

# → 9th ADVANCED TRAINING COURSE ON LAND REMOTE SENSING: AGRICULTURE

16–20 September 2019  
Université catholique de Louvain | Belgium

Practical on pre-processing of optical time series including S2

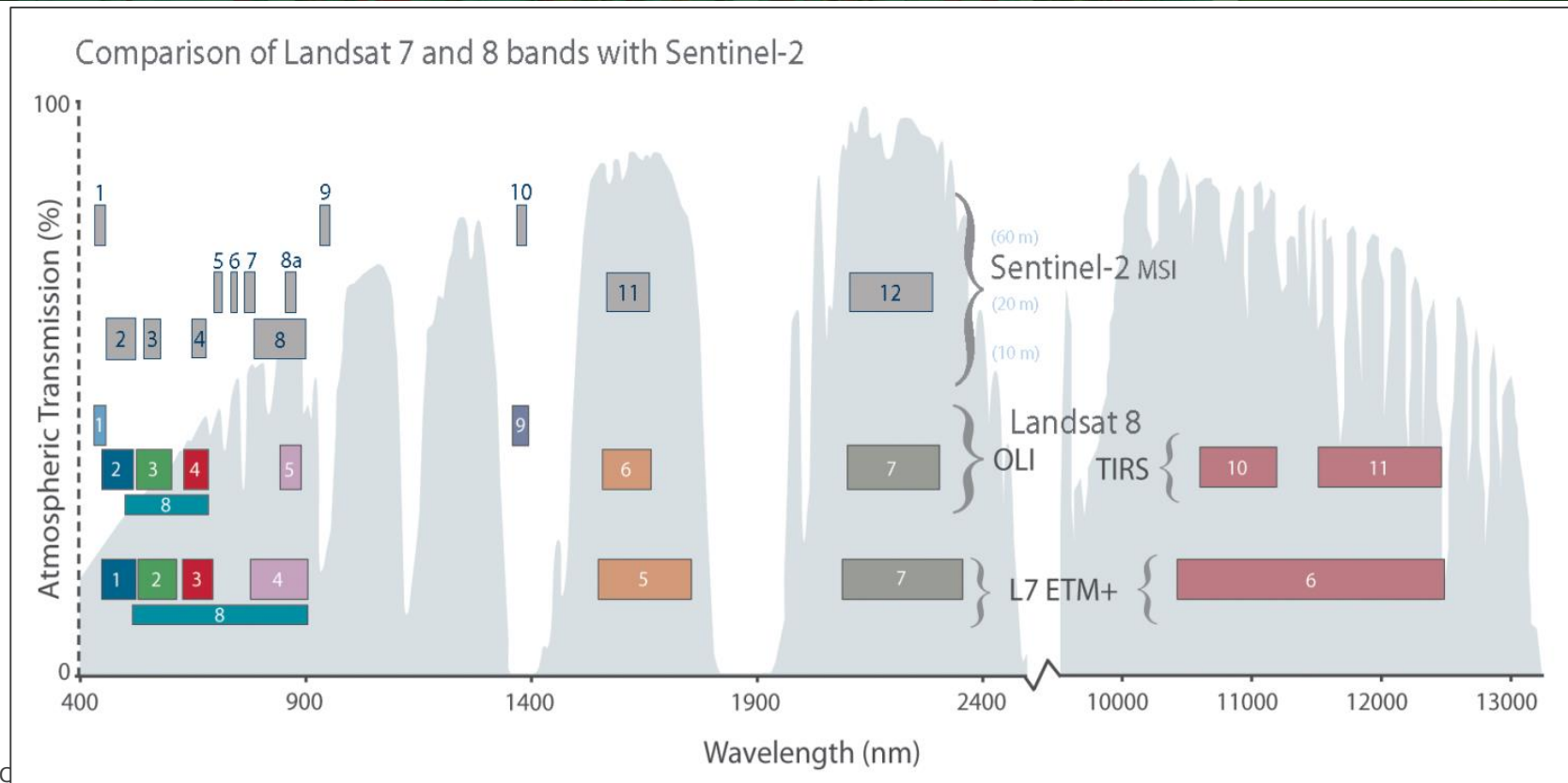
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ESA/ESRIN

Hosted by



- ✓ Overview of Sentinel-2
  - ✓ *Spectral bands*
  - ✓ *Level 2A products*
- ✓ Pre-processing chain starting from S2 L2A data
  - ✓ *Resampling*
  - ✓ *Subset*
  - ✓ *Band Maths*
  - ✓ *Radiometric Indices*
  - ✓ *S2 Biophysical processor*
- ✓ Graph Builder
- ✓ Batch Processing
- ✓ Time series analysis

# Sentinel-2 spectral bands



# Sentinel-2 L2A data overview



**Sen2Cor** is the Atmospheric Correction processor used in the ESA Payload Data Ground Segment to generate S2 L2A data and it is distributed via STEP to be used as SNAP plug-in or via command line.

- ✓ Bottom-of-atmosphere (BOA) reflectances in cartographic geometry (UTM/WGS84)
- ✓ Products additionally include:
  - *Scene Classification Map*
  - *Water Vapor Map*
  - *Aerosols Optical Thickness Map*
- ✓ Algorithm includes:
  - *Cloud and cloud shadow detection*
  - *Cirrus detection and correction*
  - *Slope effect correction*
  - *BRDF effect correction*

*Beyond Sen2Cor, Sentinel-2 data can be atmospherically corrected using others processors:*

*MAJA (developed by CESBIO/CNES)*

*i-COR (developed by VITO)*

*CorA (developed by Brockmann Consult)*

*LaSRC (developed by NASA GSFC/USA)*

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# Sentinel-2 L2A data overview

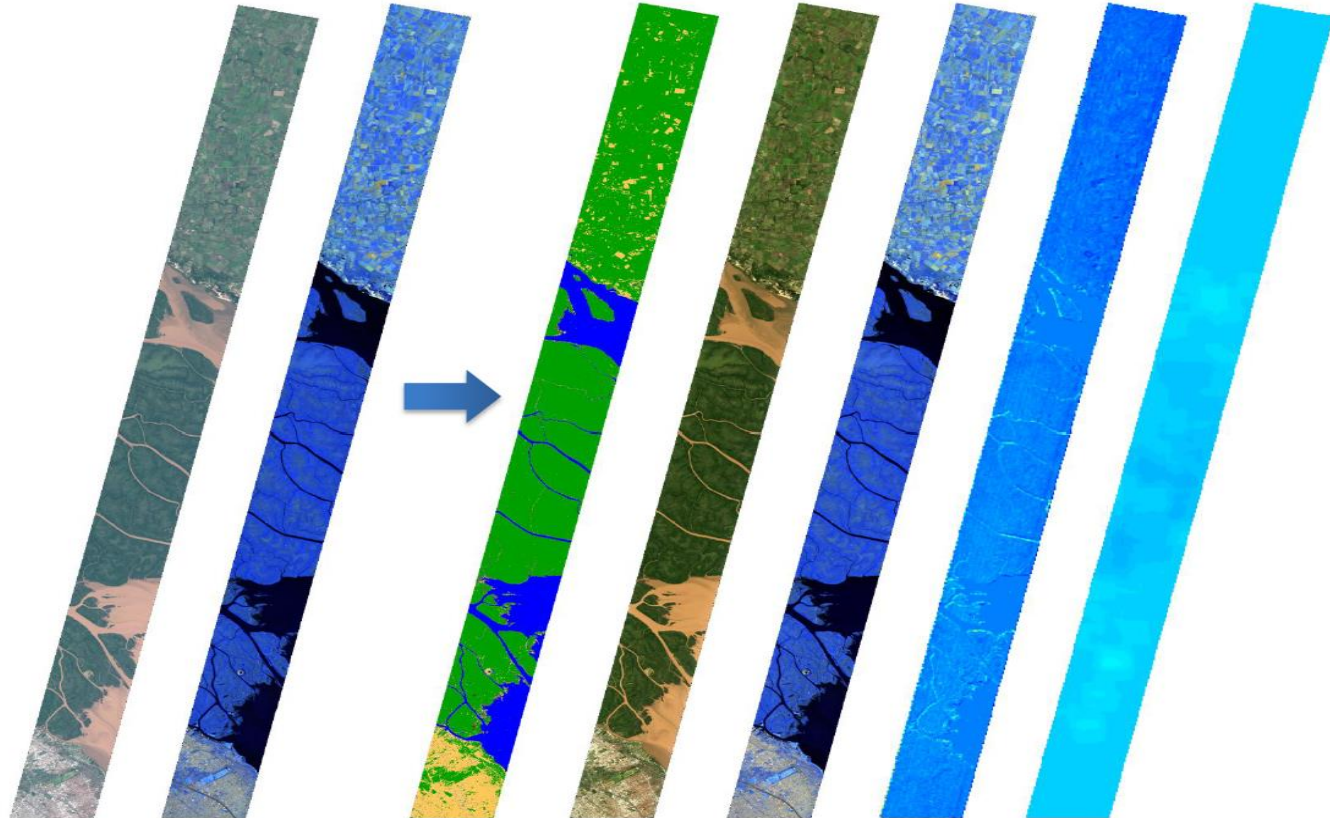
From left to right:

## Level-1C [TOA]

- [RGB] B4-B3-B2
- [RGB] B12-B11-B8a

## Level-2A [BOA]

- Scene Classification
- [RGB] B4-B3-B2
- [RGB] B12-B11-B8a
- Water Vapour
- Aerosols Optical Thickness



Essential pre-processing steps:

## Resampling

The S2 products are multi-size

- B2, B3, B4 and B8 @ 10m
- B5, B6, B7, B8A, B11 and B12 @ 20m
- B1, B9 and B10 @ 60m

Needed if the user wants to combine bands with different spatial resolution

## Subset (spatially/spectrally)

The S2 data are distributed in tiles 100x100 km<sup>2</sup> ortho-images in UTM/WGS84 projection.

Needed if the AOI covers a portion of the S2 scene or if only a subset of bands are useful in the next step (this will reduce the computation time)

## Re-projection

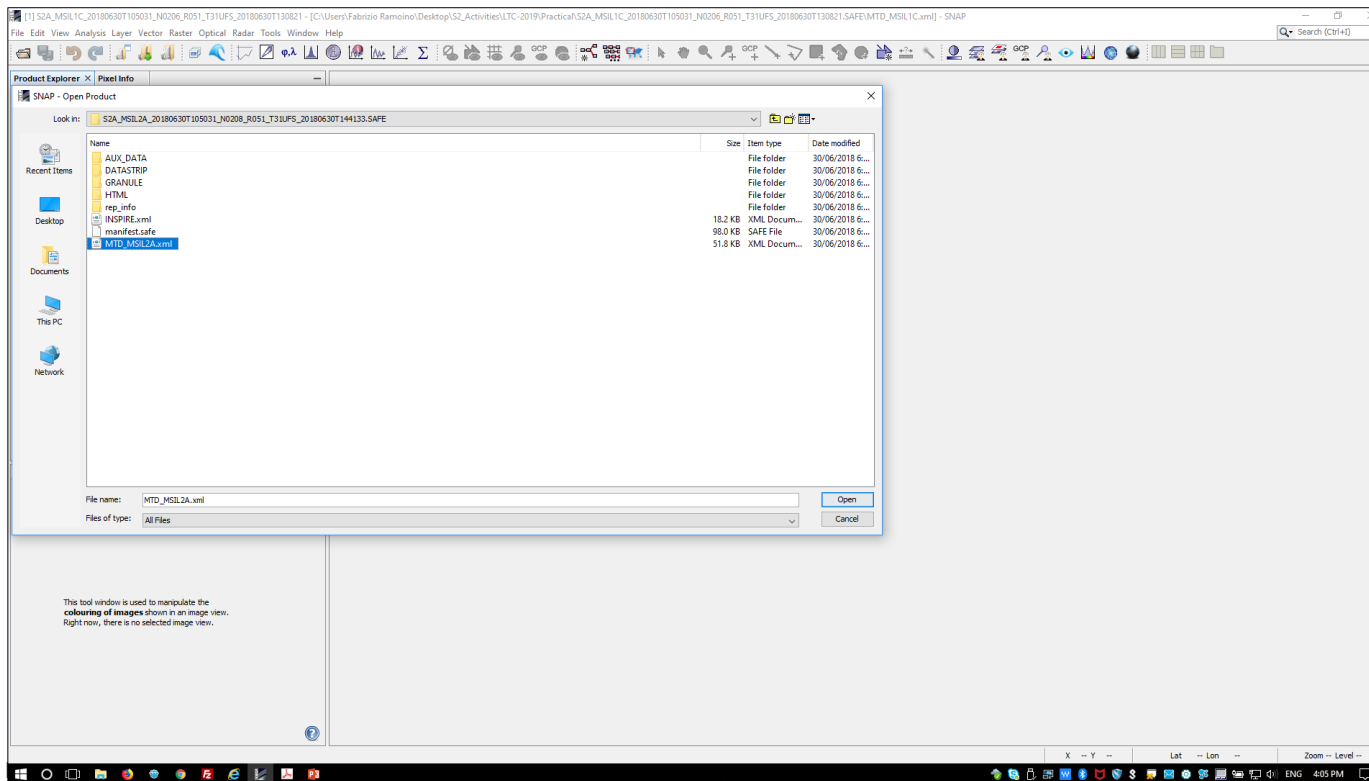
If the AOI covers more than one S2 tile in different UTM zones the user needs to re-project in a common CRS before to mosaic them.

If the user wants to merge different data sources projected in different CRS.

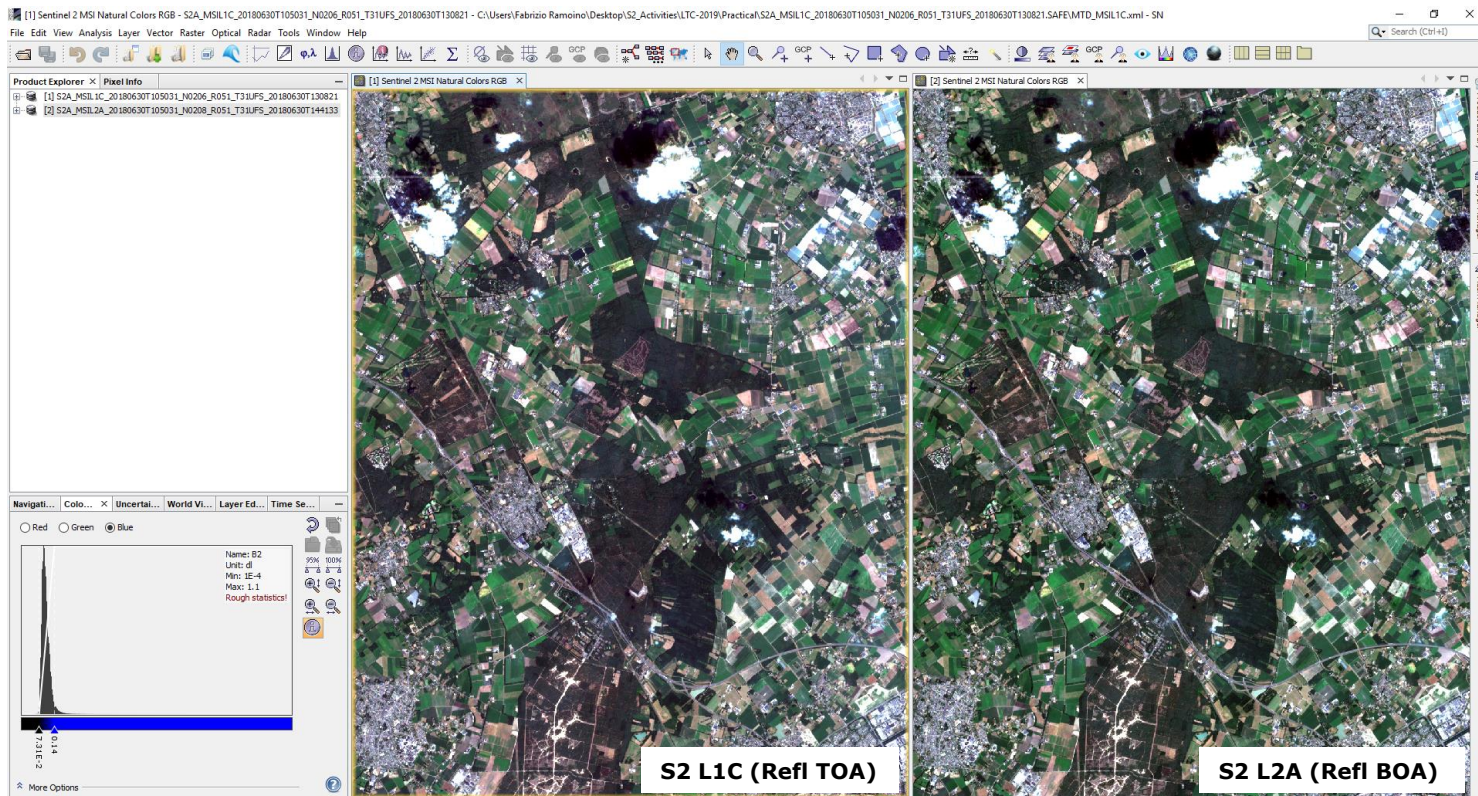
To export the view in KMZ and visualise your output in Google Earth.

# Open a Sentinel-2 data

Click on 'File' → 'Open Product...' → select the 'MTD\_MSIL2A.xml' file



# Visualize Sentinel-2 data



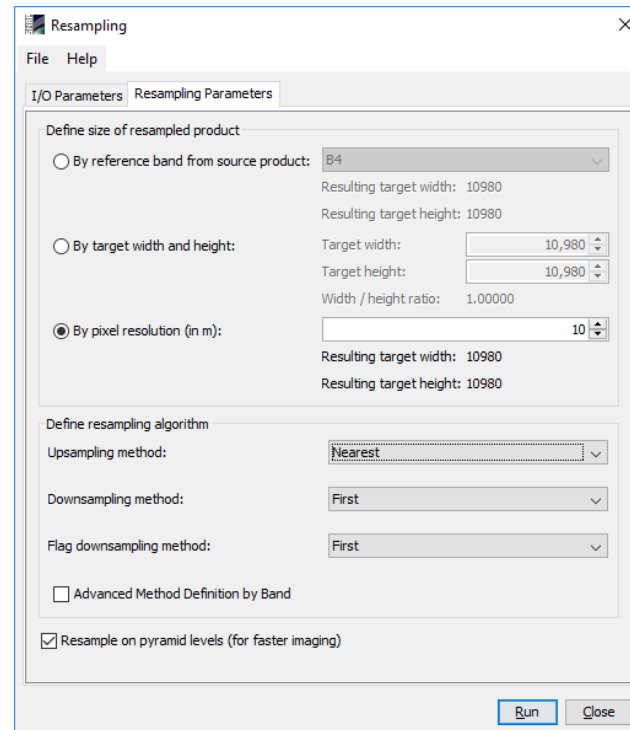
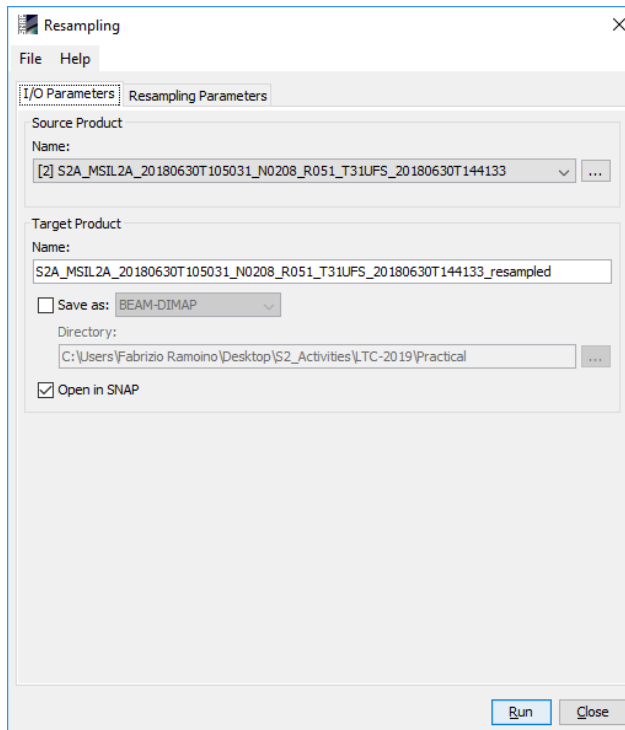


# Resampling

- 1) Select the product in the Product Explorer window.
- 2) Click on 'Raster' → 'Geometric Operations' → 'Resampling'

In the pop-up window set up the parameters as shown in the Figures:

- ✓ Unselect 'Save as:'
- ✓ '10m' as pixel resolution
- ✓ 'Nearest' as Upsampling method
- ✓ Click on 'Run'

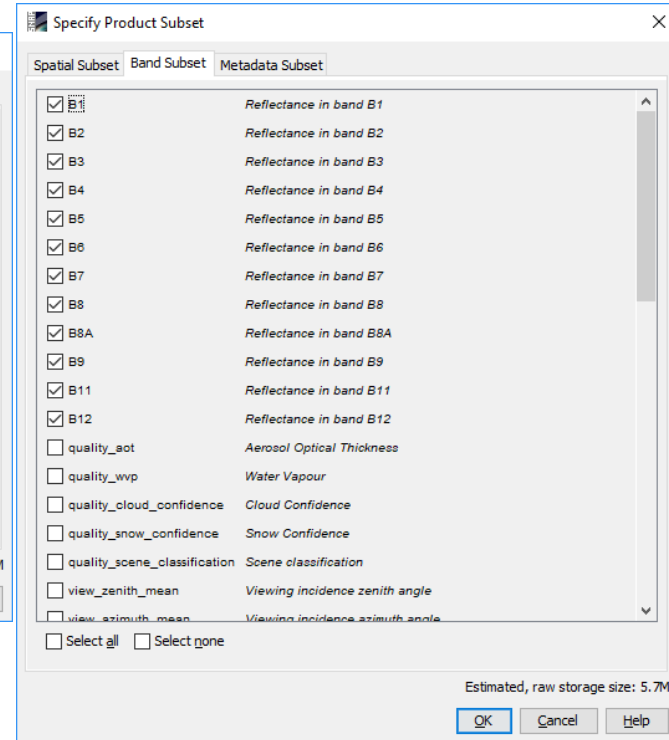
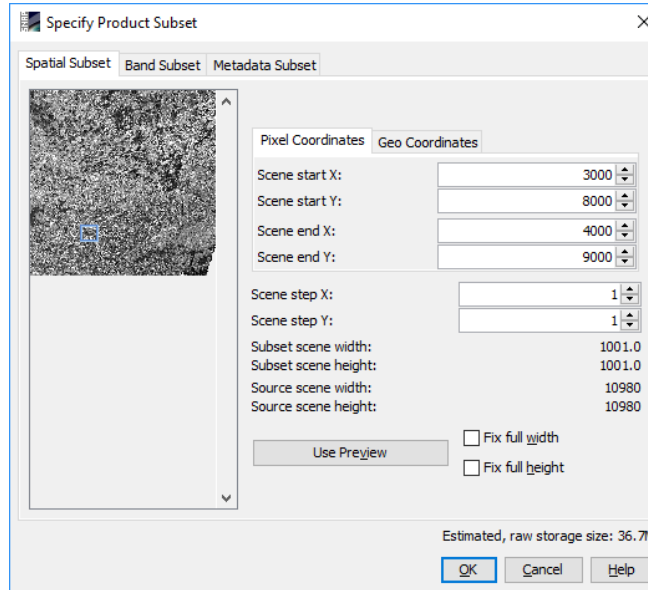


# Subset (spatially/spectrally)

- 1) Select the new product in the Product Explorer window.
- 2) Click on 'Raster' → 'Subset...'

In the pop-up window set up the parameters as shown in the Figures:

- ✓ Define the X and Y pixels range or the X and Y geo-coordinates to crop the input product
- ✓ Define which bands you want to export
- ✓ Click on 'Run'



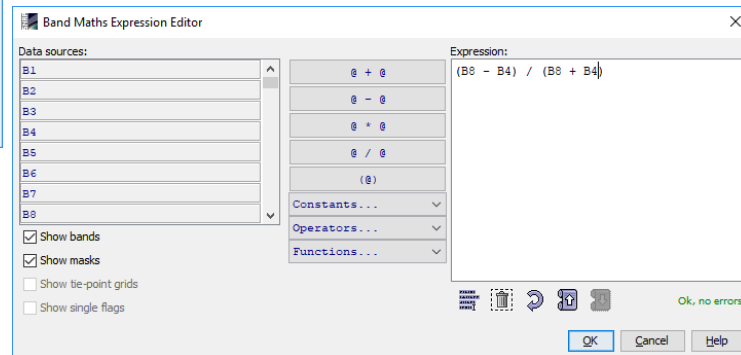
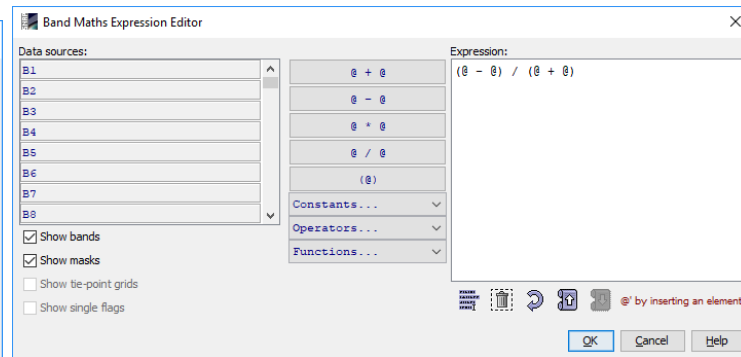
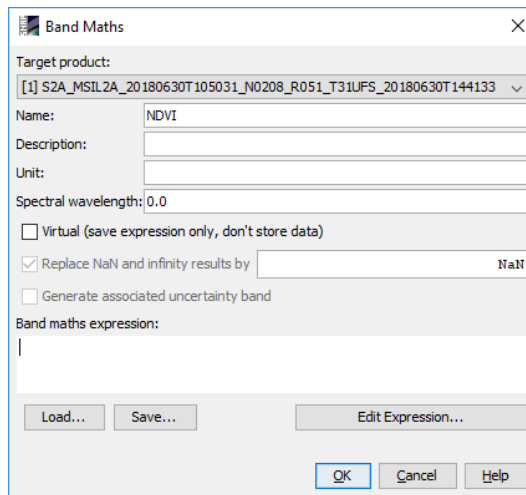
# Band Maths (e.g. NDVI)



- 1) Select the product in the Product Explorer window.
- 2) Click on 'Raster' → 'Band Maths...'

In the pop-up window set up the parameters as shown in the Figures:

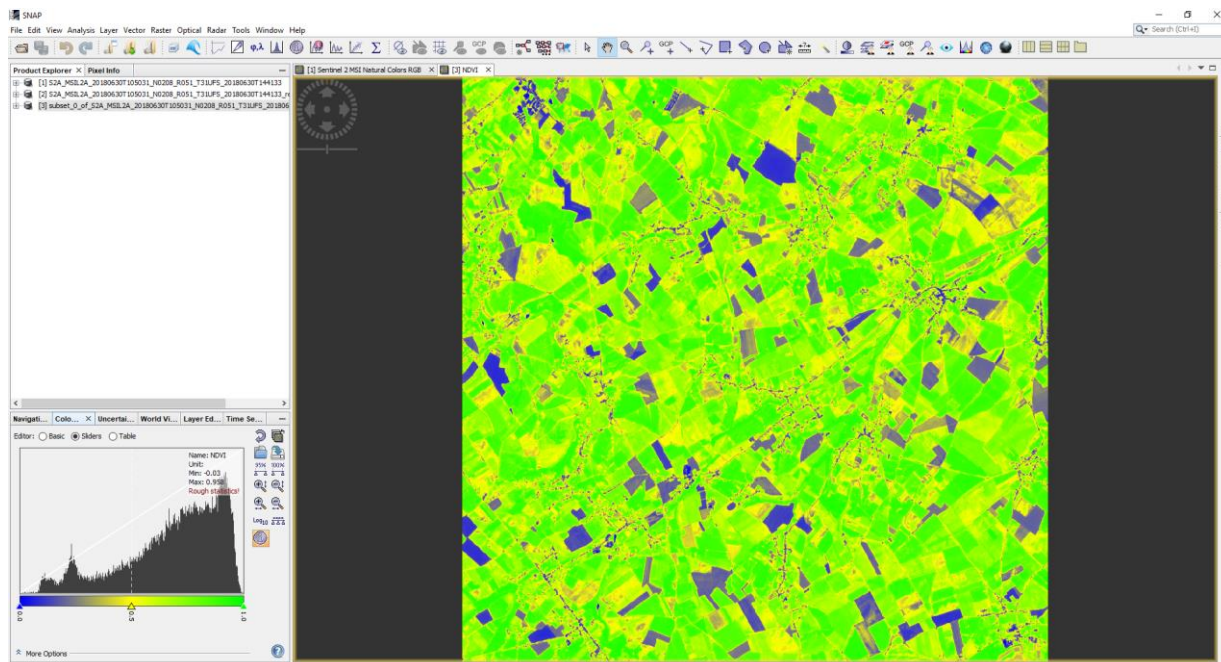
- ✓ Change the Name: 'NDVI'
- ✓ Unselect 'Virtual' box
- ✓ Click on 'Edit Expression...'
- ✓ Create your expression using '@' and after replace them with the bands
  - ✓  $(@ - @) / (@ + @)$
  - ✓  $(B8 - B4) / (B8 + B4)$
- ✓ Click on 'Run'



# Output Visualization

When the processing is finished the output will be automatically opened in the 'Product Explorer' of SNAP. Select the product in the Product Explorer window.

Using the Colour Manipulation (bottom left) you can modify the colour palette.



**Radiometric indices are quantitative measures of features that are obtained by combining several spectral bands**

## Vegetation indices

*DVI, RVI, PVI*

*NDVI, WDV, TNDVI, GNDVI*

*SAVI, TSAVI, MSAVI, MSAVI2*

*GEMI*

*ARVI*

*NDI45*

*MTCI, MCARI, PSSRa*

*S2REP, REIP, IRECI*

## Soil indices

*BI*

*BI2*

*RI*

*GEMI*

## Water indices

*NDWI*

*NDWI2*

*MNDWI*

*NDPI*

*NDTI*

# Radiometric Indices (e.g. NDVI)



$$\frac{(NIR - Red)}{(NIR + Red)}$$

↓

$$\frac{(B8 - B4)}{(B8 + B4)}$$

The screenshot shows the SNAP (Sentinel Application Platform) interface. The main window displays a satellite image of a rural landscape. The 'Thematic Land Processing' menu is open, showing 'Vegetation Radiometric Indices' > 'NDVI Processor'. The 'NDVI Processor' dialog box is open, showing 'Source Product' as '[4] subset\_1\_of\_S2A\_MSIL2A\_20180630T105031\_N0208\_R051\_T31UFS\_20180630T144133\_resampled' and 'Target Product' as '\_R051\_T31UFS\_20180630T144133\_resampled\_ndvi'. The 'Red factor' is set to 1.0, 'NIR factor' is 1.0, 'Red source band' is B4, and 'NIR source band' is B8. The 'Open in SNAP' checkbox is checked. The 'Run' button is highlighted.



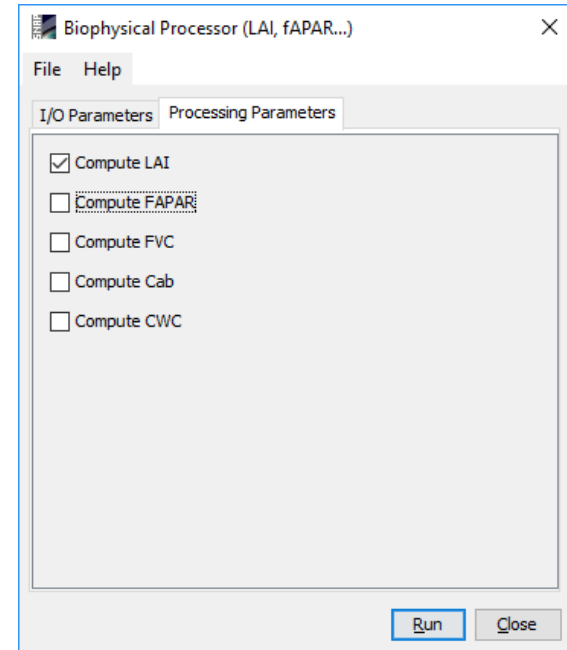
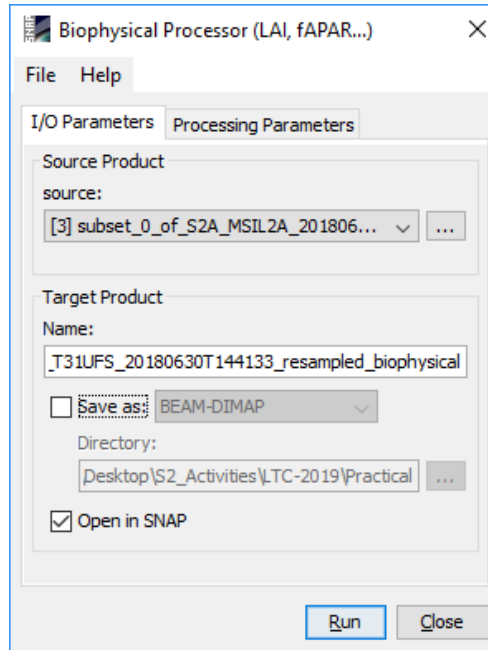
# Biophysical processor (L2B)

- 1) Select the new product in the Product Explorer window.
- 2) Click on 'Optical' → 'Thematic Land Processing' → 'Biophysical processor (LAI, fAPAR, ...)'

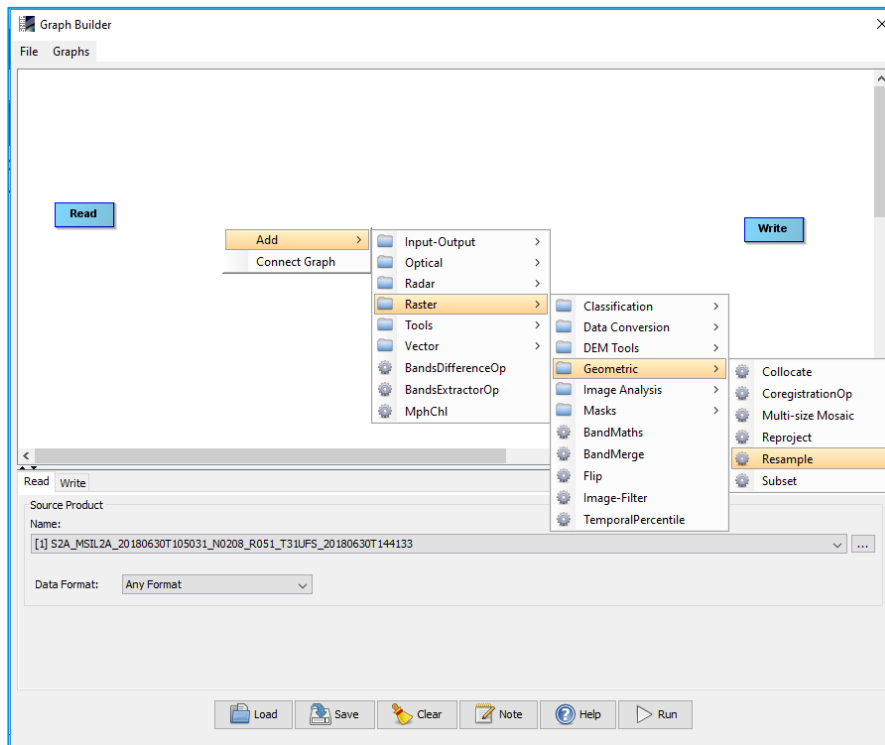
In the pop-up window set up the parameters as shown in the Figures:

- ✓ Unselect 'Save as:'
- ✓ Select only 'LAI'
- ✓ Click on 'Run'

- LAI: Leaf Area Index
- fAPAR: Fraction of Absorbed Photosynthetically Active Radiation
- FVC: Fraction of vegetation cover
- Cab: Chlorophyll content in the leaf
- CWC: Canopy Water Content



The Graph Builder allows the user to assemble graphs from a list of available operators and connect operator nodes to their sources. Right click on the top panel to add an Operator.





We can create our processing chain adding to the default blocks 'Read' and 'Write':

## 'Rempling'

'Raster' → 'Geometric' → 'Resample'

## 'Subset'

'Raster' → 'Geometric' → 'Subset'

## 'Band Maths'

'Raster' → 'BandMaths'

## 'S2rep' (S2 Red-Edge Position Index)

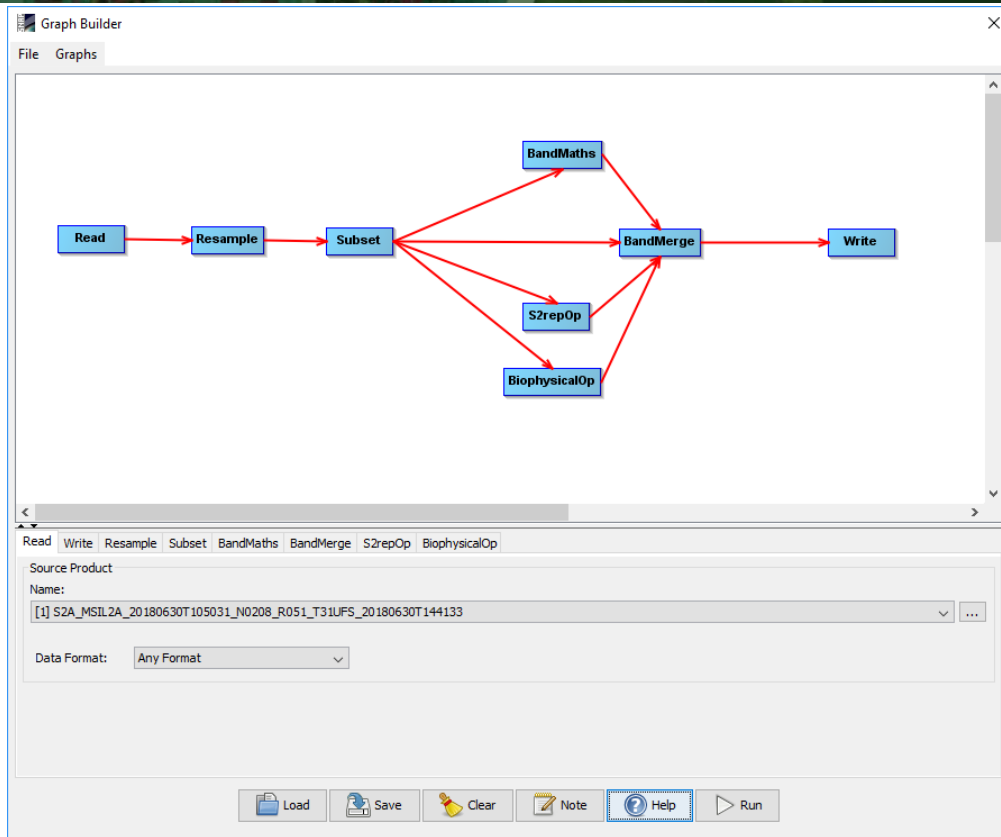
'Optical' → 'Them. Land Proc.' → 'Veg. Rad. Ind.' → 'S2repOp'

## 'Biophysical Processor'

'Optical' → 'Thematic Land Processing' → 'BiophysicalOp'

## 'Band Merge'

'Raster' → 'BandMerge'



# GraphBuilder (Resample module)



The screenshot shows the Graph Builder application window. The top part displays a workflow graph with the following steps: Read → Resample → Subset → (parallel split to BandMaths, S2repOp, and BiophysicalOp) → BandMerge → Write. Below the graph is the configuration panel for the 'Resample' module. The 'By pixel resolution (n m)' option is selected. The resulting target width and height are both 10980. The upsampling method is set to 'Nearest', and the downsampling method is 'First'. A red error message 'Expression is invalid.' is visible at the bottom of the configuration panel.

Graph Builder  
File Graphs

Read Write Resample Subset BandMaths BandMerge S2repOp BiophysicalOp

By reference band from source product:  
Resulting target width: 1830  
Resulting target height: 1830

By target width and height:  
Target width: 10,980  
Target height: 10,980  
Width / height ratio: 1.00000

By pixel resolution (n m):  
Resulting target width: 10980  
Resulting target height: 10980

Define resampling algorithm

Upsampling method: Nearest

Downsampling method: First

Flag downsampling method: First

Advanced Method Definition by Band

Resample on nvrnmid levels (for faster imacon)

Expression is invalid.

Load Save Clear Note Help Run



# GraphBuilder (Subset module)



The screenshot shows the Graph Builder application window. The main workspace contains a workflow graph with the following steps: Read → Resample → Subset → (parallel split to BandMaths, S2repOp, and BiophysicalOp) → BandMerge → Write. Below the graph is a toolbar with icons for Load, Save, Clear, Note, Help, and Run. The configuration panel below the toolbar includes:

- Source Bands: B5, B6, B7, B8, B8A, B9, B11, B12
- Copy Metadata
- Pixel Coordinates  Geographic Coordinates
- Reference band: B1
- X: 3000, Y: 8000
- Width: 1000, height: 1000
- Sub-sampling X: 1, Sub-sampling Y: 1

At the bottom left of the configuration panel, there is a red error message: "Expression is invalid."



# GraphBuilder (BandMaths module)



The screenshot shows the GraphBuilder interface with a workflow graph and an Arithmetic Expression Editor dialog.

**Workflow Graph:**

```
graph LR; Read --> Resample; Resample --> Subset; Subset --> BandMaths; Subset --> S2repOp; Subset --> BiophysicalOp; BandMaths --> BandMerge; S2repOp --> BandMerge; BiophysicalOp --> BandMerge; BandMerge --> Write;
```

**Arithmetic Expression Editor Dialog:**

- Target Band: NDVI
- Target Band Type: float32
- Band Unit: [empty]
- No-Data Value: 0.0
- Expression: [empty]

**Arithmetic Expression Editor Details:**

- Data sources: B1, B2, B3, B4, B5, B6, B7, B8
- Operators: +, -, \*, /, ()
- Expression:  $(B5 - B4) / (B5 + B4)$
- Options:  Show bands,  Show masks,  Show tie-point grids,  Show single flags
- Status: Ok, no errors.
- Buttons: OK, Cancel, Help

Expression is invalid.



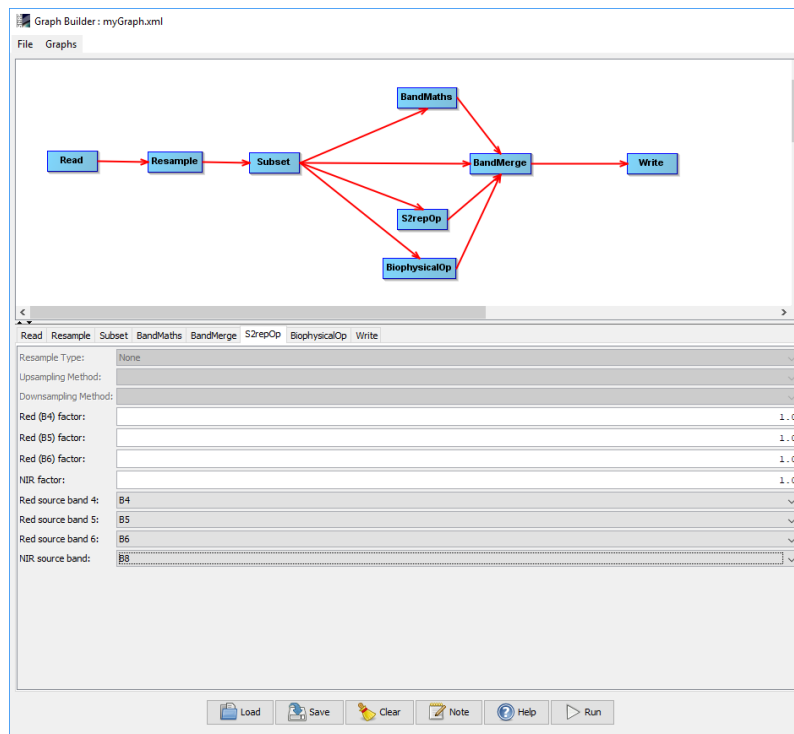
# GraphBuilder (S2repOp module)

The Sentinel-2 Red-Edge Position Index algorithm is based on linear interpolation, as presented by Guyot and Baret (1988). Red edge, as the inflection point of the strong red absorption to near infrared reflectance, includes the information of both crop (chlorophyll content) N and growth status.

$$705 + 35 \times \frac{(Red + NIR) - Red_2}{(Red_3 - Red_2)}$$



$$705 + 35 \times \frac{(B4 + B7) - B5}{(B6 - B5)}$$

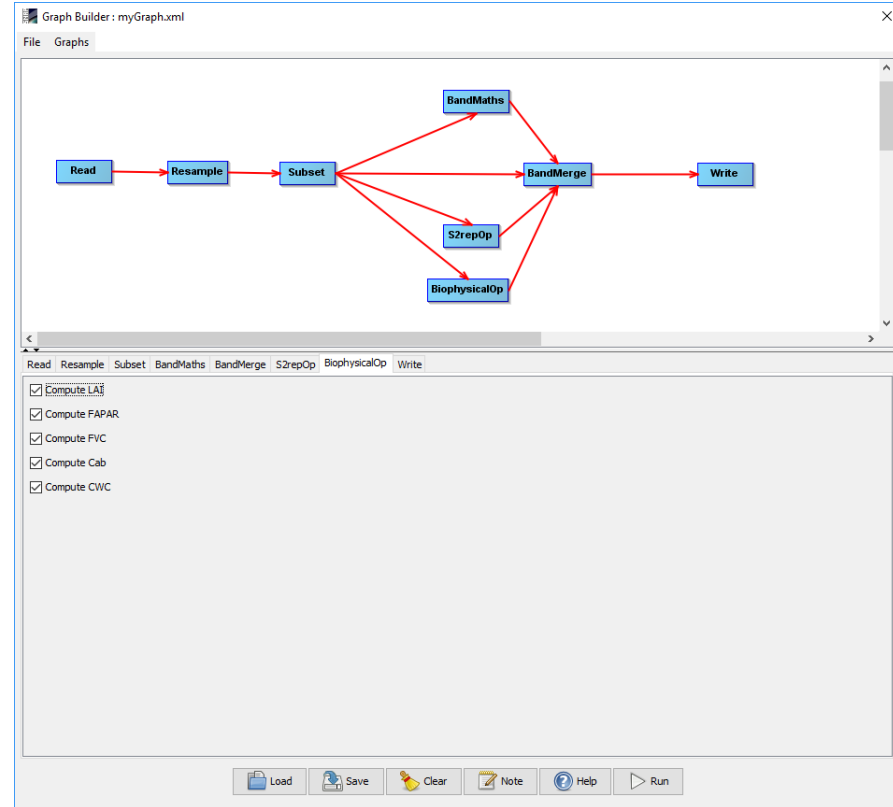


# GraphBuilder (BiophysicalOp module)

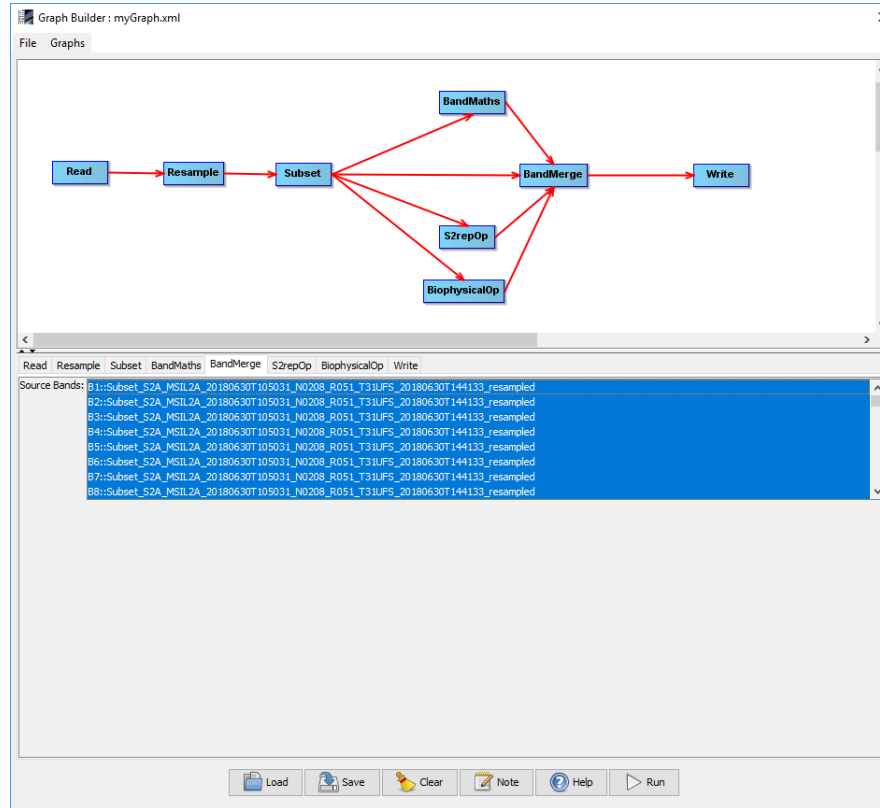


The Biophysical Processor computes Level-2B Biophysical products from Sentinel-2 reflectances. From Bottom Of Atmosphere normalized reflectance data, it derives a set of biophysical variables, namely:

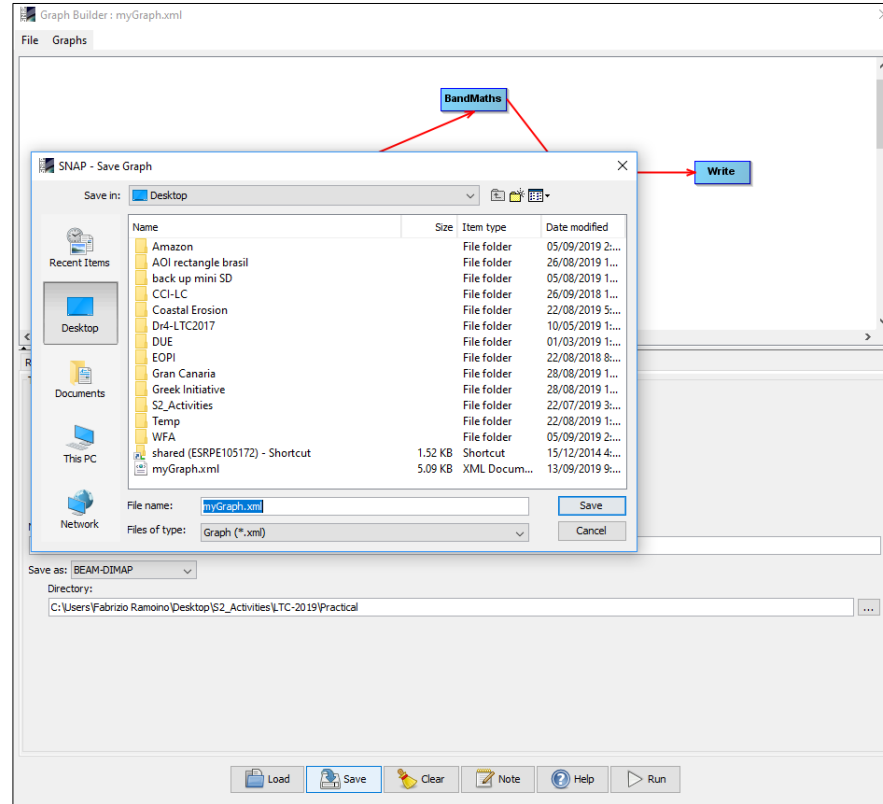
- ✓ LAI: Leaf Area Index
- ✓ fAPAR: Fraction of Absorbed Photosynthetically Active Radiation
- ✓ FVC: Fraction of vegetation cover
- ✓ Cab: Chlorophyll content in the leaf
- ✓ CWC: Canopy Water Content



# GraphBuilder (Band Merge module)



# GraphBuilder (Save the graph)





# Batch Processing



The Batch Processing tool allows you to execute a single reader/writer graph for a set of products. Select the Batch Processing tool from the Graphs menu and then press the "Load" button to browse for a previously saved graph. Next, add products in the I/O tab by pressing the "Add" button. Set the target folder where the output will be written to and then press "Run".

The screenshot shows the 'Batch Processing : S2\_Processing-Graph.xml' window. It features a menu bar with 'File' and 'Graphs'. Below is a tabbed interface with 'I/O Parameters' selected, containing sub-tabs for 'Resample', 'Subset', 'BandMaths', 'S2repOp', 'BiophysicalOp', and 'BandMerge'. A table lists 8 products with columns for File Name, Type, Acquisition, Track, and Orbit. Below the table is a 'Target Folder' section with a 'Save as:' dropdown (set to 'BEAM-DIMAP'), a 'Directory:' text field (set to 'C:\Users\Fabrizio Ramoino\Desktop\S2\_Activities\UTC-2019\Practical'), and checkboxes for 'Skip existing target files' (unchecked) and 'Keep source product name' (checked). On the right side of the table, there are icons for adding, removing, and moving products, along with a bell icon and the text '8 Products'. At the bottom, there are buttons for 'Run remote', 'Load Graph' (highlighted with a dashed border), 'Run', 'Close', and 'Help'.

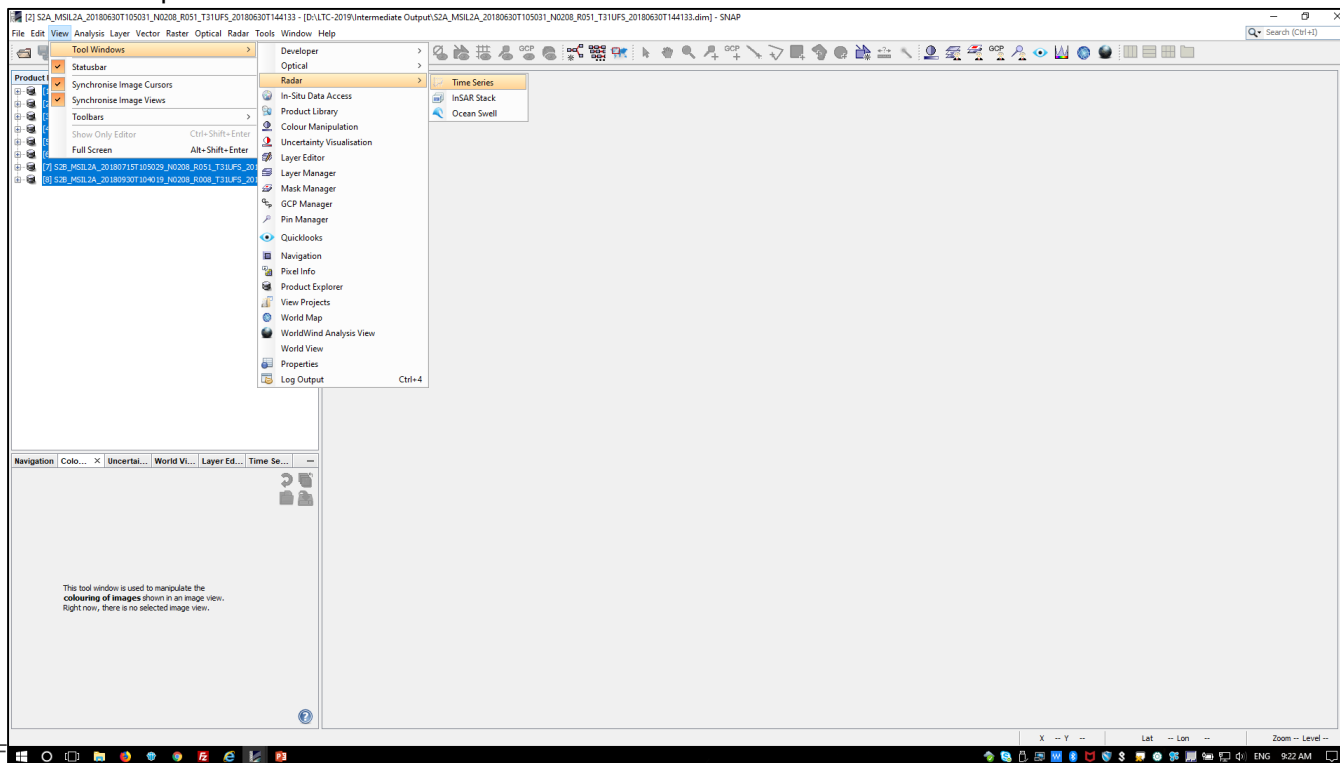
File Name	Type	Acquisition	Track	Orbit
S2A_MSIL1C_20180630T105031_N0206_R051_T31UFS_20180630T130821	S2_MSI_Level-1C	30Jun2018	99999	99999
S2A_MSIL2A_20180421T105031_N0207_R051_T31UFS_20180421T125911	S2_MSI_Level-2A	21Apr2018	99999	99999
S2A_MSIL2A_20180508T104031_N0207_R008_T31UFS_20180508T175127	S2_MSI_Level-2A	08May2018	99999	99999
S2A_MSIL2A_20180630T105031_N0208_R051_T31UFS_20180630T144133	S2_MSI_Level-2A	30Jun2018	99999	99999
S2A_MSIL2A_20180806T104021_N0208_R008_T31UFS_20180806T142805	S2_MSI_Level-2A	06Aug2018	99999	99999
S2A_MSIL2A_20180918T105021_N0208_R051_T31UFS_20180918T141223	S2_MSI_Level-2A	18Sep2018	99999	99999
S2B_MSIL2A_20180715T105029_N0208_R051_T31UFS_20180715T152821	S2_MSI_Level-2A	15Jul2018	99999	99999
S2B_MSIL2A_20180930T104019_N0208_R008_T31UFS_20180930T165224	S2_MSI_Level-2A	30Sep2018	99999	99999



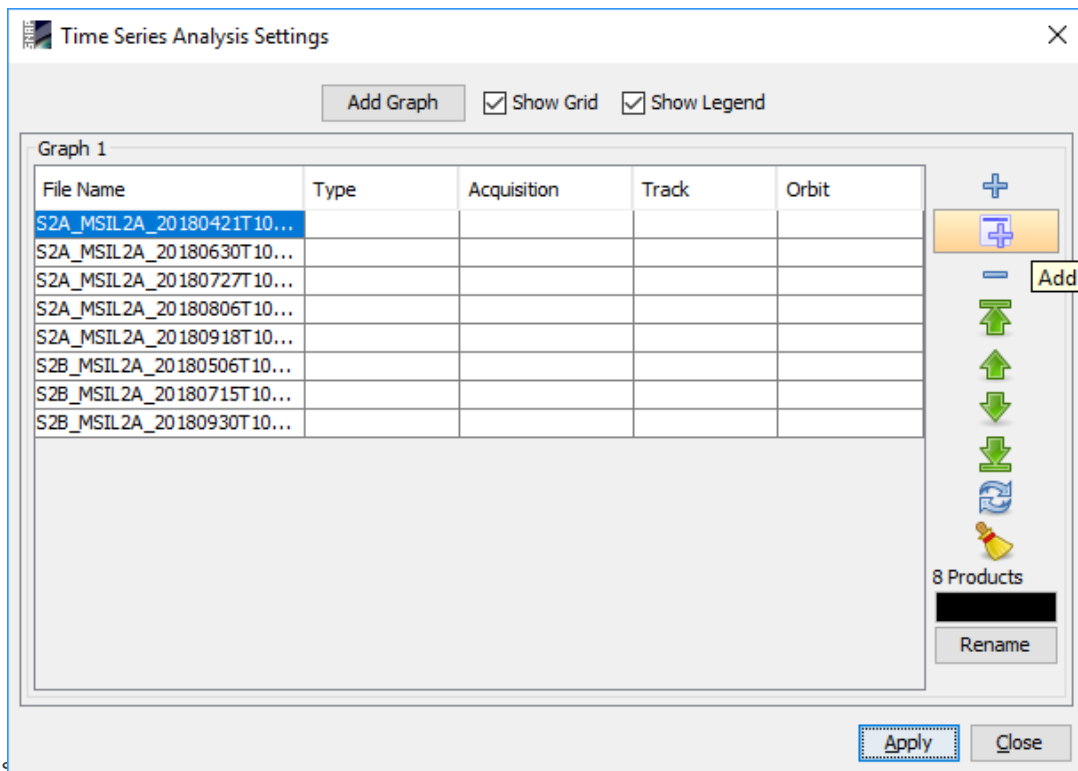
# Time Series



Due to the short time you can find the batch processing output in the 'Intermediate Output' folder in DIMAP format. Open them in SNAP and then open the Time Series Window. 'View' → 'Tool Windows' → 'Radar' → 'Time Series'



To populate the time series you can add all the products opened in SNAP or browsing from your disk.



Time Series Analysis Settings

Add Graph  Show Grid  Show Legend

Graph 1

File Name	Type	Acquisition	Track	Orbit
S2A_MSIL2A_20180421T10...				
S2A_MSIL2A_20180630T10...				
S2A_MSIL2A_20180727T10...				
S2A_MSIL2A_20180806T10...				
S2A_MSIL2A_20180918T10...				
S2B_MSIL2A_20180506T10...				
S2B_MSIL2A_20180715T10...				
S2B_MSIL2A_20180930T10...				

8 Products

Rename

Apply Close

# Time Series



The screenshot shows the SNAP (Sentinel Application Platform) interface. The main window displays a satellite image of a forested area. A 'Product Explorer' panel on the left lists several Sentinel-2 MSI products. A 'Graph 1' window in the bottom left shows a time series plot of a metric (likely NDVI) over time, with the x-axis labeled 'Acquisition Date' and the y-axis labeled 'NDVI'. The plot shows a peak in NDVI around August 14th. An 'Available Bands' dialog box is open in the center, listing various bands and indices such as B1, B2, B3, B4, B5, B6, B7, B8, B8A, B9, B11, B12, FAPAR, FCOVER, LAI, LAI\_Cab, LAI\_Cw, LAI\_Cw\_flags, LAI\_flags, quality\_sot, quality\_cloud\_confidence, quality\_scene\_classification, quality\_snow\_confidence, quality\_wvp, and s2rep. The 'NDVI' checkbox is checked.

Band/Flag	Description
<input type="checkbox"/> B1	Reflectance in band B1 (443.0 nm)
<input type="checkbox"/> B2	Reflectance in band B2 (490.0 nm)
<input type="checkbox"/> B3	Reflectance in band B3 (560.0 nm)
<input type="checkbox"/> B4	Reflectance in band B4 (665.0 nm)
<input type="checkbox"/> B5	Reflectance in band B5 (705.0 nm)
<input type="checkbox"/> B6	Reflectance in band B6 (740.0 nm)
<input type="checkbox"/> B7	Reflectance in band B7 (783.0 nm)
<input type="checkbox"/> B8	Reflectance in band B8 (842.0 nm)
<input type="checkbox"/> B8A	Reflectance in band B8A (865.0 nm)
<input type="checkbox"/> B9	Reflectance in band B9 (945.0 nm)
<input type="checkbox"/> B11	Reflectance in band B11 (1610.0 nm)
<input type="checkbox"/> B12	Reflectance in band B12 (2190.0 nm)
<input type="checkbox"/> fapar	FAPAR
<input type="checkbox"/> fapar_flags	FAPAR flags
<input type="checkbox"/> fcover	FCOVER
<input type="checkbox"/> fcover_flags	FCOVER flags
<input type="checkbox"/> flags	s2rep specific flag
<input type="checkbox"/> lai	LAI
<input type="checkbox"/> lai_cab	LAI_Cab
<input type="checkbox"/> lai_cab_flags	LAI_Cab flags
<input type="checkbox"/> lai_cw	LAI_Cw
<input type="checkbox"/> lai_cw_flags	LAI_Cw flags
<input type="checkbox"/> lai_flags	LAI flags
<input type="checkbox"/> quality_sot	Aerosol Optical Thickness
<input type="checkbox"/> quality_cloud_confidence	Cloud Confidence
<input type="checkbox"/> quality_scene_classification	Scene classification
<input type="checkbox"/> quality_snow_confidence	Snow Confidence
<input type="checkbox"/> quality_wvp	Water Vapour
<input type="checkbox"/> s2rep	

ESA UNCLASSIFIED

2016 | Slide 28



European Space Agency