Operational flood risk management based on meteorological ensemble predictions (case study: Mulde)

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Project Goals

The general aim of this project consists in a flood risk management system which combines numerical weather forecasts, hydrological modelling with a GIS-based estimation of resulting flood risks within a river basin of the mesoscale. Under consideration of the fast reaction of mountainous watersheds and the uncertainties of numerical weather forecasts ensemble predictions will be used to consider the uncertainties of the meteorological inputs. The transformation of the ensemble predictions of rainfall into runoff ensembles is done by a spatial distributed flood forecast model. The result will be an ensemble of flood forecasts at each time step. The different discharge values at the flood gauges are related to specific local risks which are specified by so-called flood protection concepts based on a detailed estimation of flood-prone areas. The risk management system determines the possible consequences and provides the information which is based on a probabilistic assessment of the uncertainties of the input values as well as uncertainties of the hydrological model used resulting from model and parameter uncertainties. Measured data of precipitation and runoff will be used for data assimilation in meteorological and hydrological models and for a probabilistic re-assessment of flood forecasts based on Bayesian statistics. The main result of this project will consist in a probabilistic assessment of flood risk in real-time which is derived from a chain of the following three model types:

- meteorological models
- hydrological models
- hydraulic models

The following sub-results will be provided:

- determination of options and limitations of ensemble precipitation predictions for flood forecasting,
- evaluation of the flood protection capabilities of reservoirs in real-time,
- development of an integrated flood management system,
- development of a methodology to consider forecast uncertainties based on ensemble predictions and hydrological uncertainties,
- hydro-meteorological data assimilation to reduce model uncertainties in real-time and
- probabilistic assessment of flood risk based on Bayesian statistics.

Flood Forecast Uncertainties

One main focus of the project is to quantify the different uncertainties of the flood forecasting:

- the input uncertainty (precipitation) and
- the hydrologic uncertainty (all other uncertainties, e.g. uncertainties of the model, its parameters or of the measured data used in real-time forecasts).

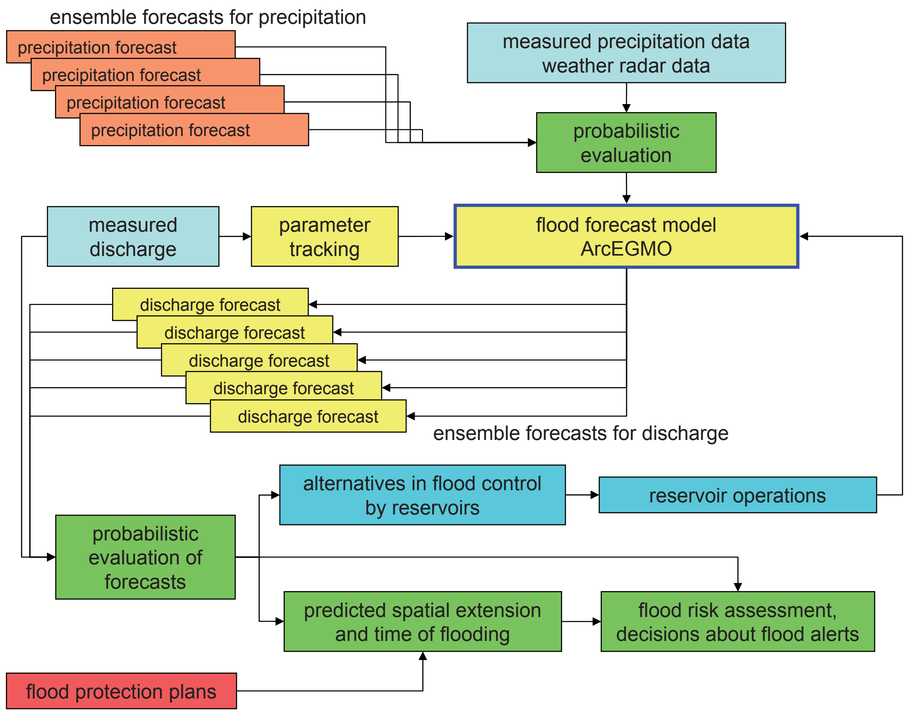

Fig. 1: Conception of an ensemble-based flood management

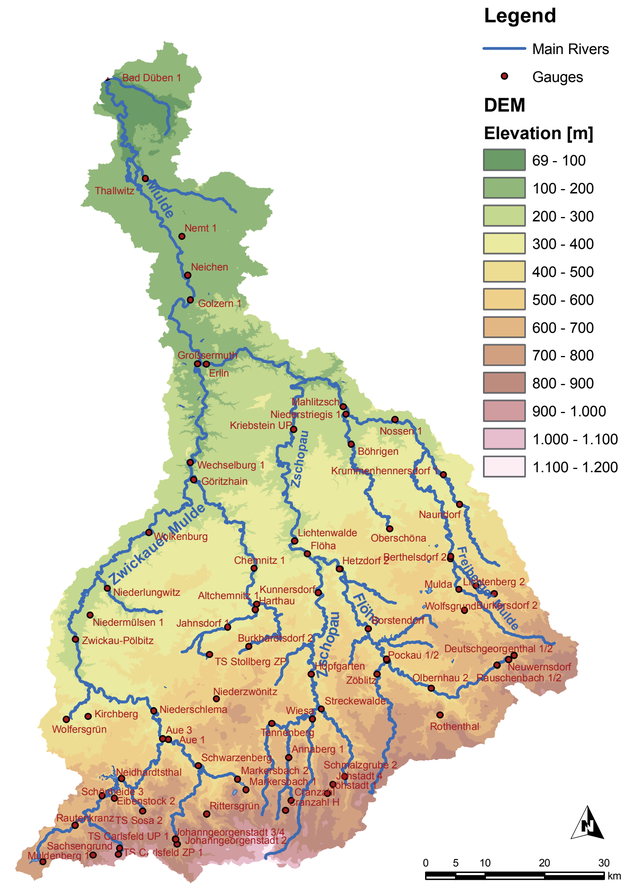

Fig. 2: Mulde river basin with gauges for flood forecasts

Study Area

The Mulde catchment (Germany, Czech Republic) has a size of 6178 km^2. It consists of several parallel subcatchments. Therefore the spatial uncertainties of the precipitations forecasts lead to large uncertainties of flood warnings with regard to the locations of a possible flooding. Within the project the uncertainties of forecasts shall be quantified.

Precipitation Forecast

Ensemble predictions of precipitation are used to assess the uncertainties of precipitation forecasts. These ensemble forecasts are based on different mesoscale systems (ECMW-Ensemble and Lagged Average Forecast Ensembles).

The evaluation of individual forecasts will be carried out by means of „Bayesian Model Averaging"(BMA). Real time radar measurements of precipitation will be used for data assimilation and assessments of the uncertainty by probabilistic means.

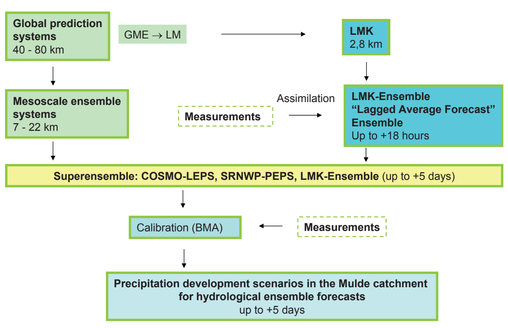

Fig. 3: Making of the precipitation forecast ensembles

Hydrological Model and Parameter Uncertainties

ArcEGMO, a deterministic rainfall-runoff model is used in this investigation. The parameter uncertainty will be considered by the application of several parameter sets generated based on the GLUE-method (Generalized Likelihood Uncertainty Estimation; Beven and Binley, 1992).

The parameters of the model will be re-calibrated with discharge data transmitted online. Special emphasis will be given on the interaction between sub-catchments. The application of three feedback mechanisms will be checked:

- the error in flood forecasts will be considered as a stochastic variable,
- single parameters and also the
- initial parameters will be updated.

IT-Tool Flood Management System

The flood management system integrates hydrological models, parameter tracking methods and modules for reservoir control and decision support. An intelligent bidirectional interface enables the real-time communication between models and databases (fig. 6). A new GIS-based component for the automated calculation of flood areas and expected flood damages is tested in a pilot area.

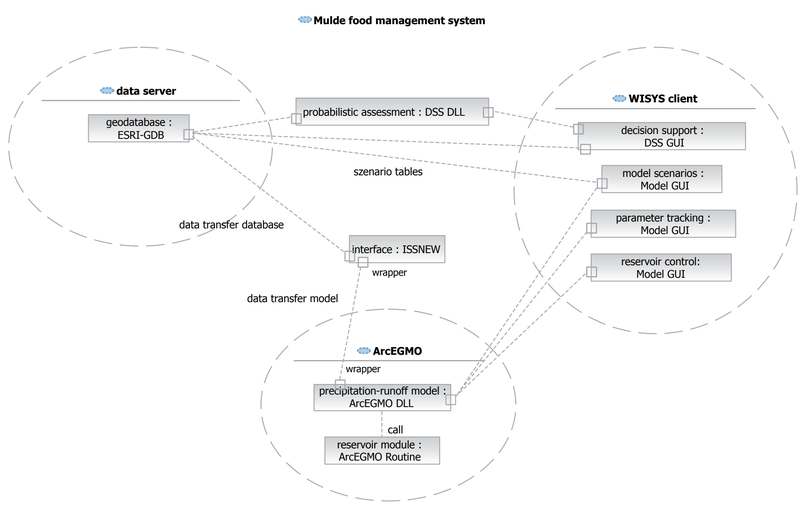

Fig. 6: Collaboration of the main components of the flood management system

Flood Management - Technical Aspects

The potential of flood protection of selected reservoirs is analyzed based on the relationships between the storage capacities in retention structures and flood risks downstream. Therefore diverse flood event types, different control strategies and technical parameters of the reservoirs are considered. On this basis the flood prediction model will be used to develop event based control strategies taking into account past flood events as well as ensemble-based scenarios. Additionally the options and limitations of using ensemble-based predictions for decision support concerning the flood control of reservoirs are determined.

Fig. 4: Eibenstock Reservoir (Foto: Foto-Design E. Hertel, Quelle: http://www.gemeinde-schoenheide.de/talsperre.htm)

Decision Support

The possible consequences of flood forecasts will be assessed by probabilistic means. Results from the probabilistic assessment of the ensemble members and the assimilation of measured data are evaluated with a belief function reasoning approach. Comprehensive flood risk analyses and maps (fig. 5) are related to the flood forecasts. As a result ensemble predictions of the potential flooding areas will be provided.

A decision support system provides recommendations for issuing alerts by multiple criteria assessment of the current hydrological situation and scenarios of future developments.

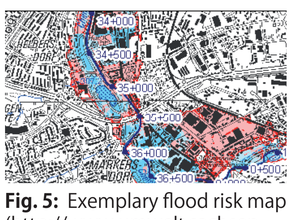

Fig. 5: Exemplary flood risk map (http://www.umwelt.sachsen.de/de/wu/umwelt/lfug/lfug-internet/wasser_13439.html)

Reference

Beven, K. & A. Binley (1992), The future of Distributed Models: Model Calibration and Uncertainty Prediction, Hydrological Processes, 6, 279-298.