Data- and Predictive Uncertainties in Flood Forecasting: How to Decide under Uncertain Information

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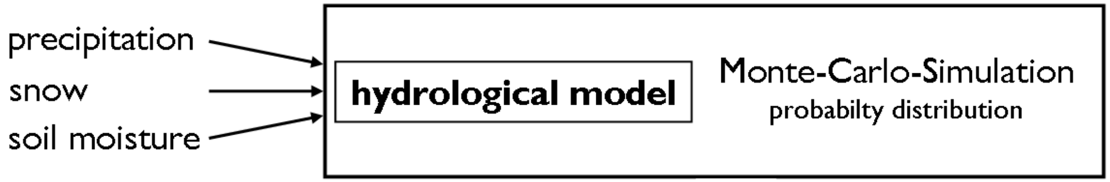
Outline

Introduction

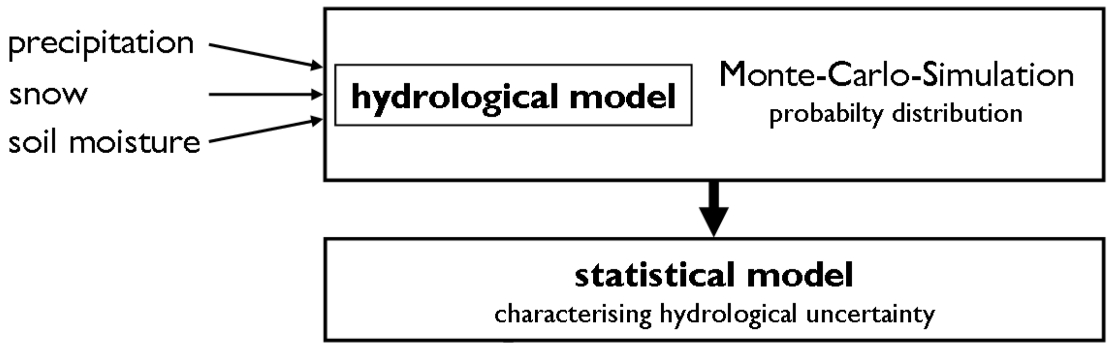
Decision under Uncertainty

- Uncertainty often missing in (German) flood prediction systems
- May affect decisions taken. e.g. Reservoir management

- Balance between information content and ease of communication
- Exceedence probabilities and corresponding flood loss estimation


precipitation
snow
soil moisture
hydrological model
Monte-Carlo-Simulation
probabilty distribution

Components of the Prediction System



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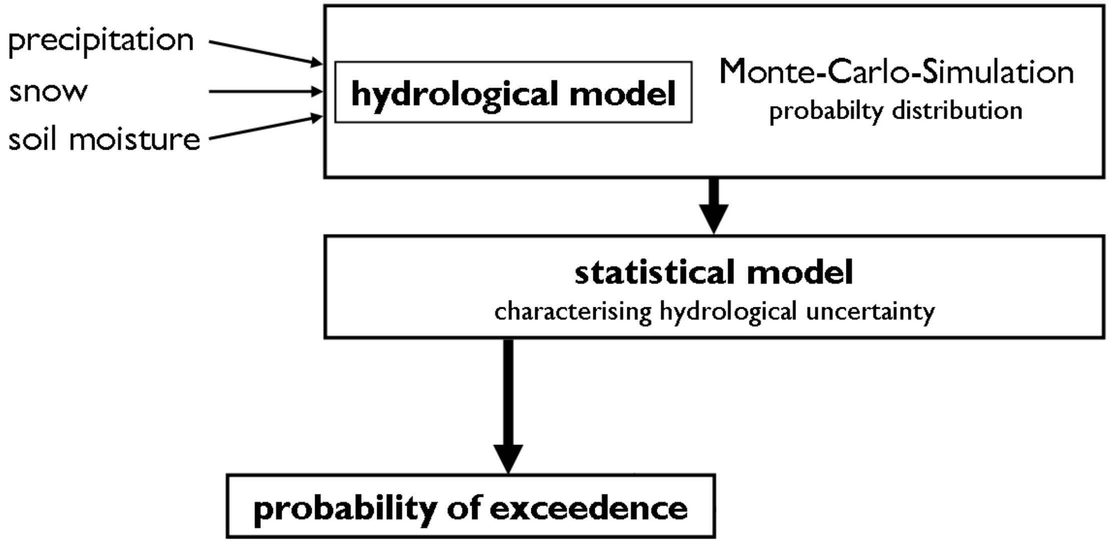

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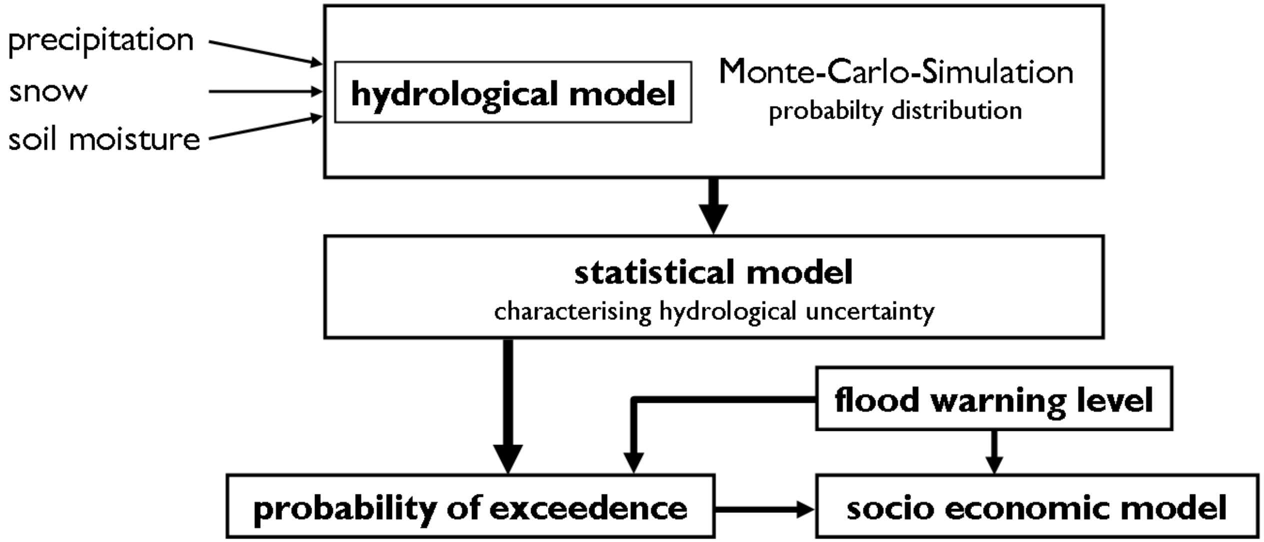

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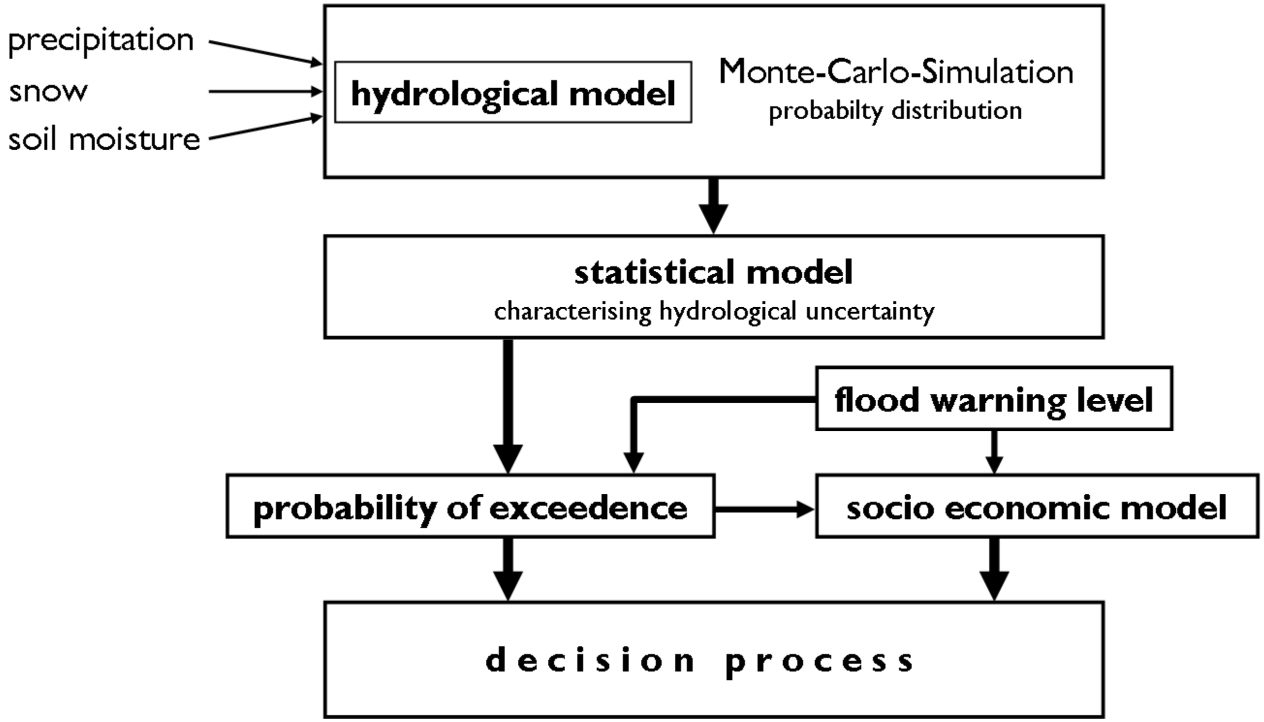

Initial state and forcing: Method and results

Initial states and forcing

- Initial states
  - Snow
  - Soil Moisture
- Rainfall predictions
  - Radar now-casting
  - COSMO-DE (Previously LMK)
  - Medium Range: ECMWF Ensemble

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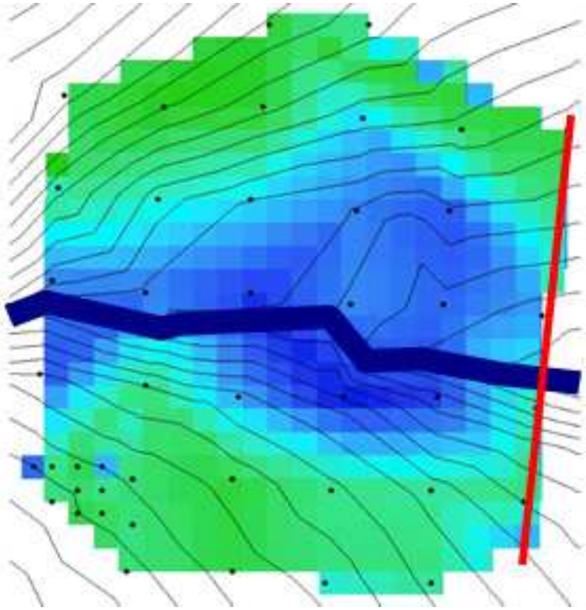

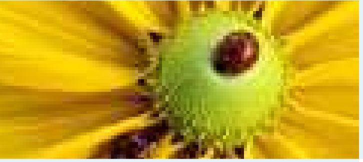

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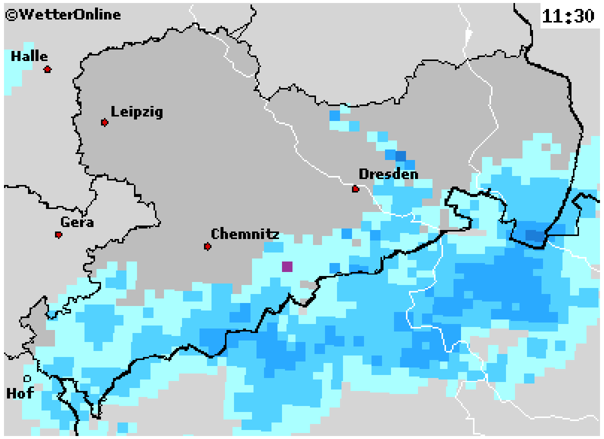

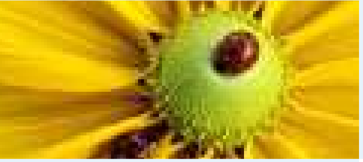

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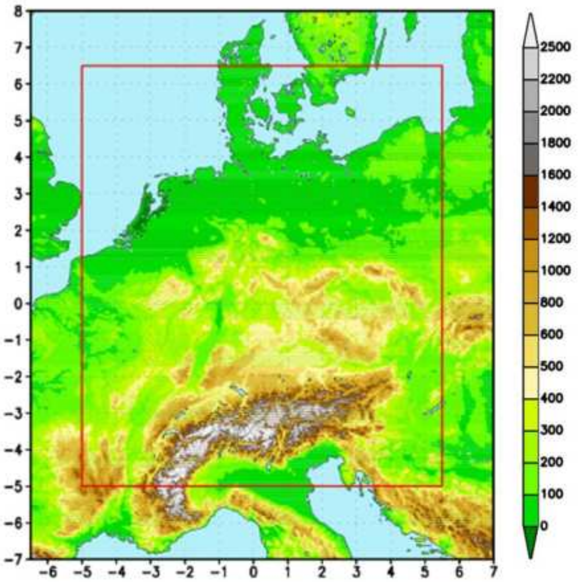

Source: www.dwd.de

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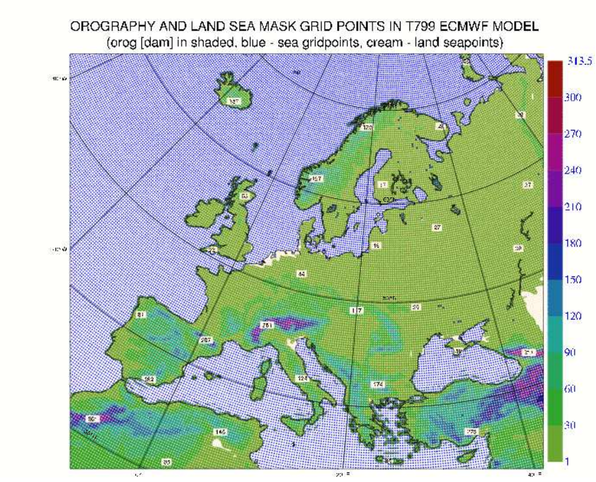
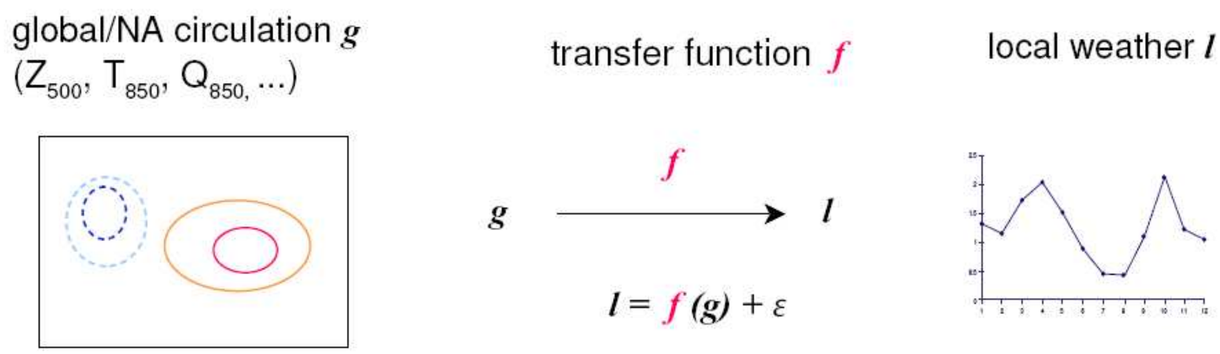


Source: www.ecmwf.int

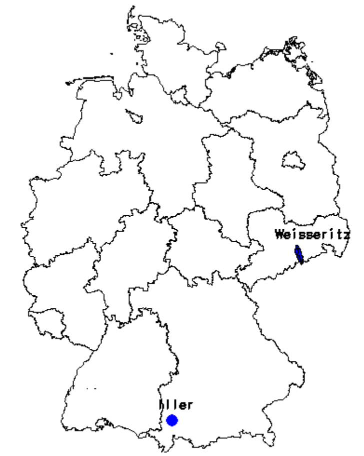
Example: Medium range forecast

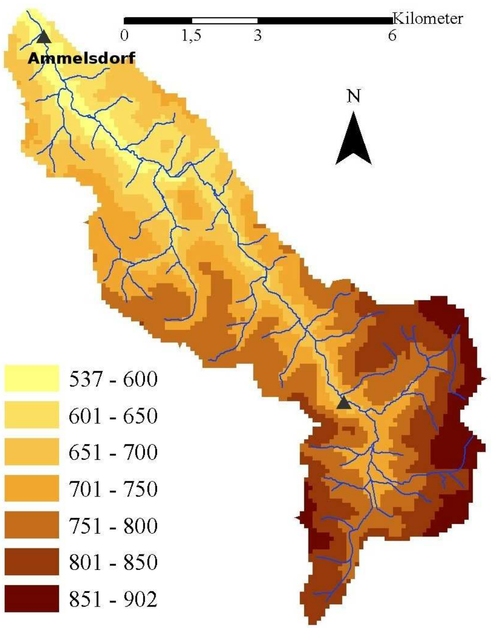
- Downscaling
- ECMWF ensemble forecasts
- Linear regression between circulation patterns and local weather
- Constraint: Preserving local covariance structure



Weisseritz Catchment

- Eastern Ore mountains at the Czech-German border
- Total area of 384 km^2
- Two large multipurpose reservoirs in the Wilde Weisseritz
- August 2002: severe flooding: Dresden main train station and villages along the river.

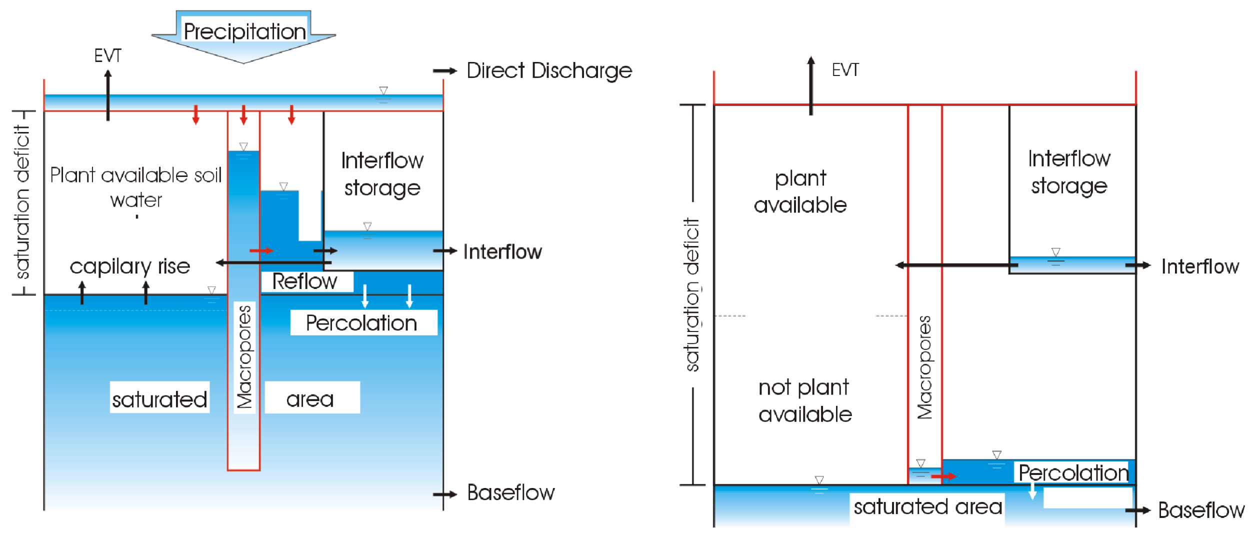




Weisseritz Catchment

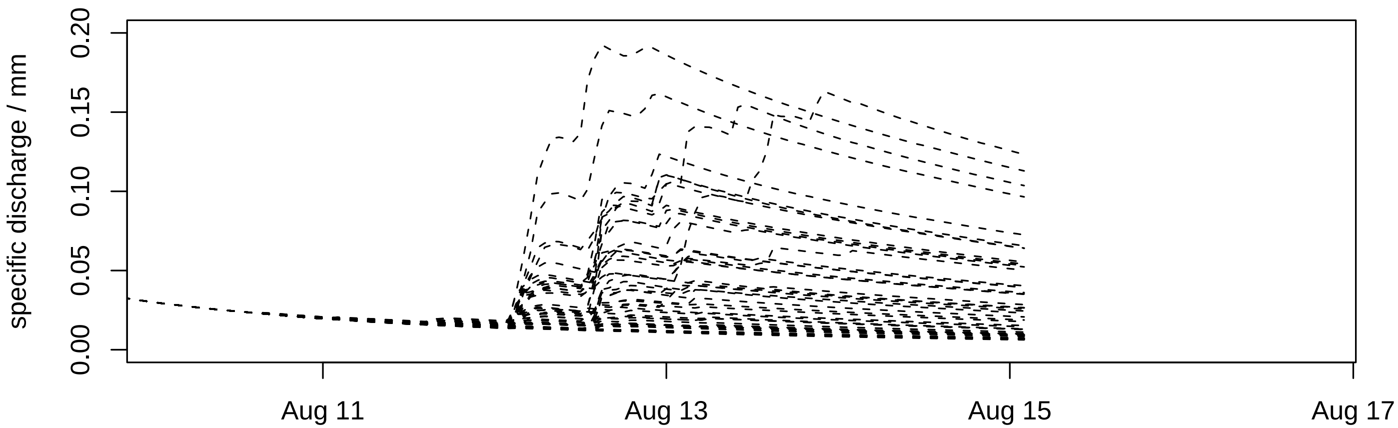
WaSiM ETH

- Deterministic, distributed rainfall-runoff model (Schulla & Jasper 1999)
- Provides methods for the interpolation of meteorological input
- Describes the soil water based on the TOP-model approach (Beven & Kirkby 1979)
- Macro pores are described with an extension by Niehoff et al. (2000)



after NIEHOFF, 2001

Ensemble Discharge Forecast



- Range of the ensemble prediction is small for times with predictable conditions
- Range much wider for the time of the extreme rainfall event
- Uncertainty clearly larger with increasing prediction times

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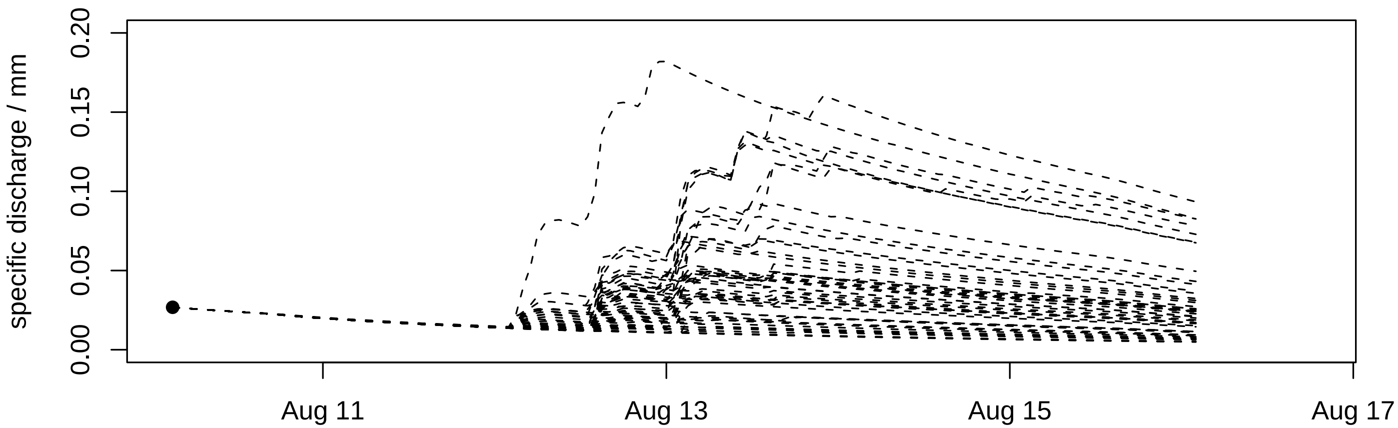

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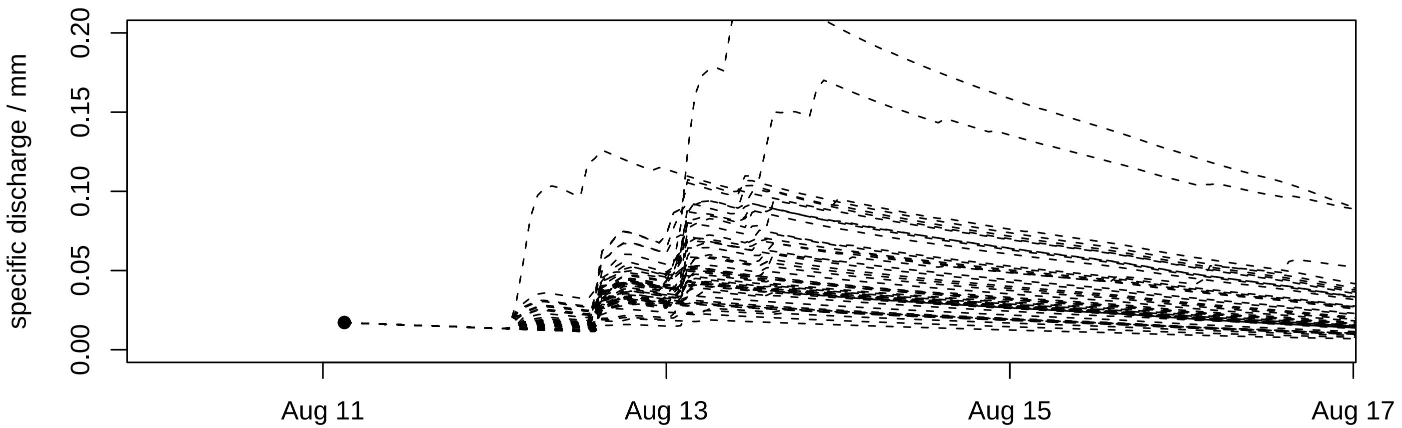

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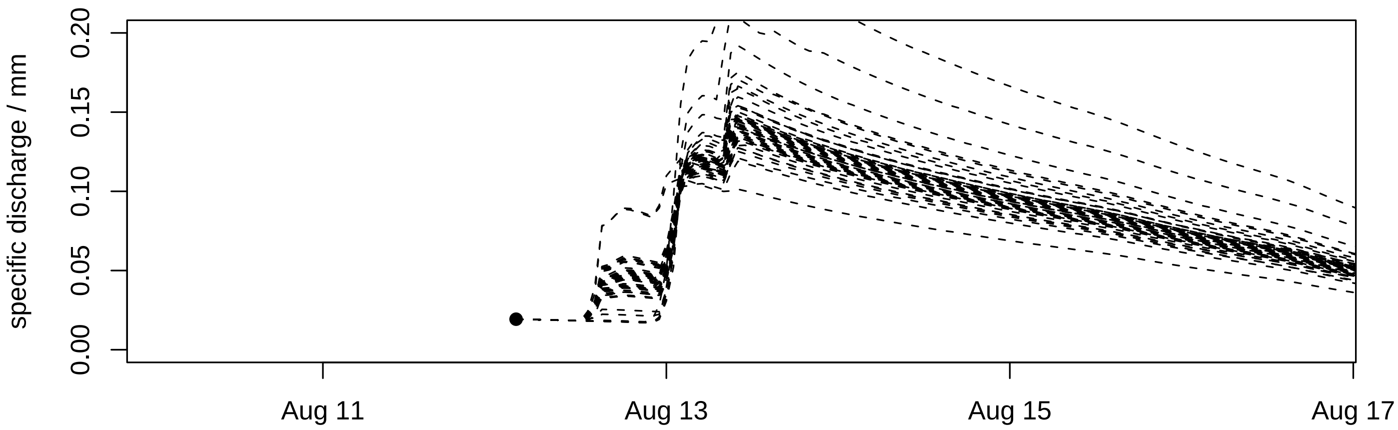

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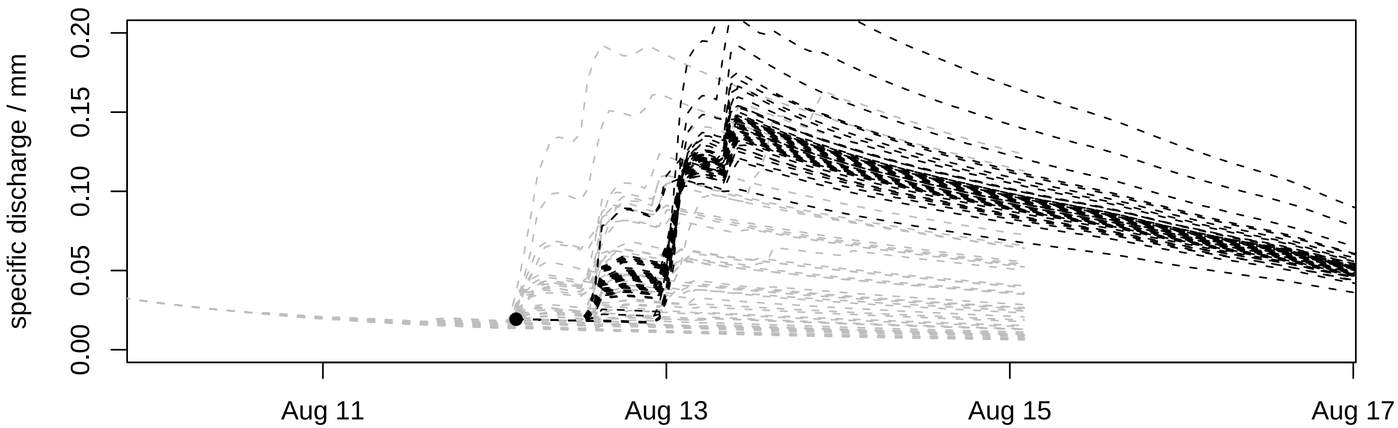

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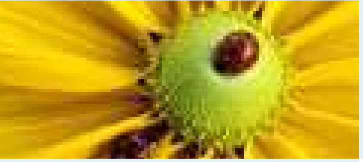
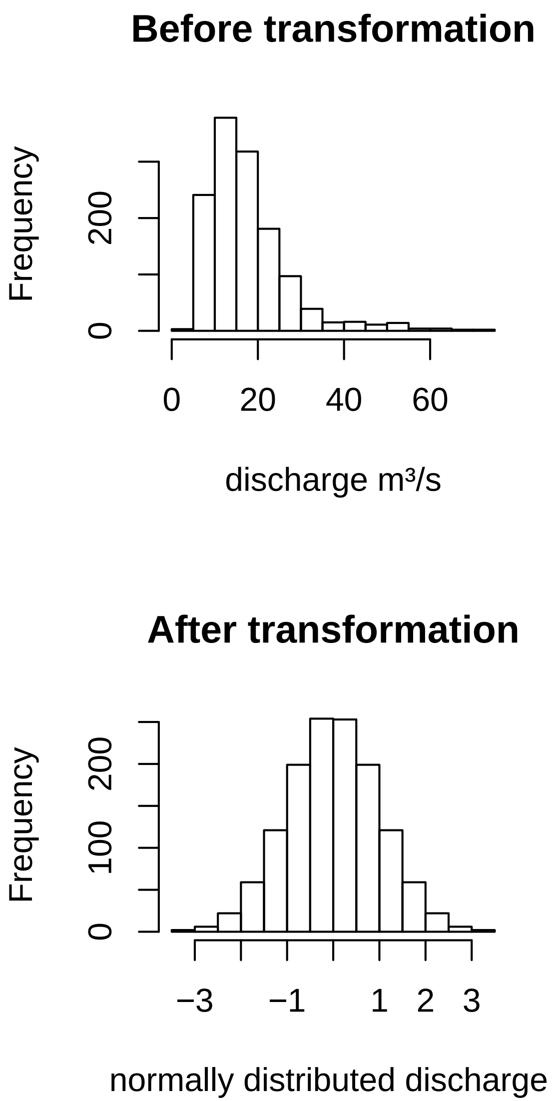
Hydrological Uncertainty Processor: Method and results



- Based on transformation of data to normal distributions.
- First order transition probability
- Likelihood function for forecast and observation
- R-package soon published



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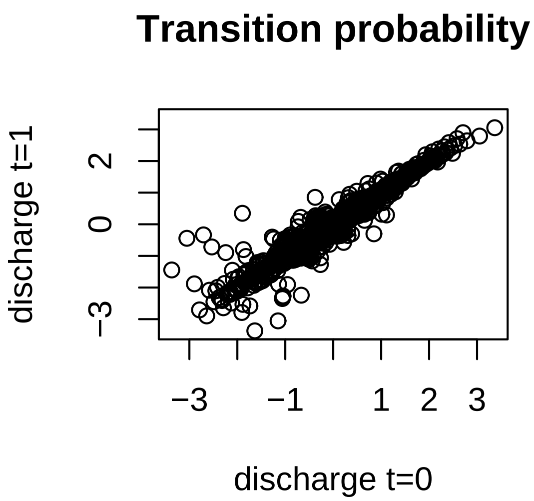

R. Krzysztofowicz and K. S. Kelly. Hydrologic uncertainty processor for probabilistic river stage forecasting. *WATER RESOURCES RESEARCH*, 36(11):3265–3277, 2000

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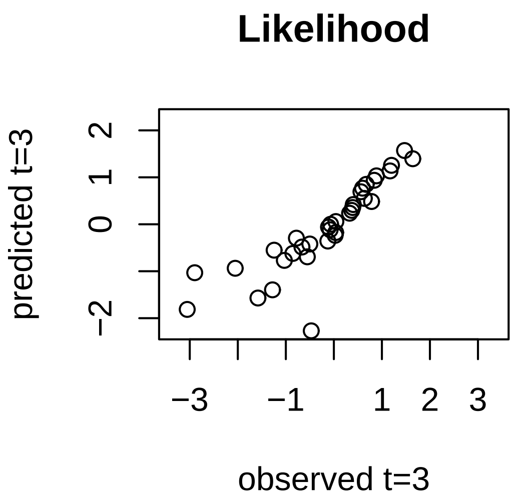

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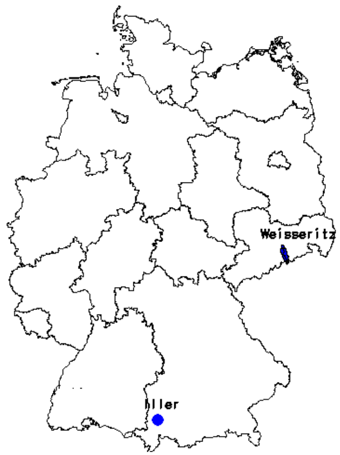
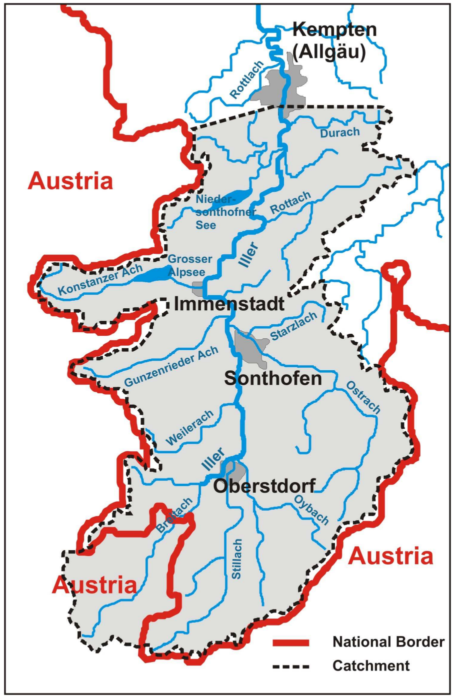
Iller catchment

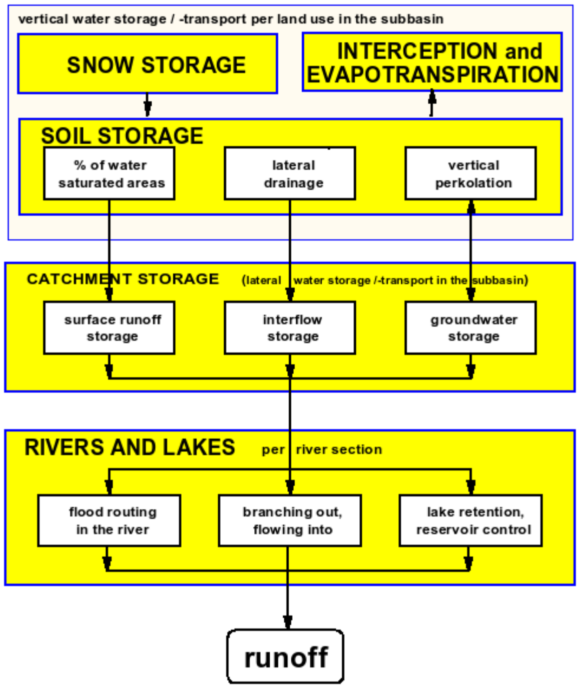
- Alps at the German-Austrian border
- Total area of 954 km^2
- 650 to 2700 m asl
- highest recorded floods (in 100 years) in May 1999 and August 2005 (850 and 900 m^3)



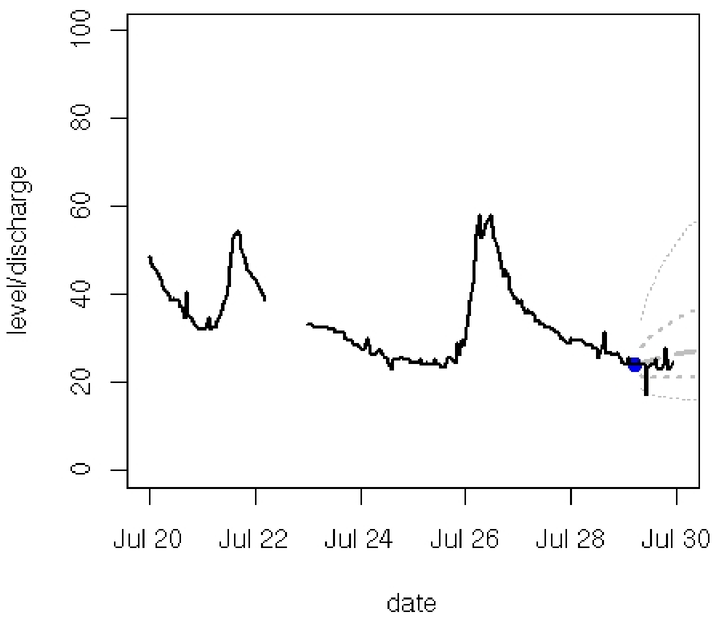


Larsim

- Conceptual, distributed rainfall-runoff model (Ludwig and Bremicker, 2007)
- Provides methods for operational flood forecasting
- Flood predictions calculated at the Bavarian Flood Warning Center

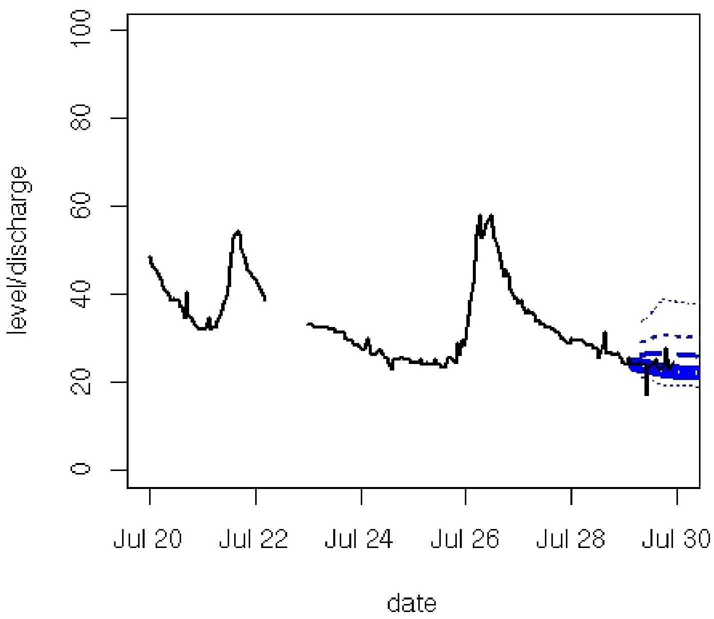


Prior expected discharge level

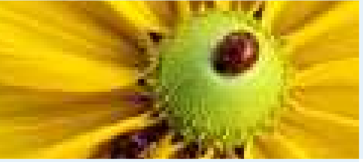


- Without prediction: First order Markov process
- Converging to probability distribution of observed discharge level for a given month

Posterior expected discharge level

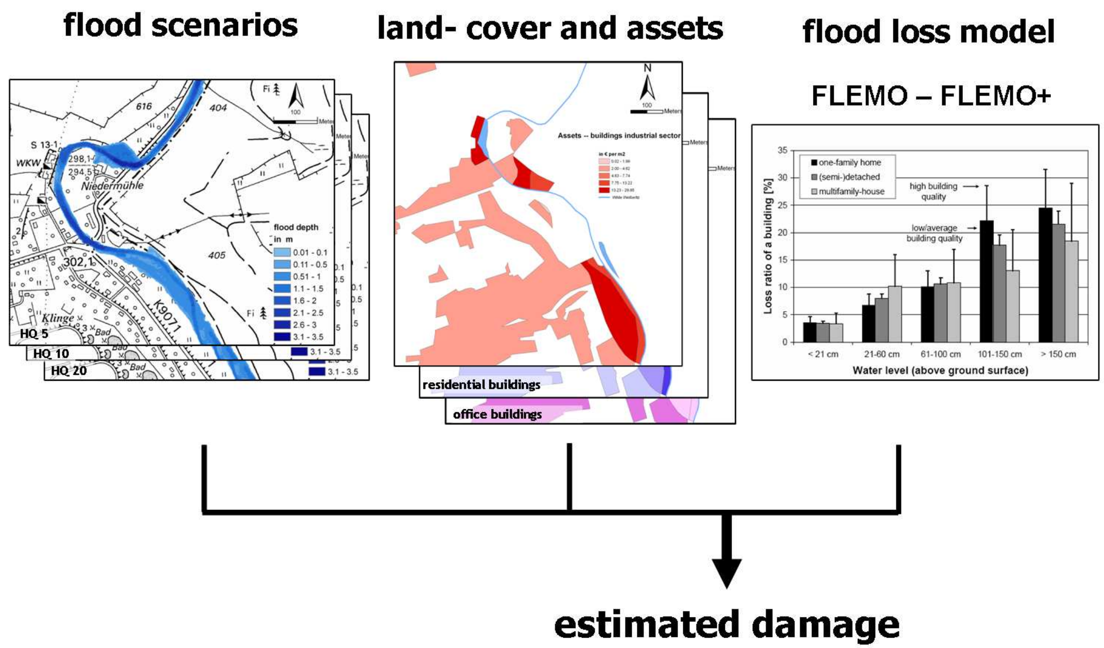


- Combination of forecast and Markov process
- Converging to probability distribution of observed discharge level for a given month



Decision making

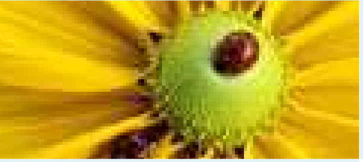
Socioeconomic Model:FLEMO



- FLEMO: losses depending on water level, building type and building quality/size.
- Second stage: effects of private precautionary measure and contamination of the floodwater.

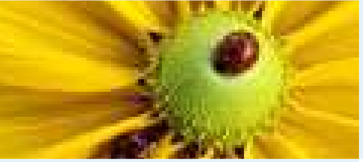
H. Kreibich, I. Seifert, et al. *Hydrological Sciences Journal*, submitted.

A.H. Thieken and H. Kreibich. *Journal of Hydrology*, submitted.



Reservoir management

- Uncertainty based management
- Probability to cause damage greater threshold (e.g. 50%) triggers scenario testing
- Scenario range:
  - Maximum damage free release
  - Maximum reduction of peak discharge
- Expected (from prediction ensemble) damage for
  - Pre-event release
  - Event itself



Conclusions

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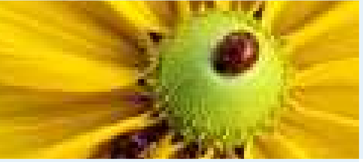
- Quantification of input uncertainties (for ECMWF ensemble)
- Quantification of model uncertainties
- Neither source of uncertainty can be excluded a priori
- Next steps:
  - combination of approaches with flood loss model
  - uncertainty of radar now-casting
  - precipitation dependent hydrological uncertainty processor



Acknowledgments

Thank you for your attention

Acknowledgments

- Funding: BMBF-Förderaktivität “Risikomanagement extremer Hochwasserereignisse” (RIMAX)
- Bavarian Flood Warning Center (Uwe Ehret) for hydrological predictions for the Iller
- Jenny Eckart for WaSiM-setup of the input data