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foto: PRÁVO/Lukáš Táborský

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Application of ensembles in flood forecasting

J. Thielen, J. Bartholmes, K. Bogner, J. Younis
European Commission, DG Joint Research Centre
Institute for Environment and Sustainability

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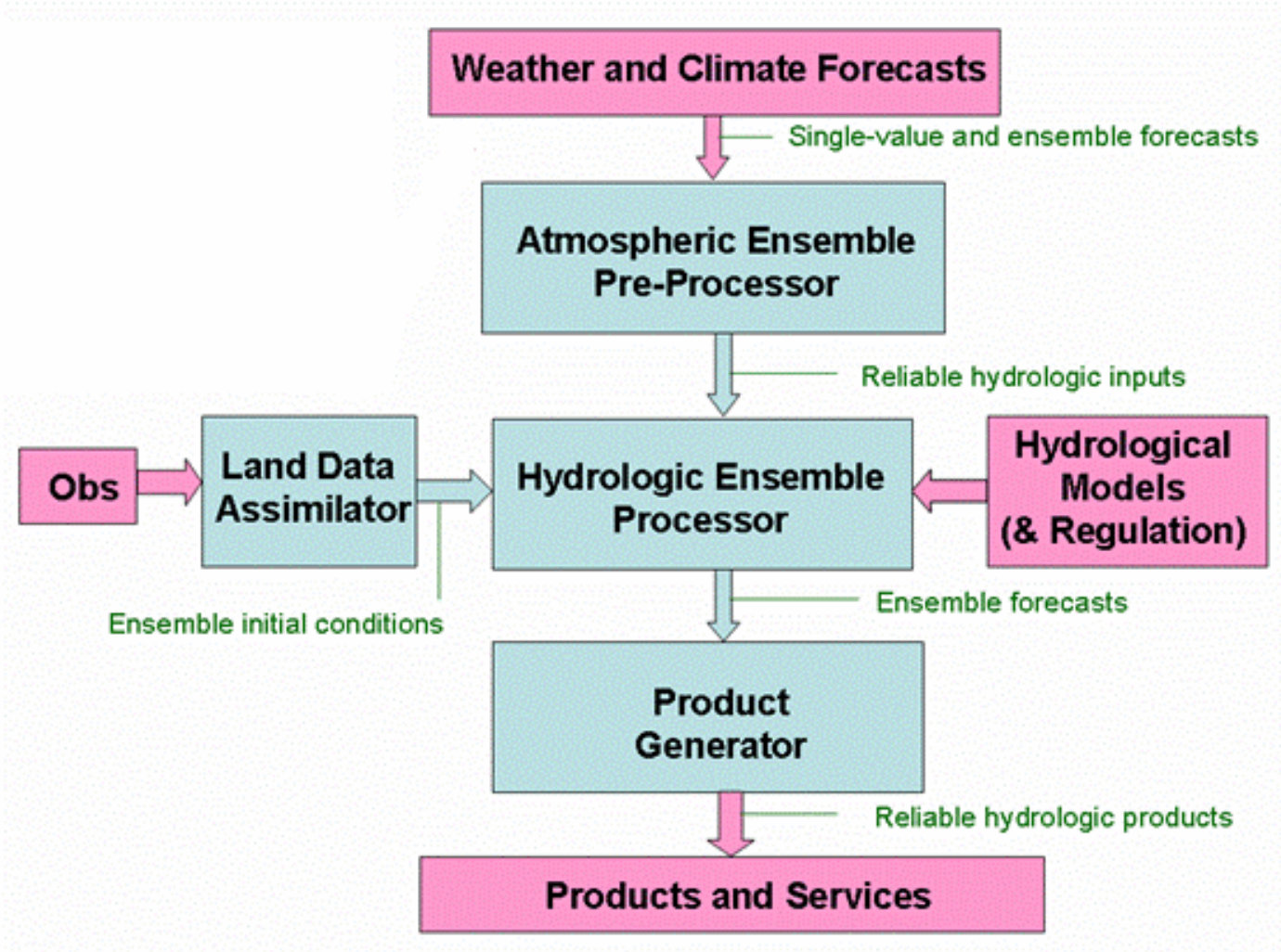
Table of Contents

(John Schaake, HEPEX)

Hydrologic Ensemble Prediction System



Main hydrological applications for EPS

Flood forecasting

- *Flashfloods (~hours, ~ local)*
- *Riverine floods (~ days, ~ regional)*

Reservoir management

- *Energy production*
- *Water management*
- *Flood control*

Droughts

- *Seasonal variations*

Climate change

LEPS (3-15 km, 1-5 days)

EPS (40-80 km, 10-15 days)

Monthly-Seasonal EPS (80-120km, 1-6 months)

Climate change scenarios

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Floods are a worldwide problem

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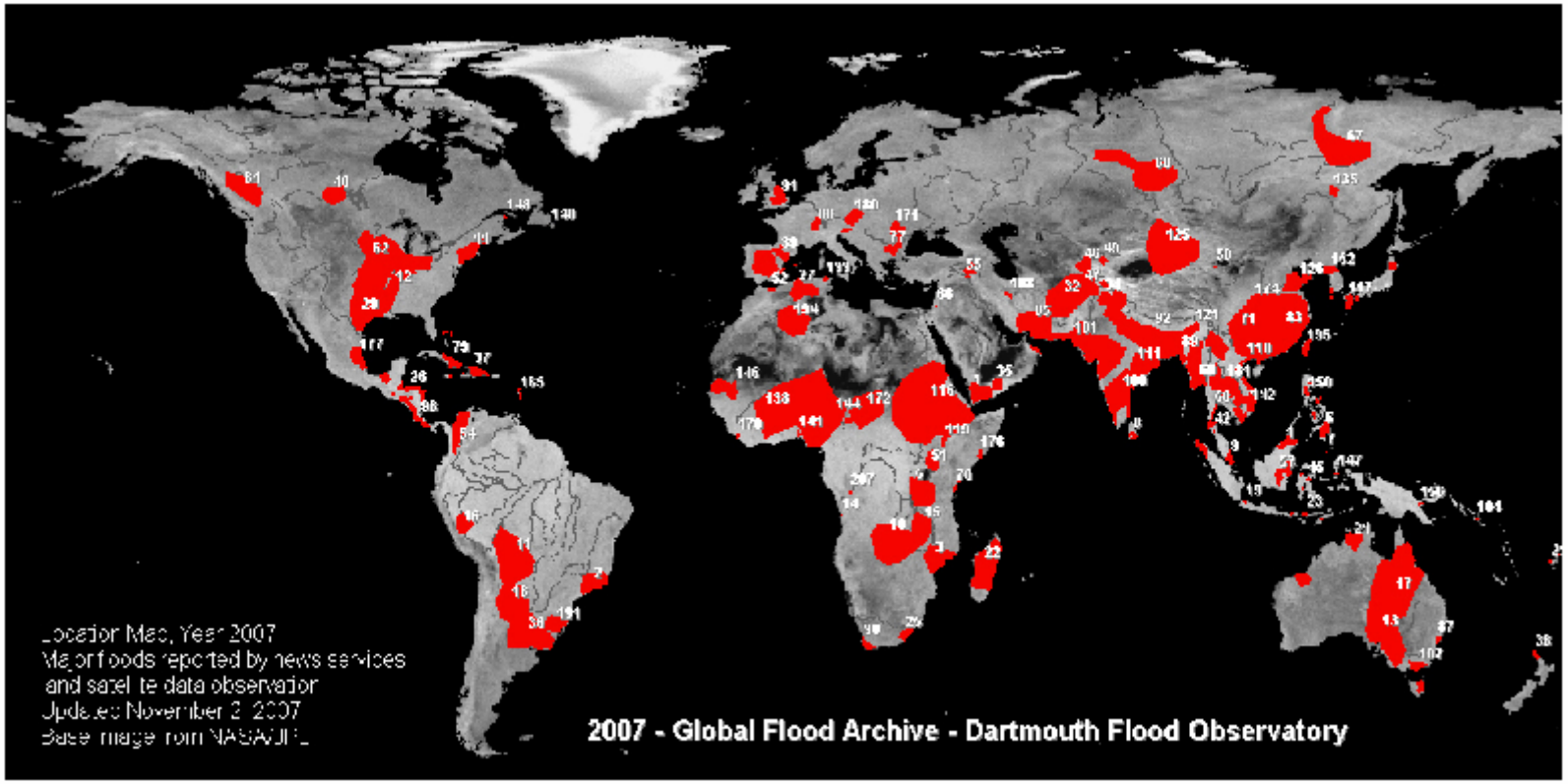

Source: http://www.dartmouth.edu/~floods/Archives/2007global.jpg

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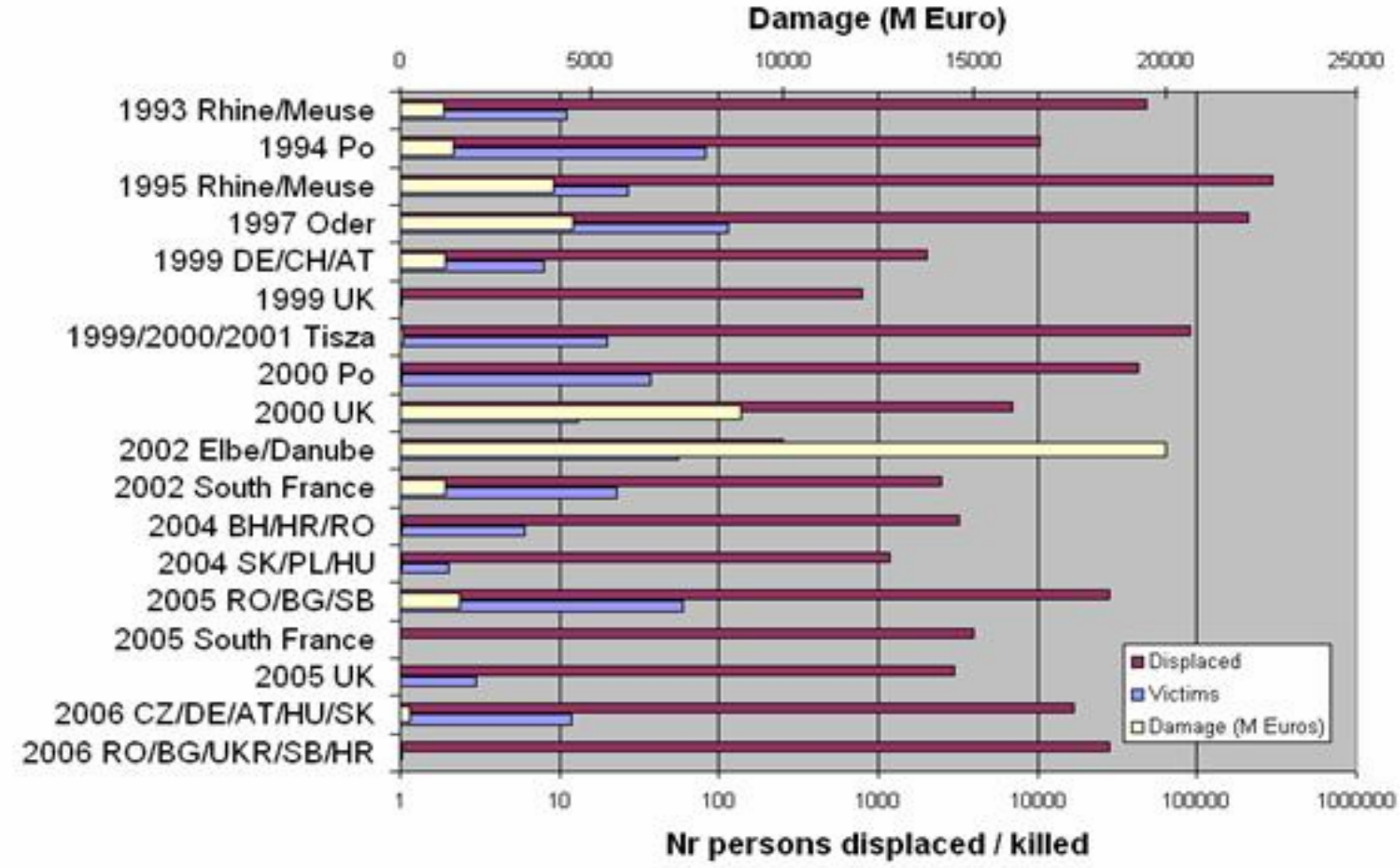
Flood victims and damage in Europe



(Source: CRED Database)

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EU Research initiatives on flood forecasting with EPS

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1999-2003 :	European Flood Forecasting System (EFFS, DG Research);
2003- :	European Flood Alert System (EFAS, EC& MS)
2004- :	Hydrological Ensemble Prediction Experiment (HEPEX, International scientific initiative)
2004- :	PREVIEW (GMES, research natural hazards incl. floods, storms, forest fires)
2004- :	FloodSite (DG Research)
2005- :	Thorpex/Tigge also for hydrological applications

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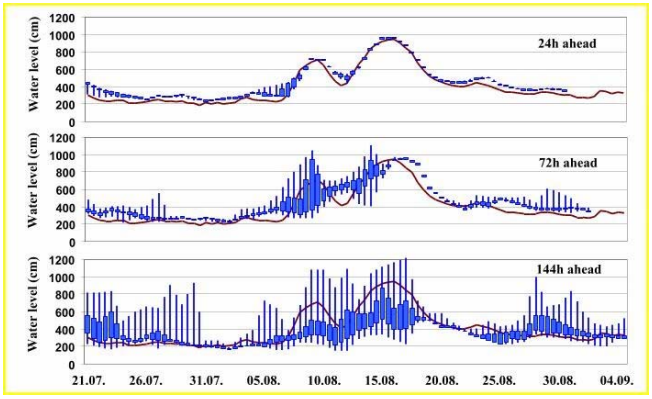
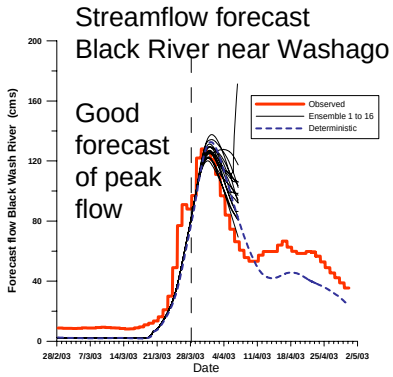
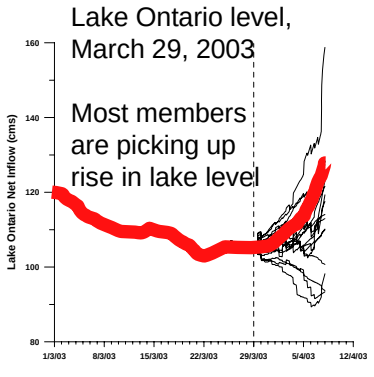
EPS in operational flood forecasting….

- In operational flood forecasting EPS are mostly in testing mode, few base decisions on EPS based forecasts



(from Czik and Balint, 2007, HU)





(from Fortyn and Pietroniro, 2007 CA)

- research results need time to be put in operational practice
- decision making based on uncertain results not straight forward
- meteorological products are not adapted for hydrology

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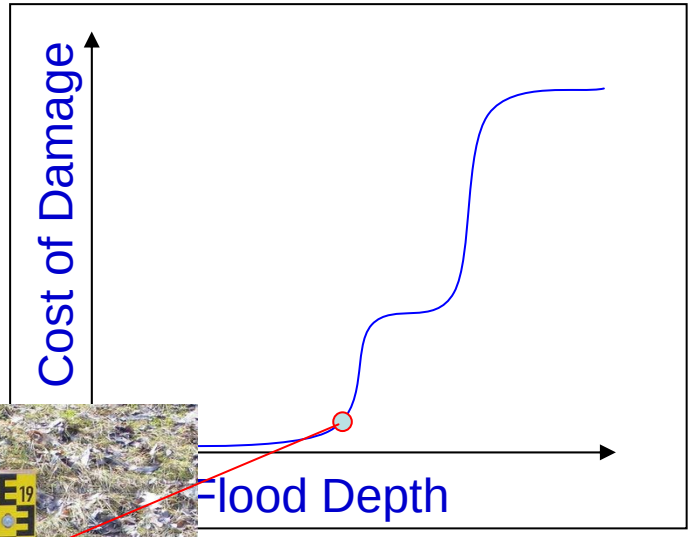
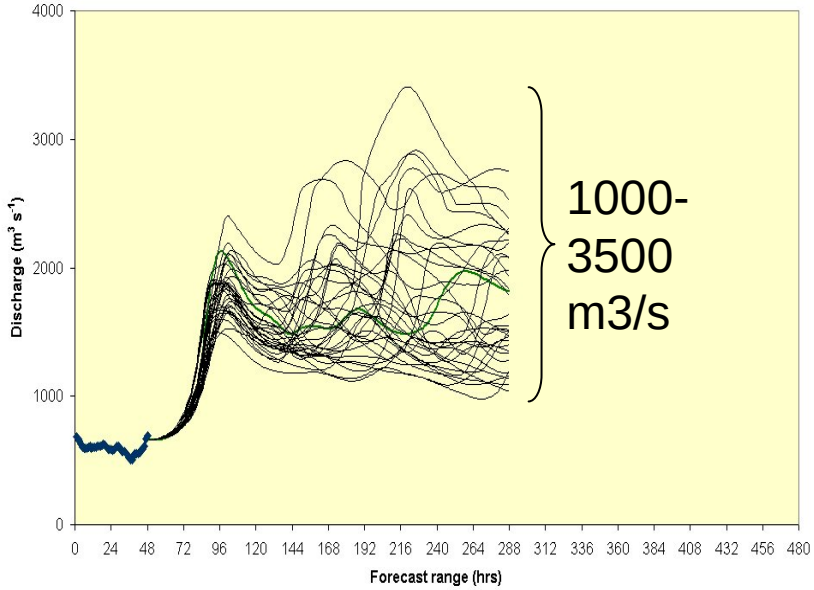
In practice: Decision making with uncertainty?

Floods occur at a precise

location and water level





EPS based forecasts can provide ranges that become *meaningless* for a decision maker

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Cost/loss based decisions…

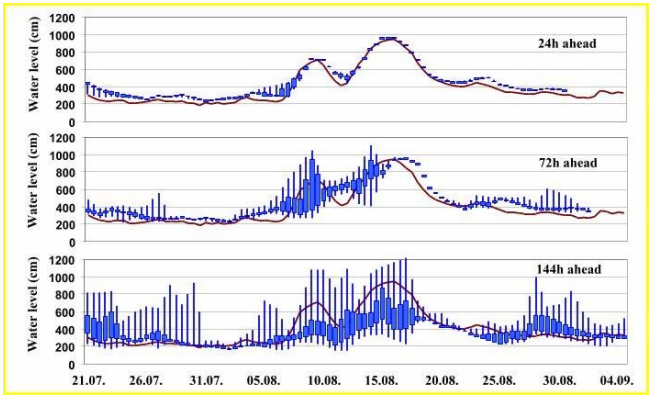
… not always applicable for decision making

- In many countries firefighters are volunteers that are called from regular jobs to help with flood protection. They can only be called when flooding is certain.

- $\frac{E}{t} = \frac{m}{t} g h$ The Energy gained through hydropower is directly proportional to the height of the water. Lowering the water level for flood protection needs to be done several days in advance and represents an important economic loss for the company.

EPS in operational flood forecasting….

•In operational flood forecasting EPS are mostly in testing mode, few base decisions on EPS based forecasts



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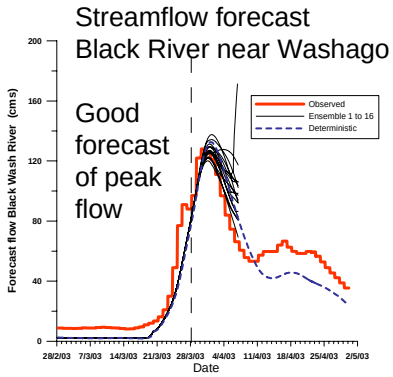
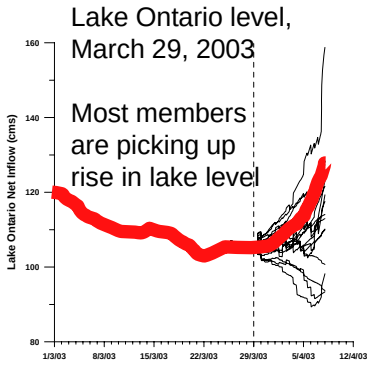


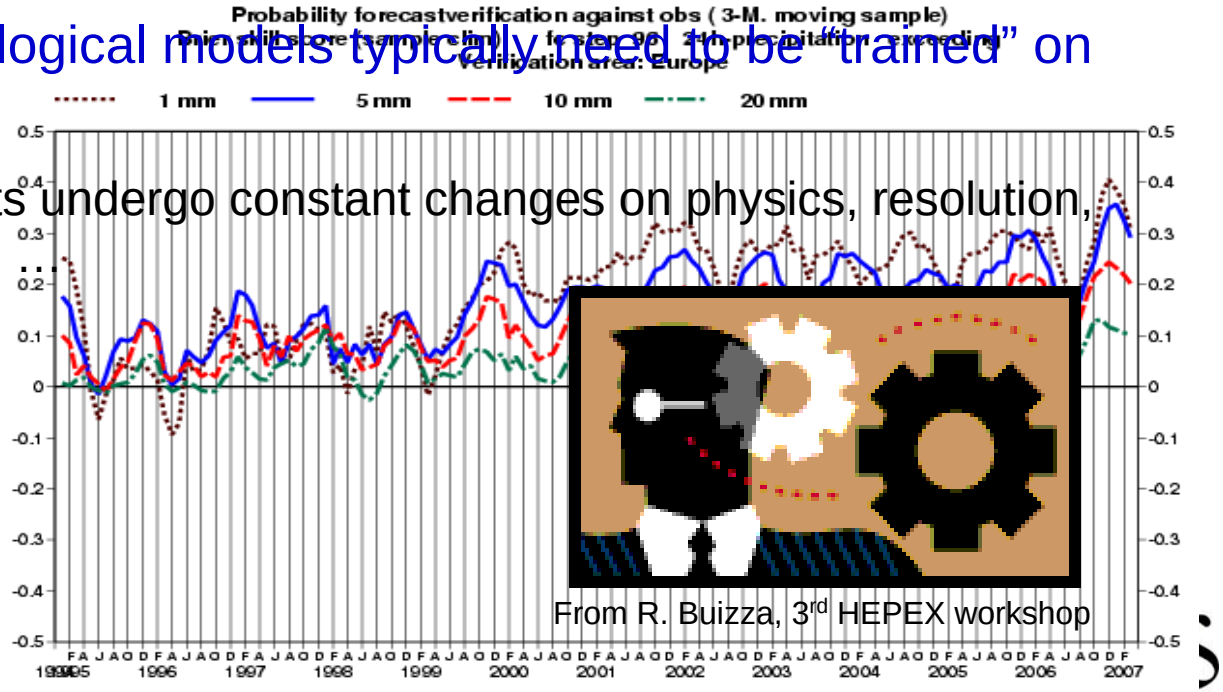


(from Fortyn and Pietroniro, 2007 CA)

- research results need time to be put in operational practice
- decision making based on uncertain results not straight forward
- meteorological products are not adapted for hydrology

Meteorological EPS forecasts versus hydrological needs….

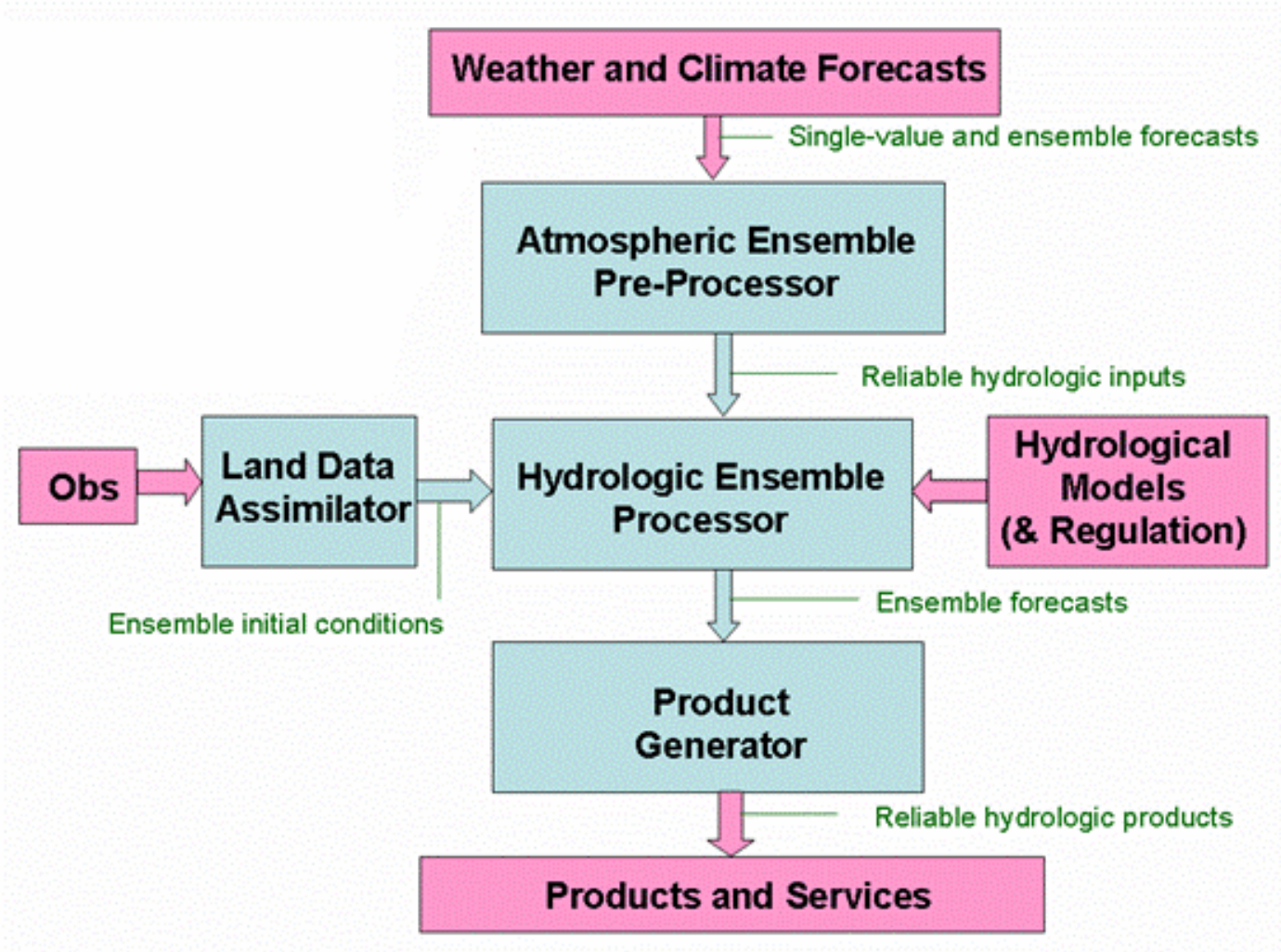
- Scale: hydrological units are irregular and often small and/or dealt with on small administrative units
- Skill: Precipitation, one of the driving forces, has still little skill – even on the large scale. Even worse for extreme precipitation
- Calibration: Hydrological models typically need to be "trained" on the data sets, but
  - weather forecasts undergo constant changes on physics, resolution, data assimilation, …

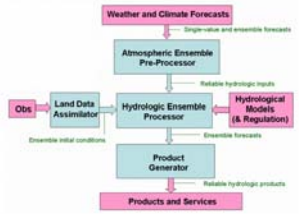


From R. Buizza, 3rd HEPEX workshop

(John Schaake, HEPEX)

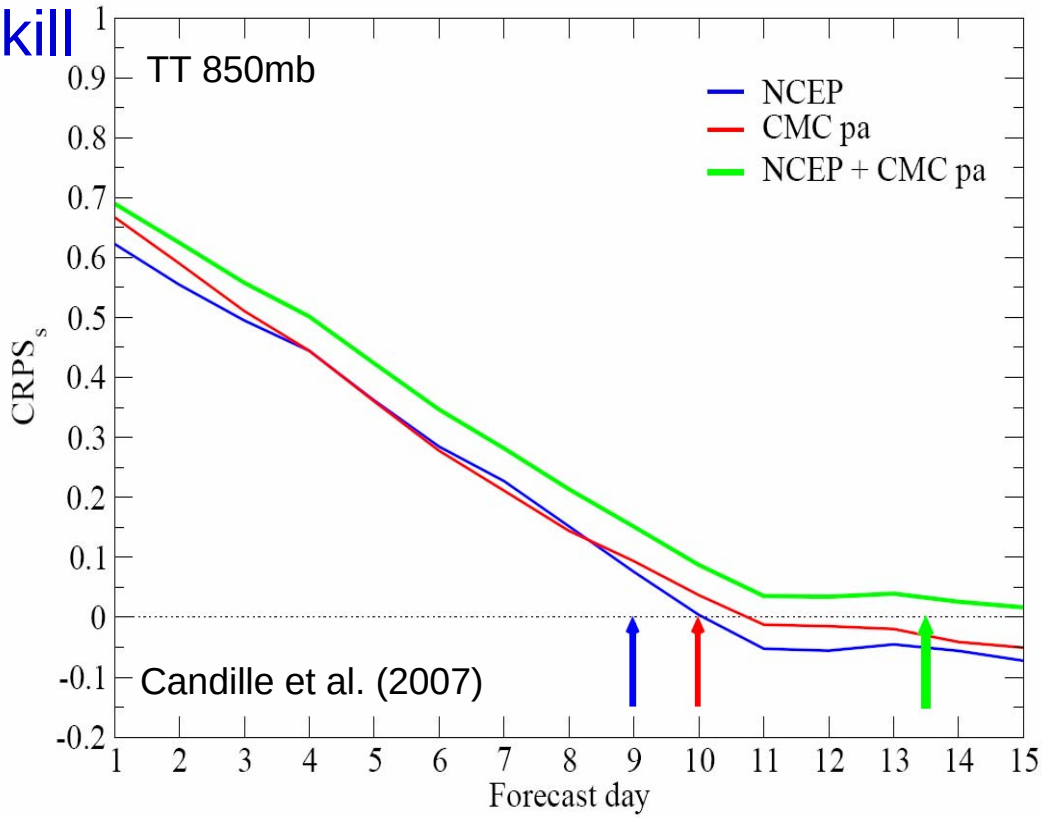
Hydrologic Ensemble Prediction System



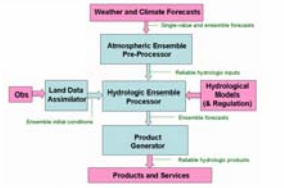


Atmospheric Ensemble (pre)processor

- improve precipitation skill
- downscaling
- bias corrections
- increase EPS sample



Meteorologists could provide guidance on these issues



Hydrological ensemble processor

- type of hydrological model (distributed, lumped, …)
- space-time resolution of hydrological model
- response time of the river basin
- climatology & water management
- risk exposure (hazard & vulnerability)

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European Flood Alert System (EFAS)

Complement Member States activities on floods with early warning information

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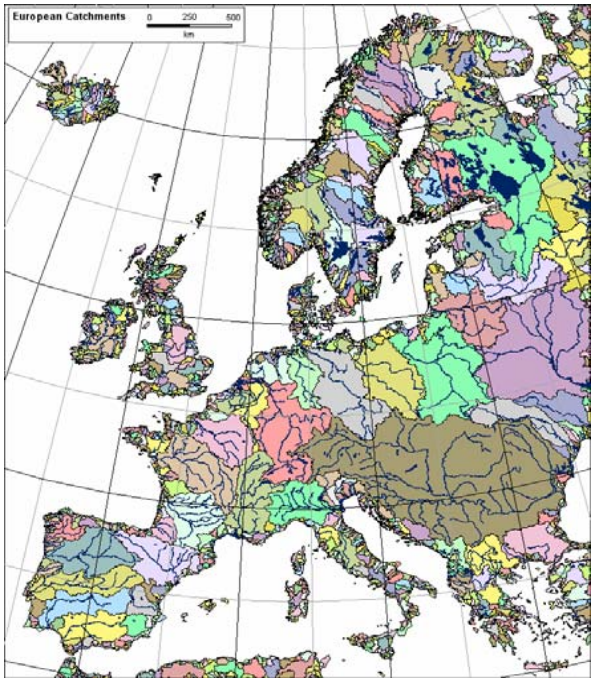

- extend warning time > 3 days by using multiple weather forecasts including EPS
- forecasting for entire river basins and the whole of Europe
- information exchange platform for operational services

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EFAS set-up

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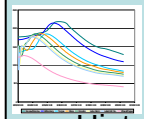
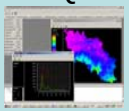
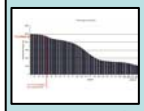
EU Flood GIS

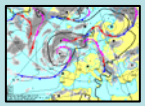
Realtime H-Q data





Historical Data

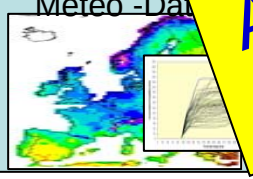




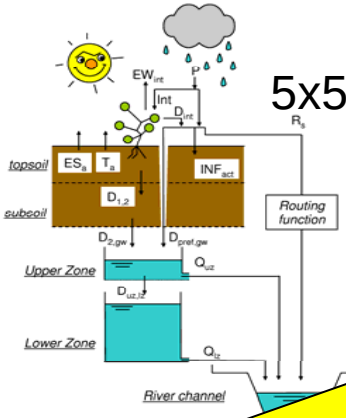
Static Data

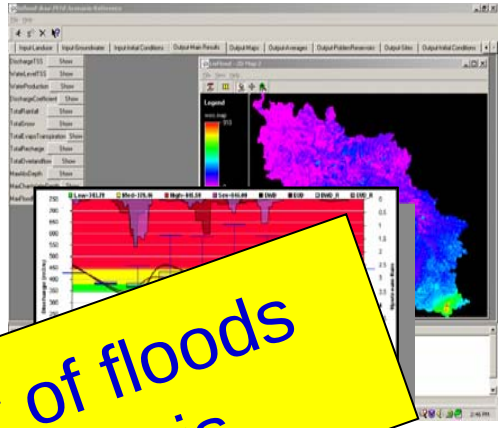
Europ. Data Layers

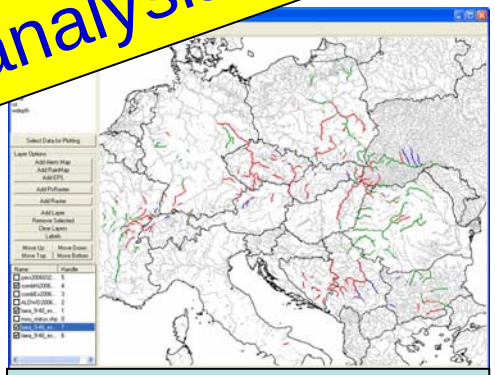
Meteo -Dat



Expert Knowledge of Member States

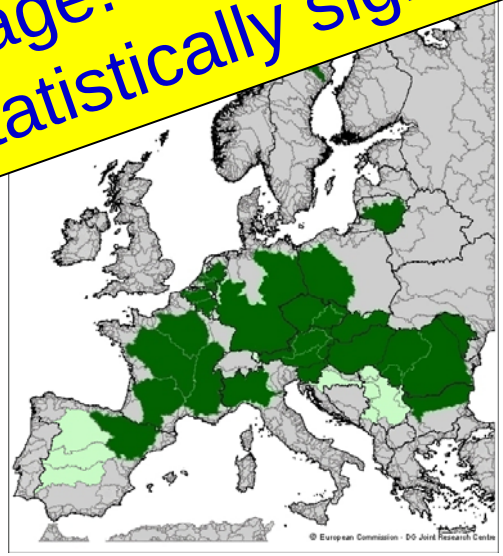






EFAS Reports

Advantage: sufficient number of floods for a statistically significant analysis



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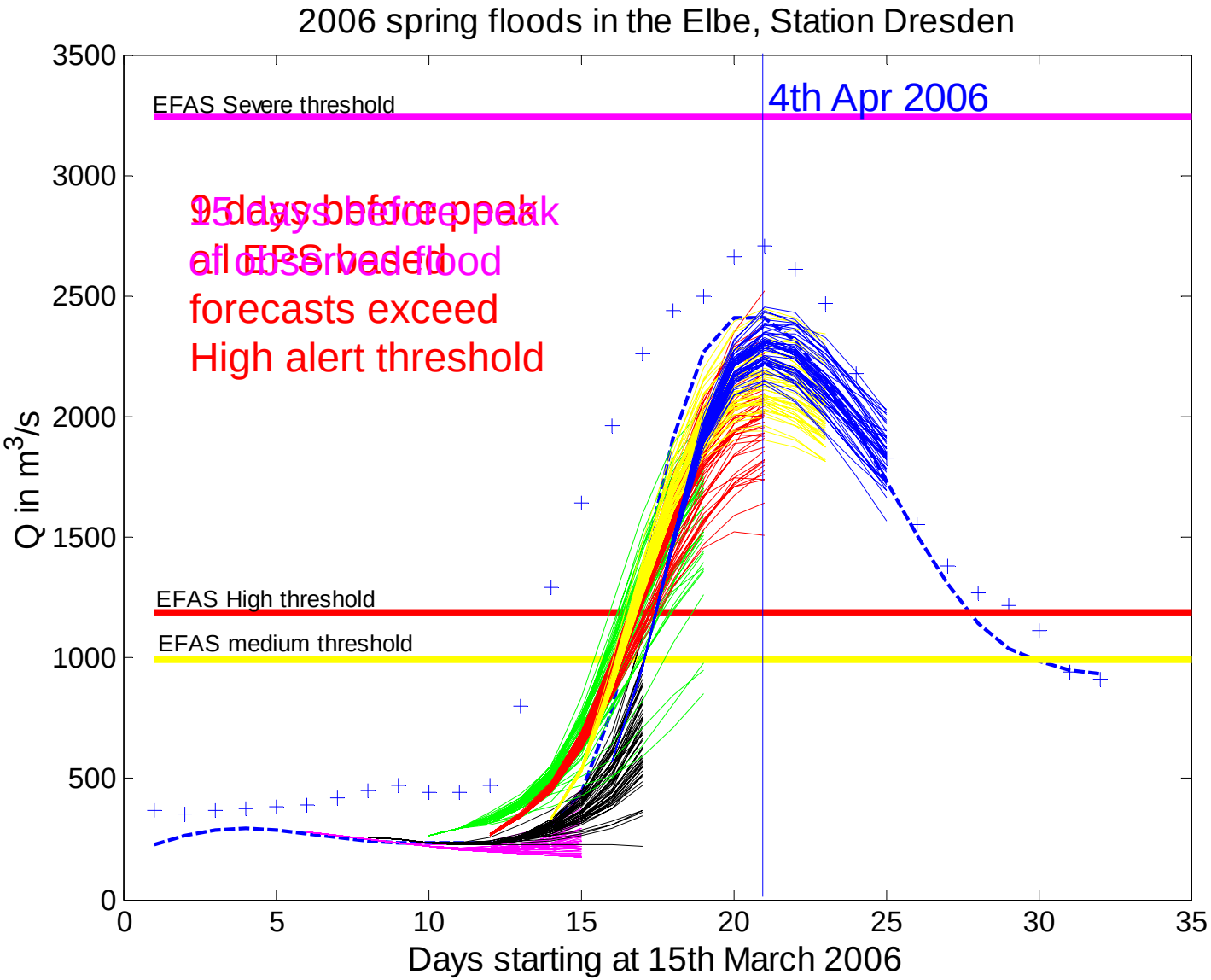
(J. Younis, EFAS-Elbe)

Example: Elbe flood March/April 2006



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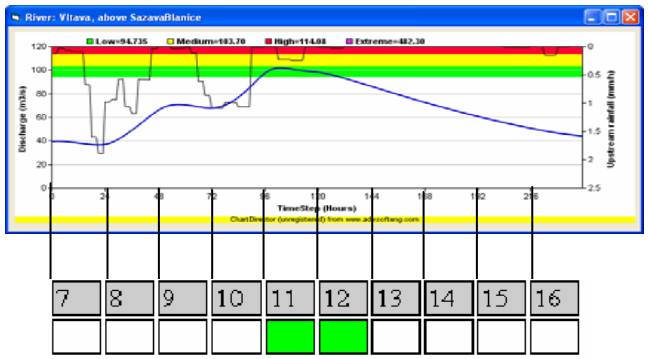
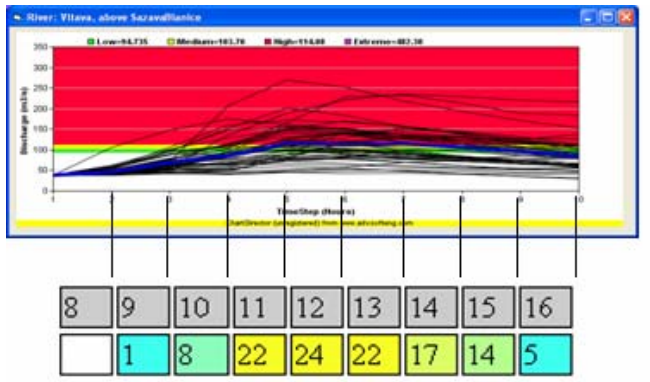
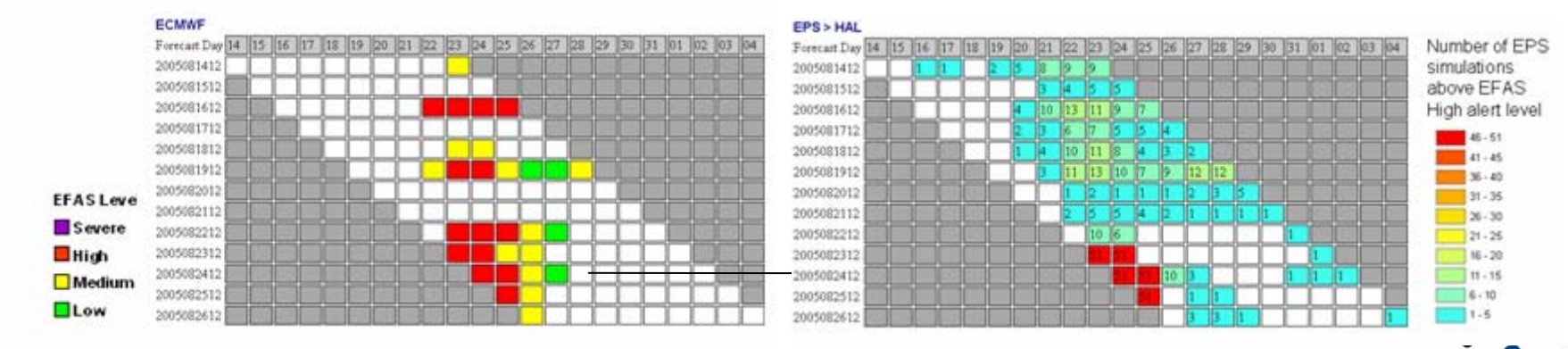
Current methodologies to reduce “uncertainty” in EFAS

- Threshold exceedance





- Persistence over n-forecasts



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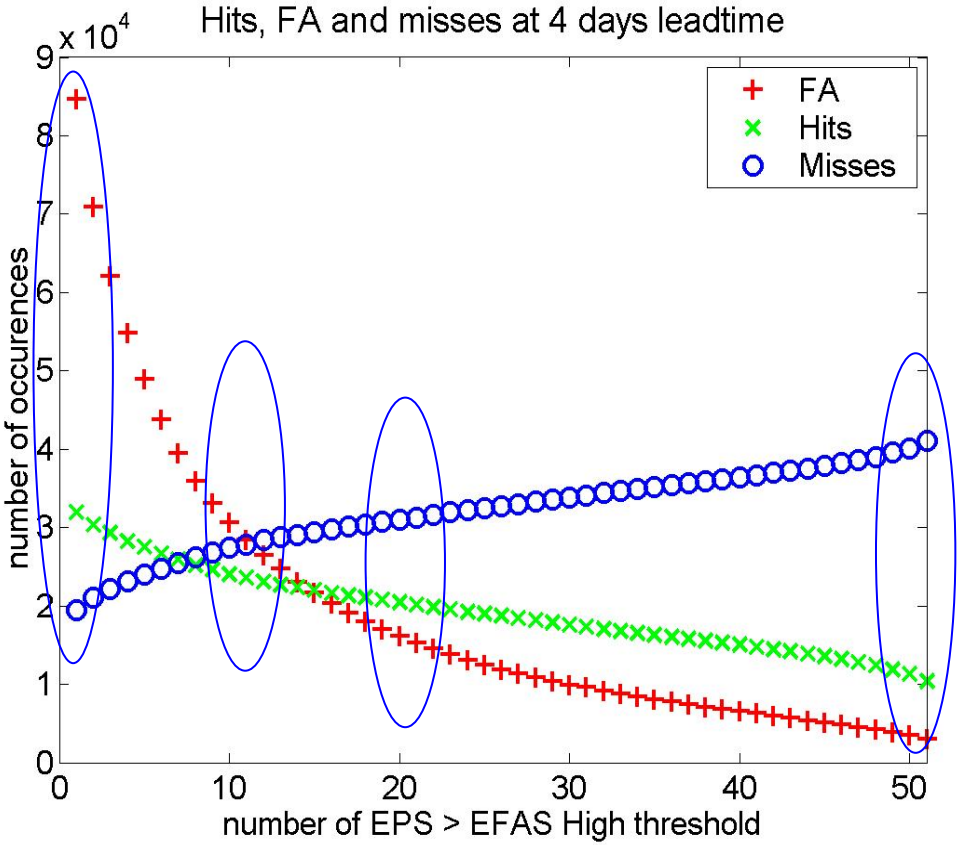
(J. Bartholmes, EFAS project)

EFAS-EPS Hits, Misses, and False Alarms (2005-2006)



Event = 1 EPS>threshold:
3x more FA then Hits

Event = 12 EPS > threshold:
Hits, Misses, and FA equal

Event = 20 EPS > threshold:
more hits than FA but also
high number of misses

Event = 50 EPS > threshold:
little FA, many misses

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(J. Bartholmes, EFAS project)

Improving skill through persistence

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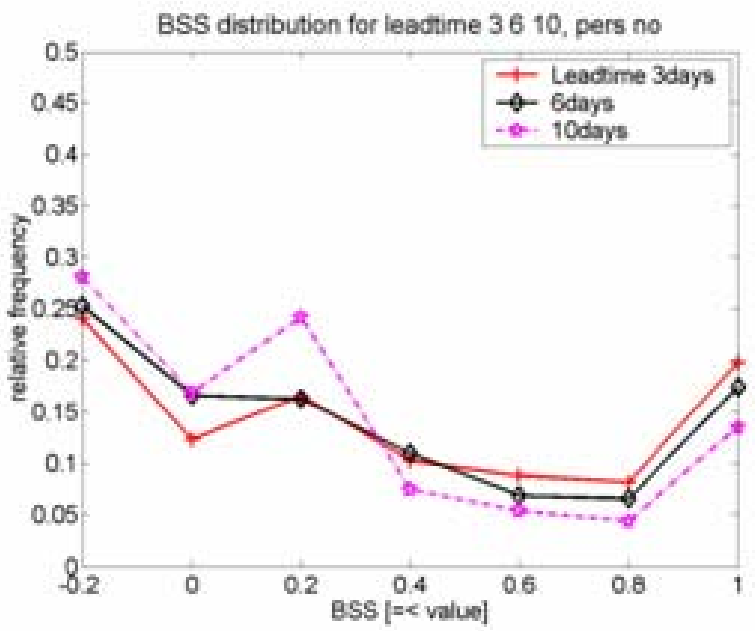
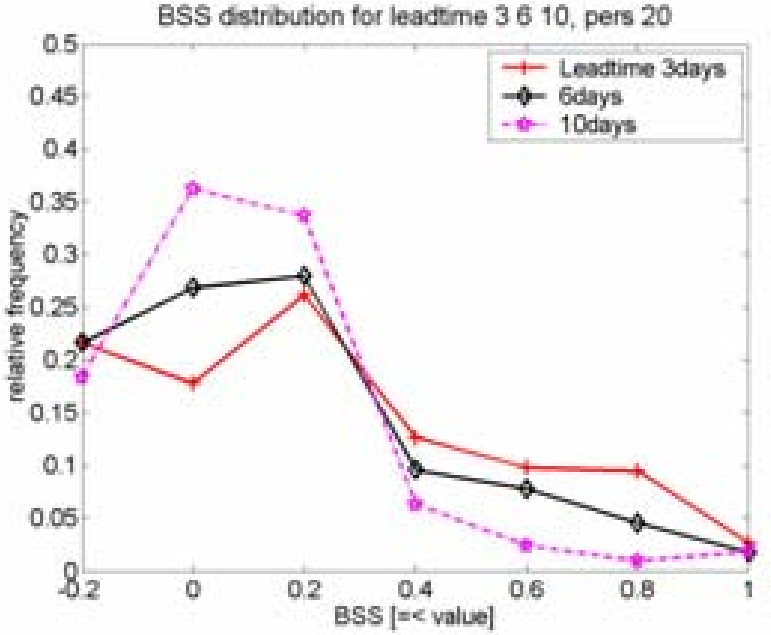


no skill skillful



no skill skillful

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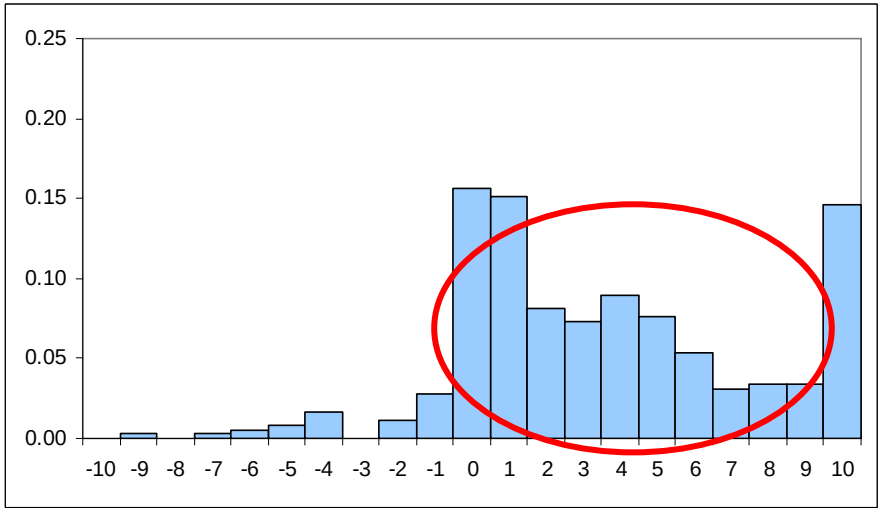
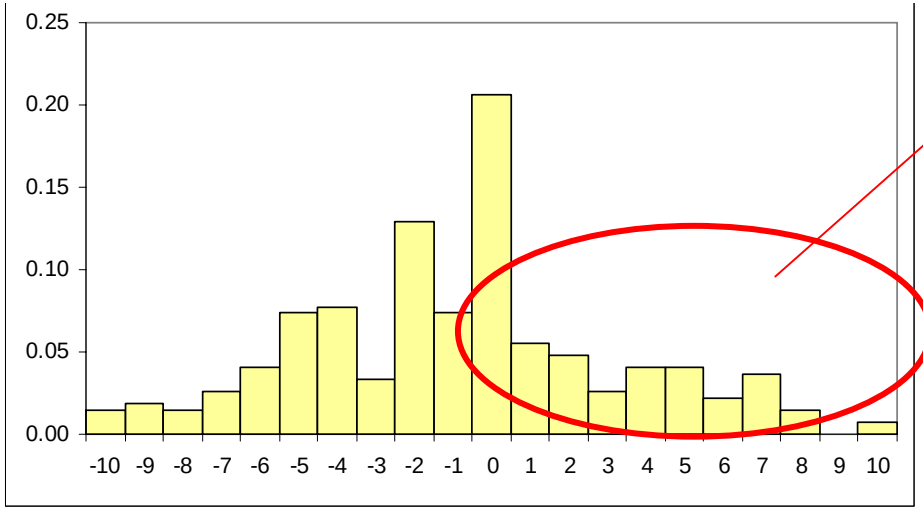
(M.-H. Ramos EFAS project)

Gain in preparedness through EPS

at least **5 EPS** above High thresholds



at least **20 EPS** above High thresholds



Danube River Basin

Summer 2005

Less gain
if waiting for too many EPS to exceed the critical threshold

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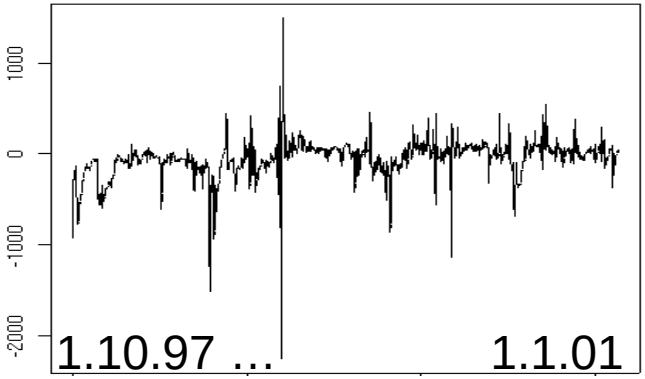
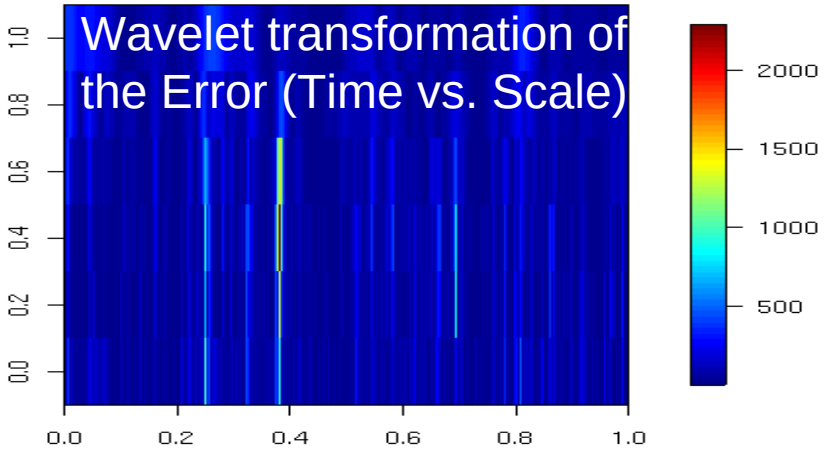
(K. *Bogner, PREVIEW project)*

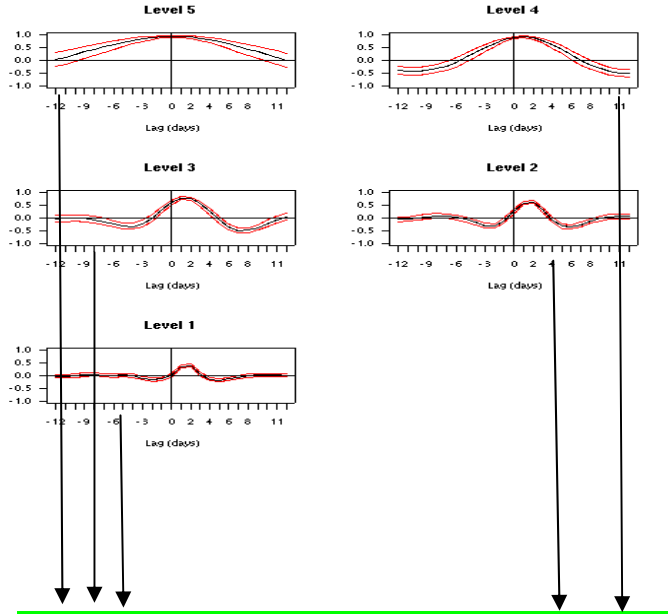
Post-processing through wavelet based error analysis and Kalman filtering

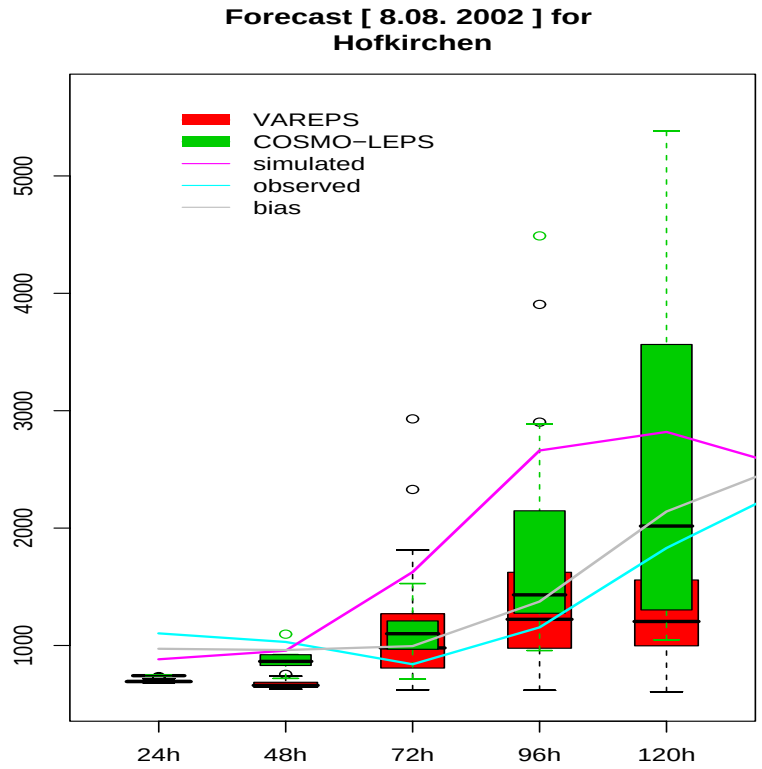
Error: Observed - Simulated

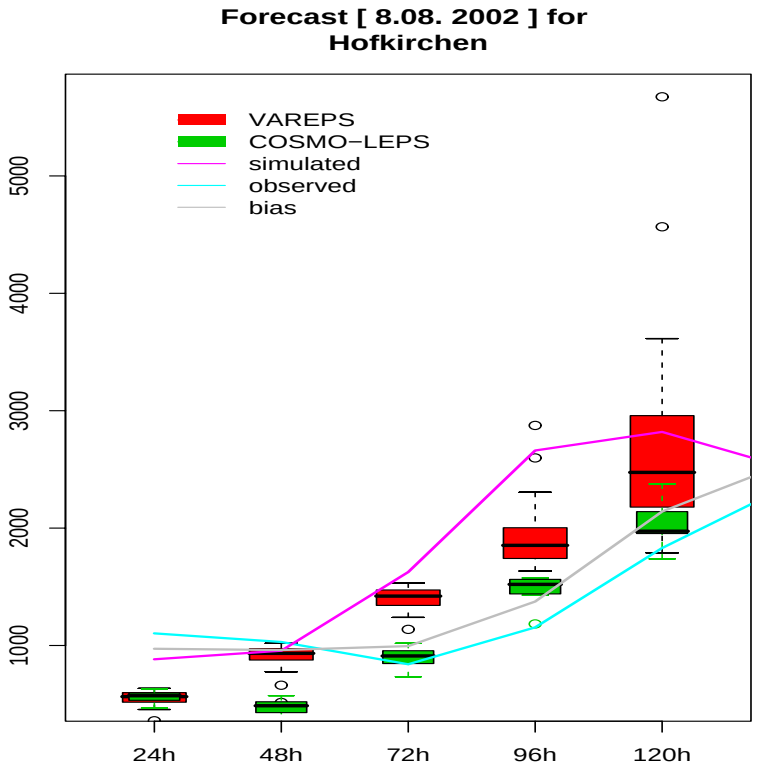




Wavelet correction







Example of 5 days forecast for the August 2002 flood event with and without bias corrected ensemble traces (Wavelet DLM)

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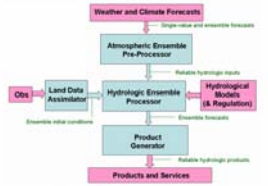

Hydrological Product Generator

Flood “Probability” f(EPS, deterministic, persistency)

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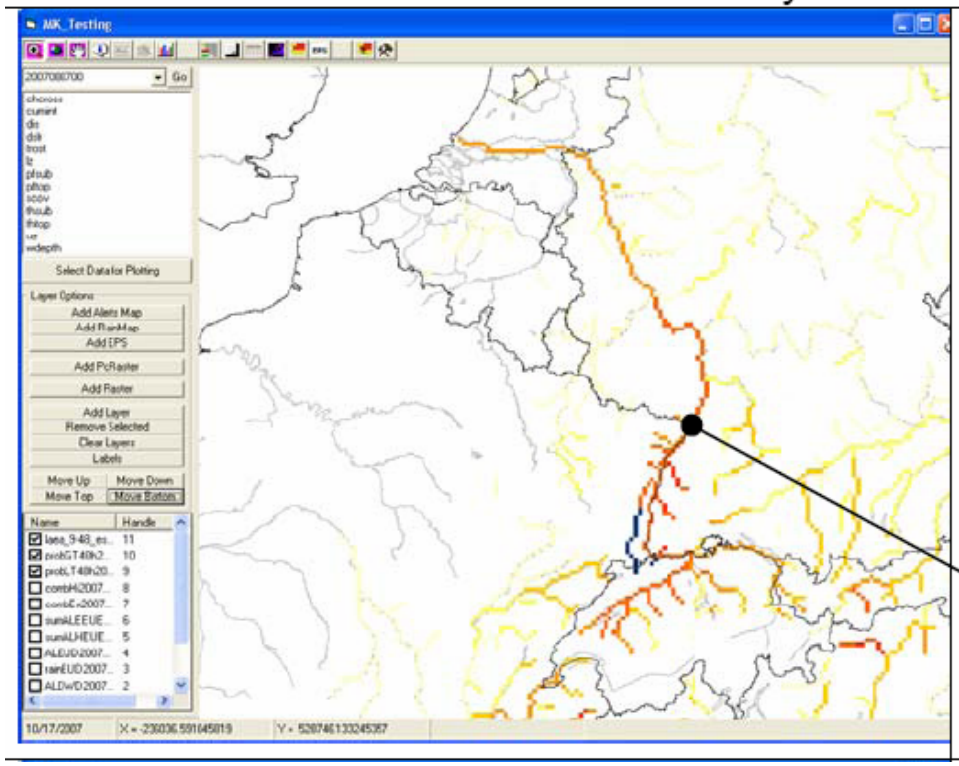
EFAS results 20070807 00:00 – 2-4 days before the floods



Probability to exceed EFAS high alert is high with 60-80% from Basel to Karlsruhe and 80-90% in Suisse tributaries.

Peak is forecasted for 9-11th depending on location.

Probability tendency increasing.

Probability value: 79.069

Date of this report: 2007080700 **DataSource:** PostEvent

Forecast Day	7	8	9	10	11	12	13	14	15	16
DWD										
ECMWF										
EPS > HAL		17	47	47	44	40	37	36	35	30
EPS > SAL			7	25	28	17	9	11	10	6

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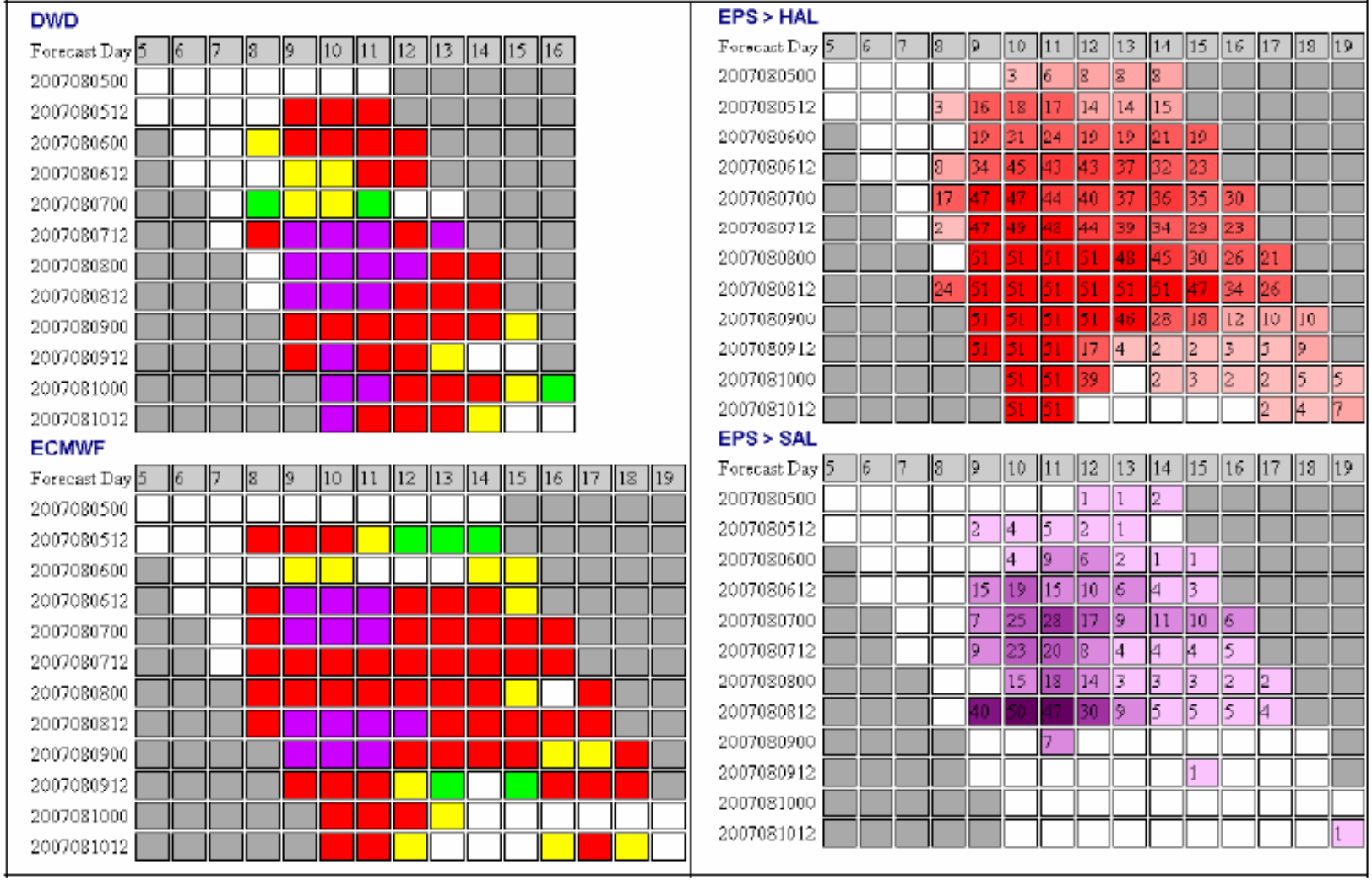
Persistence diagrams for *Point B*: Maxau (Karlsruhe) for deterministic forecasts (left) and EPS forecasts (right)



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Summary

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- EPS are increasingly tested and applied for operational flood forecasting for early warning (LEPS, EPS, seasonal)
- EPS based forecasts allow earlier detection of floods and provide early warning. Decision making for Civil Protection based on EPS remains difficult
- Uncertainty of EPS based flood forecasts can be reduced significantly through the use of threshold exceedance, persistency criterion and post-processing

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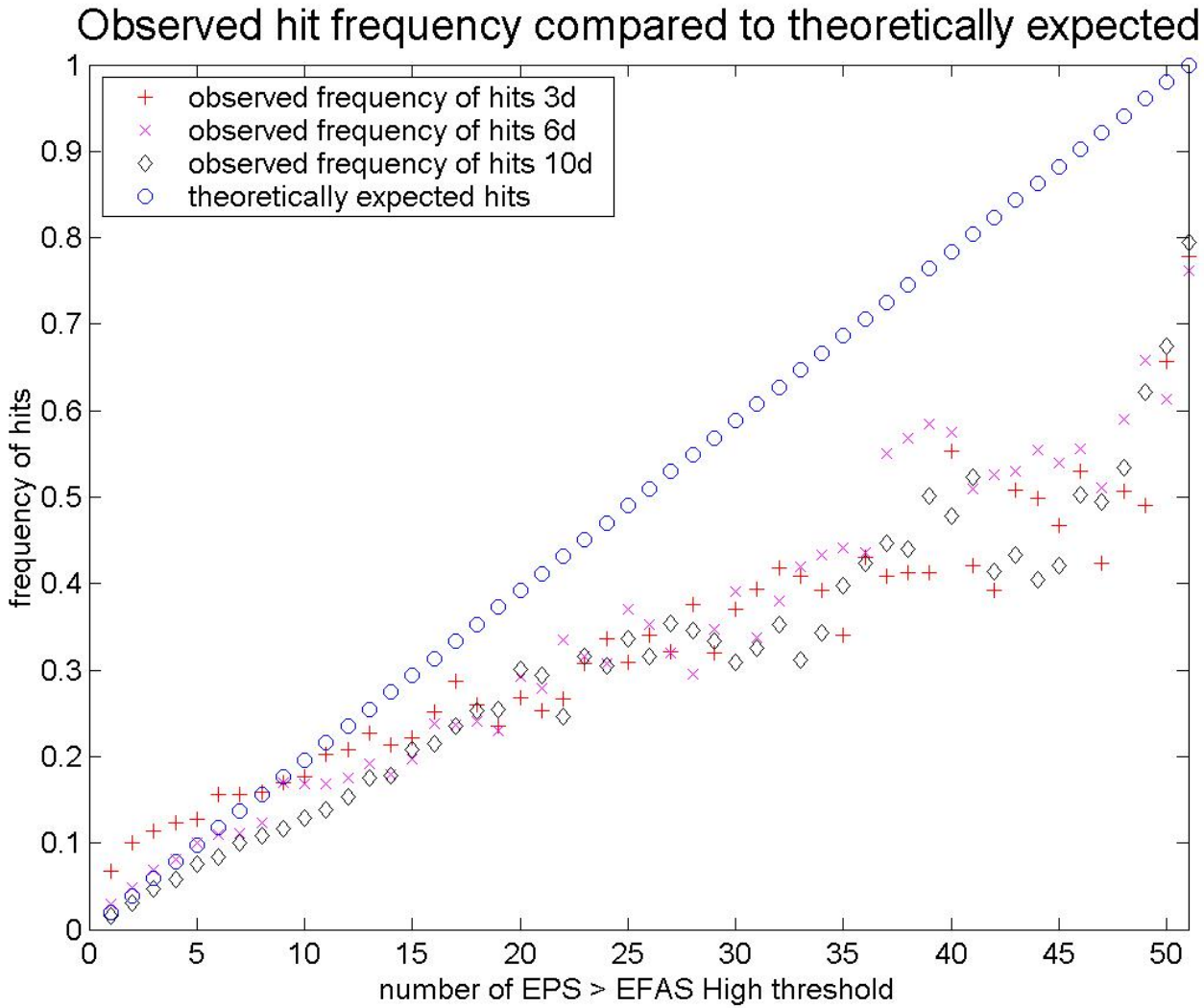
What needs to be addressed…

- Improve input on hydrological relevant scale: Skill in precipitation forecasts, initial spread, downscaling, combine scales, increase EPS sample, …
- Re-forecasts: Hydrologists need long-term re-forecasts for calibration (Det & EPS)
- Intelligent post-processing needed to reduce uncertainty even further. Data availability!
- derive reliable and useful products for experts, end-users (Civil Protection) and the public


Photo with courtesy of U. Hoehne
HEPEX goal:
“To bring the international hydrological and meteorological communities together to demonstrate how to produce reliable hydrological ensemble forecasts to make decisions for the benefit of public health and safety, the economy and the environment.”


Observed hit frequency compared to theoretically expected
observed frequency of hits 3d
observed frequency of hits 6d
observed frequency of hits 10d
theoretically expected hits
frequency of hits
number of EPS > EFAS High threshold
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5
10
15
20
25
30
35
40
45
50