Indicator version: v1.1

Indicator for Forecasting Unusually Wet and Dry Conditions

This Factsheet provides a detailed technical description of the "Indicator for Forecasting Unusually Wet and Dry Conditions", which is implemented in the European Drought Observatory (EDO) of the Copernicus Emergency Management Service (https://emergency.copernicus.eu/). The indicator, which is computed based on forecasted Standardized Precipitation Index (SPI) values derived from the long-range (i.e. seasonal) forecast system (SEAS51) of the European Centre for Medium-Range Weather Forecasts (ECMWF), is used to highlight those regions of continental Europe where unusually wet or dry periods are forecasted for the next 1, 3, or 6 months. An example of the indicator is shown in Figure 1.

Variables	Temporal scale	Spatial scale	Coverage
Long-range precipitation forecasts (from ECMWF - SEAS51)	Monthly	1 degree (~110 km)	World

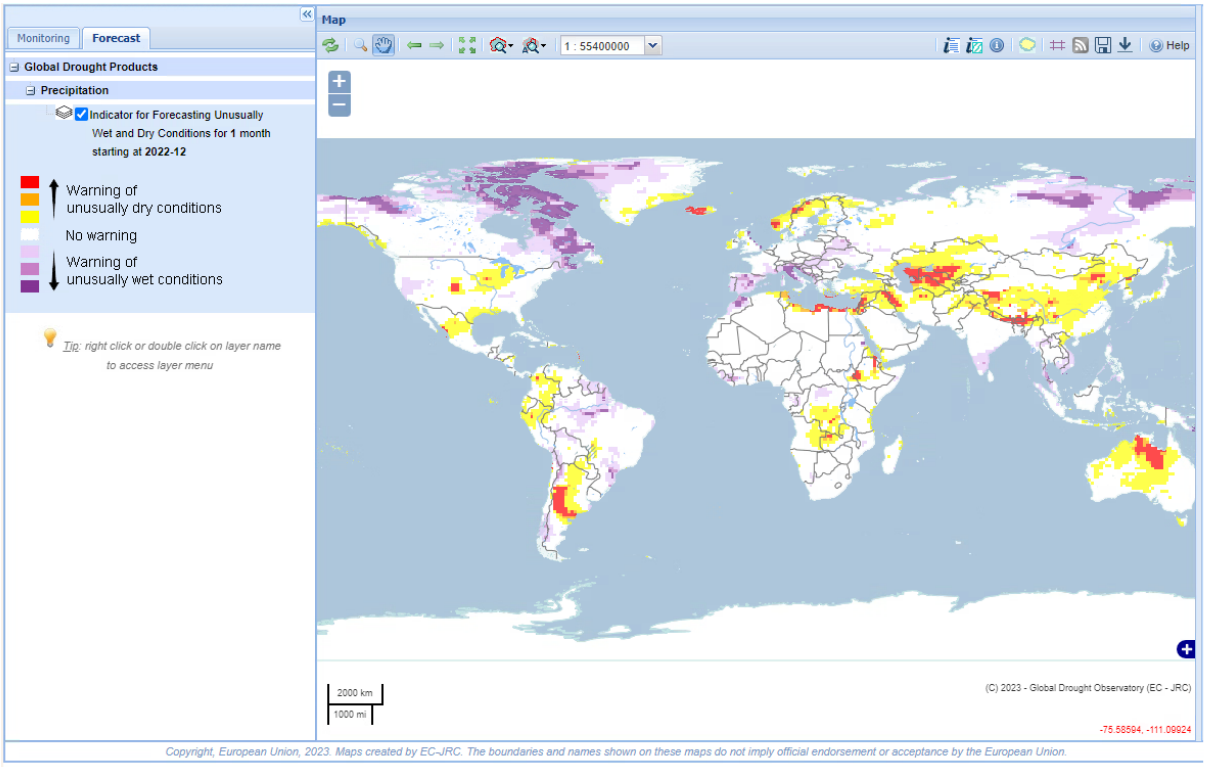

Figure 1*: Example of the Indicator for Forecasting Unusually Wet and Dry Conditions, for the 1-month SPI forecast accumulation period (SPI-1), for January 2023. Early warning of unusually wet conditions is indicated in purple, and that of unusually dry conditions is indicated in yellow and red.*

1. Brief overview of the indicator

The Indicator for Forecasting Unusually Wet and Dry Conditions provides early warnings of persistent unusually wet and dry precipitation conditions over Europe. The indicator, the technical details of which are fully described by Lavaysse et al. (2020), is computed from forecasted Standardized Precipitation Index (SPI) values for 1-month, 3-month, and 6-month accumulation periods (i.e. SPI-1, SPI-3 and SPI-6). The SPI forecasts are derived from forecasted precipitation provided by ECMWF's latest probabilistic (ensemble) seasonal forecast system 51 (SEAS51), which became operational in October 2022. The indicator provides early warnings of unusual precipitation periods only when and where the forecast is considered robust (i.e. with at least 40% of ensemble members associated with intense forecasts) corresponding with significant SPI values. Different alarm levels are indicated by a colour-legend, depending on both the severity and the level of significance of the forecast, and according to the 36-year reference (or "re-forecast") period of SEAS51 (i.e. 1981-2016).

2. What the indicator shows

The Indicator for Forecasting Unusually Wet and Dry Conditions highlights geographic regions where a significant forecast of unusually wet and dry conditions, based on three SPI forecast accumulation periods (SPI-1, SPI-3 and SPI-6), is detected. The date of the selected forecast indicates the start of the forecast period. Thus, the forecast for SPI-3 of January 2023, for example, is based on the 3-month SPI forecast accumulation period of January to March 2023. For forecasted events, different alarm levels are indicated by a colour-legend, based on both the severity of the forecast (i.e. intensity of the most extreme ensemble members) and the level of significance of the forecast (i.e. coherence of the ensemble members). The alarm levels, which are linked with a return period of the forecast intensities, based on the 36-year reference period (1981-2016), are shown in Table 1.

Table 1*: Alarm levels and colour-legend used in the Indicator for Forecasting Unusually Wet and Dry Conditions, in the Copernicus European Drought Observatory. (For details, see Lavaysse et al., 2020).*

ALARM LEVELS		INTERPRETATION
WET	DRY	
0		No alarm
1	1	An unusual wet or dry event is forecasted, with large model reliability and / or forecast intensity. This forecast has a 10-year return period (based on the 36-year re-forecast period of SEAS51).
2	2	An unusual wet or dry event is forecasted, with a continued increase in model reliability and a larger forecast intensity. This forecast represents a 20-year return period.
3	3	Maximum level of alert. An unusual wet or dry event is forecasted, with both model reliability and forecast intensity at their maximum (based on the 36-year re-forecast period of SEAS51).

3. How the indicator is calculated

The Indicator for Forecasting Unusually Wet and Dry Conditions, which is described in detail in Lavaysse et al. (2020), is computed from forecasted precipitation derived from the long-range (i.e. seasonal) forecast system (SEAS51) of the European Centre for Medium-Range Weather Forecasts (ECMWF). The long-range probabilistic forecast of SEAS51 consists of a 51-member ensemble forecast (ENS), which is integrated for 7 months, and later extended a further 6 months for a total forecast length of 13 months. These annual-range forecasts were designed primarily to give an outlook for the El Niño-Southern Oscillation (ENSO) recurring climate pattern. The SEAS5 seasonal forecast system is described by Johnson et al. (2019). While SEAS51 has a spatial resolution of 1 degree (~ 110 km), in order to focus on large-scale events, which are better represented and forecasted in climate prediction models, and have greater potential impacts on human activity and health.

Following the same methodology described in Lavaysse et al. (2020), the SEAS51 forecasted precipitation is first transformed to values of the Standard Precipitation Index or SPI (McKee et al., 1993; Edwards and McKee, 1997), for three SPI forecast accumulation periods: one month (SPI-1), three months (SPI-3), and six months (SPI-6). For the SPI calculations, the continuous probability function for each accumulation period is derived from the entire set of precipitation values during the 36-year SEAS51 re-forecast period (1981-2016). In order to detect anomalous precipitation conditions, unusually dry conditions are considered to begin at SPI threshold values of -1 or less, and unusually wet conditions at SPI threshold values of +1 or more. These thresholds result in the detection of a sufficiently robust number of events of important precipitation anomalies (i.e. about 16% of the sample-size), for statistical purposes.

According to Lavaysse et al. (2015), one of the most reliable ways to provide a "dichotomous" (i.e. above or below a threshold) forecast of unusually dry conditions, based on a probabilistic (ensemble) system, is to use the 40th percentile (P40) of the ensemble members, which have been sorted from driest to wettest for each grid point, month and SPI forecast accumulation period. When the SPI of the P40 member is below -1, the forecast of unusually dry conditions is considered reliable or robust. Conversely, when the SPI of the 60th percentile (P60) ensemble member is greater than +1, unusually wet conditions are reliably forecast. Despite the loss of spatial coherence of the forecast that is entailed by sorting the ensemble members, the ranking enables the direct derivation of thresholds, and calculation of forecast intensity.

Analysis by Lavaysse et al. (2020) reveals a large spatial variability of internal (i.e. between members) and inter-annual variance of the SPI, for all forecast accumulation periods. For some regions (e.g. Northern Russia), the coherence between members may be more than three times that for other regions (e.g. Pacific Ocean). In general, this coherence depends on the latitude. The inter-annual variance appears to be generally higher than the internal variance. This variability is less dependent on latitude, with lowest values mainly over dry regions (e.g. Arabian Peninsula, Northern Australia).

To compensate for spatial variability of the model variance, which will affect the detection of anomalous events, the forecast thresholds are adjusted (corrected) to give a statistically appropriate number of detected events (~ 16% of the sample size). The corrected forecast thresholds are defined independently, for each month and SPI forecast accumulation period. Therefore, the forecast of unusually dry conditions is robust when the P40 ensemble member is below the adjusted dry threshold (or -1 if no correction), while the forecast of unusually wet conditions is robust when the P60 ensemble member is above the adjusted wet threshold (or +1 if no correction).

Once there is a reliable forecast of unusually wet or dry conditions, the intensity of the forecast is derived based on the Extreme Forecast Index (EFI) and Shift of Tails (SOT) products, developed by ECMWF (Lalaurette, 2003; Zsoter, 2006; Owens and Hewson, 2018). The EFI was developed to establish the severity of forecasted events, by indicating where the cumulative distribution function (CDF) of the ensemble forecast (ENS) substantially differs from climatology (represented by the CDF of the model climate). Here, the mean forecasted SPI is computed for the tails (i.e. extreme 40%) of the ensemble forecast's CDF. This adapted EFI method takes account of both the coherence of ENS members to predict an extreme anomaly, and the anomaly's intensity, is particularly appropriate for extreme events, as it is less affected by a strong anomaly in the middle of the CDF.

In Figure 2, the red curve indicates the CDF of the SPI ensemble forecast, for the 51 sorted members, forecasted for a grid point during dry conditions, while the blue curve indicates the CDF of the SPI ensemble forecast during wet conditions. For the red curve, the forecast of unusually dry conditions is considered robust, as the 40th percentile (P40) is less than -1, while for the blue curve, the forecast of unusually wet conditions is considered robust, as the 60th percentile (P60) is greater than +1. The surface area bounded by the P40 or P60 members, and the "normal" CDF is calculated (shaded red and blue areas), and provides the intensity of the forecasted dry or wet event, respectively.

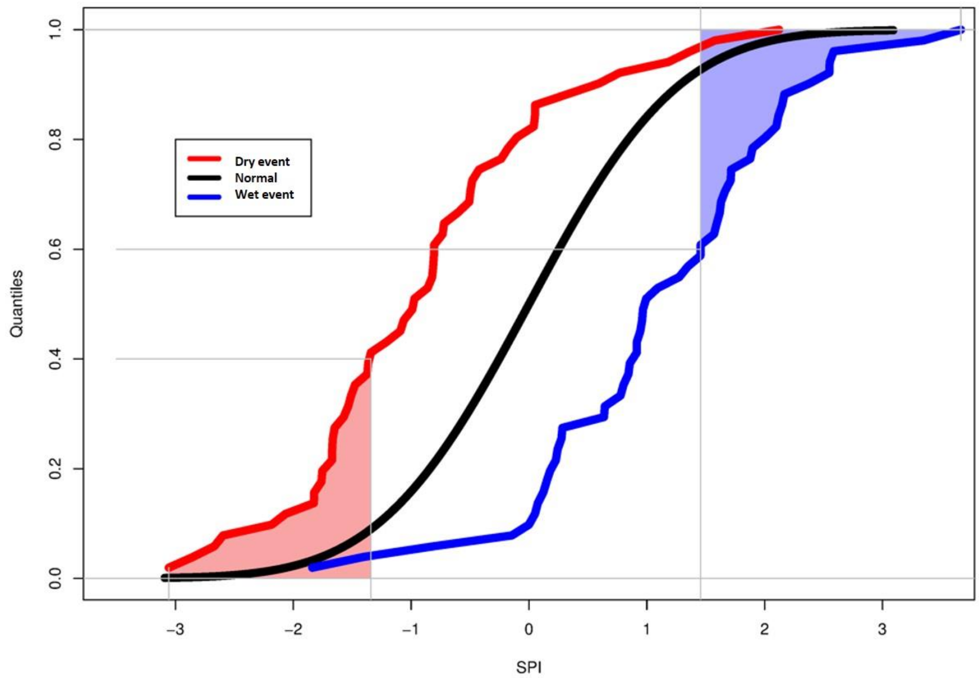

Figure 2: Illustration of the calculation of the Extreme Forecast Index (EFI) / Shift of Tails (SOT), for forecasted SPI. The intensity of the forecast is calculated from the areas shaded in red (for forecasted dry conditions) and blue (for forecasted wet conditions).

The forecast product derived from the integral of members in the tails of the CDF of the SPI ensemble forecast, is not straightforward to interpret and to use, and this issue may be amplified by the spatial variability of the model. To address this point, the same calculation has been done for the full 36-year re-forecast period (i.e. 1981-2016) of the SEAS51 seasonal forecast system. The resulting climatology of the forecast intensities highlights the large spatial variability of these values.

Calculation of the same index during the SEAS51 36-year re-forecast period enables computation of the "return period" (recurrence interval) for the unusually wet and dry conditions, for different regions. The forecast intensity is thus transformed into an equivalent return period for the event, highlighting regions where significant anomalous precipitation conditions are forecasted (e.g. Figure 1). Different "alarm levels" are derived (see Table 1) by combining both the level of significance of the forecast (i.e. coherence of the members), and the severity of the anomalous condition (i.e. intensity of the most extreme ensemble members). For our purposes, the second driest or wettest members are used to remove potential outliers, and are defined as the 90th percentile.

Lavaysse et al. (2020) provide further details on the method for computing the Indicator for Forecasting Unusually Wet and Dry Conditions. The study also explores the relationship between the three alarm levels and (a) the significance of the forecast (i.e. coherence of the members, defined as the percentage of members below -1 or above +1, for dry and wet conditions respectively), and (b) the severity of the extreme condition (i.e. intensity of the extreme ensemble members, defined as the SPI of the second driest or wettest members). The study also analyses the coherence between SEAS51 historical re-forecasts ("hindcasts") and the forecasted unusually wet and dry conditions, and describes the validation of both sets of simulations (hindcasts and forecasts).

4. How to use the indicator

The map showing the Indicator for Forecasting Unusually Wet and Dry Conditions, is automatically updated on a monthly basis on the European Drought Observatory web-site, based on the most recent seasonal precipitation forecasts provided by the ECMWF long-range (i.e. seasonal) forecast system (SEAS51). The maps of the indicator can be used to identify regions where there is a good probability that unusually wet or dry conditions could occur, and where the intensity is expected to be strong (depending on the alarm level).

The likely duration of the anomalous conditions can be selected from a list of the 1-month, 3-month and 6-month SPI forecast accumulation periods (i.e. SPI-1, SPI-3 and SPI-6). The indicator data are available from October 2022 up to and including the current month. As mentioned in Section 2, the date of the selected forecast indicates the start of the forecast period.

5. Strengths and weaknesses of the indicator

Strengths:

- Detection of significant forecasts of anomalous conditions (described by Lavaysse et al., 2015).
- Provision of comprehensive and robust information that combines the intensity and the coherence of the forecasts.
- Provision of early warning, with different alarm levels, indicating the return period of the forecasted unusually wet or dry conditions.
- Optimized quality of the forecasts (based on historical re-forecasts or "hindcasts").

Weaknesses:

- The main weakness of the product is related to the quality of the forecasts. Skill of precipitation forecasts at seasonal timescales in state-of-the-art systems is highly dependent on location and season. For example, the areas where ENSO is the dominant driver of precipitation variability tend to be the locations with highest skill due to the high predictability of ENSO. Regions/seasons with other dominant drivers (e.g. the North Atlantic Oscillation) tend to show a lower predictability.
- Although the 1 degree (~ 110 km) SEAS51 resolution enables the indicator to focus on large-scale events, the coarser spatial resolution may lead to possible mixing of sub-grid-cell (i.e. local) signals, particularly over mountainous and coastal regions.

- Introduction of potential bias in calculating the return period, due to climate evolution. The start of the SEAS51 reference period is more than 40 years ago (1981). Due to a changing climate - which affects the frequency of extreme events - return periods may be either over- or under-estimated. In addition, because of real-time constraints, there are some differences in the quality of the land surface initial conditions, which may affect the precipitation forecasts. However these differences are likely to generate only minor bias.

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