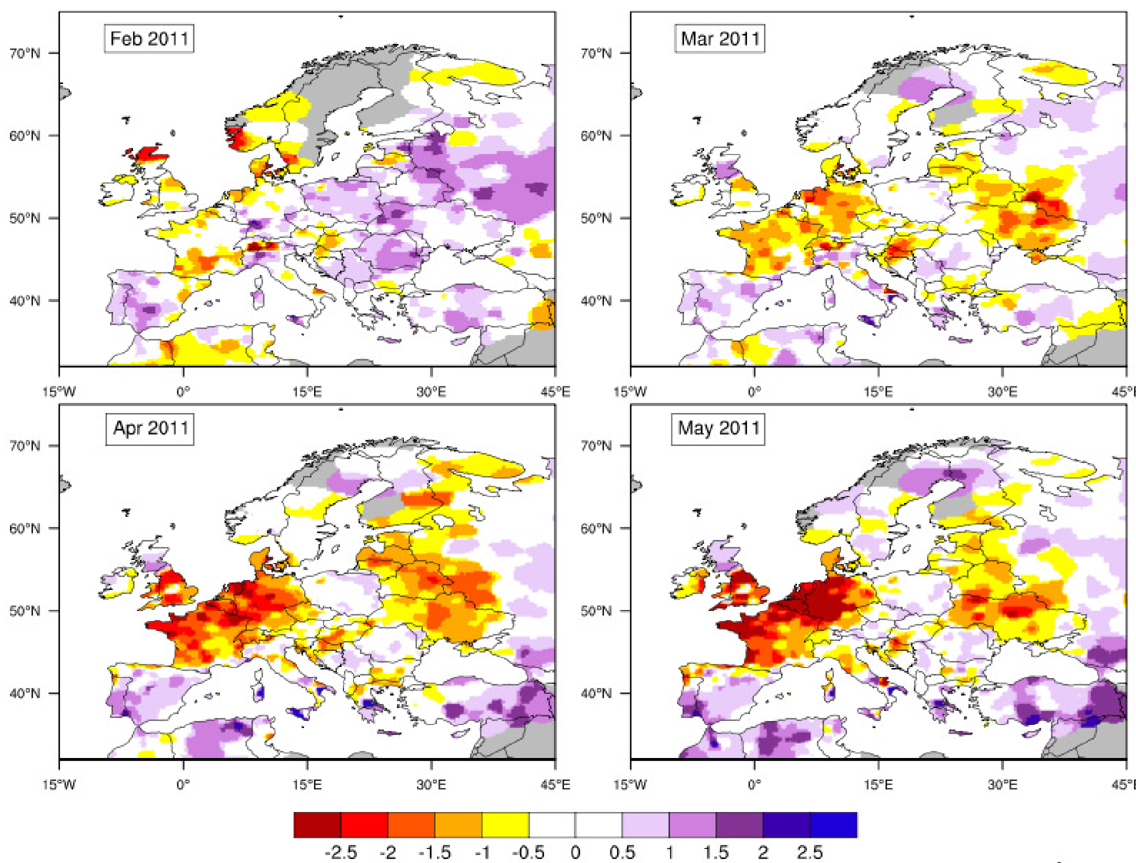
SPI: Standardized Precipitation Index

Type	Temporal scale	Spatial scale	Geo. coverage
Precipitation	Monthly (for a range of accumulation periods)	Data dependent	Europe and Global



Reference: Drought News - May 2011,
Desert Action, IES, JRC.

Key message

The Standardized Precipitation Index (SPI-*n*) is a **statistical indicator** comparing the total precipitation received at a particular location during a period of *n* months with the long-term rainfall distribution for the same period of time at that location. SPI is calculated on a monthly basis for a moving window of *n* months, where *n* indicates the rainfall accumulation period, which is typically 1, 3, 6, 9, 12, 24 or 48 months. The corresponding SPIs are denoted as SPI-1, SPI-3, SPI-6, etc.

In order to allow for the statistical comparison of wetter and drier climates, SPI is based on a transformation of the accumulated precipitation into a standard normal variable with zero mean and variance equal to one. SPI results are given in **units of standard deviation** from the long-term mean of the standardized distribution.

In 2010 WMO selected the SPI as a key meteorological drought indicator to be produced operationally by meteorological services.

Relevance of the Product to drought monitoring

A reduction in precipitation with respect to the normal precipitation amount is the primary driver of drought, resulting in a successive shortage of water for different natural and human needs. Since SPI values are given in units of standard deviation from the standardised mean, negative values correspond to drier periods than normal and positive values correspond to wetter periods than normal. The magnitude of the departure from the mean is a **probabilistic measure of the severity** of a wet or dry event.

Since the SPI can be calculated over different rainfall accumulation periods, different SPIs allow for estimating different potential impacts of a meteorological drought:

- SPIs for short accumulation periods (e.g., SPI-1 to SPI-3) are indicators for immediate impacts such as reduced soil moisture, snowpack, and flow in smaller creeks;
- SPIs for medium accumulation periods (e.g., SPI-3 to SPI-12) are indicators for reduced stream flow and reservoir storage; and
- SPIs for long accumulation periods (SPI-12 to SPI-48) are indicators for reduced reservoir and groundwater recharge, for example.

The exact relationship between accumulation period and impact depends on the natural environment (e.g., geology, soils) and the human interference (e.g., existence of irrigation schemes). In order to get a full picture of the potential impacts of a drought, SPIs of different accumulation periods should be calculated and compared. A comparison with other drought indicators is needed to evaluate actual impacts on the vegetation cover and different economic sectors.

Technical Information

1. Product

- **Data sources**:
    - Daily precipitation totals collected from **SYNOP stations** via the GTS and administered by JRC-MARS
    - **GPCC** (Global Precipitation Climatology Centre) monthly gridded precipitation from

Deutscher Wetterdienst

- **GPCC Reanalysis** – based on the highest density of stations available in the archive with strict automated and manual quality control interpolated to 1° grid. Available from 1901 – 2009.
- **GPCC monitoring** – based on GTS stations and some CLIMAT stations with automated and manual quality control interpolated to 1° grid. Available from 1986 to present with 2-month lag.
- **GPCC first guess** – based on GTS stations with only automated quality control interpolated to 1° grid. Available from 2005 to present with 5-day time lag.

- **E-OBS** daily gridded precipitation from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://eca.knmi.nl) (Haylock *et al.,* 2008). Based on GTS stations and stations provided by National Institutions, homogenized for consistency and with strict quality controls applied. Available from 1950-present with approx. 2-month time lag.

- **Geographic coverage**:
  - **SYNOP stations**: Europe
  - **GPCC**: Global
  - **E-OBS**: Europe

- **Spatial scale**:
  - **SYNOP stations**: Station SPI interpolated to 0.25°
  - **GPCC** (all products): 1°
  - **E-OBS**: 0.25°, 0.5°

- **Temporal scale:**

  Typically of 1-, 3-, 6-, 12-, 24-, 48-months, or even longer time-periods depending on the potential impact and regional characteristics. For statistical reasons a minimum rainfall accumulation period of one month is recommended. SPI is then calculated for every month with a moving window of the selected time-length.

- **Frequency of data collection:**
  - **SYNOP stations**: Daily – accumulated into monthly totals at the end of each month.
  - **GPCC**: Monthly.
    - **GPCC monitoring**: 2-month delay in availability.
    - **GPCC first guess**: 5-day delay in availability.
  - **E-OBS**: Monthly. Approx. 2-month delay in availability.

2. Methodology

a. Detailed Methodology for the Calculation of the Indicator

Computation of the SPI involves fitting a probability density function to a given frequency distribution of precipitation totals for a station or grid point and for an accumulation period. For EDO we use the gamma probability density function. The statistics for the frequency distribution are calculated on the basis of a reference period of at least 30 years (see point 2.b).

The parameters of the probability density function are then used to find the cumulative probability of the observed precipitation for the required month and temporal scale. This cumulative probability is then transformed to the standardised normal distribution with mean zero and variance one, which results in the value of the SPI. The procedure of transforming the observed rainfall via the cumulative distribution functions (CDF) of the Gamma distribution and the standardised normal variable to the SPI is illustrated in Figure 1:

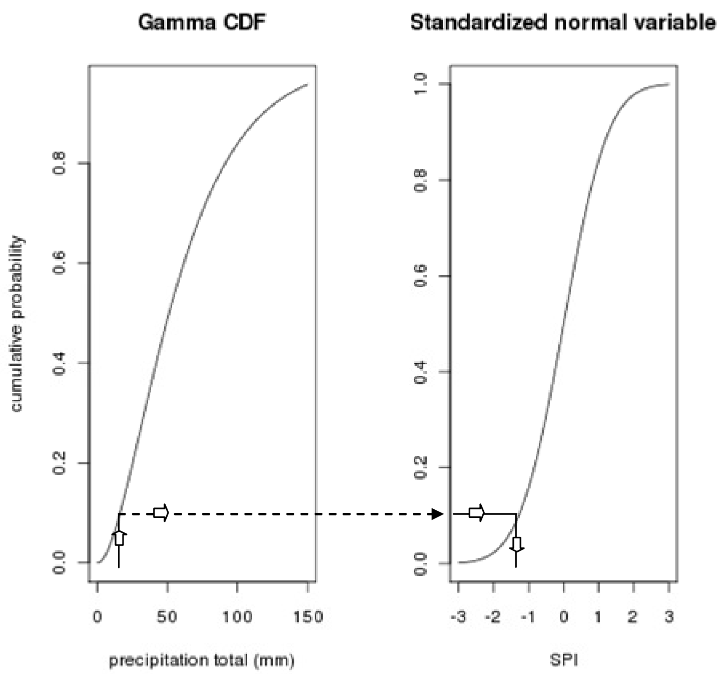


Figure 1: *Transformation of the observed rainfall via the Gamma cumulative distribution function (CDF) and the CDF of the standardized normal variable to the SPI.*

The Gamma distribution has been adopted by most centres around the world as a model from which to compute SPI. It is described by only two parameters, but offers considerable flexibility in describing the shape of the distribution, from an exponential to a Gaussian form. It has the advantage that it is bounded on the left at zero and therefore excludes the possibility of negative precipitation. Additionally, it is positively skewed with an extended tail to the right, which is especially important for dry areas with low mean and a high variability in precipitation.

b. Reference Period for Calculating the Statistics

The World Meteorological Organization (WMO) recommends that precipitation totals for the at least 30 years are used as reference time-line for calculating rainfall statistics. Several investigators recommend calculating the statistics for the SPI from even longer time periods (e.g., 50 or more years) in order to ensure an accurate representation of extreme events. The current WMO standard reference period is 1961-1990. However several Member States use more recent periods (e.g., 1971-2000, 1981-2010) in order to accommodate changes in the precipitation regime due to climate change and to compare actual rainfall figures to a more recent situation. In order to ensure comparability of the results across Europe and across scales it is highly recommended to use a common reference period for the calculation of the SPI. Considering the results of an inventory of the reference periods used in various Member States, the specific needs for accurately representing extreme events, and possible changes in the rainfall regimes due to climate change, the Water Scarcity and Drought Expert Group strongly recommends using the period **January 1971 to December 2010 as Reference Period** for the calculation of the SPI.

In the case that a lack of data would significantly restrict the number of rainfall stations to be used, a shorter reference period may be used (e.g., 1981-2010). However, in all cases, the Reference Period used should be clearly indicated with all data presented.

Use of the product for drought and/or land degradation monitoring

SPI is presented in the form of maps or time series graphs for a single location. The value of the SPI gives a measure of the severity of a wet or dry event as summarised in Table 1.

SPI Value	Class	Cumulative Probability	Probability of Event [%]	Colour
SPI ≥ 2.00	Extreme wet	0.977 – 1.000	2.3%	Blue
1.50 < SPI ≤ 2.00	Severe wet	0.933 – 0.977	4.4%	Purple
1.00 < SPI ≤ 1.50	Moderate wet	0.841 – 0.933	9.2%	Lilac
-1.00 < SPI ≤ 1.00	Near normal	0.159 – 0.841	68.2%	White
-1.50 < SPI ≤ -1.00	Moderate dry	0.067 – 0.159	9.2%	Yellow
-2.00 < SPI ≤ -1.50	Severe dry	0.023 – 0.067	4.4%	Orange
SPI < -2.00	Extreme dry	0.000 – 0.023	2.3%	Red

Table 1 – *SPI Classification following McKee et al. (1993)*

Quality Information

1. Strength & weaknesses

[+] SPI gives a measure of the rainfall deficit (or surplus) at a location that is unambiguously comparable with other locations and periods in time

[+] SPI is easy to interpret with boundaries set to describe the severity of the rainfall deficit (or surplus)

[+] Because the SPI can be computed for a range of accumulation periods it can be made use of by a whole range of user groups, from agriculture to water management

[-] Fitting a distribution to the data is an approximation. If the fit is not good, the SPI value may not be representative

[-] For SPI computed at station level, depending on the station density, the spatial representativeness of interpolated SPI will vary.

[-] Since the gamma distribution is bounded on the left at zero, it is not defined for zero precipitation. If the data includes observations of zero precipitation a mixed distribution is used that takes account of the probability of zero precipitation and the cumulative probability $H(x)$ becomes

$$H(x) = q + (1-q)G(x),$$

where *q* is the probability of zero, calculated from the frequency of zero precipitation observations in the time series, and *G(x)* is the cumulative probability calculated from the gamma distribution for non-zero observations.

This approach introduces two problems for regions with many observations of zero precipitation. Firstly, the minimum value SPI can take is determined by the probability of zero – for example if the probability of zero is 0.5, the minimum possible value of SPI is 0 (see Figure 1). Secondly, with fewer observations to compute the parameters of the gamma distribution the fit becomes less well defined. Therefore, for regions with a high probability of zero rainfall, the SPI should be interpreted with care and, where possible, alternative drought indicators should be used in addition. A high probability for zero rainfall is characteristic of an arid climate and in such cases the concept of a drought needs to be adapted. In such cases it may be useful to restrict the calculation and analysis to the normal rainy season(s). In Europe this applies to very limited areas.

2. Performance of the indicator

SPI has been selected by the WMO as a key indicator for monitoring drought. As a result it is used by drought monitoring centres worldwide. There are many examples of its successful application in research oriented literature. The main area of contention for performance is the selection of the statistical distribution used to model the reference period. Guttman (1999) suggests a Pearson type-III distribution over the Gamma distribution initially used by McKee *et al.* (1993, 1995).

In EDO SPI computed with reference statistics from the Gamma distribution is used, but we also calculate SPI for the Pearson type-III and Normal distributions.

References

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