Drought: SPI (Standardised Precipitation Index) and SPEI (Standardized Precipitation Evapotranspiration Index)

Introduction

Some climate indices in Climate Insights are presented as annual climatology for both baseline and future periods such as growing degree day (GDD) and heating degree day (HDD), while others have been used to carry out further statistical summaries to derive more meaningful parameters, which means that the relevant layers presented in Climate Insights are re-analysis data, instead of the indices themselves. For example, Standardised Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) are applied to calculate the probability of droughts for a specific period of interest, while SPI and SPEI themselves are not directly accessible. In addition, all indices are calculated for the future periods based on the ensemble of GCM or RCM projections. The corresponding data layers should be explained from a perspective of statistical probability.

Standardized Precipitation Index (SPI)

The SPI is the most used indicator worldwide for detecting and characterising 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 timescales. 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). The long-term gamma distribution of Climate Insights SPI product is based on data from a reference period from 1981 to 2010 (included).

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.

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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. A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. In primary agricultural regions, a 3-month SPI might be more effective in highlighting available moisture conditions than the slow-responding Palmer Index or other currently available hydrological indices.

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, soil moisture) and the human interference (e.g., existence of irrigation schemes). 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, to evaluate the actual impacts on the vegetation cover and different economic sectors.

SPI classification scheme used in Climate Insights

SPI	Category
[+, -] 2.00 and above/below	extremely [wet, dry]
[+, -] 1.50 to 1.99	severely [wet, dry]
[+, -] 1.00 to 1.49	moderately [wet, dry]
[+, -] 0.00 to 0.99	Mildly [wet, dry] or near normal [wet, dry]

The SPI classification scheme used in Climate Insights is presented in *Table 3*. At present, 1/3/6/12-month SPIs (SPI-1/3/6/12) are provided ***for primary assessment***. However, other accumulation periods of interest (e.g., 24, 48 months, but also require longer baseline periods) could be provided under emerging market requests. In Climate Insights, a drought event is defined as a SPI-n ≤ -1.0 (n=1, 3, 6, 12, etc). The probability of droughts (%) is summarised for a specific accumulation period (n). A demonstration is presented to display the changes in SPI-3 drought probability for two periods.

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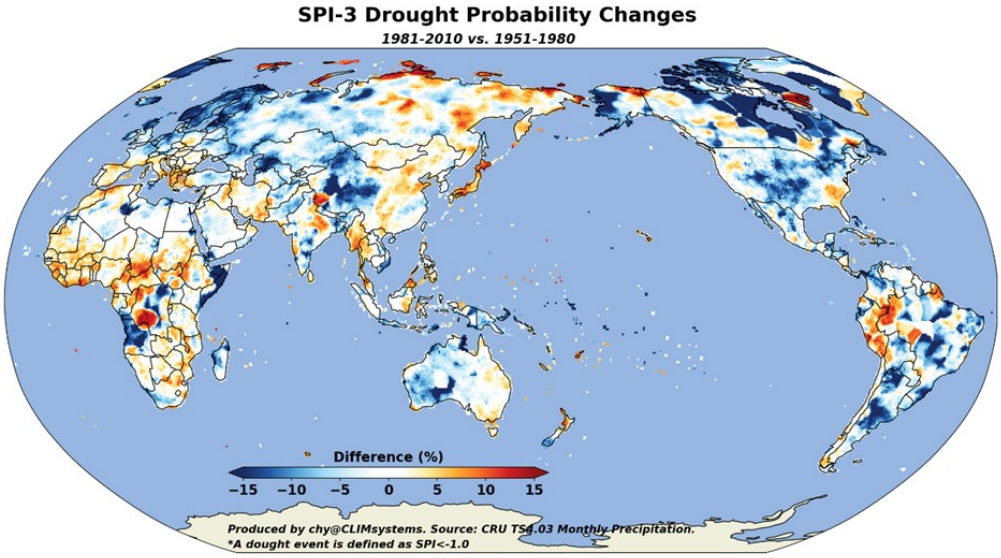
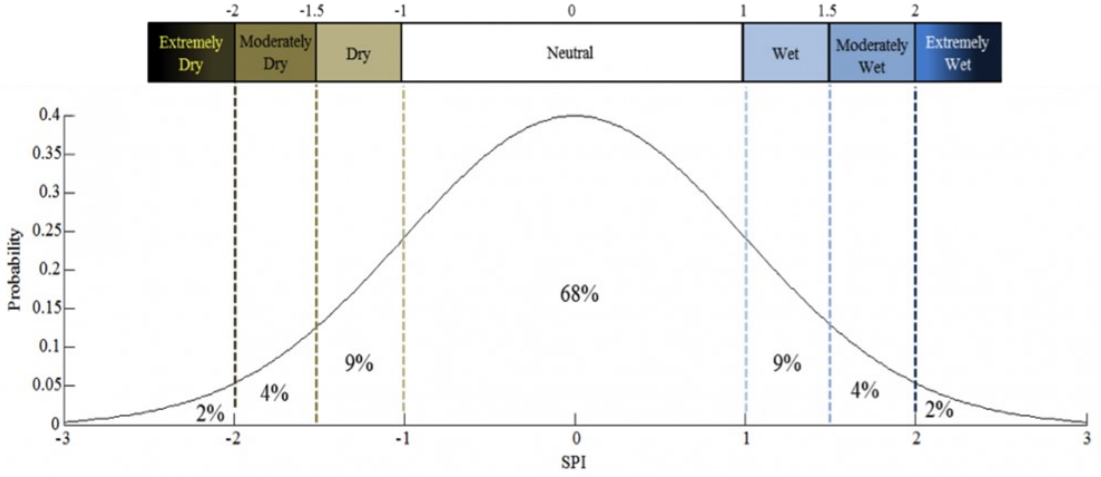


A demonstration of the changes in SPI-3 drought probability for two periods

During the reference period from 1981 to 2010, the drought probability should be about 15% (9%+4% +2%) from the perspective of statistics, which is determined by the definition of SPI. However, precipitation patterns may change in another period. Accordingly, the probability would change and might be over or below 15%. When a probability is over 15%, it means that there may be more droughts, vice versa. This is the same case for the following SPEI.



Probability distributions of SPI classification schemes during the baseline period (1981-2010)

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Standardised Precipitation-Evapotranspiration Index (SPEI)

Because SPI is based only on precipitation, it does not address the effects of high temperatures on drought conditions, such as damaging cultivated and natural ecosystems, 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 fulfils the requirements of a drought index since its multi-scalar character enables it to be used by different scientific disciplines to detect, monitor, and analyse droughts. Like the (Self-calibrated Palmer Drought Severity Index (sc-PDSI) and the SPI, the SPEI can measure drought severity according to its intensity and duration and can identify the onset and end of drought episodes. The SPEI allows comparison of drought severity through time and space, since it can be calculated over a wide range of climates, as can the SPI. Moreover, Keyantash and Dracup (2002) indicated that drought indices must be statistically robust and easily calculated and have a clear and comprehensible calculation procedure. All these requirements are met by the SPEI.

The SPEI is based on the original SPI calculation procedure. The SPI is calculated using monthly (or weekly) precipitation as the input data. The SPEI uses the monthly (or weekly) difference between precipitation and potential evapotranspiration PET. This represents a simple climatic water balance which is calculated at different time scales to obtain the SPEI. Several equations exist to estimate PET based on available data (e.g. the Thornthwaite equation, the Penman-Monteith equation, the Hargreaves equation, etc), and the SPEI is not linked to any particular one. In Climate Insights, the Thornthwaite equation is employed to estimate global PET as it only requires temperature as its input parameter.

A crucial advantage of the SPEI over other widely used drought indices that consider the effect of PET on drought severity is that its multi-scalar characteristics enable identification of different drought types and impacts in the context of global warming.

The SPEI classification scheme used in Climate Insights is presented in the table below. In Climate Insights, a drought event is defined as a SPEI-n ≤ -1.0. Moreover, only the probability of droughts is accessible for end-users. Other description is basically the same to the SPI. A demonstration is presented to display the changes in SPEI-3 drought probability for two periods. It should be pointed out that the drought probability should be about 15% (9%+4%+2%, similar to Fig.6) from the perspective of statistics for the baseline period (1981-2010), in which precipitation and PET are employed to derive the gamma distribution parameters that are then applied to other periods.

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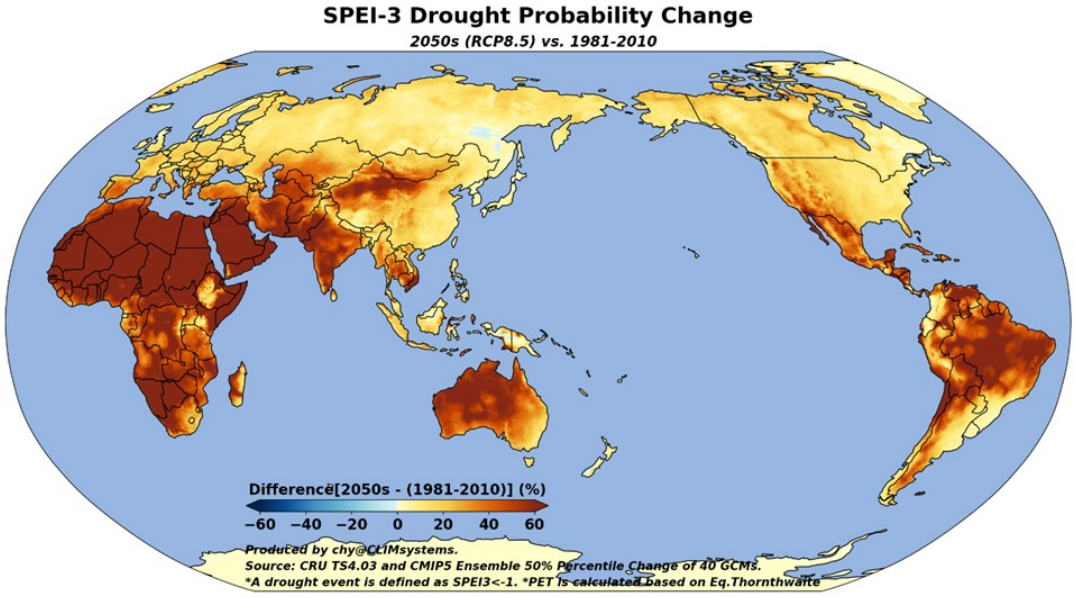
In Climate Insights, the probability of drought is summarized from the accumulation periods of 1/3/6/12-months at present.

SPEI classification scheme used in Climate Insights

SPEI	Category
[+, -] .00 and above/below	extremely [wet, dry]
[+, -] 1.50 to 1.99	severely [wet, dry]
[+, -] 1.00 to 1.49	moderately [wet, dry]
[+, -] 0.00 to 0.99	Mildly [wet, dry] or near normal [wet, dry]



A demonstration of the changes in SPEI-3 drought probability for two periods