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

Ву

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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 path¹, .



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,

SNAP SNAP																							-			×
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		Manage External Tools																								
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		Options																								Layer Manager
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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.

Options																					\times
🧬 😻	Performa	nce W		Keymap	Appeara	ince	S-1 S1TBX	S2TBX	s	S-3 STBX							C	L Fi	lter (C	trl+F)	
System																					
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Cache Path	C:\Us	ers\FAL	AH FA	AKHRI\.sr	ap\var\c	ache															
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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 (\underline{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.

SNAP			- 0 X
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help			Q . Search (Ctrl+I)
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Thematic Land Processing >	Biophysical Processor (LAI, fAPAR)	>	Let 1
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	SEN-ET	Download ECMWF ERAS reanalysis data	2 de la
	Forest Cover Change Processor	Download sentinel data	fanz
		Estimate aerodynamic roughness Estimate daily exopotranopiration Estimate fraction of green vegetation Estimate land surface reary fluxes	90
Navigation World View Colour Manipulation × Uncertainty Visualisation	-	Estimate leaf reflectance and transmittance	14
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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 (E)

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 (\underline{E}) the following points are clearly showing the meaning of the S3 name.

MMM_SL_L_TTTTTT_yyyymmddThhmmss_YYYYMMDDTHHMMSS_YYYYMMDDTHHMMSS_[i nstance 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 Identifierttttttttttttttttttt

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_2 340_LN2_0_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.

Read Resample Subset BiophysicalOp Write_reflectance Subset_reflectance Subset_sun_zenith Write_sun_zenith BandMaths_mask Write_mask Write_biophysical
- Target Product
Name:
S2_reflectance
Save as: BEAM-DIMAP
Directory:
/media/disk/ana/Sen_ET_tutorial

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 20meter pixel resolution by hand.

	B5		~
By reference band from source product:	Resulting target width:	5490	
	Resulting target height:	5490	
	Target width:		10,980 🗘
OBy target width and height:	Target height:		10,980 🌲
	Width / height ratio:	1.00000	
			60 🌲
By pixel resolution (in m):	Resulting target width:	1830	
	Resulting target height:	1830	
ad Resample BiophysicalOp Subset Subset(2) BandMa			
By reference band from source product:	Resulting target width:	1830	
	Resulting target height:	1830	
	Resulting target height: Target width:	1830	10,980
) By target width and height:		1830	10,980
○ By target width and height:	Target width:	1830	
○ By target width and height:	Target width: Target height:		
	Target width: Target height:		10,980
	Target width: Target height: Width / height ratio:	1.00000	10,980
 By target width and height: By pixel resolution (in m): Define resampling algorithm 	Target width: Target height: Width / height ratio: Resulting target width:	1.00000	10,980

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,

Read	Resample	BiophysicalOp	Subset Subset	(2) BandMaths	Write Write(2)	Write(3)	Write(4)		
source	Danus:	82 83							Γ
		84							
		B5							
		B6							
		87 88							
		B8A							
🔽 Co	py Metadati	a –							1
O Pix	el Coordinat	tes 🔿 Geogra	phic Coordinates						
Refere	nce band:	B1						~]
X:		0			Y:		0		
Width:		5490			height:		5490		
Sub-sa	mpling X:	1			Sub-sampling Y:		1		

Read Resample BiophysicalOp Subset Subset(2) BandMaths Write Write(2) Write(3) Write(4)

Source Bands:	quality_snow_confidence			
	quality_scene_classification			
	view_zenith_mean			
	view_azimuth_mean			I
	sun_zenith			
	sun_azimuth			
	view_zenith_B1			
	view_azimuth_B1			
🔽 Copy Metadata				
O Pixel Coordinates	O Geographic Coordinates			
Reference band:	B1			\sim
Х:	0	Y:	0	
Width:	5490	height:	5490	
Sub-sampling X:	1	Sub-sampling Y:	1	

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</pre>

Read Resample	BiophysicalOp Subset Subset(2) BandMaths Write Write(2) Write(3) Write(4)
Target Band:	quality_mask_S2
Target Band Type:	float32
Band Unit:	
No-Data Value:	0.0
Expression:	if (quality_scene_dassification >=8 && quality_scene_dassification <=10) quality_scene_dassification == 3 then 0 else 1

Graph Builder / SZ_PREPROCESSING.cml	,
le Graphs	
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and Resample BiophysicalOp Subset Subset(2) BandMaths Write Write(2) Write(2) Write(3)	
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	u) m)

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)-

[1] S2A_MSIL2A_202108						Band	lMath	- [D:\	Sen-E1	r\data\p
File Edit View Analysis Li	ayer Vector Raster Opt				<u> </u>	B	<u>M</u>	<u>Mr</u>	Ľ,	Σ
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	and Maths									
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	dd Land Cover Band									
-	roup Nodes by Type									
	pen RGB Image Window									
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C	lose Product									
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Digital elevation mode	(DEM):									
ACE2_5Min (Auto Dow ACE30 (Auto Downloa ASTER 1sec GDEM CDEM (Auto Downloa Copernicus 30m Globa Copernicus 90m Globa GETASSE30 (Auto Do SRTM 1Sec Grid	ad) d) al DEM (Auto Downlo al DEM (Auto Downlo wnload)	-								
SRTM 1Sec HGT (Auto SRTM 3Sec (Auto Dov										
Resampling method:	BILINEAR INTERP	OLATION								
Elevation band name:										
	(ок	Cance	:						

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 function to create an elevation band and save it

as a separate image, as shown below:

_	Graph Builder : add_elevation.xml	\times
File	Graphs Read AddElevation Subset Write	
Na [1	urce Product me:)

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

Graph Builder : a	add_elevation.xml	>
File Graphs		
Read	AddElevation Subset Write	
Read AddElevation	Subset Write	
Digital Elevation Model		~
DEM Resampling Meth	DICUBIC_INTERPOLATION	~
Elevation Band Name:	elevation	

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.

File	h Builder : add_landcover.xml raphs	>
	Read AddLandCover Subset Write	
Na	AddLandCover Subset Write	
De	Format: Any Format 🧹	
	📔 Load 📎 Clear 📝 Note 🏝 Save 🕢 Help 🕞 Run	

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.**

Read AddLandCo	ver Subset Write
	AAFC Canada 2017 Crop
	AAFC Canada 2018 Crop
	AAFC Canada Clay Pct
	AAFC Canada Sand Pct
	CCILandCover-2015
	GLC2000
	GlobCover
	JaxaForestMap-2016
	MODIS 2007 Tree Cover Percentage
	MODIS 2010 Tree Cover Percentage
External Files	
Resampling Method:	NEAREST_NEIGHBOUR V
	Integer data types will use nearest neighbour
	🖹 Load 🏷 Clear 📝 Note 🏝 Save 🔞 Help ▷ Run

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.

Read AddLandCove	Subset	Write			
Source Bands:	mask				
		er_CCILandCover-2015			
🛃 Copy Metadata					
Pixel Coordinates	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	aphic Coordinates			
Reference band:	mask	raphic Coordinates			
				-	~
x:	0		Y:	0	
Width:	5490		height:	5490	
Sub-sampling X:	1		Sub-sampling Y:	1	
	Load	🍋 Clear 🥤	🖉 Note 🛛 🔼 Save	🕐 Help >	Run
Read AddLandCover	Subset	Write			
Target Product					
Name:					
CCI_landcover					
	•				
Save as: BEAM-DIMA	P	~			
Directory:					
D:\Sen-ET\DATA	PPREPRO	CESSED\S2\Landcover			
	D		*		-
	📄 Load	🏷 Clear 🛛	🖉 Note 🛛 🚬 Save	🕜 Help 🛛 🕞	Run

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,

Product Node Properties		
Name	land_cover_CCILandCover-2015	
Description	CCILandCover-2015	
Modified		
Raster Band Properties		
Unit	class	
Data Type	int16	
Raster size	5490 × 5490	
Valid-Pixel Expression		
No-Data Value Used		
No-Data Value	0.0	
Spectral Wavelength	0.0	
Spectral Bandwidth	0.0	
Ancillary Variables		
Ancillary Relations		

Name Name of the element	۲
	Close Help
Iand_cover_CCILandCover-2015 - Name	×
land_cover_CCILandCover-2015	
	OK Cancel

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-structuralparameters/31942/10?u=falahfakhri

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roduct Explorer × Pixel Info Geometric	🛛 🕅 ΙΔε 🗠 Σ	S & # 4 °S			
Preprocessing					
Thematic Land Processing 1 Thematic Water Processing 1					
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	MERIS/(A)ATSR SMA SEN-ET	C Atmospheric Correction			
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			Estimate aerodynamic roughnes	s	
vigation World View Colour Manipulation × Uncertainty Visualisation	-		Estimate daily evapotranspiration	n	
	25		Estimate fraction of green veget		
	in a		Estimate land surface energy flu Estimate leaf reflectance and trai		
			Estimate longwave irradiance	nsmittance	
			Estimate net shortwave radiation	,	
			Prepare ERA5 reanalysis data		
This tool window is used to manipulate the			Produce maps of vegetation stru	uctural parameters	
colouring of images shown in an image view. Right now, there is no selected image view.			Sharpen LST Warp to template		
Estimate leaf reflectance and transmitt	ance		X - Y -	Lat - Lon -	Zoom Level
ile Help					
I/O Parameters Source Product					
Plant biophysical properties product:					
[1] BiophysicalOp			~ .		
Target Product					
-					
Name:					
Name: BiophysicalOp_processed					
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Name: BiophysicalOp_processed	LEAFREFLECTA	NCE_TRANSMIT	ANCE		
Name: BiophysicalOp_processed Save as: BEAM-DIMAP v Directory:	LEAFREFLECTA	NCE_TRANSMIT	ANCE		
Name: BiophysicalOp_processed Save as: BEAM-DIMAP Directory: D:\Sen-ET\DATA\PPREPROCESSED\S2	LEAFREFLECTA	NCE_TRANSMIT	ANCE	···	
Name: BiophysicalOp_processed Save as: BEAM-DIMAP Directory: D:\Sen-ET\DATA\PPREPROCESSED\S2	LEAFREFLECTA	NCE_TRANSMIT	ANCE .		

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**.

Fstimate leaf reflectance and transmittance	\times
File Help	
I/O Parameters Processing Parameters	
Display execution output	
Output image:	
Run Close	e Help

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

🎇 Estimate leaf ref	lectance and tr	ansmittance		×	
File Help					
I/O Parameters Pro	cessing Paramet	ters			
Display execution	n output				
Output image:					
Select					×
Look in:		ECTANCE_TRANSMITANCE	~	🗈 💣 🎫	
Recent Items					
Desktop					
Documents					
This PC					
9-	File name:	Leafreflectancetransmitta	ance.dim		Select
Network	Files of type:	All Files		~	Cancel

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 product³ 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				\times
File Help					
I/O Parameters Processing Parameters					
Source Products					
Sentinel-2 sun zenith angle product:	074611	10001 D 105 T	20015 2021	000071	
[1] subset_0_of_S2A_MSIL2A_20210829T	074611_	NU3U1_R135_1	385LF_2021	1082911	×
Plant biophysical properties product: [2] BiophysicalOp					7
Target Product Name:					
_S2A_MSIL2A_20210829T074611_N0301_	R135_T3	3SLF_2021082	9T104722_re	esampled_pro	ocessed
Save as: BEAM-DIMAP 🗸	٦				
Directory:					
D:\Sen-ET\DATA\PPREPROCESSED\S2	2\FRACTI	ON_GREEN_VE			
Open in SNAP					
			Run	Close	Help
					<u> </u>
Estimate fraction of vegetation which is green					×
File Help					
L/O Parameters Processing Parameters					
Display execution output					
Minimum fraction of vegetation which is green:			und an		0.2
Output image: D:'Sen-ET'DATA'PPR		\$2\FRACTION_GREEN	The high and the fields	ator greenan	
				Run Ci	ose Help
Estimate fraction of vegetation which is green					
File Help					×
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ETTS .	×	\$2\FRACTION_GREEN	VE\fraction_veget	ation_green.dim	0.2
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C Estimate fraction of vegetation which is green Starting tool execution 0% C Usershell HK ERWERT Acceletable peak toons C C C C C C C C C C C C C	Cancel				0.2



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 \sim 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

E 300 Fie Edi Vien Andrije Liger Vector Rate Optical Bater Tools Window Help Fie Edi Vien Andrije Liger Vector Rate Optical Bater Tools Window Help Field User Andrije Liger Vector Viene Spectral University Product Explorer X / Parel Mo Product Rater Vector Viene Product Rater Processing A (SPARL) A Product Rater Procesing A (SPARL) A Product Rater Processing A (SPARL) A Product Rate		_
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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-snapscripts\auxdata\LUT\ESA_CCI_LUT.csv



The process will take a few minutes to be completed,

SNAP - Produce maps of veg	getation structural paramet $ imes$
The target product has be\CCI_landcover_proces	een successfully written to ssed.dim
and has been opened in S	NAP.
Total time spend for proce	essing: 00:00:06.778
Don't show this messa	age anymore.
	OK Cancel
E 3140 File Edit View Analysis Layer Vector Rather Optical Radar Tools Window Help ← 및 및 III () () ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	- □ × @r.tean.(2141) @@meter.2 @%結&\$\$\$\$ \$\$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$
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Navigation - (c) g World View Colour Manp	

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,

ile Edit View Analysis Layer Vector Raster Opt	ical Radar Tools Window He Spectrum View		18 1 1 2 5 CK NA HT 8 500	-		1 4		B 079	. ~	-	• Search		tt.
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					Sharpen LST								
This tool window is used to manipulate					Warp to temp	late							
colouring of images shown in an in Right now, there is no selected image													
		0											

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

Estimate aerodynamic roughness
File Help
I/O Parameters Processing Parameters
Source Products
Plant biophysical properties product:
[1] BiophysicalOp v
Vegetation structural parameters product:
[2] produced_map_veg_stru_param
Target Product Name: BiophysicalOp_processed Save as: BEAM-DIMAP Directory:
D:\Sen-ET\DATA\PPREPROCESSED\S2\Aerodynamic_roughness Open in SNAP
Run Close Help

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,

SNA	AP - Estimate aerodynamic roughness $\qquad imes$	1
()	The target product has been successfully written to \Aerodynamic_roughness \BiophysicalOp_processed.dim	
	and has been opened in SNAP.	
	Total time spend for processing: 00:00:02.632	
	OK Cancel	

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:

	_		83516_0179_056_220_2340_LN2_O_NT_0 3516_0179_056_220_2340_LN2_O_NT_004	
S3B_SL_2_LST20210830T071446_20210830T0717	746_20210831T183516_0179_056_220_2340_LI	N2 ~ C	P Search S3B_SL_2_LST	
Name	Date modified	Туре	Size	
cartesian_in.nc	17/01/2022 15:40	NC File	4,728 KB	
cartesian_tx.nc	17/01/2022 15:40	NC File	42 KB	
flags_in.nc	17/01/2022 15:40	NC File	659 KB	
geodetic_in.nc	17/01/2022 15:40	NC File	8,816 KB	
geodetic_tx.nc	17/01/2022 15:40	NC File	1,653 KB	
geometry_tn.nc	17/01/2022 15:40	NC File	3,404 KB	
indices_in.nc	17/01/2022 15:40	NC File	973 KB	
LST_ancillary_ds.nc	17/01/2022 15:40	NC File	9,899 KB	
LST_in.nc	17/01/2022 15:40	NC File	3,815 KB	
met_tx.nc	17/01/2022 15:40	NC File	35,499 KB	
time_in.nc	17/01/2022 15:40	NC File	62 KB	
xfdumanifest.xml	17/01/2022 15:40	XML Document	116 KB	

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 (<u>A</u>) Select the graph and click Open,

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File Graphs
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BandMaths_mask Write_mask
Read Subset Subset_AOI Reproject Subset_LST Subset_obs_geometry Write_obs_geometry BandMaths_mask Write_LST Source Product Name: [2] subset_0_of_538_5L_2_LST20210830T071446_20210830T071746_20210831T183516_0179_056_220_2340_LN2_0_NT_004
Data Format: Any Format 🗸
💼 Load 💊 Clear 📝 Note 🏩 Save 🕐 Help 🕞 Run

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,

Product Explorer × P	Pixel Info											
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	milo											

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.

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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,

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Co	ov Metad	lata							

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

Road Subset	Subset(2) Reproject Subset(3) Subset(4) BandMaths Write(2) Write(3) Write
Read Subset Source Bands:	Subset(2) Reproject Subset(3) Subset(4) BandMaths Write(2) Write(3) Write UST doud_in longitude_in latitude_in x_tk y_tK latitude_tx longitude_tx
• •	
Read Subset	Subset(2) Reproject Subset(3) Subset(4) BandMaths Write(2) Write(3) Write Istitude_tx I Istitude_tx I I IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII
Read Subset Target Band:	Subset(2) Reproject Subset(3) Subset(4) BandMaths Write(2) Write(3) Write mask
Target Band Typ	e: float32
Band Unit: No-Data Value: Expression:	0.0 f doud_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.

•						1			[
Read	Subset	Subset(2)	Reproject	Subset(3)	Subset(4)	BandMaths	Write(2)	Write(3)	Write	
Targe	t Product									
	_									
Name										
Band	_LST									
Save	as: BEAN		~							
			Ý							
	irectory:									
				D\S3\LST						

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:

SNAP					- 0 >
File Edit View Analysis Layer Vector Raster Opt	ical Radar Tools Window H	ep :			Q . Search (Oti+I)
a 🖫 🤊 (* 🔤	Spectrum View Spectral Unmixing			治田石四日 大田 トゥヘム。	‡ \ ⊋ II * * *
Product Explorer × Pieel Info	Geometric Preprocessing	2	-		
	Thematic Land Processing	3	Biophysical Processor (LAI, fAPAR)		
	Thematic Water Processing	F	Soil Radiometric Indices > Vegetation Radiometric Indices > Water Radiometric Indices >		
			MERIS/(A)ATSR SMAC Atmospheric Correction		
			SEN-ET)	Download ECMWF ERAS reanalysis data	
			Forest Cover Change Processor	Download sentinel data Estimate serodynamic roughness	
				Estimate daily evapotranspiration Estimate fraction of green vegetation	
				Estimate land surface energy fluxes	
				Estimate leaf reflectance and transmittance	
				Estimate longuave inadiance	
				Estimate net shortwave radiation	
				Prepare ERA5 reanalysis data	
				Produce maps of vegetation structural parameters	
				Sharpen LST	
				Warp to template	

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).

Warp to template	projection, resolution and extent	
le Help		
O Parameters Proce	ssing Parameters	
Source Products		
Source image:		
[1] Band_observation	1_geometry	~
Template image:		
	ce_S2A_MSIL2A_20211021T075951_N0301_R035_T37SGU_resa	~
Target Product		
Name:		
BAND_WARP		
Save as: BEAM-I	DIMAP V	
Directory:		
D:\Sen-ET\DATA	\PPREPROCESSED\S3\WARP	
Open in SNAP		
		- T
	Run Close	Hel
		>
warp to template	e projection, resolution and extent	
File Help		
I/O Parameters Proc	essing Parameters	
Display execution	output	
Resample algorithm:		~
Output image:	D:\Sen-ET\DATA\PPREPROCESSED\\$3\WARBAND_WARP`im	
Warp to temp	late projection, resolution and extent	
Starting tool exec	aution	
	0%	
	Cancel	
	anData\local\Temp\tmpomo6bko2 tif	
rs\FALAH FAKHRI\A	opData\Local\Temp\tmpome6bko2.tif pData\Local\Temp\tmpalj15w5d.tif n SamplesPerPixel. Defining non-color channels as ExtraSan n SamplesPerPixel. Defining non-color channels as ExtraSan	plac
ples doesn't match	n SamplesPerPixel. Defining non-color channels as Extrasan n SamplesPerPixel. Defining non-color channels as ExtraSam	ples.



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,

Sharpen LST with data mining sharpener File Help	×
I/O Parameters Processing Parameters	
Source Products	
Sentinel-2 reflectance product:	
[2] Bands_Reflectance_S2A_MSIL2A_20211021T075951_N0301_R035_T37SGU_resampled_20	v
Sentinel-3 LST product:	
[5] IOUTPUT_LST!	v
High resolution DEM:	
[6] Band_Elevation_SRTM_elevation!	v
High resolution sentinel-3 geometry product:	
[4] BAND_WARP	v
LST quality mask product:	
[7] Band_mask_\$3	v
Target Product	
Name:	
LST_SHARPEN_BAND	
Save as: BEAM-DIMAP	
Directory:	
D:\Sen-ET\DATA\PPREPROCESSED\\$3\Sharpen_LST	
Open in SNAP	
	Run Close Help

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.

S3B_SL_2_LST___20210830T071446 20210830T071746_20210831T183516_0179_056_220_2340_LN2_O_NT_004.SEN3

e Help		
Processing Parameters		
Display execution output		
ate and time (UTC) of Sentinel-3 acquisitio	on: 2021-08-30 07:14	
evation band:	elevation	
ood quality mask values:	1	
pmogeneity inclusion threshold:		ο.
oving window size:		3
arallel jobs:		
utput image:	D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dim	

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

Sharpen LST with data mining sharpener	r			\times
File Help				
I/O Parameters Processing Parameters				
Display execution output				
Date and time (UTC) of Sentinel-3 acquisition:	2021-08-30 07:14			
Elevation band:	elevation			
Good quality mask values:	1			
Homogeneity inclusion threshold:				0.0
Moving window size:				30
Parallel jobs:				1
Output image:	D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_S	SHARPEN_BA	ND.dim	
	Sharpen LST with data mining sharpener Starting tool execution		×	
		(Cancel	
FAKHRIsnaplauxdata\sen-et-conda-Win D:\Sen-ET\DATA\PPREPROCESSED\S2\BANDS' sentime]_]_lstD:\Sen-ET\DATA\PPREP D:\Sen-ET\DATA\PPREPROCESSED\S2\LEUA D:\Sen-ET\DATA\PPREPROCESSED\S3\WARP\E D:\Sen-ET\DATA\PPREPROCESSED\S3\WARA\E	54/serret-snap-scripts///python.exm""(C/Users 54/serret-snap-scripts//.dat_mining_shappere.pu \Bands_Reflectarce_S2A_MSIL2A_202110278951_N0 ROCCESSED\S31\ST\UOTUPTL_IST.dimhigh_res_dem TION\Band_Elevation_SRTM_elevation!.dimhigh_res 3and_mask_S3.dimlst_quality_mask 3and_mask_S3.dimdate_time_utc "2021-08-30 07: emity_thres10d 0.0moving_window.size 30pi	/"senting 301_R035_T; 'es_geom 14"elev;	375GU_res; ation_ban	ampled delev
I/O Parameters Processing Parameters I/O pisplay execution output 2021-08-30 07:14 Date and time (UTC) of Sentinel-3 acquisition: 2021-08-30 07:14 Elevation band: elevation Good quality mask values: 1	Charges I CT with state mining shares			
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I/O Parameters Processing Parameters I/O biplay execution output 2021-08-30 07:14 Date and time (UTC) of Sentinel-3 acquisition: 2021-08-30 07:14 Elevation band: elevation Good quality mask values: 1 Homogeneity inclusion threshold:	Sharpen LST with data mining sharpener	r		
C Display execution output Date and time (UTC) of Sentinel-3 acquisiton: Z021-08-30 07:14 Elevation band: elevation Good quality mask values: 1 Homogeneity inclusion threshold:				
Date and time (UTC) of Sentinel-3 acquisition: 2021-08-30 07:14 Elevation band: elevation Good quality mask values: 1 Homogeneity inclusion threshold: Moving window size: Parallel jobs: Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dim Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dim Number of training elevents for is 6981 representing 79% of avaiable low-resolution data. Swed WEM Saved				
Elevation band: elevation Good quality mask values: 1 Homogeneity inclusion threshold: Moving window size: Parallel jobs: Output image: D:\Sen-ET!DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dm Output image: D:\Sen-ET!DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dm Output image: D:\Sen-ET!DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dm NNO: Sharpening Sweak UMB Saved MEM S				
Good quality mask values: I Homogeneity inclusion threshold: Moving window size: Parallel jobs: Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm Window of training elements for is 6981 representing 79% of avaiable low-resolution data. Sweed WEM Swe	Date and time (UTC) of Sentinel-3 acquisition:	2021-08-30 07:14		
Homogeneity inclusion threshold: Moving window size: Parallel jobs: Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA Sender HEM Sender HEM	Elevation band:	elevation		
Moving window size: Parallel jobs: Dutput image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATAB D:\Sen	Good quality mask values:	1		
Parallel jobs: Output image: D:\Sen-ET\DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dim D:\Sen-ET\DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dim D:\Sen-ET\DATA\PPREPROCESSED\\$3\Sharpen_LST\LST_SHARPEN_BAND.dim When of training alements for is 6981 representing 79% of avaiable low-resolution data. NFO: Sharpening aved MEM aved MEM	Homogeneity inclusion threshold:		0.0	
Output image: D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dm NFO: Sharpening awed MEM awed MEM	Moving window size:		30	
Iomogeneity CV threshold: 0.18 Windor of training elements for is 6981 representing 79% of avaiable low-resolution data. NFO: Sharpening Swed MEM Swed MEM Swed MEM Swed MEM Residual analysis Anad MEM Swed MEM Residual analysis Residual bias: -0.02286174317596941 R residual bias: -0.02286174317596941 R residual bias: -0.02286174317596941	Parallel jobs:		1	
Wumber of training elements for is 6981 representing 79% of avaiable low-resolution data. NPRO Sharpening Sawed MEM Sawed MEM	Output image:	D:\Sen-ET\DATA\PPREPROCESSED\S3\Sharpen_LST\LST_SHARPEN_BAND.dim		
Jumber of training elements for is 6981 representing 79% of avaiable low-resolution data. NPO: Sharpening Sawed MEM Sawed MEM Sawed MEM Sawed MEM NPO: Residual analysis Sawed MEM Sawed MEM Sawed MEM R residual bias: -0.02286174317596941 R residual bias: -0.02286174317596941				
	Number of fraining elements for is 69 INPO; Sharpening Saved HEM Saved HEM Saved HEM Saved HEM Saved HEM Saved HEM Saved HEM Saved HEM Saved HEM Ka residual bias: -0.02286174317596644 LR residual bias: -0.02286174317596644	1		
Run Close			He	

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,



Download ECMWF ERA5 reanalysis data	\times
File Help	
I/O Parameters Processing Parameters	
Source Products	
Target Product Name:	
ECMWF_ERA5_data	
Save as: BEAM-DIMAP	
Directory: D:\Sen-ET\DATA\PPREPROCESSED\S3\Download_ECMWF_ERA5_reanalysis_data	
Coop in SNAR	
Open in SNAP	
Copen in SNAP	Help

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)

S3B_SL_2_LST___20210830T071446 20210830T071746_20210831T183516_0179_056_220_2340_LN2_O_NT_004.SEN3

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

Download air temperature data Download air humidity data Download pressure data Download vind speed data Download dear-sky incoming solar radiation Download downward solar radiation data Overwrite flei fi it exists		PPREPROCESSED/(S3)/Download_ECMWP_ERA5_reanalysis_data/ECMWP_data.nc
ea of interest (format: N/W5/E): at date for date download (YYYY-494-CD): d date for data download (YYYY-494-CD): Download air temperature data Download air temperature data Download air temperature data Download air temperature data Download dar Leadownload data Download download data (must be NetCDF): to which download data (must be NetCDF):	2021-08-29 2021-08-31	Starting tool execution 0% Cancel
rt date for date download (YYYY-4M4-CD): d date for data download (YYYY-4M4-CD): Download air hemetrature data Download air hemidity data Download air hemidity data Download diverseure data Download diverseure data Download diverseure data Download deverseure data Download download data (must be NetCDF):	2021-08-29 2021-08-31	Starting tool execution 0% Cancel
d date for data download (YYYY 484-DD); Download air temperature data Download air hunklity data Download opresure data Download dwind speed data Download dee-sky incoming soler radiation data Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF);	2021-08-31	Starting tool execution 0% Cancel
Download air temperature data Download air humidity data Download pressure data Download vind speed data Download dear-sky incoming solar radiation Download dear-sky incoming solar radiation data Overwrite file if it exists to which download data (must be NetCDF):	n data	Starting tool execution 0% Cancel
Download ar humidity data Download pressure data Download wind speed data Download dear-sky incoming solar radiation Download dear sky incoming solar radiation data Download download data (must be NetCDF):		Starting tool execution 0% Cancel
Download pressure data Download wind speed data Download clear-sky incoming solar radiation Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF):		Starting tool execution 0% Cancel
Download wind speed data Download dear-sky incoming solar radiation Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF):		0% Cancel
Download dear-sky incoming solar radiation Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF):		Cancel
Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF):		
Download downward solar radiation data Overwrite file if it exists to which download data (must be NetCDF):		
Overwrite file if it exists to which download data (must be NetCDF):	D:\Sen-ET\DATA	
e to which download data (must be NetCDF):	D:\Sen-ET\DATA	PPREPROCESSED\\$3\Download_ECMWF_ERA5_reanalysis_data\ECMWF_data.nc
	D: gener para	PPREPROCESSED(5.3 (Download_ECHWP_ERAS_reanaysis_data (ECHWP_data.nc
		Run Close
Download ECMWF ERA5 reanalysis data Help Parameters Processing Parameters Display execution output		
	42/34/28/53	
art date for date download (YYYY-MM-DD):		
	2021-08-31	
d date for data download (YYYY-MM-DD):		
		SNAP - Download ECMWF ERA5 reanalysis data 🛛 🗙
d date for data download (YYYY-MM-DD): Download air temperature data		
d date for data download (YYYY-MM-DD): Download air temperature data Download air humidity data		SNAP - Download ECMWF ERAS reanalysis data The target product has been successfully written toECMVF_data.dm and has been opened in SNAP.
d date for data download (YYYY-4M+DD); 0 ownload air temperature data 0 ownload air humidity data 0 ownload pressure data 0 ownload vind speed data 0 ownload clear-sky incoming solar radiation		The target product has been successfully written to #ECMVF_data.dm and has been opened in SNAP.
d date for data download (*^^* MH-DD): 2 Download air temperature data 3 Download air humidity data 3 Download pressure data 3 Download wind speed data		The target product has been successfully written to VECMWF_data.dim
ea of interest (format: N/W/S/E):	2021-08-29	

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,

ECMWF_ data.nc

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:

Prepare ERA5 reanalysis surface meteorological data	2
le Help	
O Parameters Processing Parameters	
Source Product	
High resolution DEM:	
[1] Band_Elevation_SRTM_elevation!	v
Target Product Name:	
ERA5_reanalysis_data	
Save as: BEAM-DIMAP	
Directory:	
D:\Sen-ET\DATA\PPREPROCESSED\S3\Prepare_ERAS	5_reanalysis_data
Open in SNAP	
	Run Close He
le Help /O Parameters Processing Parameters	
Display execution output	
Elevation band:	elevation
	DF): D:\Sen-ET\DATA\PPREPROCESSED\\$3\Download_ECMWF_ERA5_reanalysis_data\ECMWF_data.nc
Date and time (UTC) for which to prepare meteorological d	
Time zone of the center of area of interest:	
Prepare air temperature data	
Prepare vapour pressure data	
Prepare air pressure data	
🛃 Prepare wind speed data	
Prepare clear-sky incoming solar radiation data	
Prepare average daily solar irradiance data	
Output image:	D: \Sen-ET\DATA\PPREPROCESSED\\$3\Prepare_ERA5_reanalysis_data\ERA5_reanalysis_data.dim
ouput inage:	D: Delife I (DATA PPREPROCESSED DSPrepare_ERAS) earlarysis_uata ERAS) reariarysis_uata.um
	Run Close H

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:

🗱 Estimate atmosphere longwave irradiance	\times
File Help	
I/O Parameters Processing Parameters	
Source Product	
Meteorological inputs product:	
[1] ERA5_reanalysis_data	
Target Product	
Name:	
Estimate_atmoshp_longwa_irr	
Save as: BEAM-DIMAP	
Directory: D:\Sen-ET\DATA\PPREPROCESSED\S3\Estimate_atmoshp_longwave_irradiance	
Open in SNAP	
	Run Close Help

Estimate atmosphere longwave irrad	iance ×
I/O Parameters Processing Parameters	
Display execution output	
Air temperature band (K):	air_temperature
Vapour pressure band (mb):	vapour_pressure
Air pressure band (mb):	air_pressure
Air temperature measurement height (m):	100.0
Output image:	D: \Sen-ET\DATA\PPREPROCESSED\S3\Estimate_atmoshp_longwave_irradiance\Estimate_atmoshp_longwa_irr.dim
	Run Close Help

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.

ir temperature band (K):	air_temperature
apour pressure band (mb):	vapour_pressure
ir pressure band (mb):	air_pressure
r temperature measurement height (m)	: 100
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	Estimate atmosphere longwave irradiance
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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,

SNAP SNAP			- 0 ×
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help			Q - Search (Ctrl+I)
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Thematic Land Processing > Thematic Water Processing >	Biophysical Processor (LAI, fAPAR) Soil Radiometric Indices Vegetation Radiometric Indices Water Radiometric Indices	3 3 3	
	MERIS/(A)ATSR SMAC Atmospheric Correction SEN-ET Forest Cover Change Processor	Download ECMWF ERAS reanalysis data Download sentinel data	
Navigation World View X Cobur Manipulation		Download sentinel data Estimate aerodynamic roughness Estimate daily evapotranspiration Estimate fraction of green vegetation Estimate land surface energy fluxes Estimate leaf reflectance and transmitta Estimate longwave irradiance	nce
Bandi - Banda - Bandi		Estimate net shortwave radiation Prepare ERAS reanalysis data Produce maps of vegetation structural p Sharpen LST Warp to template	parameters
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		Х - У -	Lat Lon Zoom Level

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.

Estimate net shortwave radiation			\times
File Help			
I/O Parameters Processing Parameters			
Source Products			
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[1] Band_Leaf_reflectance			~ · · · · ·
Plant biophysical properties product:			
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Vegetation structural parameters product	4		
[3] map_veg_stru_pa			
Meteorological inputs product:			
[4] ERA5_reanalysis_data			~)
Solar zenith angle product:			
[5] BAND_WARP			~
Target Product			
Name:			
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D: \Sen-ET\DATA\PPREPROCESSED\S	3\Estimate_net_shortwave_radidation		
Open in SNAP			
			Run Close Help



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,



Estimate land surface energy fluxes	
e Help	
D Parameters Processing Parameters	
Source Products	
Sharpened land surface temperature product:	~
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ear area index product:	× [
/egetation structural parameters product:	
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Fraction of green vegetation product:	
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Aerodynamic roughness product:	×
Meteorological inputs product:	
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Net shortwave radiation product:	
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ongwave irradiance product:	×
Sentinel-2 mask:	
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Farget Product	
Name:	
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Directory: C:\Users\FALAH FAKHRI\AppData\Local\Temp	
Open in SNAP	
V Open in Store	

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

Estimate Iano	d surface energy fluxes		×
File Help		The result of warp process should be added	
I/O Parameters	Processing Parameters	process should be added up in here and not the result of LST	
Source Products Sharpened land	s I surface temperature product:		
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LST view zenith [13] BAND_WA	angle products		~
Leaf area index	product:		
[3] Biophysical			
[4] map_veg_s	ctural parameters product:		
	in vegetation product:		
[5] Band_Fract	tion_Veg_Green		
[6] Aerodynamic ro	ughness product:		
Meteorological in			
[7] ERA5_rean			
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We have observed the following error when the name of the mask resulted from S2 pre-processing is other than "mask":

🚋 💼 Metadata
🖶 💼 Vector Data
🖶 💼 Tie-Point Grids
🖮 📾 Bands
bandmath_bandmath
<pre>Attributerrop: None:ype coget: nas no attribute readrivers 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, incall return self.main(?arg, **kwangs) File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen=et-conda=Win64\lib\site=packages\click\core.py", line 764, incall return self.main(?arg, **kwangs) File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen=et-conda=Win64\lib\site=packages\click\core.py", line 717, in main rv = self.ninoke(ct) File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen=et-conda=Win64\lib\site=packages\click\core.py", line 555, in invoke return callback(?arg, **kwangs) File "C:\Users\FALAH FAKHRI\.snap\auxdata\sen=et-conda=Win64\lib\site=packages\click\core.py", line 555, 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=FICATATAPREPROCESSED\S2\SAND_MATH_MASK\S2A_MSIL2A_20211021T075951_N0301_R035_T375GU_resampled_BandMath.dim does not contain band mask Process exited with value 1 Finished tool execution in 53 seconds</module></pre>

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:

le Edit View Analysis Layer Vector Raster	Spectrum View		🖿 🖃 🔊 🗁 🕅 eð 🕅 🚳 🕼	×Σ 3835678	Q + Search (Orl+1)	5 3
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	Thematic Land Processing	3	Biophysical Processor (LAI, fAPAR)			3
	Thematic Water Processing	2	Soil Radiometric Indices			
			Vegetation Radiometric Indices			1
			Water Radiometric Indices			
			MERIS/(A)ATSR SMAC Atmospheric Correction			1
			SEN-ET >	Download ECMWF ERAS reanalysis data		
			Forest Cover Change Processor	Download sentinel data		
				Estimate aerodynamic roughness		
				Estimate daily evapotranspiration		
				Estimate fraction of green vegetation		
				Estimate land surface energy fluxes		
				Edimate level reflectance and transmittance		
				Estimate longwave irradiance		
				Estimate net shortwave radiation		
				Prepare ERAS reanalysis data		
				Produce maps of vegetation structural parameters		
				Sharpen LST		
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rigation World View A Colour Manipu	woon	-				
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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.

Estimate daily evapotranspiration	\times
File Help	
I/O Parameters Processing Parameters	
Source Products	
Instantenous energy fluxes product:	
[1] ES_LAND_SUR_EN_FLU	~
Meteorological inputs product: [2] ERA5_reanalysis_data	√
Target Product Name: ES_DAILY_EVATRNS	
Save as: BEAM-DIMAP	
Directory:	
Directory: D:\Sen-ET\DATA\DAILY_EVAPOTRANS	
Directory: D:\Sen-ET\DATA\DAILY_EVAPOTRANS	
Directory: D:\Sen-ET\DATA\DAILY_EVAPOTRANS	

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,



References And Links

- A. <u>https://www.esa-sen4et.org/</u>
- B. <u>https://forum.step.esa.int/</u>
- C. <u>https://senbox.atlassian.net/wiki/spaces/SNAP/pages/50855941/Configure+Python+to+</u> <u>use+the+SNAP-Python+snappy+interface</u>
- D. https://www.python.org/downloads/windows/
- E. https://scihub.copernicus.eu/
- F. <u>https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-2-msi/naming-</u> <u>convention</u>
- G. https://www.mdpi.com/2072-4292/12/9/1433/htm
- H. https://cds.climate.copernicus.eu/api-how-to