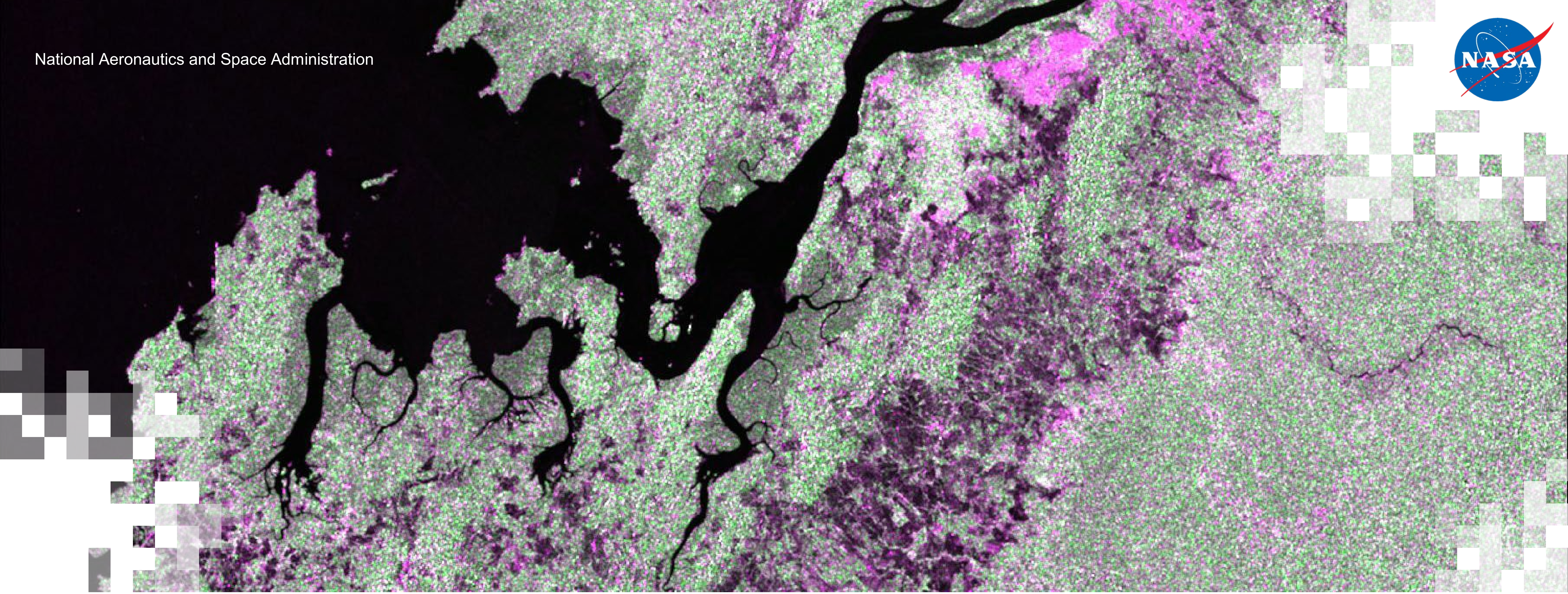
National Aeronautics and Space Administration



Forest Mapping and Monitoring with SAR Data: Mangrove Mapping

Erika Podest, Amber McCullum, Juan Luis Torres Perez, Sean McCartney

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
    - amberjean.mccullum@nasa.gov
    - juan.l.torresperez@nasa.gov

Homework and Certificates

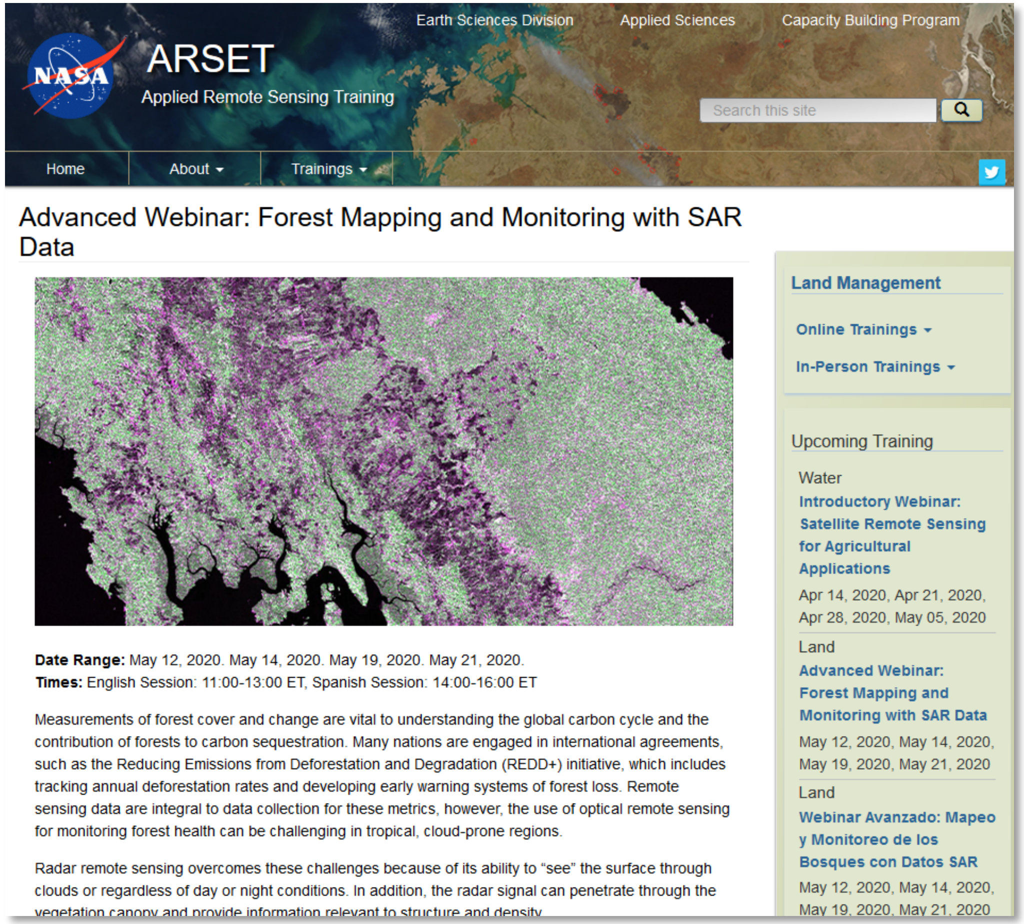
- **Homework:**
  - One homework assignment
  - Answers must be submitted via Google Forms
- **Certificate of Completion:**
  - Attend all three live webinars
  - Complete the homework assignment by **Thursday, June 4th** (access from ARSET website)
  - You will receive certificates approximately two months after completion of the course from: 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 you 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



Course Outline

Part 1: Time Series Analysis of Forest Change

Part 2: Land Cover Classification with Radar and Optical Data

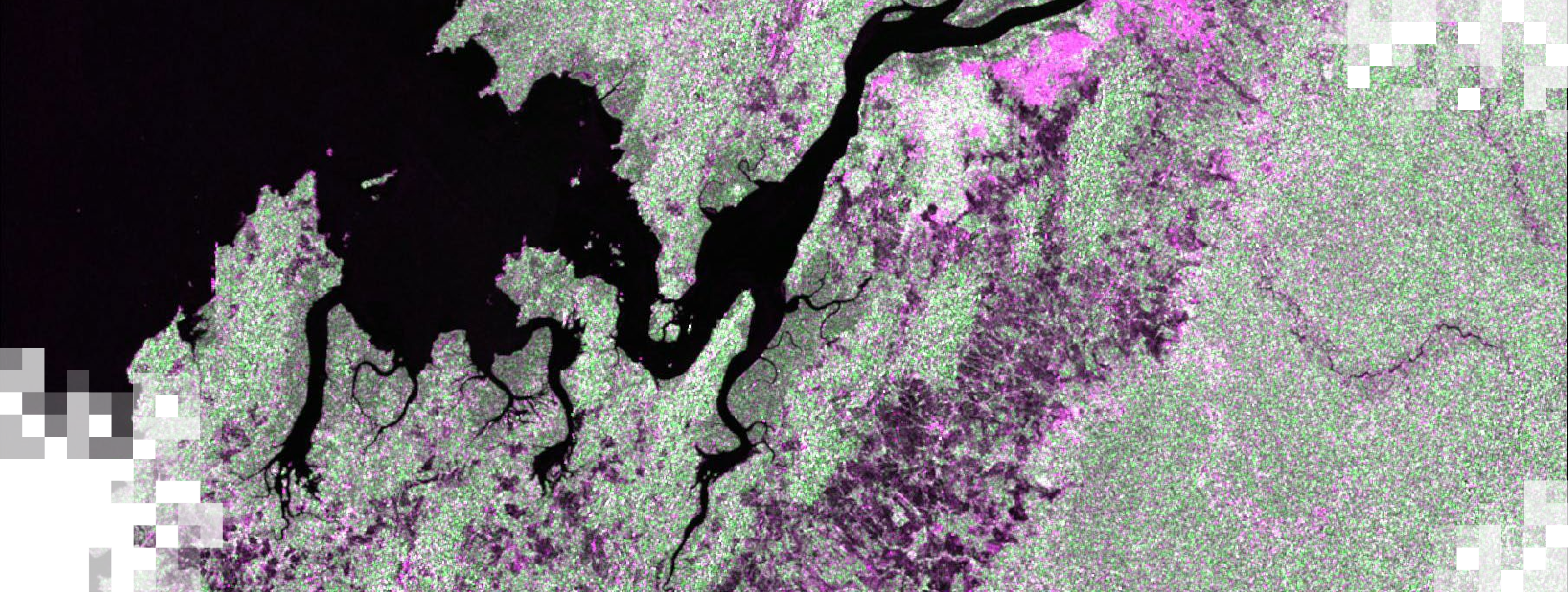
Part 3: Mangrove Mapping

Part 4: Forest Stand Height Estimation

Learning Objectives

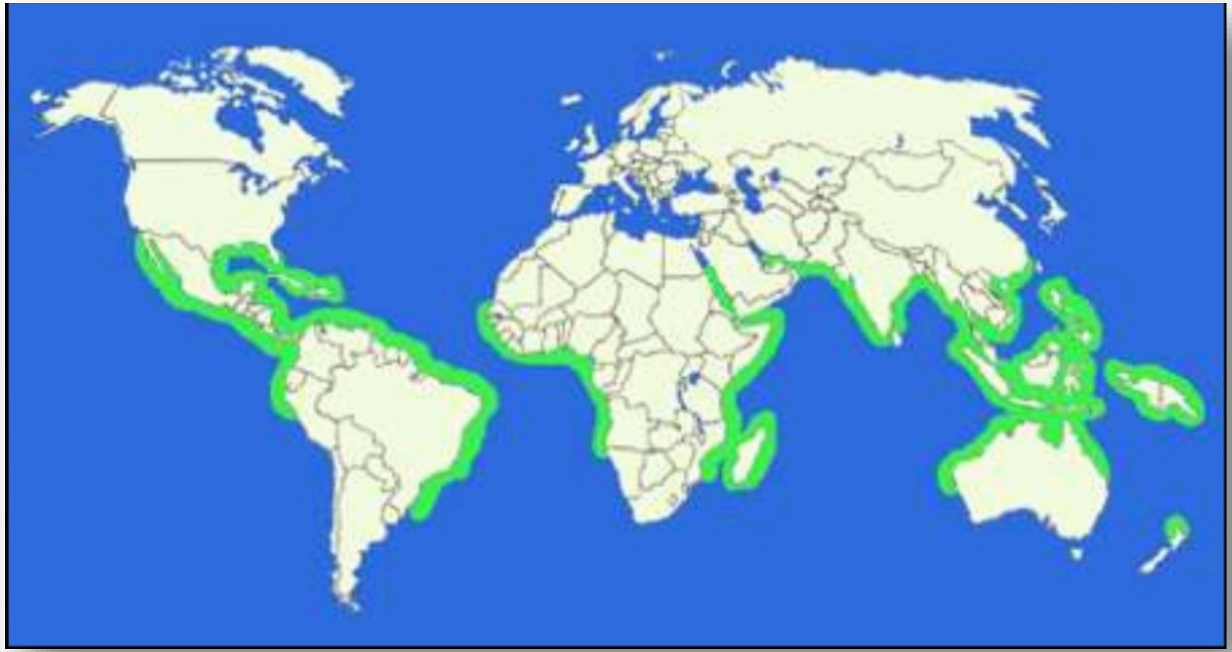
By the end of this presentation, you will be able to:

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



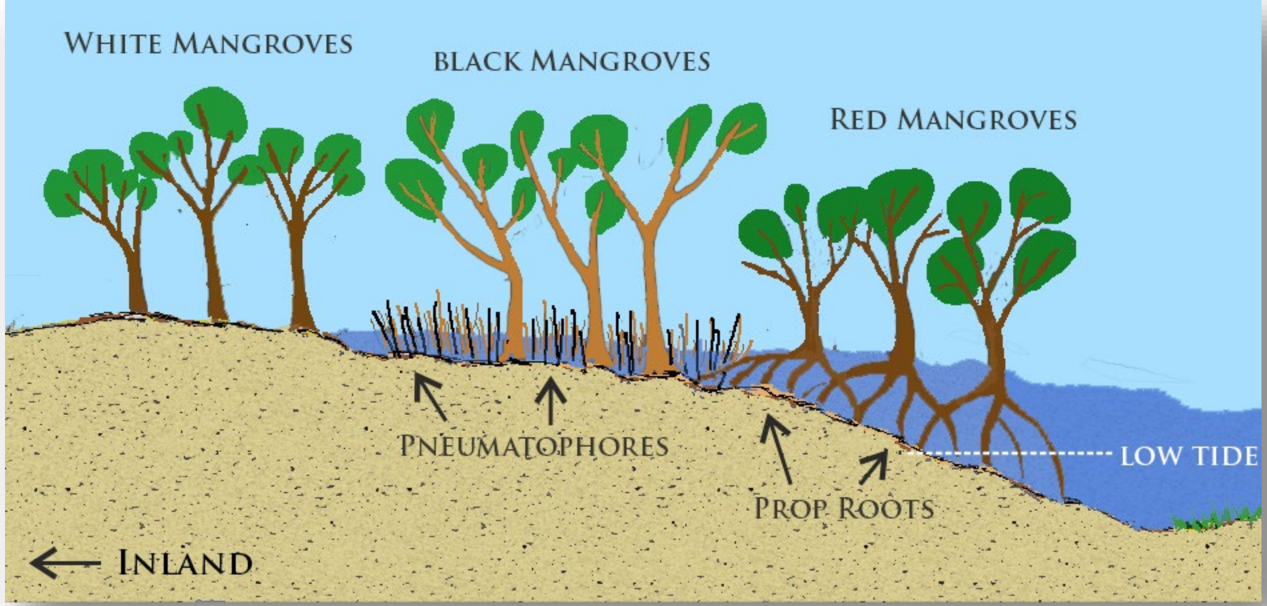
Mangrove Ecosystems

Mangrove Ecosystems - Distribution and Role



Source: wetlandsandwildlife.wordpress.com

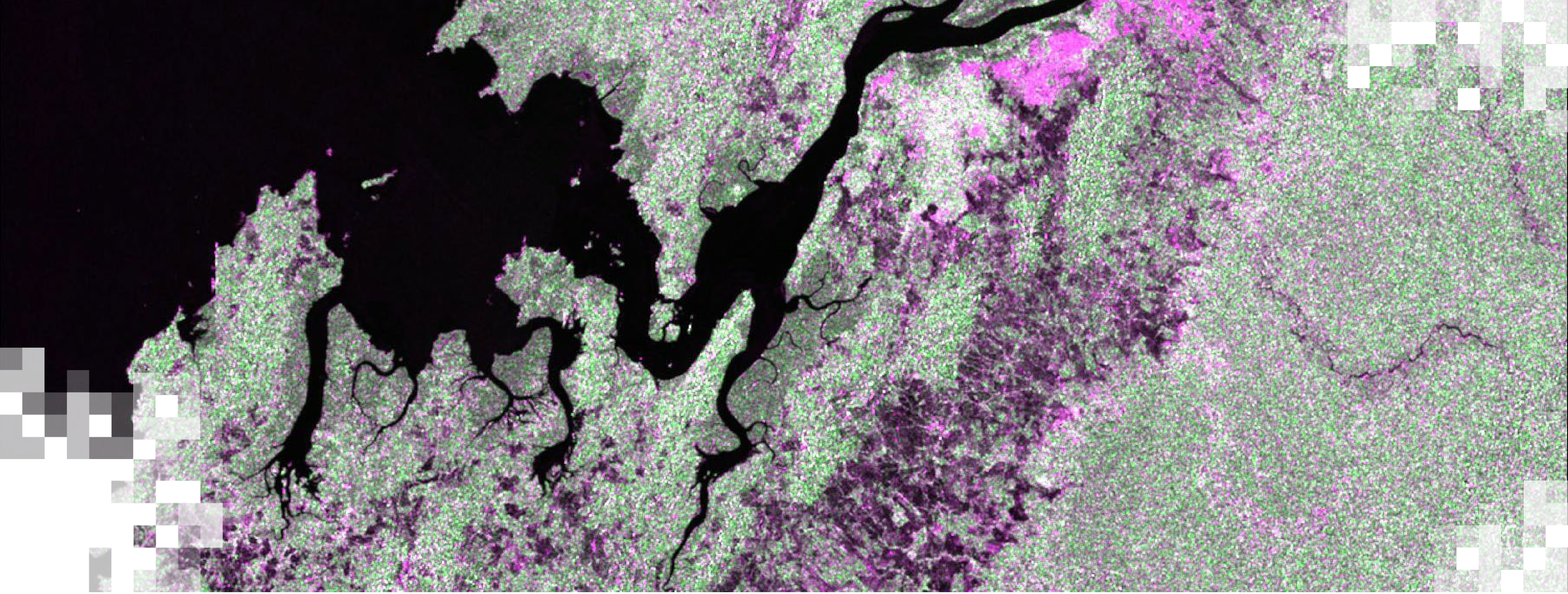
Mangrove Ecosystems - Types



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

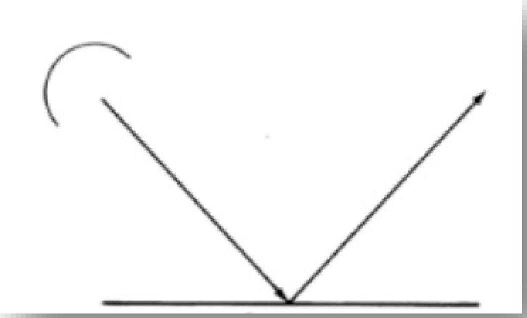


SAR Signal Characteristics and Mangrove Ecosystems

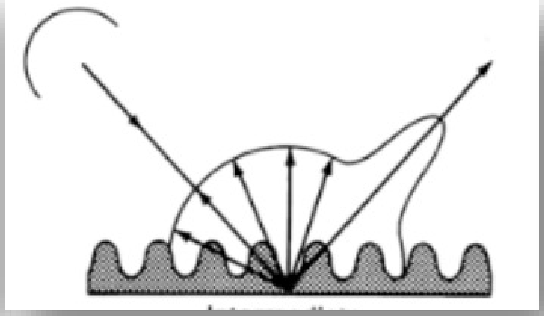
Radar Backscattering Mechanisms

- 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.

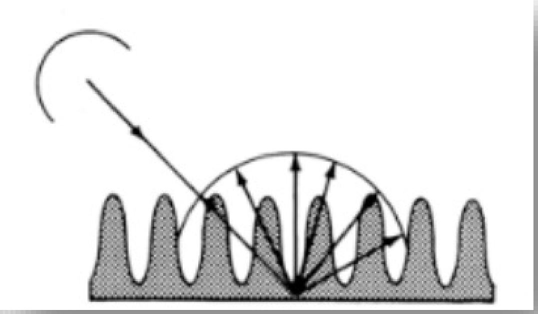
Backscattering Mechanisms:



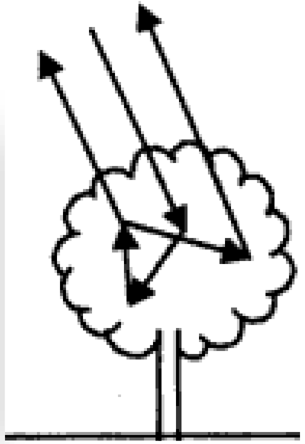
Smooth Surface



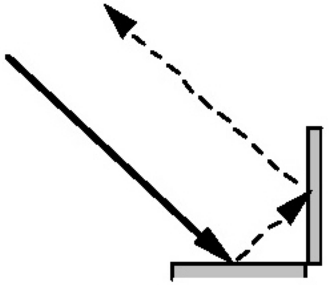
Rough Surface



Rougher Surface



Volume Scattering



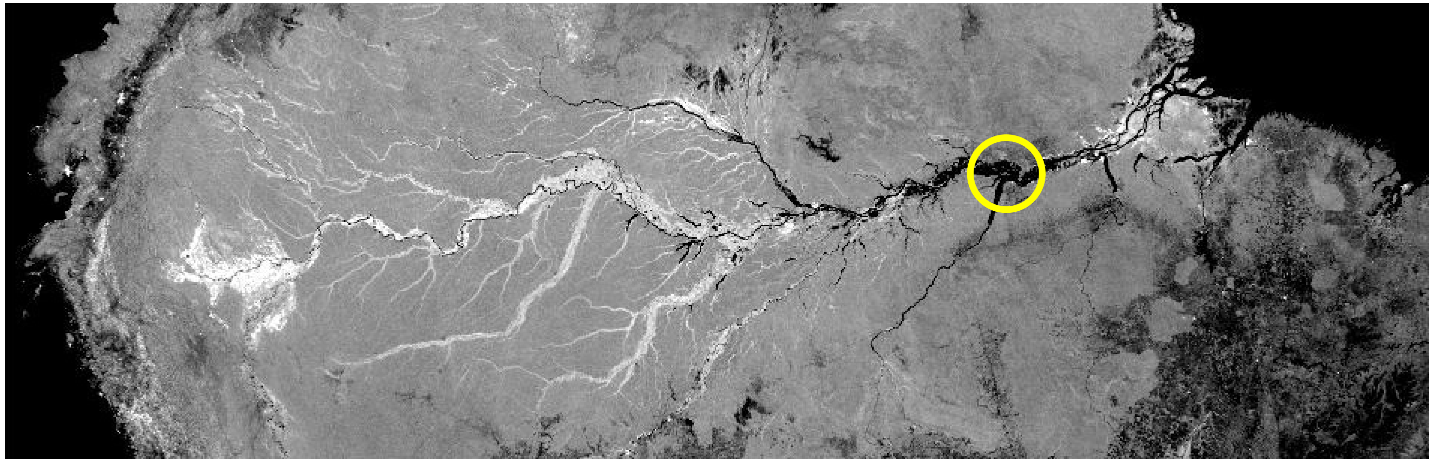
Double Bounce

Examples of Radar Interaction

Smooth Surface Reflection (Specular Reflection)

Smooth, Level Surface
(open water, road)

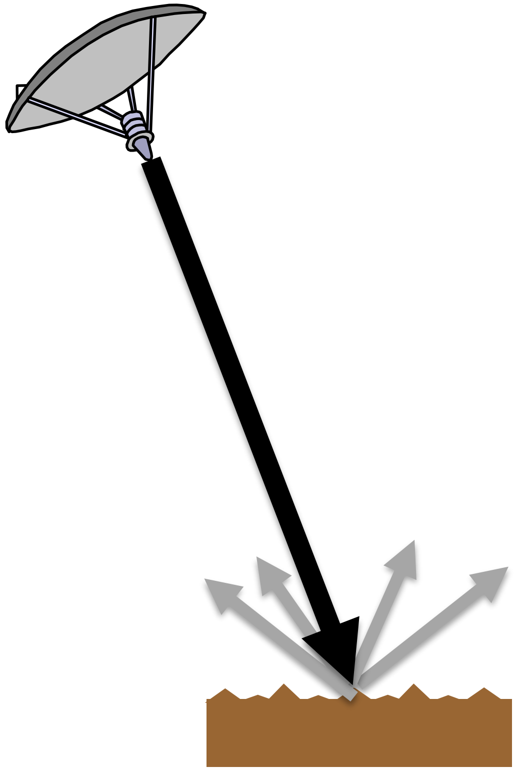
SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-band, HH, 3 km)



Pixel Color

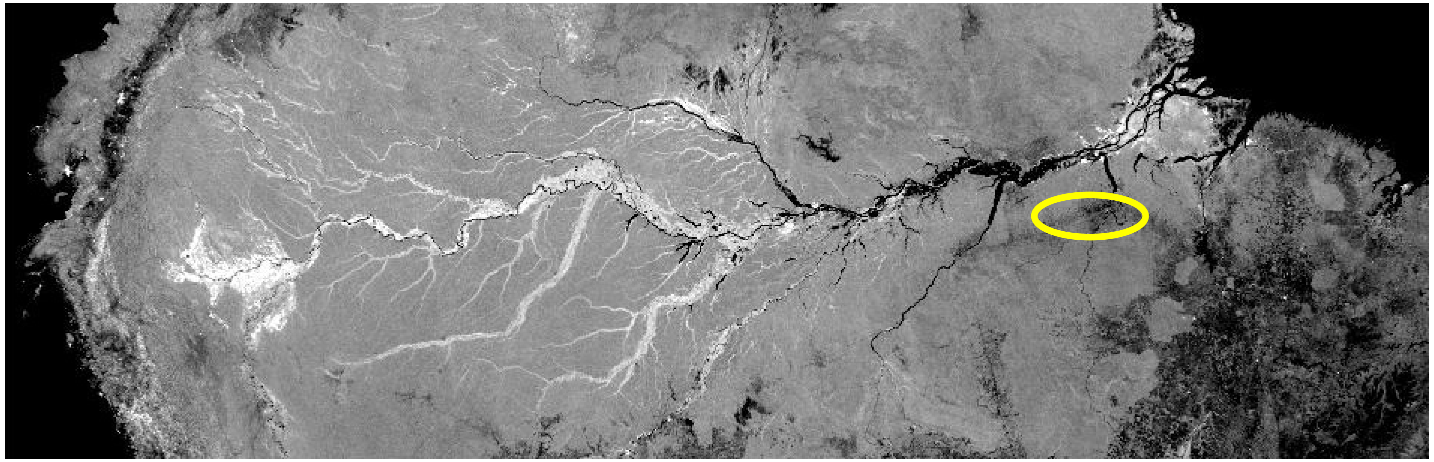
Examples of Radar Interaction

Rough Surface Reflection



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

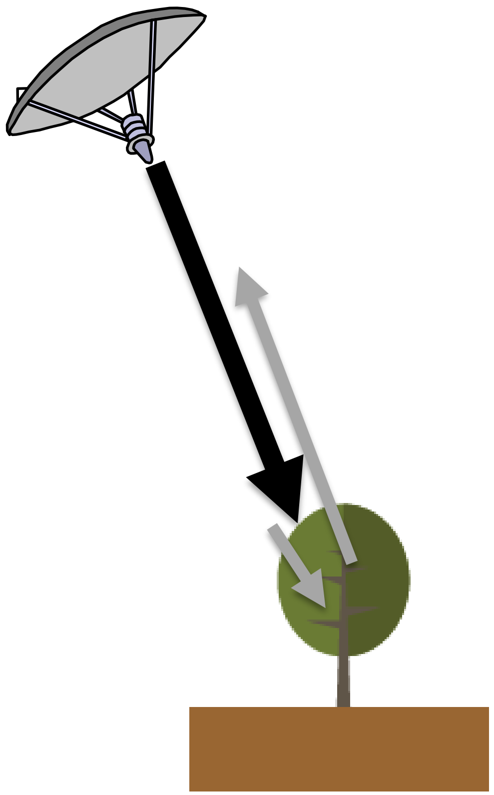
SMAP Radar Mosaic of the Amazon Basin
April 2015 (L-band, HH, 3 km)



Pixel Color

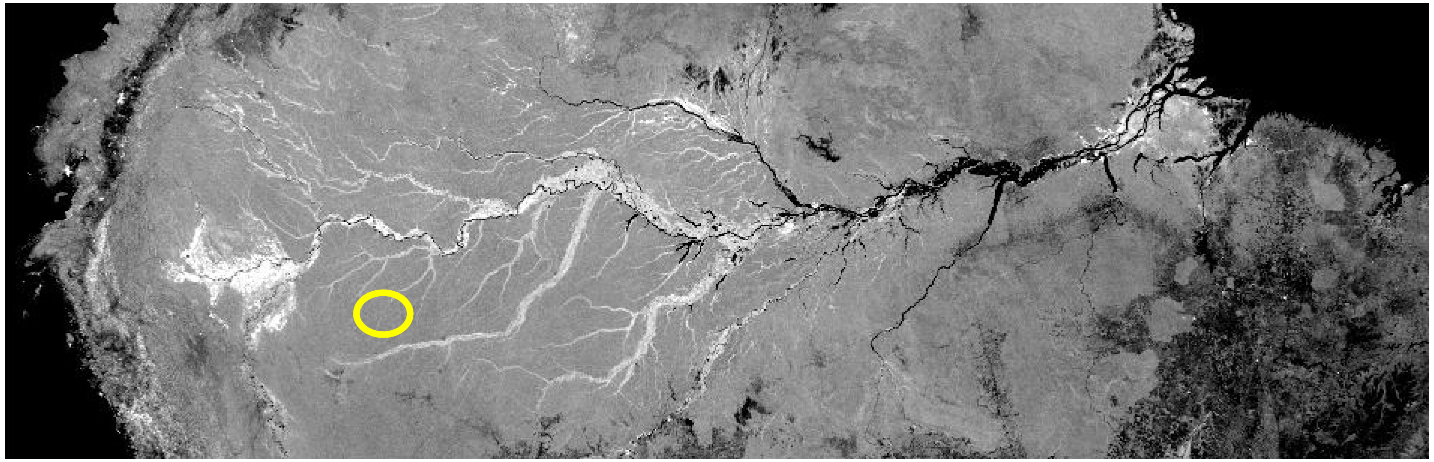
Examples of Radar Interaction

Volume Scattering by Vegetation



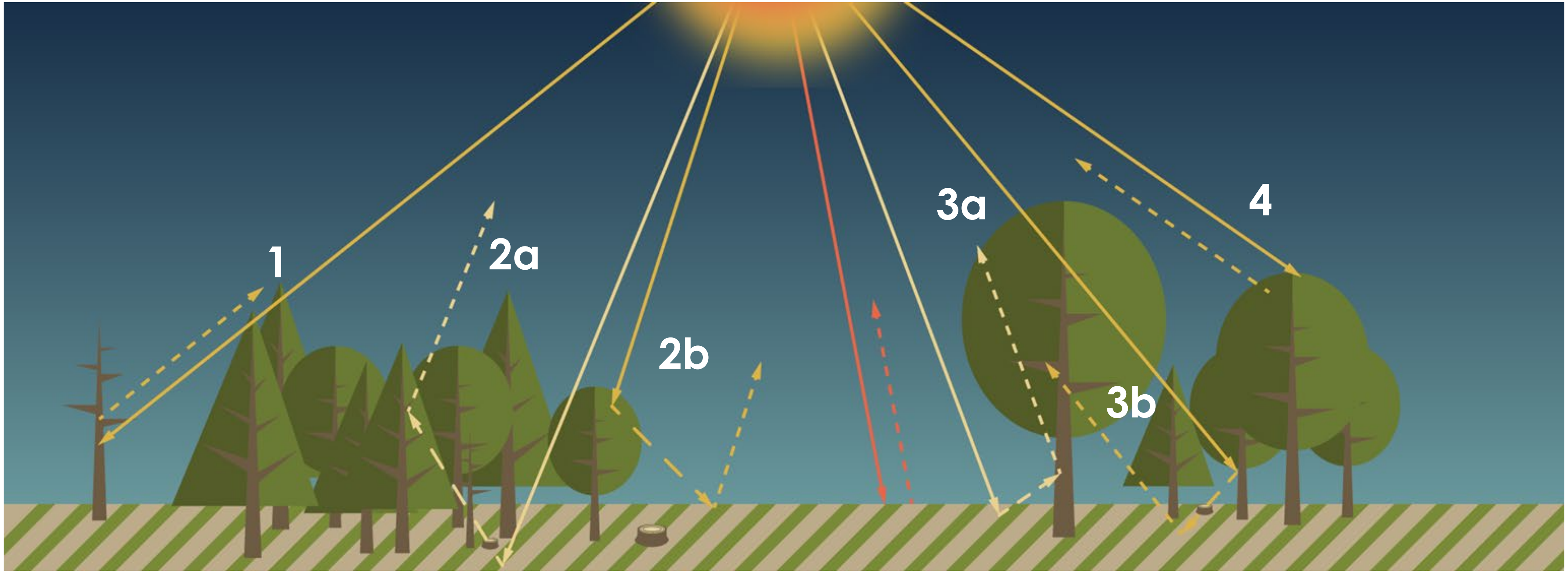
Vegetation

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



Pixel Color

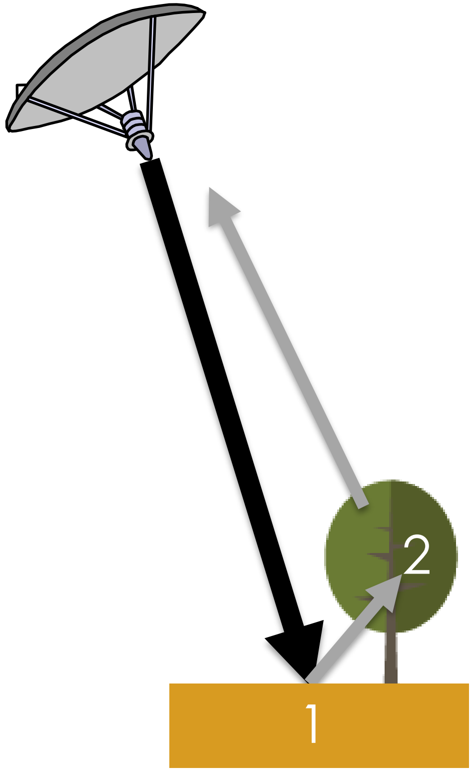
Radar Backscattering in Vegetation



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.

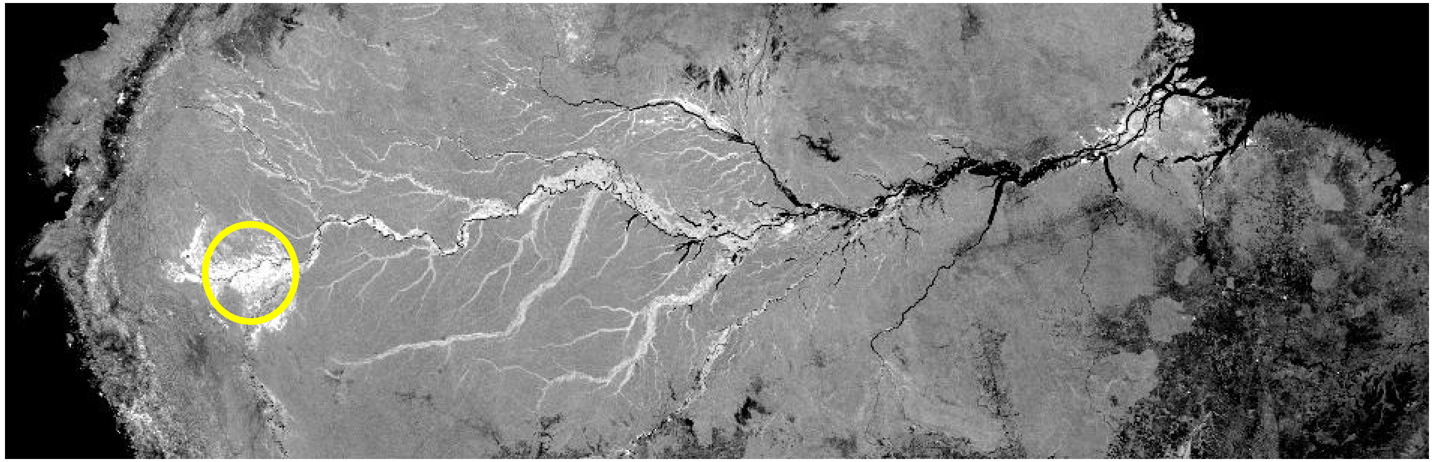
Examples of Radar Interaction

Double Bounce



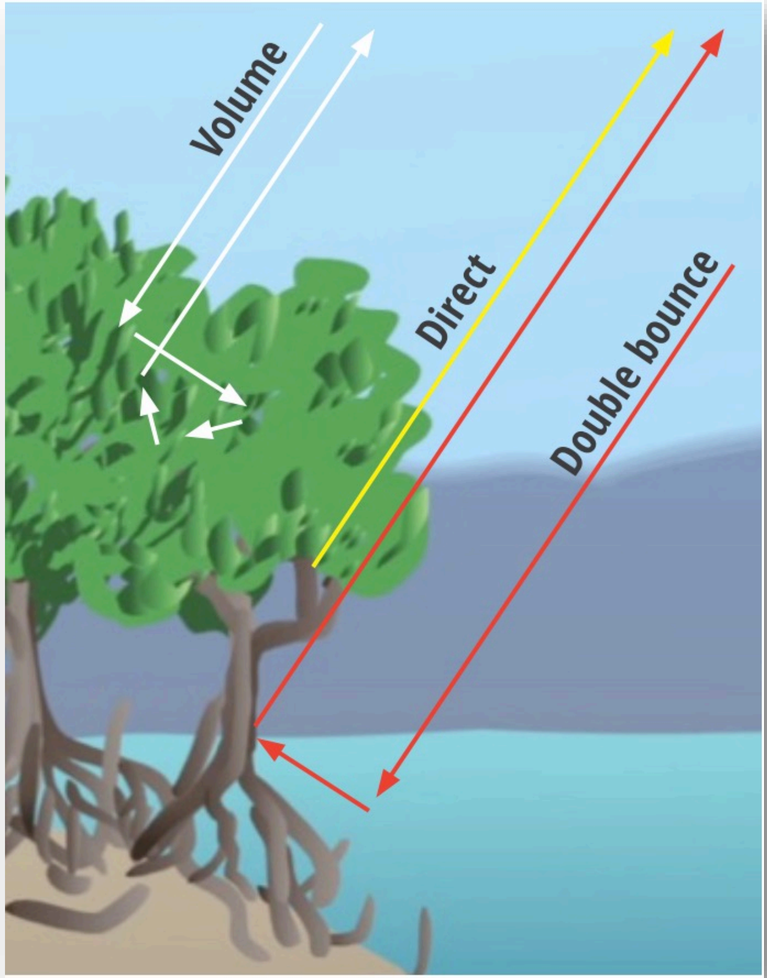
Inundated Vegetation

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



Pixel Color

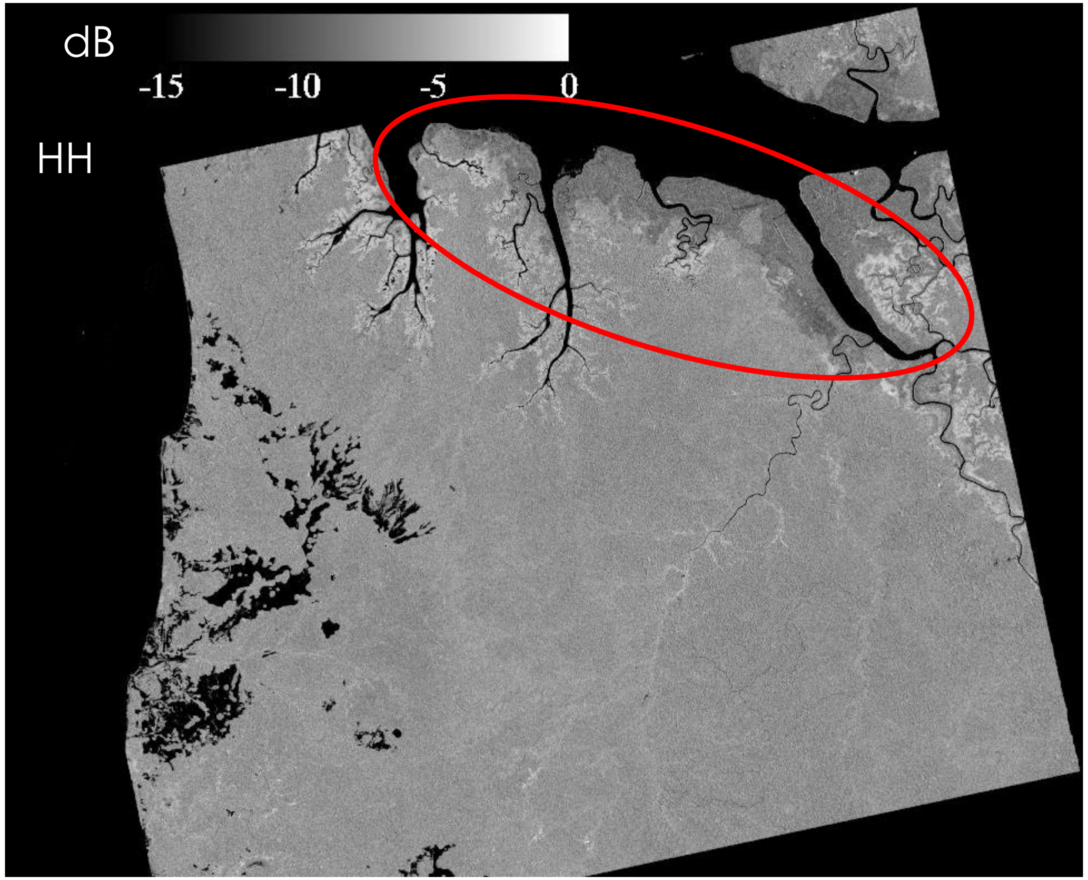
Radar Signal Interaction with Mangrove Ecosystems

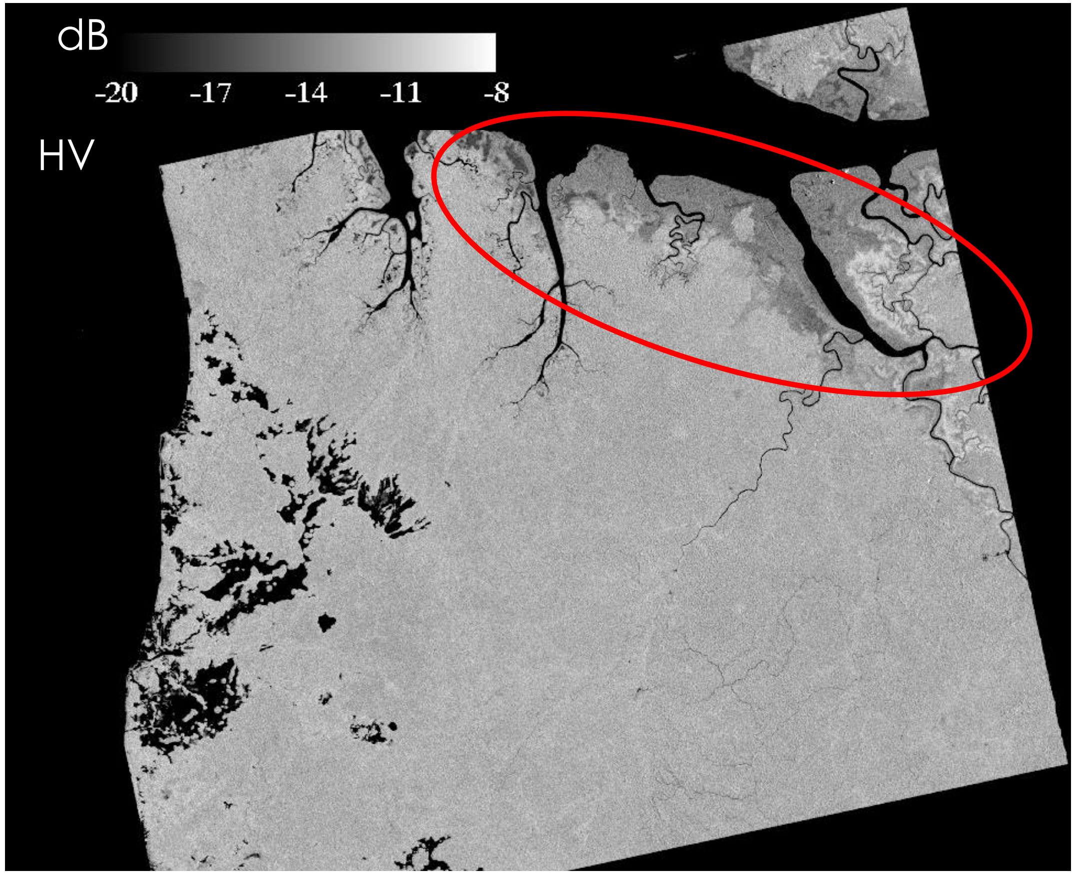


Source: SERVIR SAR Handbook Chapter 6 by Marc Simard

Polarization Interaction with Mangrove Ecosystems

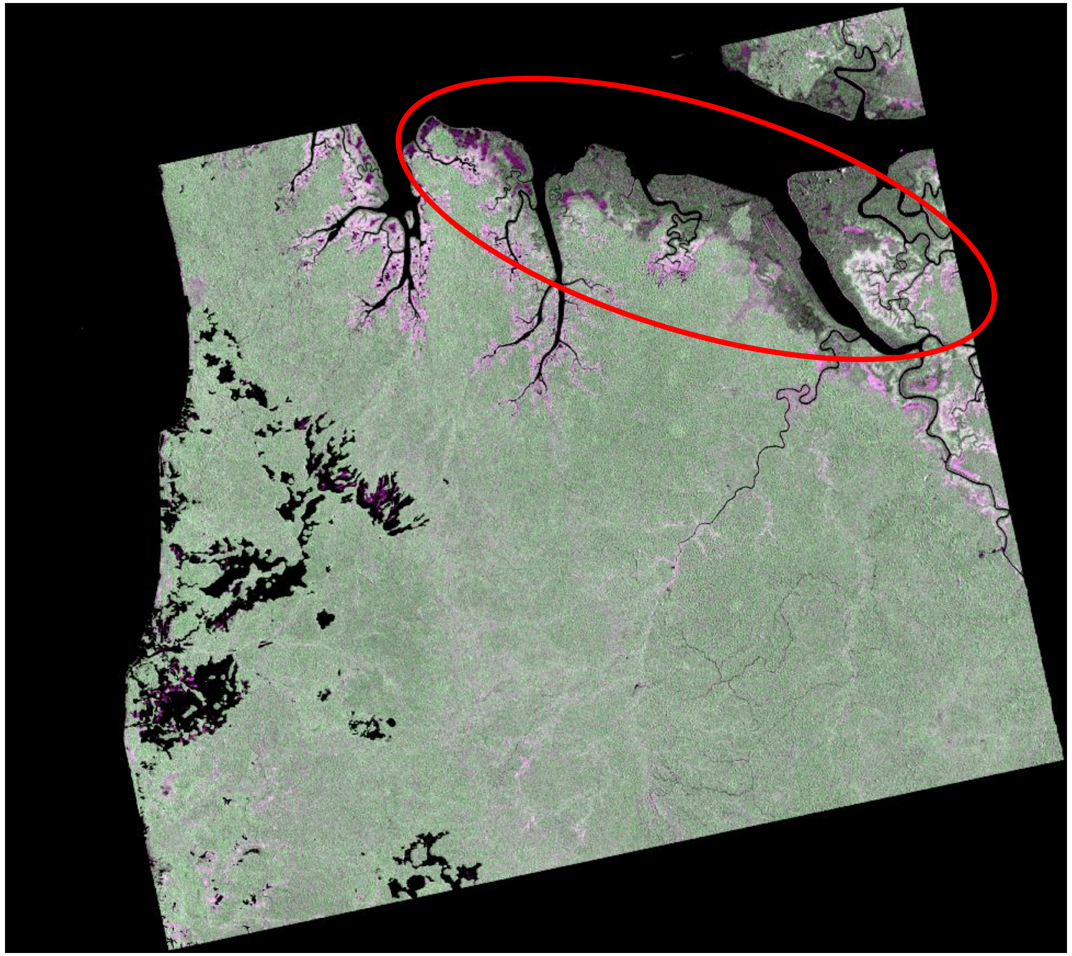
L-band ALOS PALSAR HH and HV over Gabon on Aug. 10, 2007





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
K	Unknown; most likely a few tens of centimeters.	Single direct bounce and volume from top of canopy.
X	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.
C	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.
L	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.
P	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.

Source: SERVIR SAR Handbook Chapter 6 by Marc Simard

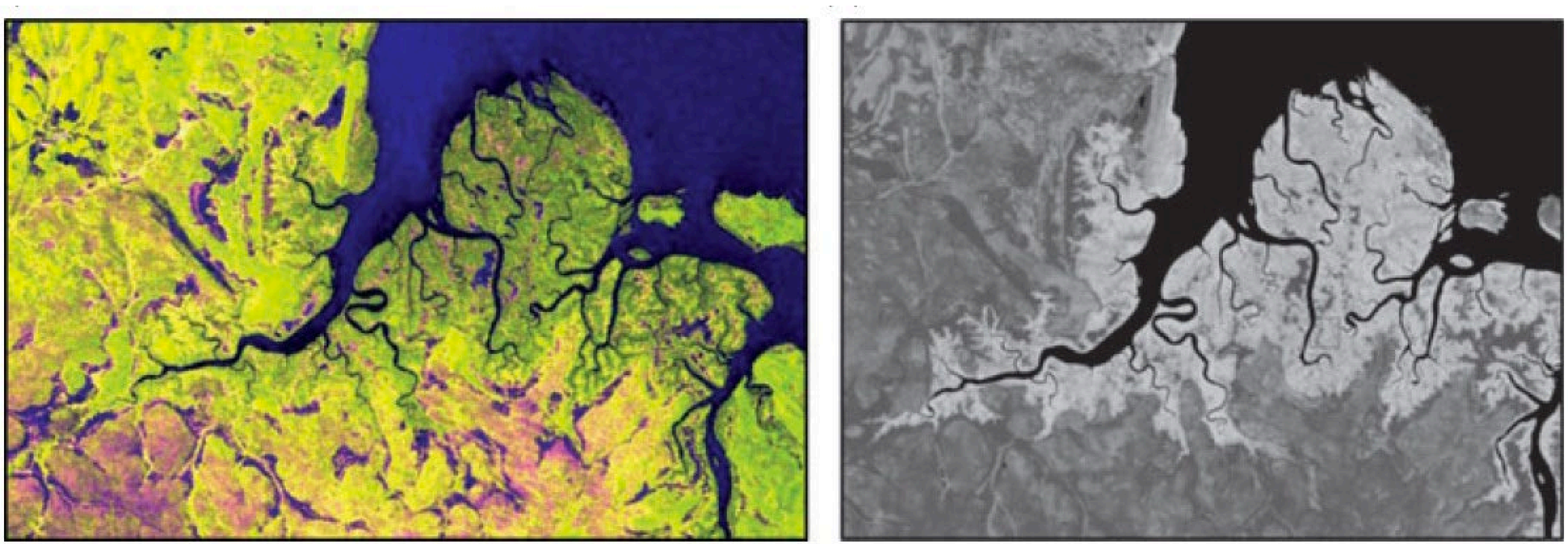
Backscatter Range for Mangroves

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

Source: SERVIR SAR Handbook Chapter 6 by Marc Simard

Challenges

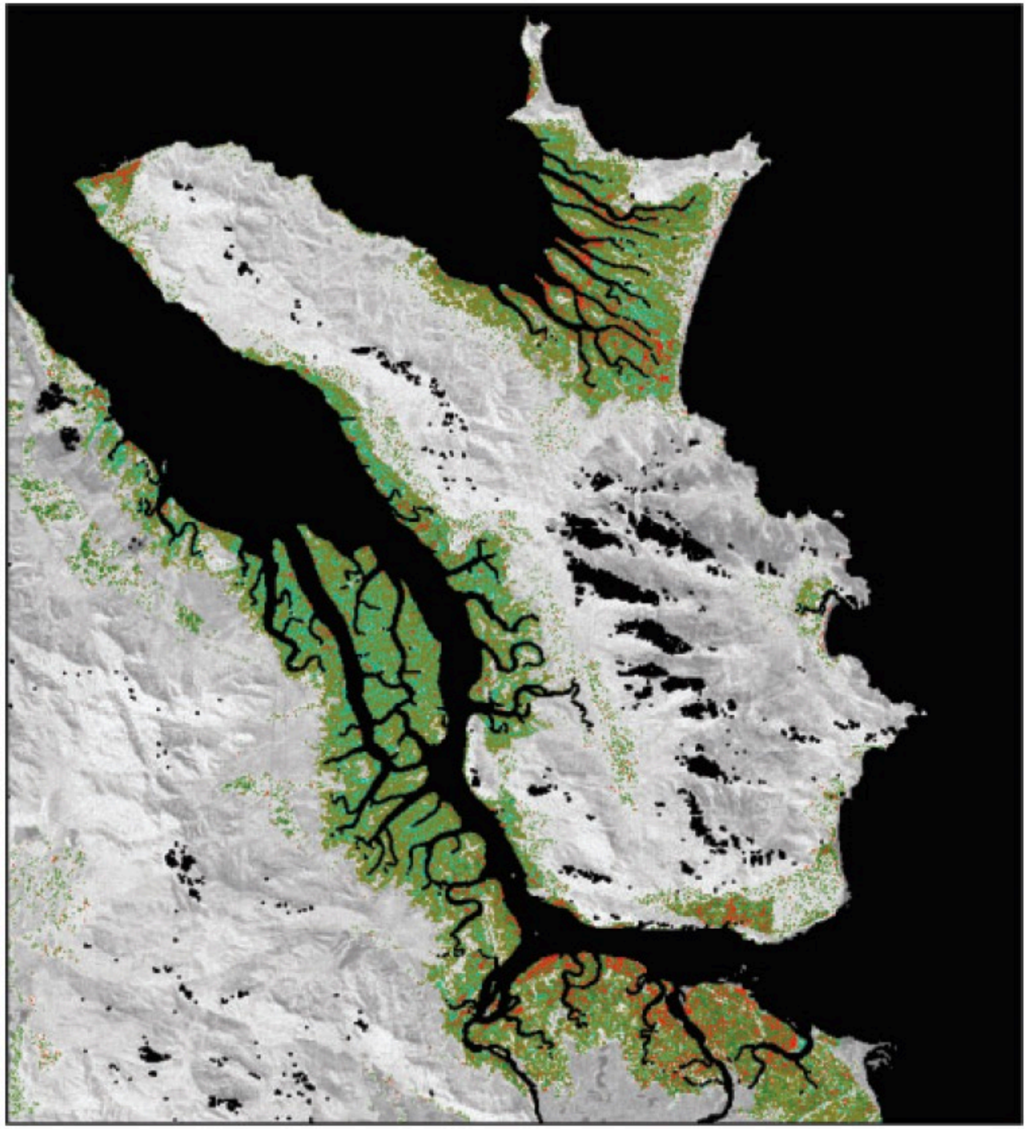
- It is difficult to map the extent of mangrove forests with just radar, especially when mangroves adjoin forests and shrublands.



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

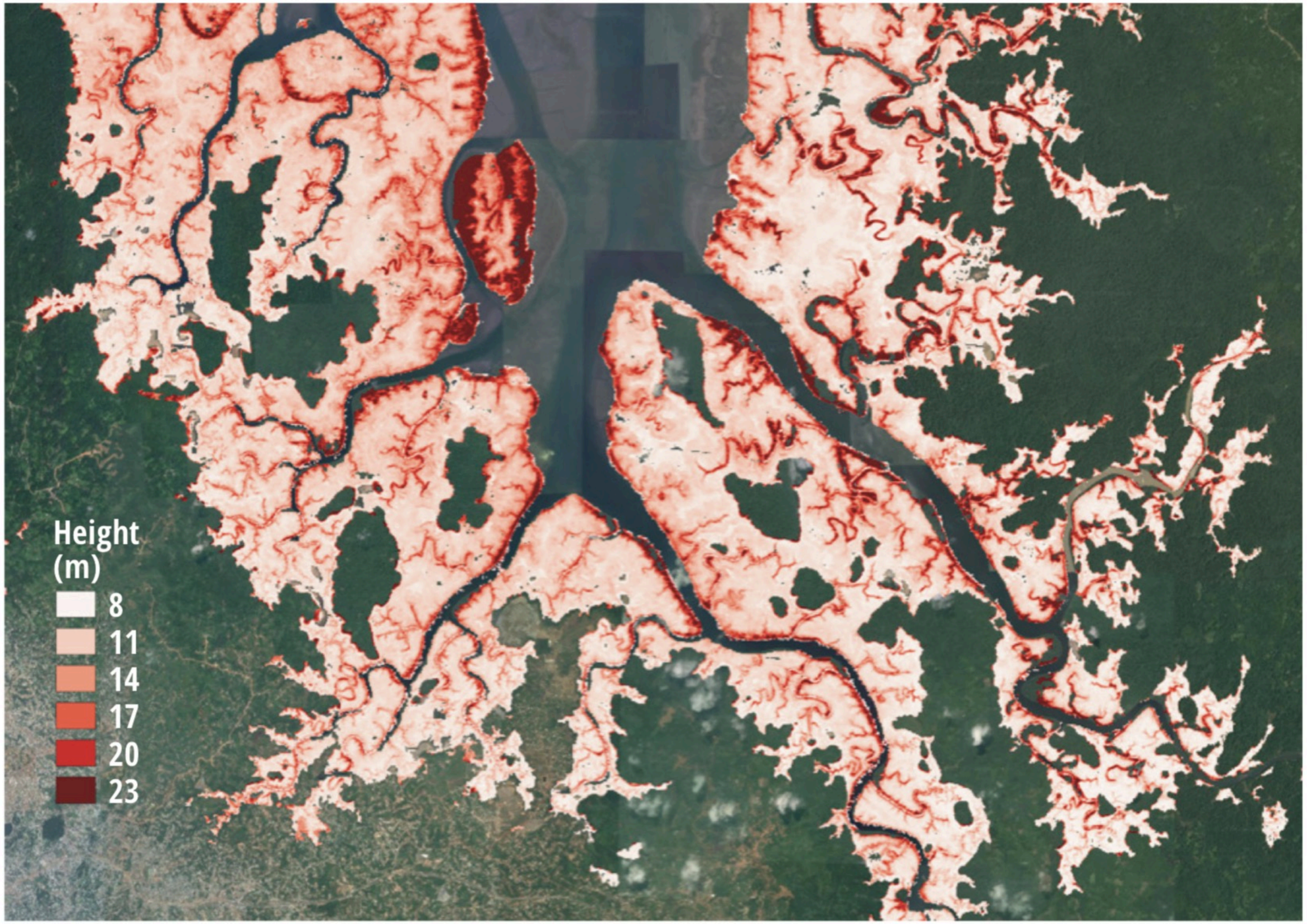
Classifying Mangroves

- 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:

SeaSAT
1978

JERS-1
1992-1998

ERS 1/2
1991-2011

ENVISAT
2002-2012

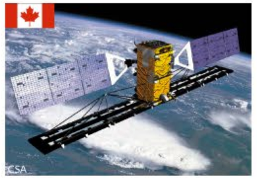
ALOS-1
2006-2011

Radarsat-1
1995-2013

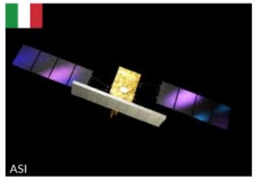
Current:

TanDEM-X
2007

Radarsat-2
2007



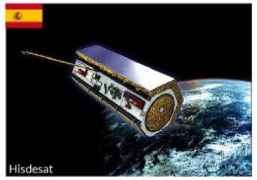
COSMO-SkyMed
2007



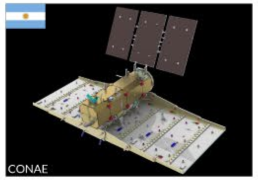
ALOS-2
2014

Sentinel-1
2014

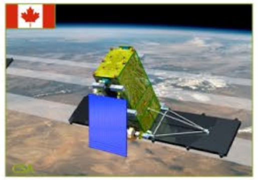
PAZ SAR
2018



SAOCOM
2018



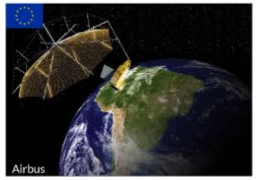
RCM
2018



Future:

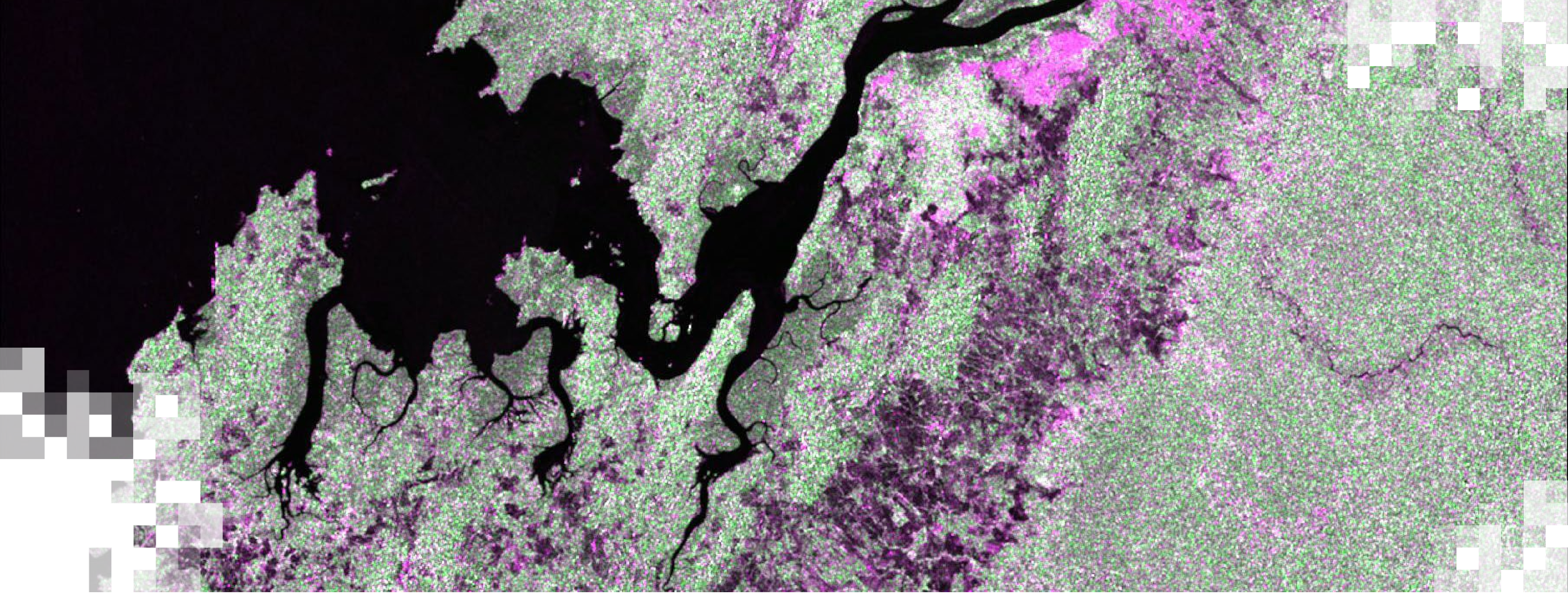
NISAR
2022

Biomass
2022



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

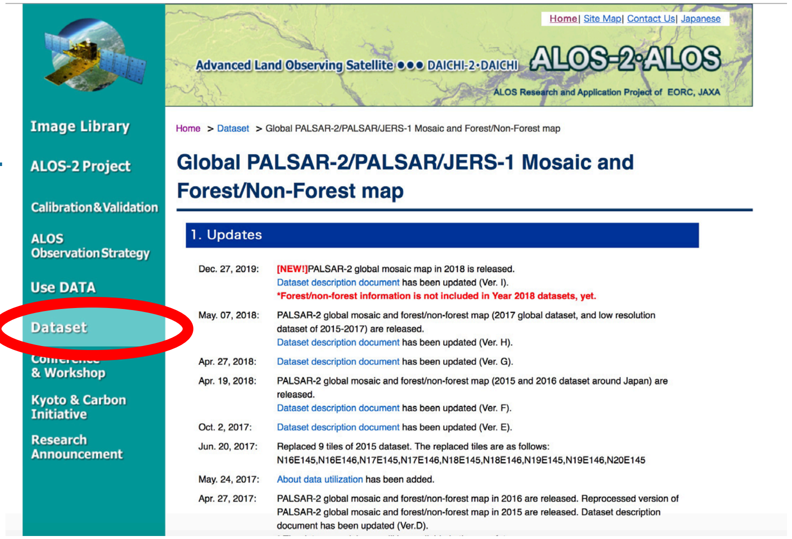
1. Access the JAXA website and register under Step 4:

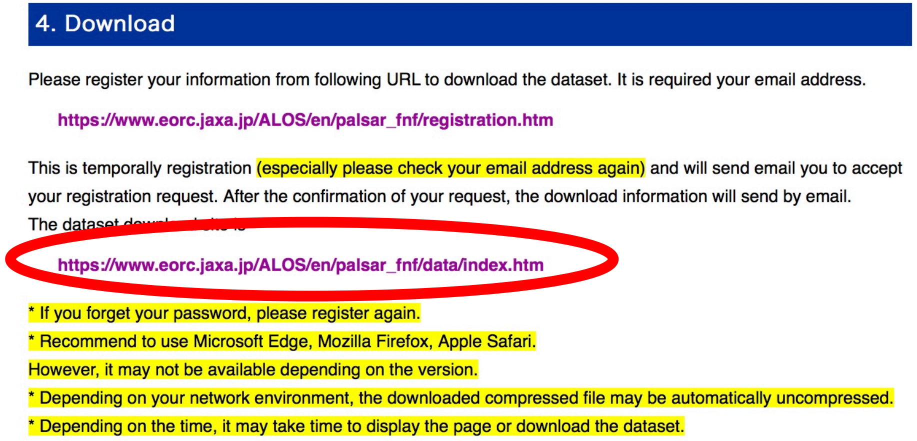
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm

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.





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

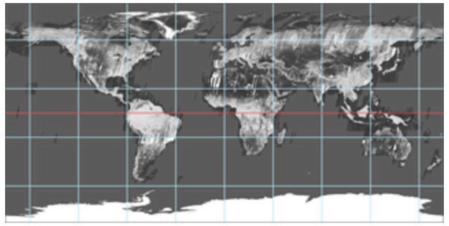
* These map uses Javascript. Please enable JavaScript on your browser.

25m resolution product

Global

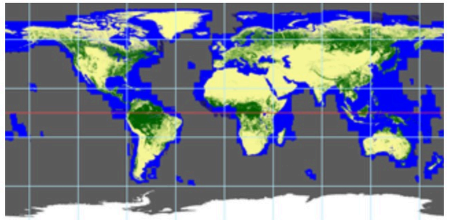
- **JERS-1 SAR Mosaic:**

  >> 1996



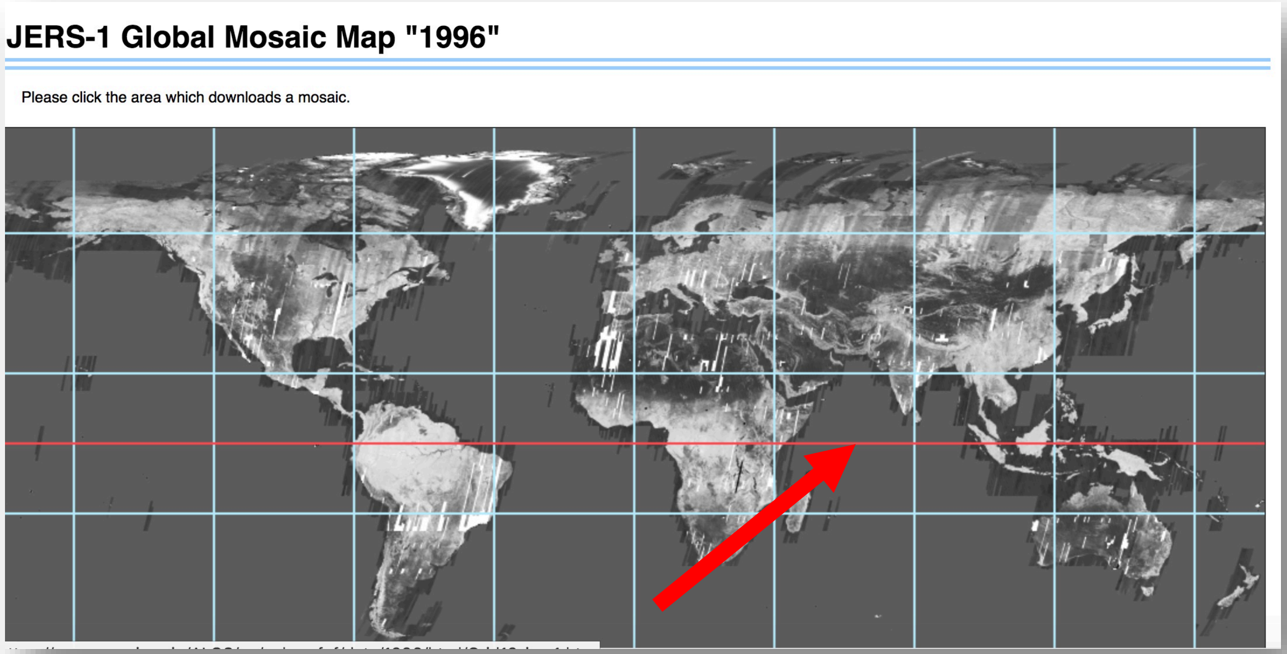
- **PALSAR/PALSAR-2 mosaic and forest/non-forest (FNF) map:**

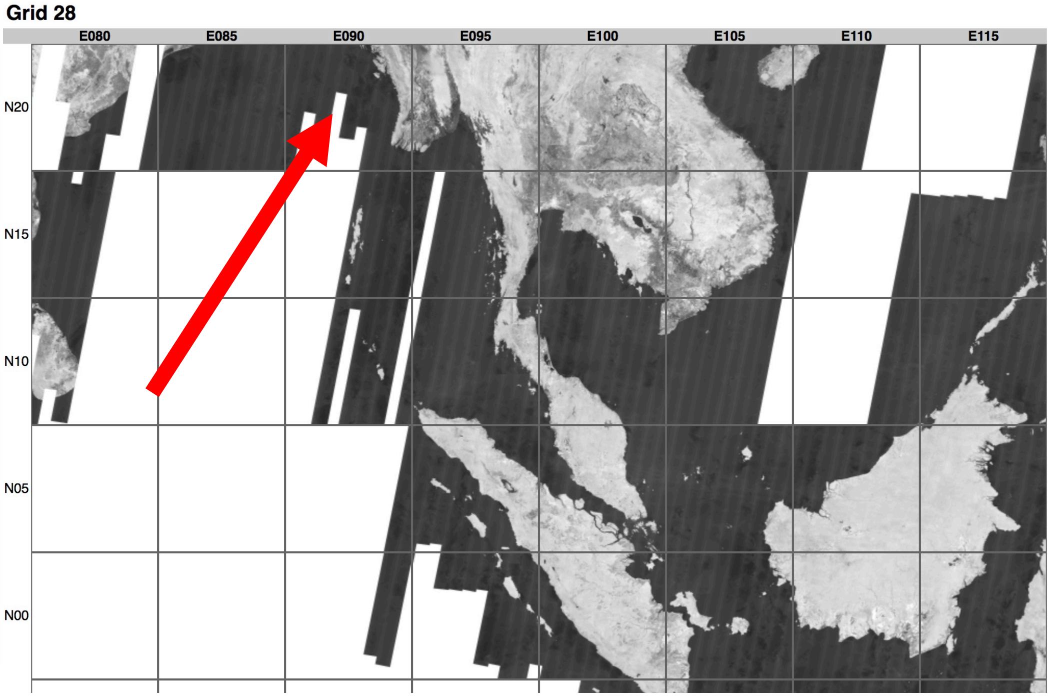
  >> 2007 >> 2008 >> 2009 >> 2010 >> 2015
  >> 2016 >> 2017 >> 2018



Download L-Band SAR Mosaic Tiles from JAXA

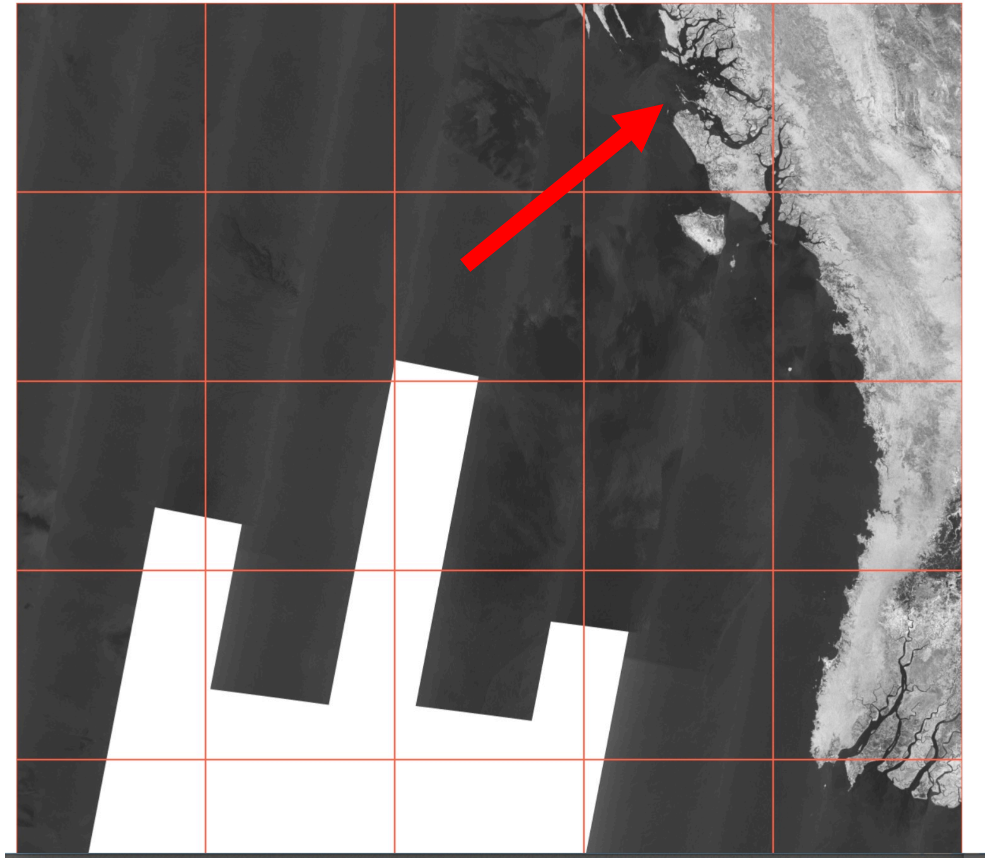
4. Select 2017 under "PALSAR/PALSAR-2 mosaic and forest/non-forest (FNF) map"
5. Our study area is the coast of Myanmar. Click on the tiles noted here





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.



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:

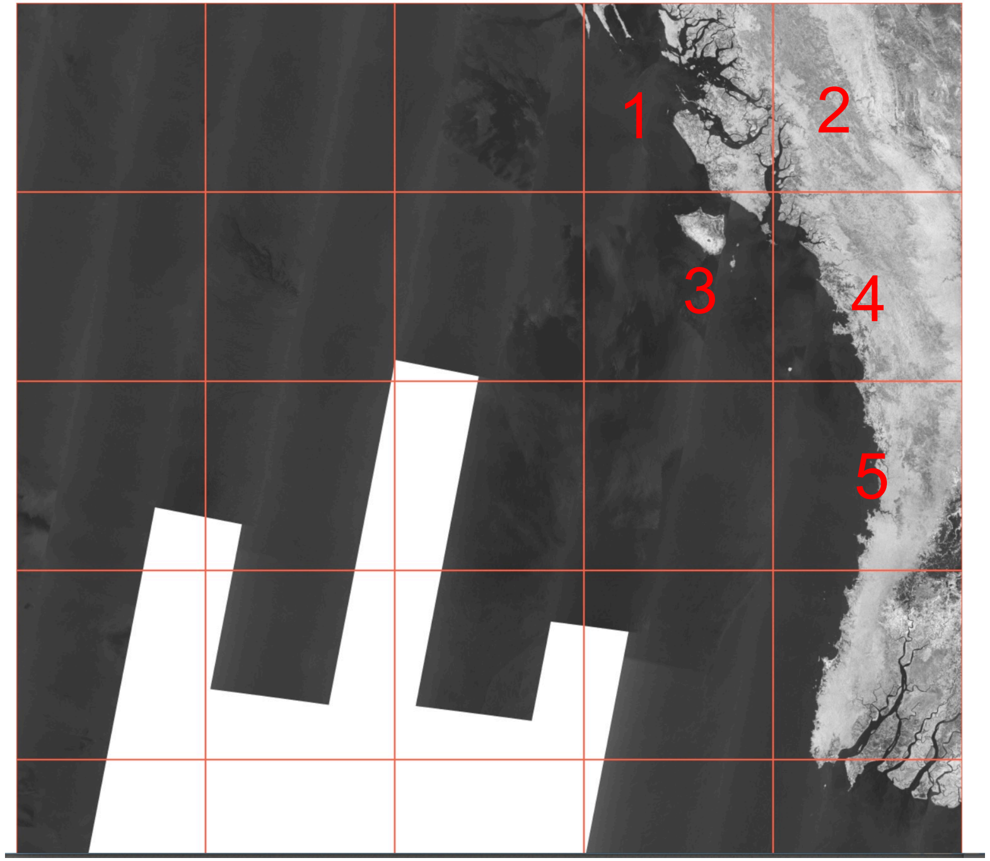
N20E093_1996

N20E094_1996

N19E093_1996

N19E094_1996

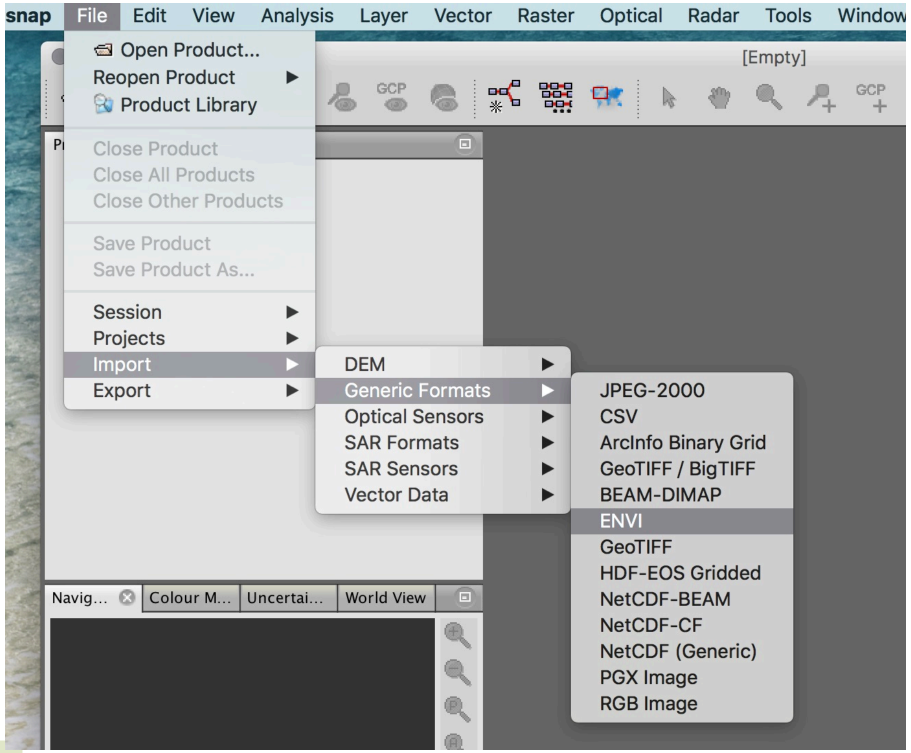
N18E094_1996

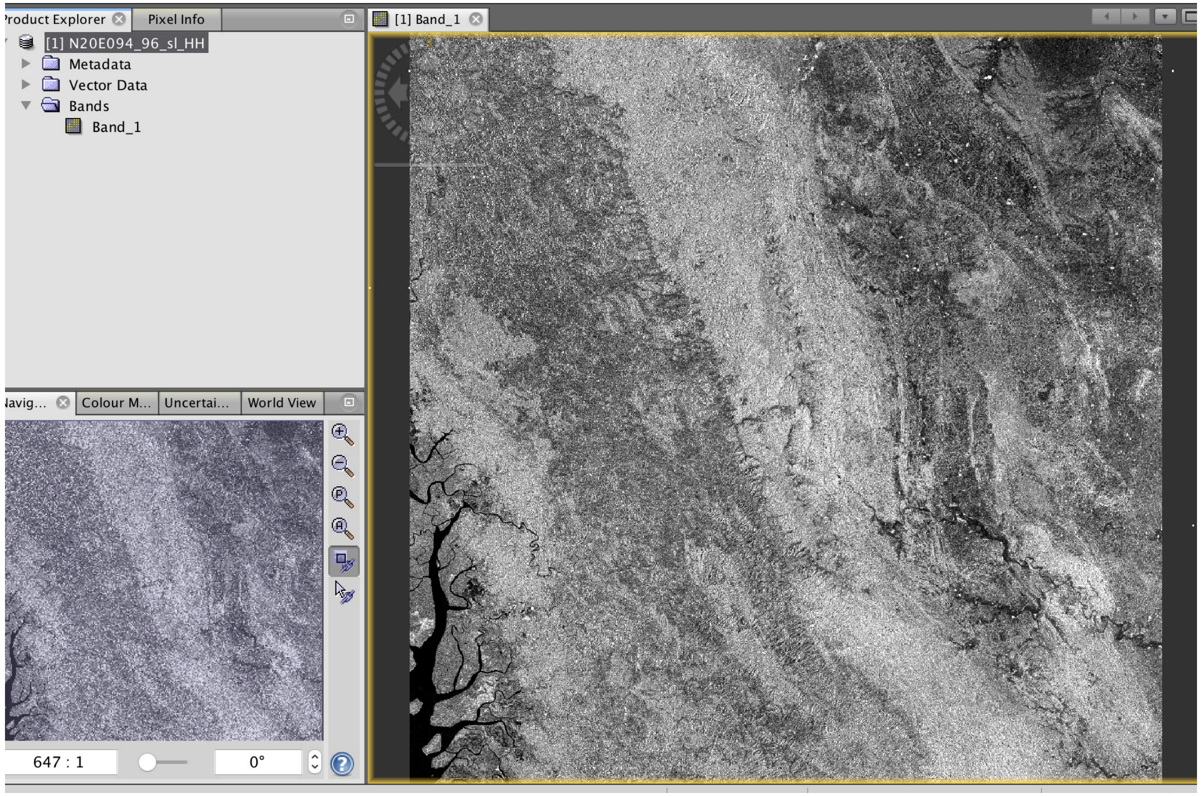


8. Unzip the files. They are in ENVI format. Open them in either ENVI, QGIS or the Sentinel Toolbox using Import.

Convert the JERS-1 Files to GeoTIFF

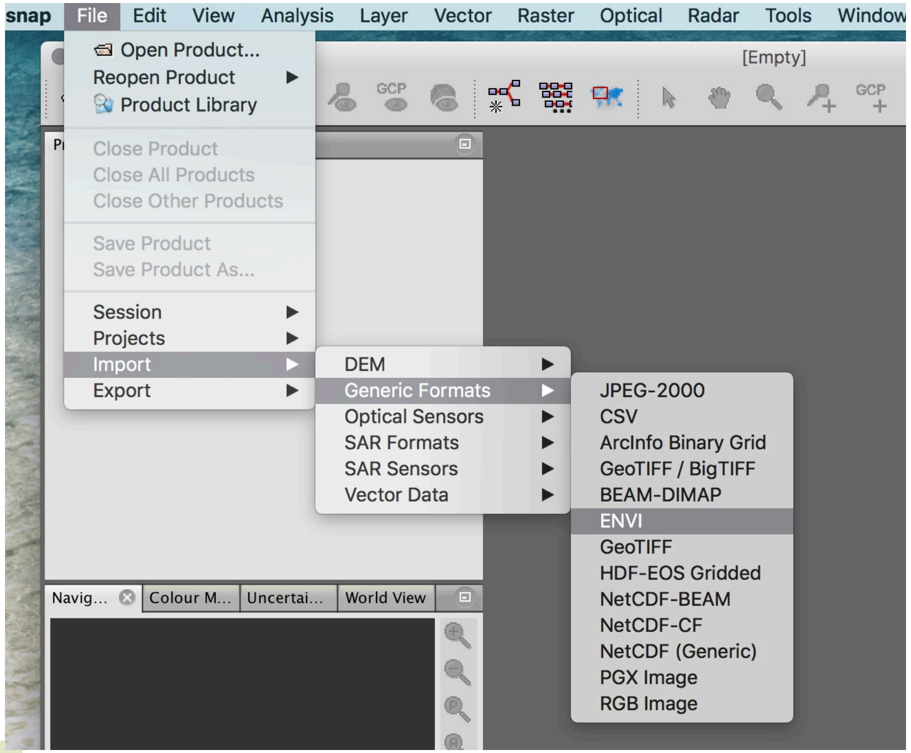
9. Open the SNAP Toolbox and go to File>Import>Generic Formats>ENVI and select the N20E094_96_sl_HH
10. Open the Bands directory and double click on Band 1 to open it

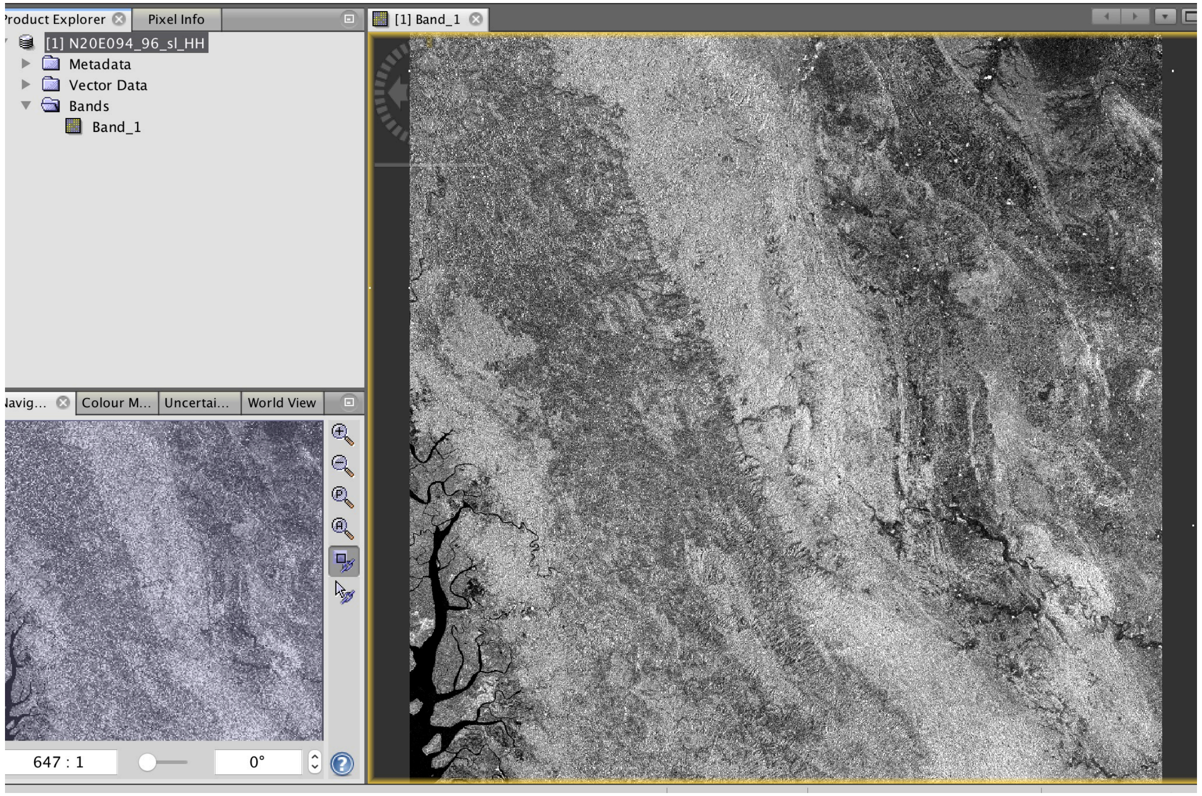




Convert the JERS-1 Files to GeoTIFF

11. Click on Band_1 and then go to File>Export>GeoTIFF
12. Repeat this same step for the other four files.



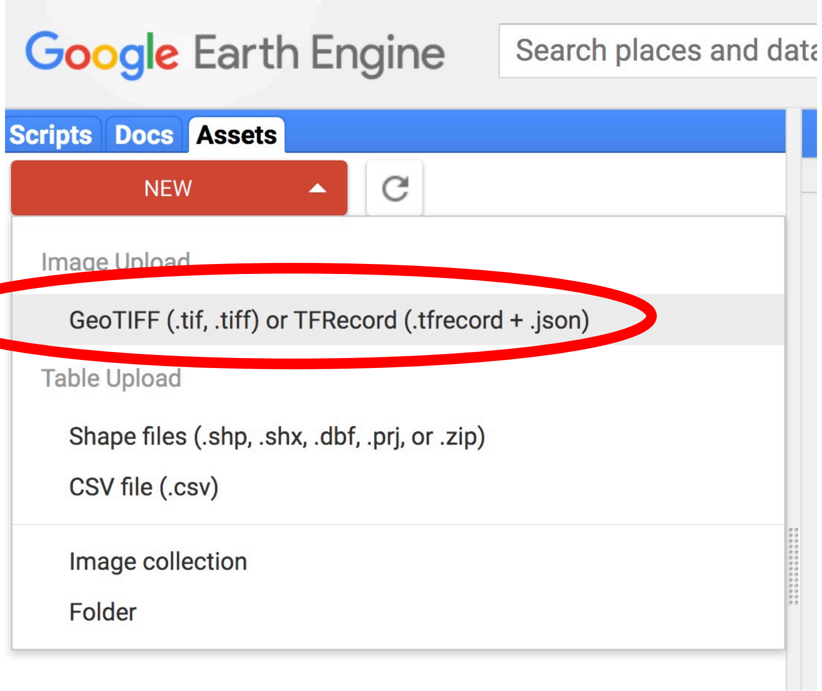


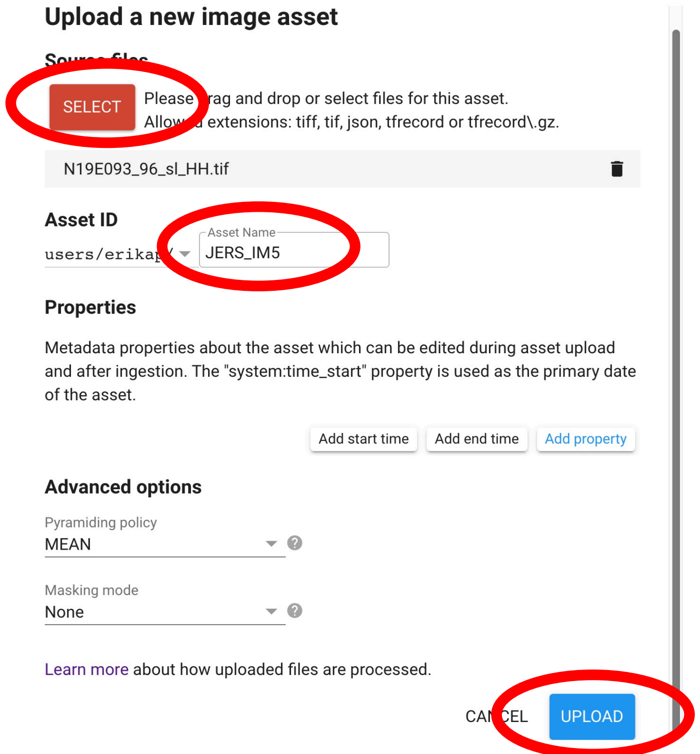
Import the JERS-1 Files into GEE

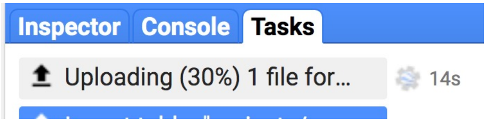
13. In the top left window select the "Assets" tab and the red NEW button and select GeoTIFF.

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.

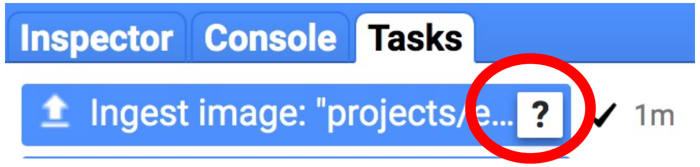


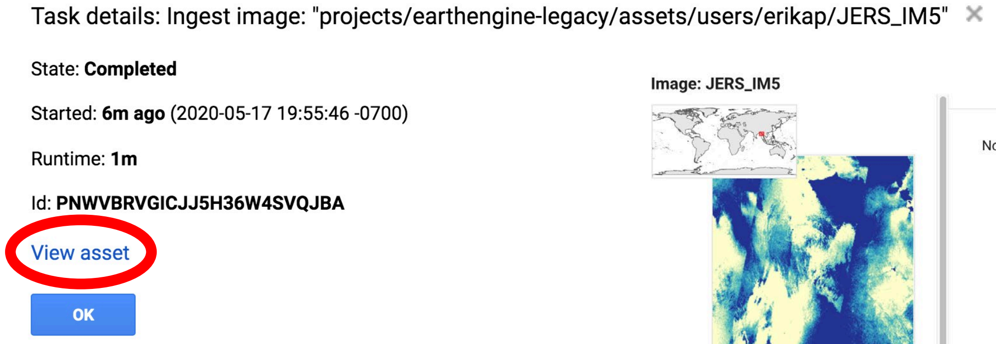


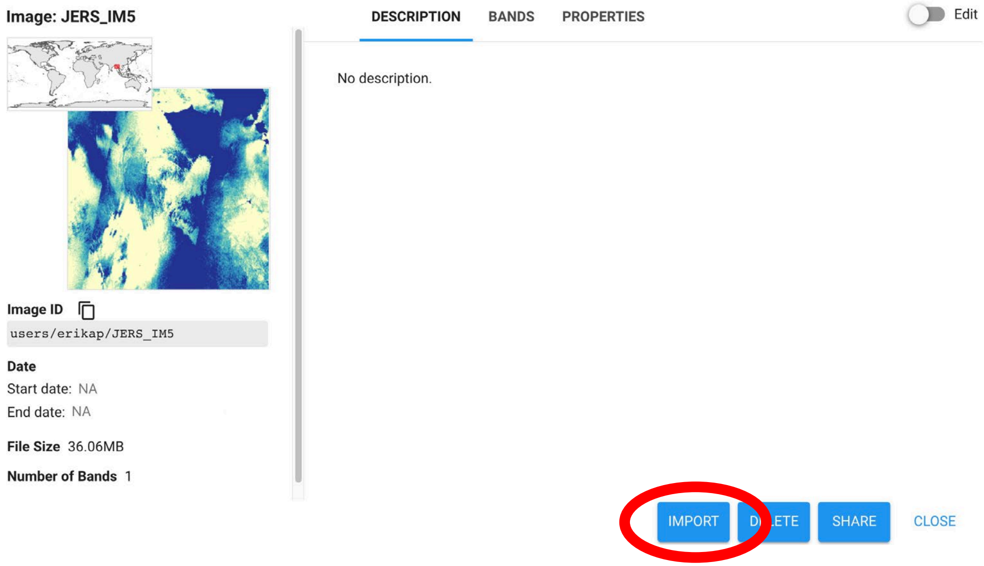


Import the JERS-1 Files into GEE

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.





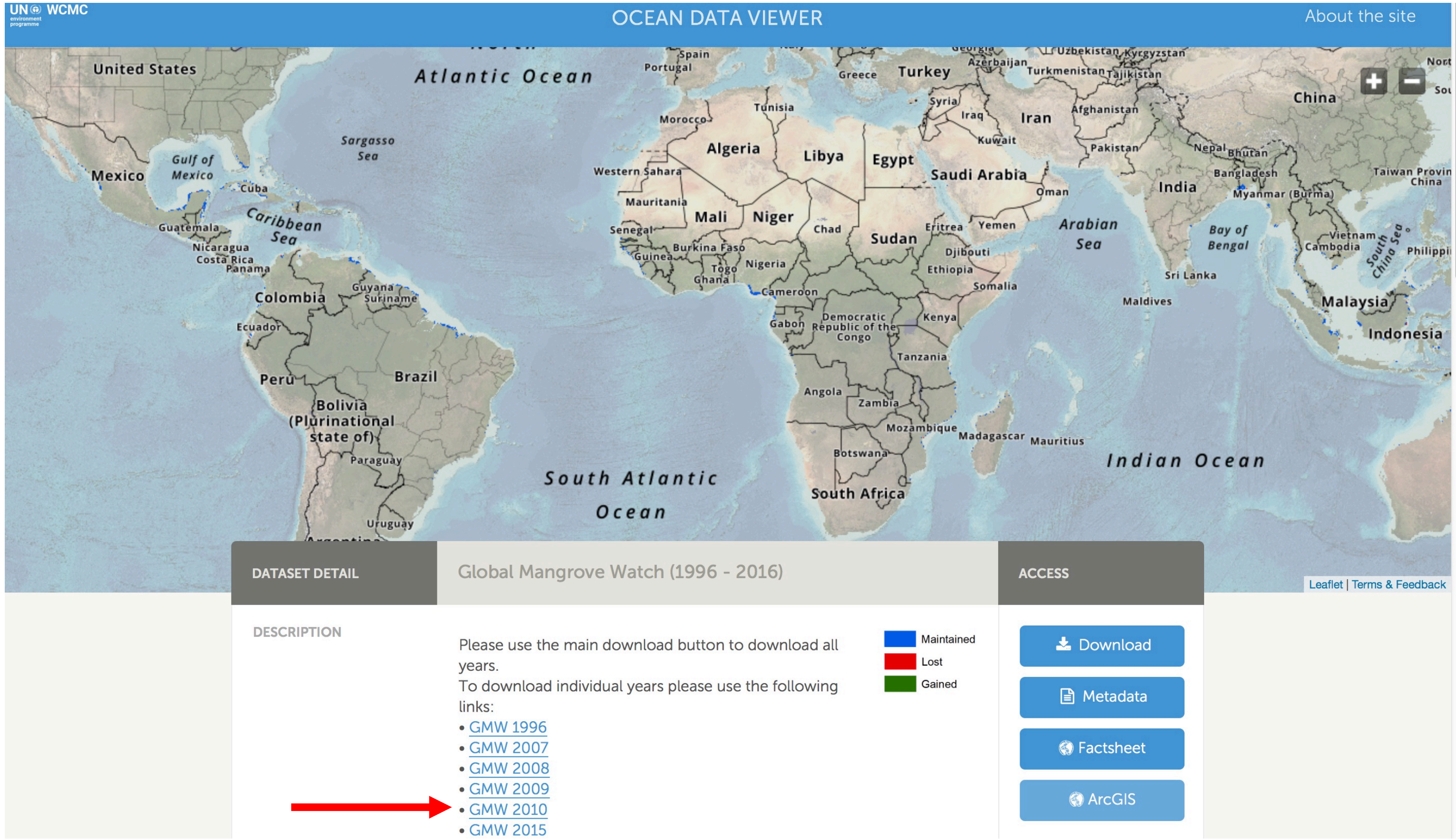


Import the JERS-1 Files into GEE

20. In the code editor on the top go to Imports and rename the files from image to JERS_1996_im1 and so on.

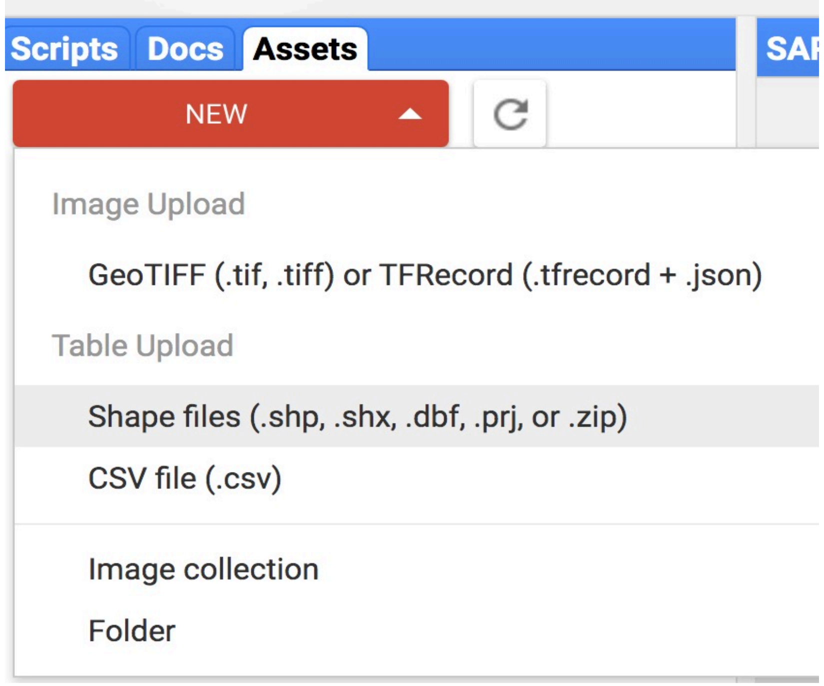
Import a Global Mangrove Distribution Vector File

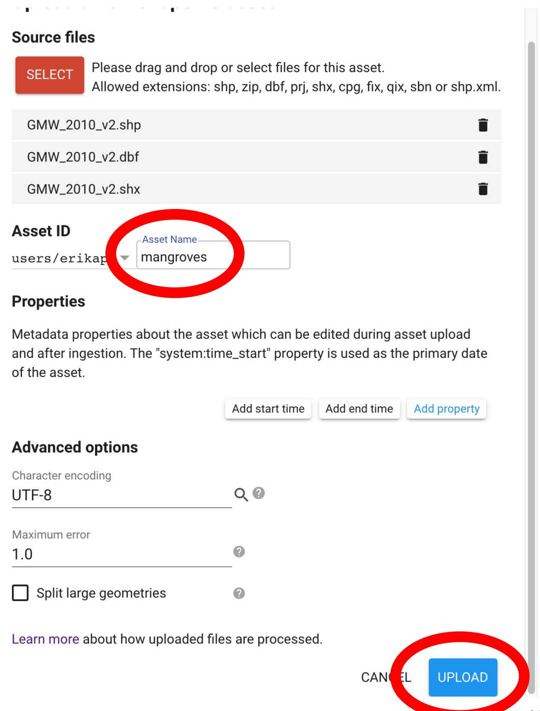
21. Go to https://data.unep-wcmc.org/datasets/45 and download the Global Mangrove Watch (GMW) **2010** file. Unzip it.



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”.





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:

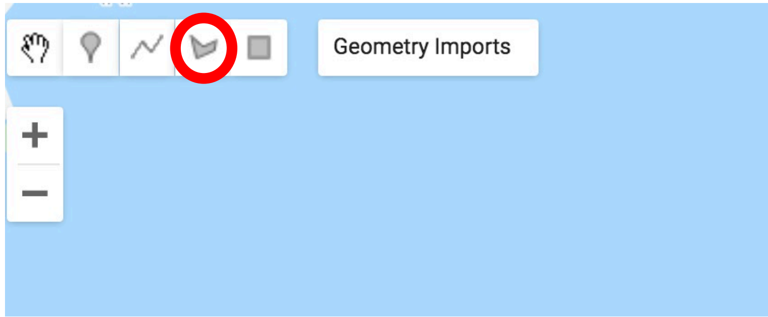
Sigma naught(dB) = 10log10(pixel_value)^2 + Calibration Factor

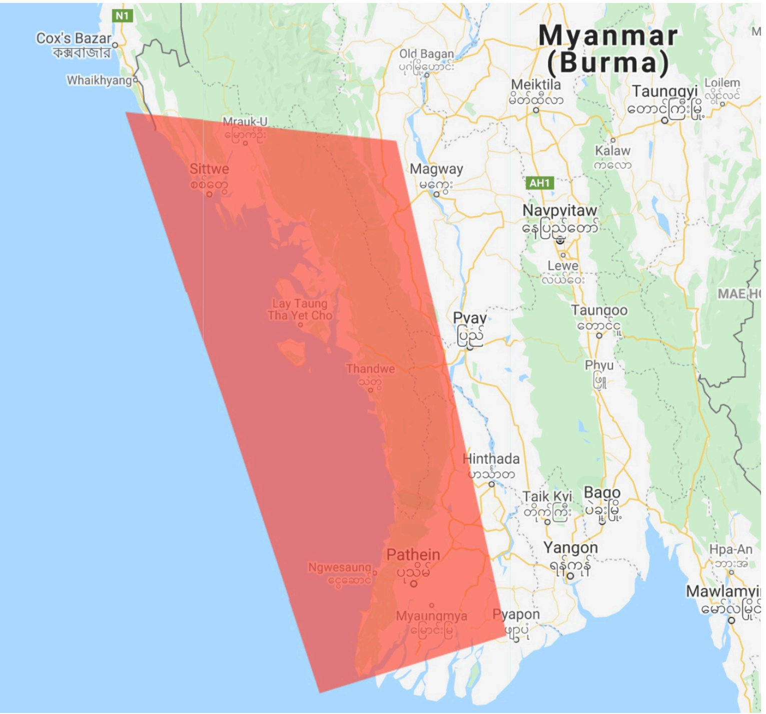
Where the Calibration Factor = -83. for the PALSAR images and -84.66 for JERS-1

```
//Convert the images to dB:γ0 =10log10 〈DN2〉 +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

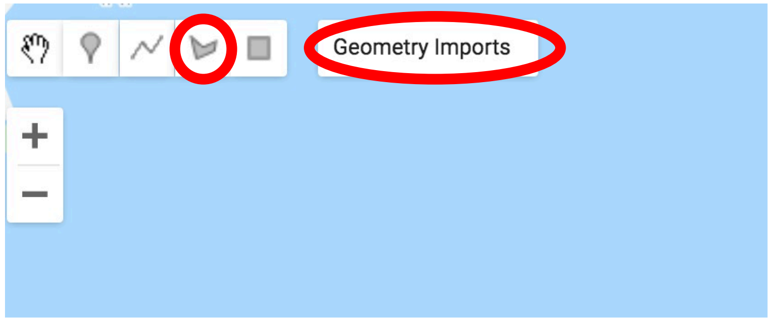
```
// Calculate the ratio between before and after
var ratio0717HV= dB_2007_HV_roi.subtract(dB_2017_HV_roi);
var ratio9617HH= dB_1996_HH_roi.subtract(dB_2017_HH_roi);
```

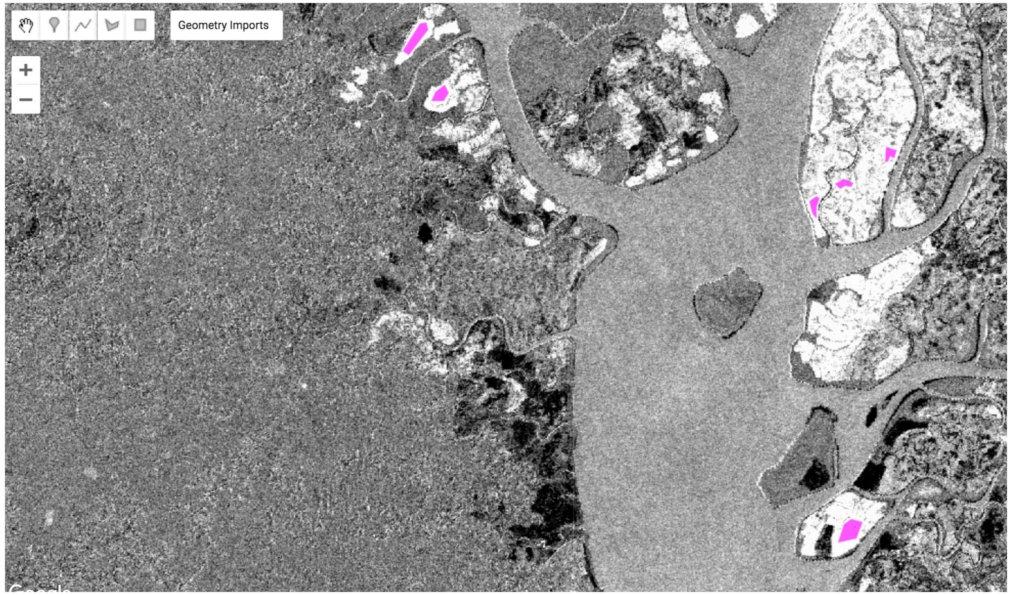
35. Display the ratio images

```
// 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".

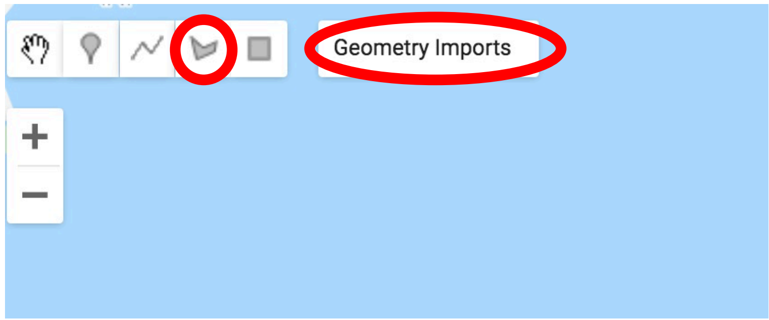


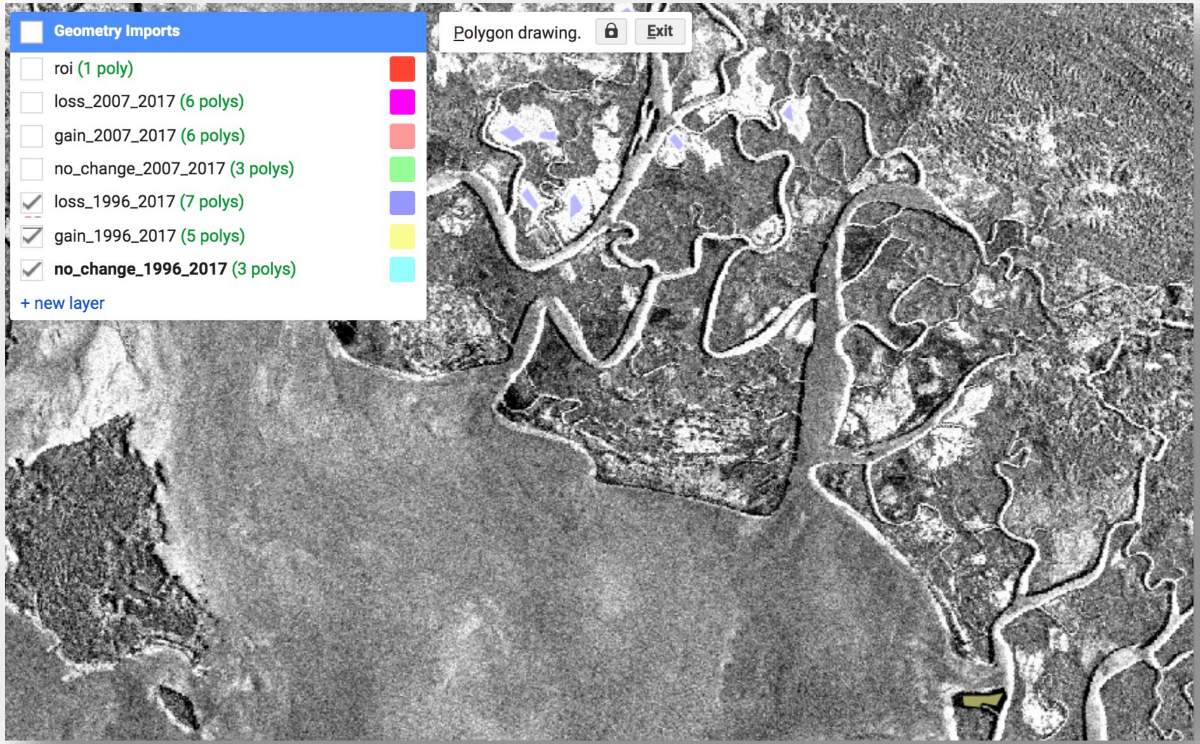


37. Select the Ratio 2007/2017 image and draw polygons on the areas that are very bright.
38. Rename the polygon from geometry to loss_2007_2017
39. Repeat steps 36-37 identifying the dark areas. Rename the polygon to gain_2007_2017.
40. Repeat steps 36-37 once again identifying areas of no change. Rename 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 2xthe 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 2xthe 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: Hba ~ 1.08*SRTM
- Maximum canopy height: Hmax ~ 0.93*1.7*SRTM
- Aboveground Biomass: B ~ 3.25*Hba 1.53

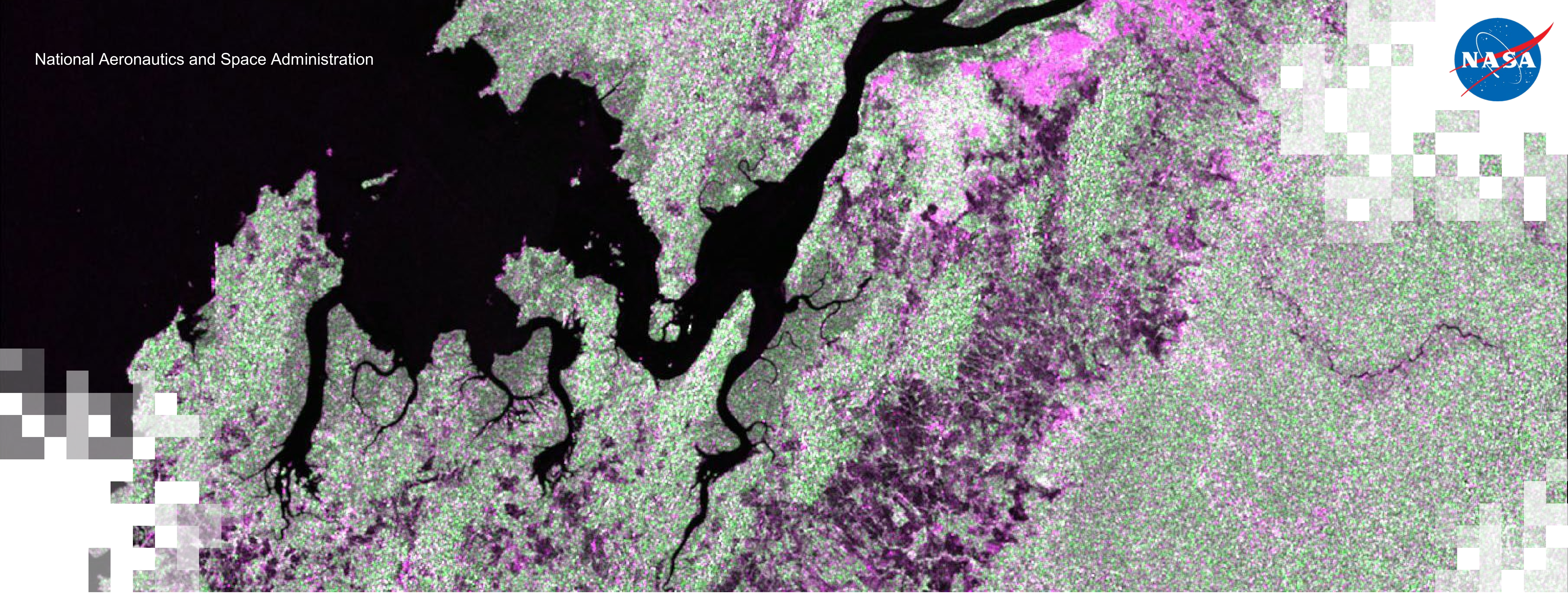
We will use the following equation:

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

National Aeronautics and Space Administration



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!