RAL IASI MetOp-A TIR Methane Dataset

User Guide

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Change Log

Issue	Author	Affected Section	Reason	Date
1.0	D.Knappett	All	Document Creation	17/08/2016

Acronyms

Acronym	Description
BT	Brightness Temperature
CEDA	Centre for Environmental Data Analysis
CF	Climate and Forecast
CH_4	Methane
ECMWF	European Centre for Medium-Range Weather Forecasts
GTOPO30	Global 30 Arc-Second Elevation
HITRAN	High-Resolution Transmission Molecular Absorption Database
IASI	Infrared Atmospheric Sounding Interferometer
IDL	Interactive Data Language
METOP	Meteorological Operational satellite programme
NCEO	National Centre for Earth Observation
RAL	Rutherford Appleton Laboratory
RSG	Remote Sensing Group
STFC	Science and Technology Facilities Council
TIR	Thermal Infrared
UTC	Coordinated Universal Time
VMR	Volume Mixing Ratio
XVMR	Column-averaged Volume Mixing Ratio

1 Introduction

1.1 Purpose and Scope

This document is the Product User Guide for the RAL IASI MetOp-A TIR methane v1.0 dataset. It provides users of the dataset with practical information on the file format and content as well as advice on how to correctly interpret the data.

1.2 Background

The RAL Remote-Sensing Group (RSG) has developed an optimal estimation scheme to retrieve global height-resolved methane distributions from measurements in the thermal infrared (7.9 micron) band of the Infrared Atmospheric Sounding Interferometer (IASI) on board MetOp-A. Using data from IASI, methane retrievals can be performed at relatively high spatial resolution, both day and night, over land and ocean. Exploiting the JASMIN-CEMS infrastructure at RAL, IASI MetOp-A data from 2007-2015 has been processed, creating the RAL IASI MetOp-A TIR methane v1.0 dataset.

1.3 Data Availability

The RAL IASI MetOp-A TIR methane v1.0 dataset is freely available via the Centre for Environmental Data Analysis (CEDA) catalogue:
http://catalogue.ceda.ac.uk/uuid/510b22c6d12e4635b604c172b583167e

For processing purposes, each IASI orbit was split into four sections, each containing 200 scan lines. The output NetCDF files correspond to the same orbit subsections; four files for each IASI timestamp, appended with '0_199', '200_399', '400_599' and '600_799' respectively.

1.4 Filename Format

The filename format adheres to the following naming convention, with the segregators defined as in Table 1:

<institution>-<processing level>-<product>-<sensor>-<additional segregator>-<IASI orbit start time>Z_< IASI orbit end time >Z_<orbit section>.nc

E.g. ral-l2-ch4-iasi_metopa-tir-20151117012700Z_20151117030859Z_0_199.nc

Table 1: File name segregator descriptions.

Segregator	Example
Institution	ral
Processing level	l1, l2, l3
Product	ch4
Sensor	iasi_metopa, iasi_metopb
Additional segregator	tir
IASI orbit start time	YYYYMMDDHHMMSSZ
IASI orbit end time	YYYYMMDDHHMMSSZ
Orbit section	0_199, 200_399, 400_599, 600_799

1.5 Data Sampling

IASI has a 2200 km swath and measures both day and night. This provides near global coverage twice per day. IASI has 4 detectors, in a 2 x 2 matrix configuration, each of which has a 12 km diameter approximately circular footprint on the ground at nadir. These detectors scan across-track to give 120 (30 x 4) observations across the 2200 km swath.

Processing was carried out using observations from only one of the four IASI detectors, choosing the measurement which had the warmest (supposedly least cloud-affected) brightness temperature (BT) in a window channel at 950 cm^{-1}.

1.6 Data Quality

The data have been quality filtered to remove problematic data, e.g. scenes which are too cloudy, have too cold surface temperature, or do not converge satisfactorily.

IASI scenes strongly affected by cloud were omitted from processing based on the difference in BT between the IASI observation at 950 cm^{-1} and that simulated on the basis of ECMWF reanalysis (the *a priori* state for a standard retrieval). Scenes were not processed if the BT difference (observation – simulation) was outside of the range -5 to 15 K.

Furthermore, only scenes having a BT larger than 240 K at 950 cm^{-1} were processed, since the retrieval information content is significantly degraded over very cold surfaces. Convergence can also be poor in these conditions, which are often affected by strong near-surface temperature inversions.

2 Data Format

2.1 General

The data is provided in NetCDF format which adheres to CF compliance standard CF-1.6.

2.2 Data Dimensions

The dataset dimensions are as described in Table 2, below.

Table 2: Dataset dimensions.

Dimension	Description	Value
pdim	Number of retrievals	Up to 6000
nmlev	Number of model levels	50
nrlev	Number of retrieval levels	12
adim	Number of methane retrieval levels for which averaging kernels are reported (only a subset to reduce the output file size)	5
rsfdim	Number of residual scale factors	2

2.3 Global Attributes

Global attributes of the dataset are set as described in Table 3, below.

Table 3: Description of the output NetCDF global attributes.

Global Attribute	Description
creator_email	RAL RSG contact email address
project	Project name (NCEO)
licence	Details of data licence
platform	Satellite platform (MetOp-A)
sensor	Instrument on-board the satellite platform (IASI)
title	Dataset description (IASI offline thermal-IR methane retrievals)
product_version	Product release version (X.XX)
processor_version	Methane processor version (X.XX)
repository_version	Subversion repository number for methane processor IDL code
build_date	Date/time of code build used for processing (YYYY-MM-DDTHH:MM:SSZ)
processing_date	Date/time processing was performed (YYYY-MM-DDTHH:MM:SSZ)
date_created	Date/time NetCDF file was created (YYYY-MM-DDTHH:MM:SSZ)
institution	Creator institute (STFC Rutherford Appleton Laboratory)
input_file	Input IASI L1b file on the CEDA archive
history	Auxiliary retrieval setup information
time_coverage_start	Start date/time of IASI orbit file processed (YYYY-MM-DDTHH:MM:SSZ)
time_coverage_end	End date/time of IASI orbit file processed (YYYY-MM-DDTHH:MM:SSZ)
references	RAL RSG website reference (http://www.ralspace.stfc.ac.uk/remotesensing)
creator_name	RAL IASI products are developed with funding from the UK National Centre for Earth Observation
geospatial_lat_max	Maximum geospatial latitude within file
geospatial_lat_min	Minimum geospatial latitude within file
geospatial_lon_max	Maximum geospatial longitude within file
geospatial_lon_min	Minimum geospatial longitude within file
processing_status	Processing status (nominal)
conventions	CF compliance version (CF-1.6)

2.4 Variable Attributes

Variable attributes of the dataset are set as described in Table 4, below.

Table 4: Description of the output NetCDF variable attributes. The retrieved methane profile and column, and their associated errors, are highlighted in light blue.

Variable	Units	Description	Dimensions
ak_vmr	1e-6	Averaging kernel for profile mixing ratios (ppmv).	pdim, nmlev, adim
ak_xvmr	1e-6	Averaging kernel for column-averaged mixing ratio (ppmv).	pdim, nmlev
ap_ch4_vmr	1e-6	A priori dry-air mole fraction of atmospheric methane (ppmv).	pdim, nrlev
ap_ch4_vmr_err	1e-6	A priori error on retrieved dry-air mole fraction of atmospheric methane (ppmv).	pdim, nrlev
ap_ch4_xvmr	1e-6	A priori column-averaged dry-air mole fraction of atmospheric methane (ppmv).	pdim
ap_ch4_xvmr_err	1e-6	Estimated error on the retrieved column-averaged mixing ratio (ppmv).	pdim
ap_surface_temperature	K	A priori surface temperature (K).	pdim
bt_diff	K	The brightness temperature difference (K) at 12 microns between observations and simulations (based on ECMWF data). Used to initially screen observations for cloud.	pdim
ch4_vmr	1e-6	Retrieved dry-air mole fraction of atmospheric methane (ppmv).	pdim, nrlev
ch4_vmr_err	1e-6	Estimated error on retrieved methane profile (ppmv).	pdim, nrlev
ch4_xvmr	1e-6	Retrieved column-averaged dry-air mole fraction of atmospheric methane (ppmv).	pdim
ch4_xvmr_err	1e-6	Estimated error on the retrieved column-averaged mixing ratio (ppmv).	pdim
chim	-	Retrieval cost function value.	1
cloud_fraction	1	Retrieved effective cloud fraction.	1
cloud_pressure	hPa	Retrieved effective cloud-top pressure (hPa).	pdim
conv	-	Flag indicating retrieval convergence (1=fully converged). Results with other values should be used with more caution.	pdim
day	-	Day of the month (1-31).	pdim
ecmwf_alt	km	Spatially interpolated ECMWF surface altitude (km).	pdim
h2o_xvmr	1e-6	Retrieved column-averaged mole fraction of atmospheric water vapour in air (ppmv).	pdim
hdo_sf	-	Retrieved HDO scaling factor (effective HDO amount compared to HITRAN assumed ratio of HDO to main water vapour isotope).	pdim
iasi_alt	km	Surface altitude (km) corresponding to IASI measurement, based on averaging GTOPO30 to 12km resolution and sampling every 0.05 degrees.	pdim
lat	degrees_north	Latitude (degrees_north).	pdim
lon	degrees_east	Longitude (degrees east).	pdim
mod_plev	hPa	Pressure levels of true state in provided averaging kernels.	nmlev
month	-	Month of the year (1-12).	pdim
nstep	-	The average number of retrieval steps (number of calls to the forward model).	pdim
pixel_number	-	IASI detector pixel (0-3).	pdim
ret_plev	hPa	Retrieval pressure levels (hPa).	nrlev
ret_plev_ak	hPa	Pressures of retrieval levels (hPa) for which averaging kernels are provided.	adim
rsf	-	Scale factors for the mean fit and across-track residual patterns.	pdim, rsfdim
rsf_err	-	Errors on residual scale factors.	pdim, rsfdim
scan_line	-	Number of scan line (0=start of orbit).	pdim

scan_position	-	Position within scan line (0-29).	pdim
surface_pressure	hPa	Surface pressure (hPa) used in the retrieval.	pdim
surface_temperature	K	Retrieved surface temperature (K).	pdim
sza	degrees	Solar zenith angle (degrees).	pdim
time_in_msec	msec	Time of day in msec since midnight (UTC).	pdim
vza	degrees	Sensor zenith angle (degrees).	pdim
xn2o_eql	1e-6	Column-averaged equivalent N2O (modelled).	pdim
year	-	Year.	pdim

3 Use of Averaging Kernels

Averaging kernels can be applied to model profiles to take into account the *prior* influence and vertical sensitivity of the IASI retrieval when performing comparisons with independent data or models. The profile and column-averaged methane averaging kernels provided in this dataset, **ak_vmr** and **ak_xvmr** respectively (see Table 3), are given in terms of mixing ratio. They provide the sensitivity of the retrieved profile (or total column average) with respect to perturbations in the "true" profile, defined on a relatively fine grid, given by the pressure levels in **mod_plev** in the NetCDF file. Sections 3.1 and 3.2 below describe how to apply the averaging kernels supplied with this dataset on their original fine grid levels. Section 3.3 describes how to convert the averaging kernels for application to an alternative fine grid (e.g. a native model grid).

3.1 Profiles

Retrieved profiles should be compared to independent data, by applying the profile averaging kernels as follows:

$$\boldsymbol{c}_{\boldsymbol{MxI}} = \boldsymbol{c}_{\boldsymbol{a}} + \boldsymbol{A}_{\boldsymbol{f}}(\boldsymbol{x}_{\boldsymbol{f}} - \boldsymbol{a}_{\boldsymbol{f}}),$$

where:

- $\boldsymbol{c}_{\boldsymbol{MxI}}$ is the expected retrieved methane vmr profile given the model profile.
- $\boldsymbol{c}_{\boldsymbol{a}}$ is the *a priori* methane vmr profile (**ap_ch4_vmr** in the retrieval output file) for a given retrieved methane profile.
- $\boldsymbol{A}_{\boldsymbol{f}}$ is the averaging kernel for the given retrieved methane vmr profile (**ak_vmr** in the retrieval output file).
- $\boldsymbol{x}_{\boldsymbol{f}}$ is the model profile interpolated onto the fine grid (given by **mod_plev**) on which the averaging kernels are defined.
- $\boldsymbol{a}_{\boldsymbol{f}}$ is the retrieval *a priori* profile (**ap_ch4_vmr** in the retrieval output file) similarly interpolated onto the fine grid on which the averaging kernels are defined.

3.2 Column-averages

In a similar manner to comparing profiles, column-averaged mixing ratios can be compared to model values using:

$$c_{MxI} = c_a + \boldsymbol{A}_{\boldsymbol{f}}(\boldsymbol{x}_{\boldsymbol{f}} - \boldsymbol{a}_{\boldsymbol{f}}),$$

where:

- c_{MxI} is the expected retrieved methane column-average vmr given the model profile.
- c_a is the *a priori* methane column-average vmr (**ap_ch4_xvmr** in the retrieval output file) for a given retrieved methane profile.
- $\boldsymbol{A}_{\boldsymbol{f}}$ is the averaging kernel for the given retrieved methane column-average vmr (**ak_xvmr** in the retrieval output file).
- $\boldsymbol{x}_{\boldsymbol{f}}$ is as defined in section 3.1.
- $\boldsymbol{a}_{\boldsymbol{f}}$ is as defined in section 3.1.

3.3 Interpolating Averaging Kernels

The value of an averaging kernel at a given fine grid level applies to an atmospheric layer, of finite thickness, centred on the grid level in question. The application of averaging kernels in sections 3.1 and 3.2 requires that the model and *a priori* profiles are interpolated onto the fine grid levels on which the averaging kernels are defined in the NetCDF file (**mod_plev**). However, comparisons can also be made using profiles defined on an alternative fine grid (e.g. a native model grid), provided that a) the differences in layer thickness between the original and new grids are taken into account and b) the new grid is sufficiently fine to ensure that the averaging kernel captures sufficient variation in both the vertical sensitivity of IASI and the methane profile. (We advise against using a grid coarser than the supplied fine grid.)

The procedure to convert an averaging kernel from its original fine grid to a new fine grid is as follows:

1. Normalise the averaging kernel by dividing its value at each grid level by the corresponding grid layer thickness. The boundaries of a layer corresponding to a given grid level are defined as half the pressure difference between the grid level pressure, p_l, and the pressures at the adjacent levels above and below it, p_{l+1} and p_{l-1} respectively, i.e.

$$\Delta p_l = \big((p_l - p_{l-1}) + (p_{l+1} - p_l)\big)/2.$$

   The normalised averaging kernel, $\boldsymbol{A_f}'$**,** for a given retrieval level, k, and fine grid level, l, can therefore be written as:

$$A_{f:kl}' = A_{f:kl}/\Delta p_l$$

2. Interpolate the normalised averaging kernels (for each retrieval level) to the new fine grid levels, linearly in pressure.

3. Multiply the normalised averaging kernel by the layer thicknesses of the new fine grid (defined as in step 1 above, applied to the new fine grid pressures).

Once the averaging kernel has been converted to the new fine grid, on which the model data is provided, the comparison methods described in sections 3.1 and 3.2 can then be applied directly.

4 General Points

- Variables other than methane are retrieved as a way of improving the methane retrieval only, so may not be optimal. They shouldn't be used as true retrieved values.
- Retrievals are more sensitive towards the ground over land, during the day-time.
- Retrievals are not very sensitive near the surface over very cold surfaces (e.g. ice).
- Day-time retrievals are generally considered more reliable.
- The retrievals seem to exhibit artefacts over dry land surface (e.g. deserts) and over mountainous regions.
- Retrievals may be subject to artefacts when there is a very high sulphate aerosol load, following volcanic eruptions.

5 Known Issues

5.1 Dataset Version v1.0

A bug causing a systematic error in the calculation of the variable h2o_xvmr (retrieved column-averaged mole fraction of atmospheric water vapour in air) has been found in processor version v5.0. As a result, the variable h2o_xvmr should only be used for diagnostic purposes in the v1.0 dataset. This bug has been fixed in processor version v5.1 for future data releases.