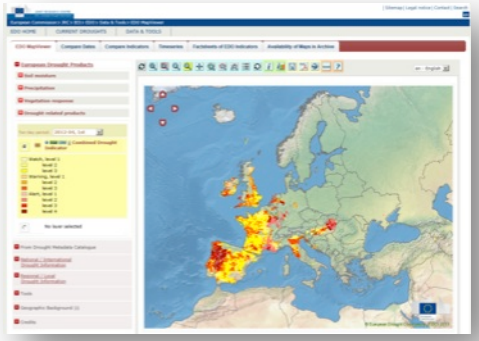
European Drought Monitoring and Prediction

Towards a comprehensive drought information system for Europe

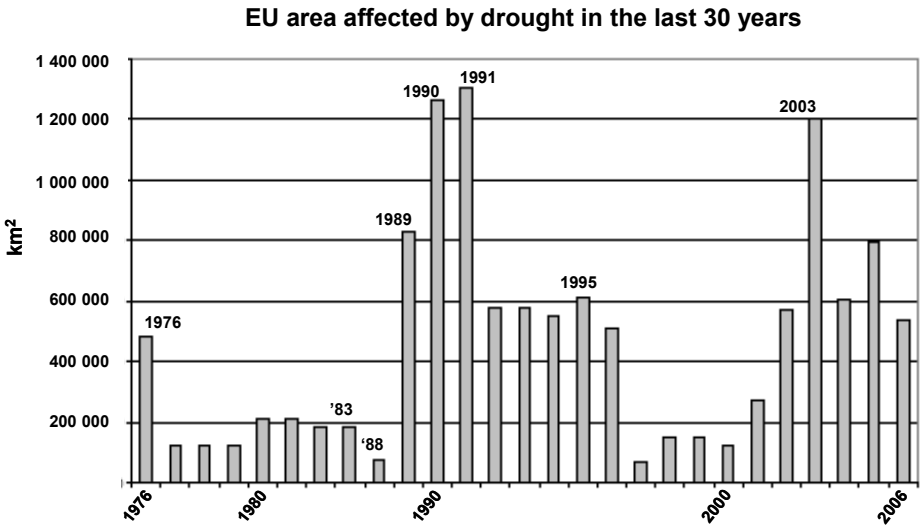
Jürgen Vogt



Climate Risk Management Unit
European Commission - Joint Research Centre (JRC)
Institute for Environment and Sustainability (IES)

1. **Introduction**
   - Drought in Europe
   - Policy Response
2. **European Drought Observatory**
   - Concept
   - Content & Tools
3. **Research Topics**
   - Drought Events Database
   - Impacts
   - Trends
   - Forecasting
   - Climate Change Projections
   - Hazard and Risk Analysis (Current & Future)

Spatial Extent and Impacts of European Droughts



~ 1/3 of EU27 Territory

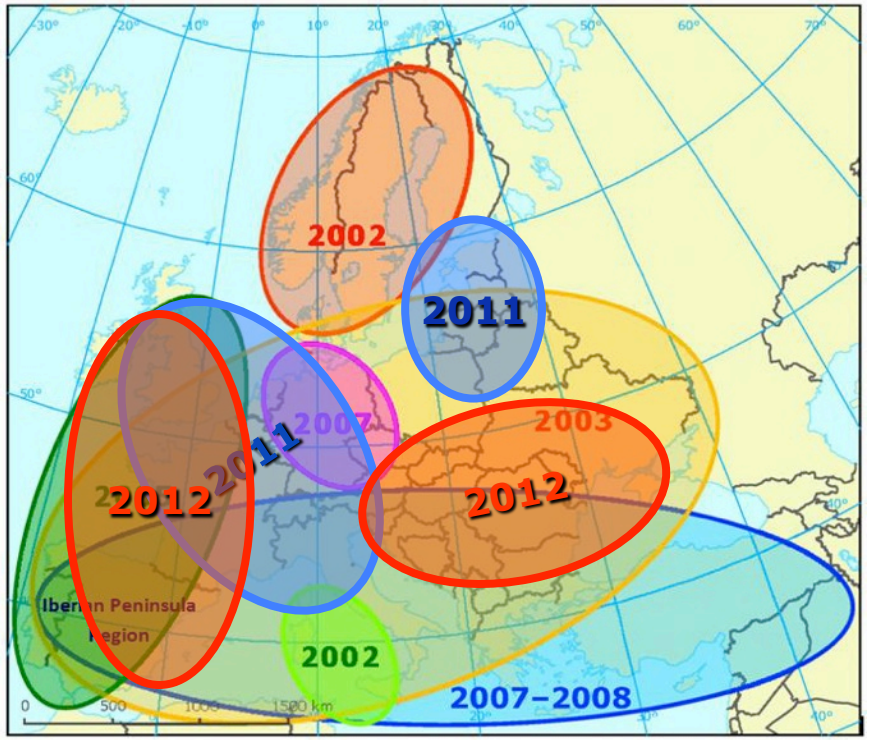
In the last 30 – 35 years Europe has repeatedly been affected by major droughts

- Over the last decade about 15% of the EU territory and 17% of the EU population have been affected on an annual basis
- The economic impacts have been estimated to at least 100 billion Euros over the last 30 years
- Environmental impacts are difficult to quantify

Source: European Commission, 2007 (WS&D, 2nd Interim Report)

Droughts affect all of Europe

- Major concern in the Mediterranean region (already water stressed)
- However, many other parts of Europe have been seriously affected
- Key issues:
  - Past & Future Trends
  - Monitoring, Forecasting & Prediction
  - Impact Assessment
  - Mitigation

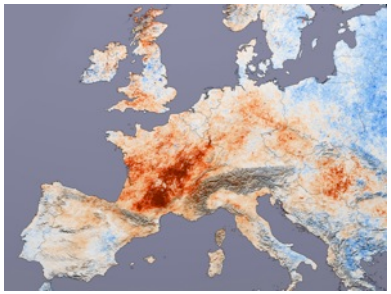


(Adapted from EEA, 2010)

Droughts affect large areas and extensive populations and therefore require international efforts

2003
Drought and Heat Wave

- 1/3 of EU Territory
- Population of > 100 million affected
- Together with a sevre heat wave
- Costs estimated to be > 8.6 billion Euros



- Serious impacts:
  - Crop losses
  - Forest fires
  - Navigation problems
  - Reduction of energy production
  - High water temperatures -> fish death
  - Damage to buildings (subsistence)

Drought on the European Agenda

European Commission: Water Framework Directive (2000)

*Major piece of legislation asking for the reform of water management in the EU. Demands for **River Basin Management Plans**, supplemented by **Drought Management Plans** in areas of drought hazard/risk.*

European Commission: Communication on Water Scarcity and Drought (2007)

*Asks for the establishment of a **European Drought Observatory** (EDO) that will integrate relevant data and research results, drought monitoring, detection and forecasting on different spatial scales, from local and regional activities to a continental overview at EU level, and will make it possible to evaluate future events.*

European Parliament: Report on the EC Communication "Towards a Stronger European Disaster Response" (2011)

… reiterates, …,the importance of establishing the European Drought Observatory, which would be responsible for studying, mitigating and monitoring the effects of drought.

European Commission: "Blueprint to Safeguard Europe's Water Resources" (2012)

The European Drought Observatory (EDO)

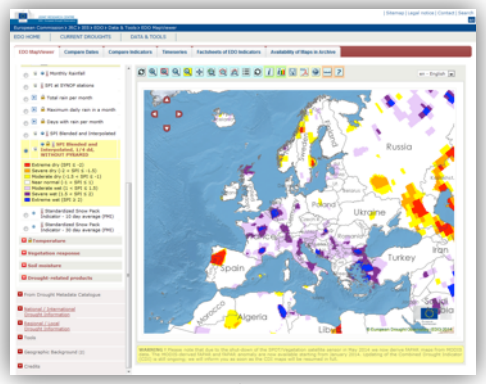
EDO:

- Internet-based tool
- provides different types of information and tools
- at multiple scales
- through multiple indicators, including high level indicators targeted to decision makers

Reports

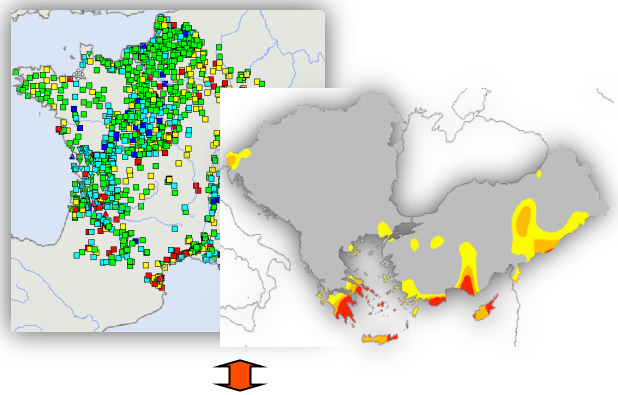
http://edo/jrc.ec.europa.eu

EDO Concepts



Web-based Platform for detection, monitoring, forecasting and information exchange

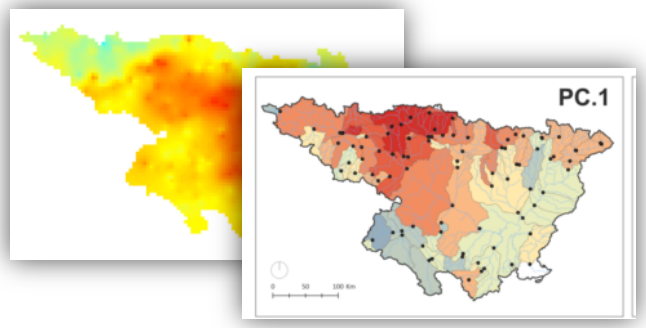
- commonly agreed products (e.g. drought indices)
- exchange of knowledge & information
- direct up- and downscaling
- real-time monitoring and forecasting (early warning, preparedness)



Multi-scale approach, integrating

- EU / continental level
- MS level
- Regional / river basin level

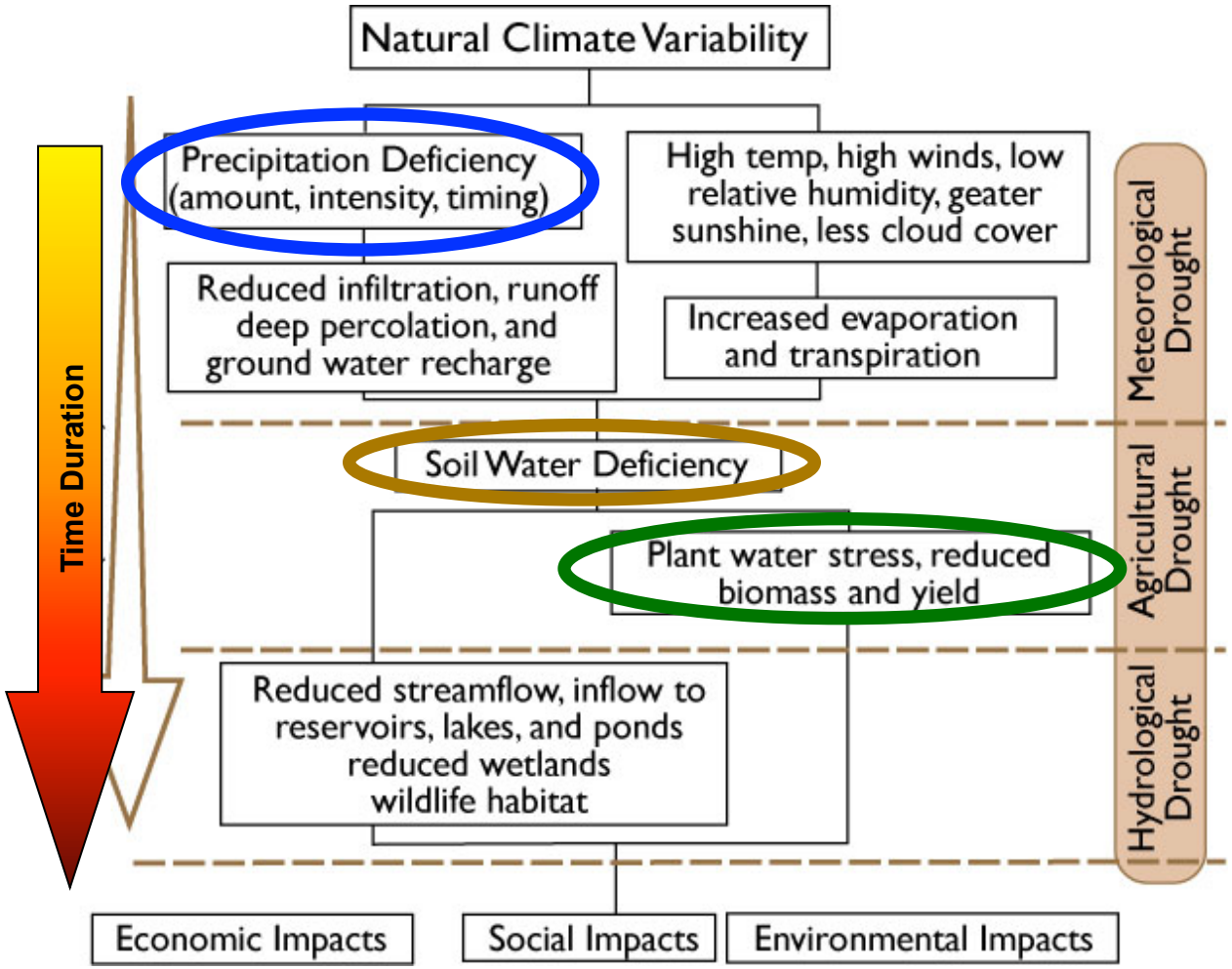
Interoperable Data Infrastructure



Subsidiarity principle

- European level information + platform (JRC)
- National datasets managed at MS level
- Regional information processed by river basin / regional environmental authorities
- De-central data holding

Multi-Indicator Approach



Continental Scale

Standardized Precipitation Index

Standardized Snowpack Indicator

Soil Moisture Anomaly

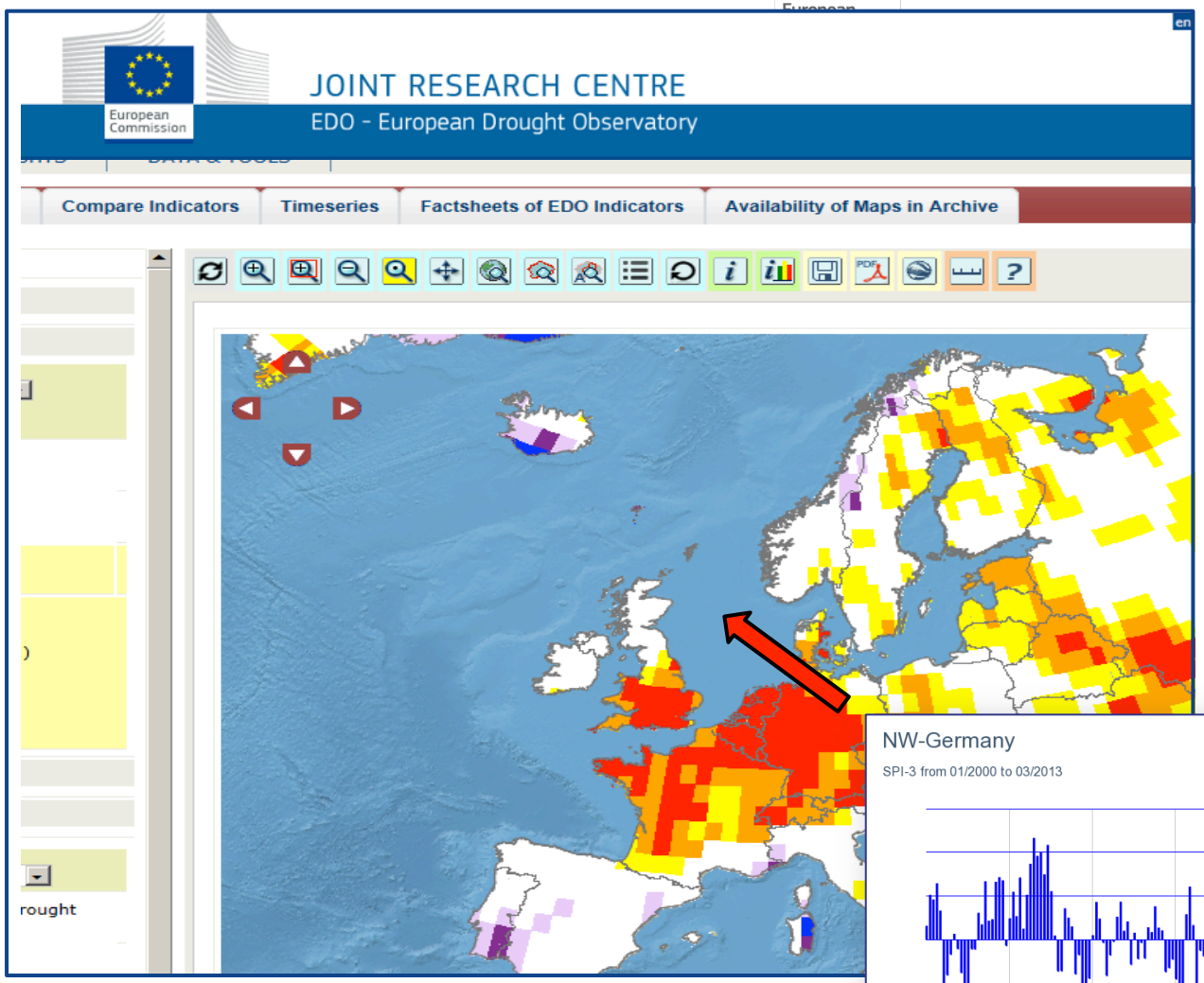
Vegetation Response

To add:

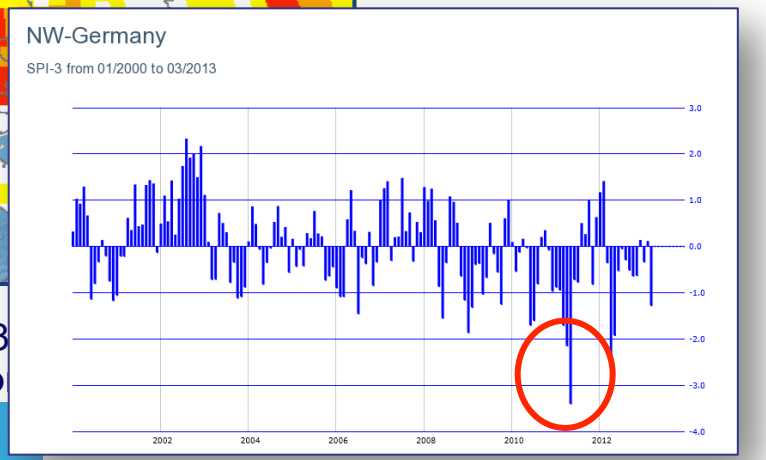
- **Low-flow Indicator**

Source: National Drought Mitigation Center, University of Nebraska-Lincoln, USA

EDO Standardized Precipitation Index (SPI)



Spring 2011



3-month Standardized Precipitation Index (SPI-3

February to April 2011, rainfall deviation from no

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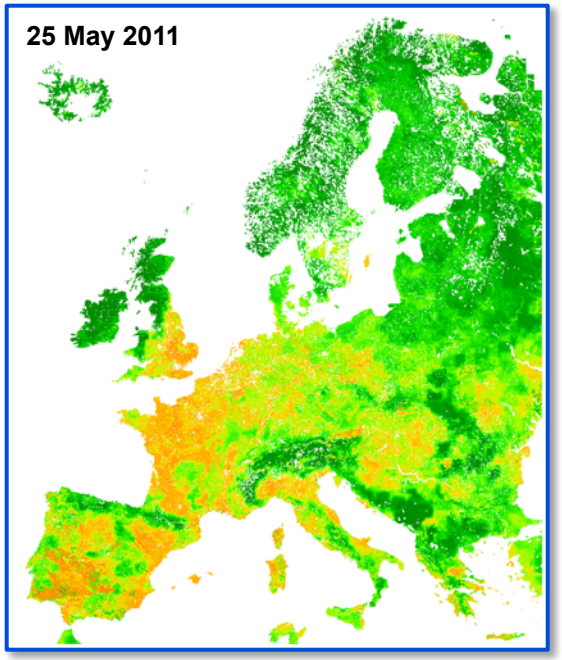
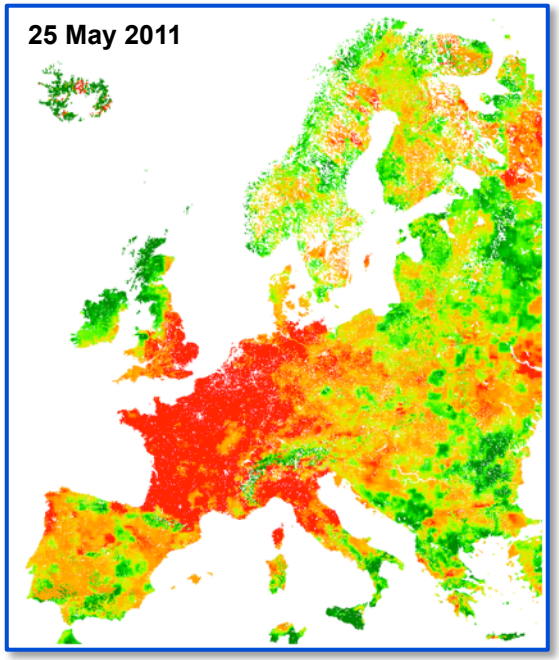
EDO Daily Soil Moisture Information

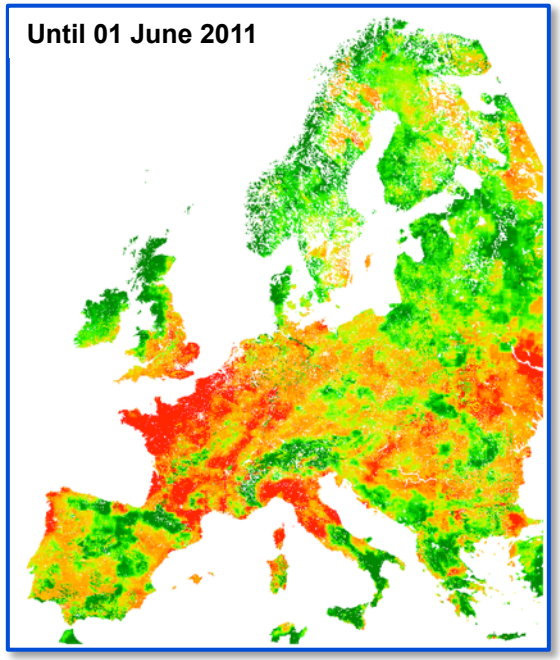
European Commission



Soil Moisture (soil suction)



Soil Moisture Anomaly



Anomaly Forecast (7 days)

Modeled on 5 x 5 km grid

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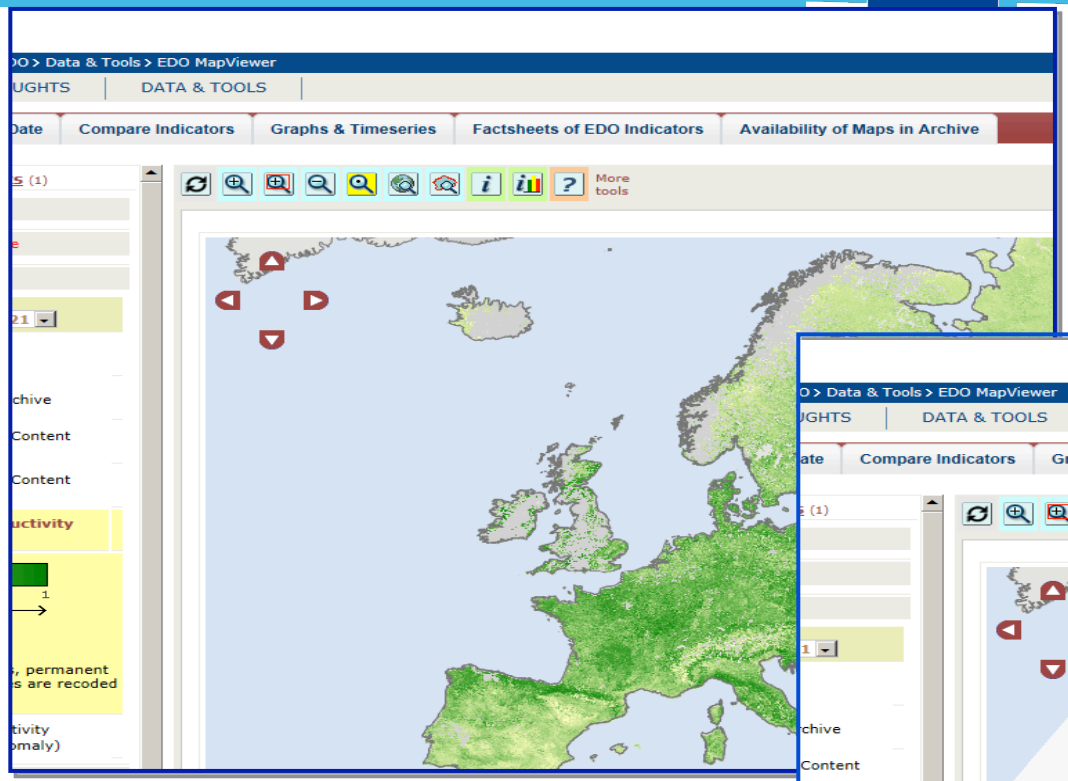
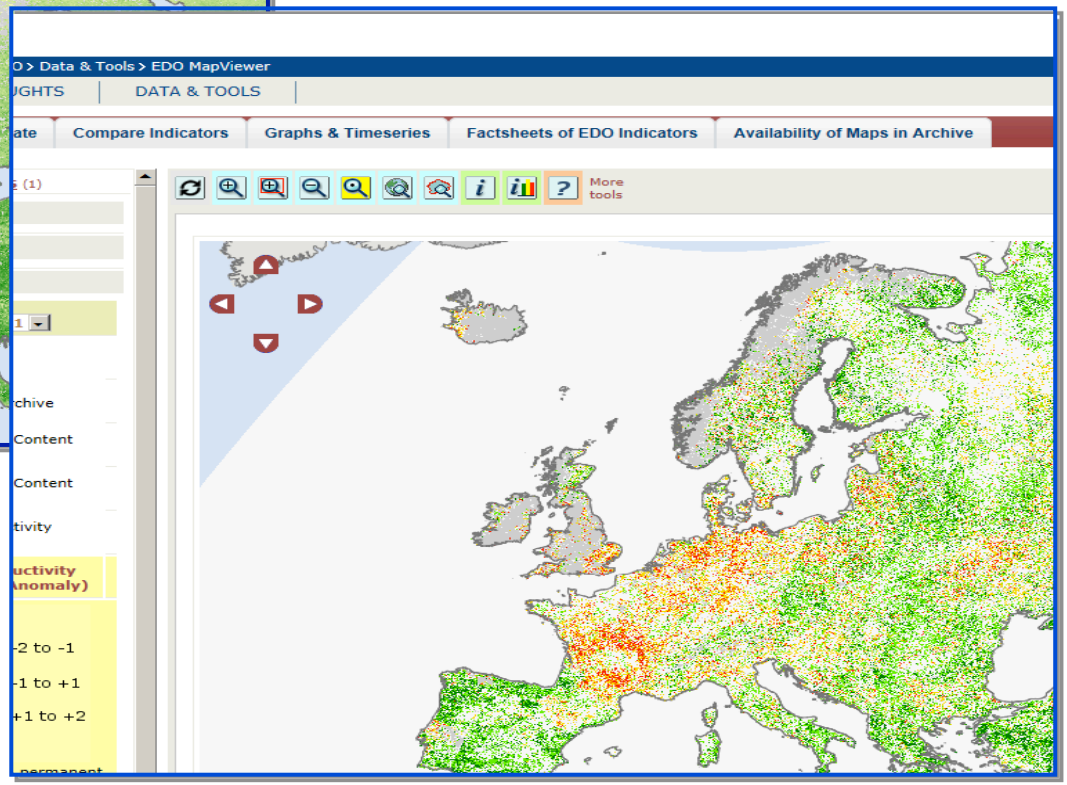
Photosynthetic Activity (fAPAR)

Remote Sensing Data - updated every 10 days



fAPAR, 21-30 May 2011
1km resolution



fAPAR Anomaly, 21-30 May 2011

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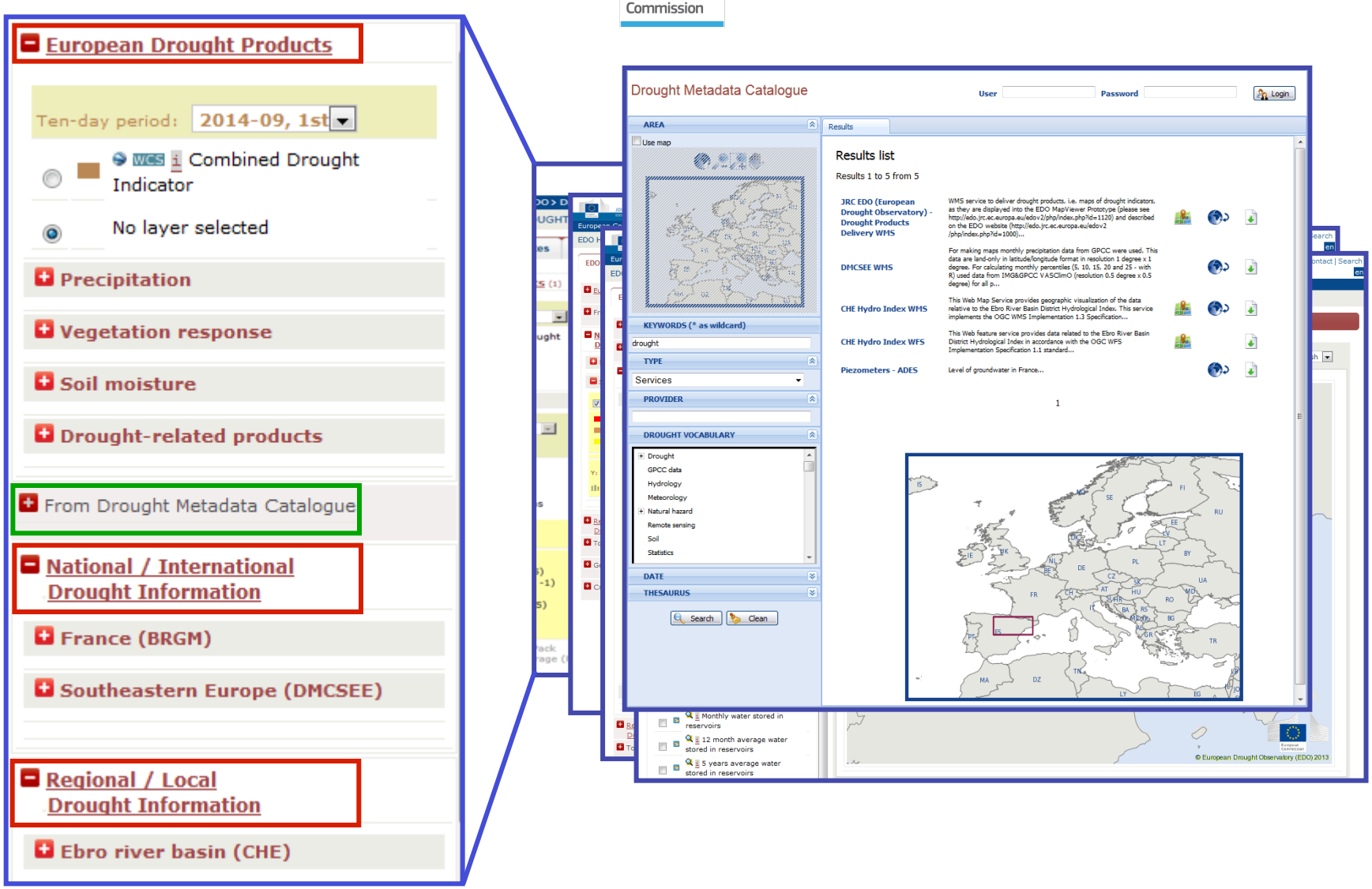
Multi-Scale Approach & Catalogue

European Commission



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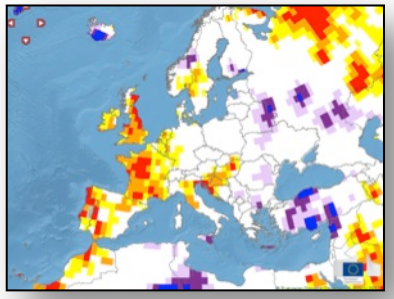
Available Indicators Continental Level

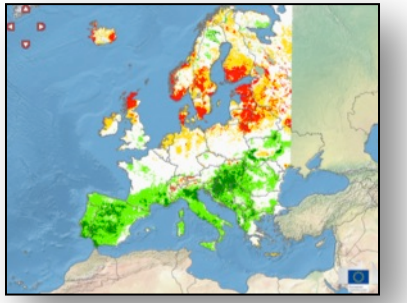
Precipitation (SYNOP, GPCC)

- ✓SPI (1, 3, 6, 9, 12, 24, 48 months)
- ✓Standardized Snow Pack (10 & 30 days)
- ✓SPI since 1973, SSPI since 2013
- ✓Resolution: 0.25 to 1.0 degree



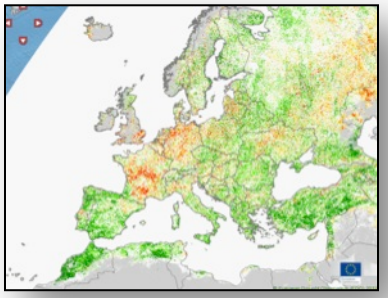
Soil Moisture (modelled, LISFLOOD)

- ✓Daily & 10-day soil moisture
- ✓Daily & 10-day soil moisture anomaly
- ✓7-day forecasted soil moisture anomaly
- ✓Since 1994 (1990)
- ✓Resolution 5 km



Vegetation Status (VEGETATION, MODIS)

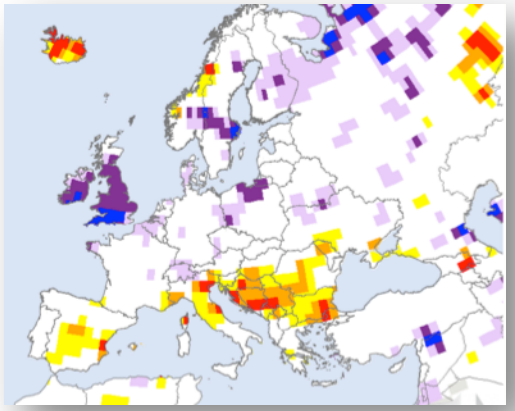
- ✓fAPAR 10-day composites.
- ✓fAPAR anomalies
- ✓Since 2002 (1999)
- ✓Resolution 1.2 km



Combined Drought Indicator (CDI)

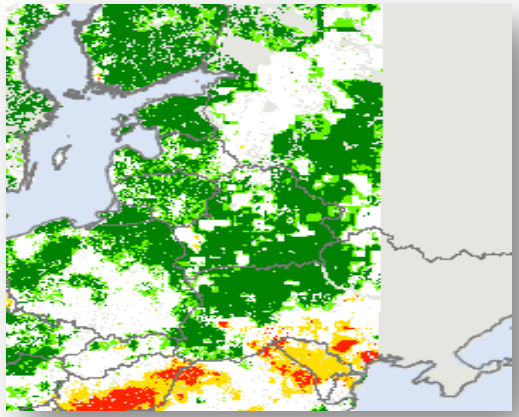
European Commission

Precipitation Anomalies (SPI)



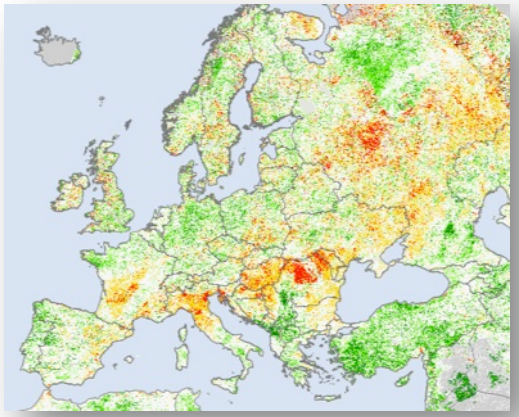
- reflects the statistically **expected frequency** (i.e. probability) of a given event
- is obtained **monthly** , calculated over **different rainfall accumulation periods**
- is obtained from the interpolation of observed **meteorological point data + Gridded GPCC data**
- **reference period**: 1981 - 2010

Soil Moisture Anomalies



- is obtained **daily** with the hydrological model LISFLOOD & aggregated to **10 days**.
- the meteorological input information is derived from observed **meteorological point data**
- is presented as **anomalies** (statistical deviation from the long-term mean)
- **reference period:** 1990-2010

fAPAR Anomalies



- is a **remote sensing derived** indicator available at intervals of **10 days**
- Is presented as **anomalies** (statistical deviation from the long-term mean)
- the available **time-series** is still short (from 1997)
- The indicator is derived from SPOT-VEGETATION and MODIS (**reference period:** 1999-2011)

Combined Drought Indicator (CDI)

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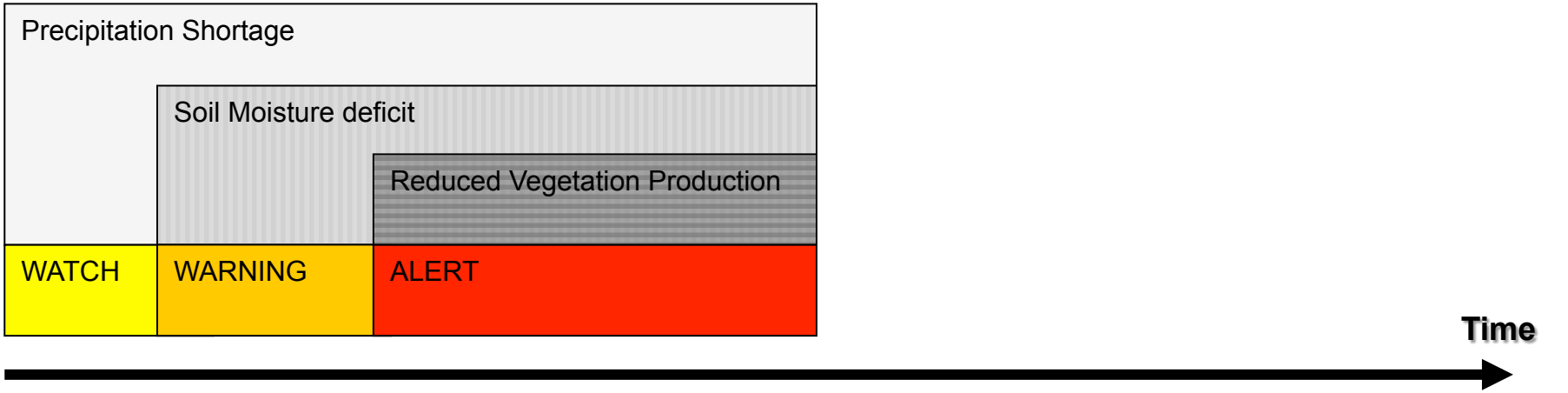
Combined Drought Indicator: Conceptual Framework

1st Combined Drought Indicator (CDI)
(Agricultural Drought)

Cause-effect relationships and related warning levels



Normal precipitation conditions	Normal Vegetation Production conditions
PARTIAL RECOVERY OF VEGETATION	FULL RECOVERY OF VEGETATION

Sepulcre-Canto, G., S. Horion, A. Singleton, H. Carrao, J.V. Vogt (2012): Development of a Combined Drought Indicator to detect agricultural drought in Europe. *Natural Hazards and Earth System Science*, 12 (11), 3519-3531.

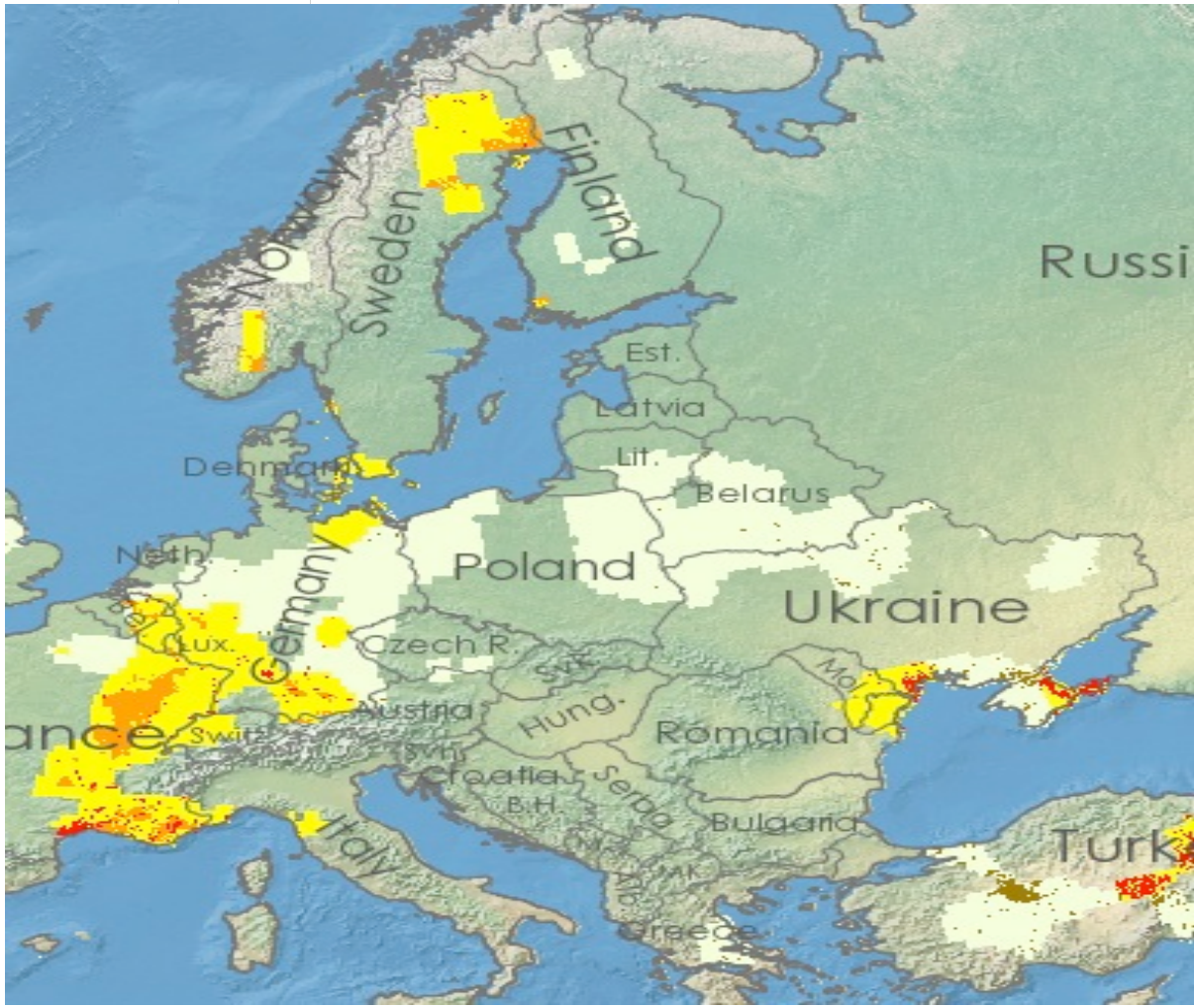
Combined Drought Indicator (CDI)

Impact	Level
Watch: rainfall deficit	1
	2
	3
Warning: soil moisture deficit	4
	5
	6
Alert: vegetation stress following rainfall/soil moisture deficit	7
	8
	9
	10

Increasing Dryness

Impact	Level
Partial Recovery of Vegetation: normal condition of rainfall still vegetation stress	11
	12
Full Recovery of Vegetation: normal condition of rainfall normal condition of vegetation productivity	13
	14

Increasing Recovery



CDI, 1-10 June 2014

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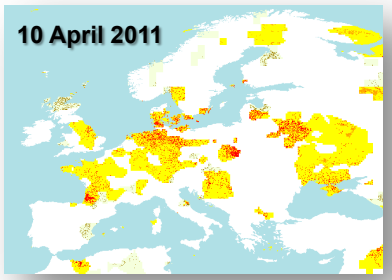
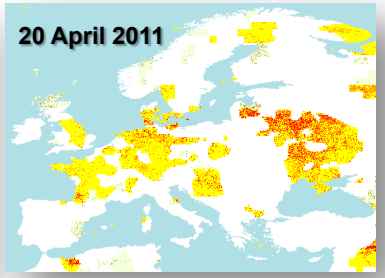
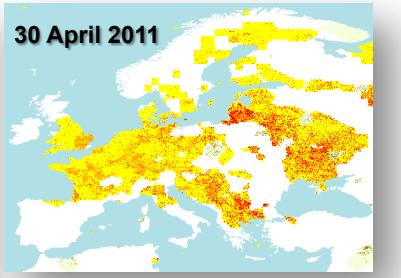
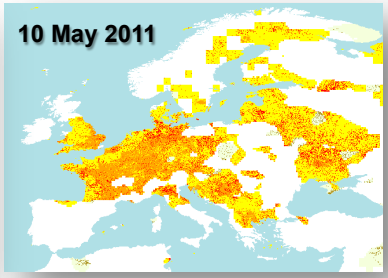
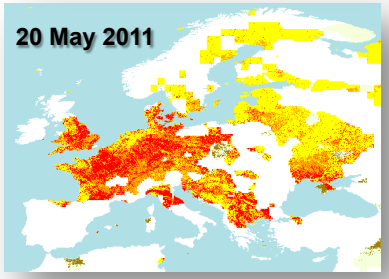
Ten-day steps

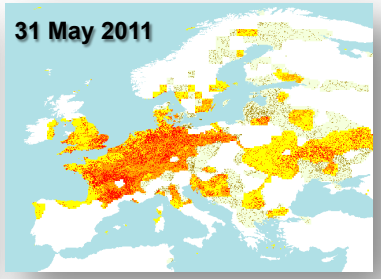


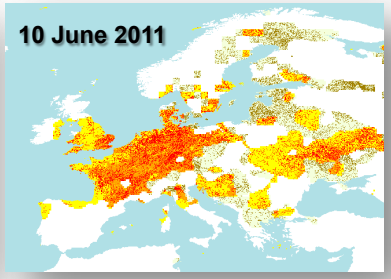


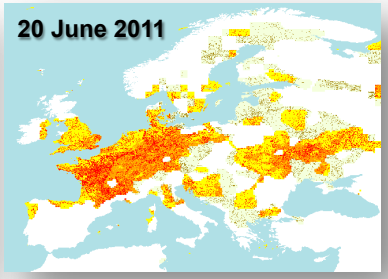


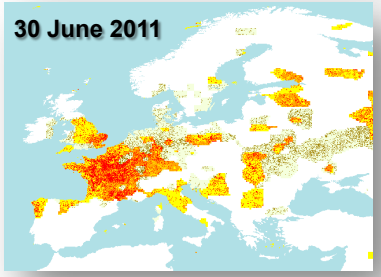


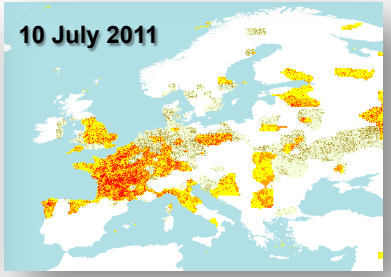


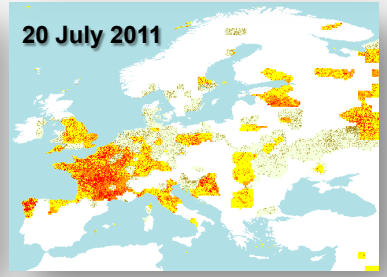


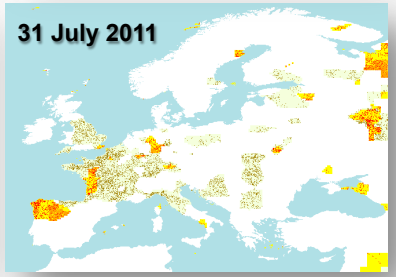




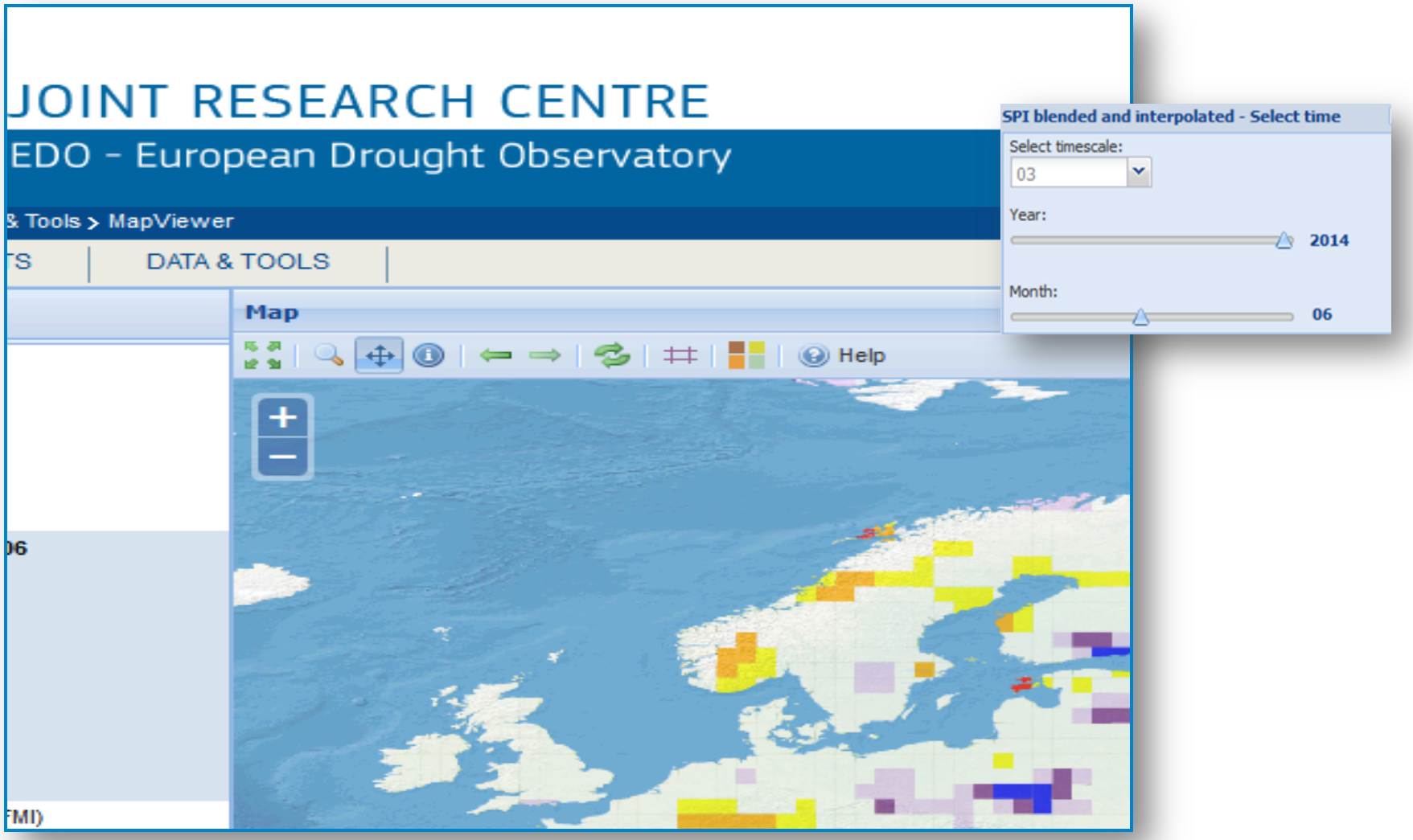




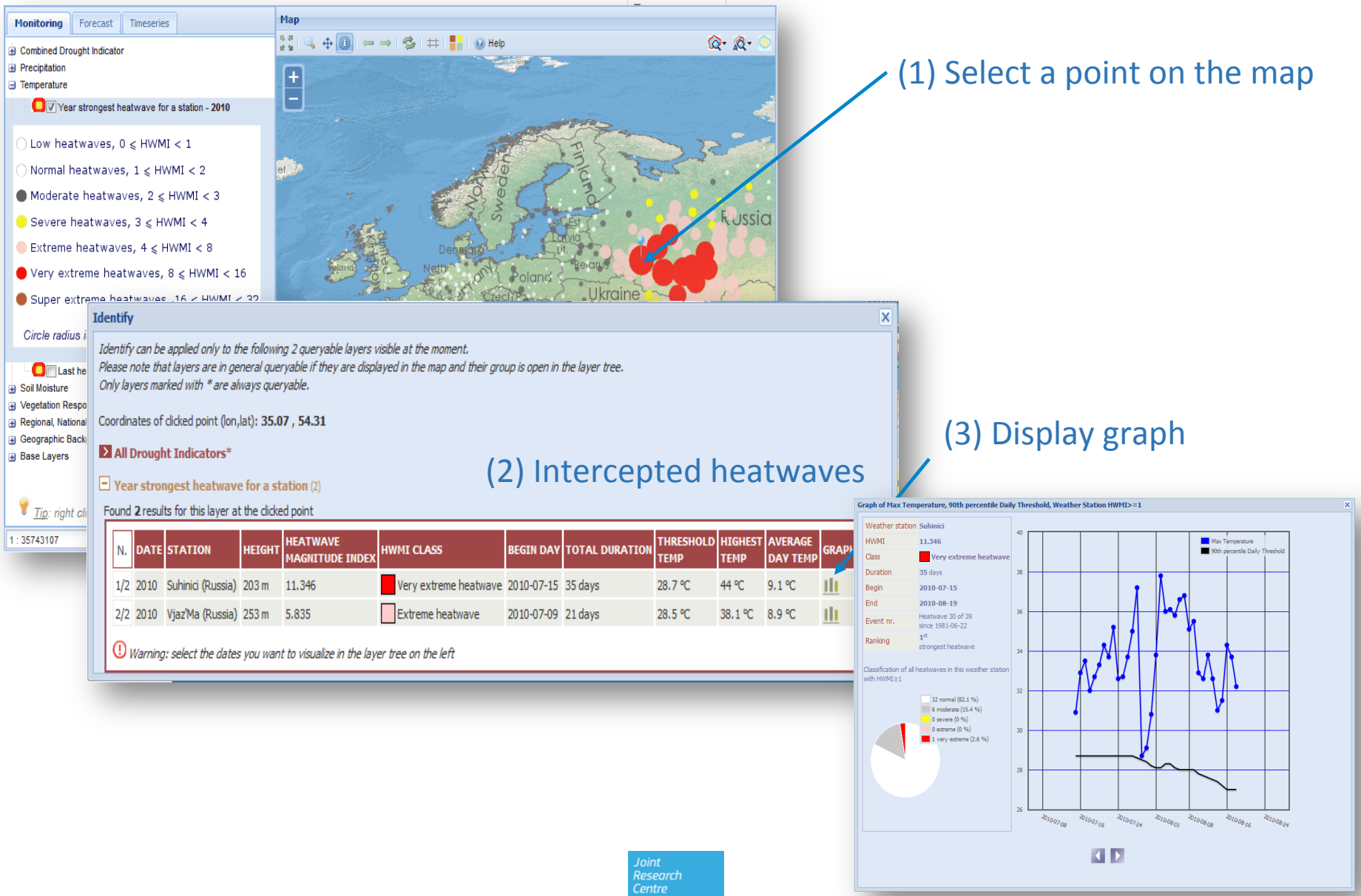




New Map Viewer



Heat Wave Layer



(1) Select a point on the map

(2) Intercepted heatwaves

(3) Display graph

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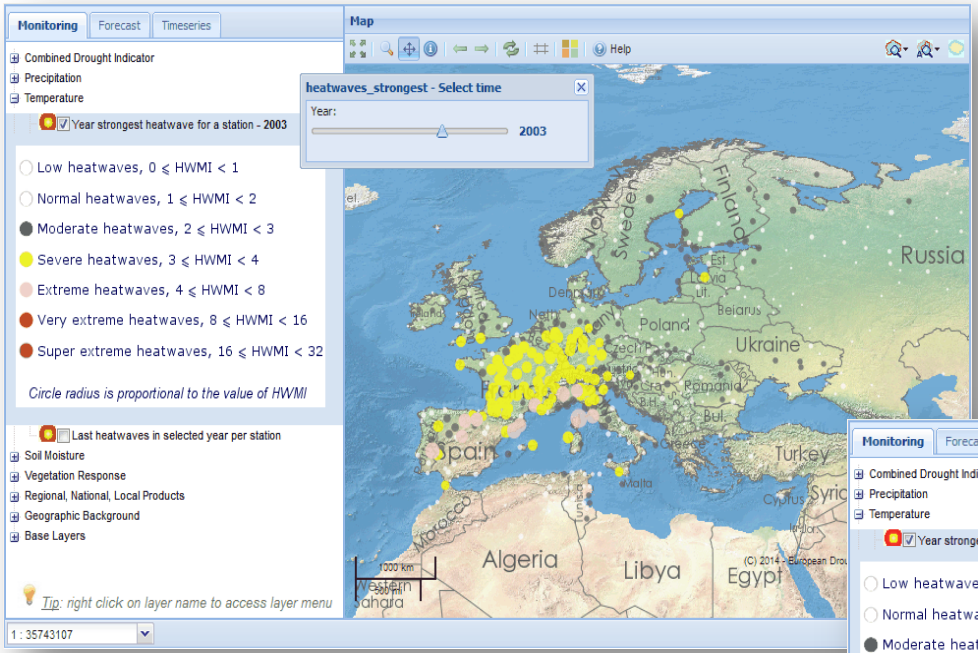
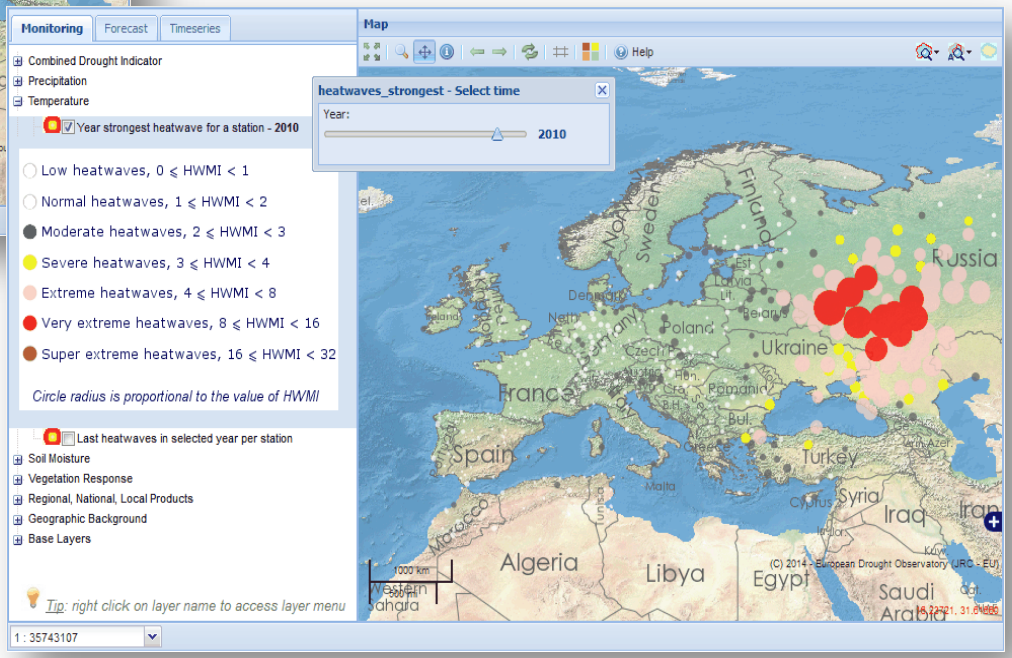
European & Russian Heat Waves

European Heat Wave 2003



Russian Heat Wave 2010



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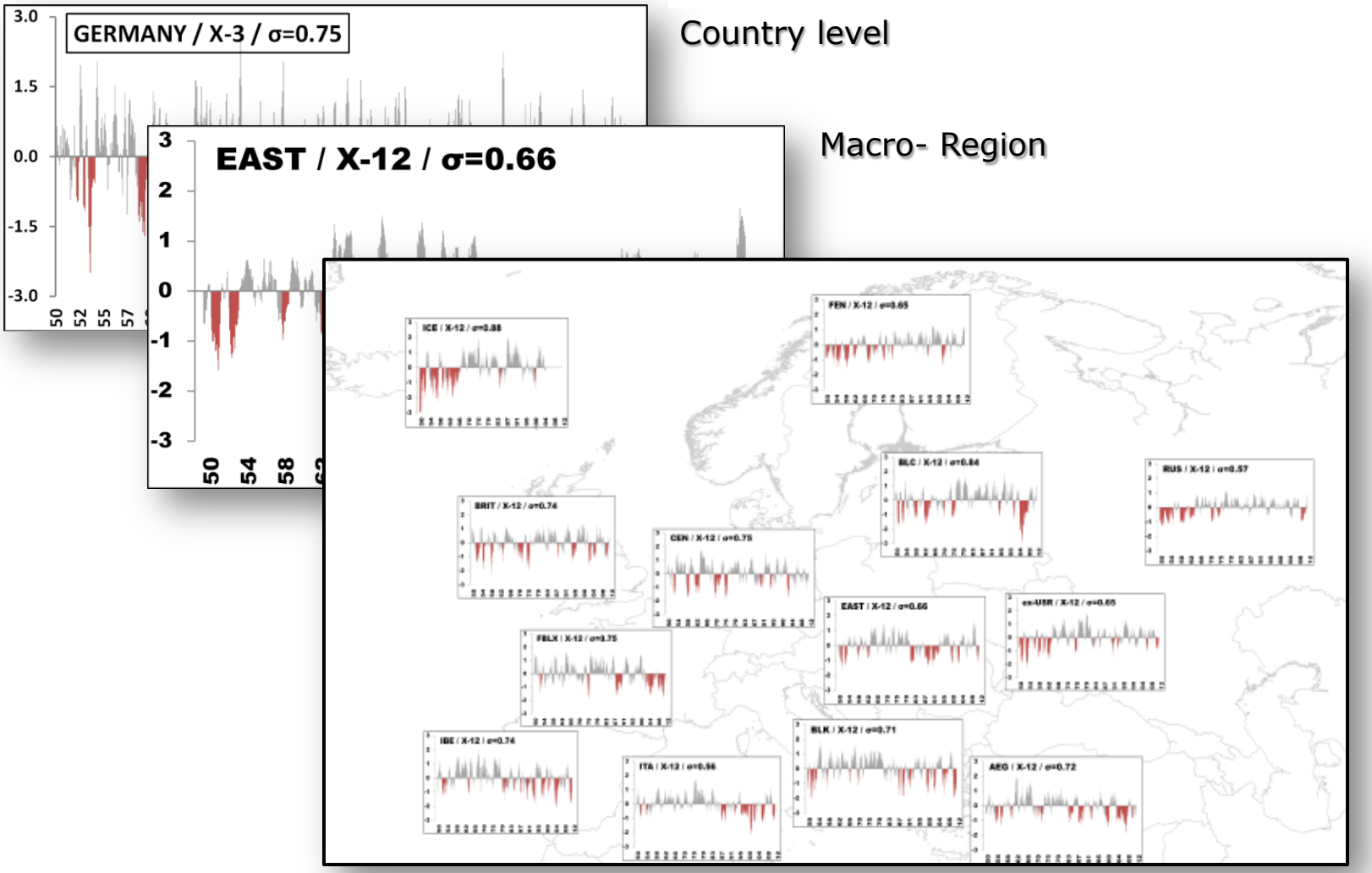
Drought Events Database



Country level

Macro- Region

E-OBS grids (v.10), 0.25˚x0.25˚ resolution
1950 - 2012

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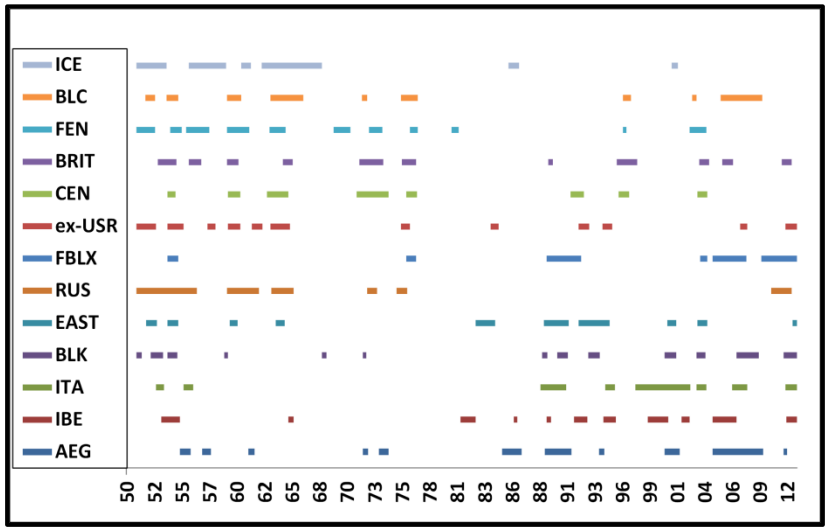
Spinoni, J., G Naumann, J Vogt; P Barbosa (2014): Constructing a pan-European database of past meteorological drought events for the period 1950-2012. *J. of Hydrology*, submitted.

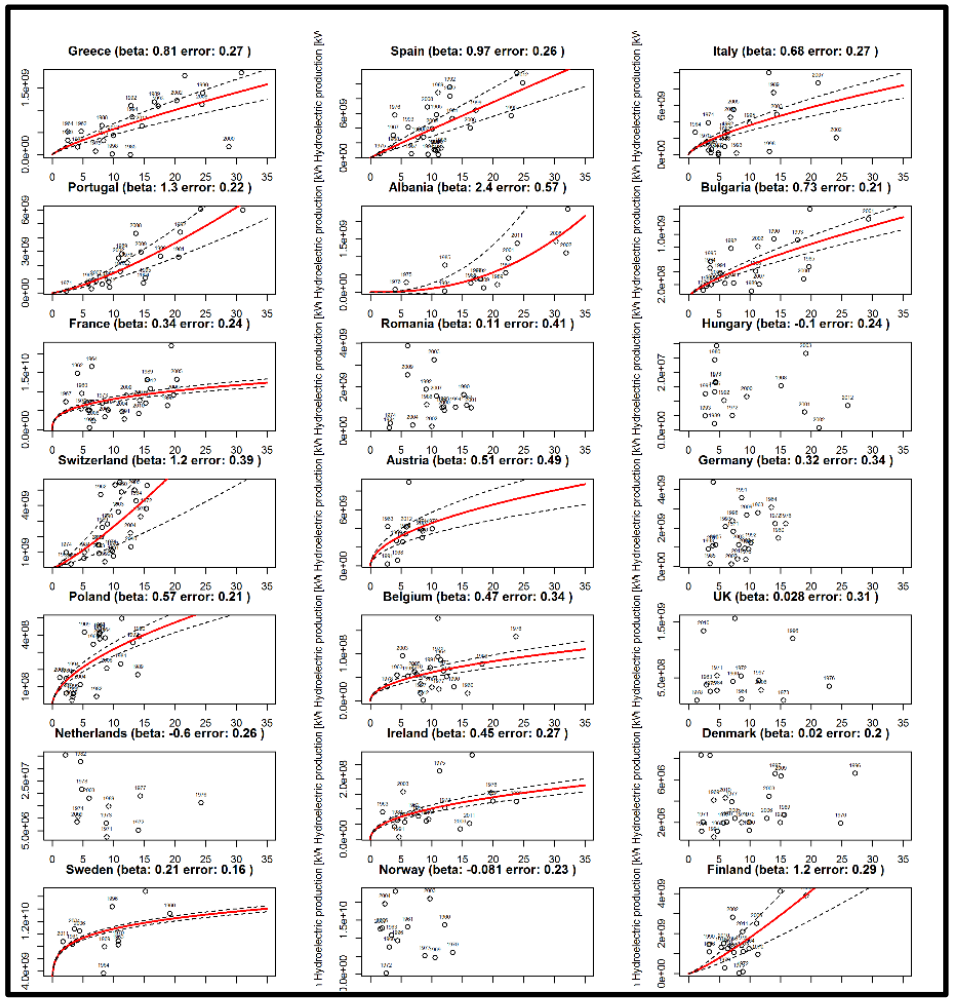
X-3	Longest	months	Most Severe	score	Widest	area
AEG	1989	9	1989	5.5	Apr-89	97.70%
IBE	1991-92	12	2005	4.4	May-95	93.30%
ITA	2006-08	16	2001-02	6	Jul-03	94.00%
BLK	2000-01	12	1952	5.4	Feb-90	99.00%
EAST	1990	10	2000-01	2.9	Mar-89	92.80%
RUS	1955-56	12	1950-51	5.1	Feb-51	81.80%
FBLX	1989-90	16	1976	5.7	Nov-78	95.40%
ex-USR	1953-54	17	1953-54	5	Dec-53	93.00%
CEN	2003	11	2003	4.3	Dec-53	98.60%
BRIT	1975-76	16	1975-76	5	Aug-95	99.40%
FEN	1959-60	14	1959-60	2.9	May-60	82.00%
BLC	2005-08	47	2005-08	16.5	Jul-06	100.00%
ICE	1950-51	19	1950-51	17.6	Apr-50	100.00%

X-12	Longest	months	Most Severe	score	Widest	area
AEG	2005-09	58	2005-09	10.4	Oct-01	80.20%
IBE	2005-07	24	2005-07	11.8	Aug-05	97.00%
ITA	1997-02	63	1997-02	16.3	Apr-02	91.40%
BLK	2007-09	26	2011-12	12.5	Mar-89	93.40%
EAST	1992-95	36	1989-91	7	Aug-52	84.50%
RUS	1950-56	69	1950-56	16.7	Jun-56	69.80%
FBLX	2009-12	41	1989-92	10	Jun-76	87.00%
ex-USR	1963-65	24	1953-55	14.1	Jun-64	95.80%
CEN	1971-74	37	1959-60	8.7	Aug-76	93.80%
BRIT	1971-74	28	1975-76	8	Sep-59	96.00%
FEN	1955-57	27	1959-61	8.6	May-60	76.40%
BLC	2005-09	48	2005-09	28	Aug-06	99.00%
ICE	1962-68	69	1962-68	29.1	Mar-51	100.00%



21 BIGGEST EVENTS

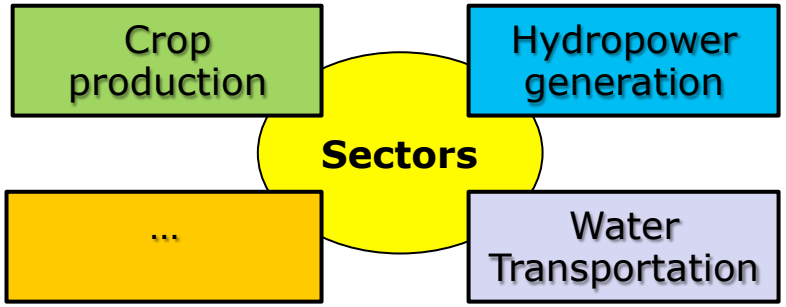
Ind	Period	Drought Macro-Area
X-3 ; X-12	1950-52	pan-European
X-3 ; X-12	1953-54	pan-European
X-3 ; X-12	1955-56	Northern Europe
X-3 ; X-12	1959-60	North-Central-Eastern Europe
X-3 ; X-12	1964	North-Central-Eastern Europe
X-3	1969	UK-Scandinavia
X-3 ; X-12	1972-74	pan-European
X-3 ; X-12	1976	Central Europe and British Islands
X-3	1983	Eastern Europe
X-3	1985	Southern Europe
X-3 ; X-12	1989-91	Southern Europe, Mediterranean
X-12	1992	Central Europe
X-3	1994	North-Eastern Europe
X-12	1995	Southern Europe
X-12	1996-97	Central and Northern Europe
X-3 ; X-12	1999-2001	Southern // Eastern EU
X-3 ; X-12	2003	European heat-wave
X-3 ; X-12	2004-05	Iberian Peninsula
X-3 ; X-12	2005-07	Baltic Republics
X-3 ; X-12	2007-08	Aegean countries
X-3 ; X-12	2011	France, England, Central Europe



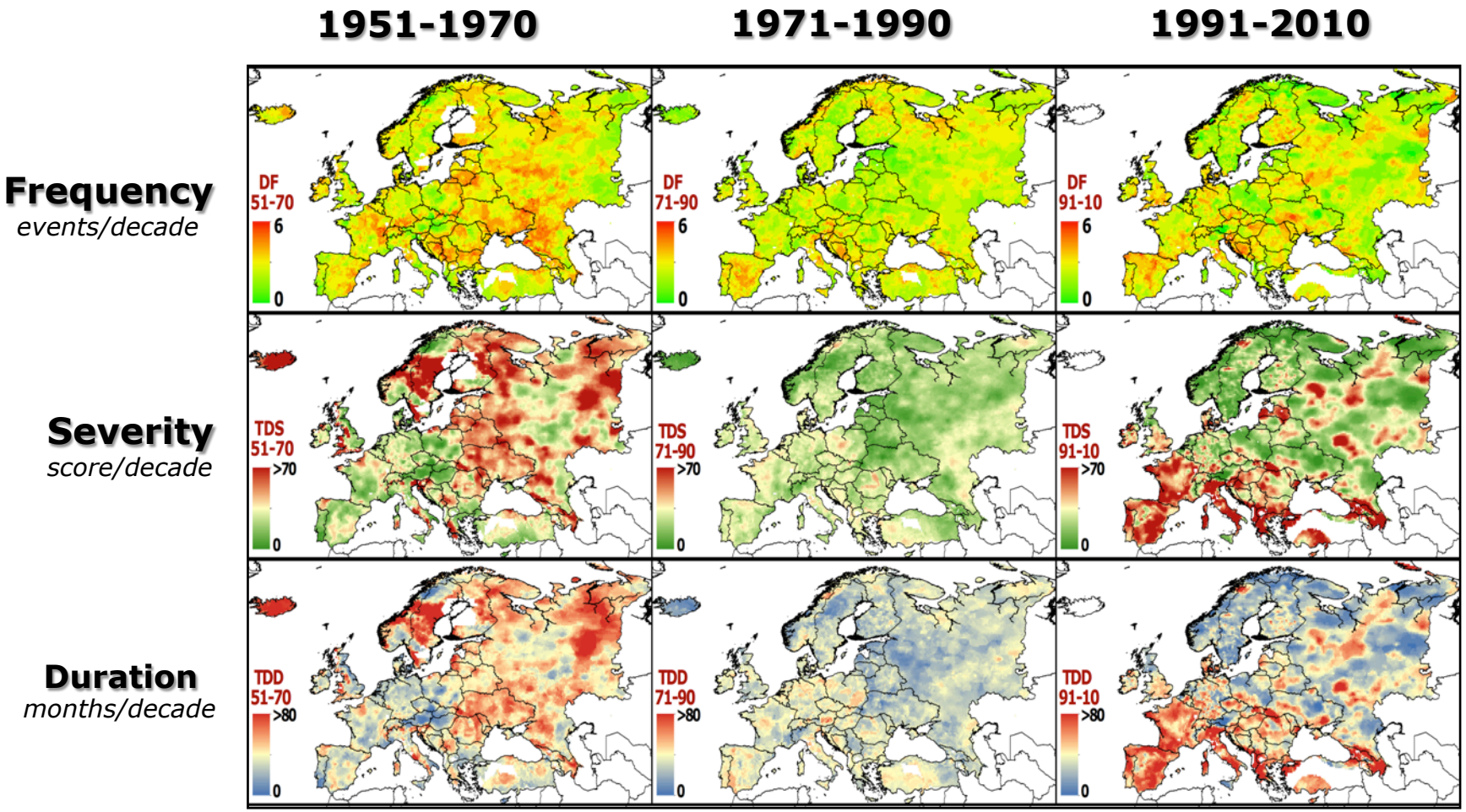
Damage $\approx \alpha S^{\beta}$
(S: drought severity)

Deriving Damage Functions:

- **Analysis per country**
- **Different economical sectors**



Example:
Drought severity vs reduction in hydropower generation



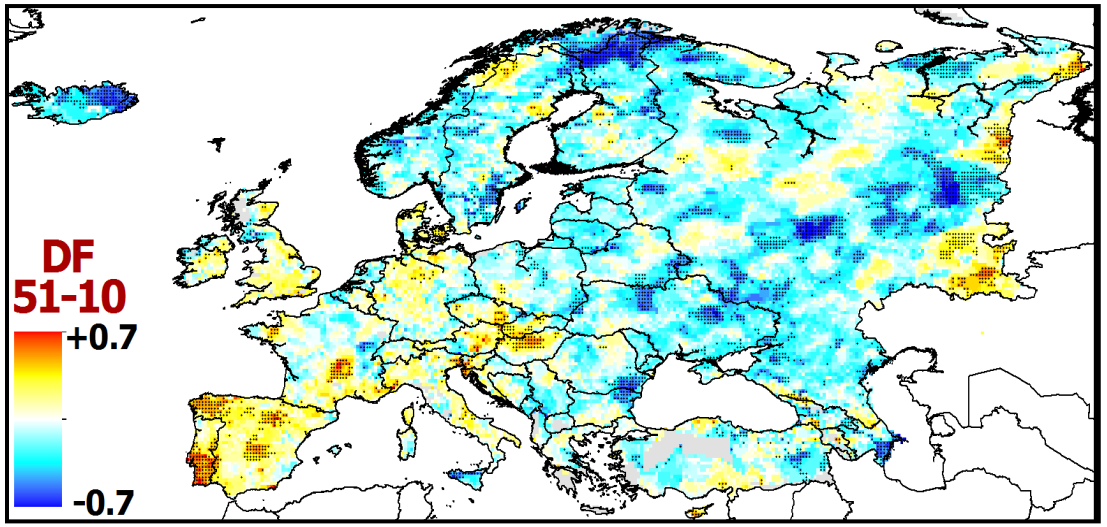
E-OBS grids (v.10), 0.25˚x0.25˚ resolution

Joint Research Centre

Spinoni, J., G Naumann, J Vogt, P Barbosa: European drought climatologies and trends based on a multi-indicator approach. *Global and Planetary Change*, submitted

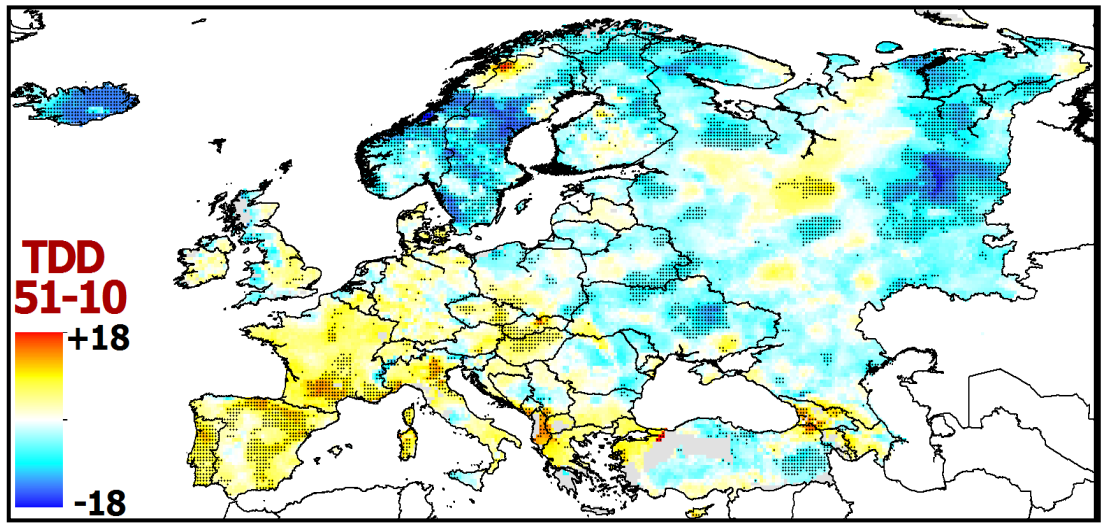
FREQUENCY

Linear Trend
(events/10years)



DURATION

Linear Trend
(total months in drought/10years)



Dots: trends significant at ≥95%.

Period: 1951–2010

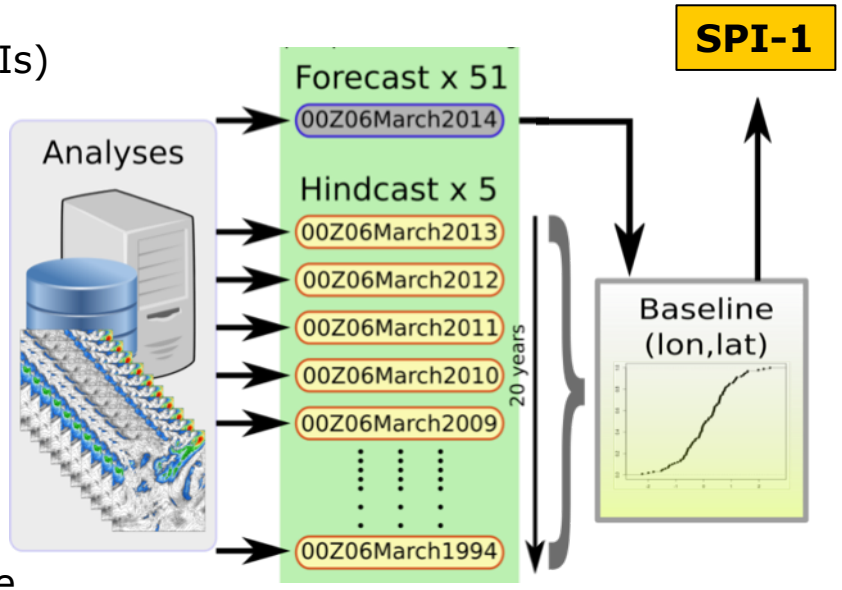
Joint Research Centre

Spinoni, J., G Naumann, J Vogt, P Barbosa: European drought climatologies and trends based on a multi-indicator approach. *Global and Planetary Change*, submitted

European Commission

Objectives:

- Testing monthly drought forecasting (using SPI-1)
- Assessment of the uncertainties
- Validation of drought forecasting vs. E-OBS
- Production of a robust index (e.g., based on 51 SPIs)

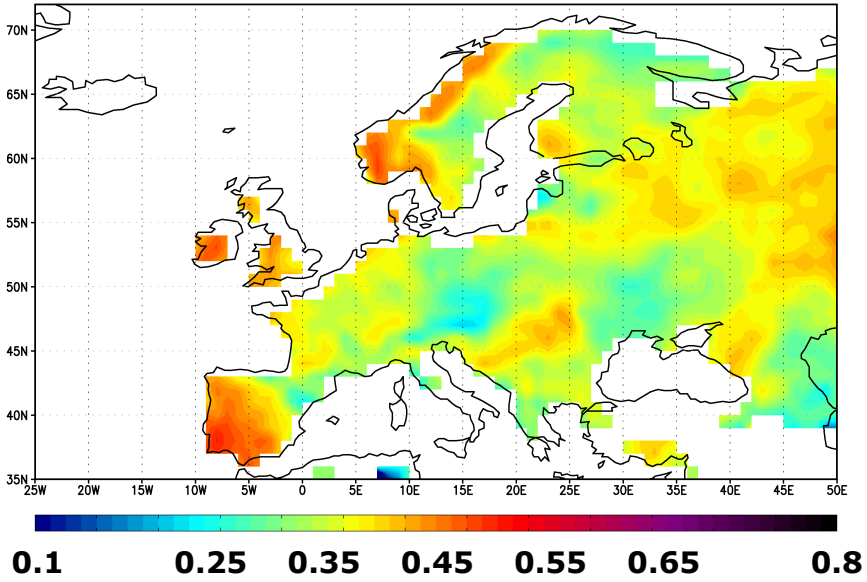


Methodology:

- ECMWF Ensemble 32-days precipitation forecast, once per week
- Hindcasts: 5 members, for the last 20 years, once per week (reference to calculate the SPI-1)
- Forecasts: 51 members, Nov 2012 – Nov 2013
- Resolution 1.0 degree

Correlation forecasted - observed SPI-1

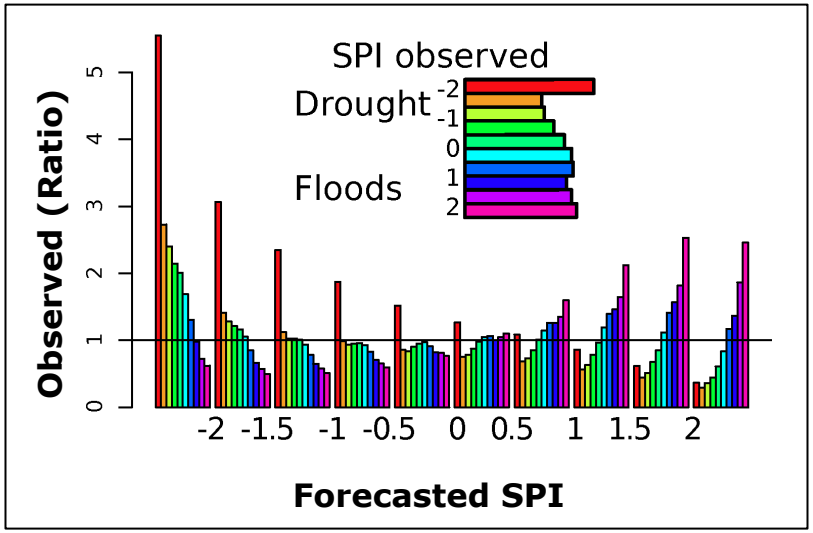
Nov. 1992 – Nov. 2012



Forecasted: ensemble mean

Observed vs. forecasted SPI-1

Nov. 1992 – Nov. 2012



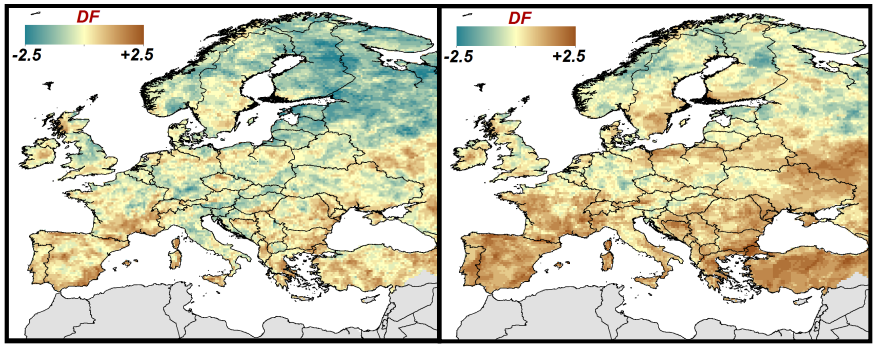
Ratio: Observed/theoretically expected

- **Approx. 1/3 of drought events correctly forecasted 1 month in advance**
- **An index based on the ~30% driest ENS members performs best**
  (prob. of detection and percent correct)
- **No significant spatial or seasonal differences**

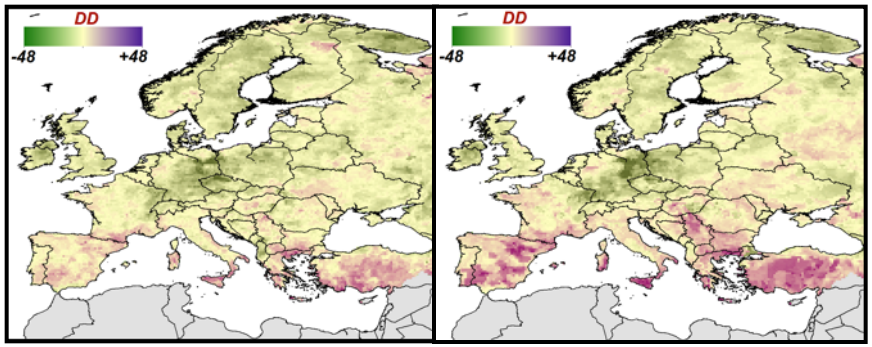
European Commission

DROUGHT FREQUENCY

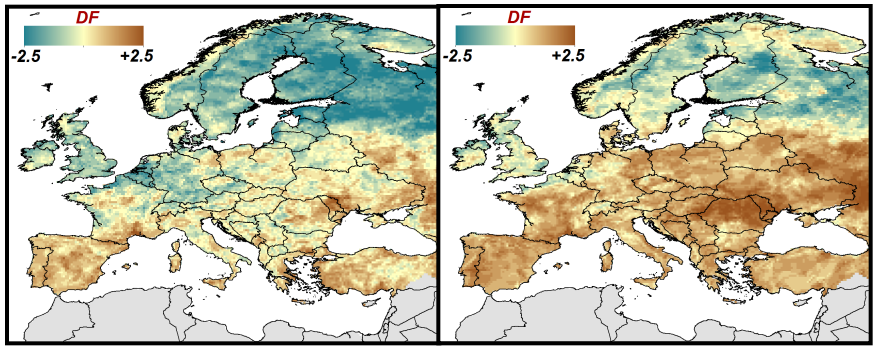
DROUGHT DURATION



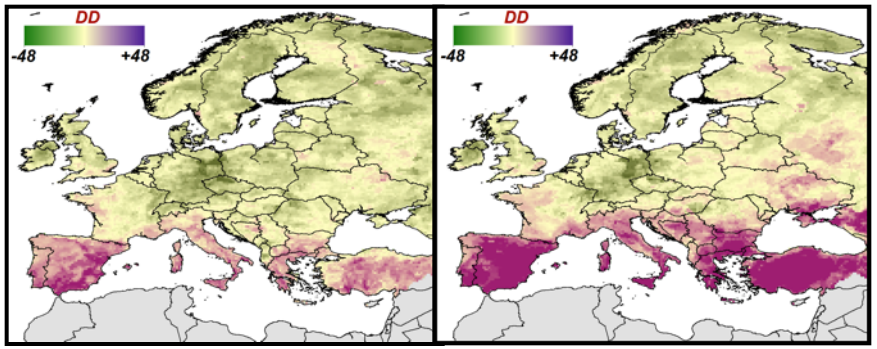
2041-70 vs 1981-10



SPI-12 SPEI-12 SPI-12 SPEI-12



2071-00 vs 1981-10



Drought Events/10years

Event Duration (months)

Scenario: A1B
Model: Racmo, v2.2, KNMI

Joint Research Centre

Probability Changes for Extremes, based on SPI

European Commission

Future Dry and Wet Periods

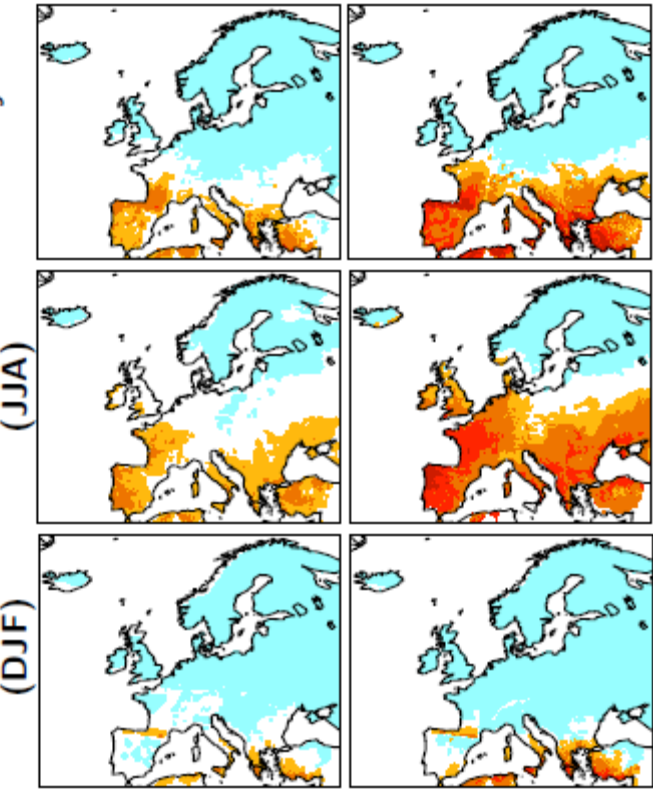
Extreme Dry

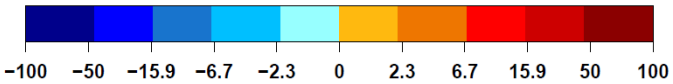
Mid Century | End Century

Yearly

SUMMER (JJA)

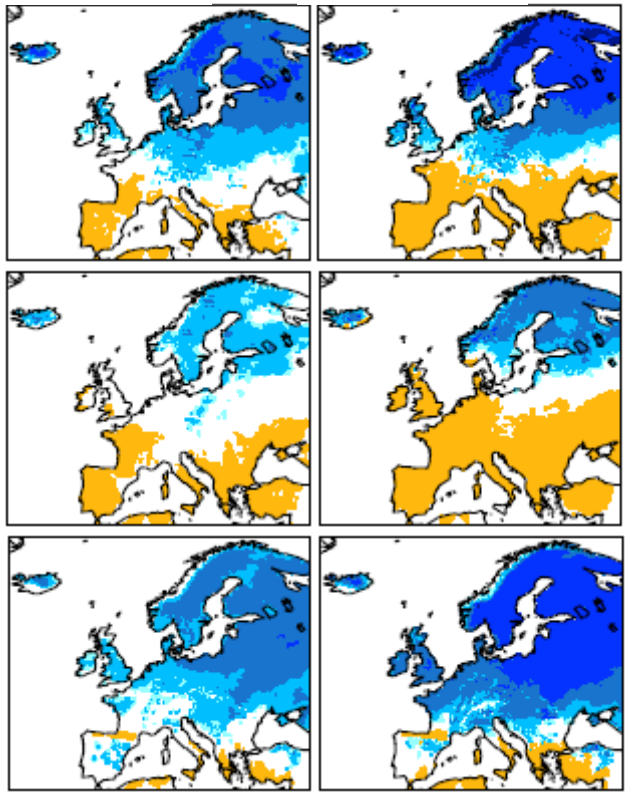
WINTER (DJF)

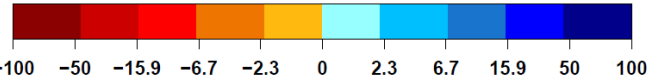




Extreme Wet

Mid Century | End Century





Probability Difference

based on SPI

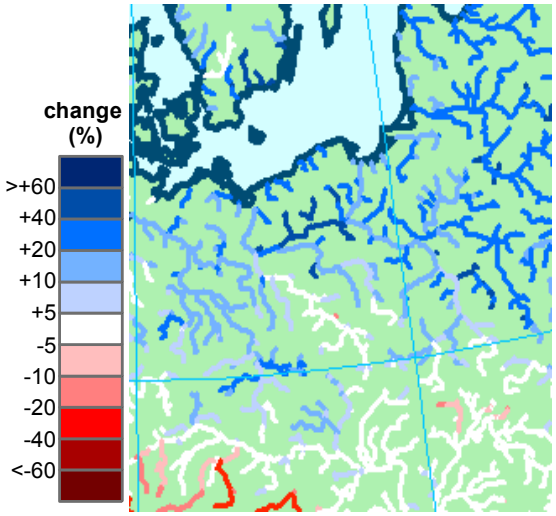
Joint Research Centre

Russo, S., A. Dosio, A. Sterl, P. Barbosa, J. Vogt (2013): Projection of Occurrence of extreme dry-wet years and seasons in Europe with stationary and non-stationary Standardized Precipitation Index. *Journal Geophysical Research: Atmospheres*, 2013, 118, 1-12.

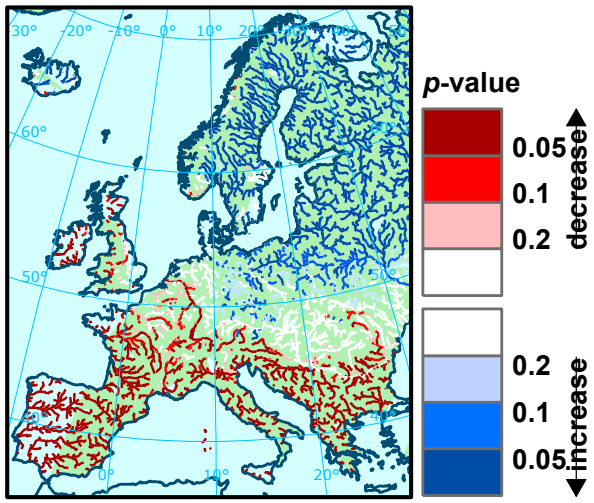
Future Streamflow Drought

European Commission

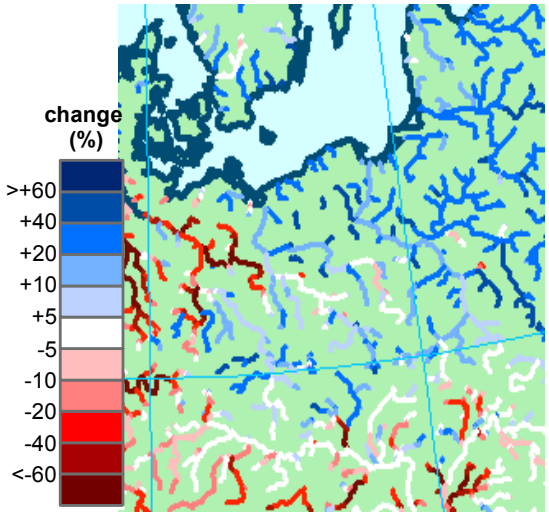
SRES A1B **ensemble mean from 12 models**



Relative change in 20-yr drought event between 1961-1990 and 2080s



Significance of change in 20-yr drought event



Relative change in 20-yr drought event between 1961-1990 and 2080s
Accounting for WATER USE

- strong increase in droughts in southern Europe
- intensive water consumption intensifies drought conditions

Joint Research Centre

Forzieri, G. L. Feyen, R. Rojas, M. Flörke, F.Wimmer, and A. Bianchi (2014): Ensemble projections of future streamflow droughts in Europe, Hydrol. Earth Syst. Sci., 18, 85–108.

Take-Away Points

- EDO is based on multiple, commonly agreed indicators
- It is implemented as a multi-scale distributed system based on interoperable map servers
- Core indicators are complemented by regionally relevant indicators
- Includes a 7-day forecast of soil moisture
- Database of past events

→ http://edo/jrc.ec.europa.eu

Ongoing:

- Analysis of impacts and derivation of impact functions
- Testing of options for medium to long-range forecasting
- Analysis of hazard, vulnerability & risk (current & future)
- Further development as part of a multi-hazard platform and as input to the Global Drought Information System

http://edo.jrc.ec.europa.eu

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European Commission

Joint Research Centre

Climate Risk Management Unit

http://ies.jrc.ec.europa.eu/