AROME Nowcasting - tool based on a convective scale operational system

RC - LACE stay report

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1. Introduction

The main objective of this study is to investigate the potential of the Latent Heat Nudging technique (LHN) in high resolution simulations using AROME Nowcasting and INCA systems. INCA analysis merges in real time all the available observations of automatic weather stations, radars (five radar stations located at Vienna airport, near city of Salzburg, near the city of Innsbruck, in southern and in western Austria) and satellites (MSG2), forecasts of NWP model (ALARO at 5km horizontal resolution and 60 vertical levels), and very high-resolution geographical and topographic data. The nowcasting system has a rapid update cycle, running every five minutes to one hour.
The operational high-resolution numerical weather prediction model requires economical assimilation schemes for radar data (D. Leuenberger and A. Rossa, 2007).
The LHN technique, conceptually simple and computationally not very expensive, which is based on Jones and Macpherson paper from 1997, has been chosen for implementation in AROME Nowcasting system at ZAMG. This technique runs alongside a 3DVAR system for other observation types (the number of observations is limited due to cut off time).

The AROME Nowcasting system is based on the AROME model configuration. For a detailed description of the AROME Nowcasting system at ZAMG, the design and the implementation see:

http://www.cnrm-game-meteo.fr/aladin/IMG/pdf/aladinworkshop2016_florianmeier.pdf.

The basic idea behind the LHN is to adjust the NWP model with the observed precipitation rate in order to get model precipitation closer to the observational data; the model latent heating profiles are scaled by an appropriate amount to reflect more accurately the heating due to the observed precipitation (Jones and Macpherson, 1997).
Two-dimensional observed (from INCA system) and simulated precipitation are compared and the difference is transformed into a three-dimensional latent heat rate increment based on the latent heating from model physics. There is a time delay between observation accumulation period and adding of the increment.
In the gridpoints where the model is too dry (but there are observed precipitation), a profile is searched in the surrounding gridpoints (replace heating profile by maximum heating profile and weight it with observed precipitation and the maximum observed in the surrounding). If the neighboured profile search fails, then an artificial profile is used.
It is also possible to use a climatological profile, rescaled accordingly to observed precipitation rate before applying it in the model (Cedilnik et al, 2004).
Also for the gridpoints where the model is too wet (i.e. the model shows more than twice the observed precipitation) the scaling of the model profile is limited to a factor.

In the present study we have focused on two specific cases in Austria. Although we analysed almost all the model outputs (the wind field, cloud fraction, relative humidity, etc) only the precipitation is shown in order to exemplify the model performance. At this moment no filtering technique is used, but additional studies should be made to investigate the impact of this technique on predicted variables and to decide if it is needed or not.

Two convective cases from July 2015 were analysed and several experiments were carried out. A short description of the large scale atmospheric structure for these two cases is presented based on the surface analyses, INCA analysis and AROME model products from ZAMG.

For the 15th July case, the main frontal activity is covering the Northern part of Austria. The convective activity starts in the afternoon along with the intensifying diurnal heating. The orographic uplift of warm and humid air advected from the South will be the triggering factor of convection (Figure 1).

For the 19th July case, most of the Central Europe is characterized by highly unstable moist warm air mass. An upper level trough is influencing weather evolution over Austria's territory. Therefore, the main characteristic for this day would be: deep convection due to the presence of an upper trough, moisturised air in lower levels (as a consequence of a cold front passage the day before), strong Cape and Showalter indices (not shown).

The analysed period is between 12 – 18 UTC (Figure 2). Starting with 18 UTC, a cold front moves northeastwardly causing heavily precipitation, but our main interest is related to the formation and evolution of the convection. The interaction between the large scale scale and mesoscale processes (such as orographic lifting or low-level convergence related to frontal situations) must be correctly represented by the numerical model for a successful forecast.

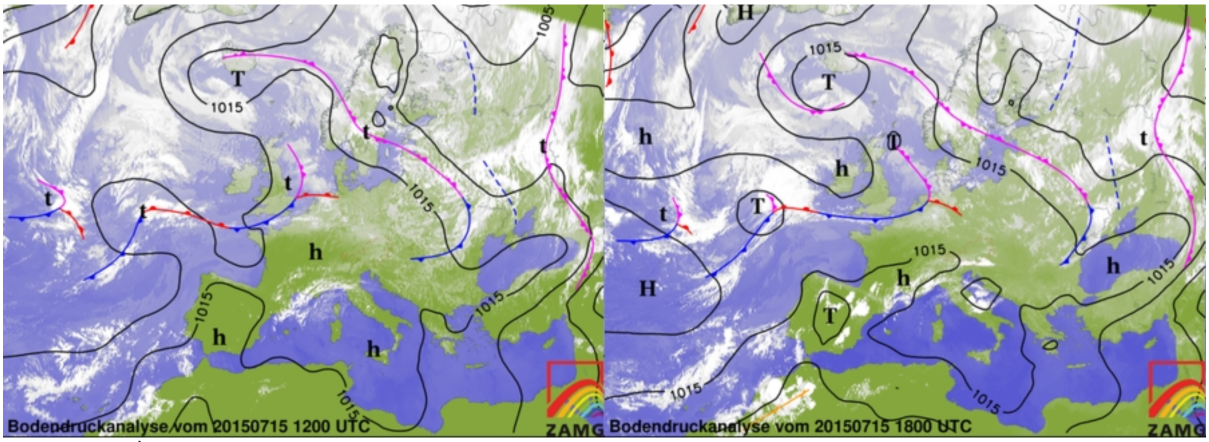

Figure 1: 15th of July 2015: MSLP analysis at 12 UTC (left) and at 18 UTC (right)

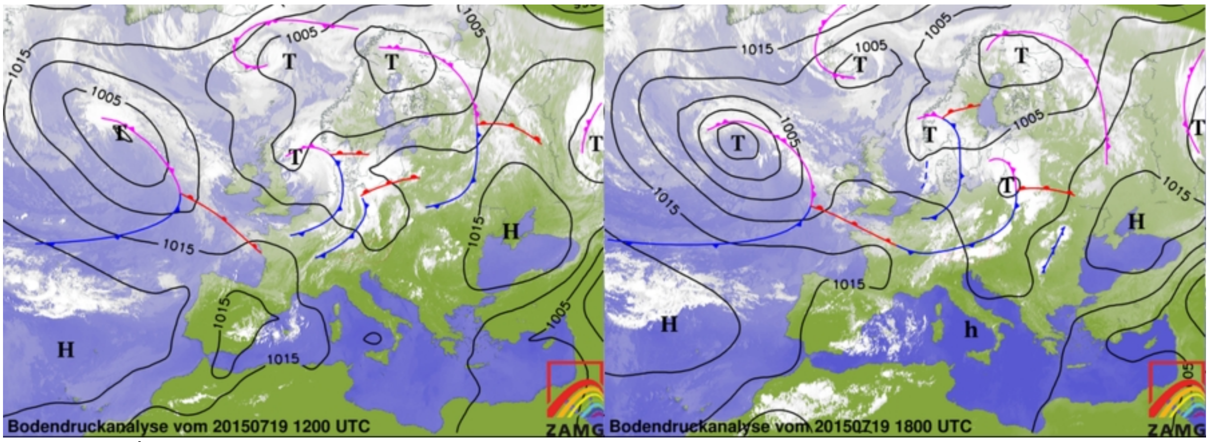

Figure 2: 19th of July 2015: MSLP analysis at 12 UTC (left) and at 18 UTC (right)

2. Experimental set-up

The evaluation of the performed experiments is based on a subjective assessment of the precipitation fields. For more accuracy an objective verification method is needed.

Two types of experiments were carried out within this study: AROME Nowcasting system was used for a first set-up in which the horizontal resolution was at 2.5 km (Table 1) and the second set-up used at 1.2 km horizontal resolution (Table 2). For all simulations at 1.2 km the initial state was obtained from the 3DVAR analysis at 2.5km horizontal resolution.

the reference – **REF** (AROME – 3DVAR) without LHN	**RLHN_ideal** - an idealised profile is applied to LHN, using as input Rapid INCA analysis (5 min nudging till 30 min)
Rapid **INCA** analysis (5 min)	**RLHN_real** - a “real” profile is applied to LHN, using as input Rapid INCA analysis (5 min nudging till 30 min) -
INCA analysis (15 min)	**ILHN** - an idealised profile is applied to LHN, using as input INCA analysis (15 min)

Table 1: the experiments carried out at 2.5 km horizontal resolution

the reference – **REF** without LHN	**RLHN** - an idealised profile is applied to LHN, using as input Rapid INCA analysis (5 min nudging till 30 min)	**FLHN** - an idealised profile is applied to LHN, using as input INCA analysis (15 min) and INCA forecast system (+30 min +45 min +60 min +75 min + 90 min for nudging)

Table 2: the experiments carried out at 1.2 km horizontal resolution

The parameters for an idealised profile (sinus shaped curve) were set through the namelist for 001 configuration. To compute the statistics, the fa_stat.py tool from epygram software was used (for both cases). For exemplification the mean latent heating tendency for 15th July 2015) is shown in figure 3.

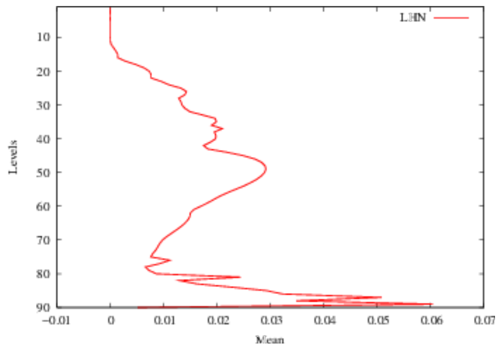

Figure 3: the real latent heating profile for LHN, 15th July 2015

3. Results

3.1 Case 1: 15th July 2015

1 h accumulated precipitation analysis

For the first case analysed the simulations are initialized at 13 UTC and integrated for 12 hours. At the same time first radar signals appeared over the Karawanken Alps, as can be noted in the INCA analysis (Figure 4). The first set of simulations are carried out at 2.5 km horizontal resolution. The red circle shows the location of the interest area. First we assess the ability of the REF simulations to capture the exact moment when the convection was triggered. It can be noticed that the forecast precipitation has a lower value than the INCA analysis (Figure 4, upper panel, left). Further the LHN scheme was applied and the simulations positioned the rain area significantly better as indicated by Figure 4 (upper and middle-right panels). For the RLHN_real simulations the precipitation amount has increased up to 20 -25 l/mp but still remaining underestimated compared with INCA analysis (35 – 40 l/mp).

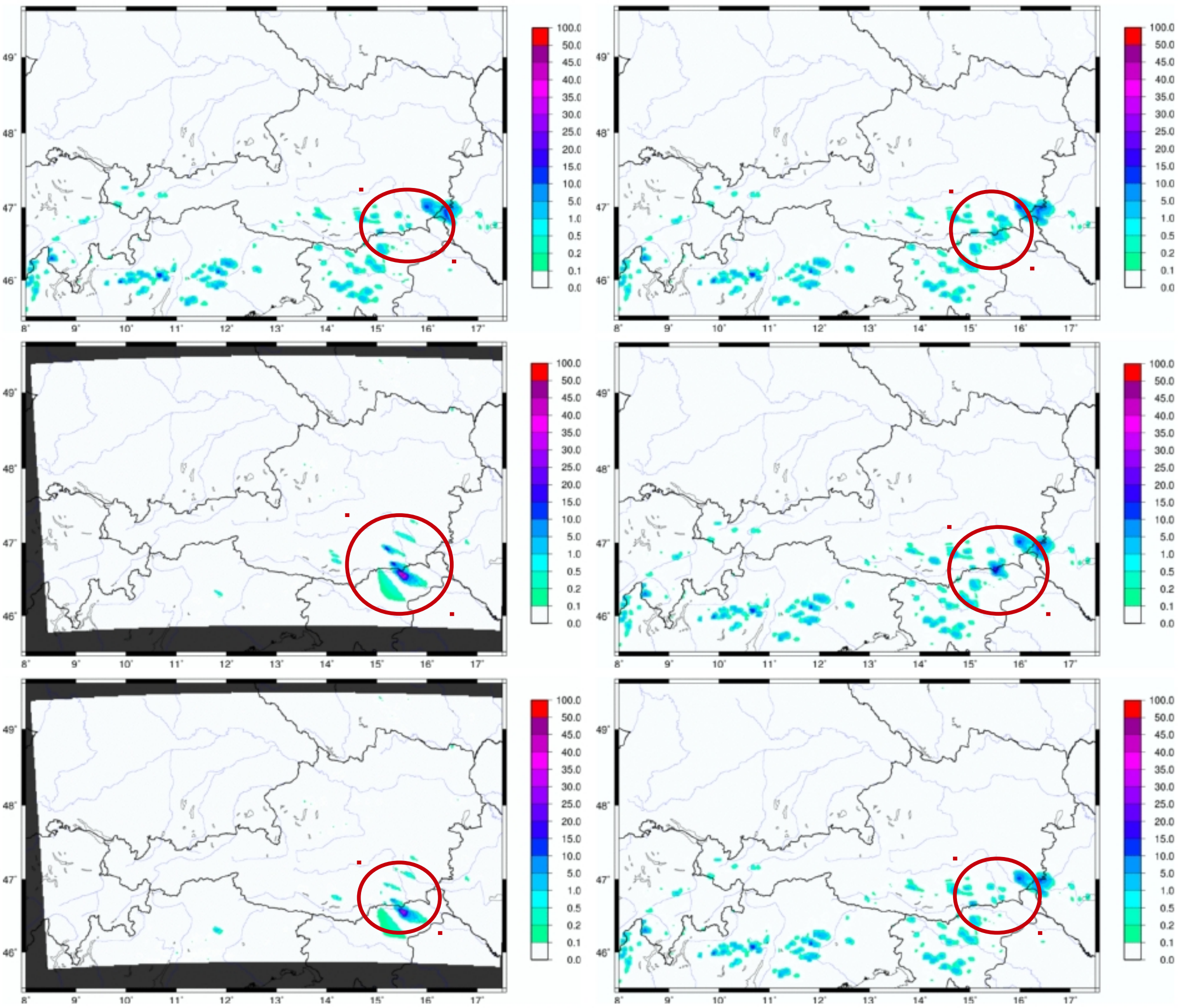

Figure 4: hourly accumulation of precipitation between 13 – 14 UTC: up: REF (left) and RLHN_ideal (right); middle: RINCA (left) and RLHN_real (right) and bottom: INCA (left) and ILHN (right), 15th of July 2015

A second set of simulations has been carried out using the 3DVAR analysis at 2.5km from AROME Nowcasting system. Figure 5 reveals the fact that increasing the horizontal model resolution to 1.2km, a neutral result of the QPF was obtained when the LHN technique was applied. In order to understand this more investigation with 1.2km-3DVAR should be carried out.

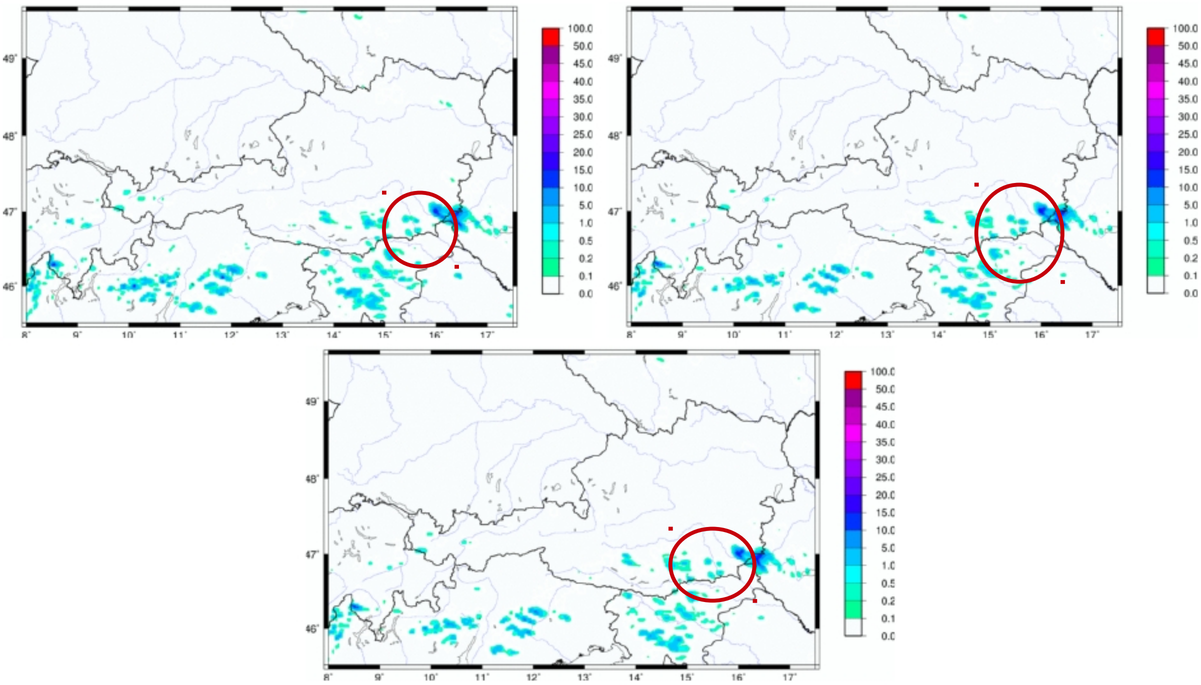

Figure 5: hourly accumulation of precipitation between 13 – 14 UTC: up : REF (left) and RLHN (right); bottom: FLHN (middle), 15th of July 2015

In figure 6 was plotted the difference between the experiments made with 1.2km horizontal resolution for hourly accumulation of precipitation. It can be noticed that it was released more latent heat for the RLHN simulations.

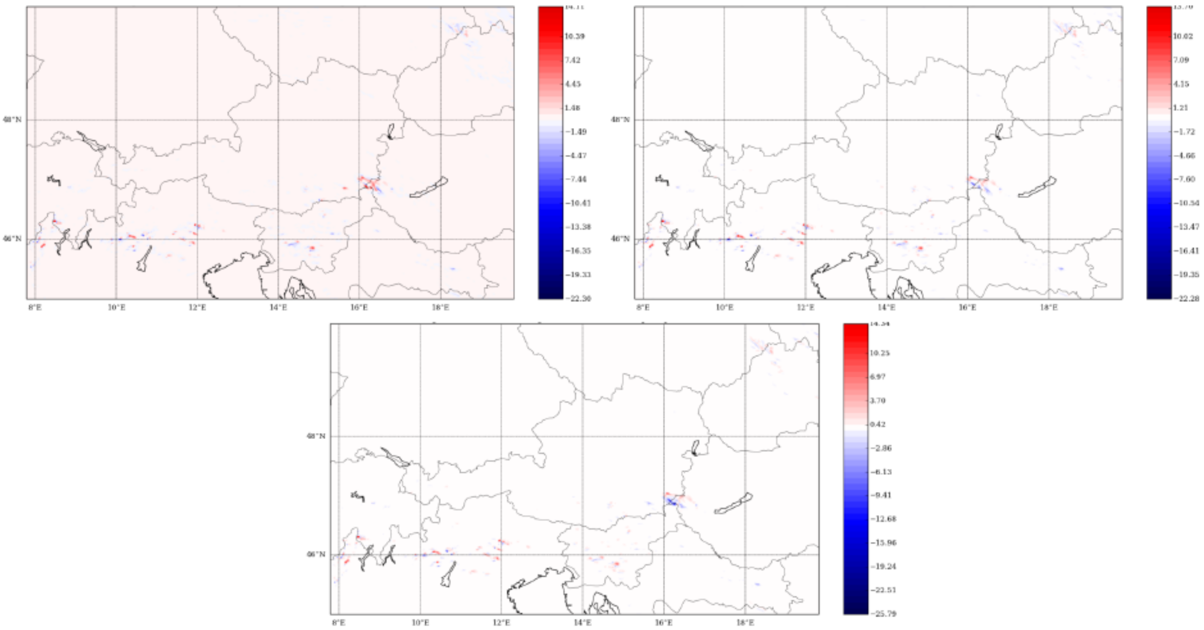

Figure 6: difference between the experiments for hourly accumulation of precipitation: up: RLHN – REF (left); FLHN – REF (right) and bottom: FLHN – RLHN, 15th of July 2015

2 h accumulated precipitation analysis

All the simulations predict the overall structure of the new convection system during the next few hours which is consistent with INCA analysis (Figure 5, red circle). The RLHN_real experiment is able to maintain the precipitation signal related to the main convective cells (Figure 7, middle- right panel).

The yellow circle contains the secondary convective cells (Figure 7). The model has a significantly difference in location versus INCA analysis. This difference is to be investigated as it could be induced by the differentiated insolation over the mountain's crests. The second convective cells are developing as middle day convection on the solar exposed crest of the Grossglockner summit (southern part of the Hohe Tauern Alps). The model has some problems in the representation of the insolation (seams to not to take into account the fact that all those cells are located on the northern part of the Karawaken Alps which is less exposed to the solar radiation). One can conclude that INCA analysis reveals the topographic influences over the convection triggering conditions but the model skips or the insolation either the exposure of the crest. Also the model shows a reduced ability to respond at the forcing during the LHN simulations. This remains as a future task to clarify the cause of the model limitations.

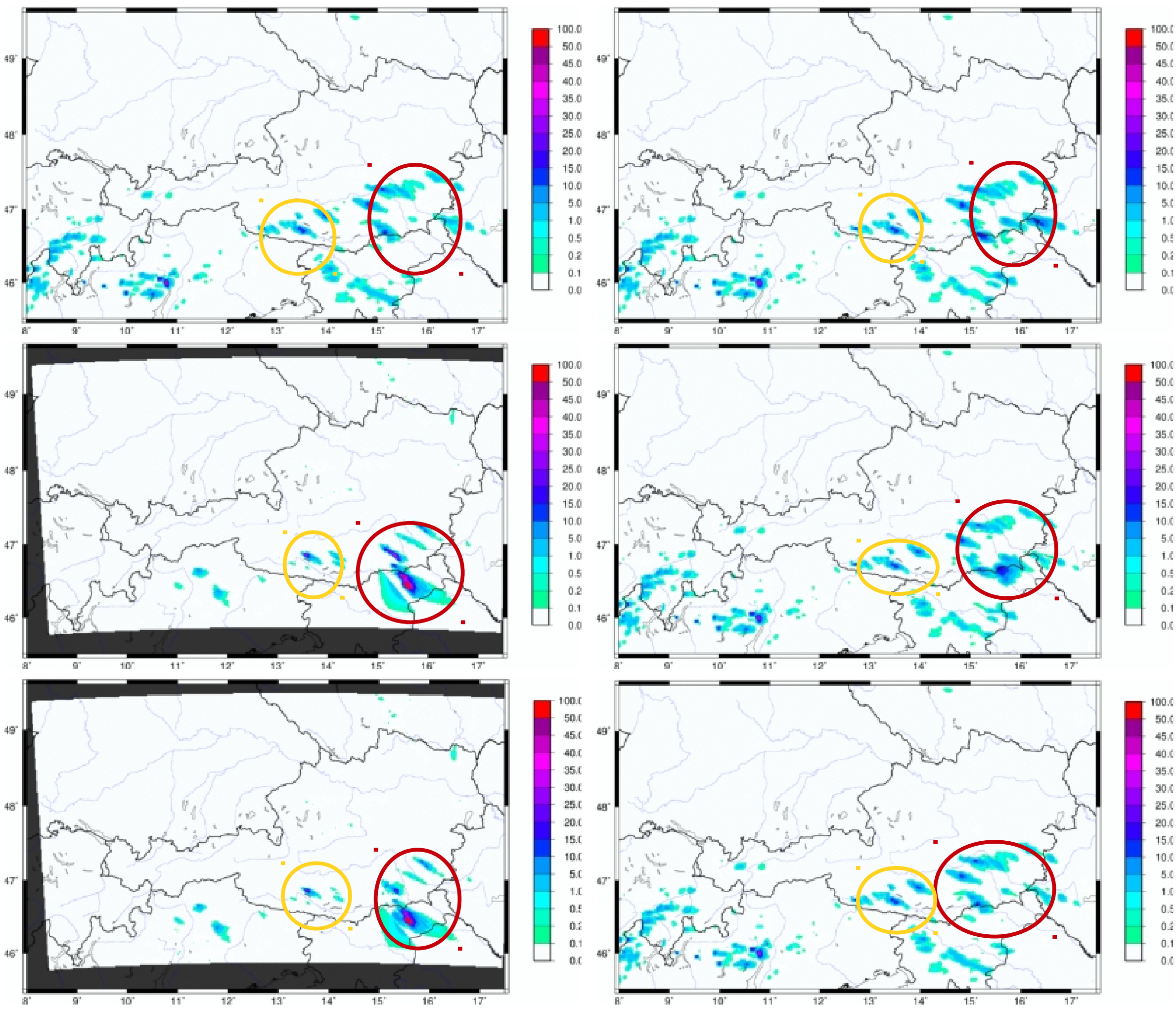

Figure 7: 2h accumulation of precipitation between 13 -15 UTC: up: REF (left) and RLHN_ideal (right); middle: RINCA (left) and RLHN_real (right) and bottom: INCA (left) and ILHN (right), 15th of July 2015

For the second set of simulations, the amount of precipitation is underestimated for both studied convective systems. LHN technique seems to reduce too much the rain amount for the new convective cells (yellow circle).

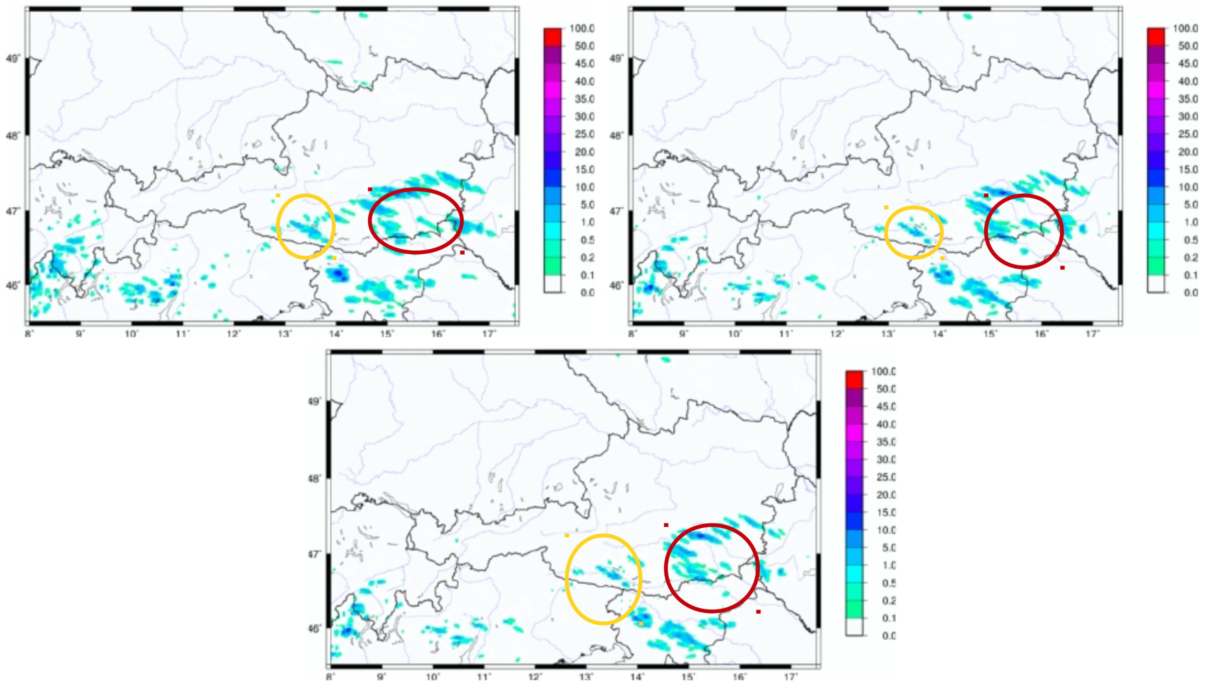

Figure 8: 2h accumulation of precipitation between 13 – 15 UTC: up: REF (left) and RLHN (right); bottom: FLHN (middle), 15th of July 2015

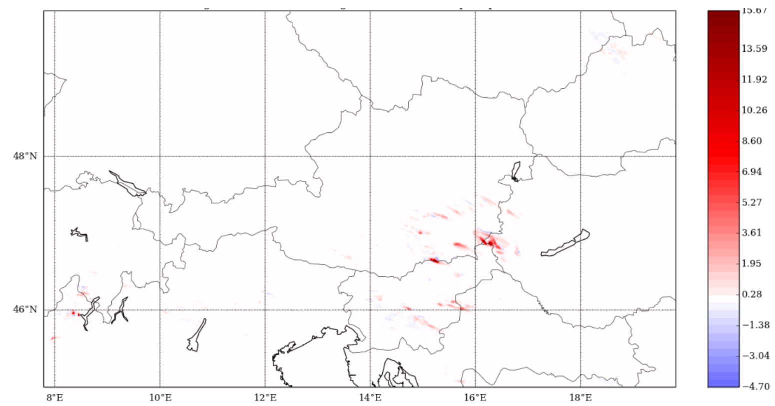

Figure 9: difference between the experiments for 2h cumulated precipitation: RLHN – FLHN (1.2km)

3 h accumulated precipitation analysis

The same problem is revealed by the experiments at the three hours of accumulated precipitation. It emphasises the overestimation of the intensity and contamination area. The model displays two well-developed cells which are not present in the INCA analysis (this fact is present in all the simulations). On the same figure the model with LHN technique (RLHN_real simulations) displays one southern cell developed most like INCA analysis. In a very near manner the RLHN_ideal experiment displays a secondary cell developed in south of the main convection area but still underestimated.

As a conclusion the model overestimates the intensity and the magnitude of the convection which the LHN technique has not the ability to solve it. But in the same time the LHN technique solves the underestimation of the model over the convective conditions (see figure 7.)

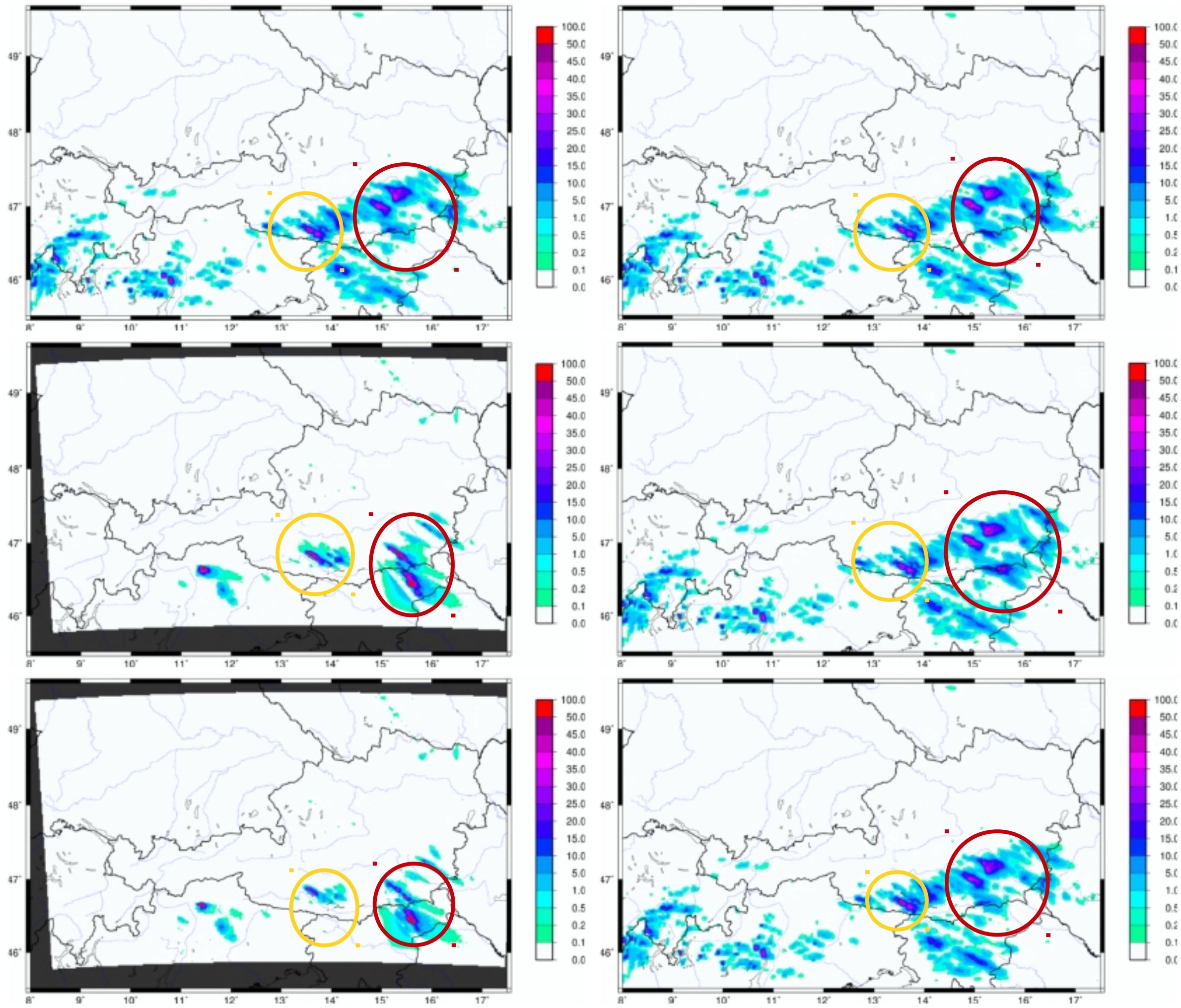

Figure 10: 3h cumulated precipitation: up: REF (left) and RLHN_ideal (right); middle: RINCA (left) and RLHN_real (right) and bottom: INCA (left) and ILHN (right), 15th of July 2015

The new developed cells (which are not present in the INCA analysis) are also visible at 1.2km horizontal resolution experiments but at a lower intensity.

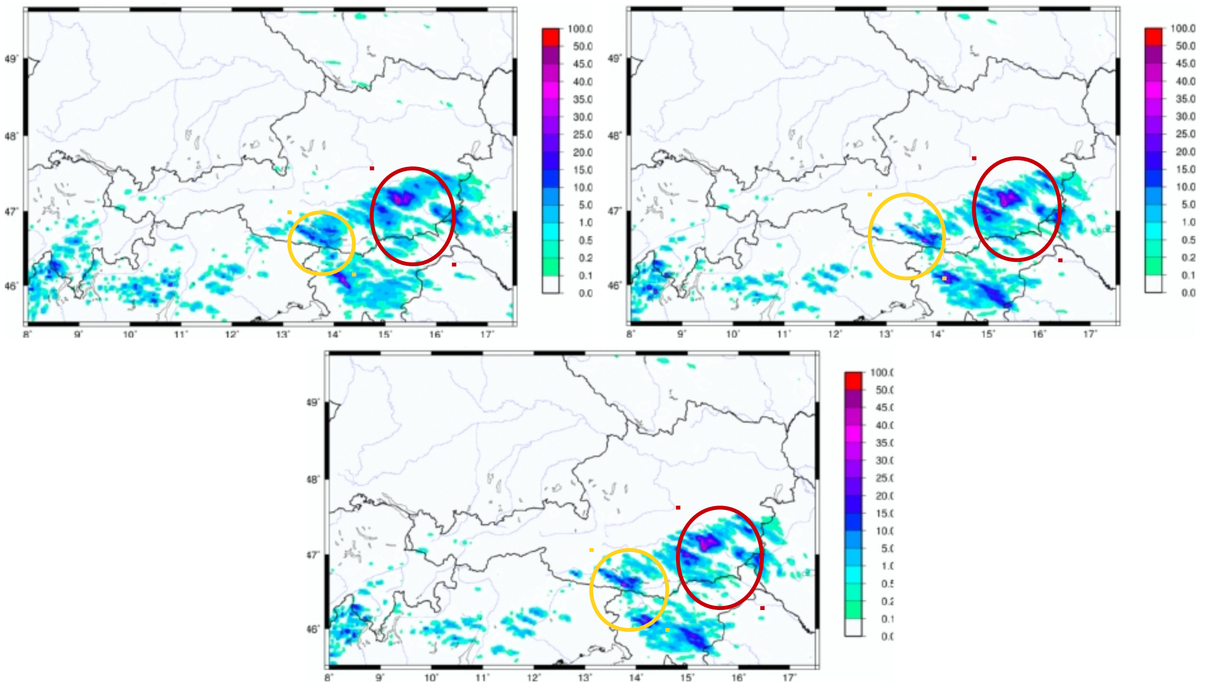

Figure 11: 3h cumulated precipitation: up : REF (left) and RLHN (right); bottom: FLHN (middle), 15th of July 2015

Short summary for the first case:

For the first set of experiments (2.5 km horizontal resolution)

- ✓ for the first convective system (red circle): the simulations with LHN technique positioned the precipitation area significantly better, increasing the precipitation amount but not enough compared with INCA analysis
- ✓ for the second convective system (yellow circle): the LHN technique showed a reduce ability to correct the difference in location of the new convective cells

For the second set of experiments (1.2 km horizontal resolution) the results are not fully comprehensive, more investigation with 1.2 km- 3DVAR should be carried out.

3.2 Case 2: 19th July 2015

<u>1 h accumulated precipitation analysis</u>

For the second case the simulations are initialized at 12 UTC when the convective system is already inside the Austrian domain and are also integrated for 12 hours. The same simulation strategy and notation as in the first case is adopted. The initial state of the REF simulations is characterized by a conditionally unstable atmosphere over the Alps ridge with large CAPE values (not shown). Compared with INCA analysis the simulated rain area by the REF experiment is overestimated (figure 12: upper panel – right). The LHN technique is not able to correct the overestimation of the area of precipitation or to correct the rainfall amount for the two convective cells.

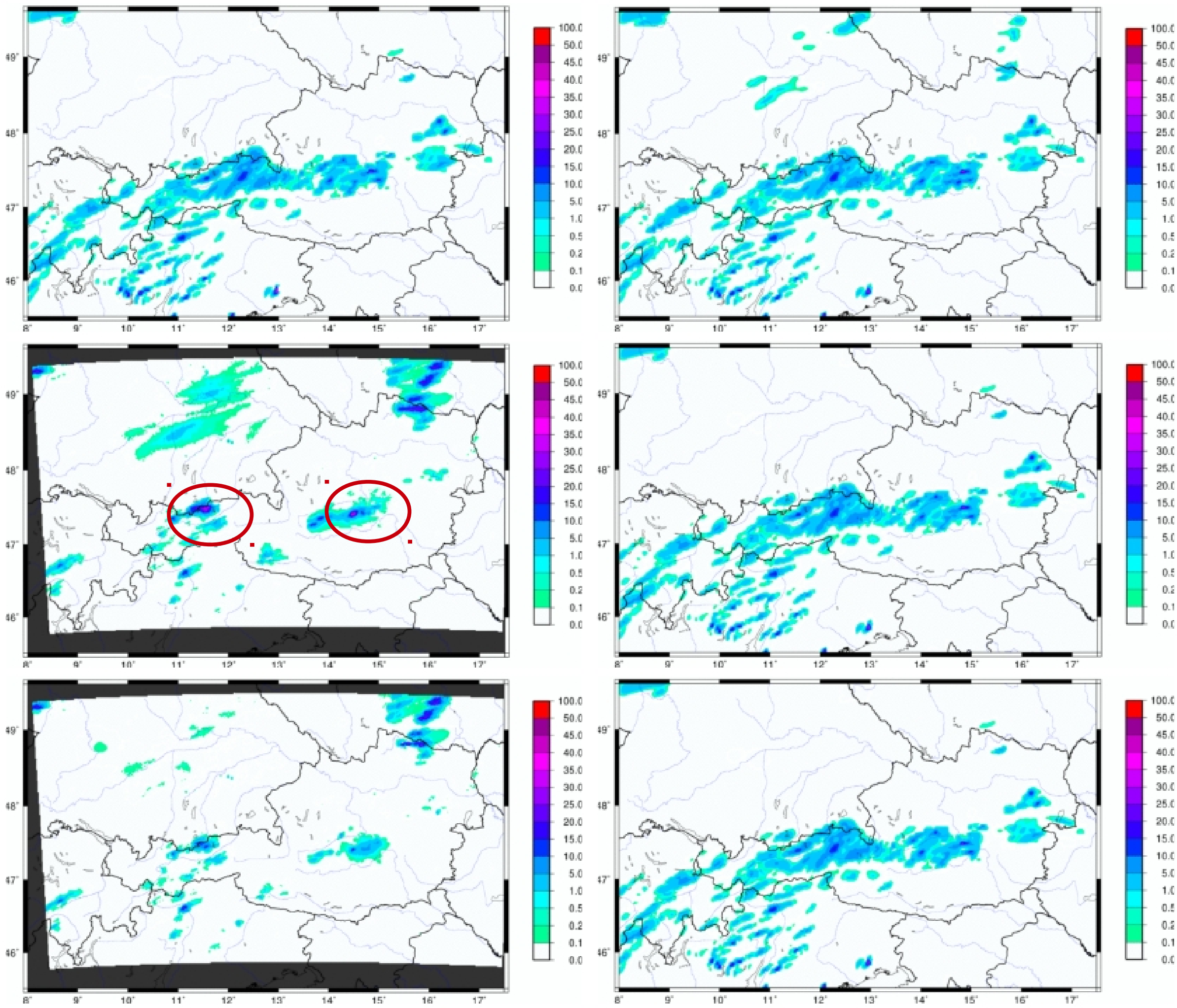

Figure 12: hourly accumulation of precipitation between 12 – 13 UTC: REF (left) and RLHN_ideal (right); middle: RINCA (left) and RLHN_real (right) and bottom: INCA (left) and ILHN (right), 19th of July 2015

<u>3 h accumulated precipitation analysis</u>

All performed experiments simulate new convective cells that are not present in INCA analysis (red circle). In addition to the previous analysis, in this particular case, we can draw the conclusion that the use of the LHN technique does not lead to corrections of the rainfall amount.

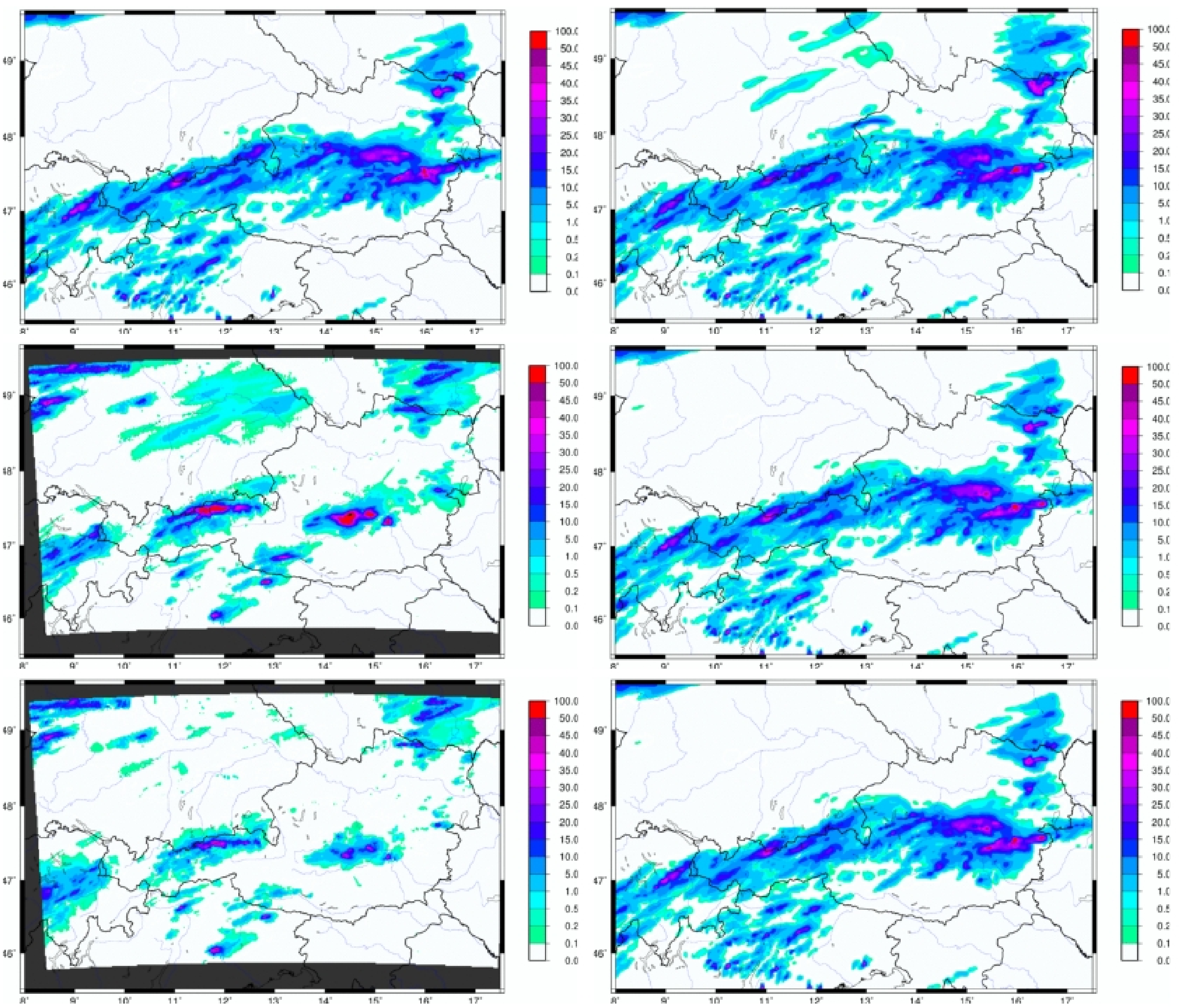

Figure 13: 3h cumulated precipitation: up: REF (left) and RLHN_ideal (right); middle: RINCA (left) and RLHN_real (right) and bottom: INCA (left) and ILHN (right), 19th of July 2015

Short summary for the second case:

2.5 km horizontal resolution experiments

- ✓ compared with REF experiments the impact of the LHN on precipitation forecast is generally neutral
- ✓ compared with INCA analysis the LHN technique is not able to correct the rainfall amount

1.2 km horizontal resolution (not shown)

- ✓ taking in consideration the entire analysis, we see no improvement when the LHN technique is applied, nor when a high spatial resolution is used

Summary

The potential of the Latent Heat Nudging technique to improve the precipitation forecast was investigated using high resolutions simulations. The results obtained are not fully comprehensive, but represent a first step towards the determination of the characteristics of the LHN scheme applied in the AROME Nowcasting system. Moreover, these results are revealing a number of important issues that need to be considered. One of them shows that the LHN technique has generally a very small positive impact on model forecasts (i.e. for the first case analysed, LHN showed a slightly improvement of the precipitation amount). However, for the second case analysed, the LHN technique was not able to correct the overestimation of the area of precipitation or to position the convective cells in the right place. Also in regards to the REF experiments we can conclude that the impact of the LHN on precipitation forecast is generally neutral.

Perspective

- ➢ experiments using 1.2 km with 3DVAR
- ➢ extended tests and tuning of the latent heat nudging for AROME Nowcasting system at 1.2 km
- ➢ re-evaluate the case studied using AROME at 1.2 km, maybe using the climatological profiles (J. Cedilnik, 2004)
- ➢ to evaluate more case studies and monthly periods (winter and summer)
- ➢ new verification approaches: objective method

Acknowledgements:

I would like to thank to my supervisors Yong Wang, Florian Meier and Christoph Wittmann for their valuable guidance, constructive suggestions and their entire support during the planning and development of this research stay.

References:

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