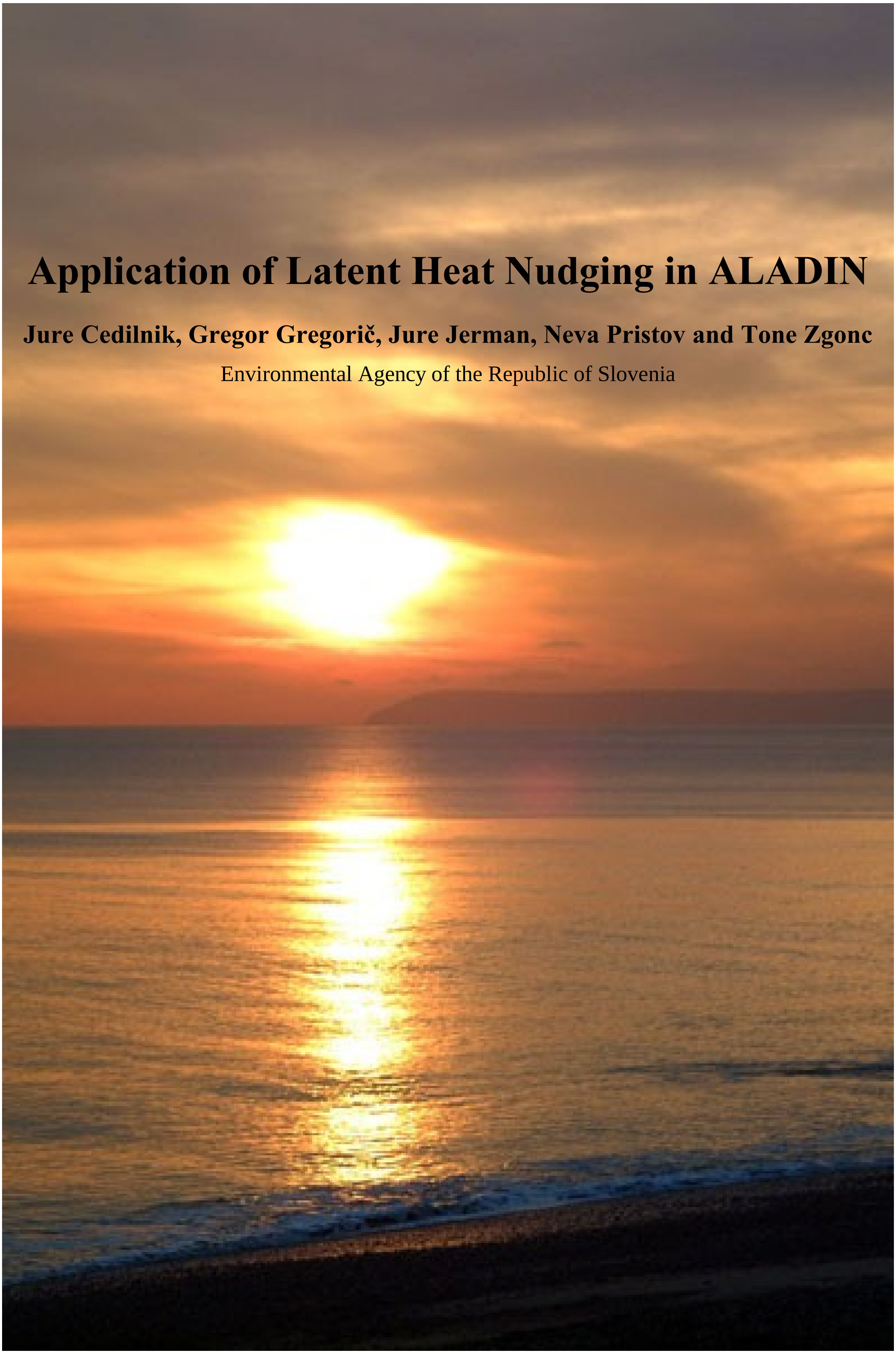

Application of Latent Heat Nudging in ALADIN

Jure Cedilnik, Gregor Gregorič, Jure Jerman, Neva Pristov and Tone Zgonc
Environmental Agency of the Republic of Slovenia

1. Summary

Latent heat nudging (LHN) is a method of forcing a NWP model with measured precipitation rates from radars. The aim is to improve analysis and short-range forecast of precipitations. The general idea of the scheme is to rescale the vertical profiles of latent heating using the ratio of observed and modelled precipitations. LHN is operationally used at the German and UK meteorological services.

A description of such a scheme applied in ALADIN is presented in this paper. The technique has generally a very small positive impact on model forecasts, which seems to last up to a few hours ahead.

2. Latent Heat Nudging procedure

LHN is a procedure where radar measured precipitation rates are used to modify latent heat profiles in the model. Model and measured precipitation rates are used to compute a weighted average according to distance from measurement point to radar. In such a manner a weighted value of precipitation rate is obtained. This weighted average may somehow be treated as precipitation analysis. For grid points far from radar, only the model value is used and closer to radar more stress is put on measured value and less on model. In our case there were three radars used: Fossalon (Italy), Kirbitzkögel (Austria) and Lisca (Slovenia). Weights for computing weighted precipitation values were computed according to the distance from the closest operational radar at the given time (at the time of nudging). The distances from all radars for the points in the model domain can be seen in Figure 1.

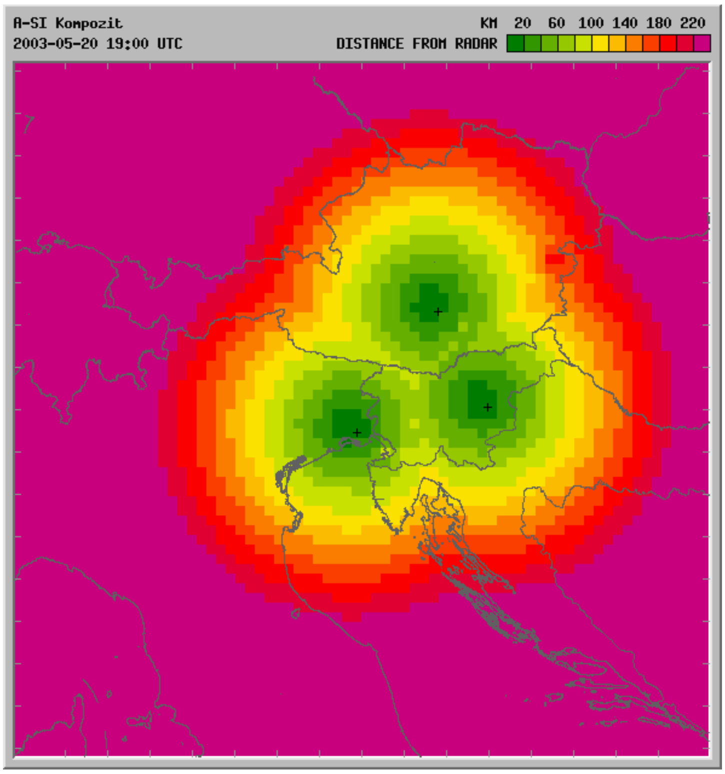

Figure 1 : Distances from three radars in the model domain area. These distances are used to compute weighted values of precipitation rate. The weights fall to zero at a distance of 120 km from the closest radar. In case of precipitation detected by more than one radar, only the value of the closest radar is used.

Radar measured hourly precipitation rates are interpolated in an eight times denser grid than the one used by the model and afterwards aggregated onto the model grid. The distance between two neighbouring grid points in the model grid is 11 km. In case of more radars detecting precipitation at the same grid point, the closest radar is used for computation of the weighted value. Such a weighted value is then used to modify model heating rate profile due to latent heat release.

As mentioned, hourly radar precipitation fields were used as input data for LHN. The fields used at different time-steps in the model were linearly interpolated between two adjacent measurements, in the very same way as coupling fields on the boundaries are interpolated in time.

The value of the weighted average of precipitation rate is:

$$RR_{analysis} = w . RR_{radar} + (1 - w) . RR_{model} \ ,$$

where w is a weight depending on the distance from a radar (shown in Figure 1).

The model heating or cooling profile due to precipitation latent heat release is rescaled by the value obtained with weighted averaging of model and measured precipitation rates (as is described in the expression above). This is done by directly rescaling the temperature tendency profile, but only that part which is connected to latent heat cooling or heating. This is described by next relation:

$$\frac{\partial T}{\partial t}_{LHN} = \frac{\partial T}{\partial t}_{model} \cdot \frac{RR_{analysis}}{RR_{model}}$$

This works fine in cases when there exists precipitation in the model and there is precipitation detected by the radar in the same grid box.

However, in case when only the model is exhibiting precipitation and there is no precipitation detected by any of the radars, the heating rate profile in the model is set to zero.

In a reverse case, when the model is not producing any precipitation and some is detected by a radar, there are generally two possibilities. Either an idealized profile could be used or (as is done in our case) a climatological profile is applied. These profiles were derived from a one year control run of the same model without any precipitation assimilation procedure. Climatological profiles for four representative months are shown in Figure 2. Such a climatological profile is rescaled according to observed precipitation rate before it is applied in the model.

In general, there are two possible uses of LHN technique. One can be to use nudging for hindcasting with the aim of obtaining the best possible precipitation analysis. The more forecast-oriented usage is for nowcasting and very short range forecasting. In a hypothetical situation, a forecaster would, say at 12 UTC (after some precipitation had already occurred), rerun the ALADIN morning run using LHN till 12 UTC and see the impact. After the LHN period, the model is left as it was.

Another way of looking at this is that LHN is a simple initialization of precipitation which could provide a positive impact on scores up to some hours ahead.

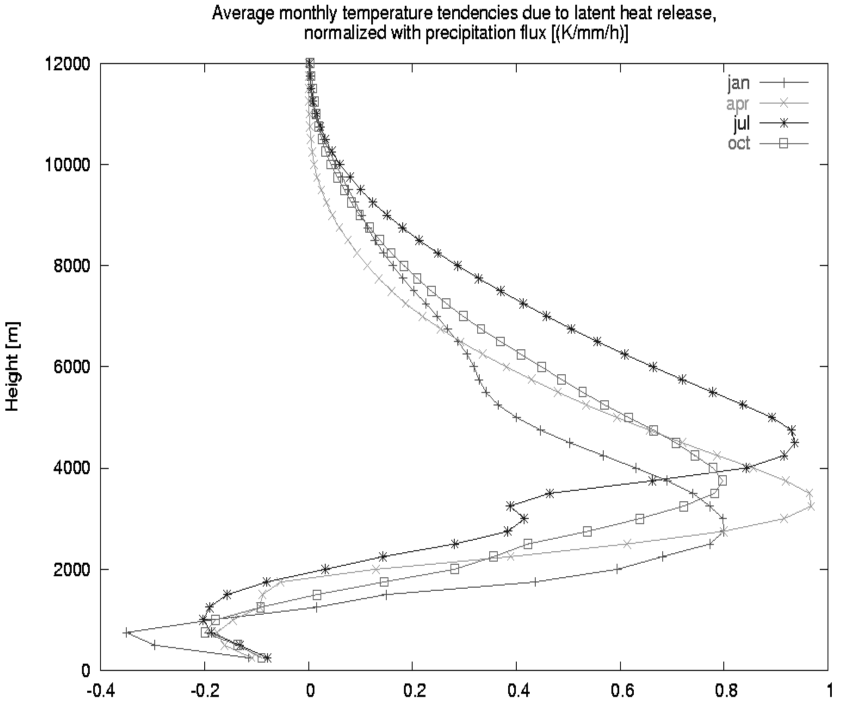

Figure 2 : Averaged monthly heating rate profiles due to latent heat release for 4 different months. These profiles were used as climatological profiles in case of no model precipitation (after being rescaled according to measured precipitation rate).

3. <u>Validation - cases</u>

The assimilation chain was applied to daily model runs throughout year 2002. Year 2002 was warmer than the 1961-1990 average (as is appropriate for climate trends). Precipitation amount in the western and southern parts of Slovenia (which receive more precipitation due to proximity of the coast and orography features) was greater than average. On the other hand there was less than average precipitation in the eastern part (where precipitation depends more on large-scale processes) . This makes year 2002 a suitable choice for tests of LHN.

Results show that LHN may successfully replace typical precipitation patterns that occur in ALADIN (exaggeration of precipitation on the mountain ridges, also due to envelope orography). Such a case of successful use of LHN is presented in Figures 3 and 4. In Figure 3, LHN is applied as in a "climatological" sense (meaning that we are also using radar data, that is yet to be measured from model time point of view), whilst in Figure 4, LHN was only active up to +5 hours of forecast.

However, there are also many cases of deterioration of the forecast. This is especially true in cases when there is less precipitation measured by the radar than there is in the model, but the positioning might be alright. LHN tries to reduce the amount by repositioning the excessive amount of precipitation, but by doing this, it deteriorates the forecast. Figure 5 shows such an example from September 22, 2002. Even when applying LHN till +18 hours of integration time (18 UTC) (Figure 6) (in "climatological" or hindcast mode), the model still wrongly repositions the precipitation amount.

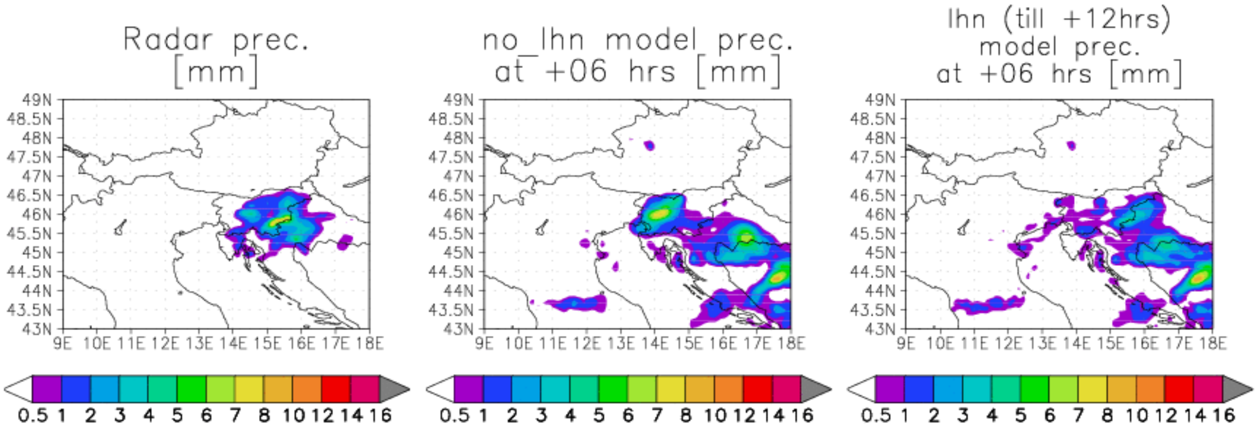

Figure 3 : Hourly accumulations of precipitation between 6 and 5 hours UTC for October 24, 2002. Left figure shows interpolated radar image (combination of three radars), the middle one shows the results of model control run (without LHN) and the image to the right is the LHN run, where nudging was performed till +12 hours of forecast (model was initialised at 00 UTC).

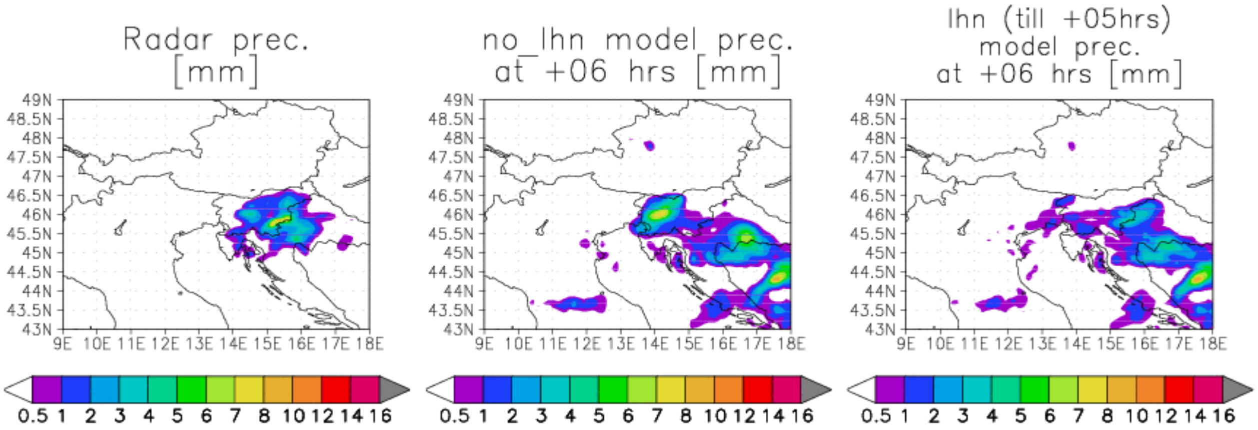

Figure 4 : Same as Figure 3, except that the LHN procedure stops at 5 hours UTC (+5hours of forecast).

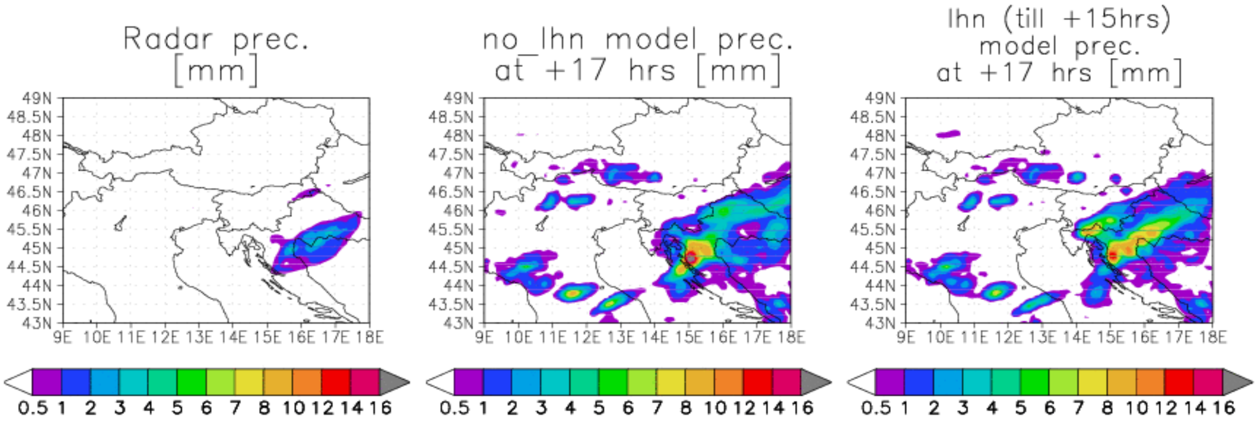

Figure 5 : Same as Figure 3, but for case on September 22, 2002, where nudging procedure was used till +15 hours (15 UTC). The hourly precipitation accumulation shown is between 17 and 16 UTC.

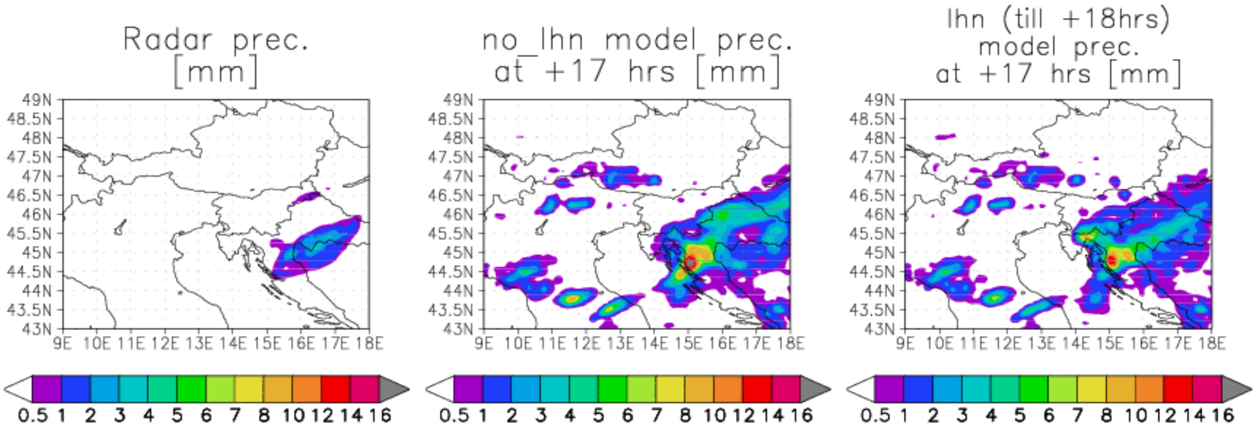

Figure 6 : Same as Figure 5, where nudging procedure was used till +18 hours (18 UTC). The hourly precipitation accumulation shown is between 17 and 16 UTC.

4. Validation - scores

Calculation of average scores (e.g. equitable threat score) is very dependent on the threshold used for computing the scores.

When selecting a high threshold (1mm/h), the results for the first few hours after the end of the nudging process are slightly positive (Figure 7), but when using a 0.1 mm/h threshold the impact of LHN is even negative (Figure 8). This statistical verification was performed on the whole year of data (2002). Rain gauge measurements were used for that purpose. The model was initialised every day at 00 UTC and LHN was performed till +12 hours of forecast.

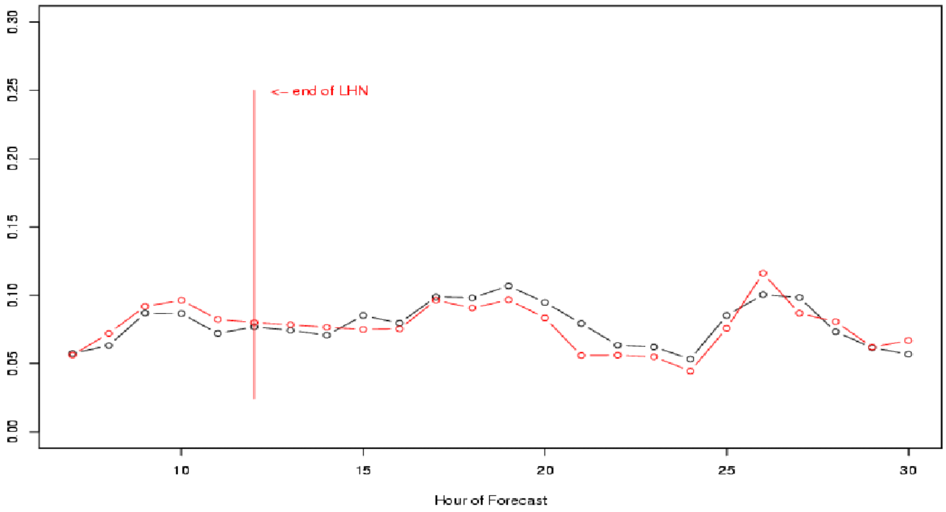

Figure 7 : Equitable threat score for 1 mm/h threshold for entire year 2002. The red line is with LHN, the black one without. The nudging was switched on till +12 hours.

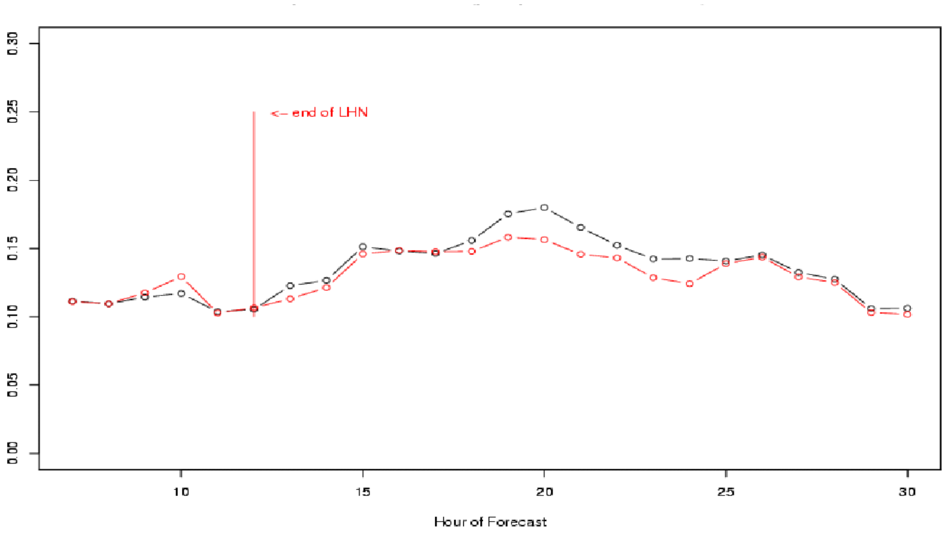

Figure 8 : Same as Figure 7, but for 0.1mm/h threshold.

5. Conclusion

After performing one year of experiments with LHN, we can conclude that there are some rather neutral impacts on precipitation forecast when using LHN.

It seems that LHN can be very strong in repositioning of the spatial pattern of precipitation (but not necessarily correctly). The impact of LHN occurs, when model is producing too much precipitation. In such a case, LHN is not capable of substantially reducing the amount, but is rather trying to move it around. We could say that LHN works better when rain is present in the model and detected by radar than in case when the radar shows (almost) nothing but there is a tendency for (convective) precipitation in the model.

This is confirmed by statistical scores results, where LHN is better with a higher threshold (when computing equitable threat score).

One might assume that LHN is not very suitable for convective processes since they are not resolved at this scale and thus using LHN with a higher resolution model would be much more beneficial. According to the German colleagues (via personal communication at the Bratislava June 2005 ALADIN workshop) the results of LHN are vastly improved when using prognostic cloud water, which is of course not the case in this experiment. They (the German meteorological service) are also using a much more sophisticated LHN technique, where they apply nudging only at the stage of cloud growth.

Another issue is that our domain was not adequately covered by radar observations. This radar "network" of three radars can not really compare to the one of DWD or UK Meteorological Office. The problem of such a small area of domain covered by radars is that the faster moving systems are only for a very brief time subjected to nudging.

CONTENTS

1.Summary.....2

2.Latent Heat Nudging procedure.....2

3.Validation - cases.....4

4.Validation - scores.....6

5.Conclusion.....7