3D-VAR data assimilation experiments for the double-nested limited area model ALADIN/Hungary

Steluţa Alexandru
National Institute of Meteorology and Hydrology
Sos. Bucureşti-Ploieşti 97, 71552, Bucharest, Romania
tel. +402 1 2303116, fax +402 1 2303143
e-mail: steluta@meteo.inmh.ro

1 Introduction

The experiments with 3D-VAR data assimilation scheme were performed with the ALADIN/Hungary model, which is a *double-nested limited area model.* This means that the boundary conditions of the model are provided by another limited area model (ALADIN/LACE), which has a bigger domain, and a lower resolution. At his turn, ALADIN/LACE model is driven by a global model (ARPEGE).

The paper is organized as follows. A description of the experiments performed with 3D-VAR scheme and of the results is presented in section 2. Conclusions and discussion follow in section 3.

2 Experiments and results

The 3D-VAR data assimilation scheme for ALADIN/Hungary model consists in minimizing a cost-function. This function is given by a sum of two terms: the background term (J_b), measures the fit of the analysis to the background (usually, the 6h forecast from the previous integration of the model), the observation term (J_o) measures the fit of the analysis to observation. (Horányi, 2003).

For the observation term of the cost function (J_o) only SYNOP and TEMP observations were considered, and the standard NMC statistics for the background term (J_b). The NMC (National Meteorological Center) method estimates the background error statistics using a set of differences between forecasts valid at the same time, but at different ranges (usually 36h - 12h differences). (Parrish and Derber, 1992).

The ALADIN model is using the digital filter initialization (DFI) to provide a filtered state valid at the initial time, starting from the analysis.

It was was found that the classical DFI might destroy some useful signals of the 3D-VAR increments (Dziedzic, 2000). Therefore, it was proposed to test the incremental digital filter initialization (IDFI), when it is assumed that the first-guess is already balanced and the analysis increment (the difference between the analysis and the first-guess) should be filtered.

In the experiments with 3D-VAR scheme for the ALADIN/Hungary model, two lateral boundary treatments were applied in cycling and in production: time-consistency and space-consistency. The time-consistency means that the lateral boundary data are coming from the same run of the coupling model, thus the information is consistent in time (the initial file is 3D-VAR analysis, and the first two lateral boundary conditions (LBC) files are coming from ALADIN/LACE model).

The space-consistency means that the first two LBC files are not coming from the same integration of the model (the first LBC file is identical with the initial file, which is the 3D-VAR analysis). The information is consistent in space. (Široká, 2001).

As evaluation tools for all the experiments, simple statistical measures (RMSE, BIAS) and diagnostic measures (time-evolution of the fields, at different levels) were used. For a subjective evaluation, maps with the mean sea level pressure increments and with the representation of different fields were drawn.

The first set of experiments was performed for one week (25.02.2002 - 02.03.2002), using in cycling the first-guess (the 6h forecast from the previous integration), obtained with the ALADIN/LACE LBC files from the assimilation cycle, in time/space consistency, and in production the operational ALADIN/LACE LBC files were used for 24h forecast. Both in cycling and in production, digital filter initialization was applied.

Figure 1 shows that 3D-VAR analysis fits closer to the observations, for all the fields, which is expected. After 6h forecast 3D-VAR is losing from the initial improvement, but not for all levels. After 24h integration, the scores are the same (not shown). Time-consistency seems to give a better forecast so far. (Alexandru [1], 2002).

One explanation of this loss of improvement is that for the 3D-VAR forecast, the same TEMP observations are used, as the global model ARPEGE. So the new information is coming only from the SYNOP data, which is not very helpful, because 3D-VAR is acting for the upper-air fields. Also, the 6h forecast is compared with the data from 06 UTC, respectively 18 UTC. And for these moments of time, the number of observations is much smaller than at 00 UTC and 12 UTC.

In the second set of experiments, different initialization methods (DFI, IDFI, and no initialization) were tested, for the same period as the previous one. The time evolution of the mean sea level pressure was checked during the 6h integration in cycling, for six different points on the domain (three are over the mountains, one is in the middle of the domain, the others are

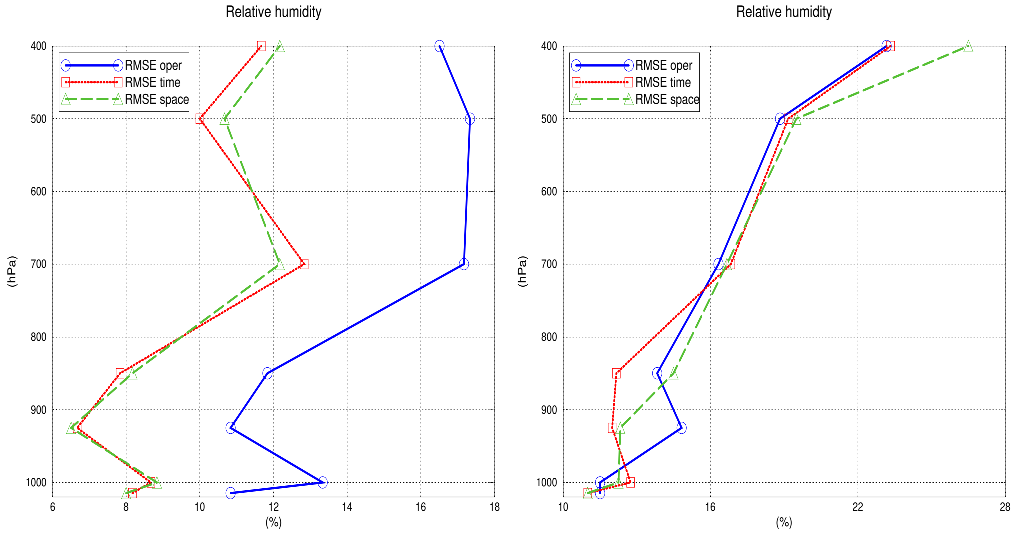

Figure 1: The vertical profile of RMSE of the operational analysis (*oper*), and using 3D-VAR scheme in time-consistency (*time*), and space-consistency (*space*), (left), and after 6h integration (right)

in the upper-right and bottom-left corners of the domain), for 02.03.2002 00 UTC (Figure 2). One can see large oscillations for some points (all three are over the mountains), when DFI was used. For other points the shapes are rather smooth, comparing with those with IDFI and no initialization, which look more irregular. These scores emphasize that for 3D-VAR experiments we have to use digital filter initialization in cycling.

The time evolution of the mean sea level pressure was checked during the 6h integration in production (not shown), for the operational forecast and using 3D-VAR scheme with different initialization methods in cycling and in production. It seems that the fields are in balance, when DFI was used in production (for the operational model, and also with 3D-VAR scheme). Without initialization, the noise appears especially for the first time-steps. This confirms that we need to apply digital filter initialization also in production.

The third set of experiments was made to see the implications of the double-nesting on the 3D-VAR results. It was realized for one month's period (25.02.2002 - 25.03.2002), using as LBC files the ALADIN/LACE and ARPEGE files (from the assimilation cycle), in space-consistency. In cycling, the 3D-VAR analysis, and ALADIN/LACE, respectively ARPEGE analysis were used as LBC files for the first-guess. Digital filter initialization was applied both in cycling and in production.

Figure 3 shows the verification of 6h forecast for relative humidity and zonal wind. The forecast using 3D-VAR scheme looks slightly better than in dynamical adaptation, for zonal wind, at almost all the upper-levels, and for relative humidity, especially near the surface. One can see that the choice of the LBC files in cycling (from the global model or from the limited

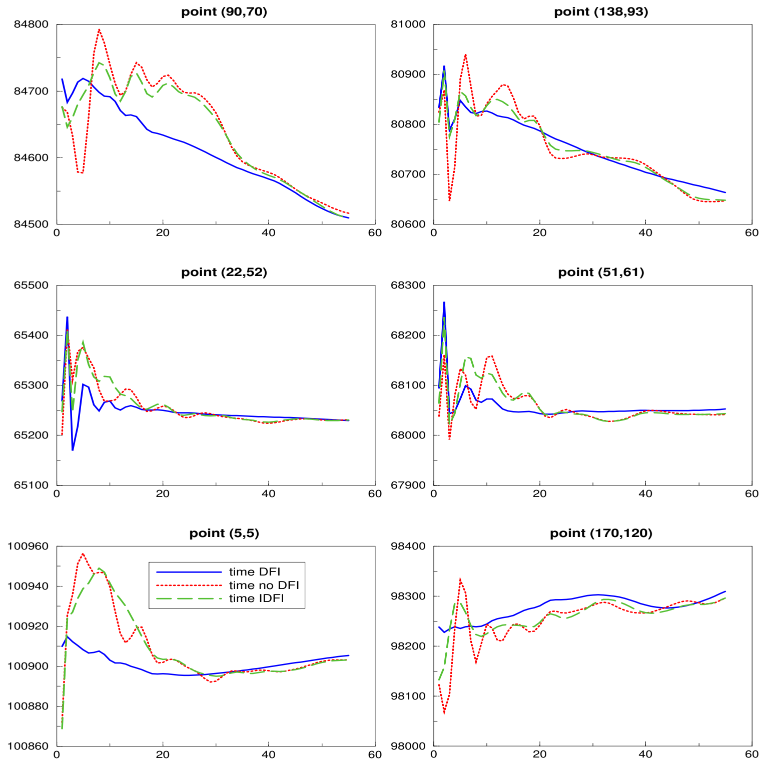

Figure 2: The time evolution of the mean sea level pressure in cycling

area model) is not so important. In the picture, the fields with the largest differences are presented. For other fields (temperature, geopotential, wind speed and direction), the scores are almost neutral. (Alexandru [2], 2002).

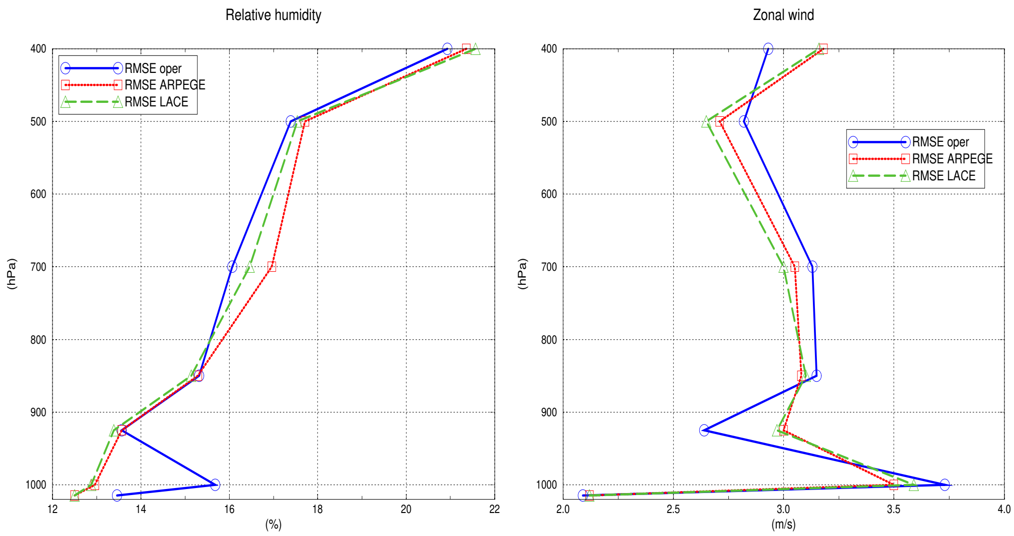

Figure 3: The vertical profile of RMSE for the operational forecast (*oper*), and using 3D-VAR scheme, with ALADIN/LACE (*LACE*) and ARPEGE LBC files (*ARPEGE*)

Other verification tools showed small differences when the two lateral boundary treatments were used. Looking on the maps with the representation of some meteorological fields, the differences for the experiments with 3D-VAR scheme and different LBC files are not visible.

3 Conclusions

After all these experiments, we can conclude that the 3D-VAR analysis fits closer to the observations, as we expected. But after 6h, the forecast is losing from the initial improvement, for some levels. Probably because the new information for the assimilation cycle is provided only by the surface data. In the upper-air, the same data were used for the global model. Future experiments using other types of data (aircraft or satellite data) are expected to improve the 3D-VAR results.

Comparing the two lateral boundary treatments, one can say that, the time consistency seems to give a better forecast so far.

Digital filter initialization need to be applied in 3D-VAR cycling, and also in production, to filter the noise that appear.

From the last set of experiments, it can be seen that the choice of the lateral boundary coupling files in cycling (from the global model or limited area model) is not important.

These first experiments with 3D-VAR scheme for ALADIN/Hungary model were performed to select from many options that we have (different first-guesses, LBC files, initialization methods, lateral boundary treatments), the best ones, to be able to study 3D-VAR scheme more in detail. Future work will rely on the case studies, with some interesting meteorological situations.

References

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