Verification of aLMo Precipitation using a Coupled Hydro-Meteorological Modeling approach for the Alpine Tributaries of the Rhine

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1 Introduction

The Alpine region is often struck by devastating flood events like the recent flooding in summer 2005. Due to its topography, this region is further vulnerable to secondary effects like flooding, landslides and erosion, which endanger environment, inhabitants and industries. A timely forecast of the events could help mitigate some of the possible consequences of extreme flooding. Recent developments in coupling hydrologic and atmospheric models show that these coupled approaches have, despite current limitations, a great potential in flood forecasting and impact assessments (e.g. Benoit et al., 2003). Especially in the case of runoff prediction in alpine catchments, the use of surface observations for flood forecasting is limited due to the short response times to precipitation events, which requires precipitation data to be available ahead of time.

The coupled atmospheric-hydrologic applications offer the possibility of verification that will be very important in the improvement of technologies associated with atmospheric models and water resources management. Jasper and Kaufmann (2003) used a coupled atmospheric-hydrologic system as a validation tool for Swiss Model (SM) forecasts in southern Switzerland. The present paper validates precipitation forecasts of the Alpine Model (aLMo) over a period of 2 years (2001-2002) in the upper stretch of the Rhine river basin.

2 Results

PREVAH is a hydrological model with a fine spatial resolution, including the simulation of glacier- and snow melt and the retention of lakes. It has proven its abilities in simulating hydrological processes in several Swiss catchments (Gurtz et al., 1999; Zappa et al., 2003). It has been applied to the Rhine basin down to the gauge Rheinfelden (34,550 km^2) with a spatial resolution of 500 by 500 m^2 using an hourly time-step. The spatial discretization of the hydrological PREVAH model (Gurz et al. 1999) relies on the aggregation of gridded spatial information into so-called hydrologic response units (Ross et al. 1979). The model contains modules to calculate evapotranspiration, snow- and glacier melt, and soil moisture.

The hydrological model has been calibrated with the use of hourly ground observations (precipitation, air temperature, wind speed, global radiation, sunshine duration and vapor pressure) during the period 1997 - 1998 after being initialized during 1996. A set of 656 stations (52 with hourly resolution, 56 which measure twice a day, and 548 rain gauges with daily resolution) were used. The calibration has been carried out separately for each of the 23 sub-catchments. Because of the presence of lakes in the investigated catchments, it was necessary to include a function which represents the retarding and flattening of flood peaks by lakes. Results show (Verbunt et al. 2006) that the model is capable to reproduce the relevant hydrological processes in the investigated catchments and that the model properly captures the extreme runoff peaks both during the calibration (1997 - 1998) and validation period (1999 - 2002).

The catchments in the upper part of the Rhine basin show a clear annual runoff cycle, caused by snow and glacier melt in spring and summer. Discharges at gauges in the lower part of the river basin are more influenced by lakes. The runoff in the Thur catchment in the northeast of Switzerland is mainly precipitation dominated, showing very strong fluctuations in runoff.

Precipitation forecasts of the atmospheric model are interpolated to the hydrological grid using a bilinear interpolation between the nodes. The verification used +19 h to +42 h aLMo forecasts for the period 2001 – 2002.

For the modeled runoff, the use of precipitation forecasts considerably increases the False Alarm Rate, while the Critical Success Index decreases. Consequences of errors in the precipitation forecasts are most pronounced for higher thresholds, while the coupled modeling system performs better for smaller precipitation events.

Fig. 1 shows the bias in annual runoff, calculated by subtracting the observed annual runoff from the simulated annual runoff amount for each investigated catchment. Although these deviations may vary over the years and show a high spatial heterogeneity, some general tendencies can be noticed.

The annual runoff in the upper Aare catchment is always overestimated, caused by an overestimation of precipitation by the NWP model in this region. This overestimation is especially evident in summer, due to too strong convection in the NWP model in mountainous areas. The model further overestimates precipitation on the northwest facing slopes. In contrast to the upper Aare region, runoff in the easternmost watershed of the Aare and the uppermost Rhine catchment is generally underestimated. This can partly be explained by the lack of advection of falling precipitation in the NWP model, which causes the precipitation in these areas to be underestimated, and which has recently been included in the aLMo with the prognostic precipitation scheme.

The heterogeneity in the runoff bias for each catchment (Fig. 1) causes the accumulated bias (not shown) to decrease in catchments further downstream. Deviations caused in upstream catchments however influence runoff volumes further downstream and are still noticeable at the lowest Rhine river gauge at Rheinfelden.

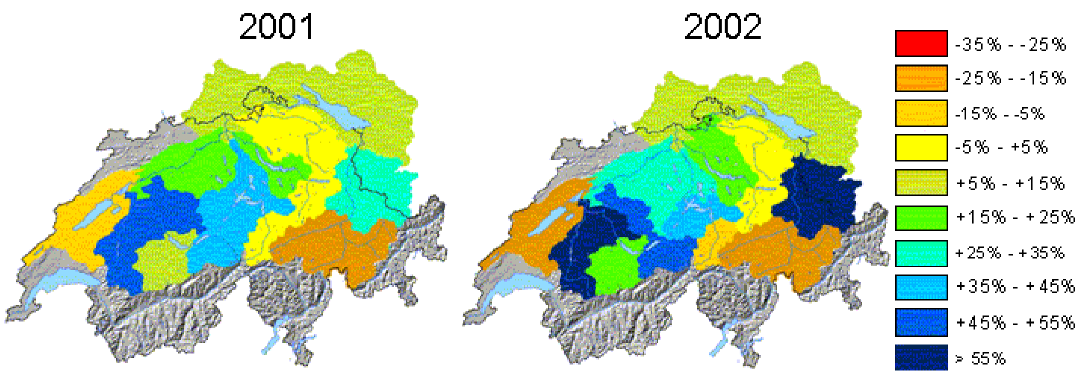

Figure 1: Annual bias of runoff simulated based on aLMo precipitation relative to observed runoff for the years 2001 (left) and 2002 (right).

3 Conclusions

These results agree with the findings of Kaufmann et al. (2003), who concluded for the SM that precipitation amount in the mountains above 1500 m is considerably overestimated in summer due to the too strong convection. This is still the case for the aLMo. It leads to clear overestimation of runoff peaks, especially during the summer season. These results also agree with those from Jasper and Kaufmann (2003), who showed that SM forecasts lead to high false alarm rates in runoff forecasts due to an overestimation of precipitation peaks in the Ticino-Verzasca-Maggia basin. Further downstream, the consequences of errors in the precipitation forecasts are still considerable but reduced mainly because of

- the retention capacity of larger lakes and
- by an underestimation of precipitation in the lower situated catchments.

The spatially distributed verification of coupled atmospheric-hydrologic model systems enables the detection of inaccuracies in numerical weather prediction models and is important to meet the ever increasing demands in operational forecasting.

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