Preparing the assimilation of IASI-NG in NWP models: a first channel selection

Francesca Vittorioso, Vincent Guidard, Nadia Fourrié, Javier Andrey-Andrés

CNRM UMR 3589, Météo-France & CNRS, GMAP/OBS, Toulouse, France

francesca.vittorioso@meteo.fr

I. Introduction

As the EUMETSAT Polar System-Second Generation (EPS-SG) is being prepared, a new generation of the hyperspectral Infrared Atmospheric Sounding Interferometer (IASI) has being designed. The IASI New Generation (IASI-NG) will measure at 16921 wavelengths in each sounding pixel, benefiting of a spectral resolution and a signal-to-noise ratio improved by a factor 2 compared to its predecessor [*Crevoisier et al.* (2014)]. Measurement precision will be improved as well starting from the 1 K in temperature and 10% in humidity IASI precision. The IASI-NG characteristics will lead to huge improvements in detection and retrieval of numerous chemical species and aerosols, and in thermodynamic profiles retrievals, as well as providing, like its predecessor, a huge contribution to Numerical Weather Prediction (NWP).

The high amount of data resulting from IASI-NG will present many challenges in the areas of data transmission, storage and assimilation. Moreover, the number of individual pieces of information will be not exploitable in an operational NWP context and the choice of an optimal data subset will be needed. For all these reasons, an appropriate IASI-NG channel selection is going to be performed aiming to select the most informative channels for NWP.

II. Observing System Simulation Experiment (OSSE) construction and 1D-Var retrievals

Four dates in the middle of each season from 2013 have been selected: February 4th, May 6th, August 6th and November 4th [*Andrey-Andrés et al.* (2017)]. The full IASI orbit for each one of these dates has been computed for a total of 5242448 simulations for each instrument (IASI scan geometry is used for IASI-NG). The experiment was carried out into four steps: ***(1)*** construction of the input database; ***(2)*** spectra simulation for both IASI and IASI-NG; ***(3)*** data perturbation; ***(4)*** introduction of perturbed input data into 1D-Var .

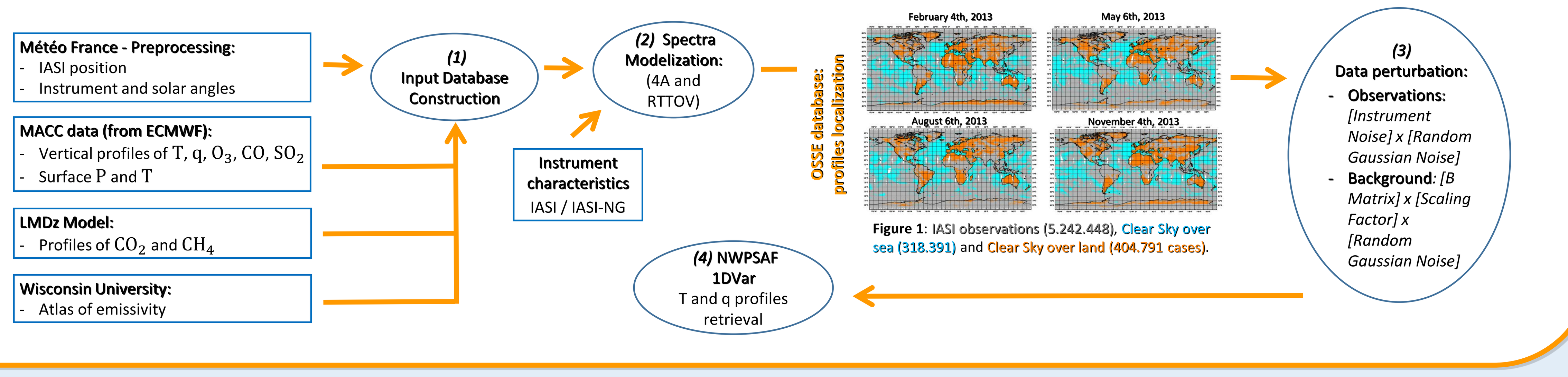


Figure 1: IASI observations (5.242.448), Clear Sky over sea (318.391) and Clear Sky over land (404.791 cases).

III. Case study

The first step of the present effort has been planned to be carried out on ***nadir*** – ***over sea*** – ***clear sky*** conditions. A subset of 1099 of the 318 391 observations matching these criteria, have been judged to be a representative sample of the overall data. The new subset contains observations for:

- *May and August*
- *polar, mid-latitudes and tropical regions*
- *day and night*

located as in Figure 2.

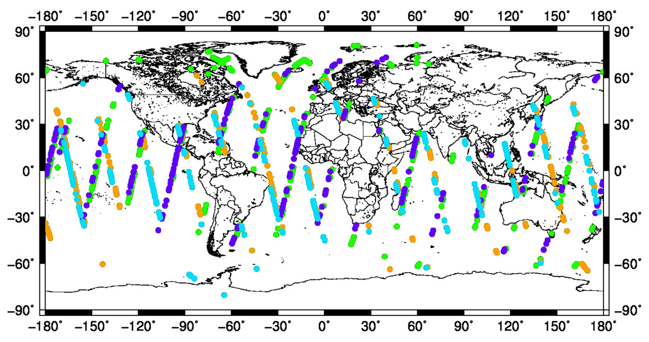


Figure 2: Subset of selected observations for preparing the IASI-NG channel selection: May/day, May/night, August/day, August/night data.

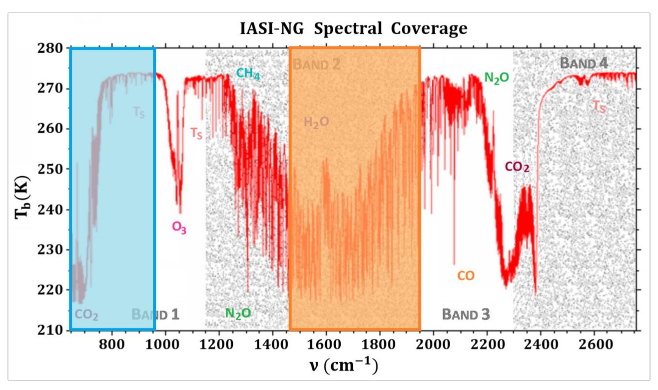
IV. Propaedeutic study towards a channel selection

Tests performed on 1D-Var output retrieved profiles, showed a good improvement in results if a full covariance matrix of the observation errors (**R** matrix) was provided in input.

Thus, in order to estimate full structure **R** matrices, a diagnostic procedure introduced by *Desroziers et al.* (2005) has been applied to different regions of the spectrum that IASI-NG is able to characterize, mainly focusing on the BAND 1 and BAND 2, that are the most relevant for assimilation. 2448 and 3112 channels have been considered for band 1 and band 2, respectively. For both bands the process has been iterated until its convergence and the 1D-Var has been run giving in input the last diagnostic iteration **R** matrix.

The Rate of Improvement for Standard Deviations (computed on the 1099 profiles of the whole case study dataset) has been computed for both bands using 1D-Var output. Figure 3 shows the good improvement in results. For what concerns temperature, the improvement is more pronounced for BAND 1, that is the "temperature band". Concerning humidity, on the other hand, the better results are in the high troposphere if considering BAND 2. The reverse is true in low troposphere, due to the different sensitivity of the involved channels.

The Degrees of Freedom for the Signal (DFS) values have been computed as well and are here shown in Table 1.



BAND 1					BAND 2			
TOT	TEMP	HUM	SKIN TEMP	DFS	TOT	TEMP	HUM	SKIN TEMP
6.9	5.1	0.5	0.98	MIN	6.4	1.6	3.2	0.09
10.1	6.0	3.6	1.02	MAX	8.7	2.9	6.2	0.97
9.0	5.6	2.4	1.00	AVERAGE	7.7	2.2	5.0	0.51
9.1	5.7	2.4	1.00	MEDIAN	7.8	2.2	5.1	0.52

Table 1: DFS values computed for retrieved profiles resulting from the use of the full **R** Matrix from diagnostic convergence iterations (7th iteration in BAND 1 and 10th iteration in BAND 2).

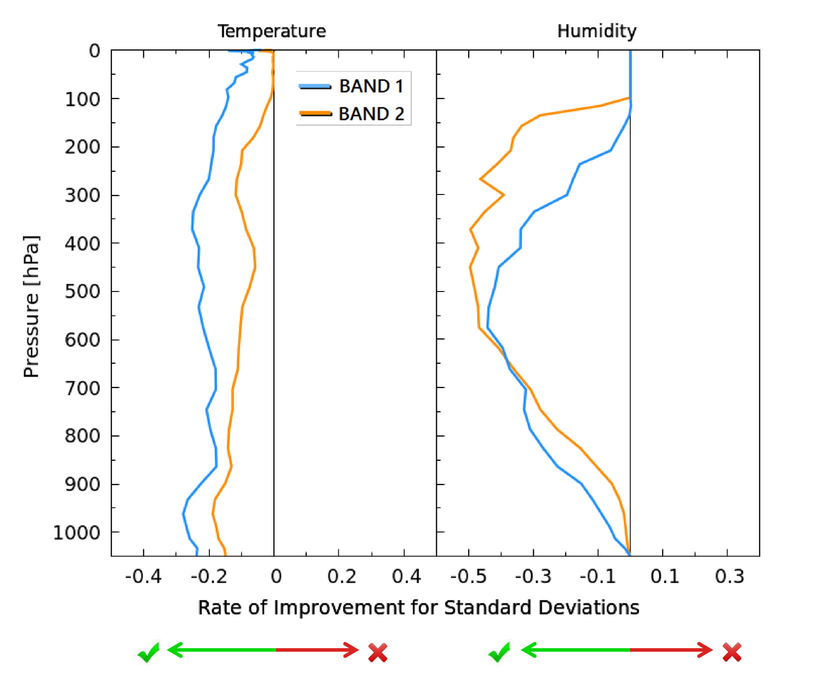


Figure 3: $Rate\ of\ Improvement = [(R-T)-(B-T)]\cdot(B-T)^{-1}$ for Standard Deviations computed from the results obtained with the last iteration diagnostic matrices.

V. A first channel selection

This step has been based on a methodology suggested by Rodgers (1996) and proved to be a good *a priori* method for determination of an optimal channel set by Rabier et al. (2002). The method relies on evaluating the impact of the addition of single channel on a figure of merit. This latter is normally a quantity reflecting the improvement of the analysis error covariance matrix **A** over the background error covariance matrix **B** (e.g. DFS or Entropy Reduction – ER).

In this very first stage, only one among the case study profiles has been picked up (August – night – mid-latitudes) and the figure of merit chosen to iterate the procedure is the **Total DFS** (Temperature + Humidity + Skin Temperature DFS). The iterative method has been implemented at this stage so that it stops when the maximum DFS does not reach any significant variations anymore. Based on an analysis of the Total DFS growth rate at each iteration, it has been decided to narrow the choice down to the channels showing a percentage of this parameter greater than 0.01% (i.e. the channels for which the Total DFS no longer varies after the fourth decimal place). These thresholds are: 665 channels for BAND 1 and 758 for BAND 2. The research results are shown here below in Figure 4 and 5. More in details, it is possible to observe the Total DFS growth with the amount of selected channels, the trend of the Temperature and Humidity Jacobians for the subset of channels selected via the growth rate criterion and finally the distribution of the selected channels on the interested spectrum areas.

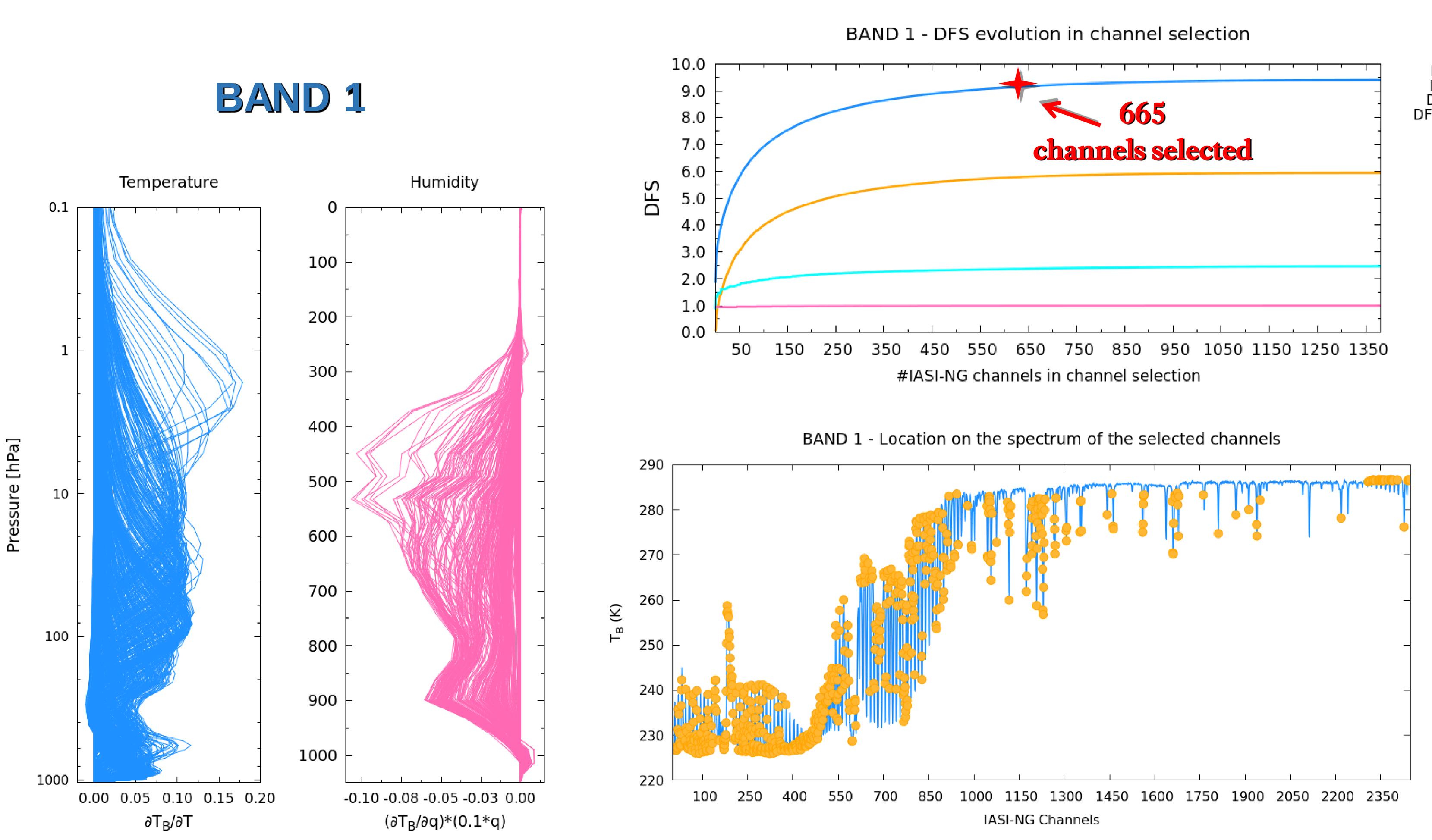


Figure 4: Main channel selection results for BAND 1. Top Right: Total DFS growth with the amount of channels selected (the contribute of Temperature, Humidity and Skin Temperature DFS at each iteration are shown as well). . Bottom Left: Temperature and Humidity Jacobians for the 665 channels selected. Bottom Right: position on the spectrum of such 665 channels.

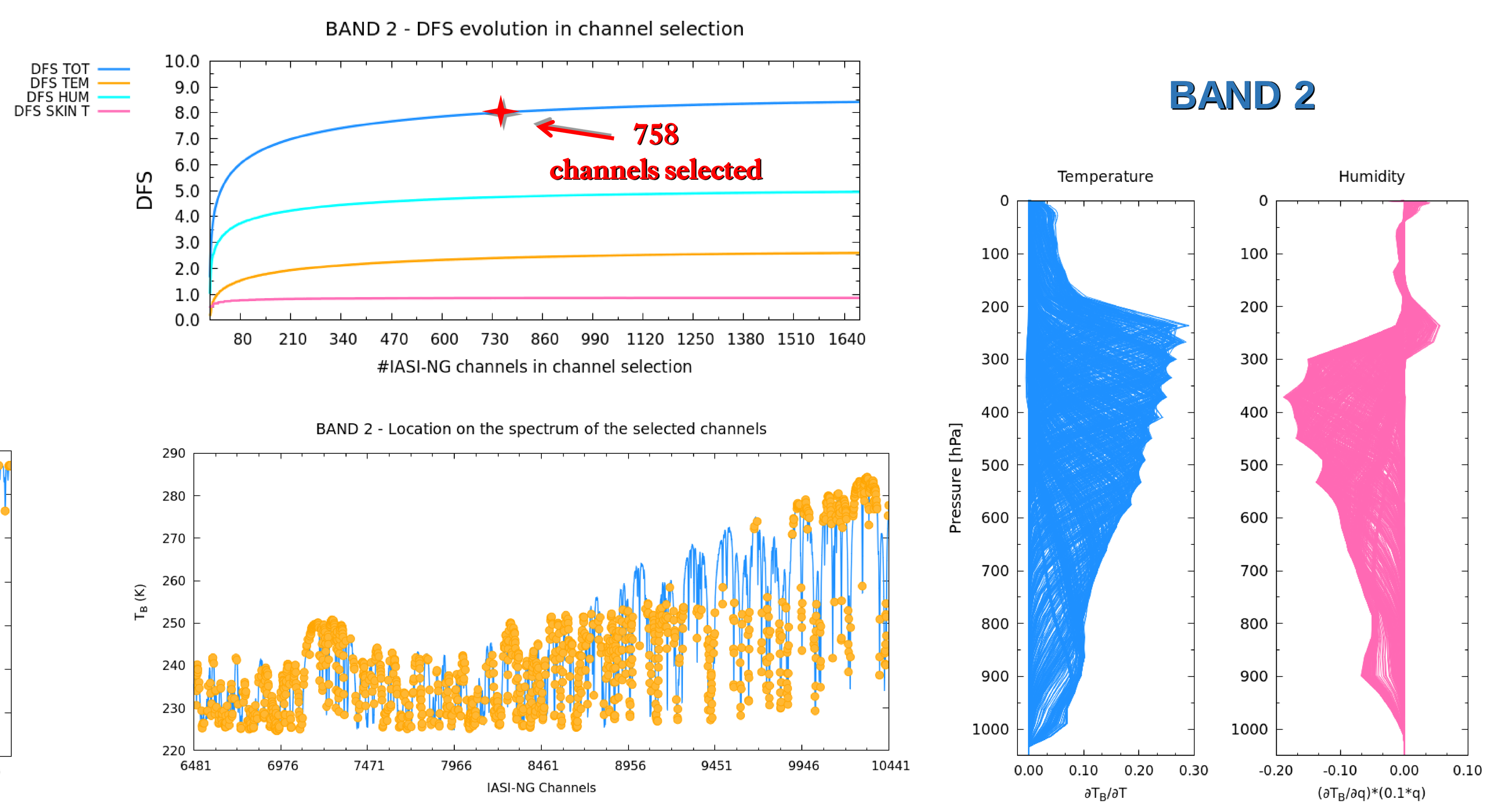


Figure 5: Main channel selection results for BAND 2. Top Left: Total DFS growth with amount of channels selected and contribute of Temperature, Humidity and Skin Temperature DFS . Bottom Right: Temperature and Humidity Jacobians for the 758 channels selected. Bottom Left: position on the spectrum of such 758 selected channels.

VI. Future works

The next step of the present study aims to refine and test this first channel selection. The procedure of section V will be spread to the whole dataset of atmospheric profiles selected as case study in section III. Another method will also be applied, based on selecting the most relevant channels relying on the characteristics of their weighting functions.

References

Andrey-Andrés, J., N. Fourrié, R. Armante, P. Brunel, C. Crevoisier, V. Guidard, and B. Tournier, 2017: A simulated observation database to asses the impact of IASI-NG hyperspectral infrared sounder. *Atmos. Meas. Tech., **2017***, 1-29. DOI: 10.5194/amt-2017-266.

Crevoisier, C., and Coauthors, 2014: Towards IASI-New Generation (IASI-NG) : impact of improved spectral resolution and radiometric noise on the retrieval of thermodynamic, chemistry and climate variables. *Atmos. Meas. Tech.*, **7**, 4367-4385. DOI: 10.5194/amt-7-4367-2014.

Desroziers, G., L. Berre, B. Chapnik, and P. Poli, 2005: Diagnosis of observation, background and analysis-error statistics in observation space. *Q. J. R. Meteorol. Soc.*, **131**, 3385–3396. DOI: 10.1256/qj.05.108.

Rodgers, C. D.,1996: Information contentand opyimisation of high spectral resolution measurements. Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research II, SPIE, **2830**, 136-147.

Rabier, F., N. Fourrié, D. Chafai, P. Prunet, 2002: Channel selection methods for Infrared Atmospheric Sounding Interferometer radiances. *Q. J. R. Meteorol. Soc.*, **128**, 1011-1027. DOI: 10.1256/0035900021643638.

Acknowledgements

This research has received funding from CNES in the framework of the IASI-NG project.