EO FOR SUSTAINABLE DEVELOPMENT IN THE CLIMATE RESILIENCE DOMAIN

DELIVERY DOCUMENT

STANDARDISED PRECIPITATION-EVAPOTRANSPIRATION INDEX (SPEI)

GRIDDED SPEI FROM ERA5 DAILY TEMPERATURE AND PRECIPITATION DATA

Produced under ESA contract 4000123980/18/I-NB

Prepared by: Mohamad Nobakht, TVUK

Approved by: Amanda Hall, TVUK

Authorized by: Carlos Domenech, GMV

Version: 1.0

Date: 20.03.2019

INTRODUCTION

The aim of this document is to provide supplementary information for the service aimed at providing the Standardised Precipitation-Evapotranspiration Index (SPEI) using long-term historical reanalysis data to the CCKP and ARC for use as a drought indicator.

The service is provided within the EO4SD Climate Resilience Cluster as one of the cluster's climate indices services offered by Telespazio VEGA UK. This product is delivered within Phase 2 of the EO for sustainable development in the Climate resilience domain, initiative supported by the European Space Agency (ESA).

PRODUCT OVERVIEW

Product title	Standardised Precipitation-Evapotranspiration Index from ERA5
Product ID	Standardised_Precipitation-Evapotranspiration_Index_v1.0
Objectives/ Outcomes	The objective is to provide gridded products at global scale for SPEI, calculated for the following time scales using a statistical distribution: • Time scales: 6, 9, 12 & 18 months • Statistical distributions: Log-logistic
Cluster	EO4SD Climate Resilience
Service Provider	Telespazio VEGA UK
Service description	The service utilizes a methodology for generating a multi-scalar drought index, which can be used by different scientific disciplines to detect, monitor and analyse droughts. The SPEI can measure drought severity according to its intensity and duration, and can identify the onset and end of drought episodes. The SPEI products are generated by analysis of over 40 years of daily precipitation and temperature data from the fifth generation of ECMWF atmospheric reanalyses (ERA5). ERA5 combines vast amounts of historical observations into global estimates using advanced modelling and data assimilation systems. More details on ERA5 can be found at [1]. To calculate the SPEI, monthly Potential Evapotranspiration (PET) are first calculated by applying Thornthwaite method [2], using daily mean temperature and latitude information. The SPEI then were calculated for different accumulation periods (time scales) using Log-logistic distribution. The reference period (i.e. calibration period) for calculating SPEI indicator has been set to 1981-2010.
Product content	The products contain SPEI values at each grid point on global scale (land only).
Input data	ERA5 daily total precipitation. ERA5 daily 2 m mean temperature.
Area of Interest	Global
Data temporal coverage	01/01/1979 – 31/01/2020

Data spatial resolution	0.25 degree lat/lon (~31 km)
Frequency	Monthly
Processing requirements	- Access to ERA5 daily total precipitation - Access to ERA5 daily mean temperature - Python 3.7
Limitations	- Uncertainties associated with the ERA5 data should be considered while interpreting the SPEI values. - The effect of reference period parameter on presenting historical drought characteristics, such as the trend, frequency, intensity and spatial extent should be taken into account when comparing the current dataset with other pre-computed SPEI datasets (see [5]).
Dissemination	Submission via EO4SD CR Platform API access for the CCKP
Delivery format	NetCDF
File names	spei6_log-logistic_EO4SD-CR_ERA5_1979-2020.nc spei9_log-logistic _EO4SD-CR_ERA5_1979-2020.nc spei12_log-logistic_EO4SD-CR_ERA5_1979-2020.nc spei18_log-logistic_EO4SD-CR_ERA5_1979-2020.nc
Projection	Geographic Lat/Lon
Implementation time frame	- V1.0: Feb 2020 - Next rollout: Depending on user feedback it could be possible to provide monthly updates and add more time scales e.g. 24 months time scale.
Validation	- Theoretical approach checked independently by Richard Bater, Acclimatise.
Potential data access issues or other areas of risk	None

METHODOLOGY

Standardised Precipitation-Evapotranspiration Index (SPEI)

Drought is one of the main natural causes of agricultural, economic, and environmental damage. The effects of drought on the environment and agriculture are evident after a long period with a shortage of precipitation, making it very difficult to determine the onset of drought, its extent and end. Quantitative indices are the most widespread approach for drought analysis, such as Palmer Drought Severity Index (PDSI) [3], based on a soil water balance equation, or the Standardised Precipitation Index (SPI) [2], based on a precipitation probabilistic approach.

Although precipitation is the main variable driving the drought extent and intensity, higher temperatures increase drought stress and enhance the drought effects. The SPEI has been formulated based on precipitation and Potential Evapotranspiration (PET), which is directly linked to temperature variations. The SPEI combines the sensitivity of PDSI to changes in evaporation demand (caused by temperature fluctuations and trends) with the simplicity of calculation and the multi-temporal nature of the SPI. 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.

Computation of SPEI

A number of equations exist to model 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. We have used Thornthwaite equation for calculating the PET for each grid location, using ERA5 2 m daily mean temperature data [4].

With a value for PET, the difference between the precipitation (P) and PET for the month *i* is calculated as:

$$D_i = P_i - PET_i$$

which provides a simple measure of the water surplus or deficit for the analysed month.

Drought indices, such as the SPEI, are usually computed at different time scales to adapt to the different response times of systems affected by drought. This is accomplished by applying a kernel function to the data prior to computation of the SPEI. Application of a kernel has the effect of smoothing the temporal variability of the resulting SPEI, allowing the major patterns to emerge from the noise. The kernel allows incorporating information of previous time steps into the calculation of the current time step, so the resulting values of the SPEI adapt to the memory of the system under study. Therefore, the calculated Di values are aggregated at different time scales, following the procedure described at [6].

For the calculation of the SPEI, the Log-logistic distribution was used because the frequencies of precipitation accumulated at different time scales are well modelled using this statistical distribution [6]. To ensure consistency for the monthly updates of SPEI product, the distribution parameters were obtained by fitting the distribution to data for a fixed reference period. The selected reference period (i.e. calibration period) for the current SPEI datasets is 1981-2010. To fit the distributions to these values and transform the values to corresponding normalized z-values, distribution parameters were estimated using unbiased Probability Weighted Moments.

The output SPEI values are normally within the range of -3 to 3. The negative values indicate dry conditions, with the larger negative values indicating stronger degrees of drought. Correspondingly, the positive values indicate wet conditions, with the larger positive values indicating higher degrees of moisture.

RESULTS

The SPEI products are delivered through the EO4SD CR platform, which provides an interface for the user to explore and visualise the data and to perform spatial sub-setting and data extraction. Figure 1 shows a snapshot of the EO4SD CR platform, where users can select the SPEI product to add to the map and perform further analysis. In this figure, the SPEI-18 for November 1995 over a spatial subset defined by the user is presented. Figure 2 shows an example of the monthly SPEI-18 values from 1979 to 2020 for Addis Ababa region in Ethiopia, presented on the EO4SD CR platform.

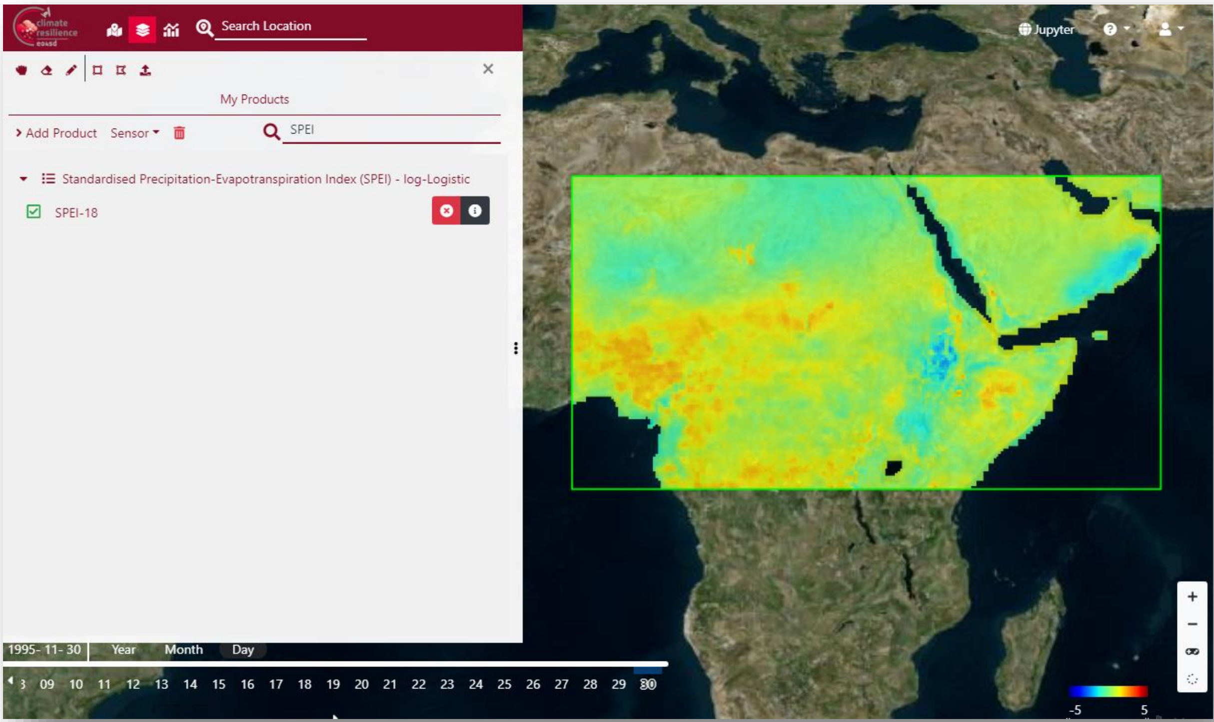

Figure 1. A subset of SPEI-18 for November 1995

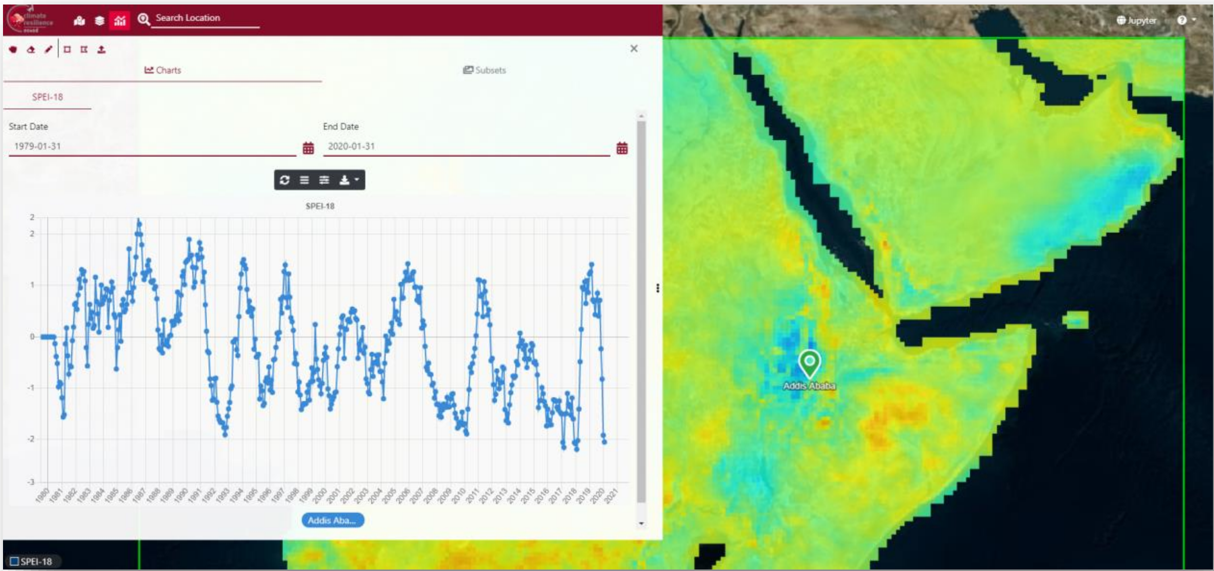

Figure 2. SPEI-18 monthly time series for Addis Ababa, Ethiopia

SUMMARY AND OUTLOOK

The datasets delivered along with this document represents the EO4SD CR Standardised Precipitation-Evapotranspiration Index from ERA5, which aims to provide drought information to be used by different scientific disciplines to detect, monitor and analyse droughts. The SPEI can measure drought severity according to its intensity and duration, and can identify the onset and end of drought episodes. This service uses aggregated daily precipitation and temperature data between 01/01/1979 and 31/01/2020 from ERA5 reanalysis data. The dataset contains SPEI index at 6, 9, 12 & 18-month time scales, at global scale with a spatial resolution of 0.25° X 0.25° degree. The results of the service will be also accessible via API to allow integration into the CCKP's existing tools.

REFERENCES

[1] Copernicus Climate Change Service (C3S) (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS), https://cds.climate.copernicus.eu/cdsapp#!/home

[2] McKee, T.B.N., J. Doesken, and J. Kleist, 1993: The relationship of drought frecuency and duration to time scales. Eight Conf. On Applied Climatology. Anaheim, CA, Amer. Meteor. Soc. 179-184.

[3] Palmer, W.C., 1965: Meteorological droughts. U.S. Department of Commerce Weather Bureau Research Paper 45, 58 pp.

[4] Thornthwaite, C. W. (1948), An approach towards a rational classification of climate, Geogr. Rev., 38, 55–94.

[5] Um, M.J., Kim, Y., Park, D. and Kim, J., 2017. Effects of different reference periods on drought index (SPEI) estimations from 1901 to 2014. Hydrology & Earth System Sciences, 21(10).

[6] Vicente-Serrano S.M., Santiago Beguería, Juan I. López-Moreno, (2010) A Multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index - SPEI. Journal of Climate 23: 1696-1718.