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

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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 been designed. The IASI New Generation (IASI-NG) will measure at 1099 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 [Créon 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 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 5242-548 simulations for each instrument (IASI scan geometry is used for IASI-NG). The experiment was carried out in four steps: (1) construction of the input database, (2) spectra simulation for both IASI and IASI-NG, (3) data perturbations: introduction of perturbed input data into 1D-Var, and (4) 1D-Var retrievals for both IASI and IASI-NG.

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 318919 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.

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.
Tests 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. 2484 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 sensitivities 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.

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 methodology 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 over the background error covariance matrix (e.g. DFS or Entropy Reduction – ER).

In this very first stage, only one among the case study profiles has been picked up (August – right – 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 0.03% (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.

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 applied to the whole dataset of atmospheric profiles selected as case study in section III. Another method will also be adopted, based on selecting the most relevant channels relying on the characteristics of their weighting functions.

References


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Figure 6: Channel selection results for BAND 1. Top Left: Total DFS growth with amount of channels selected (7 channels are selected). Bottom Left: Temperature and humidity Jacobians for the 7 channels selected. Bottom Right: position on the spectrum of each DFS channel.

Figure 7: Channel selection results for BAND 2. Top Left: Total DFS growth with amount of channels selected (7 channels are selected). Bottom Left: Temperature and humidity Jacobians for the 7 channels selected. Bottom Right: position on the spectrum of each DFS channel.