

SAR for Flood Mapping using Google Earth Engine

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28 August 2019

Learning Objectives

By the end of this presentation, you will be able to understand:

- the information content in SAR images relevant to flooding
- how to generate a flood map using Google Earth Engine

Flooding Definition from a Radar Perspective:

The temporary or permanent occurrence of a water surface:

- beneath a vegetation canopy (tall or short standing vegetation)
- without any standing vegetation (referred to as open water)



SAR Signal Scattering Over Inundated Regions

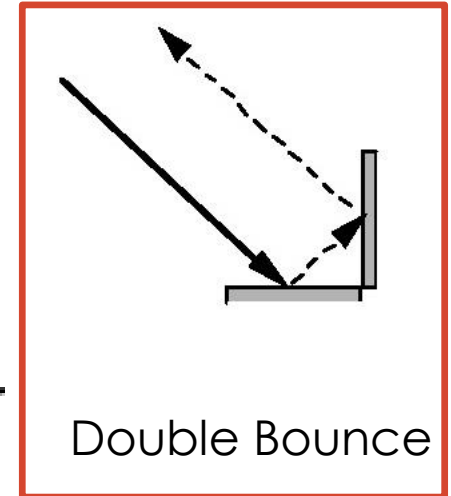
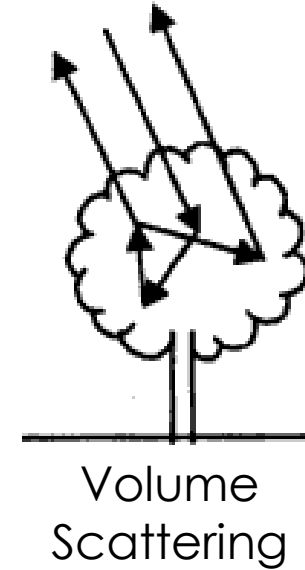
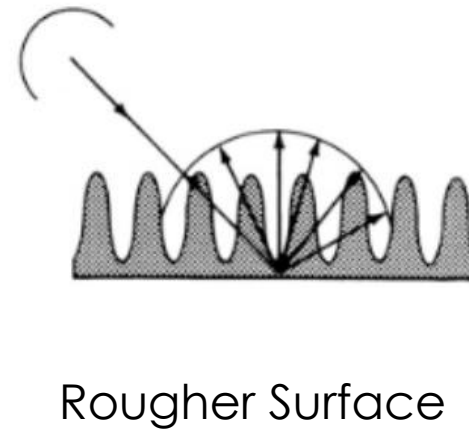
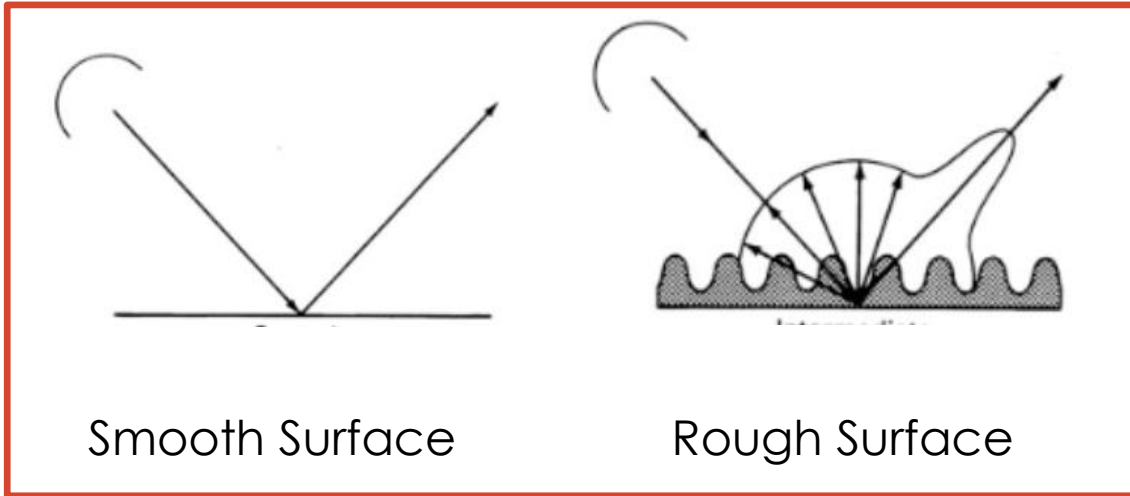
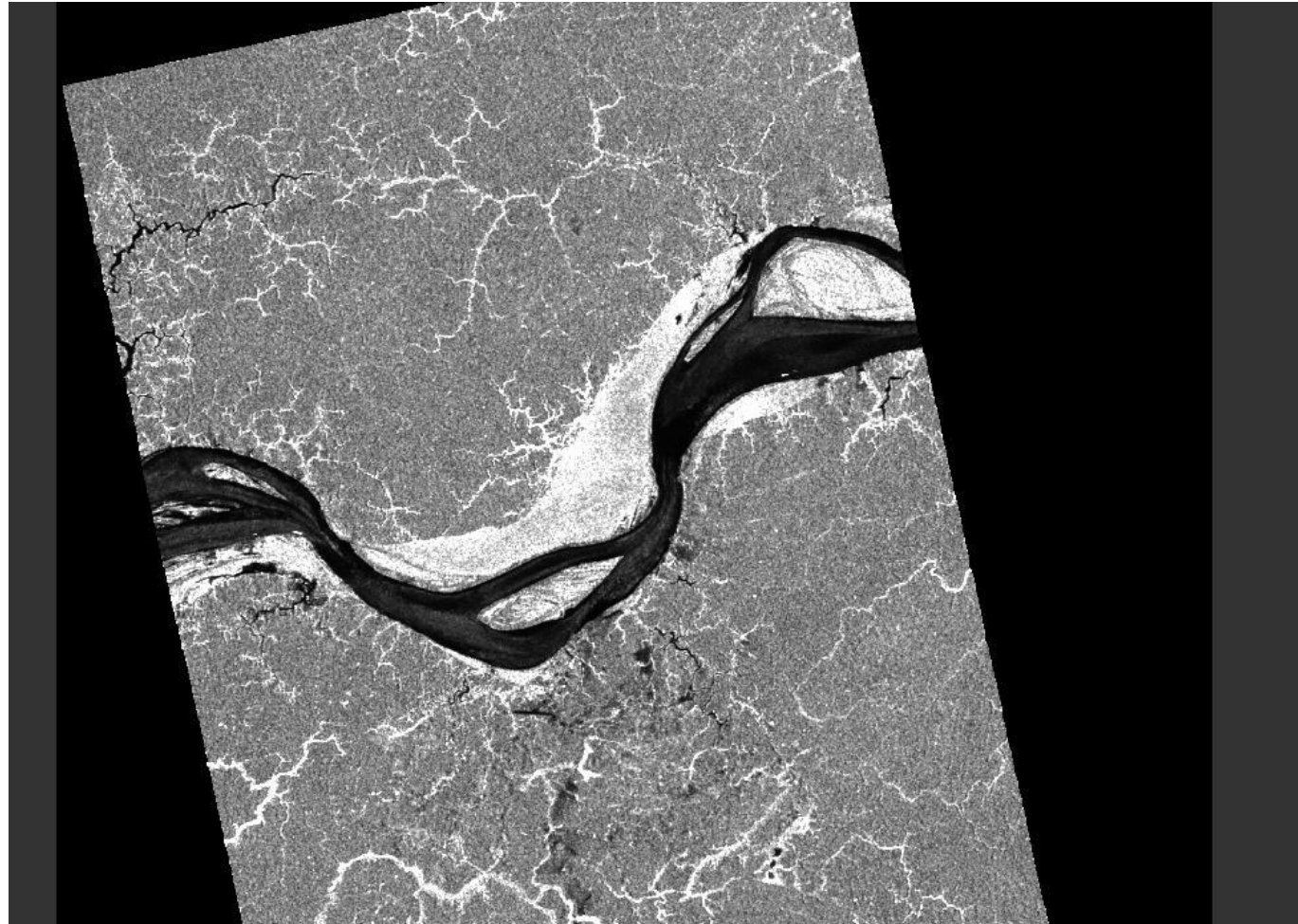


Image Credits: top: Ulaby et al. (1981a)

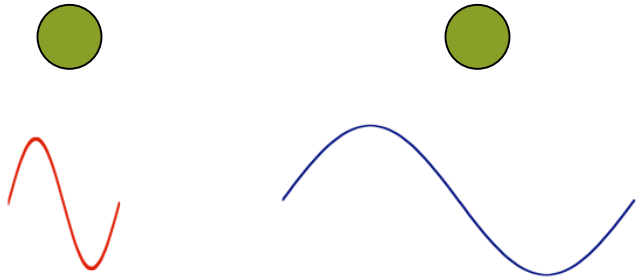
SAR Signal Scattering Over Inundated Regions

PALSAR Image (L-band) near Manaus, Brazil

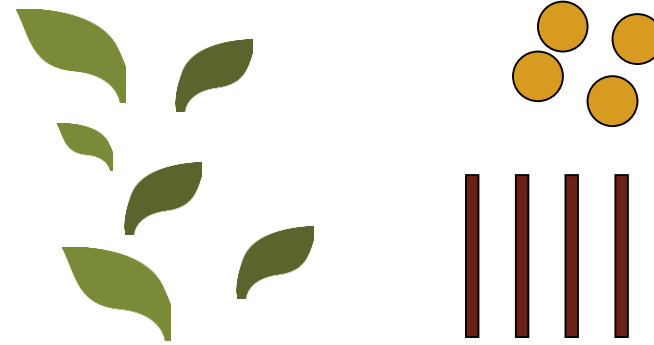


Surface Parameters Related to Structure

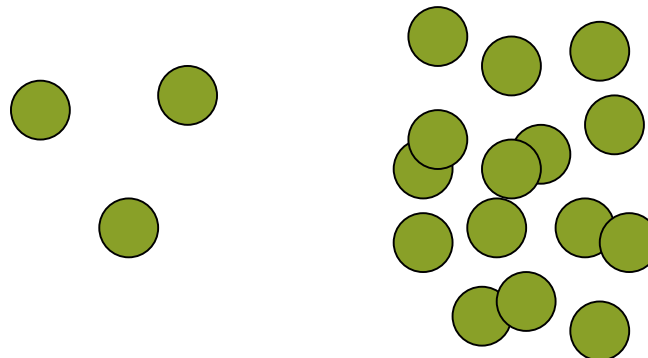
Size Relative to Wavelength



Orientation




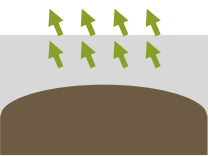
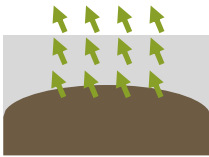
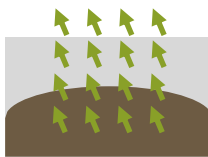


Density



Wavelength and SAR Signal Response Over Flooded Vegetation

- Penetration is the **primary factor** in wavelength selection
- Generally, the longer the wavelength, the greater the penetration into the target

Vegetation			
Dry Alluvium			
	X-band 3 cm	C-band 5 cm	L-band 23 cm

Band Designation*	Wavelength (λ), cm	Frequency (ν), GHz (10^9 cycles \cdot sec $^{-1}$)
Ka (0.86 cm)	0.8 – 1.1	40.0 – 26.5
K	1.1 – 1.7	26.5 – 18.0
Ku	1.7 – 2.4	18.0 – 12.5
X (3.0 cm, 3.2 cm)	2.4 – 3.8	12.5 – 8.0
C (6.0)	3.8 – 7.5	8.0 – 4.0
S	7.5 – 15.0	4.0 – 2.0
L (23.5 cm, 25 cm)	15.0 – 30.0	2.0 – 1.0
P (68 cm)	30.0 – 100.0	1.0 – 0.3

*wavelengths most frequently used in SAR are in parenthesis

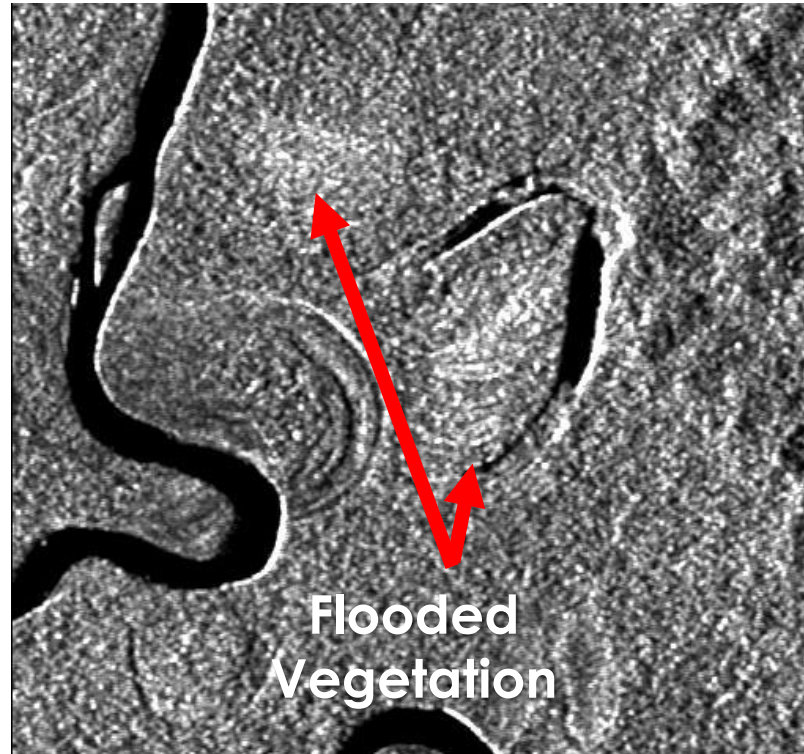
Signal Penetration Over Flooded Vegetation

Multifrequency AIRSAR data in Manu National Park, Peru

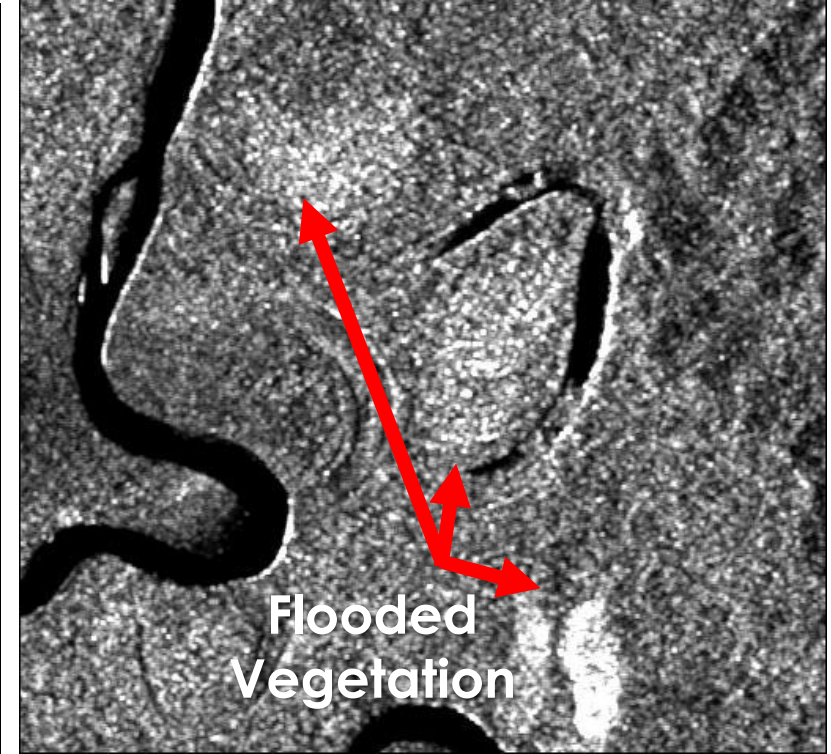
C-Band



L-Band



P-Band



Polarization

- The radar signal is polarized
- The polarizations are usually controlled between H and V:
 - HH: Horizontal Transmit, Horizontal Receive
 - HV: Horizontal Transmit, Vertical Receive
 - VH: Vertical Transmit, Horizontal Receive
 - VV: Vertical Transmit, Vertical Receive
- Quad-Pol Mode: when all four polarizations are measured
- Different polarizations can determine physical properties of the object observed

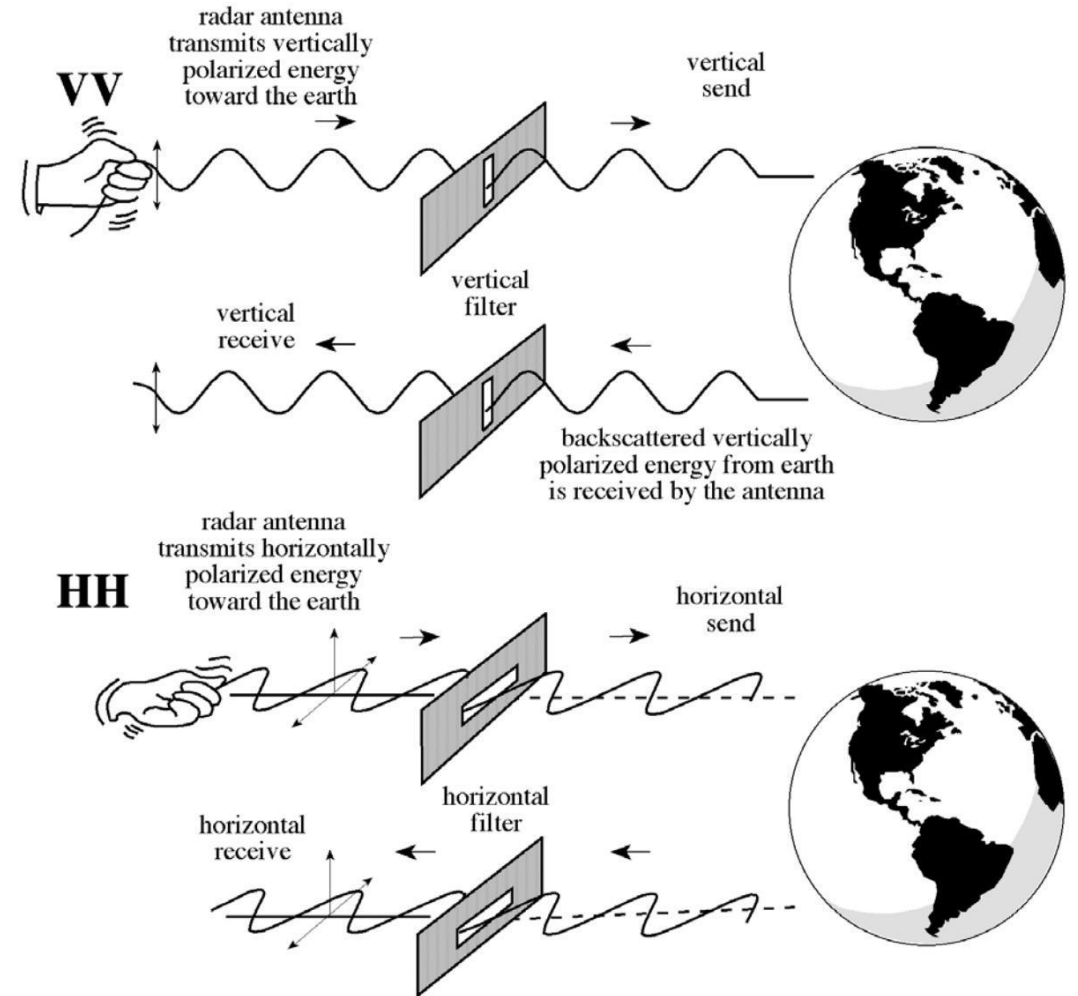
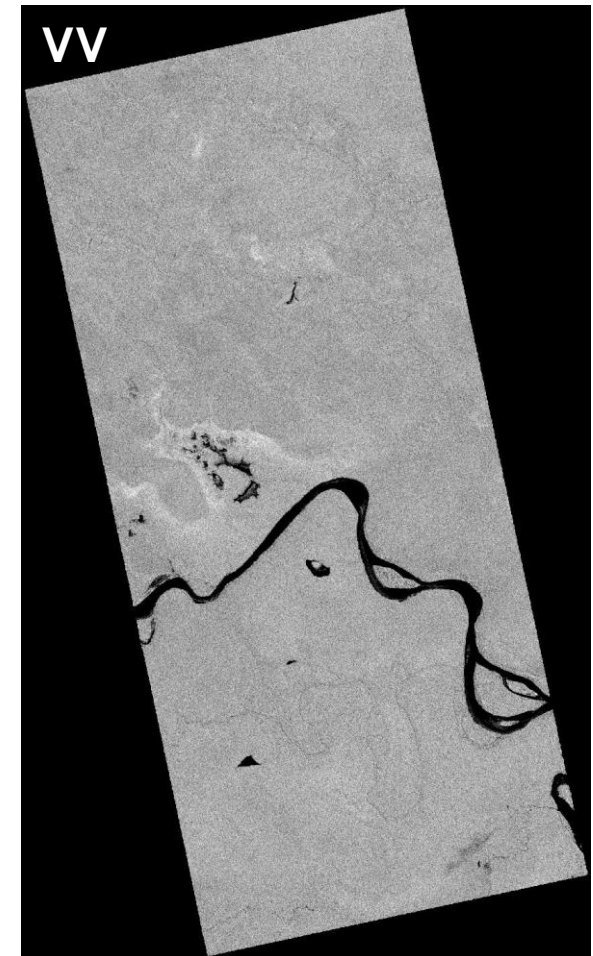
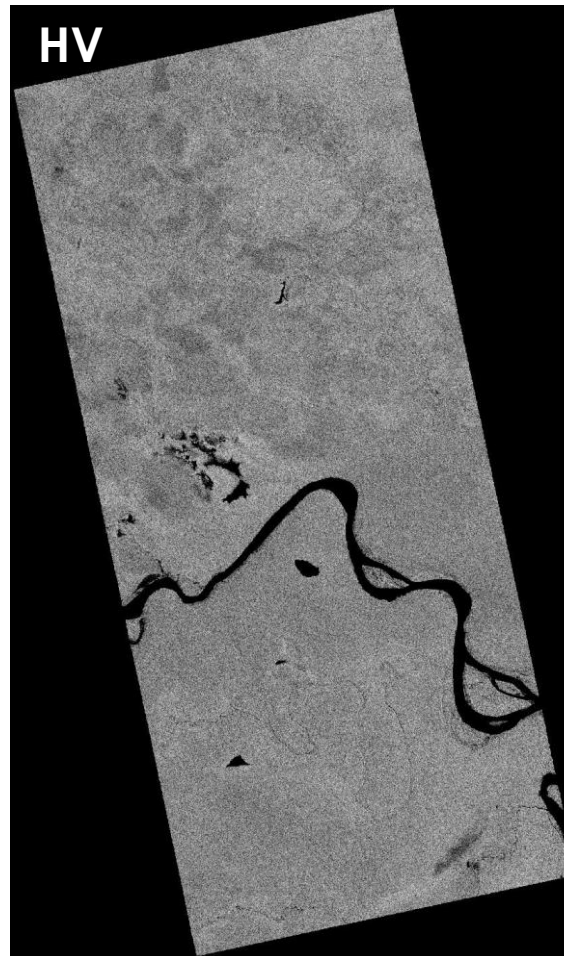
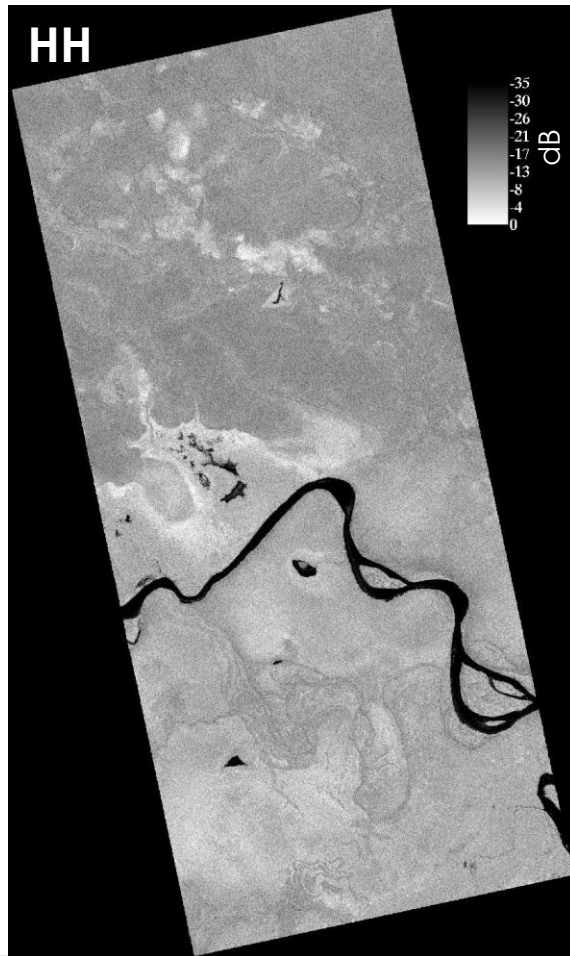


Image Credit: J.R. Jensen, 2000, Remote Sensing of the Environment

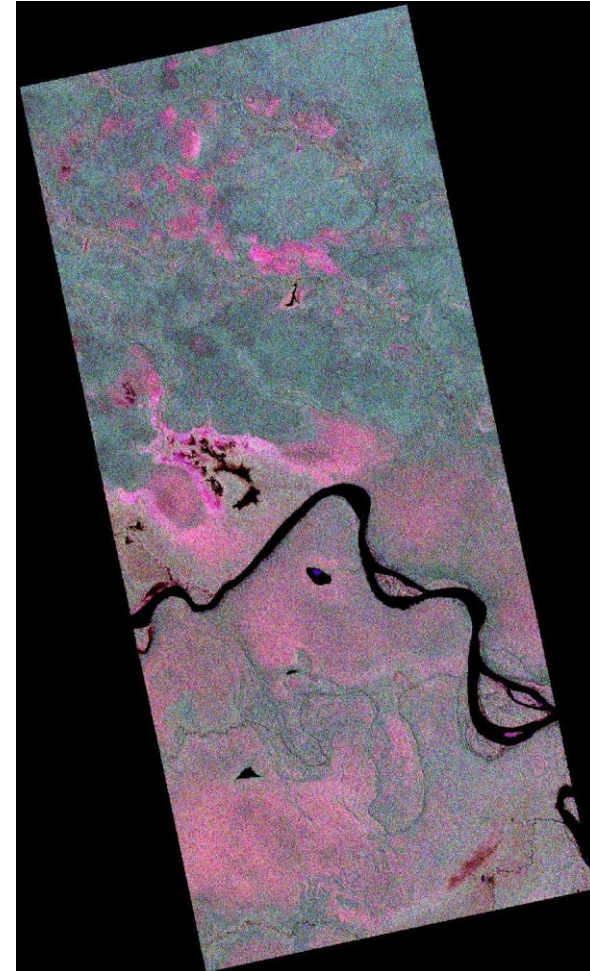
Multiple Polarizations for Detection of Inundated Vegetation

Images from PALSAR (L-band) over Pacaya-Samiria in Peru



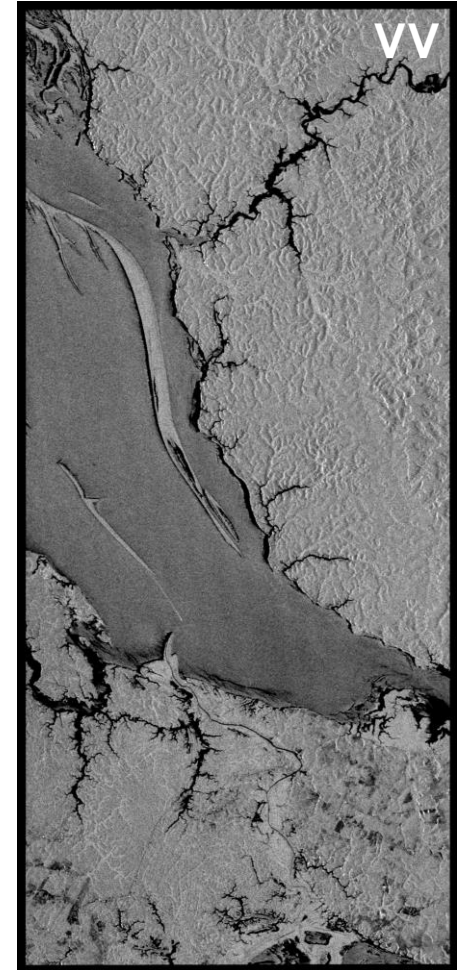
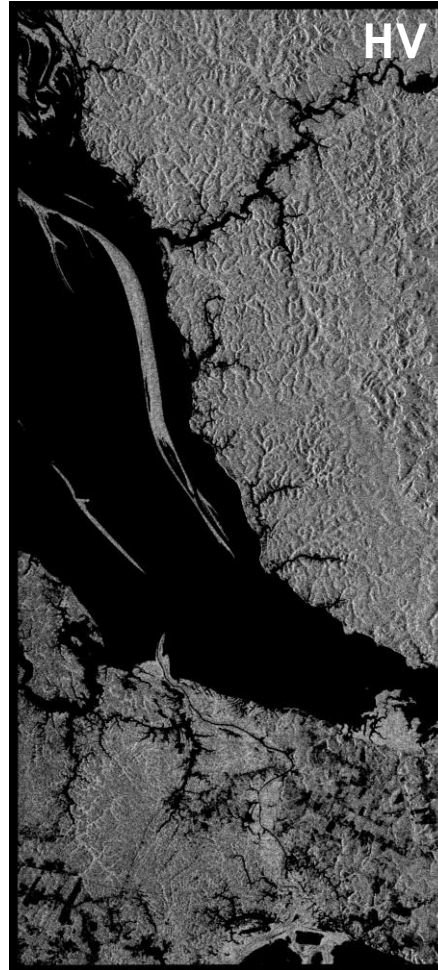
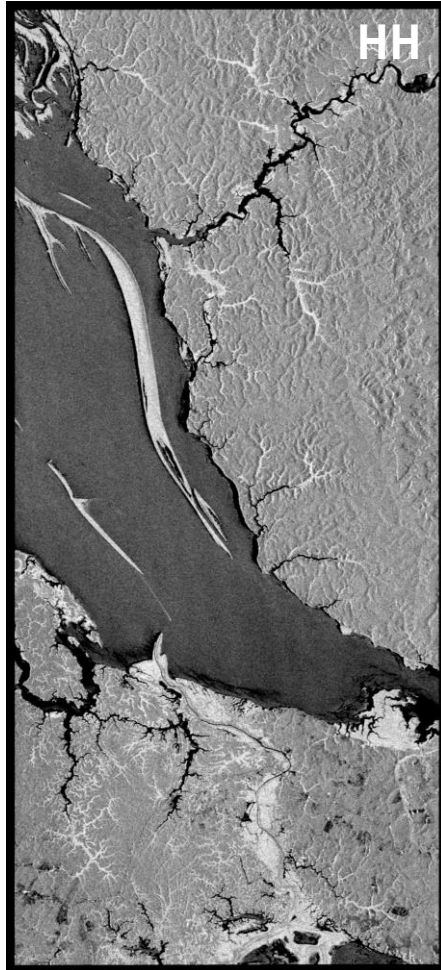
Multiple Polarizations for Detection of Inundated Vegetation

Images from PALSAR (L-band) over Pacaya-Samiria in Peru (HH-HV-VV)



Multiple Polarizations for Detection of Open Water

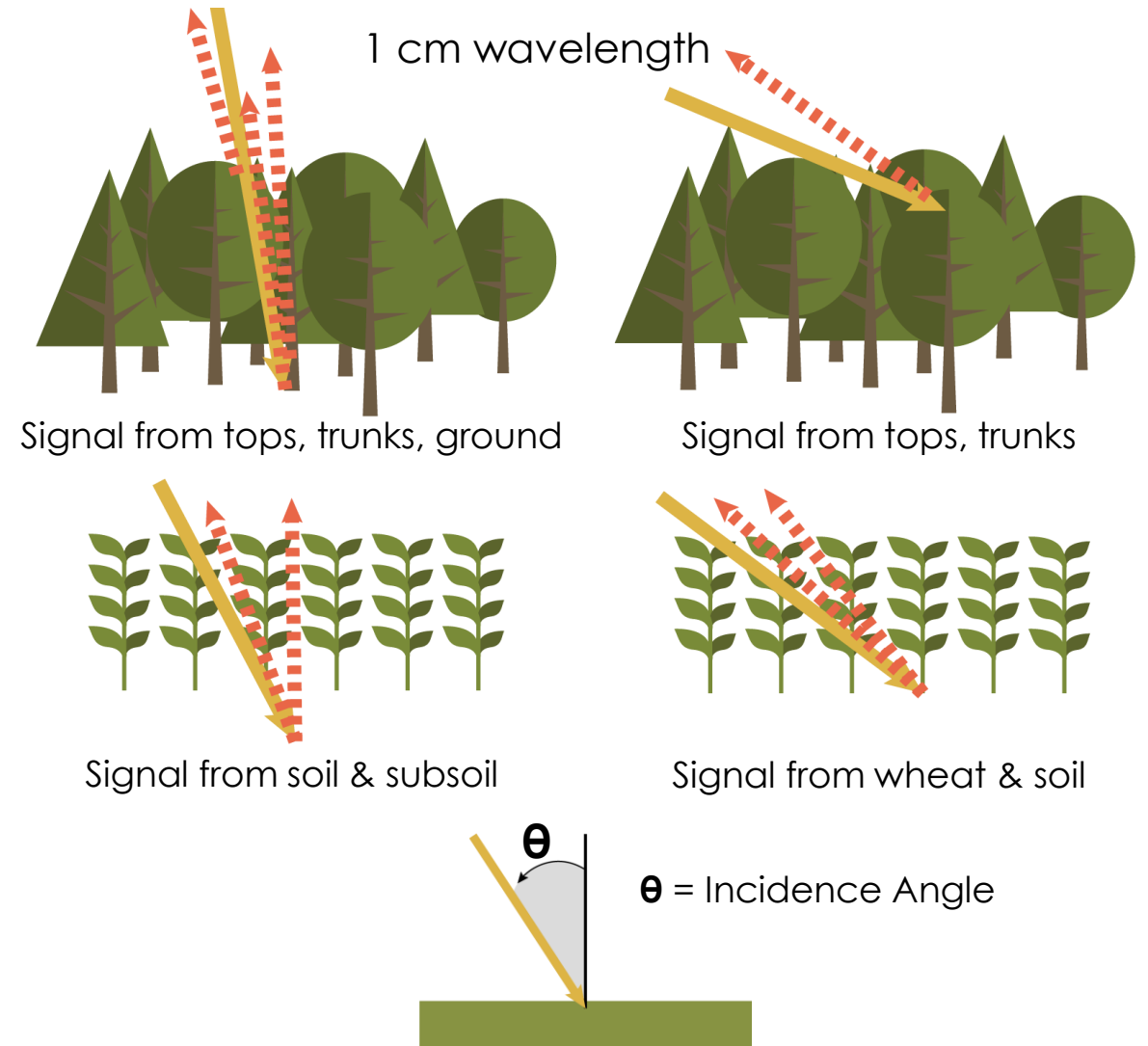
Images from PALSAR (L-band) near Manaus, Brazil



Incidence Angle

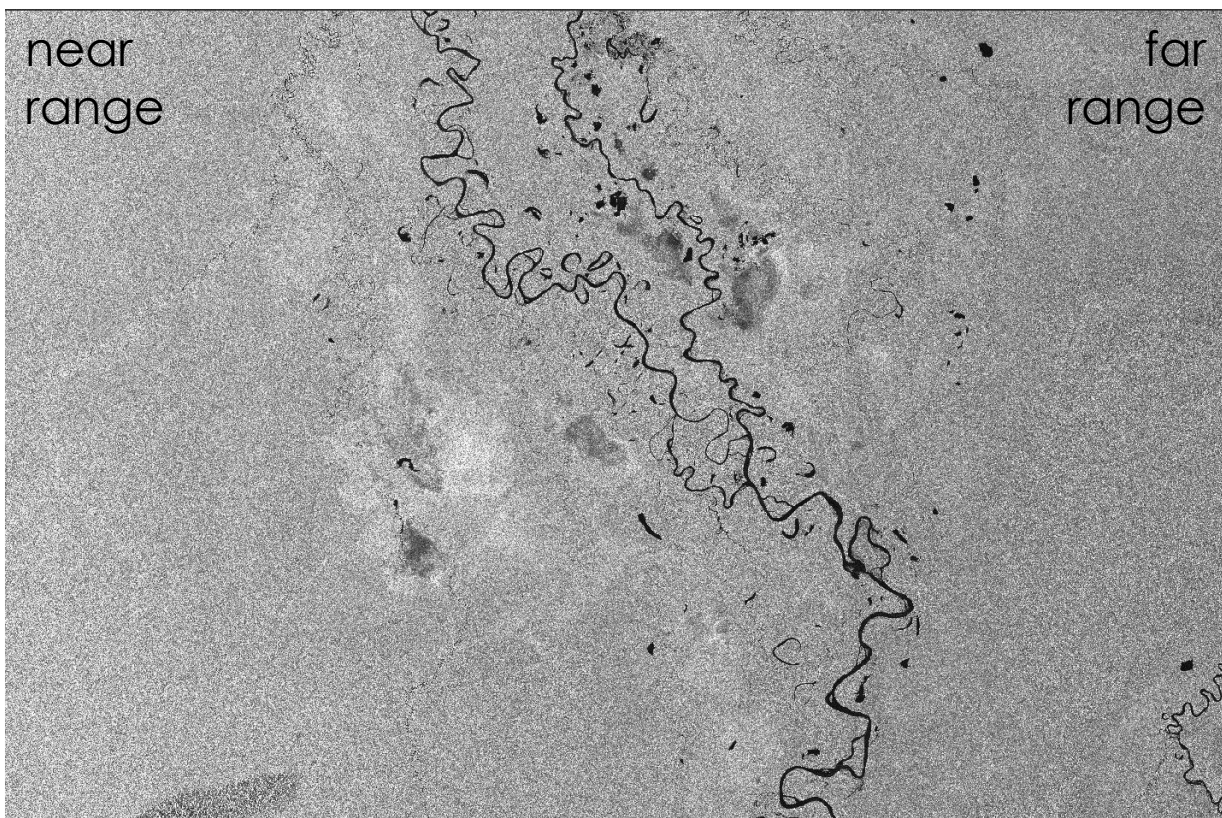
Local Incidence Angle:

- the angle between the direction of illumination of the radar and the Earth's surface plane
- accounts for local inclination of the surface
- influences image brightness
- is dependent on the height of the sensor
- the geometry of an image is different from point to point in the range direction

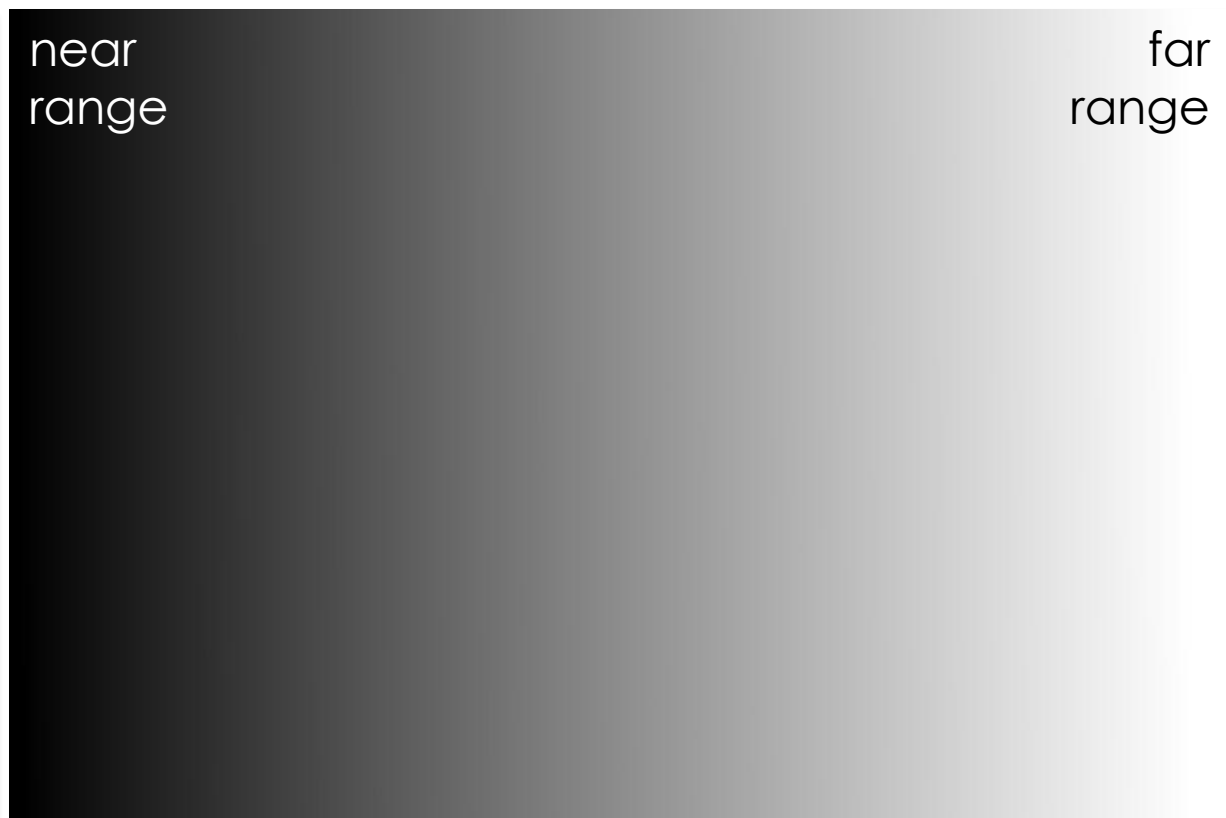


Images Based on: top: Ulaby et al. (1981a), bottom: ESA

Effect of Incidence Angle Variation

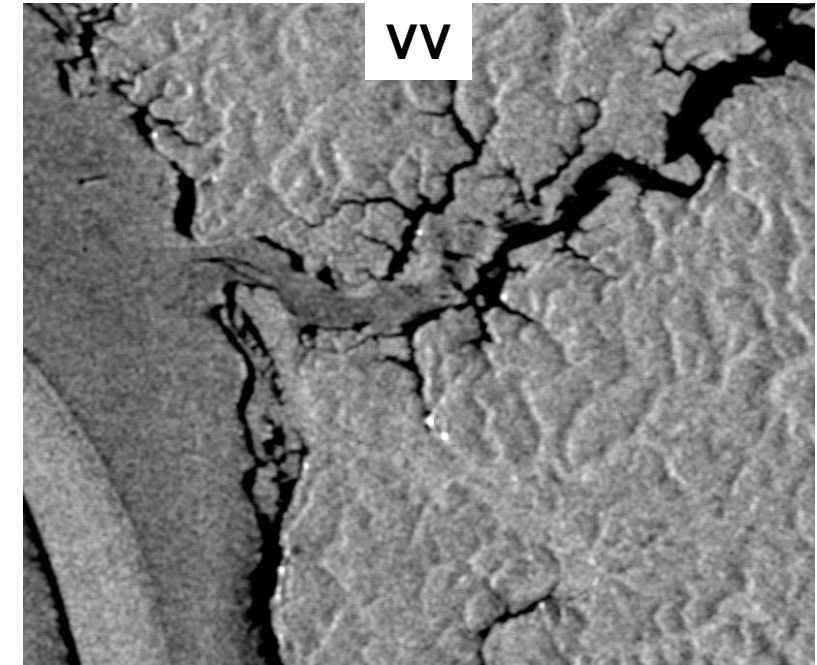
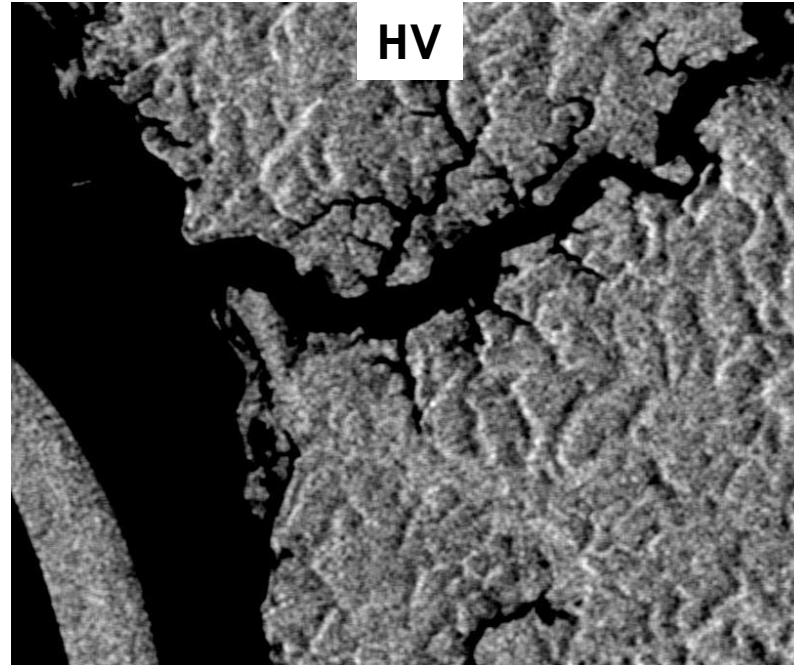
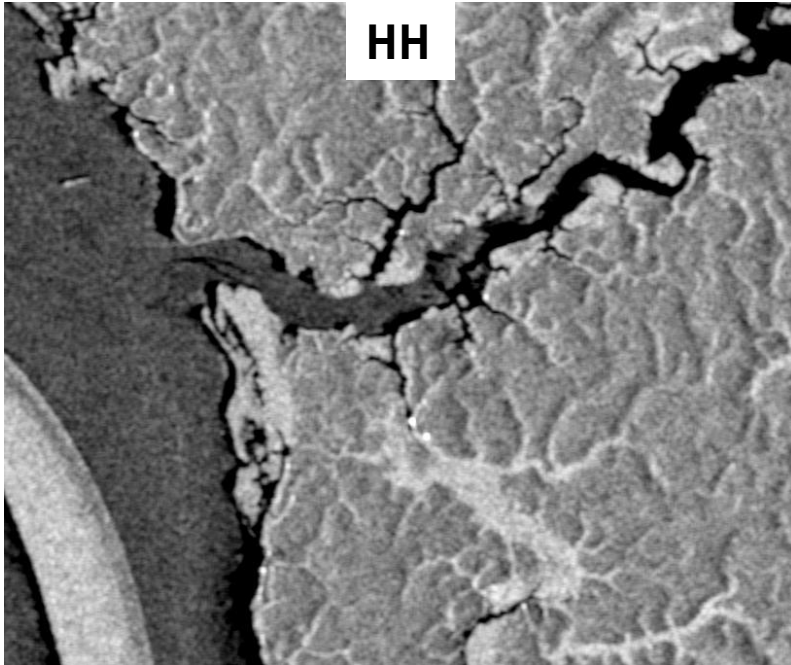


Sentinel-1



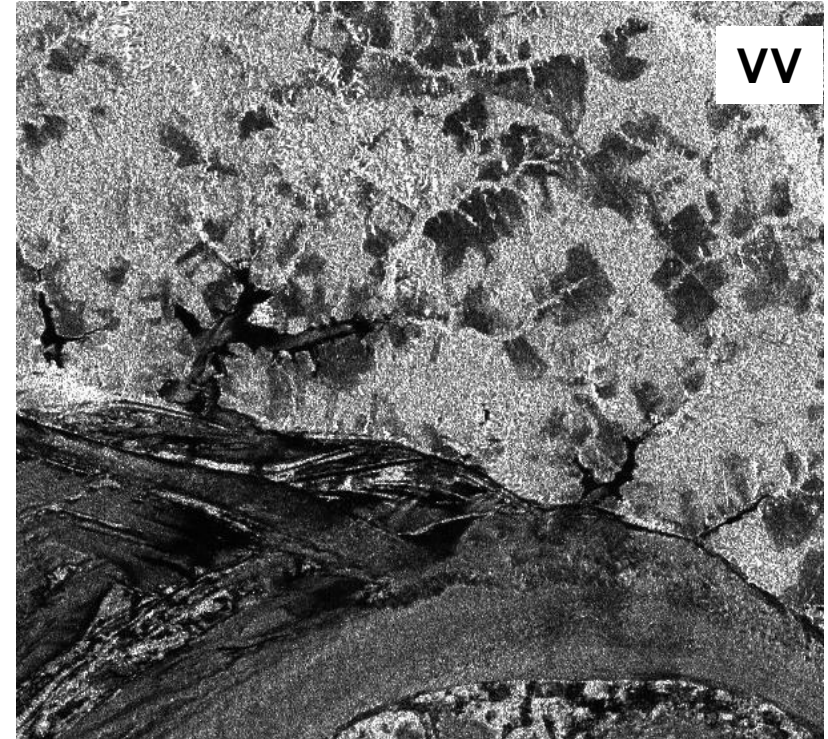
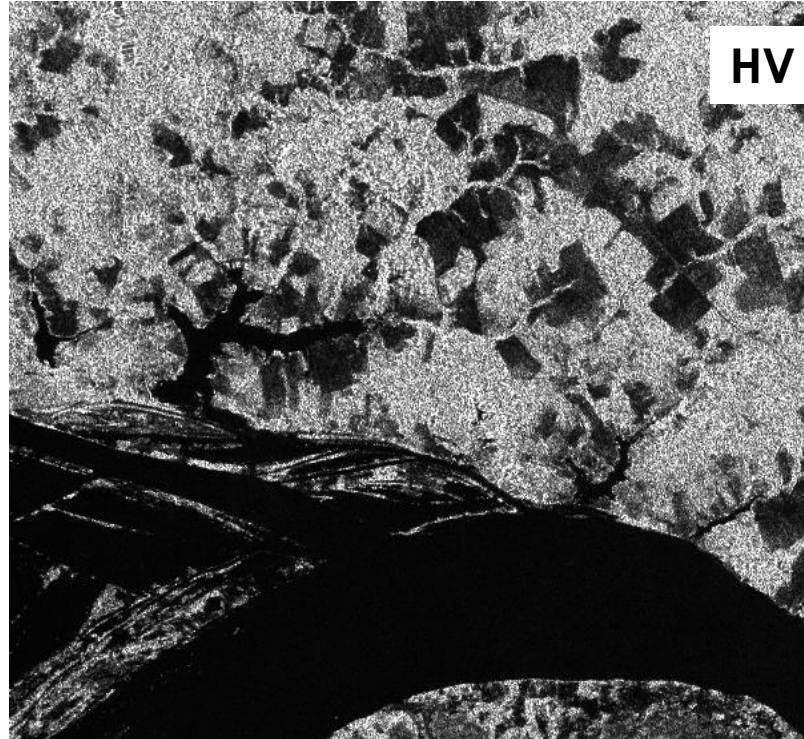
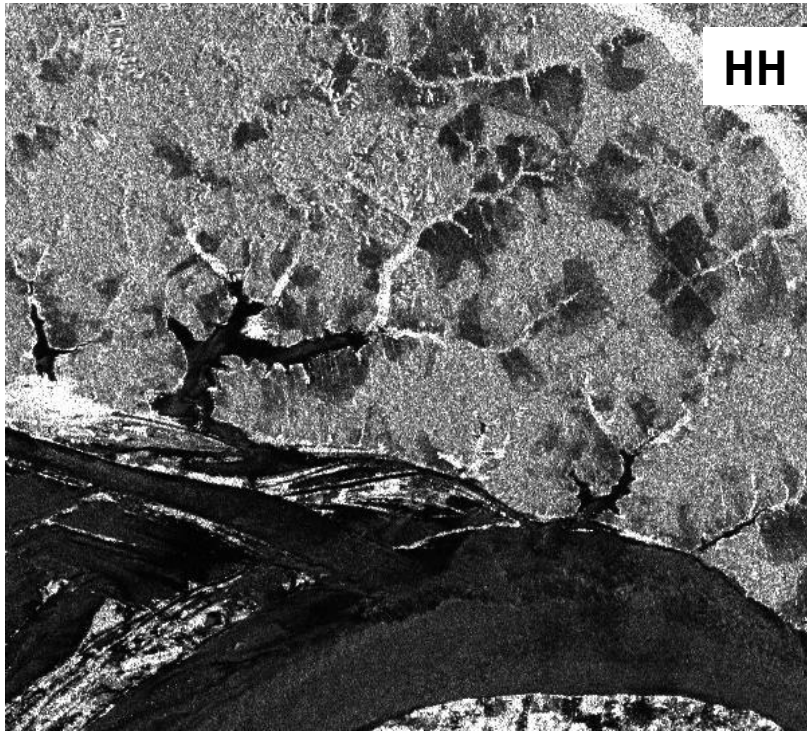
Source of Confusion: Wind

Images from PALSAR (L-band) near Manaus, Brazil



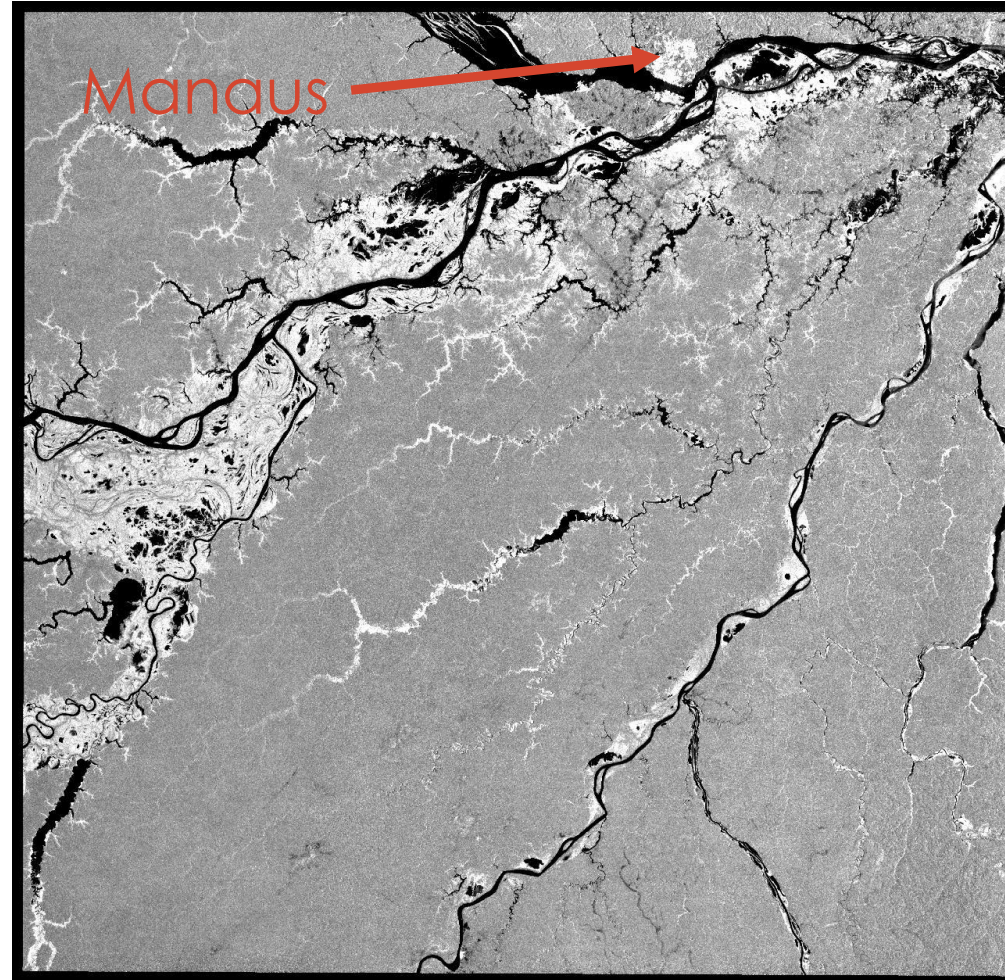
Source of Confusion: Open water and low vegetation

Images from PALSAR (L-band) near Manaus, Brazil

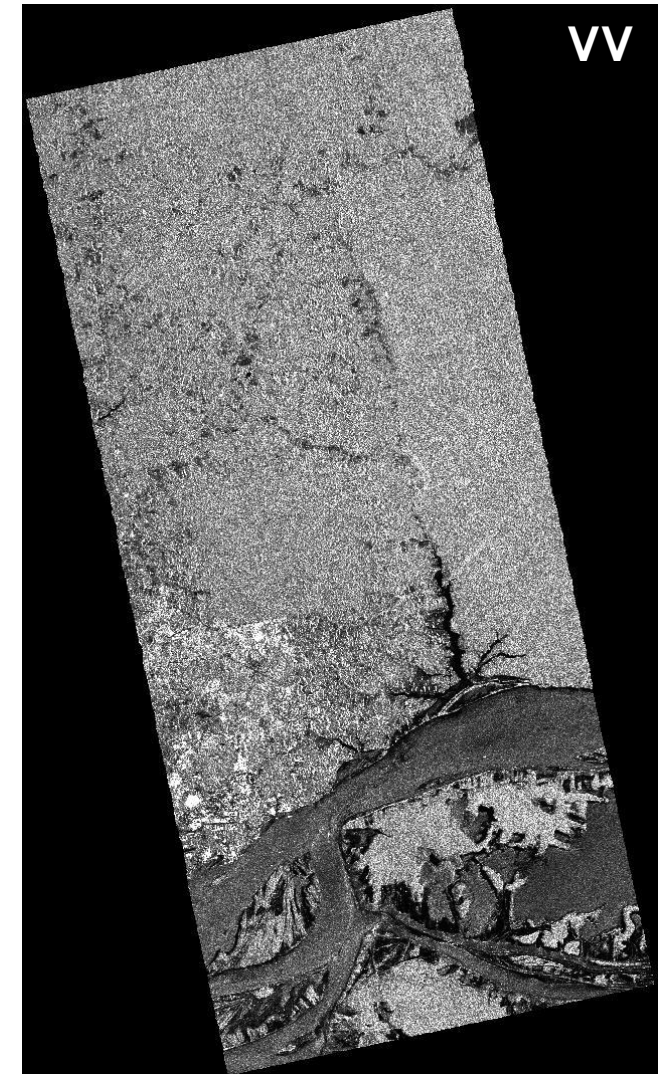
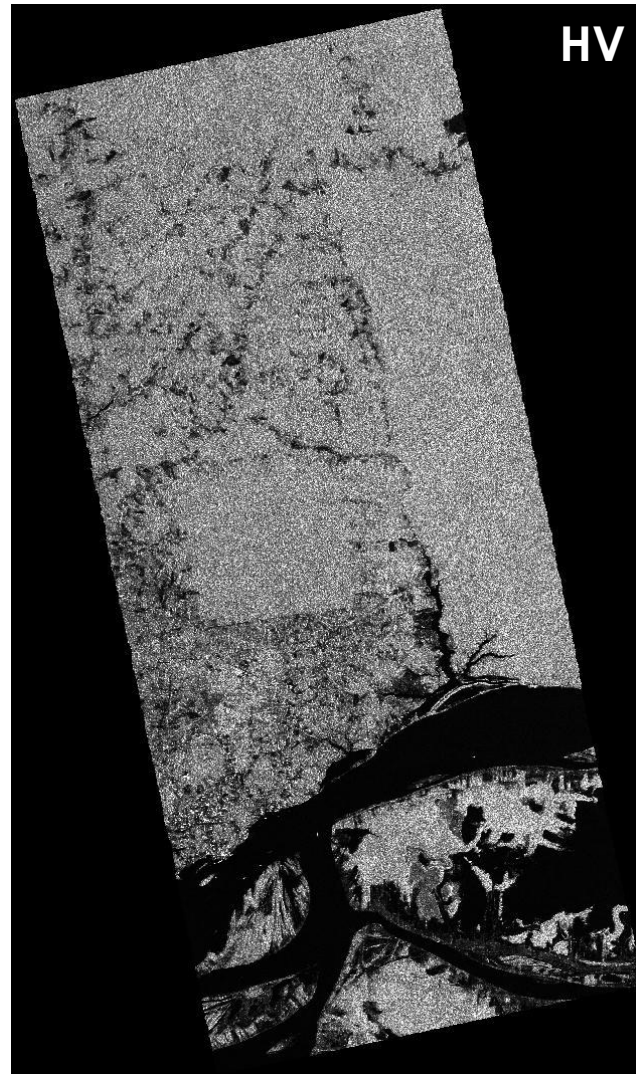
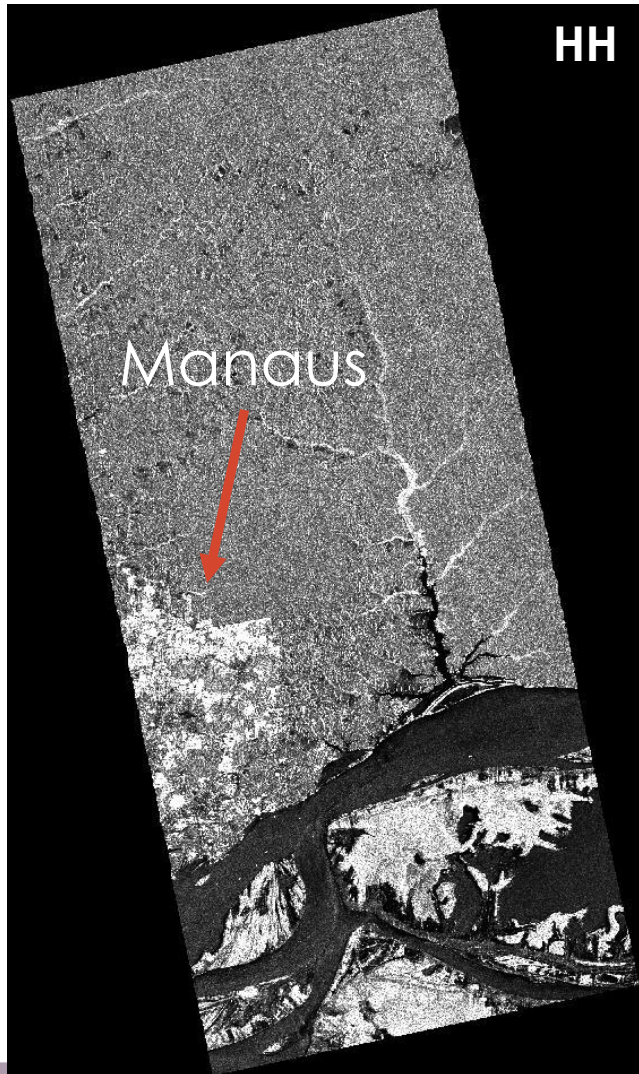


Source of Confusion: Urban Areas

Images from PALSAR (L-band) near Manaus, Brazil



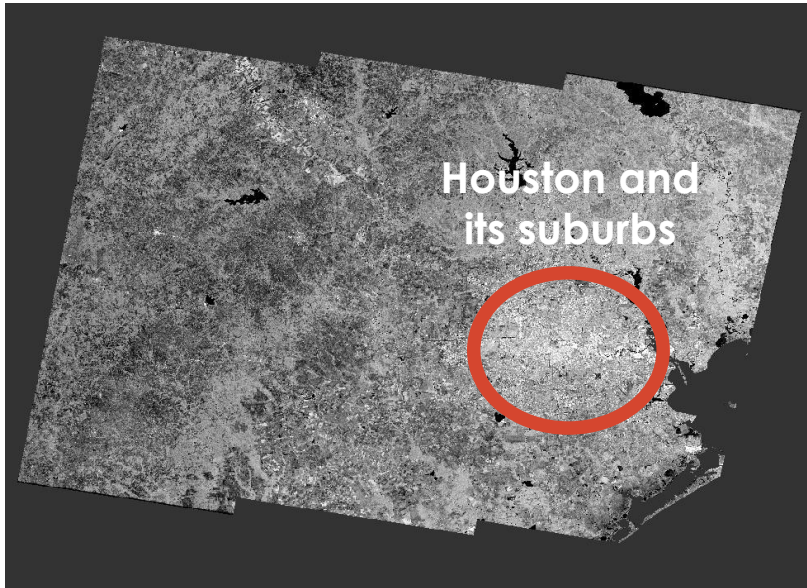
Source of Confusion: Urban Areas with Different Polarizations



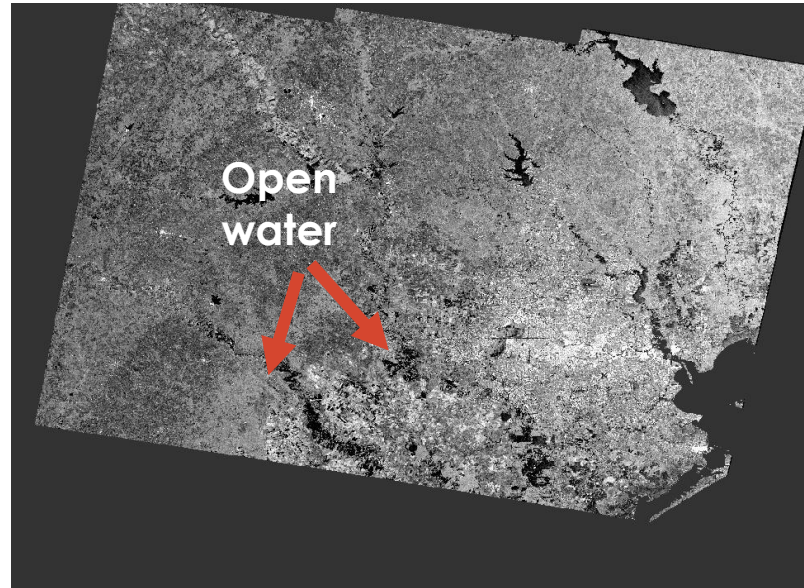
Hurricane Harvey in Houston Texas – August 2017

Sentinel-1 Images (VV)

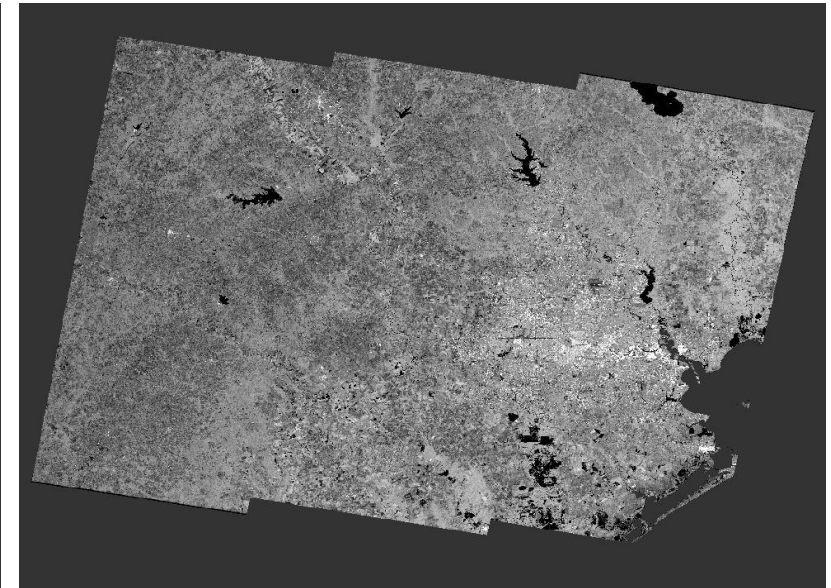
Aug 18, 2017
(Before the Event)



Aug 30, 2017
(During the Event)

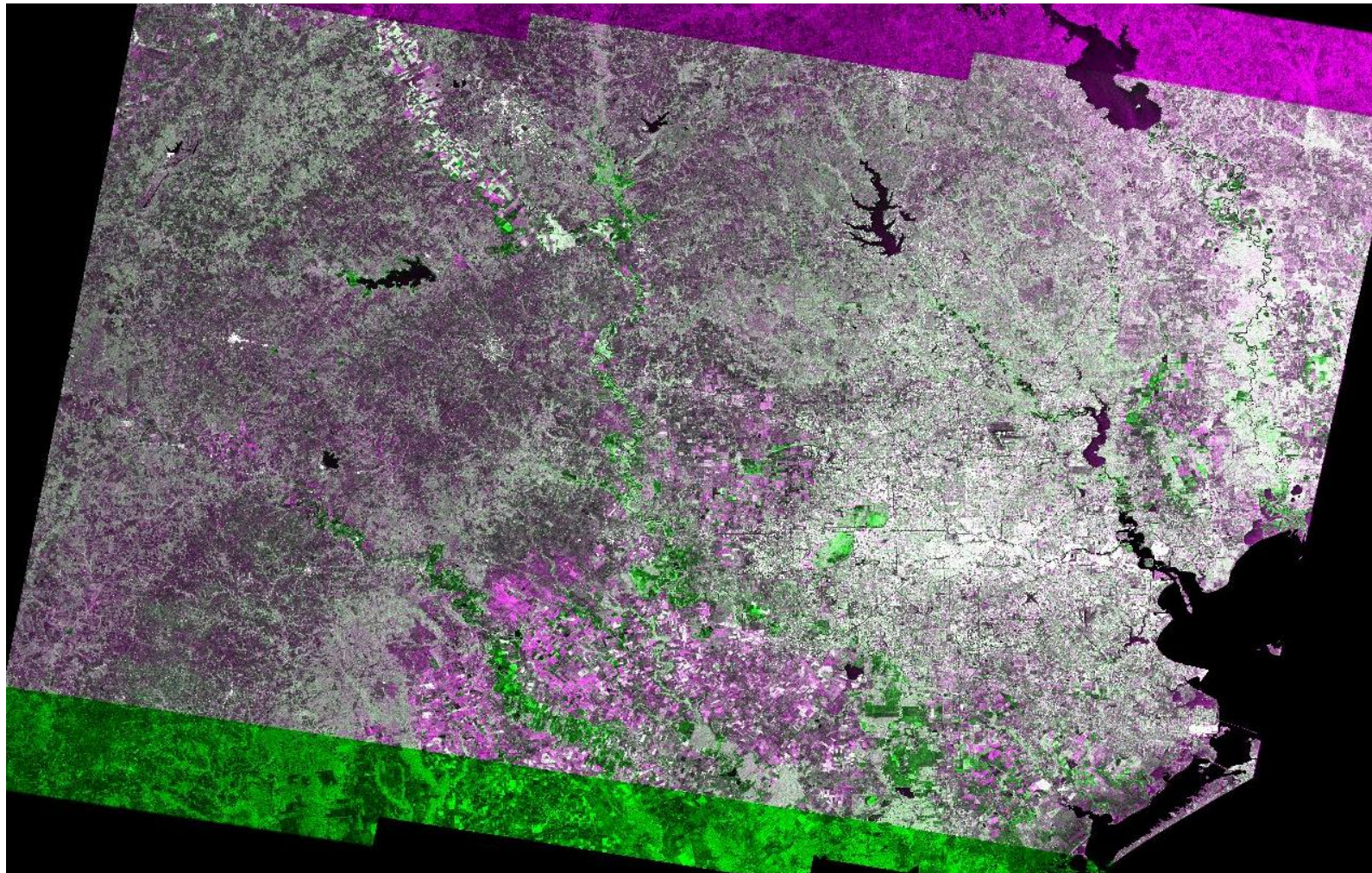


Sep 5, 2017
(After the Event)



Hurricane Harvey in Houston Texas - Before and During the Event

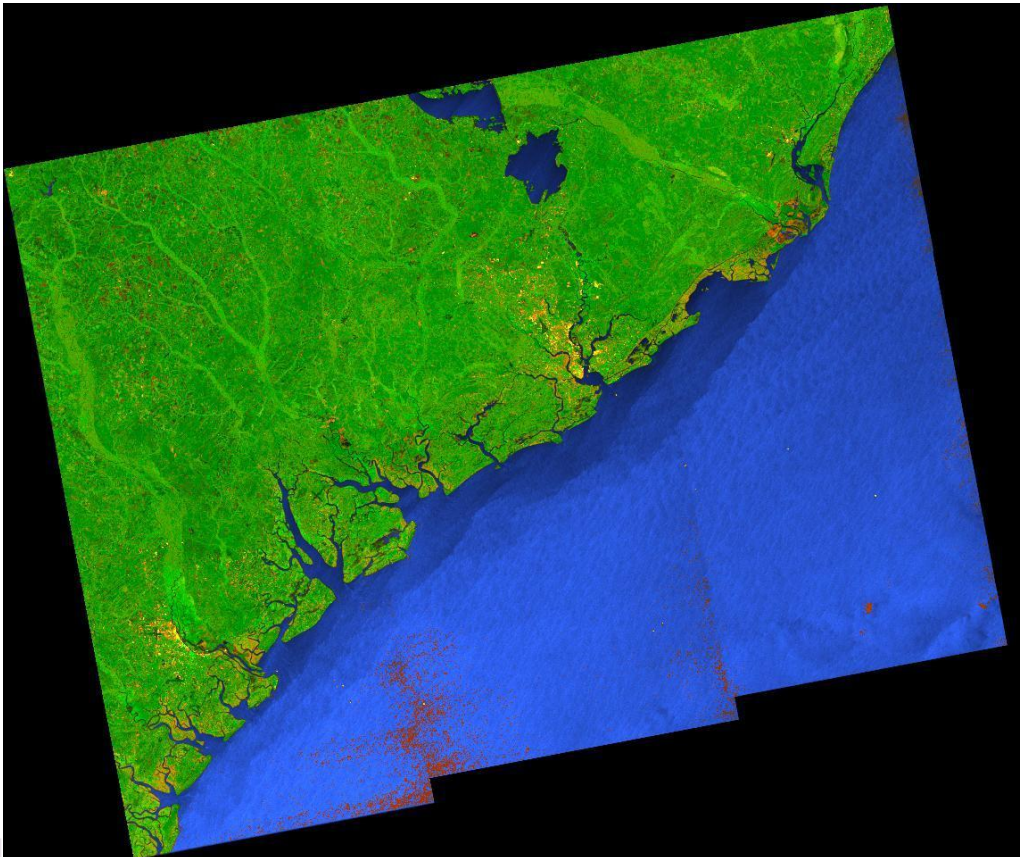
Sentinel-1 Radar Images, RGB: Aug 30 (R), Aug 18 (G), Aug 30 (B)



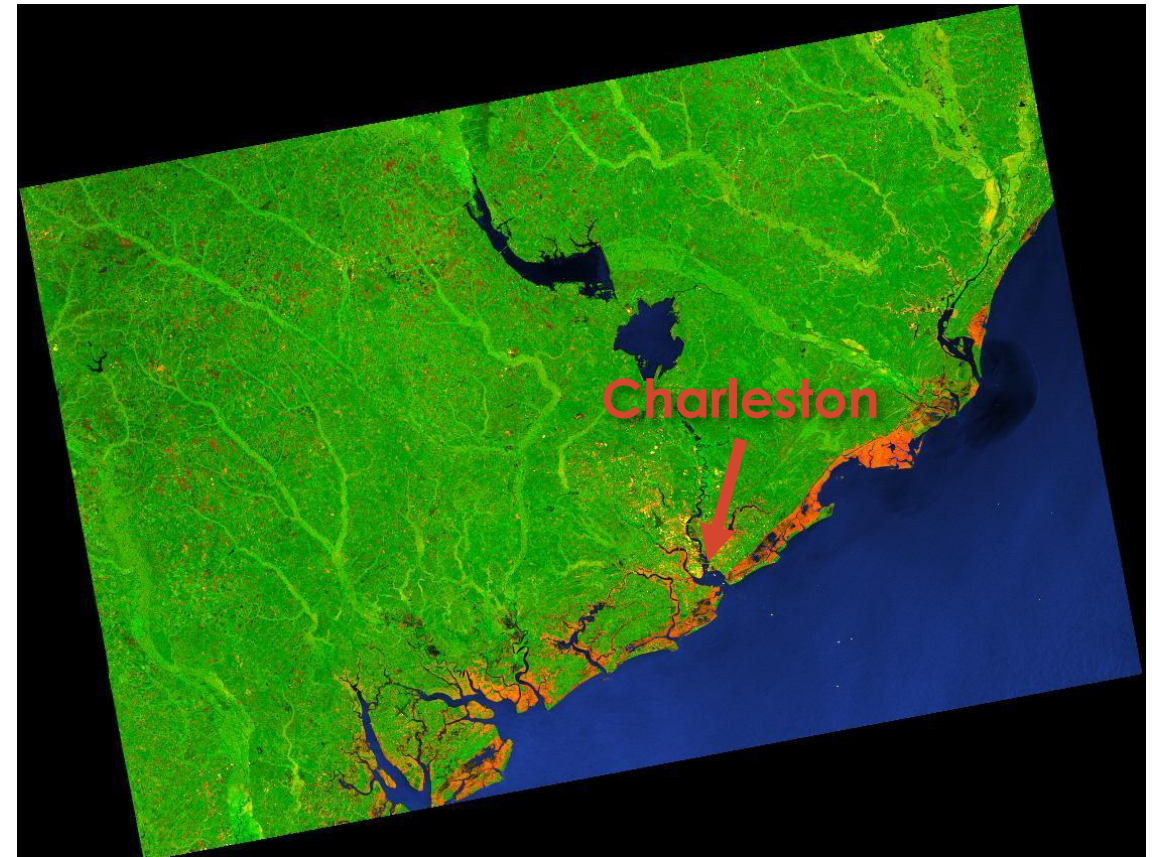
Hurricane Matthew on the East Coast of the U.S. – Coastal Flooding

Sentinel-1 Radar Images (R-VV; G-VH; B-VV/VH)

Oct 4, 2016
(Before the Event)



Oct 16, 2016
(After the Event)



Geometric Distortion

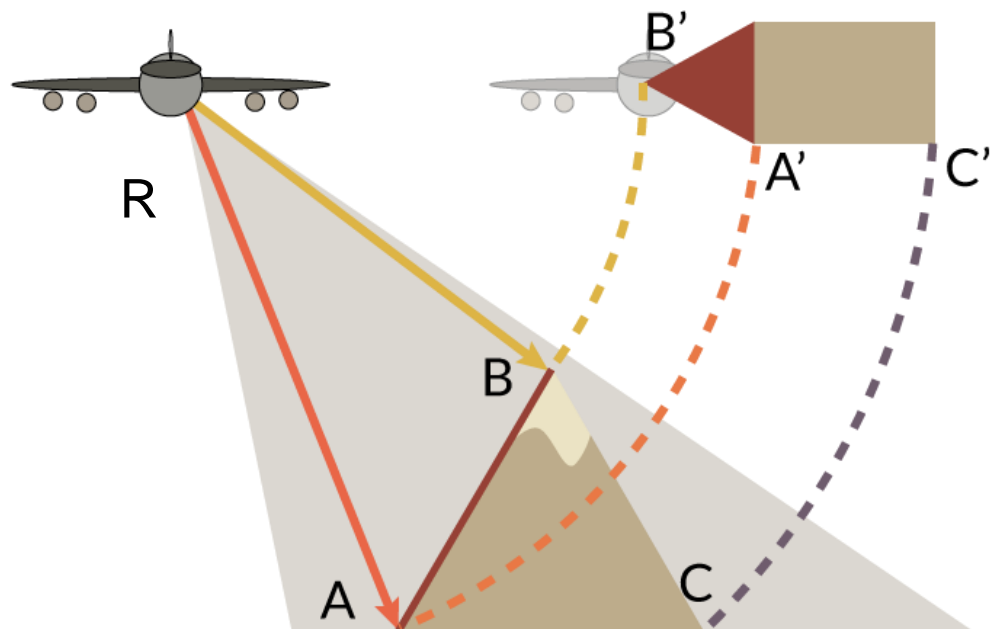
Layover

$$AB = BC$$

$$A'B' < B'C'$$

$$RA > RB$$

$$RA' > RB'$$

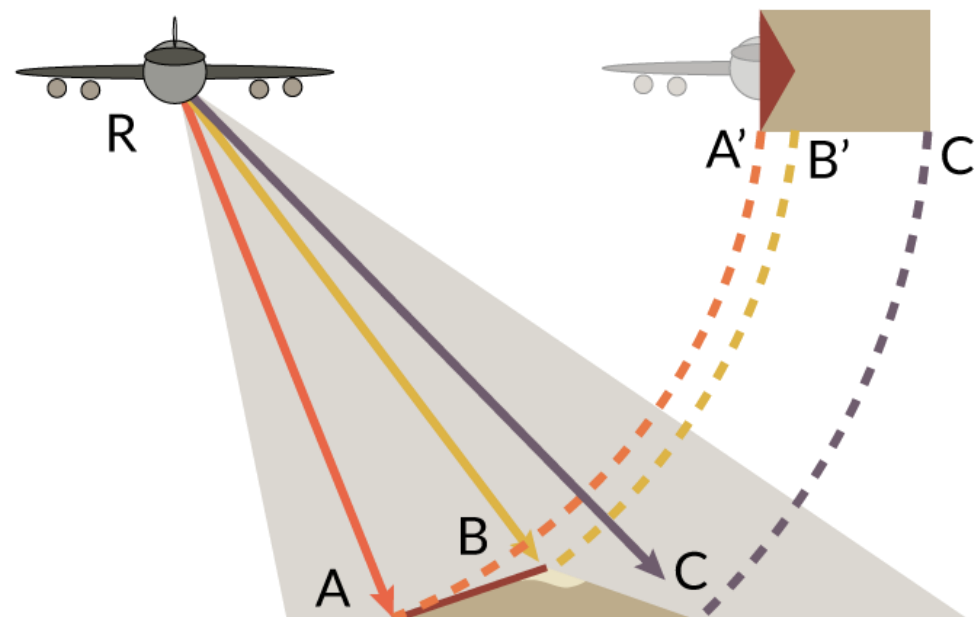


Foreshortening

$$RA < RB < RC$$

$$AB = BC$$

$$A'B' < B'C'$$



Images based on NRC images

Shadow

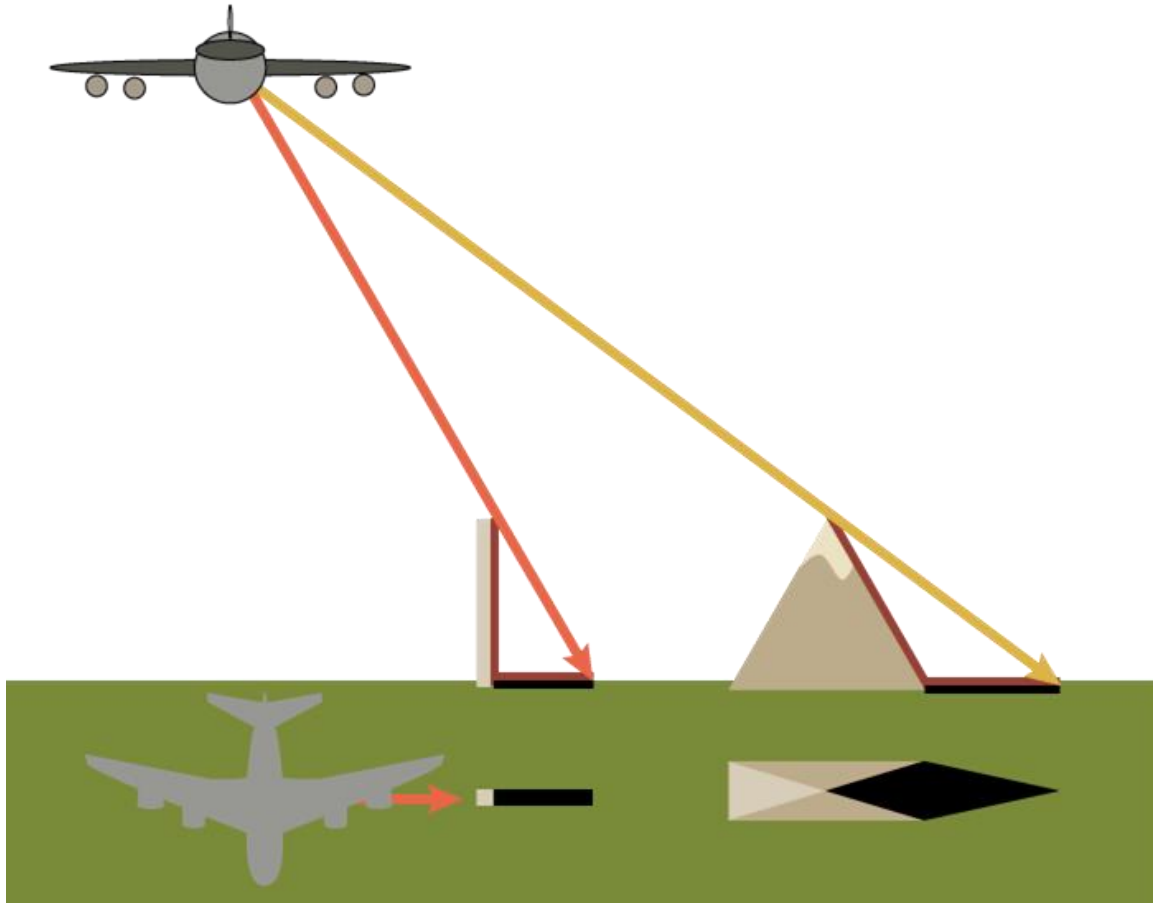
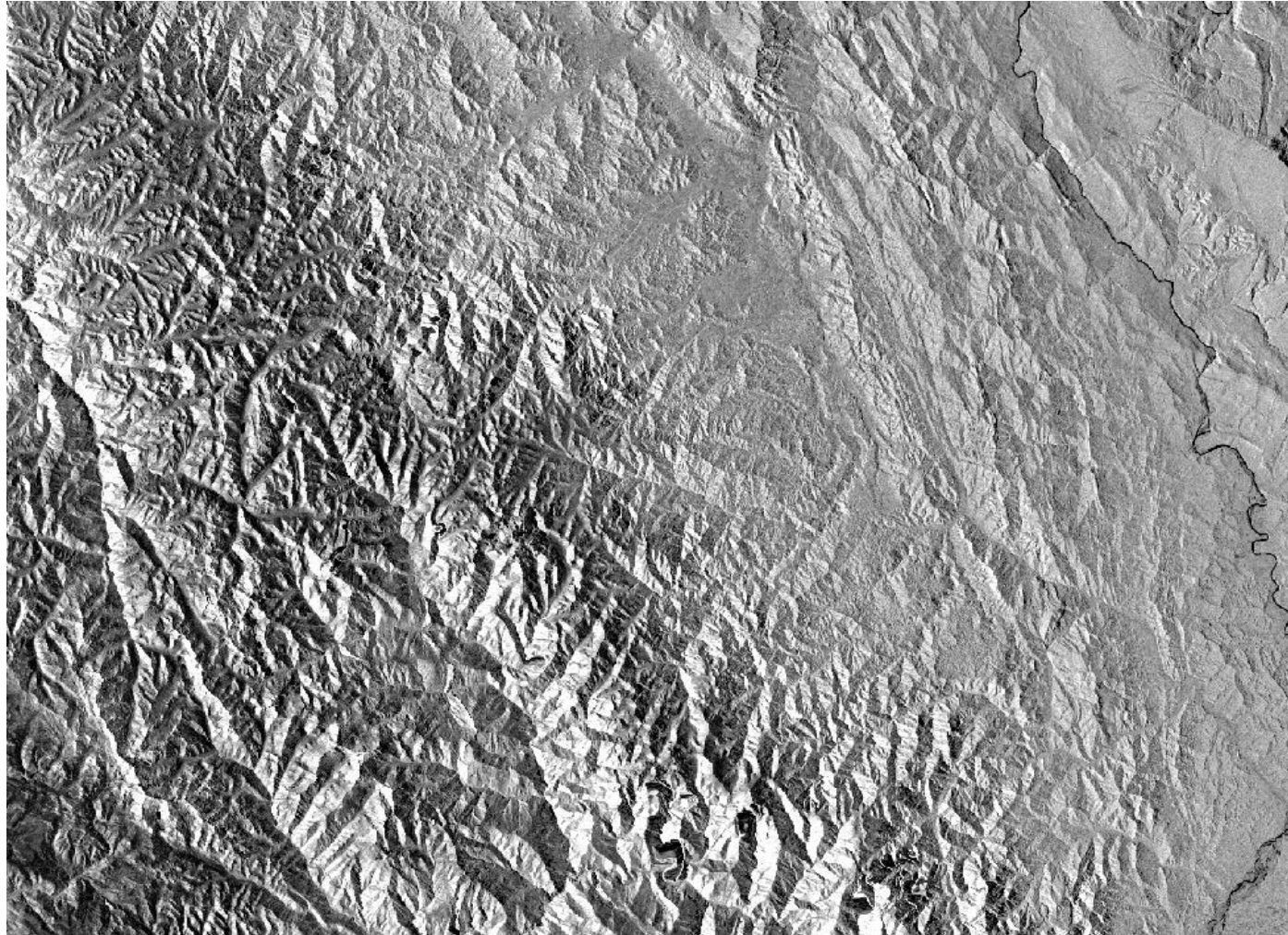


Image (left) based on NRC images



Radiometric Distortion

Sentinel-1 Radar Image Over the Andes

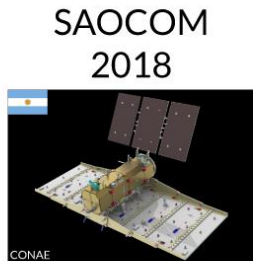
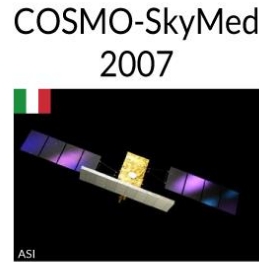


Radar Data Available

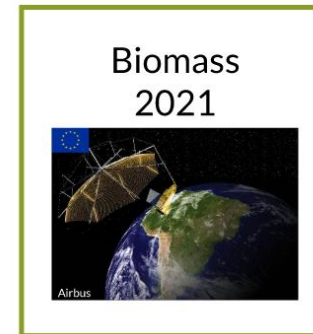
Legacy:



Current:



Future:



freely
accessible

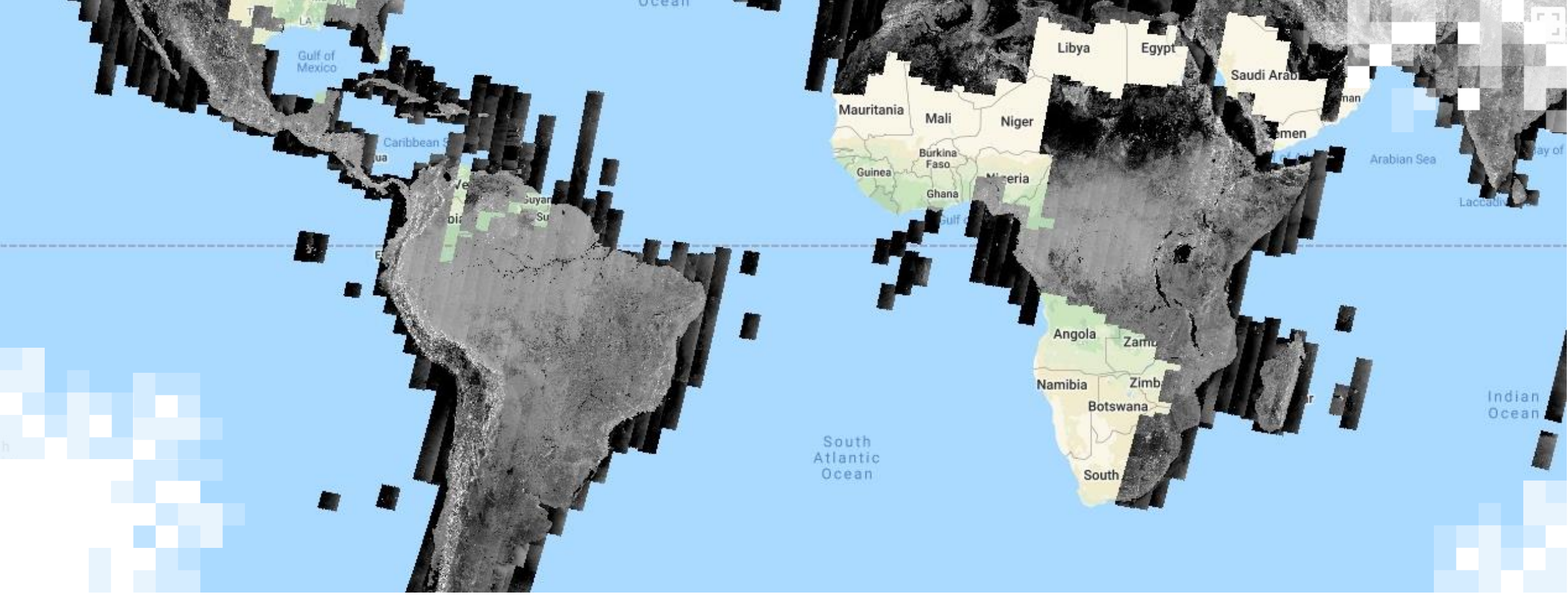
Image Credit: Franz Meyer, University of Alaska, Fairbanks

NASA-ISRO SAR Mission (NISAR)

- High spatial resolution with frequent revisit time
- Expected launch date: beginning of 2022
- Dual frequency L- and S-band SAR
 - L-band SAR from NASA and S-band SAR from ISRO
- 3 years science operations (5+ years consumables)
- All science data will be made available free and open

NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath >240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3-10 meters mode-dependent SAR resolution	Small-scale observations
3 years since operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
>30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, North and South
Noise Equivalent Sigma Zero ≤ -23 db	Surface characterization of smooth surfaces

Slide Courtesy of Paul Rosen (JPL)

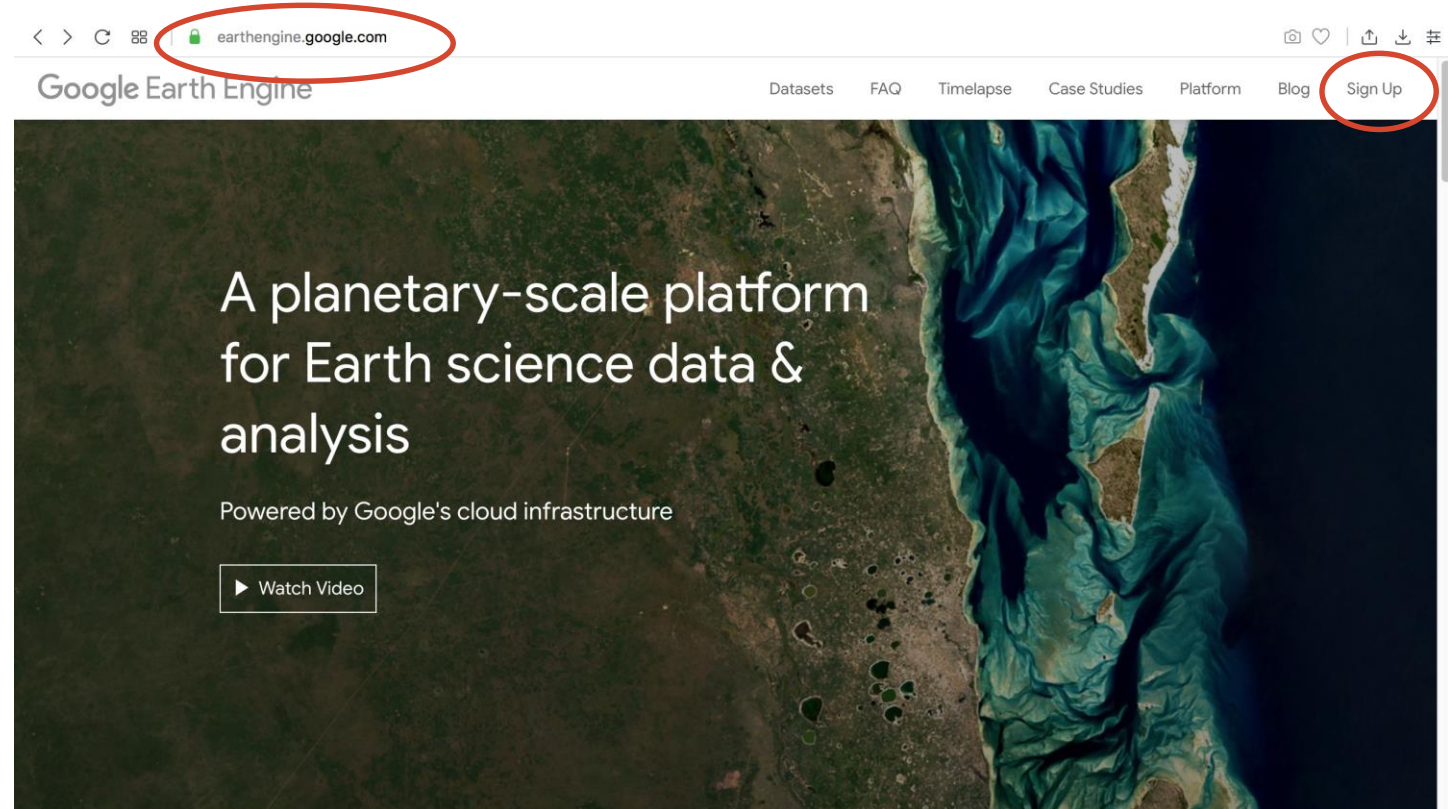


Hands-on Exercise Using Google Earth Engine

Google Earth Engine

<https://earthengine.google.com>

- Cloud based geospatial processing platform
- Available to scientists, researchers, and developers for analysis of the Earth's surface
- Contains a catalog of satellite imagery and geospatial datasets (including Sentinel-1):
- <https://developers.google.com/earth-engine/datasets/catalog/>
- Uses Javascript code editor
- Sign up for a (free) account



Meet Earth Engine

Google Earth Engine Code Editor

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

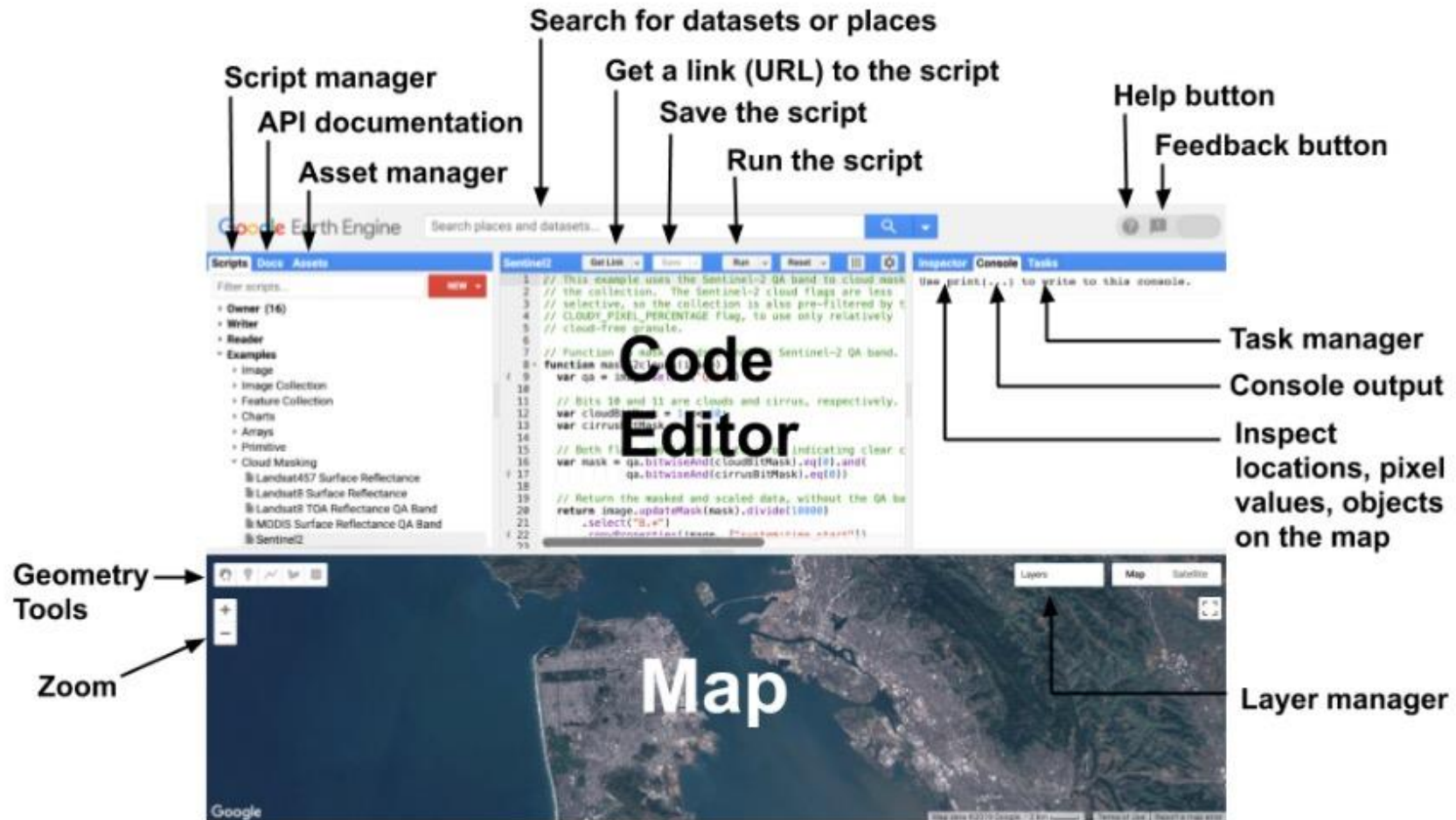


Image Credit: [Google](https://www.google.com)

Sentinel-1 Data

Two satellites: A & B

- C-band data
- Each satellite has global coverage every 12 days
- Global coverage of 6 days over the equator when using data from both satellites

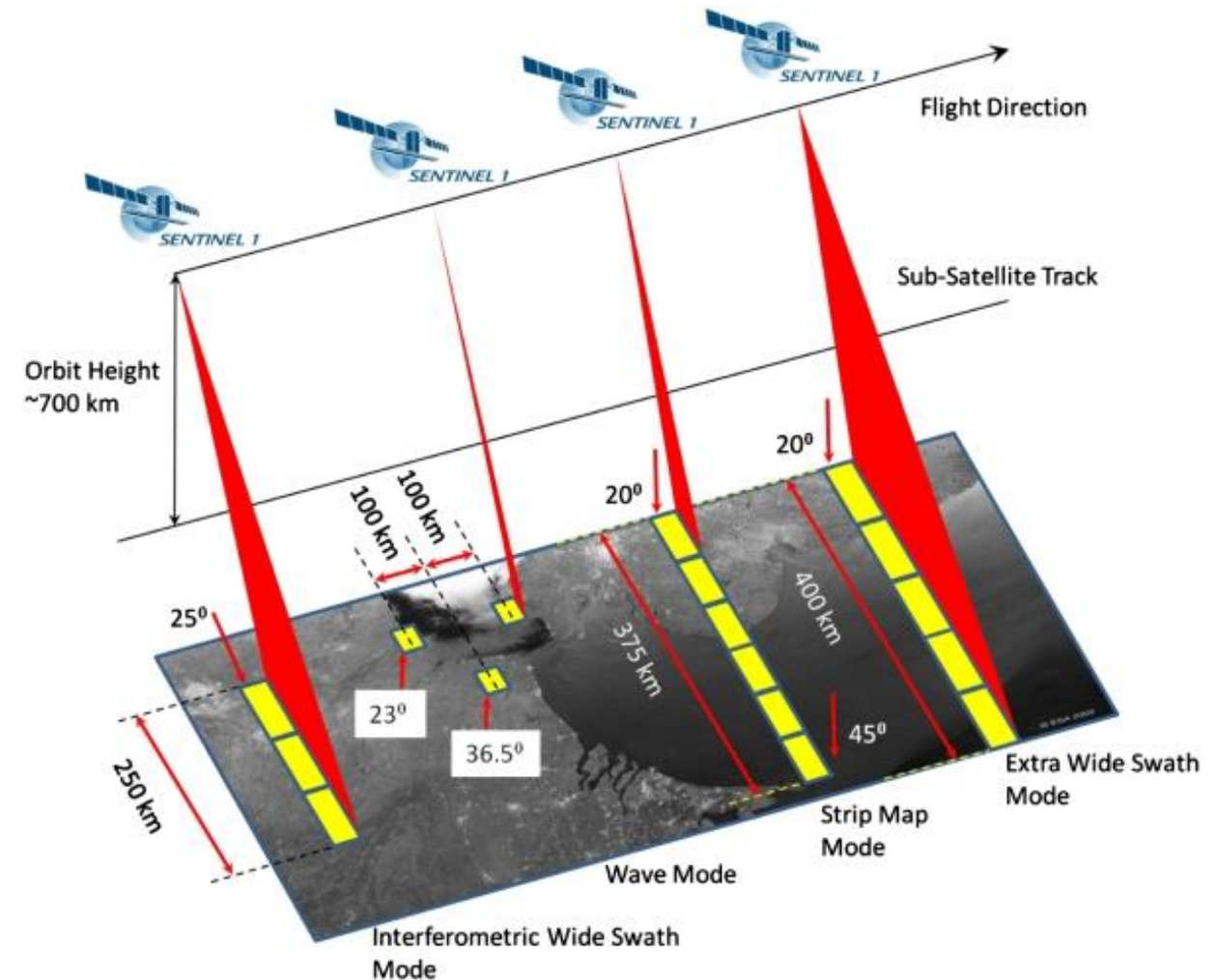


Image Credit: [ESA](#)

Sentinel-1 Data

Different Modes:

- Extra Wide Swath – for monitoring oceans and coasts
- Strip Mode – by special order only and intended for special needs
- Wave Mode – routine collection for the ocean
- *Interferometric Wide Swath* – routine collection for land **(this is the one you want to use for flood mapping)**

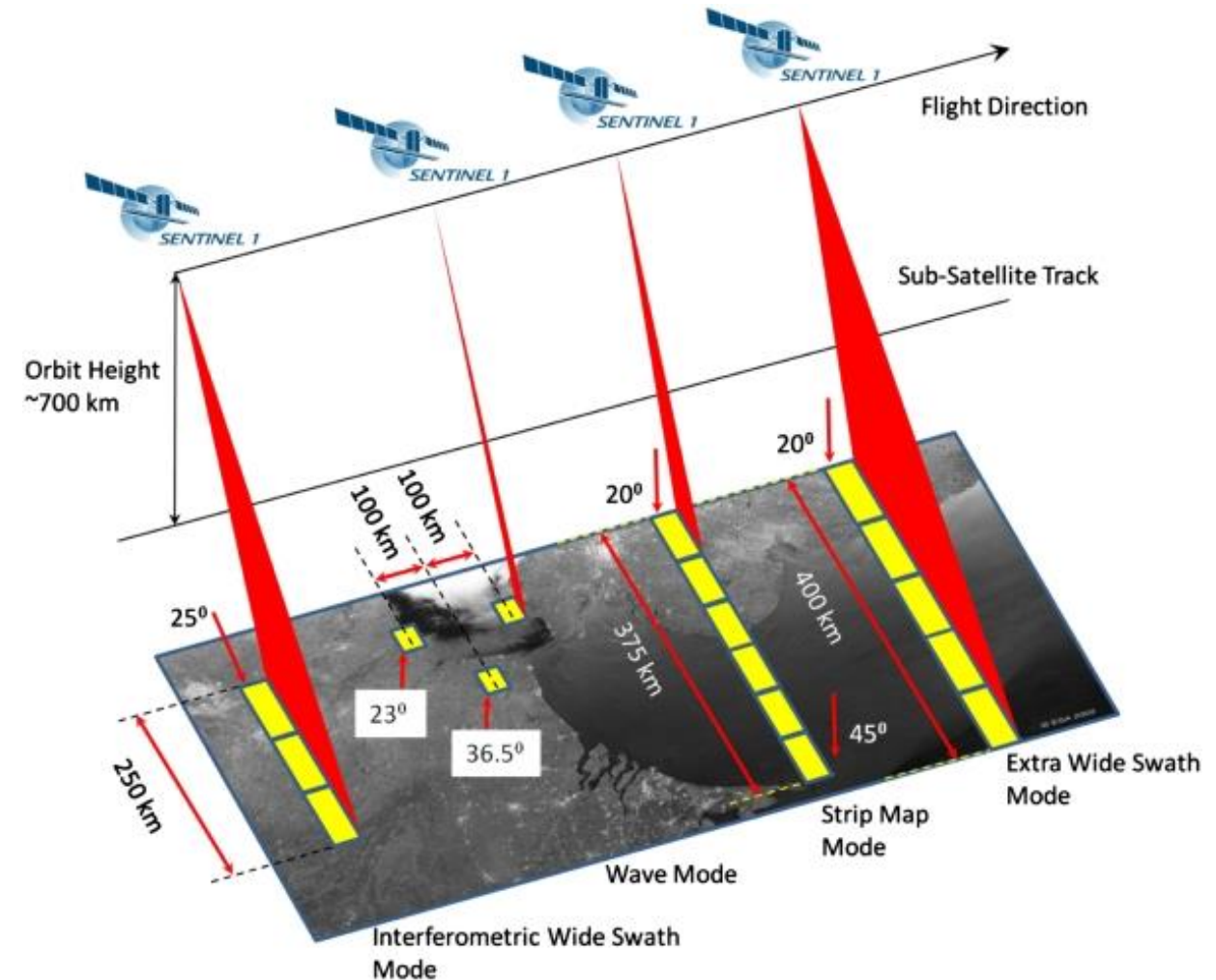


Image Credit: [ESA](#)

Sentinel-1 Catalog

https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S1_GRD

The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. This collection includes the S1 Ground Range Detected (GRD) scenes, processed using the Sentinel-1 Toolbox to generate a calibrated, ortho-corrected product. The collection is updated weekly.

This collection contains all of the GRD scenes. Each scene has one of 3 resolutions (10, 25 or 40 meters), 4 band combinations (corresponding to scene polarization) and 3 instrument modes. Use of the collection in a mosaic context will likely require filtering down to a homogenous set of bands and parameters. See [this article](#) for details of collection use and preprocessing. Each scene contains either 1 or 2 out of 4 possible polarization bands, depending on the instrument's polarization settings. The possible combinations are single band VV or HH, and dual band VV+VH and HH+HV:

1. VV: single co-polarization, vertical transmit/vertical receive
2. HH: single co-polarization, horizontal transmit/horizontal receive
3. VV + VH: dual-band cross-polarization, vertical transmit/horizontal receive
4. HH + HV: dual-band cross-polarization, horizontal transmit/vertical receive

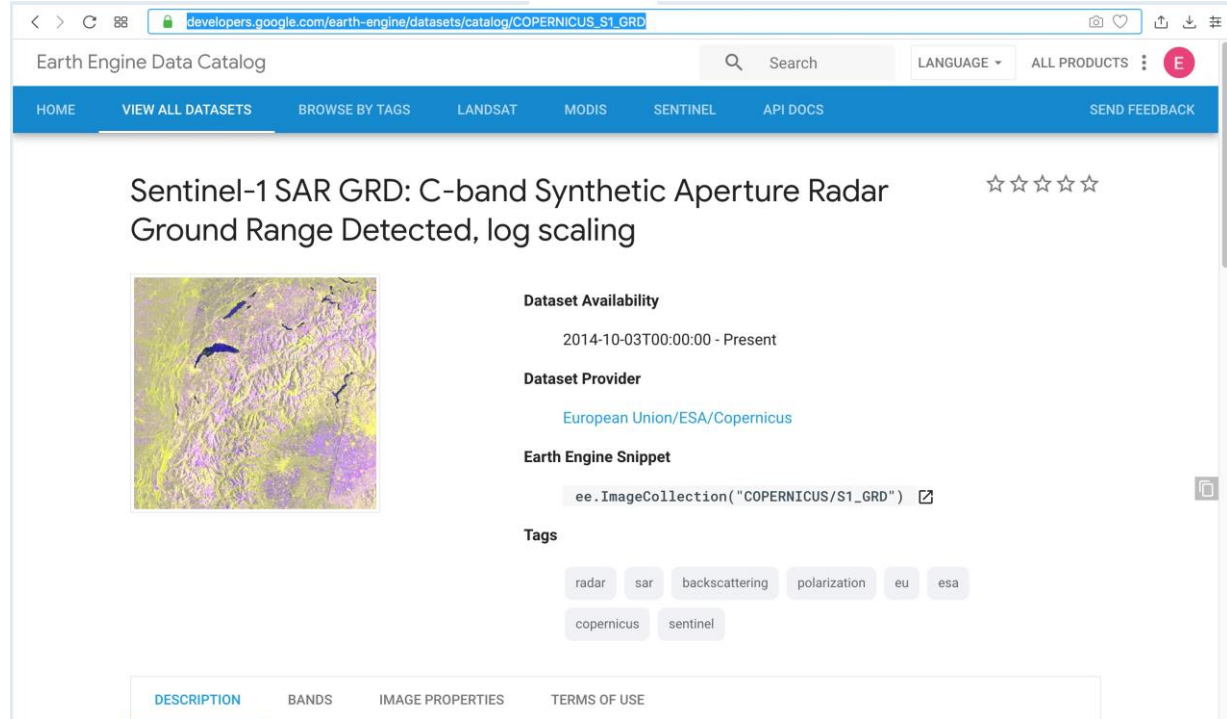
Each scene also includes an additional 'angle' band that contains the approximate viewing incidence angle in degrees at every point. This band is generated by interpolating the 'incidenceAngle' property of the 'geolocationGridPoint' gridded field provided with each asset.

Each scene was pre-processed with [Sentinel-1 Toolbox](#) using the following steps:

1. Thermal noise removal
2. Radiometric calibration
3. Terrain correction using SRTM 30 or ASTER DEM for areas greater than 60 degrees latitude, where SRTM is not available. The final terrain-corrected values are converted to decibels via log scaling ($10 \cdot \log_{10}(x)$).

For more information about these pre-processing steps, please refer to the [Sentinel-1 Pre-processing article](#).

This collection is computed on-the-fly. If you want to use the underlying collection with raw power values (which is updated faster), see COPERNICUS/S1_GRD_FLOAT.



The screenshot shows the Earth Engine Data Catalog interface. The main heading is "Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling". Below the heading is a thumbnail image of a SAR radar image. To the right of the image, there are details about the dataset: "Dataset Availability" (2014-10-03T00:00:00 - Present), "Dataset Provider" (European Union/ESA/Copernicus), and "Earth Engine Snippet" (`ee.ImageCollection("COPERNICUS/S1_GRD")`). There are also tags for "radar", "sar", "backscattering", "polarization", "eu", "esa", "copernicus", and "sentinel". At the bottom, there are tabs for "DESCRIPTION", "BANDS", "IMAGE PROPERTIES", and "TERMS OF USE".

Focus Area

Our demo is focused on floods that occurred in March of 2019 in Mozambique due to Cyclone Idai

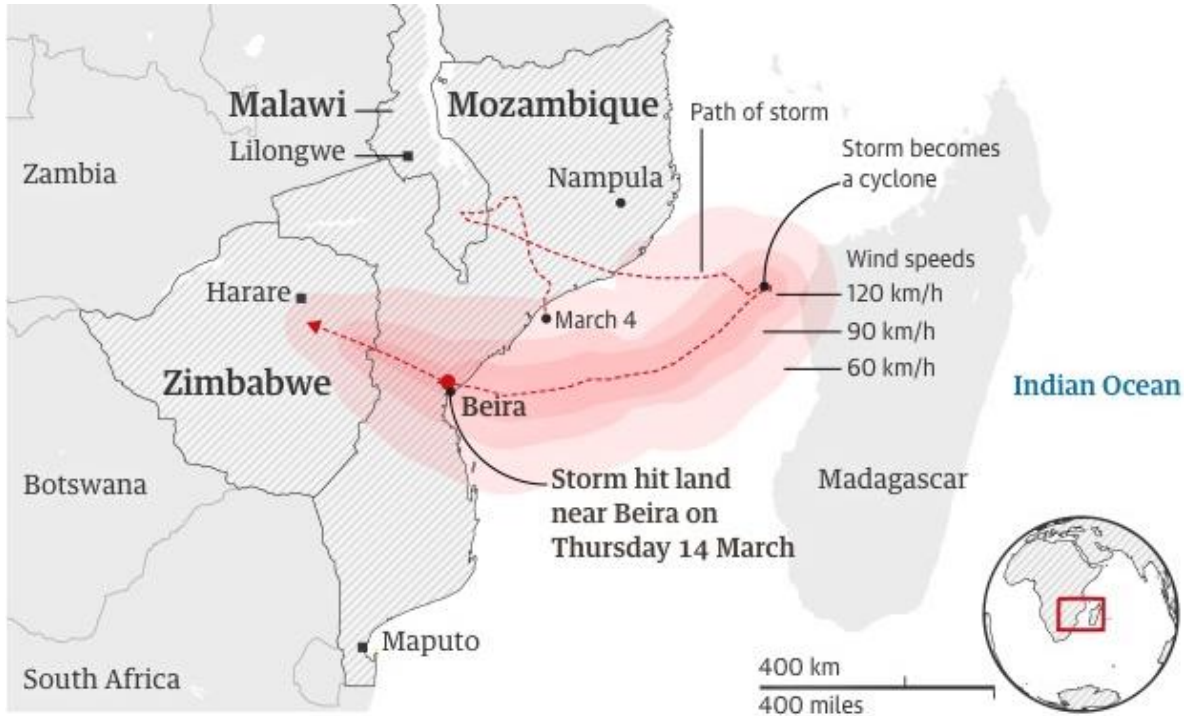
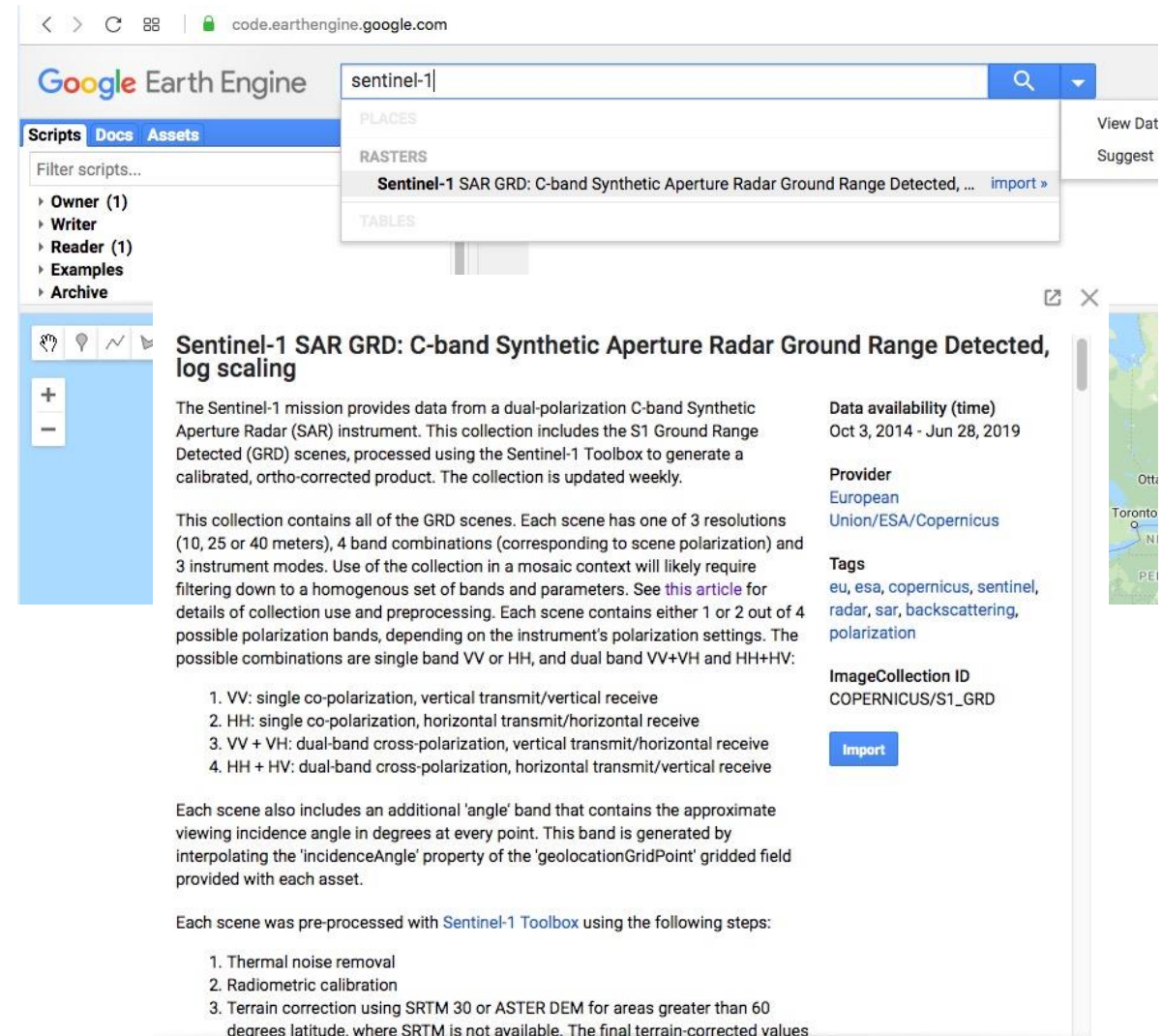


Image Credits: (left) Global Disaster Alert and Coordination System; (right) Flooded homes in the Buzi district outside Beira, Mozambique. Credit: Reuters/Siphiwe Sibeko/File Photo

Visualize Sentinel-1 Data

1. Start by opening Google Earth Engine: <https://code.earthengine.google.com>
2. Search for Sentinel-1 data
3. A window with a description of the data will open showing:
 - the steps taken to process the data (thermal noise removal, radiometric calibration, terrain correction)
 - bands and resolution
 - metadata (important parameters are mode and orbit properties - descending or ascending)



The screenshot shows the Google Earth Engine web interface. The search bar at the top contains the text "sentinel-1". Below the search bar, a dropdown menu displays search results under the "RASTERS" category, with the top result being "Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, ...". The main content area shows the details for this collection, including a description, metadata, and an "Import" button. The interface also shows a sidebar with navigation options like "Scripts", "Docs", and "Assets", and a map on the right side.

Google Earth Engine | code.earthengine.google.com

Search: sentinel-1

RASTERS

- Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, ... import »

Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling

The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. This collection includes the S1 Ground Range Detected (GRD) scenes, processed using the Sentinel-1 Toolbox to generate a calibrated, ortho-corrected product. The collection is updated weekly.

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4. HH + HV: dual-band cross-polarization, horizontal transmit/vertical receive

Each scene also includes an additional 'angle' band that contains the approximate viewing incidence angle in degrees at every point. This band is generated by interpolating the 'incidenceAngle' property of the 'geolocationGridPoint' gridded field provided with each asset.

Each scene was pre-processed with [Sentinel-1 Toolbox](#) using the following steps:

1. Thermal noise removal
2. Radiometric calibration
3. Terrain correction using SRTM 30 or ASTER DEM for areas greater than 60 degrees latitude. where SRTM is not available. The final terrain-corrected values

Data availability (time)
Oct 3, 2014 - Jun 28, 2019

Provider
European Union/ESA/Copernicus

Tags
eu, esa, copernicus, sentinel, radar, sar, backscattering, polarization

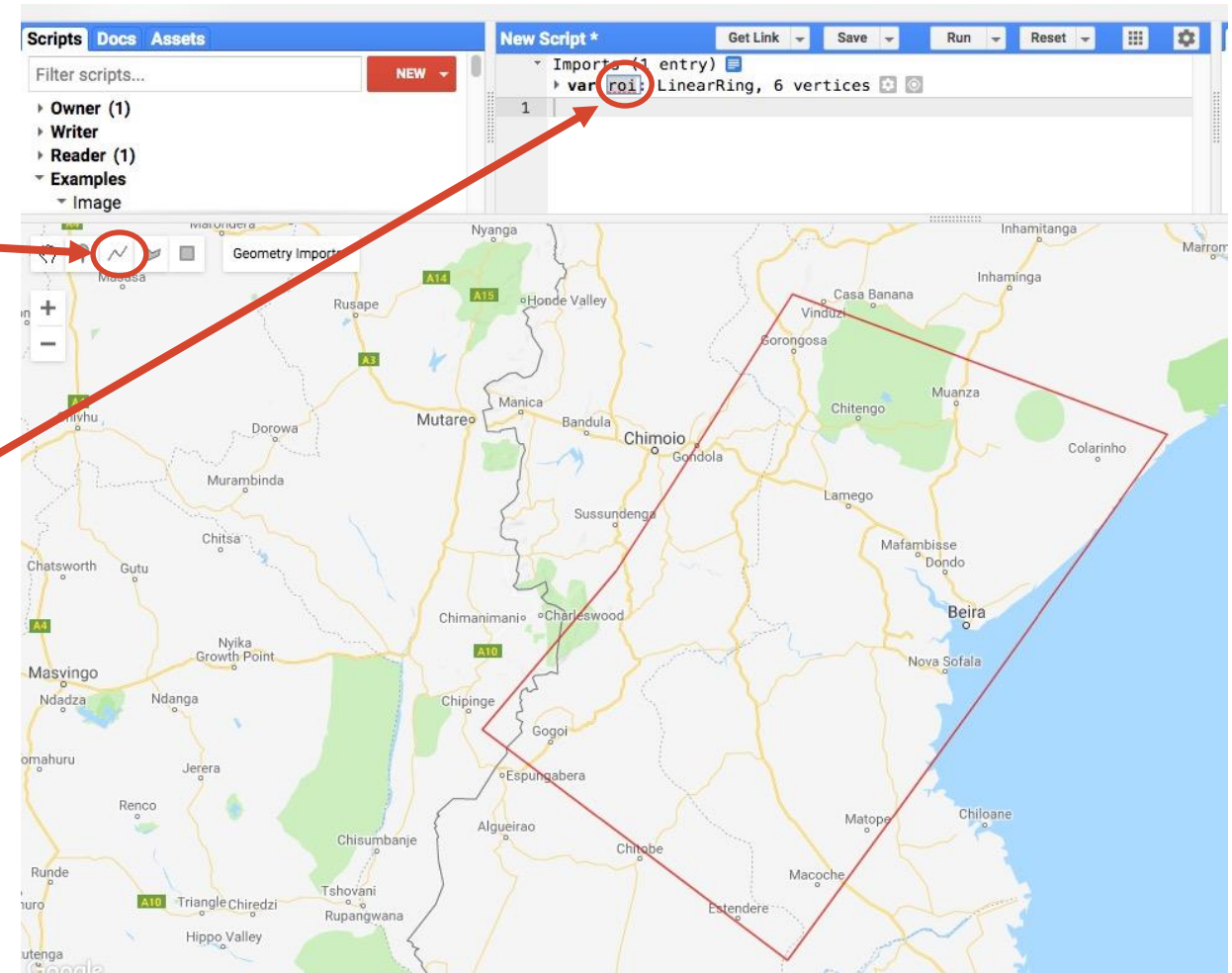
ImageCollection ID
COPERNICUS/S1_GRD

Import

Select Area of Interest

Define your area of interest

4. Zoom into Beira in Mozambique
5. Select the “draw a line” icon
6. Draw a rectangle similar to the one here over our area of interest
7. Rename “geometry” to “roi” (region of interest) - as indicated here



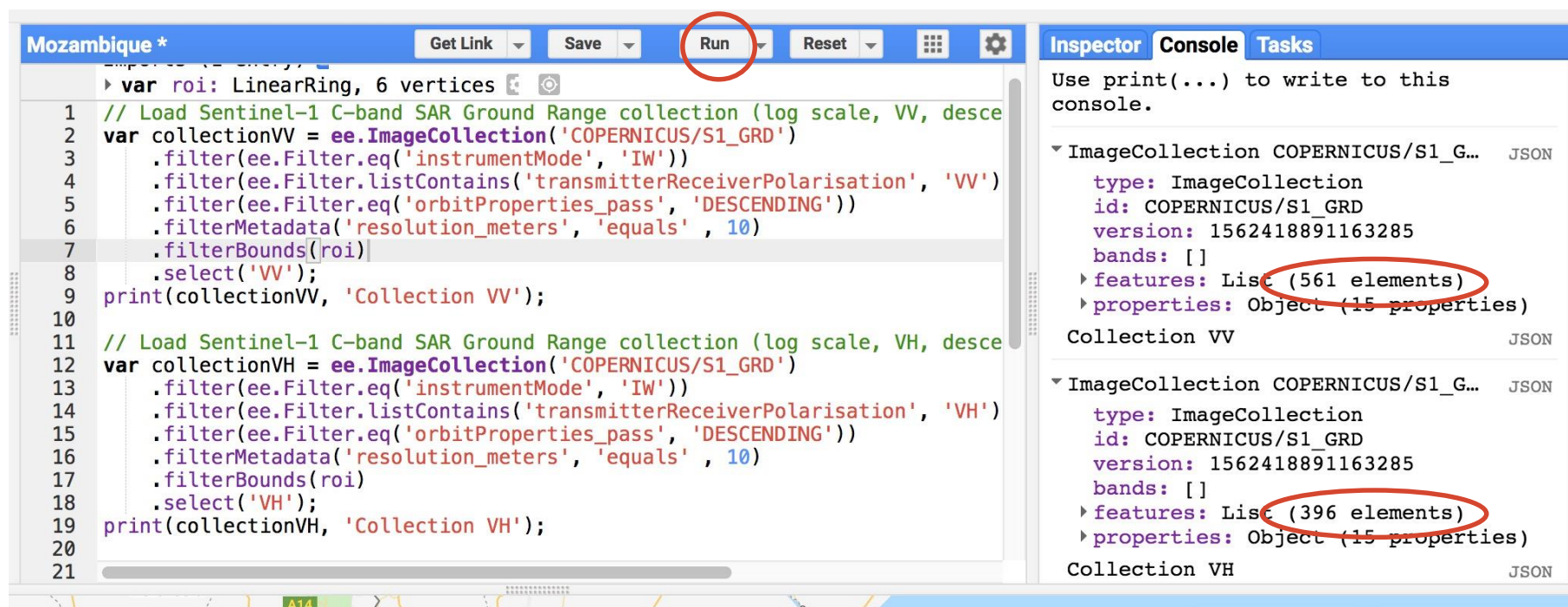
Filter the Sentinel-1 Data

```
// Load Sentinel-1 C-band SAR Ground Range collection (log scale, VV, descending)
var collectionVV = ee.ImageCollection('COPERNICUS/S1_GRD')
  .filter(ee.Filter.eq('instrumentMode', 'IW'))
  .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VV'))
  .filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
  .filterMetadata('resolution_meters', 'equals', 10)
  .filterBounds(roi)
  .select('VV');
print(collectionVV, 'collection VV');
```

```
// Load Sentinel-1 C-band SAR Ground Range collection (log scale, VH, descending)
var collectionVH = ee.ImageCollection('COPERNICUS/S1_GRD')
  .filter(ee.Filter.eq('instrumentMode', 'IW'))
  .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))
  .filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
  .filterMetadata('resolution_meters', 'equals', 10)
  .filterBounds(roi)
  .select('VH');
print(collectionVH, 'collection VH');
```


Filter the Sentinel-1 Data

8. Copy the code from the previous slide to the Code Editor
9. Select **Run** in the top menu
 - The right window will show the results for VV (561 images) and VH (396 images)
 - The image number will vary depending on the size of your area of interest



The screenshot shows a code editor window titled "Mozambique *" with a "Run" button circled in red. The code defines a region of interest (roi) and filters Sentinel-1 C-band SAR Ground Range data for VV and VH polarizations. The console window on the right shows the results of the filtering process, with the number of features for each collection circled in red.

```
var roi: LinearRing, 6 vertices
1 // Load Sentinel-1 C-band SAR Ground Range collection (log scale, VV, desc
2 var collectionVV = ee.ImageCollection('COPERNICUS/S1_GRD')
3   .filter(ee.Filter.eq('instrumentMode', 'IW'))
4   .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VV'))
5   .filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
6   .filterMetadata('resolution_meters', 'equals', 10)
7   .filterBounds(roi)
8   .select('VV');
9 print(collectionVV, 'Collection VV');
10
11 // Load Sentinel-1 C-band SAR Ground Range collection (log scale, VH, desc
12 var collectionVH = ee.ImageCollection('COPERNICUS/S1_GRD')
13   .filter(ee.Filter.eq('instrumentMode', 'IW'))
14   .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))
15   .filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
16   .filterMetadata('resolution_meters', 'equals', 10)
17   .filterBounds(roi)
18   .select('VH');
19 print(collectionVH, 'Collection VH');
20
21
```

Inspector Console Tasks

Use print(...) to write to this console.

- ImageCollection COPERNICUS/S1_G... JSON
 - type: ImageCollection
 - id: COPERNICUS/S1_GRD
 - version: 1562418891163285
 - bands: []
 - features: List (561 elements)
 - properties: Object (15 properties)Collection VV JSON
- ImageCollection COPERNICUS/S1_G... JSON
 - type: ImageCollection
 - id: COPERNICUS/S1_GRD
 - version: 1562418891163285
 - bands: []
 - features: List (396 elements)
 - properties: Object (15 properties)Collection VH JSON

Filter the Sentinel-1 Data by Date

```
//Filter by date
var beforeVV = collectionVV.filterDate('2019-02-15', '2019-02-24');
var afterVV = collectionVV.filterDate('2019-03-15', '2019-03-21');
var beforeVH = collectionVH.filterDate('2019-02-15', '2019-02-24');
var afterVH = collectionVH.filterDate('2019-03-15', '2019-03-21');
print(beforeVV, 'Before VV');
print(afterVV, 'After VV');
print(beforeVH, 'Before VH');
print(afterVH, 'After VH');
```


Filter the Sentinel-1 Data by Date

10. Copy the code from the previous slide into the Code Editor

11. Select **Run** in the top menu

- The right window will show the results for: before (VV and VH) 6 images after (VV and VH) 6 images

The screenshot displays a code editor window titled "Mozambique *" with a toolbar containing "Get Link", "Save", "Run" (circled in red), and "Reset". The code in the editor is as follows:

```
14 .filter(ee.Filter.listContains('transmitterReceiverPolarisation', 'VH'))
15 .filter(ee.Filter.eq('orbitProperties_pass', 'DESCENDING'))
16 .filterMetadata('resolution_meters', 'equals', 10)
17 .filterBounds(roi)
18 .select('VH');
19 print(collectionVH, 'Collection VH');
20
21 //Filter by date
22 var beforeVV = collectionVV.filterDate('2019-02-15', '2019-02-24');
23 var afterVV = collectionVV.filterDate('2019-03-15', '2019-03-21');
24 var beforeVH = collectionVH.filterDate('2019-02-15', '2019-02-24');
25 var afterVH = collectionVH.filterDate('2019-03-15', '2019-03-21');
26 print(beforeVV, 'Before VV');
27 print(afterVV, 'After VV');
28 print(beforeVH, 'Before VH');
29 print(afterVH, 'After VH');
30
```

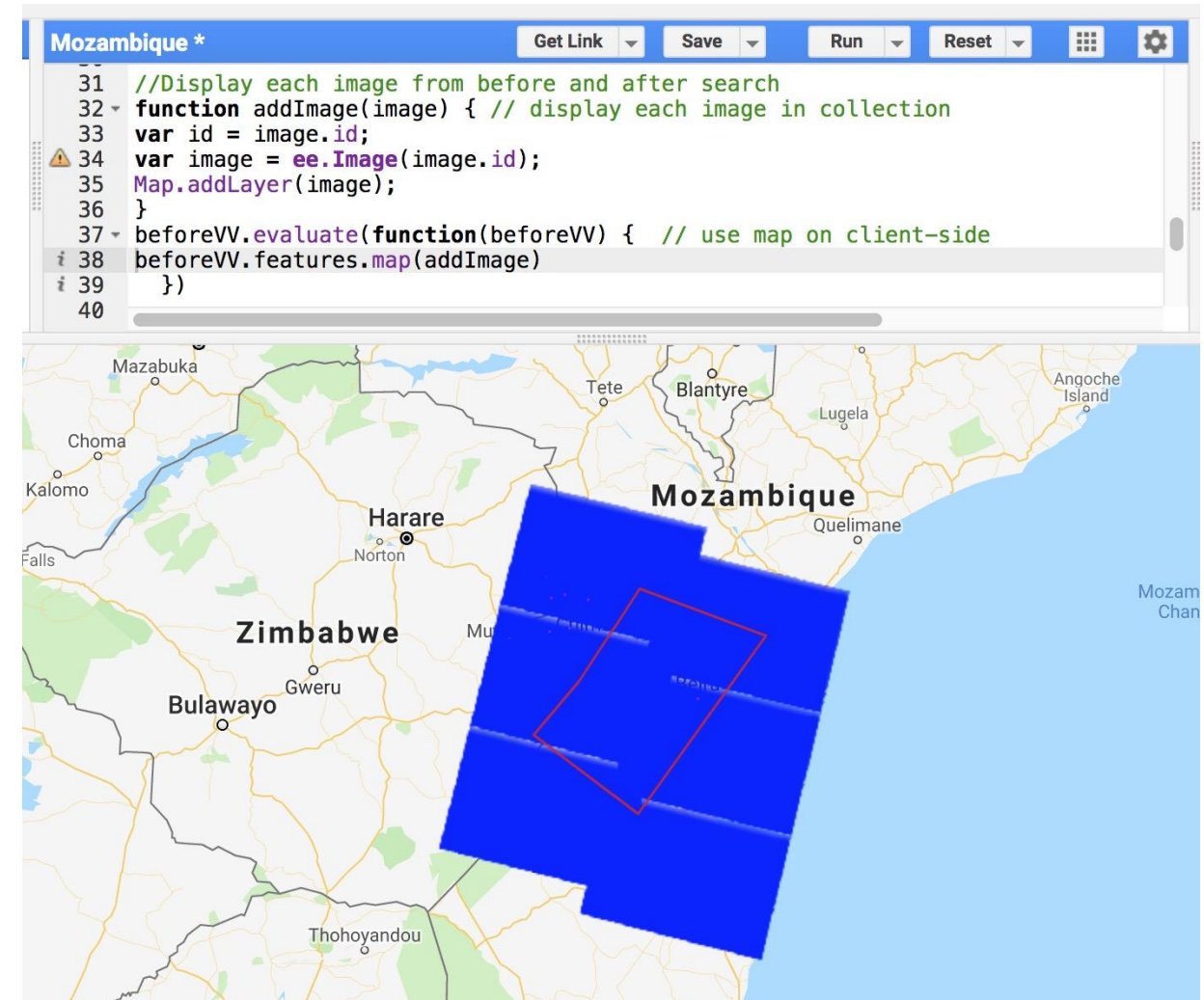
The right-hand side of the image shows the "Inspector" window with two JSON objects. The first object is "ImageCollection COPERNICUS/S..." with properties: type: ImageCollection, id: COPERNICUS/S1_GRD, version: 1562418891163285, bands: [], features: List (6 elements) (circled in red), and properties: Object (15 properti...). Below it is "Before VV" (JSON). The second object is another "ImageCollection COPERNICUS/S..." with the same metadata and features: List (6 elements) (circled in red).

Display the Sentinel-1 Data by Date

```
//Display each image from before and after search
function addImage(image) { // display each image in collection
var id = image.id;
var image = ee.Image(image.id);
Map.addLayer(image);
}
beforeVV.evaluate(function(beforeVV) { // use map on client-side
beforeVV.features.map(addImage)
})
```


Display the Individual Images

12. Copy the previous code to the Code Editor
13. Select **Run** in the top menu
 - 6 images from before VV will be displayed



The screenshot shows a code editor window titled "Mozambique *" with a menu bar containing "Get Link", "Save", "Run", and "Reset". The code in the editor is as follows:

```
31 //Display each image from before and after search
32 function addImage(image) { // display each image in collection
33   var id = image.id;
34   var image = ee.Image(image.id);
35   Map.addLayer(image);
36 }
37 beforeVV.evaluate(function(beforeVV) { // use map on client-side
38   beforeVV.features.map(addImage)
39 })
40
```

Below the code editor is a map of Mozambique and surrounding regions. A large blue rectangular area is overlaid on the map, indicating the search area. The map shows major cities like Harare, Bulawayo, and Mozambique, as well as geographical features like the Mozambique Channel and the Zambezi River. The blue area is centered over the Mozambique Channel and extends into the Mozambique and Zimbabwe regions.

Display Mosaic

Filter the Sentinel-1 Data by Date and Create a Mosaic for Before & After

```
//Filter by date
var beforeVV = collectionVV.filterDate('2019-02-15', '2019-02-24').mosaic();
var afterVV = collectionVV.filterDate('2019-03-15', '2019-03-21').mosaic();
var beforeVH = collectionVH.filterDate('2019-02-15', '2019-02-24').mosaic();
var afterVH = collectionVH.filterDate('2019-03-15', '2019-03-21').mosaic();

// Display map
Map.centerObject(roi, 7);
Map.addLayer(beforeVV, {min:-15,max:0}, 'Before flood vV', 0);
Map.addLayer(afterVV, {min:-15,max:0}, 'After flood vV', 0);
Map.addLayer(beforeVH, {min:-25,max:0}, 'Before flood vH', 0);
Map.addLayer(afterVH, {min:-25,max:0}, 'After flood vH', 0);
```


Display Mosaic

14. Copy the previous code to the Code Editor
15. Select **Run** in the top menu
16. Go to the Layers manager on the top right of the map pane
17. De-select all layers
18. Select **Before flood VH**

The screenshot displays a web-based GIS application interface. At the top, there is a menu bar with options: 'Get Link', 'Save', 'Run', and 'Reset'. Below the menu is a code editor window titled 'Mozambique *' containing the following JavaScript code:

```
21 //Filter by date
22 var beforeVV = collectionVV.filterDate('2019-02-15', '2019-02-24').mosaic();
23 var afterVV = collectionVV.filterDate('2019-03-15', '2019-03-21').mosaic();
24 var beforeVH = collectionVH.filterDate('2019-02-15', '2019-02-24').mosaic();
25 var afterVH = collectionVH.filterDate('2019-03-15', '2019-03-21').mosaic();
26
27 // Display map
28 Map.centerObject(roi, 7);
29 Map.addLayer(beforeVV, {min:-15,max:0}, 'Before flood VV');
30 Map.addLayer(afterVV, {min:-15,max:0}, 'After flood VV');
31 Map.addLayer(beforeVH, {min:-25,max:0}, 'Before flood VH');
32 Map.addLayer(afterVH, {min:-25,max:0}, 'After flood VH');
33
```

To the right of the code editor is an 'Inspector' panel with a 'Console' tab. The console shows the following output:

```
Use print(...) to write to console.
ImageCollection COPERNICUS Collection VV
ImageCollection COPERNICUS Collection VH
```

Below the code editor is a map view of Mozambique. A red rectangle highlights a specific area on the map. The map shows various locations including Harare, Epworth, Chitungwiza, Marondera, Chivhu, Gutu, Masvingo, Renco, and Chi. The map data is attributed to ©2019 AfriGIS (Pty) Ltd with a 50 km scale bar.

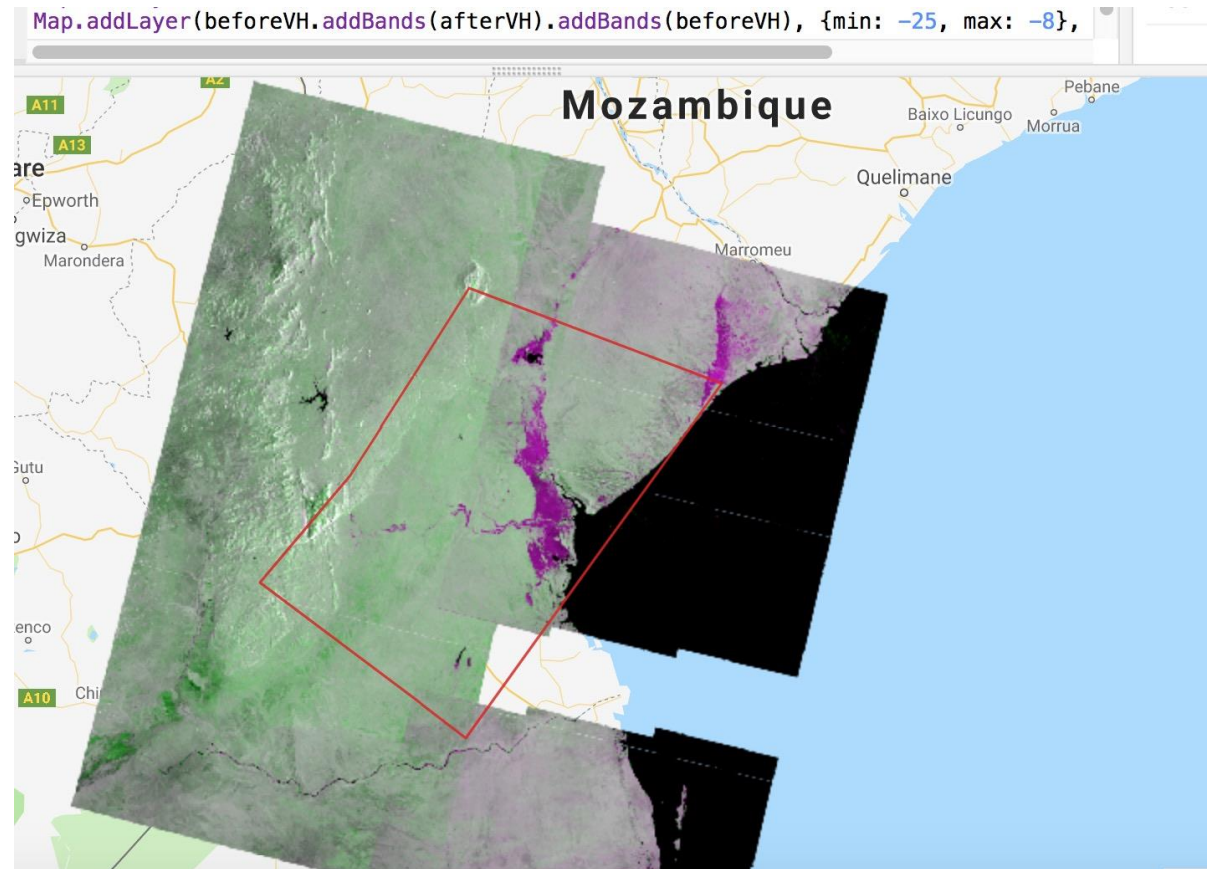
On the right side of the map, there is a 'Layers' panel with the following layers and their visibility status:

- After flood VH
- Before flood VH
- After flood VV
- Before flood VV

Display RGB

```
Map.addLayer(beforeVH.addBands(afterVH).addBands(beforeVH), {min: -25, max: -8},  
'BVH/AVV/AVH composite', 0);
```

19. Copy the above code to the Code Editor
20. Select **Run** in the top menu
21. Go to the Layers manager on the top right of the map pane
22. De-select all numbered layers (Layer 6, Layer 7, Layer 8, etc.)
23. Select **BVH/AVV/AVH composite**



Apply Speckle Filter

```
//Apply filter to reduce speckle
var SMOOTHING_RADIUS = 50;
var beforeVV_filtered = beforeVV.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
var beforeVH_filtered = beforeVH.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
var afterVV_filtered = afterVV.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
var afterVH_filtered = afterVH.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');

//Display filtered images
Map.addLayer(beforeVV_filtered, {min:-15,max:0}, 'Before Flood VV Filtered',0);
Map.addLayer(beforeVH_filtered, {min:-25,max:0}, 'Before Flood VH Filtered',0);
Map.addLayer(afterVV_filtered, {min:-15,max:0}, 'After Flood VV Filtered',0);
Map.addLayer(afterVH_filtered, {min:-25,max:0}, 'After Flood VH Filtered',0);
```

Apply Speckle Filter

24. Copy the previous code to the Code Editor

25. Select **Run** in the top menu

26. Go to the Layers manager

27. De-select all layers

28. Select **Before flood VH** and **Before flood VH Filtered**

29. Zoom into an area and turn the layers on and off one at a time

The screenshot displays a web-based GIS application interface. At the top, there is a code editor window titled "Mozambique *" with a toolbar containing "Get Link", "Save", "Run", and "Reset" buttons. The code editor contains the following JavaScript code:

```
33 Map.addLayer(beforeVH, addbands(afterVH).addbands(beforeVH), {min: -25, max: 0}, 'BVH/AVV/AVH C');
34
35 //Apply filter to reduce speckle
36 var SMOOTHING_RADIUS = 50;
37 var beforeVV_filtered = beforeVV.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
38 var beforeVH_filtered = beforeVH.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
39 var afterVV_filtered = afterVV.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
40 var afterVH_filtered = afterVH.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
41
42 //Display filtered images
43 Map.addLayer(beforeVV_filtered, {min:-15,max:0}, 'Before Flood VV Filtered',0);
44 Map.addLayer(beforeVH_filtered, {min:-25,max:0}, 'Before Flood VH Filtered',0);
45 Map.addLayer(afterVV_filtered, {min:-15,max:0}, 'After Flood VV Filtered',0);
46 Map.addLayer(afterVH_filtered, {min:-25,max:0}, 'After Flood VH Filtered',0);
47
48 //var DIFF_UPPER_THRESHOLD = -3;
49
```

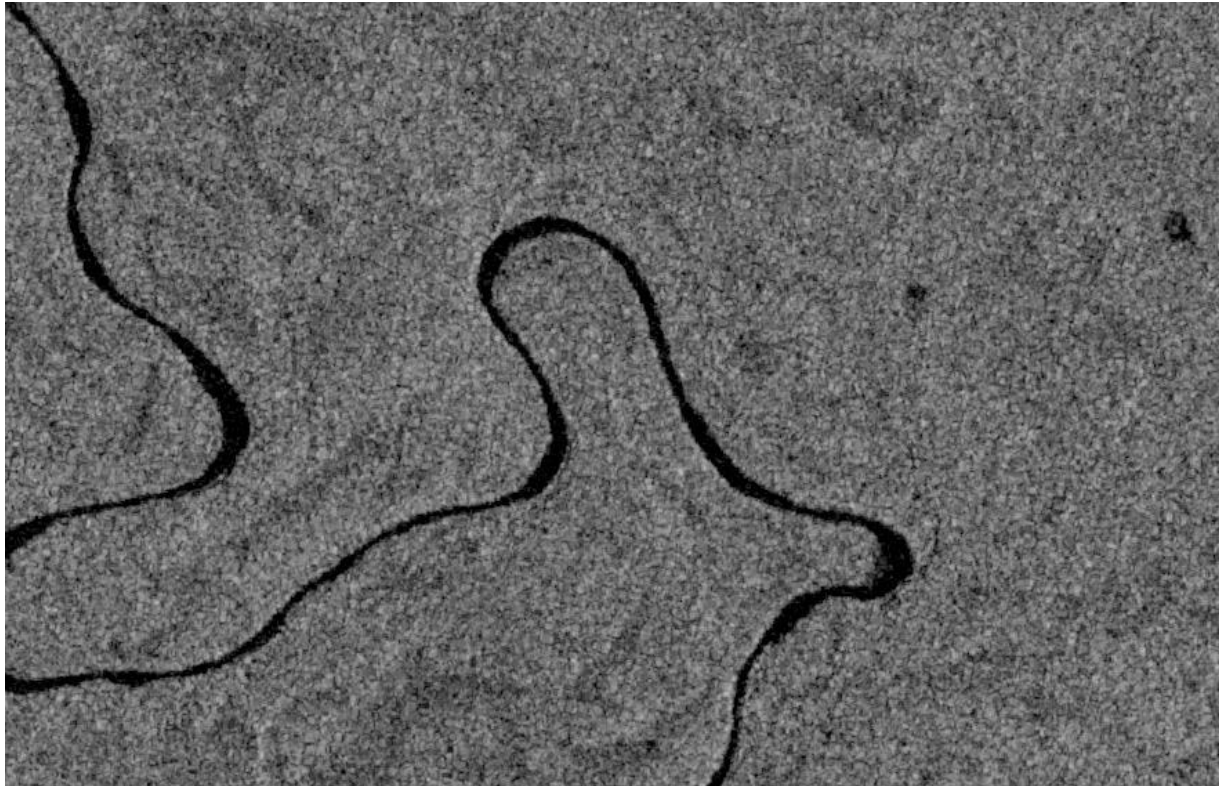
To the right of the code editor is a console window with tabs for "Inspector", "Console", and "Tasks". The console shows the output of the code execution:

```
Use print(...) to write to this console.
> ImageCollection COPERNICUS/S1_GRD (561 el... J1
  Collection VV J1
> ImageCollection COPERNICUS/S1_GRD (396 el... J1
  Collection VH J1
```

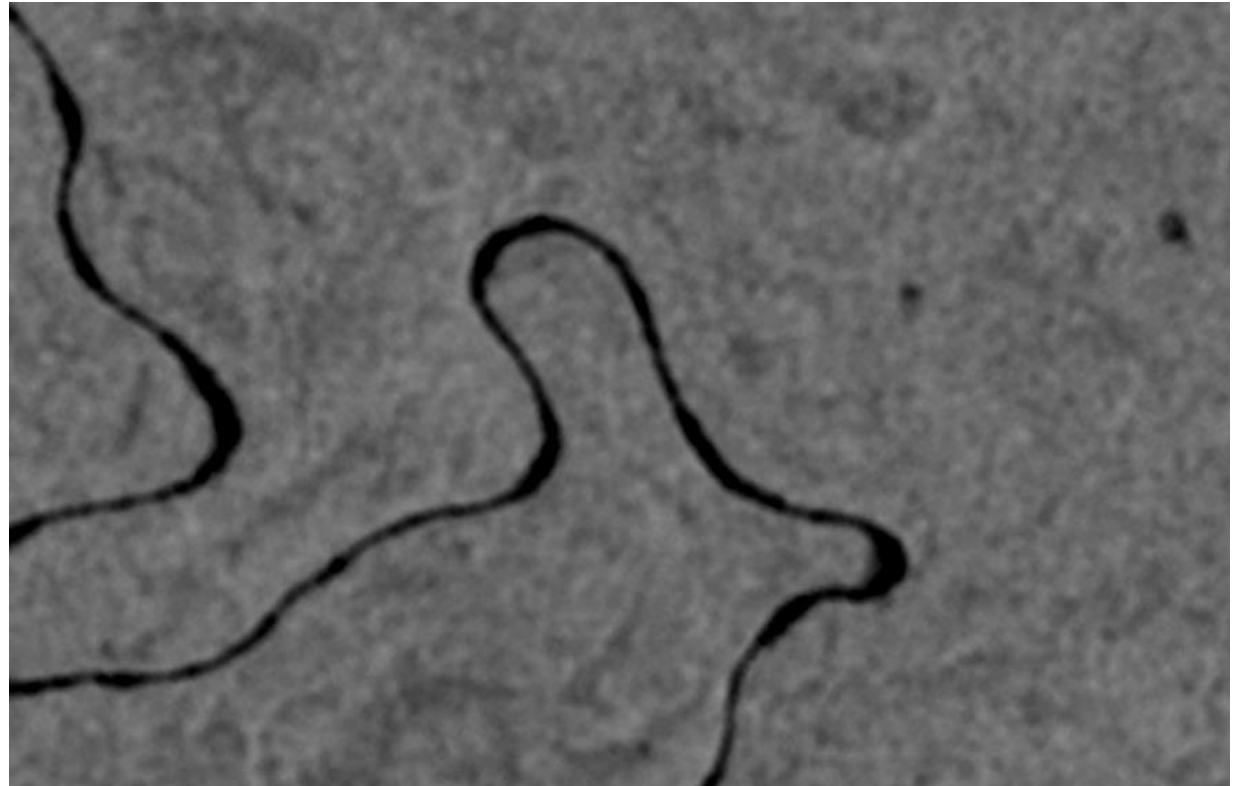
Below the code editor is a map of Mozambique. The map shows the country's coastline and major cities like Harare, Beira, and Limpopo. A red rectangle highlights a specific area on the coast. To the right of the map is a "Layers" panel with a "Map" tab selected. The panel lists several layers with checkboxes:

- After Flood VH Filtered
- After Flood VV Filtered
- Before Flood VH Filtered
- Before Flood VV Filtered
- BVH/AVV/AVH composite
- After flood VH
- Before flood VH
- After flood VV
- Before flood VV

Apply Speckle Filter



Original

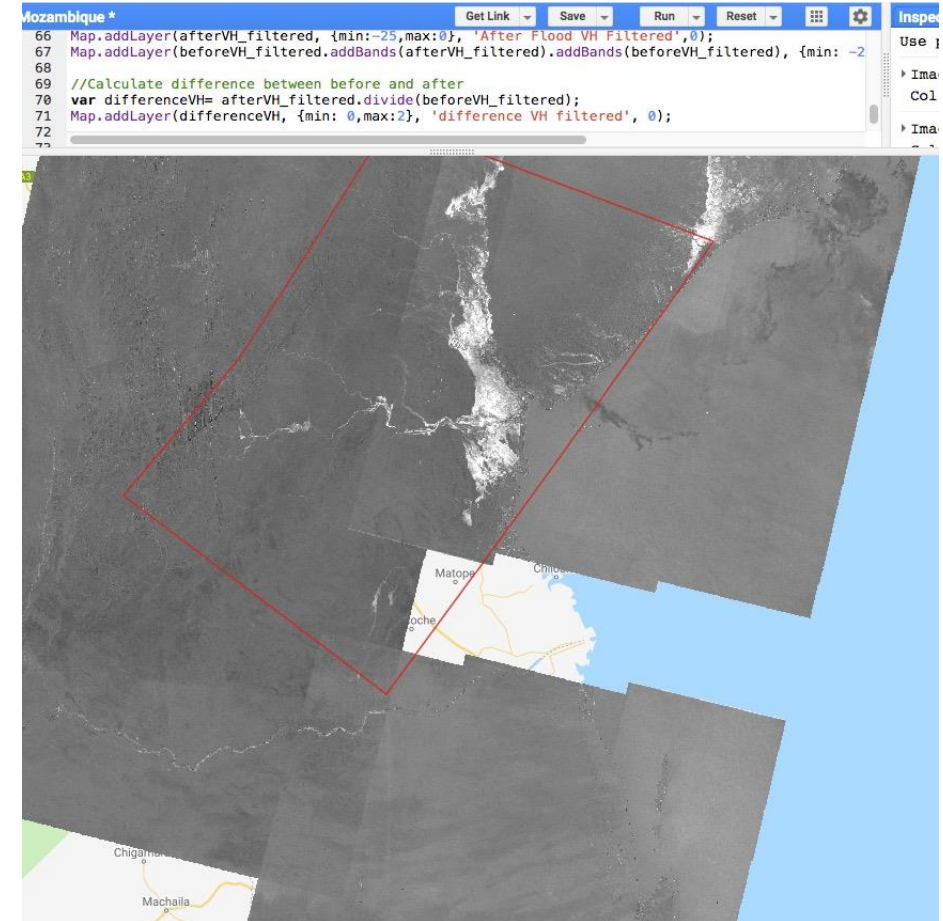


Filtered

Calculate Difference Between Before and After

```
// calculate difference between before and after  
var differenceVH=  
afterVH_filtered.divide(beforeVH_filtered);  
Map.addLayer(differenceVH, {min: 0,max:2},  
'difference VH filtered', 0);
```

30. Copy the above code to the Code Editor
31. Select **Run** in the top menu
32. Go to the Layers manager
33. De-select all layers
34. Select **difference VH filtered**



Apply a Threshold

```
//Apply Threshold
```

```
var DIFF_UPPER_THRESHOLD = 1.25;
```

```
var differenceVH_thresholded = differenceVH.gt(DIFF_UPPER_THRESHOLD);
```

```
Map.addLayer(differenceVH_thresholded.updateMask(differenceVH_thresholded), {palette:"0000FF"}, 'flooded areas - blue', 1);
```

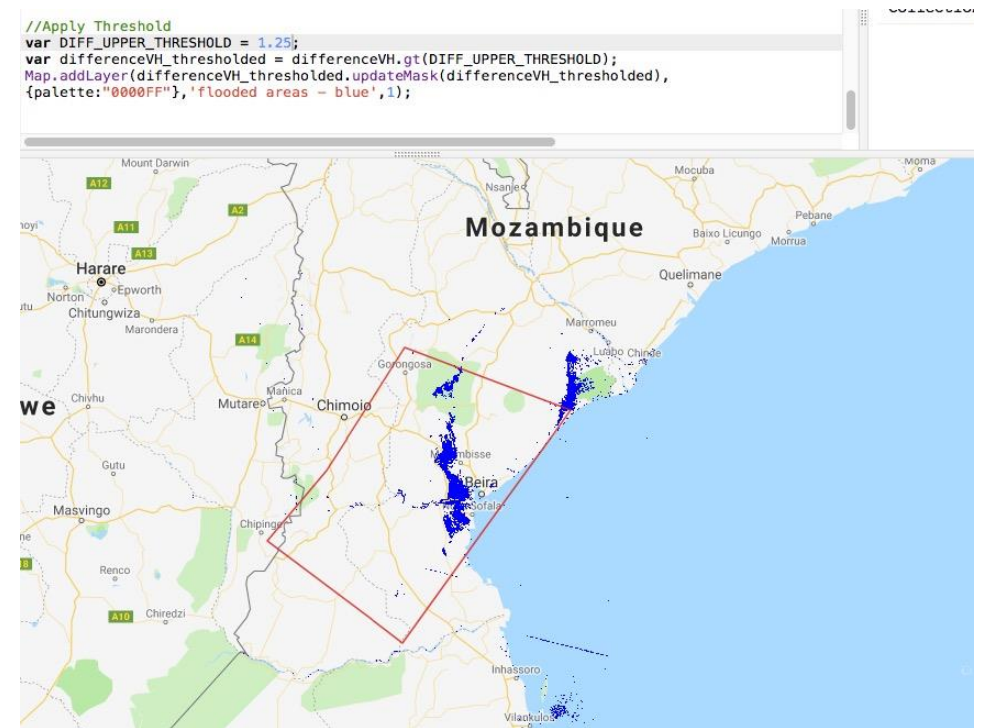
35. Copy the above code to the Code Editor

36. Select **Run** in the top menu

37. Go to the Layers manager

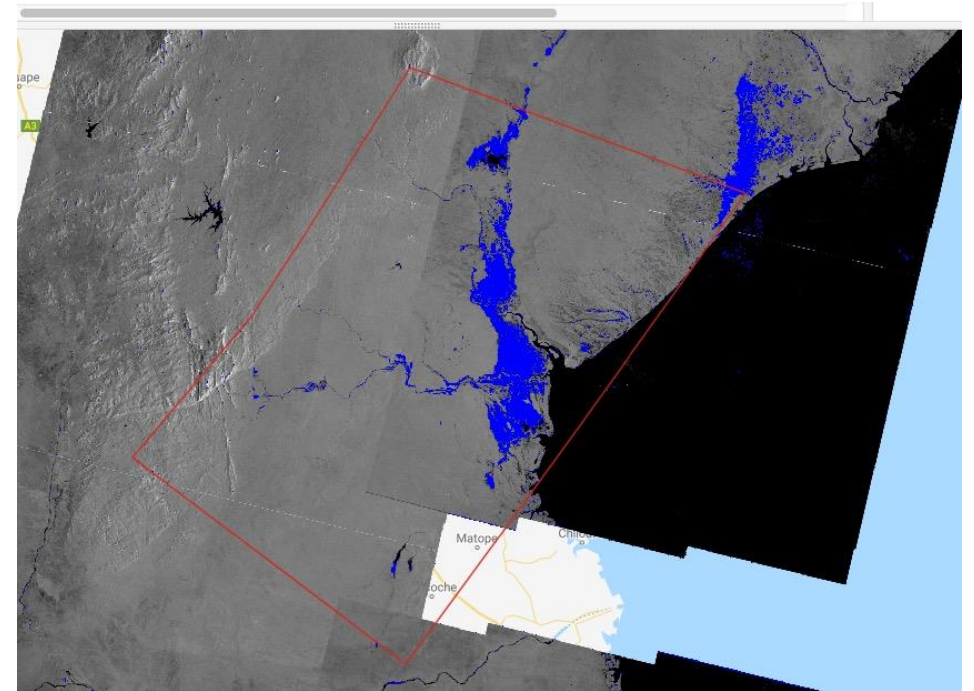
38. De-select all layers

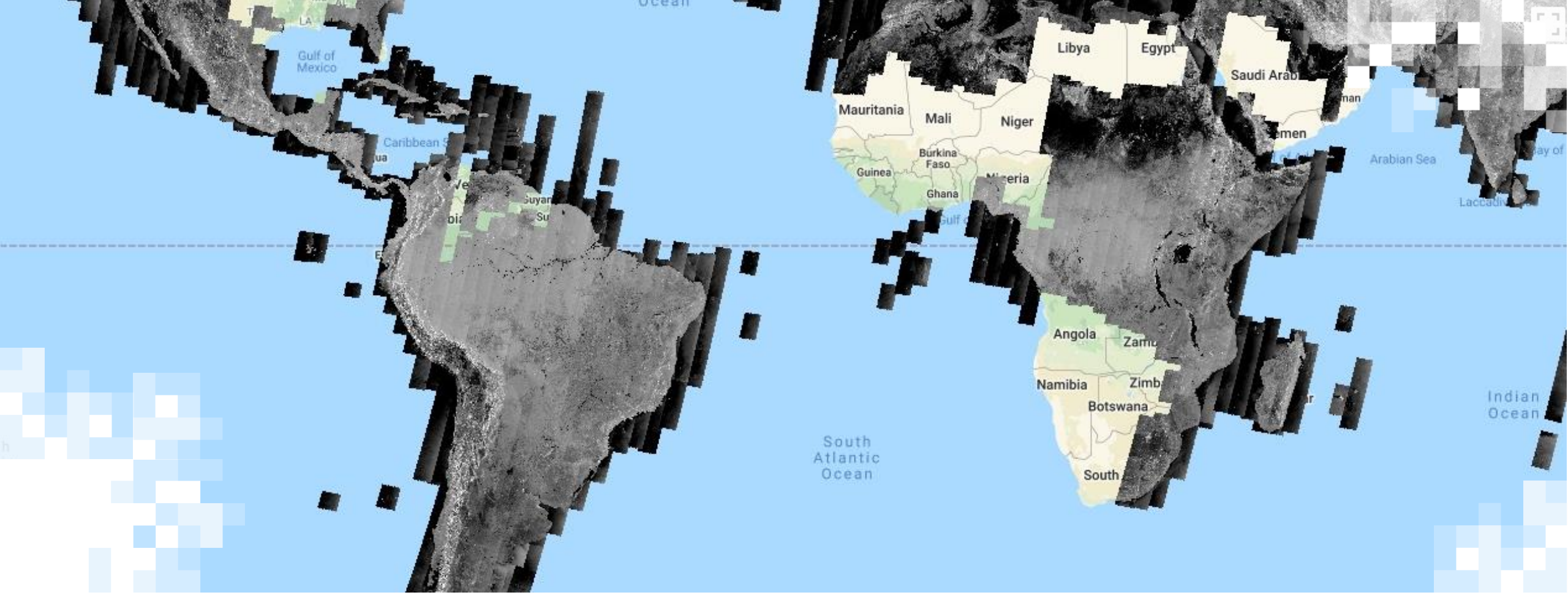
39. Select **flooded areas - blue**



Overlay the SAR Image

40. Go to the Layers manager
41. De-select all layers
42. Select **flooded areas – blue** and **After Flood VH Filtered**





THANK YOU

Contacts

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 - <http://arset.gsfc.nasa.gov>