Research and developments at ZAMG July – December 2004

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1. INCA – A high-resolution analysis and nowcasting system based on ALADIN forecasts

A common characteristic of today's numerical weather prediction (NWP) models is that their forecast errors in the nowcasting range, up to a few hours, are not significantly smaller than those at +12 or +24 hours. This is because NWP models start from analysis fields that may already differ significantly from observed values at the observation locations. No matter which method is used, be it variational analysis, optimum interpolation, or nudging, NWP analyses are strongly constrained by the model's dynamics and physics. The INCA analysis module is specifically designed for forecasting applications, not for model initialization. For temperature, humidity, and wind it is three-dimensional and has a time resolution of 1 hour. For precipitation it is two-dimensional, with a time resolution of 15 minutes. Horizontal resolution is 1 km, vertical resolution 200 m. The vertical coordinate is geometric height z above a "valley floor surface" which is basically the lower envelope of the terrain.

The analysis starts with an ALADIN forecast as first guess. Then an error field is created from the differences between the model forecast and the actual observations at the stations. Since we have a certain number of mountain stations, we can compute the error field in three-dimensions. In the future we may include AMDAR data into the system to obtain improved vertical structures. The spatial interpolation of the point differences is done by distance weighting in the horizontal, and potential-temperature distance weighting in the vertical. The variables used are potential temperature and specific humidity up to now but will be changed to liquid water potential temperature and total water content in the future (e.g. to get a better analysis of low clouds). Figure 1 shows as an example analyses of 2 m temperature and relative humidity. It is a low-stratus situation and in the relative humidity analysis one can see the boundary of the cloudiness at the Alpine foothills. A rather complex temperature structure arises because of the presence of the stratus in low areas, leading to inversions, and the normal decrease of temperature with height in the Alpine areas.

Nowcasting of temperature and humidity is currently based on a simple weighting algorithm that gives a smooth transition from the analysis to the ALADIN forecast after several hours. Figure 2 shows the reduction in temperature forecast error that can be gained. In the future, error motion vectors (EMVs) will be used instead of the prescribed weighting. This will allow better compensation of phase-shift errors in the ALADIN forecast, for example those associated with fronts.

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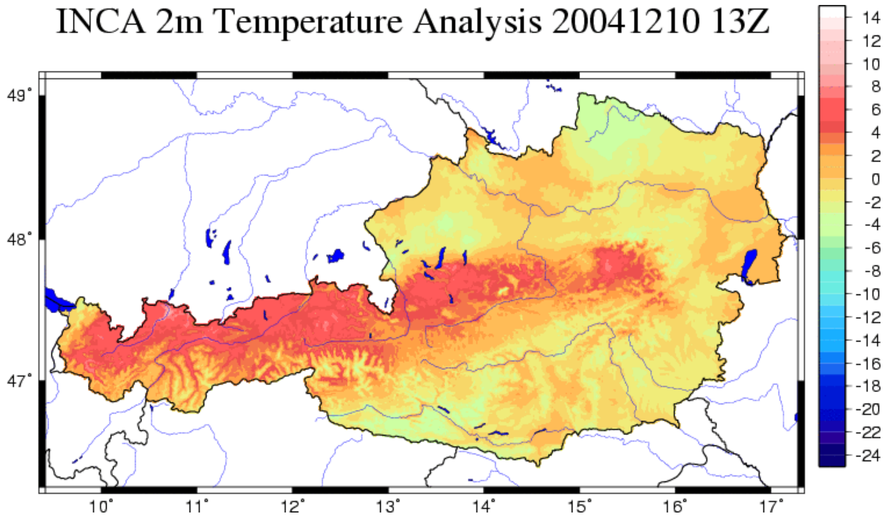

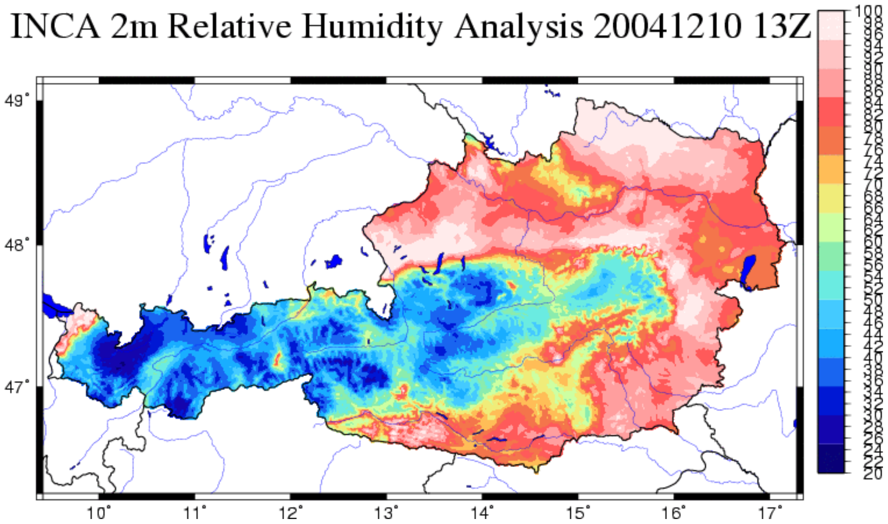

Figure 1 : INCA 1 km Analysis of 2m temperature and 2m relative humidity during a low-stratus episode. It is based on the operational ALADIN forecast, station observations, and high-resolution topographic data.

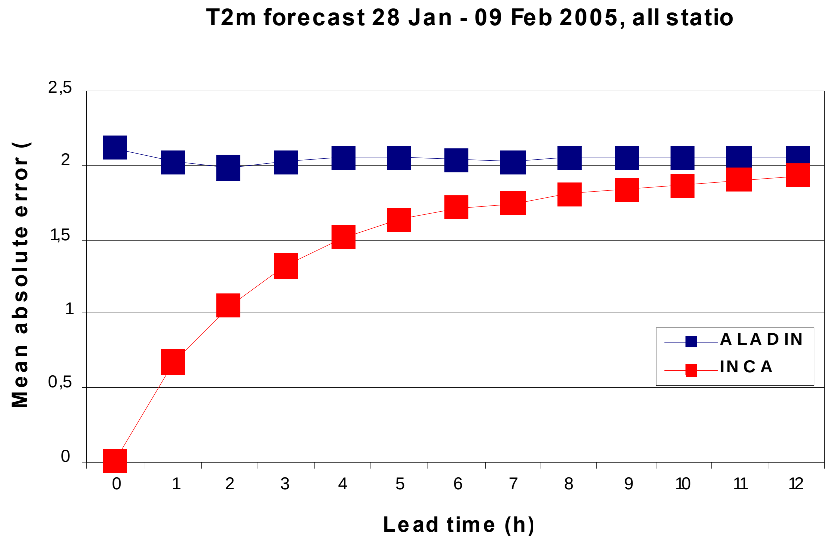

Figure 2 : Comparison of ALADIN and INCA T2m forecast error (mean over ~140 stations) as a function of lead time.

2. Quantitative evaluation of the orographic precipitation problem in ALADIN

During orographic upslope flow situations, the ALADIN model tends to predict excessive rainfall on peaks and ridges and rather dry conditions with negligible precipitation in valleys and basins. Moreover, the modelled precipitation field is connected to the flow-oriented steepness of the model topography in an extremely close and direct way (Figure 3), most likely much closer than in reality.

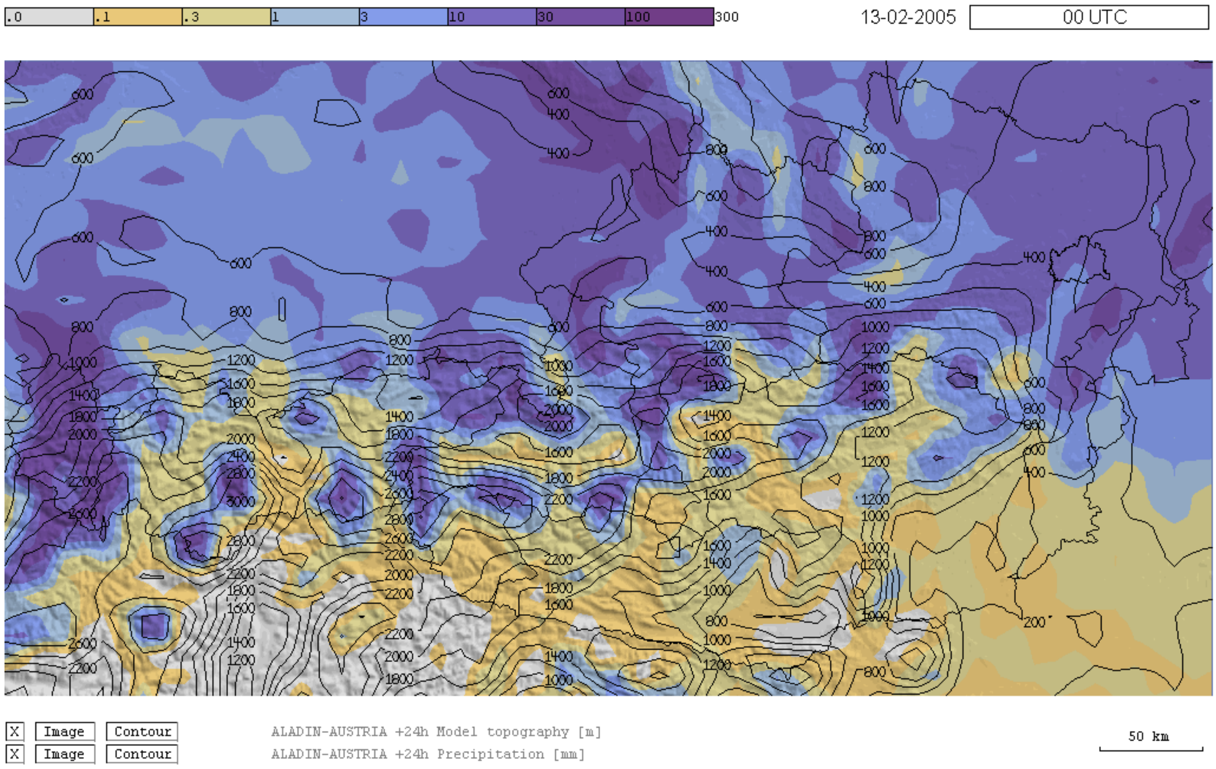

Figure 3 : Typical example of a 24-hourly ALADIN cumulative precipitation forecast (colors). The model topography is shown in isolines, the actual terrain by shading.

We think that the overestimation of upwind/downwind and peak/valley precipitation contrasts is to a large degree caused by the diagnostic treatment of cloud water in ALADIN. It causes precipitation maxima to more or less coincide with vertical velocity maxima in the model, whereas in reality considerable amounts of cloud water (and also precipitation, in the case of snow) may be advected onto the downwind side of a mountain.

In order to obtain a quantitative diagnosis of the problem, ALADIN point forecasts of 24-hourly rainfall (for the lead time period +0 to +24h) are compared to station observations. The comparison is performed on monthly precipitation sums. Figure 4 shows results for the months Dec 2004 and Jan 2005, where a number of orographic upslope events affected the northern Alpine slopes. Figure 4 shows that inner Alpine valleys generally show ratios < 1, and < 0.5 in several areas. Along the northern Alpine rim a systematic overestimation of precipitation by a factor of 1.5-2 is found.

It is instructive to analyse some of the small-scale features, such as the precipitation ratio maximum near the center of the domain, South-East of the city of Salzburg. This is an area that is in reality located on the downwind side of a steep, high mountain (Dachstein) and experiences strong sheltering effects. The model, however, does not resolve the valley. Instead there is an area with a relative topography maximum. Thus (as can be seen in Figure 3) orographic precipitation enhancement is predicted instead of sheltering.

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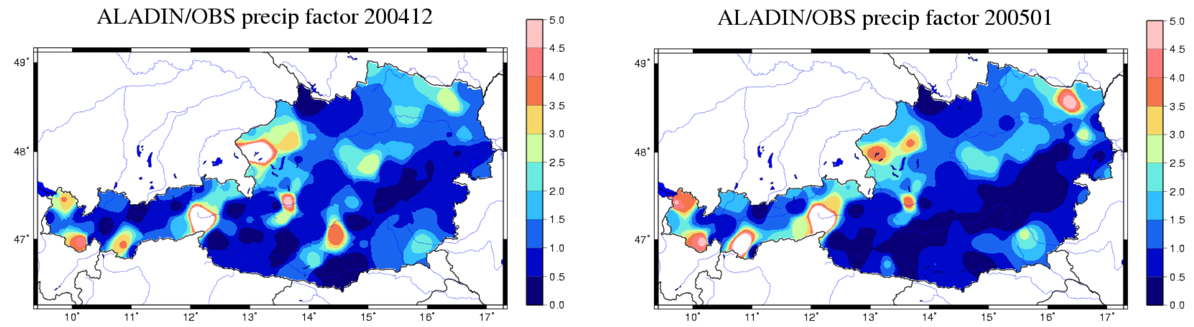

Figure 4 : Interpolated ratio of precipitation predicted by ALADIN (+0 to +24 h) and observed at stations during the months Dec 2004 and Jan 2005. Inner Alpine valleys generally show ratios <1, with values <0.5 in many places. Along the northern Alpine rim a systematic overestimation of precipitation is found.

3. Stratus prediction

Using the Seidl-Kann (SK) inversion cloudiness scheme, satisfactory low stratus forecasts are obtained for lowland areas in the operational ALADIN run at ZAMG. A good stratus prediction in basins (even if they are very wide, such as the Linz basin in Upper Austria) was however found to require switching off, or setting to a very small value, the "horizontal" diffusion of temperature. This is because the spurious vertical component of this diffusion too strongly smoothes inversions. Thus, in order to get the full benefit of the SK scheme operationally, the T-diffusion would have to be switched off. Since we were not sure whether this has detrimental effects in situations with strong temperature gradients, a few tests were carried out, for example on the storm case of 19 Nov 2004. The results showed no obvious problems, and little difference in forecast fields between the experimental and operational runs. This means we will most likely switch to a rather small T-diffusion operationally.

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4. Evaluation of mesoscale precipitation forecasts in the Southern Alpine area

A comparison of precipitation forecasts for different regions in Austria shows that the northern upslope precipitation areas (Salzburg, Upper Austria) show a higher predictability than the upslope areas in the South (Carinthia). The orographic situation appears to be the main reason for this. In the south, the primary upslope precipitation belts are the mountain ranges in Italy and Slovenia. Austrian areas are located downwind of these "primary" upslope areas. Several fall and wintertime heavy precipitation events (1999-2003) during southerly flows were analysed and compared with ALADIN forecasts. The existence of systematic forecast errors for parts of Carinthia and East Tyrol was documented and analysed with regard to the dependency on certain weather situations. The results show that regions downwind of strong primary upslope areas show a high percentage of cases in which the precipitation amounts are underestimated by ALADIN. Even in the presence of synoptic-scale lifting (e.g. frontal passage), over-pronounced lee-side downward motion and overestimated loss of water in the upslope areas result in an underestimation of precipitation amounts in the downwind regions. Further it was examined whether comparison of upstream soundings (e.g. Udine) with ALADIN pseudo-TEMPs can give additional prognostic information regarding precipitation patterns and the expected quality of the ALADIN forecast. The results show that only in a few cases differences between TEMP and pseudo-TEMP can be linked with deviations between observed and modelled precipitation patterns in the downwind areas.

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5. Verification of dynamically downscaled wind

For the 4-month period March-June 2004, 6-hourly forecasts (up to +48h) of
a) the operational (9.6 km) run,
b) the *dynad* (2.3 km) run,
c) the *dynad* (2.3 km) run without envelope,
were compared. The main results are the following. There is little difference between b) and c), as expected. The envelope is not important at this resolution. All stations taken together, there is no clear signal of improvement from a) to b). If stations are grouped according to elevation, a moderate positive signal is found for the highest stations (2000-3400m), especially mountain top stations. Individual stations show up to 15-20% improvement in mean absolute error (MAE) in b) compared to a), but there are also stations which show worsening of the same amount (that's why in the mean over all stations there is no positive signal). In most cases, the changes in MAE reflect to a large degree simply changes in bias.

We had expected that at least for those stations which are inside deep valleys, and thus very poorly represented at the operational resolution, the 2.3 km *dynad* run would bring significant improvements both in wind speed and wind direction. It turns out this is not the case. Apparently the wind regime in those valleys is strongly influenced by thermally induced flows (valley winds) which are not improved by the *dynad* run.

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6. Development of a LAM ensemble prediction system using ALADIN

Limited-area models provide highly structured forecast fields both in space and time. However, often the small-scale features are extremely sensitive to uncertainties of the model and/or initial conditions. To obtain a guidance for the forecaster with regard to this uncertainty, the project "ALADIN Limited Area Ensemble Forecasting" has been started at ZAMG. It is an ensemble forecast system with 11 members, in which perturbed initial conditions are created using a breeding method. In a second step, the Ensemble Transform Kalman Filter (ETKF) technique will be applied to the breeding vectors. The NWP model used is ALADIN with reduced horizontal and vertical resolutions (16 km, 31 levels). The domain covers the whole of Europe and large parts of the North Altantic ocean.

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