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Flash Flood Prediction with Neural Networks using Ensemble Methods to address Input and Model Uncertainties

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Short-term flood and inundation forecasts, especially for spatially limited, convective heavy rainfall events, are challenging due to the very short lead time of heavy rainfall predictions. They are subject to different uncertainties. Due to the short forecasting period, data-driven machine learning methods have been developed to predict the inundated areas in almost real time. The time-consuming numerical, hydrodynamic simulation of flooding depths and flow velocities is replaced by a surrogate model.

We use a neural network as surrogate model, which is trained with a large ensemble of hydrodynamically simulated water levels and flow velocities for a specific catchment using an ensemble of spatial and temporal surface runoff. The surface runoff is calculated by the hydrological model RoGeR at a 5 m resolution and spatial and temporal varying heavy rainfall events as input. The neural networks are able to predict spatially resolved maximum water depths, maximum discharges and maximum flow velocities for an event in the specific catchment area of 25km² in significantly less than one second.

The fast prediction time allows to consider uncertainties in the forecast. Uncertainties in flood forecasts typically result mainly from uncertain precipitation input (or forecast), initial conditions (e.g. soil moisture), lack of data of relevant parameters or their limited transferability in space. Although the model error of the hydrological and hydraulic model itself, such as assumptions about geometry and parameters or underlying flow equations, is an important source of uncertainty, we address in this presentation only the uncertainties of input and initial conditions.

To generate ensemble calculations that represent the probability distribution of predicted flood height and velocity, we create a large ensemble of input variables by statistically varying the initial soil moisture as well as the location and intensity of the precipitation fields. Since the trained neural network topology is another source of uncertainty, differently trained networks with different network topologies are also considered in the ensembles.

Using the ensembles, we can specify prediction intervals for spatially resolved maximum water

levels, maximum discharge and flow velocities, which result from the uncertainty of the model input, model parameters and the inaccuracy of the surrogate model. Using the ensemble approach, we discuss the impact of the different sources of uncertainty on the predictions.

As an example, it is found that the statistical variation of the meteorological input data has a greater influence on the prediction interval width than the statistical variation of the initial soil moisture. In general, it can be concluded that sufficient variability in the training data needs to be covered to make reasonable uncertainty predictions.