

# Forest Mapping and Monitoring with SAR Data: Mangrove Mapping

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May 19, 2020



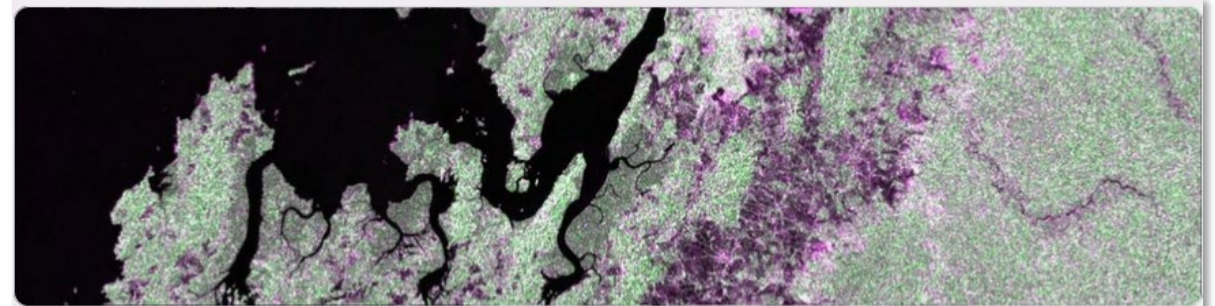
# Course Structure

- Four, 2-hour sessions on **May 12, 14, 19, and 21**
- There will be 2 sessions per day presenting the same material in
  - English (11:00-13:00 EST)
  - Spanish (14:00-16:00 EST)
  - **Please only sign up for and attend one session per day.**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - <https://arset.gsfc.nasa.gov/land/webinars/forest-mapping-sar>
  - Q&A: Following each lecture and/or by email
    - [erika.podest@jpl.nasa.gov](mailto:erika.podest@jpl.nasa.gov)
    - [amberjean.mccullum@nasa.gov](mailto:amberjean.mccullum@nasa.gov)
    - [juan.l.torresperez@nasa.gov](mailto:juan.l.torresperez@nasa.gov)



# Homework and Certificates

- **Homework:**
  - One homework assignment
  - Answers must be submitted via Google Forms
- **Certificate of Completion:**
  - Attend all three live webinars
  - Complete the homework assignment by **Thursday, June 4<sup>th</sup>** (access from ARSET website)
  - You will receive certificates approximately two months after completion of the course from: [marines.martins@ssaihq.com](mailto:marines.martins@ssaihq.com)



## Homework: Advanced Webinar: Forest Mapping and Monitoring with SAR Data

This homework includes questions from the lectures and exercises from all sessions of this webinar. Some questions refer to portions of the exercise that can be best answered as you are completing the steps. Thus, it may be best to record your answers on a sheet of paper or elsewhere before submitting them here. You will not be able to save your answers and come back to complete this form at a later time.



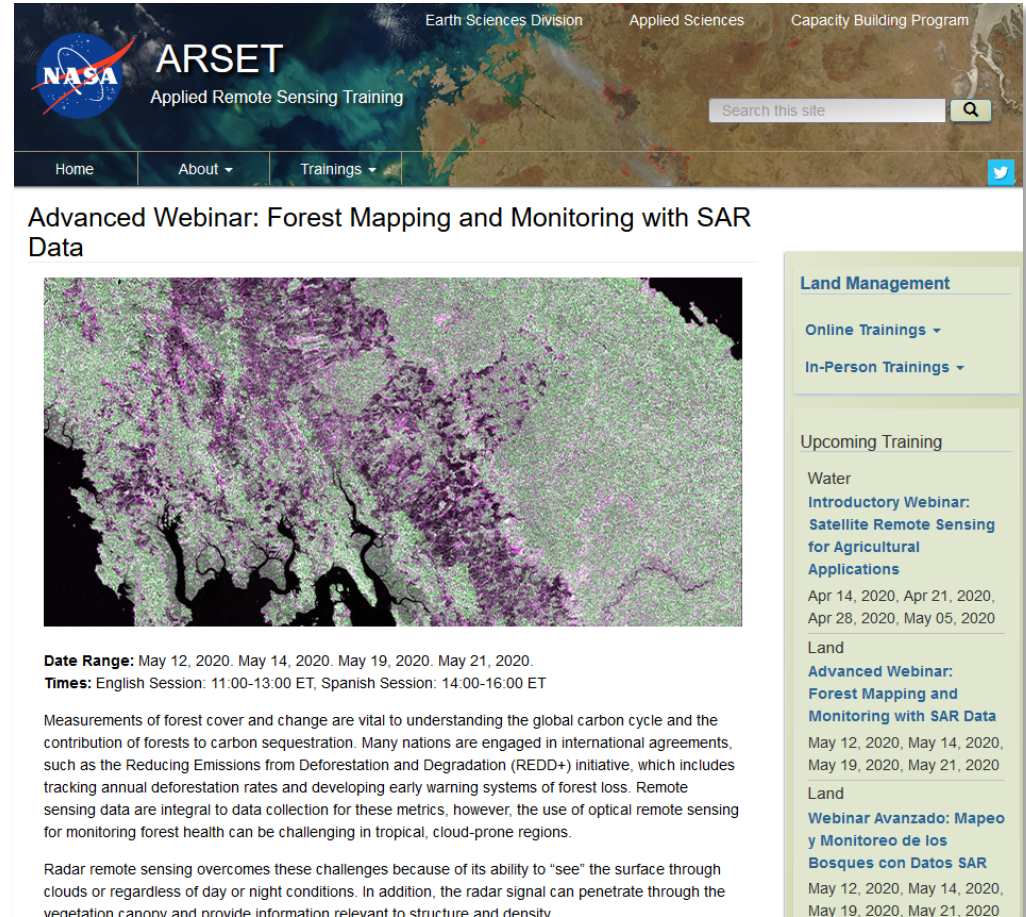
# Prerequisites and Course Materials

- **Prerequisites:**

- Please complete these two courses or have equivalent experience:
  - [Introduction to Synthetic Aperture Radar](#)
  - [Advanced Webinar: SAR for Landcover Applications](#)
- Set-up a Google Earth Engine Account (free) here:
- <https://earthengine.google.com>

- **Course Materials:**


- <https://arset.gsfc.nasa.gov/land/webinars/forest-mapping-sar>



The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo, the text 'ARSET Applied Remote Sensing Training', and navigation links for 'Earth Sciences Division', 'Applied Sciences', and 'Capacity Building Program'. A search bar is present. Below the header, there are navigation tabs for 'Home', 'About', and 'Trainings'. The main content area features a large image of a forest map with purple and green overlays. To the right of the image is a sidebar with navigation links for 'Land Management', 'Online Trainings', and 'In-Person Trainings'. Below the image, the text reads: 'Advanced Webinar: Forest Mapping and Monitoring with SAR Data'. The 'Date Range' is listed as 'May 12, 2020, May 14, 2020, May 19, 2020, May 21, 2020'. The 'Times' are 'English Session: 11:00-13:00 ET, Spanish Session: 14:00-16:00 ET'. The main text describes the importance of forest cover measurements for carbon sequestration and deforestation monitoring. A sidebar on the right lists 'Upcoming Training' for 'Water' and 'Land'. The 'Land' section lists the 'Advanced Webinar: Forest Mapping and Monitoring with SAR Data' with dates 'May 12, 2020, May 14, 2020, May 19, 2020, May 21, 2020'. Below that, it lists 'Webinar Avanzado: Mapeo y Monitoreo de los Bosques con Datos SAR' with the same dates.



# Course Outline



Part 1: Time Series  
Analysis of Forest  
Change



Part 2: Land Cover  
Classification with  
Radar and Optical  
Data



**Part 3: Mangrove  
Mapping**



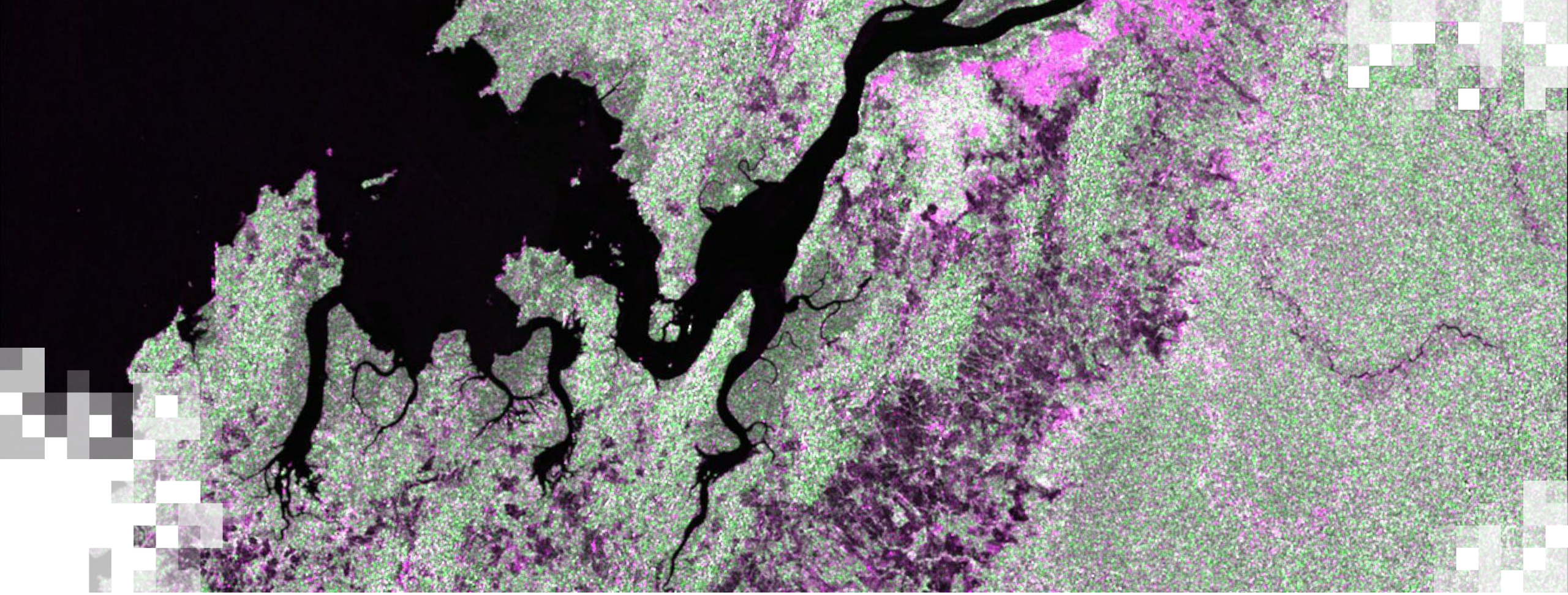
Part 4: Forest Stand  
Height Estimation



# Learning Objectives

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

- Identify the radar signal interaction with mangrove ecosystems
- Recognize the challenges in using SAR for mapping mangroves



# Mangrove Ecosystems

# Mangrove Ecosystems - Distribution and Role

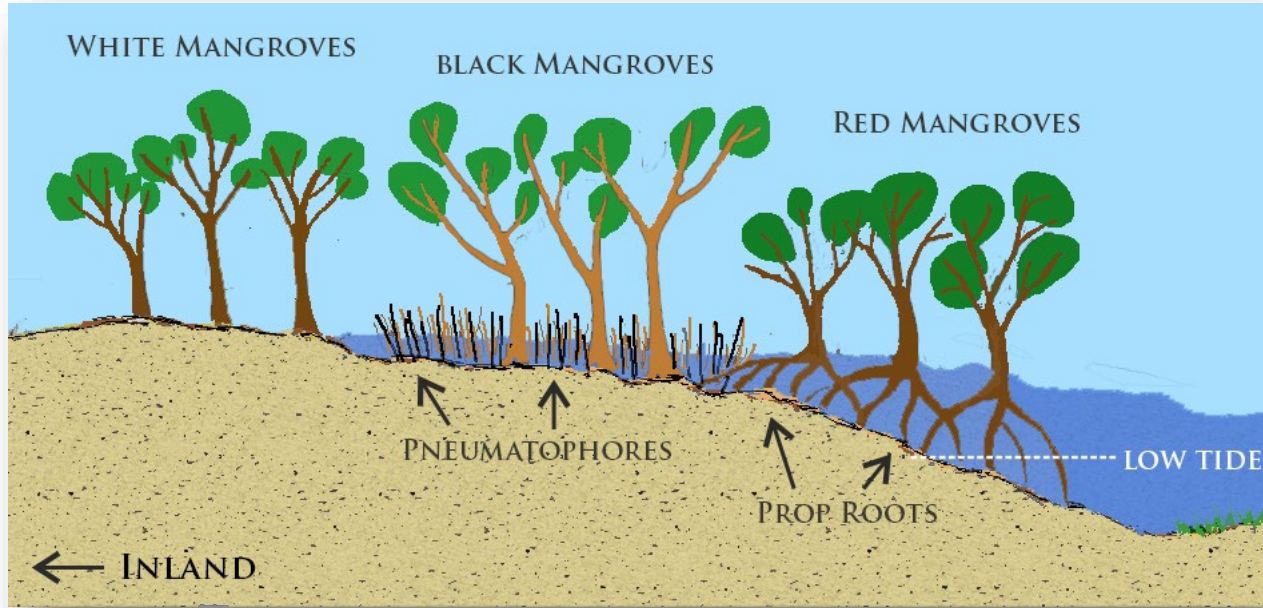


Source: [wetlandsandwildlife.wordpress.com](http://wetlandsandwildlife.wordpress.com)





# Mangrove Ecosystems - Types



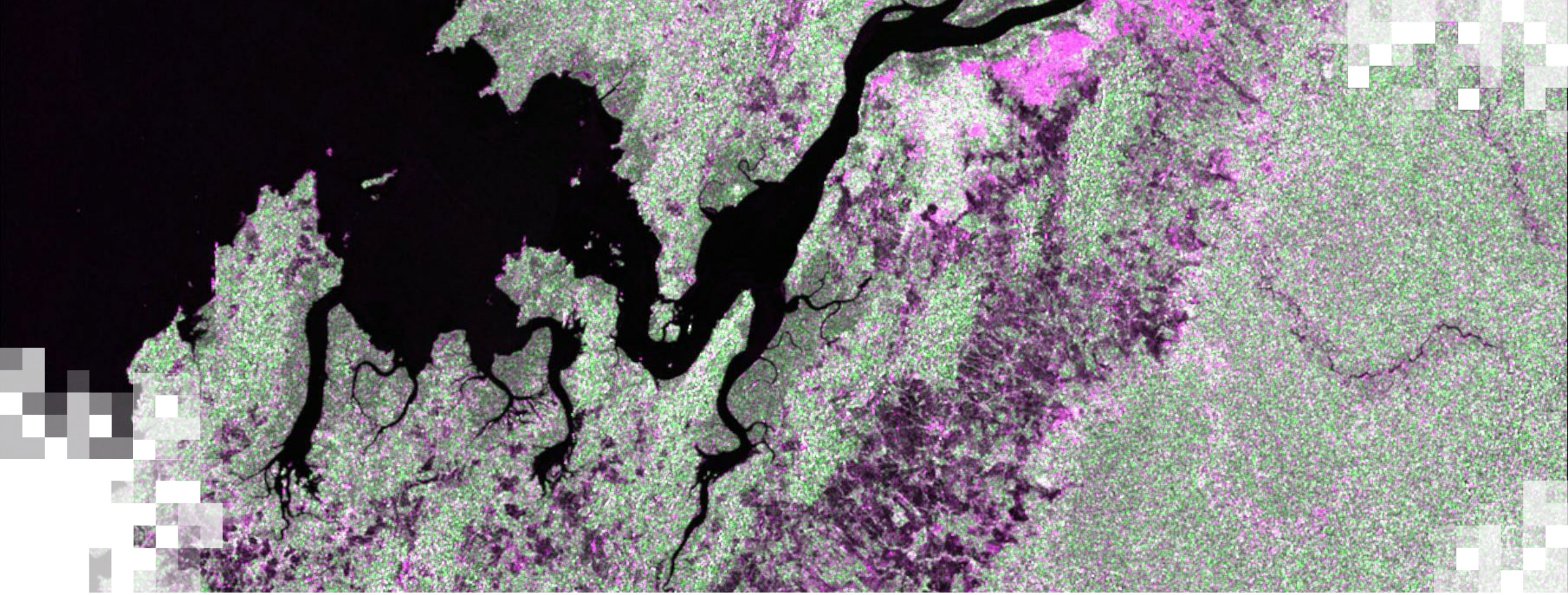
Source: Ecolombianos and Ecologiapolitica



# Challenges in Mapping Mangrove Ecosystems

- Need for high resolution imagery
- Cloud cover
- High and low tides impact the characteristics of the signal



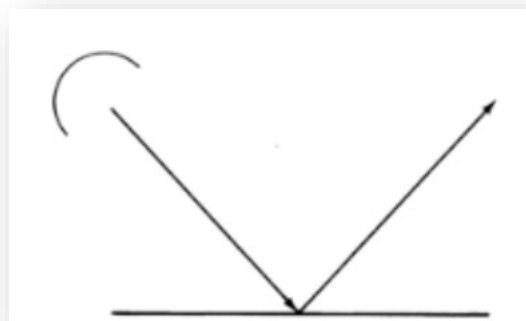


# SAR Signal Characteristics and Mangrove Ecosystems

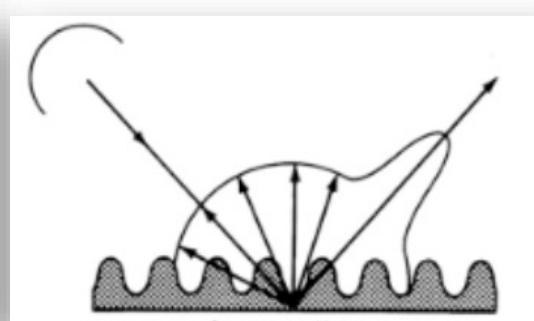
# Radar Backscattering Mechanisms

- The scale of the surface relative to the wavelength determines whether it is rough or smooth and how it appears (bright or dark) on the image.

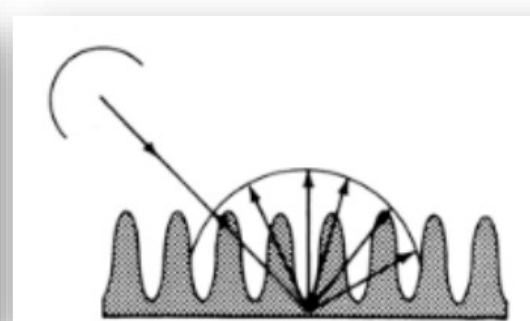
Backscattering Mechanisms:



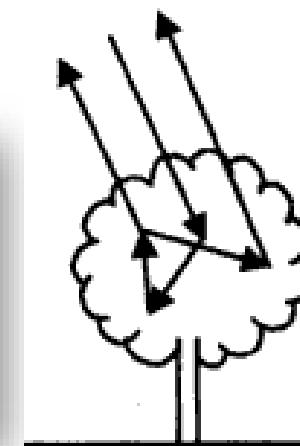
Smooth Surface



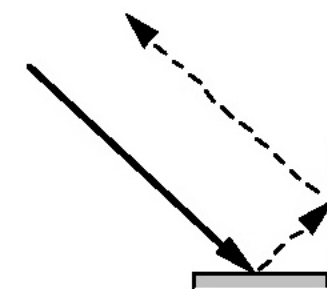
Rough Surface



Rougher Surface



Volume Scattering

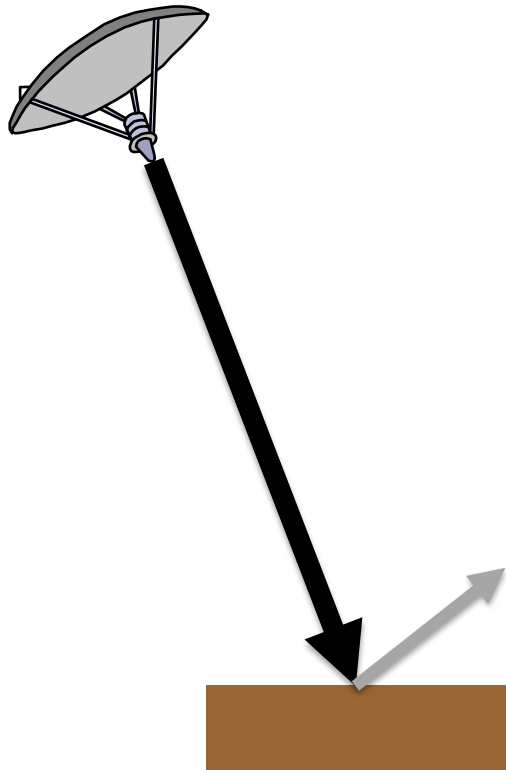


Double Bounce



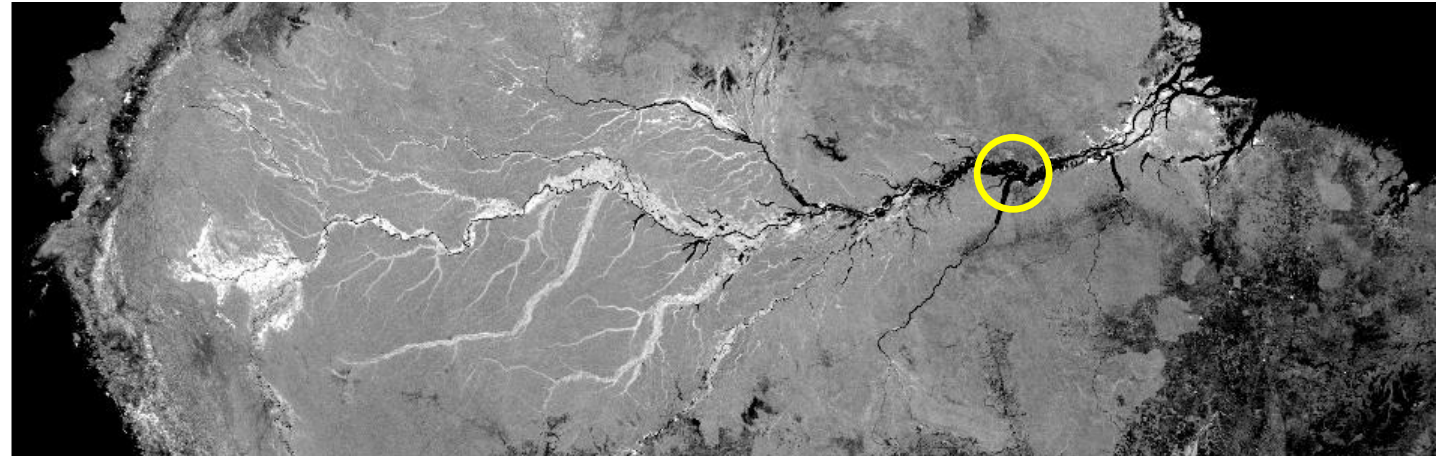
# Examples of Radar Interaction

## Smooth Surface Reflection (Specular Reflection)



Smooth, Level Surface  
(open water, road)

SMAP Radar Mosaic of the Amazon Basin  
April 2015 (L-band, HH, 3 km)



Pixel Color



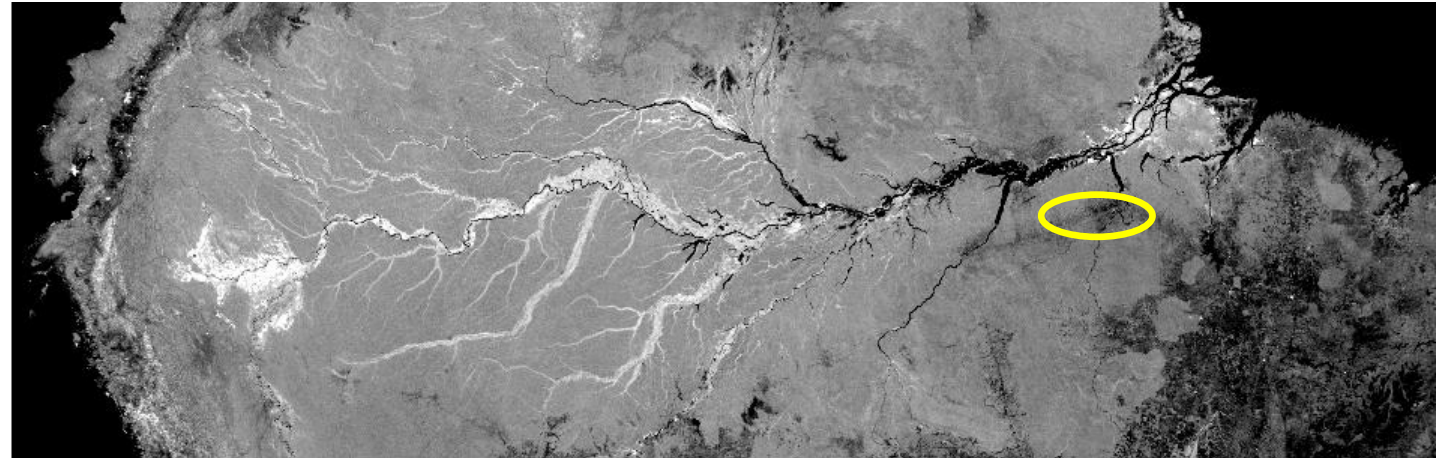
# Examples of Radar Interaction

## Rough Surface Reflection



Rough, Bare Surface (deforested areas,  
tilled agricultural fields)

SMAP Radar Mosaic of the Amazon Basin  
April 2015 (L-band, HH, 3 km)

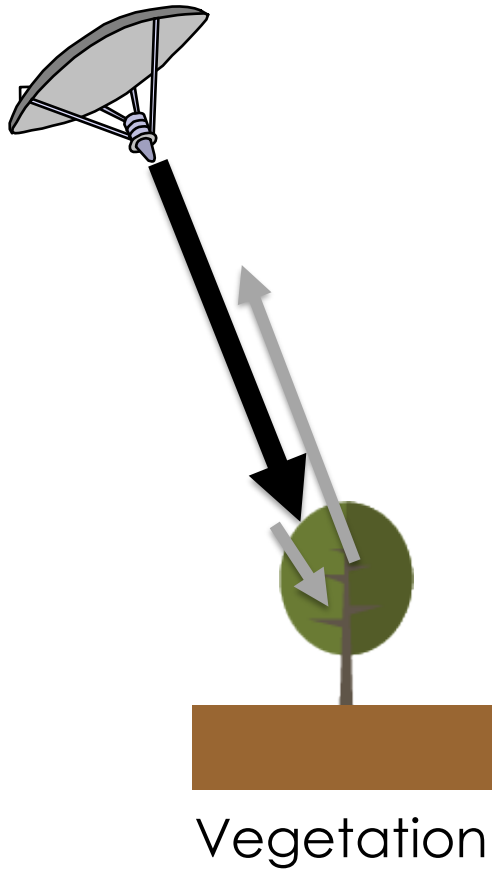


Pixel Color

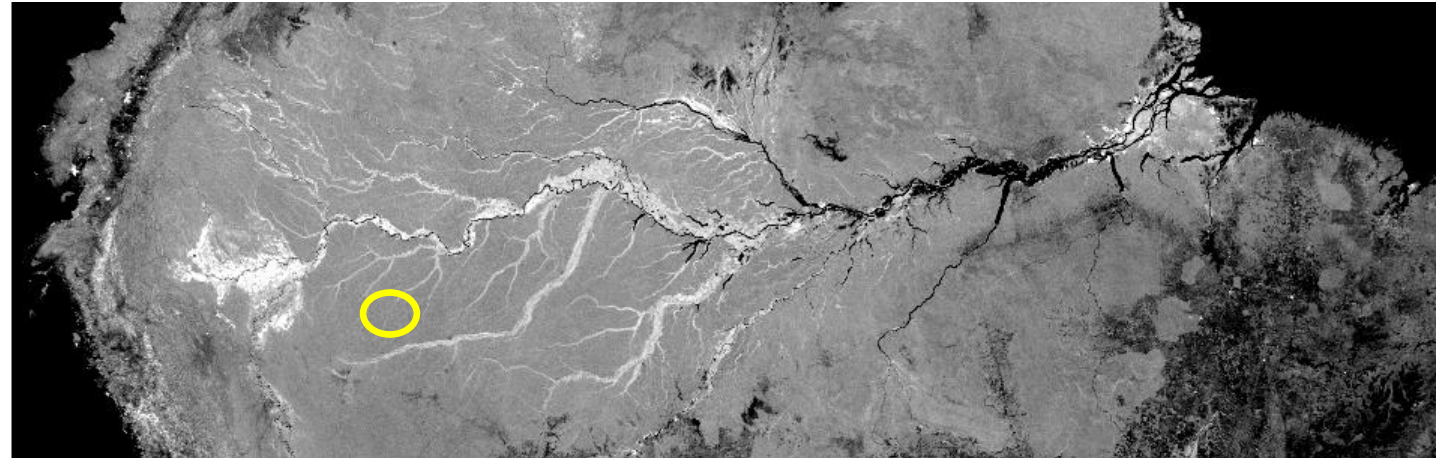


# Examples of Radar Interaction

## Volume Scattering by Vegetation



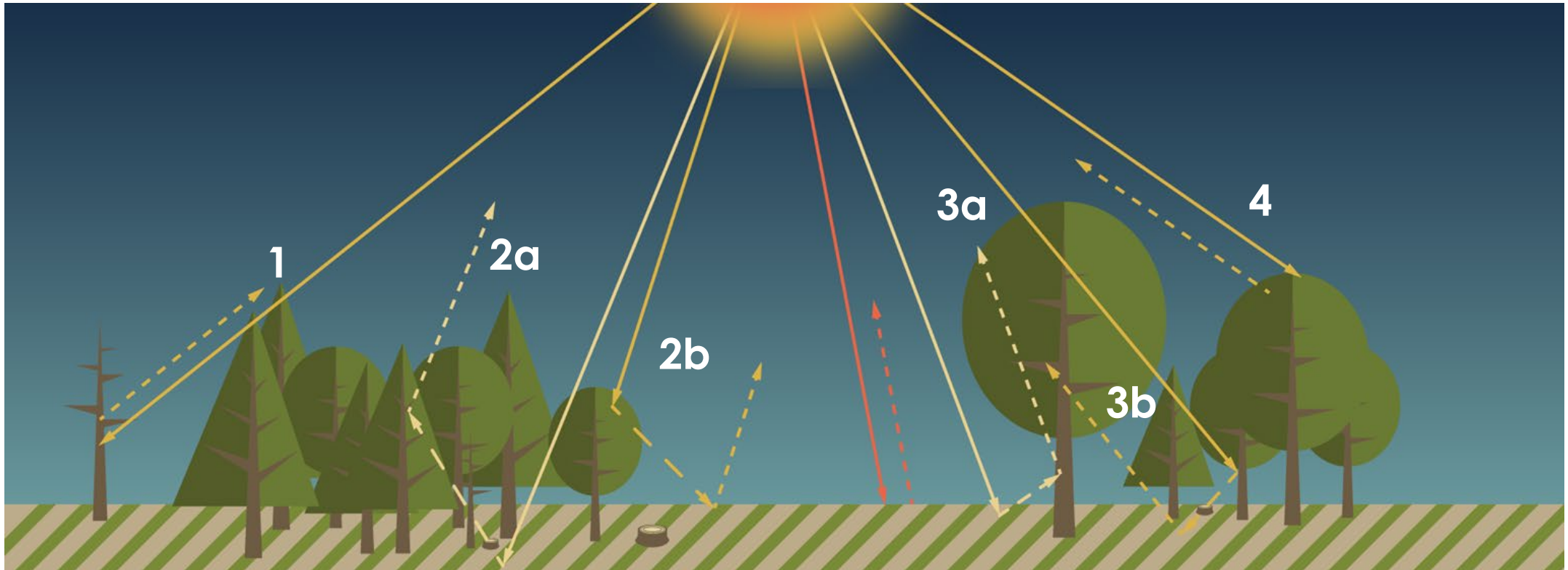
SMAP Radar Mosaic of the Amazon Basin  
April 2015 (L-band, HH, 3 km)



Pixel Color



# Radar Backscattering in Vegetation



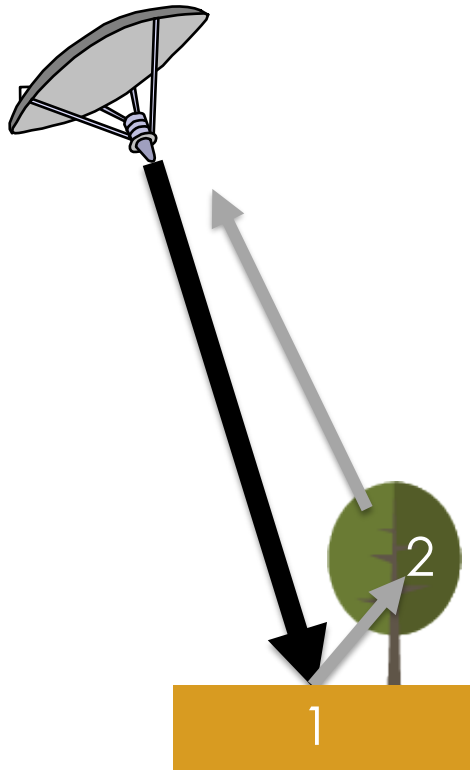
Dominant backscattering sources in forests: (1) direct scattering from tree trunks, (2a) ground-crown scattering, (2b) crown-ground scattering, (3a) ground-trunk scattering, (3b) trunk-ground scattering, (4) crown volume scattering.





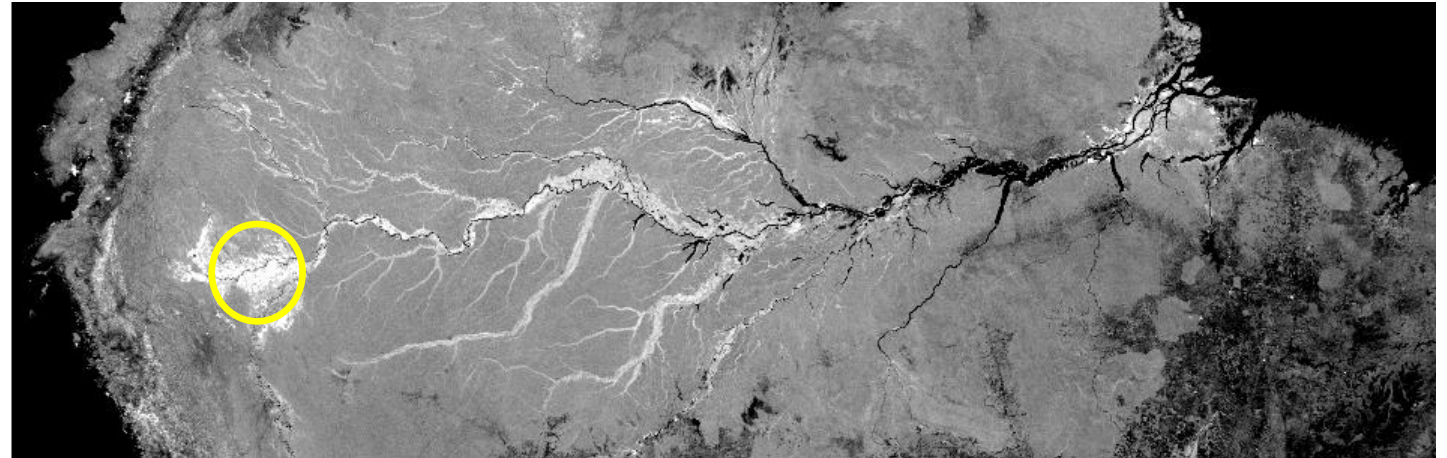
# Examples of Radar Interaction

## Double Bounce

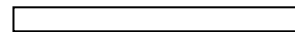


Inundated Vegetation

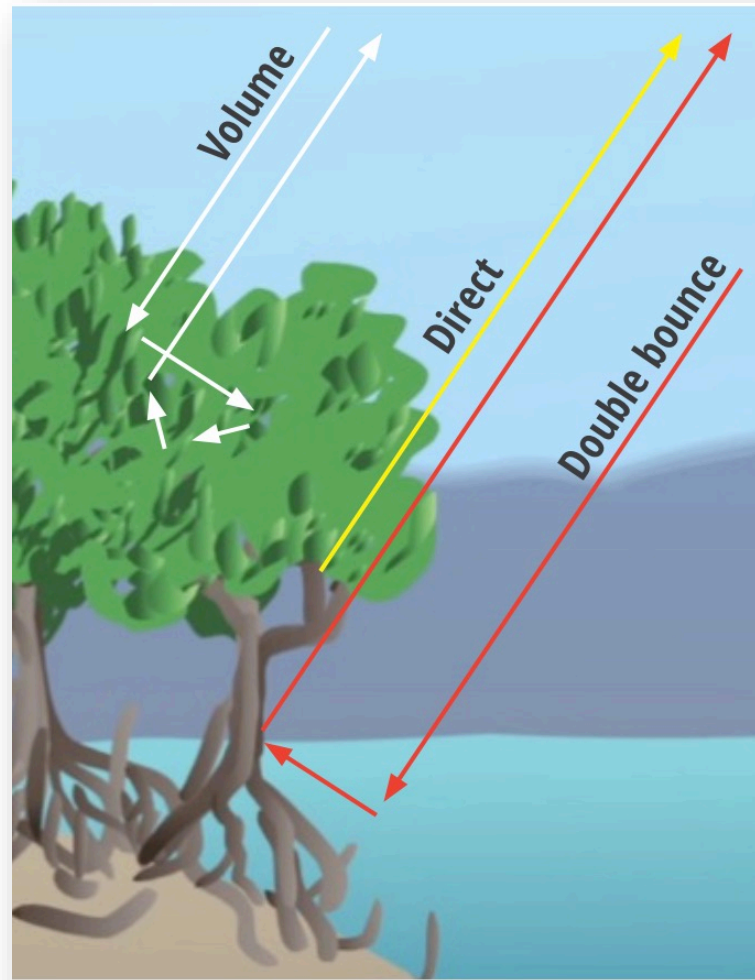
SMAP Radar Mosaic of the Amazon Basin  
April 2015 (L-band, HH, 3 km)



Pixel Color



# Radar Signal Interaction with Mangrove Ecosystems

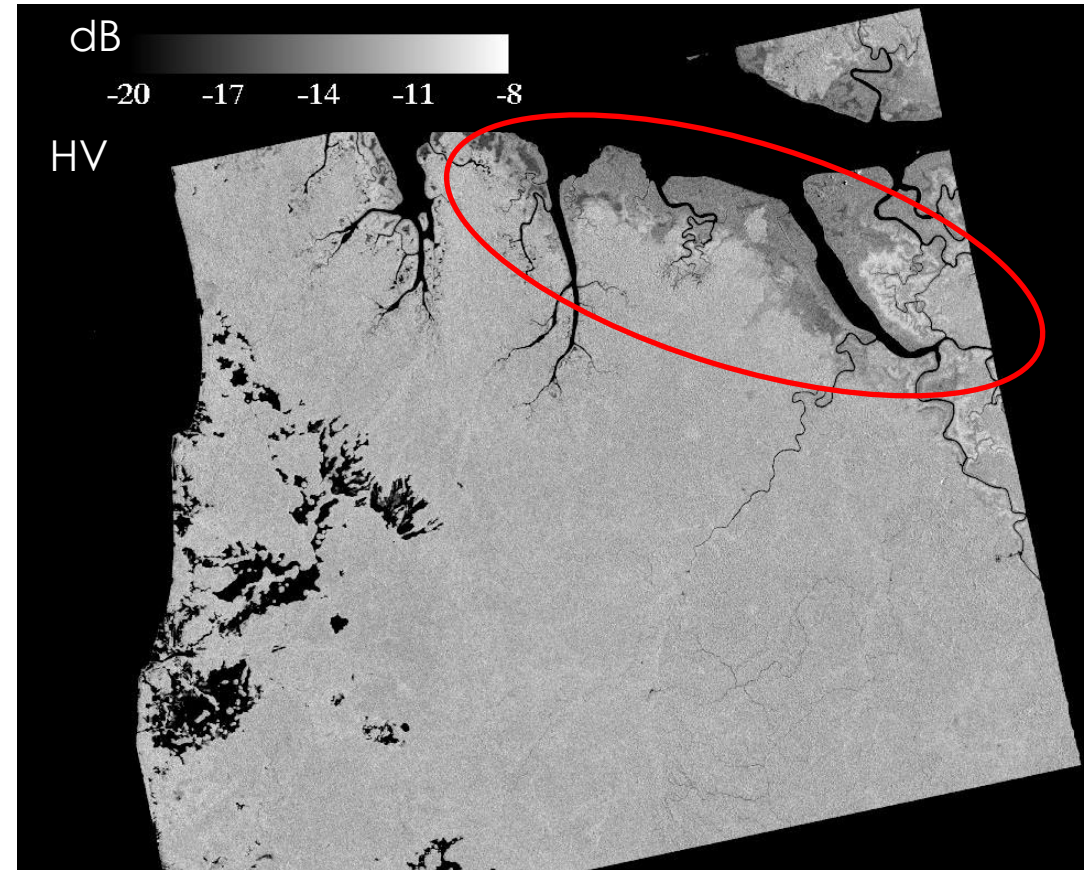
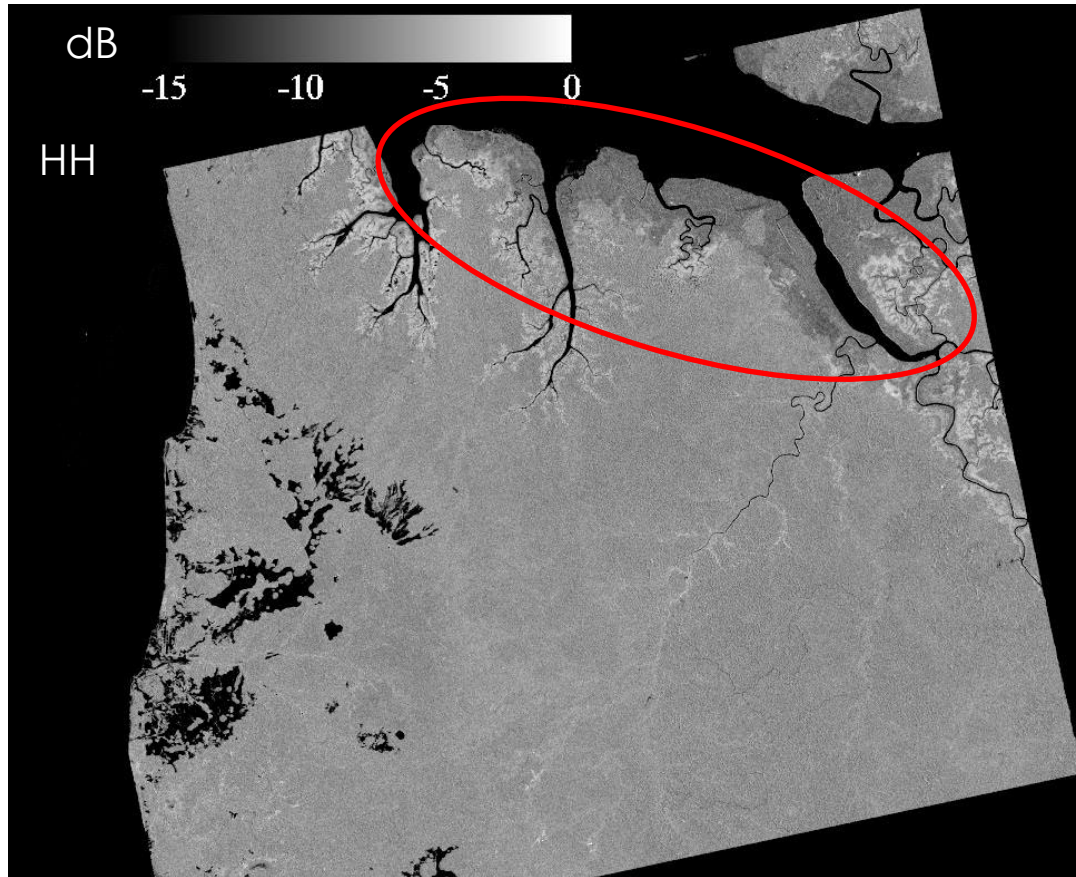


Source: SERVIR SAR Handbook Chapter 6 by Marc Simard



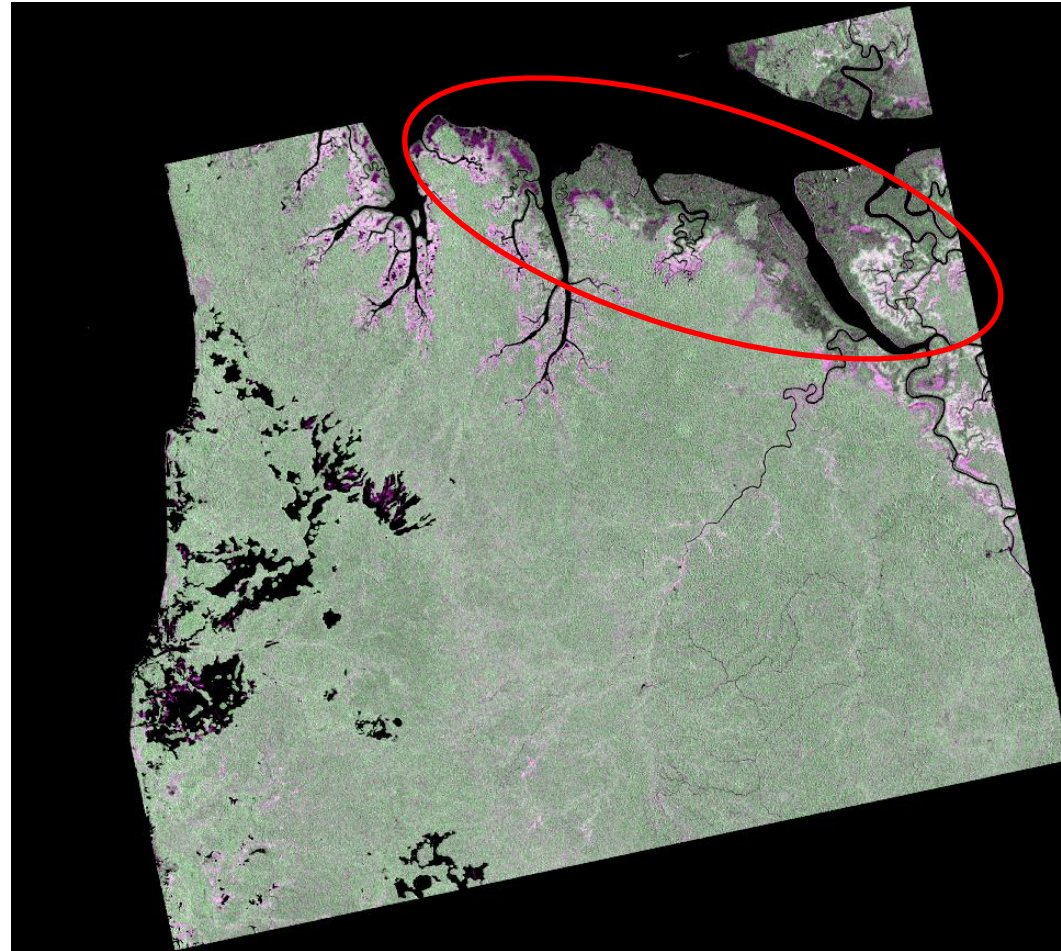
# Polarization Interaction with Mangrove Ecosystems

L-band ALOS PALSAR HH and HV over Gabon on Aug. 10, 2007



# Polarization Interaction with Mangrove Ecosystems

L-band ALOS PALSAR RGB HH/HV/HH over Gabon on Aug. 10, 2007

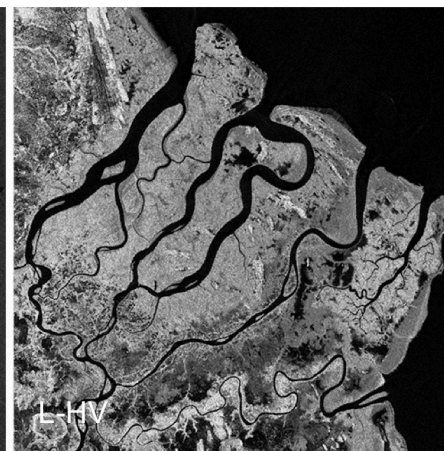


# Radar Signal Interaction at C- and L Bands

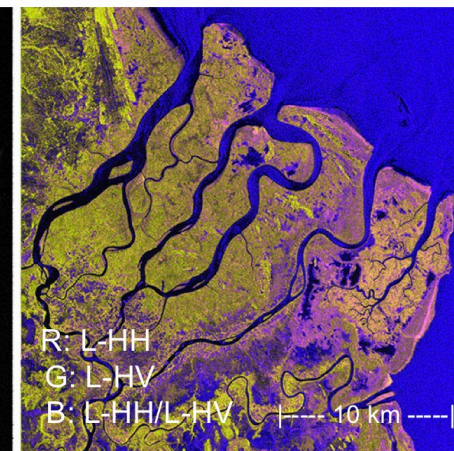
Location:  
Rufiji Delta, Tanzania



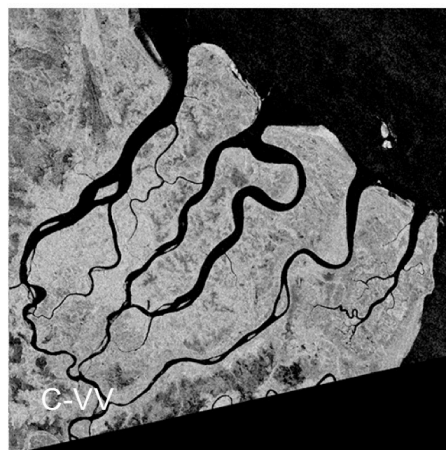
L-HH: -6.6 (+/- 2.5) dB



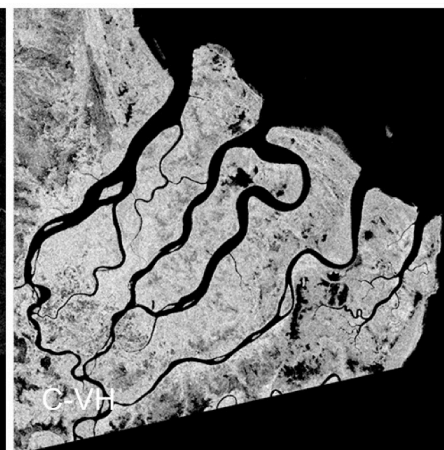
L-HV: -14.7 (+/- 3.2) dB



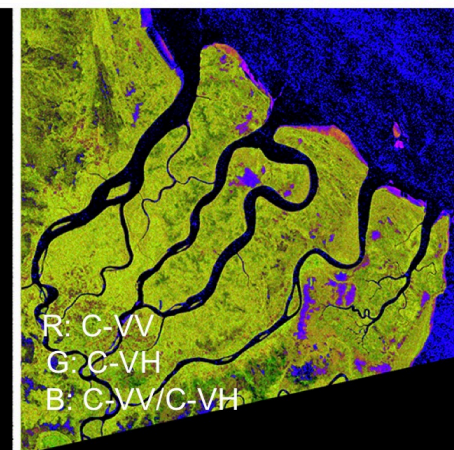
Observation date: 3-SEP-2017



C-VV: -7.2 (+/- 1.3) dB



C-VH: -12.9 (+/- 1.3) dB



Observation date: 30-AUG-2017

Source: A Layman's Interpretation Guide to L-band and C-band Synthetic Aperture Radar data by CEOS and GFOI



# Radar Signal Interaction with Mangroves at Different bands

BAND	MANGROVE FOREST PENETRATION DEPTH	TYPE OF SCATTERING CAUSED BY MANGROVE FORESTS
<b>K</b>	Unknown; most likely a few tens of centimeters.	Single direct bounce and volume from top of canopy.
<b>X</b>	Interferometric measurement indicate penetration reaches, in the mean sense, Lorey's height (~1/3 of top forest height).	Single direct bounce and volume from top of canopy, with a small surface and double bounce component. The latter increase dramatically in open forests and at low biomass.
<b>C</b>	Comparison of SRTM C- and X-band show it is similar to C-band. Down to the equivalent of Lorey's height (~1/3 of top forest height)	Single direct bounce and volume from upper canopy, with a small surface and double bounce component. The latter increase dramatically in open forests and at low biomass.
<b>L</b>	Microwave penetration into canopy is as large as half the canopy height.	Single direct bounce dominates in tall forests, with volume dominating with shorter shrub mangroves. The contribution of double bounce increases significantly at low biomass and in open forests. In large red mangrove forest, with large aerial roots, microwaves will get absorbed and volume dominates again, although diminished.
<b>P</b>	Similar to L-band, where microwave penetration into canopy is as large as half the canopy height.	Single direct bounce dominates in tall forests, but the contribution of double bounces increases significantly at low biomass. In large red mangrove forest, with large aerial roots, microwaves will get absorbed and volume dominates again at biomass slightly larger than at L-band.



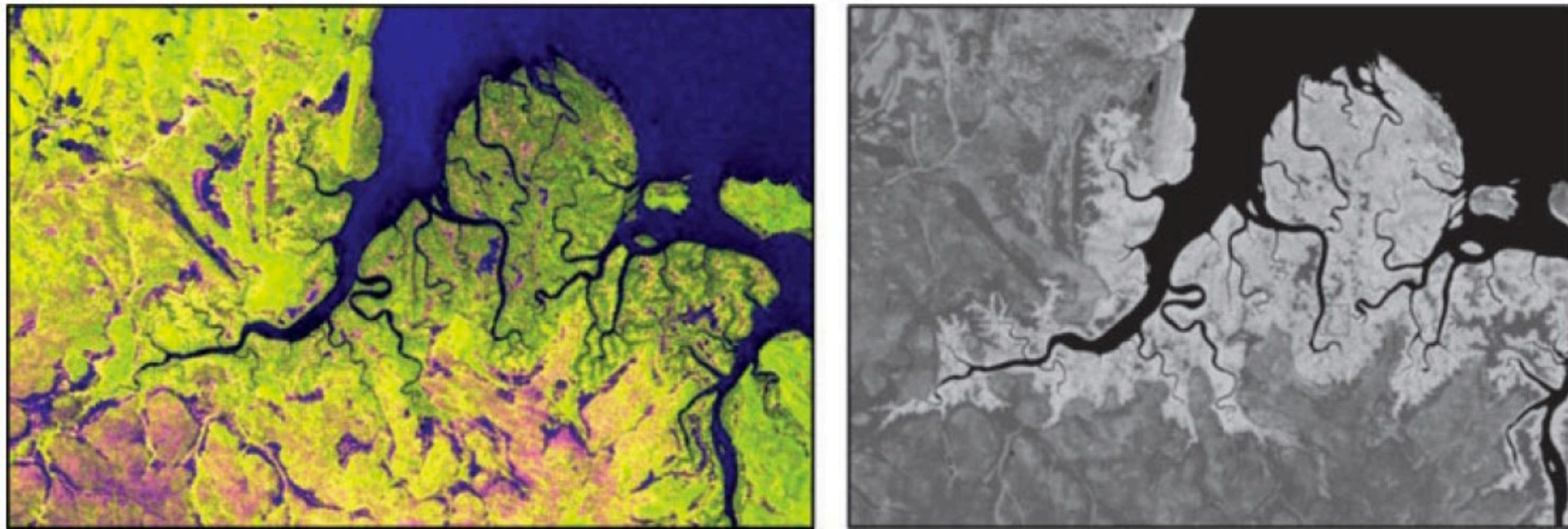
# Backscatter Range for Mangroves

RADAR BAND	SHRUB MANGROVES	TALL MANGROVES
<b>P-HH</b>	Around -17dB	Around -8dB (may increase with AGB)
<b>P-HV and P-VH</b>	Around -22dB	Around -14dB (may increase with AGB)
<b>P-VV</b>	Around -10dB	Around -7dB (may increase with AGB)
<b>L-HH</b>	-25dB to -15dB	Reduces from -5dB to -18dB with AGB
<b>L-HV and L-VH</b>	-25 to -20dB	Reduces from -15 dB to -22dB with AGB
<b>L-VV</b>	-20dB to -12 dB	Reduces from -8 to -16dB with AGB
<b>C-HH</b>	About -12dB	Varies about -7dB (no relationship to AGB)
<b>C-HV</b>	-20 to -15dB	varies about -14dB (no relationship to AGB)
<b>C-VV</b>	About -12dB	Varies about -6dB (no relationship to AGB)



# Challenges

- It is difficult to map the extent of mangrove forests with just radar, especially when mangroves adjoin forests and shrublands.



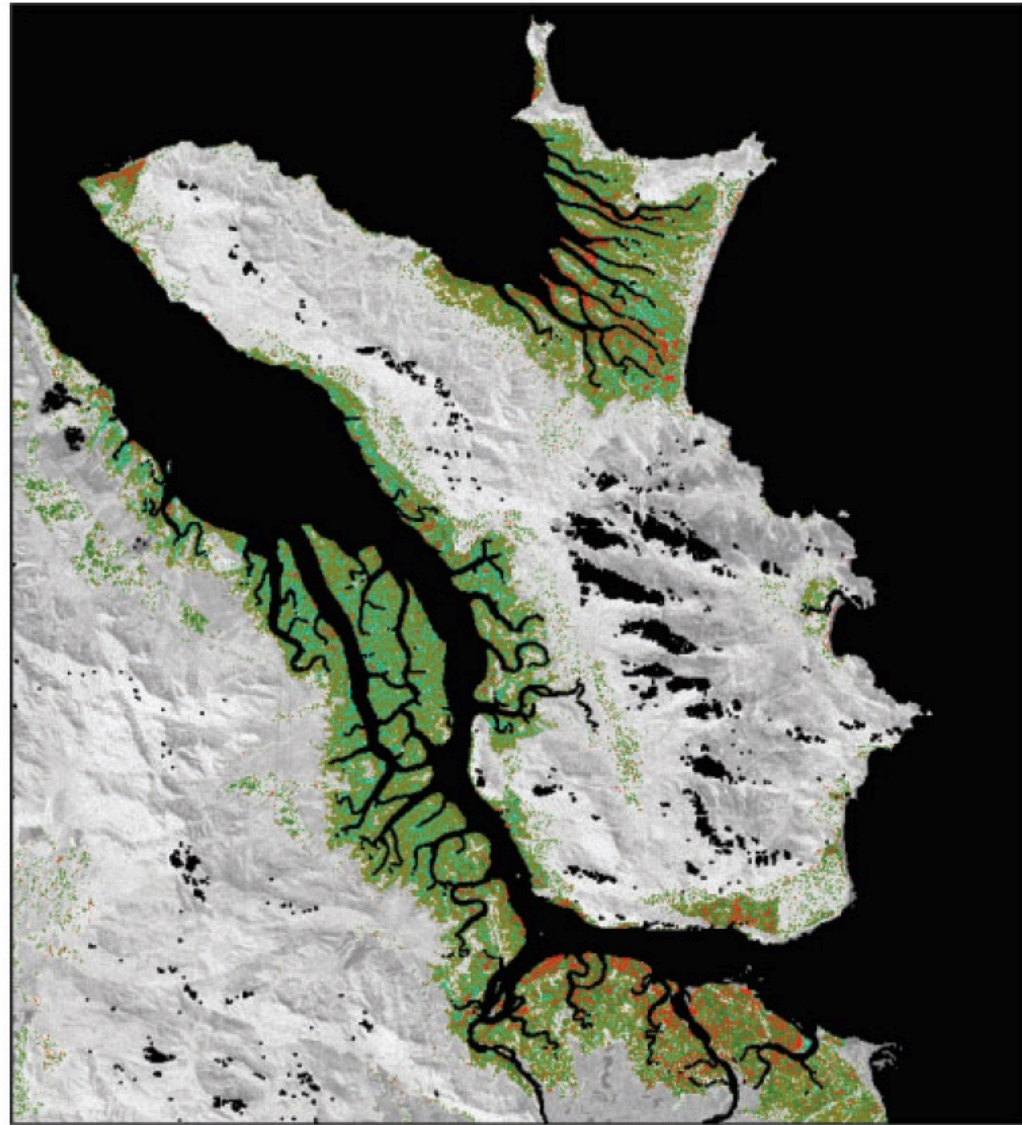
Source: Lucas et al., 2014. Contribution of L-band SAR to Systematic Global Mangrove Monitoring





# Classifying Mangroves

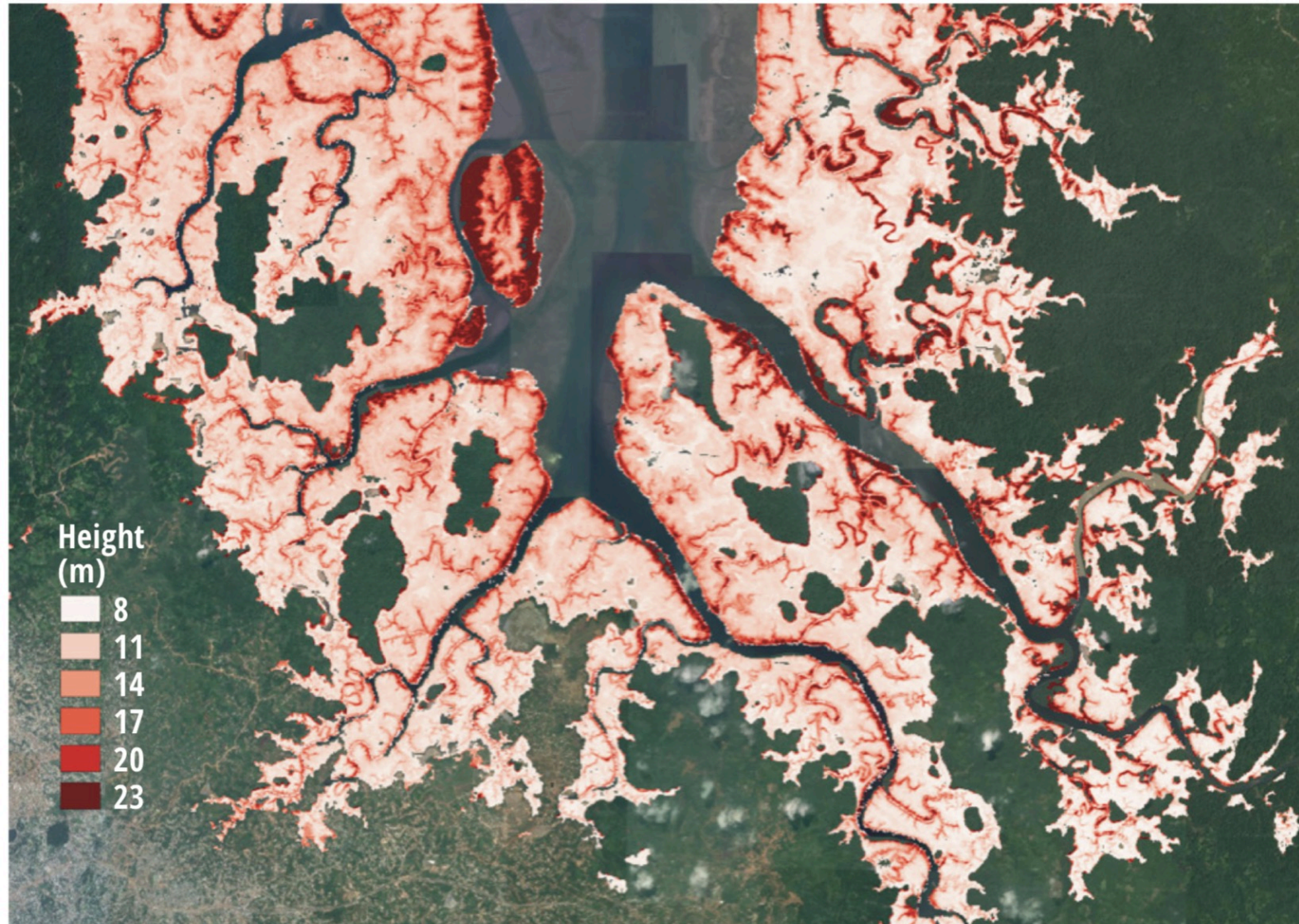
- One solution is to confine mapping of mangroves to those areas that have a higher likelihood of occurring.
- Another approach is to use radar in combination with data from different sensors.



Source: Lucas et al., 2014. Contribution of L-band SAR to Systematic Global Mangrove Monitoring



# Mangrove Canopy Height

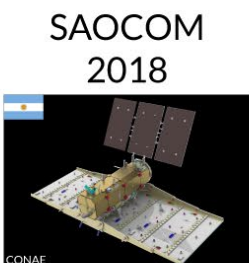
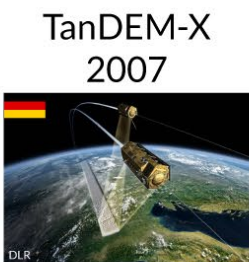


# Radar Data Available

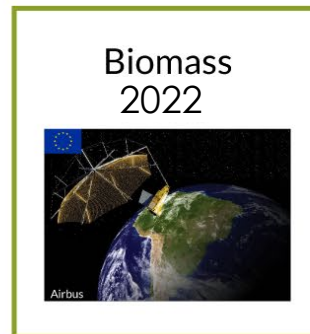
Legacy:



Current:



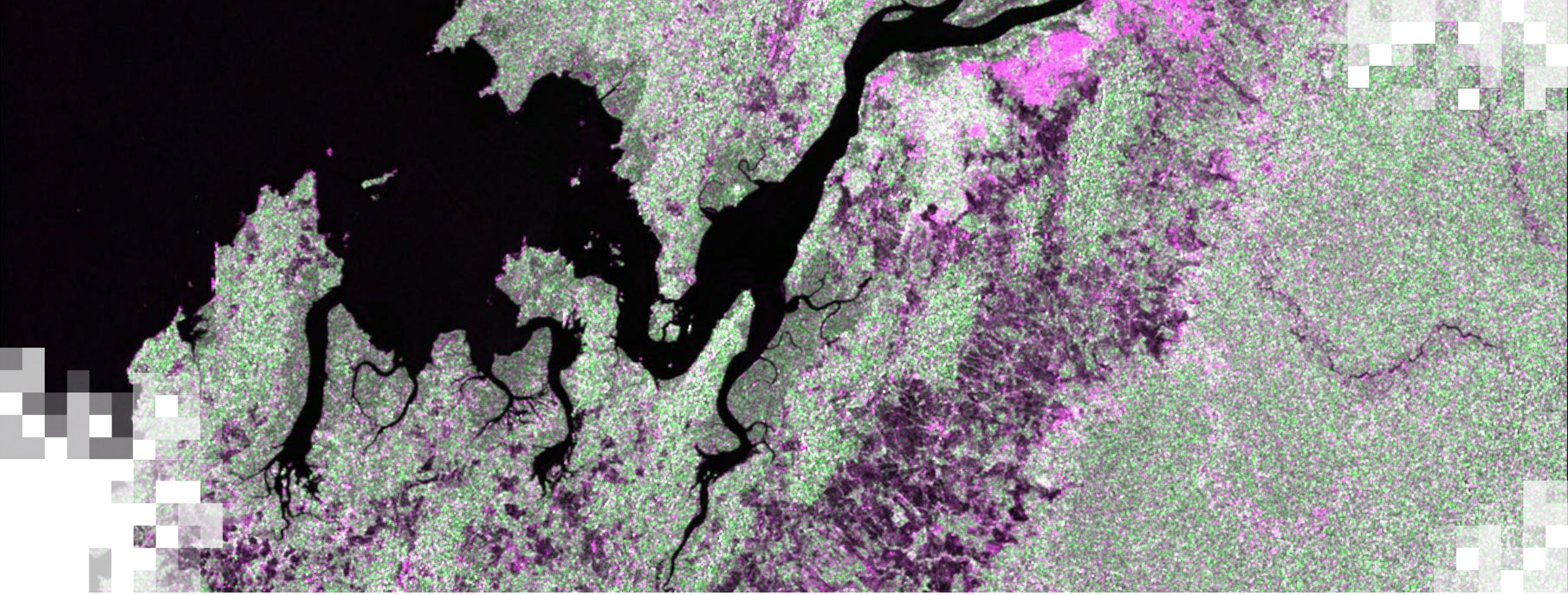
Future:



Freely Accessible

Image Credit: Franz Meyer, University of Alaska, Fairbanks





## Hands-on Exercise

# Exercise Overview

- Process and analyze radar images,
- Monitor land use change
- Estimate above ground biomass for mangrove forests



# Software and Data

- Software:
  - SNAP - <http://step.esa.int/main/download/>
  - GEE
- Analysis ready data to be used:
  - ALOS PALSAR -1 (images and mosaics)
  - ALOS PALSAR -2 (only mosaics are freely available)
  - JERS-1 Mosaic
  - Global Mangrove Watch - 2010



# Download L-Band SAR Mosaic Tiles from JAXA

1. Access the JAXA website and register under Step 4:

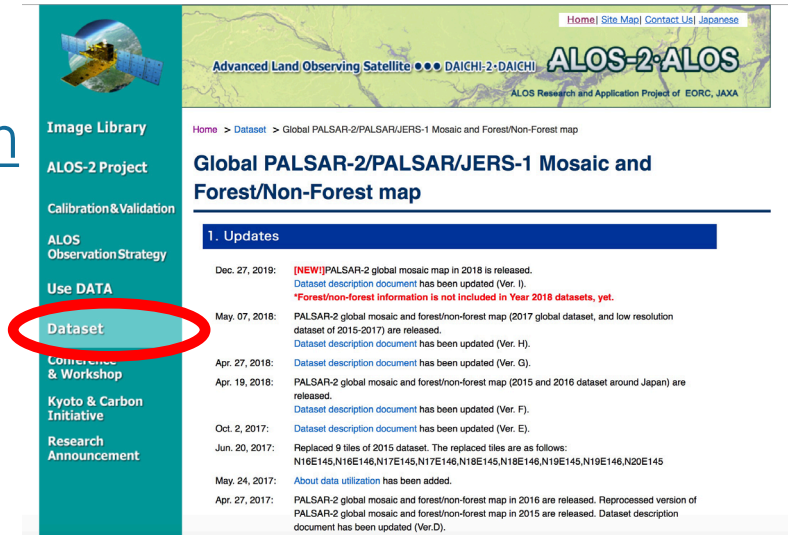
[http://www.eorc.jaxa.jp/ALOS/en/palsar\\_fnf/fnf\\_index.htm](http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm)

2. Select "Dataset" on the left column:

- Select "Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map."

- Scroll down to Step 4 "Download" and select the downloading link.

Log into your account using the email and password created during the registration process.



The screenshot shows the JAXA website interface. On the left, a navigation menu is visible with the 'Dataset' option circled in red. The main content area displays the title 'Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map' and a section titled '1. Updates' containing a list of recent dataset releases and updates, including dates and descriptions of new data or changes to existing data.

## 4. Download

Please register your information from following URL to download the dataset. It is required your email address.

[https://www.eorc.jaxa.jp/ALOS/en/palsar\\_fnf/registration.htm](https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/registration.htm)

This is temporally registration (especially please check your email address again) and will send email you to accept your registration request. After the confirmation of your request, the download information will send by email.

The dataset download link is

[https://www.eorc.jaxa.jp/ALOS/en/palsar\\_fnf/data/index.htm](https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm)

\* If you forget your password, please register again.

\* Recommend to use Microsoft Edge, Mozilla Firefox, Apple Safari.

However, it may not be available depending on the version.

\* Depending on your network environment, the downloaded compressed file may be automatically uncompressed.

\* Depending on the time, it may take time to display the page or download the dataset.



# Download L-Band SAR Mosaic Tiles from JAXA

## 3. Select 1996 under “JERS-1 SAR mosaic”

### Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest / Non-forest Map

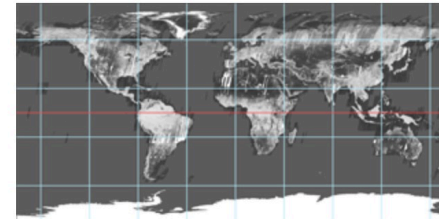
• These map uses Javascript. Please enable JavaScript on your browser.

#### 25m resolution product

##### Global

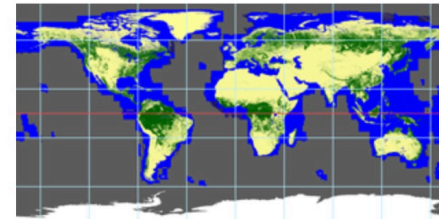
- JERS-1 SAR Mosaic:

< 1996



- PALSAR/PALSAR-2 mosaic and forest/non-forest (FNF) map:

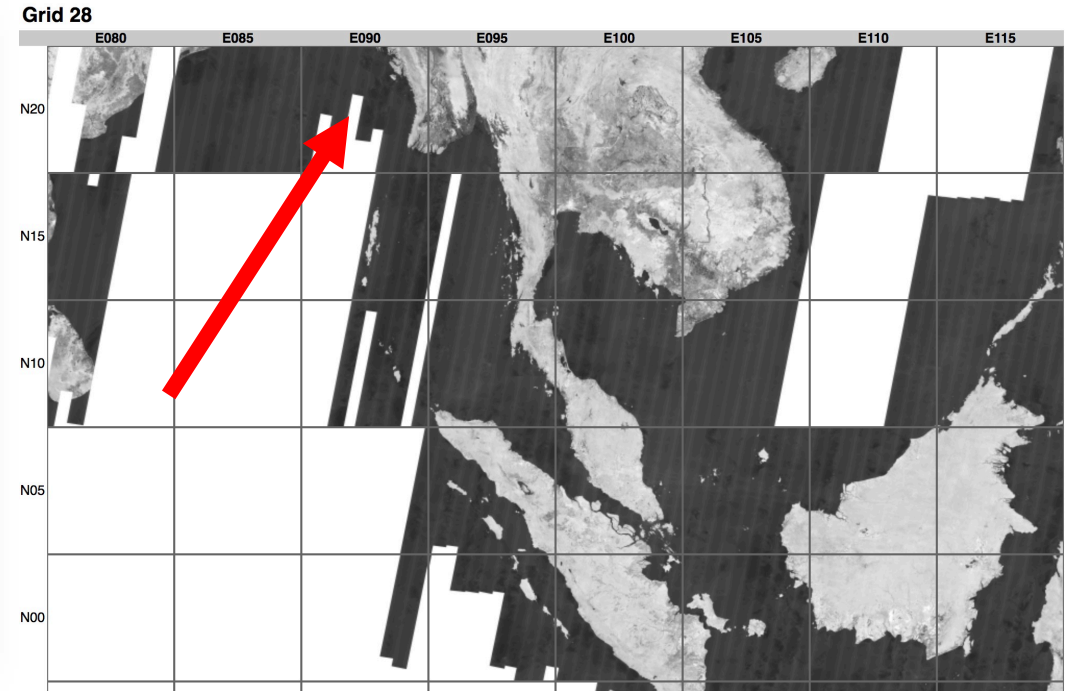
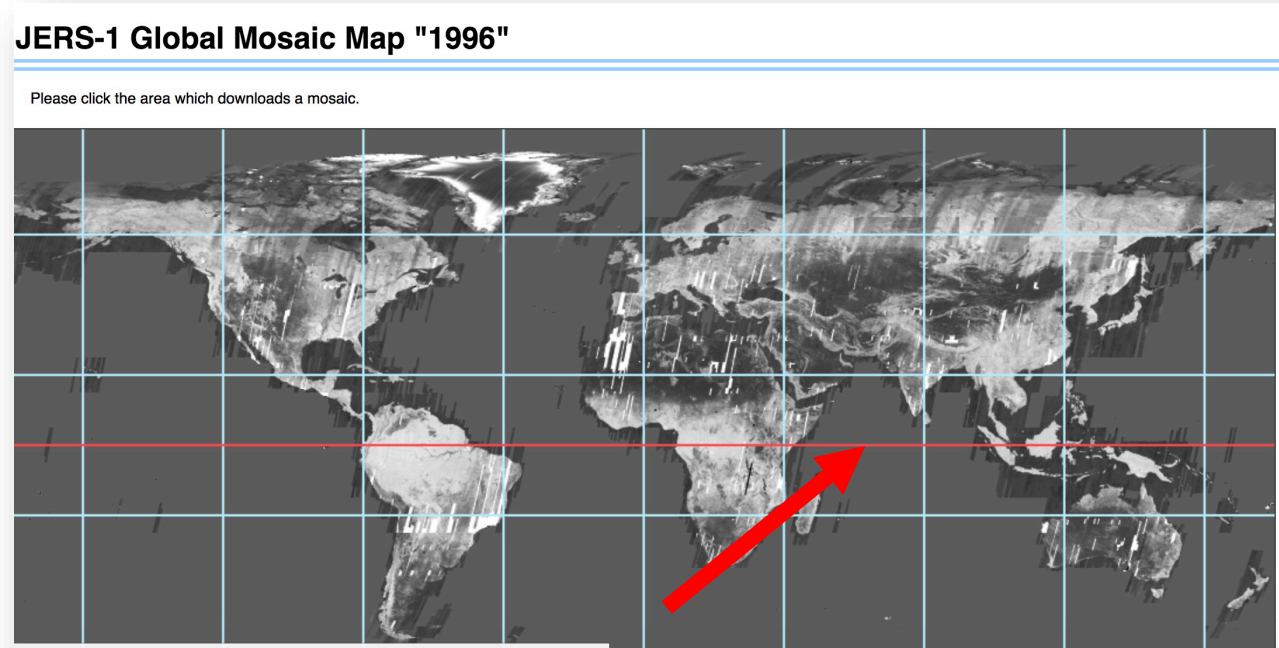
>> 2007 >> 2008 >> 2009 >> 2010 >> 2015  
>> 2016 >> 2017 >> 2018





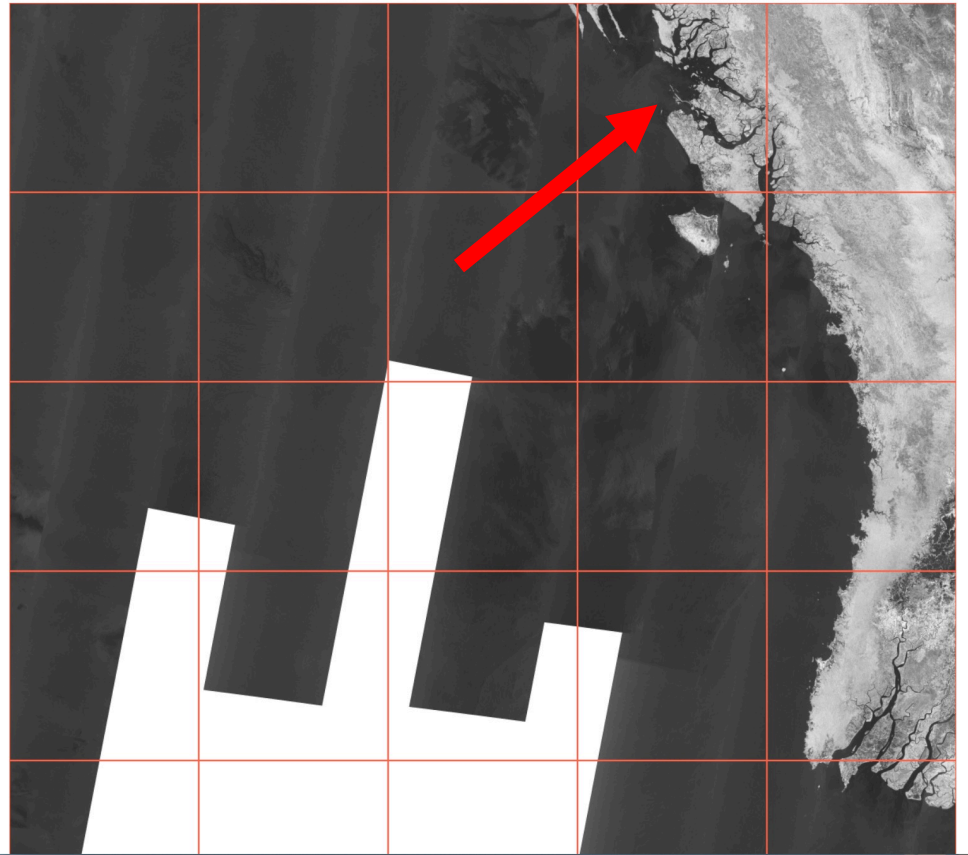
# Download L-Band SAR Mosaic Tiles from JAXA

4. Select 2017 under “PALSAR/PALSAR-2 mosaic and forest/non-forest (FNF) map”
5. Our study area is the coast of Myanmar. Click on the tiles noted here




# Download L-Band SAR Mosaic Tiles from JAXA

6. Click on the tile noted on the left and a new window will open. Select download.



N20E093\_1996

Year	Type	Image	Download
1996	HH		



# Download L-Band SAR Mosaic Tiles from JAXA

7. Repeat the same process and download tiles 2-5. You should have downloaded the following five tiles:

**N20E093\_1996**

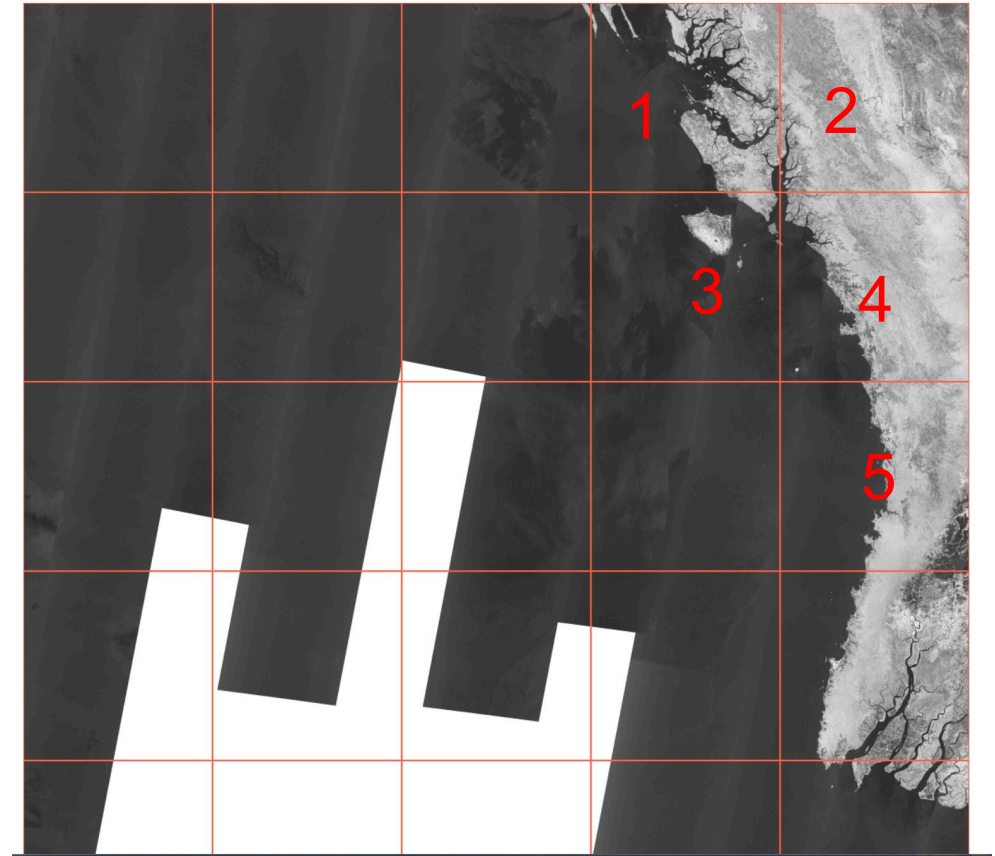
**N20E094\_1996**

**N19E093\_1996**

**N19E094\_1996**

**N18E094\_1996**

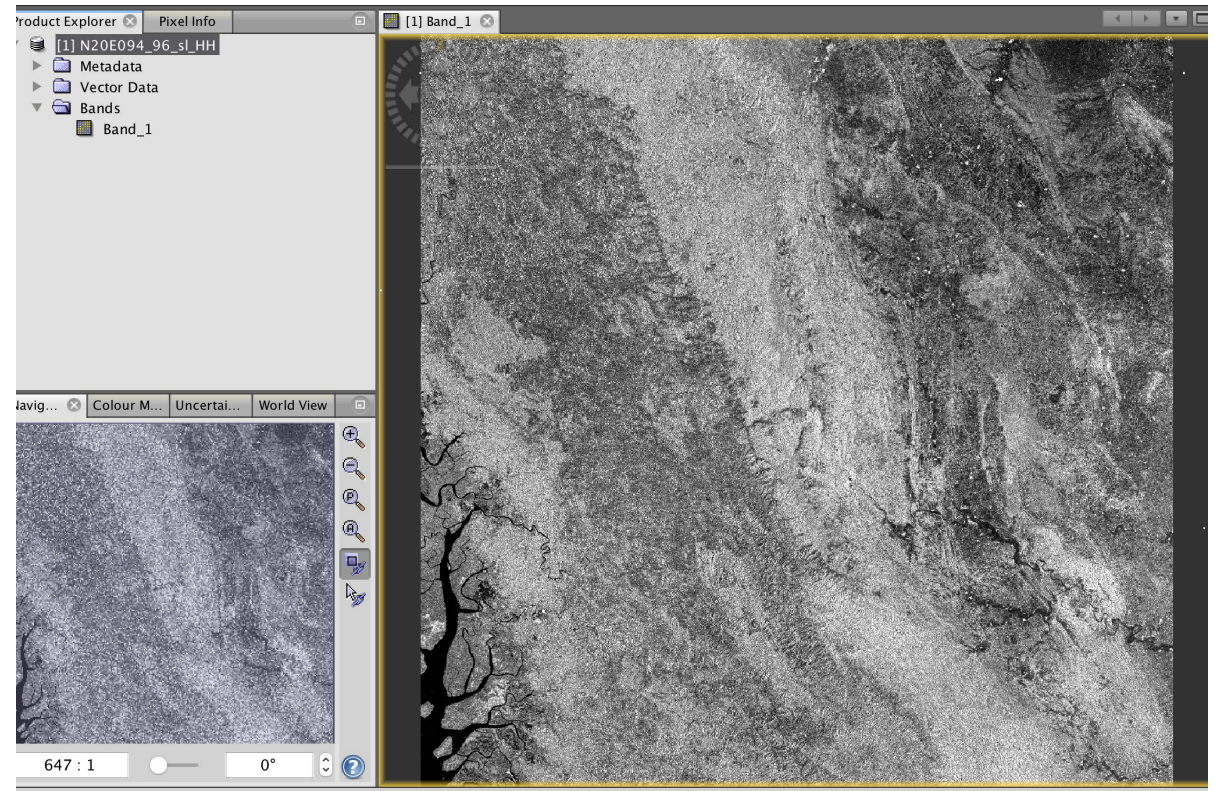
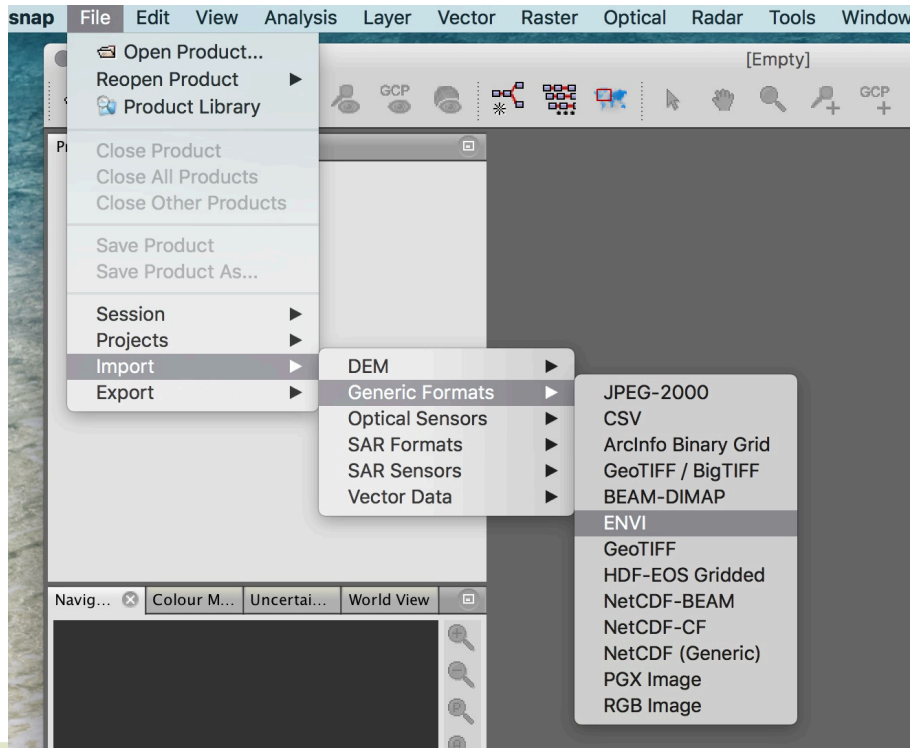
8. Unzip the files. They are in ENVI format. Open them in either ENVI, QGIS or the Sentinel Toolbox using Import.



# Convert the JERS-1 Files to GeoTIFF

9. Open the SNAP Toolbox and go to File>Import>Generic Formats>ENVI and select the N20E094\_96\_sl\_HH

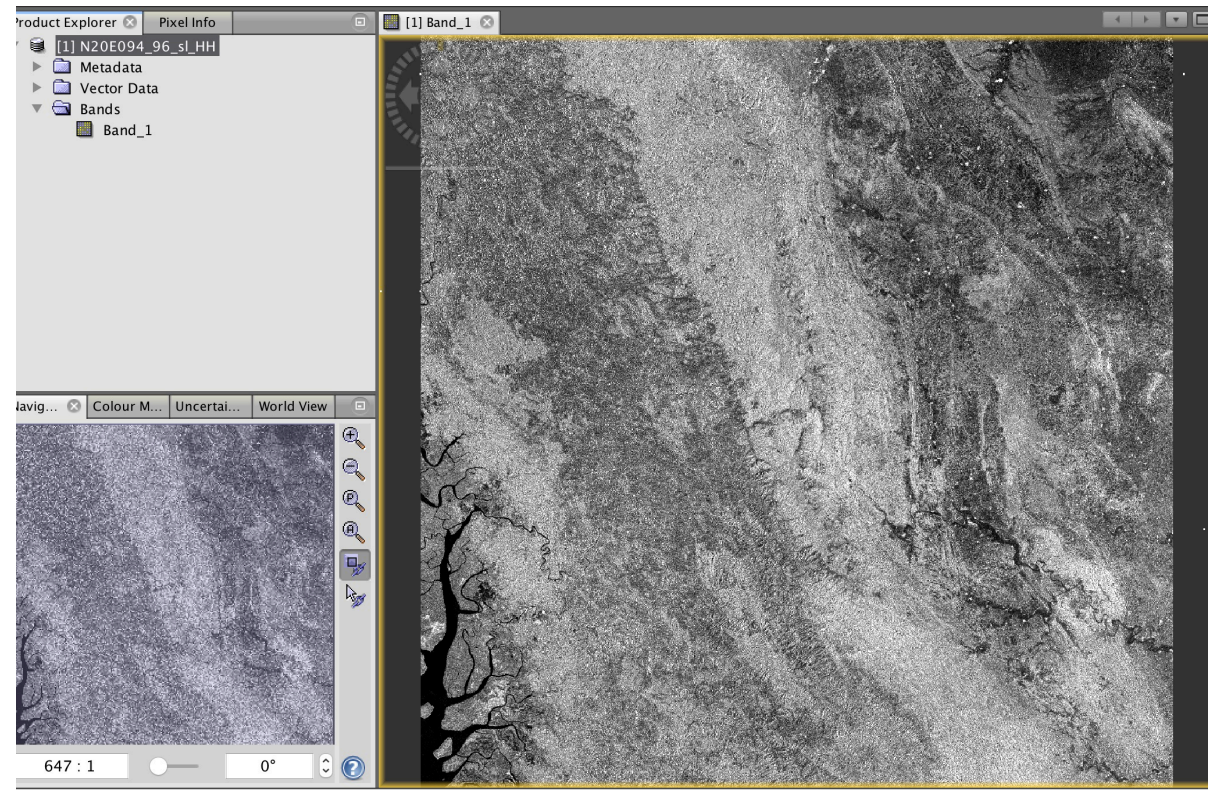
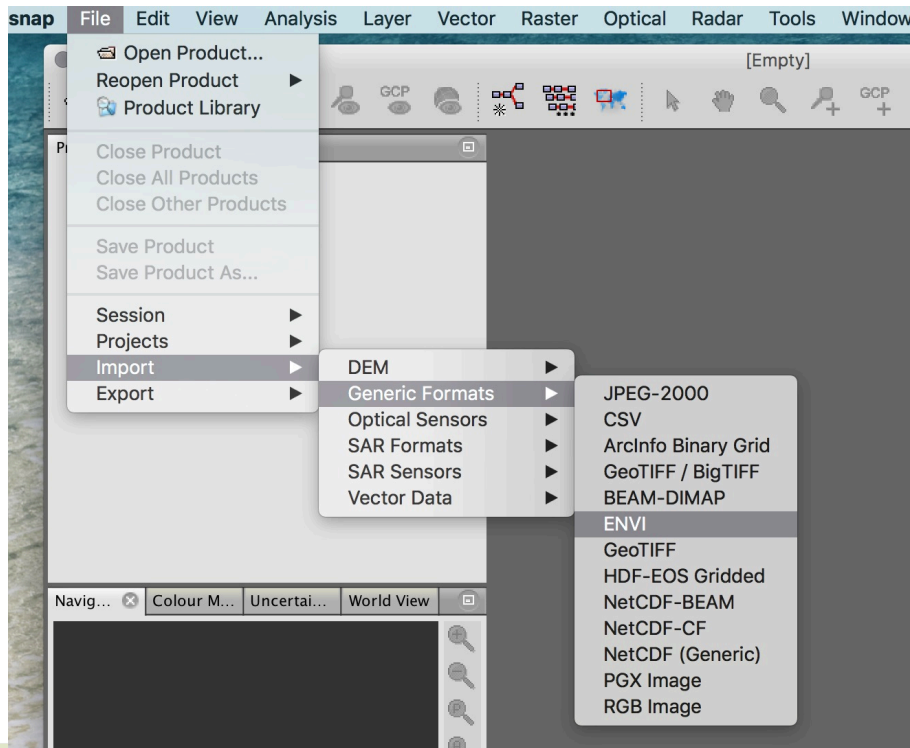
10. Open the Bands directory and double click on Band 1 to open it



# Convert the JERS-1 Files to GeoTIFF

11. Click on Band\_1 and then go to File>Export>GeoTIFF

12. Repeat this same step for the other four files.



# Import the JERS-1 Files into GEE

13. In the top left window select the "Assets" tab and the red NEW button and select GeoTIFF.

14. A new window will open. Either select or drag your file into "Source files".

15. Under "Asset ID" name your file and then click on upload. The "Tasks" tab in the right window will indicate the uploading process. Wait until it is finished.

The screenshot displays the Google Earth Engine interface. The 'Assets' tab is selected, and the 'NEW' button is highlighted with a red circle. A dropdown menu is open, showing options for file uploads, with 'GeoTIFF (.tif, .tiff) or TFRecord (.tfrecord + .json)' circled in red. The 'Upload a new image asset' dialog is open, showing the 'Source files' section with a 'SELECT' button circled in red. The 'Asset ID' section shows the 'Asset Name' field containing 'JERS\_IM5', also circled in red. The 'Properties' section is visible, and the 'Advanced options' section shows 'Pyramiding policy' set to 'MEAN' and 'Masking mode' set to 'None'. The 'Tasks' tab in the right sidebar shows 'Uploading (30%) 1 file for...' with a progress indicator. At the bottom of the dialog, the 'CANCEL' and 'UPLOAD' buttons are visible, with 'UPLOAD' circled in red.



# Import the JERS-1 Files into GEE

16. In the "Tasks" tab in your right most window click on the ? next to the file you uploaded.
17. A new window will open. Select "View Asset".
18. A new window will open. Select "Import" in the bottom right.
19. Repeat this process for the other 4 images. Assign each one a different name.



Task details: Ingest image: "projects/earthengine-legacy/assets/users/erikap/JERS\_IM5" x

State: **Completed**

Started: **6m ago** (2020-05-17 19:55:46 -0700)

Runtime: **1m**

Id: **PNWVBRVGCJJ5H36W4SVQJBA**

[View asset](#)

OK

Image: JERS\_IM5

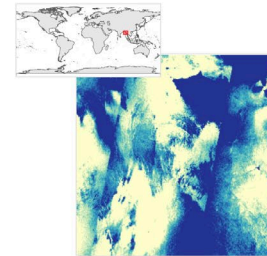


Image ID

users/erikap/JERS\_IM5

**Date**

Start date: NA

End date: NA

**File Size** 36.06MB

**Number of Bands** 1

DESCRIPTION BANDS PROPERTIES

Edit

No description.

[IMPORT](#)

[DELETE](#)

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# Import the JERS-1 Files into GEE

20. In the code editor on the top go to Imports and rename the files from image to JERS\_1996\_im1 and so on.

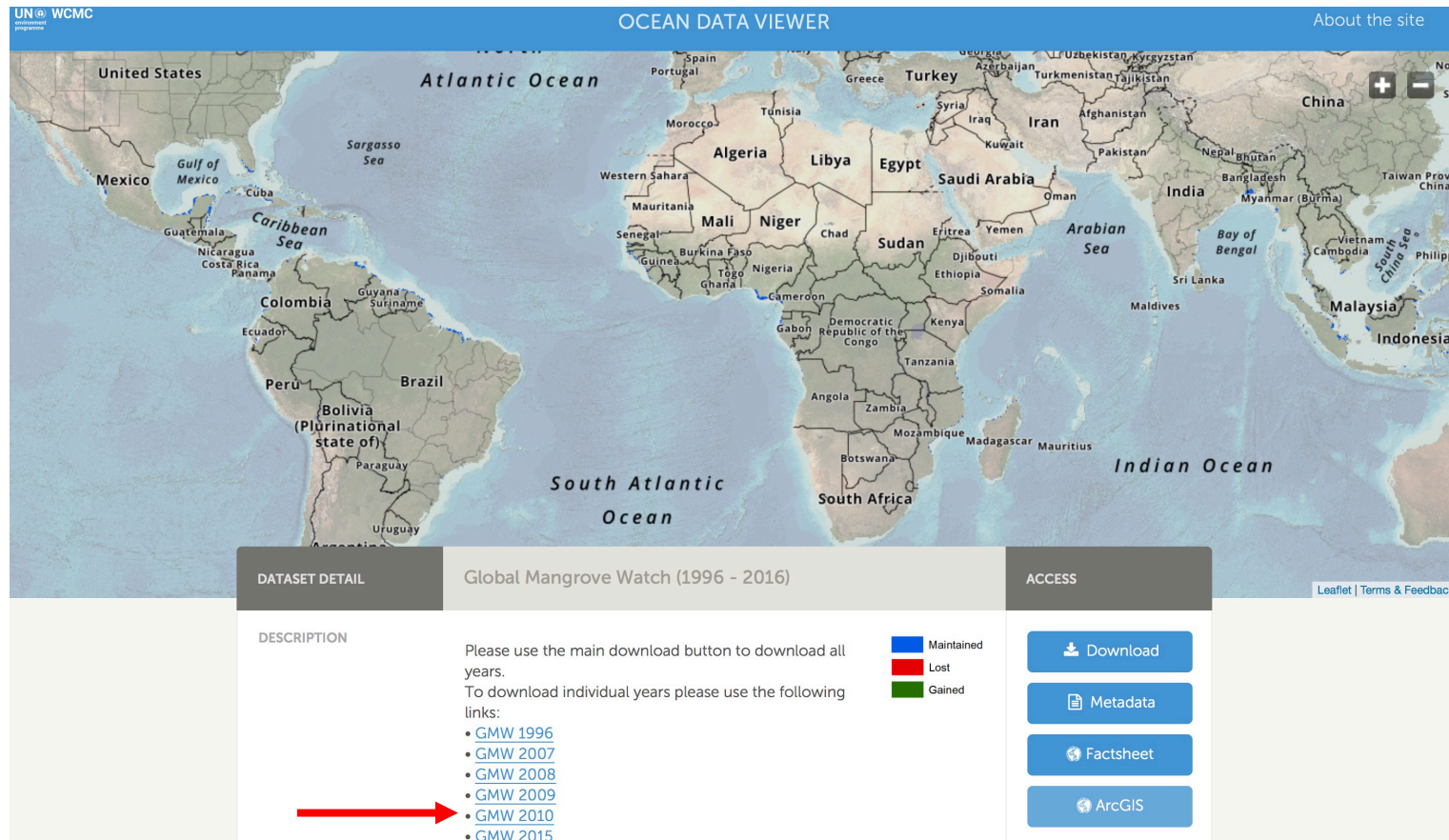
```
var POLYGON: Polygon, 4 vertices
▶ var JERS_1996_im5: Image users/erikap/JERS_IM5 (1 band)
▶ var JERS_1996_im2: Image users/erikap/JERS_IM2 (1 band)
▶ var JERS_1996_im3: Image users/erikap/JERS_IM3 (1 band)
▶ var JERS_1996_im1: Image users/erikap/JERS_IM1 (1 band)
▶ var image: Image users/erikap/JERS_IM4 (1 band)
```





# Import a Global Mangrove Distribution Vector File

21. Go to <https://data.unep-wcmc.org/datasets/45> and download the Global Mangrove Watch (GMW) **2010** file. Unzip it.



The screenshot displays the 'OCEAN DATA VIEWER' interface for the 'Global Mangrove Watch (1996 - 2016)' dataset. The top navigation bar includes the UNEP WCMC logo, the title 'OCEAN DATA VIEWER', and a link 'About the site'. The main area features a world map with mangrove distribution data overlaid. Below the map, there are three tabs: 'DATASET DETAIL', 'Global Mangrove Watch (1996 - 2016)', and 'ACCESS'. The 'DATASET DETAIL' tab is active, showing a 'DESCRIPTION' section with a legend for 'Maintained' (blue), 'Lost' (red), and 'Gained' (green). A red arrow points to the 'GMW 2010' link in the list of years. The 'ACCESS' section contains buttons for 'Download', 'Metadata', 'Factsheet', and 'ArcGIS'. The bottom right corner of the interface has links for 'Leaflet', 'Terms & Feedback', and 'Sou'.



# Import a Global Mangrove Distribution Vector File

22. Go to the “Assets” tab in the upper left window and click on “NEW” and then on “Shape files”.

23. Select or drag and drop your file into the “Source files” of the new window. Name your vector file as mangroves and select Upload.

24. Once the file is finished follow steps 16-18 to import the file

25. It will appear under Imports in the code Editor. Rename it to “mangroves”.

The image shows two screenshots of a web interface. The left screenshot shows the 'Assets' tab with a 'NEW' button and a dropdown menu where 'Shape files (.shp, .shx, .dbf, .prj, or .zip)' is selected. A red arrow points to this option. The right screenshot shows the asset creation form with 'mangroves' entered in the 'Asset Name' field, which is circled in red. At the bottom right, the 'UPLOAD' button is also circled in red.



# Load the PALSAR Global Mosaics and SRTM Elevation

26. Load the PALSAR Global Yearly Mosaics for 2007, 2010 and 2017.

```
// Load the PALSAR Global Yearly Mosaics - L-Band, 25 meter resolution  
var PALSAR_2007 = ee.Image('JAXA/ALOS/PALSAR/YEARLY/SAR/2007');  
var PALSAR_2010 = ee.Image('JAXA/ALOS/PALSAR/YEARLY/SAR/2010');  
var PALSAR_2017 = ee.Image('JAXA/ALOS/PALSAR/YEARLY/SAR/2017');
```

27. Load the SRTM 30 meter elevation file

```
//Load the SRTM 30 meter DEM  
var srtm = ee.Image('USGS/SRTMGL1_003');
```



# Create a JERS Mosaic

28. Create a mosaic from the 5 JERS-1 images uploaded:

```
// Mosaic the JERS-1 images  
var JERS_1996 = ee.ImageCollection([  
  JERS_1996_im5, JERS_1996_im2, JERS_1996_im3, JERS_1996_im1, JERS_1996_im5  
]).mosaic();
```



# Apply a Speckle Filter

29. Apply a speckle filter to the PALSAR and JERS-1 images

```
//Apply a filter to reduce speckle  
var SMOOTHING_RADIUS = 30;  
var PALSAR_2007_filtered = PALSAR_2007.select('HH',  
'HV').focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');  
var PALSAR_2010_filtered = PALSAR_2010.select('HH',  
'HV').focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');  
var PALSAR_2017_filtered = PALSAR_2017.select('HH',  
'HV').focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');  
var JERS_1996_filtered = JERS_1996.focal_mean(SMOOTHING_RADIUS, 'circle', 'meters');
```



# Convert the PALSAR and JERS-1 Images to dB

30. Convert the images to dB with the following formula:

$$\text{Sigma naught(dB)} = 10\log_{10}(\text{pixel\_value})^2 + \text{Calibration Factor}$$

Where the Calibration Factor = -83. for the PALSAR images and -84.66 for JERS-1

```
//Convert the images to dB: $\gamma_0 = 10\log_{10} \langle DN^2 \rangle + CF$ 
```

```
//CF= calibration factor. CF=-83.0 for PALSAR and CF=-84.66 for JERS
```

```
var dB_1996_HH = JERS_1996_filtered.pow(2).log10().multiply(10).add(-84.66);
```

```
var dB_2007_HH = PALSAR_2007_filtered.select('HH').pow(2).log10().multiply(10).add(-83.0);
```

```
var dB_2007_HV = PALSAR_2007_filtered.select('HV').pow(2).log10().multiply(10).add(-83.0);
```

```
var dB_2010_HH = PALSAR_2010_filtered.select('HH').pow(2).log10().multiply(10).add(-83.0);
```

```
var dB_2010_HV = PALSAR_2010_filtered.select('HV').pow(2).log10().multiply(10).add(-83.0);
```

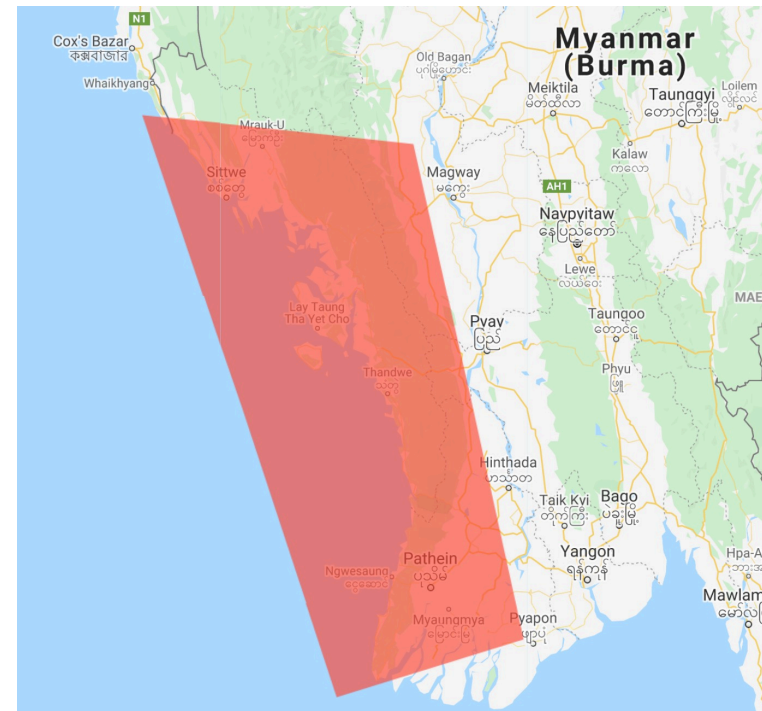
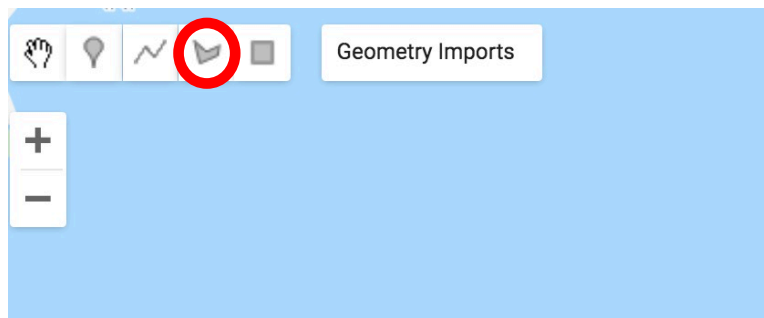
```
var dB_2017_HH = PALSAR_2017_filtered.select('HH').pow(2).log10().multiply(10).add(-83.0);
```

```
var dB_2017_HV = PALSAR_2017_filtered.select('HV').pow(2).log10().multiply(10).add(-83.0);
```



# Select a Region of Interest

31. In the upper left select the polygon icon and draw your area of interest as shown here. Rename the polygon from geometry to roi.



# Clip the Images to Region of Interest

32. The PALSAR mosaics are global. This step clips it to the region of interest specified in the previous step.

```
//Clip the images to our area of interest  
var dB_2007_HH_roi = dB_2007_HH.clip(roi);  
var dB_2007_HV_roi = dB_2007_HV.clip(roi);  
var dB_2010_HH_roi = dB_2010_HH.clip(roi);  
var dB_2010_HV_roi = dB_2010_HV.clip(roi);  
var dB_2017_HH_roi = dB_2017_HH.clip(roi);  
var dB_2017_HV_roi = dB_2017_HV.clip(roi);  
var dB_1996_HH_roi = dB_1996_HH.clip(roi);  
var srtm_roi = srtm.clip(roi);
```





# Add the Images and Vector to “Layers”

33. Add the images and vector to the “Layers” bar in order to display them

```
// Add the images and vector to "Layers" in order to visualize them
Map.centerObject(roi, 7);
Map.addLayer(srtm_roi ,{min:-5,max:40}, 'SRTM', 0);
Map.addLayer(mangroves, {color: 'red'}, 'Mangroves', 0);
Map.addLayer(dB_1996_HH_roi ,{min:-25,max:0}, 'JERS', 0);
Map.addLayer(dB_2007_HV_roi,{min:-27,max:-5}, 'PALSAR HV 2007', 0);
Map.addLayer(dB_2010_HV_roi,{min:-27,max:-5}, 'PALSAR HV 2010', 0);
Map.addLayer(dB_2017_HV_roi,{min:-27,max:-5}, 'PALSAR HV 2017', 0);
Map.addLayer(dB_2007_HH_roi,{min:-15,max:-3}, 'PALSAR HH 2007', 0);
Map.addLayer(dB_2010_HH_roi,{min:-15,max:-3}, 'PALSAR HH 2010', 0);
Map.addLayer(dB_2017_HH_roi,{min:-15,max:-3}, 'PALSAR HH 2017', 0);
Map.addLayer(dB_2007_HV_roi.addBands(dB_2017_HV_roi).addBands(dB_2007_HV_roi), {min: -25,
max: -3}, 'RGB 2007/2017/2007', 0);
Map.addLayer(dB_1996_HH_roi.addBands(dB_2017_HH_roi).addBands(dB_1996_HH_roi), {min: -25,
max: 0}, 'RGB 1996/2017/1996', 0);
Map.addLayer(dB_2007_HV_roi.addBands(dB_2010_HV_roi).addBands(dB_2017_HV_roi), {min: -27,
max:-5}, 'RGB 2007/2010/2017', 0);
```



# Calculate the Ratio Between Images from Two Dates

34. Calculate the ratio between images from two different dates. In this case between 1996 and 2017 and between 2007 and 2017. Note that since the images are in log scale, they are subtracted in order to determine the ratio between them

```
// Calculate the ratio between before and after  
var ratio0717HV= dB_2007_HV_roi.subtract(dB_2017_HV_roi);  
var ratio9617HH= dB_1996_HH_roi.subtract(dB_2017_HH_roi);
```

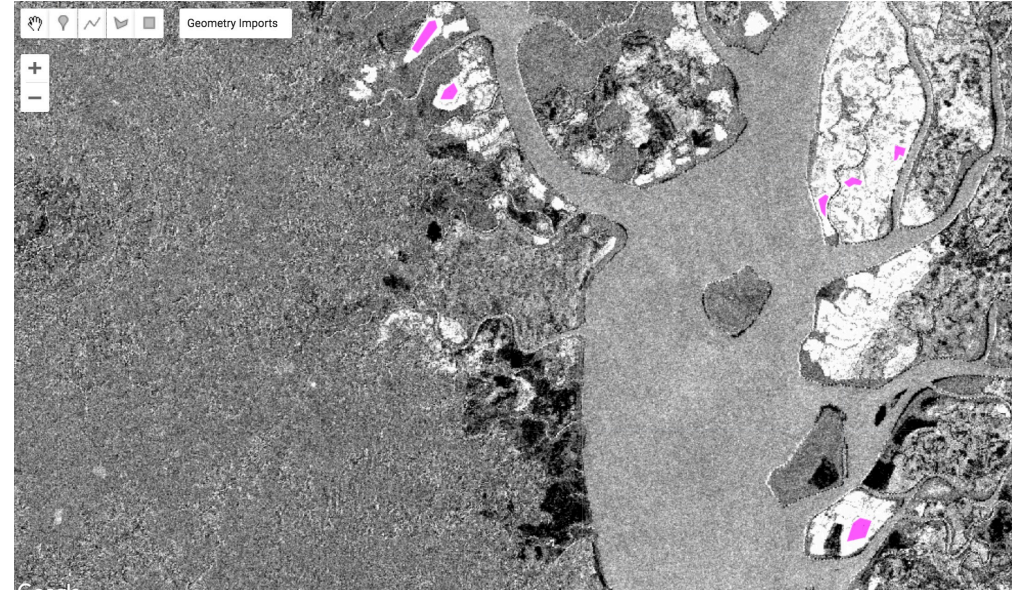
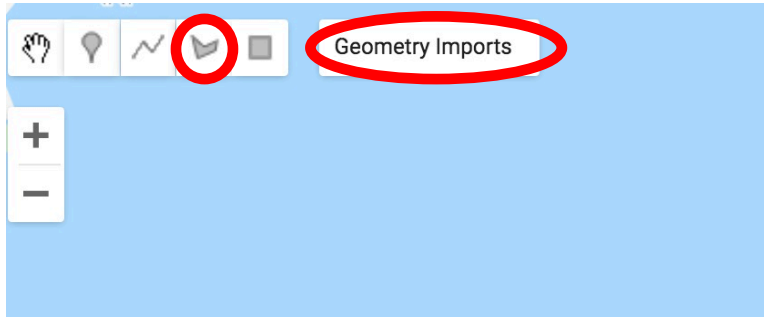
35. Display the ratio images

```
// Display the ratio images  
Map.addLayer(ratio0717HV, {min: -9,max:9}, 'Ratio HV 2007/2017', 0);  
Map.addLayer(ratio9617HH, {min: -9,max:9}, 'Ratio HH 1996/2017', 0);
```



# Select Polygons of Change/No Change in the Ratio Images

36. Select the polygon icon in the left window and under "Geometry Imports" select "new layers".



37. Select the Ratio 2007/2017 image and draw polygons on the areas that are very bright.

38. Rename the polygon from geometry to loss\_2007\_2017

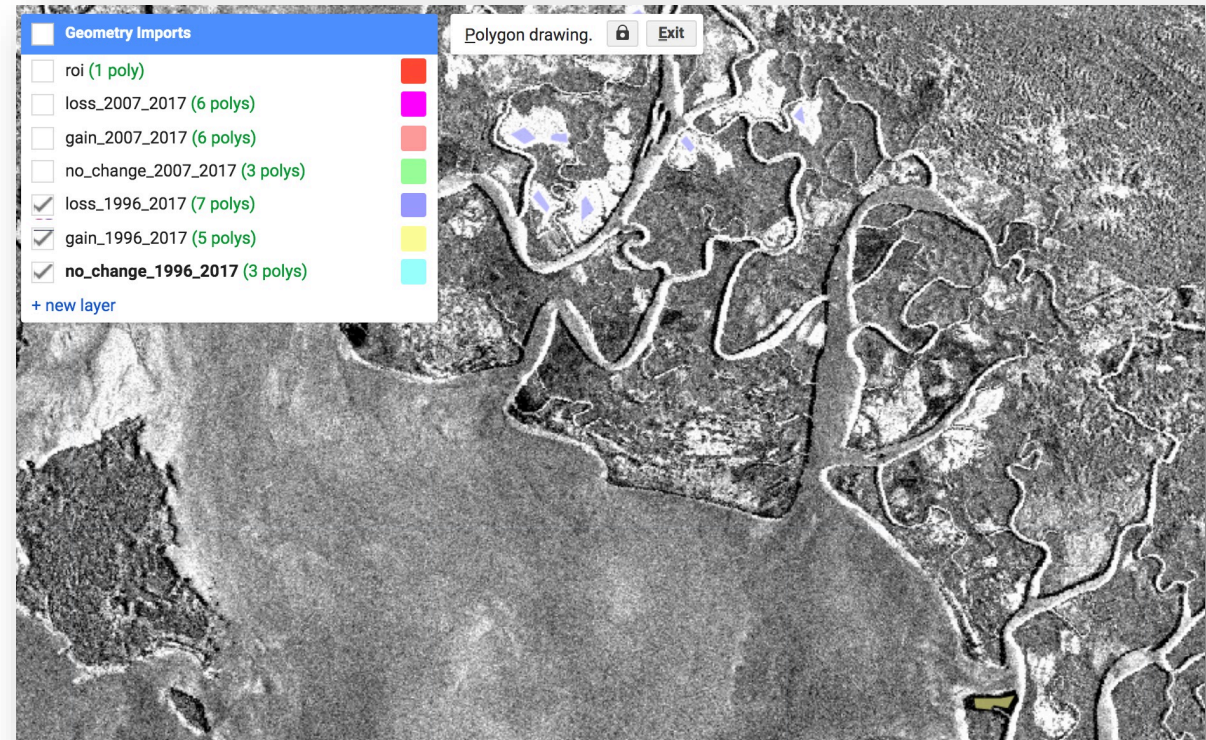
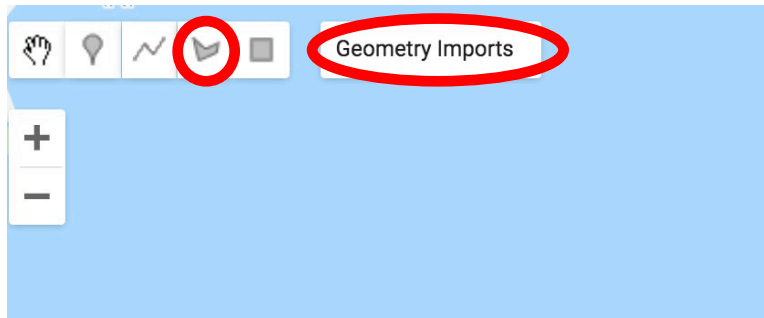
39. Repeat steps 36-37 identifying the dark areas. Rename the polygon to gain\_2007\_2017.

40. Repeat steps 36-37 once again identifying areas of no change. Rename the polygon to no\_change\_2007\_2017



# Select Polygons of Change/No Change in the Ratio Images

41. Select the Ratio 1996/2017 image and repeat steps 36-37. Name the polygons loss\_1996\_2017, gain 1996\_2017 and no\_change\_1996\_2017.



# Calculate Statistics for the Polygons

42. Create a variable called reducers that combines the mean and standard deviation

```
// Combine the mean and standard deviation reducers.  
var reducers = ee.Reducer.mean().combine({  
  reducer2: ee.Reducer.stdDev(),  
  sharedInputs: true  
});
```



# Calculate Statistics for the 2007/2017 Polygons

43. Calculate the mean and standard deviation for each of the polygon groups

```
// Compute the mean and stdv for the loss_2007_2017 polygons
var stats_loss_2007_2017 = ratio0717HV.reduceRegion({
  reducer: reducers,
  geometry: loss_2007_2017,
  scale: 25
});
```

```
// Compute the mean and stdv for the gain_2007_2017 polygons
var stats_gain_2007_2017 = ratio0717HV.reduceRegion({
  reducer: reducers,
  geometry: gain_2007_2017,
  scale: 25
});
```

```
// Compute the mean and stdv for the no_change_2007_2017_polygons
var stats_no_change_2007_2017 = ratio0717HV.reduceRegion({
  reducer: reducers,
  geometry: no_change_2007_2017,
  scale: 25
});
```



# Calculate Statistics for the 1996/2017 Polygons

44. Calculate the mean and standard deviation for each of the polygon groups

```
// Compute the mean and stdv for the loss_1996_2017 polygons
var stats_loss_1996_2017 = ratio9617HH.reduceRegion({
  reducer: reducers,
  geometry: loss_1996_2017,
  scale: 25
});
// Compute the mean and stdv for the gain_1996_2017 polygons
var stats_gain_1996_2017 = ratio9617HH.reduceRegion({
  reducer: reducers,
  geometry: gain_1996_2017,
  scale: 25
});
// Compute the mean and stdv for the no_change_1996_2017_polygons
var stats_no_change_1996_2017 = ratio9617HH.reduceRegion({
  reducer: reducers,
  geometry: no_change_1996_2017,
  scale: 25
});});
```



# Print the Results

45. Calculate the mean and standard deviation for each of the polygon groups

```
// Print the mean and standard deviation for each polygon class
print('Mean/STDV Loss 2007/2017', stats_loss_2007_2017, 'Mean/STDV Gain
2007/2017', stats_gain_2007_2017, 'Mean/STDV No Change 2007/2017',
stats_no_change_2007_2017, 'Mean/STDV Loss 1996/2017',
stats_loss_1996_2017, 'Mean/STDV Gain 1996/2017', stats_gain_1996_2017,
'Mean/STDV No Change 2007/2017', stats_no_change_1996_2017);
```

```
Mean/STDV Loss 2007/2017      JSON
▼Object (2 properties)      JSON
  HV_mean: 15.04624259712423
  HV_stdDev: 2.2845270209351307
Mean/STDV Gain 2007/2017    JSON
▼Object (2 properties)      JSON
  HV_mean: -12.269471914354899
  HV_stdDev: 1.6680151743270302
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)      JSON
  HV_mean: -0.13437158616300546
  HV_stdDev: 1.2081545235466205
-----
Mean/STDV Loss 1996/2017    JSON
▼Object (2 properties)      JSON
  b1_mean: 11.977338114461622
  b1_stdDev: 2.1298539786810466
Mean/STDV Gain 1996/2017    JSON
▼Object (2 properties)      JSON
  b1_mean: -7.8316633976789465
  b1_stdDev: 3.2175732077914265
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)      JSON
  b1_mean: -0.9608912166640242
  b1_stdDev: 1.3226423194246957
```





# Calculate Thresholds for Mangrove Loss and Gain

46. Calculate threshold for Loss and Gain for each Ratio Image. Start with 2x the standard deviation and adjust it according to the results desired.

2007/2017 Thresholds:

Loss: 12.8

Gain: -10.6

1996/2017 Thresholds

Loss: 9.8

Gain: -4.6

```
Mean/STDV Loss 2007/2017      JSON
▼Object (2 properties)        JSON
  HV_mean: 15.04624259712423
  HV_stdDev: 2.2845270209351307
Mean/STDV Gain 2007/2017      JSON
▼Object (2 properties)        JSON
  HV_mean: -12.269471914354899
  HV_stdDev: 1.6680151743270302
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)        JSON
  HV_mean: -0.13437158616300546
  HV_stdDev: 1.2081545235466205
```

```
Mean/STDV Loss 1996/2017      JSON
▼Object (2 properties)        JSON
  b1_mean: 11.977338114461622
  b1_stdDev: 2.1298539786810466
Mean/STDV Gain 1996/2017      JSON
▼Object (2 properties)        JSON
  b1_mean: -7.8316633976789465
  b1_stdDev: 3.2175732077914265
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)        JSON
  b1_mean: -0.9608912166640242
  b1_stdDev: 1.3226423194246957
```



# Calculate Thresholds for Mangrove Loss and Gain

47. Calculate threshold for Loss and Gain for each Ratio Image. Start with 2x the standard deviation and adjust it according to the results desired.

2007/2017 Thresholds:

Loss: 10.4

Gain: -8.9

1996/2017 Thresholds

Loss: 7.7

Gain: -4.4

```
Mean/STDV Loss 2007/2017      JSON
▼Object (2 properties)        JSON
  HV_mean: 15.04624259712423
  HV_stdDev: 2.2845270209351307
Mean/STDV Gain 2007/2017      JSON
▼Object (2 properties)        JSON
  HV_mean: -12.269471914354899
  HV_stdDev: 1.6680151743270302
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)        JSON
  HV_mean: -0.13437158616300546
  HV_stdDev: 1.2081545235466205
```

```
Mean/STDV Loss 1996/2017      JSON
▼Object (2 properties)        JSON
  b1_mean: 11.977338114461622
  b1_stdDev: 2.1298539786810466
Mean/STDV Gain 1996/2017      JSON
▼Object (2 properties)        JSON
  b1_mean: -7.8316633976789465
  b1_stdDev: 3.2175732077914265
Mean/STDV No Change 2007/2017 JSON
▼Object (2 properties)        JSON
  b1_mean: -0.9608912166640242
  b1_stdDev: 1.3226423194246957
```



# Apply Thresholds

## 48. Apply thresholds and display the masks

```
//Apply Thresholds based on mean and stdv of polygons
```

```
var LOSS_THRESHOLD_2007_2017 = 10.40;
```

```
var GAIN_THRESHOLD_2007_2017 = -8.90;
```

```
var LOSS_THRESHOLD_1996_2017 = 7.70;
```

```
var GAIN_THRESHOLD_1996_2017 = -4.40;
```

```
var LOSS_0717 = ratio0717HV.gt(LOSS_THRESHOLD_2007_2017);
```

```
var GAIN_0717 = ratio0717HV.lt(GAIN_THRESHOLD_2007_2017);
```

```
var LOSS_9617 = ratio9617HH.gt(LOSS_THRESHOLD_1996_2017);
```

```
var GAIN_9617 = ratio9617HH.lt(GAIN_THRESHOLD_1996_2017);
```

```
//Display Masks
```

```
Map.addLayer(LOSS_0717.updateMask(LOSS_0717),{palette:"FF0000"},"Vegetation Loss 07/17",1);
```

```
Map.addLayer(GAIN_0717.updateMask(GAIN_0717),{palette:"FF0000"},"Vegetation GAIN 07/17",1);
```

```
Map.addLayer(LOSS_9617.updateMask(LOSS_9617),{palette:"FF0000"},"Vegetation Loss 96/17",1);
```

```
Map.addLayer(GAIN_9617.updateMask(GAIN_9617),{palette:"FF0000"},"Vegetation GAIN 96/17",1);
```



# Clip the Radar Images and Elevation File

49. Clip the radar images and elevation files using the mangroves vector file

```
//Clip the radar images and elevation to the mangrove vector files
var mangroves_2007_HH = dB_2007_HH.clip(mangroves);
var mangroves_2007_HV = dB_2007_HV.clip(mangroves);
var mangroves_2017_HH = dB_2017_HH.clip(mangroves);
var mangroves_2017_HV = dB_2017_HV.clip(mangroves);
var mangroves_1996_HH = dB_1996_HH.clip(mangroves);
var elevation = srtm.clip(mangroves)
```

```
//Add the images to the layers bar
Map.addLayer(mangroves_2007_HH ,{min:-15,max:-3}, 'Mangrove 2007 HH', 0);
Map.addLayer(mangroves_2007_HV ,{min:-27,max:-5}, 'Mangrove_2007 HV', 0);
Map.addLayer(mangroves_2017_HH ,{min:-15,max:-3}, 'Mangrove_2017 HH', 0);
Map.addLayer(mangroves_2017_HV ,{min:-27,max:-5}, 'Mangrove_2017 HV', 0);
Map.addLayer(mangroves_1996_HH ,{min:-25,max:0}, 'Mangrove_1997 HH', 0);
Map.addLayer(elevation ,{min:-5,max:30}, 'Mangrove Elevation', 0);
```



# Calculate Mangrove Biomass from Canopy Height

50. Estimate mangrove biomass using canopy height estimates from SRTM DEM.

SRTM, elevation corresponds to basal area weighted height (also called Lorey's height). The maximum height is generally 1.6X this value. (Simard et al., 2019).

Apply an allometric equation directly to the DEM. There are several generic equations relating SRTM to canopy height and aboveground biomass:

- Basal area weighted height:  $H_{ba} \sim 1.08 * SRTM$
- Maximum canopy height:  $H_{max} \sim 0.93 * 1.7 * SRTM$
- Aboveground Biomass:  $B \sim 3.25 * H_{ba}^{1.53}$

Use the following equation: Above ground biomass =  $3.25 * (1.08 * SRTM)^{1.53}$

```
//Calculate above ground biomass from SRTM canopy height 3.25*(1.08*SRTM)^1.53  
var biomass_height = mangroves_elevation.multiply(1.08).pow(1.53).multiply(3.25);
```



# Calculate Mangrove Biomass from Canopy Height

51. Estimate mangrove biomass using canopy height estimates from SRTM DEM.

We will apply an allometric equation directly to the DEM. There are several generic equations relating SRTM to canopy height and aboveground biomass:

- Basal area weighted height:  $H_{ba} \sim 1.08 * SRTM$
- Maximum canopy height:  $H_{max} \sim 0.93 * 1.7 * SRTM$
- Aboveground Biomass:  $B \sim 3.25 * H_{ba}^{1.53}$

We will use the following equation:

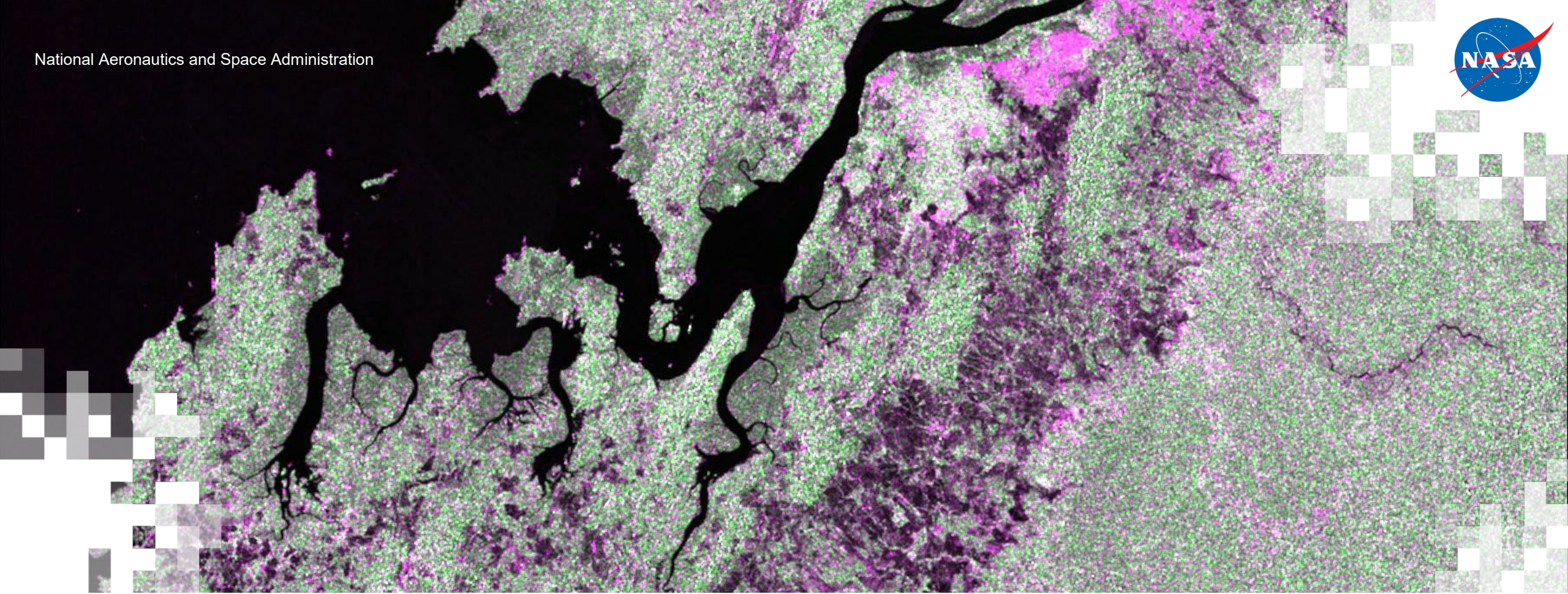
$$\text{Above ground biomass} = 3.25 * (1.08 * SRTM)^{1.53}$$



# Google Earth Engine Code

[https://code.earthengine.google.com/3959fba364e740a13656d8b49d411aea?accept\\_repo=users%2Fwolterpt%2FSAR\\_TimeSeries\\_PTW](https://code.earthengine.google.com/3959fba364e740a13656d8b49d411aea?accept_repo=users%2Fwolterpt%2FSAR_TimeSeries_PTW)





## Next Session: Estimating Forest Height with SAR

May 21, 2020



# Questions

- Please enter your questions into the chat box.
- We will post the questions and answers to the training website following the conclusion of the course.





**Thank You!**

