ECMWF Feature article

from Newsletter Number 119 – Spring 2009

METEOROLOGY

Use of ECMWF lateral boundary conditions and surface assimilation for the operational ALADIN model in Hungary

www.ecmwf.int/en/about/news-centre/media-resources

doi:10.21957/tmd053pm9g

This article appeared in the Meteorology section of ECMWF Newsletter No. 119 – Spring 2009, pp. 29-35.

Use of ECMWF lateral boundary conditions and surface assimilation for the operational ALADIN model in Hungary

Gergely Bölöni, László Kullmann, András Horányi
Hungarian Meteorological Service (OMSZ), Budapest

Since October 2008 ECMWF data is being used to provide the lateral boundary conditions (LBCs) for the operational ALADIN limited area model run at the Hungarian Meteorological Service (OMSZ). This model was originally coupled with the ARPEGE French global model for its LBCs. In the last two years several attempts have been made to use LBC data from the ECMWF IFS (Integrated Forecast System) in an experimental framework, i.e. in a non-real-time manner (*Kertész,* 2007). These investigations were mostly done as part of the ECMWF "SPFRCOUP" Special Project led by Météo-France with the participation of several ALADIN partners. Results suggested a potential improvement of the ALADIN forecasts when using LBC data from the IFS model.

Following a request from OMSZ, ECMWF started to provide LBC data for Hungary on a daily basis for pre-operational testing in May 2008. This made it possible to run real-time parallel tests at OMSZ to compare the forecast accuracy using ARPEGE and ECMWF LBC data. At the same time the optimal interpolation surface assimilation scheme was also tested. The parallel tests showed that ALADIN forecasts using ECMWF LBC data had a better performance and this led to the operational use of ECMWF LBC data since the beginning of October 2008.

This article will briefly describe the most important technicalities associated with the preparation of LBC data for the ALADIN model from the ECMWF global fields. Results of the parallel tests using ECMWF LBC data, including various options for the use of surface initial conditions, will be presented and recent experience of the operational use of the ECMWF LBC data will be discussed.

Preparation of the ECMWF LBC data for ALADIN

The preparation of LBC data for ALADIN from ECMWF forecast information consists of running appropriate configurations of the ARPEGE/ALADIN software. Initially it is necessary to prepare a global dataset using the ARPEGE file format (ARPEGE configuration 901). Then the global ARPEGE file needs to be interpolated to the limited area (ARPEGE/ALADIN configuration e927). Besides the format change, the first step includes an adjustment of the surface fields to convert the ECMWF (TESSEL surface scheme) surface variables into those used in ARPEGE/ALADIN (ISBA surface scheme). This is necessary because the surface schemes in the two global models are rather different, e.g. they have different number of surface layers. Refer to *Saez* (2008), *Ivatek-Sahdan & Bölöni* (2005) and *Kertész* (2006) for more detailed technical descriptions of the ALADIN LBC data preparation from ECMWF global data.

ECMWF started to run the abovementioned applications for OMSZ in May 2008 and to disseminate the LBC files to our service. Following approval of the ECMWF Technical Advisory Committee, the Centre has undertaken the regular running of this application while its maintenance (preparation of the executables, testing of changes when the resolution of the ECMWF LBC data is increased, etc.) remains an OMSZ responsibility. It is worth noting that the same ECMWF LBC data prepared for Hungary can be used by all RC LACE (Regional Cooperation for Limited Area Modelling in Central Europe) countries as either an alternative or as a backup of the ARPEGE LBC data. Both the Czech Hydrometeorological Institute (CHMI) and the Environmental Agency of the Republic of Slovenia (ARSO) have already taken up this option.

Use of ECMWF LBC data in an experimental phase

During the summer of 2008 tests were carried out using the pre-operational real-time LBC data from ECMWF. The main purpose was to investigate the impact of using ECMWF instead of ARPEGE as LBC data both in the assimilation cycle and in the production forecasts. Due to data availability constraints, our ALADIN integrations used LBC files from the previous ECMWF BC run, that is, with a lag of 6 hours.

The experiments included local atmospheric initial conditions provided by a three-dimensional variational (3D-Var) data assimilation in the same way as in the operational model at that time (*Randriamampianina,* 2006 and *Bölöni,* 2006). On the other hand several strategies were tried for the use of surface initial

doi:10.21957/tmd053pm9g

conditions. To explain the necessity of tackling the issue of surface ICs, we have to mention that at the time of these experiments the operational ALADIN model in Hungary did not include a local surface assimilation but used interpolated ARPEGE analysis to initialize the surface fields. A local OI surface assimilation was tested since the beginning of 2008 but still in an ARPEGE LBC framework. In order to define the best possible operational setup a natural idea was to perform the experiments with ECMWF LBC data including various options for the use of surface ICs. Based on these considerations the following experiments were run:

- ***ECM1.*** Surface initial conditions and lateral boundary conditions from ECMWF.
- ***ECM2.*** Surface initial conditions from ARPEGE and lateral boundary conditions from ECMWF.
- ***ECM3.*** Local surface assimilation (OI) and lateral boundary conditions from ECMWF.

These three experiments were compared with our actual operational run at that time, using ARPEGE LBCs both in the assimilation cycle and the production forecasts. As mentioned earlier, no local surface assimilation was included in this control run (HUN) but the interpolated ARPEGE analysis was used as surface IC. Verification of the forecasts was carried out against SYNOP and TEMP observations over the whole operational model domain (Figure 1). The experiments and the obtained results will now be discussed.

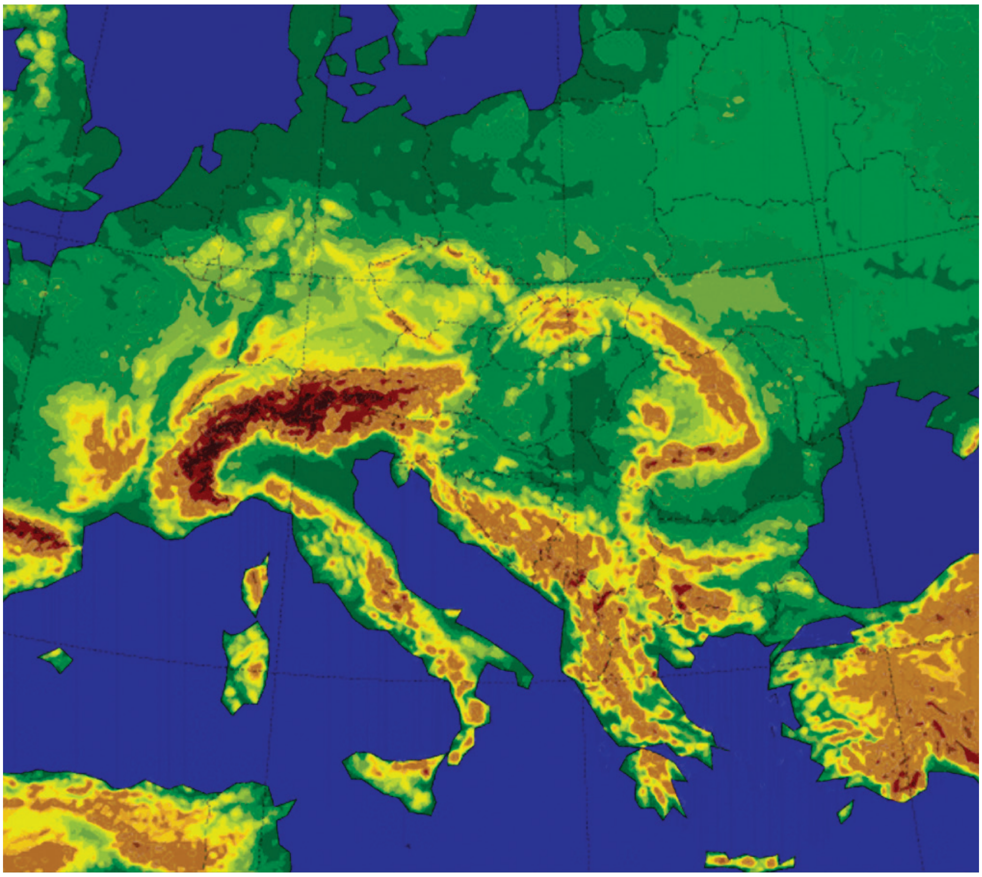

Figure 1 The operational ALADIN domain and its orography at OMSZ.

doi:10.21957/tmd053pm9g

Surface initial conditions and lateral boundary conditions from ECMWF (ECM1)

In this experiment all ARPEGE fields were replaced by ECMWF fields. This means that ECMWF fields were used both for surface ICs and LBCs. In all other aspects the experiment is the same as HUN. The parallel test was run for the period 17 to 29 July 2008. Some results are shown in Figure 2 in terms of the bias and root mean square error (RMSE).

Verification results reflect a degradation of the forecast for ECM1 compared to HUN near the surface. This degradation is most pronounced for 2-metre temperature and relative humidity as illustrated in Figures 2a and 2b. A similar feature was found in our earlier tests (*Kertész,* 2007) and the degradation is, in our understanding, purely due to the surface ICs. This is consistent with the fact that far from the surface (above 850 hPa) ECM1 performs better than HUN for most of the variables. To illustrate this point, results for the 700 hPa geopotential are given in Figure 2c.

The reason for the inferior results near the surface when using surface ICs generated from ECMWF fields is most likely associated with the different surface schemes applied in ARPEGE and ECMWF (ISBA and TESSEL respectively). The surface schemes differ in several aspects and a detailed investigation would be needed to identify the origin of the problem and to improve configuration 901 of the ARPEGE/ALADIN software in this aspect. It is worth noting that Figure 2 shows results from the 00 UTC runs but results from the 12 UTC runs are very similar.

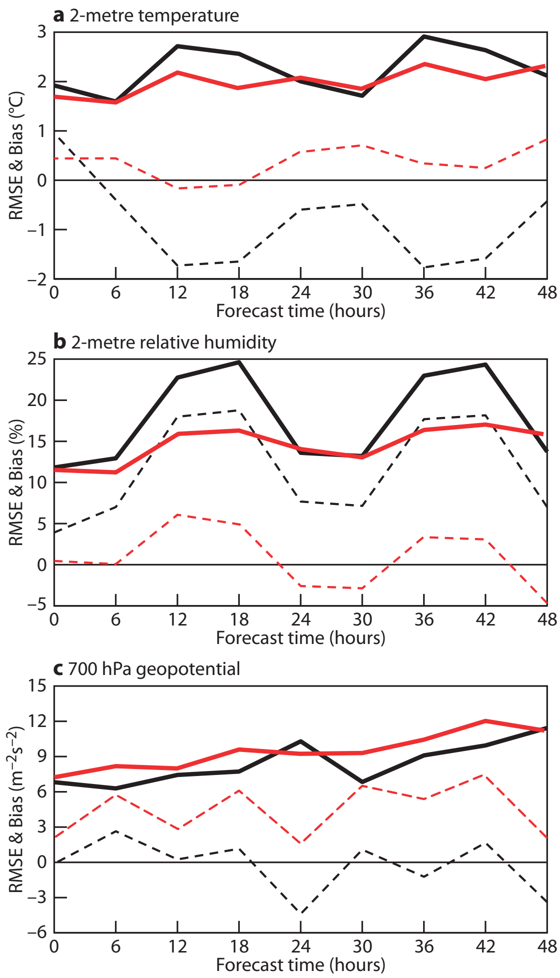

Figure 2 RMSE (full lines) and bias (dashed lines) for (a) 2-metre temperature, (b) 2-metre relative humidity and (c) 700 hPa geopotential for experiments ECM1 (black lines) and HUN (red lines) for 17 to 29 July 2008.

doi:10.21957/tmd053pm9g

Surface initial conditions from ARPEGE and lateral boundary conditions from ECMWF (ECM2)

This experiment is the same as ECM1 except that it uses surface ICs from ARPEGE as in HUN. In other words, this experiment differs from HUN only in the use of the LBCs and not in the use of the ICs. The experiment was run for the period 1 to 14 August 2008. Figure 3 shows some results from these experiments.

Results near the surface are rather neutral for most of the parameters, though a small improvement in RMSE for 2-metre temperature bias and mean sea level pressure can be seen in Figures 3a and 3b. Higher in the atmosphere ECM2 has a slightly smaller error than HUN for most of the variables. This is illustrated by the results for 700 hPa temperature and relative humidity that are shown in Figures 3c and 3d. Results based on the 12 UTC runs are again very similar to those shown for 00 UTC.

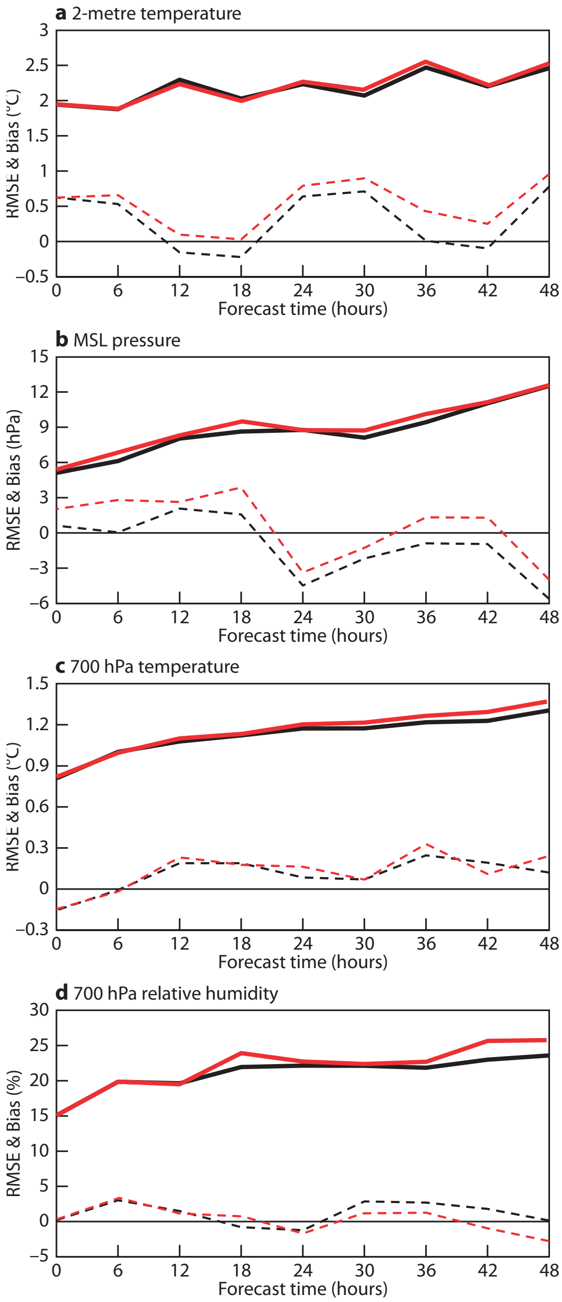

Figure 3 RMSE (full lines) and bias (dashed lines) for (a) 2-metre temperature, (b) mean sea level pressure, (c) 700 hPa temperature and (d) 700 hPa relative humidity for experiments ECM2 (black lines) and HUN (red lines) for 1 to 14 August 2008.(red lines) for 17 to 29 July 2008.

Optimal interpolation (OI) surface assimilation and lateral boundary conditions from ECMWF (ECM3)

ECM3 differs from the other two experiments in the treatment of surface ICs, namely by running a local OI assimilation for the surface instead of using interpolated ARPEGE or ECMWF analysis fields.

Before carrying out the two LBC tests already described (i.e. ECM1 and ECM2), the local surface assimilation was found to improve the forecast at 2 metres and so a decision was taken to implement it operationally. However, before this operational implementation, we wanted to repeat the surface assimilation test using LBCs from ECMWF instead of ARPEGE to see the interaction of both modifications compared to the operational run by that time (HUN). Some results are shown in Figure 4.

Results from this test show an improvement in the 2-metre forecast (Figures 4a and 4b); this is mostly due to the surface assimilation. In addition, due mainly to the use of LBCs from ECMWF, there are also improvements higher in the atmosphere (Figures 4c and 4d). One should notice, however, that the bias in 2-metre relative humidity is degraded during the day (forecast ranges +12 hours, +36 hours in the 00 UTC runs). This seems to be a shortcoming of the local surface assimilation and certainly needs further investigation. At the same time the RMSE of 2-metre relative humidity has improved.

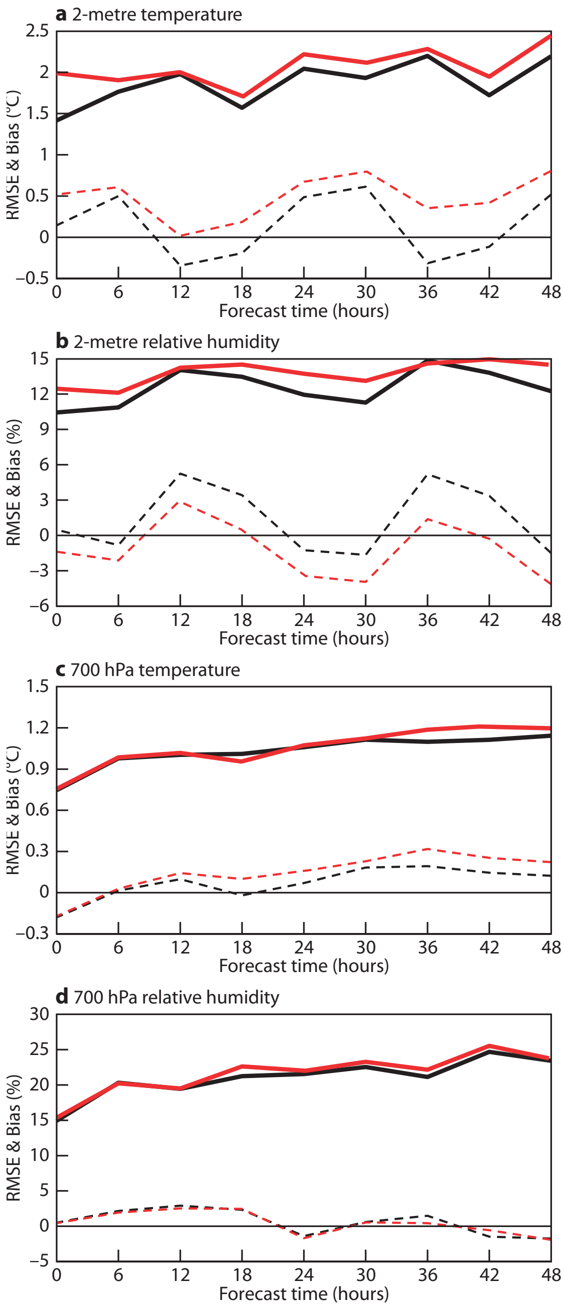

Figure 4 RMSE (full lines) and bias (dashed lines) for (a) 2-metre temperature, (b) 2-metre relative humidity, (c) 700 hPa temperature and (d) 700 hPa relative humidity for experiments ECM3 (black lines) and HUN (red lines) for 22 August to 7 September 2008.

doi:10.21957/tmd053pm9g

Use of ECMWF LBC data in the fully operational context

Based on the parallel tests, the operational ALADIN model in Hungary has been coupled with ECMWF LBC data since the beginning of October 2008. We now summarize the performance of the operational model during the autumn and winter of 2008. It should be noted, however, that it is not easy to choose a good measure of performance, as we have not been running a reference model coupled with ARPEGE LBCs since the operational switch in October. Another consideration is that the change in the LBC forcing was introduced together with the local surface assimilation; therefore it is not easy to distinguish between the impact of these two elements. Nevertheless, we have tried to find signals of the LBC change in our objective verification scores which are now described.

Temporal evolution of the bias

One approach is to plot the time evolution of bias and RMSE scores for a long period (1 May 2008 to 7 January 2009) and see if a noticeable change appears when the operational changes are implemented.

In Figure 5 the 2-metre temperature bias scores are shown for the 24-hour forecasts. These results show a pronounced bias reduction around mid-September - values near to zero till mid-November and then slightly increasing again with an opposite sign. Thus, for these scores, the LBC change realised in October does not show up clearly. We can also state that the dependence of the bias on the actual weather was stronger than the dependence on the changes in the operational suite in this period. This statement is also strengthened by the fact that the bias of the ECMWF model (T799 deterministic) changed in a similar way to that of the ALADIN model. One might also notice that the ECMWF and ALADIN results are closer in the second half of the period (i.e. when the LBC switch in ALADIN was implemented). However this fact does not match the exact date of the switch. A last consideration is that, beside the LBC change, the 2-metre scores shown in Figure 5 might also reflect the other component of the operational change, namely the implementation of the OI surface assimilation.

In order to analyze the impact of the LBC change more independently from that of the surface assimilation we show the bias time evolutions for 700 hPa temperature and relative humidity in Figure 6 for a somewhat shorter period (September – October 2008). It can be seen that for both parameters the bias runs a bit closer to zero in the second half of the period, which might be due to the use of new LBC data. However, one should also notice that the temperature bias is significantly increased by the end of October, and even grew larger than earlier in the period. Therefore, we cannot state firmly that the change to using ECMWF LBCs is clearly visible in the time evolution of bias scores within this period.

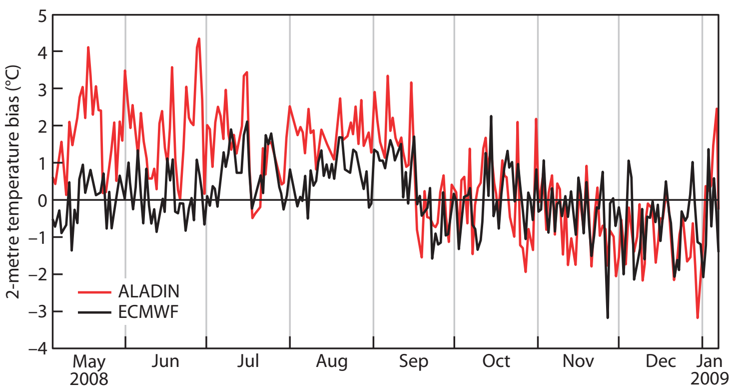

Figure 5 Temporal evolution of the 2-metre temperature bias for the operational ALADIN model and the deterministic ECMWF model (T799) for Hungary for the 24-hour forecasts for 1 May 2008 to 7 January 2009.

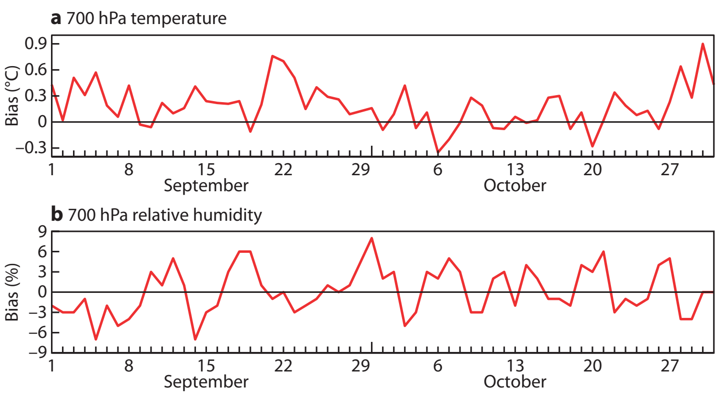

Figure 6 Temporal evolution of the bias of (a) temperature and (b) relative humidity at 700 hPa for the operational ALADIN model in Hungary for the 24-hour forecasts for 1 September to 31 October 2008.

Seasonal and monthly averages

Another way of trying to find a signal for the impact of the change in the operational use of LBCs is to compare the average bias for three months (October to December) in 2007 with that for 2008, assuming that a long period behaviour of the weather can be considered as similar in these two consecutive years. Figure 7 compares the bias and RMSE of 2-metre temperature for the two years. One can observe an improvement in the bias in 2008. This may be due to both the OI surface assimilation and the use of ECMWF LBC data. The RMSE scores are rather similar for 2007 and 2008, except the analysis that appears much better for 2008, very probably due to the OI surface assimilation.

A similar comparison was done for higher in the atmosphere. The temperature and relative humidity scores are shown for 850 hPa in Figure 8 for October 2007 and 2008. These scores indicate an improvement for the year 2008, which can possibly be attributed to the use of the ECMWF LBC data but also might come from the fact that October 2008 was more predictable than October 2007 (the relative humidity bias is especially impressive for 2008 being almost zero all over the integration range).

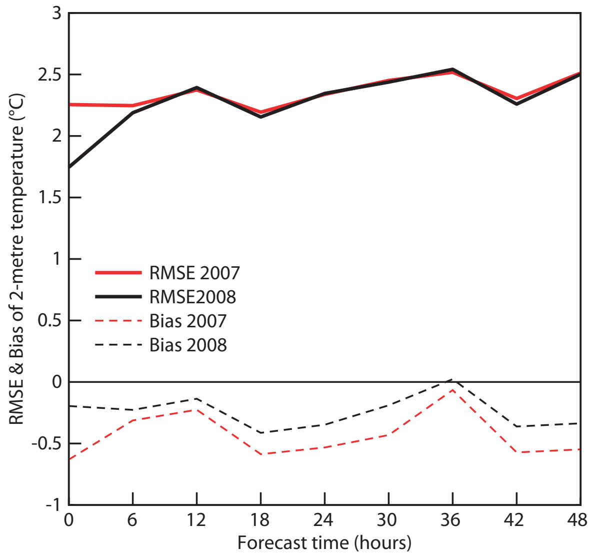

Figure 7 RMSE and bias of the 2-metre temperature for the operational ALADIN model for Hungary for the periods: 1 October 2007 to 10 January 2008 and 1 October 2008 to 10 January 2009.

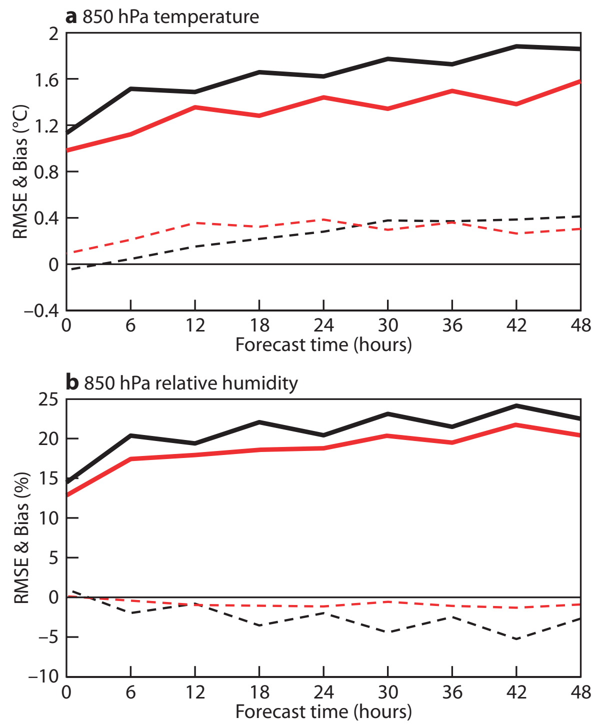

Figure 8 RMSE (full lines) and bias (dashed lines) for (a) temperature and (b) relative humidity at 850 hPa for the operational ALADIN model for Hungary for October 2007 (black lines) and October 2008 (red lines).

doi:10.21957/tmd053pm9g

Concluding remarks and recommendations

The parallel tests of the experimental phase indicate that ALADIN forecasts can be improved by using LBC data from the ECMWF model if a local atmospheric and surface assimilation provides the initial conditions. Following our tests, ECMWF data are, at the moment, not recommended to be used as ICs for the surface because the ALADIN model seems to be very sensitive to the inconsistencies between the TESSEL and ISBA surface physics. This problem might be solved in the framework of the SRNWP Interoperability Programme of EUMETNET. In addition, due to the lagged use of ECMWF LBC data (LBC fields are used from the run 6-hours earlier), we do not recommend the use of ECMWF fields as atmospheric ICs, as in this case 6-hour ECMWF forecasts would be used as ICs for ALADIN (*Kertész,* 2007). The most obvious cure to this problem is to run a local atmospheric analysis within the ALADIN model itself.

The use of ECMWF LBC data together with surface assimilation was implemented operationally in Budapest at the beginning of October due to the promising results found in the parallel tests. In the operational phase we found it rather difficult to show clear signals of improvements in the objective scores due to the fact that a reference forecast using ARPEGE LBC data was not available. However, we found some improvement of the statistical scores computed for the autumn and winter of 2008 compared to those of computed for 2007. A part of this improvement may possibly come from the change in the LBC use.

This investigation has been of great value to the operational activities at OMSZ and many people have contributed to its success. First of all we are very grateful to Iván Mersich (former president of OMSZ) for his anticipation in entering the Boundary Condition Project many years ago in order to keep the possibility for using IFS data as LBCs for the ALADIN model. Thanks are due to the SPFRCOUP Special Project in general and to Claude Fischer and Francois Bouttier from Météo-France in particular for supporting the idea of a Special Project and for the ALADIN partners for taking care of its coordination. In addition the first exploratory work of the use of ECMWF lateral boundary conditions by Sándor Kertész is greatly appreciated. Last, but not least, we are very grateful to ECMWF staff (especially Umberto Modigliani, Alfred Hofstadler, Dominique Lucas and Axel Bonet) for making it possible to carry out the tests described and also for providing the LBC data with a very high reliability in the last 9 months.

Further Reading

Bölöni, G., 2006: Development of a variational data assimilation system for a limited area model at the Hungarian Meteorological Service. *Időjárás,* **110,** 309–329.

Kertész, S., 2006: Preparing ALADIN BCs on ECMWF HPCF. *RC LACE internal Report* (www.rclace.eu/File/private/Local_Documents/ECMWF/sp_bc_gen_v3.pdf).

Kertész, S., 2007: Using T799 IFS initial and boundary conditions in the ALADIN/HU model. *RC LACE Internal Report* (www.rclace.eu/File/Data_Assimilation/2007/ifs_bc_ks_full.pdf).

Randriamampianina, R., 2006: Impact of high resolution satellite observations in the ALADIN/HU model. *Időjárás,* **110,** 329-349.

Saez, P., 2008: Notice d utilisation de la configuration 901 ISBA. *Météo-France Online Documentation* (www.cnrm.meteo.fr/gmapdoc/spip.php?article38).

Ivatek-Sahdan, S. & **G. Bölöni,** 2005: How to prepare IC & LBC from ECMWF EPS members. *RC LACE Internal Report* (www.rclace.eu/File/Public_Manuals/LBC/GB_SIS_ECMWF_IC_and_LBC_4_ALADIN_2005.pdf).