Deep convection triggering experiments

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Introduction

Model ALADIN/VIENNA usually overestimates convective precipitation and cloudiness over mountainous south-western and southern part of Austria. During the summer period, convective activity over the southern slopes of Alps is often prognosed (almost everyday) but not observed. Even if there is some convection detected by radar, it is normally not so much widespread and it starts much later than the model simulates. It happens, that convective processes are activated by the model even during night time when there is no reason for that. Another problem is, that model is not selective enough and convective precipitation very often cover quite big area with just small precipitation rates about 0.1-0.2 mm/h. In reality, the precipitation incoming from convective cloudiness are more localized and therefore higher in amount. Hence, the main goal of our investigation is experimenting with the deep convection scheme in order to delay convection triggering. We consider, that the correct timing of deep convection triggering can cause better simulation of convective processes regarding their amount and geographical positioning. However, one has to keep in mind, that precipitation forecast (and especially convective one) is probably the most challenging task which NWP deals with.

Experiments arrangement

A) *Simple threshold for second KUO-type triggering condition*

The second KUO condition is testing, whether the sum of moisture convergence (multiplied by effective latent heat and dp) from the bottom to the actual model level is bigger than zero. Adding a threshold to that value, one only forces convective activity to start higher up. This of course make convective clouds a bit more shallow and less convective precipitation is hence produced. From the experiments we have learned, that the convective cloudiness and precipitation were also not so widely spreaded and were more compact and organized. Although, there was no time delay in convection triggering observed.

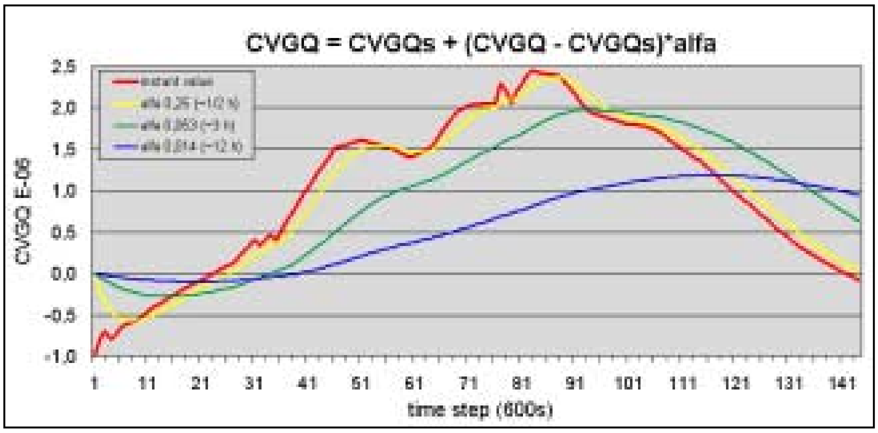
B) *Cumulated moisture convergence used as an additional condition in triggering*

Accumulated moisture convergence (from the beginning of integration, for given gridpoint and model level) was used as an additional (i.e. third) condition for triggering of convective processes in order to produce some delay. Until a threshold for accumulated moisture convergence is reached, second KUO condition is set to zero undependently on its original value. It means, that all possible convective activity is cancelled even if the first KUO condition (positive buoyancy) and the second KUO condition (positive instantaneous moisture convergence) are itself fulfilled.

C) *Time delay equation for moisture convergence*

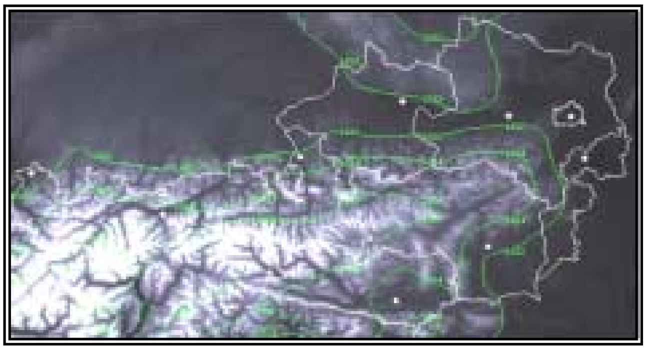
Application of time delay equation to the moisture convergence entering deep convection scheme is another possibility how to create some time lag of convective activity in the model (original idea of Jun-Ichi Yano). One can write such equation in the following way:

$$\psi'_{new} = \psi_{old} + \left(\psi_{new} - \psi_{old}\right)\frac{\delta t}{\tau + \delta t}$$

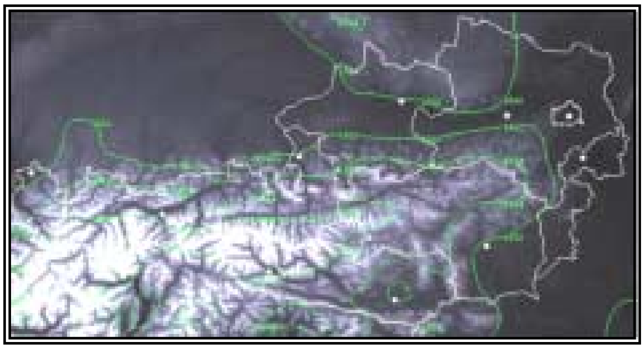


where ψ'_{new} is modified moisture convergence to be used immediately inside the deep convection scheme for triggering purposes, while afterwards it is stored to the ψ_{old} variable representing the value of moisture convergence from the previous time step. Further, ψ_{new} is an instantaneous value of moisture convergence (the original one used in the second KUO condition), δt is physical time step and τ is the expected time lag. Having such modification of moisture convergence as an combination of instantaneous and the old value (modified one from the previous time step), there is no more need to touch anything in the KUO tests inside deep convection routine. A graphical representation of such approach is shown in the picture, where alfa coefficient is already computed for physical time step 600s and for three different time lags: 1/2h (yellow curve), 3h (green curve) and 12h (blue curve). Red curve stands for the instantaneous moisture convergence (hypothetical values). The time shift and a corresponding smoothing of the original curve dependent on alfa coefficient is obvious.

Case studies (used within the experiments)



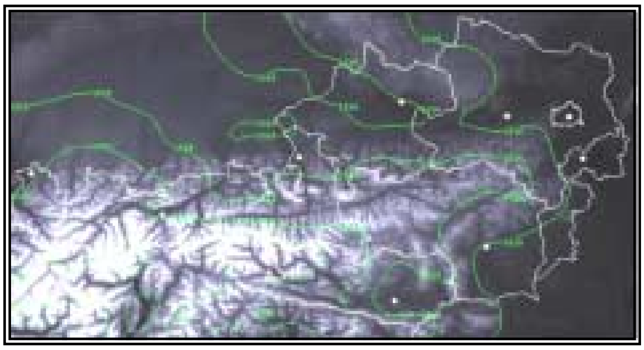
04.08.2003 – An anticyclonic weather situation with weak north-westerly flow and no front passage. Convective precipitation were prognosed too early and at the wrong position. There was almost no precipitation observed in the western and southern part of Austria, while in the north-eastern and eastern territory they were detected by radar but to the contrary almost ignored by model forecast (since they were too much widespread and not so intensive). Model predicted some stratiform precipitation as well (in the south-western part of the visualisation domain) even though, there was no front passing across Austria. (MSLP from 12 UTC on the picture)



05.08.2003 – Very similar situation to the previous day. Convective processes were released soon after 12 UTC in the north-eastern and south-eastern part of Austria and last till 5 pm, while model underestimated them in the same manner as the previous day. Later on (4-9 pm) convection was observed also over the Alps near south-western borders of Austria which was quite well predicted by model with the exception, that forecasted convective precipitation were again too widespread and situated for instance to the southern slopes of Alps in southern Austria as well, which was not observed. (MSLP from 12 UTC on the picture)

17.08.2003 – Again an anticyclonic weather situation with weak south-western flow. Convective precipitation and cloudiness were developed too early in the ALADIN/VIENNA forecast and were too widespread. There was a convective activity prognosed by the model also during night time. It was situated mostly to the southern slopes of Alps in the southern part of Austria, even if there was nothing observed by radar or TAWES at that place (just 12 hours later on). (MSLP from 12 UTC on the picture)

18.08.2003 – An cold front crossed Austria around the noon, propagating from the west to the east. Quite a lot of precipitation over almost whole domain was predicted and also observed. Convective part was dominating in the model forecast concerning the area it covered. It seems that the timing of convective activity was better now, but still to much widespread in comparison with the radar measurements. (MSLP from 12 UTC on the picture)



Simple threshold for second KUO-type triggering condition

The first set of experiments was rather simple and it had only to show the possibility to manipulate convective precipitation forecast through the changed triggering conditions. Since the second KUO condition tests the positivity or negativity of the vertical sum of moisture convergence (from the bottom to the actual model level), this experiment only forced convection to be activated in some higher model leves. It means, that the simulated convective cells were more shallow and hence less convective precipitation was produced. However, depending on the threshold value, there were also some locations where convection was cancelled at all and then local extremes in the other places even increased. It very well coresponds to the fact, that convective patterns were more compact and better localized (i.e. not so much widespread as the reference). One can see the effect of applying such threshold on the convective precipitation maps from the 17th of August 2003 17 UTC (**Fig.4-6**), in comparison with the visible satellite image (**Fig.1**), hourly precipitation rate estimated by radar measurement (**Fig.2**) and hourly precipitation rate measured by surface station's network interpolated into regular grid (**Fig.3**).

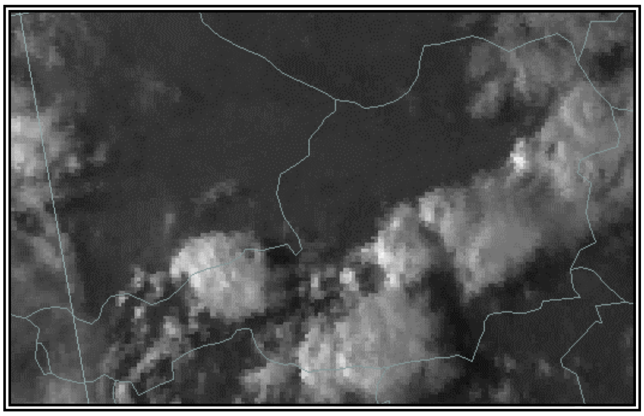


Fig.1 Visible satellite image from METEOSAT

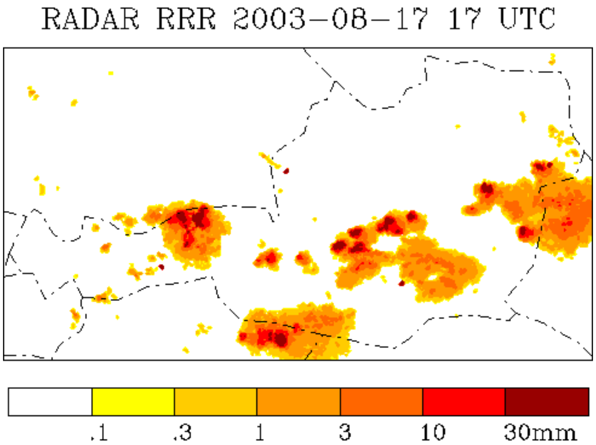


Fig.2 Hourly precipitation rate estimated by radar measurement

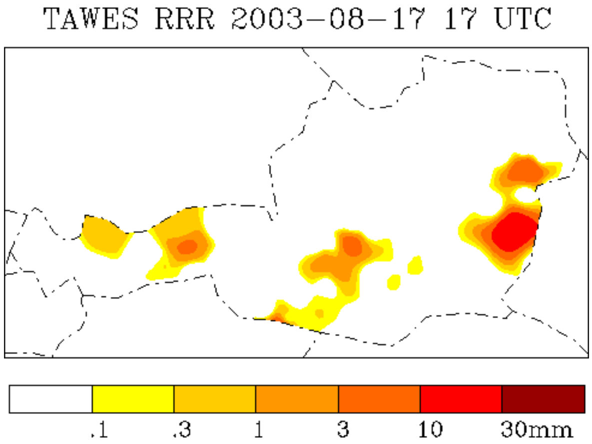


Fig.3 Hourly precipitation rate interpolated from the local obs. network

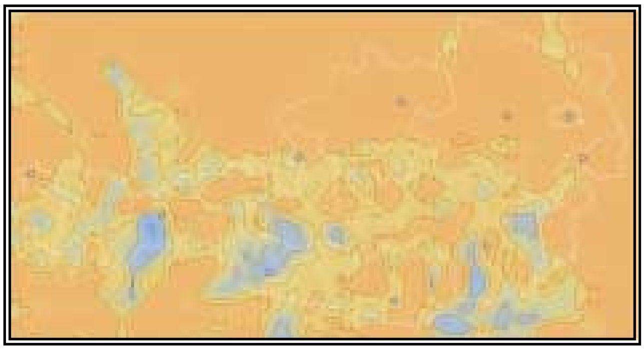


Fig.4 Convective precipitation (hourly rate) operational forecast (REF)

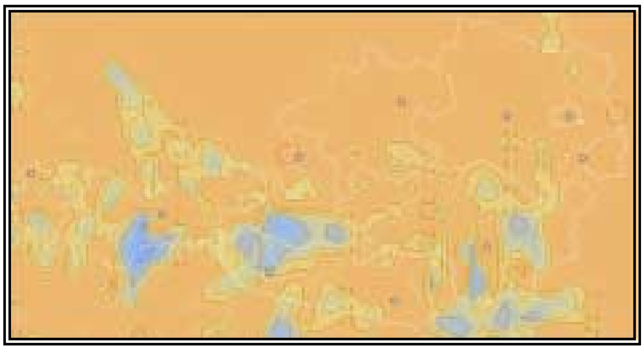


Fig.5 Convective precipitation (hourly rate) experiment with smaller threshold (1000)

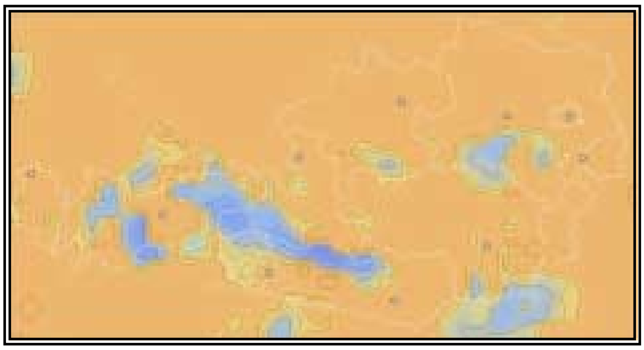


Fig.6 Convective precipitation (hourly rate) experiment with bigger threshold (3000)

Cumulated moisture convergence used as an additional condition in triggering

We have used the moisture convergence accumulated from the beginning of integration, with positive as well as negative values in input, as an additional condition for triggering of convective activity for given gridpoint and within given model level. We tested such an approach in order to simulate in a very simplified way the storage of moisture within developing of convective cloudiness. Setting-up a threshold to be reached by this accumulated value, we forced model to start convection with the appropriate time delay. We have tried several thresholds (which are of course situation dependent), having the best results with the value 5.E-06. This was corresponding to the reduction of active layers for selected set of grid points by approximately 70% (for threshold 3.E-06 it was for example only 25%). The experiments with such a threshold for accumulated moisture convergence indicate improvement in convective precipitation timing (which is logical, since we suppress any convective activity before the threshold is reached) but what is more, some enhancement of their localization was observed as well. Generally, we have less convective patterns with obviously better organisation (not as widespread as the reference) and with a slightly higher convective precipitation rates in more localized extremes (**Fig.7**-**20**). Another positive impact was observed (**Fig.21**-**27**), when convective activity was extended to the later hours in accordance with the radar and satellite measurements (while convection in the reference forecast was already almost inactive). Our assumption about different evolution of deep convection with better timing can be proved also by the forecast for next day (+42 hours), when our experiment seems to be closer to the observations as the reference (**Fig.28**-**34**). Time lag of the beginning of convective precipitation is well figured on meteogram for LIENZ (which is in our area of interest) for period 17.08.2003 - 18.08.2003 (**Fig.36**). The delay against the reference (**Fig.35**) is significant. However, an unrealistic increase of stratiform precipitation rates (approx. 2-3 times more than in reference) was observed as well. This unwanted feature was common for all the experiments as some compensation for the convective precipitation decrease.

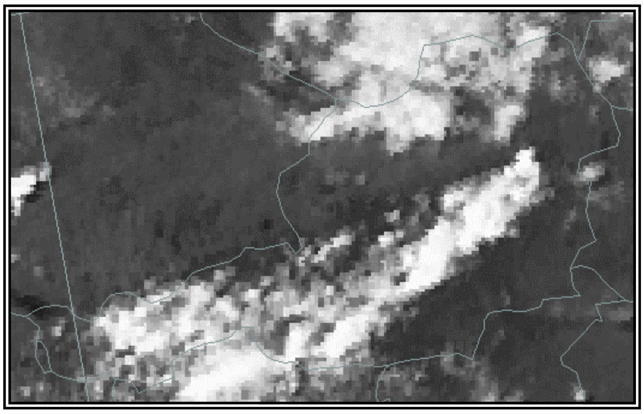


Fig.7 Visible satellite image from METEOSAT

All figures are related to the **17th** of **August 2003**, **14:00 UTC**. (+14 h)

REF – operational forecast of al25_t2
EXP – experiment with threshold
for accumulated moisture
convergence (5.E-06)

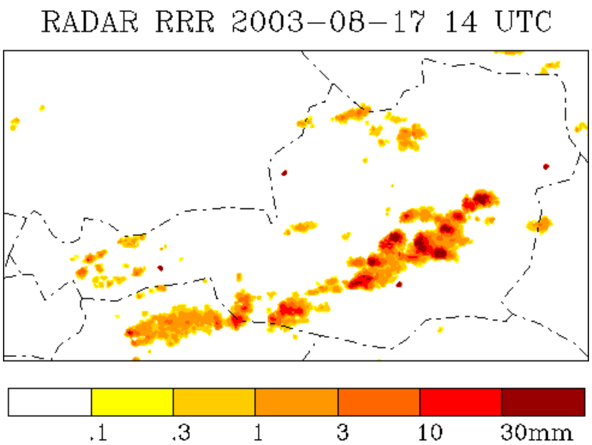


Fig.8 Hourly precipitation rate estimated by radar measurement

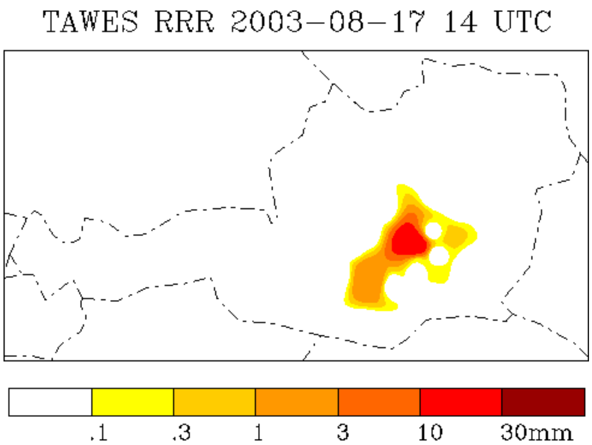


Fig.9 Hourly precipitation rate interpolated from the local obs. network

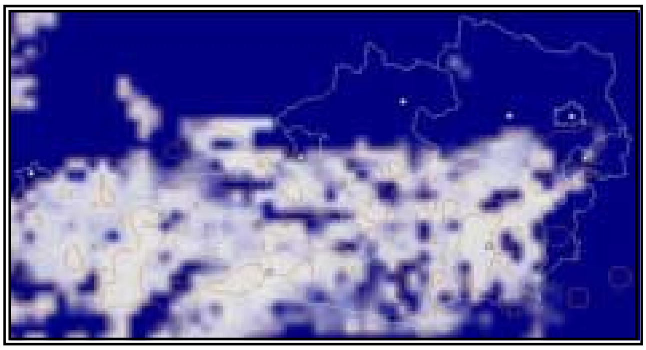


Fig.10 Convective cloudiness and precipitation prognosed by ALADIN (REF)

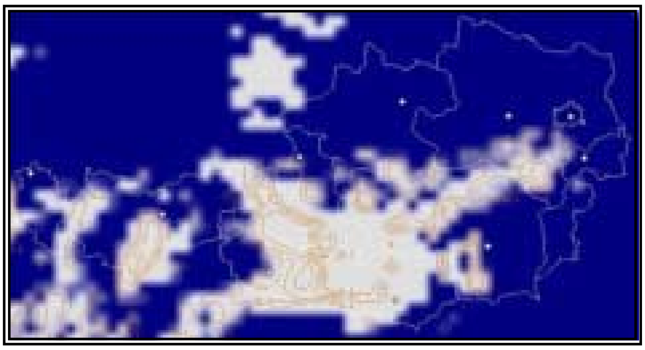


Fig.11 Convective cloudiness and precipitation prognosed by ALADIN (EXP)

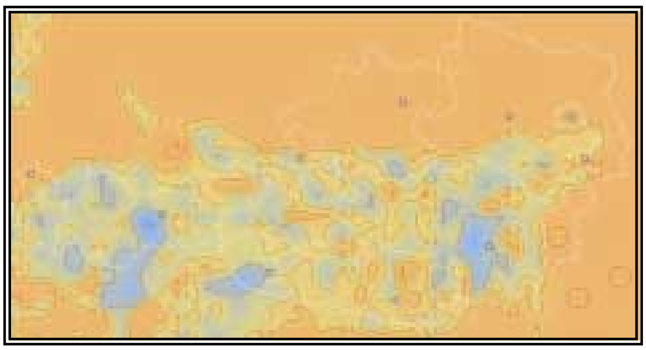


Fig.12 Convective precipitation (hourly rate)

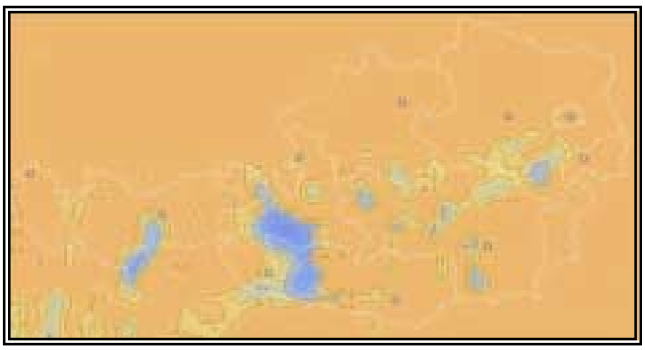


Fig.13 Convective precipitation (hourly rate)

prognosed by ALADIN (REF) prognosed by ALADIN (EXP)

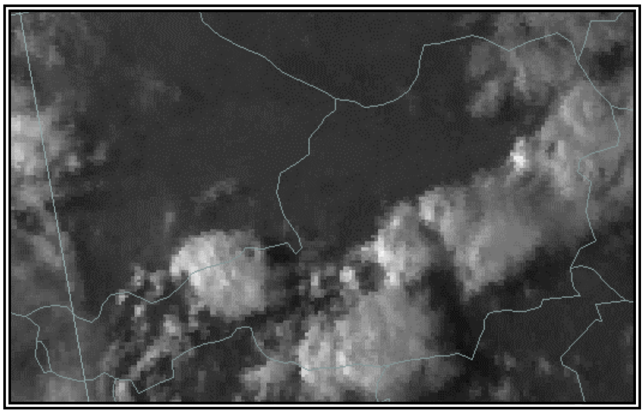


Fig.14 Visible satellite image from METEOSAT

All figures are related to the **17th** of **August 2003**, **17:00 UTC**. (+17 h)

REF – operational forecast of al25_t2
EXP – experiment with threshold
for accumulated moisture
convergence (5.E-06)

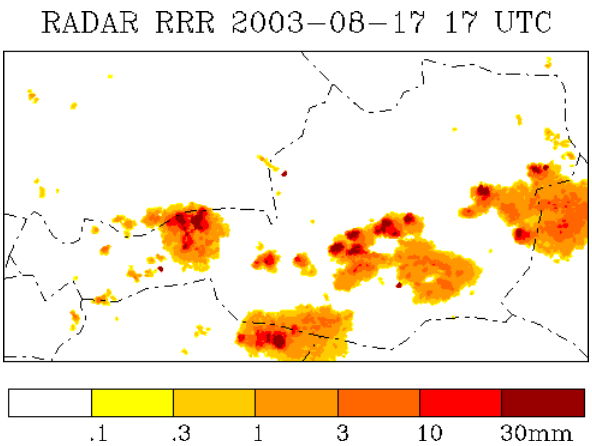


Fig.15 Hourly precipitation rate estimated by radar measurement

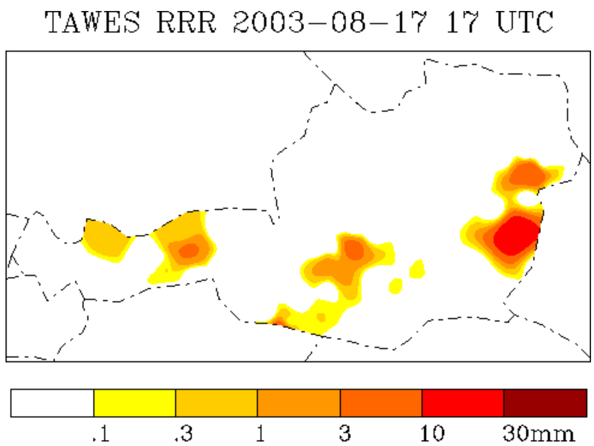


Fig.16 Hourly precipitation rate interpolated from the local obs. network

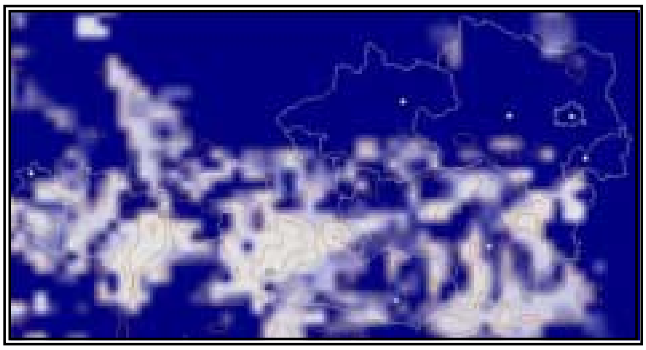


Fig.17 Convective cloudiness and precipitation prognosed by ALADIN (REF)

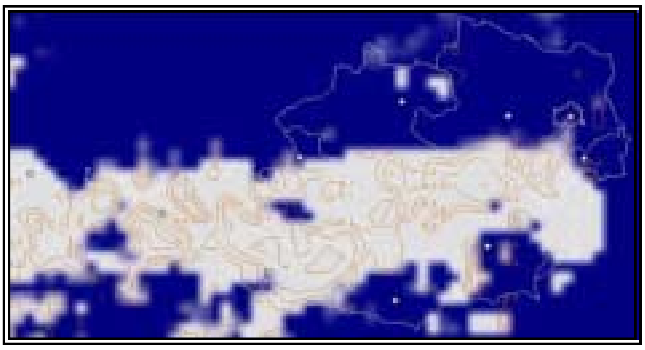
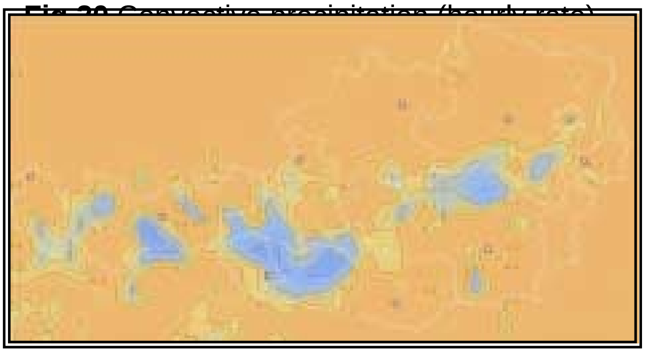
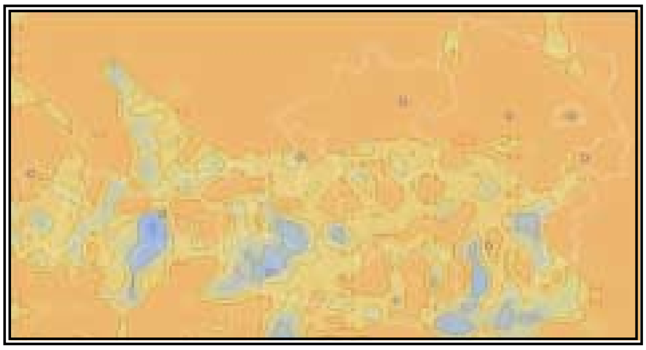


Fig.18 Convective cloudiness and precipitation prognosed by ALADIN (EXP)

Fig.19 Convective precipitation (hourly rate)

Fig.20 Convective precipitation (hourly rate)





prognosed by ALADIN (REF)
prognosed by ALADIN (EXP)

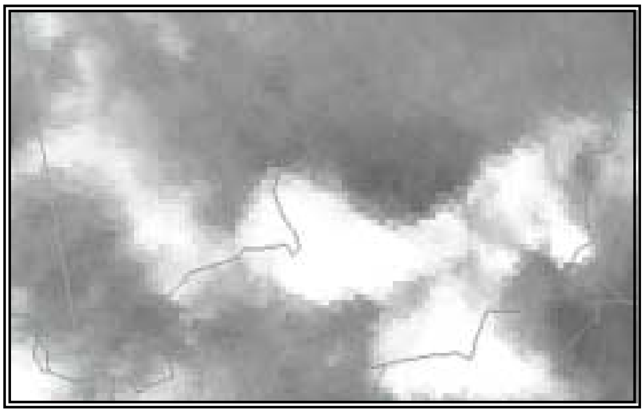


Fig.21 WV satellite image from METEOSAT

All figures are related to the **17th** of **August 2003**, **19:00 UTC**. (+19 h)

REF – operational forecast of al25_t2
EXP – experiment with threshold
for accumulated moisture
convergence (5.E-06)

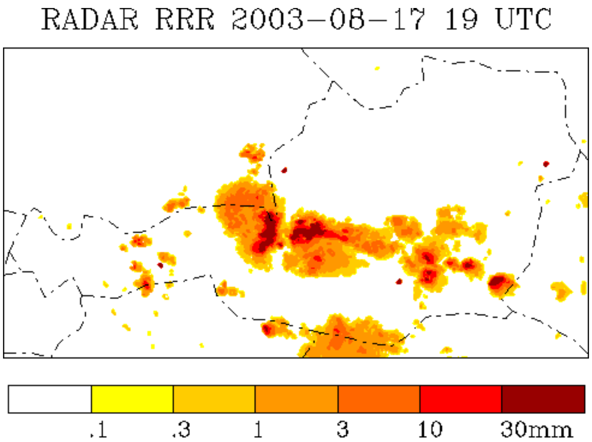


Fig.22 Hourly precipitation rate estimated by radar measurement

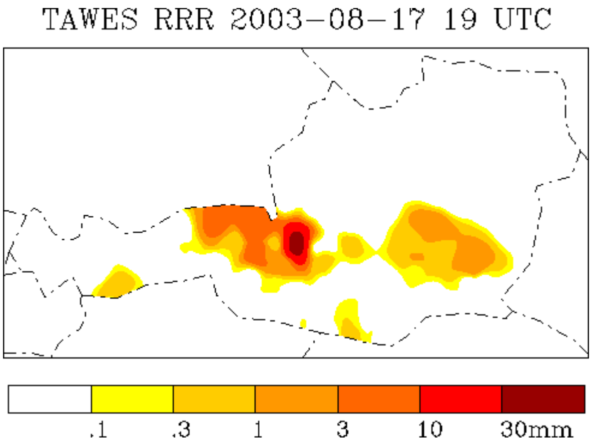


Fig.23 Hourly precipitation rate interpolated from the local obs. network

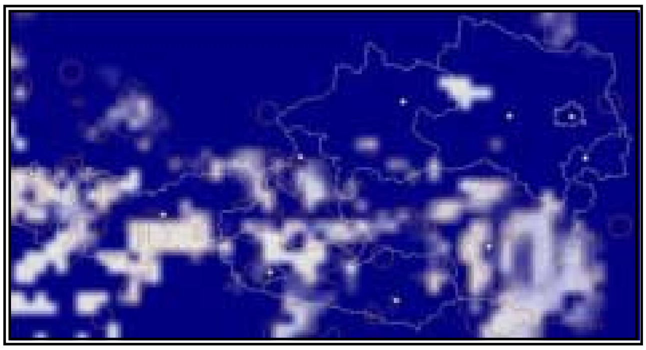


Fig.24 Convective cloudiness and precipitation prognosed by ALADIN (REF)

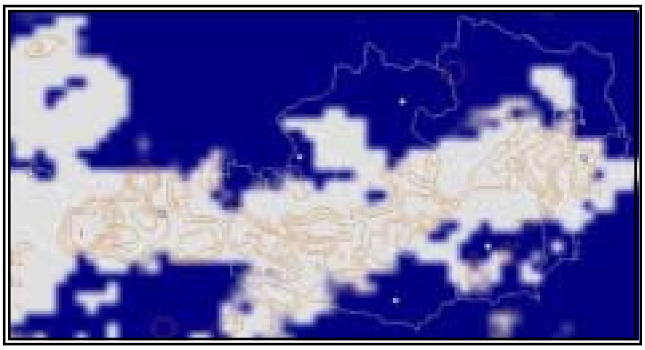
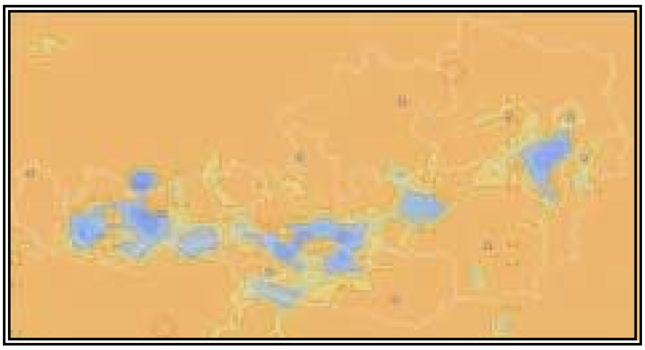
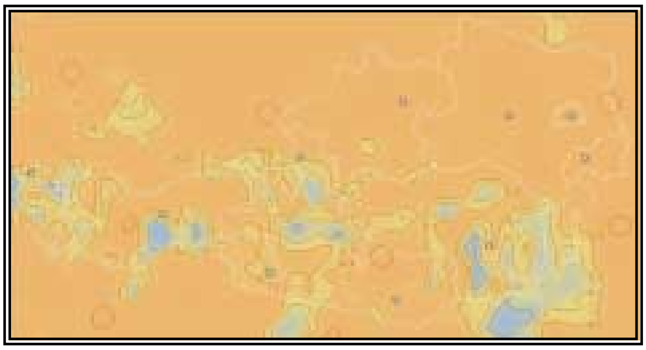


Fig.25 Convective cloudiness and precipitation prognosed by ALADIN (EXP)

Fig.26 Convective precipitation (hourly rate)
Fig.27 Convective precipitation (hourly rate)





prognosed by ALADIN (REF)
prognosed by ALADIN (EXP)

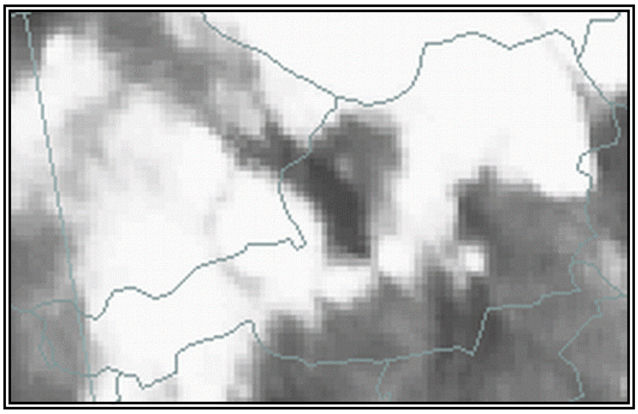


Fig.28 WV satellite image from METEOSAT

All figures are related to the **18th** of **August 2003**, **18:00 UTC**. (+42 h)

REF – operational forecast of al25_t2
EXP – experiment with threshold for accumulated moisture convergence (5.E-06)

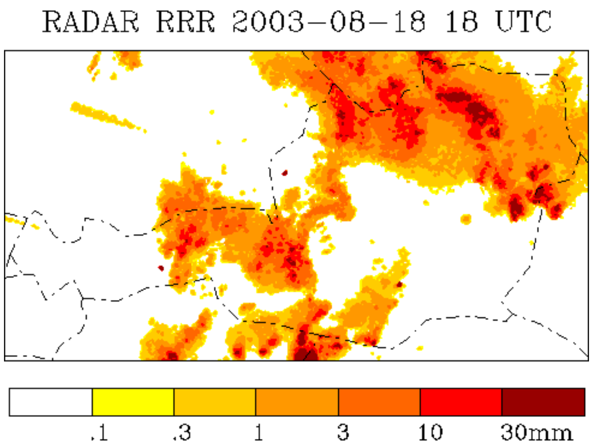


Fig.29 Hourly precipitation rate estimated by radar measurement

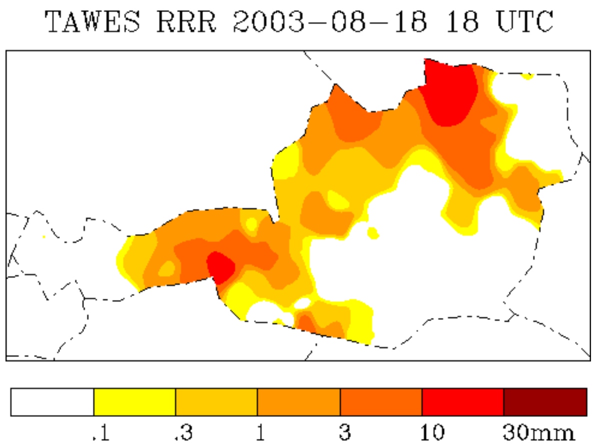


Fig.30 Hourly precipitation rate interpolated from the local obs. network

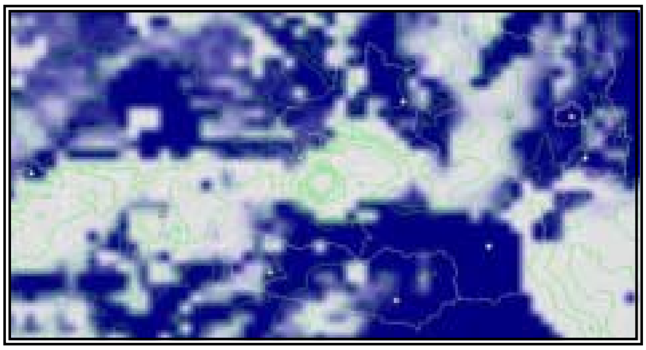


Fig.31 Convective cloudiness and precipitation prognosed by ALADIN (REF)

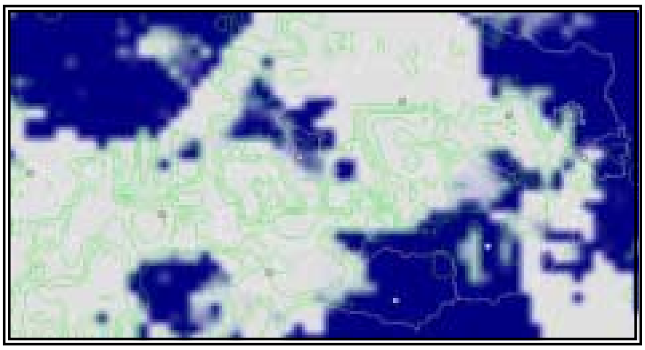
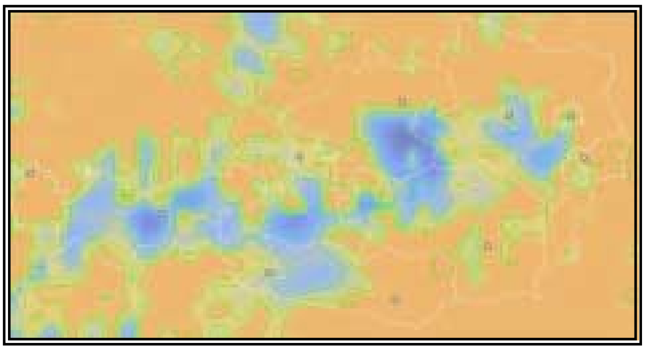
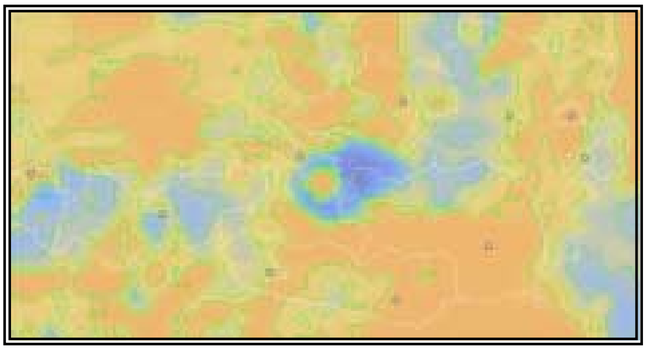


Fig.32 Convective cloudiness and precipitation prognosed by ALADIN (EXP)

Fig.33 Convective precipitation (hourly rate)
Fig.34 Convective precipitation (hourly rate)





prognosed by ALADIN (REF)
prognosed by ALADIN (EXP)

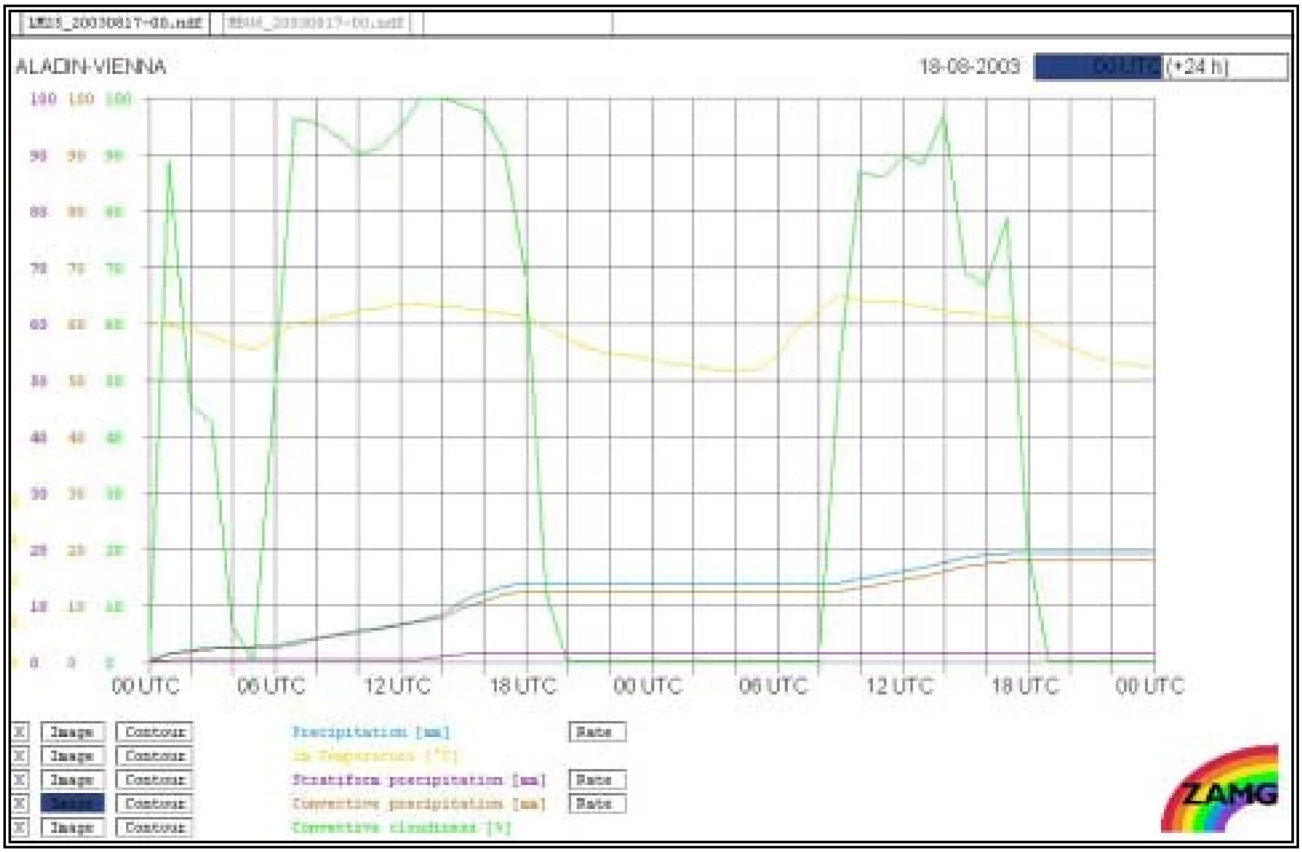


Fig.35 Meteogram for LIENZ for period 17.08.2003 - 18.08.2003 (al25t2 – REF:oper)

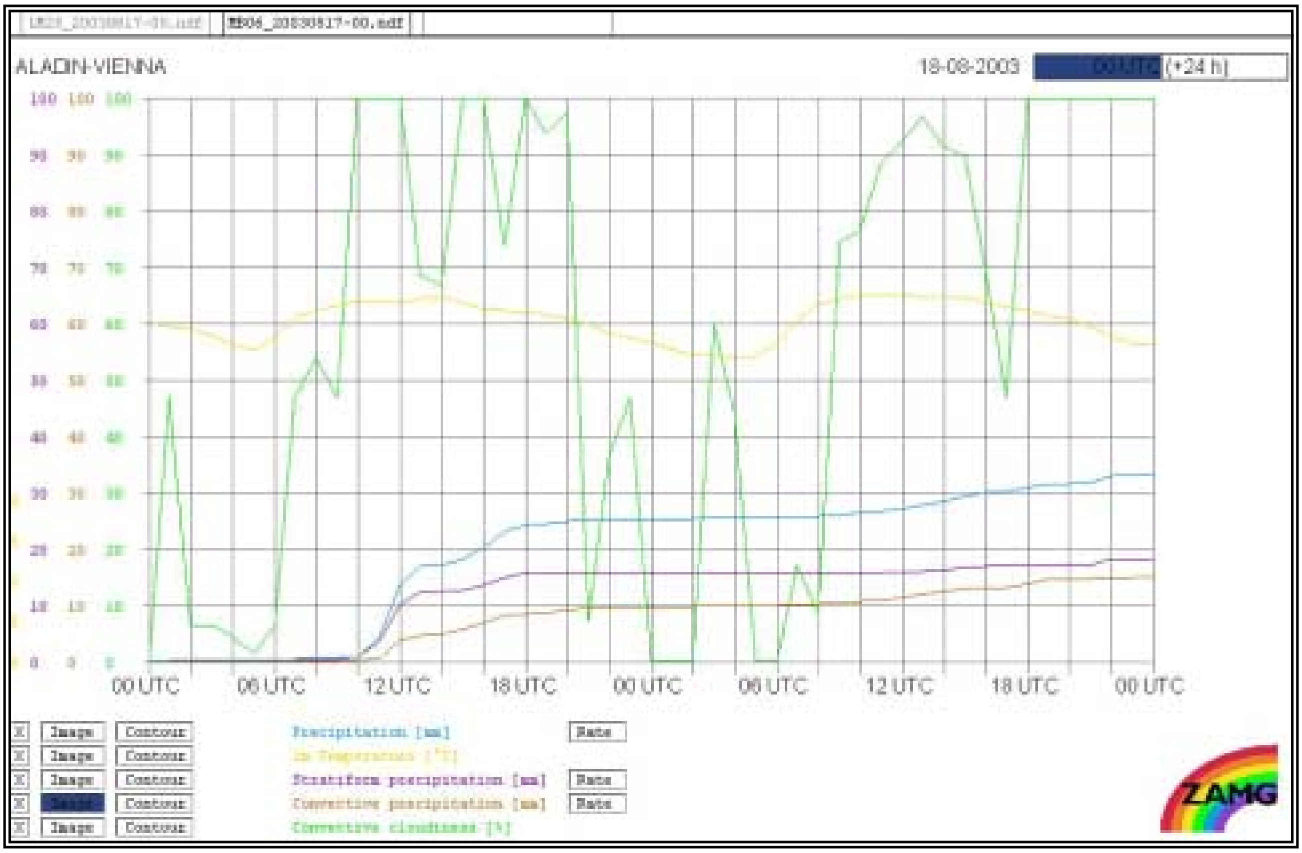


Fig.36 Meteogram for LIENZ for period 17.08.2003 - 18.08.2003 (al25t2 – EXP:5.E-06)

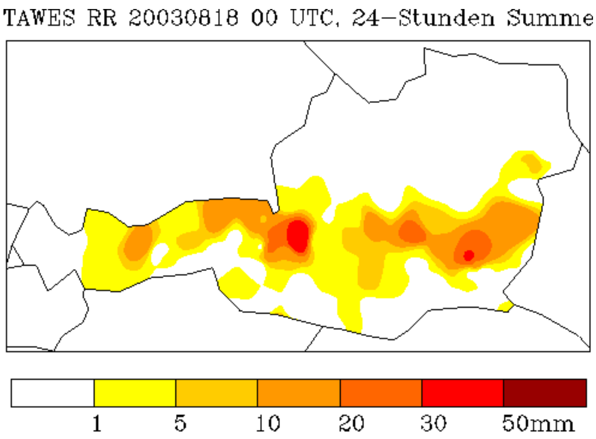


Fig.37 24-hours precipitation rate interpolated from the local obs. network

Positive impact on the reduction of the area covered by convective precipitation is obvious also from the 24-hours precipitation rate maps. One can see, that our experiment with delayed beginning fo deep convection (**Fig.39**) is in better correlation with the observed data (**Fig.37**) than the operational forecast (**Fig.38**), which is too much widespread. To the contrary, again an significant increase of stratiform precipitation in our experiment was observed. On the **Fig.40** and **41** one can see the total predicted precipitation – so the convective parts must be substracted from them.

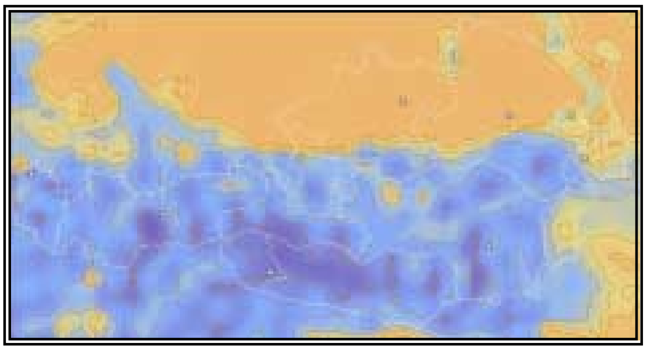


Fig.38 Convective precipitation (24-hours rate) prognosed by ALADIN (REF)

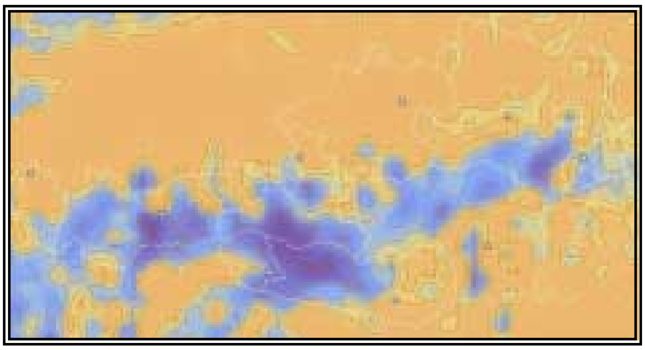


Fig.39 Convective precipitation (24-hours rate) prognosed by ALADIN (EXP)

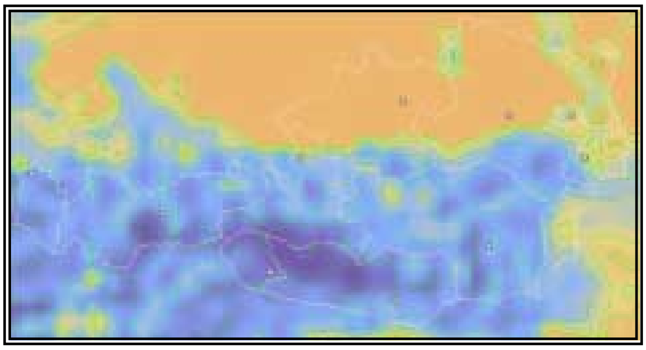


Fig.40 Total precipitation (24-hours rate) prognosed by ALADIN (REF)

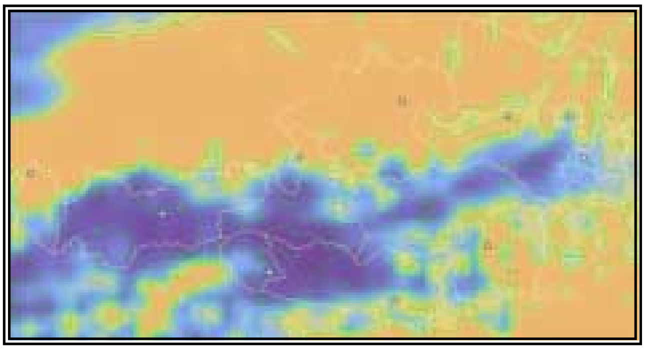


Fig.41 Total precipitation (24-hours rate) prognosed by ALADIN (EXP)

Time delay equation for moisture convergence

Another way of delaying initiation of convective processes in model is to modify one of the lounching parameters – moisture convergence, rather than triggering functions itself. This was done by the time delay equation applied on instantaneous moisture convergence and the stored value from the previous time step. We achieved required effect by combination of those two values together with decelerating coefficient. Several values for τ (expected time lag) were tested. Significant decrease of convective precipitation rates was observed and the area covered by them was reduced as well (see **Fig.42**-**57** for different decelerating coefficients - delays, with the case of August the 17th on the left and the case of August the 04th on the right side). However, the time delay of convective activity produced by model was not so obvious, since the most active cells were present from the very beginning of integration while the weaker ones just disappeared.

Further, there was almost no change of the original structure observed and the convective patterns didn't change their locations very much. Again the negative impact of abnormal increase of stratiform precipitation at the same time, as for the previous experiments, was observed. One can see this feature on the meteograms for selected grid point within our area of interest (**Fig.58** and **59**).

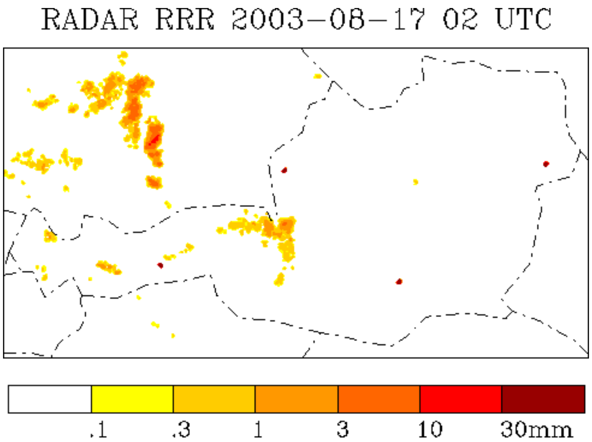


Fig.42 Hourly precipitation rate estimated by radar measurement

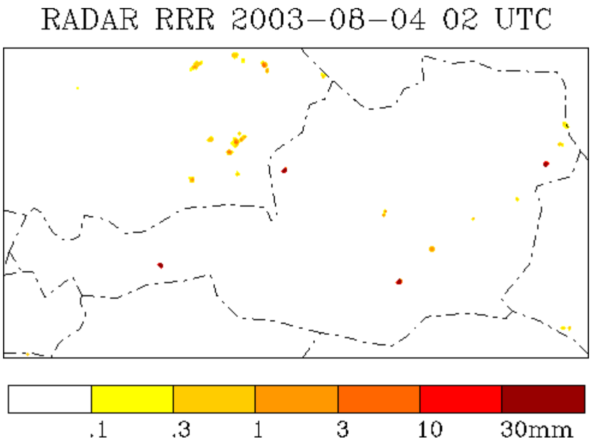


Fig.43 Hourly precipitation rate estimated by radar measurement

Fig.44 Convective precipitation (hourly rate) prognosed for 02 UTC (REF)

Fig.45 Convective precipitation (hourly rate) prognosed for 02 UTC (REF)

Fig.46 Convective precipitation (hourly rate) prognosed for 02 UTC (delay ~0.5h)

Fig.47 Convective precipitation (hourly rate) prognosed for 02 UTC (delay ~0.5h)

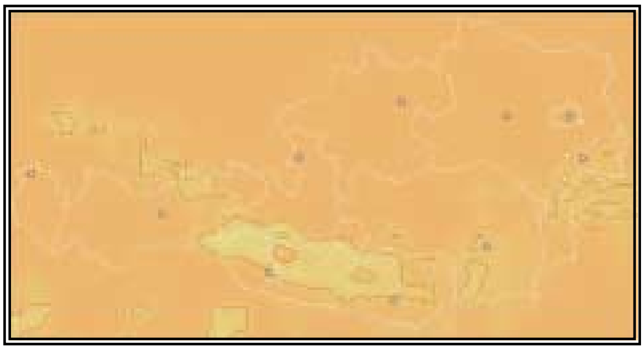


Fig.48 Convective precipitation (hourly rate) prognosed for 02 UTC (delay ~12h)

Fig.49 Convective precipitation (hourly rate) prognosed for 02 UTC (delay ~12h)

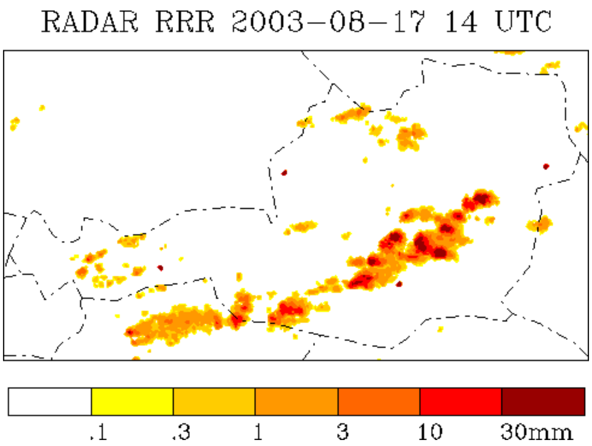


Fig.50 Hourly precipitation rate estimated by radar measurement

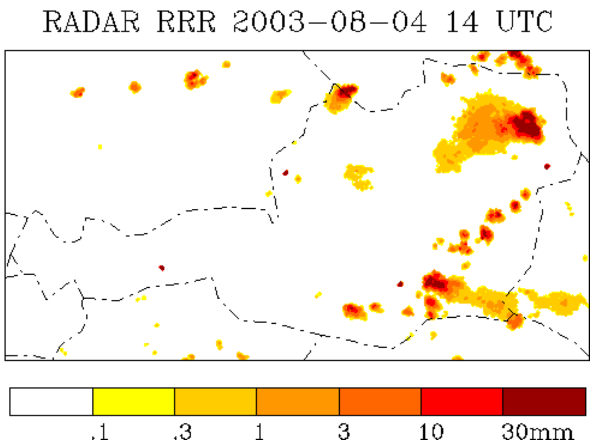


Fig.51 Hourly precipitation rate estimated by radar measurement

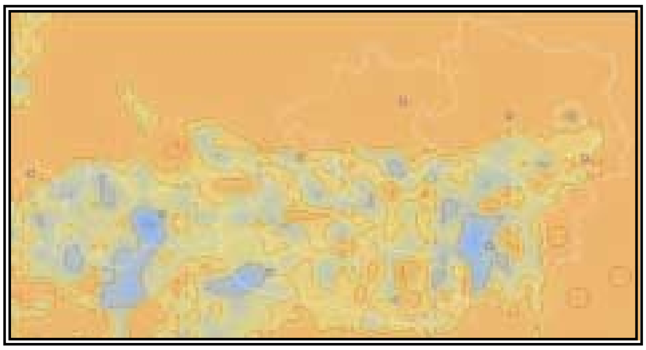


Fig.52 Convective precipitation (hourly rate) prognosed for 14 UTC (REF)

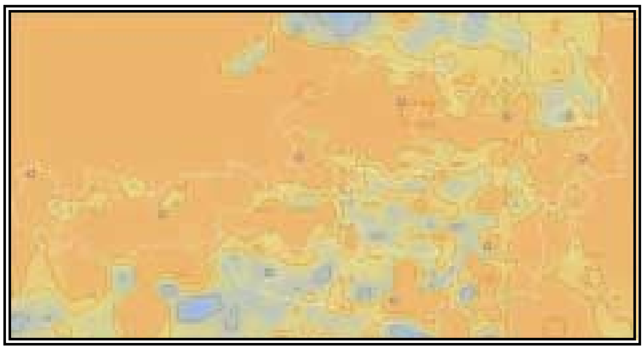


Fig.53 Convective precipitation (hourly rate) prognosed for 14 UTC (REF)

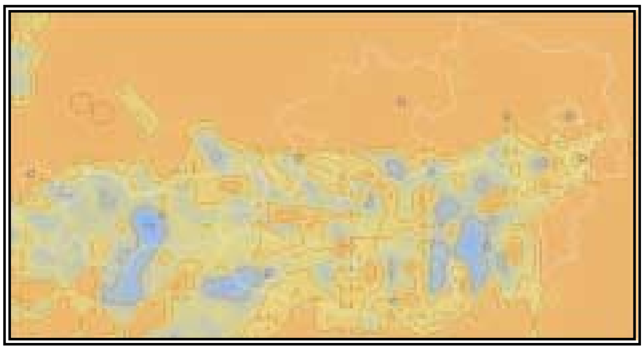


Fig.54 Convective precipitation (hourly rate) prognosed for 14 UTC (delay ~0.5h)

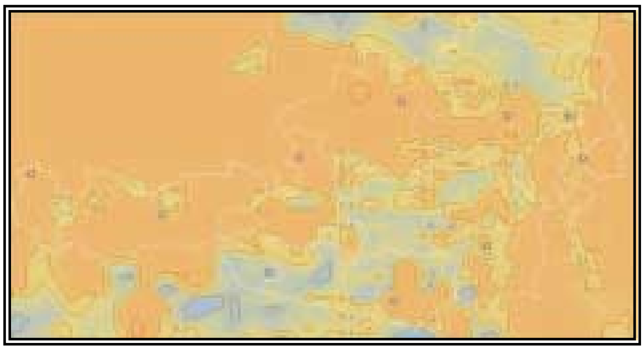


Fig.55 Convective precipitation (hourly rate) prognosed for 14 UTC (delay ~0.5h)

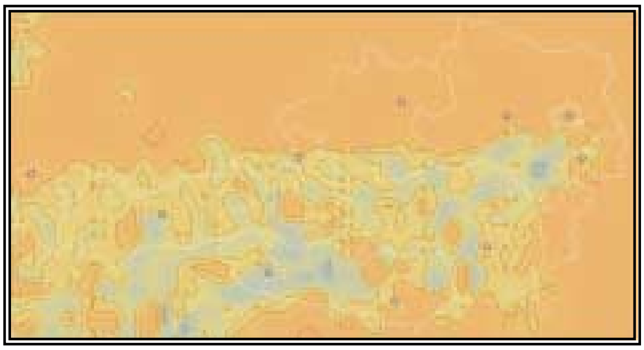


Fig.56 Convective precipitation (hourly rate) prognosed for 14 UTC (delay ~12h)

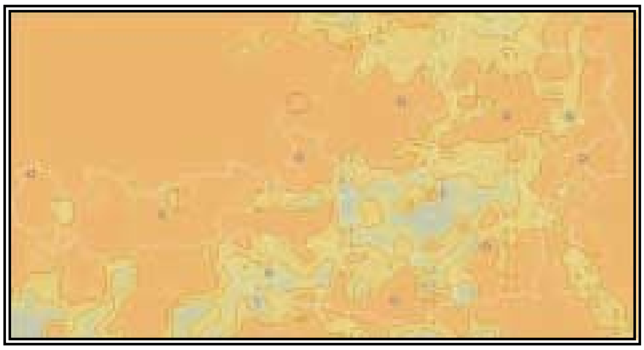


Fig.57 Convective precipitation (hourly rate) prognosed for 14 UTC (delay ~12h)

Fig.58 Meteogram for period 17.08.2003 - 18.08.2003 (REF – al25_t2 oper)

Fig.59 Meteogram for period 17.08.2003 - 18.08.2003 (EXP with delay ~12h)

Conclusion

Although the application of time delay equation seems to be more clean concerning the code modification, than the approach with accumulated moisture convergence used as an additional KUO condition in triggering, it was not as successful as we would have liked. With the small decelerating coefficients we need, it can happen, that the modified moisture convergence used for trigger will never converge to the historicaly maximal instantaneous values and it will be temporaly smoothed too much. And this will not be the same as to release convection later on but with the unchanged “strength”. It seems that manipulating the input only (without any changes in triggering) doesn’t give better results than those achieved by additional triggering condition. The convection was getting weaker and weaker (together with smaller and smaller decelerating coefficients) along the whole integration till the moment it completely disappeared.

In their current form, none of these approaches can be used operationally and there must be further research done in order to solve the problem of too early released convection. However, our investigation has shown, that better timing of convection can be profitable to its future evolution (which is quite positive fact). Last but not least, we have learned again something more about deep convection parameterization – especially about its triggering and we hope, our experiments could be a good starting point for the next research.

Finally, it’s worth to say, that there are more ideas to be tested which arrived along with the above mentioned experiments but there was no time left to try them. For example a kind of combination of the experiment with the accumulation of moisture convergence and the one with the time delay equation. As was proposed by Jean-Francois Geleyn, one can think about this problem as about the bathtube, the tap and the sink. The bathtube will be a cumulated quantity dimensionally equivalent to the time integral of instantaneous moisture convergence (our reservoir), the tap will be instantaneously computed moisture convergence (charging our reservoir) and the sink will be dependent on the time lag and on the total accumulated moisture (which will be used in the second KUO triggering condition). Of course, in case it will be consumed in deep convection, an appropriate volume of moisture must be then substracted from our reservoir. For possible operational application also some kind of cycling will be required (in order not to start always with empty reservoir).

Remark

It is important to know, that all mentioned experiments were carried out on the code of al25_t2 export version of ALADIN model. During our investigation we spotted and localized the problem of convective cloudiness diagnostics. Since the new Xu-Randall scheme is used here for convective cloudiness diagnostics as well, it can happen that it is diagnosed in special case of saturation or oversaturation even if convective condensate in the appropriate layer equals zero! Unfortunately, this means that convective cloudiness in output is not quite reliable and the problem of Xu-Randall scheme may have also some other negative side effects. However, we believe that the precipitation forecast itself was not touched by this bug.