Intra-ACP Climate Services and Related Applications Programme – ClimSA

WORKSHOP - SADC Region

WEFE NEXUS, Climate Variability, and Environmental Monitoring

South Africa, Johannesburg, June 10th – 13th 2024

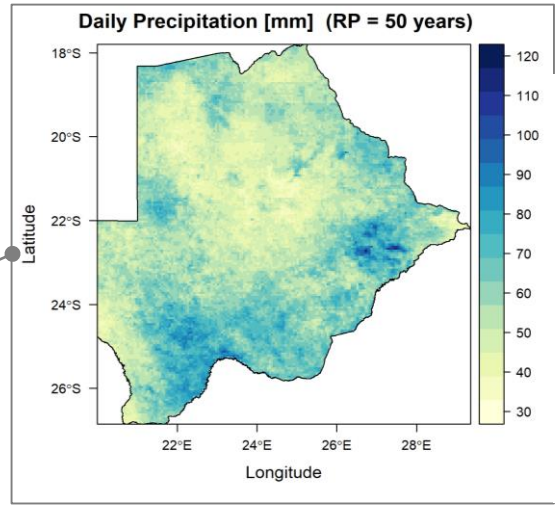
Climate Variability module – Introduction

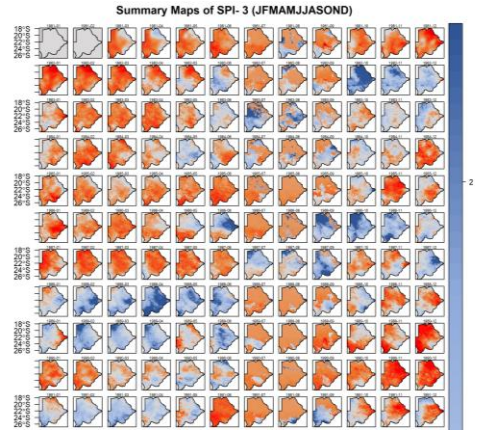
Cesar CARMONA, Marco PASTORI

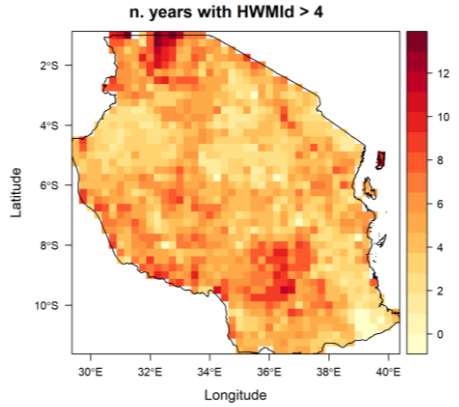
South Africa, Johannesburg, June 10th 2024

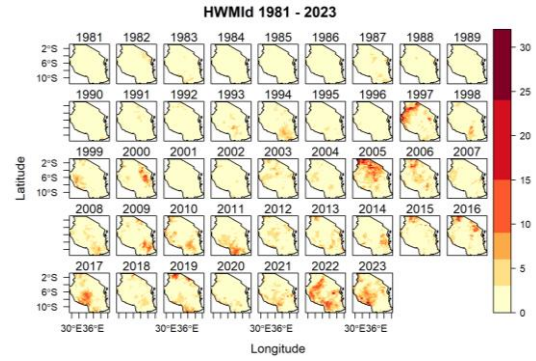
European Commission
Joint Research Centre

Climate Variability Module - Context









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WEFE Nexus process and Modelling

Supporting knowledge on the different themes
Understanding interactions and feedback

identify available data (and tools) already developed, and development priorities identified and in relation to Nexus components

Inventroy of current status

Development priorities

Evidence

Understanding Energy balance

Understanding the water balance-quality

Understanding Climate variability

Understanding Food security

Understanding Ecosystems

Understanding the WEFE interactions

Identification of collaboration and points of interest

NEXUS assessment

Scenarios

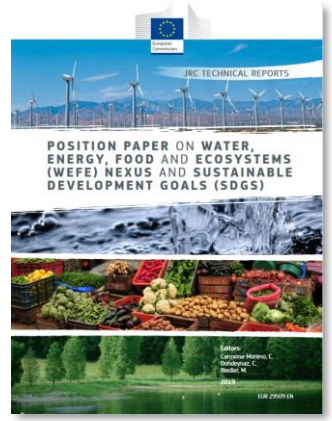
Strategic Fremework support

Nexus solutions

Dev. Measures

NEXUS Policy dialogue

Dialogue
development of scenarios, engagement of experts and stakeholders
identification of Nexus Solutions



ref.
Position Paper on WEFE NEXUS and SDGs, 2019

eNexus tool

DATA for modelling

Baseline Report
Open DATA
Copernicus
Survey

Thematic modelling

Hydro: SWAT / LISFLOOD
Agri: GISEPIC
Climate: SPI, L-Moments
Quality: SWAT, GREEN

Multi Objectives & Optimisation

MOO methods: single objective, multi objective, water vs bioenergy, crop land allocation, crop management optimization, water demands assessment

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Climate Variability Module

WHY A CV MODULE ?

- ✓ Extreme temperature and precipitation events play a **pivotal role in informing hazard mitigation and management strategies**
- ✓ A comprehensive evaluation of the spatial and temporal distribution of extreme events is essential for **shaping policies related to Water Resource Management and other critical areas**
- ✓ Significant deviations in temperature and precipitation have far-reaching **consequences across socio-economic domains**, including those aligned with the **Water-Energy-Food-Ecosystems (WEFE) Nexus** and the **Sustainable Development Goals** (SDGs)
- ✓ Insights into the **average frequency of precipitation deficits or heatwave** trends are **crucial for formulating sustainable measures in the mid-to-long term**.
- ✓ Given Africa's reliance on rainfall patterns for rainfed agriculture and their impact on river regimes, **understanding climate variability becomes particularly significant.**

Climate Variability Module

WHY A CV MODULE ?

Example of Benefits

- ✓ **Risk assessment**: Determining whether an activity, project, or investment should be authorized based on the associated risk zone.
- ✓ **Infrastructure Sizing:** Sizing infrastructure based on the variability of climatic variables and the estimated return periods of risks.
- ✓ **Complementary to Early Warning Systems**: This analysis serves as a complementary tool to Early Warning Systems, enabling the identification of potential risk areas and assessing the frequency of extreme climatic events.
- ✓ **Adaptation for Sustainability:** Ex: Agriculture and/or infrastructure must be adapted to a 50% precipitation deficit with a return period of 5-10-20 years.

Climate Variability Module

HOW?

OBJECTIVE: The module aims to contribute to a better understanding of the variability and climate risks and their impacts on water resources in transboundary river basins

Several Indicators of climate variability (CV) can be estimated and spatial and temporally analysed and mapped.

Pre-defined DATA Input can be retrieved and loaded into the local spatial DB (CHIRPS, ERA-5 reanalysis data are already available)

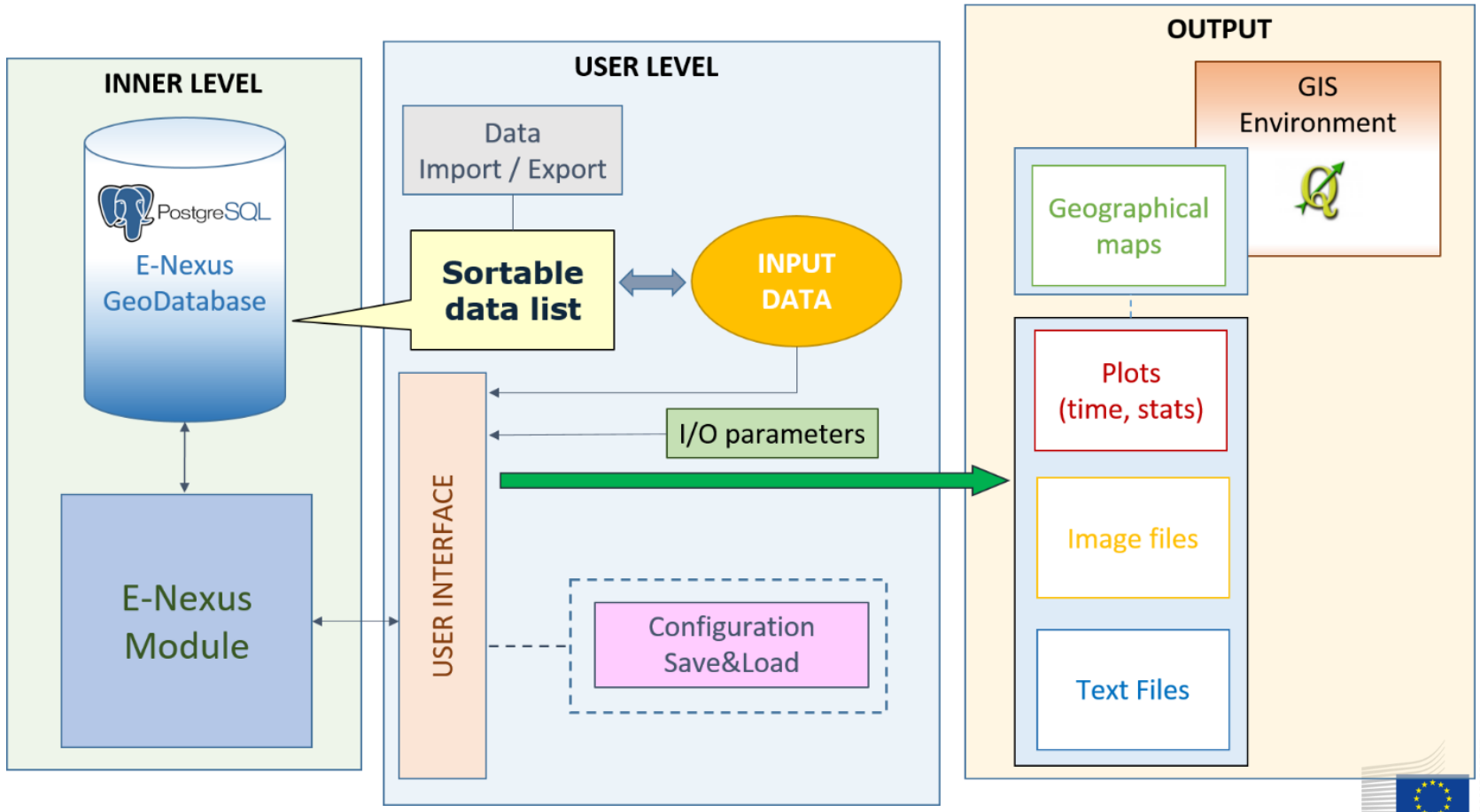
Climate Variability Module

HOW?

Overall conceptual scheme

Input datasets

- Rainfall (CHIRPS)
- Temperature (ERA5)



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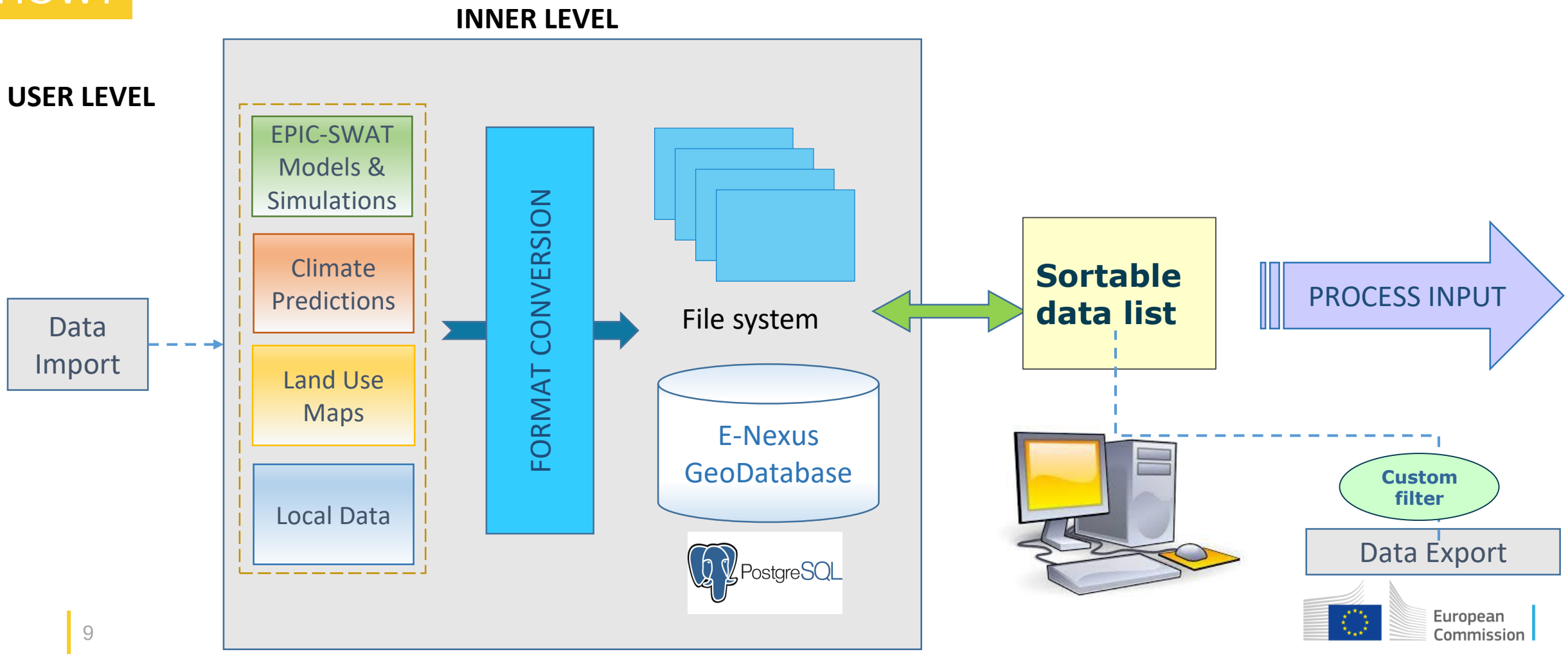
Climate Variability Module

Data input architecture

HOW?



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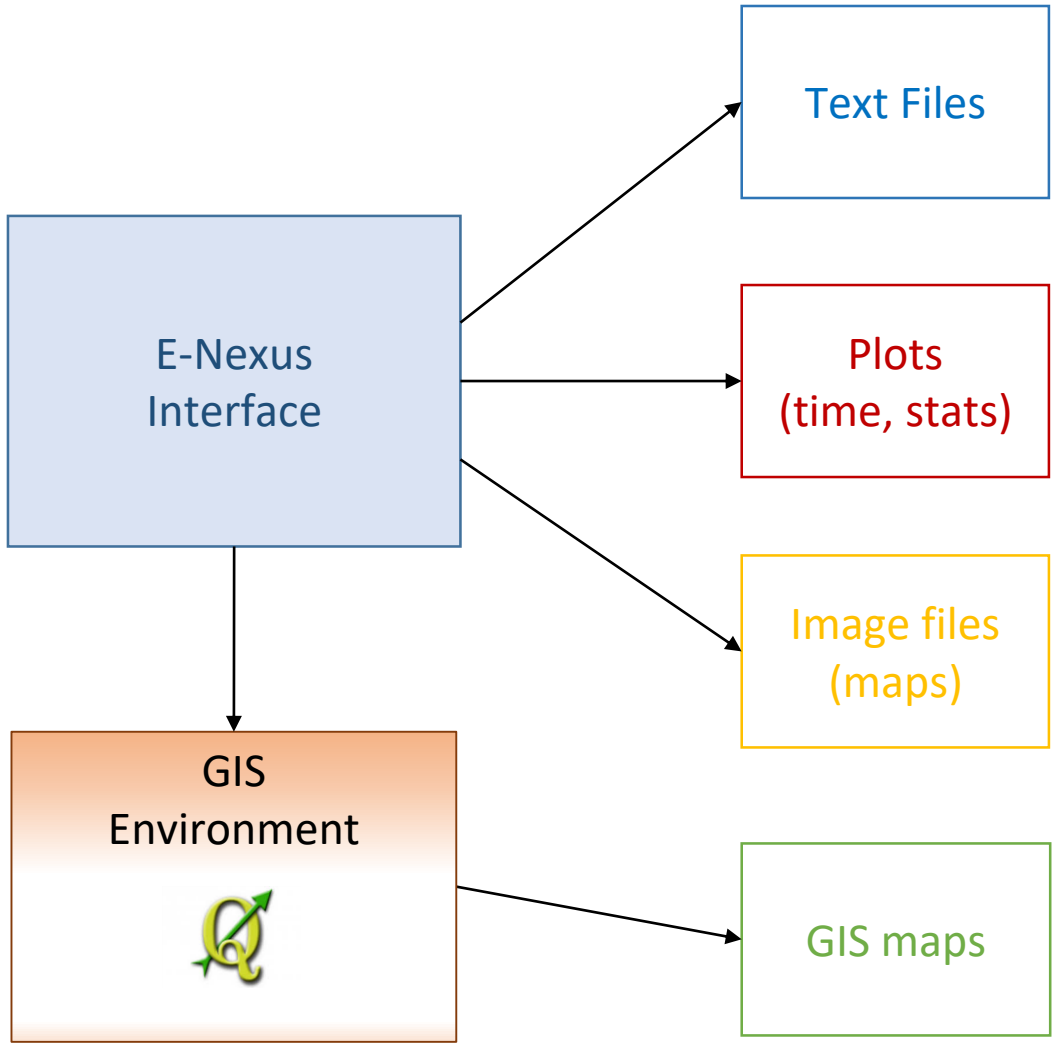
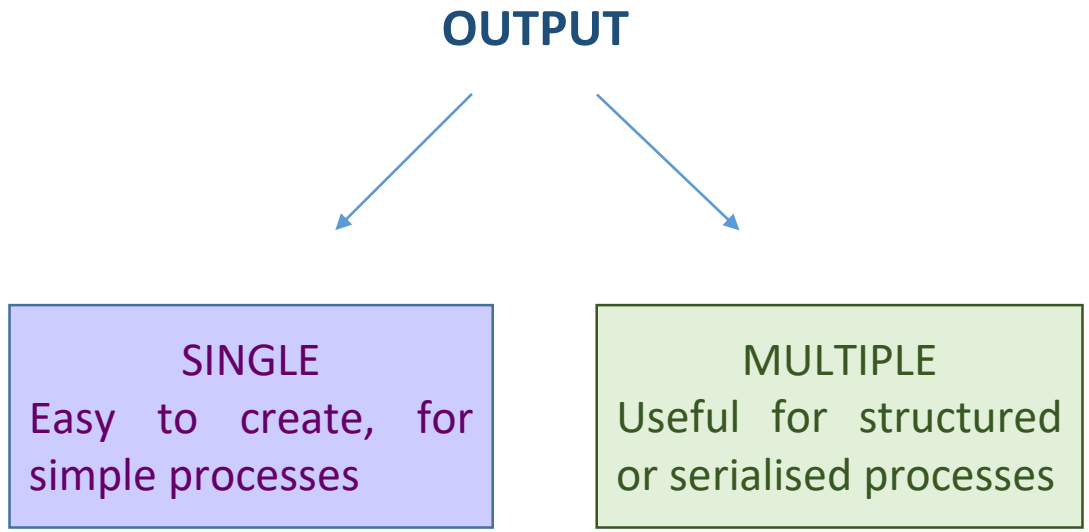
Output management





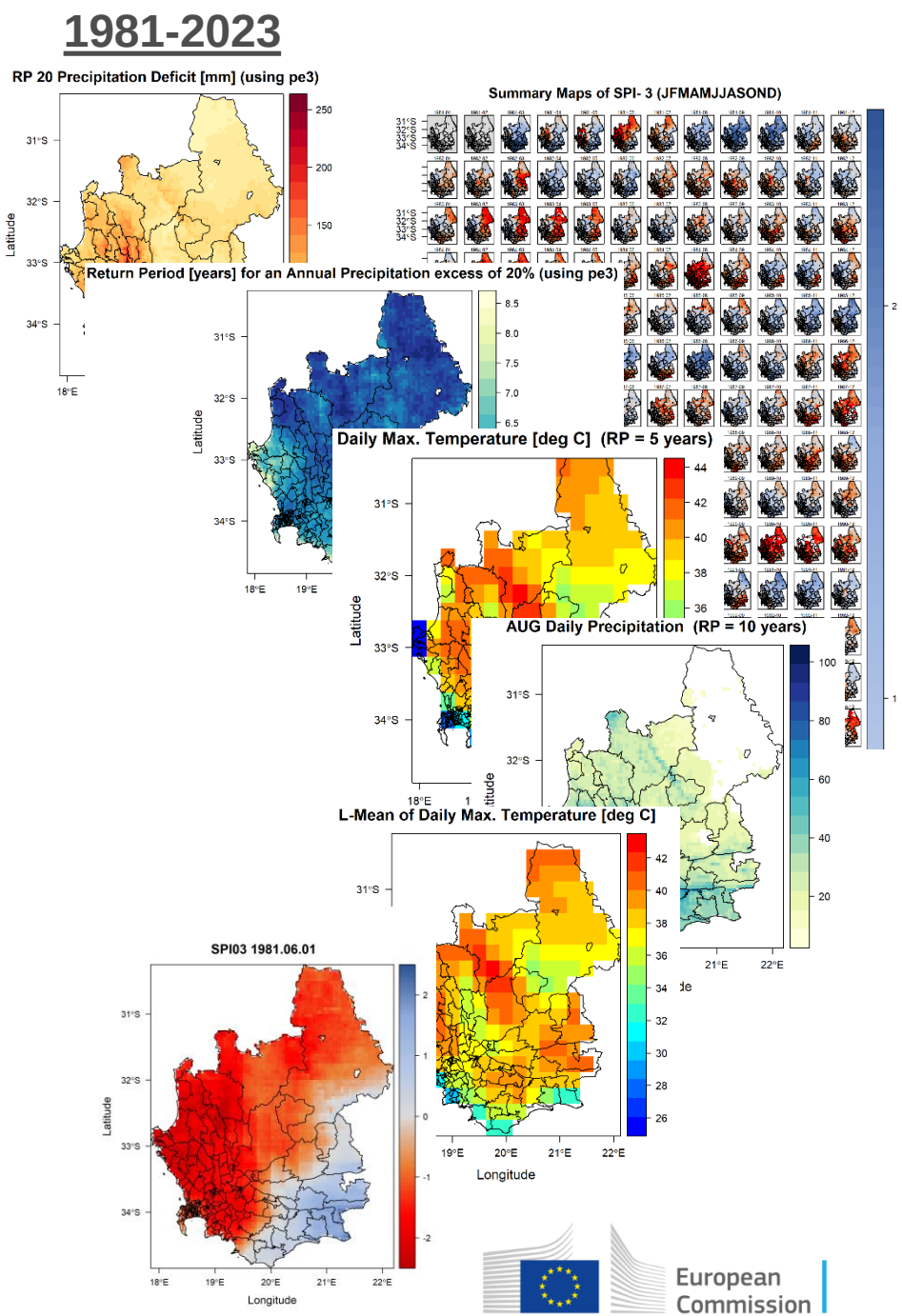
The typical output is produced and saved as a file of a format previously chosen by the user.

More complex or iterative processes can produce multiple objects, which are usually stored to the destination folder.

Climate Variability Module

OUTPUT INDICATORS

- Analyses by L-Moments for the assessment of **recurrence of extreme events**, related to precipitation and heat waves.
- **Return period** for a given % precipitation **excess/deficit**;
- yearly **HWMId** (**daily Heat Wave Magnitude Index**)
- number of years within 1981 and 2023 with HWMId exceeding values of 4 (heat waves extreme or more severe)
- **User configurable SPI** (Standard Precipitation Index) **for different range of timescales and periods**
- **Dry Spells**



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Climate Variability Module

OUTPUT INDICATORS

Some key concepts useful for all indicators

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Climate variability analysis with L-Moments

Two types of data can be used to estimate the return of extreme weather events (rainfall/temperature)

- In the case of ground-based weather stations [Hosking, 1990] (Refran-CV):The regional frequency analysis is complete. It is based on regionalisation using time series from ground stations with similar statistical behaviour in order to obtain more reliable estimates.

- In the case of satellite data (E-Nexus): The regionalisation step can be omitted because the data is already spatialised. This is the case with E-Nexus.

Climate Variability Module

Advantages of the L-moments Methodology

Increased Robustness:

- Less susceptible to sampling variability the presence of outliers (L-moments minimise the impact of outliers, reliable even with small or limited sample sizes);
- Methodology well suited to missing data and data with noise, which is often the case in developing countries.

Efficient Computation:

- Best performance with a short/limited time series of data.

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NOT TO BE DETAILED TODAY BUT FOR YOUR REFERENCE

THEORY

L-moment coefficients

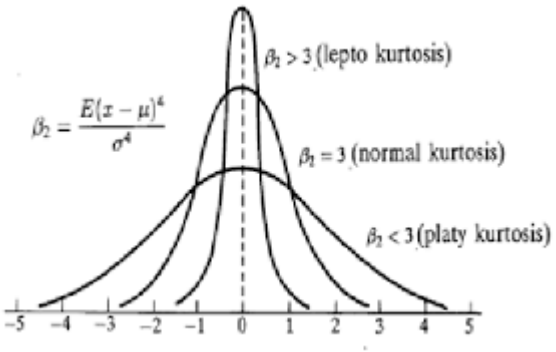
Finally, L-moments are evaluated as shown below:

L-moment mean (L-mean)
L-mean $= t_1 = l_1$

L-moment Variation coefficient (L-CV)
L-CV $= t_2 = l_2/l_1$

L-moment skew coefficient (L-Skewness)
L-Skewness $= t_3 = l_3/l_2$

L-moment kurtosis coefficient (L-Kurtosis)
L-Kurtosis $= t_3 = l_4/l_2$



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THE RETURN PERIOD

- The event x with return period T is defined as the event that occurs on average after T years since the last record and is the inverse of the probability of the annual occurrence of x.

$$T_{excess} = \frac{1}{1 - P}$$

- If P is the cumulative rainfall distribution function, the return periods for rainfall deficit or excess are calculated as follows →

$$T_{deficit} = \frac{1}{P}$$

- The **return period** (also known as a recurrence interval or repeat interval) refers to the **average time or estimated average time between specific events**

- For example, a “10-year drought” has a 10% chance of being exceeded in any given year, while a “50-year drought” has a 2% chance of being exceeded in any one year. Note that this doesn’t mean a 100-year drought will occur exactly once every 100 years

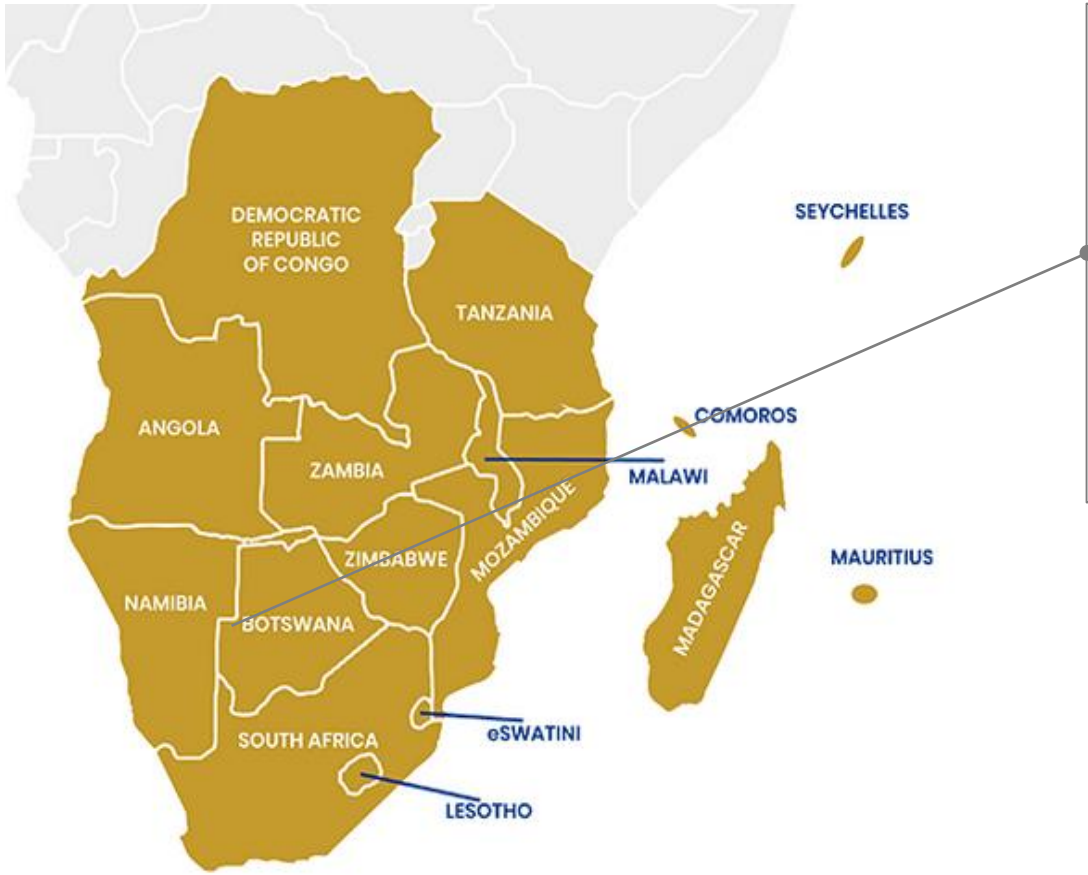
- **Return periods** are essential for decision-making: determining whether a project should proceed in a specific risk zone, designing structures, support to assess risk and guide planning and infrastructure development
- But they **do not guarantee precise timing** or **predictability of specific events**

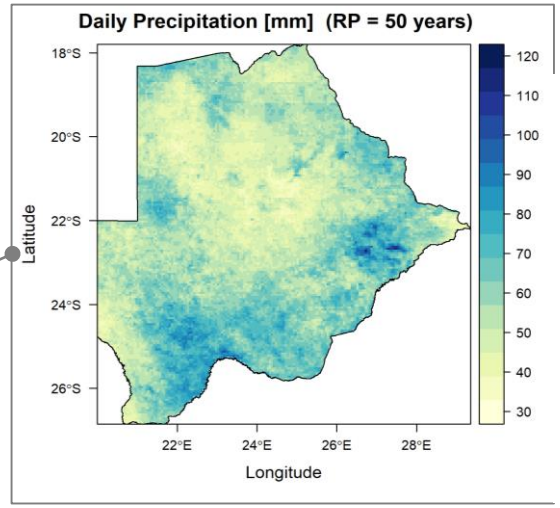
Climate Variability module – INPUT DATA

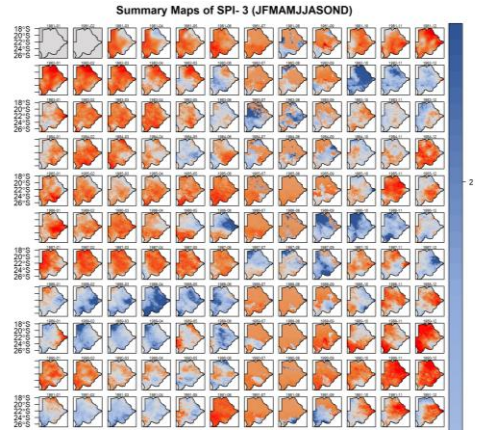
Cesar CARMONA, Marco PASTORI

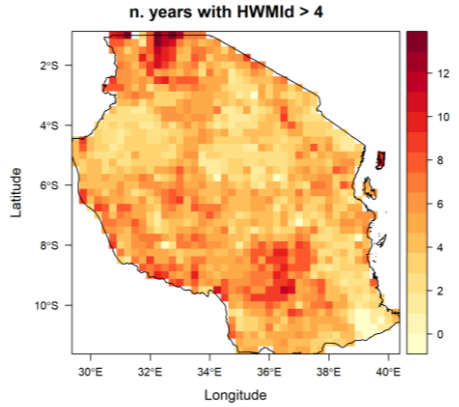
South Africa, Johannesburg, June 10th – 13th 2024

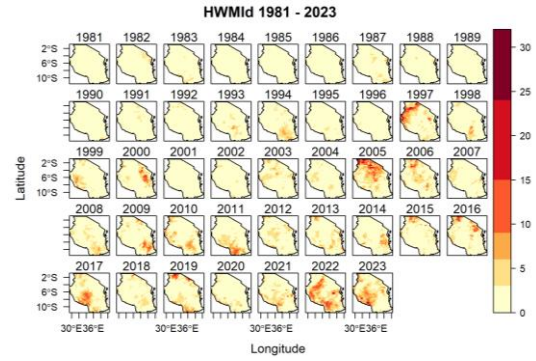
Climate Variability Module - DATA











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E-Nexus Climate Variability Module - DATA

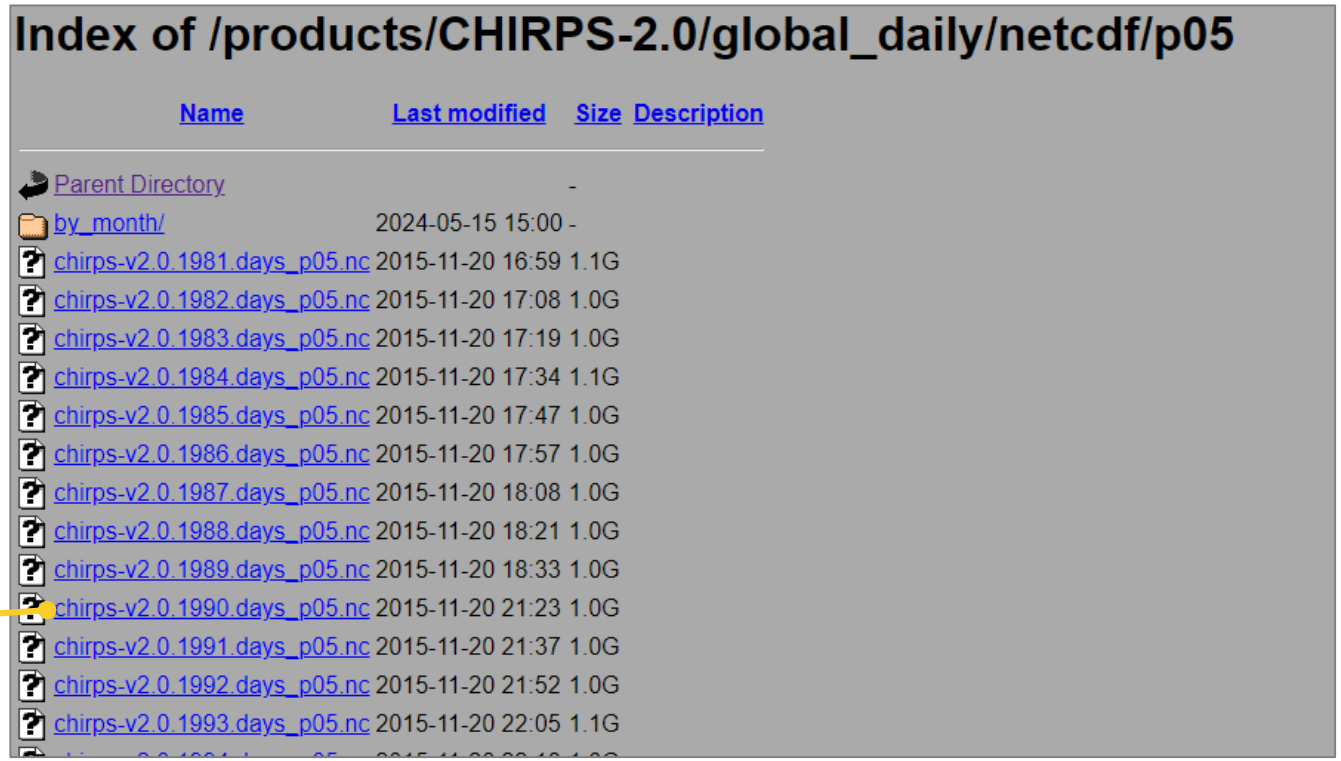
Input data **downloading** and pre-processing

E-Nexus Climate Variability Module - DATA

Precipitation data - CHIRPS - download

Since CHIRPS data (precipitation) are **freely available** and **regularly updated** online, a functionality to update download data has been included
- it just takes to download data from the following link (global daily data, NetCDF format):
https://data.chc.ucsb.edu/products/CHIRPS-2.0/global_daily/netcdf/p05/

As shown on image, **every single file contains daily precipitations covering an entire year**, as indicated by its name.



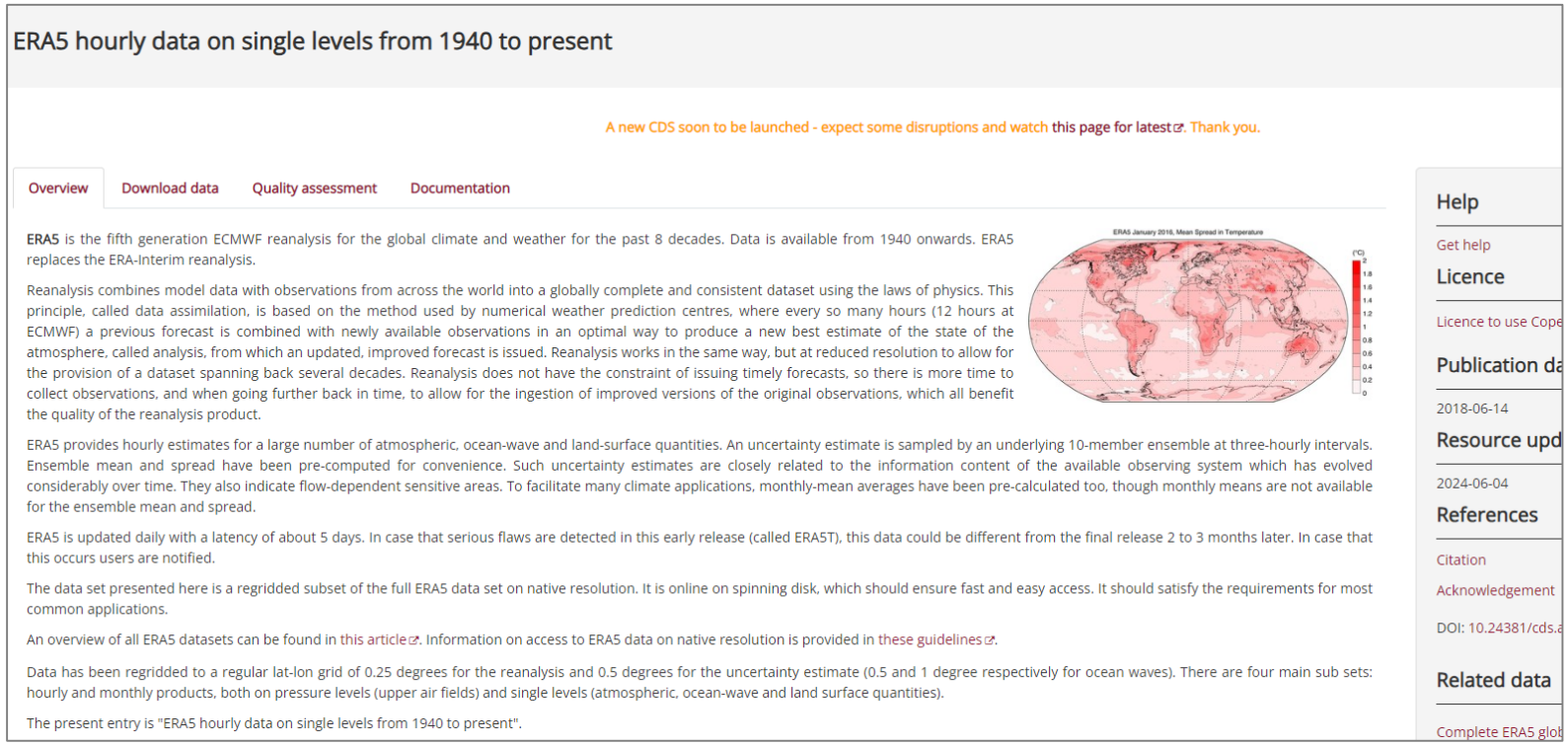
E-Nexus Climate Variability Module - DATA

Temperature data – from ERA5 dataset

ERA5 Temperature data are available through the section of land hourly data: https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form

Note: In order to have ERA5 data available for download, it takes to **login into ECMWF portal**.

Such process could take a few days to accept the registration and have an active user profile.



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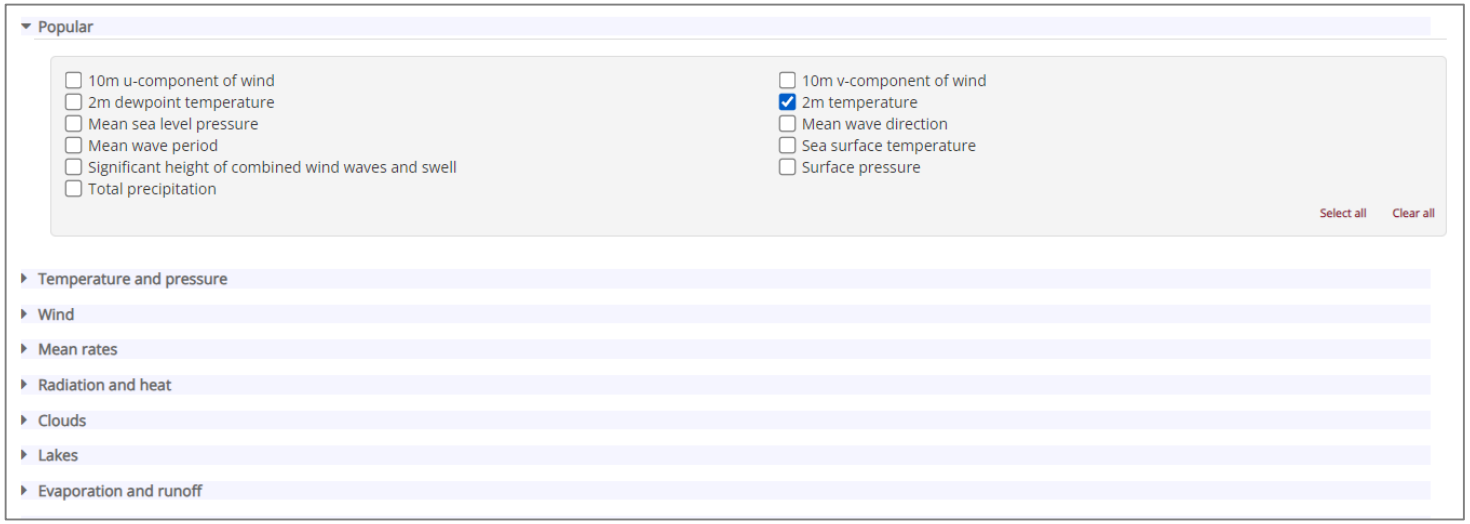
E-Nexus Climate Variability Module - DATA

Temperature data – from ERA5 dataset



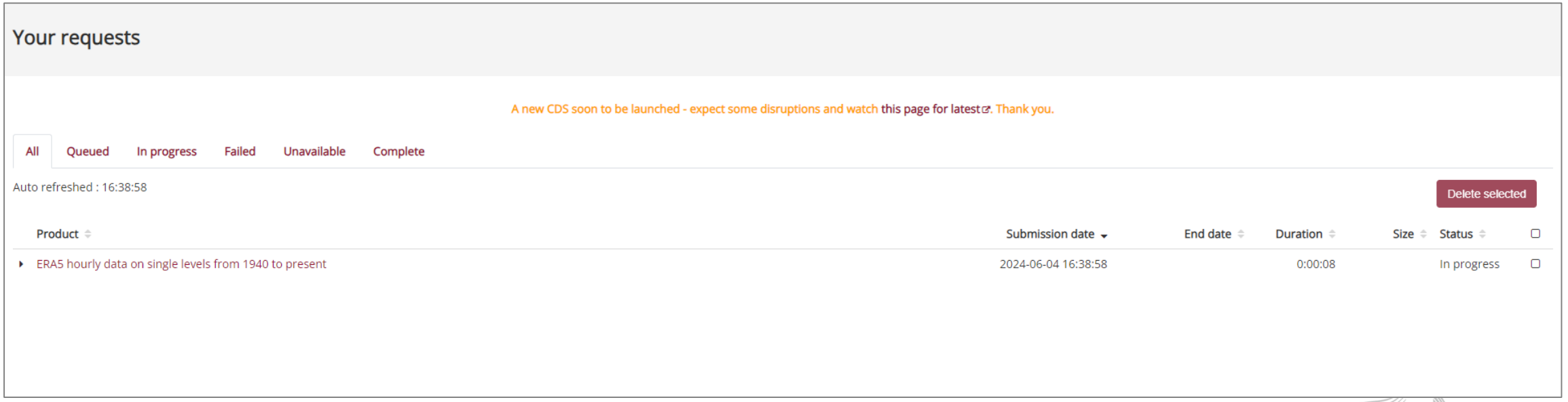
From the download page:
it takes to focus on a specific piece of data in terms of type, time and space.
The selection is made through multiple checkbox panels, each one related to a particular element.
The selection is finally confirmed by clicking on ***Submit Form*** button at the bottom of the page.

1. **Variable**: 2m temperature
2. **Year**: select one (no multiple selection allowed!)
3. **Month**: select all
4. **Day**: select all
5. **Time**: select all
6. **Geographical area**: check **Sub-region extraction**, it takes to enter the specific boundaries
7. **Format**: NetCDF

E-Nexus Climate Variability Module - DATA

Temperature data – from ERA5 dataset

Once the selection is made, the download is not immediate: a data request will be sent to the server, so it will be possible to actually download it after a variable amount of time (usually, within minutes). It is always possible to check for the status of all submitted request from the user request page.
Please note that any request will not be permanently available, but it will be deleted after some days.



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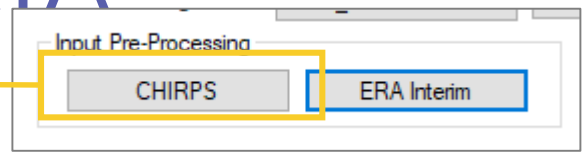
E-Nexus Climate Variability Module - DATA

Input data downloading and **pre-processing**

E-Nexus Climate Variability Module - DATA

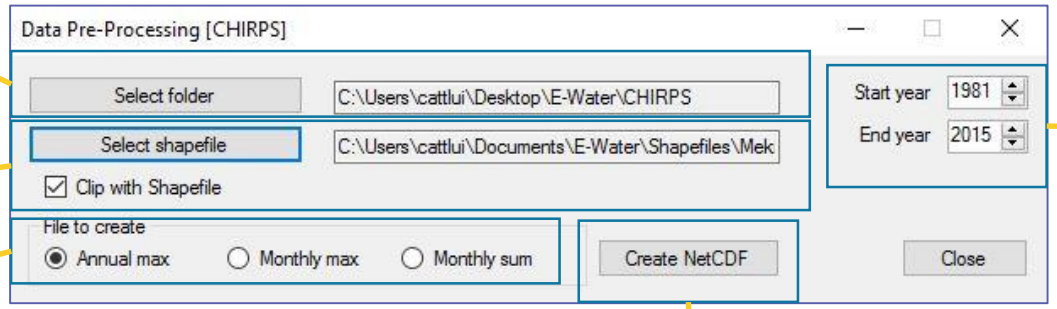
CHIRPS pre-processing



Input folder

Clip with shapefile

Aggregation



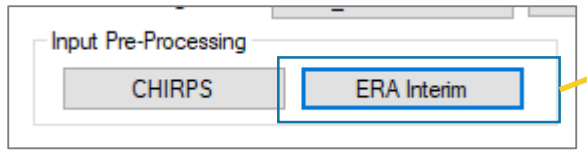
Period selection

Create file

Each raw CHIRPS file has a sample name ***chirps-v2.0.<year>.days_p05.nc**** (e.g. ***chirps-v2.0.2001.days_p05***) and **should not be changed** before the process.
Before starting the process, it is necessary to select the folder containing all annual files (**input folder**) and specify the total period (start/end years) and the temporal aggregation, which can be annual (daily precipitation maximum), monthly (monthly precipitation or maximum of daily values) or daily.
Optionally, it is also possible to clip the file within a specific area using a shapefile (*.shp*) (check the option first). When all parameters are set, it is possible to create the NetCDF file, which will be used as input for further climate variability processes.

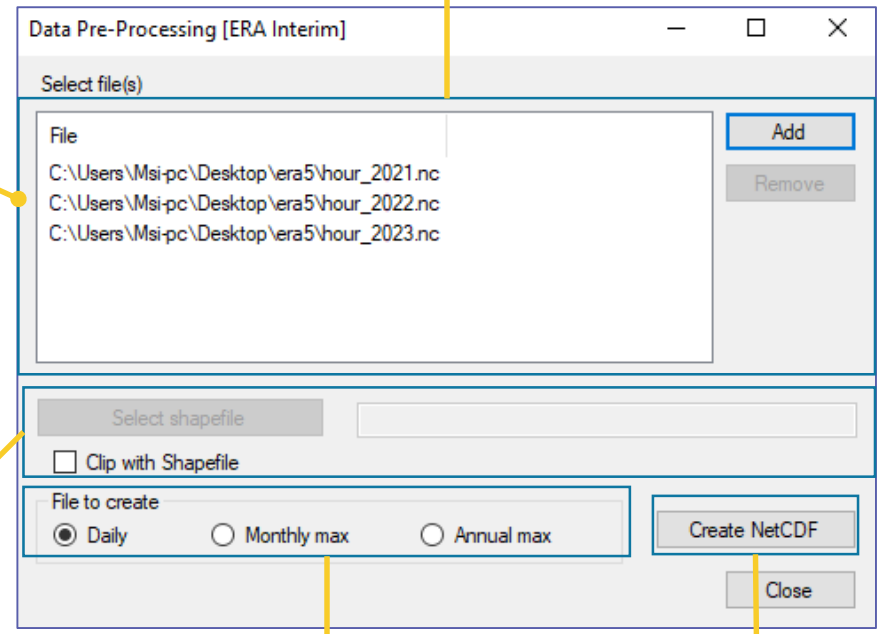
* Global daily data, vers.2 with 0.05° resolution

E-Nexus Climate Variability Module - DATA



ERA5 pre-processing

1. All files to be merged must be added to the list on the left, as shown on image (multi-selection is possible).
2. The time is automatically detected, but it necessary to provide the whole interval without skipping any year (e.g. pre-processing data for period 1981-1990 should include all the 10 years).
3. It is possible to select temporal aggregation (daily, monthly or annual maximum) and also clipping the file within a specific area by using a shapefile (.*shp*) (check the option first).
4. Finally, all files will be merged into one NetCDF file (***Create NetCDF***) to be used for temperature processes.



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Thank you

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