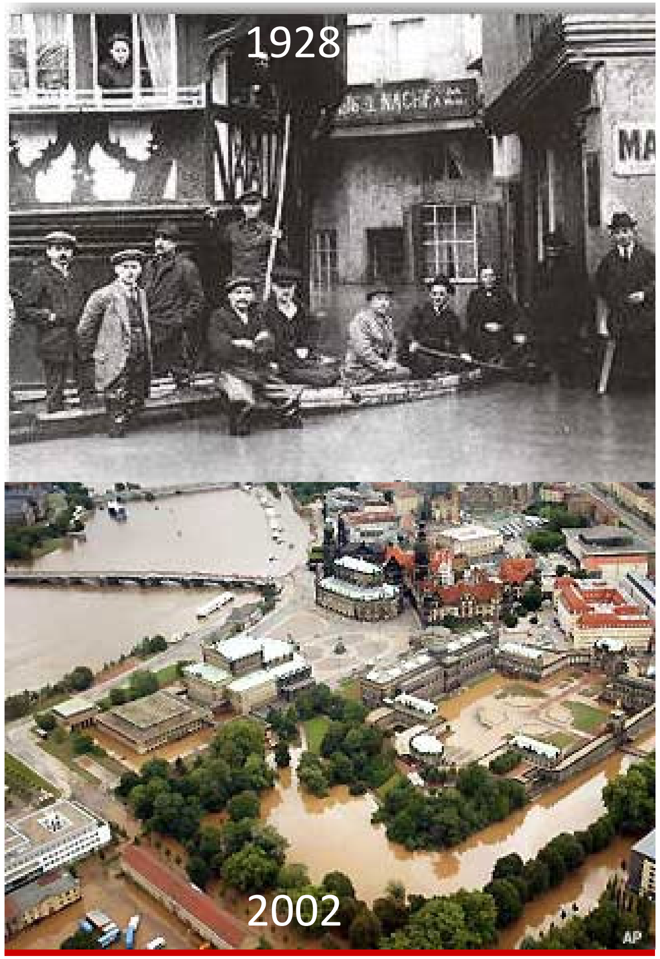

Decision support systems and decision making under known uncertainty

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DSS and DM under known uncertainty

1 Decision Making under Uncertainty

Flood forecasts are uncertain by nature.

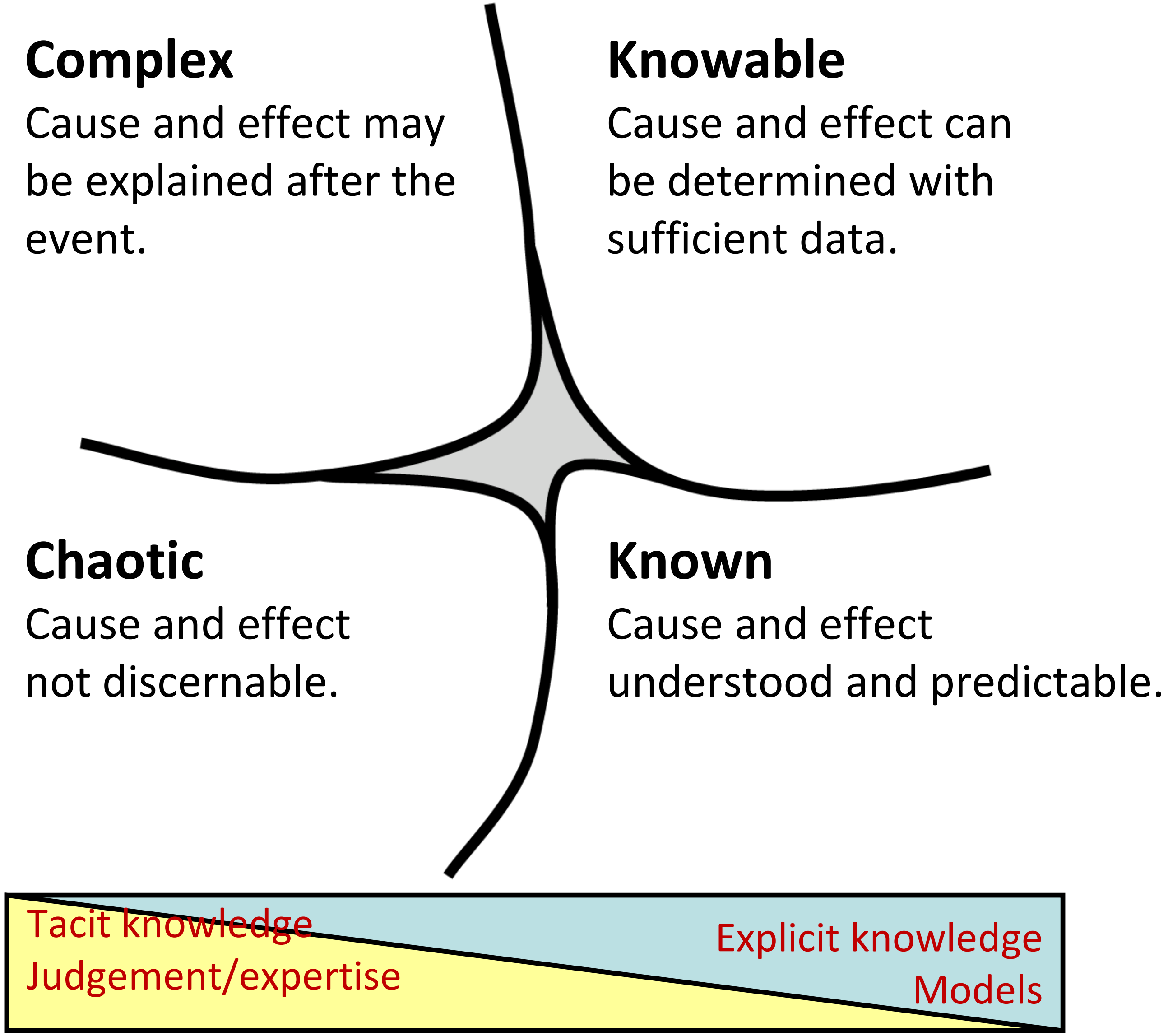
Decisions in flood management have to consider uncertainty.

What about unpredictable situations?

Decision Support Systems (DSS)

- A decision support system (DSS) is a socio-technical system, which supports decision makers in combining personal judgement with the output of a computer in order to gain substantial information for decision making within a decision process.
- Decision makers (often groups of persons) have goals and preferences.
- The decision process is driven by human actors. Psychology plays an important role!
- Types of decision problems:
  - Strategic (long term process, complex negotiations,…)
  - Tactical
  - Operational (control problems, often a priori structured,…)

Decision Contexts (Cynefin Sensemaking Framework)



Snowden 2002,
French & Niculae 2005

Traditional DSS: “Known” Context

- Based on the rationality assumption.
  - Decision makers are able to understand all aspects of the decision problem.
  - All relevant data are accurate and accessible for the decision makers.
  - Cause-effects and consequences of actions are known.
  - Decision makers search for an optimum, which means the highest benefit.
- Decision recommendation is prescriptive.
- No unexpected events happen.
- This is the world of pure deterministic modelling and decision making.

Risk Informed DSS: “Known/Knowable” Contexts

- Rationality assumption weakened (still a rational decision maker, but he/she knows about uncertainty)
- Cause effects are known, but uncertainty is admitted
  - The exact outcome is not known
  - The possible outcomes are known
  - There is quantitative information about uncertainty
  - The probability that a particular outcome will occur is known or can be estimated for each outcome
- Residual risk can be quantified within planning (e.g. failure of structures) – but can this risk be quantified a priori for the actual forecast?
- This is the world of probabilistic forecasts and risk informed decision making.

Adaptive DSS: “Complex” Context

- Extreme situations resp. disasters: do we expect to see “unknown uncertainty”?
  - Unexpected failures of the model chain (unobserved situation!)
  - Unpredictable failures of structures, wrong decisions etc.
- The application of a DSS alone does not ensure the success of the decision process (believing the models = mishandling?).
- In case of complex or even chaotic contexts, decision makers may want to find transitions into the space of knowable and known contexts.
- One of the differences between humans and computers: we can make decisions independent from any algorithm/rule etc.
  - An adaptive DSS can make use of different sources of information or even artificial intelligence for automatic adaptation attempts,
  - But it should be controllable “by hand”, using tacit expert knowledge.

Some Questions for Flood Managers

- When should we issue a flood alert/warning/alarm, and which level, and who is addressed?
- How should controllable structures be operated?
- Which flood defence measures should be initiated?
- If a protection of all humans and all valuable goods is not possible: who is first?
- Is there a worst case we should be prepared for, how probable is that and what consequences would this have?
- Is Cynefin a suitable framework for crisis response in flood management?
  - How can I classify the situation?
  - Cynefin is controversly discussed in the systems analytic community (e.g. demand for better representation of stochastic processes)

2

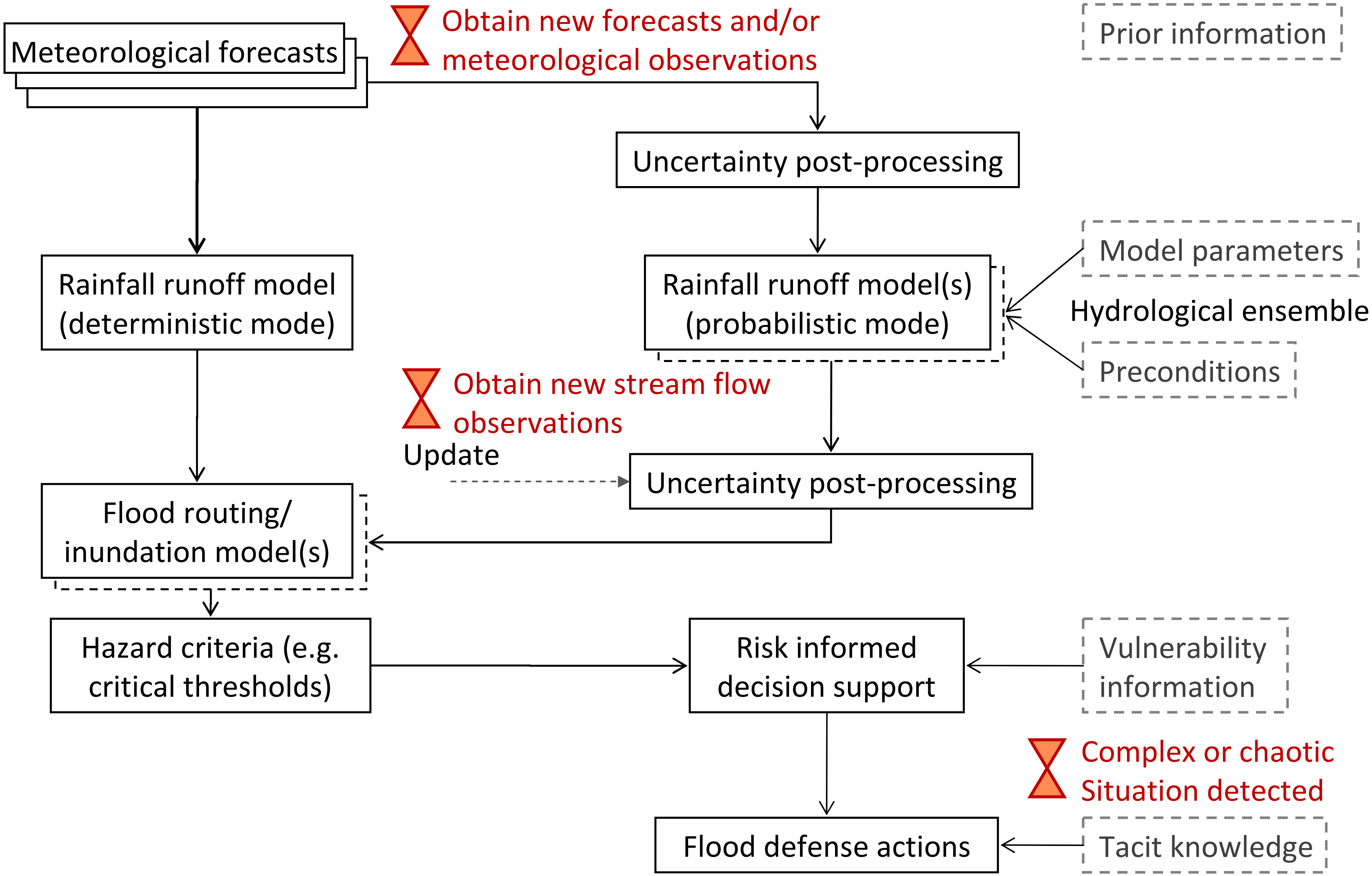
DSS architecture for operational flood management

The Domain of the technical systems: known and knowable.

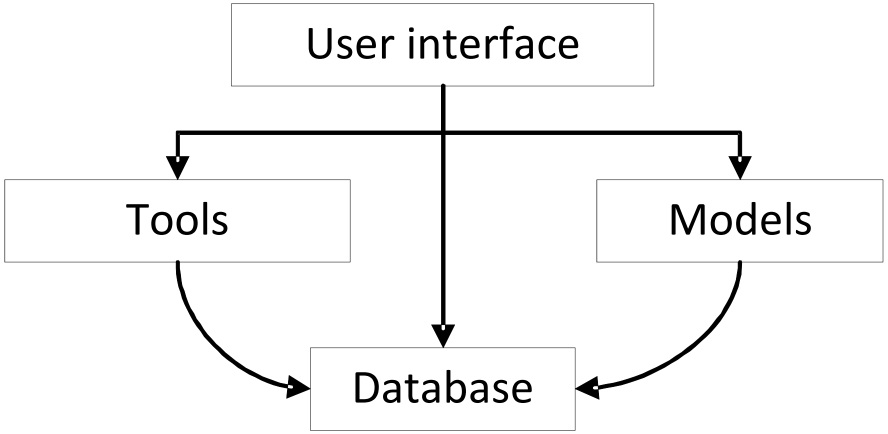
Model the behaviour of the physical system under changed load.

Process uncertainty through model chains & communicate.

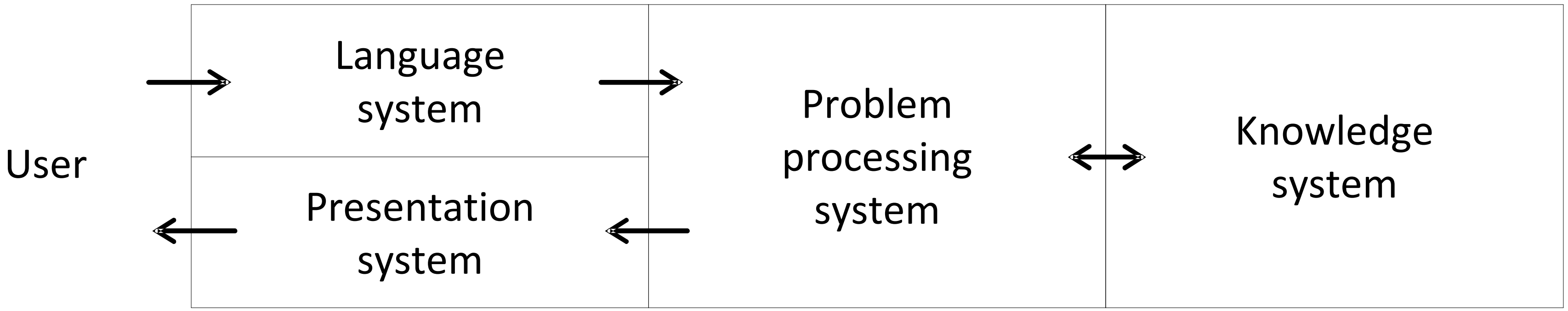
DSS Functionalities



Different Views on Generic DSS Architectures



Hahn & Engelen, 2000



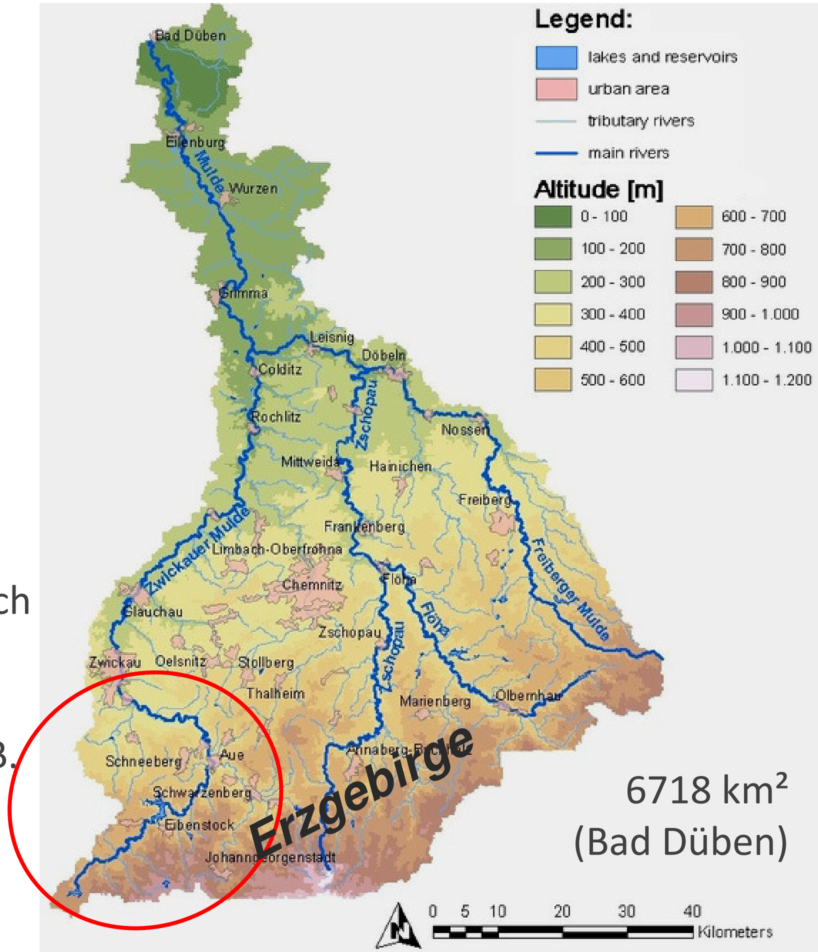
Dos Santos & Holsapple, 1989

Some DSS Design Considerations

- Run 1000’s of hydrological/hydraulic simulations within a short time window
  - Computational efficiency of the models: conceptual models, replacement models (e.g. GIS based inundation simulation)
- Manage a tremendous amount of data: online database
- Prepare user interaction to switch between computer operation and manual operation for decision support
  - Adaptive user interfaces
- Use generic standards for communication between sensors, databases, models, user interfaces, e.g.:
  - OpenMI model interface
  - INSPIRE water object model
  - OpenGIS, including sensor data standard
- Institutional structures/responsibilities may be of importance

4 Case study: Ensemble hindcasts for the Mulde river

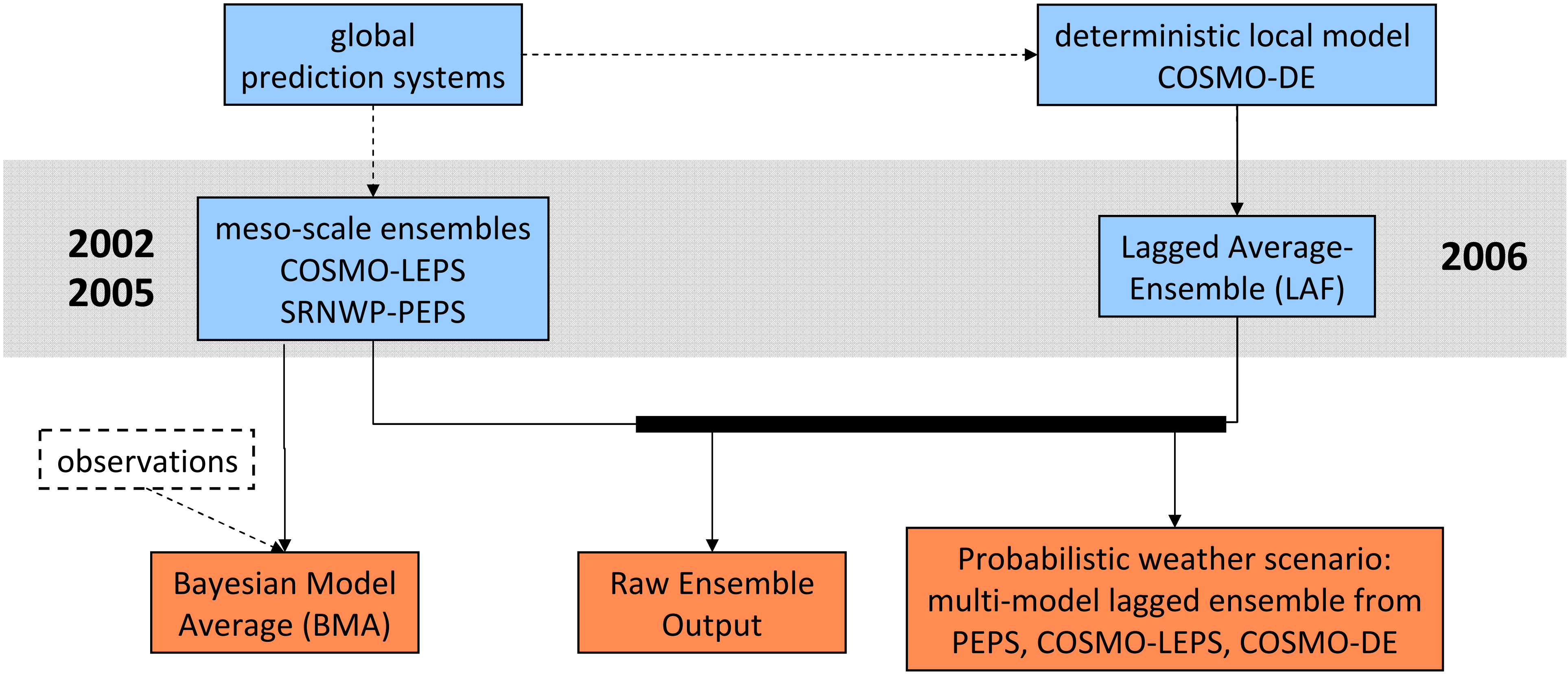
Partners:
Ruhr University Bochum (Scientific coordinator: Prof. A. Schumann)
German National Weather Service DWD
Büro für Angewandte Hydrologie Berlin
DHI-WASY Berlin/Dresden
Flood Management Authority of Saxonia
Funding:
German Ministry of Education and Research (BMBF), action: risk management of extreme floods (rimax)
Scientific coordinator: gfz Potsdam, Prof. B. Merz



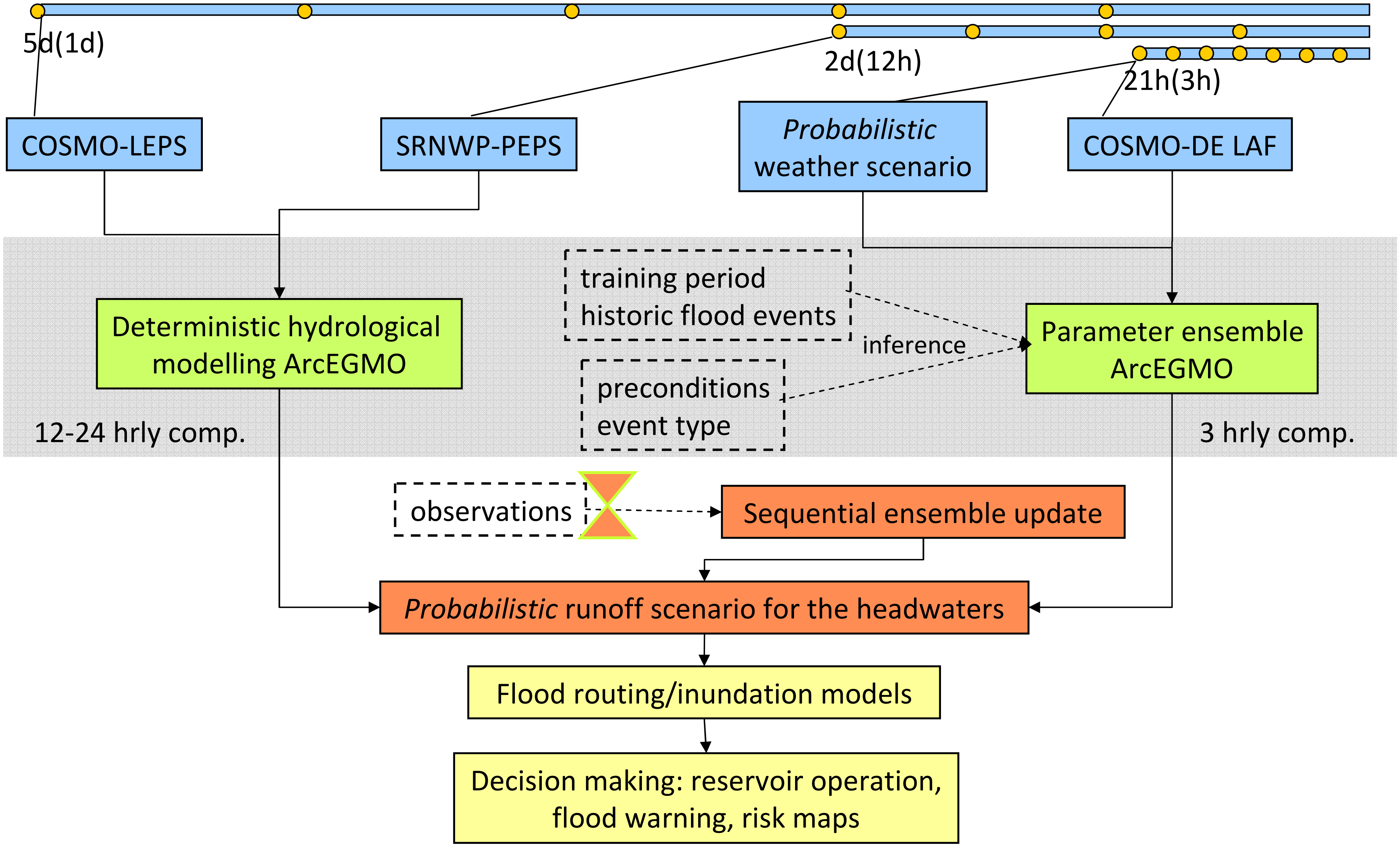
Mulde Case Study: Ensemble-based DSS

- Characteristics of the Mulde river basin:
  - Mountainous, fast reaction to rainfall events (<12h)
  - Several vulnerable cities
  - Study area: 6200 km² (sub-basins > 100 km²)
- Aims of the case study:
  - Demonstrate and discuss the application of ensemble flood forecasts (mainly for head waters, based on hindcasts)
  - Are ensemble forecasts advantageous for decision makers (show probabilities of threshold exceedance, extend lead time)?
- Develop an exemplary DSS including hydrological models
- Follow up:
  - Implementation of the hydrological forecast at local flood authorities
  - Further evaluation of ensembles, wait for physical COSMO-DE EPS (short term, convection resolving forecast considered most important)

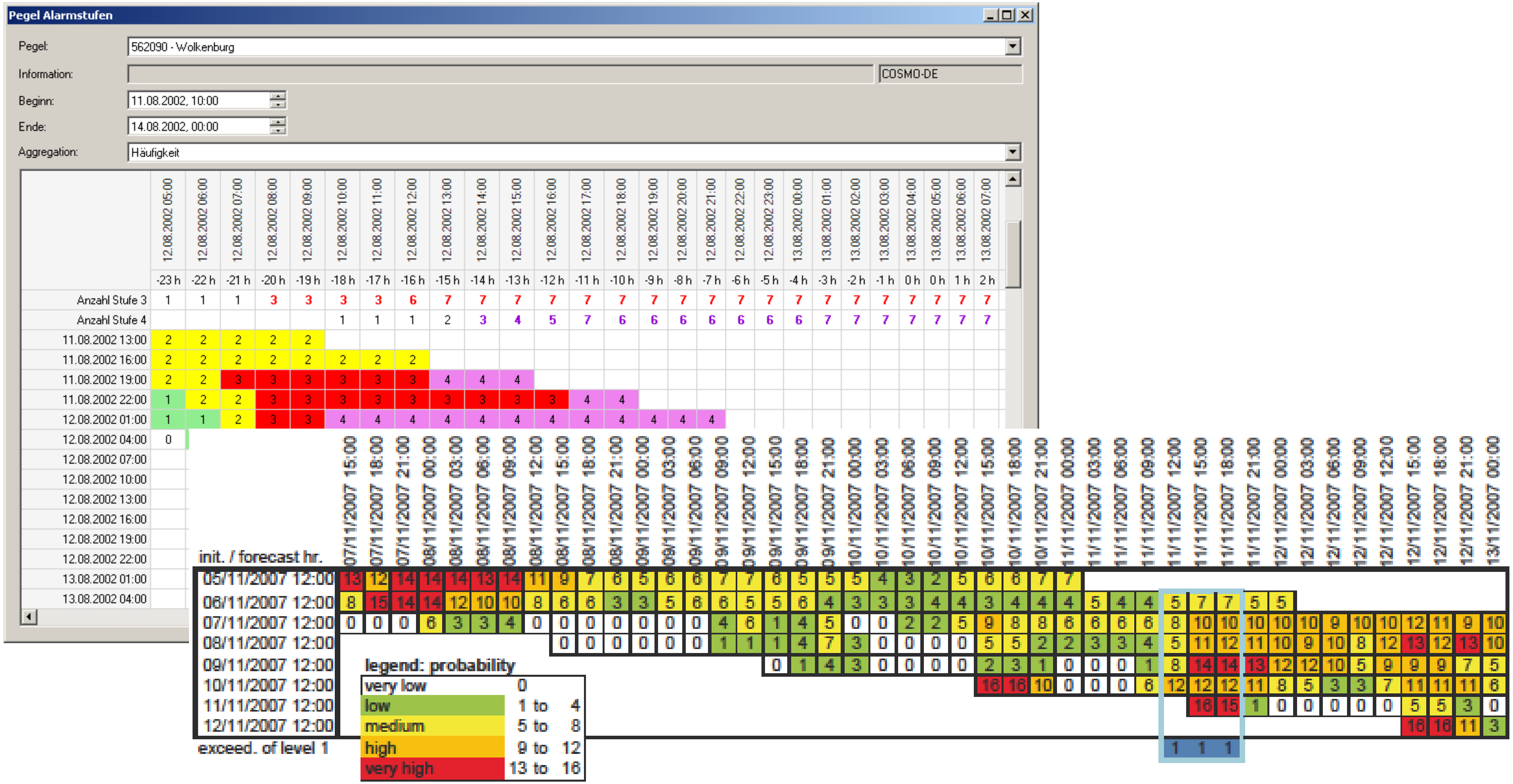
Meteorological Ensembles



Hydrological Ensembles



Persistence Charts

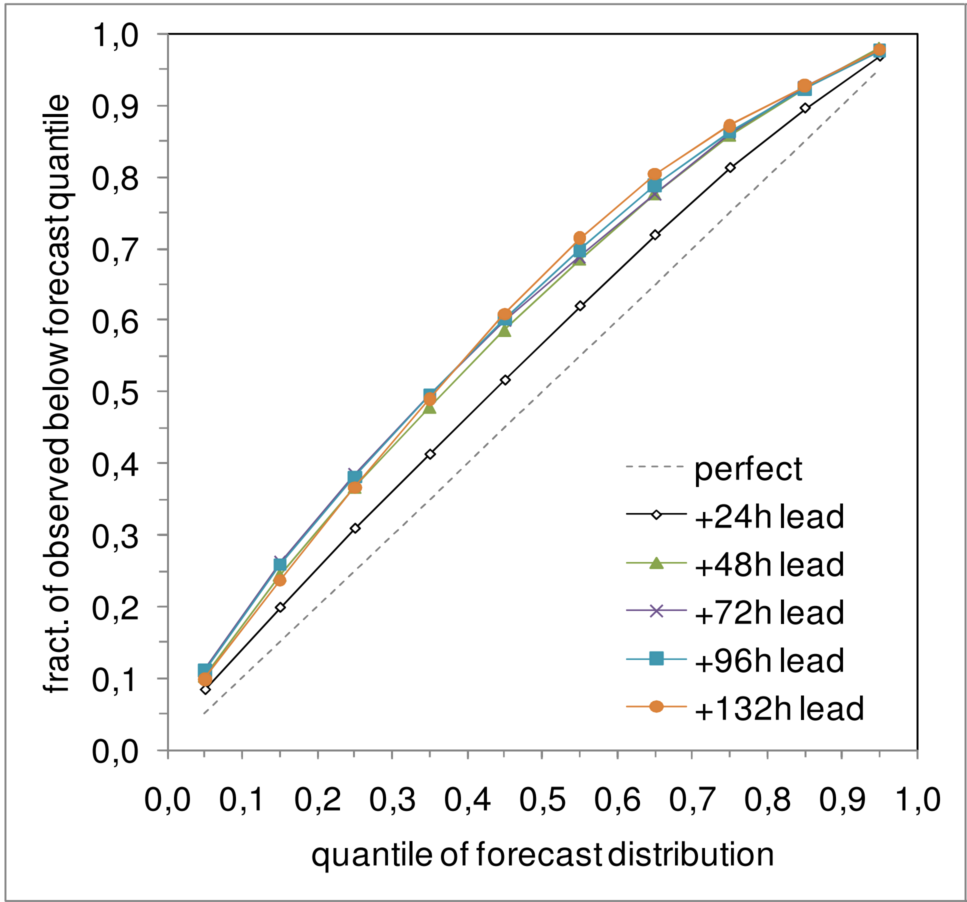


e.g. used by EFAS (Thielen et al. 2008) to show temporal developments

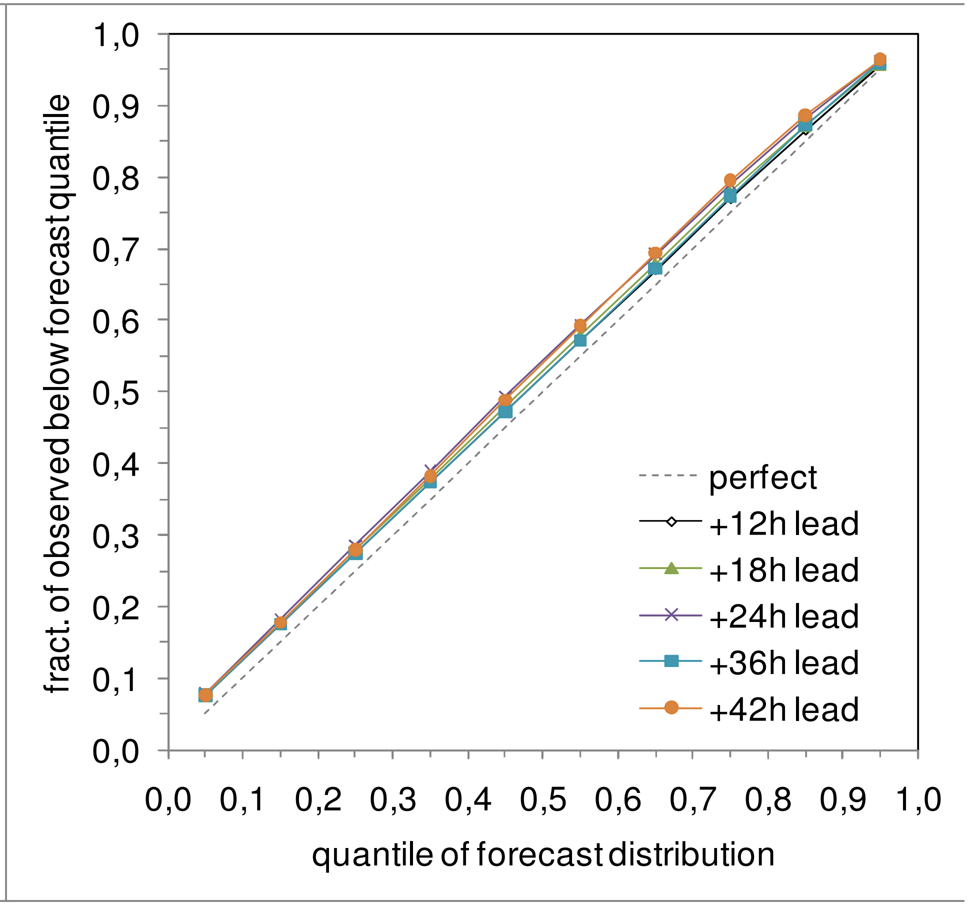
Left: Predicted alert level (COSMO-DE 08/2002 lagged average ensemble)

Right: Probability of exceeding level 1 (COSMO-LEPS 11/2007)

Reliability of Flood Alerts



COSMO-LEPS/ArcEGMO



SRNWP-PEPS/ArcEGMO

Assumption: all ensemble members have equal weight and describe probability distribution (originally frequencies of ensemble members but not necessarily probabilities)

Conclusions

- Decision making in flood management has to deal with uncertainty. Ensemble predictions can be an integral part of an operational flood management system.
- We need more hindcasts to develop decision rules!
- Limited resources and uncertainties (data & knowledge, computing time, cognitive capabilities…) require adaptive approaches for the operational application of a probabilistic flood prediction chain within a DSS.
- DSS are only one of many sources of information
  - they normally rely on explicit knowledge.
  - In case of complex or even chaotic situations, other sources including tacit knowledge should be considered within the decision process.

Thank you for your attention!

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