CHANGE DETECTION USING OPTICAL DATA IN SNAP

EXERCISE 1 (Exploring S2 data)

Data: Sentinel-2A Level 1C:

- **S2A_MSIL1C_20190603T032541_N0207_R018_T48RXT_20190603T063053.SAFE**

1. Open file
   1.1. 'File' / 'Open Product'
   1.2. Browse to: /Ex-1/S2A_MSIL1C_20190603T032541_N0207_R018_T48RXT_20190603T063053.SAFE
   1.3. Select the 'MTD_MSIL1C.xml' and click 'Open'

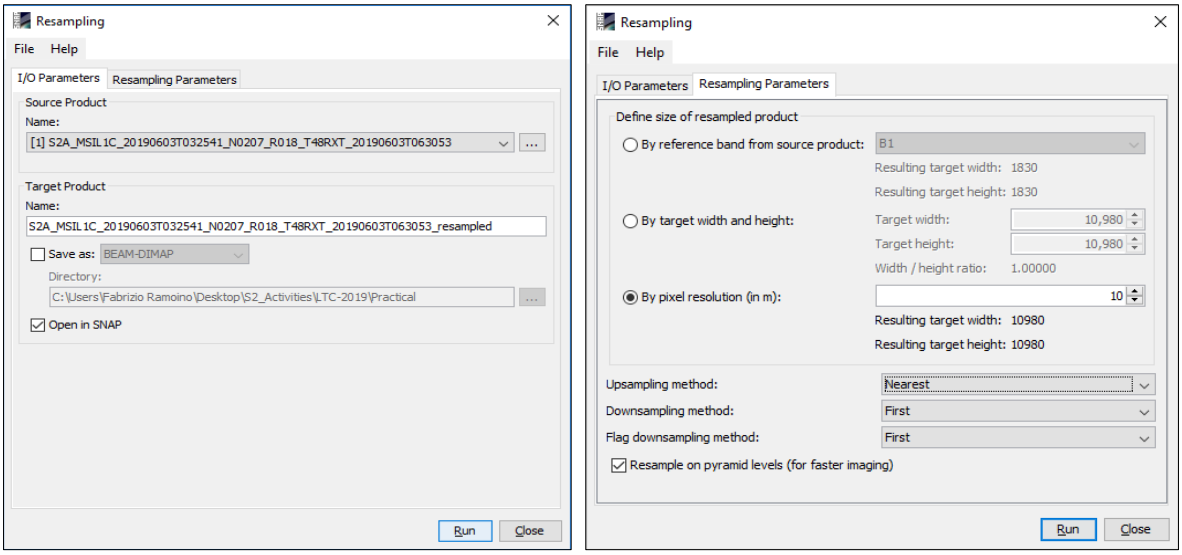
2. View metadata
   2.1. Select plus icons by filenames in "Product Explorer", expand "Metadata / Level-1C_User_Product / General_Info" folder and click on "Product_Info". Here you can see the basic product information such as acquisition date, processing level and processing baseline (indicates quality of preprocessing)
   2.2. Double click on "Product_Image_Characteristics". Here you can see the solar irradiance per band and correction factors necessary to convert from Top of Atmosphere Reflectance to Top of Atmosphere Radiance.

3. View image single bands
   3.1. Select "Bands" folder in "Product Explorer" window and view each band by double clicking on band name.

4. View multiple viewers
   4.1. Close metadata views, leaving only viewers with bands
   4.2. Select: 'Window' / 'Tile Horizontally'
   4.3. Synchronise views by selecting the relevant icons in the "Navigation" tab 

5. View RGB image view
   5.1. Close all viewers
   5.2. Select image name in "Product Explorer" window
   5.3. Select: 'Window' / 'Open RGB Image Window'
   5.4. Leave default natural colour combination and click OK

6. Resampling at 10m
   6.1. Select image name in "Product Explorer" window
   6.2. Select: 'Raster' / 'Geometric Operations' / 'Resampling'
   6.3. In the pop-up window set up the parameters as shown in the Figures below



6.4. Click 'Run'

7. Select the newly created product

7.1. Now all the bands have the same spatial resolution of 10m.

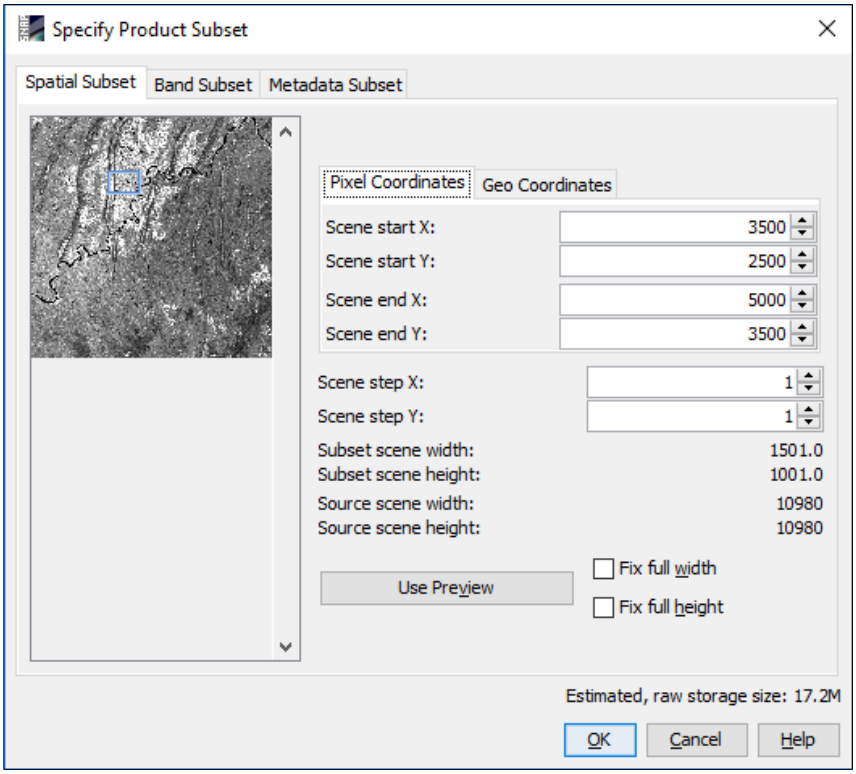
8. Crop

8.1. Zoom into Chongqing University

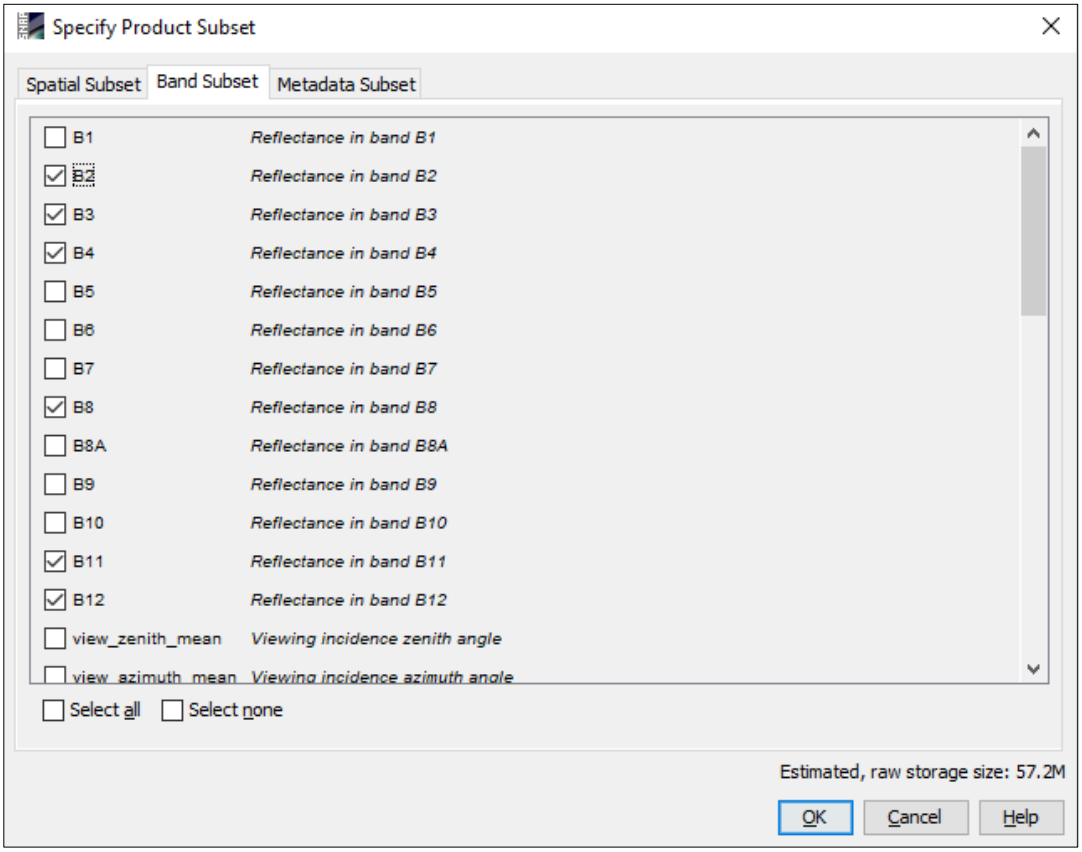
8.2. Select: 'Raster' / 'Subset…'

8.3. Specify: 'Spatial Subset' parameters (as shown in Figure below)

- Scene start X: **3500**
- Scene start Y: **2500**
- Scene end X: **5000**
- Scene end Y: **3500**



8.4. Specify: ‘Band Subset’ parameters selecting **B2**, **B3**, **B4**, **B8**, **B11** and **B12** (as shown in Figure below)

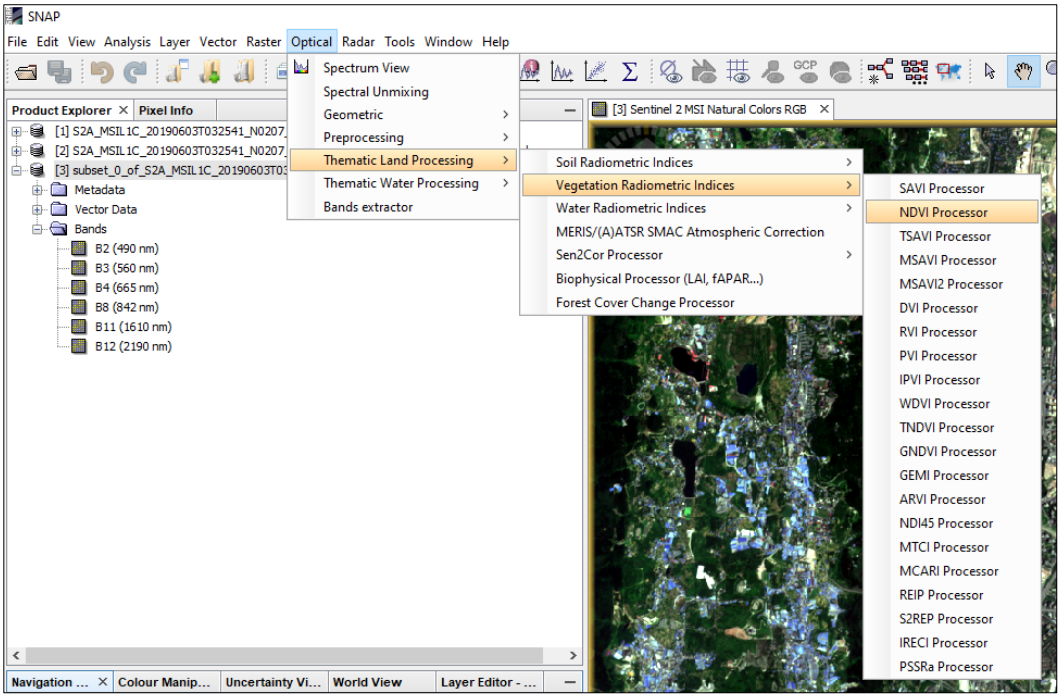


8.5. Click ‘OK’

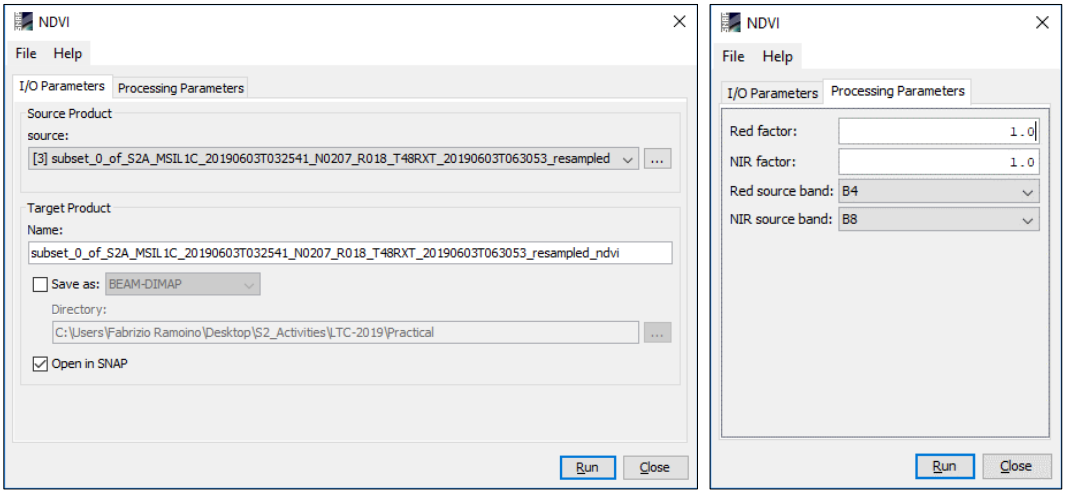
9. Save the newly created subset image
   - 9.1. Select product in “Product Explorer”
   - 9.2. Select: ‘File’ / ‘Save Product As…’
   - 9.3. Select “Yes” to convert to BEAM DIMAP format (SNAP native file format)
   - 9.4. Select an output filename and location, and click “Save”
   - 9.5. In order to view the saved file with the filename you specified, close the cropped image and reopen it

10. Open the newly created product
    - 10.1. Close all viewers
    - 10.2. Select image name in “Product Explorer” window
    - 10.3. Select: ‘Window’ / ‘Open RGB Image Window’
      - 10.3.1. Leave default natural colour combination and click ‘OK’
      - 10.3.2. Select B12 for Red, B11 for Green and B4 for Blue and click ‘OK’
    - 10.4. Synchronise views by selecting the relevant icons in the “Navigation” tab
    - 10.5. Select: ‘Window’ / ‘Tile Horizontally’ and compare the images

11. Normalized Difference Vegetation Index (NDVI) via Radiometric Indices module
    - 11.1. Select the newly generated product [3] in “Product Explorer”
    - 11.2. Select: ‘Optical’ / ‘Thematic Land Processing’ / ‘Vegetation Radiometric Indices’ / ‘NDVI Processor’



11.3. In the pop-up window set up the parameters as shown in the Figures below



11.4. The input product is the number [3] and the Red source band is B4 and the NIR source band is B8

11.5. Click 'Run'

12. <u>Open the newly created NDVI product</u>

12.1. Close all viewers

12.2. Select the newly generated product on the Product Explorer window

12.3. Double click on the 'ndvi' band

12.4. The band is shown in grey scale colour

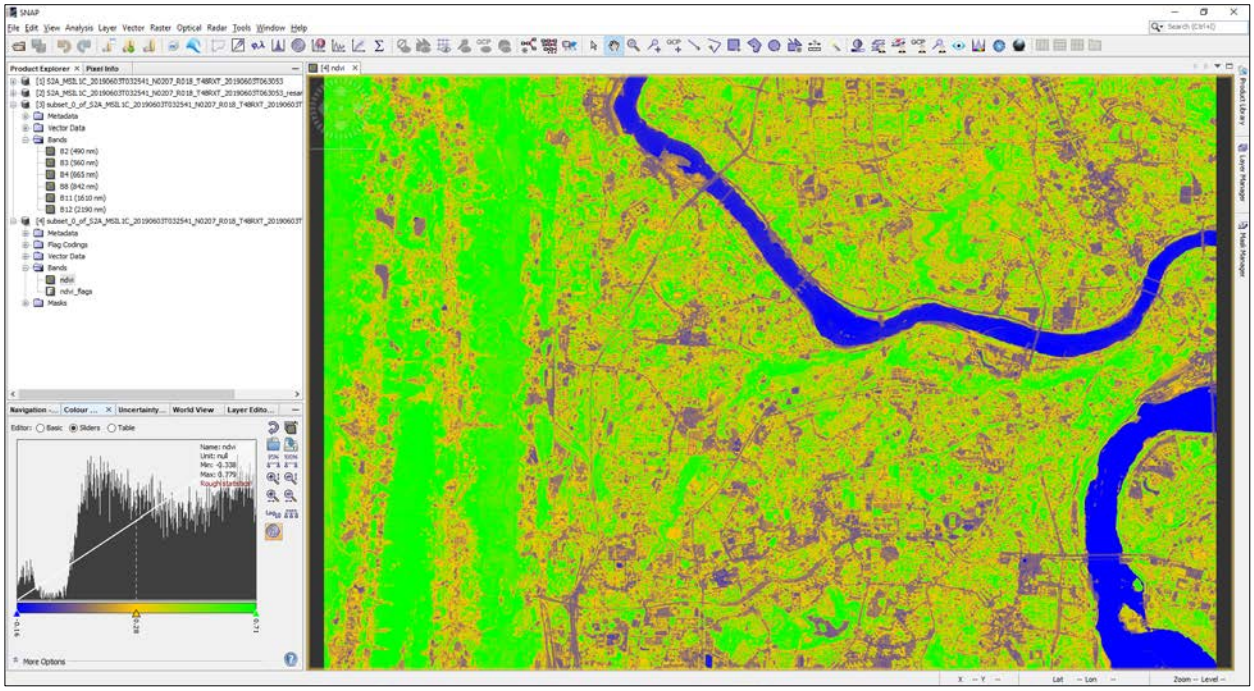
13. <u>Colour Manipulation</u>

13.1. Select 'ndvi' image displayed

13.2. Select: "Colour Manipulation" tab

13.3. Click on "Auto-adjust to 95% of all pixels" icon 

13.4. [Min: Blue]; [Mean: Orange]; [Max: Green] obtaining as output an image where high values of NDVI are green and low ones are blue as shown in the figure below


SNAP
File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help
Product Explorer
Pixel Info
Metadata
Vector Data
Bands
B2 (490 nm)
B3 (560 nm)
B4 (665 nm)
B8 (842 nm)
B11 (1610 nm)
B12 (2190 nm)
Flag Codings
ndvi
ndvi_flags
Masks
Navigation
Colour
Uncertainty
World View
Layer Edito
Editor: Basic Sliders Table
Name: ndvi
Unit: null
More Options
Product Library
Layer Manager
Mask Manager

EXERCISE 2 (Burned area estimation)

Data: Sentinel-2A Level-2A:
Subset_S2A_MSIL2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m.data
Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TNE_20170704T112431_10m.data
The data have been atmospherically corrected, resampled at 10m, cropped spatially and spectrally (B2, B3, B4, B8, B11, B12) and exported in BEAM-DIMAP (SNAP native file format).

1. Open files
   1.1. 'File' / 'Open Product'
   1.2. Browse to:
   /data/Ex-2/Subset_S2A_MSIL2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m.dim
   /data/Ex-2/Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TNE_20170704T112431_10m.dim
   1.3. Click 'Open'

2. View RGB image view
   2.1. Select image name in "Product Explorer" window
   2.2. Select: 'Window' / 'Open RGB Image Window'
   2.3. Leave default natural colour combination and click OK
   2.4. Repeat the steps 2.1, 2.2 and 2.3 for the second product [2]

3. View multiple viewers
   3.1. Select: 'Window' / 'Tile Horizontally'
   3.2. Synchronise views by selecting the relevant icons in the 'Navigation' tab 

4. NBR (Normalized Burn Ratio)

The Normalized Burn Ratio (NBR) was designed to highlight burned areas and estimate fire severity and is calculated applying the equation reported below:

$$NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)} = \frac{(B8 - B12)}{(B8 + B12)}$$

Pre-fire, healthy vegetation has very high near-infrared reflectance and low reflectance in the shortwave infrared portion of the spectrum. Recently burned areas on the other hand have relatively low reflectance in the near-infrared and high reflectance in the shortwave infrared band. A high NBR value generally indicates healthy vegetation while a low value indicates bare ground and recently burned areas.

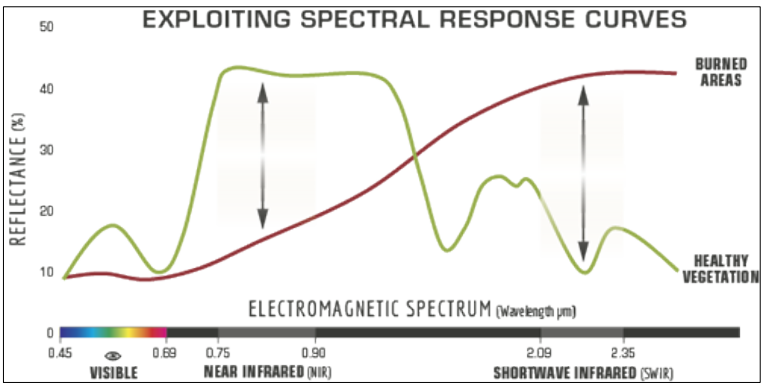
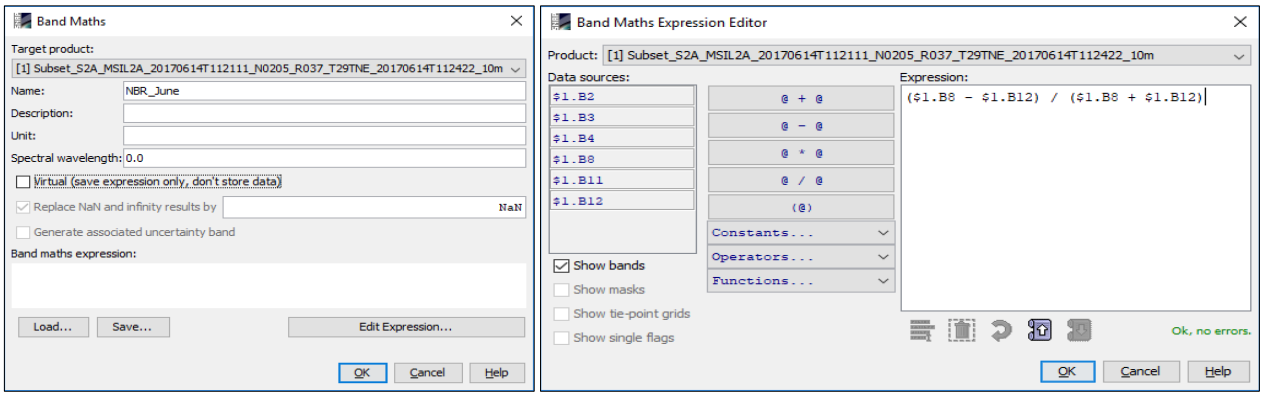


Image Credit: US Forest Service

4.1. By Band Maths
   4.1.1. Select: 'Raster' / 'Band Maths…'
   4.1.2. Set up the I/O and the processing parameters as shown in the Figure below
   4.1.3. Change the output name in 'NBR_June'
   4.1.4. Deselect "Virtual"

4.1.5. Select “Edit Expression…”

4.1.6. Type in the following expression in the ‘Expression’ field: “($1.B8 – $1.B12) / ($1.B8 + $1.B12)”



4.1.7. Click ‘OK’

4.1.8. The newly created NBR band is added as band of the input product

4.1.9. Replicate the action for the second product [2] changing the output name ‘NBR_July’

5. <u>View NBR bands</u>

5.1. Select ‘NBR_June’ band name in “Product Explorer” window and double click

5.2. Repeat for the ‘NBR_July’ band associated to the second image

5.3. Synchronise views by selecting the relevant icons in the “Navigation” tab

5.4. Select: ‘Window’ / ‘Tile Horizontally’

6. <u>Colour Manipulation</u>

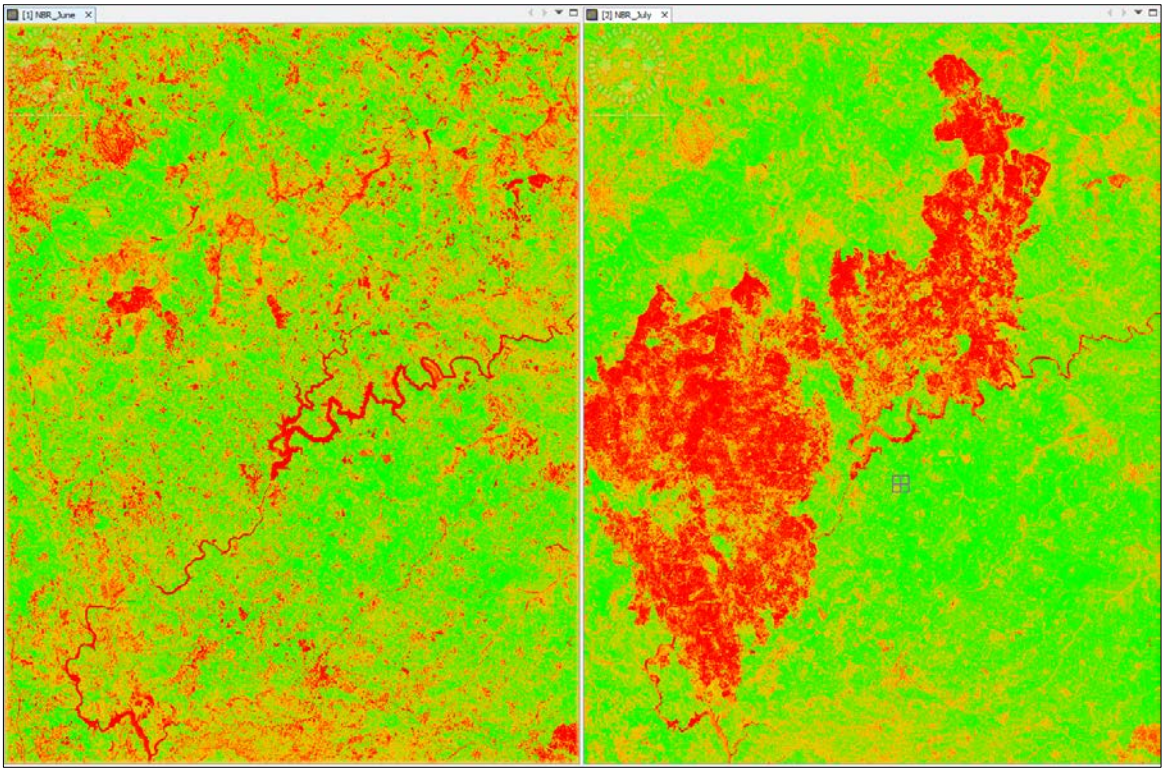
6.1. Select NBR_June image displayed

6.2. Select: “Colour Manipulation” tab

6.3. Click on “Auto-adjust to 95% of all pixels” icon 

6.4. [Min: Red]; [Mean: Orange]; [Max: Green]

6.5. Repeat for the NBR_July obtaining the following result



7. Burn Severity

Normalized Burn Ratio is frequently used to estimate burn severity. Imagery collected before a fire will have very high near infrared band values and very low mid infrared band values and a Imagery collected over a forest after a fire will have very low near infrared band values and very high mid infrared band values. Higher dNBR indicate more severe damage. Areas with negative dNBR values may indicate increased vegetation productivity following a fire.

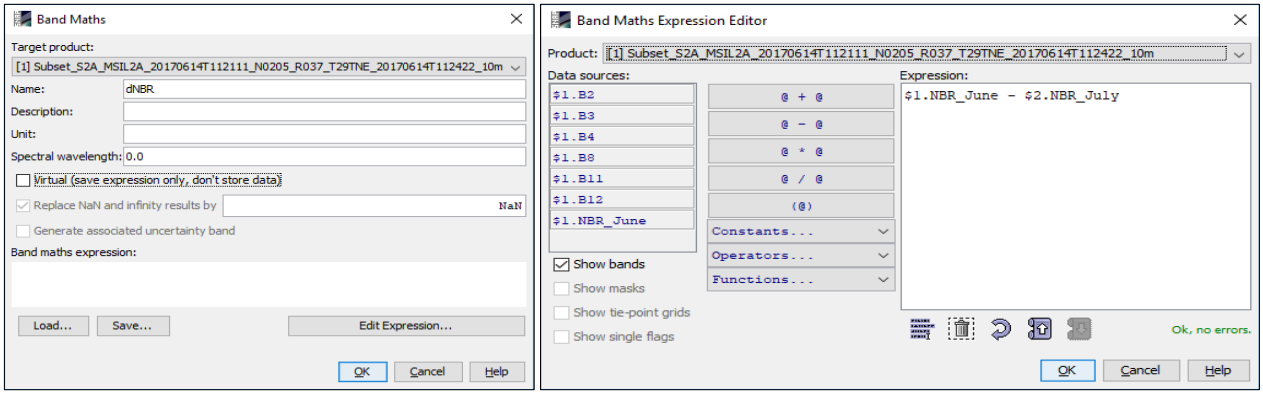
$$dNBR\ or\ \Delta NBR = PrefireNBR - PostfireNBR = NBR_{June} - NBR_{July}$$

The meaning of the ΔNBR values can vary by scene, and for best results interpretation in specific instances should always be based on some field assessment. However, the table below from the USGS FireMon program can be useful as a first approximation for interpreting the NBR difference.

dNBR	Burn Severity
< -0.25	High post-fire regrowth
-0.25 to -0.1	Low post-fire regrowth
-0.1 to +0.1	Unburned
0.1 to 0.27	Low-severity burn
0.27 to 0.44	Moderate-low severity burn
0.44 to 0.66	Moderate-high severity burn
> 0.66	High-severity burn

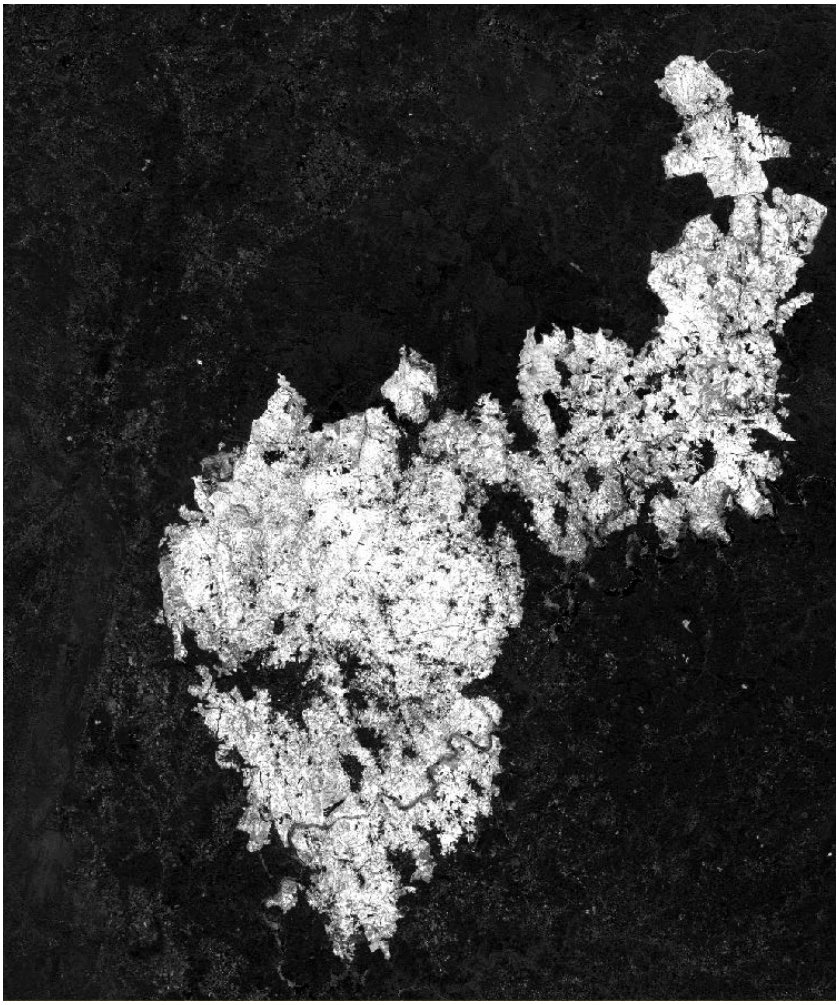
7.1. Select: 'Raster' / 'Band Maths…'
7.2. Set up the I/O and the processing parameters as shown in the Figure below
7.3. Change the output name in 'dNBR'
7.4. Deselect "Virtual"
7.5. Select "Edit Expression…"

7.6. Type in the following expression in the ‘Expression’ field: “$1.NBR_June - $2.NBR_July”



7.7. The symbols “$1.” and “$2.” are the links to the different products

7.8. Obtaining the following result



7.9. The brightest pixels represent high dNBR meaning high-severity burn.

8. Colour Manipulation

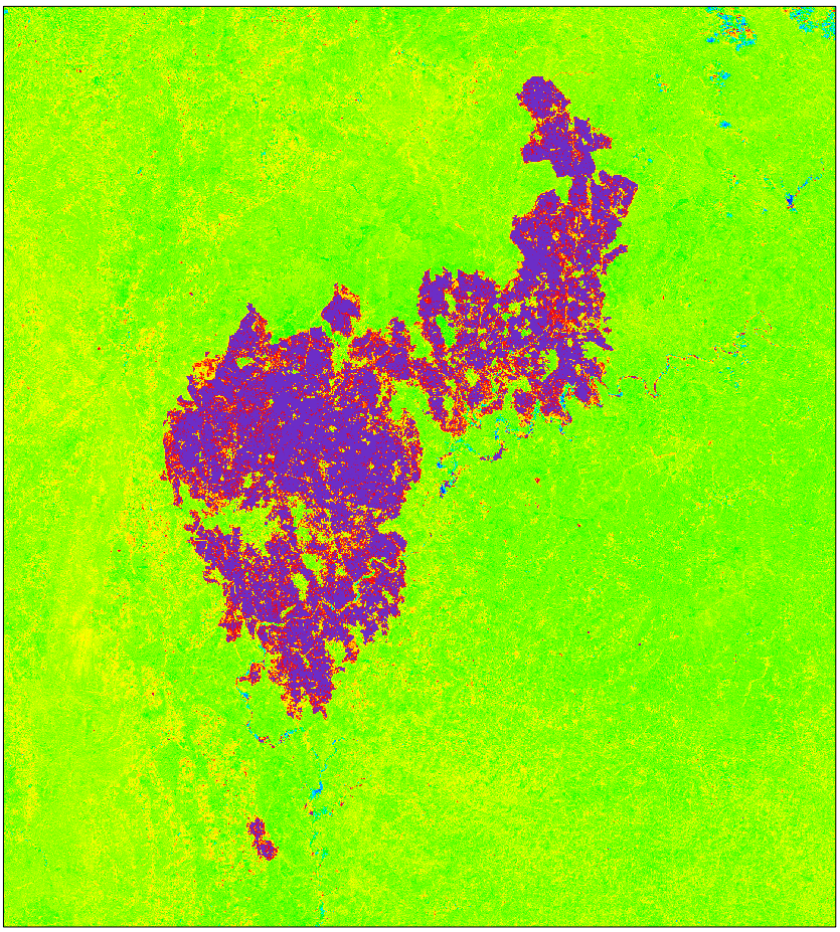
8.1. Select dNBR band displayed on the screen

8.2. Go to “Colour Manipulation” tab (bottom left) and select ‘Basic’ as editor

8.3. Import colour palette from text file clicking on the icon  and selecting the file named 'dNBR_ColourPalette.cpd'

8.4. In order to take the range from the file click 'No' on the pop-up message

dNBR	Burn Severity	Colour Palette
< -0.25	High post-fire regrowth	
-0.25 to -0.1	Low post-fire regrowth	
-0.1 to +0.1	Unburned	
0.1 to 0.27	Low-severity burn	
0.27 to 0.44	Moderate-low severity burn	
0.44 to 0.66	Moderate-high severity burn	
> 0.66	High-severity burn	



EXERCISE 3 (Water change detection)

Data: Sentinel-2A Level 2A:

- **S2A_MSIL2A_20170101T082332_N0204_R121_T34HCH_20170101T084543.SAFE**
- **S2A_MSIL2A_20180116T082251_N0206_R121_T34HCH_20180116T120458.SAFE**

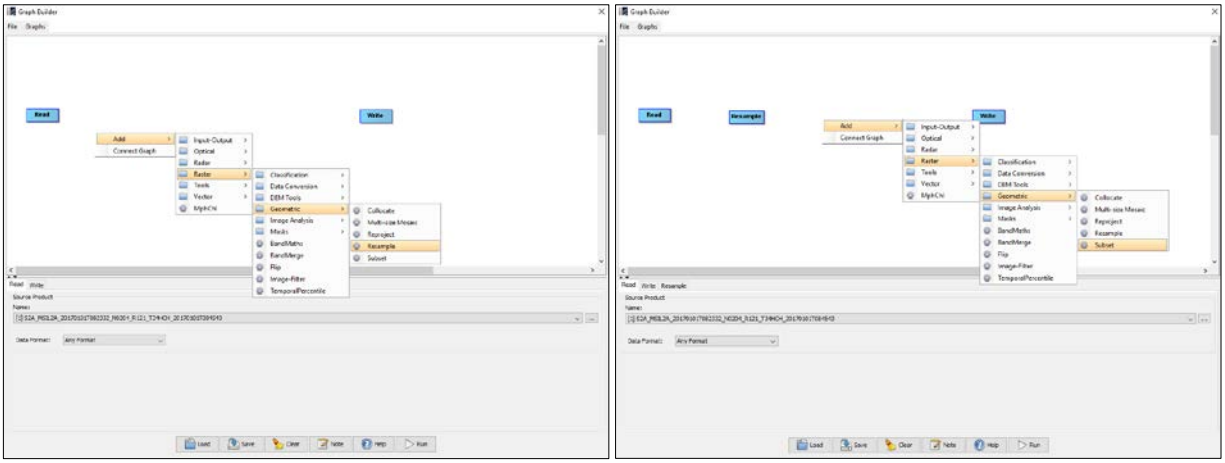
1. Open file
   1.1. 'File' / 'Open Product'
   1.2. Browse to:
   /data/Ex-3/S2A_MSIL2A_20170101T082332_N0204_R121_T34HCH_20170101T084543.SAFE
   /data/Ex-3/S2A_MSIL2A_20180116T082251_N0206_R121_T34HCH_20180116T120458.SAFE
   1.3. Select the 'MTD_MSIL2A.xml' file for each product and click 'Open'

2. View RGB image view
   2.1. Select the first product in "Product Explorer" window
   2.2. Select: 'Window' / 'Open RGB Image Window'
   2.3. Leave default natural colour combination and click OK
   2.4. Repeat the steps 2.1, 2.2 and 2.3 for the second product [2]

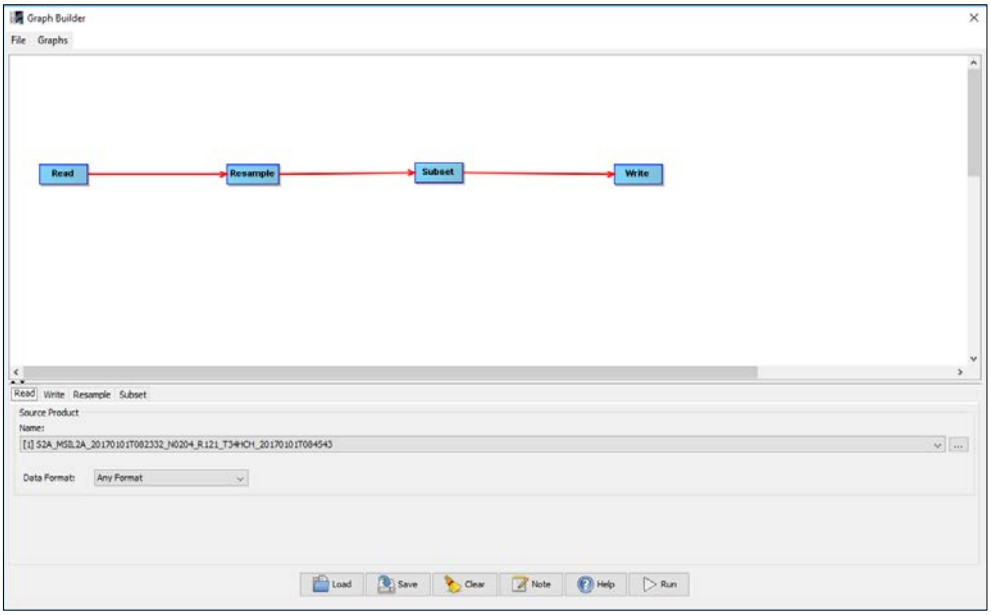
3. View multiple viewers
   3.1. Select: 'Window' / 'Tile Horizontally'
   3.2. Synchronise views by selecting the relevant icons in the 'Navigation' tab 

The Sentinel-2 data contains 13 spectral bands at different spatial resolution (10, 20 and 60 meters), therefore before to apply the processing involving bands at different resolution we need to resample them.
Due to the short time slot dedicated to the practical we will focus the attention to the Waterskloof Dam (South Africa) running a pre-processing graph that will subset spatially and spectrally the original product. The steps to set-up the pre-processing graph in SNAP are shown below.

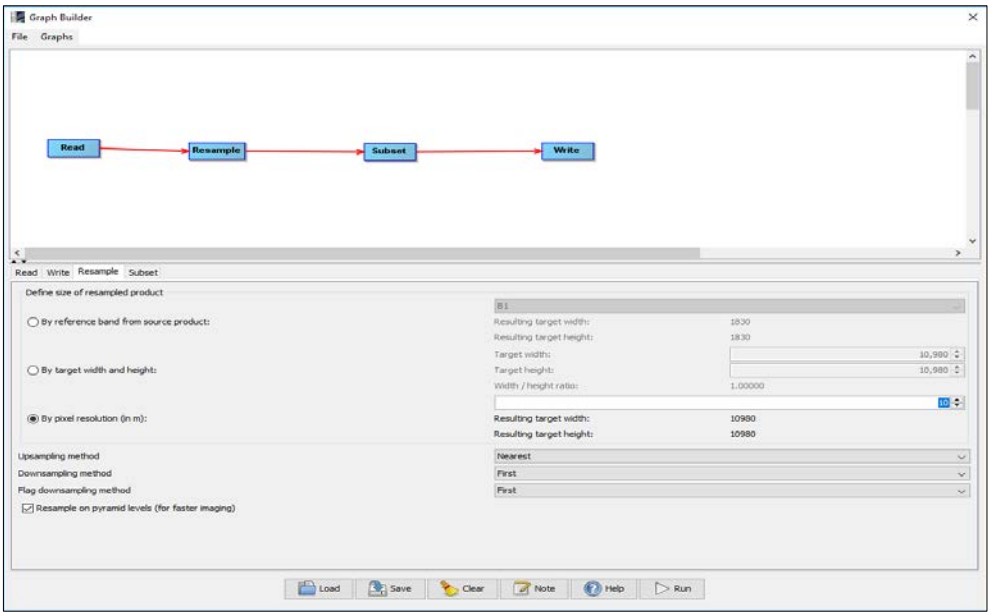
4. Pre-processing Graph Builder
   4.1. Select the product in "Product Explorer" window
   4.2. Select: 'Tools' / 'GraphBuilder' or the icon 
   4.3. In the GraphBuilder window we can start to build our graph clicking the right button of the mouse and add all the SNAP modules that we need.
   4.4. Resample Module: 'Add' / 'Raster' / 'Geometrics' / 'Resample'
   4.5. Subset Module: 'Add' / 'Raster' / 'Geometrics' / 'Subset'



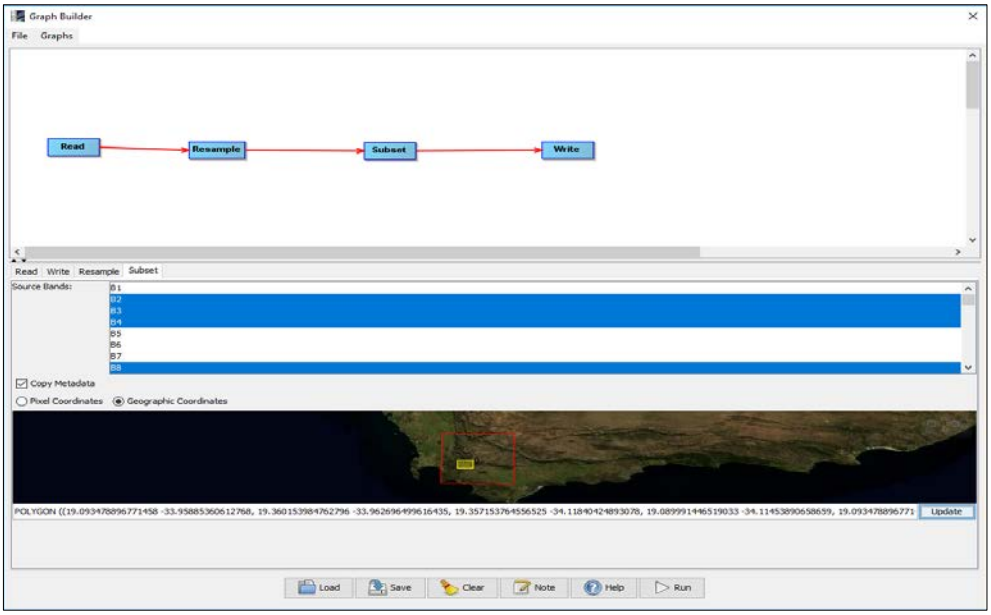
   4.6. Right click on the GraphBuilder window and select 'Connect Graph'
   4.7. Once that all the modules of the graph are connected we can set up the parameters as shown below



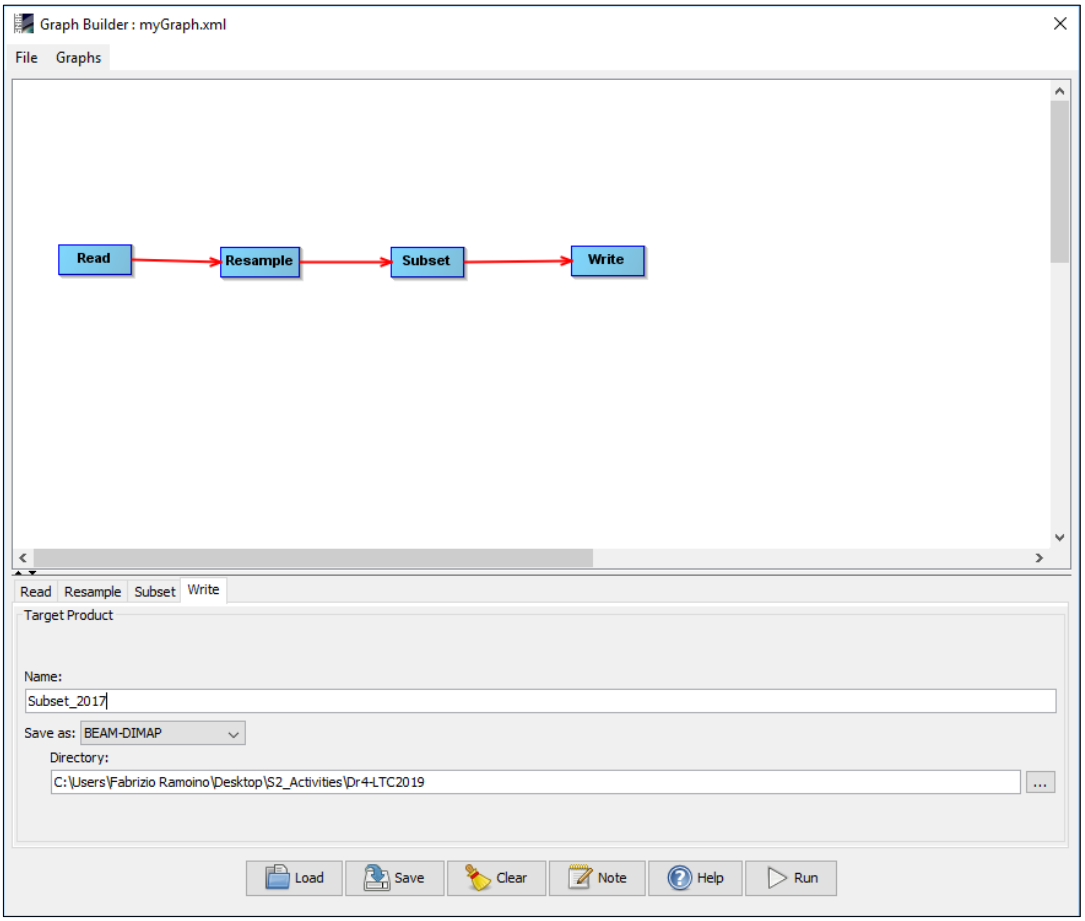
Reader: Select the product acquired on 2017.



Resample: Select the third option 'By pixel resolution (in m)' and specify 10.



Subset: From the Source Bands select B2, B3, B4, B8, B11 and B12. To crop spatially select 'Geographic Coordinates' option and copy and paste the polygon on the 'Waterskloof Dam Polygon.txt' file and click on 'update'.



Write: Rename the output to 'Subset_2017'

4.8. Click 'OK'

4.9. Repeat the process for the second product [2] changing the output name 'Subset_2018'

5. Open the newly created product
   5.1. Close all viewers
   5.2. Select image name in “Product Explorer” window
   5.3. Select: ‘Window’ / ‘Open RGB Image Window’
      5.3.1. Leave default natural colour combination and click ‘OK’
   5.4. Select: ‘Window’ / ‘Tile Horizontally’ and compare the images
   5.5. Synchronise views by selecting the relevant icons in the “Navigation” tab

6. NDWI-2 (Second Normalized Difference Water Index)

The second Normalized Difference Water Index algorithm was developed by McFeeters (1996) to detect surface waters in wetland environments and to allow for the measurement of surface water extent. The equation is similar to NDVI, except that it uses Green (B3) and the Near InfraRed (NIR) wavelengths.

$$NDWI2 = \frac{(Green - NIR)}{(Green + NIR)} = \frac{(B3 - B8)}{(B3 + B8)}$$

The NDWI-2 makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features. A high NDWI-2 value generally indicates presence of water. The water curve is characterised by a high absorption at near infrared wavelengths range and beyond. Because of this absorption property, water bodies as well as features containing water can easily be detected, located and delineated with remote sensing data.

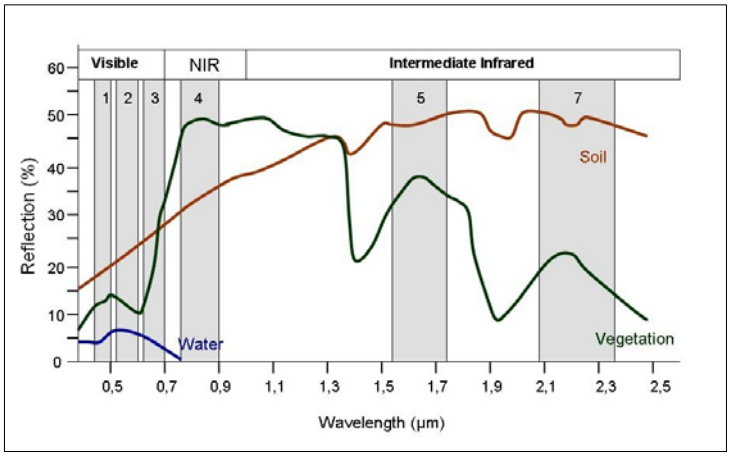
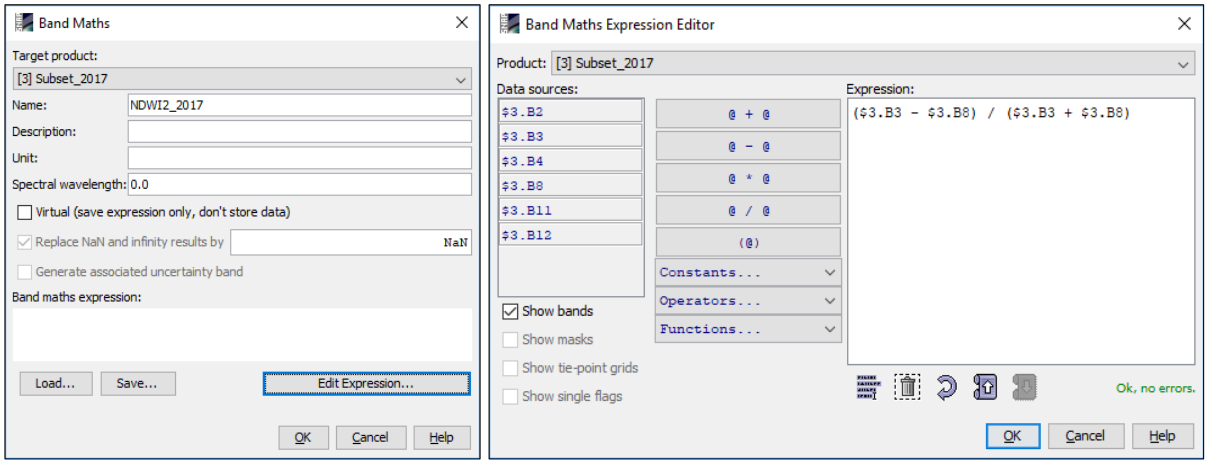


Image Source: Siegmund, Menz 2005 with modifications

6.1. Create New NDWI2 Band (based on band maths expression)
   6.1.1. Select: ‘Raster’ / ‘Band Maths…’
   6.1.2. Set up the I/O and the processing parameters as shown in the Figure below
   6.1.3. Change the output name in ‘NDWI2_2017’
   6.1.4. Deselect “Virtual”
   6.1.5. Select “Edit Expression…”
   6.1.6. Type the following expression in the ‘Expression’ field: “($3.B3 – $3.B8) / ($3.B3 + $3.B8)
      6.1.6.1. The symbol ‘$’ is the link to the product as displayed in the Product Explorer Window.

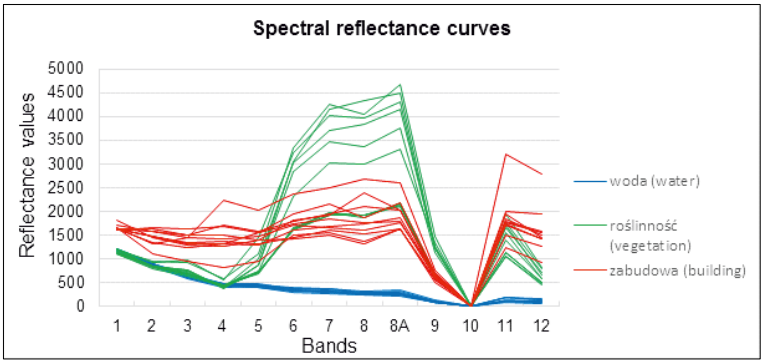


6.1.7. Click 'OK'

6.1.8. Repeat the process for the second product [4] changing the output name 'NDWI2_2018'

7. SWM (Sentinel Water Mask)

The Sentinel Water Mask algorithm was presented by Marta Milczarek during ESA Land Training Corse 2017 winning the best poster award in the category "Optical Remote Sensing". SWM provides quick and effective detection of water.



After analysis of spectral reflectance curves for water and other types of land cover (Figure above), two bands with the highest reflectance for water (Blue and Green) and two with the lowest one (NIR and SWIR) were selected and new index formula was developed:

$$SWM = \frac{(Blue + Green)}{(NIR + SWIR)} = \frac{(B2 + B3)}{(B8 + B11)}$$

7.1. Create New SWM Band (based on band maths expression)

7.1.1. Select: 'Raster' / 'Band Maths…'

7.1.2. Set up the I/O and the processing parameters as shown in the Figure below

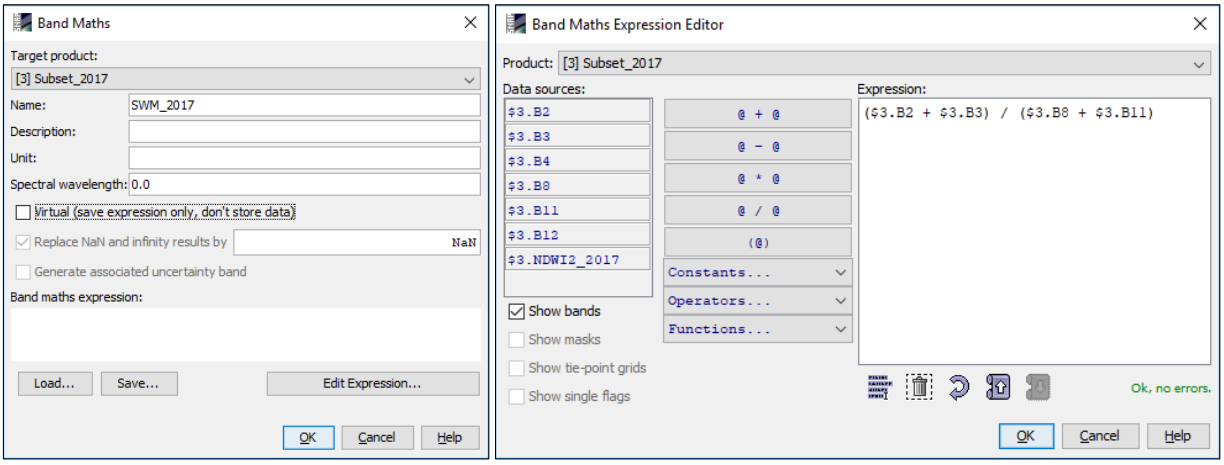
7.1.3. Change the output name in 'SWM_2017'

7.1.4. Deselect "Virtual"

7.1.5. Select "Edit Expression…"

7.1.6. Type the following expression in the 'Expression' field: "($3.B2 + $3.B3) / ($3.B8 + $3.B11)

7.1.6.1. The symbol '$' is the link to the product as displayed in the Product Explorer Window.



7.1.7. Click 'OK'

7.1.8. Repeat the process for the second product [4] changing the output name 'SWM_2018'

7.1.8.1. The symbol '$' is the link to the product as displayed in the Product Explorer Window.

8. <u>Create Water band based on NDWI2 and SWM</u>

8.1. Close all viewers

8.2. Select product in "Product Explorer" window

8.3. Select: 'Raster' / 'Band Maths…'

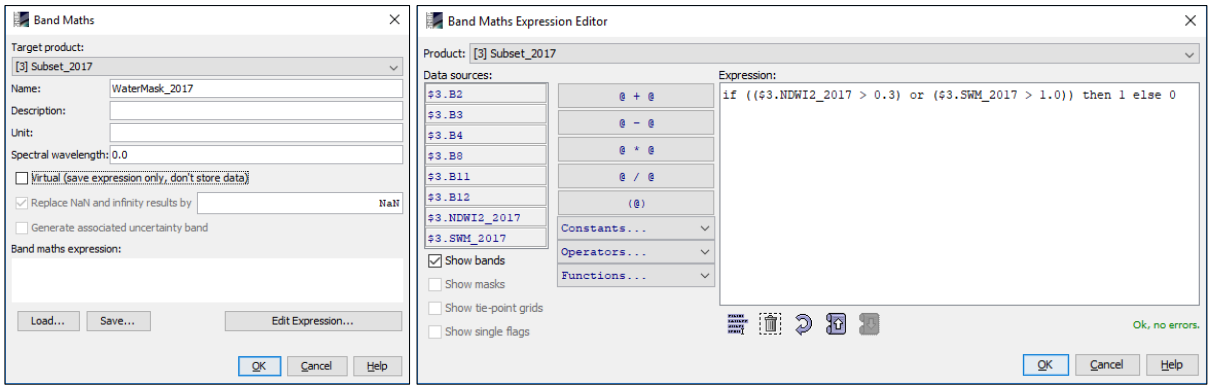
8.4. Set up the I/O and the processing parameters as shown in the Figure below

8.5. Change the output name in 'WaterMask_2017'

8.6. Deselect "Virtual"

8.7. Select "Edit Expression…"

8.8. Type the following expression: "if (($3.NDWI2_2017 > 0.3) or ($3.SWM_2017 > 1.0)) then 1 else 0"



8.9. Click 'OK'

8.10. Repeat the process for the second product [4] changing the output name 'WaterMask_2018'

8.10.1. The symbol '$' is the link to the product as displayed in the Product Explorer Window.

9. <u>Water Change detection</u>

9.1. Close all viewers

9.2. Select product in "Product Explorer" window

9.3. Select: 'Raster' / 'Band Maths…'

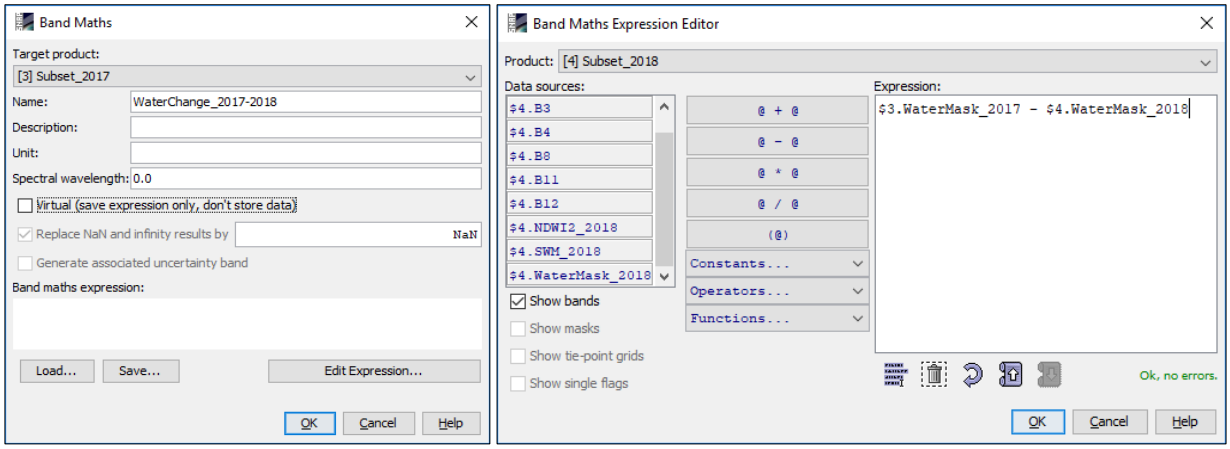
9.4. Set up the I/O and the processing parameters as shown in the Figure below

9.5. Change the output name in 'WaterChange'

9.6. Deselect "Virtual"

9.7. Select "Edit Expression…"

9.8. Type the following expression: "$3.WaterMask_2017 - $4.WaterMask_2018"



9.9. Click 'OK'
9.10. Open the newly generated product
9.11. Select: "Colour Manipulation" tab
9.12. [-1.0: Blue]; [0.0: White]; [1.0: Red]

The red pixels indicate water decreasing, the white ones represent no change in water level and the blue pixels are associated to an increasing of the water.