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Evaluation of medium-range runoff forecasts for a 50 km^2 watershed

David Kneis (1), Gerd Bürger (2), and Axel Bronstert (1)

(1) Institute of Earth- and Environmental Sciences, Potsdam University, Germany (dkneis@uni-potsdam.de), (2) Pacific Climate Impacts Consortium, University of Victoria, Canada

Forecasting of medium-range runoff for small mountainous catchments is a particular challenge for a number of reasons: (1) Reaction times are short, thus hydrological forecasts necessarily rely on the uncertain output of numerical weather prediction (NWP) models, (2) There is a high sensitivity to positional errors in the quantitative precipitation forecast (QPF) as well as to errors in quantitative precipitation estimation (QPE), (3) Given that rainfall is spatially variable, small catchments are generally more likely to experience extreme areal precipitation than larger river basins, (4) Runoff-coefficients are typically high and flood events originate from both heavy rainfall or/and snow melt. Nevertheless, there is a demand for medium-range hydrological forecasts for small catchments which can be used for the purposes of early warning and the proactive management of multi-purpose reservoirs. We studied the quality of runoff forecasts for the Lehnmühle Reservoir watershed (50 km^2) located at the border between Germany and Czech Republic (Weißeritz River). For this catchment, we set up the conceptual, semi-distributed hydrological model LARSIM which is in operational use at many flood forecasting centres. LARSIM is typically run as a continuous model with stream flow assimilation enabled during the simulation period. The usual time step of in- and output is 1 h. We produced medium-range forecasts (actually 'hindcasts') of runoff by driving the calibrated hydrological model with NWP data of the past. For the period 2000–2008, we computed daily forecasts with a maximum lead time of +120 h based on the 51-member ensemble prediction issued by the ECMWF (European Centre for Medium-range Weather Forecast). Expanded downscaling, a variant of empirical downscaling, was used to make the spatially coarse ECMWF forecast applicable to the target scale. For the period 2005–2008, we also tried the deterministic COSMO-EU forecast (+78 h maximum lead time, 7$\times$7 km resolution) disseminated by the German Weather Service as an alternative model input. The quality of the forecasts was assessed by comparing the predicted change in stream flow ΔQ (not the flow rate itself) to the corresponding observations using several measures of skill. According to our results, the ensemble-based runoff forecast performs better than deterministic forecasts for lead times greater than +48 h. However, for the studied catchment both the deterministic and the ensemble forecast are uncertain in such a way that they cannot be recommended for the purpose of early warning or the dynamic control of multi-purpose reservoirs. Even if a relative error in the predicted ΔQ of $\pm$ 30% is tolerated, considerable fractions of the forecasts (in the order of 50%) turn out to be underpredictions or false alarms. We can show that this is due to both the insufficient quality of precipitation forecasts as well as deficits in hydrological modelling. We conclude that further efforts to quantify and reduce uncertainties from multiple sources are necessary to improve the quality of medium-range hydrological predictions for small catchments.