GOSTEAM Hands-on Activity Template *(Classroom-Formal)*

Title:

Mapping flooded area using radar satellite remote sensing: a case study of flooding in Germany July 2021

Short Description (Max 500 words):

a) Practical exercise where students will process radar satellite imagery data from Sentinel-1 mission to map flooded area in Germany July 2021
b) Learn to how to process radar images using Sentinel processing software SNAP toolbox, and simple visualization and overlay using OpenStreet Map and QGIS
c) Extract water surface areas and identify flooded areas
d) Discussion on causes of flooding and useful of satellite remote sensing for disaster rescue

Keywords (Up to 5):

Flood, radar, mapping, water surface

Information about the Implementation

Age and language of the students:

Language: English

Age:	9-12	12-15	15-18	18+
	☐	☐	☒	☐

Number of Lessons – Duration (per lesson):

Number of Lessons: 3 Duration per Lesson: 45

Subjects

For which subject(s) the activity is usable, is it an interdisciplinary activity?

Science ☐

Physics ☐ Chemistry ☐ Biology ☐ Geosciences ☒ Environmental ☒ Other ☐

Technology ☐
Engineering ☐
Arts ☐
Mathematics ☐

Information about the Scenario

Curriculum and country:

Link of the current activity to the curriculum:

Country: Sweden

Class: geography

Grade: 10-12

Topic: Cartography

Objectives (Max 100 words):

Description of the learning objectives

- knowledge on radar satellite remote sensing and radar images from Sentinel-1 mission.
- knowledge on how to classify water surfaces from radar satellite images.
- knowledge on simple analysis using QGIS and OpenStreet Map.

Materials (Max 100 words):

Which resources and materials (software, hardware) are needed?

- Computer with internet connection
- Software: QGIS, Sentinel data processing software SNAP toolbox

Spatial concepts, skills and abilities:

Which spatial concepts and skills are covered by the activity?

Spatial concepts:

Primitives: Identity/Name ☐ Location ☒ Space/Time ☒

Simple: Distance ☒ Direction ☐ Connectivity ☐ Movement ☐

	Boundary [X]	Shape/Area [X]	Adjacency [ ]	
Difficult:	Overlay [X]	Buffer [X]	Topology [ ]	Coordinate [ ]
	Map [X]	Scale [ ]	Shortest Path [ ]	Navigation [ ]
	Surface [ ]	Slope/Gradient [ ]	Aspect [ ]	Contour [ ]
Complex:	Interpolation [ ]	Map Projection [ ]	Spatial Dependency [ ]	
Other:				

Spatial skills:

- [X] Map literacy
- [ ] Navigation/orientation
- [ ] Estimating distances and directions
- [ ] Recognizing and understanding patterns/Understand and identify models of spatial organization
- [X] Select an ideal location based on the given spatial features
- [X] Visualization
- [ ] Understand and identify spatial correlations/ dependencies
- [ ] Categorize spatial entities/ geographic features and identify hierarchies
- [ ] Compare spatial entities and draw analogies among them
- [ ] Identify/determine connections/relations
- [ ] Understanding scale in space and time
- [X] Delineation of spatial regions/ zones based on given features/ properties

Short Description

Navigation/orientation: Finding one's way in unfamiliar environments, interpreting and giving walking and driving directions.
Estimating distances and directions: Measure paths, weighted distances, angles.
Map literacy: Using, interpreting/understanding, learning from, and communicating acquired spatial knowledge from maps, comprehension of geographic features represented as points, lines, or polygons.
Recognizing and understanding patterns/Understand and identify models of spatial organization. Delineation of spatial regions/zones based on given features/properties: Regionalization processes, pattern recognition and clustering identification in the 2d and/or the 3d world.
Select an ideal location based on the given spatial features: Single or multi-criteria siting and optimal areas identification.
Visualization: Visualizing spatial entities from written/oral verbal descriptions, from their 2d or graphical representations or through mental transformations; such as axis rotation or perspective taking.
Understand and identify spatial correlations/ dependencies: The ability to realize, identify and explain patterns, clusters and relevant spatial dependencies.
Categorize spatial entities/geographic features and identify hierarchies: Identify the hierarchical form of data and gradients between spatial entities.

Compare spatial entities and draw analogies among them: Calculate and compare different geometric objects' shapes, area and, boundaries.
Identify/determine connections/relations: The ability to identify links and common characteristics among spatial entities and between humans and spatial entities.
Understanding scale in space and time: The understanding of changes/transitions through space and time for different spatio-temporal scales.

Geospatial concepts and spatial abilities documentation (see Section 3.2):
http://www.gosteam.eu/wp-content/uploads/2021/05/GOSTEAM_IO1_A1_final.pdf

Description of the activity in detail

Classroom activities

Lesson 1 (45 minutes):

- The first lesson is more focused on theoretical backgrounds, also get students involved in discussion.
- Short introduction on flooding news (BBC news and pictures), damages, and ask students what we can do to mitigate flooding damages and how to arrange the flooding-after rescue?
- Introduction to the importance of satellite remote sensing for mapping flooded area, by showing some impressive satellite images from Sentinel-1 (DLR Germany provides some good satellite images).
- The teacher presents the basics of radar satellite remote sensing (definition, how it works, spatial and temporal resolutions, advantages and disadvantages etc.)
- Introduction to satellite mission Sentinel-1 and show students on how to download the Sentinel-1 radar satellite data, and considering what aspects for data choice.
- Present how to classify water body from other areas (explain why water surface appears dark in satellite images)

Lesson 2 (45 min)

- The second lesion is more focused on the whole data processing
- Divide students into groups, so they could help each other during hands-on exercises.
- The lecturer will demonstrate each data processing steps for students by taking example for satellite image in July 2021. Explain the functions and purpose of Sentinel-1 processing software SNAP. Students can directly ask questions during the processing.
- Sentinel-1 processing software SNAP processing includes mainly: open and display satellite radar imagery data, subset, calibration, geometric correction, thresholding selection to extract water surface area and flooded area; saving results into GeoTIFF data.
- Display the extracted water surface area in QGIS using OpenStreet Map as background. Then identify which areas are heavily flooded and which areas not. Expected result is shown in Figure 1.

Lesson 3. (45 min)

- Lesson 2 demonstrates all steps-by-steps processing for extracting water surface area. There are lots of parameter choices in the data processing which will affect the extracted water surface area. Let the students compare and discuss the influence of different parameter choices on the water surface area/flooded area extraction. Also discussion some problems on extracted flooded area.

- Finish the lesson and the topic by discussing advantages and disadvantages of using radar satellite imagery data. And also ask students about what they think about this topic and exercise, and any other questions to discuss.

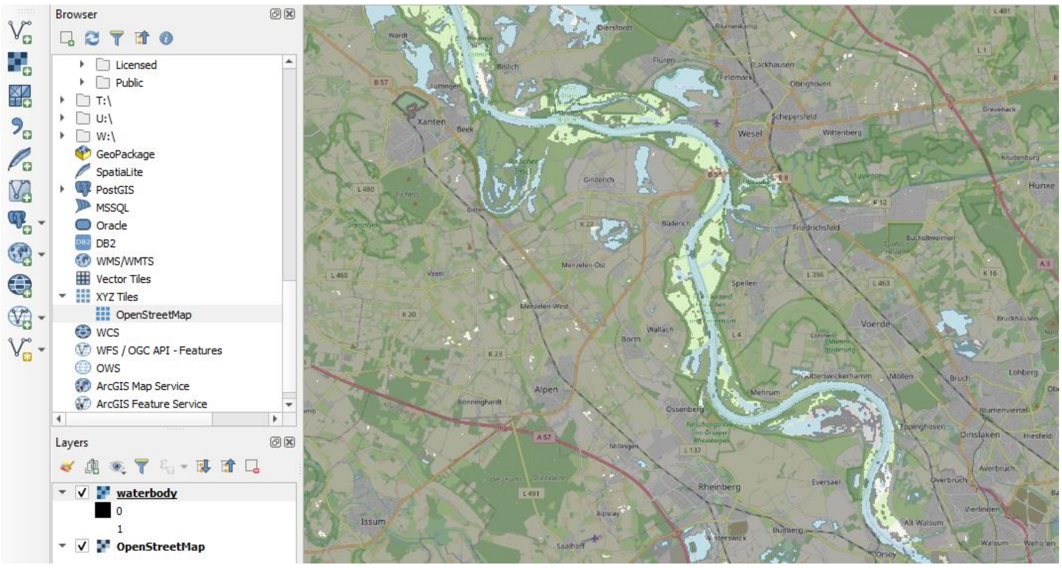


Figure 1: Extracted water and flooded area (blue) in Germany July 2021 from Sentinel-1 radar satellite image

Processing steps

1. **Downloading of Sentinel-1 data (data are free but registration is needed)**

All data from Sentinel missions can be downloaded for free from the Copernicus Open Access Hub at https://scihub.copernicus.eu/, but registration is needed. Many useful resources (e.g. User Guide's) can also be found at the aforementioned website. It is important to remember that the Sentinel-1 (1A and 1B, two missions) data are available only from April 2014 when the Sentinel-1A satellite mission was launched.

After login on the Copernicus Open Access Hub, we can search for the data available in the area of interest. Hold your right button of your mouse to define the Area of Interest by drawing a polygon on the map window, as show in Figure A1 (the region covering Lund and nearby water bodies). On the left panel for search, check the Mission: Sentinel-1 and select the options under Satellite Platform, Product Type and Sensor Mode. You can also define the time period of interest under Sensing period. Then hit the Search icon. The Data Hub will search for any product whose footprint intersects the selected region.

From media and newspaper on the flooding event, the satellite image taken on July 15, 2021 is relevant. Then we will select the image covering our study area for further analysis. This

image is :
S1A_IW_GRDH_1SDV_20210715T055027_20210715T055052_038784_049389_5004

Then we will download it. The download file will be in ZIP file.

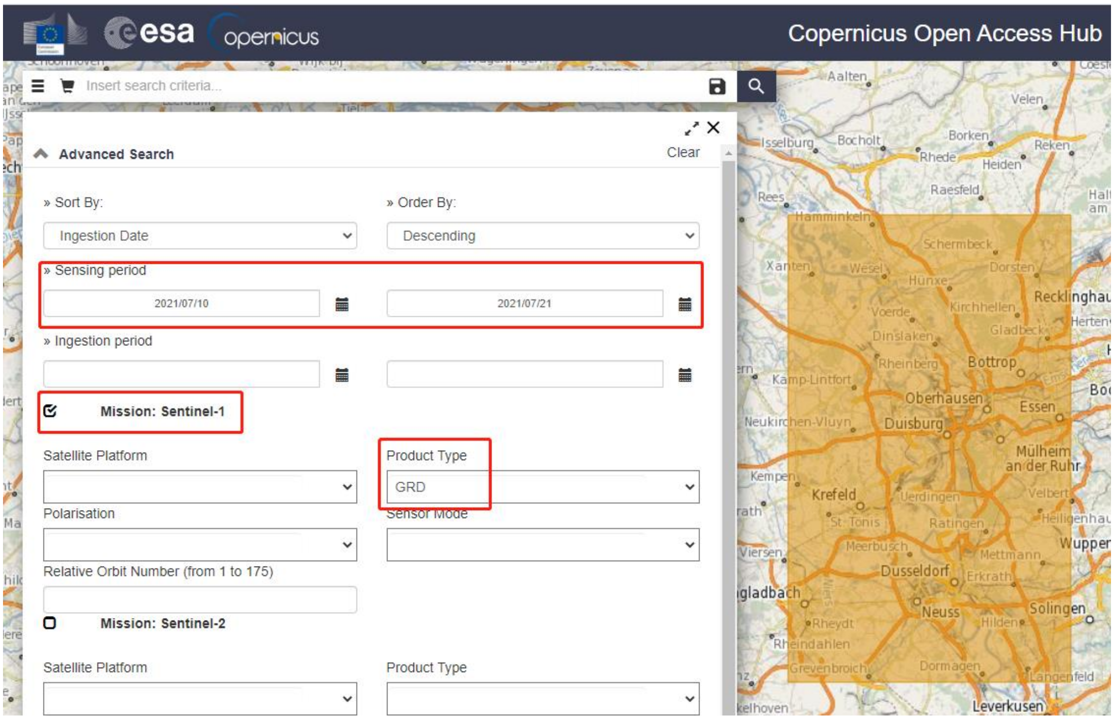


Figure 2. Screen copy of the data hub interface to search data for an area of interest.

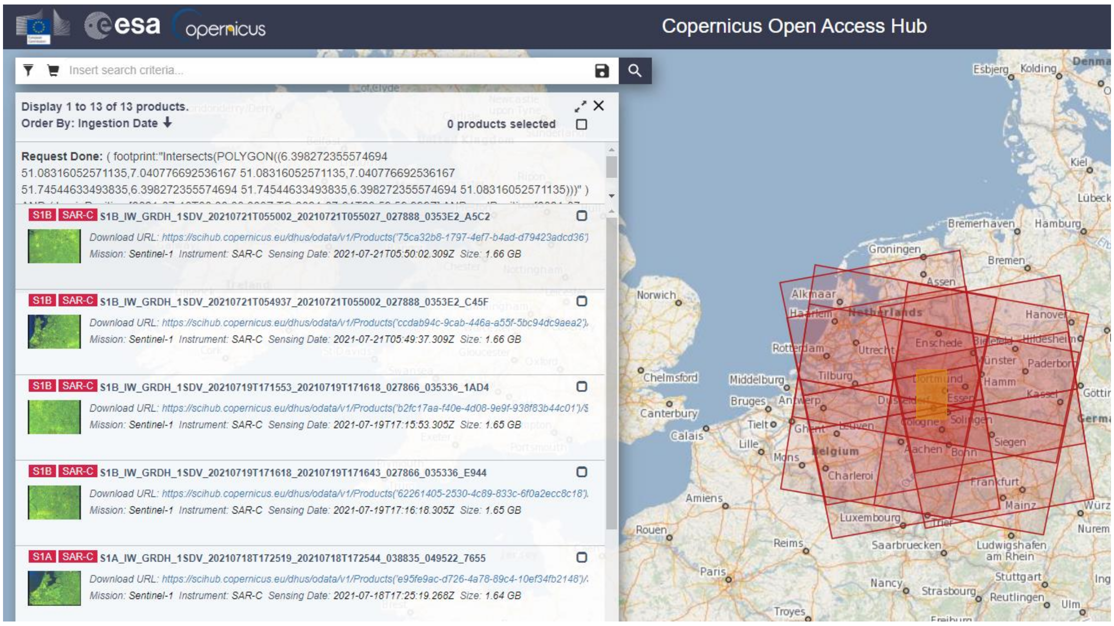


Figure 3. Screen copy of the data hub interface to search data for an area of interest, 13 images available from Sentinel-1 during July 10-21, 2021 covering the flooded area in Germany

2. Interface and windows of the SNAP Toolbox

Now open SNAP Toolbox and just drag the downloaded ZIP file to SNAP.

On the SNAP toolbox interface, get familiar with the main menu and three main windows (left upper, left bottom, and right, as shown in Figure 4). Also try the Tabs.

On the top left, it is the **<u>Product Explorer window</u>**, on the bottom left a **<u>Navigation/Colour Manupulation/World View window</u>** where you can navigate the image, see the histogram of image, and see the footprint of the image in the world map. The right window is **<u>Main Image Viewer.</u>**

Once the product is loaded in SNAP, you will see different folders related to the image. The first folder is called "**Metadata**". Under "**Abstract Metadata**" you will see the information of the image regarding the mission, the acquisition information as mode and date, the pass of the satellite (Ascending/Descending), the polarisation among other.

On the folder "**Bands**" you will see the image for the polarisation available saved as "**Amplitude_VV**" and/or "**Amplitude_VH**" and, you will find virtual bands for the **Intensity** (the square of the Amplitude).

Once the image is open in the **Main Viewer**, it is possible to see the **World View** of the image to see where it is located. Directly on the **Main Viewer**, you can explore the image with the mouse, moving it, zooming in and out, or it can be done by selecting the tap Navigation located to the right from the World View Tap on the bottom left.

Pre-processing of SAR images generally consist of four steps: **<u>Subset,</u>** **<u>Calibration, Speckle Filtering and Terrain Correction</u>**.

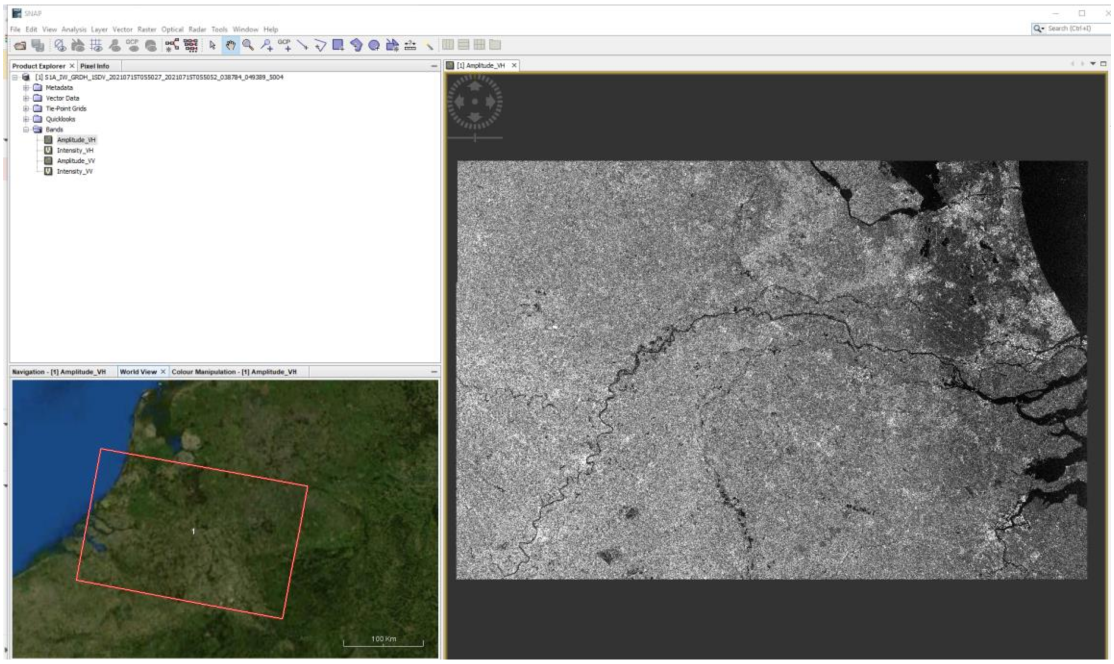


Figure 4. The interface and windows of the SNAP Toolbox

3. Subset

The entire satellite image is too large. We just need a small subset to process to demonstrate how to extract the flooded area. Thus we need to make a subset.

To do the subset, you can zoom in the image on the Main Viewer to define the extent of the area on which the Subset is going to be made. Then go to the **“Raster” Menu -> “Subset”**, you can see and adjust the extent of the subset or you can also define the subset by Pixel Coordinates or Geo Coordinates. In this exercise, please type the coordinates (latitude and longitude) as shown in Figure 5 to perform the subset. A new subset file will be automatically added under Product Explorer.

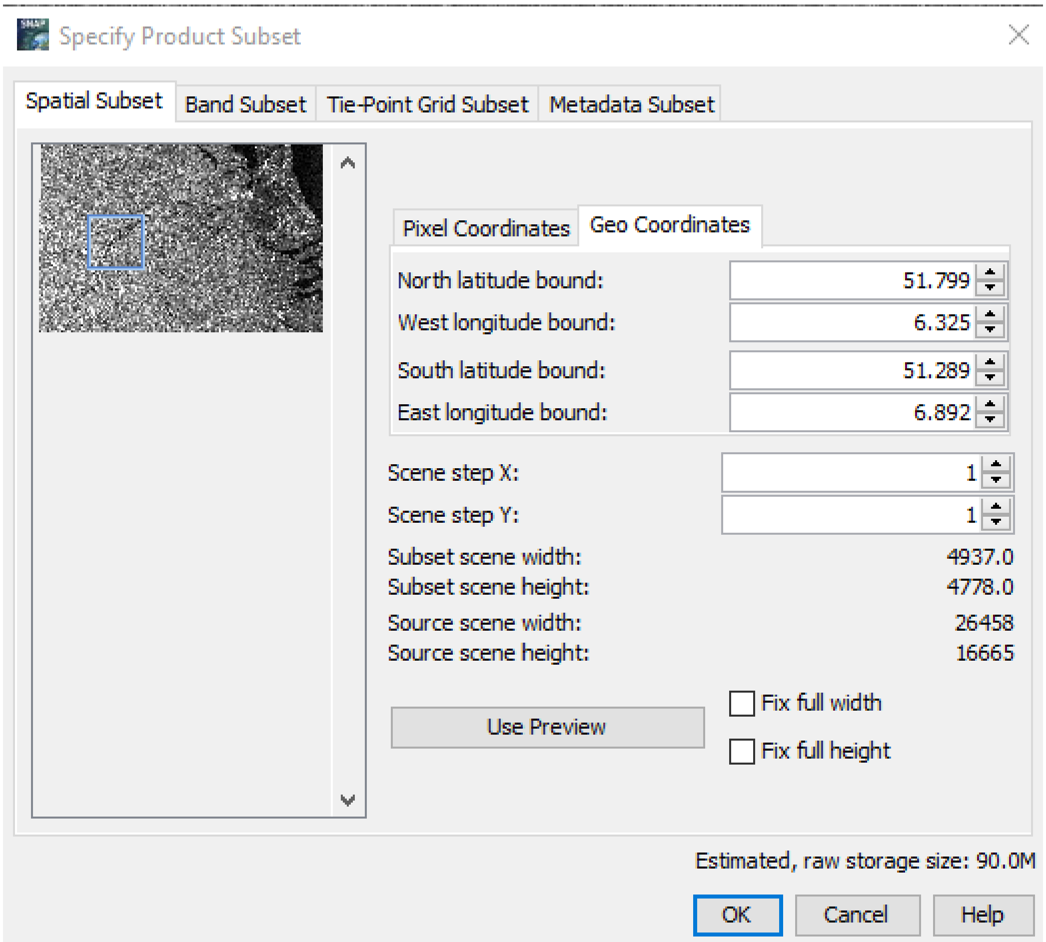


Figure 5. Subset using Geo Coordinates in the SNAP Toolbox

4. Calibration

Radiometric calibration is done to convert the pixel values from simple digital numbers to a physical quantity that is the backscatter in this context. To do this, go to “**Radar**” Menu -> “**Radiometric**” -> “**Calibrate**”.

Now, select the input image (this subset image) in the “I/O Parameters” Tab. Here, the name of the Output can be defined as well and can be changed as you prefer, but better to keep it as default. In the “Processing Parameter” tab the polarisation to calibrate can be selected (if not all of them want to be calibrated, keep them unselected as we want to use both VH and VV for this exercise). Different types/outputs of the calibration can be selected. By default, Sigma0 is selected and it is also what you need to use for this exercise (**Figure 6**).

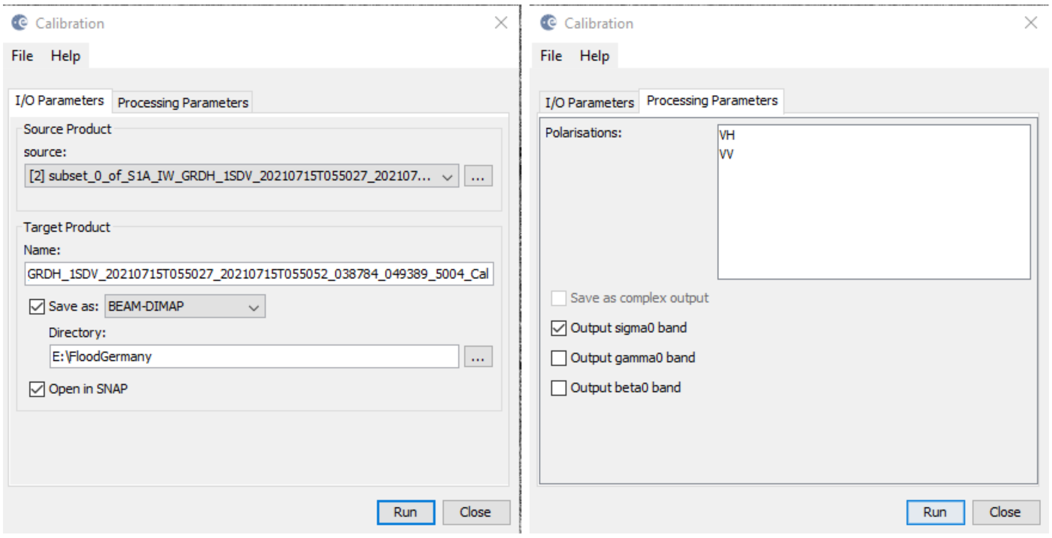


Figure 6. Radiometric calibration in the SNAP Toolbox

5. Speckle Filtering

As you can see there are speckles in radar images. After radiometric calibration, speckle filtering can be performed. To do this: "**Radar**" menu -> "**Speckle Filtering**" -> "**Single Product Speckle Filter**".

On the "I/O Parameter" tab, the input image to use is the one obtained **after** the calibration, and the name for the Output file can be defined (**Figure 7**). On the "Processing Parameter" tab, there is a list of different filters to use. In this case, the Lee Filter is selected with a Filter window size 7 by 7 for X and Y.

After performing the Speckle Filtering, a new file will be added automatically. Make a comparison of the calibrated image and the image after speckle filtering, the later image is cleaner/smoother but note the spatial resolution is degraded (coarser).

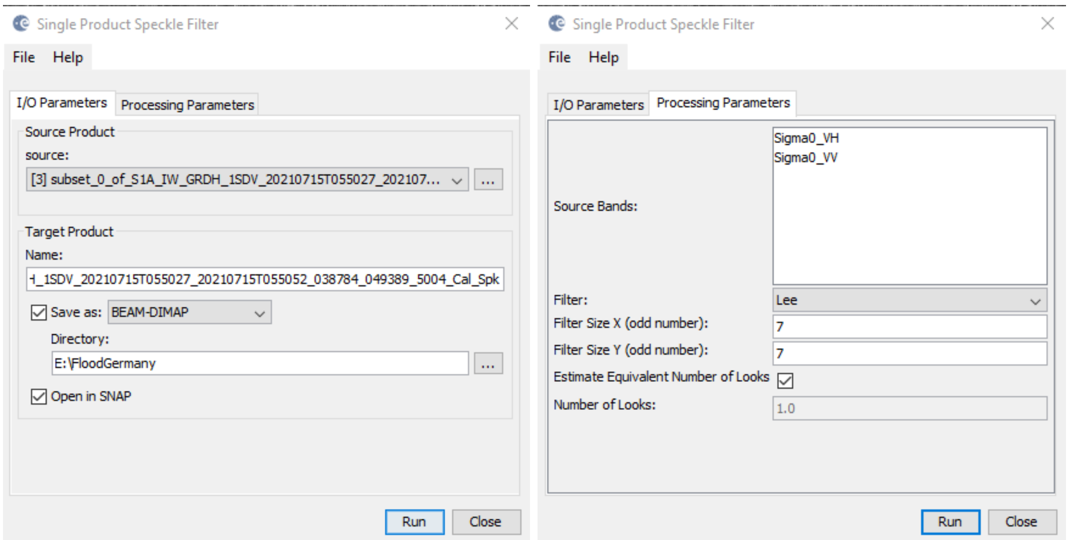


Figure 7. Speckle Filtering in the SNAP Toolbox

6. Terrain Correction

In order to use the image on a map, a geometry correction needs to be done to project the image into a map system taking into account the terrain, especially if there is a mountain area. To do this: “**Radar**” menu -> “**Geometric**” -> “**Terrain Correction**” -> “**Range-Doppler Terrain Correction**”.

On the “I/O Parameter” tab, the input image is going to be the image obtained from the Speckle Filtering process and the name of the output file can be defined. On the “Processing Parameter” tab the Digital Elevation Model defined by default is the SRTM 3Sec (Auto Download) which is automatically downloaded for the area of the image but if there is another source for the DTM information, here can be selected to do the correction. Here, by default, the map projection selected is the WGS84 (DD), but depending on the case, this can be changed as well. For this exercise, the values defined by default are used for the correction (**Figure 8**))

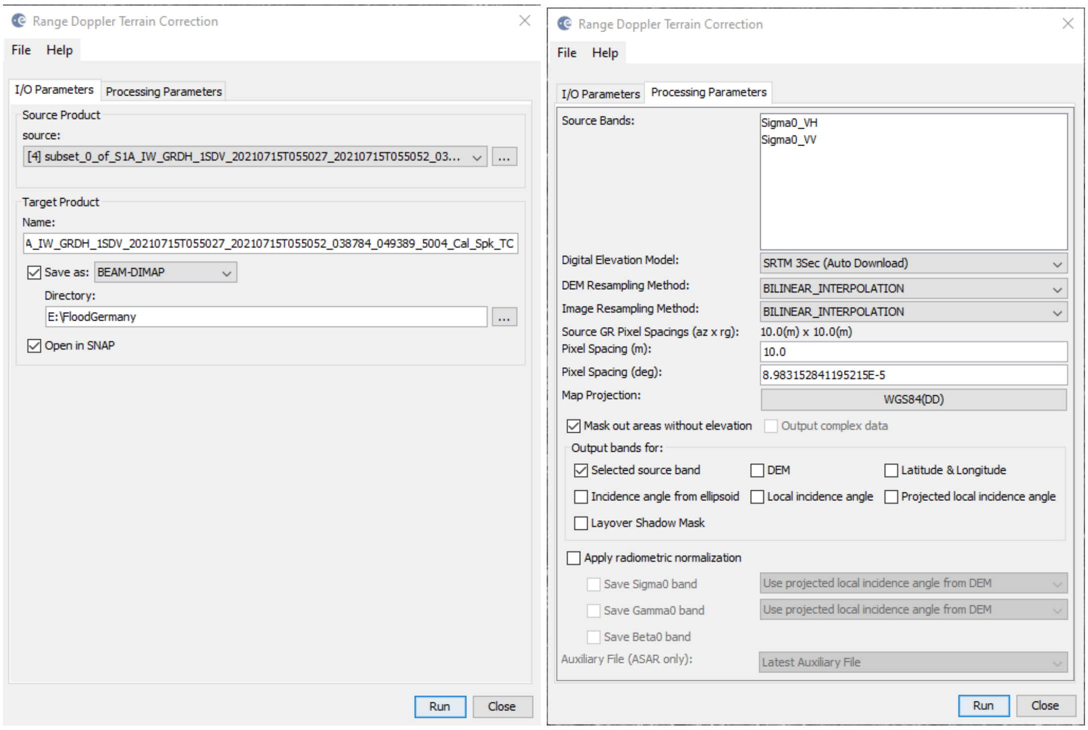


Figure 8. Speckle Filtering in the SNAP Toolbox

7. Separating water from non-water using a threshold

The histogram of the backscatter of the image gives information of interest. In SNAP, the histogram can be seen by selecting the tab “**Colour Manipulation**” located next to the “Navigation” tab at the bottom left panel. In general, it is easy to work with images in dB format rather than in a linear format because usually, the difference between low and high backscatter wants to be seen. So, to have a better visualisation of them, a conversion to a logarithmic scale can be made by right-clicking on the band and select the option “**Linear to/from dB**”. With this, you will see that the new histogram is clearer than the one obtained previously.

Once the histograms from the images are obtained, in general we will see something similar like the following **Figure 9**; There are generally two peaks (in our case, the area of waterbody is quite small and thus less number of dark pixels. If you make a subset with the waterbody accounting for the majority, then the two peaks in the histogram will be more evident). One more to the left associated with an area of low backscatter pixels and another more to the right with higher backscatter pixels. **This is because generally the water surfaces lead to specular reflections and thus low backscatter values, while high values correspond to diffuse reflection from non-water class.** Thus we can use a certain threshold based on the histogram to make a separation between water and non-water areas; that is the way we can extract the water surfaces.

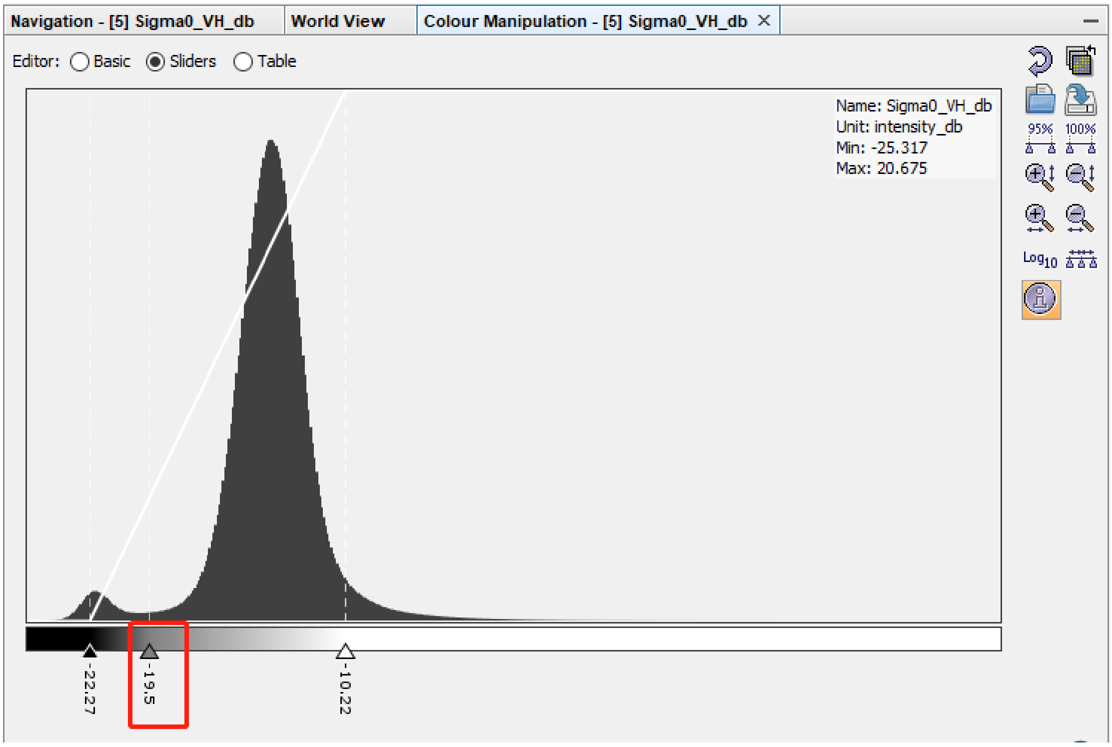


Figure 9. Histogram of the Sigma0 of a SAR image from SNAP Toolbox

To make the separation easier to perform, we can apply **Band Maths** to assign different values to water surfaces and non-water surfaces. In SNAP, go to "**Raster**" menu, and then "**Band Maths**". On this window, as shown in **Figure 10**, type the name (e.g. **Water**) for the new band/image. Then click **Edit Expression** to write the mathematical and logical operation there. For example, we can write *"1 * (Sigma0_VH_db < -19.5)"* to generate a new image. On the new image, all pixels with Sigma0_VV less than the defined threshold will be assigned as the value of 1 (water surfaces), and other pixels as the value of 0 (non-water surfaces). The extracted water surfaces image is shown in **Figure 11**.

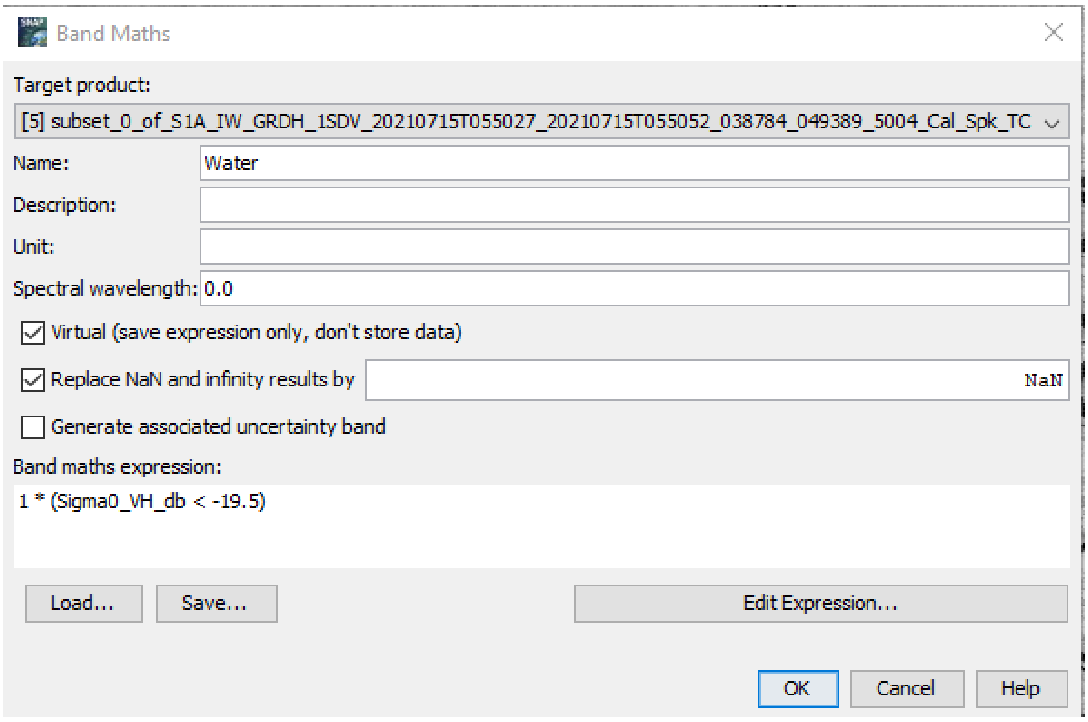


Figure 10. Example of extracted water surfaces after Band Maths with SNAP toolbox

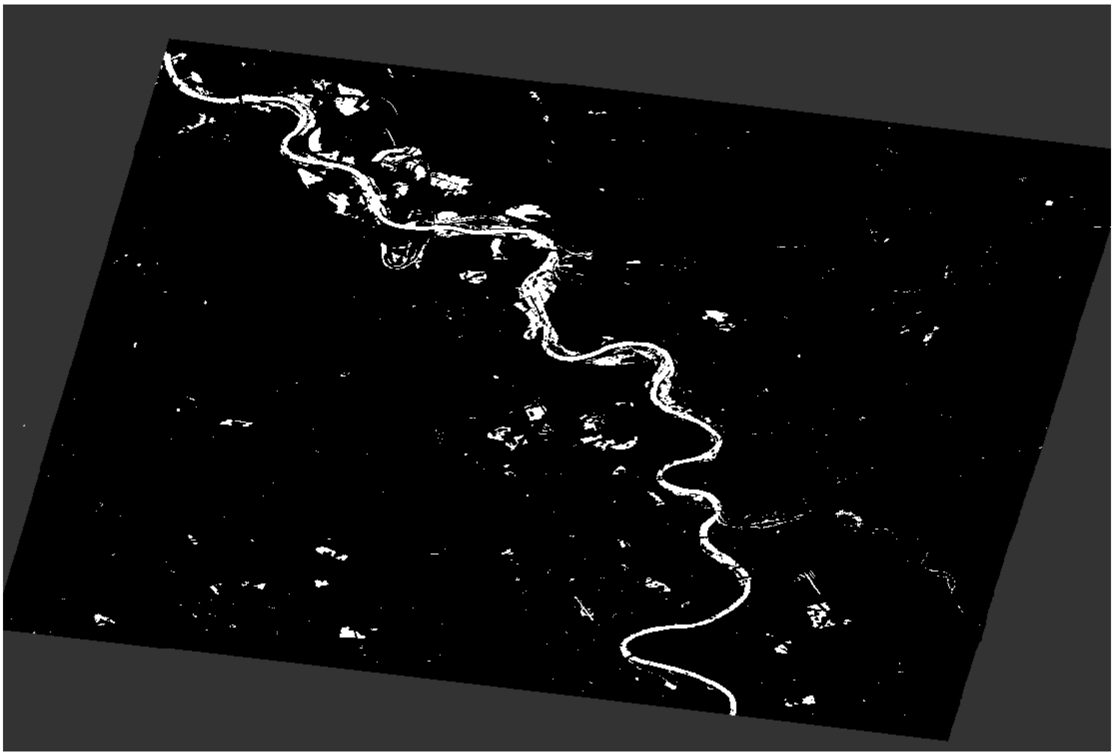


Figure 11. Example of extracted water surfaces after Band Maths with SNAP toolbox

8. Saving extracted waterbody as GeoTIFF

Most likely you would like to save processed data (particularly the water surfaces image) to the local hard disk. It is also better to save the image in the standard format as GeoTIFF because it can be easily read in QGIS to overlay with global map or satellite images for visualization and further processing.

To save selected bands/images at different format, go to SNAP menu “**Raster**”, then “**Band Extractor**” . The following window as shown in Figure 8 will pop up. On this window under the tab “I/O Parameters”, there are lots of different formats to select for the Save as (now the Geotiff is selected). Under the tab “Processing parameters”, certain single band or several bands can be selected. In this case, select the **Water** band. Here you can also rename the output file to ‘subset_S1A_20210715_Water’ (Figure 12).

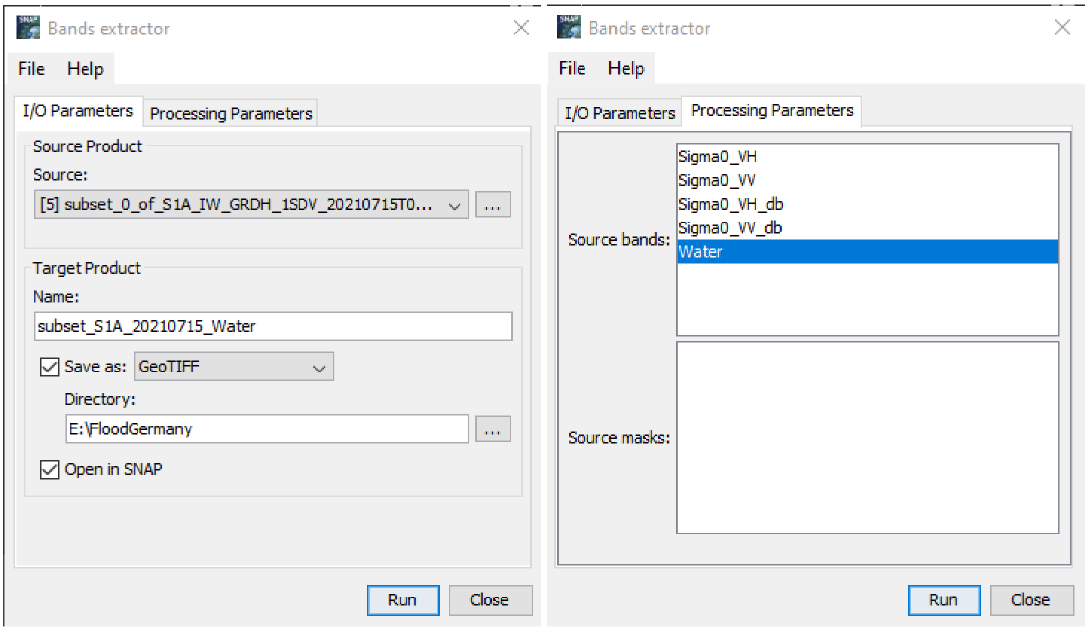
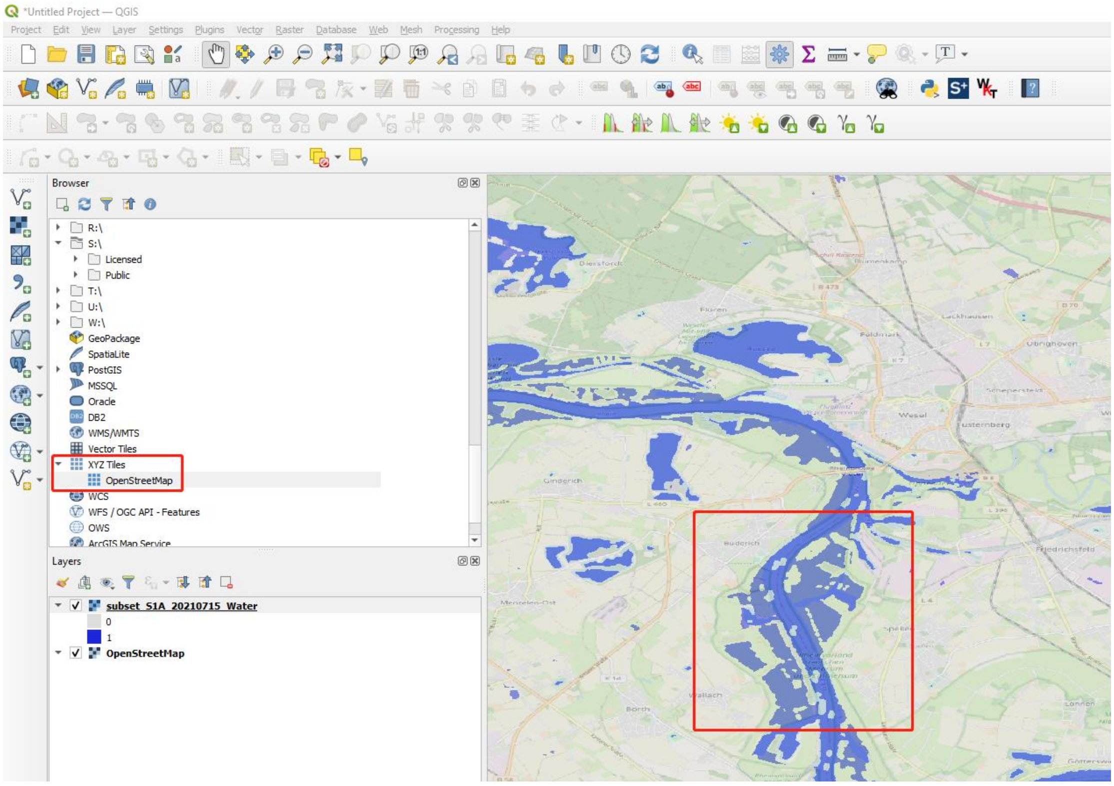


Figure 12 Example of extracted water surfaces after Band Maths with SNAP toolbox

9. Displaying extract flooded area in QGIS

Now open QGIS and load the ‘subset_S1A_20210715_Water’ GeoTIFF file from last step. Right click the file and select Properties, then adjust Symbology to show different colors for pixel value 0 and pixel value 1 (Water). On the Propoerties setting, we can also set transparency to 30-50% in order to see better when overlaying OpenStreetMap.

Now go to QGIS main menu **View → Panels** to check **Brower.** Scroll down on the **Browser** panel to find **XYZ Tiles** and then click **OpenStreetMap. The OpenStreetMap** will be loaded (Figure 13). Now we can look at which area is flooded. Check the river and some areas along the river were flooded (Figure 13). Such information can help us to make rescue plans after the flood events.



Online activities

Description of activities for distance learning in home-schooling

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References (if any):

Assessment (if any):

Not necessary