The Impact of the Alps on COSMO-LEPS Forecasts for the August 2005 Flood Event

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1 Introduction

In August 2005, heavy precipitation for three days caused tremendous floods in Switzerland and in adjacent neighborhood countries (MeteoSwiss, 2006). A low pressure system over Italy transported warm and very moist air at the eastern edge of the Alps to the northern side where the air impinged on the northern slopes of the Alpine ridge (the mesoscale flow is shown later in Fig. 5). The heavy precipitation period started on August 20. During the following 72 hours, more than 100 mm precipitation occurred in a large area from the western Alps to the north-eastern Alpine foreland. In central Switzerland, more than 150 mm were observed and at some locations even more than 300 mm. Fig. 1 shows a precipitation analysis for the event, derived from about 400 rain gauges and a high-resolution precipitation climatology.

The global ensemble prediction system (EPS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) missed the intensity of this event, while the COSMO-LEPS forecast with initialization time 19.8.2005 1200 UTC provided a very appropriate warning (Walser, 2006). COSMO-LEPS is the limited-area EPS of COSMO. It makes high-resolution ensemble forecast available for central and southern Europe by a dynamical downscaling of selected ECMWF EPS members (see Marsigli et al., 2005) and is particularly benefical for the prediction of extreme weather events (e.g. Walser et al., 2006).

The aims of this study are twofold. First, we investigate the impact of the Alps on the amount and spatial distribution of precipitation for this extreme event. Second, we asses

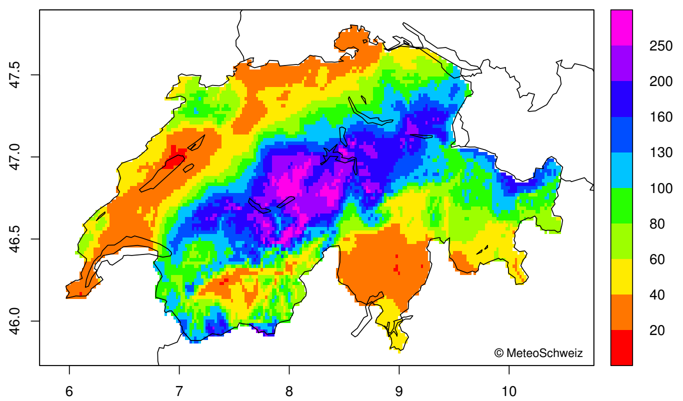

Figure 1: Accumulated precipitation from 20 Aug 2005 0600 UTC to 23 Aug 2005 0600 UTC (courtesy C. Frei, MeteoSwiss).

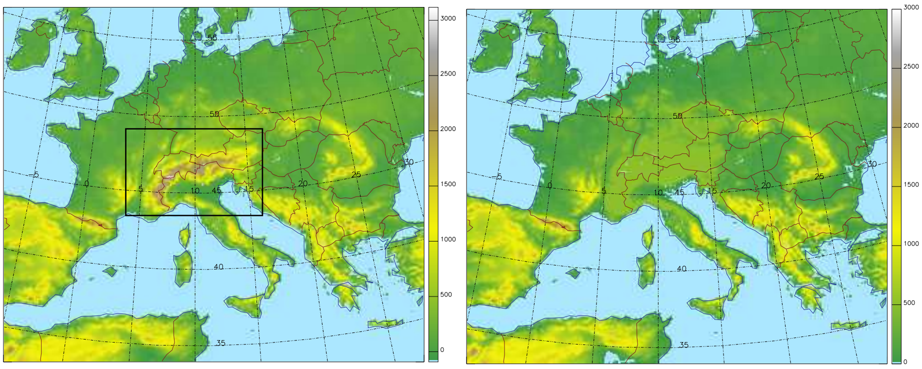

Figure 2: COSMO-LEPS model domain for experiments with (left) operational orography for the OPR experiment and (right) orography limited to 500 m in a rectangle including the Alpine arc for the FLAT experiment. The domain for the HR experiment with 2.2 km horizontal grid-spacing is indicated in the right panel.

the benefit of using a cloud-resolving EPS with a very detailed orography compared to the driving COSMO-LEPS forecast. The outline is as follows: Section 2 presents the experimental set-up of the experiments. Section 3 compares the probabilistic precipitation forecasts for the event with different settings, while Section 4 further analyzes the experiments on the basis of one specific member. Finally, the conclusions are provided in Section 5.

2 Experimental setup

COSMO-LEPS experiments are performed using three different configurations. The first setting corresponds to the operational set-up of COSMO-LEPS with a horizontal grid-spacing of 10 km, hereafter referred to as OPR[1]. For the second setting, referred to as FLAT, the orography is limited to 500 m a.s.l. in a rectangle encompassing the Alpine arc (which includes also the Jura, the Vosges, and the Black Forest). This change in orography required also adaptations of the roughness length. For grid points with reduced orography, the roughness length is set to 0.5 m which is a typical value for the Swiss plateau. The third setting provides a cloud-resolving ensemble for the Alpine region with a grid-spacing of 2.2 km driven by the OPR experiment. The model domains including the orography for the OPR and FLAT experiments are illustrated in Fig. 2. All experiments are based on version 3.19 of the non-hydrostatic limited-area COSMO model (formerly LM; see Steppeler et al. 2003) using the leapfrog kernel.

3 Comparison of probabilistic precipitation forecasts

In this section, probabilistic precipitation forecasts of the three ensemble experiments are compared. We first focus on the experiments OPR and FLAT. Fig. 3 shows probability maps for precipitation between August 20, 0600 UTC and August 23, 0600 UTC, which corresponds to the period with the largest observed 72-h precipitation amounts. The different panels indicate the probability to exceed 50 mm, 100 mm, and 150 mm, respectively. The OPR experiment (panels in middle row) shows high probabilities for large precipitation amounts for the region in which large values were observed (cf. Fig. 1), e.g. more than 60% probability

[1]This ensemble is based on a ECMWF EPS forecast with initial time 19.8.2005 1200 UTC while the operational COSMO-LEPS ensemble for this initial time was based on the ECMWF EPS forecasts for 0000 UTC and 1200 UTC.

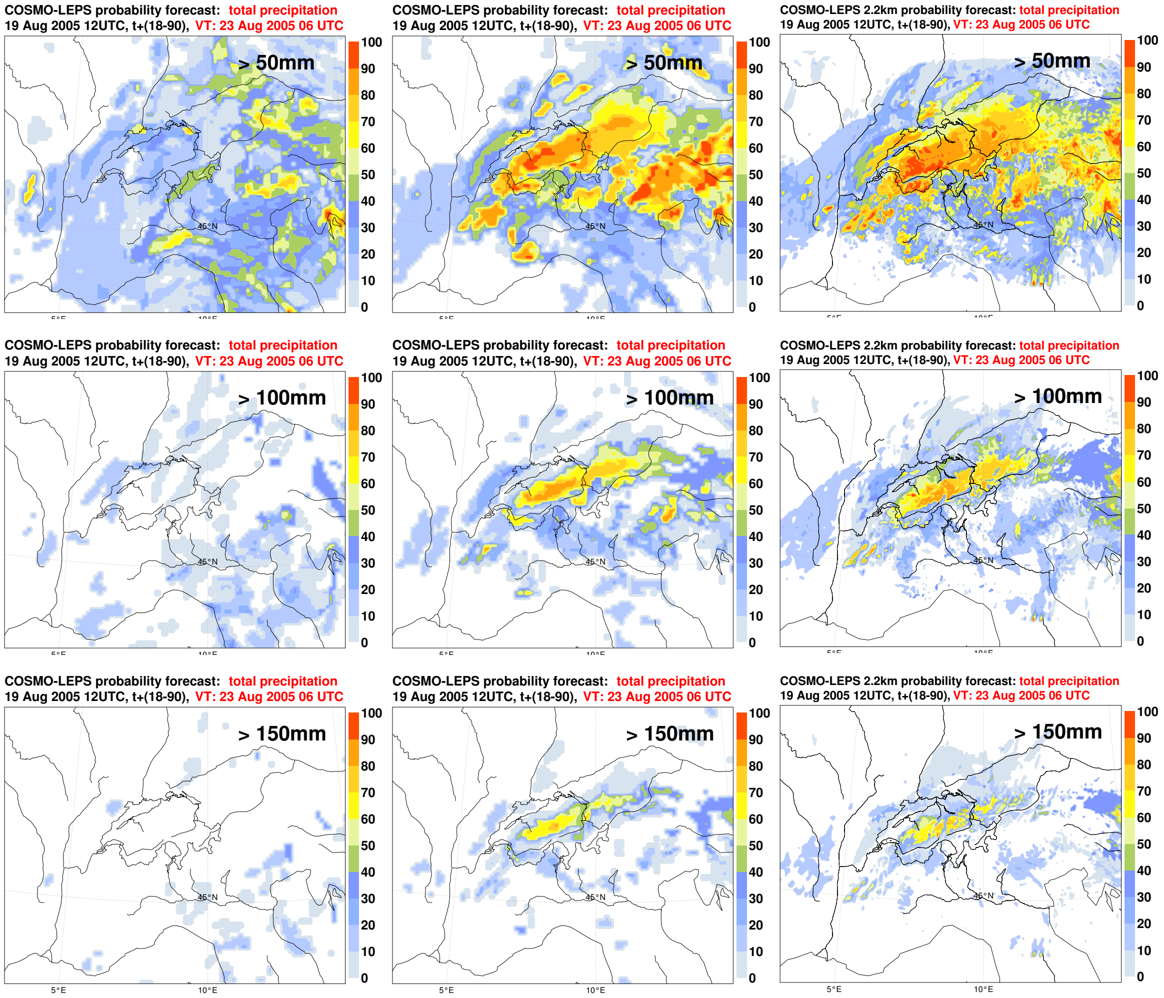

Figure 3: Ensemble experiments for initial time 19.8.2005 1200 UTC. The panels indicate the probability for accumulated precipitation between forecast hours 18-90 exceeding the thresholds 50 mm, 100 mm, and 150 mm, for the FLAT (left), the OPR (middle), and the HR (right) experiments, respectively (see text).

for precipitation exceeding 150 mm on the northern slopes of the Alps. In contrast, the FLAT experiment reveals probabilities of less than 40% for most parts of Switzerland even for the lowest threshold of 50 mm. In addition, the probabilities in this experiment are only marginal or even zero for amounts of more than 100 mm and in particular for more than 150 mm. Only for the Appenine, the FLAT ensemble predicts higher probabilities than the OPR ensemble with the threshold 50 mm.

The FLAT members produce clearly less precipitation compared to the OPR members, and the FLAT members do not compensate the large deficit on the northern slopes with higher precipitation amounts in other regions, although a comparison of the humidity transport does not show significant differences between the two experiments (not shown). Hence, the precipitation efficiency is clearly lower in the FLAT experiment.

For all three thresholds, the HR experiments provides, as expected, probability pattern with higher spatial variability than the OPR experiments, but the larger-scale pattern are very similar with similar amplitudes. This study cannot objectively evaluate the benefit of these local probability information provide by the HR experiments. However, we note some appropriate fine-scale features with regard to the observations (Fig. 1), e.g. no warning for

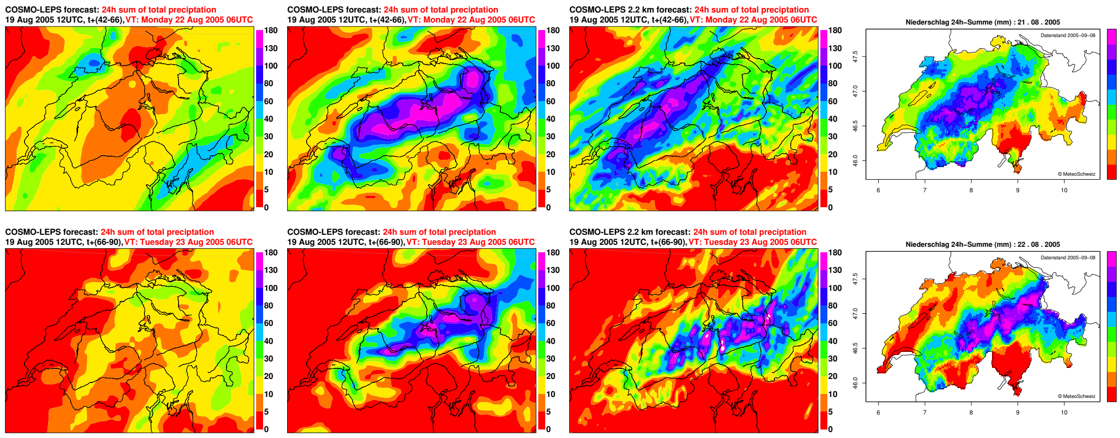

Figure 4: Member representing the largest cluster of the experiments FLAT (left), OPR (second row) and HR (third row), as well as a precipitation analysis (right) for 24-h precipitation sums valid at August 22 (top) and August 23, 2005 0600 UTC (bottom). The ensemble experiments have initial time 19.8.2005 1200 UTC.

the comparatively dry inneralpine Rhone valley.

4 Further analysis

The three experiments are investigated regarding the spatial distribution and timely evolution of the precipitation on the basis of one individual ensemble member. The member representing the largest cluster is chosen. It has a weight of 31% in the probabilistic products. Detailed information for the clustering procedure of COSMO-LEPS are given in Montani et al. (2003).

Figure 4 shows the observed and predicted 24-h precipitation sums for August 21 and August 22 (0600 - 0600 UTC on the following day), respectively. On August 21, the convective precipitation systems moved from northeast to southwest over the Swiss plateau and the northern Alpine slopes. In the morning of the following day, the flow changed to north, leading to prolonged heavy precipitation on the northern Alpine slopes. The OPR member simulates the evolution of this event well, while the FLAT member shows the same flow patterns (see below) but clearly lower precipitation amounts on the northern side of the Alps for both days. The precipitation systems occurring in the OPR member are also simulated in the FLAT member but they are typically less intense and cross Switzerland on tracks shifted somewhat to the south, indicated by the precipitation maxima in the south-eastern part of Switzerland. On the second day, the precipitation systems move quickly to the south and loose rapidly their intensity during the course of the day.

The flow characteristic on the northern side of the Alps is hardly changed due to the missing Alps. This is consistent with the very similar synoptic in the two members. Figure 5 shows the geopotential at 700 hPa of both members for August 22, 0000 UTC. In the FLAT member the cyclone is slightly shifted to the north. Hence, the mesoscale flow is only marginally affected by the elimination of the Alpine barrier. However, for such an analysis the simulation period may be too short. In addition, it should be noted, that the driving global simulation (providing initial and lateral boundary conditions) is the same for both experiments and hence includes the Alpine barrier, even though with the coarse resolution T255 (about 80 km horizontal grid-spacing) used by the ECMWF EPS.

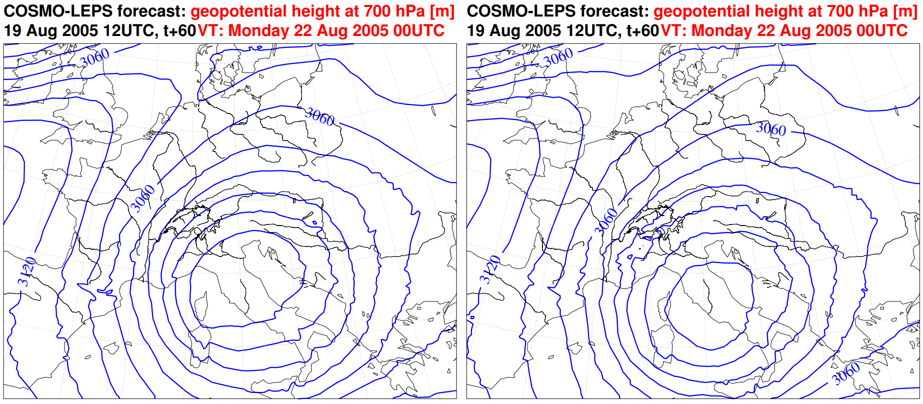

Figure 5: Geopotential at 700 hPa for 22.8.2005 0000 UTC of one selected member from the FLAT (left) and the OPR (right) experiment with initial time 19.8.2005 1200 UTC.

In contrast to the probability maps, the comparison of the HR and the OPR member points out a discrepancy between the two experiments for the validation time August 22 0600 UTC. The precipitation in the south-western Alps seems to be better captured by the HR member. However, this member predicts the band with the highest precipitation amounts in central and eastern Switzerland not along the Alpine slopes, but clearly shifted to the north. The OPR member, on the other hand, produces the highest amounts in the central Switzerland rather shifted to the south with respect to the analysis. The precipitation peaks are clearly overestimated in the OPR member, while they agree quite well with the analysis in the HR member. Further inspections revealed, that the unexpected large difference between the two HR and the OPR member, in particular for the eastern Alps, are related to the Tiedtke convection scheme which produces in the OPR member the large overestimation in the eastern Alps. In the HR experiment the scheme is switched off due to the explicit treatment of convection using a 2.2 km horizontal grid. On the following day, the differences between the HR and the OPR member are much smaller. The fine-scale structures provided in the HR member matches well the observed pattern, but the exact location of the maxima is just partly captured.

5 Conclusion

The sensitivity experiment points out, that the complex orography of the Alpine area was a key ingredient for the large precipitation amounts in this event. The ensemble forecast without the Alpine barrier did not produce an extreme precipitation event. The missing precipitation on the northern and central Alpine region is not distributed to other regions. The deficit is obvious for both flow regime, the north-easterly flow on August 21 and for the northerly flow on August 22, respectively. Hence, the lifting of air masses impinging on the Alpine slopes as well as convection triggering in the complex orography in the first phase of the heavy precipitation period played a major role. The application of an ensemble with a 2.2 km horizontal grid-spacing for this event highlighted the potential of convection-resolving numerical weather predictions. While the probability forecasts with 2.2 km and with its driving 10 km ensemble provided appropriate and similar results, large differences are found between corresponding members pointing out also distinct failures with regard to the observations. These results support the necessity of high-resolution ensemble forecasting systems which are able to consider the complex orography of the Alpine area and take into account the predictability limits of such an extreme event, in order to achieve further progresses in the prediction of heavy precipitation at a local scales.

Acknowledgments

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