Earth Observation Data Analysis: Homework #3

Due on July 2016

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Contents

1. 2 Download a MSI/S2 image over Central Italy (Pescara river estuary, 42.46 N, 14.21 E) within the period 5-12 August 2016 and perform data quality check

The Aterno-Pescara is a river system in Abruzzo, eastern central Italy.

With the spectral bands of the satellite images from Sentinel-2, it is possible to quantify the concentration of chlorophill and torbidity of the water, meaning the existence of suspended sediments.

For this HW we're going to use the ESA RSS Cloud-toolbox facility to process the images in SNAP, courtesy of ESA/ESRIN team.

Figure 1: Pescara river estuary

3 Perform data quality check

- File name: "S2A_MSIL2A_20170411T100031_N0204_R122_T33TVH_20170411T100025" (MTD_MSIL2A.xml
- Platform: "SENTINEL-2"
- Start date: "11-APR-2017 10:00:31.026000"
- Stop date is: "11-APR-2017 10:00:31.026000"

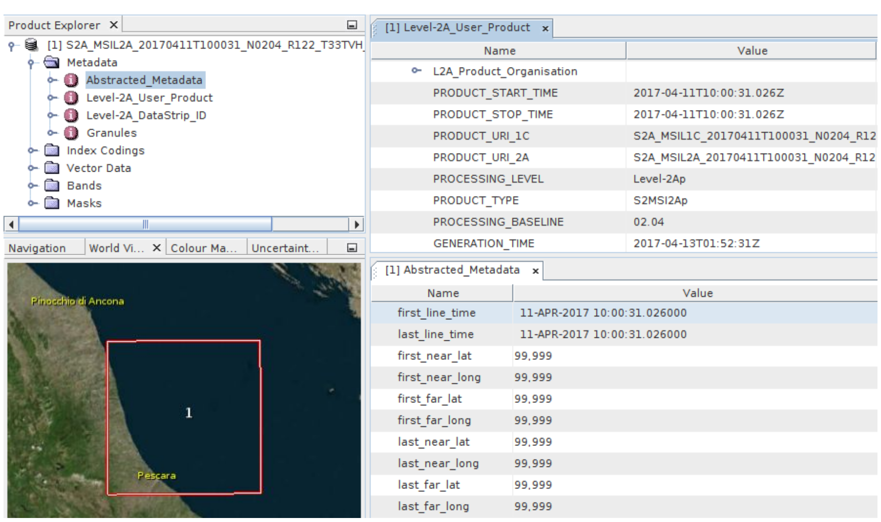


Figure 2: S2-L2 info

The sum of specifics bands in RED, BLUE and GREEN bands

0.620 nm - 0.670 nm (Red - R);
0.545 nm - 0.565 nm (Green - G);
0.459 nm - 0.479 nm (Blue - B).

allows to create an RGB composite image of our file stack using, in our case, the bands:

RED: B4 (665 nm)
GREEN: B3 (560 nm)
BLUE: B2 (490 nm)

Figure 3: S2-L2 composite RGB image

4. Apply atmospheric correction to image data if needed and compare the results with and without this correction

Our file is a Level-2A product, meaning that the main output is an orthoimage Bottom-Of-Atmosphere (BOA) corrected reflectance product so it doesn't need additional atmospheric corrections.

5. Select a ROI (Region of Interest) around the Pescara river estuary

The ROI around Pescara river estuary won't be computed with the conventional tool of SNAP but resampling the image and making a subset.

1. Resampling: the image needs first to be resampled because the bands have different spatial resolutions. In 'Raster - Geometric Operations - Resampling' we choose band "B2" as "reference band" (the best resoluted) and "Upsampling method - Bicubic" (showing the best results).

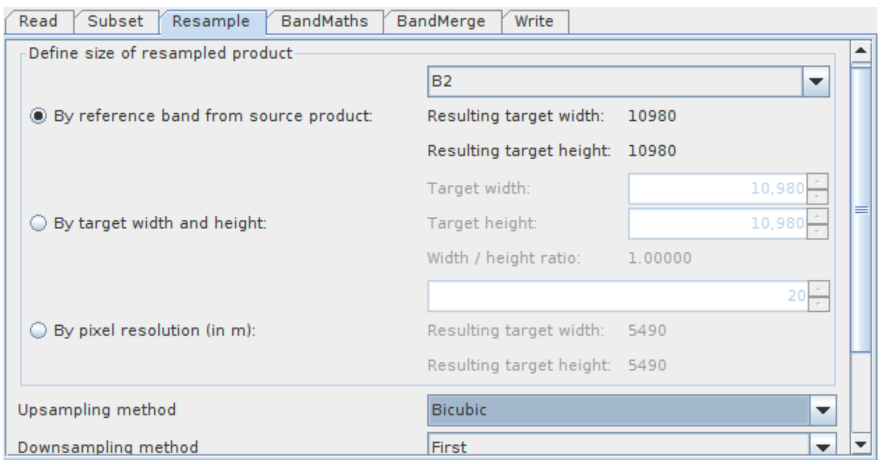


Figure 4: Resampling parameters

2. Subset: After resampling it is possible to make a subset, using all the bands as "Source Bands" and catching the desidered part of the image in "Geographic Coordinates".

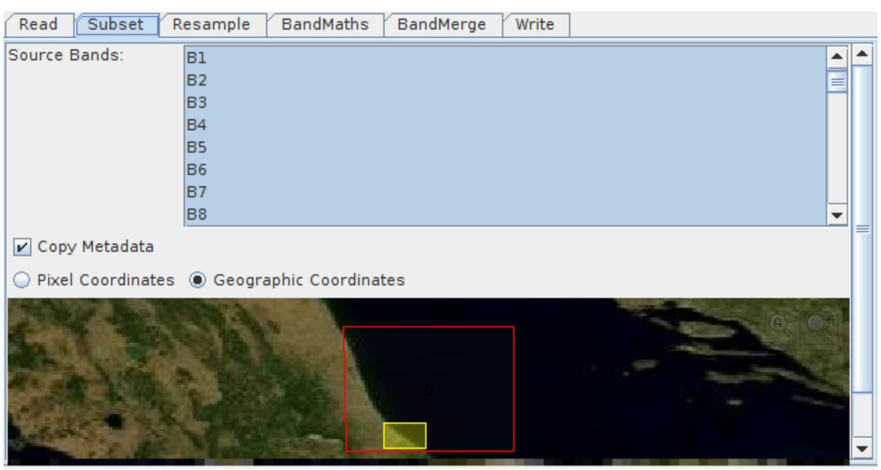


Figure 5: Subset parameters

The RGB of the resulting image:

Figure 6: ROI RGB of Pescara river estuary

6. Perform and display channel data correlation of selected ROI

Before implementing the correlation, It is useful to create a mask band to filter the useful information. We extract the 'scl_water' band from the folder 'Masks - Scl' and create a new band called 'water'.

In the rest of the project we'll use this band to mask the land and focus the results on the coast and the sea.

SNAP software includes a package for correlation between bands but it's not so intuitive (because of the insufficient documentation) so the correlation will be done with a programming interface that allows the manipulation of the images with Python.
The code below computes the image data processing:

```
import numpy as np  # Mathematical tool
import pandas as pd # Dataframe tool
import matplotlib.pyplot as plt # Data visualization tool
import seaborn as sns # Statistical data visualization tool
%matplotlib inline

# Image Subset path
subset = ProductIO.readProduct("/application/pi/Desktop/track1/Subset_S2A_MSI
L2A_20170411T100031_N0204_R122_T33TVH_20170411T100025BandMath_resampled.dim")

```

```
subset.getNumBands()  # Get the number of the bands
bands = [subset.getBandAt(i).getName() for i in
         range(subset.getNumBands())] # Create a list of the bands names
mybands = bands[1:12]  # Take bands we need (from 1 to 11)
mybands.append("water") # Add also the "water" mask
print mybands

raster_data = {} # Create a dictionary (band name:data) to insert the band data

for band in mybands: # For every (considered) band name, do:
    band_data = subset.getBand(band)  # Get the band data from the image with
                                    #that name
    w = band_data.getRasterWidth()  # Get the width
    h = band_data.getRasterHeight() # Get the height
    band_data_data = np.zeros(w * h, np.float32) # Create a matrix of
                                                  #zeros (n,m) = (width,height)
    band_data.readPixels(0, 0, w, h, band_data_data) # Read pixel values
    #band_data_data.shape = h, w        #optional, check indices of the matrix
    raster_data[band] = band_data_data # Insert the matrix in the dictionary


#print raster_data['B1']            # Ex. print band 1 values

bands_df = pd.DataFrame(raster_data) # Create a dataframe object with
                                    #the band matrices
mask = bands_df.water.isnull() == False # Fix NaN values of the water mask

correl=bands_df[mask].corr(method='pearson', min_periods=1) # Computer the
                        #correlation between the bands (Pearson method)

# Plot parameters
plt.rc("figure", figsize=(10, 8))
ax=sns.heatmap(correl, cmap='Reds', vmax=1.0, vmin=-1.0 , linewidths=2.5,
        annot=True)
plt.yticks(rotation=0)
plt.xticks(rotation=90)
#f,ax = plt.subplots(figsize=(11,9))
fig = ax.get_figure()
fig.savefig('correlation.png')
plt.show()
```

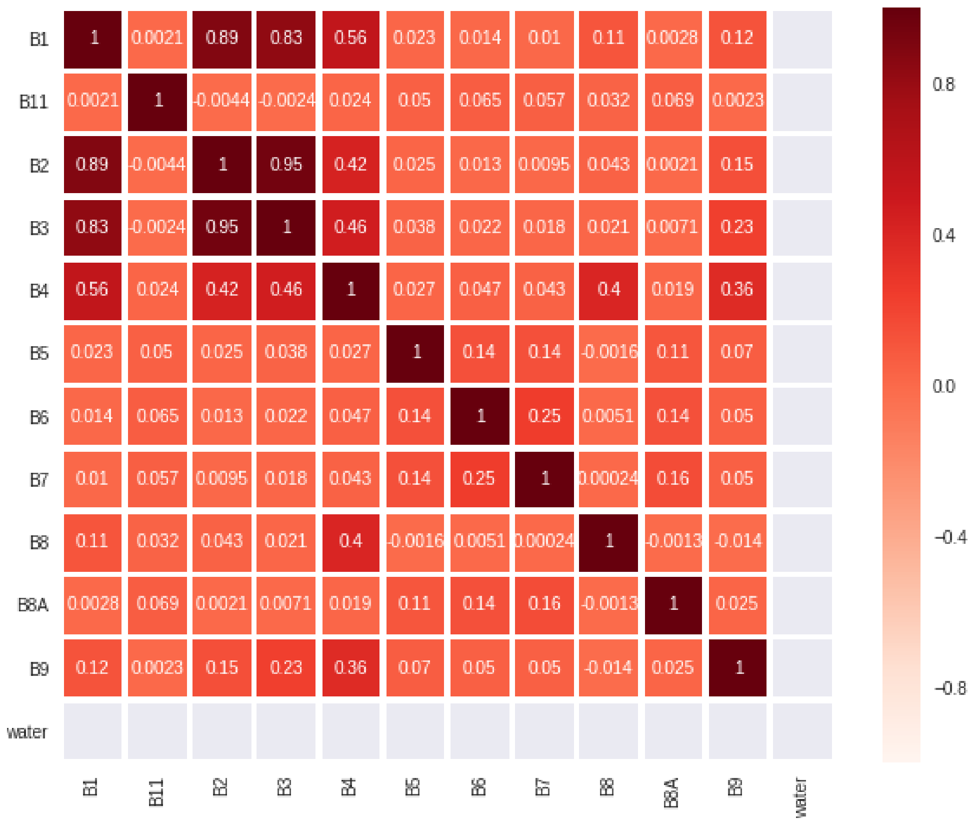


Figure 7: Correlation Plot (Pearson method)

7. Implement at least 3 regressive algorithms to estimate chlorophyll-a (Chl-a) using SNAP processing tool

The successful implemented algorithms to estimate chlorophyll-a (Chl-a) found for the project are the MCI and the NASA-GSFC algorithms.

1. **Maximum Chlorophill Index algorithm**

   The MCI is an algorithm already implemented in SNAP and it is used for satellite detection and monitoring of algal blooms and eutrophic, turbid, and oligotrophic waters. It is shown to be a versatile tool in monitoring intense surficial algal blooms with chlorophyll concentrations in the 10300 mg m 3 range.

   In 'Thematic Water Processing - S2 MCI Processor', choose as preset 'S2MSI L2 MSI'.

   B6: 740 nm

B4: 665 nm
B5: 705 nm

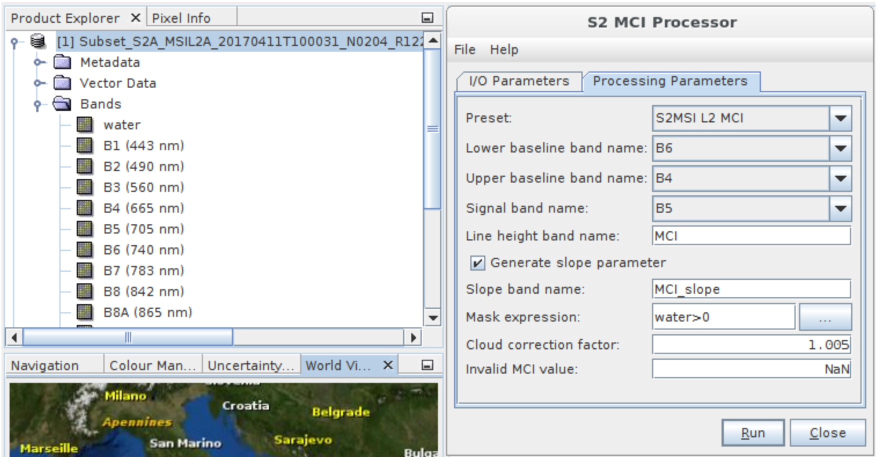


Figure 8: SNAP MCI Implementation

NB: 'Mask expression': water > 0

2. **NASA-GSFC algorithm**

The NASA-GSFC is an algorithm that returns the near-surface concentration of chlorophyll-a in mg/m3 and it is based on an empirical relationship derived from in situ measurements of chlorophyll-a and blue-to-green band ratios.

The algorithm is a fourth-order polynomial relationship between a ratio of Rrs and chlor_a

$$log_{10}(chrol\_a) = a_0 + \sum_{i=1}^{4} a_i log_{10}(\frac{Rrs(\lambda_{blue})}{Rrs(\lambda_{green})})^i \tag{1}$$

Where:

$Rs(\lambda_{blue})$: the greatest of several input values
a_0 - a_4: sensor specific coefficients

We use the SeaWIFS sensor parameters producing a band math algorithm:

```
0.2515 +
-2.3798 * log10(pow((max(B1,B2)/ B3),1)) +
1.5823 * log10(pow((max(B1,B2)/ B3),2)) +
-0.6372 * log10(pow((max(B1,B2)/ B3),3)) +
-0.5692 * log10(pow((max(B1,B2)/ B3),4))
```

NB: 'valid-pixel expression' adding: && $(water > 0)$

8. Apply the Chl-a retrieval algorithms around the Pescara river estuary and compare their results

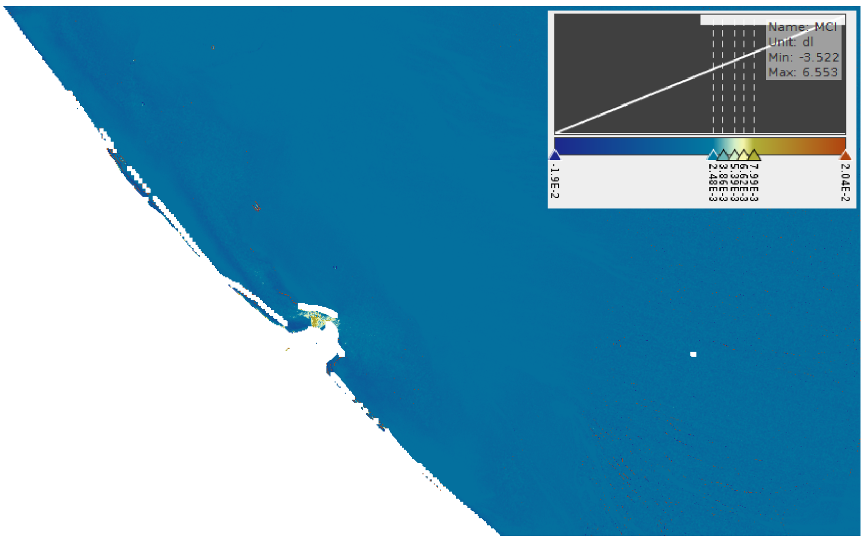


Figure 9: MCI Chl-a algorithm

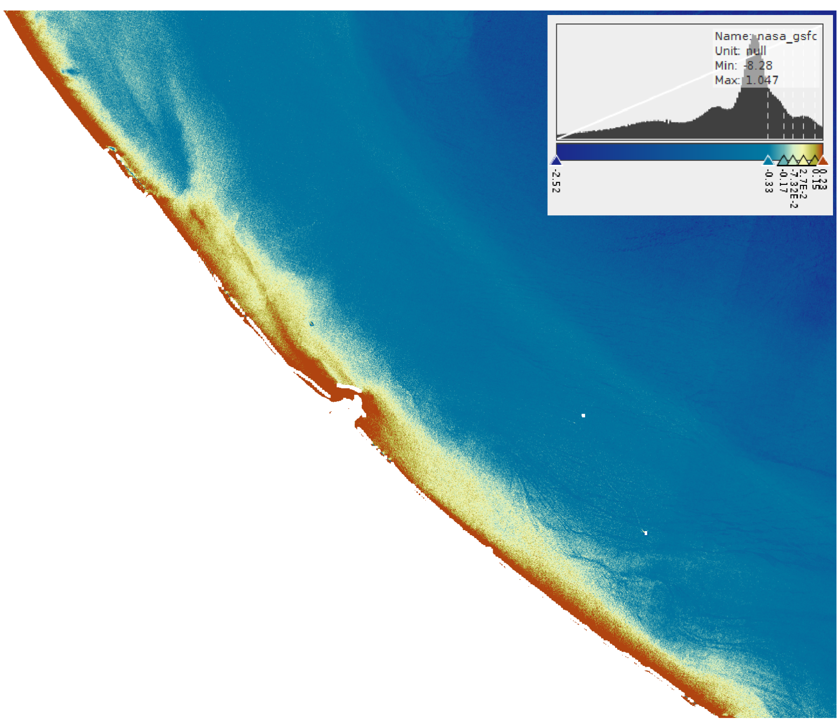


Figure 10: NASA-GSFC Chl-a retrieval algorithm

9. Implement at least 2 regressive algorithms to estimate total suspended sediments (TSS) using SNAP

Two algorithms were found to estimate the turbidity of the water, Total Suspended Sediment and Suspended Particular Matter.

1. **Total Suspended Sediment**

   It is a linear relation described by the formula:

   $$TSS = 48.35 * X - 25.04 \tag{2}$$

   Where: X = (555+620)/(555+490)

   Bands 555 and 620 are substituted with the closest available ones: 560nm (B3) and 665nm (B4).

   Band math algorithm:

   ```
   48.35 * ((B3-B4)/(B3-B2)) - 25.04
   ```

   NB: 'valid-pixel expression' adding: && $(water > 0)$

   More informations at: `https://ijer.ut.ac.ir/article_665_7705af8d4ac67ad12303a7468d2f72ff.pdf`

2. **Suspended Particular Matter**

   The SPM algorithm is expressed by the formula:

   $$SPM = \frac{A\rho_w}{1 - \frac{\rho_w}{C}} \tag{3}$$

   Where:

   ρ_w: 665nm band
   A: 289.29gm $\hat{}$3
   C: 0.1686

   Band math algorithm:

   ```
   (289.29 * B4)/(1 - B4/0.1641)
   ```

   NB: 'valid-pixel expression' adding: && $(water > 0)$

   More informations at: `http://www.sciencedirect.com/science/article/pii/S0034425714000224`

10. Apply the TSS retrieval algorithms around the Pescara river estuary and compare their results

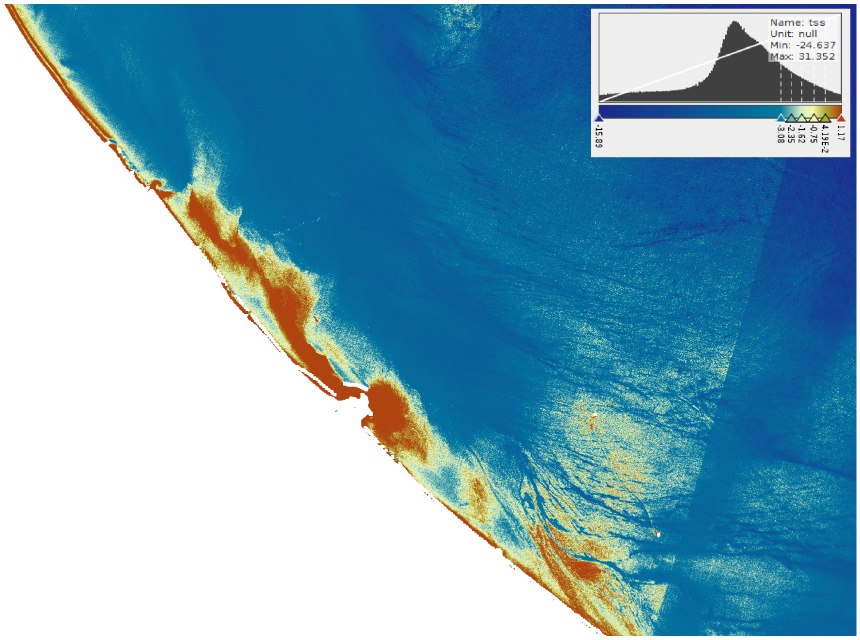


Figure 11: Total Suspended Sediments retrieval algorithm

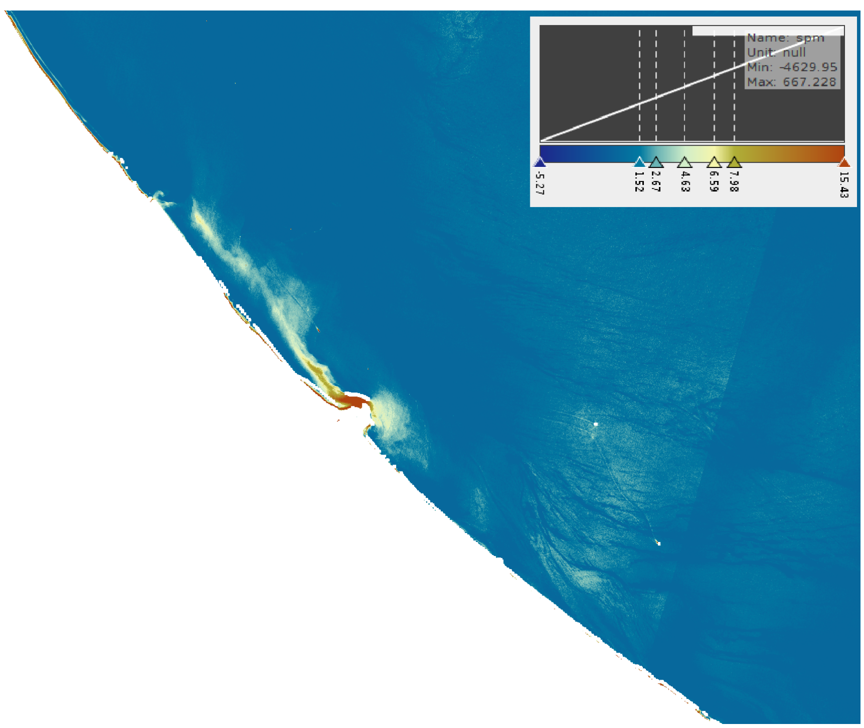


Figure 12: Suspended particular matter retrieval algorithm

11. 12. 13. 14. Download all MSI/S2 images over Central Italy (Pescara river estuary, 42.46 N, 14.21 E) within a certain period from https://scihub.copernicus.eu and apply the chosen Chl-a and TSS retrieval algorithm to MSI image time series

First access to the satellite images from Copernicus site `https://scihub.copernicus.eu`. Parameters can be set to retrieve the appropriate products:

- Mission: Sentinel-2
- Product type: S2MSI2Ap
- Sensing period: 01-05-17 / 31-07-17
- Ingestion period: 01-05-17 / 31-07-17
- Targeting area: Pescara river estuary

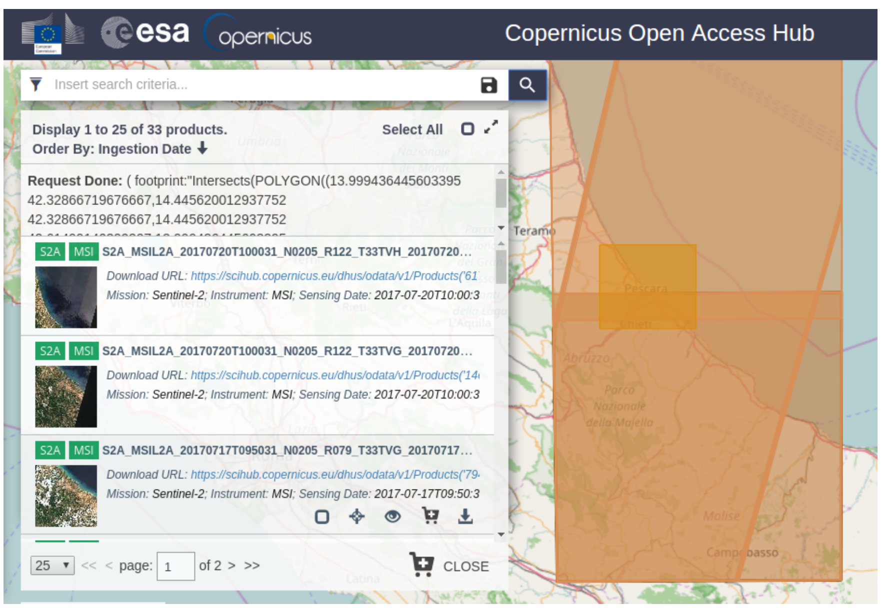


Figure 13: Copernicus

All the computations described in the previous points can be made in one-shot, for every image, with the graph builder tool.

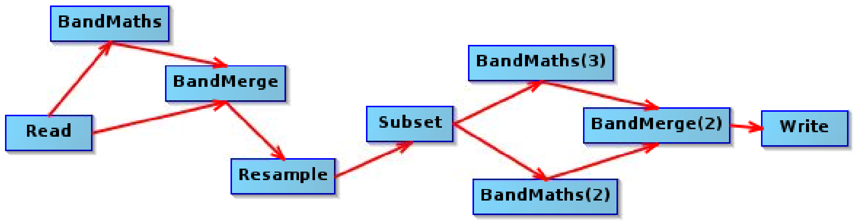


Figure 14: Graph Builder

Where:

- Read: load the source product
- BandMaths: create the water mask
- BandMerge: merge the water mask in source product
- Resample: resize all the bands to the band B2
- Subset: select the ROI of Pescara river estuary
- BandMaths(2): implement NASA-GSFC algorithm
- BandMaths(3): implement SPM algorithm
- BandMerge(2): merge the algorithms in a product
- Write: write the final product

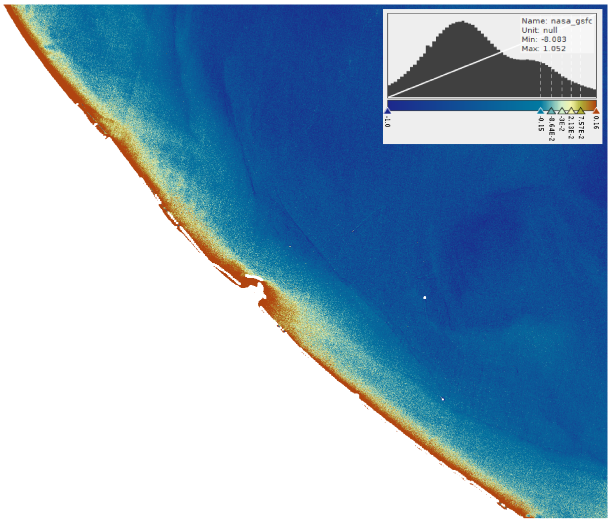
NB: graph builder tool doesn't provide the 'valid-pixel expression' choice (to mask the water) so the two algorithms are modified in this way:

- NASA-GSFC algorithm:

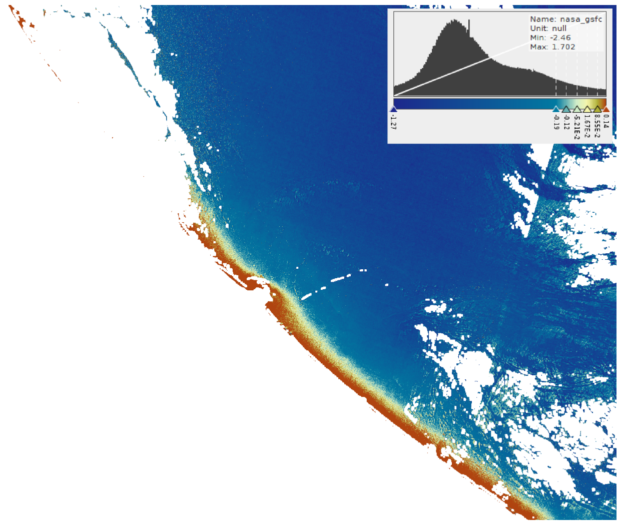
```
if water>0 then
( 0.2515 -2.3798 * log10(pow((max(B1,B2)/ B3),1)) +
1.5823 * log10(pow((max(B1,B2)/ B3),2)) +
-0.6372 * log10(pow((max(B1,B2)/ B3),3)) +
-0.5692 * log10(pow((max(B1,B2)/ B3),4)) )  else  NaN
```

- SPM algorithm:

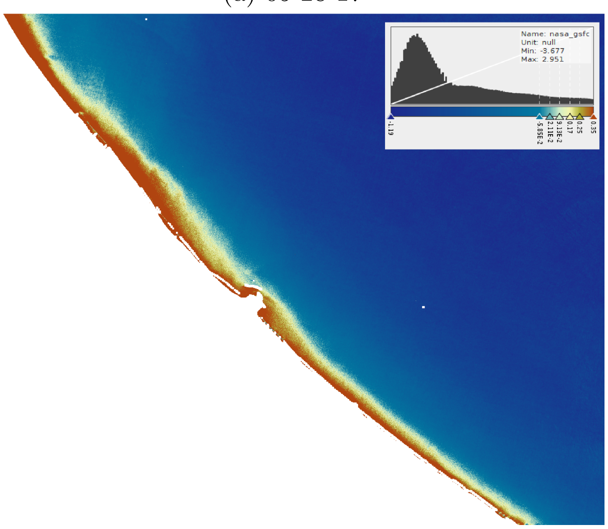
```
if water>0 then ( (289.29 * B4)/(1 - B4/0.1641) ) else NaN
```



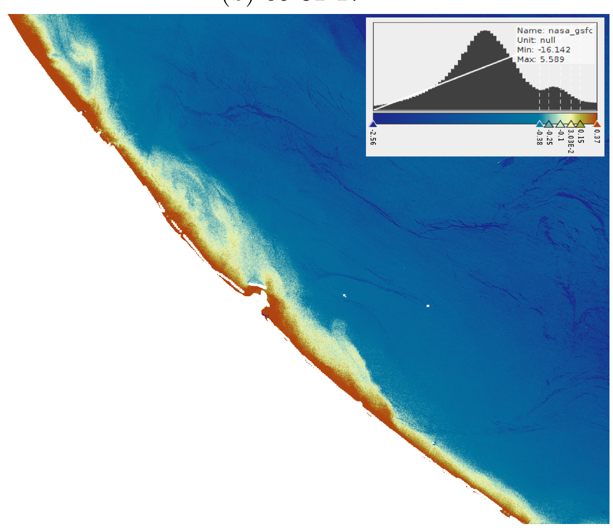
(a) 05-28-17



(b) 05-31-17

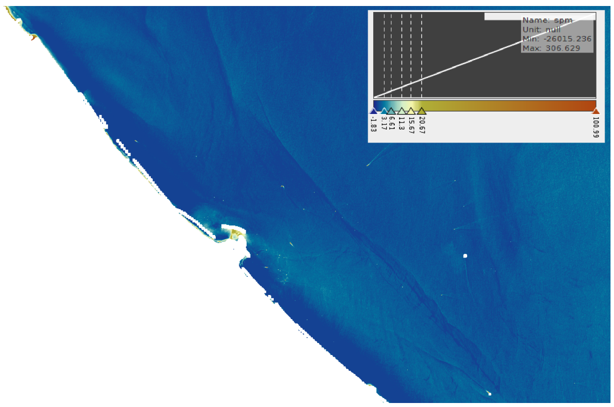


(c) 06-07-17

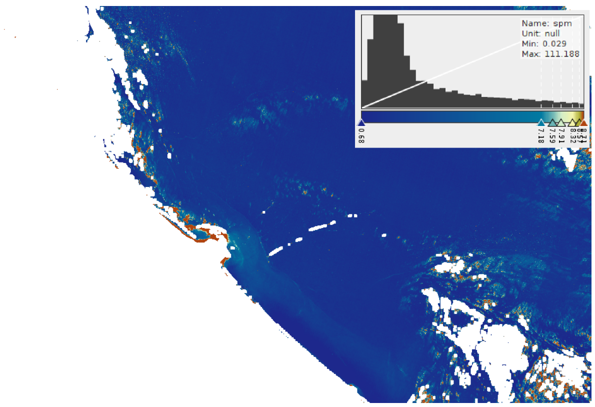


(d) 07-07-17

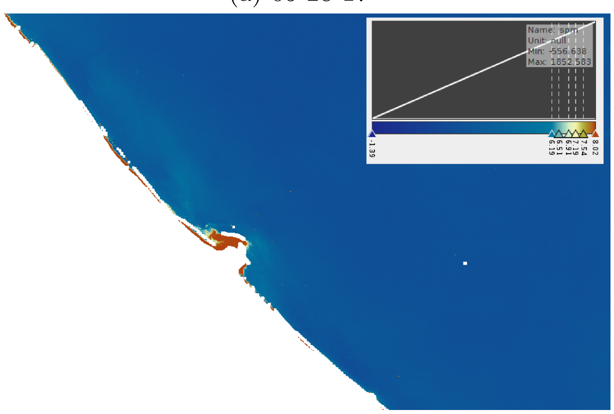
Figure 15: NASA-GSFC time series algorithm



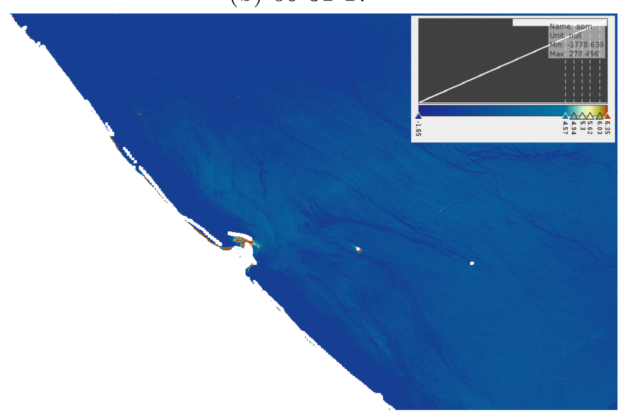
(a) 05-28-17



(b) 05-31-17



(c) 06-07-17



(d) 07-07-17

Figure 16: SPM time series algorithm

Annotations and Bugs

There is a faster way, not only to compute all the operations, but to compute also all the images in one-shot with the Batch Processing.

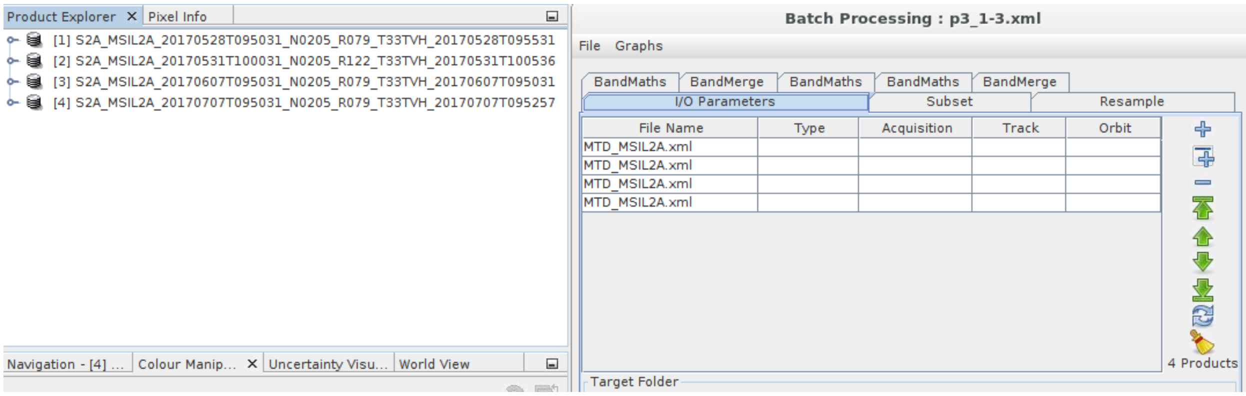


Figure 17: Batch Processing configuration

Unfortunately the images have the same names in their respective folders and can't be changed without producing an importing error in SNAP. If we try instead to process them with their original name, SNAP overwrites them as they were the same image (the first or the last one).

Extra

In 1898 Nikola Tesla was the first, in the history of mankind, to show the first scientific usage of electromagnetic signals.

His invention consisted of an indoor pool, a 4-foot-long miniature ship and a control box equipped with various lever.

The deck of the ship was studded with antennae for receiving signals, with the tallest located in the center and two others topped with small light bulbs. The lights would help an operator gauge the position and direction of the vessel in the cover of darkness. Its motion was driven by a screw propeller, with a keel and rudder situated in the standard positions for a nautical vessel. Inside the boat's hull, there was an electric motor driving both the propeller and rudder, a storage battery and a mechanism for receiving the radio signals sent from the control box.

Figure 18: Nikola Tesla Museum, Belgrade, Serbia

Without the limits of a wired connection between the controls and the remote device, Tesla's invention would allow operators to effect changes in speed and direction, and control on-board gadgets (such as lights or moving parts), even from a moving vehicle.

Some people watching his invention couldn't believe it and claimed that there was someone below moving the boat or that he was controlling it with the power of his mind.

Have a good summer!

Alessandro Gallo