Agricultural Drought Indices in Current Use in France and Europe: Strengths, Weaknesses and Limitations

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World Meteorological Organization

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RA VI and the concept of drought

- Drought is a recurrent event in Europe which is part of natural climate variability. It may occur in all European climatic zones.
- It differs from aridity, which is restricted to low rainfall regions like Mediterranean area and which is a permanent feature of climate.
- An increase in mean summer water deficit during the past 30 years.
- Climate change scenarios predict significant decrease in summer precipitations in Southern Europe.
- Recent droughts in Europe are a good illustration of the potential impact of increasing drought frequency.
- Different types of drought can be defined : meteorological drought, hydrological drought, agricultural drought and socioeconomic drought
- Agricultural drought deals with agricultural impacts, focusing on precipitation shortages, evapotranspiration and soil water deficits
- Drought can be viewed in three dimensions: intensity, duration and the area it covers.

Drought indices

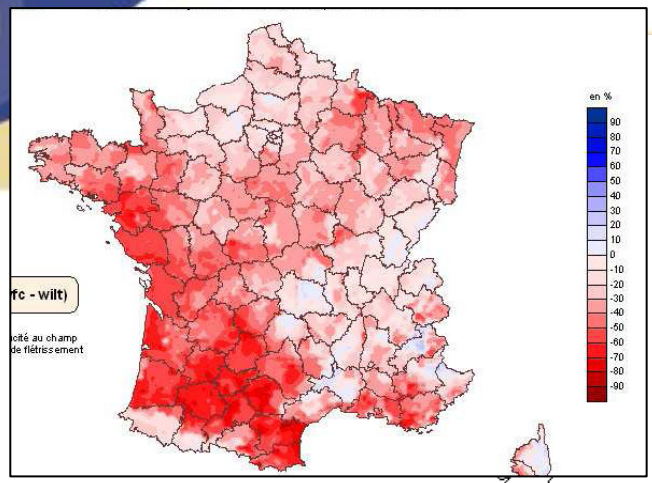
- A drought index value is typically a single number far more useful than raw data for decision making.
- WMO defines a drought index as an index which is related to some of the cumulative effects of a prolonged and abnormal moisture deficiency.
- Choice of relevant drought indices depends on the socio-economic activity domain ⇒ **No universal drought index**
- Drought monitoring can be based on a synthesis of multiple drought indices.
- The complexity of drought indices depends on the number of parameters taken into account.
- A huge diversity of drought indices are used in RA VI. The following tables give

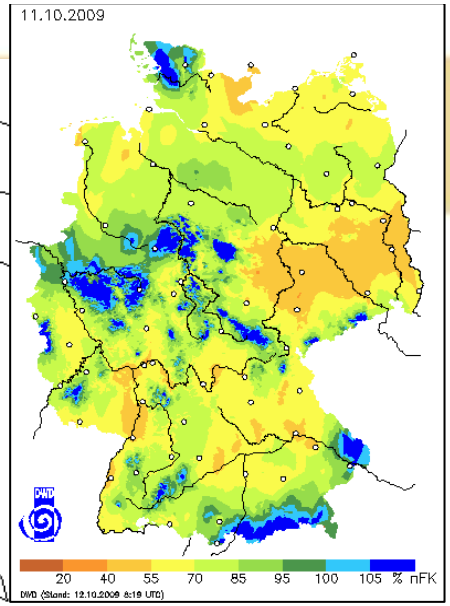
Some agricultural Drought indices run in Europe

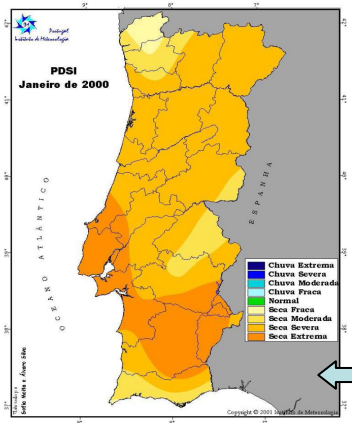
- National Rainfall Index (RI) - Gommes et Petrassi (1994)
- Dry Conditions and Excessive Moisture Index (DM Index) - Meshcherskaya et Blazhevich (1997)
- Crop-Specific Drought Index (CSDI) - Meyer et al. (1993)
- Keetch-Byram Drought Index (KBDI) - USDAFS, 1999
- SVAT model Soil water index: SWI from ISBA model - Météo-France
- SVAT model AMBAV model - DWD
- Crop Moisture Index (CMI) - Palmer (1968)
- Palmer Drought Standardised Index (PDSI) - Palmer (1965)
- Self Calibrated PDSI (SC-PDSI) - Wells et al. (2004)

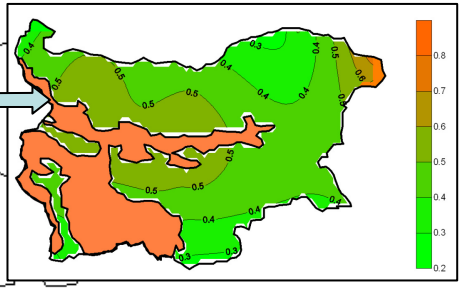
European context

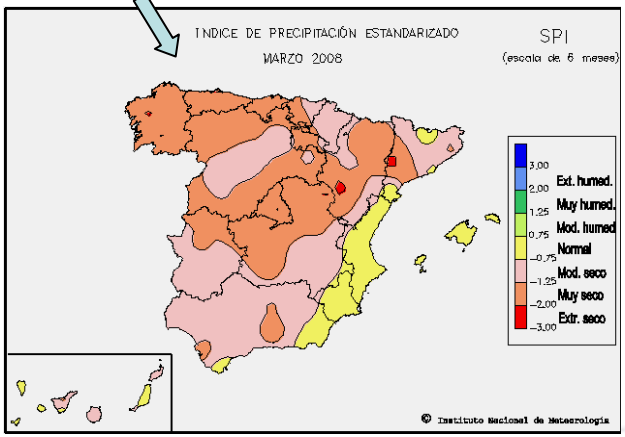
- At the moment there is no uniform approach for drought monitoring in Europe (Hahne 2008).
- Drought indices in different European countries usually refer to the intensity and spatial extent of droughts. The prediction is made by coupling agrometeorological models with meteorological data.
- For example in Germany the Deutsche Wetterdienst uses the Martonne index, SPI (Standardized Precipitation Index) and the output from the water balance model in order to assess the intensity of droughts.
- Other European countries have carried out research studies on drought indices but not used for forecasting. In Great Britain research has been done on the DSI (Drought Severity Index), in Portugal on the PDSI (Palmer Drought Severity Index) and in Greece on the RDI (Reconnaissance Drought Index).
- There are several international projects at European level that aim to standardize the definitions of drought and to develop plans and anticipation of actions in case of drought.
- Two major european initiatives : JRC research activities and DMCSEE established in 2006 as a joint venture of UNCCD and WMO.











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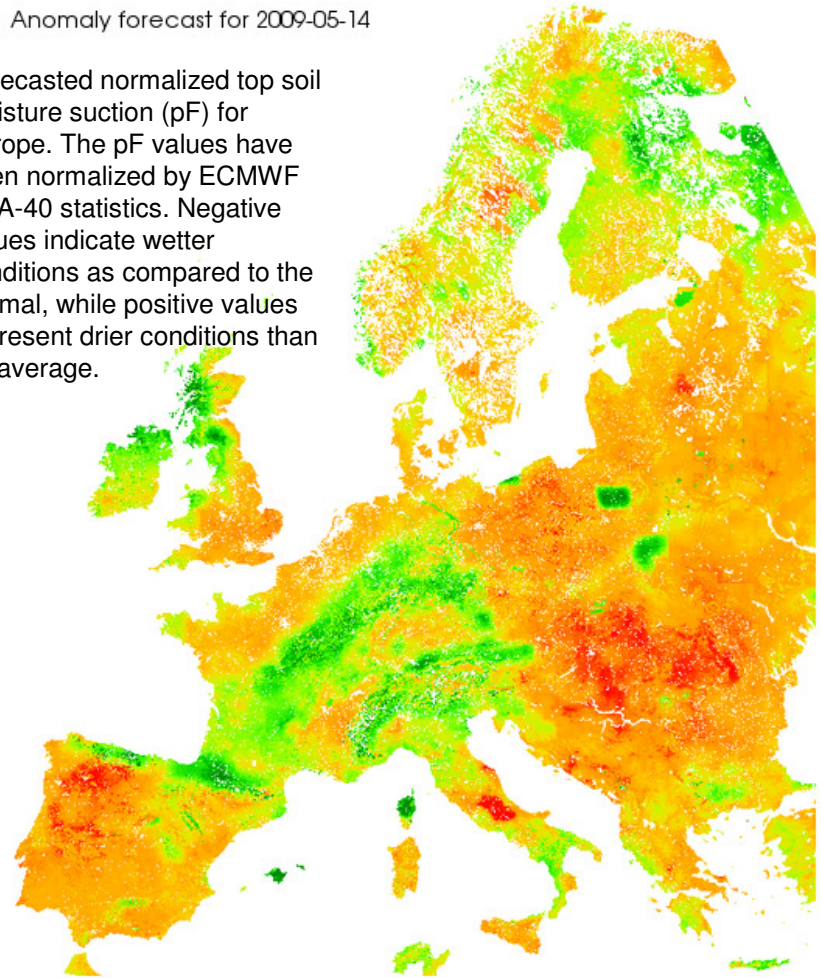
Joint Research Center approach

- The NAHA-IES (Natural Hazard of the Action Institute for Environment and Sustainability) project is under the lead of the JRC.
- The aim is to try to establish a system for monitoring, detection and forecasting of droughts at European level.
- Precipitation anomalies, soil moisture and soil moisture anomalies are available freely on the JRC website.
- Precipitation anomalies are represented by monthly SPI.
- In the forecasting mode the European Flood Alert System (EFAS) produces information on the development of soil moisture in Europe for up to ten days ahead.



Forecasted normalized top soil moisture suction (pF) for Europe. The pF values have been normalized by ECMWF ERA-40 statistics. Negative values indicate wetter conditions as compared to the normal, while positive values represent drier conditions than on average.

Results are currently under investigation and have to be considered preliminary.

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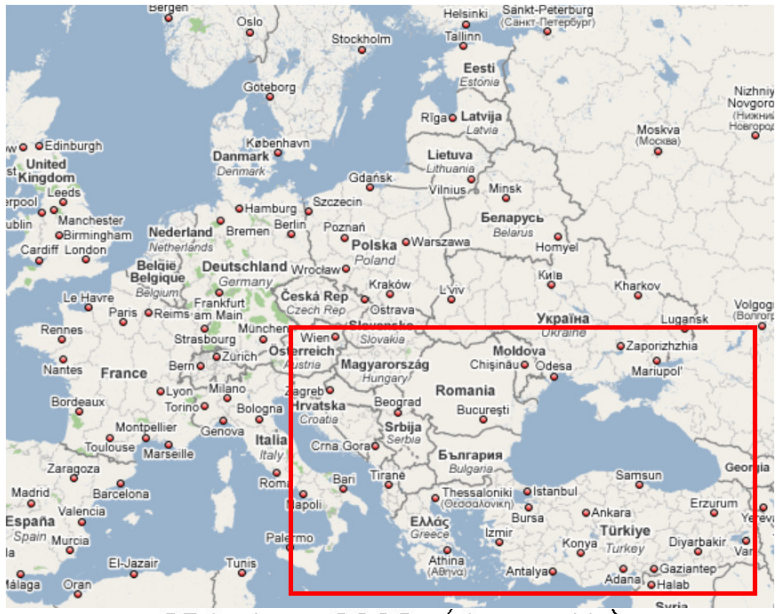
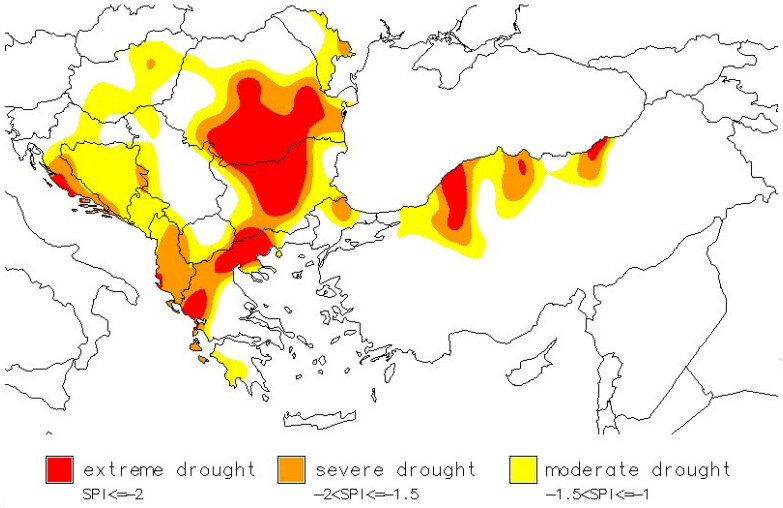
Drought Management Center for South Eastern Europe (DMCSEE)

- Based in Slovenia and within the context of the UNCCD (United Nations
- DMCSEE is primary a network : DMCSEE consortium was established from representatives of NMHS, national UNSDD focal points and representatives of academic spheres.
- The goal is to improve drought preparedness and reduce drought impacts.
- Drought monitoring is currently based on Global Precipitation Climatology Centre (*GPCC*) data, maps of the SPI, Percentiles and Precipitation for the region.
- DMCSEE is also developing suite of products to monitor drought and precipitation conditions in South-eastern European region.
- PDSI and SPI were chosen to be first drought indicators implemented in the framework of DMCSEE.



SPI Aug 2008 (1 month)
GPCC final analysis



Operational drought indices in France

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Drought indices for Agriculture in France

- Two drought indices are currently run by Météo-France in a operational context:

- Operational water balance with two reservoirs
- SVAT model (SIM model)

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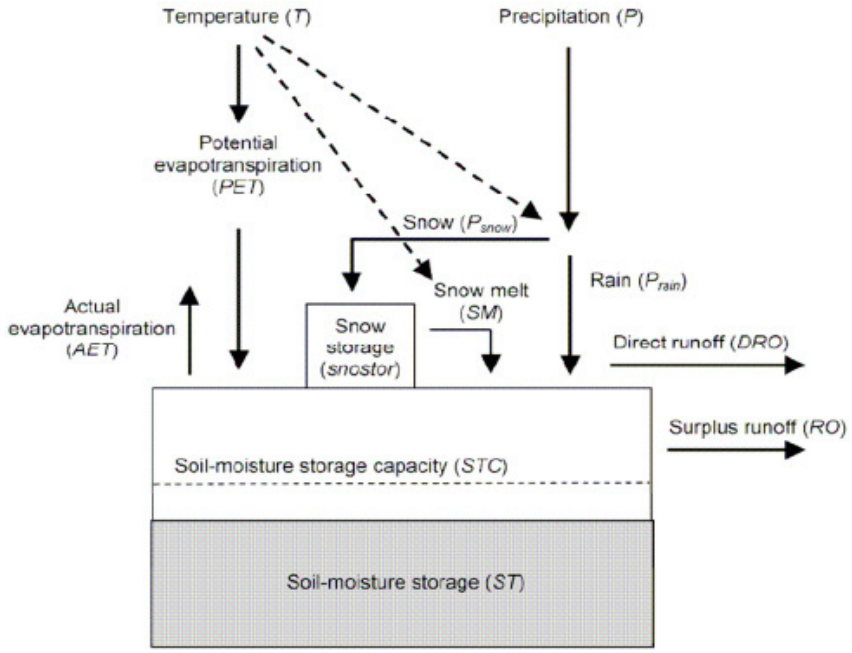
Drought indices for Agriculture in France

- Simplified operational water balance with two reservoirs
- Choisnel and Jacquart (1995)
- Fixed sizes, soil depth=1m
- Applied all over France on fescue grass
- 4 cases for the available water
- RU= 50 &100 mm (sandy)
- RU=150 mm (clayey)
- RU=200 mm (silty)
- Input daily data: rainfall and PET
- Output data: remaining water (value, percentage) and run-off



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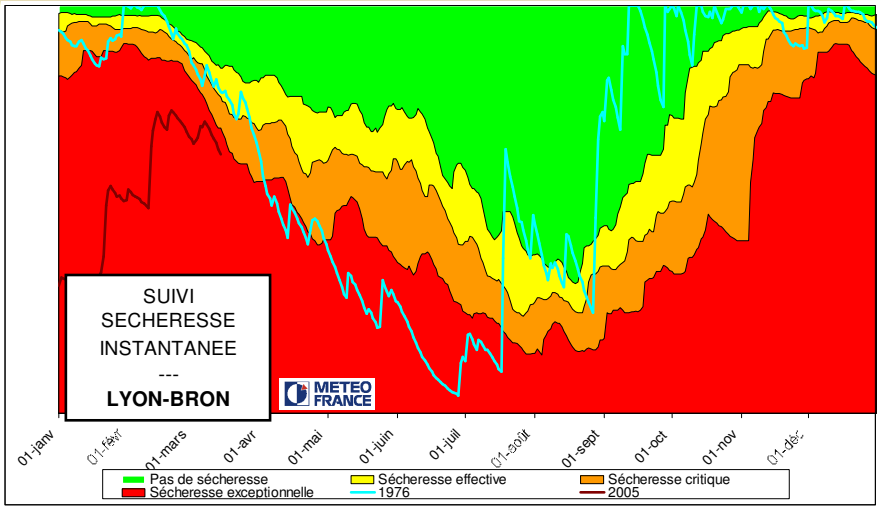
Drought indices for Agriculture in France

Strengths:

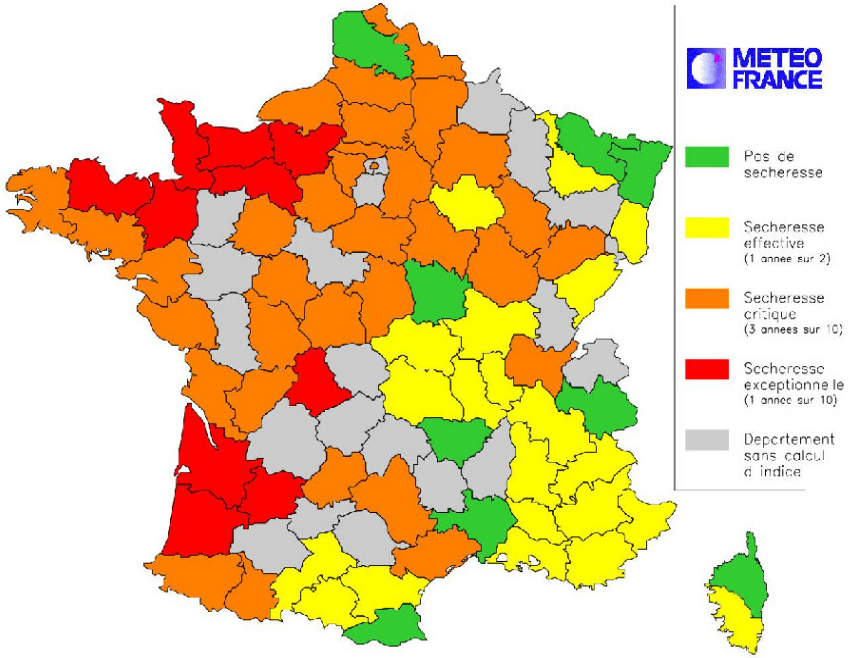
- Easy to calculate at station level
- Synthetic view of the water balance
- Accurate
- Drought assessment can be performed through a comparison of modeled water content with different statistical thresholds in order to assess the relative frequency of the event.

Limitations :

- No interaction of crop and soil kinds
- Spatialization



Suivi instantane de la secheresse en date du 2010/05/29



Drought indices for Agriculture in France

- The second index is extracted from the SAFRAN ISBA MODCOU (SIM) hydrometeorological model which is used in order to provide consistent computation of variables within the hydrological cycle.
- The SIM hydrometeorological chain consists in three independent modules : the SAFRAN atmospherical analysis, the ISBA SVAT model and the MODCOU hydrogeological model.
- This hydrometeorological suite is described in Habets et al. (2008), Noilhan and Mahfouf (1996) and Quintana-Seguí et al. (2008).

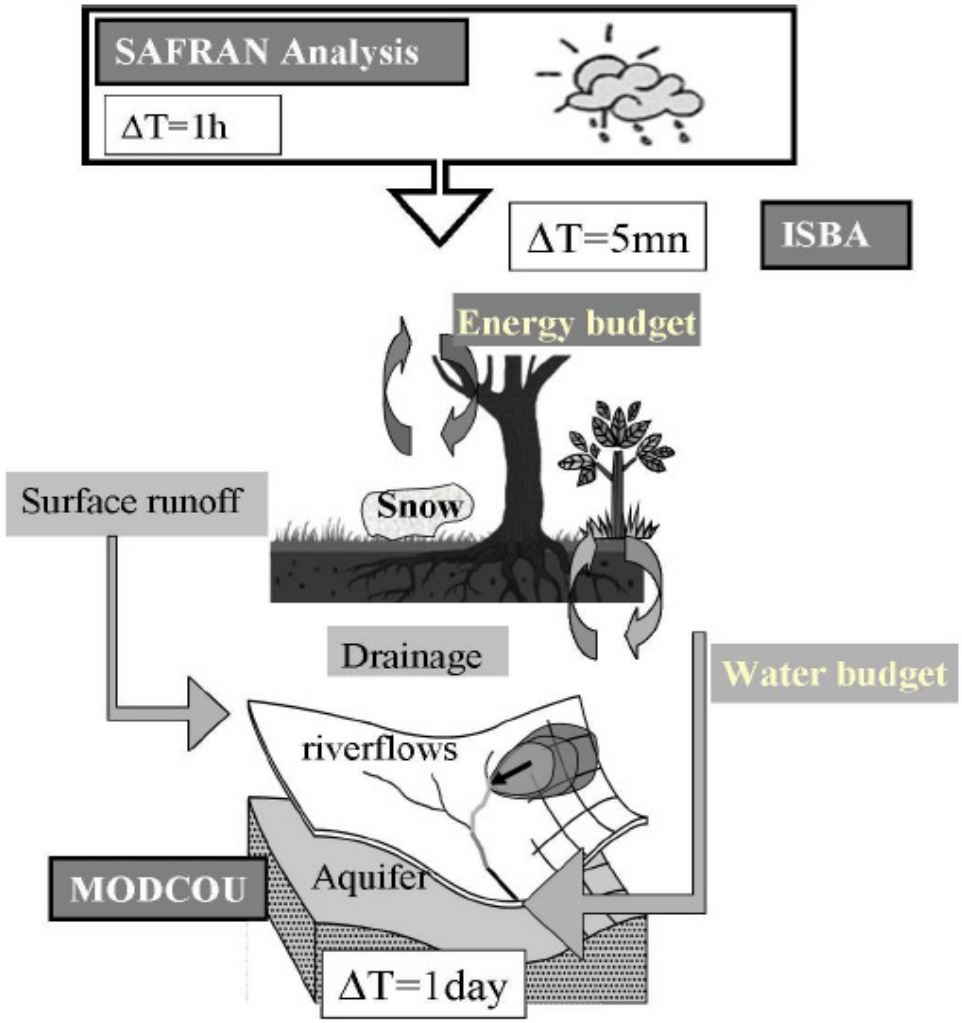


Figure 1. The SIM hydrometeorological model consists in three independant modules: the SAFRAN atmospherical analysis, the ISBA land surface model, and the MODCOU hydrogeological model

Safran-Isba-Modcou (SIM)

Safran
atmospheric analysis system

Optimal Interpolation of ERA-40 + ground observations

Gridded **rainfall, snowfall**, temperature, humidity, wind speed, visible, infrared radiation (8km, hourly)

Isba
land surface scheme

Computation of water and energy budgets with soil and vegetation databases (ECOCLIMAP)

Evapotranspiration, **soil moisture**, snow cover, drainage, runoff, etc. (8km, 5 min)

Drainage and runoff

Modcou
hydrogeological model

Flow routing, multilayer aquifers

Flow (3-hourly) and water table levels (1-8km)

Drought indices for Agriculture in France

- SIM: consistent computation of variables within the hydrological cycle

	Variable	Drought type
Safran	Precipitation	Meteorological
Isba	Soil Wetness Index	Agricultural
Modcou	River flow	Hydrological

- SAFRAN model deals with meteorological drought and ISBA model deals with agricultural drought.
- SWI drought index is calculated thanks to the SIM model
- One of the key output of this model is the Soil Water Index which is defined as a normalized soil water content index which ranges from 0 (water content at wilting point) and 1 (water content at field capacity).
- $$SWI = \frac{w - w_{wilt}}{w_{fc} - w_{wilt}}$$
  - w : water content
  - w_{wilt} : wilting point
  - w_{fc} : field capacity

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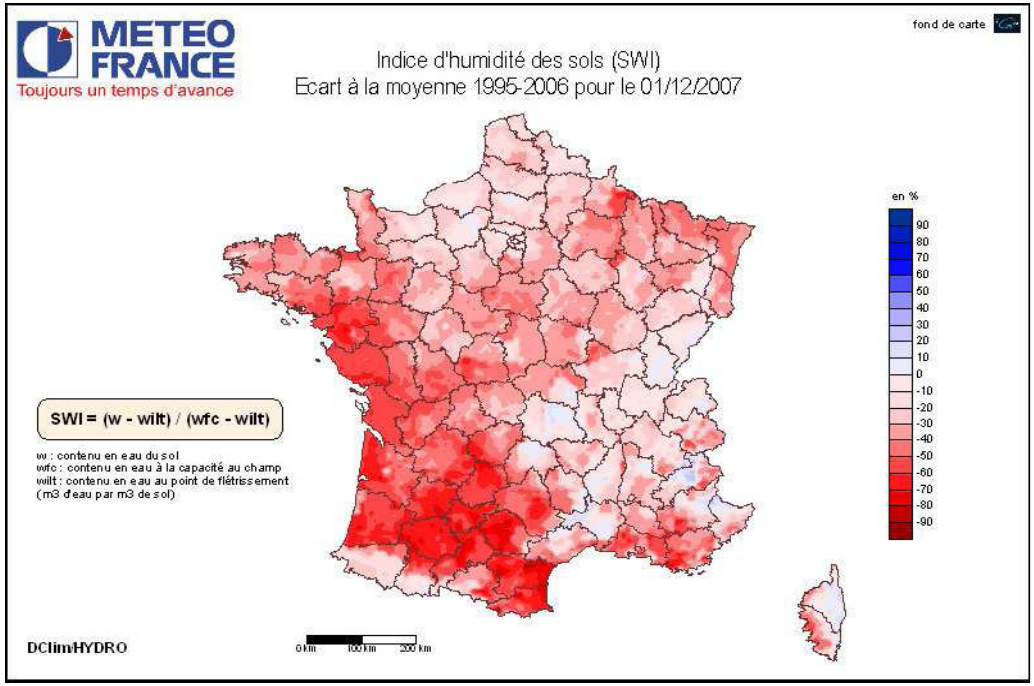
Drought indices for Agriculture in France

- Soil Water Index maps are published and disseminated through the web site of Météo-France on a monthly basis. Ratio to mean maps are also provided by comparison of the current year with climatology. This index is useful in order to asses impact on agriculture.
- Those maps are disseminated every 10 days through the website of Météo-France
- This information is provided freely
- Daily products are available for expertise.



Soil Water Index anomaly over France (December 2007). Negative values indicate drier conditions as compared to the normal, while positive values represent wetter conditions than on average.

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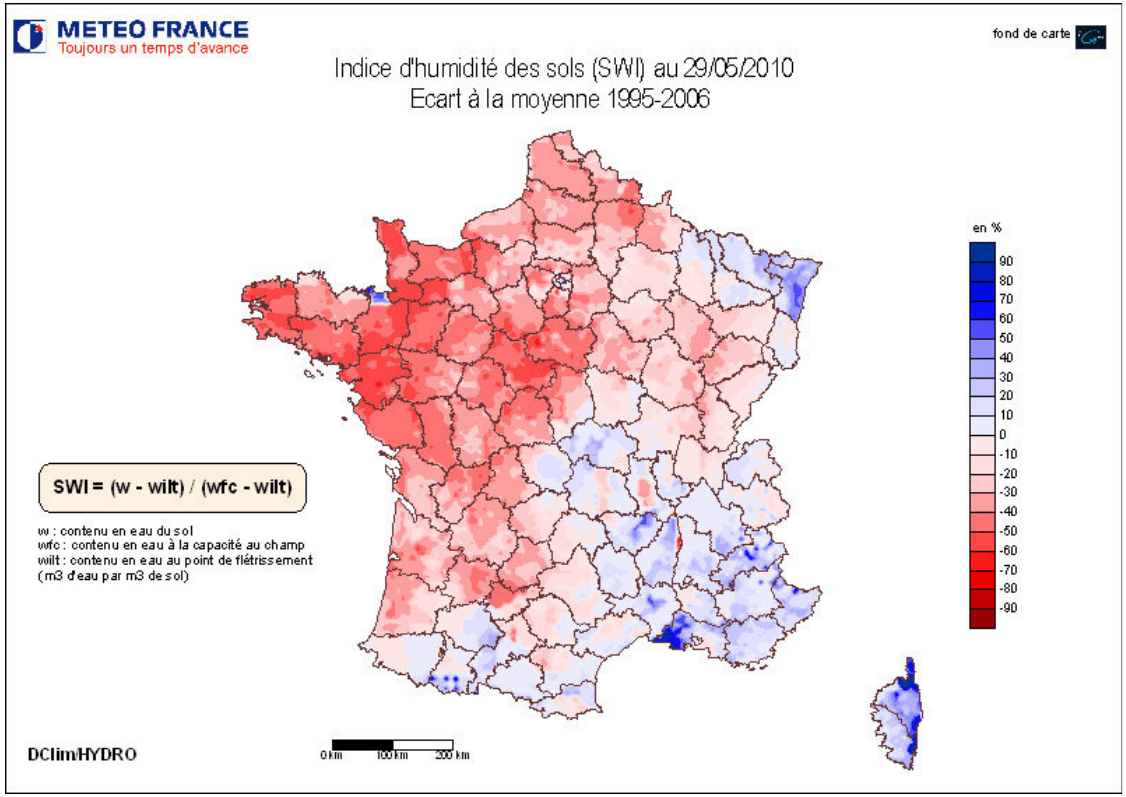
Drought indices for Agriculture in France

Strengths:

- State-of-the-art hydrological modelling
- Spatial resolution : 8 km
- Realistic soil and vegetation parametrization

Limitations :

- Complex hydrometeorological suite.
- Run at national level only



Experimental drought indices in France

Jean-Philippe Vidal, Éric Martin,
Laurent Franchistéguy, Jean-Michel Soubeyroux,
Martine Baillon and Michèle Blanchard

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Standardized drought indices

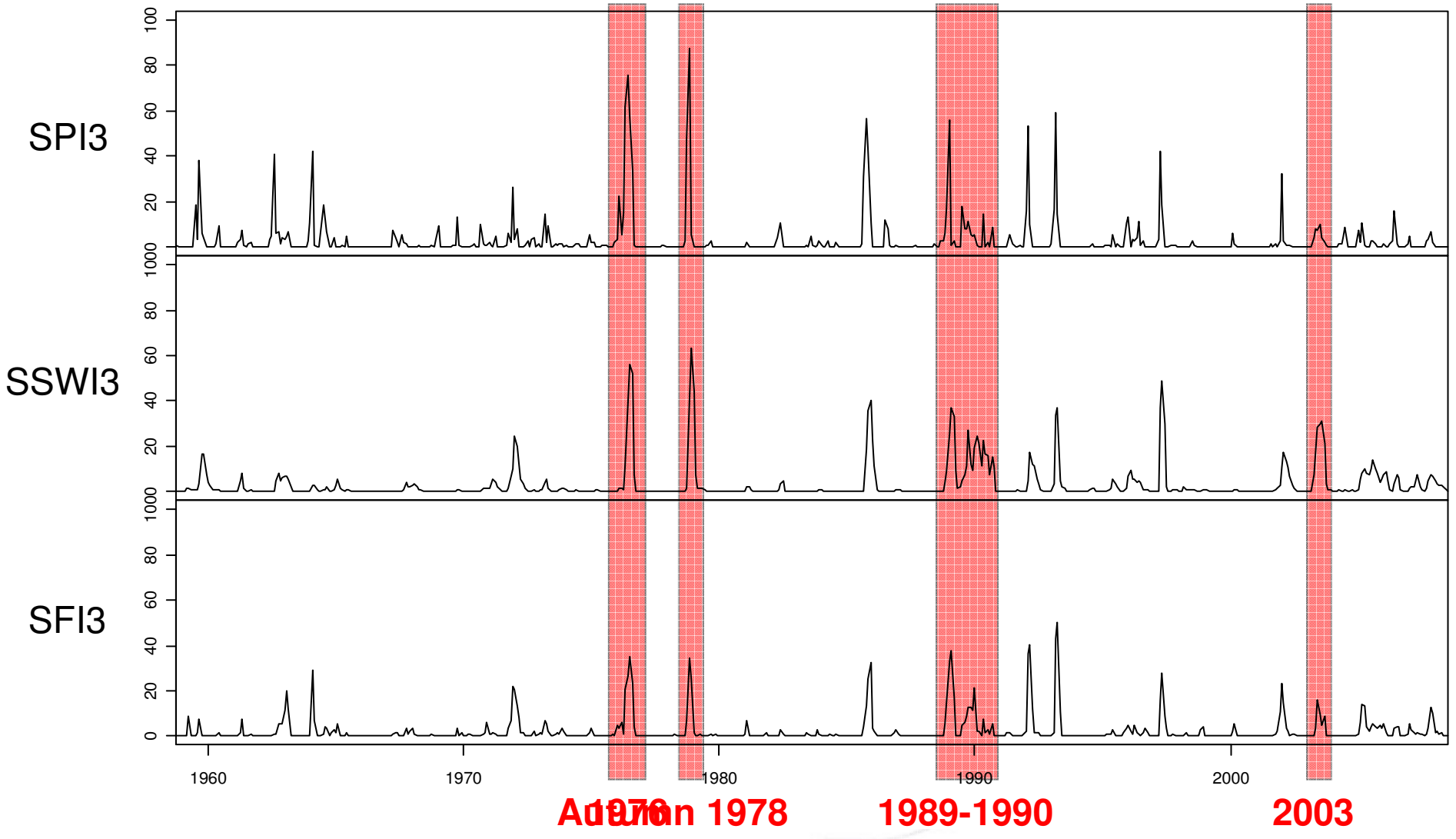
- **Approach**
  - Use of a monthly variable summed/averaged over n months
  - Kernel density estimates for each calendar month and grid cell
  - Quantile-quantile projection onto normal distribution

- **Advantages**
  - Computation with reference to 50-year local climate
  - Correspondance index value / non-exceedance probability
  - Spatial consistency
  - Different time scales: 1 to 24 months

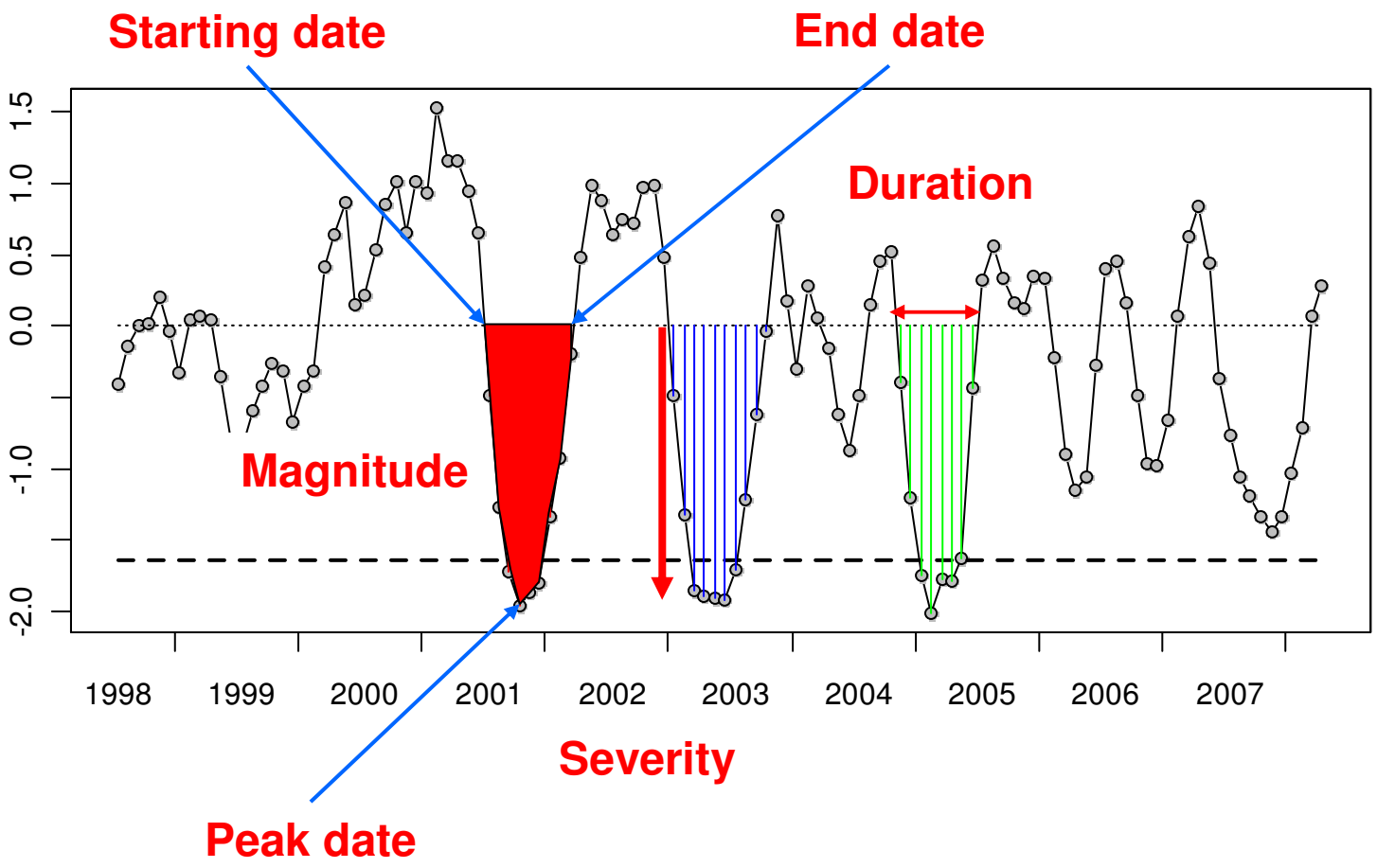
- **Indices**
  - Standardized Precipitation Index (**SPI**) → 8km grid
  - Standardized Soil Wetness Index (**SSWI**) → 8km grid
  - Standardized Flow Index (**SFI**) → >900 hydrometric stations

Standardized drought indices : Overview of dry periods

Area affected by drought (% of France area), 3-month indices, threshold 5%



Standardized drought indices
From indices to events – Local scale



Threshold
P = 5%

Grid cell located near Toulouse (south-west), SSWI3

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Standardized drought indices
From indices to events – National scale

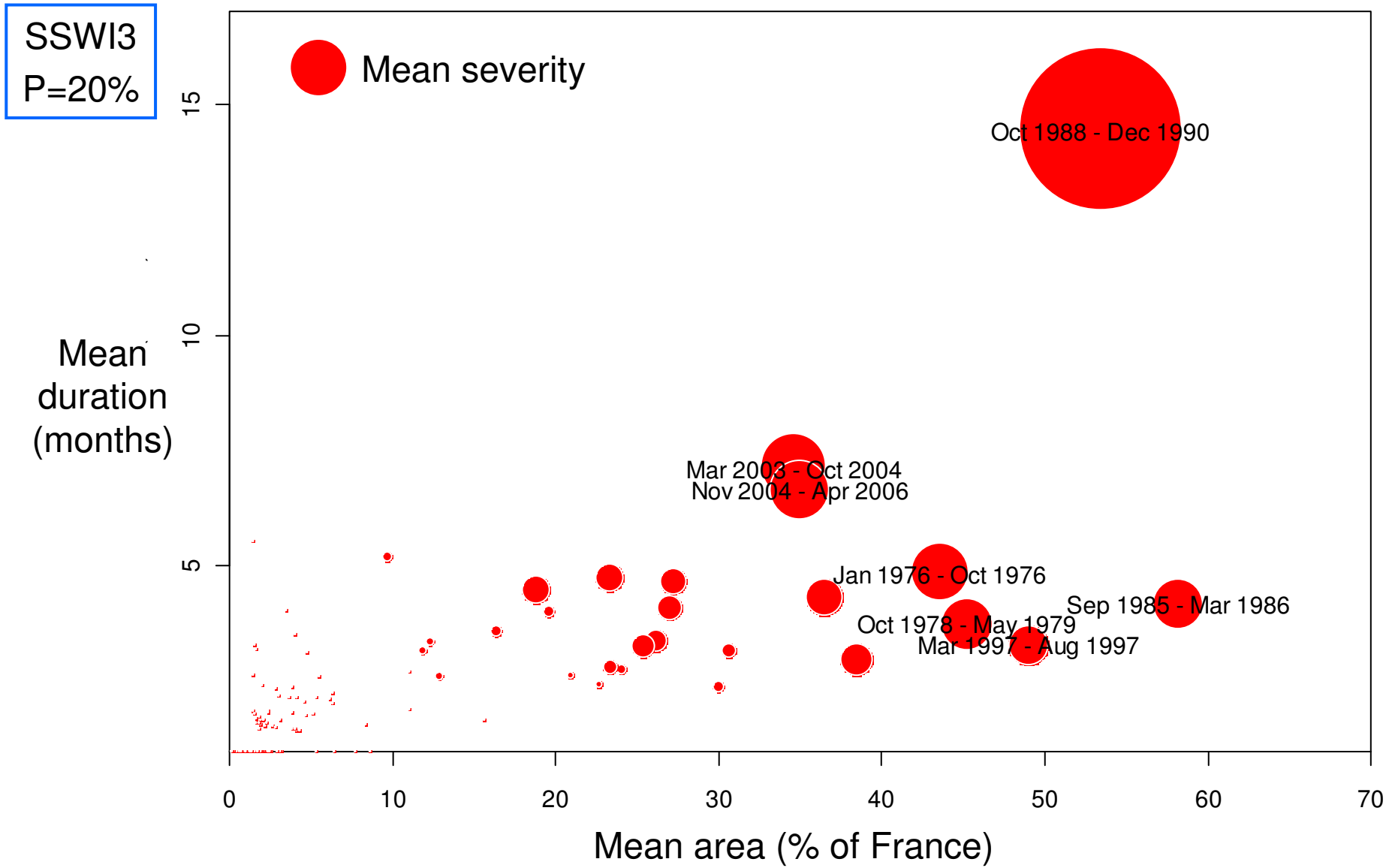
- **Droughts are developping in both space and time**

- Spatio-temporal event identification
  - **Event envelop**: index threshold (ex: P=20%)
  - **Spatial contiguity**: cluster identification at each time step
  - **Temporal continuity**: minimum common area between two time steps

- Spatio-temporal characteristics
  1. **[**Duration, severity, magnitude**]** combined with **area**
  2. Identification of most severe events through

     Severity–Area–Time Scale (SAT) curves inspired from *depth-area-duration* analysis of storm precipitation (WMO, 1969; Andreadis et al., 2005)

Standardized drought indices
Mean characteristics



Standardized drought indices

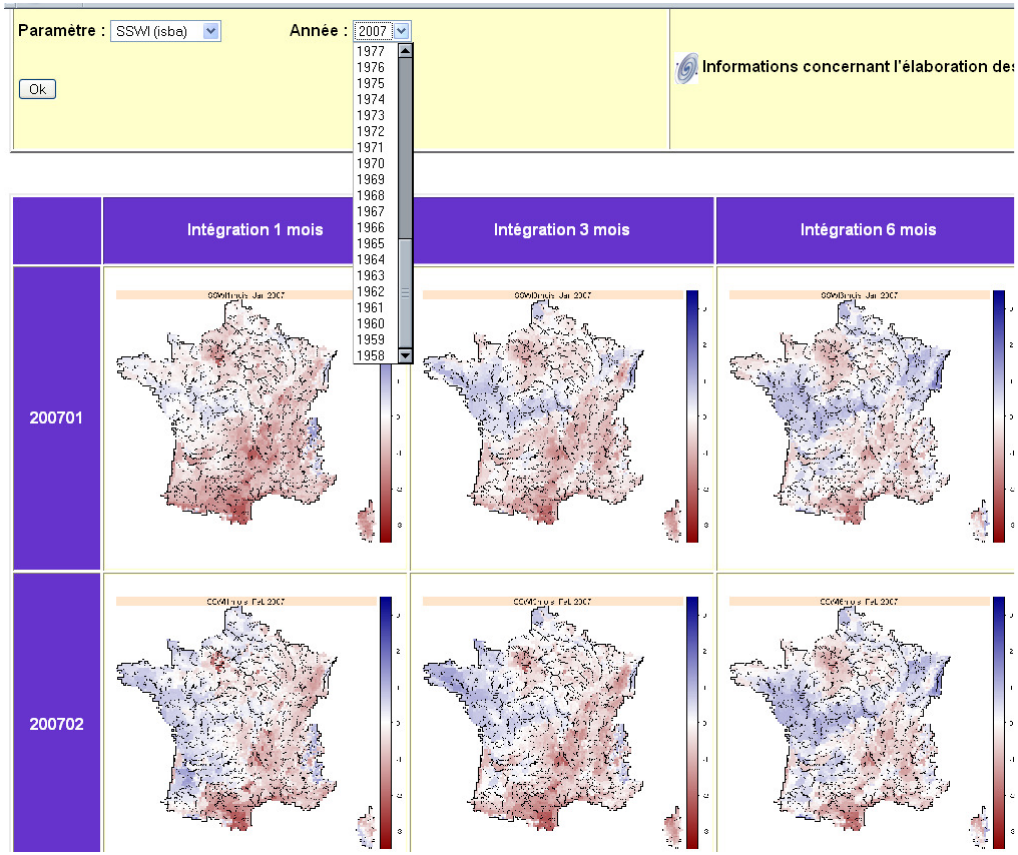
- A panel fof standardized indices from 1958 et 2008 is available for different different time scales.

Strengths:

- Standardized drought indices are powerful analysis tools for characterizing events in space and time
- Drought reanalysis offers identification and description of past drought events at both local and national scale in France

Limitations :

- Not operational



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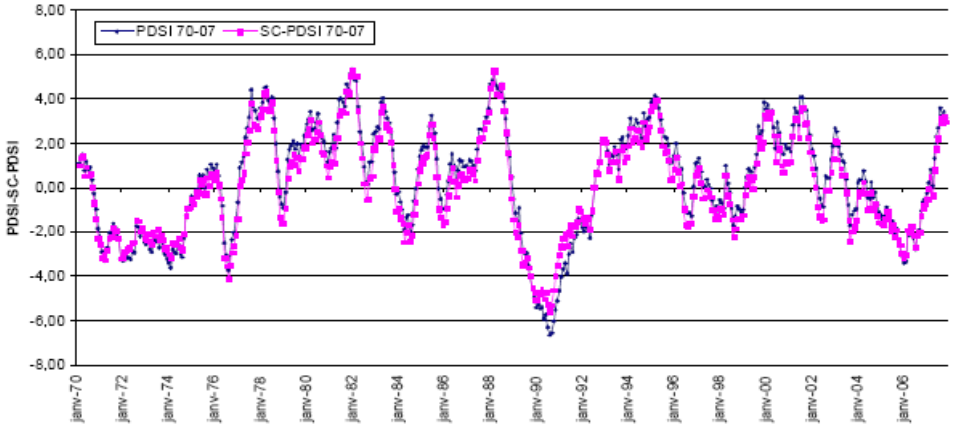
PDSI and SC-PDSI implementation

- Test of PDSI and SC-PDSI ((Self Calibrated Palmer Drought Severity Index) in France and comparison with SWI index (2008).
- Palmer Index is well described, but complex and empirical
- In France SC-PDSI seems more consistent than PDSI.
- Similar drought index classification can be performed with SSWI 12.
- Drought detection seems more accurate with SSWI index, but validation with natural disasters databases is tricky.



PDSI and SC-PDSI for Bourges weather station. PDSI was initially tuned for Iowa/Kansas climate

- Further work : calculation of SC-PDSI directly with Météo-France SVAT outputs

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Thank you for your attention

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Useful links

- http://natural-hazards.jrc.it/index.html (Joint Research Center website)
- http://www.dmcsee.org/dmcsee/index.html (Drought Mitigation Center for South Eastern Europe website)
- http://www.geo.uio.no/edc/ (European Drought Center website)
- http://www.hydrology.uni-freiburg.de/forsch/aride/ (Assessment of the Regional Impact of Droughts in Europe project website)
- http://drought.unl.edu/ (NCDC website)
- http:// www.aemet.es (Spanish NMS website)
- http:// www.dwd.de (German NMS website)
- http://www.meteo.pt/pt/ (Portugiese NMS website)
- http://www.meteo.fr/ (Météo-France website)