



Common borders. Common solutions.

Chlorophyll Calculation through Satellite Images

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HELLAS



Eutrophication

Eutrophication is the increase in the rate of the supply of organic matter to an ecosystem, which is related to nutrient enrichment in the primary production in the system. Eutrophication processes:

- contribute to an accelerated algal bloom and higher forms of plant life that produce an undesirable disturbance of the equilibrium of the organisms present in the water
- may affect benthic primary producers through increases in water column light attenuation and depleted oxygen concentration at the bottom
- deterioration of the water quality, harmful algal blooms, fish kills, reduction of essential fish habitats



Why we measure chlorophyll-a

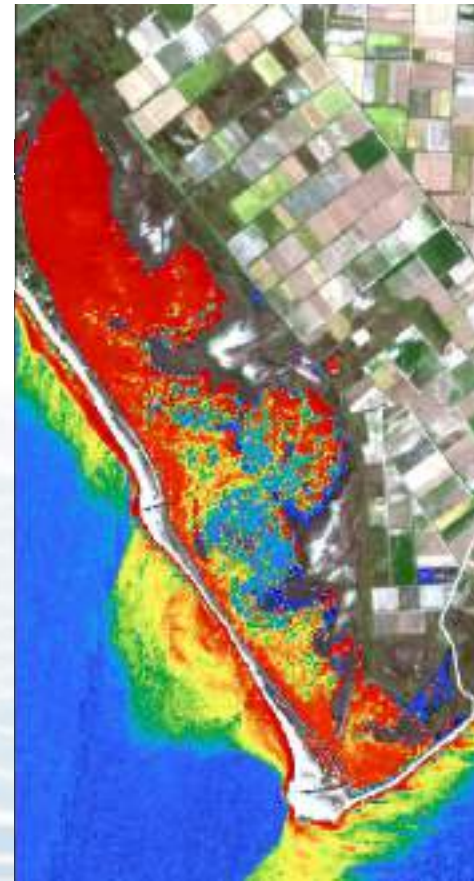
- The photosynthetic pigment Chl-a is a key indicator of phytoplankton biomass. Thus, the estimation of Chl-a concentration is essential for monitoring of water quality
- Phytoplankton is the group of organisms responding first to nutrient enrichment, with an excessive growth
- The increase in phytoplankton reflects symptomatic signs of alteration in both the nutrient cycles and the structure of the trophic network, both related to eutrophication
- **The biomass of phytoplankton, represented by chlorophyll-a, is an important indicator to evaluate the state of eutrophication of water bodies**



Why remote sensing monitoring is important

- Coastal systems and lakes provide key ecosystem services, such as human welfare and wellbeing, climate, water and natural hazard regulation, primary production, biotic diversity, habitat and food for bivalves, crustaceans, fish and birds, erosion prevention and wild life refuge
- There is a high need for monitoring water quality
- Frequent in-situ monitoring is limited and requires a lot of effort and funding
- Satellite remote sensing is a feasible way to monitor water quality over large regions with reasonable frequency

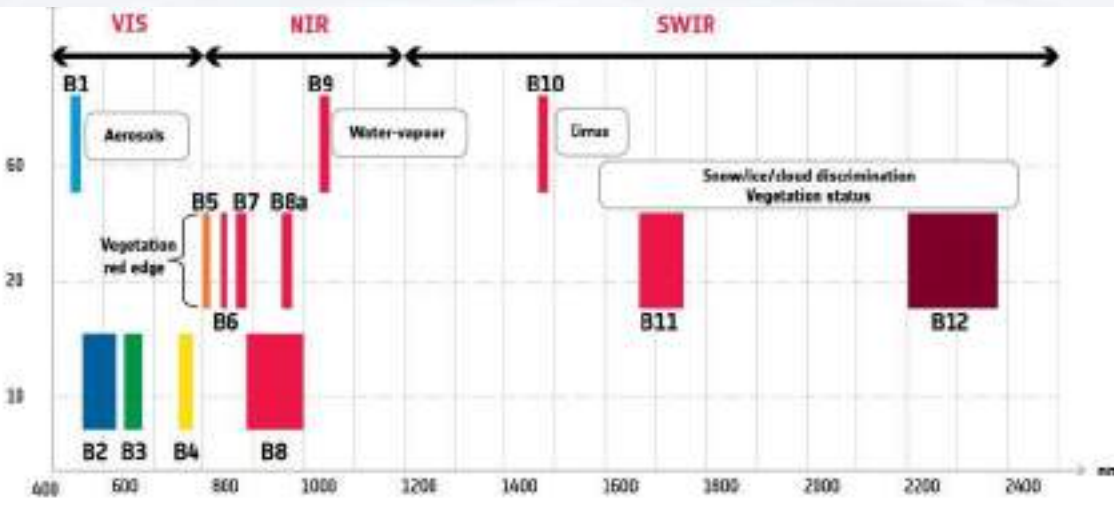
How we measure chlorophyll-a



Satellites used in remote sensing

Time period: 2015 – 2021

- **Sentinel 2A and 2B:** polar orbit, phased at 180° to each other
- Equipped with multispectral instrument (MSI) with 13 spectral bands
- Wide swath width (290 km)
- Revisit: 5 days at equator (2 satellites)
- Level 1C and 2A (atmospherically corrected)



Atmospheric Bands

Red edge and shortwave infrared Bands

Visible and Near-infrared Bands



Satellites used in remote sensing

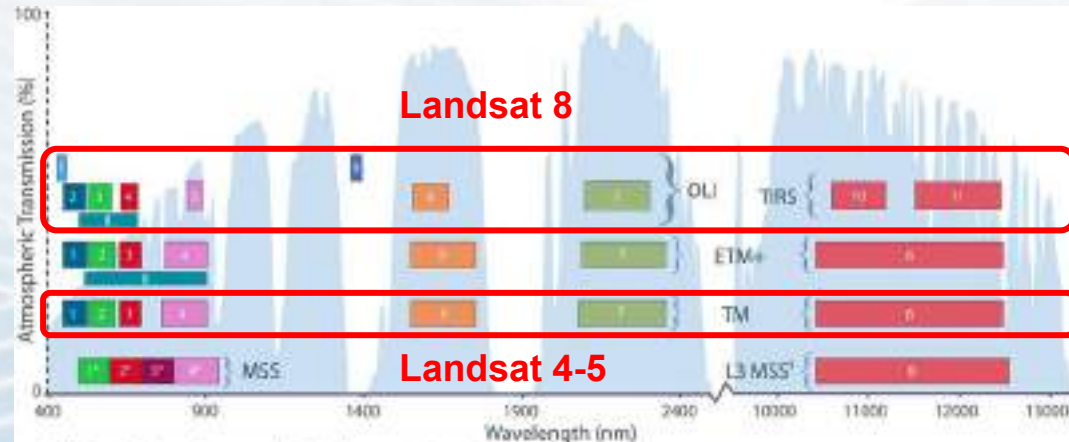
Time period: 2009-2011

- **Landsat 4-5 TM**
- Equipped with Thematic Mapper (TM) sensor with 6 spectral bands and 1 thermal infrared band
- Revisit: 16 days



Time period: 2013-2015

- **Landsat 8**
- Equipped with Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) with 9 spectral bands
- Revisit: 5 days



*MSS bands 1-4 were known as bands 4-7, respectively, on Landsats 1-3

† The 240 m thermal band on Landsat 3 was out of spec within three weeks of launch and turned off in March 1979

How to access Satellite Images Copernicus Open Access Hub



Copernicus Open Access Hub

<https://scihub.copernicus.eu/dhus/>

Basic Steps to retrieve satellite image

1. Select the Area of Interest
2. Define Sensing Period
3. Select Satellite Platform
4. Select Product Type
5. Define Cloud Cover

Copernicus Open Access Hub

The screenshot displays the Copernicus Open Access Hub interface. At the top, the ESA logo and 'Copernicus' text are visible. Below the search bar, a list of products is shown, including details like 'Request Date' and 'Download URL'. A map on the right shows a satellite coverage area over a region, with a yellow box highlighting a specific area. Red arrows point to the 'Add to Cart', 'Download', and 'Quicklook' icons in the product list. A text box at the bottom right states 'Satellite is not covering the whole area'.

Display 1 to 13 of 13 products.
Order By: Ingestion Date ↓

Request Date: 1 footprints, 1 footprints (POLYGOON) [24.28.5595359479008
40.70675900-1964.19.25.230342030021704 40.70675900-1964.19.25.230342030021704
41.17620202691150.24.296693308479008 41.17620202691150.24.296693308479008

Quicklook Add to Cart Download

Satellite is not covering the whole area

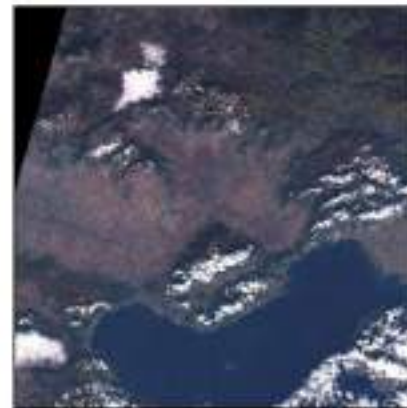


Copernicus Open Access Hub

Footprint



Quicklook



Copernicus Open Access Hub

<https://sentinelat.readthedocs.io/en/stable/>

```
from sentinelat import SentinelAPI, read_geojson, geojson_to_wkt
from datetime import date

api = SentinelAPI('user', 'password', 'https://scihub.copernicus.eu/dhus')

# search by polygon (WKT format), time, and SciHub query keywords
footprint = geojson_to_wkt(read_geojson('/path/to/map.geojson'))

products = api.query(footprint,
                    date = ('20151219', date(2015, 12, 29)),
                    order_by = 'ingestiondate',
                    orbitdirection: 'DESCENDING',
                    platformname = 'Sentinel-2',
                    producttype = 'S2MSI1C',
                    cloudcoverpercentage = (0, 20))

# download all results from the search
api.download_all(products)

# GeoJSON FeatureCollection containing footprints and metadata of the scenes
api.to_geojson(products)
```


How to access Satellite Images Earth Explorer



Earth Explorer

<https://earthexplorer.usgs.gov/>



The screenshot shows the Earth Explorer web application. On the left, there is a sidebar with search criteria options. The main area displays a satellite map of a region with a search criteria summary overlay. The overlay lists five steps for retrieving a satellite image.

1. Enter Search Criteria

To enter your search area, type in an address or place name, enter coordinates or click the map to define your search area. The address map view, use the map documentation, and/or [USGS 100m \(img\)](#).

Select a Geospatial Method
Feature (2/5)

Search Limits the search result limits. Add words, and a Country Feature Class, and/or Feature Type to refine your search of ascending file and [View Features](#).

Feature Name
Country (as address)
State
Feature Type

Buttons: Done, Download Data, Download Data, No coordinates selected, Add Map, Add Coordinates, Clear Coordinates, Add Range, Show Date, Show Status, Search from: 1/1/2010 to 1/1/2010, Search results: 0

Search Criteria Summary

Basic Steps to retrieve satellite image

1. Select the Area of Interest
2. Define Sensing Period
3. Select Satellite Platform
4. Select Product Type
5. Define Cloud Cover



Earth Explorer

The screenshot shows the USGS Earth Explorer interface. At the top left is the USGS logo with the tagline "science for a changing world". Below it, the text "Earth Explorer" and "Manage Criteria" are visible. On the right side of the top navigation bar, there are links for "New Dashboard", "Help", "Feedback", and "Log out".

The main content area is titled "2. Select Your Data Set(s)". Below this title, there is a paragraph of instructions: "Check the boxes for the data sets you want to search. You can use multiple data sets. Use the Additional Criteria at the end of the list below. Click the check box next to the map to show a 3D view of the data." Below the instructions, there is a checkbox labeled "Use Data Set Metadata" and a "Show/Hide" button.

A list of data sets is displayed on the left side, each with a checkbox and a name: "Water Quality", "Landsat", "3000 Legacy", "Commercial Satellites", "Encore/Net Data", "Digital Elevation", "Digital Line Graphs", "Digital Maps", "E-Data", "Global Firewatch", "ACORN", "DODV", "Land Cover", "Land Use", "LDBP", "NARS (FWS) Collections", "Water", "Soils", "Vegetation/Canopy", and "USGS National". The "Soils" and "Additional Criteria" buttons are highlighted with red boxes.

At the bottom of the list, there are three buttons: "Clear All Criteria", "Additional Criteria", and "Apply".

The right side of the interface features a large satellite map of a region, likely the Colorado Plateau, with a search criteria summary box at the top right and a "Clear Search Criteria" button. A "3D" button is also visible in the top left corner of the map area.



Earth Explorer

The screenshot displays the USGS Earth Explorer interface. The top navigation bar includes the USGS logo and the text "USGS science for a changing world". Below this, the "Earth Explorer" title and "Manage Criteria" link are visible. The main content area is titled "3. Additional Criteria (Optional)" and contains a dropdown menu for "Land Cover". The dropdown menu is open, showing a list of options: "All", "Less than 10%", "Less than 20%", "Less than 30%", "Less than 40%", "Less than 50%", "Less than 60%", "Less than 70%", "Less than 80%", "Less than 90%", and "Less than 100%". A red box highlights this dropdown menu. Another red box highlights the "Apply" button at the bottom of the criteria list. The background of the interface shows a satellite map of a region, likely the Mediterranean area, with various geographical features and labels. The bottom of the page features a dark blue footer with logos for the European Union and the U.S. Department of the Interior, along with navigation links and a small portrait of a man in the bottom right corner.



Earth Explorer

The screenshot shows the USGS Earth Explorer interface. At the top left is the USGS logo with the tagline "science for a changing world". Below it, the text "Earth Explorer" and "Manage Criteria" is visible. On the right side of the top bar, there are links for "Home", "Help", "Feedback", and "Log out (username@domain)".

The main content area is divided into a left sidebar and a main map area. The sidebar contains a "Search Criteria Summary" section and a "4 Search Results" section. The first result is highlighted with a red box. Red arrows point from text labels to specific elements in this box: "Image Footprint" points to a small thumbnail image, "Download" points to a download icon, "Metadata" points to a document icon, and "Add to Cart" points to a cart icon.

The main map area displays a satellite image of a coastal region with a grid overlay. A search criteria summary box is visible in the top right corner of the map area, showing coordinates and a "Clear" button.

At the bottom of the page, there is a footer with links for "USA Privacy Policy", "Legal", "Accessibility", "Site Map", and "Contact USGS". Below that, it says "U.S. Department of the Interior | U.S. Geological Survey | White House | Congress | Buy U.S. Savings Bonds | FEMA".

Image Footprint

Download

Metadata

Add to Cart



Sentinel filename scheme

S2A_MSIL1C_20200729T090601_N0209_R050_T35TKF_20200729T112307.SAFE

mission ID

Product
Level

sensing
start time

PDGS Processing
Baseline number

Relative Orbit
number

Tile Number
field

Product
Discriminator

Identifies a **Level-1C** product acquired by **Sentinel-2A** on the **29th of July, 2020 at 9:06:01 AM**. It was acquired over **Tile 35TKF** during **Relative Orbit 050**, and processed with **PDGS Processing Baseline 02.09**.

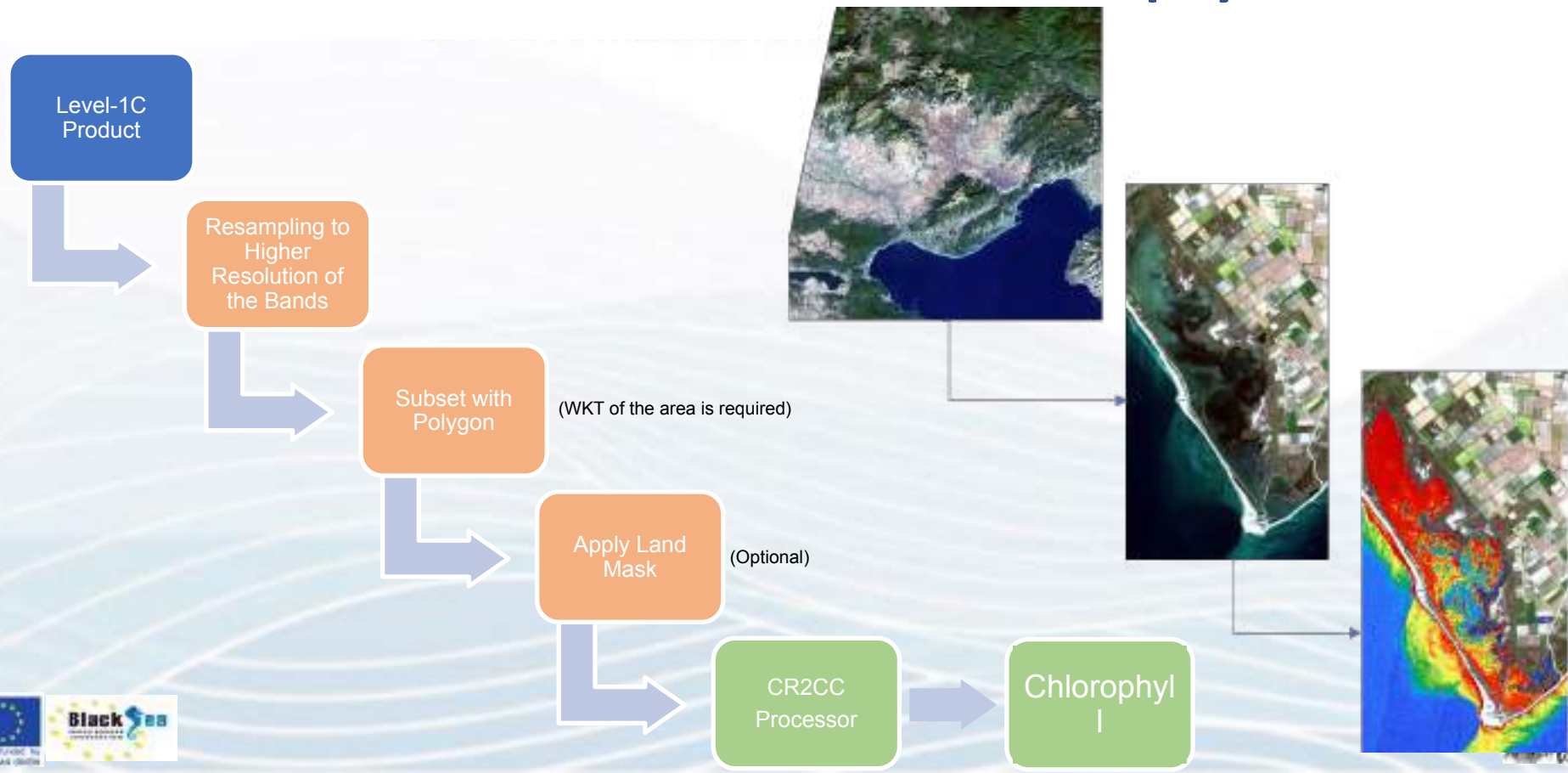
- All the bands included in the file are in JPEG2000 format.
- In addition, a “**True Colour Image**” in JPEG2000 format is included within the Tile folder of Level-1C products in this format and a **manifest** xml file that tells the computer what is inside the file.



Calculate Chlorophyll from Sentinel-2 and Landsat 8 Images



Sentinel 2 and Landsat 8 Products to Chlorophyll



C2RCC Processor

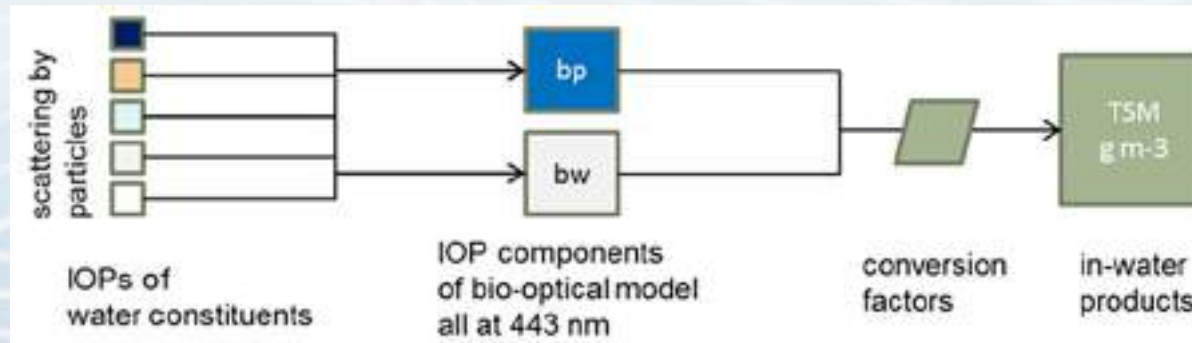
The Case-2 Regional CoastColour (C2RCC) processor **relies on a large database of simulated water leaving reflectances**, and related **top-of atmosphere radiances**.

Neural networks are trained in order to perform:

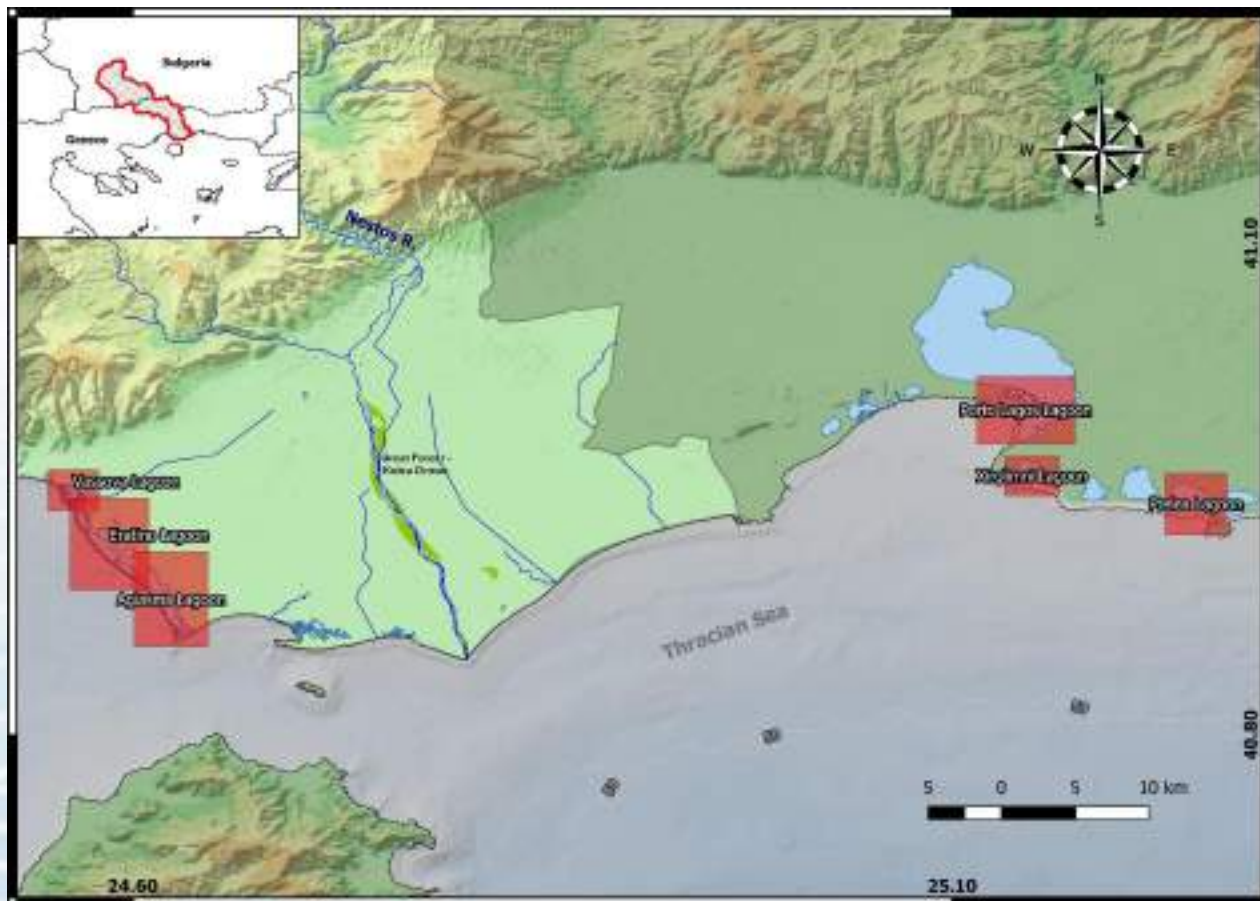
- the **determination of the water leaving radiance** from the top of atmosphere radiances, as well as
- the **retrieval of inherent optical properties (IOP)** of the water body.

The **conversion from IOPs to concentration** is done using **scaling factors**.

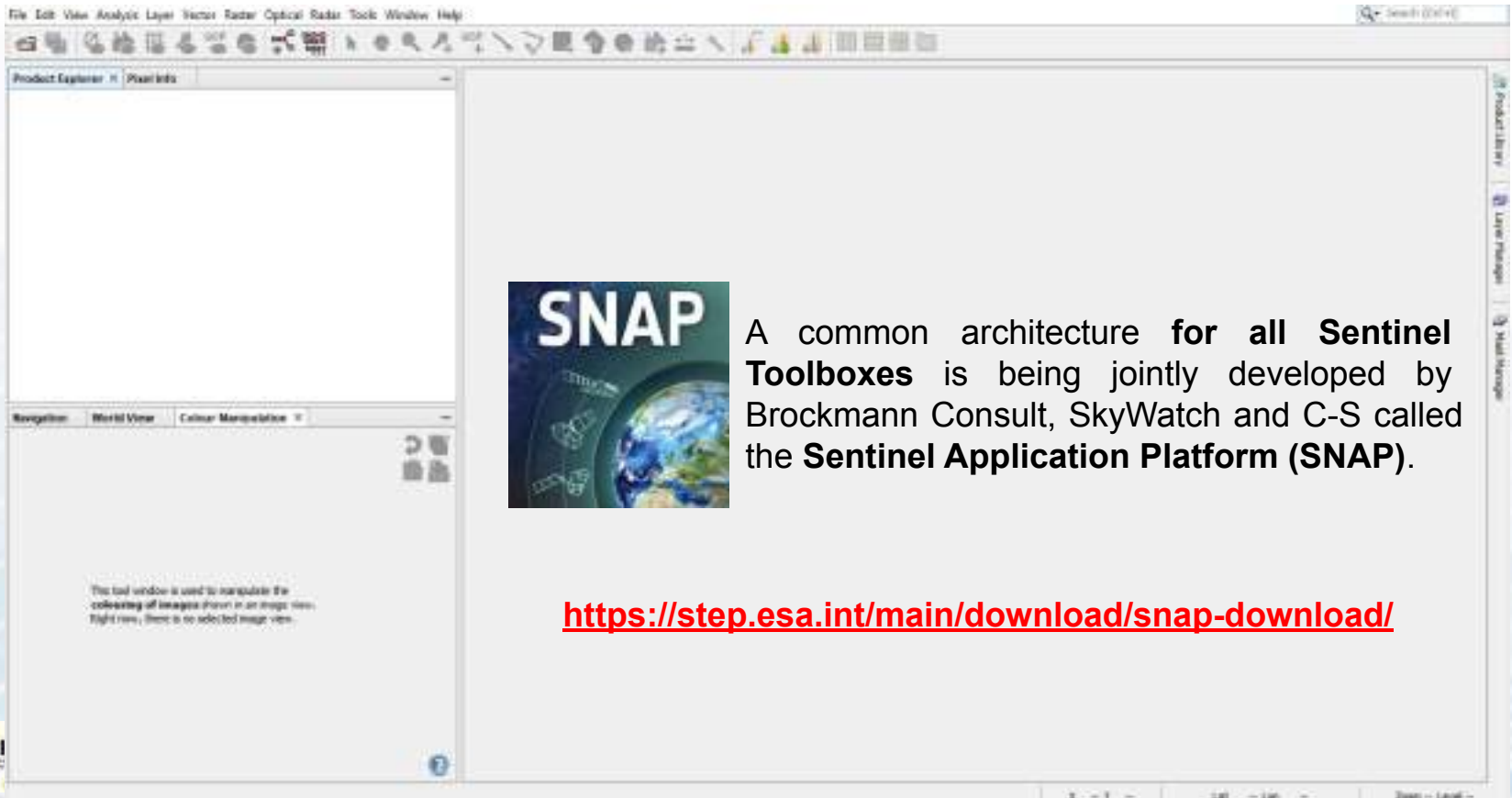
CR2CC is capable of processing data from **Sentinels-2 and 3, MERIS, VIIRS, MODIS, and Landsat-8**.



Test Site



Sentinel Application Platform (SNAP)

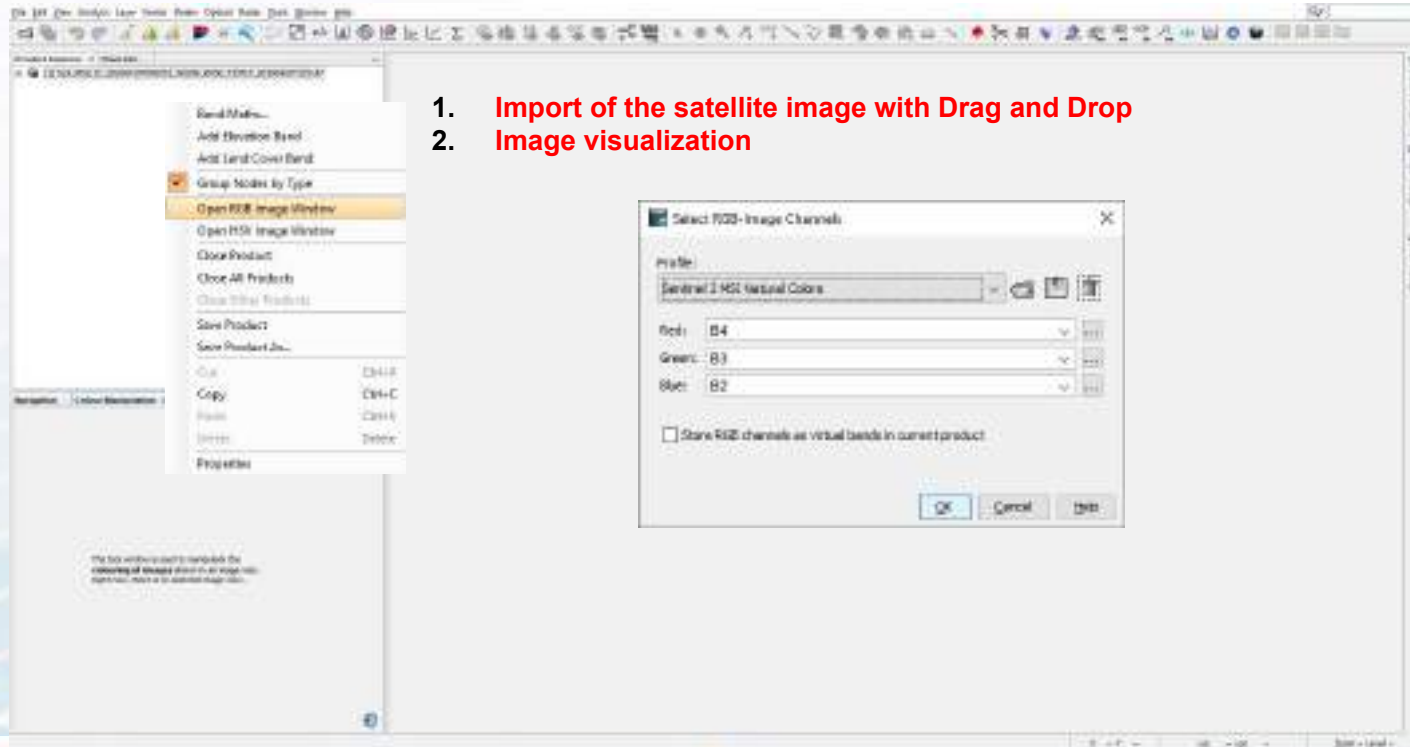


A common architecture **for all Sentinel Toolboxes** is being jointly developed by Brockmann Consult, SkyWatch and C-S called the **Sentinel Application Platform (SNAP)**.

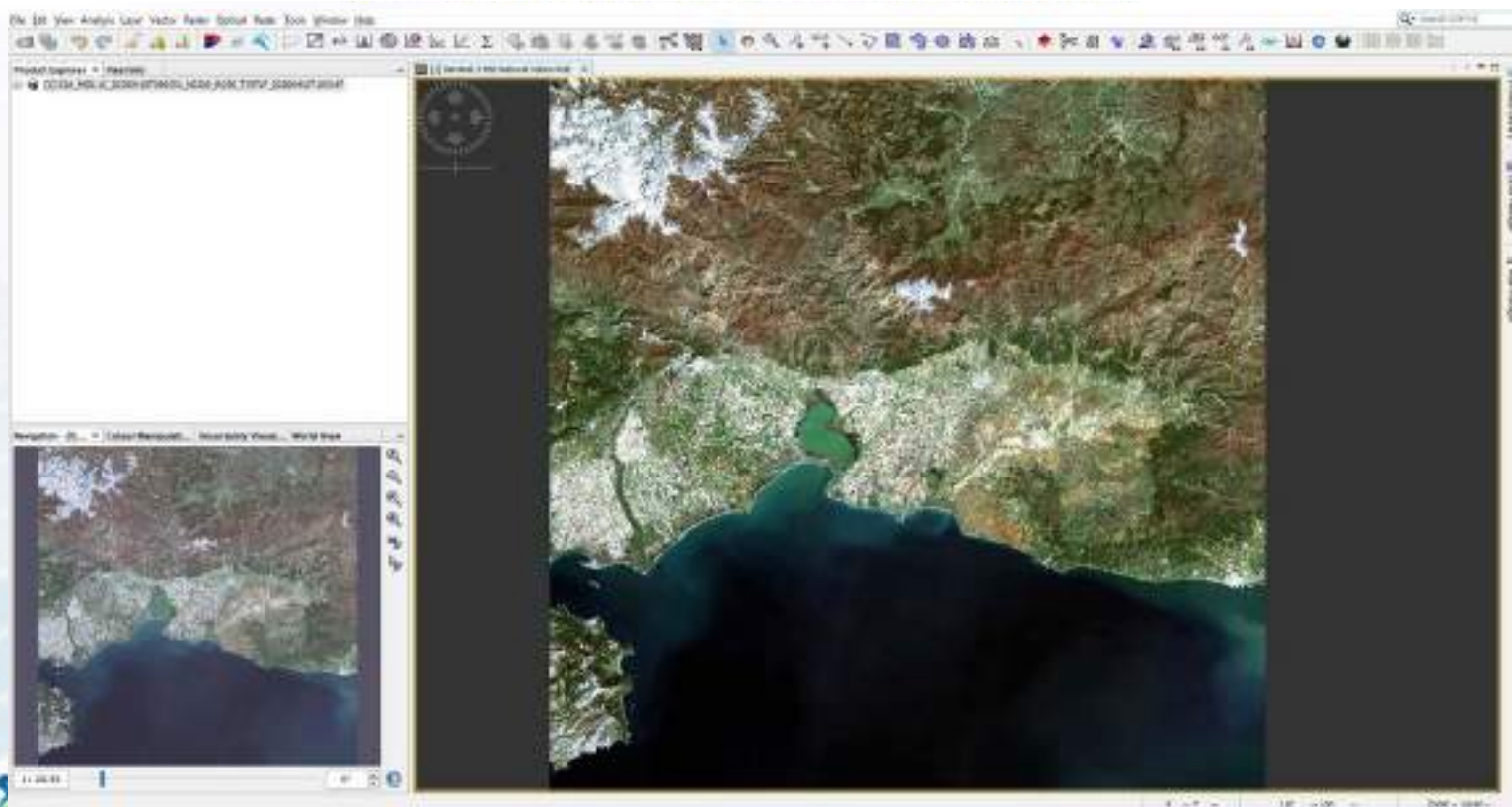
<https://step.esa.int/main/download/snap-download/>



SNAP – Import of the satellite image



SNAP – Image visualization



SNAP - Area of Interest

The screenshot displays the SNAP (Scientific Data Mining) software interface. The main window shows a satellite map with a purple polygon drawn over a green area. A red box highlights the 'Draw polygon' tool in the top toolbar. A context menu is open over the polygon, showing options like 'Export Selected Points', 'Export Multi-Poly', and 'Export Selected Area as File'. A blue box with yellow text reads 'Well-known text (WKT) Representation of geometry in text'. A white box with red text reads 'CTRL + C'. The bottom left corner features logos for the European Union and Black & Veatch.

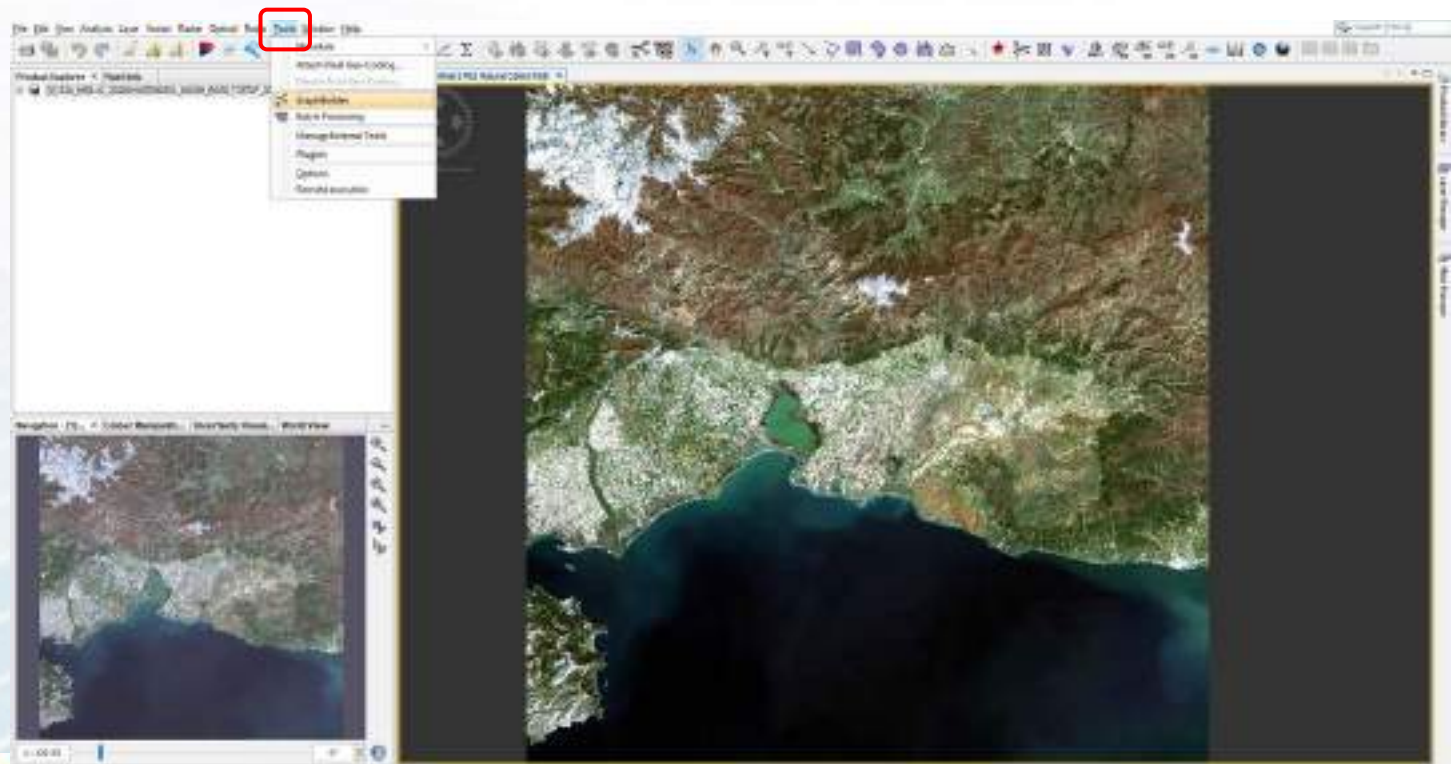
Draw polygon

Well-known text (WKT)
Representation of geometry in text

CTRL + C



SNAP – Graph Builder



SNAP – Graph Builder

Tools Graph
Builder

The screenshot shows the SNAP Graph Builder window. The main workspace contains a graph with two nodes: 'Raster' and 'Geometric'. The 'Add' menu is open, showing the following categories: Input-Output, Optical, Radar, Raster, Tools, and Vector. The 'Raster' category is expanded, showing: Classification, Data Conversion, DEM Tools, Geometric, Image Analysis, Mask, BandMaths, BandMerge, Flip, Image-Filter, Subset, and TemporalComposite. The 'Geometric' category is also expanded, showing: Collocate, CoregistrationOp, Multi-Use Mosaic, Resample, and Resample. The 'Resample' option is highlighted in the 'Geometric' sub-menu. The 'Connect Graph' button is visible at the bottom of the 'Add' menu.

1. Add Raster Geometric Resample
2. Add Raster Subset
3. Connect Graph



SNAP – Graph Builder

The screenshot displays the SNAP Graph Builder interface. The main workspace shows a workflow graph with four nodes: 'Read', 'Resample', 'Subset', and 'Write', connected sequentially by red arrows. A red rounded rectangle highlights this entire graph. Below the graph, the configuration panel for the 'Resample' node is visible, showing options for defining the size of the resampled product (e.g., 'By reference band size or coverage product') and the resampling algorithm (e.g., 'Nearest').

File: Graphs

```
graph LR; Read --> Resample; Resample --> Subset; Subset --> Write;
```

Read | Resample | Subset | Write

Read | Write | Resample | Subset

Define size of resampled product:

- By reference band size or coverage product:
 - Resulting target width: 30000
 - Resulting target height: 30000
 - Target width: 40,000
 - Target height: 40,000
 - width (height ratio): 1.00000
- By target width and height:
- By pixel resolution in m:

Define resampling algorithm:

- Upsampling method: Nearest
- Downsampling method: First
- Flag downscaling method: First

Advanced Method Definition by Band

Load | Clear | Help | Save | Print | Run



SNAP – Graph Builder - Resample

The screenshot displays the SNAP Graph Builder interface. A workflow is shown with four nodes: Read, Resample, Subset, and Write, connected by red arrows. The Resample node is highlighted with a red box. Below the graph, the configuration panel for the Resample node is visible, showing options for defining the size of the resampled product.

Read → Resample → Subset → Write

Resample Configuration Panel:

- Define size of resampled product:
 - By reference band size source product:
 - Resulting target width: 3000
 - Resulting target height: 3000
 - By target width and height:
 - Target width: 3000
 - Target height: 3000
 - Width (Height ratio): 1.0000
 - By area resolution in m:
 - Resulting target width: 3000
 - Resulting target height: 3000
- Define resampling algorithm:
 - Upsampling method: Nearest
- Downsampling method: First
- Flag downscaling method: First
- Advanced Method Definition by Band

Buttons: Load, Clear, Help, Save, Print, Run



SNAP – Graph Builder - Subset

The screenshot displays the SNAP Graph Builder interface. The main workflow consists of four nodes: Read, Resample, Subset, and Write, connected in a linear sequence. The Subset node is currently selected, and its configuration panel is highlighted with a red box. The configuration panel includes the following settings:

- Data Metadata
- Pixel Coordinates Geographic Coordinates
- Reference band: 1
- X: 0, Y: 0
- Width: 2048, Height: 1208
- Sub-sampling X: 1, Sub-sampling Y: 1

The interface also shows a Product Explorer on the left, a Navigation pane at the bottom left, and a toolbar at the bottom of the Graph Builder window.



SNAP – Graph Builder - Subset

The screenshot displays the SNAP (Sentinel Application Platform) Graph Builder interface. The main window shows a workflow graph with four nodes: Read, Resample, Subset, and Write, connected by red arrows. A red box highlights the Subset node, which is currently selected. Below the graph, the Subset node's configuration panel is visible, showing options for Copy Metadata, Point Coordinates, and Geographic Coordinates. A map window below the configuration panel shows a geographic reference area with a yellow box indicating the subset location. The map window also displays the coordinates of the subset area: 44.6251465 46.8645695 47.3613, 23.58887945251461 46.0160981304002, 23.58887945251465 41.8163901894002. The interface includes a Product Explorer on the left, a Navigator window showing a satellite image, and a Color Manipulation window. The bottom status bar shows the current zoom level and other navigation controls.



SNAP – Graph Builder

The screenshot displays the SNAP Graph Builder interface. The main window, titled "Graph Builder (.SHP1.xml)", shows a workflow graph with four steps: Read, Resample, Subset, and Write, connected by red arrows. Below the graph, the "Read" step is selected, showing options for "Copy Metadata", "Pixel Coordinates", and "Geographic Coordinates". The "Reference band" is set to "1". A map view below the options shows a satellite image of a forested area with a yellow bounding box. The "Save" button is highlighted with a red circle. The interface also includes a "Product Explorer" on the left, a "Navigation" window with a "World View" of the forest, and a "Zoom" window on the right showing a zoomed-in view of the forest. The bottom status bar shows the scale "1: 139.67".

```
graph LR; Read --> Resample; Resample --> Subset; Subset --> Write;
```

Product Explorer | Product Info

Navigation | (1) RGB | World View | Color Manipulation | (0) Sentinel

Read | Resample | Subset | Write

Copy Metadata

Pixel Coordinates | Geographic Coordinates

Reference band: 1

348251461 46445093473615, 255807948252464 412365941 412365941 255807948252464 412365941 255807948252464 412365941 255807948252464

Load | Clear | Help | **Save** | Help | Run

1: 139.67

Scale: Level

SNAP – Graph Builder

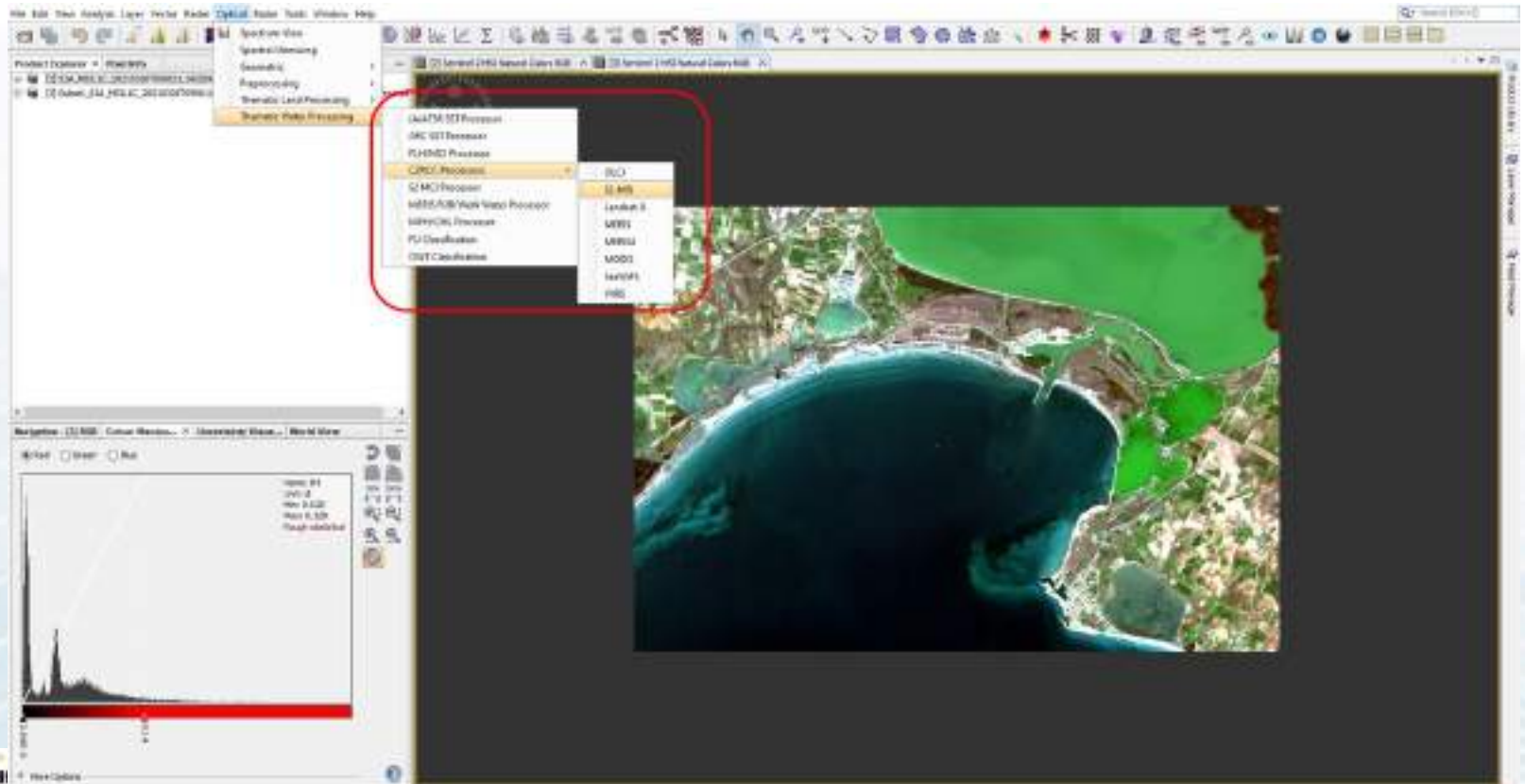
Initial



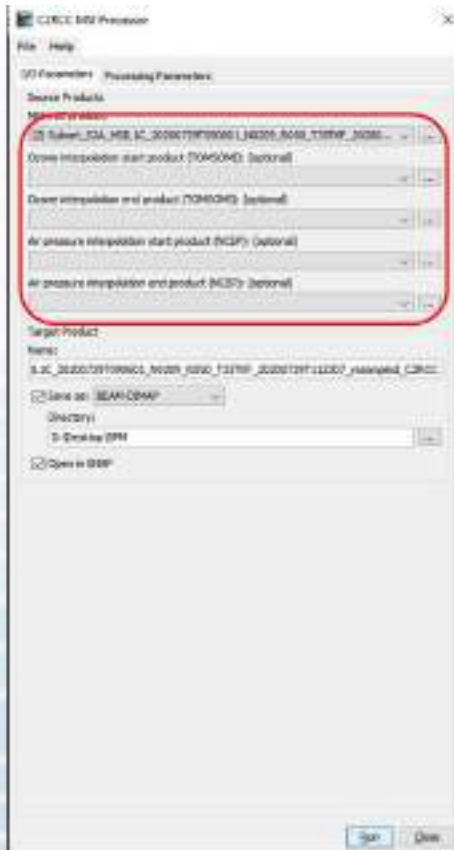
Resample - Subset



SNAP – C2RCC Processor



SNAP – C2RCC Processor



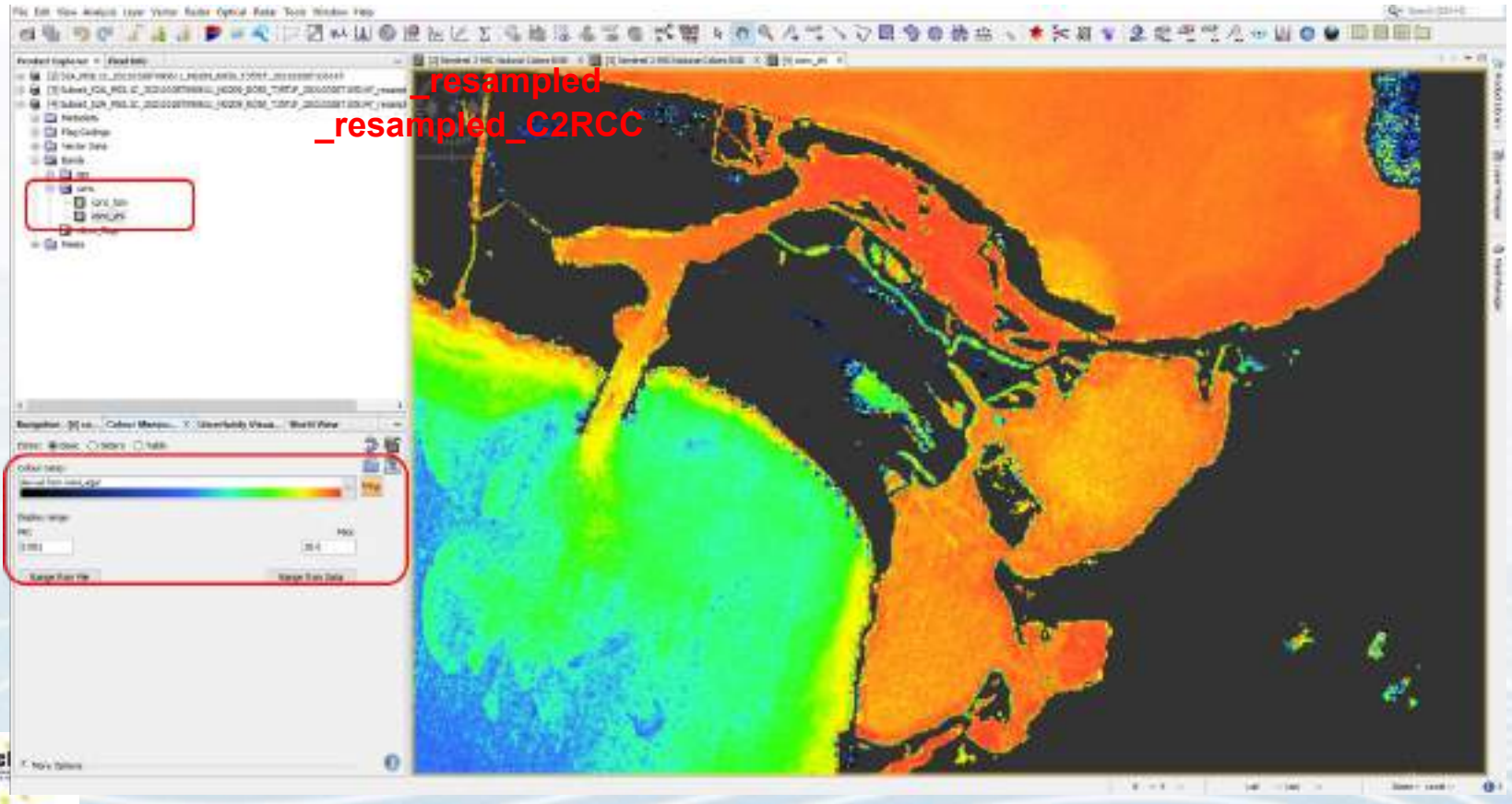
- Salinity
- Temperature
- Ozone
- Pressure

SNAP – C2RCC Processor

Variables

```
<parameters>
  <validityExpression>=0 &gt; 0 &exp/comp; 00 &lt; 0.1</validityExpression>
  <salinity>37.1</salinity>
  <temperature>15.1</temperature>
  <ctdtemp>336.0</ctdtemp>
  <pressure>1000.0</pressure>
  <seawater>0.0</seawater>
  <TDRfac>1.72</TDRfac>
  <CTDtemp>3.1</CTDtemp>
  <CTDexp>1.04</CTDexp>
  <CTDfac>21.0</CTDfac>
  <thresholdStress005>0.05</thresholdStress005>
  <thresholdStressFlare0ea>0.1</thresholdStressFlare0ea>
  <thresholdClustPower65>0.955</thresholdClustPower65>
  <uncertainty>water>true</
  <set>C2RCC-Net</set>
  <outputAsFile>false</outputAsFile>
  <deriveFromFishAndTransmitters>false</deriveFromFishAndTransmitters>
  <outputRtna>false</outputRtna>
  <outputRtna60>false</outputRtna60>
  <outputRtna0kann>false</outputRtna0kann>
  <outputRtna0k</outputRtna0k>
  <outputRtna0down</outputRtna0down>
  <outputRtna0up</outputRtna0up>
  <outputAcRelectance>false</outputAcRelectance>
  <outputRtna0</outputRtna0>
  <outputRtna0</outputRtna0>
  <outputEd>true</outputEd>
  <outputUncertainties>true</outputUncertainties>
</parameters>
```

SNAP – C2RCC Processor



Calculate Chlorophyll from Landsat 4-5



Landsat Products to Chlorophyll

The Blue-Green Ratio Model

$$Chl - a \propto R(\lambda_{Blue}) / R(\lambda_{Green})$$

$R(\lambda_{Blue})$ reflectance in the blue region at 440 nm, Chl-a strongly absorb light

$R(\lambda_{Green})$ reflectance in the blue region at 550 nm, reflectance is minimally absorbed by pigments

Landsat Products to Chlorophyll

The Two-Band NIR-Red Ratio Model

$$Chl - a \propto R(\lambda_{NIR}) / R(\lambda_{Red})$$

$R(\lambda_{Red})$

reflectance in the red region, wavelength usually located around the point of maximum chlorophyll-a absorption $660 \text{ nm} < \lambda_{Red} < 690 \text{ nm}$

$R(\lambda_{NIR})$

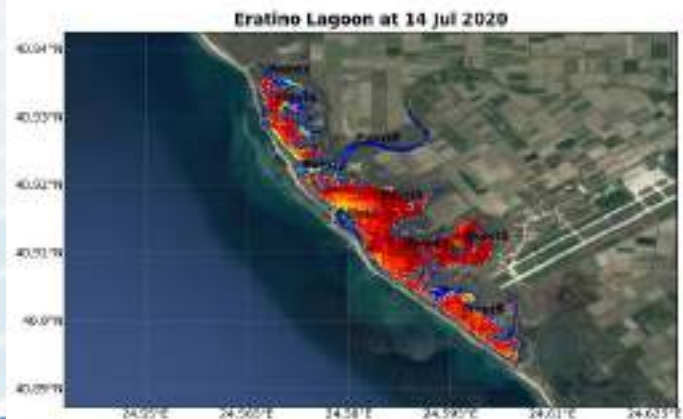
reflectance in the near-infrared, near-infrared wavelength, λ_{NIR} , may be found at two different positions in the NIR:

- between 700 nm and 720 nm, known as λ_2 , where absorption of the water constituents is minimal or
- beyond 710 nm, known as λ_3



Results





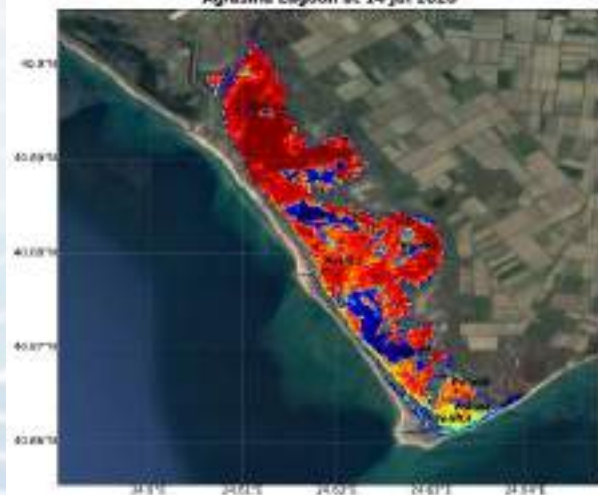
Aglasma Lagoon at 25 Feb 2020



Aglasma Lagoon at 25 Apr 2020



Aglasma Lagoon at 14 Jul 2020



Aglasma Lagoon at 22 Oct 2020





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EUROPEAN UNION



Common borders. Common solutions.

Thank You

Maria Zoidou

Democritus University of Thrace, Greece