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)
Global Flood Alert System

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
Results – long term run 1990-2010
Results – long term run 1990-2010

First results
First results

Results – long term run 1990-2010

Station: SAO_FIDELIS,BR  River: PARAIBA_DO_SUL

Statistics - Multi Hazard March 2011

<table>
<thead>
<tr>
<th></th>
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ECMWF Workshop: Meteorological Operational System, 2011
Results – long term run 1990-2010

First results
Results – long term run 1990-2010

First results
Thresholds

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

Station: CONCEICAO DO ARAGUAIA, BR  River: ARAGUAIA

- Observed discharge

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

Discharge \([m^3/s]\)

- 0.002812814 - 1,000
- 1,000.000001 - 2,500
- 2,500.000001 - 5,000
- 5,000.000001 - 10,000
- 10,000.000001 - 50,000
- 50,000.000001 - 100,000
- 100,000.000001 - 500,000
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 8\textsuperscript{th} 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

Percentage of EPS exceeding the high alert level

A forecast for each day

Flood forecasted with 15 days of lead time
### 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| 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| 81| 88| 96| 98| 98| 98| 96| 98| 98| 98| 94| 92| 90|    |    |    |    |    |    |    |    |    |    |
| 08/01/2011   | 12| 45| 71| 92| 100|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 | 5 | 14| 20| 25| 25| 24|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 06/01/2011   | 2 | 2 | 4 | 10| 14| 18| 24| 27| 27| 27| 24|    |    |    |    |    |    |    |    |    |    |    |    |
| 07/01/2011   | 4 | 6 | 15| 33| 39| 39| 41| 47| 43| 39|    |    |    |    |    |    |    |    |    |    |    |    |    |
| 08/01/2011   | 2 | 4 | 8 | 25| 53| 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 | 4 | 4 | 4 | 4 | 4 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 05/01/2011   | 2 | 4 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 4 | 2 |    |    |    |    |    |    |    |    |    |    |    |    |
| 06/01/2011   | 4 | 4 | 10| 10| 10| 10| 6 | 2 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 07/01/2011   | 2 | 4 | 4 | 8 | 10| 12| 10| 12| 4 |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 08/01/2011   | 2 | 4 | 2 | 2 | 2 | 2 | 4 | 8 | 10| 12| 12| 4 |    |    |    |    |    |    |    |    |    |    |

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*ECMWF Workshop: Meteorological Operational System, 2011*
Results

Forecast of 16\textsuperscript{th} June 2010
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 peak rainfall during the rainy seasons

- Good agreement between ERAI and deterministic, but deterministic is closer to GPCPv2.2
- Stronger Oct-Dec 2010 anomaly in deterministic 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/Deterministic 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.
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 decision makers?

Averages over the HoA
### Seasonal forecasts: April 2010 to August 2011

**System 3**
- 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)?

**System 4**

<table>
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**Averages over the HoA**

- ERAI precipitation anomaly (percentile)
  - >60
  - 60–45
  - 45–30
  - 30–15
  - <15

- % ensemble members below P30
  - >60%
  - 15%–30%
  - 30%–45%
  - 45%–60%
  - <15%
Precipitation anomalies and link with ENSO

Regression ERAI Nino3.4 SST Sep-Nov. precip

Anom. correlation SST Nino3.4 precip HoA

• 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

- 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

Oct-Dec 2010 Forecasts

- 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?

Mar-May 2011 Forecasts
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.