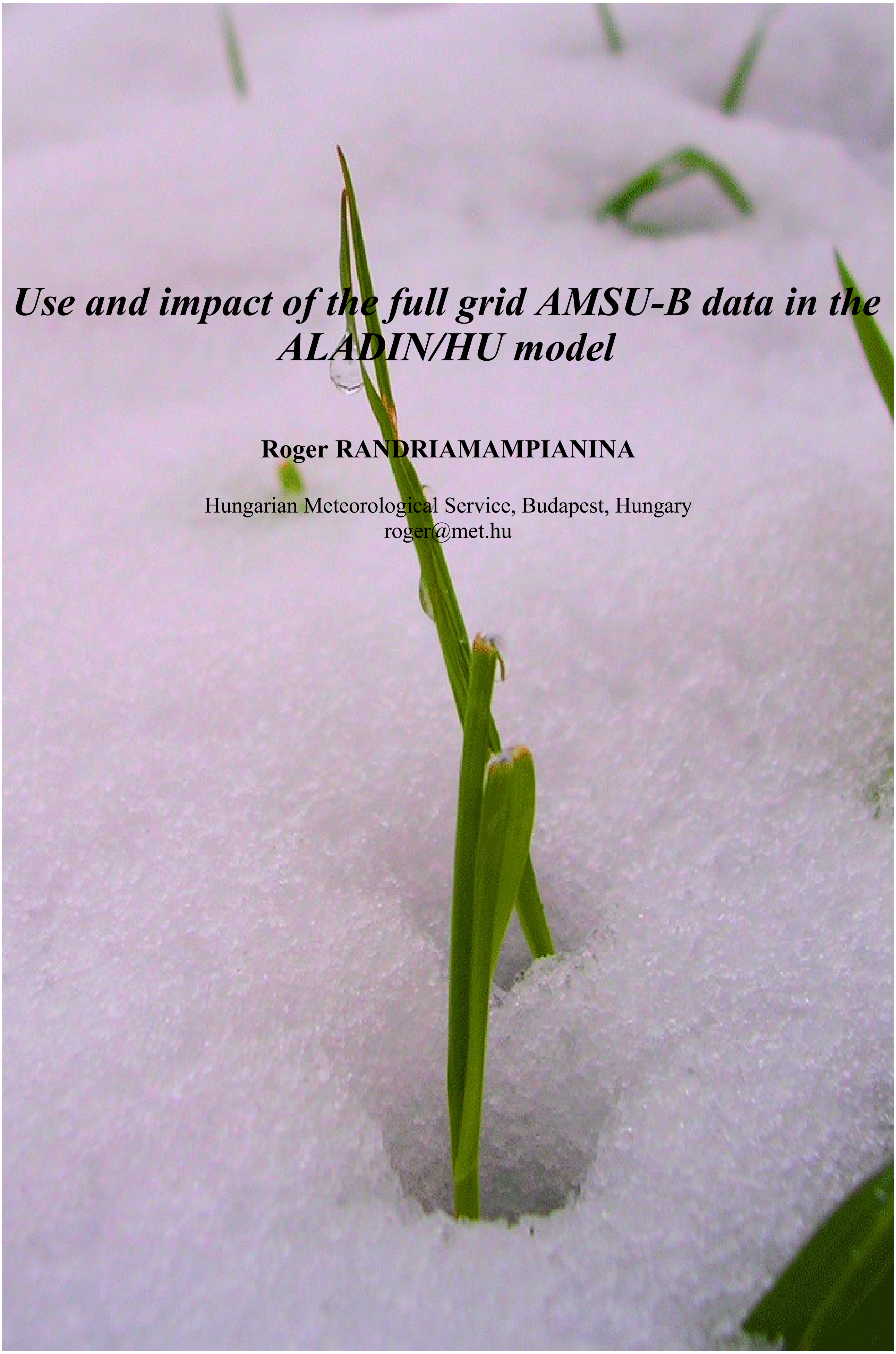

Use and impact of the full grid AMSU-B data in the ALADIN/HU model

Roger RANDRIAMAMPIANINA

Hungarian Meteorological Service, Budapest, Hungary
roger@met.hu

1 Abstract

In the frame of the continuous development of the ALADIN 3D-Var system at the Hungarian Meteorological Service (HMS) our aim is to use as many observations and in as fine resolution as possible. The AMSU-A data are already implemented in the data assimilation system of the limited area model ALADIN Hungary (ALADIN/HU) and used operationally. Our recent work consists of studying the impact of E-AMDAR, atmospheric motion vectors (AMV) and full grid AMSU-B data on the model analysis and short-range forecasts. We use the locally received ATOVS data as well as the ones pre-processed at EUMETSAT and transmitted through the EUMETCast broadcasting system. In this paper we discuss the implementation and the impact of AMSU-B data assimilated in full grid – one-by-one field of view (FOV) – on the ALADIN/HU model. Update of the model and the bias correction programme was necessary to handle all the 90 scan angles instead of the 30 used in the default ARPEGE/ALADIN code. We observed positive impact of the AMSU-B data on the analysis and short-range forecasts of temperature near the surface, and on short-range forecasts of the temperature and humidity in the lower troposphere. Use of the AMSU-B data improves the short-range forecasts of the precipitation.

2 Introduction

In most numerical weather prediction (NWP) centres satellite data are assimilated in the form of raw radiances. The positive impact of the AMSU-B data on the global models has been proved by different studies (*English et al.*, 2003; *Chouinard* and *Hallé* (2003); *Gérard et al.*, 2003). However, the AMSU-B data are not used in their full resolution (not all FOV) in the three- and four-dimensional variational (3D- or 4D-Var) global assimilation system due to the model resolution.

Many investigations have been performed to evaluate the impact of the AMSU-B data in a limited area model (*Jones et al.*, 2002; *Candy* (2005)). These studies showed positive impact on the analysis of moisture and short-range forecast of precipitation. Our goal was to improve our short-range forecast of precipitation, assimilating the AMSU-B data in as fine resolution as possible. Thus, different resolution of the AMSU-B (3x3 and 1x1 FOV) data were investigated using the 3D-Var ALADIN/HU, testing different thinning distances in the assimilation process.

This paper investigates the impact of AMSU-B data assimilated in different thinning distances (60-km, 80-km and 120-km) in order find the best improvement in the analysis and short-range forecasts.

Section 2 describes the main characteristics of the ALADIN/HU model and its assimilation system. Section 2.1 illustrates the local pre-processing of satellite data, section 2.2 illustrates briefly the use of different AMSU-B channels in our analysis system, while section 2.3 provides a short description of the bias correction method, used in ALADIN/HU. Section 3. presents the results of the investigation of full grid AMSU-B data, and in section 4. we draw some conclusions and discuss further developments.

3 The ALADIN/HU model and its assimilation system

At the Hungarian Meteorological Service (HMS) the ALADIN/HU model runs in its hydrostatic version. In this study the cycle Cy28t3 of the ARPEGE/ALADIN codes (see Table 1) was used in 12-km horizontal resolution and with 37 vertical levels from the surface up to 5 hPa height. The 3D-Var system was applied to assimilate both conventional – surface (SYNOP), radisonde (TEMP) and aircraft (AMDAR) – and satellite (ATOVS) observations. As the variational technique computes the observational part of the cost function in the observational space, it was necessary to simulate radiances from the model parameters. In the ARPEGE/ALADIN we use the RTTOV (see table 1) radiative transfer code to perform this transformation (*Saunders et al.*, 1998). In the RTTOV we have 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. A good estimation of the background error covariance matrix is also essential for the variational technique to be successful. The background error covariance - the so-called "B" matrix – was computed using the standard NMC method (*Parrish and Derber,* 1992; *Berre* (2000); *Široká et al.,* 2003). The 3D-Var is running in 6-hour assimilation cycle generating an analysis at 00, 06, 12 and 18 UTC. In this study, we performed a 48-hour forecast once a day (see Table 1).

Table 1: The ALADIN/HU 3D-Var applied in the study

Model	- Hydrostatic version - Horizontal res.: 12km - 37 vertical levels	al28/cy28t3
3D-Var	- Cov. Matrix B: std NMC - 6 hour assim. cycling - RTM model: RTTOV - Coupling files: ARPEGE long cut-off files - Satellite observations: - Selected channels: - Humidity assimilation	 RTTOV-7 Coupling: every 3h NOAA-15,16&17 AMSU-A&B AMSU-A(5-12), AMSU-B(3-5) multivariate
Surface	- Surface analysis	No, interpolation of ARPEGE surface fields to ALADIN grid
Forecast:	- 48 hour	From 12 UTC

3.1 Pre-processing of satellite data

The ATOVS data are received through our HRPT antenna and pre-processed with the AAPP (ATOVS and AVHRR Pre-processing Package) software package. We used AMSU-A, level 1-C radiances in our study.

For technical reasons our antenna is able to receive data only from two different satellites. To acquire the maximum amount of satellite observations, the NOAA-15 and the NOAA-16 satellites were chosen, that have orbits perpendicular to each other and pass over the ALADIN/HU domain at about 06 and 18 UTC and 00 and 12 UTC, respectively. In addition to our local reception, data retransmitted trough the EUMETCast broadcasting system that contain data measured by NOAA-17 were also investigated.

For each assimilation time we used the satellite observations that were measured within ±3 hours. The number of paths over the ALADIN/HU domain within this 6-hour interval varies up to three.

3.2 Use of the AMSU-B channels

In the ARPEGE/ALADIN (*cy28t3*) model AMSU-B channels 3, 4 and 5 are used. From both sides of scanning edges, nine pixels were removed to avoid big biases. Over land only channels 4 and 5 are used with some restrictions related to the model orography. They are used when the model orography is less than 1500 m and 1000 m, respectively. All the above-mentioned three channels are used over sea. The following restrictions are applied to blacklist all channels: 1- where the surface temperature is less than 278 K; 2- where the absolute value of the first-guess departure (observation-minus-background) of the channel 2 is less than 5 K.

3.3 Bias correction

The direct assimilation of satellite measurements requires the correction of biases computed as the difference between the observed radiances and those simulated from the model first guess. These biases arising mainly from instrument characteristics or inaccuracies in the radiative transfer model can be significant. The method developed by *Harris and Kelly* (2001) was used to remove this systematic error. This scheme is based on separation of the biases into scan-angle dependent and state dependent components. The air-mass dependent bias is expressed as a linear combination of set of state-dependent predictors.

In the experiments, four predictors computed from the first-guess fields were selected (p1 - the 1000-300hPa thickness, p2 - the 200-50hPa thickness, p3 - the skin temperature and p4 - the total column water) for the AMSU-A data.

A carefully selected sample of background departures for the AMSU-A and channel set was used to estimate the bias, in a two-step procedure. First, scan bias coefficients were computed by separating the scan-position dependent component of the mean departures in the latitude bands. Secondly, after removing the scan bias from the departures, the predictor coefficients for the state-dependent component of the bias were obtained by linear regression. At the end of this estimation procedure, bias coefficients for the AMSU-A were stored in a file. The data assimilation system could then access the coefficients in order to compute bias corrections for the latest observations, using update state information for evaluating the air-mass dependent component of the bias. The brightness temperatures were corrected accordingly, just prior to assimilation. In the ALADIN/HU assimilation system the bias correction file computed by the LAM model is used (*Randriamampianina,* 2005).

As in the cy28t3 of the ARPEGE/ALADIN codes, the default maximum number for the scan angle is 30. The model and the bias correction programme were updated to handle the 90 scan angles of the full-grid AMSU-B.

3.4 Description of the experiments

The aim of this investigation was to exploit the AMSU-B data in as fine resolution as possible. From technical point of view the use of these data in 3x3 FOV resolution (same resolution as the AMSU-A data) is the simplest way. This run was compared to the ones with AMSU-B data assimilated in full grid as follows:

NAMV- using surface, radiosonde, aircraft (AMDAR) and satellite (AMSU-A) observations (control observations) in assimilation. This was the control run.

SBX3- using control observations and AMSU-B data reduced in 3x3 FOV, thinned in 80km resolution in the assimilation.

SFB8- using control observations and AMSU-B data in full grid (1x1 FOV), thinned in 80km resolution in the assimilation.

SFB6- using control observations and AMSU-B data in full grid, thinned in 60km resolution in the assimilation.

SFB1- using control observations and AMSU-B data in full grid, thinned in 120km resolution in the assimilation.

A two-week period (07.02.2005-21.02.2005) was chosen to evaluate the impact of different settings of the AMSU-B data in the assimilation system. The scores of each run were evaluated objectively. The bias and root-mean-square error (RMSE) were computed from the differences between the analysis/forecasts and observations (surface and radiosondes). The accumulated amount of precipitation was also compared to the one computed from the surface measurement for a few interesting situations within the period of study.

4 Results and discussion

The impact of the AMSU-B data was estimated comparing the runs with and without the assimilation of these data. The performance of the different settings in the assimilation of the AMSU-B data was evaluated comparing the scores of the runs to each other. The main results are classified as follows:

4.1 Influence of the assimilation of AMSU-B data on temperature and humidity bias

The use of the AMSU-B in the assimilation process caused a weak heating and cooling effect in the troposphere and around the tropopause, respectively (Fig. 1) and resulted in more moist conditions in the troposphere in the analysis and forecast. As it was found during the everyday subjective verification, the forecasts issued from the 3D-Var cycles were more “dry” than those of the spin-up model (or dynamical adaptation). This “drying” effect of the 3D-Var resulted in overestimated temperature and worsened forecast in certain cases. In such situations the “wetting” effect of the AMSU-B data could increase the forecast accuracy. On the other hand, the only humidity observation we had and used was that from radiosonde measurements.

4.2 Impact of AMSU-B data on the analysis and short-range forecasts

As discussed above, the systematic addition of moisture in the model leaded to a positive impact not only on the temperature analysis and forecast - except for the 6-hour forecast where remarkable difference in the RMSE could be observed (Fig. 2) - but also on the forecast of relative humidity. Figure 3 shows clear positive impact on the 48-hour forecast of the relative humidity.

The impact on the analysis and forecasts of geopotential, wind speed and wind direction was found to be neutral (not shown).

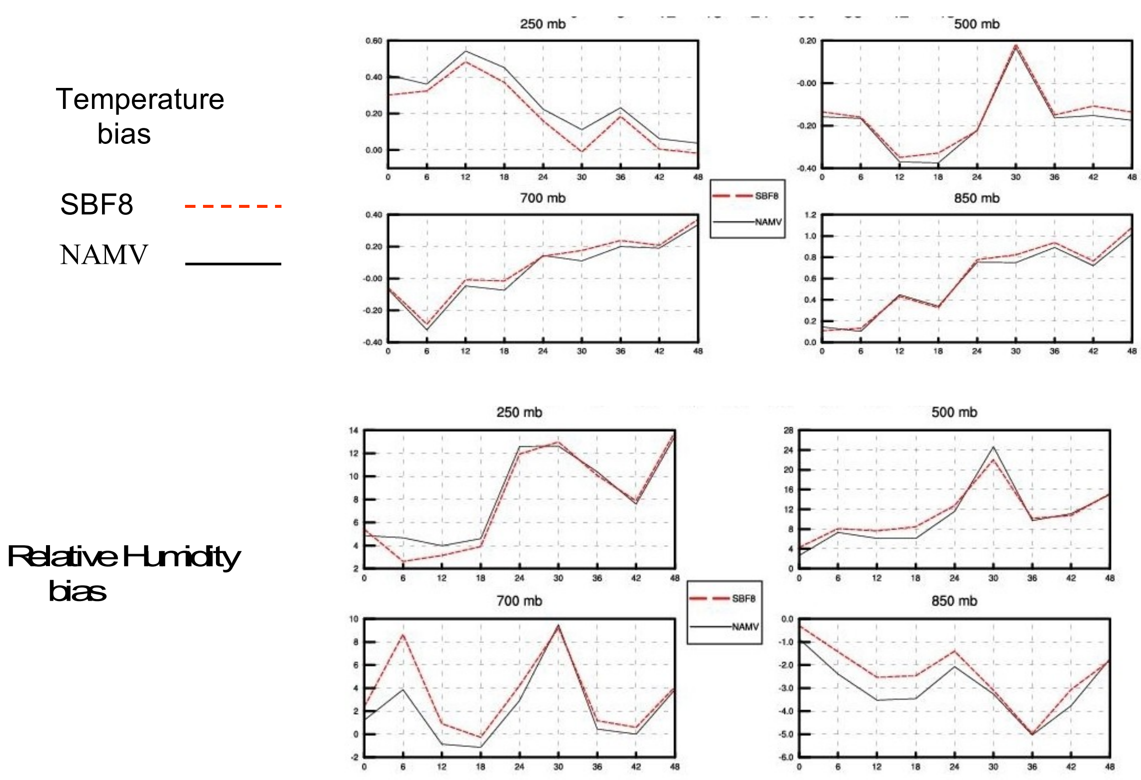

Figure 1. Temperature and relative humidity biases for the runs with (SBF8: dashed line) and without (NAMV: solid line) AMSU-B data at the analysis (0) and subsequent forecast times.

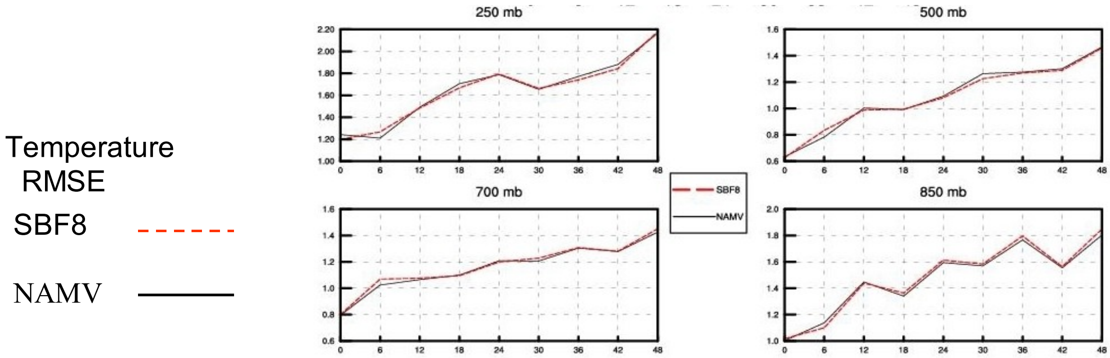

Figure 2. Root-mean-square error (RMSE) of temperature for the runs with (SBF8: dashed line) and without (NAMV: solid line) AMSU-B data at the analysis (0) and subsequent forecast times.

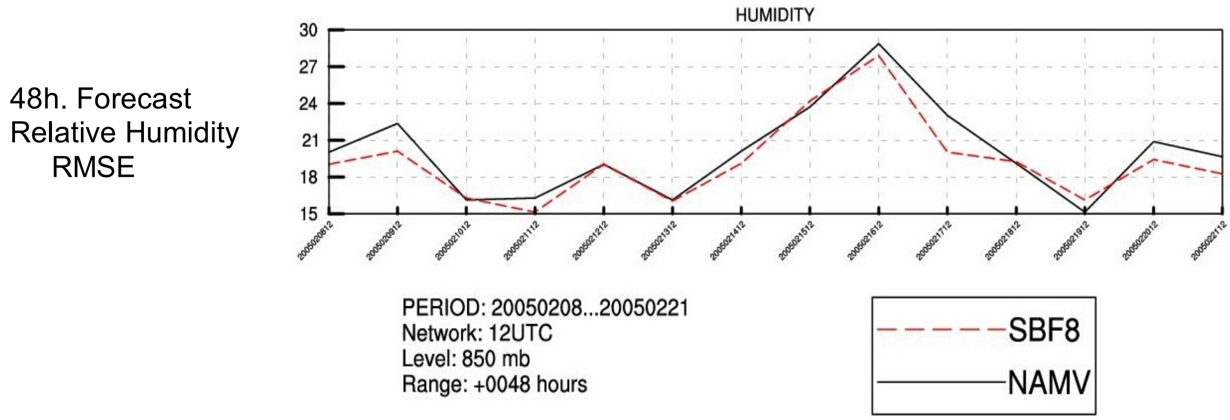

Figure 3. RMSE for the 48-hour forecast of relative humidity for the runs with (SFB8) and without (NAMV) assimilation of AMSU-B data.

4.3 Evaluation of the different usage of the AMSU-B data

To find the best usage of the AMSU-B in the assimilation system, four settings were compared: three runs with full grid using different thinning distances (SFB8: 80 km, SFB6: 60 km and SBF1: 120 km) in the assimilation system, and one run with reduced (3x3 FOV) number of observations (SBX3, thinning distance: 80 km). Using full grid AMSU-B data in 80 km resolution (run SBF8) improved the forecast of all the parameters (see Fig. 4). Nevertheless, we have to mention that SBF8 provides less accurate 6-hour forecasts of temperature than SBF6, SBF1 or SBX3. Comparing the scores of individual daily 6-hour forecasts, it was found that experiments with full grid AMSU-B “failed” to predict (on the 6-hour forecast, valid for 18UTC 18 February 2005) the presence of a low-pressure region over the Southern part of Italy, causing large bias in the forecast of geopotential and temperature (not shown).

48h. Forecast
Relative Humidity
RMSE

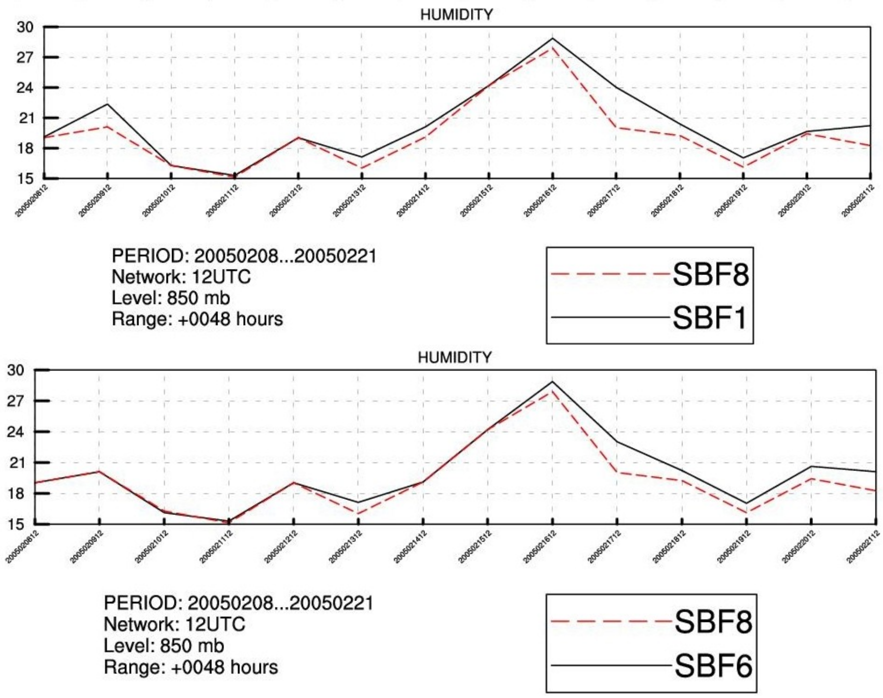

Figure 4. RMSE for relative humidity of individual runs

4.4 Comparison of 6-hour cumulative precipitation forecasts

Figure 5. shows the observed and predicted cumulative precipitation for the territory of Hungary. All the runs (with and without AMSU-B data) gave quite good prediction of the rainfalls observed in the Western part of the country. The precipitation patterns in the Eastern part, however, were only predicted by runs that used the AMSU-B data in full grid.

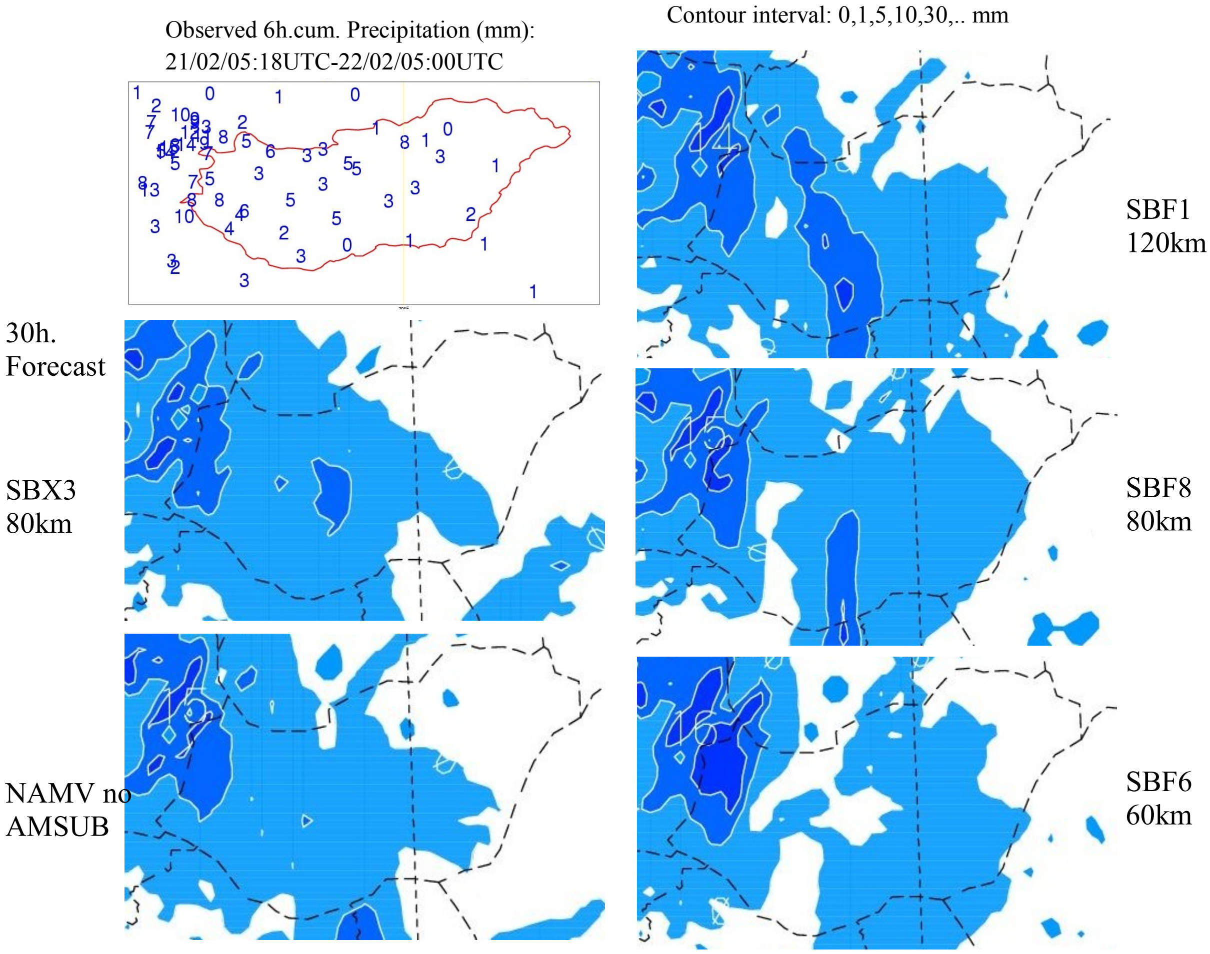

Figure 5. Rainfall observations (top, upper left) compared to the predictions of 6-hour (f30-f24) accumulated precipitation amount valid for 00 UTC 22nd Feb. 2005.

4.5 Subjective and objective scores evaluated during the use of the AMSU-B in parallel suite

The performance of the main models used by the forecasters are evaluated subjectively everyday. See Tóth (2004) for more details about the subjective verification system at the HMS. It concerns mainly the ECMWF products and three versions of the ALADIN/HU model: 1- the operational one (OPER or HUN2), that actually uses a 3D-Var system assimilating the surface, the radiosonde and the aircraft measurements and the ATOVS AMSU-A radiances to create the initial condition for the forecast model; 2- the one that uses the ARPEGE analysis as initial condition (the so-called dynamical adaptation) and 3- a system that is being tested, which uses the 3D-Var analysis system that also incorporates the full-grid AMSU-B data to create the initial condition (TEST2). Figure 6. shows the subjective scores for the forecasts of precipitation up to 24-hours (the first day and 24-hours cumulated precipitation), where one can see that the dashed line one time below and three times above the solid line. This means one day with worse forecast against three days with improved forecasts of the first two-week of November 2005. Note, that in the subjective verification 10 means perfect and 0 means very bad forecast, and that only a small domain occupying approximately the Hungarian territory and the close surrounding region is evaluated. According to the objective verification, performed for the whole ALADIN/HU domain, a positive impact was observed for the period from 2nd of November to 19th of November 2005 (Fig. 7) when comparing the 24-hour forecast of precipitation with the surface gauges data. Small but significant impact on the analysis and all the forecasts ranges of temperature at 1000 hPa is shown in Figure 8.

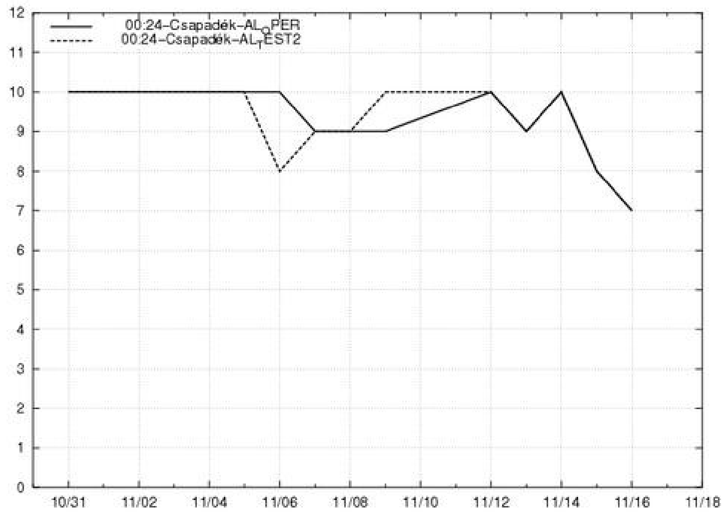

Figure 6. Subjective scores for the 24-hour cumulated precipitation of the run in parallel suite, using AMSU-B data (dashed line), and the operational run (solid line). Comparison valid for the Hungarian territory and the close surrounding regions. Forecast from 00 UTC network

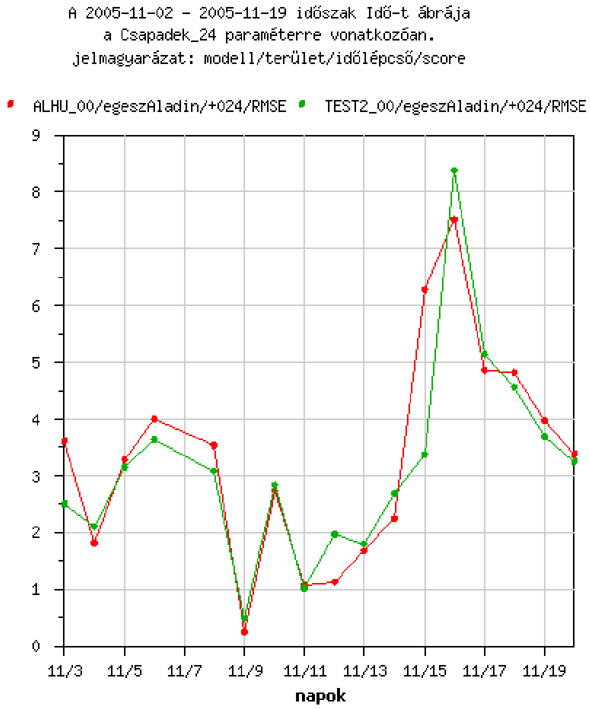

Figure 7. Objective scores for the 24-hour cumulated precipitation of the run in parallel suite, using AMSU-B data (green line), and the operational run (red line). Comparison valid for the whole ALADIN/HU domain. Forecast from 00 UTC network

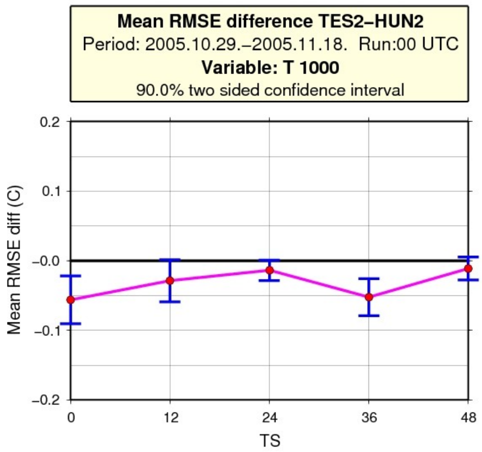

Figure 8. Significance test of the impact of the AMSU-B data on the temperature at 1000 hPa height. A small but significant reduction in RMSE values of the analysis and at all forecast ranges can be observed

5 Conclusion and future plans

Our experiments showed that the resolution of the input AMSU-B data is important for their better use in a LAM. It is preferable to assimilate the AMSU-B data in full grid.

We found that the "optimal thinning distance" for our system is 80 km.

The impact of the AMSU-B data on the analysis and short-range forecast of temperature, geopotential and wind fields was found to be rather slightly positive than neutral during the testing period. Positive impact on the forecast of relative humidity was observed. The use of the AMSU-B improves the forecast of precipitation. Clear positive impact of the AMSU-B data on the temperature was observed in the lower model levels during their use in the parallel suite.

The AMSU-B data are in operation since the end of January 2006.

The AMSU-B data slightly increased the bias of the relative humidity in the middle troposphere (Fig. 1). One of the important issues in the near future is to update the bias handling procedure in the LAM system. We plan to implement the SEVIRI clear sky radiances in our system.

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CONTENTS