INVESTIGATION OF THE AMV DATA DERIVED FROM METEOSAT-8 IN THE ALADIN/HU ASSIMILATION SYSTEM

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ABSTRACT

The work on Atmospheric Motion Vectors (AMV) at the Hungarian Meteorological Service (HMS) started with the qualitative evaluation of the retrieved wind vectors according to the quality indicator (QI) found in the BUFR file. This consisted of the computation of statistics for the observation departure (obs-guess) and for the analysis increment (obs-analysis) from a few days objective analysis. The default configuration in the ARPEGE/ALADIN model on the use of AMV data is that these data are not used over land for regions having latitude greater than 30 degrees. We found that the higher the quality indicator, the better the fit to the observation in the “obs-guess” and “obs-analysis” statistics. An other objective of our study was to investigate the use of AMV data over land. Our preliminary results showed that data over land seems to have similar quality as those over sea. After a detailed study of the quality of the retrieved wind vectors, a test run was performed with the default configuration. The results showed positive impact of AMV data, mainly, on the analysis. The evaluation of thresholds used in the quality control for the AMV data showed that the same quality of the observation departure can be kept using data having quality indicator (QI) more than 80% instead of the default value (85%). The three performed additional runs showed neutral impact over the whole ALADIN/HU domain, but positive impact was observed when zooming into our “target areas” (Carpathian basin and Hungary). Moreover, we observed clear positive impact of the AMV data on the forecasts of precipitation. The obtained results were supported by case studies.

INTRODUCTION

The local development of the three-dimensional variational (3D-Var) analysis system in Hungary started in 2000, when the system was implemented. It included the radiosonde (TEMP) and the surface (SYNOP) observations only. At that time the French global model (ARPEGE) analyses were used as initial conditions for the operational ALADIN forecasting system. Our goal at the HMS is to improve our analysis and short-range forecasts using all the available local data in the optimal way (using highest resolution possible). The first observations investigated in our analysis system were the ATOVS radiances (Randriamampianina et al., 2006) and the aircraft data (Randriamampianina et al., 2005). The 3D-Var ALADIN/HU analysis system became operational in May 2005. Due to their temporal and spatial resolutions, data from the geostationary satellites – like the AMV data - can be very useful for regional and mesoscale models. The investigation of the AMV data at the HMS started in 2005.

Payan and Rabier, 2004 investigated the use of the quality indicators (QI) of the AMV data in the ARPEGE/ALADIN assimilation system. Their studies were done with the global model, so the use of the adopted quality control in a limited area model requires additional investigation. The AMV data used in our study were those transmitted trough the EUMETCast broadcasting system in BUFR format.

THE ALADIN/HU MODEL AND THE ASSIMILATION SYSTEM USED IN THE STUDY

At the HMS, the ALADIN/HU model runs in its hydrostatic version. In this study, the 3D-Var system was applied to assimilate both conventional (surface, radiosonde, aircraft and AMV) and satellite (ATOVS) observations. As a consequence of the direct radiance assimilation, it is necessary to simulate radiances from the model parameters. The RTTOV radiative transfer code, which has 43 vertical levels, was used to perform this transformation in the ARPEGE/ALADIN models. 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. The background error covariance matrix is computed using the standard NMC method (*Berre* (2000); *Široká et al.,* 2003). No surface analysis was applied. The analysed surface fields from the global

ARPEGE model are interpolated into the ALADIN grid. The 3D-Var is running in 6-hour assimilation cycle generating an analysis at 00, 06, 12 and 18 UTC. In this study, a 48-hour forecast was performed twice a day from 00 and 12 UTC. The domain of the ALADIN/HU comprises part of western and eastern Europe as well as part of the Mediterranean sea (Fig. 1).

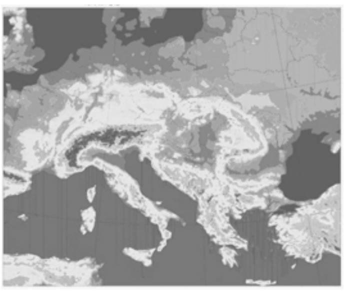
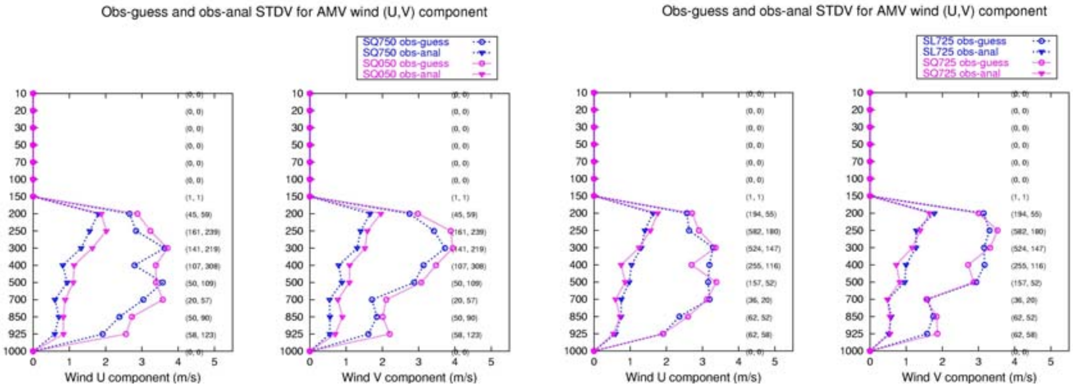


***Figure 1*: The domain of the ALADIN/HU limited area model**

THE QUALITY OF THE AMV DATA

First of all, we were interested on the quality of the QI found in the BUFR data. By this, we mean the relation between the QI, the retrieved winds and our assimilation system. For this purpose we performed a few days objective analysis, using observation with different QI in the assimilation process. The following settings were investigated: (1) all data with QI more than 30% assimilated over sea in thinning 50 km resolution, (2) all data with QI more than 70% assimilated over sea in 50 km thinning resolution, (3) all data with QI more than 70% and assimilated over sea in 25 km thinning resolution and (4) all data with QI more than 70% and assimilated also over land in 25 km thinning resolution. Comparing (1) with (2), one can see the “sensitivity” of the analysis system to the quality of the AMV data. Figure 2/a shows the observation departure and the analysis increment values for the settings (1 – SQ050) and (2 – SQ750). The results indicate that the higher the QI the smaller the standard deviation of both the mentioned values. Consequently, higher QI correspond to better quality of the retrieved winds. Comparing (3 – SQ725) and (4 – SL725), we evaluate the quality of the data retrieved over land with those retrieved over sea. The statistics related to the use of data retrieved over sea and the addition of data over land are very similar (Fig. 2/b).



(a) **(b)**

***Figure 2:* The statistics (standard deviation) of the observation departure (obs-guess) (circles) and the analysis increment (obs-analysis) (triangles) when using data with QI more than 30% (pink or light dark – SQ050) and data with QI more than 70% (blue or dark – SQ750) (a); and when using data over sea only (pink or light dark – SQ725) and the addition of data over land also (blue or dark – SL725) (b).**

Figure 3 shows the observation departure as a function of the QIs for the wind V component derived from cloudy water vapour channels. One can see that changing the default threshold (85%) to 80%, the same quality of the analysis can be guaranteed. Better statistics were found when analysing the winds derived from infrared and visible channels (not shown).

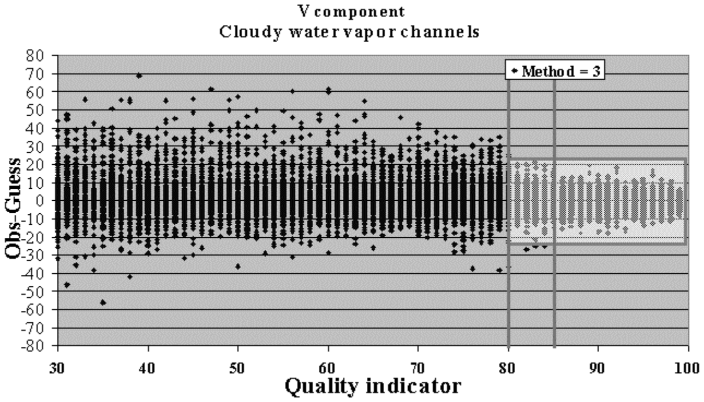


Figure 3: **The distribution of obs-guess as a function of the quality indicators (QI) for winds derived from cloudy water-vapour channels.**

IMPACT OF THE AMV DATA ON THE ANALYSIS AND SHORT-RANGE FORECASTS

Considering that the ALADIN/HU domain covers more land than sea, and the default threshold value of the QI for the quality control of the AMV data in the ARPEGE/ALADIN analysis system is 85%, we decided to study three configurations for the use of the AMV data. The following settings were investigated, dividing the atmosphere into three layers (Table1.a/b/c):

a)	**used over sea only**		
WDEF	P>800hPa	800-350hPa	P<350hPa
HRV	QI>85%	not used	not used
IR	QI>85%	not used	QI>85%
CWV	QI>85%	not used	QI>85%

b)	**used over sea only**		
W80P	P>800hPa	800-350hPa	P<350hPa
HRV	QI>80%	not used	not used
IR	QI>80%	not used	QI>80%
CWV	QI>80%	not used	QI>80%

c)	**used over land also**		
WLAN	P>800hPa	800-350hPa	P<350hPa
HRV	QI>85%	not used	not used
IR	QI>85%	not used	QI>85%
CWV	QI>85%	not used	QI>85%

Table 1. **Description of the configurations on the use of the AMV data in the impact studies**

Beyond the above mentioned configurations, we performed one additional experiment without AMV data. In this study, among the observation, the radiosonde, the surface, the aircraft and the ATOVS (AMSU-A and AMSU-B) data were used (Randriamampianina et al., 2005 and 2006). The impact of the AMV data was studied for the period from 04.12.2004 to 10.01.2005, with a five-day warm up period. Thus, the evaluation period was one month (10.12.2004 – 10.01.2005).

The bias and root-mean-square error (RMSE) were computed from the differences between the analysis/forecasts and observations (surface and radiosondes) as well as analysis/forecasts and long cut-off ARPEGE analyses. Significance tests of the objective verification scores were also performed. The significance was examined based on statistical t-test regarding the difference in the expected values of the RMSE scores of the compared experiments. Plots were provided together with error bars that represent the interval in which the RMSE difference falls with 90% confidence. Consequently we considered a difference to be significant if the corresponding error bar did not include the zero difference line. In the comparison the first model (usually the test model) was better than the second (usually the control model) one if the mean score was negative, indicating an average reduction of the error.

We can see from Fig. 3 that only a small amount of AMV data was selected, thus the relative amount of active data was smaller than those from aircraft or radiosonde observations (Fig. 4). Changing the threshold from 85% to 80% allowed to use a bit more observation, but the addition of observations over land increased the number of active data in the analysis process more than double.

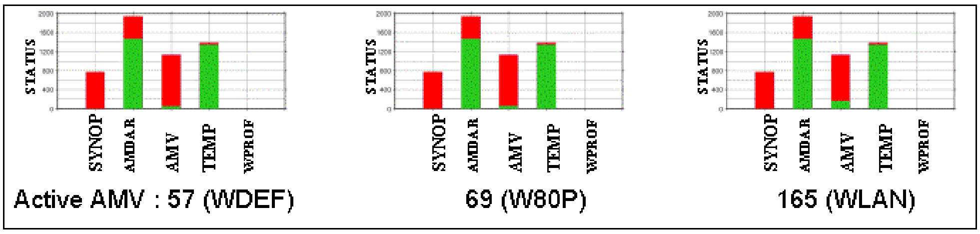


Figure 4: **Relative contribution - the relative number of active (green or light dark) and rejected (red or dark) observations - of different wind (V component) observations in the analysis.**

COMPARISON OF THE ANALYSIS AND FORECASTS AGAINST LONG CUT-OFF ARPEGE ANALYSES

The comparison of the analyses and short-range forecasts against long cut-off ARPEGE analyses showed small differences in root-mean-square errors (RMSE), when estimating the scores over the whole ALADIN/HU domain. The significance test showed small but almost significant positive impact of the AMV data on the forecast of geopotential and wind speed. Clear positive impact on the analysis and remarkable improvement in the forecasts of humidity were also observed (Fig. 5).

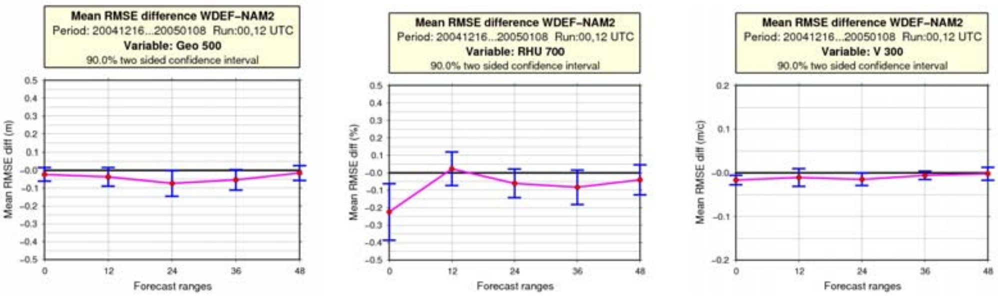


Figure 5**: Significance test: Geopotential (left), relative humidity (centre) and wind speed (right) RMSE difference. The RMSE was computed from differences against analyses. WDEF is the run with AMV using the default threshold (85%) and NAM2 is the run without AMV.**

Despite the small impact of AMV data, obtained over the whole ALADIN/HU domain, clear positive impact was found when making a zoom to our target areas (Carpathian basin and Hungary) (Fig. 6). No remarkable impact was found when changing the threshold only. But, using the AMV over land showed, however, small reduction of the RMSE of the analysis and short-range forecasts for geopotential within the target area. More sensitivity on the relative humidity was observed in the scores evaluated over the Carpathian basin (Fig. 7). Mainly, the significance test of scores evaluated over target areas showed larger and more significant impact.

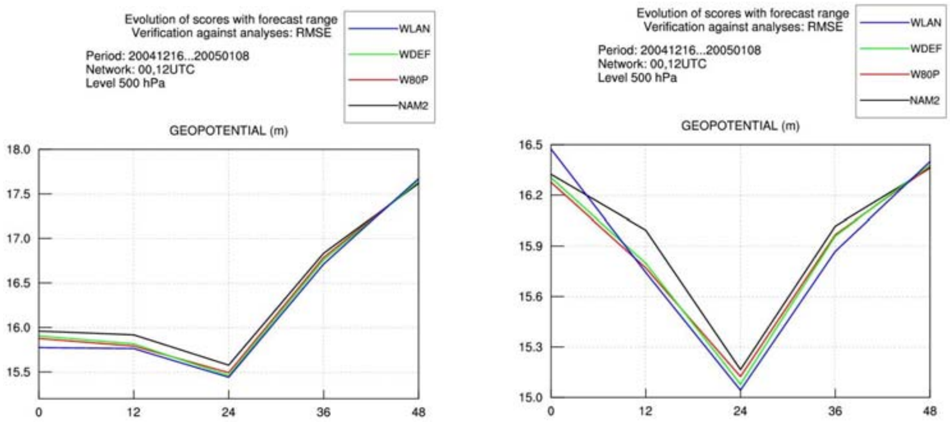


Figure 6**: RMSE for different runs evaluated over the Carpathian basin (left) and Hungary (right). The RMSE was computed from differences against analyses.**

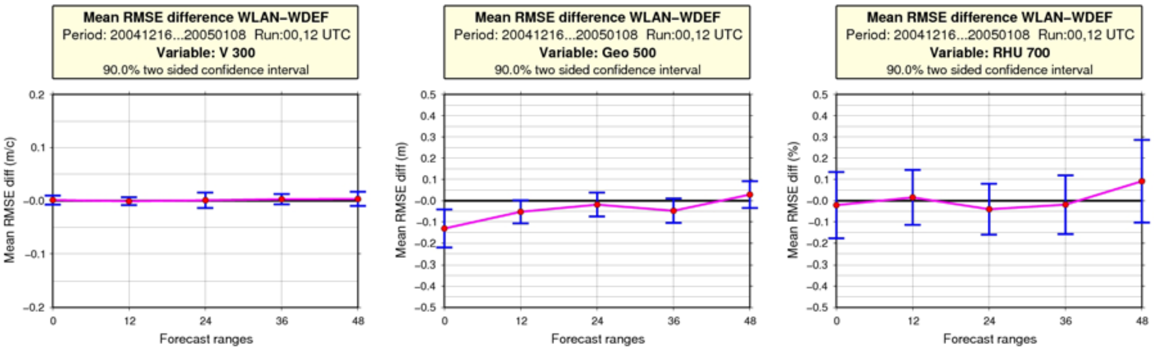


***Figure 7*: Significance test: Wind speed (left), geopotential (centre) and relative humidity (right) RMSE difference. The RMSE was computed from differences against analyses evaluated over Carpathian basin. WLAN and WDEF are runs with addition of AMV over land and data over sea only, respectively.**

COMPARISON OF THE ANALYSIS AND FORECASTS AGAINST OBSERVATIONS

Mainly, comparison against observations showed neutral impact of the AMV data on upper-air fields, since the evaluation was done over the whole ALADIN/HU domain. We observed small but significant positive impact of the AMV data on the mean sea level pressure (Fig. 8). Unfortunately, our verification system, is not able to do any zooming computation on the upper-air fields. This part of the software is under development. But, it works well in the evaluation/computation of scores against any surface measurements.

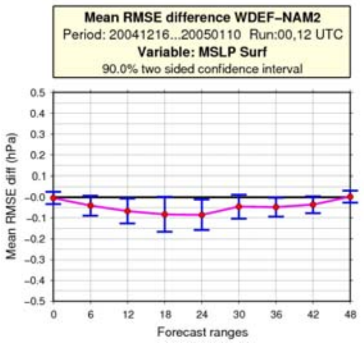
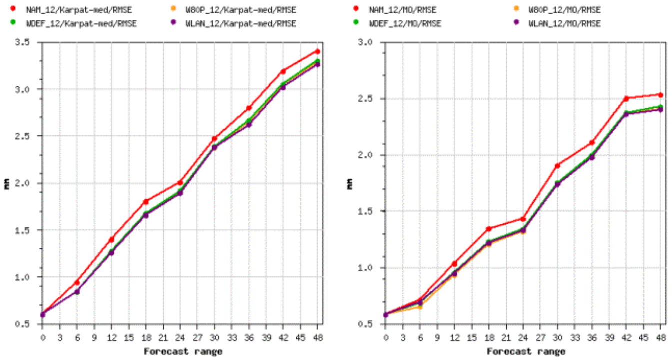


***Figure 8*: Significance test of the mean sea level pressure RMSE difference. The RMSE was computed from differences against observations evaluated over the whole ALADIN/HU domain.**

Clear positive impact of the AMV data on the forecasts of precipitation was observed for all the forecast ranges over both of our target areas. Positive impact was observed, mainly, for day-2 from 00 UTC, and almost for all forecast ranges for forecasts from 12 UTC (Fig. 9).



Over Carpathian basin

Over Hungary

***Figure 9*: RMSE of the 6-h cumulated precipitation. Comparison against the surface gauges for the 12 UTC network. One can see that all runs with AMV show a remarkable reduction of the error over almost all forecast ranges.**

CASE STUDIES

Three cases studies were carried out to describe the impact of the AMV data in case of extreme weather conditions. The *first case* was found within the evaluation period, when the eastern part of the ALADIN/HU domain (our target area) was influenced by a Mediterranean cyclone, with a centre situated over Corsica. The cyclone, having a complex frontal system passed through Central Europe during the period of 26-29 Dec. 2004 (Fig. 10). Such systems are the typical reasons of large proportions of winter precipitation over Central Europe. The choice was also based on day to day plots of BIAS and RMSE scores of forecast for relative humidity (Fig. 11) and 6-h cumulated precipitation (not shown). Fig. 12 shows a clear positive impact of the AMV data for all the investigated configurations during the above mentioned period. Surface measurements (displayed numbers in Fig 12. – unfortunately, not well visible) prove that 6-hour cumulated precipitation patterns forecasted by runs with WDEF, W80P and WLAN data are more close to the reality than those obtained by the run without AMV data.

The *second case* represented a situation when Hungary was situated between a cyclone (in the east) and a zone of high pressure over western Europe, with large pressure gradient over the country. Thus, according to the observation, the wind gust over western and eastern Hungary reached 21, 30 m/s and 16, 18 m/s, respectively (Fig. 13). Both the forecasts – achieved with and without AMV data - were satisfactorily good, but the use of the AMV data made a slight positive correction in the forecast of highest wind gust, increasing the western pick and decreasing the eastern one.

The *third case* (summer case) corresponded to a situation, when the central and to a certain extent the eastern parts of Europe were influenced by a large cyclone with a warm front. This cyclone was crossing the southern part of eastern Europe and moved from the south to the north bringing a warm humid air from the Adriatic sea and causing very intensive precipitation over western part of Hungary (in Keszthely the measured cumulated 24 hour precipitation was 109 mm, in Vesprém: 49 mm, in Sármellék: 69 mm and in Pápa: 84.2 mm), in Austria (Retz: 44 mm, Vienna: 43 mm, Lassnitzhoehe: 40 mm) and also in Slovenia (Ljubian/Bezigrad: 50 mm) etc. Figure 14 shows a remarkable positive impact of the AMV data on both the day-2 24-hour cumulated precipitation (upper panels), as well as on the day-1 forecast (lower panels). The progress in the forecasts could be observed not only on the position of the precipitation patterns, but also on the precipitation intensity. For example, the day-1 forecast for the maximum precipitation was very good for both, location and amount: the location was just a few kilometres east from the real position and the measured intensity was 109 mm compared to the forecasted 107,2 mm.

Weather conditions over Europe (26-29.12.2004) (A=Low, M=High)

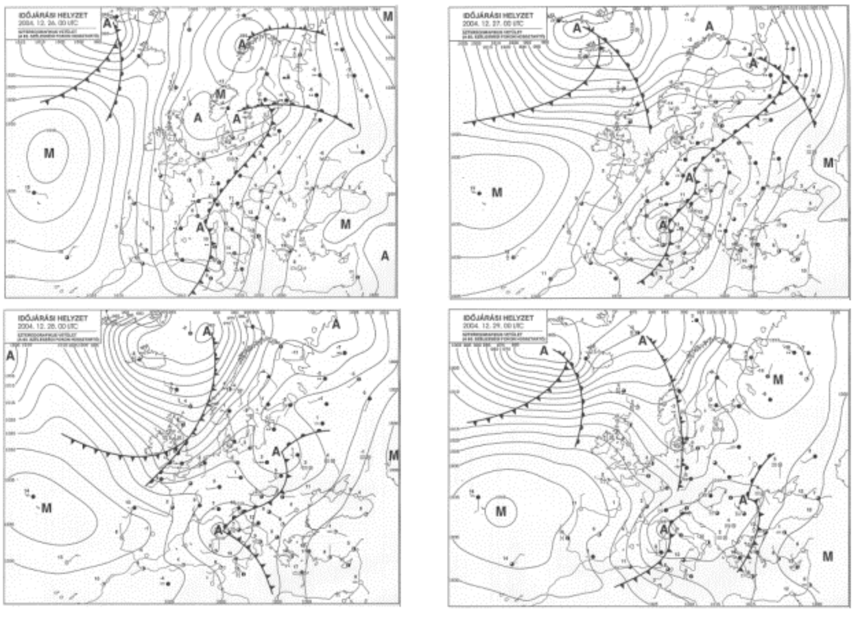


***Figure 10*: The weather condition over Europe during the period of 26-29 December 2004.**

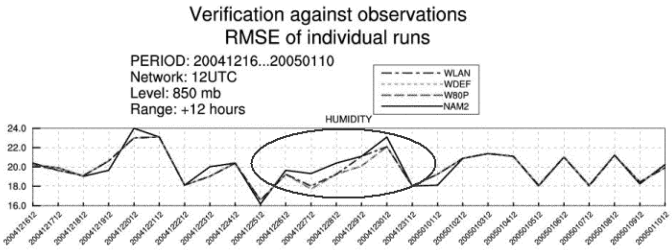


***Figure 11*: Comparison of the time series of the day-to-day RMSE for relative humidity of individual runs with (WLNA,WDEF and W80P) and without (NAM2) AMV data.**

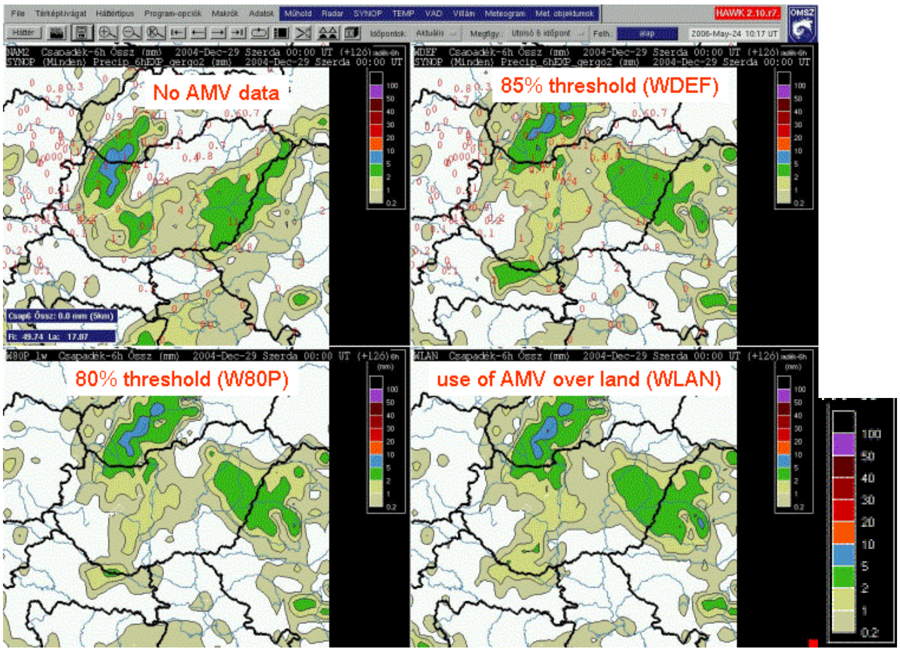


***Figure 12*: 6-hour cumulated precipitation patterns for 12 hour forecast range (valid for 29 Dec. 2004 00 UTC) from 28 Dec. 2004 12 UTC runs displayed by the HAWK visualization tool.**

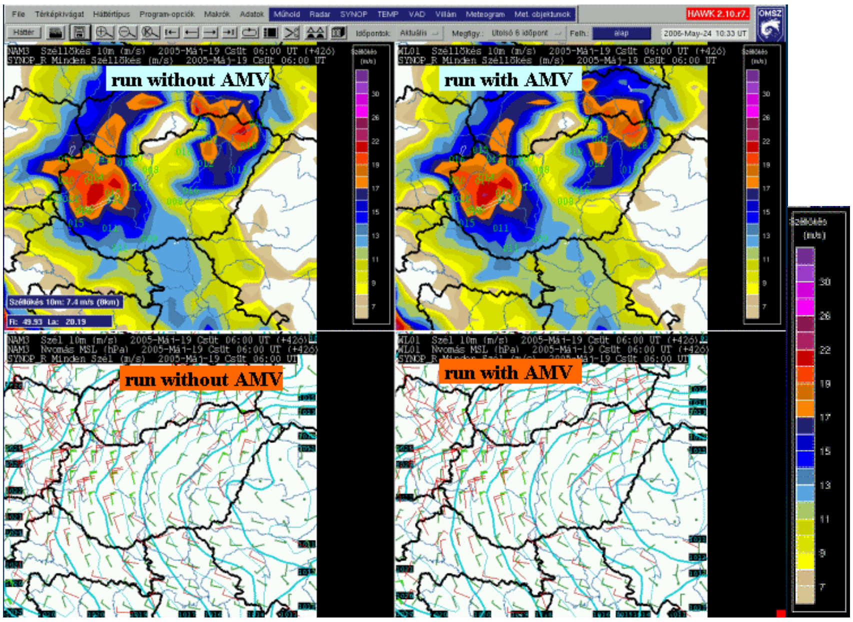


***Figure 13*: 42-hour forecast of wind gust (upper panels), 10m wind (measured - green arrows and measured red arrows) and mean sea level pressure (lower panels) for Thursday 19 may 2005 at 06 UTC.**

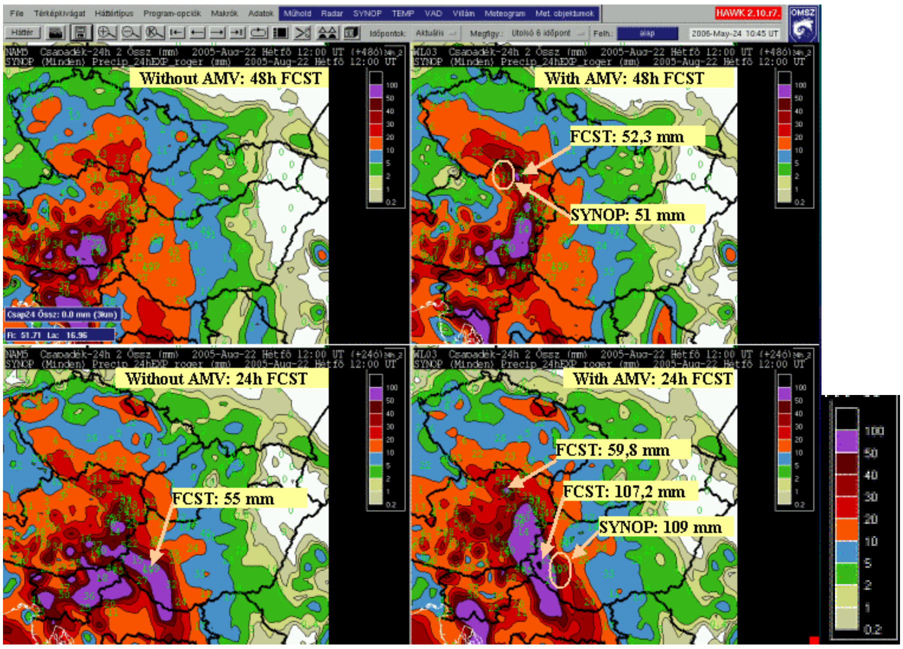


Figure 14**: Forecasted 24-hour cumulated precipitation patterns for day-2 (upper panels) and day-1 (lower panels), valid for Monday 22 August 2005, 12 UTC. (FCST stands for forecasted value and SYNOP stands for the measured value)**

CONCLUSIONS

Our investigation regarding the quality of AMV winds showed that the higher the QI the better the fit to the observation of the "obs-guess" and "obs-analysis". Although a big amount of data is transmitted, only few of them are used in the assimilation process. Comparison against the observations showed neutral impact of the AMV in the troposphere over the whole ALADIN/HU domain. We observed small but significant positive impact of the AMV on the mean sea level pressure. Over the whole ALADIN/HU domain the comparison against long cut-off ARPEGE analyses showed slightly positive impact of the AMV on geopotential, wind speed and humidity. Zooming over our areas of interest, we observed a remarkable positive impact of the AMV data. A significant positive impact of the AMV on the precipitation over our areas of interest was found. Case studies showed clear positive impact of the AMV data in case of extreme weather conditions. The above discussed results looked very encouraging, so we decided to add the AMV data in the operational analysis system.Despite our satisfaction with the results, in order to use more good quality data in the pre-processing, the revision of the quality control is needed.

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