Med-CORDEX phase 3:
Common protocol for the Baseline runs for the CORDEX-CMIP6 framework

Version 0: S. Somot, 8 avril 2022 , creation of the file after the MedCDX workshop
Version 1: S. Somot, 24 june 2022, preparation of the MedCDX SC meeting
Version 2: S. Somot, 6 july 2022, first draft
Version 3: E. Coppola, S. Somot, 29 sept 2022, first official draft, posted on zenodo
Version 4: S. Somot, 18 oct 2022, contact points for LULC change (FPS-LUCAS)
Version 5: S. Somot, 2 aug 2023, include the results of the workshop discussions, posted on zenodo
Version 6: S. Somot, 3 aug 2023, change in the aerosol section for eval runs, posted on zenodo

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A. Introduction

Since its launch in 2009, one of the main strength and originality of the Med-CORDEX initiative within CORDEX is the setting, coordination and use of coupled RCMs also called Regional Climate System Models (RCSM) or Regional Earth System Models (RESM) including at least the representation of atmosphere, land-surface and ocean components but sometimes also the rivers, the ocean biogeochemistry, the natural and anthropogenic aerosols, the waves, or a complex surface hydrology representation (Ruti et al. 2016, Somot et al. 2018b, check the Med-CORDEX publication list, the phase 1 and phase 2 model and simulation lists for more information). The added-value of this originality has been recognized in the IPCC-AR6 WG1 report in 2021 (see Chapter 10, Chapter 12, Chapter Atlas, and the IPCC Interactive Atlas). This led the Med-CORDEX community to propose a new coordinated ensemble of RCSM simulations as baseline runs for the third phase of Med-CORDEX, in line with the CORDEX-CMIP6 experiment protocol and associated data request issued in 2021 by the CORDEX Science Advisory Team.

The goals of the current document are to:
- present the main scientific objectives targeted by these baseline runs
- recall the process leading to the chosen common protocol
- describe the agreed common protocol for the simulations (evaluation runs and scenario runs)
- However, this document does not list the participating institutes, models and simulations and does not include the data request and the description of the file naming. Those information are available aside (https://www.medcordex.eu/simulations-phase3.php).

Note that in addition to the baseline runs, the phase 3 of Med-CORDEX includes other modelling initiatives.

B. Main scientific objectives addressed by the baseline runs

Under the CORDEX umbrella, the Med-CORDEX initiative is the only one offering the possibility to have an ensemble of Regional Climate System Models (RCSM) or Regional Earth System Models (RESM) to study the climate of the Mediterranean basin from multiple perspectives. With the increase of model resolution and the possibility of the climate community to reach more and more the simulation of processes relevant at local scale, with such a coordinated experiment it would be much more likely to serve the needs of the impact community within a risk assessment framework.
One of the main objectives of these baseline simulations would be to create an ensemble of high resolution coupled simulations driven by the ERA5 reanalysis and the CMIP6 models to fill the research gaps as for example those highlighted in the IPCC AR6 WGI & WGII report. Several research questions could focus for example on the impact of global warming for

different hazards in the Mediterranean basin at several global warming levels (GWLs). Examples of these could be:

- marine and atmospheric heatwave
- Drought and heavy rain events
- Severe Mediterranean storms (including Medicanes)
- coastal erosion and floodings
- Coastal urban heat stress
- Sea Level extremes and mean sea Level rise
- Dust outbreaks
- Compound hazards

All this information could be used by the impact community to assess the risk for the marine and coastal ecosystems, the coastal urban areas, and the small island's environment, tourism, fluvial and marine transportation, fisheries and aquaculture, energy production.

C. The steps of the definition of the Med-CORDEX phase 3

- Discussions within the Med-CORDEX Steering Committee since 2020
- Publication of the IPCC-AR6 in 2021, emergence of the use of ERA5 as lateral boundary conditions for RCMs in 2021, availability of the CMIP6 GCM simulations from 2020
- Publication of the CORDEX-CMIP6 experiment protocol and associated data request by the CORDEX SAT in 2021
- On-Line Mini-Workshop on Med-CORDEX baseline runs and the new CORDEX-CMIP6 protocol, Monday 28th, Tuesday 29th, March 2022

Following those steps and in particular the mini-workshop, the Med-CORDEX modelling community decided to launch its phase 3. See an overview of phase 3 here.

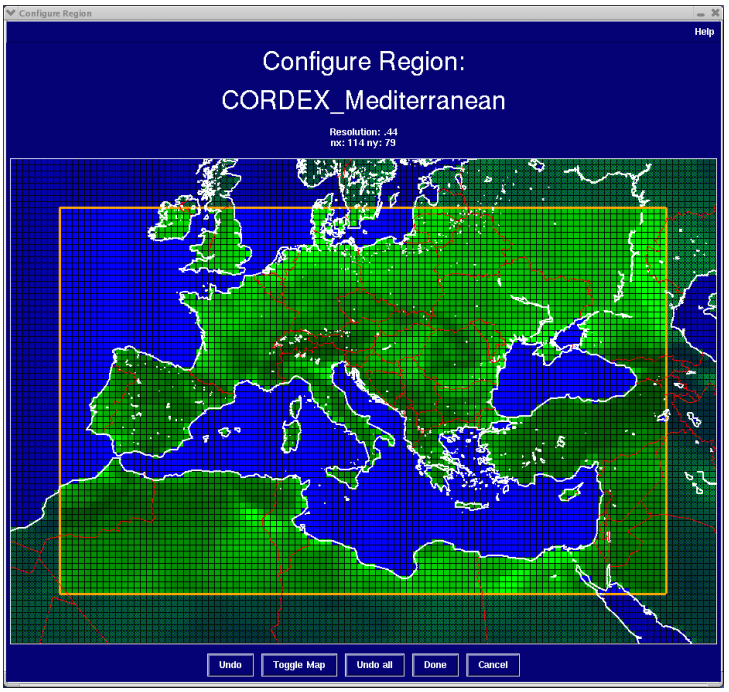
D. Common Protocol

Major novelties with respect to Phase 2 protocol are highlighted in blue. Information to be updated is underlined in yellow.

IMPORTANT NOTE: this protocol should be seen as a complement to the official CORDEX-CMIP6 experiment protocol and associated data request. So please, use the three documents to prepare your runs:
https://cordex.org/experiment-guidelines/cordex-cmip6/experiment-protocol-rcms/
https://cordex.org/experiment-guidelines/cordex-cmip6/data-request/

1. Minimal Domain

Same as in the Med-CORDEX phase 1 and phase 2 (for a precise definition see domain #12 in https://www.medcordex.eu/cordex_domains_250610.pdf). The domain is kept small in order to allow running at 12 km and welcoming new modelling groups with less computer resources. Covering the whole Mediterranean and Black Seas river catchment basins (except for the Nile) is mandatory to allow the river coupling.
NB: Eastward extension (if possible in new settings) welcome to better cover the Black Sea and the whole Turkey country. Southward extension welcome to better cover the Mediterranean countries in North Africa.



2. Minimal model configuration

2.1 Fully-coupled RCSM with atm-land-river-ocean (ALRO). Note that river coupling (outside Nile) is mandatory in Phase 3. It is particularly relevant for scenario simulations. Other

components such as marine biogeochemistry, interactive aerosols, interactive vegetation, complex surface hydrology, land-use land cover change, cities, glaciers or waves are very welcome but not mandatory.
2.2 Atmosphere/Land minimal resolution: 0.11° or 12 km is now mandatory in Phase 3
2.3 Ocean minimal resolution: 1/12° or 10 km is now mandatory in Phase 3
2.4. The number of vertical levels is free for the ocean and atmosphere models. For the ocean, try to ensure that vertical resolution is enough to solve the surface mixed layer
2.5 River: Land-to-ocean coupling may be done with simple approaches but using an up-to-date river routine scheme is recommended
2.5 Using a common ocean bathymetry is recommended. An ocean bathymetry file (already used by NEMOMED12 and MITgcm) can be provided in netcdf format for those who want to adopt a common bathymetry and model grid. Please contact Romain Pennel at LMD (romain.pennel@lmd.ipsl.fr).
2.6 Coupling frequency: at least 1 hour is recommended for atmosphere-ocean coupling and at least 1 day for river-ocean coupling.

3. Evaluation runs (also called Hindcast) : EVAL

3.1 Period: minimum 1979-2020. Extension to previous years (1950-1978) and to recent years are welcome.
3.2 Atmosphere Lateral Boundary conditions: Use ERA5 reanalysis from ECMWF. For the lateral forcing, it is recommended to use at least the 6-hourly frequency and the full-resolution version of ERA5
3.3 Ocean Lateral Boundary conditions in Near-Atlantic: use ORAS5 reanalysis from ECMWF (data available at https://www.cen.uni-hamburg.de/icdc/data/ocean/easy-init-ocean/ecmwf-oras5.html for the 1979-2018 period). Use at least the monthly frequency for the ocean forcing including the 3D temperature and salinity information as well as the sea level information. Contrary to ORAS4, no correction for the sea level is needed (contact point for ORAS5: Alessandro Anav at ENEA, alessandro.anav@enea.it, Florence Sevault at CNRM, florence.sevault@meteo.fr). ORAS5 covers the period 1958-now with a break in the atmospheric forcing in 1978-1979 and in 2014-2015. It has 5 members available. Is it recommended to use member opa0.
More information available here:
https://www.ecmwf.int/en/research/climate-reanalysis/ocean-reanalysis
https://www.cen.uni-hamburg.de/icdc/data/ocean/easy-init-ocean/ecmwf-oras5.html
3.4 Sea level is a key scientific variable with a strong interest for the users. We intend to provide relevant information on sea level in this phase 3. Modelling groups should therefore be careful with the sea level representation in their model (zos variable). We advise to follow the IPCC-SROCC recipe, also used in Sannino et al. (2022). Contact: gianmaria.sannino@enea.it). The list of the global components (ice melting, thermosteric, dynamic…) included in the evaluation simulations thanks to the ORAS5 lateral forcing should be clarified.
3.5 SST outside the coupling area: use ERA5 SST for consistency with a least a monthly frequency. Tests with higher-resolution SST datasets outside the coupling zone (e.g. CMEMS products) are welcome

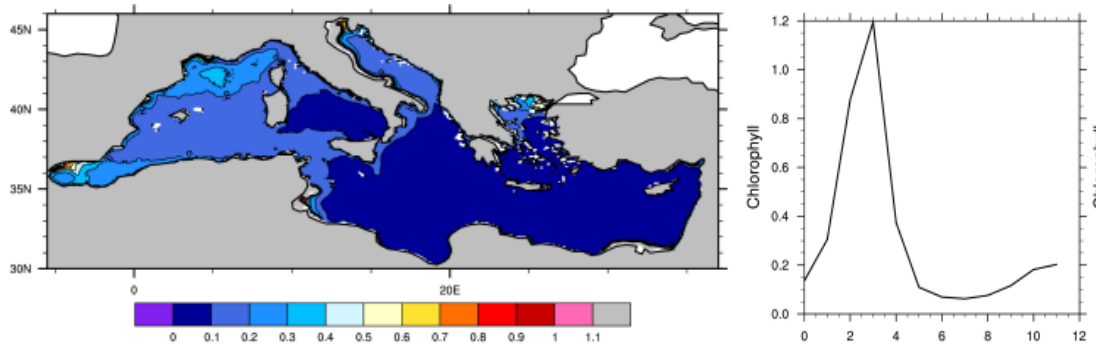
3.6 GHG: realistic evolution for past runs should be implemented following CMIP6 forcing recommendations. Time series can be provided by CNRM if needed (contact pierre.nabat@meteo.fr)
3.7 Aerosol representation: Following the CORDEX-CMIP6 protocol, *"A static aerosol dataset (e.g. a regional model's default climatology) is considered as a minimum requirement. It is strongly encouraged that for the evaluation experiment, RCM groups apply up-to-date regional or global aerosol datasets with realistic variability in time (monthly variation and trend) and space."* The use of the state-of-the-art monthly mean aerosol optical properties dataset derived from MERRA-2 aerosol reanalysis (Gelaro et al. 2017, Buchard et al. 2017, *https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/)* is advised. The use of interactive and prognostic aerosol schemes is also allowed. See the CORDEX-CMIP6 protocol for more information (contact: fabien.solmon@aero.obs-mip.fr). The dataset is available through the AERIS data portal with a reference doi: https://doi.org/10.25326/383.
3.8 Sea albedo: recommendation is to use an ocean albedo depending on the zenital angle, that is to say depending on space and time (see Dubois et al. 2012). If constant, the albedo should be around 0.07 for the Mediterranean Sea.
3.9 Land-surface characteristics : to be documented by each modelling group. Use of land-use/land-cover map changes is allowed (dataset covering the whole Med-CORDEX domain and expertises are available in the CORDEX FPS LUCAS, contact persons: diana.rechid@hereon.de, peter.hoffmann@hereon.de).
3.10 Nile river discharge: we propose to use a common seasonal cycle (12 values) with an annual value of 444 m³/s that is equivalent at 14 km³/y in agreement with Nixon (2003) and FAO information. (contact: Erika Coppola, coppolae@ictp.it). Here are the proposed values, same as in Phase 2. Note that a split in 2 river mouths has been proposed for NEMOMED12 users (contact: florence.sevault@meteo.fr).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
Values (m^3/s)	336	396	407	399	472	615	634	557	412	373	372	352	444

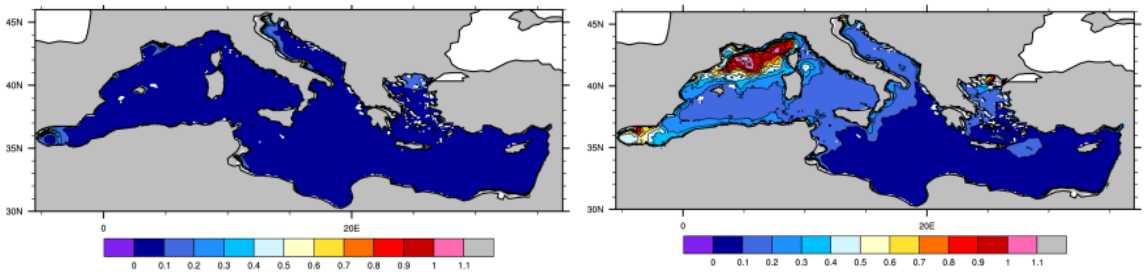
NB: the decision has been taken taking into account Dubois et al. (2012) for the state of the art during the CIRCE project, values used currently in Med-CORDEX models (NEMOMED8, NEMOMED12, MITgcm, GETM), advice from J. Polcher (LMD), Nixon (2003), Global River Data Center (GRDC, Germany) dataset available at the Nelson Institute website (https://nelson.wisc.edu/sage/data-and-models/riverdata/station_table.php?qual=256&filenum=1609) and FAO information (http://www.fao.org/nr/water/aquastat/countries_regions/egy/)
3.11 Suez canal: closed but sensitivity tests are welcome. To our knowledge, no literature available so far on the impact of the Mediterranean Sea - Suez Canal exchanges.
3.12 Black Sea representation: an explicit representation of the Black Sea and of the exchanges with the Aegean Sea is allowed but not mandatory. If the Black Sea is not explicitly represented in the model, a simple parameterization of the integral effect of the Black Sea on the Mediterranean water budget should be implemented as the Black Sea represents a major input of water to the Mediterranean Sea. See for example Sevault et al. (2014) for a typical implementation of such parameterization in which the E-P-R Black Sea

water budget is used as a freshwater volume input for the Mediterranean Sea. More complex parameterizations can be developed for example to take into account the effect of the local atmospheric pressure and wind.

3.13 Surface chlorophyll climatology for the ocean: if you don't use on-line biogeochemistry model, we propose to use a common 12-map climatology for the surface Chlorophyll derived from the L3 ESA-CCI dataset averaged over the 2003-2011 period. Please contact Romain Pennel at LMD (romain.pennel@lmd.ipsl.fr).



(left) Spatial map of the yearly average value of the surface cholorophyll (g/L) and (right) monthly-mean seasonal cycle at the LION buoy location (NW Mediterranean Sea). figure from Florence Sevault (pers. comm.)



Spatial map of the surface chlorophyll (g/L) averaged for the (left) July-August months and (right) March-April months. figure from Florence Sevault (pers. comm.)

3.14 Coupling over the near-atlantic buffer.

No agreement has been reached.

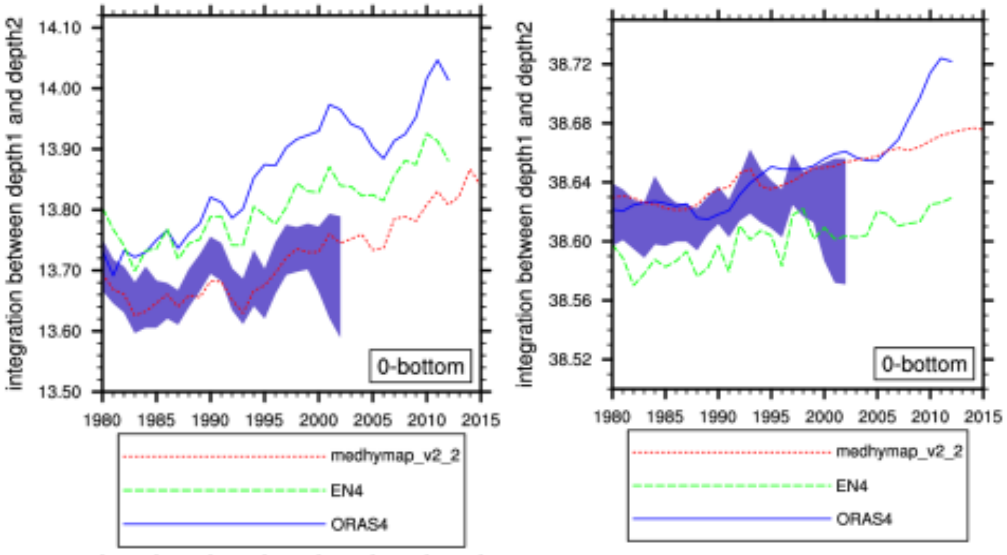
3.15 Inside-domain nudging in the atmosphere (grid-point nudging, spectral nudging or no specific nudging). Spectral nudging is allowed but should be documented by the modelling groups. Grid-point nudging is not allowed. It is anticipated that most of the models will run without nudging inside the domain.

3.16 Atmospheric-Land initial conditions and spin-up: do not matter (probably 1st of January 1979 in ERA-Int). A 1-year spin-up is the minimum requirement for the atmosphere-land component.

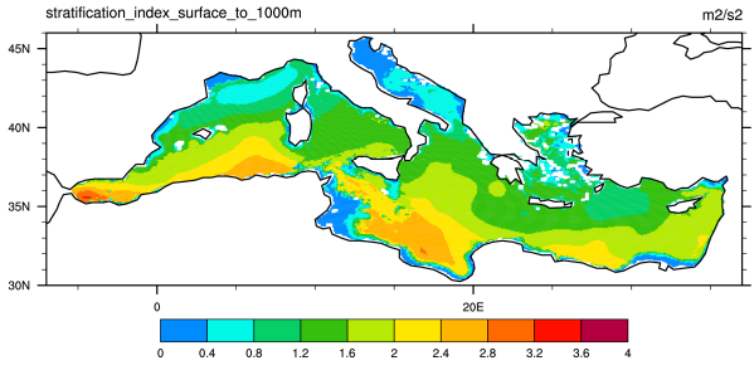
3.17 Ocean Initial Conditions:

The recently-developed and evaluated MedHYMAPv2.2 dataset for the 1970s is recommended. We recommend starting from a Summer month using the year 1975 from the

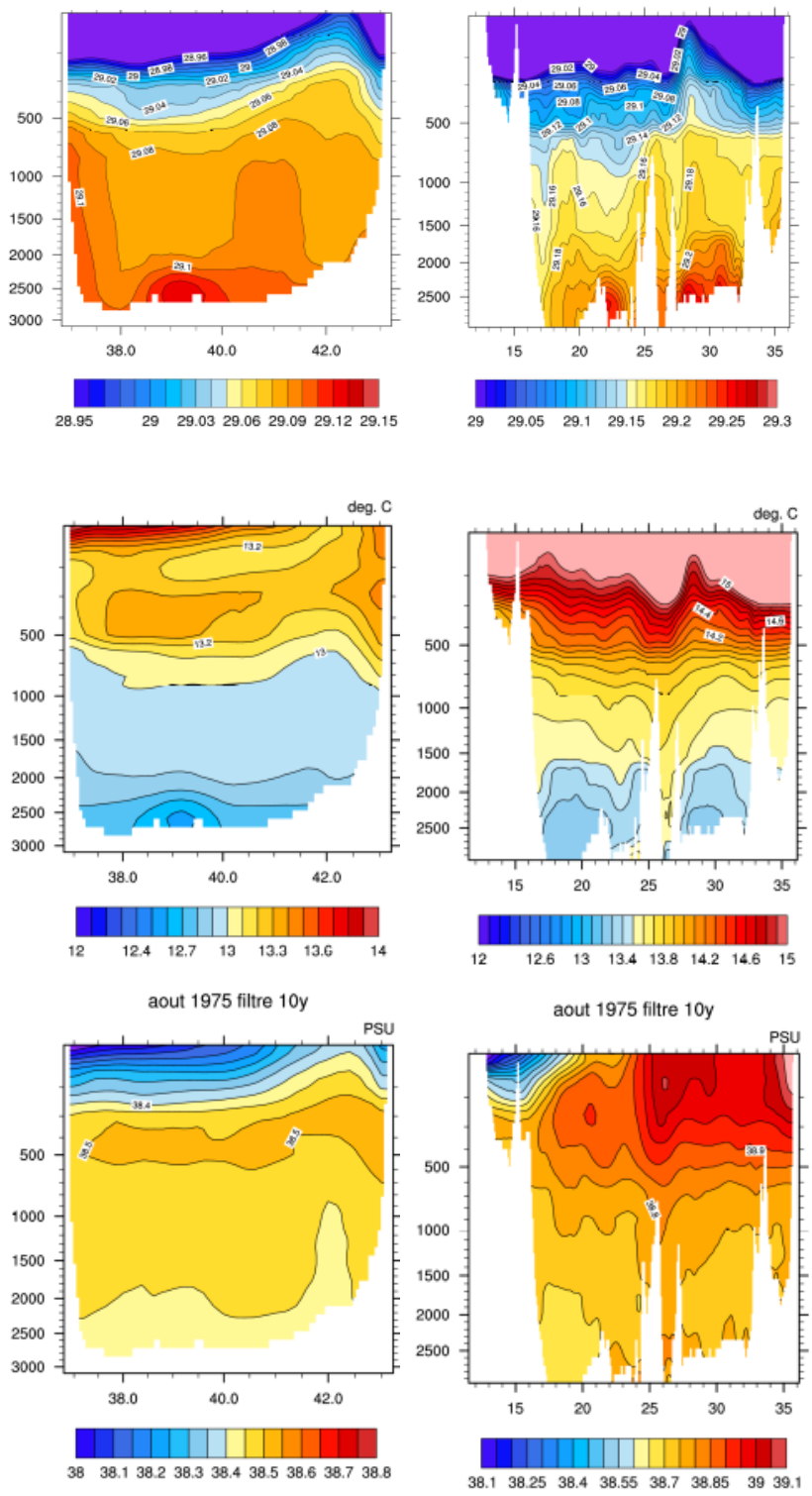
10-year filtered dataset version. It is provided by IMEDEA (contact: gabriel.jorda@ieo.csic.es).



Interannual time series of the Mediterranean Sea (left) heat content (expressed in °C) and (right) salt content (in psu) for the advised IMEDEA-MedHYMAPv2.2 dataset (red) compared to EN4 (green), ORAS4 (blue) and Med-Atlas/Rixen dataset (purple). figure from Florence Sevault (pers. comm.)



Average Stratification Index over the 0-1000m depth and the 1980-2012 period (in m2/s2) for the advised IMEDEA-MedHYMAPv2.2 dataset. figure from Florence Sevault (pers. comm.)



Vertical section for (left) the Western Mediterranean Sea (South-North section at 5°E) and (right) the Eastern Mediterranean Sea (West-East section at 34°N) for the month of August 1975 of the 10-year filtered version of the advised IMEDEA-MedHYMAPv2.2 dataset for the potential density (top), the potential temperature (middle) and salinity (bottom). figure from Florence Sevault (pers. comm.)

3.18 Ocean Spin-up strategy: based on the community experience, we prefer to recommend stability criteria for the model run at the end of the spin-up or after the spin-up period [TO BE DECIDED] than to set a common spin-up length or strategy. For the ocean, we advise to keep the model trends below an acceptable level based on observed trends including acceptable errors (minimum acceptable thresholds to be provided over a given period and for different variables and layers, contact: gabriel.jorda@ieo.es . NOT YET AVAILABLE). Spin-up strategy should be documented by each modelling group.

4. Historical (HIST) and scenario (SCEN) runs

4.1 Principle: keep as much as possible consistency with the driving GCMs (ALBC, OLBC, SBC, land-use-land-cover, aerosols, GHG).
4.2 Use CMIP6 GCMs to drive your model
4.3 GCM Selection: a task force has been set. The basic principles defined by the EURO-CORDEX GCM selection task force (Sobolowski et al. 2023, 10.5281/zenodo.7673399) is kept but with adaptation and addition of criteria specific for the Med-CORDEX initiative and in particular for the use of coupled RCM [see the current status of the task team work here, Somot et al. 2023, https://zenodo.org/record/8207473, and here, https://wcrp-cordex.github.io/cmip6-for-cordex/CMIP6_studies_table_MED.html, UPDATE OF THOSE DOCUMENTS EXPECTED]. (contact: samuel.somot@meteo.fr). When you have chosen your driving GCMs, please file the official Med-CORDEX and CORDEX list of runs (see section E.3)
4.4 OLBC bias correction: we recommend to use a bias correction for temperature and salinity if the GCM shows significant biases with respect to the ORAS5 reanalysis. Use the difference between the reanalysis and the GCM over a common time period as a constant correction for the whole HIST+SSP runs. If you share the same forcing GCM as another group, please use the same correction terms.
4.5 Scenario choice: Priority 1 is SSP3-7.0, Priority 2 is SSP1-2.6, Priority 3 is SSP5-8.5 and Priority 4 is SSP2-4.5.
4.6 Minimum period: 1960-2100 (1950-2100 recommended). Extension to 1850 is welcome.
4.7 We advise to run a twin control run (without GHG and aerosol future evolution) if possible to check model stability
4.8 Nile: Keep it constant in time as in EVAL but sensitivity tests to the main protocol are welcome
4.9 Surface ocean chlorophyll: Keep it constant except for the models including the on-line biogeochemistry coupling
4.10 Black Sea representation: same as in EVAL
4.11 Ocean Initial Conditions: same as in EVAL but less relevant
4.12 Atmosphere initial conditions: same as in EVAL but do not matter
4.13 Spin-up strategy: same criteria as in EVAL, to be document
4.14 Sea level is a key scientific variable with a strong interest for the users. We intend to provide relevant information on sea level in this phase 3. Modelling groups should therefore be careful with the sea level representation in their model (zos variable). We advise to follow the IPCC-SROCC recipe, also used in Sannino et al. (2022). Contact: G. Sannino, ENEA,

gianmaria.sannino@enea.it). In historical and scenario simulations, we recommend adding a posteriori the globally-averaged thermosteric effect (variable zostoga) as they are usually not included into the driving fields. You can de-drift this variable if needed.

E. Model outputs

The Med-CORDEX Baseline run list is an adaptation and extension of the official CORDEX-CMIP6 Data Request:
https://cordex.org/experiment-guidelines/cordex-cmip6/data-request/

1. List of variables

So far, only Data Request for the atmosphere, land surfaces, ocean physics, aerosols and river are available. However lists for new components (e.g. ocean biogeochemistry, wave, …) can be developed following CMIP6 and CORDEX frameworks. The links below are permanent links even if we update the files.

- Updated Med-CORDEX list for the atmosphere and land-surface (contact: Marco Reale, mreale@ogs.it) : https://zenodo.org/record/7419220

- Med-CORDEX list for the ocean (contact: Samuel Somot, samuel.somot@meteo.fr): https://zenodo.org/record/8207552

- Med-CORDEX list for the rivers (contact: Erika Coppola, coppolae@ictp.it): https://zenodo.org/record/7112672

- Med-CORDEX list for the aerosols (contact: Pierre Nabat, pierre.nabat@meteo.fr): https://zenodo.org/record/7112859

You can also find the CORDEX-CMIP6 CMOR tables on github:
https://github.com/WCRP-CORDEX/cordex-cmip6-cmor-tables/tree/main/Tables

2. File format, file naming and archive specifications

IMPORTANT NOTE:
Model naming is a key aspect of the data specifications in CORDEX. Indeed any modification of the model configuration (e.g. resolution, tuning, spectral nudging, coupling a new component, changing a parameterization) should lead to a change in the model name. It was not always done during Phase 1 and 2 especially when resolution was changed, which created issues for the data users. So please be careful. New model names should be registered.

- CF-CMOR netcdf format respecting the CMIP6-CORDEX standard for file naming and variable naming. More specifically:

- Archive specifications (contact: Grigory Nikulin <grigory.nikulin@smhi.se>). The creation of a new document describing CORDEX-CMIP6 archiving specifications is on-giong. A first version has been distributed by G. Nikulin. We are waiting for the final document. Warning: There are many changes in CMIP6 compared to CMIP5 (global attributes, file naming, etc.) that should be taken into account. Realms that were missing in CORDEX-CMIP5 should be added (such as ocean, river, aerosol) and new CORDEX-CMIP6 CMOR tables should be created
(e.g https://github.com/WCRP-CORDEX/cordex-cmip6-data-request/issues/5).
When ready, the new archive specifications will be available here.
https://cordex.org/experiment-guidelines/cordex-cmip6/
You can still access the CORDEX-CMIP5 documents for atmosphere and land-surface and the Med-CORDEX documents for ocean and river:
http://is-enes-data.github.io/cordex_archive_specifications.pdf
www.medcordex.eu/references.php (contact: samuel.somot@meteo.fr , coppolae@ictp.it)

3. Data sharing

- We need to keep updated the lists of models and runs. Med-CORDEX is maintaining a version of these lists (shared google doc format to collect the information on the fly, contact: samuel.somot@meteo.fr) and you can find the last official version of the lists on zenodo: https://zenodo.org/communities/medcordex/ or on the CORDEX github (contact: Jesus Fernandez <fernandej@unican.es>):
https://github.com/WCRP-CORDEX/simulation-status/blob/main/CMIP6_downscaling_plans.csv
and
https://wcrp-cordex.github.io/simulation-status/CORDEX_CMIP6_status.html#MED-11

- We propose a 2-stage framework. First stage for data sharing with the other Med-CORDEX participants for multi-model evaluation and science studies. Second stage for data sharing with external data users.
- Stage 1: The data (a limited list of variables) can be shared using a common working space provided by ENEA for Med-CORDEX (contact: gianmaria.sannino@enea.it).
DOCUMENT ON HOW-TO-USE-IT TO BE LINKED HERE
- Stage 2: CF-CMOR-ESGF standards + publication on ESGF nodes. The ENEA central portal which hosted the Med-CORDEX phase 1 and phase 2 simulations will not host phase 3 runs. Every producing centre has to find its own way to share its dataset.

4. Quality check

There is no clear strategy so far for the quality checking of the files before the publication on the ESGF as the Quality Checker from DKRZ (QA-DKRZ) used in the first phase of CORDEX is not maintained anymore and is working only for atmosphere and land variables. The software called prepare is one of the options.

F. Model documentation and simulation errata

See the CORDEX-CMIP6 protocol document. Published articles or technical reports describing each model and/or run is welcome and can be linked to the official list of models. In addition, a centralised organisation of the main model metadata has been created for model documentation and will be shared when ready (contact: samuel.somot@meteo.fr). A similar document will be created later for the Med-CORDEX simulation errata.

G. Tentative Timeline

- March 2022: On-line workshop with the main decisions on the experiment protocol
- July 2022: Share the first protocol draft
- Sept 2022: The first protocol version is available on-line in zenodo
- March-September 2022: Start of the dedicated task forces on the remaining blocking points
- 2023: 7th International Med-CORDEX workshop
- 2023: Start of the evaluation runs and of the scenario runs
- 2024: Evaluation runs are finished, evaluated and used scientifically (publication)
- 2024: IPCC-AR7 calendar is set
- 2025: Scenario runs are assessed (publication)
- 2026: Evaluation runs are available on the ESGF
- 2026: Med-CORDEX special issue on the analyses
- 2027: Scenario runs are available on the ESGF
- XXXX: contributions to new IPCC reports
- XXXX: contributions to the new MedECC reports
- 2025/2026 (?): CMIP7 simulations are available
- 2027/2028 (?): cut off date for publications to be assessed in IPCC-AR7
- 2029 (?): IPCC-AR7 WG1 is published

- Opportunities to meet and discuss the baseline runs
    - Med-CORDEX workshop: March 2022, May 2023
    - Med-CLIVAR workshop, 4-8 October 2022, Marrakech, Morocco
    - CORDEX ICRC, 25-29 September 2023, Trieste, Italy, Med-CORDEX side event
    - WCRP OSC conference, 23-27 Octobre 2023, Kigali, Rwanda

H. References

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