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FIRST RESULTS ON IASI ASSIMILATION IN THE GLOBAL CANADIAN FORECAST SYSTEM

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1. INTRODUCTION

IASI (Infrared Atmospheric Sounding Interferometer) is a key payload of the recently launched European operational meteorological polar satellite METOP. This hyperspectral infrared sounder measures the thermal radiation emitted by the earth and its atmosphere at high spectral resolution (8461 spectral channels between 645 and 2760 cm^{-1} and an apodised resolution of 0.5 cm^{-1}). It provides information on atmospheric temperature and water vapor profiles, other minor atmospheric constituents (ozone, methane, etc...), aerosols, clouds and surface properties. In most operational meteorological centers, radiances of hyperspectral infrared sounders such as IASI or AIRS (Atmospheric InfraRed Sounder, 2378 channels) are assimilated when they are not affected by clouds ("clear radiances") to provide information on temperature and water vapor fields. Here, we present the results of 4Dvar assimilation experiments of clear IASI radiances in the operational Canadian GEM model (800x600 grid, 58 vertical levels and a top at 10.0 hPa). Our assimilation setup is original in several ways including the use of sub-pixel information provided by the Advanced Very High Resolution Radiometer (AVHRR) to help cloud characterization.

2. ASSIMILATION SETUP

At the Canadian Meteorological Center (CMC), IASI data is obtained from NOAA/NESDIS. The level 1.c BUFR files received contain 616 channels with the warmest field in 2 X 2 pixels retained (U3 files). A 128 channel set was selected for assimilation. Among these 128 channels, 85 are water vapor sensitive channels. The channel selection was performed by studying the Jacobian profiles to discard channels with too much sensitivity to the surface, sensitivity above the model top or sensitivity to greenhouse gases such as ozone which are not yet part of the model state. Shortwave channels of band 3 were not selected because IASI radiometric noise is too high in this band and to avoid possible sun contamination.

The IASI assimilation setup was derived from the AIRS assimilation setup (AIRS clear radiances are assimilated operationally at CMC since June 2008). To summarize, a cloud detection scheme is first applied. If the field of view is declared clear, all the selected channels (with some restrictions above land and sea-ice) will be assimilated. If the field of view is declared cloudy, the CO_2 slicing algorithm (Smith et al. 1978) is applied to estimate the cloud height. Channels with local Jacobian safely above cloud height are judged suitable for assimilation. The cloud detection scheme is made of two parts: the first one is described in Garand and Nadon 1998 and the second is essentially based on a comparison between the surface temperature estimated by inversion of the radiative transfer equation for some windows channel and model's surface temperature with different thresholds above sea and above land. Details of the CO_2 slicing implementation are provided in Garand and Beaulne 2004.

3. CLOUD DETECTION

The AIRS data are provided with a daytime cloud fraction estimated using one visible channel. This information is missing with IASI data but is favorably replaced by the AVHRR radiance cluster analysis performed by EUMETSAT. Results of the latest IASI Monitoring inter-comparison (Hilton et al.) suggested that the cloud detection scheme first tried at CMC with IASI, which didn't use any sub-pixel information, may not be sufficiently stingent. The AVHRR/3 imager onboard METOP giving coincident spatially and temporally

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observation of a IASI field of view (12 kilometers in diameter at nadir) at a finer scale (1 km) provides sub-pixel information very useful for cloud and surface characterization. An unsupervised classification algorithm (dynamic clusters) is applied in radiance space to all the AVHRR pixels (of the order of 100) included in the IASI field of view of interest. As a result of this classification, up to 6 classes are obtained. Each class j is characterized by the fraction of the IASI field of view covered α_j (%) and by the corresponding mean μ_{ij} and standard deviation σ_{ij} of the radiance of each AVHRR channels i.

Mean radiances of visible and near infrared AVHRR channels 1, 2 and 3a are first converted to albedo and then used for daytime cloud detection using thresholds. Care is taken to avoid sun glint contamination.

Mean radiances of thermal infrared AVHRR channels 4 and 5 are used to classify the given class as clear or cloudy using the same method used to perform IASI cloud detection. If a class is cloudy, an effective cloud height, assuming an overcast opaque cloud, is estimated. The highest effective cloud height, corresponding to the coldest class, is used to validate the cloud top height estimated by the CO_2 slicing method. In principle, the estimation of CO_2 slicing should give a cloud higher than the effective height. But in some situations where the fraction covered by the coldest class is too low, it is possible to get an effective cloud higher than the CO_2 slicing. In such situation the coldest AVHRR effective height is used to decide which IASI channels to assimilate.

In addition of these tests, a field homogeneity test is performed. For the whole IASI field of view a local variance is estimated for each AVHRR channel and is used to set heterogeneous IASI field of view as cloudy.

4. 4DVAR ASSIMILATION EXPERIMENTS

We performed two 4Dvar assimilation experiments. In the control experiment, the following observations are assimilated:

- Conventional observations
- Quickscat winds
- AMSU-A and AMSU-B microwave radiances from NOAA and AQUA platforms
- SSM-I microwave radiances from DMSP platforms
- GOES infrared radiances (water vapor channel)
- AIRS infrared radiances (87 channels)
- GPS radio occultation (refractivity profiles)

In the test experiment the 128 pre-selected IASI channels are considered for assimilation. The assimilation experiments were performed on a time period from November 20th to December 9th 2008. The forecasts were first validated against radiosondes. As often the case with satellite data, the impact is much more significant in the southern hemisphere. For temperature, winds and geopotential height the agreement with observations is better in terms of standard deviation for the test experiment, and the difference between the test and the control increases with forecast range. In terms of bias the impact is relatively neutral. A bias tends to develop in the low stratosphere. For dew point depression, the impact is positive for short range forecasts and tends to be neutral at longer ranges. As an illustration, profiles of mean and standard deviation of differences between observations and 120 hours forecasts are given in fig.1.

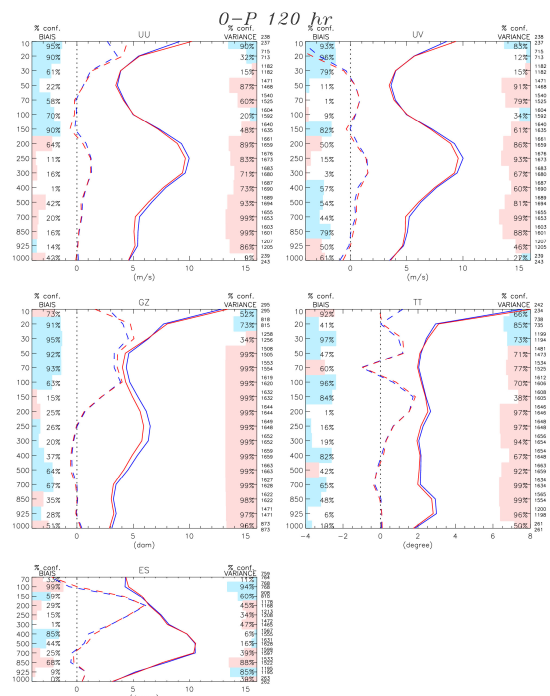

Fig. 1 Validation of 120 hours forecast againt radiosondes in the southern hemisphere for temperature (TT), geopotential height (GZ), wind (UU and UV) and dew point depression (ES). The red ligne corresponds to the test experiment whereas the blue line corresponds to the control experiment. Red shaded areas indicate where the test experiment is better and blue shaded areas indicate where the control experiment is better at indicated significance level.

As radiosondes repartition is uneven, it is also possible to compare forecasts with analysis to get a better global coverage. It is customary to plot the correlation anomaly coefficient versus the forecast range to compare forecast skills. In fig. 2, 3 and 4 the correlation anomaly coefficient of 500 hPa geopotential height is displayed for the two experiments and 3 geographical areas: world, northern hemisphere and southern hemisphere.

The global impact is positive and it is again clearly visible that most of the gain comes from southern hemisphere.

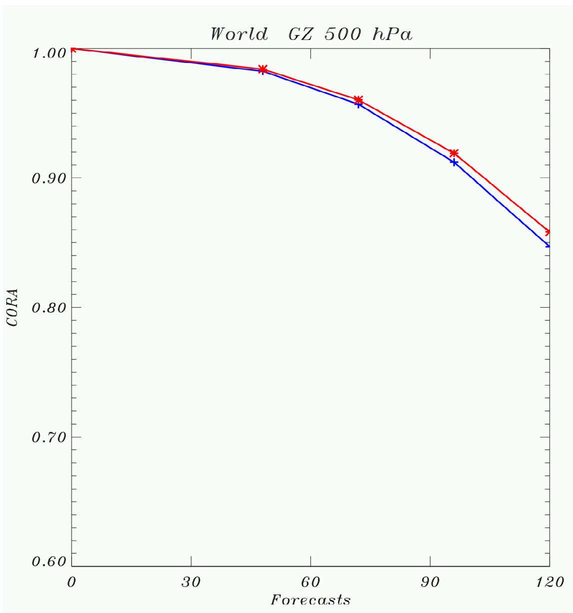

Fig. 2 Global correlation anomaly coefficient for the geopotential height at 500 hPa of the control experiment (blue) and the IASI test experiment (red).

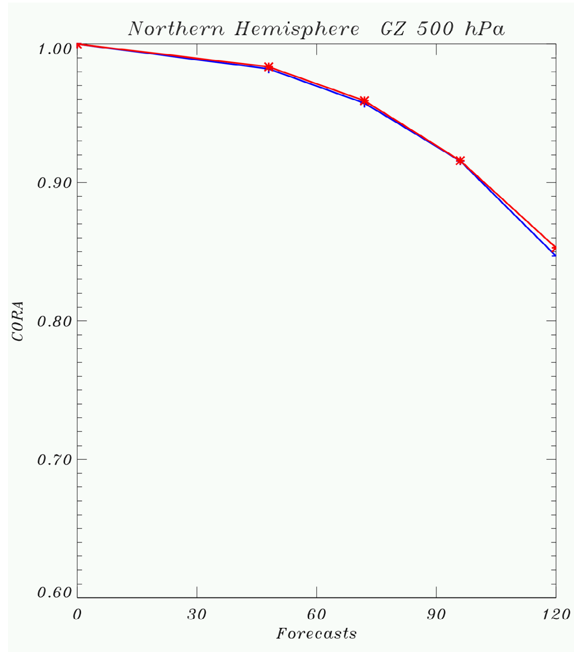

Fig. 3 Northern hemisphere correlation anomaly coefficient for the geopotential height at 500 hPa of the control experiment (blue) and the IASI test experiment (red).

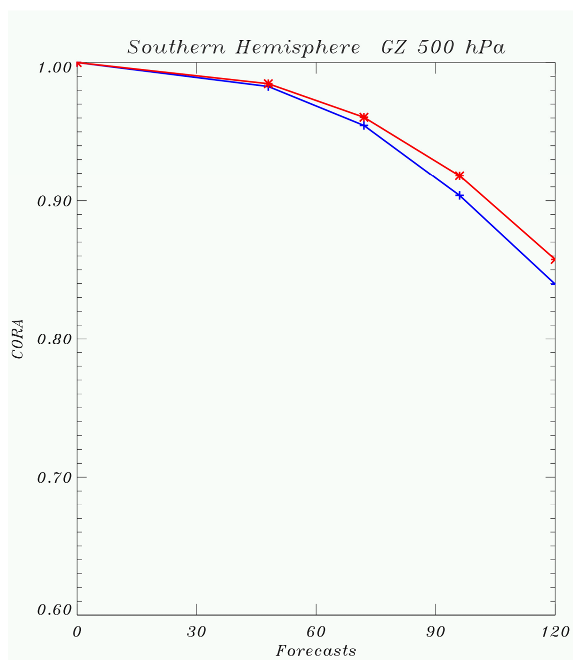

Fig. 4 Southern hemisphere correlation anomaly coefficient for the geopotential height at 500 hPa of the control experiment (blue) and the IASI test experiment (red).

5. CONCLUSION AND PERSPECTIVES

The AIRS assimilation setup previously developed at CMC has been adapted to the IASI instrument with an improved cloud detection using sub-pixel information provided by the AVHRR instrument.
The results of first 4Dvar assimilation experiments in winter 2008 displayed a clear positive impact of the assimilation of IASI radiances on top of data already assimilated operationally, especially in the southern hemisphere. No particular problem related to the assimilation of water vapor channels was observed. Nevertheless, we are aware that other operational centers reported difficulties related to assimilation of channels in the 6.2-7.3 µm region. The balance in the selection of temperature and water vapor channels could evolve in the future. Assimilation experiments in the GEM model "Meso-strato" with a higher model top (0.1 hPa, 80 levels) are planned in the near future, allowing higher peaking channels. The observed biases in the lower stratosphere are under investigation and are expected to be reduced in that new configuration.

6. REFERENCES

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