Probabilistic Flood Forecasting with the Use of a Limited-area Ensemble Prediction System

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Abstract

A high-resolution atmospheric ensemble forecasting system, based on 51 runs of the Local Model, has been used to make probabilistic runoff forecasts for a 5 day forecasting period in the alpine tributaries of the Rhine basin. The case-studies 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. For both cases, the deterministic simulations yield large forecast failures, while the coupled hydrologic-EPS provides appropriate forecast guidance with reliable uncertainty intervals. The use of clustering techniques showed that the clustering methodology does not reduce ensemble spread.

Introduction

To mitigate the consequences of flooding events, it is of utmost importance to produce reliable forecasts with sufficient lead-time. In the last decade, much research has therefore been devoted to estimate uncertainty in numerical weather forecasts by using ensemble predictions (e.g. Buizza et al, 1999). Recent developments show an increased use of limited-area models within ensemble systems (LEPS, e.g. Montani et al, 2003). However, despite these developments in the atmospheric forecasts, most hydrological forecasting systems still produce deterministic forecasts, finding a single estimate without quantifying the uncertainty. This study therefore explores the feasibility of a coupled hydrologic-LEPS system to quantify uncertainty in hydrological flood forecasting in the alpine tributaries of the Rhine river basin.

Model and catchment description

The area investigated is the Rhine river basin down to the gauge Rheinfelden (34,550 km^2). The catchment has a complex topography with an altitude range from 262 m up to 4225 m a.s.l. The catchment has been subdivided into 23 sub-catchments for the hydrological calibration (1997-1998) and validation (1999-2002).
The distributed hydrological model PREVAH (Precipitation Runoff EVApotranspiration HRU-related model) is used. PREVAH is capable to simulate the relevant hydrological processes in catchments with different runoff regimes both during the calibration and validation period (Figure 1). The runoff generation module is based on the conception of the HBV-model. The model further contains modules to calculate evapotranspiration, snow- and glacier melt and soil moisture.
The global ensembles provide initial and boundary conditions for the limited-area ensemble members (Figure 2). The limited-area ensembles (LEPS) use the LM with a grid-spacing of about 10 km. Output from the 5-day LEPS forecasts are used as input for the hydrologic model.

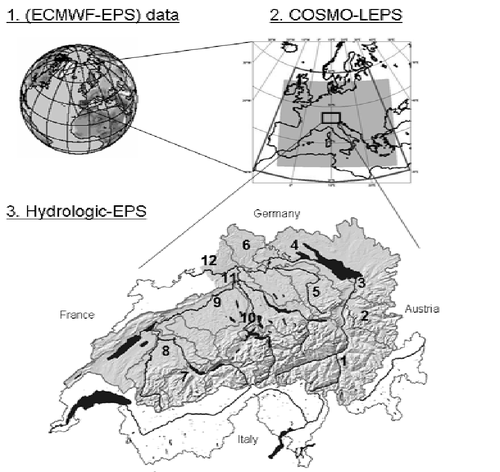

Fig 2: Coupling strategy of the couplid hydrologic-LEPS system

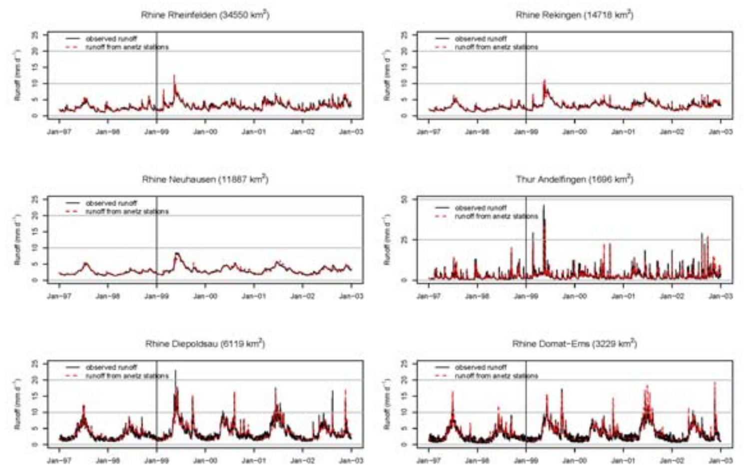

Fig 1: Calibration and validation results for selected catchments over the period 1997-2002.

Results

Figure 3 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.
In an operational environment, a hydrologic ensemble forecasts with 51 members is hardly feasible due to the large amount of required computer resources. The clustering method with 5 and 10 representative members (RMs), respectively, is therefore investigated.
Figure 4 shows that the use of the clustering technique, does not decrease ensemble spread. The 5 and 10 RMs ensembles cover the total ensemble fairly well. Further analyses showed that the representative members provide a larger spread than randomly selected members.

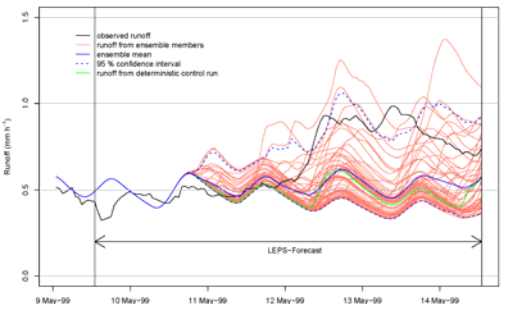

Fig 3: Comparison of probabilistic runoff forecasts with deterministic forecasts for the May 1999 flood event in the Ill catchment (Austria, 1281 km2).

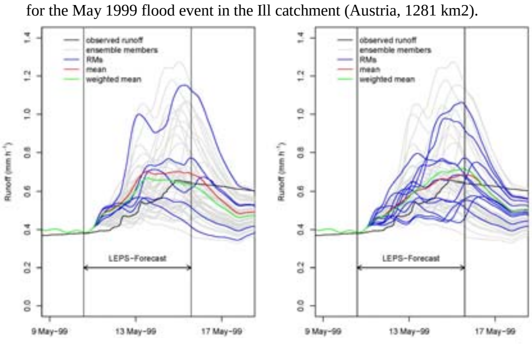

Figure 4: Results for the total ensemble (51 members) compared to 5 and 10 representative members for the Reuss-Luzern (2251 km^2) catchment.

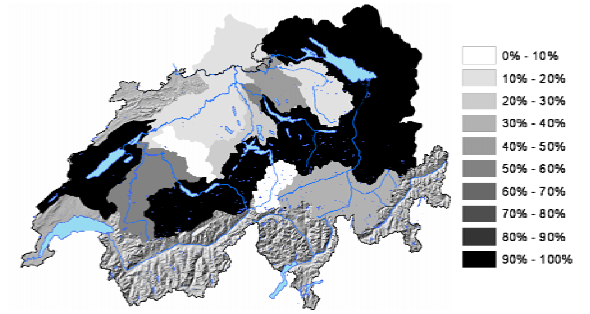

Fig 5:Probability of exceeding the 80% level of the maximum ever measured May discharges.

Conclusions

- The hydrological PREVAH model is capable to simulate the relevant hydrological processes and correctly captures the flood peaks in the catchments of the Rhine basin till Rheinfelden.
- The coupled hydrologic-LEPS forecasting system enables a quantification of forecast uncertainties and provides probability maps (Fig. 5), which could be used as warning systems.
- The use of representative members considerably reduces computation time without a reduction in forecast spread.

References

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