Seamless forecasting of floods and droughts on a global scale

FLORIAN PAPPENBERGER, **FREDRIK WETTERHALL**, EMANUEL DUTRA, FRANCESCA DI GIUSEPPE, KONRAD BOGNER, LORENZO ALFIERI, HANNAH L. CLOKE, JUTTA THIELEN, PETER SALAMON, VERA THIEMIG

Seamless forecasting of extreme events on a global scale

• Hires forecasts	10 days	Twice daily
• Ensemble forecasts	10-15days	Twice daily
• Extended ensemble forecasts	15-32 days	Twice weekly
• Seasonal forecasts	7 months	Monthly

– Any merged forecast will have “seams”, they are not seamless!

Seemingly seamless forecasting of floods and droughts on a global scale

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Seamless forecasting of extreme events on a global scale

10 days

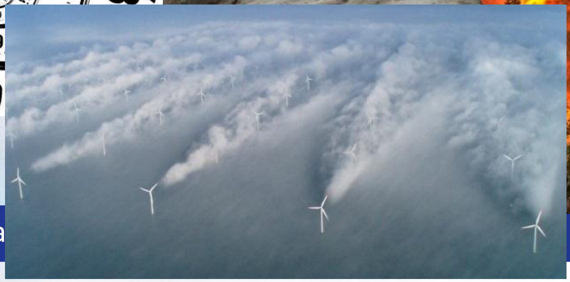
ECMWF product	Floods	Wildfire	Droughts	Malaria	Wind	Cyclone
High resolution	✓				✓	✓
Ensemble	✓	✓			✓	✓
Monthly			✓	✓		✓
Seasonal			✓	✓		
Re-Analysis	✓	✓	✓	✓		✓

6/12 Months

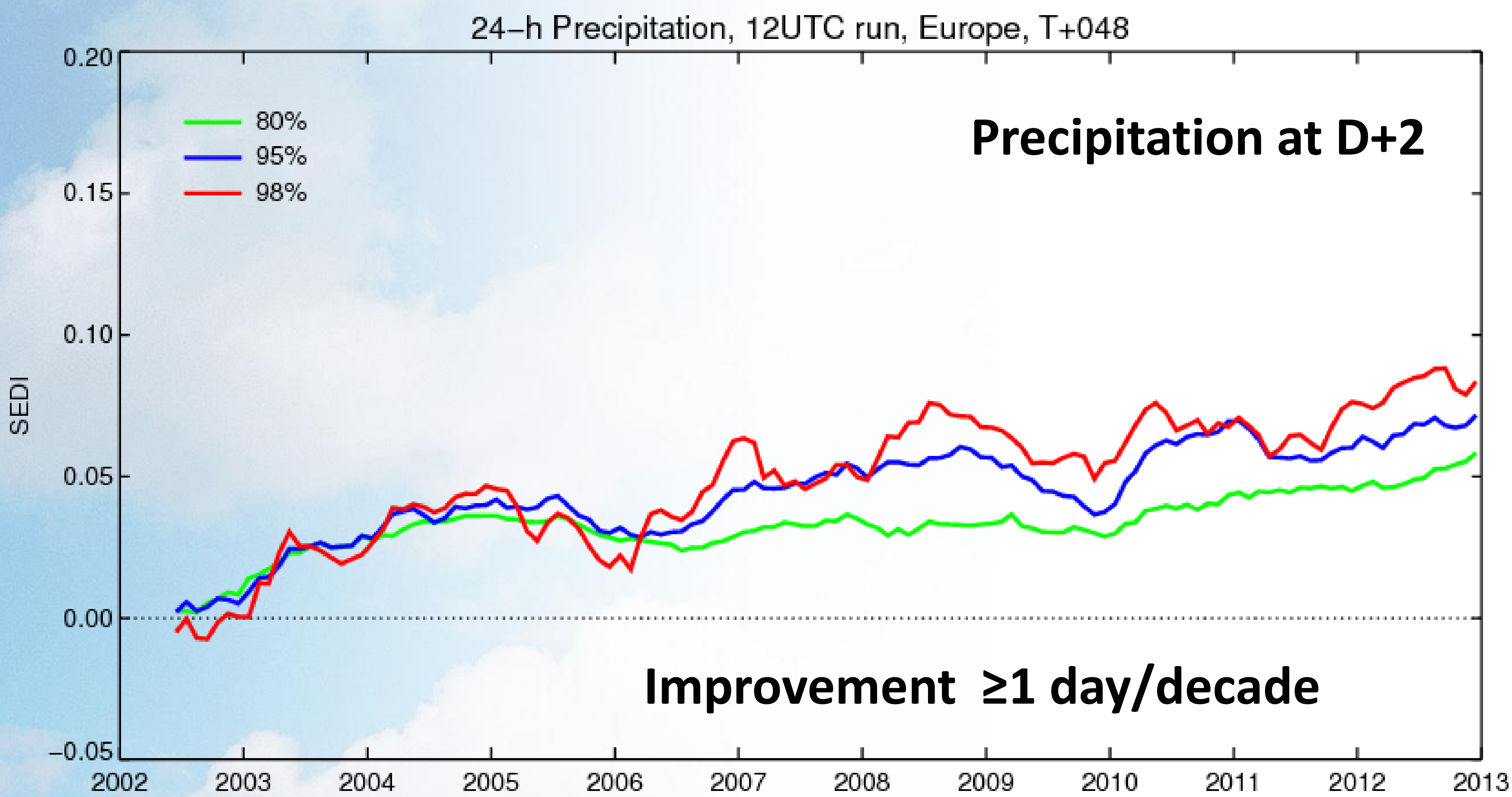
Climate






Evaluating extremes: Evolution of forecast skill



Evaluating extremes: ECMWF 'Severe Event Catalogue'

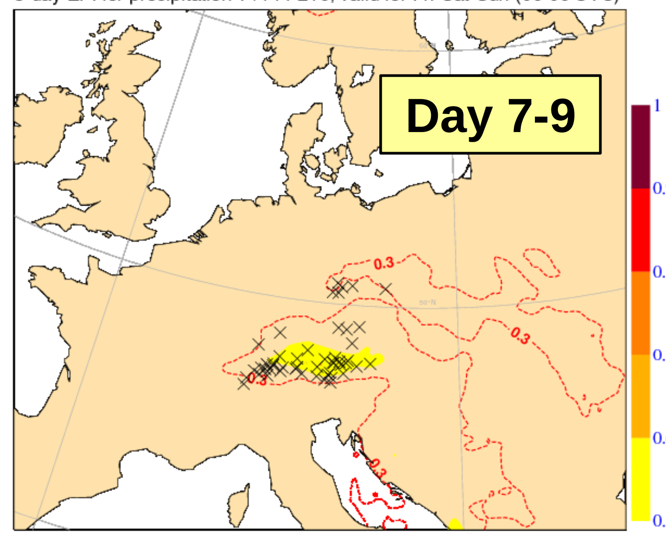
Jun 2013	Flood	Central Europe
Aug 2013	Flood	Russia
Sep 2013	Flood	Colorado
Oct 2013	Windstorm	NW Europe
Nov 2013	Typhoon Haiyan	Philippines
Nov 2013	Extreme rainfall	Sardinia, Italy
Nov 2013	Windstorm	Scandinavia
Dec 2013	Windstorm	NW Europe
Dec 2013	Windstorm+flood	British Isles
Dec 2013	Ice storm	Canada and US
Dec 2013	Extreme snowfall	Israel
Jan 2014	Cold spell	US
Jan 2014	Extreme snowfall	Central/Southern Europe
Feb 2014	Freezing rain	Slovenia
Feb 2014	Windstorm+flood	British Isles
Feb 2014	Extreme snowfall	Eastern US
Mar 2014	Windstorm	Scandinavia
Apr 2014	Tornadoes	US Midwest
May 2014	Flood	Balkans

The daily, weekly to monthly scale: EFI, EFAS and GloFAS

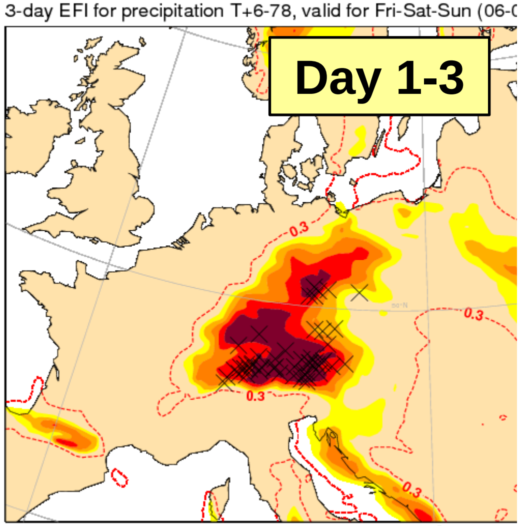
Extreme Forecast Index

- First indication already 8-9 days ahead of potential extreme event in this area
- Signal got gradually stronger closer to the event
- From 4-5 days in advance the area of extreme observed precipitation was highlighted quite well with EFI close to 1

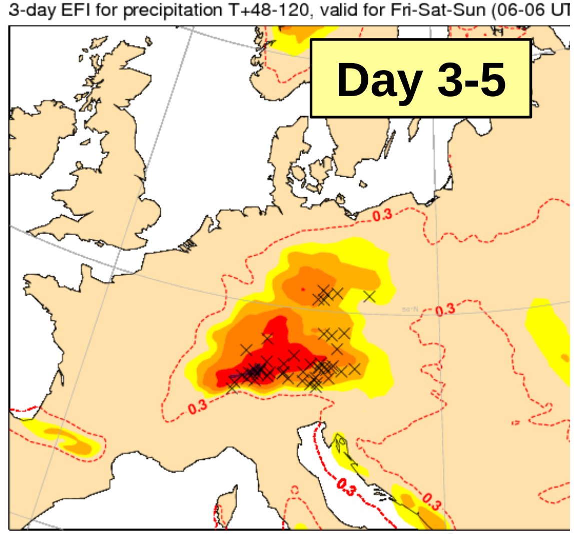
3-day EFI for precipitation T+144-216, valid for Fri-Sat-Sun (06-06 UTC)



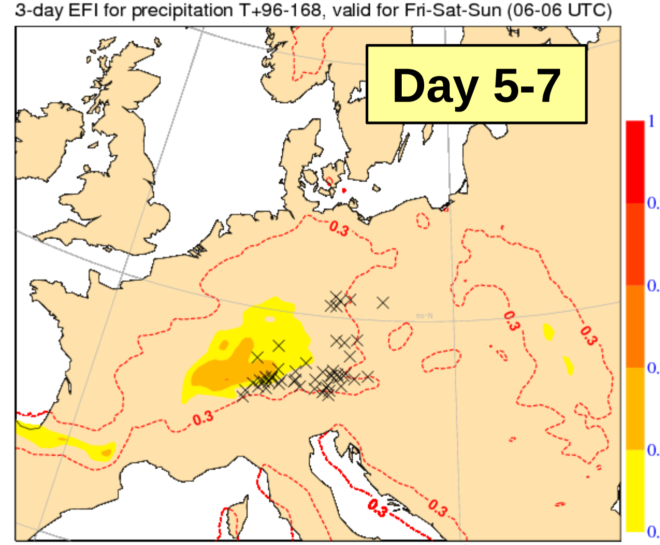
3-day EFI for precipitation T+6-78, valid for Fri-Sat-Sun (06-0



3-day EFI for precipitation T+48-120, valid for Fri-Sat-Sun (06-06 UT



3-day EFI for precipitation T+96-168, valid for Fri-Sat-Sun (06-06 UTC)

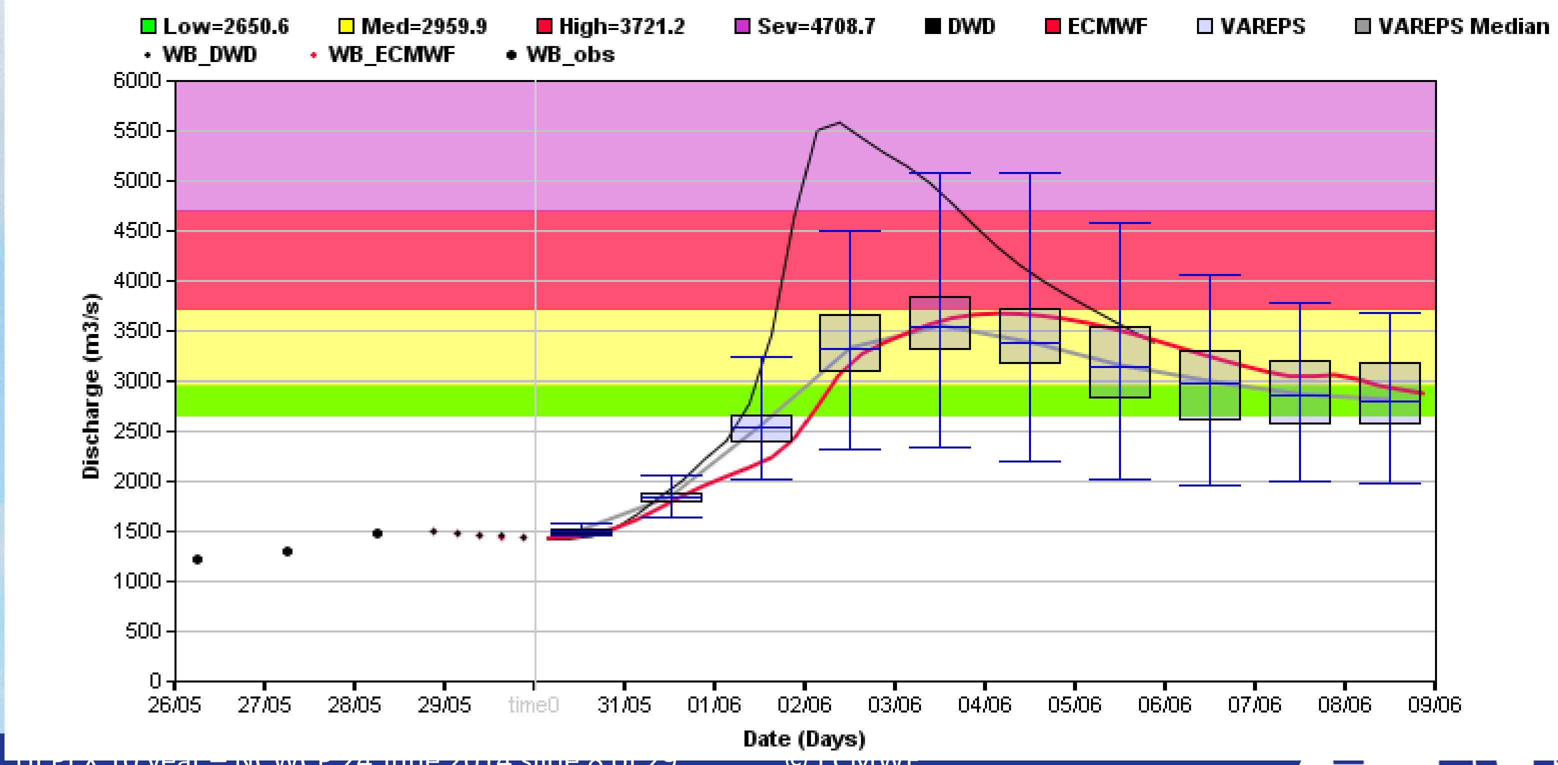


EFAS - Floods in Central Europe June 2013

The image shows the EFAS multi-model streamflow prediction for Passau, Germany. Forecast date is 30/05/2013 12 UTC. The colours indicate the different alert levels.

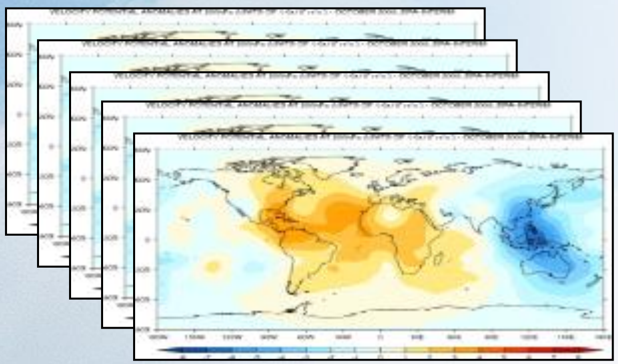
The box plots show the ECMWF EPS, the red line the ECMWF Highres, the black line the DWD COSMO.

The forecasts gives a clear indication of a flooding in 3-4 days



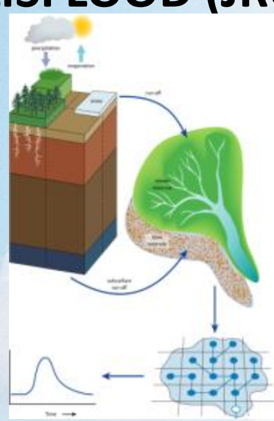
GloFAS – (Global Flood Awareness System)

Global probabilistic weather forecast 51 members (ECMWF)

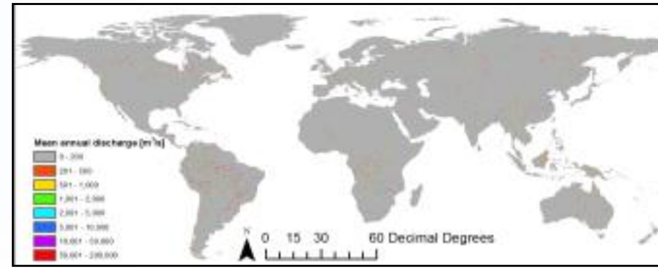


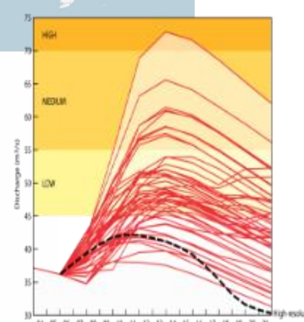
Simplified LISFLOOD (JRC)

-Groundwater
-Routing

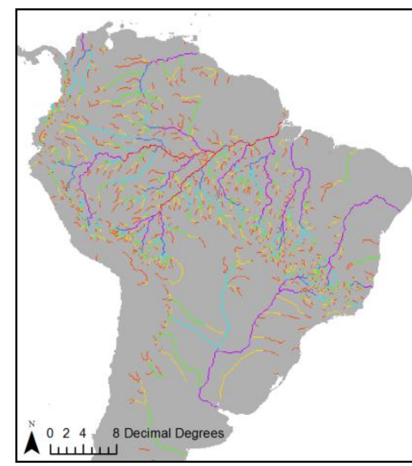


Decision support information





Spatial resolution 0.1 degree

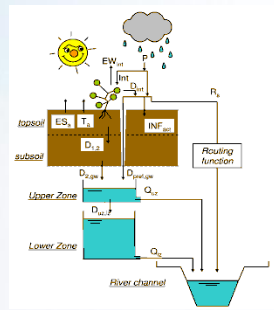


Calculation of thresholds

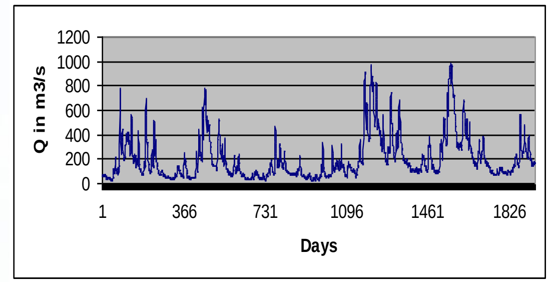
Concept

Era-Interim

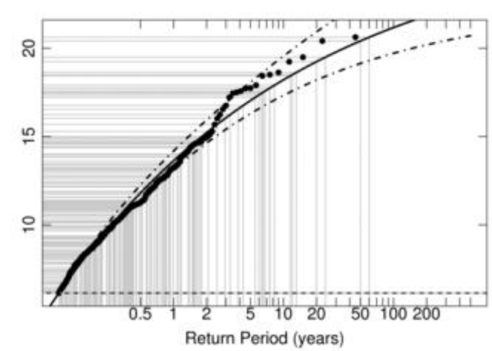
HTESSEL/Lisflood



Simulated discharge time series



Return period statistics



Thresholds

- Q20
- Q5
- Q2
- Q1.3

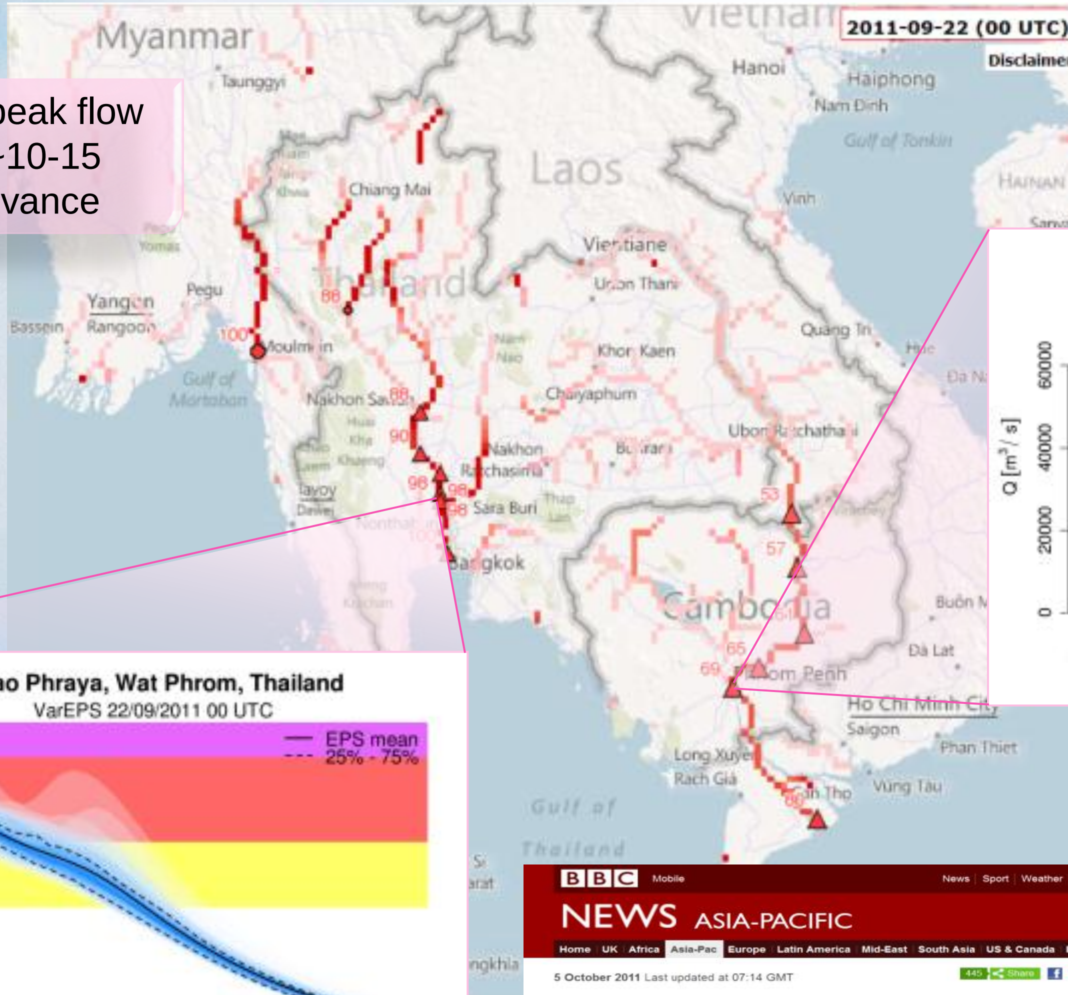
•Thresholds are derived from simulated time series.

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

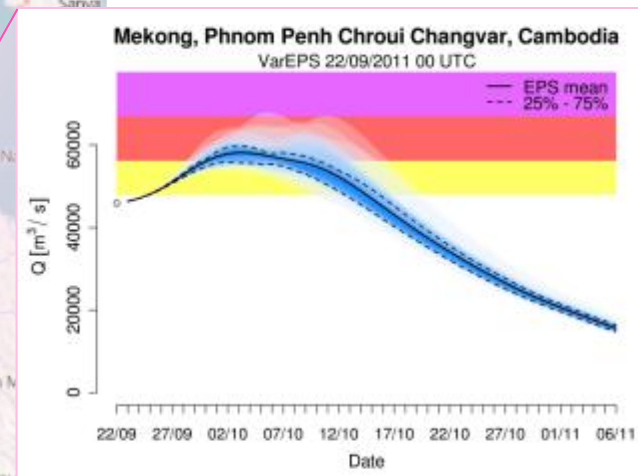
ECMWF

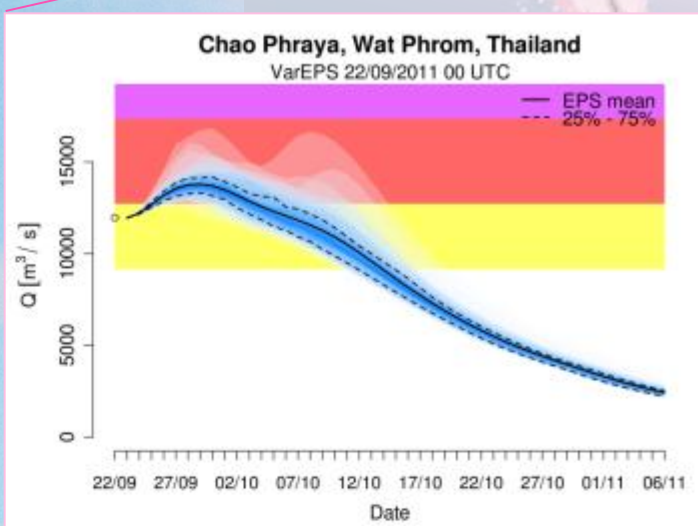
SE Asia floods Sept/Oct 2011 (Chao Praya and Mekong)

Forecast peak flow detected ~10-15 days in advance



Ensemble streamflow predictions



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5 October 2011 Last updated at 07:14 GMT

Thailand floods: More than 200 die, temples threatened

More than 200 people have died in monsoon flooding in Thailand since mid-July, officials say.

More heavy rain is forecast, reservoirs are at full capacity and rivers are overflowing.

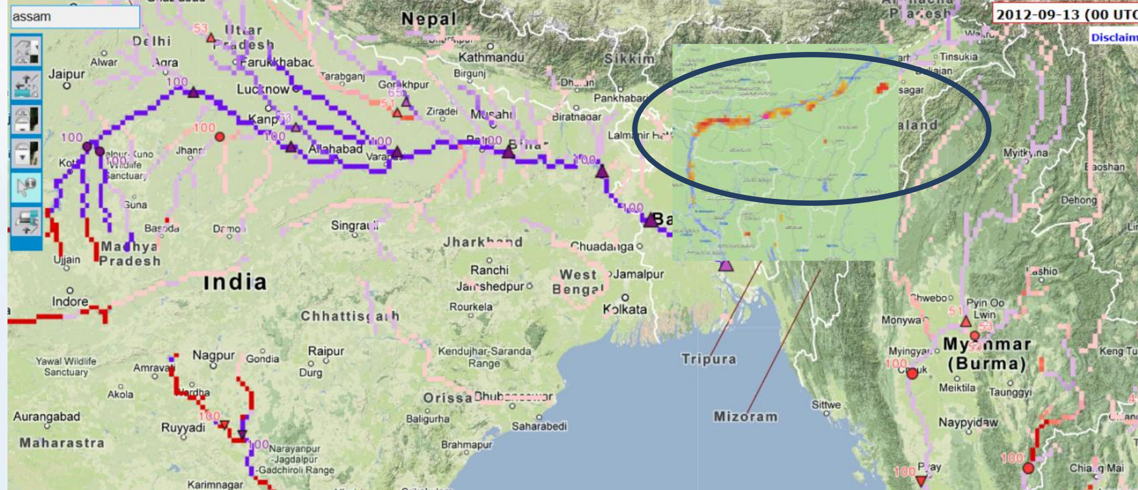
Water has inundated 58 of Thailand's 77 provinces, with 25 still badly hit. Huge tracts of farmland are submerged, threatening this year's rice crop.

Flooding in Ayutthaya threatens ancient Buddhist temples

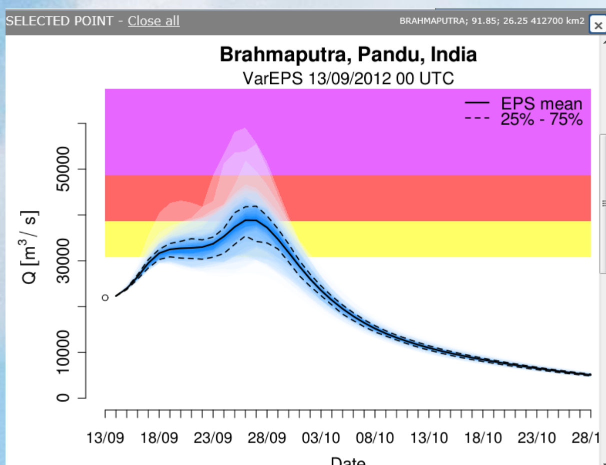
ECMWF

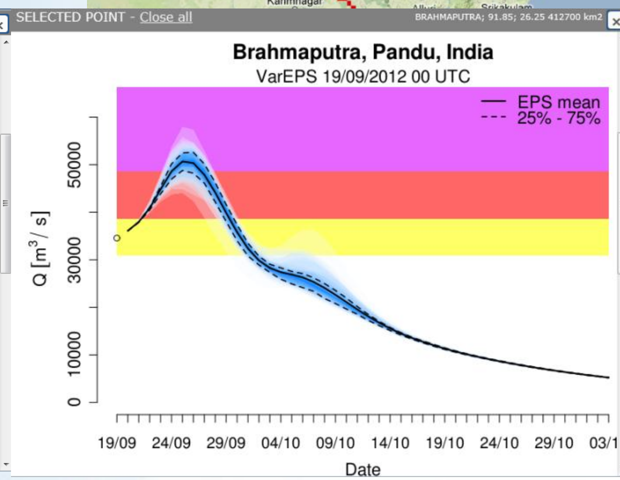
Assam (India) Floods: September –October 2012

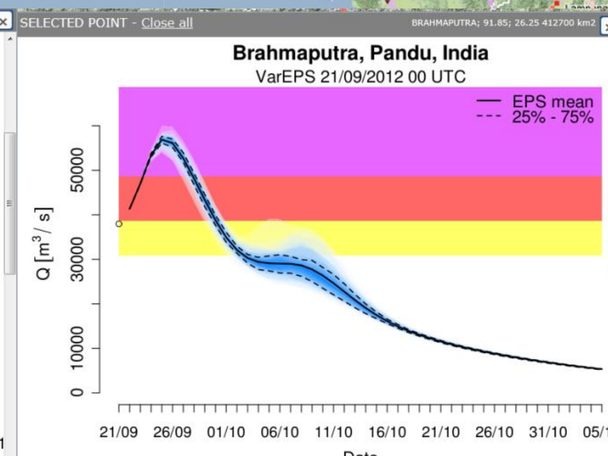
Duration in Days	*Dead*	*Displaced*
27	*21*	*2000000*



Global Flood Awareness System (GloFAS) Forecasts







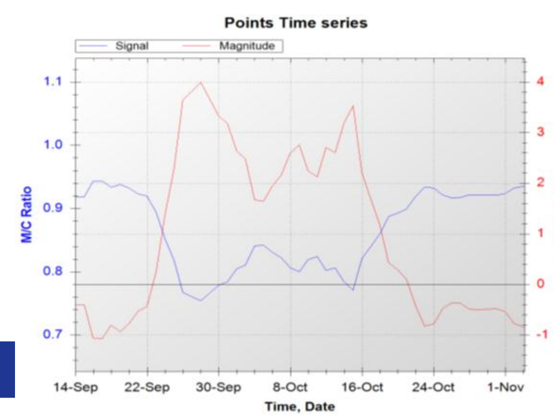
		September																		October														
Day		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dartmouth								First Peak																				Second Peak						
GloFAS	9/13/2012				14	57	76	73	71	69	75	78	37	51	53	43	16	4	22	2														
	9/19/2012							100	100	100	100	45	80	75	47	98	71	4	75	25														
	9/21/2012									100	100	100	100	100	96	47	98	55	98	84	29	22	25	29	22	22								
	9/23/2012											100	100	100	100	100	22	96	4	100	37	18	10	14	25	29	31	27	18	10	6			
	9/27/2012															100	100	100	100	100	78	49	65	10	35	53	63	51	35	22	6	2	2	2
GFDS												M>2		Magnitud > 3							Magnitud >2											M> 3		
Summary GloFAS vs. GFDS								No match				Match																						

Description, Probability of ensemble streamflow predictions to exceed the:	
100	Medium, warning threshold [%] (Return period > 2 years).
100	High warning threshold [%] (Return period > 5 years).
100	Severe warning threshold [%] (Return period > 20 years).

Magnitude: relative importance of peaks in time series

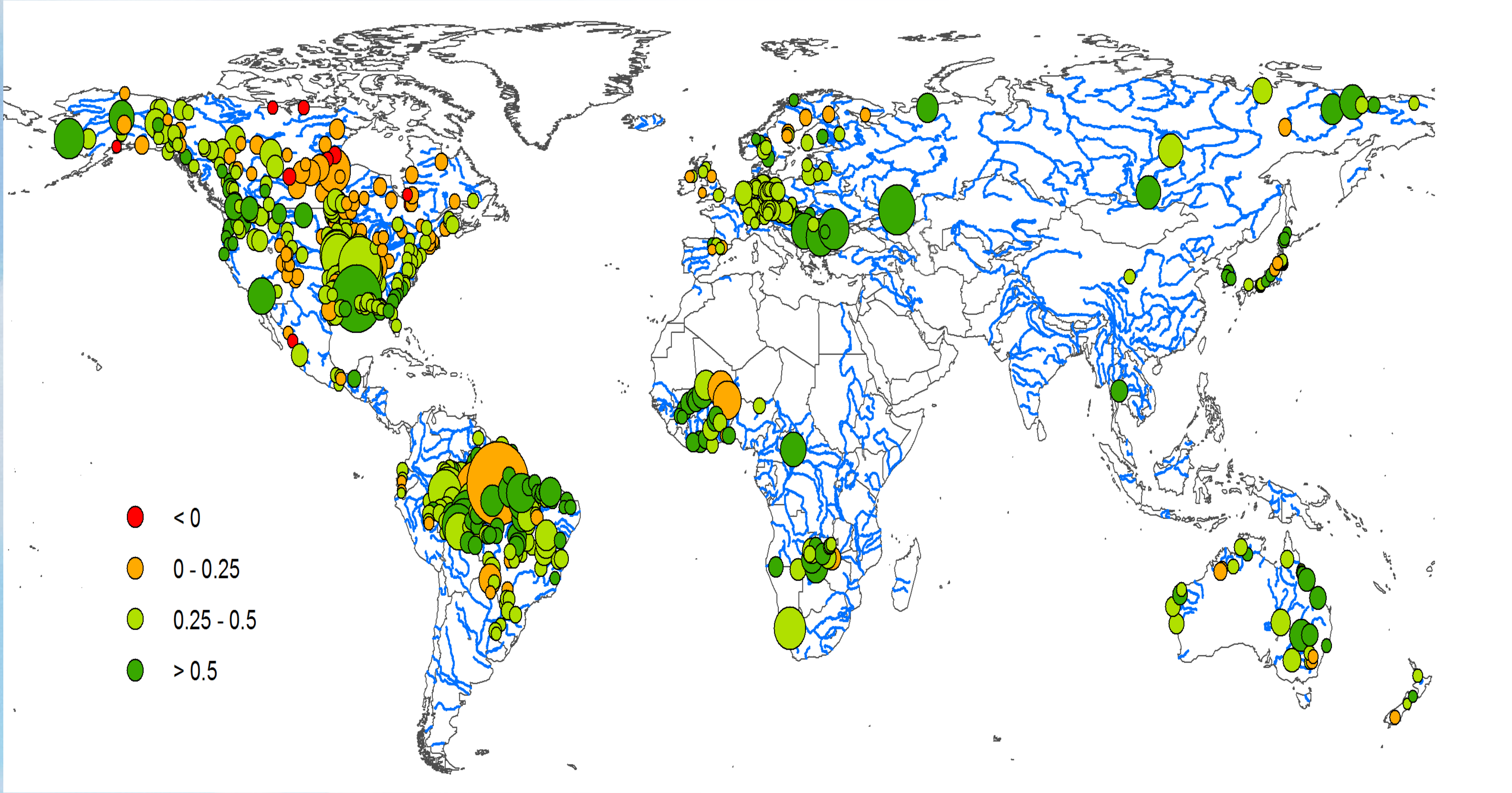
$$m = \frac{s - avg(s)}{sd(s)}$$

Global Flood Detection System (GFDS)



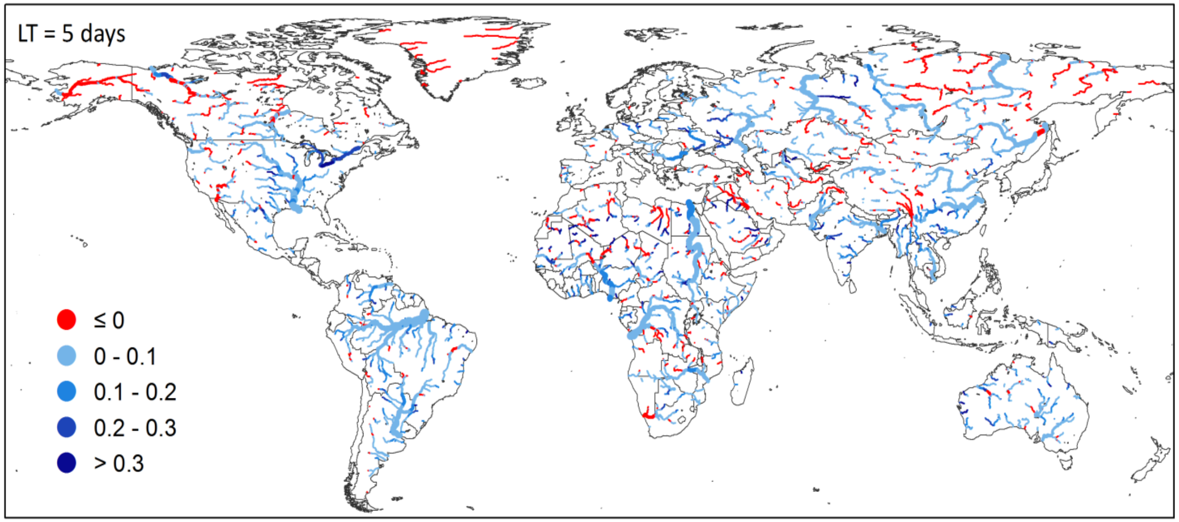
HEPEX 1

GloFAS – Validation

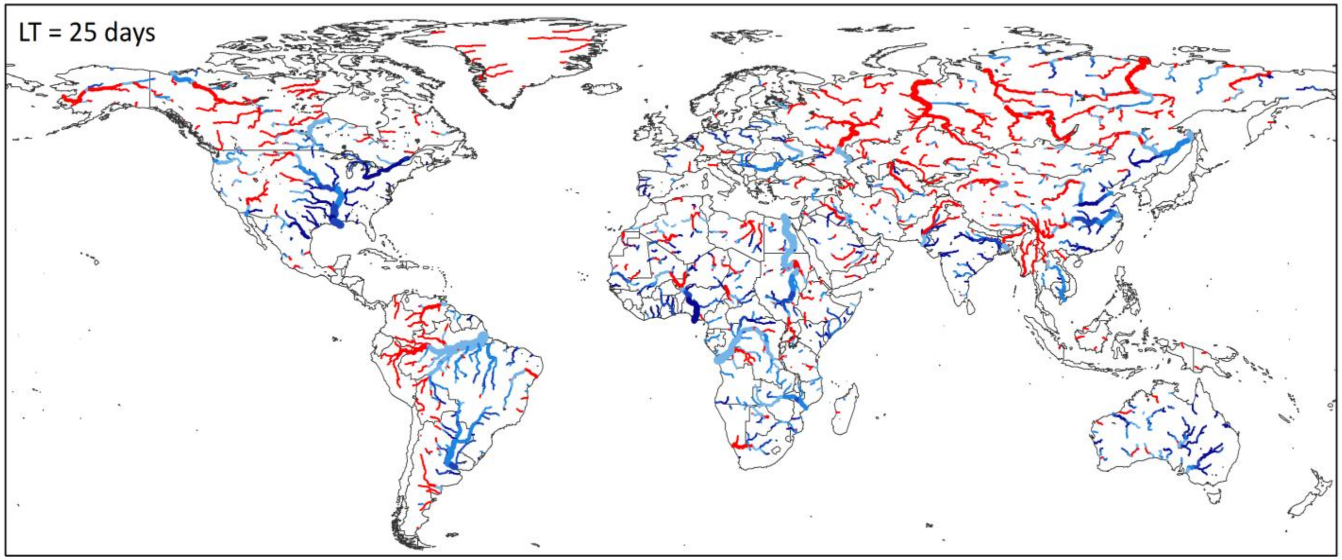


Peirce's skill score of simulated versus observed discharge at each of the 620 stations considered. Circle size is proportional to the upstream area of each river station.

GloFAS validation CRPSS

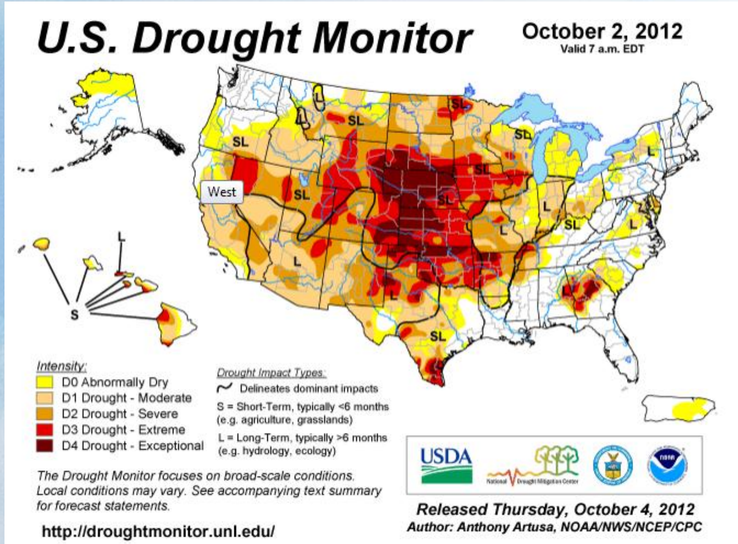


CRPSS maps of HEPS for 2009-2010 (**above 0 skillfull**)

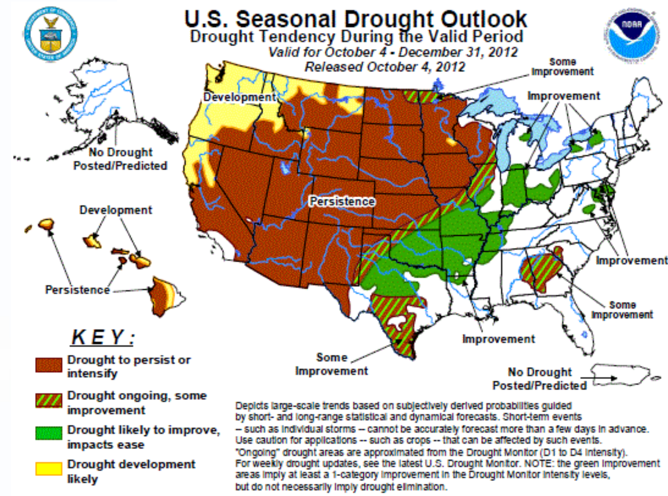


.... To the seasonal and monthly scale: Drought

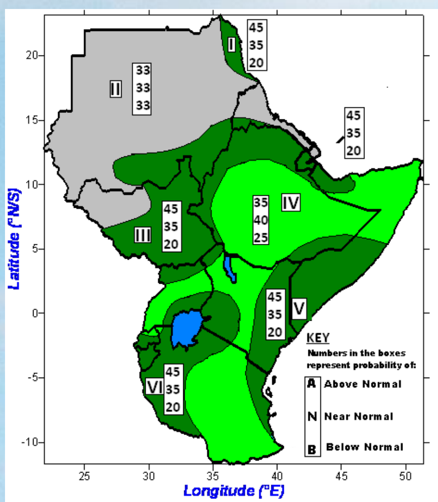
Examples of current systems



http://droughtmonitor.unl.edu/



http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html



WMO Regional Climate Outlook Products

http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html

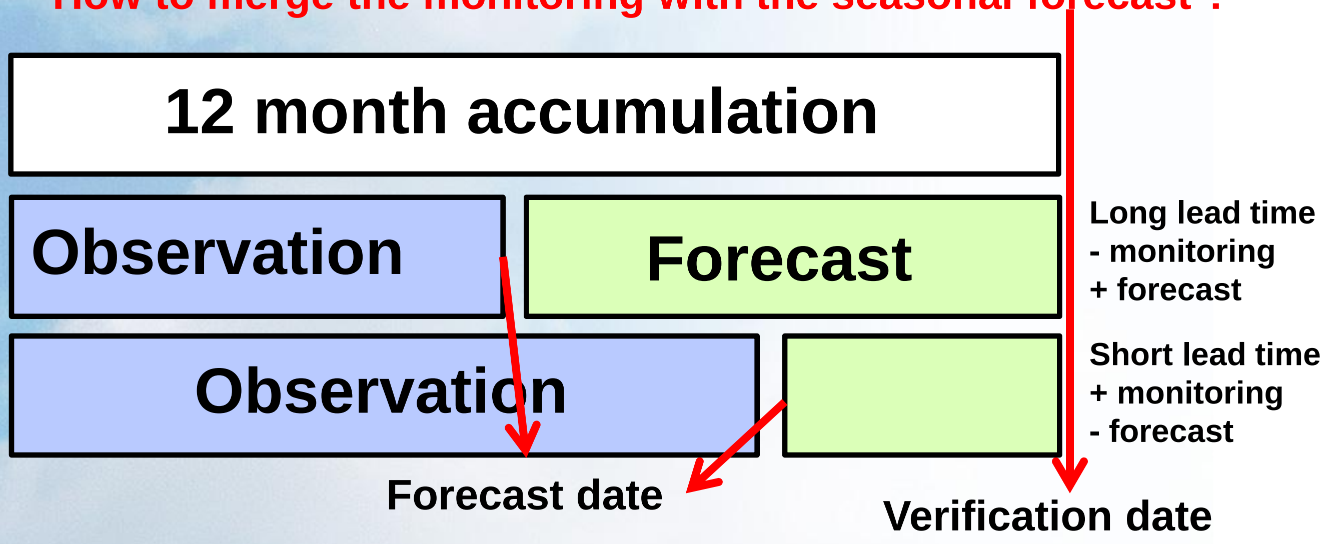
Greater Horn of Africa consensus Climate output for Sep-Dec 2012 (ICPAC)
http://www.icpac.net/Forecasts/forecasts.html

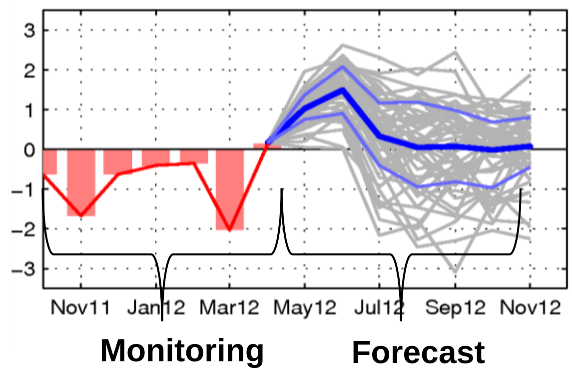
These seasonal outlooks merge models with forecasters experience

Can we process model data and provide a useful and straightforward product to forecasters ? A meteorological drought index ?

Monitoring and forecasting SPI: merging data

How to merge the monitoring with the seasonal forecast ?





Probabilistic forecasts

1) **Spatial averaging of monitoring and forecast to the target region**

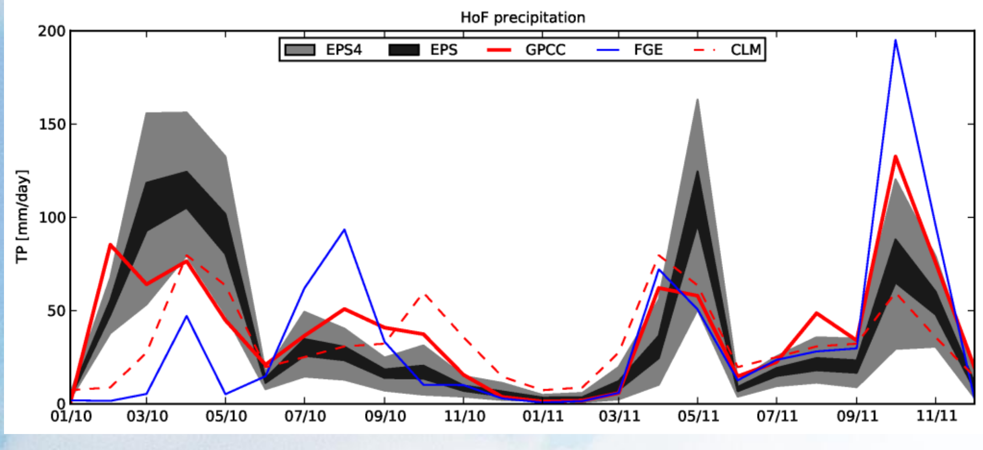
2) **Bias correct seasonal forecast**

$$P'_{m,l} = \alpha_{m,l} P_{m,l} \qquad \alpha_{m,l} = \overline{P}_{m}^{mon} / \overline{P}_{m,l}$$

3) **Merge monitoring and forecasts to create the SPI**

Yoon et al 2012, *J. Hydrometeor*
Dutra et al. 2013 HESS

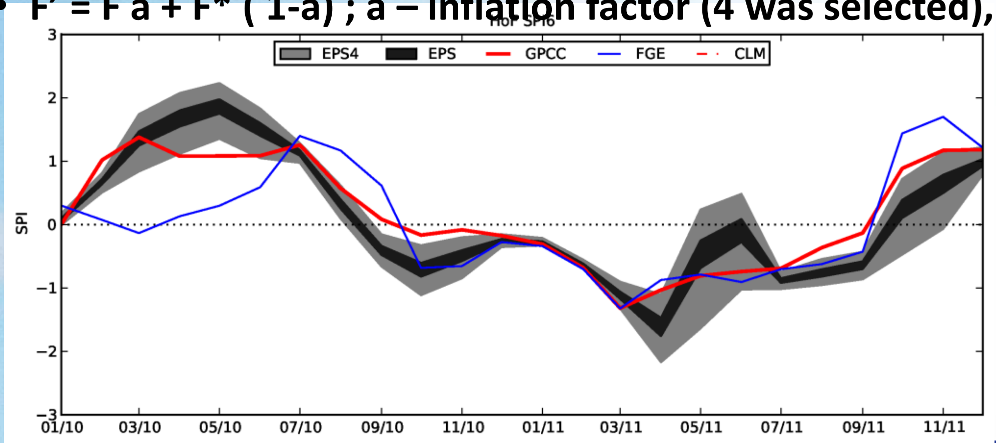
Probabilistic monitoring of SPI



Monthly precipitation in the Horn of Africa

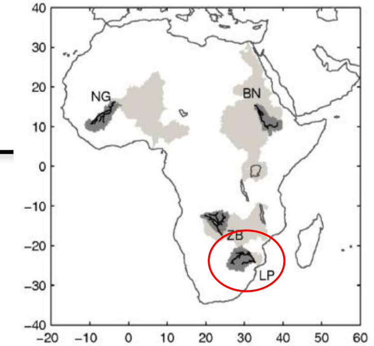
Initial results showed that monthly means of the EPS had a reduced spread:

- **The EPS is not designed to generate a large spread in the first forecast hours and/or to generate monthly means;**
- **If we use a longer forecast lead time (e.g. 5 days), we would increase the spread, but loose skill**
- **Artificially increase the monthly means forecast spread:**
- **F' = F a + F* (1-a) ; a – inflation factor (4 was selected), F* the forecast ensemble mean**

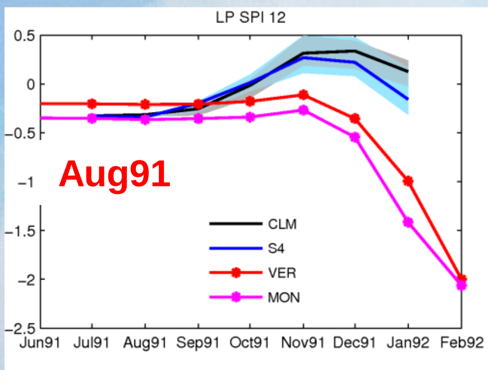


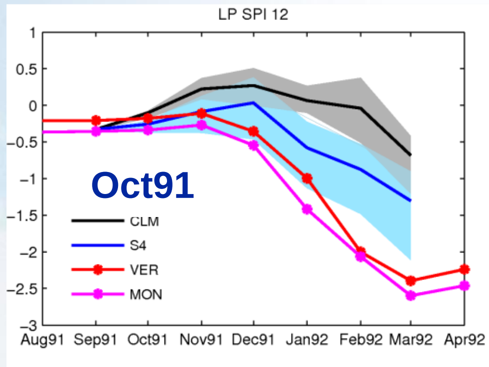
SPI6 in the Horn of Africa

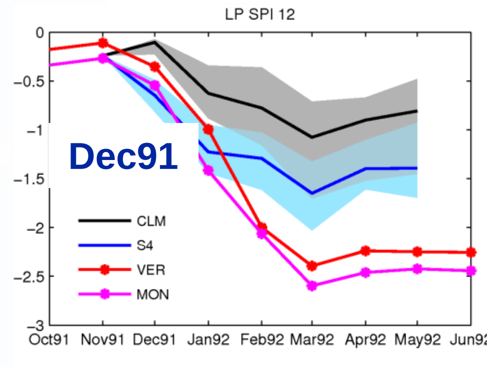
Monitoring and forecasting SPI: merging data

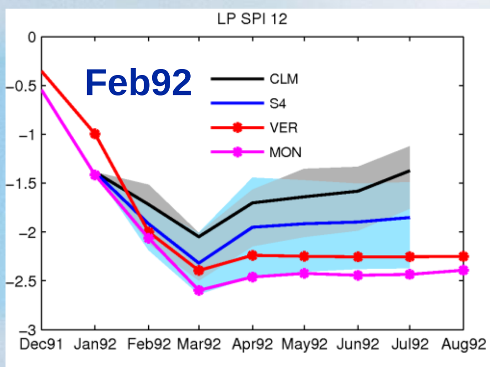


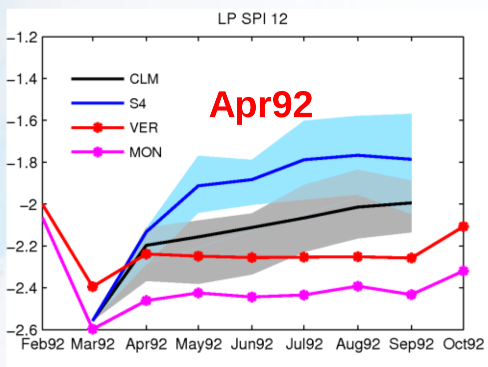
Limpopo 1991/1992 drought: SPI-12
Example of displaying the seasonal forecasts, S4 (blue), CLM (gray).

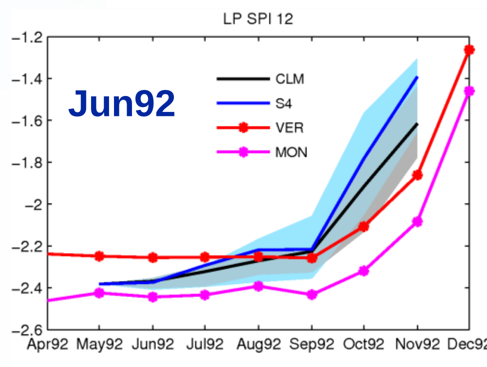






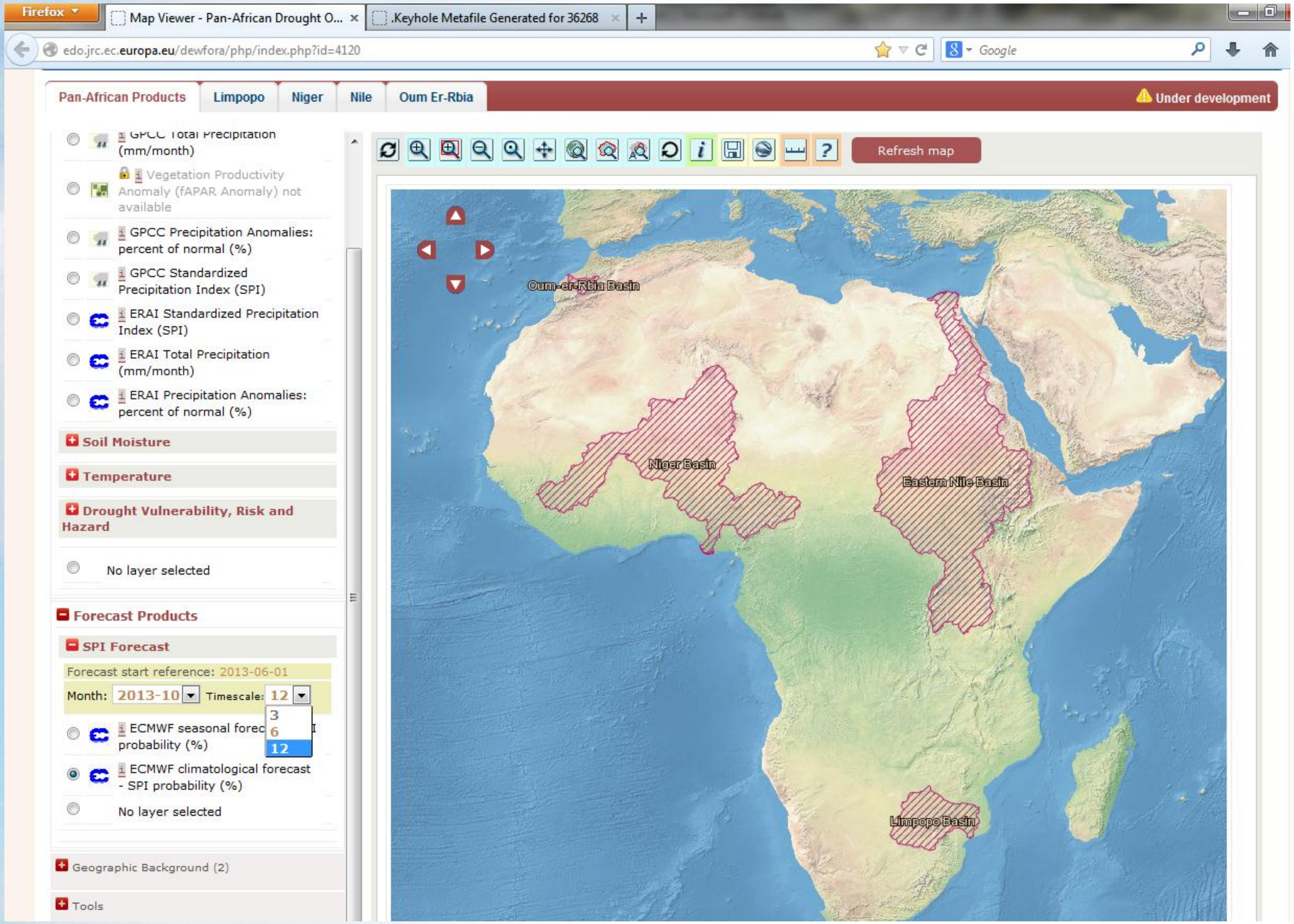




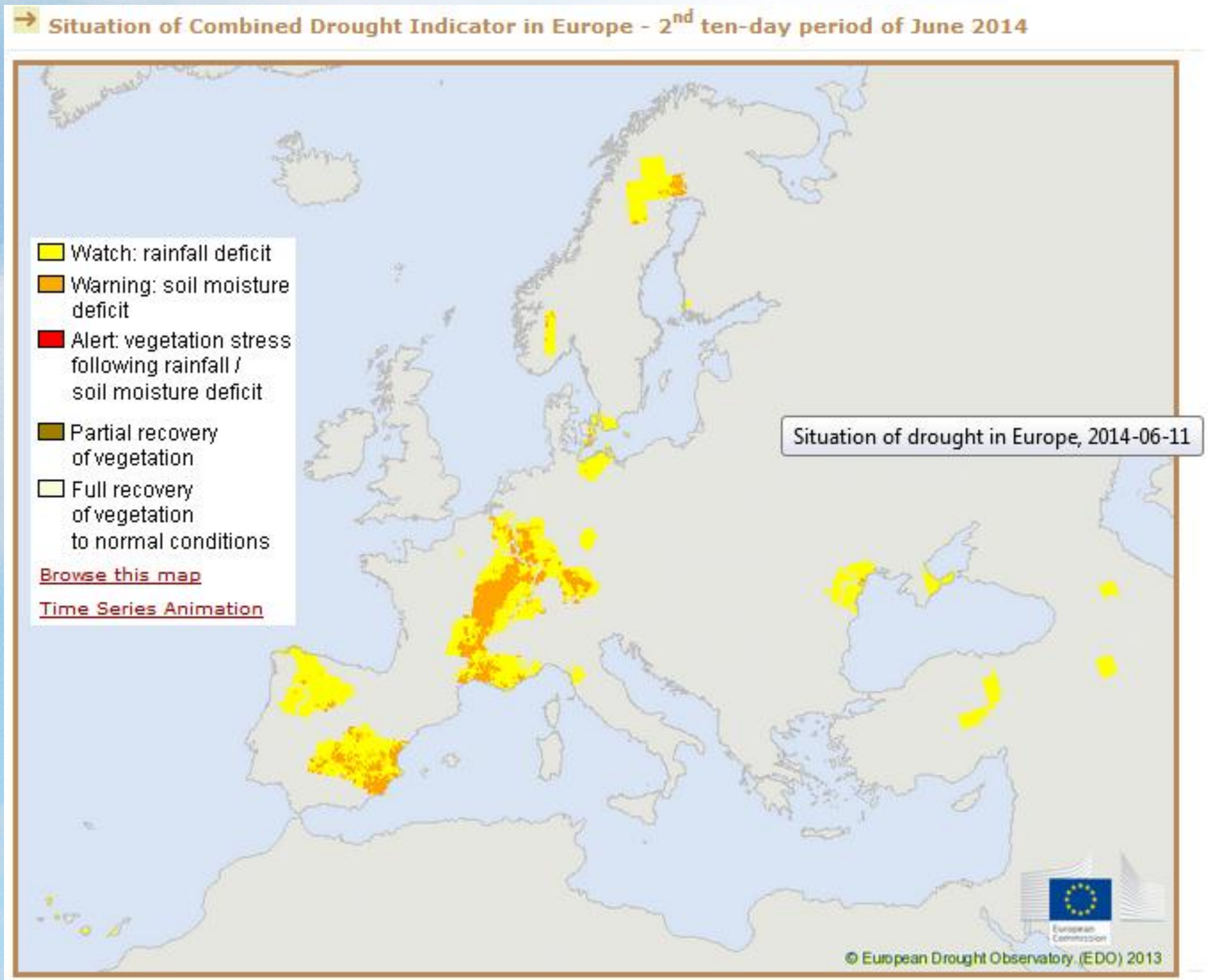


Monitoring (magenta: ERA-Interim) in good agreement with verification (red, GPCP)

Pan-African map viewer (JRC)

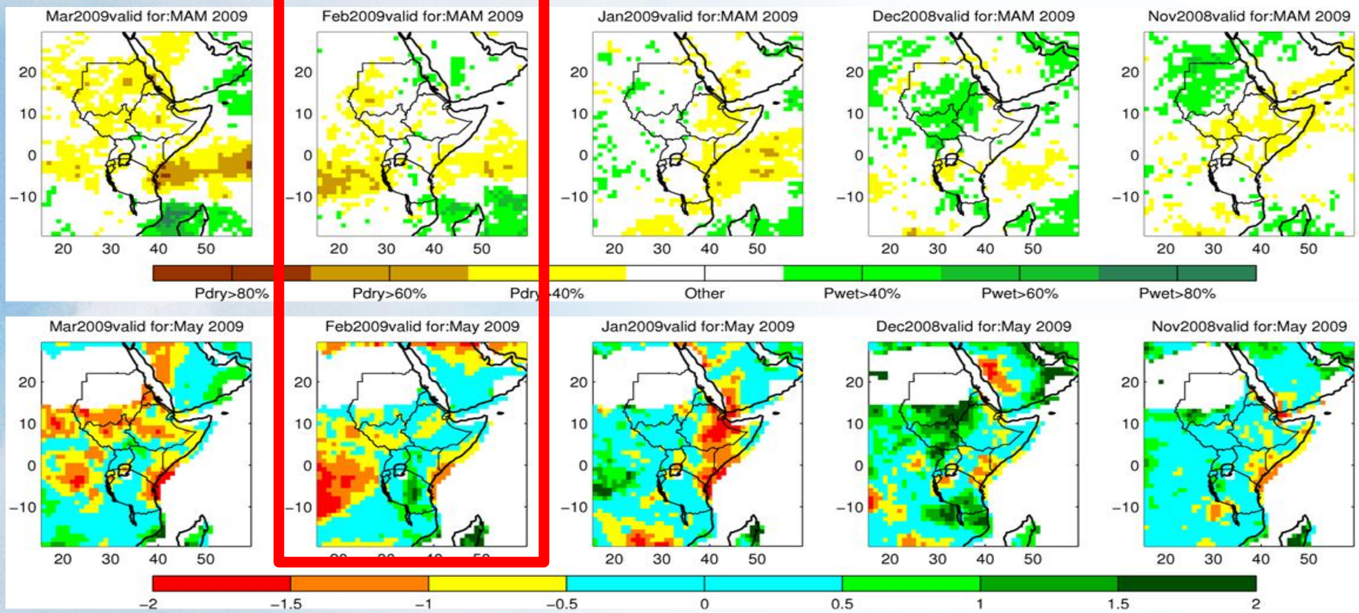


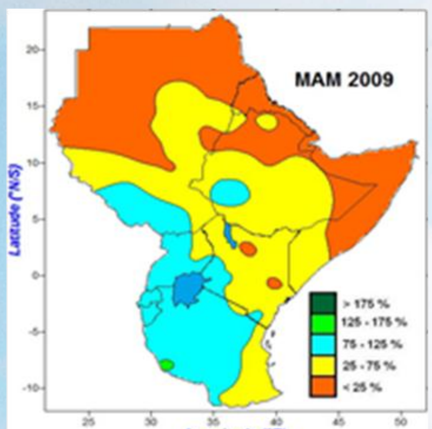
European drought observatory (JRC) June 2014

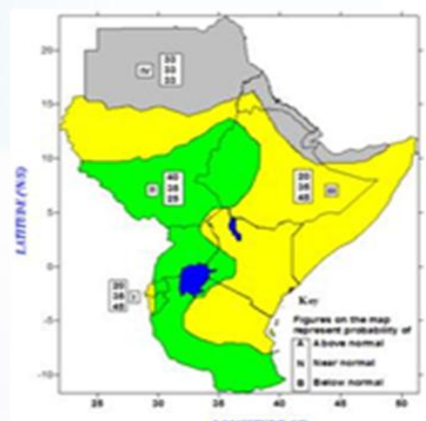


ECMWF

Use of system-4 in the consensus framework – MAM 2009







Combining the outlook and SYS-4's March forecast would have helped adjust the wet forecast over Ethiopia and Sudan to dry

.

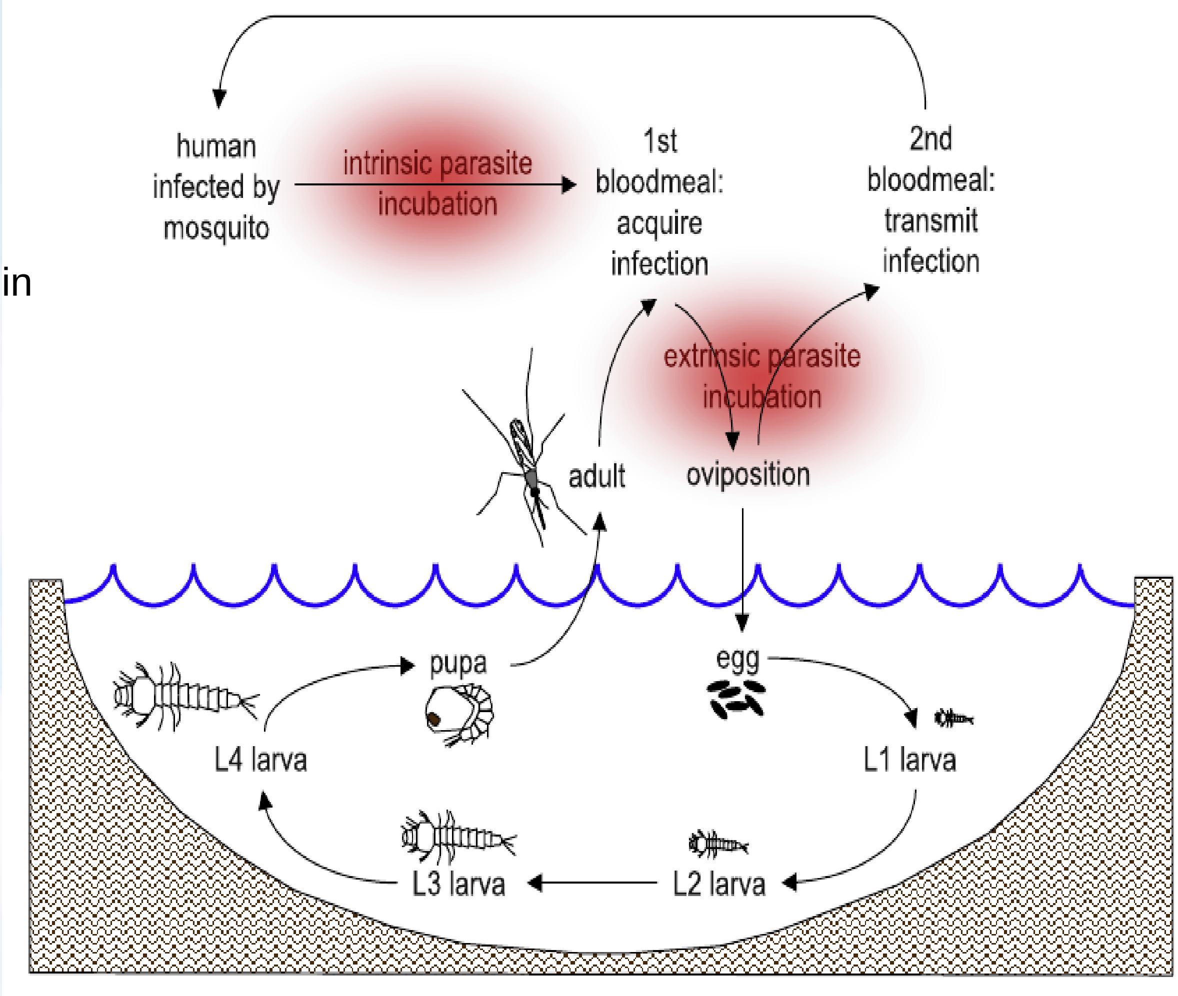
ECMWF

.... To the seasonal and monthly scale: Malaria

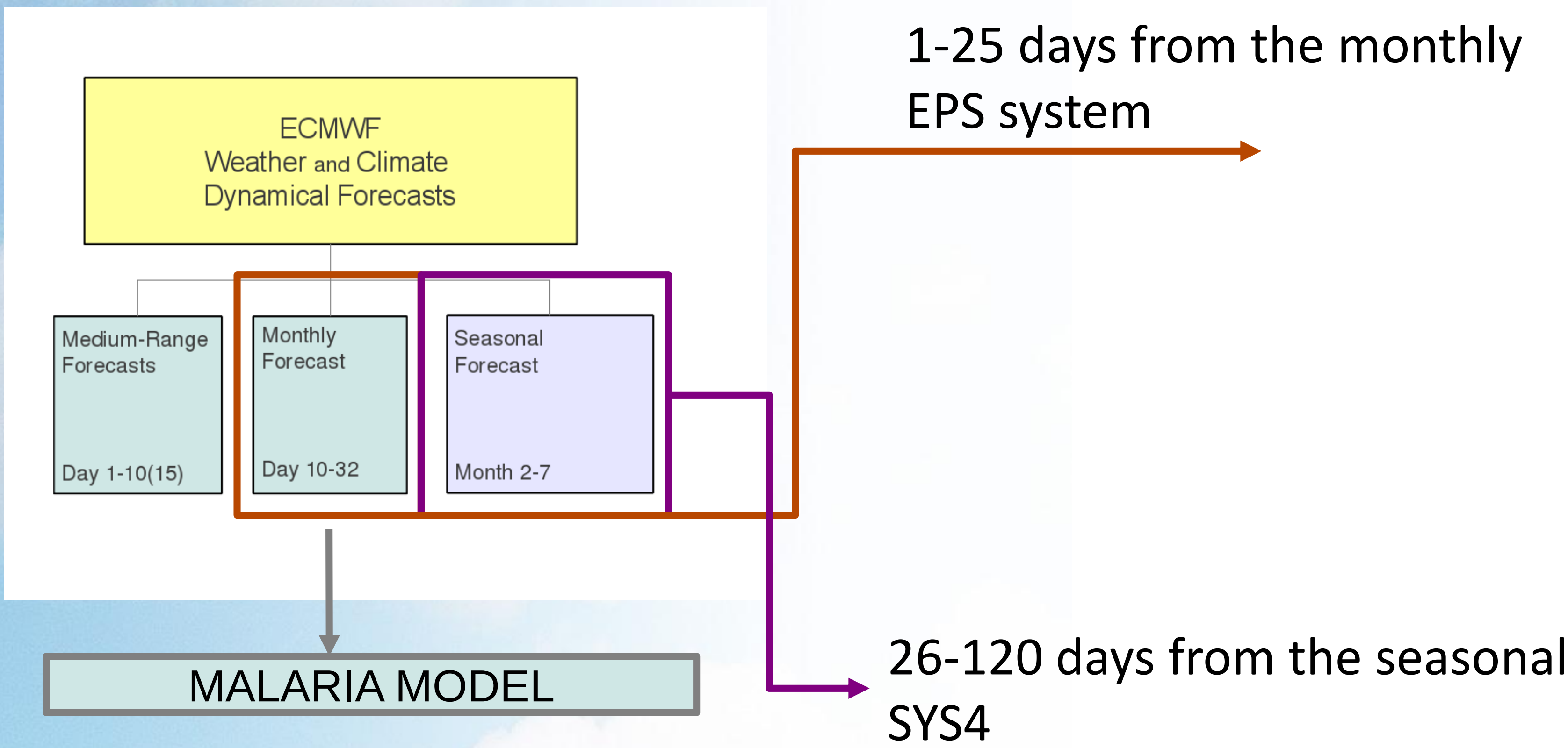
Malaria is constrained by weather/climate conditions

Rainfall : provides breeding sites for larvae.

Temperature: larvae growth, vector survival, egg development in vector, parasite development in vector (plasmodium falciparum/ plasmodium vivax)



Input fields for the malaria prediction system



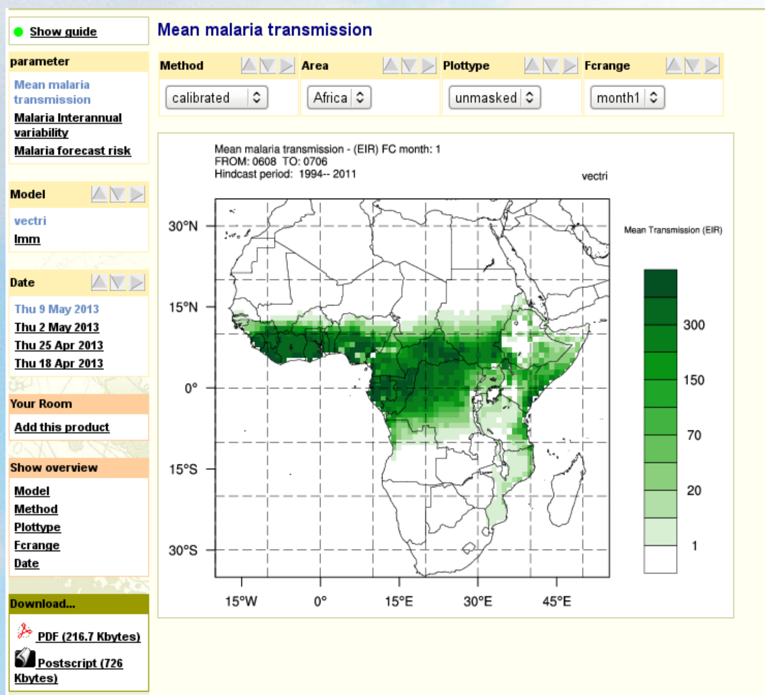
Fields are bias corrected using their own hindcast against the same set of observation to guarantee seamlessness

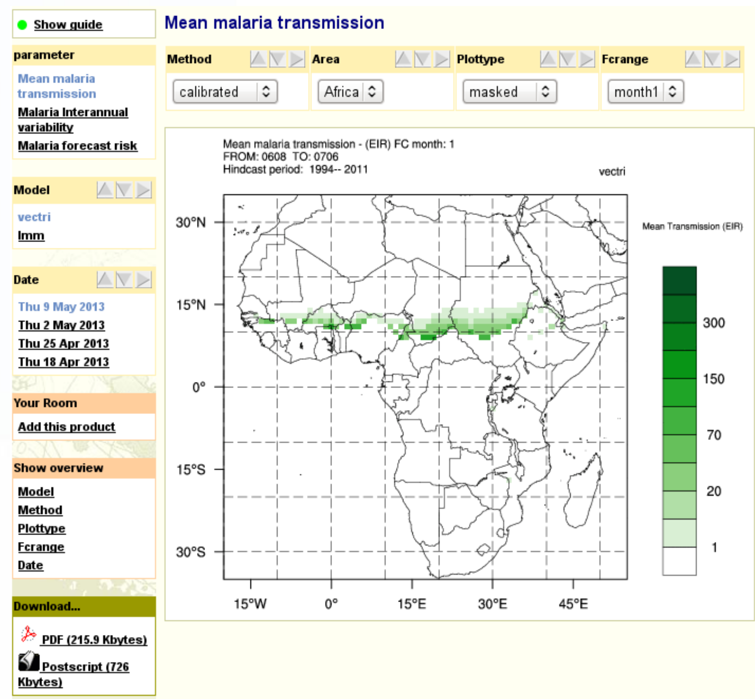
Malaria Product 1: Mean transmission

EIR is a measure of the transmission intensity, it is the number of infective bites per person per unit time

An annual average of 500 is very high 100 intermediate, and in epidemic zones it is often below 10 per year.

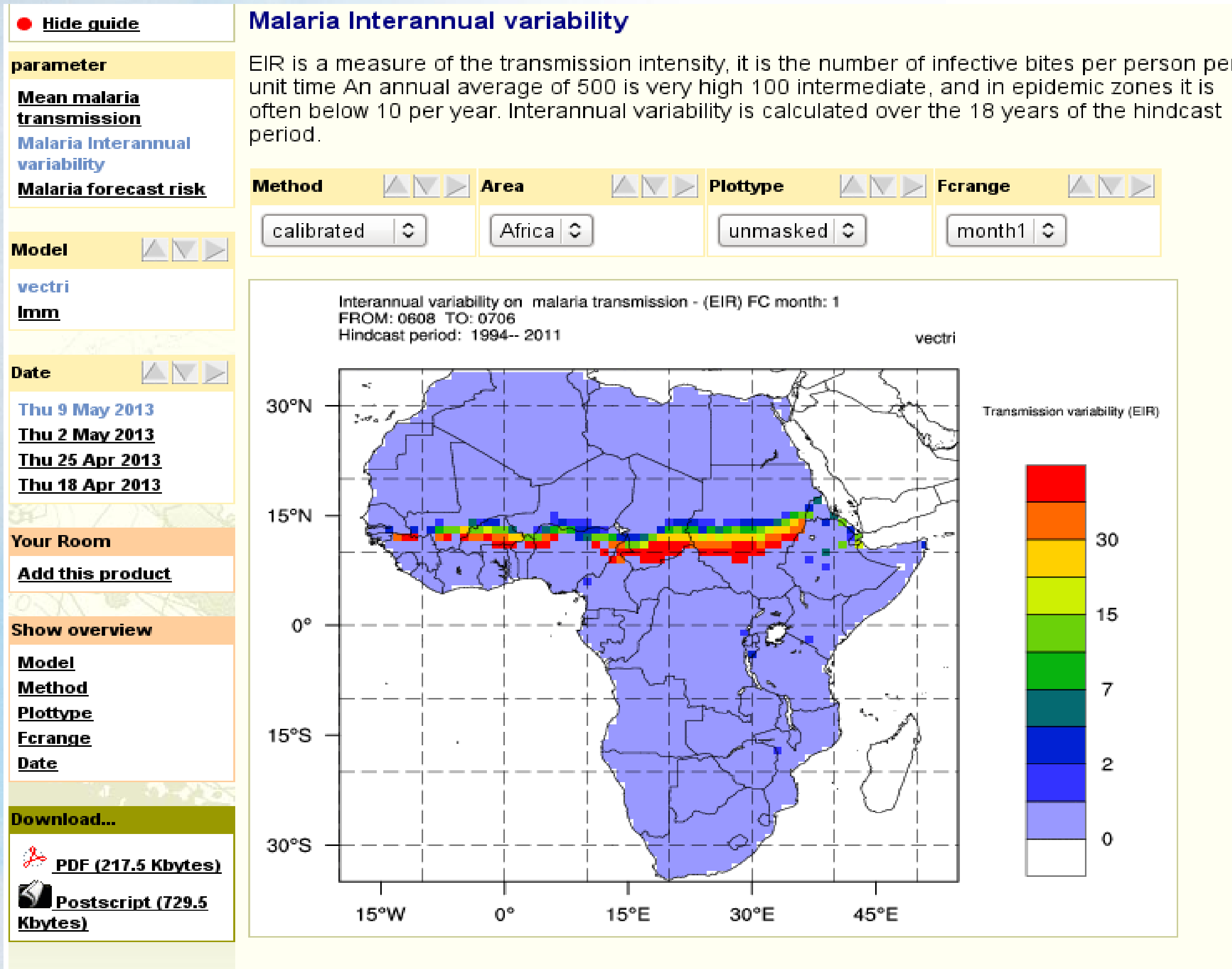
Mean transmission is calculated over the hindcast period (not including the forecast)





Malaria Product 2: Mean inter-annual variability

Inter-annual variability is calculated using the hindcast years. It shows areas where the malaria is epidemic for that period of the year.

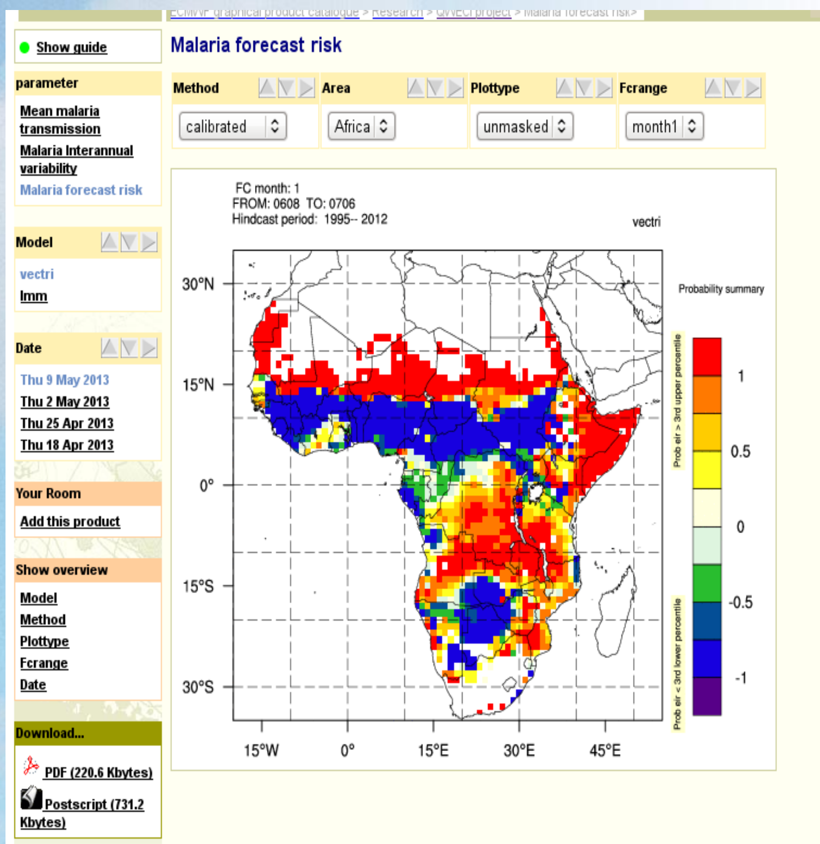


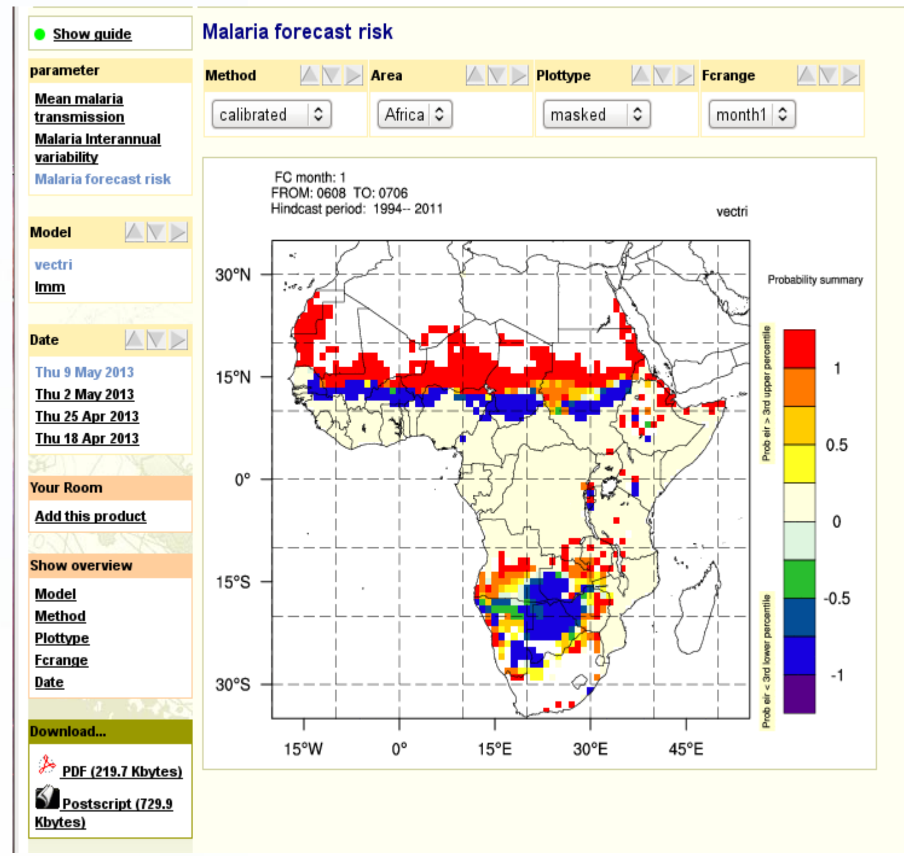
Malaria Product 3: Forecast Probability

Forecast probability summary:

Shows the number of ensemble members which predicts transmission above or below the 3th upper or lower percentile

1 = all the 51 members in agreement





Questions?

Take home messages:

1. Hydrological forecasts are important for all time scales

2. Models can be implemented globally but their skill needs to be assessed locally

References:

- Special issue on droughts in HESS
- GloFAS paper in HESS
- ECMWF newsletter

