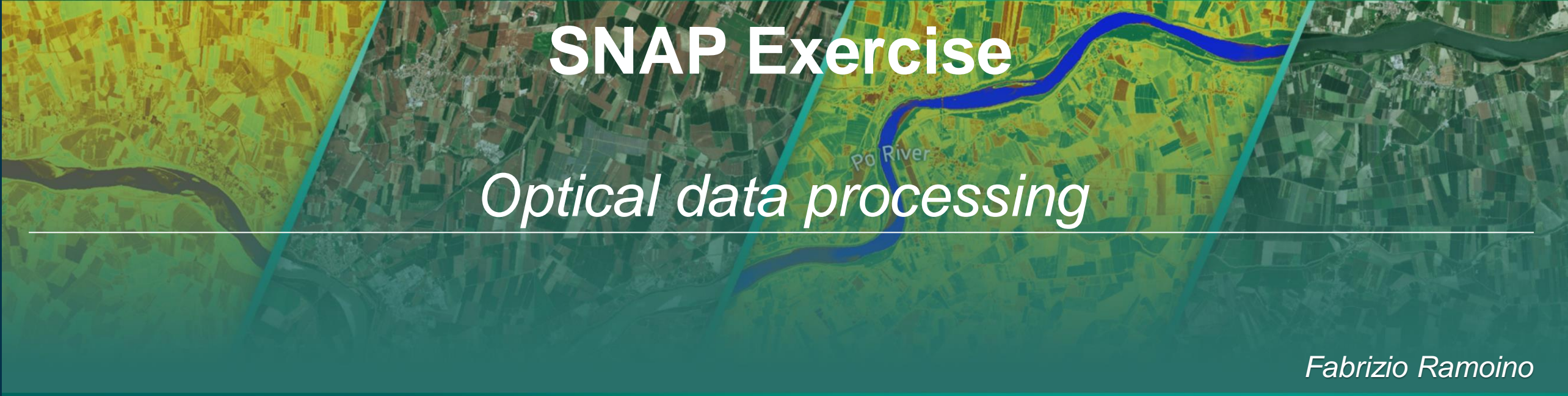




SNAP Exercise

Optical data processing



Fabrizio Ramoino

- ✓ Overview of Sentinel-2
 - ✓ *Spectral bands*
 - ✓ *Level 2A products*

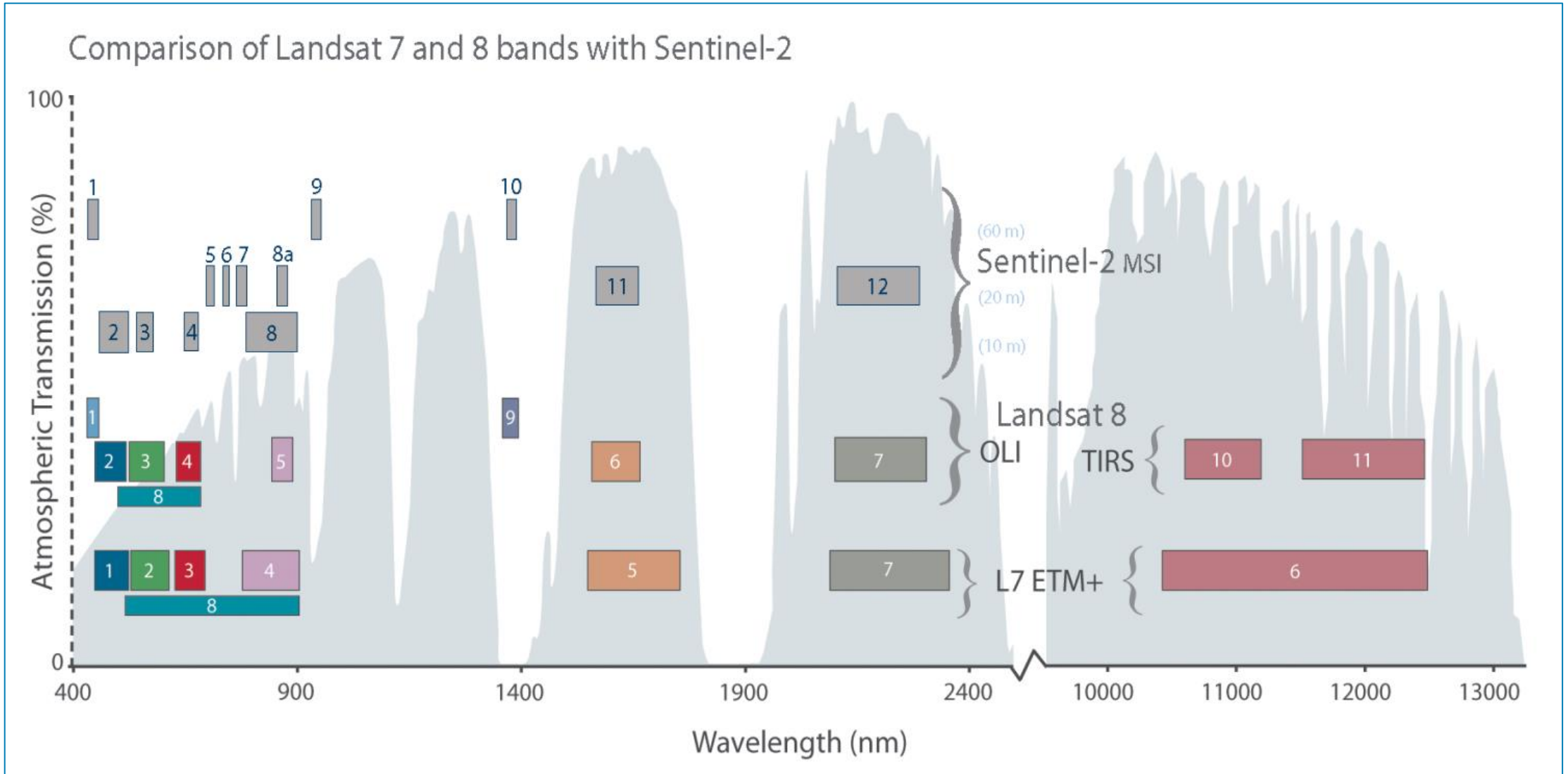
- ✓ Pre-processing chain starting from S2 L2A data
 - ✓ *Resampling*
 - ✓ *Subset*
 - ✓ *Band Maths*
 - ✓ *Radiometric Indices*
 - ✓ *S2 Biophysical processor*

- ✓ Graph Builder

- ✓ Batch Processing

- ✓ Time series analysis

Sentinel-2 spectral bands



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)

.....

Sentinel-2 L2A data overview

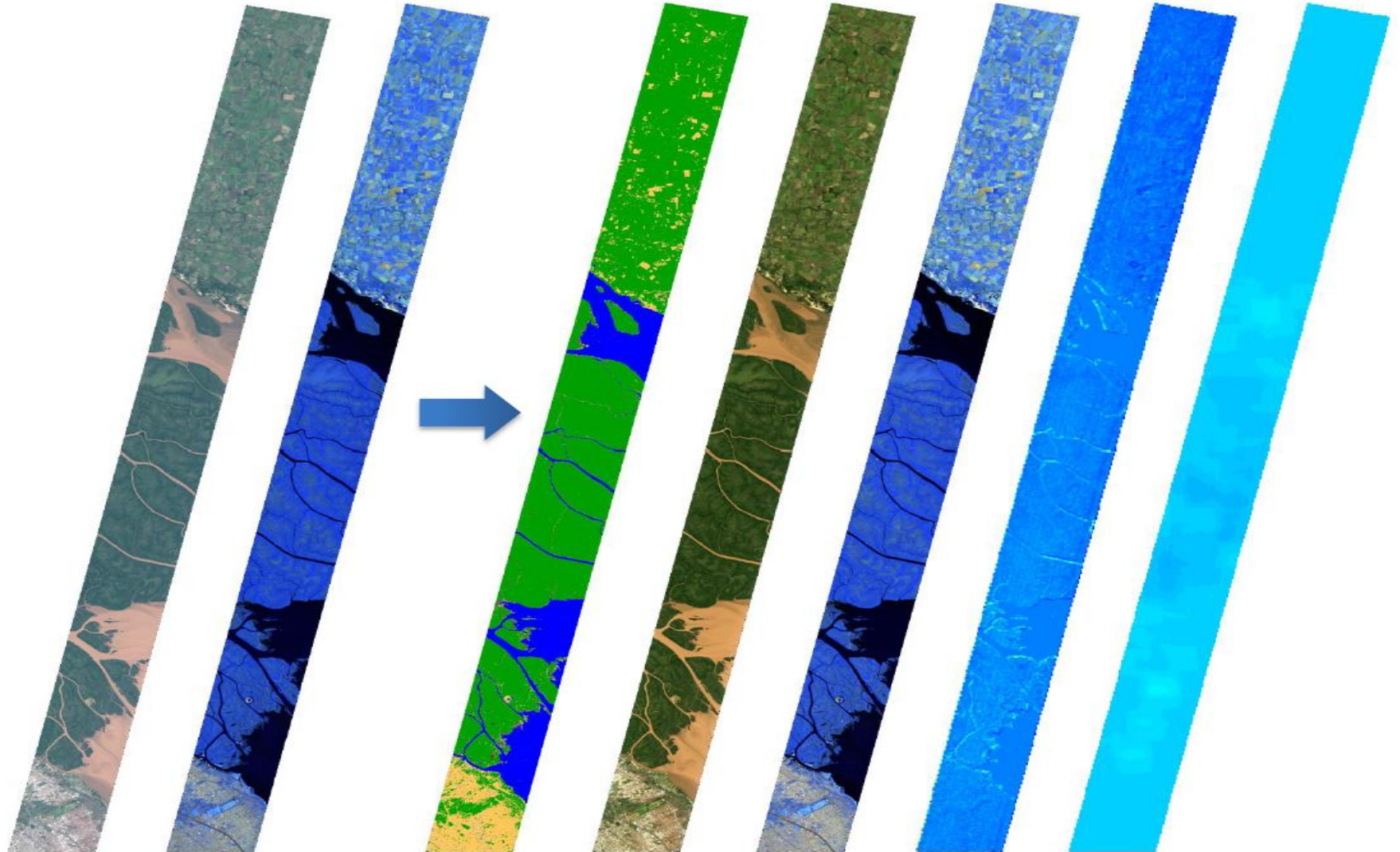
From left to right:

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 km² 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.

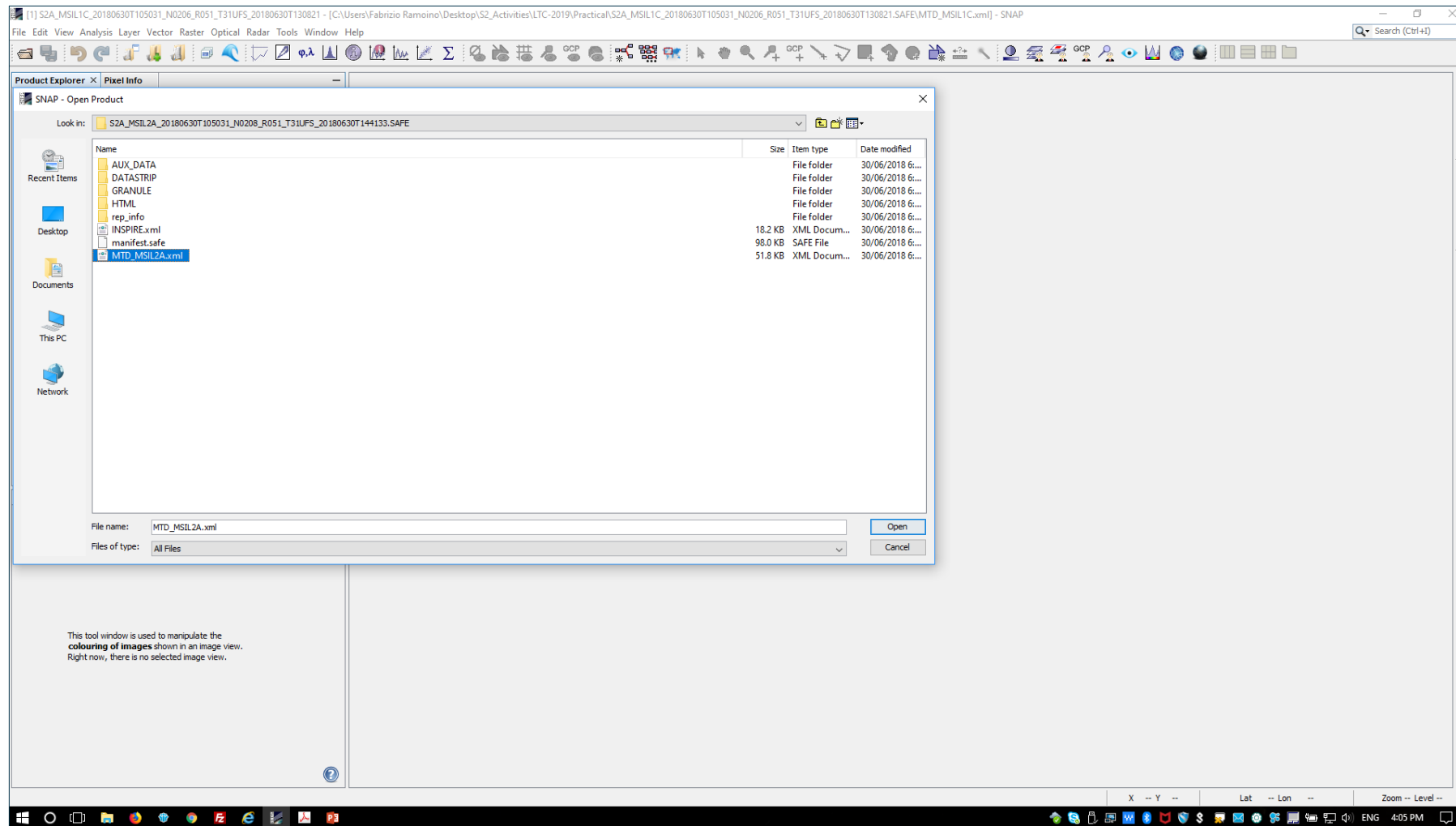
If the user wants to merge different data sources projected in different CRS.

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

Open Sentinel-2 data



Click on 'File' → 'Open Product...' → select the 'MTD_MSIL2A.xml' file



Visualize Sentinel-2 data



[1] Sentinel 2 MSI Natural Colors RGB - S2A_MSIL1C_20180630T105031_N0206_R051_T31UFS_20180630T130821 - C:\Users\Fabrizio Ramoino\Desktop\S2_Activities\LTC-2019\Practical\S2A_MSIL1C_20180630T105031_N0206_R051_T31UFS_20180630T130821.SAFE\MTD_MSIL1C.xml - SN

File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help

Search (Ctrl+F)

Product Explorer X Pixel Info

- [1] S2A_MSIL1C_20180630T105031_N0206_R051_T31UFS_20180630T130821
- [2] S2A_MSIL2A_20180630T105031_N0206_R051_T31UFS_20180630T144133

Navigati... Colo... X Uncertai... World Vi... Layer Ed... Time Se...

Red Green Blue

Name: B2
Unit: dl
Min: 1E-4
Max: 1.1
Rough statistics!

7.31E-2 0.14

95% 100%
8 8 8 8

More Options

X -- Y -- Lat -- Lon -- Zoom -- Level --

ENG 4:15 PM

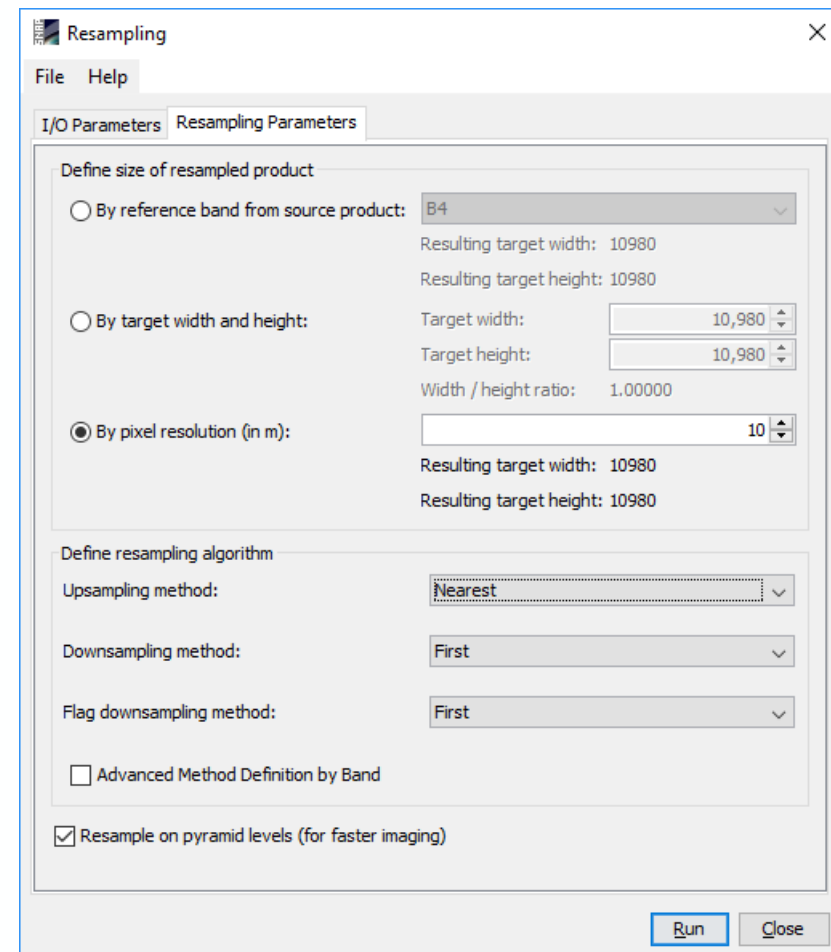
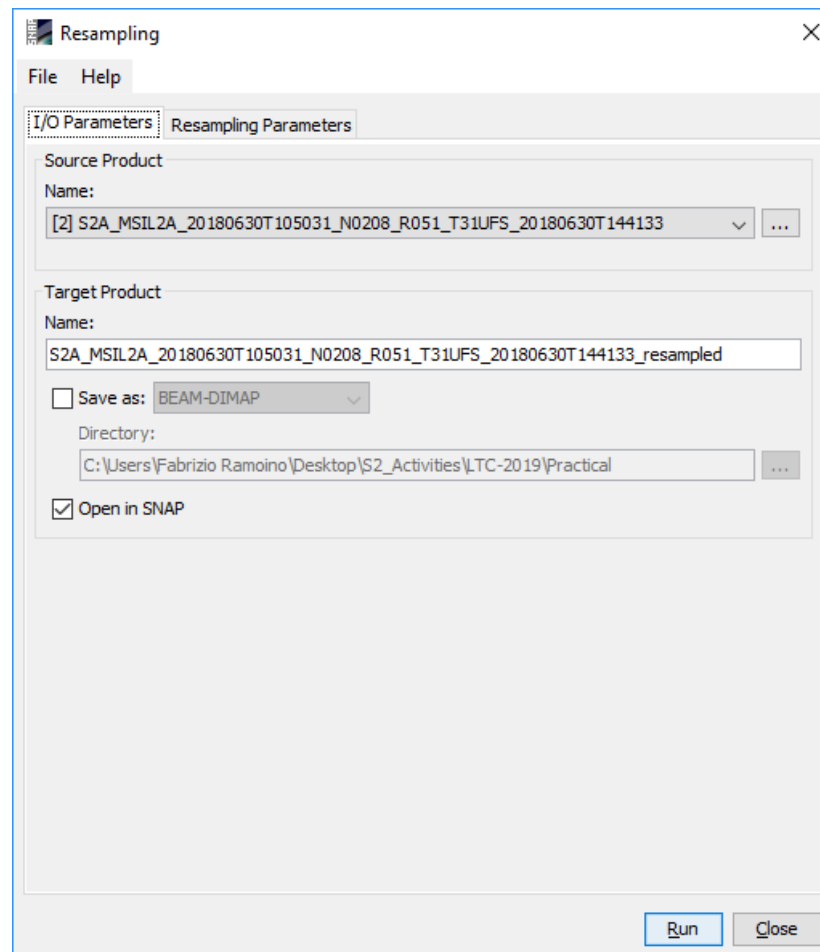


Resampling

- 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'

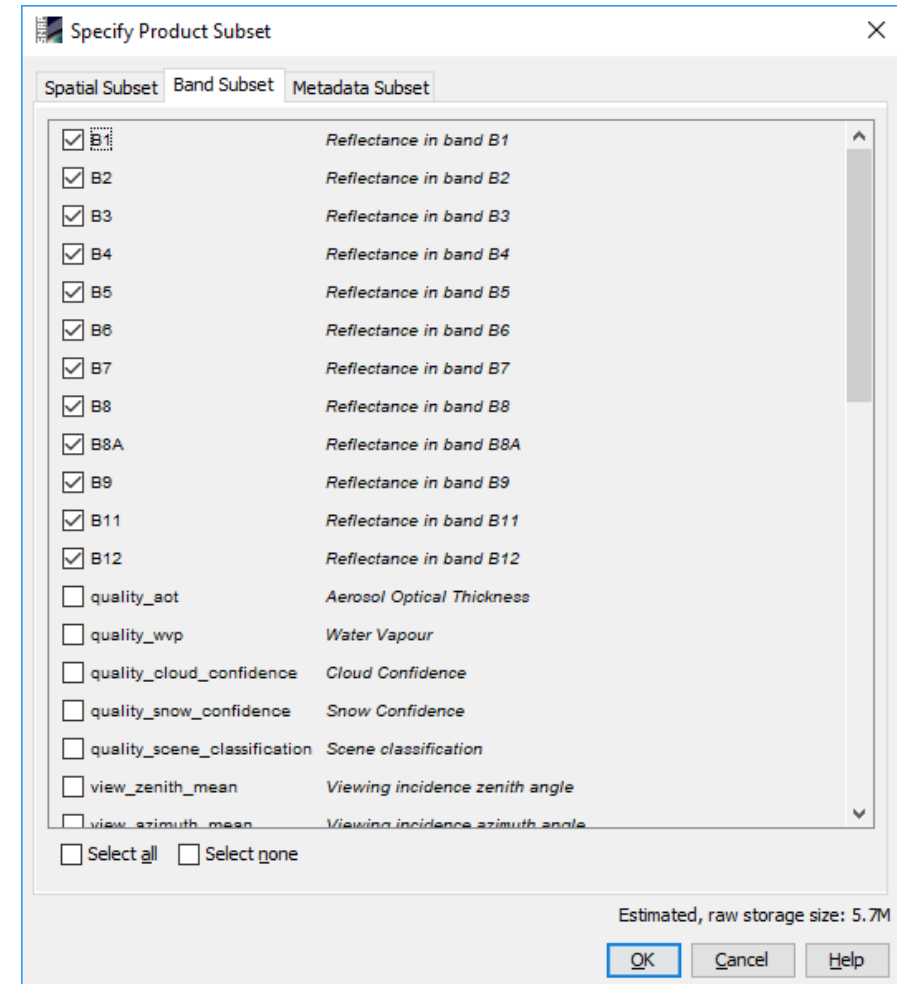
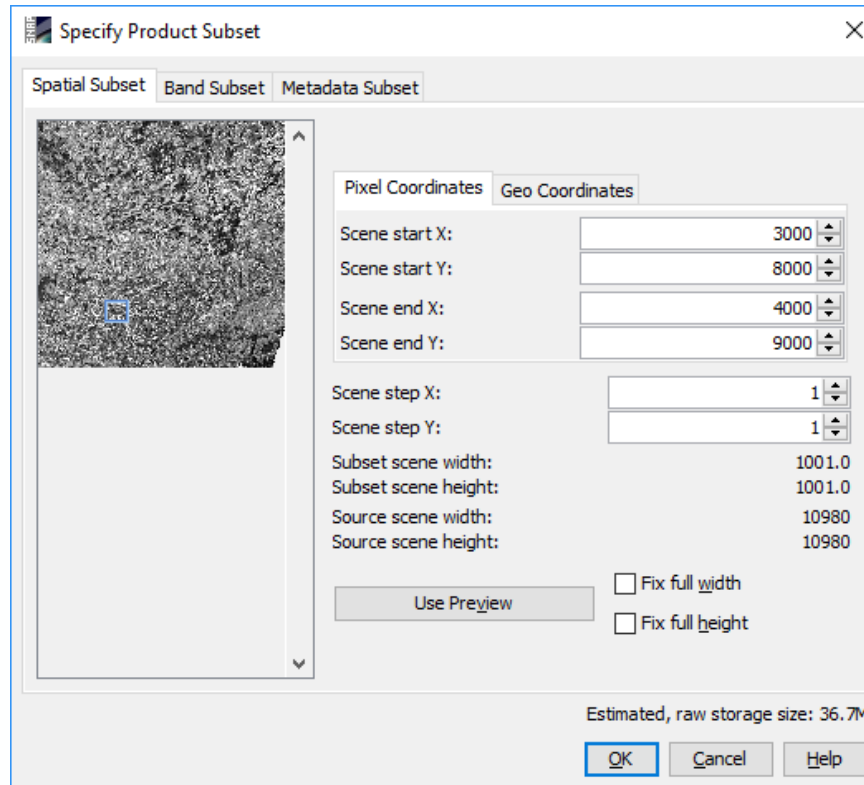


Subset (spatially/spectrally)

- 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'

Band Maths

Target product:
[1] S2A_MSIL2A_20180630T105031_N0208_R051_T31UFS_20180630T144133

Name: NDVI

Description:

Unit:

Spectral wavelength: 0.0

Virtual (save expression only, don't store data)

Replace NaN and infinity results by NaN

Generate associated uncertainty band

Band maths expression:

Load... Save... Edit Expression...

OK Cancel Help

Band Maths Expression Editor

Data sources:
B1
B2
B3
B4
B5
B6
B7
B8

Expression:
 $(@ - @) / (@ + @)$

Show bands
 Show masks
 Show tie-point grids
 Show single flags

OK Cancel Help

Band Maths Expression Editor

Data sources:
B1
B2
B3
B4
B5
B6
B7
B8

Expression:
 $(B8 - B4) / (B8 + B4)$

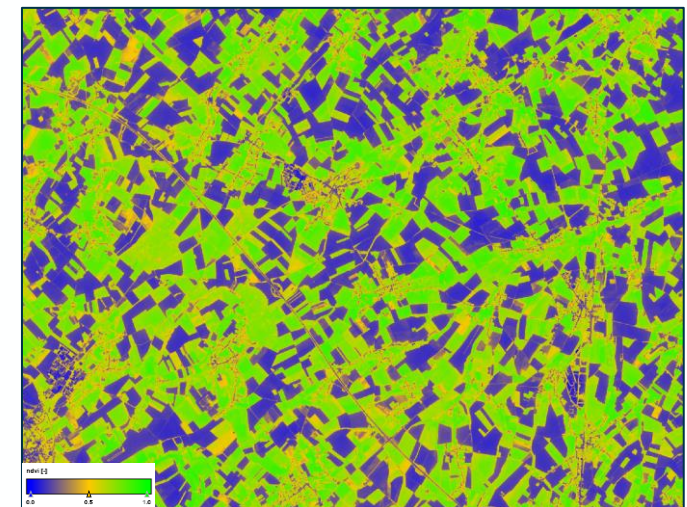
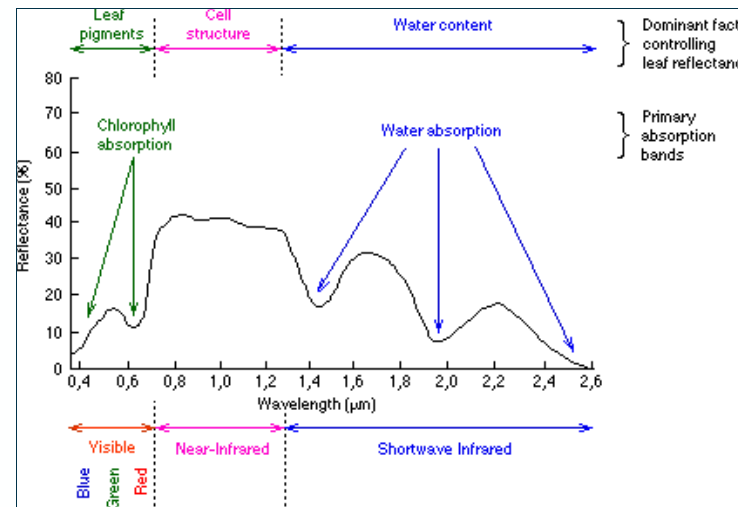
Show bands
 Show masks
 Show tie-point grids
 Show single flags

OK Cancel Help

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) algorithm exploits the strength and the vitality of the vegetation on the earth's surface. Even if it is an old and classic method it is still much used to estimate the health of green vegetation and post processed high definition images for precision agriculture.

- *Vegetation has high NIR and low Red reflectance*
- *Other land cover have NIR and Red which are much close together*
- *-1.0 to +1.0*
- *vegetation from 0.3 to 0.8, depending on health/intensity*
- *water (sea, lakes, rivers) low positive or even negative*
- *bare soil low positive values from 0,1 to 0,2*

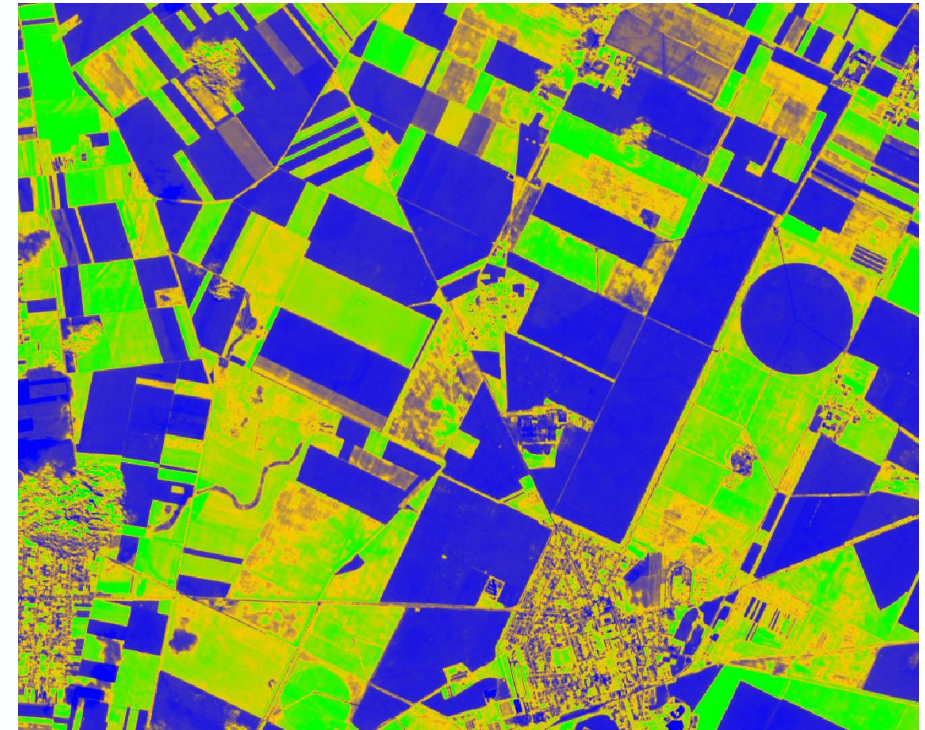


$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} = \frac{(B_8 - B_4)}{(B_8 + B_4)}$$

Enhanced Vegetation Index (EVI)

The enhanced vegetation index (EVI) is an 'optimized' vegetation index designed to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences. EVI is computed following this equation:

$$EVI = G \times \frac{(NIR - Red)}{(NIR + C_1 \times Red - C_2 \times Blue + L)} = \frac{(B_8 - B_4)}{(B_8 + 6 \times B_4 - 7.5 \times B_2 + 1)}$$



where:

- NIR/red/blue are atmospherically-corrected and partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectances
- L is the canopy background adjustment that addresses non-linear, differential NIR and red radiant transfer through a canopy
- C1, C2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band.

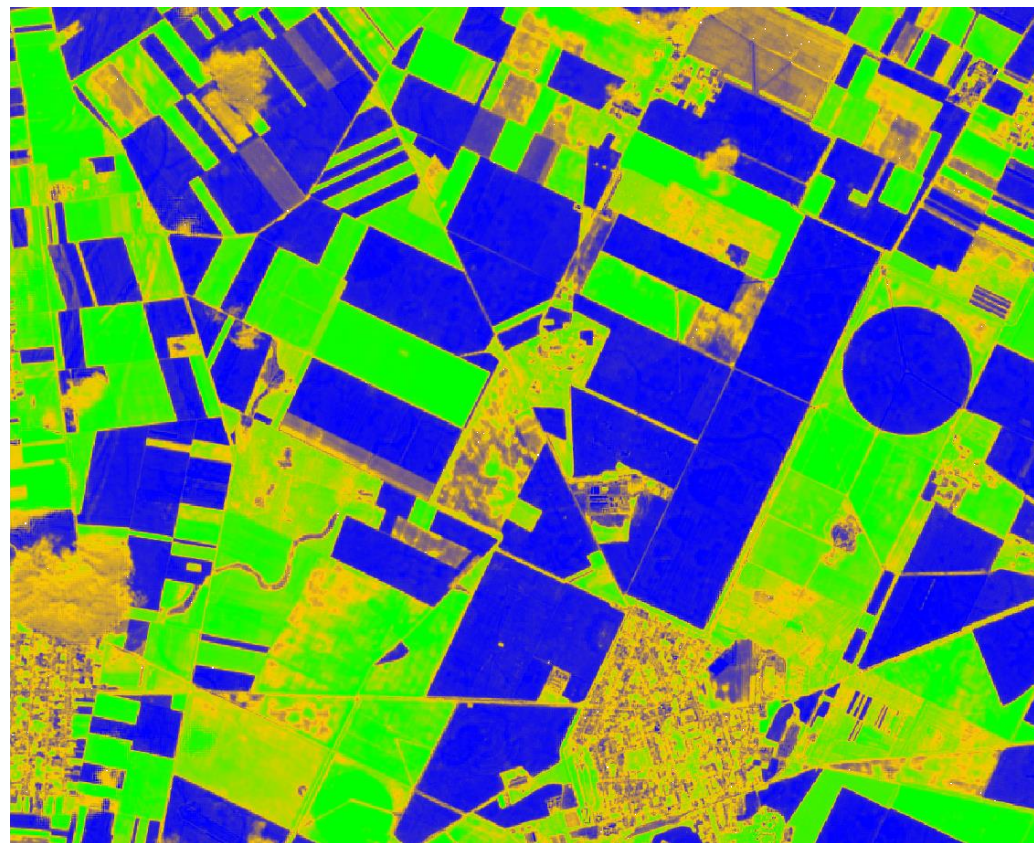
The coefficients adopted Sentinel-2 are: L=1, C₁ = 6, C₂ = 7.5, and G (gain factor) = 2.5.

Normalized Difference Moisture Index (NDMI)

The Normalized Difference Moisture Index (NDMI) detects moisture levels in vegetation using a combination of near-infrared (NIR) and short-wave infrared (SWIR) spectral bands. It is a reliable indicator of water stress in crops.

NDMI can detect water stress at an early stage, before the problem has gone out of hand. Further, using NDMI to monitor irrigation, especially in areas where crops require more water than nature can supply, helps to significantly improve crop growth.

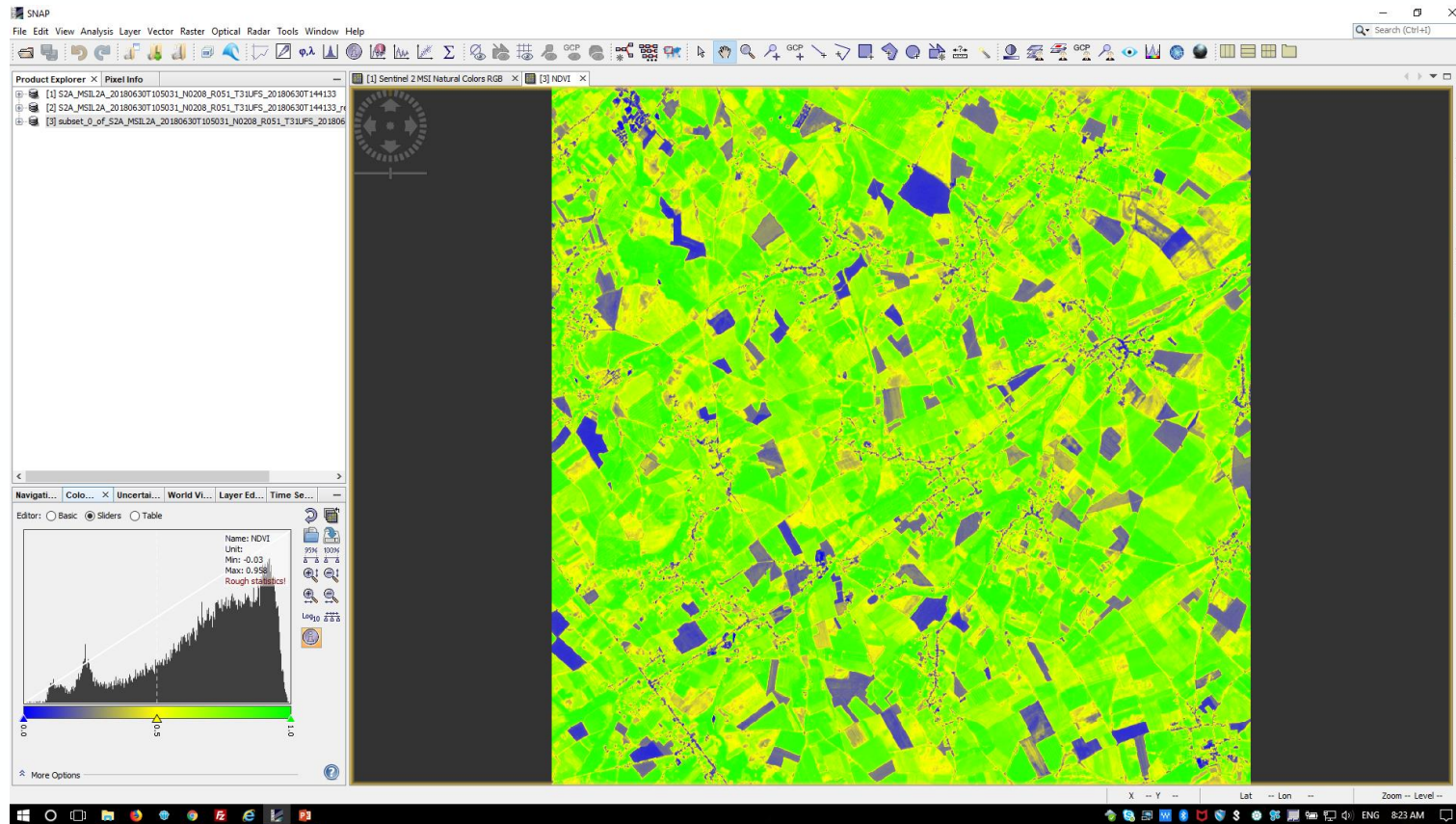
$$NDMI = \frac{NIR - SWIR_1}{NIR + SWIR_1} = \frac{(B_8 - B_{11})}{(B_8 + B_{11})}$$



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*

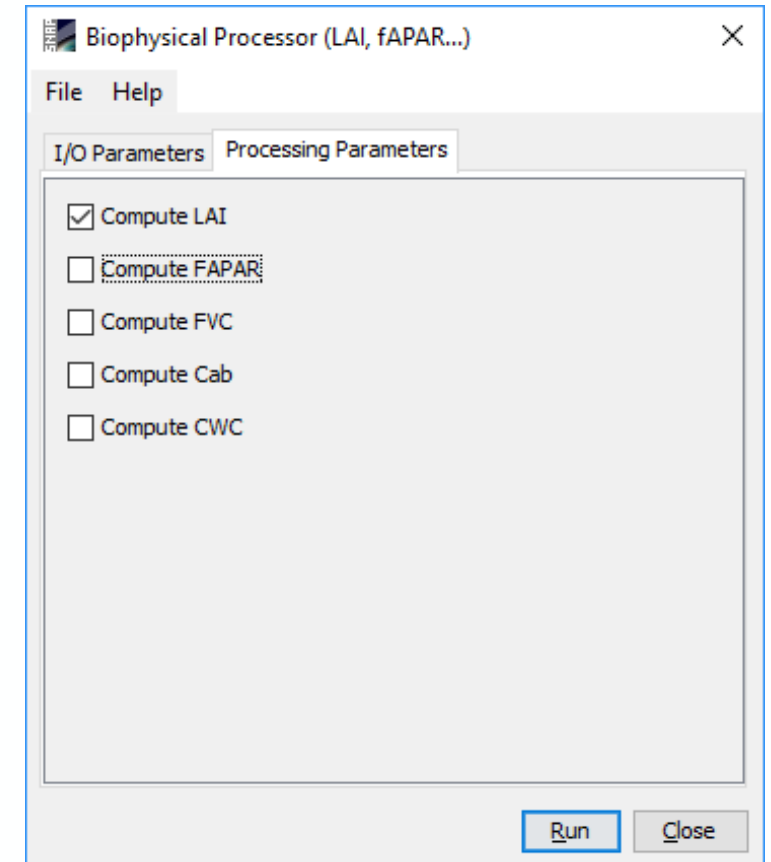
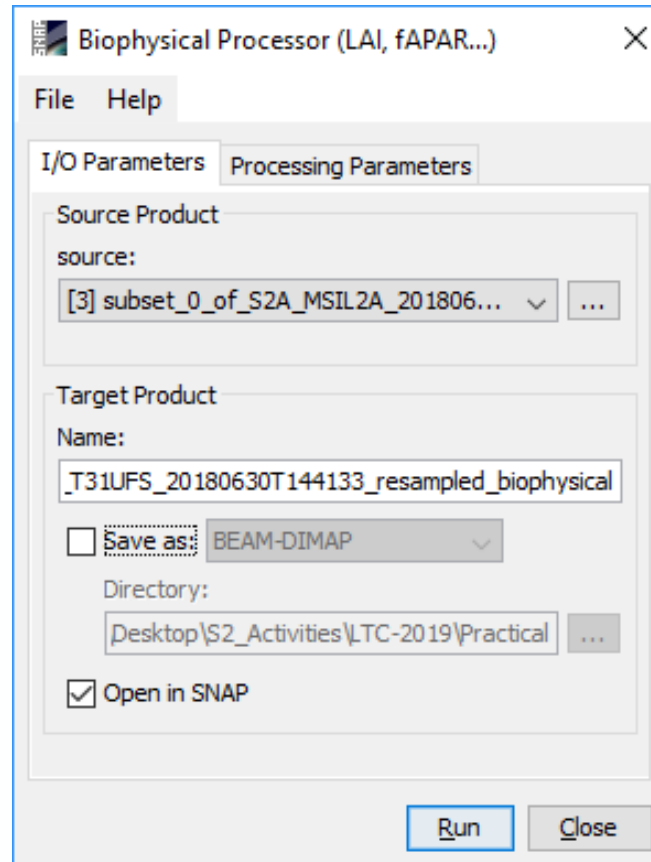
Biophysical processor (L2B)

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

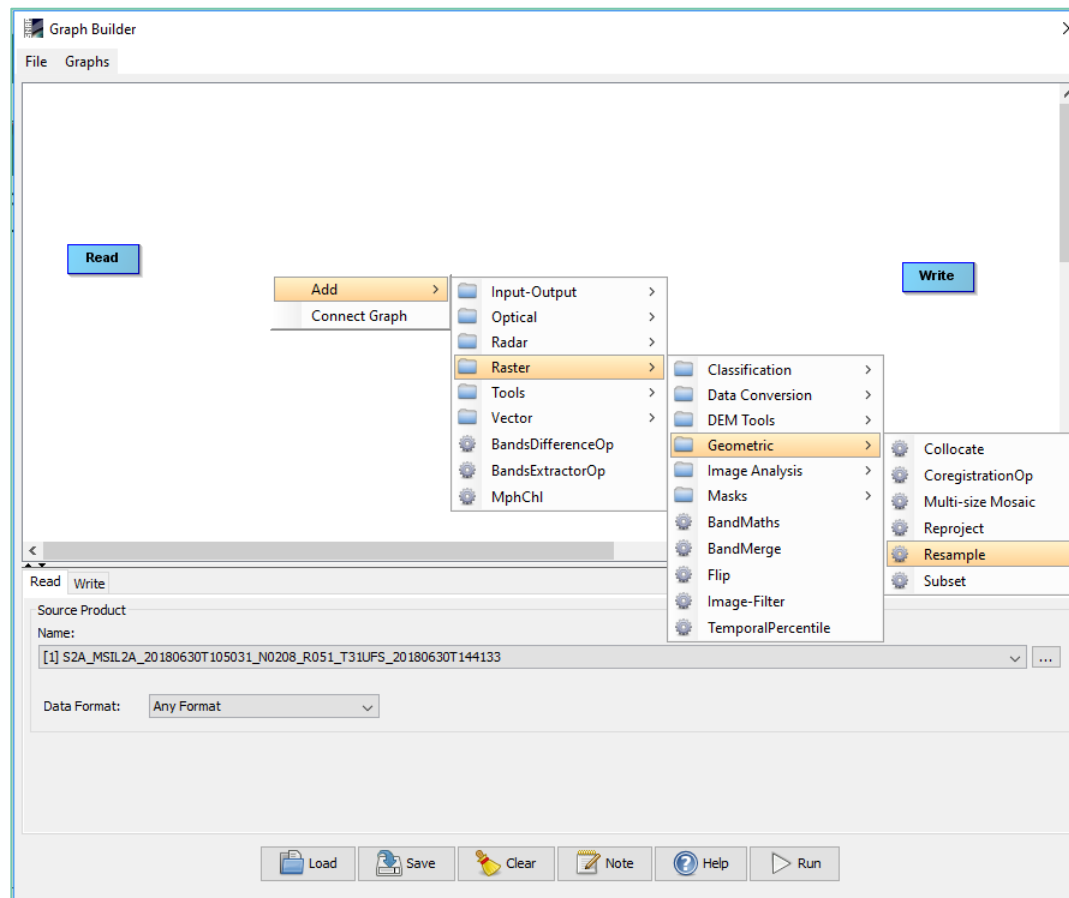
In the pop-up window set up the parameters as shown in the Figures:

- ✓ 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)

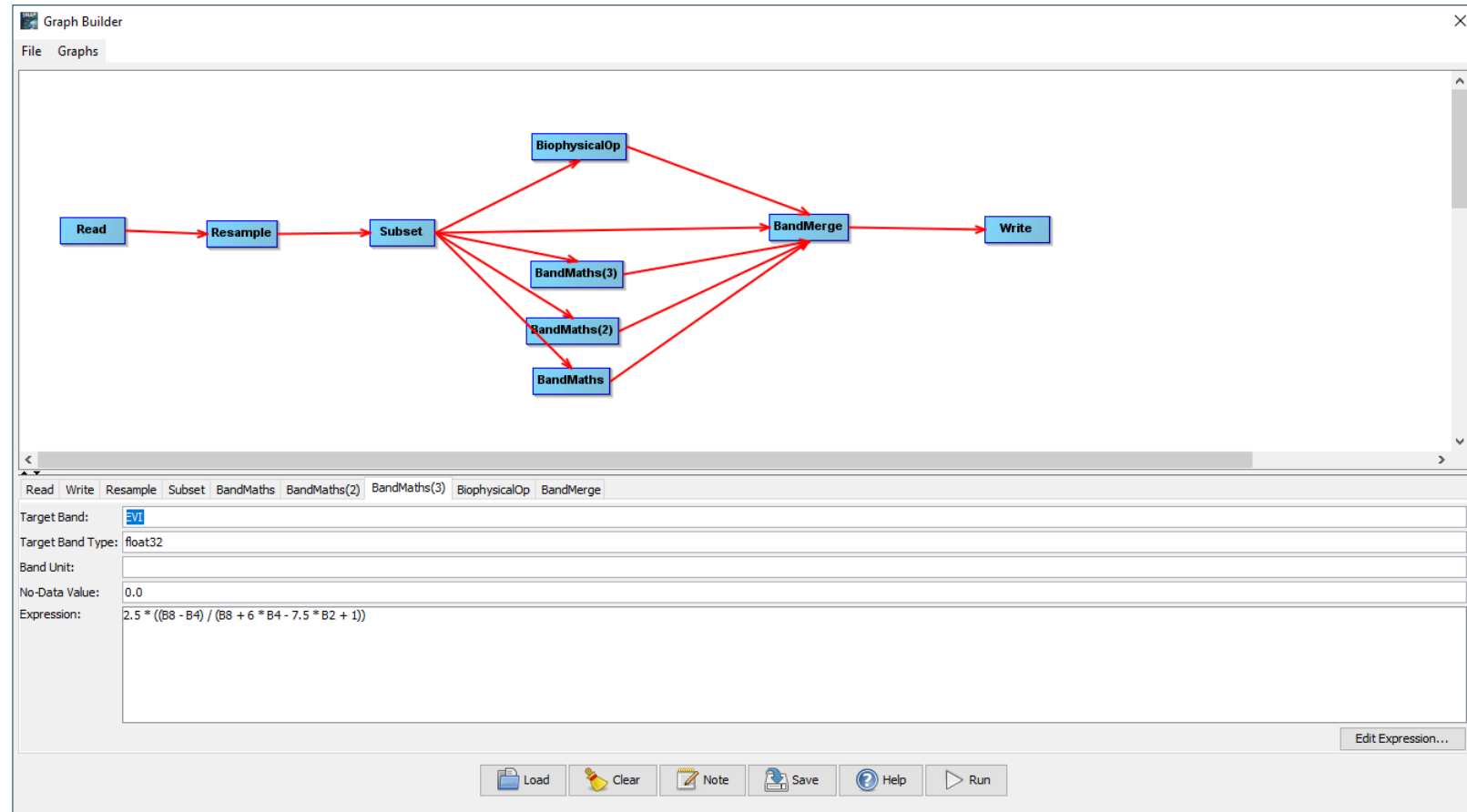
'Optical' → 'Them. Land Proc.' → 'Veg. Rad. Ind.' → 'S2repOp'

'Biophysical Processor'

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

'Band Merge'

'Raster' → 'BandMerge'



GraphBuilder (Resample module)



The screenshot shows the Graph Builder application window. At the top, there is a menu bar with 'File' and 'Graphs'. Below it is a workspace containing a workflow graph with the following nodes and connections:

- Read** connects to **Resample**.
- Resample** connects to **Subset**.
- Subset** connects to **BandMaths**, **S2repOp**, **BiophysicalOp**, and **BandMerge**.
- BandMaths**, **S2repOp**, and **BiophysicalOp** all connect to **BandMerge**.
- BandMerge** connects to **Write**.

Below the graph, there are tabs for each module: Read, Write, Resample, Subset, BandMaths, BandMerge, S2repOp, and BiophysicalOp. The **Resample** tab is active, showing the following configuration options:

- 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 (in 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 pyramid levels (for faster imaging)

At the bottom of the configuration panel, there is a red error message: "Expression is invalid." Below this are buttons for Load, Save, Clear, Note, Help, and Run.



GraphBuilder (Subset module)



The screenshot shows the Graph Builder application window. At the top, there is a menu bar with 'File' and 'Graphs'. Below it is a workspace containing a workflow graph with the following nodes and connections:

- Read** connects to **Resample**.
- Resample** connects to **Subset**.
- Subset** connects to **BandMaths**, **S2repOp**, **BiophysicalOp**, and **BandMerge**.
- BandMaths**, **S2repOp**, and **BiophysicalOp** all connect to **BandMerge**.
- BandMerge** connects to **Write**.

Below the workspace is a tabbed interface with tabs for 'Read', 'Write', 'Resample', 'Subset', 'BandMaths', 'BandMerge', 'S2repOp', and 'BiophysicalOp'. The 'Subset' tab is active, showing the following configuration:

- Source Bands:** A list of bands from B5 to B12, with B5 through B12 selected (highlighted in blue).
- Copy Metadata**
- Pixel Coordinates** (selected), **Geographic Coordinates**
- Reference band:** B1
- X:** 3000, **Y:** 8000
- Width:** 1000, **height:** 1000
- Sub-sampling X:** 1, **Sub-sampling Y:** 1

At the bottom of the configuration panel, there is a red error message: "Expression is invalid." Below this are buttons for 'Load', 'Save', 'Clear', 'Note', 'Help', and 'Run'.



GraphBuilder (BandMaths module)

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} = \frac{(B_8 - B_4)}{(B_8 + B_4)}$$

$$EVI = G \times \frac{(NIR - Red)}{(NIR + C_1 \times Red - C_2 \times Blue + L)} = \frac{(B_8 - B_4)}{(B_8 + 6 \times B_4 - 7.5 \times B_2 + 1)}$$

$$NDMI = \frac{NIR - SWIR_1}{NIR + SWIR_1} = \frac{(B_8 - B_{11})}{(B_8 + B_{11})}$$

The screenshot shows the Graph Builder interface with a workflow graph and an Arithmetic Expression Editor dialog. The graph consists of the following steps: Read → Resample → Subset → (BandMaths, S2repOp, BiophysicalOp) → BandMerge → Write. The Arithmetic Expression Editor dialog is open, showing the following details:

- Target Band: NDVI
- Target Band Type: float32
- Band Unit: (empty)
- No-Data Value: 0.0
- Expression: (empty)

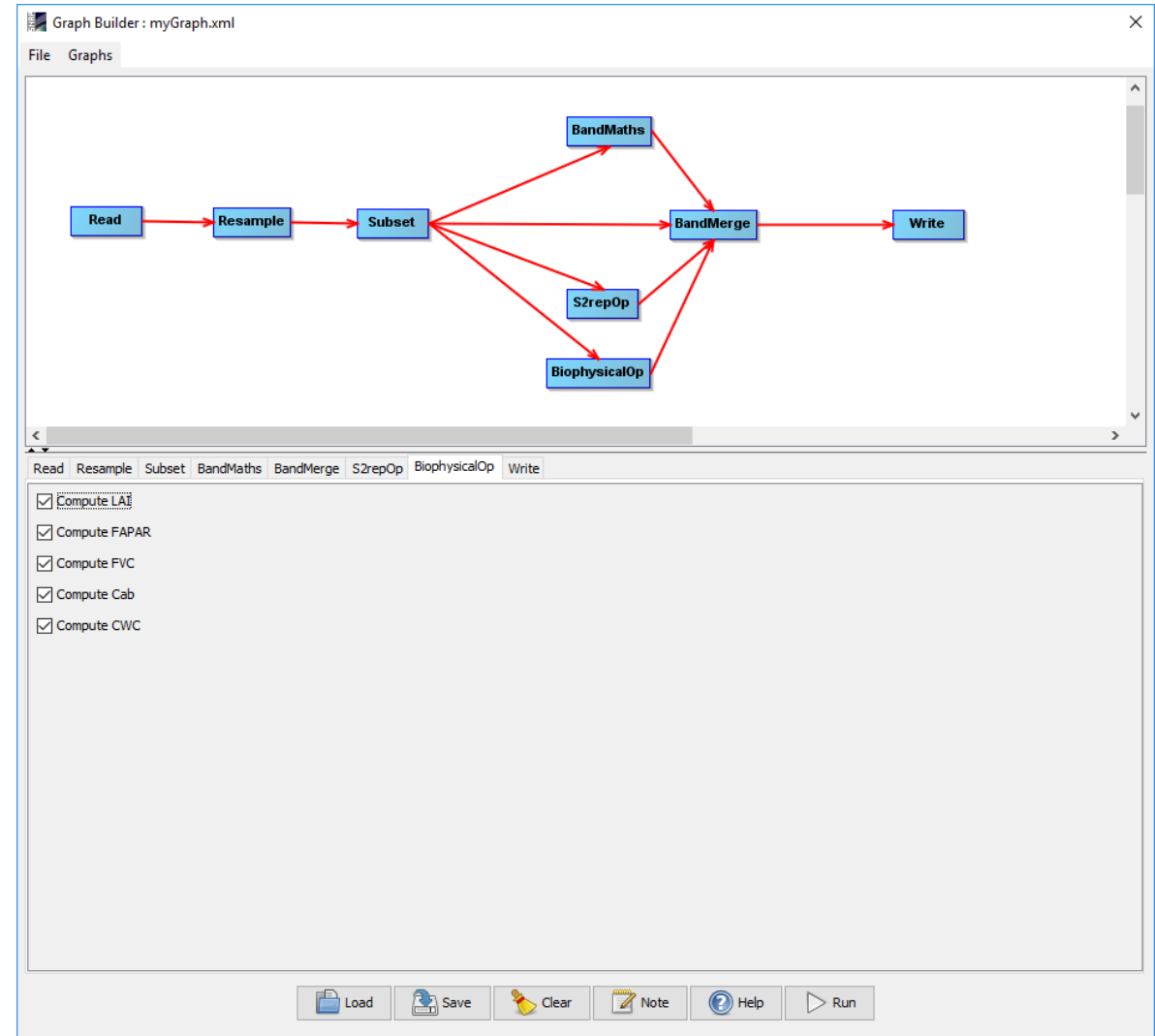
The Arithmetic Expression Editor dialog includes a list of data sources (B1 to B8), a list of operators (+, -, *, /, @), and a list of functions (Constants..., Operators..., Functions...). The expression field contains the formula: $(B_8 - B_4) / (B_8 + B_4)$. The status bar at the bottom indicates "Expression is invalid."

GraphBuilder (BiophysicalOp module)

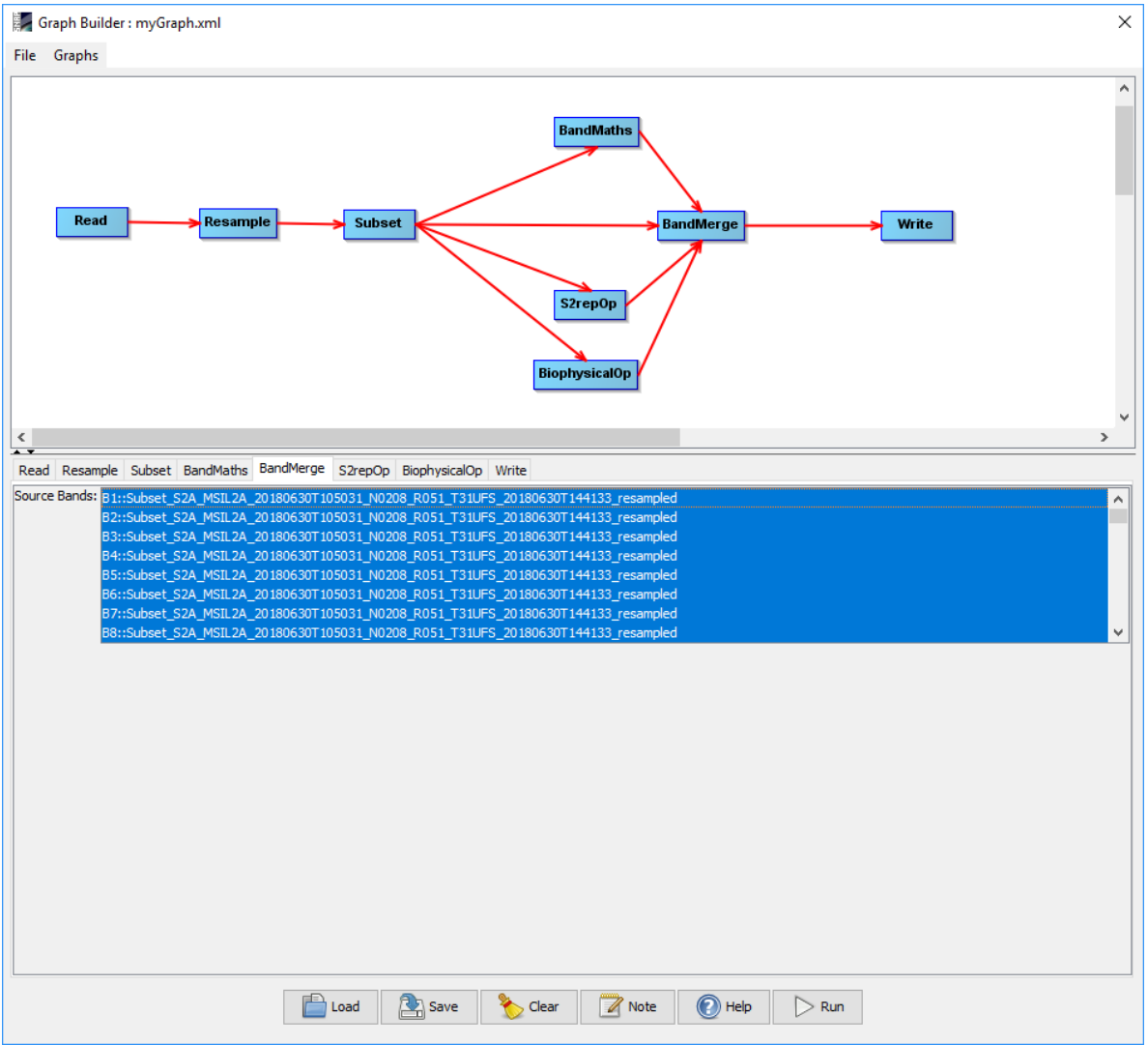
The Biophysical Processor computes Level-2B Biophysical products from Sentinel-2 reflectances.

From Bottom Of Atmosphere normalized reflectance data, it derives a set of biophysical variables, namely:

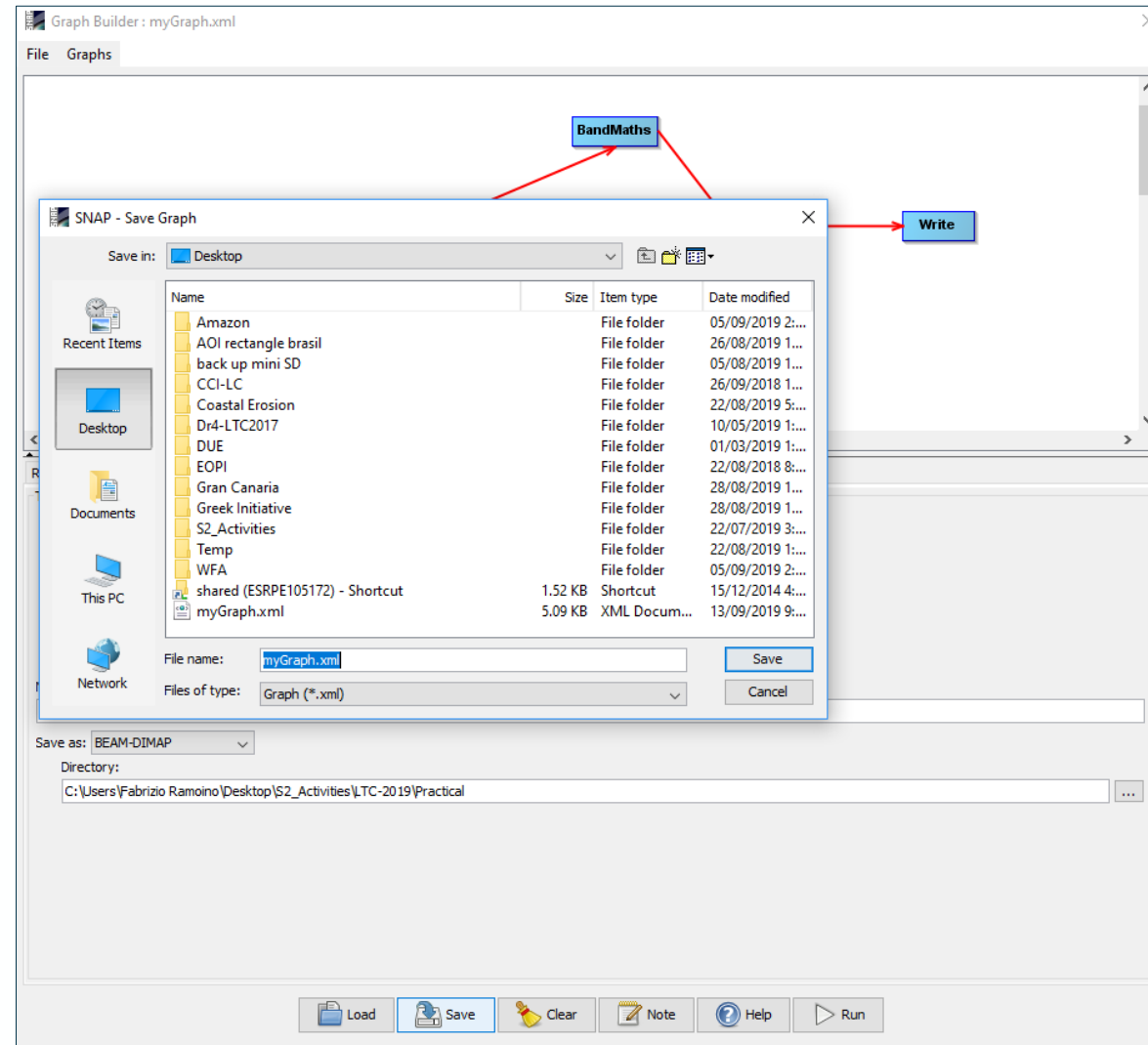
- ✓ LAI: Leaf Area Index
- ✓ fAPAR: Fraction of Absorbed Photosynthetically Active Radiation
- ✓ FVC: Fraction of vegetation cover
- ✓ Cab: Chlorophyll content in the leaf
- ✓ CWC: Canopy Water Content



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".

Batch Processing : S2_Processing-Graph.xml

File Graphs

I/O Parameters Resample Subset BandMaths S2repOp BiophysicalOp BandMerge

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

Target Folder

Save as: BEAM-DIMAP

Directory: C:\Users\Fabrizio Ramoino\Desktop\S2_Activities\ LTC-2019\Practical

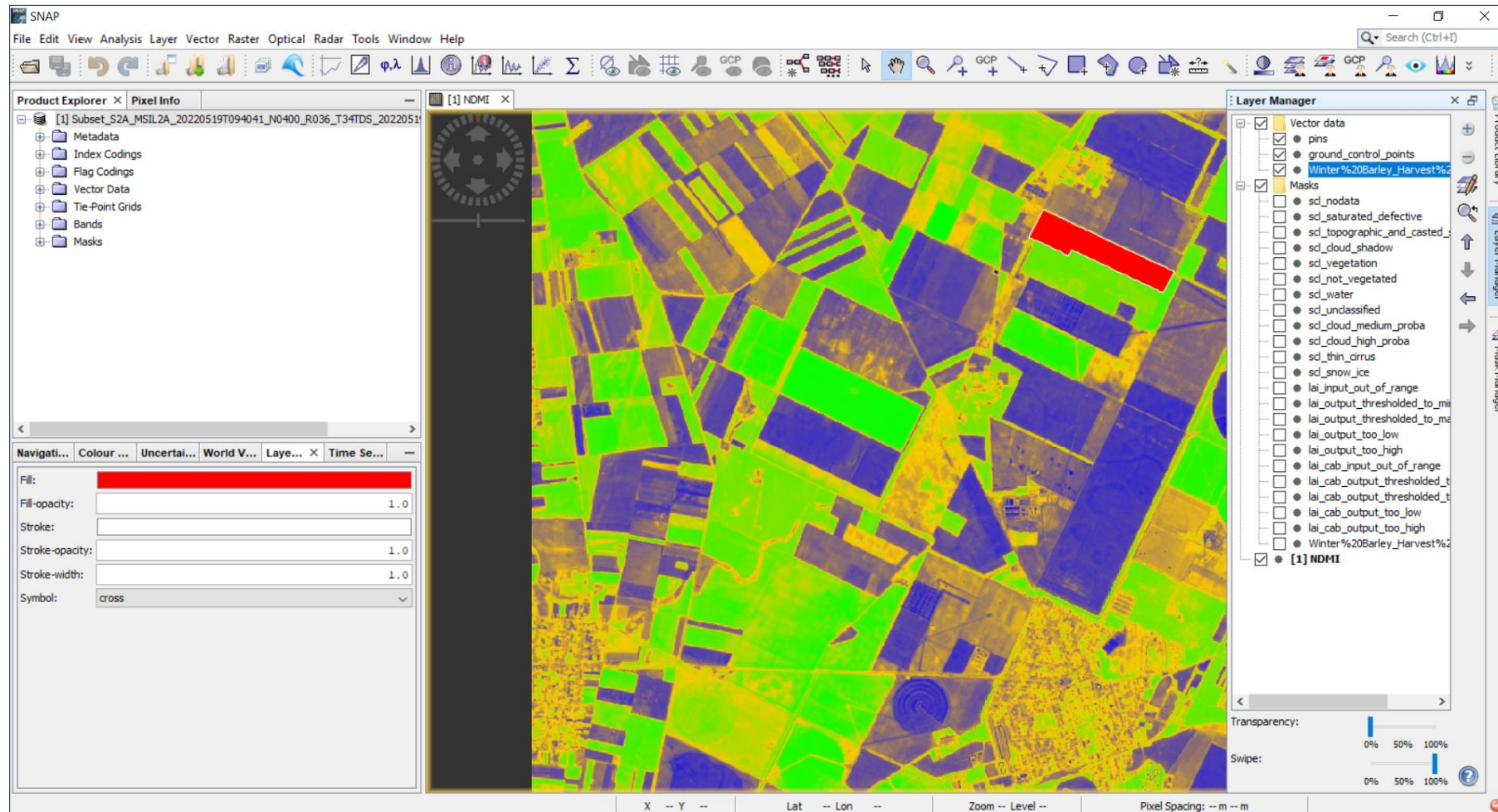
Skip existing target files Keep source product name

Run remote Load Graph Run Close Help



Import vector files (.SHP)

- 1) Select the product in the Product Explorer window.
- 2) Click on 'Vector' → 'Import' → 'ESRI Shapefile' → Select the SHP file (only one) in the '*\auxiliary data\extracted fields'



Vector file - Geometry

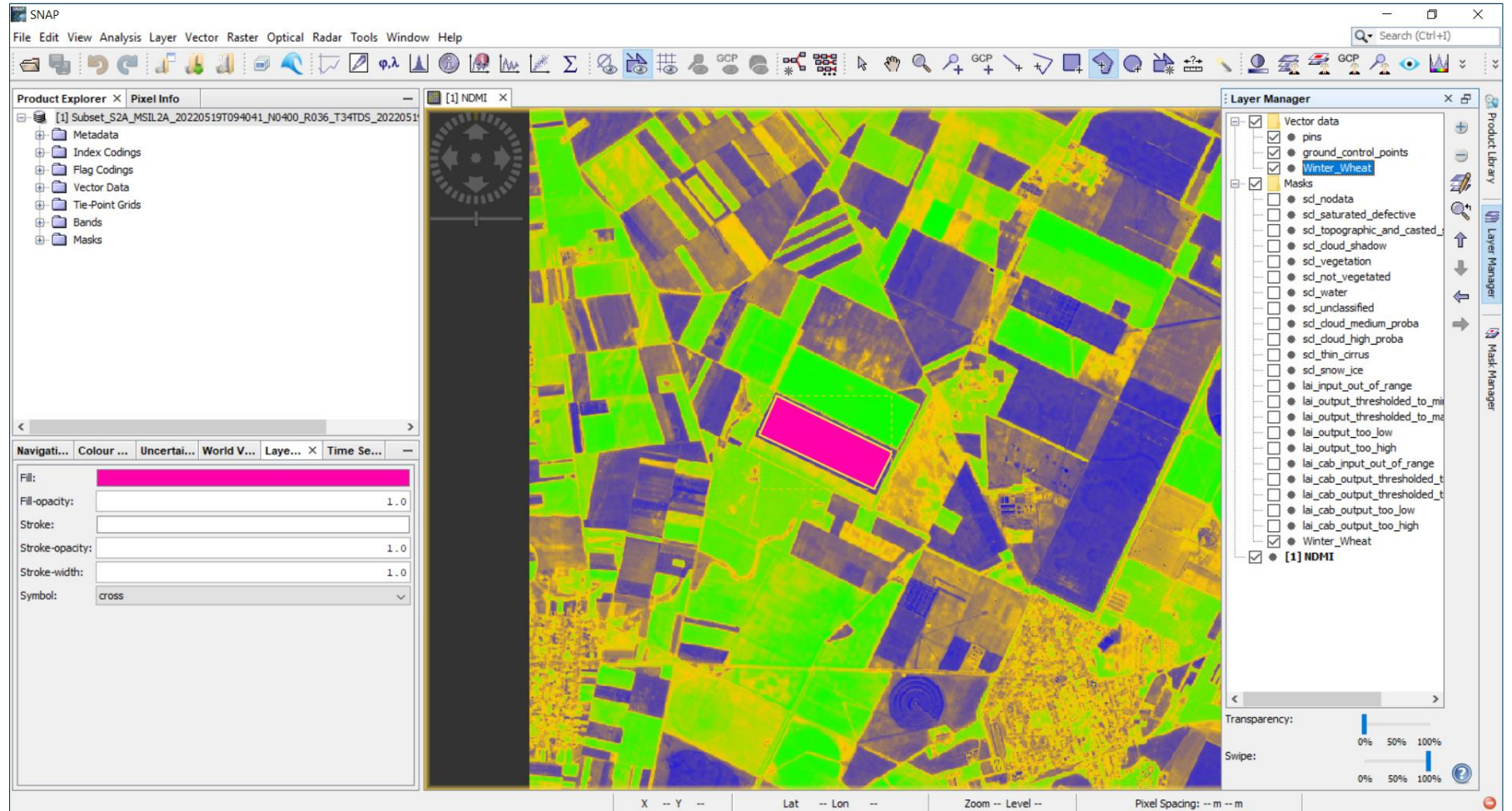
- 1) Select the product in the Product Explorer window.
- 2) Click on 'Vector' → 'New Vector Data Container'

Edit the Geometry's name

Click on the Polygon drawing tool

Draw your polygon

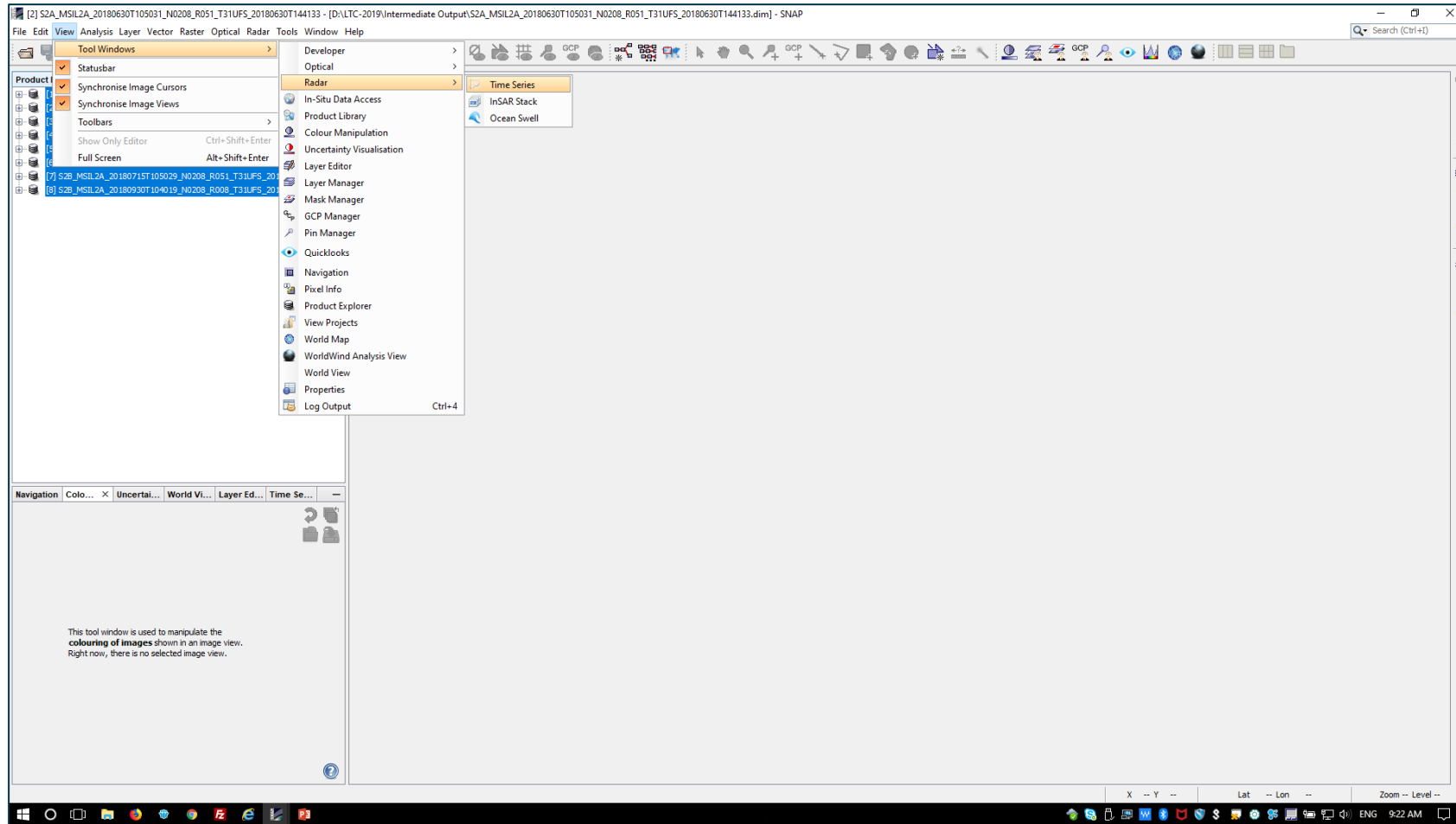
The polygon geometry can be used
as ROI for time series analysis



Time Series

Due to the short time you can find the batch processing output in the 'S2-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

Apply Close

Time Series Analysis



The screenshot shows the SNAP (Sentinel Application Platform) interface. The main window displays a satellite image of a field. An 'Available Bands' dialog box is open, listing various bands and indices, with 'NDVI' selected. A 'Graph 1' window in the bottom left shows a line graph of NDVI values over time from March to October 2018.

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

Acquisition Date	NDVI
17Mar18	0.12
06May18	0.07
25Jan18	0.06
14Aug18	0.35
03Oct18	0.07

