Technical Review of USER MANUAL FOR SEN-ET SNAP PLUGIN V1.1.0 March 19, 2020

By

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Introduction

This review is including a stepwise of pre-processing Sentinel 3 (S3), and Sentinel 2 (S2), in order to create a step by step tutorial, and help with possible fails or errors that could occur when running the plug-in for the first time. It is not our aim to repeat the points that have been explained in the SEN-ET manual (A). This report goes step by step, processing the S3, and S2 data, and pointed out important notes that can be of guidance for all users. Other relevant issues and errors have been debriefed in the STEP-FORUM as well (B).

In some occasions, multi flowchart alternative processes have been explained, to give users the freedom and flexibility of implementing their stepwise processes more easily.

SNAP configuration with Python 3.6

The SNAP configuration with python has been well explained in here (C), however, for Windows users, and Python users not Anaconda or Miniconda, the following notes are worth noticing.

As a general note never mix conda, and pip for any python packages installations, because this could be influencing other applications and platforms, be advised to select only pip or conda.

As it is suggested in the main manual SEN_ET to configure SNAP with Python 3.6, please follow the upcoming notes:

A – In $C:\ drive create a folder, name it for example python36.

B – Download python 3.6 version that is compatible with your system from the following website (D) start installation and navigate to the folder that has been created within C:\pyton36;

untick the two boxes of the path, thisis in case of another python version was already added up to the path[1], .

C – Follow the upcoming points in order to create virtual environment,

First: Open Command Prompt and enter pip install virtualenv.

Second: Download the desired python version (do NOT add to PATH!), and remember the path\to\new_python.exe of the newly installed version, this point has been done as it has been explained above.

Third: To create a virtualenv, open Command Prompt and enter, virtualenv \path\to\env -p path\to\new_python.exe

As it is also recommended to create the virtual environment folder in C:\VENV.

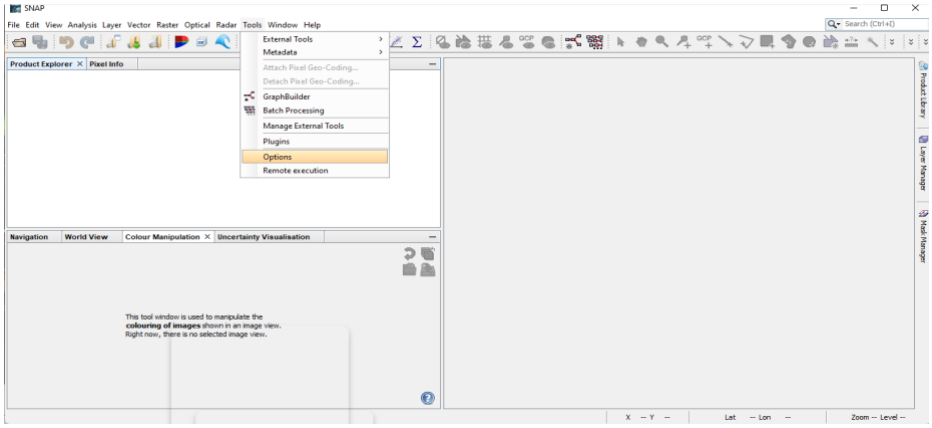
[1] Or if the user does not want to add the path to the computer system, the choice is free.

Now the virtual environment of python3.6 is ready to be configured with SNAP, easily and smoothly.

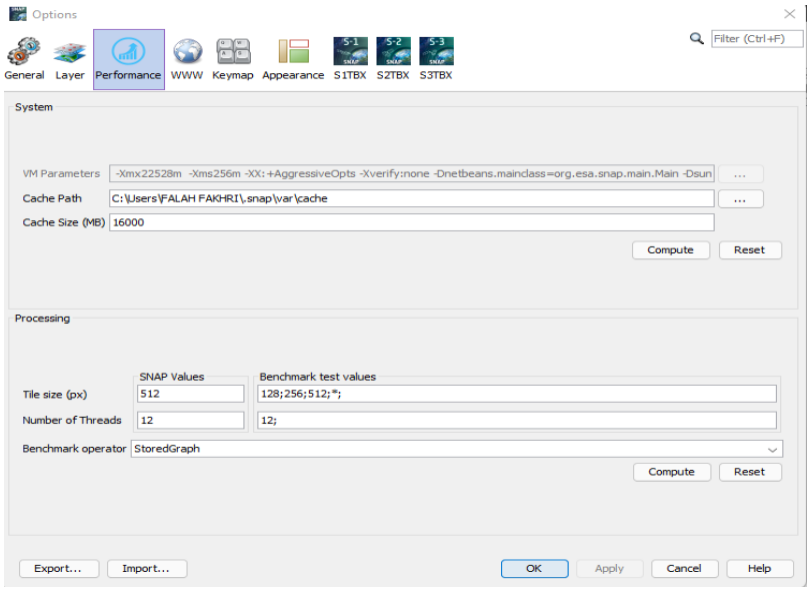
System requirements and installation

As it is stated very clear in the main SEN_ET document at paragraph 3.1 “the system requirements,” one important point is that around 20 GB of RAM are required, and even the more the better.

Launch SNAP and navigate to the tools tab and this option as it is depicted below,



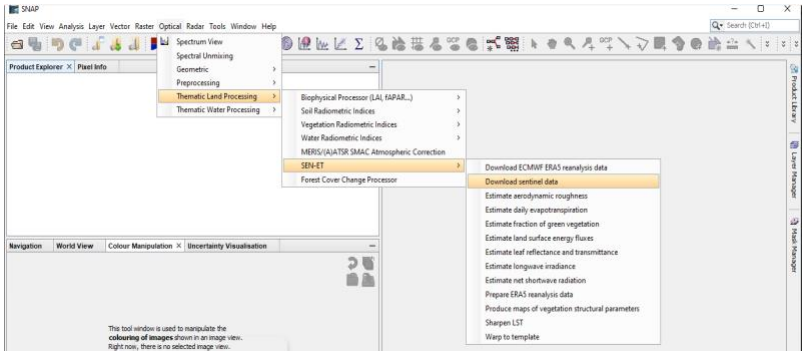
A new panel will appear. From the performance, change the Cache Size (Mb). It is recommended to be 70 % - 80 % of the total RAM. In the example less than this suggestion is used, only 16 GB of the total 32 GB- Then press apply tab and cick ok.



The installation of Sen-ET SNAP plugin explained in paragraph 3.2 of the official tutorial. Now the user is ready to download,and install it.

Download S2 and S3 images

Many options are available via the SEN_ET plug-in. However, the open Hub from (E) gives more flexibility of searching and using the Graphical User Interface GUI map to easily determine the area of interest AOI, without a need to previous creating geojson AOI, and avoid any error of offline products.



Some notes related to the Name and Date of the images:

- **S2 naming convention**

The compact naming convention is arranged as follows:

MMM_MSIXXX_YYYYMMDDHHMMSS_Nxxyy_ROOO_Txxxxx_<Product Discriminator>.SAFE

The products contain two dates:

The first date (YYYYMMDDHHMMSS) is the datatake of the sensing time.

The second date is the "<Product Discriminator>" field, which is 15 characters in length, and is, used to distinguish between different end user products from the same datatake. Depending on the instance, the time in this field can be earlier or slightly later than the datatake sensing time.

The other components of the filename are:

MMM: is the mission ID(S2A/S2B)

MSIXXX: MSIL1C denotes the Level-1C product level/ MSIL2A denotes the Level-2A product level

YYYYMMDDHHMMSS: the datatake sensing start time

Nxxyy: the PDGS Processing Baseline number (e.g. N0204)

ROOO: Relative Orbit number (R001 - R143)

Txxxxx: Tile Number field

SAFE: Product Format (Standard Archive Format for Europe)

For more information related to the S2 name, please visit (F)

An example of file name,

S2A_MSIL2A_20210829T074611_N0301_R135_T38SLF_20210829T104722

- **S3 naming convention**

Before selecting the S3 image, let's have a look at the naming convention of the S3 image,

According to the (E) the following points are clearly showing the meaning of the S3 name.

MMM_SL_L_TTTTTT_yyyymmddThhmmss_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_[instance ID]_GGG_[class ID].SEN3

Where:

MMM is the mission ID:

S3A = SENTINEL-3A

S3B = SENTINEL-3B

S3_ = for both SENTINEL-3A and 3B

SL is the data source/consumer (SL = SLSTR)

L is the processing level

"0" for Level-0

"1" for Level-1

"2" for Level-2

underscore "_" if processing level is not applicable

TTTTTT is the data Type ID

Level 0 SLSTR data:

"SLT___" = ISPs.

Level-1 SLSTR data:

"RBT___" = TOA Radiances and Brightness Temperature

"RBT_BW" = browse product derived from "RBT___".

Level-2 SLSTR data:

"WCT___" = 2 and 3 channels SST for nadir and along track view

"WST___" = L2P sea surface temperature

"LST___" = land surface temp

"FRP___" = Fire Radiative Power

"WST_BW" = browse product derived from "WST___"

"LST_BW" = browse product derived from "LST___".

yyyymmddThhmmss is the sensing start time

YYYYMMDDTHHMMSS is the sensing stop time

YYYYMMDDTHHMMSS is the product creation date

[instance ID] consists of 17 characters, either uppercase letters or digits or underscores "_".

The instance id fields include the following cases, applicable as indicated:

1. Instance ID for the instrument data products disseminated in "stripes":

Duration,"_", cycle number, "_", relative orbit number,"_", 4 underscores "_", i.e.
DDDD_CCC_LLL_____
2. Instance ID for the instrument data products
disseminated in "frames":
Duration, "_", cycle number, "_", relative orbit number, "_", frame along track coordinate, i.e.
DDDD_CCC_LLL_FFFF
3. Instance ID for the instrument data products disseminated in "tiles".
Two sub-cases are applicable:
a) tile covering the whole globe:
"GLOBAL_____"
b) tile cut according to specific
geographical criteria:
Tile Identifier
ttttttttttttttttt
4. Instance ID for auxiliary data:
17 underscores "_"

GGG identifies the centre which generated the file

[class ID] identifies the class ID for instrument data products with conventional sequence P_XX_NNN where:

P indicates the platform (O for operational, F for reference, D for development, R for reprocessing)

XX indicates the timeliness of the processing workflow (NR for NRT, ST for STC, NT for NTC)

NNN indicates the baseline collection or data usage.

.SEN3 is the filename extension

Example of filename:

S3B_SL_2_LST____20210830T071446_20210830T071746_20210831T183516_0179_056_220_2340_LN2_O_NT_004.zip.

- **Time selection of S2, and S3**

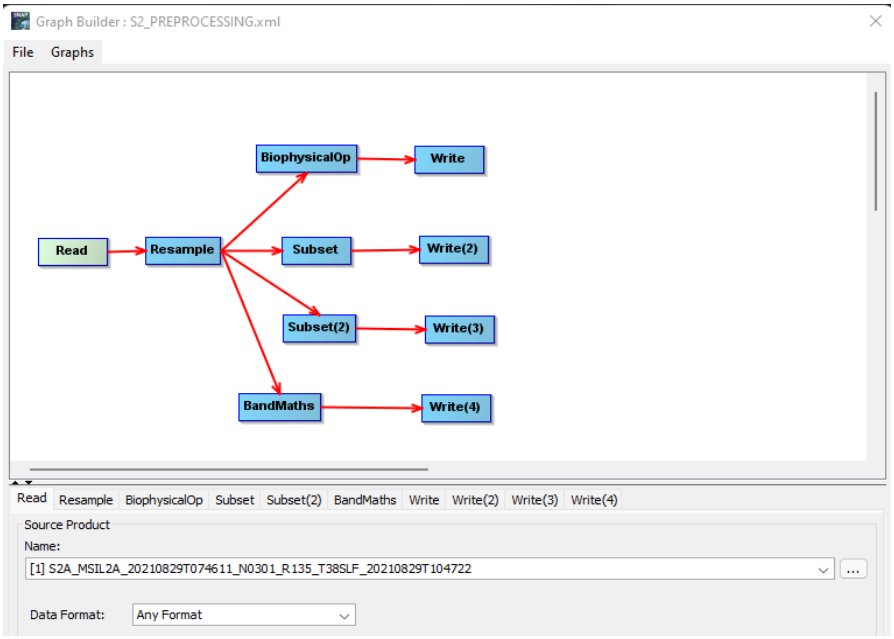
After this detail on the explanation of the S2 and S3 name convention, we will focus on the the time for selecting S3 images. This is preferaby during mornings with low cloudiness and low view zenith angle. The time of S3 should be compatible with the time of S2, for more details please read (G).

Sentinel 2 processing

1. Pre-processing

A series of processing steps will be explained in stepwise points. If the user has her/his own way of doing the S2-pre-process using python, snappy or GPT, it is out scope of this review. The aim here, as pointed out previously, is to simplify the main manual of SEN_ET, and overcoming some errors.

The pre-process graph is located in the "graphs" folder (home/*name_of_user*/.snap/graphs) and it is called "sentinel_2_pre_processing.xml". To open it, go to Tools/Graph Builder/Load. By the default the Load points to the graphs folder. Select the file and the graph will be displayed in the Graph Builder tool. The downloaded L2A Sentinel-2 scene (example below) will be chosen and the pre-process will start over the whole scene. This process can take from several minutes to several hours, depending on the capacity of the computer.

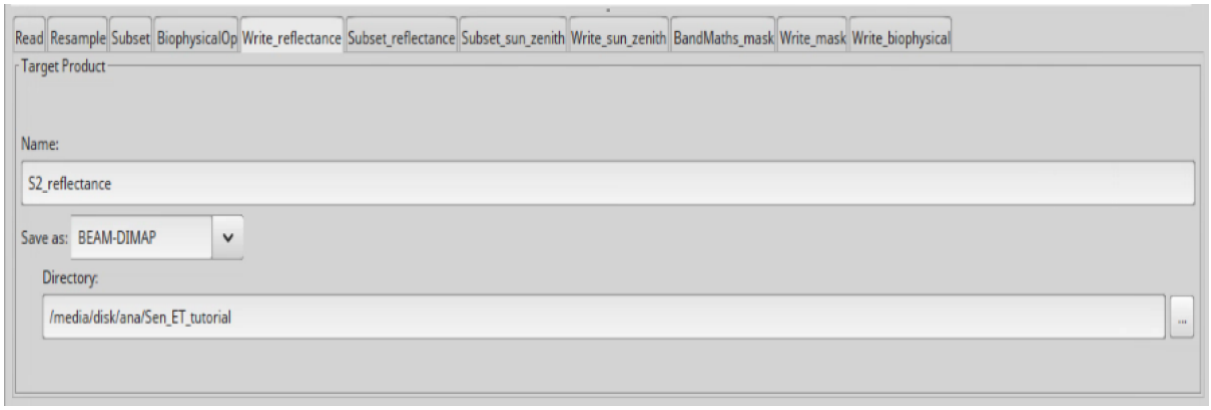


Output of the first pre-process is,

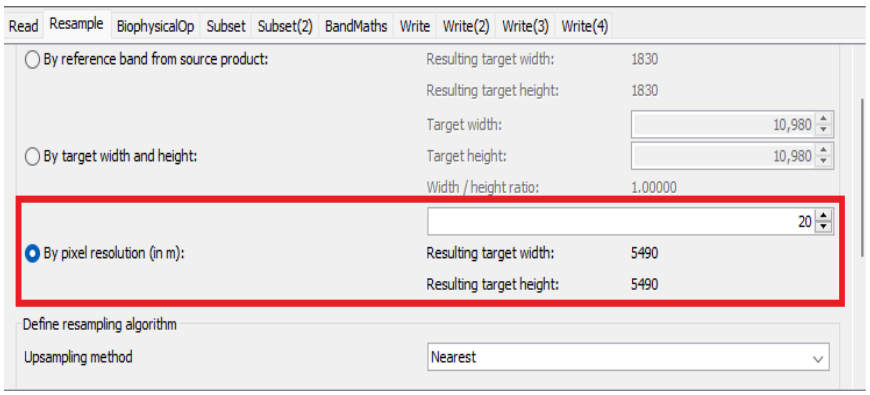
- S2_biophysical parameters (LAI, FAPAR, Fcover, Cab, Cw),
- S2_reflectance - product containing the 20 m reflectance bands (B2, B3, B4, B5, B6, B7, B8A, B11, B12)
- S2_mask - product containing cloud mask derived from scene quality flags
- S2_sun_zenith_angle - product containing the scene sun zenith angle band.

The parameters required to do the pre-processing have to be specified for each processor in the graph. There are 5 processors and 4 products to write. Each write function requires to specify the whole path where it is going to be saved (Directory path), and a comprehensive band name (for instance

"S2_reflectance" in the figure below). It is advisable to change the default names, to avoid mistakes when pre-processing the S3 data later.



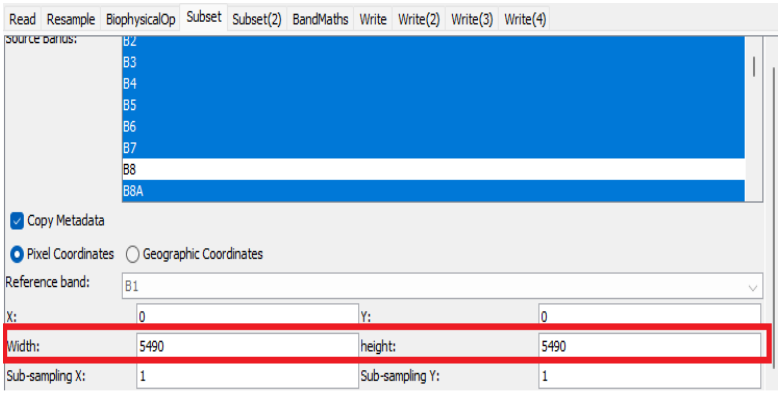
In the Resample function the user can resample the scene by reference band (i.e., band B5 (705 nm), B6 (740 nm), B7 (783 nm), B8b (865 nm), B11 (1610 nm) and B12 (2190 nm), or by specifying the 20-meter pixel resolution by hand.

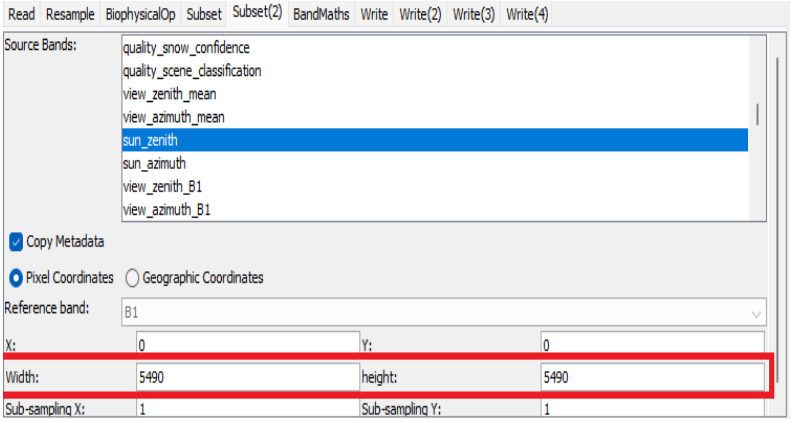


An important point should be noticed while subseting the bands, or the sun_zenith angle, the UI subset graph does not work properly, when selecting a reference band: the width and height are not updated accordingly. The GUI should validate if the entered coordinates [x,y,w,h] are valid for the reference band, please have a look at details of problem in the following link,

https://forum.step.esa.int/t/s2-resampling-on-a-subset-not-supported/21410/23?u=falahfakhri

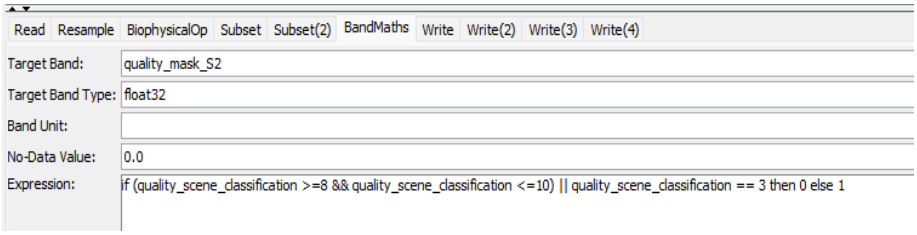
To solve this problem, specify the number of rows and columns of the 20-meter band resolution, which they equal to 5490 * 5490, width, and height respectively, same thing is applied to the subset of sun_zenith angle, as are depicted in the figures below,

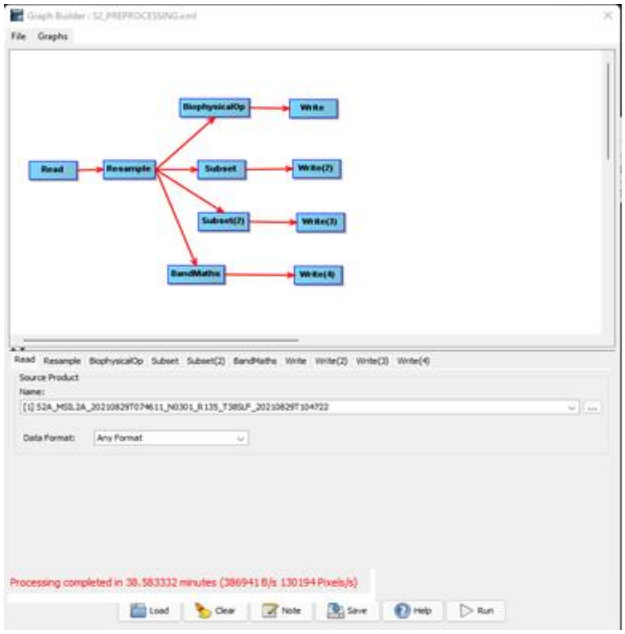




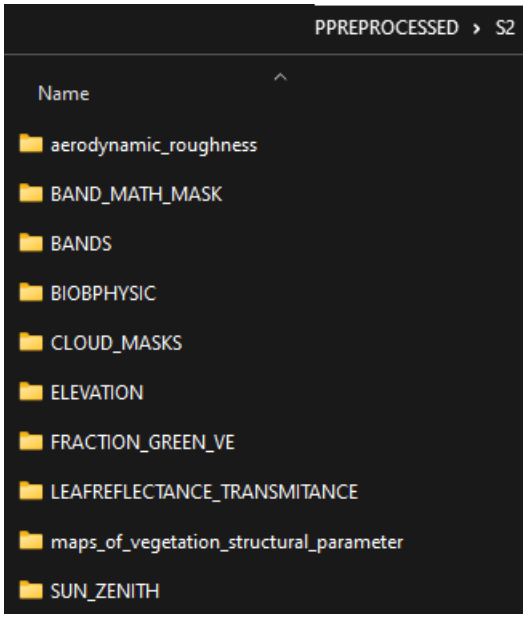
Create a new mask band by applying the following equation,

if (quality_scene_classification >=8 && quality_scene_classification <=10) || quality_scene_classification == 3 then 0 else 1



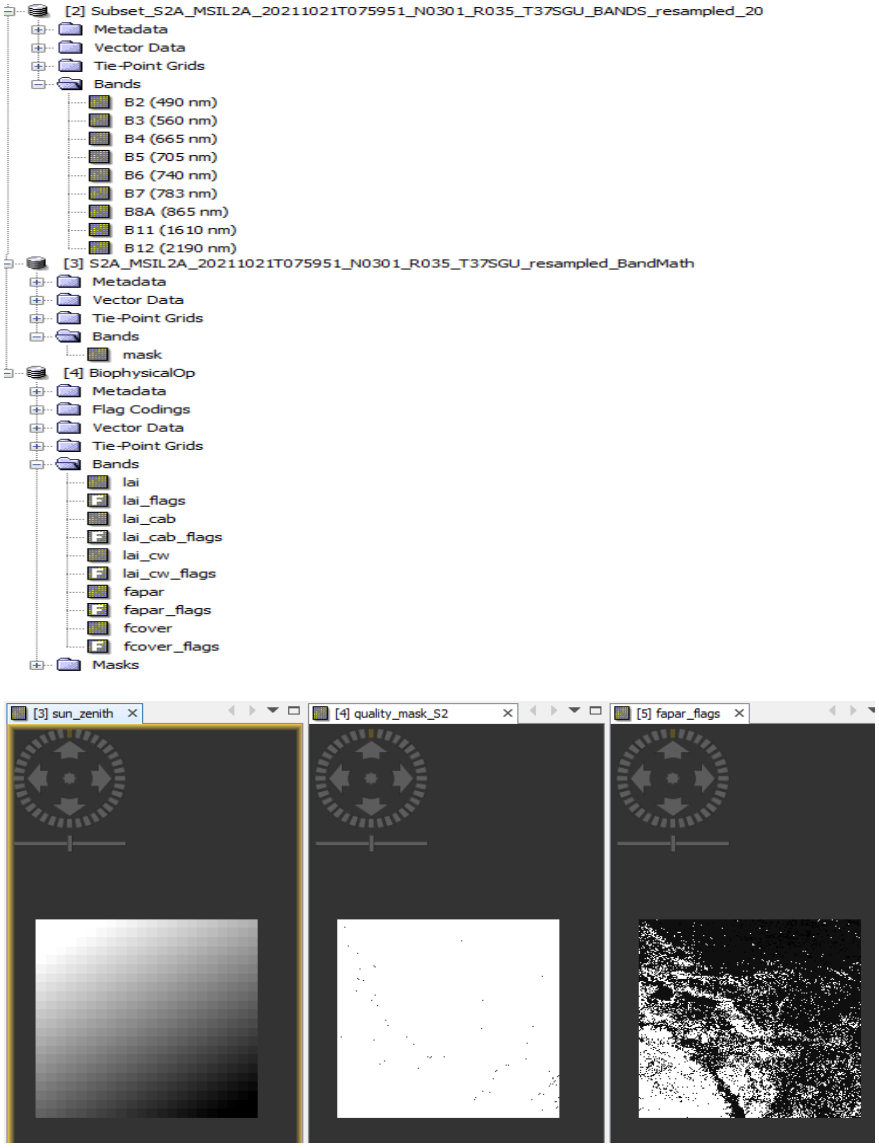


Then navigate and create a folder to save the results, the following picture is a hint directory,



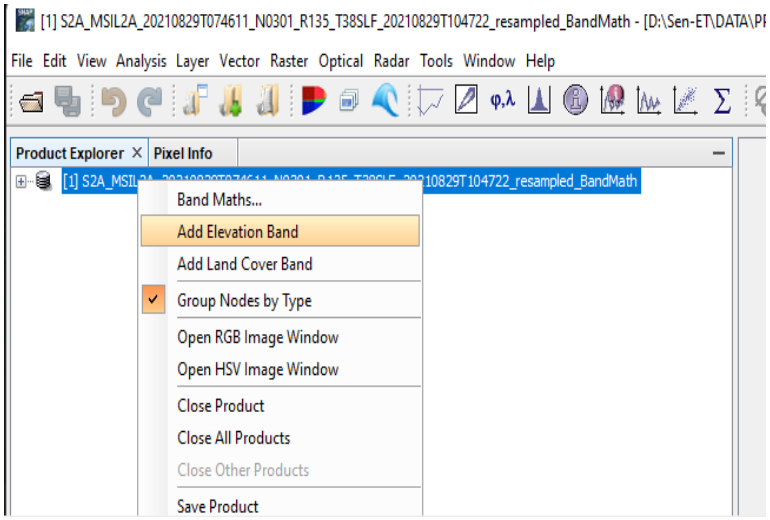
It is worth mentioning that it is possible to dismantle any process chain into smallest steps, this in most cases will end any an individual process quicker than the long chain graph or process. But it is also depending on the machine processor and RAM, as we said earlier.

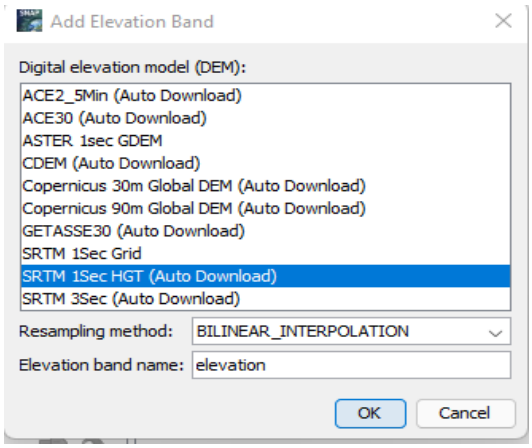
Processing of a whole S2 scene has been completed in 38.583332 minutes as showed below,



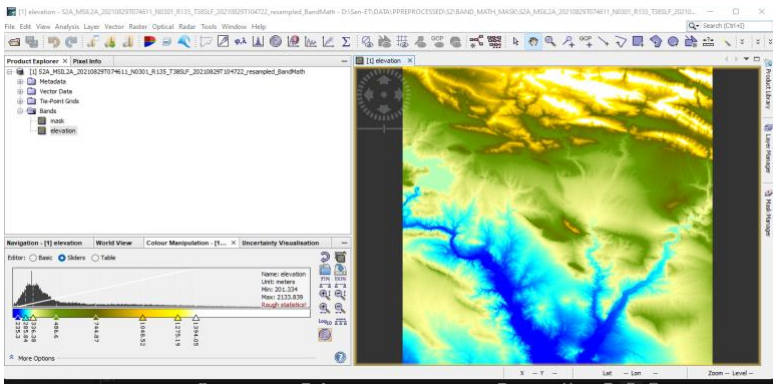
2. Add an elevation band

Now it is time to add an elevation band: drag and drop the band mask (S2_mask), calculated in the previous step, in the Product Explorer or navigate to the folder where you can find this product and select the file that ends with the *.dim extension. Highlight the mask product and right click on it, then navigate to the band elevation band, a new window will pop out, select SRTM 1 Sec HGT (Auto Download)-

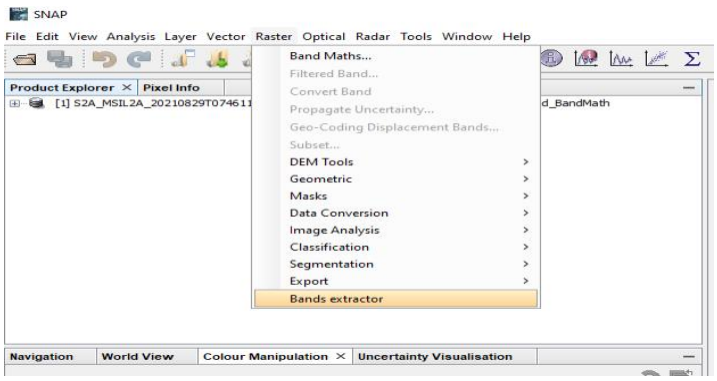




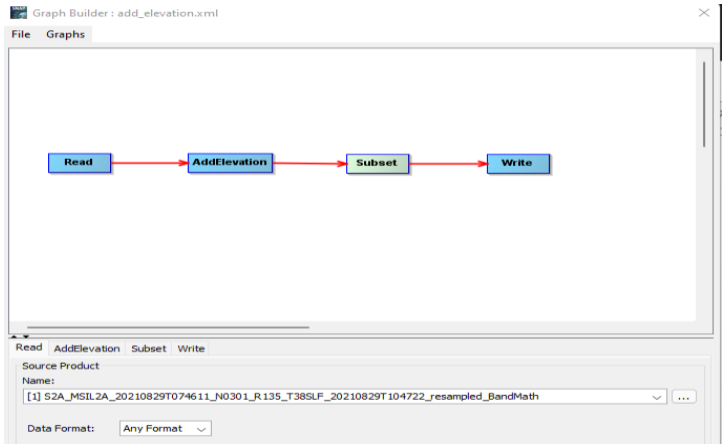
The elevation band will be added as shown in the figure below:



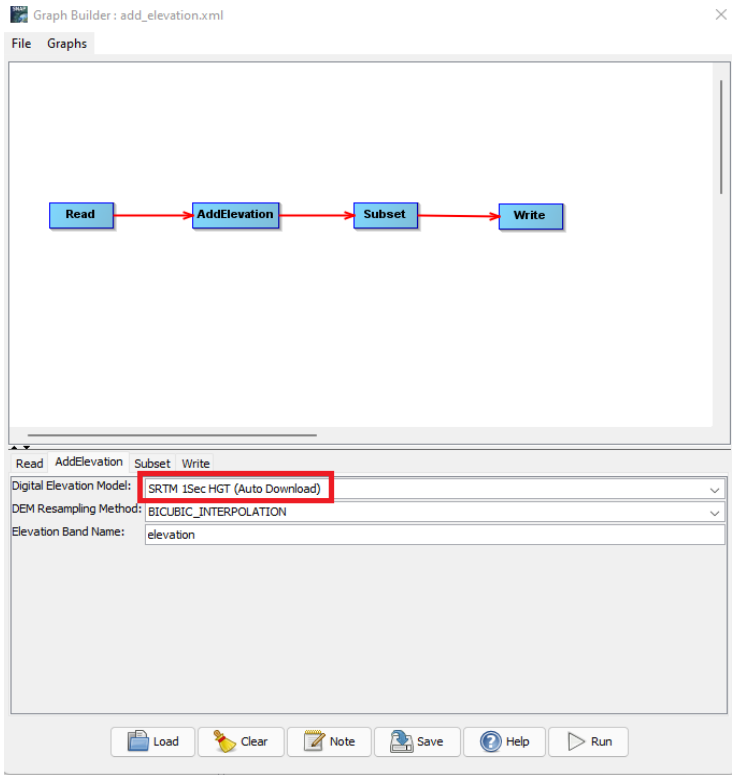
Then, if you wish, you can extract and save this band separately: from the Raster tab go to Bands Extractor.



Or you can directly use the Graph Builder to add the functionto create an elevation band and save it as a separate image, as shown below:

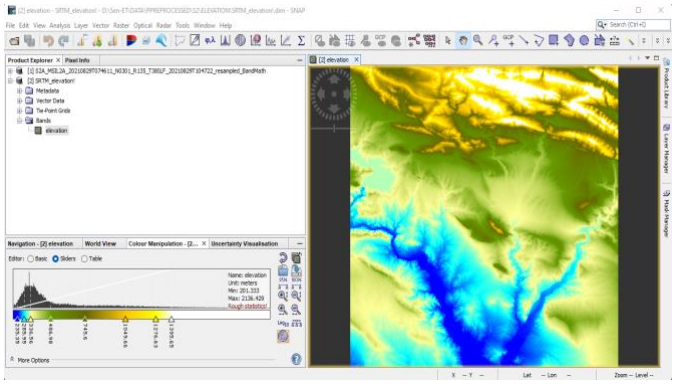


Select the SRTM 1s auto download, and change the preferred DEM resample Method or leave the default one.



In the write part, type in the name of the product and the navigate to the output directory in order to save the result.

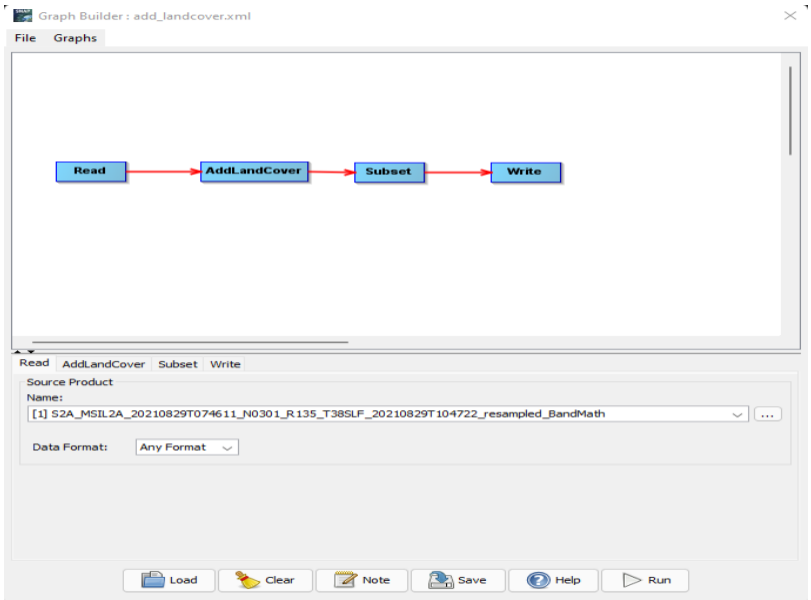
An elevation band will be appeared in the Product Explorer after the successfully ending the process as it is shown below:



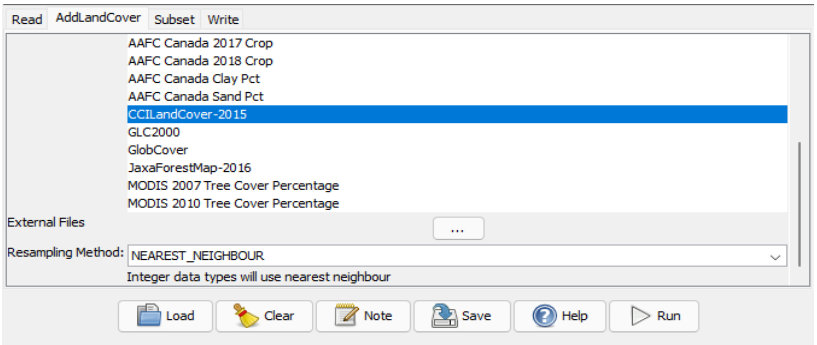
3. Add Landcover band

As it has been explained, there are multiple choices for creating bands, like in the case of the elevation band. In here we will directly create a landcover map using the graph builder, as it is depicted below,

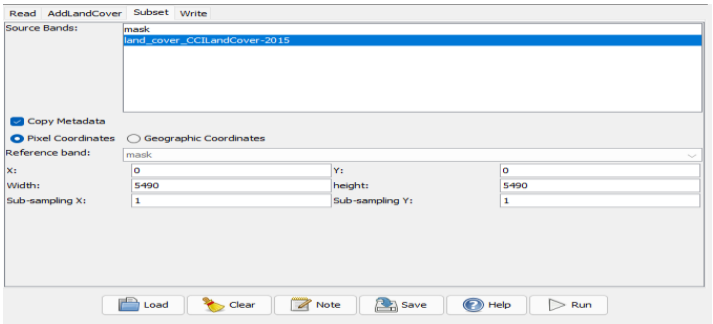
The input is the Sentinel 2 mask that has been previously created.

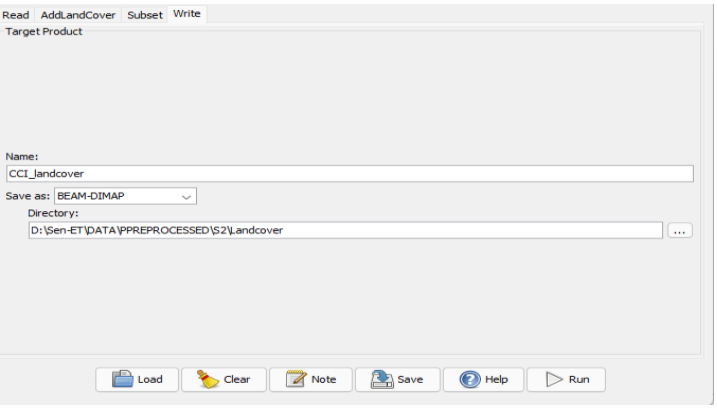


In the second tab AddLandCover, select the CCLandcover – 2015, also the user can change the resample mode or leave the default one. **Only this land cover map is accepted.**

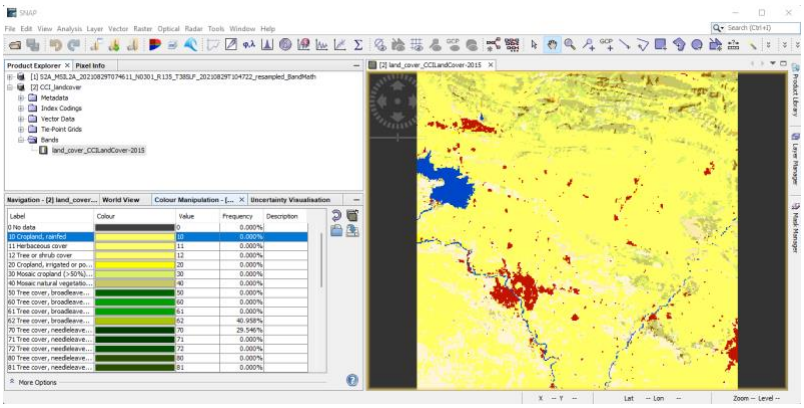


In the subset tab select the landcover layer and in the write tab, type in the name and navigate to the save directory, and press Run. This step is compulsory.

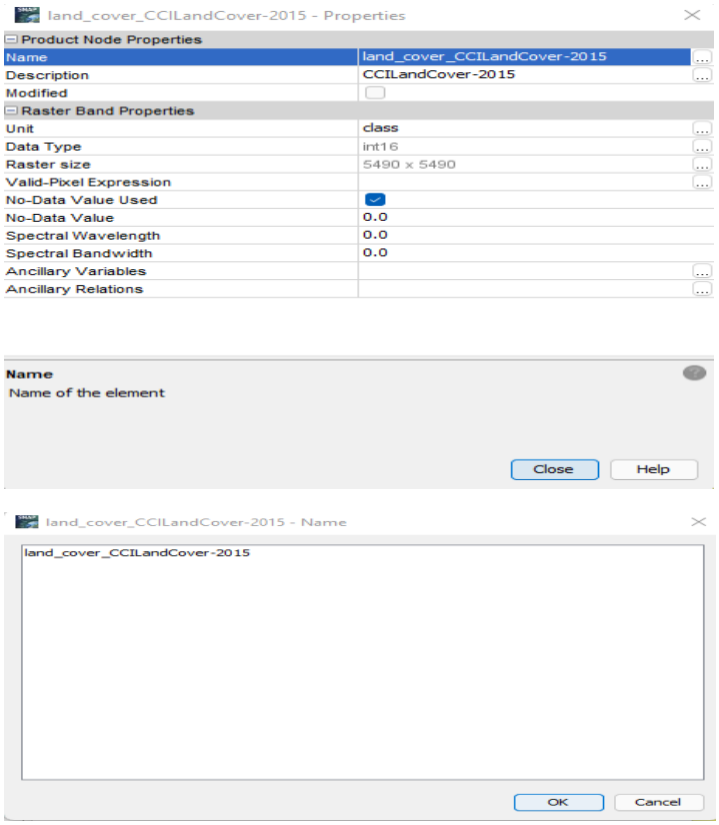




Once the process has successfully ended, a new band of Land cover will be added up to the Product Explorer panel, as it is depicted below:



It is worth mentioning that the name of landcover should be edited up to be **CCILandCover-2015,** because in the next step for producing maps of vegetation structural parameters, an error will appear if the name is other than the expected (CCILandCover-2015)[2]. Right click on the band name and properties, a new panel will pop up, choose the first field name by clicking on the dots. A new panel will pop up, which gives the user the capability of changing the name. Edit the name and press ok,



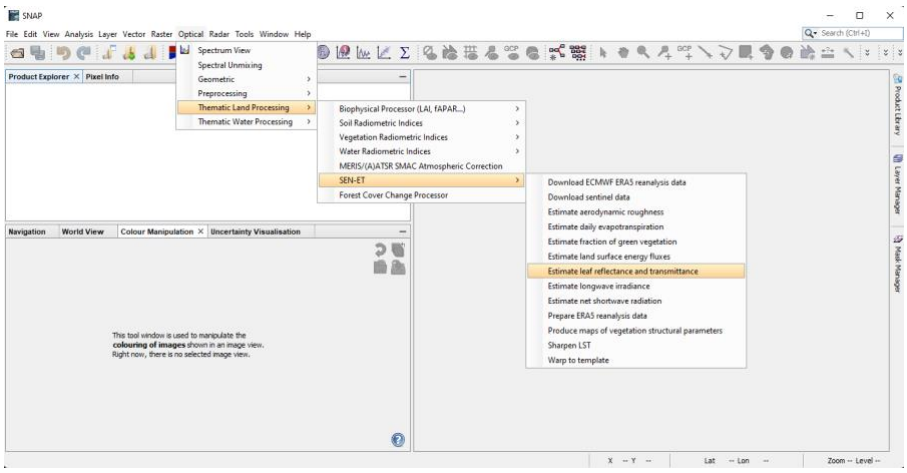
The name will appeared as illustrated below. Finally right click on the CCI_landcover and save product.

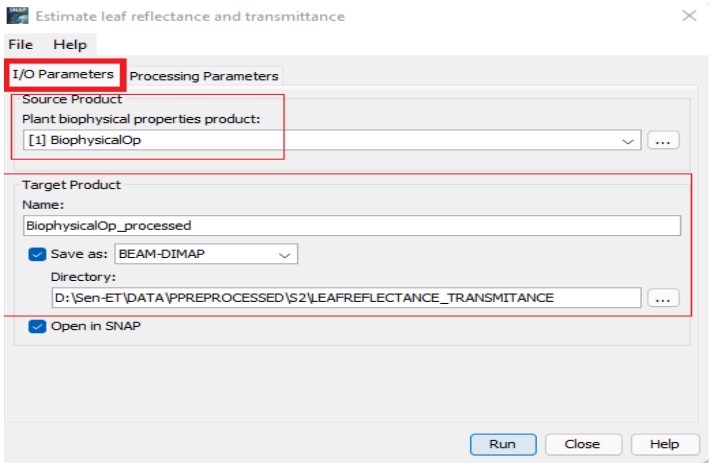
4. Estimate leaf reflectance and transmittance

The input is the S2 biophysical properties product, the outputs of Sentinel-2 pre-processing graph. From the optical tab, navigate to Thematic Land processing, and then to the SEN-ET plugin. From there select “Estimate leaf reflectance and transmittance operator”, a new window will pop up:

[2] See the comments to this probem in the STEP Forum here:

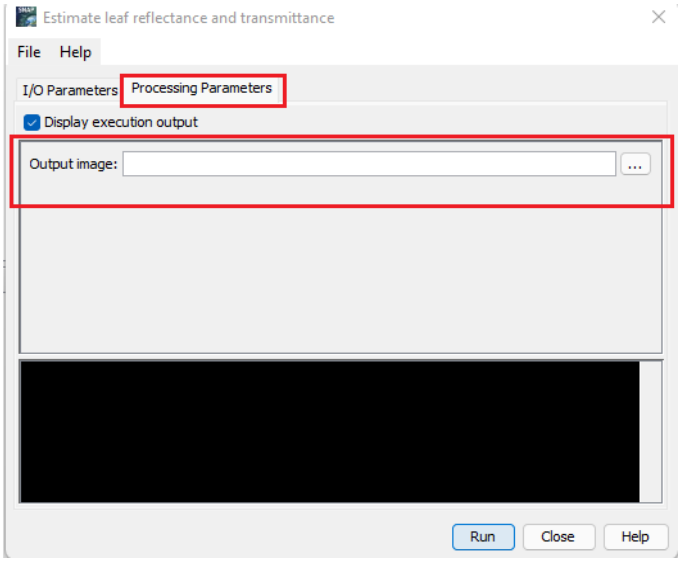
https://forum.step.esa.int/t/produce-maps-of-vegetation-structural-parameters/31942/10?u=falahfakhri



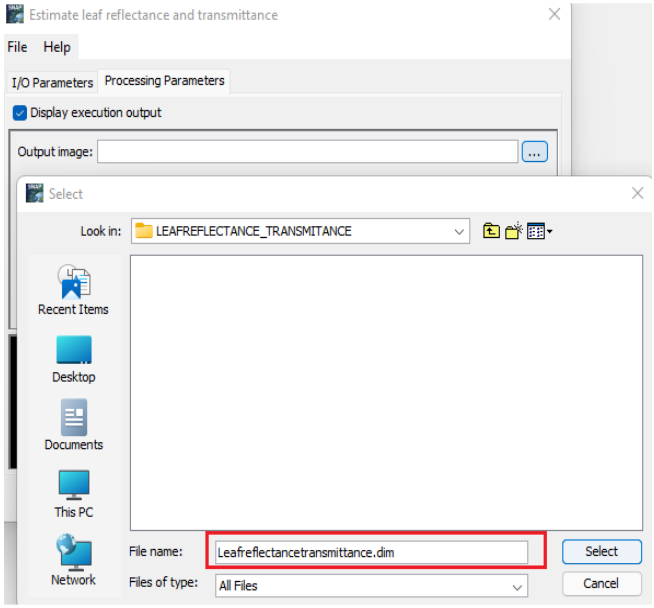


In the I/O parameters tab select the source product, the biophysicalOp layer (the name of the file changes depending on what you wrote in the pre-processing “Write_biophysical”).It is recommende to change the target name to the preferred name, and navigate to the save directory. Remember to always add the saving Directory up.

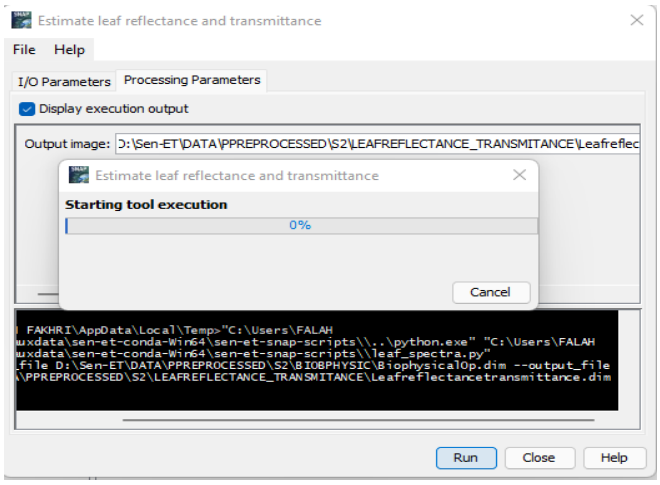
In the processing parameter tab, navigate to the directory that already has been selected in I/O parameters, and name the output layer. Do not forget the extension of SNAP ***.dim**.

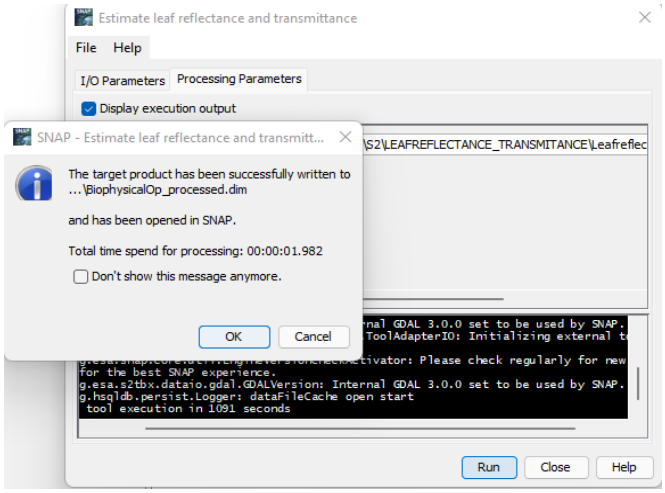


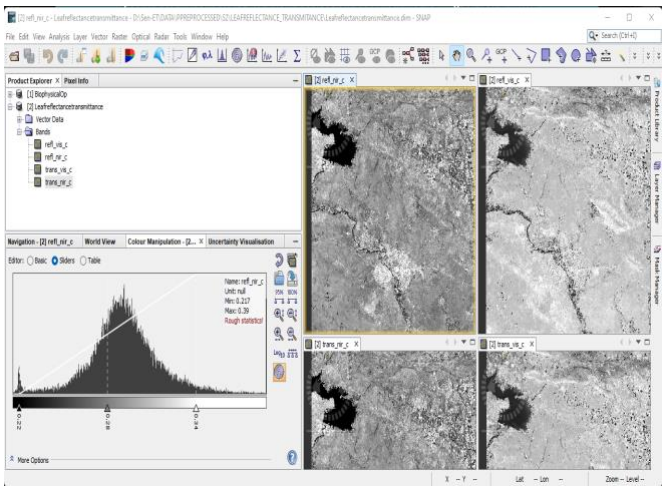
It is worth mentioning that the process will take a few minutes.



Once the process has finished, a new product layer will be appeared in the Product Explorer as it is shown below:





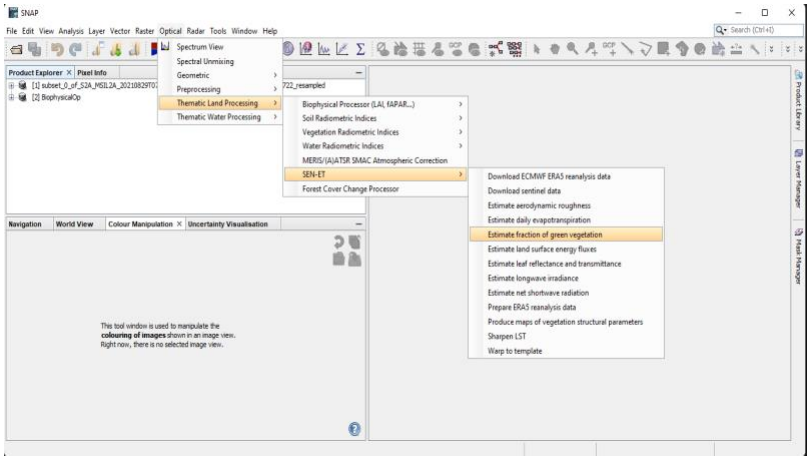


5. Estimate fraction of green vegetation

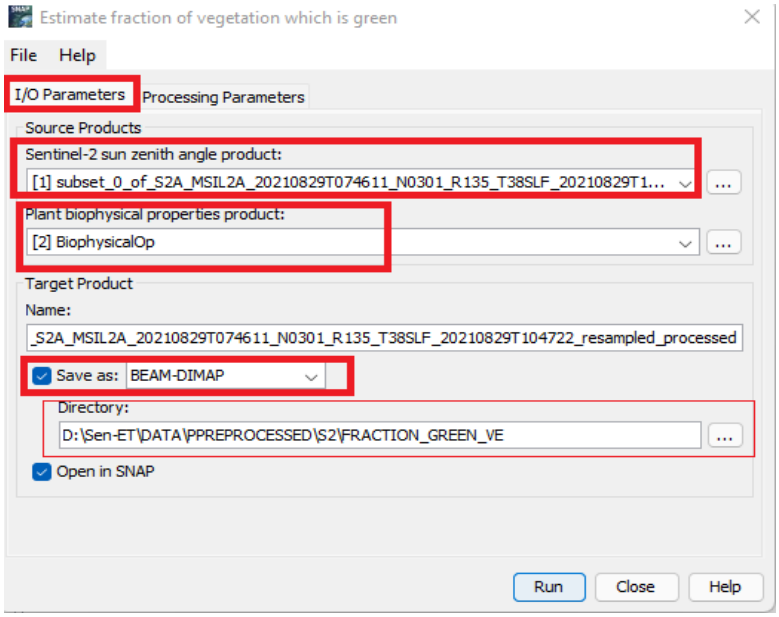
The input of this operator is the Sentinel-2 sun zenith angle product[3] and the S2 biophysical properties product - output of Sentinel-2 pre-processing. From the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN_ET plugin, finally click the Estimate Fraction of Green Vegetation operator, a new panel will pop up. In the IO/parameters, choose carefully the two inputs each one in its right source slot as it illustrated below. Save the product in your directory.

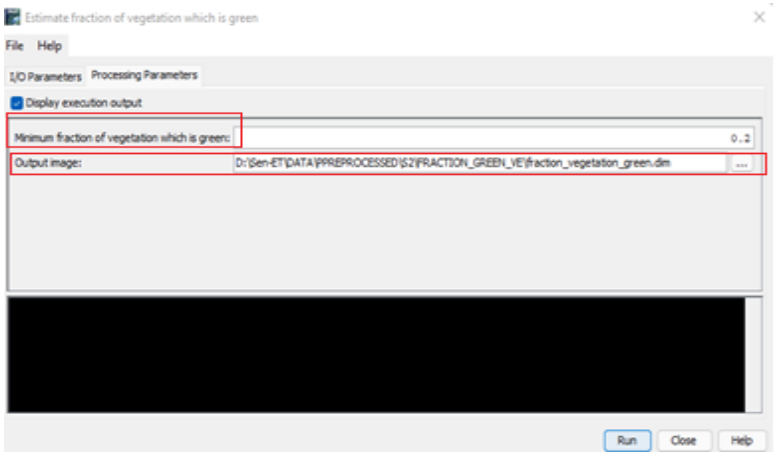
In the second tab, the processing parameters, navigate to the save directory and name the results, the extension of the result should be *.dim. With regard to the other parameters, the minimum fraction of green vegetation, this can be changed according to the user experience or left by default. Finally click Run to proceed.

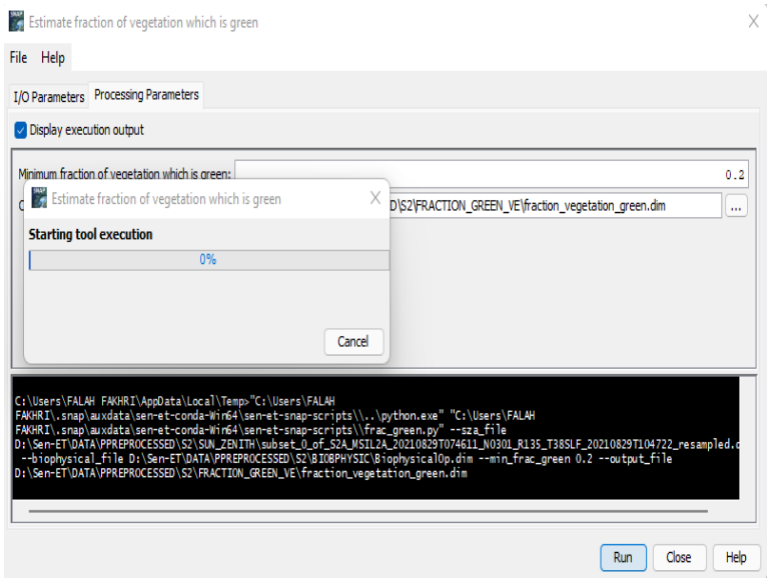
Again, the process will take a few minutes and if no progress is visualized in the starting tool execution do not worry about this.

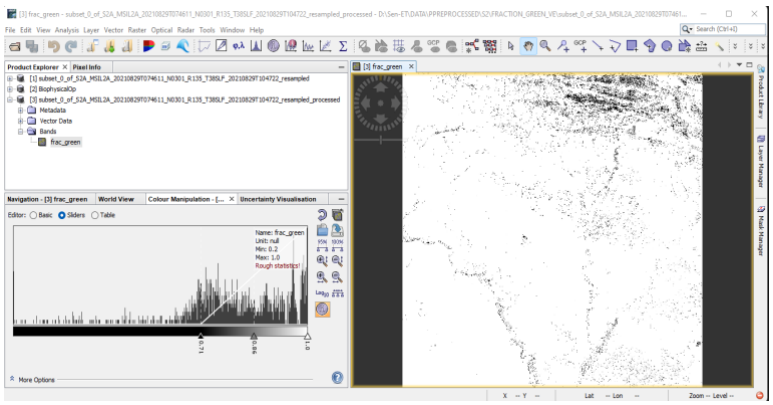


[3] This is the output of Sentinel-2 which has been pre-processed separately in previous steps.


Estimate fraction of vegetation which is green
File Help
I/O Parameters
Processing Parameters
Source Products
Sentinel-2 sun zenith angle product:
[1] subset_0_of_S2A_MSIL2A_20210829T074611_N0301_R135_T38SLF_20210829T1...
Plant biophysical properties product:
[2] BiophysicalOp
Target Product
Name:
_S2A_MSIL2A_20210829T074611_N0301_R135_T38SLF_20210829T104722_resampled_processed
Save as:
BEAM-DIMAP
Directory:
D:\Sen-ET\DATA\PPREPROCESSED\S2\FRACTION_GREEN_VE
Open in SNAP
Run
Close
Help


Estimate fraction of vegetation which is green
File Help
I/O Parameters
Processing Parameters
Display execution output
Minimum fraction of vegetation which is green:
0.2
Output image:
D:\Sen-ET\DATA\PPREPROCESSED\S2\FRACTION_GREEN_VE\fraction_vegetation_green.dim
Run
Close
Help


Estimate fraction of vegetation which is green
File Help
I/O Parameters
Processing Parameters
Display execution output
Minimum fraction of vegetation which is green:
0.2
Estimate fraction of vegetation which is green
Starting tool execution
0%
Cancel
C:\Users\FALAH FAKHRI\AppData\Local\Temp>"C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\\..\python.exe" "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\\frac_green.py" --sza_file D:\Sen-ET\DATA\PPREPROCESSED\S2\SUN_ZENITH\subset_0_of_S2A_MSIL2A_20210829T074611_N0301_R135_T38SLF_20210829T104722_resampled.d --biophysical_file D:\Sen-ET\DATA\PPREPROCESSED\S2\BIOPHYSIC\BiophysicalOp.dim --min_frac_green 0.2 --output_file D:\Sen-ET\DATA\PPREPROCESSED\S2\FRACTION_GREEN_VE\fraction_vegetation_green.dim
Run
Close
Help



6. Produce maps of vegetation structural parameters

The inputs of this operator are:

- The CCI Land-cover product
- The S2 plant biophysical properties product
- The S2 fraction of green vegetation product

The Parameters are:

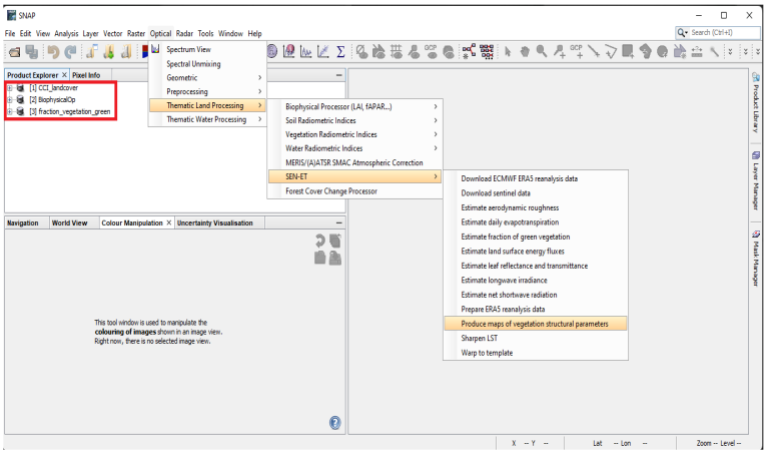
- Land-cover band - Name of land-cover band as produced by the “Add landcover” graph
- Look-up table - File containing the look-up table. Examples of default location:

~/.snap/auxdata/sen-et-conda- 64/sen-et-snap-scripts/auxdata/LUT

~/SEN-ET/sen-et-snap-master /auxdata/LUT

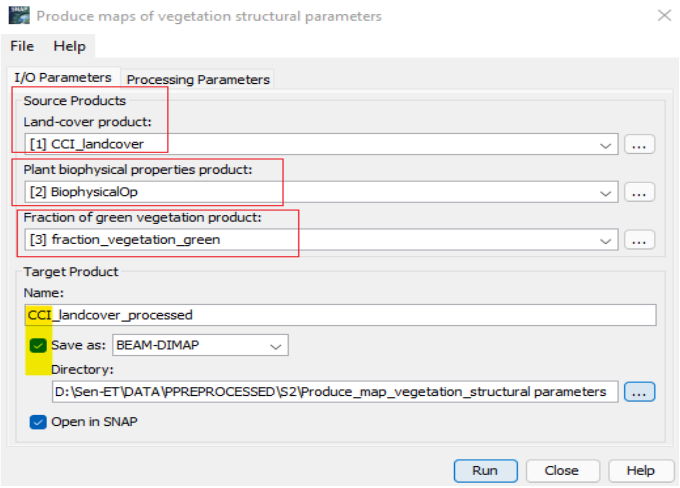
where ~ is the user directory.

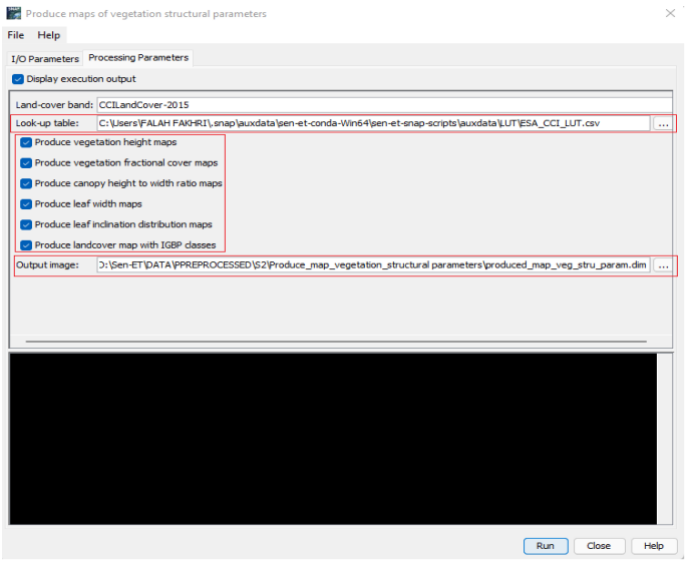
- Produce vegetation height maps - indicate if the vegetation height maps should be produced
- Produce vegetation fractional cover maps - indicate if the vegetation fractional cover maps should be produced
- Produce canopy height to width ratio maps - indicate if the canopy to width ratio maps should be produced
- Produce leaf width maps - indicate if the leaf width maps should be produced
- Produce leaf inclination distribution maps - indicate if the leaf inclination distribution maps should be produced
- Produce landcover map with IGBP classes - indicate if the landcover map with IGBP classes should be produced



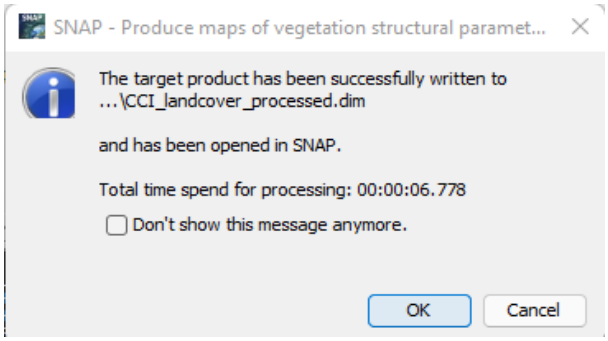
Choose carefully the source of each product and tick the save box, and do not forget to navigate to the save directory and tick all the parameters boxes, and add up the LUT.

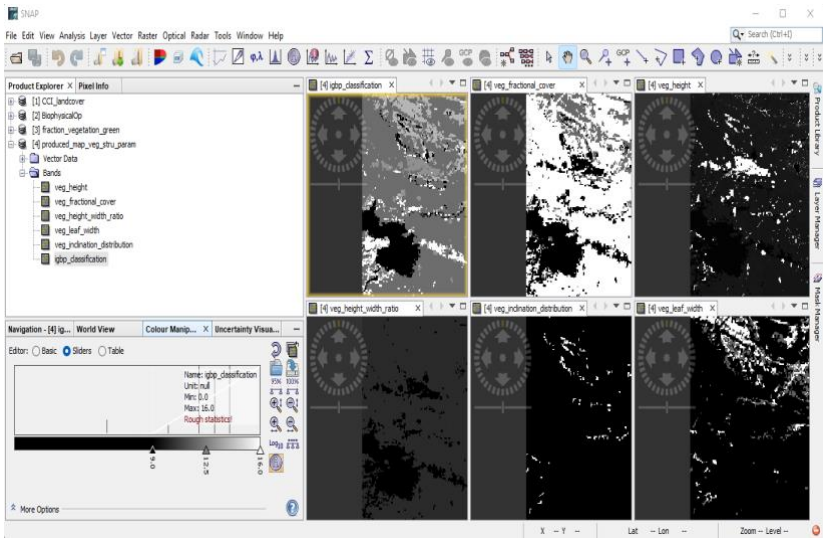
C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\auxdata\LUT\ESA_CCI_LUT.csv





The process will take a few minutes to be completed,





7. Estimate aerodynamic roughness

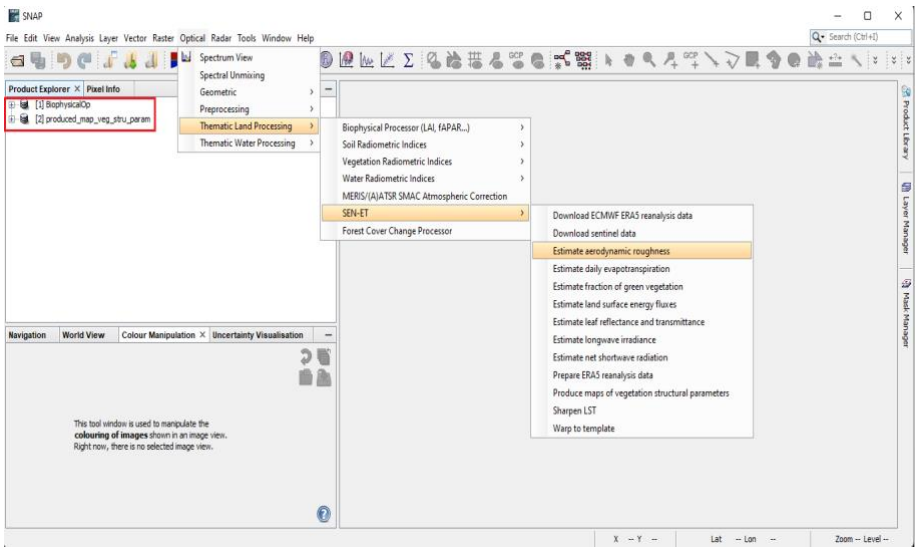
The inputs of this operator are:

- S2 plant biophysical properties product
- S2 vegetation structural parameters product

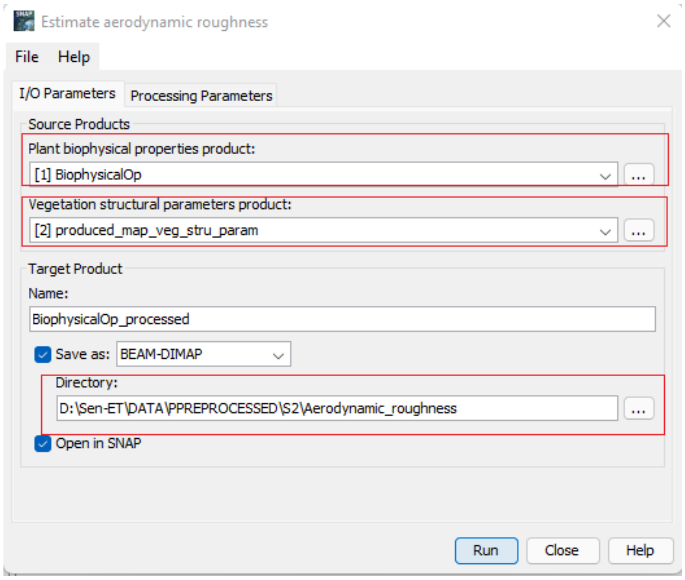
And it produces ony one output:

- Soil roughness

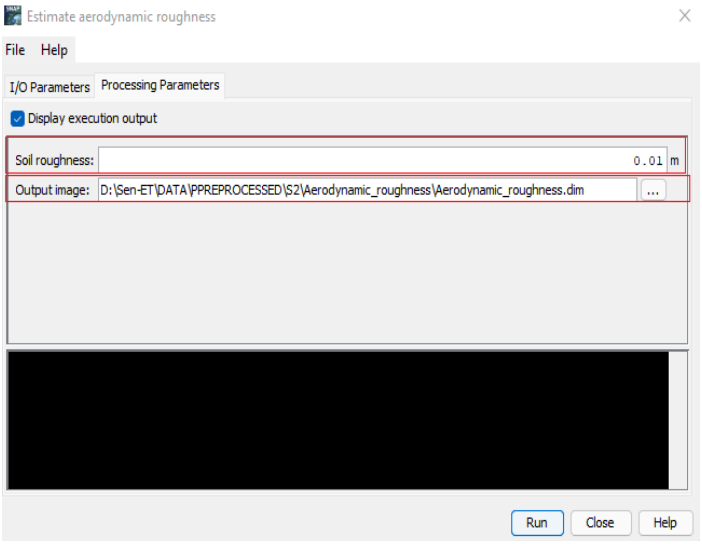
Drag and drop the products into Product Explorer, then from optical tab navigate to Thematic Land processing, and next to the SEN-ET plugin, from that select “Estimate aerodynamic roughness” operator as it is shown below, once it is selected the operator window will pop up,



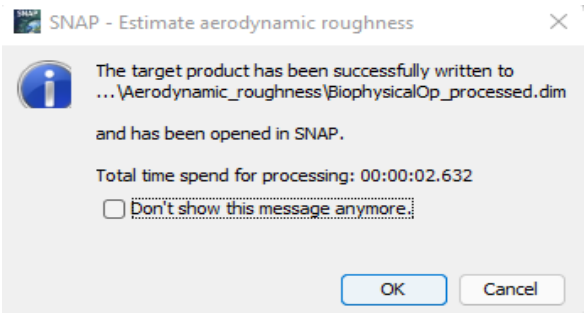
Select the source product carefully and navigate to the save directory within the I/O parameter tab:



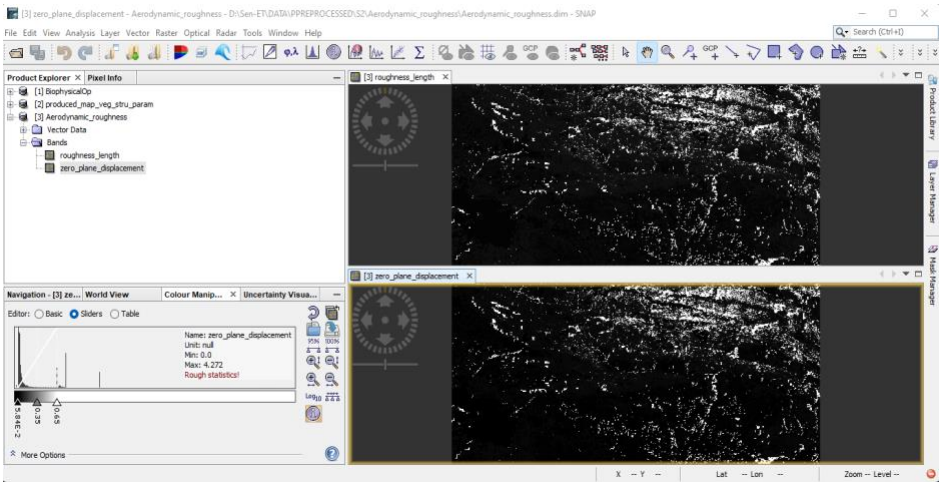
In the second tab, processing parameter, you can introduce the soil roughness index according to your study area, or leave it by default. Indicate the save directory and the product, with the *.dim extension. Finally click Run, please see below,



The process time takes a few minutes, and as usual, once it has finished, a new product will be added up to the product explorer,



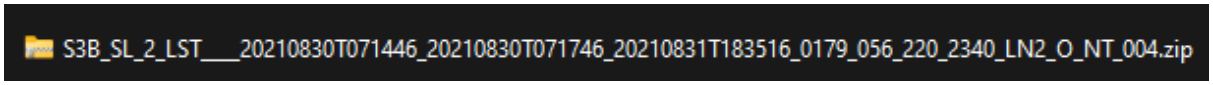
With this operator, the user reached the end of the S2 pre-processing. Next the user is ready to move forward to the S3 pre-processing steps in the next section.

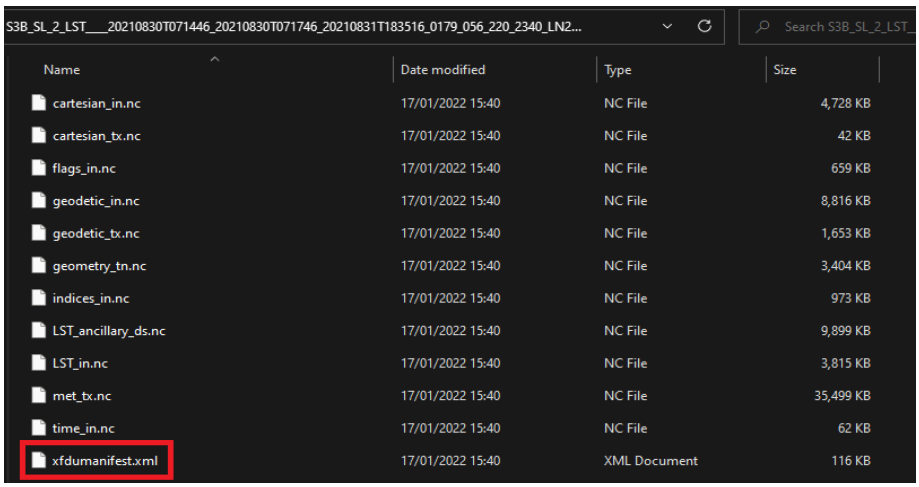


Sentinel 3

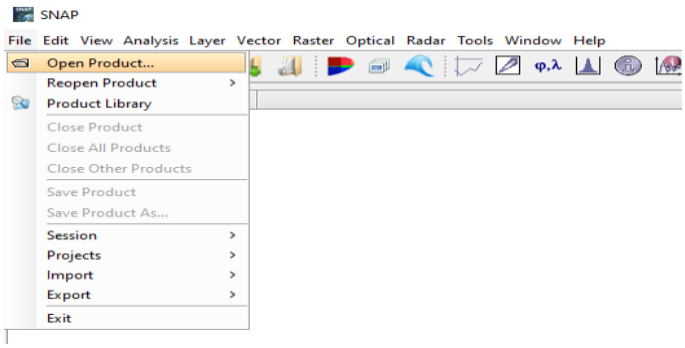
1- Pre-processing

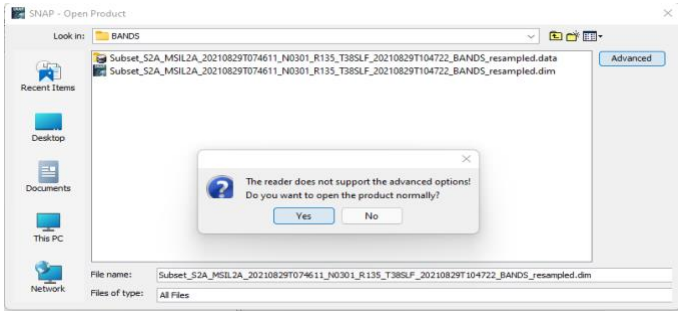
First of all unzip the S3_.zip product to get S3_.SEN3 product, open the last, drag and drop *.xml file, in the Product Explorer as shown below:

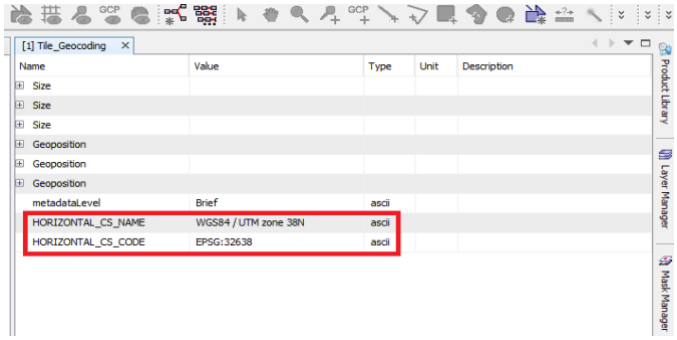




Before getting into the S3 pre-processing details, some important geometric information should be taken from the pre-processed S2. From the File /Open product, navigate to the folder of the pre-processed extracted bands, double click on the product, or click advanced, and then say yes in the new popped up window, or use the easiest way of dragging and dropping the product from its container folder; In the Product Explorer expand the image, then the Metadata, Granules, Geometric_Info, and double click on Tile_Geocoding. The outlined information is needed in the next S3_pre-processing steps, specifically in the Reprojection step. See the figures below:



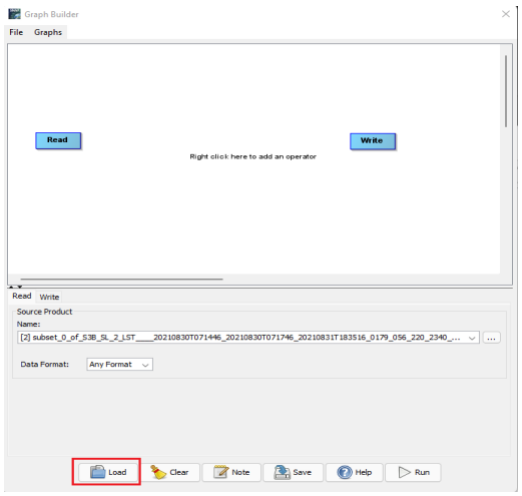


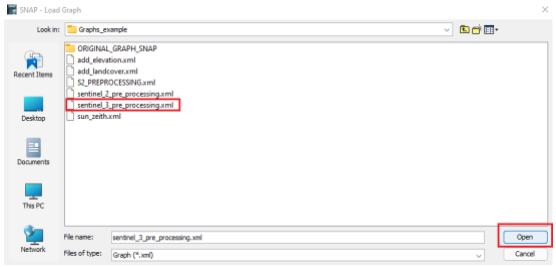


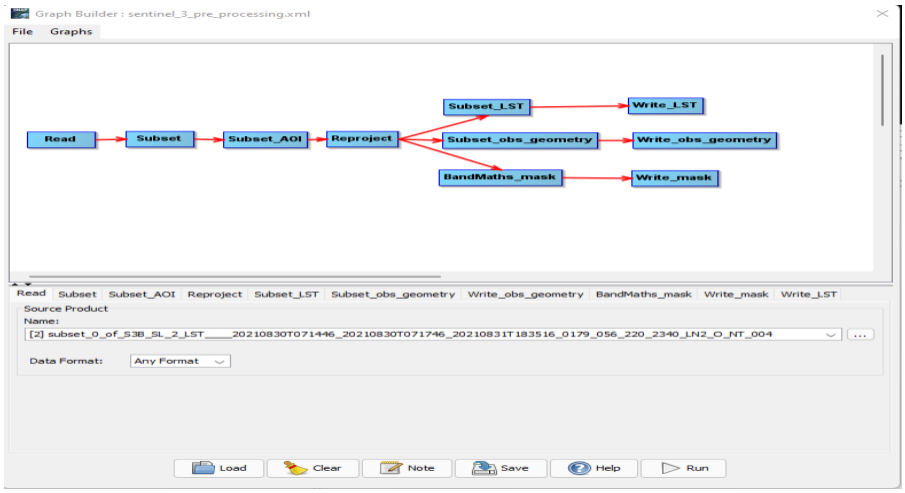
Back to the S3 pre-processing, from the main tab, Open Product or drag and drop the file with the *.xml extension into Product Explorer directly.

From Tools bar, click on the Graph symbol as it is depicted below and navigate to load the graph of S3 pre-process.

A new panel will pop up, from Load navigate to the directory where the graph has been saved, in (A) Select the graph and click Open,







Inputs

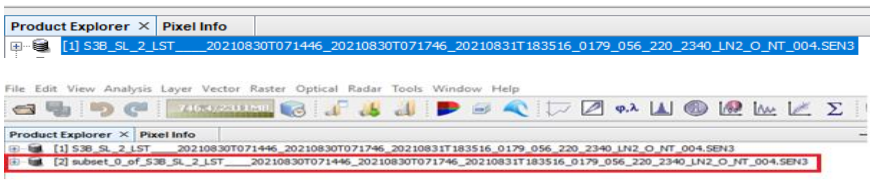
- Sentinel-3_L2A - Sentinel-3 scene has been cropped and reprojected as explained above, it is worth mentioning that aftermath using the snipped S2 Geo coordinates the S3 product will automatically get the same S2 projection.
- AOI_WKT Area of interest formatted as well-known text (WKT)

Outputs

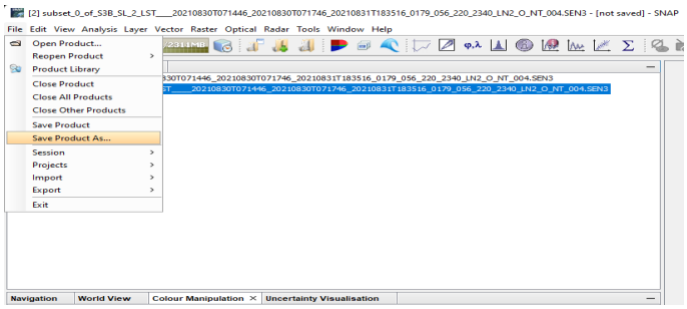
- S3_observation_geometry - product containing the scene sat_zenith_tn, solar_zenith_tn, longitude_tx, latitude_tx bands
- S3_mask - product containing cloud mask derived from scene's quality images
- S3_LST - product containing land surface temperature data

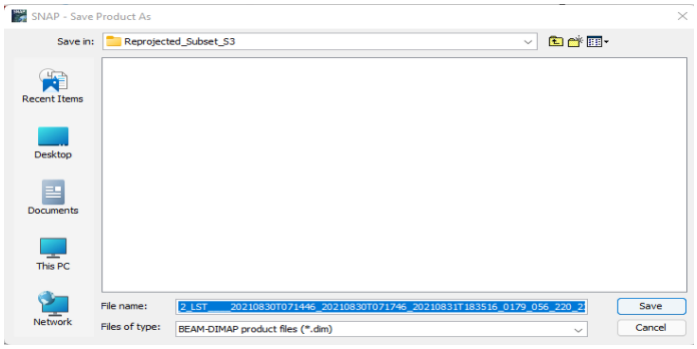
Regrettably, the pre-processing S3 graph that has been mentioned above gives multiple errors. The reason might be related to the newer SNAP version (v 8). The graph should be updated accordingly. To overcome this problem, we can generate a new graph ourselves or subset the S3 data manually.

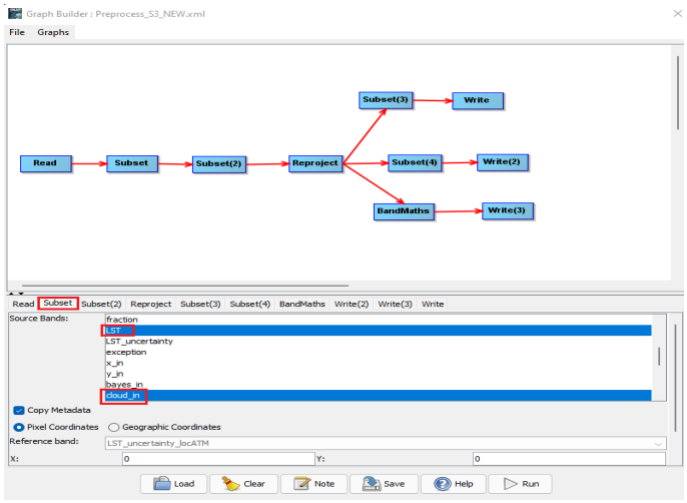
Highlight the S3 product by clicking on it, and from Raster navigate to the Subset as explained above. In the Geo Coordinates type in the coordinates of S2 product and press OK, once it is finished, a new cropped S3 product will be added up to the Product Explorer, the word subset_ has been automatically added up in the front of the S3 product name,



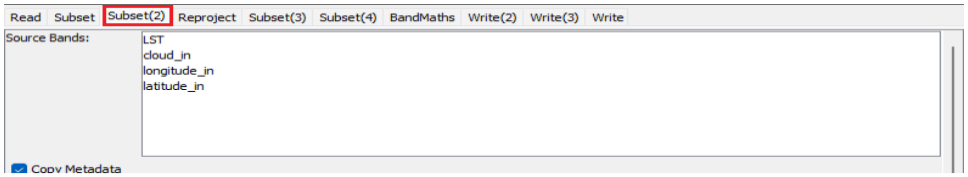
Highlight the subset S3 product, from File/Save Product As, a new window will appear click Yes, and navigate to the directory where you want to save the result, and then click Save. The subset is not necessary though and does not affect the process chain in case of applying the process to the whole scene, except for memory needs of the machine: both ways of working are correct.



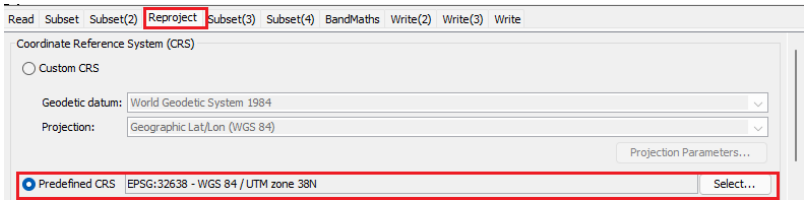


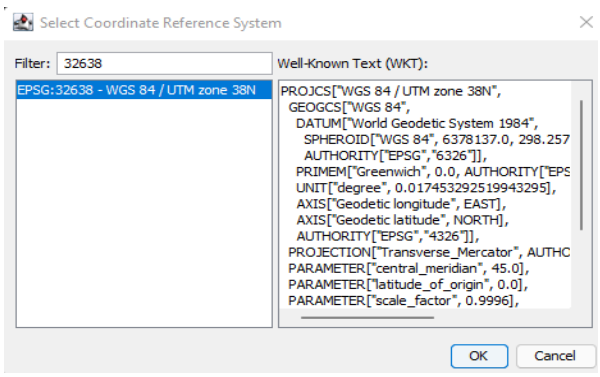


The first tab is assigned to Read the product, and the Subset is allocated to select the LST, and the cloud_in bands, while in the third Subset2 nothing is needed to be set up,



The Reprojection step has been already done through the subset step, when we used the S2 geo coordinates as reference; however, in the tab of reprojection, a confirmation of the Coordinate Reference System CRS is needed, to be matched with the S2 CRS. Tick in the Predefined CRS and click Select in order to choose the right CRS, to be matched with the S2 CRS. A new panel will pop up, type there the required CRS and click Ok,

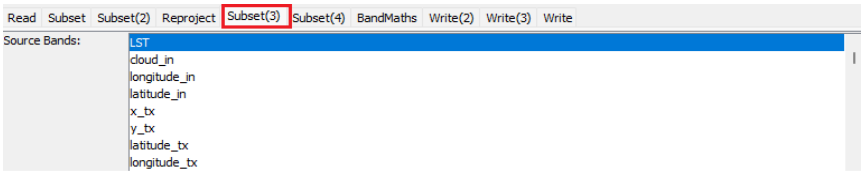


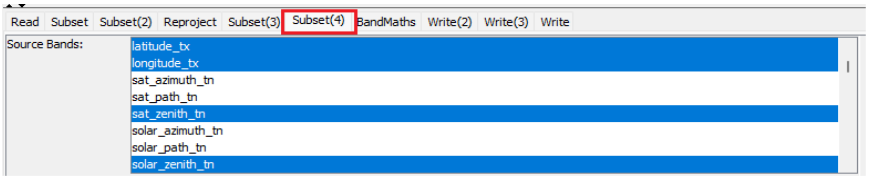


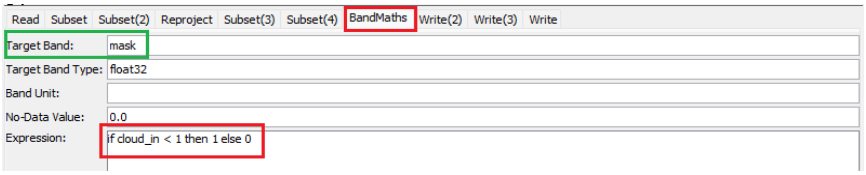
Moving to the next tab Subset(3), select the LST. In the Subset(4), select the latitude_tx, longitude_tx, sat_zenith_tn, and, solar_zenith_tn.

Finally, in the BandMaths, type in the following equation:

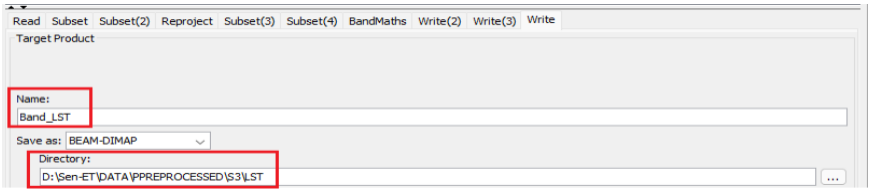
if cloud_in < 1 then 1 else 0





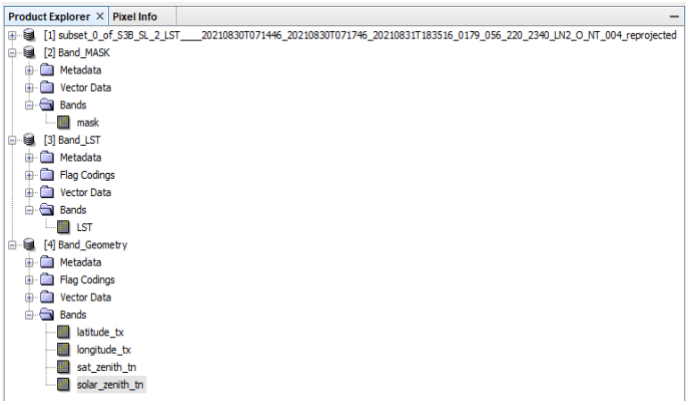


The rest of the tabs are, Write_LST, Write_mask, and Write_geometry. Give a proper name to the products and navigate to the directory where they will be stored.



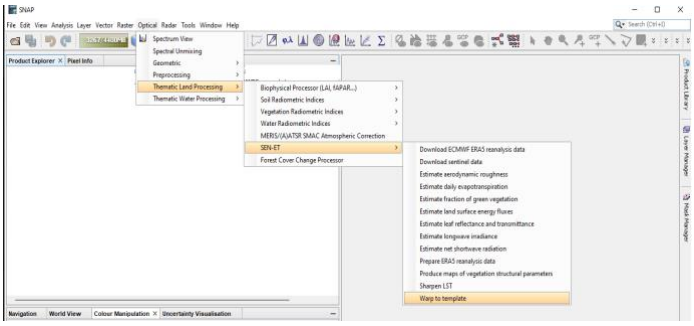
Note that the target name for the LST, and mask bands, or another characters or symbols should be added up, or the name changed completely, because the name of band is already “mask”, or “LST”, and it needs to be different.

The pre-processing will take a few minutes and the new products will be automatically added up to the Explorer Product window, please see the figure below.



2- Warp to template

From optical tab navigate to Thematic Land processing, and next to the SEN-ET plugin, from that select wrap to template operator as it is shown below:

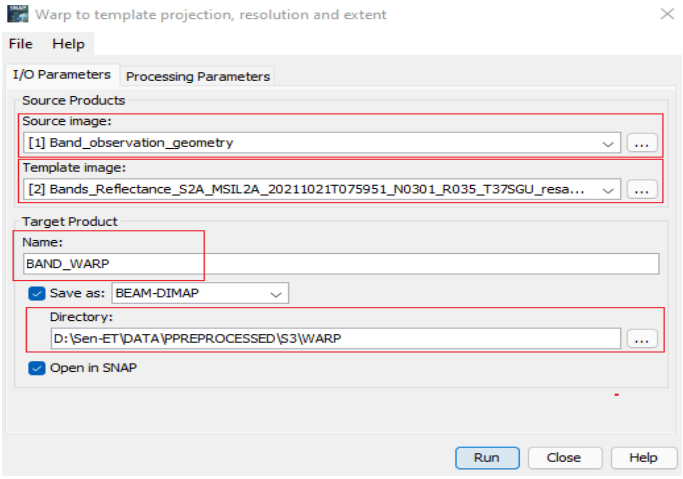


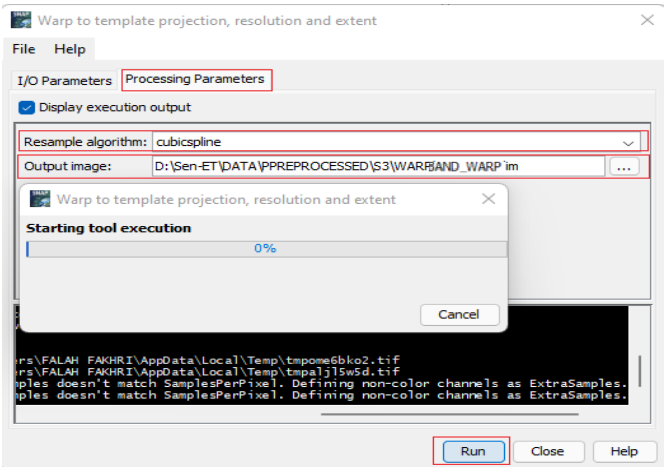
This tool is to simply reproject, resample and subset the S3 geometry bands to match Sentinel-2 Region Of Interest (ROI) extent and spatial resolution. You can use the reflectance bands as the template image.

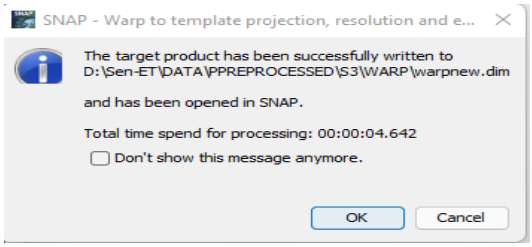
Inputs

- Source image: the Sentinel-3 observation geometry created with the pre-processing graph.
- Template image: Sentinel-2 reflectance bands as the template image.
- Resample algorithm - choose one of the available resample algorithms.

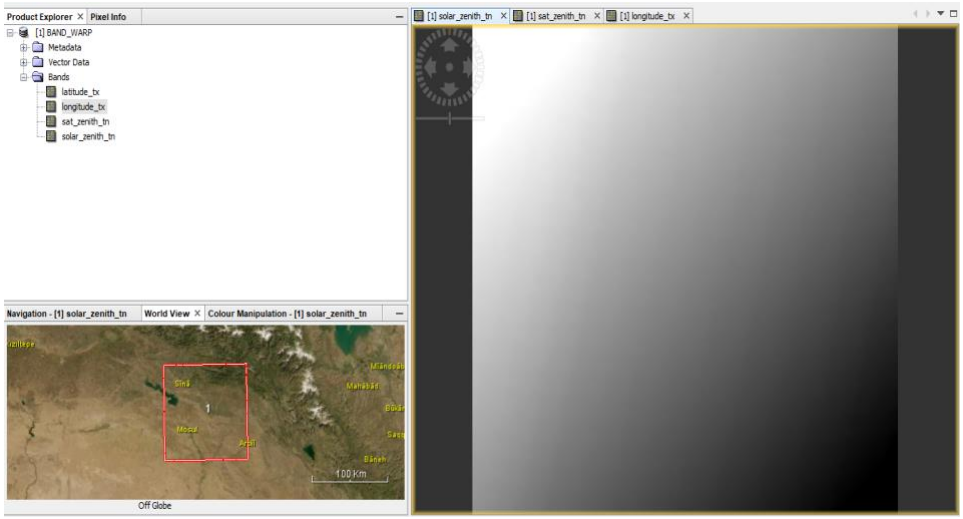
Output image: name of the image to be created (introduce whole path).







The final warp product will be automatically added up to the Product Explorer, expand the product and open any band you wish to investigate the result,

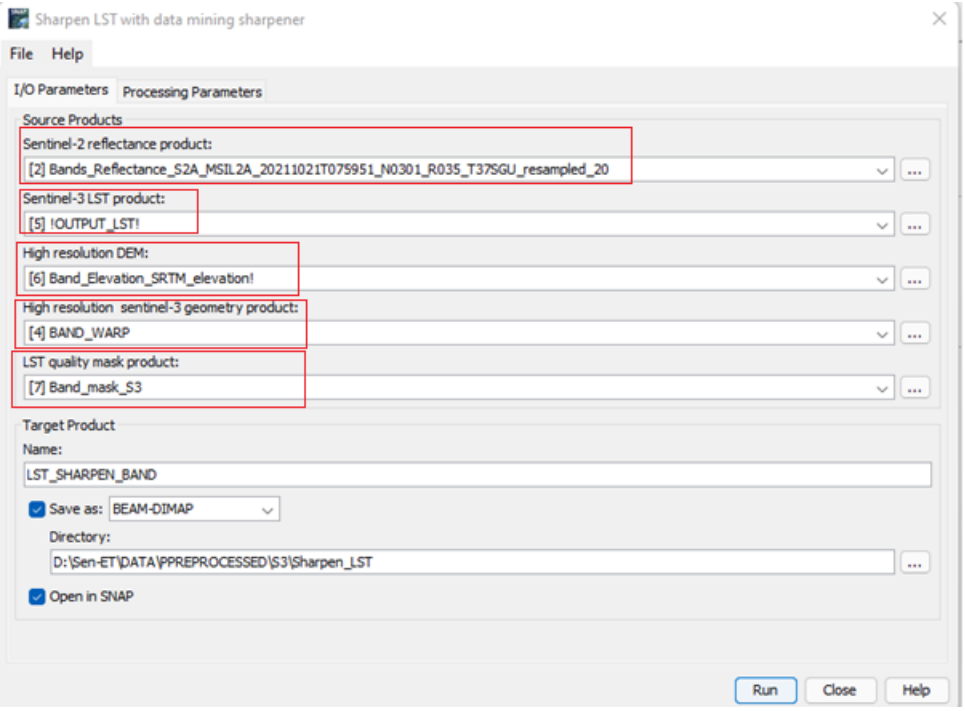


3- Sharpen LST

The function expects the following inputs:

- Sentinel-2 reflectance product - output of Sentinel-2 pre-processing.
- Sentinel-3 LST product - output of Sentinel-3 pre-processing.
- High resolution DEM - output of Add elevation graph.
- High resolution Sentinel-3 observation geometry product - output of Warp to template operator.
- LST quality mask product – the S3-mask output of Sentinel-3 pre-processing (“cloud_in”)

The Inputs are depicted in the below figure,



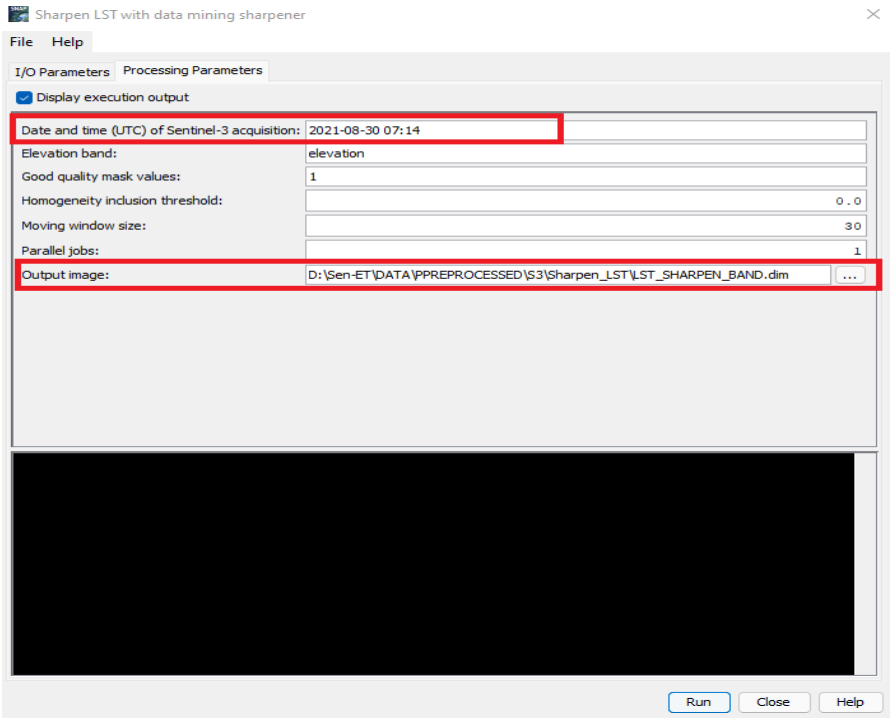
Processing parameters:

- Date and time (UTC) of Sentinel-3 acquisition (YYYY-MM-DD HH:MM).
- Elevation band - Name of the elevation band ("elevation").
- Good quality mask values: 1
- Homogeneity inclusion threshold: leave this by default or choose your value
- Moving window size: leave this by default or choose your value
- Parallel jobs: leave this by default or choose your value

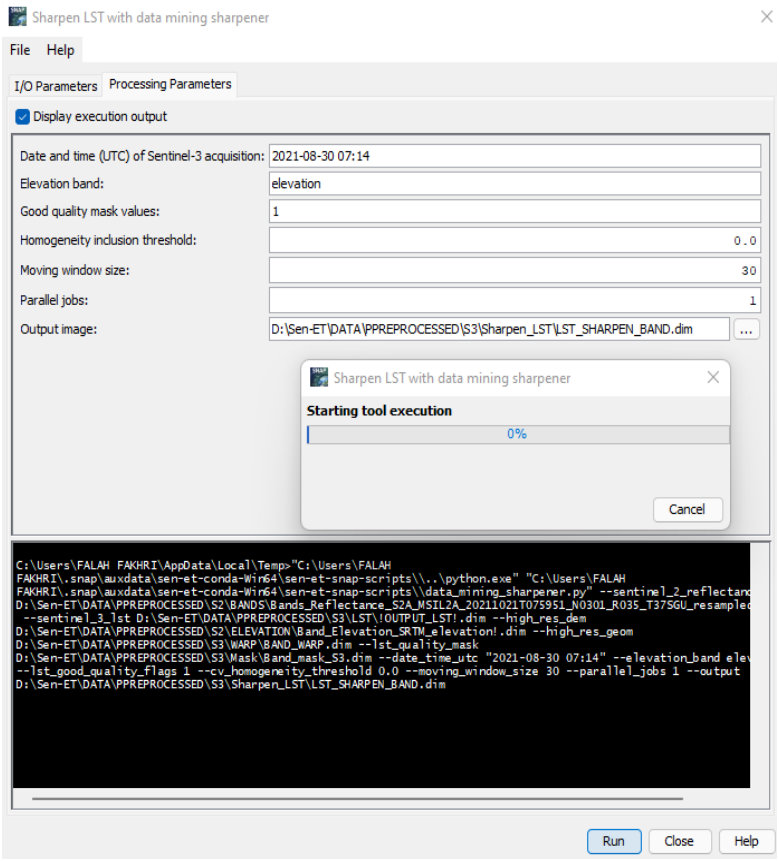
Output

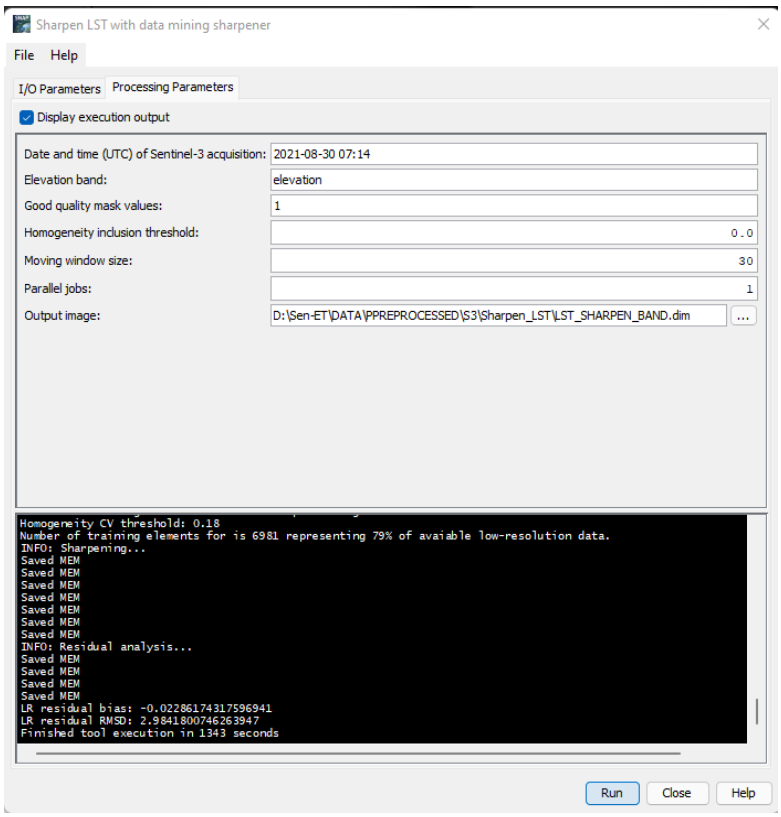
- Output image - Product containing the sharpened Land Surface Temperature band.

Specify the date and time of S3, and also do not forget to navigate to the output directory and write the name of the output product with *.dim extension: this name should be same to the one in Target product of the I/O Parameters as illustrated in the figure above.

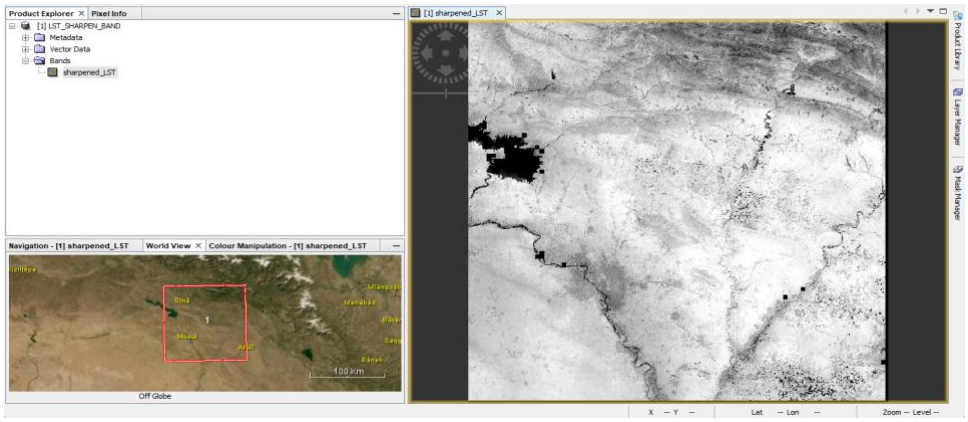


The process will take a few minutes, please have a look at the figures below,





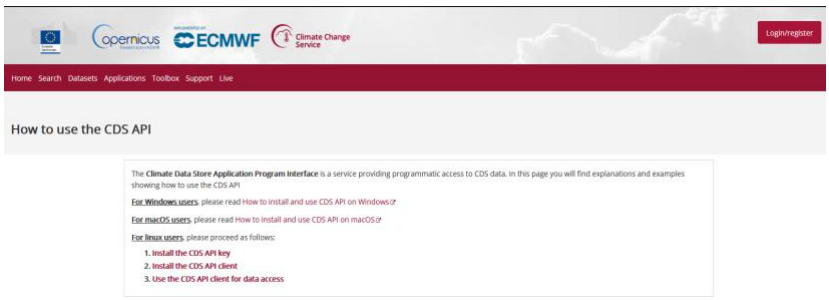
It is worth mentioning that the total time shown in the figure above is not correct, the process takes almost 15 – 20 minutes for the whole scene.



4- Download ECMWF ERA5 reanalysis data

This operator downloads ECMWF ERA5 reanalysis data from the Climate Data Store (CDS).

Note that this requires CDS registration and the CDS key located in the right directory, as indicated on the Sen-ET manual. To register, the first step required is to create a new account. If you do not have one yet in the following link (https://cds.climate.copernicus.eu/api-how-to)

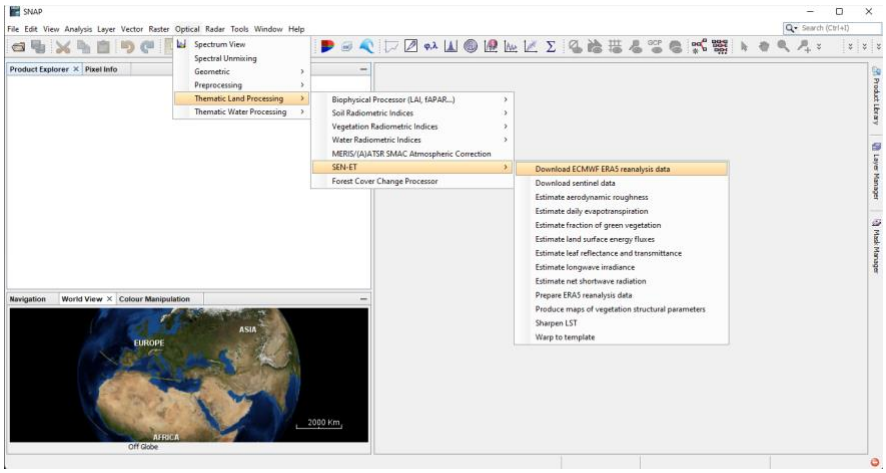


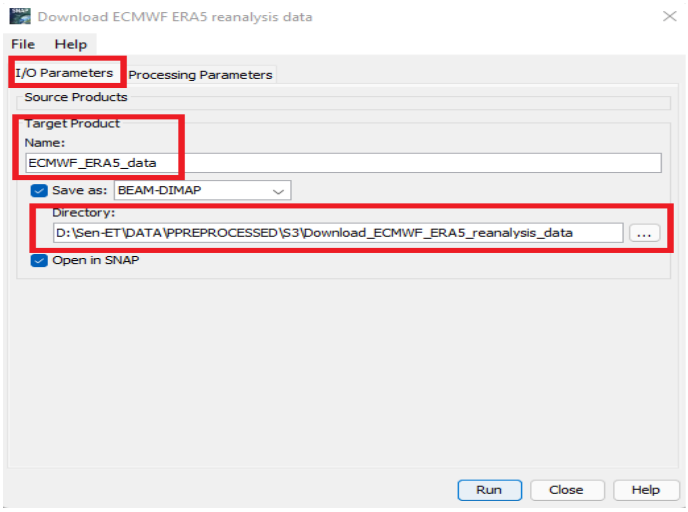
After creating an account, an email will automatically be sent to your email address, confirm your registration, and set the password up. The **Climate Data Store Application Program Interface** is a service providing programmatic access to CDS data. In this page you will find explanations and examples showing how to use the CDS API,

For Windows users, please read How to install and use CDS API on Windows

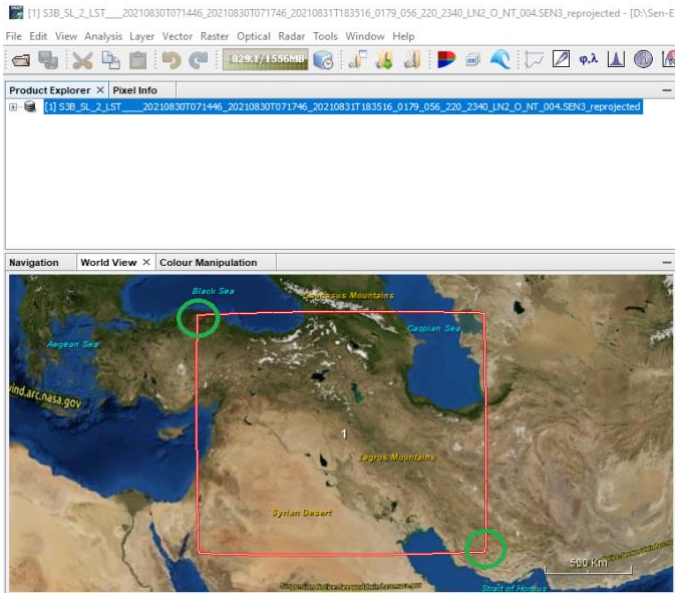
Once the access is established, go back to SNAP.

From the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN_ET plugin, ultimately click Download ECMWF ERA5 reanalysis data, a new window of the operator will pop up, In the first I/O Parameters set the name of the target data, and the directory where the downloading of the data will take place,



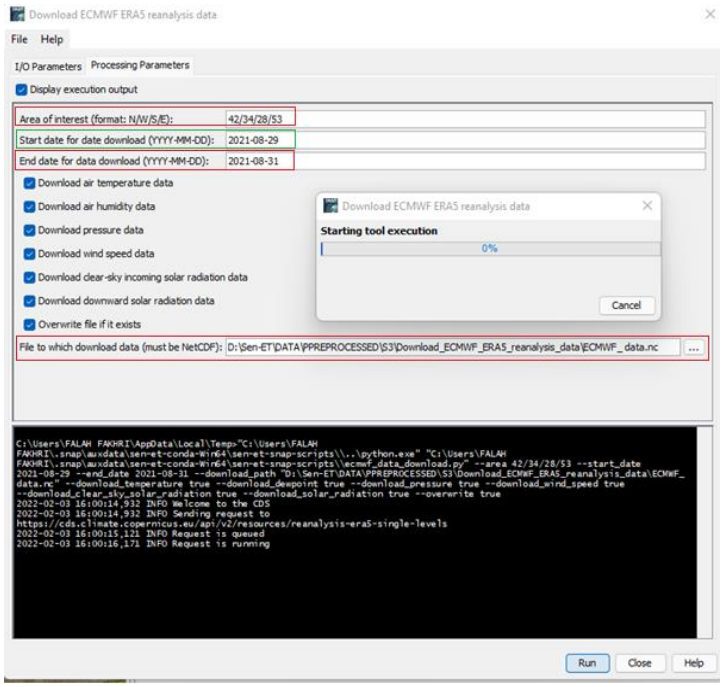


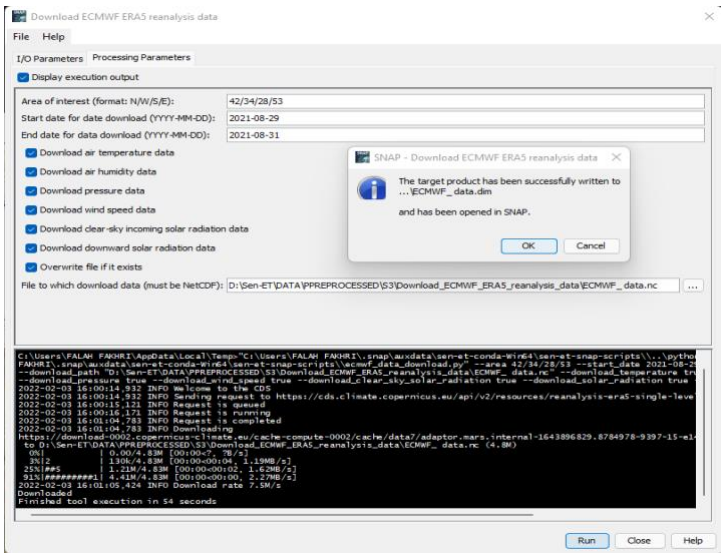
In the Processing parameters, set the Area of interest (format: N/W/S/). A way of easily match the AOI it is to open the S3 reprojected product in the Product Explorer, and click on the World View Window, as depicted in the figure below. From the World View Window, move the cursor from the upper left, to the lower right corners, and take note of the coordinates. It is also possible to select a bigger area than the AOI, it is not compulsory to match the S3 AOI.



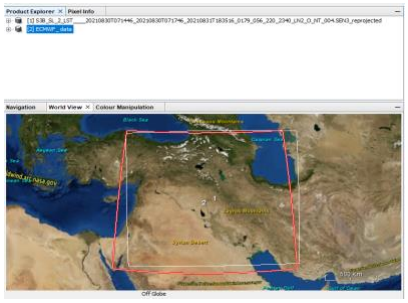
Regarding to the start and end date, set the start date 1 day before the Sentinel-3 overpass (in our example here: (2021-08-29) and the end date one day after overpass (e.g., 2021-08-31)

The download will take few minutes, once the process ended click Ok, see the figures below:



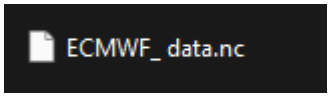


Check out the World View Window if the downloaded ECMWF ERA5 data is covering the AOI; The red rectangle is the frame of the data in the figure below:



Output

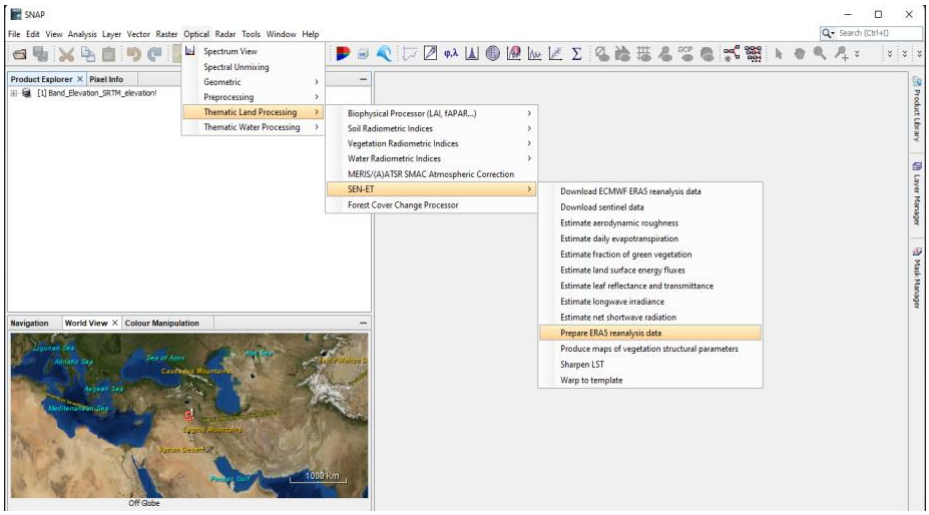
- File to which download data (NetCDF) -product containing the ECMWF ERA5 reanalysis data,



5- Prepare ERA5 reanalysis data

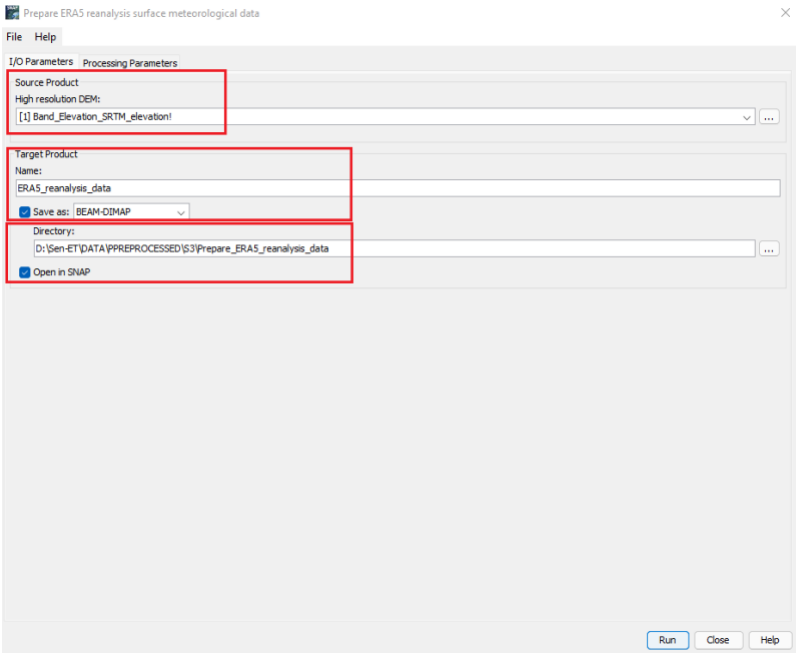
This operator prepares ERA5 reanalysis surface meteorological data based on the ECMWF ERA5 reanalysis data and the high-resolution DEM, in other words, the meteorological data already downloaded is extracted to match-up the satellite overpass time.

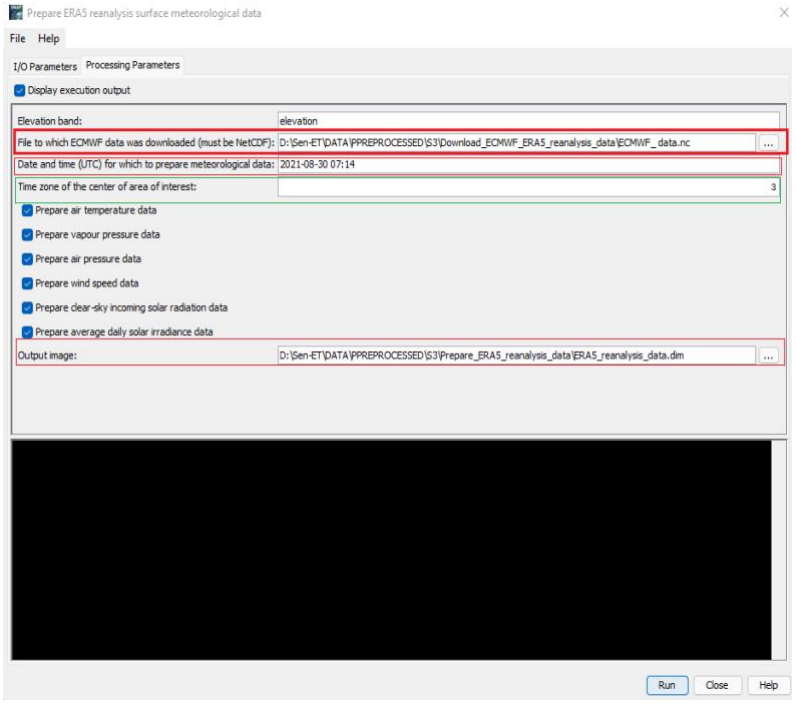
From the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN_ET plugin, ultimately click on Prepare ECMWF ERA5 reanalysis data, a new window of the operator will pop up.



In the first I/O parameter set the input, target name and the directory where the product is going to be saved, as it has been indicated in other steps before.

In the Processing Parameters tab, set the time, and other values as illustrated in the figures below:





Inputs

- High resolution DEM - output of Add elevation.

Parameters

- Elevation band - name of the elevation band (“elevation”), to subset and resample the data. to match the other datasets (S2, and S3).
- File with ECMWF data downloaded (NetCDF).
- Date and time (UTC) of the meteorological data (YYYY-MM-DD HH:MM).

- Time zone of the centre of area of interest: set the time and date of the Sentinel-3 overpass the time zone (for instance, the Iraqi northern part covered by S2 it is located at UTC+3 hours, thus type in 3 in this slot), see the figure below:

Parameters to be prepared (by default all of them appear selected):

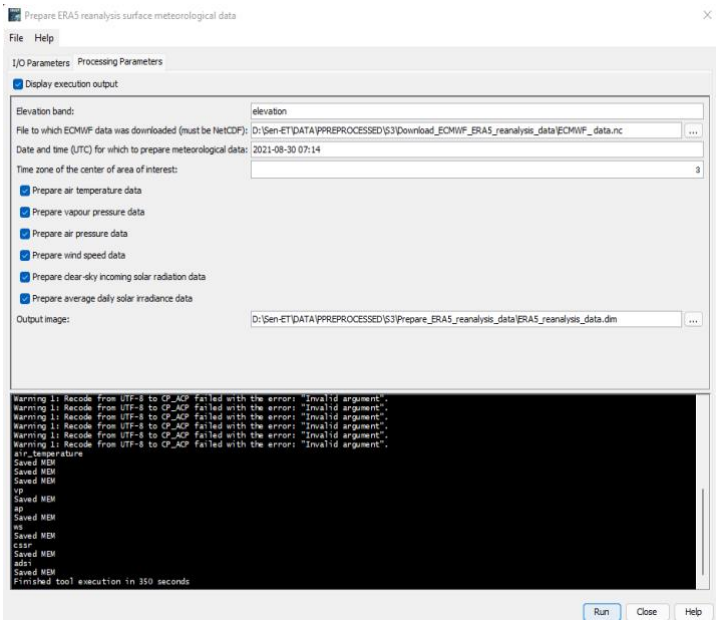
- Prepare air temperature data - indicate if air temperature data should be prepared.
- Prepare vapour pressure data - indicate if vapour pressure data should be prepared.
- Prepare air pressure data - indicate if air pressure data should be prepared.
- Prepare wind speed data - indicate if wind speed data should be prepared.
- Prepare clear-sky incoming solar radiation data - indicate if clear-sky incoming solar radiation data should be prepared.
- Prepare average daily solar irradiance data - indicate if average daily solar irradiance data should be prepared.

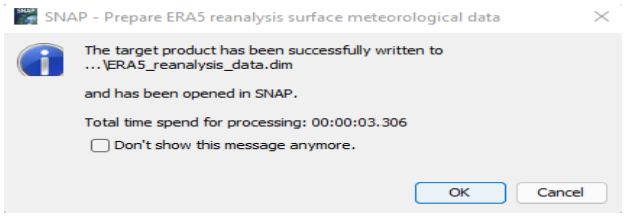
Output image:

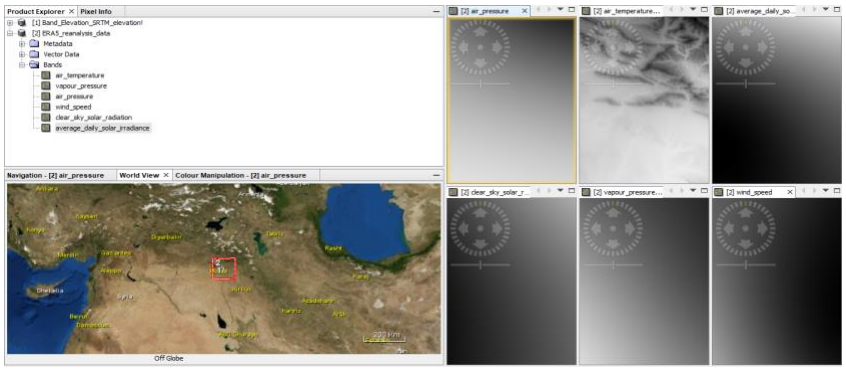
- Output image - Product containing the ERA5 reanalysis surface meteorological data

As usual, indicate the whole path where the output image will be stored.

The process will take a few minutes to be done,

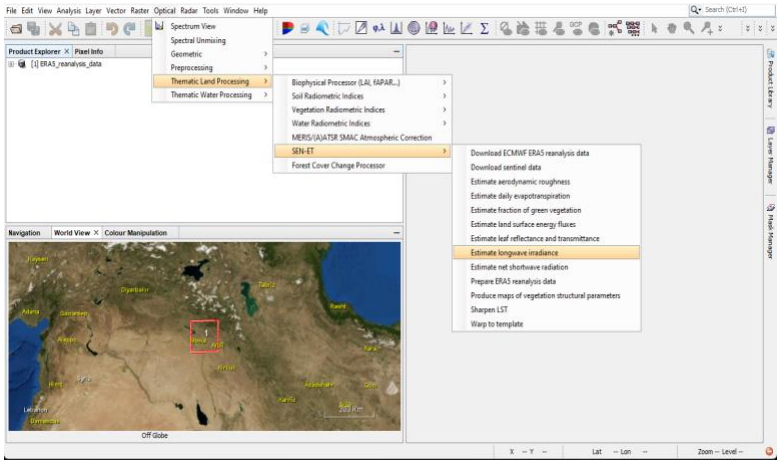




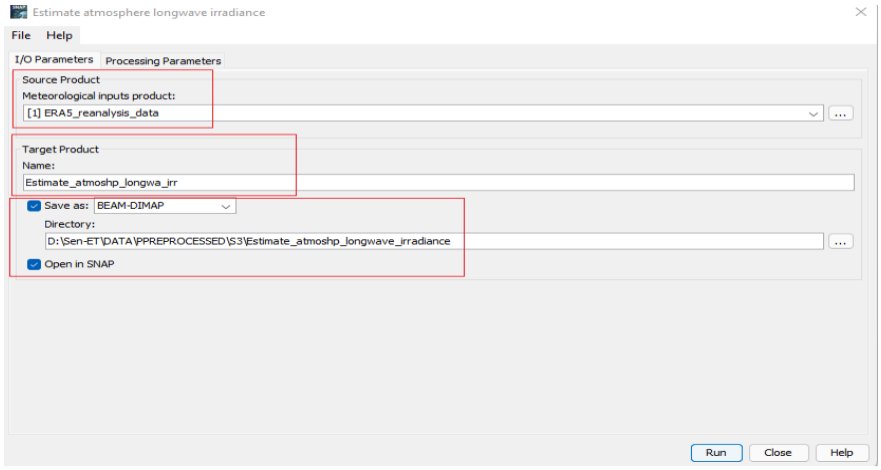


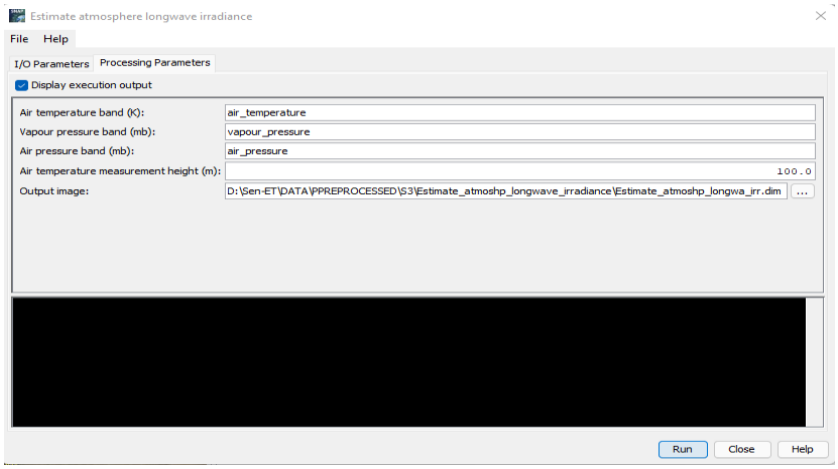
6- Estimate longwave irradiance

From the main tab, Optical tab, navigate to the *Thematic Land processing*, and then to the SEN-ET plugin, click on *Estimate longwave irradiance*, a new window of the operator will pop up.



In the first I/O parameters set the target and the output directory, and in the Processing parameter, set the inputs as illustrated below, then click on Run to proceed:





This operator estimates atmosphere longwave irradiance (Wm^{-2}) based on meteorological inputs.

Inputs

- Meteorological inputs product - output of Prepare ERA5 reanalysis data operator.

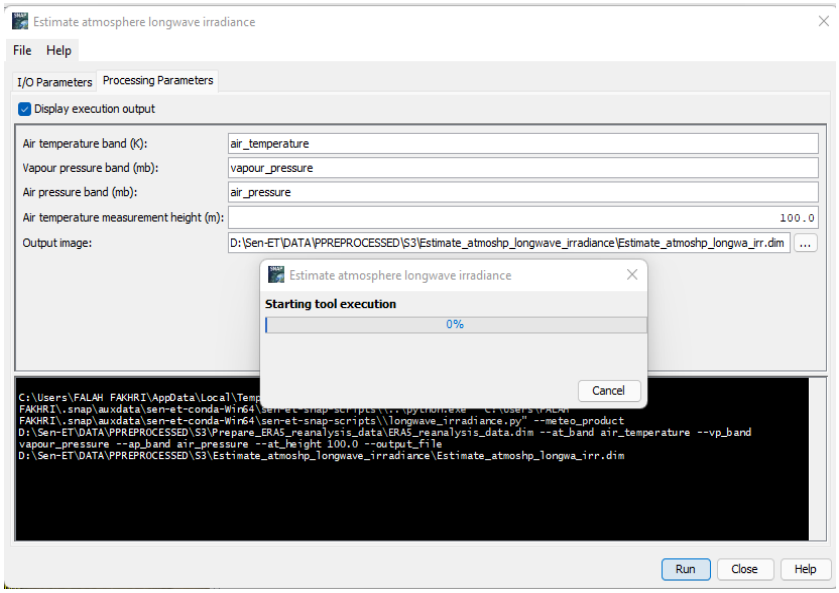
Parameters

- Air temperature band (K) - name of the air temperature band.
- Vapour pressure band (mb) - name of the vapour pressure band.
- Air pressure band (mb) - name of the air pressure band.
- Air temperature measurement height (m).

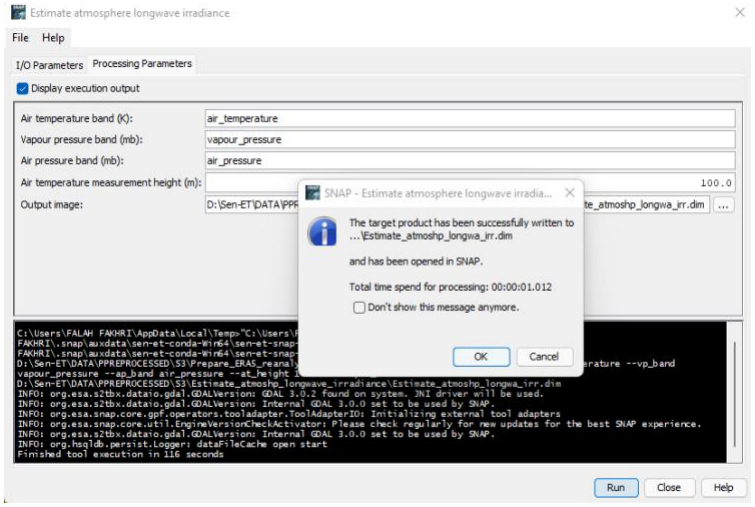
Output

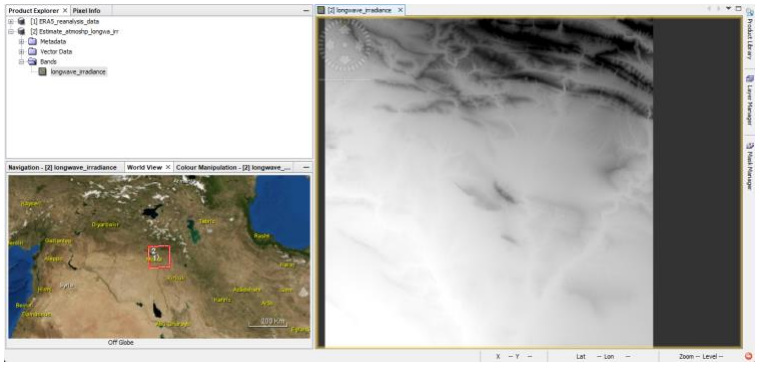
- Output image - Product containing the atmosphere longwave irradiance data.

Indicate the whole path where the output image (*.dim) will be stored.



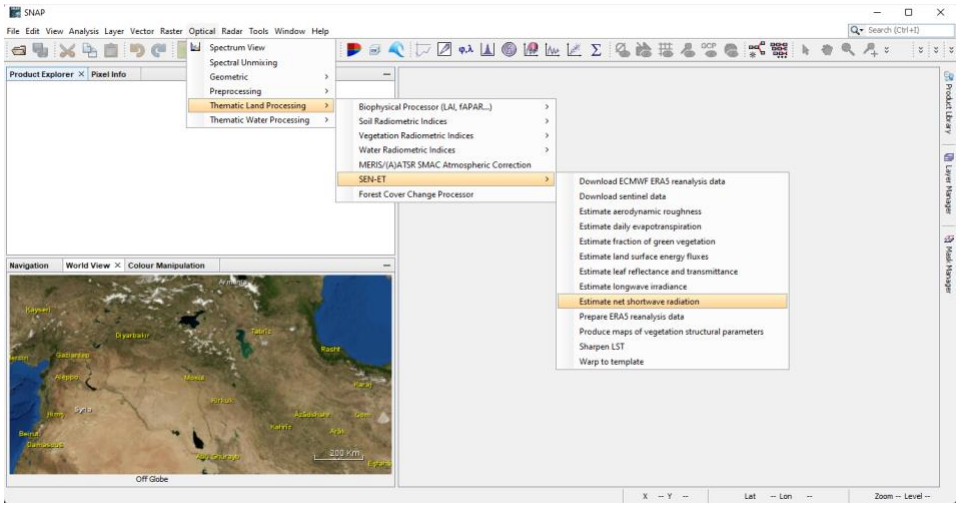
The process will take a few minutes to finish, once finished press Ok and as usual the new product will be automatically added up to the Product Explorer,





7- Estimate net shortwave radiation

From the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN-ET plugin, ultimately click on *Estimate shortwave radiation*, a new window of the operator will pop up,



In I/O parameters, set up all the input parameters and notice that the *Sun zenith angle product* is the S3 observation geometry product after being put through the *Warp to template* operator.

This operator estimates net shortwave radiation based on meteorological and biophysical inputs.

Inputs:

- Leaf spectral properties product - output of Sentinel-2 *Estimate leaf reflectance and transmittance* operator.
- Plant biophysical properties product - output of Sentinel-2 pre-processing.
- Vegetation structural parameters product - output of Sentinel-2 maps of *vegetation structural parameters* operator.
- Meteorological inputs product - output of *Prepare ERA5 reanalysis data* operator.
- Sun zenith angle product - Sentinel-3 observation geometry product after being put through Warp to template operator.

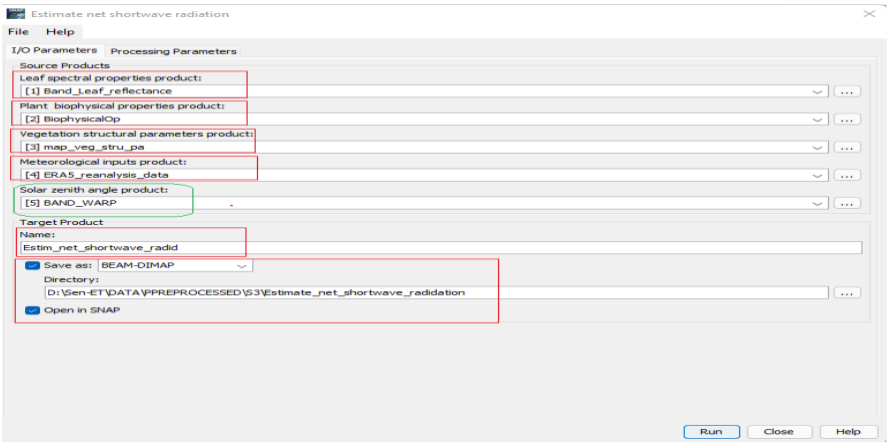
Parameters:

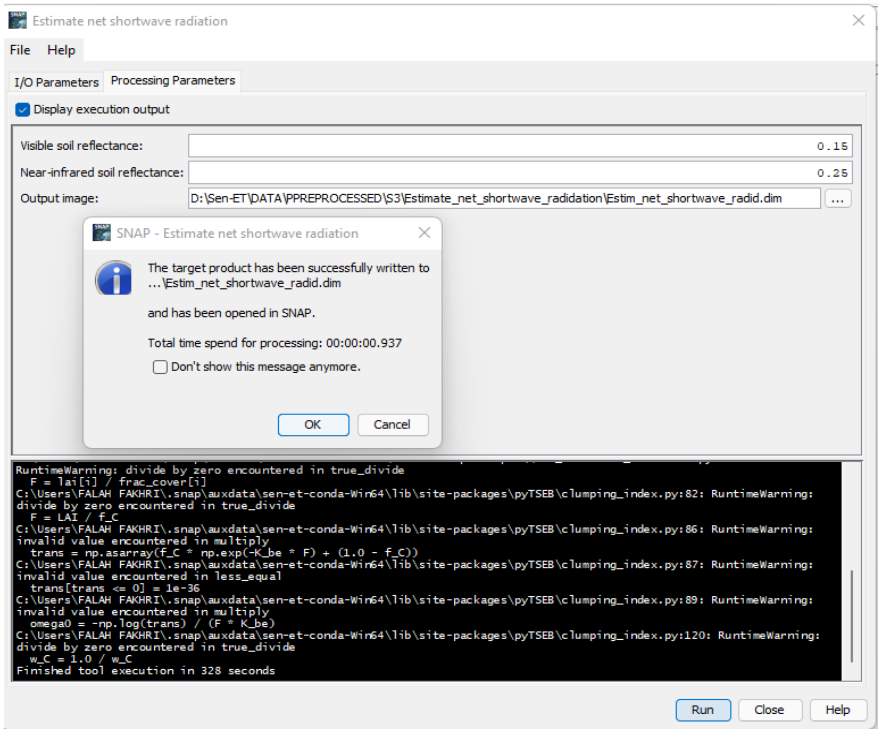
- Visible soil reflectance: by default is 0.15
- Near-infrared soil reflectance: by default is 0.25

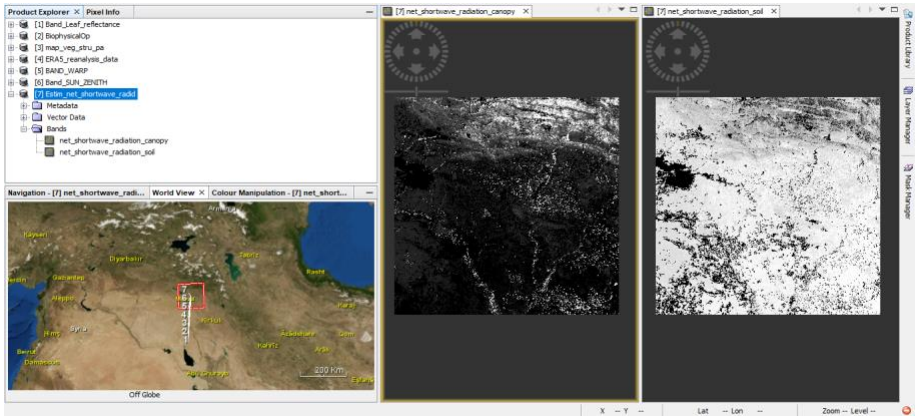
Output:

- Output image - Product containing the *net shortwave radiation data.*

Indicate the whole path where the output image (*.dim) will be stored.



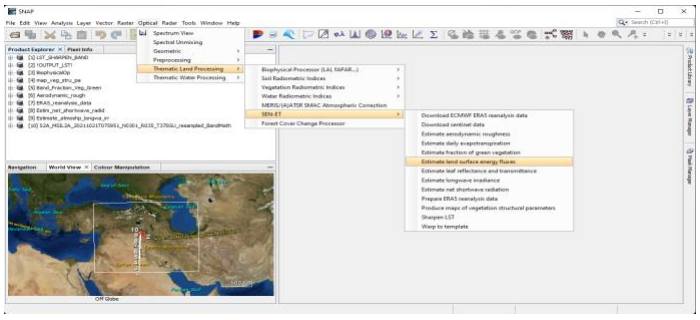


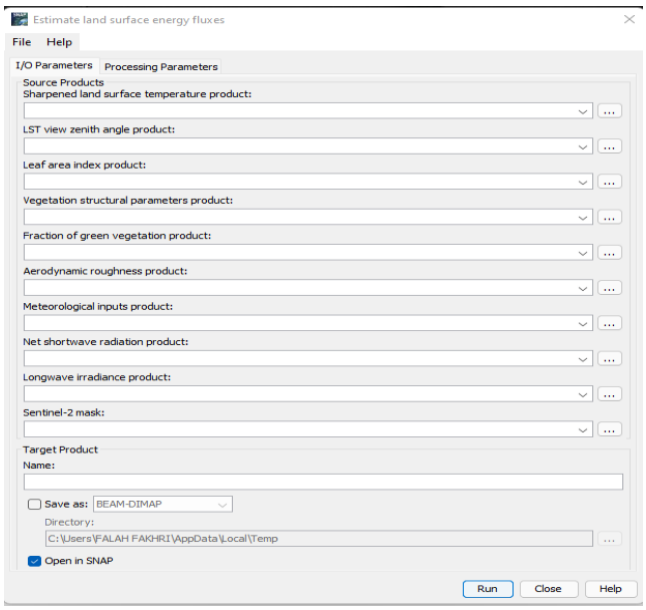


8- Estimate land surface energy fluxes

This operator estimates land surface energy fluxes (latent, sensible, ground heat and net radiation) using One-Source Energy Balance model for bare soil pixels and Two-Source Energy Balance model for vegetated pixels.

As usual, from the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN-ET plugin, click on *Estimate land surface energy fluxes* operator, a new panel will pop up. Please see the figures below,





Be aware about the input of the first I/O parameters: select all inputs or source products and navigate to the folder where to save the result, name the output file name, and do not forget the *.dim extension.

The process will take a few minutes to be done, once the process has finished an automatically result will be added up to the Product Explorer, click Ok to discover the result,

Inputs

- Sharpened land surface temperature product - output of Sharpen LST operator.
- The LST view zenith angles are stored in the S3 observation geometry warp.
- Plant biophysical properties product - output of Sentinel-2 pre-processing.
- Vegetation structural parameters product - output of maps of vegetation structural parameters operator.
- Fraction of green vegetation product - output of *Estimate fraction of green vegetation* product.
- Aerodynamic roughness product - output of *Estimate aerodynamic roughness* operator.
- Meteorological inputs product - output of *Prepare ERA5 reanalysis data* operator.
- Net shortwave radiation product - output of *Estimate net shortwave radiation* operator.
- Longwave irradiance product - output of *Estimate longwave irradiance* operator.
- Sentinel-2 mask product - output of Sentinel-2 pre-processing.

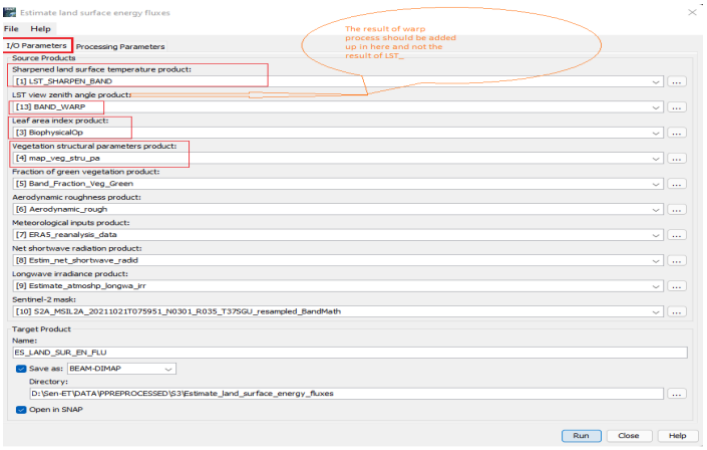
The processing parameters, as explained below, leave as default, or change according to the background experience,

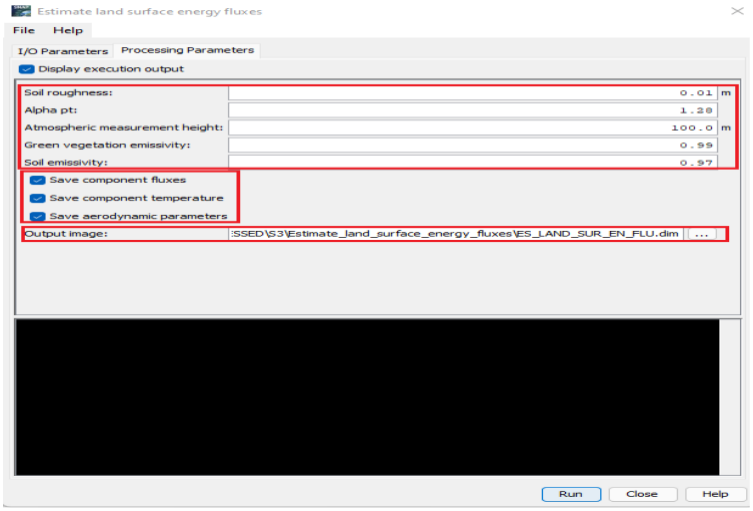
- Soil roughness
- Alpha pt
- Atmospheric measurement height
- Green vegetation emissivity

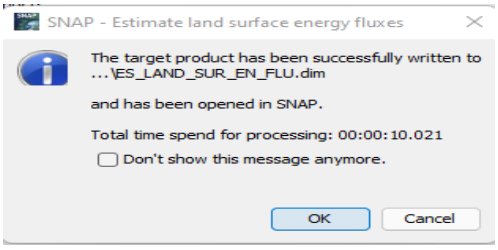
- Soil emissivity (tick):
    - Save component fluxes - indicate if component fluxes data should be saved
    - Save component temperature - indicate if component temperature data should be saved
    - Save aerodynamic parameters - indicate if aerodynamic parameters data should be saved

Output

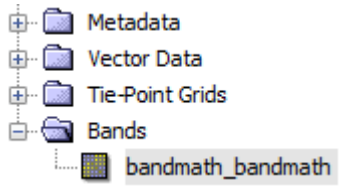
- Output image - Product containing the land surface energy fluxes





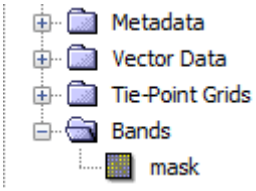


We have observed the following error when the name of the mask resulted from S2 pre-processing is other than “mask”:

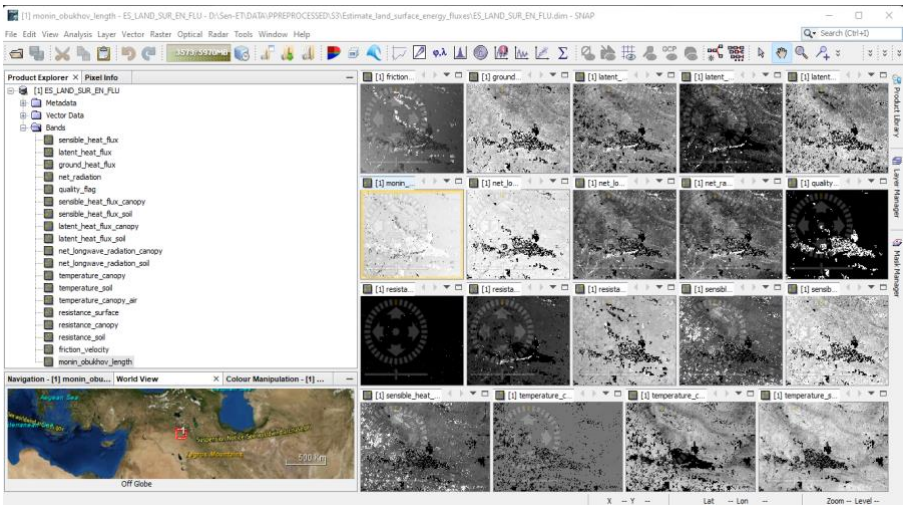



```
AttributeError: 'NoneType' object has no attribute 'readPixels'
During handling of the above exception, another exception occurred:
Traceback (most recent call last):
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\\energy_fluxes.py", line 188, in <module>
    main()
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\lib\site-packages\click\core.py", line 764, in __call__
    return self.main(*args, **kwargs)
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\lib\site-packages\click\core.py", line 717, in main
    rv = self.invoke(ctx)
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\lib\site-packages\click\core.py", line 956, in invoke
    return ctx.invoke(self.callback, **ctx.params)
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\lib\site-packages\click\core.py", line 555, in invoke
    return callback(*args, **kwargs)
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\\energy_fluxes.py", line 55, in main
    mask = su.read_snappy_product(mask, 'mask')[0].astype(np.float32)
  File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen-et-conda-Win64\sen-et-snap-scripts\snappy_utils.py", line 29, in read_snappy_product
    raise RuntimeError(file_path + " does not contain band " + band_name)
RuntimeError: D:\Sen-ET\DATA\PPREPROCESSED\S2\BAND_MATH_MASK\S2A_MSIL2A_20211021T075951_N0301_R035_T37SGU_resampled_BandMath.dim does
not contain band mask
Process exited with value 1
Finished tool execution in 53 seconds
```

Something similar happened before with the Landcover layer name.



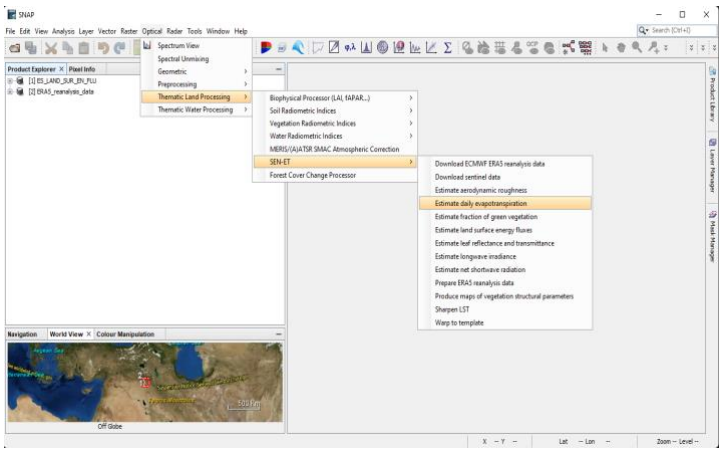
Now the result are ready to be inspected,



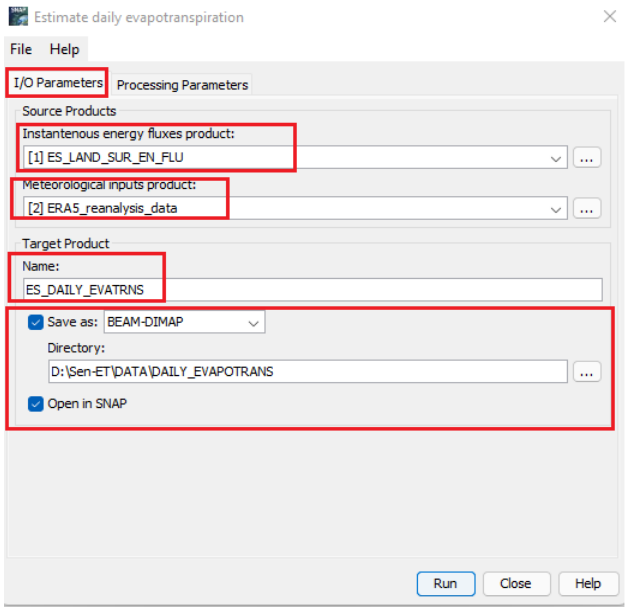
9- Estimate daily evapotranspiration

Finally, this operator estimates the daily evapotranspiration by extrapolating instantaneous latent heat flux using daily solar irradiance.

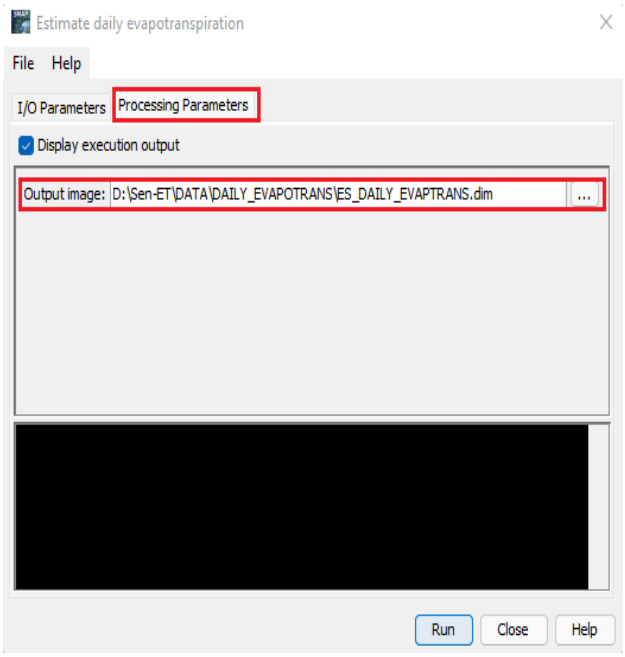
From the main tab, Optical tab, navigate to the Thematic Land processing, and then to the SEN-ET plugin, click on *Estimate daily evapotranspiration* operator, a new panel with two parameters tabs will pop up:

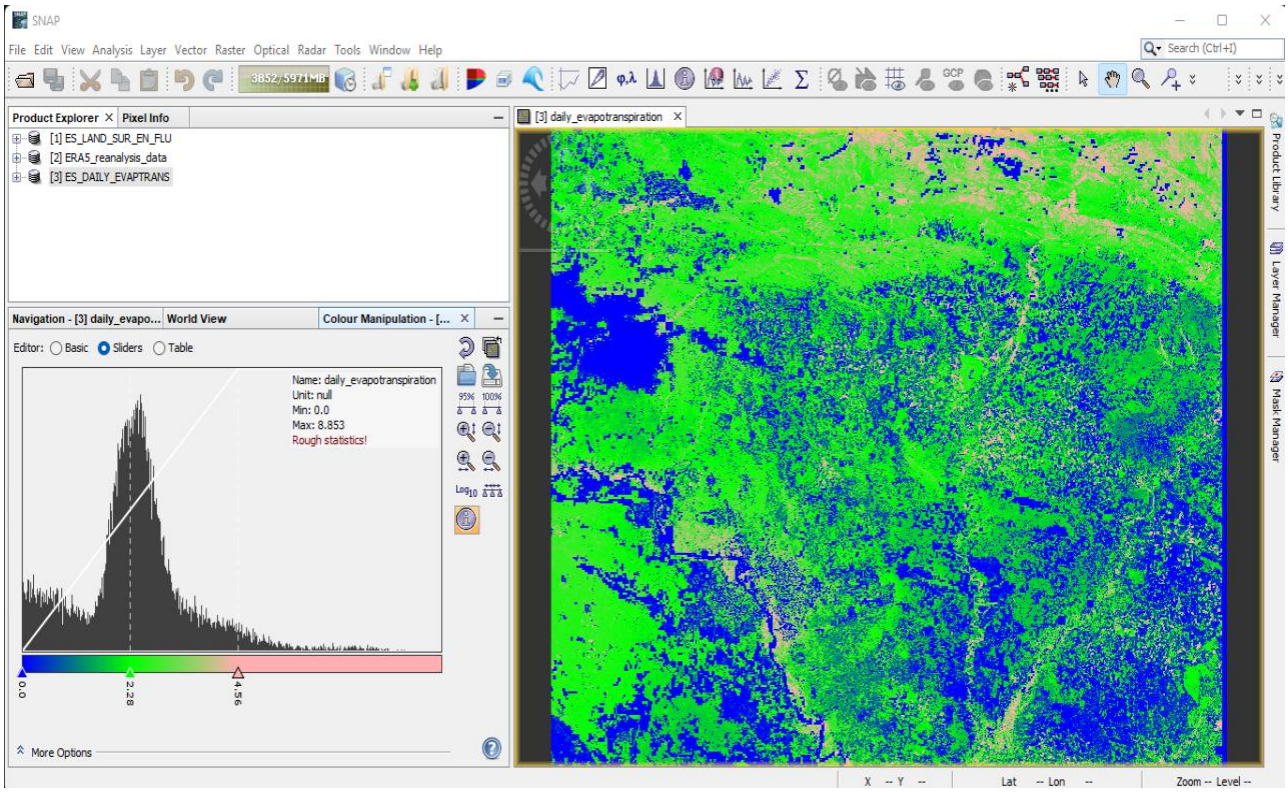


Specify the input of the first parameter (I/O parameters), give a name to the target, and tick the save box, and navigate to the folder where to save the result.



In the *Processing parameters*, navigate to the folder where to save the result but the difference in here as has been mentioned multiple times is, to add an extension *.dim to the name of the target. Then click Run to proceed. The process will take a few seconds, once it is done an automatic result will be added up to the Product Explorer,


Estimate daily evapotranspiration
File Help
I/O Parameters
Processing Parameters
Display execution output
Output image: D:\Sen-ET\DATA\DAILY_EVAPOTRANS\ES_DAILY_EVAPTRANS.dim
...
Run
Close
Help


SNAP
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help
Search (Ctrl+I)
Product Explorer
Pixel Info
[1] ES_LAND_SUR_EN_FLU
[2] ERA5_reanalysis_data
[3] ES_DAILY_EVAPTRANS
[3] daily_evapotranspiration
Navigation - [3] daily_evapo...
World View
Colour Manipulation - [...
Editor: Basic Sliders Table
Name: daily_evapotranspiration
Unit: null
Min: 0.0
Max: 8.853
Rough statistics!
0.0
2.28
4.56
More Options
Product Library
Layer Manager
Mask Manager
X -- Y --
Lat -- Lon --
Zoom -- Level --

References And Links

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