National Aeronautics and Space Administration

SAR Application for Mapping the Kerala Floods

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Objectives

By the end of this exercise, you will:

- Know where to access SAR data
- Know how to use the Sentinel-1 Toolbox to process SAR data
- Be able to generate a flooding classification from a SAR image
- Be able to use Google Earth Engine to generate flood classifications from SAR images

Requirements

- Sentinel Toolbox installed in your computer
  - http://step.esa.int/main/download/

Note

This is a three-part exercise:

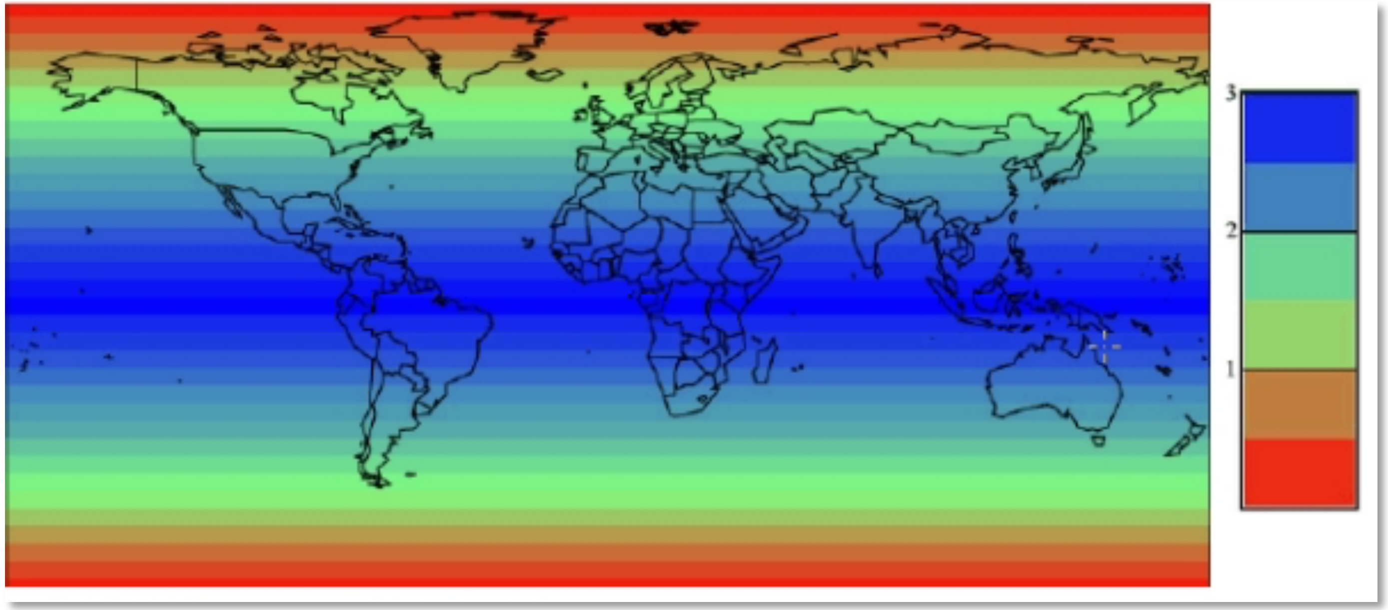
- Part 1 will focus on access and processing of Sentinel-1 SAR data
- Part 2 will focus on generating a flood classification using SNAP
- Part 3 will focus on generating a flood classification using Google Earth Engine

Part 1: Outline

- Download Sentinel-1 images through the Alaska Satellite Facility website
- Subset the image
- Perform radiometetric correction
- Apply a speckle filter
- Perform geometric correction

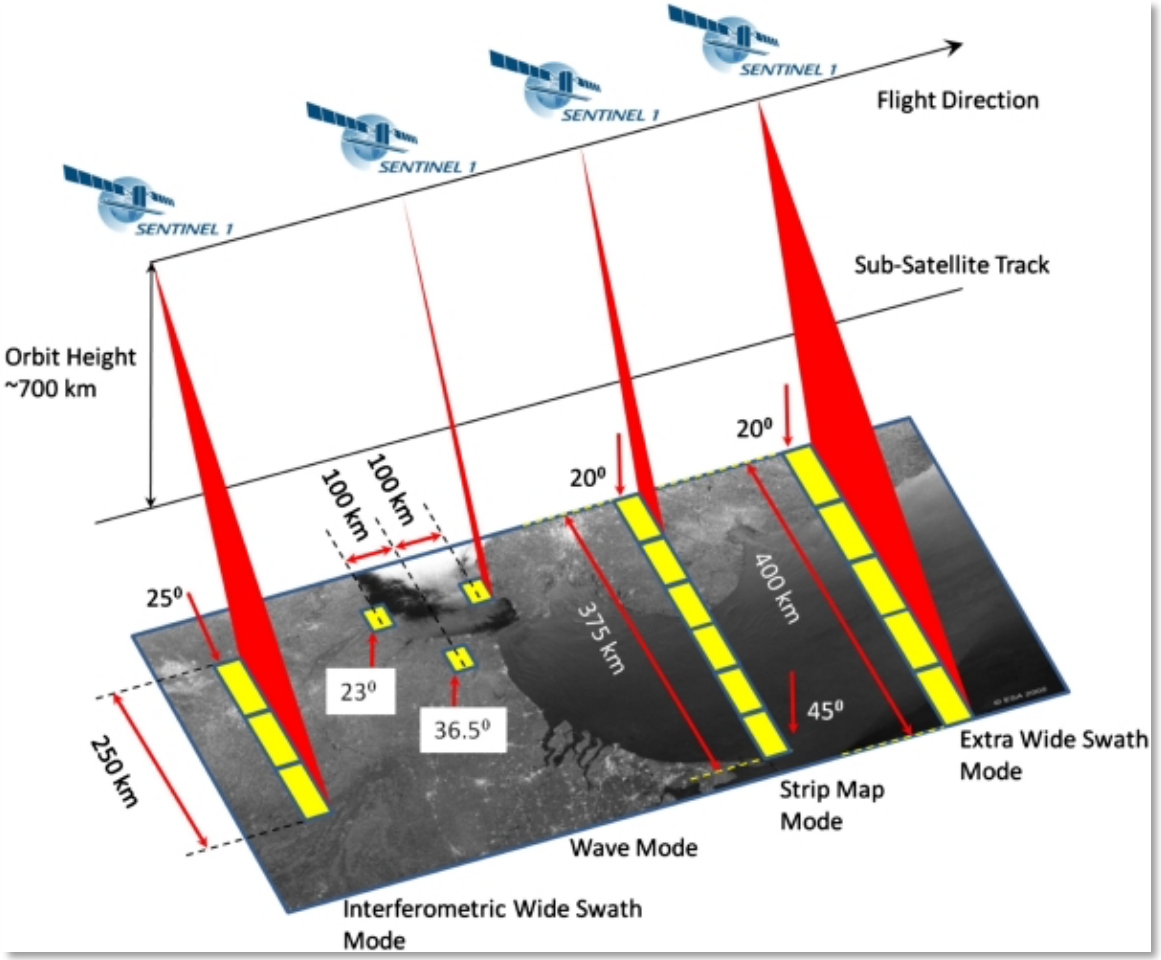
Sentinel-1 Coverage

- Sentinel-1
  - Two satellites: A & B
  - Each satellite has global coverage every 12 days
  - Global coverage of 6 days over the equator when using data from both satellites



Sentinel-1: Modes of Aquisition

1. Extra Wide Swath – for monitoring oceans and coasts
2. Strip Mode – by special order only and intended for special needs
3. Wave Mode – routine collection for the ocean
4. Interferometric Wide Swath – routine collection for land



How to Access Sentinel-1 Images

- Alaska SAR Facility
  - http://www.asf.alaska.edu/sentinel/
- European Space Agency Portal
  - http://sentinel.esa.int/web/sentinel-data-access/access-to-sentinel-data/

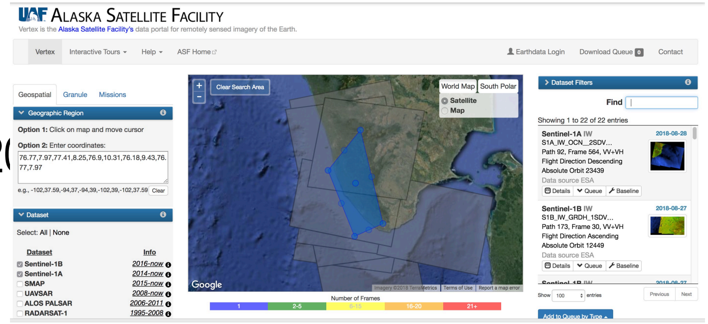
Sentinel-1 Toolbox

- An open source software developed by ESA for processing and analyzing radar images from different satellites
- Includes the following tools
  - Calibration
  - Speckle noise
  - Terrain correction
  - Mosaic production
  - Polarimetry
  - Interferometry
  - Classification

Accessing, Opening and Displaying SAR Data

Accessing Sentinel-1 Data

1. Go to the Alaska Satellite Facility Sentinel Data Portal: https://vertex.daac.asf.alaska.edu/
2. Identify your area (76.77,7.97,77.41,8.25,76.9,10.31,76.18,9.43,76.77,7.97)
3. Identify images of interest (Sentinel-1 A/B)
4. Click on “Optional Search Criteria” and specify July 1, 2018-Aug. 30, 2



5. Click on “Search” at the bottom of the page
6. Select granule S1A_IW_GRDH_1SDV_20180704T004106_20180704T004131_022637_0273E1_B4B0 from Jul. 4, 2018. Path 165 Frame 563. This image represents conditions before the flood.
7. Download the L1 Detected High-Res Dual-Pol (GRD-HD) Product
8. Select granule S1A_IW_GRDH_1SDV_20180821T004109_20180821T004134_023337_0289D5_B2B2 from Aug. 21, 2018. Path 165 Frame 563. This image represents conditions after the flood.
9. Download the L1 Detected High-Res Dual-Pol (GRD-HD) Product

Accessing Sentinel-1 Data

Granule Information

Data courtesy of ESA

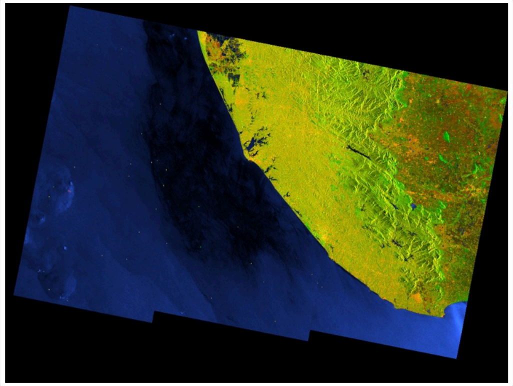
Dataset: Sentinel-1A
Granule: S1A_IW_GRDH_1SDV_20180704T004106_20180704T004131_022637_0273E1_B4B0

Granule Details

- Acquisition Date: 2018-07-04
- Beam mode: IW
- Path: 165
- Frame: 563
- Ascending/Descending: Descending
- Polarization: VV+VH
- Absolute Orbit: 22637
- Frequency: C-Band

Accessing this data requires you to log in. Some datasets also require a proposal, or agreement with a EULA which is presented after log in

Products	Download
L1 Detected High-Res Dual-Pol (GRD-HD) (821.96 MB)	Queue / Download
L2 Ocean (OCN) (5.70 MB)	Queue / Download
L1 Single Look Complex (SLC) (3.49 GB)	Queue / Download



Full Resolution Browse Image

Granule Information

Data courtesy of ESA

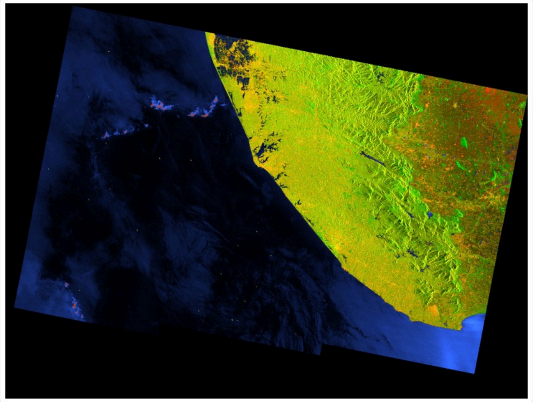
Dataset: Sentinel-1A
Granule: S1A_IW_GRDH_1SDV_20180821T004109_20180821T004134_023337_0289D5_B2B2

Granule Details

- Acquisition Date: 2018-08-21
- Beam mode: IW
- Path: 165
- Frame: 563
- Ascending/Descending: Descending
- Polarization: VV+VH
- Absolute Orbit: 23337
- Frequency: C-Band

Accessing this data requires you to log in. Some datasets also require a proposal, or agreement with a EULA which is presented after log in

Products	Download
L1 Detected High-Res Dual-Pol (GRD-HD) (812.43 MB)	Queue / Download
L2 Ocean (OCN) (5.69 MB)	Queue / Download
L1 Single Look Complex (SLC) (3.43 GB)	Queue



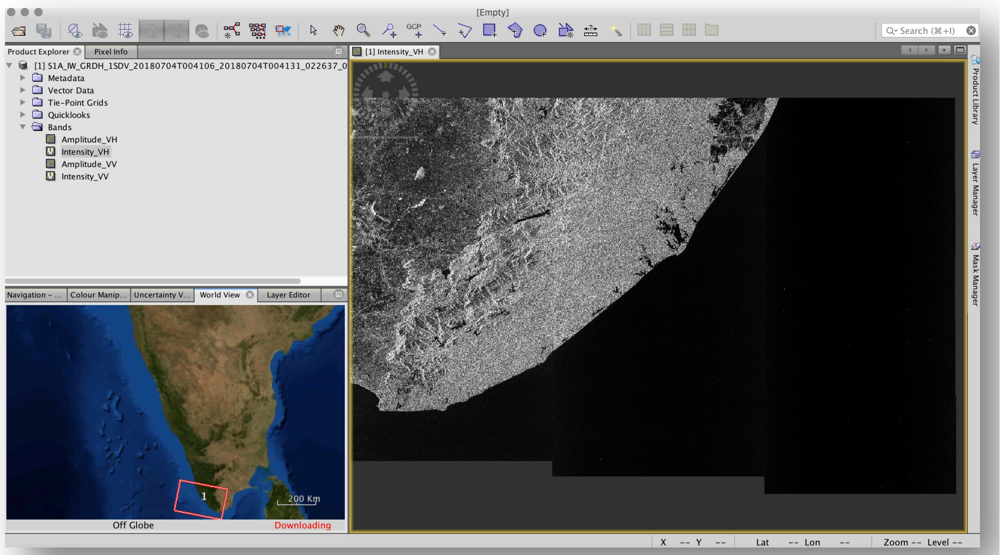
Full Resolution Browse Image

Opening the Data with the Sentinel Toolbox

1. Initiate the Sentinel Toolbox by clicking on its desktop icon
2. In the Sentinel Toolbox interface, go to the **File** menu and select **Open Product**
3. Select the folder containing your Sentinel-1 file, and double click on the **.zip** file (do not unzip the file; the program will do it for you). Open the second file

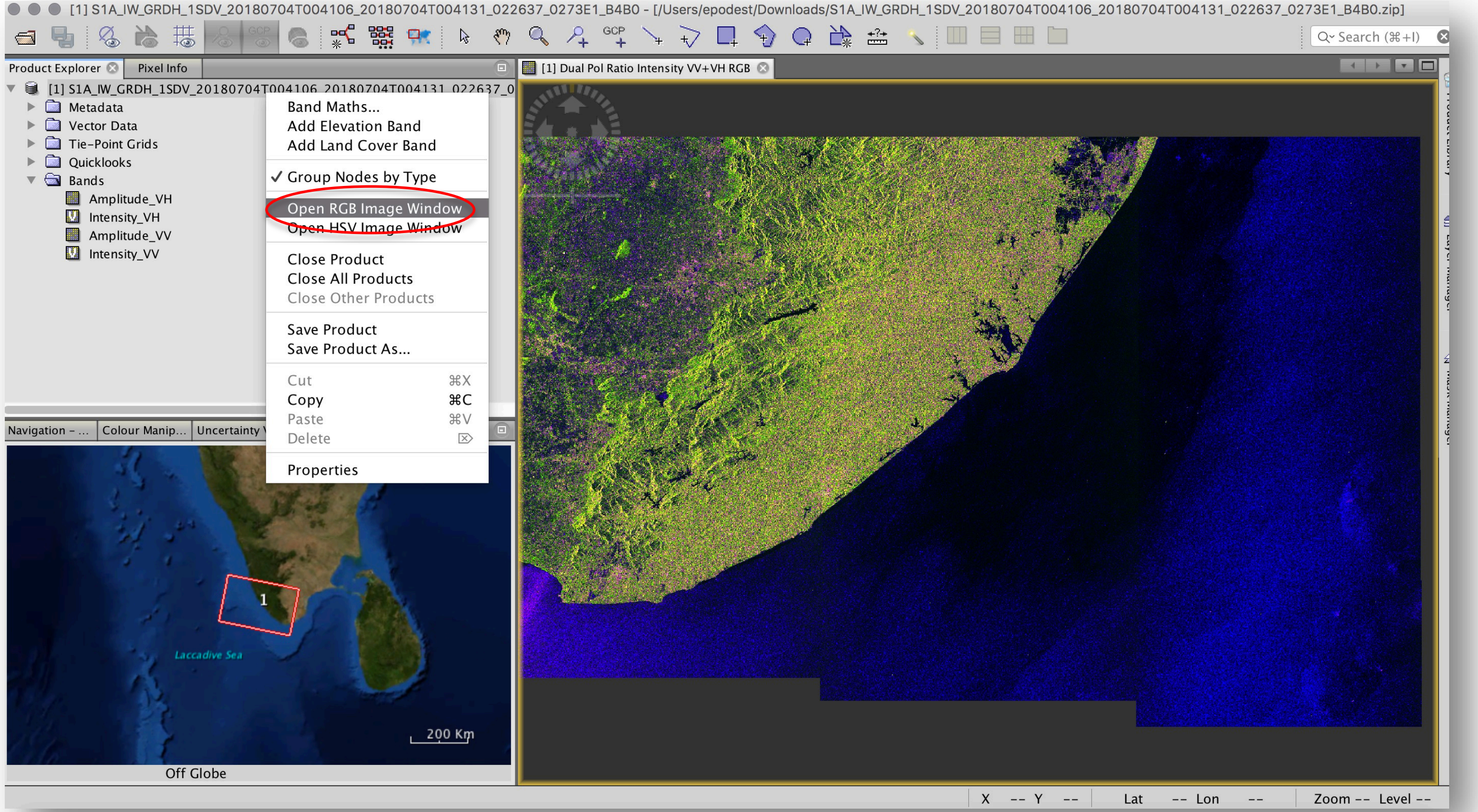
Opening the Data with the Sentinel Toolbox

4. The Product Explorer window of the Sentinel Toolbox contains your file. Double click on the file to view the directories within the file, which contain information relevant to the image, including:
    - Metadata: parameters related to orbit and data
    - Tie Point Grids: interpolation of latitude/longitude, incidence angle, etc.
    - Bands: intensity and amplitude (intensity is the amplitude squared)
5. The Worldview window (lower left) shows the footprint of the image selected. Note that it is inverted because it is oriented in the same way it was acquired.



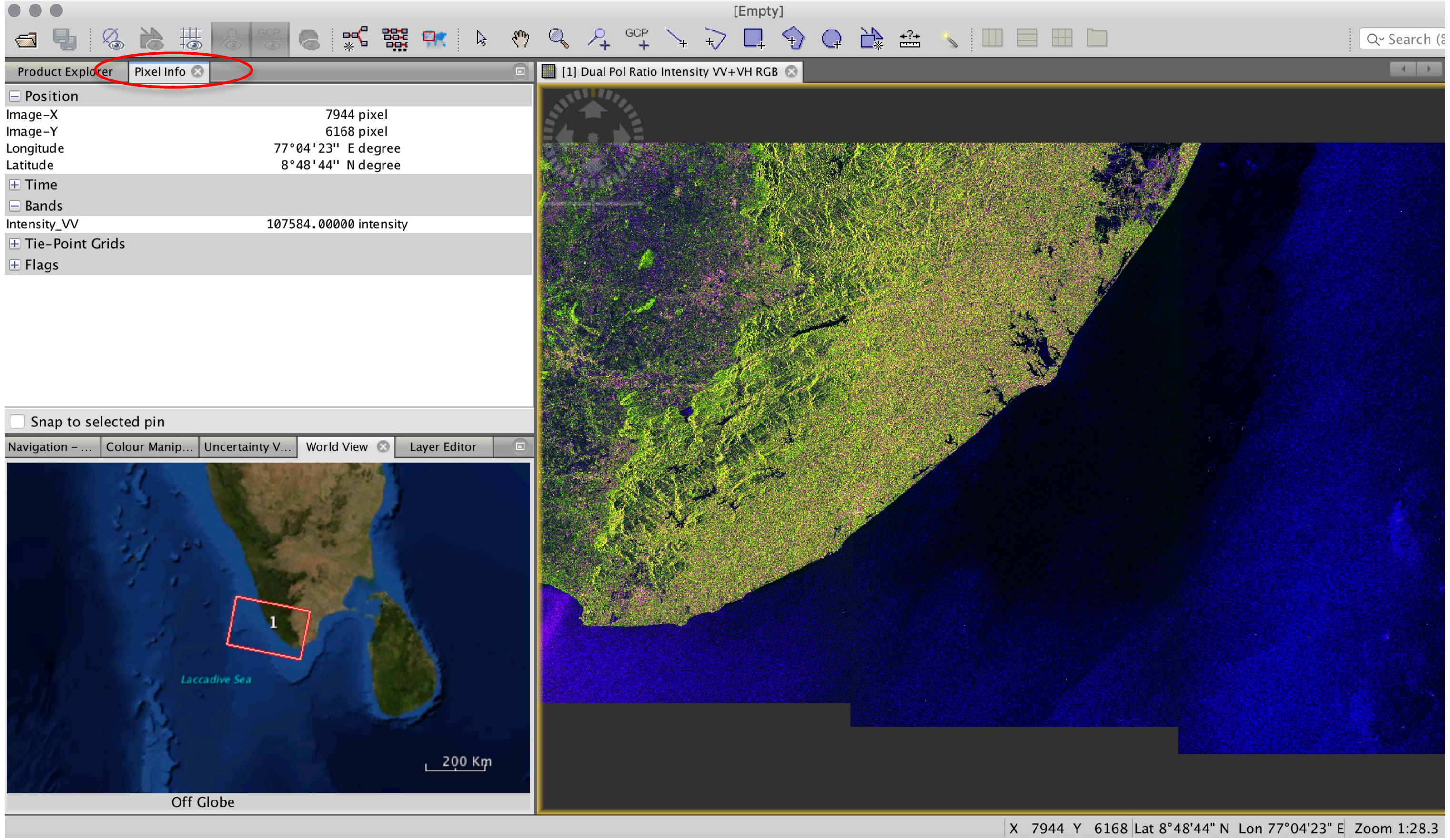
Opening the Data with the Sentinel Toolbox- RGB Image

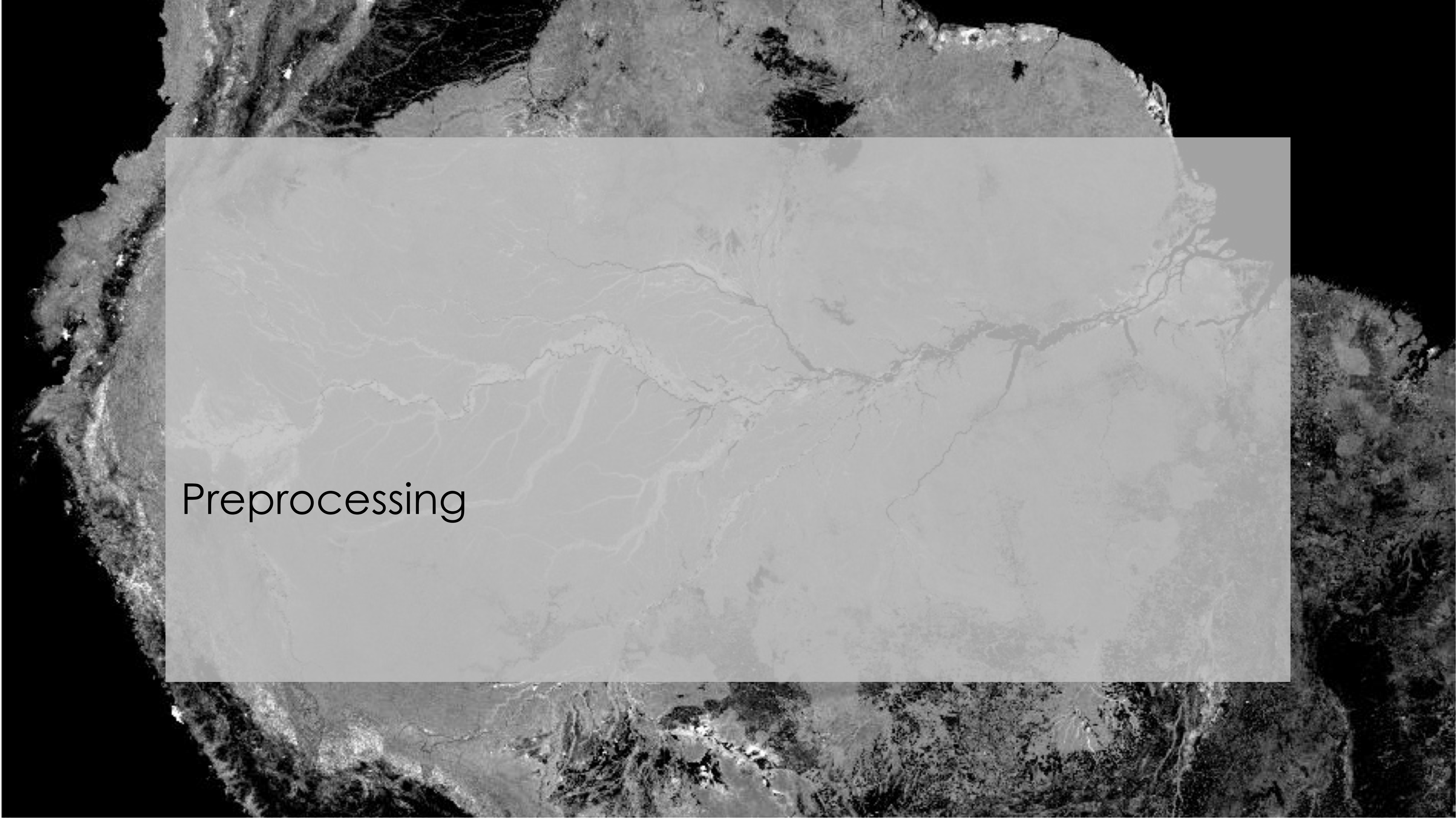
6. Go back to the **Product Explorer** tab
7. Select the file name of the first Sentinel-1 dataset. Afterwards, select **Open RGB Image Window** to display a color image of VV, VH, and VV/VH ratio



Opening the Data with the Sentinel Toolbox- Pixel Information

In the upper left window select "Pixel Info" to see the value and the lat/lon of each pixel in the image opened



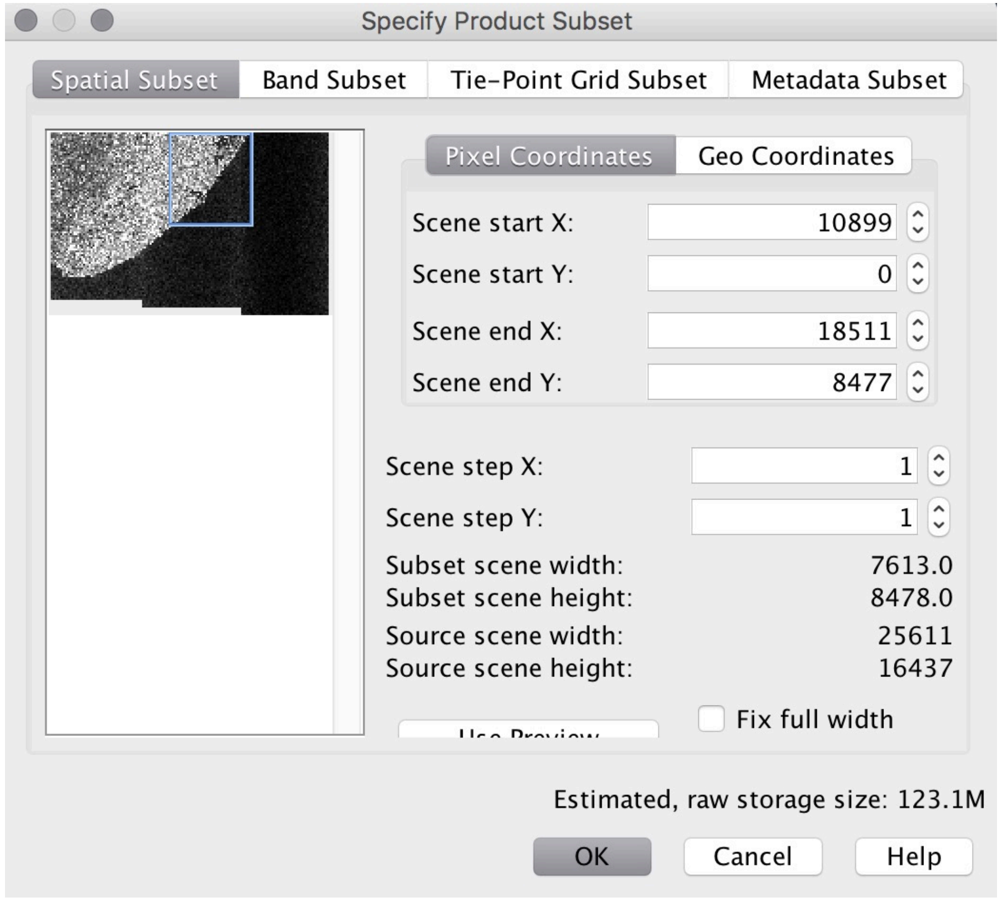


Preprocessing

Data Preparation

Defining a Subset

Select “Raster” and then “Subset”. Repeat the subset for the 2nd image.



Preprocessing: Geometric and Radiometric Calibration

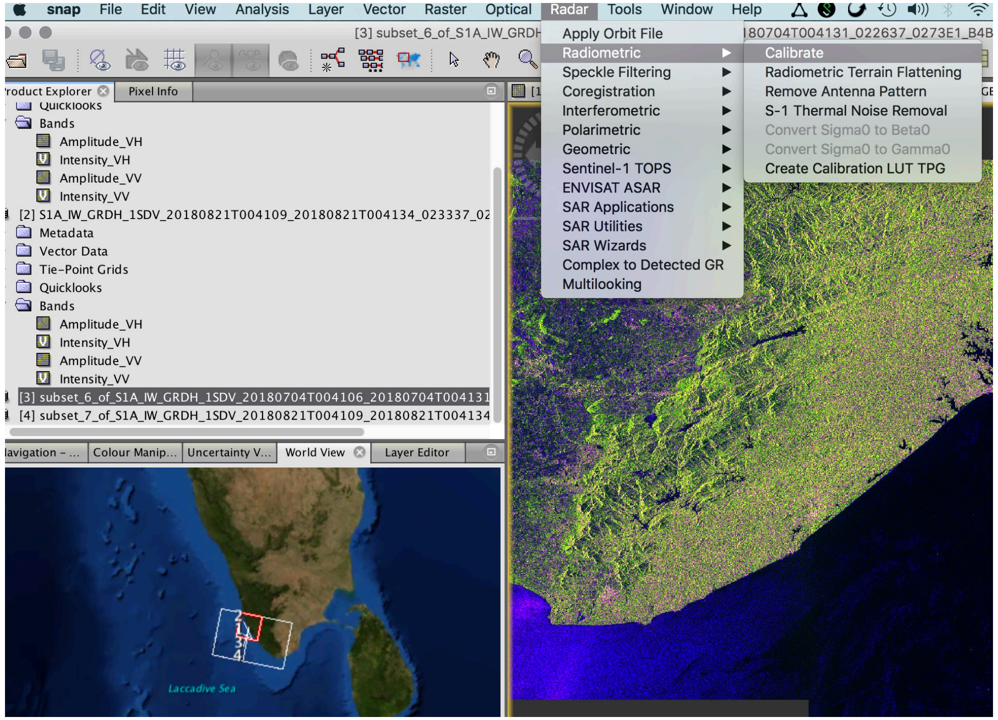
- The objective in performing a calibration is to create an image where the value of each pixel is directly related with the backscatter of the surface.
- This process is essential for analyzing the images in a quantitative way. It is also important for comparing images from different sensors, modalities, processors or acquired at different times.

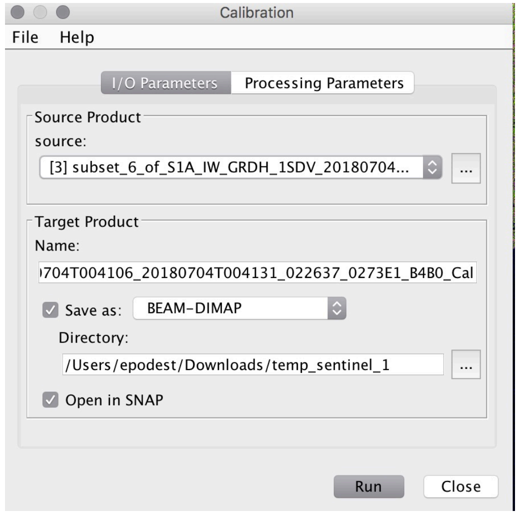
Example: Preprocessing – Radiometric Calibration

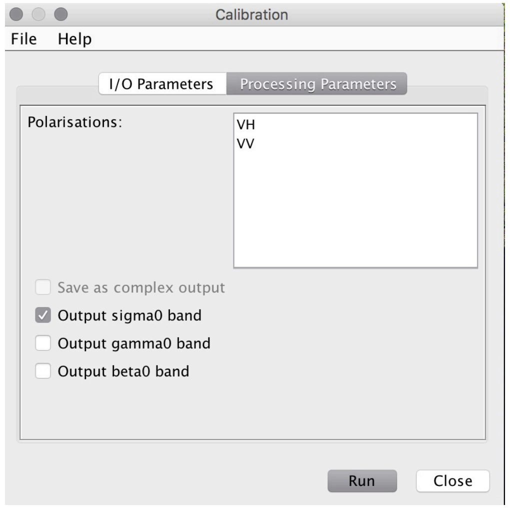
Select "Radar- Radiometric- Calibrate". Run on each subset.

The main radiometric distortions are due to:

1. Signal loss as it propagates
2. Non-uniform antenna pattern
3. Difference in gain
4. Saturation
5. Speckle



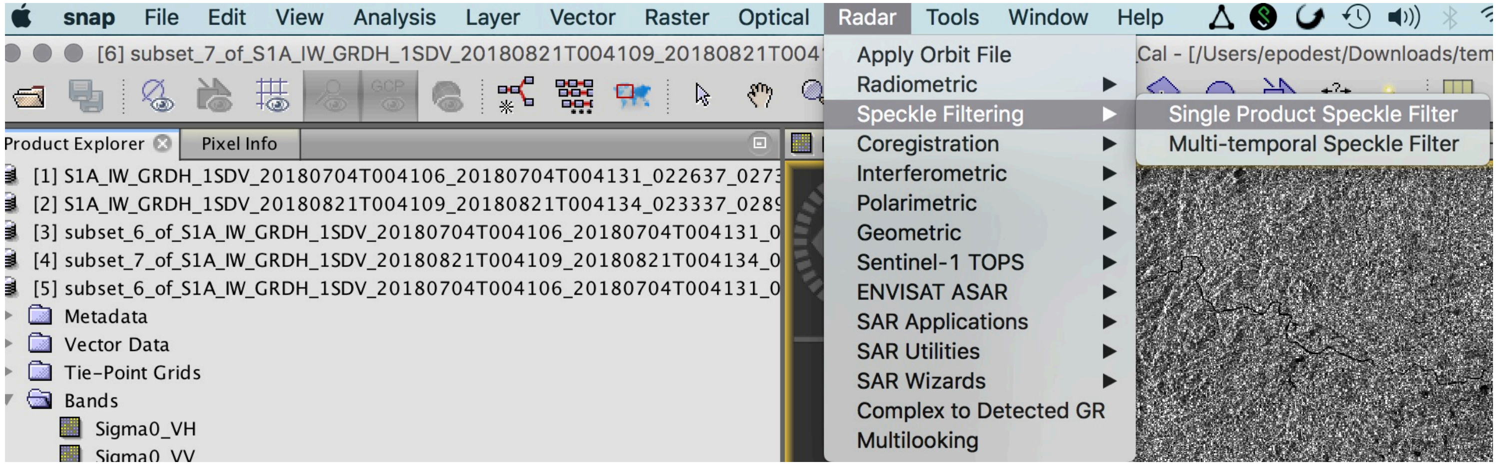


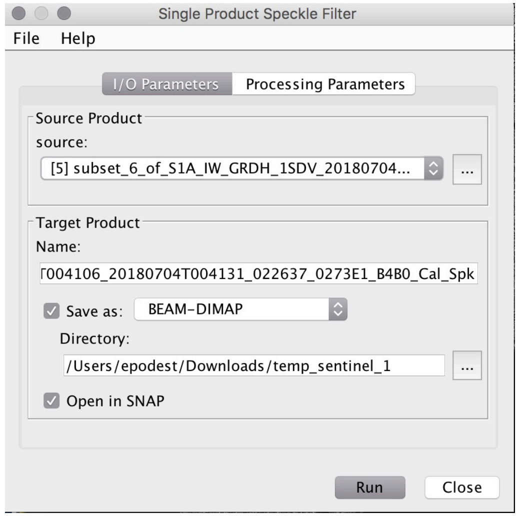


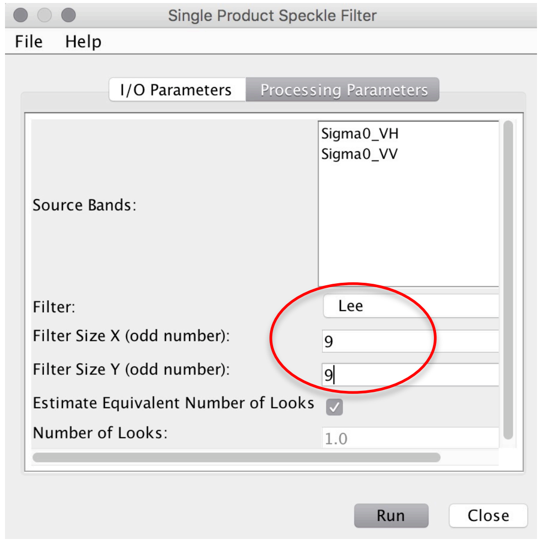
Example: Preprocessing – Speckle Filter

Select "Radar- Speckle Filtering- Single Product". Apply to each subset.

- Speckle is part of radar images and makes interpretation difficult because the "salt and pepper" effect corrupts information about the surface
- There are many techniques to extract information from radar images that have lots of speckle
  - In this case, we will use the Lee filter







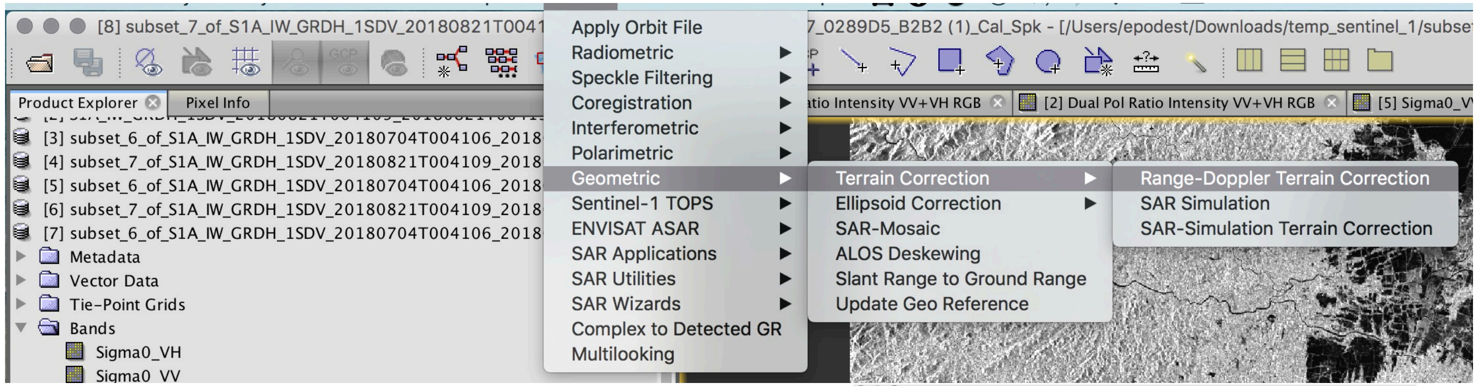
Example: Preprocessing – Geometric Calibration

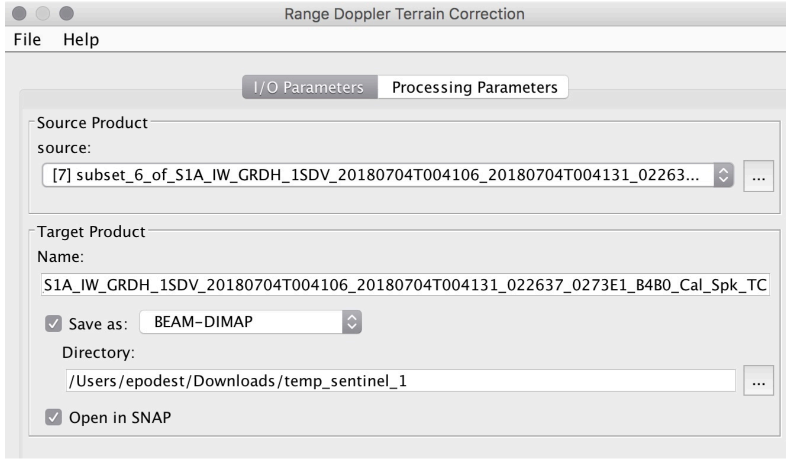
Select "Radar- Geometric- Terrain Correction- Range Doppler"

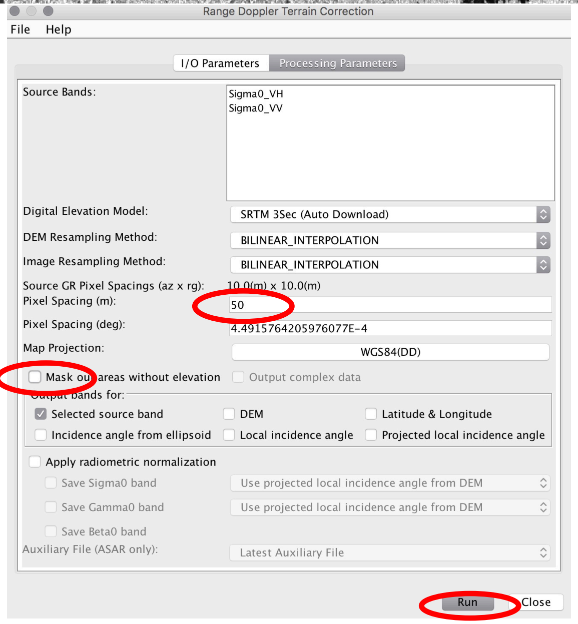
The main geometric distortions are due to:

1. Slant Range
2. Layover
3. Shadow
4. Foreshortening

- The algorithm uses a DEM to make corrections
- The corrected image is in its correct orientation

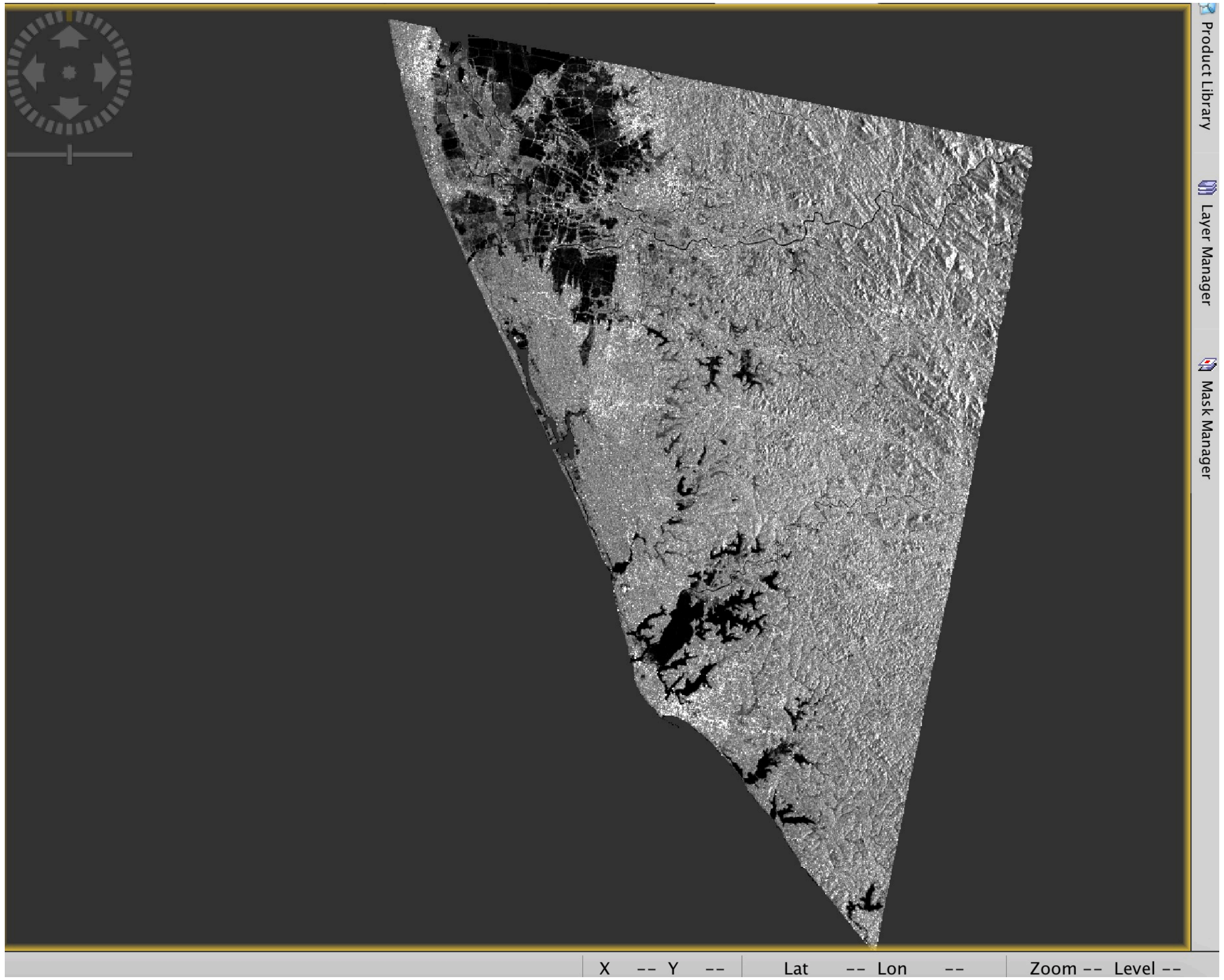






Example: Preprocessing – Geometric Calibration

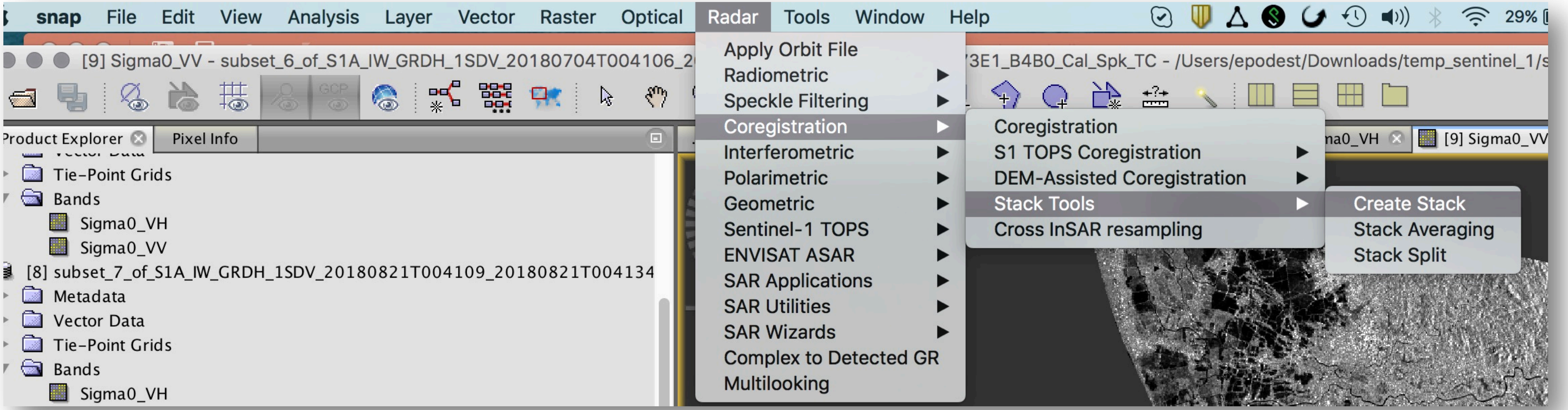
Select "Radar- Geometric- Terrain Correction- Range Doppler"



Data Preparation

Stack the two images

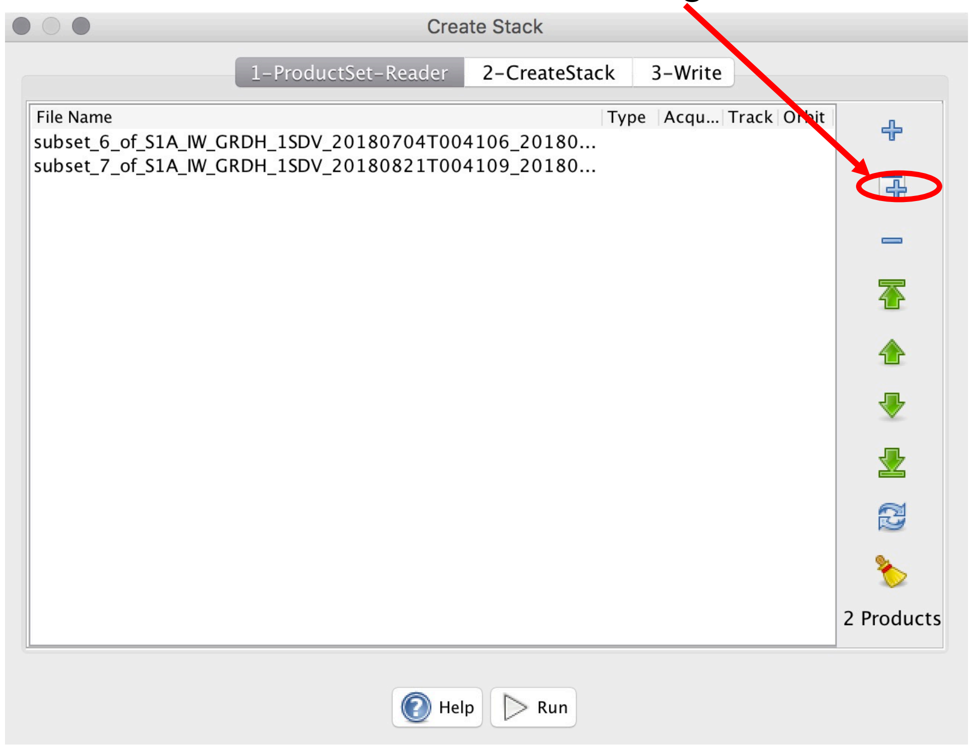
Select "Radar>Coregistration>Stack Tools>Create Stack



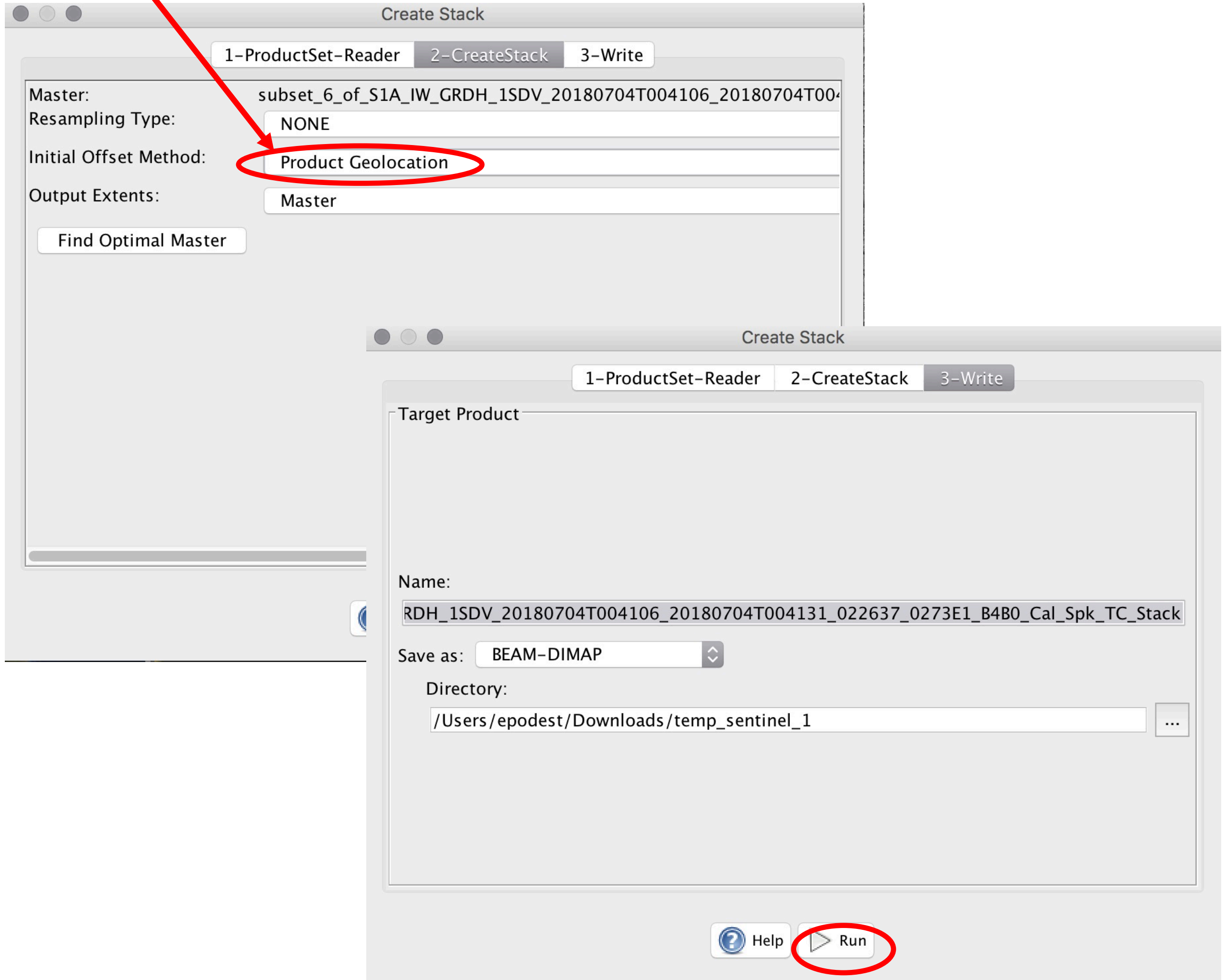
Data Preparation

Stack the two images

Load images



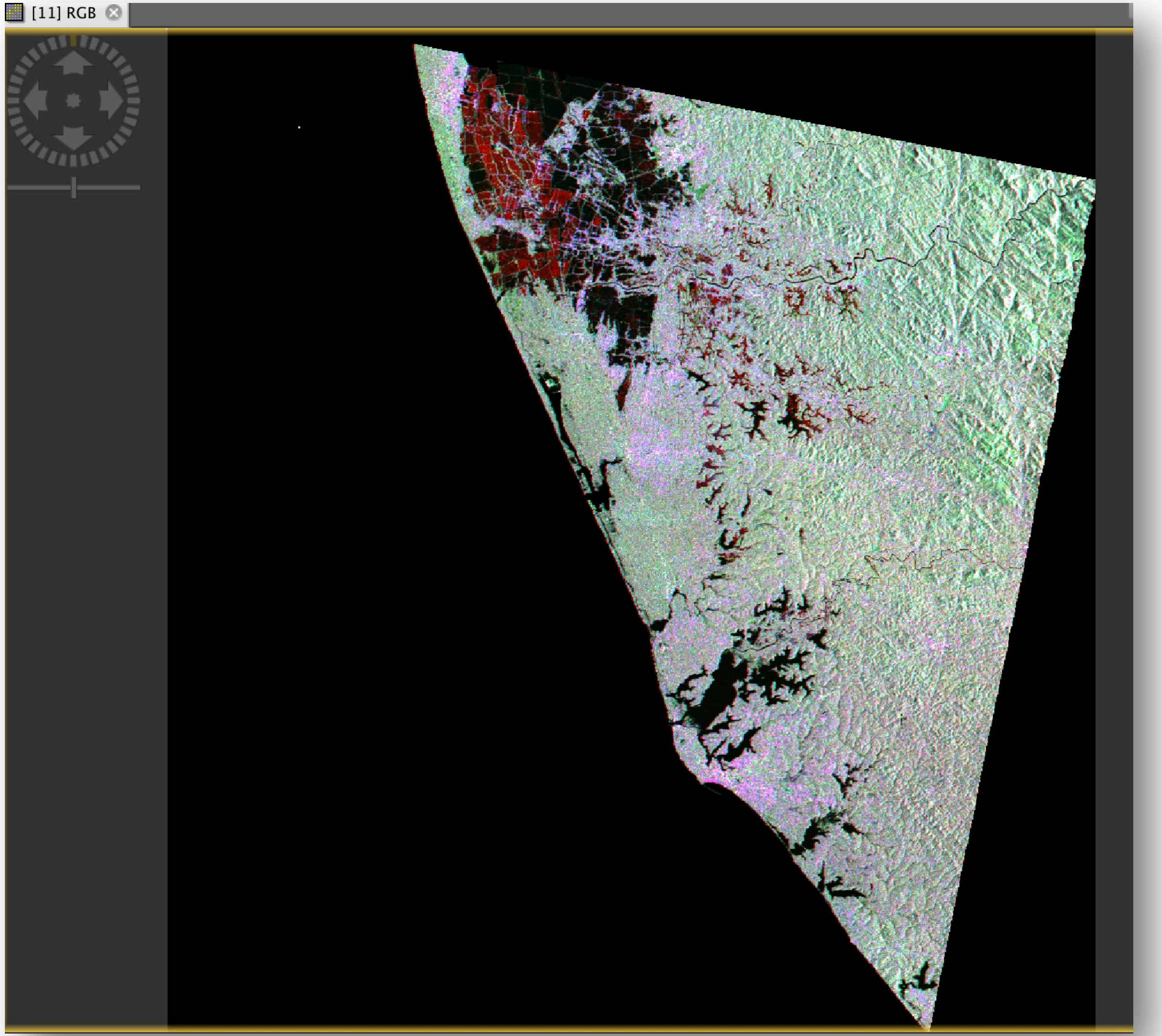
Specify "Product Geolocation"



Data Preparation

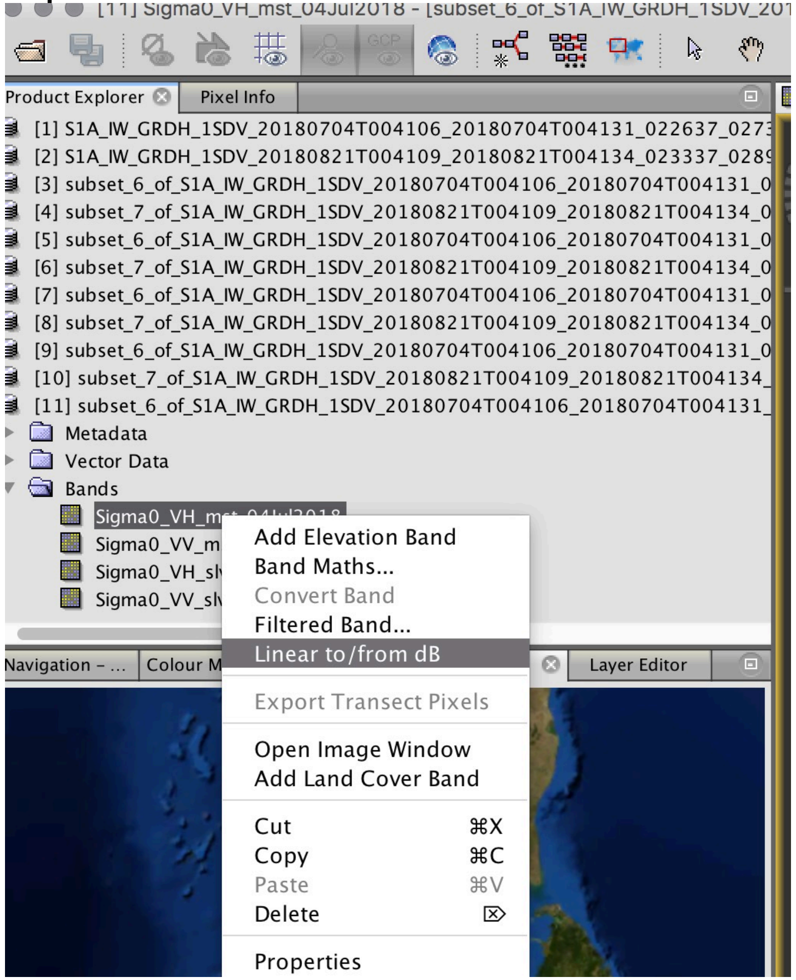
Create a Multi-temporal RGB

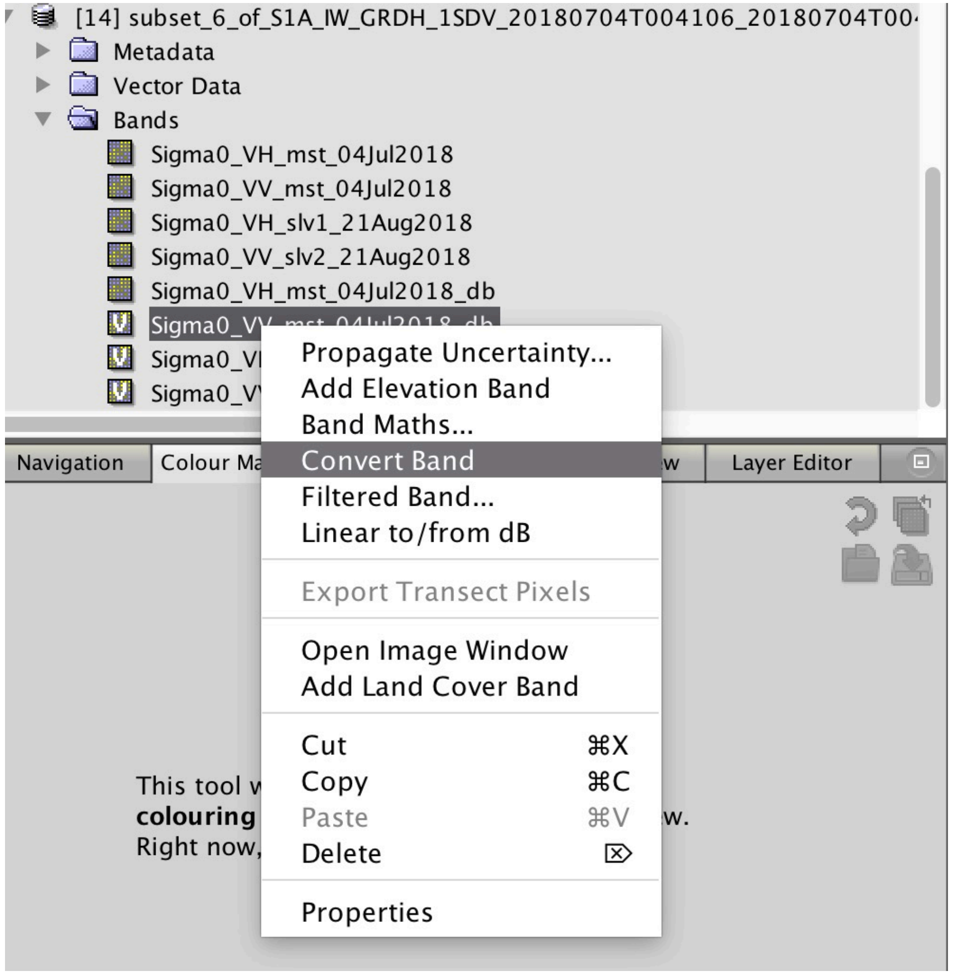
R- Jul. 4 VV
G- Aug. 21 VH
B- Aug. 21 VV

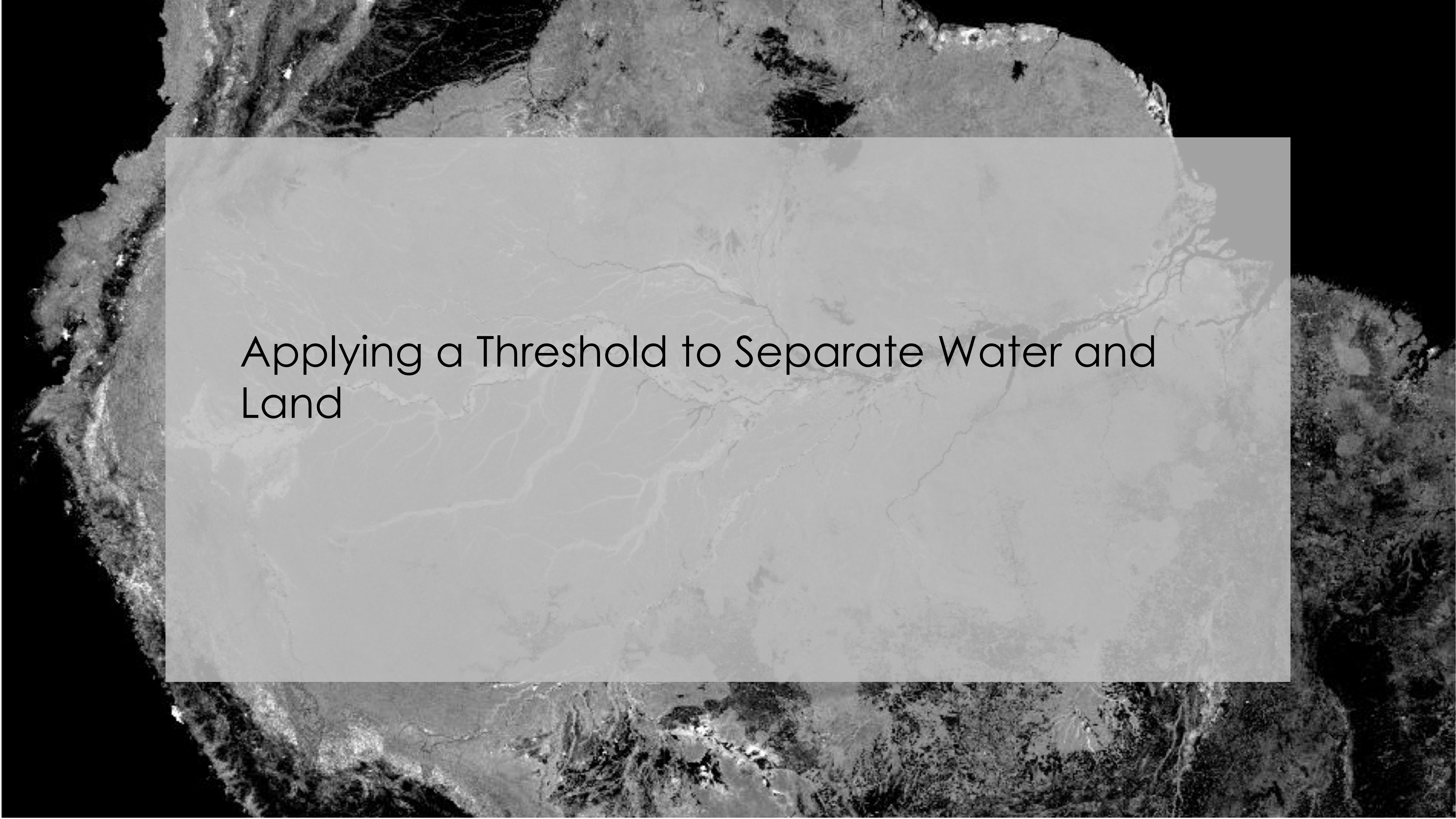


Data Preparation

Convert Values to dB and "Convert Band" so that the dB image created is saved. Repeat for all bands within the stack.



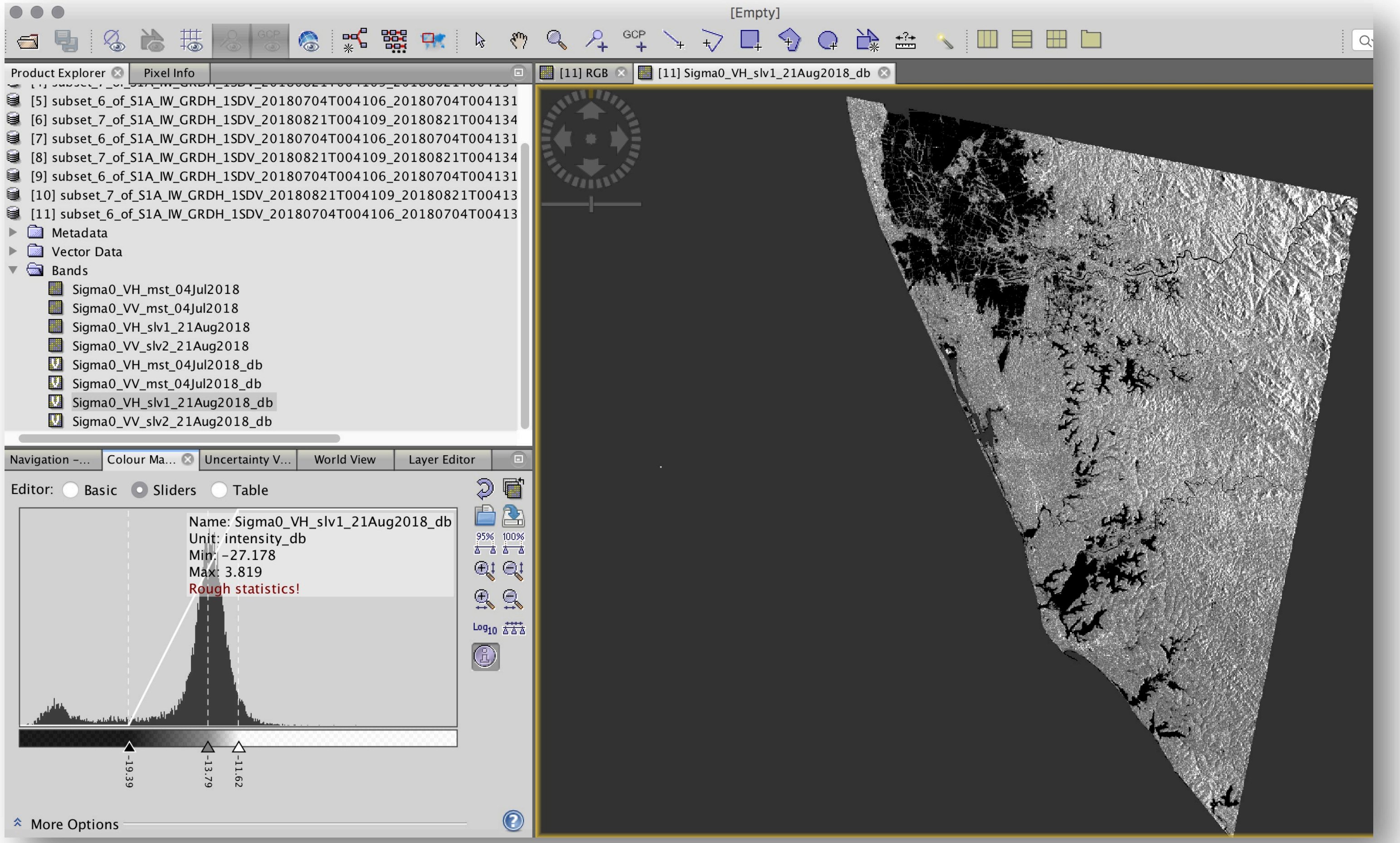




Applying a Threshold to Separate Water and Land

Classifying Water and Land by Creating a Threshold

1. Load the Aug. 21 VH dB image and analyze the image histogram in the lower left window
2. Identify a threshold between high values and low values
3. Select the value that separates water from everything else. In this case -19.39 dB

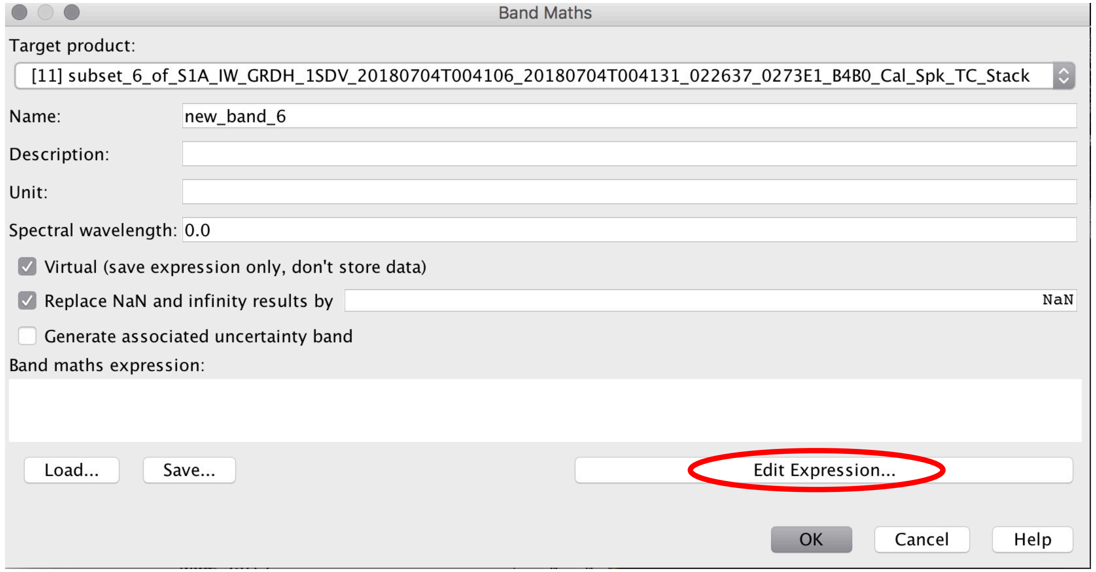


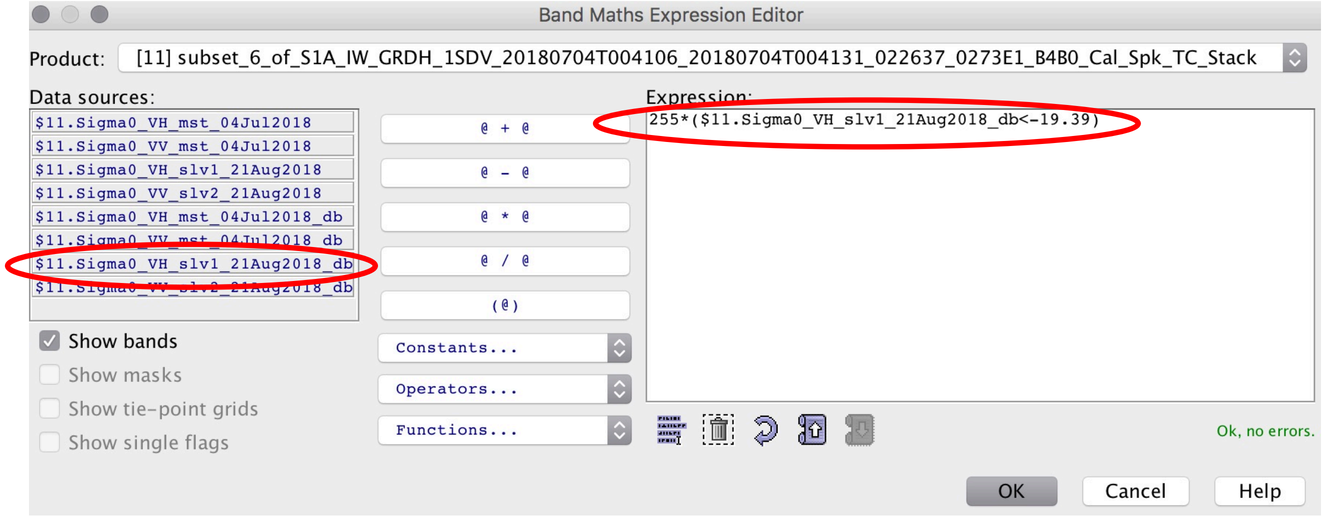
Classifying Water and Land by Creating a Threshold

Select “Raster- Band- Math”

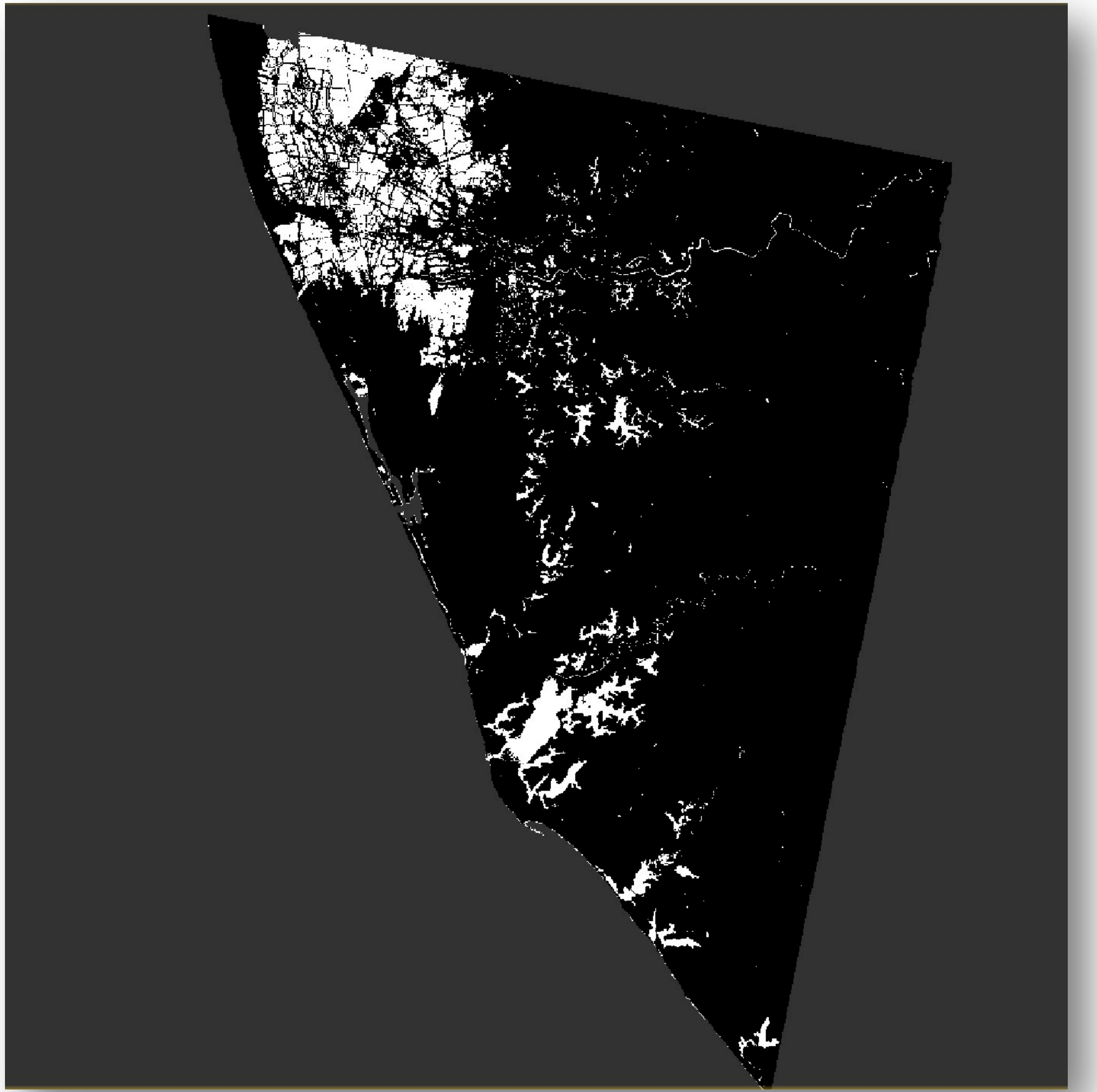
1. To segment the image, apply band math
2. Edit the expression so that it indicates:

   255*(Sigma0_VH<-19.39)
3. The result will be an image where water will have a value of 255. Call this new image “water”



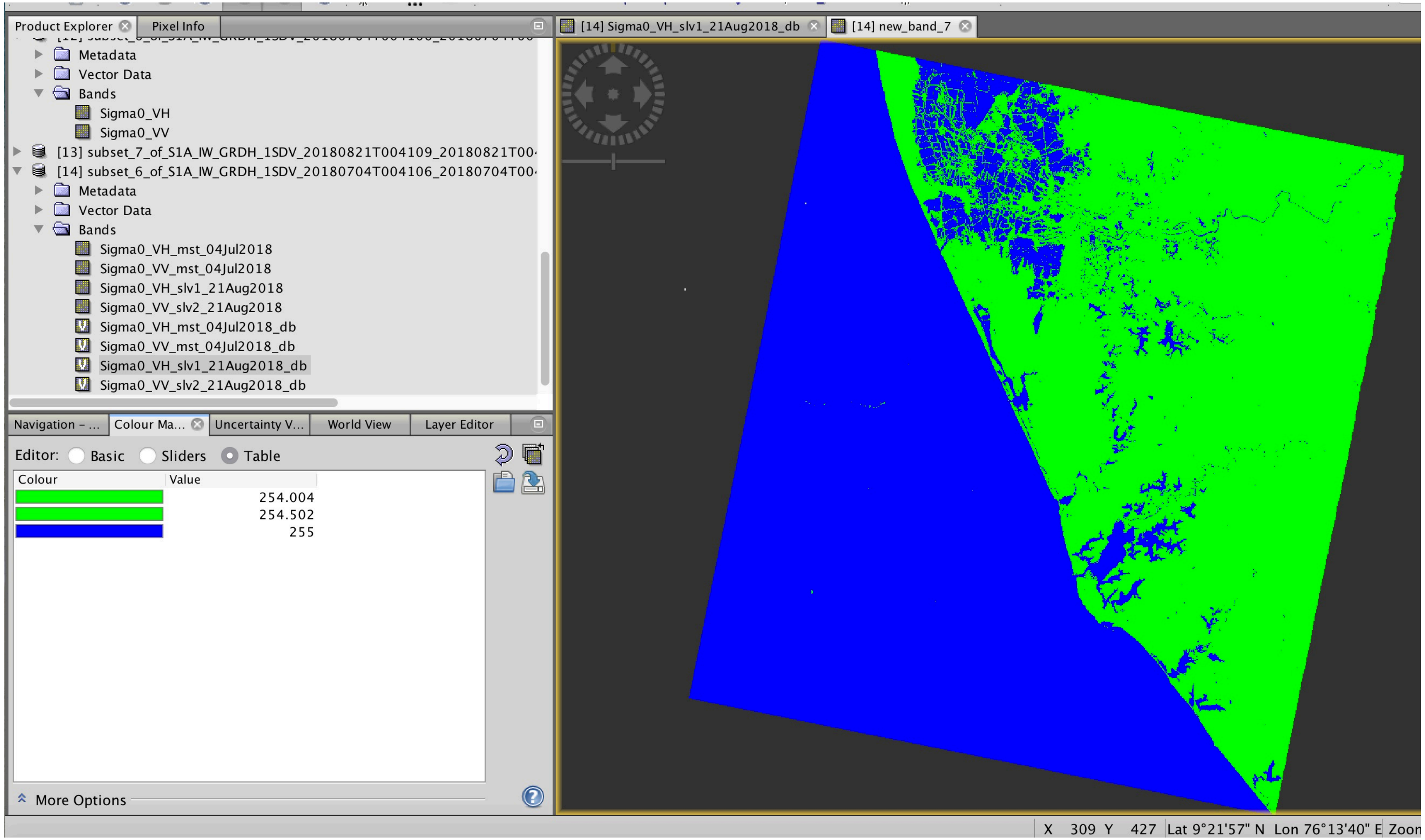


Threshold Result to Separate Water and Land



Result: Threshold to Separate Water and Land

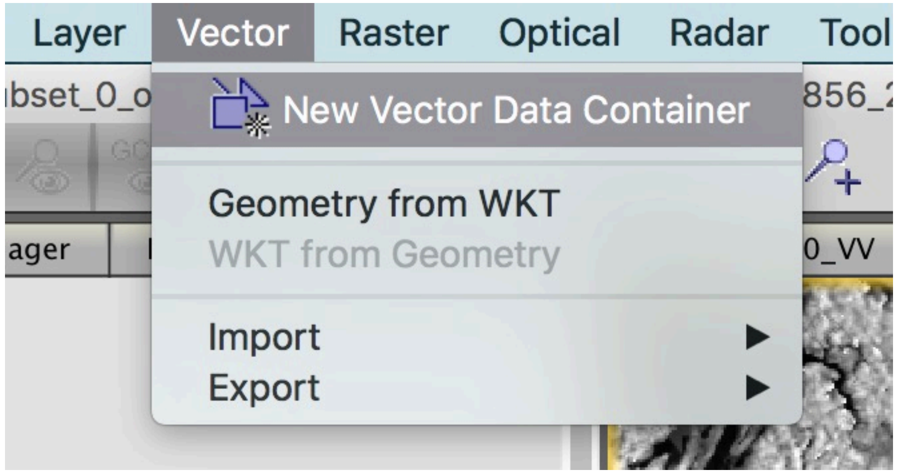
To change the colors, go to the color manipulation window on the bottom left and select **Table**. There you can assign a color to each of the 3 classes.

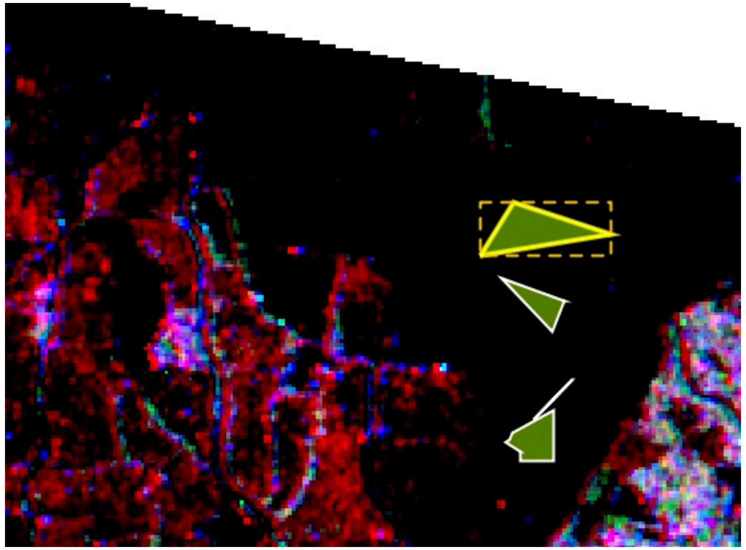


Supervised Classification

Training Area Selection

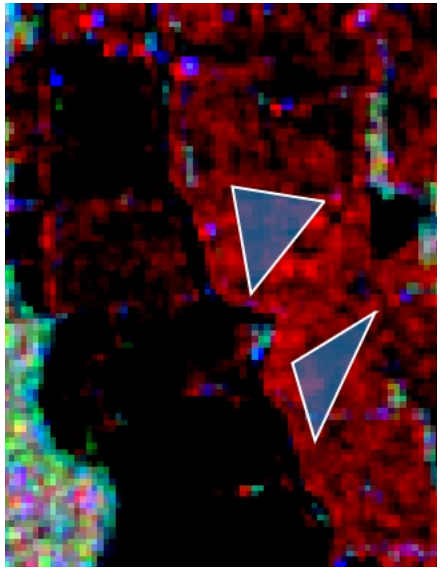
1. Select training areas by:
   - displaying the image as RGB
   - selecting from the main menu **Vector>New Vector Data Container** and providing a name for your first training class (in this case permanent water)
   - in the Tools menu along the top bar, select the Polygon Drawing Tool
   - create a polygon of the area representative of open water.

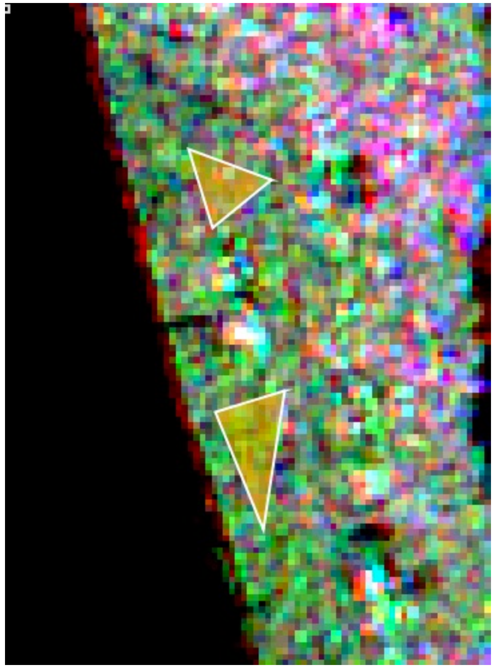


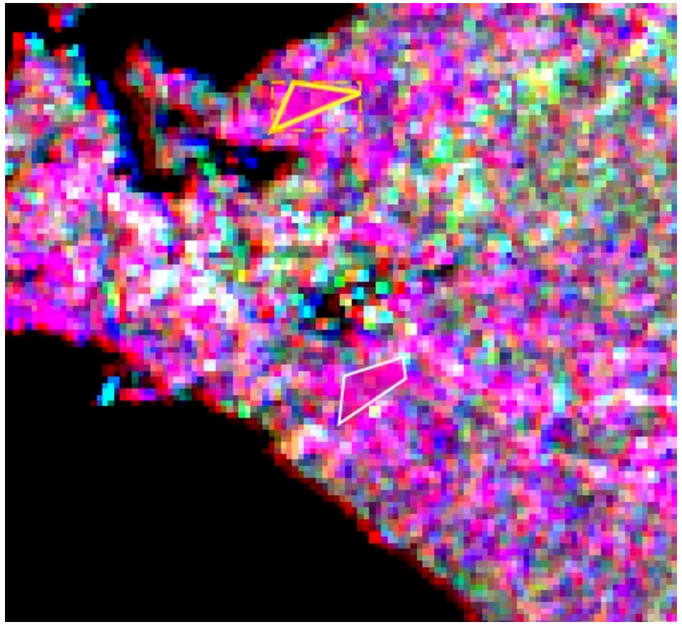


Training Area Selection

2. Define the remaining training areas:
   - Repeat these same steps for each class.
     - flood water, dry land, wet land

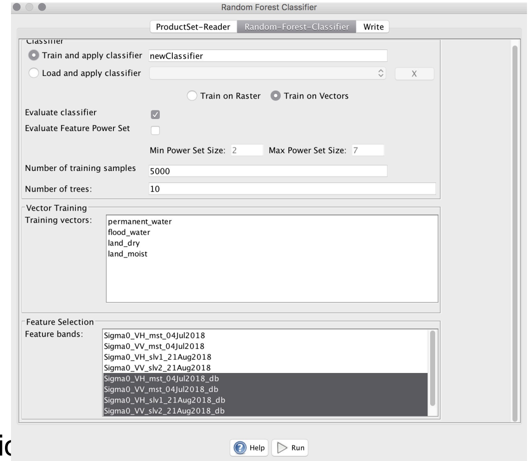






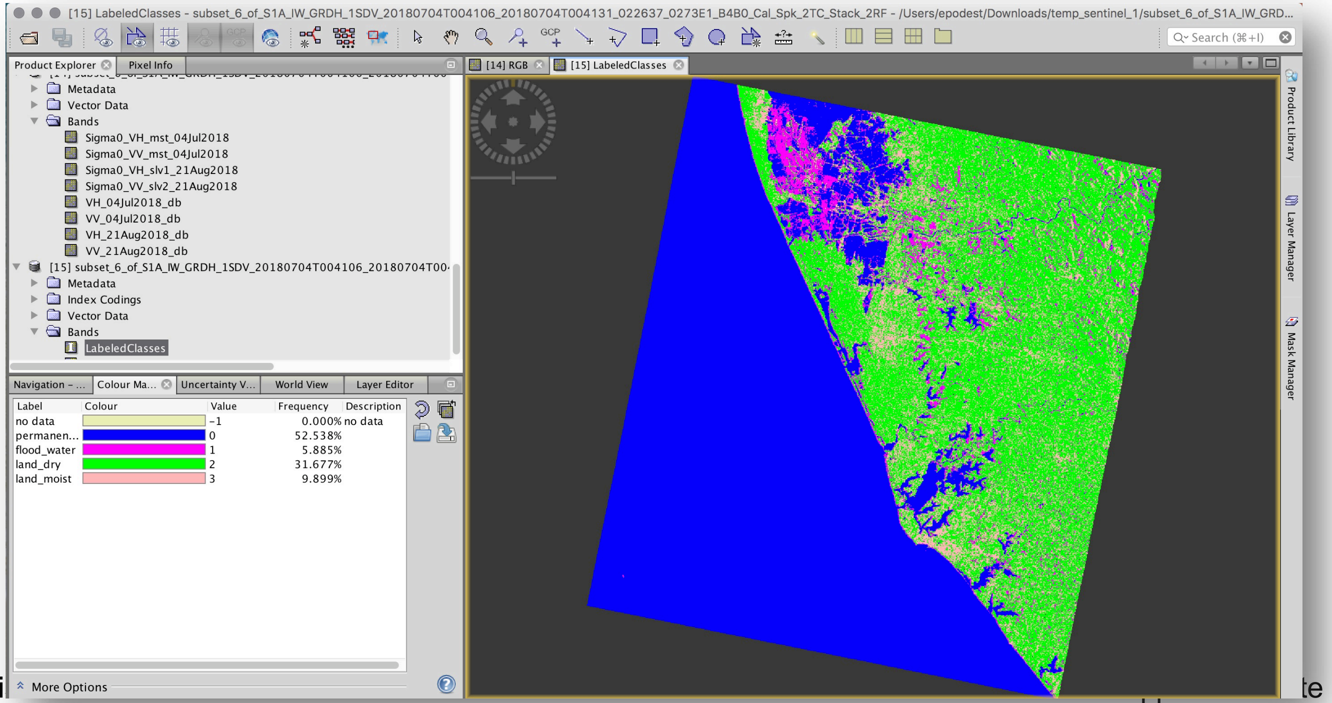
Running the Random Forest Classifier

3. Run the Random Forest Classification by:
   - selecting in the top menu **Raster >Classification>Supervised Classification > Radom Forest Classifier**
   - in the pop-up window, select the file that you want to classify. To load it, select the add-opened files on the column on the right (the second one down). Load the calibrated, speckle filtered, terrain corrected file.
   - The second tab, Random Forest Classifier, will have a list of the training areas selected. Keep the defaults. Run it.



Running the Random Forest Classifier

4. Display the results:
   - a new image with extension _RF will be added in the product explorer window. Display the bands>labeled classes image.
   - In the color manipulation tab of the bottom left window, assign the desired colors to each class.



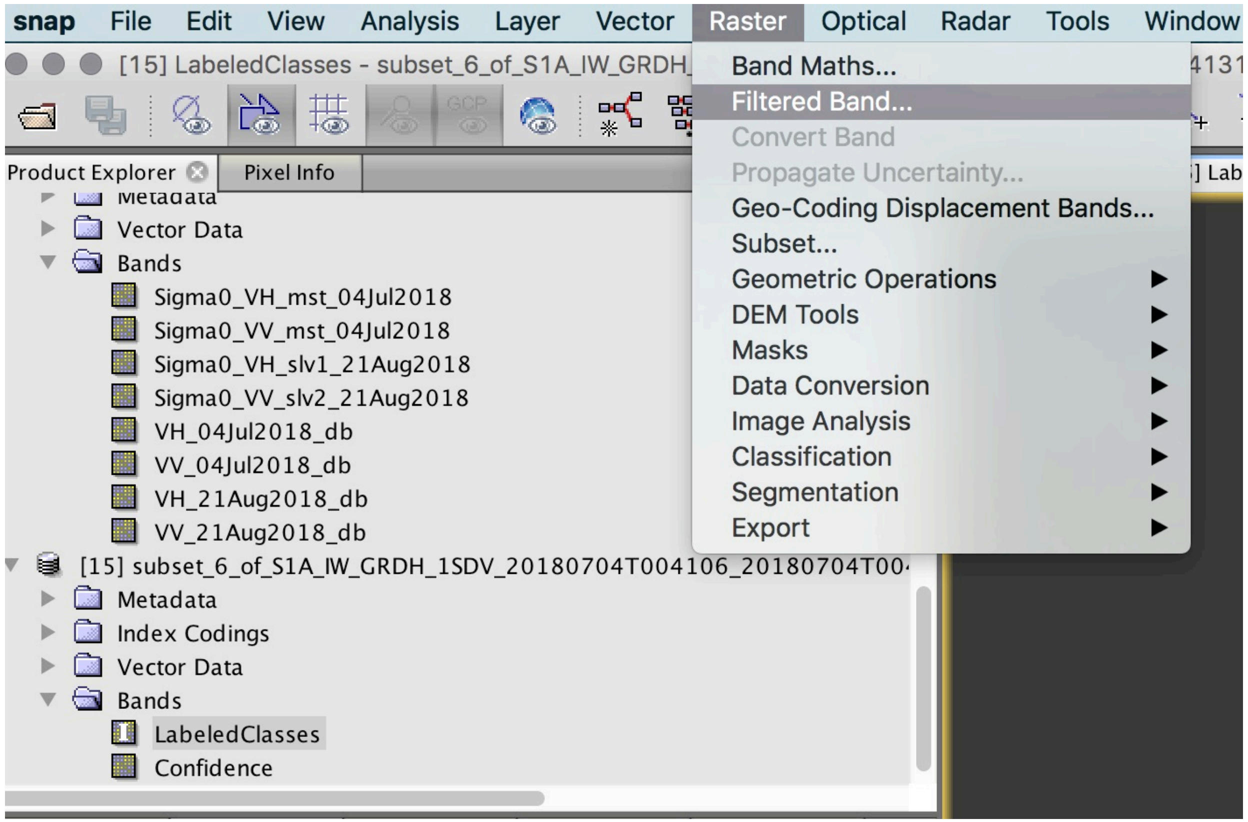
Running the Random Forest Classifier

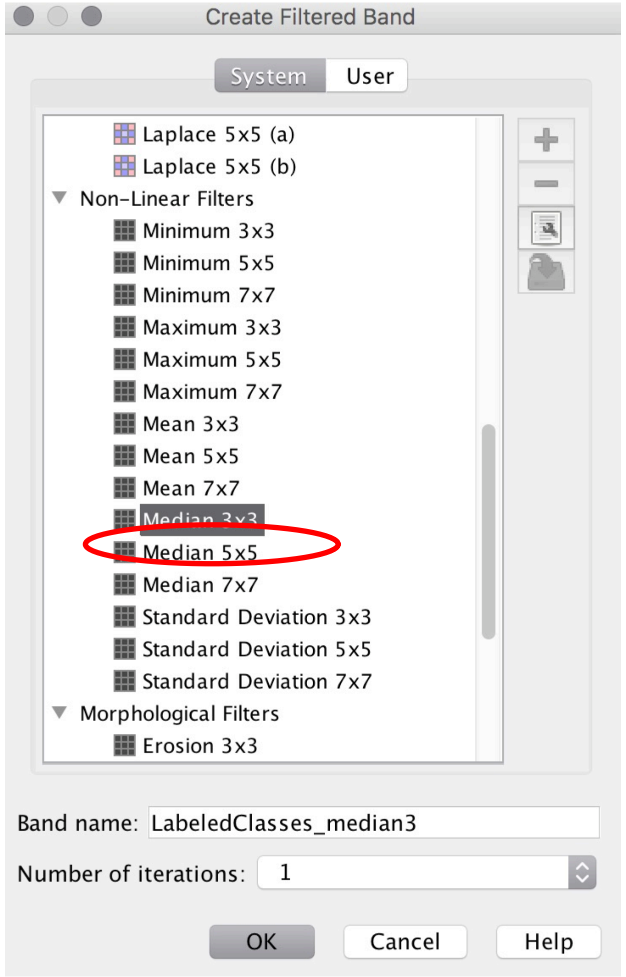
5. Accuracy assessment:
   – while Random Forest is running, a separate text window will display the classification validation results:

```
RandomForest classifier newClassifier2

Cross Validation
Number of classes = 4
   class 0.0: permanent_water
    accuracy = 0.9984 precision = 1.0000 correlation = 0.9967 errorRate = 0.0016
    TruePositives = 256.0000 FalsePositives = 0.0000 TrueNegatives = 360.0000 FalseNegatives = 1.0000
   class 1.0: flood_water
    accuracy = 0.9951 precision = 0.9868 correlation = 0.9869 errorRate = 0.0049
    TruePositives = 150.0000 FalsePositives = 2.0000 TrueNegatives = 464.0000 FalseNegatives = 1.0000
   class 2.0: land_dry
    accuracy = 0.9935 precision = 0.9774 correlation = 0.9809 errorRate = 0.0065
    TruePositives = 130.0000 FalsePositives = 3.0000 TrueNegatives = 483.0000 FalseNegatives = 1.0000
   class 3.0: land_moist
    accuracy = 0.9968 precision = 1.0000 correlation = 0.9853 errorRate = 0.0032
    TruePositives = 76.0000 FalsePositives = 0.0000 TrueNegatives = 539.0000 FalseNegatives = 2.0000

Using Testing dataset, % correct predictions = 99.1896
Total samples = 1235
RMSE = 0.09002070714423868
Bias = -0.0016207455429497752

Distribution:
   class 0.0: permanent_water            514   (41.6194%)
   class 1.0: flood_water                302   (24.4534%)
   class 2.0: land_dry                   263   (21.2955%)
   class 3.0: land_moist                 156   (12.6316%)
```

Refining Your Classification Results

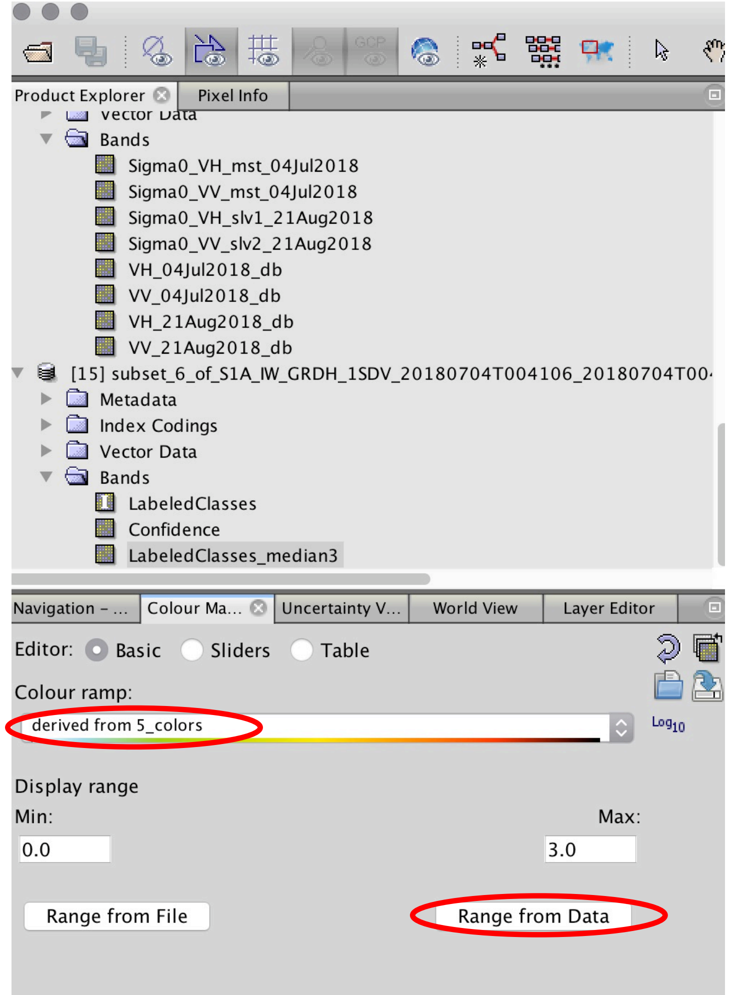
6. Refine the classification results by applying a filter:



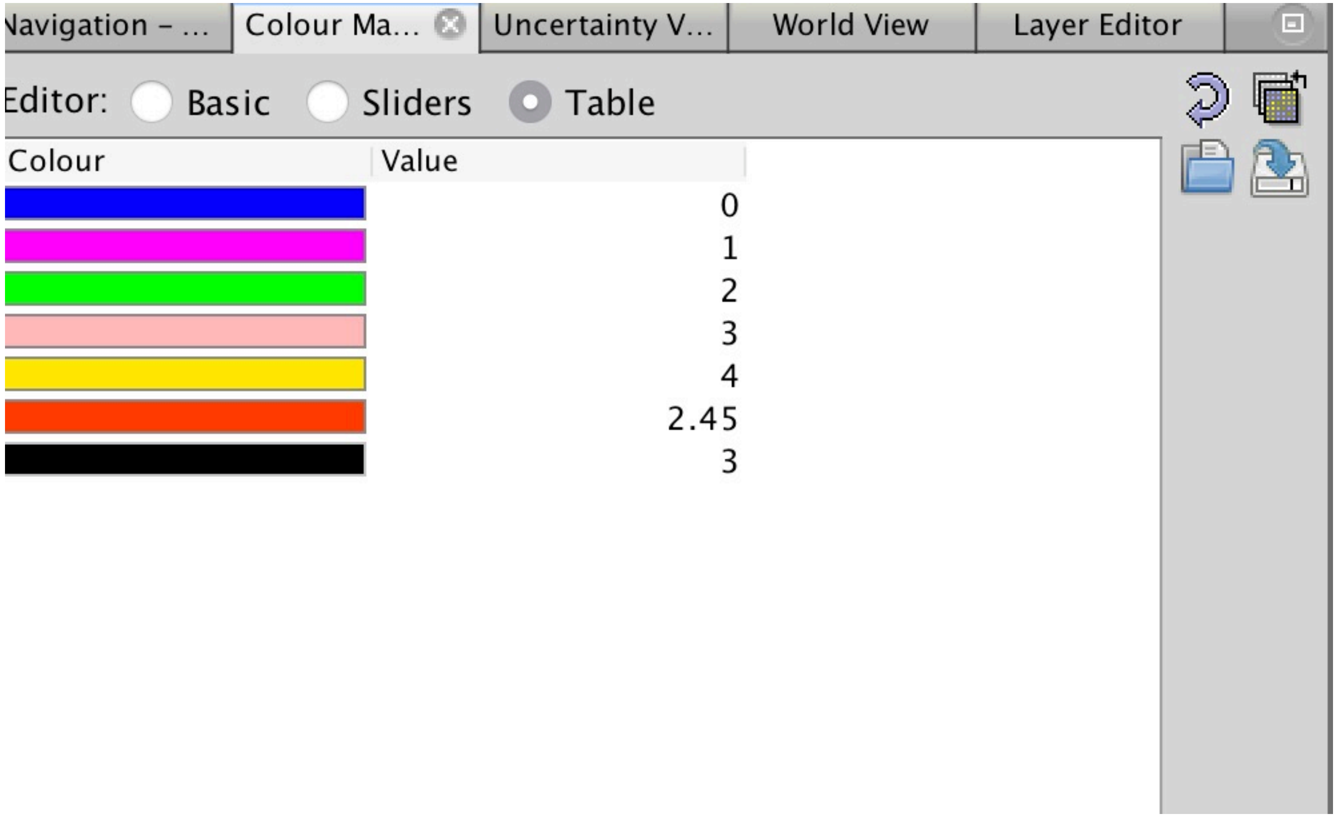


Refining Your Classification Results

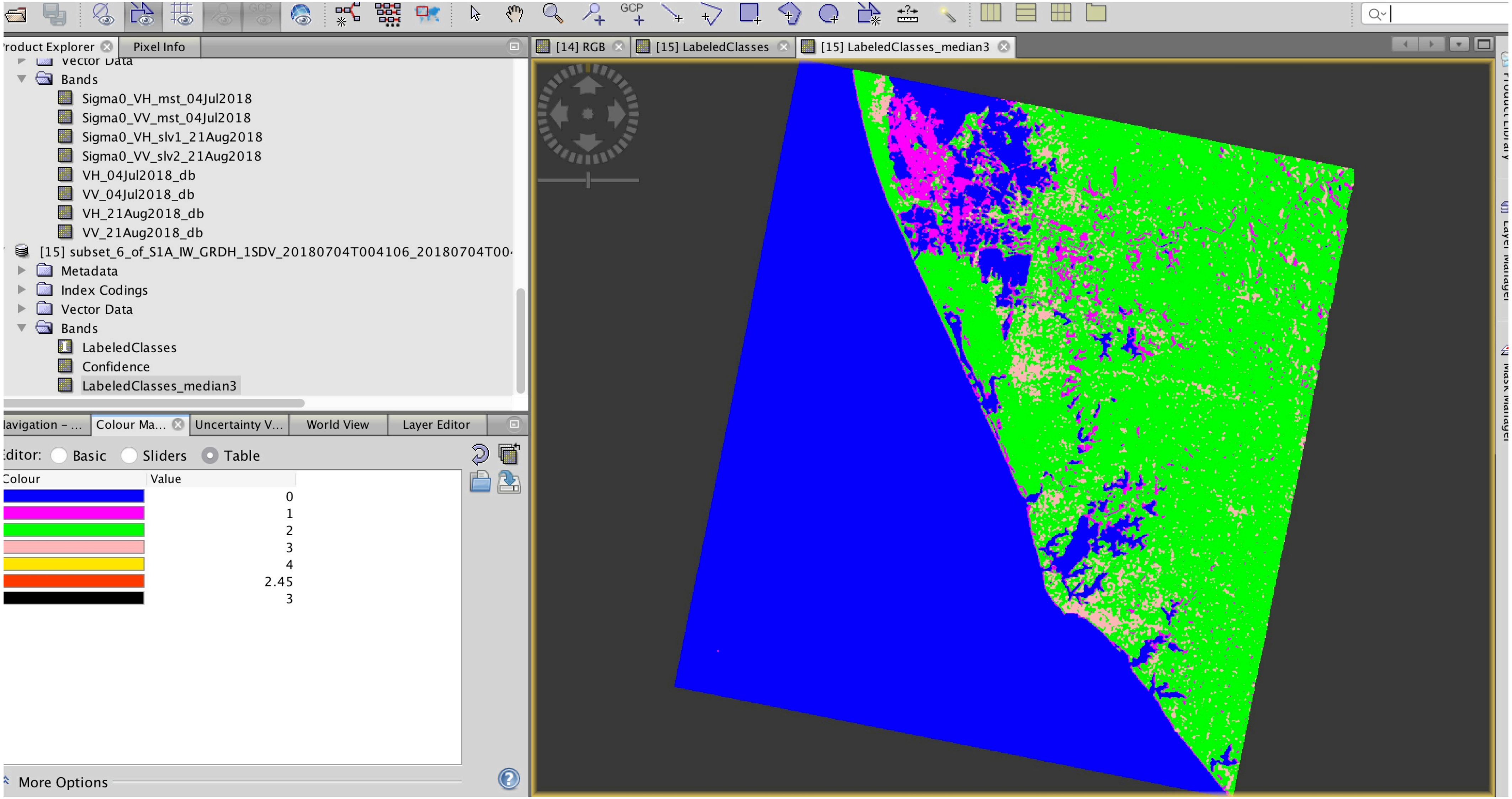
7. Go to the Color Manipulation Window



Under the "Table" tab assign numbers and colors to your classes



Refined Classification Results



Google Earth Engine

Metadata and Filtering

https://code.earthengine.google.com/

To create a homogeneous subset of Sentinel-1 data, it will usually be necessary to filter the collection using metadata properties. The common metadata fields used for filtering include these properties:

1. `transmitterReceiverPolarisation` : ['VV'], ['HH'], ['VV', 'VH'], or ['HH', 'HV']
2. `instrumentMode` : 'IW' (Interferometric Wide Swath), 'EW' (Extra Wide Swath) or 'SM' (Strip Map). See this reference for details.
3. `orbitProperties_pass` : 'ASCENDING' or 'DESCENDING'
4. `resolution_meters` : 10, 25 or 40
5. `resolution` : 'M' (medium) or 'H' (high). See this reference for details.

Sentinel-1 Preprocessing on Google Earth Engine

- Google Earth Engine uses the following preprocessing steps (as implemented by the Sentinel-1 Toolbox) to derive the backscatter coefficient in each pixel:
- **Apply orbit file**
  - Updates orbit metadata with a restituted orbit file.
- **GRD border noise removal**
  - Removes low intensity noise and invalid data on scene edges. (As of January 12, 2018)
- **Thermal noise removal**
  - Removes additive noise in sub-swaths to help reduce discontinuities between sub-swaths for scenes in multi-swath acquisition modes. (This operation cannot be applied to images produced before July 2015)
- **Radiometric calibration**
  - Computes backscatter intensity using sensor calibration parameters in the GRD metadata.
- **Terrain correction** (orthorectification)
  - Converts data from ground range geometry, which does not take terrain into account, to σ° using the SRTM 30 meter DEM or the ASTER DEM for high latitudes (greater than 60° or less than -60°).

Flood Mapping

new_flooding *

Get Link | Save | Run | Reset

```
// Load Sentinel-1 images to map a flooding in Kerala in 2018.
// This script was originally written by Simon Ilyushchenko (GEE team)
// Default location
var geometry = /* color: #d63000 */ee.Geometry.Point([76.40, 9.53]);
var pt = geometry

// Load Sentinel-1 C-band SAR Ground Range collection (log scaling, VV co-polar)
var collection = ee.ImageCollection('COPERNICUS/S1_GRD').filterBounds(pt)
.filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))
.filter(ee.Filter.eq('instrumentMode', 'IW'))
.filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
.select('VH');

// Filter by date
var before = collection.filterDate('2018-07-04', '2018-07-06').mosaic();
var after = collection.filterDate('2018-08-21', '2018-08-23').mosaic();

// Threshold smoothed radar intensities to identify "flooded" areas.
var SMOOTHING_RADIUS = 100;
var DIFF_UPPER_THRESHOLD = -3;
var diff_smoothed = after.focal_median(SMOOTHING_RADIUS, 'circle', 'meters')
.subtract(before.focal_median(SMOOTHING_RADIUS, 'circle', 'meters'));
var diff_thresholded = diff_smoothed.lt(DIFF_UPPER_THRESHOLD);

// Display map
Map.centerObject(pt, 13);
Map.addLayer(before, {min:-30,max:0}, 'Before flood');
Map.addLayer(after, {min:-30,max:0}, 'After flood');
Map.addLayer(after.subtract(before), {min:-10,max:10}, 'After - before', 0);
Map.addLayer(diff_smoothed, {min:-10,max:10}, 'diff smoothed', 0);
Map.addLayer(diff_thresholded.updateMask(diff_thresholded),
{palette:"0000FF"},'flooded areas - blue',1);
```

Flood Mapping Results