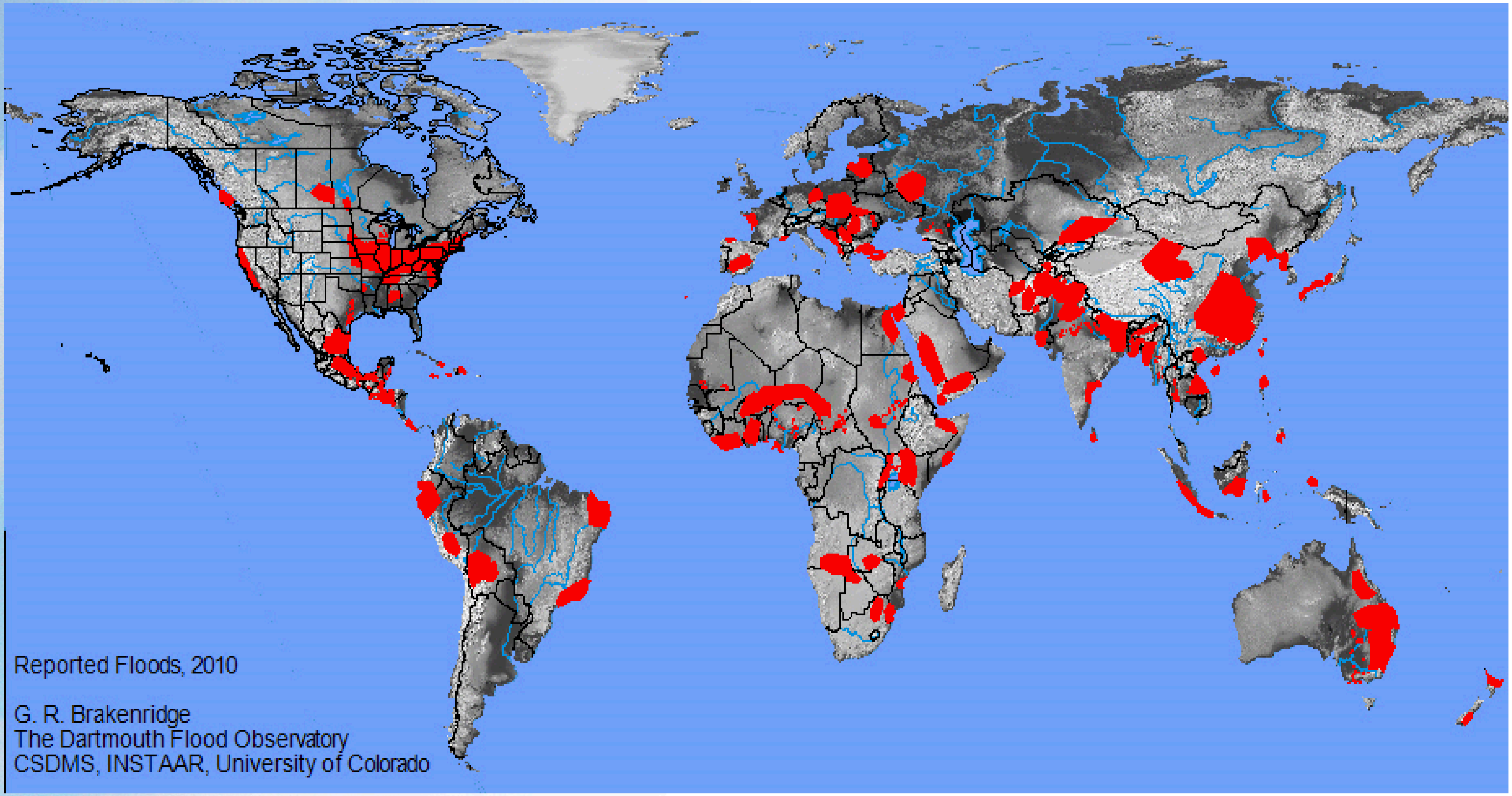
Flood Forecasting

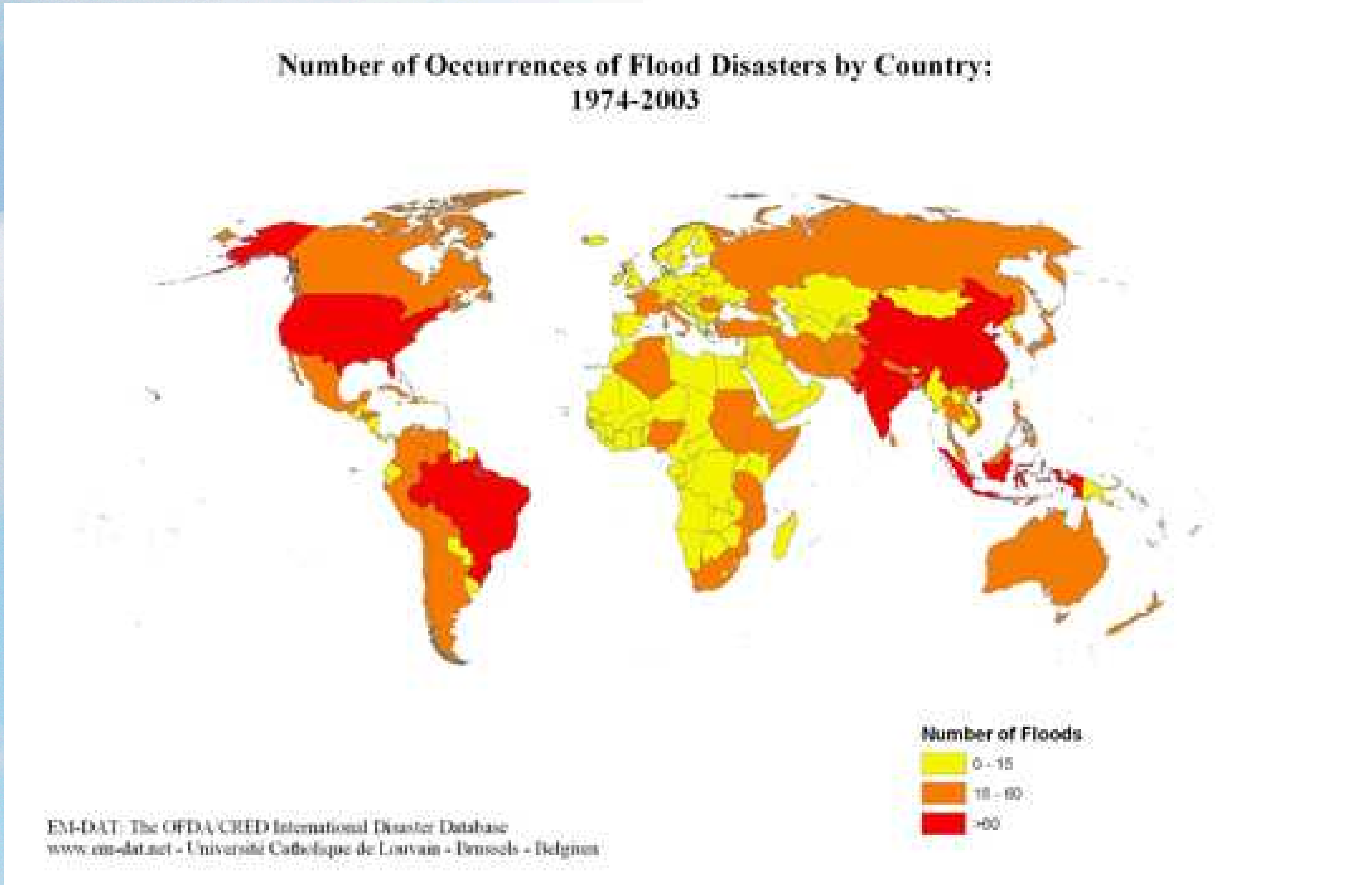
Fredrik Wetterhall
(fredrik.wetterhall@ecmwf.int)
European Centre for Medium-Range Weather Forecasts

Flooding – a global challenge

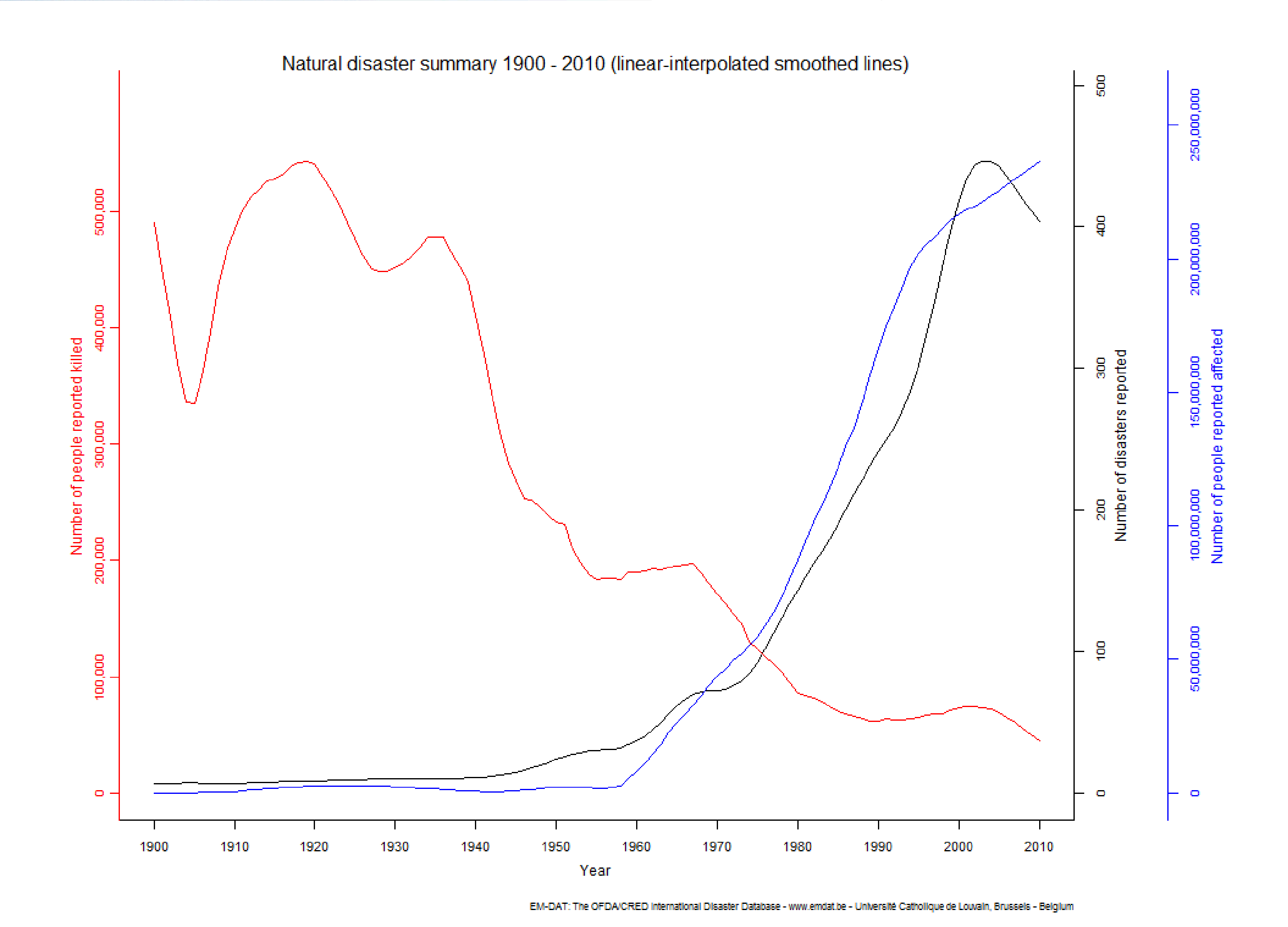
Number of floods



Flooding – a global challenge



Flooding – a global challenge



Flooding – an individual disasters

Causes of flooding

- snowmelt runoff
- rainfall
- ice jams and other obstructions
- coastal storms (tsunamis, cyclones, hurricanes)
- urban stormwater runoff;
- dam failure (or the failure of some other hydraulic structure).

Etc …

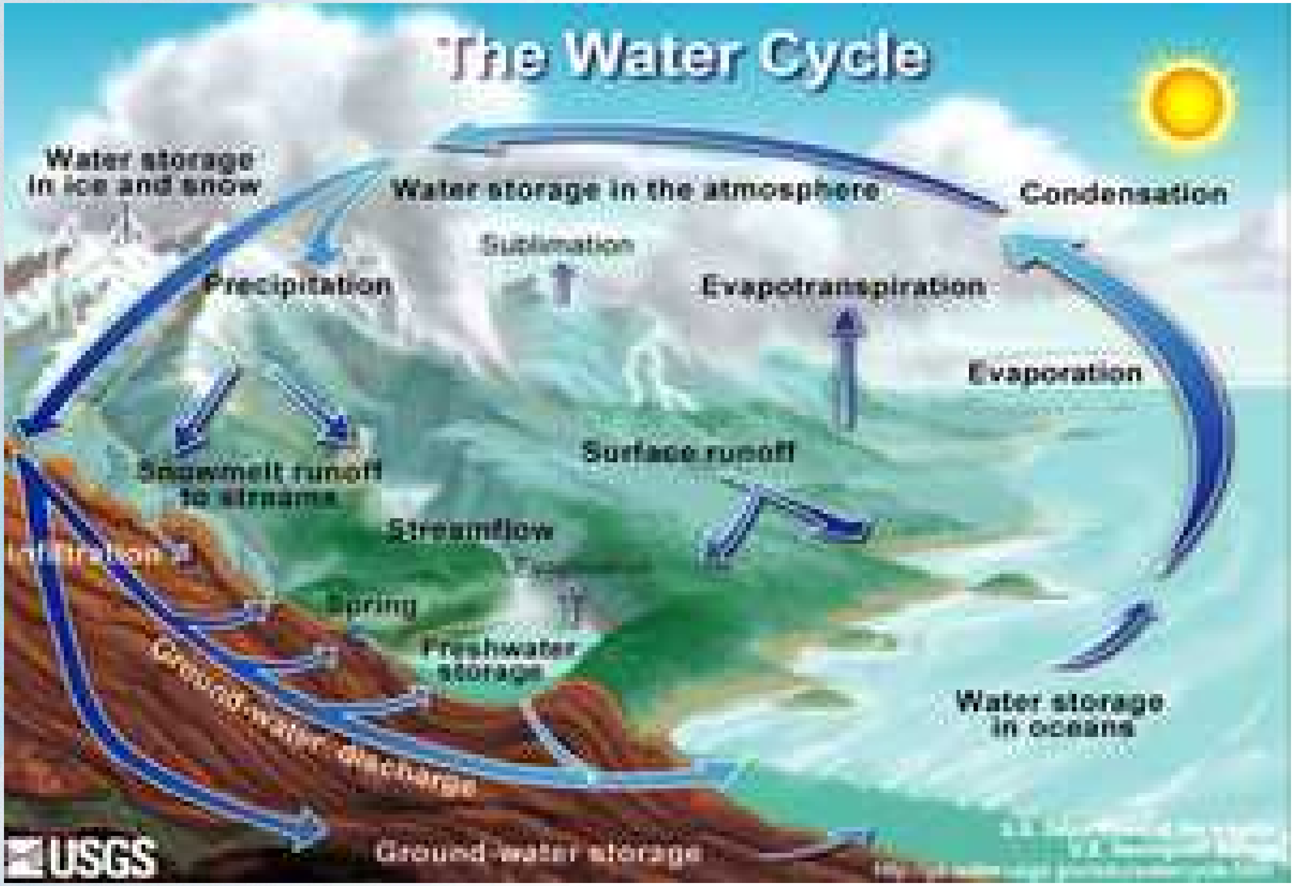
Fit for purpose

In flood forecasting there is no one-size-fits-all.

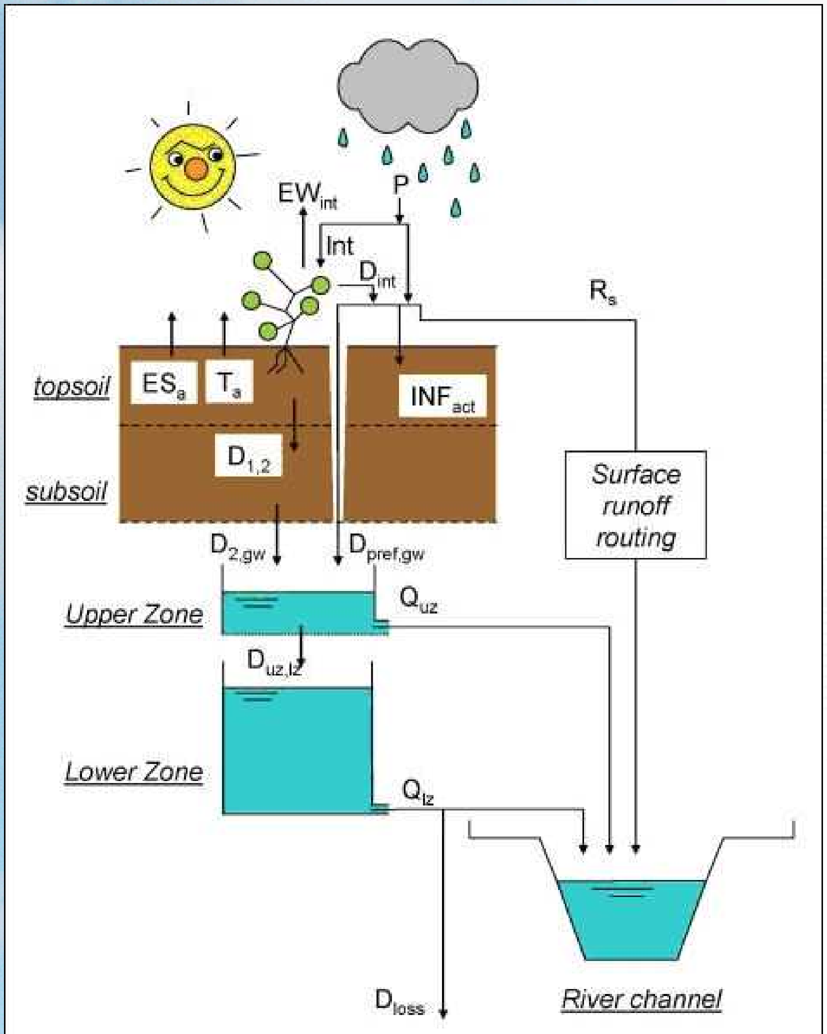
Integration of different systems and methods is a major challenge.

Any system does not have to be perfect but suitable.

Hydrology – modelling the water cycle on land



LISFLOOD

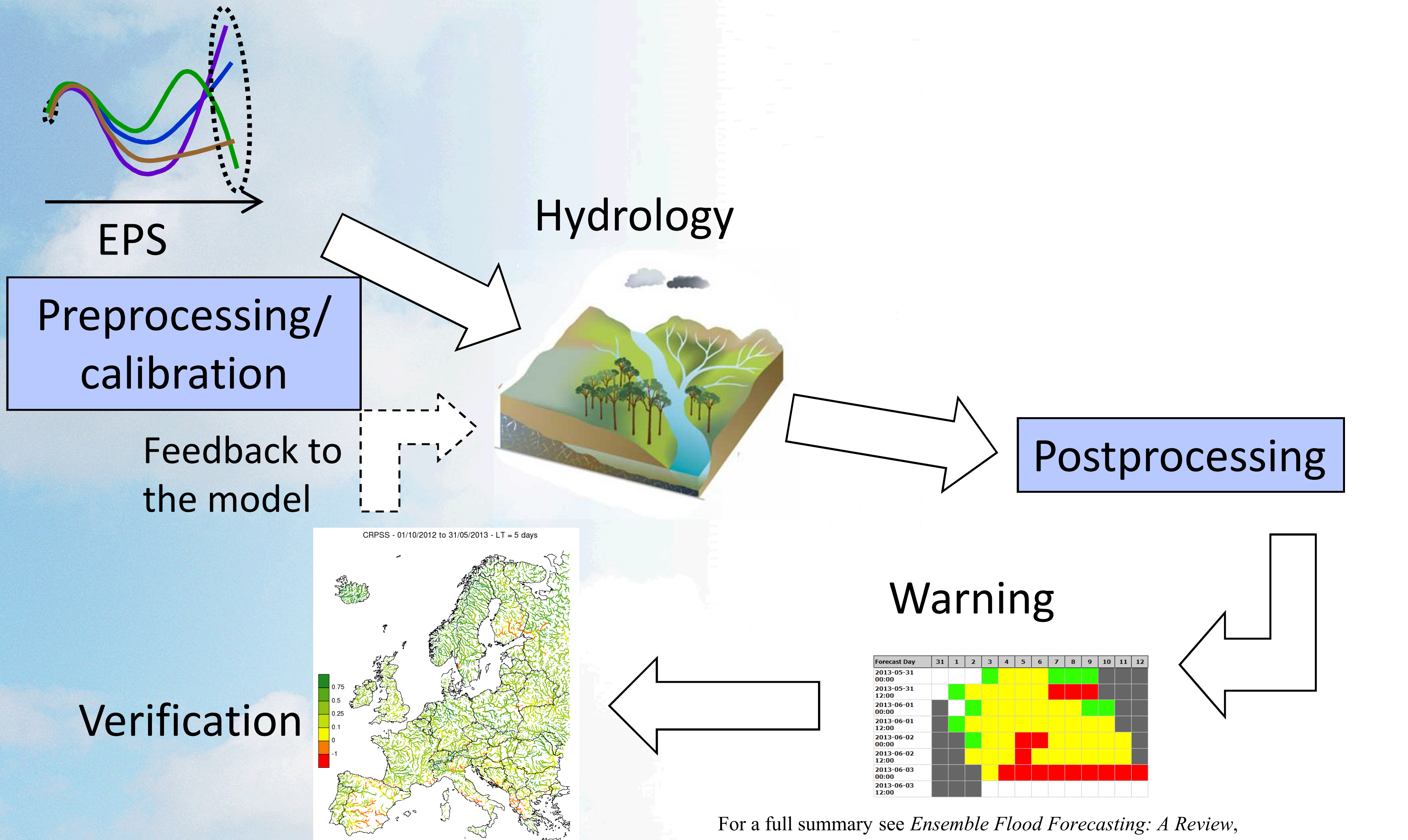


Input: Precipitation
Temperature
Evapotranspiration

Intermediate: Snow pack
Soil water
Ground water

Output: Runoff
Discharge

Forecasting chain using Ensemble Prediction Systems of Numerical Weather Predictions



For a full summary see *Ensemble Flood Forecasting: A Review*, Cloke H.L., and Pappenberger, F., 2009, Journal of Flood Risk Management

ECMWF

EPS - Why ensembles???

Why EPS in flood forecasting???

- **Allows to take account of uncertainty in this boundary condition and eventually for a 'better' forecast (see other presentations)**
- ***"the use of meteorological ensembles to produce sets of hydrological predictions increased the capability to issue flood warnings"* (Balint et al., 2006, p.67)**
- ***"The hydrological ensemble predictions have greater skills than deterministic ones"*. (Roulin, 2007)**
- ***"The use of EPS in hydrological forecasting proved to be of great added value to a flood early warning system, as the EPS-based forecasts showed in general higher skill than the deterministic-based ones"*. (Bartholmes et al., 2008)**
- **Cloke and Pappenberger (2009, *Journal of Hdrology*) list a large number of case studies and long term evaluations showing the added value of EPS**

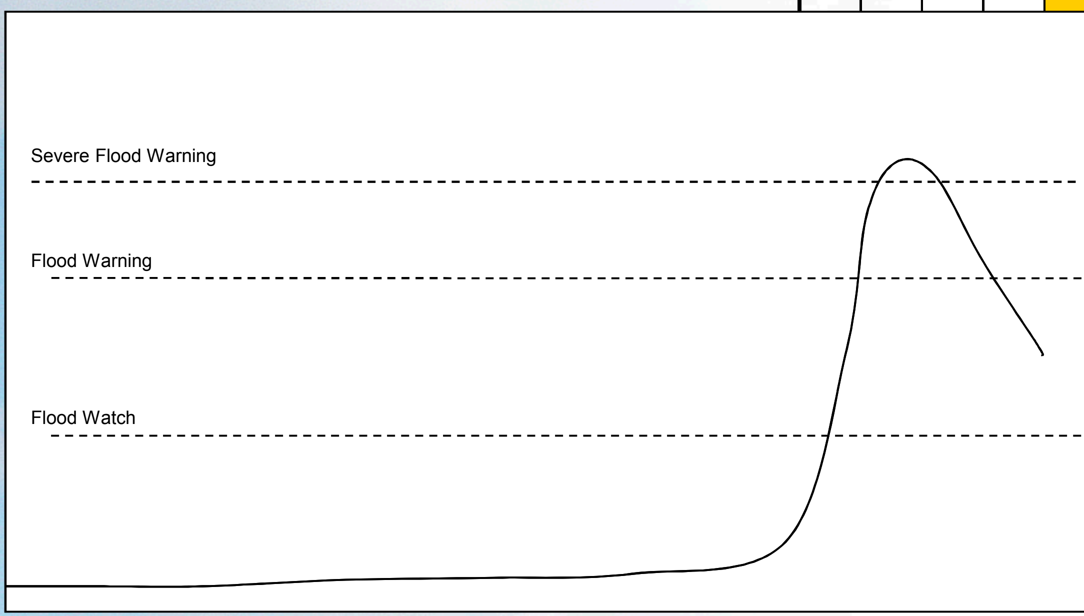
EPS in hydrology – who uses it?

- Most case studies indicate that there is added value in using EPS in comparison to deterministic forecasts
- A few are convinced of the potential, but are cautious about the added value – mostly quoting the inaccuracy of precipitation predictions as reasons
- Most case studies have severe weaknesses in the analysis:
  - No report of false alarm
  - Qualitative statements only (sometimes only loosely linked to the displayed figures)
  - Comparison only done against proxy observations
  - decision support or communication of these forecasts to end-users is not adequately considered

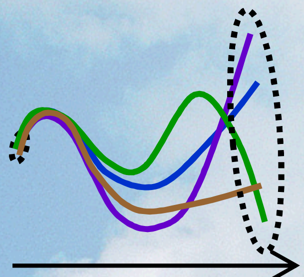
EPS how is it used?

Lead time (Large Catchment) in days											
10	9	8	7	6	5	4	3	2	1	0.5	0
Lead time (Small Catchment) in hours											
60	54	48	42	36	30	24	18	12	6	2	0
Routine & enhanced forecasting											
			Initiate enhanced monitoring								
					Flood Advisory Teleconferences						
					Staff Preparedness						
						Flood awareness raising with public					
						Structural checks and watercourse clearances					
							Deploy temporary and demountable defences				
								Operate active control structures			
				Deployment of staff to respond operationally to floods and/or monitor flooding in communities							
									Issue Flood Warnings to professional partners		
									Issue Flood Warnings to public		
									Issue Severe Flood Warnings to public and partners		

Light yellow	Monitoring & forecasting
Dark yellow	Event preparation
Light blue	On-site activities
Orange	Warning dissemination



Forecasting chain in flood forecasting



EPS

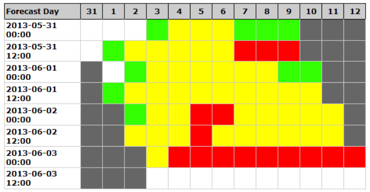
Preprocessing/ calibration

Feedback to the model

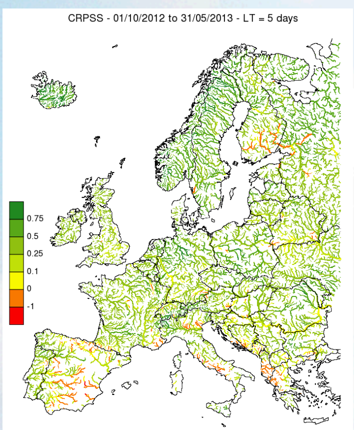
Hydrology

Postprocessing

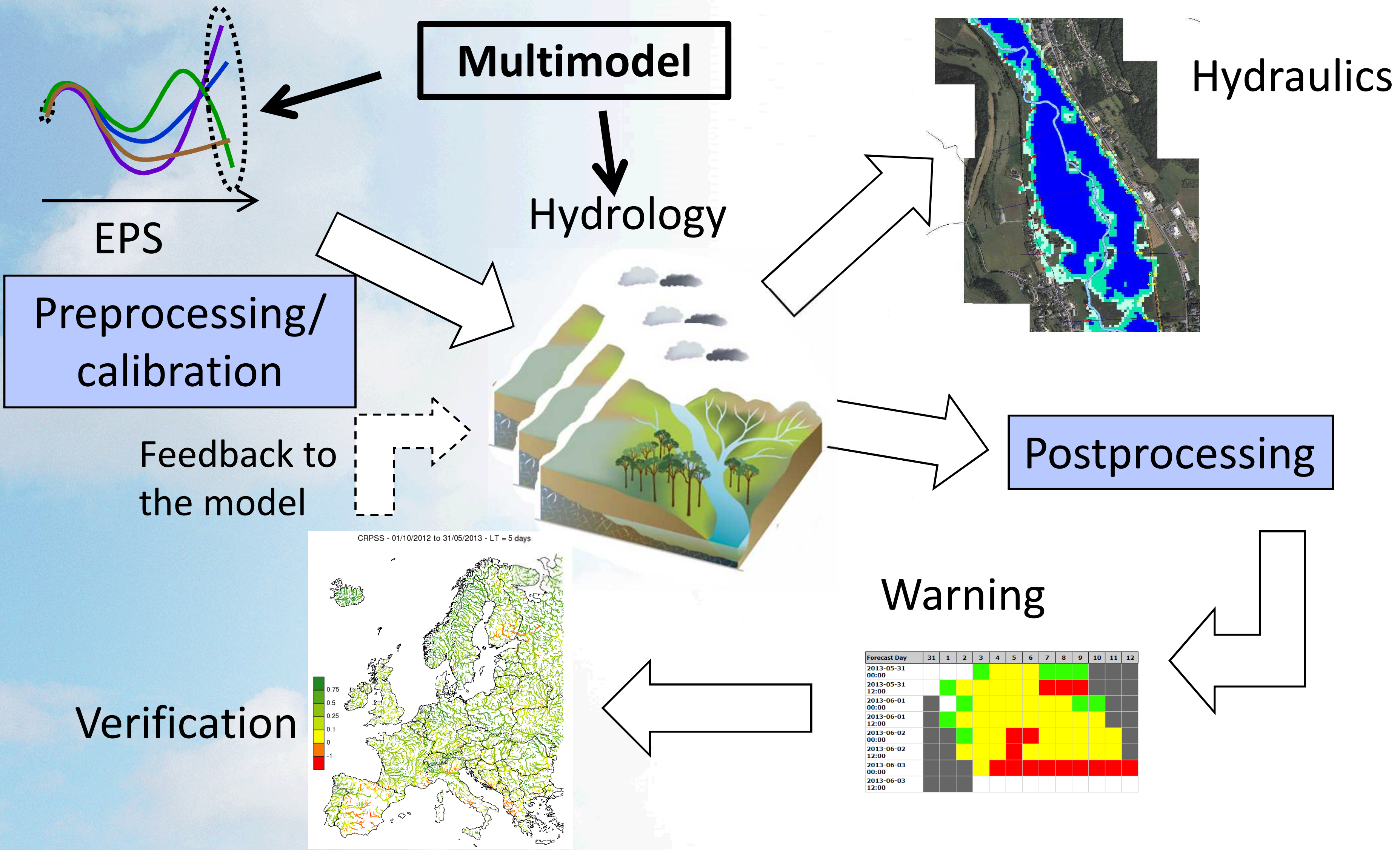
Warning



Verification



Forecasting chain in FUTURE flood forecasting

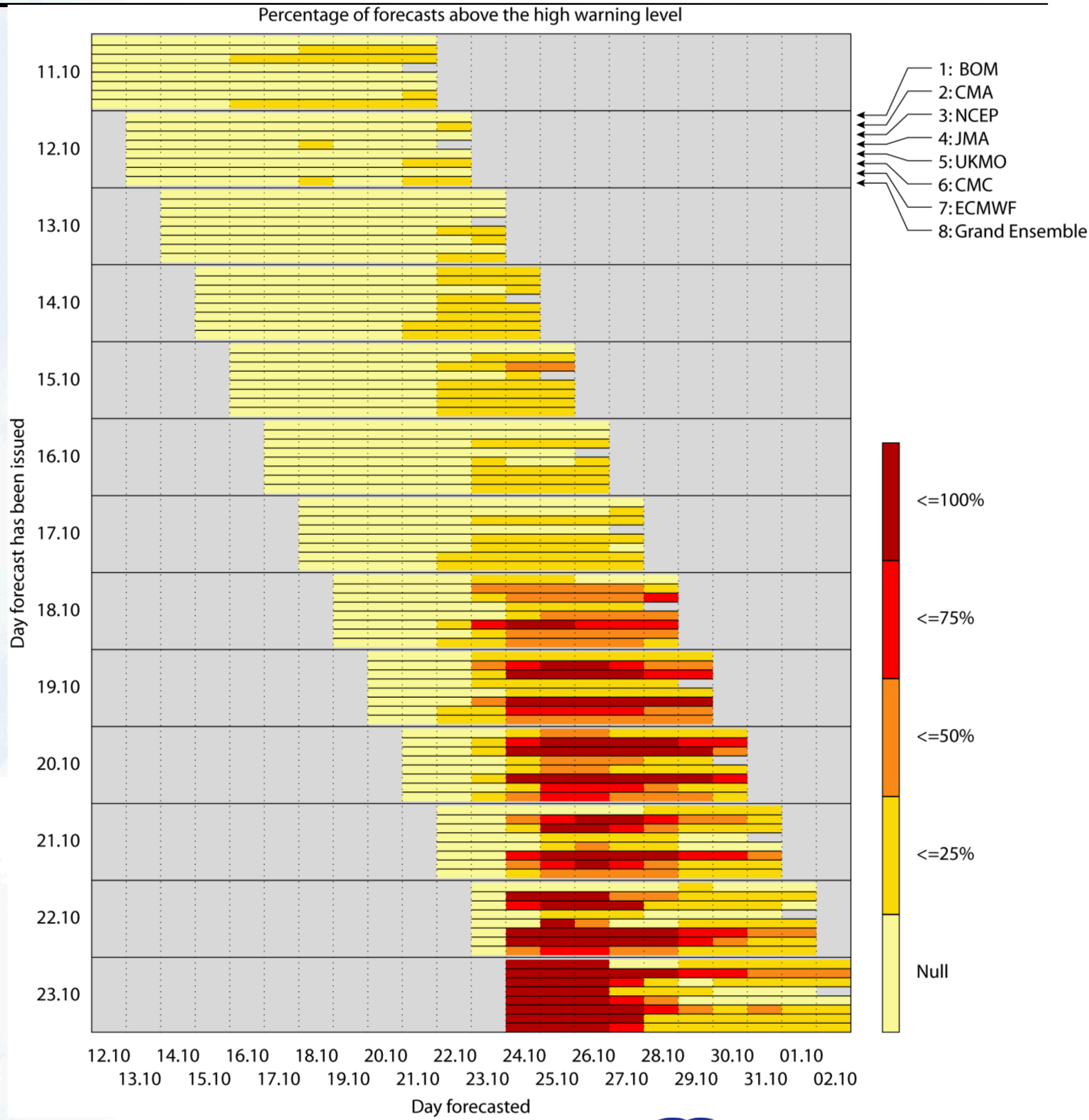


Warning & Decisions

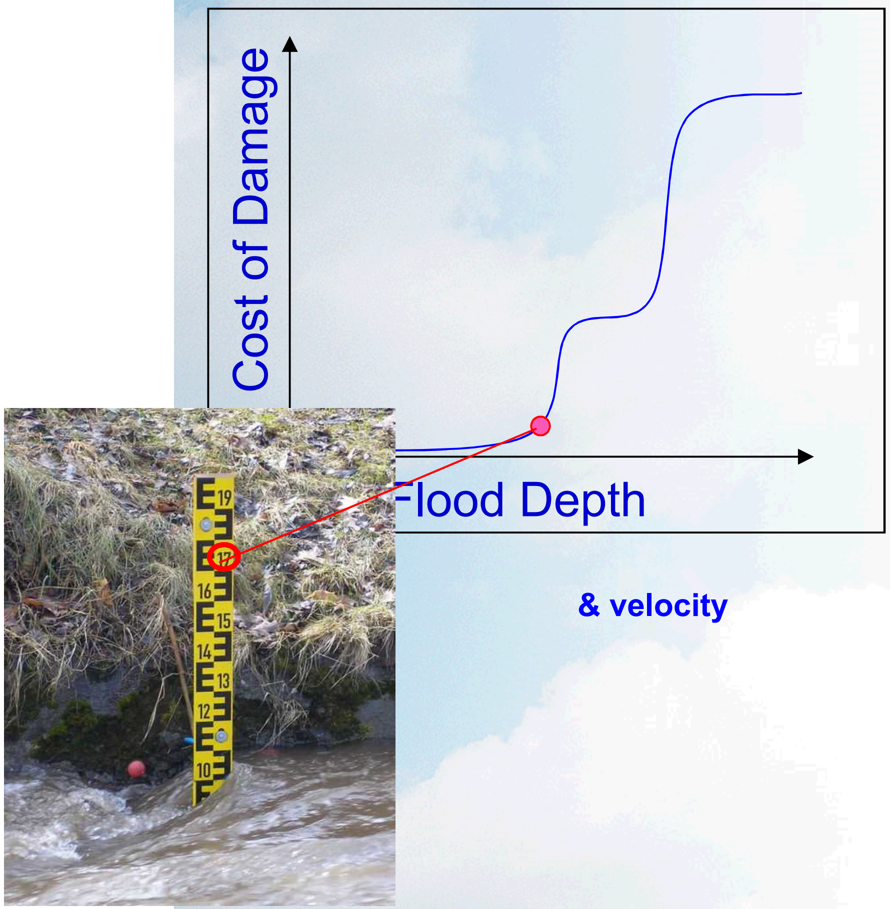
Bartholmes et al. (2008) investigated several options for a warning system based on EPS:

- Number of Ensembles above threshold
- Persistency
- Combining different forecasts to derive warning decisions

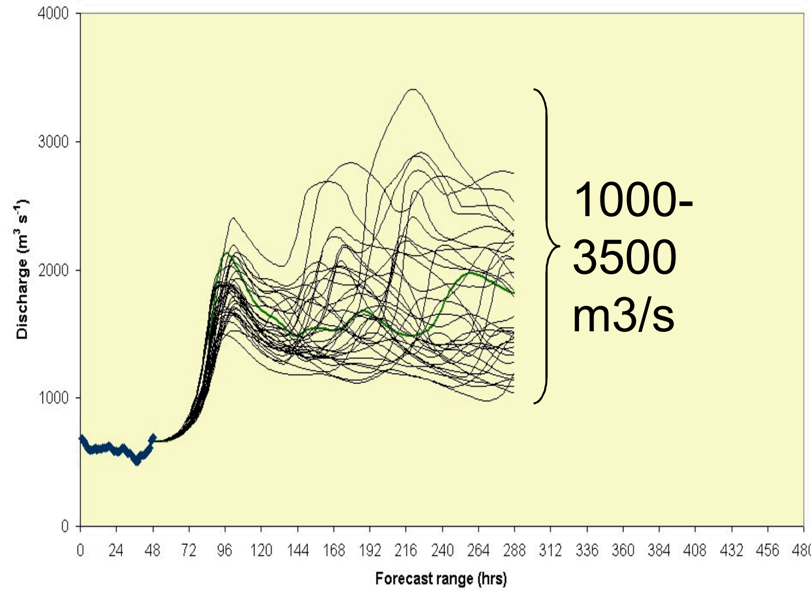
The results indicate that it is possible to derive binary decisions. The quality of such a system can be enhanced by using multiple EPS (see TIGGE case study later)



In practice: Decision making with uncertainty?



& velocity



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

Cost/loss based decisions…

… difficult to apply in 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.

European Flood Alert System

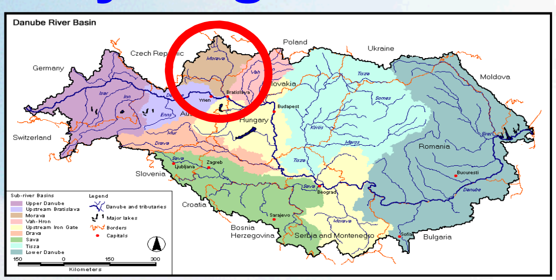
- EFAS was launched 2003 at the Joint Research Centre (IT)
- Financial support from different DG's in the European Commission and the European Parliament.
- 5 Member States detached experts to the JRC for 4 years (AT, CZ, DE, HU, SK)
- EFAS team consists of 10-12 hydrologists, meteorologists, GIS experts, Web-development, and Programmers
- In October 2012 EFAS went fully operational, with three centres in Europe (dissemination, operation and hydrological data collection), where ECMWF has responsibility for the operational computations

EFAS main objectives

Added value

Novel information

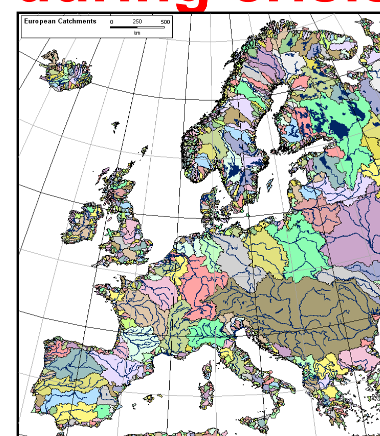
- -Catchment based information
- -Lead times up to 10-15 days
- -Probabilistic information
- -Operationally targeted research



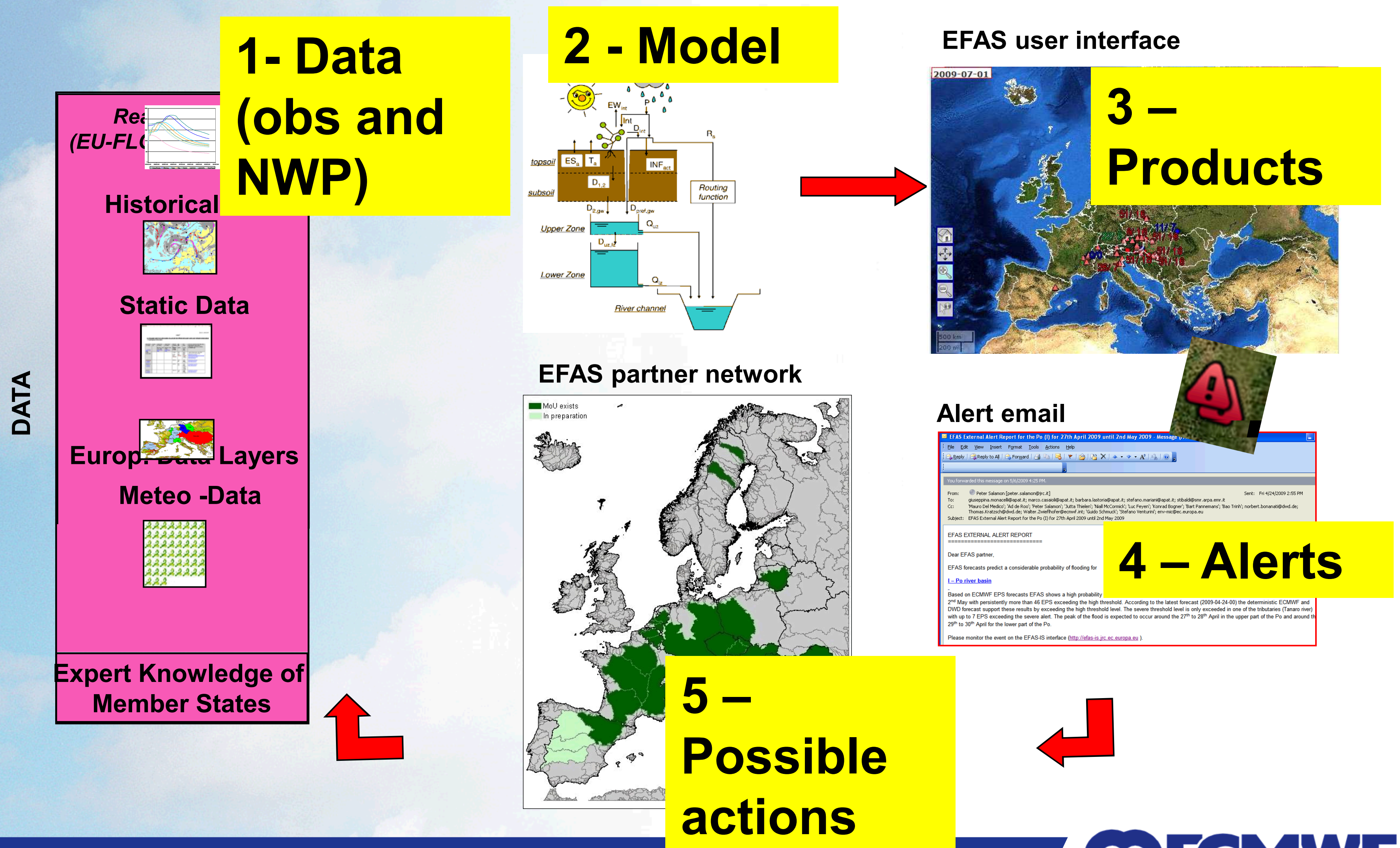
National water authorities

- -Comparable information across Europe
- -Tool for international aid assistance during crisis

International Civil Protection

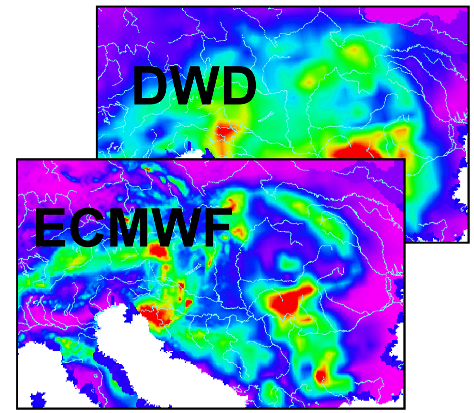


EFAS http://www.efas.eu/

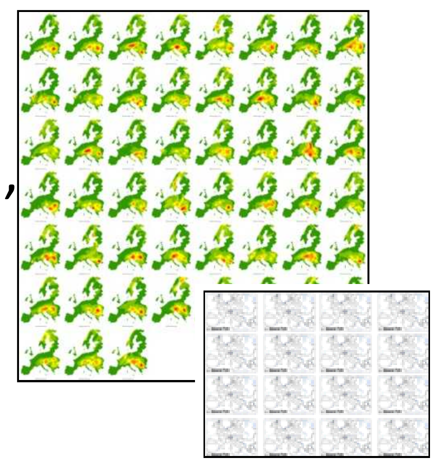


EFAS - Data – Weather forecasts

- Deterministic
  - DWD - global model, 20 km, 7 days)
  - DWD - EU, 7 km, 3 days)
  - ECMWF - global, 16 km, 15 days)



- Ensembles
  - ECMWF ENS (global, staggered time and spatial resolution, [32 km, 1-10 days], [60km, 11-15 days], 51 members)
  - COSMO-LEPS (EU, 7 km, 5 days, 16 members)

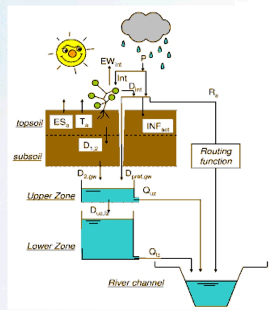


EFAS Technical Scheme

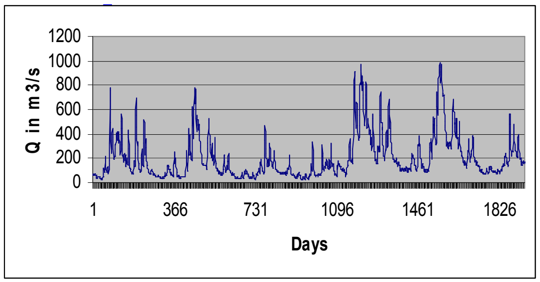
Meteorological observations

N years

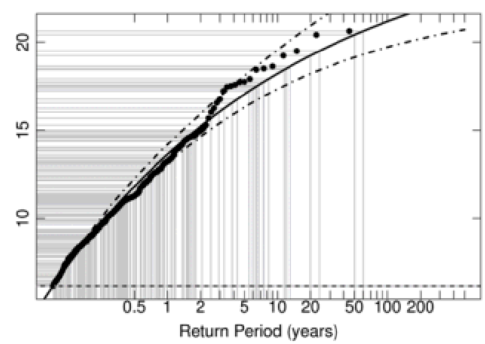
LISFLOOD



Discharge time



Return period statistics



Thresholds

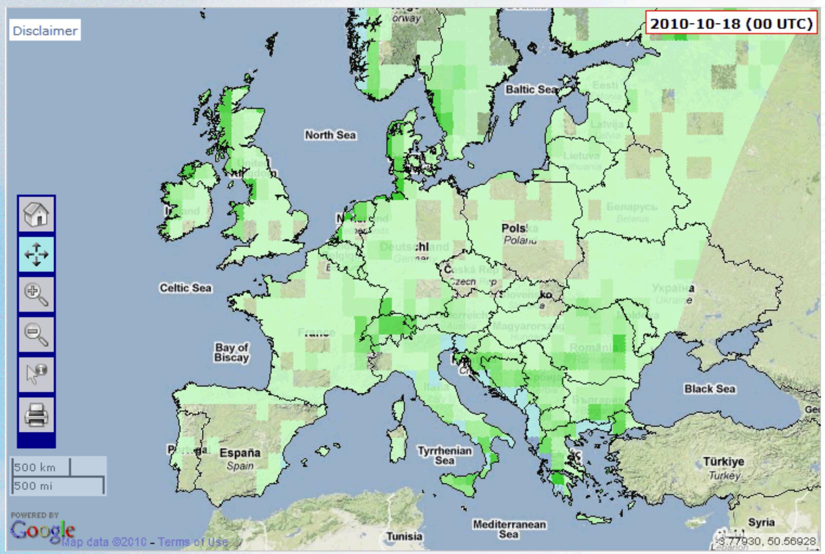
- Q20
- Q5
- Q2
- Q1.3

•Thresholds are derived from simulated time series.

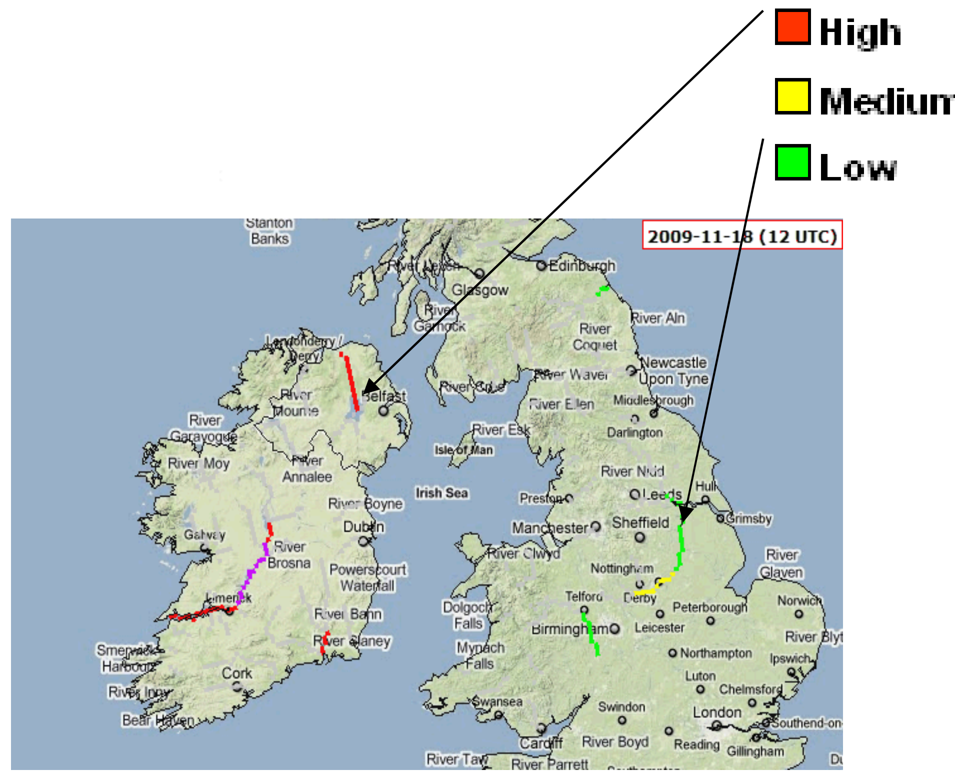
• The same model set-up and parameterisations are used in the forecasts to remain model consistent

EFAS - Visualising threshold exceedance

Probability of exceeding precipitation thresholds



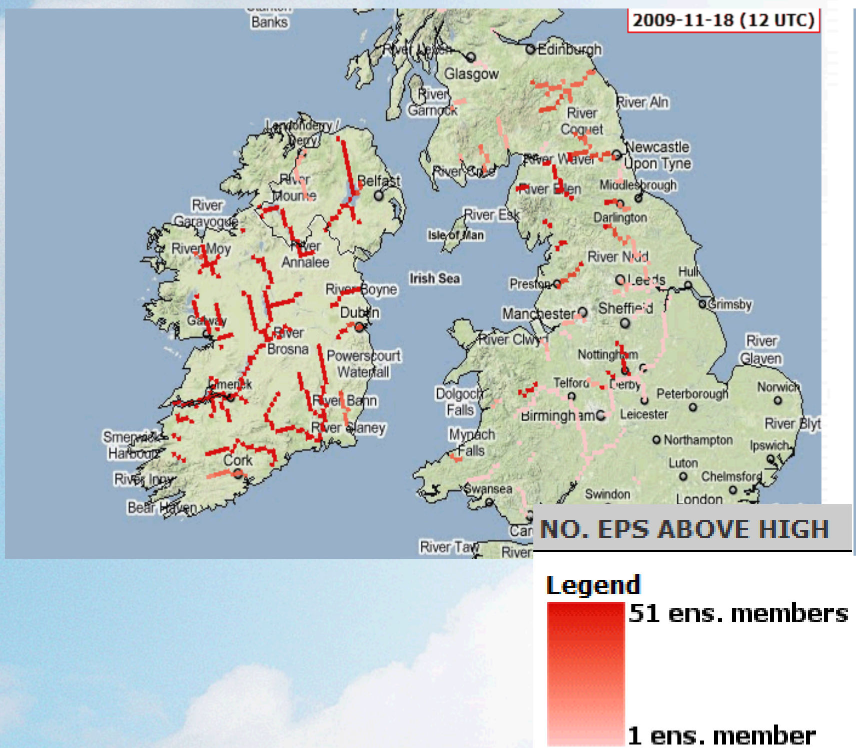
Highest EFAS threshold exceeded with ECMWF NWP



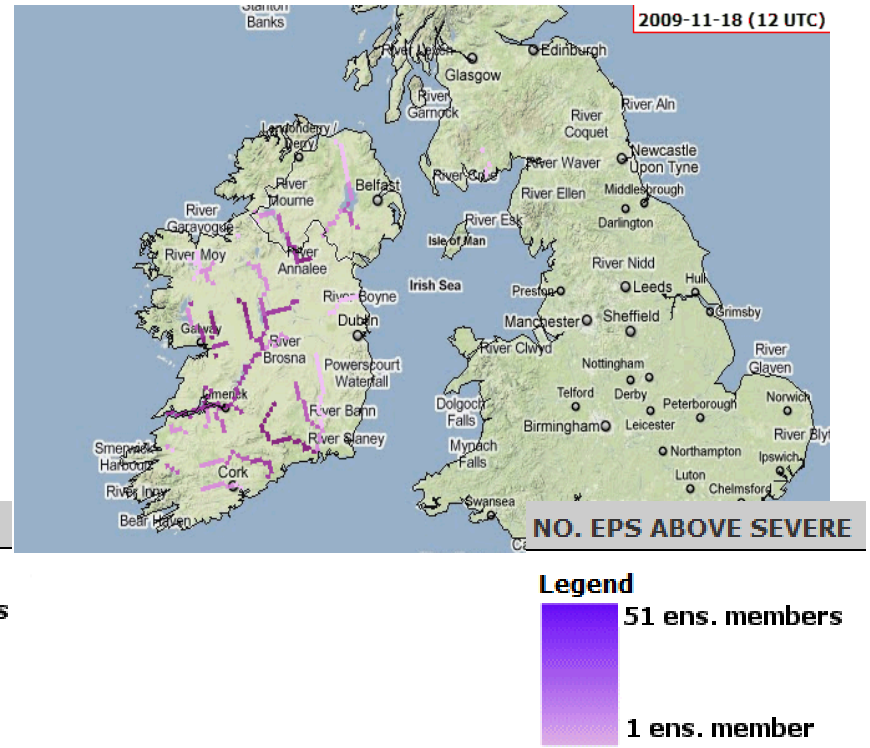
ECMWF

EFAS - Exceedance of EPS

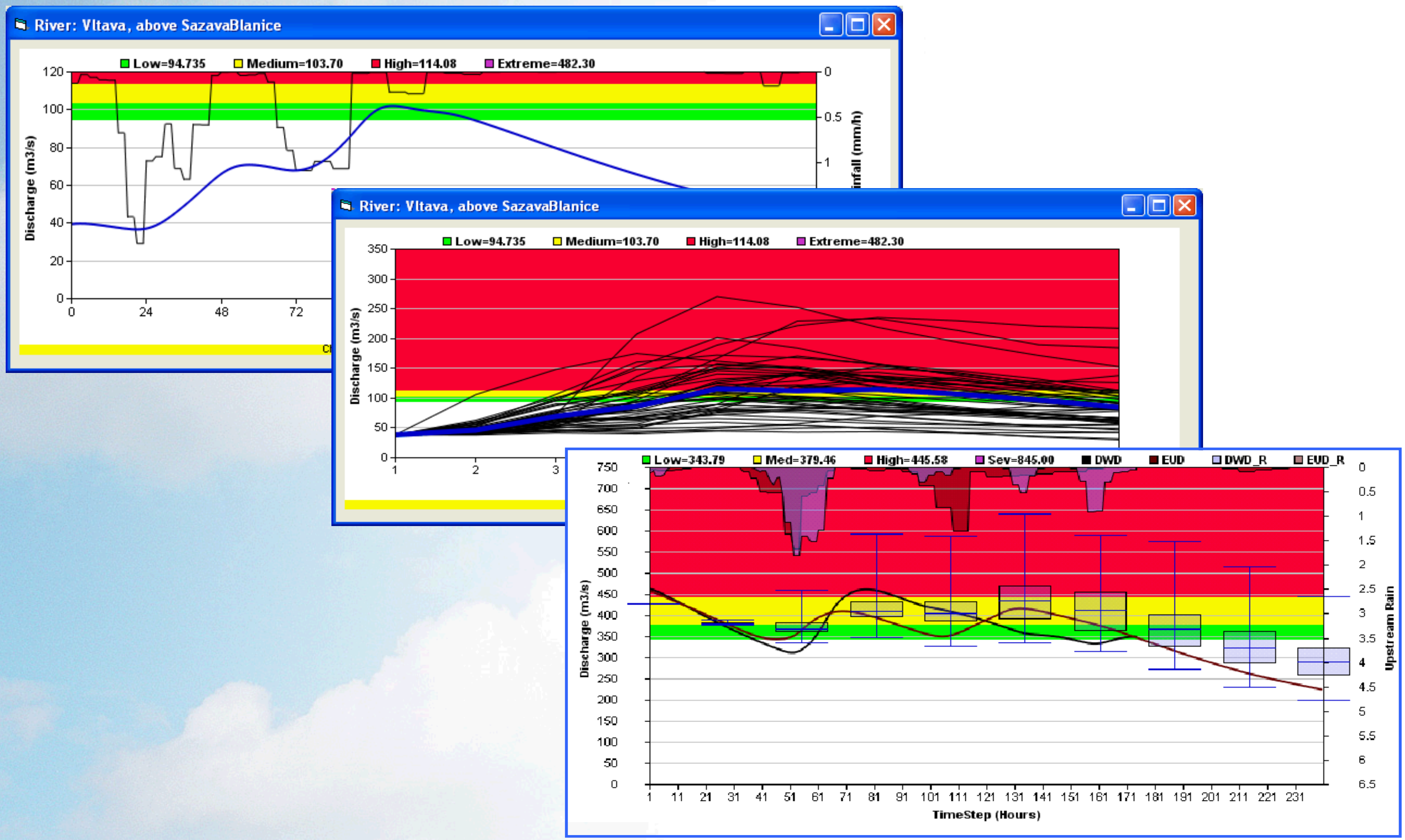
Nr of EPS above *High* threshold



Nr of EPS above *Severe* threshold

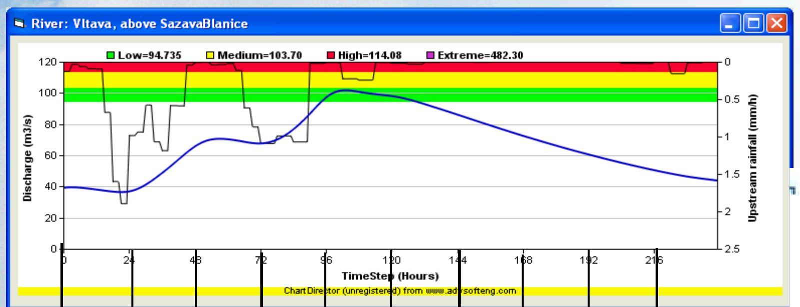


EFAS - Time series



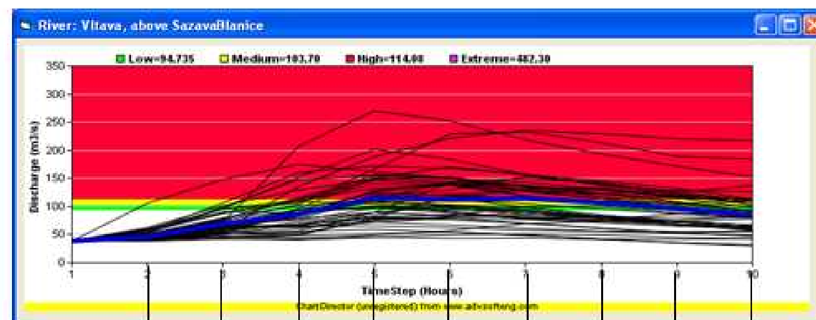
EFAS - Time series simplified

Single deterministic forecasts



7	8	9	10	11	12	13	14	15	16

EPS forecasts



Forecast Day	8	9	10	11	12	13	14	15	16
EPS > HAL		1	8	22	24	27	17	14	5
EPS > SAL									

EFAS - Condensing information

River: **Basin:** Shannon

Forecast Day	15	16	17	18	19	20	21	22	23	24
DWD										
ECMWF										
EUE > HAL				13	23	23	16	17	15	14
EUE > SAL					2	1	2	2	1	
COS > HAL				5	6					
COS > SAL				1	2					

Nr of EPS exceeding thresholds

EFAS - Looking back in time

Event forecast

Previous forecasts

Today's forecast

ECMWF

Forecast Day	12	13	14	15	16	17	18	19	20	21	22	23	24
2009111200													
2009111212													
2009111300													
2009111312													
2009111400													
2009111412													
2009111500													
2009111512													

EUE > HAL

Forecast Day	12	13	14	15	16	17	18	19	20	21	22	23	24
2009111200													
2009111212										1			
2009111300													
2009111312								2	1	1	1		
2009111400							1	5	7	7	7	7	
2009111412							1	3	5	6	4	4	
2009111500								7	11	12	10	6	4
2009111512							13	23	23	16	17	15	14

Evaluation of persistence in time and consistence between forecasts are important

Summary

- 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

Thanks for listening!

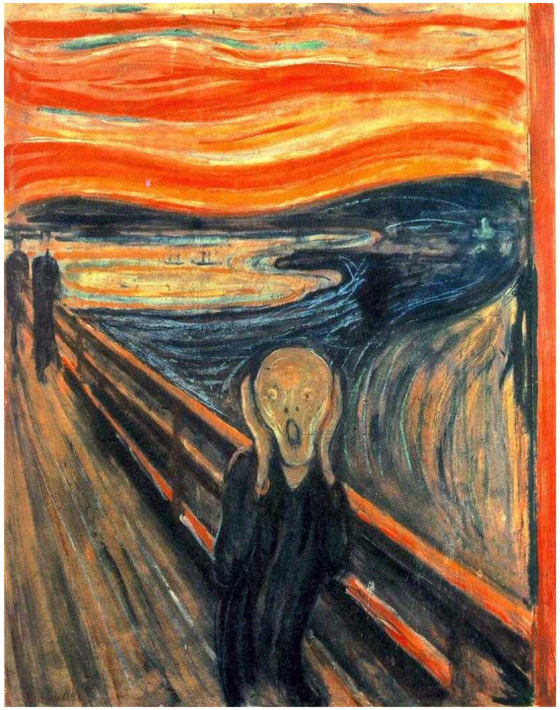
- References can be provided on request, email me

fredrik.wetterhall@ecmwf.int

or Florian

florian.pappenberger@ecmwf.int

“ In case of flooding “



ECMWF