Rapid Update Cycle with ALADIN/HU

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1. Introduction

The current Hungarian operational ALADIN suite preforms three-dimensional variational assimilation (3DVAR) every six hours (i.e. four times a day). Observational time window is ranging from 0 to 6 hours, depending on observation type and availability. This is also a common operational practise for most NWP systems. The goal of my stay at Hungarian meteorological service (HMS) was to test a more frequent (3-hour) assimilation cycle - for this reason called rapid update cycle (RUC). In this case, the observational time window is also reduced to maximally 3 hours, so in the absence of temporal data assimilation scheme, the observations can enter into the model at more realistic times. Since the handling of temporal distribution of observations is improved, it can be understood as one of possible intermediate steps towards temporal data assimilation schemes (e.g. four dimensional variational assimilation). 3-hour RUC with ALADIN was implemented and tested for the period of 14 days. Also an experimental 1-hour RUC was implemented, but not yet evaluated. The motivation for RUC experiments comes from the encouraging results with RUC regional forecasting system at National centre for Environmental Prediction (NCEP, Benjamin et al., 2003). However, the success of increasing the cycle frequency is questionable because of spin-up problems related to short-term first guess. Frequent analysis might also too much rely on less accurate observation types between the main synoptic observing times.

2. Experimental setup

2.1. Description of experiments

This section provides information about the setup of preformed experiments. They were based on ALADIN/HU operational domain and model settings: ALADIN cycle 28t3, approximately 8 km horizontal resolution and 49 vertical levels. Upper-air analysis was provided by local 3DVAR. No surface analysis was performed, but the surface and soil fields were taken from ARPEGE analysis or 3-hour forecast every 3 hours. ARPEGE short-range forecasts were also used as boundary conditions (Figure 1). In all the experiments, Hungarian operational background error covariances (standard NMC type) and bias correction coefficients were used. There was no special definition or rescaling of background errors for 3-hour cycle. All available observation types were used, including surface reports (SYNOP), radiosoundings (TEMP), satellite atmospheric motion vectors (AMV), aircraft reports (AMDAR), wind profilers (WP) and NOAA radiances (AMSU-A, AMSU-B). An experimental 3-hour assimilation cycle (hereafter RUC3) was performed and evaluated using two reference

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	eksp. name	RUC3			REF6			RUC6		
obs. type	variables	assim.freq.	window	selection	assim. freq.	window	selection	assim.freq.	window	selection
SYNOP	p_s	3h	0	at time	6h	0	at time	6h	0	at time
TEMP	T, q, u, v	6h	0	at time	6h	0	at time	6h	0	at time
AMDAR	T, u, v	3h	+/-1.5h	closest	6h	+/-1h	closest	6h	+/-1.5h	closest
AMV	u, v	3h	0	at time	-	-	-	6h	0	at time
WP	u, v	3h	+/-0.5h	all	6h	+/-0.5h	all	6h	+/-0.5h	all
AMSU-A,B	rad.(T, q)	3-6h	+/-1.5h	all*	6h	+/-3h	all	6h	+/-3h	all*

Table 1: Overview of assimilated observation types, assimilation frequency, observational time window and the way of selecting of observations used in the experiments RUC3, REF6 and RUC6. In experiments marked with (*), NOAA 15 AMSU-B radiances are also assimilated.

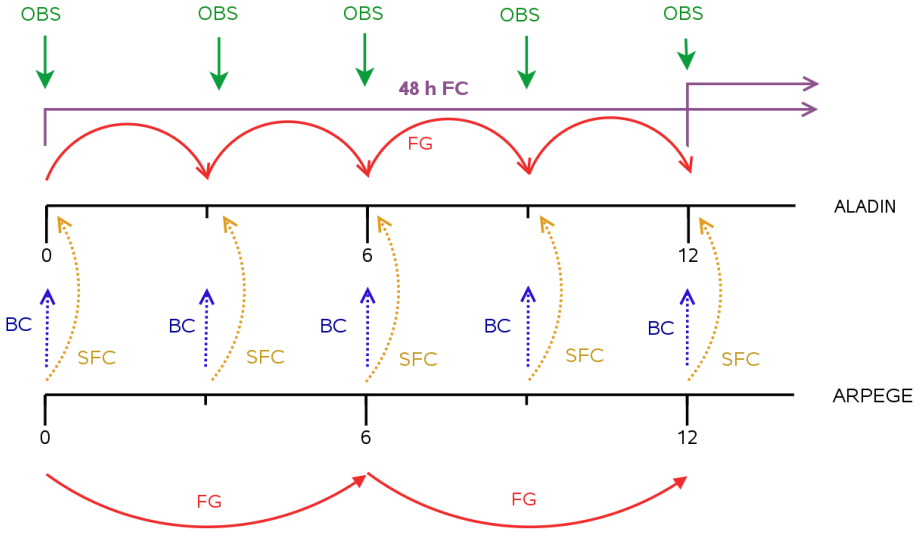

Figure 1: Design of the RUC3 experiment: ALADIN 3DVAR assimilation every 3 hours (green), first guesses (red), boundary conditions from ARPEGE (blue), surface analyses from ARPEGE (orange) and production runs (violet).

6-hour assimilation cycle experiments. One of them (named REF6) used the observations in a way very similar to operational practise at HMS. The reason for another reference experiment (named RUC6) is that observational usage in RUC3 was afterwards found to be suboptimal. RUC6 was performed in order to obtain a 6-hour cycle reference with the same (also suboptimal) observational setup as RUC3. An overview of observational strategy for all the experiments is presented in Table 1. A detailed description of observational usage for different observation types is given in the next subsection. Additional experiment of 1-hour cycle (RUC1) was also carried out, but the comparison period was much shorter in this case (8 - 11 October after a 4-day warm-up period), because the computation was quite time consuming. Experiments started from ARPEGE analysis at 4 October 2007 0 UTC. After a four days (4 - 8 October) warm-up period, the 48-hour forecasts were performed twice a day (at 0 and 12 UTC).

2.2. Usage of observations

The RUC3 experiment was designed to assimilate as much observations as possible within 3-hour assimilation window. Figure 2 shows the total number of observations for each observation type as well as their status after screening (active, passive, rejected, blacklisted). Total sum of observations in the assimilation cycle is increasing with the cycle frequency. This is the main reason why RUC3 analyses could be more precise. The REF6 experiment, which was already available before finishing the RUC3, uses the operational observation windows (which are for some observation types different

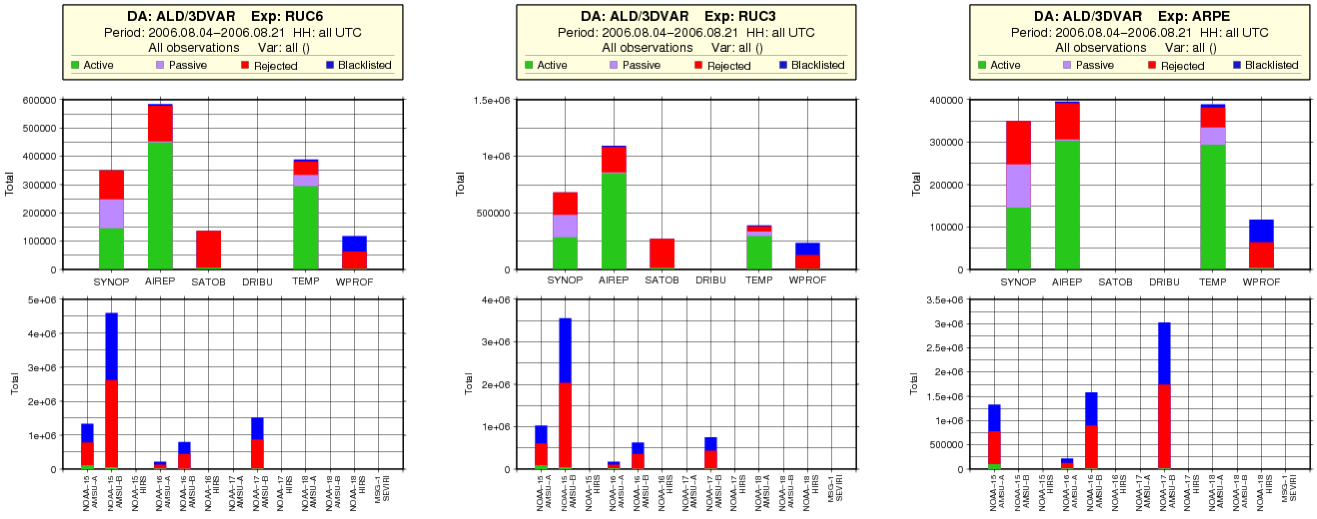

Figure 2: The number and status of observations in the assimilation cycle for different data types: RUC6 (left), RUC3 (in the middle) and REF6(right). Note that the vertical scale (number of observations) for the experiments is different.

from those in RUC3). It also has more correct satellite data, because it does not use erroneous NOAA 15 AMSU-B channel. Because of those important differences in settings of RUC3 and REF6, the reliable comparison was not possible. In order to have two experiments with the same way of using observations, RUC6 was designed. The performance of it was expected to be poorer than the performance of REF6.

2.2.1. SYNOP reports

SYNOP reports were available at the time of analysis for all the experiments. The number of observations in RUC3 was twice as many as in RUC6 and REF6, because RUC3 had twice more analyses.

2.2.2. TEMP reports

Since radiosoundings are available only at main synoptic observing times, the total number of TEMP observations was the same in all the experiments. If we consider radiosoundings as the most valuable (high-quality) data source, an important characteristics of 3-hour cycle is that it uses sounding data only for every second analysis. The intermediate analysis than relies on other (less complete or less accurate) observation types.

2.2.3. AMDAR reports

In RUC3 experiment, +/-1.5 hour time window was applied for AMDAR reports, in order to cover all the observations between two subsequent analyses. Closest observations to the time of the analysis were used. In the operational practise at HMS and also in REF6, the time window was only +/- 1 hour. This difference was corrected in RUC6, where the time window was set to +/-1.5 hour. That means that in RUC3, there are twice more observations than in RUC6 and approximately three times more than in REF6.

2.2.4. AMV reports

AMV reports were available at the time of analysis for all the experiments, so there were twice more observations in RUC3 compared to RUC6. In REF6, no AMV observations were included. The impact of the absence of AMV in REF6 cannot be estimated, but is considered small.

2.2.5. WP reports

All available wind profiler measurements within +/-0.5 hour time window were assimilated. Total number of observations in RUC3 is twice as many as in REF6 and RUC6 because there are twice more analyses.

2.2.6. NOAA AMSU A, B reports

Radiances from NOAA satellites (15, 16 and 17) satellites were used in the presented experiments. They were used in way that all available observations were assimilated. In RUC3, +/- 1.5 hour window was used and in two other experiments, +/- 3 hour window was applied. Experiment RUC3 assimilated NOAA 15 AMSU-B radiances, which are actually incorrect and unfortunately avoided filtering. This was realised too late in the RUC3 experiment, so in RUC6, those radiances were intentionally used for a reference. Like in the operational practise, there was no NOAA 15 AMSU-B in REF6. The number of measurements in RUC3 and RUC6 should be equal. However, a difference of about 10% was found for unknown reasons (Figure 2).

3. Results

3.1. Objective verification of RUC3 against RUC6

This section provides some results, obtained by comparing 48-hour forecasts (starting from 0 and 12 UTC analyses). Main meteorological fields at different forecast times were verified against ECMWF analysis, resulting in vertical time crossections of objective scores. We first compare the RUC3 and RUC6 experiments, which have very similar (not optimal) observational usage. The comparison investigates the effect of increasing the cycle frequency. Figures 3 and 4 present the verification of RUC3 against RUC6. Clear improvements of scores were detected for 0 UTC runs in geopotential, humidity and wind fields. Improvements in geopotential can be found mostly for the second day in upper troposphere as well as near the surface. There is almost no impact on temperature field. For humidity, improvements can be found in the first 12 hours, but also through the whole integration period. They are located in the mid-troposphere (800-300 hPa). RUC3 also improves wind, which is better forecast in the layer between 500 and 200 hPa. This effect is seen after 12 hours of integration. In 12 UTC runs, the improvements are much smaller, but the improved variables and locations are similar compared to 00 UTC runs.

Surface verification using SYNOP data offer the evaluation of RUC3 for some additional variables. The root mean square error (RMSE) of 6-hour and 12-hour precipitation amounts (Figure 5) are somewhat better for RUC3. The impact of bias is mixed. Some positive impact of RUC can also be found in 2 m temperature fields (Figure 6). Verification using SYNOP generally shows smaller improvements of RUC3 compared to verification against ECMWF analysis.

3.2. Objective verification of RUC3 against REF6

The comparison of RUC3 with RUC6 experiment indicated some important improvements of 3-hour cycling (only positive or no impact for all variables). In this subsection, we compare the RUC3 to REF6, which is similar to operational assimilation cycle at HMS (only it does not use

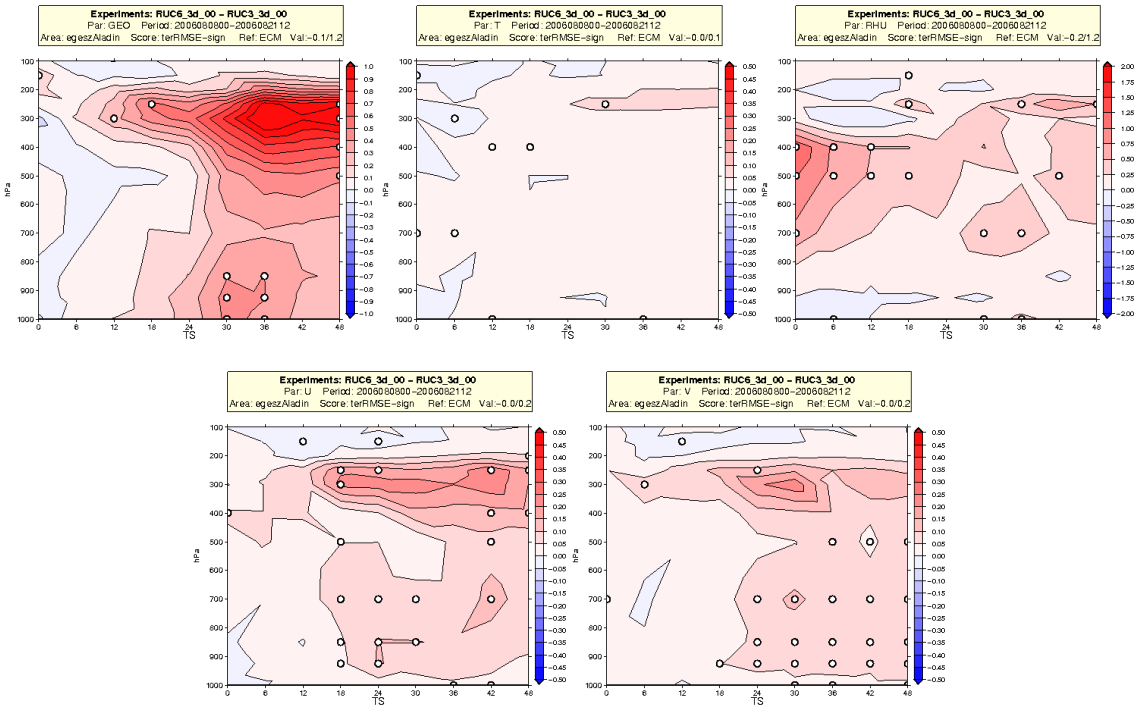

Figure 3: Verification of main meteorological fields against ECMWF analysis at 0 UTC. The vertical crossection of RMS difference RUC6 - RUC3 for different forecast ranges is shown. Red colors indicate better performance of RUC3, and blue that control experiment was better. Meteorological variables (from upper-left corner): geopotential (m), temperature (deg. C), relative humidity (%) and u and v wind components (m/s). Significant differences are marked with circles.

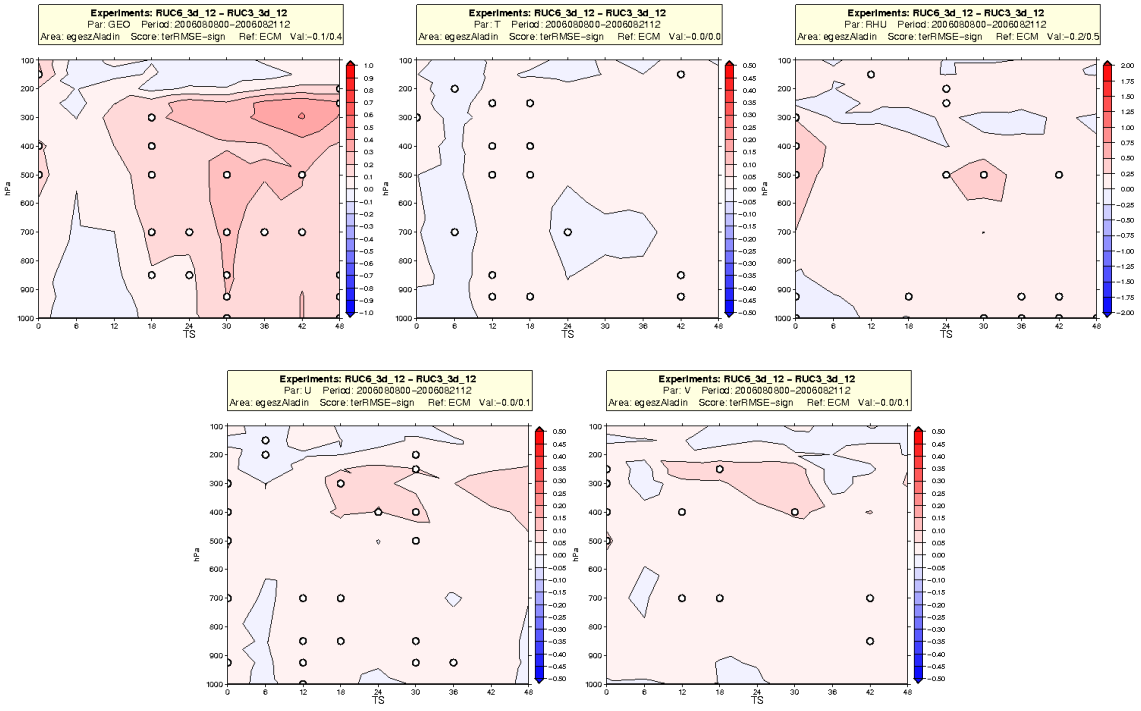

Figure 4: Same as in Figure 3 except that verification is performed against 12 UTC ECMWF analysis.

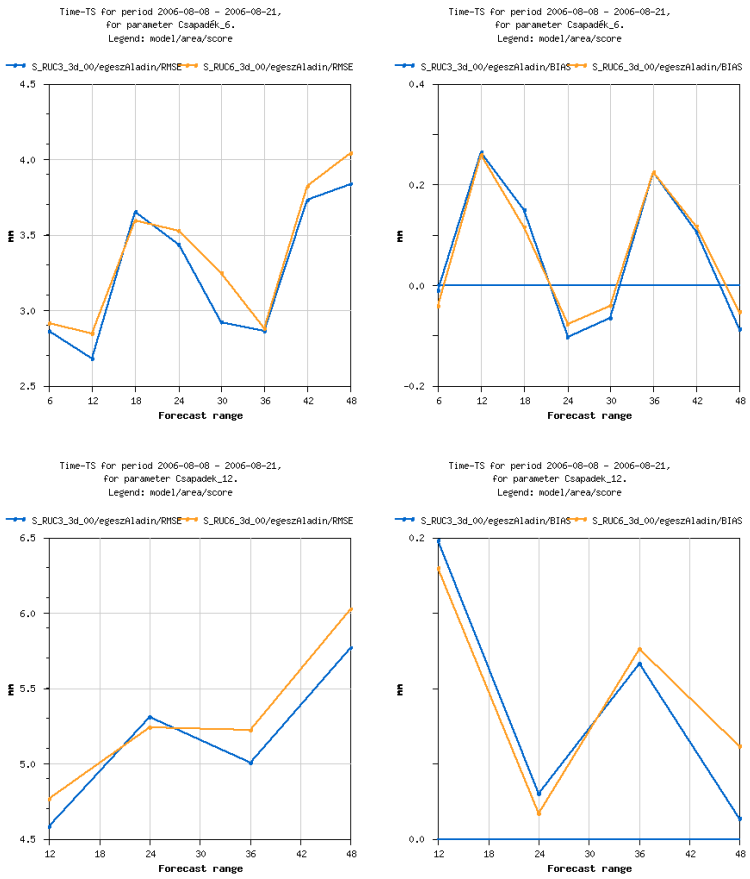

Figure 5: Verification of 6-hour (top) and 12-hour (bottom) precipitation amounts for RUC3 (blue) and RUC6 (red) against SYNOP reports. Time evolution of RMSE (left) and BIAS (right) scores for forecasts, starting at 0 UTC.

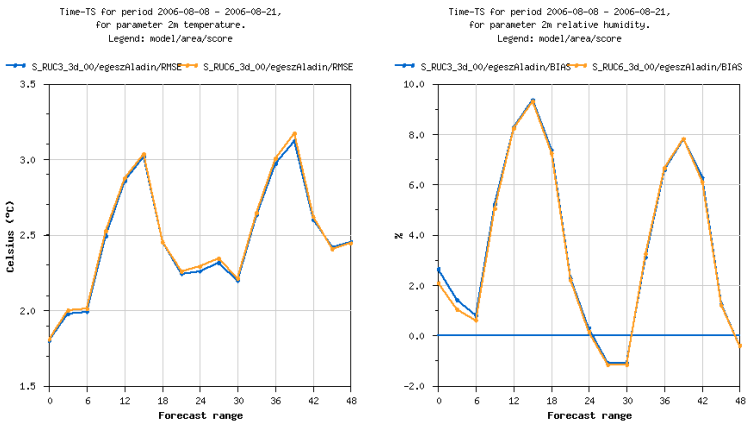

Figure 6: Verification of 2 m temperature for RUC3 (blue) and RUC6 (red) against SYNOP reports. Time evolution of RMSE (left) and BIAS (right) is shown. Some very small improvements can be found in the first 6 hours.

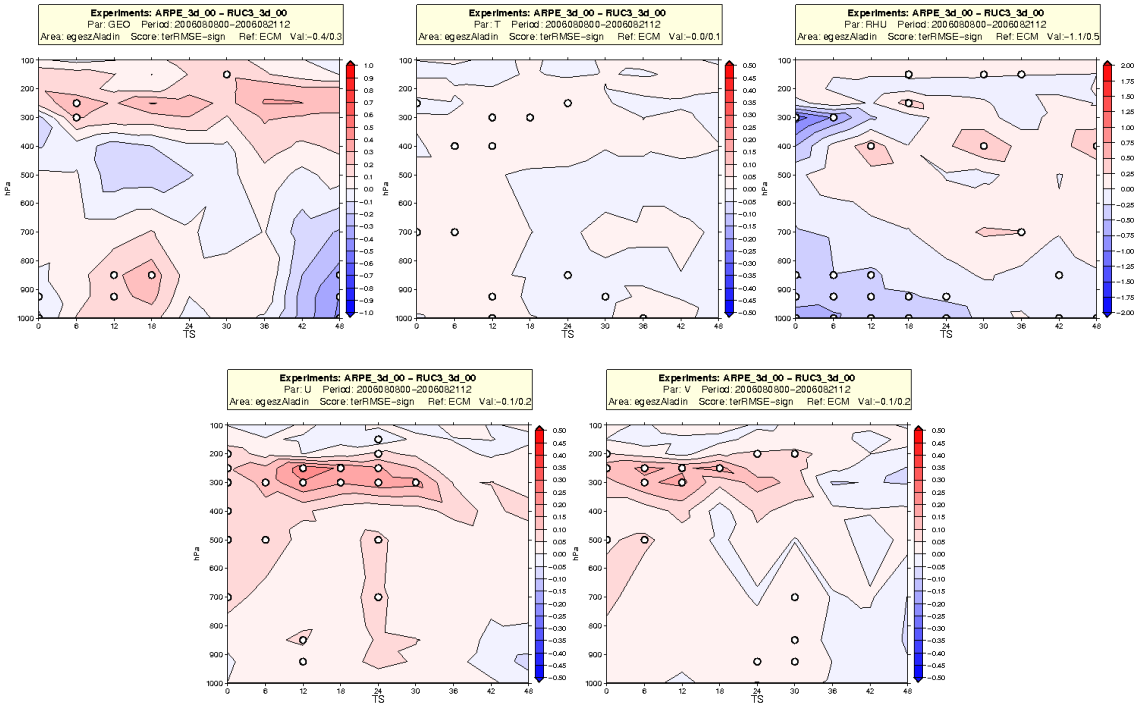

Figure 7: Verification of main meteorological fields against ECMWF analysis at 0 UTC. The vertical crossection of RMS difference REF6 - RUC3 for different forecast ranges is shown. Meteorological variables (from upper-left corner): geopotential (m), temperature (deg. C), relative humidity (%) and u and v wind components (m/s). Significant differences are marked with circles.

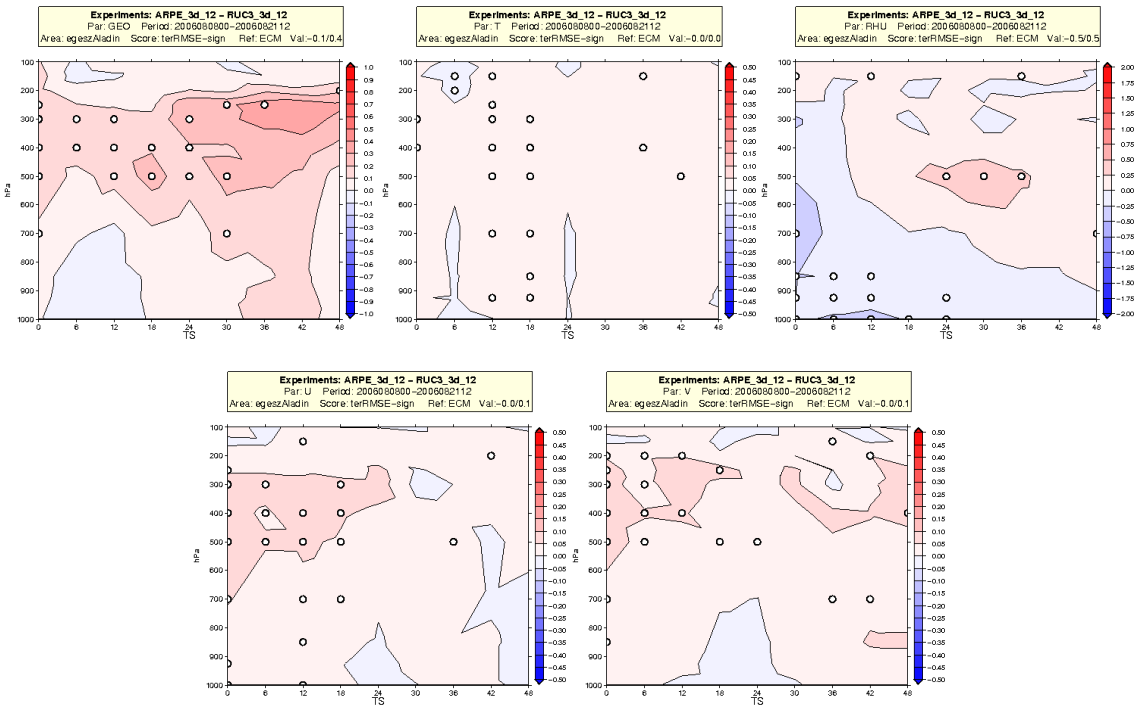

Figure 8: Same as in figure 7 except that verification is performed against 12 UTC ECMWF analysis.

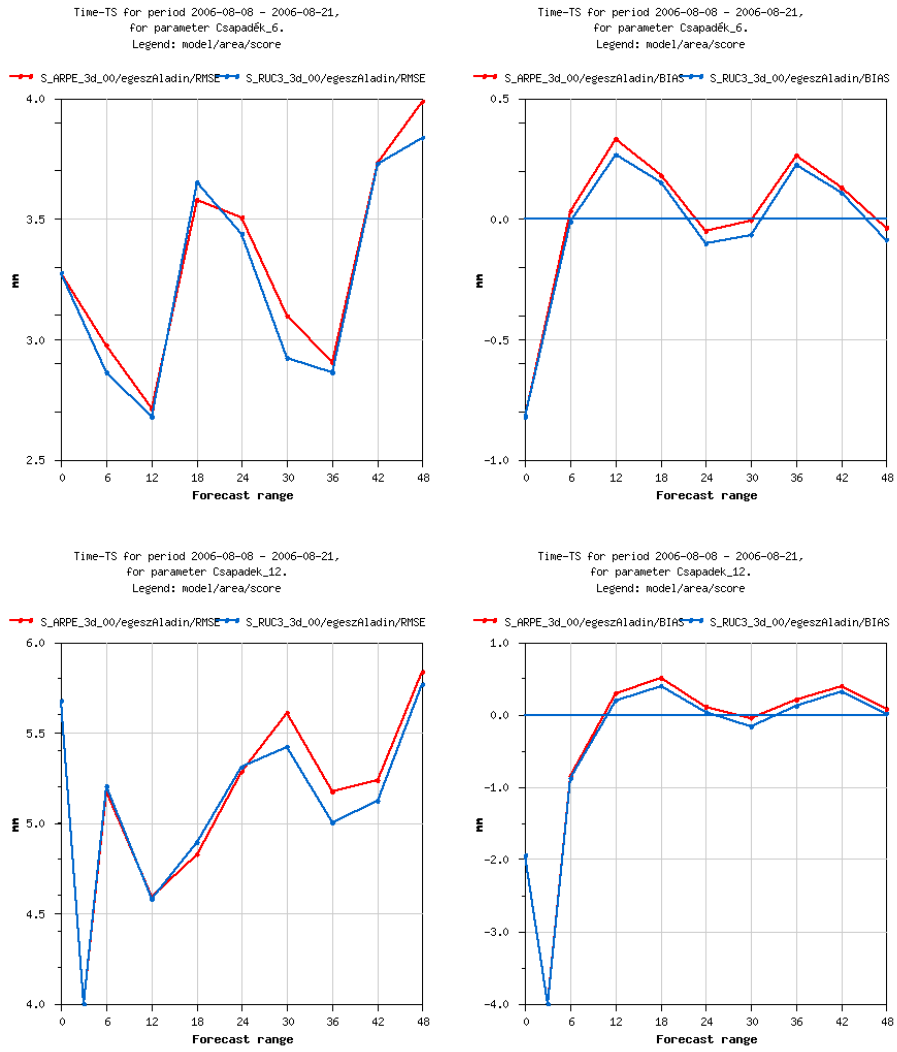

Figure 9: Verification of 6-hour (top) and 12-hour (bottom) precipitation amounts for RUC3 (blue) and REF6 (red) against SYNOP reports. Time evolution of RMSE (left) and BIAS (right) scores for forecasts, starting at 0 UTC. Results for the forecasts, starting at 12 UTC are similar.

AMV observations). Comparison combines the possible improvements of RUC3 against quite good 6-hour cycle setup, but on the other side, degradations of suboptimal observation strategy. The experiments are therefore not very well comparable. The verification against ECMWF analysis shows that the impact of RUC3 and REF6 are both positive and negative (Figures 7 and 8). There are improvements in geopotential field near the surface and in the upper-troposphere (in both 00 and 12 UTC runs), but some degradations in the mid-troposphere and near the surface after 36 hours of forecast. No significant temperature differences were observed. Large degradations are observed in relative humidity field, especially near the surface and for the first 12 hours of forecast. this might have serious consequences on precipitation forecasts. Wind field is again slightly better forecast by RUC3, the improvements are largest at around 300 hPa (but are less than 1 m/s). To sum up, maybe there are some more improvements than degradations of RUC3 against REF6.

Surface verification using SYNOP reports show that 6-hour (Figure 9) and 12-hour precipitation amounts are somewhat better forecast by RUC3. Small improvements can be found for the whole extent of time integration. However, the degradations can be found for 24-hour accumulations (not shown). Some small positive impact can also be found in 2 m temperature fields for the first 6 - 12 hours of integration (Figure 10). For wind and relative humidity, one can observe some degradations and improvements at the same time (not shown). Degradations are present in the forecasts of mean

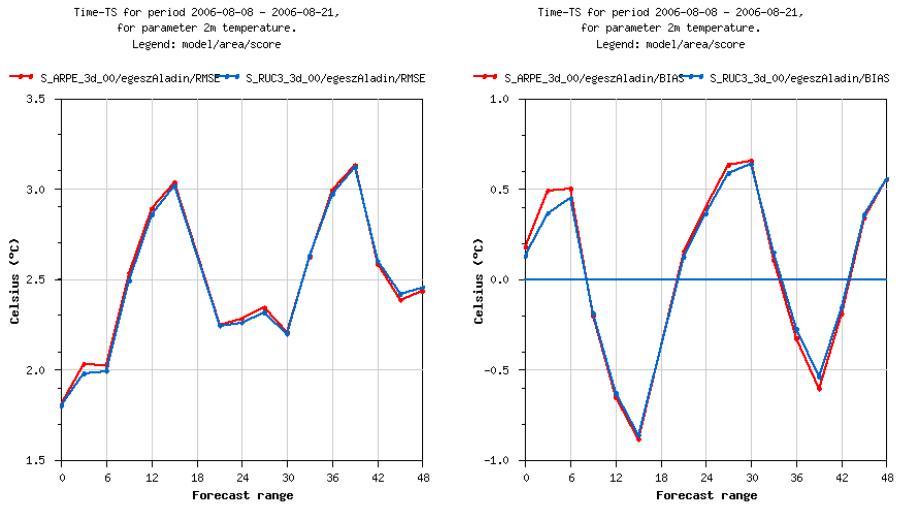

Figure 10: Verification of 2 m temperature for RUC3 (blue) and REF6 (red) against SYNOP reports. Time evolution of RMSE (left) and BIAS (right) is shown. Some very small improvements can be found in the first 6 hours.

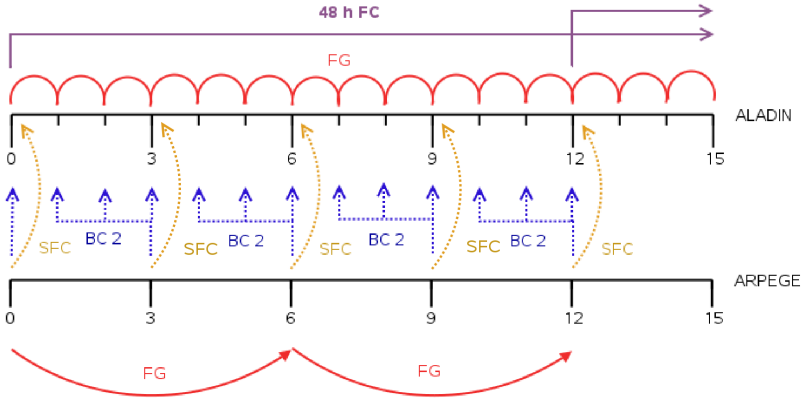

Figure 11: Design of the prototype of RUC1: ALADIN 3DVAR analysis times (every hour), first guesses (red), boundary conditions from ARPEGE (blue), surface analysis from ARPEGE (orange) and production runs (violet).

sea level pressure. Verification using classical scores generally shows very poor or no improvements of RUC3 against reference experiment.

3.3. Comments on the RUC1 experiment

The RUC1 experiment was only the first attempt to learn about the main issues when applying 1-hour assimilation cycle. Because of the 1-hour time window there are much less observations available for each analysis. Boundary coupling becomes rather complicated in RUC1. In current implementation, ARPEGE analysis or 3-hour forecast were used for initial time coupling every three hours (when they are available). For other network times, the ALADIN 3DVAR analysis itself was used for the first boundary coupling file. As the second boundary condition, we used the nearest ARPEGE analysis/forecast. That means that also the coupling frequency was ranging from 1 to 3 hours. Surface and soil fields were taken from ARPEGE every 3 hours. Experiment setup is presented in Figure 11. Another question is the quality of first guess, which is now 1 hour forecast. Such a

guess can be too much affected by a DFI initialisation, which is performed prior to integration at every analysis time. The results of RUC1 are not enough reliable because of very short time period and are therefore not presented in this report.

3.4. Location of the scripts and results

Scripts, used for the presented experiments, can be found on **/users/strajnar/al28t3/assim**, which can be seen from any supercomputer at HMS. Operational Hungarian 3DVAR scripts were used and modified where necessary. Some additional functions and include scripts were added.

RUC3 assimilation cycle:
assim_3d_RUC3.sh
assim_main.sh
mydef.sh
undef.sh

RUC1 assimilation cycle:
RUC1/assim_3d_RUC1.sh
RUC1/assim_main.sh
RUC1/mydef.sh
RUC1/undef.sh

other:
obs_scripts/link_tovs (new)
prod_3d_RUC3.sh
RUC1/prod_3d_RUC1.sh

Results of experiments (analysis and forecasts) can be found on the archive **/archive/users/strajnar/al28t3/assim/3d/** under the experiment name (RUC3, RUC1). Forecasts are archived in netcdf file format.

4. Discussion and opened questions

The results of experiments raise many questions. The performance of 3-hour cycle was slightly better than of 6-hour cycle for a suboptimal observation setup. That means that 3-hour cycling has some potential to preform better than 6-hour cycle and also that 3-hour guess has an acceptable quality. At the same time, the comparison with most reliable reference (REF6) shows generally small and mixed impact of 3-hour cycling. This mixed impact does not offer a reliable estimate of how much degradation was caused by wrong observations and what was the effect of shortening the cycle length. After finding that RUC3 setup was not optimal, it was much easier to perform another reference 6-hour cycle (RUC6) with the similar setup than to correct and rerun 3-hour cycle. But in order to obtain the results which would clearly demonstrate the effect of increasing the cycle frequency, the RUC3 has to be repeated, taking more care to choose the best strategy of using observations.

An important question is the effect of having no radiosounding data in the analysis. In 3-hour cycling, there might be too little quality observations in the intermediate (data poor) analyses. Another possible reason for no significant improvements against 6-hour cycle could be due to the inaccuracy of the first guess. The quality of very short-range forecasts could be too low during the spin-up period. To check this, verification of first guesses should be performed. And finally, applying the same background covariance structures as for 6-hour cycling can also be questionable.

5. Conclusions and outlook

Rapid update cycle (3-hour) with ALADIN/HU was implemented and tested for the 14 days period. There was also an attempt to test a hourly cycle, which was implemented, but not yet sufficiently validated. For a specific suboptimal observation setup, it was shown that 3-hour assimilation cycle performs slightly better than 6-hour cycle. The success of experimental 3-hour cycle can be compared to that of operational 6-hour cycle, with some small improvements in geopotential and wind, but degradations for relative humidity. The reason for that degradation could be in using wrong satellite radiances. The future work should for now first concentrate on 3-hour RUC. Additional experiments are needed, using observations with more care (quality, time windows), and maybe also including some new available observations (NOAA 18, SEVIRI, SYNOP temperature and relative humidity).

Ackowledgements

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