Impact of the ATOVS data on the mesoscale ALADIN/HU model

Roger Randriamampianina and Regina Szoták
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1. Introduction

The pre-processing and the implementation of ATOVS data into the ALADIN three-dimensional variational (3d-var) data assimilation system at the Hungarian Meteorological Service (HMS) was described in Randriamampianina (2003). This report presents the first results of the study on the impact of ATOVS data on the analysis and forecasts of the ALADIN model.

Section 2 gives brief description of the characteristics of the ALADIN/HU model. Section 3 introduces the pre-processing of ATOVS data. Description of the experiments done for the impact study is shown in Section 4. Section 5 presents the results of the impact study, followed by some selected cases in Section 6. In Section 7 we draw some conclusions and discuss further tasks.

2. Main characteristics of the ALADIN/HU model and its assimilation system

The hydrostatic version of the ALADIN model was used in this study. The horizontal resolution of ALADIN/HU is 6.5 km. It has 37 vertical levels from surface up to 5 hPa. We use the 3d-var technique as an assimilation system. An important advantage of the variational technique is that the computation of the cost function for observations part is done in the observations space. Thus, for the assimilation of radiances, we have to be able to determine them from the model parameters. For this purpose we need a radiative transfer code. In our case (ARPEGE/ALADIN) we use the RTTOV code (Saunders et al., 1998), which uses 43 vertical levels. Above the top of the model, an extrapolation of the profile is performed using a regression algorithm (Rabier et al., 2001). Below the top of the model, profiles are interpolated to RTTOV pressure levels. Assimilation systems require a good estimation of background error covariances - the so-called "B" matrix. B matrix was computed for the new domain using the "standard NMC method" (Parrish and Derber, 1992). A 6-hour assimilation cycling was chosen, consequently the 3d-var is running 4 times a day at 00, 06, 12 and 18 UTC. We perform a 48-hour forecast once a day, from 00 UTC.

3. Data pre-processing

We receive the ATOVS data through a HRPT antenna. The AMSU-A, level 1C, data are pre-processed by the *AAPP* (ATOVS and AVHRR Pre-processing Package) package. We use the pre-processing chain *OULAN-BATOR-OBSORT-toODB* to create the ODB files. The output of the *AAPP* is read in direct way in the *OULAN* pre-processing package.

Choice of Satellite :

Because of its technical specifications, our antenna receives data from only two satellites at the same time. Data from NOAA-15 are available over the domain of ALADIN/HU at about 06 and 18 UTC, while data from NOAA-16 are available around 00 and 12 UTC. The orbit of the NOAA-17 is between the orbits of the other two satellites, a bit closer to that of NOAA-16. We know that NOAA-15 has problem not only with the AVHRR instruments but also with some microwave channels (AMSU-A-11 and AMSU-A-14). Nevertheless, NOAA-15 and NOAA-16 were chosen for the impact study, to guarantee the maximum amount of observations at each assimilation time.

Extraction of ATOVS data :

Satellite data observed and pre-processed in the interval of ±3 hours from the assimilation time are treated. The maximum number of orbits found at one assimilation time varies up to 3.

Bias correction :

The systematic error of the satellite data can be shown comparing the observed radiances with the computed (simulated) ones. The systematic error arises mainly from errors in the radiative transfer model, instrument calibration problems or biases in the model fields.

The bias-correction coefficients for data from NOAA-15 and NOAA-16 were computed according to Harris and Kelly (2001) for the study period. Note, that the bias coefficients were computed for different latitude bands. Figure 2 demonstrates the bias, computed for the same latitude band, for NOAA-15 and NOAA-16.

Channel selection :

Analysing the bias of the brightness temperature, specific for each AMSU-A channel, inside all possible latitude bands, we decided to keep the same number of channels as in the ARPEGE model (see Table 1). Our study is interesting from the point of view of use of AMSU-A data over land (see Table 1), because the percentage of land over the ALADIN/HU domain is more than 70 %.

Observation statistics and assimilation of radiances :

It is necessary to check the efficiency of ATOVS data based on statistics (theoretical standard deviation - *rmtberr_noaa.dat* constant file) used to handle the observation in case of new data and, in our case, "new model configuration" (more examples can be seen in Randriamampianina and Rabier, 2001). The "observation (AMSU-A radiances) minus guess (computed radiances)" data were compared with the "observation minus analysis" ones for this purpose (Figs 3-6). These figures show statistics computed from a few days (2003.02.20 - 2003.02.25) of cycling. The distance between the two curves indicates how the addition of the AMSU-A data could modify the first-guess fields during the assimilation. The larger the distance the bigger the impact of the observations (so, of AMSU-A) on the analysis. These results are comparable to those computed in Randriamampianina and Rabier (2001). Another test was done before starting the experiments, which consisted in reproducing the above-mentioned experiment after reducing the theoretical standard deviation by half. We did not find any considerable changes in the results. So we decided to keep the original values of the theoretical standard-deviation at this stage, as it is used in ARPEGE.

channel number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
over land					x	x	x	x	x	x	x	x			
over sea					x	x	x	x	x	x	x	x			
over sea ice							x	x	x	x	x	x			
cloudy pixel								x	x	x	x	x			

Table 1 : The use of AMSU-A channels. Note, that "over land" channels 5 and 6 are used when the model orography is less than 500 m and 1500 m, respectively.

4. Experiments design

In the experiments, two thinning techniques (80 and 120 km resolution) were investigated. The impact of ATOVS data was studied for a two-week period (from 2003.03.20 to 2003.03.06). Surface (SYNOP) and radiosonde (TEMP) observations were used in the control run. The impact was evaluated comparing the control run with runs using TEMP, SYNOP and ATOVS data. Examining the first results, we found that the impact of ATOVS data on analysis and forecasts depends on the way the control variables (vorticity, divergence, temperature and surface pressure, specific humidity) are handled (in particular, the assimilation of specific humidity in univariate form or with all control variables using the multivariate formulation).

The following experiments were carried out:

T8000 - TEMP, SYNOP and AMSU-A data were assimilated. The AMSU-A data were thinned at 80 km resolution. The multivariate formulation was used for all control variables.

T1200 - TEMP, SYNOP and AMSU-A data were assimilated. The AMSU-A data were thinned at 120 km resolution. The multivariate formulation was used for all control variables.

Aladt - TEMP and SYNOP were assimilated - control run. It is our 3d-var cycling running as parallel suite. The multivariate formulation was used for all control variables.

Touhu - TEMP, SYNOP and AMSU-A data were assimilated. The AMSU-A data were thinned at 80 km resolution. The specific humidity was assimilated as an univariate control variable, whereas the other control variables were assimilated using a multivariate formulation.

12uhu - TEMP, SYNOP and AMSU-A data were assimilated. The AMSU-A data were thinned at 120 km resolution. The specific humidity was assimilated as an univariate control variable, whereas the other control variables were assimilated using a multivariate formulation.

Aluhu - TEMP and SYNOP were assimilated - control run. The specific humidity was assimilated as an univariate control variable, whereas the other control variables were assimilated using a multivariate formulation.

Dynam - Dynamical adaptation run - the operational run in Hungary.

Objective verification :

This report presents the results of the objective verification. The bias and the root-mean-square error (RMSE) were computed from the differences between the analysis/forecasts and the observations (SYNOP and TEMP).

5. Most important results

Using multivariate formulation :

- We found that AMSU-A data have positive impact on the analysis and forecasts of geopotential height when assimilating them in both 80 and 120 km resolutions. Especially, on lower levels (i.e. below 700 hPa), the impact was positive for all forecast ranges. Positive impact on the short-range (i.e. until 12 hour) forecast was observed for all model levels (see Fig. 7).

- A neutral impact on the analysis and forecasts of wind speed was observed.
- A neutral impact of AMSU-A data on the temperature profile was found.
- Regarding the relative humidity fields, a negative impact was observed.

The "stability" of the negative impact of AMSU-A data on relative humidity fields shows that its source might be in the way the humidity measurements are assimilated. We decided to separate specific humidity from the multivariate formulation and assimilate it alone (univariate form).

Assimilating the humidity in univariate form :

- The impact of AMSU-A data on the forecast of geopotential height was somewhat less, but positive, compared to the run with multivariate formulation.
- Positive impact on temperature above 700 hPa was observed from the 24-hour forecast range (see Fig. 8)
- Concerning the impact on relative humidity, an improvement could be observed (Fig. 9). It is important to mention that we found a big improvement at all model levels when assimilating the humidity data in univariate form, especially for levels around the tropopause (see Fig. 10). It can be also observed on the run without ATOVS data (see Fig. 11).
- A neutral impact was found for wind speed.

Influence of resolution :

We performed comparisons to evaluate the influence of the resolution of ATOVS data (thinning distance) on analysis and forecast. In general, the positive impact of ATOVS data on geopotential and temperature was stronger in case of finer (80 km) resolution of ATOVS data. The 120-km resolution gave "better" impact on relative humidity, wind speed and wind direction when using the multivariate formulation. Assimilating the humidity data in univariate form, the finer resolution gave "better" impact on relative humidity (see Fig. 12).

We concluded, that the positive impact was somewhat stronger in general when ATOVS data were assimilated at finer resolution, especially when the specific humidity was assimilated in univariate form.

Comparison of 3d-var and dynamical adaptation :

We can conclude that the 3d-var analysis of wind, geopotential and humidity fields was closer to the observation compared to the ARPEGE analysis (see Fig. 13), which is the initial condition for the dynamical adaptation. However the dynamical adaptation gave better results on forecasts of temperature for lower levels (see Fig. 14).

6. Selected cases

We concluded, that the impact of ATOVS data on the forecast on different parameters was slightly positive or neutral in general. In the following, we chose certain cases within the studied period to compare the runs with and without ATOVS data with a special attention on the forecast of precipitation. Exploring the reasons of the negative impact on the forecast of humidity it was ascertained, that in some cases no ATOVS data was available at all (e.g. 24 February, see Fig. 15), or the negative impact was characteristic for territories located rather far from the satellite pass (e.g. 28 February, see later). It indicates, that the negative impact may refer to the absence of ATOVS data, so that the ATOVS data did not have the possibility to correct the "bad quality" first-guess fields.

We examined what differences we receive in the spatial distribution of cumulative precipitation depending on the use (here we mean inclusion or exclusion) of the ATOVS data in the 3d-var runs. The results of this study are given in Figs 16-21.

Figures 16 and 17 show that from the synoptical point of view, there is no big differences between the maps created from results of the runs with (below) and without (above) ATOVS data. The objective verification, however, showed a positive impact (Fig. 15) of ATOVS data on humidity fields on this particular day (2 March).

Figures 18 and 19 show differences in cumulative precipitation between the runs with (below) and without (above) ATOVS data at the Eastern cost of Poland and Western part of Bielorussia. According to the real situation, presented in Fig. 19, there was some precipitation over the mentioned area. One can see that the run with ATOVS data could slightly better describe this situation (4 March).

In Figs 18 and 21 we examined a situation, when ATOVS data were available over a very small part of the ALADIN/HU domain. Analysing the 24 hour cumulative precipitation, one can say that the run with ATOVS data gave poorer results than the run without ATOVS data for cases, when the rainy territories (West-Southwest) were located far away from the satellite pass (East). Moreover, in Fig. 15 (see the 24 h forecast on Feb. 28 as an example), one can see that the impact of ATOVS data was slightly negative.

Detailed analyses of the above mentioned cases provide important additional information for the impact study compared to statistical evaluation. Thus, the indices of the objective verification sometimes might be not enough for thorough assessment of the impact of satellite data on analysis and forecast.

7. Summary, further suggestions and experiments

- The assimilation of the ATOVS data into the limited-area model ALADIN/HU gave neutral impact in general (the positive and negative impacts were slight).
- Because of the problems related to humidity, it is recommended to assimilate the humidity data in univariate form. (It would be expedient to change the assimilation of humidity from multivariate to univariate in the version of 3d-var running actually in parallel suite in Budapest.)
- The impact of the ATOVS data on the forecast of temperature was slightly negative in the lower levels. To avoid so, it is recommended to investigate the use of channels sensitive to the lower atmospheric layers (levels 5, 6 and 7), before performing any further experiments.
- Since the impact of ATOVS data with finer (80 km) resolution was somewhat "better", than that of 120 km resolution data, it is recommended to further perform the assimilation of ATOVS data at finer resolution.
- Further experiments should be done to clarify, what kind of expectations we can have in respect of assimilation of ATOVS data.
- It would be necessary to perform similar experiments for other periods as well.
- We suggest to perform further experiments to study the changes in the impact of ATOVS data on the forecast in extreme weather conditions.

Summing up, we can state that at the present stage no definite positive impact of ATOVS data on the forecast can be proved in the 3d-var data assimilation system of the ALADIN model, so it is necessary to continue the experiments.

References

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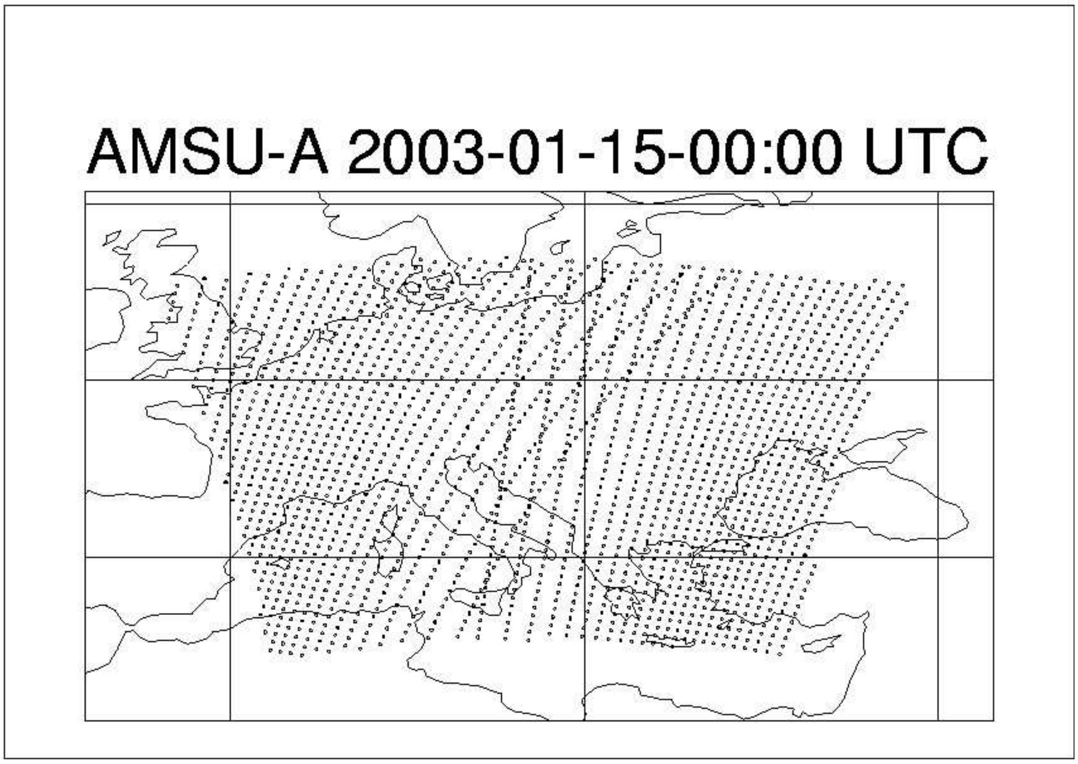
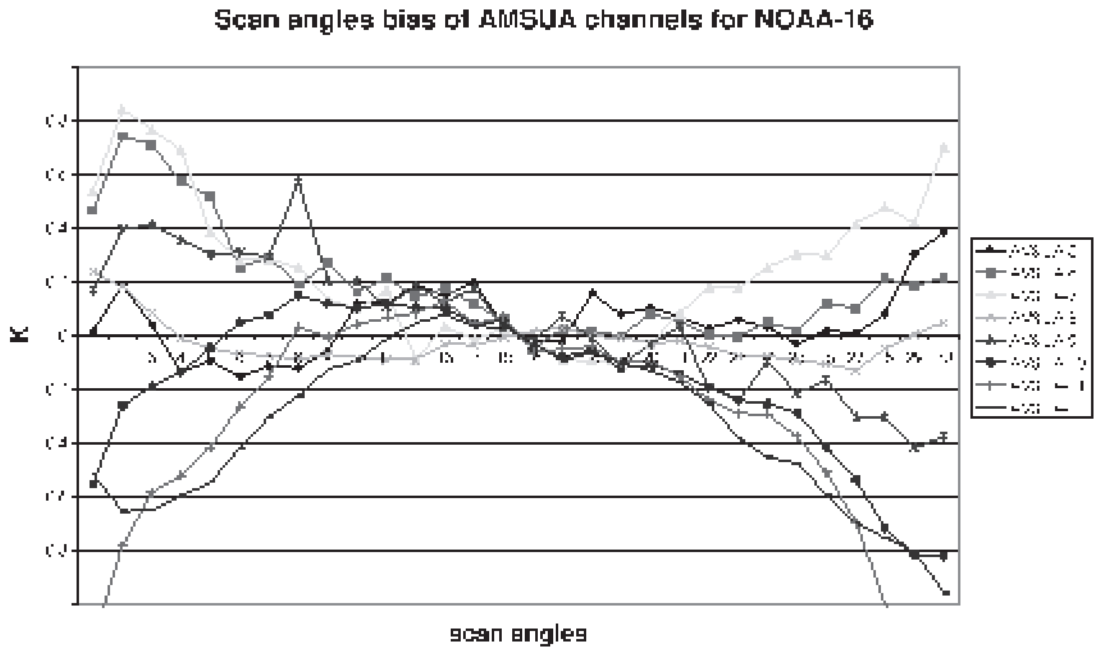


Figure 1 : Satellite data over the ALADIN/HU domain (C+I zone).



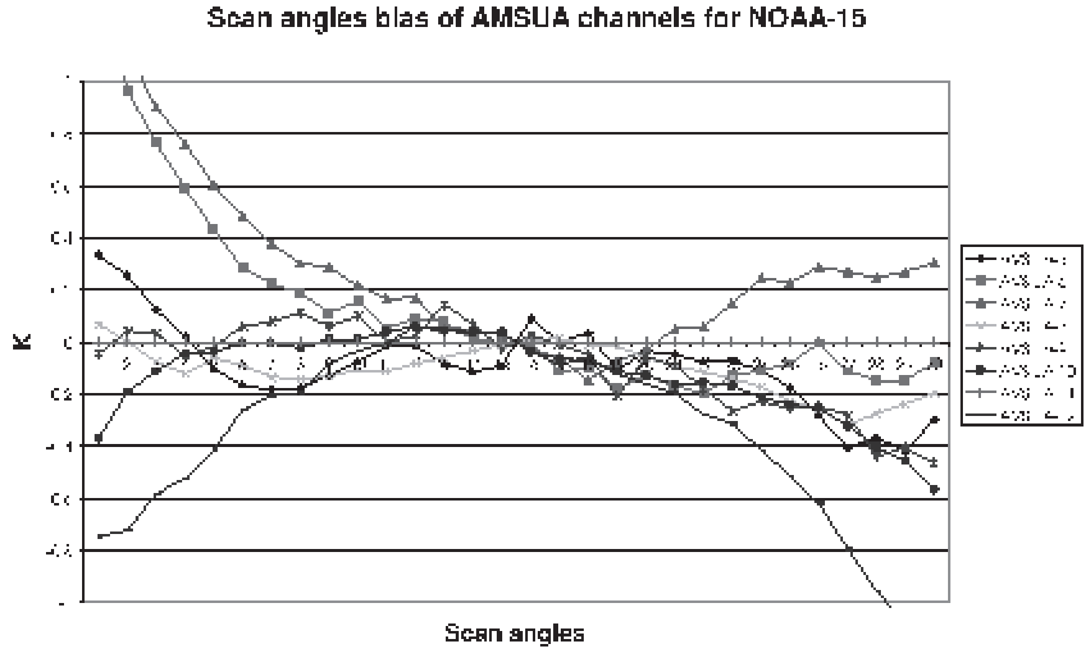


Figure 2 : Bias (in Kelvin degree) specific to the scan angles varies with latitude band. In these figures biases were computed for the same latitude band.

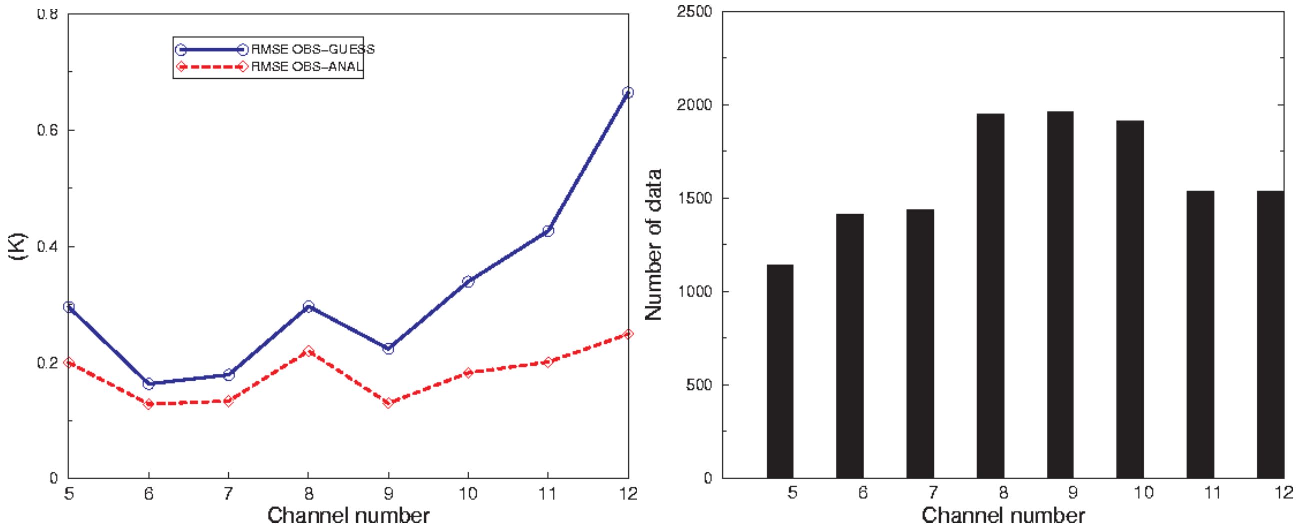


Figure 3 : Example of statistics of observation minus guess (solid line) and observation minus analysis (dashed line) for AMSU-A at 00 UTC for a five days cycling (from 2003.02.20 to 2003.0225) (left hand side). On the right one can find the number of data used in the computation of the statistics. The impact of AMSU-A is larger at higher layers of the atmosphere (channels 9-12

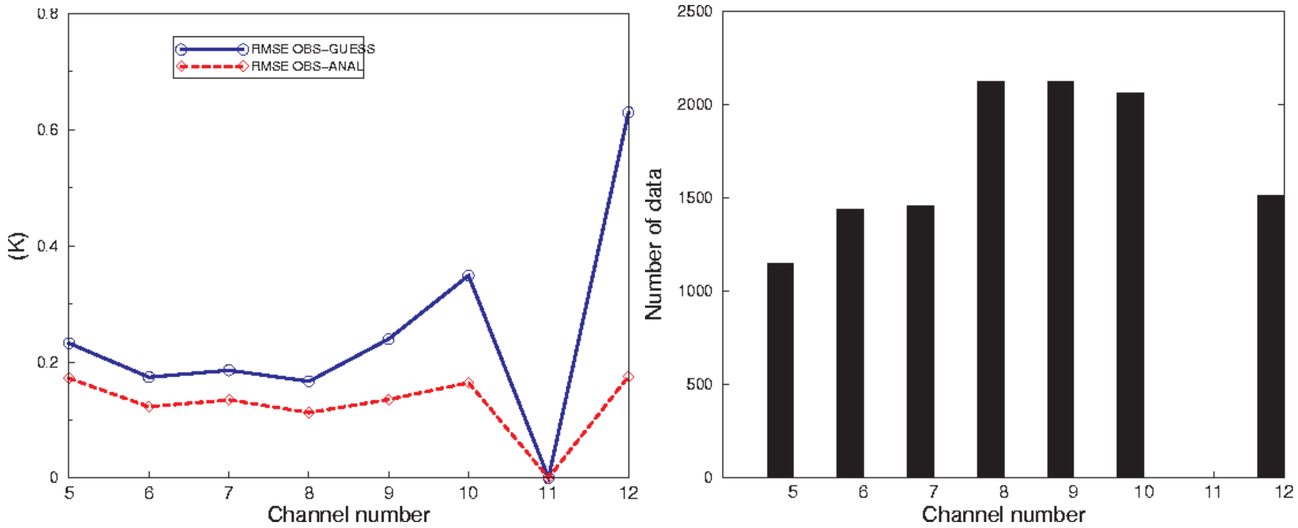


Figure 4 : Example of statistics of observation minus guess (solid line) and observation minus analysis (dashed line) for AMSU-A at 06 UTC for a five days cycling (from 2003.02.20 to 2003.0225) (left hand side). On the right one can find the number of data used in the computation of the statistics. Note, that around 06 UTC we receive data from NOAA-15, which has problem with AMSU-A channel 11. The impact of AMSU-A is larger at higher layers of the atmosphere (channels 9-12).

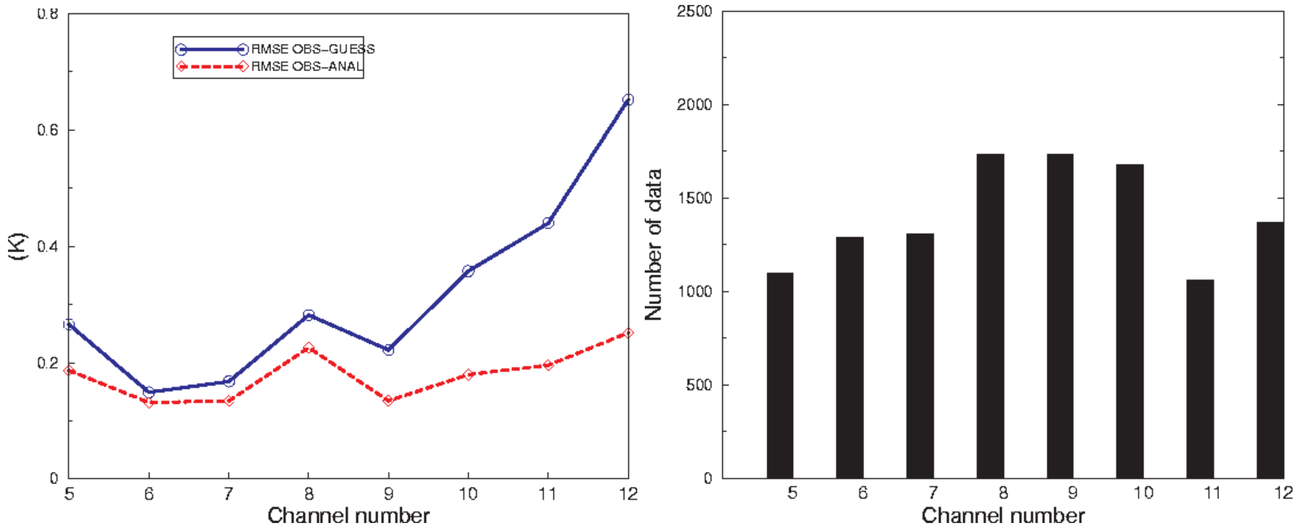


Figure 5 : Example of statistics of observation minus guess (solid line) and observation minus analysis (dashed line) for AMSU-A at 12 UTC for a five days cycling (from 2003.02.20 to 2003.0225) (left hand side). On the right one can find the number of data used in the computation of the statistics. The impact of AMSU-A is larger at higher layers of the atmosphere (channels 9-12).

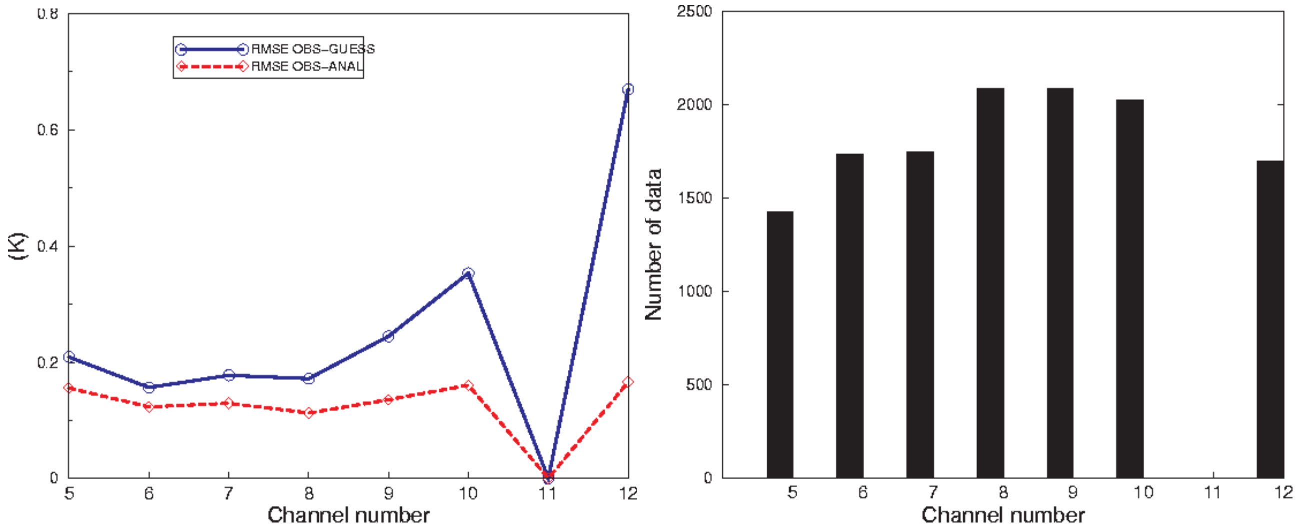


Figure 6 : Example of the statistics of the observation minus guess (solid line) and the observation minus analysis (dashed line) for AMSU-A at 18 UTC(left hand side). On the right one can find the number of data used in the computation of the statistics. Note, that around 18 UTC we receive data from NOAA-15, which has problem with AMSU-A channel 11. The impact of AMSU-A is larger at higher layers of the atmosphere (channels 9-12).