WaSCIA: Addressing Water Stress and Drought in Senegal through the Integration of Earth Observations and Climate Data

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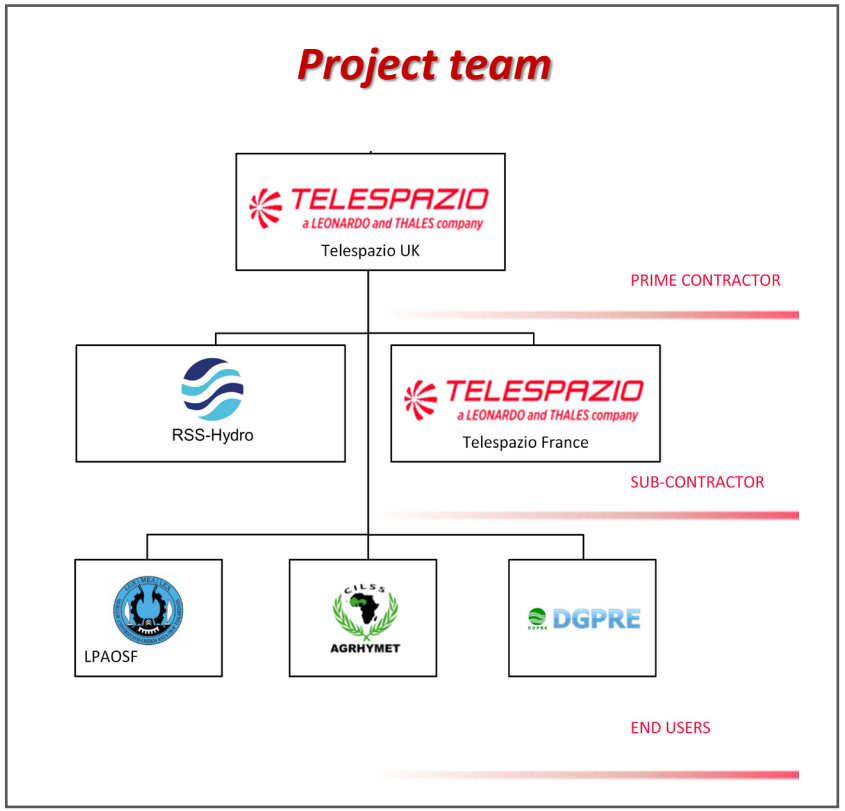
Project Consortium

- This has been a collaborative effort led by Telespazio UK, working in partnership with European and African institutes.
- Experts from multiple disciplines
- Vital local knowledge from regional experts
- The consortium comprised of:
  - **Telespazio UK**
  - **Telespazio France**
  - **RSS-Hydro**
  - **AGRHYMET** (Centre Regional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle)
  - **LPAOSF** (Laboratoire Physique de l'Atmosphère et de l'Océan Simeon Fongang)
  - **DGPRE** (Direction de la Gestion et de la Planification des Ressources en Eau Sénégal)



Introduction

Background

Water Stress and Climate Indices for Africa (WaSCIA) is an ESA funded project that aims to deliver high-quality Water Stress and Climate Indices through an easy-to-use web interface to help the management of drought and water stress in Africa.

Objectives

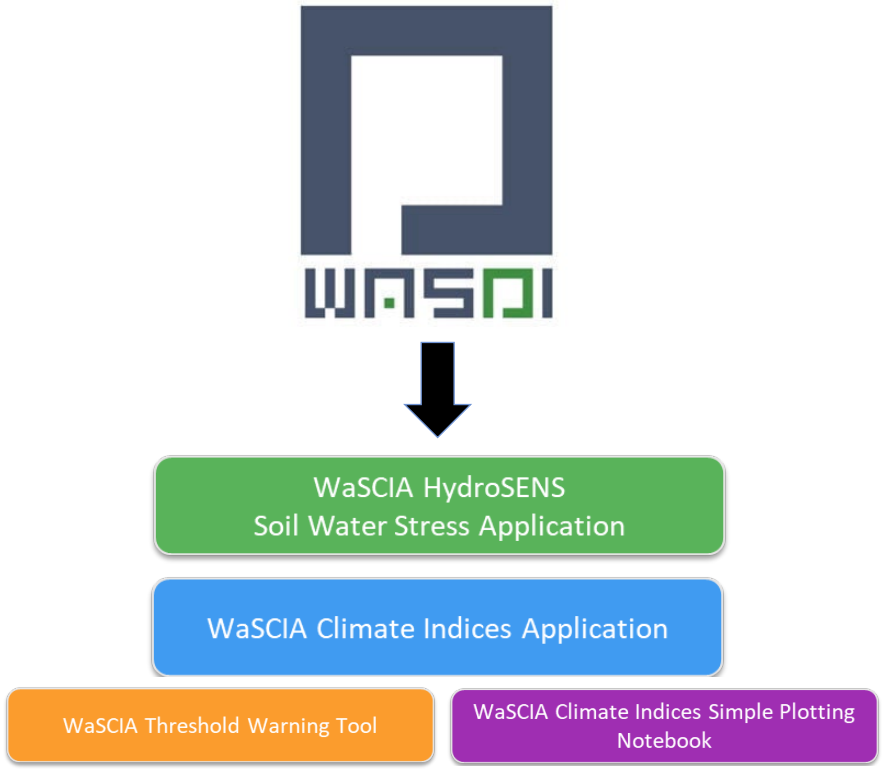
The WaSCIA project has developed a range of tools to provide:

- **Easy to access water stress information** derived from EO data
- **Easy to access to climate indices** derived from ERA5 reanalysis data
- Provide tools for analysing data**, aiding in decision making**

WaSCIA Solution

- **2 WaSCIA Applications** hosted on the cloud platform WASDI
- **2 Jupyter Notebooks** developed for data visualisation and analysis

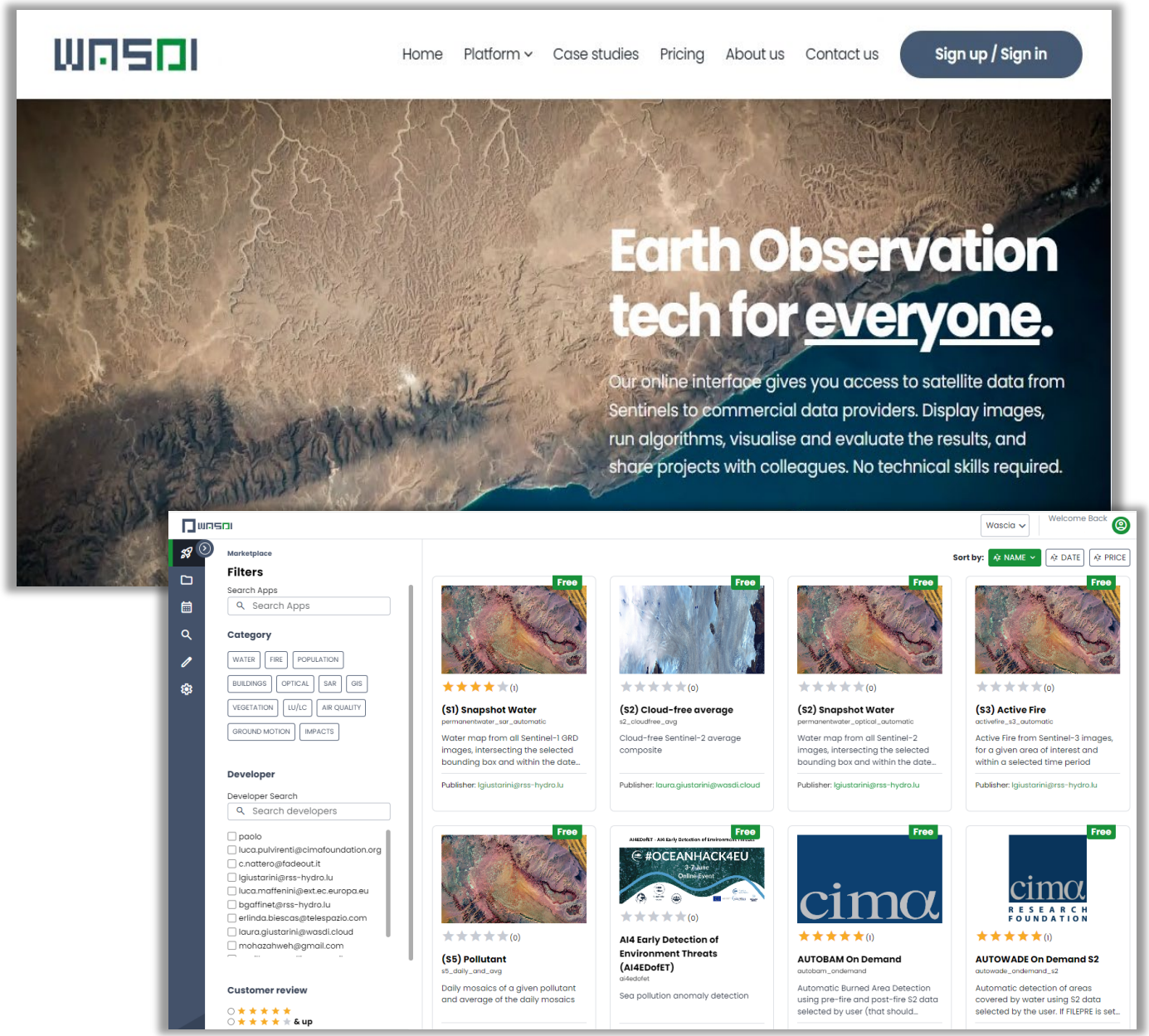
WaSCIA Components:



Cloud Platform

WASDI – Providing Easy Access to EO data

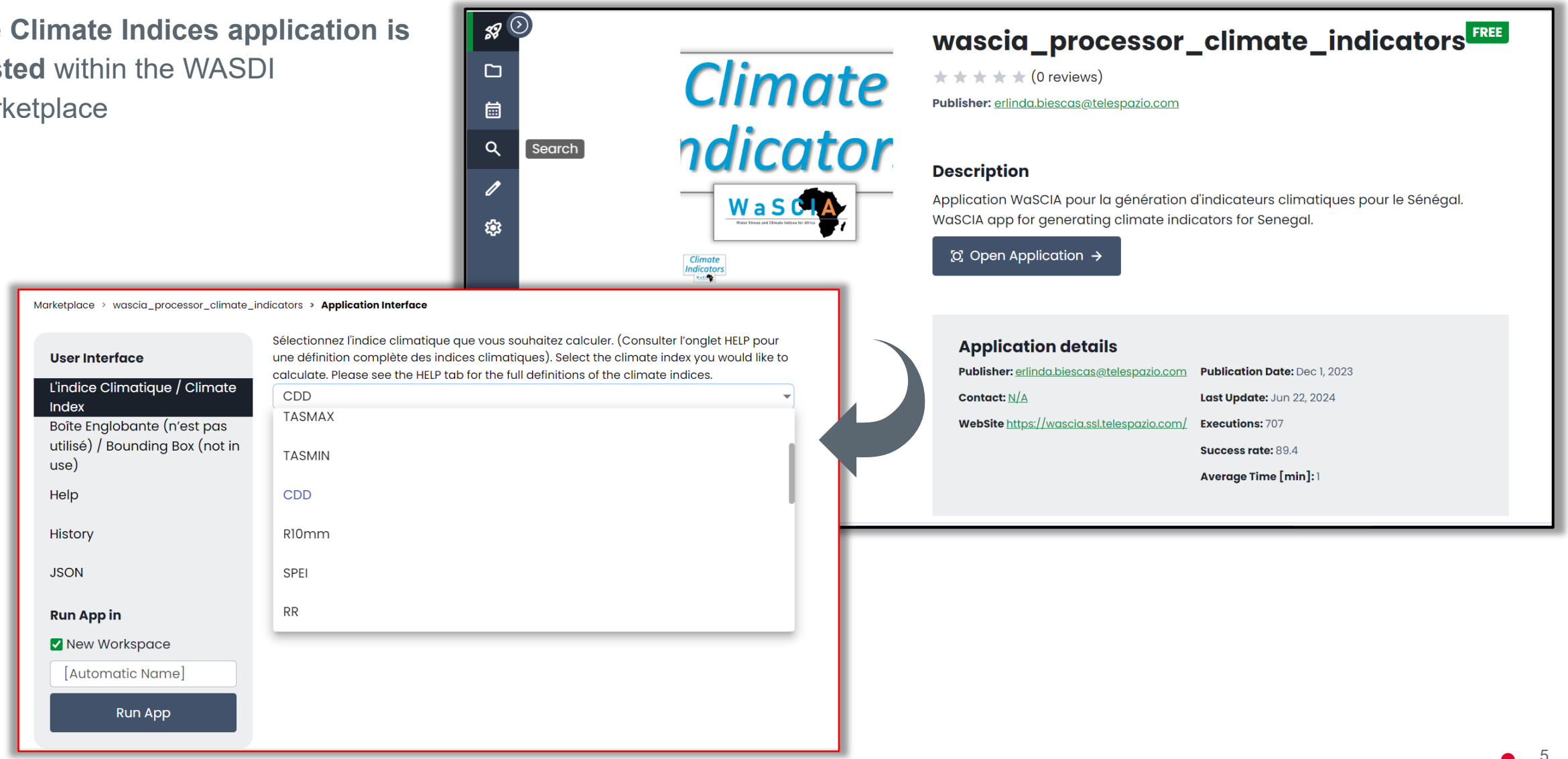
- **Web Advanced Space Developer Interface** (WASDI) is a scalable cloud-based analytical platform that allows EO experts to develop and deploy online applications, without the need for any specific IT/Cloud skills.
- The WASDI platform is already set up to function as an environment for EO product visualisation, analyses and dissemination.
- The platform offers end users the opportunity to run EO applications from both a dedicated user-friendly interface and an API based software interface.
- Reduces the computational requirements of the end user, making data access easier.



Climate Indices Application

WaSCIA Climate Indices Application

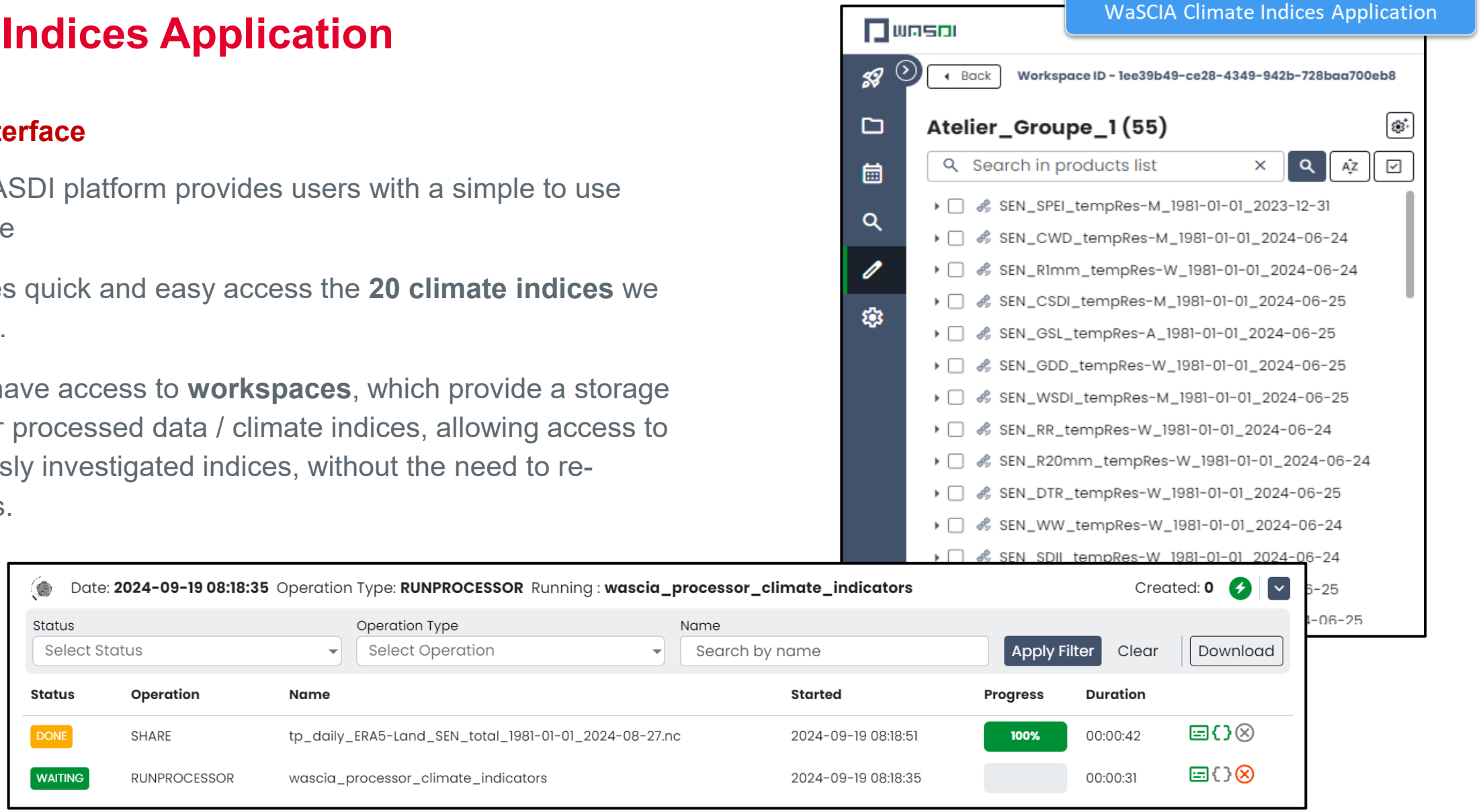
- The **Climate Indices application is hosted** within the WASDI marketplace



Climate Indices Application

Simple Interface

- The WASDI platform provides users with a simple to use interface
- Provides quick and easy access the **20 climate indices** we provide.
- Users have access to **workspaces**, which provide a storage area for processed data / climate indices, allowing access to previously investigated indices, without the need to re-process.



Climate Indices Application

Methodology: WaSCIA Climate Indices application generates Climate Indices from ERA5-Land reanalysis data for Senegal.

Input Data

- **ERA5-Land** reanalysis data:
  - **Hourly temperature** and **precipitation** data
  - 0.1 degrees spatial resolution
  - 1981 to five days behind real-time
  - Accessed in WASDI directly from the Copernicus Climate Data Store
- **Potential Evapotranspiration (PET)** data:
  - 1981 to December 2023
  - Dataset extended every January to add the previous year
  - Provided by University of Bristol

Data Preparation

- ERA5-Land reanalysis data hourly data is resampled to daily values and cropped to the borders of Senegal:
  - **Daily mean temperature** (t2m), averaging the hourly temperature values for each day.
  - **Daily maximum temperature** (tasmax), taking the maximum hourly temperature for each day.
  - **Daily minimum temperature** (tasmin), taking the minimum hourly temperature for each day.
  - **Daily total precipitation** (tp), taking the accumulated precipitation for each day
- PET data is cropped to the Senegal borders.

Data Processing Algorithms

- These 5 pre-processed variables are the inputs needed to calculate all the climate indices
- Climate indices calculated according to Guidelines from the World Meteorological Organisation: WCDMP_72_TD_1500_en_1.pdf (ecad.eu)
- The data is resampled to the most appropriate temporal resolution – e.g. yearly, monthly, weekly

WaSCIA Climate Indices Application

Climate Indices Application

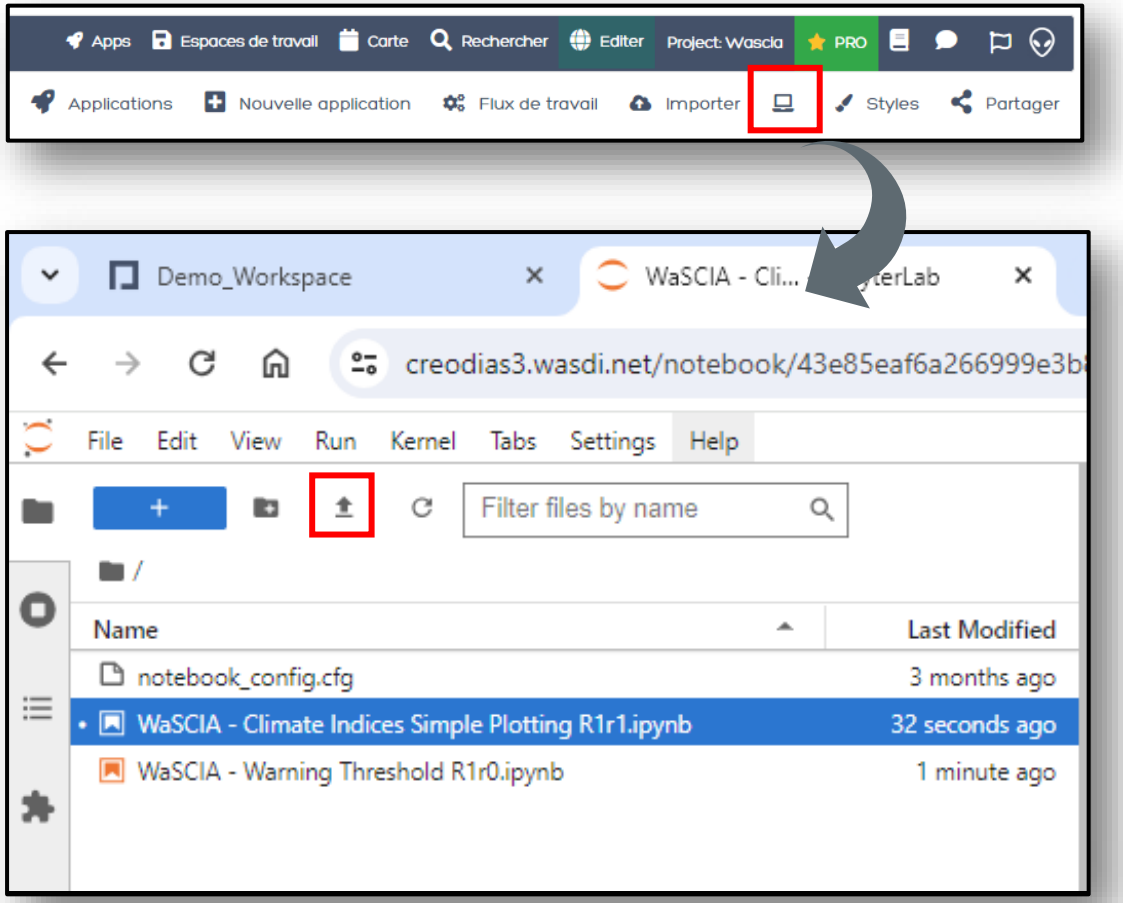
User selection

Acronym	Climate Indices Available	Unit	Temporal Resolution	Definition
TP	Total Precipitation	mm	Daily	Total precipitation
T2M	Mean 2 metre Temperature	°C	Daily	Mean temperature of the air at 2m above the surface
TASMAX	Maximum Temperature	°C	Daily	Maximum temperature
TASMIN	Minimum Temperature	°C	Daily	Maximum temperature
CDD	Maximum number of Consecutive Dry Days	days	Monthly	Maximum number of consecutive dry days (< 1 mm precipitation) (Drought spell)
CWD	Maximum number of Consecutive Wet Days	days	Monthly	Maximum number of consecutive wet days (≥ 1 mm precipitation) (Wet spell)
TX90p	Warm Day-times	days	Monthly	Warm day-times: Count of days where daily maximum temperature (TX) > 90th percentile.
TN10p	Cold Nights	days	Monthly	Cold nights: Count of days where daily minimum temperature (TN) < 10th percentile.
SPEI	Standardised Precipitation Evapotranspiration Index	-	Monthly	A multi-scalar drought index based on climatic data
RR	Precipitation sum	mm	Weekly	Sum of precipitation over a selected period
R1mm	Wet Days (≥1 mm rainfall)	days	Weekly	Number of days with precipitation ≥ 1 mm
R10mm	Heavy precipitation days	days	Weekly	Number of days with precipitation ≥ 10 mm
R20mm	Very heavy precipitation days	days	Weekly	Number of days with precipitation ≥ 20 mm
WW	Warm and Wet days	days	Weekly	Number of days where mean temperature and total precipitation are both above the 75th percentile
WSDI	Warm-spell Duration Index	days	Monthly	Count of days in a span of at least six days where the daily maximum temperature (TX) > 90th percentile.
CSDI	Cold-spell Duration Index	days	Monthly	Count of days in a span of at least six days where the daily minimum temperature (TN) < 10th percentile
OGSL	Optimum Growing Season Length	days	Yearly	Annual count of days between the first span of at least six days where the daily mean temperature **(TG) > 33°C** and the first span in second half of the year of at least six days where **TG < 33°C**
GDD	Growing Degree Days	°C	Weekly	Sum of daily mean temperatures above **10°C** and less than **40°C** for a given period
DTR	Mean of Diurnal Temperature Range	°C	Weekly	Mean difference between daily maximum temperature (TX) and daily minimum temperature (TN) on a given day (°C)
SDII	Simple Daily Intensity Index	mm	Weekly	Mean precipitation amount on a wet day

Jupyter Notebooks

- We have developed a suite of **Jupyter Notebooks** which sit alongside the generated **climate indices.**
- Enables users to easily interact with the data and extract valuable insights without the requirement for coding experience.
- The Jupyter notebooks are available to users to download from the **WaSCIA project website**. After this, the users just need to upload them into their own WASDI workspace to use them.

Jupyter notebooks are available here:

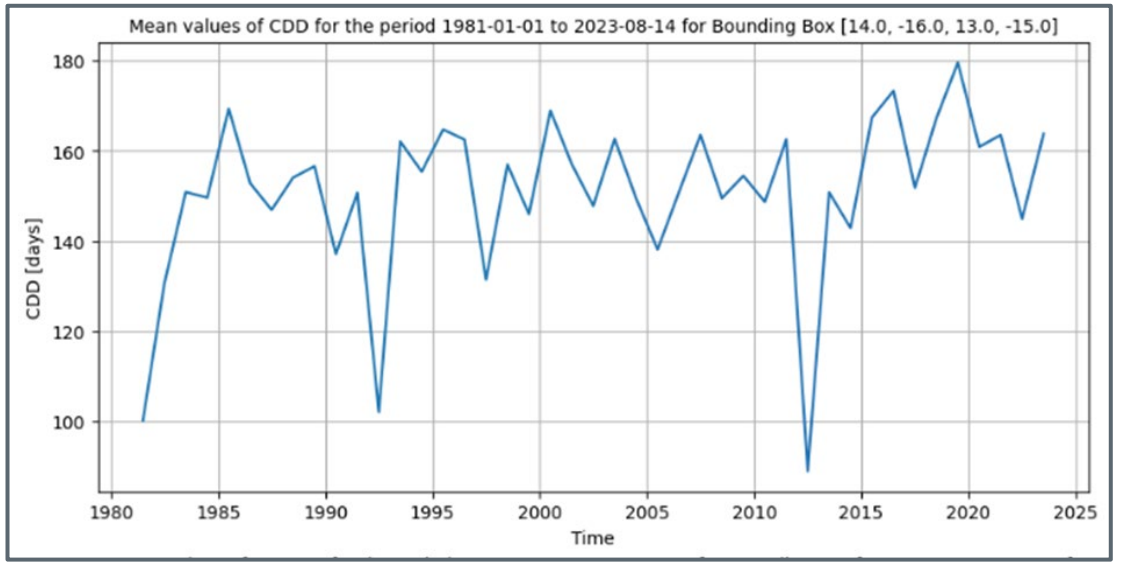


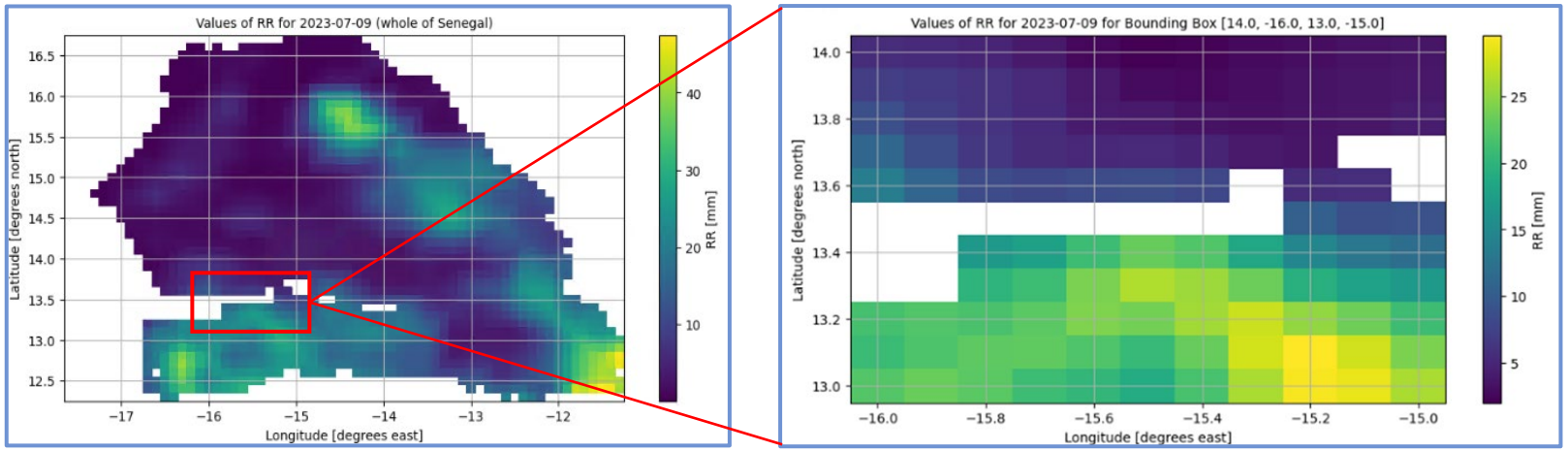
Climate Indices Simple Plotting – Output

WaSCIA Climate Indices Simple Plotting Notebook

- This tool allows users to visualise the **20 climate indices** as a spatial representation or as a timeseries.

- Within the Notebook, there are step-by-step instructions, outlining how these plots can be adapted to answer their questions. These include:
  - Applying bounding boxes
  - Time constraints
  - Single date analysis
  - Plotting two indices simultaneously





Threshold Warning Tool

- We also provide a Jupyter Notebook that enable users to **compare the climatology and the in-season time-series** of a selected climate index.

- **Climatology Generation:** For the selected climate index, the notebook will calculate the climatology of that index, using historical data from the baseline period 1991 to 2020. This can be used as a reference to understand how the climate index typically varies throughout the year.
- **Threshold Definition:** For the comparison of a specific year with the climatology data (1991-2020), the warning thresholds can be set in the following ways:

  - **Percentiles**: To calculate percentiles of the baseline climatology data for the specific climate index, e.g. 90th percentile or 10th percentile are useful to highlight the climate extremes.
  - **Standard deviation**: To calculate the standard deviation of the baseline climatology data for the specific climate index.

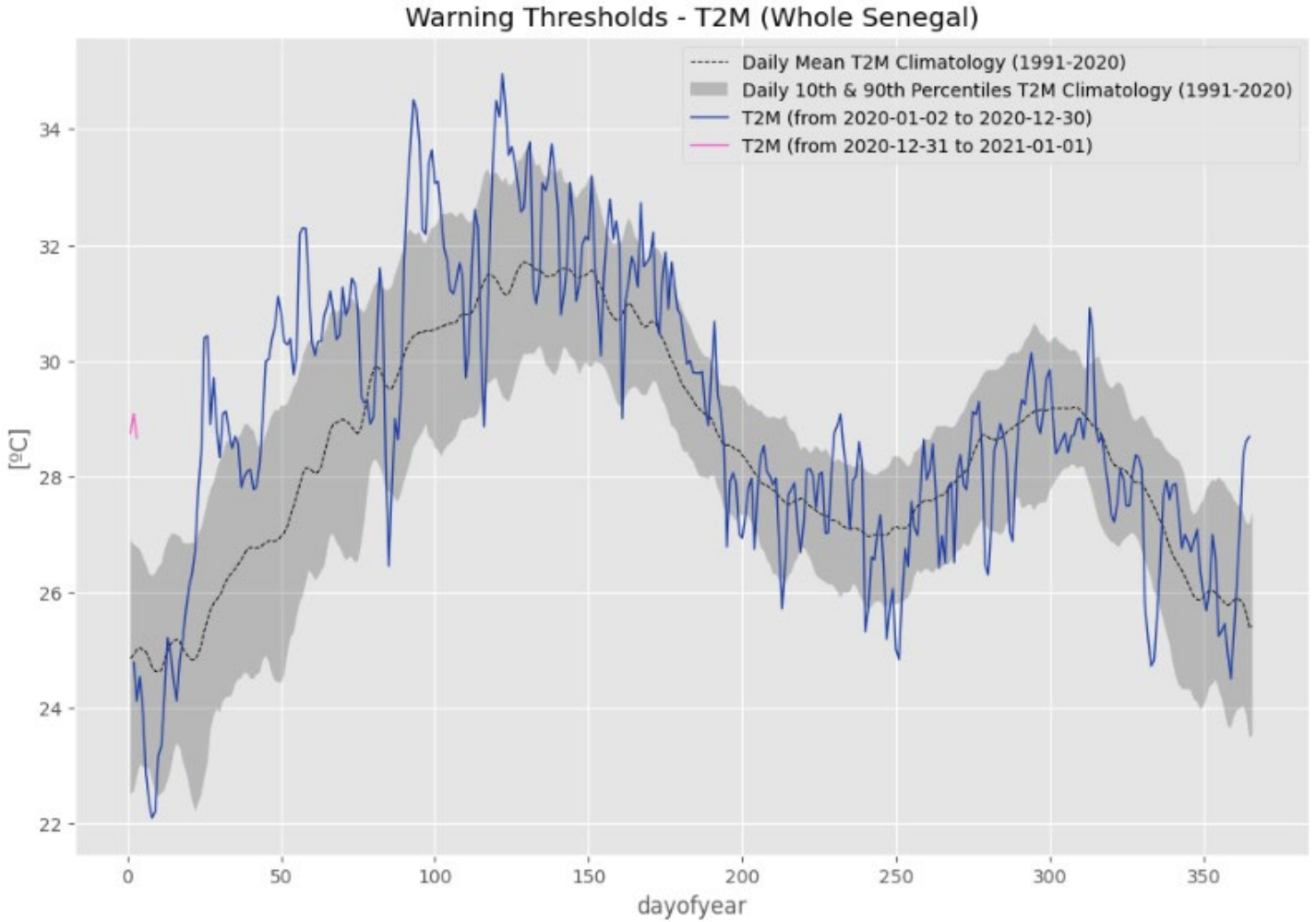
  - **Absolute Values**: To define absolute threshold values, such as 4 or more heavy precipitation days (precipitation above 20 mm) per week, which may be considered a warning threshold for flooding at a specific location.

- **Decision Support:** The tool generates a user-friendly plot of the climatology and the time series of a selected climate index. It also provides a description of the plot, so the user can easily detect the periods that fall outside of the thresholds selected.

Threshold Warning Tool

Example Output

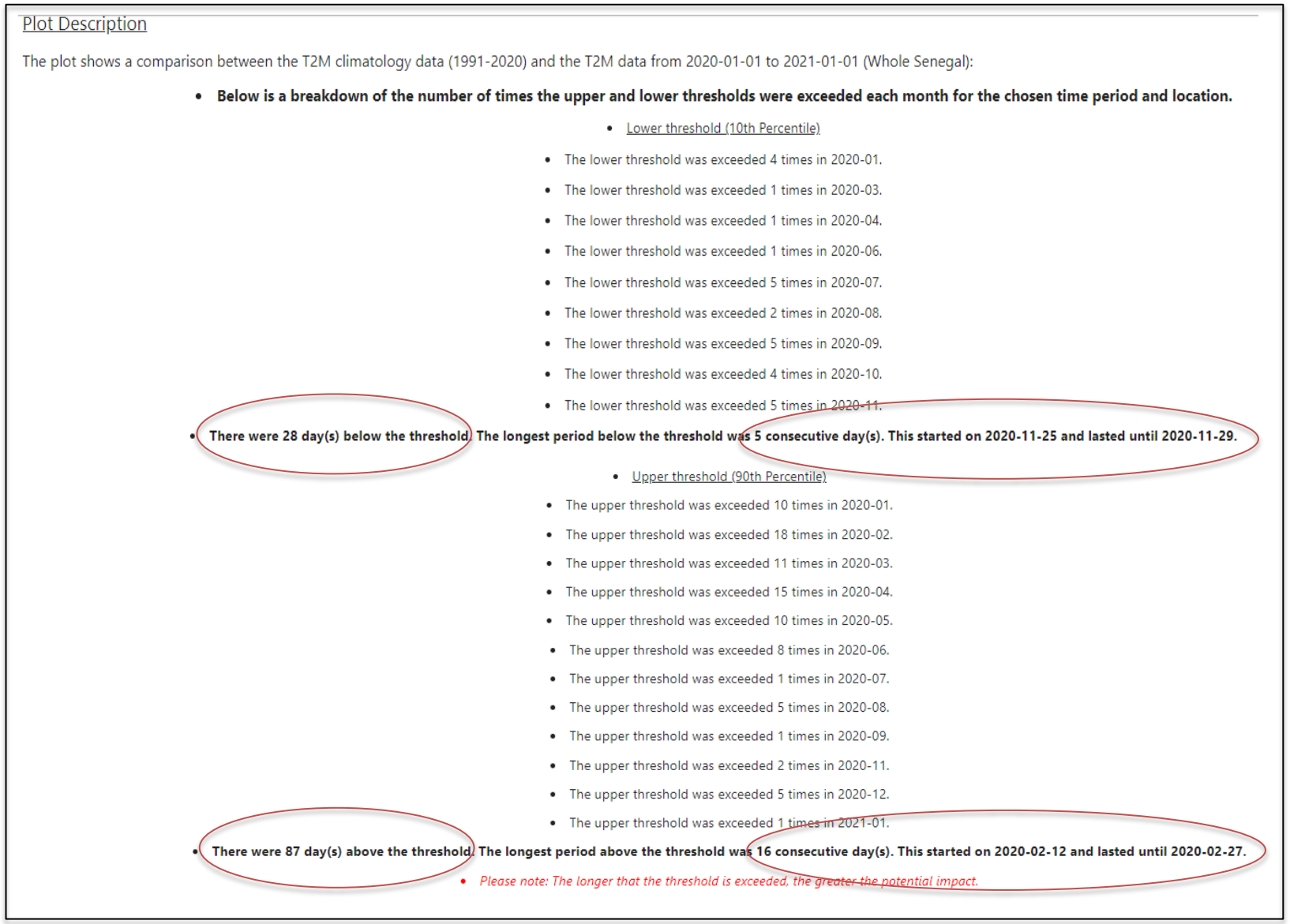
- Example looking at the average temperature (T2M), over the whole of Senegal for the year 2020
- The threshold used is percentiles, with these set at 90th and 10th
- Shaded area indicates the 10th and 90th percentile for the climatology
- Dashed line is the climatological mean
- 2020 timeseries in blue overlayed, provides clear visualisation of periods where temperature was above or below the designated threshold for a given day.



Threshold Warning tool

Example Output

- Additionally, the plot is accompanied by descriptive text to help summarise the plot.
- This includes information on:
  - ➢ Number of times the upper and lower threshold were exceeded for the chosen time period and location
  - ➢ Number of exceedances by month
  - ➢ The longest periods exceeding the upper and lower thresholds and the dates these occurred



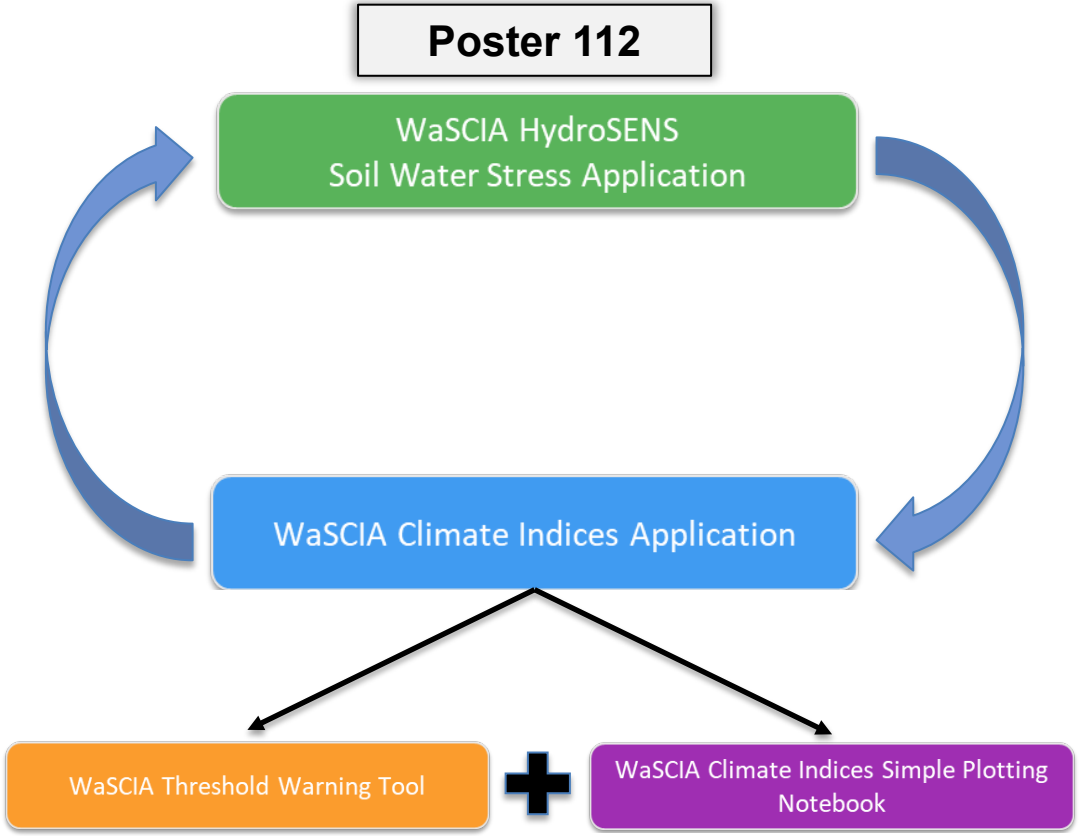
Plot Description

The plot shows a comparison between the T2M climatology data (1991-2020) and the T2M data from 2020-01-01 to 2021-01-01 (Whole Senegal):

- **Below is a breakdown of the number of times the upper and lower thresholds were exceeded each month for the chosen time period and location.**
  - Lower threshold (10th Percentile)
    - The lower threshold was exceeded 4 times in 2020-01.
    - The lower threshold was exceeded 1 times in 2020-03.
    - The lower threshold was exceeded 1 times in 2020-04.
    - The lower threshold was exceeded 1 times in 2020-06.
    - The lower threshold was exceeded 5 times in 2020-07.
    - The lower threshold was exceeded 2 times in 2020-08.
    - The lower threshold was exceeded 5 times in 2020-09.
    - The lower threshold was exceeded 4 times in 2020-10.
    - The lower threshold was exceeded 5 times in 2020-11.
    - **There were 28 day(s) below the threshold. The longest period below the threshold was 5 consecutive day(s). This started on 2020-11-25 and lasted until 2020-11-29.**
  - Upper threshold (90th Percentile)
    - The upper threshold was exceeded 10 times in 2020-01.
    - The upper threshold was exceeded 18 times in 2020-02.
    - The upper threshold was exceeded 11 times in 2020-03.
    - The upper threshold was exceeded 15 times in 2020-04.
    - The upper threshold was exceeded 10 times in 2020-05.
    - The upper threshold was exceeded 8 times in 2020-06.
    - The upper threshold was exceeded 1 times in 2020-07.
    - The upper threshold was exceeded 5 times in 2020-08.
    - The upper threshold was exceeded 1 times in 2020-09.
    - The upper threshold was exceeded 2 times in 2020-11.
    - The upper threshold was exceeded 5 times in 2020-12.
    - The upper threshold was exceeded 1 times in 2021-01.
    - **There were 87 day(s) above the threshold. The longest period above the threshold was 16 consecutive day(s). This started on 2020-02-12 and lasted until 2020-02-27.**
    - *Please note: The longer that the threshold is exceeded, the greater the potential impact.*

Using tools in conjunction

- The WaSCIA project developed two applications: **Climate Indices** application and **HydroSENS-SWS** application.
- **HydroSENS-SWS** is a soil moisture analysis tool providing users with daily soil moisture and evaporative water loss (EWL)
- The applications are designed to be used together, for example:
  - A user concerned about water stress in a region
  - They use the **HydroSENS-SWS** application to check soil moisture and EWL over the past few days and see this is low.
  - They use the **Climate Indices** application to analyse the climate variables that could have caused this.



  - They use the **Threshold Warning Tool** to identify any events over the last couple of months that are above or below a defined threshold.
  - They use the **Climate Indices Simple Plotting Notebook** to plot a spatial map and timeseries to better understand the extent of the impact and its relation to climatology.

Workshops

- During the WaSCIA project, we collaborated with our regional partners, to not only **improve the applications**, but also to organise in-country and online workshops

- User workshop held in **Dakar, Senegal**

- The webinar aimed to provide participants with a comprehensive understanding of WaSCIA and its capabilities for analysing climate data.

- In country users provided vital feedback that helped us tailor the applications

- **User feedback session**, provided us with feedback on improvements.

Conclusion / Summary

- WaSCIA provides **easy access** to high-resolution soil data and pre-processed climate indices
- Reduces the need for computationally expensive processing or coding experience, making it **more accessible**.
- Provides tools to analyse data, **empowering** users to make informed drought management and mitigation decisions.
- This approach could be used to help users in vulnerable areas, like Senegal, monitor droughts, protect harvests, and enhance food security.

WaSCIA

Water Stress and Climate Indices for Africa

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