Postprocessing of the aLMo Precipitation with the Neighborhood Method

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1 Introduction

The resolution of numerical weather prediction models is advancing to finer scales. With increasingly smaller scales, the predictability is decreasing due to the sensitivity of the forecasts to errors in the initial state and in the model formulation. This is especially true for precipitation, a meteorological field with a high temporal and spatial variability. The exact time of onset and location of a single convective cell for example cannot be predicted even with the highest-resolving models. The uncertainty in time and space should be accounted for when using model output fields on the grid scale.

The neighborhood method (Theis *et al.*, 2005) accounts for the probability related to local-scale spatial and temporal model uncertainty. It solves for the above-mentioned predictability problem by sampling a temporal and spatial neighborhood around each grid cell to derive a probabilistic forecast. Doing this, the neighborhood method provides a way to derive a probabilistic forecast from a deterministic model.

In the present study, precipitation forecasts of the Swiss set-up of the COSMO model with a grid spacing of 7 km, the Alpine Model (aLMo), are used as input.

2 Optimizing the neighborhood size

Method

The neighborhood size has an important impact on the magnitude of the predicted probabilities. It is, however, difficult if not impossible to determine an optimal neighborhood size based on objective verification alone (Theis 2005). With this unpromising prospect, I chose to base the optimization on a graphical comparison of the forecast probabilities with actual precipitation measurements of August – October 2006. Of course, an objective evaluation of the neighborhood determined in this way must follow later.

Spatial radius of neighborhood

Theis *et al.* (2005) tested three different sizes for the neighborhood. A small, a medium and a large neighborhood with a spatial radius of 3, 6 and 10 grid points, respectively, were used. Here, four sizes of 3, 5, 10 and 20 grid point radius are compared graphically (Figure 1). While the smallest radius gives more detail than is meaningful for a probabilistic method, the largest radius on the other hand blurs the information too strongly.

Shape of the neighborhood

Theis *et al.* (2005) tested different spatial shapes. The impact proved to be quite small and at times even detrimental. Therefore, a circular neighborhood was chosen here, without further experimenting with spatial shape. In the time dimension, they chose a spatial radius depending on the temporal distance to the central point. This implies a space-time dependency. Here, it is assumed that the time and space dimensions are independent. This

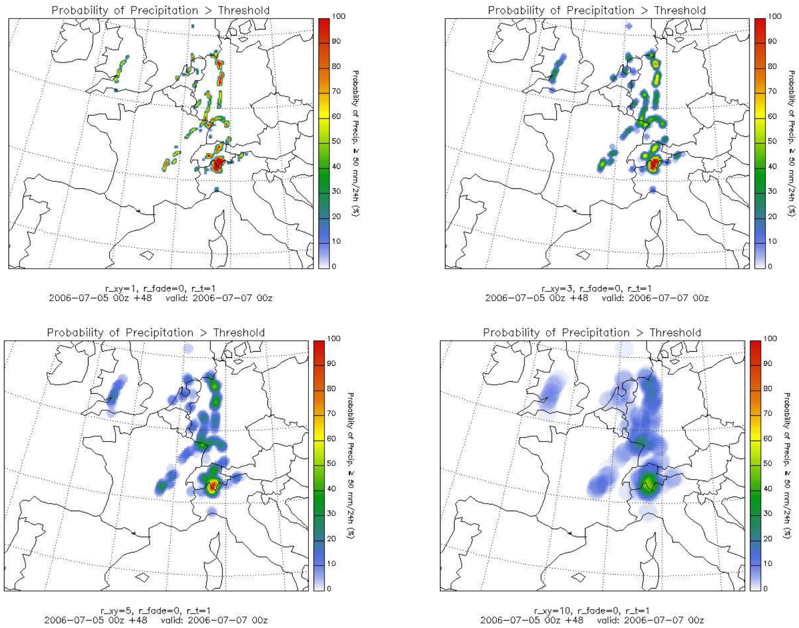

Figure 1: Probabilities of precipitation for spatial neighborhood radius of 1, 3, 5, and 10 grid points, in this order.

assumption is true if the ambient wind is nearly zero, and becomes increasingly inaccurate with increasing advection. The resulting neighborhood is cylindrical as opposed to the ellipsoidal neighborhood of Theis *et al.* (2005).

Linearly fading weights

The circular neighborhood shape in space, in combination with localized strong precipitation peaks, leads to a dotted plot of probabilities, with a circular dot surrounding each major precipitation peak (Figure 1). Such an unwanted feature could be smoothed out in a next step, but it is more meaningful to do this as part of the neighborhood processing by adding an additional zone around the neighborhood with decreasing weights. For simplicity, the weights were chosen to decrease linearly. The physical reasoning behind such a zone, or sponge-layer, as it could be called, is that given a forecast at the central point, a thunderstorm is equally likely to appear within a certain radius, but that beyond this radius the likelihood decreases and finally reaches zero at some larger distance. Figure 2 shows the weight depending on the spatial distance of a grid cell to the neighborhood center for two neighborhood sizes.

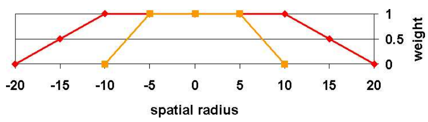

Figure 2: Weights for two different spatial sizes of the neighborhood. Red: Zone of equal weight and fading zone of 10 gridpoint radius each. Orange: 5 gridpoint radius each.

Temporal radius

The temporal radius of the neighborhood finally represents the uncertainty in time of a rainfall prediction. For convective precipitation, it is known to span several hours. However, tests with temporal radius of 0, 1, 3, and 6 hours showed relatively little influence for a case

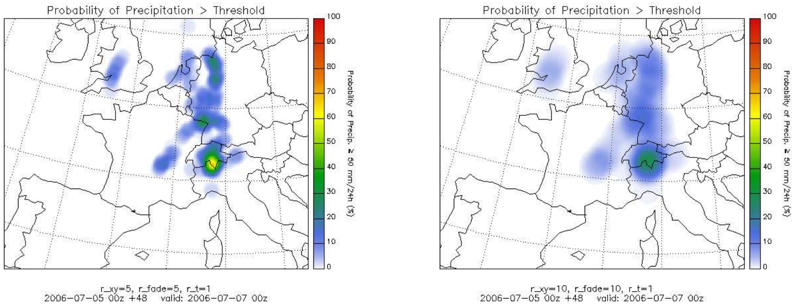

Figure 3: Same as Figure 1 but with a fading zone of same width as the spatial radius added, for 5 (left) and 10 (right) gridpoint radius.

with frontally induced thunderstorms. This might be different if no front is involved, but the rainfall accumulation of 6 hours or even more of 24 hours already has a smoothing effect on the time scale, rendering the temporal extent of the neighborhood less critical.

3 Cases

Threshold 25 mm / 6 h

Figure 4 displays a case last summer with a small region of strong precipitation over southern Switzerland. The probabilities for precipitation above the threshold level of 25 mm / 6 h reach 50% in that region. Although probabilities and single precipitation events cannot be compared directly, large probabilities should coincide with rainfall above the threshold for a majority of cases. The probabilities generally decrease with increasing neighborhood size, thus the frequent occurence of moderate probabilities with actual rainfall above the threshold as in Figure 4 indicates that the chosen neighborhood size might still be slightly larger than optimal.

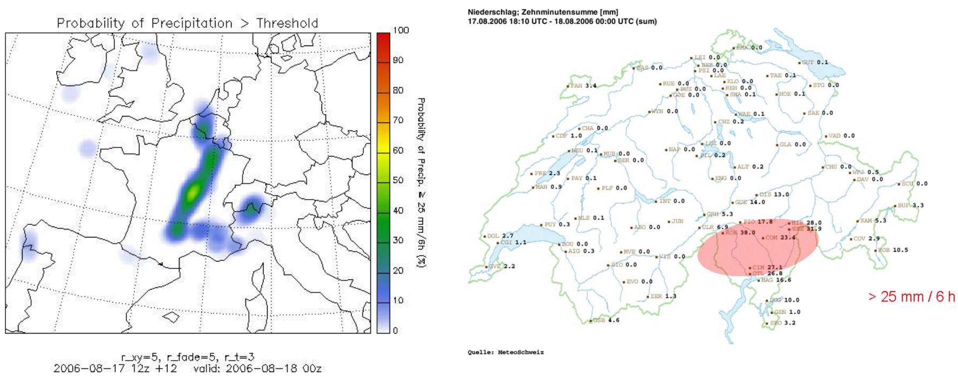

Figure 4: Probabilities predicted by the neighborhood method (left) and actual rainfall sum (right) for 2006-08-18 00:00 UTC

Threshold 50 mm / 24 h

Figure 5 shows a case with strong precipitation over northern Switzerland. The region of probabilities of 50% and more for precipitation above the threshold level of 50 mm / 24 h nicely fits with the observed precipitation.

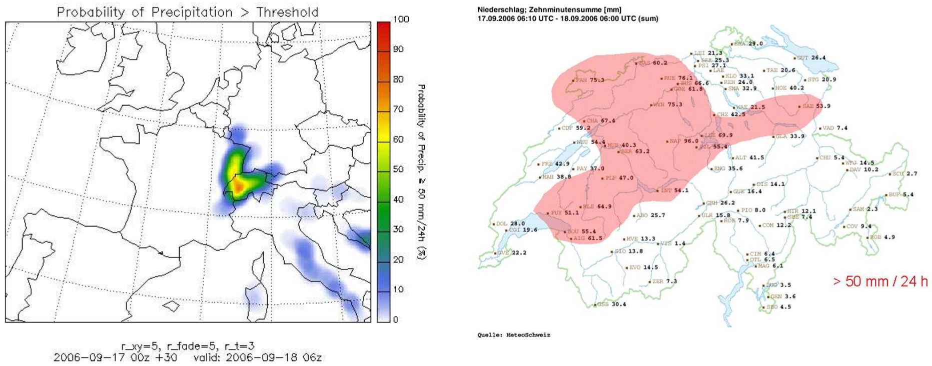

Figure 5: Probabilities predicted by the neighborhood method (left) and actual rainfall sum (right) for 2006-09-18 06:00 UTC

4 Conclusions and Outlook

The neighborhood method is used to derive a probabilistic forecast from a deterministic model. The probability is related to local-scale spatial and temporal model uncertainty. The resulting plots are compared to real cases and are optimized in this way. A spatial radius of five grid cells with an additional zone of decreasing weights with the same width gives probabilities which are in accordance with the observed events and non-events. The spatial radius is kept constant within the temporal radius of 3 hours, however the extent of the neighborhood in time is of lesser importance. This choice seems to be near the optimal size judging from the graphical comparison with the effective precipitation. A throughout validation however, using objective verification, will have to follow to prove the quality of the probability forecast with the chosen neighborhood.

The neighborhood method is able to represent the local uncertainty concerning the prediction of the exact position and onset of precipitation. It does not account for the uncertainty related to synoptic forcing, which can be done using a model ensemble forecast. A combination of the ensemble and the neighborhood methods would combine both synoptic-scale and small-scale uncertainties.

References

Theis, S., 2005: Deriving probabilistic short-range forecasts from a deterministic high-resolution model. Ph. D. thesis, Univerisity Bonn, Germany.

Theis, S. E., A. Hense, and U. Damrath, 2005: Probabilistic precipitation forecasts from a deterministic model: a pragmatic approach. *Meteorol. Appl.*, **12**, 257 – 268, doi:10.1017/S1350482705001763