European Extreme Events Climate Index: brief notes about the input dataset and the components' definition

The European Extreme Events Climate Index (E^3CI) is a "in progress experiment" to define a synthetic index aimed at providing information about the areas affected by different types of weather-induced hazards and the severity of such events. In the first stage, based on the corresponding index developed for North America (Actuaries Climate Index, ACI; actuariesclimateindex.org), five components returning information about main hazards are included: cold and heat stresses, droughts, heavy precipitations, intense winds. The data will be made available on different Administrative unit levels; currently, data at Country level are produced. Then, two additional indicators related to detect frequency and severity of atmospheric conditions potentially leading to fires and hailstorms have been included in the suite.

The assessment of the components exploits ERA5 (doi:10.24381/cds.adbb2d47), the fifth-generation atmospheric reanalysis produced by European Centre for Medium-Range Weather Forecasts [ECMWF] (https://youtu.be/FAGobvUGl24). ERA5 covers the entire Globe on regular latitude-longitude grids at 0.25° x 0.25° resolution from January 1950 to present. Hourly data on many atmospheric parameters together with estimates of uncertainty are available on Climate Data Store of Copernicus Climate Change Service [C3S]. ERA5 is updated daily with a latency of about 5 days permitting a constant update of the components forming E^3CI.

For each component, an indicator is used as proxy for several hazards. The reference value is computed on 1981-2010 time span while, at monthly basis, a standardized anomaly respect to the reference value is computed.

For what concerns theseven components, they are defined as follows:

i) HEAT STRESS[1][2]

BASELINE CALCULATION: On the reference period 1981-2010, for each calendar day, the maximum temperature of the surrounding five days is considered. The 95th percentile among the 150 values (5 days x 30 years) is computed and assumed as threshold.. Then, the exceedance value at monthly basis is computed as:

$$HS_{j,k} = \sum_{i=1}^{n_j} \max\left[0;\ T_{max_{i,j,k}} - T_{max_{95,j}}\right]$$

where $T_{max_{i,j,k}}$ represents the maximum temperature (day i, month j, year k)

Over the reference period, for each month j, the mean value $\mu(HS_j)$ and the standard deviation $\sigma(HS_j)$of the cumulative exceedance value are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the cumulative value of daily exceedance beyond the corresponding threshold ($HS_{j,k}$) is standardized according to the formula:

[1] PLEASE PAY ATTENTION, IN JULY 2023, THE FORMULATIONS ADOPTED FOR HEAT AND COLD STRESSES HAVE BEEN UPDATED TO MAKE THEM HOMOGENEOUS WITH THE OTHER COMPONENTS. INDEED, IN THIS WAY, ALL THE INDICATORS REPORT INFORMATION NOT ONLY ABOUT THE FREQUENCY BUT ALSO ABOUT THE SIGNIFICANCE OF EXTREME EVENTS. THE OLD FORMULATIONS ARE REPORTED IN APPENDIX 1 WHILE THE FILES WITH THE VALUES AT COUNTRY SCALE ARE RETRIEVABLE HERE.

[2] Rousi, E., Kornhuber, K., Beobide-Arsuaga, G., Luo, F., & Coumou, D. (2022). Accelerated western European heatwave trends linked to more-persistent double jets over Eurasia. Nature Communications, 13(1). https://doi.org/10.1038/s41467-022-31432-y

$$HS_{std,j,k} = \frac{HS_{j,k} - \mu(j, T_{max})}{\sigma(j, T_{max})}$$

ii) COLD STRESS

BASELINE CALCULATION: On the reference period 1981-2010, for each calendar day, the minimum temperature of the surrounding five days is considered. The 5th percentile among the 150 values (5 days x 30 years) is computed and assumed as threshold.. Then, the exceedance value at monthly basis is computed as:

$$CS_{j,k} = \sum_{i=1}^{n_j} \max\left[0;\ abs(T_{min_{i,j,k}} - T_{min_{95,j}})\right]$$

where $T_{min_{i,j,k}}$ represents the maximum temperature (day i, month j, year k)

Over the reference period, for each month j, the mean value $\mu\left(CS_j\right)$ and the standard deviation $\sigma\left(CS_j\right)$of the cumulative exceedance value are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the cumulative value of daily exceedance beyond the the corresponding threshold ($CS_{j,k}$) is standardized according to the formula:

$$CS_{std,j,k} = \frac{CS_{j,k} - \mu(j, T_{min})}{\sigma(j, T_{min})}$$

i) DROUGHT

BASELINE CALCULATION: Standard Precipitation Index (SPI) [3] is assumed as reference indicator considering 3 months as accumulation period of interest (SPI-3). Over 1981-2010, for each month j, the 30 cumulated values are fitted to a gamma probability distribution which is then transformed into a normal distribution.

STANDARDIZED ANOMALY COMPUTATION: For each month j and year k,$SPI - 3_{j,k}$ value represents units of standard deviation from the long-term reference mean. According to the canonical approach, positive SPI indicate values greater than median precipitation and negative values indicate less than median precipitation. In E^{3}CI, to maintain the consistency with the other components, the opposite of $SPI - 3_{j,k}$ is taken.

iv) EXTREME PRECIPITATION

BASELINE CALCULATION: On the reference period 1981-2010, for each month j, the 95th percentile of daily precipitation is computed. Then, the exceedance value at monthly basis is computed as:

[3] McKee, T.B., N.J. Doesken and J. Kleist. 1993. The relationship of drought frequency andduration to time scale. In: Proceedings of the Eighth Conference on Applied Climatology,Anaheim, California, 17–22 January 1993. Boston, American Meteorological Society, 179–184.Edwards, D.C. and T.B. McKee. 1997. Characteristics of 20th Century Drought in the UnitedStates at Multiple Time Scales. Climatology Report Number 97-2. Colorado State University, FortCollins.

$$EP_{j,k} = \sum_{i=1}^{n_j} \max[0;\ P_{i,j,k} - P_{95,j}]$$

where $P_{i,j,k}$ represents the daily precipitation (day i, month j, year k)

Over the reference period, for each month j, the mean value $\mu(EP_j)$and the standard deviation $\sigma(EP_j)$of the exceedance value are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the exceedance value is standardized according to the formula:

$$EP_{std,j,k} = \frac{EP_{j,k} - \mu(EP_j)}{\sigma(EP_j)}$$

v) EXTREME WINDS

BASELINE CALCULATION: On the reference period 1981-2010, for each month j, the 95th percentile of daily maximum wind speed is computed, $w_{95,j}$. Then, at monthly basis, Local Loss Index (LLI, Donat et al., 2011; doi:10.5194/nhess-11-1351-2011) is calculated as:

$$LLI_{j,k} = \sum_{i=1}^{n_j} max\left[0; \left(\frac{w_{max,ij,k}}{w_{95,j}} - 1\right)^3\right]$$

Where $w_{max,ij,k}$ is the maximum wind speed computed considering mean hourly values. Over the reference period, for each month j, the mean value $\mu(LLI_j)$and the standard deviation $\sigma(LLI_j)$are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the exceedance value is standardized according to the formula:

$$LLI_{std,j,k} = \frac{LLI_{j,k} - \mu(EP_j)}{\sigma(EP_j)}$$

vi) HAILSTORMS LEADING CONDITIONs

BASELINE CALCULATION: On the reference period 1981-2010, for each month j, the exceedance of SHIP[4] indicator values from the threshold value is computed. Subsequently, for each month j, the mean value $\mu(ES_j)$ and the standard deviation $\sigma(ES_j)$ of the exceedance value are calculated. Then, at monthly basis, the exceedance of SHIP indicator values from the threshold value is computed

$$ES_{j,k} = \sum_{i=1}^{n_j} \max[0;\ S_{i,j,k} - 1]$$

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the exceedance value is standardized according to the formula:

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[4] Czernecki, B., Taszarek, M., Marosz, M., Półrolniczak, M., Kolendowicz, L., Wyszogrodzki, A., & Szturc, J. (2019). Application of machine learning to large hail prediction - The importance of radar reflectivity, lightning occurrence and convective parameters derived from ERA5. Atmospheric Research, 227, 249–262. https://doi.org/10.1016/j.atmosres.2019.05.010

https://www.spc.noaa.gov/exper/soundings/help/ship.html

$$ES_{std,j,k} = \frac{ES_{j,k} - \mu(ES_j)}{\sigma(ES_j)}$$

vii) FOREST FIRE LEADING CONDITIONS

BASELINE CALCULATION: On the reference period 1981-2010, for each month j, the exceedance of FWI[5] indicator values from the high danger threshold[6] value is computed. Subsequently, for each month j, the mean value $\mu(EF_j)$ and the standard deviation $\sigma(EF_j)$ of the exceedance value are calculated. Then, at monthly basis, the exceedance of SHIP indicator values from the threshold value is computed

$$EF_{j,k} = \sum_{i=1}^{n_j} \max[0;\ F_{i,j,k} - 21.3]$$

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the exceedance value is standardized according to the formula:

$$EF_{std,j,k} = \frac{EF_{j,k} - \mu(EF_j)}{\sigma(EF_j)}$$

viii) E^3CI

For each month j and year k, the European Extreme Events Climate Index is given by the mean of the different components. Different and more effective formulations are currently under development.

[5] Van Wagner, C. E. (1987). Development and structure of the Canadian Forest Fire Weather Index System. Vol. 35 (1987), 35, 35.

[6] https://climate-adapt.eea.europa.eu/en/metadata/indicators/fire-weather-index-monthly-mean-1979-2019

APPENDIX 1 (heat stress and cold stress old computation formula from January 1981- May 2023)

i) HEAT STRESS

BASELINE CALCULATION: On the reference period 1981-2010, for each calendar day, the maximum temperature of the surrounding five days is considered. The 95th percentile among the 150 values (5 days x 30 years) is computed and assumed as threshold. For each month j, the mean value $\mu(j, T_{max})$and the standard deviation $\sigma(j, T_{max})$of the number of days exceeding the corresponding threshold are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k,the number of days exceeding the corresponding threshold ($HS_{j,k}$) is standardized according to the formula:

$$HS_{std,j,k} = \frac{HS_{j,k} - \mu(j, T_{max})}{\sigma(j, T_{max})}$$

ii) COLD STRESS

BASELINE CALCULATION: On the reference period 1981-2010, for each calendar day, the minimum temperature of the surrounding five days is considered. The 5th percentile among the 150 values (5 days x 30 years) is computed and assumed as threshold. For each month j, the mean value $\mu(j, T_{min})$and the standard deviation $\sigma(j, T_{min})$of the number of days lower than the corresponding threshold are calculated.

STANDARDIZED ANOMALY COMPUTATION: Each month j and year k, the number of days lower than the corresponding threshold ($CS_{j,k}$) is standardized according to the formula:

$$CS_{std,j,k} = \frac{CS_{j,k} - \mu(j, T_{min})}{\sigma(j, T_{min})}$$