Geophysical Research Abstracts,
Vol. 11, EGU2009-13214, 2009
EGU General Assembly 2009

Operational hydrological forecasting in Bavaria. Part II: Ensemble forecasting

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In part I of this study, the operational flood forecasting system in Bavaria and an approach to identify and quantify forecast uncertainty was introduced. The approach is split into the calculation of an empirical 'overall error' from archived forecasts and the calculation of an empirical 'model error' based on hydrometeorological forecast tests, where rainfall observations were used instead of forecasts. The 'model error' can especially in upstream catchments where forecast uncertainty is strongly dependent on the current predictability of the atrmosphere be superimposed on the spread of a hydrometeorological ensemble forecast.

In Bavaria, two meteorological ensemble prediction systems are currently tested for operational use: the 16-member COSMO-LEPS forecast and a poor man's ensemble composed of DWD GME, DWD Cosmo-EU, NCEP GFS, Aladin-Austria, MeteoSwiss Cosmo-7.

The determination of the overall forecast uncertainty is dependent on the catchment characteristics:
1. Upstream catchment with high influence of weather forecast
a) A hydrological ensemble forecast is calculated using each of the meteorological forecast members as forcing.
b) Corresponding to the characteristics of the meteorological ensemble forecast, each resulting forecast hydrograph can be regarded as equally likely.
c) The 'model error' distribution, with parameters dependent on hydrological case and lead time, is added to each forecast timestep of each ensemble member
d) For each forecast timestep, the overall (i.e. over all 'model error' distribution of each ensemble member) error distribution is calculated
e) From this distribution, the uncertainty range on a desired level (here: the 10% and 90% percentile) is extracted and drawn as forecast envelope.
f) As the mean or median of an ensemble forecast does not necessarily exhibit meteorologically sound temporal evolution, a single hydrological forecast termed 'lead forecast' is chosen and shown in addition to the uncertainty bounds. This can be either an intermediate forecast between the extremes of the ensemble spread or a manually selected forecast based on a meteorologists advice.

2. Downstream catchments with low influence of weather forecast
In downstream catchments with strong human impact on discharge (e.g. by reservoir operation) and large influence of upstream gauge observation quality on forecast quality, the 'overall error' may in most cases be larger than the combination of the 'model error' and an ensemble spread. Therefore, the overall forecast uncertainty bounds are calculated differently:
a) A hydrological ensemble forecast is calculated using each of the meteorological forecast members as forcing. Here, additionally the corresponding inflow hydrograph from all upstream catchments must be used.
b) As for an upstream catchment, the uncertainty range is determined by combination of 'model error' and the ensemble member forecasts
c) In addition, the 'overall error' is superimposed on the 'lead forecast'. For reasons of consistency, the lead forecast must be based on the same meteorological forecast in the downstream and all upstream catchments.
d) From the resulting two uncertainty ranges (one from the ensemble forecast and 'model error', one from the

’lead forecast’ and ’overall error’), the envelope is taken as the most prudent uncertainty range.

In sum, the uncertainty associated with each forecast run is calculated and communicated to the public in the form of 10% and 90% percentiles. As in part I of this study, the methodology as well as the useful- or uselessness of the resulting uncertainty ranges will be presented and discussed by typical examples.