

IASI-NG simulations for OSSEs

database description and validation

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March 2016

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Abstract

The highly accurate measurements of the hyperspectral infrared sounder IASI are exploited for Numerical Weather Prediction (NWP), atmospheric chemistry and climate monitoring. As the second generation of the European Polar System (EPS-SG) is being prepared, a new generation of IASI has been designed and will be on board MetOp-SG: IASI-NG. In order to prepare the arrival of this new instrument, and to evaluate its impact on various applications, a set of IASI and IASI-NG simulated data has been carried out to build a common database for future Observing System Simulation Experiments (OSSEs). This document describes the information available in this database and the procedure followed to perform the IASI and IASI-NG simulations. The validation of these simulated data is also presented by comparison of the latter with the observations carried out by the IASI instrument.

Contents

1	Introduction	2
2	Description of IASI and IASI-NG IR sounders	2
3	Data sources and used RT models	4
3.1	Data sources and inputs for RT models	4
3.2	4A RT model	6
3.3	RTTOV 11	7
3.4	Configuration of the simulations	7
3.5	Fortran library to access the dataset	8
4	Results	9
4.1	Simulation results	9
4.2	Simulation global validation	12
4.3	One orbit full spectrum validation	13
4.4	Models comparison	14
5	Summary and conclusions	14
6	Acknowledgements	15
A	NetCDF files description	18

1 Introduction

In the frame of the second generation of EUMETSAT MetOP satellites (MetOP-SG program), the Infrared Atmospheric Sounder Interferometer (IASI) instrument will be replaced by an upgraded version, named IASI NewGeneration (IASI-NG). Two of the main advantages of this new instrument is that the spectral resolution will be doubled and its radiometric noise decreased by a factor 2 (Bermudo et al., 2014; Crevoisier et al., 2014).

In order to characterize the future benefits of IASI-NG compared to IASI, the *Centre National de Recherches Météorologiques* (CNRM, Météo France and CNRS) has prepared a database of IASI and IASI-NG simulated data using the same configuration for both instruments for the scientific community. These simulations used two different Radiative Transfer (RT) models: a parallelized-modified version of 4A (Scott and Chedin, 1981; Tournier et al., 1995) and RTTOV 11 (Matricardi et al., 2004; Hocking et al., 2015). The results of the simulations have been included in the database as well as the atmospheric state used to obtain the simulations and some additional information like vertical profiles of clouds or corresponding IASI observations. The latter information has led to perform a comparison between simulated data and observed IASI data and between the simulations from the two RT models.

This document is organized as follows: the section 2 describes IASI and IASI-NG infrared sounders, section 3 details data and radiative transfer models used to run the simulations. Presentation and validation of the simulations are found in section 4. Summary and conclusions can be found in section 5.

2 Description of IASI and IASI-NG IR sounders

The Infrared Atmospheric Sounder Interferometer (IASI) (Cayla, 2001; Simeoni et al., 1997) is a space-born interferometer able to characterize the Earth infrared spectra in the range from 645 to 2760 cm^{-1} (15.5 to 3.63 μm) with a spectral resolution of 0.25 cm^{-1} and 8461 channels. The pixel size at nadir viewing is 12 km, being acquired 4 pixels per field of regard (fig. 1). The accuracy of its measurements is better than 1 K for temperature retrievals and 10% below 500 hPa for relative humidity retrievals with a vertical resolution finer than 1 km (Diebel et al., 1996). Currently, two IASIs are in flight on board MetOp-A and MetOp-B satellites, launched in 2006 and 2012 respectively. A third IASI will be launched on 2018 on board MetOp-C satellite. In total, the IASI program is expected to provide a minimum of 15 years of continuous data.

The revision of the IASI instrument in the context of the European meteorological satellite program (EPS-SG) is called IASI New Generation (IASI-NG). This new instrument will expand the dataset of the Earth infrared spectra from IASI up to near 2400 (Bermudo et al., 2014). The first instrument will be launched on board the Metop-SG satellite on 2021. IASI-NG is based in a Mertz interferometer. According to the specifications, both the radiometric resolution (NedT) and the absolute radiometric

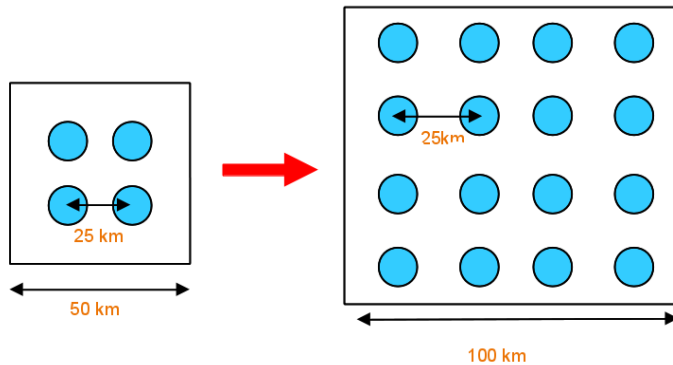


Figure 1: Pixel scheme for IASI (left) and IASI-NG (right) sounders

calibration have to be half of those from IASI (fig. 2). The number of channels will be doubled, reducing the spectral resolution from 0.25 to 0.125 cm^{-1} . The number of pixels taken at the same time will be multiplied by 4, passing from 4 pixels for current IASI to 16 pixels for IASI-NG but pixel size and total number of pixels remains unchanged. A summary of the main figures from both instruments is shown in table 1.

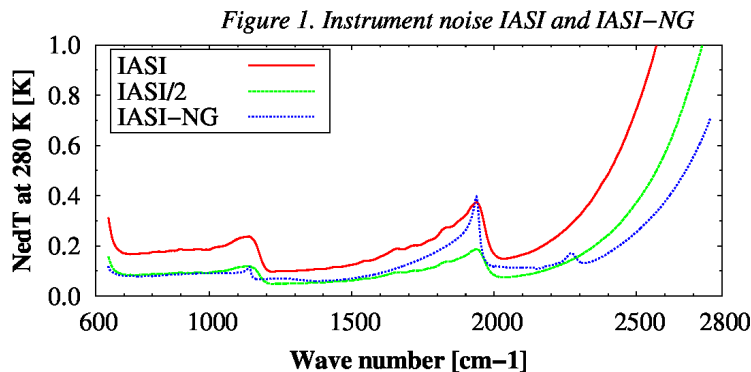


Figure 2: NedT noise at 280 K for IASI and IASI-NG (source data from E. Pequignot, CNES)

Main figures	IASI	IASI-NG
Pixels in field of regard	4	16
Channels	8461	16921
Radiometric resolution (NedT)		IASI/2
Spectral sampling	0.25 cm^{-1} @L1C	IASI/2
Absolute Radiometric Calibration	<0.25 K @280K	IASI/2
Spectral bands	3 bands	4 bands
Mass	235 kg	350 kg
Power	240 W	500 W

Table 1: Principal differences between IASI and IASI-NG sounders

The instrument concept of IASI-NG is not a direct follow-up of IASI on a technological point of view. IASI-NG instrument concept is based in a Mertz interferometer

allowing to assess the Self Apodization issue by a Field Effect Compensation. The field effect compensation is realized by introducing optics with correct optical index at given Optical Path Difference (OPD).

The optics moves two prisms synchronously to realize the path difference required by the signal analysis and the compensation of the self apodization function in the field. This combined movement is made by linking the two internal prisms on two pendulums operated by the same motor (Bermudo et al., 2014). Two different materials were considered at the beginning for these prisms: KBr and ZnSe, each one with different characteristics for the noise. At the current stage of IASI-NG development the KBr material has been chosen.

3 Data sources and used RT models

3.1 Data sources and inputs for RT models

Four different dates have been chosen within the year 2013. Each date corresponds to the middle of each season: February 4th (North Hemisphere Winter), May 6th (NH Spring), August 6th (NH Summer) and November 4th (NH Fall), to cover the maximum possible meteorological variability. All IASI observations, onboard MetOP-A satellite, that were measured from the 21:00 UTC of the previous day to the 21:00 UTC of the mentioned dates were selected to build a database of 5,242,448 observations (fig. 3).

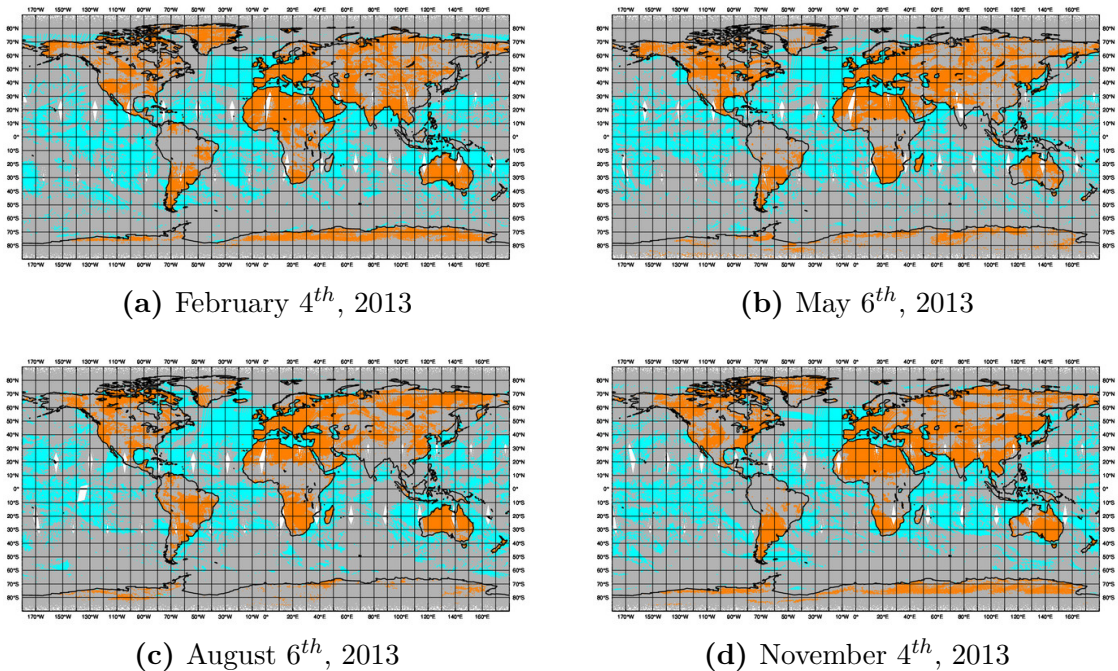


Figure 3: All observations for each selected date (5,241,953 gray dots), and clear cases over sea (418,400 observations, cyan dots) and over land surfaces (354,993 observations, orange dots)

The informations taken from the Météo-France observation archive were: longitude, latitude, date, time, IASI azimuth and zenith angles, solar azimuth and zenith angles, AVHRR cloud cover, land-sea mask values (from Météo-France model ARPEGE) and value of the IASI observations for the 314-channels selection monitored operationally at Météo-France in 2013. Table 2 presents a summary on the number of observations per land-type and AVHRR cloud mask. The column labelled as *No cld flag* corresponds with observations produced by the *Centre of Meteorologie Satellitaire (CMS)* of Météo-France. This centre delivers IASI observations from a direct acquisition faster than EUMETSAT. That is the reason for Météo-France to work with two IASI data suppliers. In 2013, the CMS did not include yet the AVHRR cloud mask in their IASI product.

	No cld flag	Clear	Partly cloudy	Cloudy	Total
Sea	49,202	418,400	1,346,276	1,649,350	3,463,228
Coast	2,791	16,180	92,499	75,634	187,104
Land	30,717	354,993	604,361	601,550	1,591,621
Total	82,710	789,573	2,043,136	2,326,534	5,241,953

Table 2: Summary of observations number per surface type and AVHRR cloud mask value.

Additional atmospheric information were extracted from the Monitoring Atmospheric Composition and Climate (MACC) project from the Copernicus programme¹: terrain elevation, surface temperature and pressure, and vertical profiles of temperature, humidity, ozone, carbon monoxide and sulphur dioxide. These vertical profiles were provided in 60 fixed pressure levels from 1013.25 to 0.2 hPa. Terrain elevation, surface temperature and pressure were 4-point bilinearly interpolated from the MACC grid to the IASI observation coordinates.

Vertical profiles of methane and carbon dioxide were added to the database (C. Crevoisier, Pers. Comm.) from LMDz model (Hourdin et al., 2006) calculations. Carbon dioxide were provided on 39 sigma levels, from close to the surface up to 8.6 hPa, meanwhile methane profiles had 19 sigma levels, from surface to 295 hPa. In vertical axis, both carbon dioxide and methane LMDz profiles were interpolated, and extrapolated above the profile maximum height, to the 60 pressure levels of the MACC profiles. The last parameter included in the database were the surface emissivity at IASI-NG spectral sampling resolution from the infrared surface emissivity of the University of Wisconsin/CIMSS (Seemann et al., 2008, UW). A 4-point bilinear interpolation was carried out in horizontal to match the IASI observation coordinates. It should be noted that no quality check has been applied on input MACC data.

The datasets of the IASI-NG OSSE NetCDF data files are organized in the following groups:

- **NetCDF file dimensions**

Profile number, pressure levels, IASI wavenumbers, IASI-NG wavenumbers and list of IASI monitored channels (for IASI observations)

¹<http://www.gmes-atmosphere.eu>

- **Coordinates**
Longitude, latitude, terrain elevation, date and time.
- **Observation parameters**
Surface pressure and temperature, IASI zenith and azimuth angles, solar zenith and azimuth angles, land-sea mask value, cloud cover value from AVHRR, 4A emissivity index, surface emissivity from UW atlas and RTTOV surface type.
- **Vertical profiles**
Temperature, humidity, carbon dioxide, ozone, carbon monoxide, methane and sulphur dioxide.
- **Cloud information**
Vertical profiles of cloud cover, ice water content, liquid water content, rain water content and snow water content.
- **Radiances**
Simulated radiances of IASI, IASI-NG A (KBr) and IASI-NG B (ZnSe).
- **Observations**
Observed brightness temperature.

Some extra details on each parameter (units, range, kind of variable...) can be found in the appendix A or obtained when reading the NetCDF files through the command `ncdump -h FILE` from a terminal.

3.2 4A RT model

The first set of simulations made available for the users were performed by the 4A (Automatised Atmospheric Absorption Atlas) fast and accurate line-by-line radiative transfer model (Scott and Chedin, 1981, <http://ara.abct.lmd.polytechnique.fr/>). 4A is developed and maintained at the Laboratoire de Météorologie Dynamique. It has been made operational (OP) in cooperation with the French company Noveltis (see <http://www.noveltis.net/4AOP/> for a description of 4AOP).

4A allows fast computation of the transmittance of a discrete atmosphere along the vertical at a very high spectral resolution ($1 \times 10^{-3} \text{ cm}^{-1}$ for this study) as well as the Jacobians (Cheruy et al., 1995) (with respect to temperature, mixing ratios and surface temperature and emissivity) for a user-defined observation level. It relies on comprehensive atlases of monochromatic optical thicknesses for up to 43 atmospheric molecular species. The atlases were created by using the line-by-line and layer-by-layer model STRANSAC (Scott, 1974) in its latest version at the release date with spectroscopy from the GEISA (Gestion et Etudes des Informations Spectroscopiques Atmosphériques, Management and Study of Spectroscopic Information) 2009 spectral line data catalogue (Jacquinet-Husson et al., 1999, 2003; Jacquinet-Husson, 2008; Jacquinet-Husson et al., 2011). The 4AOP-2012 also includes up-to-date continua of N_2 , O_2 and H_2O . It is the reference forward radiative transfer model for the CNES/EUMETSAT IASI Level 1 Cal/Val activities and operational processing.

3.3 RTTOV 11

The second set of simulations were produced by the RTTOV (Radiative Transfer for TOVS) model. RTTOV (Matricardi et al., 2004) is a fast radiative transfer model for passive visible, infrared (IR) and microwave (MW) satellite-borne sensors and is used in various applications including data assimilation, atmospheric retrievals and the generation of simulated satellite imagery. RTTOV takes as input vertical profiles of pressure, temperature, water vapour and optionally other trace gases, and scattering particle parameters along with associated surface parameters. The outputs are top-of-atmosphere (TOA) radiances and brightness temperatures (BTs) for the selected instrument channels. To carry out the fast computation of optical depths, RTTOV uses a linear regression to compute optical depths on a fixed set of pressure levels. The coefficients for this linear regression are pre-computed and stored in coefficient files which are specific to each instrument.

Most RTTOV coefficient files are based on a fixed set of 54 levels, from 1050.0 to 0.005 hPa, but coefficients have also been generated on a set of 101 levels, from 1100.0 to 0.005 hPa, for some instruments, more explicitly the IR hyperspectral sounders AIRS, IASI, CRIS, IASI-NG and IRS. RTTOV can accept input profiles on an arbitrary set of pressure levels. An internal interpolator maps the input profile onto the coefficient levels and, again, the computed optical depths back onto the input levels (Hocking, 2014). The latest version of the software, RTTOV 11 additional options have been added to supply more coherence in input vertical profile units (Hocking et al., 2015).

3.4 Configuration of the simulations

Regarding the atmospheric chemistry, a total of 16 vertical atmospheric constituent profiles were ingested by for 4A for the simulations: H₂O, CO₂, O₃, N₂O, CO, CH₄, SO₂, HNO₃, OCS, CH₃D, N₂ and the CFCs 11, 12 and 14. For H₂O, CO₂, O₃, CO, CH₄, and SO₂ species, the vertical profiles were taken from the database and for the other species, a standard profile provided by 4A were used. All the profiles were linearly interpolated to the 44 levels (44L) of 4A as, contrary to what can be thought, 60 levels (60L) are not significantly closer to IASI observations than 44L simulations. Figure 4 presents bias and standard deviation of the differences between 44L/60L model simulations and the observations and no significant impact is observed when running in 60L. Additionally computing time is multiplied by a factor of around 2.2 in the new Météo-France supercomputer for 60L vertical resolution when compared to 44L configuration. RTTOV simulations were run in 60 levels with the latest coefficients file (in 101 levels) and only 5 vertical profiles of atmospheric constituents were provided to the model: H₂O, CO₂, O₃, CO, and CH₄.

For surface emissivity, 4A simulations have used the available model surface emissivity values for sea and sea ice (101 and 102 4A surface emissivity indexes respectively). Land surface emissivities were taken from the UW IR atlas of emissivities (Seemann et al., 2008) from 2013. RTTOV also used the UW atlas of emissivities but for the year 2007 as RTTOV uses precomputed values of the atlas to speed up the calculations, and not directly the product of the Wisconsin university.

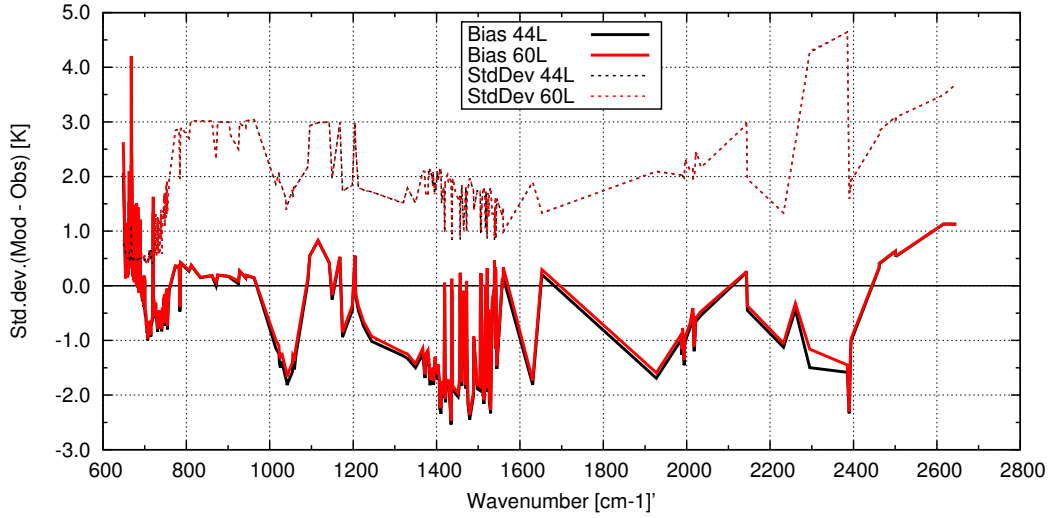


Figure 4: Bias and standard deviation of 44L and 60L 4A model simulation versus observation differences for a subset of clear 687 IASI simulations.

Once the simulations were carried out, a random gaussian noise were added to the simulations using the standard noise NedT at 280K provided by the CNES (fig. 2). Two different noises were considered for IASI-NG depending on the material of prism of the instrument (KBr or ZnSe). The IASI-NG simulations corresponding with a prism on KBr are named as *rng* in the database files and those considering a prism on ZnSe are named *ngb*. A general overview of the database construction is shown in figure 5

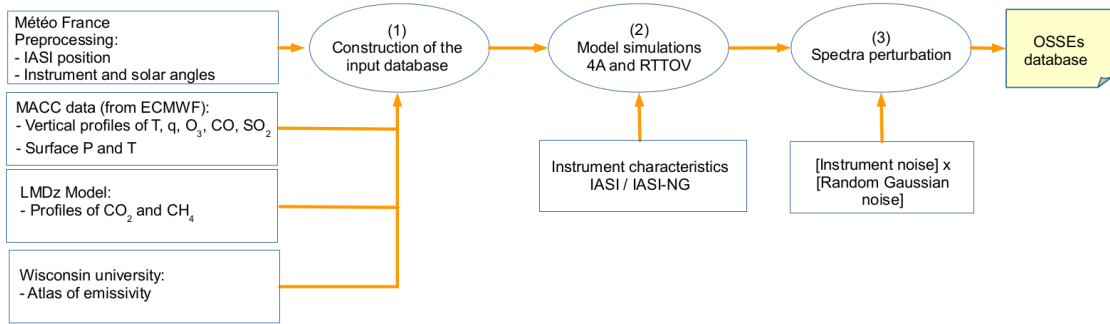


Figure 5: Flow chart of the simulation database construction from the input information to the final database

3.5 Fortran library to access the dataset

A Fortran library has been created to work with the dataset. This library can be delivered upon request. It has been prepared to work with GNU or INTEL compilers. If a different compiler is desired it is only needed to modify adequately the Makefile.

4 Results

4.1 Simulation results

All information available in the database for a 4A single simulated case is shown in figure 6. This figure presents the data belonging of an IASI observation taken out in the Pacific (179.0 W, 24.55 N) on the February 3rd, 2013 at 21:13:46 UT. The upper panel of the figure shows the results from full IASI (black) and IASI-NG (gray) spectrum simulations. IASI-NG presents a higher variability on the spectrum compared to IASI, potentially allowing to improve the retrievals of new atmospheric compounds. Just below this panel, the differences between the spectrum of the two instrument are shown for the 8,461 IASI channels, being higher in the bands of CO₂, O₃, CH₃ and water vapour, profiles available in the dataset, and N₂O, profile taken from each model. For the first group of profiles, these differences could arise from the interpolation of the database profile to the model levels.

The third panel, labelled as *QC* for Quality Check, presents the differences between the IASI simulated spectrum and the corresponding observation for the 314 available channels at Météo France archive. For the presented case, these differences range between -3 to 3 K excluding the region between 2,280 and 2,400 cm⁻¹ where they grow up to around 7 K. Those bands associated to the input vertical profiles present larger differences than the regions corresponding to surface properties. The region between 2,280 and 2,400 is strongly affected by the so-called *Ghost effect* (Lezeaux, 2007; Bormann et al., 2010). This effect is caused by the IASI compensation device and it has disappeared the October 7th, 2015 when the device was turned off (Maraldi et al., 2015).

The rest of the plots in the figure present the surface emissivity used in the simulation (just below the QC panel) and the vertical profiles of temperature, cloud properties and atmospheric constituents. The observation coordinates, as well as the surface pressure and temperature, land-sea mask, cloud cover and instrument and solar zenith and azimuth angles are displayed in the bottom of the figure.

Figure 7 presents averaged spectra of IASI and IASI-NG (KBr material) for 5 different latitude-belts from North to South pole. The limits for each belt are: 70°N-90°N (North pole), 20°N-70°N (Mid-lat North Hemisphere), 20°S-20°S (Tropics), 20°S-70°S (Mid-lat South Hemisphere) and 70°S-90°S (South pole). These results have been produced using only simulations associated to clear observations. Expected results from considering all the simulations should not be very different as no cloud information has been used when running the models. Table 3 presents the number of simulations per band and AVHRR cloud flag.

As expected both IASI and IASI-NG simulated spectra present a very similar aspect, with sharper structures in IASI-NG coming from sharper instrument response function. An average difference of around 20 K is observed when comparing North and South pole simulations. This difference is originated by the higher surface elevation of the Antarctic continent joint to colder air masses taking place at the Earth South pole.

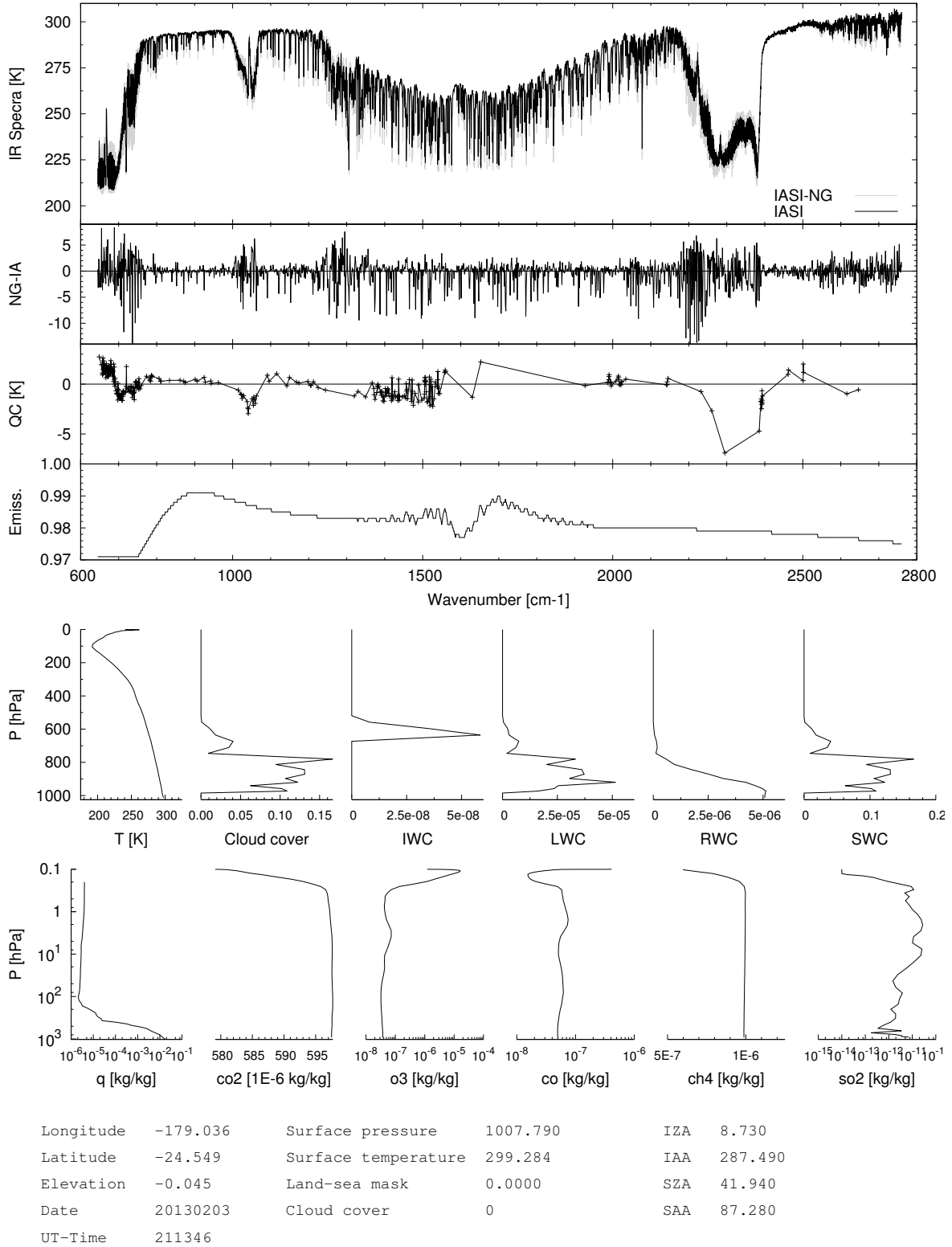


Figure 6: Panel for a single 4A simulation including all available information in the database

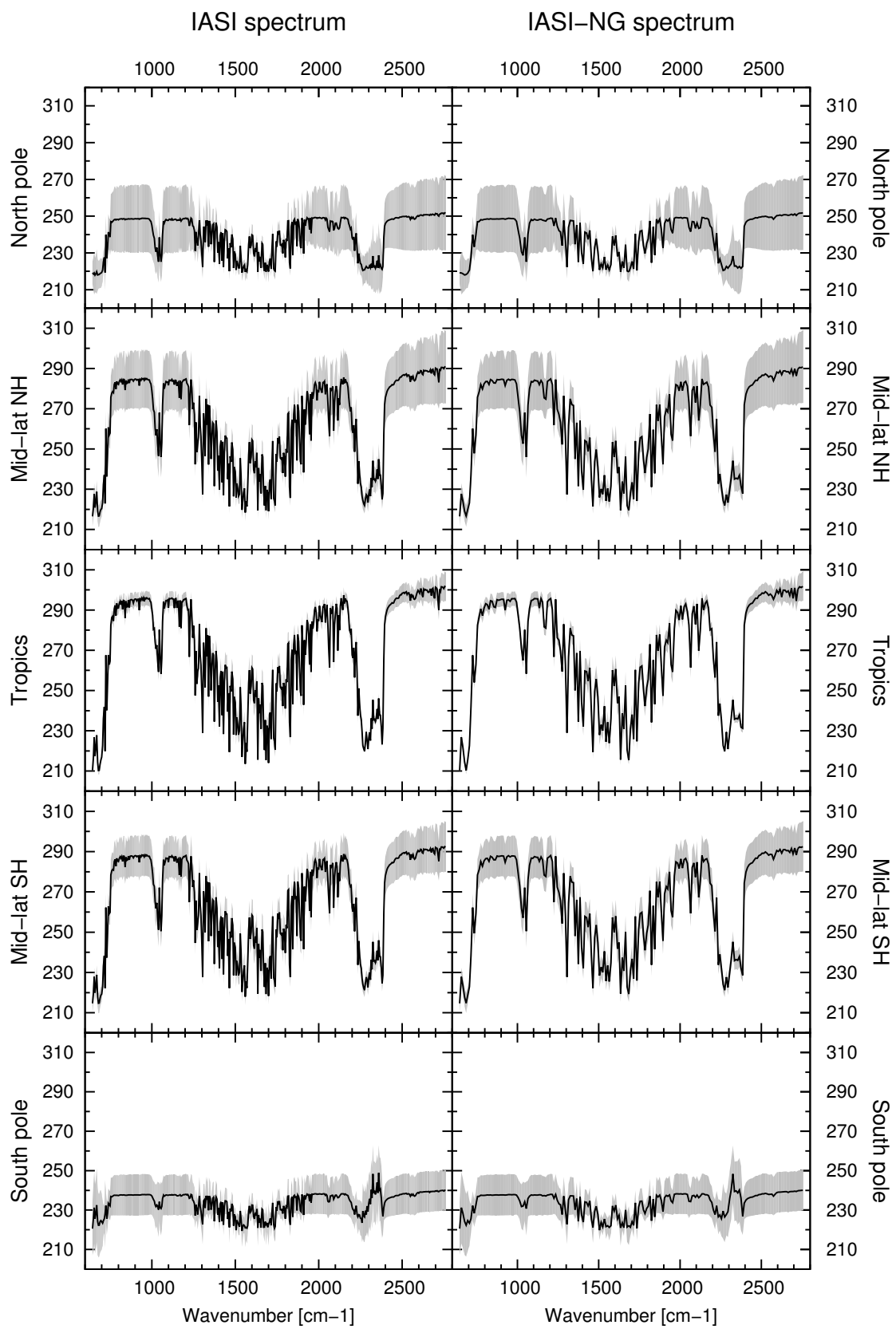


Figure 7: IASI and IASI-NG averaged simulated spectra for different Earth latitude belts

Lat-band	No cld flag	Clear	Partly cloudy	Cloudy	Total
North Pole	308	24,739	202,626	267,869	495,542
Mid-lat NH	82,402	311,372	601,094	598,305	1,593,173
Tropics	0	271,653	516,959	372,931	1,161,543
Mid-lat SH	0	159,580	540,066	799,668	1,499,314
South Pole	0	22,229	182,391	287,761	492,381
Total	82,710	789,573	2,043,136	2,326,534	5,241,953

Table 3: Number of simulations per latitude band and AVHRR cloud flag for the four dates

4.2 Simulation global validation

In order to validate the model simulations, they have been compared to the subset of 314 channels observation available at Météo-France storage system. Figure 8 presents the bias and the standard deviation of these differences for the 789,573 clear observations taken under clear conditions according to AVHRR. On one side, standard deviations of model simulation minus observation differences present a very similar behaviour for the two models with values around 4 K for surface channels and 2 K or lower in the bands of CO-2, O-3, CH₄ or water vapour. On the other side, the biases observed in the latter bands are larger than surface channels. In the case of 4A simulations, the solar contribution was taken into account showing a very small bias, around 0.1 K on average, for the last 7 considered channels (7267, 7269, 7424, 7426, 7428, 7885 and 8007).

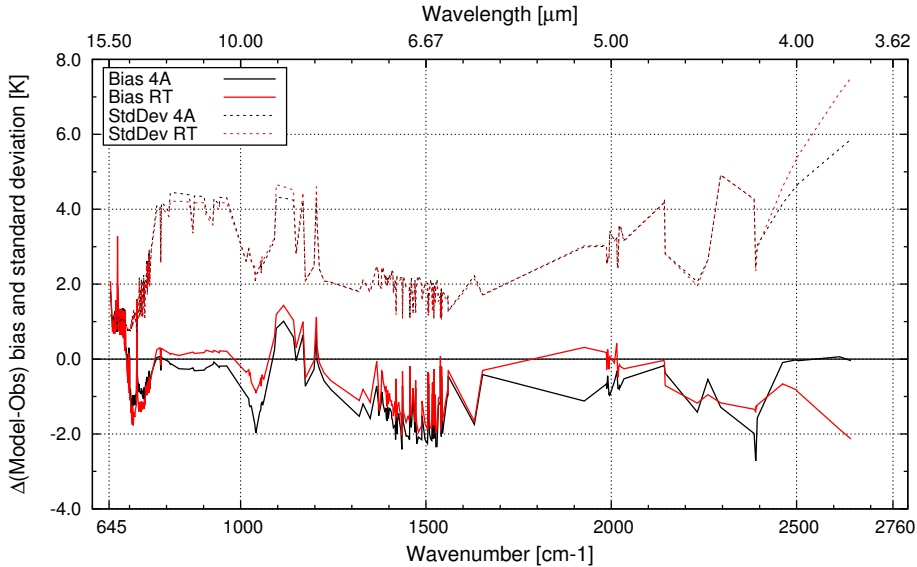


Figure 8: Bias (straight lines) and standard deviation (dash lines) of model simulations minus observations differences for the 789,573 observations taken under clear conditions according to AVHRR cloud flag

Similar validations have been carried out for each one of the 96 hourly files. The maps and the validation plots for each file are available in separate files.

4.3 One orbit full spectrum validation

A full orbit data has been downloaded from EUMETSAT data center to perform a full spectrum validation. The selected orbit begins the 2013-08-06 at 20:35:59 and ends the same date at 22:17:06. Within this orbit, MetOp-A satellite overpasses the western areas of England, the Iberian Peninsula, Africa and the Pacific Ocean (figure 9). Only the 10,525 clear cases according to AVHRR have been selected to compute the differences between the model simulations and the observations (figure 10).

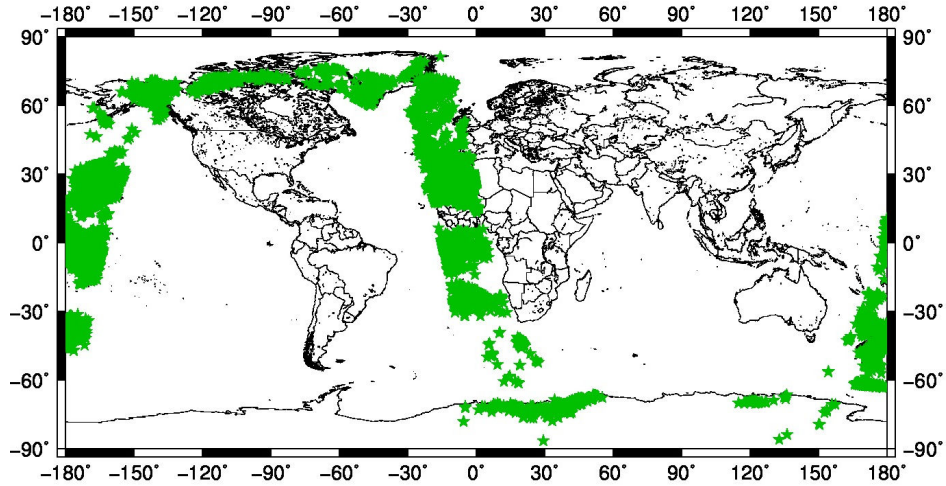


Figure 9: Map of 10,525 AVHRR clear IASI pixels for the MetOP-A orbit beginning the 2013-08-06 at 20:35:59.

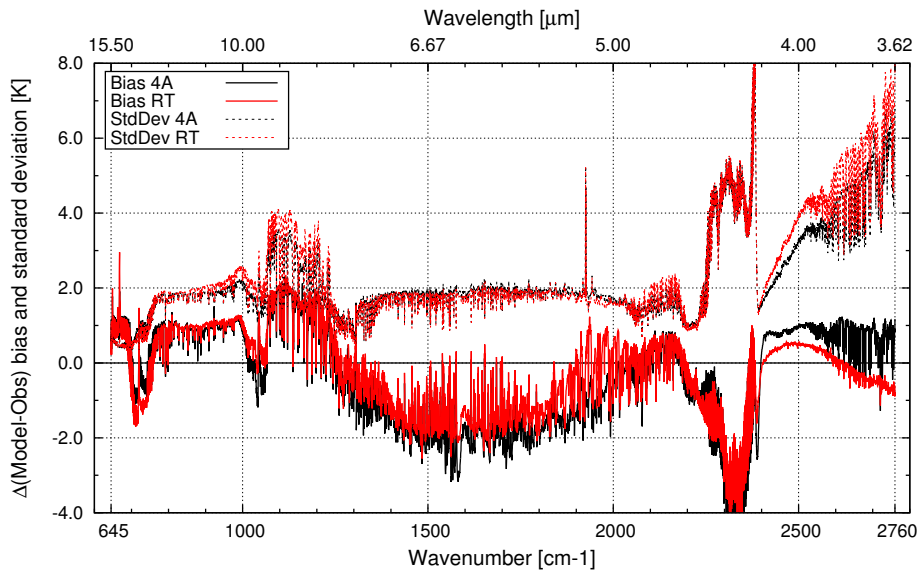


Figure 10: Bias (straight lines) and standard deviation (dash lines) of model simulations minus observations differences for 10,525 AVHRR clear IASI pixels for the MetOP-A orbit beginning the 2013-08-06 at 20:35:59.

4.4 Models comparison

Bias and standard deviation of the two model simulation differences (4A-RTTOV) is shown in figure 11. Only one point over 4 has been drawn. Surface regions of the spectrum present a bias negative for 4A of around 0.5 K. A positive value is observed for the CO₂ band around 720 cm⁻¹ meanwhile O₃, CH₄ and H₂O bands show a negative bias. The effect of not considering the solar effect in RTTOV simulations is appreciated for the wavenumbers greater than 2,400 cm⁻¹, resulting in bias higher than 1K and standard deviation included between 2K and 6K. Excluding the solar region of the spectrum, standard values vary between 0.2K and 1K.

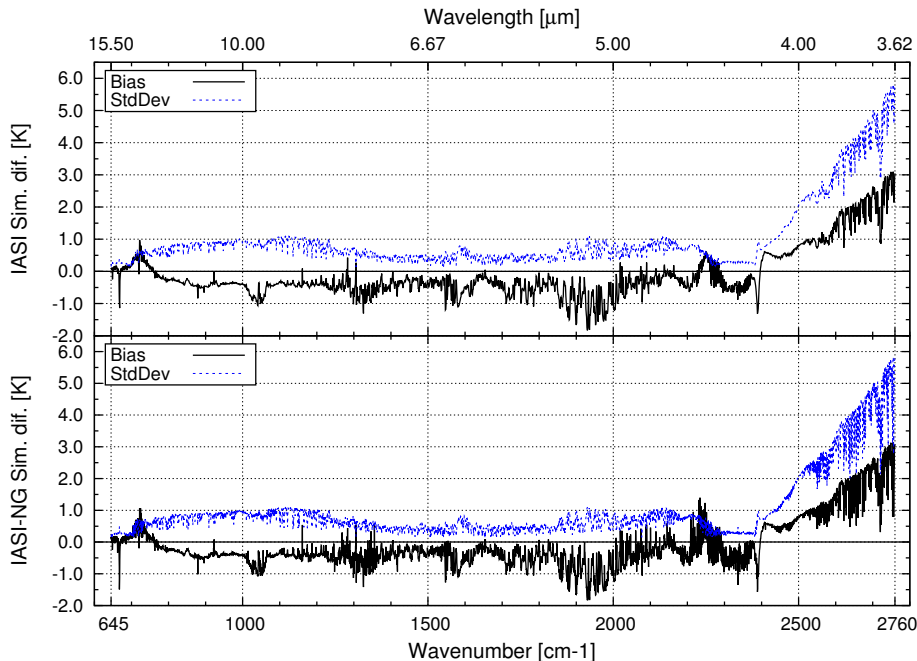


Figure 11: Bias and standard deviation of (4A-RTTOV) IASI/IASI-NG simulation differences for the 789,573 AVHRR clear cloud flag subset subsampled to 1 point over 4

5 Summary and conclusions

In order to prepare the arrival of IASI-NG IR sounder on-board MetOP Second Generation satellites a comprehensive set of IASI and IASI-NG data has been prepared by Météo-France for those user interested on estimating the impact of IASI-NG compared to IASI. For this purpose, two models have been used.

This set of simulations includes a total of 5,241,953 different atmospheres over the whole world and belonging to four different dates, one in the middle of each season to be used as reference for future OSSE studies. Each atmosphere includes a comprehensive description of the atmospheric state including vertical profiles of T, H₂O, CO₂, O₃, CO, CH₄ and SO₂, surface properties and instrument viewing geometry. A small subset of 314 IASI observed channels is also provided for each one of the simulations.

The latter have been validated against the instrument observations. Additionally no significant differences have been found between both models excluding the solar region of the spectrum, where RTTOV was run without considering the solar contribution.

For each model, the simulated data has been divided into 96 uncompressed NetCDF files, corresponding to one hour. Each one of these hour files weights around 11 GB and can be downloaded from the *Pôle Atmosphere* FTP server.

6 Acknowledgements

This work has been made possibly thanks to the support of IASI-NG CNES TOSCA project. We are grateful to Raymond Armante, Bernard Tournier and Pascal Brunel for helping in the tuning up of 4A and RTTOV models. Cyril Crevoisier is thanked for providing the CO₂ and CH₄ profiles from LMDz model. Thanks are also given to Copernicus project of the European comission.

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A NetCDF files description

A) Dimensions group

Index for values corresponding to the container dimensions

- ATMOSPHERE
longname: Indexes of available atmospheres
kind: integer 4 bytes
- LEVEL
longname: Vertical profile pressure levels
kind: real 4 bytes
- WNU_IASI
longname: IASI spectrum
- wavenumbers
kind: real 4 bytes
- WNU_IANG
longname: IASI-NG spectrum wavenumbers
kind: real 4 bytes
- OBSCHANNELLIST
longname: Observations channel list
kind: integer 4 bytes

B) Coordinates group

Space/time coordinates of the atmosphere descriptions

- LON
longname: Longitude
kind: real 4 bytes
range: $lon \in [-180, 180[$
units: degrees
source: MF database
- LAT
longname: Latitude
kind: real 4 bytes
range: $lon \in [-90, 90]$
units: degrees
source: MF database
- ELE
longname: Terrain elevation (described in the IFS model)
- *kind*: real 4 bytes
units: Geopotential units,
 $z = ele/G_0$, $G_0 = 9.80665 m^2/s^2$
source: MACC experiment
- DAT
longname: Date
kind: integer 4 bytes
format: YYYYMMDD
source: MF database
- TIM
longname: Time
kind: integer 4 bytes
format: HHMMSS
source: MF database

C) Observation parameters group

Diverse observation characteristics

- PSU
longname: Surface pressure
kind: real 4 bytes
units: hPa
source: MACC experiment
- IZA
longname: Instrument (IASI) Zenith Angle
kind: real 4 bytes

- units*: degrees
 - source*: MF database
- IAA
 - longname*: Instrument (IASI) Azimuth Angle
 - kind*: real 4 bytes
 - units*: degrees
 - source*: MF database
- SZA
 - longname*: Solar Zenith Angle
 - kind*: real 4 bytes
 - units*: degrees
 - source*: MF database
- SAA
 - longname*: Solar Azimuthal Angle
 - kind*: real 4 bytes
 - units*: degrees
 - source*: MF database
- LSM
 - longname*: Land sea mask
 - kind*: real 4 bytes
 - units*: adimensional
 - range*: [0, 1], sea = 0, land = 1
 - source*: MF database
- CLC
 - longname*: Cloud cover mask from
- AVHRR pixels
 - kind*: integer 4 bytes
 - units*: cloudy scene percentage
 - range*: [0, 100], clear = 0, cloudy = 100
 - source*: MF database
- EMI
 - longname*: 4A emissivity index
 - kind*: integer 4 bytes
- ERT
 - longname*: Wisconsin university emissivity (IASI-NG resolution, 16921 channels)
 - kind*: integer 2 bytes, array of 16921 values
 - units*: adimensional
 - scale factor*: 0.001, *emissivity* = 0.001 * *ert*
 - range*: [0, 1000]
 - source*: RTTOV preprocessing
- RST
 - longname*: RTTOV surface type
 - kind*: integer 4 bytes

D) Vertical profiles group

Vertical profiles available

- TEM
 - longname*: Temperature vertical profile
 - kind*: real 4 bytes, array of 60 levels per profile
 - units*: K
 - source*: MACC experiment
- Q
 - longname*: Specific humidity vertical profile
 - kind*: real 4 bytes, array of 60 levels per profile
 - units*: kg/kg
 - source*: MACC experiment
- CO₂
 - longname*: Carbon dioxide profile
 - kind*: real 4 bytes, array of 60 levels per profile
 - units*: kg/kg
 - source*: LMDz model simulations
- O₃
 - longname*: Ozone vertical profile
 - kind*: real 4 bytes, array of 60 levels per profile
 - units*: kg/kg
 - source*: MACC experiment
- CO
 - longname*: Carbon monoxide vertical profile
 - kind*: real 4 bytes, array of 60 lev-

- els per profile
units: kg/kg
source: MACC experiment
- CH4
longname: Methane vertical profile
kind: real 4 bytes, array of 60 levels per profile
units: kg/kg
- so2
longname: Sulphur dioxide vertical profile
kind: real 4 bytes, array of 60 levels per profile
fill value: -999.9
source: MACC experiment

E) Cloud information group

Vertical profiles available

- CC
longname: Cloud cover
kind: real 4 bytes, array of 60 levels per profile
units:
source: MACC experiment
- IWC
longname: Ice water content
kind: real 4 bytes, array of 60 levels per profile
units:
source: MACC experiment
- LWC
longname: Liquid water content
kind: real 4 bytes, array of 60 levels per profile
- els per profile
units: kg/kg
source: MACC experiment
- RWC
longname: Rain water content
kind: real 4 bytes, array of 60 levels per profile
units: kg/kg
source: MACC experiment
- SWC
longname: Snow water content
kind: real 4 bytes, array of 60 levels per profile
units: kg/kg
source: MACC experiment

F) Radiances group

Simulated radiances

- RIA
longname: IASI simulated radiance
kind: real 4 bytes, array of 8461 channels per spectra
units: W/m²/sr/cm-1
source: Noise-perturbed model simulation
- RNG
longname: IASI-NG simulated radiance
kind: real 4 bytes, array of 16921 channels per spectra
units: W/m²/sr/cm-1
source: Noise-perturbed model simulation
- NGB
longname: IASI-NG simulated radiance
kind: real 4 bytes, array of 16921 channels per spectra

units: W/m²/sr/cm-1

source: Noise-perturbed model simulation

G) **Observations group**

Available observation values

- OMA

longname: Observation marker

kind: integer 1 bytes

values: 0 or 1, Available data = 1, Unavailable 0

units: adimensional

- OBT

longname: Observed Brightness Temperature

kind: real 4 bytes, array of 314 channels per observation

units: K

source: MF database