Flood mapping tutorial

When doing flood mapping, consider the type of SAR imagery that you use:

- C band is preferable to X or L band, as the difference in backscatter between land and water surface is higher in windy conditions
- In heavily forested areas, L (23 cm) band can penetrate the forest canopy – very effective.
- For polarisation, HH polarization is the best to use for flood mapping, as this again heightens the contrast between the land and water surfaces. This is caused by a low scattering of the horizontal component of the signal from the smooth water surface.
- An increase in surface roughness decreases your ability to discriminate between water and land more when using VV than using HH, but both still work.
- Always be mindful that some land surfaces will have a similar backscatter to water. Water-lookalike surfaces such as smooth natural surfaces like sand, bare ground, streets, or radar shadowing effects behind vertical objects like buildings and topography.
- SAR is great for detecting flooding beneath vegetation. The multiple bounce effect causes an increase in backscatter from the water surface and flooded vegetation (corner reflection, like on buildings), which is reduced on dry ground.
    - Note the opposite effect when compared to flooding on bare soil.
- For these reasons, polarimetric SAR imagery (dual or quad pol) is more accurate than single pol at separating flooded and non-flooded areas since they interact with various surfaces in different ways (HH, VV, HV, VH). Combining them is the most effective way of mapping flooding but it is not always necessary.

Your options for detecting flood using SAR data can involve:

- Visual image interpretation (manual),
- Thresholding,
    - Empirical or automatic
- Change detection procedures using multitemporal SAR data, including interferometry.
- Contextual classifiers like object or texture-based approaches,
    - As opposed to traditional pixel-based detection.
- IActive contour models
- Integration of ancillary data: DEMs, slope information, topographical maps, land cover maps

Often you combine several methods to improve flood mask extraction.

Flood mapping using radar imagery:

- Using SNAP and the **Alaska Data Search Vertex**
- Download the following images using https://search.asf.alaska.edu/
        - For easy download, use Google Chrome, and make sure to sign-in to the site. This way you can directly download images to your computer.
    - Data: Sentinel-1A IW GRDH 1SSV:
- S1A_IW_GRDH_1SSV_20150320T114745_20150320T114810_005115_0066FA_82D7
- S1A_IW_GRDH_1SSV_20150904T114747_20150904T114812_007565_00A772_B9FD
    - Change the search type to 'List search' and copy in the two scene names.
    - You can click on the scenes to preview, click on the little shopping cart to add to cart, then click the 'Downloads' cart in the top right corner, click Data download in the bottom of the 'Downloads' window, and select 'Download all'.
    - Don't unzip them, SNAP is designed to read the files as is.
- Open **SNAP**
    - To download SNAP Desktop: https://step.esa.int/main/download/snap-download/
    - Open the two S1 images:
        - Click 'File', → 'Open Product' (hold down control to select multiple files'
        - Or drag and drop the two zipped folders (each containing one S1 scene) into the product list.
        - Rename the images (right click and select 'properties') to shorten them. Delete everything after the date (after 20150320, for example).
    - Inspect the images.
        - Select the little plus icon next to the file name, expand the 'Bands' folder and double click on Amplitude.
        - Do this for both images, and place them next to each other in the viewing window.
        - Synchronise the display:
            - In the 'Navigation menu' click the button called 'Synchronise views across multiple image windows'
                - This syncs the images based on the geographic location.
        - On which image can you see the flood?
        - Where were the images acquired? And how can we see that exactly?
            - Hint: Check the Metadata for each image
        - Where in the world is this flood?
            - Hint: In the 'Navigation box' (lower left part of SNAP', click 'World View'
        - What else do we see in the images?
            - any radar image distortions?
                - Layover, foreshortening, shadows
        - From which angle was the photo taken?
    - Crop the images:
        - Display the images in full again (in the same window, so you only see one at a time), an, while 'synchronize views' is still active, move and zoom the

viewer around so only the image is visible (no grey background) in both instances.

        - Then click on the 'Raster' menu at the top, → 'Subset', and → 'OK' to create a subset.
            - It will subset the image you have selected in the viewer. Now do the same for the other one.
            - Close both images and open your new subsets in the product list.
    - Multi-look the images by 3x3
        - Click 'Radar' → 'SAR Utilities' → 'Multilooking'.
        - In this menu, click "Processing Parameters", select both bands and change "Number of Range Looks" and "Number of Azimuth Looks" both to 3.
        - Keep all other options default.
        - Select "Run"
        - What does multi-looking do?
            - Reduces speckle = noise in the image
    - Calibrate images:
        - Click 'Radar' → 'Radiometric', and 'calibrate.
        - Keep all options default.
        - What does calibration do?
            - Changes the amplitude to a standard backscatter value, through radiometric correction.
            - Before this we can only do a visual comparison, now we can do a quantitative comparison too.
            - Produces a sigma nought image.
    - Terrain-correct the images:
        - 'Radar' → 'geometric' → 'terrain correction' → 'Range-Doppler Terrain Correction'
        - For one of the images, select 'DEM' as well under 'Output bands for'.
        - Keep all other options default. This DEM is important later.
        - What does terrain correction do?
            - It corrects distances and fits it to a DEM, thereby considering the local variations in geometry (i.e., terrain height). The automatic DEM that is used, the STRM, only covers +- 60 degrees latitude. You will therefore need to use a different DEM outside of this range.
    - Stack terrain corrected images
        - 'Radar' → 'Coregistration' → 'stack tools' → 'Create stack'.
        - In the first tab (1-ProcuctSet-Reader) use the plus icons to insert the terrain corrected images to the list.
        - In the second tab (2-CreateStack) select "Product Geolocation" as the "Initial Offset Method".
        - In the third tab (3-Write) select the output name and directory. Then select "Run".
    - Convert bands to decibel.
        - In the "Product Explorer" window, right click on the band name, and select "Linear to/from dB".
        - Now right click on the new dB band and select "Convert Band".
        - Save the images to keep the changes.

        - You can check the 'colour manipulation' tab for both bands to see how we are fitting the image to a bell curve.
        - Delete the other two (old) bands.
    - Check the coregistration
        - Check that the images line up correctly and look similar by opening and viewing the bands.
        - One way to do this:
            - Click 'Layer' → 'layer manager'. (on the very right of the screen)
            - Click on the round 'plus' icon to add a layer.
            - Select 'image of band/tie-point grid'.
            - Select 'next' and select one of the other bands from the stack, repeating the steps above for the third band.
            - In the 'Layer Manager' window, select and deselect the check boxes of the three bands to compare the flood image with the before image, and the DEM.
        - Or just open the bands as you did before and switch between them.
    - Create an RGB composite:
        - Right click on the stacked image in the product explorer window and select 'Open RGB Image Window'.
        - Select the 20th of March image (the 'before') as 'Red', and September 4th as both 'green' and 'blue'.
        - Click 'OK'
        - Click on 'colour manipulation' in the 'Navigation' menu and stretch the histograms until the image is as clear as possible.
        - What can you see on the image?
            - What does each colour represent?
            - Why is the flood area red, when we chose the 'before' image as red?
    - Calculate the size of the flooded area:
        - Find the values for the flooded pixels:
            - Select the flood band in the stacked image and double click to view it.
            - In the navigation tab, press 'colour manipulation' and choose the 'sliders' editor.
                - Make sure 'Expand and shrink horizontally' is not enabled (the little magnifying glass).
            - Move around the arrows to manipulate the view, to get an understanding of what the histogram shows us.
            - What does this histogram show? Which part of the histogram is the flooded pixels?
                - The small peak
            - Read the value from the arrow, as your max value for flooded pixels.
            - Alternatively, choose the band and, at the top of the screen click 'Analysis' → 'Histogram'
            - You can now see the value distribution of the flood image in a more readable format to get the right value.
            - If you cant see the whole histogram, press the 'Zoom all' button at the button of the viewer.

- Create a flood mask layer:
  - Click ‘Raster’ → ‘Band maths…’
  - Make sure the right layer is chosen
  - And give it an appropriate name (like floodmask)
  - Click ‘Edit Expression’
  - In the expression tab, write:
    - If (*flood band)* < (*upper value you chose from the histogram*) then 1 else NaN
  - And click ‘OK’. Click OK again to create your flood mask band.
- Calculate extend of flooding:
  - Select your flood mask layer. Click ‘Analysis’ → ‘Statistics’
  - Read the number of pixels in the image (only ones with non NaN values are counted).
  - From this pixel value, calculate the size of the flood.
    - Each pixel is $10m^2$
  - How do we convert this to km^2?
    - /100 to get the values in m^2 and then divide by 1,000,000 to get it in km^2
    - Also known as dividing your pixel value by 10,000
- Create a flood mask layer for the ‘before’ image using them same method, using the same threshold value, then read the pixel value, and calculate the size of the river before. Calculate the difference = size of affected area.

- If you want to export a layer and view it somewhere else, like QGIS or Google Earth. Click ‘File’ → ‘Export’.
  - It exports the current layer you are viewing.
  - For Google Earth: → ‘Other’ → ‘View as Google Earth KMZ’
  - For QGIS: → ‘GeoTIFF/Big TIFF’

Flood mapping using optical imagery:

- Using EO Browser and QGIS:
- ## EO Browser steps:
    - https://apps.sentinel-hub.com/eo-browser/
    - Log in (top of the page), to be able to export imagery from the platform.
    - In the search bar (top of the page) search for Agh-Ghala, Iran
    - On the Discover page, make sure 'Sentinel-2' is the checked data source (specifically L2A data)
        - And set the time range from the start to end of April 2019
    - Press search and look through the list of images. Click on one of the images of 2019-04-05 to display the data for that day (it mosaics images from the same day together, so they all show the same thing)
        - Here is a link directly, just in case: EO Browser 2019-04-05 Link
    - Now you see the flood which struck this town, as EO Browser will have moved from 'Discover' to 'Visualise'.
    - Play around with the visualisation options for a bit and get a sense of what you can see and do in EO-Browser.
    - Click on the 'Download Image' button the right of the screen, to export imagery (clipped to the extent visible and the data source you chose (Sentinel-2)).
        - Click 'Analytical':
            - Image format: TIFF (8-bit is fine)
            - Image resolution: HIGH
            - Coordinate system: Popular Web Mercator
                - It is important that we download the data in a coordinate system that uses metres instead of lat and long, for easier calculations later.
            - Layers:
                - We only want to export raw layers. This means that we export data with the original pixel values, instead of a colour visualisation where the band data is lost in favour of RBG information.
                - Export layers B02, B03, B04, B08, B11
- ## QGIS steps:
    - To download QGIS: https://qgis.org/en/site/forusers/download.html
- Open up QGIS, open a new project, take the unzipped downloaded folder, and drag it into the QGIS window to add all the bands.
- Change name of bands to something appropriate (red/band 4/etc.)
- Change the image extent, if needed
- Create RGB composites:
    - Raster tab at the top → miscellaneous → build virtual raster
        - Choose the appropriate input layers.
        - Check 'Place each input file into a separate band'.
        - Click Run
    - True colour (4,3,2)
    - False colour (8,4,3)

- Create band indices:
    - Raster tab at the top → Raster calculator
        - Choose where to save “output layer”.
        - Write in Raster calculator expression.
    - NDVI:
        - (B8 – B4)/(B8 + B4)
        - Double click on the band gradient or name of the band (or right click and choose ‘Properties’). Make sure you are in the “Symbology menu” → set ‘Render type’ to ‘singleband grey’ or ‘..pseudocolour’.
                - Set the min and max to -1 and +1 (since these are the limits of a normalised difference index)
            - Why would we use NDVI?
            - It is a vegetation index – is it appropriate for flood mapping?
    - Modified NDVI:
        - (B3 – B11)/(B3 + B11)
        - Double click on the band gradient. Make sure you are in the “Symbology menu” → set ‘Render type’ to ‘singleband grey’ or ‘pseudocolour’.
                - Set the min and max to -1 and +1 (since these are the limits of a normalised difference index)
            - Why are we using these bands? And why is it better than NDVI? Compare the NDVI and MNDVI and tell us what you can see.
                - The NDVI shows high values for vegetation, low values (around 0) for urban or bare ground, and negative values for water bodies. With areas that are partially flooded, or areas with flooded vegetation, it can be difficult to distinguish between flooding and urban areas.
                - The MNDVI is better for water bodies (flooding), since water bodies have high index values and both urban and vegetation have low index values.
                    - Water absorbs SWIR, while both urban and vegetation emits SWIR.
            - What else is this band index good for?
                - Snow mapping, which also does not emit SWIR radiation but reflects visible light. As opposed to clouds, which reflect both.
- Create a threshold map using the MNDVI:
    - Let’s first make sure we choose the right threshold:
        - Double click on the band gradient again.
        - Set the band minimum to what you think the minimum could be for the flooded areas.
            - Hint: use the ‘Identify Features’ function (Ctrl + shift + i) and click on different places on your map to get a sense of what values are where.
        - Set the maximum to 1.
        - Set the ‘Contrast Enhancement’ to ‘Clip to MinMax’ to hide other pixels from your map.
        - And display it over your true colour map, to see your chosen flood extent.

        - Play around with different minimum values until you are satisfied with the extent.
    - Now we will remove the hidden values from the layer (You may wish to save your layer as a separate file before doing this)
        - To save a layer: Right click the layer, click ‘export’, and then ‘Save As’
    - Click on the ‘processing’ tab at the top of the screen → ‘processing toolbox’ → ‘raster analysis’ → ‘reclassify by table’.
        - Make sure the correct raster layer is chosen (MNDVI)
        - Click on the little menu next to ‘reclassification table’.
            - Add a row, type in your desired minimum and maximum, and a value for all pixels to contain (like 1).
            - Add another row, where min = -1 and max is your flood minimum. And set the value for this to -9999 (the standard nodata value in QGIS).
            - Click ‘OK’ and then ‘Run’.
    - Now we have a layer with only pixels over the flooded area.
- Convert to vector and calculate flooded area:
    - At the top of QGIS, click ‘Raster’ → ‘Conversion’ → ‘Polygonise (Raster to vector)
        - (You may have to save your reclassified raster layer as a file for this step to work)
    - You can find this in two ways:
        - Click on ‘View’ at the top → ‘Panels’ → check ‘Statistics’.
        - In the ‘Processing Toolbox’ → ‘Vector table’ → ‘Field calculator’
    - Make sure you have your vector layer chosen and in the field below/the expression box type in “sum($area)
        - The resulting number is very large. What is the unit of the number you get?
            - And how do we convert it into something more readable.
            - Answer: m^2, and to convert it we divide by 1,000,000 to get km^2
- TO find the size of each individual polygon in the layer instead of the total layer, use ‘Vector’ at the top → ‘geometry tools’ → ‘add geometry attributes’, and then choosing the desired vector layer.
- The answer you get will depend on the size of the area you choose to calculate it for.
    - Use ‘Clip Vector by extent’ in the Processing Toolbox to change the size of the layer, if needed.
- If you want, you can go back to EO Browser and download images of the area on a different day. That way you can do the same analysis again and calculate the difference in water bodies to get the true size of the flood.