 C (SURFACE-LEV OBS: < -90 C), OR > +40 C
        22 = HUMIDITY: ABOVE 300 HPA LEVEL
        23 = HUMIDITY: EXCEEDING ALLOWED VALUE (120%)
        24 = HUMIDITY: FORCED TO BE SATURATED (T>0)
        25 = HUMIDITY: FORCED TO BE SATURATED (T<0)
        26 = HUMIDITY: FORCED TO BE <= 100% (T>0)
        27 = HUMIDITY: FORCED TO BE <= 100% (T<0)
        28 = HUMIDITY AT 2M: HEIGHT OR HEIGHT DISTANCE TO OROGRAPHY TOO LARGE
        29 = WIND DIRECTION: MISSING
        30 = WIND SPEED: MISSING
        31 = WIND DIRECTION: FLAGGED , OR ABSOLUTE VALUE > 360 DEGREES
        32 = WIND SPEED: FLAGGED
        33 = WIND SPEED: < 0 (DRIBU: <= 0) , OR > 150 M/S (P > 700HPA: > 90 M/S)
        34 = WIND AT 10M: HEIGHT OR HEIGHT DISTANCE TO OROGRAPHY TOO LARGE
        35 = WIND SPEED: SHEAR TOO LARGE
        36 = WIND DIRECTION: SHEAR TOO LARGE
        37 = PRECIPITATION: AMOUNT EXCEEDING THRESHOLD LIMIT
        38 = ZENITH PATH DELAY MISSING OR TOO SMALL
0
   events        19 2021   22 23  24  2526  27  28  29  30 31 32 33   3435 36 37   38
   ------
0 *SYNOP
SYNOP Manual La  67  1 0    0 16 178  49 0   0 200  47  58  0  0  0 2739 0  0  0    0
SYNOP Automatic2623  1 0    0  0 190 102 1   1 11435573559  0  0  0 1851 0  0  0    0
SHIP             13  0 0    0  0   3   0 0   0   0   0   0  0  0  0    3 0  0  0    0
...
TEMP Land         0 43 0 1214  0  23  69 0   0   0  95  95 24 24  0   99 1  0  0    0
...
GPS by LPTR       0  0 0    0  0   0   0 0   0   0   0   0  0  0  0    0 0  0  0   71
...
```

Figure 8.14: Example file `YUSTATS`, forth part (incomplete).

```
1
0 ---HOURLY MAX. TOTAL NUMBER OF STATIONS WITH ACTIVE OBSERVATION INCREMENTS
+                (only for MPP applications)
+ ---                   multi-   |  upper-air   | surface- | surface
+                       level    | single-level |  level   | pressure
+      1. hour :          1224         2608         3589       3960
+      2. hour :          1331         2617         3995       4372
+      3. hour :          1293         2550         3995       4439
+      4. hour :          1374         2531         3428       4115
+     total max.  :       1374         2617         3995       4439
+     array bounds:       1351         2500         4000       4350
```

Figure 8.15: Example file `YUSTATS`, fifth part.

8.2.7 `YUVERIF` — Nudging: Verification File VOF

`YUVERIF` is called 'Verification Observation File' VOF and lists all the active observations, of which the observation time lies within a selected period between the beginning and the end of the model integration time. It is important to note that under normal circumstances it never lists all the observations which are used actively in the nudging (and which e.g. enter the statistics shown in file `YUSTATS`). This is due to the use of a finite temporal weight function for the relaxation, so that the nudging also uses data that are older than the beginning of the model integration time. In a data assimilation cycle, moreover, it normally also uses data with observation time later than the end of the model run. These data outside the model integration time are never written to `YUVERIF`.

`YUVERIF` is written only if the `NAMELIST` variables '`lverif = .TRUE.`' and '`mveripr` ≥ 2'. Passive reports and the deviations of the observed values from the model values, i.e. the observation increments, are optionally included. Furthermore, `YUVERIF` can be post-processed

```
+     !!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!!
+     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
0     WARNING: array size for multi-level observations is too small
      =======  to accommodate all observations
       --> Increase "MAXMLO" (namelist) by  312: usually ok for local obs. array
           =================                    (possibly still insufficient for
                                                the global obs increment array!)
...
0     WARNING: array size for GPS observations is too small
      =======  to accommodate all observations
       --> Increase "MAXGPO" (namelist) by 1190: usually ok for local obs. array
           =================                    (possibly still insufficient for
                                                the global obs increment array!)
...
1
0     !!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!! CAUTION !!!!!
+     ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
+     WARNING: array size for multi-level obs. increments is
      =======  too small to accommodate all obs. increments
        -->  Increase "MAXMLO" (namelist) from 350 to at least 373
          or increase "MAXGPO" (namelist) from2000 to at least2046
          or increase "MAXTVO" (namelist) from   1 to at least  24
             =================
+     WARNING: array size for upper-air single-level obs. increments is
      =======  too small to accommodate all obs. increments
        -->  Increase "MAXUSO" (namelist) from 2500 to at least 2617
             =================
+     WARNING: array size for surface-level obs. increments is
      =======  too small to accommodate all obs. increments
        -->  Increase "MAXSGO" (namelist) from 4000 to at least 4089
             =================
```

Figure 8.16: Example file `YUSTATS`, warning messages related to specified array sizes.

```
VOF: Verification Observation File: Version 3
Verification period: initial date and hour 2009022409
                     start: 0.0000 , end:  3.0000
Set-up of the reference model run, used for threshold quality control (QC):
- LM-grid: pole:  40.00 -170.00 , lower left corner:  -20.000  -18.000
           resolution: 0.06250 0.06250 , upper right:  21.000   23.500
           domain size:  665  657  40
- Initial date and time: 2009022409
- QC time step :   720. [s]
- QC thresholds: upper-air, vertical table:    5.00    1.00   10.00    1.00
                 upper-air, constant part :    0.00  500.00    0.00    0.00
                 upper-air, time factor   :    0.10    0.20    0.10    0.03
                 surface  , constant part :   12.00  500.00   12.00    0.70
                 surface  , time factor   :    0.10    0.20    0.10    0.03

Number of model runs to compare with observations: 1
Domain used for verification (rotated pole: see above):
     lower left corner: -20.000 -18.000 , upper right:  21.000  23.500
     domain size:  665  657
Types assigned to "model runs" in table below:
     = 0: the "model run" is one straightforward model integration
     > 0: the "model run" comprises of x-hourly periods from a series of cycled
          integrations starting at x-hour intervals (x = 6, 12 or 24), and
          the initial date and time relates to the latest of these integrations
     = 2: the "model run" is a series of analyses
        |             |forecast time | horiz. | number |
 model  |   initial   |at the end of | mesh   |   of   |
  run   |date and hour| verification | width  |vertical| description of
no.|type| of the run  | period [hrs] |[1/deg.]| levels | the model run
 1   02   2009022412        0.0000      16.00     40     analysis

  -4 COMO-METO    910  4580    30   247   293 12 800        102       2000 2  0  279  253
  603  650   -9   -9     -9  2286   32    0          0  64  42
    78
  -4 COMO-SGN_    910  4580    30   247   293 12 829        102       2000 2  0  279  253
  433 9999   -9   -9     -9  2275   32    0          0  64  -9
   -92
  -4 COMO-BKG_    910  4580    30   247   293 12 830          0          0 0  0  279  253
  411 9999   -9   -9     -9  2274   32    0          0  64  -9
  -114
  -1 004          337  5446    98     0     0  9 123        200          0 0  0  227  395
   47    5   -9   -9     -9     0    1    0          0  64  -9 -9   -9 17777777777 17777777777   -9
   -30   117  9999 9999  9999  -9  -9   -9   -9
  -1 63551         84  6746   120     0     0  4 165        200          0 0  0  230  604
 9999 9999   -9   -9 101510     0    8    0          0  64 510 -9   -9 17777777777  1777777777   -9
  9999  9999  9999 9999   -58  -9  -9   -9   -9
   0 07497        677  4562   120   868  1649  1  11        412         40 2  2  253  252
  -10    2 2785  522  91790   868    0    0  203004020   1 501  3 2500 17714653400  1766252774   -9
   -9   -9   -9   2  -9   -9
   -90     9   692  -27    48  13    0   -9   -9 9999 9999 9999 9999 9999
  -1 Q671         948  4839   120   750   749  1  14          0          0 0  0  284  295
    7  -19 2726 1000     -9   750    6    0         20    1  -9 -9   -9 17777777777  1762277775   -9
  -174   211   -40   15  9999  -9  -9   -9   -9
  -3 EU5331      1215  4842   152  -999   495  2 244  140000000          0 0  0  312  296
    1  -26 2685  655  88251  1150    7    0  400140600 384  -9
   156    91   -18 -118
  -3 EU5331      1207  4839   153  -999   481  2 244  140000001      10000 1  0  311  295
    6  -35 2693  585  88251  1150    7    0  400140600 384  -9
   158   -18    69 -240
   6 EU5331      1207  4839   153  -999   481  2 244  140000000          0 0  4  311  295
    6  -35 2693  585  88251  1150    7    0  400140600 384
    3  -26 2690  629  88144  1160    7    0  400140600 384
    7  -35 2680  570  86970  1270    7    4  400140600 384
   -1  -31 2670  639  85808  1380    7    4  400140600 384
    2  -41 2665  624  84868  1470    7    4  400140600 384
    4  -51 2655  667  84038  1550    7    4  400140600 384
   158   -18    69 -240  9999
   129    75    45 -199  9999
   191   -20    22 -291  9999
   135    63     6 -257  9999
   140    -6    18 -295  9999
   120   -78   -29 -270  9999
   9999
  -3 EU5331      1210  4840   153  -999   477  2 244  140000001      10000 1  0  311  296
    3  -26 2690  629  88144  1160    7    0  400140600 384  -9
   151    75    47 -178
  -3 EU5331      1212  4840   153  -999   495  2 244  140000102       2000 2  0  312  296
    2  -21 2688  640  88251  1150    7    0  400140600 384  -9
   173   142    12 -133
  -3 EU5331      1202  4837   154  -999   458  2 244  140000001      10000 1  0  310  295
   -1  -31 2695  543  88251  1150    7    0  400140600 384  -9
    56    16    95 -317
  -3 EU5331      1204  4839   154  -999   481  2 244  140000102       2000 2  0  311  295
    2  -31 2693  552  88251  1150    7    0  400140600 384  -9
   122    28    69 -274
  -9 xxxxx          0     0     0     0     0  0   0          0          0 0  0    0    0
```

Figure 8.17: Example file `YUVERIF`.

by means of additional programs to include also the deviations e.g. from different forecast runs and to derive statistical quantities. Thus, it can be used for monitoring, validation, and verification purposes.

Figure 8.17 shows a short example for `YUVERIF`. The file begins with a header part which is mostly self-explanatory. Note that the '`initial date and hour of the run`' entry in the table at the end of the file header relates to the formal initial time of the forecast, which is set to the final model integration time for an assimilating run. Then, the file body with the list of reports follows. In the current example, it consists of a subset of the reports already shown in Figures 8.6 and 8.7 for `YUOBSDR`, namely 3 GPS ZTD (IWV), 1 scatterometer, 1 buoy, 2 Synop, 6 aircraft single-level, and 1 aircraft multi-level report. The last line of the file has always the same form in order to indicate the end of file.

Each report consists of a report header, a regular report body, and an optional report body extension which contains the devations of the observed values from the model values. In the report header und regular body, there are entries consisting of long bit patterns. These entries are written to `YUVERIF` as octal numbers, so that each digit consists of 3 bits. This makes it easy to directly make out in the formatted ASCII file, which bits are set.

The following description details the VOF file body for the case that the observations are read from NetCDF observation input files. If the observations are read from an AOF file, not all the details are exactly as described here, particularly the flags.

Report Header

For each type of report, the header has the same format and consists of 15 entries in one line:

report header

1. basic report type: $> \ 0$: multi-level report : number of vertical levels
   $= \ 0$: complete synoptic surface-level report (SYNOP)
   $= -1$: short surface-level report (with cloud and precipitation)
   $= -2$: very short surface-level report (without cloud and precip)
   $= -3$: upper-air single-level report
   $= -4$: GPS report on integrated water vapour (IWV)
2. station identity
3. longitude of observing station [1/100 deg]
4. latitude of observing station [1/100 deg]
5. observation time, relative to initial verification hour (see VOF header) [min]
6. station altitude [m]
7. height of model orography at station location [m]
8. observation type (see Figure 8.12)
9. code type (see Figure 8.12)
10. station characteristics (bit pattern as octal number, see below)
11. report flag word (reasons for status ≥ 1) (bit pattern as octal number, see below)
12. report status $= 0$: active report, i.e. used by nudging (or LETKF)
    $= 1$: single-level aircraft set passive because used as part of a multi-level rep.
    $= 2$: passive report, i.e. not used by nudging (or LETKF)
13. threshold quality control (QC) flag for extrapolated surface pressure from multi-level radiosonde report $= 0$: active data used, value ok
    $= 1$: active data used, value not ok
    $= 2$: only passive data used, value ok
    $= 3$: only passive data used, value not ok
    $= 4$: no data at all usable

14., 15. x- resp. y-coordinate of model grid point to which report is assigned

The station characteristics is given by the following bit pattern (the description related to a bit number is true only if that bit takes the value of 1):

bit numbers of : **station characteristics**

0 : single-level report set passive because it is used as part of a multi-level report
1 : report set passive because at least 1 flag at positions 2−6 or 20−21 is set
2 : flag: station location outside of user-specified area
3 : flag: distance between model orography and station altitude too large
4 : flag: suspicious aircraft identity
5 : flag: observation or code type excluded at station location (user-specified)
6 : flag: redundant report
7 : report located at sea grid point
8 : station correction indicator
9 / 10 : station suspicion indicator / important station indicator
13−19 : instrument specification word (only for obs reports read from AOF file)
20 : flight track error flag
21 : flight thinning flag
22−25 : indicator for phase of flight (aircraft), code table WMO descriptor '0 08 004':
$= 2$: unsteady $= 3, 4$: level flight
$= 5$: ascending $= 6$: descending $= 7$: missing value
26−27 : aircraft roll angle (WMO descriptor '0 02 064', not used for report status)

The report flag word indicates all reasons why a whole report is not used actively in the assimilation (nudging or LETKF). This flag word is given by the following bit pattern (a flag is true if the bit is set to 1; the report flag is equal to the quality check flags for reports in the NetCDF feedobs file, see 'Feedback File Description'):

bit numbers of : **report flag word**
0 : passive report type (at observation location)
1 : blacklisted (or not on whitelist)
2 : suspicious location or date/time
4 : location not in valid area
5 : location not in valid height range
6 : incorrect surface (land, ice, etc.)
10 : redundant report
11 : flight track error flag
12 : report merged into another report (e.g. aircraft single-level into multi-level report)
13 : thinning
19 : no active observations in report

Note that the report flag word is written only if the observations are read from NetCDF observation input files. If the observations are read from an AOF file, a different flag word (not described here) is used.

Report Body

The regular report body contains all the observed values and the quality flags for the individual data. It has 22 entries for complete synoptic surface-level reports, the last 6 of which are written to the VOF in a second line. For the other basic types of reports, the last few entries are omitted in such a way that the body length is as follows:

body length = 22 : for complete synoptic surface-level reports
= 16 : for short surface-level reports (see also report header)
= 11 : for upper-air single-level or very short surface-level reports
= 10 : for (each observation level of) multi-level reports
= 11 : for ground-based GPS reports on ZTD / IWV (integ. water vapour)

For multi-level reports, the regular report body consists of as many lines with 10 entries each as there are observation levels. The following list declares the complete set of 22 entries:

regular report body

1.	zonal wind component	[1/10 m/s]
	(for GPS reports : derived IWV (ice-to-water saturat. + bias adjusted)	[1/100 mm])
2.	meridional wind component (GPS: reported IWV [1/100 mm])	[1/10 m/s]
3.	temperature	[1/10 K]
4.	relative humidity (ice-to-water saturation adjusted)	[1/10 %]
5.	pressure	[Pa]
6.	height (GPS: zenith total delay (ZTD) [mm])	[m]
7.	observation status flag (bit pattern as decimal number, see below)	
	(if bit is set to 1 then the obs is *active unless* – the QC flag is set, or – status ≠ 0 in report header)	
8.	QC flag (bit pattern as decimal number, see below)	
	(if bit is set to 1 then the obs is *rejected* by the threshold quality control; bit 3 for height is also set if upper-air obs is below model orography)	

9. main flag word for wind, temperat., humidity, pressure (as octal number, see below)
10. level identity (bit pattern) or pressure code (SYNOP) (as decimal number, see below)
11. (3-hourly) pressure tendency (GPS: zenith wet delay [mm]) [10 Pa/3h + 500]
12. low cloud cover [octas]
13. (horizontal) visibility [10 m]
14. combined cloud and weather group (code tables as octal number, see below)
15. SYNOP: combined weather & ground group (code tables as octal number, see below)
    single-level aircraft: degree of turbulence (WMO decriptor '0 11 031' as octal number)
16. precipitation amount rr over 12 hrs ('-1' denotes: $0 < rr < 0.1$ mm) [1/10 mm]
17. minimum temperature (at 2 m during past 12 hrs) [1/10 K]
18. maximum temperature (at 2 m during past 12 hrs) [1/10 K]
19. (only for AOF read :) min. ground temperature (at 5 cm in past 12 hrs) [1/10 K]
20. maximum wind speed of gusts over 1 hour [m/s]
21. maximum wind speed of gusts over 6 hrs [m/s]
22. (only for AOF read :) global radiation, sum over 1 hour [10 kJ/m2]

Missing values are denoted by $'-9'$ for quantities which do not take negative values, by $'-999'$ for height, and by $'9999'$ otherwise. Entries 7, 8, 9, 10, 14, and 15 are detailed by the following lists:

main flag word (entry 9)

main flag groups on : horiz. wind / temperature / humidity / pressure or geopot.
bit position for flag groups: 0 , 7 , 14 , 21
bit position within flag groups of 7 bits each (a 1-bit flag is set if the bit set to 1):

0 : – aircraft wind : roll angle (code table, WMO descriptor '0 02 064')
    – otherwise : 2-bit dataset quality flag (WMO descriptor '0 33 002':
        0 : data ok , 1 : data suspect , 3 : missing info ,
        set for aircraft, wind profiler, RASS data)
2 : blacklisted
3 : gross error
4 : not in valid height range :
    – surface-level data : height or height distance to orography too large
    – upper-air humidity: above 300 hPa level
5 : bad reporting practice :
    – SYNOP pressure : bad reporting practice
    – aircraft height : not measured, derived from p using std. atmosphere
    – upper-air height : without temperature obs
    – buoy wind : zero wind speed
    – radar VAD wind : small wind speed
    – aircraft wind : bad roll angle quality
    – dew point : temperature not active
    – mixing ratio : temperature or pressure not active
    – relative humidity : temperature not active (if needed)
    – generally : sensor not at appropriate height, or
        : measurement duration not appropriate
6 : – gross error for multi-level temperature or wind found in special check :
        - temperature : lapse rate check
        - horiz. wind : wind speed shear or directional shear check
    – (rel.) humidity : $> 96\,\%$ and bias-corrected to saturation
    – upper-air pressure : derived from reported height using model atmosphere

bit 28 (of main flag word): flag indicating observation level is below surface

bit numbers for : **observation status flag** (entry 7) and **QC flag** (entry 8)
0 : horizontal wind
1 : temperature
2 : humidity
3 : pressure (surface-level obs) / height (upper-air obs)
5 : IWV (vertically integrated water vapour)
6 : ZTD (zenith total delay of GPS signal)

level identity / **pressure code** (entry 10)

level identity (for non-SYNOP observations)		pressure code (for SYNOP observations)	
bit	meaning	code	meaning
0	maximum wind level	0	sea level
1	tropopause	1	station level pressure
2	TEMP D part	2	850 hPa level geopotential
3	TEMP C part	3	700 hPa level geopotential
4	TEMP B part	4	500 gpm level pressure
5	TEMP A part	5	1000 gpm level pressure
6	surface level	6	2000 gpm level pressure
7	significant wind level	7	3000 gpm level pressure
8	significant temperature level	8	8000 gpm level pressure
(several bits can be set at the same time)		9	900 hPa level geopotential
		10	1000 hPa level geopotential
		11	500 hPa level geopotential

combined cloud and weather group (entry 14)

bits	meaning	
0 – 3	type of high cloud	[VUB WMO Code table 0509]
4 – 7	type of middle cloud	[VUB WMO Code table 0515]
8 – 11	cloud base height	[VUB WMO Code table 1600]
12 – 15	type of low cloud	[VUB WMO Code table 0513]
16 – 19	cover of low cloud if > 0, else of middle cloud	[VUB WMO Code table 2700]
20 – 23	total cloud cover	[VUB WMO Code table 2700]
24 – 30	present weather	[VUB WMO Code table 4677]

combined weather and ground group (entry 15, for SYNOP obs)

bits	meaning	
0 – 8	present weather	[WMO descriptor ’0 02 003’]
9 – 13	past weather	[WMO descriptor ’0 02 004’]
14 – 19	time period of past weather	[VUB WMO Code table 4019, keys 0 – 7]
		(1 : 6 h, 2 : 12 h, 3 : 18 h, 4 : 24 h , 5 : 1 h, 6 : 2 h, 7 : 3 h)
20 – 21	accuracy flag for low cloud cover	(0 : high accuracy , 1 : low accuracy)
22 – 27	state of ground	[WMO descriptor ’0 02 062’]
28 – 30	(precip obs duration	(2 : 12 hrs , 0 : otherwise))

Some VUB WMO Code tables relate to WMO descriptors in the following way:

VUB WMO table 0509 ≈ (code figures 10 – 19 of WMO decriptor ’0 20 012’) − 10
VUB WMO table 0513 ≈ (code figures 20 – 29 of WMO decriptor ’0 20 012’) − 20
VUB WMO table 0515 ≈ (code figures 30 – 39 of WMO decriptor ’0 20 012’) − 30
VUB WMO table 4677 ≈ code figures 00 – 99 of WMO decriptor ’0 20 003’

In VUB WMO Code table 2700, code figures $0-8$ indicate the cloud cover in octas, and code figure 9 indicates sky or clouds invisible. VUB WMO Code table 1600 is defined as follows:

$0: < \ 50\,\mathrm{m}\,, \quad 1: < \ 100\,\mathrm{m}\,, \quad 2: < \ 200\,\mathrm{m}\,, \quad 3: < \ 300\,\mathrm{m}\,, \quad 4: < 600\,\mathrm{m}\,, \quad 5: < 1000\,\mathrm{m}\,,$
$6: < 1500\,\mathrm{m}\,, \quad 7: < 2000\,\mathrm{m}\,, \quad 8: < 2500\,\mathrm{m}\,, \quad 9: \geq 2500\,\mathrm{m}$ or cloud-free $,\quad 15:$ undefined.

Report Body Extension for Increments

The regular report body is followed by an optional report body extension if the `NAMELIST` variable '`mruntyp` ≥ 0'. It consists of observation increments or full model values of the (assimilating) model run which writes `YUVERIF`. This part can be extended by analogous increments from several other model runs, e.g. forecasts, by use of a post-processing program `lmstats` which can read and write extended `YUVERIF` files. Here, the extended format of `YUVERIF` is described which can contain the increments from one or several runs.

Similarly to the regular report body, the number of entries (increments) per model run depends on the basic type of reports. Moreover, the number of runs, for which the increments of an observation level are written to the same line, also depends on that type. Both the number of entries and the number of runs on the same line are given in the following list:

increment body length

basic type of report	# entries	# runs per line
complete synoptic surface-level report	14	1
short surface-level report	9	2
very short surface-level report	5	3
upper-air single-level report	4	4
multi-level report (each obs. level)	5	3
ground-based GPS report	1	12

For multi-level reports, this means that the five increments from the first run followed by twice five increments from the next two runs are written to one line for the first observation level. Analogously, the increments from these three runs are then written for the other observation levels line by line. Finally, an extra line is added for multi-level reports only with the three surface pressure increments (in [Pa]) from the three runs, before the process is repeated for the next (one, two, or) three runs, and so on. The following list declares the complete set of 14 increment entries:

report body extension on increments

1. zonal wind component (for GPS reports: IWV [1/100 mm]) [1/100 m/s]
2. meridional wind component [1/100 m/s]
3. temperature [1/100 K]
4. relative humidity [1/10 %]
5. pressure (surface-level reports) | geopotential (upper-air) [Pa] | [m2/s2]
6. total cloud cover (full model value instead of increment) [octas]
7. low cloud cover (full model value instead of increment) [octas]
8. (horizontal) visibility (full model value instead of increment) [10 m]
9. precipitation amount (full model value instead of increment) [1/10 mm]
10. minimum temperature (at 2 m during past 12 hrs) [1/10 K]
11. maximum temperature (at 2 m during past 12 hrs) [1/10 K]
12. minimum ground temperature (at 5 cm during past 12 hrs) [1/10 K]
13. max. wind speed of gusts (time range as in regular body) [m/s]
14. global radiation, sum over 1 hour [10 kJ/m2]

8.2.8 YUPRINT — Nudging: Other Aspects

`YUPRINT` provides a large variety of information. Much of it has been used mainly at the stage of developing and testing new pieces of code. Instead of inflating this documentation by explaining all types of statements in detail, only the most important ones are described here, including those which are most likely to be of some value for monitoring the model run. A small part of the information written to `YUPRINT` is also written to the standard output or to file `YUCAUTN`. These parts are described in the respective sections 8.2.9 and 8.2.5. Much of the information is 'local', i.e. it relates only to a certain sub-domain which accommodates the grid point with coordinates given by the `NAMELIST` variables '`ionl`','`jonl`' and which coincides with the area processed by one node on an MPP (massively parallel platform, i.e. with distributed memory) computing environment. Also, most types of information are given only at the first timestep, or once per hour.

After some self-explanatory header information about the run, some details about the processing of aircraft data and cloud observations, the numbers of single-level reports '`NSGOB`', of multi-level reports '`NMLOB`', and of GPS reports '`NGPOB`' currently stored on each sub-domain (related to nodes '`CART_ID`') are provided (Figure 8.18). '`NTOTSGO`', '`NTOTMLO`', and '`NTOTGPO`' denote the number of reports which have been read at previous timesteps. '`GLOBAL NUMBER`' relates to the number of reports on the total model domain.

The lines (starting with) '`airep`' provide the following information for an aircraft report: number of active reports, internal report index, passive report flag, end of nudging period in [timesteps], timestep in [h], station identity, observation time, beginning and end of individual nudging time window relative to observation time in [h], time in [h] for which analysis increments are to be computed currently, end of period for which these analysis increments are valid, temperature observation error in [K], temperature nudging coefficient for aircrafts in [s^{-1}], observation level pressure in [Pa]. Time is always specified relative to the initial model time except where indicated differently.

```
 NUMBER OF SINGLE- AND MULTI-LEVEL AND GPS DATA TO BE PRINTED:
 NODE:      CART_ID  | NTOTSGO | NTOTSG | NTOTMLO | NTOTML | NTOTGPO | NTOTGP
                0           0      128         0       38         0      152
                1           0      864         0      163         0     3023
...
               14           0       78         0        6         0       11
 MAX. LOCAL NUMBER:         0     5810         0      430         0     4046
 LOCAL ARRAY SIZE :               8360                557              11704
 GLOBAL NUMBER    :         0    14748         0     1150         0    15611
.........
airep     0   13   0  630 0.011  EU3080     -0.5   0.5   1.5   0.0 0.03 0.8 0.0006  72990.
.........
mladm:  45 multi-level reports
mladm     1    0    1  141   55  02591    -999.00   2.67  0.00  3.00  3.00  0.00  0.12  0.00  0.12
...
mladm    45    0  128  135   87  EU7654   -999.00   0.33  0.00  1.50  1.50  0.00  0.80  0.00  0.80
sgadm:  429 surface-level and 354 upper-air single-level reports
sgadm     1  843    0  217  119  22892       0.00-999.00  0.50  0.00  0.00  0.94  0.00  0.94  0.00
...
sgadm   429    0 1750   19  101  LF4B     -999.00   1.17  0.00  1.50  1.17  0.00  0.24  0.00  0.24
sgadm   430   13    0  131   84  EU3080     -0.47-999.00  0.50  0.00  0.00  0.01  0.00  0.01  0.00
...
sgadm   783    0  785  171   70  EU0301   -999.00   1.52  0.00  1.50  1.50  0.00  0.01  0.00  0.01
gpadm:  181 GPS reports
gpadm     1    1  701   91   22  BUDP-BKG_  -0.50   0.50  1.00  1.00  1.00  0.47  0.53  0.00  0.69
...
gpadm   181    0 1327  114   13  VEST-NGAA-999.00   1.08  0.00  1.50  1.50  0.00  0.30  0.00  0.30
.........
ps    -QC: 60195      11 Obs/Mod/Thresh  853.60  849.22  4.30, Time Obs/Mod   0.0   0.0
uv    -QC: 08495       0 Obs/Mod/Thr 24.7  -5.2 -16.0  -4.3 27.9, Time O/M  2.4  0.0, P   10.
IWV-sc-QC: 60571       0 Obs/Mod/Thr    5.56   10.79  5.13, T O/M  1.8  0.0, bias|w   0.0  0.0
V-mult-QC: 08019     137                           , Time Obs/Mod   0.0   0.0, P  916.- 368.
```

Figure 8.18: Example file `YUPRINT`, first part related to observation statistics and quality control.

The lines '`mladm`', '`sgadm`', and '`gpadm`' provide the local number of currently active multi-level, single-level, resp. GPS reports or stations and list the following items of them: station indices for 2 reports (i.e. 1 report in the past and 1 report in the future), grid point coordinates, station identity, 2 observation times in [h] (i.e. for the 2 reports; '-999' denotes missing report), lengths of the decreasing part, selected increasing part, and minimum possible increasing part of the temporal weight function, the 2 temporal weights according to the temporal function selected, the 2 temporal weights assuming that temporal linear interpolation cannot be applied.

A statement containing '`-QC:`' is made whenever the quality status of an observation changes due to the threshold quality control (QC), i.e. when an observation does not pass the QC for the first time, or when it is accepted after it has failed the QC in the past.

After some information e.g. on extrapolating surface pressure and on processing of aircraft data and multi-level data, `YUPRINT` provides the following self-explanatory lists (Figure 8.19): surface-level observations interpolated to the lowest model level, multi-level observation increments from TEMP, PILOT, or AIRCRAFT reports or (in a different format) as derived from GPS-ZTD reports.

The lines '`ps_spread`' (Figure 8.20) relate to the spreading of pressure observation increments at the lowest model level. They consist of the station identity, the local part of the nudging weights (i.e. temporal and quality weight) of the 2 reports from the station, the total weight at grid point `(ionl2,jonl2)` from all the reports processed previously (including the present report), the 2 observation increments (in [Pa]), the total sum of weighted increments at that grid point, the distance (in [km]) of the station to that point, the indication whether that point is within the area of influence, and the orography-dependent correction of the lateral weights at that point. The line '`ps-ana.incr.`' provides the local coordinates of point `(ionl2,jonl2)` and the final surface pressure analysis increment at that point.

```
Interpolation of surface-level observations to the lowest model level ke
========================================================================
(upper-air single-level reports are also listed here)
(station height differences with the flag "s" are scaled as for the extrapolation of pressure)
       |  obs: observed values / ke: obs. interpolated to level ke / inc: obs. increments at ke |
Sta.   | height  | surf. pressure |    10m - horizontal wind    | 2m-temperature | 2m-rel humid.|t
 id    | diff. * | obs / ke / inc | 10m-obs /  at ke  /   inc    | obs / ke / inc | obs/ ke /inc |
EU1312        0.  227.3************ 28.2 13.7********** -3.2 -4.1 221.4******  2.4********** 0.00
10946     s  53.  937.6  931.4  0.4  1.9 -0.7  3.2 -1.8  0.0  0.0 273.9 272.6  0.0 0.89 0.94-0.07
......
Vertical profiles of observation increments from TEMP, PILOT, AIRCRAFT
======================================================================
station 06610    , (255,271), 56 levels ; mbotlv, mtoplv    6   2   8   4   1  12
  u-incr  v-incr  T-incr   Qd-incr RH-incr pressure height pot. T. 06610
****************   1.578  -0.00099  -0.219  95800.    535. 278.36
****************   1.553******************  95659.    547. 278.36
****************   1.455******************  95113.    593. 278.41
****************   1.324******************  94394.    654. 278.69
****************   1.156******************  93483.    732. 279.08
****************   1.009  -0.00075  -0.180  92700.    799. 279.32
   1.055  -0.039   0.916  -0.00074  -0.178  92500.    817. 279.39
   1.027  -0.045   0.955******************  92367.    828. 279.43
...
station ZIMM-BKG_, (260,271), 24 levels ; mbotlv, mtoplv    0   0   5   0   0  11
        quality weight    Qd-incr RH-incr pressure height pot. T. ZIMM-BKG_
         0.48531          -0.00050  -0.128  90514.    990. 279.89
         0.57270          -0.00048  -0.127  89441.   1085. 280.17
.....
Integrated water vapour IWV values from processing of ground-based GPS
======================================================================
timestep:    0
    obs  #  satu-  obs IWV:   adjusted:    IWV      model w.  satu- extra-
   time it- rated  repor-   re-      ice,   from  model  cloud  rated polat.
STA  hr erat. lev    ted trieved   bias qv-obs    IWV    ice  model quot  p-int  p-rep
ZIMM- 0.5   1   0 *******   5.72   5.72   5.72   6.24   6.24  10.61  0.6  914.6*******
```

Figure 8.19: Example file `YUPRINT`, second part related to observations and observation increments.

```
ps_spread 63112    , weights 0.97 0.03  0.58, (wght.) incr  -52.83   -2.9   -5.9, dist  171. T 0.9
ps_spread 63101    , weights 0.97 0.03  0.91, (wght.) incr  -47.35   12.6  -10.8, dist  163. T 0.9
...
End of ps_ana_i: weight sqr   3.55, net weight 0.000409, ana incr -0.3988  1.0000
ps-ana.incr.   18 126       -0.399
.........
mul-kl: 01400     3, p,z: obs/v-cut:     0.  8253.  -400.  9165.100000.  -400. -1597. 10474.: no k
air-kl: EU1337    1 23720., height at obs/cutoff: 10949.  7722. 14176., k-range 13  6
thresh RH k 40 40 285 385 10142       34.,mx omy:k+1,k: 1.000 0.735,RH incr 0.045-0.092
...
airmy: EU3080    131  84 1,omyk1/2 0.011 0.000 vCS-fac 1.000 0.935 dz  2571. omym 0.716381
...
sfc-kl: 06610     2 94994., height at obs/cutoff:  563.9 -400.0, k-range 41
sfc-kl: 06610     3 94994., height at obs/cutoff:  563.9  572.4, k-range 40
sfc-cor 06610     4 35 167 103  140.,spr-par: ob,cutof   564.*******,at k   564.  480  402
omyk: 06610     4 3 0.972 0.028 1.000 0.972 0.028  269.27 T 0.00   563.9   563.9 1.0
.........
zuwi,om?u: 06610 -0.0419 0.7773 0.1840
ztwi,om?t: 06610 -0.0086 0.9657 0.3401
zqwi,om?q: 06610 -0.00344256 0.5075 0.1302
.........
mul-infl(km) 277. EU4591    352 477, z: obs,v-cut:  2082.  3508.  1391.  4567., k-range: 34 20
air-infl(km) 492. SAS903    234 517 20647., zu/vwi,omyu   0.025  -0.042  0.7700
sfc-infl(km) 140. 06610     167 103 94994., zqwi,omyq,2 0.198833  6.1970  3.8493
...
thresh uv k 31 31 260 452 01427       24.,mx omy:k+1,k: 0.642 0.490,uv incr   1.9   0.1
thrair T  k 27 31 27 358 478 EU7654     1607.  1721.,max omy: 0.792,T  incr   0.0  -1.9
air-cor EU1337    1 13 167 103  408.,spr-par: ob,cutof 10949.  7722. 14176.,at k  7368.  640   43
thrair uv k 13 13  6 167 103 EU1337    10949.  7368.,max omy: 0.240,uv incr   1.0  -2.1
```

Figure 8.20: Example file `YUPRINT`, third part related to spreading of observation increments.

The lines ’`sfc-kl`’ , ’`sfc-cor`’ , ’`sfc-infl`’ , and ’`omyk:`’ for surfac-level data resp. ’`mul-kl`’ , ’`air-kl`’ , ’`ras-cor`’ , ’`air-cor`’ , ’`mul-infl`’ and ’`air-infl`’ for upper-air data provide a variety of information on the spreading of observation increments (Figure 8.20). The lines ’`thresh`’ and ’`thrair`’ also relate to the spreading of surface-level resp. upper-air single-level data and consist of the observation type (’`uv`’ for wind, ’`T`’ for temperature, ’`RH`’ for humidity), the current vertical model level, the lowest (for upper-air data only) and uppermost model level influenced by the observation, the grid point coordinates of the station, the station identity, the height at the observation point, the value of the spreading parameter (usually height) at the current model level, the maximum spatial weight at any grid point on the previous (for surface-level data only) and current model level within the local sub-domain, and the 2 observation increments. The entry ’`vCS-fac`’ in the lines ’`airmy`’ denote the reduction factor of the scale of the vertical weight function below and above a single-level aircraft observation. The lines ’`zuwi`’ (or ’`ztwi`’ , ’`zqwi`’) provide the station identity, the sum of weighted zonal wind (resp. temperature or humidity) increments, the sum of weights, and the sum of squared weights from the previously processed and the present observations at the lowest but fifth model level at grid point `(ionl,jonl)`.

The same applies to lines ’`omu`’ (see Figure 8.21, resp. ’`omt`’ , ’`omq`’) and lines ’`ntstep= .... ztwi`’ (without squared weights) except that the sum is over all observations. The lines ’`nudge_horiz_wind`’ or ’`Tqnudge`’ deliver the local coordinates of grid point `(ionl2,jonl2)`, the model level, and the analysis increments of the wind components resp. of temperature, of specific humidity from nudging temperature data, and of humidity from nudging humidity data at that point. The lines ’`itera q11`’ indicate the iteration in solving the Poisson equation to derive geostophic surface pressure increments from wind increments based on 10-m wind data. From these pressure increments, geostrophic wind field can be derived again, from which the maximum relative change in [0.1 %] in the iteration and the maximum magnitude of the wind increments are also given for the subdomain with point `(ionl2,jonl2)`. Furthermore, ’`zdfi_max`’ and ’`max(psaigeo_1)`’ provide the largest positive and negative geopotential resp. pressure increment on that subdomain. The arrays of lines ’`nudging,`’ list the analysis increments as a result of different processes as indicated, at the given six pres-

```
ntstep=   0, k=35, T / qv / qc : 276.84 0.004943 0.000000  18 126, ztwi / omyt:   0.00 0.00000
Tqnudge: T,q-ana.incr.   18 126  35   0.0008  0.000000  0.000000
omu: weight/ sqr/ weighted incr 35   0.0000   0.0000   0.0000   0.0000
omu: weight     / weighted incr 35   0.0001153         1.3699  -0.4132
.........
geostroph_ps_corr: uv-ana.incr.   18 126   0.0000   0.0000
itera q11 umax =    1    120.014440    0.164226
itera q11 umax =    2     64.963402    0.164223
...
itera q11 umax =   50      2.570915    0.175688
 zdfi_max =   8  0.2562859401204606  -2.629577730880562E-002
 max(psaigeo_1):   8  0.2927315768875584  -3.061252112578843E-002
 max(psaigeo_2):   8  0.2634584191988025  -2.755126901320959E-002
.........
nudge_horiz_wind: uv-ana.incr.   18 126  35   0.0138  -0.0056
   0  34 651   3: max. unreduced geost. incr. on total domain, v-gr.pt:    2.75
   0  34 185 106: max. unreduced geost. incr. on inner domain, u-gr.pt:    0.59
   0  34 224 134 0.83: reduced geost. incr. at i/jonl:  -0.001  -0.002
.........
nudging, pressure                     3767. 23293. 55121. 85067.100053. 101361.
nudging, p-incr, no T-change         -0.005 -0.031 -0.072 -0.112 -0.131  -0.133
nudging, p-incr, T-corr, no T-nudge   0.007  0.042  0.080 -0.030 -0.124  -0.133
nudging, p-incr, T-nudge, no evapo.  -1.694 -7.566 -1.024 -0.020 -0.113  -0.133
nudging, p-incr, T-nudge complete    -0.025 -0.112 -0.030 -0.085 -0.128  -0.133
nudging, T-incr, T-corr, no T-nudge   0.000  0.000  0.001  0.002  0.002   0.002
nudging, T-incr, T-nudge, no evapo.   0.023  0.006 -0.166  0.002  0.002   0.002
nudging, T-incr, T-nudge complete     0.000  0.000 -0.002  0.001  0.001   0.001
nudging, q-incr, RH-nudge, no evapo.  0.000  0.000  1.327  0.000  0.000   6.580
nudging, q-incr, T+RH-nudge complete  0.000  0.000  0.019  0.000  0.000   0.206
nudging, u-incr, geostrophic          0.000  0.000  0.000 -0.002 -0.001   0.000
nudging, v-incr, geostrophic          0.000  0.000  0.000  0.000  0.000   0.000
```

Figure 8.21: Example file `YUPRINT`, forth part related to weighted increments and balancing.

sure levels at grid point `(ionl,jonl)`. Mostly self-explantory information on the geostrophic wind correction is given by the lines containing '`geost. incr.`' (not shown).

Last but perhaps most essentially, nearly self-explanatory lists of the coordinates of the grid points, at which the maximum absolute values for the analysis increments occur on each model level, are provided together with the values of the increments themselves (Figure 8.22). This is done at each timestep that new analysis increments are computed, and it allows to monitor which variables at which levels are explicitly influenced by the nudging.

```
Analysis increments at timestep   12
max. (ABS of) analysis increments of mass field
(prior to condensation / evaporation except for pressure increments)
le- T-corr global T-incr  global qv-incr due  gl.  qv-incr  global RH-incr global  p-incr  global
vel   [K]  coord.    [K]  coord. to T-incr coord.   [g/kg]  coord.    [%]  coord.    [Pa]  coord.
 1  0.000   0   0   0.04 634  91   0.0000   0   0   0.0000   0   0   0.00   0   0   0.689 635  92
 2  0.000   0   0   0.08 640  87   0.0000   0   0   0.0000   0   0   0.00   0   0   0.740 273 189
...
 9  0.000   0   0  -0.04 326 582   0.0000   0   0   0.0000   0   0   0.00   0   0   1.600 268 196
10  0.000   0   0   0.05 325 185   0.0000   0   0   0.0001 113 320   0.11 113 320   1.743 533 518
...
38 -0.067 195 648   0.07 114  40   0.0000   0   0  -0.0326 300 225  -0.62 300 226  13.929 195 648
39 -0.067 195 648   0.07 114  40   0.0000   0   0  -0.0329 300 225  -0.62 301 225  14.097 195 648
40 -0.067 195 648   0.07 114  40   0.0000   0   0   0.1434 520  84  -1.47 649 645  14.215 195 648
...
max. (ABS of) increments of horizontal wind field components in [m/s]
(ana incr: analysis increments
 net incr: net observation increments
 geo corr: geostrophic wind correction)
le- u-ana  global  v-ana  global  u-net  global  v-net  global  u-geo  global  v-geo  global
vel  incr  coord.   incr  coord.   incr  coord.   incr  coord.   corr  coord.   corr  coord.
 1   0.06 258 343   0.05 599 131  -13.3 540  82    7.1 483 345   0.00   0   0   0.00   0   0
 2   0.09 280 248   0.10  60 594  -11.2 540  82   -9.0  42 319   0.00   0   0   0.00   0   0
...
13   0.11 292 111   0.15 105 508    8.3 292 111   -9.0 337  64   0.00   0   0   0.00   0   0
14   0.16 113  40  -0.14 114  40    9.4 175  25    9.4  55  16   0.00 193 109   0.00 649  26
...
33   0.17 420  64  -0.22  23 249   -9.6 641 218   10.1 621 200  -0.13  16 238  -0.22  23 249
...
39   0.20 410  55   0.23 344 648   -9.1 642 220    7.3 255  88  -0.01  16 238  -0.02  23 249
40   0.20 410  55   0.23 344 648   -9.2 642 220    7.4 258  84   0.00  16 238  -0.01  23 249
```

Figure 8.22: Example file `YUPRINT`, fifth part related to analysis increments.

8.2.9 Standard Output — Basic Monitoring of Nudging

As already mentioned e.g. in Section 8.2.5, warning messages containing the label ’`CAUTION`’ are also issued to the standard output, if the values of the `NAMELIST` variables ’`maxmlo`’, ’`maxuso`’, ’`maxsgo`’, or ’`maxgpo`’ are not large enough to hold in memory and process all observations. In such a case, the program will not crash or stop (see Section 8.2.5). In the standard output, such a message is written for each individual multi-level observation report, which cannot be used due to insufficient array size. Furthermore, summary messages indicate how many reports of which type had to be discarded for that reason.

Figure 8.23 lists the types of regular messages that are also written to the standard output by the nudging. The first line specifies the length of regular time boxes (in [h]) in which analysis increments are computed once and then used to update the model variables at all timesteps within the time box (this length corresponds to ’`NAMELIST`’ variable ’`tconbox`’ (in [s])). ’`AI-box`’ denotes the time box interval (in [h]), and ’`mean`’ the middle of the interval, i.e. ’`mean`’ declares the time (in [h]) for which the temporal weights used to compute the analysis increments are exactly valid. ’`next: AI`’ denotes the time (in [h]) at which new analysis increments are to be computed for the next time, and ’`obs process`’ the next time at which new observations must be read again from the AOF. If the observations are read from NetCDF observation input files, the ’`obs process`’ entry does not have any meaning and is simply equal to zero.

Next, the path name of the `BLACKLIST / WHITELIST` file is given. This is followed by a list of NetCDF observation input files which do not exist due to missing data, but which would be read if they existed. Then for each of the existing NetCDF observation input files, the number of reports are indicated and the time interval from which all reports have to be read currently. This last type of lines is written again whenever new observations are read, which is typically once every hour.

```
!! Analysis Increments ("AI") held constant during time boxes of ca 0.067 hours
   hour: AI-box: [0.000,0.056], mean: 0.028, next: AI: 0.07, obs process.: 0.00

 open and read BLACKLIST / WHITELIST from ./blklsttmp
 NOTE: NO FILE ./cdfin_tempdrop (.nc)
 NOTE: NO FILE ./cdfin_amdar_ml (.nc)
 NOTE: NO FILE ./cdfin_amdar_vp (.nc)
 NOTE: NO FILE ./cdfin_acars_uk (.nc)
 NOTE: NO FILE ./cdfin_acars_us (.nc)
 NOTE: NO FILE ./cdfin_synop_mob (.nc)
 NOTE: NO FILE ./cdfin_metar (.nc)
 NOTE: NO FILE ./cdfin_satob (.nc)
processing   415 reports from  -58 -  241 [min] from file cdfin_temp
processing    14 reports from  -58 -  241 [min] from file cdfin_tempship
processing     7 reports from  -58 -  241 [min] from file cdfin_pilot
processing     5 reports from  -58 -  241 [min] from file cdfin_pilot_p
processing  2829 reports from  -28 -  151 [min] from file cdfin_amdar
processing  3709 reports from  -28 -  151 [min] from file cdfin_acars
processing   118 reports from  -28 -   91 [min] from file cdfin_wprof
processing    20 reports from  -28 -   91 [min] from file cdfin_rass
processing   556 reports from  -28 -   91 [min] from file cdfin_radar_vad
processing  8662 reports from  -58 -  151 [min] from file cdfin_synop
processing   335 reports from  -58 -  151 [min] from file cdfin_ship
processing   246 reports from  -58 -  151 [min] from file cdfin_buoy
processing 16369 reports from  -58 -  151 [min] from file cdfin_gps_zenith
processing   705 reports from  -58 -  151 [min] from file cdfin_ascat
processing     0 reports from  -58 -  151 [min] from file cdfin_qscat
```

Figure 8.23: First part of example messages on nudging written to standard output.

Next (see Figure 8.24), the path name of the NetCDF feedobs (or feedback) file is given. At timestep zero and after each time box defined by '`tconbox`', the number of reports and number of individual observations that are currently written to the feedobs file are also indicated, as well as the numbers of reports and obserations already having been written at previous timesteps.

It follows a line with '`NUMBER OF (SINGLE OR PAIRS OF) REPORTS WITH OBS INCREMENTS`'. This provides the total number of increment reports (resp. stations in case of temporal linear interpolation of observations), which have been used to compute the observation increments (for the purpose of nudging or of writing a NetCDF feedobs or VOF file) at the timestep given at the beginning of the line. In the subsequent lines, it is specified how many of these increment reports are multi-level, upper-air single-level, surface-level, surface pressure, and scatterometer increment reports. The multi-level reports are further distinguished between radiosonde TEMP, PILOT balloon, wind profiler, radar VAD wind, aircraft, RASS temperature, and GPS humidity (from ZTD resp. IWV observations) increment reports. (An additional entry is added for preparing the use of retrievals from satellite radiance data; this number is always zero here.) This whole block of lines is also written at '`tconbox`' intervals and is quite helpful for monitoring the assimilation.

```
Creation of NetCDF feedobs file fof_*
OPENED: /e/uwork/fe12sra/test/09022409/lme/sx9/zlm4m/zwtyp/fof_20090224090000.nc
      feedobs file: # newrep  4734, oldrep     0, newobs  38392, oldobs       0
    STEP    0: NUMBER OF (SINGLE OR PAIRS OF) REPORTS WITH OBS INCREMENTS:  8744
               1259 multi-level: 106 TEMP,  2 PILOT,  16 WINDPROF,  20 RADAR-VAD
                                 225 AIRCRAFT, 1 RASS,  889 GPS,    0 RETRIEVALS
               1999 sing-lev aircraft, 2878 in-situ surface, 2444 surf. pressure
                164 scatterometer

Temperature correction for (surface) pressure nudging: top at 400hPa in layer 14
================================================================================
                               (*): relative to the surface pressure increment
height T-corr pressure  z-z    dp level |height T-corr pressure  z-z    dp level
       K/hPa full hydro correl (*)      |       K/hPa full hydro correl (*)
 7746. -0.000 374. 374. 0.000  0.000 14 | 9030. -0.000 312. 312. 0.000  0.000 14
 7110. -0.016 410. 410. 0.001  0.001 15 | 8587.  0.000 332. 332. 0.000  0.000 15
 6506. -0.069 446. 446. 0.013  0.008 16 | 8157.  0.000 354. 354. 0.000  0.000 16
 5933. -0.121 482. 482. 0.038  0.022 17 | 7742.  0.000 375. 375. 0.000  0.000 17
 5391. -0.172 519. 519. 0.076  0.045 18 | 7344. -0.010 397. 397. 0.000  0.000 18
 4878. -0.220 555. 556. 0.122  0.076 19 | 6962. -0.129 419. 419. 0.007  0.007 19
 4395. -0.267 592. 592. 0.177  0.115 20 | 6598. -0.272 441. 441. 0.033  0.025 20
 3941. -0.310 628. 628. 0.237  0.161 21 | 6252. -0.408 462. 462. 0.073  0.055 21
 3516. -0.351 663. 663. 0.301  0.214 22 | 5924. -0.538 483. 483. 0.127  0.097 22
 3119. -0.386 697. 697. 0.366  0.272 23 | 5616. -0.659 504. 504. 0.190  0.149 23
 2749. -0.419 730. 730. 0.433  0.334 24 | 5327. -0.767 524. 524. 0.259  0.209 24
 2408. -0.448 762. 762. 0.501  0.399 25 | 5058. -0.867 543. 543. 0.335  0.276 25
 2093. -0.473 792. 792. 0.568  0.465 26 | 4809. -0.951 561. 561. 0.411  0.348 26
 1806. -0.492 820. 820. 0.631  0.530 27 | 4580. -1.021 578. 578. 0.487  0.423 27
 1544. -0.507 847. 847. 0.690  0.594 28 | 4371. -1.077 594. 594. 0.560  0.498 28
 1308. -0.518 871. 871. 0.745  0.656 29 | 4181. -1.120 609. 609. 0.631  0.571 29
 1097. -0.525 893. 893. 0.795  0.713 30 | 4011. -1.150 622. 622. 0.694  0.641 30
  911. -0.529 913. 913. 0.839  0.766 31 | 3860. -1.169 635. 634. 0.753  0.706 31
  748. -0.530 931. 931. 0.878  0.813 32 | 3728. -1.182 645. 645. 0.805  0.765 32
  608. -0.528 946. 946. 0.911  0.855 33 | 3614. -1.187 655. 655. 0.850  0.818 33
  489. -0.526 959. 959. 0.938  0.891 34 | 3517. -1.188 663. 663. 0.890  0.863 34
  391. -0.522 970. 970. 0.958  0.922 35 | 3437. -1.185 670. 670. 0.921  0.902 35
  311. -0.517 979. 979. 0.973  0.947 36 | 3372. -1.181 675. 675. 0.948  0.933 36
  249. -0.512 986. 987. 0.984  0.966 37 | 3321. -1.176 680. 680. 0.967  0.958 37
  202. -0.508 992. 992. 0.991  0.981 38 | 3283. -1.171 683. 683. 0.982  0.976 38
  168. -0.504 996. 996. 0.996  0.992 39 | 3255. -1.167 685. 685. 0.993  0.990 39
  144. -0.502 999. 999. 1.000  1.000 40 | 3235. -1.164 687. 687. 1.000  1.000 40
```

Figure 8.24: Second part of example messages on nudging written to standard output.

Next, two examples for the temperature correction balancing the surface pressure nudging are given, one for a grid point with surface pressure close to 1000 hPa, and one for an elevated grid point. The information provided at each model level consists of the height (in [m]), the temperature correction (in [K/hPa]), the full pressure and the hydrostatic pressure (in [hPa]), the quotient between the (hypothetic) height increment at upper levels and at the surface, the quotient between the resulting upper-air pressure increment and surface pressure increment, and the model level index.

The lines containing '`dt,dt2,dtdeh`' describe that at timestep 0, the length of the timestep is halved outside the nudging, but set to the original length temporarily within the nudging. Before that, the size of the coarse grid used to speed up the Poisson solver is indicated.

Messages are also written whenever two-dimensional surface analysis based on Synop observations are written to Grib files. '`t2m`' relates to 2-m temperature, '`r2m`' to 2-m relative humidity, '`fff`' to 10-m wind speed, and '`prc`' to precipitation.

The lines with '`maybe not written to YUVERIF`' indicate reports, that are flagged not to have been written to the VOF or NetCDF feedobs files at the time when they are deleted internally for the reason of being too old to be used any more. Most often, this relates to multi-level aircraft reports which may have been created only after the observation time. This can happen, when new observations with the same aircraft identifier (station ID) are read. Then, all multi-level reports are deleted first, and multi-level reports are derived again based on all the single-level reports from the same aircraft, even if some of those reports are older than the current model time. Normally, the aircraft observations missing on the feedobs file(s) should already have been written as a single-level report report or as part of another multi-level report. Lines of the type considered can also relate to other observation types. Typically, this occurs for redundant reports from stations which issue very frequent reports of observation types where temporal linear interpolation is applied between active reports.

The lines starting with '`nudge:`' render the last timestep of the model run, the index of (the lowest, middle, or top) model level, and temperature and specific humidity ('`Tq`') resp. pressure and zonal wind ('`pu`') at grid point `(ionl,jonl)` in unformatted form. This often allows to diagnose tiny differences between runs done with slightly different model versions

```
 coarse grid size for Poisson solver =   63  63
     STEP 0: dt,dt2,dtdeh: within the nudging   40.  80. 0.0111
     STEP 0: dt,dt2,dtdeh: outside the nudging  20.  40. 0.0056
  Surface analysis GRIB output file <lansfc> opened
 t2m- GRIB field written on file
 r2m- GRIB field written on file
 fff- GRIB field written on file
 fff- GRIB field written on file
...
  NOTE: m-l report EU5185    , 2.05 [hrs], 99892. [Pa] maybe not written to YUVERIF
  NOTE: GPS report ZIM2-LPTR , 2.53 [hrs],******* [Pa] maybe not written to YUVERIF
  NOTE: m-l report EU3421    , 1.95 [hrs], 65764. [Pa] maybe not written to YUVERIF
...
 nudge: Tq   270  40  276.9854634975543  4.096394061700189E-003
 nudge: pu   270  40  1775.909540306221  -2.396582502917388
 nudge: Tq   270  20  256.6670491482951  1.044913113842654E-003
 nudge: pu   270  20  -96.66768992558980  19.39489036339958
 nudge: Tq   270  1  211.5194561088256  3.947515866446530E-006
 nudge: pu   270  1  766.6450024472723  -1.518195750920522
```

Figure 8.25: Third part of example messages on nudging written to standard output.

or configurations and helps to identify the existence of errors which lead to violations of bit-identical reproducibility. Note that once such a difference or error is present at a grid point to which observations are assigned, then the nudging process will usually spread it very quickly to the whole model domain including point `(ionl, jonl)`.

It is further mentioned, again, that '`CAUTION`' messages related to insufficient array sizes are also written to the standard output (see also Section 8.2.5). This includes messages on individual multi-level reports, on multi-level aircraft reports (e.g. '`CAUTION for maxmlo: nexceair 0 11`'), as well as summary messages.

Finally, there are messages (Figure 8.26), which are not written by the nudging itself, but which are related to the set-up of the data assimilation as a whole. It lists the originating process for a number of 2-dimensional grib fields which are used as part of the initial condition of the model integration. Time range indicator 13 means that the corresponding field has been produced by an COSMO-Model assimilation integration, whereas a value of 0 indicates that the field originates from a snow analysis (for '`T_SNOW`' , '`W_SNOW`', and '`W_I`'), a sea surface temperature analysis, or another external data collection and interpolation process. Additional element number 20 for '`W_SO`' implies finally that the initial soil moisture fields are produced by the variational soil moisture analysis instead of the nudging-based COSMO-Model assimilation run.

```
 Note: analysis field LAI      with time range indicator  0   is used
 Note: analysis field VIO3     with time range indicator  0   is used
 Note: analysis field HMO3     with time range indicator  0   is used
 Note: analysis field PLCOV    with time range indicator  0   is used
 Note: analysis field ROOTDP   with time range indicator  0   is used
 Note: analysis field LAI      with time range indicator  13   is discarded
 Note: analysis field ROOTDP   with time range indicator  13   is discarded
 Note: analysis field PLCOV    with time range indicator  13   is discarded
 Note: analysis field HMO3     with time range indicator  13   is discarded
 Note: analysis field VIO3     with time range indicator  13   is discarded
 Note: analysis field RHO_SNOW with time range indicator  13   is discarded
 Note: analysis field T_ICE    with time range indicator  13   is discarded
 Note: analysis field H_ICE    with time range indicator  13   is discarded
 Note: analysis field H_ICE    with time range indicator  0   is used
 Note: analysis field T_ICE    with time range indicator  0   is used
 Note: analysis field RHO_SNOW with time range indicator  0   is used
 Note: analysis field W_SNOW   with time range indicator  0   is used
 Note: analysis field T_SNOW   with time range indicator  0   is used
 Note: analysis field W_I      with time range indicator  0   is used
 Note: analysis field T_SNOW   with time range indicator  13   is discarded
 Note: analysis field W_SNOW   with time range indicator  13   is discarded
 Note: analysis field W_I      with time range indicator  13   is discarded
 Note: analysis field T_SO     with time range indicator  13   is discarded
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  13   is used
 Note: analysis field T_SO     with time range indicator  0   is used
 Note: analysis field W_SO       with add. element number   20   is used
...
 Note: analysis field W_SO       with add. element number   20   is used
 Note: analysis field W_SO       with add. element number   0   is discarded
...
 Note: analysis field W_SO       with add. element number   0   is discarded
```

Figure 8.26: Example messages on the originating processes for 2-dimensional grib fields which are part of the initial condition.

8.2.10 YUSURF — 2-D Surface Analyses

`YUSURF` relates to the determination of two-dimensional analyses which are based mainly on observations and can be used for verification purposes and as input for separate analysis schemes such as the variational soil moisture analysis. There are four types of analyses, namely the 2-m temperature analysis, the 2-m relative humidity analysis, the 10-m wind speed analysis, and the precipitation analysis. While the latter is based purely on observations, the first three include the corresponding fields of the model run as first guess fields. The basic functions and parameters of the successive correction schemes are first outlined in `YUSURF` (Figure 8.27).

Then, some basic information is provided for the analysis at grid point `(ionl,jonl)` for each analysis variable, analysis date, and correction scan (Figure 8.28). The squared distance '`zdistm`' (in [km^2]) to that point, the distance scaled by the scan radius ('`zrormx`'), and the horizontal weight '`wwa`' are written up for each observation influencing that point.

```
                                         SURFACE (ANY 2-D) ANALYSIS RUN
                                          ------------------------------
   -2M TEMPERATURE ANALYSIS
   -2M RELATIVE HUMIDITY ANALYSIS
   -PRECIPITATION ANALYSIS
   -10M WIND SPEED ANALYSIS

 ANALYSIS DATE: MON 16.04.2012  06 UTC

 Total precipitation amount in the last 12. hours
 ------------------------------------------------
 Precipitation analysis parameters:
 Weights function:   W   = H(R) * V(H)
 where           :   H(R)= (RMAX**2-R**2)/(RMAX**2+R**2)
                     V(H)= 0.5*(COS(H/HMAX*PI)+0.5
                     HMAX= MAX(MOD_ORO ,    400.) m
 Analysis function:  A = SUM(W*D)/SUM(W)

 Number of scans:     3
 Scan 1, radius:   40000. m
 Scan 2, radius:   70000. m
 Scan 3, radius:  110000. m
 No smoothing

 2m temperature analysis sucessive correction parameters:
--------------------------------------------------------
 Weights function:   W   = H(R) * V(H)
 where           :   H(R)= (RMAX**2-R**2)/(RMAX**2+R**2)
                     V(H)= (HMAX**2-H**2)/(HMAX**2+H**2)
                     HMAX= MAX(MOD_ORO/2.7 ,    300.) m
 Increment function: I = SUM(W*D)/SUM(W)

 Number of scans:    3
 Scan 1, radius:  200000. m
 Scan 2, radius:  100000. m
 Scan 3, radius:   50000. m

 2m Rel. Humid. Analysis Sucessive Correction parameters:
...............................................................................
 10m wind speed analysis sucessive correction parameters:
--------------------------------------------------------
 Weights function:   W   = H(R) * V(H)
 where           :   H(R)= (RMAX**2-R**2)/(RMAX**2+R**2)
                     V(H)= (HMAX**2-H**2)/(HMAX**2+H**2)
                     HMAX= MAX(MOD_ORO/3.0 ,    300.) m
 Increment function: I = SUM(W*D)/SUM(W)

 Number of scans:    3
 Scan 1, radius:  200000. m
 Scan 2, radius:  100000. m
 Scan 3, radius:   50000. m
```

Figure 8.27: Example file `YUSURF`, first part on description of methods.

After a description of the grid point itself, station identity, latitude, longitude, height, observation increment, and total weight of the increment at the grid point are also provided for these observations. For precipitation observations assigned to the grid point itself, this is complemented by the vertical distance '`zvdis`' and vertical weight '`zwi`' in the lines starting with '`zmodor`'. Finally, the resulting analysis increment of the scan and some statistics on the analysis are provided.

```
 Total number of surface observations extracted from ODR:  nobtot= 1049
 zdistm=189364. zrormx=0.947 wwa=0.055
...
 zdistm=192541. zrormx=0.963 wwa=0.038

 Diagnostic 2M TEMPERATURE analysis   scan 1
  grid point  ix=167  iy=103  lat= 47.54  lon=   8.74  height= 462.
 Observations influencing this grid point:

 stat_id     lat      lon   height  increment  weight
 06771       45.84     8.93    352.    -1.21    0.08
 06770       46.00     8.96    301.     0.02    0.16
...
 10733       49.30     8.91    240.    -0.33    0.02
 Resulting t2m analysis increment:  -0.15
......................................................................
 Diagnostic 2M TEMPERATURE analysis   scan 2
......................................................................
 Resulting t2m analysis increment:  -0.25
......................................................................
 Diagnostic 2M TEMPERATURE analysis   scan 3
......................................................................
 Resulting t2m analysis increment:  -0.04

 *** STATISTICS ON ANALYSIS OF 2M TEMPERATURE; UNIT=DEGREES
      SUM OF CHANGES       =  60422.7556
      NO. OF ANAL. POINTS  =      194081
      AVERAGRE CHANGE      =      0.3113
      STANDARD DEVIATION   =      0.8121
      MAX. CHANGE          =      3.9370
      MAX. POSITIVE CHANGE =      3.9370
      AT MODEL LAT./LON.   =     -3.3500      0.4500
      MAX. NEGATIVE CHANGE =     -1.9850
      AT MODEL LAT./LON.   =     -4.7750      3.8250
................................................................................
 Diagnostic 2M REL. HUMIDI analysis   scan 3
................................................................................
 Diagnostic 10M WIND SPEED analysis   scan 3
................................................................................
 zdistm= 14959. zrormx=0.374 wwa=0.623
 zdistm= 26371. zrormx=0.659 wwa=0.217
.........
 zmodor= 462. rpaght= 540. zvdis=  78. zvdmax= 462. zwi=0.931 wwa=0.511
 zmodor= 462. rpaght= 445. zvdis= -17. zvdmax= 462. zwi=0.997 wwa=0.210

 Diagnostic PRECIPITATION  analysis   scan 1
  grid point  ix=167  iy=103  lat= 47.54  lon=   8.74  height= 462.
 Observations influencing this grid point:

 stat_id     lat      lon   height  increment  weight
 06679       47.48     8.90    540.    11.00    0.51
...
 Q942        47.77     8.82    445.     2.00    0.21
 Resulting prc analysis increment:   7.61

 *** STATISTICS ON ANALYSIS OF PRECIPITATION AMOUNT; UNIT=mm
      SUM OF CHANGES       = 497251.8071
      NO. OF ANAL. POINTS  =      194081
      AVERAGRE CHANGE      =      2.5621
      STANDARD DEVIATION   =      8.7602
      MAX. CHANGE          =    137.0000
      MAX. POSITIVE CHANGE =    137.0000
      AT MODEL LAT./LON.   =      5.3250     -0.7250
      MAX. NEGATIVE CHANGE =      0.0000
      AT MODEL LAT./LON.   =     -5.0000     -2.8000
```

Figure 8.28: Example file `YUSURF`, second part on current analyses.

8.3 NetCDF Feedobs File

For data assimilation or verification purposes, a special NetCDF '*feedobs*' file (sometimes also (mis)called '*feedback*' file) can be written. This file contains the observations themselves from a specifiable period within the model integration period (see `Namelist` parameter '`hversta`', etc.). Moreover, it also accommodates estimated observation errors and other pieces of information which depend on the model state of the COSMO run itself. This includes the quality control flags, bias corretions, as well as the simulated observations derived from the model state exactly at the respective observation times.

The purpose of the feedobs file is to serve as input for a Local Ensemble Transform Kalman Filter (LETKF) analysis, or for a utility, which computes the simulated observations from various model runs and writes them into an extended NetCDF *feedback* file. This feedback file then contains all the input information required for grid point verification. Its format (and in principle its contents) are identical to that of the feedobs file, except that such feedback files can contain the simulated observations from more than just one model run. The format is described in a separate documentation '`Feedback File Definition`' which can also be found on the COSMO web site (`www.cosmo-model.org`).

The file name of the feedobs file has the following form:

`'fof_' // yyyymmddhhttss // '.nc'`

with : `yyyy`: year , `mm`: month , `dd`: day , `hh`: hour , `tt`: minute , `ss`: second .

(`yyyy` means 'year' in 4 digits, while the other quantities are expressed in 2 digits each.) The date and time refers to '`verification_ref_date`' and '`verification_ref_time`' as described in the '`Feedback File Definition`. As the file name starts with `'fof'`, the feedobs file is also sometimes called '*fof*' file.

Considering the purpose of the NetCDF feedobs file, it should contain all the observations that are potentially used for grid-point verification. This means that it contains many more observation types than actively used in data assimilation, i.e. e.g. in a LETKF analysis. However, it does not include all types of 'exotic' observations present e.g. in an original surface synoptic report, and it also fails to contain all the header and complementary information (e.g. on the instrumentation) from the originial observation reports. Thus, the feedobs file cannot be considered a complete surrogate or extension of the original BUFR observation files resp. NetCDF observation input files.

8.4 Output of Forecast Fields

The results of the model forecast can be written to Grib (Edition 1) or NetCDF files. The Grib Code is explained in Section 5.1 in more detail. The files, to which the forecast fields are written, obey to the *File Name Conventions* explained in Section 6.2. Depending on the type of data, the filenames get a certain extension:

`'p'` Forecast fields on pressure levels.

`'z'` Forecast fields on geometric z-levels.

`'s'` Synthetic satellite images.

All fields on model levels, soil and surface fields are written to a file without extension.

All fields can be written for the full domain or a subdomain, if the `NAMELIST` parameters `ydomain = 's'` and `slon, slat, elon, elat` in the group `/gribout/` are specified. To distinguish NetCDF from Grib files, the NetCDF files contain the suffix `.nc`.

The output of the forecast fields is controlled by the `NAMELIST`-group `gribout` (the name of this group comes from the time, when only Grib was implemented, but it it also valid for NetCDF output). It is possible to specify several instances of this group. The `NAMELIST` parameter `ngribout` in the group `IOCTL` has to be set accordingly. For every instance you have to define a list of variables for output and a description of the special kind of output. For that purpose you have to set the `NAMELIST` variables contained in `gribout` (see Section 7.14) properly:

- Specifying the list of variables for output:
  - `yvarml(:)`: Variables on model levels.
    e.g. `yvarml = 'U', 'V', 'HSURF'`.
  - `yvarpl(:)`: Variables on pressure levels.
  - `plev(:)`: A list of pressure levels to which the model variables are interpolated.
  - `yvarzl(:)`: Variables on z-levels.
  - `zlev(:)`: A list of z-levels to which the model variables are interpolated.
  - `yvarsl(:)`: Variables that contain images for channels of selected satellites.

  By specifying `yvarxl = 'default'` ($\mathtt{x} \in \{\mathtt{m}, \mathtt{p}, \mathtt{z}, \mathtt{s}\}$), a predefined list of variables is written. Table 8.1 gives a list of basic model variables that can be specified for output. The second column indicates whether a variable is in a special default list for output.

- Specifying the time steps, when these variables shall be written:
  There are two ways of specifying the output steps:
  - With a list of time steps (`ngrib(:)`) or alternatively a list of hours (`hgrib(:)`), e.g.
    `ngrib = 0, 2, 4, 24, 138, 400`
    `hgrib = 0.0, 0.5, 1.0, 1.75, 4.3`
    Up to 100 different output steps can be specified.

  - With a list of begin-, end- and increment steps given in time steps (`ncomb(:)`) or in hours (`hcomb(:)`). The values have to be given in triples, e.g.

    ```
    hcomb = 0.0, 12.0, 1.0, 12.0, 24.0, 0.5, 24.0, 48.0, 2.0
    ```

    With this specification, the following output is performed:

    - ∗ From forecast hour 0.0 to 12.0 results are written every hour.
    - ∗ From forecast hour 12.0 to 24.0 results are written every 30 Minutes.
    - ∗ From forecast hour 24.0 to 48.0 results are written every 2 hours.

  If nothing is specified for these variables, results will be written every hour starting with the beginning of the forecast.

- Specifying the domain for which these variables shall be written:
  With the variable `ydomain` you can specify whether the variables are written for the full domain (`ydomain = 'f'`: default) or for a subdomain (`ydomain = 's'`). In case of a subdomain you also have to define the start- and endpoints of this subdomain (`slon, slat, elon` and `elat`) in rotated geographical coordinates.

- Specifying the time unit of the forecast range:
  With the variable `ytunit` the time unit of the forecast range (form of the output file name) can be specified.

- Specifying the system where the variables are written to:
  There are two possibilities:

  - `ysystem = 'FILE'`: The results are written to grib files in the directory `ydir`.
  - `ysystem = 'BASE'`: This possibility is not implemented yet.

- Specifying the packing rate for the Grib code:
  `nrbit` gives the number of bits that will be used for storing one real variable of the model. Possible values are 4, 8, 16, 24, 32 and 48.

- Specifying control output:
  If `lcheck = .TRUE.`, minimum, maximum and mean values of the fields are calculated and written to file `YUCHKDAT`.

Table 8.1: Basic output fields for the COSMO-Model

Field	defaults	Meaning
U	mpz	zonal wind speed
V	mpz	meridional wind speed
W	m z	vertical wind speed
T	mpz	temperature
QV	m	specific water vapor content
QC	m	specific cloud water content
QI	m	specific cloud ice content
QR	m	specific rain content
QS	m	specific snow content
QG		specific snow content

PP		deviation from reference pressure
P	m z	pressure
PS	m	surface pressure
PMSL	m	surface pressure on mean sealevel
HHL	m	geometrical height of half levels
HSURF	m	height of surface topography
T_S	m	temperature of surface
T_SNOW	m	temperature of snow surface
T_G	m	temperature at the boundary soil-atmosphere
T_M	m	temperature between upper and medium soil layer
T_SO	m	temperature of (multi-layer) soil levels
QV_S	m	specific water vapor content at the surface
WG_1	m	water content of the upper soil layer
WG_2	m	water content of the medium soil layer
WG_3		water content of the lower soil layer
W_SO	m	water content of (multi-layer) soil levels
TKVM		turbulent diffusion coefficients for momentum in the atmosphere
TKVH		turbulent diffusion coefficients for heat and moisture in the atmosphere
W_I	m	water content of interception water
W_SNOW	m	water content of snow
T_CL	m	temperature between medium and lower soil layer
W_CL	m	climatological water content of the lowest soil layer
TCM	m	turbulent diffusion coefficients for momentum at the surface
TCH	m	turbulent diffusion coefficients for heat and moisture at the surface
CLCT	m	total cloud cover
CLCH	m	cloud cover with high clouds
CLCM	m	cloud cover with medium clouds
CLCL	m	cloud cover with low clouds
DPSDT		tendency of the surface pressure
BAS_CON	m	index of lower boundary of convective clouds
TOP_CON	m	index of upper boundary of convective clouds
HBAS_CON	m	height of lower boundary of convective clouds
HTOP_CON	m	height of upper boundary of convective clouds
ASOB_S	m	average solar radiation budget (surface) (mean value over forecast)
ATHB_S	m	average thermal radiation budget (surface) (mean value over forecast)
APAB_S	m	average photosynthetic active radiation (surface) (mean value over fcast.)
ASOB_T	m	average solar radiation budget (model top) (mean value over forecast)
ATHB_T	m	average thermal radiation budget (model top) (mean value over forecast)
VIO3		vertical integrated ozone content
HMO3		ozone maximum
Z0	m	roughness length * g
FR_LAND	m	part of land in the grid cell

SOILTYP	m	soil type of the land
PLCOV		degree of plant covering
LAI		leaf area index
ROOTDP		root depth
ALB_RAD	m	albedo of the ground
RLAT	m	geographical latitude
RLON	m	geographical longitude
FC		Coriolisparameter
RAIN_GSP	m	rain, precipitation (sum over forecast)
SNOW_GSP	m	snow, precipitation (sum over forecast)
RAIN_CON	m	rain, convective (sum over forecast)
SNOW_CON	m	snow, convective (sum over forecast)
U_10M	m	zonal wind in 10m
V_10M	m	meridional wind in 10m
T_2M	m	temperature in 2m
TD_2M	m	dew-point in 2m
TMIN_2M	m	minimum temperature in 2m
TMAX_2M	m	maximum temperature in 2m
PRR_CON		rate of precipitation, convective rain
PRS_CON		rate of precipitation, convective snow
PRR_GSP		rate of precipitation, scale rain
PRS_GSP		rate of precipitation, scale snow
AUMFL_S	m	average u-momentum flux (surface)
AVMFL_S	m	average v-momentum flux (surface)
ASHFL_S	m	average sensible heat flux (surface)
ALHFL_S	m	average latent heat flux (surface)
RUNOFF_S	m	surface water drainage; (sum over forecast)
RUNOFF_G	m	soil water drainage; (sum over forecast)
VMAX_10M	m	maximal windspeed in 10m
FI	p	geopotential height
OMEGA	p	vertical velocity p-dot in pressure coordinate system
RELHUM	pz	relative humidity
TOT_PREC	m	total precipitation

References

Baldauf, M., 2013. A new fast-waves solver for the Runge-Kutta dynamical core. COSMO Technical Report No. 21, Consortium for Small-Scale Modelling, http://www.cosmo-model.org/content/model/documentation/techReports/default.htm.

Baldauf, M., 2014. The COSMO model: towards cloud-resolving NWP. In *Recent Developments in Numerical Methods for Atmosphere and Ocean Modelling - Proceedings of a Seminar*, pp. 107–122. ECMWF, Reading, UK.

Davies, H. and R. Turner, 1977. Updating prediction models by dynamical relaxation: An examination of the technique. *Quart. J. R. Met. Soc.*, 103, 225–245.

Dudhia, J., 1993. A nonhydrostatic version of the Penn State / NCAR mesoscale model: Validation tests and simulation of an Atlantic cyclone and cold front. *Mon. Wea. Rev.*, 121, 1493–1513.

Hess, R., 2001. Assimilation of screen-level observations by variational soil moisture analysis. *Meteorol. Atmos. Phys.*, 77, 155–166.

Jacobsen, I. and E. Heise, 1982. A new economic method for the computation of the surface temperature in numerical models. *Contr. Atmos. Phys.*, 55, 128–141.

Kain, J. and J. Fritsch, 1993. Convective parameterization for mesoscale models: The Kain Fritsch scheme. In *The Representation of Cumulus Convection in Numerical Models, Meteor. Monogr., Vol. 24, No. 46*, pp. 165–170. American Meteorological Society, Boston.

Kessler, E., 1969. *On the Distribution and Continuity of water substance in the atmospheric circulations*, Volume 32 of *Meteorological Monographs Vol. 10*. American Meteorological Society, Boston.

Klemp, J. and R. Wilhelmson, 1978. The Simulation of Three-dimensional Convective Storm Dynamics. *J. Atmos. Sci.*, 35, 1070–1096.

Liu, X.-D., S. Osher, and T. Chan, 1994. Weighted essentially non-oscillatory schemes. *J. Comput. Phys.*, 115, 200–212.

Louis, J.-F., 1979. A parametric model of vertical eddy fluxes in the atmosphere. *Bound. Layer Meteor.*, 17, 187–202.

Lynch, P., D. Girard, and V. Ivanovici, 1997. mproving the efficiency of a digital filtering scheme. *Mon. Wea. Rev.*, 125, 1976–1982.

Mellor, G. and T. Yamada, 1974. A hierarchy of turbulence closure models for planetary boundary layers. *J. Atm. Sc.*, 31, 1791–1806.

Mironov, D., 2008. Parameterization of lakes in numerical weather prediction. Description of a lake model. COSMO Technical Report No. 11, Deutscher Wetterdienst, Deutscher Wetterdienst, D-63004 Offenbach, Germany.

Mironov, D. and R. B., 2004. Testing the new ice model for the global NWP system GME of the German Weather Service. Technical documentation, 1220, WMO, WMO, Geneve, Switzerland.

Müller, E., 1981. Turbulent flux parameterization in a regional-scale model. In *ECMWF Workshop on planetary boundary layer parameterization*, pp. 193–220. 25-27 November, 1981.

Ritter, B. and J.-F. Geleyn, 1992. A comprehensive radiation scheme for numerical weather prediction models with potential applications in climate simulations. *Mon. Wea. Rev.*, 120, 303–325.

Schaer, C., D. Leuenberger, O. Fuhrer, D. Lüthi, and C. Girard, 2002. A new terrain-following vertical coordinate formulation for atmospheric prediction models. *Mon. Wea. Rev.*, 130, 2459–2480.

Schraff, C., 1996. Data assimilation and mesoscale weather prediction: A study with a forecast model for the Alpine region. Publication 56, Swiss Meteorological Institute, Zürich.

Schraff, C., 1997. Mesoscale data assimilation and prediction of low stratus in the Alpine region. *Meteorol. Atmos. Phys.*, 64, 21–50.

Skamarock, W. and J. Klemp, 1992. The stability of time-split numerical methods for the hydrostatic and nonhydrostatic elasic equations. *Mon. Wea. Rev.*, 120, 2109–2127.

Skamarock, W., P. Smolarkiewicz, and J. Klemp, 1997. Preconditioned Conjugate Gradient Solvers for Helmholtz Equations in Nonhydrostatic Models. *Mon. Wea. Rev.*, 125, 587–599.

Sommeria, G. and J. W. Deardorff, 1977. Subgrid-scale condensation in models of non-precipitating clouds. *J. Atmos. Sci.*, 34, 344–355.

Stauffer, D. and N. Seaman, 1990. Use of four-dimensional data assimilation in a limited-area mesoscale model. Part I: Experiments with synoptic-scale data. *Mon. Wea. Rev.*, 118, 1250–1277.

Stauffer, D. and N. Seaman, 1994. Multiscale four-dimensional data assimilation. *J. Appl. Meteor.*, 33, 416–434.

Stephan, K., S. Klink, and C. Schraff, 2008. Assimilation of radar-derived rain rates into the convective-scale model COSMO-DE at DWD. *Quart. J. R. Meteor. Soc.*, 134, 1315–1326.

Thomas, S., C. Girard, G. Doms, and U. Schättler, 2000. Semi-Implicit Scheme for the DWD Lokal-Modell. *Meteorol. Atmos. Phys.*, 73, 105–125.

Tiedtke, M., 1989. A comprehensive mass flux scheme for cumulus parameterization in large-scale models. *Mon. Wea. Rev.*, 117, 1779–1799.

Wicker, L. and W. Skamarock, 2002. Time-splitting methods for elastic models using forward time schemes. *Mon. Wea. Rev.*, 130, 2088–2097.