EUROPEAN SPACE AGENCY CONTRACT REPORT

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WASCIA – WATER STRESS AND CLIMATE INDICES FOR AFRICA

User Handbook – English version

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CHANGE LOG

Reason for change	Issue	Revision	Date	Page(s) and Paragraph(s) affected
Initial version	1	0	06/09/2024	All
Comments from ESA	1	1	10/10/2024	Section 2.1, reference to Dunia platform

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1 INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This document is D11 deliverable for the ESA Water Stress and Climate Indices for Africa (**WaSCIA**) project. It is the English version of the User Handbook for the tools developed in the project. A version of the User Handbook in French is also available. This document is of public access.

1.2 CONTENTS OF DOCUMENT

Following this introductory section, the document layout is as follows:

Section 2 presents an Introduction

Section 3 presents the HydroSENS-SWS application

Section 4 presents the Climate Indicators application

Section 5 presents the Climate Indices Simple Plotting Jupyter Notebook

Section 6 presents the Threshold Warning Notebook

Section 7 presents and example of how to use the WaSCIA applications

Section 8 presents Common issues and bugs

1.3 REFERENCES

1.3.1 Applicable Documents

The following applicable documents are those referenced in the Contract or approved by the Agency. They are referenced in this document in the form [AD n.]:

AD	Title	Version / Date
AD 1.	Statement of Work - ESA Express Procurement [Plus] - [EXPRO+] - EO AFRICA - NATIONAL INCUBATORS EXPRO+	1.0 26/10/2021
AD 2.	KPT91865-AO11039-Proposal-EOAFRICA-R1r0.pdf	1.0 18/02/2022
AD 3.	WASCIA-KO-Minutes_1.0.pdf	1.0 07/10/2022

1.3.2 Reference Documents

The following reference documents are those referenced within this document. They are referenced in this document in the form [RD n.]. They are not applicable documents.

RD	Title / source	Version / Date
RD 1.	Mohamed, H. A., Clark, J. A., & Ong, C. K. (1988). Genotypic Differences in the Temperature Responses of Tropical Crops. Journal of Experimental Botany, 39(8), 1121–1128. https://doi.org/10.1093/jxb/39.8.1121	1988

1.4 ACRONYMS AND TERMS

The following acronyms and terms are used in the document and have the identified meaning.

Acronym / Term	Definition
API	Application Programming Interface
DGPRE	Direction de la Gestion et de la Planification des Ressources en Eau
DIAS	Dynamic Innovation Architecture System
EO	Earth Observation
IT	Information Technology
LPAOSF	Laboratoire de Physique de l'Atmosphére et de l'Océan – Siméon FOndang

Acronym / Term	Definition
SW	Software
TPZ UK	Telespazio UK
WaSCIA	Water Stress and Climate Indices for Africa
WASDI	Web Advanced Space Developer Interface

2 INTRODUCTION

Welcome to the WaSCIA User Guide. The project, led by Telespazio UK in collaboration with RSS-Hydro, Telespazio France, AGRHYMET, LPAOSF, and DGPRE, has developed the following tools to provide climate and soil moisture information and decision support for Senegal:

- **WaSCIA HydroSENS-SWS Application**
- **WaSCIA Climate Indicators Application**
- **WaSCIA Jupyter Notebooks**
    - ***WaSCIA Climate Indices Simple Plotting Notebook***
    - ***WaSCIA Threshold Warning Notebook***

This user guide has been prepared to help you effectively access and use the WaSCIA tools. This guide is designed to walk you through the steps to set up your accounts, access the necessary applications and generate personalised outputs. By following this guide, you will not only gain the knowledge needed to operate the WaSCIA applications and tools, but you'll also be able to conduct thorough assessments of water stress and drought conditions for Senegal.

2.1 WASDI

The flexible user interface used by WaSCIA is the Web Advanced Space Developer Interface (WASDI). This cloud-based platform aims to provide easily accessible, decision relevant information to its end users. WASDI is a fully scalable cloud-based analytical platform that allows Earth Observation (EO) experts to develop and deploy Dynamic Innovation Architecture System (DIAS) based EO online applications, without the need for any specific IT/ Cloud skills. The platform offers end users the opportunity to run EO applications from both a dedicated user-friendly interface and an API based software interface. Users can also explore a catalogue of EO data products.

The WaSCIA applications are deployed on WASDI and are accessible through the **WASDI Marketplace**. These are accompanied by a suite of **Jupyter notebooks** which sit alongside the generated outputs and enable users to easily interact with the data and extract valuable insights.

Before accessing and using any of the WaSCIA applications, users will need to create an account on WASDI. The following instructions explain how to access and register for a WASDI account.

Additional documentation for how to access and use WASDI can be found here:

- WASDI : Web Advanced Space Developer Interface — WASDI documentation center documentation
- Signing Up and Signing In — WASDI documentation center documentation

The selection of the WASDI platform, was done by the team based on its technical capabilities and its free cost access. Nevertheless, during the project execution, the WASDI's business model changed, making the system maintenance cost-prohibitive for African partners. However, all the WaSCIA tools have been designed to be easily deployed in any other platform with similar characteristics. The EO Africa Dunia service platform (https://dunia.esa.int/) is an example of an alternative to WASDI, with no cost for eligible users.

2.1.1 WASDI Access

The steps here described allows to access the WASDI online platform.

1) Open a web page from your favorite browser (preferably Google Chrome**,** otherwise Mozilla Firefox, Edge or Safari) and search '**wasdi**' (Figure 2-1).

Figure 2-1. Using your preferred browser, search 'wasdi'.

2) Select the link for to **https://www.wasdi.net**, as shown in Figure 2-2.

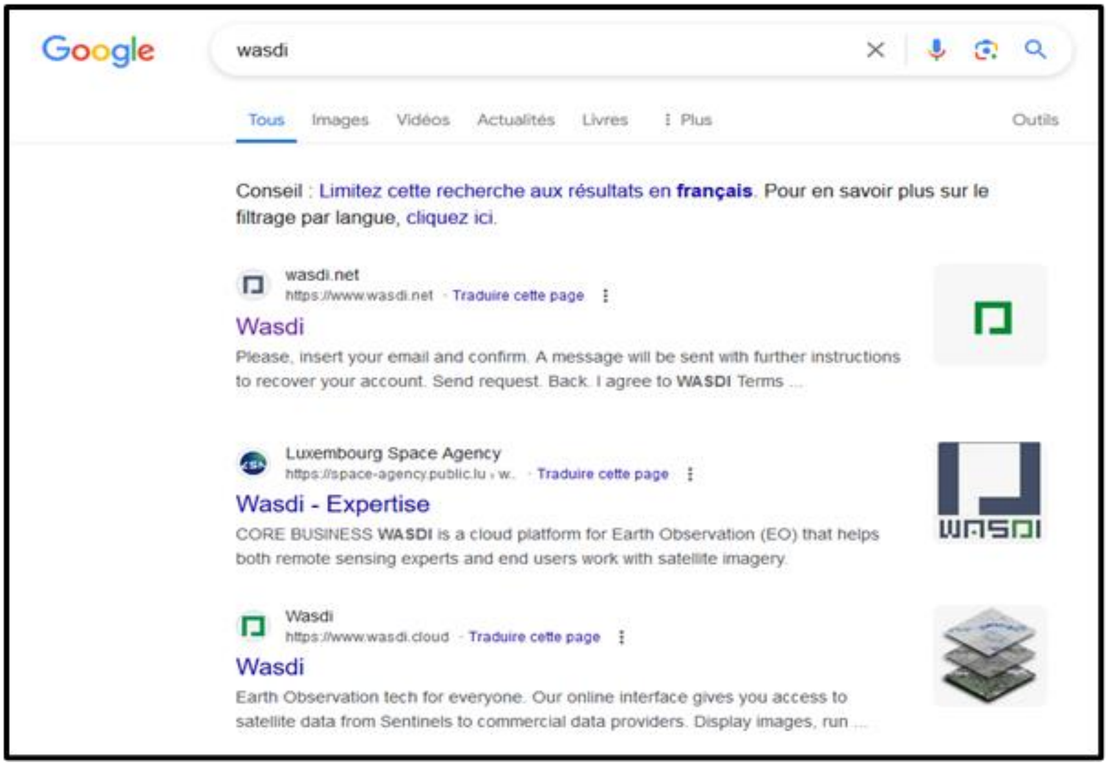


Figure 2-2. Select the link corresponding to wasdi.net.

2.1.2 Create a WASDI account

To **create an account** follow these steps:

1) Click the '**Sign up / Sign in**' button in the top right-hand corner of the screen

2) If you do not have an account, register by filling in your details in the form (Figure 2-3)

3) Once you have an account, click the 'Sign up / Sign in' button again, and this time fill in your username and password to enter your account.

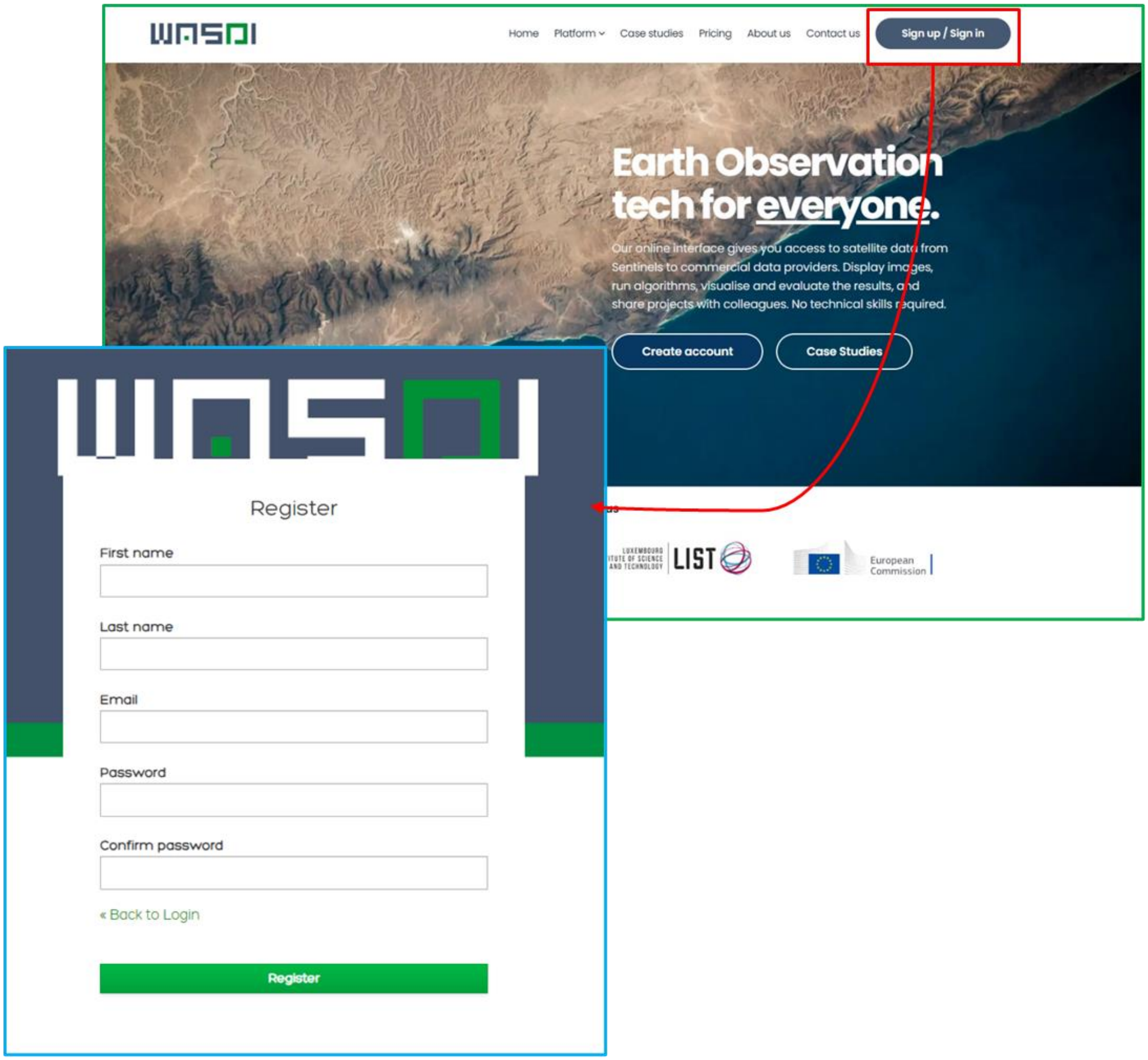


Figure 2-3. Location of sign in / sign up button (top) and the WASDI registration form.

<u>Note</u>: have your **login and password** ready, as you will need them for the next steps

2.1.3 Finding your way around WASDI

When you log in to your WASDI account, you will arrive in the Marketplace, which presents a **catalogue of all the applications** available on WASDI, see Figure 2-4.

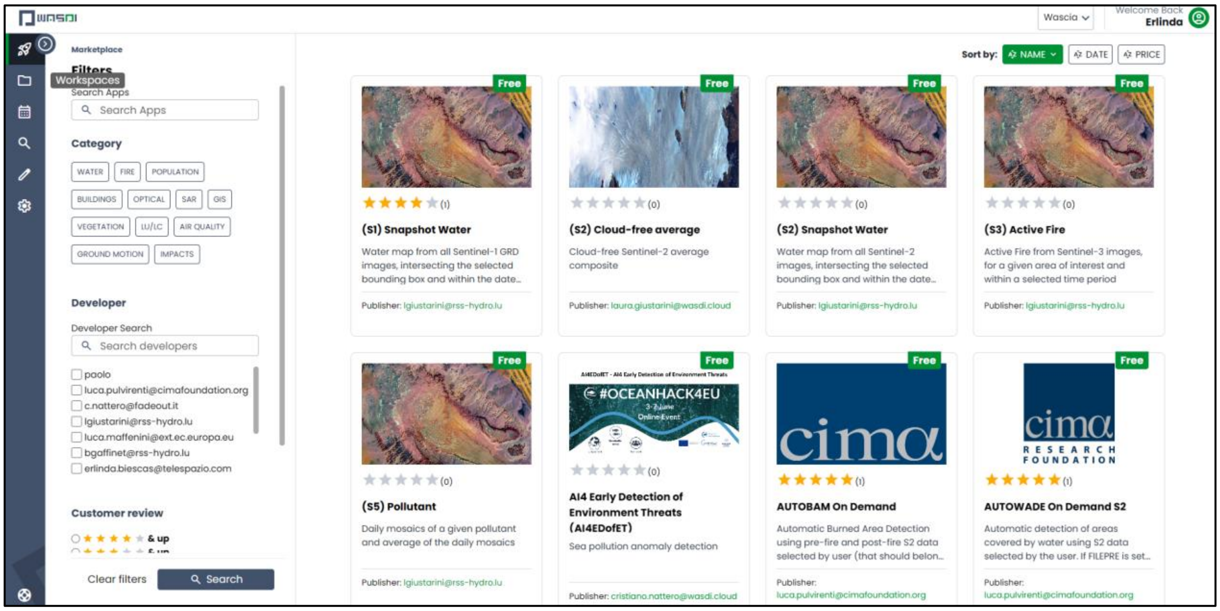


Figure 2-4. Catalogue of the applications available on WASDI (up to August 2024).

You can choose a theme (*CATEGORY*), a developer (*DEVELOPER*) or search for a specific application by typing its name in the search bar (*SEARCH APP*).

A navigation panel on the left-hand side allows you to navigate between different parts of WASDI, see Figure 2-5.

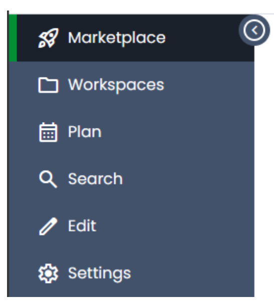


Figure 2-5. Navigation panel on WASDI.

2.1.4 WASDI Workspaces

The WASDI platform allows users to create their own personal workspaces, where their data will be saved. Users can repeatedly access the data in their workspaces, removing the need to re-download and process data each time. Users can create multiple workspaces allowing them flexibility in their data storage.

To access a workspace, go to the navigation panel shown in Figure 2-5 and select 'Workspaces'. This page will show you all your workspaces, see Figure 2-6. In these workspaces you'll find the data generated by an application. Each workspace can be deleted at will by clicking on the icon.

Note: The data within your workspace will not automatically update to include the latest data. The data will be the same as when you generated it. If you require the latest data for your application, you will need to re-process the data and add it to your existing workspace

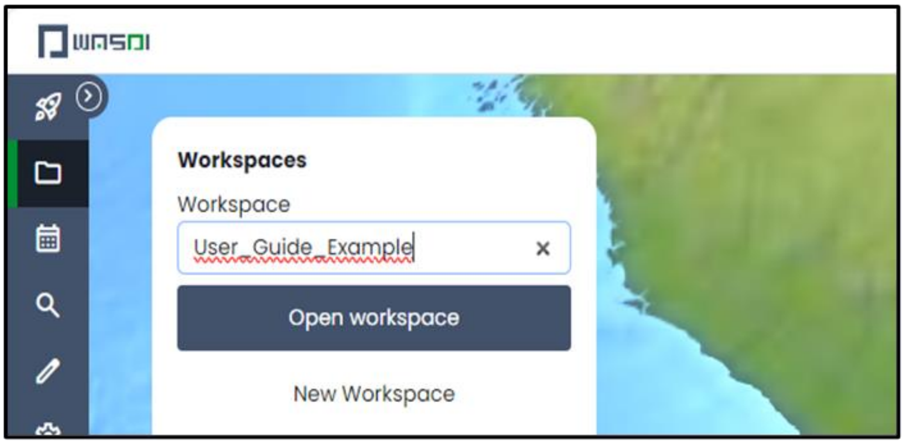


Figure 2-6. WASDI Workspace access.

2.1.5 Accessing the WaSCIA applications

The WaSCIA applications are deployed on WASDI and are accessible through the **WASDI Marketplace**.

1) In the search bar type **'wascia'** and search.
2) The WaSCIA applications are named **wascia_hydrosens-sws** and **wascia_processor_climate_indicators**.
3) Both applications will appear, you can select the one that you wish to run, see Figure 2-7.

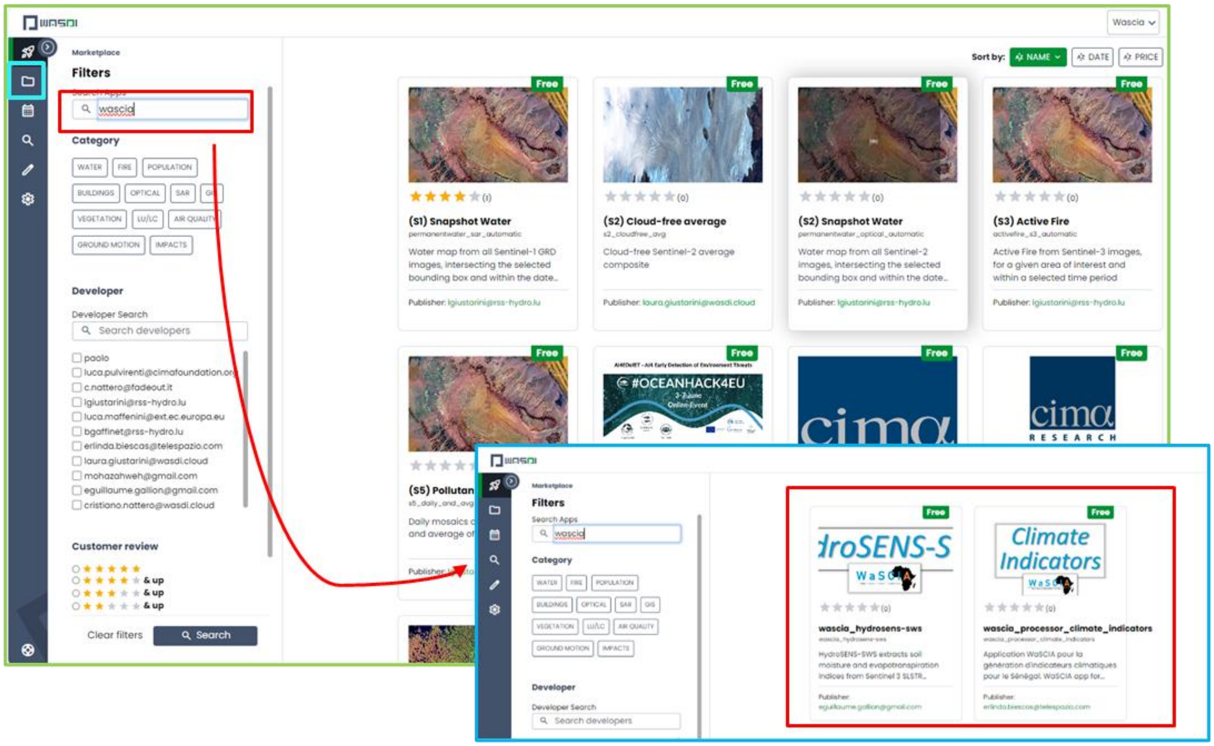


Figure 2-7. Accessing the WaSCIA applications through the WASDI search engine.

3 HYDROSENS-SWS APPLICATION

WaSCIA HydroSENS-Soil Water Stress (SWS) application generates Soil Moisture and Evaporative Water Loss outputs from Sentinel-3 images, for Senegal.

It comprises the following elements:

- Simplified Triangle Processor, for calculating evaporative losses and soil wetness dynamics from Sentinel-3 imagery.
- Random Forest Downscaling, for downscaling to 30 m of the Sentinel-3 derived indicators.

Here we will outline the use of the ***wascia_hydrosens-sws*** application.

3.1 OPENING THE APPLICATION

Follow the steps in Section 2.1.5 (Figure 2-7) and select the HydroSENS-SWS application (***wascia_hydrosens-sws***), see Figure 3-1.

1) Select '**Open Application'** to begin.

The ***wascia_hydrosens-sws*** application window will open.

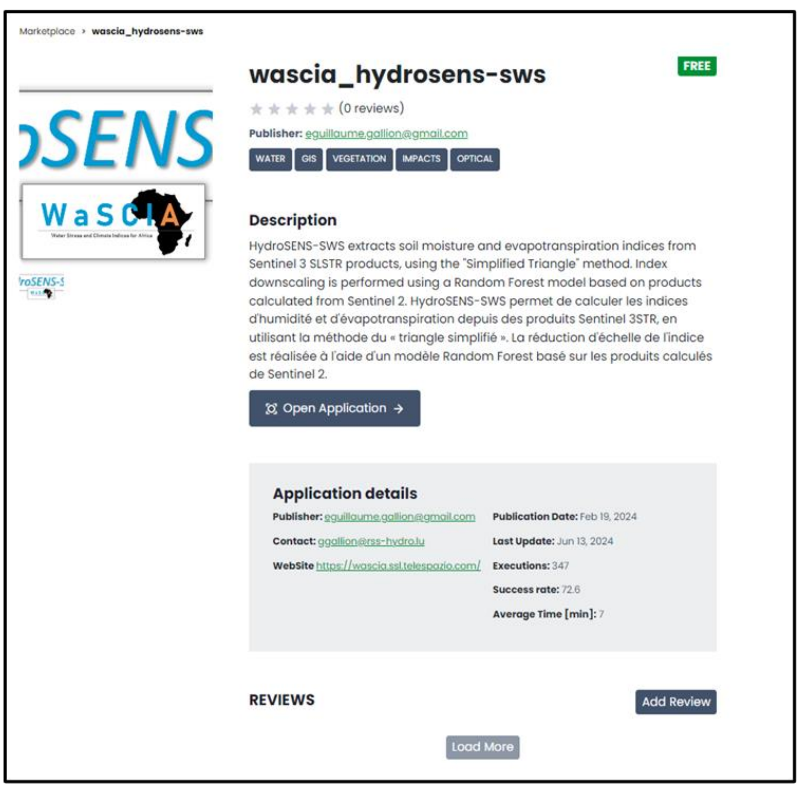


Figure 3-1. Access to the *wascia_hydrosens-sws* application.

3.2 PARAMETER SELECTION

To use the HydroSENS-SWS application, a series of parameters needs to be selected to define the type of processing to perform. If this is your first time running the application, you will need to **create a new** workspace and name it.

In the **application window**, consult the **'Help'** for a full description of the application.

1) In the right-hand panel in the '**Sentinel-3 parameters**' tab (Figure 3-2), select your desired options from the drop-down boxes. Here you will define:
    a. **Date**: Indicate the **day on which** the analysis will **start** (the application will automatically run for this day and the following 6 days - one week in total)
    b. Choose whether you wish to save the **scatter graphs**
    c. Choose whether you wish to calculate a **weekly index**
    d. **Variable type**: Choose whether you wish to view the average, minimum, maximum (for soil moisture and evapotranspiration)
    e. Choose whether you wish to perform the **downscaling** (reduction to 20m resolution)
    f. Choose the **percentage of cloud cover** tolerated for Sentinel-2 products (from 0 to 15%).

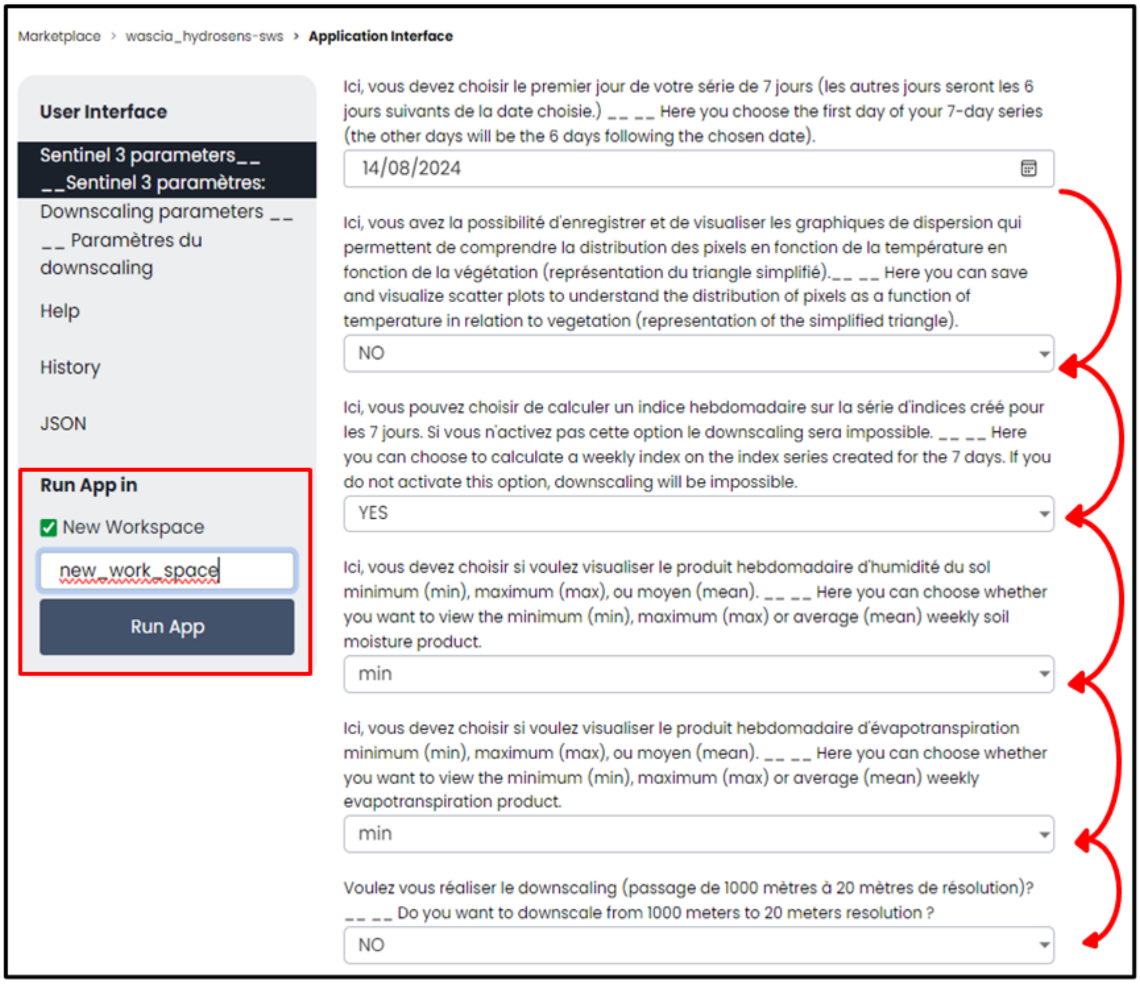
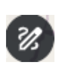


Figure 3-2. wascia_hydrosens-sws application interface.

2) Next, move to the **'Downscaling parameters'** tab (Figure 3-3) and select a study area for downscaling.

   a. Use the  icon to draw a **polygon**.

   b. Once validated, it will appear in **BLUE** as seen in Figure 3-3**.**

> **<u>Warning</u>**: There can be several errors that occur during this process. If you encounter any, please see Section 7 for a list of common errors.

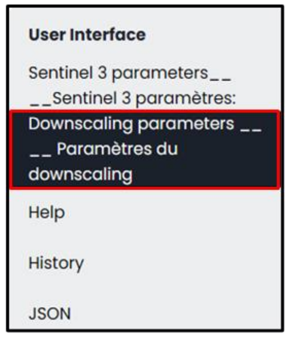


Figure 3-3. 'Downscaling parameters' tab in wascia_hydrosens-sws.

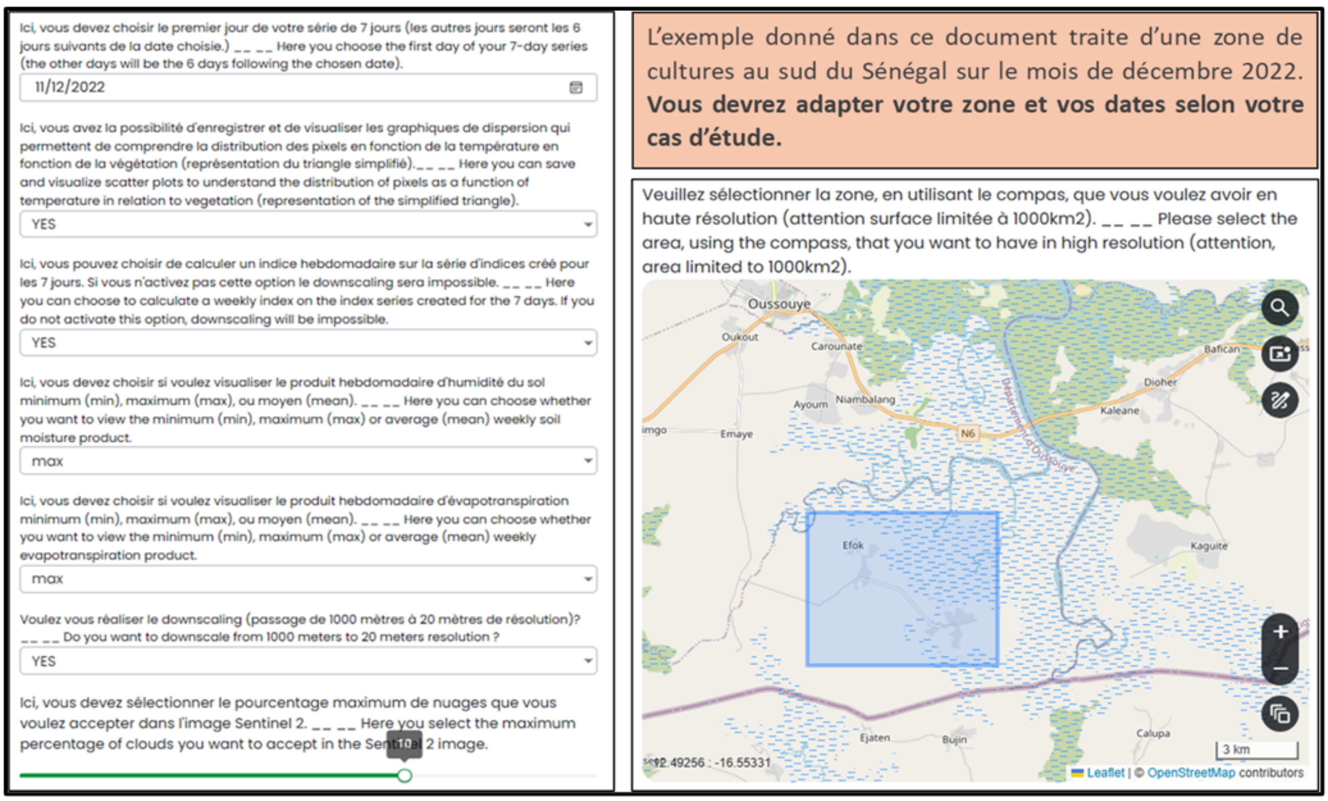


Figure 3-4. Example of parameter selection through the wascia_hydrosens-sws application for a case study of December 2022, in Southern Senegal.

3) In the right-hand panel, under '**Run App in'**, select the workspace in which you wish to run the app.

    a. To run the app in a **new workspace**, enter the name you wish to give your new workspace.

    b. To run the app in an existing workspace, deselect the 'New Workspace' box, and search for your **existing workspace**.

4) Select '**Run'** to launch the application.

3.3 MONITORING PROGRESS OF THE APPLICATION

Once the application has been started, you are redirected to your workspace. Here you can monitor the progress of the application through the workspace interface.

1) Select the icon in the bottom right to open the **Workspace processes list**. This allows you to see the status of running tasks.

2) If you are not in your workspace, you can access this from the home page of WASDI by clicking on the folder icon highlighted in Figure 2-7.

3) Once you expand the progress monitor, you'll find the following line, showing the **elapsed time and percentage of completion**.

4) You can also follow the **progress bar** at the bottom of the page.

5) Please wait until the end of the execution:

6) The application will inform you if there has been an error while processing your request.

<u>Note</u>:
- There may be missing days among the 7 days selected for execution.
- Weekly indices may not be calculated for a given day due to missing pixels (data not available).
- Downscaling may not be performed if the study area selected in the parameters is located in an area not covered by the weekly indices.

3.4 NAMING CONVENTIONS

The output data products are generated in GeoTIF format and have the following naming convention:

{data type}_{spatial resolution}_{coverage}_{metric}_{date}

e.g. **EWL_1000_w_max_20231010**

Where:

- **{data type}: EWL** = evapotranspiration; **SM** = soil moisture
- **{spatial resolution}:** resolution in meters. **1000** = 1000 m resolution, **20** = 20 m resolution
- **{coverage}: w** = week, **d** = day
- **{metric}: max** = maximum of weekly series values, **min** = minimum of weekly series values, **mean** = average of weekly series values.
- **{date}:** date in format **YYYYMMDD.** This variable only appears in files with **w** for weekly products.

If selected, the Triangle Representation plots are generated in PNG format. This graphic also shows the distribution of temperature in relation to vegetation on the Sentinel-3 image. The file naming convention is:

{date}_ Triangle_Representation

e.g. **20230821_Triangle_Representation**

Where:

- **{date}:** date in format **YYYYMMDD.** This variable only appears in files with **w** for weekly products.
- **Triangle_Representation:** Graphic representation of the triangle, used to calculate indices.

3.5 DISPLAYING RESULTS

From within your workspace, the products that have been created are displayed in the left-hand panel.

1) **Double-click** on the product you want to view. This will expand the available list of bands.

2) **Double-click** the file named '**band_1'** to activate it, see Figure 3-5.

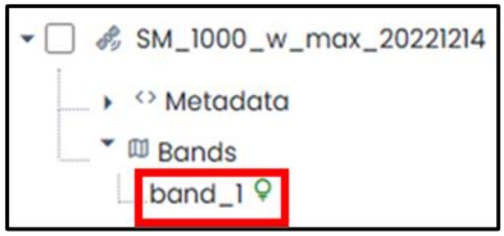


Figure 3-5. Output will be displayed by double clicking this file.

A few data **visualisation tools** are available in WASDI (see Figure 3-6):

1) Click on  to display the legend.

2) Click on  to remove the product from the display.

3) Adjust the opacity of the product by moving the slider 

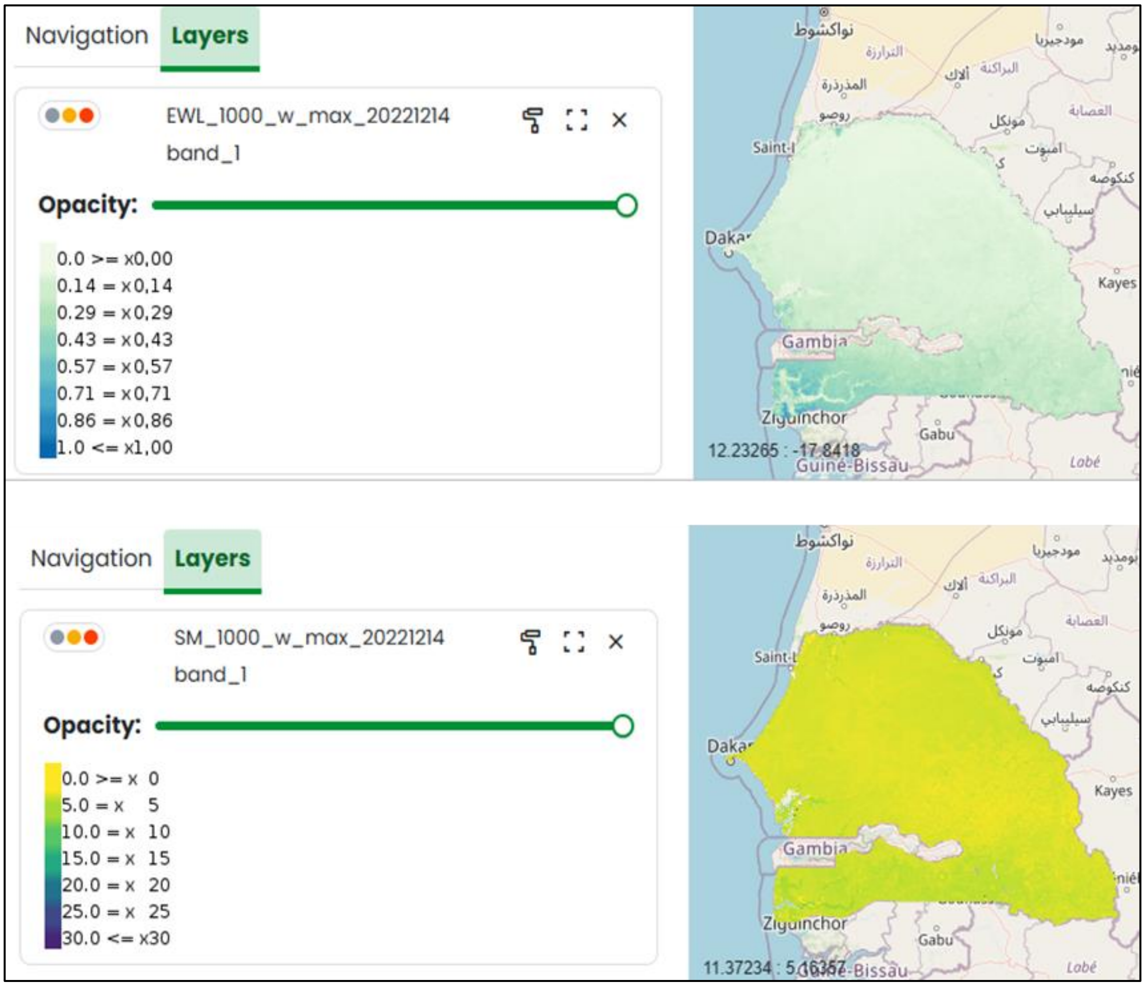


Figure 3-6. Examples of the visualisation tools available to display the data generated by wascia_hydrosens-sws.

3.6 DOWNLOAD RESULTS

To download products, **select the products** you are interested in and press the '**download**' button (Figure 3-7). Once downloaded, the files, in GeoTIF format, can be viewed in other software programs for better visualisation and understanding.

Figure 3-7. Data selection and download button for downloading data.

3.7 PERFORM A NEW DOWNSCALING (OPTIONAL)

It is possible to **perform a second downscaling** on a second study area but using the same input dates. There are two steps to follow:

3.7.1 Clean your Workspace

You need to **delete products** previously created in connection with your current study area.

1) Navigate to the relevant workspace.
2) Select the **Sentinel-2** product and the **indices** calculated with it (NDVI, NDMI, NDWI, NDBI), see Figure 3-8.
3) Click '**Delete [5]'** products, see Figure 3-8.

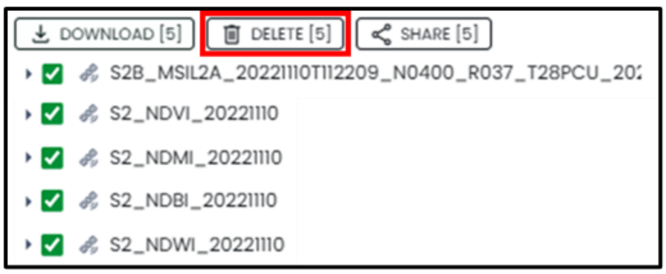


Figure 3-8. How to clean your workspace.

3.7.2 Run the application

Before you can run the application again, you need to reset the parameters.

1) To do this, go back to the **WASDI Marketplace** and open again the application, see Section 3.1.
2) Select the parameters in the '**Sentinel-3 parameters'** tab as described in Section 3.2.
3) In the "Downscaling parameters", choose your **new zone of interest** (depending on the availability of your previously calculated weekly index data).
4) To run the app in your existing workspace, deselect the "New Workspace" box, and search for your **existing workspace**.
5) Select '**Run'** to launch the application

Note:

- All selected parameters, other than the study area, must be identical to the previous selection.
- Wait for the processing to finish. You can monitor progress as shown in Section 3.3 and view and download results as shown in Sections 3.5 and 3.6.

4 CLIMATE INDICATORS APPLICATION

The WaSCIA Climate Indicators application generates Climate Indices from ERA5-Land reanalysis data, for Senegal. Users are able to generate 20 different climate indices. The outputs are saved to the user's selected WASDI workspace and can be explored and plotted using a Jupyter Notebook.

Here we will outline the steps needed to use the ***wascia_processor_climate_indicators*** application and associated Jupyter Notebooks. This application allows the generation and analysis of the climate indices highlighted in Table 4-1. Note that the Agricultural Indicators GSL and GDD, relating to crops, have been tailored slightly to better represent the crop types grown in Senegal, groundnut, and millet [RD 1].

Table 4-1. Climate Indicators calculated from ERA5-Land data.

Indicator	Acr.	Units	Temporal Resolution	Input Variables	Formula
Total Precipitation	TP	mm	Daily	Precipitation	Total precipitation for each day
Mean 2 metre Temperature	T2M	°C	Daily	Temperature	Mean temperature of the air at 2m above the surface for each day
Maximum Temperature	TASMAX	°C	Daily	Temperature	Maximum temperature for each day
Minimum Temperature	TASMIN	°C	Daily	Temperature	Minimum temperature for each day
Maximum number of consecutive dry days (Drought spell)	CDD	Days	Monthly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Count the largest number of consecutive days where: $\boldsymbol{RR_{ij} < 1\ mm}$
Maximum number of consecutive wet days (Wet spell)	CWD	Days	Monthly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Count the largest number of consecutive days where: $\boldsymbol{RR_{ij} > 1\ mm}$
Warm Daytimes: Percentage of days when TX	TX90p	Days	Monthly	Temperature	Let TX_{ij} be the daily maximum temperature on day *i* in period *j* and let $TX_{in}90$ be the calendar day 90^{th} percentile centred on a 5-day

> 90th percentile					window. The percentage of time for the base period is determined where: $TX_{ij} > TX_{in}90$
Cold Nights: Percentage of days when TN < 10th percentile	TN10p	Days	Monthly	Temperature	Let TN_{ij} be the daily minimum temperature on day *i* in period *j* and let $TN_{in}10$ be the calendar day 10th percentile centred on a 5-day window. The percentage of time for the base period is determined where: $TN_{ij} < TN_{in}10$
Standardised Precipitation Evapotranspiration Index (SPEI)	SPEI	-	Monthly	Precipitation & Evapotranspiration	With a value for *PET*, the difference between the precipitation (*P*) and *PET* for the month *i* is calculated as: $D_i = P_i - PET_i$ the calculated Di values are aggregated at different time scales, following the procedure described by Vicente-Serrano et al. (2010)
Precipitation Sum	RR	mm	Weekly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Then sum values are given by: $RR_j = \sum_{i=1}^{I} RR_{ij}$
Wet Days	R1mm	Days	Weekly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Then counted is the number of days where: $RR_{ij} \geq 1\ mm$
Heavy Precipitation days	R10mm	Days	Weekly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Then counted is the number of days where: $RR_{ij} > 10\ mm$
Very Heavy Precipitation days	R20mm	Days	Weekly	Precipitation	Let *RRij* be the daily precipitation amount for day *i* of period *j*. Then counted is the number of days where: $RR_{ij} > 20\ mm$
Warm and Wet days	WW	Days	Weekly	Precipitation &Temperature	Let *TGij* be the daily mean temperature at day *i* of period *j* and let *TGin75* be the calendar day 75th percentile calculated for a 5-day window cantered on each calendar day in the 1991–2020 period. Let *RRwj* be the daily precipitation amount at wet day *w* (*RR* ≥ 1.0 mm) of period *j* and let *RRwn75* be the 75th percentile of precipitation at wet days in

					the 1991–2020 period. Then counted is the number of days where: $TG_{ij} > TG_{in75}\ AND$ $RR_{wj} > RR_{wn75}$
Warm Spell Duration Index	WSDI	Days	Monthly	Temperature	Let *TXij* be the daily maximum temperature on day *i* in period *j* and let *TXin90* be the calendar day 90th percentile of daily maximum temperature calculated for a five-day window centred on each calendar day in the base period (1991-2020). Then counted is the number of days where, in intervals of at least six consecutive days: $TX_{ij} > TX_{in90}$
Cold Spell Duration Index	CSDI	Days	Monthly	Temperature	Let *TNij* be the daily minimum temperature on day *i* in period *j* and let *TNin10* be the calendar day 10th percentile of daily minimum temperature calculated for a five-day window centred on each calendar day in the base period (1991-2020). Then counted is the number of days where, in intervals of at least six consecutive days: $TN_{ij} < TN_{in10}$
Growing Season Length - Optimum	GSL	Days	Yearly	Temperature	Let *TGij* be the daily mean temperature on day *i* in period *j*. Count the annual (1 Jan to 31 Dec in Northern Hemisphere, 1 July to 30 June in Southern Hemisphere) number of days between the first occurrence of at least six consecutive days where: $TG_{ij} > 33^oC$ and the first occurrence after 1 July (1 Jan in Southern Hemisphere) of at least six consecutive days where: $TG_{ij} < 33^oC$
Growing Degree Days	GDD	ºC	Weekly	Temperature	Let *TGii* be the daily mean temperature at day *i* of period *j*. BEDD is calculated by: $BEDD = \sum_{i=1}^{I} \min\left[\max\left[TG_{ij} - T_{low}, 0\right], T_{high} - T_{low}\right]$

					where T_{high} and T_{low} are effective temperature upper and lower thresholds respectively. $T_{low} = 10^oC$ $T_{high} = 40^oC$
Mean Diurnal Temperature Range	DTR	ºC	Weekly	Temperature	Let *TXij* be the daily maximum temperature on day *i* in period *j*. Let *TNij* be the daily minimum temperature on day *i* in period *j*. If I represent the total number of days in *j* then the mean diurnal temperature range in period *j* is: $\boldsymbol{DTR_j = \frac{\sum_{i=1}^{I}(TX_{ij} - TN_{ij})}{I}}$
Simple Daily Intensity Index	SDII	mm	Weekly	Precipitation	Let *RRwj* be the daily precipitation amount on wet day *w* (RR ≥ 1 mm) in period *j*. Then mean precipitation number of wet days is given by: $\boldsymbol{SDII_j = \frac{\sum_{w=1}^{W} RR_{wj}}{W}}$ Where *W* is number of wet days.

4.1 OPENING THE APPLICATION

To locate the WaSCIA Climate Indicators application, follow the steps in Section 2.1.5 (Figure 2-7) and select the application '***wascia_processor_climate_indicators'***.

1) Select '**Open Application'** to begin.
2) The ***wascia_processor_climate_indicators*** application window will open, see Figure 4-1.

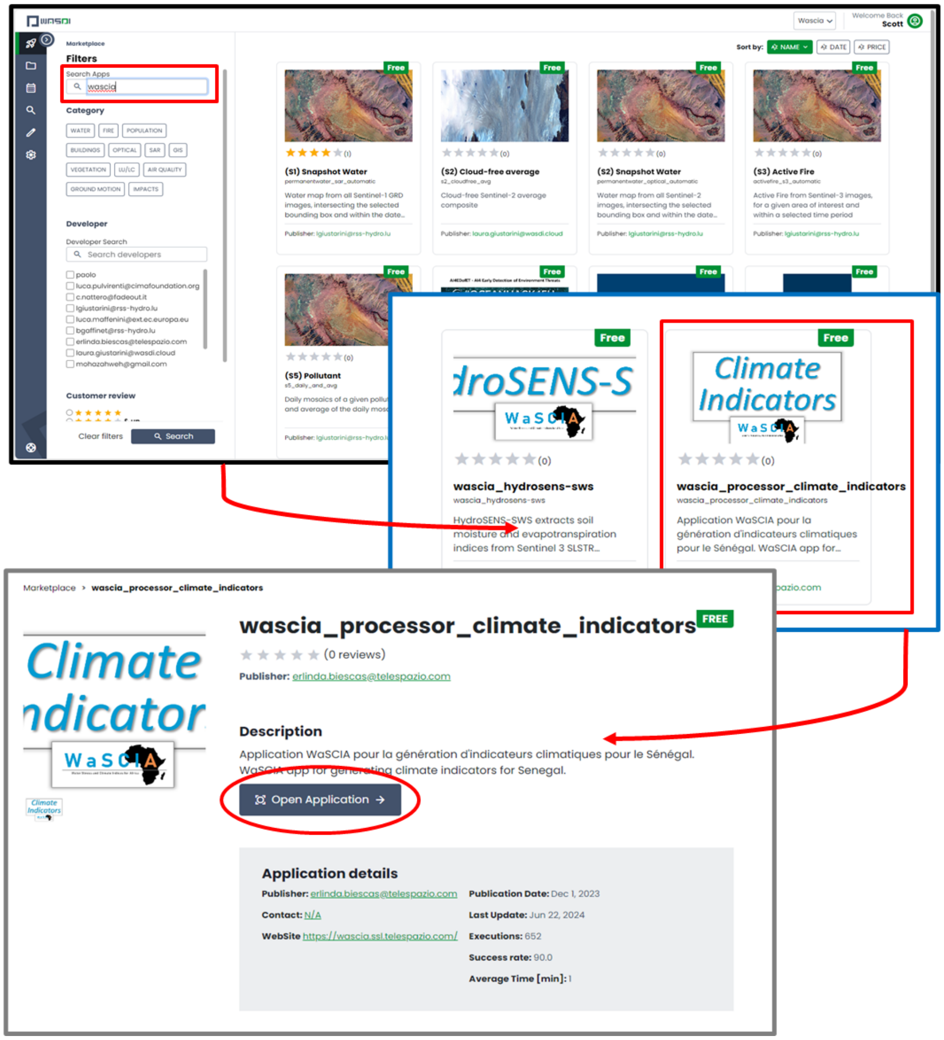


Figure 4-1. Opening the wascia_processor_climate_indicators application.

4.2 RUNNING THE APPLICATION

Before running the application, you need to select the climate index your wish to calculate.

In the **application window**, consult the '**Help'** for a full description of all the indices that are available, as well as information on the format of the files that are produced. Figure 4-2 provides a visual representation of the steps below.

1) Under the '**Climate Index'** tab, select the Climate index of interest from the dropdown list.

2) Under '**Run App in'**, select the workspace in which you wish to run the app.

a. To run the app in a new workspace, enter the name you wish to give your **new workspace** (recommended), or one will be automatically generated.

b. To run the app in an existing workspace, deselect the "New Workspace" box, and search for your **existing workspace**.

3) Select **'Run'** to run the application.

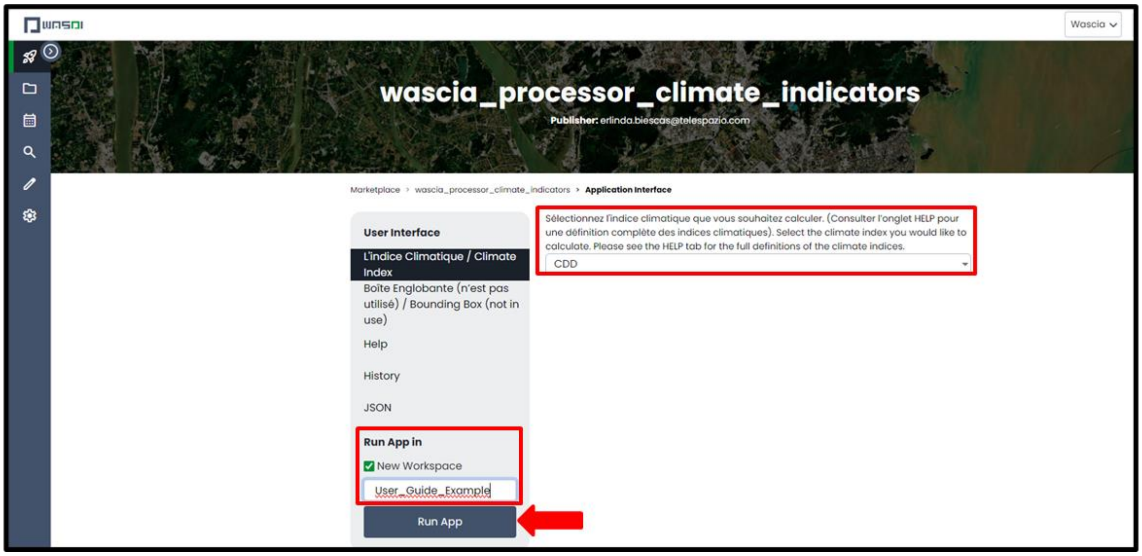


Figure 4-2. Steps to run wascia_processor_climate_indicators application.

4.3 MONITORING PROGRESS OF THE APPLICATION

Once the application has been started, WASDI will start to process your chosen index. You are redirected to your workspace where you can monitor the progress of the application through the workspace interface.

1) Select the icon in the bottom right to open the **Workspace processes list**. This allows you to see the status of running tasks, see Figure 4-3.

2) If you are not in your workspace, you can access this from the home page of WASDI by clicking on the folder icon highlighted in Figure 2-6.

Once completed, you will see the input data required to create the index, as well as the output index itself, in your workspace, see top image in Figure 4-3.

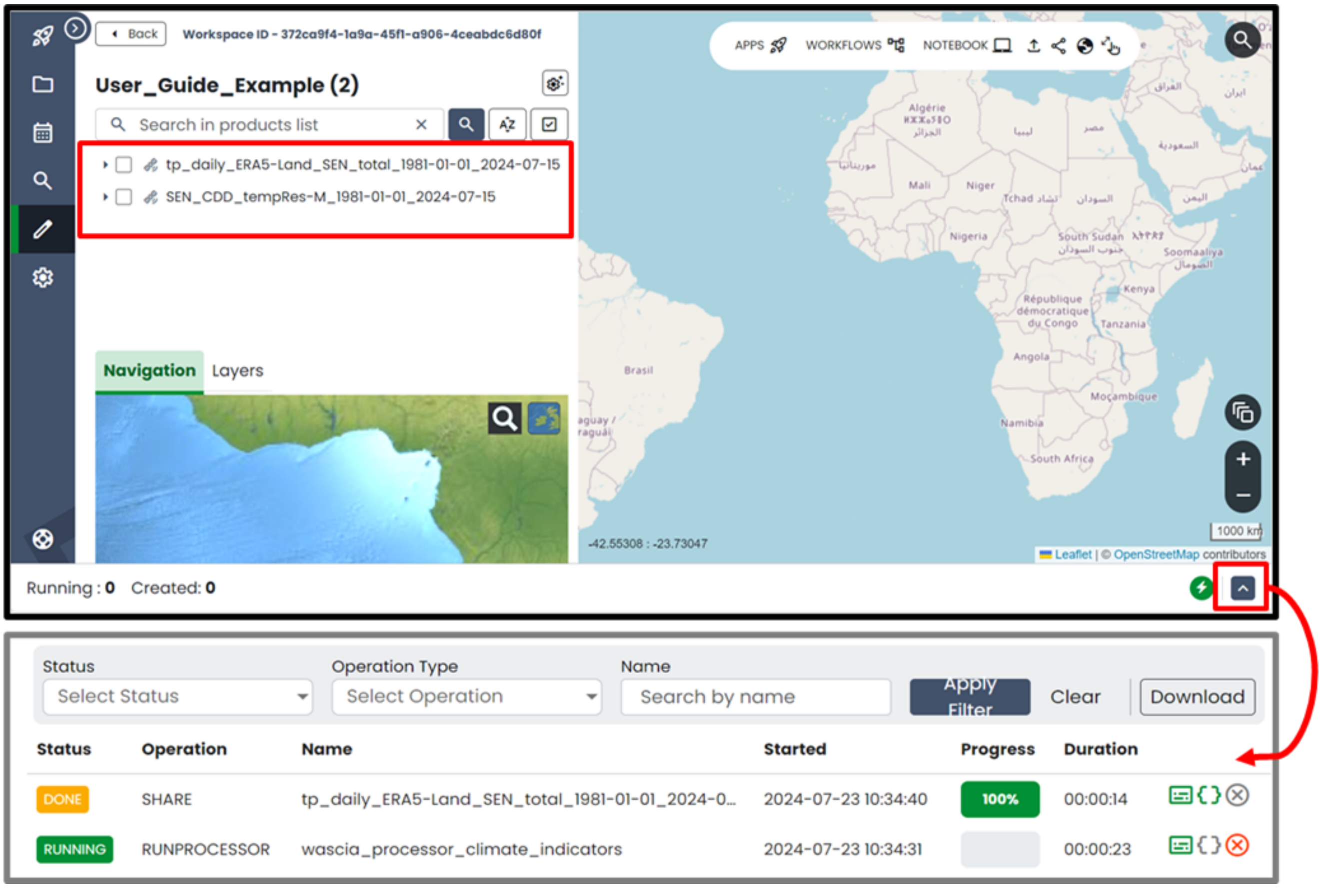


Figure 4-3. Monitoring progress of the wascia_processor_climate_indicators application.

4.4 REVIEWING THE APPLICATION OUTPUTS

Repeat the steps in Sections 4.2 and 4.3 to generate all the climate indices of interest.

Navigate to the workspace where the climate indices have been saved and you should have a list of the data products similar to Figure 4-4. These files are a mixture of input data files (tasmin, tasmax, t2m and tp, and pet) and the computed indices of your choice. Ignore the input data files as they are not needed.

The output indices are generated in netcdf format and have the following naming convention:

SEN_{climate index}_tempRes-{temporal resolution}_{start date}_{end date}.nc

Where:

SEN: Spatial coverage of the output climate index (SEN= Senegal)

{climate index}: Abbreviation of your chosen climate index

{temporal resolution}: Temporal resolution of the output climate index (Y = yearly, M = monthly, W = weekly)

{start date}: Start date of the timeseries, automatically taken from the input dataset

{end date}: End date of the timeseries, automatically taken from the input dataset

Figure 4-4. Example of workspace with some climate indices computed.

5 CLIMATE INDICES SIMPLE PLOTTING JUPYTER NOTEBOOK

This notebook has been prepared to demonstrate some simple plotting of the WaSCIA climate indices.

Designed to sit alongside the user's WASDI workspace. After running the climate indices application (***wascia_processor_climate_indicators***) and generating the climate indices of interest, the notebook will read these output data files directly from the user's workspace.

The notebook provides a number of plotting functions to generate a range of common **timeseries** and **heatmap plots**.

While not all the plots will be relevant for all of the indices, these plots are intended as examples, and we encourage the users to select the most appropriate plot for their purpose and/or adapt the code as necessary.

5.1 ACCESSING THE JUPYTER NOTEBOOK

Note: Before using this Jupyter Notebook you need to generate all the climate indices of interest by running the 'WaSCIA Climate Indices' application in WASDI from your personal workspace. The notebook will read these output data files directly from your workspace.

To access the **Jupyter Notebooks**:

1) Download the Climate Indices Simple Plotting Jupyter Notebook from the WaSCIA project website: WaSCIA Publications (Figure 5-1). Save the Notebook to your device.

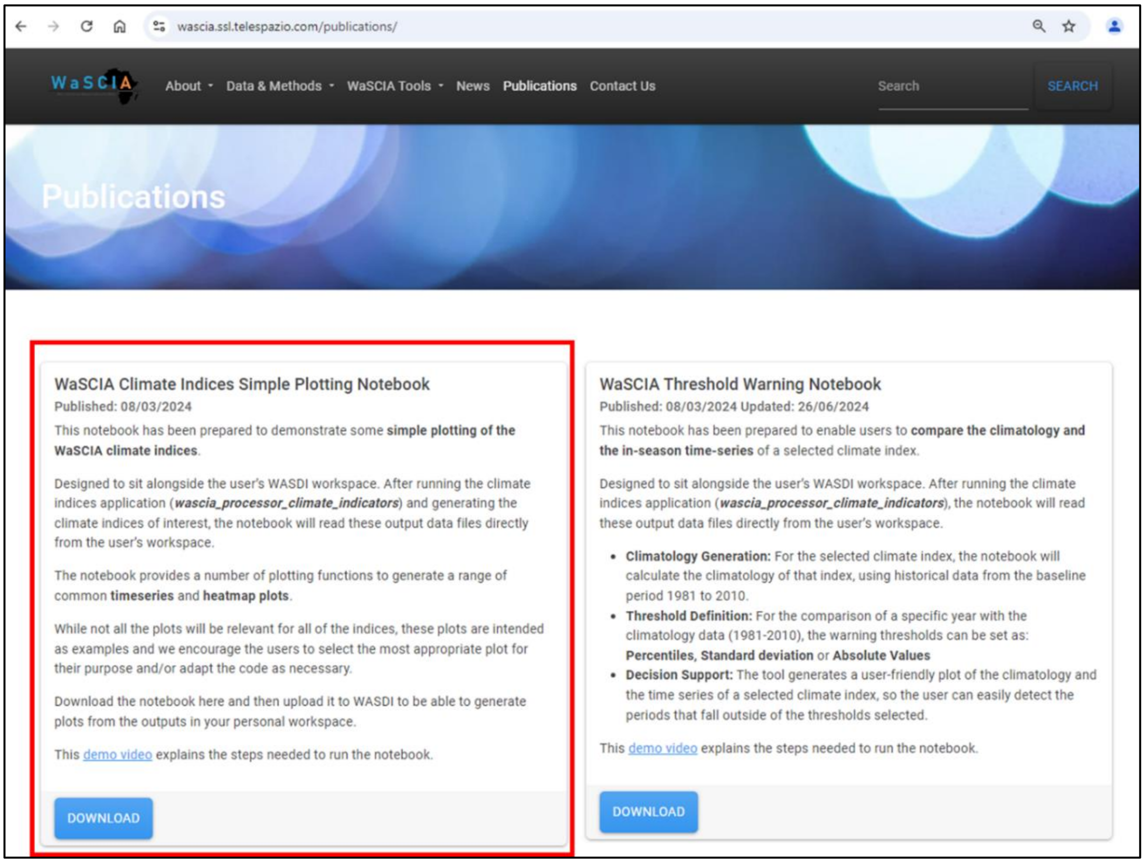


Figure 5-1. Download the Climate Indices Simple Plotting Notebook from the Publications page of the WaSCIA website.

2) Return to your workspace on WASDI and select the '**Notebook**' button (highlighted in Figure 5-2).

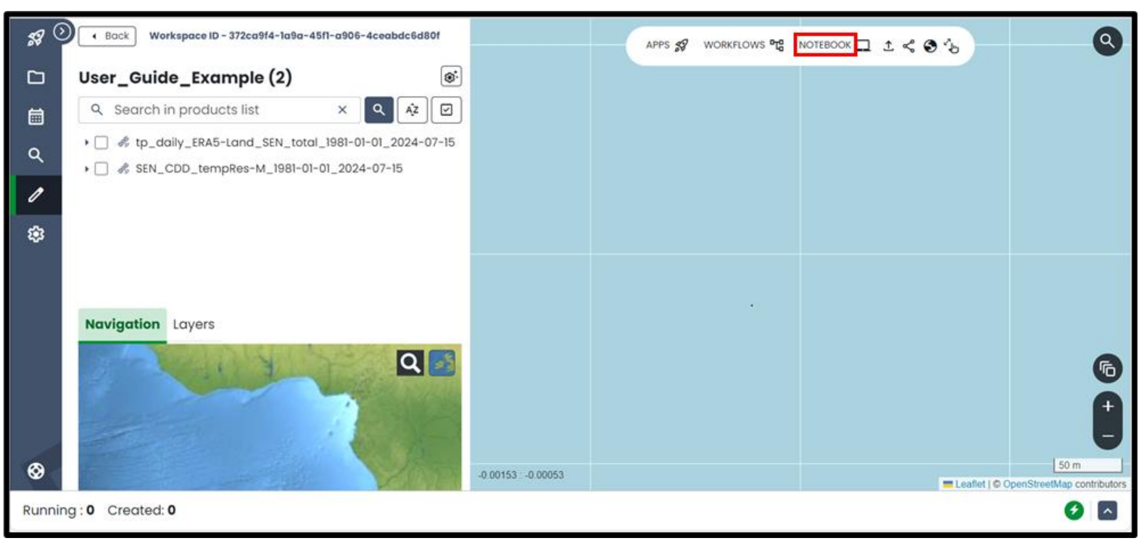


Figure 5-2. Location of the Notebook button in WASDI.

3) An alert pop-up will inform you that WASDI is preparing your notebook (Figure 5-3) followed by an update pop-up, that indicates the Notebook is ready.
   If the Notebook does not automatically open, click on the '**Notebook'** button again.

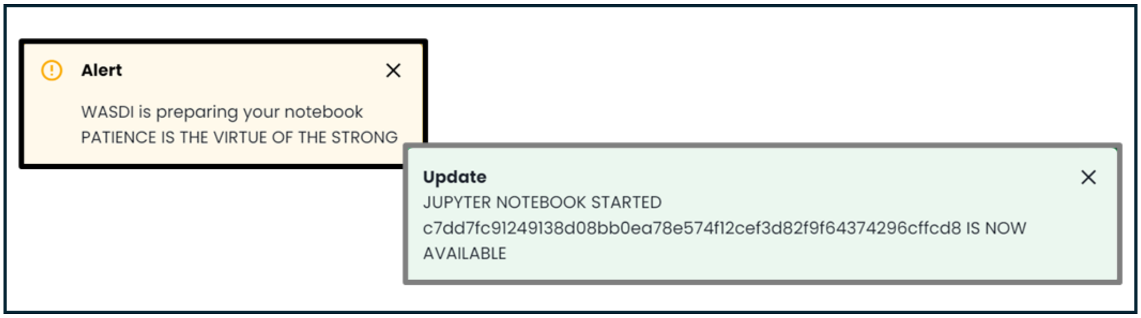


Figure 5-3. Alerts that are shown once clicking on the Notebook from the workspace.

4) Moving to the new tab that has opened in your browser, you will now need to upload the Notebooks you downloaded in Step 1. Click on the icon highlighted at the top left of Figure 5-4.

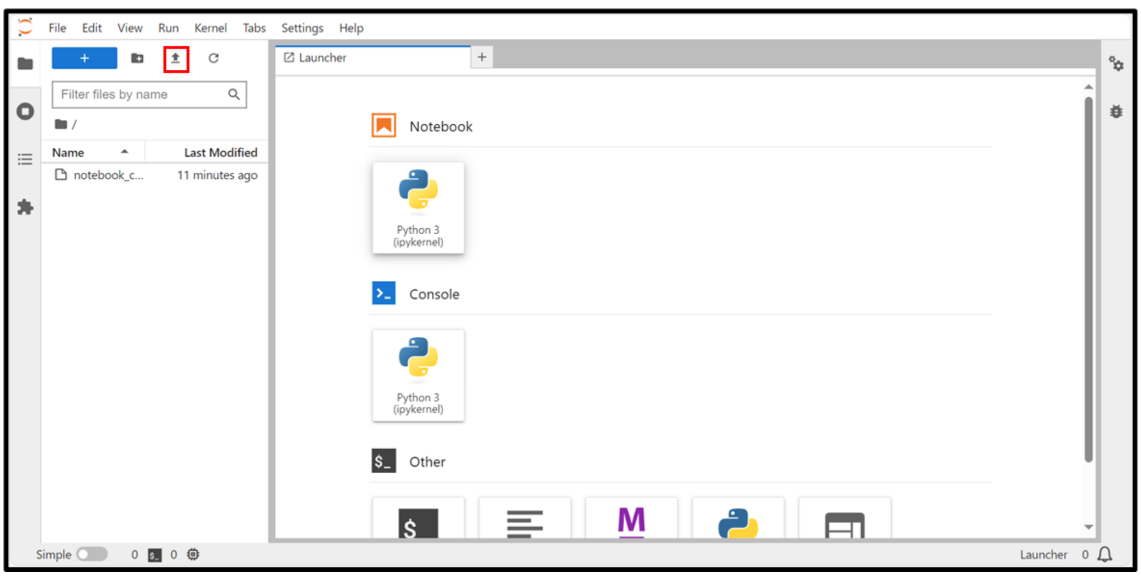


Figure 5-4. Location of the icon required to upload a Notebook.

5) Browse to find the '**WaSCIA – Climate Indices Simple Plotting'** Notebook, select it and upload it. This will load the notebook in the left-hand panel.

6) Select the notebook and it will open in the right-hand window (Figure 5-5).

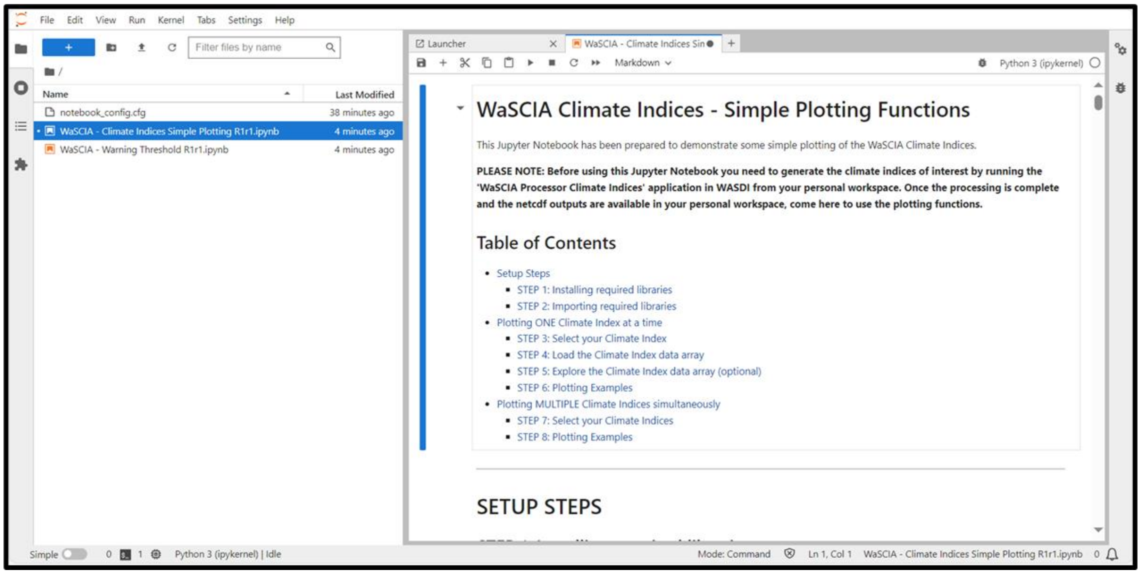


Figure 5-5. Layout of the Jupyter Notebook once the Notebooks have been uploaded and the Climate Indices Simple Plotting script selected.

5.2 RUNNING THE CLIMATE INDICES SIMPLE PLOTTING NOTEBOOK

Now that you have successfully opened the Notebook, you can start to analyse your data using the following steps:

1) Select the first cell, then select the 'Run' icon highlighted in Figure 5-6.
   Note: *you will use this icon to run each cell in the Notebook.*

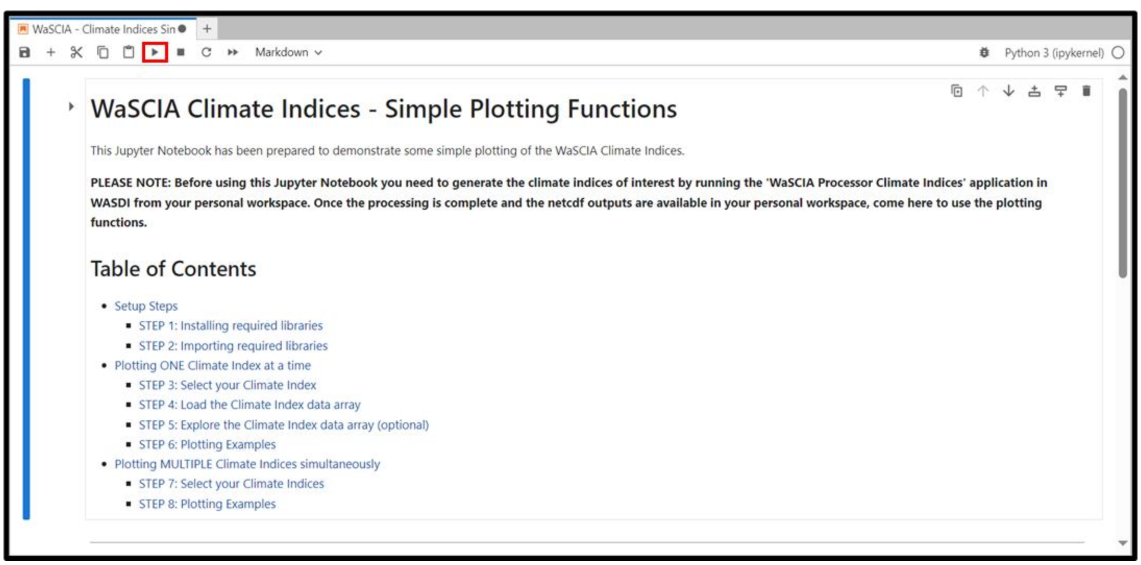


Figure 5-6. Location of the icon needed to run each cell in the Notebook.

2) Run the next cells to install the required libraries (Step 1) and import them into the Notebook (Step 2) (Figure 5-7).
   Note: At this point you will be prompted to enter you WASDI username, password, and the name of the workspace that your data is located within. This connects the Notebook to your WADSI workspace.

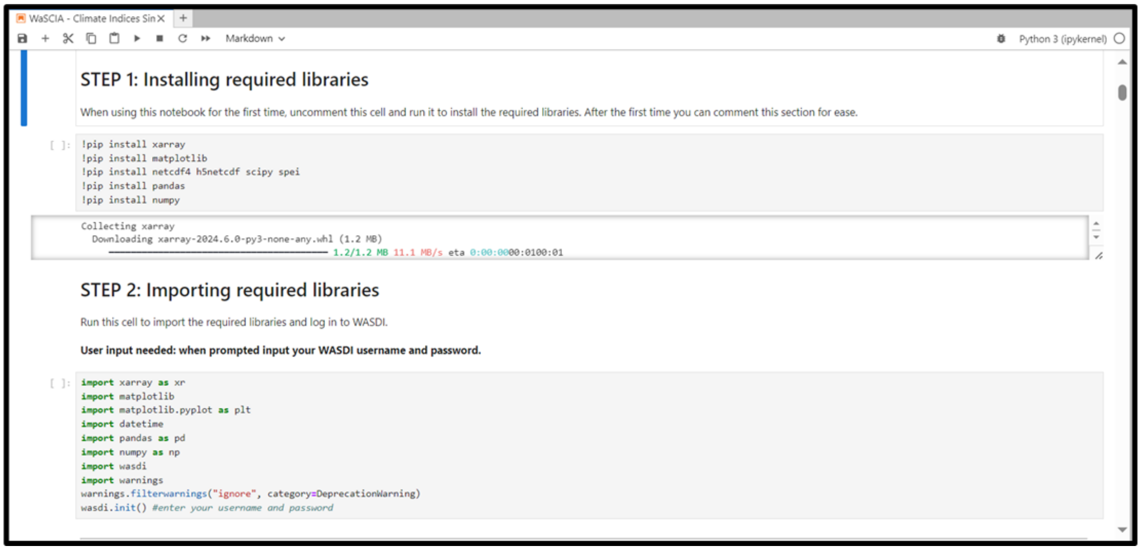


Figure 5-7. Cells that need to be run to install the required libraries.

3) In the next cell (Step 3), specify the name of the **climate index** you wish to analyse (Figure 5-8).

> ***Note:*** *This must be a climate index you have already computed and have stored in your WASDI workspace.*

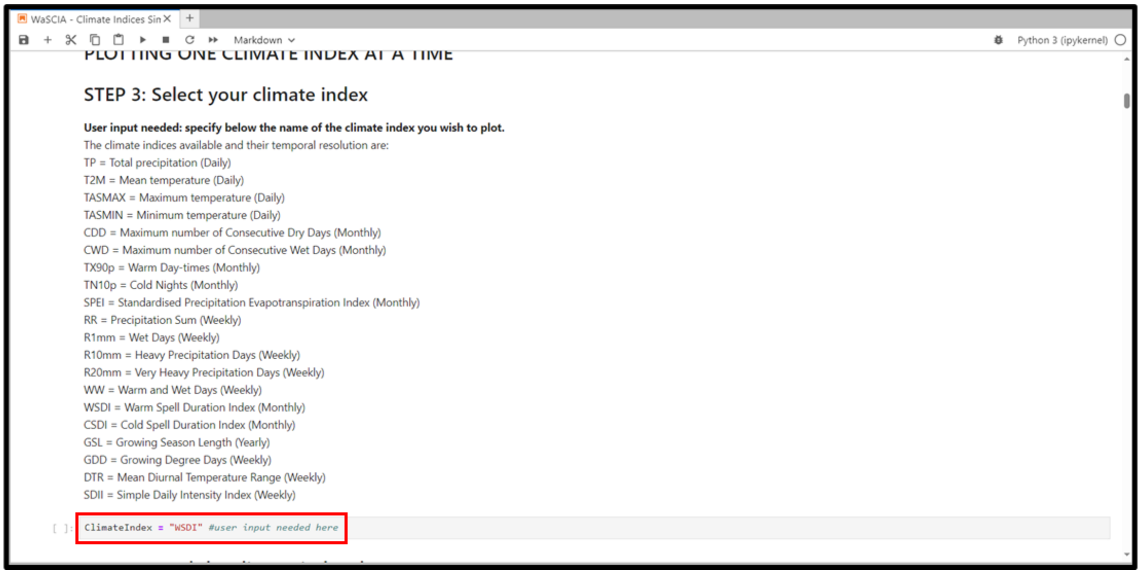


Figure 5-8. Location of the user input requirements stated in Step 3, selecting your climate indices for analysis.

4) Run the next cells to load the climate index datafile from the workspace (Step 4), and if desired explore the contents of the data files (Step 5, optional).

5) In the next cell (Step 6: Example Plotting Functions) example code is provided below to create a timeseries plot or a map plot for the selected climate index. Select the plot type that you wish to produce (Figure 5-9, top image). The available plot options are:

Timeseries plots

- PLOT A: To plot the mean data values a selected time period and area of interest.
- PLOT B: To plot the maximum data values a selected time period and area of interest.
- PLOT C: To plot the minimum data values a selected time period and area of interest.
- PLOT D: To plot the climate index values for a selected time period and selected location.

Map plots

- PLOT E: To plot the mean data values a selected time period and area of interest.

- PLOT F: To plot the maximum data values a selected time period and area of interest.
- PLOT G: To plot the minimum data values a selected time period and area of interest.
- PLOT H: To plot the climate index values for an individual date and selected area interest.

6) Follow the guidance in the Notebook to adjust the plot variables for the dates and area of interest (Figure 5-9, bottom image). The user inputs needed are:

   a. **Plot start and end dates** (in the format YYYY-MM-DD)

      PlotStartDate: choose any date from the period available 1981-01-01 - (present - 5 days)

      PlotEndDate: choose any date from the period available 1981-01-01 - (present - 5 days)

   b. **Plot area** (Senegal or Bounding_box)

      PlotArea: Input 'Senegal' to plot the whole of Senegal

      PlotArea: Input 'Bounding_box' to plot only a Bounding box (see below)

   c. **Bounding box coordinates** (in the format XX.x) (only needed if Input 'Bounding_box' used above):

      TopLeftCornerLat: Input a latitude for the top left corner of your box. Options between the limits: 11.5 to 17.2

      TopLeftCornerLon: Input a longitude for the top left corner of your box. Options between the limits: -20.3 to -8.8

      BottomRightCornerLat: Input a latitude for the bottom right corner of your box. Options between the limits: 11.5 to 17.2

      BottomRightCornerLon: Input a longitude for the bottom right corner of your box. Options between the limits: -20.3 to -8.8

Note: When entering the user inputs please pay attention to the specific format required for dates and coordinates. Please only specify values from the available ranges.

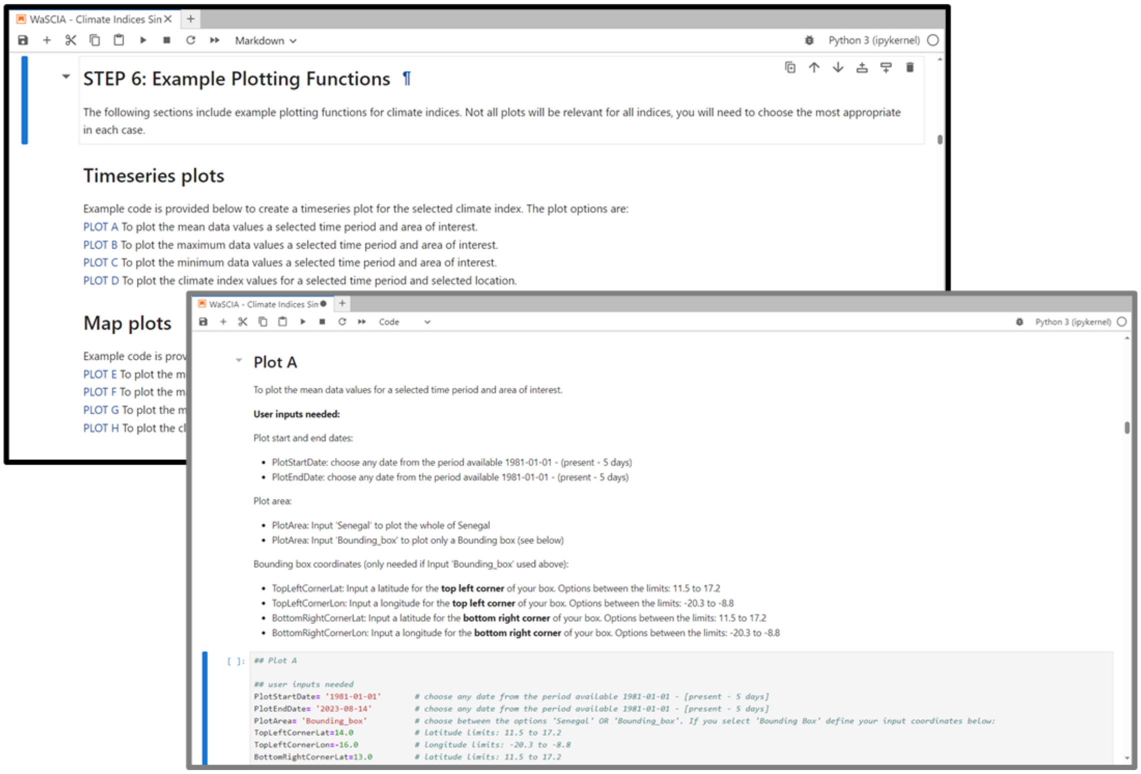


Figure 5-9. Plot types available in the Notebook (top image), and instructions that are provided for each plot (bottom image).

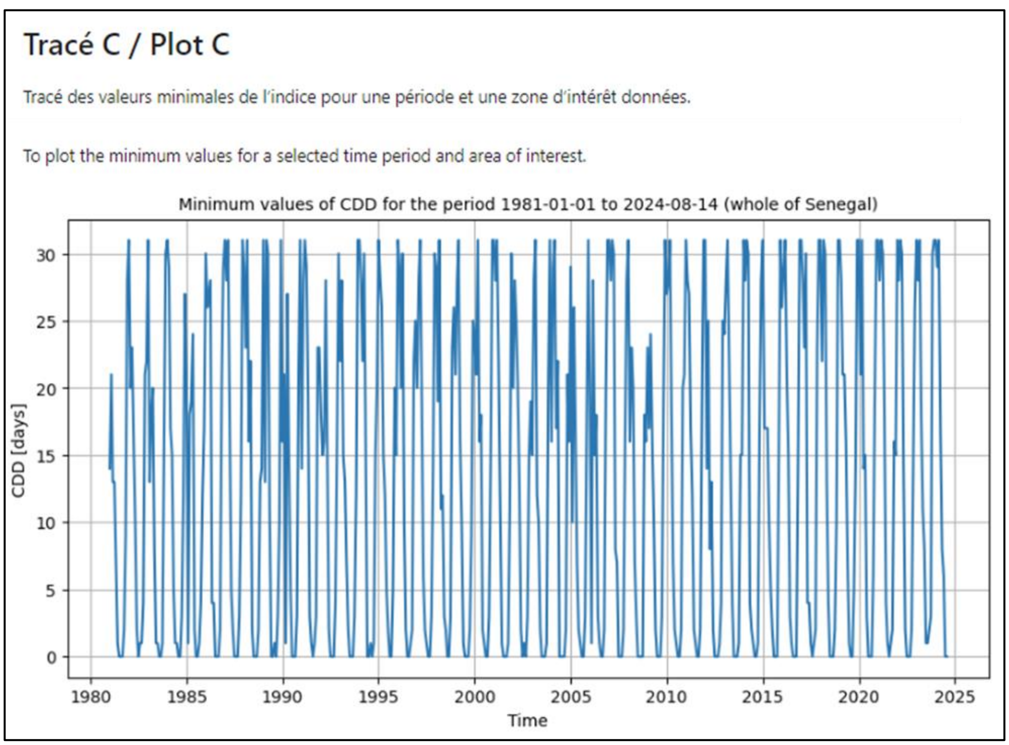


Figure 5-10. Example time-series plot for CDD for the period 1981-01-01 to 2024-08-14 for the whole of Senegal.

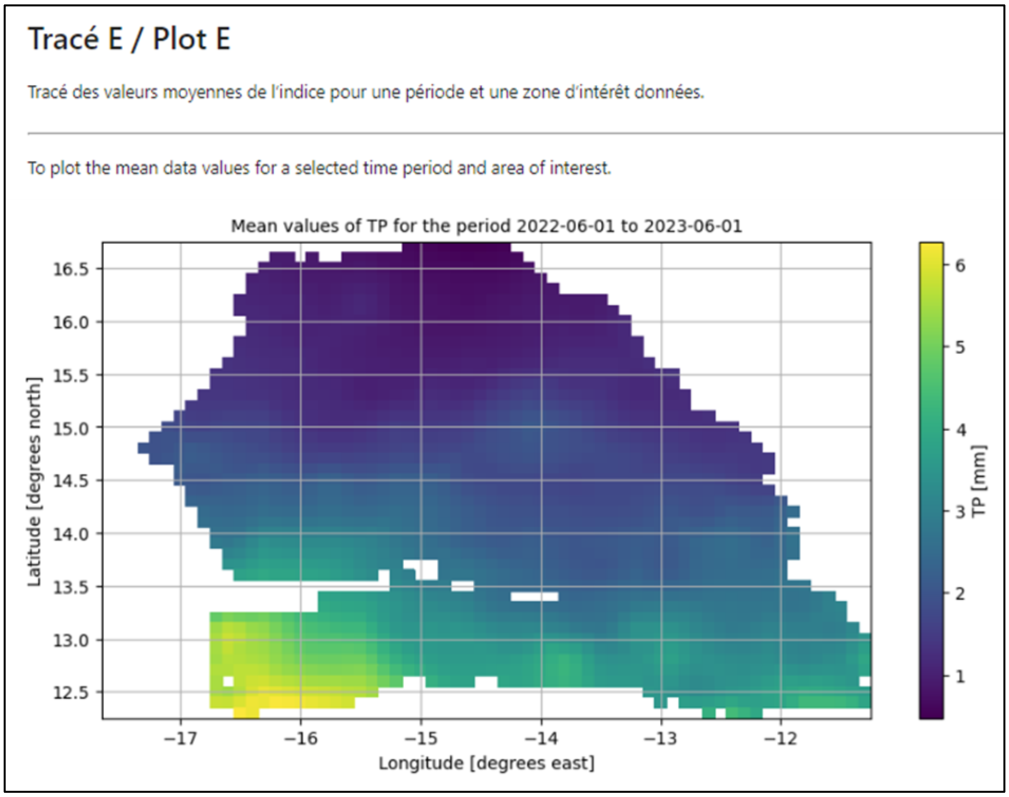


Figure 5-11. Example map plot for Total Precipitation (TP) for the period 2022-06-01 to 2023-06-1 for the whole of Senegal.

7) It is also possible to plot multiple climate indices side-by-side (Step 7, Figure 5-12). Following the same process as above, select two or more climate indices of interest that you have stored in your WASDI workspace. Follow the guidance in the Notebook to select the plot type and adjust the plot variables for the dates and area of interest.

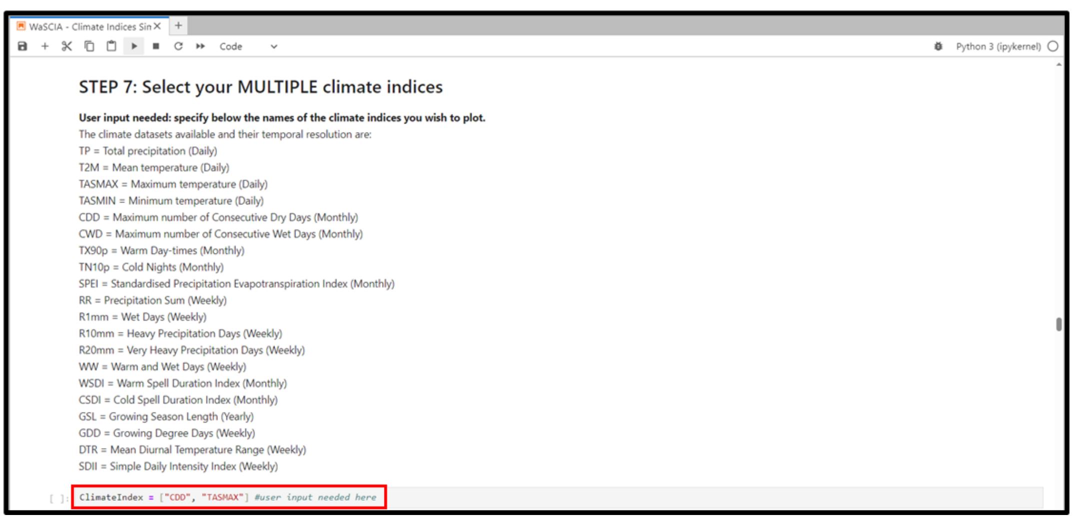


Figure 5-12. Possibility to select two climate indices to analyses on the same plots.

6 THRESHOLD WARNING NOTEBOOK

This notebook has been prepared to enable users to **compare the climatology and the in-season time-series** of a selected climate index.

Designed to sit alongside the user's WASDI workspace. After running the climate indices application (***wascia_processor_climate_indicators***), the notebook will read these output data files directly from the user's workspace.

- **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 the 90th and 10th percentiles of the baseline climatology data for the specific climate index to highlight the climate extremes. This approach accounts for the variability in local climate.
  - **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.

6.1 ACCESSING THE JUPYTER NOTEBOOK

Note: Before using this Jupyter Notebook you need to generate all the climate indices of interest by running the 'WaSCIA Climate Indices' application in WASDI from your personal workspace. The notebook will read these output data files directly from your workspace.

To access the **Jupyter Notebooks**:

1) Download the Warning Threshold Jupyter Notebook from the WaSCIA project website: WaSCIA Publications (Figure 6-1). Save the Notebook to your device.

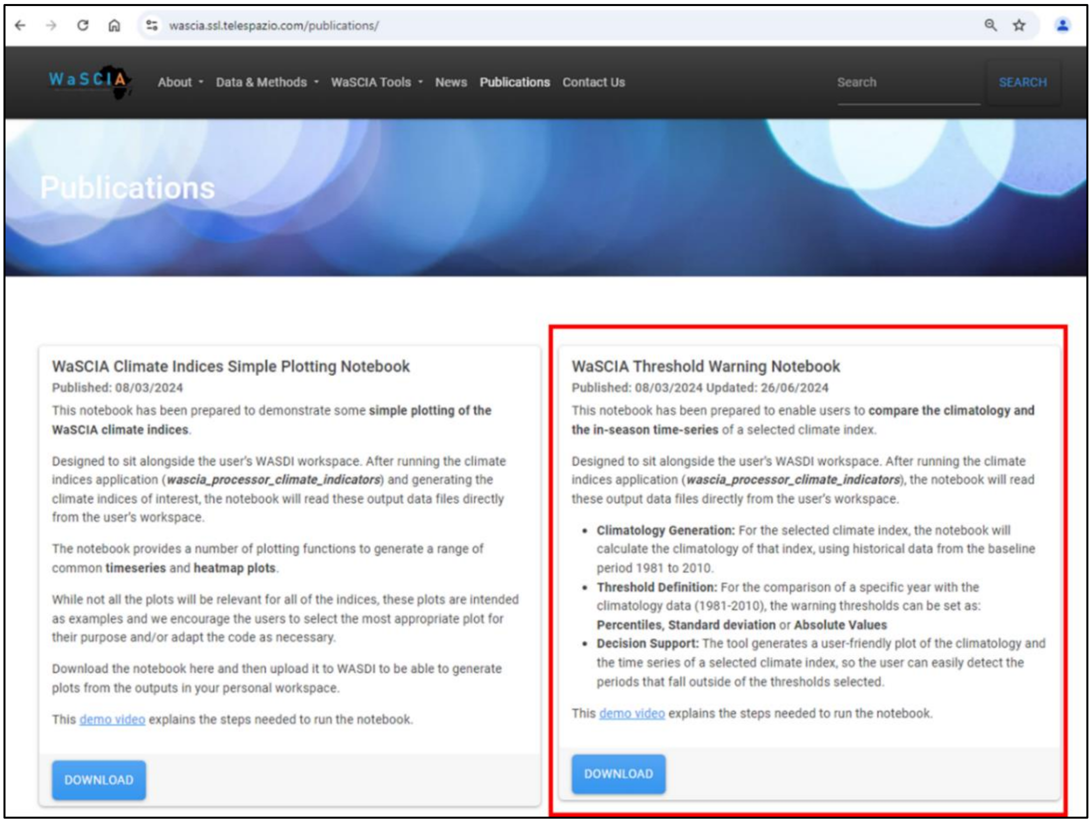


Figure 6-1. Download the Threshold Warning Notebook from the applications tab on the WaSCIA website.

2) Return to your workspace on WASDI and select the '**Notebook'** button highlighted in Figure 6-2.

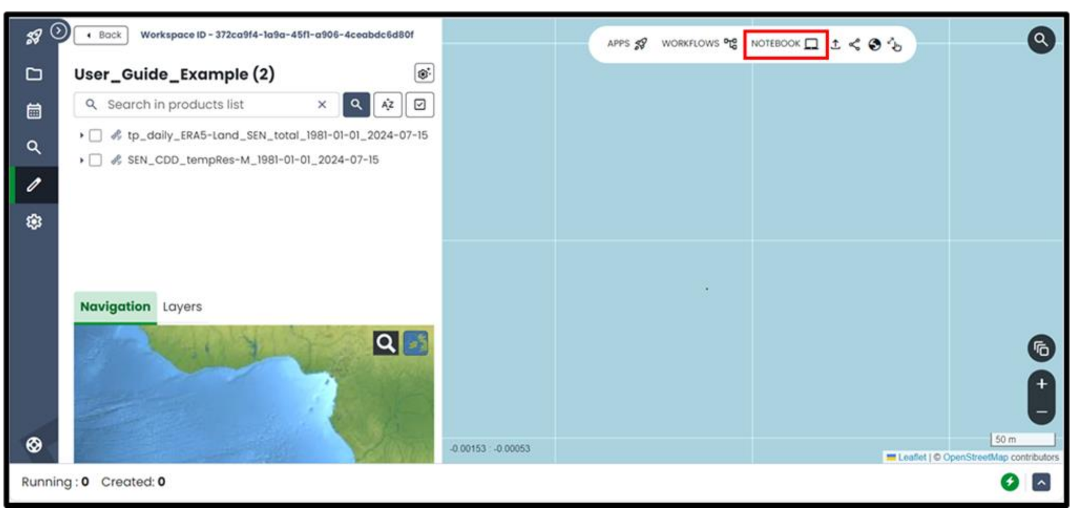


Figure 6-2. Location of the Notebook tab.

3) An **alert pop-up** will inform you that WASDI is preparing your notebook (Figure 6-3) followed by an **update pop-up**, that indicates the Notebook is ready.

   If the Notebook does not automatically open, click on the ***Notebook*** *button again.*

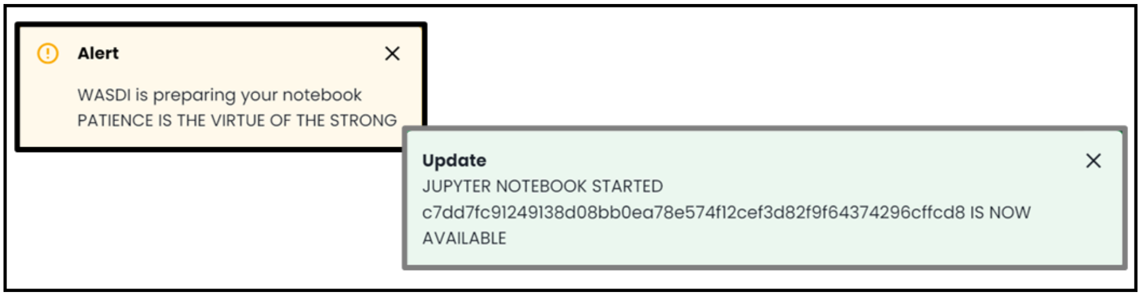


Figure 6-3. Alerts that are shown once clicking on Notebook from the workspace.

4) Moving to the new tab that has opened in your browser, you will now need to upload the Notebooks you downloaded in Step 1. Click on the icon highlighted in Figure 6-4.

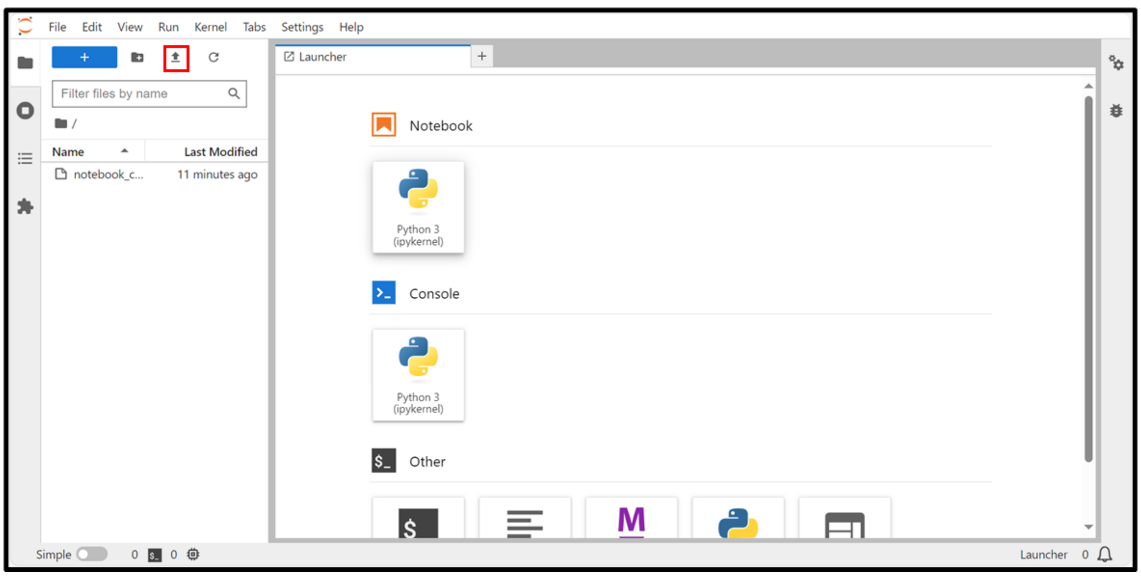


Figure 6-4. Jupyter Notebook window and button for uploading a Notebook.

5) Browse to find the **'WaSCIA – Warning Threshold'** Notebook, select it and upload it. This will load the notebook in the left-hand panel.

6) Select the notebook and it will open in the right-hand window, see Figure 6-5.

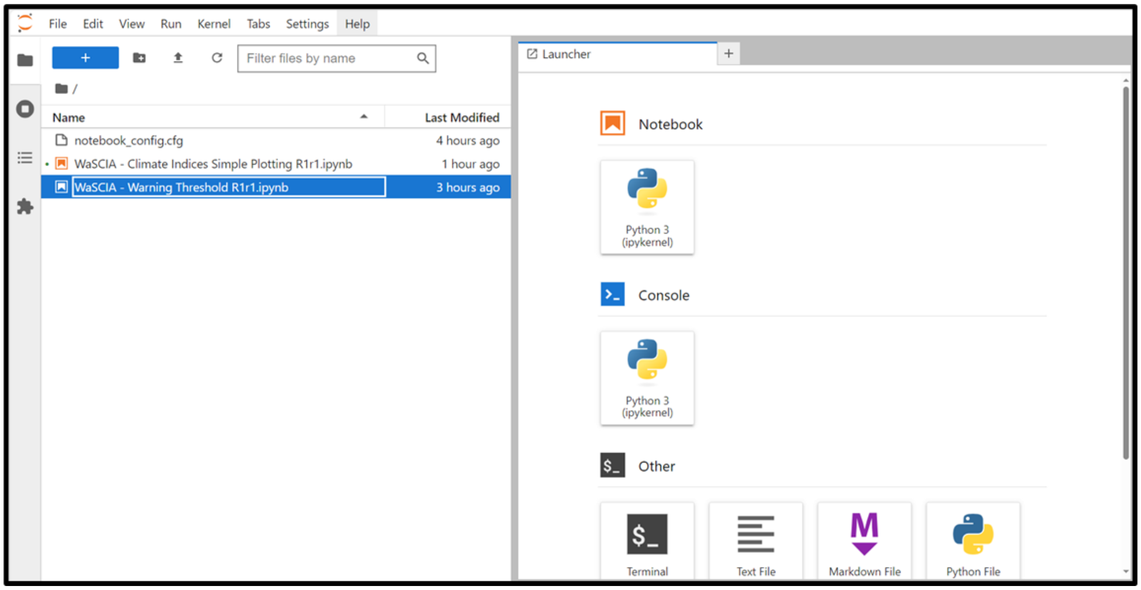


Figure 6-5. Layout of the Jupyter Notebook once the Warning Threshold Notebook has been uploaded.

6.2 RUNNING THE WARNING THRESHOLD NOTEBOOK

Now that you have successfully opened the Notebook, you can start to analyse your data using the following steps:

1) Select the first cell, then select the ‘Run’ icon highlighted in Figure 6-6.
   ***Note:** you will use this icon to run each cell in this Notebook.*

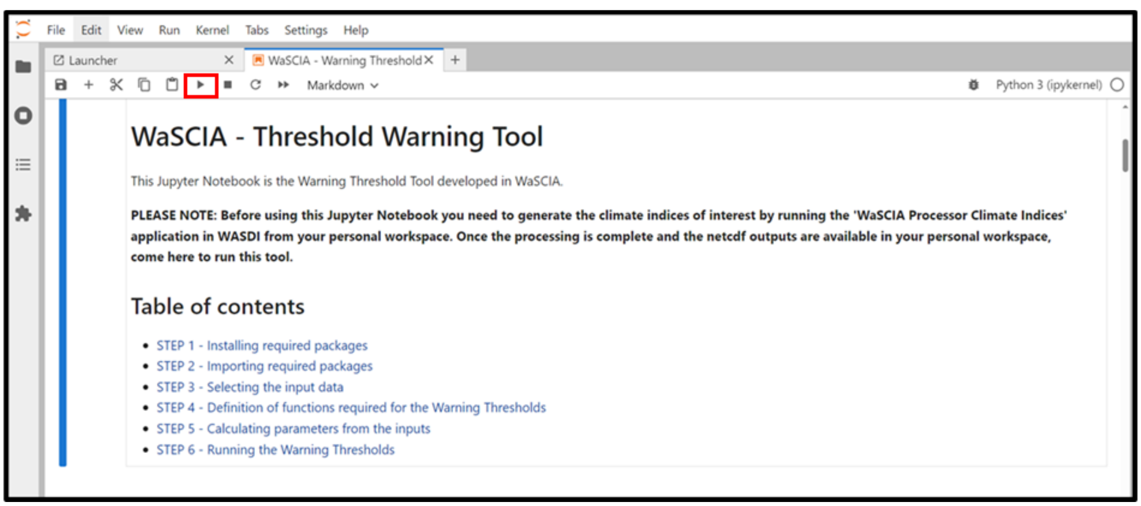


Figure 6-6. Location of the icon needed to run each cell in the Notebook.

2) Run the next cells to install the required libraries (Step 1) and import them into the Notebook (Step 2) (Figure 6-7).
   Note: At this point you will be prompted to enter you WASDI username, password, and the name of the workspace that your data is located within. This connects the Notebook to your WADSI workspace.

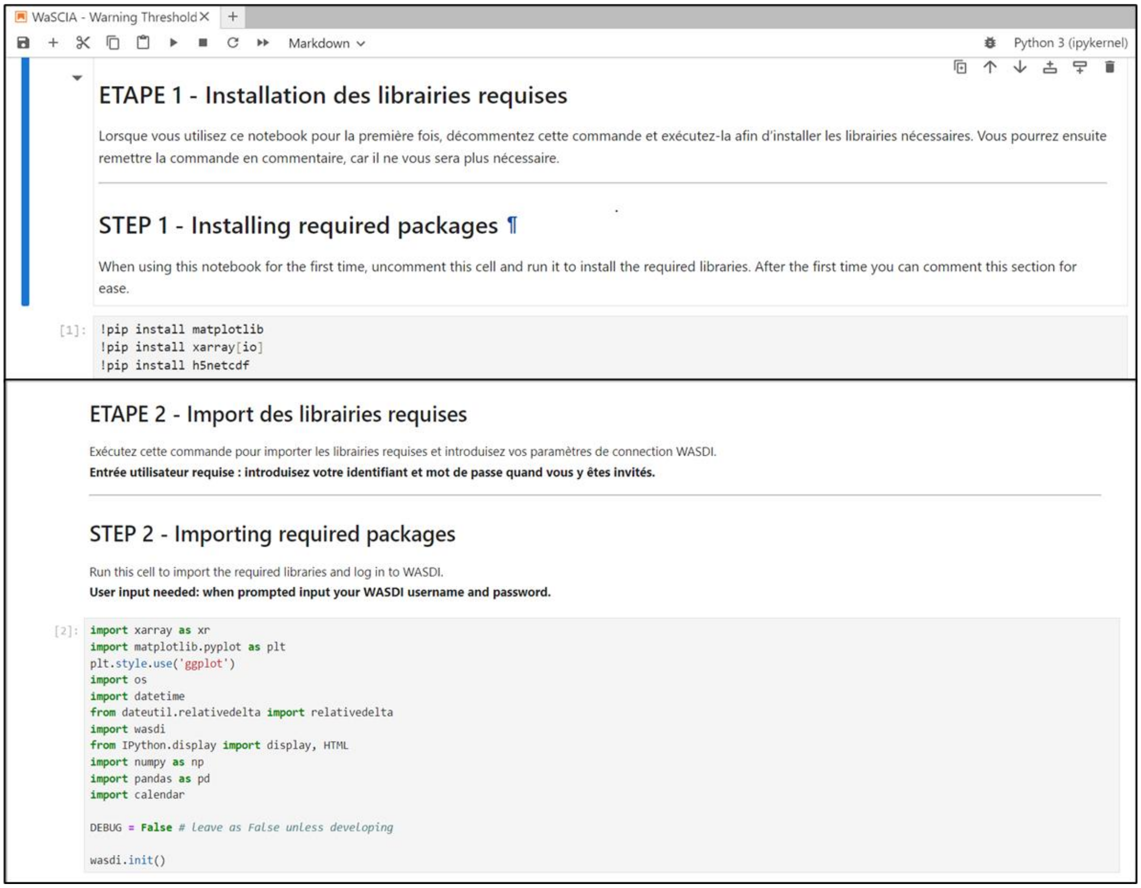


Figure 6-7. Cells that need to be run to install the required libraires.

3) In the next cell (Step 3), specify the name of the **climate index** you wish to analyse (Figure 6-8).

> **Note:** This must be a climate index you have already computed and have stored in your WASDI workspace.

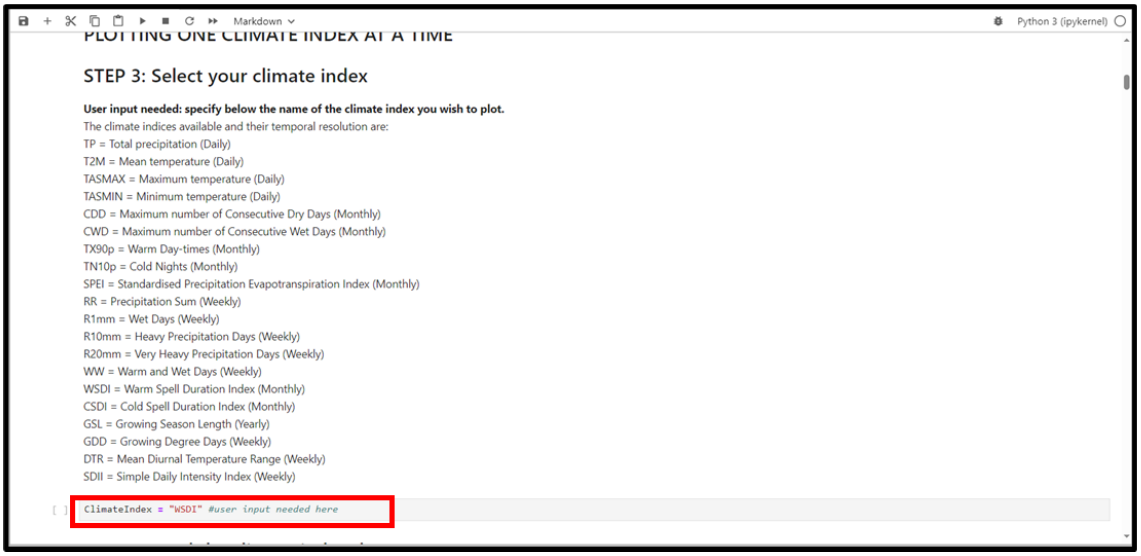


Figure 6-8. Selecting the climate indices for analysis.

4) Specify the ‘**Area of analysis’** from the options provided: the whole of Senegal or define a bounding box using used with the latitude and longitude coordinates of the corners. See Figure 6-9.

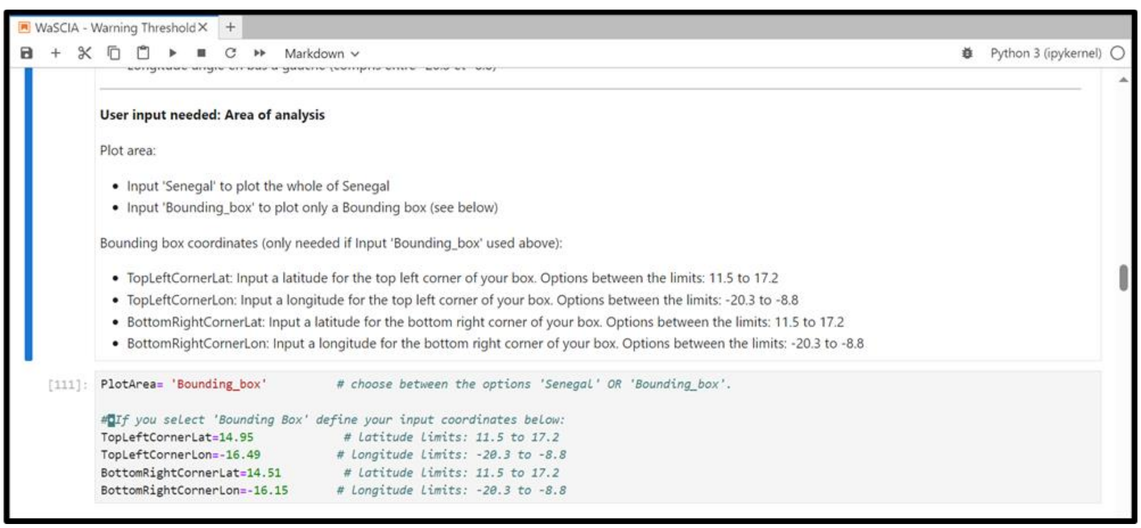


Figure 6-9. Selecting the area of interest for analysis.

5) Specify the **‘Period of analysis’** by selecting a start date, followed by the analysis period in number of months. Figure 6-10 shows an example for the analysis from the 1st of January 2022, for a period of 12 months.

Figure 6-10. Selecting the period of interest.

6) Select the **'Threshold type'** to be used for the analysis, see Figure 6-11. The available options are:
    a. Standard Deviation
    b. Percentile (Set at 10th and 90th percentiles)
    c. An absolute value (a value defined by the user, this can be based on known thresholds or limits).

These thresholds are calculated from the climatology (1991 – 2020) of the climate indices selected.

Figure 6-11. Options available to set the threshold for this analysis.

7) Run the remaining cells of the Notebook to generate two outputs:

- **Threshold Warnings Plot:** The plot is generated for the selected climate index, area of interest, period of interest and thresholds, see Figure 6-12. It shows a comparison between the climate index values and the climatology, by plotting:
    i. The mean climatology for the climate index selected (black dotted line)
    ii. The thresholds specified calculated from the mean climatology for the climate index selected (grey shaded area)
    iii. The values of the climate index for the time period selected (coloured line)

- **Plot Description**: The plot description provides a breakdown of the number of times the upper and lower thresholds were exceeded each month for the chosen time period and location, see Figure 6-13. This allows you to assess how the climate index for period of interest compares to the thresholds selected.

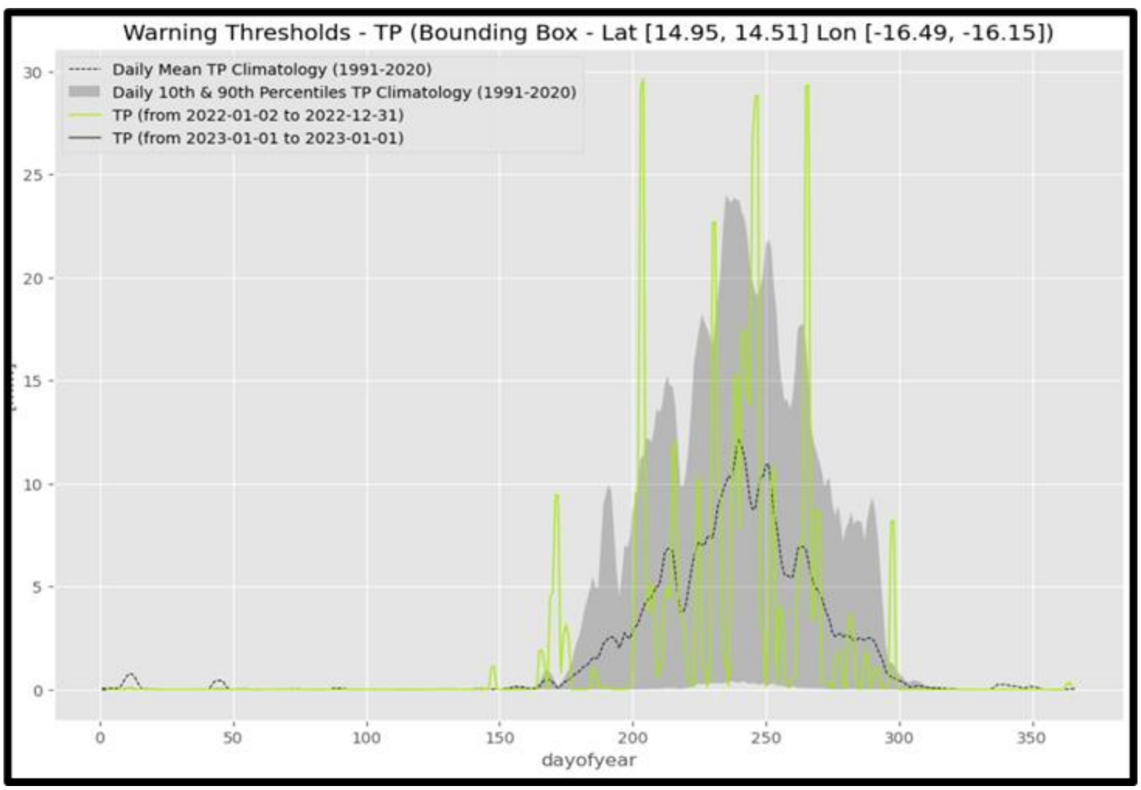


Figure 6-12. Threshold Warning plot.

The plot shows a comparison between the TP climatology data (1991-2020) and the TP data from 2022-01-01 to 2023-01-01 (Bounding Box - Lat [14.95, 14.51] Lon [-16.49, -16.15]):

- **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 5 times in 2022-01.
  - The lower threshold was exceeded 7 times in 2022-02.
  - The lower threshold was exceeded 2 times in 2022-03.
  - The lower threshold was exceeded 4 times in 2022-04.
  - The lower threshold was exceeded 6 times in 2022-05.
  - The lower threshold was exceeded 2 times in 2022-06.
  - The lower threshold was exceeded 1 times in 2022-07.
  - The lower threshold was exceeded 2 times in 2022-08.
  - The lower threshold was exceeded 3 times in 2022-09.
  - The lower threshold was exceeded 2 times in 2022-10.
  - The lower threshold was exceeded 2 times in 2022-11.
  - The lower threshold was exceeded 1 times in 2022-12.
- **There were 37 day(s) below the threshold. The longest period below the threshold was 4 consecutive day(s). This started on 2022-01-04 and lasted until 2022-01-07.**
  - Upper threshold (90th Percentile)
  - The upper threshold was exceeded 2 times in 2022-01.
  - The upper threshold was exceeded 2 times in 2022-03.
  - The upper threshold was exceeded 3 times in 2022-05.
  - The upper threshold was exceeded 11 times in 2022-06.
  - The upper threshold was exceeded 4 times in 2022-07.
  - The upper threshold was exceeded 2 times in 2022-08.
  - The upper threshold was exceeded 5 times in 2022-09.
  - The upper threshold was exceeded 2 times in 2022-10.
  - The upper threshold was exceeded 2 times in 2022-11.
  - The upper threshold was exceeded 3 times in 2022-12.
- **There were 36 day(s) above the threshold. The longest period above the threshold was 8 consecutive day(s). This started on 2022-06-17 and lasted until 2022-06-24.**
- *Please note: The longer that the threshold is exceeded, the greater the potential impact.*

Figure 6-13. Threshold Warning plot description.

7 EXAMPLE OF ANALYSIS OVER A LOCATION IN SENEGAL

This section shows an example of how to use the WaSCIA applications in a case study of December 2022, in Southern Senegal.

7.1 CLIMATE INDICATORS APPLICATION

Run the WaSCIA Climate Indices application (***wascia_processor_climate_indicators***) to generate the climate indices of interest, for the dates of interest. By default, the applications will generate data products for the whole of Senegal.

An example of how the climate indices can be used to identify periods of extreme climate:

➔ **Total precipitation (TP)** can be used to identify periods of low rainfall, e.g**.** during mid-December 2022 which is the dry season (Figure 7-1)

➔ **TASMAX** can be used to identify periods of extreme high temperatures, e.g. above 34.8°C in mid-December 2022 (Figure 7-2)

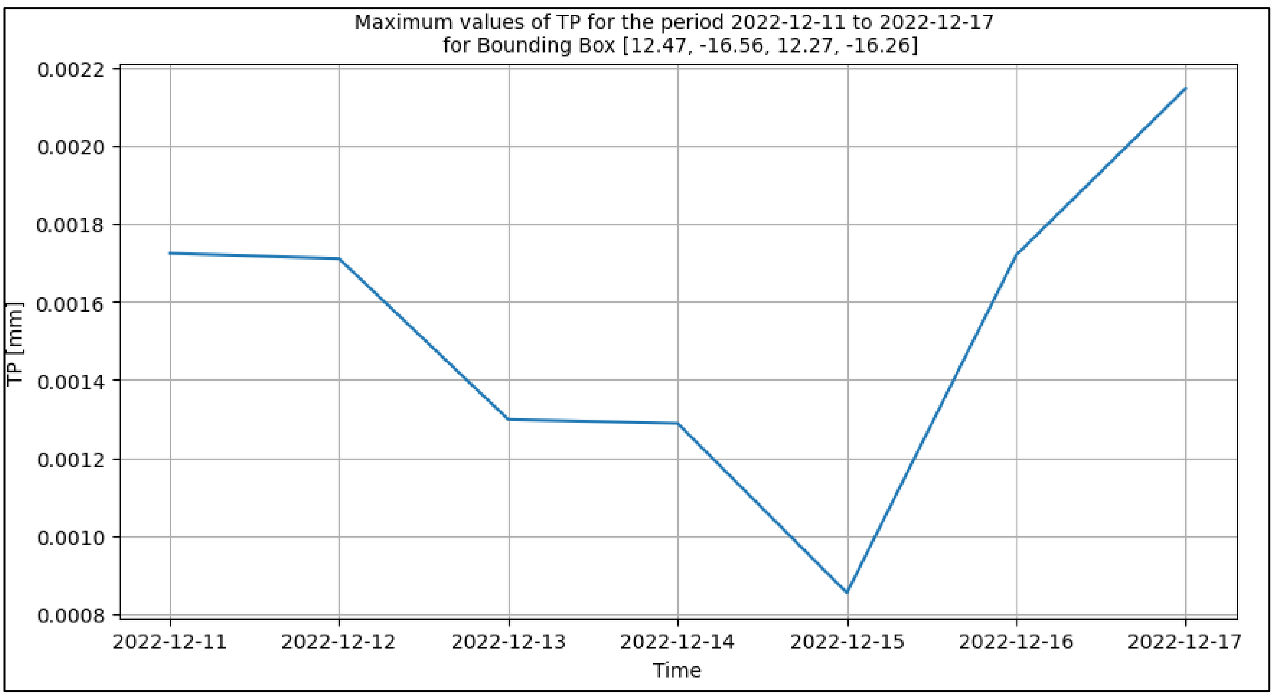


Figure 7-1. Maximum daily precipitation between 11th December 2022 and the 17th of December 2022.

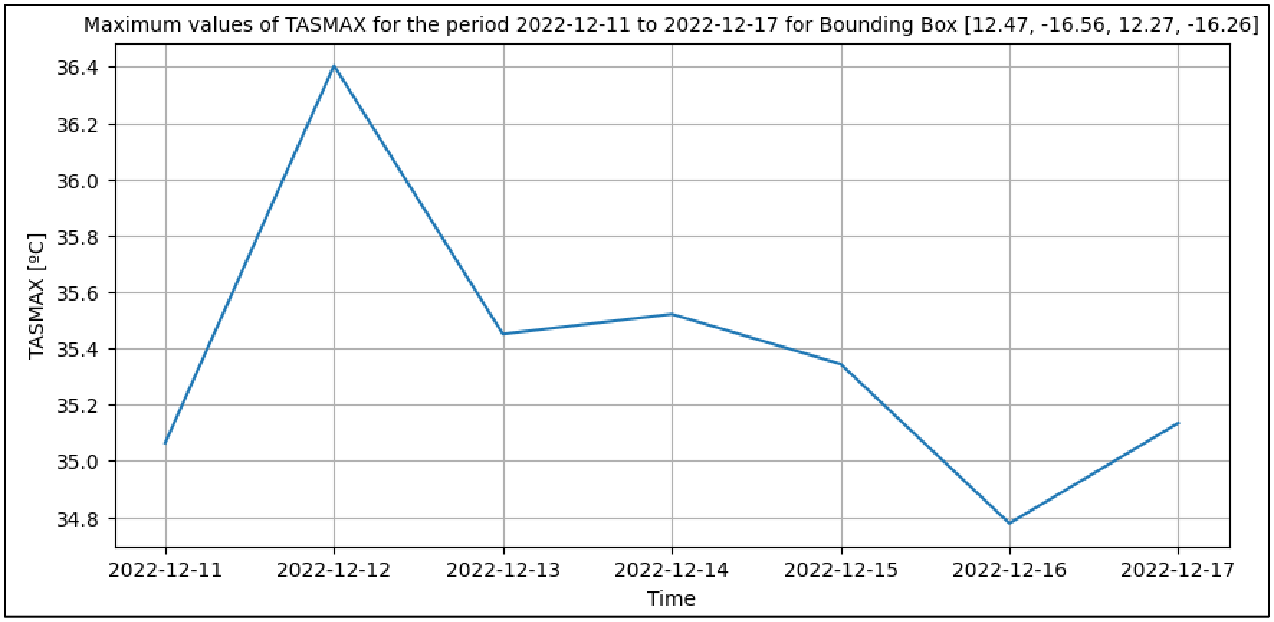


Figure 7-2. Maximum temperatures between 11th December 2022 and the 17th of December 2022.

7.2 HydroSENS-SWS Application

Run the WaSCIA HydroSENS-SWS application (***wascia_hydrosens-sws***) for the dates of interest for whole of Senegal. Analyse the results in the context of the climate indices results.

Figure 7-3 shows the evapotranspiration and soil moisture outputs of the wascia_hydrosens-sws application. In this output we see :

- ➔ **Soil moisture and evapotranspiration** are (relatively) high in some areas despite the lack of precipitation
  - o Analysis carried out shortly after the rainy season (December 2022)

- ➔ There is a **gradual decrease** in soil moisture and evapotranspiration (moving away from the last rainy season into January 2023).

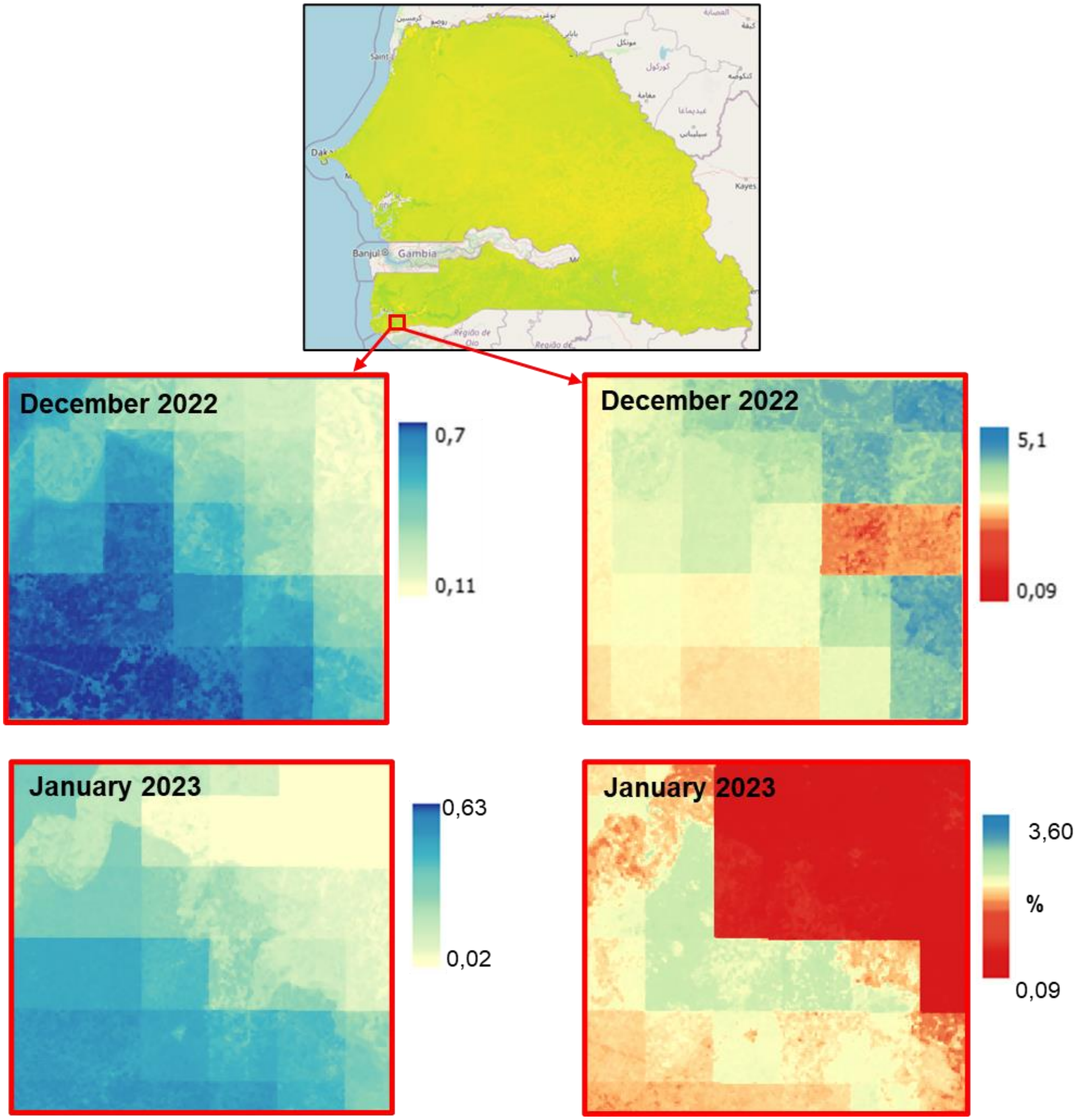


Figure 7-3. Examples of the output from the *wascia_hydrosens-sws application. Top centre - Location of analysis. Middle (left) – evapotranspiration Dec 2022, (right) soil moisture Dec 2022. Bottom (left) evapotranspiration Jan 2023, (right) soil moisture Jan 2023.*

8 COMMON ISSUES AND BUGS

Here are some of the common issues and bugs that can be encountered when running the WaSCIA applications.

8.1 HYDROSENS-SWS APPLICATION

When selecting the Study Area for downscaling, (Section 3.2) there are a number of known errors and bugs.

1) **Display problem** (Figure 8-1).

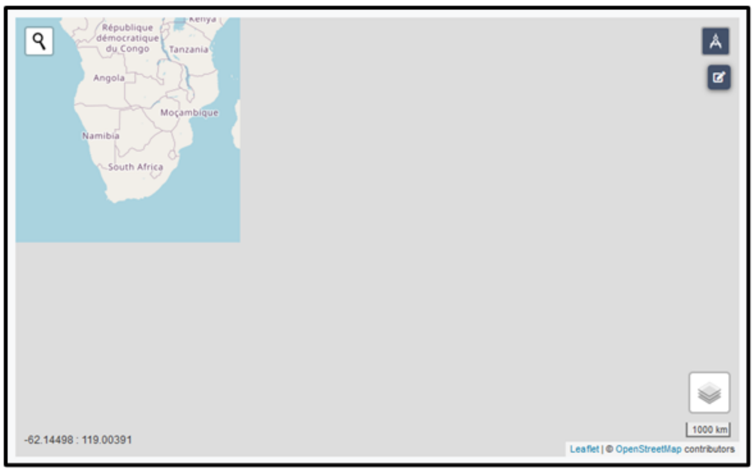
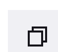


Figure 8-1. Display issue that commonly occurs.

To display the map correctly, please minimize  your browser window and then maximise it again. This should fix the display issue.

2) **Polygon size** is limited. If the Study Area you select is too large, you will see this pop-up alert (Figure 8-2).

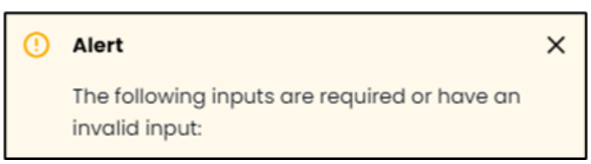


Figure 8-2. Alert message that is shown as a result of selecting an invalid area.

To resolve this please select a smaller area (less than 1000 km^2).

8.2 CLIMATE INDICES SIMPLE PLOTTING NOTEBOOK

When running the Jupyter Notebook, there are a number of things to remember to ensure your plots are generated correctly.

1) **User inputs: within expected range**
   Please choose inputs for your plots from the range of available values. If you choose values outside this range, the plots will be generated empty.

   The user inputs needed and available ranges are:

   a. **Plot start and end dates** (in the format YYYY-MM-DD)

      PlotStartDate: choose any date from the period available 1981-01-01 - (present - 5 days)

      PlotEndDate: choose any date from the period available 1981-01-01 - (present - 5 days)

   b. **Plot area** (Senegal or Bounding_box)

      PlotArea: Input 'Senegal' to plot the whole of Senegal

      PlotArea: Input 'Bounding_box' to plot only a Bounding box (see below)

   c. **Bounding box coordinates** (in the format XX.x) (only needed if Input 'Bounding_box' used above):

      TopLeftCornerLat: Input a latitude for the top left corner of your box. Options between the limits: 11.5 to 17.2

      TopLeftCornerLon: Input a longitude for the top left corner of your box. Options between the limits: -20.3 to -8.8

      BottomRightCornerLat: Input a latitude for the bottom right corner of your box. Options between the limits: 11.5 to 17.2

      BottomRightCornerLon: Input a longitude for the bottom right corner of your box. Options between the limits: -20.3 to -8.8

User inputs needed:

Plot start and end dates:

- PlotStartDate: choose any date from the period available 1981-01-01 - (present - 5 days)
- PlotEndDate: choose any date from the period available 1981-01-01 - (present - 5 days)

Plot area:

- PlotArea: Input 'Senegal' to plot the whole of Senegal
- PlotArea: Input 'Bounding_box' to plot only a Bounding box (see below)

Bounding box coordinates (only needed if Input 'Bounding_box' used above):

- TopLeftCornerLat: Input a latitude for the **top left corner** of your box. Options between the limits: 11.5 to 17.2
- TopLeftCornerLon: Input a longitude for the **top left corner** of your box. Options between the limits: -20.3 to -8.8
- BottomRightCornerLat: Input a latitude for the **bottom right corner** of your box. Options between the limits: 11.5 to 17.2
- BottomRightCornerLon: Input a longitude for the **bottom right corner** of your box. Options between the limits: -20.3 to -8.8

```
## Plot A

## user inputs needed
PlotStartDate= '1981-01-01'      # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotEndDate= '2024-07-30'        # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotArea= 'Bounding_box'         # choose between the options 'Senegal' OR 'Bounding_box'. If you select 'Bounding Box' define your input coordinates below:
TopLeftCornerLat=14.0            # latitude limits: 11.5 to 17.2
TopLeftCornerLon=-16.0           # longitude limits: -20.3 to -8.8
BottomRightCornerLat=13.0        # latitude limits: 11.5 to 17.2
BottomRightCornerLon=-15.0       # longitude limits: -20.3 to -8.8
```

Figure 8-3. User inputs needed for the Climate Indices plots.

2) **User inputs: plot start and end dates**
Please input the start and end dates in the desired format (YYYY-MM-DD) **ONLY** to ensure that they are recognised by the code.

User inputs needed:

Plot start and end dates:

- PlotStartDate: choose any date from the period available 1981-01-01 - (present - 5 days)
- PlotEndDate: choose any date from the period available 1981-01-01 - (present - 5 days)

Plot area:

- PlotArea: Input 'Senegal' to plot the whole of Senegal
- PlotArea: Input 'Bounding_box' to plot only a Bounding box (see below)

Bounding box coordinates (only needed if Input 'Bounding_box' used above):

- TopLeftCornerLat: Input a latitude for the **top left corner** of your box. Options between the limits: 11.5 to 17.2
- TopLeftCornerLon: Input a longitude for the **top left corner** of your box. Options between the limits: -20.3 to -8.8
- BottomRightCornerLat: Input a latitude for the **bottom right corner** of your box. Options between the limits: 11.5 to 17.2
- BottomRightCornerLon: Input a longitude for the **bottom right corner** of your box. Options between the limits: -20.3 to -8.8

```
## Plot A

## user inputs needed
PlotStartDate= '1981-01-01'      # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotEndDate= '2024-07-30'        # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotArea= 'Bounding_box'         # choose between the options 'Senegal' OR 'Bounding_box'. If you select 'Bounding Box' define your input coordinates below:
TopLeftCornerLat=14.0            # latitude limits: 11.5 to 17.2
TopLeftCornerLon=-16.0           # longitude limits: -20.3 to -8.8
BottomRightCornerLat=13.0        # latitude limits: 11.5 to 17.2
BottomRightCornerLon=-15.0       # longitude limits: -20.3 to -8.8
```

Figure 8-4. Correct input format for plot start and end dates (YYYY-MM-DD)

3) **User inputs: coordinates**

When plotting only a Bounding box, you are asked to specify the corner coordinates. Please input the coordinates in the desired format (XX.x) **ONLY** to ensure that they are recognised by the code. Please use a decimal point (.) and not a comma (,).

User inputs needed:

Plot start and end dates:

- PlotStartDate: choose any date from the period available 1981-01-01 - (present - 5 days)
- PlotEndDate: choose any date from the period available 1981-01-01 - (present - 5 days)

Plot area:

- PlotArea: Input 'Senegal' to plot the whole of Senegal
- PlotArea: Input 'Bounding_box' to plot only a Bounding box (see below)

Bounding box coordinates (only needed if Input 'Bounding_box' used above):

- TopLeftCornerLat: Input a latitude for the **top left corner** of your box. Options between the limits: 11.5 to 17.2
- TopLeftCornerLon: Input a longitude for the **top left corner** of your box. Options between the limits: -20.3 to -8.8
- BottomRightCornerLat: Input a latitude for the **bottom right corner** of your box. Options between the limits: 11.5 to 17.2
- BottomRightCornerLon: Input a longitude for the **bottom right corner** of your box. Options between the limits: -20.3 to -8.8

```
## Plot A

## user inputs needed
PlotStartDate= '1981-01-01'      # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotEndDate= '2024-07-30'        # choose any date from the period available 1981-01-01 - [present - 5 days]
PlotArea= 'Bounding_box'         # choose between the options 'Senegal' OR 'Bounding_box'. If you select 'Bounding Box' define your input coordinates below:
TopLeftCornerLat=14.0            # latitude limits: 11.5 to 17.2
TopLeftCornerLon=-16.0           # longitude limits: -20.3 to -8.8
BottomRightCornerLat=13.0        # latitude limits: 11.5 to 17.2
BottomRightCornerLon=-15.0       # longitude limits: -20.3 to -8.8
```

Figure 8-5. Correct input format for Bounding box coordinates (decimal points have been used)

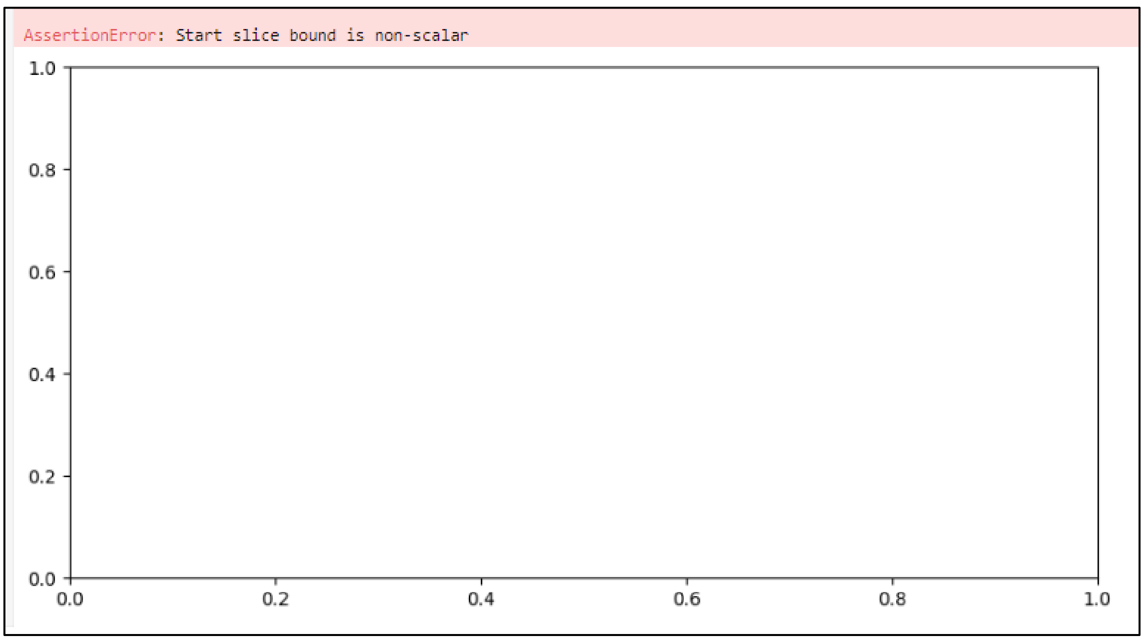


Figure 8-6. Plot error received when commas are used in the input Bounding box coordinates.

[End of Document]