Floods, droughts and fires: Demonstrating the value of ECMWF forecasts in hydrology

Florian Pappenberger
Fredrik Wetterhall
Emanuel Dutra

Floods, droughts and fires

Objective: Demonstrate how ECMWF system can be used for 3 natural hazards: floods, droughts and fire on three examples:

Global Flood Alert System - experimental system which is developed in collaboration with the Joint Research Centre and is based on the European Flood Alert/Awareness System. This system is run in a pre-pre-operational mode since April 2011

Global Fire Risk Forecasting - experimental system which shows the potential of using ECMWF data for a global Fire Risk Forecast. Study is financed by the Joint Research Centre and is based on the European Forest Fire Information System

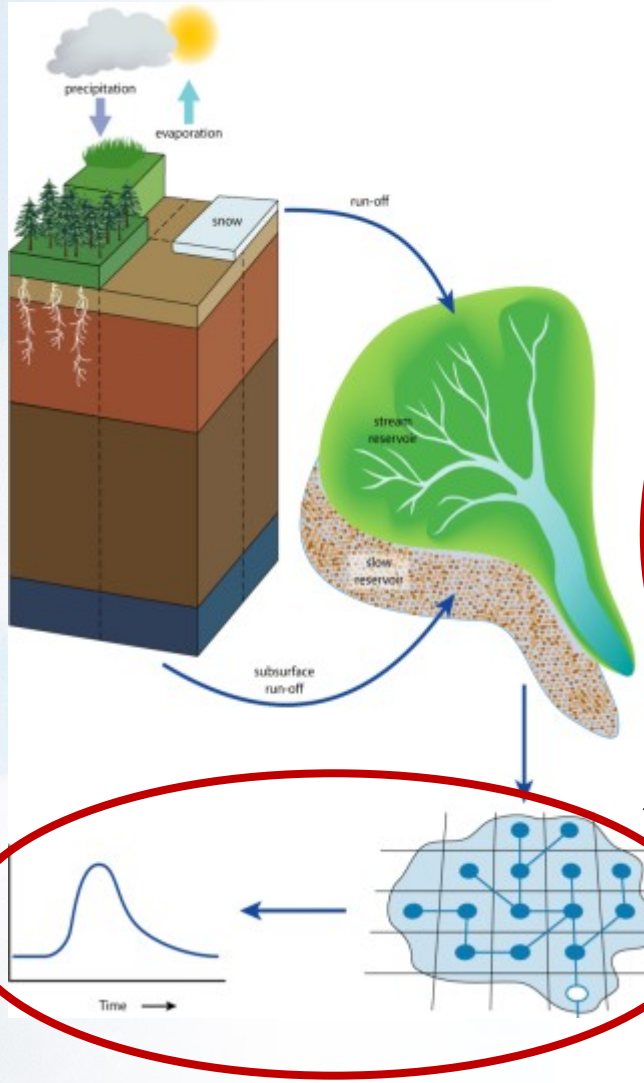
Droughts - Monitoring and forecasts droughts using ECMWF products on the example of the recent event on the Horn of Africa. Part of the DEWFORA (FP7) research project.

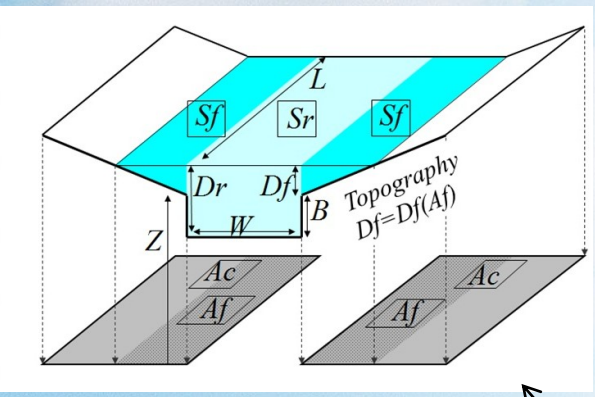
Floods

Jutta Thielen, Peter Burek, Konrad Bogner.
Lorenzo Alferi (all JRC)

Global River Routing: Concept

HTESSEL





CaMa-Flood (evaluation focus)

LISFLOOD (routing) (flood forecast focus)

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ECMWF

Global Flood Alert System

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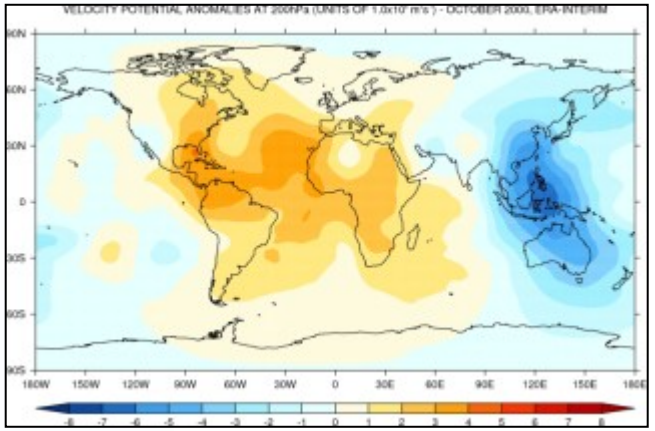
Triggered by:

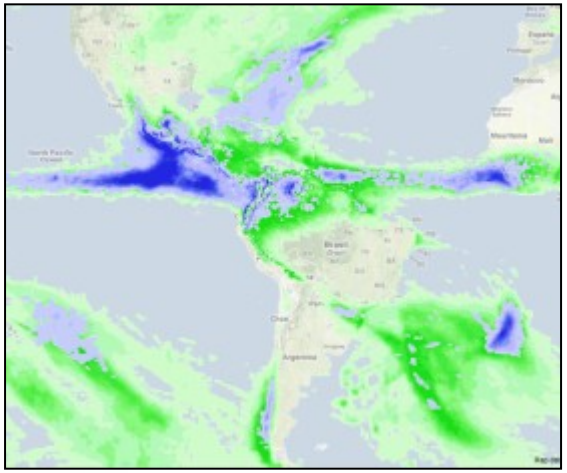
Long term run - Calibration
ERA Interim (offline, corrected) (ECMWF)

- **global atmospheric reanalysis produced by the ECMWF**
- **covers the period from 1/1/1979 - 31/12/2010**
- **Resolution: ~ 79 km**



Forecast
51 members of VarEPS (ECMWF)

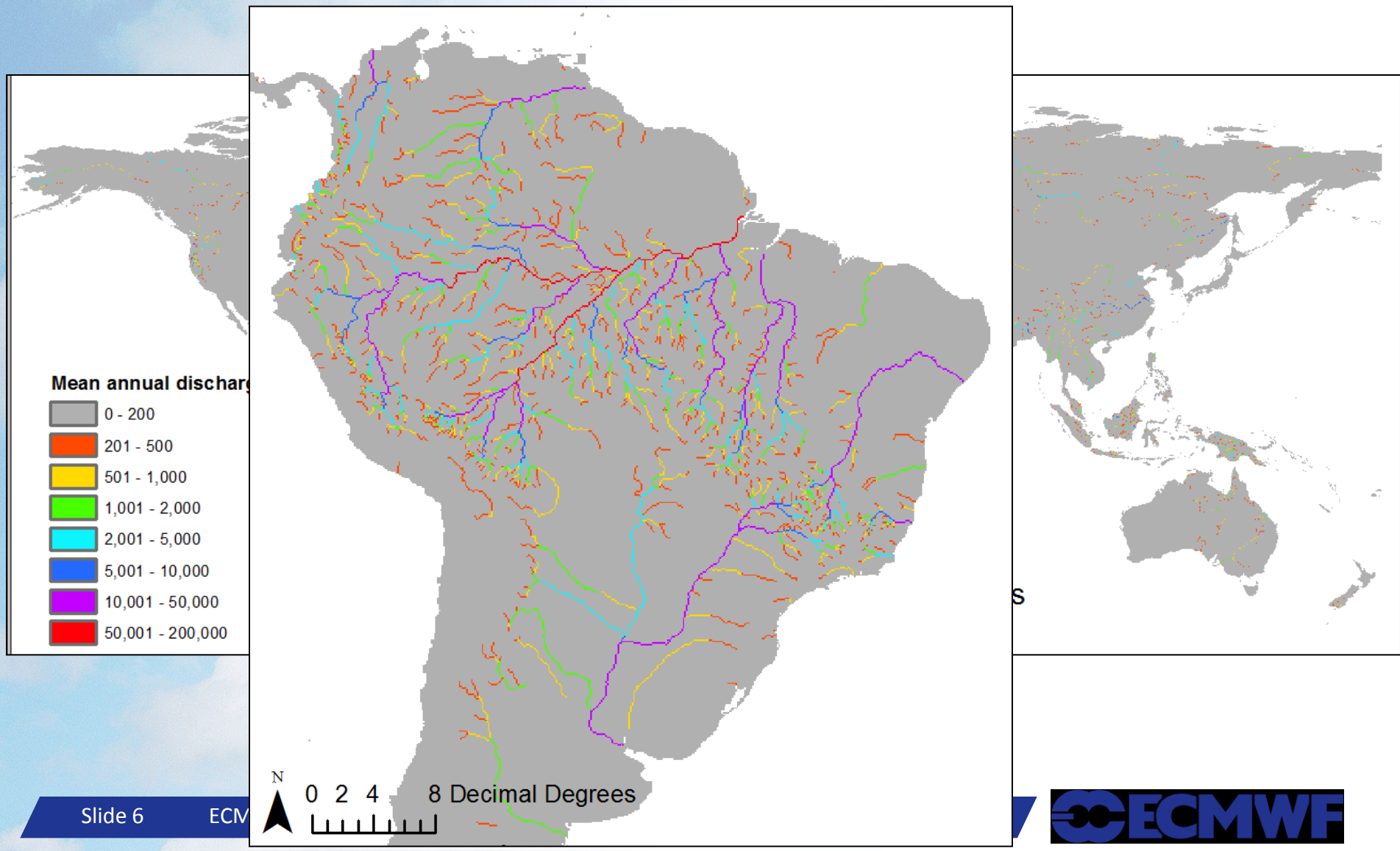
- **Forecast of meteorological variables**
- **Resolution: ~ 32 km for the first 10 days, ~ 65 km from day 11 onward**



Number of VarEps members exceeding 50 mm (green) or 150 mm (blue) in 10 days on the 01/07/2011

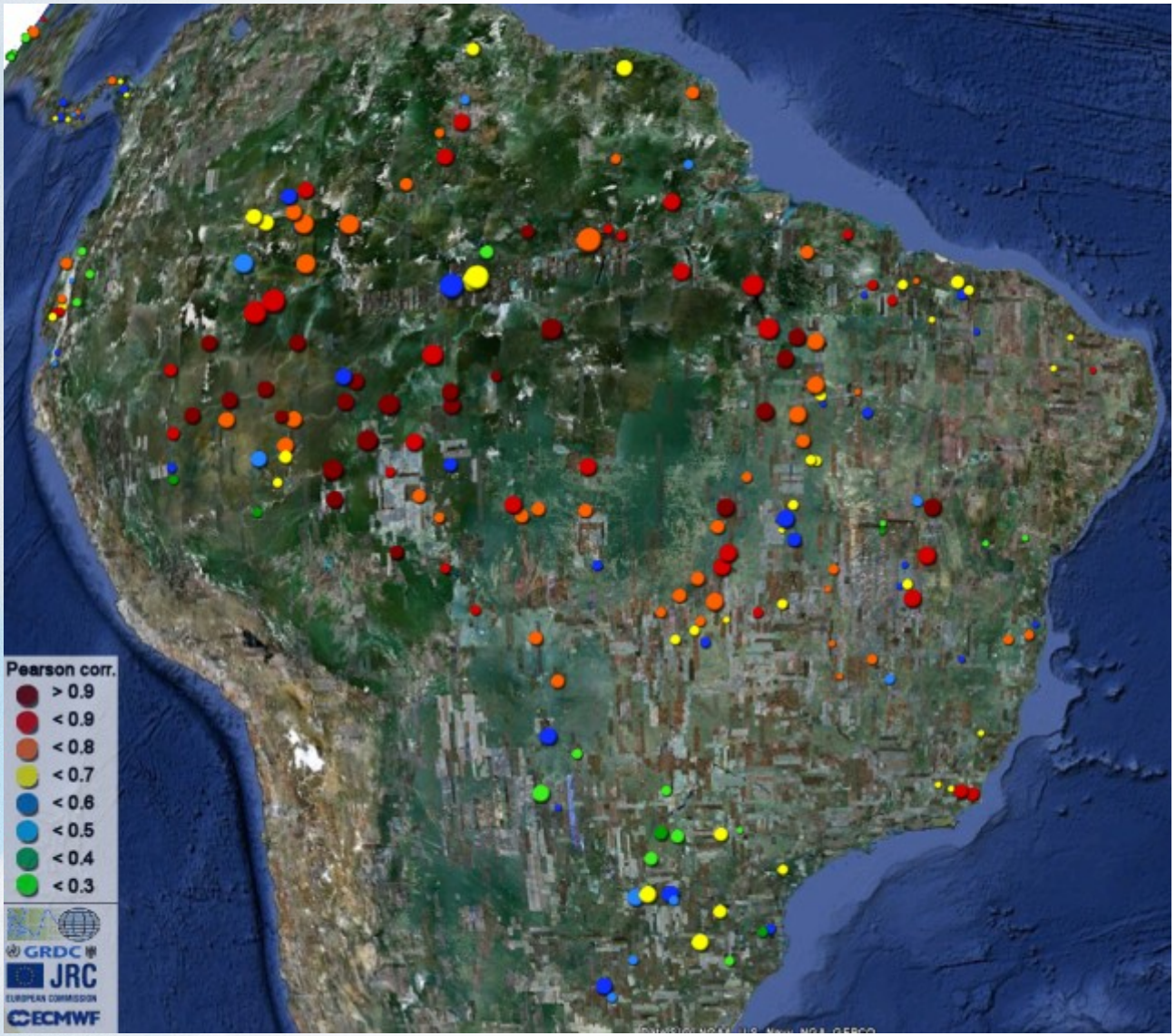
ECMWF

Results – long term run 1990-2010



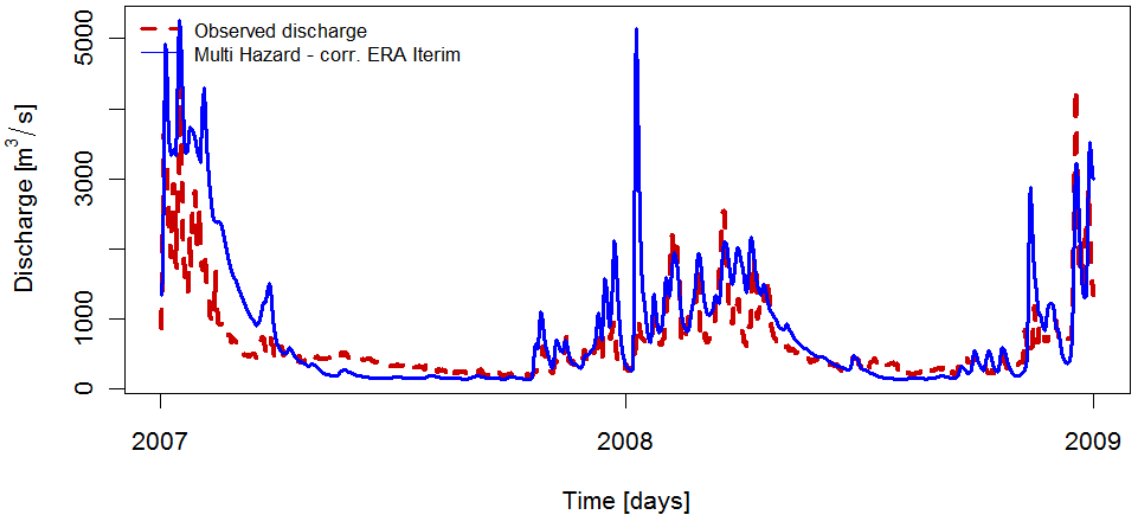
Results – long term run 1990-2010

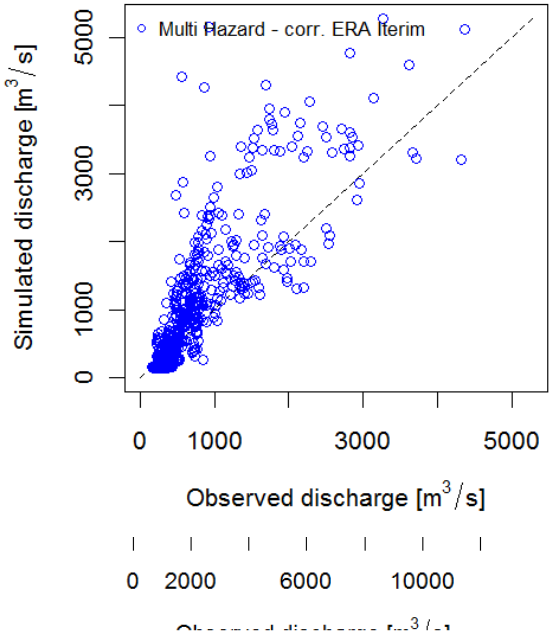
First results



Results – long term run 1990-2010

First results





Statistics - Multi Hazard March 2011

	Obs.	corr ERA I.
NS		0.0615
Pearson		0.[illegible]
RMSE		588.9
MAE		337.5
ME		-191.8
Mean	667	870
95 %	2001	3305
99 %	2940	4380
Max	4372	5267

NS: Nash-Sutcliffe
Pearson: Pearson correlation
RMSE: Root mean square error
MAE: Mean absolute error
ME: Mean error

Max	4767	12438

NS: Nash-Sutcliffe
Pearson: Pearson correlation
RMSE: Root mean square error

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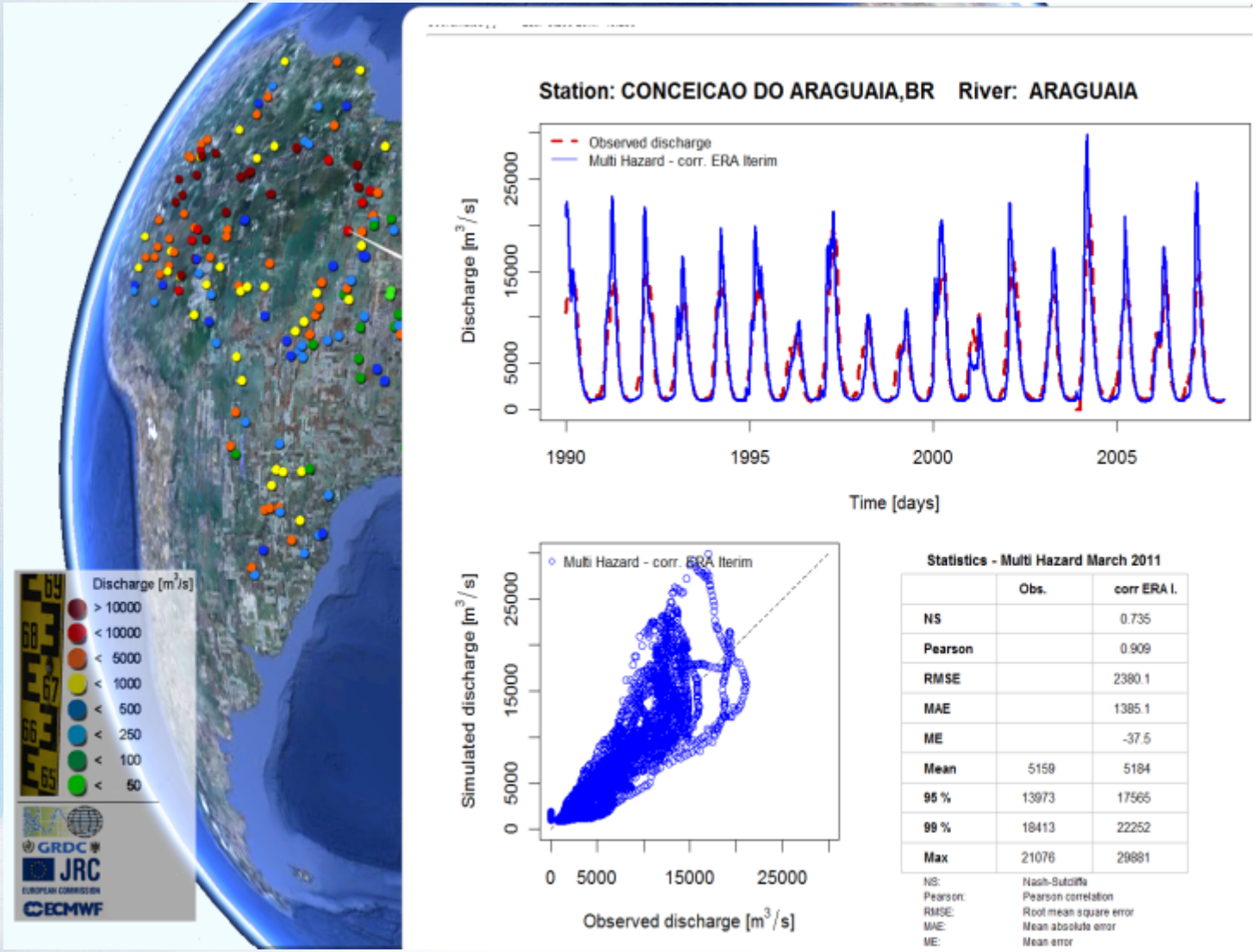
Results – long term run 1990-2010

First results



Statistics - Multi Hazard March 2011

	Obs.	corr ERA I.
NS		0.735
Pearson		0.909
RMSE		2380.1
MAE		1385.1
ME		-37.5
Mean	5159	5184
95 %	13973	17565
99 %	18413	22252
Max	21076	29881

NS: Nash-Sutcliffe
Pearson: Pearson correlation
RMSE: Root mean square error
MAE: Mean absolute error
ME: Mean error

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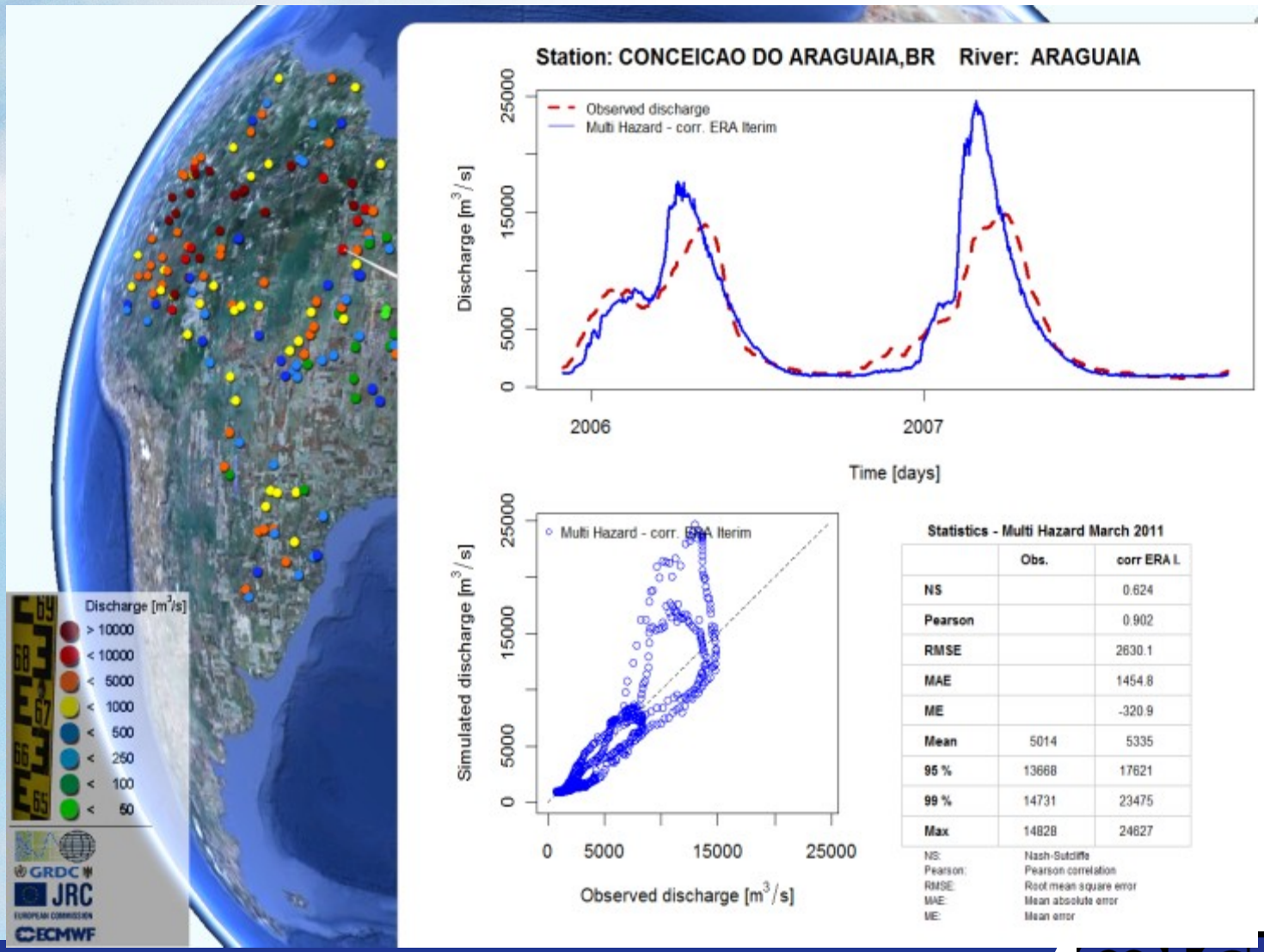
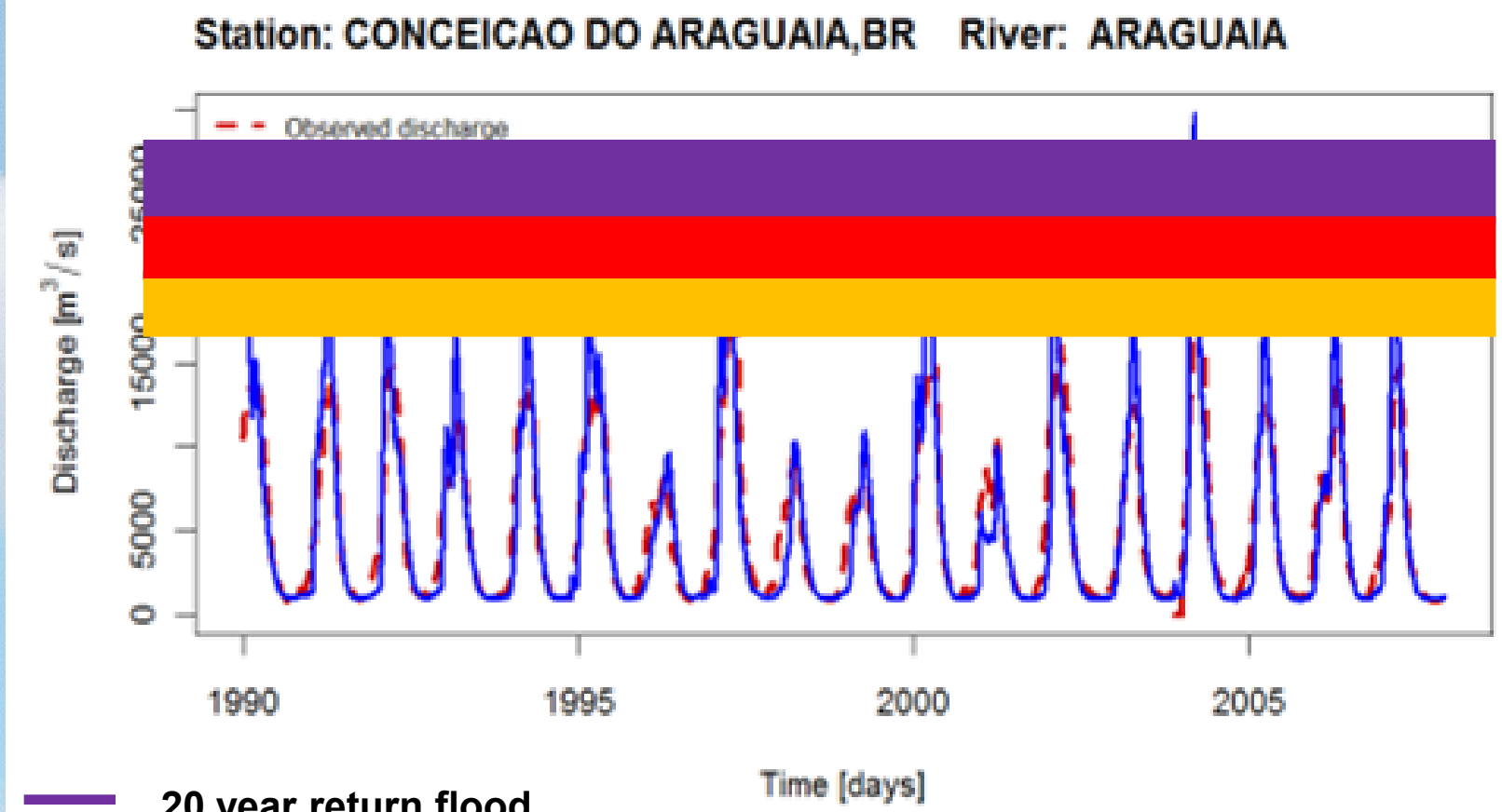
Results – long term run 1990-2010

First results



Thresholds

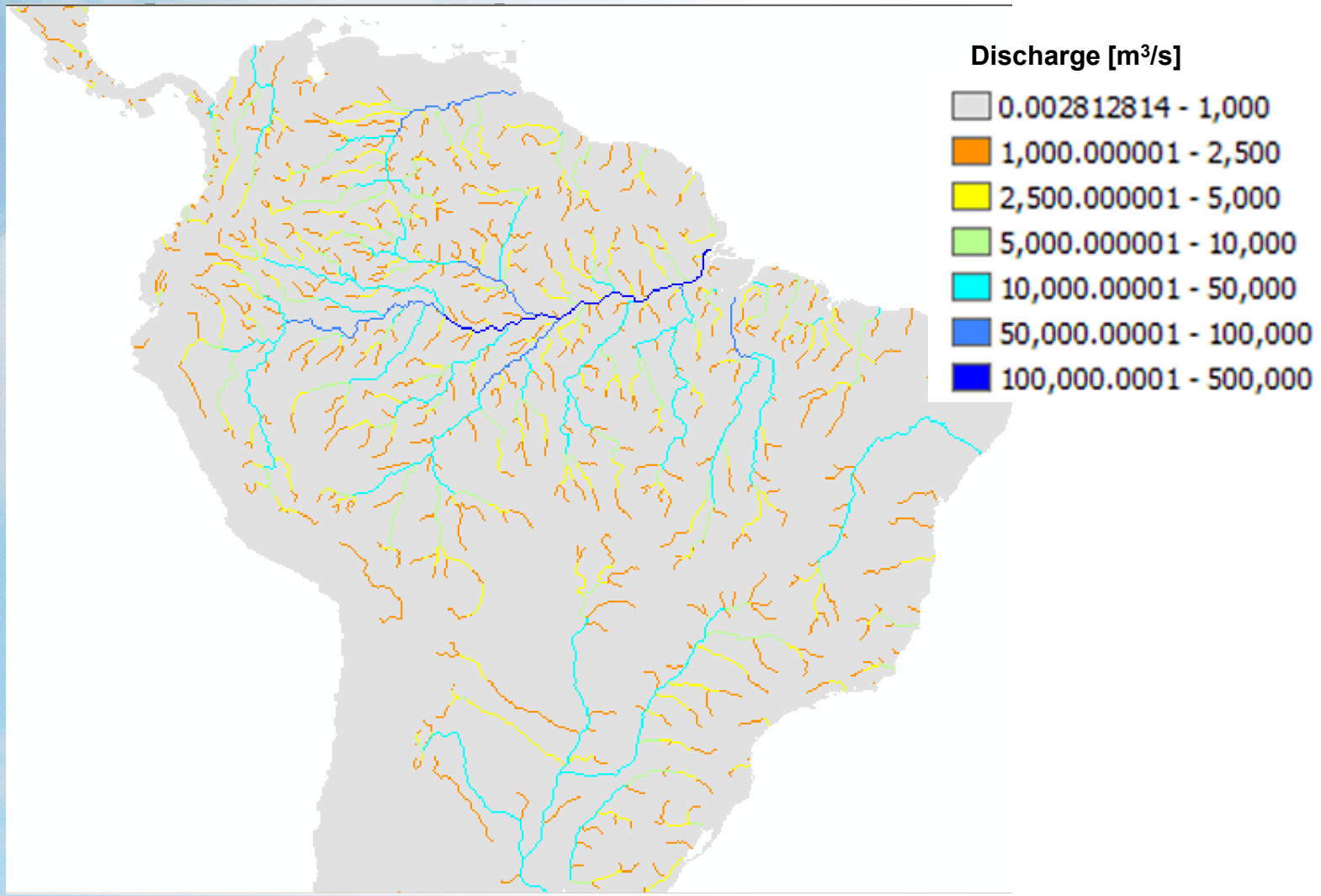
Threshold calculation 1990-2010
2,5, 20 year return flood from long term simulation



20 year return flood
5 year return flood
2 year return flood

5 year return flood 1990-2010

Threshold calculation 1979-2010
5 year return flood from long term simulation

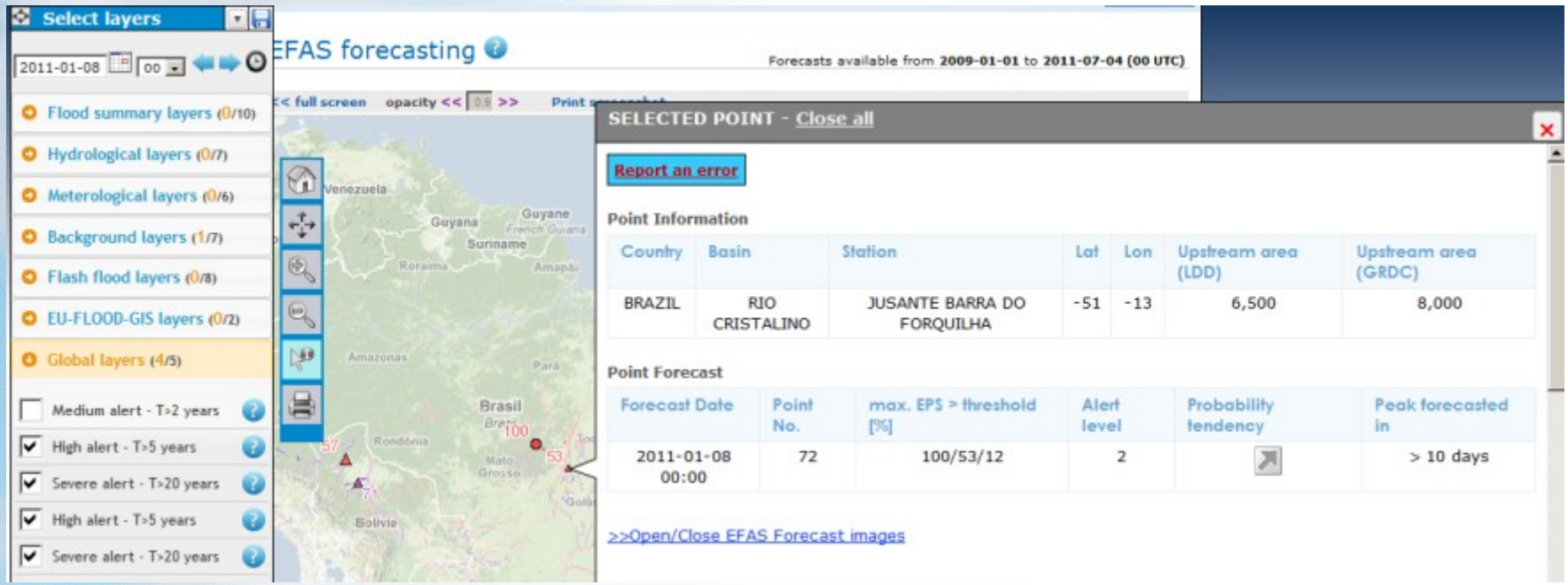


Results

Example of a forecast plot:

Forecast 8th January 2011 – Jusante Barra do Forquilha – Rio Cristalino

- max. half of the EPS member exceeds high alert level in more than 10 days

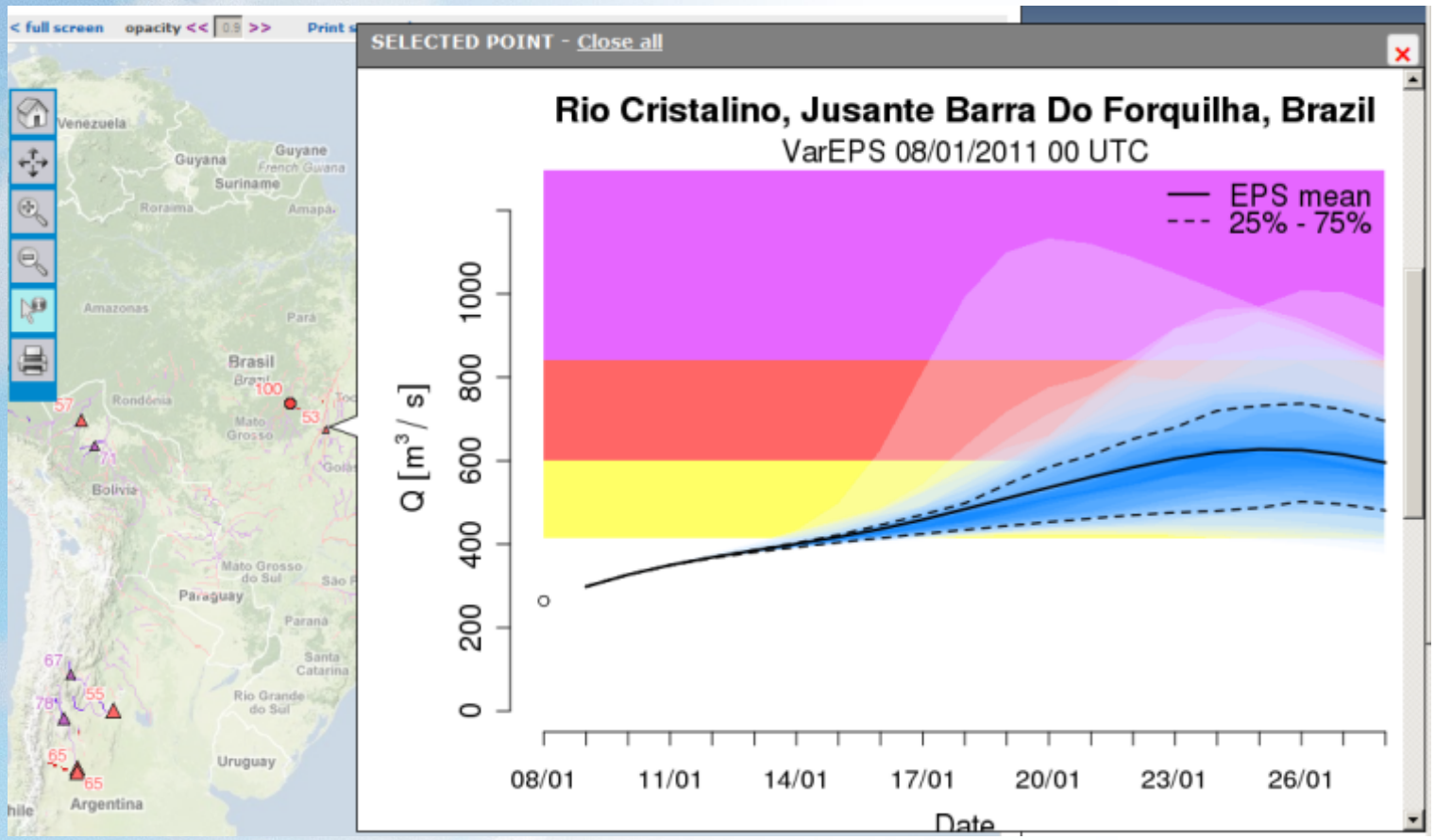


Results

Example of a forecast plot:

Forecast 8th January 2011 – Jusante Barra do Forquilha – Rio Cristalino

- half of the EPS member exceeds high alert level in more than 10 days



Severe threshold
=
20 year return period

high threshold
=
5 year return period

medium threshold
=
2 year return period

Results

Persistence Plot

High alert = exceeding 5 year return period

Forecasted days in January 2011

High Alert Level

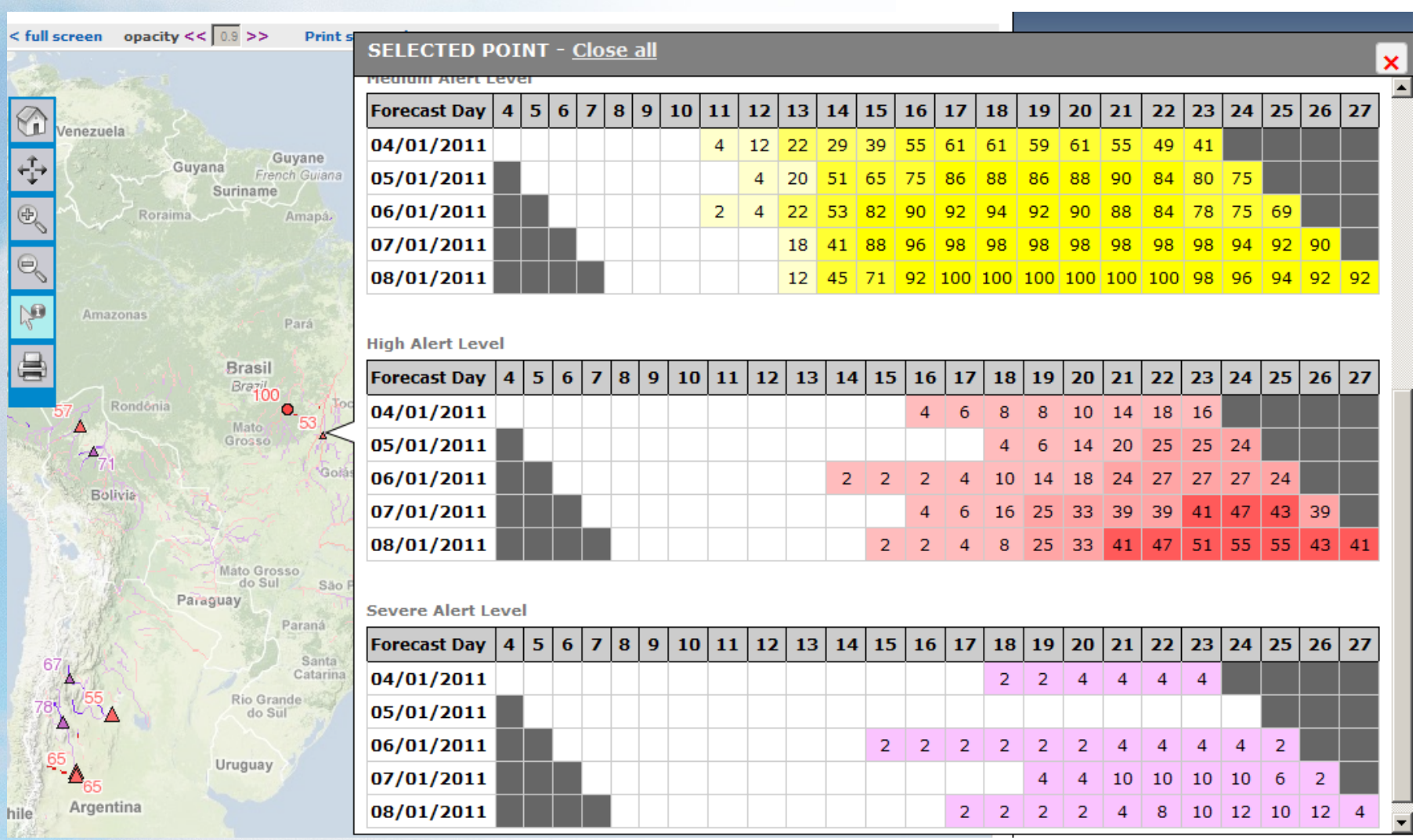
Forecast Day	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
04/01/2011													4	6	8	8	10	14	18	16				
05/01/2011															4	6	14	20	25	25	24			
06/01/2011											2	2	2	4	10	14	18	24	27	27	27	24		
07/01/2011																				41	47	43	39	
08/01/2011												2	2	4	8	25	33	41	47	51	55	55	43	41

Flood forecasted with 15 days of leadtime

A forecast for each day

Percentage of EPS exceeding the high alert level

Results



SELECTED POINT - Close all

Medium Alert Level

Forecast Day	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
04/01/2011								4	12	22	29	39	55	61	61	59	61	55	49	41				
05/01/2011									4	20	51	65	75	86	88	86	88	90	84	80	75			
06/01/2011								2	4	22	53	82	90	92	94	92	90	88	84	78	75	69		
07/01/2011										18	41	88	96	98	98	98	98	98	98	98	94	92	90	
08/01/2011										12	45	71	92	100	100	100	100	100	100	98	96	94	92	92

High Alert Level

Forecast Day	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
04/01/2011													4	6	8	8	10	14	18	16				
05/01/2011															4	6	14	20	25	25	24			
06/01/2011											2	2	2	4	10	14	18	24	27	27	27	24		
07/01/2011													4	6	16	25	33	39	39	41	47	43	39	
08/01/2011												2	2	4	8	25	33	41	47	51	55	55	43	41

Severe Alert Level

Forecast Day	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
04/01/2011															2	2	4	4	4	4				
05/01/2011																								
06/01/2011												2	2	2	2	2	2	4	4	4	4	2		
07/01/2011																4	4	10	10	10	10	6	2	
08/01/2011														2	2	2	2	4	8	10	12	10	12	4

Results

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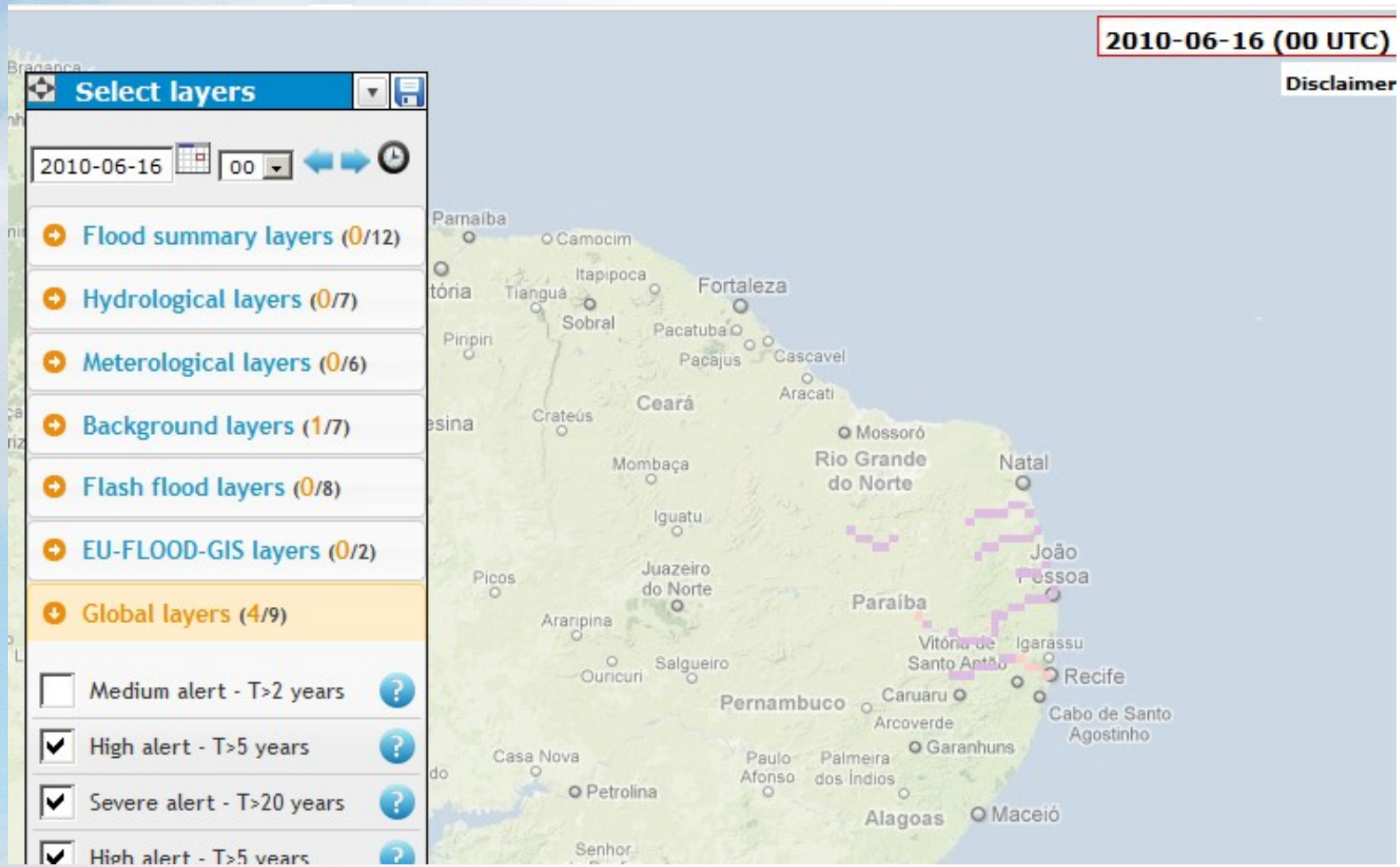
Forecast of 16th June 2010

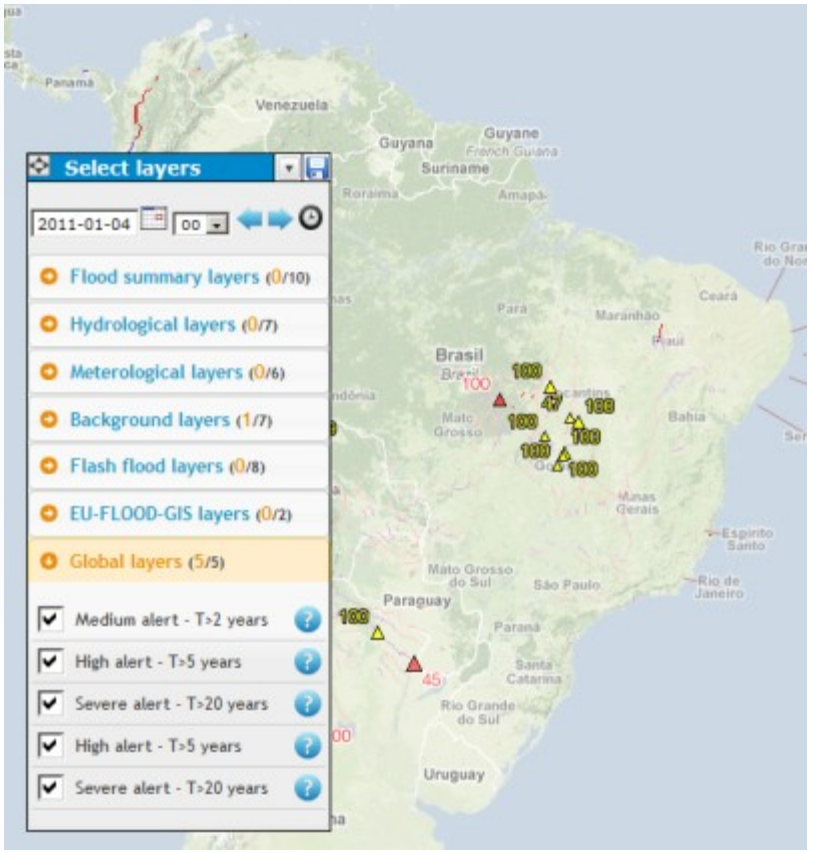


ECMWF

Results

Forecast of 26th December 2010

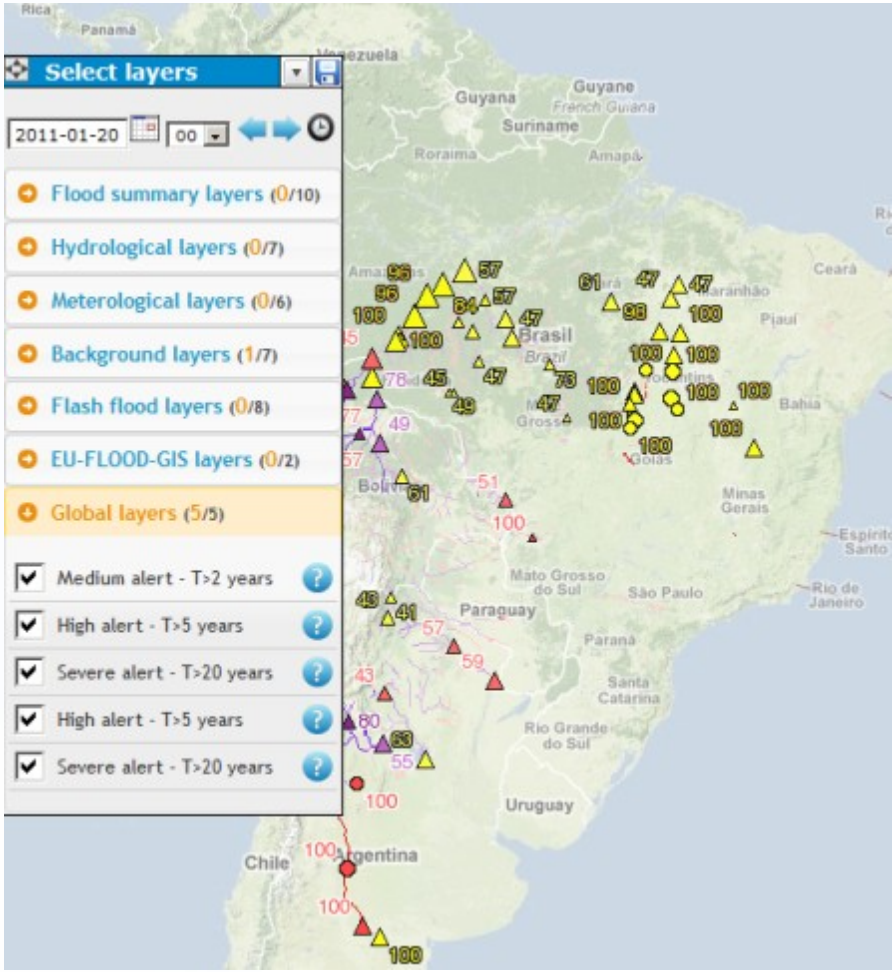
Forecast of 4th January 2011



Results

Forecast of 12th January 2011

Forecast of 20th January 2011



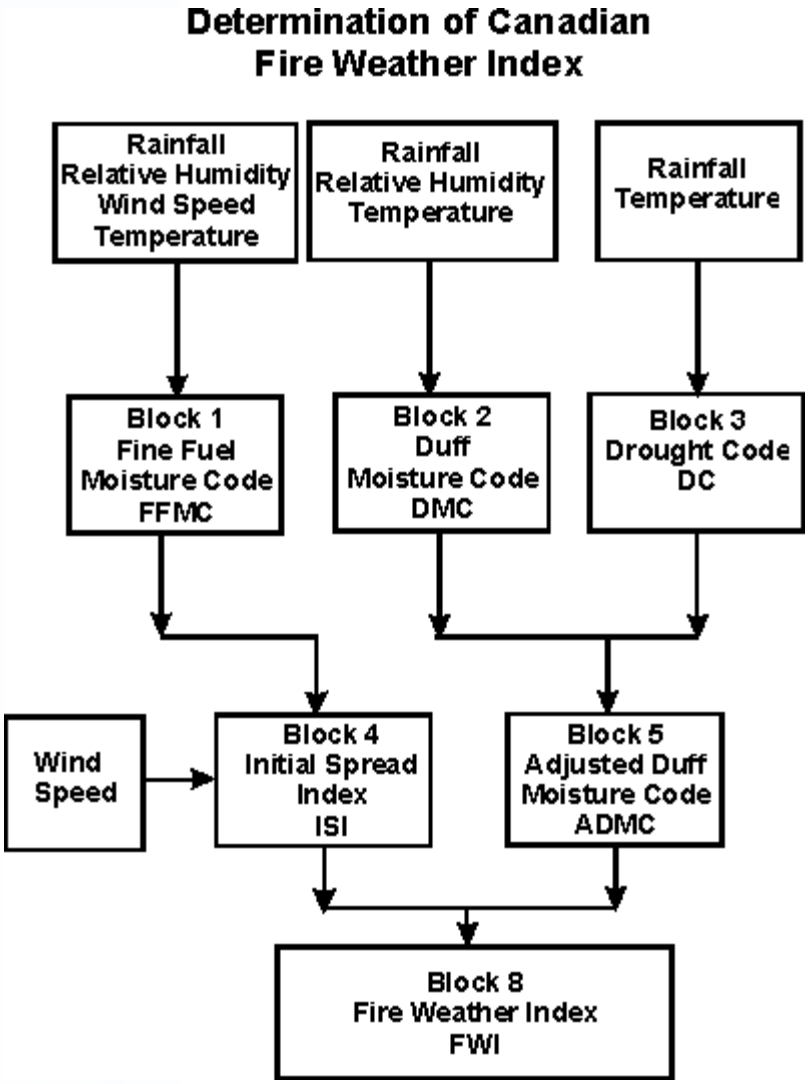
http://efas-is.jrc.ec.europa.eu

Fire

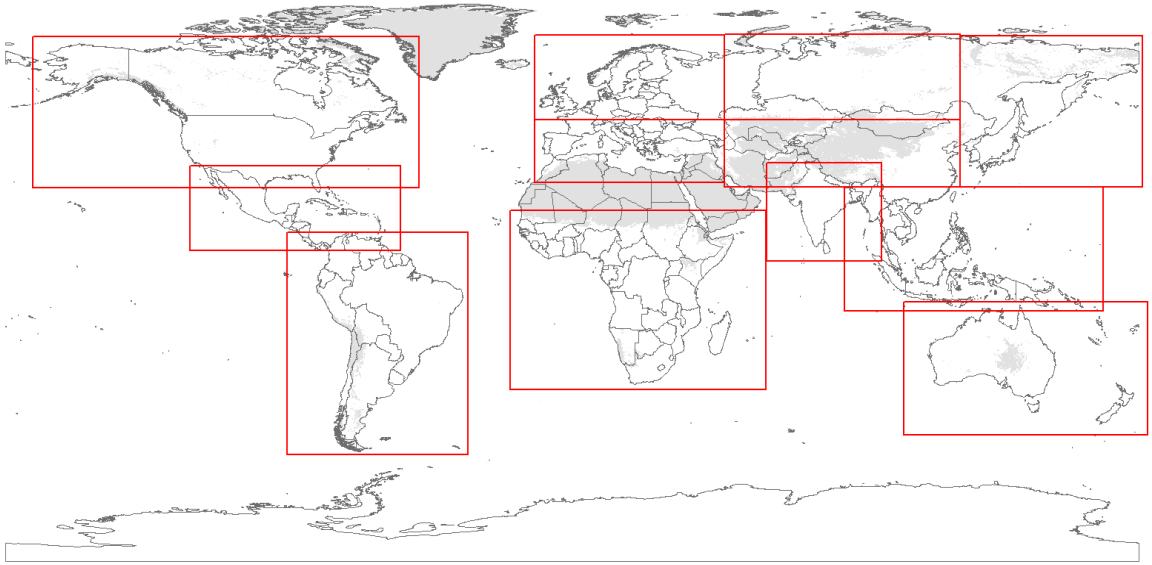
Contributions by:
Johannes Kaiser
Jutta Thielen*
Andrea Camia*
Jesus San Miguel*
*(JRC)

The Canadian Fire Weather Index

- All analysis is based on the Canadian Fire Weather Index
- Aim is to use ECMWF products (re-analysis, EPS forecasts)
- Verification against Satellite



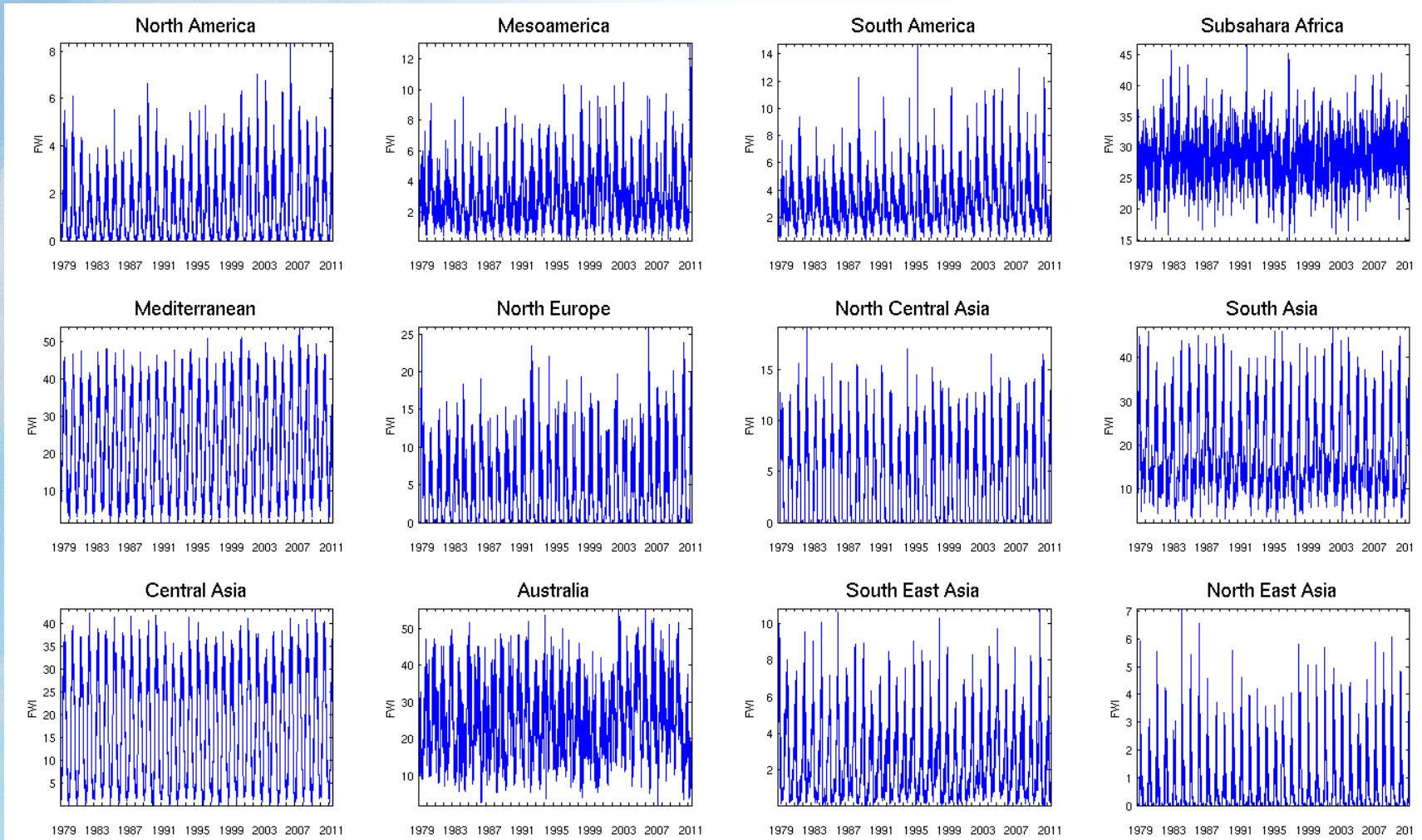
Analysis



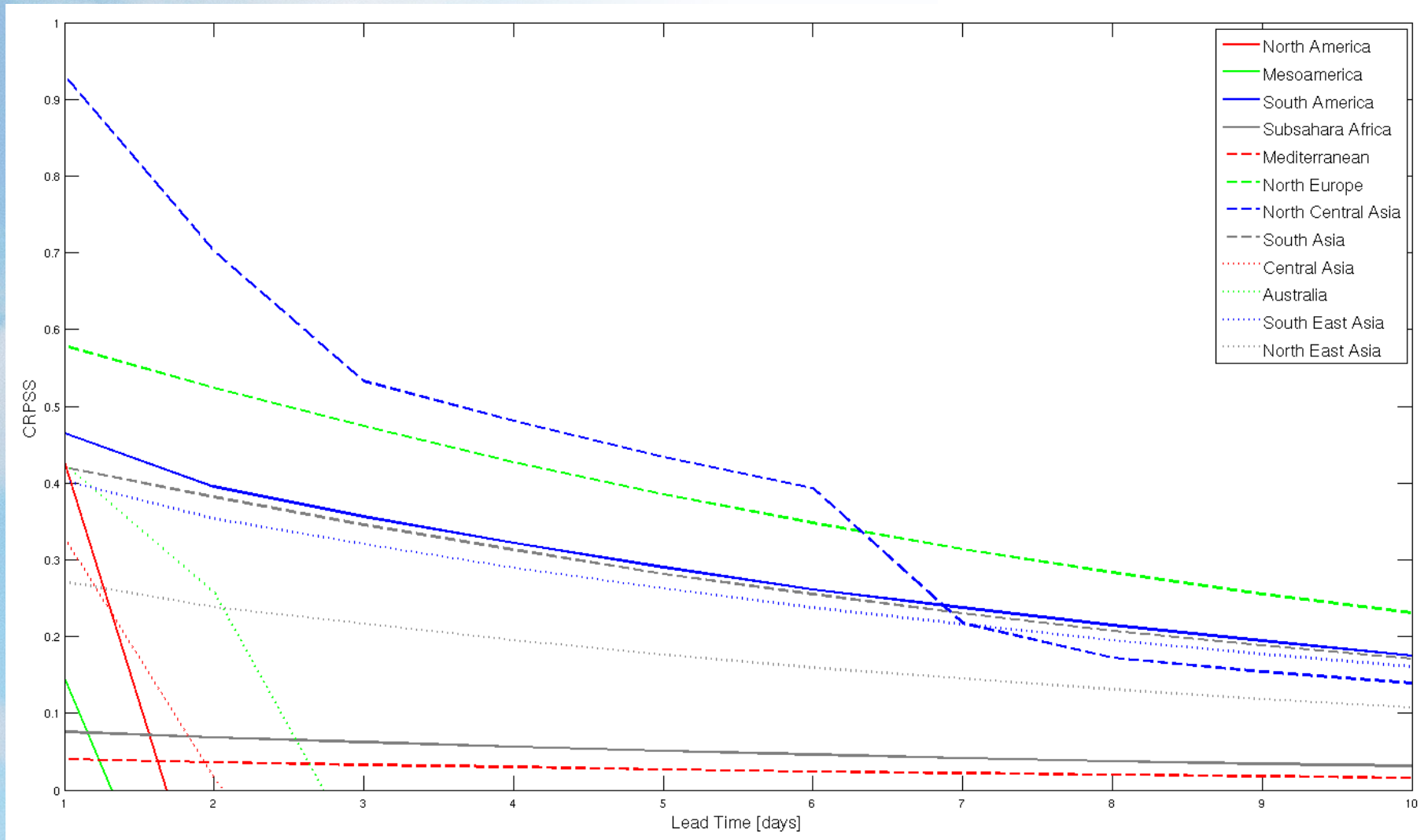
- Analysis performed on “World regions of the UN International Strategy for Disaster Reduction”. These regions reflect a mix of socio-eco-political and fire regime criteria

ERA-Interim

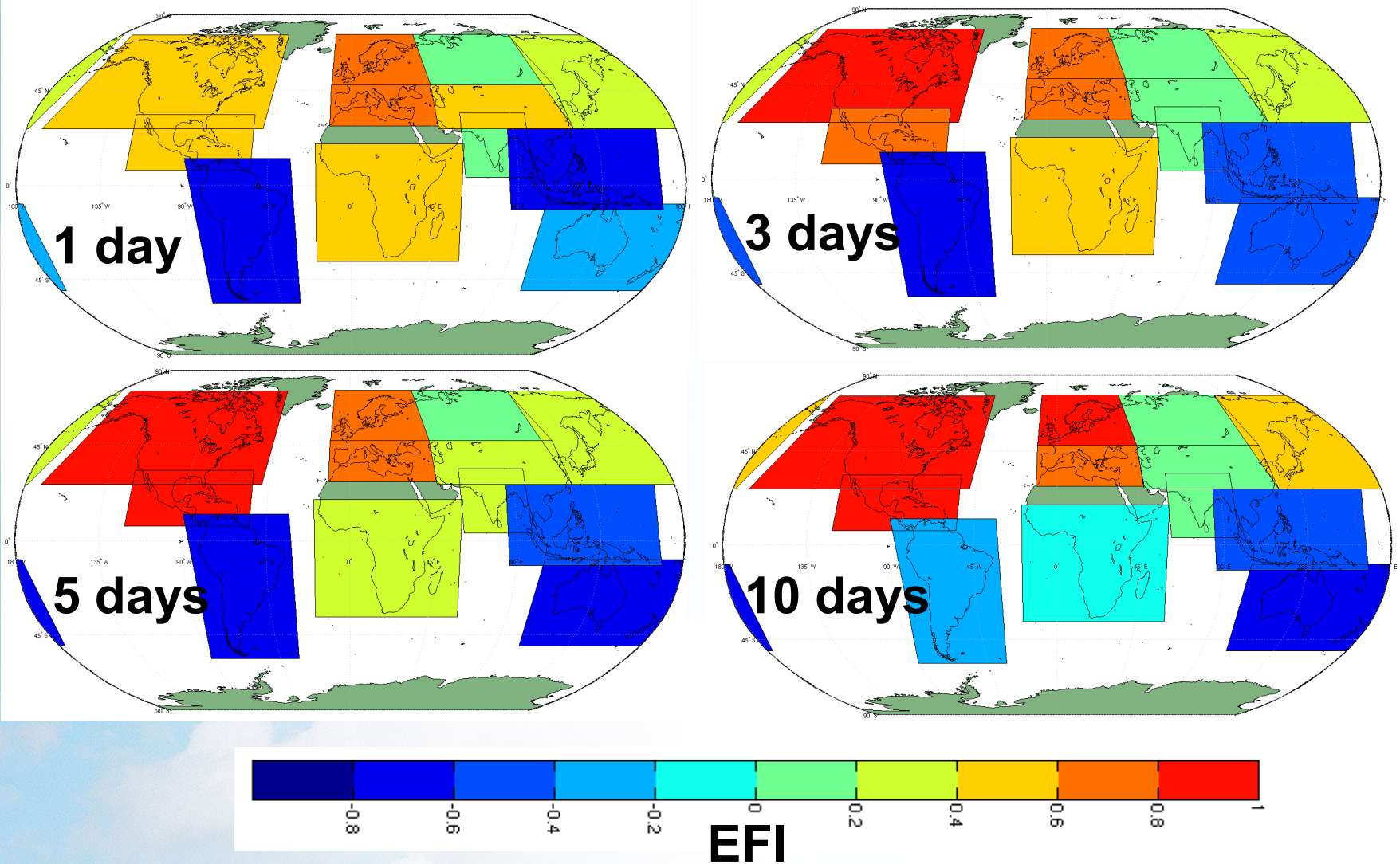
Temporal evolvement from 1979 to 2010 of the Fire Weather index using ERA Interim reanalysis data as forcing for 15 world regions



CRPSS for domains



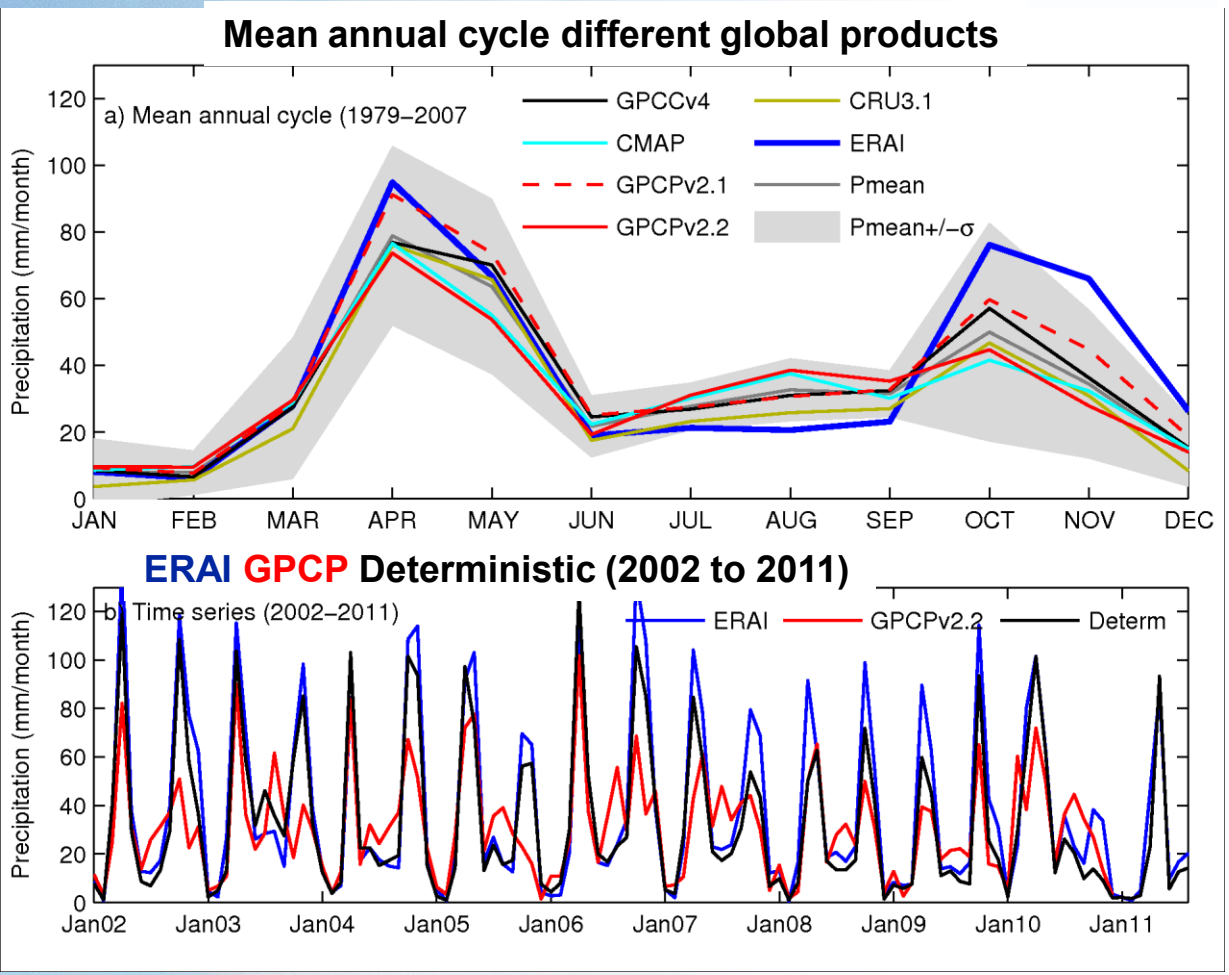
Example of using the EFI for the 18th of August 2008 for lead times of 1, 3, 5 and 10 days (regions)



DROUGHT
The 2010/11 drought in the Horn of Africa:
Monitoring and forecasts using ECMWF products

Contributions by:
Emanuel Dutra
Fredrik Wetterhall
Souhail Boussetta
Gianpaolo Balsamo
Linus Magnusson

Comparison of precipitation products in the HoA



- **Large uncertainty between products;**
- **Significant differences between GPCPv2.1 and GPCPv2.2**

- **Two rainy seasons (March-June - high; October-December –low);**

- **ERA-Interim seems to "overestimate" the peck rainfall during the rainy seasons**

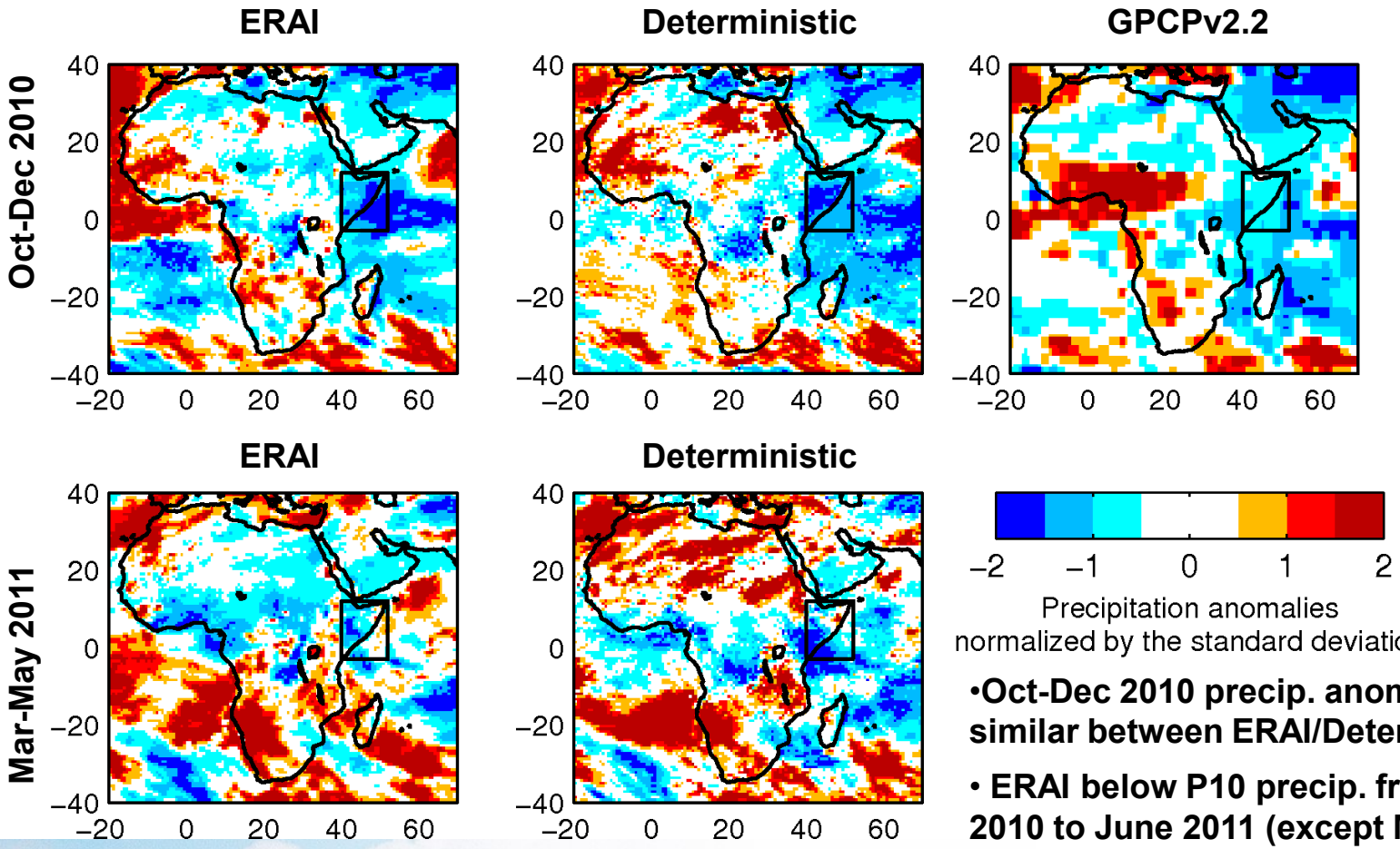
- **Good agreement between ERAI and deterministic, but determ. Is closer to GPCPv2.2**

- **Stronger Oct-Dec 2010 anomaly in determ. Than in ERAI**

- **What should be used as ground truth ?**

Averages over the HoA

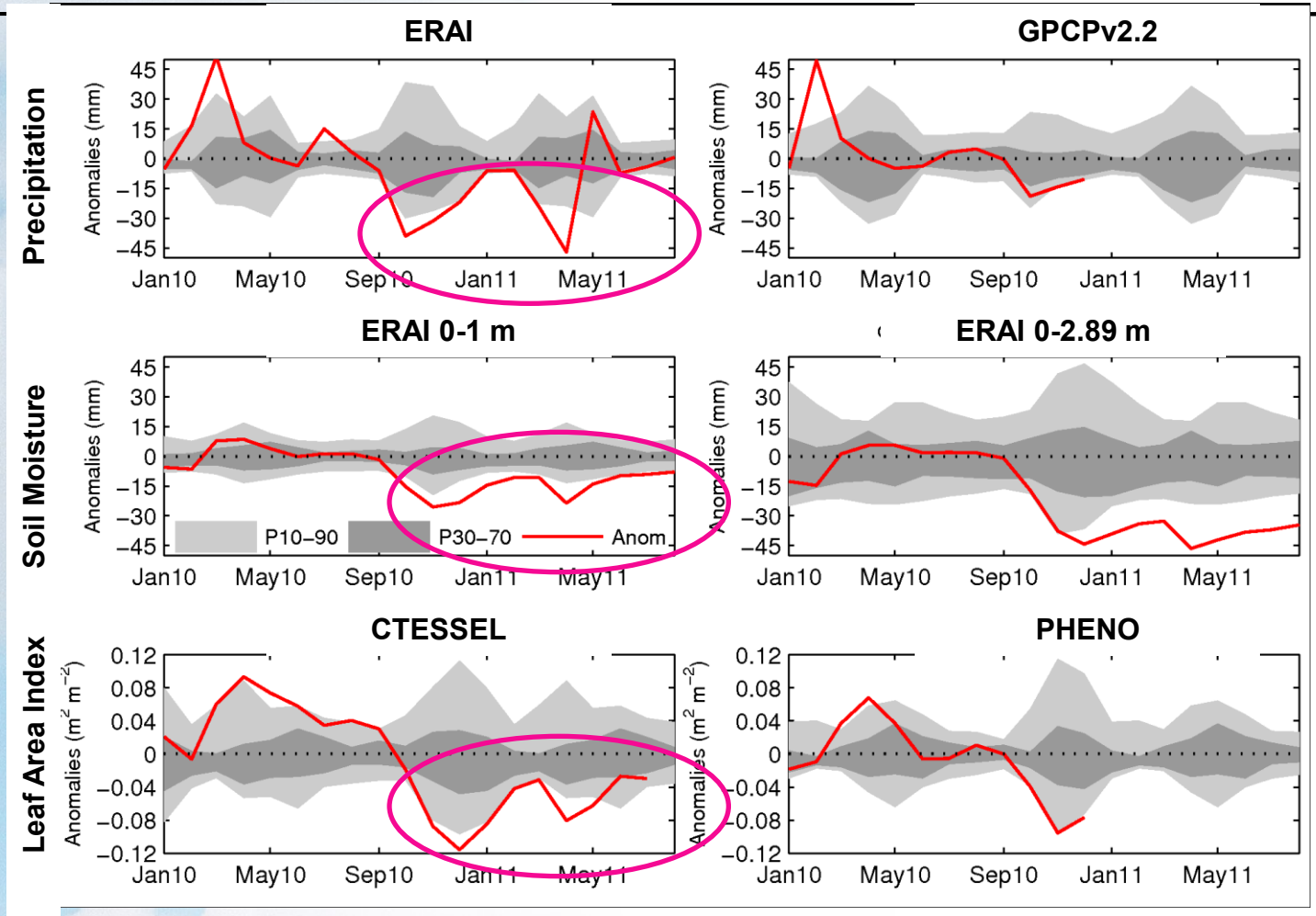
ERA-Interim/deterministic forecasts monitoring (precipitation)



- **Oct-Dec 2010 precip. anomaly pattern similar between ERAI/Determ and GPCP**
- **ERAI below P10 precip. from September 2010 to June 2011 (except May 2011, also in deterministic)**
- **2010/2011 accumulated precipitation (Aug– Jul) was the lowest in the 32 years record of ERAI.**

Averages over the HoA

ERA-Interim monitoring (soil moisture, LAI)

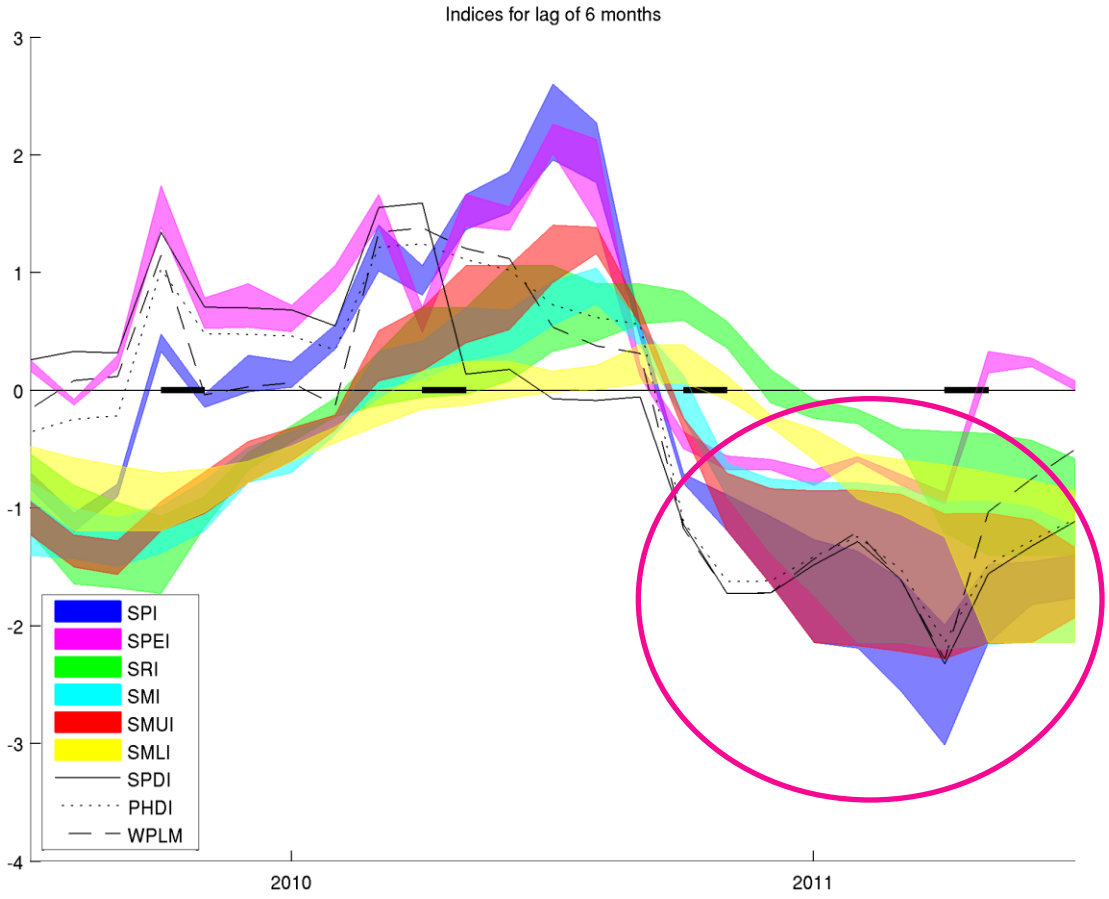


- **Precipitation anomalies are followed by soil moisture**
- **LAI anomalies follow the reduced water availability**
- **Soil moisture and LAI anomalies are consistent with long recover (memory effect)**

Averages over the HoA

ERA-Interim monitoring (drought indices)

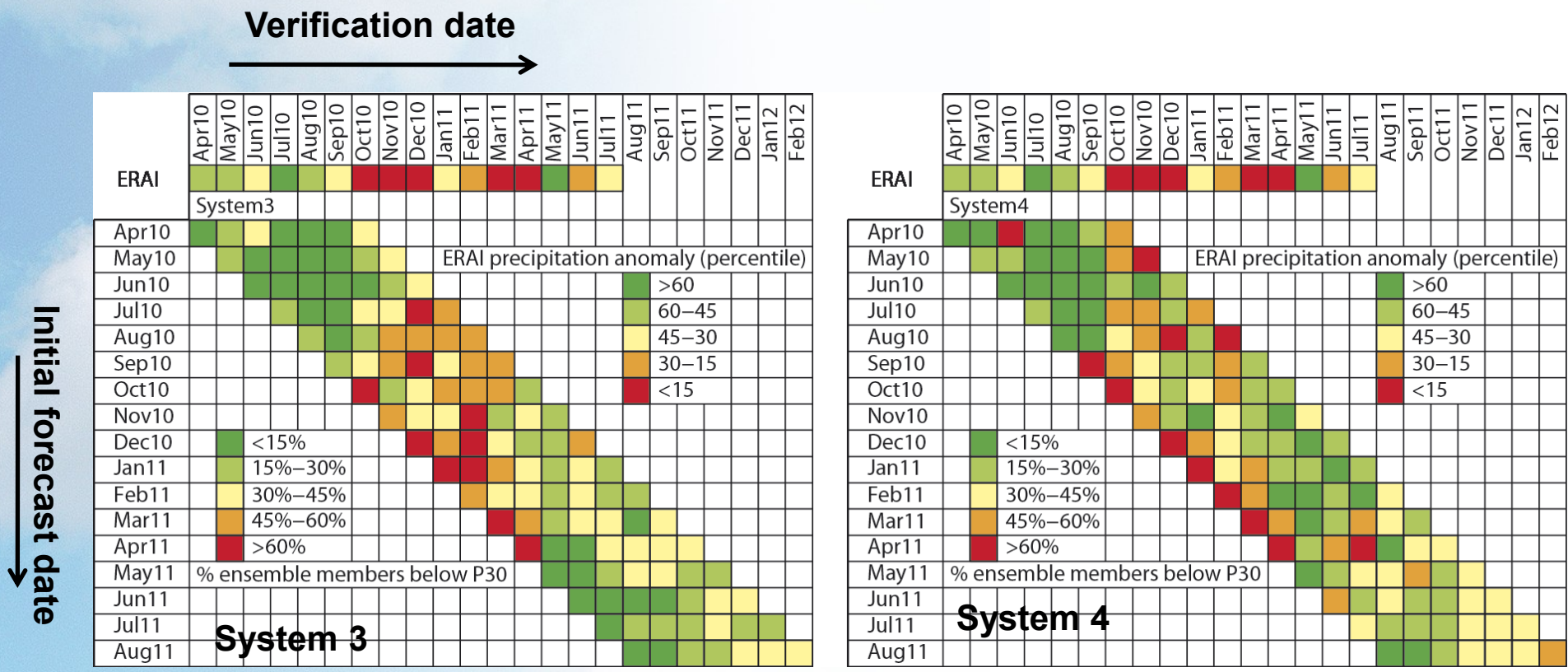
- **Drought indices calculated from ERAI 2010/2011**



- **All indices identify an anomalous situation;**
- **Different onset-intensity;**
- **Large uncertainty;**
- **Would this be helpful for decisions makers ?**

Averages over the HoA

Seasonal forecasts: April 2010 to August 2011

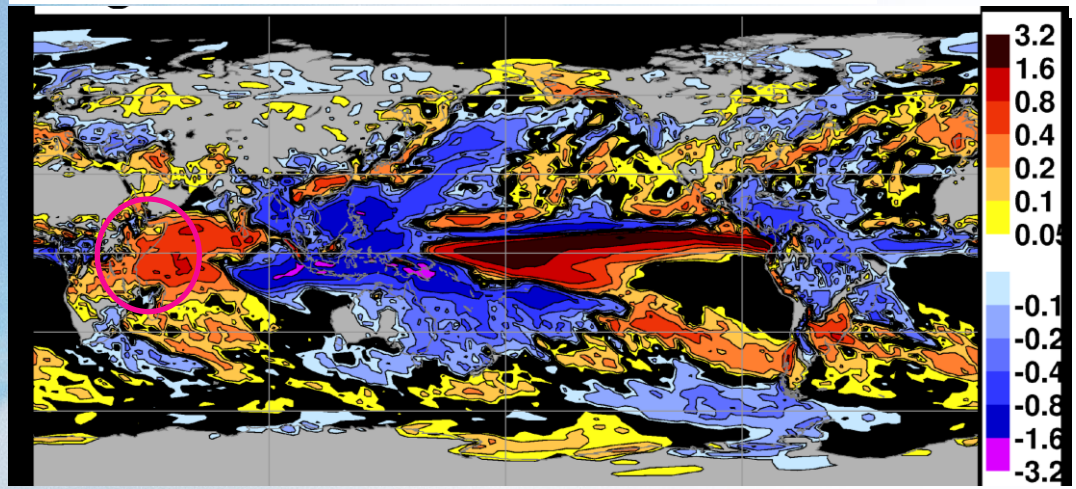


- Good in the first month of forecasts (S4 better)
- Forecasts of dry conditions for Oct-Dec 2010 since July 2010
- March-April 2011 very noisy, no consistency in the forecast
- Why the difference in skill between Oct-Dec / March-May (in both systems) ?

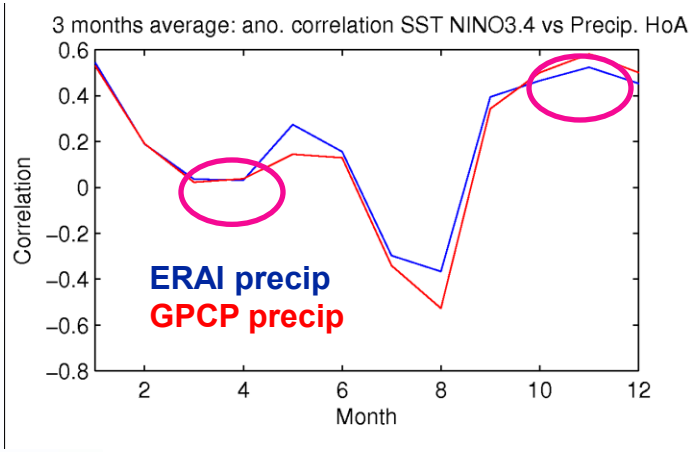
Averages over the HoA

Precipitation anomalies and link with ENSO

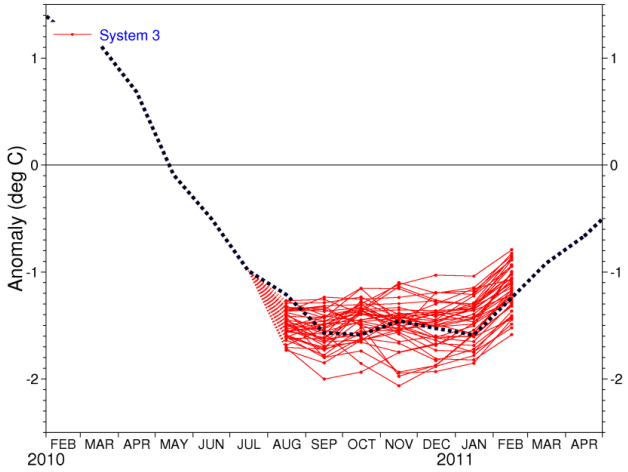
Regression ERAI Nino3.4 SST Sep-Nov. precip



Anom. correlation SST Nino3.4 precip HoA



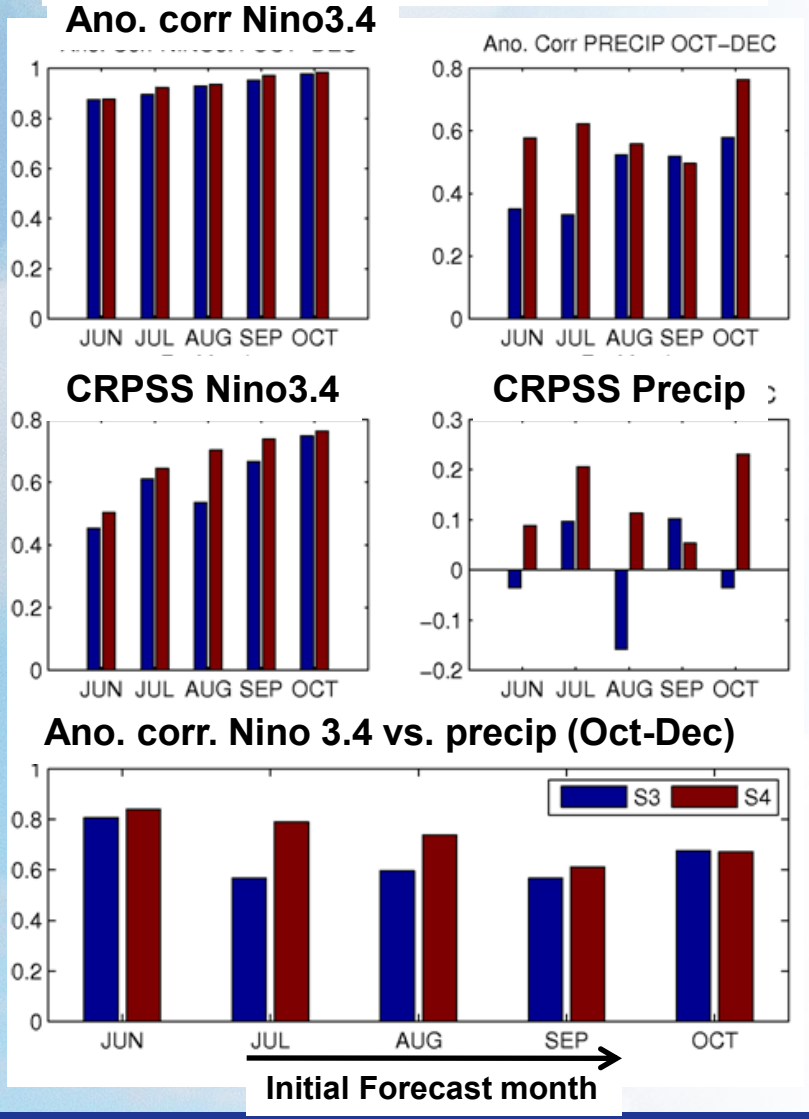
S3 Nino3.4 forecast Aug 2010



- **Oct-Dec precipitation anomalies (both ERAI and GPCP) connected with Nino3.4 : Some predictability in S3/S4 ? Associated with the Indian Ocean dipole**
- **Main rainy season March-June no relation with Nino3.4 (difficult for S3/S4 ?), mainly driven by ITCZ**
- **2010 strong La Niña (2th strongest since 1979)**

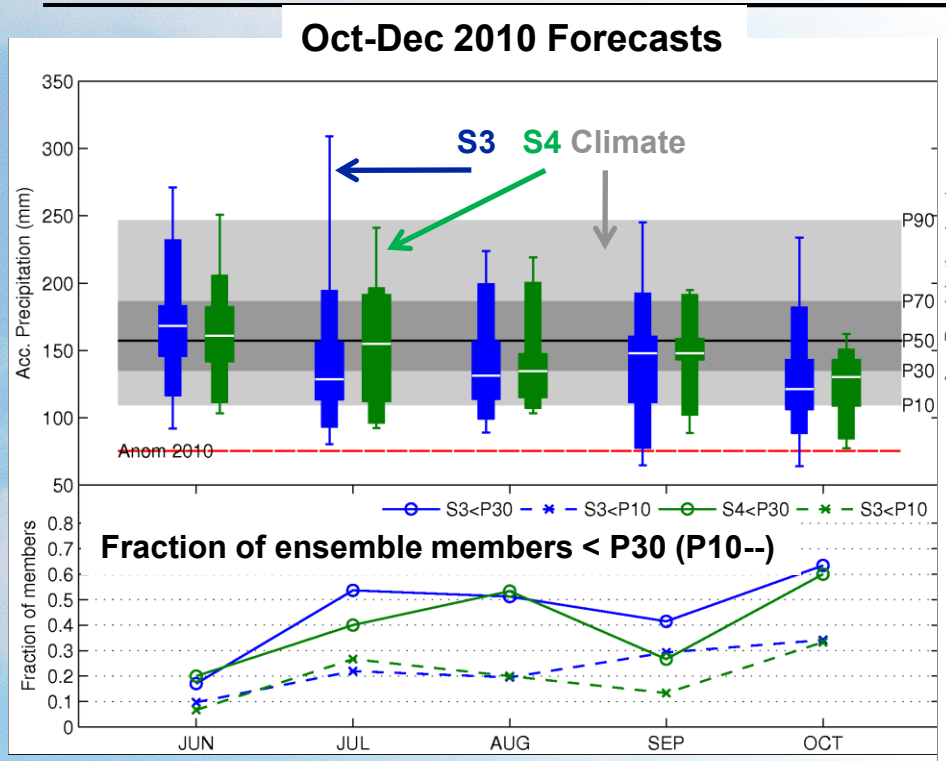
Seasonal forecasts S3/S4 skill

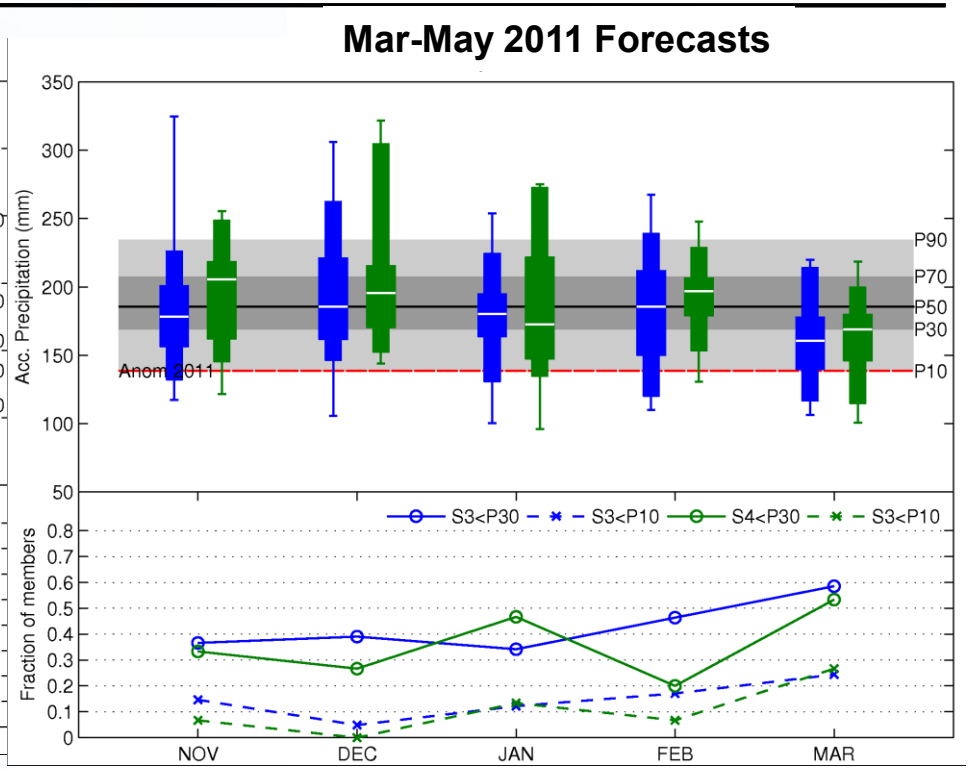
Skill of S3/S4 SSTs, precip for Oct-Dec



- Both S3/S4 show a good skill for Nino3.4 (Oct-Dec) 4 months in advance.;
- S3 skill for precipitation is very low (CRPSS<0 Jun, Aug, Oct).;
- S4 shows some skill in predicting precipitation in the HoA region;
- The teleconnection between Nino3.4 and precip is present in both S3 and S4 up to 4 months in advance.
- Precip scores for Mar-May are very low in both S3/S4 (especially for Apr)

Seasonal forecasts 2010/11





- **From July 2010 onwards S3 > 50% (below percentile 30) and >20% (below percentile 10), persistent;**
- **S4 similar S3 but predicting normal situation in September (only 15 ensemble members, S3 has 41);**
- **Mar-May 2011 forecasts from Nov to Feb indicated normal conditions, only the March forecasts pointed to a dry situation;**
- **Would this information be useful to the population ? Decision makers ?**
- **How to process / deliver these forecasts to users ?**

Overview

- **ERA-Interim monitoring**
  - ERAI precipitation comparable with other global datasets (large uncertainty)
  - 2010/11 anomaly of precipitation well captured by ERAI, with a consistent signal in soil moisture and LAI anomalies
  - Ongoing analysis with more drought indexes. The results point to the feasibility of using ERA-Interim as a monitoring tool for drought conditions (near-real time update very important)
- **Seasonal Forecasts**
  - October to December precipitation anomalies in 2010 were predicted from July onwards, due to the strong La Niña situation;
  - S4 outperforms S3 in the prediction of precipitation and nino3.4 (S4 is penalized in the 2010/11 case study – hindcast period: 15 ensemble members);
  - October-December 2011 forecasts point to normal situation;
- **Ongoing:**
  - Further analysis of the ENSO-Indian Ocean-Precipitation (HoA);
  - Drought indices based on ERAI, more case studies (Russia 2010), extend drought indices from monitoring to seasonal forecasts.
  - Disseminate these results as possible applications of ERAI and seasonal forecasts to end users.