River Routing models to support NWP verification

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Acknowledgements: G Balsamo, Jutta Thielen, Ad de Roo, HL Cloke, K Bogne …r

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- Support NWP: Diagnostics
- Support NWP: Evaluation
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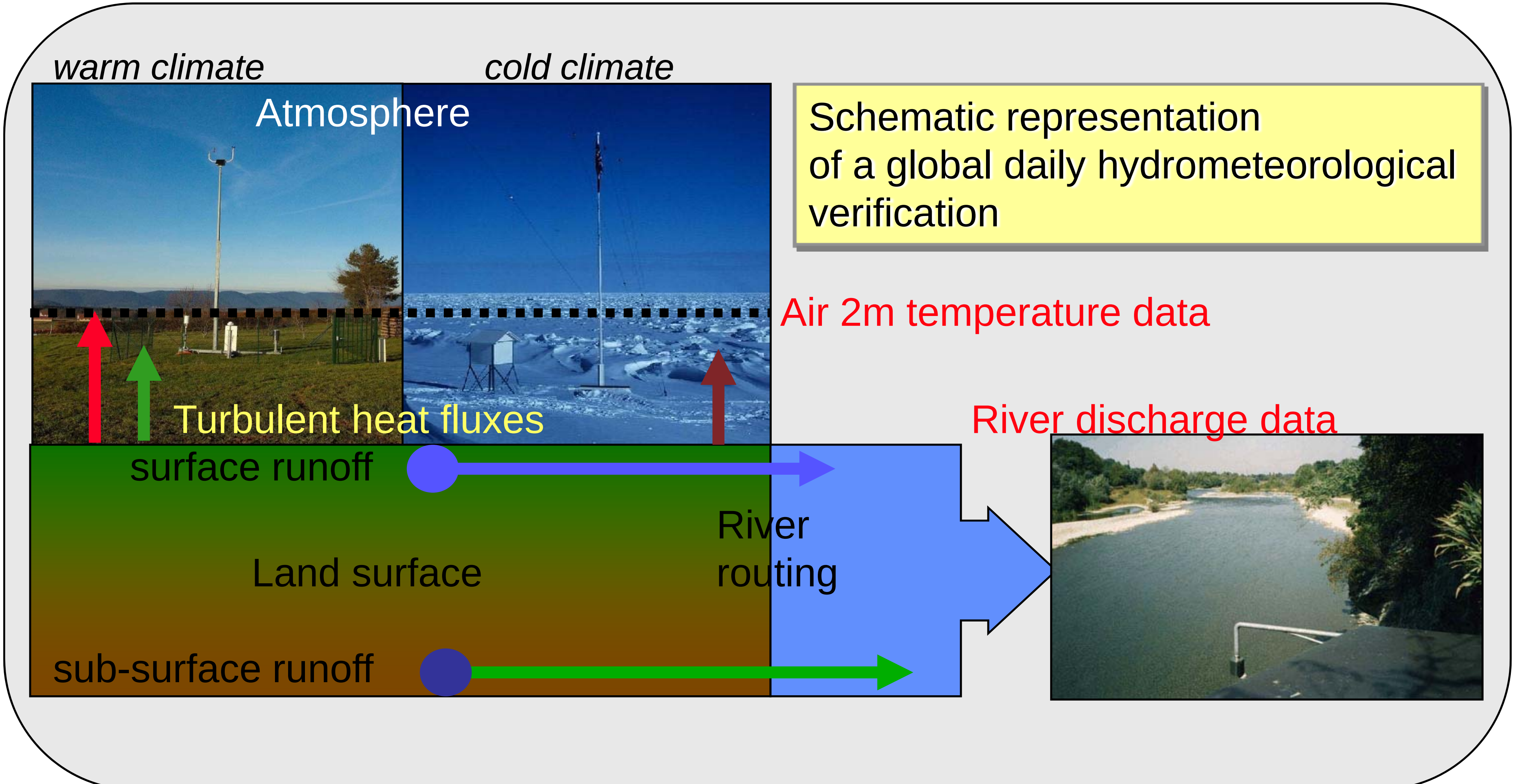
- Summary

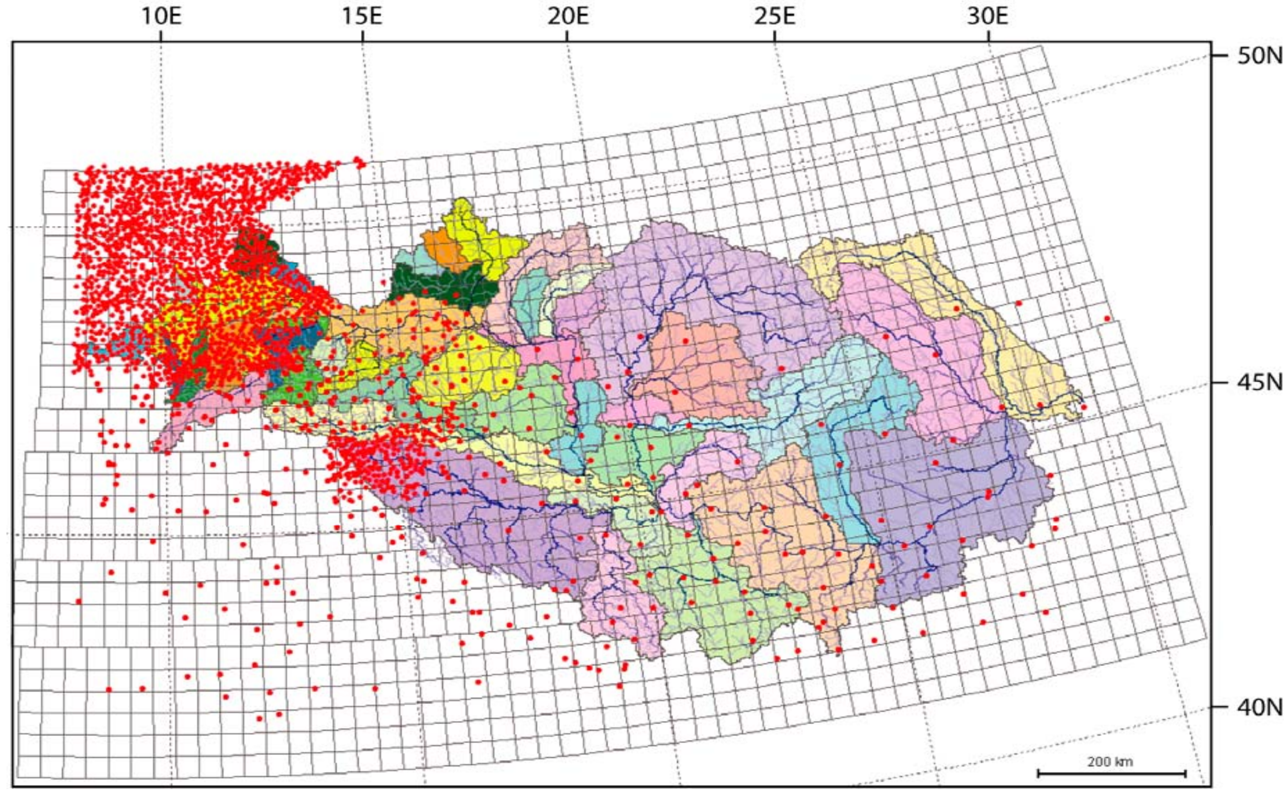
Hydro-meteorological verification



Balsamo et al. (submitted)

Properties of a discharge based evaluation

- Discharge is a:
  - ➢ Spatial Integrator
  - ➢ Temporal Integrator
  - ➢ Process Integrator
- 'Holistic' Evaluation
- End-user targeted



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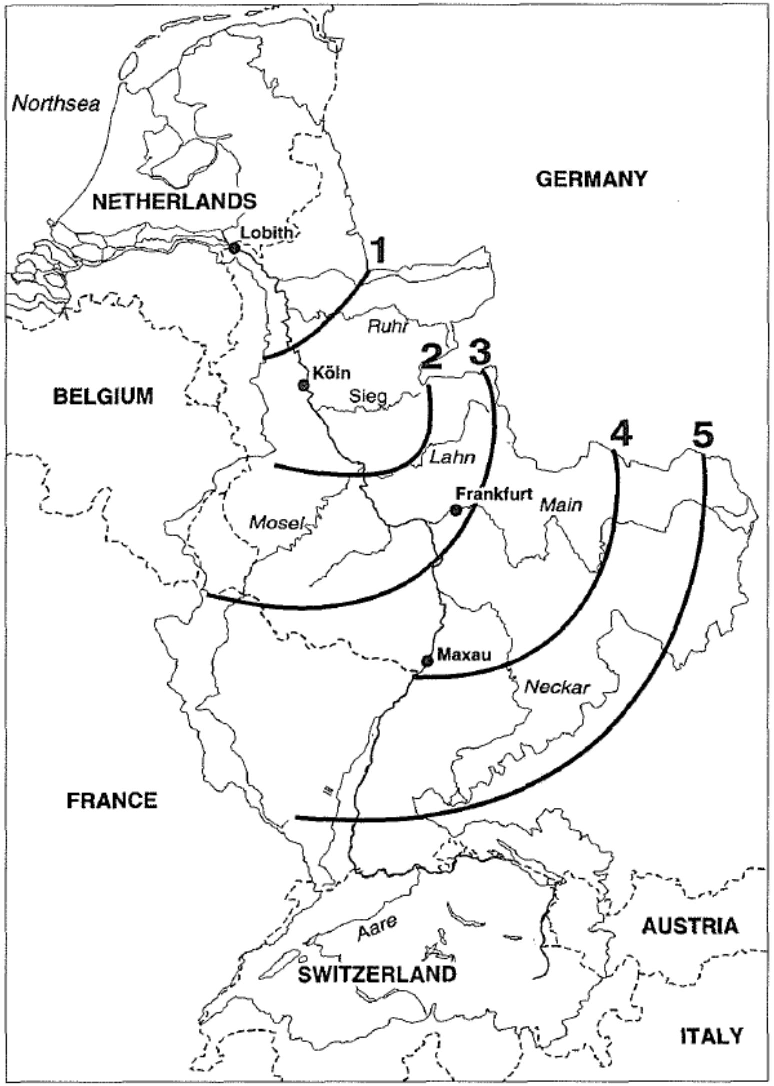
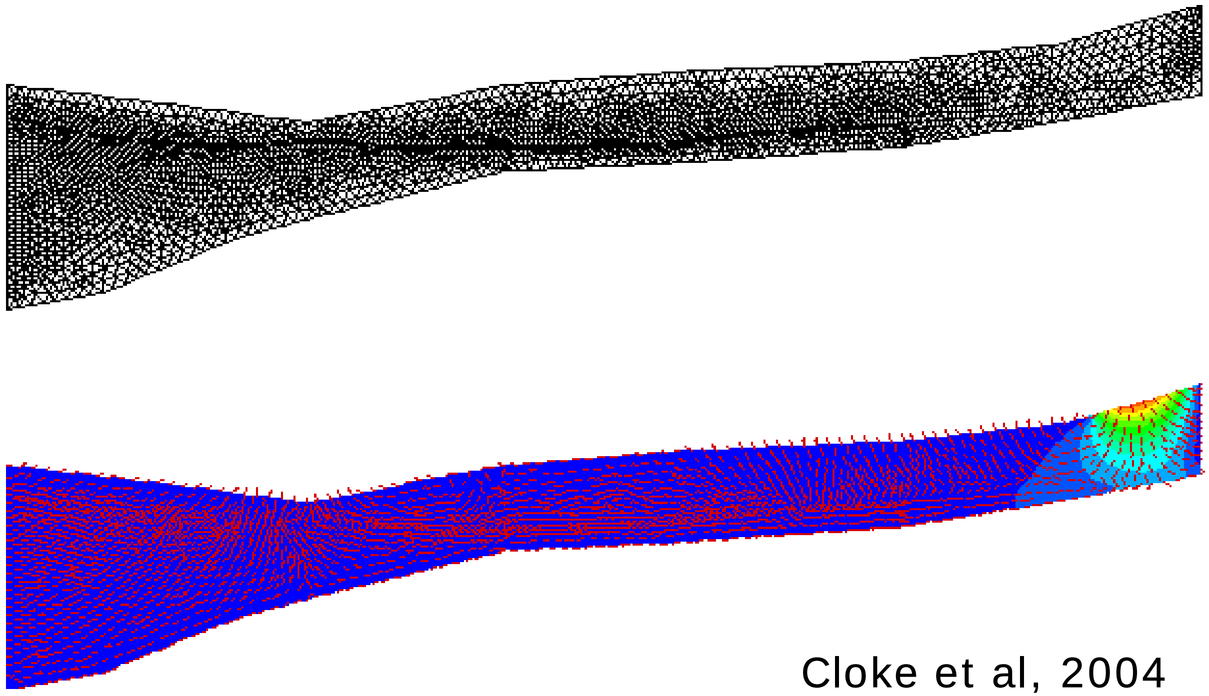


(Parmet, 1997)

Properties of a discharge based evaluation

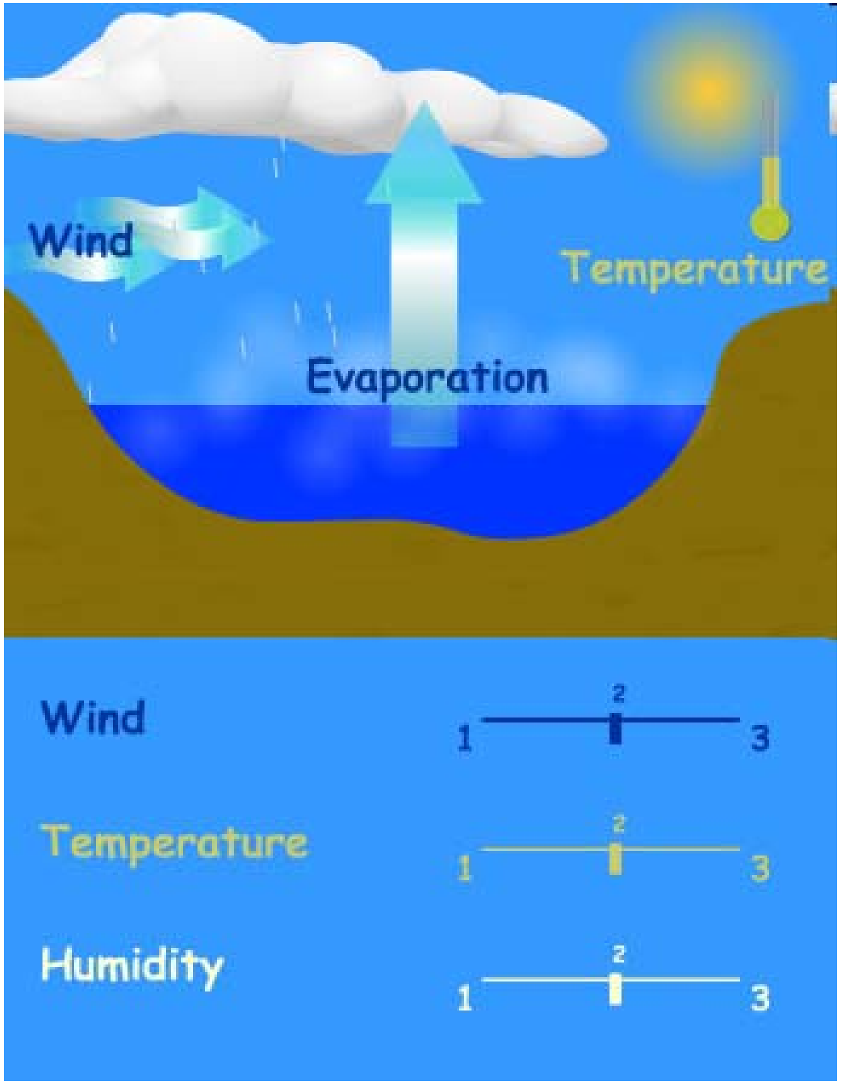
- Discharge is a:
  - Spatial Integrator
  - Temporal Integrator
  - Process Integrator
- ‘Holistic’ Evaluation
- End-user targeted



Cloke et al, 2004

Properties of a discharge based evaluation

- Discharge is a:
  - Spatial Integrator
  - Temporal Integrator
  - Process Integrator
- 'Holistic' Evaluation
- End-user targeted

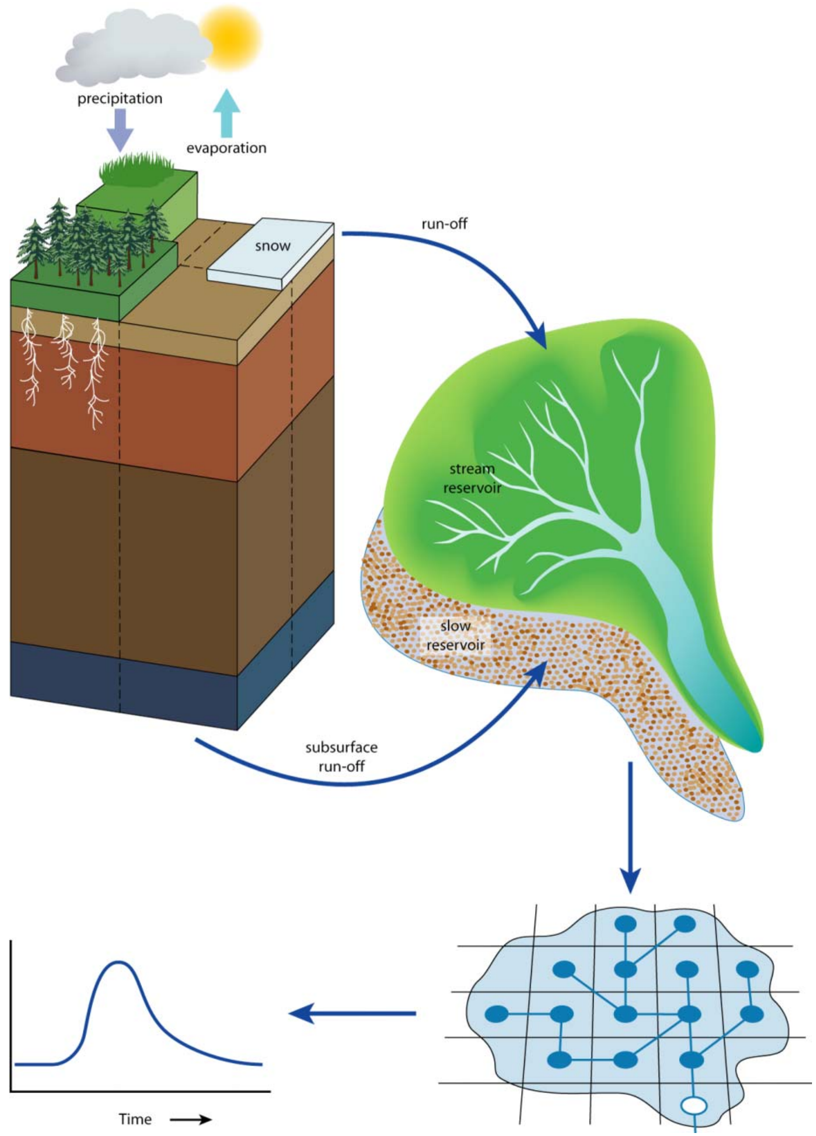


Properties of a discharge based evaluation

- Discharge is a:
  - Spatial Integrator
  - Temporal Integrator
  - Process Integrator
- ‘Holistic’ Evaluation
- End-user targeted (Value)

Example I: Land-surface scheme HTESSEL & TRIP2

HTESSEL

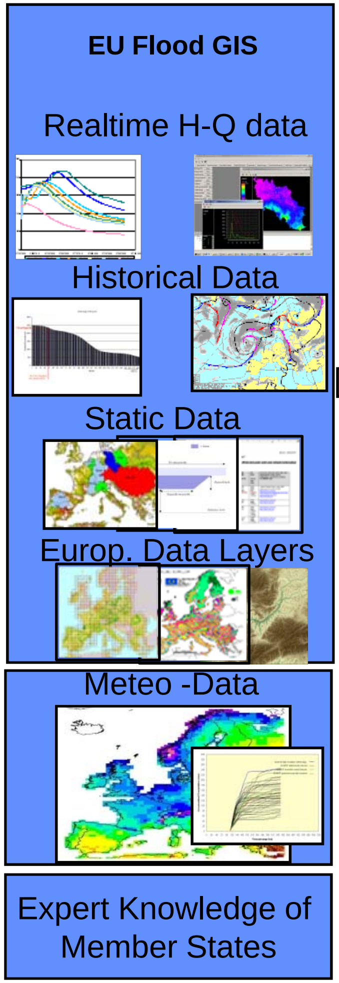


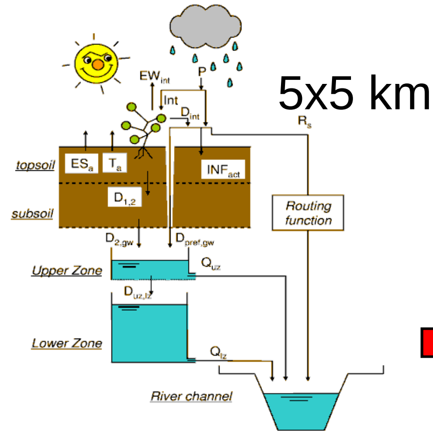
TRIP2

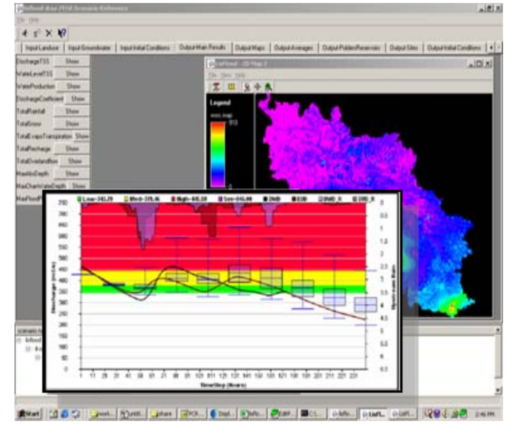
Pappenberger et al. in press

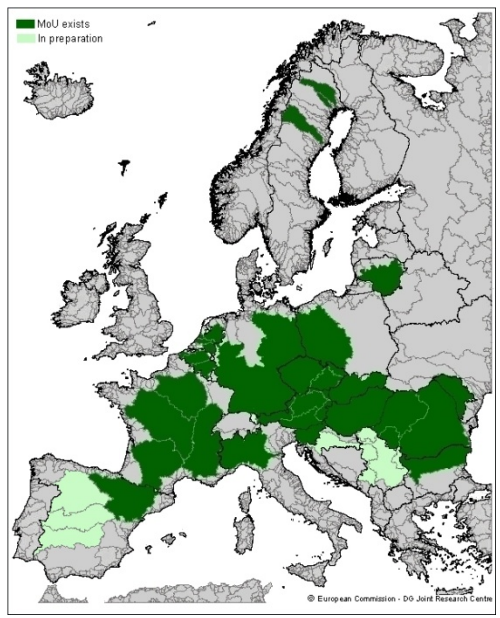
Example II: LISFLOOD (part of the European Flood Alert System)

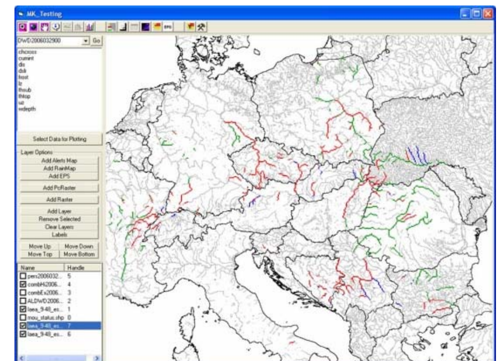
Joint Research Centre
of the European Commission
Thielen et al. 2007









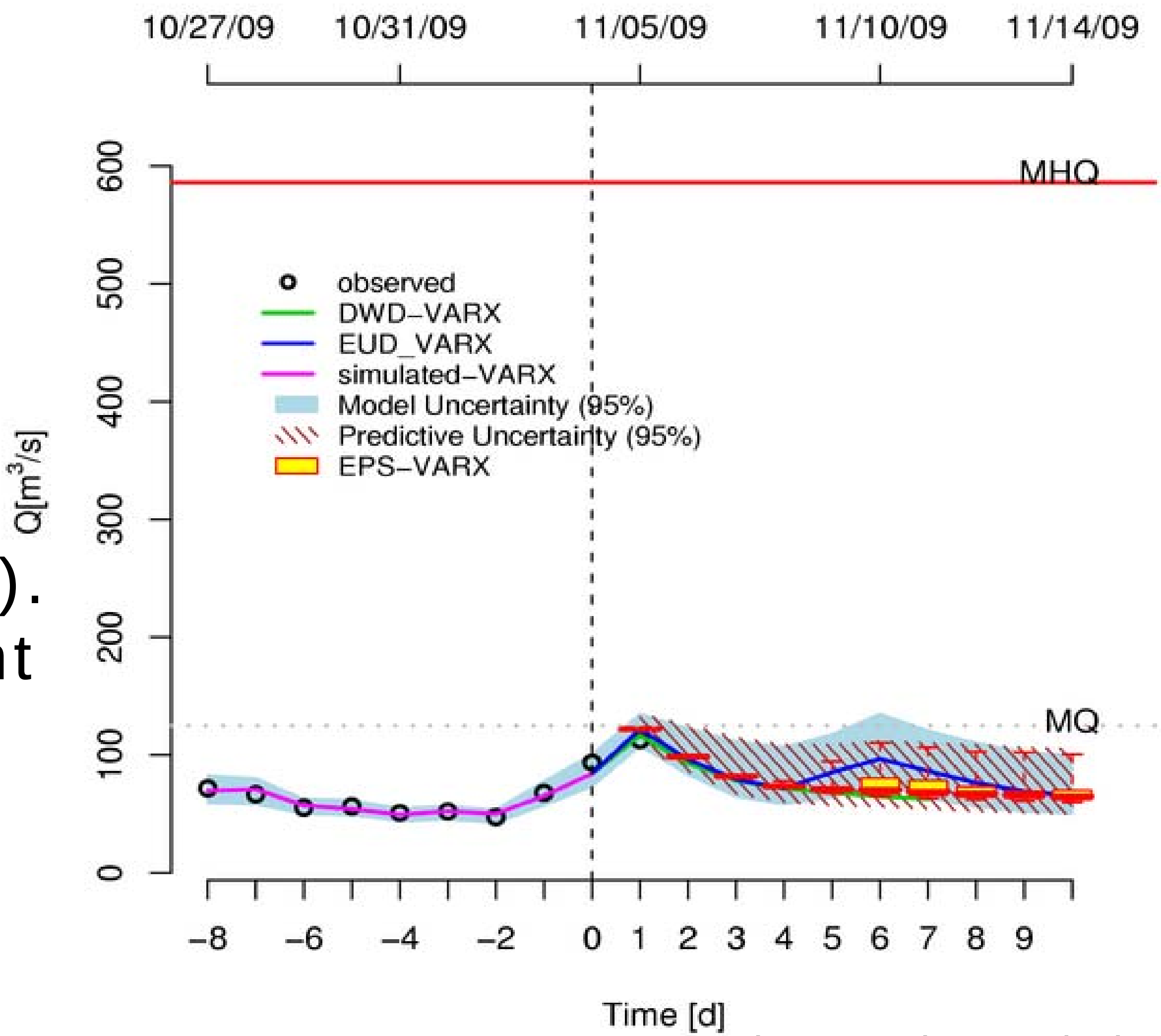


EFAS Reports

Lisflood

Support NWP: Diagnostics

Model and Predictive Uncertainty for the Danube (Neu Ulm). Application of the Wavelet-VARX error correction + Hydrological Uncertainty Processor (Krzysztofowicz, 1999). The routing component gives and indication where model improvements can be most effective

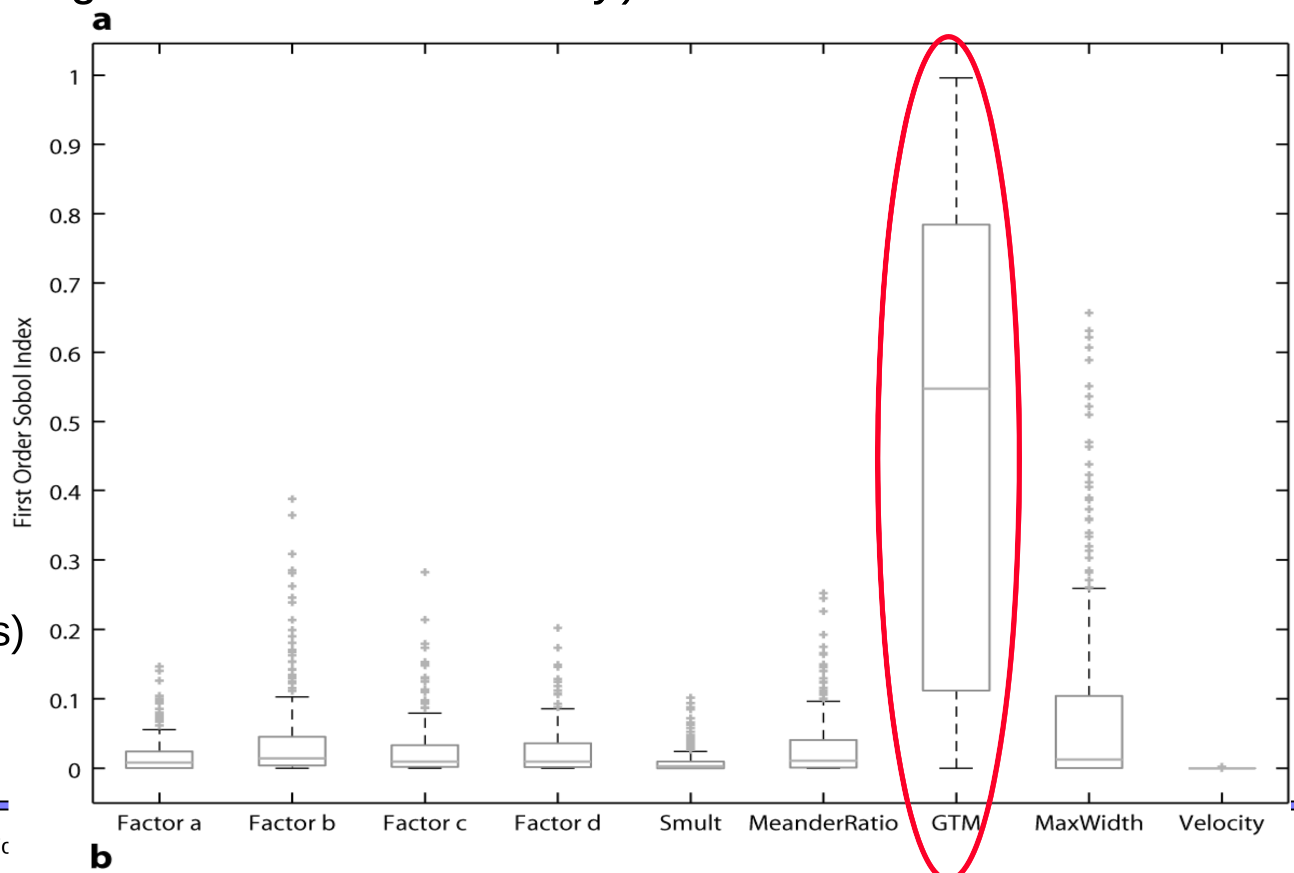


Lisflood

Bogner and Pappenberger (submitted)

Support NWP: Diagnostics

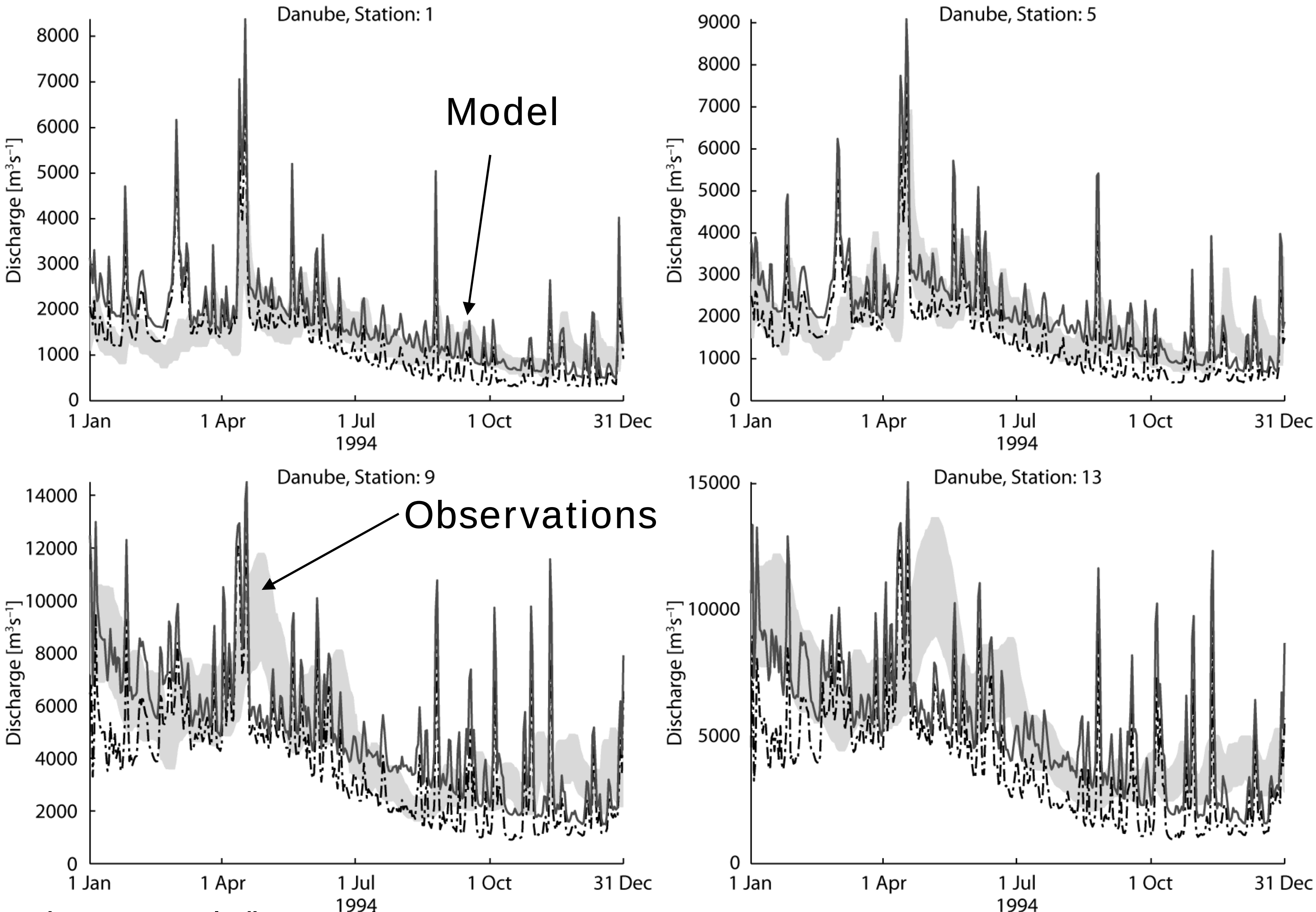
We can further conduct a more in depth analysis for example by using the SOBOL Sensitivity analysis, which will tell us in the case of HTESSEL, that the most sensitivity to the river routing comes from the Groundwater delay parameter (GTM) indicating, that further research is needed on the split between surface-groundwater flow (e.g. adding a third outflow) and/or the free outflow (e.g. adding a groundwater boundary).



Pappenberger et al. (in press)

HTESSEL

Support NWP: Diagnostics



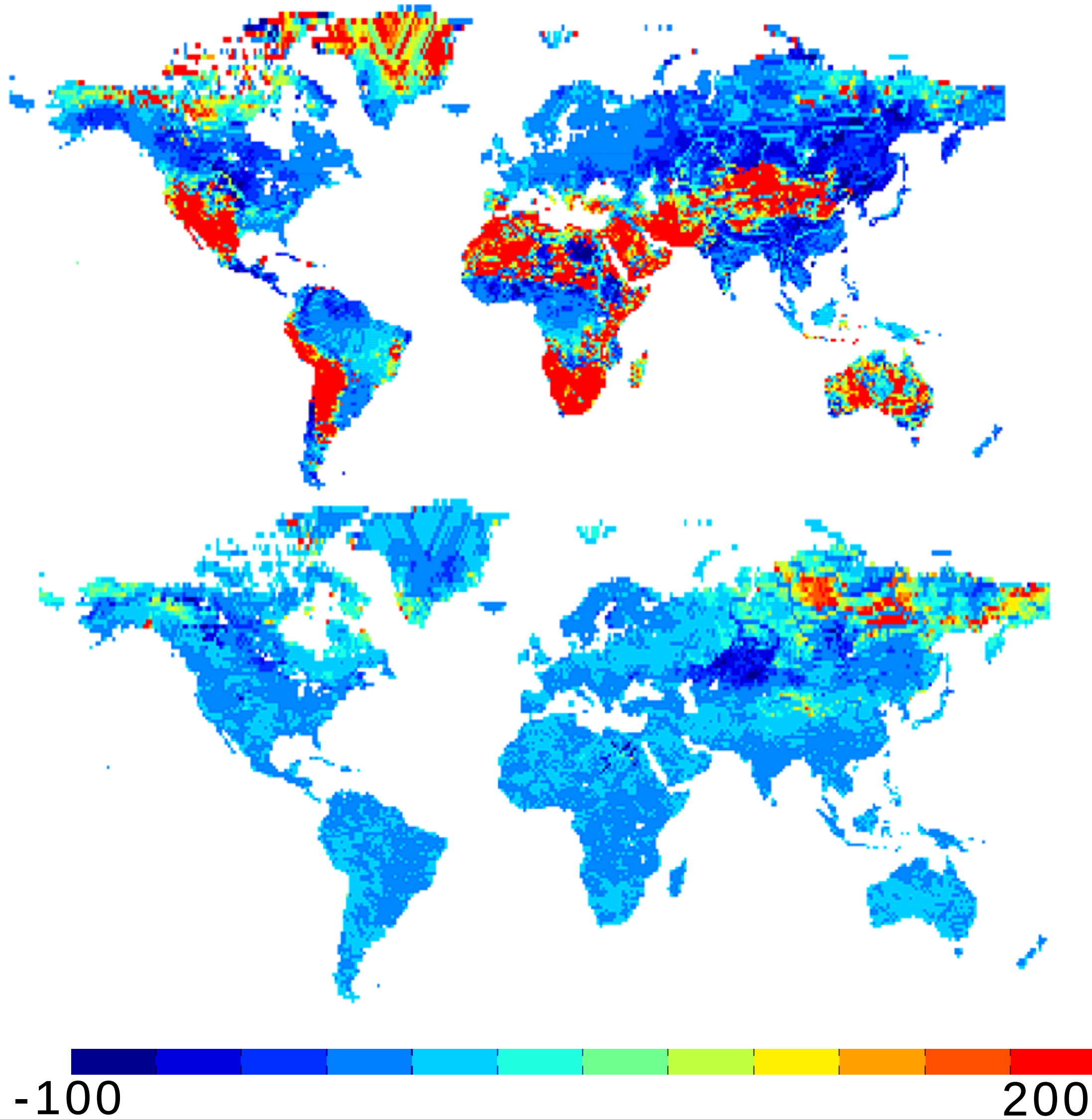
HTESSEL

Pappenberger et al. (in press)

Support NWP: Diagnostics

Relative differences (in %) for the river discharges obtained by TESSEL compared to HTESSEL (top panel) and by SNOWHTESSEL compared to HTESSEL (bottom panel) for the month of **January** (mean of 1986-1995)

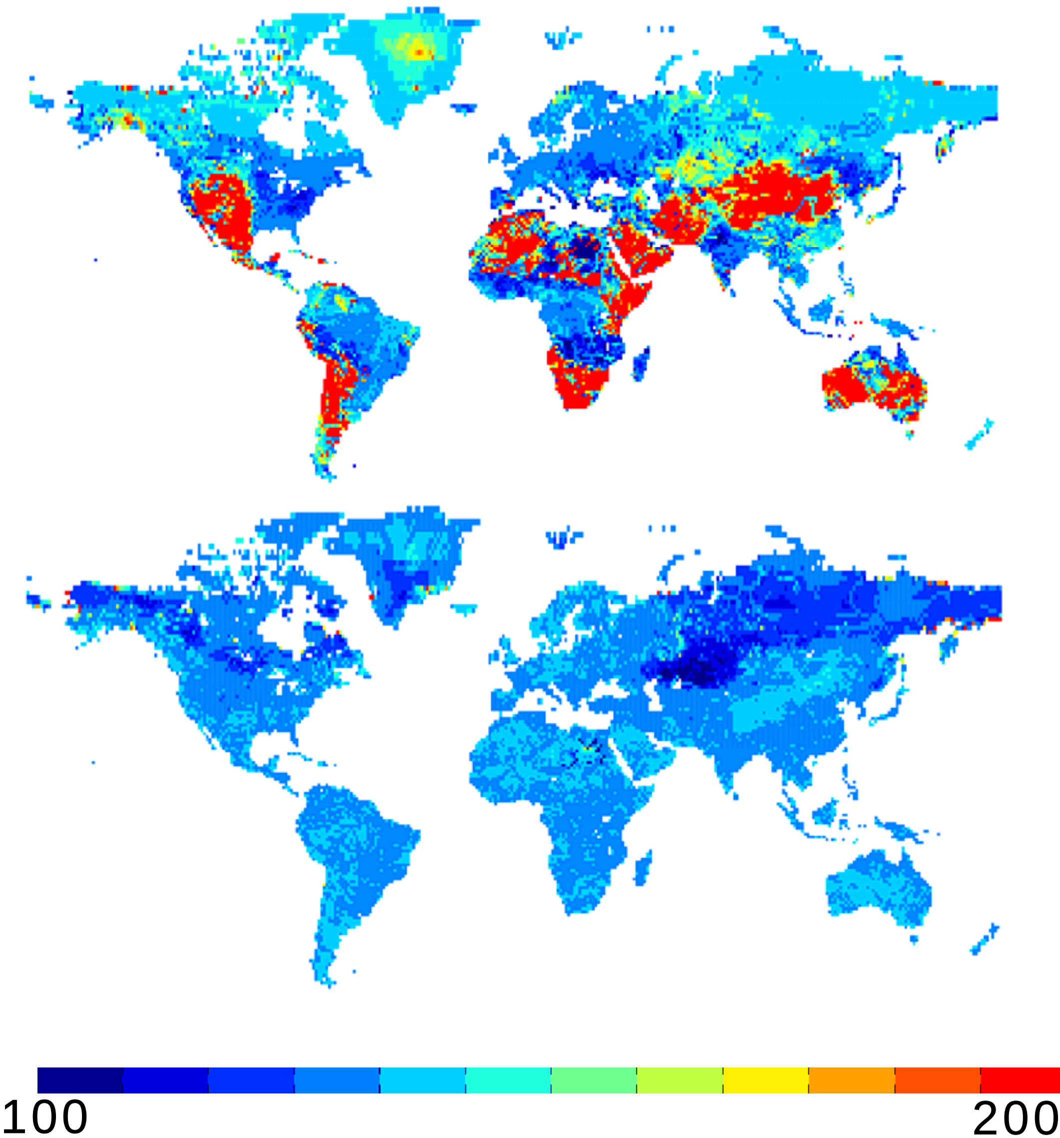
Balsamo et al., submitted



HTESSEL

Support NWP: Diagnostics

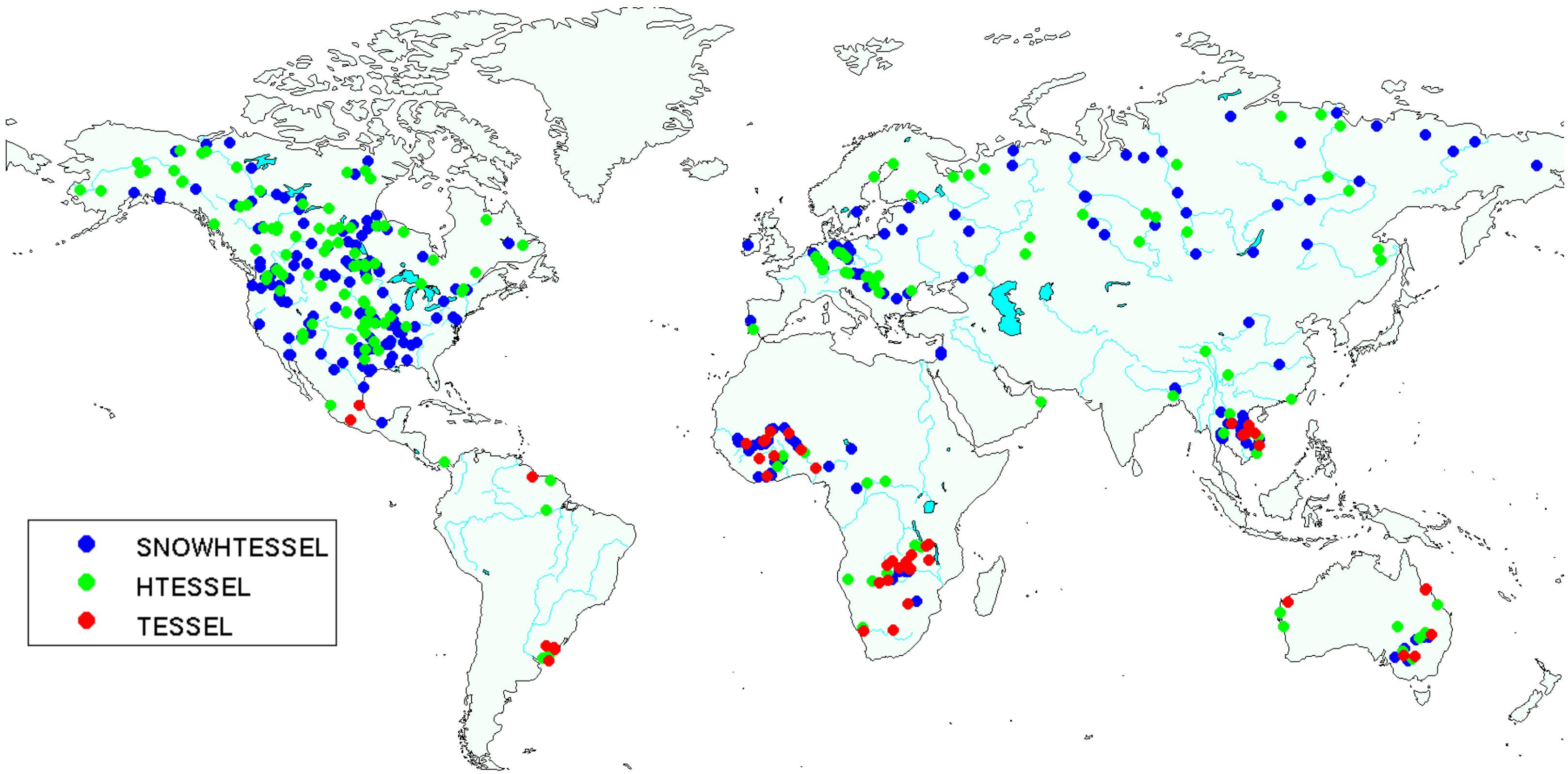
Relative differences (in %) for the river discharges obtained by TESSEL compared to HTESSEL (top panel) and by SNOWHTESSEL compared to HTESSEL (bottom panel) for the month of **June** (mean of 1986-1995)



Balsamo et al., submitted & see poster Dutra

HTESSEL

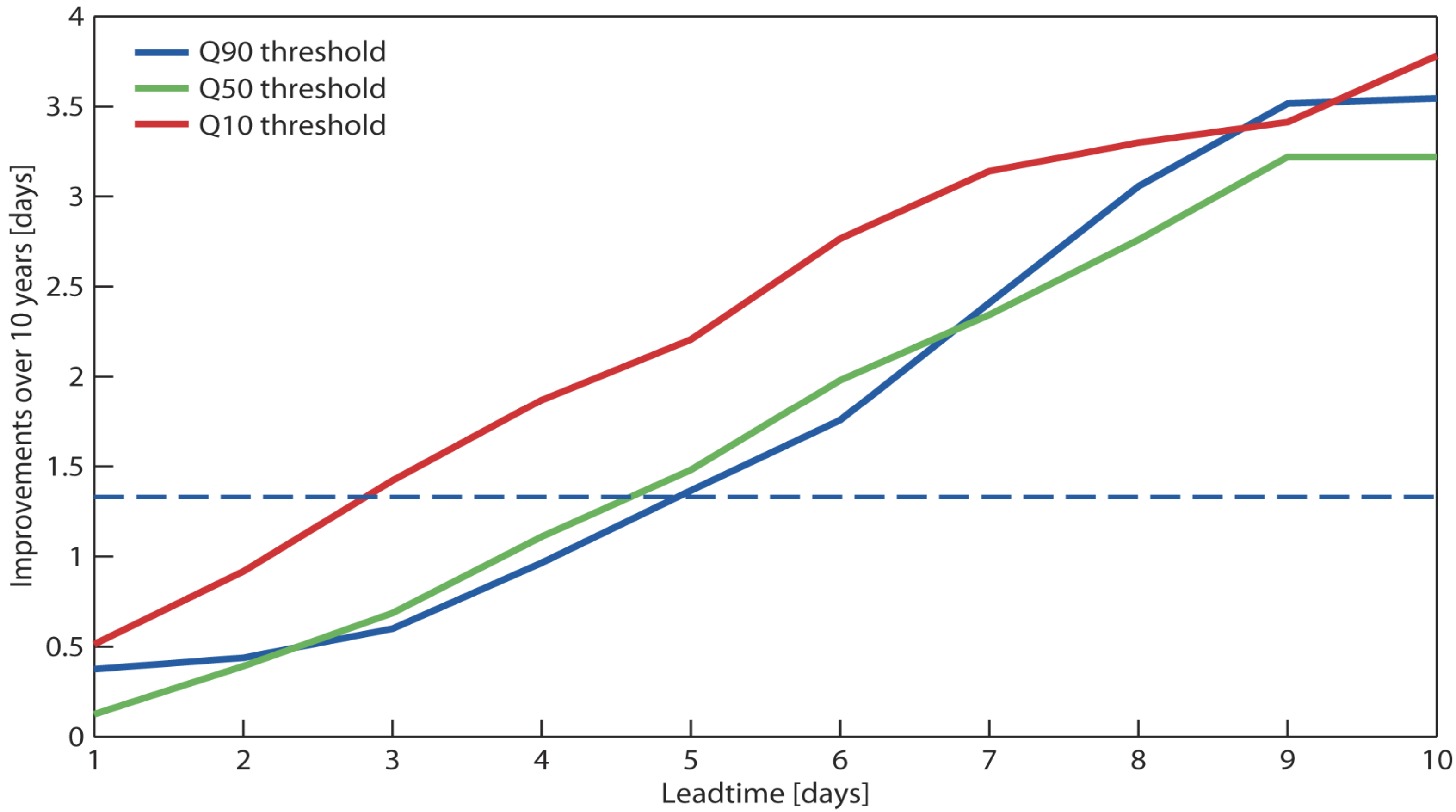
Support NWP: Evaluation



Indication of best correlated modelled and observed river discharges. Models include SNOWHTESSEL (blue), HTESSEL (green), and TESSEL (red). Balsamo et al., submitted

HTESSEL

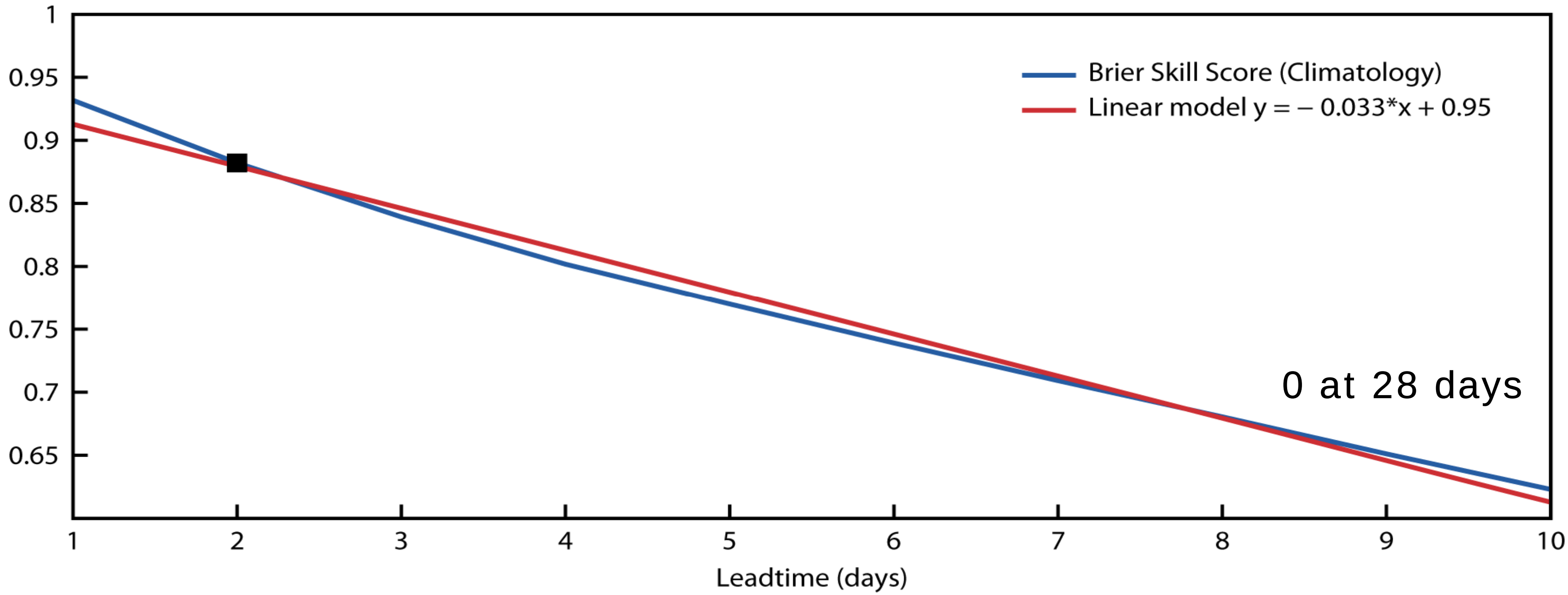
Support NWP: Evaluation



Gain in lead time over a decade for three thresholds (ETS score). The dotted straight line indicates the average gain for precipitation as published by Ghelli and Primo (2009) from Pappenberger and Thielen (submitted)

Lisflood

Support NWP: Evaluation

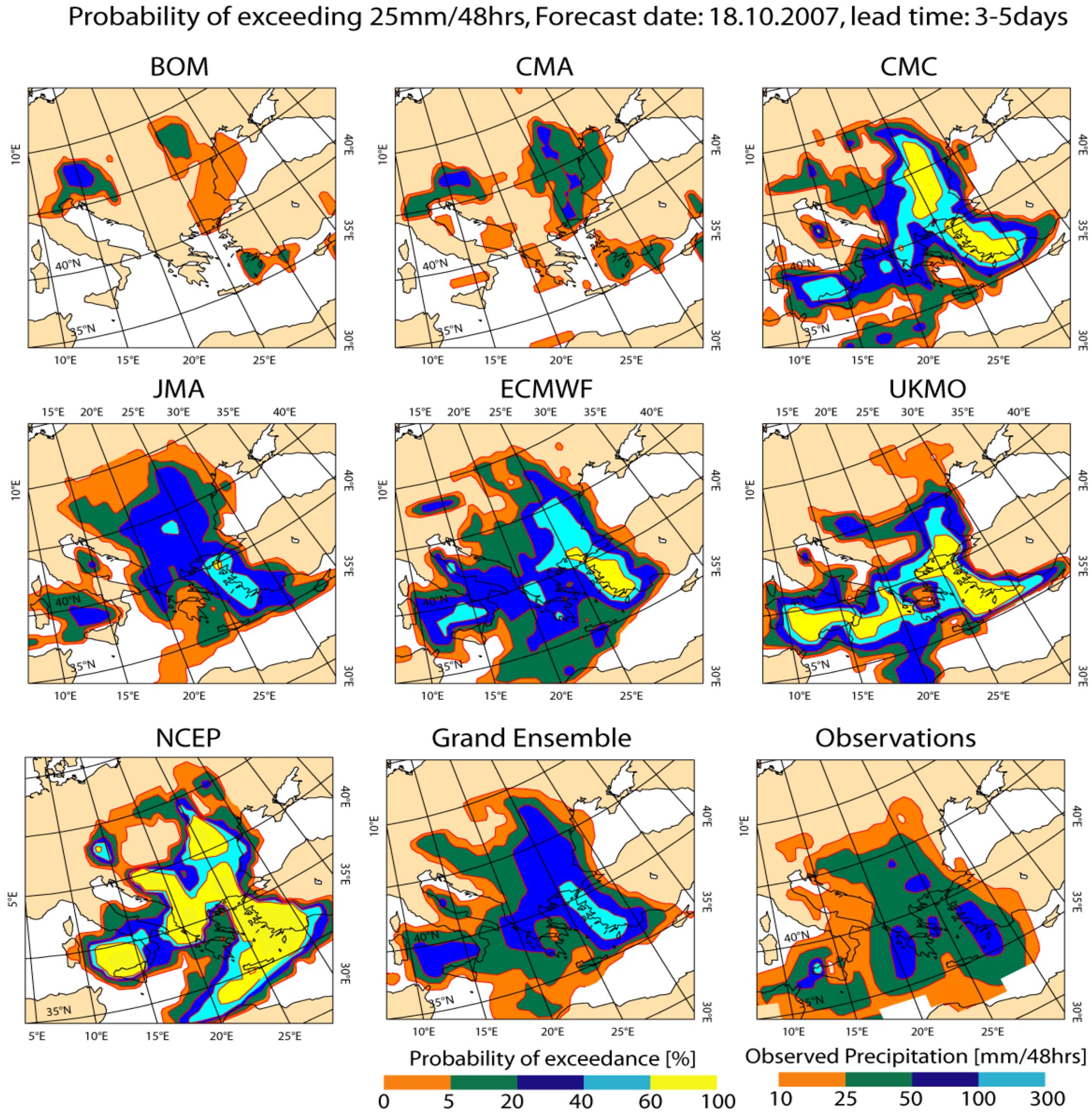


Average Brier Skill Score (Q50) across Europe for the entire evaluation time (from Pappenberger and Thielen (submitted))

Lisflood

Support NWP: Evaluation by Model Comparison

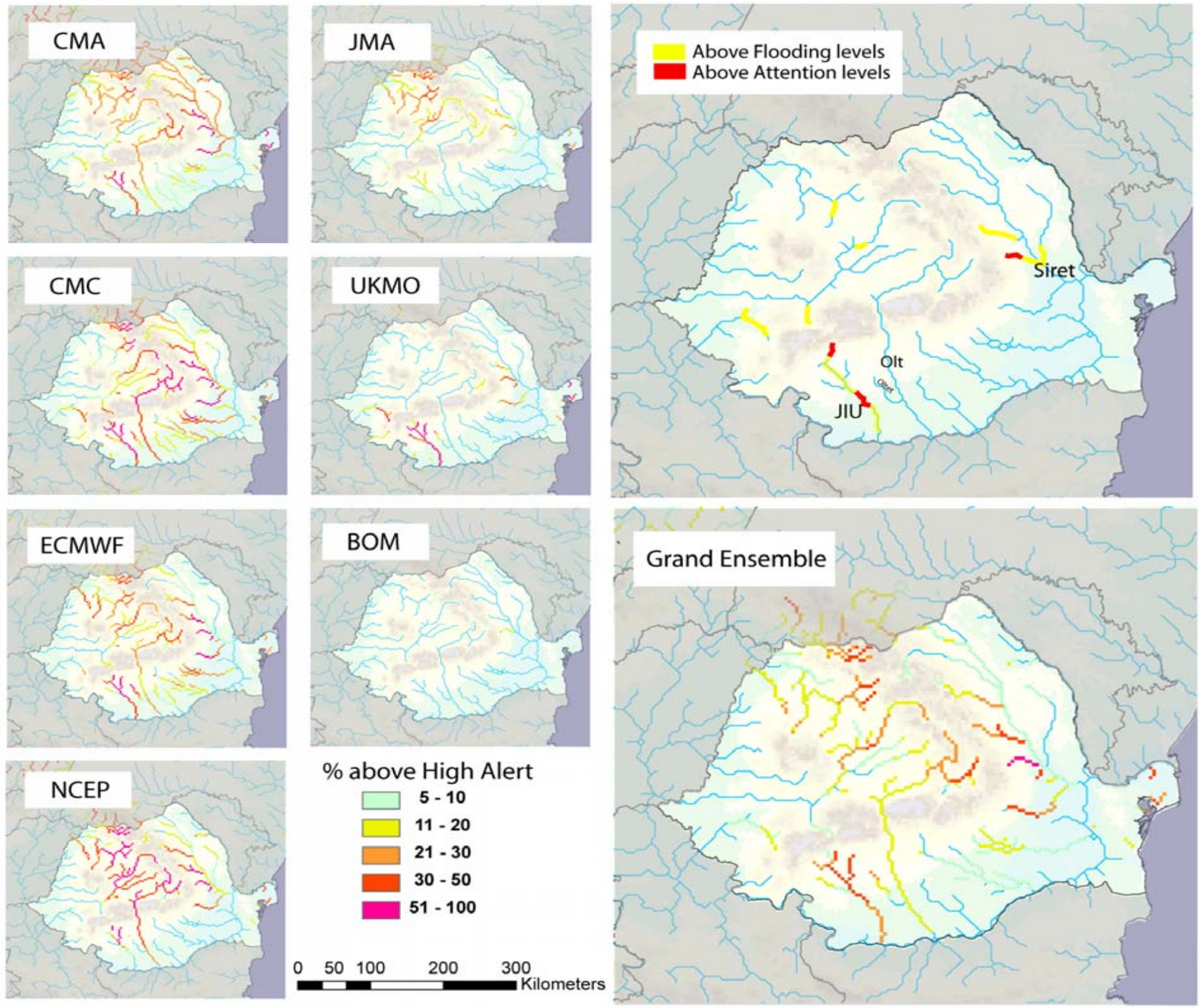
7 different forecasts for the October 2007



Lisflood

Support NWP: Evaluation by Model Comparison

Warning maps: Allow for the comparison of integrated forecast fields from different models



Lisflood

Support NWP: Severe Weather

One of the ECMWF goals is to produce better forecasts for severe weather. The Extreme Forecast Index focuses on meteorological forecasts.

River routing can assist the development and support of such a goal:

Example 1: Flood Forecasting in the Po (precipitation induced)

Example 2: Flood Forecasting in Danube 2006 (Precipitation and Temperature induced)

Support NWP: Extreme Weather: Po floods (April 2009)

(photo A Contaldo, Photonews, available from

http://torino.repubblica.it/)

http://peppecaridi2.wordpress.com

(Buizza et al., ECMWF newsletter, summer 2009)

EPS/EFAS probabilistic flood prediction for Northern Italy: the case of 30 April 2009

ROBERTO BUIZZA, FLORIAN PAPPENBERGER, PETER SALAMON, JUTTA THIELEN, AD DE ROO

ENSEMBLE hydrological predictions generated by the European Union Joint Research Centre European Flood Alert System (JRC EFAS) driven by the ECMWF Ensemble Prediction System (EPS) have been used to assess the risk of flooding of the Po' river at the end of April 2009. This case illustrates the added value of using probabilistic flood predictions to signal the possible occurrence of flooding, and confirms statistically-based results published in the scientific literature. It shows that the key advantage of ensemble prediction systems, compared to systems that rely on one single forecast, is that they can be used not only to identify the most likely outcome, but also to assess the probability of occurrence of extreme/rare events.

Medium-range ensemble prediction systems are today part of the operational suite at many meteorological centres. Nine centres (in Australia, Brazil, Canada, China, England, Japan, Korea and the USA; see, for example, Buizza et al., 2005) run global, medium-range ensemble prediction systems, and many regional centres are running limited area ensemble prediction systems (e.g. in Australia, England, France, Germany, Italy, Norway and Spain). The past decade has seen an increased use of ensemble forecasts; see, for example, the work done within the DEMETER project on establishing the utility of coupled multi-model ensemble forecasts, in particular in the agriculture and health sectors; www.ecmwf.int/research/demeter/.

Another area where the value of an ensemble approach has been widely recognized is hydrology, which has seen several institutions developing and testing ensemble-based flood prediction systems that use ensemble weather forecasts as initial and boundary conditions (see, for example, the work done within the HEPEX project, *Thielen et al.*, 2008). One of these hydrological ensemble systems for flood prediction is EFAS, developed and successfully implemented by JRC in Ispra, Italy.

Probabilistic prediction of severe water level conditions with EPS/EFAS

The EPS/EFAS flood prediction system runs twice-a-day at JRC using forecasts of the weather variables required by the hydrological model to predict river discharge levels. EFAS probabilistic forecasts use data from the ECMWF EPS as initial and boundary weather conditions.

The ECMWF EPS

The EPS has changed several times since its implementation in 1992 (see *Palmer et al.*, 2007 for more details). Since 11 March 2008, the ECMWF EPS runs twice-a-day, at 00 and 12 UTC, with a variable resolution (*Buizza et al.*, 2006 and *Vitart et al.*, 2008). It includes 51 members: one starting from unperturbed initial conditions (defined by interpolating the high-resolution T799L91 analysis to the ensemble resolution) and 50 members starting from perturbed initial conditions.

The perturbed initial conditions are constructed as a linear combination of the perturbations with the fastest growth over a 48-hour period, provided by singular vectors computed with a T42L62 model and a total energy norm. The perturbed forecasts are integrated with a stochastic scheme designed to simulate the effect on forecast error of random model errors due to uncertainties in the parametrized physical processes (the stochastic physics).

The 00 UTC EPS is run at T399L62 resolution from day 0 to day 10 with persisted sea-surface-temperature anomalies, and then at T255L62 resolution from day 10 to day 15 (day 32 every Thursday at 00 UTC) coupled with an ocean model. Every Thursday the ensemble is extended to 32 days to cover the monthly forecast range. The 12 UTC EPS has the same configuration as that run at 00 UTC, but uses persisted sea-surface-temperature anomalies also between day 10 and 15, instead of a coupled ocean model.

The JRC EFAS

The European Flood Alert System (EFAS) was launched in 2003 by the European Commission with the aim to increase preparedness for floods in trans-national European river basins (*Thielen et al.*, 2009; *Bartholmes et al.*, 2009). The system being developed has two main objectives:

- To complement European Member States activities on flood preparedness and to achieve longer early warning times.
- To provide the European Commission with an overview of ongoing and expected floods in Europe for improved international aid and crisis management in the case of large transnational flood events that might need intervention on an international level.

The EFAS prototype that is currently run operationally is set up for the whole of Europe on a 5-km grid. Twice daily it provides the national hydrological centres with

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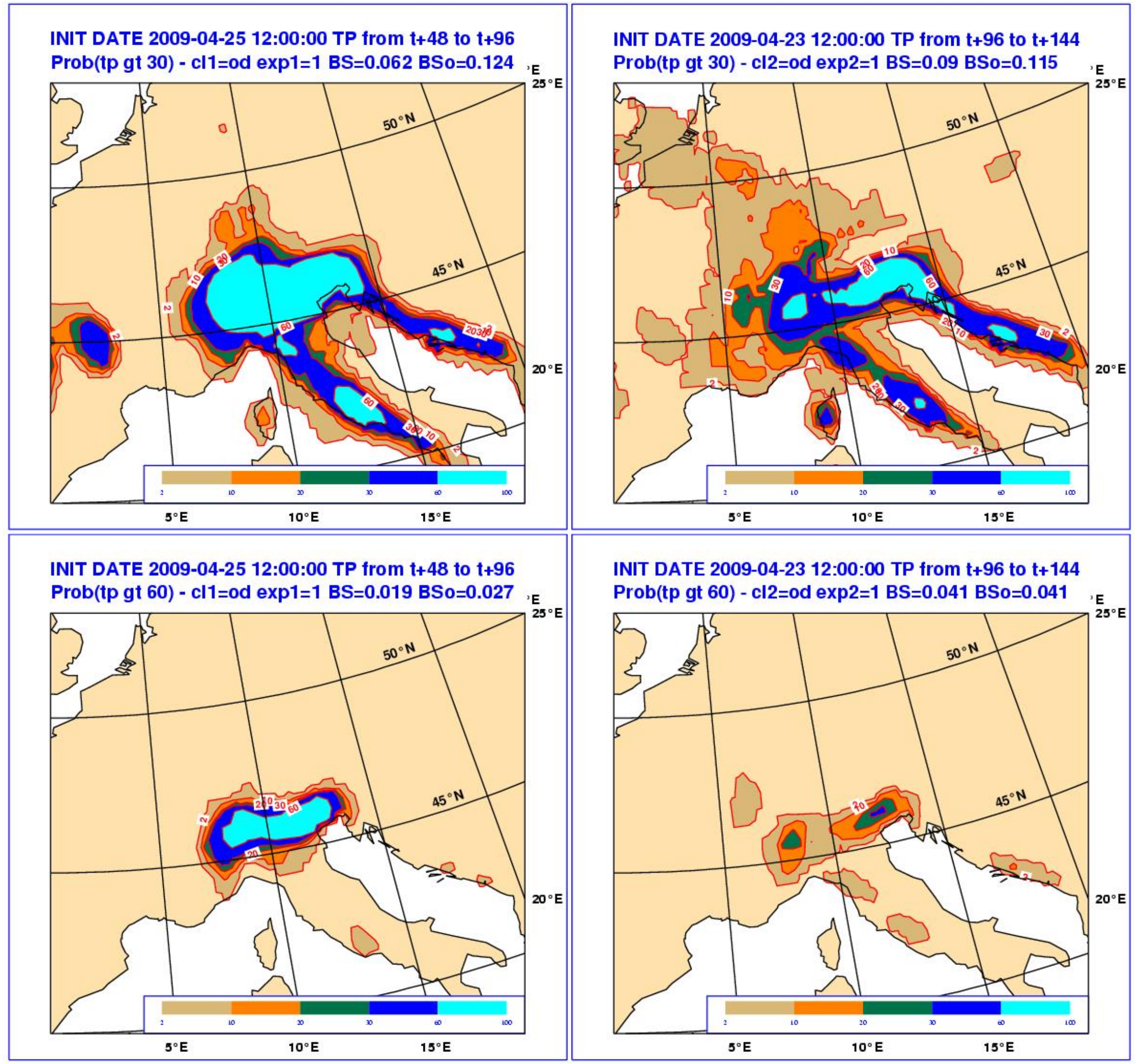
Roberto Buizza, Florian Pappenberger, ECMWF, Reading, UK
Peter Salamon, Jutta Thielen, Ad de Roo, JRC, Institute for Environment and Sustainability, Ispra, Italy

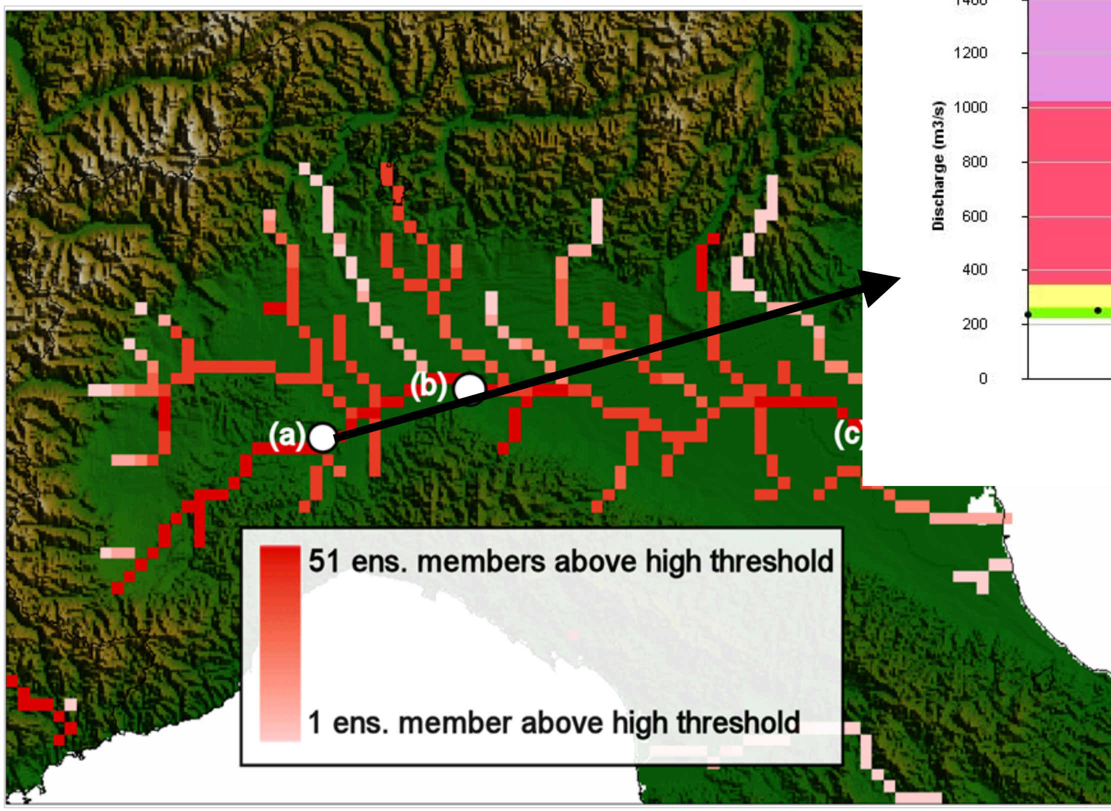
Support NWP: Extreme Weather: Po floods (April 2009)

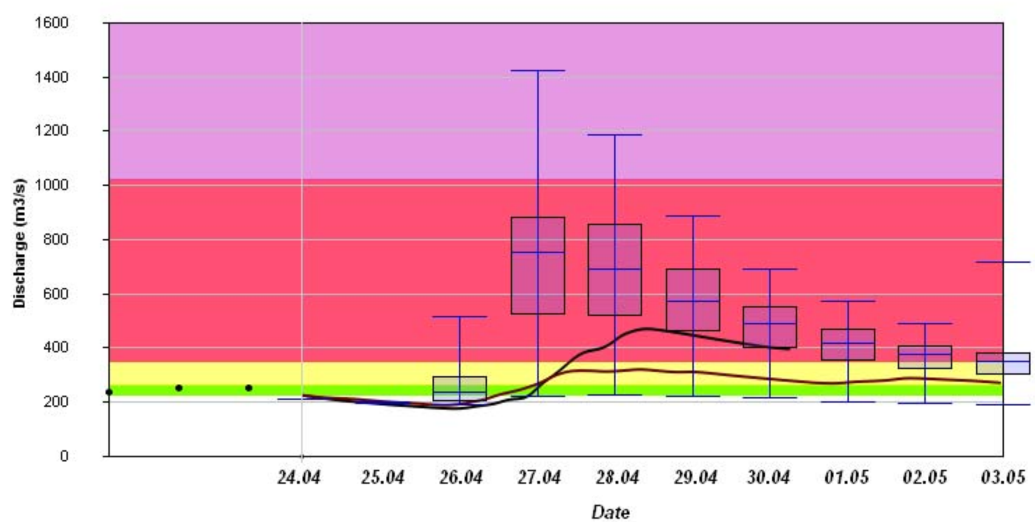
The left panels show the t+48-to-96h forecast probability of occurrence of rainfall in excess of 15mm (top) and 30mm (bottom), issued on the 25th of April. The right panels show the corresponding t+96-to-144h forecast probability issued on the 23rd of April.



Support NWP: Extreme Weather: Po floods (April 2009)

Lisflood





Buizza et al., 2009

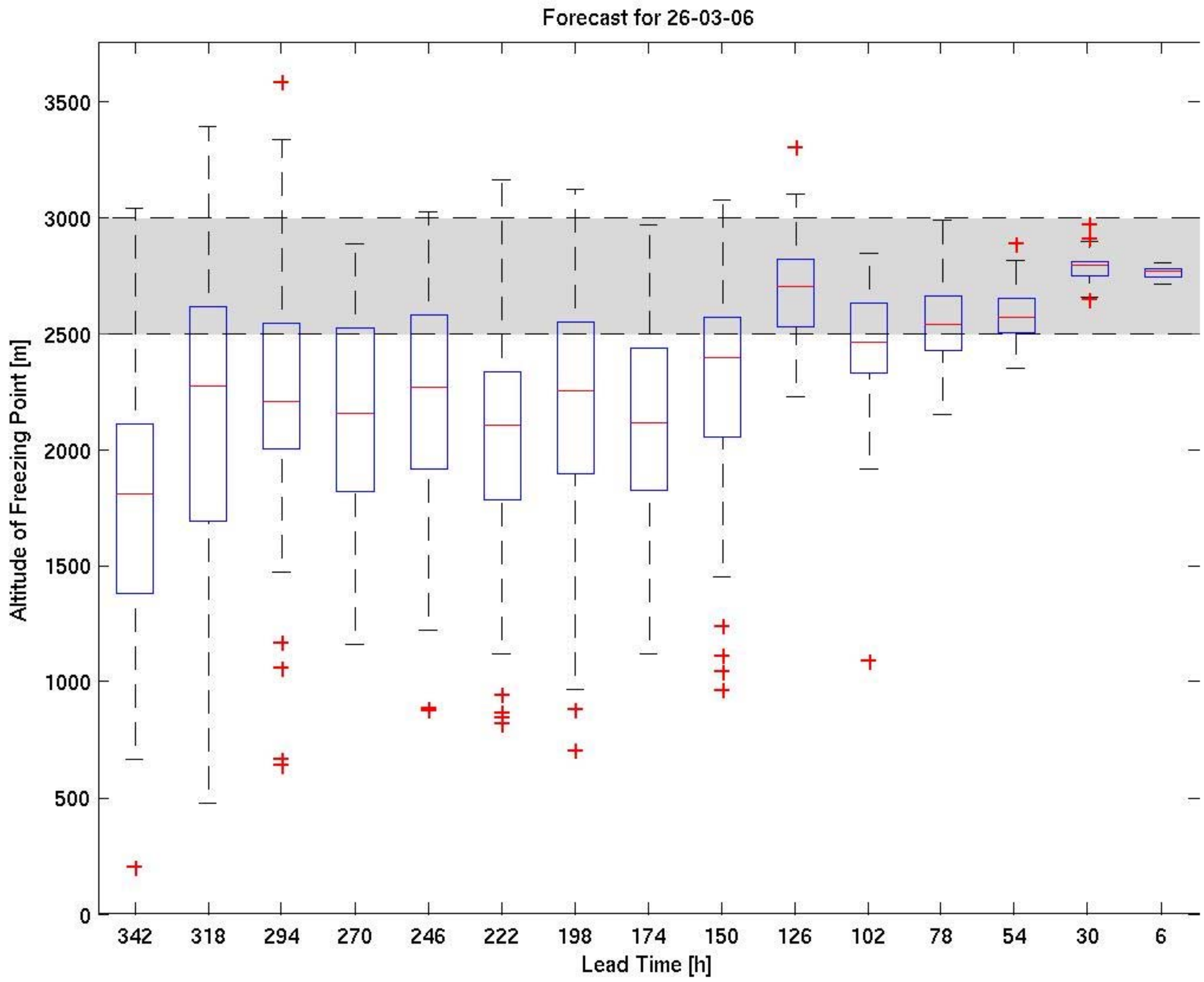
Number of ensemble members based on the ECMWF EPS forecast from the 24th of April 00 UTC simulating discharges which exceed the EFAS high alert level for the Po river basin.

Support NWP: Extreme Weather: Danube 2006 floods

High Danube levels caused significant flooding in parts of Serbia, Bulgaria and Romania, with damage to property and infrastructure in localities near the shores of the river. The 2006 European floods were one of the most devastating natural disaster from the History of Romania.

The flooding was caused by snowmelt and in particular rain on snow.

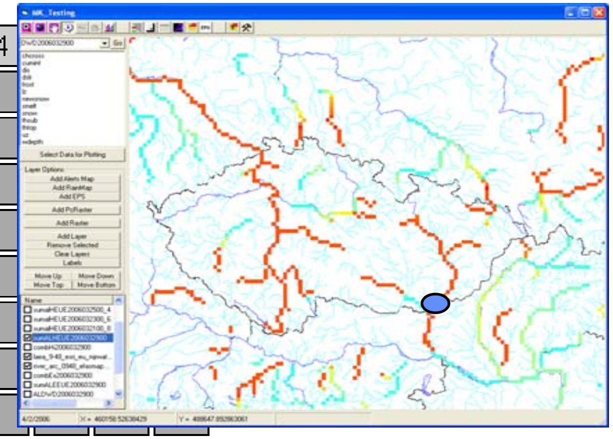
Support NWP: Extreme Weather: Danube 2006 floods



Support NWP: Extreme Weather: Danube 2006 floods

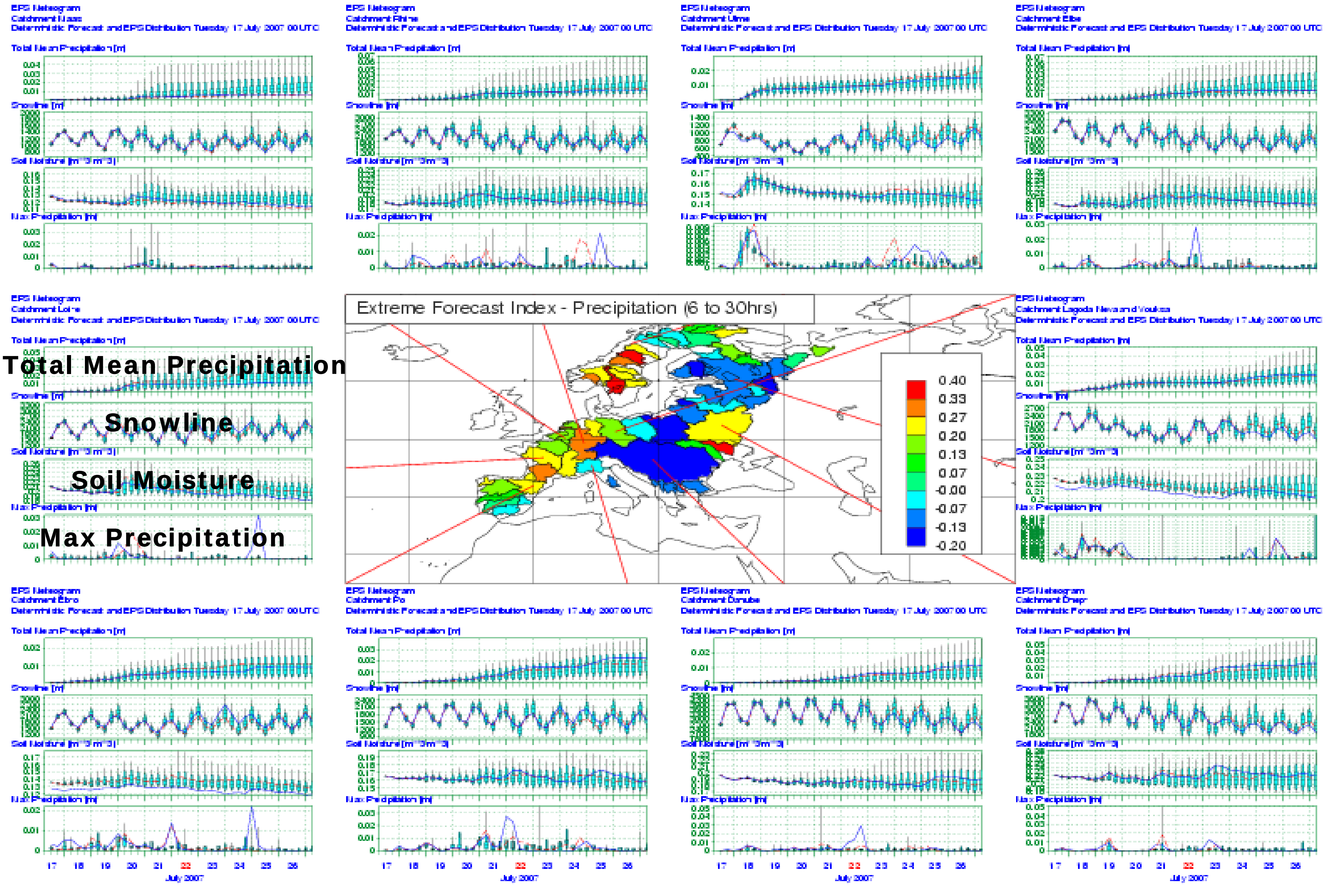
EPS > HAL

Forecast Day	18	19	20	21	22	23	24	25	26	27	28	29	30	31	01	02	03	04			
2006031800										1											
2006031812										1											
2006031900										1	1										
2006031912											3										
2006032000										4	15	19									
2006032012										5	11	18									
2006032100											12	25	31								
2006032112										9	22	26	28								
2006032200										1	20	31	37	32							
2006032212										6	27	28	22	22							
2006032300											17	29	31	18	14						
2006032312										5	26	36	34	31	26						
2006032400											27	40	36	28	29	32					
2006032412											28	33	29	29	25	20					
2006032500											25	46	44	42	43	40	22				
2006032512											33	40	39	38	36	29	16				
2006032600											41	48	46	46	46	42	21	9			
2006032612											33	45	45	47	45	41	20	10			
2006032700											2	46	47	49	50	50	40	28	18		
2006032712											36	50	51	51	51	51	49	36	27		
2006032800												39	49	51	51	51	51	48	34	29	
2006032812												36	51	51	51	51	51	51	42	38	
2006032900												51	51	51	51	51	51	51	50	47	34



46 - 51
41 - 45
36 - 40
31 - 35
26 - 30
21 - 25
16 - 20
11 - 15
6 - 10
1 - 5

Lisflood



17th of July 2007

Conclusions

River Routing:

1. Can help you to identify where to improve your model in particular the Land Surface Scheme and benchmark
2. Evaluate performance integrated over multiple forecast fields (e.g. temperature, precipitation, evaporation) taking account of co-variances and spatio-temporal correlations in an enduser value oriented framework
3. Support the goal of improving extreme weather predictions

Comments? Now or Florian.Pappenberger@ecmwf.int

Announcement: EGU2010 Session HS4.8 on Large scale hydrology (Support Application deadline 04.12.2009!!!!!)

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For earlier publications please go to http://www.ecmwf.int/staff/florian_pappenberger/pub_index.html