



#### SAR Application for Mapping the Kerala Floods

Erika Podest and Amita Mehta

19 November 2018

#### **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
  - -<u>http://step.esa.int/main/download/</u>

#### 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



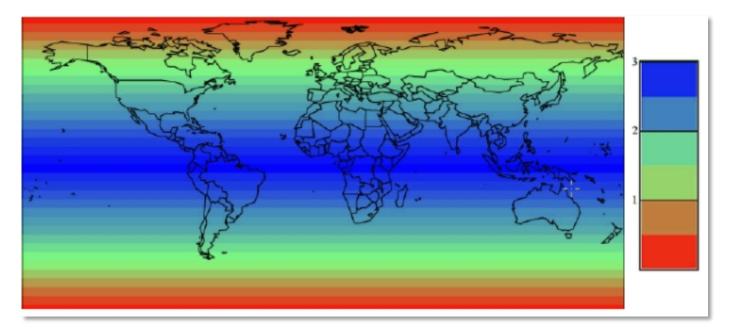
#### Part 1: Outline

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



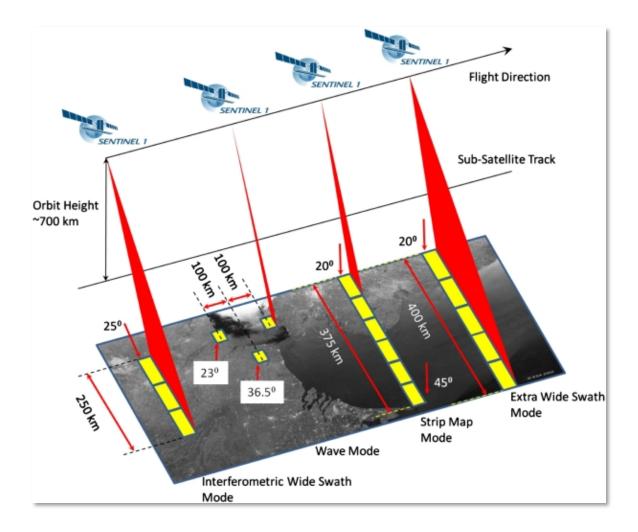
#### Sentinel-1 Coverage

- 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

- 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
  - <u>http://www.asf.alaska.edu/sentinel/</u>
- European Space Agency Portal
  - <u>http://sentinel.esa.int/web/sentinel-data-access/access-to-sentinel-data/</u>

#### 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: <u>https://vertex.daac.asf.alaska.edu/</u>
- 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, 20
- 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





Full Resolution Browse Image

#### Granule Information Data courtesy of ESA

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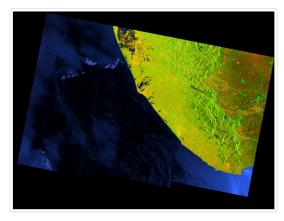
#### Dataset: Sentinel-1A Granule: S1A\_IW\_GRDH\_1SDV\_20180821T004109\_20180821T004134\_023337\_0289D5\_B2B2

#### **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





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#### Full Resolution Browse Image

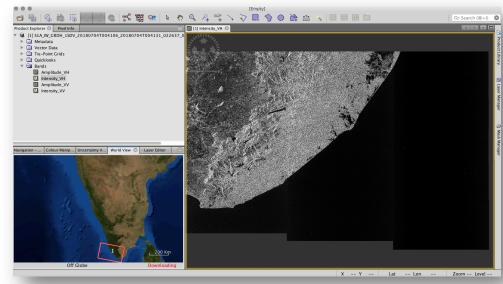
National Aeronautics and Space Administration

# 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

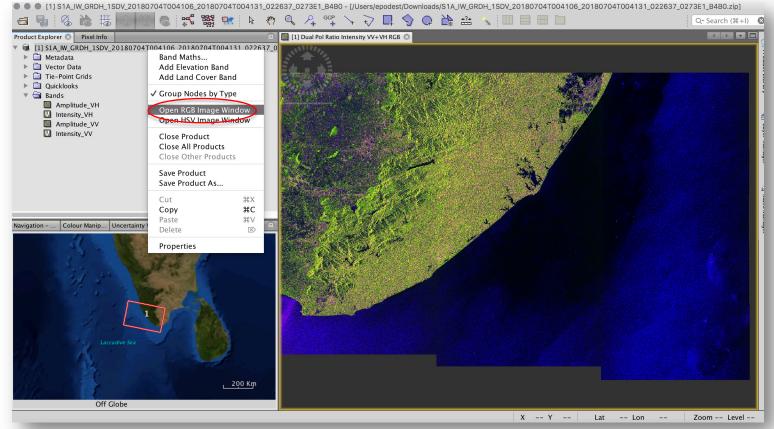
- 4. The Product Explorer window of the Sentinel Toolbox contains your file. Double click on the file to view the directories within the file, which contain information relevant to the image, including:
  - Metadata: parameters related to orbit and data
  - Tie Point Grids: interpolation of latitude/longitude, 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

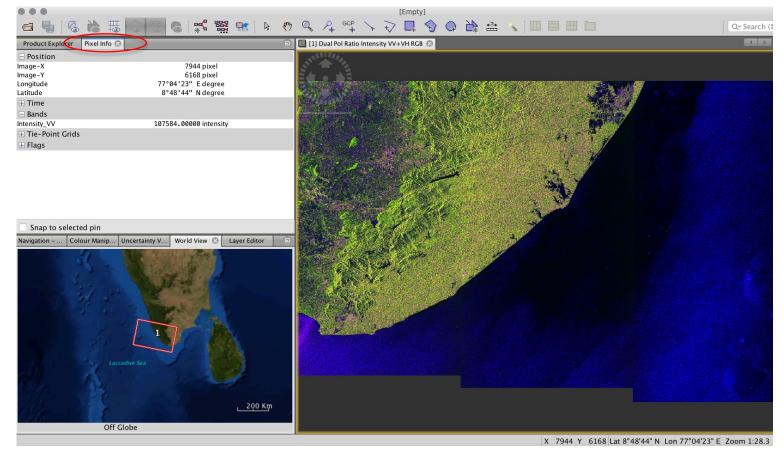
#### 6. Go back to the Product Explorer tab

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 2<sup>nd</sup> image.

$\bullet \bigcirc \bullet$	Speci	fy Product Subset			
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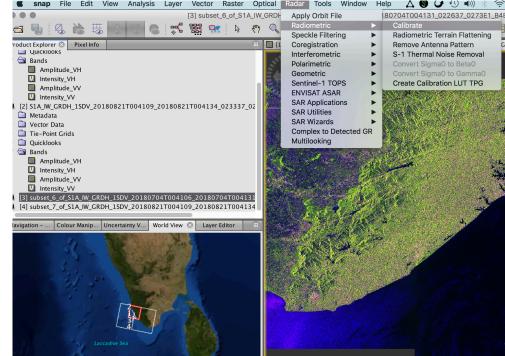
#### Preprocessing: Geometric and Radiometric Calibration

- 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:

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

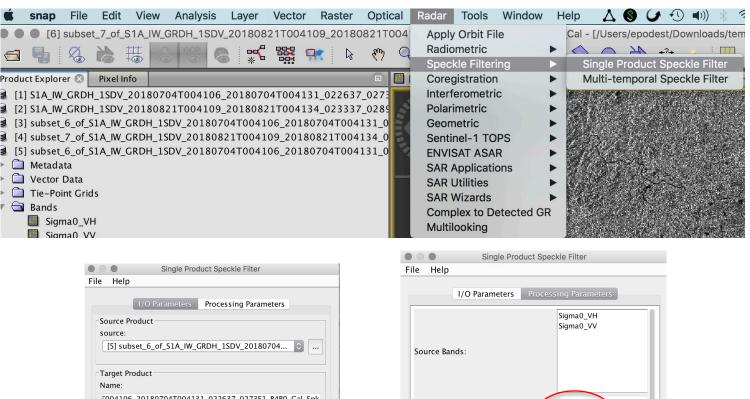


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#### Example: Preprocessing – Speckle Filter

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



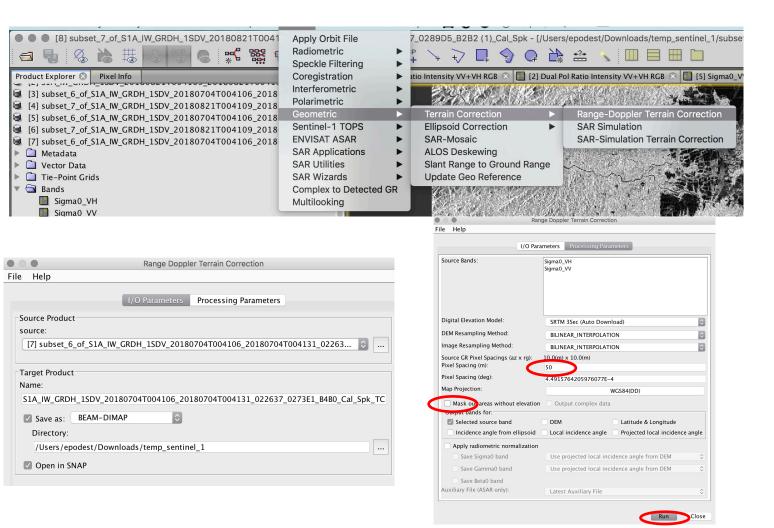
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/Users/epodest/Downloads/temp_sentinel_1	Estimate Ed	quivalent Number	of Looks 🔽	
Open in SNAP	Number of	Looks:	1.0	
Run Close				Run

Close

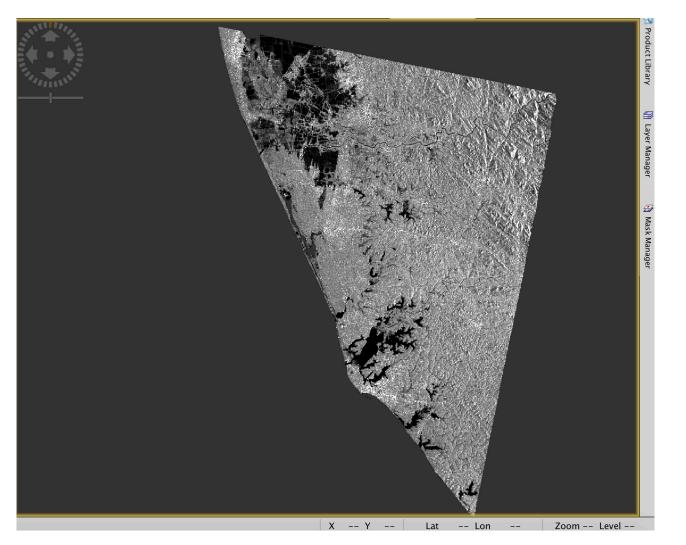
### Example: Preprocessing – Geometric Calibration Select "Radar- Geometric- Terrain Correction- Range Doppler"

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"

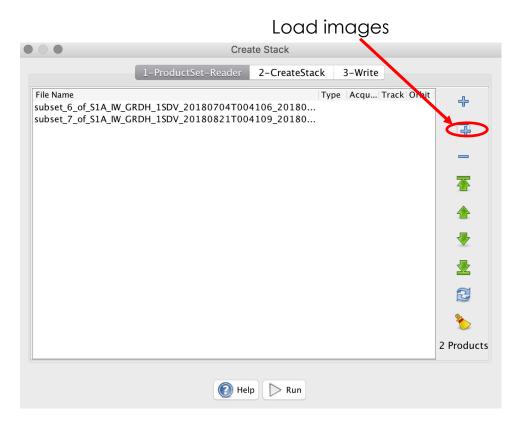


#### Data Preparation Stack the two images

#### Select "Radar>Coregistration>Stack Tools>Create Stack

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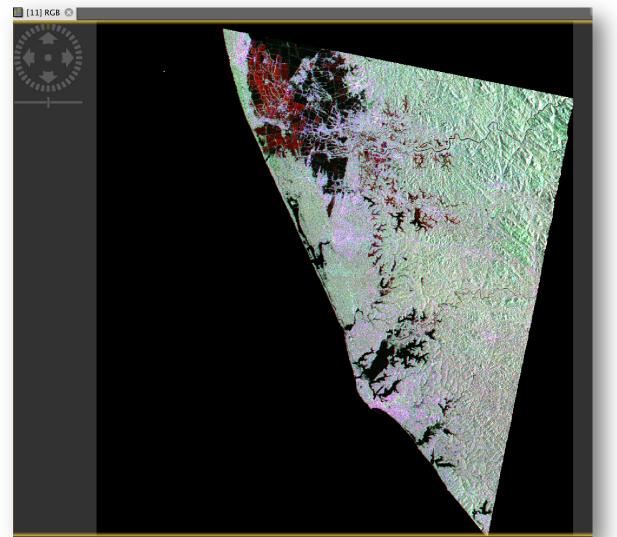
## Data Preparation Stack the two images



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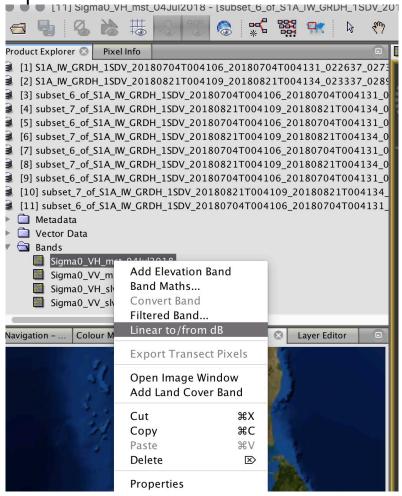
### Data Preparation Create a Multi-temporal RGB

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.

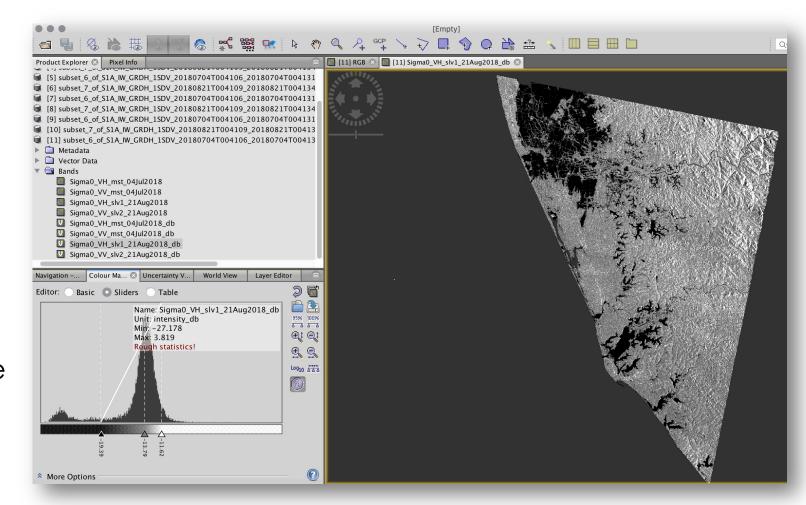


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# Applying a Threshold to Separate Water and Land

#### 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
- Select the value that separates water from everything else. In this case -19.39 dB



#### Classifying Water and Land by Creating a Threshold

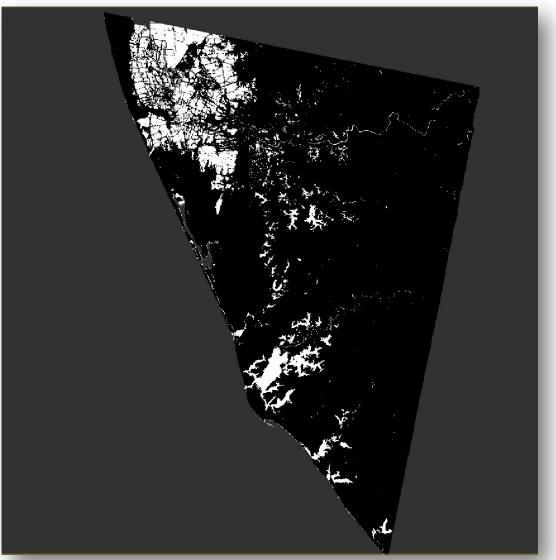
Select "Raster-Band-Math"

- 1. To segment the image, apply band math
- Edit the expression so that it indicates:
   255\*(Sigma0\_VH<-19.39)</li>
- 3. The result will be an image where water will have a value of 255. Call this new image "water"

$\bullet \odot \bullet$	Band Maths
Target product:	
[11] subset_6	_of_S1A_IW_GRDH_1SDV_20180704T004106_20180704T004131_022637_0273E1_B4B0_Cal_Spk_TC_Stack
Name:	new_band_6
Description:	
Unit:	
Spectral wavelen	gth: 0.0
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🔽 Replace NaN	l and infinity results by NaN
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Band maths expr	ression:
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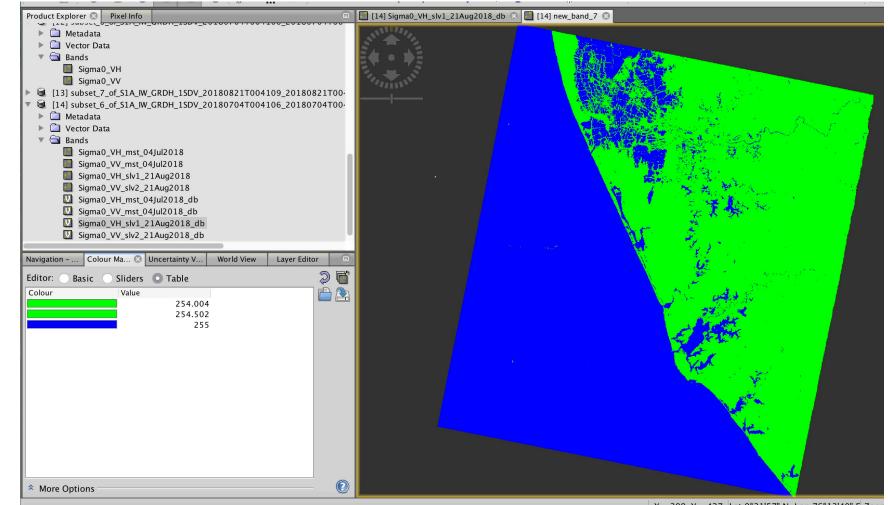
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#### Threshold Result to Separate Water and Land



#### Result: Threshold to Separate Water and Land

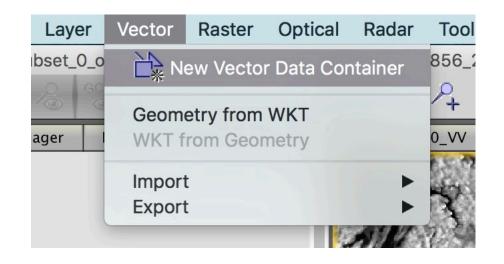
To change the colors, go to the color manipulation window on the bottom left and select **Table**. There you can assign a color to each of the 3 classes.



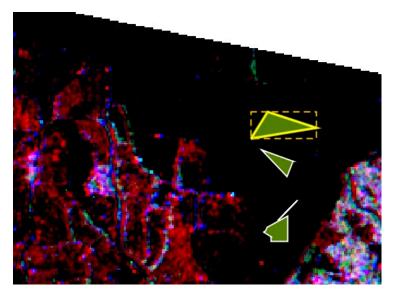
# Supervised Classification

#### 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.



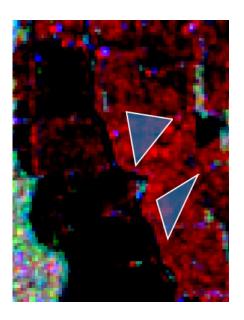


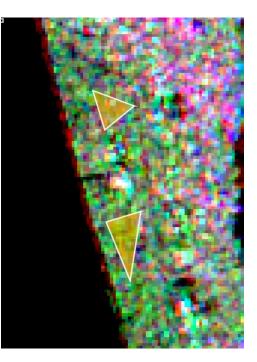


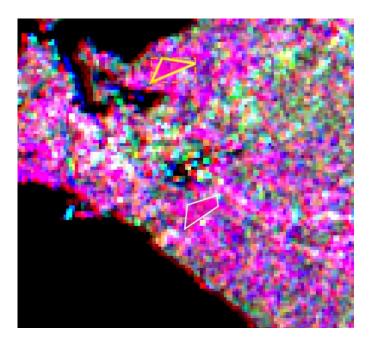
#### Training Area Selection

2. Define the remaining training areas:

- Repeat these same steps for each class.
  - flood water, dry land, wet land







#### Running the Random Forest Classifier

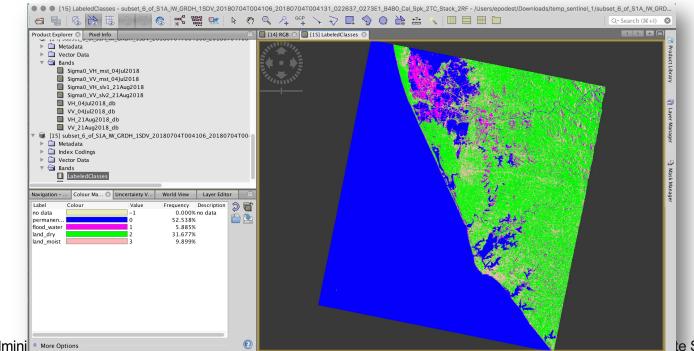
- 3. Run the Random Forest Classification by:
  - selecting in the top menu Raster >Classification>Supervised Classification > Radom Forest Classifier
  - in the pop-up window, select the file that you want to classify. To load it, select the add-opened files on the column on the right (the second one 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.

Random Forest Classifier	
ProductSet-Reader Random-Forest-Classifier Write	
Classifier O Train and apply classifier	Random Forest Classifier
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Train on Raster O Train on Vectors	Target Product
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: permanent_water flood_water	
land_dry land_moist	
land_moist	
	Name:
Feature Selection	subset_6_of_S1A_IW_GRDH_1SDV_20180704T004106_20180704T004131_022637_0273E1_B4B0_Cal_Spk_2TC_Sta
Feature bands: Sigma0_VH_mst_04Jul2018 Sigma0_VV_mst_04Jul2018	Save as: BEAM-DIMAP
Sigma0_VH_slv1_21Aug2018	
Sigma0_VV_sIv2_21Aug2018 Sigma0_VH_mst_04Jul2018_db	Directory:
Sigma0_VV_mst_04Jul2018_db Sigma0_VH_slv1_21Aug2018_db	/Users/epodest/Downloads/temp_sentinel_1
Sigma0_VV_SIV2_21Aug2016_db	

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#### 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.



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#### Running the Random Forest Classifier

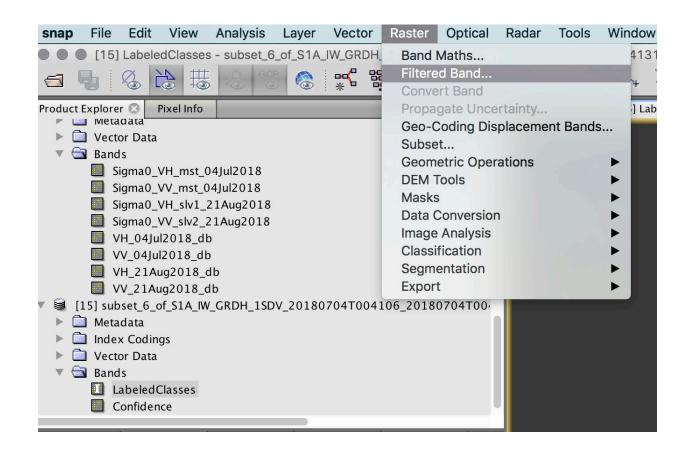
#### 5. Accuracy assessment:

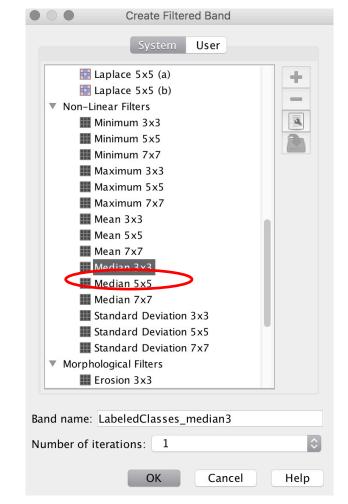
- while Random Forest is running, a separate text window will display the classification validation results:

```
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 drv
   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:
                                        514 (41.6194%)
   class 0.0: permanent water
   class 1.0: flood_water
                                        302 (24.4534%)
                                        263 (21.2955%)
   class 2.0: land dry
                                        156 (12,6316%)
   class 3.0: land_moist
```

## Refining Your Classification Results

#### 6. Refine the classification results by applying a filter:





## Refining Your Classification Results

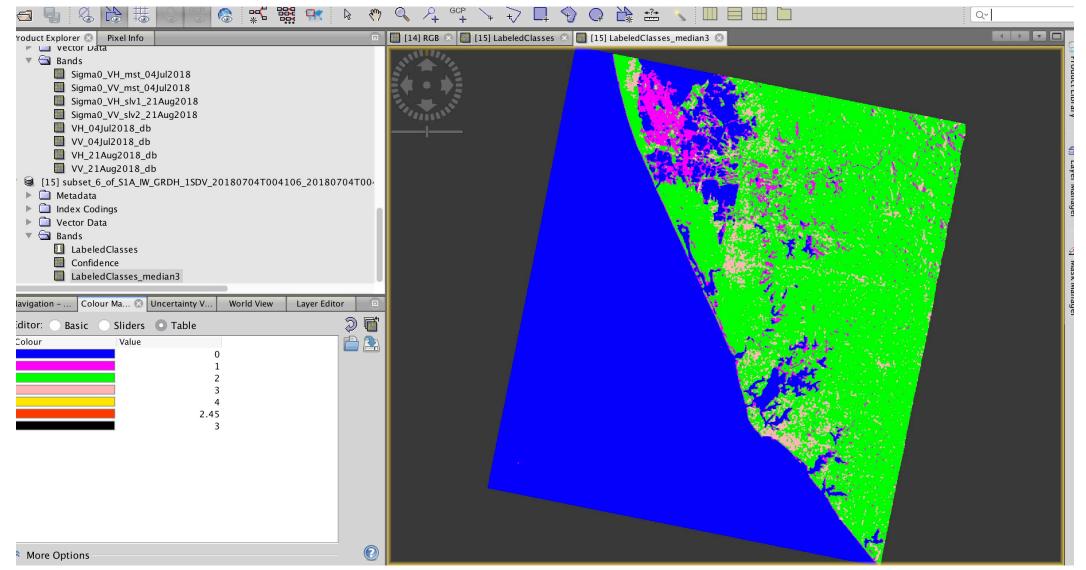
#### 7. Go to the Color Manipulation Window

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Sigma0_VV_mst_04Jul2018	
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VH_04Jul2018_db	
VV_04Jul2018_db	
VH_21Aug2018_db	
VV_21Aug2018_db	
[15] subset_6_of_S1A_IW_GRDH_1SDV_20180704T004106_20	180704T00 <sup>,</sup>
Metadata	
Index Codings	
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Confidence	
LabeledClasses_median3	
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Min:	Max:
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Under the "Table" tab assign numbers and colors to your classes

Navigation –	Colour Ma 🙁	Uncertainty V	World View	Layer Editor	
Editor: 🔵 Bas	sic Sliders	Table			) 📹
Colour	Value				
		0			
		1			
		2			
		3			
		2.45			
		3			

### **Refined Classification Results**



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## 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']
- 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 <u>Sentinel-1</u> <u>Toolbox</u>) 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 <u>SRTM 30 meter DEM</u> or the <u>ASTER DEM</u> for high latitudes (greater than 60° or less than 60°).

# Flood Mapping

new_fl	ooding *	Get Link	Save	-	Run	Reset 👻	 *
1	<pre>// Load Sentinel-1 images to map a flooding in Kerala in 2018.</pre>						
2	<pre>// This script was originally written by Simon Ilyushchenko (GEE team)</pre>						
3	// Default location						
i 5	<pre>var geometry = /* color: #d63000 */ee.Geometry.Point([76.40, 9.53]); var pt = geometry</pre>						
6	var pt = geometry						
7	<pre>// Load Sentinel-1 C-band SAR Ground Range collection (log scaling, VV co-polar)</pre>						
8	<pre>var collection = ee.ImageCollection('COPERNICUS/S1_GRD').filterBounds(pt)</pre>						
9	.filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))						
10	.filter(ee.Filter.eq('instrumentMode', 'IW'))						
11	<pre>.filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))</pre>						
12	<pre>.select('VH');</pre>						
13							
14	<pre>// Filter by date // Filter by date // Filter by date // Filter by date</pre>						
15 16	<pre>var before = collection.filterDate('2018-07-04', '2018-07-06').mosaic(); var after = collection.filterDate('2018-08-21', '2018-08-23').mosaic();</pre>						
17	Val alter = cottection. (itterbate( 2010-00-21 , 2010-00-25 ). (inosaic())						
18	<pre>// Threshold smoothed radar intensities to identify "flooded" areas.</pre>						
19	<pre>var SMOOTHING_RADIUS = 100;</pre>						
20	var DIFF_UPPER_THRESHOLD = -3;						
21	<pre>var diff_smoothed = after.focal_median(SMOOTHING_RADIUS, 'circle', 'meters')</pre>						
22	<pre>.subtract(before.focal_median(SMOOTHING_RADIUS, 'circle', 'meters'));</pre>						
23	<pre>var diff_thresholded = diff_smoothed.lt(DIFF_UPPER_THRESHOLD);</pre>						
24							
25	// Display map						
26 27	<pre>Map.centerObject(pt, 13); Map.addLayer(before, {min:-30,max:0}, 'Before flood');</pre>						
28	Map.addLayer(after, {min:-30,max:0}, 'After flood');						
29	<pre>Map.addLayer(after.subtract(before), {min:-10,max:10}, 'After - before', 0);</pre>						
30	<pre>Map.addLayer(diff_smoothed, {min:-10,max:10}, 'diff smoothed', 0);</pre>						
31	Map.addLayer(diff_thresholded.updateMask(diff_thresholded),						
32	<pre>{palette:"0000FF"},'flooded areas - blue',1);</pre>						
33							

#### Flood Mapping Results

