PROBABILISTIC RUNOFF FORECASTING USING A COUPLED ATMOSPHERIC-HYDROLOGIC ENSEMBLE PREDICTION SYSTEM

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Abstract: A high-resolution atmospheric ensemble forecasting system, based on 51 runs of the Local Model (LM), has been used to make probabilistic runoff forecasts for a 5 day forecasting period in the alpine tributaries of the Rhine basin. The investigated cases are the spring 1999 flood, when a combination of snowmelt and heavy precipitation caused severe floods in Central Europe and the November 2002 flash flood in the Alpine Rhine area. This study focuses on the feasibility of ensemble prediction system (EPS) for runoff forecasting. Runoff predictions from the deterministic forecast are compared with those obtained from probabilistic atmospheric forecasts. For both cases, the deterministic simulations yield large forecast failures, while the hydrometeorologic EPS provides appropriate forecast guidance with proper uncertainty intervals. The use of clustering techniques showed that the clustering methodology does not reduce ensemble spread.

Keywords*: COSMO-LEPS, runoff prediction, forecast uncertainties, hydrological ensemble prediction*

Introduction: The investigated alpine region is exposed to a high frequency of extreme precipitation events and is further vulnerable to its secondary effects like flooding, landslides and erosion which endanger environment, inhabitants and industries.
To mitigate the consequences of such events, it is therefore of utmost importance to produce reliable forecasts with sufficient lead-time. Much research has therefore been devoted to estimate uncertainty in weather forecasts by using ensemble predictions (e.g. Buizza et al, 1999). Because hydrological models preferably require input data with a high spatial resolution, recent developments show an increased use of limited-area models within ensemble systems which lead to the Limited-area Ensemble Prediction System (LEPS, e.g. Montani et al, 2003)
However, despite these developments in the atmospheric forecasts, most operational hydrological forecasting systems still produce deterministic forecasts, finding a single estimate without quantifying the uncertainty. Only very recently probabilistic approaches are used to quantify uncertainties of flood predictions (Siccardi et al, 2005). This study therefore explores the feasibility of a coupled LEPS-hydrologic system to quantify uncertainty in hydrological flood forecasting in the alpine tributaries of the Rhine River basin. Results further address the impact of ensemble size on the hydrological forecast spread.

Results

Figure 1 shows the advantages of probabilistic runoff forecasts compared to the deterministic runoff forecast. The deterministic forecast strongly underestimates the measured runoff, which is mainly determined by the daily cycle in snowmelt. Although the ensemble median is close to the deterministic forecast, some of the ensemble members are capable to correctly capture the observed flood peaks three days in advance.

While the deterministic forecast only produces one single estimate without quantifying its uncertainty, the use of LEPS forecasts enables to quantify the uncertainty of flood predictions. Figure 2 shows the use of quantile-ranges in flood forecasting and illustrates that the coupled atmospheric-hydrologic LEPS system performs well for the selected catchments.

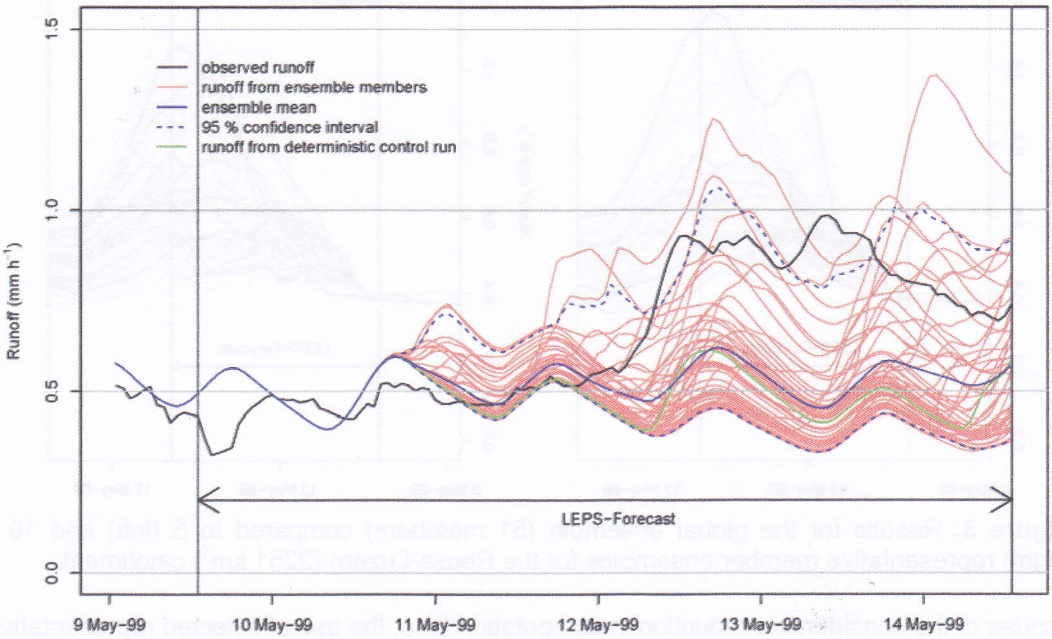

Figure 1: The comparison of probabilistic runoff forecasts with the deterministic forecast for the spring 1999 flood event in the Ill-Gisingen catchment (Austria, 1281 km^2).

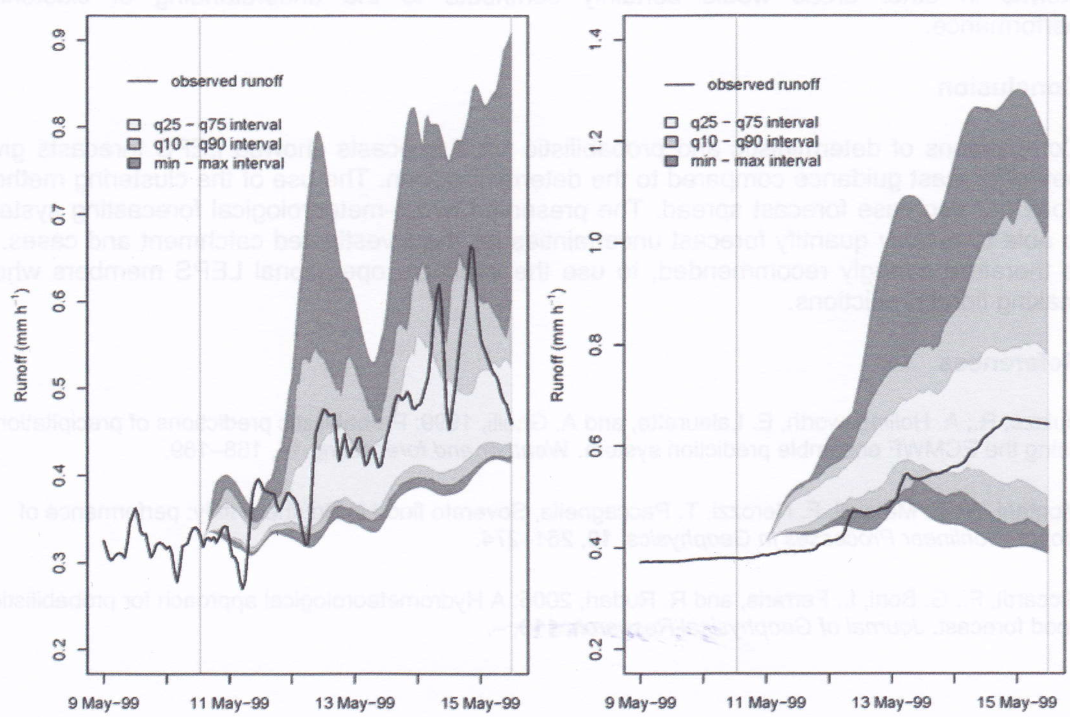

Figure 2: Predicted inter-quantile ranges for the Aare-Hagneck (5128 km^2, left) and the Reuss-Luzern (2251 km^2, right) compared to observed runoff.

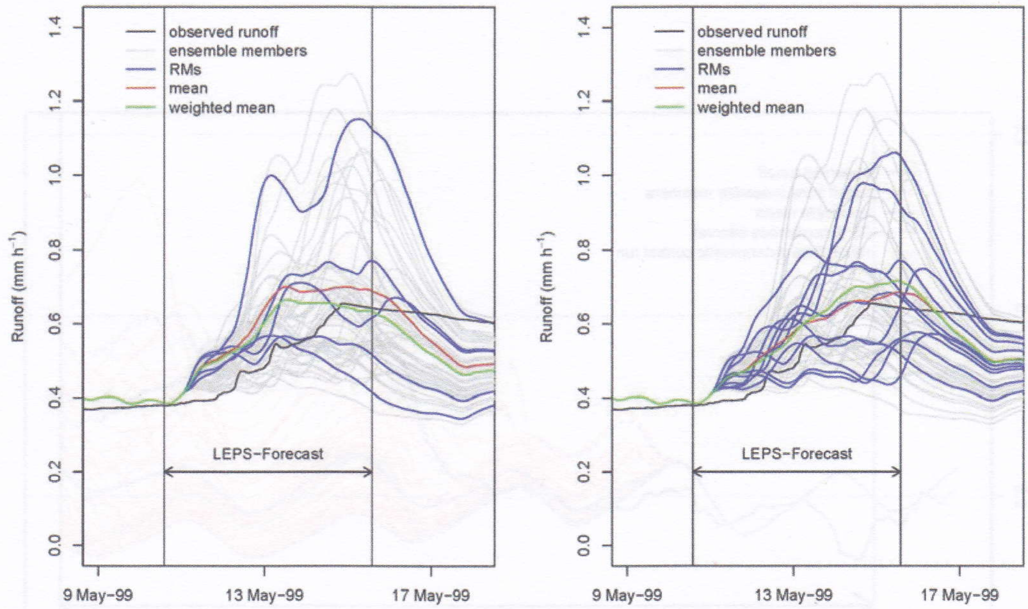

Figure 3: Results for the global ensemble (51 members) compared to 5 (left) and 10 (right) representative member ensembles for the Reuss-Luzern (2251 km^2) catchment.

Because of the considerable reduction in computation time, the use of selected representative members (RMs) has been investigated. Figure 3 shows that the use of the clustering technique, which selects 5 or 10 representative members out of the 51, does not decrease ensemble spread. The 5 and 10 RMs cover the total ensemble fairly well. Both the weighted and unweighted mean of the two RMs ensembles agree well with the observed runoff peak. Further analyses showed that the representative members produce a larger spread than randomly selected members. It should however be mentioned that the results are based on only two case-studies on the northern side of the Alps. Additional analyses for convective storms in other areas would certainly contribute to the understanding of clustering performance.

Conclusion

Comparisons of deterministic and probabilistic flood forecasts showed LEPS forecasts give better forecast guidance compared to the deterministic run. The use of the clustering method does not decrease forecast spread. The presented hydro-meteorological forecasting system is able to reliably quantify forecast uncertainties for the investigated catchment and cases. It is therefore strongly recommended, to use the available operational LEPS members when making flood predictions.

References

Buizza, R., A. Hollingsworth, E. Lalaurette, and A. Ghelli, 1999: Probabilistic predictions of precipitation using the ECMWF ensemble prediction system. *Weather and forecasting* **14**, 168–189.

Montani, A., C. Marsigli, F. Nerozzi, T. Paccagnella, Soverato flood in Southern Italy: performance of global. *Nonlinear Processes in Geophysics*, **10**, 261–274.

Siccardi, F., G. Boni, L. Ferraris, and R. Rudari, 2005: A Hydrometeorological approach for probabilistic flood forecast. *Journal of Geophysical Research*, **110**, –.