### ESA contract 4000140187/23/NL/SC/rp (ENEUM)



# **Deliverable 5.2**

# **Applied Radar Remote Sensing**

## Practical Exercise Workbook







FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

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### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 1 – TUTORIAL

Radar Earth Observation – ESA EO Data Access and resources, applications, Copernicus OA Hub





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

### 1 | Exercise outline

In this exercise, we will:

- acquire skills in retrieving satellite imagery from both ESA and third-party missions
- conduct specific analyses utilizing the EO Browser
- install ESA SNAP and execute fundamental image operations
- explore the spectral curve of various surface types





## 2 | Background

Most of the ESA's Earth observation datasets are easily accessible online, free of charge. Users can acquire access by completing a simple registration process.

The Copernicus Data Space Ecosystem provides full, free and open access to large amount of Earth observation data, along with scalable interfaces integrated with the Copernicus Sentinel satellites. This includes a range of both new and historical Sentinel images, commercial datasets, as well as Copernicus Contributing Missions.

Sentinel data is also accessible through Copernicus Data and Information Access Services (DIAS), which are platforms designed to facilitate the discovery, retrieval, and use of Copernicus satellite data, including data from the Sentinel missions. There are several DIAS platforms available, each offering a user-friendly interface and tools for working with the data.

The ESA Hub allows checking searches online by browsing and viewing product metadata and measurements without downloading them. Sentinel products are provided for download over HTTP in \*ZIP archive file format.

Sentinel Hub is a doud-based platform that provides access to satellite data, particularly from the ESA Sentinel missions. The platform offers a variety of services and tools for the retrieval, processing, and analysis of satellite imagery. It is commonly used by researchers, developers, and businesses to access Earth observation data for various applications, including environmental monitoring, agriculture, urban planning, and more. EO Browser is an online platform developed by Sentinel Hub that allows users to visualize and explore satellite imagery, particularly from the Copernicus Sentinel missions. Sentinel Hub provides the backend infrastructure and access to the satellite data, while EO Browser serves as the user interface for interacting with that data.

ESA not only provides satellite data from its own Earth Observation (EO) satellite resources, but also facilitates access to Third Party Missions (TPMs), which are non-ESA EO missions. Integrating data from these diverse sources is crucial for enhancing the sustainability of satellite services, expanding the scope of monitored parameters, and promoting scientific development. Researchers and students alike can request third-party data, but it's important to be aware of licensing conditions, especially for users in certain countries, where national legislation on data access may apply.







### 3 | How to access ESA data

To access data from the European Space Agency (ESA), user can use various platforms and tools provided by ESA. Here are some key sources:

#### Earth Online Portal

The Earth Online Portal serves as a gateway to a diverse range of Earth observation resources. It includes a directory for discovering missions and datasets, offering convenient access to satellite data, operational updates, events, and tools to enhance data utilization.

#### Sentinel Online

The Sentinel online platform offers technical details about the Copernicus Sentinel missions and allows systematic access to processed data, which is readily accessible on the website. User registration is required for access.

#### **Copernicus Contributing Missions Online**

To obtain data with higher resolution, users can visit the Copernicus Contributing Missions website. This platform offers comprehensive information on all Contributing Missions that provide data complementing the Copernicus Sentinels, addressing the requirements of the Copernicus Services. Eligible users can access the data for free upon registration and confirmation of their user category.





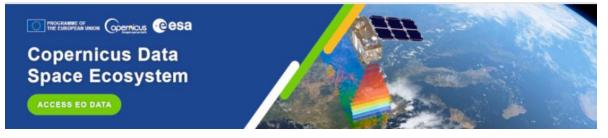




### 4 | Copernicus Data Space Ecosystem

https://dataspace.copernicus.eu/

 Since 24 January 2023 a new Copernicus Data Space Ecosystem has been launched to provide free and open access to Earth Observation data from all Sentinel satellites with new features for visualisation and data processing.



• The previous Copernicus Data Hub distribution service that has been providing access to Copernicus data is offering access to Sentinel data with a gradual ramp-down of the operations capacity and data offering.

| opernicus   | Coperr  | nicus Open A  | ccess Hub  | @esa 🚺   |
|---|---|---|--|--|
| Welcome to the Coperni  | cus Open Access Hub   |   |  | Reports & Stats  |
| Sentinel-1, Sentinel-2, Sentinel-3<br>Since 24 January 2023 a new Co<br>new features for visualisation and<br>and the roadmap for the full relea<br>The Copernicus Data Hub distrib<br>migration to the new Copernicus<br>the Copernicus Data Hub distribi<br>operations capacity and data offe<br>Sentinel Data are also available v | ution service will continue its ful<br>Data Space Ecosystem by all use<br>ution service will continue offerin | arting from the In-Orbit Commi<br>as been launched to provide a<br>ed to the news for latest inform<br>II operations until the end of<br>r communities. As from July 2(<br>g access to Sentinel data with<br>ation Access Services (DIAS) th<br>th the Data Hub Interface. Diss | ssioning Review (IOCR).<br>access to all Sentinel data with<br>mation on the services available<br>June 2023 to allow a smooth<br>D23 and until September 2023,<br>h a gradual ramp-down of the<br>arough several platforms .<br>cover how to use the APIs and | Data updated hourly         Image: Signal state of the last 24 bit of |
|   | us access to historic data via the A<br>support please send an e-mail to o                                    |   |  | Resources DHUS Open Source Portal Copernicus Copernicus Portal   |
| Open Hub  | API Hub   | S-5P Pre-Ops  | POD Hub  | Ceesa Sentinel Online  |

• Sentinel Data are also available via the Copernicus Data and Information Access Services (DIAS) through several platforms.







The Copernicus Data Space Ecosytem allows us to access a wide range of Earth observation data from the Copernicus Sentinel missions and more. The Copernicus Data Space Ecosytem provides tools for easy discovery, visualization and download which will be continuously upgraded.



#### **Discover our services**



from the Copernicus Sentinel missions and more. The Copernicus Data Space Ecosylem provides tools for easy discovery, visualization and download which will be continuously upgraded.

DISCOVER THE DATA



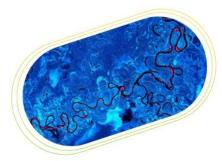
The service provides a powerful data analytics wrivionment. Access a set of high-quality data roccessing tools to extract information valuable o conduct public, private or commercial citivities. The Copernicus Data Space Scosystem is set to be the next level of user tata procession and distribution inforstructure

ACCESS THE TOOLS

#### Ecosystem

The Copernicus Data Space Ecosystem is the next step in the evolution of Earth observation data. The Ecosystem aims to gather tools and resources to unlock the full potential of this data. This allows to build a thriving, open and expanding Ecosystem to increase the impact or Earth Observation data for a sustainable society.

FIND OUT MORE



#### **Copernicus Browser**

Explore and engage with satellite imagery, using our user-friendly and intuitive browser. Open to all and easy to navigate.



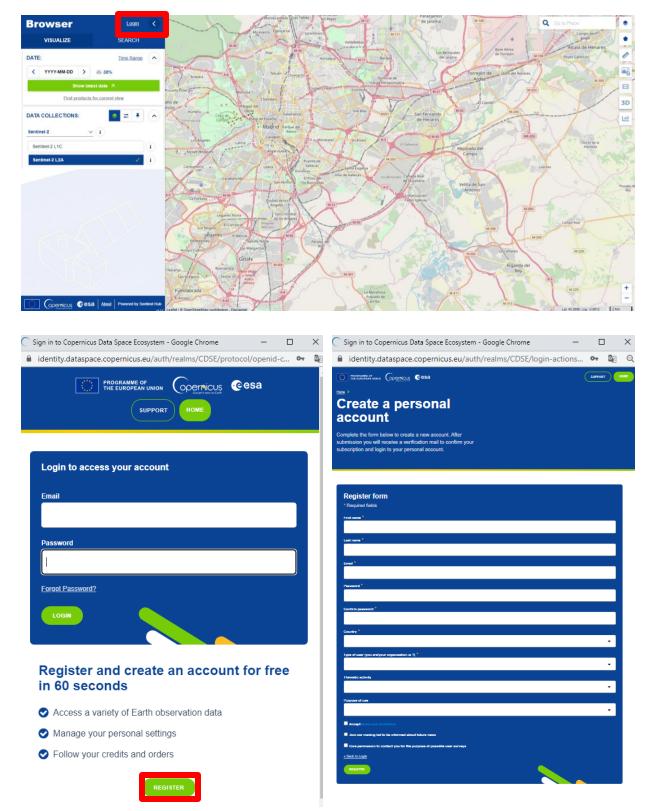






#### 4.1. Registration and login

- We can register a new user or log in as an existing user to the portal.
- The Copernicus Data Space Ecosytem allows us to browse and visualize satellite images freely, but we need to register and create an account to be able to download them.

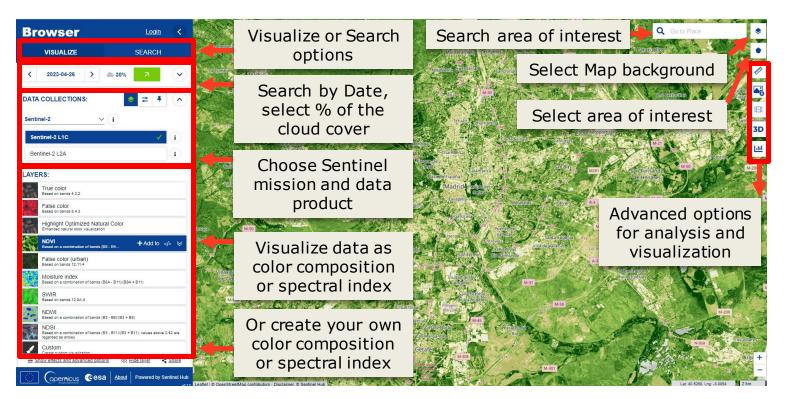


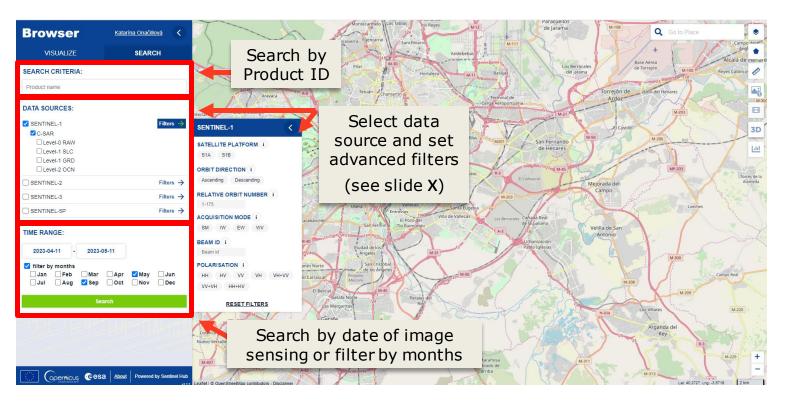






After registration and login, it is possible to visualize or search EO data products within portal. We can choose various satellite platforms, product types, polarizations, and sensing modes for individual satellites:









E.g. Sentinel-1 C-SAR - SAR Instrument that provides an all-weather, day and night imagery at C-band at high and medium resolutions for land, coastal zones and ice observations.

| SENTINEL-1  | Levels of product types  |
|-------------|--|
| C-SAR       | - unprocessed raw data   |
| Level-0 RAW | <ul> <li>(Single Look Complex) contains complex images with amplitude and<br/>phase in the slant range by azimuth imaging plane, in the image<br/>plane of satellite data acquisition</li> </ul> |
| Level-1 SLC | <ul> <li>(Ground Range Detected) consists of focused SAR data that has been<br/>detected, multi-looked and projected to ground range using an Earth</li> </ul>                                   |
| Level-1 GRD | ellipsoid model  |
| Level-2 OCN | <ul> <li>(Ocean) provide geo-located geophysical products derived from<br/>Level-1 for wind, wave and currents applications</li> </ul>   |

| Filters $\rightarrow$ | SENTINEL-1   |   |
|-----------------------|--|---|
|                       | SATELLITE PLATFORM i<br>S1A S1B                    | The available Sentinel-1 data includes products from the Sentinel-1 satellite constellation, including Sentinel-1A (operational since 2014) and Sentinel-1B (operational from 2016 to 2022)   |
|                       | Ascending Descending                               | Determines wheter the data was recorded during a descending orbit (flight direction: north-south) or an ascending orbit (flight direction: south-north)   |
|                       | 1-175  | The Relative Orbit Number is the number of full orbits since the relative orbit 1 to the end of a cycle   |
|                       | ACQUISITION MODE i<br>SM IW EW WV                  | Sentinel-1 operates in 4 instrument acquisition<br>modes: Stripmap (SM), Interferometric Wide Swath<br>(IW), Extra-Wide Swath (EW), Wave (WV)   |
|                       | BEAM ID i<br>Beam id                               | Depending on the acquisition mode, different swaths and identifiers are possible  |
|                       | POLARISATION i<br>HH HV VV VH VH+VV<br>VV+VH HH+HV | Determines with which polarisation the data was<br>acquired. The first letter indicates the polarisation<br>when sending the signal, the second letter when<br>receiving the signal. Data can be acquired in single<br>polarisation HH or VV or in dual polarisation HHHV<br>or VVVH depending on the instrument mode |
|                       |  |   |

#### RESET FILTERS





#### 4.2. Search results

After defining the search criteria, we get the results that can be further viewed, analysed or downloaded.



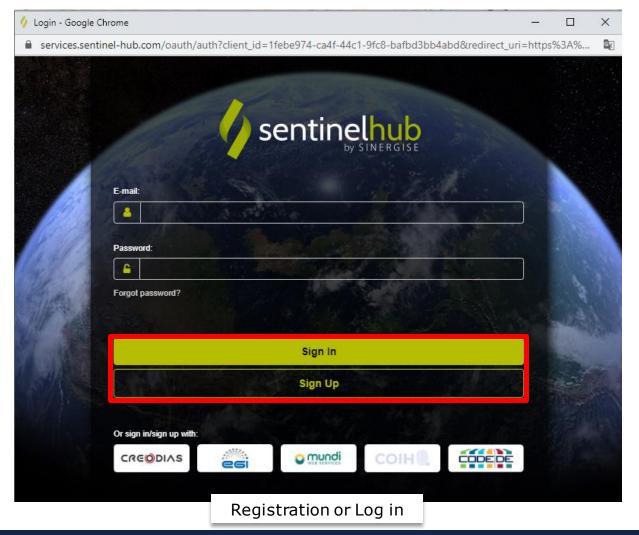




### 5 | Sentinel Hub - EO Browser

https://apps.sentinel-hub.com/eo-browser/

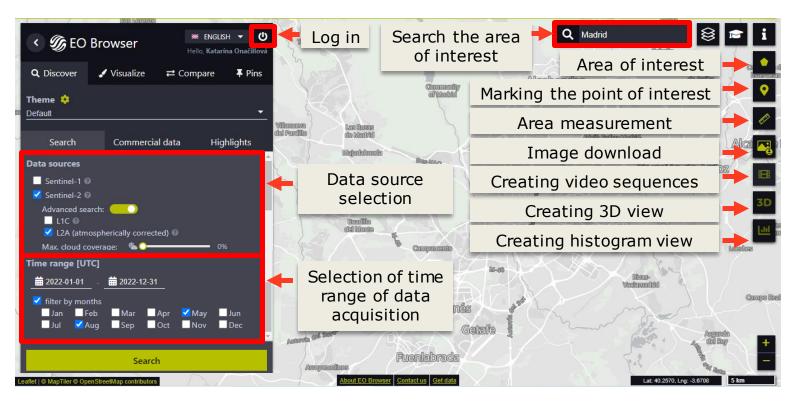
EO Browser, developed by Sentinel Hub, is an online platform that empowers users to explore and visualize satellite imagery from Earth observation (EO) missions, with a focus on the Copernicus program. Offering an intuitive and user-friendly interface, the platform is widely utilized for educational, research, and environmental monitoring purposes. Key features encompass direct access to Copernicus Sentinel data, enabling users to visualize and analyze imagery within the browser. Customization options allow users to tailor their view by adjusting parameters like date and cloud cover, catering to specific research needs. The platform's educational utility is evident in its use in educational settings, introducing students to Earth observation and remote sensing through its accessible interface. Additionally, EO Browser facilitates timelapse creation for monitoring changes in the Earth's surface over time. EO Browser is a valuable tool for those interested in exploring and understanding satellite imagery for a wide range of applications, including environmental monitoring, agriculture, forestry, and urban planning.



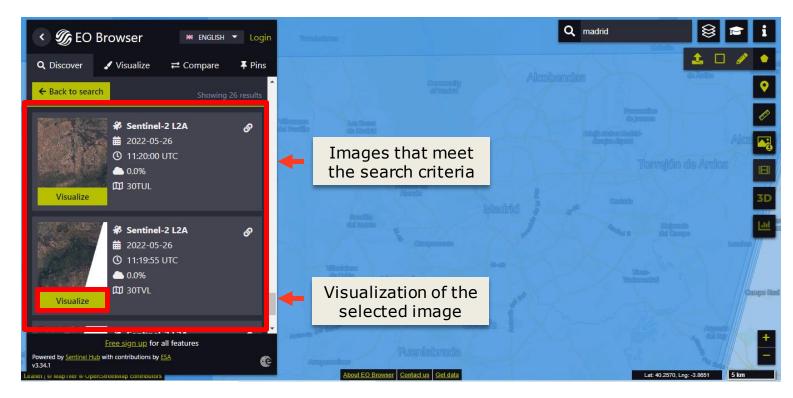








After the search, the selected image can be visualised in the browser.

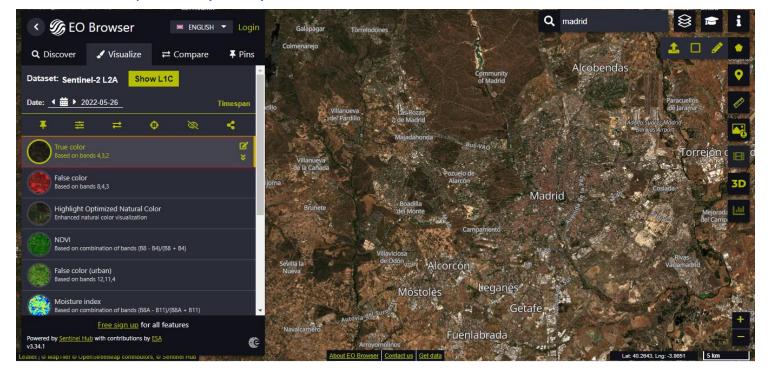






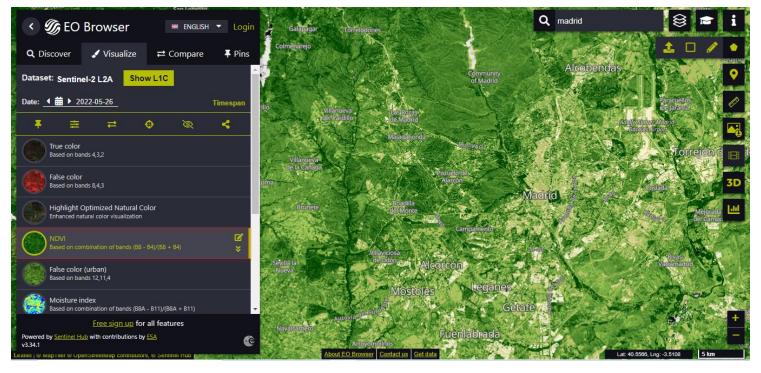
### 5.1 Optical data

In the visualisation tab, we can change the view mode (available are visualization options in the form of color compositions and spectral indices).



#### True color composition (R-G-B)

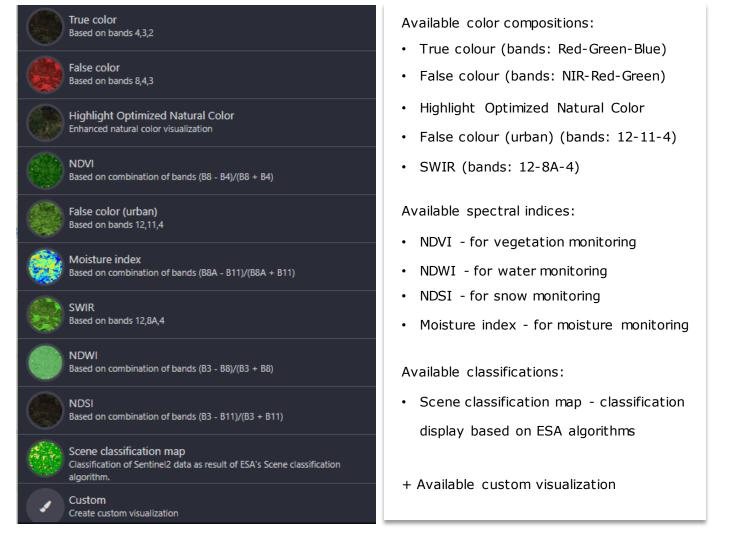
#### Normalised difference vegetation index (NDVI)



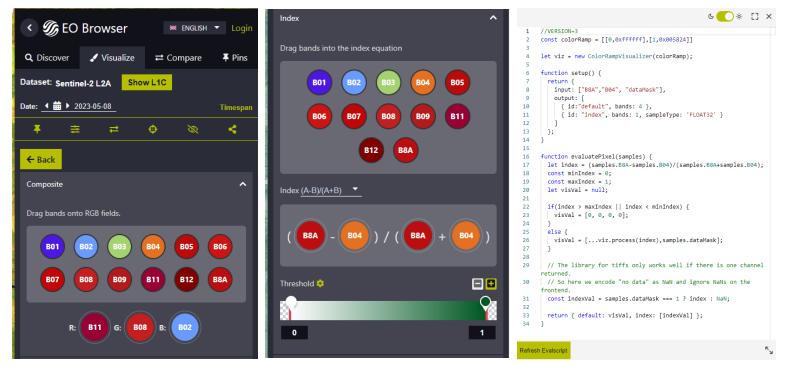




### Other visualization options



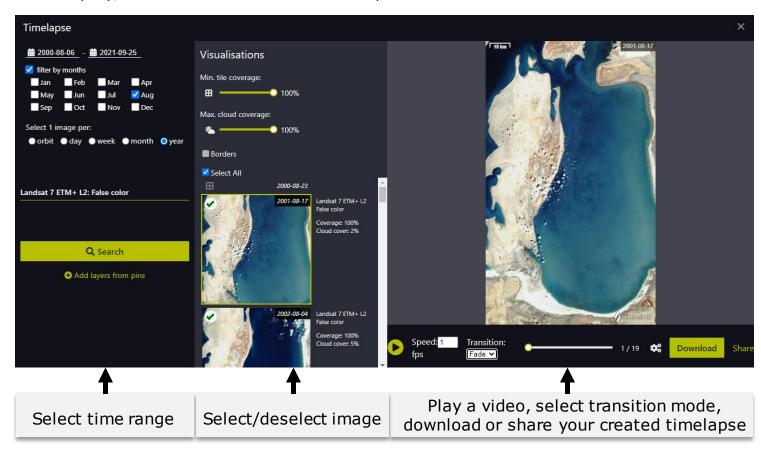
We can also use a visualisation for custom color combinations or spectral indices of default bands or the scripting tool and use additional datasets.







An important visualisation tool of EO Browser is the *Timelapse* function. We can choose multiple images filtered by date or month and select one image per orbit, day, week, month or year. We can set prefered tile coverage and % of cloud cover. Then we can select all or only some images and play, download or share the timelapse visualisation.





The resulting timelapse of images from the Landsat 7 satellite showing the disappearance of the Aral Sea by 2020







#### 5.2. Radar data

When displaying radar data, we have the option to choose from various types of visualizations.



In accordance with specific requirements, the terrain can be displayed using different polarizations, cross- polarizations, and corrections.

| Dataset: Sentinel-1 AWS-IW-VVVH                        |          | VH - linear gamma0                                  |
|--|----------|---|
| Date: ◀  ▶ 2023-05-15 7                                | Timespan | <u> </u>  |
| <br>▼  | <        | VH - linear gamma0 - orthorectified                 |
| SAR urban  | ď        | VH - linear gamma0 - radiometric terrain corrected  |
| RGB ratio  |          | VV - decibel gamma0                                 |
| Enhanced visualization                                 |          | VV - decibel gamma0 - orthorectified                |
| Enhanced visualization - orthorectified                |          | VV - decibel gamma0 - radiometric terrain corrected |
| Enhanced visualization - radiometric terrain corrected |          | VV - linear gamma0                                  |
| VH - decibel gamma0                                    |          | VV - linear gamma0 - orthorectified                 |
| VH - decibel gamma0 - orthorectified                   |          | VV - linear gamma0 - radiometric terrain corrected  |
| VH - decibel gamma0 - radiometric terrain corrected    |          | Custom<br>Create custom visualization               |

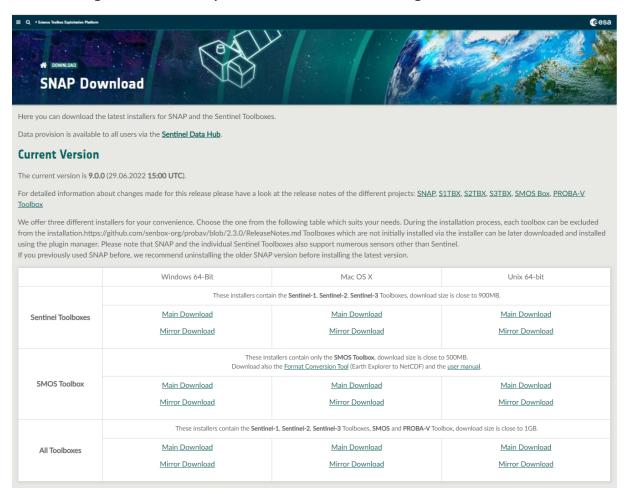




## 6 | Sentinel Application Platform (SNAP)

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

ESA Sentinel Application Platform (SNAP) is a software toolkit developed by the European Space Agency (ESA) for processing and analyzing Earth observation data, particularly data from the Sentinel satellites. SNAP is part of the Sentinel Toolbox and is freely available to the public. It provides a user-friendly interface and a comprehensive set of tools also for working with a variety of other remote sensing data.



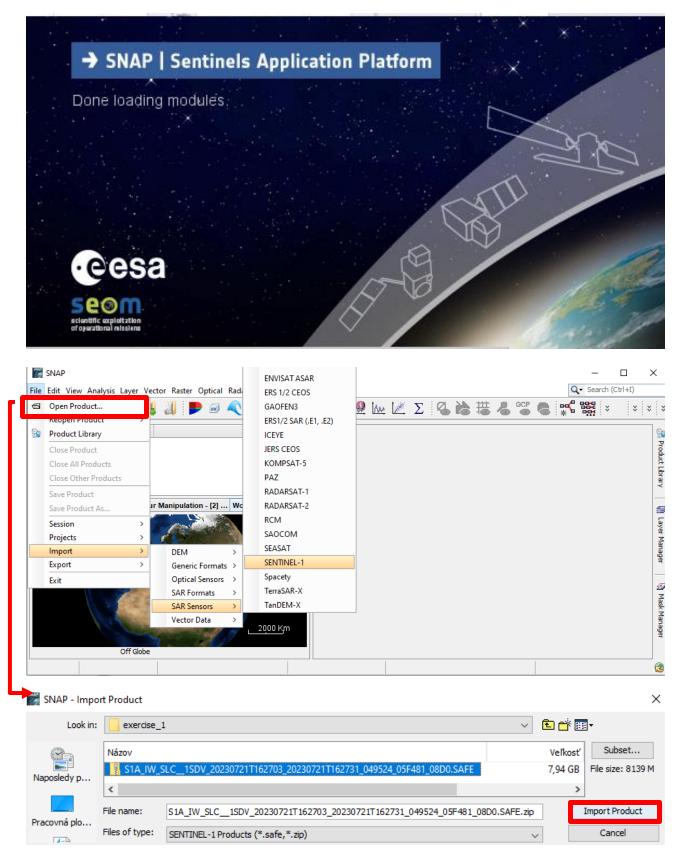
SNAP is widely used in the scientific community and by remote sensing professionals for a variety of applications, including land cover mapping, environmental monitoring, and disaster response. It is an open-source tool, and its modular architecture allows for the integration of plugins and additional functionalities.







After installing and starting the software, we can open an image using File – Open Image or by Import option:







| Product Explorer ×     Pixel Info     —       ⊞… €     [1] S1A_IW_SLC1SDV_20230721T162703 |   | Band Maths<br>Add Elevation Band |        |                   | 🛃 Product Library |
|---|---|----------------------------------|--------|-------------------|-------------------|
| < >   |   | Add Land Cover Band              |        |                   | orary             |
| Navigation Colour Ma World × –  | ¥ | Group Nodes by Type              |        |                   |                   |
|   |   | Open RGB Image Window            |        |                   | 5                 |
|   |   | Open HSV Image Window            |        | color composition | Layer Manager     |
| and the second  |   | Close Product                    |        |                   | Mana              |
| N COMPANY   |   | Close All Products               |        |                   | iger              |
|   |   | Close Other Products             |        |                   |                   |
|   |   | Save Product                     |        |                   | <i>3</i>          |
|   |   | Save Product As                  |        |                   | lask              |
|   |   | Cut                              | Ctrl+X |                   | Mask Manager      |
| <u>_200</u> 0 Km  |   | Сору                             | Ctrl+C |                   | iger              |
| Off Globe   |   | Paste                            | Ctrl+V |                   |                   |
|   |   | Delete                           | Delete |                   | 2                 |

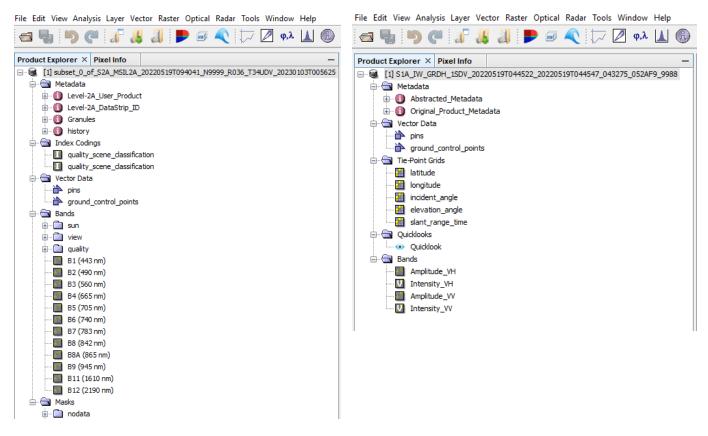
| 🎆 Selec  | t RGB-Image Channels                               | ×                     | [1] RGB ×         |  |   |
|----------|--|-----------------------|-------------------|--|---|
| Profile: |  | × 🛋 💾 🏢               |                   | Sec. 4   | Ser.                                    |
| Red:     | Intensity_IW1_VH                                   | ~                     | and A             |  | the                                     |
|          | fixed range min                                    | max                   | Same Sta          |  | 1                                       |
| Green:   | Intensity_IW1_VV                                   | ~                     | STON Y            | a produce  | Star Wall                               |
|          | fixed range min                                    | max                   | - and - and -     | and the second sec |   |
| Blue:    | Intensity_IW1_VV                                   | ~                     | No.               | Charles Martin   |   |
|          | fixed range min                                    | max                   |                   |  | K S                                     |
| □ Stor   | e RGB channels as virtual bands in current product | Expressions are valid |                   |  |   |
|          |  |                       | Increases and a   |  | Desta de California de la calegra de la |
|          |  |                       | ♠                 |  |   |
|          | Displ  | ay image in o         | -<br>different po | olarizations   |   |





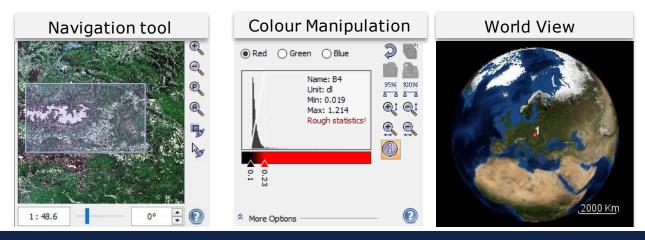


Upon opening an image, users can explore the image data through the Product Explorer window. This encompasses opening RGB composite images, navigating metadata, inspecting spectral bands, and reviewing image masks. In the case of radar images, amplitude or intensity can be visualized in various polarizations.



In the bottom-left Window Group, we can see 4 tools:

- Navigation tool to navigate within the opened image
- Colour Manipulation to view the histogram for the opened image and manipulate individual channels or assign new colours to the image
- Uncertainty Visualisation to visualise the uncertainty information associated with a band shown in an image view
- *World View* to see the position of our selected image



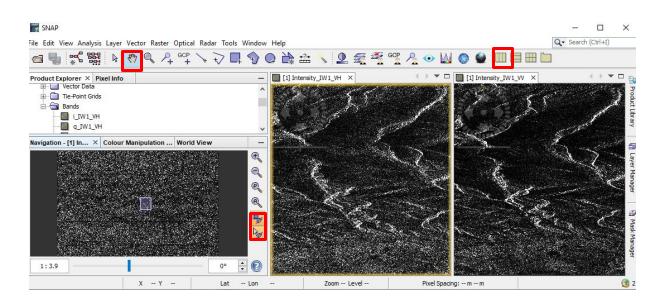




To simultaneously view and compare multiple opened images, utilize the *Tile* function (e.g. *"Tile Horizontally" or "Tile Vertically").* 

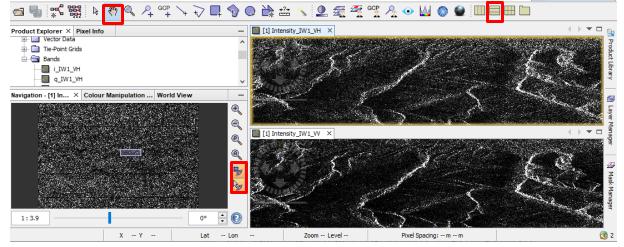
Ensure that the cursor is visible and that simultaneous manipulation of all images is possible by navigating to the Navigation tab and verifying that the following is checked:

synchronises views across multiple image windows synchronises cursor positions across multiple image windows



 [1] Intensity\_IW1\_VH - [S1A\_IW\_SLC\_1SDV\_20230721T162703\_20230721T162731\_049524\_05F481\_08D0] - [Z:\Projekty\2023\_ESA\_ENEUM\07\_ucebne\_materialy\Radarovy\_DPZ\pra...
 ×

 File
 Edit
 View
 Analysis
 Layer
 Vector
 Radar
 Tools
 Window
 Help

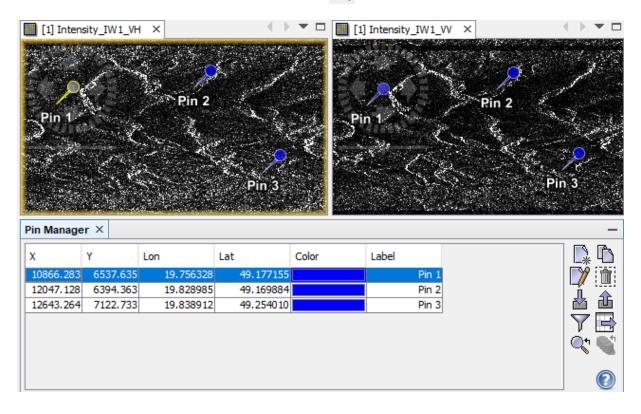




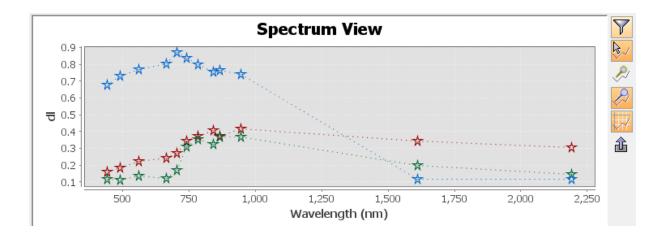




For localization purposes, we can add various pins to different pixels and add the description to them (*View – Tool Windows – Pin Manager* or by clicking on the icon of *Pin placing tool*  $P_{+}$ 



To observe spectral information of these various pins, we can use the tool Spectrum View  $[\!\!M]$ 







## 7 | Third party missions

https://earth.esa.int/eogateway/missions/third-party-missions

In addition to providing users with data from its own Earth observing (EO) satellites, the European Space Agency (ESA) has played a significant role in providing access to Earth Observation missions not under ESA ownership or operation—referred to as Third Party Missions (TPM). With a history spanning over 45 years, the TPM program involves a series of Earth Observation-focused satellites owned by various commercial and public organizations worldwide. The TPM initiative currently includes over 50 missions, contributing data from more than 60 instruments to support users engaged in research and development endeavors.

### 7.1. Access to TPM data

Users have the ability to explore and download Earth Observation (EO) data from the extensive catalog of missions operated and supported by the European Space Agency through the ESA EO Catalogue (EO-CAT):

https://eocat.esa.int/sec/#data-services-area



User can find here:

- mission, instrument and product news and descriptions;
- collection descriptions;
- data access links;
- information on selected Earth/environmental topics and applications of satellite data

Data are also accessible through the TPM L-OADS web interface:

https://tpm-ds.eo.esa.int/collections/

For more information, see the lecture: <u>1. Radar Earth Observation and</u> evolution – current and next generation missions, ESA EO Data Access and resources, applications

### THANK YOU FOR FOLLOWING THE EXERCISE!





### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 2 – TUTORIAL

SAR for Land Applications 1 – SAR basics for Land monitoring using SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

### 1 | Exercise outline

In this exercise, we will:

- Learn how to retrieve a land-use / land cover (LULC) classification based on Sentinel-1 image products
- Explore different types of analysis for the detection of discrete land cover classes.
- Use supervised and unsupervised classification algorithms to classify the satellite image into classes

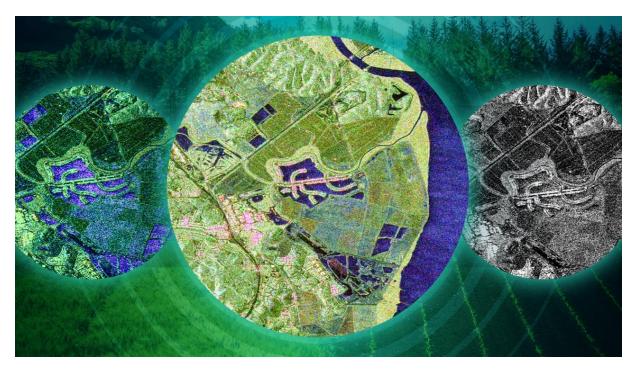




## 2 | Background

#### Mapping land cover using Sentinel-1 data

Mapping land cover using Sentinel-1 data relies on the radar backscatter signals obtained from the satellite. The backscatter intensity, polarization, and texture of the radar imagery are analyzed to distinguish between different land cover types. Supervised classification methods involve training a dassifier with labeled samples of land cover types, while unsupervised methods group pixels based on their spectral similarity without prior training. The accuracy of the land cover classification is validated using ground truth data, and the results can be refined iteratively to improve accuracy. The final land cover maps provide valuable information for various applications, including urban planning, agriculture, forestry, and environmental monitoring.



Source: https://eo4society.esa.int/event/7th-advanced-training-course-radar-polarimetry/

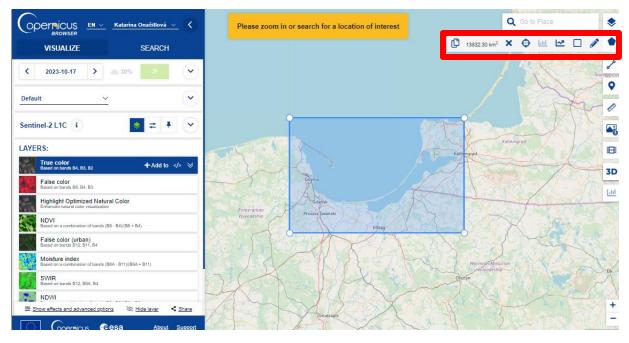






#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 images of the same area in northern Poland, downloaded for year 2023 from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



However, the feature space of S1 data, referring to the number of variables available for predicting target classes, is restricted when compared to optical data. As a result, this tutorial utilizes two images captured in the same year but during different seasons. This approach enables the characterization of surfaces based on their temporal attributes to some extent. Consequently, Image 1 was obtained during the month with minimal precipitation (February), while Image 2 was acquired towards the beginning of July, a period associated with the highest precipitation.



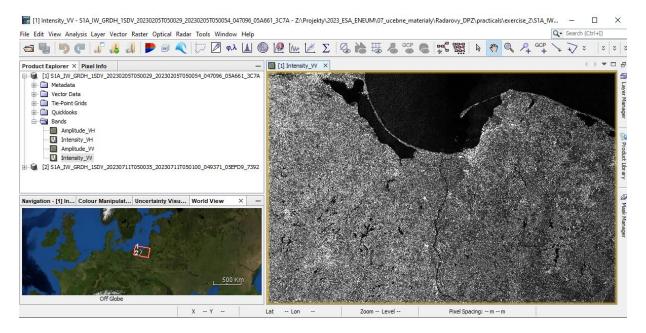


#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, dick Open Product and open 2 Sentinel-1 GRDH downloaded products with HH and HV polarizations acquired on 5 February and 11 July 2023 by double click on the zipped folders. The opened products will appear in Product Explorer window:

S1A\_IW\_GRDH\_1SDV\_20230205T050029\_20230205T050054\_047096\_05A661\_3C7A.zip S1A\_IW\_GRDH\_1SDV\_20230711T050035\_20230711T050100\_049371\_05EFD9\_7392.zip

Click + to expand e.g. the content of product [1] from 5 February 2023, then expand Bands folder and double click on Intensity\_VV band to visualize it. Depending on your computer's capabilities, this process could take some time. To minimize the data load, the next step involves creating a subset that encompasses only a portion of the dataset.



Preview of the S1 GRDH product

Note: The image appears inverted because it was captured during an ascending pass.







#### 3.1 Pre-processing

We need to apply identical pre-processing steps to both of our scenes:

#### Create a subset

There is no need to process the whole image, instead, we can reduce the loaded data to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Navigate to Raster – Subset tab and at Switch to "Geo Coordinates" Enter the following numbers: North latitude bound: 54.70 West longitude bound: 20.60

South latitude bound: 20.60 South latitude bound: 54.10 East longitude bound: 16.90

Confirm with Run and repeat the step for the second S1 image.

| Pixel Coordinates       Geo Coordinates         North latitude bound:       54.70 ÷         Vest longitude bound:       20.60 ÷         South latitude bound:       54.10 ÷         East longitude bound:       16.90 ÷         Scene step X:       1 ÷         Subset scene width:       22460.0         Source scene width:       22460.0         Source scene width:       2544         Source scene width:       26544         Source scene width:       26544         Source scene width:       26544         Source scene width:       16669         Use Preview       Fix full width         Fix full height       16669 | Spatial Subset | Band Subset | Tie- | Point Grid Subset Metadata Subset   |                |   |
|---|----------------|-------------|------|---|----------------|---|
| ×   |                |             | < >  | North latitude bound:<br>West longitude bound:<br>South latitude bound:<br>East longitude bound:<br>Scene step X:<br>Scene step Y:<br>Subset scene width:<br>Source scene width:<br>Source scene width: | Fix full width | 20.60 ÷<br>54.10 ÷<br>16.90 ÷<br>1 ÷<br>22460.0<br>10590.0<br>26544 |

#### Apply orbit file

Navigate to Main Menu - Radar - Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Repeat for the second image.

| C Apply Orbit File X  | C Apply Orbit File ×  |
|---|---|
| File Help   | File Help   |
| I/O Parameters Processing Parameters Source Product source: [3] subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_202302 v | I/O Parameters     Processing Parameters       Orbit State Vectors:     Sentinel Precise (Auto Download)       Polynomial Degree:     3 |
|   | Do not fail if new orbit file is not found  |
| Target Product  |   |
| Name:   |   |
| subset_0_of_S1A_IW_GRDH_Orb   |   |
| Save as: BEAM-DIMAP   |   |
| Directory:  |   |
| Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8   |   |
| Open in SNAP  |   |
|   |   |
|   |   |
|   |   |
| Run Close   | Run Close   |







Note: If precise orbits are not yet available for your product, restituted orbits can be selected which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product

#### Radiometric calibration

Navigate to Main Menu – Radar – Radiometric - Calibrate

In the I/O Parameters tab, select the product from the previous step (\_Orb) as a source product. For the target product name, add \_Cal at the end of the name as suggested In the case of this final product of preprocessing, please, save it to your folder for this exercise

In the Processing Parameters accept all default settings and then click Run.

Repeat for the second image. The saving might take some time.

Note: Thermal Noise Removal is not applied in this tutorial but should be considered when working with larger subsets or entire images.

| Calibration X  | Calibration X   |
|--|---|
| File Help  | File Help   |
| I/O Parameters Processing Parameters Source Product source: [5] subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb $\checkmark$    | I/O Parameters     Processing Parameters       Polarisations:     VH<br>VV                    |
| Target Product Name: subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb_Cal Save as: BEAM-DIMAP Directory: Z:\ESA_RADAR\exercise_2 | ENVISAT Auxiliary File: Latest Auxiliary File<br>Save as complex output<br>Output sigma0 band |
| Close  | Output gamma0 band Output beta0 band Run Close  |







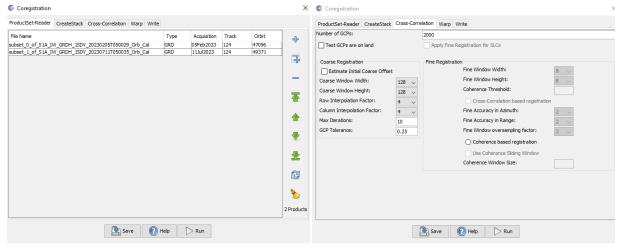
#### 3.2 Coregistration

After both images were radiometrically calibrated in the previous step, the coregistration brings both into one stack. Image coregistration is the process that involves aligning two or more images geometrically, ensuring that corresponding pixels depict the same area on the Earth's surface. While orbit state vectors alone can suffice to coregister images, for precise offset tracking, additional data from a digital elevation model (DEM) is necessary to enhance coregistration accuracy.

Navigate to Main Menu – Radar – Coregistration – Coregistration

In the ProductSet-Reader tab, load the last two preprocessed products (calibrated and with orbit files applied)

In the Write tab name the target product and set the directory to save it Leave all other settings as predefined



Note: If the coregistration fails it is advisable to increase the number of GCPs and also to have the initial coarse offset estimated by the operator.

In addition to verifying the accuracy of the residuals, it is advisable to visually inspect the stack's quality. One way to do this is by creating an RGB representation of both the master and slave products, which helps determine if the images are properly aligned.

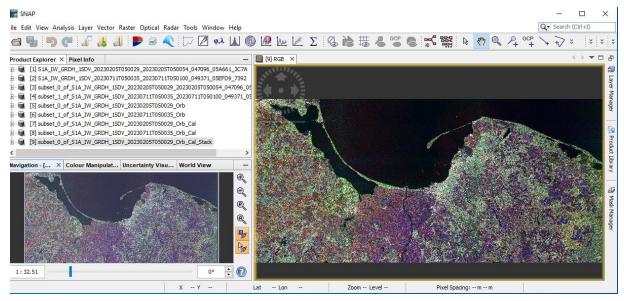
|   | 🎆 Sele   | ect RGB-Image Channels X                             |
|---|----------|--|
| Right click on the output stack product<br>– Open RGB Image Window: | Profile: |  |
|   | Red:     | \$9.Sigma0_VV_mst_05Feb2023 ~                        |
| Choose February VV for the red channel,                             |          | fixed range min max                                  |
| •   | Green:   | \$9.Sigma0_VH_mst_05Feb2023 v                        |
| February VH for the green channel,                                  |          | fixed range min max                                  |
| and July VV for the blue channel.                                   | Blue:    | \$9.Sigma0_VV_slv2_11Jul2023 v                       |
|   |          | fixed range min max                                  |
|   |          | Expressions are valid                                |
|   | Sto      | ore RGB channels as virtual bands in current product |
|   |          |  |
|   |          | OK Cancel Help                                       |







Magnify an area featuring distinct surfaces, such as the boundary between land and water. The RGB image should be vivid and well-defined, except for alterations in land cover or scattering mechanisms that may have transpired between the first and second image acquisitions. In the figure, rivers, roads, and agricultural fields are distinctly depicted in all colors. White pixels represent high backscatter in all three bands (urban areas), while black pixels denote low backscatter values in all three bands (water). Blue pixels signify a slightly shifted shoreline in July compared to February.



#### Speckle Filter

Despeckling removes thermal noise introduced by the sensor from the image to remove potential sources of error in analysis.

Navigate to Radar > Speckle Filtering Single Product Speckle Filter. In the I/O Parameters select the last stack product and in the Speckle-Filter tab, choose the simple Lee Sigma filter with default window sizes.

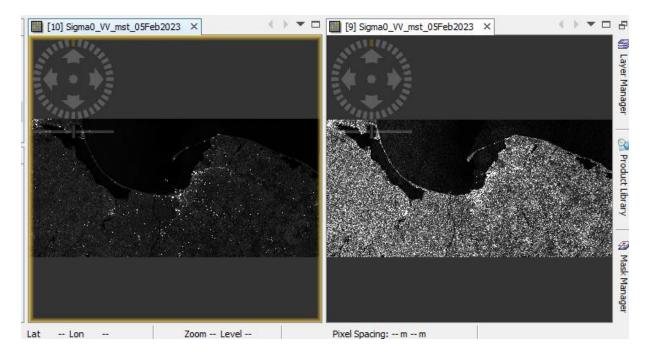
| 📀 Single Product Speckle Filter   | $\times$ | Single Product S    | Speckle Filter   | ×         |
|---|----------|---------------------|--|-----------|
| File Help   |          | File Help           |  |           |
| I/O Parameters Processing Parameters  |          | I/O Parameters Pro  | ocessing Parameters  |           |
| Source Product<br>source:<br>[9] subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb_Ca v    |          | Source Bands:       | Sigma0_VH_mst_05Feb2023<br>Sigma0_VV_mst_05Feb2023<br>Sigma0_VH_slv1_11Jul2023<br>Sigma0_VV_slv2_11Jul2023 |           |
| Target Product<br>Name:<br>subset 0_of_S1A_IW_GRDH_ISDV_20230205T050029_Orb_Cal_Stack_Spk |          |                     |  |           |
|   |          | Filter:             | Lee Sigma  | ~         |
| Directory:  |          | Number of Looks:    | 1  | ~         |
| Z:\Pracovnici\onacillova\ESA_ENEUM  |          | Window Size:        | 7x7  | ~         |
|   |          | Sigma:              | 0.9  | ~         |
| Open in SNAP  |          | Target Window Size: | 3x3  | ~         |
| Run Clos  | 2        |                     |  | Run Close |
| Run Clos  | ie -     |                     |  | Kun Close |





8

You can compare the image pre and post-filtering by doule-click on the VV polarizations and utilizing the Split Window feature found in the toolbar. As usual, different types of filters will yield somewhat varied outcomes.



Sigma0 VV before (left) and after (right) application of a speckle filter

#### **Terrain-Correction**

Navigate to Radar – Geometric – Terrain Correction – Range Dopler Terrain Correction. The last step in our graph for image pre-processing is to apply terrain correction to the product, ensuring that all the pixels are moved to the right locations (eg if the nadir angle of the image is off, it will align the pixels correctly so it is closer to a top-down view of the imagery).

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-Doppler Terrain Correction

In the I/O Parameters tab set as "Source Product" the velocity product.

In "Target Product", keep the default name and set the Directory

In the Processing Parameters tab set:

Digital Elevation Model: SRTM 1Sec HGT (AutoDownload)





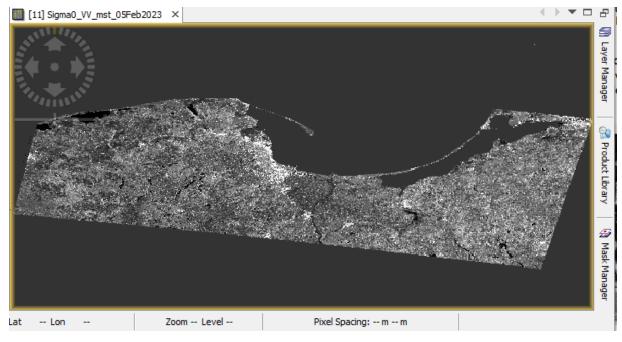


Map Projection: In this tutorial, we opt for WGS84 as the Map Projection, which relies on geographic coordinates (latitude and longitude). However, for subsequent utilization in a geographic information system (GIS), projected coordinate systems like UTM (Automatic) could also be chosen.

Keep defaults values for the other parameters. Click Run.

| 📀 Range Doppler Terrain Correction   | $\times$ | 📀 Range Doppler Terrain Correcti                                       | on X   |  |
|--|----------|--|--|--|
| File Help  |          | File Help  |  |  |
| I/O Parameters Processing Parameters   |          | I/O Parameters Processing Paramet                                      | ters   |  |
| Source Product<br>source:<br>[10] subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb_Cal_Stack_Spk v .<br>Target Product<br>Name:<br>subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb_Cal_Stack_Spk_TC | •        | Source Bands:  | Sigma0_VH_mst_05Feb2023<br>Sigma0_VV_mst_05Feb2023<br>Sigma0_VH_slv1_11Jul2023<br>Sigma0_VV_slv2_11Jul2023 |  |
| Save as: BEAM-DIMAP  |          | Digital Elevation Model:   | SRTM 1Sec HGT (Auto Download) 🗸  |  |
| Directory:   | _        | DEM Resampling Method:   | BILINEAR_INTERPOLATION ~   |  |
|  |          | Image Resampling Method:   | BILINEAR_INTERPOLATION V   |  |
| Open in SNAP   |          | Source GR Pixel Spacings (az x rg):                                    | 10.0(m) x 10.0(m)  |  |
|  |          | Pixel Spacing (m):   | 10.0   |  |
|  |          | Pixel Spacing (deg):   | 8.983152841195215E-5   |  |
|  |          | Map Projection:  | WGS84(DD)  |  |
|  |          | Mask out areas without elevation Output complex data Output bands for: |  |  |
|  |          |  |  |  |
|  |          | Incidence angle from ellipsoid   | Local incidence angle Projected local incidence angle  |  |
|  |          | Layover Shadow Mask  |  |  |
|  |          | Apply radiometric normalization  |  |  |
|  |          | Save Sigma0 band   | Use projected local incidence angle from DEM $\qquad \bigtriangledown$                                     |  |
|  |          | Save Gamma0 band   | Use projected local incidence angle from DEM $\qquad \bigtriangledown$                                     |  |
|  |          | Save Beta0 band  |  |  |
|  |          | Auxiliary File (ASAR only):  | Latest Auxiliary File  |  |
|  |          |  |  |  |
| Run Clo  | ose      | L  | Run Close  |  |

### Geocoded image product after Terrain Correction







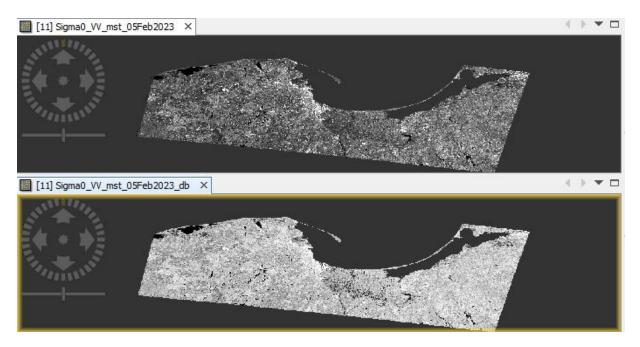


#### Conversion to dB scale

Sigma0\_VV values typically fall within the range of 0 to 1, with mean backscatter values of 0.07 (VV) and 0.02 (VH). This indicates a prevalence of dark pixels and a scarcity of bright pixels with higher values, resulting in diminished visual contrasts from a statistical perspective.

To rectify this and achieve a more standardized distribution of values, the logarithmic function is applied to the radar image. This transformation converts pixel values into a logarithmic scale, enhancing contrasts by shifting brighter values towards the mean while expanding the range of darker values (as depicted in Figure 18, on the right). The calibrated dB data typically spans from approximately -35 to +10 dB.

To execute this transformation, right-click on each of the four terraincorrected bands and choose **Linear to/from dB**. Confirm by selecting Yes to generate a virtual band, denoted by the symbol and the "\_db" suffix. These virtual bands are not physically stored on the hard drive but can still be displayed based on the underlying mathematical expression.



Sigma0 VV before (top) and after (bottom) conversion to dB scale







#### Unsupervised classification

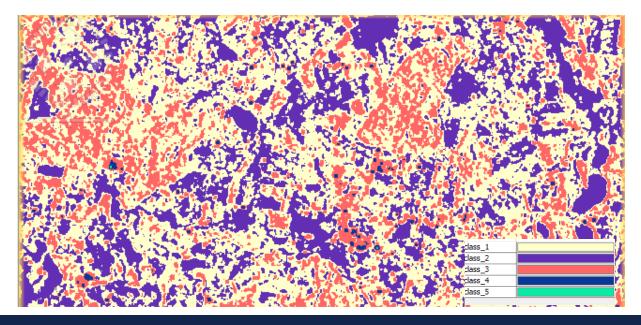
An unsupervised classification serves as an effective method for identifying and grouping pixels that share similar characteristics.

To initiate the K-Means Cluster Analysis, navigate to **Raster > Classification > Unsupervised Classification** and select the terraincorrected stack as the input product. In the second tab, specify the number of clusters as e.g. 5, choose all dB bands as the source bands, and confirm by clicking Run. This process may take several minutes as the classifier iterates 30 times, utilizing random cluster centers within the multi-dimensional feature space to identify pixels with similar properties.

| 🞇 K-Means Cluster Analysis  | X 🛛 🞇 K-Means Cluste   | r Analysis X   |
|---|------------------------|--|
| File Help   | File Help              |  |
| I/O Parameters Processing Parameters  | I/O Parameters Pro     | ocessing Parameters  |
| Source Product<br>Source product:   | Number of clusters:    | 10   |
| [11] subset_0_of_S1A_IW_GRDH_1SDV_20230205T050029_Orb_Cal_Stack_Spk_TC v  | . Number of iterations | 30   |
|   | Random seed:           | 31415  |
| Target Product Name: subset_0_of_S1A_JW_GRDH_1SDV_20230205T050029_Orb_Cal_Stack_Spk_TC_kmeans  Save.as; DEAM-DIMAP Directory: Z:\Pracovnicl\pnacliova\ESA_ENEUM | Source band names      | Sigma0_VH_mst_05Feb2023<br>Sigma0_VV_mst_05Feb2023<br>Sigma0_VH_slv1_11Jul2023<br>Sigma0_VH_slv2_11Jul2023<br>Sigma0_VH_mst_05Feb2023_db<br>Sigma0_VH_slv1_11Jul2023_db<br>Sigma0_VV_slv2_11Jul2023_db |
| Open in SNAP  | ROI-mask:              | ×  |
| Run Close   | ie                     | Run Close  |

The output is a product with a single band (class indices), where each pixel is assigned to one of the 5 dusters. While these dusters may not directly represent semantic land cover classes, they exhibit homogeneity in terms of their backscatter characteristics.

Double click to open the "class\_indices" band under Bands folder. Zoom into the area and explore the most frequent classes and their distribution.









As depicted in Figure, you can utilize the Color Manipulation tab to allocate colors and even labels to these clusters, enabling you to assess how well they align with general land use and land cover classifications.

Navigation - [12] class indices Colour Manipulation - [12] class indices × World

| Label   | Colour | Value | Frequency | Description        |
|---------|--------|-------|-----------|--------------------|
| dass_1  |        | 0     | 53.205%   | Cluster 0, Center. |
| dass_2  |        | 1     | 29.475%   | Cluster 1, Center  |
| dass_3  |        | 2     | 16.913%   | Cluster 2, Center  |
| dass_4  |        | 3     | 0.397%    | Cluster 3, Center. |
| class_5 |        | 4     | 0.010%    | Cluster 4, Center  |

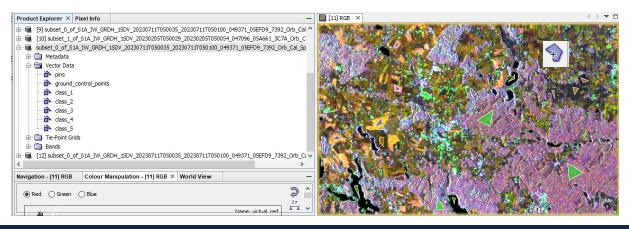
The benefit of employing an unsupervised classification lies in its independence from prior knowledge about the study area or the data, yet it effectively groups pixels with similar traits. However, the drawback is that the usefulness of the result heavily depends on the chosen number of classes. As illustrated in the example, water is segmented into five distinct classes (3-7), whereas urban areas are consolidated into a single class (8). If there is overlap between classes, it may be necessary to opt for a higher number of clusters and then merge them afterward. Conversely, having too many classes can complicate the identification of patterns within the data.

### Supervised classification

Now, we will perform the one type of supervised classification – Random forest classification. For this we will create some training data by identifying polygons containing the different land cover types:

- Select the last subset product by dicking on it. Navigate to Vector > New Vector Data Container.
- Create new data containers e.g. for 5 different classes.
- Start with creating the data container for, e.g. "class1".Click OK.

The newly created vector data container should appear under "Vector Data" in the Product Explorer. Now let's start creating training polygons for these different containers on ice type using the Polygon drawing tool:







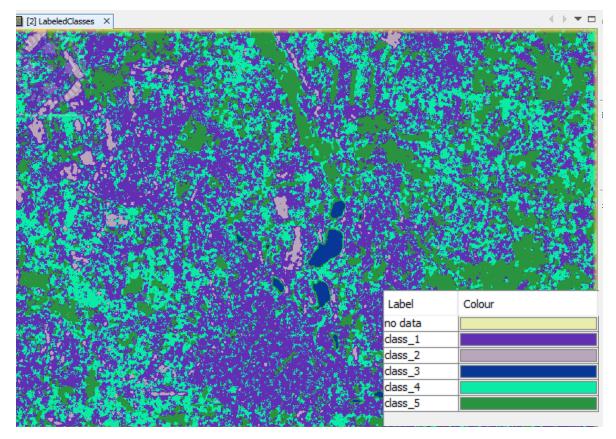
#### Random forest classifier

Navigate to Raster > Classification > Supervised classification >Random Forest classifier

- In the Random-Forest-Classifier select the all Training vectors that we have created.
- Select at least two Feature bands (poalrisations)
- Click on RUN.

The output final product should be now opened in the Product Explorer Window. Double-click on the "LabeledClasses" band under Bands folder to visualize it.

| ProductSet-Reader Random-            | -Forest-Classifier Write   |
|--------------------------------------|--|
| Classifier                           |  |
| Train and apply classifier           | newClassifier  |
| O Load and apply classifier          | newClassifier $\checkmark$ X   |
|                                      | Train on Raster  Train on Vectors  |
| Evaluate classifier                  |  |
| Evaluate Feature Power Set           |  |
|                                      | Min Power Set Size: 2 Max Power Set Size: 7                                  |
| Number of training samples           | 5000   |
| Number of trees:                     | 10   |
| Vector Training                      |  |
| dass_2<br>dass_3<br>dass_4<br>dass_5 |  |
| Feature Selection                    |  |
| Sigma0_<br>Sigma0_                   | VH_mst_113ul2023<br>VY_mst_113ul2023<br>VH_sk1_05Feb2023<br>VY_sk2_05Feb2023 |
|                                      |  |
|                                      |  |



Compare the results of supervised and unsupervised classification.

For more information, see the lecture: <u>2. SAR remote sensing for land</u> applications 1 – SAR basics

# THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 3 – TUTORIAL

SAR for Land Applications 2 – Interferometric SAR data processing, using SNAP software





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# 1 | Exercise outline

In this exercise, we will:

- Learn how to retrieve Digital elevation model (DEM)
- Perform necessary data processing for making an interferogram
- Understand the information content in SAR interferometric images

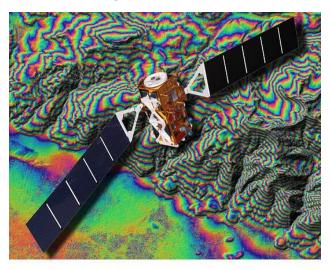




# 2 | Background

#### Deformation Mapping and Change Detection using Sentinel-1 data

Satellites constantly monitor Earth from space, providing vital data essential for rapid land cover change assessment and disaster management. The radar on board the Copernicus Sentinel-1 mission can detect ground conditions and penetrate clouds, functioning day and night.



DEM generation with Sentinel-1 data offers a powerful method for deriving accurate and detailed elevation information over large areas, especially in regions with limited ground survey data or challenging terrain conditions.

DEM generation with Sentinel-1 data involves acquiring pairs of SAR images, processing them into interferograms, unwrapping the interferometric phase to obtain absolute phase values, removing the topographic phase contribution, converting the corrected phase into elevation values using appropriate algorithms, assessing the quality of the generated DEM, refining it if necessary, validating the accuracy, and utilizing the DEM for visualization and various applications such as terrain analysis and environmental monitoring.

Sentinel-1 derived DEMs find applications in topographic mapping, hydrological modeling for water flow and flood risk assessment, environmental monitoring for changes like erosion and landslides, natural resource management for agriculture and forestry, disaster management for assessing terrain accessibility and planning evacuation routes, infrastructure planning for designing roads and bridges, dimate change studies for analyzing impacts on coastal erosion and glacier retreat, and remote sensing applications including orthorectification and 3D visualization.

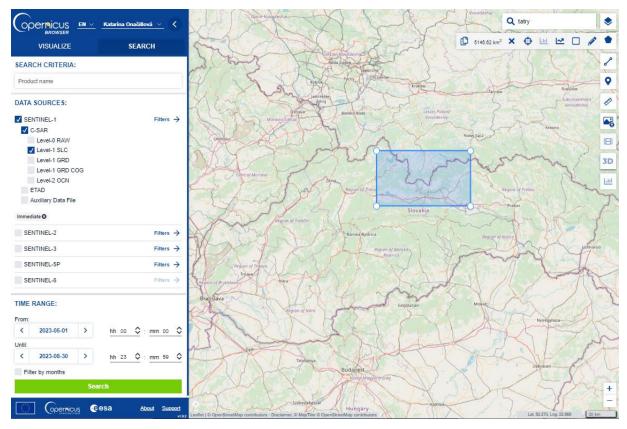






### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 SLC images of the same area for High Tatras, Slovakia, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



To ensure successful DEM generation, selecting image pairs with specific properties is crucial. These include:

• A short **temporal baseline**, minimizing the time between acquisitions to reduce temporal decorrelation risks, particularly over changing surfaces like vegetation or water areas. Sentinel-1 radar (C-band) is susceptible to decorrelation, especially over vegetation, so image pairs with minimal vegetation cover are preferable.

• A suitable **perpendicular baseline**, ideally between 150 and 300 meters, to capture topographic variations effectively through parallax-like effects. Smaller baselines may not produce pronounced topographic effects, while larger ones can lead to decorrelation.

• Consideration of the primary mission focus of Sentinel-1 for deformation retrieval rather than DEM generation, resulting in predominantly short baselines below 30 meters. Finding image pairs with short temporal and large perpendicular baselines can be challenging.

• Ensuring **suitable atmospheric conditions**, avoiding images acquired during rainy periods or with high water vapor content in the atmosphere to minimize phase delays and maintain measurement quality.







### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products by double click on the zipped folders. The opened products will appear in Product Explorer window.

S1A\_IW\_SLC\_\_1SDV\_20230721T162703\_20230721T162731\_049524\_05F481\_08D0.SAFE.zip S1A\_IW\_SLC\_\_1SDV\_20230802T162703\_20230802T162731\_049699\_05F9EC\_E68C.SAFE.zip

To access the information within the product, double-click on it to reveal the directories, which include:

- Metadata: containing parameters pertaining to orbit and data.
- Tie Point Grids: providing interpolation data for latitude/longitude, incidence angle, etc.
- Quicklooks: presenting a visible image of the entire scene in radar coordinates.
- Bands: consisting of complex values for each subswath "i" and "q", along with intensity

Select intensity image for swath IW1 VV – double click on it to View it Note: Each SAR image is flipped north—south it maintains the same orientation as its acquisition (in this case, ascending track).

#### Check baseline information

As previously mentioned, the quality of DEM generation relies heavily on the characteristics of the satellite images, particularly the spatial acquisition, of the satellites during termed the arrangement perpendicular baseline. A larger perpendicular baseline yields more detailed interferograms, enhancing the representation of elevation changes. For instance, a perpendicular baseline of 151 meters, as illustrated in Figure 8, produces denser fringe patterns, facilitating better terrain change description compared to baselines of 67 meters or 27 meters.

The time interval between the first and second images, known as the temporal baseline, also significantly impacts interferogram quality. Shorter temporal baselines, ideally around 6 or 12 days for Sentinel-1 data, minimize phase decorrelation issues, particularly over natural surfaces. As illustrated in Figure 9, longer temporal baselines result in poorer interferogram quality, particularly over areas with natural surfaces, where reliable height information cannot be extracted. If such areas dominate the interferogram, DEM extraction becomes unfeasible.

To examine the baseline details of your image pair, navigate to Radar > Interferometric > InSAR Stack Overview.





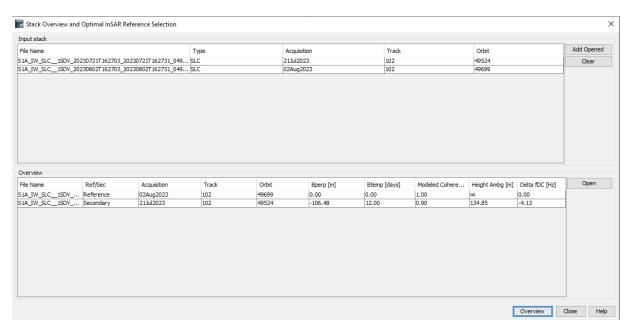


Initially, select "Add Opened" to import the two Sentinel-1 products into the list above, where their acquisition date, track, and orbit information should appear.

Next, click on "Overview" to access their metadata.

In the lower list, you'll find details such as:

- the perpendicular baseline (Bperp) in meters,
- the temporal baseline (Btemp) in days,
- the modelled coherence ranging from 0 to 1,
- the height ambiguity indicating the height difference represented by one color cycle in the interferogram,
- the mean Doppler centroid frequency difference.



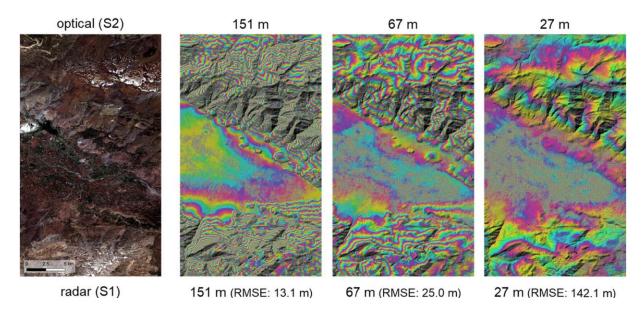


Figure: Effect of the perpendicular baseline on the interferogram (Braun 2021)







#### 2.3 Coregistration

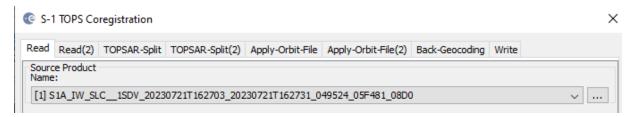
To utilize the phase difference between the acquisitions, it is necessary to initially construct a stack comprising both products. Image coregistration makes use of image statistics to align both products at sub-pixel accuracy. While orbit state vectors alone can suffice to coregister images, for precise offset tracking, additional data from a digital elevation model (DEM) is necessary to enhance coregistration accuracy.

Navigate to Main Menu – Radar – Coregistration – S1 TOPS Coregistration -S1 TOPS Coregistration

In the Read tab, select the 20230721 SLC product and in the Read(2) tab select the 20230802 SLC product

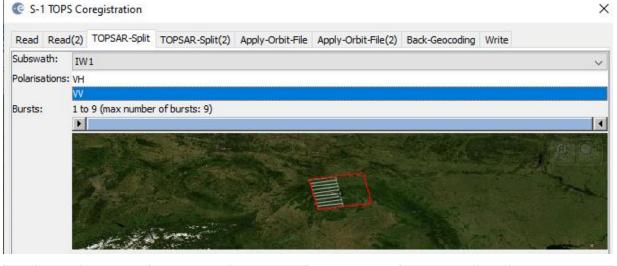
In TOPSAR-Split and TOPSAR-Split(2) tabs select Subswath: IW1 Polarizations:VV

In the Apply Orbit File and Apply Orbit File(2) tabs select leave default parameters and uncheck "Do not fail if new orbit is not found" option



Read (2) TOPSAR-Split TOPSAR-Split(2) Apply-Orbit-File Apply-Orbit-File(2) Back-Geocoding Write

| Source Product<br>Name:   |   |  |
|---|---|--|
| [2] S1A_IW_SLC1SDV_20230802T162703_20230802T162731_049699_05F9EC_E68C | ~ |  |



Read Read(2) TOPSAR-Split TOPSAR-Split(2) Apply-Orbit-File Apply-Orbit-File(2) Back-Geocoding Write

| Orbit State Vectors:                       | Sentinel Precise (Auto Download) 🗸 |  |  |  |
|--|------------------------------------|--|--|--|
| Polynomial Degree:                         | 3                                  |  |  |  |
| Do not fail if new orbit file is not found |                                    |  |  |  |







In the Back-Geocoding select SRTM 1Sec HGT (AutoDownload) In the Write tab, select the directory to save your processing outputs

Note: SRTM data is accessible only within the latitudinal range of 60° North to 54° South. If your area falls outside this coverage, alternative DEMs with AutoDownload functionality can be utilized, or an external DEM stored as a GeoTiff and projected in geographic coordinates/WGS84 can be employed.

|                                  | SAR-Spiit(2) | Apply-Orbit-File | Apply-Orbit-File(2) | Back-Geocoding | Write |
|----------------------------------|--------------|------------------|---------------------|----------------|-------|
| ital Elevation Model:            | SRTM 1Sec    | HGT (Auto Downl  | oad)                |                |       |
| M Resampling Method:             | BILINEAR_    | INTERPOLATION    |                     |                |       |
| sampling Type:                   | BILINEAR_    | INTERPOLATION    |                     |                |       |
| Mask out areas with no elevation |              |                  |                     |                |       |
| ] Output Deramp and Demod Phase  |              |                  |                     |                |       |
| Disable Reramp                   |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  |              |                  |                     |                |       |
|                                  | A.           | Save 🕐           | Help 🕞 Run          |                |       |

Once coregistration is finalized, it is recommended to visually inspect the stack's quality. This can be achieved through an RGB representation of the reference and secondary products, indicating if the images are appropriately aligned:

Right-click on the output coregistrated product – Open RGB Image Window

Choose the reference for red and green channels, and the secondary image for the blue channel.Click OK.

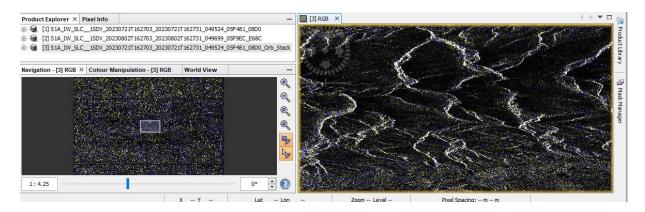
GEOG

| 🎇 Selec  | t RGB-Image Channels                               | ×              |
|----------|--|----------------|
| Profile: |  |                |
|          | ~ 🚭  |                |
| Red:     | \$3.Intensity_IW1_VV_mst_21Jul2023                 | ~              |
|          | fixed range min                                    | max            |
| Green:   | \$3.Intensity_IW1_VV_mst_21Jul2023                 | ~              |
|          | fixed range min                                    | max            |
| Blue:    | \$3.Intensity_IW1_VV_slv1_02Aug2023                | ~              |
|          | fixed range min                                    | max            |
|          | Expressi   | ions are valid |
| Stor     | e RGB channels as virtual bands in current product |                |
|          |  |                |
|          | OK Cancel  | Help           |





Zoom into a region with contrasting surfaces, such as the boundary between land and water. The RGB image should be dear and sharp, without being overly influenced by one of the images (e.g., appearing yellow for the reference or blue for the secondary image). The only acceptable exceptions are changes in land cover or scattering mechanisms which occurred in the time between the image acquisitions.



#### 2.4 Forming a Raw Interferogram

The next phase of interferometry involves generating an interferogram using the coregistered SLC images. To do this, follow these steps:

From the main menu bar, go to Radar – Interferometric - Products and finally select Interferogram Formation.

In the I/O Parameters tab, choose the "Orb\_Stack" product that was generated during the coregistration process.

By default, the output target is set to the same directory and appends "ifg" to the filename.

For standard processing, there's no need to modify the defaults in the Processing Parameters tab.

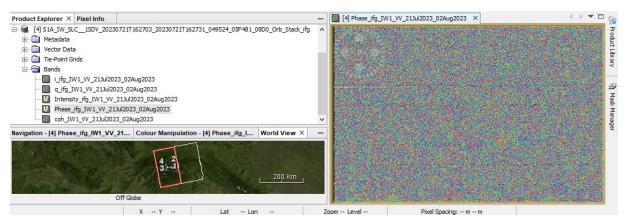
| 📀 Interferogram Formation   | ×    | Interferogram Formation                  | ×                             |
|---|------|--|-------------------------------|
| File Help   |      | File Help                                |                               |
| I/O Parameters Processing Parameters  |      | I/O Parameters Processing Parameters     | ]                             |
| Source Product  |      | Subtract flat-earth phase                |                               |
| Source product:   | _    | Degree of "Flat Earth" polynomial        | 5 🗸                           |
| [3] S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack ~ |      | Number of "Flat Earth" estimation points | 501 🗸                         |
|   |      | Orbit interpolation degree               | 3 ~                           |
| Target Product  |      | Subtract topographic phase               |                               |
|   | - 11 | Digital Elevation Model:                 | SRTM 3Sec (Auto Download) 🗸 🗸 |
| S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_0rb_Stack_ifg   | - 11 | Tile Extension [%]                       | 100 🗸                         |
| Bave as: BEAM-DIMAP   |      | Output Elevation                         |                               |
|   |      | Output Orthorectified Lat/Lon            |                               |
| C:\Users\Onačilová\S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_flt_ML       |      | ☐ Include coherence estimation           |                               |
| Open in SNAP  |      | Square Pixel                             | Independent Window Sizes      |
|   |      | Coherence Range Window Size              | <u> </u>                      |
|   |      | Coherence Azimuth Window Size            | 10                            |
|   |      | Concretice Azind at Wildow Size          | 3                             |
|   |      |  |                               |
| Run Cla   | se   |  | Run Close                     |
|   |      |  |                               |







Raw Interferogram — Phase Image should appear int he View tab.



The interferogram is displayed in a rainbow color scale ranging from topography, atmosphere and potential surface deformation (considered zero). The patterns, also called fringes appear in an interferogram as cycles of arbitrary colors, with each cycle representing half the sensor's wavelength.

#### 2.5 TOPS Debursting

The next stage in interferometry using Sentinel-1 TOPS mode (IWS) data involves "debursting" or merging the bursts to remove the seamlines, a step not required with Sentinel-1 or other stripmap SAR data.

To perform debursting, follow these steps:

From the main menu bar, navigate to Radar, then Sentinel-1 TOPS, and finally S-1 TOPS deburst.

In the I/O Parameters tab, choose the "Orb\_Stack\_ifg" product generated during the interferogram formation process. By default, the output appends "deb" to the filename.

There is no need to make changes in the Processing Parameters tab.

| 🕼 S-1 TOPS Deburst   | ×    | C S-1 TOPS Deburst                                     | ×  |
|--|------|--|----|
| File Help  |      | File Help  |    |
| I/O Parameters Processing Parameters Source Product  |      | I/O Parameters Processing Parameters Polarisations: VV |    |
| source:<br>[4] S1A_JW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg v |      |  |    |
| Target Product   |      |  |    |
| Name:  |      |  |    |
| S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg_deb              |      |  |    |
| Save as: BEAM-DIMAP  |      |  |    |
| Directory:   |      |  |    |
| C:\Users\Onačillová\S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML                     |      |  |    |
| Open in SNAP   |      |  |    |
|  |      |  |    |
|  |      |  |    |
|  |      |  |    |
| Run C  | lose | Run Clo  | se |





#### 2.6 Goldstein Phase Filtering

There are two methods to minimize noise in the interferogram: filtering and multi-looking. While our standard procedure involves applying filtering initially, it's also possible to opt for multi-looking first.

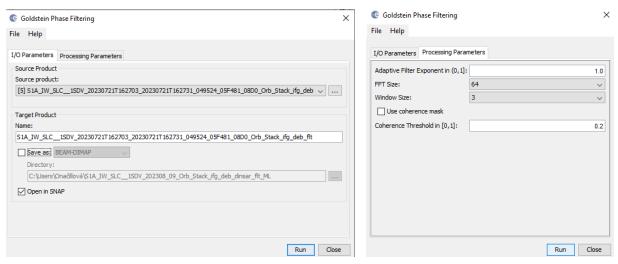
To begin filtering:

Go to Radar, then Interferometric, then Filtering, and select Goldstein Phase Filtering from the top main menu bar.

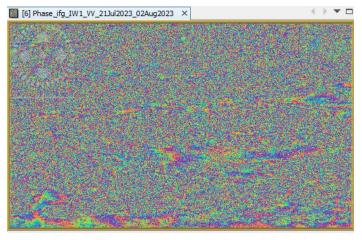
In the I/O Parameters tab, choose the "deb" product generated in the previous step.

By default, the output name includes "flt."

There's no necessity to adjust the default settings in the Processing Parameters tab for basic processing.



Double-click on the output raster in the Bands folder of the new product to see the result.



#### Create subset (optional)

In the earlier stages of processing, empty pixels along the interferogram's perimeter may have been created, particularly in regions not overlapped by both input images. To remove these sections, employ the Subset function found under Raster. This approach will also decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.







### 2.7 Phase Unwrapping

Unwrapping in SNAP follows three distinct steps:

- **1. Export of the wrapped phase** (and definition of the parameters)
- **2. Unwrapping of the phase** (performed outside SNAP by snaphu)
- 3. Import of the unwrapped phase back into SNAP

#### Export of the wrapped phase

Export your interferogram or your subset interferogram from Sentinel-1 Toolbox to SNAPHU:

From the top main menu bar, navigate to **Radar > Interferometric > Unwrapping > Snaphu Export:** 

In the Snaphu Export window:

In Read tab, select the product created in the previous step

In Snaphu Export tab, you also need to specify a target folder for exported files. Create a new target folder for this step by entering a path and new folder name (e.g. "snaphu\_export). If the selection of the directory does not work, simply copy and paste the path of your working directory into the text field.

In Snaphu Export tab, select TOPO as Statistical-cost mode and select 200 pixels for Row Overlap and Column Overlap if you want to multilook. Depending on the number of processors of your computer, you can also increase the Number of Processors variable.

Select MCF.

Click Run to create the SNAPHU\_Export file

The folder now holds files used for phase unwrapping: the coherence image (\*.img) and metadata (\*.hdr), the wrapped phase: image (\*.img) and metadata (\*.hdr), the unwrapped phase: only the metadata (\*.hdr), because the image (\*.img) is first to be created by snaphu in the next step, a configuration file (snaphu.conf) containing the parameters defined in the export operator

| C Snaphu Export   | X C Snaphu Export ×   |
|---|---|
| Read SnaphuExport   | Read SnaphuExport   |
| Source Product<br>Name:   | Target folder: C:\Users\Onačilová\snaphu_15_02                                  |
| [6] S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg_deb_fit views | Statistical-cost mode: TOPO v   |
| Data Format: Any Format 🗸   | Initial method:         MCF         V           Number of Tile Rows:         10 |
| Advanced options  | Number of Tile Kows: 10 Number of Tile Columns: 10                              |
| Advanced options  | Number of Processors: 4   |
|   | Row Overlap: 200  |
|   | Column Overlap: 200   |
|   | Tile Cost Threshold: 500  |
|   |   |
|   |   |
|   |   |
|   |   |
|   |   |
|   |   |
|   | 🔠 Save 🕡 Help 🕞 Run   |
| Error: [NodeId: SnaphuExport] Please add a target folder  | Computing raster data 1% Cancel   |
| Save 🕢 Help   | 1% Cancel   |





#### Unwrapping of the phase

You should see the wrapped interferogram phase "Phase\_ifg\*.img", coherence "coh\_\*.img", and a "snaphu.conf" file.

For the next step, you will need to instal SNAPHU in Windows. SNAPHU is a tool for phase unwrapping of interferometric information. To use it as an executable file (\*.exe) in Windows it has to be compiled first so all required drivers (\*.dll) are installed correctly. Follow the steps for installation here: file:///C:/Users/Ona%C4%8Dillov%C3%A1/Downloads/Installation\_SNAPHU\_English\_ABraun.pdf

To start unwrapping, check the location of the interferogram exported from SNAP. If snaphu.exe is not in your system's PATH variable: Copy it in there as well. It is recommended to store the data and snaphu on the same disk. Open Command Window Here.

Type snaphu and hit Enter. The help menu should be displayed.

| 🔤 Príkazový riadok   |  | _ | × |
|--|--|---|---|
| C:\Users\Onačillo  | vá>snaphu                                      |   |   |
| snaphu v1.4.2  |  |   |   |
| usage: snaphu [o   | ptions] infile linelength [options]            |   |   |
| most common optio  | ns:  |   |   |
| -t   | use topography mode costs (default)            |   |   |
| - d  | use deformation mode costs                     |   |   |
| - S  | use smooth-solution mode costs                 |   |   |
| -f <filename></filename>   | read configuration parameters from file        |   |   |
| -o <filename></filename>   | write output to file                           |   |   |
| -a <filename≻< td=""><td>read amplitude data from file</td><td></td><td></td></filename≻<>   | read amplitude data from file                  |   |   |
| -c <filename≻< td=""><td>read correlation data from file</td><td></td><td></td></filename≻<> | read correlation data from file                |   |   |
| -b <decimal></decimal>   | perpendicular baseline (meters)                |   |   |
| -i   | do initialization and exit                     |   |   |
| -l <filename></filename>   | log runtime parameters to file                 |   |   |
| - V  | give verbose output                            |   |   |
| mst  | use MST algorithm for initialization (default) |   |   |
| mcf  | use MCF algorithm for initialization           |   |   |
|  |  |   |   |
| type snaphu -h fo  | r a complete list of options                   |   |   |
|  |  |   |   |

The command to start the unwrapping is shown in the file snaphu.conf. Open it with a text editor. The beginning of the "snaphu.conf" file shows the command to call Snaphu

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PAVLA JOZEFA ŠAFÁRIKA



TAV GEOGRAFIE

C:\Users\Onačillová>snaphu -f snaphu.conf Phase\_ifg\_IW1\_VV\_21Jul2023\_02Aug2023.snaphu.img 22957 snaphu v1.4.2 27 parameters input from file snaphu.conf (84 lines total) Logging run-time parameters to file snaphu.log Creating temporary directory snaphu\_tiles\_6272 Unwrapping tile at row 0, column 0 (pid 4340) Unwrapping tile at row 0, column 1 (pid 2800) Unwrapping tile at row 0, column 2 (pid 6940) Unwrapping tile at row 0, column 3 (pid 4268)

The Snaphu program can take a long time to run. At the end it writes **unwrapped phase to "Unw\_ifg\*.img" file** 

#### Import of the unwrapped phase

Now, we import the unwrapped phase. From the top main menu bar, select Radar > Interferometric > Unwrapping, and then Snaphu Import that converts it back into the BEAM DIMAP format and adds the required.

Read-Phase: should be set to the wrapped product that you exported(before the export)

Read-Unwrapped-Phase: select the unwrapped phase product: Navigate to folder where you exported for Snaphu. Select the "UnwPhase\_ifg\*.snaphu.hdr" file. Note: The error message will then vanish if you proceed to the next tab.

SnaphuImport: Leave the option "Do NOT save Wrapped interferogram in the target product"

unchecked, because it is required in the later step.

Write: To store the imported unwrapped band in a separate product (recommended), add `\_unw' to the end of the output name and click Run.

| C Snaphu Import  | X C Snaphu Import X  |
|--|--|
| Advanced options   | 1Read Phase 2Read Universapped Phase 3-Snaphulimport 4-Write   |
| 1-Read-Phase     2-Read-Univrapped-Phase     3-Snaphulimport     4-Write       Source Product<br>Name:   | Name:           S1A_IV_SLC_1SDV_20230721T162703_00230721T162731_049524_05F481_0800_0rb_Stack_ifg_deb_fit           Save as:         BEAMOUMAP           Directory:         C: Likers\Onačllová\(\$1A_JW_SLC_1SDV_202308_09_0rb_Stack_ifg_deb_dinser_fit_ML |
| Snaphu Import     Snaphu Import     Aread-Phase     Z-Read-Univrapped Phase     3-SnaphuImport     4-Write     Do NOT save Wrapped interferogram in the target product | X<br>Save Run  |

Finally, a new product is added to the Product Explorer which contains the the unwrapped phase that we can display.

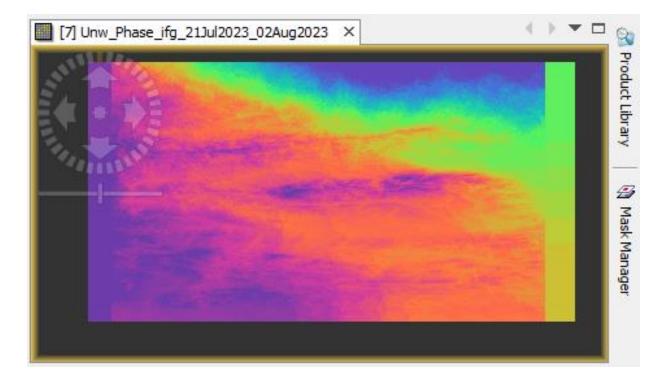






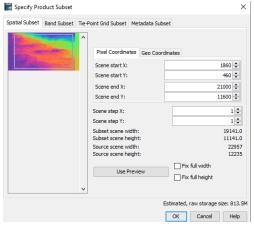
Select the Unw\_Phase\_ifg band. Double click on this unwrapped phase to see if the unwrapping was successful. It should be a smooth raster with little variation except for the areas of expected deformation.

All fringe patterns are summarized to absolute changes. Go to the Colour Manipulation tab and select "100%" to stretch color scale to full range of unwrapped data. Unwrapped phase is still in radians. Phase is reference image minus coregistered image. If reference image is earlier, then negative phase is land moving toward satellite (negative range change)



#### Create subset (optional)

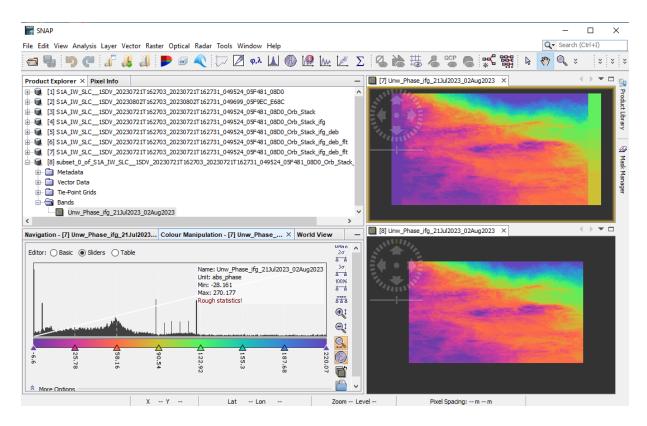
In the earlier stages of processing, empty pixels along the interferogram's perimeter may have been created, particularly in regions not overlapped by both input images. To remove these sections, employ the Subset function found under Raster. This approach will also decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.











#### 2.8 Phase to elevation

The unwrapped phase data is now a continuous raster, but it has not yet been converted into a metric measure. To achieve this conversion from radian units to absolute heights, the Phase to Elevation operator, found under **Radar > Interferometric > Products**, is employed. This operator translates the phase values into surface elevations along the line-of-sight (LOS) in meters. The LOS represents the direct line between the sensor and a specific pixel. To ensure accuracy, a Digital Elevation Model (DEM) is utilized to align the elevation values correctly.

The I/O Parameters tab should be set to the last subset unwrapped product

Default for target product name is to add " dem" to the name

Navigate to the Processing Parameters tab and select SRTM 1Sec HGT (AutoDownload) as the input DEM.

| PhaseToElevation DEM Generation     X   | PhaseToElevation DEM Generation                        |
|---|--|
| File Help   | File Help  |
|   |  |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameters                   |
| Source Product  | Digital Elevation Model: SRTM 1Sec HGT (Auto Download) |
| source:   | DEM Resampling Method: BILINEAR_INTERPOLATION          |
| [8] subset_0_of_S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_orb_Stack_ifg_deb v   |  |
| Target Product  |  |
| Name:   |  |
| subset_0_of_S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg_deb_flt_dem |  |
| Save as: BEAM-DIMAP   |  |
| Directory:  |  |
| C:\Users\Onačilová\S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML                             |  |
| Open in SNAP  |  |
|   |  |
|   |  |
|   |  |
| Run Close   | Run Close  |
| Run Cose  |  |

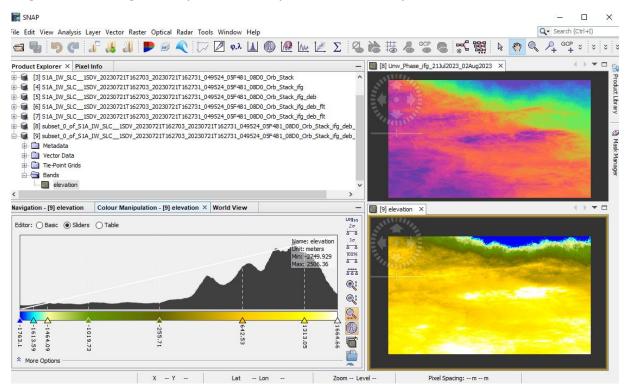




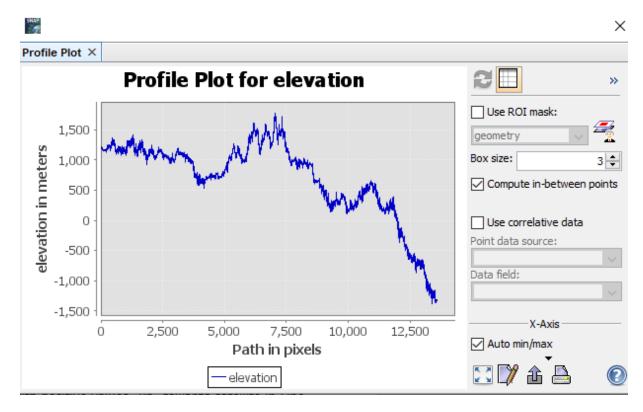


Now, we can display elevation result. Again, better to stretch colors. Displacements is now in meters.

Sign was changed so positive displacement is "up" towards satellite



## Profile plot









#### 2.9 Terrain Correction

SNAP calls geocoding with topography "Terrain Correction." From the top main menu bar, select Radar, then Geometric, then Terrain Correction, and then Range-Doppler Terrain Correction.

The I/O Parameters tab should be set to the last elevation product Default for target product name is to add "\_TC" to the name

| 📀 Range Doppler Terrain Correction  | ×   |
|---|-----|
| File Help   |     |
| I/O Decomptore Decision   |     |
| I/O Parameters Processing Parameters  |     |
| Source Product  |     |
| source:   | _ ! |
| [9] subset_0_of_S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg_deb_fit_dem v | ••  |
|   |     |
| Target Product  |     |
| Name:   |     |
| subset_0_of_S1A_IW_SLC1SDV_20230721T162703_20230721T162731_049524_05F481_08D0_Orb_Stack_ifg_deb_flt_dem_TC    |     |

Under Processing Parameters tab, select the elevation band as the input Select SRTM 1Sec HGT (AutoDownload) as input DEM.

If you want to export the data as a KMZ file to view it in Google Earth, WGS84 must be selected as Map Projection (latitude and longitude).

If you want to compare the quality of the InSAR DEM, you can select DEM as a further output.

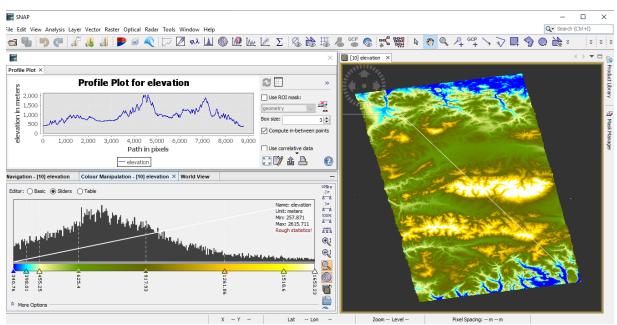
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | >           >           >                   |
|--|---|
| RTM ISec HGT (Auto Download)            LINEAR_INTERPOLATION            93339(m) x 4. 1900-8092086498(m)            .93339         25165771965981E-4           WGS84(DD) | ~   |
| RTM ISec HGT (Auto Download)            LINEAR_INTERPOLATION            93339(m) x 4. 1900-8092086498(m)            .93339         25165771965981E-4           WGS84(DD) | ~   |
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | ~   |
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | ~   |
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | ~   |
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | ~   |
| LINEAR_INTERPOLATION LINEAR_INTERPOLATION .93339(m) x 4. 190048092086498(m) .93339 25165771965981E-4 WGS84(DD)   | ~   |
| LINEAR_INTERPOLATION   |   |
| .93339(m) x 4. 190048092086498(m)<br>.93339<br>25165771965981E-4<br>WGS84(DD)  | ~   |
| .93339<br>25165771965981E-4<br>WGS84(DD)   |   |
| 25165771965981E-4<br>WGS84(DD)   |   |
| WGS84(DD)  | -   |
|  | _   |
| Output complex data  |   |
| Jourput complex data   |   |
| EM Latitude & Longitude  |   |
| ocal incidence angle Projected local incidence angle   |   |
|  |   |
|  |   |
| se projected local incidence angle from DEM  |   |
|  |   |
| se projected local inductice angle in on plan  |   |
| tect Auviliary File  |   |
| Incorrection 7.1 lic   |   |
|  | se projected local incidence angle from DEM |

•eesa





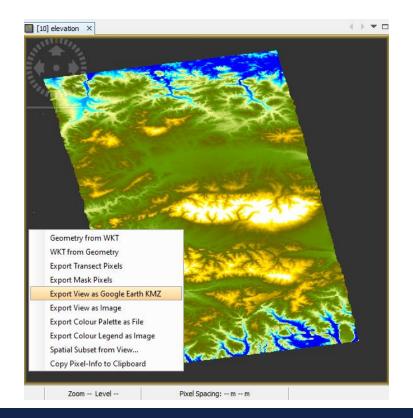
Now, double-click on the "elevation" raster to display the geocoded elevation raster output. Product is now evenly spaced in latitude and longitude and shows the elevation for the study area. You can create profile to see the elevation diversity.



### 2.10 Export .kmz to Google Earth

Geocoded products (projected to WGS84) can be exported as a KMZ file to view in Google Earth (Pro):

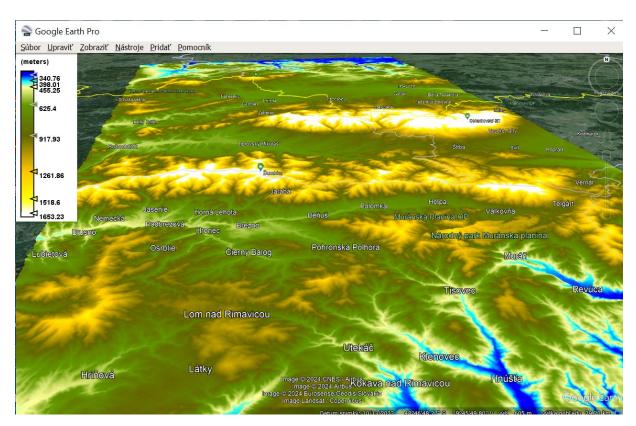
Select an appropriate color scale and color ramp from the Color Manipulation tab. dick Right on the elevation raster in the View tab (or navigate to File > Export > Other > View As Google Earth KMZ) Choose a directory to save the output .kmz and provide a fitting filename, then confirm with Save.







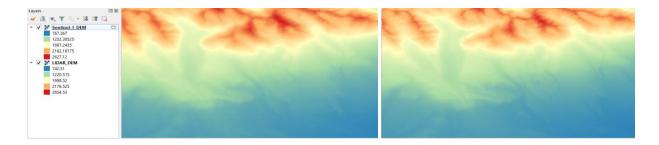
Open the resulting KMZ file in Google Earth to observe the elevation patterns overlaid on the satellite image base map.



### Compare with LiDAR-derived DEM

Compare your Sentinel-1 derived DEM with Digital Elevation Model (DEM 5.0) with a resolution of 1 meter per pixel created from airborne laser scanning data by ÚGKK SR. "Source of ALS data: ÚGKK SR".

Open QGIS and comapre small LiDAR-derived DEM sample with our resulted DEM derived using Sentinel-1 data. We can observe that there are small differences in the elevation.









Comparing Sentinel-1 derived DEMs and LiDAR derived DEMs, LiDAR typically offers higher precision. This is because LiDAR directly measures the distance between the sensor and the Earth's surface using laser pulses, resulting in highly accurate elevation data. On the other hand, Sentinel-1 derived DEMs are generated using synthetic aperture radar (SAR) data, which can be affected by factors such as vegetation cover and terrain roughness, potentially leading to less precise elevation measurements compared to LiDAR. Therefore, in terms of precision, LiDAR derived DEMs are generally considered more accurate and reliable.

However, Sentinel-1 derived DEMs may be more cost-effective compared to LiDAR due to the lower cost associated with satellite data acquisition and processing. In this case, Sentinel-1 data are free of charge, available for everyone after the registration. Also, for large-scale mapping, monitoring, or areas with limited budget or accessibility, Sentinel-1 derived DEMs may be preferable.

For more information, see the lecture: <u>3. SAR remote sensing for land</u> <u>applications 2 – Introduction to Interferometric SAR</u>

# THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 4 – TUTORIAL

Forestry with Sentinel-1: Single Image Analysis and Time Series to detect forest change using SNAP software







FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

- Generate Radiometrically Terrain Corrected (RTC) Images from Sentinel-1 GRD products to monitor forest extent, structure and biomass
- Perform statistical analyses using Scatterplots, Histogram Analysis, Profile Plot etc.
- Process SAR data with SNAP using single-date and multi-temporal processing and generate time series analysis of multi-temp dataset
- Emphasize the critical role of SAR in sustainable resource management and forest conservation





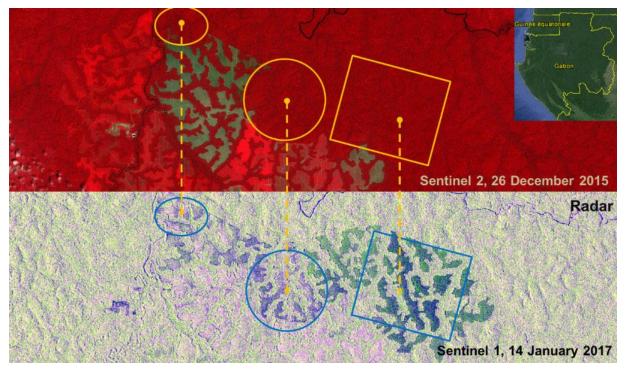
# 2 | Background

### Forestry Mapping with Sentinel-1 data

Sentinel-1 synthetic aperture radar (SAR) data presents a versatile tool for comprehensive forestry mapping and monitoring. By analyzing SAR images acquired at different times, changes in forest cover can be effectively detected, providing insights into deforestation, reforestation, and forest degradation.

Sentinel-1 has a significant potential in sustainable forest management through its ability to detect clear-cut and partial-cut areas, classify forest types, estimate biomass, and identify disturbances. Regarding climate change mitigation, the mapping of forest fire scars using Sentinel-1 data is crucial for understanding a forest's carbon history and accurately estimating carbon emissions.

Additionally, SAR data allows for the classification of various forest cover types, aiding in forest management and conservation efforts. Furthermore, SAR data offers valuable information for assessing habitat quality and carbon stocks.



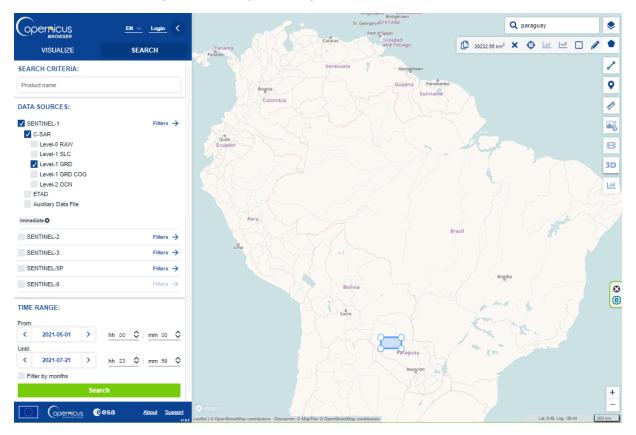
Source: https://sentinels.copernicus.eu/documents/247904/3428726/Sentinel-1-2-rubber-plantation-full.jpg





### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 GRDH images using dual polarization (VV/VH) acquired in interferometric wide swath mode for the area in Paraguay, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open one of the downloaded products by double click on the zipped folders. The opened products will appear in Product Explorer window. The Navigation and World View tabs above the preview window can help you to locate the scene.

S1B\_IW\_GRDH\_1SDV\_20210510T092747\_20210510T092812\_026840\_0334D4\_5415.SAFE

To access the information within the product, double-click on it to reveal the directories, open the Metadata folder and double click on Abstracted Metadata.

If you open one of the bands of the image by double clicking the band name, you can see also information on the pixels in the scene by opening the tab Pixel Info (next to Product Explorer) and sliding the mouse over the pixels of interest.



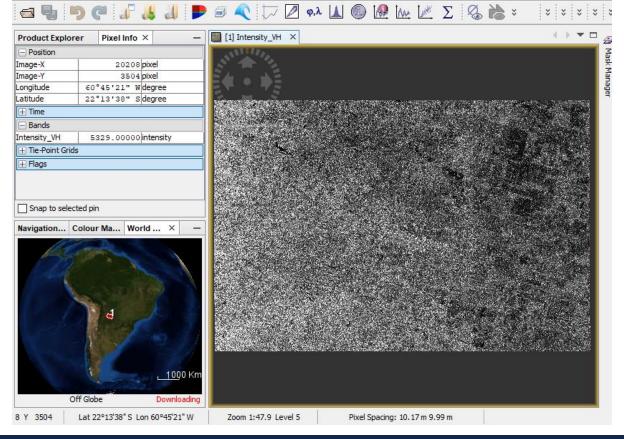




| ile Edit View Analysis Layer Vector Raster                | Optical Radar Tools Wi  | ndow Help                         |          | Q 8      | Search (Ctrl+I)                                    |
|---|-------------------------|-----------------------------------|----------|----------|--|
| ය 🖣 🦻 🦿 🖉 🎜 🖡 🗍 🖡   | ) 🗟 🔨 🏷 🖉               | φ,λ 🔝 🕼 🌆 🖾 🛛                     | Σ 🔏      | <b>*</b> | * * * *  |
| Product Explorer × Pixel Info -                           | [1] Abstracted_Metadata | ×                                 |          |          | $\longleftrightarrow \bullet \bullet \bullet \Box$ |
| □ [1] S1B_IW_GRDH_1SDV_20210510T092747                    | _ Name                  | Value                             | Туре     | Unit     | Description 👯                                      |
| 🖨 🔄 Metadata  | Orbit_State_Vectors     |                                   |          |          | ^  |
| ⊕…① Abstracted_Metadata     ⊕…① Original Product Metadata | SRGR_Coefficients       |                                   |          |          |  |
| Vector Data   | Doppler_Centroid_Coef   | ffic                              |          |          |  |
| 🕀 🛅 Tie-Point Grids                                       | Band_IW_VH              |                                   |          |          |  |
| 🗈 🛅 Quicklooks  | Band_IW_VV              |                                   |          |          |  |
| 🖮 📾 Bands   | PRODUCT                 | S1B_IW_GRDH_1SDV_20210510T092     | 25 ascii |          | Product nar  |
|   | PRODUCT_TYPE            | GRD                               | ascii    |          | Product typ  |
| Amplitude_VV  | SPH_DESCRIPTOR          | Sentinel-1 IW Level-1 GRD Product | ascii    |          | Description  |
| Intensity_VV  | MISSION                 | SENTINEL-1B                       | ascii    |          | Satellite mis                                      |
| < >>  | ACQUISITION_MODE        | IW                                | ascii    |          | Acquisition (                                      |
| lavigation Colour Ma World × –                            | antenna_pointing        | right                             | ascii    |          | Right or left                                      |
|   | BEAMS                   | -                                 | ascii    |          | Beams used   |
| 145000  | SWATH                   | -                                 | ascii    |          | Swath name   |
|   | PROC_TIME               | 10-MAY-2021 11:37:06.249409       | uint32   | utc      | Processed t  |
|   | Processing_system_ide   | nti ESA Sentinel-1 IPF 003.31     | ascii    |          | Processing :                                       |
|   | orbit_cycle             | 160                               | int32    |          | Cycle  |
| b   | REL_ORBIT               | 39                                | int32    |          | Track  |
|   | ABS_ORBIT               | 26840                             | int32    |          | Orbit  |
|   | STATE_VECTOR_TIME       | 10-MAY-2021 09:26:43.000000       | uint32   | utc      | Time of orbi                                       |
|   | VECTOR_SOURCE           | -                                 | ascii    |          | State vecto  |
| 00 Km   | incidence_near          | 30.172282790866234                | float64  | deg      |  |
| Lat -22.21Lon -61.01 Elev 18                              | incidence_far           | 45.86733632952139                 | float64  | deg      |  |

🞇 [1] Intensity\_VH - [S1B\_IW\_GRDH\_1SDV\_20210510T092747\_20210510T092812\_026840\_0334D4\_5415] - [Z:\Projekty\2023\_ESA\_ENE... - 🛛 🛛 🗙

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







Q - Search (Ctrl+I)

#### A: SINGLE-DATE ANALYSIS

#### Create a subset

There is no need to process the whole image, instead, we can reduce the loaded data to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

You can define the subset area by either zooming into the region of interest or by defining pixel or geographic coordinates. In this exercise we use the following geographic coordinates, that you can enter manually:

Navigate to Raster - Subset tab

and at Switch to "Geo Coordinates" in Spatial Subset tab

Enter the following numbers:

North latitude bound: -22.774 West longitude bound: -60.334 South latitude bound: -23.278 East longitude bound: -61.631

#### Confirm with OK.

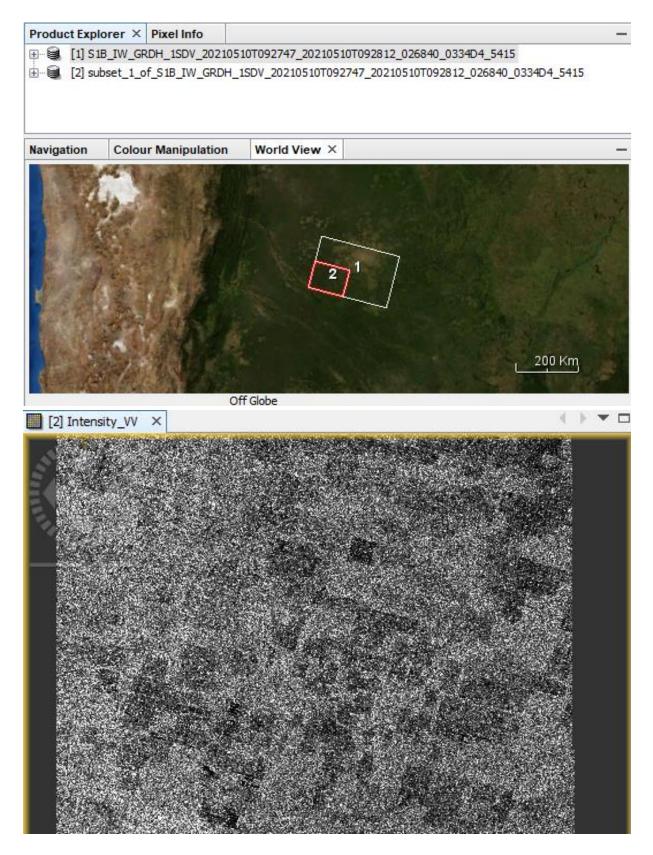
| 🞆 Specify Product Subset     |   | ×  |
|------------------------------|---|--|
| Spatial Subset Band Subset 1 | ie-Point Grid Subset Metadata Subset  |  |
|                              | <ul> <li>Pixel Coordinates Geo Coordinate</li> <li>North latitude bound:</li> <li>West longitude bound:</li> <li>South latitude bound:</li> <li>East longitude bound:</li> <li>Scene step X:</li> <li>Scene step Y:</li> <li>Subset scene width:</li> <li>Source scene width:</li> <li>Source scene height:</li> <li>Source scene height:</li> <li>Use Preview</li> </ul> | es<br>-22.774 ÷<br>-60.334 ÷<br>-23.278 ÷<br>-61.631 ÷<br>1 ÷<br>1 ÷<br>11505.0<br>8638.0<br>26030<br>16863<br>Fix full width<br>Fix full height |
|                              | Estim   | ated, raw storage size: 379.1  |







The new subset will appear in your Product Explorer window. You can open one of its bands by double-click on the selected band if you expand Bands folder within the product.







### Apply orbit file

- Navigate to Main Menu Radar Apply orbit file
- In the I/O Parameters tab, select the subset product and name the target product. There is no need to save the output as BEAM-DIMAP
- In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Note: If precise orbits are not yet available for your product, restituted orbits can be selected which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product.

| C Apply Orbit File X   | @ Apply Orbit File  | ×         |
|--|---|-----------|
| File Help  | File Help   |           |
| I/O Parameters Processing Parameters Source Product Source Product [2] subset_1_of_S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415  Target Product Name: subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb Save as: BEAM-DIMAP Directory: [2:\Projekty\2023_ESA_ENELM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12 Open in SNAP | I/O Parameters       Processing Parameters         Orbit State Vectors:       Sentinel Precise (Auto Download)         Polynomial Degree: | ×<br>3    |
| Run Close  |   | Run Close |

#### Apply radiometric correction

- Go to Radar > Radiometric > Calibrate and select the result product from previous step
- Under the Processing Parameters tab select both polarizations and select the **Output beta0** band option. The radiometric correction is necessary to remove any image-dependent radiometric bias.

| Calibration X   | Calibration X   |
|---|---|
| File Help   | File Help   |
| I/O Parameters Processing Parameters Source Product source: [3] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb   | I/O Parameters Processing Parameters Polarisations: VH VV   |
| Target Product Name: subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal Save as: BEAM-DIMAP Directory:ENEUM\07_ucebne_materialy\Radarovy_DP2\practicals\exercise_12 Open in SNAP | ENVISAT Auxiliary File: Latest Auxiliary File<br>Save as complex output Output sigma0 band Output gamma0 band Dutput beta0 band Dutput beta0 band |
| Run Close   | Run Close   |



#### Radiometric Terrain Flattening

- Flatten Terrain
- Go to Radar > Radiometric > Radiometric Terrain Flattening
- Under Processing Parameters select SRTM 1Sec HGT (Auto Download)
- For DEM Resampling Method, use Bicubic\_interpolation

| length Radiometric Terrain Flattening  | 🤇 🚭 Radiometric Terrain Flattening 🛛 🛛 🗙   |
|--|--|
| File Help  | File Help  |
| I/O Parameters Processing Parameters Source Product source: [4] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal  | I/O Parameters Processing Parameters Source Bands: Beta0_VH Beta0_VV   |
| Target Product Name: subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF  Directory:  ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12  Open in SNAP | Digital Elevation Model:       SRTM 1Sec HGT (Auto Download)       >         DEM Resampling Method:       BICUBIC_INTERPOLATION       >         External DEM Apply EGM       Output Terrain Flattened Gamma0         Output Simulated Image       Output Terrain Flattened Sigma0         Mask out areas without elevation |
|  | Additional Overlap Percentage[0,1]:       0.1       Oversampling Multiple:       1.0   |
| Run Close  | Run Close  |

The output of this process will be transformed Beta0 into Gamma0

#### Multilooking

Go to Radar > Multilooking:

In "Processing Parameters" multilook the image by a factor 5x5 - change "Number of Range Looks" and "Number of Azimuth Looks" both to 5. If the "GR Square pixel" option is enabled, an equal number of looks will be applied in both the azimuth and range directions.

| File Help     I/O Parameters   Source Product   source:   [5] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF <   Target Product   Name:   subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF <   Directory:  RNEUMI/07_ucebne_materially/Radarovy_DPZ/practicals/exercise_12   Open in SNAP     File   Help     I/O Parameters     Processing Parameters     Source Bands:   Gamma0_VH   Gamma0_VV     I/O Parameters     Source Bands:   Gamma0_VV     I/O Parameters     Source Bands:     Gamma0_VV     Gamma0_VV     I/O Parameters     Source Bands:     Gamma0_VV     Gamma0_VV     I/O Ra Square Pixel     Independent Looks     Number of Range Looks:   Source   I/O Open in SNAP     I/O Open in SNAP     I/O Open in SNAP     I/O Open in SNAP     I/O Detection for complex data is done without resampling.                             | C Multilooking   | × | Multilooking  |  | Х  |
|--|--|---|---|--|----|
| Source Product   source:   [5] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF   Target Product   Name:   subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML   Save: assi   BEAM-DIMAP   Directory:  ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   Open in SNAP     Source Bands:     Gamma0_VH   Gamma0_VV     Gamma0_VV     Gamma0_VV     Gamma0_VV     Gamma0_VV     Source Bands:     Gamma0_VV     Gamma0_VV     Gamma0_VH     Gamma0_VH     Gamma0_VV     Source Bands:     Gamma0_VH     Gamma0_VH  < | File Help  |   | File Help   |  |    |
| Name:   subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML   Save as:   BEAM-DIMAP   Directory:  ENEUM\07_ucebne_materialy\Radarovy_DP2\practicals\exercise_12   Open in SNAP     Mean GR Square Pixel:   50.0   Output Intensity   Note: Detection for complex data is done without resampling.  | Source Product<br>source:  |   | Source Bands:   | Gamma0_VH  |    |
|  | Name:<br>subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML<br>Save as: BEAM-DIMAP<br>Directory:<br>ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12 |   | Number of Range Looks:<br>Number of Azimuth Looks:<br>Mean GR Square Pixel:<br>Output Intensity | 5<br>5<br>50.0<br>Note: Detection for complex data |    |
| Run Close Run Close  | Run Close  |   |   | Run Clos   | se |





#### Create elevation band

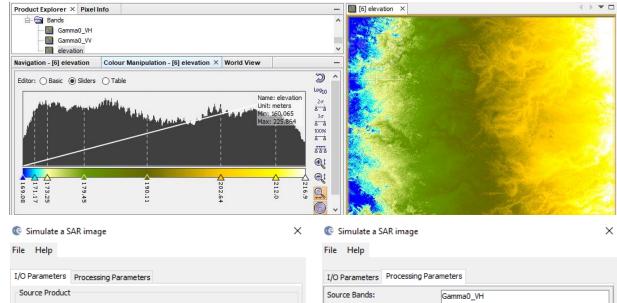
Go to Raster > DEM Tools > Add Elevation Band:

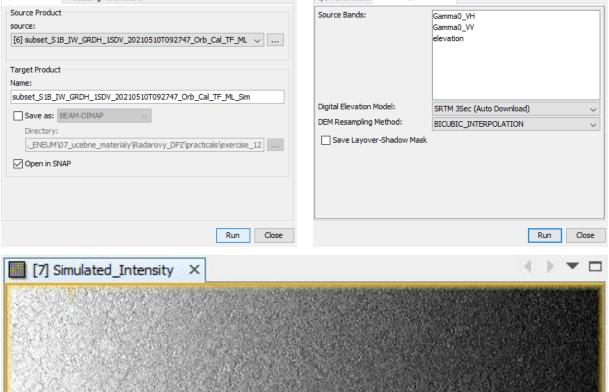
- Select the appropriate elevation band to add to the image, e.g. SRTM 3 sec (AutoDownload)
- After having added the elevation band, go to Radar > Geometric > Terrain Correction > SAR Simulation and run the SAR simulation.

#### Add Elevation Band

| Digital elevation model       | (DEM):             |         |        |  |  |
|-------------------------------|--------------------|---------|--------|--|--|
| ACE2_5Min (Auto Dow           | vnload)            |         |        |  |  |
| ACE30 (Auto Downloa           | d)                 |         |        |  |  |
| ASTER 1sec GDEM               |                    |         |        |  |  |
| CDEM (Auto Download           | i)                 |         |        |  |  |
| Copernicus 30m Globa          | l DEM (Auto Downlo | oad)    |        |  |  |
| Copernicus 90m Globa          | l DEM (Auto Downlo | oad)    |        |  |  |
| GETASSE30 (Auto Download)     |                    |         |        |  |  |
| SRTM 1Sec Grid                |                    |         |        |  |  |
| SRTM 1Sec HGT (Auto Download) |                    |         |        |  |  |
| SRTM 3Sec (Auto Download)     |                    |         |        |  |  |
| Resampling method:            | BILINEAR_INTERP    | OLATION | ~      |  |  |
| Elevation band name:          | elevation          |         |        |  |  |
|                               |                    |         |        |  |  |
|                               |                    | OK      | Cancel |  |  |

 $\times$ 











### Terrain Correction

Go to Radar > Geometric > Terrain Correction > Range-Doppler Terrain Correction

- In the I/O Parameters select the last simulated product
- Under Processing Parameters tab select:
  - Digital Elevation Model: SRTM 3Sec (Auto Download)
  - DEM Resampling Method: Bilinear Interpolation
    - Check the "Mask out areas without elevation" box
    - Check the "Apply radiometric normalisation" box

| 📀 Range Doppler Terrain Correction X  | C Range Doppler Terrain Correction  | × |
|---|---|---|
| File Help   | File Help   |   |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameters  |   |
| Source Product source: [7] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML_Sim  Target Product Name: subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML_Sim_TC | Source Bands: Simulated_Intensity<br>Gamma0_VH<br>Gamma0_VV<br>elevation                                |   |
| Save as: BEAM-DIMAP   | Digital Elevation Model: SRTM 3Sec (Auto Download) 🗸  | 1 |
| Directory:  | DEM Resampling Method: BILINEAR_INTERPOLATION ~   |   |
| Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   | Image Resampling Method: BILINEAR_INTERPOLATION   |   |
| Open in SNAP  | Source GR Pixel Spacings (az x rg):         50.0(m) x 50.0(m)           Pixel Spacing (m):         50.0 |   |
|   | Pixel Spacing (deg):         4,4915764205976077E-4  | 1 |
|   | Map Projection: WGS84(DD)   | 1 |
|   | Mask out areas without elevation Output complex data  |   |
|   | Output bands for:   |   |
|   | Selected source band DEM Latitude & Longitude   |   |
|   | Incidence angle from ellipsoid Local incidence angle Projected local incidence angle                    |   |
|   | Layover Shadow Mask   |   |
|   | Apply radiometric normalization   |   |
|   | $\odot$ Save Sigma0 band Use projected local incidence angle from DEM $\sim$                            |   |
|   | Save Gamma0 band Use projected local incidence angle from DEM 🗸 🗸                                       |   |
|   | Save Beta0 band   |   |
|   | Auxiliary File (ASAR only): Latest Auxiliary File   |   |
| Run Close   | Run Close   | e |

#### Convert gamma0 to dB

In the Product Explorer select first the Gamma0\_VH band, then go to Raster > Data Conversion > Linear to/from dB and repeat with the Gamma0\_VV band.

This will create two Virtual bands (with a V icon). Right dick on each > Convert Band to transform them.

#### Compute difference image from gamma0 [dB]: VV-VH

Open Raster > Band Maths: Name it "Gamma0-VV\_VH". Click on 'Edit Expression' and enter the expression Gamma0\_VV\_dB - Gamma0\_VH\_dB

Convert virtual raster







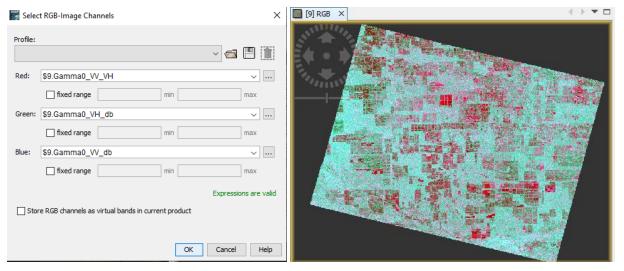
| Band Maths X   | 🞇 Band Maths Expres                     | ssion Editor   | ×   |
|--|---|--|---|
| Target product:  | Data sources:                           |  | Expression:   |
| [8] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML_Sim_TC v   | Simulated_Intensity_VH                  | @+@  | Gamma0_VV_db - Gamma0_VH_db   |
| Name: Gamma0-VV_VH   | Gamma0_VH                               | @ - @  |   |
| Description:   | Gamma0_VV                               | @*@  |   |
| Unit:  | elevation_VH                            | @/@  |   |
| Spectral wavelength: 0.0   | Gamma0_VH_db<br>Gamma0_VV_db            |  |   |
| Virtual (save expression only, don't store data)   | Gammad_vv_ub                            | (@)<br>Constants V   |   |
| Replace NaN and infinity results by NaN  |   | Operators V  |   |
| Generate associated uncertainty band   |   | Functions V  |   |
| Band maths expression:   | Show bands                              |  |   |
| Gamma0_VV_db - Gamma0_VH_db  | Show masks                              |  |   |
| Load Save Edit Expression  | Show tie-point grids Show single flags  |  | 📑 📋 🔉 🎦 🖉 Ok, no errors.  |
| OK Cancel Help   |   |  | OK Cancel Help  |
| OK Cancel Help   |   |  | OK Cancel Nep   |
| Product Explorer × Pixel Info  | - [8] Gamm                              | a0-VV_VH ×   | < > <b>-</b>  |
| ■ € [1] S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415  | ALL | V. Alterna   |   |
| <ul> <li>[2] subset_1_of_S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_</li> <li>[3] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb</li> </ul> | 5415                                    |  |   |
|  |   |  |   |
| [5] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF   | 2411                                    |  |   |
| [6] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML  |   |  |   |
| <ul> <li>[7] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML_Sim</li> <li>[8] subset_S1B_IW_GRDH_1SDV_20210510T092747_Orb_Cal_TF_ML_Sim_TC</li> </ul>  | · · ·                                   |  | and the second secon |
|  |   | $p_{1}^{2} = p_{1}^{2} + p_{2}^{2} + p_{3}^{2} + p_{3$ | the second second second second   |
| Navigation - [8] Gamma0-VV_VH Colour Manipulation - [8] Gamma0-VV_VH World View  | /× -                                    |  |   |
|  |   | 302  |   |
| Off Globe Downlo   |   |  |   |

#### Display as RGB view

Go to Window > Open RGB Image Window (or right-click on the last product in the Product Explorer and Open RGB window) and select: Red: the difference band "Gamma0\_VV\_VH"

Green: "Gamma0\_VH\_db"

Blue: "Gamma0\_VV\_db"



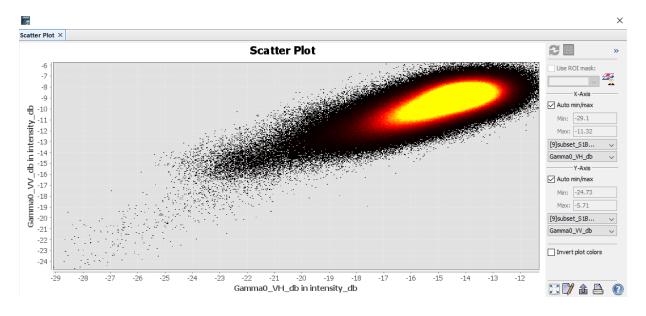




### Statistical analysis

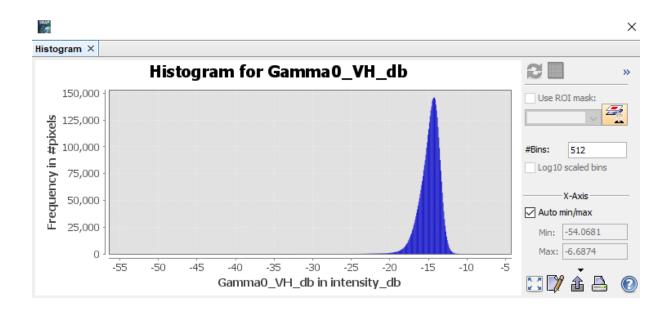
#### Scatterplot

Open Analysis > Scatter Plot and in the right panel select the Gamma0\_VH\_dB as X-axis input and Gamma0\_VV\_dB as Y-axis input, then click the Refresh View button.



#### Histogram

Select e.g. the Gamma0\_VH\_dB band and open Analysis > Histogram. Click the Refresh View button.



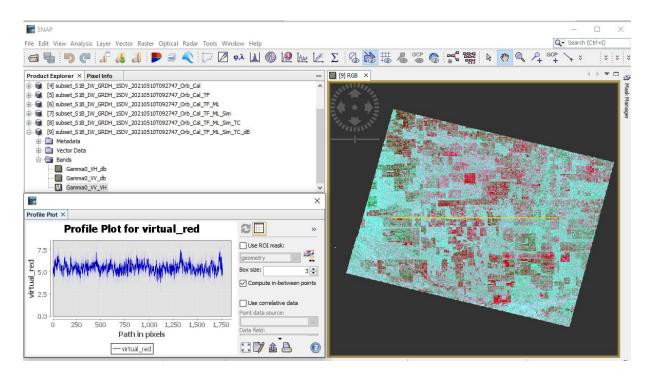






#### Profile Plot

Select the Gamma0\_VV\_VH band. In the toolbar select the Polygon or the Line tool and draw a shape on your region of interest. Open Analysis > Profile Plot. This operation can be done for any of the other bands.







## **B: MULTITEMPORAL ANALYSIS**

Load both Sentinel-1 products by navigating to File - Open Product.

### Build a pre-processing graph

Use the graph builder tool to create workflow for data processing:

Go to Tools>GraphBuilder

Right click and add, in the order below, each of the preprocessing steps:

The first tool is Read

Add>Radar>Apply-Orbit-File and keep pre-defined parameters. Check "Do not fail if new orbit file is not found"

Add>Radar>Radiometric>Calibration and select Output beta0 band Add>Radar>Radiometric>Terrain Flattening will add terrain flattening Add>Radar>Geometric> Terrain Correction>Terrain Correction The last tool is Write

Click on each tool, and connect them by dragging the red arrows from one tool to the next, respecting the order above

🎆 Graph Builder Х File Graphs ~ Calibration Terrain-Correction Read Write **Terrain-Flattening** Apply-Orbit-File < 1 з Read Write Apply-Orbit-File Calibration Terrain-Flattening Terrain-Correction Orbit State Vectors: Sentinel Precise (Auto Download)  $\sim$ Polynomial Degree: 3 Do not fail if new orbit file is not found

Then got to File>Save Graph to save the workflow as a XML file.





| Read     | Write     | App     | ly-Orbit-Fi | e Calibration   | Terrain-Flattening | Terrain-Correction |      |        |        |
|----------|-----------|---------|-------------|-----------------|--------------------|--------------------|------|--------|--------|
| Polarisa | ations:   |         |             | VH<br>VV        |                    |                    |      |        |        |
| ENVISA   | T Auxili  | iary Fi | le:         | Product Auxilia | ary File           |                    |      |        | $\sim$ |
| Sa       | ve as co  | omplex  | k output    |                 |                    |                    |      |        |        |
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| Ou       | itput ga  | imma0   | band        |                 |                    |                    |      |        |        |
| 🖂 Ou     | itput be  | ta0 ba  | and         |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         |             |                 |                    |                    |      |        |        |
|          |           |         | E Loa       | ad 🏷            | Clear 📝 Not        | e 🖹 Save 🔞         | Help | [> Run |        |

#### Batch processing

Navigate to Tools > Batch Processing: Using the Add opened symbol select the files you want to process.

| 🞇 Batch Processing     |      |               |            |          | ×           |
|------------------------|------|---------------|------------|----------|-------------|
| File Graphs            |      |               |            |          |             |
| I/O Parameters         |      |               |            |          |             |
| File Name              | Туре | Acquisition   | Track      | Orbit    | ÷           |
| S1B_IW_GRDH_1SDV_20210 | GRD  | 10May2021     | 39         | 26840    |             |
| S1B_IW_GRDH_1SDV_20210 | GRD  | 21Jul2021     | 39         | 27890    |             |
|                        |      |               |            |          |             |
|                        |      |               |            |          | <b>*</b>    |
|                        |      |               |            |          | ▲<br>◆<br>◆ |
|                        |      |               |            |          | -           |
|                        |      |               |            |          | - 22        |
|                        |      |               |            |          |             |
|                        |      |               |            |          | ٠           |
|                        |      |               |            |          | 2 Products  |
|                        | Ru   | in remote Loa | d Graph Ru | un Close | Help        |





# Using the Load Graph button, load the .xml-file you just saved

| SHAP                       | Batch Processing : myG                                 | raph        | xml                     |                                  |       |                            |                |        | ×                |
|----------------------------|--|-------------|-------------------------|----------------------------------|-------|----------------------------|----------------|--------|------------------|
| File                       | Graphs   |             |                         |                                  |       |                            |                |        |                  |
|                            | Load Graph   |             | Calibration             | Terrain-Flattening               |       | reain Correction           | Meit           |        |                  |
|                            | Save Graph   |             |                         |                                  | g ie  |                            |                |        |                  |
|                            | View Graph XML   |             | pe                      | Acquisition                      |       | Track                      | Orbit          |        | ÷                |
| S1B                        |  | GR          |                         | 10May2021<br>21Jul2021           |       | 39<br>39                   | 26840<br>27890 |        | 규                |
| -                          |  | _           |                         |                                  |       |                            |                |        | _                |
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|                            |  |             | 1                       | Run remote                       | Load  | l Graph Ru                 | ın             | Close  | Help             |
|                            |  |             |                         |                                  |       |                            |                |        |                  |
| File                       | Batch Processing : myG<br>Graphs                       | iraph       | .xml                    |                                  |       |                            |                |        | ×                |
| File                       | Graphs   |             |                         | Terrain-Flattenin                | ng Ti | errain-Correction          | Writ           | te     | ×                |
| File                       | Graphs   | t-File      |                         | Terrain-Flattenin<br>Acquisition | ng Ti | errain-Correction<br>Track | Write<br>Orbi  |        | ×                |
| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Ti | Track<br>39                | Orbi<br>2684   | t<br>0 |                  |
| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name                     | t-File<br>T | Calibration<br>ype<br>D | Acquisition                      | ng Ti | Track                      | Orbi           | t<br>0 | 우<br>[루          |
| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Tr | Track<br>39                | Orbi<br>2684   | t<br>0 | +<br>4           |
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| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Ti | Track<br>39                | Orbi<br>2684   | t<br>0 | +<br>-<br>-<br>- |
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| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Ti | Track<br>39                | Orbi<br>2684   | t<br>0 | +<br>-<br>-<br>- |
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| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Ti | Track<br>39                | Orbi<br>2684   | t<br>0 |                  |
| File<br>I/O<br>File<br>S1B | Graphs Parameters Apply-Orbit Name IW_GRDH_1SDV_20210. | t-File<br>T | Calibration<br>ype<br>D | Acquisition<br>10May2021         | ng Ti | Track<br>39                | Orbi<br>2684   | t<br>0 | +<br>-<br>-<br>- |

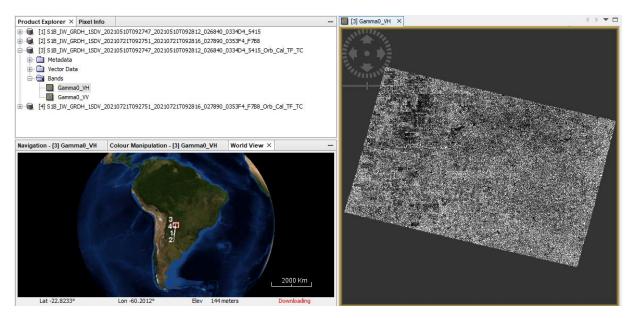
Adjust the output folder, click Run.

Note: this step might take several minutes/hours to run.





View the output product, e.g. by doulble-click on Gamma0\_VH terrain corrected band.



#### Create stack

Go to Radar > Coregistration > Stack Tools > Create Stack In the CreateStack tab, select Product Geolocation as Initial Offset Method In the Write tab, adjust the stack name if needed, adjust the output folder and click Run. This step will might take few minutes.

| 2-(                                 | CreateStack 3-Write  |            |             |       |       |        |
|-------------------------------------|--|------------|-------------|-------|-------|--------|
| File Name                           |  | Туре       | Acquisition | Track | Orbit | _<br>_ |
| S1B_IW_GRDH_1SDV_202                | 10510T092747_20210510T092812_026840_0334D4_5415_Orb_Cal_TF_TC                        | GRD        | 10May2021   | 39    | 26840 | l "    |
| S1B_IW_GRDH_1SDV_202                | 10721T092751_20210721T092816_027890_0353F4_F7B8_Orb_Cal_TF_TC                        | GRD        | 21Jul2021   | 39    | 27890 |        |
|                                     |  |            |             |       |       |        |
| 📀 Create Stack                      |  |            |             |       |       |        |
| Create Stack                        | -CreateStack 3-Write   |            |             |       |       |        |
|                                     | -CreateStack 3-Write<br>S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334 | D4_5415_Or | b_Cal_TF_TC |       |       |        |
| 1-ProductSet-Reader 2               |  | D4_5415_Or | b_Cal_TF_TC |       |       |        |
| 1-ProductSet-Reader 2<br>Reference: | S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334                         | D4_5415_Or | b_Cal_TF_TC |       |       |        |







| Create Stack  | × |
|---|---|
| 1-ProductSet-Reader 2-CreateStack 3-Write   |   |
| Target Product  |   |
| Name:   |   |
| S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415_Orb_Cal_TF_TC_Stack |   |
| Save as: BEAM-DIMAP V<br>Directory:   |   |
| 7 Devide 19922 FOA DEFINING weber websiteling device DOTING States in A                 |   |
|   |   |
| Save 🕢 Help 🕞 Run   |   |

#### Convert bands to dB

In the Product Explorer select the processed Gamma0\_VH band, then go to Raster > Data Conversion > Linear to/from dB and repeat with the Gamma0\_VV band.

| Converts bands to/from dB   | ×     |
|---|-------|
| File Help   |       |
|   |       |
| I/O Parameters Processing Parameters  |       |
| Source Product  |       |
| source:   |       |
| [5] S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415_Orb_Cal_TF_TC_Stack | ~     |
|   |       |
| Target Product  |       |
| Name:   |       |
| S1B_IW_GRDH_1SDV_20210510T092747_20210510T092812_026840_0334D4_5415_Orb_Cal_TF_TC_Stack_dB  |       |
| Save as: BEAM-DIMAP   |       |
| Directory:  |       |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_4           |       |
| Open in SNAP  |       |
|   |       |
|   |       |
|   |       |
|   |       |
| Run   | Close |
|   |       |







#### Display an RGB

Right-click on the last product – Open RGB Image Window and select different band combinations to see the change of backscatter between different acquisitions. Explore values over forest area and fields.

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| EN LA MARKEN AND AND AND AND AND AND AND AND AND AN  |  | max                   |
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|  | Red:         \$7.Gamma0_VV_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_VV_slv2_21Jul2021_db   | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min   | max max               |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
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|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
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|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |
|  | Red:         \$7.Gamma0_W_mst_10May2021_db           fixed range         min           Green:         \$7.Gamma0_W_slv2_21Jul2021_db           fixed range         min           Blue:         \$7.Gamma0_VH_slv1_21Jul2021_db | max                   |





## Time Series Analysis (using single scenes, not a stack)

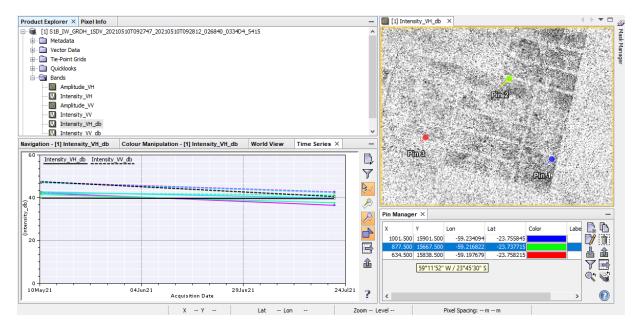
Tool cannot use a stack, it needs single images instead

Navigate to View > Tool Windows > Radar > Time Series to open the Time Series tab at the bottom left of your SNAP window.

Click on Settings (top right of Time Series tab) and add individual (preprocessed) images. Click Apply.

Using the time series tab, hover your mouse over the area to see

the behaviour of single pixels over or use Pin Manager to see the behaviour of the selected Pins.



Explore values to identify forest area and fields.

For more information, see the lecture: <u>4. SAR remote sensing for forestry</u>

# THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 5 – TUTORIAL

Crop Classification with S1 and S2 data using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

- Use radar (Sentinel-1) and optical (Sentinel-2) data to dassify and analyse different crop types and their health over an area
- Data pre-processing will be perfomed, an then the crop types will be estimated by classification of the data, based on the Random Forest algorithm
- Land crops growth and health will be observed using NDVI time series





# 2 | Background

# Crop classification using Sentinel-1 and Sentinel-2 data

Crop classification using Sentinel-1 data relies on the radar backscatter signals obtained from the satellite. The backscatter intensity, polarization, and texture of the radar imagery are analyzed to distinguish between different crop types.

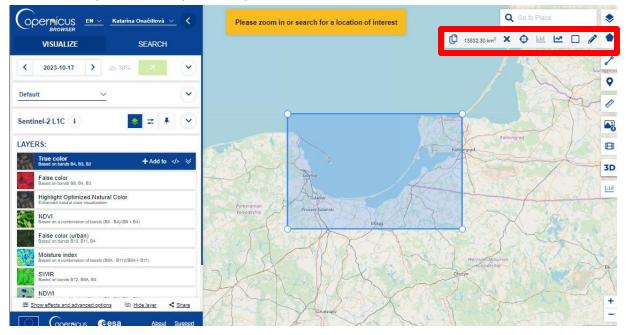
Supervised classification methods involve training a classifier with labeled samples of land cover types, while unsupervised methods group pixels based on their spectral similarity without prior training. The accuracy of the land cover classification is validated using ground truth data, and the results can be refined iteratively to improve accuracy. The final land cover maps provide valuable information for various applications, including urban planning, agriculture, forestry, and environmental monitoring.





#### 2.1 Study area and data used

For this exercise, we will use Sentinel-1 and Sentinel-2 images to explore fields in Kacik, near Gdansk and Baltic Sea coast northern Poland, downloaded for year 2023 from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open Sentinel-1 GRDH downloaded products with HH and HV polarizations acquired on 11 July 2023 by double click on the zipped folders. The opened products will appear in Product Explorer window:

S1A\_IW\_GRDH\_1SDV\_20230711T050035\_20230711T050100\_049371\_05EFD9\_7392.SAFE

Click + to expand the content of product, then expand Bands folder and double click on Intensity VV band to visualize it. Depending on your computer's capabilities, this process could take some time. To minimize the data load, the next step involves creating a subset that encompasses only a portion of the dataset.

| Product Explorer × Pixel Info   | -                 | [1] Intensity_VV ×   | ( ) 🔻 🗆 💋  |
|---|-------------------|--|--|
| □       [1] \$1.4_IW_GRDH_1SDV_20230711T050035_20230711T050100_049371_05EFD9_7392         □       □ |                   |  | Mark Hanager   |
| Navigation - [1] Intensity_VV Colour Manipulation - [1] Intensity_VV × World View   |                   |  |  |
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#### 3. Pre-processing

For classification purposes, three bands are utilized per acquisition: VV (or HH for SentineI-1), VH, and their ratio VV/VH (or HH/VH for PALSAR). Out of the 13 bands per SentineI-2 data acquisition, only the 10 with spatial resolutions of 10 m or 20 m are utilized.

#### 3.1 Sentinel-1 preprocessing

The Sentinel-1A data were obtained in IW mode and retrieved from the ESA Scientific Data Hub at https://scihub.copernicus.eu/ in GRDH format. These data require calibration (converting from Digital Numbers to Radar Backscattering Coefficient s0) and orthorectification (transforming from image geometry to a geographical projection) within a geographical subset. Subsequently, a filter is applied to mitigate Speckle noise, which is inherent in radar imagery.

#### Apply orbit file

Satellite positions are recorded using a Global Navigation Satellite System (GNSS). To ensure the fast delivery of Sentinel-1 products, orbit details produced by an onboard navigation system are included in the Sentinel-1 products. Subsequently, the Copernicus Precise Orbit Determination (POD) Service further enhances the accuracy of the orbit positions.

Navigate to Main Menu – Radar – Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Note: If precise orbits are not yet available for your product, restituted orbits can be selected which may not be as accurate as the Precise orbits but will be better than the predicted orbits available within the product.

| C Apply Orbit File X   | Apply Orbit File     X   |
|--|--|
| File Help  | File Help  |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters   |
| Source Product<br>source:<br>[1] S1A_IW_GRDH_1SDV_20230711T050035_20230711T050100_049371_05EFD9_7392 v                             | Orbit State Vectors:       Sentinel Precise (Auto Download)       ~         Polynomial Degree:       3         Image: Do not fail if new orbit file is not found |
| Target Product Name:   |  |
| S1A_IW_GRDH_ISDV_20230711T050035_20230711T050100_049371_05EFD9_7392_Orb           Save as:         BEAM-DIMAP           Directory: |  |
| C: Users\Onačillová\S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML   |  |
|  |  |
| Run Close  | Run Close  |







#### Speckle Filter

Despeckling removes thermal noise introduced by the sensor from the image to remove potential sources of error in analysis.

Navigate to Radar > Speckle Filtering > Single Product Speckle Filter: In the Processing Parameters tab, choose the Lee filter with default window sizes and click Run.

Note: Selecting the size of the speckle filter depends on the targets (point target, distributed target) and the target size (for example field sizes).

| C Single Product Speckle Filter ×   | C Single Product  | Speckle Filter ×   |
|---|---|--|
| File Help   | File Help   |  |
| I/O Parameters Processing Parameters Source Product [2] S1A_IW_GRDH_1SDV_20230711T050035_20230711T050100_049371_05EFD9_7392_Orb  Target Product Name:   | I/O Parameters Pr<br>Source Bands:  | Amplitude_VH<br>Intensity_VH<br>Amplitude_VV<br>Intensity_VV |
| STA_IW_GRDH_ISDV_20230711T050035_20230711T050100_049371_05EFD9_7392_Orb_Spk         Save as;       BEAM-DIMAP         Directory:       C:\Users\Onačilovå\\$1A_IW_SLC_1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML         Open in SNAP | Filter:<br>Number of Looks:<br>Window Size:<br>Sigma:<br>Target Window Size | Lee Sigma v<br>1 v<br>7x7 v<br>0.9 v<br>1x3 v                |
| Run Close   |   | Run Close  |

Open the output of the Lee sigma filter and compare it with the image before Speckle filtering. Filtered image looks sharpened and without noise comparing with the image before applying Speckle filter.







### Calibration

S1 Level-1 products are not radiometrically corrected or calibrated, by default1. Radar reflectivity is stored as Digital Numbers (DNs) in S1 products, and must be converted to physical units (radar backscatter).

Navigate to Main Menu - Radar - Radiometric - Calibrate

In the I/O Parameters tab, select the last filtered product and name the target product.

In the Processing Parameters you can select one or both polarization and accept all default settings and then click Run

| Calibration   | ×  | Calibration ×  |
|---|----|--|
| File Help   |    | File Help  |
| I/O Parameters Processing Parameters Source Product Source: [3] S1A_JW_GRDH_1SDV_20230711T050035_20230711T050100_049371_05EFD9_7392_Orb_Spk v   |    | I/O Parameters         Processing Parameters           Polarisations:         VH           VV         VV                                 |
| Target Product           Name:           S1A_IW_GRDH_ISDV_202200711T050035_20220711T050100_049371_05EFD9_7392_Orb_Spk_Cal           Save as:         BEAM-DIMAP           Directory:         C:\Users\Conačilová\\$1A_IW_SLC_1SDV_202208_09_Orb_Stack_ifg_deb_dinsar_fit_ML           Qopen in SNAP         ISNAP |    | ENVISAT Auxiliary File: Latest Auxiliary File<br>Save as complex output<br>Output sigma0 band<br>Output gamma0 band<br>Output beta0 band |
| Run Ci  | se | Run Close  |

# Terrain-Correction

The last step in our graph for image pre-processing is to apply terrain correction to the product, ensuring that all the pixels are moved to the right locations (eg if the nadir angle of the image is off, it will align the pixels correctly so it is closer to a top-down view of the imagery).

Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-Doppler Terrain Correction

In the I/O Parameters tab set as "Source Product" the last calibrated product.

In "Target Product", keep the default name and set the Directory In the Processing Parameters tab set:

Digital Elevation Model: SRTM 3Sec (Auto Download)

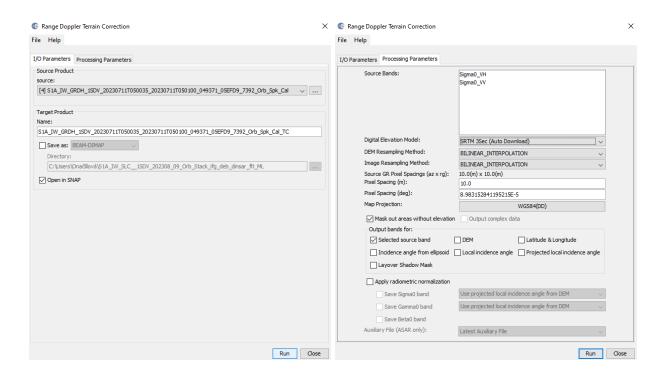
Map Projection: WGS84(DD)

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.









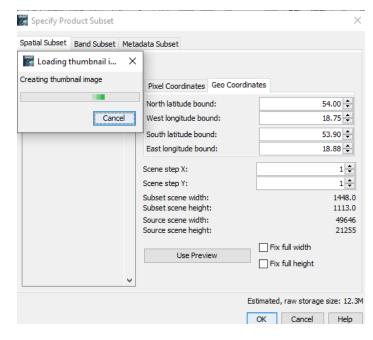
#### 3.1 Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Go to the Subset tab and at "Geo Coordinates" set:

North latitude bound: 54.00 West longitude bound: 18.75 South latitude bound : 53.90 East longitude bound : 18.88

Note: There is no need to wait till thumbnail image will be created when entering coordinates.







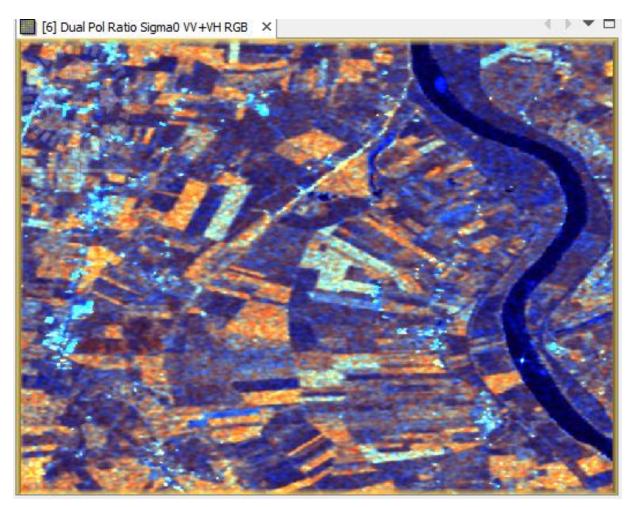


Visualize the output subset by double-click on VH and VV polarization.



Visualize the final subset image using RGB:

Go to Window > Open RGB Image Window (or right-click on the last product in the Product Explorer and Open RGB window) and select the band combinations for final RGB image: VH, VV, VV/VH.





# 2.4 Image classification

We will perform a random forest classification. For this we will create some training data by identifying polygons containing the different crop/land cover types:

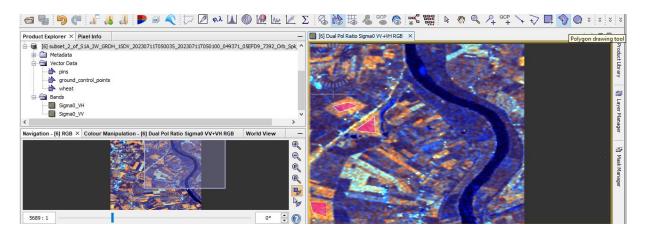
- wheat
- maize
- Rapeseed
- barley
- grassland
- river

Select the last subset product by clicking on it. Navigate to Vector  $\!\!\!>$  New Vector Data Container.

Create new data containers – separate for each type of ice mentioned above. Start with creating the data container for, e.g. "wheat".Click OK.

| 🎆 New Ve     | ctor Data Container | < |
|--------------|---------------------|---|
| Name:        | wheat               |   |
| Description: |                     |   |
|              |                     |   |
|              |                     |   |
|              | OK Cancel Help      |   |

The newly created vector data container should appear under "Vector Data" in the Product Explorer. Now let 's start creating training polygons for these different containers on ice type using the Polygon drawing tool:

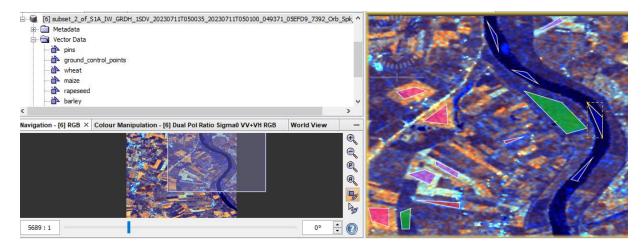


Repeat this step and create training polygons for all remaining classes.









Wheat (red), maize (violet), rapeseed (light blue), barley (cyan), grassland (green) and water (blue) training polygons. Save the final product with your created vector data containers to your folder.

#### Random Forest image classification

Navigate to Raster > Classification > Supervised classification > Random Forest Classifier

- In the ProductSetReader tab select the saved product with your training data.
- In the Random-Forest-Clasiffier select the classes/training vectors (all polygon vector containers) and feature bands (select both Sigma0\_VH and Sigma0\_VV polarisations) that you'd like to include into image classification.
- In the Write tab by default, the output target is set to the same directory and appends "RF" to the filename.
- Click RUN.

| 🎇 Random Forest Classifier   |   |
|--|---|
| ProductSet-Reader Random-  | Forest-Classifier Write                     |
| Classifier   |   |
| Train and apply classifier   | newClassifier                               |
| O Load and apply classifier  | newClassifier V X                           |
|  | ◯ Train on Raster                           |
| Evaluate classifier  |   |
| Evaluate Feature Power Set   |   |
|  | Min Power Set Size: 2 Max Power Set Size: 7 |
| Number of training samples   | 5000  |
| Number of trees:   | 10  |
| Vector Training  |   |
| Training vectors: wheat<br>maize<br>rapeseed<br>barley<br>grassland<br>river |   |
| Feature Selection  |   |
| Feature bands: Sigma0_V<br>Sigma0_V  |   |
| L  | Save 🕜 Help 🕞 Run                           |







#### 2.5 Post-processing

The final product should now appear in the ProductExplorer. Visualize this output classified image and classes by double-click on the layer "LabeledClasses" under Bands folder in the Product Explorer.

Navigate to Colour Maniulation tab to change the colours of individual crop type classes and other ones and explore the frequency and distribution of these classes through the classified image and table.



Navigation - [7] LabeledClasses

Colour Manipulation - [7] LabeledClasses ×

| Label     | Colour | Value | Frequency | Description |
|-----------|--------|-------|-----------|-------------|
| no data   |        | -1    | 0.000%    | no data     |
| wheat     |        | 0     | 17.464%   |             |
| maize     |        | 1     | 6.689%    |             |
| rapeseed  |        | 2     | 0.453%    |             |
| barley    |        | 3     | 25.091%   |             |
| grassland |        | 4     | 46.439%   |             |
| river     |        | 5     | 3.863%    |             |



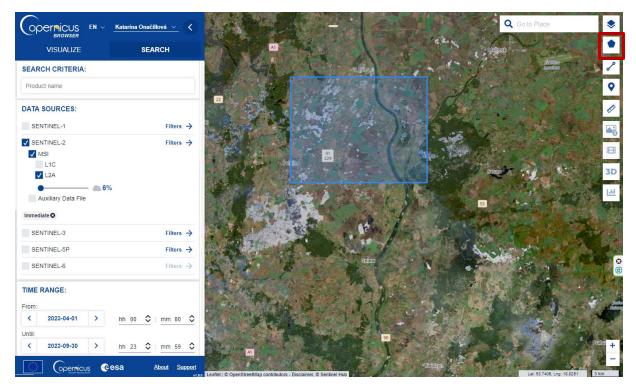




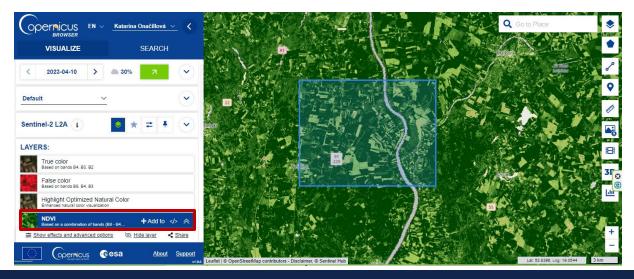
#### 2.6 Crop types characteristics using spectral indices

Now, let's explore also Sentinel-2 data for the same area.

- Navigate to the Copernicus Browser website:
- <u>https://browser.dataspace.copernicus.eu</u>
- Create the area of interest by using rectangle.
- For the best results, search for Sentinel-2 L2A products with low cloud cover, e.g. less than 6%.
- Set the time range from 01-04-2023 to 31-09-2023 to monitor crops during the growth season. And click on Search.

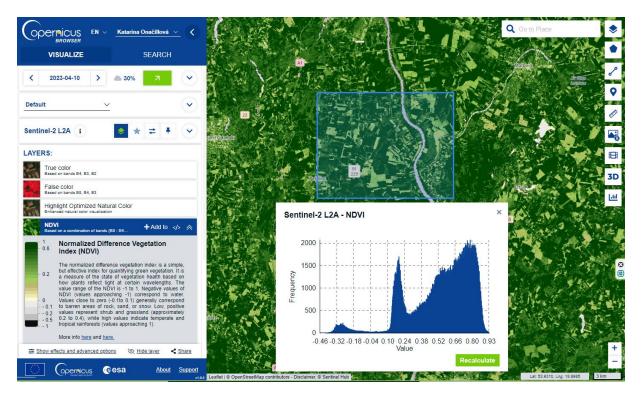


- Visualise at least one of the images start e.g. from 10-04-2023 and select, e.g. NDVI layer.
- At the top right panel select Histogram option.
- Explore NDVI values for the selected image.

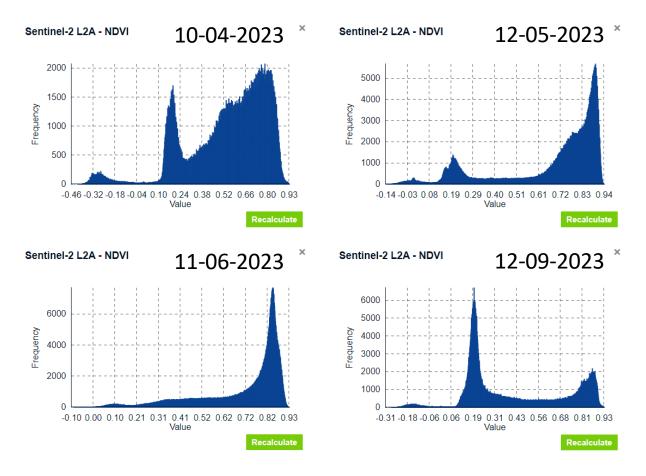








Then, move to another date, e.g. 27-05-2023 and dick on "Recalculate" to refresh the histogram values for this acquisition date. Explore the NDVI values during the growth season by visualising histogram for NDVI values of several dates.





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During the growth season, NDVI (Normalized Difference Vegetation Index) values typically exhibit fluctuations reflecting changes in vegetation dynamics. At the beginning of the season (April), NDVI values may be relatively low as vegetation starts to emerge and develop. As the season progresses and vegetation becomes more abundant and healthier, NDVI values tend to increase, reaching their peak during the peak of the growing season when vegetation is at its fullest and most vibrant (May). This period is characterized by high NDVI values, indicating dense and healthy vegetation rich in chlorophyll and other nutrients. After reaching the peak, NDVI values may start to decline as vegetation undergoes senescence or experiences stress due to factors such as water scarcity or disease (June-September). Monitoring NDVI values throughout the growth season provides valuable insights into vegetation health, growth patterns, and overall ecosystem dynamics.

For more information, see the lecture: <u>5. SAR and optical remote sensing</u> for precision agriculture 1

# THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 6 – TUTORIAL

Crop Classification with S1 time series data using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

- Use radar Sentinel-1 data to classify and analyse time-series for different types of crop fields
- Data pre-processing will be perfomed, an then the crop types will be estimated by classification of the data, based on the Random Forest algorithm
- Land crops growth and health will be observed using RGB composites and backscatter values of different crop types using time series





# 2 | Background

## Crop classification using Sentinel-1 time-series

Crop classification using Sentinel-1 data involves the analysis of radar backscatter signals to differentiate between different types of crops based on their unique radar signatures.

Sentinel-1 data, with its frequent revisit times and all-weather capability, is particularly useful for crop classification as it provides consistent and reliable information regardless of weather conditions.

Crop classification using Sentinel-1 data relies on the radar backscatter signals obtained from the satellite. The backscatter intensity, polarization, and texture of the radar imagery are analyzed to distinguish between different crop types.



These images show the same multi-temporal radar composite acquired over the Flevoland test site in the Netherlands. The grainy appearance of the left image is characteristic of radar images and often a limiting factor in using them at high resolution. The right image demonstrates how a new mathematical technique based on multiple images, which was improved in the campaign, can dramatically enhance the appearance of the image and data quality.

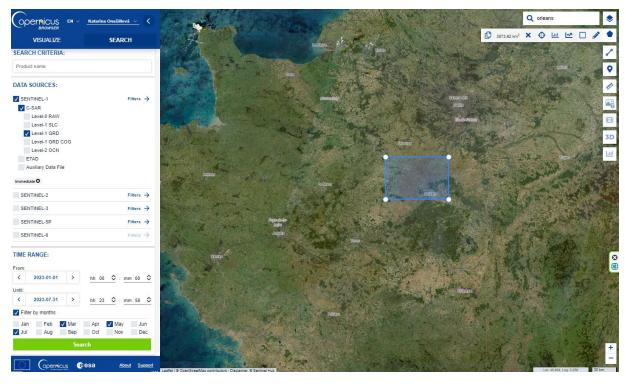






#### 2.1 Study area and data used

For this exercise, we will use three Sentinel-1 images to explore fields in Orleans, France, downloaded for year 2023 from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



#### 2.2. SNAP - Open and explore products

Open SNAP Desktop, click Open Product and open three Sentinel-1 GRDH downloaded products with HH and HV polarizations acquired on 11 July 2023 by double click on the zipped folders. The opened products will appear in Product Explorer window:

S1A\_IW\_GRDH\_1SDV\_20230308T174046\_20230308T174111\_047556\_05B5EA\_6563.SAFE S1A\_IW\_GRDH\_1SDV\_20230519T174049\_20230519T174114\_048606\_05D890\_2249.SAFE S1A\_IW\_GRDH\_1SDV\_20230730T174053\_20230730T174118\_049656\_05F897\_BEA3.SAFE







## 3. Pre-processing

### 3.1 Create subsets

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size - creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Go to the Subset tab and at "Geo Coordinates" set:

North latitude bound: 48.10 West longitude bound: 1.40 South latitude bound : 48.20 East longitude bound : 1.50

Note: There is no need to wait till thumbnail image will be created when entering coordinates.

Save the output subsets to your folder – we will need them for the next step.

| Specify Product Subs     | et      |  |  |               | ×   |
|--------------------------|---------|--|--|---------------|---|
| Spatial Subset Band Subs | et Tie- | Point Grid Subset  | Metadata Su  | bset          |   |
|                          |         | Pixel Coordina<br>North latitude I<br>West longitude<br>South latitude I<br>East longitude<br>Scene step X:<br>Scene step Y:<br>Subset scene wi<br>Source scene wi<br>Source scene he<br>Use P | bound:<br>bound:<br>bound:<br>bound:<br>idth:<br>eight:<br>idth: |               | 48.10 -<br>1.40 -<br>48.20 -<br>48.20 -<br>1.50 -<br>1.50 -<br>1.50 -<br>20393.0<br>2367.0<br>26167<br>16675<br>ull width<br>ull height |
|                          |         |  |  | Estimated, ra | aw storage size: 184.1M   |

· e esa





OK

Cancel

Help

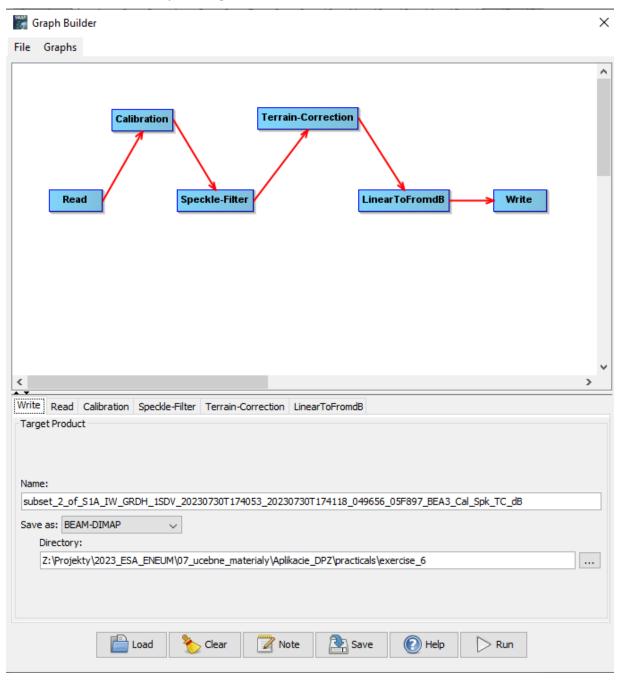
# 3.2 Build a pre-processing graph

Use the graph builder tool to create workflow for data processing:

Go to Tools > GraphBuilder Right click and add, in the order below, each of the preprocessing steps:

- The first tool is Read
- Add>Radar>Radiometric>Calibration
- Add>Radar>Speckle Filtering>Speckle-Filter
- Add>Radar>Geometric>Terrain Correction>Terrain Correction
- Add>Raster>Data Conversion>LinearToFromdB
- The last tool is Write

Click on each tool, and connect them by dragging the red arrows from one tool to the next, respecting the order above.







5

Leave the default parameters for individual tools, except Speckle-Filter: - here, select Filter: Lee

Then got to File>Save Graph to save the workflow as a XML file ",crops\_graph".

| 🎆 SNAP - Save | Graph              |  |         |                             | ×                                 |
|---------------|--------------------|--|---------|-----------------------------|-----------------------------------|
| Save in:      | exercise_6         | i                                      |         | v 🗈 💣                       | • 🔢 🕶                             |
|               | Názov<br>subset_2_ | of_S1A_IW_GRDH_1SDV_20230711T050035_20 | Veľkosť | Typ položky<br>Priečinok sú | Dátum úpravy<br>29. 2. 2024 20:24 |
| Naposledy p   |                    |  |         |                             |                                   |
| Pracovná plo  | File name:         | crops_graph.xml                        |         |                             | Save                              |
| A-L           | Files of type:     | Graph (*.xml)                          |         | ~                           | , Cancel                          |

#### Batch processing

SHAP

Navigate to Tools > Batch Processing: Using the Add opened symbol select the files you want to process.

| Batch Processing                      |      |             |            |           | ×          |
|---------------------------------------|------|-------------|------------|-----------|------------|
| File Graphs                           |      |             |            |           |            |
| I/O Parameters                        |      |             |            |           |            |
| File Name                             | Туре | Acquisition | Track      | Orbit     | ÷          |
| subset_0_of_S1A_IW_GRDH_1SDV_20230308 | GRD  | 08Mar2023   | 59         | 47556     |            |
| subset_1_of_S1A_IW_GRDH_1SDV_20230519 |      | 19May2023   | 59         | 48606     | <b>-</b>   |
| subset_2_of_S1A_IW_GRDH_1SDV_20230730 | GRD  | 30Jul2023   | 59         | 49656     |            |
|                                       |      |             |            |           | <b>*</b>   |
|                                       |      |             |            |           |            |
|                                       |      |             |            |           |            |
|                                       |      |             |            |           | -          |
|                                       |      |             |            |           |            |
|                                       |      |             |            |           |            |
|                                       |      |             |            |           |            |
|                                       |      |             |            |           | 8          |
|                                       |      |             |            |           | 3 Products |
|                                       |      | Run remote  | Load Graph | Run Close | Help       |
|                                       |      |             |            |           |            |

# Using the Load Graph button, load the .xml-file you just saved

| 🎽 Ba | atch Processing    |                 |      |             |       |       | >   |
|------|--------------------|-----------------|------|-------------|-------|-------|-----|
| ile  | Graphs             |                 |      |             |       |       |     |
| l    | Load Graph         |                 |      |             |       |       |     |
| 5    | Save Graph         |                 |      |             |       | - 1.0 |     |
|      | View Graph XML     |                 | Туре | Acquisition | Track | Orbit | - ÷ |
|      |                    | SDV_20230308    | GRD  | 08Mar 2023  | 59    | 47556 |     |
| ubse | t_1_of_S1A_IW_GRDH | 1_1SDV_20230519 | GRD  | 19May2023   | 59    | 48606 |     |
| ubse | t 2 of S1A IW GRDH | 1 1SDV 20230730 | GRD  | 30Jul2023   | 59    | 49656 |     |







# Adjust the output folder, click Run.

Batch Processing : crops\_graph.xml

#### File Graphs

| I/O Parameters | Calibration | Speckle-Filter | Terrain-Correction | LinearToFromdB Write |       |       |   |
|----------------|-------------|----------------|--------------------|----------------------|-------|-------|---|
| File Name      |             |                | Туре               | Acquisition          | Track | Orbit | ÷                                       |
| ubset_0_of_S14 | A_IW_GRDH_  | 1SDV_20230308  | 3 GRD              | 08Mar2023            | 59    | 47556 |   |
| ubset_1_of_S1A | A_IW_GRDH_  | 1SDV_20230519  | ) GRD              | 19May2023            | 59    | 48606 | <b>-</b>                                |
| ubset_2_of_S1A | A_IW_GRDH_  | 1SDV_20230730  | ) GRD              | 30Jul2023            | 59    | 49656 | _                                       |
|                |             |                |                    |                      |       |       | الله الله الله الله الله الله الله الله |
|                |             |                |                    |                      |       |       |   |

Note: this step might take several minutes to run.

When the process finishes it opens all of the output products in the Product Explorer window.

| Produ | ct Explorer $\times$ | Pixel Info    |  |
|-------|----------------------|---------------|--|
| 🕀 🗐   | [1] S1A_IW_GR        | DH_1SDV_2023  | 30308T174046_20230308T174111_047556_05B5EA_6563                          |
| i - S | [2] S1A_IW_GR        | DH_1SDV_2023  | 30519T174049_20230519T174114_048606_05D890_2249                          |
| 🛉 🛢   | [3] S1A_IW_GR        | DH_1SDV_2023  | 30730T174053_20230730T174118_049656_05F897_BEA3                          |
| ÷- 🗎  | [4] subset_0_o       | f_S1A_IW_GRD  | H_1SDV_20230308T174046_20230308T174111_047556_05B5EA_6563                |
| ÷- 🗎  | [5] subset_1_o       | f_S1A_IW_GRD  | H_1SDV_20230519T174049_20230519T174114_048606_05D890_2249                |
| ÷ 🛢   | [6] subset_2_o       | f_S1A_IW_GRD  | H_1SDV_20230730T174053_20230730T174118_049656_05F897_BEA3                |
| i - 🗐 | [7] subset_2_o       | f_S1A_IW_GRD  | H_1SDV_20230730T174053_20230730T174118_049656_05F897_BEA3_Cal_Spk_TC_dB  |
| ÷- 🗎  | [8] subset_1_o       | f_S1A_IW_GRD  | H_1SDV_20230519T174049_20230519T174114_048606_05D890_2249_Cal_Spk_TC_dB  |
| ÷ 😫   | [10] subset_2_       | of_S1A_IW_GRI | DH_1SDV_20230308T174046_20230308T174111_047556_05B5EA_6563_Cal_Spk_TC_dB |
|       |                      |               |  |

#### Create stack

Go to Radar > Coregistration > Stack Tools > Create Stack In the Product-Set-Reader tab select the last three products from the previous step.

| 🥝 Create Stack  |      |             |       |       |   |
|---|------|-------------|-------|-------|---|
| 1-ProductSet-Reader 2-CreateStack 3-Write   |      |             |       |       |   |
| File Name   | Туре | Acquisition | Track | Orbit |   |
| subset_2_of_S1A_IW_GRDH_1SDV_20230308T174046_20230308T174111_047556_05B5EA_6563_Cal_Spk_TC_dB | GRD  | 08Mar2023   | 59    | 47556 |   |
| subset_1_of_S1A_IW_GRDH_1SDV_20230519T174049_20230519T174114_048606_05D890_2249_Cal_Spk_TC_dB | GRD  | 19May2023   | 59    | 48606 |   |
| subset 2 of S1A IW GRDH 1SDV 20230730T174053 20230730T174118 049656 05F897 BEA3 Cal Spk TC dB | GRD  | 30Jul2023   | 59    | 49656 | 구 |







×

In the CreateStack tab, select Product Geolocation as Initial Offset Method (Note: we did not use apply orbit file function, but the product geolocation is accurate enough for the purpose of our analysis)

| Create Stack           |   | ×      |
|------------------------|---|--------|
| 1-ProductSet-Reader    | 2-CreateStack 3-Write   |        |
| Reference:             | subset_2_of_S1A_IW_GRDH_1SDV_20230730T174053_20230730T174118_049656_05F897_BEA3_Cal_Spk_TC_dB |        |
| Resampling Type:       | NONE  | $\sim$ |
| Initial Offset Method: | Product Geolocation   | $\sim$ |
| Output Extents:        | Master  | $\sim$ |
| Find Optimal Referen   | ce  |        |

In the Write tab, adjust the stack name if needed, adjust the output folder and click Run. This step will might take few minutes.

After the process is finished, we can see the new final "Stack" product in the Product Explorer window.

### Display RGB time series

Now we can look at some RGB composites of this time series Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter between one-day acquisition.

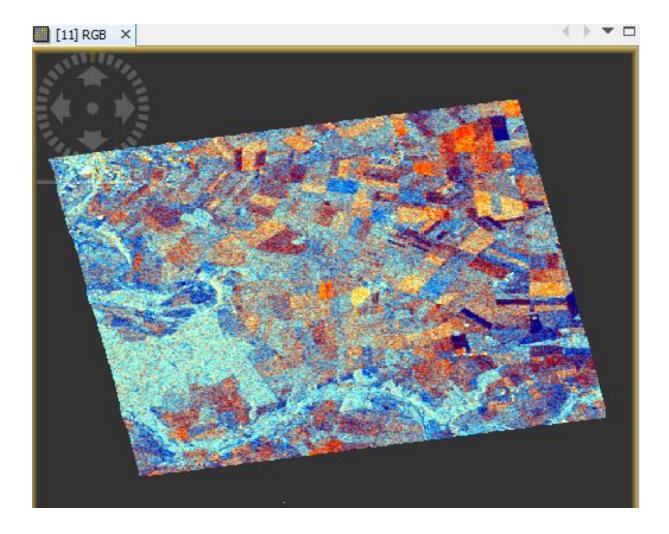
Firstly, we can look at polarimetric composite of the same day. For this, select:

Red: Sigma0\_VV\_db\_mst\_08Mar2023 Green: Sigma0\_VH\_db\_mst\_08Mar2023 Blue: Sigma0\_VH\_db\_mst\_08Mar2023-Sigma0\_VV\_db\_mst\_08Mar2023

| Selec                 | t RGB-Image Channels   | ×    | Edit Blue Expression                |                | ×                                |
|-----------------------|--|------|-------------------------------------|----------------|----------------------------------|
| Profile:              |  |      | Product: [11] subset_2_of_S1A_IW_GR | RDH_2023_Stack | ~                                |
|                       |  |      | Data sources:                       |                | Expression:                      |
|                       | · · · · · · · · · · · · · · · · · · ·                            |      | \$11.Sigma0_VH_db_mst_08Mar2023     | @ + @          | \$11.Sigma0_VH_db_mst_08Mar2023- |
| Red:                  | \$11.Sigma0_VV_db_mst_08Mar2023                                  | ~    | \$11.Sigma0_VV_db_mst_08Mar2023     | Q - Q          | \$11.Sigma0_VV_db_mst_08Mar2023  |
|                       |  |      | \$11.Sigma0_VH_db_slv1_19May2023    | @*@            |                                  |
|                       | fixed range min max  |      | \$11.Sigma0_VV_db_slv2_19May2023    |                |                                  |
| Green:                | \$11.Sigma0_VH_db_mst_08Mar2023                                  | ~    | \$11.Sigma0_VH_db_slv3_30Jul2023    | @/@            |                                  |
|                       |  |      | \$11.Sigma0_VV_db_slv4_30Jul2023    | (@)            |                                  |
|                       | fixed range min max  |      |                                     | Constants ~    |                                  |
| Blue:                 | \$11.Sigma0_VH_db_mst_08Mar2023- \$11.Sigma0_VV_db_mst_08Mar2023 | ~    |                                     | Operators ~    |                                  |
|                       | fixed range min max  |      |                                     | Functions V    |                                  |
| Expressions are valid |  |      | Show bands                          |                |                                  |
|                       |  |      | Show masks                          |                |                                  |
|                       |  |      | Show tie-point grids                |                |                                  |
|                       |  |      | Show single flags                   |                | 📑 📋 🔉 🔁 🚪 Ok, no errors.         |
|                       | OK Cancel  | Help |                                     |                | OK Cancel Help                   |







Another RGB composition we can generate is to look at images of the same polarisation but for different dates:

Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter for different acquisitions. For this, select:

# Red:

# Sigma0\_VH\_db\_mst\_08Mar2023

Green: Sigma0\_VH\_db\_slv\_18May2023

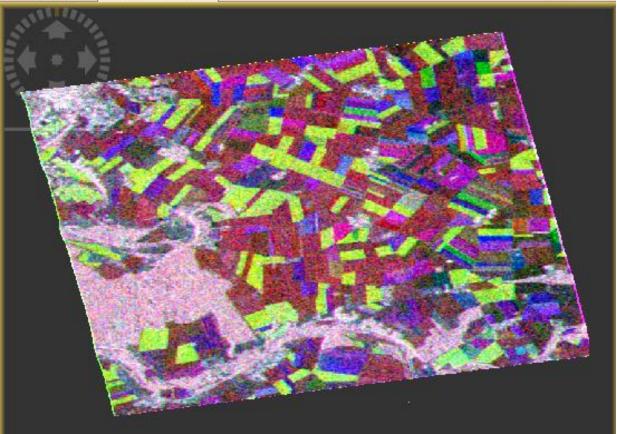
Blue: Sigma0\_VH\_db\_slv\_30Jul2023

ÚSTAV GEOGRAFIE

|        |                              |                          | - 🗃 🖪 🏢              |
|--------|------------------------------|--------------------------|----------------------|
| Red:   | \$11.Sigma0_VH_db_i          | mst_08Mar2023            | ~                    |
|        | fixed range                  | min                      | max                  |
| Green: | \$11.Sigma0_VH_db_s          | slv1_19May2023           | ~                    |
|        | fixed range                  | min                      | max                  |
| Blue:  | \$11.Sigma0_VH_db_s          | slv3_30Jul2023           | ~                    |
|        | fixed range                  | min                      | max                  |
|        |                              | F                        | Expressions are vali |
|        |                              |                          |                      |
| Sto    | re RGB channels as virtual l | bands in current product |                      |



#### [11] RGB × [11] RGB (2) ×

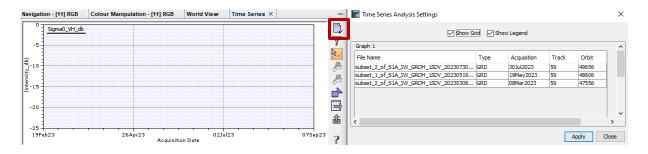


#### Time Series Analysis (using single scenes, not a stack)

Tool cannot use a stack, it needs single images instead

Navigate to View > Tool Windows > Radar > Time Series to open the Time Series tab at the bottom left of your SNAP window.

Click on Settings (top right of Time Series tab) and add individual (preprocessed) images. Click Apply.



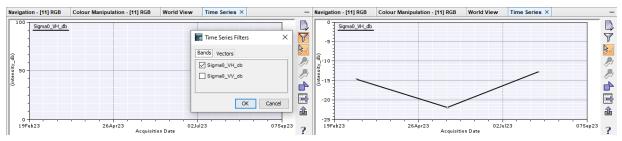




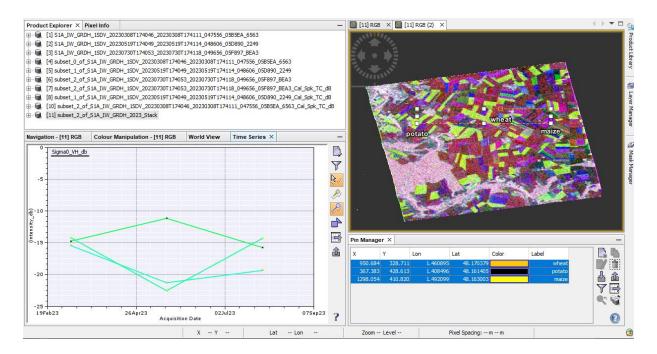


( ) < </p>

Select also polarisation for which you want to explore time-series and dick OK.



Using the time series tab, hover your mouse over the area to see the behaviour of single pixels over or use Pin Manager (View-Tool Windows-Pin Manager) to see the behaviour of the selected Pins.



Explore backscatter values of different crop types within the time range.

For more information, see the lecture: <u>6. SAR and optical remote sensing</u> for precision agriculture 2

### THANK YOU FOR FOLLOWING THE EXERCISE!







## UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 7 – TUTORIAL

Wildfire Mapping with Sentinel-1 & Sentinel-2 using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

## 1 | Exercise outline

In this exercise, we will:

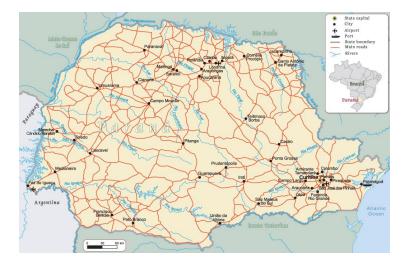
- Detect wildfires on Sentinel-1 and Sentinel-2 images
- Export subset as image to perform another analysis in QGIS
- Map burned areas and quantify burn severity using Normalised Burn Ratio index
- Develop a graph for automated processing using Batch processing
- Create Stack and RGB composites for two Sentinel-1 temporal datasets to observe wildfire burn scars





## 2 | Background

Fires in the grasslands close to a vital South American river delta present serious threats to both nearby wetland ecosystems and human well-being, caution environmental experts.



The wildfires around the important riverside port of Rosario, essential for transporting Argentina's extensive grain harvest, have raised concerns among local residents and activists.

Fires in the grasslands close to a vital South American river delta present serious threats to both nearby wetland ecosystems and human wellbeing, caution environmental experts. The wildfires around the important riverside port of Rosario, essential for transporting Argentina's extensive grain harvest, have raised concerns among local residents and activists.

The Parana River, South America's second-longest river after the Amazon, experienced its lowest water levels since 1944 in 2021 as reported by official data. This decline is attributed to multiple cycles of drought and reduced rainfall in upstream Brazil. In August 2022, the water level remained exceptionally low. The wildfires, many intentionally set by farmers preparing the land for new crops, generated a thick haze that reached Buenos Aires, located approximately 190 miles (300 km) south of Rosario. Residents were displeased with the presence of soot in the air, leading popular weather apps to issue forecasts simply describing the conditions as "smoke."



Wildfires burning in the wetlands of the Paraná River Delta, Argentina, 19 August, 2022







#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-2 images and two Sentinel-1 GRDH images of the same area in Paraná River Delta, Argentina, using the Tile Number \*20HQJ\* downloaded for two days of summer 2022 (before and after the wildfires) from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].

#### 2.2. SNAP - Open and explore product

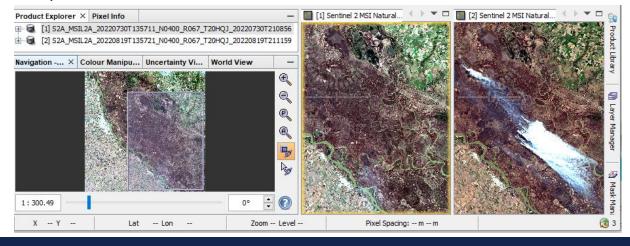
Open SNAP Desktop, click Open Product and open 2 downloaded products (unzipped) by double click on the metadata "MTD MSIL2A.xml" inside the folder. The opened products will appear in Product Explorer window. S2A MSIL2A 20220730T135711\_N0400\_R067\_T20HQJ\_20220730T210856.SAFE.zip S2A\_MSIL2A\_20220819T135721\_N0400\_R067\_T20HQJ\_20220819T211159.SAFE.zip

#### A: Detecting wildfires on Sentinel-2 image

- 1. Select the first product in the Product Explorer window.
- 2. Right click on the product.
- 3. Open RGB Image Window.
- 4. In the pop-up window select 'Sentinel 2 MSI Natural colors (Red: B4; Green: B3; Blue: B2)'.

| Product Explorer × Pixel Info                 | -                       | Selec               | t RGB-Image Channels |           |       | ×     |                 |
|---|-------------------------|---------------------|----------------------|-----------|-------|-------|-----------------|
|   | _T20HQJ_20220819T211159 | Profile:<br>Sentine | 2 MSI Natural Colors |           |       |       | Product Library |
| Navigation - [1] Colour Manipu Uncertainty Vi |                         | Red:                | B4                   |           | ~     |       | orary           |
| 65-00   |                         | _                   |                      | iin       | max   |       | - a             |
|   | G                       | Green:              | B3                   | t         | · · · |       | Layer Manager   |
| 2   |                         | Blue:               | fixed range          | in        | max   |       | anager          |
|   |                         | DIUC.               |                      | in        | max   |       |                 |
|   | 2000 Km                 |                     |                      | OK Const  |       | 11-l- | Mask Man        |
| Off Globe                                     |                         |                     |                      | OK Cancel |       | Help  | Mana            |
| X Y Lat Lon                                   | Zoom Level              |                     | Pixel Spacing: m m   |           |       | 6     | 3               |

- 5. Repeat the process for the second product.
- 6. Tile two opened RGB Windows, e.g. horizontally
- 7. In the Navigation window, zoom in to the wildfire region and syhnchronise views to see the same area before and after wildfires

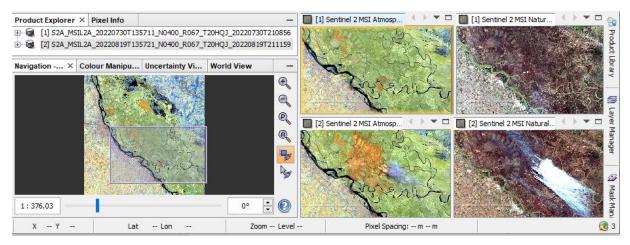






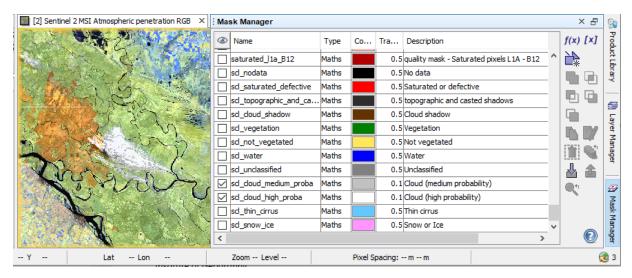
Do the same process for obtaining the color composition in false colors:

- 1. Select the first product in the Product Explorer window.
- 2. Right click on the product.
- 3. Open RGB Image Window.
- 4. In the pop-up window select 'Sentinel 2 MSI Atmospheric penetration (Red: B12; Green: B11; Blue: B8A)'.
- 5. Apply color manipulation (stretching) for RGB
- 6. Repeat the process for the second product.
- 7. Tile opened RGB Windows, e.g. evenly
- 8. If necessary, in the Navigation window, zoom in again to the wildfire region and synnchronise views to see area before and after wildfires



Now let's detect the smoke plume:

- 1. Keep only the Sentinel 2 MSI Atmospheric penetration composition with visible smoke plume from 19 August open
- 2. Go to Mask Manager, and scroll down to the Maths masks
- 3. Select: "scl\_cloud\_medium\_prob" and "scl\_cloud\_high\_proba"
- 4. To visualize the masked areas better, lower the transparency(e.g. 0.1)



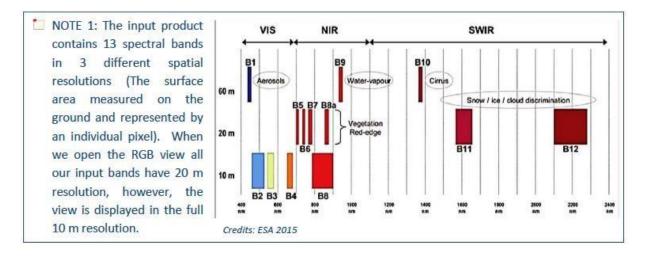
## Fire + cloud plume map





#### Let's export this View as an image and safe as a GeoTIFF:

Because of multiple S2 spatial sizes, we first have to resample the data. Resample to highest spatial resolution: 10 m (e.g. B2).



Raster->Geometric->Resampling:

- Keep I/O names
- In Resampling Parameters, select B2 (10 m)

| Resampling X  | 🎬 Resampling                                 | ×  |
|---|--|--|
| File Help   | File Help                                    |  |
| I/O Parameters Resampling Parameters  | I/O Parameters Resampling Parameters         |  |
| Source Product Name:  | Define size of resampled product             |  |
| [1] S2A_MSIL2A_20220730T135711_N0400_R067_T20HQJ_20220730T210856 V              | By reference band from source product:       | B2 v<br>Resulting target width: 10980                                    |
| Target Product  |  | Resulting target height: 10980   |
| Name:<br>S2A_MSIL2A_20220730T135711_N0400_R067_T20HQJ_20220730T210856_resampled | O By target width and height:                | Target width:         10,980 +           Target height:         10,980 + |
| Save as: BEAM-DIMAP   |  | Width / height ratio: 1.00000  |
| Directory:<br>C:\Users\Onačilová  | O By pixel resolution (in m):                | 20 🜲   |
| Open in SNAP  |  | Resulting target height: 5490  |
|   | Define resampling algorithm                  |  |
|   | Upsampling method:                           | Nearest ~  |
|   | Downsampling method:                         | First 🗸  |
|   | Flag downsampling method:                    | First v  |
|   | Advanced Method Definition by Band           |  |
|   | Resample on pyramid levels (for faster image | ging)  |
| Run Close   | L  | Run Close  |







#### Let's create a subset based on the current view

• Display the image. Note that now many more color options are available. Select MSI Atmospheric penetration

| Select RGB-Image Channels ×  | 🞆 Select RGB-Image Channels  | × |
|--|--|---|
| Profile:<br>Sentinel 2 MSI Natural Colors<br>Sentinel 2 MSI Natural Colors<br>Sentinel 2 MSI False-color Infrared<br>Sentinel 2 MSI False-color Urban<br>Sentinel 2 MSI Agriculture  | Profile:          Sentinel 2 MSI Atmospheric penetration       V       Image: Ima |   |
| Sentinel 2 MSI Atmospheric penetration         Sentinel 2 MSI Healthy Vegetation         Sentinel 2 MSI Healthy Vegetation         Sentinel 2 MSI Natural with Atmospherical Removal         Blue:       B2         Imax         fixed range       min | Green: B11 v   |   |
| Store RGB channels as virtual bands in current product OK Cancel Help  | Store RGB channels as virtual bands in current product OK Cancel Help  | • |

• Make a zoom and add the cloud masks again

| I1] SZA_MSIL2A_20220730T135711       III] SZA_MSIL2A_20220819T135721  | le Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help      |                        |                | Q - Search                            | (CUI+I)    |
|---|--|------------------------|----------------|---------------------------------------|------------|
| I 1 S2A_MSI.2A_20220730T135711         I 2 S2A_MSI.2A_20220819T135721         I 3 S2A_MSI.2A_20220819T135721         I 1 5 S2A_MSI.2A_20220819T135721         I 2 S2A_MSI.2A_20220819T13572   | = 🖣 🆻 🦪 🔏 👢 🖉 🖻 🔍 🏹 🖉 ቀኦ 🔟 🚳 🧟   | Μ. Δ. Σ. 🗞 🕅           | ; ₩ <b>%</b> % |                                       | * * *      |
| Image: 12 S2A_MSIL2A_202208197135721       Image: 17 S2A_MSIL2A_202208197135721       Description       Image: 17 S2A_MSIL2A_202208197135721         Image: 15 S2A_MSIL2A_202208197135721       No400_R067_T20HQ1_202208197211159_resampled       Image: 17 S2A_MSIL2A_202208197135721       Image: 17 S2A_MSIL2A_202208197135721 </th <th>roduct Explo × Pixel Info - 🔲 [3] Sentinel 2 MSI Atmospheric penetration RGB ×</th> <th>Mask Manager</th> <th></th> <th></th> <th>×₽</th>   | roduct Explo × Pixel Info - 🔲 [3] Sentinel 2 MSI Atmospheric penetration RGB × | Mask Manager           |                |                                       | ×₽         |
| Image: Sig S2A_MSIL2A_202208197135721_N0400_R067_T20HQ1_202208197211159_resampled       Image: Girus_douds       Maths       O.S. quality dassification - Cirus ^         Image: Colon Unce Wort       Image: Colon Unce Waths   |  | Name                   | Type Co        | Tra Description                       | f(x) [x]   |
| <ul> <li>snow_and_ice_areas</li> <li>snow_and_ice_areas</li> <li>maths</li> <li>0.5 quality classification - Snow</li> <li>sd_nodata</li> <li>Maths</li> <li>0.5 No data</li> <li>Sd_sturated or defective</li> <li>sd_sturated_defective</li> <li>Maths</li> <li>0.5 Saturated or defective</li> <li>sd_sturated_defective</li> <li>Maths</li> <li>0.5 Source or defective</li> <li>sd_sturated_defective</li> <li>Sd_</li></ul>  |  | cirrus_clouds          | Maths          | 0.5 quality classification - Cirrus 🔨 |            |
| × Colo Unce Worl  |  | snow_and_ice_areas     | Maths          | 0.5 quality classification - Snow     |            |
| Image: Solution and Solutical Advecting Soluticand Solution and Solution and Solution and S |  | sd_nodata              | Maths          | 0.5 No data                           |            |
| Image: Signal problem       Image: Signal pro   | × Colo Unce Worl   | sd_saturated_defective | Maths          | 0.5 Saturated or defective            |            |
| Image: Section of the section of th |  | scl_topographic_and_ca | Maths          | 0.5 topographic and casted sha        | L.         |
| Image: Solution of the solution | A CARLER OF LAND A LAND  | sd_cloud_shadow        | Maths          | 0.5 Cloud shadow                      |            |
| Image: Set of the set of |  | sd_vegetation          | Maths          | 0.5 Vegetation                        |            |
| Image: Section of the section of th |  | sd_not_vegetated       | Maths          | 0.5 Not vegetated                     |            |
| Image: Section of the section of t  |  | sd_water               | Maths          | 0.5 Water                             | 1.         |
| Sd_cloud_medium_proba Maths 0.1 Cloud (medium probability)<br>Sd_cloud_high_proba Maths 0.1 Cloud (high probability)<br>Sd_cloud_high_proba   | L'and La                                | sd_unclassified        | Maths          | 0.5 Unclassified                      | <b>A</b> 1 |
|   | Same - Contraction   | sd_cloud_medium_proba  | Maths          | 0.1 Cloud (medium probability)        | 1          |
|   |  | sd_doud_high_proba     | Maths          | 0.1 Cloud (high probability)          |            |
|   |  | sd_thin_cirrus         | Maths          | 0.5 Thin cirrus                       |            |

 Right-mouse button -> Spatial Subset from View - in the Band Subset you can select all or only few bands to be exported

| [5] Current Profile RGB × | ( ) * □  | 🞇 Specify Product Subset         | ×  | 👹 Specify Product Subset               | ×  |
|---------------------------|--|----------------------------------|--|--|--|
|                           | roduct Librar  | Spatial Subset Band Subset Tie-f | Point Grid Subset Metadata Subset                | Spatial Subset Band Subset Tie-Po      | oint Grid Subset Metadata Subset                 |
|                           | brary  | 1.                               | Pixel Coordinates Geo Coordinates                | <ul> <li>✓ B1</li> <li>✓ B2</li> </ul> | Reflectance in band B1                           |
| S MAR                     | Geometry from WKT  | 6 a.2.                           | Scene start X: 4,397 -<br>Scene start Y: 3,410 - | ш<br>В 3                               | Reflectance in band B2                           |
|                           | Export Transect Pixels Export Mask Pixels                      |                                  | Scene end X: 10,979 🔹                            | ☑ 84 ☑ 85                              | Reflectance in band B4<br>Reflectance in band B5 |
|                           | Export View as Image   | L'and a                          | Scene end Y: 10,337 -<br>Scene step X: 1         |  | Reflectance in band B6                           |
|                           | Export Colour Palette as File<br>Export Colour Legend as Image |                                  | Scene step Y: 1<br>Subset scene width: 6583.0    | <ul> <li>✓ B7</li> <li></li> </ul>     | Reflectance in band B7 V                         |
| 1. 00 M                   | Spatial Subset from View<br>Copy Pixel-Info to Clipboard       | ~                                | Subset scene hei 6928.0                          | Select all Select none                 |  |
| N.                        | A A A A A A A A A A A A A A A A A A A                          |                                  | Estimated, raw storage size: 11395.5M            | 1                                      | Estimated, raw storage size: 11395.5M            |
|                           |  |                                  | OK Cancer Hep                                    | ]                                      | OK Cancel help                                   |
|                           |  |                                  |  |  |  |



Pixel Spacing: -- m -- m



2

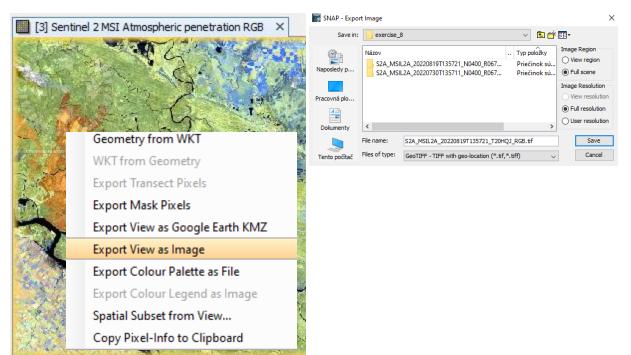
#### Let's reproject the image in Latitude & Longitude coordinates

- Raster->Geometric Operations->Reprojection
- Select the default: Geographic Lat/Ion (WGS 84)
- Run (writing might take some time)

| 🔀 Reprojection  | K Reprojection X   |
|---|--|
| File Help   | File Help  |
| File Help I/O Parameters Reprojection Parameters Source Product Name: [4] subset_0_of_S2A_MSIL2A_20220819T135721_N0400_R067_T20HQJ_20220819T211159_resampled v Target Product Name: subset_0_of_S2A_MSIL2A_20220819T135721_N0400_R067_T20HQJ_20220819T211159_resampled_reprojected v Save as: BEAM+DIMAP v Directory: [2:FESA_DREUM/exercise_B] | File       Help         I/O Parameters       Reprojection Parameters         Coordinate Reference System (CRS)       © Custom CRS         © Custom CRS       Geodetic datumi:         World Geodetic System 1984       >         Projection:       Geographic Lat/Lon (WGS 84)         Projection Parameters       Projection Parameters         O Predefined CRS       Select         Use CRS of       [1] S2A_MSIL2A_20220730T135711_N0400_R067_T20HQ1_20220730T210856         Output Settings |
| ☑ Open in SNAP<br>Run Close   | ✓ Preserve resolution       ✓ Reproject tie-point grids         Output Parameters       No-data value:       NaN         ▲ Add delta lat/on bands       Resampling method:       Nearest       ✓         Output Information       Scene width: 7846 pixel       Center longitude:       60°01'58' W         Scene height: 6929 pixel       Center latitude:       33°07'20' S         CRS:       WGS84(DD)       Show WKT  |

#### Now we can export View as GeoTiff

- Right mouse button: Export View as Image
- Select: Full scene, Full resolution, GeoTIFF



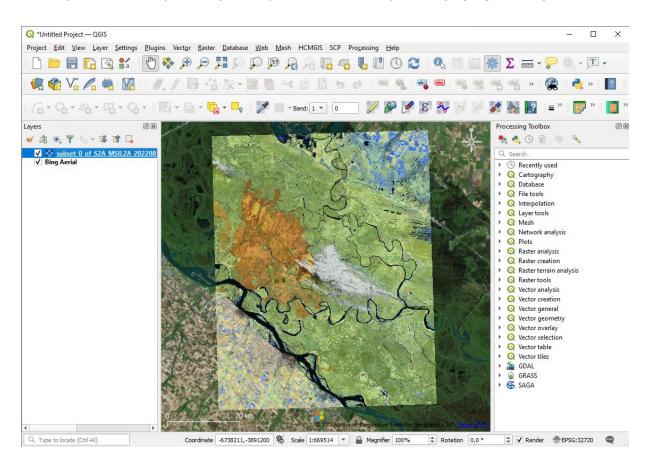






#### Now we open the output image in QGIS

- We can overlay it to e.g. Google Satellite or Bing aerial image:
- Web->OpenLayers plugin->Google Maps->Google Satellite
- Move the Subset above the satellite
- Play with Transparency: Properties->Transparency (e.g. 80%)





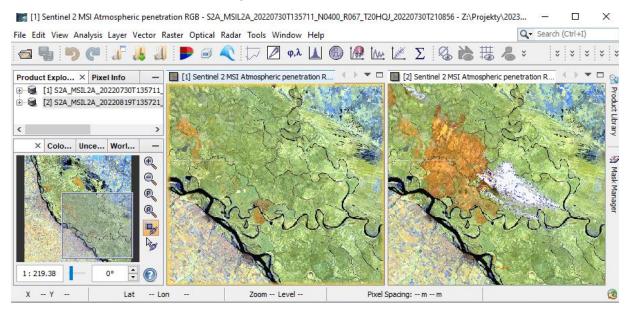


#### **B: Burned area mapping with Sentinel-2**

How to quantify the impact of the Paraná wildfire?

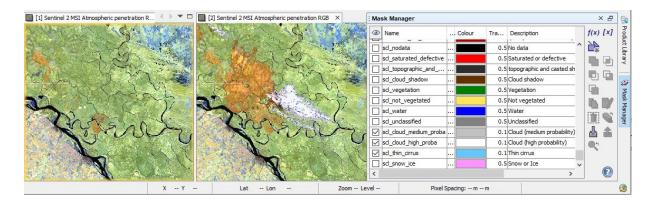
#### Let's have look to the before & after images:

- Open RGB Image Window:
- Select: MSI Atmospheric penetration
- Window-> Tile horizontally, zoom in



#### Let's create a cloud mask:

- Go to Mask Manager, and scroll down to the Maths masks
- Select: cloud medium & cloud high probability & Thin cirrus
- To visualize them better, lower the transparency (e.g. 0.1)



Now we make a cloud band based on the selected mask

Band math expression







#### We make a cloud band based on the selected mask

- Navigate to Raster Band Maths
- Name the new mask: *clouds*

| 🞆 Band Maths   |                       |                                | ×  | 실 New Logical Band Mat  | hs E | xpression  |                        |        |                |                   |       | ×                      |
|--|-----------------------|--------------------------------|----|---|------|--|------------------------|--------|----------------|-------------------|-------|------------------------|
| Target product:<br>[1] S2A_MSIL2A_20<br>Name:<br>Description:<br>Unit:<br>Spectral wavelength: | clouds                | 067_T20HQJ_20220730T210856     |    | Data sources:<br>scl_cloud_shadow<br>scl_vegetation<br>scl_not_vegetated<br>scl_water<br>scl_unclassified<br>scl_cloud_medium_proba | ^    | @ and @<br>@ or @<br>not @<br>(@)<br>Constants ~ |                        | loud_r |                | m_prol<br>proba o |       | hin_cirrus             |
| Replace NaN and  | ated uncertainty band |                                | aN | scl_cloud_high_proba<br>scl_thin_cirrus<br>Show bands<br>Show masks<br>Show tie-point grids   | ~    | Operators V<br>Functions V                       |                        |        |                |                   |       |                        |
| Load Sa  | ave                   | Edit Expression OK Cancel Help | •  | Show single flags   |      |  | anni<br>surai<br>surai |        | <b>Э</b><br>ок |                   | ancel | Dk, no errors.<br>Help |

#### Adding the cloud mask as a band

- On the image, right click-> Band Maths
- Make sure to deactivate "Virtual". We want to store the data!
- Go to "Edit Expression"
- Select Clouds

Repeat for the second image

| 🛃 Band Maths                          |  | ×   | Band Maths Expression E                                | dito | r                   |   |                           |          |      |          | ×              |
|---------------------------------------|--|-----|--|------|---------------------|---|---------------------------|----------|------|----------|----------------|
| Target product:<br>[2] S2B_MSIL2A_202 | 220824T135709 N0400 R067 T20HQJ 20220824T19500 | 4 ~ | Product: [2] S2B_MSIL2A_2022                           | 082  | 4T135709_N0400_R067 |   |                           | 24T 19   | 5004 |          | ~              |
| Name:                                 | cloud_mask                                     |     | Data sources:<br>\$2.scl_not_vegetated                 | ^    | @+@                 |   | Expression:<br>\$2.clouds |          |      |          |                |
| Description:<br>Unit:                 |  |     | \$2.scl_water<br>\$2.scl_unclassified                  |      | @-@                 |   |                           |          |      |          |                |
| Spectral wavelength:                  | 0.0<br>ression only, don't store data)         |     | \$2.scl_cloud_medium_proba<br>\$2.scl_cloud_high_proba |      | @*@<br>@/@          |   |                           |          |      |          |                |
| Replace NaN and                       |  | NaN | \$2.scl_thin_cirrus<br>\$2.scl_snow_ice                |      | (@)                 |   |                           |          |      |          |                |
| Generate associa                      | ated uncertainty band                          |     | \$2.clouds   | ×    |                     | ~ |                           |          |      |          |                |
|                                       | 2F 1 A   |     | Show bands<br>Show masks                               |      | Functions           | ~ |                           |          |      |          |                |
| Load Sa                               | eve Edit Expression                            | _   | Show tie-point grids                                   |      |                     |   |                           | බ        | 5    | <b>m</b> | Ok, no errors, |
|                                       |  | ۱p  | Show single flags                                      |      |                     |   |                           | ¢У<br>ОК |      | Cancel   | Help           |

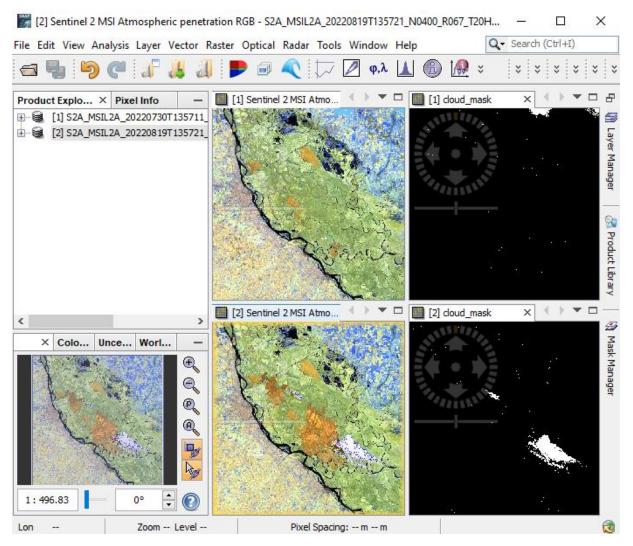




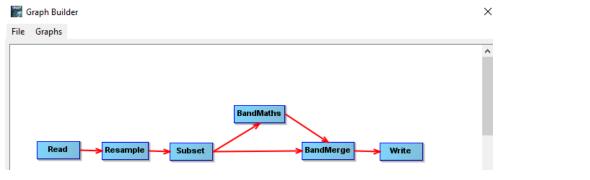


#### Vizualize all products

- Windows: Tile evenly
- Navigation: zoom all



#### Tools – Graph Builder



- Add->Raster->Geometric->Resample
- Add->Raster->Geometric->Subset
- Add->Raster->BandMaths
- Add->Raster->BandMerge
- Save your created graph

| 🎆 SNAP - Save | Graph          |           |           | ×              |
|---------------|----------------|-----------|-----------|----------------|
| Save in:      | exercise_9     | - v       | 🗈 💣 🎹     | <b>.</b>       |
| Naposledy p   | Názov          |           | Veľkosť . | . Dátum úpravy |
|               | File name:     | wildfires | .xml      | Save           |
| Pracovná plo  | Files of type: | Graph (*  | ⊧.xml) ∨  | Cancel         |

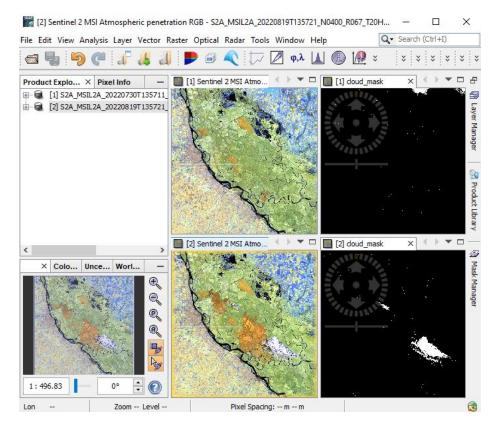




#### **Tools – Batch processing**

This allows to process both images at the same time.

- Click on Add opened
- Load your graph
- Make sure to refresh



#### 🚪 Batch Processing

| File Graphs                    |                 |             |            |           |             |
|--------------------------------|-----------------|-------------|------------|-----------|-------------|
| S2A_MSIL2A_20220730T13         | 5               |             |            |           |             |
| S2A_MSIL2A_20220819T13         |                 | 19          |            |           |             |
| Tile Name                      | туре            | Acquisition | Track      | Orbit     |             |
| S2A_MSIL2A_20220730T13         | S2_MSI_Level-2A | 30Jul2022   | 99999      | 99999     | 4           |
| S2B_MSIL2A_20220824T135        | S2_MSI_Level-2A | 24Aug2022   | 99999      | 99999     |             |
|                                |                 |             |            |           | _           |
|                                |                 |             |            |           | <b></b>     |
|                                |                 |             |            |           |             |
|                                |                 |             |            |           | ▲<br>★<br>★ |
|                                |                 |             |            |           |             |
|                                |                 |             |            |           |             |
|                                |                 |             |            |           | ٠           |
|                                |                 |             |            |           | 2 Products  |
| Target Folder                  |                 |             |            |           |             |
| Save as: BEAM-DIMAP            | $\sim$          |             |            |           |             |
| Directory:                     |                 |             |            |           |             |
| C: \Users \Onačillová \Desktop | ESA_ENEUM\exer  | cise_8      |            |           |             |
| Skip existing target files     | Keep source pr  | oduct name  |            |           |             |
|                                | Rur             | remote      | Load Graph | Run Close | Help        |







×

#### Resample

- Select a reference band: B2 at 10 m.
- Resampling method: Bilinear

| Batch Processing : myGraph.xml        |                                    | ×  |
|---------------------------------------|------------------------------------|----|
| File Graphs                           |                                    |    |
| I/O Parameters Resample Subset BandM  | aths BandMerge                     |    |
| Define size of resampled product      |                                    | ^  |
|                                       | B2 🗸 🗸                             |    |
| By reference band from source product | :: Resulting target width: 10980   |    |
|                                       | Resulting target height: 10980     |    |
|                                       | Target width: 10,980 🔹             |    |
| O By target width and height:         | Target height: 10,980 🔹            |    |
|                                       | Width / height ratio: 1.00000      |    |
|                                       | 100 🗘                              |    |
| O By pixel resolution (in m):         | Resulting target width: 1098       |    |
|                                       | Resulting target height: 1098      |    |
| Define resampling algorithm           |                                    |    |
| Upsampling method                     | Bilinear                           |    |
|                                       | Inner                              |    |
| Downsampling method                   | First 🗸                            |    |
|                                       |                                    |    |
| Flag downsampling method              | First 🗸                            | ¥  |
|                                       | Run remote Load Graph Run Close He | lp |

#### Subset

- Select bands: B3, B8, B12, Cloud\_mask
- Select Geographic coordination
- Click on A, zoom in to the area of interest
- Select a yellow box within the red square

|                             | Resample | Subset    | BandMaths   | BandMerge |      |                  |          |
|-----------------------------|----------|-----------|-------------|-----------|------|------------------|----------|
| ource Ba <mark>n</mark> ds: | B1<br>B2 |           |             |           |      |                  | ^ '      |
|                             | 83       |           |             |           |      |                  |          |
|                             | 84<br>85 |           |             |           |      |                  |          |
|                             | B6       |           |             |           |      |                  |          |
|                             | B7       |           |             |           |      |                  |          |
|                             | B8       |           |             |           |      |                  | <b>v</b> |
| Copy Metada                 | ta       |           |             |           |      |                  |          |
| ) Pixel Coordina            | ates 🔍 G | eographic | Coordinates |           |      |                  |          |
| eference band:              |          | cographic | coordinates |           |      |                  |          |
| eference band:              | 81       |           |             |           |      |                  | Y        |
|                             |          |           |             |           |      | 6                | C C A    |
|                             | 1        | SET.      |             |           |      | Real Property in | 200      |
| N. C. Start                 |          |           |             |           | 3-44 |                  |          |
| Sept.                       |          |           |             |           |      |                  |          |
|                             | 1 Sta    |           |             |           |      | 1                |          |

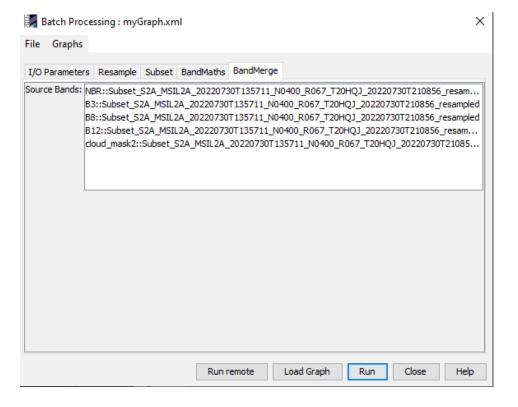




| Band          | Math                   |                   | 50 EXP                  | LOITING SPE                      | CTRAL RESPONSE CURVES                  |
|---------------|------------------------|-------------------|-------------------------|----------------------------------|--|
| • Go t        | o "Edit Expre          | ession"           | 40                      | <u></u>                          | BURNED                                 |
|               | : Normalize            |                   | NCE CS 30               |                                  |  |
| (вя-в         | 12)/(B8+B12            | 2)                |                         |                                  | M                                      |
| 🛃 Batch Pro   | ocessing : myGraph.xml |                   | 10                      |                                  | HEALTHY                                |
| File Graphs   | 5                      |                   |                         | ELECTROMA                        | GNETIC SPECTRUM (Wavelength µm)        |
| I/O Paramete  | ers Resample Subset Ba | ndMaths BandMerge | 0.45 gs 0.69<br>VISIBLE | 0.75 0.90<br>NEAR INFRARED (NIR) | 2.09 2.35<br>SHORTWAVE INFRARED (SWIR) |
| Target Band:  | NBR.                   |                   |                         |                                  |  |
| Target Band T | ype: float32           |                   |                         |                                  |  |
| Band Unit:    | Arithmetic Expression  | on Editor         |                         | ×                                |  |
| No-Data Value | Data sources:          |                   | Expression:             |                                  |  |
| Expression:   | B3 ^                   | @+@               | (B8- B12)/(B8+ B12)     | ^                                |  |
|               | B8                     | @-@               |                         |                                  |  |
|               | B12<br>cloud_mask2 ¥   | @*@               |                         |                                  |  |
|               | Show bands             | @/@               |                         |                                  |  |
|               | Show masks             | (@)               |                         |                                  |  |
|               | Show tie-point grids   | Constants ~       |                         |                                  |  |
|               | Show single flags      | Operators ~       |                         | Ok, no errors.                   |  |
|               |                        |                   | OK Car                  | ncel Help                        |  |
|               |                        |                   | Ed                      | it Expression                    |  |
|               |                        | Run remote Loa    | ad Graph Run C          | lose Help                        |  |

#### **Band merge**

• Keep the source bands: NBR, B3, B8, B12, cloud\_mask





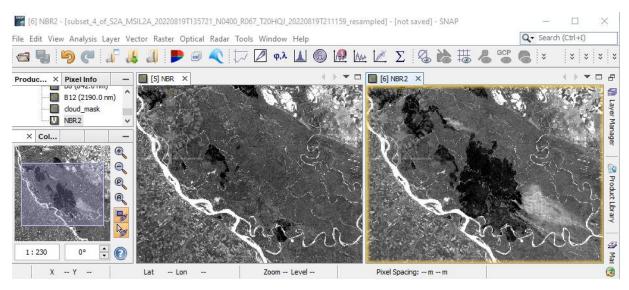


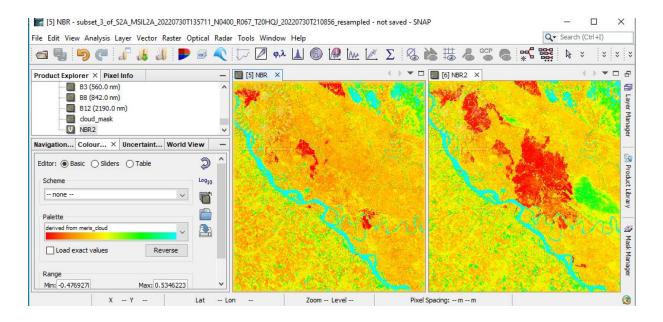


#### Running and visualizing the NBR band

Try a color table:

• Colour manipulation: Open color table, choose a color gradient, e.g. ,derived from meris\_cloud"



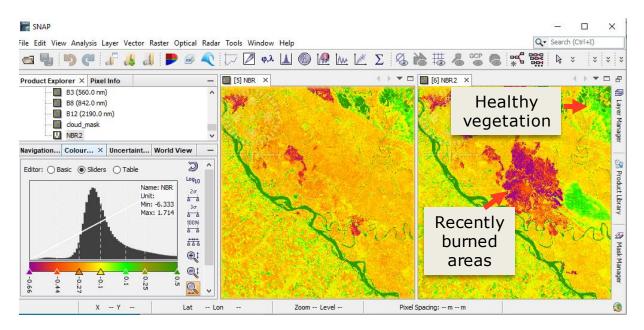






You can also set the position of sliders and color them for better visualization or change ranges of values in the Table tab.

NBR ranges between -1 and 1. A high NBR value indicates healthy vegetation. A low value indicates bare ground and recently burnt areas. Non-burnt areas usually have values close to zero.



#### Burn severity - dNBR

The difference between the pre-fire and post-fire NBR obtained from the images is used to calculate the delta NBR (dNBR or  $\Delta$ NBR), which then can be used to estimate the burn severity. A higher value of dNBR indicates more severe damage, while areas with negative dNBR values may indicate regrowth following a fire. The formula used to calculate dNBR is illustrated below:

dNBR or  $\triangle NBR = PrefireNBR - PostfireNBR$ 

Go to Raster – Band Maths and Edit Expression

| 🞆 Band Maths 🛛 🕹  | Band Maths Expression Editor  |   |  |
|---|---|---|--|
| Target product:         [5] subset_3_of_S2A_MSIL2A_20220730T135711_N0400          Name:       dNBR         Description: | Product: [5] subset 3 of<br>Data sources:<br>\$5.83<br>\$5.88<br>\$5.812<br>\$5.cloud_mask<br>\$5.NBR<br>S5.NBR<br>S5.NBR<br>S5.NBR<br>S5.NBR<br>S5.NBR | © + @           @ + @           @ - @           @ * @           @ / @           (@)           Constants ~           Operators ~           Functions ~ | 135711_N0400_R067_T20HQJ_2022073   ~<br>Expression:<br>\$5.NBR- \$6.NBR2 |
| Load Save Edit Expression   | Show tie-point grids  |   | 📑 🗎 🔉 🔝 💹 Ok, no errors.   |
| OK Cancel Help  |   |   | OK Cancel Help   |

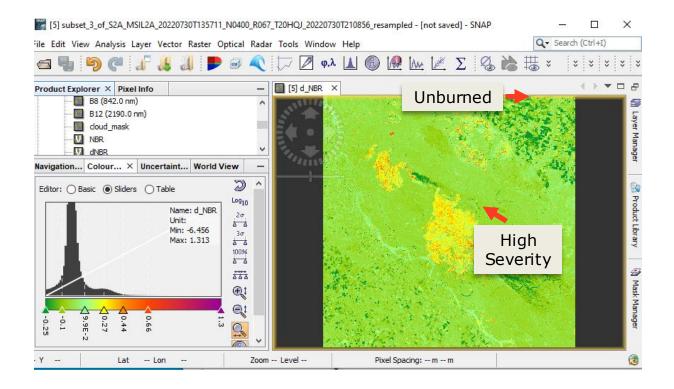




Set the position of sliders and color them for better visualization or change ranges of values in the Table tab.

# NBR ranges between -1 and 1. A high NBR value indicates healthy vegetation. A low value indicates bare ground and recently burnt areas. Non-burnt areas usually have values close to zero.

dNBR values can vary from case to case, and so, if possible, interpretation in specific instances should also be carried out through field assessment; in order to obtain the best results. However, the United States Geological Survey (USGS) proposed a classification table to interpret the burn severity, which can be seen below in the table.



| Severity Level                      | dNBR Range (scaled by 10 <sup>3</sup> ) | dNBR Range (not scaled) |
|-------------------------------------|---|-------------------------|
| Enhanced Regrowth, high (post-fire) | -500 to -251                            | -0.500 to -0.251        |
| Enhanced Regrowth, low (post-fire)  | -250 to -101                            | -0.250 to -0.101        |
| Unburned                            | -100 to +99                             | -0.100 to +0.99         |
| Low Severity                        | +100 to +269                            | +0.100 to +0.269        |
| Moderate-low Severity               | +270 to +439                            | +0.270 to +0.439        |
| Miderate-high Severity              | +440 to +659                            | +0.440 to +0.659        |
| High Severity                       | +660 to +1300                           | +0.660 to +1.300        |

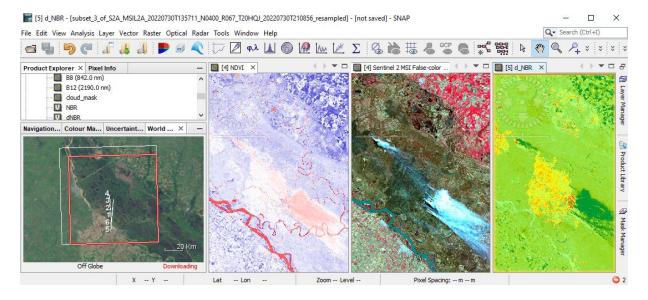




ÚSTAV GEOGRAFIE

#### Comparison: Severity map, NDVI and false color composition

To compare different views of the same area and explore it more in detail, create also NDVI and false color composition. You can observe, that areas with high NDVI values correspond to the barren areas affected by wildfires. False color composition also depicts areas affected by fire – these areas are shown in dark pixels. False color composite B8-B4-B3 of the Sentinel 2 image (during fire), with superimposed ongoing wildfire sites, note that the smoke direction is corresponding to the wind direction.





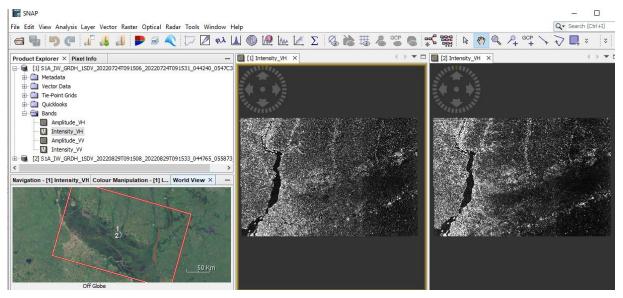


#### C: Burned area mapping using Sentinel-1

Load both Sentinel-1 products (pre-fire and post-fire) that you have in the folder for this exercise by navigating to File - Open Product.

S1A\_IW\_GRDH\_1SDV\_20220724T091506\_20220724T091531\_044240\_0547C3\_961B.SAFE S1A\_IW\_GRDH\_1SDV\_20220829T091508\_20220829T091533\_044765\_055873\_EED3.SAFE

Visualize the input products – open e.g. Intensity\_VH for both products by double-click on it under the Bands folder.



#### 1. Pre-processing

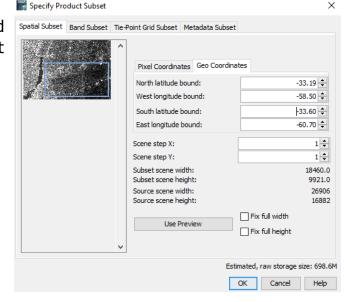
We need to apply identical pre-processing steps to both of our scenes:

#### Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Select the first product and Go to the Subset tab and at "Geo Coordinates" set: North latitude bound: -33.19 West longitude bound: -58.50 South latitude bound: -33.60 East longitude bound: -60.70

Repeat for the second image.









#### Thermal noise removal

Navigate to Main Menu – Radar – Radiometric – S-1 Thermal Noise Removal In the I/O Parameters tab, select the last subset product with applied orbit file and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters you can select both polarization and make sure that the "Remove Thermal Noise" option is selected.

Repeat for the second subset image.

| S-1 Thermal Noise Removal   | × | S-1 Thermal Noise Remov  | al                      | × |
|---|---|--|-------------------------|---|
| File Help   |   | File Help  |                         |   |
| I/O Parameters Processing Parameters Source Product [3] subset_0_of_S1A_IW_GRDH_ISDV_20220829T091508_20220829T091533_044765_055873_EED3  Target Product Name: subset_0_of_S1A_JW_GRDH_ISDV_20220829T091508_20220829T091533_044765_055873_EED3_trv Save as: BEAM-DIMAP Directory: C1Projekty/2022_ESA_ENEUM/07_ucebne_materialy/Wplikacie_DP2/practicals/exercise_6 Open in SNAP |   | File Help  I/O Parameters Processing Pai Polarisations:  Remove Thermal Noise Re-Introduce Thermal Noise | WH<br>W<br>Output Noise |   |
| Run Clos  | • |  |                         |   |

#### Calibration

With our image now subsetted and with TNR, we must apply image calibration. This step is necessary to normalize the values in the image into backscatter values so we can compare multiple images in a time series.

Navigate to Main Menu - Radar - Radiometric - Calibrate

In the I/O Parameters tab, select the product with thermal noise removal and name the target product. In the case of this final product of preprocessing, please, save it to your folder for this exercise

In the Processing Parameters select both bands as input and accept all default settings and then click Run

Repeat for the second image. The saving might take some time.

| Calibration X  | © Calibration ×   |
|--|---|
| File Help  | File Help   |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters  |
| Source Product<br>source:<br>[5] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_202208 v   | Polarisations: VH<br>VV   |
| Target Product Name: H_1SDV_20220829T091508_20220829T091533_044765_055873_EED3_thr_Cal Save as: BEAM-DIMAP Directory: Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Aplikacie_DP2\pr Open in SNAP | <ul> <li>Save as complex output</li> <li>✓ Output sigma0 band</li> <li>Output gamma0 band</li> <li>Output beta0 band</li> </ul> |
| Run Close  | Run Close   |





#### Speckle Filter

Despeckling removes thermal noise introduced by the sensor from the image to remove potential sources of error in analysis.

Navigate to Radar > Speckle Filtering Single Product Speckle Filter. In the Speckle-Filter tab, choose the simple Lee Sigma filter with default window sizes.

| C Single Product Speckle Filter ×  | C Single Product S               | peckle Filter >        |
|--|----------------------------------|------------------------|
| File Help  | File Help                        |                        |
| I/O Parameters Processing Parameters   | I/O Parameters Pro               | cessing Parameters     |
| Source Product<br>source:<br>[7] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_202208 v |                                  | Sigma0_VH<br>Sigma0_VV |
| Target Product Name: DV_20220829T091508_20220829T091533_044765_055873_EED3_tnr_Cal_Spk | Filter:                          | Lee Sigma 🗸            |
| Directory:   | Number of Looks:<br>Window Size: | 1 ~                    |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Aplikacie_DPZ\pr                        |                                  | 7x7 ~<br>0.9 ~         |
| Open in SNAP   | Target Window Size:              | 3x3 ~                  |
|  |                                  |                        |
| Run Close  |                                  | Run Close              |

#### Terrain-Correction

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-**Doppler Terrain Correction** 

- In the I/O Parameters tab set as "Source Product" the speckle-filtered product.
- In "Target Product", keep the default name and set the Directory
- In the Processing Parameters tab set:
- Digital Elevation Model: SRTM 3Sec (Auto Download)
- Keep defaults values for the other parameters. Click Run.

Approximate processing time: 2.5 minutes.







| 📀 Range Doppler Terrain Correction   | × C Range Doppler Terrain Correct   | tion X   |  |
|--|-------------------------------------|--|--|
| File Help  | File Help                           |  |  |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parame    | eters  |  |
| Source Product<br>source:<br>[9] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_20220829T091533_04 v       | Source Bands:                       | Sigma0_VH<br>Sigma0_VV   |  |
| Target Product<br>Name:<br>V GRDH 1SDV 20220829T091508 20220829T091533 044765 055873 EED3 tmr Cal Spk TC |                                     |  |  |
|  | Digital Elevation Model:            | SRTM 3Sec (Auto Download) v  |  |
| Directory:   | DEM Resampling Method:              | BILINEAR_INTERPOLATION ~   |  |
| rojekty\2023_ESA_ENEUM\07_ucebne_materialy\Aplikacie_DPZ\practicals\exercise_6                           | Image Resampling Method:            | BILINEAR_INTERPOLATION ~   |  |
| Open in SNAP   | Source GR Pixel Spacings (az x rg): | 10.0(m) × 10.0(m)  |  |
|  | Pixel Spacing (m):                  | 10.0   |  |
|  | Pixel Spacing (deg):                | 8.983152841195215E-5   |  |
|  | Map Projection:                     | WGS84(DD)  |  |
|  | Mask out areas without elevation    | in   |  |
|  | Output bands for:                   |  |  |
|  | Selected source band                | DEM Latitude & Longitude   |  |
|  |                                     | Local incidence angle     Projected local incidence angle              |  |
|  | Layover Shadow Mask                 |  |  |
|  | Apply radiometric normalization     |  |  |
|  | Save Sigma0 band                    | Use projected local incidence angle from DEM $\qquad \bigtriangledown$ |  |
|  | Save Gamma0 band                    | Use projected local incidence angle from DEM $\qquad \bigtriangledown$ |  |
|  | Save Beta0 band                     |  |  |
|  | Auxiliary File (ASAR only):         | Latest Auxiliary File 🗸 🗸  |  |
| Run Close  | •                                   | Run Close  |  |

Do not forget to save these two output terrain corrected products. We will need them saved for the next step.

#### Create stack

Go to Radar > Coregistration > Stack Tools > Create Stack

In the Product-Set-Reader tab select the last three products from the previous step.

| 📀 Create Stack                               |      |             |       |       | ×      |
|--|------|-------------|-------|-------|--------|
| 1-ProductSet-Reader 2-CreateStack 3-Write    |      |             |       |       |        |
| File Name                                    | Туре | Acquisition | Track | Orbit | -<br>- |
| subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508 | GRD  | 29Aug2022   | 68    | 44765 |        |
| subset_1_of_S1A_IW_GRDH_1SDV_20220724T091506 | GRD  | 24Jul2022   | 68    | 44240 |        |
|  |      |             |       |       | 4      |







In the CreateStack tab, select Product Geolocation as Initial Offset Method (Note: we did not use apply orbit file function, but the product geolocation is accurate enough for the purpose of our analysis)

| Create Stack                   | >  |
|--------------------------------|--|
| 1-ProductSet-Reader            | 2-CreateStack 3-Write  |
| Reference:<br>Resampling Type: | subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_20220829T091533_044765_055873_EED3_tnr_Cal_Spk_TC<br>NONE |
| Initial Offset Method:         | Product Geolocation v  |
| Output Extents:                | Master ~   |
| Find Optimal Refere            | nce  |

In the Write tab, adjust the stack name if needed, adjust the output folder and click Run. This step will might take few minutes.

After the process is finished, we can see the new final "Stack" product in the Product Explorer window.

#### 2 Display RGB time series

Now let 's have a look at some RGB composite of this time series Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter signal for different dates:

Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter for different acquisitions. For this, select :

Red: Sigma0\_VH\_slv\_24Jul2022

Green:Sigma0\_VV\_slv2\_24Jul2022

Blue: Sigma0\_VH\_mst\_29Aug2022

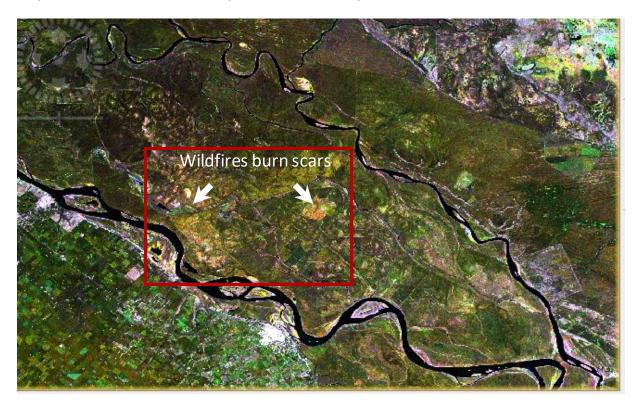
| Red:   | \$13.Sigma0_VH_slv1_24Jul2022 | <u> </u> |  |  |
|--|-------------------------------|----------|--|--|
|  | fixed range min               | max      |  |  |
| Green:   | \$13.Sigma0_VV_slv2_24Jul2022 | ~        |  |  |
|  | fixed range min               | max      |  |  |
| Blue:  | \$13.Sigma0_VH_mst_29Aug2022  | ~        |  |  |
|  | fixed range min               | max      |  |  |
| Expressions are valid                                  |                               |          |  |  |
| Store RGB channels as virtual bands in current product |                               |          |  |  |







Explore the final RGB composite to identify wildfires.



For more information, see the lecture: <u>7. SAR and optical remote sensing</u> for mapping wildfires

THANK YOU FOR FOLLOWING THE EXERCISE!







## UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



## EXERCISE 8 – TUTORIAL

Sentinel-1 & Sentinel-2 for Snow and Ice using the SNAP software and EO Browser





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

## 1 | Exercise outline

In this first exercise for mapping snow and ice, we will:

- Learn the basic steps to calculate glacier velocity using Sentinel-1 data
- Perform preprocessing of data
- Use velocity vector to see direction and speed of glacier flow





## 2 | Background

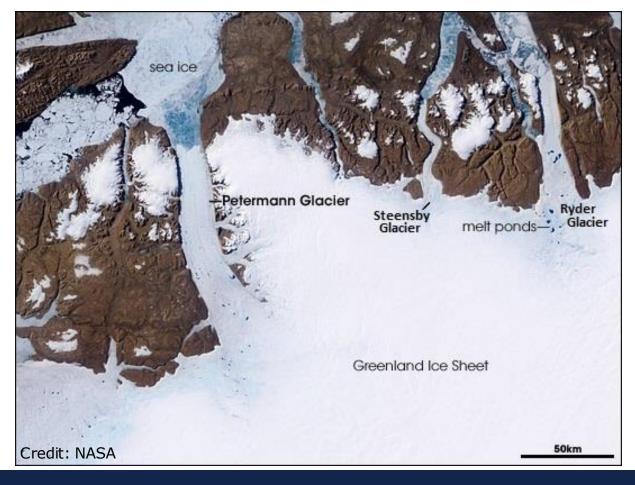
#### Mapping snow and ice using Sentinel-1 and Sentinel-2 data

The Greenland ice sheet ranks as the Earth's second-largest mass of ice. As the dimate undergoes changes, there's a notable increase in surface melting of the ice sheet, leading to a greater discharge of freshwater into the ocean. This phenomenon significantly contributes to the global rise in sea levels.

Monitoring glacier velocity is crucial for understanding glacier dynamics and its impact on global sea levels. Satellite data serves as a valuable tool for tracking glacier velocity across expansive areas.

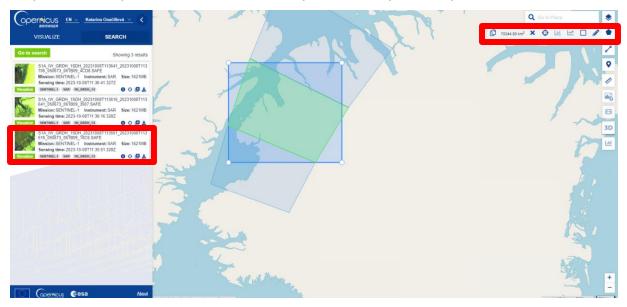
Monitoring glacier velocity is crucial for understanding glacier dynamics and its impact on global sea levels. Satellite data serves as a valuable tool for tracking glacier velocity across expansive areas. Two primary methods are commonly employed to measure ice flow speed using satellite data: SAR interferometry and feature/speckle tracking (utilizing optical or SAR data) between consecutive acquisitions. This tutorial will focus on the latter method, specifically applied to Sentinel-1 data.

The Petermann Glacier, a substantial tidewater glacier, drains over 4% of the Greenland ice sheet via the 90 km long Petermann Fjord, ultimately terminating in a floating ice tongue spanning an area of approximately 900 km<sup>2</sup>. An estimated 12 billion tonnes of ice are discharged into the ocean annually, with an approximate ice flow speed of 1 km/year.



#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 images of the same area in northern Greenland, downloaded for year 2023 from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].

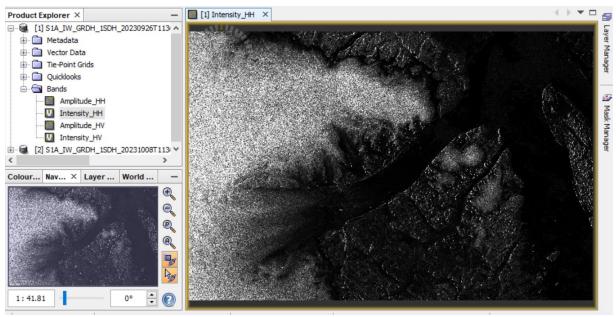


#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, dick Open Product and open 2 Sentinel-1 GRDH downloaded products with HH and HV polarizations acquired on 26 September and 8 October 2023 by double click on the zipped folders. The opened products will appear in Product Explorer window:

S1A\_IW\_GRDH\_1SDH\_20230926T113616\_20230926T113641\_050498\_061508\_2030.zip S1A\_IW\_GRDH\_1SDH\_20231008T113616\_20231008T113641\_050673\_061B09\_3507.zip

Click + to expand the contents of product [1] from 26 September 2023, then expand Bands folder and double click on Intensity\_HH band to visualize it.







The scene appears to be "mirrored" due to the fact that it was captured during a descending pass, with the satellite moving from north to south and looking towards the right (in this case, west). As a result, the view displays pixels in the order of data acquisition, as the image has not yet been projected into cartographic coordinates.

#### 3.1 Pre-processing

We need to apply identical pre-processing steps to both of our scenes:

#### Apply orbit file

Navigate to Main Menu – Radar – Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Repeat for the second image.

| C Apply Orbit File ×   | C Apply Orbit File X   |
|--|--|
| File Help  | File Help  |
| I/O Parameters Processing Parameters Source Product source: [1] S1A_IW_GRDH_1SDH_20230926T113616_20230926T113641_0 v           | I/O Parameters Processing Parameters Orbit State Vectors: Sentinel Precise (Auto Download) Polynomial Degree: 3 Do not fail if new orbit file is not found |
| Target Product Name: S1A_IW_GRDH_1SDH_20230926T113616_Orb Save as: BEAM-DIMAP Directory: Z:\ESA_RADAR \exercise_8 Open in SNAP |  |
| Run Close  | Run Close  |

#### Thermal noise removal

Navigate to Main Menu – Radar – Radiometric – S-1 Thermal Noise Removal

In the I/O Parameters tab, select the product with applied orbit file and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters you can select only HH polarization (or it is possible within the next step calibration) and make sure that the "Remove Thermal Noise" option is selected.

Repeat for the second image.







| S-1 Thermal Noise Removal   | C S-1 Thermal Noise Removal     X |
|---|---|
| File Help   | File Help   |
| File       Help         I/O Parameters       Processing Parameters         Source Product       Source product:         [3] S1A_IW_GRDH_ISDH_20230926T113616_20230926T113641_0           Target Product       Name:         S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr          Save as:       BEAM-DIMAP         Directory:          C: \Users\UGE\pocuments          ✓ Open in SNAP | I/O Parameters       Processing Parameters         Polarisations:       HH         HV       Remove Thermal Noise         Re-Introduce Thermal Noise       Output Noise  |
|   |   |
| Run Close   | Run Close   |

#### Calibration

Navigate to Main Menu - Radar - Radiometric - Calibrate

In the I/O Parameters tab, select the product with thermal noise removal and name the target product. In the case of this final product of preprocessing, please, save it to your folder for this exercise

In the Processing Parameters you can select only HH polarization and accept all default settings and then click Run

Repeat for the second image. The saving might take some time.

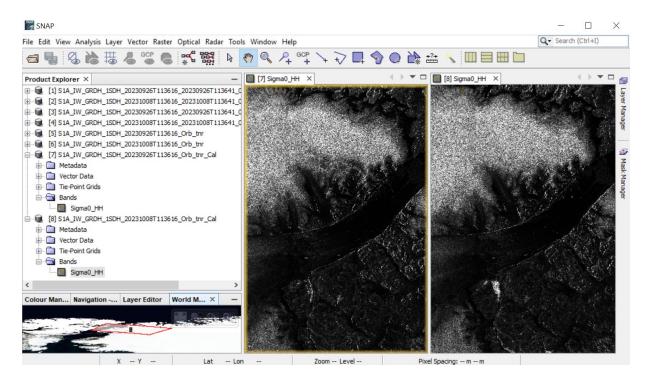
| Calibration X  | Calibration X   |
|--|---|
| File Help  | File Help   |
| I/O Parameters Processing Parameters Source Product source: [5] S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr   Target Product Name: S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr_Cal Save as: BEAM-DIMAP Directory: Z:\ESA_ENEUM\exercise_8 Open in SNAP | I/O Parameters       Processing Parameters         Polarisations:       HH         ENVISAT Auxiliary File:       Latest Auxiliary File         Save as complex output       Output sigma0 band         Output gamma0 band       Output beta0 band |
| Run Close  | Run Close   |





If you finish all preprocessing steps, you should have eight products in the Product Explorer. Open the Bands folder of the last two products, double click on Sigma\_HH for both of the products and Tile them Horizontally. You can see little differences between these two acquisition dates.

Let's corregistrate these images and track the offset.



#### 3.2 Coregistration

Image coregistration is the process that involves aligning two or more images geometrically, ensuring that corresponding pixels depict the same area on the Earth's surface. While orbit state vectors alone can suffice to coregister images, for precise offset tracking, additional data from a digital elevation model (DEM) is necessary to enhance coregistration accuracy.

Navigate to Main Menu – Radar – Coregistration – DEM-Assisted Coregistration In the ProductSet-Reader tab, select/leave only the last two preprocessed products and name the target product In DEM-Assisted-Coregistration tab set: "Digital Elevation Model": ACE30 (Auto Download) DEM Resampling method: BICUBIC\_INTERPOLATION Resampling Type: BISINC\_5\_POINT\_INTERPOLATION







| C DEM Assisted Coregistration                       |        |             |       |       | $\times$  | © DEM Assisted Coregistration | n X                            |
|---|--------|-------------|-------|-------|---|-------------------------------|--------------------------------|
| ProductSet-Reader DEM-Assisted-Coregistration Write |        |             |       |       | ProductSet-Reader DEM-Assisted-Coregistration Write |                               |                                |
| File Name   | Туре   | Acquisition | Track | Orbit | +   | Digital Elevation Model:      | ACE30 (Auto Download) 🗸        |
| S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr_Cal        | GRD    | 26Sep2023   | 26    | 50498 | Ŧ   | DEM Resampling Method:        | BICUBIC_INTERPOLATION V        |
| S1A_IW_GRDH_1SDH_20231008T113616_Orb_tnr_Cal        | GRD    | 08Oct2023   | 26    | 50673 | -   | Resampling Type:              | BISINC_5_POINT_INTERPOLATION V |
|   |        |             |       |       | 4   | Tile Extension [%]:           | 100                            |
|   |        |             |       |       | _   | Mask out areas with no elevat | ion                            |
|   |        |             |       |       |   |                               |                                |
|   |        |             |       |       | Ŧ   |                               |                                |
|   |        |             |       |       | *   |                               |                                |
|   |        |             |       |       |   |                               |                                |
|   |        |             |       |       | *   |                               |                                |
|   |        |             |       |       | 2   |                               |                                |
|   |        |             |       |       | *   |                               |                                |
|   |        |             |       |       | 2 Products  |                               |                                |
| Save  | 🕐 Help | [⊃ Run      |       |       |   |                               | Save 🕖 Help 🕞 Run              |

In Write tab name the output product and select the directory to save it. Then, click on RUN. This process may take some time. The resulting product will include two HH polarizations - "mst" = master (the main/first image used for co-registration) and "slv" = slave image.

| C DEM Assisted Coregistration                       | × | Product Explorer ×  |
|---|---|---|
| ProductSet-Reader DEM-Assisted-Coregistration Write |   |   |
| Target Product                                      |   |   |
|   |   |   |
|   |   | B [3] S1A_IW_GRDH_1SDH_20230926T113616_20230926T113641_   |
|   |   | Image: Height Handlick Hei  |
|   |   | Image: Since State St |
| Name:   |   | Image: [6] S1A_IW_GRDH_1SDH_20231008T113616_Orb_thr   |
| S1A_JW_GRDH_1SDH_20230926T113616_Orb_tm_Cal_Stack   |   | [7] S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr_Cal  |
| Save as: BEAM-DIMAP<br>Directory:                   |   |   |
| Z: [ESA_RADAR  exercise_8                           |   |   |
|   |   | 🖶 🧰 Metadata  |
|   |   | 🖶 🛅 Vector Data   |
|   |   | 🖶 🛅 Tie-Point Grids   |
|   |   | 🖮 📾 Bands   |
|   |   | Sigma0_HH_mst_26Sep2023   |
| Save 💽 Help 🕞 Run                                   |   | Sigma0_HH_slv1_08Oct2023  |

#### 3.1 Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Go to the Subset tab and at "Pixel Coordinates" set: Scene start X: 1000 Scene start Y: 5000 Scene end X: 22000 Scene end Y: 16500

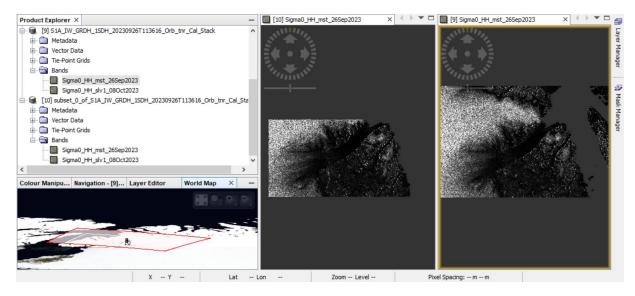






| Specify Product Subset X   | Specify Product Subset X  |
|--|---|
| Spatial Subset Band Subset Tie-Point Grid Subset Metadata Subset   | Spatial Subset Band Subset Tie-Point Grid Subset Metadata Subset                          |
| Pixel Coordinates       Geo Coordinates         Scene start X:       1000 ÷         Scene start Y:       5000 ÷         Scene end X:       22000 ÷         Scene end X:       16500 ÷         Scene step X:       1 ÷         Subset scene width:       21001.0         Subset scene width:       21001.0         Source scene width:       25440         Source scene height:       16629         Use Preview       Fix full height | ✓ Sigma0_HH_mst_28Sep2023         ✓ Sigma0_HH_siv1_08Oct2023                              |
| Estimated, raw storage size: 1842.8M   | Estimated, raw storage size: 1842.8M  |
| OK Cancel Help   | OK Cancel Help  |
| Spatial Subset Band Subset Tie-Point Grid Subset Metadata Subset   | Spatial Subset Band Subset Tie-Point Grid Subset Metadata Subset                          |
| I latitude         I longitude         Incident_angle         elevation_angle         slant_range_time   | Abstracted_Metadata     Original_Product_Metadata     Processing_Graph     Slave_Metadata |
|  | Estimated, raw storage size: 1842.8M  |
| Estimated, raw storage size: 1842.8M   | Estimated, raw storage size: 1042.0M  |
| OK Cancel Help   | on Cancel Hep   |

Open the subset image and compare it with previous product image of the entire area. Double click on HH polarization rasters in Bands folder to open them. Tile them e.g. Horizontally to compare them.







#### Offset Tracking

Offset Tracking is employed to determine the movement of a feature between two acquisitions by conducting cross-correlation on designated Ground Control Points (GCP) within coregistered images (master and slave) in both slant-range and azimuth directions. The velocity of movement is subsequently calculated using the offsets derived from the crosscorrelation (refer to NOTE 5). The velocities calculated on the GCP grid are then interpolated to generate a velocity map. This method is commonly utilized for estimating glacier motion.

To conduct Offset-Tracking, we must configure various parameters. Initially, we establish the spacing of the Ground Control Point (GCP) grid in pixels in the range and azimuth directions. We opt for a spacing of 60 pixels (equivalent to 600 meters) in both directions, striking a balance between detail and smoothness in our output. It's worth noting that higher resolutions entail longer processing times.

Subsequently, we address the dimensions of the Registration Window. The size of this window hinges on the maximum velocity of the glacier, gleaned from literature or historical data, and the time span between data acquisitions. Given that our images were captured 13 days apart and the maximum speed of the Petermann Glacier is approximately 5 meters per day, the surface of the glacier could potentially shift by a maximum of 60 meters. Consequently, we maintain the default setting of 128 pixels (equivalent to 1280 by 1280 meters). Additionally, to mitigate false high values, we specify the known maximum glacier velocity as 5 meters per day. Therefore, we need to establish:

#### Grid Azimuth Spacing (in pixels): 65 Grid Range Spacing (in pixels): 65 Max Velocity (m/day): 5.0

| Confracting X   | C Offset Tracking X  |
|---|--|
| File Help   | File Help  |
| I/O Parameters Processing Parameters Source Product Source product: [10] subset_0_of_S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr_Cal v | I/O Parameters Processing Parameters Output Grid Grid Azimuth Spacing (in pixels): 65 Registration Window Width: 128   |
| Target Product Name: subset_0_of_S1A_IW_GRDH_1SDH_20230926T113616_Orb_thr_Cal_Stack_vel Save as: BEAM-DIMAP Directory:              | Grid Range Spacing (in pixels):       65       Registration Window Height:       128         Grid Azimuth Spacing (in meters):       650.0       Registration Oversampling:       16         Grid Range Spacing (in meters):       650.0       Cross-Correlation Threshold:       0.1         Grid Azimuth Dimension:       255       Average Box Size:       5          Grid Range Dimension:       391       Max Velocity (m/day):       5.0         Total Grid Points:       99705       Radius for Hole Filling:       4 |
| C:\Users\UGE\pocuments  | Resampling Type: BICUBIC_INTERPOLATION  Spatial Average Fill Holes ROI Vector Mask:  |
| Run Close   | Run Close  |

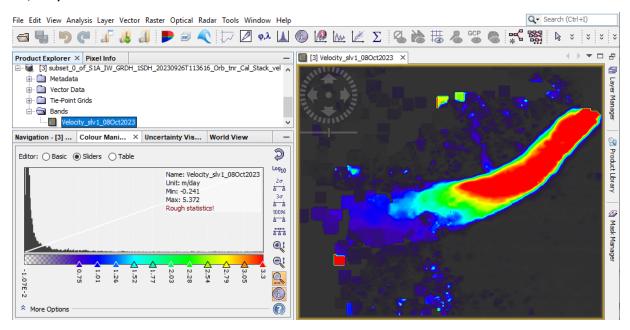




#### Offset Tracking

Once the processing finishes, a new product emerges in the Product Explorer window. Extend the velocity product and click twice on the Velocity\_slv1\_08Oct2023 band to unveil it in the View window.

Open Colour Manipulation tab – select sliders and explore velocity values in m/day in this area.

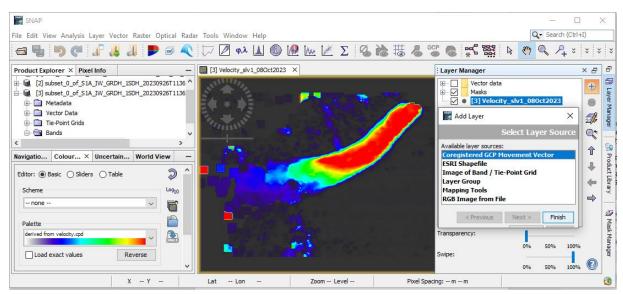


#### Add velocity vector to see direction and speed

#### Navigate to Layer > Layer Manager

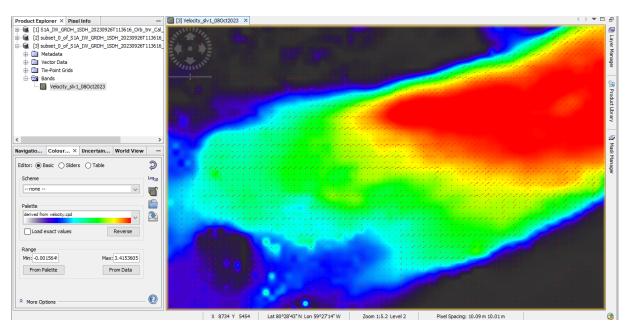
From the Layer Manager window, deselect Vector data to remove the grid Click on the "+" button to open the Add Layer window

In the Add Layer window, dick Coregistered GCP Movement Vector and click on Finish. You will see the velocity vectors displayed on the GCP grid showing direction and speed.









Peterman Glacier velocity vectors. Contains modifed Copernicus Sentinel data 2023

#### Terrain correction

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

- Navigate to Main Menu: Radar Geometric Terrain Correction Range-Doppler Terrain Correction
- In the I/O Parameters tab set as "Source Product" the velocity product.
- In "Target Product", keep the default name and set the Directory
- In the Processing Parameters tab set:
- Digital Elevation Model: ACE30 (Auto Download)
- Map Projection: Click on the tab next to Map projection (WGS84(DD) select Predefined CRS and click on "Select". In "Filter" search for 32621 (EPSG: 32621 - WGS84 / UTM Zone 21N) and when you find it dick OK to both windows.

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.







| C Range Doppler Terrain Correction  | X C Range Doppler Terrain Correction X  |
|---|---|
| File Help   | File Help   |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameters Source Bands: Velocity_slv1_08Oct2023  |
| Source Product<br>source:<br>[3] subset_0_of_S1A_IW_GRDH_1SDH_20230926T113616_Orb_thr_Cal_Stack_vel v |   |
| Target Product<br>Name:   |   |
| subset_0_of_S1A_IW_GRDH_1SDH_20230926T113616_Orb_tnr_Cal_Stack_vel_TC                                 | Digital Elevation Model: ACE30 (Auto Download)  |
| Save as: BEAM-DIMAP   | DEM Resampling Method: BILINEAR_INTERPOLATION   |
| Directory:  | Image Resampling Method: BILINEAR_INTERPOLATION  Source GR Pixel Spacings (az x rg): 10.0(m) × 10.0(m)  |
| Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8   | Pixel Spacing (m): 10.0   |
| ☑ Open in SNAP  | Pixel Spacing (deg): 8,983152841195215E-5   |
|   | Map Projection: WGS84(DD)   |
|   | Mask out areas without elevation         Output bands for:         Selected source band       DEM         Incidence angle from ellipsoid       Local incidence angle         Incidence angle from ellipsoid       Local incidence angle         Layover Shadow Mask         Apply radiometric normalization         Save Sigma0 band       Use projected local incidence angle from DEM         Save Gamma0 band       Use projected local incidence angle from DEM         Auxiliary File (ASAR only):       Latest Auxiliary File         Run       Close |
| 🛃 Select Coordinate Reference System  | ×   |
| Filter: 32621 W   | Vell-Known Text (WKT):  |
|   | PROJCS["WGS 84 / UTM zone 21N",  GEOGCS["WGS 84",   |

#### Visualize

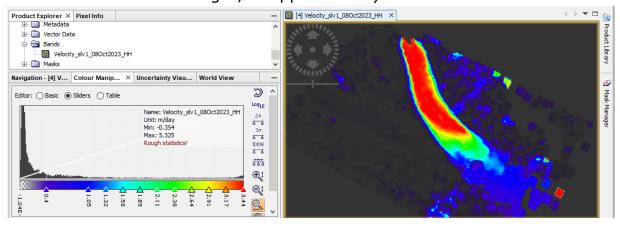
Close Range Doppler Terrain Correction window. Let's open the terrain corrected velocity. Expand the new georeferenced product and open the Velocity\_slv1\_08Oct2023\_HH band by double click on it in View window.

DATUM["World Geodetic System 1984",

OK

Cancel

We can stretch the histogram a little in the Colour Manipulation tab (move the white slider on the right, to approx. 0.45).



For more information, see the lecture: <u>9. SAR and optical remote sensing</u> for mapping ice

### THANK YOU FOR FOLLOWING THE EXERCISE!







### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 9 – TUTORIAL

Sentinel-1, Sentinel-2 for Snow and Ice using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

### 1 | Exercise outline

In this exercise, we will:

- Perform our own sea ice classification using created training data and Random forest classificator
- Understand the capabilities and limitations of Synthetic Aperture Radar (SAR) in detecting and monitoring sea ice.
- Discriminate between open water and different types of the sea ice
- Identify areas with varying degrees of ice deformation
- Perform classification using Sentinel-2 data NDSI

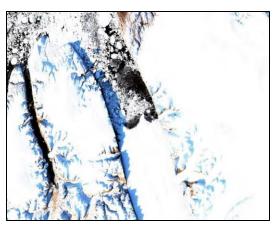




## 2 | Background

#### Mapping snow and ice using Sentinel-1 and Sentinel-2 data

Sea ice refers to frozen seawater that forms when ocean water freezes due to low temperatures. It typically occurs in polar regions, such as the Arctic and Antarctic, where temperatures drop low enough for the surface of the ocean to freeze. Sea ice can vary in thickness and extent, ranging from thin, seasonal ice that forms and melts each year to thicker, multi-year ice that persists through multiple seasons.



Sea ice plays a crucial role in regulating the Earth's climate, reflecting sunlight back into space and influencing ocean circulation patterns. Additionally, sea ice provides habitat for various species of marine life and serves as a platform for indigenous communities and scientific research.

Sea ice encompasses various types, including first-year ice formed during a single winter season, and multi-year ice, which survives multiple melt seasons and is thicker and more consolidated. Sea ice can also be categorized into additional types such as deformed ice, level ice, young ice, and open water ice:

Deformed Ice: results from the compression and ridging of sea ice due to the movement and collision of ice floes

Level Ice: refers to relatively flat and uniform sea ice surfaces that have not undergone significant deformation or ridging

Young Ice: Young ice is newly formed sea ice that has not yet reached its maximum thickness or strength.

Open Water Ice: describes areas of sea ice where the ice cover has become fragmented or broken, leaving patches of open water exposed.

Sentinel-1 SAR imagery provides all-weather, day-and-night capability, allowing for continuous monitoring of sea ice regardless of atmospheric conditions or sunlight. By analyzing Sentinel-1 SAR images, researchers can monitor changes in sea ice extent, thickness, and movement over time, providing valuable information for climate studies, navigation, and environmental management. Additionally, these data can be used to detect and monitor other features, such as icebergs, ice floes, enhancing our understanding of polar environments and their role in the Earth's climate system.

Sentinel-2 satellite imagery is also valuable for mapping ice due to its high spatial resolution and multispectral capabilities. By capturing detailed images of ice-covered regions, Sentinel-2 facilitates the monitoring of ice extent, ice type classification, glacier movement, and changes in ice dynamics over time.

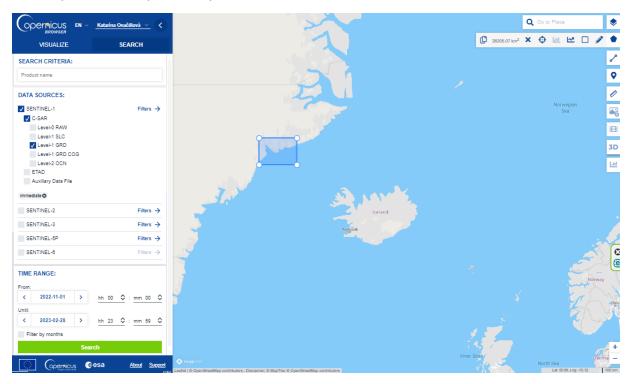






#### 2.1 Study area and data used

For this exercise, we will use Sentinel-1 GRDH image and Sentinel-2 L2A image over the Straight of Denmark between Greenland and Iceland, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].

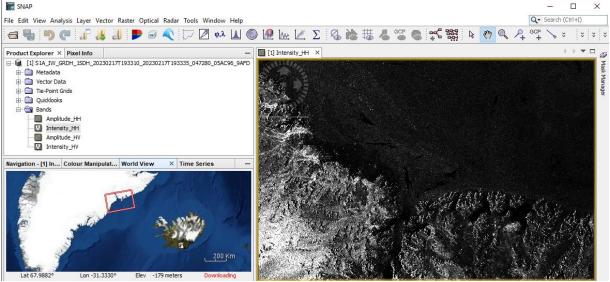


#### Part A: Sea ice mapping with Sentinel-1

#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open downloaded Sentinel-1 GRDH product by double click on it. The opened product will appear in Product Explorer window. The Worldview window (at the bottom-left corner) shows the coverage of the image opened. Double click on e.g. "Intensity\_HH" band within Bands folder to visualize it.

S1A\_IW\_GRDH\_1SDH\_20230217T193310\_20230217T193335\_047280\_05AC96\_9AFD.SAFE.zip







#### 2.3 Pre-processing

We need to apply identical pre-processing steps to our scene:

Apply orbit file

Navigate to Main Menu > Radar > Apply orbit file

In the I/O Parameters tab, select the opened product. By default, the output target is set to the same directory and appends "Orb" to the filename. There is no need to save the output as BEAM-DIMAP (we will save the time this way).

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

| C Apply Orbit File  | < 📀 Apply Orbit File X  |
|---|---|
| File Help   | File Help   |
| I/O Parameters Processing Parameters Source Product source: [1] S1A_TW_GRDH_1SDH_20230217T 193310_20230217T 193335_047280_05AC96_9AFD   Target Product Name: S1A_TW_GRDH_1SDH_20230217T 193310_20230217T 193335_047280_05AC96_9AFD_Orb  Six_start Start | I/O Parameters       Processing Parameters         Orbit State Vectors:       Sentinel Precise (Auto Download)          Polynomial Degree:       3         Do not fail if new orbit file is not found       3 |
| Run Close   | Run Close   |

#### Thermal noise removal

Navigate to Main Menu – Radar > Radiometric > S-1 Thermal Noise Removal In the I/O Parameters tab, select the product with applied orbit file. By default, the output target is set to the same directory and appends "thr" to the filename. There is no need to save the output as BEAM-DIMAP.

In the Processing Parameters keep both HH and HV polarisations and make sure that the "Remove Thermal Noise" option is selected.

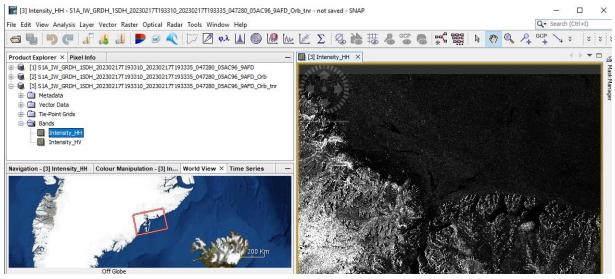
| 😨 S-1 Thermal Noise Removal  | 📀 S-1 Thermal Noise Removal          |
|--|--------------------------------------|
| File Help  | File Help                            |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters |
| Source Product Source product:   | Polarisations: HH<br>HV              |
| [2] S1A_IW_GRDH_1SDH_20230217T193310_20230217T193335_047280_05AC96_9AFD_0rb $\lor$   | Remove Thermal Noise Output Noise    |
| Target Product   | Re-Introduce Thermal Noise           |
| Name:  |                                      |
| S1A_IW_GRDH_1SDH_20230217T 193310_20230217T 193335_047280_05AC96_9AFD_0rb_thr           Save as:         BEAM-DIMAP           Directory: |                                      |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_4         Open in SNAP                                   |                                      |
|  |                                      |
| Run Close  | Run Close                            |







### The image should then look something like this (view e.g. Intensity\_HH):



#### Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size – creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

Select the last product with applied Thermal noise removal. Go to the Subset tab and at "Pixel Coordinates" set:

Scene start X: 5500 Scene start Y: 3000 Scene end X: 17300 Scene end Y: 15100

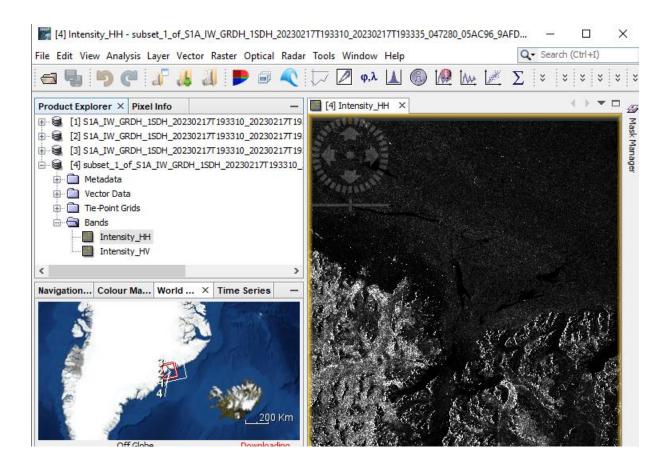
Now, the image is prepared for classification. Open the final product, e.g. Intensity\_HH to see the output image.

| Spatial Subset | Band Subset         | Tie-P | oint Grid Subset                  | Me | tadata Sub | et          |                               |          |              |
|----------------|---------------------|-------|-----------------------------------|----|------------|-------------|-------------------------------|----------|--------------|
|                |                     | ^     | Pixel Coordina                    |    |            |             |                               |          |              |
|                | State of the second |       | Scene start X:                    |    |            |             |                               | 5500     | ÷            |
|                |                     |       | Scene start Y:                    |    |            |             |                               | 3000     | +            |
|                |                     |       | Scene end X:                      |    |            |             |                               | 17300    | ÷            |
|                |                     |       | Scene end Y:                      |    |            |             |                               | 15100    | ÷            |
|                |                     |       | Scene step X:                     |    |            |             |                               | 1        | ÷            |
|                |                     |       | Scene step Y:                     |    |            |             |                               | 1        |              |
|                |                     |       | Subset scene w                    |    |            |             |                               | 118      |              |
|                |                     |       | Subset scene he                   | -  |            |             |                               | 121      |              |
|                |                     |       | Source scene w<br>Source scene he |    |            |             |                               |          | 5334<br>5643 |
|                |                     |       | Use F                             | _  |            |             | c full width<br>c full height |          |              |
|                |                     | *     |                                   |    |            |             |                               |          |              |
|                |                     |       |                                   |    | E          | stimated, i | aw storage                    | size: 10 | 89.          |
|                |                     |       |                                   |    |            | OK          | Cancel                        | н        | elp          |









#### 2.4 Image classification

Today we will perform a random forest classification. For this we will create some training data by identifying polygons containing the different ice types:

- Deformed Ice
- Level Ice
- Young Ice
- Open Water

Select the last subset product by clicking on it. Navigate to Vector > New Vector Data Container.

Create four new data containers – separate for each type of ice mentioned above.

Start with creating the data container for, e.g. deformed\_ice" and repeat this step for other three types.

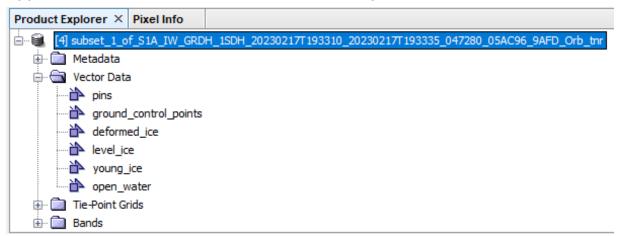
| 🎆 New Ve     | ector Data Container | ×    |
|--------------|----------------------|------|
| Name:        | deformed_ice         |      |
| Description: |                      |      |
|              | OK Cancel            | Help |







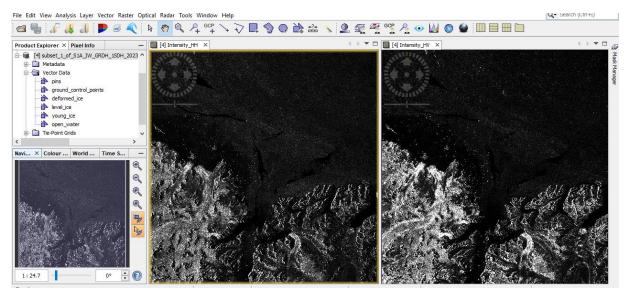
The newly created four vector data containers for each ice type should appear under "Vector Data" in the Product Explorer.



Now let's start creating training polygons for these different containers on ice type using the Polygon drawing tool:

Open both HH and HV polarisations to better identify different types of ice.by double clicking on them.

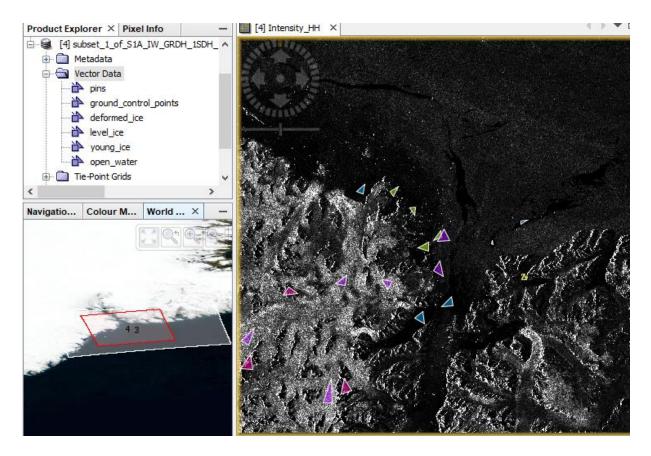
Then, dick on the icon Tile Horizontally (or navigate to the main menu - Window and select this option).











Deformed (Pink), Level (Violet), Young ice (Green) and Open water (Blue) Sea Ice Polygons. Save the final product with your created vector data containers to your folder.

#### Random Forest image classification

Navigate to Raster > Classification > Supervised classification > Random Forest Classifier

- In the ProductSetReader tab select the saved product with your training data.
- In the Random-Forest-Clasiffier select the classes/training vectors (all our sea ice polygon vector containers) and feature bands (select both Intensity\_HH and Intenisty\_HV polaristaions) that you'd like to include into image classification.
- In the Write tab by default, the output target is set to the same directory and appends ",RF" to the filename.

| ProductSet-Reader     | Random-                 | Forest-Classifier Write                     |
|-----------------------|-------------------------|---|
| Classifier            |                         |   |
| Train and apply of    | lassifier               | newClassifier                               |
| O Load and apply o    | lassifier               | newClassifier V X                           |
|                       |                         | ◯ Train on Raster                           |
| Evaluate classifier   |                         |   |
| Evaluate Feature Pov  | ver Set                 |   |
|                       |                         | Min Power Set Size: 2 Max Power Set Size: 7 |
| Number of training sa | mples                   | 5000  |
| Number of trees:      |                         | 10  |
| Vector Training       |                         |   |
|                       | young_ic<br>open_wa     |   |
| Feature Selection     |                         |   |
|                       | Intensity,<br>Intensity |   |
|                       |                         |   |

• Click RUN.

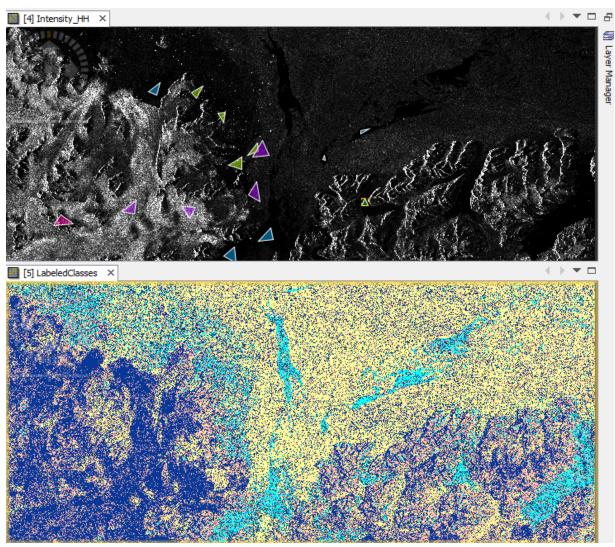
∙eesa



#### 2.5 Post-processing

The final product should now appear in the ProductExplorer. Visualize this output classified image and classes by double-click on the layer "LabeledClasses" under Bands folder in the Product Explorer.

Navigate to Colour Maniulation tab to change the colours of individual sea ice classes and exlore the frequency of these classes through the classified image and table.



| Navigation - [5] LabeledClasses |        | Colour Manip | Colour Manipulation - [5] Label $	imes$ |             |  |  |  |  |
|---------------------------------|--------|--------------|---|-------------|--|--|--|--|
| Label                           | Colour | Value        | Frequency                               | Description |  |  |  |  |
| no data                         |        | -1           | 0.000%                                  | no data     |  |  |  |  |
| deformed_ice                    |        | 0            | 19.440%                                 |             |  |  |  |  |
| level_ice                       |        | 1            | 42.332%                                 |             |  |  |  |  |
| young_ice                       |        | 2            | 33.787%                                 |             |  |  |  |  |
| open_water                      |        | 3            | 4.442%                                  |             |  |  |  |  |







#### Part B: Sea ice mapping with Sentinel-2

#### 2.6 SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open downloaded Sentinel-2 by double-clik on the metadata "MTL.txt" inside the unzipped folder (or click on Import Product). The opened product will appear in Product Explorer window.

S2A\_MSIL2A\_20230221T140211\_N0509\_R010\_T25WER\_20230221T185001.SAFE.zip

Select (by clicking on it) the product in the Product Explorer window. The Worldview window (at the bottom-left corner) shows the coverage of the image opened.

Now, let's visualize the image using True colour composition:

- Right click on the product.
- Open RGB Image Window.
- In the pop-up window select 'Sentinel 2 MSI Natural colors' (Red: B4; Green: B3; Blue: B2)

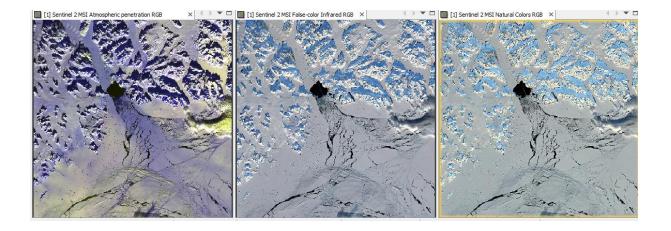
Now, let's visualize the image using False colour composition:

- Right click on the product.
- Open RGB Image Window.
- In the pop-up window select 'Sentinel 2 MSI False Colour-Infrared' (Red: B8; Green: B4; Blue: B3)

Now, let's visualize the image using another False colour composition:

- Right click on the product.
- Open RGB Image Window.
- In the pop-up window select 'Sentinel 2 MSI Atmospheric-Penetration' (Red: B12; Green: B11; Blue: B8A)

Tile Windows, e.g. Horizontally, to explore the Sentinel-2 image features.









#### 2.7 Resample

Resample the bands to the pixel size of the VIS bands: In the main SNAP menu, select Raster > Geometric > Resampling In the I/O Parameters tab, the source product is set to our only product in the SNAP, change the name of the target resampled product if needed Do not save the output product - disable the box "Save as:" (if selected). In the Processing Parameters tab, use e.g. B2 with 10 m resolution to resample all the bands to 10 m as output spatial resolution.

| Resampling ×   | 🞇 Resampling                                    | ×   |
|--|---|---|
| File Help  | File Help                                       |   |
| I/O Parameters Resampling Parameters   | I/O Parameters Resampling Parameters            |   |
| Source Product Name: [1] S2A_MSIL2A_20230221T140211_N0509_R010_T25WER_20230221T185001 v                                | Define size of resampled product                | ~   |
| Target Product Name:   | -   | target width: 10980<br>target height: 10980<br>idth: 10,980 |
| S2A_MSIL2A_20230221T140211_N0509_R010_T25WER_20230221T185001_resampled   | Target he                                       |   |
| Directory:          rojekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_9         Open in SNAP |   | 20 🔹<br>target width: 5490<br>target height: 5490           |
|  | Define resampling algorithm                     |   |
|  | Upsampling method: Neares                       | t v   |
|  | Downsampling method: First                      | ~   |
|  | Flag downsampling method: First                 | ~   |
|  | Advanced Method Definition by Band              |   |
|  | Resample on pyramid levels (for faster imaging) |   |
| Run Close  | L   | Run Close   |

#### 2.8 Normalized Difference Snow Index

Next, we will calculate Normalized Difference Snow Index (NDSI) in SNAP.

The Sentinel-2 NDSI is a ratio of two bands: one in the VIR (Band 3) and one in the SWIR (Band 11). Values above 0.4 are usually snow. The Sentinel-2 NSDI can be used to differentiate between cloud and snow cover as snow absorbs in the short-wave infrared light, but reflects the visible light, whereas cloud is generally reflective in both wavelengths. Most potential cloudy pixels have NDSI values in a range between -0.1 and +0.2.

To calculate NDSI, select the last subset product, navigate to the main SNAP menu and select Raster - Band Maths (deselect the box "Virtual").







SNAP menu and select Raster - Band Maths (deselect the box "Virtual"). Click on Edit Expression to calculate the NDSI using the equation below and click OK:

 $\rho(VIS) - \rho(SWIR) / \rho(VIS) + \rho(SWIR)$ 

 $\rho$  = Top of atmosphere reflectance VIS = Visible band (0.56 µm) SWIR = Short-Wave Infrared Band (1.6 µm)

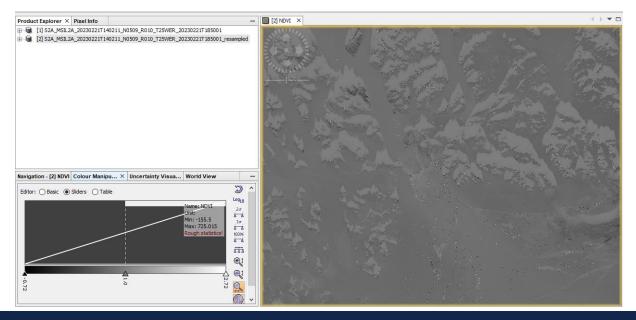
Replace the bands in the equation with the corresponding bands for Sentinel 2:

| Band Maths  | Band Maths Expression Editor   | ×    |
|---|--|------|
| Target product: [2] S2A MSIL2A 20230221T140211 N0509 R010 T25 | Product: [2] S2A_MSIL2A_20230221T140211_N0509_R010_T25WER_20230221T185001_resampled  Data sources: Expression:   | ~    |
| Name:       NSDI         Description:                         | S2:B4 <ul> <li>(2:B5</li> <li>(2:B5</li> <li>(2:B5</li> <li>(2:B5</li> <li>(2:B3-\$2:B11)/(\$2:B3+\$2:B11)</li> <li>(2:B3-\$2:B11, [2:B3+\$2:B11)</li> <li>(2:B3-\$2:B11,</li></ul> | ors. |
| OK Cancel Help  | OK Cancel Help   |      |

 $\rho(B3) - \rho(B11) / \rho(B3) + \rho(B11)$ 

Open the output product in the Product Explorer by double click on the new raster NDSI within Bands folder.

Go to Color Manipulation tab and go to Table – set the thresholds of slider to three values – minimum value, up to 0.4 (usually pixels with no snow), higher than 0.4 (usually snow pixels) and maximum value.

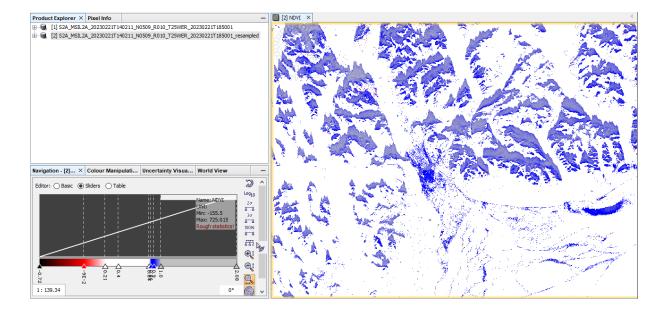






Explore the image: values above 0.4 are usually snow pixels (shades of grey for the lowest probability of snow and shades of white for the highest probability of snow). The Sentinel-2 NSDI can be also used to differentiate between cloud and snow cover as snow absorbs in the short-wave infrared light, but reflects the visible light, whereas cloud is generally reflective in both wavelengths.

Most potential doudy pixels have NDSI values in a range between -0.1 and +0.2. Add 4 new sliders and change their colour to e.g. red to highlight these values of potentially cloudy pixels.



For more information, see the lecture: <u>8. SAR and Optical remote sensing</u> for mapping snow

### THANK YOU FOR FOLLOWING THE EXERCISE!







### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 10 - TUTORIAL

Flood Monitoring with Sentinel-1 & Sentinel-2 using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this first exercise for mapping floods, we will:

- Detect floods on Sentinel-1 images
- Develop a graph for automated processing using Batch processing
- Create binary mask for flood mapping





## 2 | Background

Floods, a commonly occurring natural disaster, result in significant damage to both lives and property. Timely information critical on floods is for emergency response. Rapid estimation of flood extent is essential for disaster risk assessment and spatial planning. Remote sensing and satellite imagery play pivotal roles in flood monitoring and mapping. Optical remote sensina, for instance, is utilized for dynamic flood monitoring by exploiting water's low reflectance in infrared bands and high reflectance in blue/green bands.



However, during severe weather conditions with heavy rainfall and intense cloud cover, optical remote sensing may struggle to provide accurate information due to a lack of cloud-free, high-quality images and difficulty in detecting water under vegetation cover.

Since October 4, 2023, the Myanmar Department of Meteorology and Hydrology (DMH) has been issuing flood advisory warnings and weather system alerts regarding water levels in major rivers. Between October 5 and 9, heavy rainfall during the late monsoon season resulted in extensive flooding in southern Myanmar. On October 9, the DMH reported that Bago township received an unprecedented 7.87 inches (200 millimeters) of rainfall, the highest recorded in 59 years. By October 10, the water level of the Bago River rose 4 feet above the danger level, leading to widespread flooding in urban and suburban areas. The impact of this flooding has been significant, affecting families, croplands, and causing displacement of people in areas including Bago City, Yangon, Taik Kyi, Hlegu, and Hmawbi townships. (DREF OPERATION Myanmar Flood 2023)

Synthetic Aperture Radar (SAR) datasets offer significant benefits in flood observation as they emit electromagnetic waves that are unaffected by weather and time of day. The Sentinel-1 satellite, which provides extensive global data coverage, can effectively detect flooding in vegetated or urban areas due to its high penetration capability.

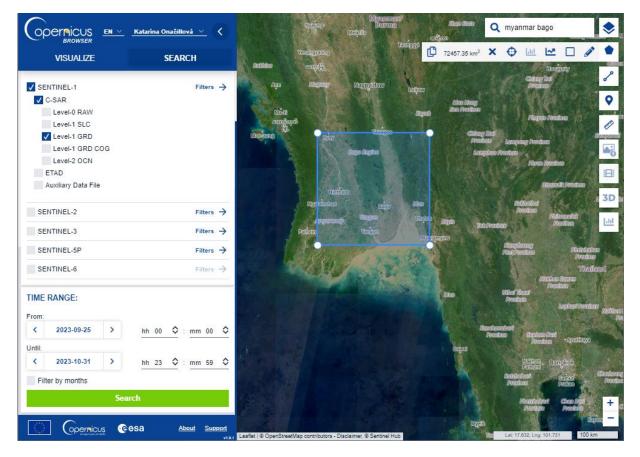






#### 2.1 Study area and data used

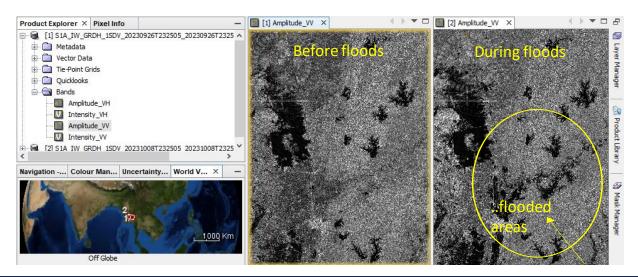
For this exercise, we will use two Sentinel-1 GRD images of the same area near Bago city, Myanmar, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products by double click on them. The opened products will appear in Product Explorer window. Go to Windows – Tile them e.g. Horizontally.

S1A\_IW\_GRDH\_1SDV\_20230926T232505\_20230926T232530\_050505\_061540\_C745.SAFE.zip S1A\_IW\_GRDH\_1SDV\_20231008T232505\_20231008T232530\_050680\_061B43\_DCF8.SAFE.zip







#### 3.1 Pre-processing

We need to apply identical pre-processing steps to both of our scenes:

#### Apply orbit file

Navigate to Main Menu – Radar – Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Repeat for the second image.

| 😨 Apply Orbit File   | ×  | C Apply Orbit File X   |
|--|----|--|
| File Help  |    | File Help  |
| I/O Parameters Processing Parameters Source Product [1] S1A_INU_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745 ✓ Target Product Name: S1A_JNU_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_Orb S1A_JNU_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_Orb S1A_JNU_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_Orb Directory: Z:\Pracovnici\onacliova\ESA_ENEUM\exercise_8  Open in SNAP |    | I/O Parameters       Processing Parameters         Orbit State Vectors:       Sentinel Precise (Auto Download)         Polynomial Degree:       3         ☑ Do not fail if new orbit file is not found       3 |
| Run Clo  | se | Run Close  |

#### Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size - creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

|                                      | 🞇 Specify Product Subset   |   |                                   |
|--------------------------------------|----------------------------|---|-----------------------------------|
| Select the last product with applied | Spatial Subset Band Subset | Tie-Point Grid Subset Meta                  | data Subset                       |
| orbit file.                          |                            | ^   |                                   |
| Go to the Subset tab and at "Pixel   | the second second          | Pixel Coordinates (                         | Geo Coordinates                   |
| Coordinates" set:                    |                            | Scene start X:                              | 9000 🖨                            |
|                                      | 2013 <b>- 1</b> - 1 - 1    | Scene start Y:                              | 4000 ≑                            |
| Scene start X: 9000                  |                            | Scene end X:                                | 23000 🜩                           |
| Scene start Y: 4000                  |                            | Scene end Y:                                | 16700 🜩                           |
| Scene end X: 23000                   |                            | Scene step X:                               | 1 🖨                               |
|                                      |                            | Scene step Y:                               | 1 🚔                               |
| Scene end Y: 16700                   |                            | Subset scene width:<br>Subset scene height: | 14001.0<br>12701.0                |
|                                      |                            | Source scene width:                         | 25570                             |
|                                      |                            | Source scene height:                        | 16745                             |
| Repeat for the second image.         |                            | Use Preview                                 | Fix full width                    |
|                                      |                            | ~   |                                   |
|                                      |                            |   | Estimated, raw storage size: 678. |







OK Cancel Help

#### Thermal noise removal

Navigate to Main Menu – Radar – Radiometric – S-1 Thermal Noise Removal In the I/O Parameters tab, select the last subset product with applied orbit file and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters you can select both polarization and make sure that the "Remove Thermal Noise" option is selected.

Repeat for the second subset image.

| 😨 S-1 Thermal Noise Removal X   | C S-1 Thermal Noise Removal   | × |
|---|---|---|
| File Help   | File Help   |   |
| I/O Parameters Processing Parameters Source product Source product: [5] subset_0_of_S1A_IW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540 v Target Product Name: subset_0_of_S1A_IW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_Orb_thr Save as: BEAM-DIMAP  Directory: [2:VPracovnici/pnacliova/ESA_ENELIM/exercise_8 ] Open in SNAP | I/O Parameters         Polarisations:       WH         W       W         Remove Thermal Noise       Output Noise         Re-Introduce Thermal Noise       V |   |

#### Calibration

With our image now subsetted and with TNR, we must apply image calibration. This step is necessary to normalize the values in the image into backscatter values so we can compare multiple images in a time series.

Navigate to Main Menu - Radar - Radiometric - Calibrate

In the I/O Parameters tab, select the product with thermal noise removal and name the target product. In the case of this final product of preprocessing, please, save it to your folder for this exercise

In the Processing Parameters select the VV band as input and accept all default settings and then click Run

Repeat for the second image. The saving might take some time.

| Calibration X  | Calibration X   |
|--|---|
| File Help  | File Help   |
| I/O Parameters Processing Parameters<br>Source Product<br>source:<br>[7] subset_0_of_S1A_IW_GRDH_1SDV_20230926T232505_202309 v   | I/O Parameters Processing Parameters Polarisations: VH VV                               |
| Target Product Name: DV_20230926T232505_20230926T232530_050505_061540_C745_Orb_tnr_Cal Save as: BEAM-DIMAP Directory: Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8 Open in SNAP | Save as complex output<br>Output sigma0 band<br>Output gamma0 band<br>Output beta0 band |
| Run Close  | Run Close   |





#### Speckle Filter

Despeckling removes thermal noise introduced by the sensor from the image to remove potential sources of error in analysis.

Navigate to Radar > Speckle Filtering Single Product Speckle Filter. In the Speckle-Filter tab, choose the simple Lee Sigma filter with default window sizes.

| C Single Product Speckle Filter   | ×  | Single Product S                            | Speckle Filter     | ×   |
|---|----|---|--------------------|-----|
| File Help   |    | File Help                                   |                    |     |
| I/O Parameters Processing Parameters  |    | I/O Parameters Pro                          | cessing Parameters |     |
| Source Product<br>source:<br>[9] subset_0_of_S1A_IW_GRDH_1SDV_20230926T232505_20230926T232530_050505_061540_C745 v        |    | Source Bands:                               | Sigma0_IV          |     |
| Target Product<br>Name:<br>subset_0_of_S1A_IV_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_0rb_thr_Cal_Sp | k  |   |                    |     |
| Save as: BEAM-DIMAP   |    | Filter:<br>Number of Looks:<br>Window Size: | Lee Sigma V        | 51. |
| Z:\Pracovnici\onacilova\ESA_ENEUM\exercise_8  |    |   | 7x7 ~<br>0.9 ~     | 51  |
| Open in SNAP  |    | Target Window Size:                         | 3x3 ~              | 1   |
|   |    |   |                    |     |
| Run Clos  | ie |   | Run Close          |     |

#### Terrain-Correction

Navigate to Radar – Geometric – Terrain Correction – Range Dopler Terrain Correction. The last step in our graph for image pre-processing is to apply terrain correction to the product, ensuring that all the pixels are moved to the right locations (eg if the nadir angle of the image is off, it will align the pixels correctly so it is closer to a top-down view of the imagery).

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-Doppler Terrain Correction

In the I/O Parameters tab set as "Source Product" the velocity product.

In "Target Product", keep the default name and set the Directory

In the Processing Parameters tab set:

Digital Elevation Model: ACE30 (Auto Download)

Map Projection: Click on the tab next to Map projection (WGS84(DD) – select Predefined CRS and dick on "Select". In "Filter" search for 32621 (EPSG: 32646 – WGS84 / UTM Zone 46N) and when you find it dick OK to both windows.

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.







| C Range Doppler Terrain Correction X  | C Range Doppler Terrain Correction  |
|---|---|
| File Help   | File Help   |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameters  |
| Source Product<br>source:<br>[11] subset_0_of_S1A_IW_GRDH_1SDV_20230926T232505_20230926T232530_050505_061540_C745_Orb_tn v    | Source Bands: Sigma0_VV   |
| Target Product<br>Name:<br>subset_0_of_S1A_JW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_0rb_tmr_Cal_Spk_TC |   |
| Save as: BEAM-DIMAP   | Digital Elevation Model: SRTM 3Sec (Auto Download) 🗸                                  |
| Directory:  | DEM Resampling Method: BILINEAR_INTERPOLATION V                                       |
| Z:\Pracovnici\onadilova\ESA_ENEUM\exercise_8  | Image Resampling Method: BILINEAR_INTERPOLATION V                                     |
| Open in SNAP  | Source GR Pixel Spacings (az x rg): 10.0(m) x 10.0(m)<br>Pixel Spacing (m): 10.0      |
|   | Pixel Spacing (m): 10.0 Pixel Spacing (deg): 8.983152841195215E-5                     |
|   | Map Projection: WGS 84 / UTM zone 46N   |
|   | Mask out areas without elevation  |
|   | Output bands for:   |
|   | Selected source band DEM Latitude & Longitude   |
|   | Incidence angle from ellipsoid Local incidence angle Projected local incidence angle  |
|   | Layover Shadow Mask   |
|   | Apply radiometric normalization   |
|   | Save Sigma0 band Use projected local incidence angle from DEM 🗸                       |
|   | Save Gamma0 band Use projected local incidence angle from DEM                         |
|   | Save Beta0 band   |
|   | Auxiliary File (ASAR only): Latest Auxiliary File                                     |
| Run Close   | Run Close   |
| Map Projection ×  | Select Coordinate Reference System  |
| Coordinate Reference System (CRS)   | Filter: 32646 Well-Known Text (WKT):  |
| O Custom CRS  | EPSG:32646 - WGS 84 / UTM zone 46N PROJCS["WGS 84 / UTM zone 46N", A GEOGCS["WGS 84", |
| Geodetic datum: World Geodetic System 1984  | DATUM["World Geodetic System 1984",   |
| Projection: Geographic Lat/Lon (WGS 84)   | SPHEROID["WGS 84", 6378137.0, 298.2572235<br>AUTHORITY("EDSC" "5236"]                 |
|   | AUTHORITY["EPSG","6326"]],<br>PRIMEM["Greenwich", 0.0, AUTHORITY["EPSG","E            |
| Projection Parameters   | UNIT["degree", 0.017453292519943295],   |
|   | AXIS["Geodetic longitude", EAST],   |
| Predefined CRS EPSG: 32646 - WGS 84 / UTM zone 46N Select   | AXISI"Geodetic latitude". NORTH1.   |
| OK Cancel Help  | OK Cancel   |
|   |   |

#### 3.2 Flood assessment

After execution, your resulting two preprocessed products should contain a single bands called Sigma0\_VV. Open all two (preprocessed) Sigma0\_VVs in the View and then go to Window -> Tile Horizontally

After ensuring that our products feature calibrated backscatter values, it's time to conduct flood assessments on the data to automatically ascertain the extent of flooding across the series of images. Areas with low backscatter indicate wet areas. Since our calibrated images contain calibrated backscatter coefficients, we can create a binary image from the products, highlighting areas below a cutoff threshold. Since the River traverses Bago city, it's crucial not to include recognized water sources in our flood mapping. To achieve this, we can incorporate the land cover band into our product in SNAP by right-clicking on the product in Product Explorer and selecting "Add Elevation Band."

|                      | 80_061B43_DCF8_Orb_tnr_Cal_Spk_TC |
|----------------------|-----------------------------------|
| 🕀 🧰 Metadata         | Band Maths                        |
| ⊕ 💼 Vector Data<br>⊟ | Add Elevation Band                |
| Sigma0_VV            | Add Land Cover Band               |
|                      |                                   |



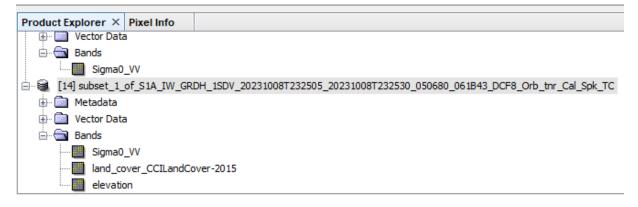




Additionally, we aim to include an elevation band to prevent misidentification of high-elevation regions as flooded. To add an elevation band, right-click on the product and choose "Add Elevation Band," then select "SRTM 1Sec HGT (Auto Download)."

| 🞇 Add Land Cover Band  | ×        | 🞆 Add Elevation Ba  | ind X   |
|--|----------|---|---|
| Land Cover Model:<br>AAFC Canada 2017 Crop<br>AAFC Canada 2018 Crop<br>AAFC Canada Clay Pct<br>AAFC Canada Sand Pct<br>CCILandCover-2015<br>GLC2000<br>GlobCover<br>JaxaForestMap-2016<br>MODIS 2007 Tree Cover Percentage<br>MODIS 2010 Tree Cover Percentage | <b>^</b> | Copernicus 90m Globa<br>GETASSE30 (Auto Dov<br>SRTM 1Sec Grid | vnload)<br>id)<br>il DEM (Auto Download)<br>il DEM (Auto Download)<br>wnload) |
| Resampling method:   |          | SRTM 1Sec HGT (Auto   |   |
| NEAREST_NEIGHBOUR  | $\sim$   | SRTM 3Sec (Auto Dow   | (nload)   |
| Integer data types will use nearest neighbour<br>Land cover band name:   |          | Resampling method:  | BILINEAR_INTERPOLATION ~  |
| land_cover_CCILandCover-2015   |          | Elevation band name:  | elevation   |
| OK Cance   | el l     |   | OK Cancel   |

Your product now should include land cover band and also elevation band



Now that we've added all the required bands, it's time to generate our new flooding band. Right-click on the product and choose "Band Maths." Enter the following expression into the text box:

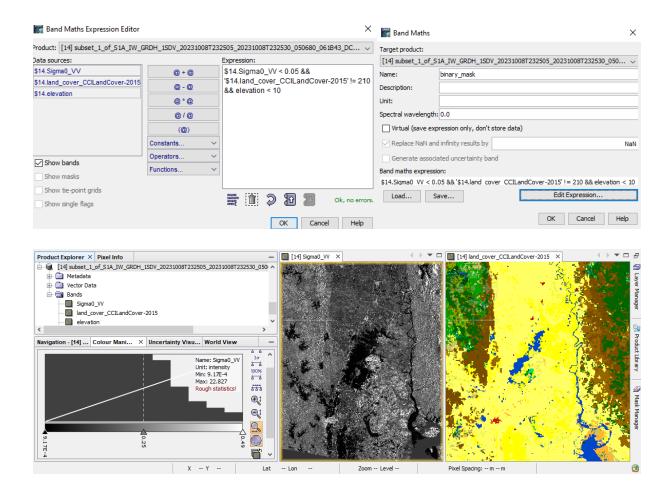
#### Sigma0\_VV < 0.05 && land\_cover != 20 && elevation < 10

This will produce a binary mask indicating areas where the backscatter is below our threshold of 0.05, not categorized as water (Class 210) in land cover, and with an elevation below 10 meters above sea level.

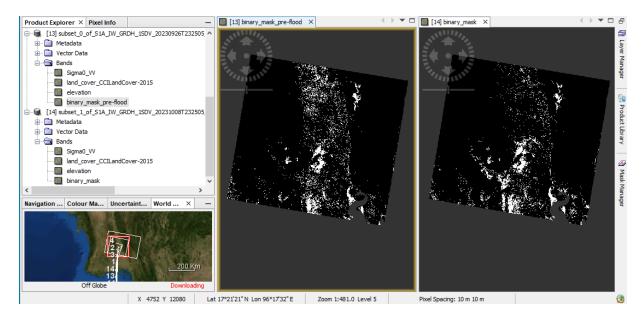








Repeat the process for the second Sentinel product. Display the two masks to check they have been generated correctly. Our output flooding binary band should look like this (For September 26<sup>th</sup> – start of flodding and October 10<sup>th</sup> - peak of flooding):





#### 3.3 Export and open binary masks in QGIS

To export this product for viewing in other GIS software and to map the changes in flooding over time, you need to save our two binary mask (start of floods and peek of floods) in TIF format in the proper folder using File-> Export->GeoTiff/BigTiff tool.

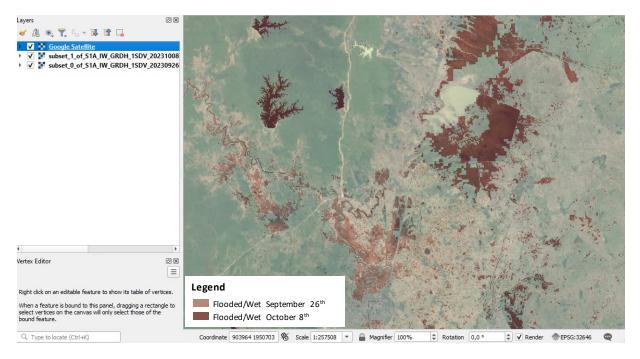
To visualize the output of our multi-temporal flood analysis, we will open the masks saved in GeoTIFF format using QGIS:

In QGIS click on the Add Raster Layer button located in the left panel, navigate to the folder containing the binary masks in TIFF format, and click Open (or drag&drop).

#### Now we open the output image in QGIS

- We can overlay it to e.g. Google Satellite or Bing aerial image:
- Web->OpenLayers plugin->Google Maps->Google Satellite
- Move the Subset above the satellite
- Play with Transparency: Properties->Transparency (e.g. 80%)

As observed, the floodwaters gradually subside over time, yet areas near the riverbanks remain saturated, displaying low backscatter and thus continuing to appear flooded.



For more information, see the lectures: 10. SAR and optical remote sensing for mapping floods 11. SAR and optical remote sensing for post-flood assessment and recovery

### THANK YOU FOR FOLLOWING THE EXERCISE!







### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 11 – TUTORIAL

Flood Monitoring with Sentinel-1, Sentinel-2 data using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

## 1 | Exercise outline

In this second exercise for mapping floods, we will:

- Detect floods using Sentinel-2 images
- Create NDVI and NDWI spectral indices to explore floods
- Create binary water mask for flood mapping
- Compare results for flood mapping using Sentinel-1 and Sentinel-2 images





## 2 | Background

Floods, a commonly occurring natural disaster, result in significant damage to both lives and property. Timely information on floods is critical for emergency response. Rapid estimation of flood extent is essential for disaster risk assessment and spatial planning. Remote sensing and satellite imagery play pivotal roles in flood monitoring and mapping. Optical remote sensina, for instance, is utilized for dynamic flood monitoring by exploiting water's low reflectance in infrared bands and high reflectance in blue/green bands.



However, during severe weather conditions with heavy rainfall and intense cloud cover, optical remote sensing may struggle to provide accurate information due to a lack of cloud-free, high-quality images and difficulty in detecting water under vegetation cover.

Since October 4, 2023, the Myanmar Department of Meteorology and Hydrology (DMH) has been issuing flood advisory warnings and weather system alerts regarding water levels in major rivers. Between October 5 and 9, heavy rainfall during the late monsoon season resulted in extensive flooding in southern Myanmar. On October 9, the DMH reported that Bago township received an unprecedented 7.87 inches (200 millimeters) of rainfall, the highest recorded in 59 years. By October 10, the water level of the Bago River rose 4 feet above the danger level, leading to widespread flooding in urban and suburban areas. The impact of this flooding has been significant, affecting families, croplands, and causing displacement of people in areas including Bago City, Yangon, Taik Kyi, Hlegu, and Hmawbi townships. (DREF OPERATION Myanmar Flood 2023)

Besides Synthetic Aperture Radar (SAR) data that we used in the first part of the exercise for mapping floods, Sentinel-2 satellites are also extensively used for flood mapping due to their ability to capture highresolution optical imagery of the Earth's surface. By analyzing these images, particularly before and after flood events, analysts can identify changes in water extent and detect flooded areas. The multispectral capabilities of Sentinel-2 allow for the differentiation of water bodies from other land cover types, enabling accurate mapping of flood-affected areas. Moreover, Sentinel-2's frequent revisits and openly available data make it a valuable resource for monitoring flood events in near real-time and supporting disaster response efforts.

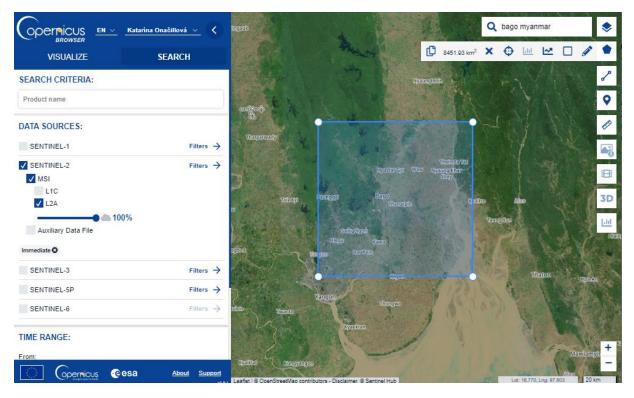






#### 2.1 Mapping floods with Sentinel-2 data

For the second part of this exercise, we will use two Sentinel-2 L2A images of the same area near Bago city, Myanmar, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



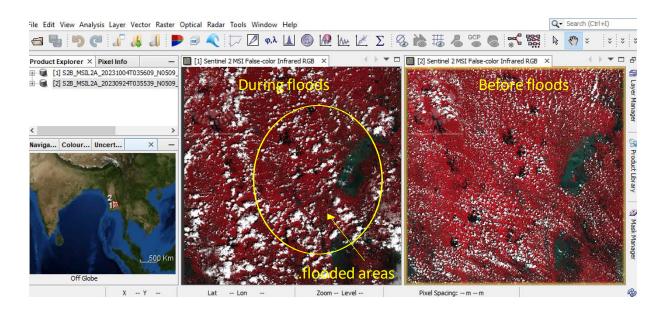
#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products (unzipped) by double click on the metadata "MTD\_MSIL2A.xml" inside the folder. The opened products will appear in Product Explorer window. Go to Windows – Tile them e.g. Horizontally.

S2B\_MSIL2A\_20231004T035609\_N0509\_R004\_T46QHE\_20231004T070950.SAFE.zip S2B\_MSIL2A\_20230924T035539\_N0509\_R004\_T46QHE\_20230924T071828.SAFE.zip

- 1. Select the first product in the Product Explorer window.
- 2. Right click on the product.
- 3. Open RGB Image Window.
- 4. In the pop-up window select e.g. 'Sentinel 2 MSI False-color Infrared (Red: B8; Green: B4; Blue: B3)'.
- 5. Repeat the process for the second product.
- 6. Tile two opened RGB Windows, e.g. horizontally
- 7. In the Navigation window, zoom in to the flooded region and synnchronise views to see the same area





### 2.3 Preprocessing

#### Resample

Resample the bands to the pixel size of the VIS bands:

In the main SNAP menu, select Raster - Geometric - Resampling In the I/O Parameters tab, the source product is set to our only product in the SNAP, change the name of the target resampled product if needed Do not save the output product - disable the box "Save as:" (if selected). In the Processing Parameters tab, use e.g. B3 with 10 m resolution to resample all the bands to 10 m as output spatial resolution. Resample both of the products.

| 🖁 Resampling 🛛 🗙  | 🞇 Resampling                                    | ×         |
|---|---|-----------|
| File Help   | File Help                                       |           |
| I/O Parameters Resampling Parameters  | I/O Parameters Resampling Parameters            |           |
| Source Product Name:  | Define size of resampled product                |           |
| Name:<br>[1] S2B_MSIL2A_20231004T035609_N0509_R004_T46QHE_20231004T070950 V | By reference band from source product:     B3   | ~         |
|   | Resulting target wid<br>Resulting target hei    |           |
| Target Product Name:  | O By target width and height: Target width:     | 10,980    |
| S2B_MSIL2A_20231004T035609_N0509_R004_T46QHE_20231004T070950_resampled      | Target height:                                  | 10,980 +  |
| Save as: BEAM-DIMAP   | Width / height ratio                            | 1.00000   |
| Directory:  | O By pixel resolution (in m):                   | 20 🔹      |
| Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8                               | Resulting target wid                            |           |
| Open in SNAP  | Resulting target hei                            | ght: 5490 |
|   | Define resampling algorithm                     |           |
|   | Upsampling method: Nearest                      | ~         |
|   | Downsampling method: First                      | ~         |
|   | Flag downsampling method:                       | ~         |
|   | ning downsampling include.                      |           |
|   | Advanced Method Definition by Band              |           |
|   | Resample on pyramid levels (for faster imaging) |           |
|   |   |           |
| Run Close   |   | Run Close |







#### Create subset

Click on the resampled product in the Product Explorer, go to the main SNAP menu and select Raster - Subset...:

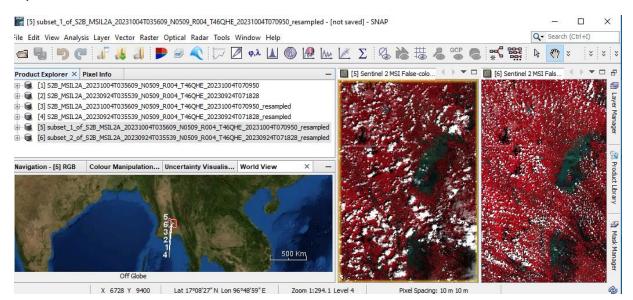
Create a subset with the following settings:

Spatial subset - Geo Coordinates: North latitude bound: 18.00, West longitude bound : 96.20, South latitude bound : 17.00, East longitude bound : 97.00

Keep the remaining parameters as default and click OK

| 🞆 Specify Pro  | oduct Subset |       |  |                         |             |                   |                           |                       | ×   |
|----------------|--------------|-------|--|-------------------------|-------------|-------------------|---------------------------|-----------------------|---|
| Spatial Subset | Band Subset  | Tie-F | oint Grid Subset   | Met                     | tadata Subs | et                |                           |                       |   |
|                |              |       | Pixel Coordina<br>Scene start X:<br>Scene start Y:<br>Scene end X:<br>Scene end Y:<br>Scene step X:<br>Scene step Y:<br>Subset scene wi<br>Source scene wi<br>Source scene wi<br>Source scene he | idth:<br>eight<br>idth: | :<br>:<br>: | Fix               | full width<br>full height | 1<br>690<br>890<br>10 | •       • <t< td=""></t<> |
|                |              |       |  |                         | Est         | imated, rav<br>OK | w storage siz<br>Cancel   |                       | 48.1M<br>Ielp   |

In the end, you should have two resampled subsets. Close original visualizations and display subsets in False color with Tile Horizontally option.







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# 2.4 Image analysis NDVI

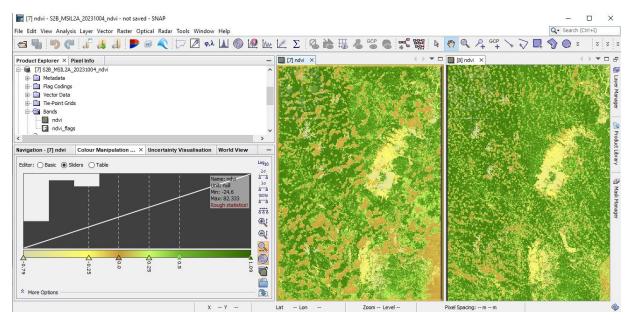
Let's calculate NDVI for the two subset images.

Navigate to Main Menu: Optical – Thematic Land Processing – Vegetation Radiometric Indices – NDVI Processor and set parameters:

| MDVI   | $\times$ | NDVI                                 | ×      |
|--|----------|--------------------------------------|--------|
| File Help  |          | File Help                            |        |
| I/O Parameters Processing Parameters   |          | I/O Parameters Processing Parameters |        |
| Source Product   |          | Red factor:                          | 1.0    |
| source:<br>[5] subset_1_of_S2B_MSIL2A_20231004T035609_N0509_R004_T46Q ∨  | 1        | NIR factor:                          | 1.0    |
|  |          | Red source band: B4                  | $\sim$ |
| Target Product   |          | NIR source band: B8                  | $\sim$ |
| Name:<br>[52B_MSIL2A_20231004_ndvi<br>Save as: BEAM-DIMAP<br>Directory:<br>Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8<br>Open in SNAP |          |                                      |        |
| Run Clos   | 2        | Run                                  | Close  |

In the Product Explorer tab double click to open resulted two new NDVI bands for each date.

Go to Colour Manipulation tab and select appropriate colour palette for vegetation index. Apply the same colour palette and set the sliders to the same values for both of the images. Synchronize Cursor Position and Views activating the two buttons in Navigation tab.



NDVI image has usually values from < -1, 1 >, where forested areas are displayed in values higher than 0.







#### NDWI

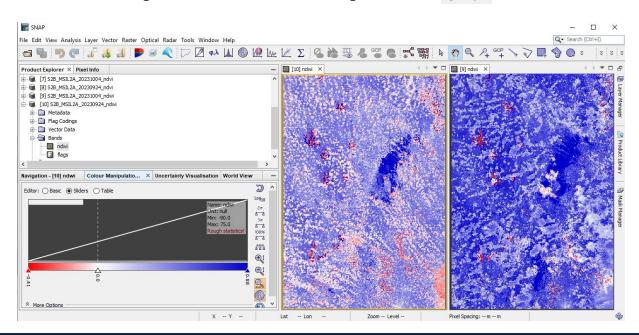
Let's calculate also NDWI for the two subset images.

Navigate to Main Menu: Optical – Thematic Land Processing – Water Radiometric Indices - NDWI Processor and set parameters:

| MDWI ×   | NDWI   | ×     |
|--|--|-------|
| File Help  | File Help  |       |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters                         |       |
| Source Product<br>source:<br>[5] subset_1_of_S2B_MSIL2A_20231004T035609 v                        | Resample Type:     None       Upsampling Method:     Nearest | ~     |
| Target Product   | Downsampling Method: First MIR factor:                       |       |
| Name:  | NIR factor:  | 1.0   |
| \$2B_MSIL2A_20231004_ndwi  | MIR source band: B12   | ~     |
| Save as:       BEAM-DIMAP         Directory:       Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8 | NIR source band: B8  | ~     |
| ✓ Open in SNAP   |  |       |
| Run Close  | Run  | Close |

In the Product Explorer tab double click to visualize resulted two new NDWI layers.

Go to Colour Manipulation tab and select appropriate colour palette for vegetation index. Apply the same colour palette and set the sliders to the same values for both of the images. Synchronize Cursor Position and Views activating the two buttons in Navigation tab.







#### 2.5 Water Mask Generation

The utilization of both NDVI and NDWI together can be advantageous for specifically identifying water bodies.

Let's create a binary mask of water and non-water pixels with a thresholding condition. Open e.g. False-color composition and define a Waterbody Region of Interest (ROI)

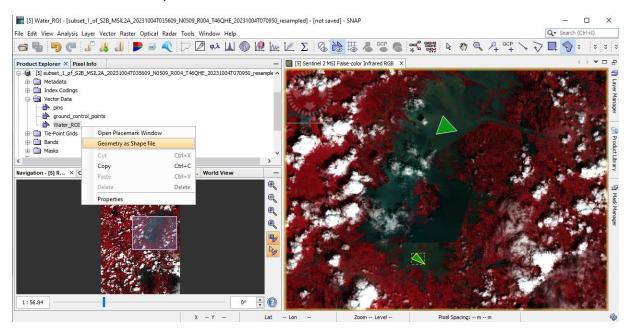
Define a new ROI (Vector->New Vector Data Container)

| Vector | Raster  | Optical   | Radar    | Tools |
|--------|---------|-----------|----------|-------|
| ы 👯    | ew Vect | or Data C | Containe | er    |

Define ROI name (f.e. Water\_ROI) and description (optional)

| 🎆 New Ve     | ctor Data Container X |
|--------------|-----------------------|
| Name:        | Water_ROI             |
| Description: |                       |
|              |                       |
|              |                       |
|              | OK Cancel Help        |

Check in VectorData folder corresponding to the active image to check the ROI has been created. Define Tool for ROI construction (Polygons Drawing Tool) and draw polygon over water area e.g. according Falsecolor Infrared composition and double-click to close it



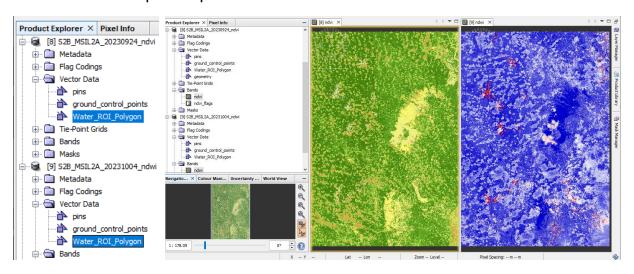
Export ROI as SHAPE file (f.i. as Water\_ROI.shp) – right click on the layer – Geometry as Shapefile – set the directory for export and close the visualization





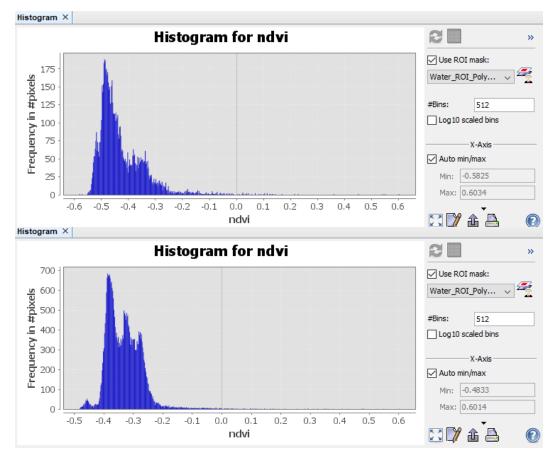
Import SHAPE file to make it available in NDVI and NDWI layers: Select NDVI product - File – Import- Vector data – ESRI Shapefile – and import your saved Water\_ROI polygon

Select NDWI product - File – Import- Vector data – ESRI Shapefile – and import your saved Water\_ROI polygon. Select NDVI and NDWI layers from Product Explorer panel and visualize them.



Calculate Histogram over ROI for NDVI and NDWI during pre-flood and during flood events:

click on NDVI layer – Navigate to Analysis->Histogram – activate Use ROI Mask tab – select Water ROI Polygon mask and press refresh button.

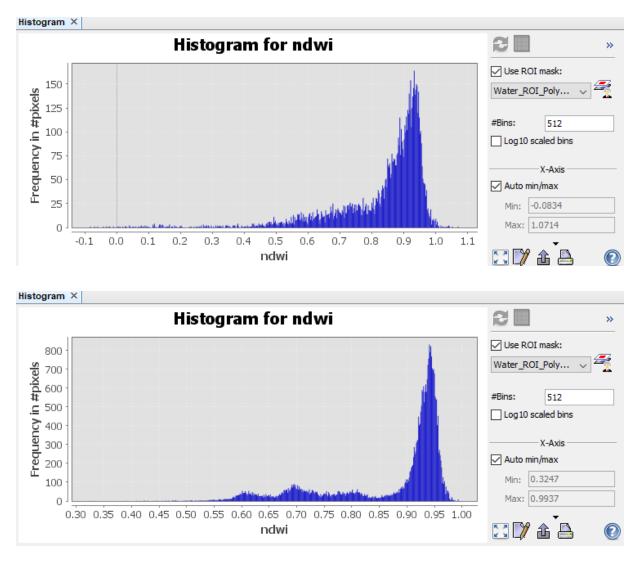






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#### Repeat for NDWI layer.



#### Proposed thresholding values

| No-flooded | NDVI<-0.15 and NDWI > 0.3 |
|------------|---------------------------|
| Flooded    | NDVI< 0.1 and NDWI > 0.35 |

Create masks for NDVI and for NDWI with a combined (AND) condition: Open Band Maths window from Raster>Band Maths or by selecting any available layer (f.i. NDWI) and clicking on the mouse's right button. Edit the formula by selecting the NDVI and NDWI properly (corresponding to the same acquisition) and applying the proper thresholds).







#### Calculate new masks for pre-flood and flood events.

| 🞇 Band Maths  |  | ×  | Band Maths            |                                  |         | ×                             |
|---|--|--|-----------------------|----------------------------------|---------|-------------------------------|
| Target product:   |  |  | Target product:       |                                  |         |                               |
| [9] S2B_MSIL2A_203  | 231004_ndwi  | ~  | [8] S2B_MSIL2A_202    | 230924_ndvi                      |         | ~                             |
| Name:   | WaterMask_flood  |  | Name:                 | WaterMask_flood                  |         |                               |
| Description:  |  |  | Description:          |                                  |         |                               |
| Unit:   |  |  | Unit:                 |                                  |         |                               |
| Spectral wavelength:  | :0.0   |  | Spectral wavelength:  | 0.0                              |         |                               |
| Virtual (save exp   | pression only, don't store data)   |  | Virtual (save exp     | pression only, don't store data) |         |                               |
| Replace NaN and   | d infinity results by  | NaN  | Replace NaN and       | d infinity results by            |         | NaN                           |
| Generate associa  | ated uncertainty band  |  | Generate associa      | ated uncertainty band            |         |                               |
| Band maths expression   |  |  | Band maths expression | on:                              |         |                               |
| \$9.ndwi > 0.3 and \$   | 7.ndvi < -0.15   |  | \$10.ndwi > 0.35 and  | d \$8.ndvi < 0.1                 |         |                               |
| Load Se   | ave  | Edit Expression  | Load Sa               | ave                              |         | Edit Expression               |
|   |  | OK Cancel Help   |                       |                                  |         | OK Cancel Help                |
| <ul> <li>(a) 228 MSL2</li> <li>(b) 3 28 MSL2</li> <li>(c) 4 328 MSL2</li> <li>(c) 5 28 MSL2</li> <li>(c)</li></ul> | A_20231004T035609_N0509_R004_T46QHE_20231004T<br>A_20230924T035599_IN0509_R004_T46QHE_20230924T<br>A_2023004T035509_IN059_R004_T46QHE_20230924T<br>A_20230924T035539_IN0509_R004_T46QHE_20230924T<br>df_S2B_JMSIL2A_20231004T035609_N0509_R004_T46QH<br>A_2023104_LA_20230924T035539_IN0509_R004_T46QH<br>A_2023104_IAdvi<br>A_20230924_IAdvi<br>A_2023104_IAdvi | (6) WaterMask_pre_flood ×  |                       | VaterMad, floo                   |         | Laver Manager     And Manager |
| 1:176.32  | 0° 🗘 🕢   | the state of the second se | an girin<br>Alina     |                                  | F. C. M |                               |

#### 2.6 Export and open binary masks in QGIS

To export this product for viewing in other GIS software and to map the changes in flooding over time, you need to save our two binary mask (start of floods and peek of floods) in TIF format in the proper folder using File-> Export->GeoTiff/BigTiff tool.

To visualize the output of our multi-temporal flood analysis, we will open the masks saved in GeoTIFF format using QGIS:

In QGIS click on the Add Raster Layer button located in the left panel, navigate to the folder containing the binary masks in TIFF format, and click Open (or drag&drop).

#### Now we open the output image in QGIS

- We can overlay it to e.g. Google Satellite or Bing aerial image:
- Web->OpenLayers plugin->Google Maps->Google Satellite
- Move the Subset above the satellite



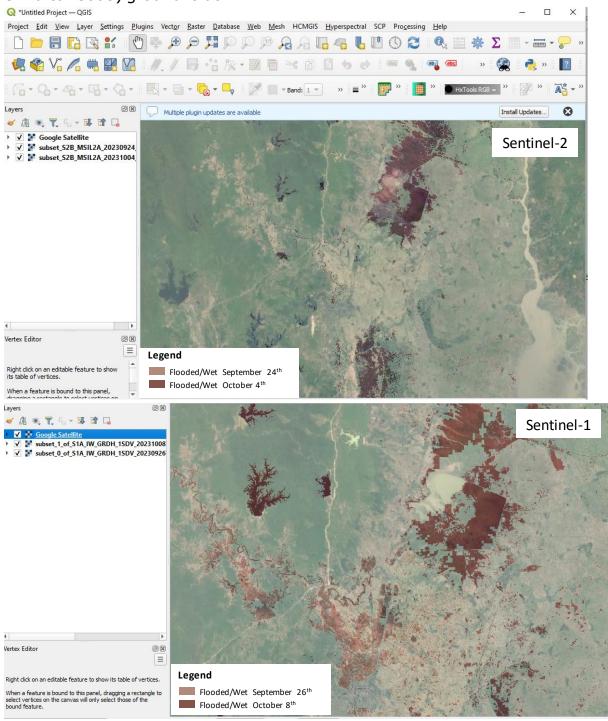




• Play with Transparency: Properties->Transparency (e.g. 80%)

As observed, the floodwaters gradually subside over time, yet areas near the riverbanks remain saturated, displaying low backscatter and thus continuing to appear flooded.

Compare masks retrieved via S1 and S2 using S2-RGB data as (quasi simultaneous) ground truth.



For more information, see the lectures: <u>10. SAR and optical remote</u> sensing for mapping floods, <u>11. SAR and optical remote sensing for post-</u><u>flood assessment and recovery</u>

## THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# **EXERCISE 12 – TUTORIAL**

Land subsidence mapping using SAR interferometry (InSAR) using the SNAP software





FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

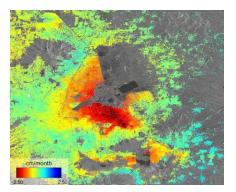
- Explore the role of synthetic aperture radar (SAR) in detecting and mapping land subsidence using Sentinel-1 data.
- Understand how to process SAR data to obtain information and understanding of surface deformations
- Emphasise the sensitivity of SAR to small surface changes and provide a comprehensive view of the subsidence dynamics.
- Learn how to detect displacement by means of band Math expression and visualize results of displacement in Google Earth.





# 2 | Background

Land subsidence, the gradual sinking of the Earth's surface, caused by natural processes like sediment compaction and human activities such as groundwater extraction, poses risks to infrastructure and ecosystems. Effective monitoring and mitigation strategies are crucial to address its impacts and ensure sustainable land use.



Subsidence in Mexico City is a significant issue that has been occurring for several decades. Excessive groundwater pumping, primarily for residential and industrial use, has been one of the primary drivers of subsidence in Mexico City. The groundwater extraction causes the clay soils to compact, leading to the sinking of the ground surface. The consequences of subsidence in Mexico City are severe. Infrastructure such as buildings, roads, and pipelines can suffer damage or even collapse as the ground sinks unevenly. Subsidence also increases the risk of flooding during periods of heavy rainfall, as the ground settles below the level of drainage systems.

Sentinel-1 satellite data through radar interferometry techniques, can monitor subtle movements of the Earth's surface. With its frequent revisits and global coverage, Sentinel-1 enables continuous monitoring over large areas, aiding researchers and policymakers in assessing risks and implementing mitigation measures for sustainable land management.



Image sources: https://www.science.org/content/article/sinking-mexicocity-linked-metro-accident-more-come, https://www.esa.int/ESA\_Multimedia/Images/2014/12/Mexico\_City\_subsidence





#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 GRD images of the same area near Bago city, Myanmar, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].

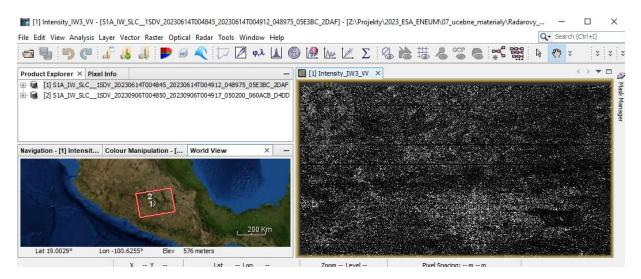


#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products by double click on them. The opened products will appear in Product Explorer window.

S1A\_IW\_SLC\_\_1SDV\_20230614T004845\_20230614T004912\_048975\_05E3BC\_2DAF.zip S1A\_IW\_SLC\_\_1SDV\_20230906T004850\_20230906T004917\_050200\_060ACB\_D4DD.zip

Right-click on the "Intensity\_IW3\_VV" band and select Open Image Window to create and visualize the image of the band (or double-click on it).









#### 2.3 Pre-processing S-1 TOPS Split

As the region of interest falls within 3 bursts of the Sentinel-1 image, there's no need to process the entire sub-swath with all bursts. Instead, extraction of Sentinel-1 TOPS bursts will be conducted per acquisition and per sub-swath. This approach reduces processing time.

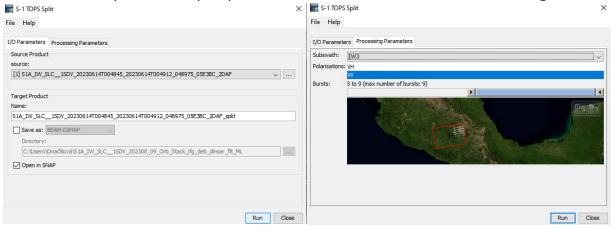
Navigate to Radar > Sentinel-1 TOPS > S-1 TOPS Split.

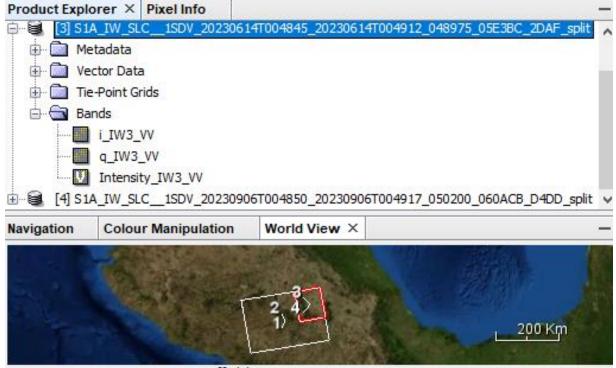
In the I/O Parameters tab, leave the default output name for the target product name. The system inserts automatically the suffix of the split process in order to discriminate the split product from the original data.

In the Processing Parameters tab, select the following parameters:

Subswath: IW3 Polarisations: VV Bursts: 3 to 5

In Bursts selection drag arrows to the specified number of bursts. Then click RUN. Repeat the split process for the second Sentinel-1 image:





Off Globe





#### 2.4 Co-registration

The first processing step is to apply the orbit files in Sentinel-1 products in order to provide accurate satellite position and velocity information.

#### Apply orbit file

Navigate to Main Menu - Radar - Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Repeat for the second image.

Save the products with applied orbit files.

| 📀 Apply Orbit File   | X C Apply Orbit File X   |
|--|--|
| File Help  | File Help  |
| I/O Parameters Processing Parameters Source Product Source: [3] S1A_IW_SLC_1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split   | I/O Parameters     Processing Parameters       Orbit State Vectors:     Sentinel Precise (Auto Download)       Polynomial Degree:     3       Ø Do not fail if new orbit file is not found |
| Target Product           Name:           S1A_TW_SLC_1SDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb           Save as:         BEAM-DIMAP           Directory:         C:Upsers\Onačilová\S1A_TW_SLC_1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML           Open in SNAP |  |
| Run Close  | e Run Close  |

#### Back-Geocoding

Next step will be to co-register the two Sentinel-1 images. For this reason the second image (slave) will be co-registered with respect to the first image (master). Sentinel-1 Back Geocoding operator co-registers two S-1 split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM).

Navigate to Radar > Coregistration > S-1 TOPS Coregistration > S-1 Back-Geocoding:

In the ProductSet-Reader click on Add Opened icon and keep only the products with the applied orbit files (in case there is more products, use remove icon to delete them).

| S-1 Back Geocoding           ProductSet-Reader         Back-Geocod | 144-14- |             |       |       |  |
|--|---------|-------------|-------|-------|--|
| File Name  | Type    | Acquisition | Track | Orbit |  |
| S1A_IW_SLC1SDV_20230614  | SLC     | 14Jun2023   | 78    | 48975 |  |
| S1A IW SLC 1SDV 20230906   | SLC     | 06Sep2023   | 78    | 50200 |  |







Back-Geocoding tab use default parameters, but also check "Output Deramp and Demod Phase" option.

| S-1 Back Geocoding               |                              | $\times$ |
|----------------------------------|------------------------------|----------|
| ProductSet-Reader Back-Geocoding | Write                        |          |
| Digital Elevation Model:         |                              | $\sim$   |
| DEM Resampling Method:           | BICUBIC_INTERPOLATION        | ~        |
| Resampling Type:                 | BISINC_5_POINT_INTERPOLATION | ~        |
| Mask out areas with no elevation |                              |          |
| Output Deramp and Demod Phase    |                              |          |
| Disable Reramp                   |                              |          |

In the Write tab, select the directory to save your processing outputs.

#### Enhanced Spectral Diversity

In the next step, the Enhanced Spectral Diversity (ESD) operator is applied after Back-Geocoding. The ESD method utilizes data from the overlapping area of adjacent bursts and conducts range and azimuth corrections for each burst.

Go to Radar > Coregistration > S-1 TOPS Coregistration > Enhanced-Spectral-Diversity

In the I/O Parameters tab, select the last back-geocoded product.

By default, the output target is set to the same directory and appends "esd" to the filename.

In the Enhanced-Spectral-Diversity tab use the default parameters.

| © S-1 Enhanced Spectral Diversity X  | 📀 S-1 Enhanced Spectral Diversity            |                                   | ×  |
|--|--|-----------------------------------|----|
| File Help  | File Help                                    |                                   |    |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters         |                                   |    |
| Source Product   | Registration Window Width:                   | 512                               | ~  |
| source:<br>[6] S1A_TW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack v | Registration Window Height:                  | 512                               | ~  |
| [6] S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb_Stack V            | Search Window Accuracy in Azimuth Direction: | 16                                | ~  |
| Target Product   | Search Window Accuracy in Range Direction:   | 16                                | ~  |
| Name:  | Window oversampling factor:                  | 128                               | ~  |
| S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd              | Cross-Correlation Threshold:                 | 0                                 | .1 |
| Save as: BEAM-DIMAP V  | Coherence Threshold for Outlier Removal:     | 0                                 | .3 |
| Directory:   | Number of Windows Per Overlap for ESD:       |                                   | 10 |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12                 | ESD Estimator:                               | Periodogram                       | ~  |
| Open in SNAP   | Weight function:                             | Inv Quadratic                     | ~  |
|  | Temporal baseline type:                      | Number of images                  | ~  |
|  | Maximum temporal baseline (inclusive):       |                                   | 4  |
|  | Integration method:                          | L1 and L2                         | ~  |
|  | Do not write target bands (store range an    | d azimuth offsets in json files). |    |
|  | Use user supplied range shift (please ente   | r it below)                       |    |
|  | The overall range shift in pixels:           | 0                                 | .0 |
|  | Use user supplied azimuth shift (please en   | ter it below)                     |    |
|  | The overall azimuth shift in pixels:         | 0                                 | .0 |
|  |  |                                   | -  |
| Run Close  | ]  | Run Clos                          | e  |
|  |  |                                   |    |







#### 2.5 Forming a Raw Interferogram

The next phase involves generating an interferogram using the the interferometric pair (master and slave), while a coherence image estimation from the stack of the coregistered complex images is included. To do this, follow these steps:

From the main menu bar, go to Radar > Interferometric > Products and finally select Interferogram Formation.

In the I/O Parameters tab, choose the "esd" product that was generated during the previous step.

By default, the output target is set to the same directory and appends "ifg" to the filename.

In the Processing Parameters tab set the following parameters:

Coherence Range Window Size: 20

Coherence Azimuth Window Size: 5

| C Interferogram Formation   | 🤇 🕼 Interferogram Formation   | $\times$ |
|---|---|----------|
| File Help   | File Help   |          |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameters  |          |
| Source Product<br>Source product:<br>[7] S1A_IW_SLC_1SDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb_Stack_esd v | Number of "Elek Easth" estimation points  | >        |
| Target Product<br>Name:   | Subtract topographic phase  | ~        |
| S1A_IW_SLCISDV_20230614T004845_20230614T004912_048975_05E38C_20AF_split_Orb_Stack_exd_ifg           Save as:         BEAH-DIMAP   | Digital Elevation Model: SRTM 3Sec (Auto Download) Title Extension [%] 100  | 1        |
| Directory:<br>Z:Projekty[2023_ESA_ENEUM][07_ucebne_materialy]Radarovy_DPZ'[practicals]exercise_12                                 | Output Elevation Output Orthorectified Lat/Lon  |          |
| Open in SNAP  | Indude coherence estimation         Independent Window Sizes           Square Pixel         Independent Window Sizes           Coherence Range Window Size         20           Coherence Azimuth Window Size         5 |          |
| Run Close   | Run Close   | :        |

#### **TOPS** Debursting

The next stage in interferometry using Sentinel-1 TOPS mode (IWS) data involves "debursting" or merging the bursts - the focused complex burst images are assembled in azimuth-time sequence to form a unified subswath image, with black-fill borders separating them. There is ample overlap between neighboring bursts and sub-swaths to guarantee continuous ground coverage. All burst images in all sub-swaths are resampled to a consistent pixel spacing grid in both range and azimuth, while retaining the phase data.

From the main menu bar, navigate to Radar > Sentinel-1 TOPS > S-1 TOPS deburst:

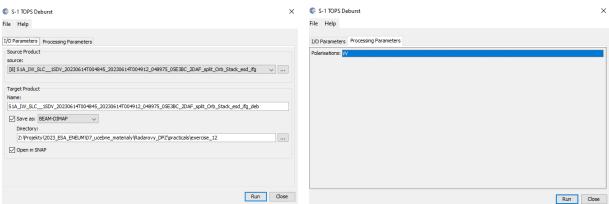
In the I/O Parameters tab, choose the "Orb\_Stack\_esd" product generated during the interferogram formation process. By default, the output appends "deb" to the filename.



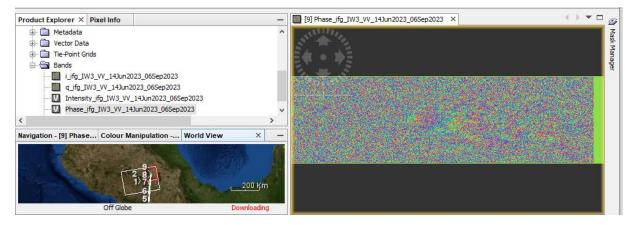




In the TOPSAR-Deburst tab select Polarizations: VV. Click on the "RUN".

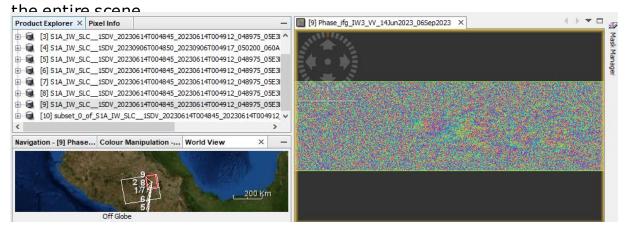


The new product will appear in the Product Explorer window. The processing might take some time depending on your machine.



#### Create subset (optional)

In the earlier stages of processing, empty pixels (green pixels on the interferogram) along the interferogram's perimeter may have been created, particularly in regions not overlapped by both input images. To remove these sections, employ the Subset function found under Raster. This approach will also decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than







ÚSTAV GEOGRAFIE

The next step involves removing the topographic phase from the debursted interferogram using a Digital Elevation Model (DEM).

To proceed with topographic phase removal, follow these steps:

From the main menu bar, navigate to Radar > Interferometric > Products Topographic Phase Removal:

In the I/O Parameters tab, choose the "Orb\_Stack\_ifg\_deb" product generated during the deburst step.

By default, the output appends "dinsar" to the filename.

The Processing Parameters tab indicates that the default setting is to download the SRTM 3-arcsecond DEM, which is suitable for basic processing. Select the "Output topographic phase band" option and keep the default parameters.

|   | X 💿 Topographic Phase Re | moval  | ×    |
|---|--------------------------|--------|------|
| File Help   | File Help                |        |      |
| I/O Parameters Processing Parameters Source Product Source Product I/O Parameters Source Product I/O point SIA_IW_SLC_1SDV_20230614f1004945_00230614f1004912_049975_0SE38C_20AF_golt_Orb_Stack_end_ifg_deb v · · · · Target Product Name: Robert_0_orf_S1A_IW_SLC_1SDV_20230614f1004945_00230614f1004912_049975_0SE38C_20AF_golt_Orb_Stack_end_ifg_deb_dnear Source Product Robert_0_orf_S1A_IW_SLC_1SDV_20230614f1004945_00230614f1004912_049975_0SE38C_20AF_golt_Orb_Stack_end_ifg_deb_dnear Source Product Comparison of the state of the | Tile Extension [%]       |        |      |
| Run Glose   |                          | Run Cl | lose |

#### Multi-Looking and Filtering

There are two methods to minimize noise in the interferogram: filtering and multi-looking. While standard procedure involves applying filtering initially, it's also possible to opt for multi-looking first.

#### Multilooking

Multi-looking involves averaging several pixels in each direction, a process referred to by radar engineers as "taking multiple looks." This leads to larger pixels and has the potential to significantly diminish noise.

The extent of multi-looking required depends on the desired spatial resolution and the spacing of the fringes.

To initiate multi-looking:

From the top main menu bar, select Radar > SAR Utilities > Multilooking. In the I/O Parameters tab, choose the "dinsar" product generated by the previous step. By default, "ML" is appended to the output name.

In the Processing Parameters tab set the following parameters:

Number of Range Looks: 8

Number of Azimuth Looks: 2







#### Multilooking

File Help

| I/O Parameters | Processing Parameters   |
|----------------|---|
| Source Product | t   |
| source:        |   |
| [11] subset_0  | )_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar 🗸                         |
| Target Product | t   |
| Name:          |   |
| subset_0_of_9  | S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML                             |
| Save as:       | BEAM-DIMAP 🗸  |
| Directory:     |   |
| Z: \Projekt    | ty/2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   |
| Open in SN     | NAD   |
| openin si      | ΥΛΓ.  |
|                |   |
|                |   |
|                |   |
|                | Run Close   |
| Multilooking   | g   |
| File Help      |   |
|                |   |
| I/O Parameters | Processing Parameters   |
| Source Bands:  | i_jfg_VV_14Jun2023_06Sep2023<br>q_jfg_VV_14Jun2023_06Sep2023<br>Intensity_jfg_VV_14Jun2023_06Sep2023_jfg_srd_VV_14Jun2023_06Sep2023 |
|                | Phase_ifg_srd_VV_14Jun2023_06Sep2023  |
|                | topo_phase_VV_14Jun2023_06Sep2023   |
|                | coh IW3 VV 14Jun2023 06Sep2023  |

#### Filtering

GR Square Pixel

Output Intensity

Number of Range Looks: 8 Number of Azimuth Looks: 2 Mean GR Square Pixel: 27.361336

To begin filtering, navigate to Radar > Interferometric > Filtering > Goldstein Phase Filtering from the top main menu bar.

In the I/O Parameters tab, choose the "ML" product generated in the previous step.

By default, the output name includes "flt."





Independent Looks

Note: Detection for complex data is done without resampling.



Run

Close

 $\times$ 

# In the Processing Parameters tab set the parameters as defined below: Adaptive Filter Exponent in (0,1]: 1.0 FFT Size: 128

| 📀 Goldstein Phase Filtering        |   |         | ×      |
|------------------------------------|---|---------|--------|
| File Help                          |   |         |        |
| I/O Parameters Processing Param    | eters   |         |        |
| Source Product                     |   |         |        |
| Source product:                    |   |         |        |
| [12] subset_0_of_S1A_IW_SLC_       | _1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dins | ar_ML ∨ | ·      |
| Target Product                     |   |         |        |
| Name:                              |   |         |        |
| subset_0_of_S1A_IW_SLC1SE          | V_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_M | IL_flt  |        |
| Save as: BEAM-DIMAP                | ~   |         |        |
| Directory:                         |   |         |        |
| Z:\Projekty\2023_ESA_ENEL          | M\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12                                 |         |        |
| ✓ Open in SNAP                     |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    | _   |         |        |
|                                    |   | Run     | Close  |
|                                    |   |         |        |
| 🖉 Caldetain Dhaca Filtarian        |   |         | ×      |
| C Goldstein Phase Filtering        |   |         | ^      |
| File Help                          |   |         |        |
| I/O Parameters Processing Param    | neters .  |         |        |
|                                    |   |         |        |
| Adaptive Filter Exponent in (0,1]: |   |         | 1.0    |
| FFT Size:                          | 128   |         | $\sim$ |
| Window Size:                       | 3   |         | $\sim$ |
| Use coherence mask                 |   |         |        |
| Coherence Threshold in [0,1]:      |   |         | 0.2    |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   |         |        |
|                                    |   | Run     | Close  |

In this step we have to save the output, which is the multilooked and filtered differential interferogram.







#### 2.6 Phase Unwrapping

Unwrapping in SNAP follows three distinct steps:

**1. Export of the wrapped phase** (and definition of the parameters)

2. Unwrapping of the phase (performed outside SNAP by snaphu)

**3. Import of the unwrapped phase** back into SNAP

#### Export of the wrapped phase

Export your interferogram or your subset interferogram from Sentinel-1 Toolbox to SNAPHU:

From the top main menu bar, navigate to Radar > Interferometric > Unwrapping > Snaphu Export.

In the Snaphu Export window:

In Read tab, select the last "fit" product created by the Goldstein Phase Filtering step

| 🕑 Sr         | aphu Export      |  | × |
|--------------|------------------|--|---|
| Read         | SnaphuExport     |  |   |
| -Sour<br>Nam | ce Product<br>e: |  |   |
| [13]         | subset_0_of_S1A  | _IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack 🗸 |   |
| C            | )ata Format:     | Any Format   | ~ |
| Ad           | vanced options   |  |   |

In Snaphu Export tab specify a target folder for export. Create a new target folder for this step by entering a path and new folder name (e.g. "snaphu\_export). If the selection of the directory does not work, simply copy and paste the path of your working directory into the text field.

Also, set the parameters as indicated below: Statistical-cost mode: DEFO Initial method: MCF Number of Tile Rows: 1 Number of Tile Columns: 1 Row Overlap: 0 Column Overlap: 0

Note: The number of tile rows, columns can be changed to e.g. "1" because we don't need multiple tiles after multilooking. Depending on the number of processors of your computer, you can also increase the Number of Processors variable.







Snaphu Export

| Read SnaphuExport       |  |   |
|-------------------------|--|---|
| Target folder:          | Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12\snaphu_export |   |
| Statistical-cost mode:  | DEFO   | , |
| Initial method:         | MCF ~  | , |
| Number of Tile Rows:    |  | 1 |
| Number of Tile Columns: |  | 1 |
| Number of Processors:   |  | 4 |
| Row Overlap:            |  | 0 |
| Column Overlap:         |  | 0 |
| Tile Cost Threshold:    | 50   | 0 |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         |  |   |
|                         | Save 🕐 Help 🕞 Run  |   |

Click Run to create the SNAPHU\_Export file. This step might take some time depending on your PC.

The folder now holds files used for phase unwrapping:

• the coherence: image (\*.img) and metadata (\*.hdr)

• the wrapped phase: image (\*.img) and metadata (\*.hdr)

 the unwrapped phase: only the metadata (\*.hdr), because the image (\*.img) is first to be created

by snaphu in the next step.

- a configuration file (snaphu.conf) containing the parameters defined in the export operator







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#### Unwrapping of the phase

You should see the wrapped interferogram phase "Phase\_ifg\*.img", coherence "coh\_\*.img", and a "snaphu.conf" file.

For the next step, you will need to instal SNAPHU in Windows. SNAPHU is a tool for phase unwrapping of interferometric information. To use it as an executable file (\*.exe) in Windows it has to be compiled first so all required drivers (\*.dll) are installed correctly. Follow the steps for installation here: file:///C:/Users/Ona%C4%8Dillov%C3%A1/Downloads/Installation\_SNAPHU\_English\_ABraun.pdf

To start unwrapping, check the location of the interferogram exported from SNAP. If snaphu.exe is not in your system's PATH variable: Copy it in there as well. It is recommended to store the data and snaphu on the same disk. Open Command Window Here.

Type snaphu and hit Enter. The help menu should be displayed.

| Príkazový riadok   |   | _ | × |
|--|---|---|---|
| C:\Users\Onačillo  | vá≻snaphu   |   |   |
| snaphu v1.4.2  |   |   |   |
|  | ptions] infile linelength [options]                   |   |   |
| most common optic  |   |   |   |
| -t   | use topography mode costs (default)                   |   |   |
| -d   | use deformation mode costs                            |   |   |
| -5   | use smooth-solution mode costs                        |   |   |
| -f <filename></filename>                                     |   |   |   |
| <pre>-o <filename> -a <filename></filename></filename></pre> | write output to file<br>read amplitude data from file |   |   |
| -c <filename></filename>                                     | read amplitude data from file                         |   |   |
| -b <decimal></decimal>                                       | perpendicular baseline (meters)                       |   |   |
| -i   | do initialization and exit                            |   |   |
| -l <filename></filename>                                     | log runtime parameters to file                        |   |   |
| -V   | give verbose output                                   |   |   |
| mst  | use MST algorithm for initialization (default)        |   |   |
| mcf  | use MCF algorithm for initialization                  |   |   |
|  |   |   |   |
| type snaphu -h fo  | or a complete list of options                         |   |   |

The command to start the unwrapping is shown in the file snaphu.conf. Open it with a text editor. The beginning of the "snaphu.conf" file shows the command to call Snaphu

```
snaphu-Poznámkový blok
Súbor Úpravy Formát Zobraziť Pomocník
# CONFIG FOR SNAPHU
# ------
# Created by SNAP software on: 17:05:40 17/02/2024
#
# Command to call snaphu:
#
snaphu -f snaphu.conf Phase_ifg_VV_14Jun2023_06Sep2023.snaphu.img 2552
```





| 🔤 Príkazový riadok  | _      | × |
|---|--------|---|
| C:\Users\Onačillová>snaphu -f snaphu.conf Phase_ifg_VV_30Aug2023_11Sep2023.snaphu.img           | g 1352 |   |
| snaphu v1.4.2   |        |   |
| 27 parameters input from file snaphu.conf (84 lines total)                                      |        |   |
| Logging run-time parameters to file snaphu.log  |        |   |
| Creating temporary directory snaphu_tiles_9176  |        |   |
| Unwrapping tile at row 0, column 0 (pid 17116)  |        |   |
| Unwrapping tile at row 0, column 1 (pid 6756)   |        |   |
| Unwrapping tile at row 0, column 2 (pid 17080)  |        |   |
| Unwrapping tile at row 0, column 3 (pid 5492)   |        |   |
| Unwrapping tile at row 0, column 4 (pid 8164)   |        |   |
| Unwrapping tile at row 0, column 5 (pid 14144)  |        |   |
| Unwrapping tile at row 0, column 6 (pid 4528)   |        |   |
| Unwrapping tile at row 0, column 7 (pid 17300)  |        |   |
| Unwrapping tile at row 0, column 8 (pid 16024)  |        |   |
| Unwrapping tile at row 0, column 9 (pid 12940)  |        |   |
| Unwrapping tile at row 1, column 0 (pid 13976)  |        |   |
| Unwrapping tile at row 1, column 1 (pid 13484)  |        |   |
| Unwrapping tile at row 1, column 2 (pid 15556)  |        |   |
| Unwrapping tile at row 1, column 3 (pid 9680)   |        |   |
| Unwrapping tile at row 1, column 4 (pid 8840)<br>Unwrapping tile at row 1, column 5 (pid 5068)  |        |   |
| Unwrapping tile at row 1, column 6 (pid 11868)  |        |   |
| Unwrapping tile at row 1, column 7 (pid 13908)  |        |   |
| Unwrapping tile at row 1, column 8 (pid 13908)  |        |   |
| Unwrapping tile at row 1, column 9 (pid 9124)   |        |   |
| Unwrapping tile at row 2, column 0 (pid 5956)   |        |   |
| Unwrapping tile at row 2, column 0 (pid 1990)<br>Unwrapping tile at row 2, column 1 (pid 11740) |        |   |
| Unwrapping tile at row 2, column 2 (pid 10028)  |        |   |

The Snaphu program can take a long time to run. At the end it writes **unwrapped phase to "Unw\_ifg\*.img" file** 

#### Import of the unwrapped phase

Now, we import the unwrapped phase. From the top main menu bar, select Radar > Interferometric > Unwrapping, and then Snaphu Import that converts it back into the BEAM DIMAP format and adds the required.

Read-Phase: should be set to the wrapped product that you exported(before the export)

Read-Unwrapped-Phase: select the unwrapped phase product: Navigate to folder where you exported for Snaphu. Select the "UnwPhase\_ifg\*.snaphu.hdr" file. Note: The error message will then vanish if you proceed to the next tab.

SnaphuImport: Leave the option "Do NOT save Wrapped interferogram in the target product" unchecked, because it is required in the later step.

Write: To store the imported unwrapped band in a separate product (recommended), add `\_unw' to the end of the output name and click Run.

Finally, a new product is added to the Product Explorer which contains the the unwrapped phase that we can display.







| C Snaphu Import X  | C Snaphu Import ×  |
|--|--|
| 1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Write   | 1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Write   |
| Source Product<br>Name:  | Source Product Name:   |
| [13] subset_0_of_S1A_JW_SLC1SDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb_Stack_esd_jfg_deb_dinsar_ML_fit v | UnwPhase_lfg_VV_14Jun2023_065ep2023.snaphu v   |
| Data Format: Any Format 🗸  | Data Format: Any Format 🗸  |
| Advanced options   | Advanced options   |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Save 🕡 Help 🕞 Run  | Save 🕖 Help 🕞 Run  |
| © Snaphu Import X  | © Snaphu Import X  |
| 1-Read-Phase 2-Read-Unwrapped-Phase 3-Snaphulmport 4-Write   | 1-Read-Phase 2-Read-Unwrapped-Phase 3-Snaphulmport 4-Write   |
| Do NOT save Wrapped interferogram in the target product  | Target Product   |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | Name:  |
|  | subset_0_of_S1A_IV_SLCISDV_20230614T004845_20230614T004912_048975_05E38C_2DAF_split_Orb_S1adk_esd_lfg_deb_dmsar_ML_fit_umm |
|  | Directory:   |
|  | Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
| Save 🖉 Help 🕞 Run  | Seve 💽 Help 🕞 Run  |

Select the Unw\_Phase\_ifg band. Double click on this unwrapped phase to see if the unwrapping was successful. It should be a smooth raster with little variation except for the areas of expected deformation.

All fringe patterns are summarized to absolute changes. Go to the Colour Manipulation tab and select "100%" to stretch color scale to full range of unwrapped data. Unwrapped phase is still in radians. Phase is reference image minus coregistered image. If reference image is earlier, then negative phase is land moving toward satellite (negative range change)

| [14] Unw_Phase_ifg_14Jun2023_06Sep2023 - subset_0_of_S1A_IW_SLC_1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stac   | ck_esd_ifg_deb_dinsa                                       | r_ML_flt_unw         | - 0            | ×     |
|--|--|----------------------|----------------|-------|
| File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help  |  | Q.                   | Search (Ctrl+1 | I)    |
| 📾 🖫 🥐 🥐 🚚 🚚 🖻 🔍 🏷 🖉 🐢 🔟 🚳 🖗 🖄 🗴 端 🐻 🥵 📚  | ****   |                      | GCP ¥          | *   * |
| Product Explorer ×         Pixel Info  | <ul> <li>[14] Umu_Phase</li> <li>[14] Umu_Phase</li> </ul> | <u>fg_14Jun2023_</u> | 65e            |       |
| Navigation - [14] Unw_Phase_ifg_14Jun2023_06Sep2023         Colour Manipulation - [14] Unw_Phase_ifg_14Jun2023_06Sep2023         World View ×         -           2         2         1000 Km         1000 Km         6         000 Km         6           0ff Globe         0ff Globe         000 Km         00 Km         00 Km         000 |  |                      |                |       |





#### 2.7 Phase to displacement

We can convert the unwrapped phase to displacements. From the top main menu bar, select Radar, then Interferometric, then Products, and then Phase to Displacement.

The I/O Parameters tab should be set to the unwrapped product that you imported.

Default for target product name is to add "\_dsp" to the name

| 😨 Phase to Displacement  | × |
|--|---|
| File Help  |   |
|  |   |
| I/O Parameters Processing Parameters   |   |
| Source Product   |   |
| source:  |   |
| [14] subset_0_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt_unw 🗸 |   |
|  |   |
| Target Product   |   |
| Name:  |   |
| subset_0_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_fit_unw_dsp    |   |
| Save as: BEAM-DIMAP  |   |
| Directory:   |   |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   |   |
| Open in SNAP   |   |
|  |   |
|  |   |
|  |   |
|  |   |
| Run Close  |   |

In the Product Explorer window select the "displacement" band from the new opened product to open the displacement product in the view window. Displacements is now in meters.

| [15] displacement - [subset_0_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_04897   | 5_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt_unw_dsp] - [not saved] - SN 🛛 🗙            |
|---|--|
| File Edit View Analysis Layer Vector Raster Optical Radar Tools Window Help   | Q - Search (Ctrl+I)  |
| 📾 🖫 ୭ (° 🔐 😃 測 🕨 🗟 🔍 🏷 🖉 🐢 🔝 🚳 🧟  | 🔤 🖉 Σ 🥝 🍓 🚟 🧶 🙄 象 🐭 🗱 🖌 🕐 🔍 🗛 οΥ × 🔹   |
| Product Explorer ×         Pixel Info           □         [12] subset_0_of_SIA_IW_SLCISDV_202306147004912_202306147004912_048975_05E38C_2           □         [14] subset_0_of_SIA_IW_SLCISDV_202306147004845_202306147004912_048975_05E38C_2           □         [15] subset_0_of_SIA_IW_SLCISDV_202306147004845_202306147004912_048975_05E38C_2           □         [15] subset_0_of_SIA_IW_SLCISDV_202306147004845_202306147004912_048975_05E38C_2           □         [15] subset_0_of_SIA_IW_SLCISDV_202306147004845_202306147004912_048975_05E38C_2           □         [15] subset_0_of_SIA_IW_SLCISDV_202306147004845_202306147004912_048975_05E38C_2           □         [16] The Point Gids           □         [16] Point Gids           □         [16] displacement | NAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_fit<br>NAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_fit_unw |
| Nafigation - [15] displacement Colour Manipulation - [15] displacement × World View   | Unit: meters<br>Min: -0.283<br>Max: 0.032  |





#### 2.8 Geocoding results—Terrain Correction

Terrain corrections aim to mitigate distortions in SAR images caused by topographical variations in the scene and the tilt of the satellite sensor. These corrections seek to ensure that the geometric representation of the image dosely aligns with real-world conditions. SNAP calls geocoding with topography "Terrain Correction."

From the top main menu bar, select Radar, then Geometric, then Terrain Correction, and then Range-Doppler Terrain Correction:

The I/O Parameters tab should be set to the displacement product that you.

Default for target product name is to add "\_TC" to the name

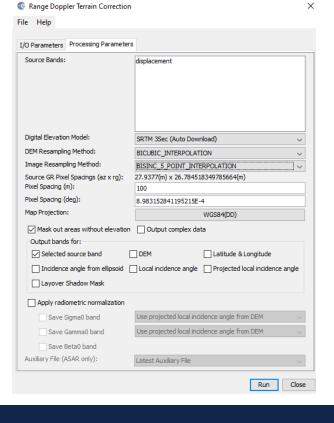
| 😨 Range Doppler Terrain Correction   | $\times$ |
|--|----------|
| File Help  |          |
|  |          |
| I/O Parameters Processing Parameters   |          |
| Source Product   |          |
| source:  |          |
| [15] subset_0_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_flt_unw_dsp 🗸 |          |
|  |          |
| Target Product   |          |
| Name:  |          |
| subset_0_of_S1A_IW_SLC1SDV_20230614T004845_20230614T004912_048975_05E3BC_2DAF_split_Orb_Stack_esd_ifg_deb_dinsar_ML_fit_unw_dsp_TC     |          |
| <b>Save asi</b> BEAM-DIMAP   |          |
| Directory:   |          |
| Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Radarovy_DPZ\practicals\exercise_12   |          |
| Open in SNAP   |          |

In the Processing Parameters tab, select the Source Band ("displacement"). Set also these parameters as following: Pixel Spacing (m): 100 Map Projection: WGS84(DD)

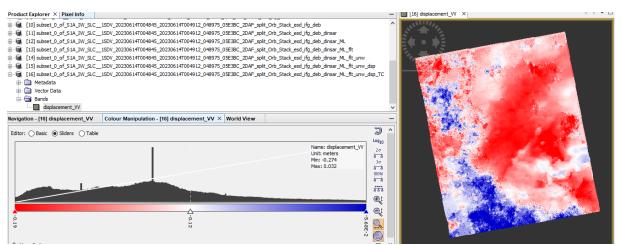
Now, we can display displacement\_vv band of geocoded result. Again, better to stretch colors. Product is now evenly spaced in latitude and longitude.

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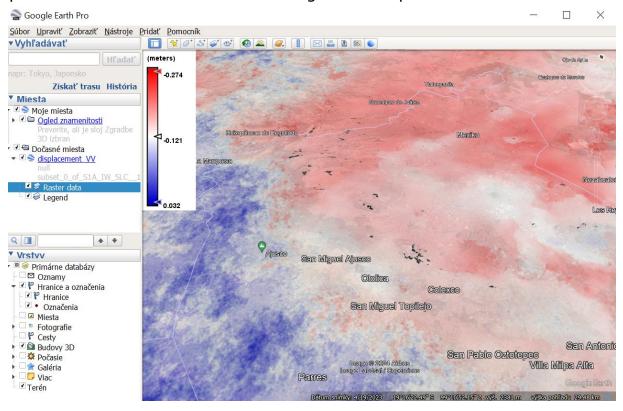
Note: By appropriate post-processing of the displacement product (masking of the incoherent values) more accurate measurements can be produced.

#### 2.9 Export .kmz to Google Earth

Geocoded products (projected to WGS84) can be exported as a KMZ file to view in Google Earth (Pro):

In the SNAP - right dick on the elevation raster in the View tab (or navigate to File > Export > Other > View As Google Earth KMZ)

Choose a directory and name to save the output .kmz, confirm with Save. Open the resulting KMZ file in Google Earth (Pro) to observe the elevation patterns overlaid on the satellite image base map.



For more information, see the lecture: 12. SAR for land subsidence

## THANK YOU FOR FOLLOWING THE EXERCISE!







# UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# **EXERCISE 13 – TUTORIAL**

Earthquake deformation with Sentinel-1 using the SNAP software



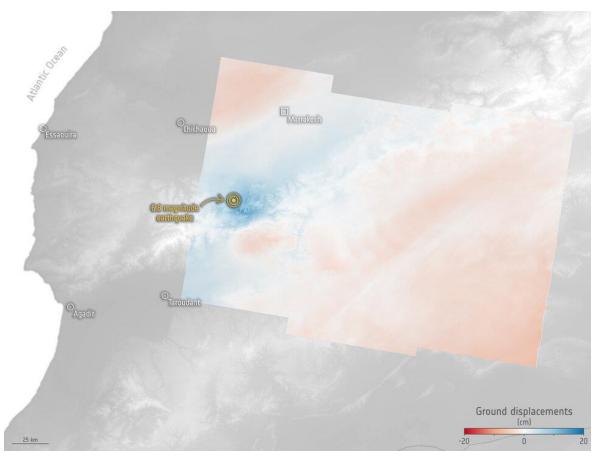


FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA

# 1 | Exercise outline

In this exercise, we will:

- Learn the basic physics of SAR interferometry
- Perform necessary data processing for making an interferogram
- Understand the information content in SAR interferometric images



#### Morocco earthquake deformation

Source: contains modified Copernicus Sentinel data (2023), processed by Aristotle University of Thessaloniki and the DIAPASON InSAR service of CNES integrated by TRE Altamira on the Geohazard Exploitation Platform GEP/ESA.



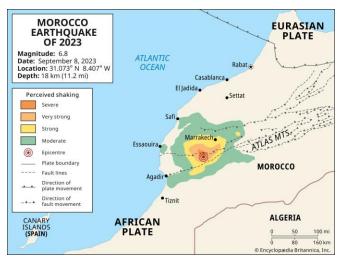


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# 2 | Background

#### Deformation Mapping and Change Detection using Sentinel-1 data

Satellites constantly monitor Earth from space, providing vital data essential for rapid damage and disaster assessment The radar management. on board the Copernicus Sentinel-1 mission can detect ground conditions and penetrate clouds, functioning day and night.



One of the mission's primary functions is to regularly monitor subtle alterations in the Earth's surface elevation. During an earthquake event, surface changes are notably more conspicuous compared to gradual movements such as subsidence or uplift. These radar images enable scientists to meticulously observe and analyze the specific impacts of earthquakes on the Earth's land surface.

On Friday 8 September 2023, the powerful 6.8 magnitude earthquake struck the Atlas Mountains, about 75 km from Marrakech. Tragically, the earthquake resulted in a significant loss of life, widespread building and home collapses, and the blockage of roads. Its impact extended to the extent that buildings even swayed on the country's northern coast.

In response to the Moroccan earthquake, the Copernicus Emergency Mapping Service was mobilized to facilitate the exchange of satellite data.







#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 SLC images of the same area near Marrakech, Morocco, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products by double click on the zipped folders. The opened products will appear in Product Explorer window.

S1A\_IW\_SLC\_\_1SDV\_20230830T062919\_20230830T062946\_050101\_06076B\_20BE.SAFE.zip S1A\_IW\_SLC\_\_1SDV\_20230911T062920\_20230911T062947\_050276\_060D5E\_D10D.SAFE.zip

To access the information within the product, double-click on it to reveal the directories, which include:

- Metadata: containing parameters pertaining to orbit and data.
- Tie Point Grids: providing interpolation data for latitude/longitude, incidence angle, etc.
- Quicklooks: presenting a visible image of the entire scene in radar coordinates.
- Bands: consisting of complex values for each subswath "i" and "q", along with intensity (where intensity represents the squared amplitude and functions as a virtual band).

Select intensity image for swath IW1 VV – double click on it to View it Note: Each SAR image is flipped north—south it maintains the same orientation as its acquisition (in this case, ascending track).







#### 3.2 Coregistration

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Image coregistration is the process that involves aligning two or more images geometrically, ensuring that corresponding pixels depict the same area on the Earth's surface. While orbit state vectors alone can suffice to coregister images, for precise offset tracking, additional data from a digital elevation model (DEM) is necessary to enhance coregistration accuracy.

Navigate to Main Menu – Radar – Coregistration –S1 TOPS Coregistration – S1 TOPS Coregistration

In the Read tab, select the 20230830 SLC product and in the Read(2) tab select the 20230911 SLC product

In TOPSAR-Split and TOPSAR-Split(2) tabs select Subswath: IW1 Polarizations:VV

In the Apply Orbit File tab select leave default parameters and uncheck "Do not fail if new orbit is not found" option

In the Write tab, select the directory to save your processing outputs

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|        |
| ,<br>, |
|        |
|        |



| S-1 TOPS Core       | egistration      |                    |                  |                     |                |       | $\times$ |
|---------------------|------------------|--------------------|------------------|---------------------|----------------|-------|----------|
| Read Read(2)        | TOPSAR-Split     | TOPSAR-Split(2)    | Apply-Orbit-File | Apply-Orbit-File(2) | Back-Geocoding | Write |          |
| Orbit State Vectors | s: Sentinel Pre  | ecise (Auto Downlo | ad)              |                     |                |       | $\sim$   |
| Polynomial Degree   | :                |                    |                  |                     |                |       | 3        |
| 🗹 Do not fail if n  | ew orbit file is | not found          |                  |                     |                |       |          |



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#### 3.3 Forming a Raw Interferogram

The next phase of interferometry involves generating an interferogram using the coregistered SLC images. To do this, follow these steps:

From the main menu bar, go to Radar – Interferometric - Products and finally select Interferogram Formation.

In the I/O Parameters tab, choose the "Orb\_Stack" product that was generated during the coregistration process.

By default, the output target is set to the same directory and appends "ifg" to the filename.

For standard processing, there's no need to modify the defaults in the Processing Parameters tab.

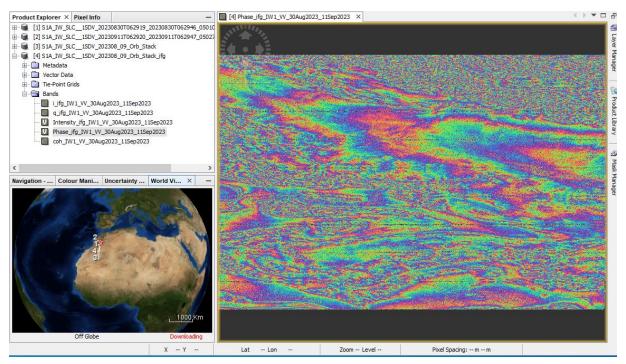
| C Interferogram Formation X   | C Interferogram Formation X  |
|---|--|
| File Help   | File Help  |
| I/O Parameters Processing Parameters Source Product Source product: [3] S1A_IW_SLC1SDV_202308_09_Orb_Stack  V | I/O Parameters     Processing Parameters       Subtract flat-earth phase     |
| Target Product Name:  | Orbit interpolation degree 3 ~   |
| S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg  | Digital Elevation Model: SRTM 3Sec (Auto Download)                           |
| Save as: BEAM-DIMAP   | Tile Extension [%]   |
| Directory:<br>Z:\Pracovnici\onacillova\ESA_ENEUM<br>Open in SNAP  | Output Elevation Output Orthorectified Lat/Lon Include coherence estimation  |
|   | Square Pixel Independent Window Sizes  |
|   | Coherence Range Window Size     10       Coherence Azimuth Window Size     3 |
| Run Close   | Run Close  |







#### Raw Interferogram — Phase Image should appear int he View tab.



#### 3.4 TOPS Debursting and Topographic Phase Removal

The next stage in interferometry using Sentinel-1 TOPS mode (IWS) data involves "debursting" or merging the bursts, a step not required with Sentinel-1 or other stripmap SAR data.

To perform debursting, follow these steps:

From the main menu bar, navigate to Radar, then Sentinel-1 TOPS, and finally S-1 TOPS deburst.

In the I/O Parameters tab, choose the "Orb\_Stack\_ifg" product generated during the interferogram formation process. By default, the output appends "deb" to the filename.

There is no need to make changes in the Processing Parameters tab.

| 💿 S-1 TOPS Deburst   | ×    | 📀 S-1 TOPS Deburst                   | $\times$ |
|--|------|--------------------------------------|----------|
| File Help  |      | File Help                            |          |
| I/O Parameters Processing Parameters                                       |      | I/O Parameters Processing Parameters |          |
| Source Product<br>source:<br>[[4] SIA_IW_SLCISDV_202308_09_Orb_Stack_ifg ~ |      | Polarisations: VV                    |          |
| Target Product<br>Name:  |      |                                      |          |
| S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb                                 |      |                                      |          |
| Z:\Pracovnici\onacillova\ESA_ENEUM   |      |                                      |          |
|  |      |                                      |          |
|  |      |                                      |          |
| Run C  | lose | Run Clos                             | e        |





The subsequent stage in all interferometry processes involves eliminating the topographic phase using a Digital Elevation Model (DEM).

To proceed with topographic phase removal, follow these steps:

From the main menu bar, navigate to Radar, then Interferometric, then Products, and finally Topographic Phase Removal.

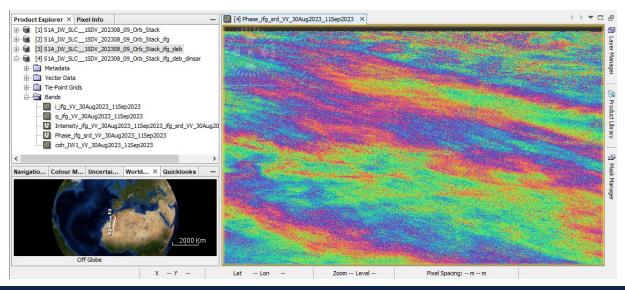
In the I/O Parameters tab, choose the "Orb\_Stack\_ifg\_deb" product generated during the deburst step. If not using TOPS mode, select "Stack\_ifg" instead.

By default, the output appends "dinsar" to the filename.

The Processing Parameters tab indicates that the default setting is to download the SRTM 3-arcsecond DEM, which is suitable for basic processing. However, in certain cases, you may require a different DEM.

| 😨 Topographic Phase Removal 🛛 🗙  | 📀 Topographic Phase Removal   | ×     |
|--|---|-------|
| File Help  | File Help   |       |
| I/O Parameters Processing Parameters   | I/O Parameters Processing Parameters  |       |
| Source Product<br>Source product:<br>[3] S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb  | Orbit Interpolation Degree:     3       Digital Elevation Model:     SRTM 3Sec (Auto Download)       Tile Extension [%]     100 | ~     |
| Target Product Name: S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar Save as: BEAM-DIMAP Directory: Z:\Pracovnici\onacillova\ESA_ENEUM | Output topographic phase band Output elevation band Output orthorectified Lat/Lon bands   |       |
| Open in SNAP   |   |       |
| Run Close  | Run   | Close |

Viewing Differential Interferogram — Phase Image







#### 3.5 Filtering and Multi-Looking Interferogram

There are two methods to minimize noise in the interferogram: filtering and multi-looking. While our standard procedure involves applying filtering initially, it's also possible to opt for multi-looking first.

To begin filtering:

Go to Radar, then Interferometric, then Filtering, and select Goldstein Phase Filtering from the top main menu bar.

In the I/O Parameters tab, choose the "dinsar" product generated in the previous step.

By default, the output name includes "flt."

There's no necessity to adjust the default settings in the Processing Parameters tab for basic processing.

| C Goldstein Phase Filtering X   | C Goldstein Phase Filtering X  |
|---|--|
| File Help   | File Help  |
| I/O Parameters Processing Parameters Source Product Source product: [4] S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar v Target Product Name: S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit Save.as; BEAM-DIMAP Directory: Z:\Pracovnici\onacillova\ESA_ENEUM V Open in SNAP | I/O Parameters       Processing Parameters         Adaptive Filter Exponent in (0, 1]:       1.0         FFT Size:       64         Window Size:       3         Use coherence mask       Coherence Threshold in [0, 1]:       0.2 |
|   |  |
| Run Close   | Run Close  |

#### 3.6 Multi-Looking Interferogram

Multi-looking involves averaging several pixels in each direction, a process referred to by radar engineers as "taking multiple looks." This leads to larger pixels and has the potential to significantly diminish noise.

The extent of multi-looking required depends on the desired spatial resolution and the spacing of the fringes.

The Morocco earthquake, with a depth of approximately 18 km, exhibits widely spaced fringes. Additionally, there is no surface rupture, allowing for increased spatial averaging without sacrificing the earthquake signal.







To initiate multi-looking:

From the top main menu bar, select Radar, then SAR Utilities, and finally Multilooking.

In the I/O Parameters tab, choose the "dinsar\_flt" product generated by the filtering step. By default, "ML" is appended to the output name.

In the Processing Parameters tab, select the Source Bands "i\_ifg", "q\_ifg", and "coh". For this scene, 17 range looks are utilized, with the calculation of 5 azimuth looks resulting in approximately 70 m output pixels.

Do not select the "Phase" band.

| C Multilooking   | $\times$ | C Multilooking                     |   |  |
|--|----------|------------------------------------|---|--|
| File Help  |          | File Help                          |   |  |
| I/O Parameters Source Product source: [5] S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit v            |          | I/O Parameters Pr<br>Source Bands: | ocessing Parameters<br>i_ifg_VV_30Aug2023_11Sep2023<br>q_ifg_VV_30Aug2023_11Sep2023<br>Intensity_ifg_VV_30Aug2023_11Sep2023_db<br>Phase_ifg_VV_30Aug2023_11Sep2023<br>coh_IVV1_VV_30Aug2023_11Sep2023 |  |
| Target Product Name: S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_flt_ML Save as: BEAM-DIMAP Directory: |          | GR Square Pixe                     | Independent Looks   |  |
| Z:\Pracovnici\onacillova\ESA_ENEUM   |          | Number of Azimuth                  | rel: 70.0857  |  |
|  |          | Output Intensit                    | y<br>Note: Detection for complex data<br>is done without resampling.  |  |
| Run Clos   | æ        |                                    | Run Close   |  |

#### Viewing Multi-Looked Interferograms

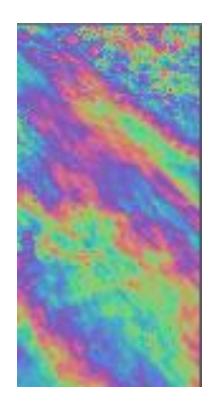
Initially, we must generate a new virtual phase band after multi-looking the complex interferogram.

#### To do this:

From the top main menu bar, navigate to Raster, then Data Conversion, and select Complex i and q to Phase.

Subsequently, you can display the newly created phase band.

As a result of this process, the fringes exhibit significantly reduced noise, and the aspect ratio has been modified, resulting in pixels that are approximately square on the ground. The new image now measures considerably smaller number of pixels than the original image.









#### 3.7 Phase Unwrapping

Unwrapping in SNAP follows three distinct steps:

- **1. Export of the wrapped phase** (and definition of the parameters)
- **2. Unwrapping of the phase** (performed outside SNAP by snaphu)
- **3. Import of the unwrapped phase** back into SNAP

#### Export of the wrapped phase

Export your interferogram or your subset interferogram from Sentinel-1 Toolbox to SNAPHU:

From the top main menu bar, navigate to Radar > Interferometric > Unwrapping > Snaphu Export.

In the Snaphu Export window:

In Read tab, select the "ML" product created by the multilooking step In Snaphu Export tab, you also need to specify a target folder for exported files. Create a new target folder for this step by entering a path and new folder name (e.g. "snaphu\_export). If the selection of the directory does not work, simply copy and paste the path of your working directory into the text field.

In Snaphu Export tab, select DEFO as Statistical-cost mode Select MCF.

Note: You can also change the number of tile rows, columns and number of processors to e.g. "1" because we don't need multiple tiles after multilooking or select 200 pixels for Row Overlap and Column Overlap if you want to multilook. Depending on the number of processors of your computer, you can also increase the Number of Processors variable.

Click Run to create the SNAPHU\_Export file

| C Snaphu Export X  | 😨 Snaphu Export         | ×                                  |
|--|-------------------------|------------------------------------|
| Read SnaphuExport  | Read SnaphuExport       |                                    |
| Source Product Name:   | Target folder:          | C: \Users \Onačilová\snaphu_export |
| [6] S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML v | Statistical-cost mode:  | DEF0 v                             |
| Data Format: Any Format 🗸                                      |                         | MCF v                              |
| Advanced options   | Number of Tile Rows:    | 10                                 |
|  | Number of Tile Columns: |                                    |
|  | Number of Processors:   | 4                                  |
|  | Row Overlap:            | 200                                |
|  | Column Overlap:         | 200                                |
|  | Tile Cost Threshold:    | 500                                |
|  |                         |                                    |
|  |                         |                                    |
|  |                         |                                    |
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|  |                         |                                    |
|  |                         |                                    |
|  |                         |                                    |
|  |                         |                                    |
| 🔁 Save 🛛 🖉 Help 🕞 Run  |                         | Save 💽 Help 🕞 Run                  |





The folder now holds files used for phase unwrapping:

- the coherence: image (\*.img) and metadata (\*.hdr)
- the wrapped phase: image (\*.img) and metadata (\*.hdr)

• the unwrapped phase: only the metadata (\*.hdr), because the image (\*.img) is first to be created

by snaphu in the next step.

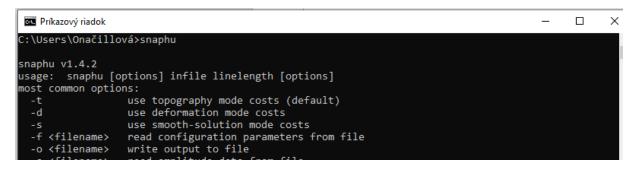
 a configuration file (snaphu.conf) containing the parameters defined in the export operator

#### Unwrapping of the phase

You should see the wrapped interferogram phase "Phase\_ifg\*.img", coherence "coh\_\*.img", and a "snaphu.conf" file.

For the next step, you will need to instal SNAPHU in Windows. SNAPHU is a tool for phase unwrapping of interferometric information. To use it as an executable file (\*.exe) in Windows it has to be compiled first so all required drivers (\*.dll) are installed correctly. Follow the steps for installation here: file:///C:/Users/Ona%C4%8Dillov%C3%A1/Downloads/Installation\_SNAPHU\_English\_ABraun.pdf

To start unwrapping, check the location of the interferogram exported from SNAP. If snaphu.exe is not in your system's PATH variable: Copy it in there as well. It is recommended to store the data and snaphu on the same disk. Open Command Window Here.



The command to start the unwrapping is shown in the file snaphu.conf. Open it with a text editor. The beginning of the "snaphu.conf" file shows the command to call Snaphu

snaphu - Poznámkový blok
Súbor Úpravy Formát Zobraziť Pomocník
# CONFIG FOR SNAPHU
# -----# Created by SNAP software on: 09:50:02 14/02/2024
#
# Command to call snaphu:
#
snaphu -f snaphu.conf Phase\_ifg\_VV\_30Aug2023\_11Sep2023.snaphu.img 1352







| 🔤 Príkazový riadok   | _      | × |
|--|--------|---|
| C:\Users\Onačillová>snaphu -f snaphu.conf Phase_ifg_VV_30Aug2023_11Sep2023.snaphu.img            | ; 1352 |   |
| snaphu v1.4.2  |        |   |
| 27 parameters input from file snaphu.conf (84 lines total)                                       |        |   |
| Logging run-time parameters to file snaphu.log   |        |   |
| Creating temporary directory snaphu_tiles_9176   |        |   |
| Unwrapping tile at row 0, column 0 (pid 17116)   |        |   |
| Unwrapping tile at row 0, column 1 (pid 6756)  |        |   |
| Unwrapping tile at row 0, column 2 (pid 17080)   |        |   |
| Unwrapping tile at row 0, column 3 (pid 5492)  |        |   |
| Unwrapping tile at row 0, column 4 (pid 8164)  |        |   |
| Unwrapping tile at row 0, column 5 (pid 14144)   |        |   |
| Unwrapping tile at row 0, column 6 (pid 4528)  |        |   |
| Unwrapping tile at row 0, column 7 (pid 17300)   |        |   |
| Unwrapping tile at row 0, column 8 (pid 16024)   |        |   |
| Unwrapping tile at row 0, column 9 (pid 12940)   |        |   |
| Unwrapping tile at row 1, column 0 (pid 13976)   |        |   |
| Unwrapping tile at row 1, column 1 (pid 13484)   |        |   |
| Unwrapping tile at row 1, column 2 (pid 15556)   |        |   |
| Unwrapping tile at row 1, column 3 (pid 9680)  |        |   |
| Unwrapping tile at row 1, column 4 (pid 8840)  |        |   |
| Unwrapping tile at row 1, column 5 (pid 5068)<br>Unwrapping tile at row 1, column 6 (pid 11868)  |        |   |
| Unwrapping tile at row 1, column 8 (pid 11808)<br>Unwrapping tile at row 1, column 7 (pid 13908) |        |   |
| Unwrapping tile at row 1, column 7 (pid 13908)<br>Unwrapping tile at row 1, column 8 (pid 13264) |        |   |
| Unwrapping tile at row 1, column 9 (pid 9124)  |        |   |
| Unwrapping tile at row 1, column 0 (pid 5956)  |        |   |
| Unwrapping tile at row 2, column 0 (pid 1990)<br>Unwrapping tile at row 2, column 1 (pid 11740)  |        |   |
| Unwrapping tile at row 2, column 2 (pid 10028)   |        |   |

The Snaphu program can take a long time to run. At the end it writes **unwrapped phase to "Unw\_ifg\*.img" file** 

#### Import of the unwrapped phase

Now, we import the unwrapped phase. From the top main menu bar, select Radar > Interferometric > Unwrapping, and then Snaphu Import that converts it back into the BEAM DIMAP format and adds the required.

Read-Phase: should be set to the wrapped product that you exported(before the export)

Read-Unwrapped-Phase: select the unwrapped phase product: Navigate to folder where you exported for Snaphu. Select the "UnwPhase\_ifg\*.snaphu.hdr" file. Note: The error message will then vanish if you proceed to the next tab.

SnaphuImport: Leave the option "Do NOT save Wrapped interferogram in the target product"

unchecked, because it is required in the later step.

Write: To store the imported unwrapped band in a separate product (recommended), add `\_unw' to the end of the output name and click Run.

Finally, a new product is added to the Product Explorer which contains the the unwrapped phase that we can display.



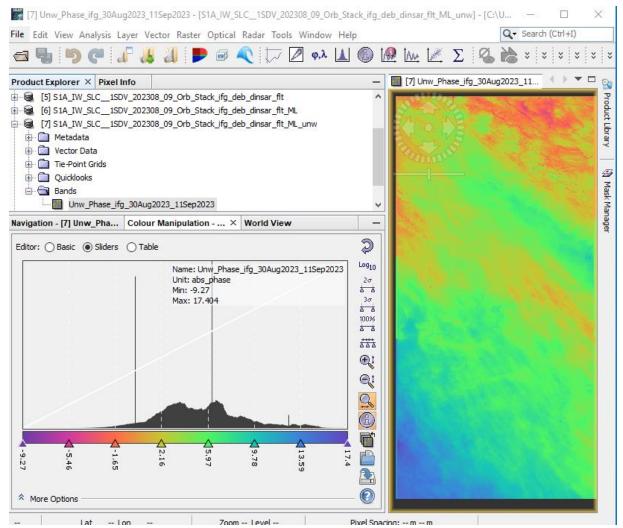




| 😨 Snaphu Import  | × | C Snaphu Import ×  |
|--|---|--|
| 1-Read-Phase 2-Read-Unwrapped-Phase 3-Snaphulmport 4-Write Source Product Name:  | < | 1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Witte<br>Target Product   |
| Snaphu Import     I-Read-Phase 2-Read-Univrapped Phase 3-SnaphuImport 4-Write     Source Product     Name:     UnivePhase_ifg_VV_30Aug2023_11Sep2023.anaphu     Data Format:     Any Format     Advanced options | × | Name:           S1A_JW_SLC15DV_202308_09_Orb_Stack_jfg_deb_dinser_fit_ML_umw            Save as:         BEAM-DINAP           Directory: |
| Snaphu Import     Read-Hwwapped Phase 3-SnaphuImport 4-Write     Do NOT save Wrapped Interferogram in the target product   | × | 🛃 Save 🔘 Help 🕞 Run  |

Select the Unw\_Phase\_ifg band. Double click on this unwrapped phase to see if the unwrapping was successful. It should be a smooth raster with little variation except for the areas of expected deformation.

All fringe patterns are summarized to absolute changes. Go to the Colour Manipulation tab and select "100%" to stretch color scale to full range of unwrapped data. Unwrapped phase is still in radians. Phase is reference image minus coregistered image. If reference image is earlier, then negative phase is land moving toward satellite (negative range change)







#### 3.8 Phase to displacement

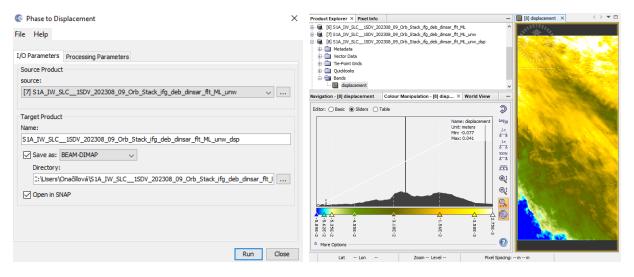
We can convert the unwrapped phase to displacements. From the top main menu bar, select Radar, then Interferometric, then Products, and then Phase to Displacement.

The I/O Parameters tab should be set to the unwrapped product that you imported.

Default for target product name is to add "\_dsp" to the name

Now, we can display displacement band of result. Again, better to stretch colors. Displacements is now in meters.

Sign was changed so positive displacement is "up" towards satellite



#### 3.9 Geocoding results—Terrain Correction

SNAP calls geocoding with topography "Terrain Correction." From the top main menu bar, select Radar, then Geometric, then Terrain Correction, and then Range-Doppler Terrain Correction.

The I/O Parameters tab should be set to the displacement product that you imported (or one of the other ML products).

default for target product name is to add "\_TC" to the name

Under Processing Parameters tab, select the Source Bands and any additional Output Bands. You can also choose what DEM to use, output spacing, and map projection.

Now, we can display displacement\_vv band of geocoded result. Again, better to stretch colors.

Displacements in meters with positive values "up" towards satellite in Lineof-Sight direction.

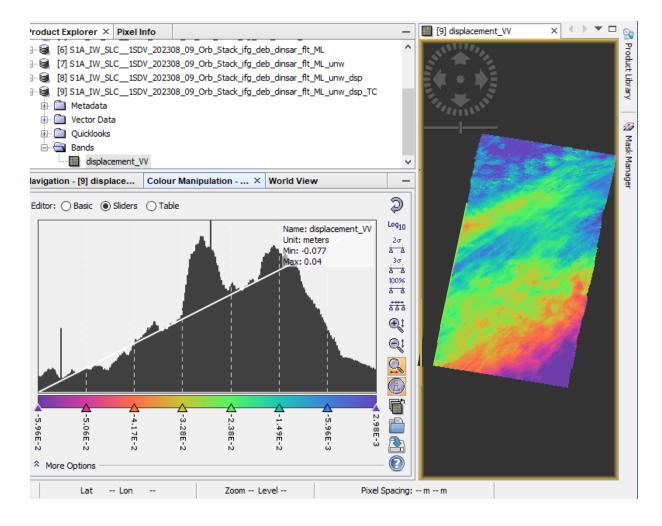
Product is now evenly spaced in latitude and longitude.







| C Range Doppler Terrain Correction X  | 📀 Range Doppler Terrain Correctio                  | on X   |
|---|--|--|
| File Help   | File Help  |  |
| I/O Parameters Processing Parameters  | I/O Parameters Processing Parameter                | ers  |
| Source Product<br>source:<br>[8] S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML_unw_dsp v | Source Bands:                                      | displacement   |
| Target Product Name:  |  |  |
| S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML_unw_dsp_TC                                 | Digital Elevation Model:                           | SRTM 3Sec (Auto Download) v  |
| Save as: BEAM-DIMAP   | DEM Resampling Method:                             | BILINEAR_INTERPOLATION V   |
| Directory:  | Image Resampling Method:                           | BILINEAR_INTERPOLATION V   |
| Jsers\Onačillová\S1A_IW_SLC1SDV_202308_09_Orb_Stack_ifg_deb_dinsar_fit_ML                           | Source GR Pixel Spacings (az x rg):                | 69.8967000000001(m) x 70.27081162268425(m)                           |
| ✓ Open in SNAP  | Pixel Spacing (m):                                 | 70.27081162268425  |
|   | Pixel Spacing (deg):                               | 6.312534410814097E-4   |
|   | Map Projection:                                    | WGS84(DD)  |
|   | Mask out areas without elevation                   | Output complex data  |
|   | Output bands for:                                  | DEM Latitude & Longitude   |
|   | Incidence angle from ellipsoid Layover Shadow Mask | Local incidence angle Projected local incidence angle                |
|   | Apply radiometric normalization                    |  |
|   | Save Sigma0 band                                   | Use projected local incidence angle from DEM $_{\rm ij}$ $_{\rm ij}$ |
|   | Save Gamma0 band                                   | Use projected local incidence angle from DEM $\sim$                  |
|   | Save Beta0 band                                    |  |
|   | Auxiliary File (ASAR only):                        | Latest Auxiliary File $\sim$   |
| Run Close   | L  | Run Close  |









#### 3.10 Displacement Profiles

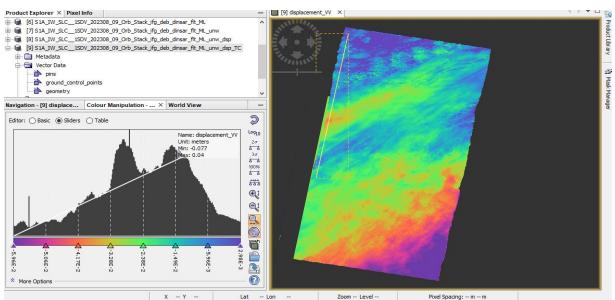
Use the line drawing tool (top bar of SNAP window) to draw a line across the signal.

Run Analysis > Profile Tool to see displacement along the profile

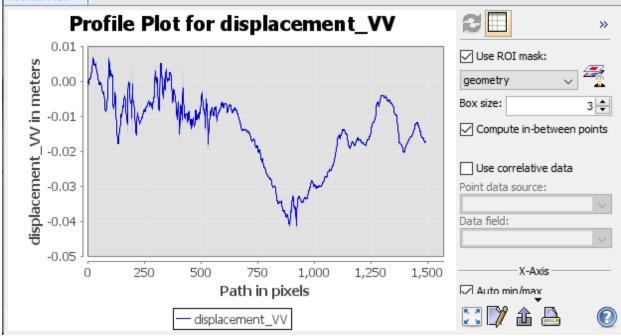
Remember that InSAR displacements are relative

In this case, displacement far from the signal is about -0.1 m, so that is probably the "true zero" offset

Maximum is about 0.24 m, but we need to subtract zero offset to get total displacement of about 0.35 m







For more information, see the lecture: 13. SAR for earthquake monitoring

### THANK YOU FOR FOLLOWING THE EXERCISE!







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FUNDED BY EUROPEAN SPACE AGENCY UNDER THE PLAN FOR EUROPEAN COOPERATING STATES, 7TH CALL FOR SLOVAKIA