Assimilation results for AIRS at Météo-France

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Abstract

A subset of channels from AIRS (Atmospheric Infra-Red Sounder) aboard AQUA satellite is provided operationally by NOAA/NESDIS to Numerical Weather Prediction (NWP) centres. Studies have been carried out to assimilate these data in the Météo-France NWP suite. They require efficient monitoring and bias correction of the observations. The impact of the assimilation of AIRS on numerical weather forecast is presented. Infrared radiances are contaminated by clouds in most cases. Therefore, there is a need for a cloud detection scheme. The method developed at NESDIS (Goldberg et al., 2003) and validated in a comparison study by Lavanant et al. (2003) has been used. A neural network approach for bias correction has been tested.

1. Introduction

The Atmospheric InfraRed Sounder (AIRS), launched by NASA in 2002 aboard the AQUA satellite, is the first instrument of a new generation called "advanced infrared sounders" (cf. Aumann et al., 2003). 2378 channels are available within the 3.7-15.4 micron range, most of them showing an excellent performance with respect to their spectral response and sensitivity.

A constant subset of 324 channels is provided by NOAA/NESDIS for AIRS centre pixel of every other AMSU field of view (*i.e.* 1 AIRS pixel out of 18). Using this product, an assimilation suite has been implemented to study the impact of AIRS data on numerical weather forecast before operational use in Météo-France's NWP system.

2. Assimilation suite

The NWP system used in this study is the French operational model ARPEGE. It is a global spectral model with a linear truncation T358 and 41 vertical levels. The horizontal grid is stretched with a factor C2.4, leading to a resolution from 25km over France to 150km at the antipodes. The assimilation system is a multi-incremental 4D-Var with T107 and T149 truncation and no stretching. The assimilation time-window has a range of 6 hours. In this study the latest version of ARPEGE is used ; it includes the assimilation of AMSU-A, AMSU-B, HIRS, EARS, and QuikScat radiances.

The subset from NOAA/NESDIS has an horizontal sampling of about 90 km ; thus no additional thinning is performed. A data quality flag is available in the provided files and is used as a first information for rejection. The screening starts with the calculation of the model-equivalent observation using RTTOV-6M radiative transfer model. Temperature and humidity profiles are needed until 0.1 hPa, so the model is extrapolated above its 1 hPa top.

Quality control includes a gross check performed on the observations and departures for every channel and a first-guess check rejecting channels whose departures are not compatible with error statistics. These statistics (for background and observation error) are crudely defined by groups of channels in various bandsof the spectrum.

Several of the 324 channels provided in the NOAA/NESDIS are blacklisted. This is the case for channels peaking above or near the model top (1hPa) where the model performance is not sufficient, for channels in the ozone band since ARPEGE only uses climatological ozone information, for channels in the short-wave region that are contaminated by solar reflection during day-time. Data over land, where surface emissivity is not known precisely enough, are rejected. The edges of the scan, showing significant biases in the radiative transfer calculation, are also discarded.

Infrared radiances are contaminated by clouds. Although implemented in the code, the ECMWF cloud detection scheme (McNally & Watts, 2001) has not been chosen for a day-one suite. Indeed, this channel by channel scheme requires the whole dataset which is quite large for an operational use. This method also results in assimilating more data in the stratosphere than in the troposphere. On day-one the NESDIS cloud detection scheme (Goldberg et al., 2003) based on several tests using AIRS selected channels and the model Sea Surface Temperature (SST) has been used. First the brightness temperature for a long-wave window channel (965.43 cm^{-1}) needs to be larger than 270 K. Then the model SST is compared to a predicted SST (from channels 918.65, 965.32, 1228.09, 1236.40 cm^{-1}) and during the night-time to a short-wave window channel (2016.095 cm^{-1}), with thresholds that have been recomputed for ARPEGE performance. This scheme has been compared to other cloud detection schemes and to MODIS cloud mask collocated with AIRS in a validation study by Lavanant et al. (2003). During the day-time an additional test has been implemented, rejecting data where AIRS VIS/NIR imager shows more than a certain percentage of cloud inside the AIRS field of view. A study of different cases showed that 5% is an acceptable threshold for residual cloud contamination.

3. Bias correction

A bias correction is applied to the observations in order to get rid of the systematic errors in the observation and forward model. A neural network (multi-layer perceptron) approach is used, following the same philosophy as Harris & Kelly (2001) : the bias is predicted for each channel in a regression (non-linear in this case) based on predictors from the model guess. The learning process is here performed on datasets declared “active” in the former cycles ; thus there is a full compatibility with the screening quality control and cloud detection.

In a first experiment all the available guess information provided to the radiative transfer model are used as predictors. The learning process is performed with respect to the first guess departures as an output. After training, the generalisation to an independent dataset is satisfactory and departure statistics exhibit a very low bias and are almost gaussian. But a large amount of the model bias is corrected this way and this leads to decrease the ability of the observations to correct the model in the assimilation process.

While performing a second experiment with a neural network trained to fit analysis departures, positive results are observed especially in the tropics where the model is too biased to handle water vapour channels correctly. Unfortunately this process creates corrected observations homogeneous with the analysis biases. This leads to a bias amplification in the analysis in the areas where the analysis is initially biased (i.e. at 150 and 700 hPa for temperature).

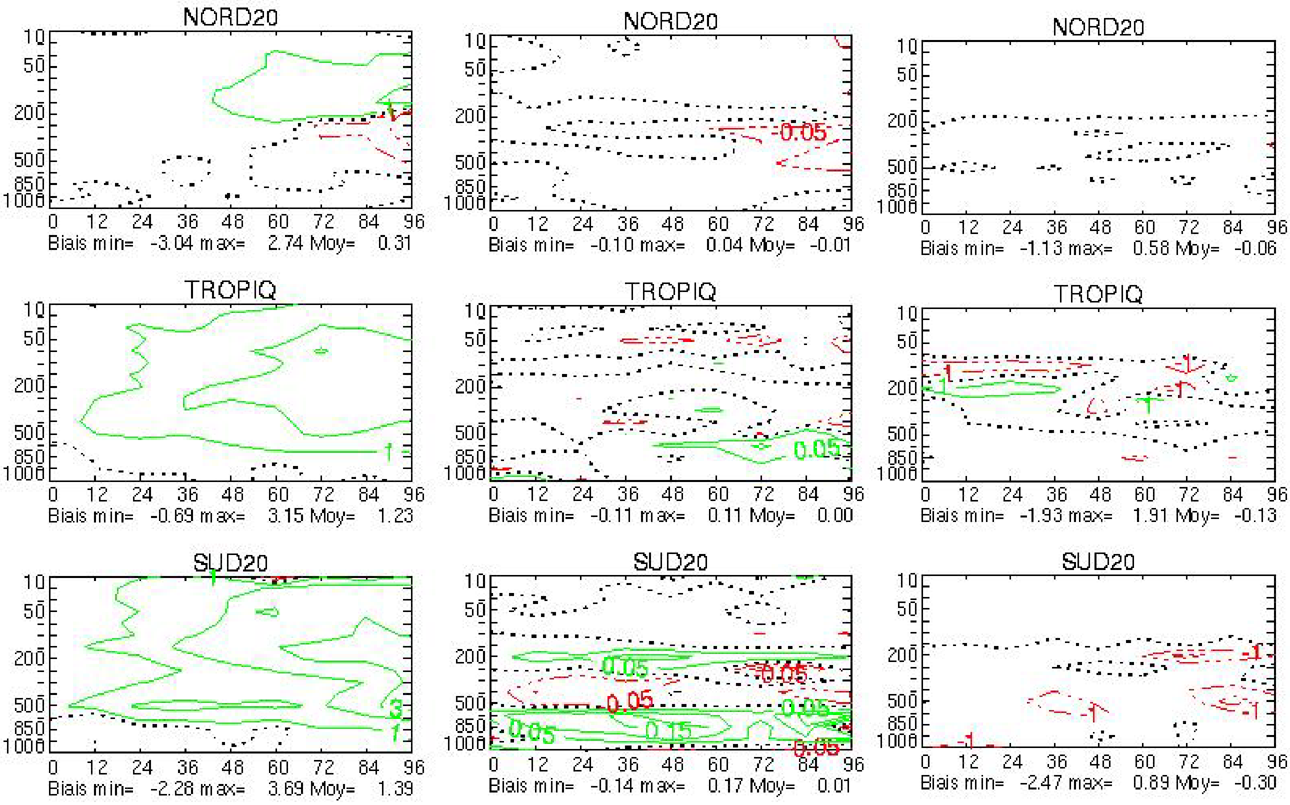
In a third experiment, the bias correction scheme is trained to fit ECMWF analysis departures, since IFS model is less biased than ARPEGE and uses the same forward model. Unfortunately ARPEGE shows a strong bias with respect to IFS above 100hPa, probably mainly because no bias correction is applied to Radiosondes at Météo-France. Thus, large departures for AIRS channels peaking above 100 hPa are observed and they result in large increments in the analysis that propagate downwards with the influence of the structure functions in the variational assimilation.

For a day-one operational assimilation, safety measures have been taken to make sure that the system is stable in time. All channels peaking higher than 100hPa have been blacklisted to get rid of too important increments in the stratosphere. The number of predictors for the neural network bias correction has been decreased in order to limit the scheme's ability to correct model biases. The remaining predictors are the scan angle, latitude, surface temperature and the brightness temperature from the guess for the considered channel

4. Impact of AIRS data on weather forecast

An impact study is performed on the period from the May 1st to May 10th 2004. The "CTRL" experiment is the most recent ARPEGE suite including the assimilation of AMSU-A, AMSU-B, HIRS, EARS, Quikscat radiances. The "EXP" experiment is the same suite with the additional assimilation of AIRS data available before the cut-off.

Fig. 1 displays the difference of absolute value of bias between CTRL and EXP with respect to radiosondes. Green lines mean a positive impact of AIRS ; red lines correspond to a negative impact. AIRS data assimilation shows a positive impact on the bias of the assimilation, especially for geopotential and temperature over the tropics and southern hemisphere. The impact of AIRS on standard deviation is slightly negative, and neutral on the model root mean square error.



a) b) c)

Figure 1: Absolute value of bias of CTRL minus EXP with respect to radiosondes for a) geopotential, b) temperature, c) humidity. The X and Y axis define respectively the forecast range and the vertical pressure levels. Positive values are represented in green, negative in red.

5. Conclusion and perspectives

AIRS data have been introduced in Météo-France 4D-Var assimilation system in preparation of an operational use. The results on weather forecast skills are slightly positive for bias and neutral for RMS.

The cloud detection used in this study provides information on a pixel-by-pixel basis. Therefore most of the information that the AIRS instrument could bring is rejected because of possible cloud contamination. We believe that the assimilation of data from cloudy pixels is one of the major issues for the full exploitation of advanced infrared sounders. The first 1D-Var experiments of retrievals in cloudy conditions are encouraging but face the problem of strong non-linearities for most AIRS channels when they are cloud-contaminated. Retrieving cloud top pressure and emissivity for the assimilation of channels that peak near the cloud top could be an alternative and needs to be studied. Finally cloud-cleared radiances presented by Goldberg et al. (2003) show an important potential benefit for NWP and will be addressed in a close future.

Even when regarding clear pixels, assimilating only a constant subset of channels means a significant loss of the available information. An encouraging approach for data mining is Principal Component Analysis as presented by Huang and Antonelli (2001) that furthermore shows special abilities in filtering the instrument noise.

6. References

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