Data impact studies at Météo-France

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1. Introduction

Pre-processed NOAA-15 and NOAA-16 radiances from NESDIS are currently being used in the four-dimensional variational (4D-Var) assimilation system of ARPEGE, the global numerical weather prediction model operational at Météo-France. The current analysis scheme consists of applying a one-dimensional variational (1D-Var) assimilation system to the pre-processed radiances to obtain quality control flags, surface temperature, vertical profiles of temperature and humidity. The radiances are then injected into 4DVar together with the surface temperature and the retrieved profiles above the top of the model (5 hPa). More details are to be found in Rabier et al. (2001). As a first illustration of the use of ATOVS data at Météo-France, the impacts on analysis and forecast of additional using NOAA-16 on top of NOAA-15 data will first be presented (Section 2). NESDIS pre-processed data undergo a number of significant pre-processing steps, i.e. limb correction, emissivity adjustment, instrument collocation. Some of these steps introduce complicated random and systematic errors in the data that are not present in the raw radiances. With the advanced data assimilation schemes such as 4D-Var many of the pre-processing steps can be bypassed and consequently more information is expected to be extracted from the data. The assimilation of ATOVS raw radiances at Météo-France is under investigation; the first results are presented in Section 3. Another development at Météo-France concerns the experimental assimilation of total column water vapour and surface wind speed over the ocean derived from the SSM/I one-dimensional variational (1D-Var) scheme developed at ECMWF. The model fit to other observations and the impacts of both retrieved products on analysis and forecast will be presented in Section 4. Then the potential benefit of using locally received ATOVS data for mesoscale applications will be pointed out in Section 5. All experimental assimilations are performed using a model with a quadratic truncature of 199 wave numbers, 31 hybrid coordinate vertical levels from the surface up to about 5 hPa and a spherical geometry with France as the pole (stretching factor of 3.5), i.e. 19 km horizontal resolution over France and 234 km at the Antipodes.

2. Addition of NESDIS NOAA-16 data

Since 21 May 2001NOAA-16 data are operationally processed at NESDIS and received at Météo-France. An experimental assimilation and forecast suite has been run in order to assess to which extent these new data are beneficial to the model. The environment used is very similar to the operational configuration for the assimilation of NOAA-15 data. Thinning results to a final resolution of 250km. A 1D-Var pre-processor is used for analysis above the top of the model, surface skin temperature retrieval and quality control. Bias correction coefficients have been computed following the method developed in *Harris and Kelly* (2001) which contains a dual bias correction with respect to the scan position, varying smoothly with latitude, as well as to the air-mass. The assimilation of NOAA-16 data on top of NOAA-15 data was found to behave better than the assimilation of NOAA-15 data only on a 19-day period in July 2001, especially in the medium-range as illustrated by the difference in 300 hPa geopotential height performance at day 4 in Figure 1. A significant positive impact of adding NOAA-16 data in the assimilation is also occasionally seen in the short range, as shown in Figure 2. In this example, the addition of NOAA-16 data in the analysis has helped to better represent the trough.

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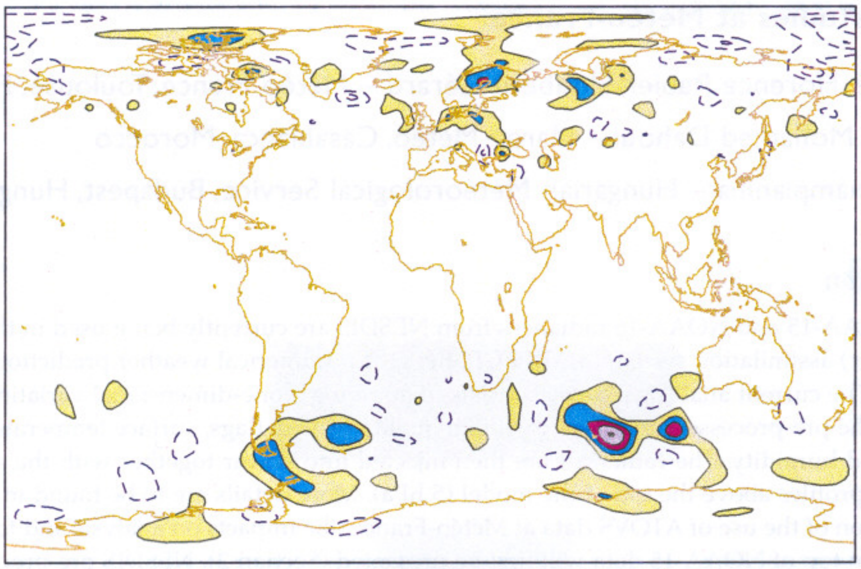

Fig. 1: 300 hPa geopotential height difference between the 96-hour forecast root-mean-square error from the experiment with only NOAA-15 ATOVS data and from the experiment with NOAA-15 and NOAA 16 ATOVS data, averaged over 19 days of assimilation (1-19 July 2001). Contour interval is 10 m. Shaded surfaces represent positive differences greater than 10 m, showing a significant improvement brought by NOAA-16 data.

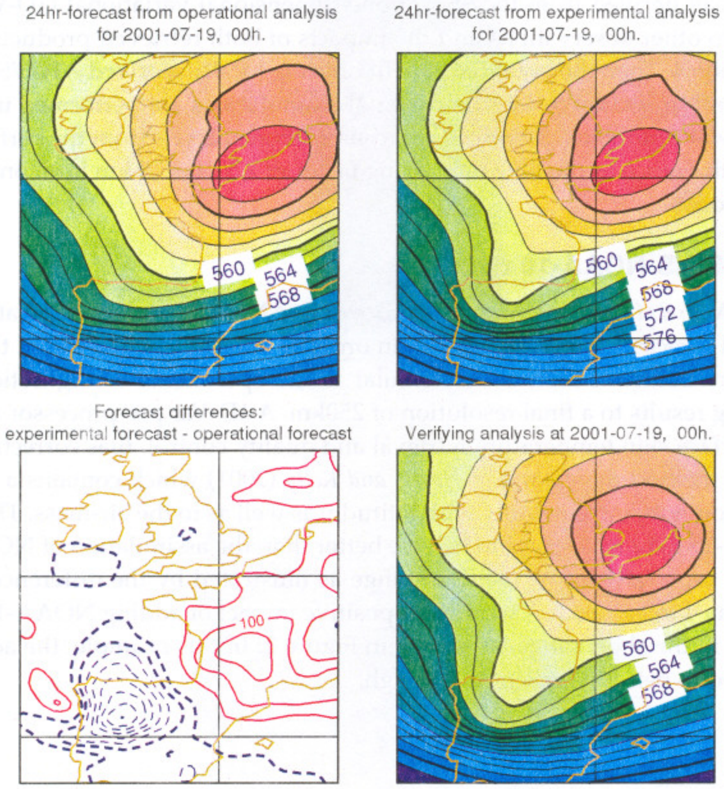

Fig. 2: 500 hPa geopotential height 24-hour forecast (contour interval 10m). On top-left the forecast with operational analysis, top-right the forecast with NOAA-16 data added in the experimental analysis, bottom-left the difference between experiments (contour interval 50m²/s² for GZ, positive values in red and negative in blue) and bottom-right the operational verifying analysis.

3. Use of ATOVS raw radiances

The assimilation of ATOVS raw radiances without collocation and 1D-Var inversion is currently under investigation. Major developments in that respect concern the extrapolation of model fields above the top of the model as an input to the radiative transfer model, the radiance bias correction, the optimal density of observations and the quality control.

The radiative transfer code currently being used (RTTOV, *Saunders et al.* 1998) requires the vertical temperature on 43 pressure levels. Under the top of the model, profiles are interpolated to RTTOV pressures levels. Above the top of the model (about 5 hPa) an extrapolation of the profiles using a regression algorithm (*Clément Chouinard,* personal communication) which extrapolates the departure from a reference profile (see Figure 3) has been tested. Regression coefficients are obtained using statistics over a dataset based on rocketsondes, satellite and perfect gas theory. Surface skin temperature at every observation point is included in the 4D-Var control variable.

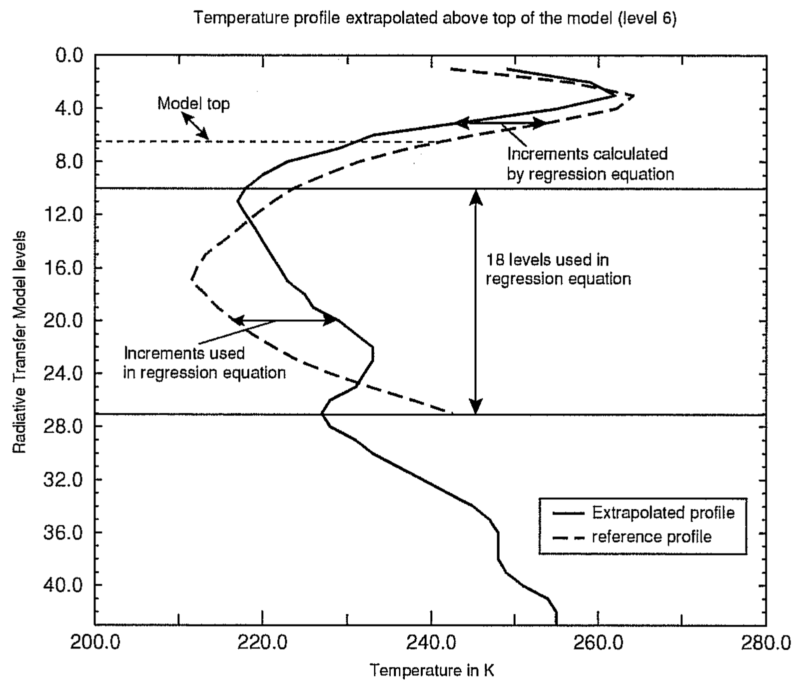

Fig. 3: Extrapolation of the temperature profile above the top of the model.

A horizontal thinning is performed to ensure a minimum distance of about 200 km between observations. Cloud and precipitation detection is necessary as in the first case temperature and humidity information cannot be extracted from the cloud contaminated infrared HIRS measurements and in the second case lower microwave channels are too sensitive to rain to be used in presence of precipitation in the field of view. The detection is done by comparing the observed to the background radiances in HIRS window channel 8 and channel 12 for cloud detection and in AMSUA-4 window channel radiance. Bias correction coefficients have been computed following the method developed in *Harris and Kelly* (2001).

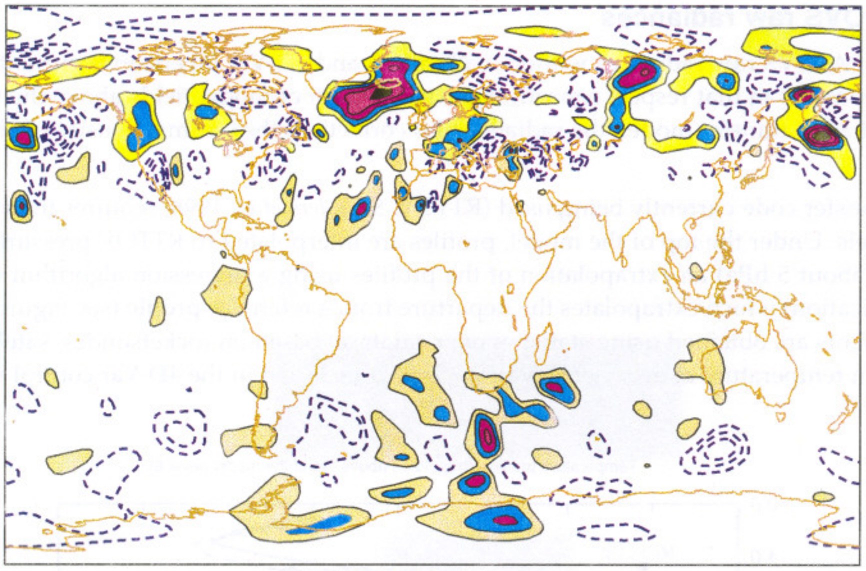

Fig. 4: 300 hPa geopotential height difference between the 96-hour forecast RMSE from the experiments with ATOVS pre-processed data and with ATOVS raw radiances, averaged over 11 days of assimilation. Contour interval is 10 m. Shaded surfaces represent positive differences greater than 10 m, showing a significant improvement brought by the raw radiances.

The assimilation of raw radiances was found to behave better than the assimilation of pre-processed radiances on a 11-day period in April 2001, especially in the medium-range as illustrated by the difference in 300 hPa geopotential height performance at day 4 in Figure 4. On a global scale raw radiances enable the 300 hPa geopotential height forecast rms error to be reduced by about 3.3% (1.9 m absolute difference). In this experiment only AMSUA from NOAA15 have been used, as HIRS instrument on board the same platform encountered some technical problems. Further experiments will be performed with both instruments and both available satellites (NOAA-15 and NOAA-16).

4. Use of SSM/I data

Experimental assimilation of total column water vapour (TCWV) and surface wind speed (SSWS) over the ocean, derived from the 1D-Var inversion (see *Phalippou* (1996) for description of the method developed at ECMWF and *Gérard and Saunders* (1999) for assimilation of TCWV at ECMWF) has been investigated at Météo-France. An horizontal thinning of the 1D-Var products has been performed, i.e. 250 km for TCWV and 125 km for SSWS. The observation errors are derived from the 1D-Var error covariance matrix and are such that an equivalent global weight is given to both model and observations between extreme values, whereas the TCWV observation errors are higher than the model errors below 10 kgm^{-2} and above 60 kgm^{-2} and the weight given to SSWS observations is weaker for SSWS lower than 6 ms^{-1} and higher for values above 12 ms^{-1}.

Assimilation experiments of these data over a two week period (1-15 January 2000) have been performed together with a control run where no SSM/I data is used. These experiments show a global moistening of the model analysis in the Northern Hemisphere (1.5% increase), in the Southern Hemisphere (2.2% increase) and in the Tropics (0.9% increase), as shown in Figure 5.a. However a drying is to be noticed in the dry tongues located off the western coasts of subtropical continents. Moreover a better coherence between first guess and analysis is noticeable as these data help to reduce the global difference between first guess and analysis. As for the assimilation of SSWS, it tends to strengthen the analysis surface wind speed in the Tropics (1.4% increase), in the Southern Hemisphere (1.2% increase) and in the Northern Hemisphere (1.1% increase), as shown in Figure 5.b. Even though the effect of assimilating SSM/I TCWV and SSWS remains in the forecasts for up to 96 hours, no significant impact is seen in the mean forecast performance.

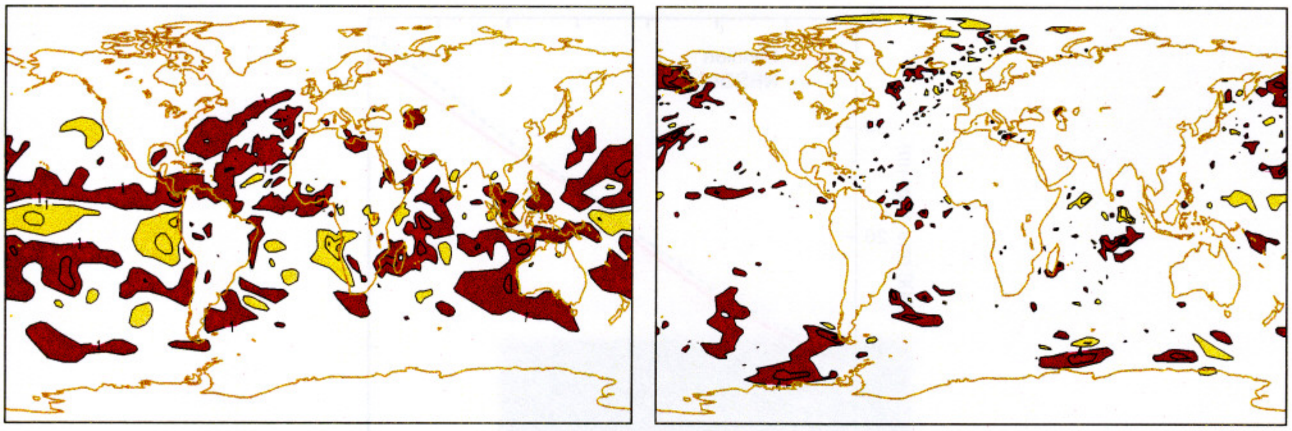

Fig. 5: (a) TCWV and (b) SSWS analysis differences between the experiment with SSM/I data and the experiment without. Units are in (a) kgm^{-2} and (b) ms^{-1} and mean difference values are indicated at the top of each panel. Contour lists are -3/-1/1/3 kgm^{-2} for TCWV and -0.8/-0.4/0.4/0.8 ms^{-1} for SSWS. Dark shaded surfaces represent positive differences, light shaded surface represent negative differences.

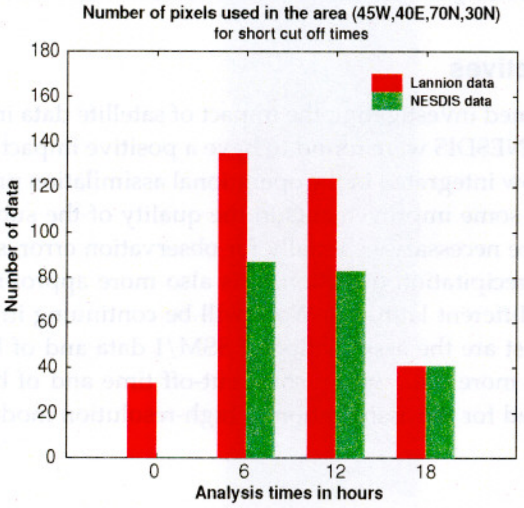

Fig. 6: Comparison of the number of AMSU-A data used in the "Lannion" area for short analysis cut-off times, received from NESDIS and Lannion, as a function of the analysis time. This number of data is averaged over six days in May 2001.

5 Use of ATOVS locally received data

The Spatial Meteorological Centre (CMS) of Météo-France in Lannion, France produces pre-processed ATOVS radiances over Europe and the Eastern Atlantic area (45°W,30°N,40°E,70°N) from HRPT data, encodes and transmits them in real-time to Toulouse. These data are available with a short time-delay. Cut-off times for the operational model runs are as short as 1h50 after the analysis time at 00 and 12 UTC, as opposed to 3h at 06 and 18 UTC. An illustration of the number of data potentially used in our system compared to NESDIS pre-processed radiances in the same area is provided in Figure 6 for the four analysis times. The relatively small amount of data at 00 and 18 UTC is due to the fact that the orbits are at the edge of Lannion reception area.

Since a specific pre-processing is applied to radiances at Lannion, a comparison of data qualities has been run. Lannion data showed to be of better quality and the standard deviation of its error had to be divided by 1.5 in the assimilation scheme for more efficient use. Preliminary assimilation experiments show a slight positive improvement in forecast performance over the European area. This impact increases with the density of the data, and thus results shown in Figure 7 correspond to a 120km horizontal sampling. The impact on geopotential is positive below 200hPa and can be seen from the 24h forecast range, especially for short cut-off. It is slightly reduced in case of long cut-off, since the difference in the amount of data received is smaller. Because of a failure of the AVHRR instrument on NOAA-15, no pre-processing could be performed at Lannion on NOAA-15 data and thus this study uses only NOAA-16 observations. More positive impact is expected from the use of data from two satellites.

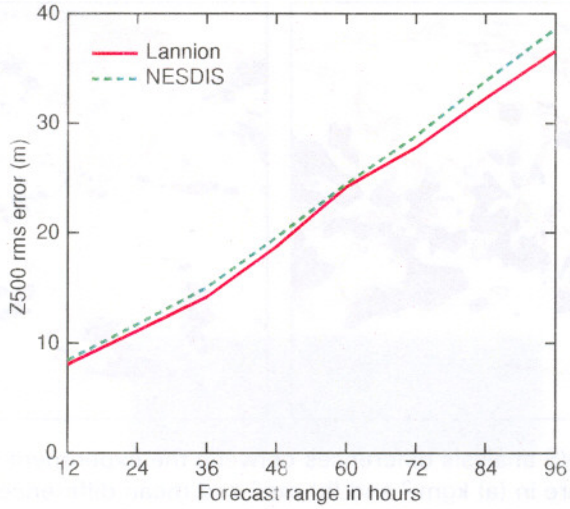

Fig. 7: RMS of the difference between 500hPa geopotential height forecast and its own verifying long cut-off analysis, averaged over 21 days over Europe, as a function of forecast range. Forecasts start from short cut-off 06 UTC analyses using Lannion and NESDIS AMSU-A NOAA16 data at 120km horizontal sampling.

6 Summary and perspectives

Several experiments were performed investigating the impact of satellite data in the French global model. NOAA-16 pre-processed radiances from NESDIS were found to have a positive impact on forecast performance on top of NOAA-15 data. These data are now integrated in the operational assimilation process. ATOVS raw radiance assimilation experiments also showed some improvements in the quality of the subsequent forecasts. To improve the analysis scheme, some tunings are necessary, especially for observation error, surface skin temperature error and thresholds used for cloud and precipitation detection. It is also more appropriate to calculate regression coefficients used in extrapolation for different latitudes. Work will be continuing in this area, until operational implementation. Other topics of interest are the assimilation of SSM/I data and of locally received ATOVS radiances. The latter has shown to provide more data within short cut-off time and of better quality after pre-processing. These results should be considered for the assimilation of high-resolution models over a limited area.

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