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This document explains how to calculate the absolute values of each climate indicator for the region of interest and reference period. The study of the climate implies, by definition, the use of long-time scales; in particular, the WMO (WMO, 2007) establishes in 30 years the standard length on which it is necessary to perform statistical analyses that can be considered representative of the average and extreme climate regimes of a selected geographical area (WMO, 2007: The Role of Climatological Normals in a Changing Climate. WCDMP-No. 61, WMO.TD No. 1377).

1. INDICATORS

This document provides useful guidelines to apply the codes, that have been developed for the computation of the following indicators:

1. WSDI (days): Warm Spell Duration Index - Number of days per period where, in intervals of at least 6 consecutive days with maximum temperature higher than the 90th percentile of maximum temperature (calculated for a 5-day window centered on each calendar day in the 1981-2010/1991-2020 period or the period on which the threshold is calculated).
2. HWN: Number of times per period where, in intervals of at least 3 consecutive days of maximum temperature higher than the 90th percentile of maximum temperature (calculated for a 31-day window centered on each calendar day in the 1981-2010/1991-2020 period or the period on which the threshold is calculated).
3. HWTXdx (°C): Maximum value between the averages of the maximum temperatures averaged for each heat wave. The heat wave is identified by the exceeding, for at least 3 consecutive days, of the 90th percentile of the maximum temperatures (calculated for a 31-day window centered on each calendar day in the 1981-2010/1991-2020 period or the period on which the threshold is calculated)
4. TXX (°C): maximum value of daily maximum temperature
5. TXN (°C): minimum value of daily maximum temperature
6. TG (°C): Mean daily temperature
7. TR (days): Tropical Nights - number of days with a minimum temperature of 20 °C
8. TX90p (days): Number of days with daily temperature above the 95th percentile (calculated using a mobile window of 5 days in the reference timeframe 1981-2010/1991-2020)
9. CDD (days): Consecutive Dry Days - largest number of consecutive days with precipitation less than 1 mm
10. FG (m/s): Mean daily wind speed at 10 m
11. RX1DAY (%): Maximum 1-day precipitation amount
12. RX5DAY (mm): Maximum 5-day precipitation amount

13. R95PTOT: Precipitation fraction due to very wet days (%).
14. PRCPTOT (mm): Total Precipitation - precipitation sum in wet days (days with precipitation greater than or equal to 1 mm)

The adopted methodology aims at computing the indicators as defined by the ETCCDI (http://etccdi.pacificclimate.org/list_27_indices.shtml).

The *MeteoLab open-source Matlab toolbox* (<https://meteo.unican.es/trac/MLToolbox/wiki>) has been used to estimate the indicators above-mentioned, adapting the available codes to the AdriaClim Project needs. The codes needed to compute the indicators are provided by the Fondazione CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici, Regional Models and geo-Hydrological Impacts Division (REMHI).

N.B. The codes have been tested for ERA5-Land daily data, therefore modifications to the codes are needed in case the input dataset is different. Here an example of the input data:

```
netcdf t2mean_1d_daily_ERA5_1950_2021 {
dimensions:
    time = UNLIMITED ; // (26207 currently)
    bnds = 2 ;
    longitude = 21 ;
    latitude = 20 ;
variables:
    int time(time) ;
        time:standard_name = "time" ;
        time:long_name = "time" ;
        time:bounds = "time_bnds" ;
        time:units = "hours since 1900-01-01 00:00:00.0" ;
        time:calendar = "gregorian" ;
        time:axis = "T" ;
    double time_bnds(time, bnds) ;
    float longitude(longitude) ;
        longitude:standard_name = "longitude" ;
        longitude:long_name = "longitude" ;
        longitude:units = "degrees_east" ;
        longitude:axis = "X" ;
    float latitude(latitude) ;
        latitude:standard_name = "latitude" ;
        latitude:long_name = "latitude" ;
        latitude:units = "degrees_north" ;
        latitude:axis = "Y" ;
    short t2m(time, latitude, longitude) ;
        t2m:long_name = "2 metre temperature" ;
        t2m:units = "K" ;
        t2m:add_offset = 278.543999580124 ;
        t2m:scale_factor = 0.0011884618227142 ;
        t2m:_FillValue = -32767s ;
        t2m:missing_value = -32767s ;
        t2m:cell_methods = "time: mean" ;

// global attributes:
        :CDI = "Climate Data Interface version 1.9.8 (https://mpimet.mpg.de/cdi)" ;
        :Conventions = "CF-1.6" ;
```

1. SOFTWARE

Two different Software can be used for our purposes:

- MATLAB (developed by MathWorks; <https://it.mathworks.com/products/matlab.html>; not Open Source)
- Octave (<https://octave.sourceforge.io/>; Open Source)

Both are programming and numeric computing platforms widely used in the scientific community.

Here a guideline to install for free Octave on your machine: <https://www.gnu.org/software/octave/download>. After installing Octave (version $\geq 4.0.0$), please install the packages *statistics* (version $\geq 1.4.3$), *netcdf* (version $\geq 1.0.14$) and *io* (version $\geq 1.9.18$) available at this link: <https://octave.sourceforge.io/packages.php>.

2. CODES

The following codes are made available to compute the indicators discussed in Section 1:

- Import_data.m
- extremesIndicators_adriacim.m
- Yearly_indicators.m
- Monthly_indicators.m
- Seasonal_indicators.m
- aggregateData.m
- aggregateDataDay_M.m
- aggregateDataDay.m
- testTrend.m
- MK.m
- movingAverage.m
- datesym.m
- datesym2datesym.m

The aim of each code is summarized below, comments explaining the content are included in the scripts.

- Import_data.m

This code transforms the netcdf data provided is a .mat format which reads the variables correctly.

- extremesIndicators_adriacim.m

This code includes a function which estimates the climate indicators in agreement with the ETCCDI.

The input arguments are:

- outputpath: folder path for output

- modelName: name of the model (e.g., ERA5-Land, ERA5)
- varagin: optional inputs.
- variables: minimum, mean and maximum temperature, precipitation, humidity, wind speed, wind direction and maximum wind speed. Ndata x Nest dimensions matrix with the daily data. Each row represents an observed day and each column a station or grid point. The data units must be: °C for temperature (Tx,Tn,Tg), mm for precipitation (Pr), % for relative humidity (Hum), m/s for wind speed (Ws) and degrees between (0°-360°) for wind direction (Wd).
- aggregation: is the aggrupation criteria, for annual write Y, for monthly M and for seasonally S (S1,S2,S3,S4 correspond to DJF,MAM,JJA and SON).
- missing: maximum percentage of missing data (i.e., NaN) per group.
- names: {'wsdi' 'hwn' 'hwtxdx' 'txx' 'txn' 'tg' 'tr' 'tx90p' 'fg' 'prcptot' 'rx1day' 'rx5day' 'r95ptot' 'cdd'}. Cell with the index name following the ECA&D definitions, recommended by the CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices, ETCCDI (<https://www.ecad.eu/indicesextremes/indicesdictionary.php>).

To launch this code the following functions are needed:

- aggregateData.m
- aggregateDataDay_M.m
- aggregateDataDay.m

that aggregate the data for year, month and season. The seasons correspond to DJF (from December to February), MAM (from March to May), JJA (from June to August) and SON (from September to November).

The codes:

- Yearly_indicators.m
- Monthly_indicators.m
- Seasonal_indicators.m

compute the climate indicators at annual/monthly/seasonal scale respectively. To launch this code, the following functions are needed:

- extremesIndicators_adriacim.m
- datesym.m
- datesym2datesym.m

The last two functions developed by MathWorks are needed for the string representation of the date.

More comments are added inside the codes. The codes provide as output the annual timeseries for each grid-point, climate indicator and pilot area. Any file has the output dimensions [N_Times x N_Punti], where N_Times is the number of timestep for the reference period and N_Punti is the number of grid points investigated.

In order to compute the trends for each indicator, the following codes provided by the *MeteoLab open-source Matlab toolbox* are used:

- testTrend.m
- MK.m
- movingAverage.m

The Mann-Kendall test (Kendall, 1975) with a 95% confidence level was used to evaluate the statistical significance of the increase/decrease trend of the aforementioned climate indicators calculated.

More details are provided inside the scripts above mentioned.

References:

Kendall, M.G. 1975. Rank Correlation Methods, 4th edition, Charles Griffin, London.