1. Steluta ALEXANDRU : "Scientific strategy for the implementation of a 3D-VAR data assimilation scheme for a double nested limited area model"

Further experiments with 3D-VAR scheme for the ALADIN/Hungary model

Introduction

In the previous ALATNET Newsletter the results of the first experiments with 3D-VAR data assimilation scheme for the double-nested limited area model ALADIN/Hungary were described. These experiments were performed only for one week (25.02.2002 - 02.03.2002), and their aim was to get a general idea about the best strategy for the application of the 3D-VAR scheme, trying to choose the best options among the several possible solutions as: first-guess, lateral boundary conditions, initialization methods to be applied in cycling and production, coupling techniques, etc. The main conclusions of these experiments were that as coupling technique, time-consistency seems to be a good choice, in cycling and in production we have to apply digital filter initialization, and it is better to use the files from the global model as lateral boundary conditions. Another conclusion was that it is better to use in cycling the analysis as the second lateral boundary conditions file. (Alexandru [2], 2002).

For these new experiments using 3D-VAR data assimilation scheme, the period was extended to one month, considering that the results will emphasize better the features of the variational assimilation, than those for one week only.

3D-VAR experiments

3D-VAR data assimilation scheme consists of the minimization of a cost function in order to get the best fit to all the available information sources. At the moment for ALADIN model, this cost function is a sum of two terms, the background term and the observation term. The ALADIN/Hungary model is using for the background term, the background error statistics computed by NMC method (Parrish and Derber, 1992), and for the observation term, only SYNOP and TEMP observations are considered.

We decided to perform experiments for one month's period (25.02.2002 - 25.03.2002). Both in cycling and in production, we have chosen to use as lateral boundary conditions (LBC), the ALADIN/LACE and ARPEGE files (from the assimilation cycle) and as coupling method the "Moroccan" solution. This latter means that in cycling, the initial and the first LBC files are the 3D-VAR analysis, and the second LBC file is the ALADIN/LACE, respectively ARPEGE analysis. In production, the initial and the first LBC files are the 3D-VAR analysis, and the second LBC file is the 6h forecast of the ALADIN/LACE, respectively ARPEGE models. It can be seen that using the "Moroccan" solution, the first two LBC files, both in cycling and in production are not coming from the same integration of the model. The first LBC file is identical with the initial file. Thus the information is consistent in space. So, as coupling technique, we used the space-consistency.

Digital filter initialization (DFI) was applied at the beginning of the integration, in cycling and in production. The integration in production was carried out only for 6h, because we had only two LBC files.

For simplicity, the notation of the experiments was chosen "*LACE*", when ALADIN/LACE LBC files were used and "*ARPEGE*" with the ARPEGE files.

Results

We have to mention first about the number of observations used in the assimilation process. In Figure 1, the typical geographical distribution of the observations is represented (the black circles show the location of SYNOP stations, and blue rhombuses are representing the TEMP stations). As we can see the number of TEMP observations at 06 UTC (around 5 stations) is much smaller, than at 00 UTC (around 20), which means that also the statistical scores do not have the same precision, as those for 00 UTC. The number of TEMP observations decreases for 12 UTC (with respect to 00 UTC), and for 18 UTC (with respect to 06 UTC). But even in this situation the scores give us a general idea about how the forecast using 3D-VAR data assimilation scheme is behaving compared to the operational one's (in dynamical adaptation).

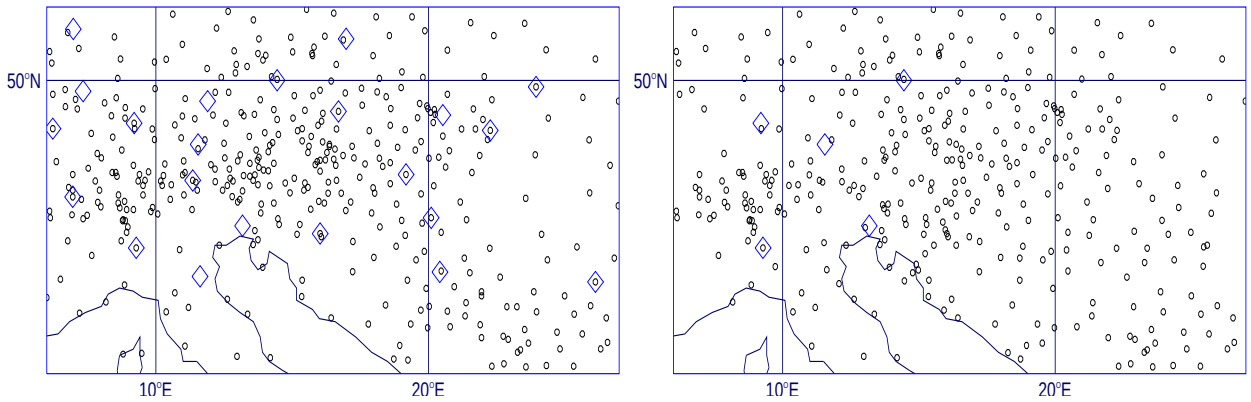

Figure 1 : Typical distribution of observations at 00 UTC (left) and at 06 UTC (right)
(black circles - SYNOP, blue rhombuses - TEMP)

The verification scores of the forecast of the model (from production) against observations (as vertical profiles, from the surface till 400 hPa) are presented in Figures 2-3. The scores of the operational forecast ("*oper*"), are plotted as reference for the 3D-VAR experiments.

- At the time 00h, the analyses for relative humidity and wind, using 3D-VAR scheme are better represented than the operational analysis, for all levels. The temperature has also better scores using 3D-VAR scheme, but the difference is not significant as for the previous fields. The geopotential analysis was improved with data assimilation, especially above 700 hPa. But this improvement shows only that the analysis is closer to the observations, which is expected.
- After 6h integration, the scores for temperature are almost neutral, with small variations near the surface. The forecast of geopotential, with data assimilation, was improved especially for some upper levels. The forecast of relative humidity, shows an improvement using the 3D-VAR scheme near the surface, but for the upper levels, the operational forecast is slightly better. The scores of the zonal wind forecast, with data assimilation, looks slightly better than in dynamical adaptation, but not for all levels. The meridional wind is better represented by the operational model (not shown).
- These last experiments emphasize that the choice of ALADIN/LACE or ARPEGE files as lateral boundary conditions is not so important. For analysis, the differences are very small, and for 6h forecast, the shapes are only slightly different, especially for wind. (Alexandru [1], 2002).

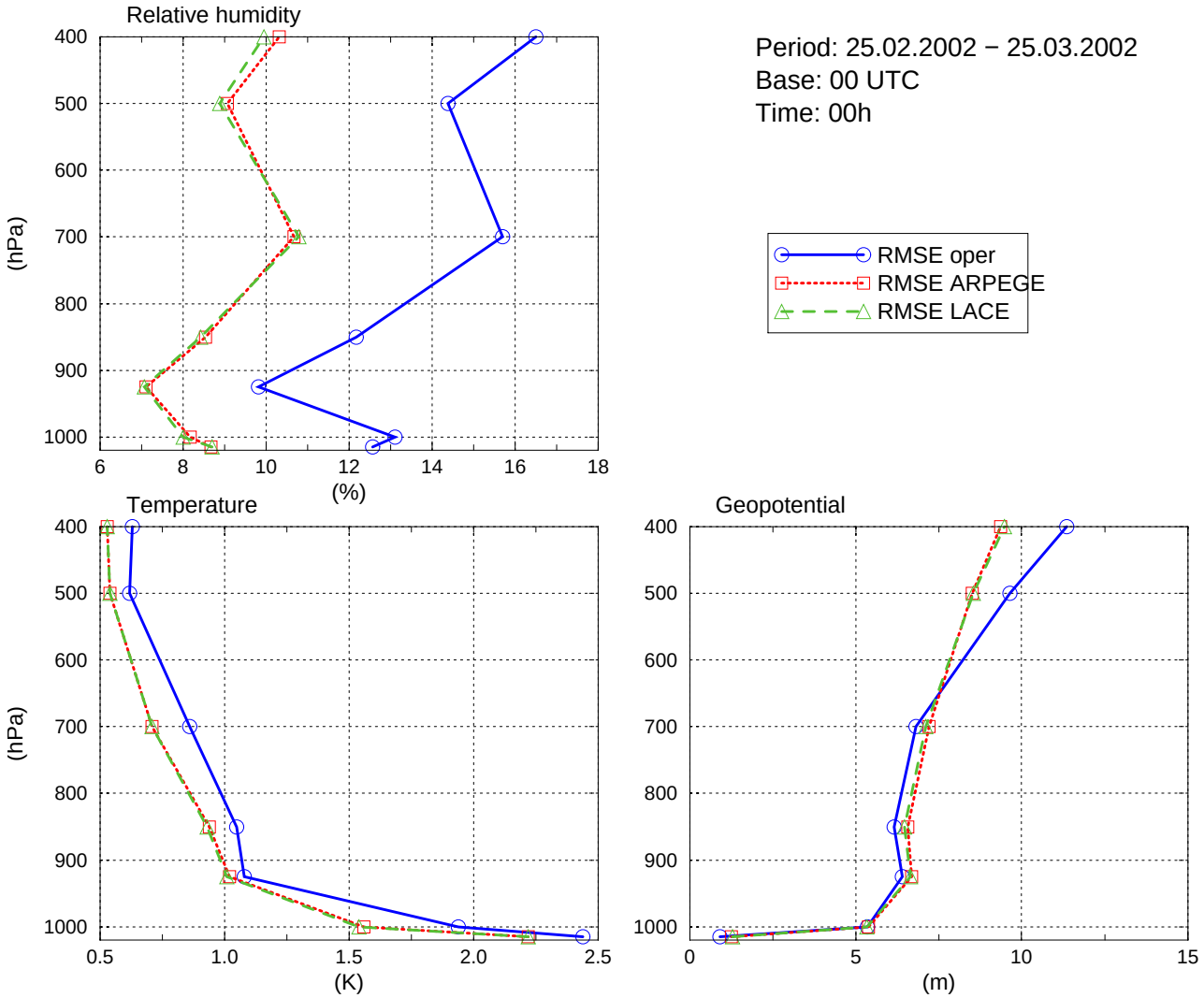

Figure 2 : The vertical profile of RMSE for the operational analysis (*oper*), and using 3D-VAR scheme with ALADIN/LACE (*LACE*) and ARPEGE LBC files (*ARPEGE*) for relative humidity, temperature, geopotential for the period 25.02.2002 - 25.03.2002, base 00 UTC

As another evaluation tools, the *"echkevo"* scores and the mean sea level pressure increments were plotted. Comparing the *"echkevo"* scores of the operational forecast (with digital filter initialization) to those using data assimilation, it was concluded that the fields are in balance. The maps with the mean sea level pressure increments did not show big differences between the 3D-VAR experiments with ALADIN/LACE and ARPEGE LBC files.

Conclusions

The results of the experiments using 3D-VAR data assimilation scheme for the ALADIN/Hungary model are described. The period of the experiments was extended to one month.

The 3D-VAR analysis fits closer to observations, as we expected. But after 6h integration, the forecast is losing from the initial improvement. The meridional wind is the only field that is better predicted in dynamical adaptation at all levels. The relative humidity and zonal wind have better scores using 3D-VAR scheme, but not for all levels. The forecasts of temperature and wind direction are very close to the operational one. For geopotential, the scores show a slight improvement after 6h integration, when 3D-VAR scheme was used.

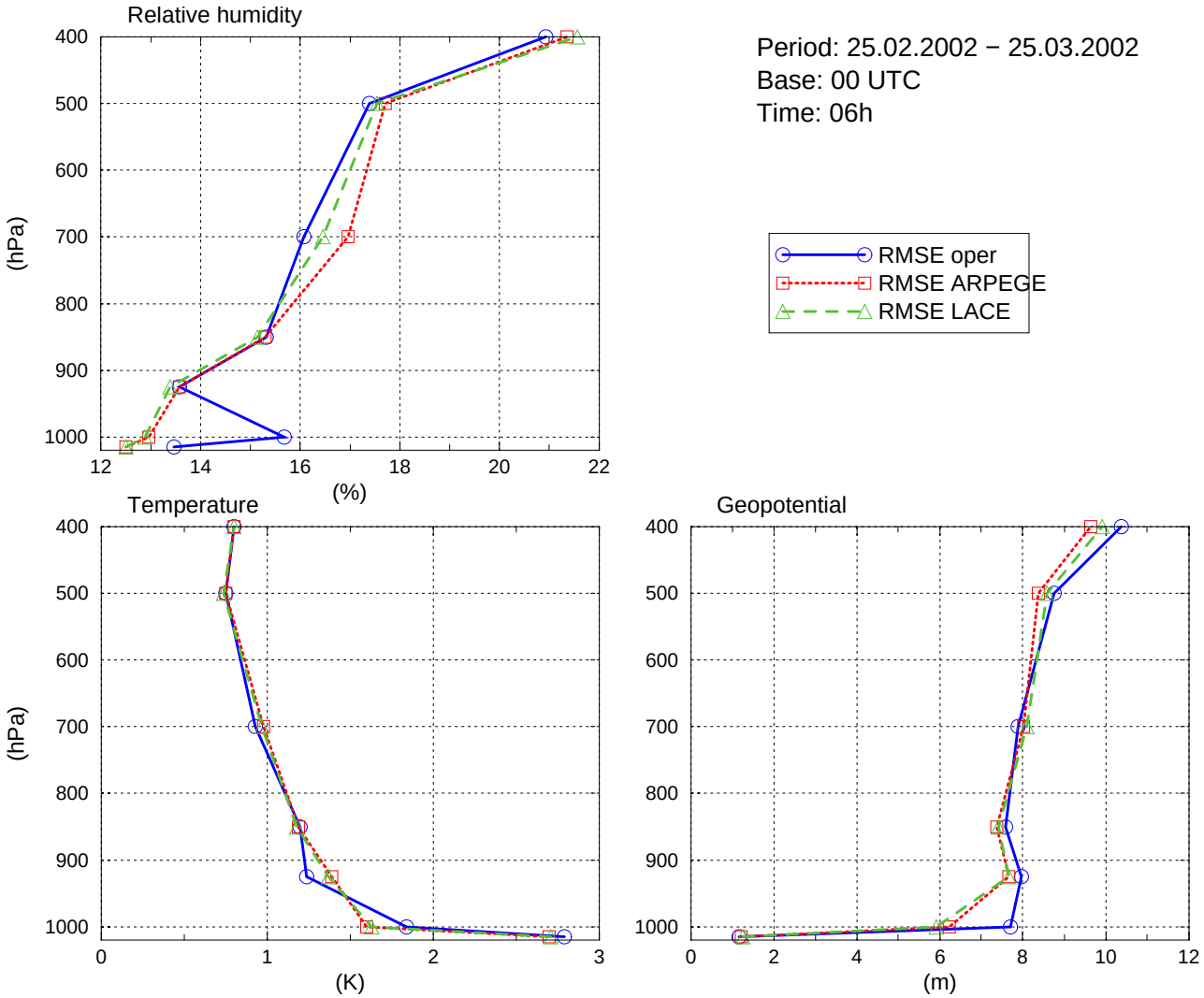

Figure 3 : The same as Figure 2, but after 6h integration

The fields are in balance, confirmed by the *"echkevo"* scores, and the maps with the mean sea level pressure increments did not show big differences between the two sets of the 3D-VAR experiments (with ALADIN/LACE and ARPEGE LBC files). This is in agreement with the verification scores, which were almost the same when different LBC files were used.

These experiments with 3D-VAR scheme for ALADIN/Hungary model were performed to select from many options that we have (different first-guess, lateral boundary conditions, initialization methods, coupling techniques, etc.), the best ones, to be able to study 3D-VAR scheme more in detail, for some interesting meteorological situations.

References

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3D-VAR experiments for the ALADIN/Hungary model :
a case study (the 17-18th of July 2002)

Introduction

After the best possible strategy for the 3D-VAR scheme for the ALADIN/Hungary model was established, the next step was to select some interesting meteorological situations, when on the one hand, the operational model (in dynamical adaptation) failed to provide a good prediction and on the other hand, when the operational forecast was reasonably good. In the first case the improvements were checked, and in the latter one, whether the 3D-VAR scheme is able to keep the good performance of the reference model. Therefore we started with a case when the operational forecast failed.

A short description of the synoptic situation of this case is presented below. On 13.07, a cold trough spread over Western Europe on 500 hPa. From this, a cold drop isolated on 14.07, moved to East, whirled over Northern Italy on 16.07, at noon, and filled slightly in between. From noon of 17.07, it got a cold supply on the backside, which made the cyclone to strengthen again and to move to East from 18.07. Between the 18-20th of July the cyclone remained over the Carpathian Basin. On 18.07, large quantity of precipitation (40-70 mm) was measured over the central part of Hungary, along the Danube river (Fig 1). (HMS, 2002).

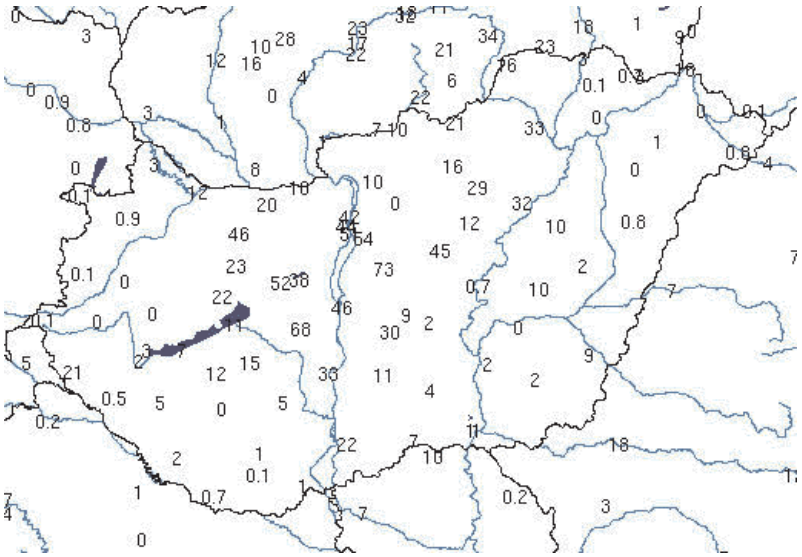

Figure 1: The quantity of precipitation measured over Hungary between 18.07 06 UTC-19.07 06 UTC

3D-VAR experiments

For this case study, three sets of experiments with 3D-VAR data assimilation scheme were chosen to be performed using different lateral boundary condition (LBC) files (from ALADIN/LACE and ARPEGE models), and different data for the observation term (SYNOP and TEMP data available at the Hungarian Meteorological Service, and data from Météo-France, zoomed over the ALADIN/Hungary domain). For the background term, standard NMC statistics were used (Parrish and Derber, 1992).

As coupling strategy, time-consistency was chosen both in cycling and in production. Time-consistency means that the lateral boundary data are coming from the same integration of the coupling model, thus the information is consistent in time. The initial file is the 3D-VAR analysis,

and the first two LBC files are coming from the coupling model (Siroká, 2001). Digital filter initialization (DFI) was applied in cycling and in production.

The assimilation cycle was started from 15.07.2002 06 UTC, i.e. three days before the event. The pictures with different forecasts (Figs 3-4) have a zoom over the integration domain.

The first set of experiments was carried out using SYNOP and TEMP data available at the Hungarian Meteorological Service (HMS) and the operational LBC files for ALADIN/Hungary (from ALADIN/LACE model) in cycling and in production. The notation for these experiments is *"3dvar"*.

The second set of experiments was performed with data from HMS, and as LBC files, the ARPEGE files, interpolated over the ALADIN/Hungary domain. For these experiments, the notation is *"3dvar ARP"*.

For the third set, data from Météo-France (which include SYNOP, AIREP, SATOB, TEMP, PILOT observations) were used for the observation term, and the operational LBC files (from ALADIN/LACE model) in cycling and in production. It was called *"3dvar TLS"*.

In Figure 2 the typical geographical distribution of the data available is plotted for 18.07 2002 00 UTC. Number **1** represents the location of SYNOP observations, **2** for AIREP, **3** for SATOB, **5** for TEMP, and **6** for PILOT data. As we can see, almost the same TEMP observations can be found in the two data sets. Data from HMS have more SYNOP observations over the central part of the domain. For data from Météo-France (MF) one can see numerous AIREP and SYNOP observations, especially in the western part of the domain.

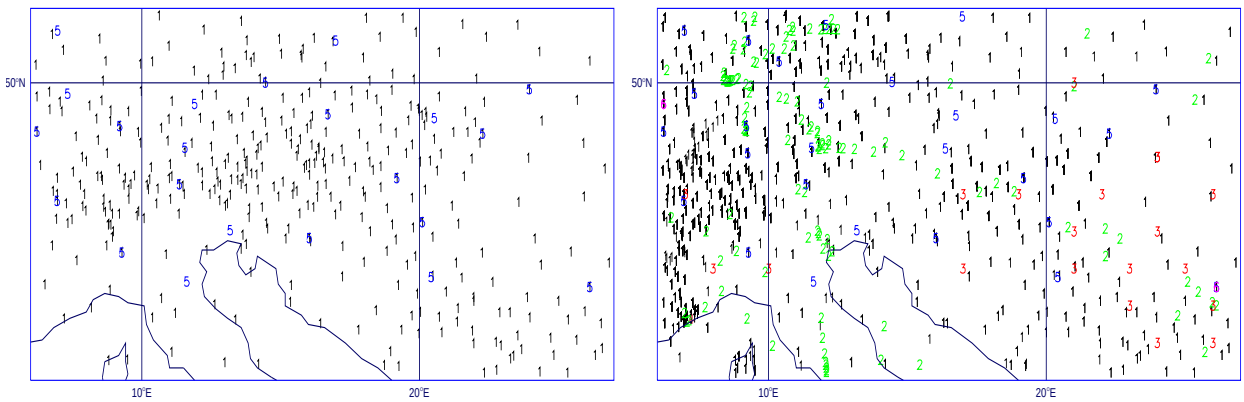

Figure 2: The typical geographical distribution of the data from HMS (left) and from MF (right) from 18.07 00 UTC

Results

The results of the 3D-VAR experiments are compared to the operational forecast of the ALADIN/Hungary model (*"oper"*). Mainly the forecasts of different fields from 17.07. 00 UTC, 12 UTC and 18.07 00 UTC runs, valid at 18.07 12 UTC are described.

17.07 00 UTC run

The operational forecast from 17.07 00 UTC run shows that the cold air is streaming from North-West, bringing cooler air in the western part of Hungary. The amount of precipitation cumulated in 24h is not bigger than 6 mm. All three sets of experiments with 3D-VAR scheme did not show a different forecast than the model in dynamical adaptation. The precipitation forecast is around 10 mm in 24h, but on a larger area than the operational model predicted (not shown). So, the models did not predict the event with more than 24h before. The 3D-Var scheme did not provide any additional information for this run.

17.07 12 UTC run

According to the 17.07 12 UTC run, the direction of the cold air remain northwesterly. The operational model forecasted an important quantity of precipitation (around 101 mm in 24h) (Fig 3). Unfortunately, the amount and also the location of the precipitation were not well predicted, being too far from the place of the event.

The amount of precipitation over the Danubian basin using 3D-VAR scheme is much higher than in the operational model. The *3d-var* experiments gave more than 10 mm in 24h, over a large area, and near the Danube are about 30 mm. There are also three small areas with higher precipitation (more than 50 mm), but farther than the real place of the rainfall. For the *3dvar ARP* set, the area with 10-30 mm precipitation, is more limited, but the location and the maximum value are closer to reality. In *3dvar TLS* experiments the area of big rainfall is well predicted, but the maximum is located too much to east. (Fig 3).

The main difference between the two models (in dynamical adaptation and with data assimilation) appears starting with this run. It was the first signal for the further event. Comparing the experiments with 3D-VAR data assimilation scheme, we can say that the closest forecast to reality was the one using ARPEGE files as lateral boundary conditions, and data from the Hungarian Meteorological Service.

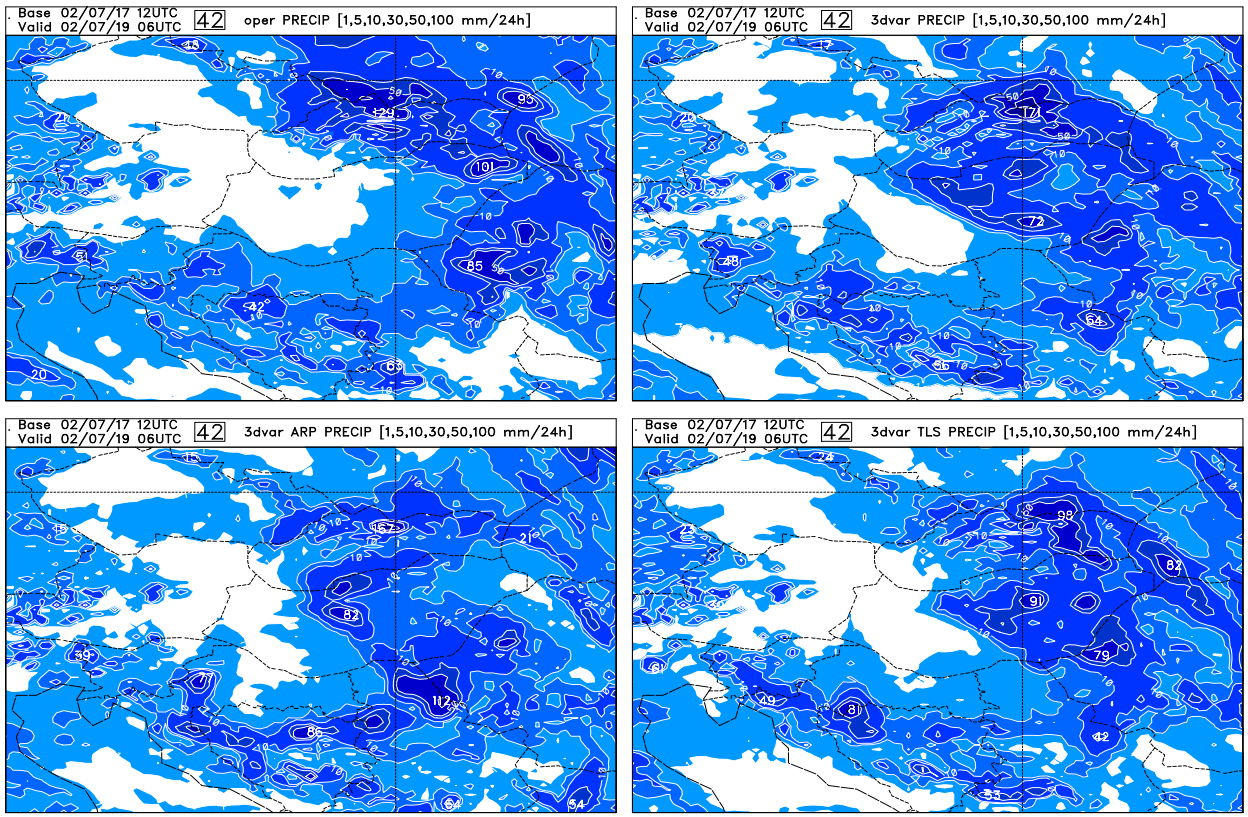

Figure 3 : The 24h precipitation forecasts of the model in dynamical adaptation (*oper*) and using 3D-VAR scheme with different data and LBC files (*3dvar*, *3dvar ARP*, *3dvar TLS*) between 18.07 06 UTC - 19.07 06 UTC, from 17.07 12 UTC run"

18.07 00 UTC run

This last run is the nearest one to the moment of the real event. The operational model still did not give any sign about the future event. One can see that the amount of predicted precipitation by the operational model is still too small (less than 10 mm in 24h), over almost the entire country (Fig 4).

The precipitation forecast of *3dvar* experiments have a good location generally, but too much extended in the south (area with more than 50 mm in 24h). The quantity of rainfall (almost 170 mm) is twice bigger than in reality. Compared to the real measurements, the forecast of *3dvar TLS* set shows the area of heavy rain, in the northern part of Hungary (so it is too high), and an overestimation of the quantity of precipitation (a maximum around 133 mm in 24h). The model with 3D-VAR scheme and ARPEGE files as LBC (*3dvar ARP*), have two small areas with more than 100 mm, and the place of large precipitation is well predicted. Indeed the maximum value of measured rainfall was about 73 mm in 24h, but we can consider that the predicted amount is acceptable in reasonable limits (Fig 4).

As a conclusion from this run, we can say that the operational model, even with 6 hours before the event was not able to predict any features of the phenomenon. All the experiments with data assimilation forecasted large quantity of precipitation. Among these the *3dvar ARP* set was the closest one to reality. (Alexandru [1], 2003).

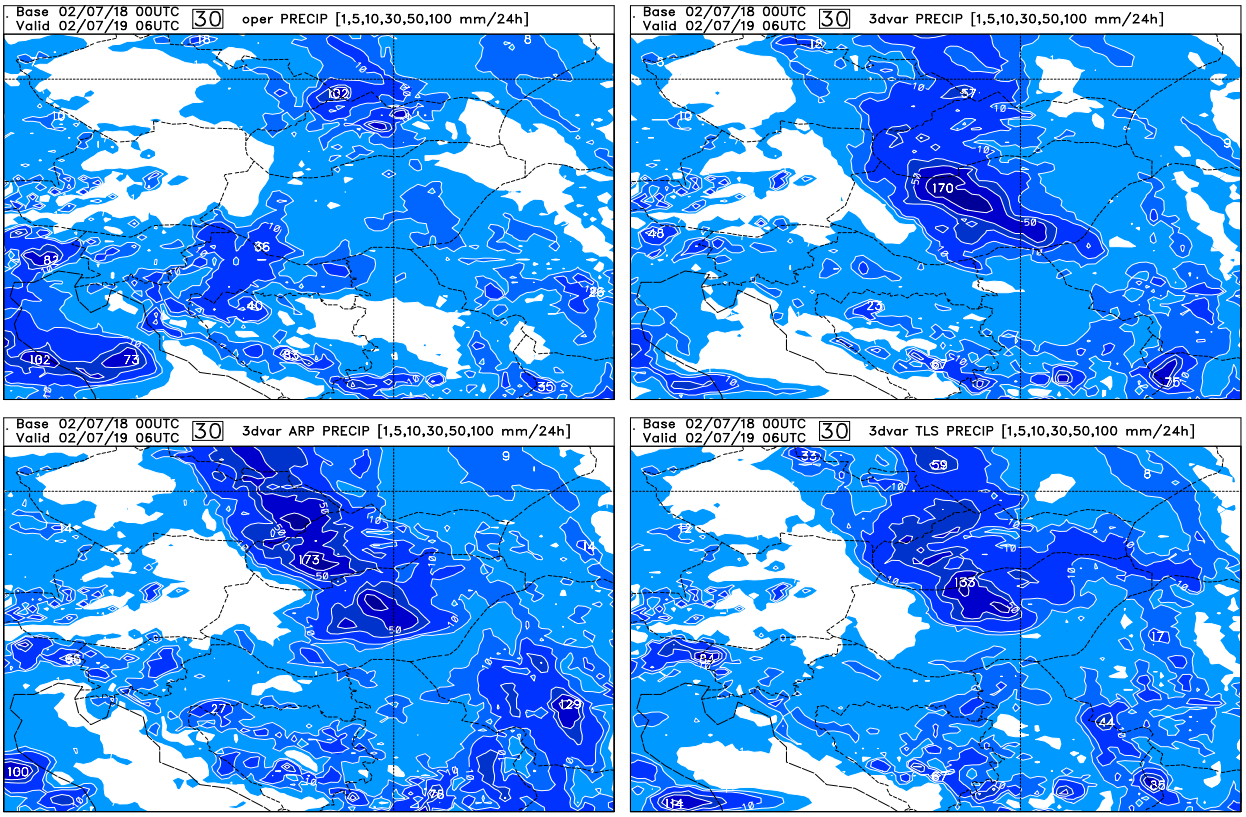

Figure 4 : The 24h precipitation forecasts of the model in dynamical adaptation ("oper") and using 3D-VAR scheme with different data and LBC files ("3dvar", "3dvar ARP", "3dvar TLS") between 18.07 06 UTC - 19.07 06 UTC, from 18.07 00 UTC run"

For all 3D-VAR experiments we plotted also maps with the temperature increments (3dvar analysis - first guess), for two levels: 15 (around 500 hPa) and 24 (around 750 hPa). Figure 5 shows only the increments for *3dvar* experiments, for the entire domain of ALADIN/Hungary model, including also the extension zone. The most worrying feature of the increments is the way that they are looking near the boundaries of the domain. It appears that they are bi-periodic. For the future, we have to find out a solution for this problem, because some spurious features could appear near to the lateral boundaries.

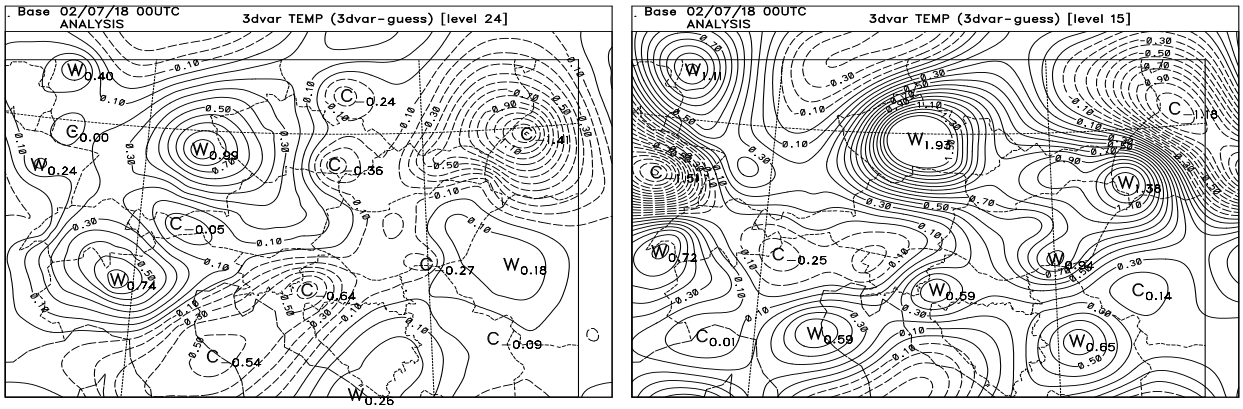

Figure 5 : The temperature increments at levels 15 and 24 for the *3dvar* experiments from 18.07 00 UTC run

The impact of observations over forecast

Working at this case study, we tried to understand how the observations influence the amount and location of precipitation, and especially which one. So we run some experiments which are similar with *3dvar* set, except that we used only SYNOP or TEMP observations available at HMS. Afterwards we removed gradually the closest TEMP stations to Hungary, then the observations between 10-26 degree longitude (remaining around 5-6 stations in the western part of the domain), and finally, the last experiments were performed using only one station in the assimilation cycle.

These experiments showed that using only SYNOP data, the precipitation forecast is overestimated and the location is not well predicted. Compared to *3dvar* results, the experiments when we assimilated TEMP observations gave a better location of precipitation and with reasonable quantities over the Danubian Basin. But also, some maximums appear in the south-eastern part of Hungary, with very big values. As we used less and less data near to Hungary the maximum of precipitation is decreasing gradually and it is moving to east.

These experiments performed only with SYNOP or TEMP data showed for this case that it is important to use observations from surface and upperair, and also the location of the data to be as close as possible to the area of interest.

Conclusions

The results of the ALADIN/Hungary model, using data assimilation for a case from the 17-18th of July 2002 were described in this report. The operational model (in dynamical adaptation) did not forecast the heavy rainfall which happened in the Danubian Basin. We tried to see how the assimilation of observations can change the actual forecast. For these experiments we used two different sets of data (from Hungarian Meteorological Service and Météo-France), and different lateral boundary conditions files (from ARPEGE and ALADIN/LACE models).

The 17.07 00 UTC run did not show any indication about the large quantity of precipitation to be occurred. All the experiments gave around 10 mm in 24h, which is a strong underestimation, compared to real values as 51 mm, or 42 mm.

The operational forecast from 17.07 12 UTC run did not predict any precipitation in the Danubian Basin. All three sets of experiments with 3D-VAR data assimilation scheme forecasted heavy rainfall in the central part of Hungary. The best location and quantity were given by the *3dvar ARP* set, with ARPEGE files as lateral boundary conditions, and data from Hungarian Meteorological Service. This run indicated the first signal about the future occurrence.

The experiments with 3D-VAR scheme from 18.07 00 UTC run gave a good forecast of the event, compared to the operational model. When ALADIN/LACE files were used as lateral boundary conditions (*3dvar* and *3dvar TLS*), the amount of precipitation seems to be overestimated (with maximum values as 170 mm and 133 mm, in 24h). The location of rainfall is better estimated, when the ARPEGE LBC files were used (*3dvar ARP*). The quantity (around 100 mm in 24h) is bigger than the real measurements, but it is acceptable. From the point of view of the forecasters, this run would not help them in elaborating a new forecast, because the time when the new information became available, was too late.

The experiments performed only with SYNOP or TEMP data showed that we cannot identify a set of observations, which are uniquely responsible for the improved prediction of the rainfall event. The most important features for the forecast are coming from the upperair observations. For this case, it is better to use observations from surface and upperair. As we removed more and more data near to Hungary, the results became more unrealistic. So also the location of the data has to be as close as possible to the area of interest, for this case.

As we could see the 3D-VAR data assimilation scheme helped to improve the forecast of the model. The amount of precipitation was significant, compared to what the operational model predicted. The next step will be to study a case when the model in dynamical adaptation had a good forecast, to be sure that the 3D-VAR scheme does not deteriorate the good features.

References

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