A step towards IASI-NG: Simulation of orbits and first impact assessment compared to IASI

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Abstract

The hyperspectral infrared sounder IASI has already demonstrated its high capabilities for both Numerical Weather Prediction (NWP), atmospheric composition and climate studies. As the second generation of the European Polar System (ESP-SG) is being prepared, a new generation of IASI has been designed and will be on board EPS-SG: IASI-NG. IASI-NG will benefits from an increased design compared to IASI: double spectral resolution and radiometric noise decreased by a factor 2. In order to get ready to use this new instrument and to evaluate its impact on various applications, a series of simulated data are being built up. This presentation will describe the way the IASI and IASI-NG data have been simulated, as well as the selected dates. Then, from these new spectra, the first assessment studies will be described, with a specific focus on the clear cases to begin with.

Keywords: IASI, IASI-NG, Satellite infrared sounder, OSSE experiment

1. Introduction

The satellite instrument Infrared Atmospheric Sounder Interferometer (IASI) (Cayla, 2001; Simeoni et al., 1997) is a spectrometer 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 view. The accuracy of its measurements is better than 10 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.

Both Numerical Weather Prediction (NWP) and atmospheric composition analysis communities have been largely benefited from the IASI measurements (Clerbaux et al., 2009; Guidard et al., 2011; Kerzenmacher et al., 2012; Lacour et al., 2012; Crevoisier et al., 2013). The thin spectral resolution of IASI joint to the huge number of channels provided by the instrument also allows to include in the NWP model significant amounts of information under cloudy conditions and the continuous development of new applications (Hilton et al., 2012).

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In the frame of the new European meteorological satellite program (EPS-SG), an update of the IASI instrument is being designed in order to expand the dataset of the Earth infrared spectra from IASI up to near 2040. This revision of IASI instrument, called IASI New Generation (IASI-NG), is based in an Mertz spectrometer. According to the specifications, both the radiometric resolution (NeDT) and the absolute radiometric calibration have to be half of those from IASI. The number of channels will be double, reducing the spectral resolution form 0.25 to 0.125 cm^{-1}. The first instrument will be launched on board the Metop-SG satellite on 2020-2021. In order to asses the future impact of IASI-NG on NWP models and atmospheric chemistry studies, the first stages of an Observation System Simulation Experiment (OSSE) is presented in this work.

The second section describes the methodology defined to carry out the OSSE. The obtained results at the current stage are shown in section 3 and, finally the section 4 presents the conclusions of the work and the future works required to finish the experiment.

2. Methodology

IASI-NG simulated spectra are supposed to be acquired under the same observations conditions than IASI conditions on board Metop-A satellite. The values of longitude, latitude, date, time, instrument zenith angle, solar zenith angle, solar azimuthal angle, a land-sea mask and cloud cover have been extracted from Météo-France preprocessing system.

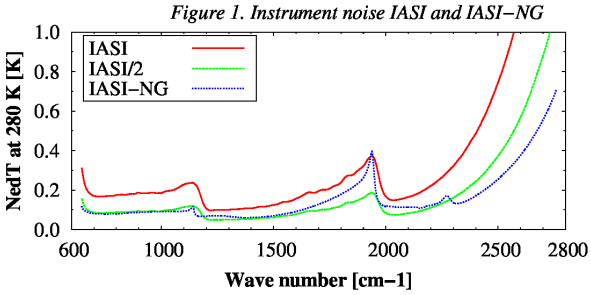


Figure 1: Noise function of IASI, IASI/2 and IASI-NG (selected material)

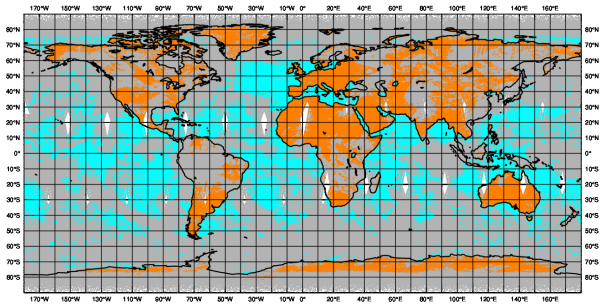


Figure 2: Map of IASI observations for February 4^{th}. Grey points correspond with all IASI observations, blue are observations under clear conditions over the sea and brown over land.

In order to have the most accurate possible description of the atmosphere, vertical profiles of temperature, humidity, ozone, carbon monoxide and sulphur dioxide from Monitoring Atmospheric Composition and Climate (MACC, http://www.gmes-atmosphere.eu/) project obtained from the European Center for Medium Weather Forecast (ECMWF) data servers (MACC experiment *fnyp*). Terrain elevation, temperature and the logarithm of the atmospheric pressure were also extracted from the same experiment. Vertical profiles of carbon dioxide and methane have been calculated by the LMDz model (Hourdin et al., 2006). All the latter information have been extracted for the full orbit of four days in 2013: February 4^{th}, May 6^{th}, August 6^{th} and November 4^{th}.

The model used with that aim a modified version of 4A-OP model (Tournier et al., 1995). The modifications made in the model were related with the input/output of the model, addition of more flexibility when reading the parameters of each simulation and improvement of the performance of the model. These simulations have been carried out for both IASI and IASI-NG.

The NWP-SAF 1D-Var beta 1 software (http://nwpsaf.eu/deliverables/metoffice_1dvar/index.html) will be used to perform the data assimilation of the OSSE data. The vertical profiles and the information used to generate the spectra will be considered as the background information, and the simlulated spectra will be observations performed by the instruments. Before the assimilation, some random Gaussian noise has been added to the data. In the case of the background information, the square root of the B-matrix diagonal elements multiplied by a random Gaussian distributed value. The average of the Gaussian distribution is 0, and the standard deviation 1. The noise added to the observations has been calculated through the multiplication of the instrument noise by random Gaussian number with the same average and standard deviation values than the background. Figure 1 shows the noises of IASI, IASI/2 (IASI-NG specifications) and IASI-NG noise.

In the first stage of this OSSE, only the 122 channels used in the Météo-France operational configuration will be used to retrieve vertical profiles of temperature and humidity. Further experiments will be done to find the most adequate channel selection for this purpose.

3. Results

A total number of 5242448 IASI observations has been obtained for the four days considered, and 418546 of them correspond to clear conditions over sea. As an example, figure 2 presents all IASI observations performed on February 4^{th}, 2013 in gray, and the clear over sea (blue) and clear over land (brown) observations. Similar maps corresponding to the other three selected days are shown in figure A.5 in the appendix.

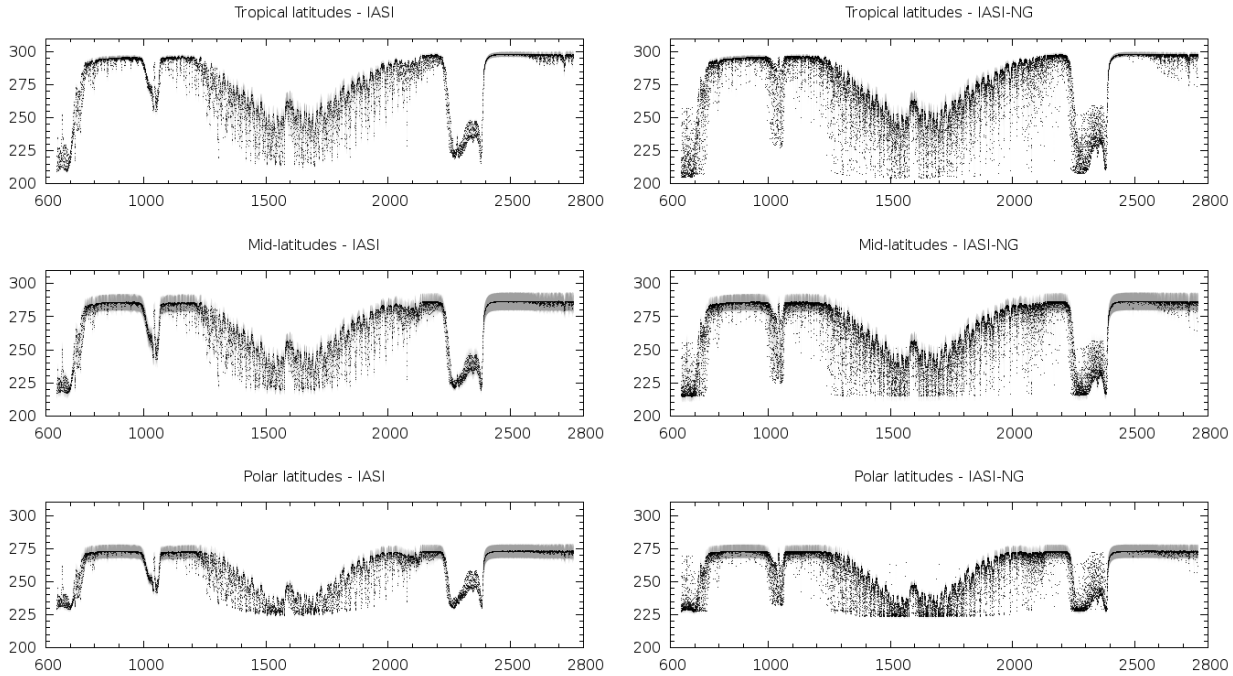
All the clear sky over sea observations corresponding to the first three selected days, 318391 of 418546, have been simulated for both instruments. These simulations have been classified by latitude and day/night conditions. The classification per latitude has been considering as tropical latitudes those latitudes below 20°, as mid-latitudes those between 20° and 75°, and as polar latitudes those above 75°. The assignment of day/night condition has been made according to the solar zenith angle. The average spectrum for each group and instrument has been plotted in figure 3 with a black line, together with the standard deviation, in a gray shadow behind the average.

An increasing standard deviation with the latitude is observed in both panels. Besides, the differences between day and night spectra for the same latitude band increases again with the latitude. The band of CO_2 between 2200 and 2400 cm^{-1} tends to reduce for increasing latitudes, being converted in quasi flat brilliance temperature in polar latitudes at night. The IASI-NG spectra presents narrow structures in comparison with IASI ones.

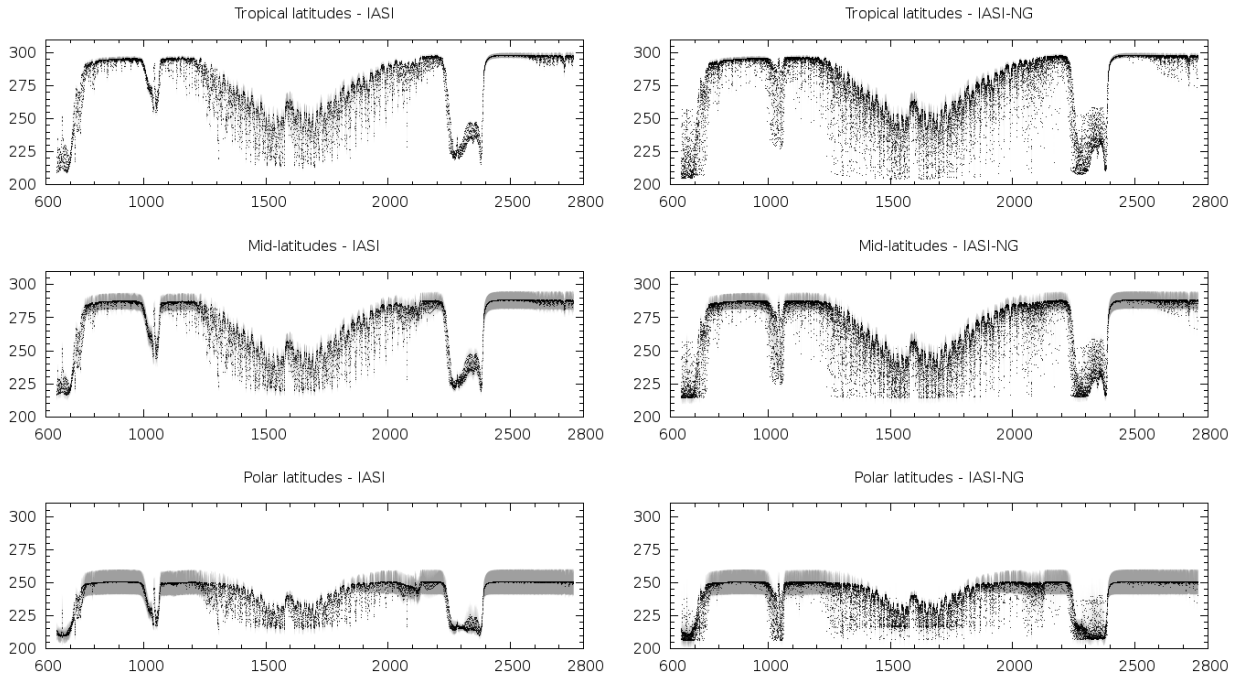
Figure 4 shows the averaged input profiles and spectra for a small set of 100 observations after adding the random Gaussian noise to both background and spectra according to the procedure of the methodology.

4. Summary and current status

IASI is an infrared sounder on board the European Metop satellites which measures the Earth spectrum from 645 to 2760 cm^{-1} into 8461 channels. In the frame of the new european Metop-SG satellite, an upgrade of IASI instrument is going to take place. This new instrument,

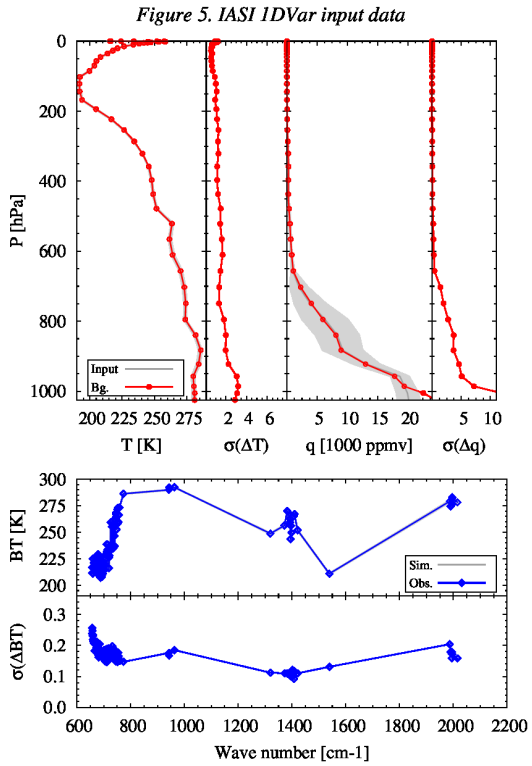


(a) Day

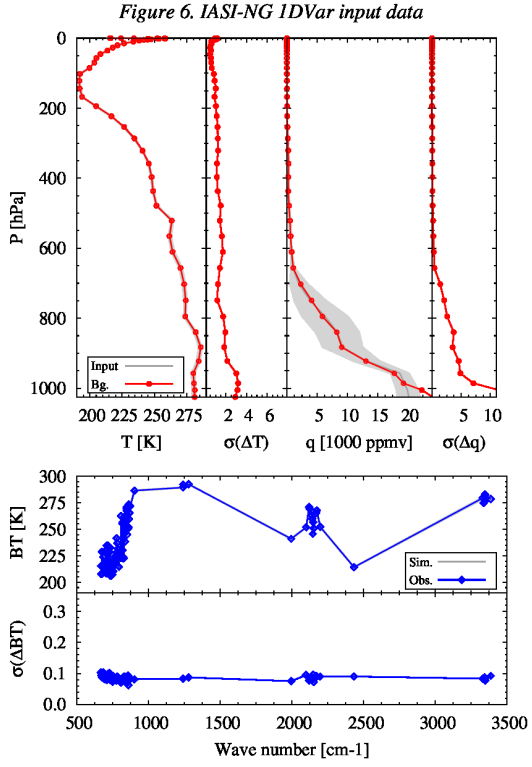


(b) Night

Figure 3: Average latitude spectra for IASI and IASI-NG. Gray area means the standard deviation of the average



(a) IASI



(b) IASI-NG, first material

Figure 4: Input data for NWPSAF 1D-Var software

IASI-NG, will half the noise and double the spectral resolution providing 16921 channels. The number of pixel per observation will be multiplied by 4, passing from 4 to 16 pixels. In this work, the basis of the OSSE experiment over IASI-NG impact, that is being conducted at Météo France, are presented.

A large databank, based on 5242448 IASI observations and accompanied of vertical profiles of different gases, has been prepared and will serve as input data to asses the impact of IASI-NG respect IASI in NWP models and atmospheric chemistry communities. Four days of 2013 have been selected, one per season, to serve as reference for posterior case studies on particular events. The objective of the databank is to described as accurate as possible the state of the atmosphere.

At the current point, 318391 simulations over sea and clear skyes have been carried out. The data used to produce the simulations and these ones have been prepared to ingest them into a 1D-Var data assimilation scheme. The next steps in OSSE planning are to calculate the scores of both IASI and IASI-NG (two materials) in the retrieval of temperature and humidity vertical profiles. The first attempt will use the current Météo-France operational channel selection but further studies will be performed to investigate the best channel selection for this purpose.

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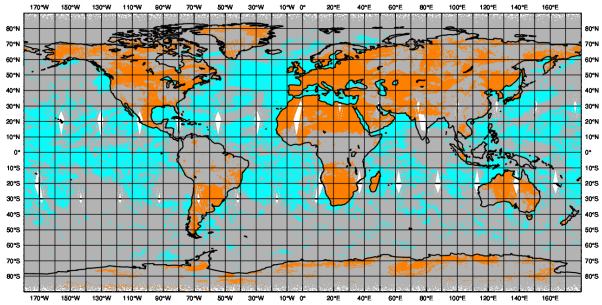
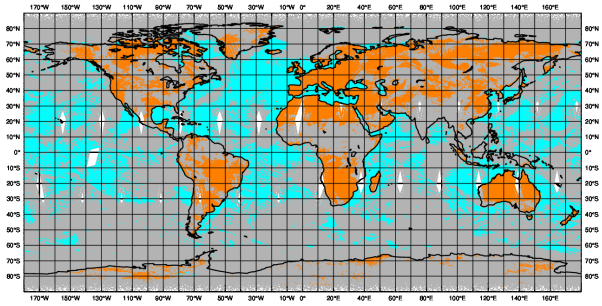
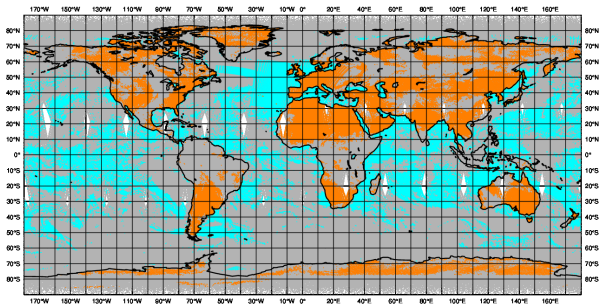
Appendix A. Localization maps



(a) May 6^{th}



(b) August 6^{th}



(c) November 4^{th}

Figure A.5: Maps of IASI observations. Grey points correspond with all IASI observations, blue are observations under clear conditions over the sea and brown over land.