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The elasticity of hydrological forecast skill with respect to initial conditions and meteorological forcing for two major flood events in Germany

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Major flood events are causing severe socio-economic damages. In Germany alone, the havoc wreaked by the 2002 and 2013 floods along the Elbe and Danube river amounted to more than 11 bn EUR. Highly skilled hydrological forecasts can help to mitigate such damages. Among several factors, these hydrological forecasts are strongly dependent on the initial conditions of the land surface at the beginning of the forecast period and the forecast skill of the meteorological forcing.

Prior research has investigated how uncertainties of the initial conditions and meteorological forcing impact hydrological forecasts. In these studies, uncertainty is investigated by coupling an ensemble of basin initial conditions (e.g., snow, soil moisture) with an ensemble of meteorological forecasts (e.g., precipitation). However, most previous hydrological predictability studies focus on seasonal forecasts (e.g., forecasts of June-July-August flow volume, initialized on April 1st), and neglect the errors in meteorological forecasts at lead times from 1-14 days.

In this study, an error growth model is proposed to investigate hydrological predictability at lead times of 1-14 days. This error growth model calculates a time-dependent weighted average between the perfect forecast and a stochastic perturbation of this. The time-dependent weights are derived from a logistic function. This error growth model thus attributes high weights to the perfect forecast for short lead times (e.g., less than five days) and low weights for longer lead times (e.g., more than five days). For longer lead times, more weight is given to the stochastic perturbation of the forecast and, hence, the ensemble spread is larger for these lead times resembling a higher uncertainty. Analogous to the error growth model, the initial conditions are calculated as a weighted average between the perfect condition and a historic condition of the land surface.

The proposed framework is tested in Germany for the 2002 and 2013 flood events along the Elbe and Danube river. The mesoscale Hydrologic Model - mHM is used to evaluate the impact of varying initial conditions and meteorological forcing. The original meteorological data used to generate ensemble forcing is provided by the German Weather Service (DWD). Common metrics such as mean absolute error (MAE) and continuous ranked probability skill scores (CRPSS) are employed to evaluate the forecast skill. Moreover, the elasticity is quantified which is defined as the change in runoff skill per unit change either in forcing or initial condition skill.

The analysis helps to understand the relative importance of basin initial conditions and meteorological forecasts for extreme floods in Germany. Results indicate that initial land surface conditions have great impact in hydrological forecast skill for short lead times (e.g., 16.9% chance of reaching actual peak discharge with historic land surface condition). For longer lead times, however, the hydrological forecast skill becomes more dependent on the forecast skill in the meteorological forcing.