Standardized Precipitation Index (SPI)

This Factsheet provides a detailed technical description of the indicator Standardized Precipitation Index (SPI), produced by the Copernicus European Drought Observatory (EDO), which is used for detecting and characterizing meteorological drought. The variable of the hydrological cycle upon which the SPI indicator produced by EDO is based, as well as the indicator's temporal and spatial scales and geographic coverage, are summarized below. An example of the SPI indicator computed for a three-month accumulation period (i.e. SPI-3), is shown in Figure 1.

Variable	Temporal scale	Spatial scale	Coverage
Precipitation	Monthly (for a range of accumulation periods)	Data dependent	Europe and global

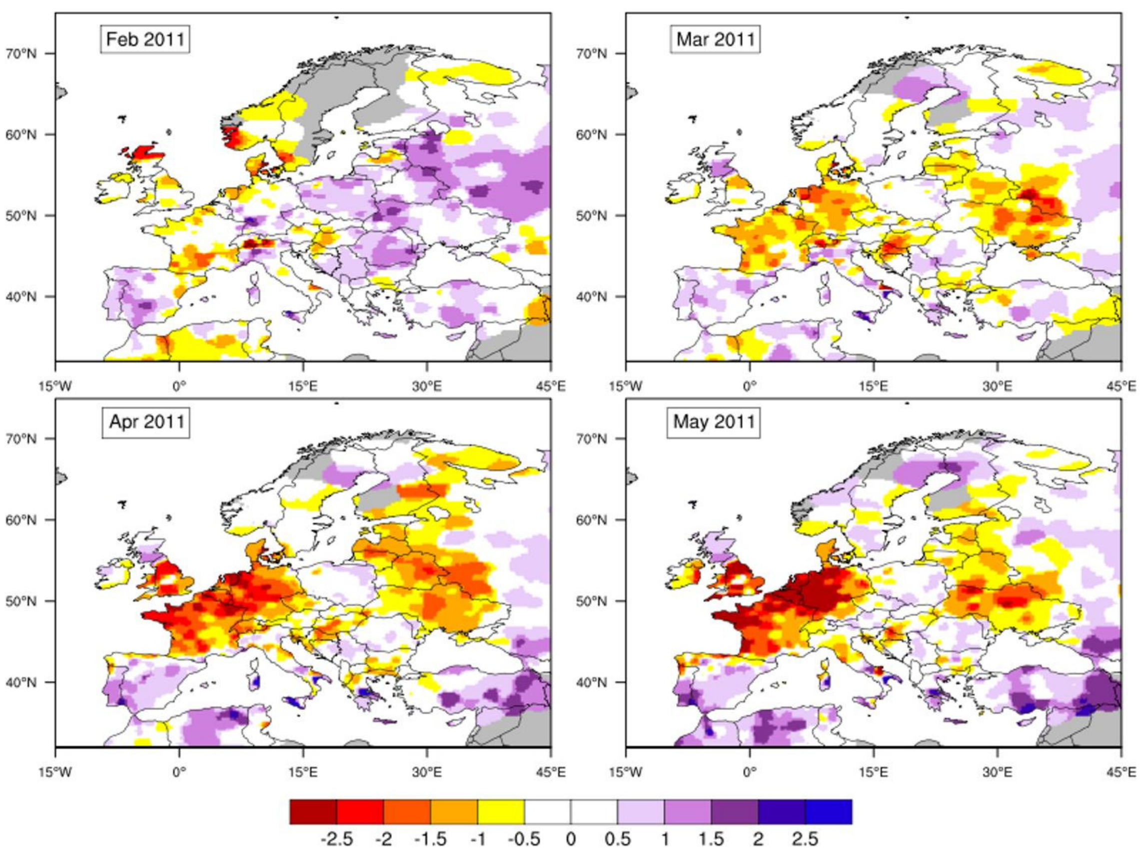

***Figure 1**: Example of the continuously updated SPI-3 indicator, produced by the Copernicus European Drought Observatory (EDO). The classification scheme used is described in Section 4 below.*

1. Brief overview of the indicator

The Standardized Precipitation Index (SPI) is the most commonly used indicator worldwide for detecting and characterizing meteorological droughts. The SPI indicator, which was developed by McKee et al. (1993), and described in detail by Edwards and McKee (1997), measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period. The historic record is fitted to a probability distribution (the "gamma" distribution), which is then transformed into a normal distribution such that the mean SPI value for that location and period is zero. For any given region, increasingly severe rainfall deficits (i.e. meteorological droughts) are indicated as SPI decreases below 1.0, while increasingly severe excess rainfall are indicated as SPI increases above 1.0. Because SPI values are in units of standard deviation from the long-term mean, the indicator can be used to compare precipitation anomalies for any geographic location and for any number of time-scales. Note that the name of the indicator is usually modified to include the accumulation period. Thus, SPI-3 and SPI-12, for example, refer to accumulation periods of three and twelve months, respectively. The World Meteorological Organization has recommended that the SPI be used by all National Meteorological and Hydrological Services around the world to characterize meteorological droughts (World Meteorological Organization, 2012).

2. What the indicator shows

A meteorological drought is defined as a period with an abnormal precipitation deficit, in relation to the long-term average conditions for a region. The SPI indicator shows the anomalies (deviations from the mean) of the observed total precipitation, for any given location and accumulation period of interest. The magnitude of the departure from the mean is a probabilistic measure of the severity of a wet or dry event. Since SPI can be calculated over different precipitation accumulation periods (typically ranging from 1 to 48 months), the resulting different SPI indicators allow for estimating different potential impacts of a meteorological drought:

- **SPI-1 to SPI-3**: When SPI is computed for shorter accumulation periods (e.g. 1 to 3 months), it can be used as an indicator for immediate impacts such as reduced soil moisture, snowpack, and flow in smaller creeks.
- **SPI-3 to SPI-12** When SPI is computed for medium accumulation periods (e.g. 3 to 12 months), it can be used as an indicator for reduced stream flow and reservoir storage.
- **SPI-12 to SPI-48**: When SPI is computed for longer accumulation periods (e.g. 12 to 48 months), it can be used as an indicator for reduced reservoir and groundwater recharge.

It should be borne in mind that the exact relationship between the accumulation period and the drought 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, the SPI should be calculated and compared for different accumulation periods. A comparison with other drought indicators is also needed, in order to evaluate the actual impacts on the vegetation cover and different economic sectors.

3. How the indicator is calculated

The statistical distribution of rainfall accumulations for defined intervals (e.g. daily; 1 month; 3 months) over a long time-series (at least 30 years), can be effectively represented by the two-parameter continuous probability distribution known as the “gamma distribution”. In order to compute the SPI for an observed rainfall accumulation for a period of interest (e.g. 1, 3, 12 or 48 months), the two parameters (i.e. shape and scale) of the gamma distribution are first calculated (or “fitted”) based on the frequency distribution of the historical non-zero rainfall accumulations for all years in the available time-series, using one of two alternative approximations of the “maximum likelihood estimators” for the gamma distribution that were developed by Thom (1958) and Greenwood and Durand (1960). For any observed rainfall accumulation the cumulative probability is then derived, based on the parameters of the gamma distribution and using algorithms provided by Press et al. (1992). Following adjustment for the probability of zero rainfall accumulation, the cumulative probability of the observed rainfall is then transformed (converted) to the standard normal random variable Z with mean zero and variance of one, using an approximation described by Abramowitz and Stegun (1965). This transformed value is the SPI.

The different input datasets used to compute SPI in EDO, are summarized in Table 1 below.

Table 1: Summary of meteorological datasets used in the computation of SPI indicator in EDO.

Data source:	**SYNOP (Surface Synoptic Observations)**	**GPCC (Global Precipitation Climatology Centre)**	**E-OBS**
Description:	- Daily precipitation totals collected from SYNOP stations via the WMO's Global Telecommunication System (GTS) and administered by JRC-MARS.	- 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 o grid. Available from 1901 - 2009. - **GPCC Monitoring** - based on GTS stations and some CLIMAT stations with automated and manual quality control interpolated to 1º grid. Available from 1986 to present with 2-month lag. - **GPCC First Guess** - based on GTS stations with only automated quality control interpolated to 1º grid. Available from 2005 to present with 5-day time lag.	- Daily gridded precipitation from the EU-FP6 ENSEMBLES project (http://ensembles-eu.metoffice.com) and data providers in ECA&D project (http://eca.knmi.nl), described by 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:	Europe	Global	Europe
Spatial scale:	Station SPI interpolated to 0.25º.	1º	0.25º, 0.5º
Temporal scale:	- Typically 1, 3, 6, 12, 24, 48 or months, or even longer depending on potential impact and regional characteristics. - A minimum rainfall accumulation period of 1 month is recommended. - SPI is calculated for each month with a moving window of selected time-length.	(Same as for SYNOP).	(Same as for SYNOP).
Frequency of data collection:	- Daily, accumulated into monthly totals at end of each month.	- Monthly. - GPCC Monitoring: 2-month delay in availability. - GPCC first guess: 5-day delay in availability.	- Monthly. - About 2-month delay in availability

4. How to use the indicator

In EDO, the SPI values for any given location and accumulation period, are classified into seven different precipitation regimes (from dry to wet), as shown in Table 2. As can be seen, increasingly severe rainfall deficits (i.e. meteorological droughts) are indicated as SPI decreases below 1.0, while increasingly severe excess rainfall is indicated as SPI increases above 1.0. In EDO, the SPI indicator can be displayed either in the form of maps, or as time series graphs for single locations.

Table 2: SPI classification scheme used in EDO.

ANOMALY	*RANGE OF SPI VALUES*	*PRECIPITATION REGIME*	*CUMULATIVE PROBABILITY*	*PROBABILITY OF EVENT (%)*	*COLOUR*
Positive	2.0 < SPI <= MAX	Extremely wet	0.977 - 1.000	2.3	**Purple**
	1.5 < SPI <= 2.0	Very wet	0.933 - 0.977	4.4	**Plum**
	1.0 < SPI <= 1.5	Moderately wet	0.841 - 0.933	9.2	**Lilac**
None	-1.0 < SPI <= 1.0	Normal precipitation	0.159 - 0.841	68.2	**White**
Negative	-1.5 < SPI <= -1.0	Moderately dry	0.067 - 0.159	9.2	**Yellow**
	-2.0 < SPI <= -1.5	Very dry	0.023 - 0.067	4.4	**Orange**
	MIN <= SPI <= -2.0	Extremely dry	0.000 - 0.023	2.3	**Red**

5. Strengths and weaknesses of the indicator

Strengths:

- The fact that SPI values are in units of standard deviation from the long-term mean, allows SPI to be computed and compared for any geographic location and for any number of time scales.
- In addition, because the SPI is normalized it is just as effective in analysing wet periods and cycles, as it is in analysing dry periods and cycles.
- The SPI indicator is based on only one input parameter (precipitation accumulations), and thus it is less complex to compute than other drought indicators, such as the Palmer Drought Severity Index, which also takes account of variations in temperature, soil moisture and evapotranspiration.

Weaknesses:

- As mentioned earlier, the parameters of the gamma distribution are calculated (fitted) using historical **non-zero rainfall** accumulations. The cumulative probability of observed rainfall is then adjusted using the probability (frequency) of **zero rainfall** accumulations. However, if there are many historical zero rainfall accumulations, the estimated gamma distribution may not adequately fit the frequency distribution of the historical rainfall. Therefore, in regions with a high probability of zero rainfall, the SPI indicator should be interpreted with care. In such cases (typical of arid climates), the concept of a drought needs to be adapted, and it may be best to restrict SPI calculation and analysis to the normal rainy season, or to use alternative drought indicators. In Europe this applies to very limited areas.
- Because SPI is based only on precipitation, it does not address the effects of high temperatures on drought conditions, such as by damaging cultivated and natural ecosystems, and increasing evapotranspiration and water stress. A new variation of SPI - the Standardized Precipitation and Evapotranspiration Index (SPEI) - has been developed (Vicente-Serrano et al., 2010), which

includes precipitation and temperature, in order to identify increases in drought severity linked with higher water demand by evapotranspiration. The SPEI has the advantage over the Palmer Drought Severity Index (PDSI), for example, in that it captures the "multiscalar" characteristic of drought, whereby water deficits accumulate over different time-scales, differentiating between hydrological, environmental, agricultural, and other droughts. Because it includes temperature, the SPEI indicator, which will be added to the European Drought Observatory in the future, is particularly suited to monitoring the effects of global warming on drought conditions.

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