SERVIR Training

Mangrove Forest and Radar

Huntsville, AL

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Course outline: Day 1

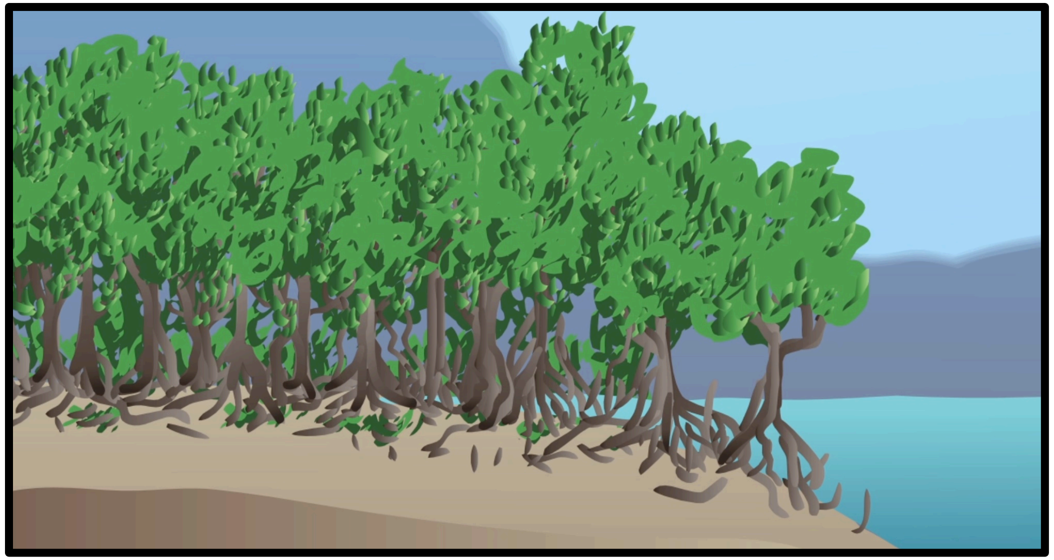
9:00 – 9:30	Session 1a Introduction to Mangrove Forest and
9:30 – 10:00	Session 1b Radar Remote Sensing
10:00 – 10h30	Photo Session/Tea Break
10:30 – 11:00	Session 2a Sources of Radar Remote Sensing Data
11:00 – 12:30	Session 2b Process radar images
12:30 – 14:00	Lunch Break
14:00 – 15:00	Session 2c Data processing in QGIS
15:00 – 16:00	Session 3a Biomass estimation
16:00 – 16:15	Tea/Coffee Break

Course outline: Day 2

09:00 – 10:00	Session 3b Biomass estimation
10:00 – 10:30	Tea/Coffee Break
10:30– 13:00	Session 3c Biomass estimation
13:00 – 14:00	Lunch Break
14:00 – 16:00	Session 4 Monitoring mangrove loss and gain
16:00 – 16:10	Tea/Coffee Break

Introduction to Mangroves

- Most **productive ecosystems** in the World.
- Thrive in the **tropical and sub-tropical regions** along the coastal regions within the intertidal zone.
- Cover a small land area (<1%) and responsible for 10% of global carbon export to Oceans.
- Provide a number of both direct and indirect services to local populations.
- Can grow up to about 60m in height and to attain high values of Above Ground Biomass (AGB)
- Occupy the riparian zone.
- Straddle both terrestrial and marine environments enabling them to support a very broad range of biodiversity.



Mangroves provides critical ecosystem services to society

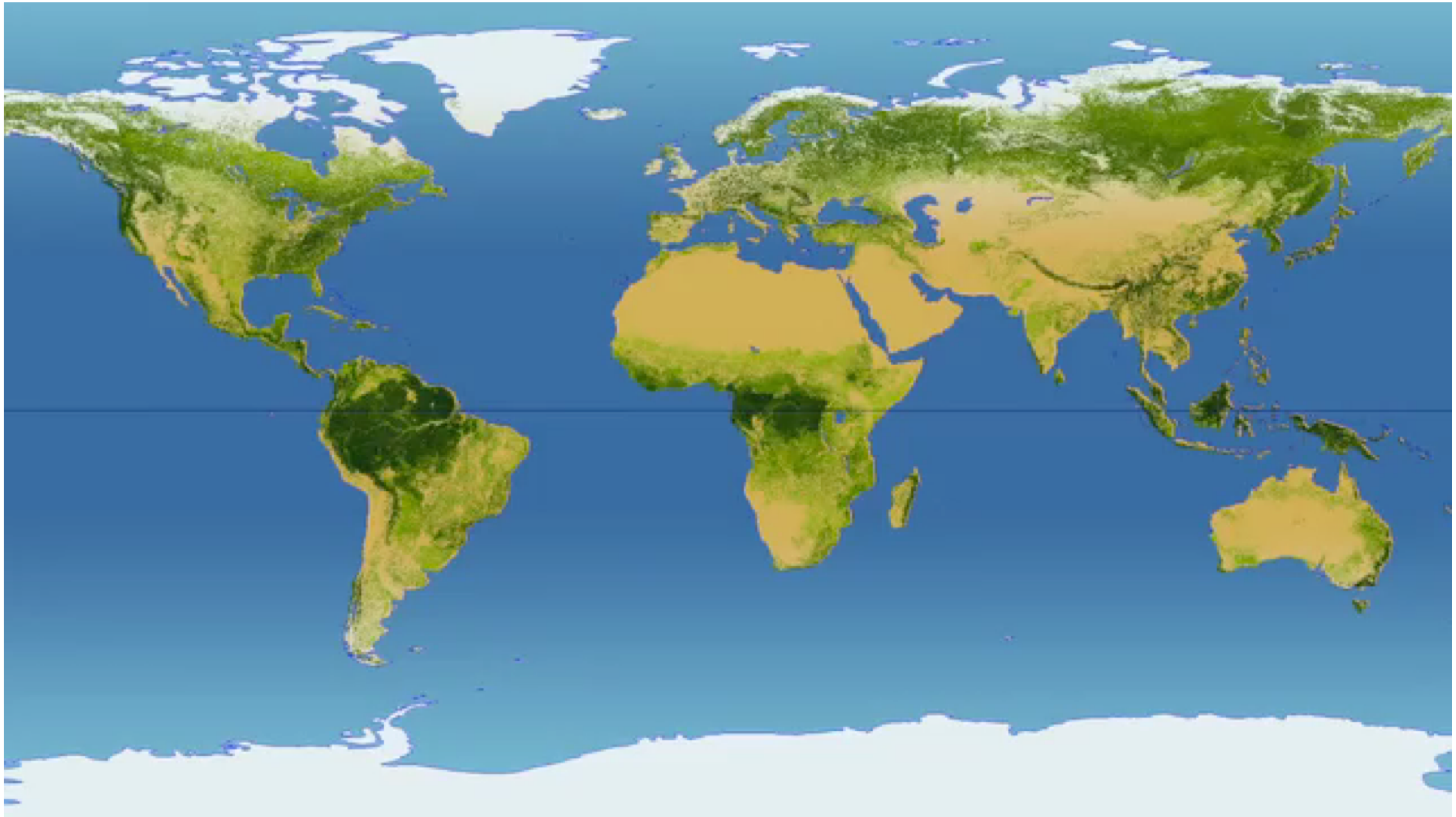
- Coastal protection against tsunamis, hurricanes, storm surges, sea level rise and erosion
- Nurseries for fish, crustaceans and amphibians maintaining fish stocks and biodiversity
- Provide lumber and coal to local communities
- Store an extraordinary amount of carbon from the atmosphere and store in soils reducing global warming rates. (up to 1000t/ha including soil C)
  - Note that Carbon is used a mitigation to reduce destruction of mangrove for other unsustainable uses.
- The estimated **economical** value varies between $200k to **$900k** per km^2 per year (UNEP report 2006);
  - Note: These numbers need to be updated with our improved knowledge and also information on forest structure which drives their economical value.

Mangroves are endangered

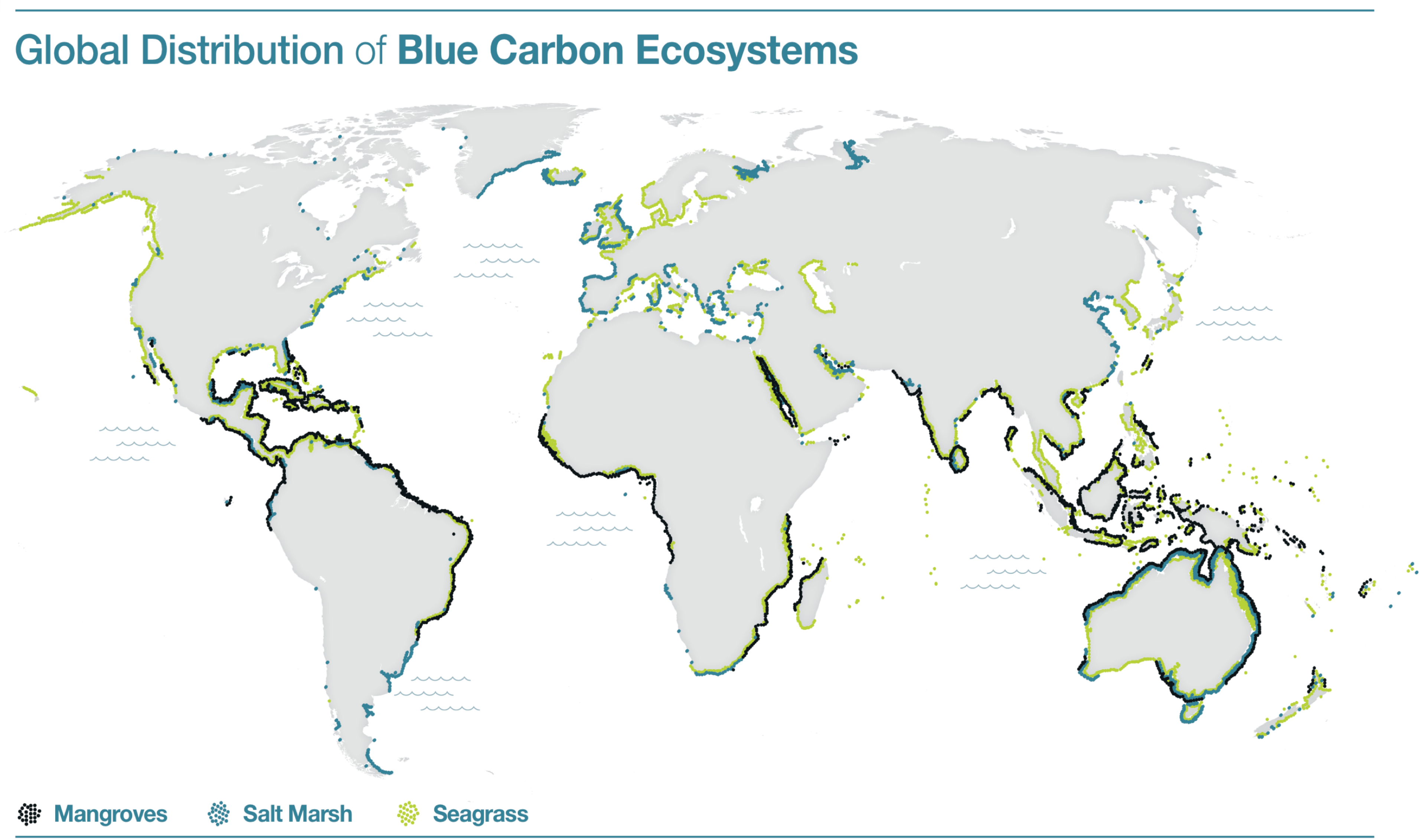
- Already **35%** of mangrove forests have **disappeared** and **60%** could be lost by **2030;**
- Endangered by climate change: sea level rise
- Mostly threatened by human activity (e.g. Urbanization, over exploitation for lumber, fresh water diversion due to construction of roads, levees and canals, pollution)

Mangrove are very important to society, however they are endangered. Most World population lives near the coasts.

Global Distribution of Mangrove Forests

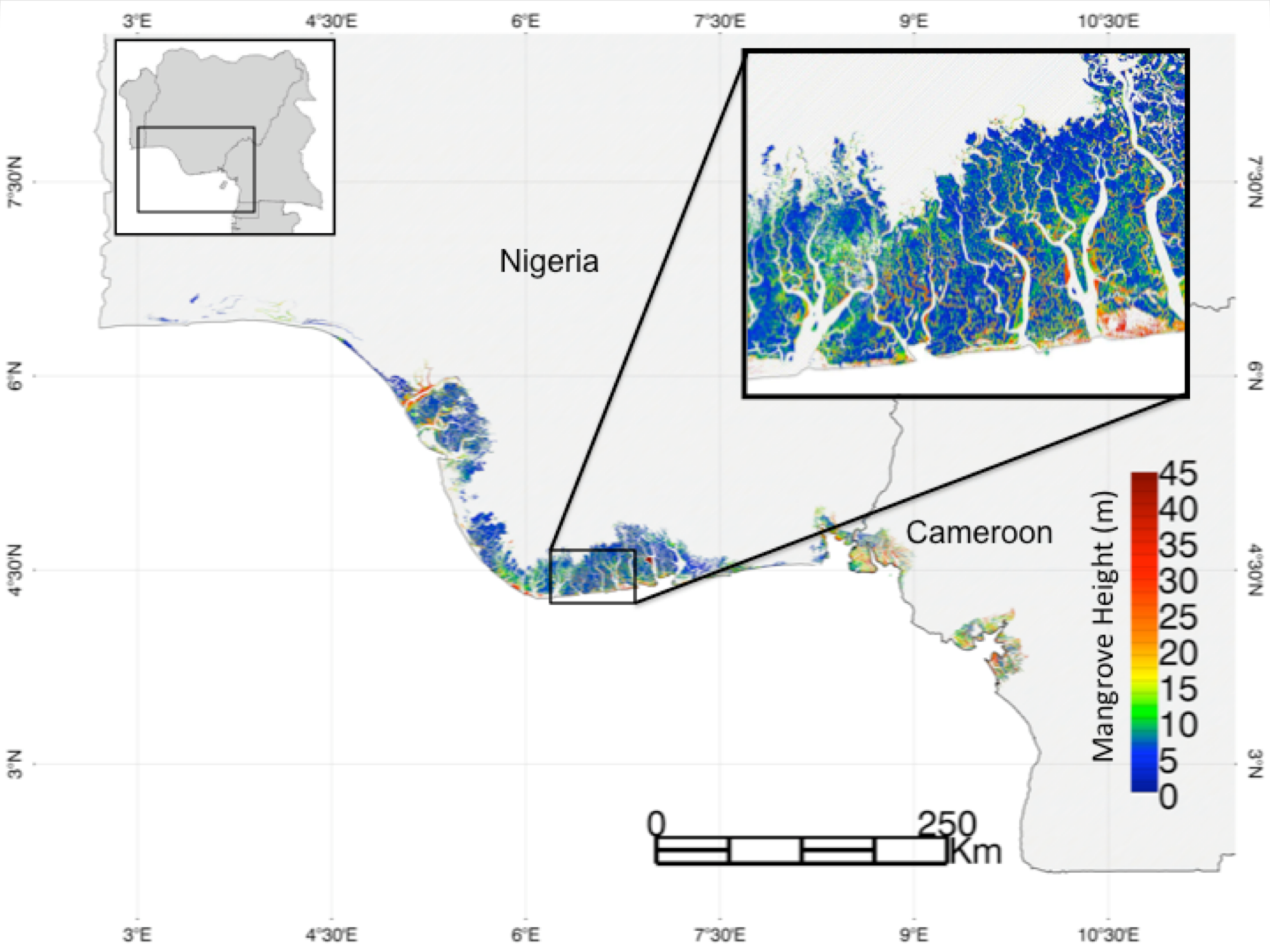


Distribution of Blue Carbon



Mangroves occupy137600-152308km^2 globally (Spalding et al, 2010; Giri et al., 2011)

Height and Biomass Map of All Mangrove Forests of Africa



Fatoyinbo & Simard, IJRSE 2012

Courtesy: Marc.simard@jpl.nasa.gov

Country	Area in km^2	Total Biomass in Mg	Mean Biomass in Mg/ha
Angola	154	1,441,200	93
Benin	18	137,719	76
Cameroon	1,483	25,334,900	171
Congo	15	267,603	178
Cote d'Ivoire	32	406,516	124
Djibouti	17	1,653,170	90
DRC	183	51,570	140
Egypt	1	8,344	117
Equatorial Guinee	181	2,922,420	161
Eritrea	49	640,038	129
Gabon	1,457	23,840,000	162
Gambia	519.11	5,509,300	106
Ghana	76	742,925	97
Guinea	1,889	18,153,800	108
Guinea Bissao	2,806	31,712,300	113
Kenya	192	2,294,820	119
Liberia	189	2,141,860	113
Madagascar	2,059	24,856,900	121
Mauritania	0.4	4,156	95
Mozambique	3,054	30,974,100	101
Nigeria	8,573	94,788,000	111
Senegal	1,200	11,462,100	95
Sierra Leone	955	10,655,600	112
Somalia	30	436,907	143
Soudan	4	135,626	113
South Africa	12	40,018	100
Togo	2	15,861	78
Tanzania	809	11,037,800	136
Africa	25,960	301,665,553	116

Countries (10) with most biomass (tons) - World

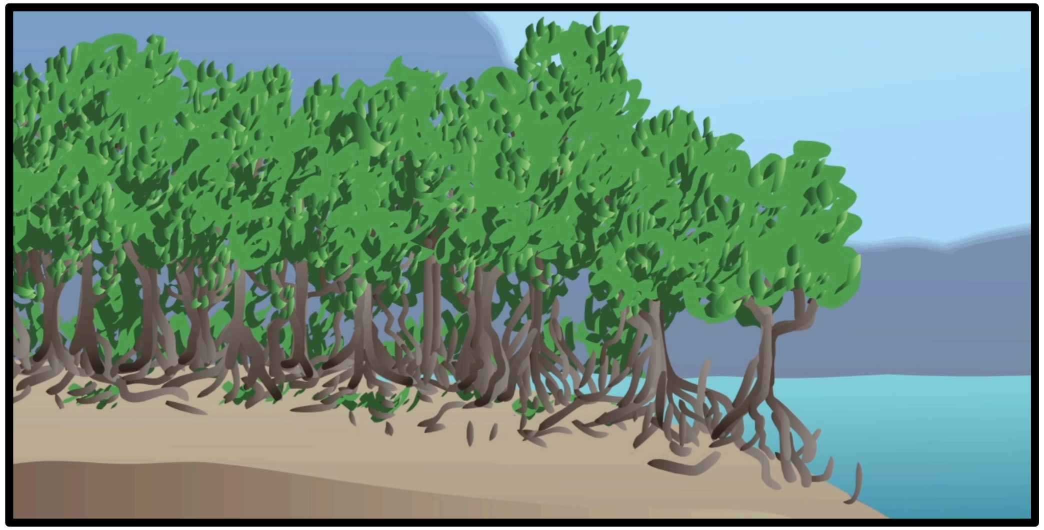
Country	Max Height (m)	Mean height (m)	Max AGB (Mg/ha)	Mean AGB (Mg/ha)	Total AGB (Mg)	Total C (Mg)	Mangrove area (ha)
Indonesia	47.5	24.7	456.4	218.5	578,630,876	1,138,076,289	2,647,499
Papua New Guinea	45.8	28.6	432.5	248.1	114,089,528	206,806,176	459,856
Australia	28.8	12.2	241.8	121.7	111,643,417	333,910,624	914,796
Brazil	40.7	20.3	260.5	94.6	97,367,688	354,985,555	1,023,164
Malaysia	35.6	20.4	308.3	176.5	92,120,954	209,655,257	522,088
Bangladesh	25.5	15.5	421.2	173.0	73,916,017	170,612,893	427,357
Nigeria	33.9	13.9	355.3	99.6	68,016,334	238,906,942	682,688
Venezuela	52.6	31.7	392.8	190.1	45,442,016	98,147,684	238,908
Cameroon	49.2	23.1	627.3	215.1	42,491,621	84,449,634	197,511

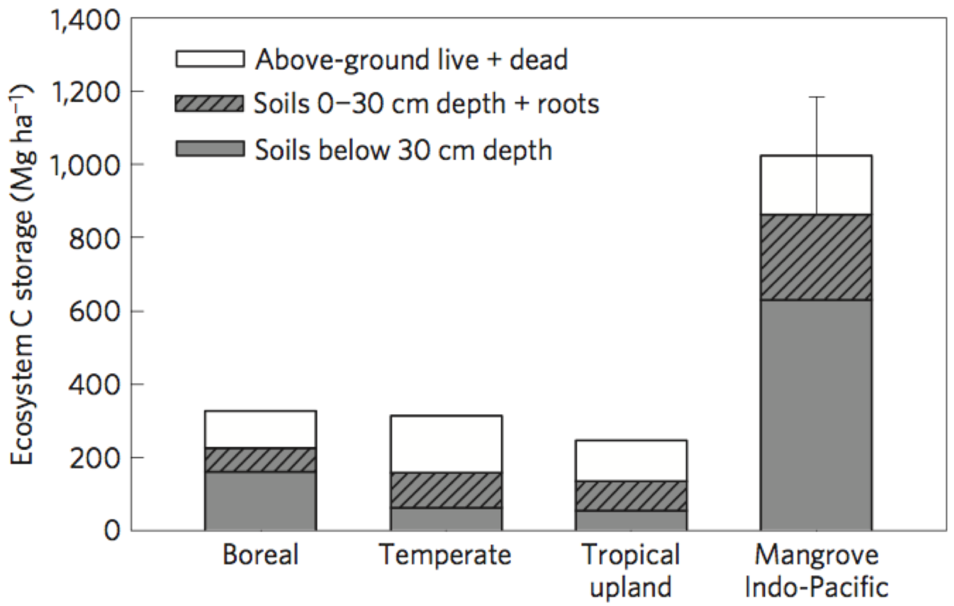
Mangrove continuum is threatened by sea level rise

Anthropogenic Marshes-Mangroves Ocean

Mangroves and ecosystem services

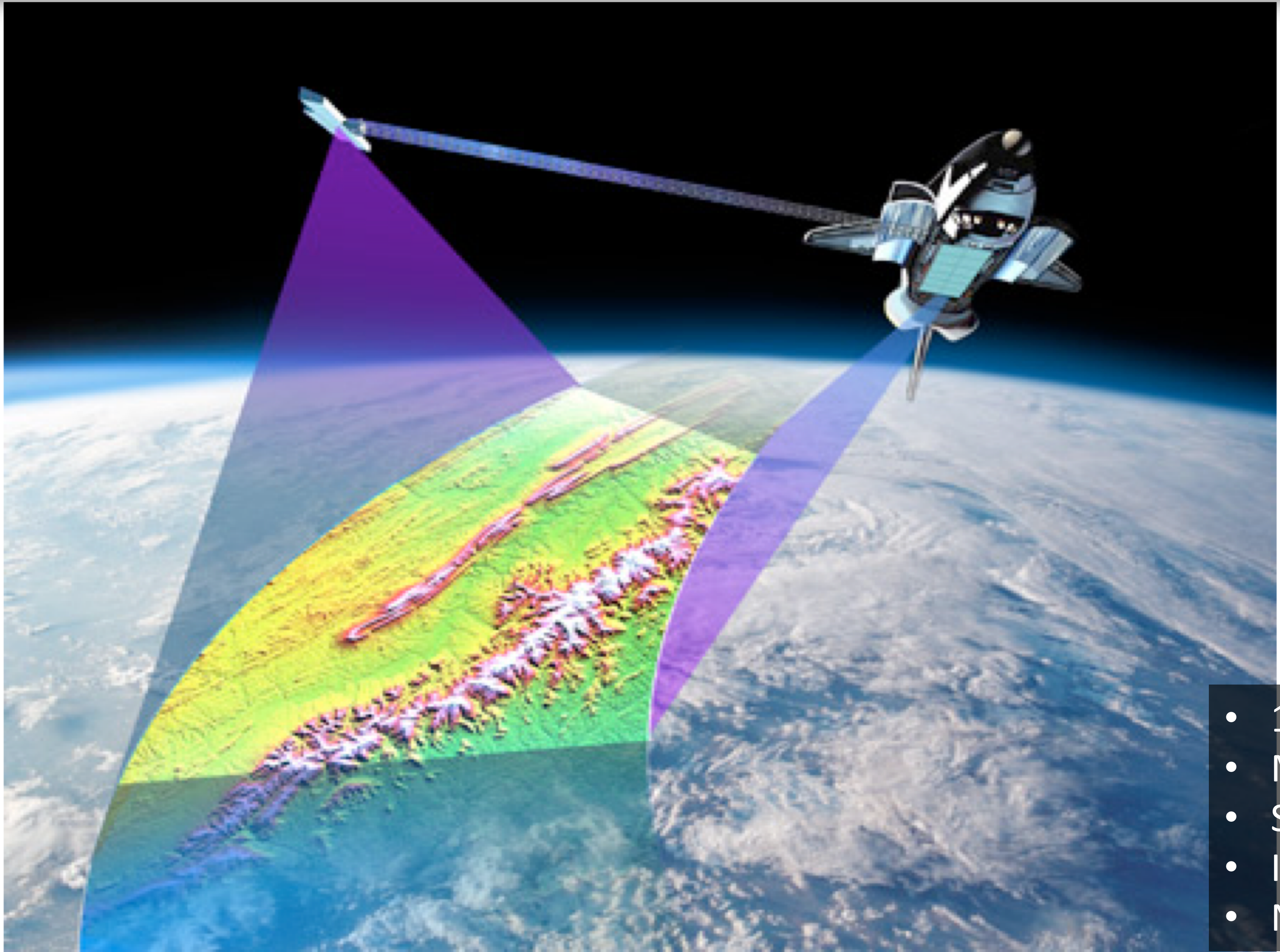
- Environmental drivers of mangrove structure: precipitation, temperature, availability of nutrients and salinity - *climate change*
- Mangroves structure divided into 4 eco-types - landscape characteristics: riverine, basin, fringe and scrub.
- Remote sensing can measure the ecosystem response in term of canopy height, above ground biomass (AGB), species distribution and spatial patterns.
- The largest driver of this loss has been the conversion of mangrove forest to aquaculture, mariculture





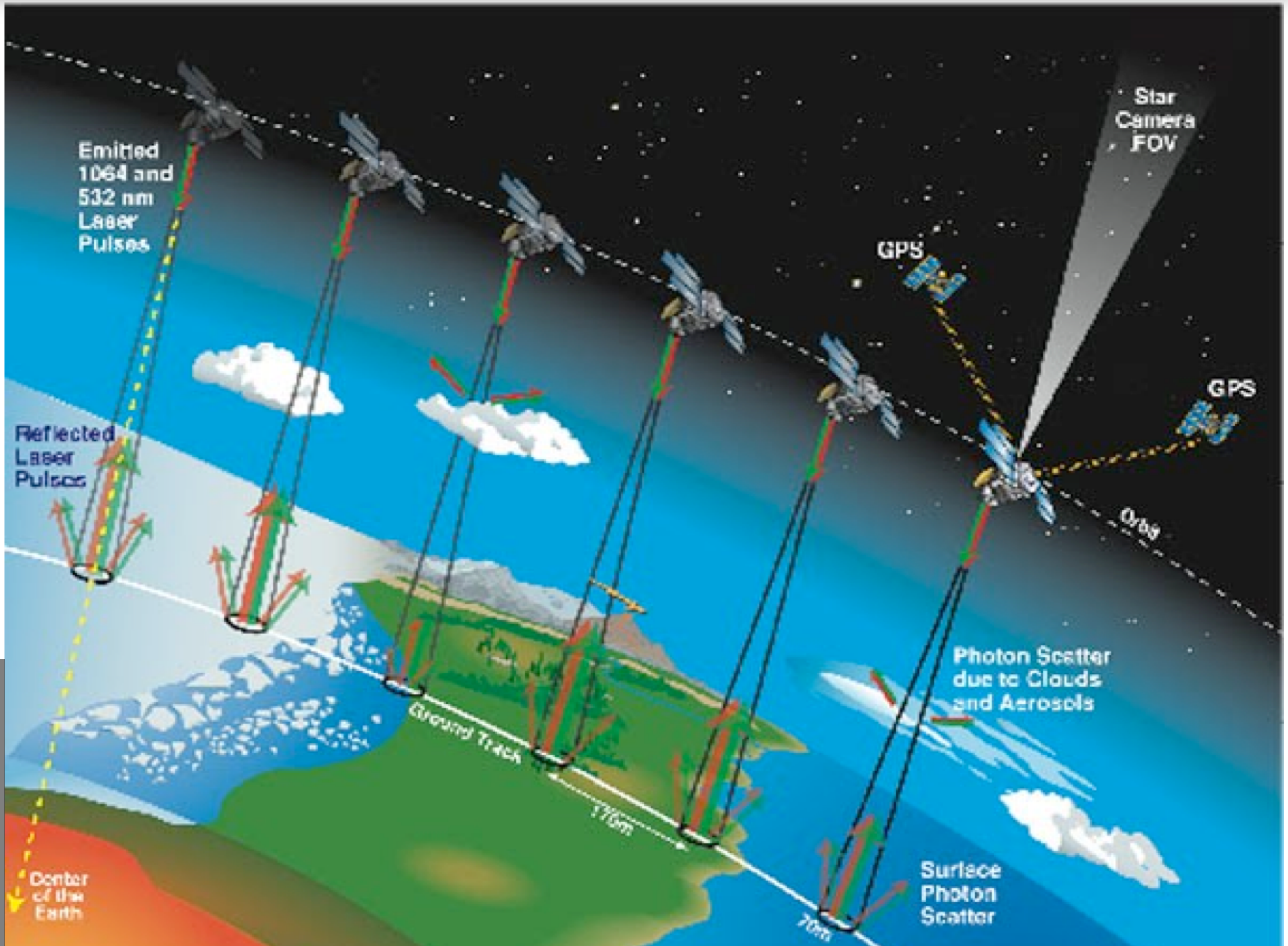
Comparison of mangrove C storage with that of major forest domains (from Donato et al. 2011).

SRTM (Shuttle Radar Topography Mission)



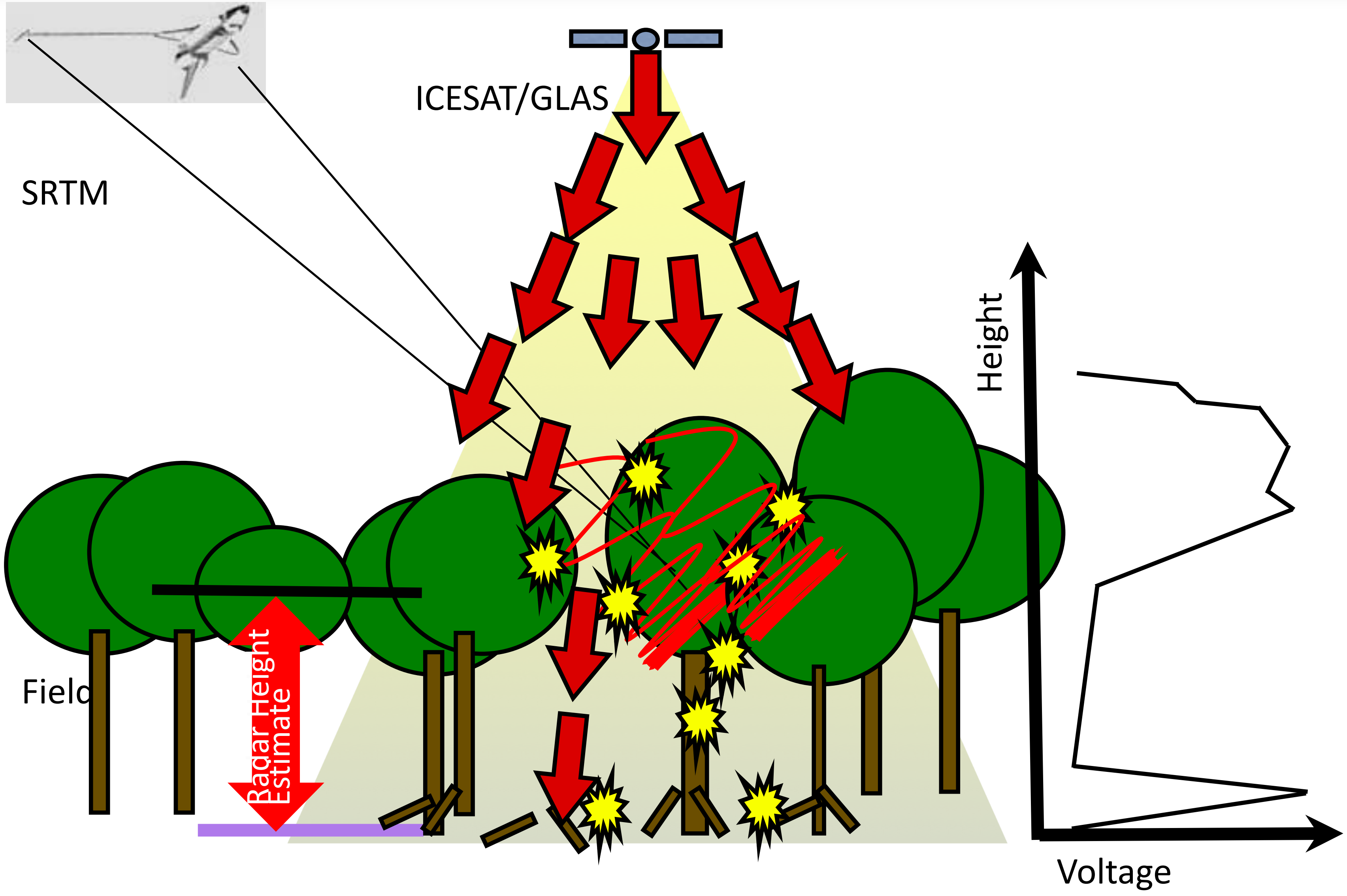
- 11-day mission, February 2000
- Mapped DSM 80% of land surface
- Spatial Sampling (30m)
- Intrinsic resolution ~60m
- New version soon NASADEM

ICESAT/GLAS (Geoscience Laser Altimeter System)



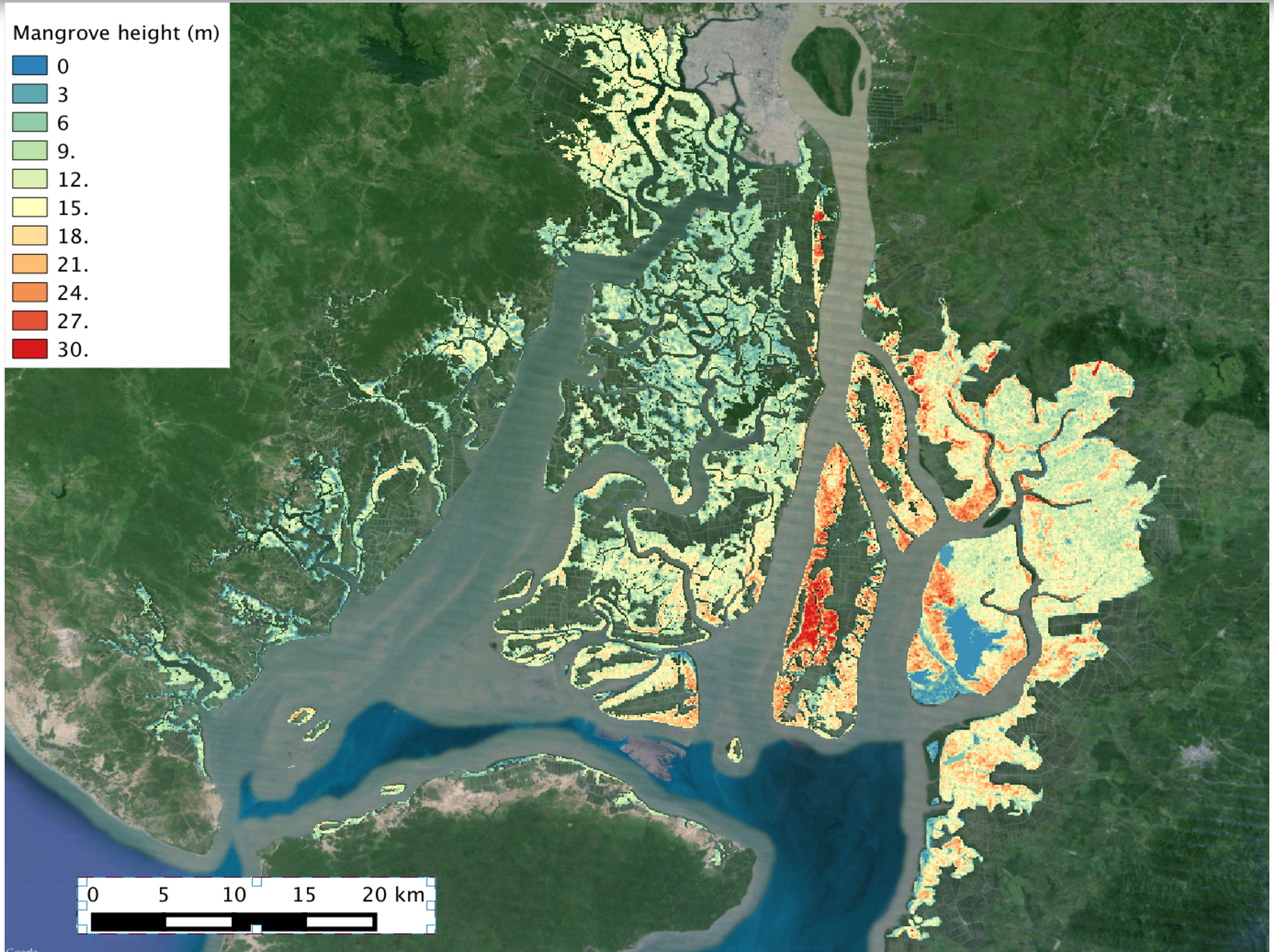
Full waveform recording
-ground elevation and forest structure
Operational period 2003-2009
~2 billion shots
70 m footprints

Mapping Mangrove Canopy Structure



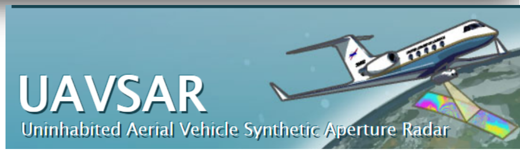
Example: Mangroves of Guayaquil, Ecuador

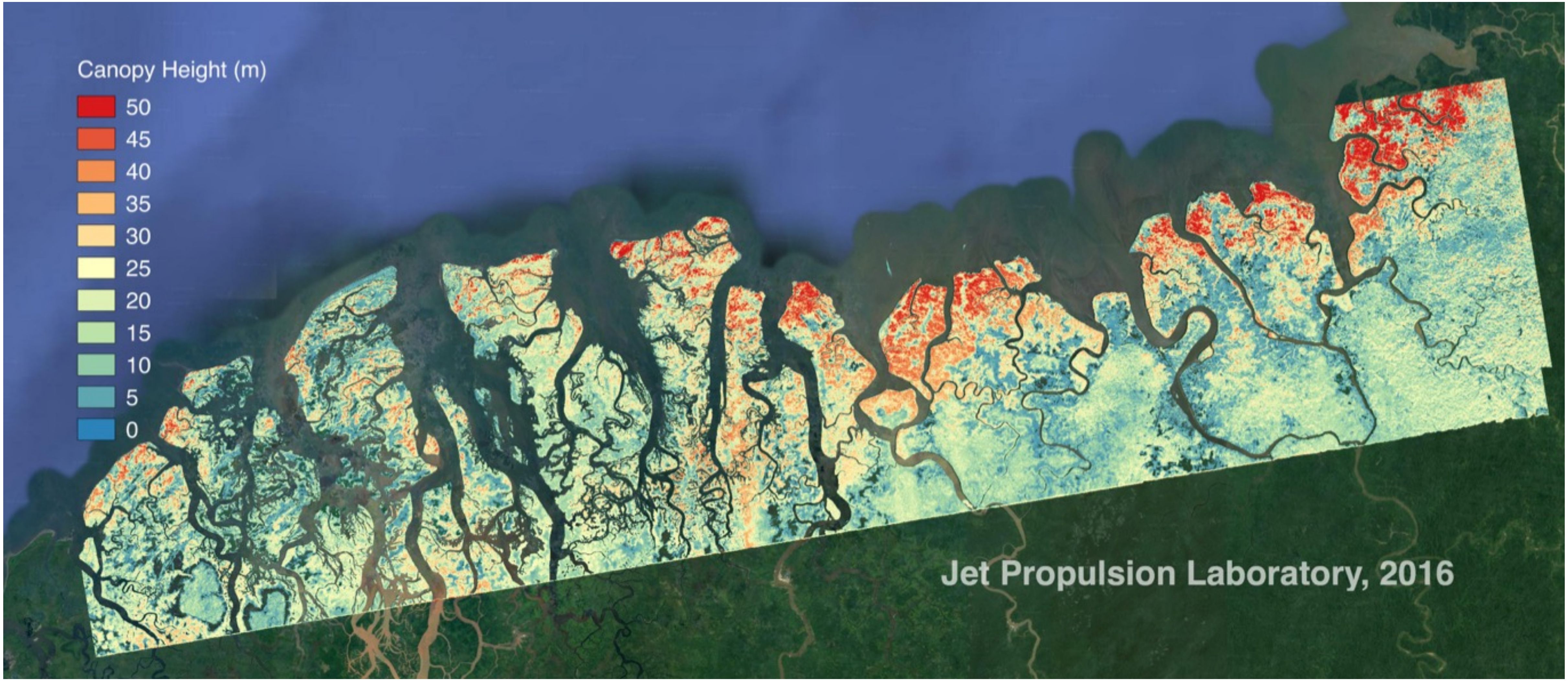
SRTM



Forest Canopy Height derived from UAVSAR (polinSAR)

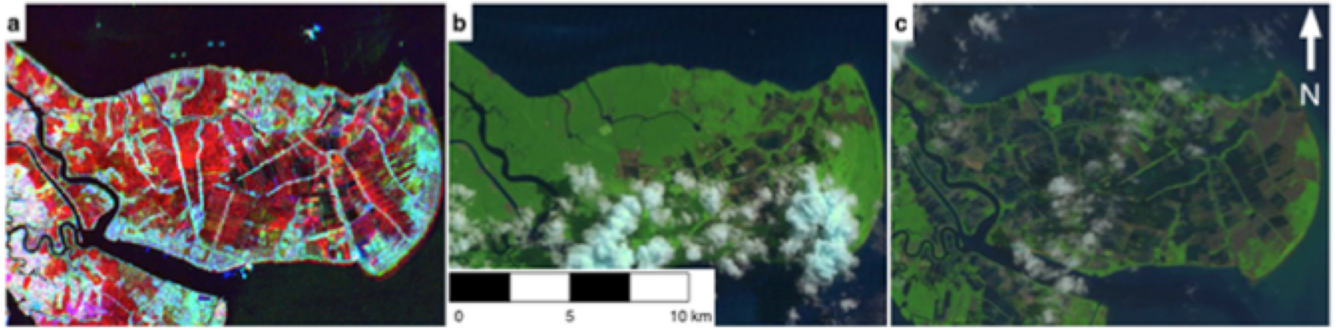
Uninhabited Aerial Vehicle Synthetic Aperture Radar – UAVSAR https://uavsar.jpl.nasa.gov/

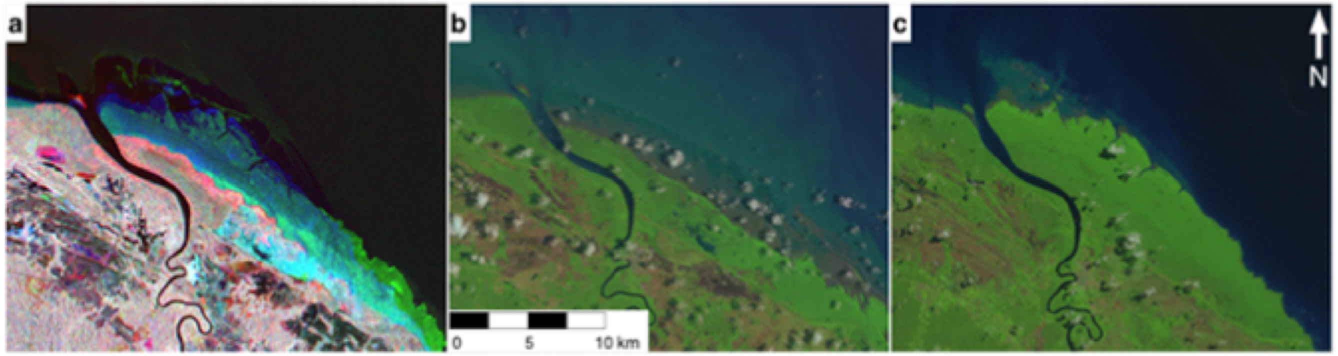


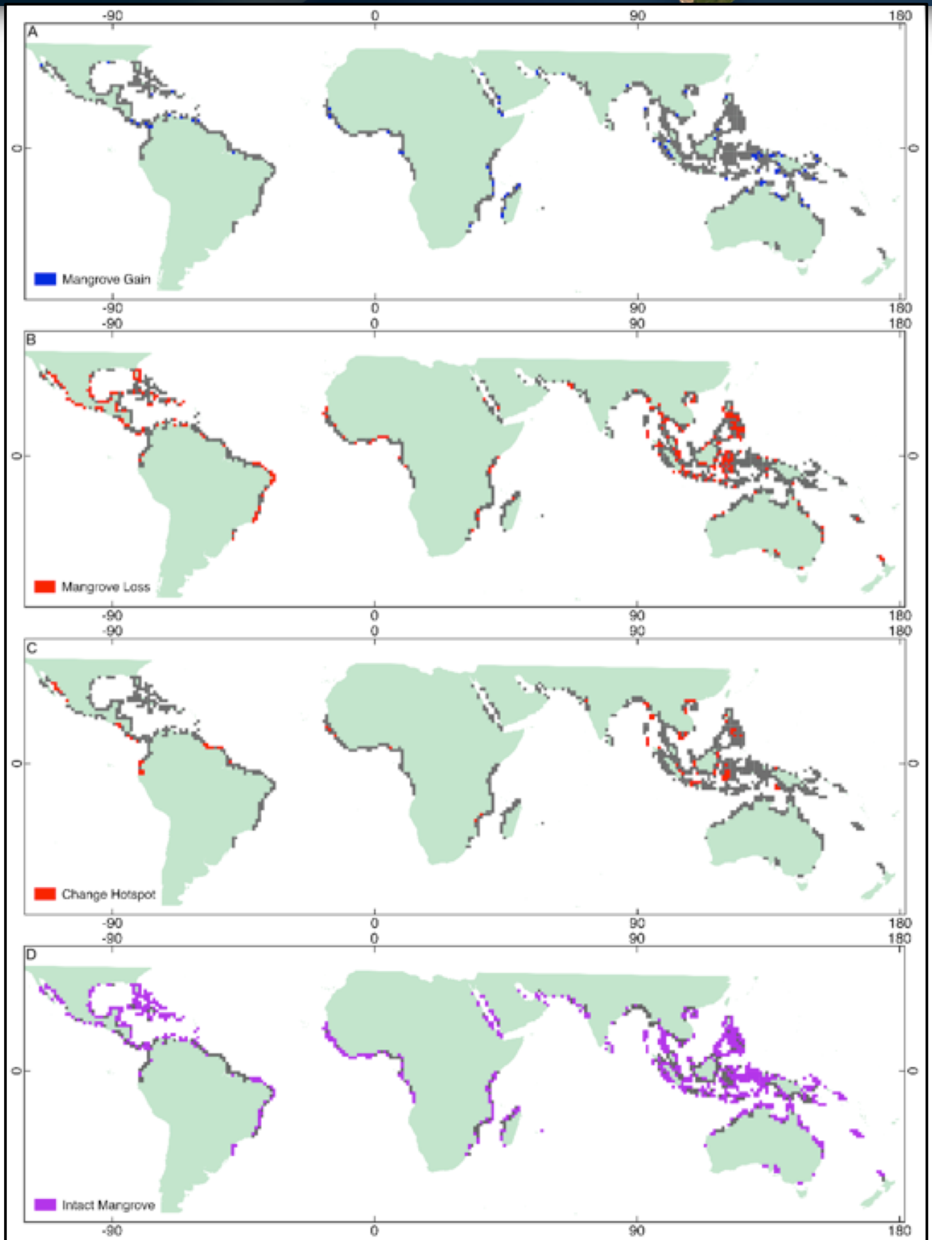


Mapping Change in Mangrove Extent and Identify Proximate Drivers of Changes and Geographical Hotspots.

Distribution and Drivers of Global Mangrove Forest Change, 1996-2010 (Thomas et al., 2017, *PLOS ONE)*

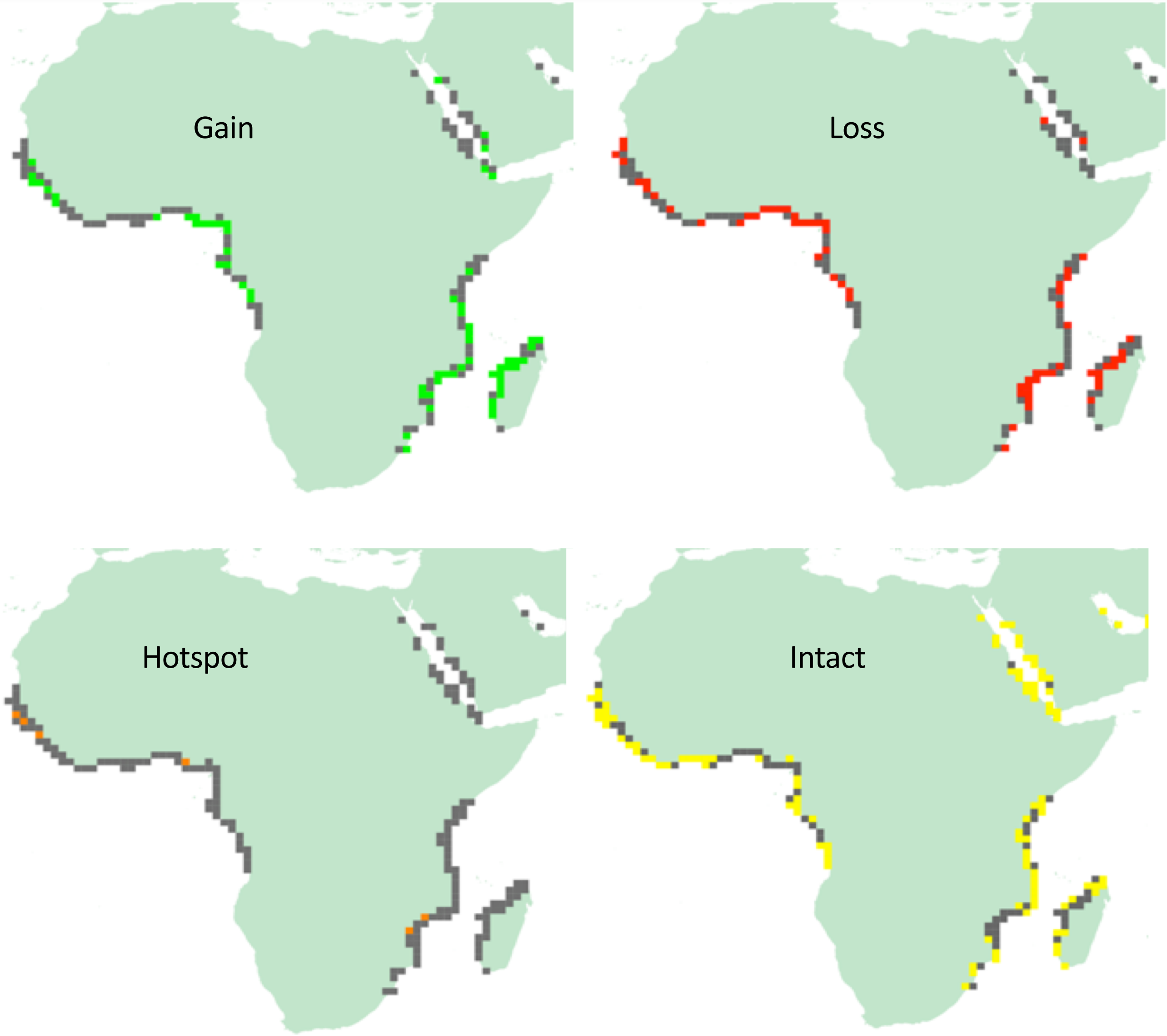






https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179302

Mapping Change in Mangrove Extent and Identify Proximate Drivers of Changes and Geographical Hotspots.



Distribution of different drivers of change in mangrove forest extent

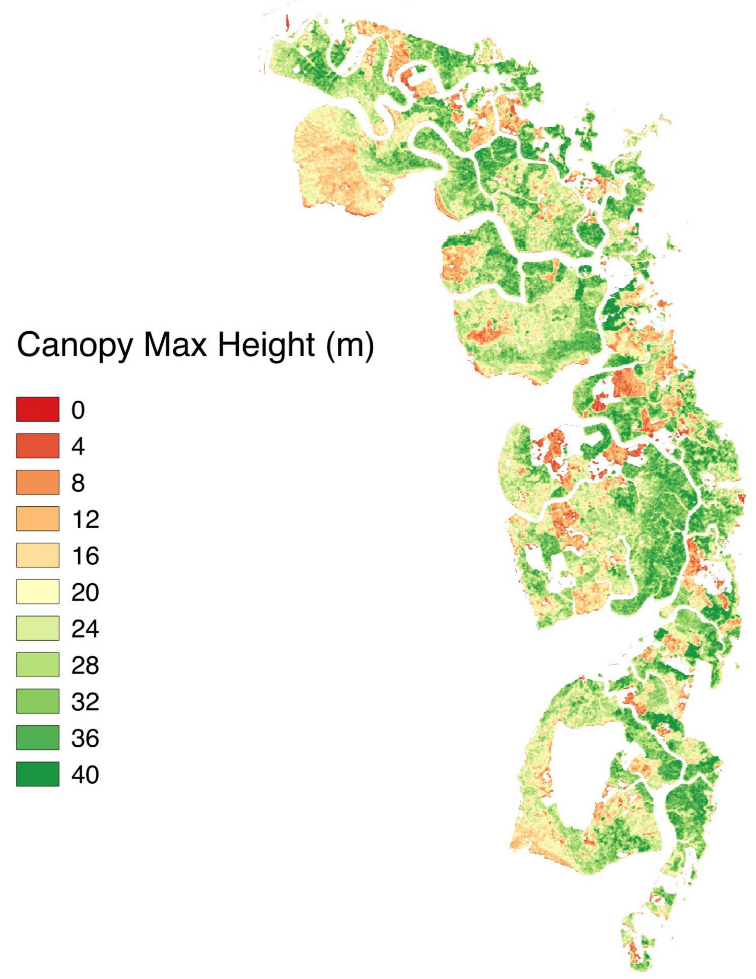
A) Advance and regrowth of mangrove extent (1996-2010)
B) Degradation from anthropogenic drivers of change including evidence of prior disturbance
C) Hotspots where substantial changes in mangrove forest extent were observed (1996-2010)
D) Tiles that contained intact mangrove (1996-2010).

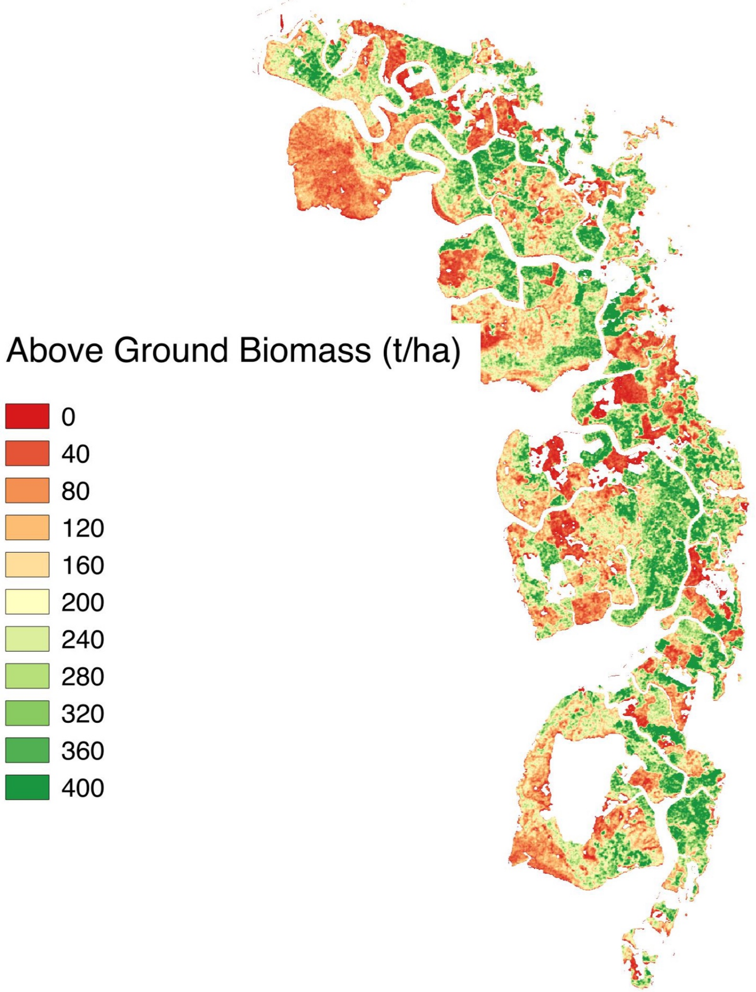
The total distribution of mangrove tiles is provided in gray.

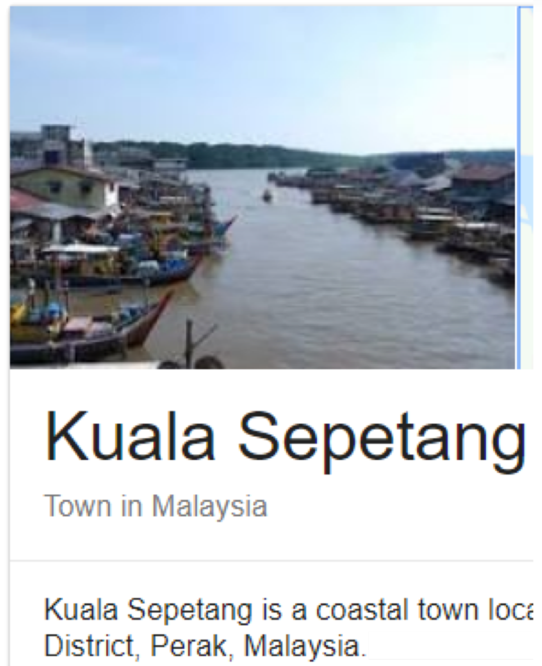
Management of entire watershed is important to the health of mangrove forests.

- Environmental drivers of mangrove structure:
  - precipitation,
  - temperature,
  - availability of nutrients and
  - salinity.

Forest Height (m) and Above Ground Biomass - Kuala Sepetang



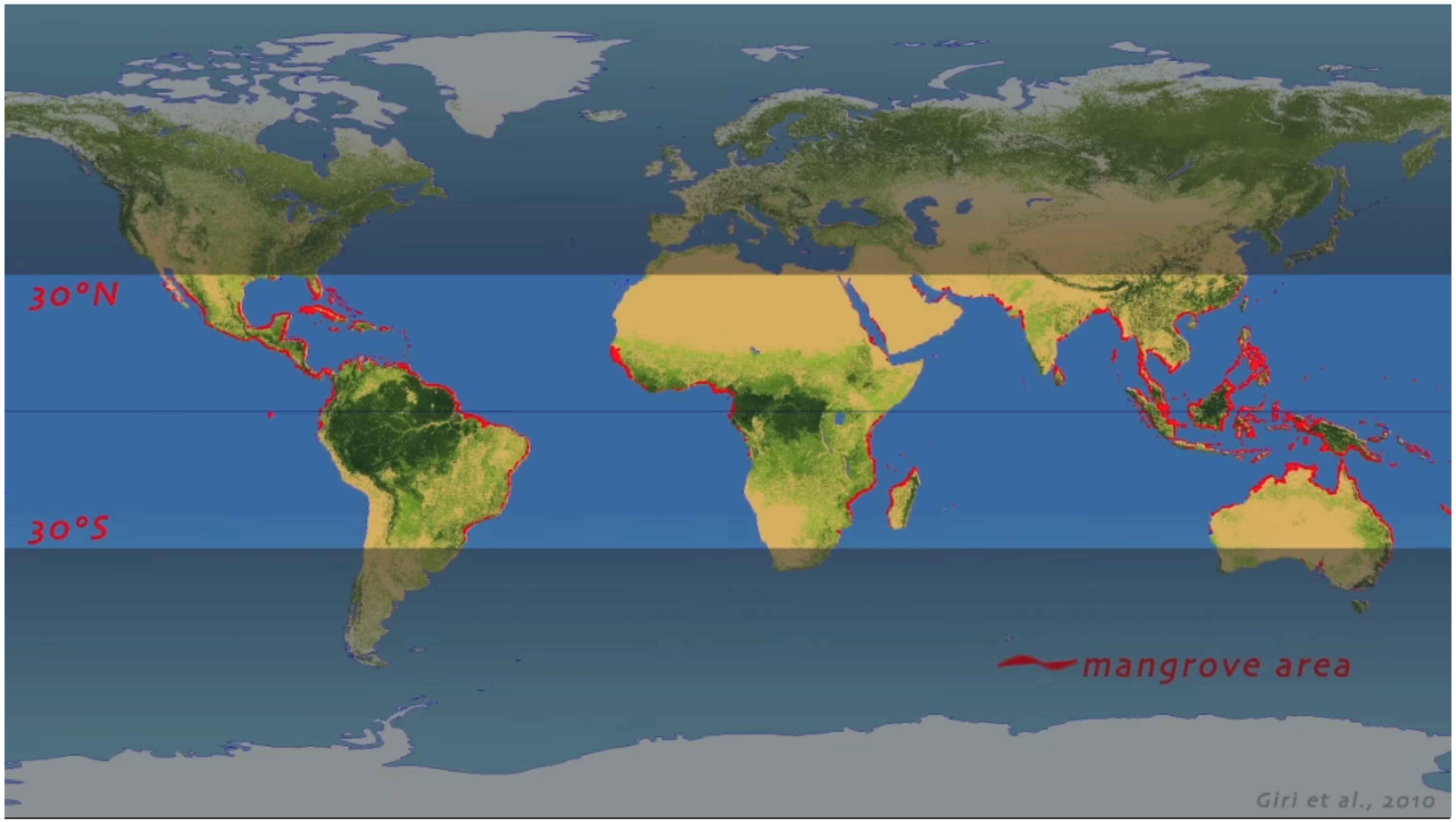




In 2000, there were about 30Mt of above ground biomass in Sepatang.

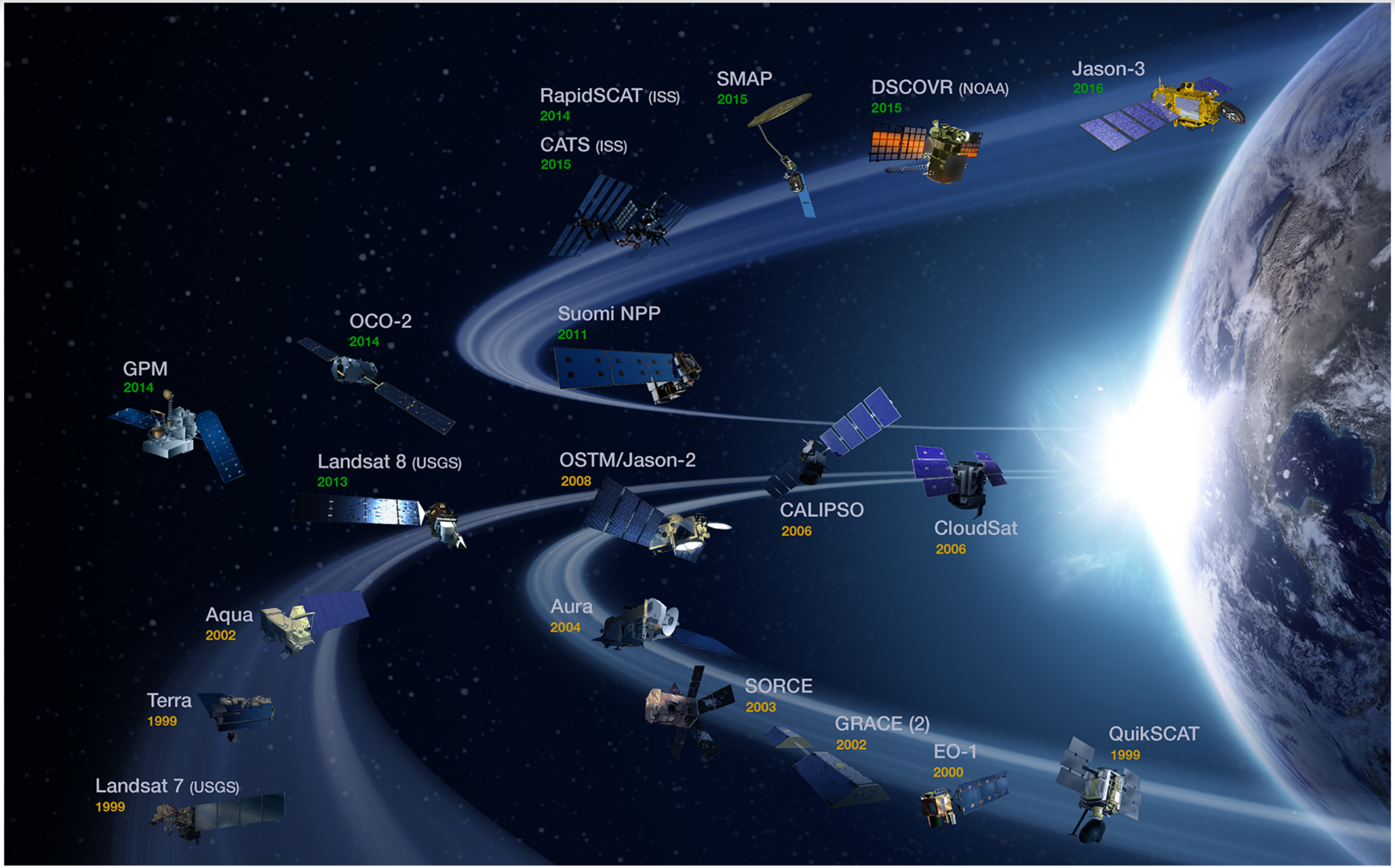
- ❑ Environmental drivers of mangrove structure:
  - precipitation
  - temperature
  - availability of nutrients
  - salinity.

NASA and Mangroves



- Mangroves are coastal ecosystems that provide important services to coastal populations. They offer natural protection against storm surges, hurricanes and tsunamis. Mangroves also contribute to fish stocks by providing nursing grounds for fish and crustaceans. https://www.youtube.com/watch?v=RjSTKItUUX0

NASA Earth Observing Satellites

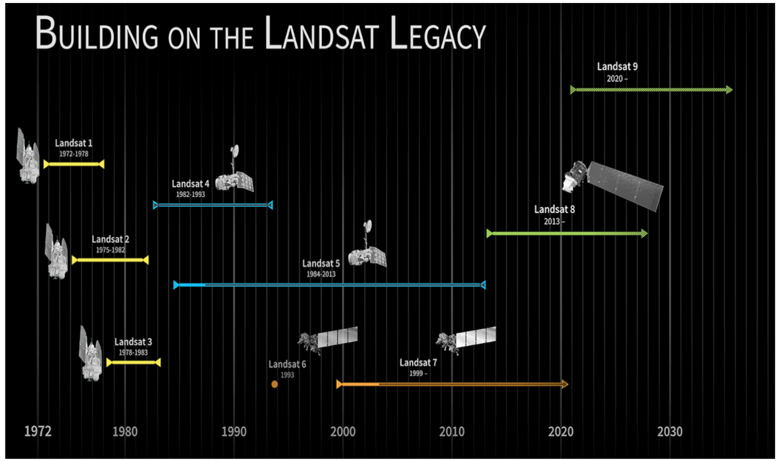


NASA's Earth Observing System is a coordinated series of polar-orbiting satellites that monitor the land surface, biosphere, solid Earth, atmosphere, and oceans for long-term global observations.

We will focus on the satellites that provide information on the Earth's biosphere.

Upcoming NASA Missions

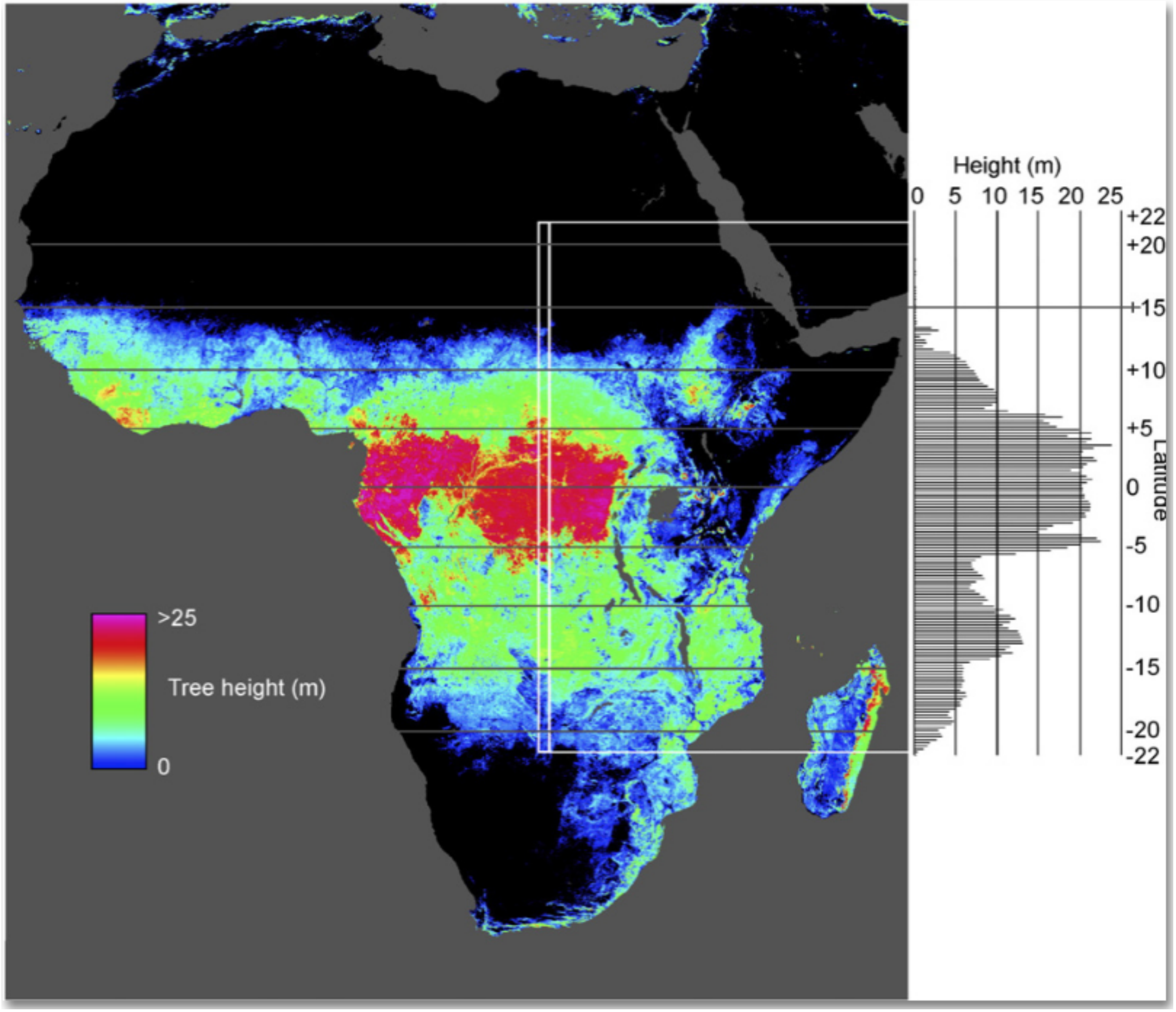
Global Ecosystem Dynamics Investigation LIDAR (GEDI)
https://gedi.umd.edu/



NASA Missions - Global Ecosystem Dynamics Investigation LIDAR (GEDI)

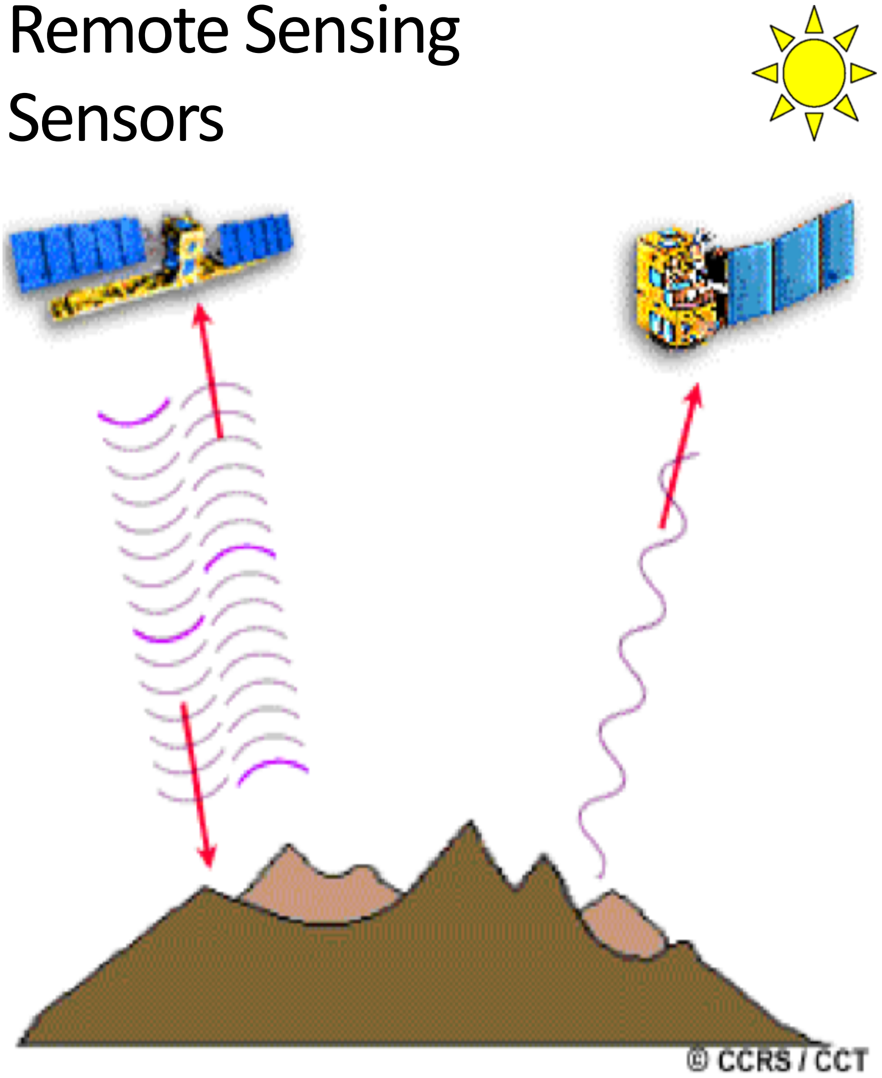
Enhanced Height/Biomass Using Fusion With Landsat

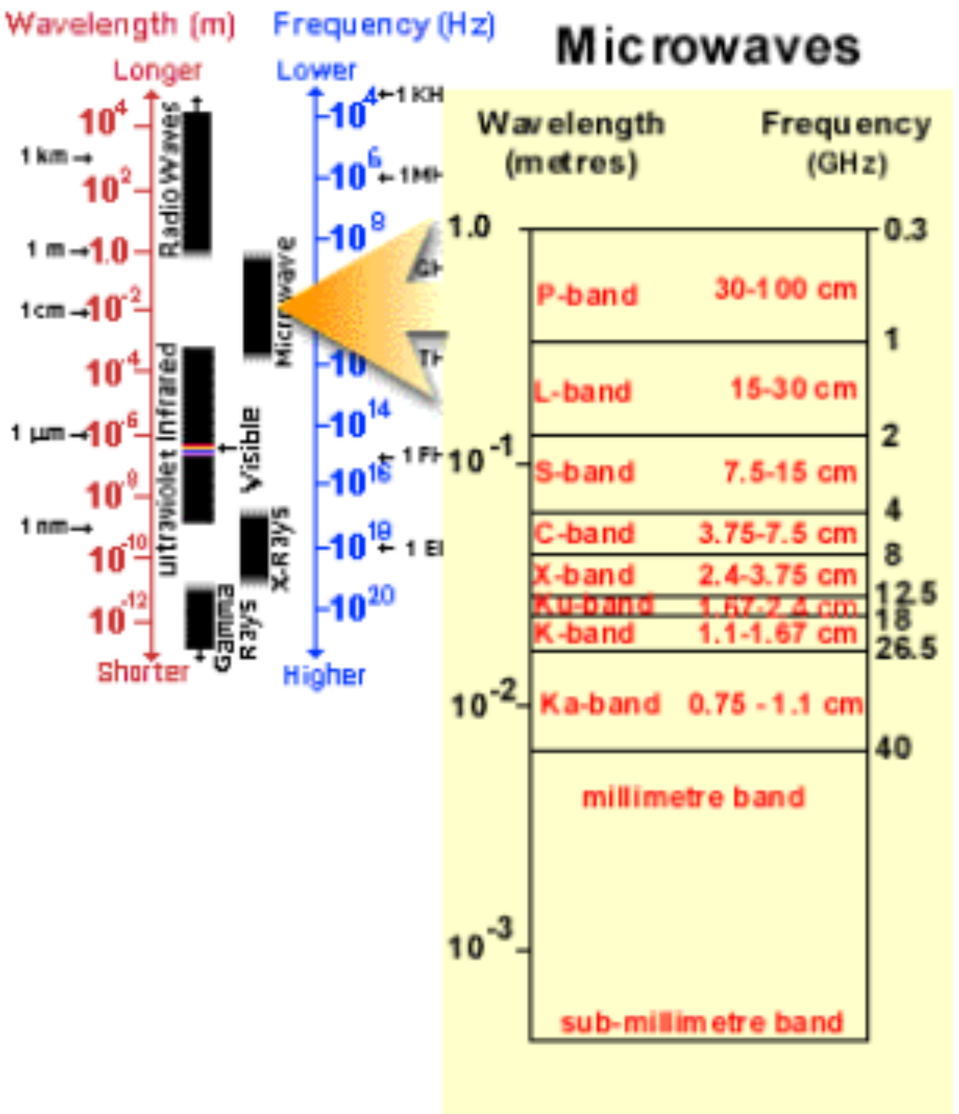
https://gedi.umd.edu/



ATBD #	Data products	Product leads	Resolution
L1A-2A	1A: Raw waveforms, 2A: Ground elevation, canopy top height, relative height (RH) metrics	Michelle Hofton Bryan Blair	25 m (~82 ft) diameter
L1B	Geolocated waveforms	Scott Luthcke Tim Rebold Taylor Thomas Teresa Pennington	25 m (~82 ft) diameter
L2B	Canopy Cover Fraction (CCF), CCF profile, Leaf Area Index (LAI), LAI profile	Hao Tang John Armston	25 m (~82 ft) diameter
L3	Gridded Level 2 metrics	Scott Luthcke Terence Sabaka Sandra Preaux	25 m (~82 ft) diameter
L4A	Footprint level above ground biomass	Jim Kellner Laura Duncanson John Armston	25 m (~82 ft) diameter
L4B	Gridded Above Ground Biomass Density (AGBD)	Sean Healey Paul Patterson	1 km (~0.6 mi) grid
Demonstrative products	Prognostic ecosystem model outputs	George Hurtt	Grid size: Variable
Demonstrative products	Enhanced height/biomass using fusion with TanDEM-X	Lola Fatoyinbo Seung-Kuk Lee	Grid size: Variable
Demonstrative products	Enhanced height/biomass and biomass change using fusion with Landsat	Matt Hansen Chenquan Huang	Grid size: Variable
Demonstrative products	Biodiversity/habitat model outputs	Scott Goetz Patrick Jantz Pat Burns	Grid size: Variable

Remote Sensing Sensors





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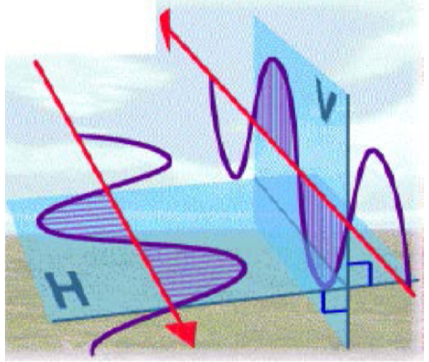
Radar frequencies and wavelength range used for remote sensing of land surfaces

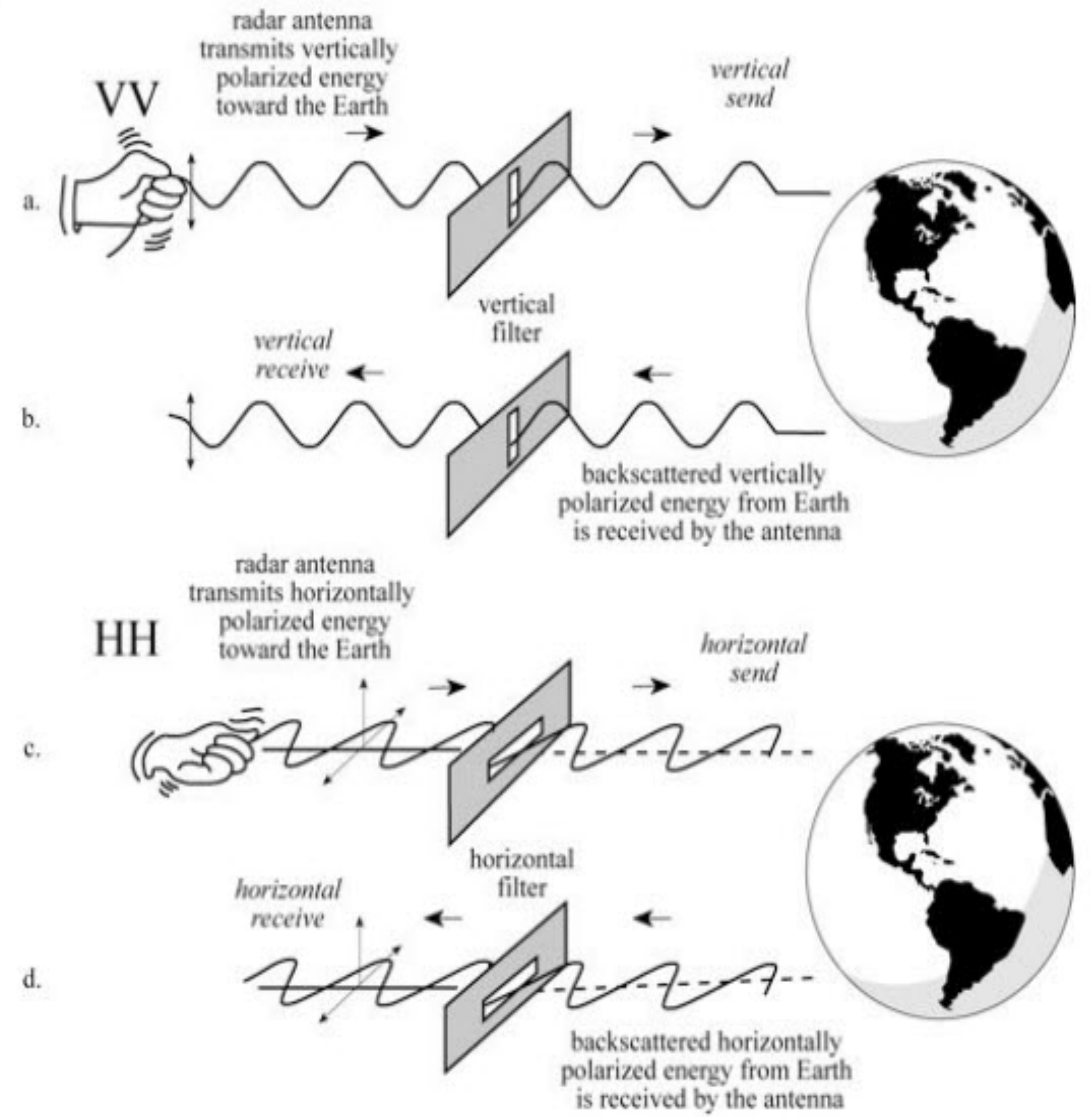
Radar Band	Wavelengths	Frequency band	Typical use
P	0.60cm to 1.2m	250-500 MHz	Biomass
L	15-30 cm	1-2 GHz	Biomass, soil moisture and ground deformation
S	8-15 cm	2-4 GHz	Agriculture monitoring
C	4-8 cm	4-8 GHz	Ice, ocean, maritime navigation
X	2.5-4	8-12 GHz	Ice and snow
Ku-Ka	1.7-2.5 cm and 0.75-1.2 cm	12-18 GHz and 27-40 GHz	Ice and snow, sea surface winds

Synthetic Aperture Radar (SAR) - Polarization

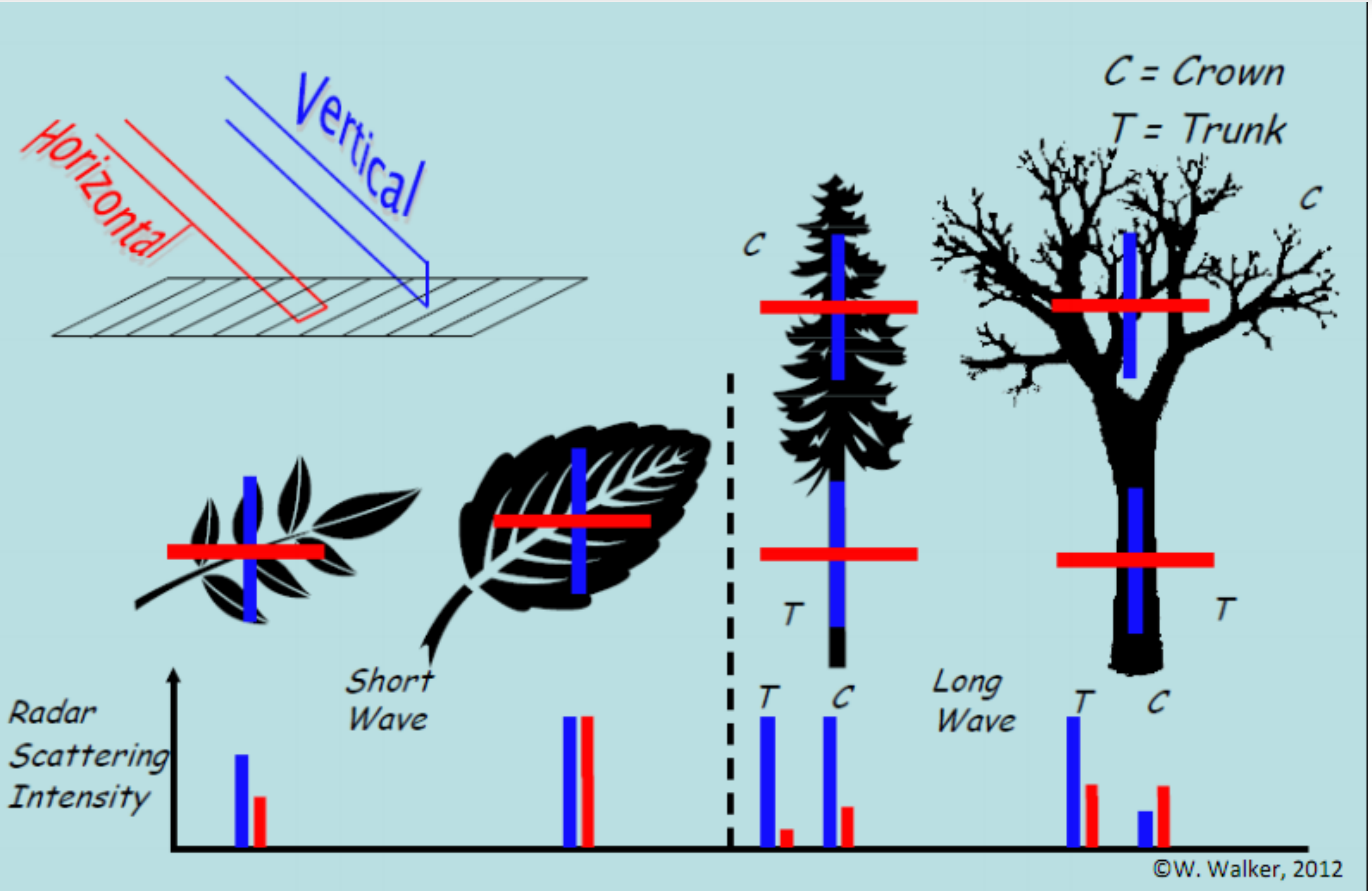
Polarization

Irrespective of wavelength, radar signals can transmit horizontal (H) or vertical (V) electric- field vectors, and receive either horizontal (H) or vertical (V) return signals, or both. The basic physical processes responsible for the like-polarised (HH or VV) return are quasi-specular surface reflection. For instance, calm water (i.e. without waves) appears black. The cross- polarised (HV or VH) return is usually weaker, and often associated with different reflections due to, for instance, surface roughness.

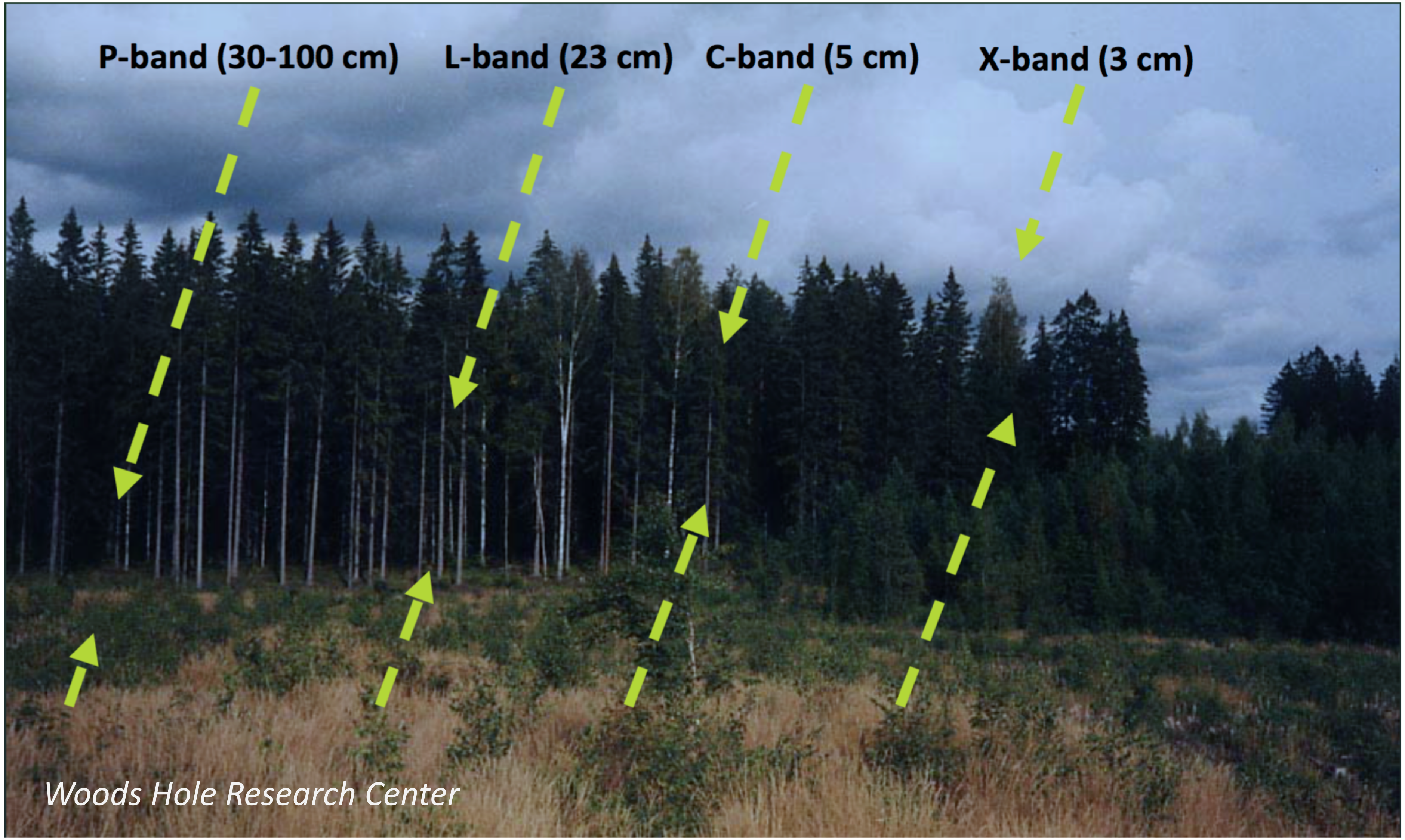




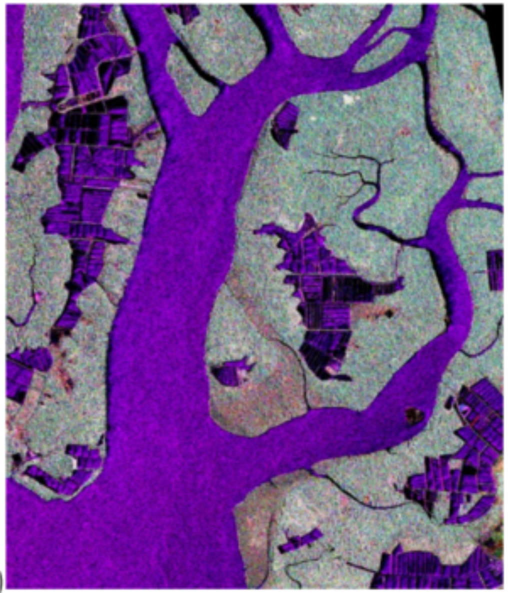
HH - for horizontal transmit and horizontal receive,
VV - for vertical transmit and vertical receive,
HV - for horizontal transmit and vertical receive,
VH - for vertical transmit and horizontal receive.

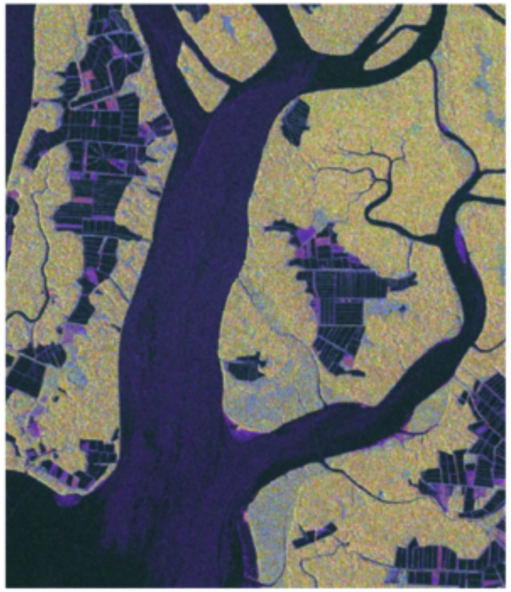

Horizontal
Vertical
C = Crown
T = Trunk
C
C
T
T
Radar
Scattering
Intensity
Short
Wave
T
C
Long
Wave
T
C
©W. Walker, 2012

Radar Wavelength Interaction with Vegetation



Radar Wavelength Interaction with Vegetation

a)


b)


c)


Figure: Color composite images of mangrove forests of the Guayas Estuary in Ecuador:
a) ALOS-PALSAR-1 HH, HV and VV in RGB respectively, and
b) Sentinel-1 VV, VH, VV in RGB respectively.
Volume scattering dominate at all polarization and at both L- and C-band.
Lower backscatter is observed for younger low density forest (<100t/ha) found along the coast at the bottom of the images.

c) A color composite (HH, HV, VV) of a 6m resolution L-band airborne (from UAVSAR) image show the distinct signature of mangrove forest whether tall (East) or short shrub forest (West).

Green indicates the dominance over HV in inland forest is more significant than in mangrove forest where all polarization configurations (HH, HV and VV)

Tea Break..!

Sources of Radar Remote Sensing Data

The Timeline of Past, Current, and Future SAR Sensors

Strait of Singapore – TerraSAR-X StripMap – © Astrium Services / Infoterra GmbH

Sources of Radar Remote Sensing Data

Platform/Instrument	Band	Where to get the data
JERS-1	L-band	http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
ALOS-1/PALSAR	L-band	http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
ALOS-2/PALSAR	L-band	http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
Sentinel-1A	C-band	https://scihub.copernicus.eu/dhus/#/home
Sentinel-1B	C-band	https://scihub.copernicus.eu/dhus/#/home
NASA's SRTM (NASADEM in 2019)	C-band DEM and	https://earthexplorer.usgs.gov/ or https://search.earthdata.nasa.gov/search?q=SRTMGL1%20V003
DLR's SRTM	X-band DEM	https://centaurus.caf.dlr.de:8443/eoweb-ng/template/default/welcome/entryPage.vm
TanDEM-X	X-band DEM (from TerraSAR-X)	https://centaurus.caf.dlr.de:8443/eoweb-ng/template/default/welcome/entryPage.vm (as of June 2018, not yet freely available)

Exercise – SNAP, QGIS

- Install SNAP
- Install QGIS
- Explore data sources:
  - ❑ALOS Mosaics - http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
  - ❑ALOS - https://vertex.daac.asf.alaska.edu/
  - ❑Sentinel 1 - https://scihub.copernicus.eu/dhus/#/home

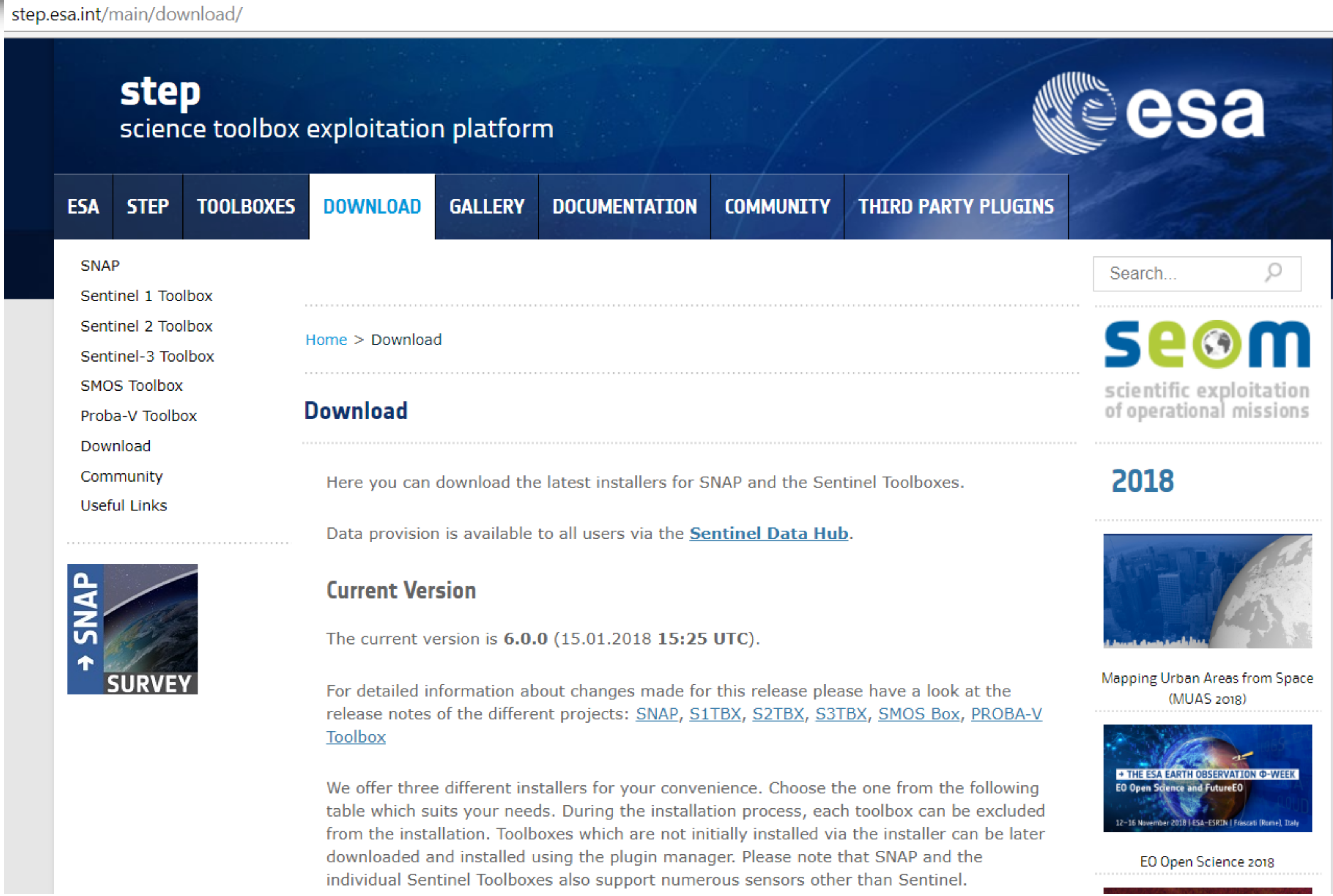
SNAP

SNAP bundles all ESA tools for the processing of Sentinel data (both SAR and optical)

Free and Open source

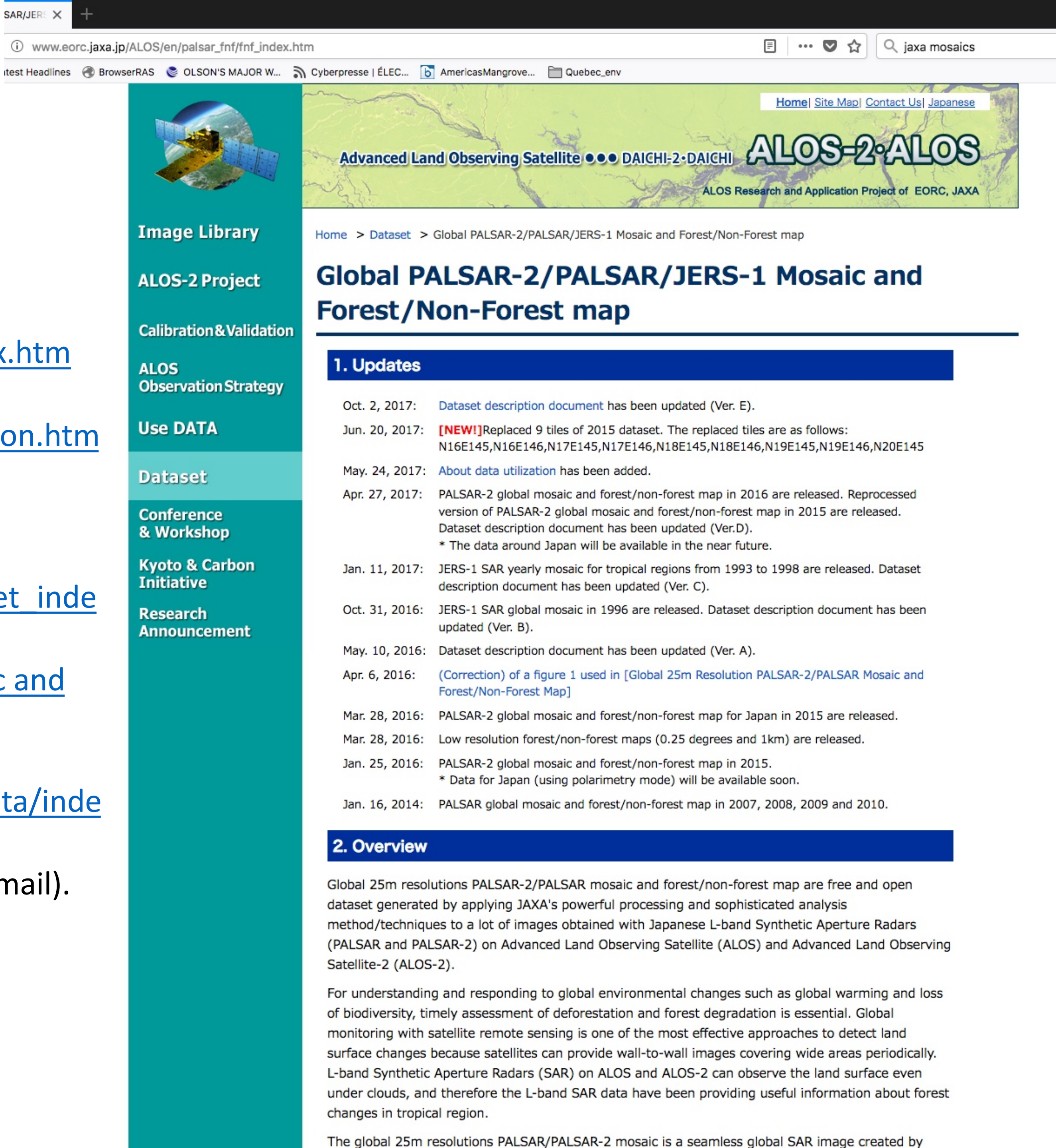
Download SNAP

SNAP=Sentinel Application Platform
http://step.esa.int/main/download/
Read info:
http://step.esa.int/main/toolboxes/snap/, STEP: http://step.esa.int/main/



Download Data

1. Click here:
   - http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
2. Scroll down to #4 “Download” and register:
   - http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/registration.htm
3. Follow instruction including confirming your email.
4. Once registered:
   1. Click on Dataset on the left hand side:
      - http://www.eorc.jaxa.jp/ALOS/en/dataset/dataset_index.htm
      - Click on “Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map”
      - Scroll down to “4.Download” and click on “http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/data/index.htm”
      - Enter username (email) and password (sent by email).



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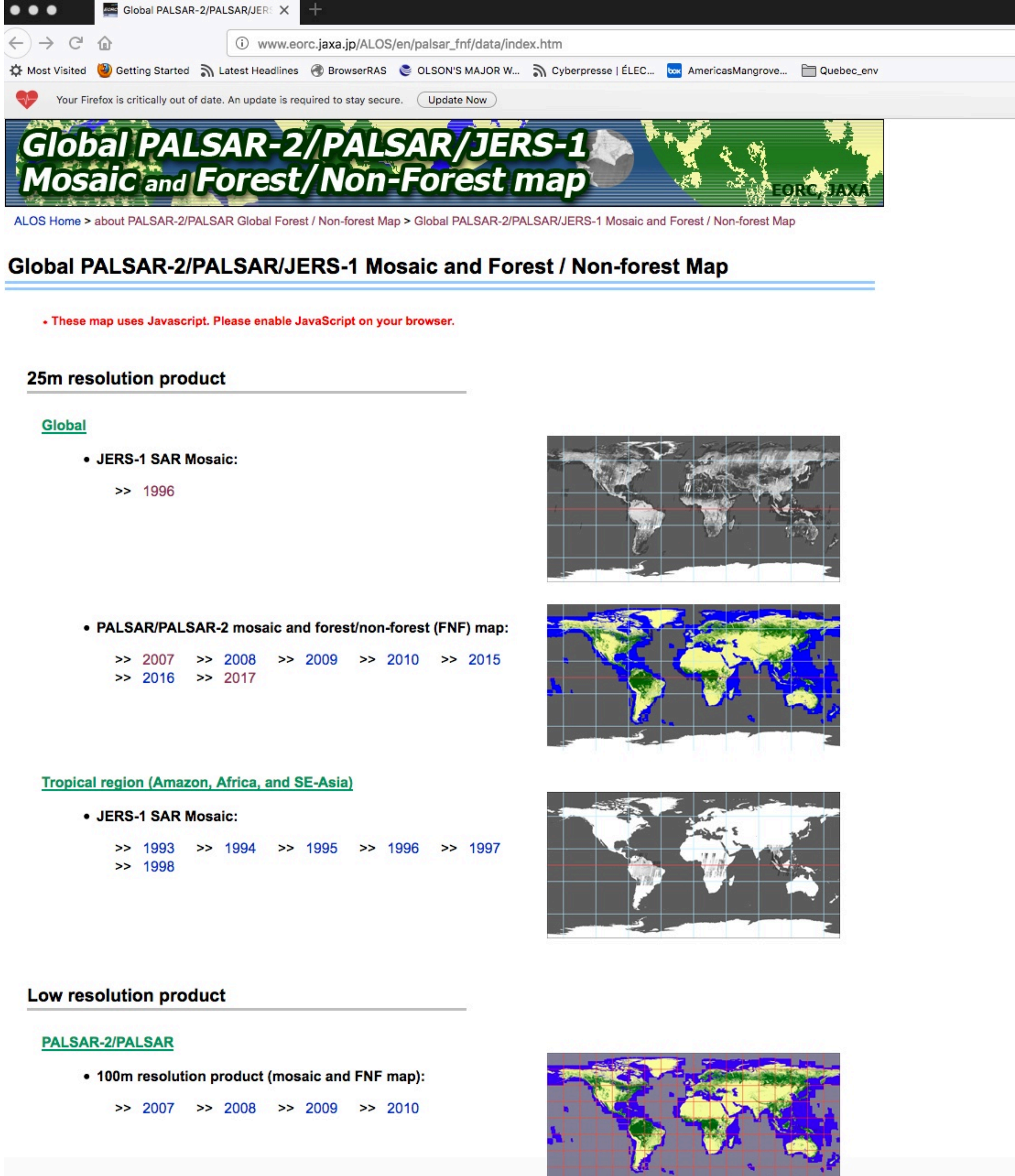
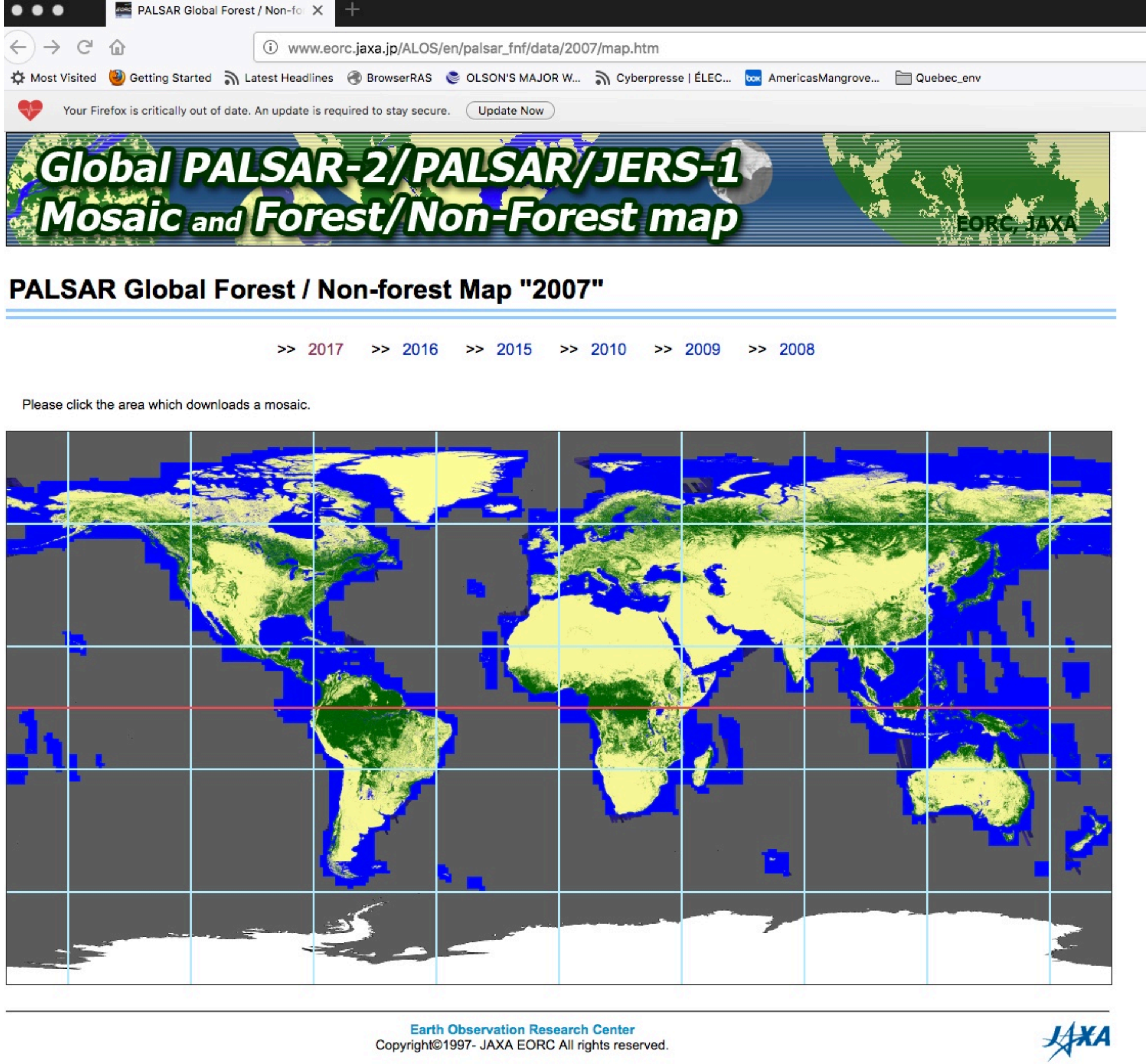
Jaxa Mosaics

- JERS-1 is a L-band HH-only instrument. Global mosaic only available for 1996
- For PALSAR, JAXA plans on generating yearly mosaics.
  - PALSAR mosaics are available for 2007, 2008, 2009 and 2010
  - PALSAR-2 mosaics are available for 2015, 2016, 2017 and soon 2018.
- Click on PALSAR 2007 for example.



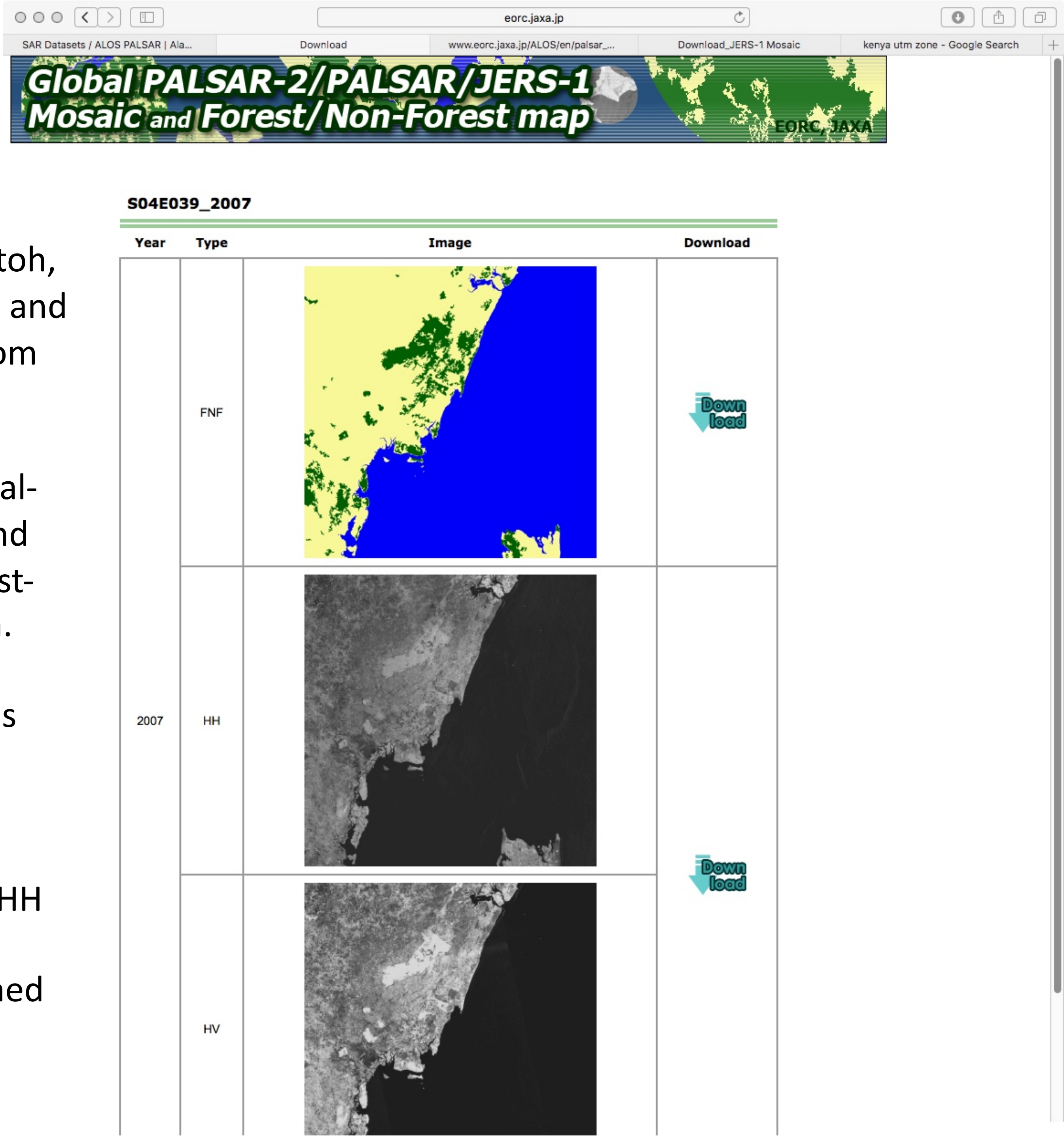
Example:
ALOS/PALSAR-1 Mosaic 2007

- Click on your favorite region.
- Example in this workshop: Kenya’s coast
- Click until you end-up at the desired location.
- Note all mosaic grid-cells are 1ºx1º.



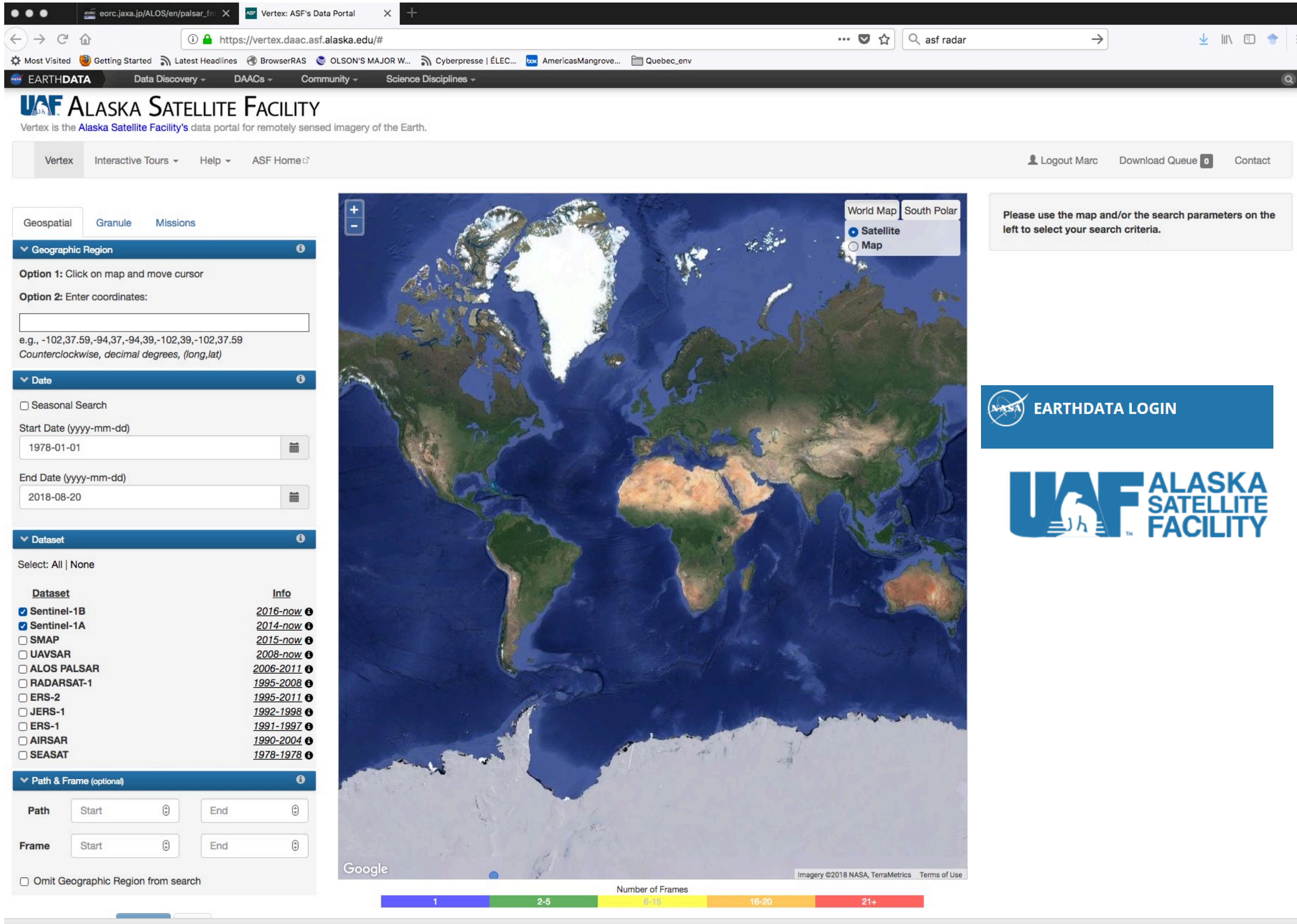
Download 1 degree cell.

- For PALSAR-1 and PALSAR-2, there are 3 mosaics:
  - FNF=Forest vs Non-Forest map (M. Shimada, T. Itoh, T. Motooka, M. Watanabe, T. Shiraishi, R. **Thapa**, and R. Lucas, “New global forest/non-forest maps from ALOS PALSAR data (2007-2010),” *Remote Sens. Environ.*, vol. 155, pp. 13–31, 2014.)
  - HH. Mosaic of Horizontal-transmit and Horizontal-receive polarization. Sensitive to both volume and surface. Excellent for monitoring wetlands, forest-inundations, urban infrastructure and expansion.
  - HV. Mosaic of Horizontal-transmit and Vertical-receive polarization. Sensitive to volumes such as vegetation density. Excellent to distinguish and monitor forests.
- Download file by cliking on “DownLoad”. The file will automatically download to computer (zipped file for HH and HV is about 65MB)
- Unzip files. They are in ENVI format that can be opened in ENVI or QGIS. You can also use gdal_translate to convert in any format.



Download raw ALOS/PALSAR-1 data

- Go to the Aalska Satellite Facility Vertex interface: https://vertex.daac.asf.alaska.edu/
- Click on “Geographic Search”
- Follow interactive instructions steps.
- Then click on top right “Earthdata Login” to register (free)
  - Follow instructions and email receipt
- Go back to:
  - https://vertex.daac.asf.alaska.edu/
  - Log in.
- Use mouse cursor to top left corner of your favorite site, click and take cursor to the bottom right corner of your site, and click again. A box will be drawn on your site. These coordinates will be written automatically in the “Geographic Region” tab.
- Enter range of dates for which you seek data.
  - For PALSAR-1, it should include dates between 2007 and 2010.
- The “Path” and “Frame” are optional.
- Click “Search” at the bottom.



SERVIR

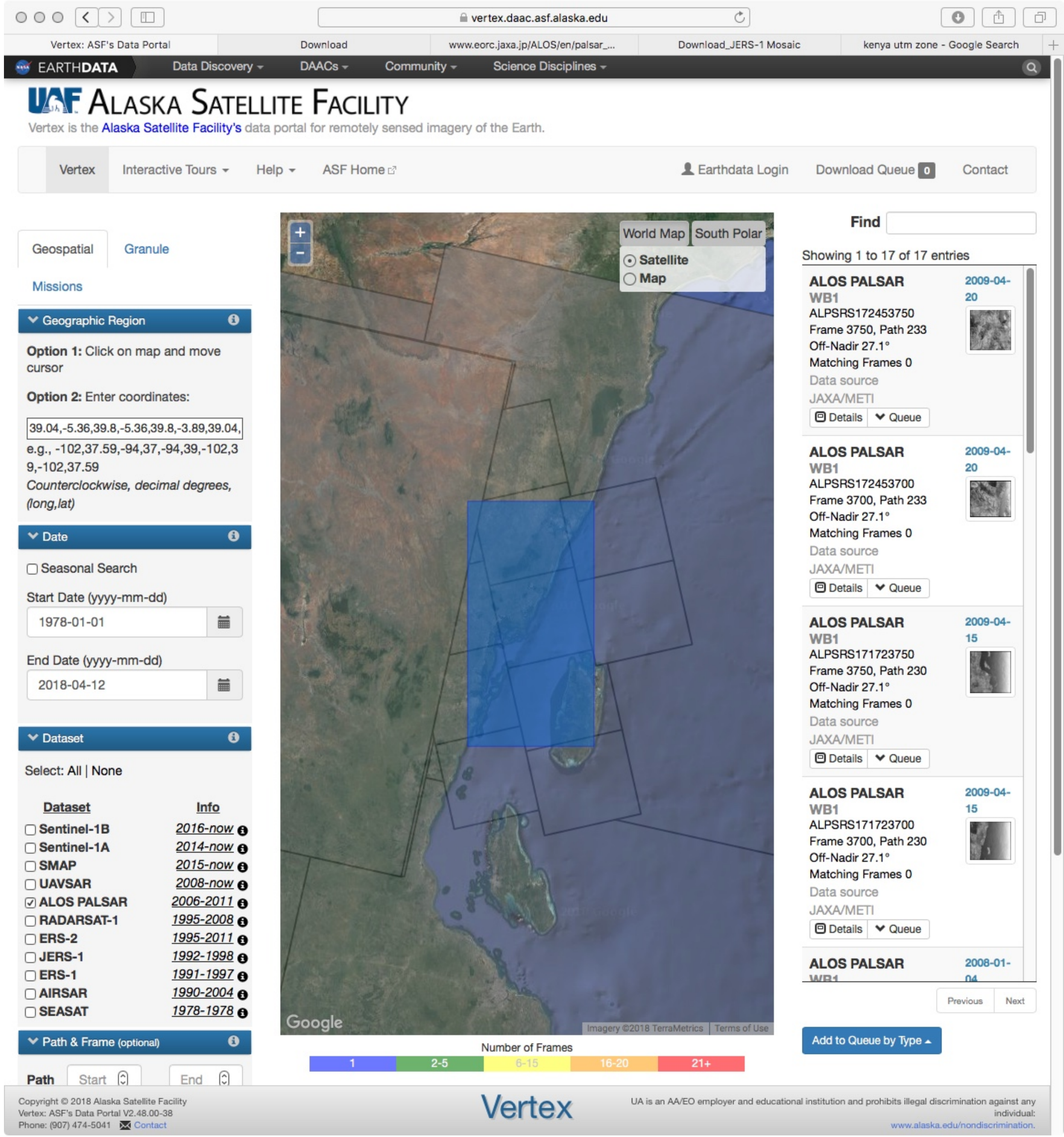
SERVIR

Select data

1. A list of files will appear on the right with browse images (i.e. low-resolution thumbnail)
2. Files with different imaging modes will be available.
   1. “WB1” is (ScanSAR) Wide-Beam #1,
   2. PLR is fully polarimetric dataset with HH, HV and VV
   3. FBD is Fine-Beam Dual polarization including HH and HV.
   4. FBS is Fine-Beam Single polarization (HH).
3. In our example, high resolution ascending-orbit images are available, along with WB1 descending-orbit images. Ascending and descending mean the targets are seen from the West and East respectively.

	WB	FBD	FBS	PLR
Swath	240km	70km	70km	30km
Resolution	100m	20m	10m	30m
Incidence angle	18-43° (27.1)	34.3°	34.3°	21.5°

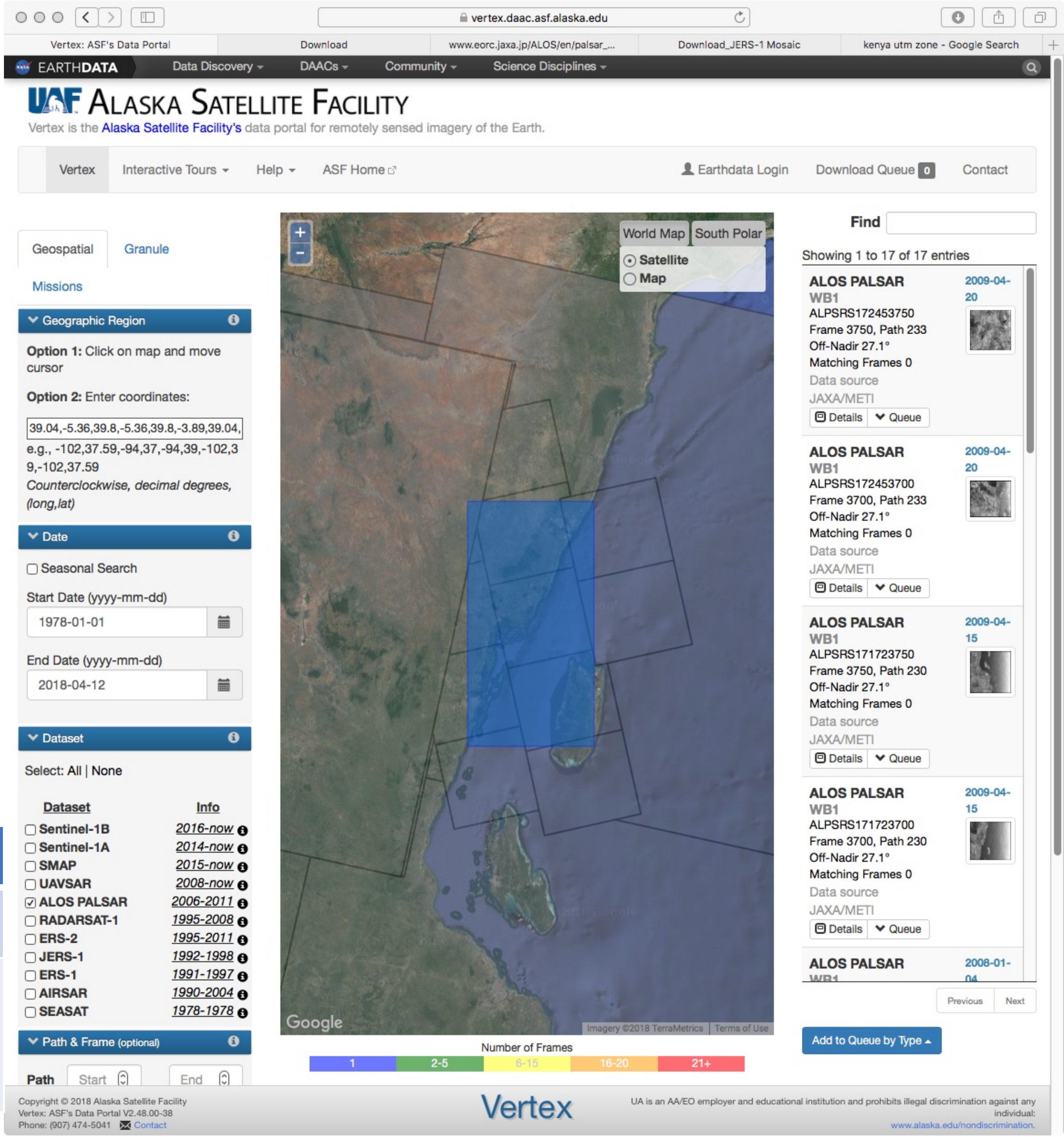
Hint: Long 39.182111, lat -5.0220668
Path: 233, Frame: 3750



Select data

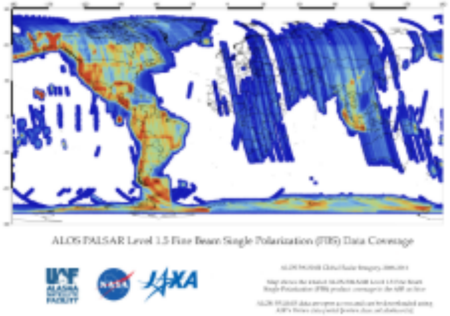
- Click on “Details” if you want information on available images
- Click on “Queue” to add them to the queue for download:
  - A drop down menu will appear with a choice of Level 1.0, 1.1, 1.5, or radiometrically terrain-corrected (RTC). This choice depends on mode. Try it out.

	1.0	1.1	1.5	RTC
Geographic projection	Radar (SLC)	Radar (SLC)	Geographic	geographic
Radiometric format	Single look pixel	Equally spaced single look pixel in radar coordinates	Multilook and calibrated but with topographic features. Data equally spaced on ground.	Science-ready

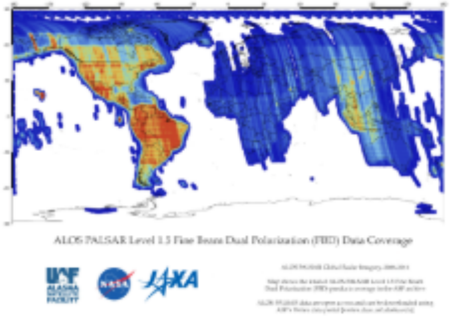


Data coverage by processing level

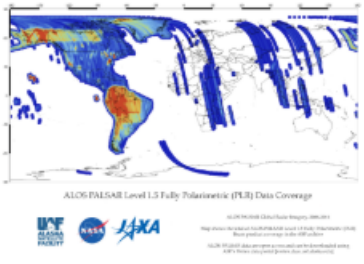
- To see if a given processing level is available at your site, click on https://www.asf.alaska.edu/sar-data/palsar/alos-acquisition-maps/



ALOS L1.5 FBS Coverage Map



ALOS L1.5 FBD Coverage Map



ALOS L1.5 Polarimetric Coverage Map

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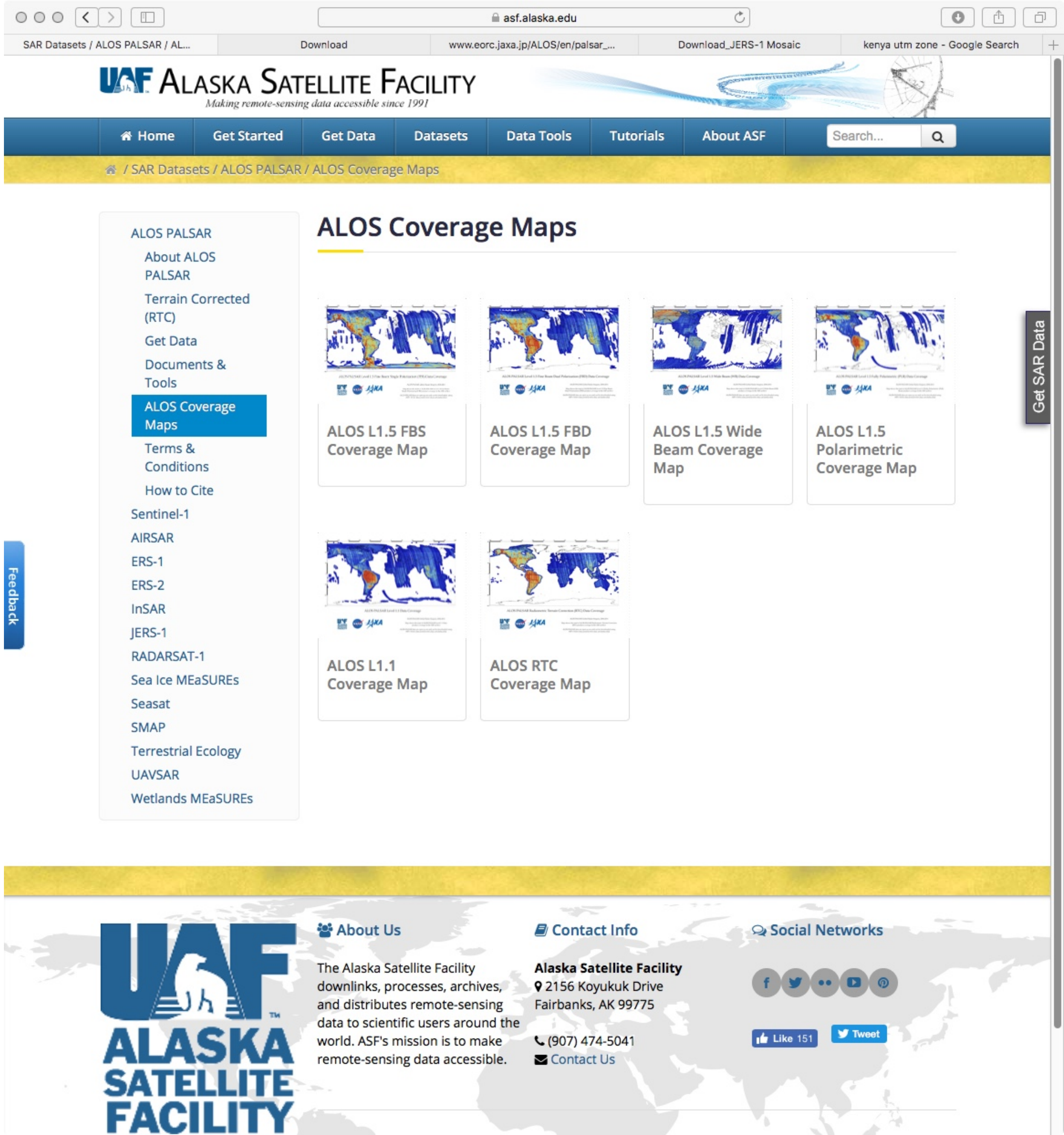
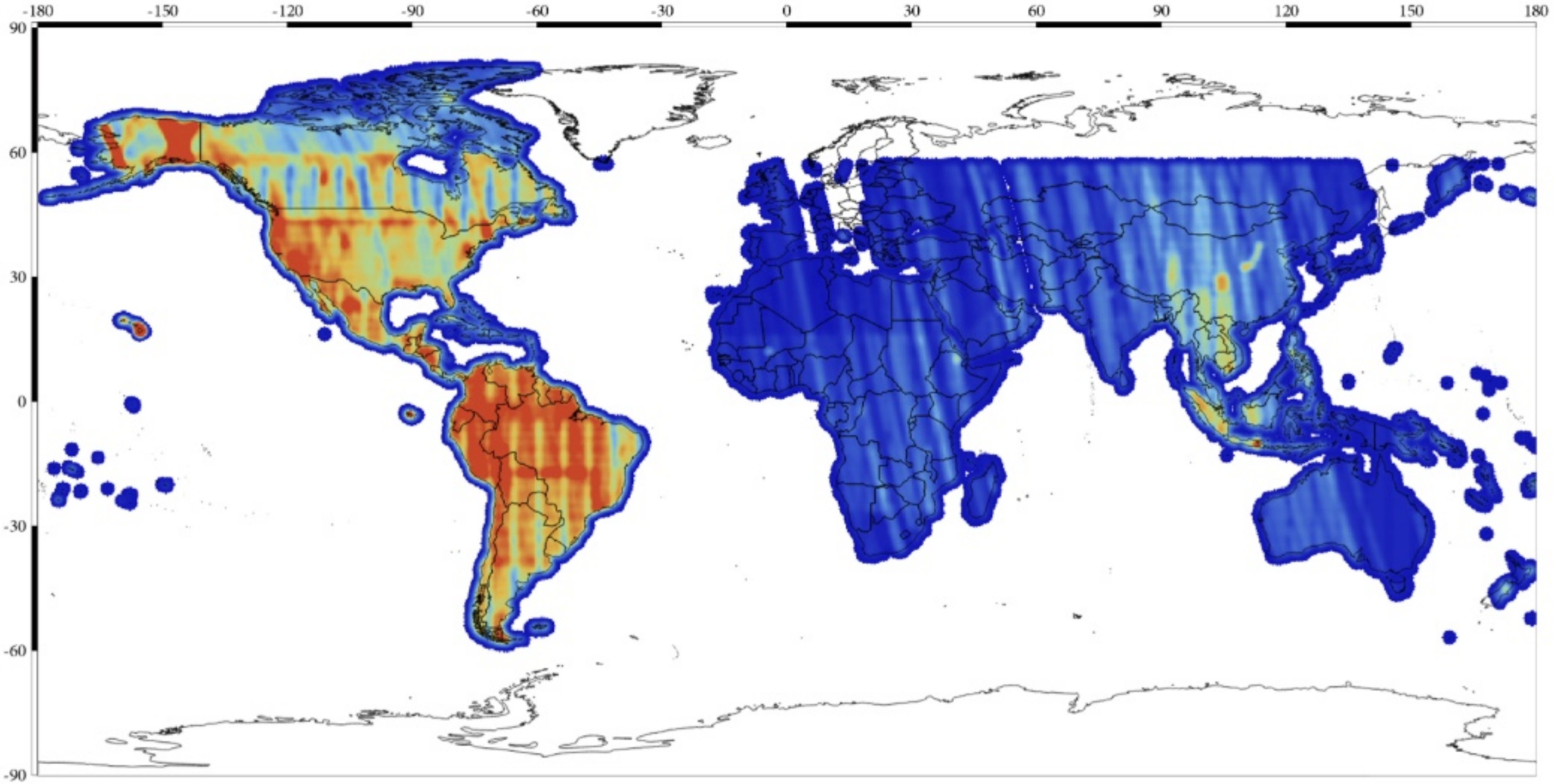


media.asf.alaska.edu

alos-rtc-map.png 3,507×2,480 pixels | Download | www.eorc.jaxa.jp/ALOS/en/palsar_... | Download_JERS-1 Mosaic | kenya utm zone - Google Search

Example of processed RTC data (by ASF): colors indicate the number of available processed scenes



ALOS PALSAR Radiometric Terrain Correction (RTC) Data Coverage

https://www.asf.alaska.edu/sar-data/palsar/alos-acquisition-maps/

SERVIR

UAF ALASKA SATELLITE FACILITY

NASA

JAXA

ALOS PALSAR Global Radar Imagery, 2006-2011

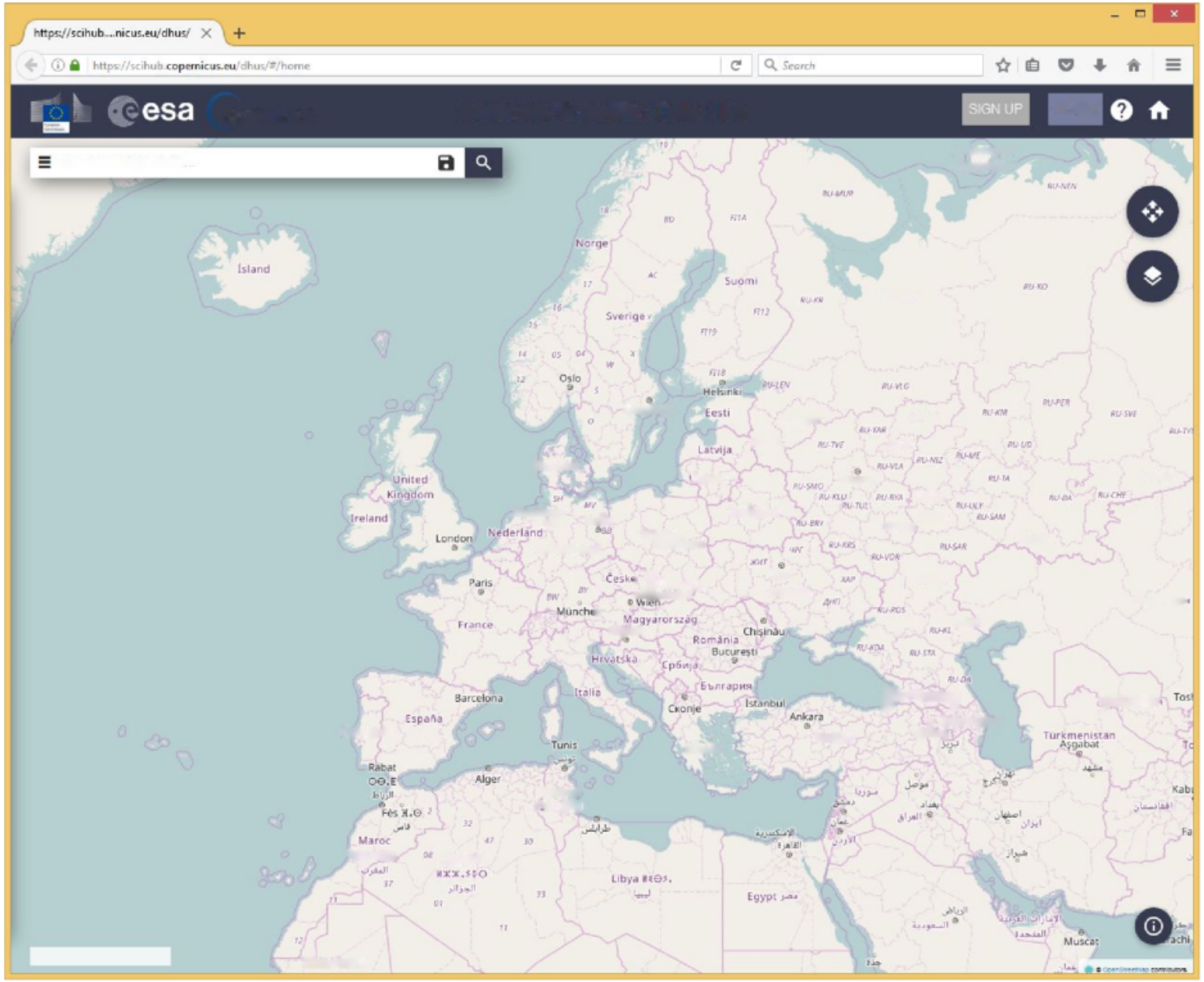
Map shows the total of ALOS PALSAR Radiometric Terrain Correction (RTC) product coverage in the ASF archive

ALOS-PALSAR data are open access and can be downloaded using ASF's Vertex data portal [vertex.daac.asf.alaska.edu]

Access and Download of Sentinel-1

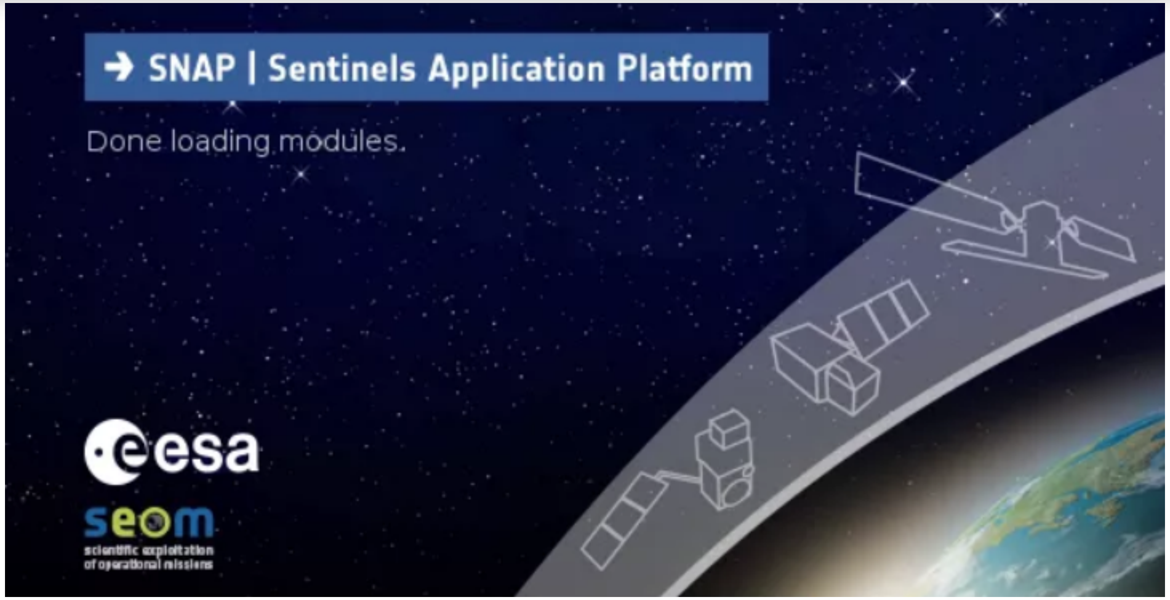
https://scihub.copernicus.eu/dhus/#/home

- Free access to the full Sentinel archive (1,2, and 3)
- The archive can be filtered spatially and/or based on several
- Results are displayed as entries in the result list and as footprints on the map



Data processing

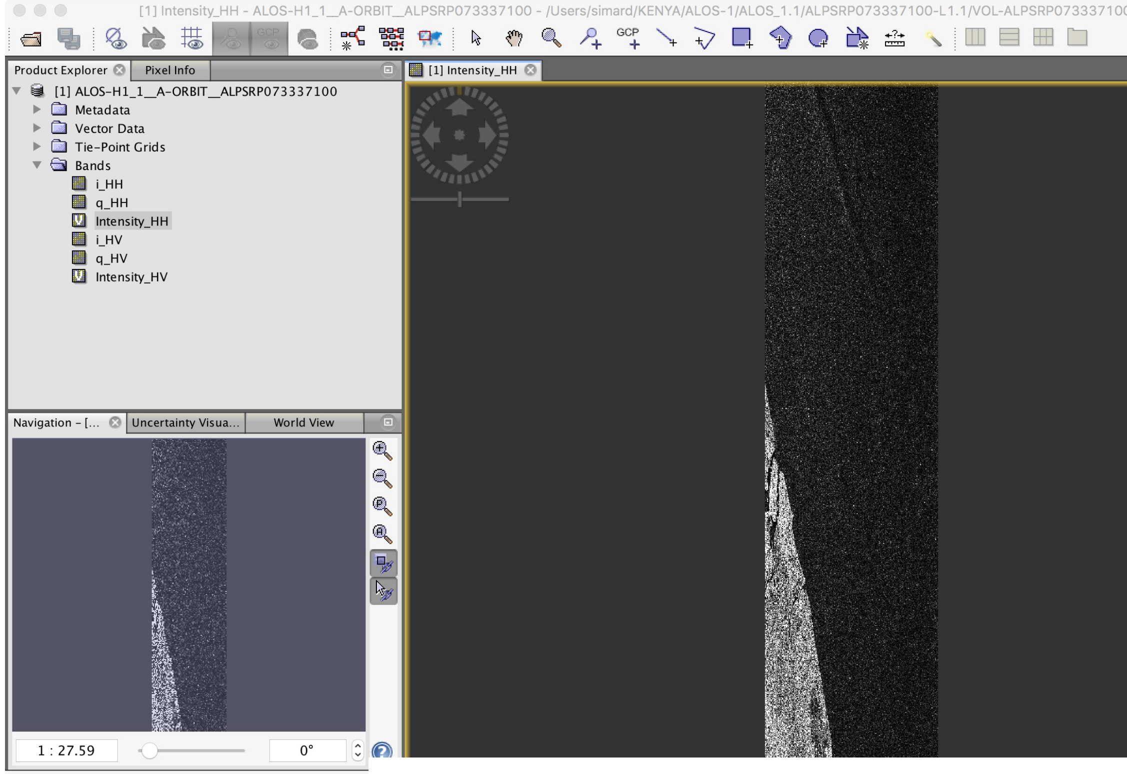
- Open radar images in SNAP
- Radiometric calibration
- Image filtering to reduce speckle
- Open in QGIS
- dB conversion

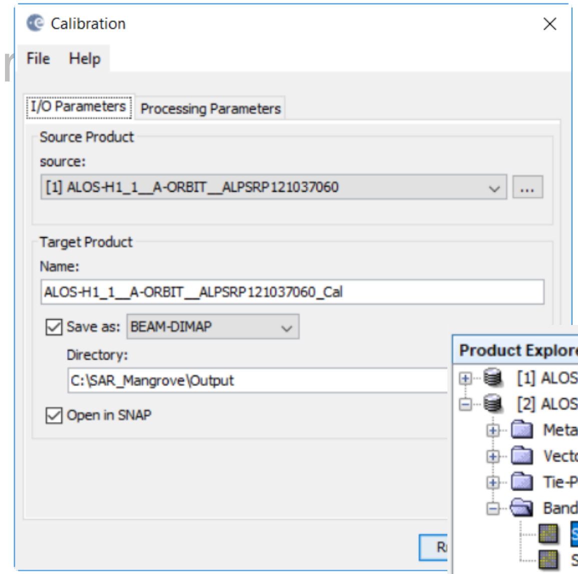


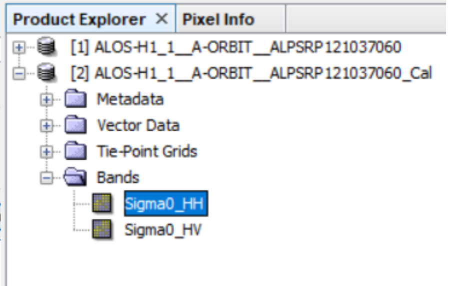
	Windows 64-Bit	Windows 32-Bit	Mac OS X	Unix 64-bit
Sentinel Toolboxes	These installers contain the **Sentinel-1**, **Sentinel-2**, **Sentinel-3** Toolboxes			
	Download	Download	Download	Download
SMOS Toolbox	These installer contains only the **SMOS Toolbox**. Download also the Format Conversion Tool (Earth Explorer to NetCDF) and the user manual.			
	Download	Download	Download	Download
All Toolboxes	These installers contain the **Sentinel-1**, **Sentinel-2**, **Sentinel-3** Toolboxes, **SMOS** and **PROBA-V** Toolbox			
	Download	Download	Download	Download

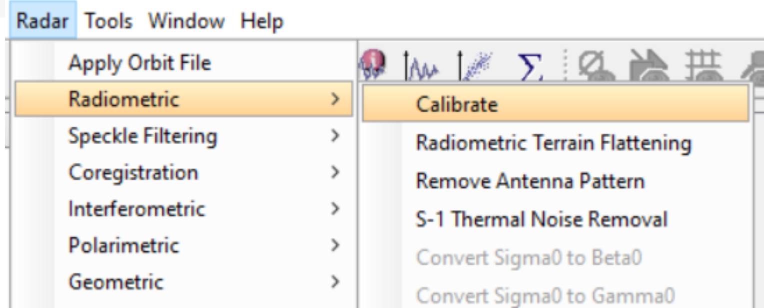
Using SNAP to process raw radar data

- Read
  - Begin processing with Level 1.1 data. The 1.5 and RTC product data are already processed. Try to use SNAP and process Level 1.1 to RTC!.
  - Drag and drop the Vol* file into "Product Explorer" window
- Calibrate
  - Go to "Radar" menu at top of screen. A window pops-up.
  - In the window, specify the input band and output file location.
  - In the same window, click on the "Processing Parameters" tab:
    - Select any "intensity" band.
    - Select beta0 band.
- Apply terrain correction
- Filter radar image (e.g. Lee Filter)
- Project to ground range
- Convert linear to decibels (dB)
- Write output



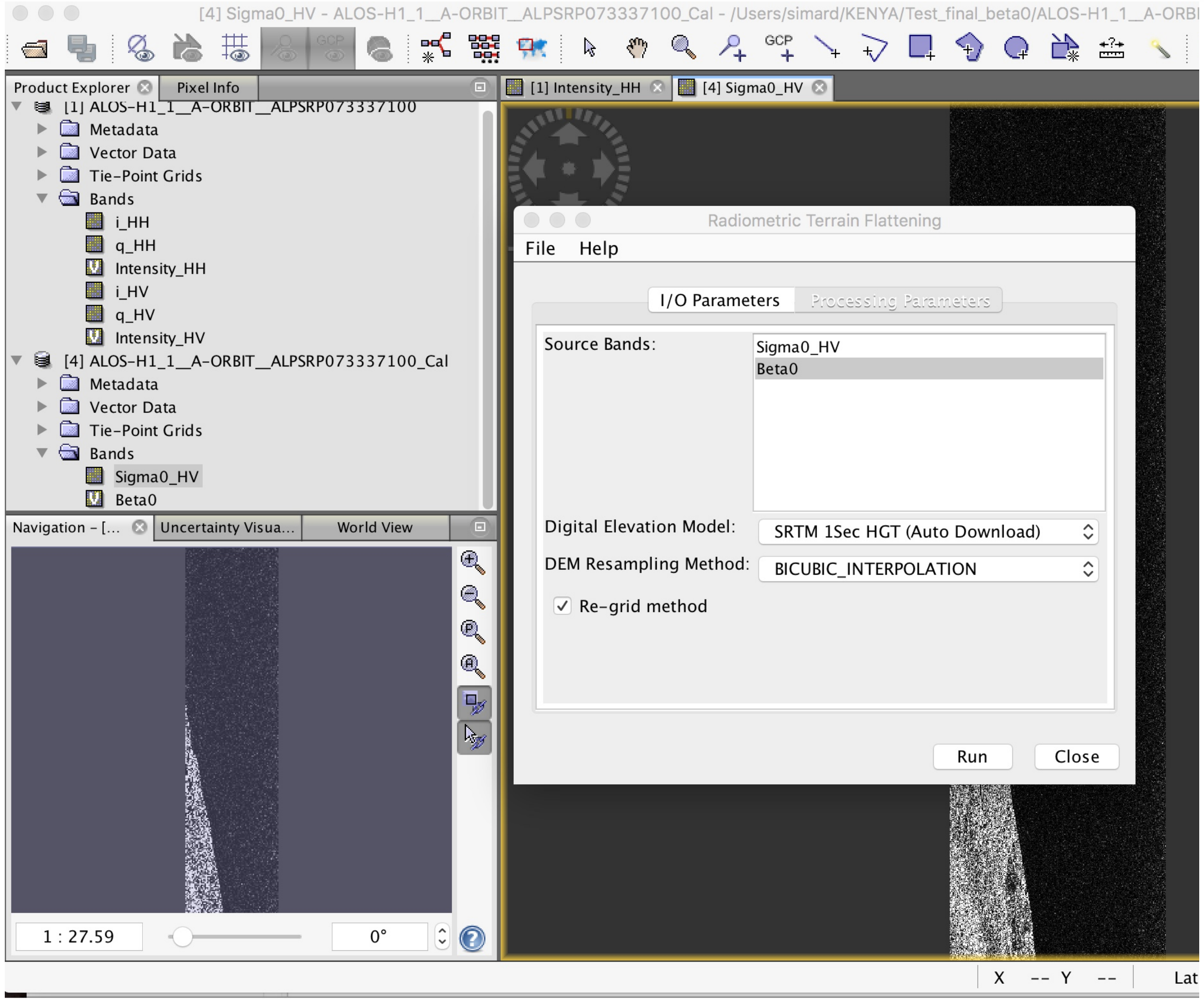






Using SNAP to process raw radar data

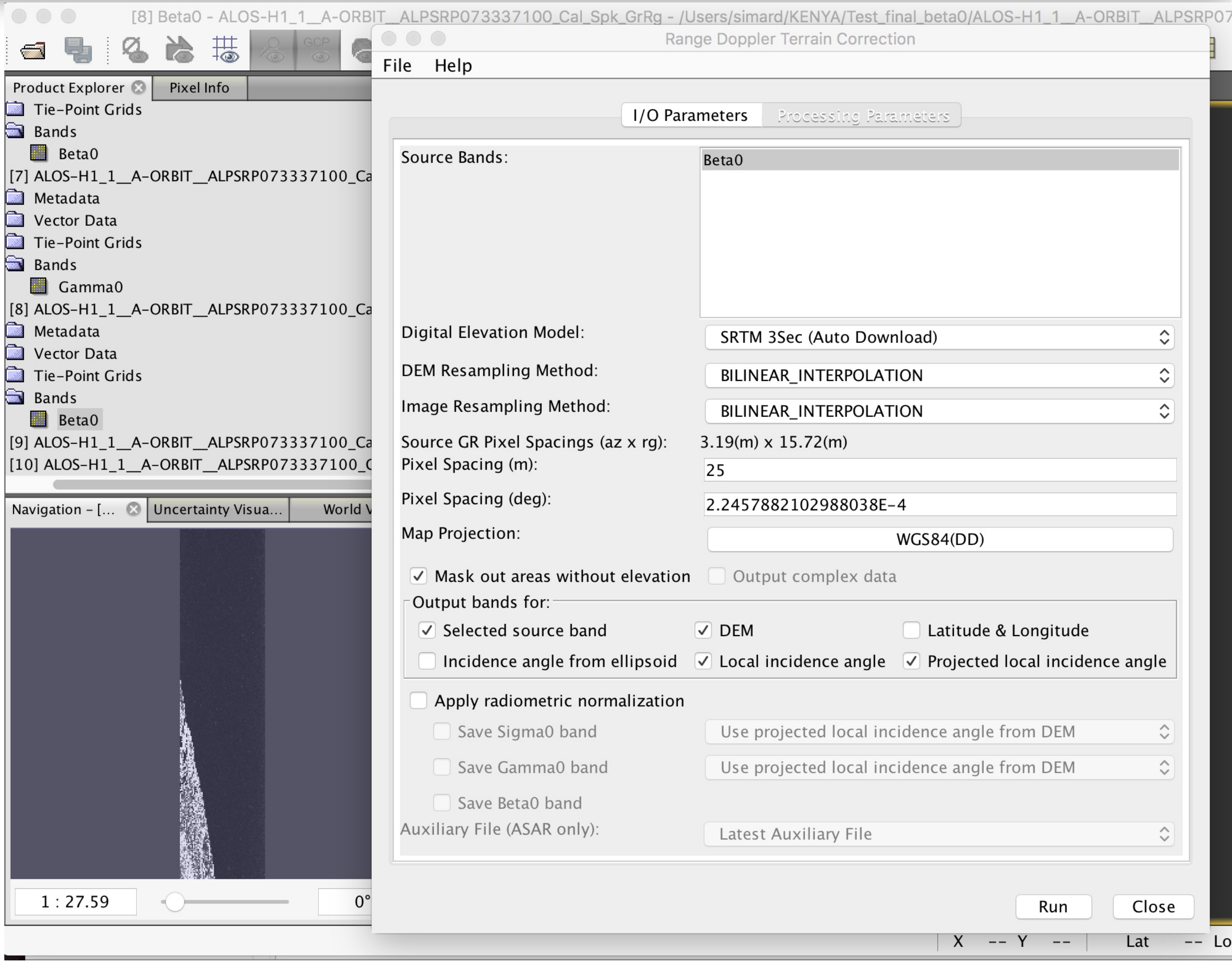
- Read
- Calibrate
- Apply terrain correction
  - Go to: “Radar” top menu and select “Radiometric”->”Radiometric Terrain Flattening”
  - In “Processing Parameters” tab, select “Beta0”
  - Click “Run”
  - Note this brings the image from Beta0 to Gamma0. i.e. removing topographic effects on backscatter.
- Filter radar image (e.g. Lee Filter)
- Project to ground range
- Convert linear to decibels (dB)
- Write output



Srtm 44_14

Using SNAP to process raw radar data

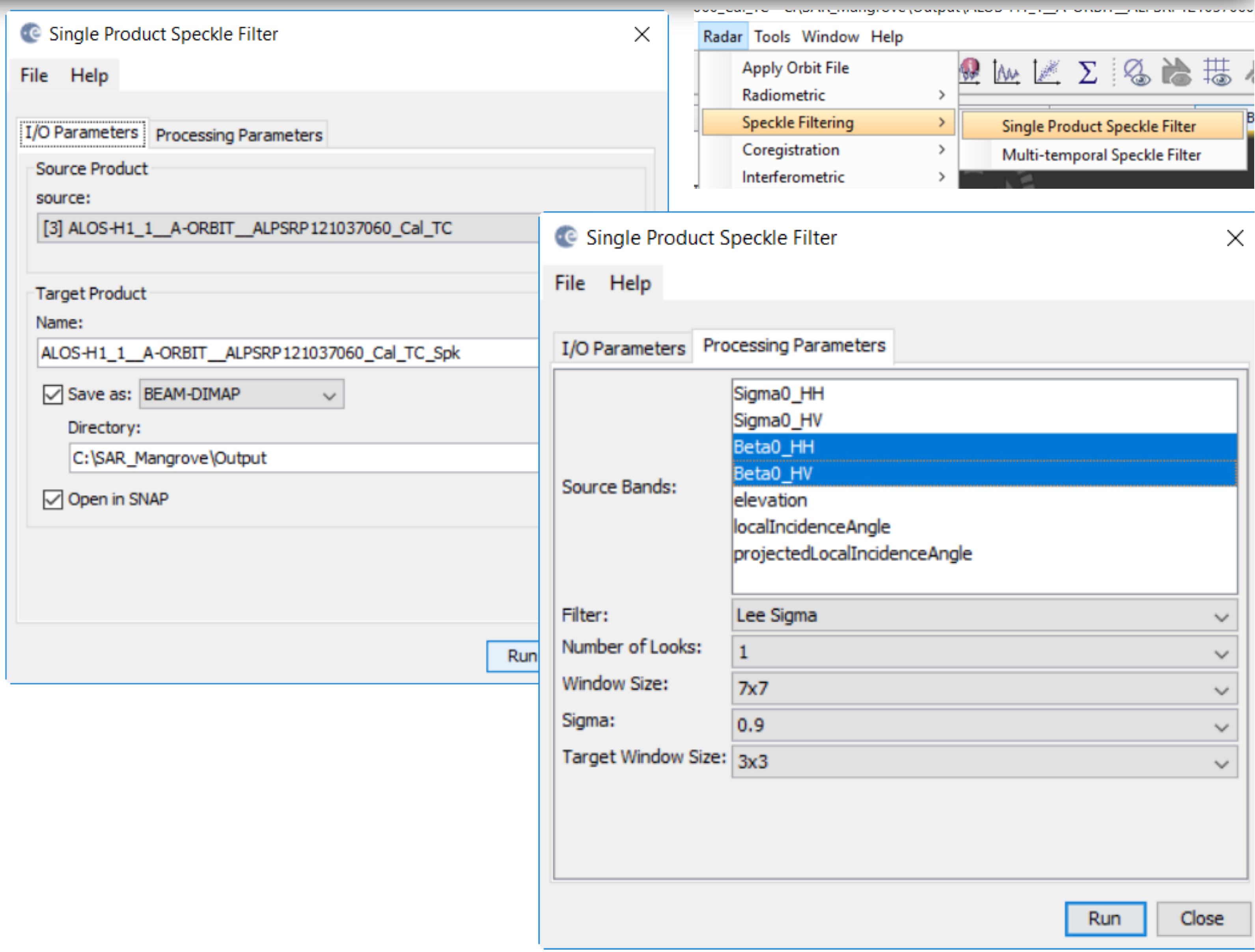
- Read
- Calibrate
- Apply terrain correction (Project to ground range)
    - “Radar”->”Geometric”->”Terrain Correction”->”Range-Doppler Terrain Correction”. Window pops-up.
    - Select input filtered band and specify output.
    - In “Processing parameters”, select Gamma0_HH or Beta
    - Select spatial resolution of output file (default is radar sampling)
    - Save useful bands: e.g. “Selected source band”, “DEM”, “projected local incidence angle”
    - If ground projection is incorrect, use the “Radar”->”Geometric”>”Terraint Correction”->”SAR-Simulation Terrain Correction”
- Filter radar image (e.g. Lee Filter)
- Convert linear to decibels (dB)
- Write output



Srtm 44_14

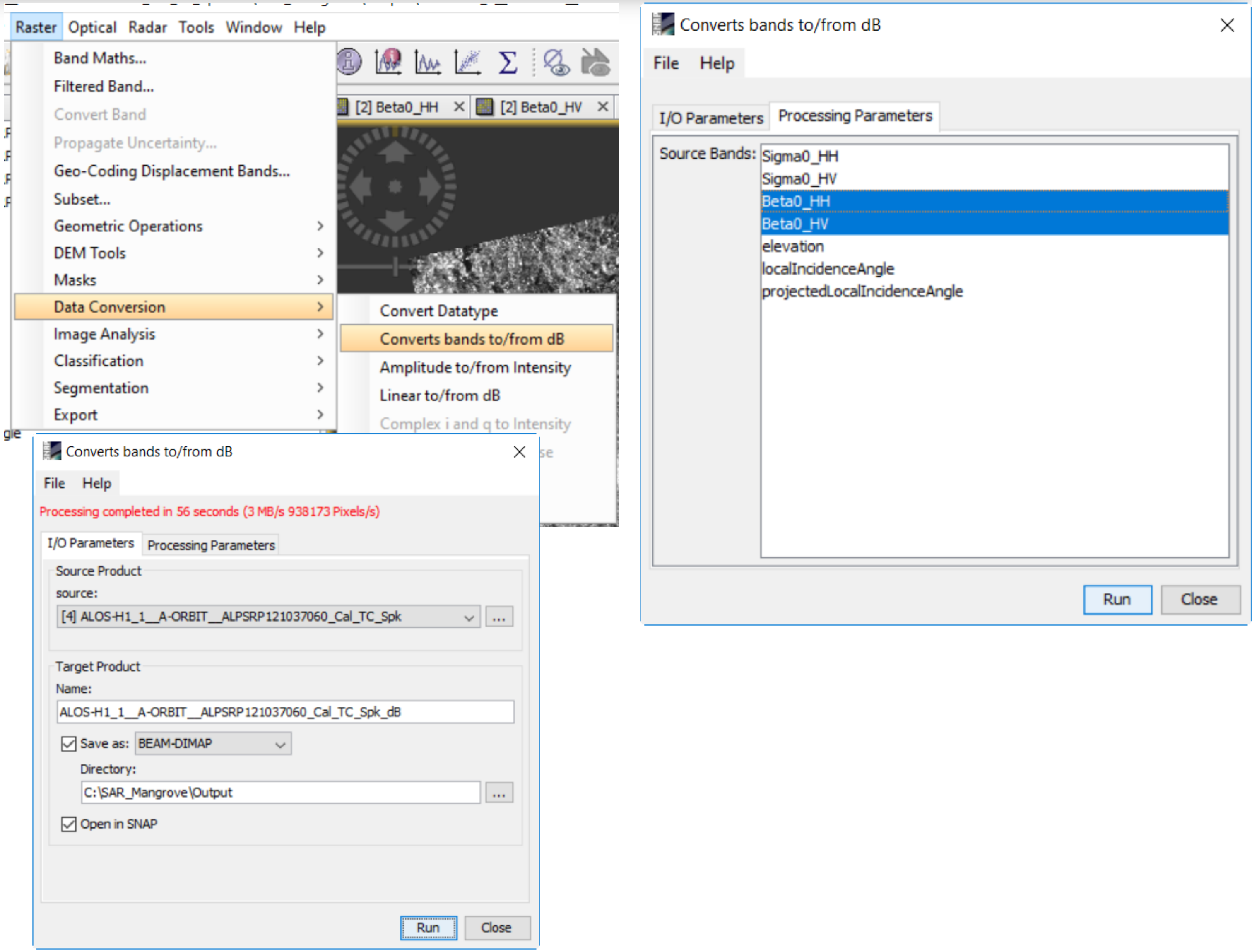
Using SNAP to process raw radar data

- Read
- Calibrate
- Apply terrain correction
- Filter radar image (e.g. Lee Filter)
  - Select Speckle Filtering -> Single Product Speckle Filter
  - Select Lee Sigma
- Convert linear to decibels (dB)
- Write output



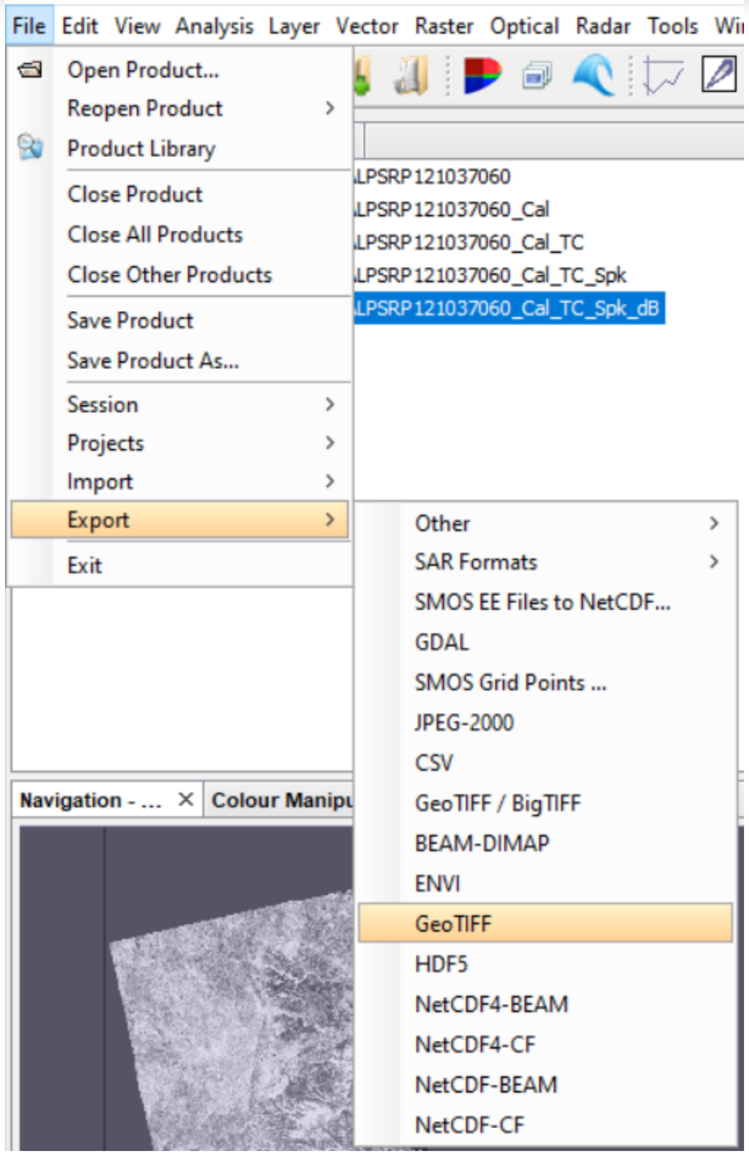
Using SNAP to process raw radar data

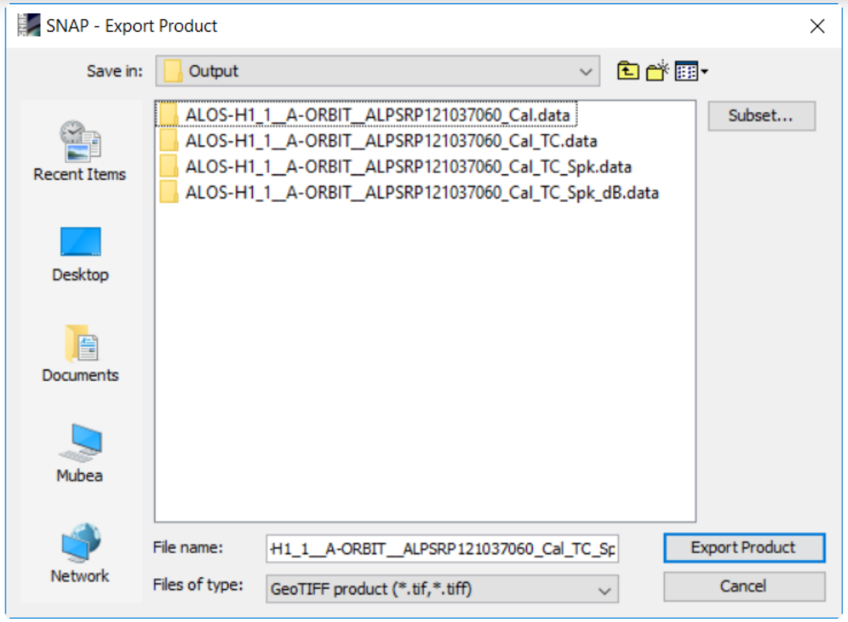
- Read
- Calibrate
- Apply terrain correction
- Filter radar image (e.g. Lee Filter)
- Project to ground range
- Convert linear to decibels (dB)
  - Top menu “Raster”->”Data Conversion”->”Converts bands to/from dB”
  - Select input band and output file.
- Write output
  - ”File”->”Export”->”Geotiff” for convenience

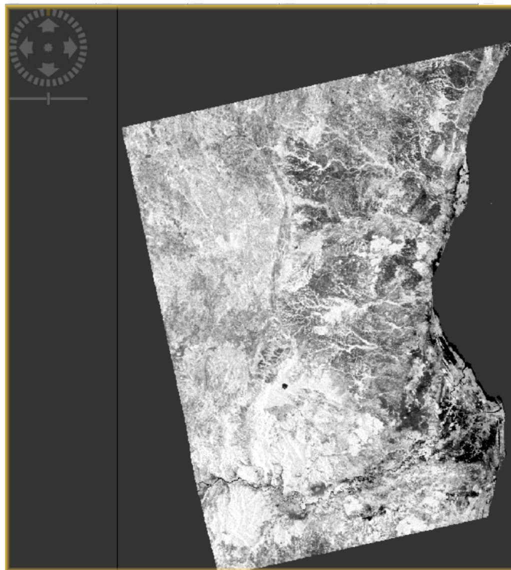


Using SNAP to process raw radar data

- Read
- Calibrate
- Apply terrain correction
- Filter radar image (e.g. Lee Filter)
- Project to ground range
- Convert linear to decibels (dB)
- Write output
    - ”File”->”Export”->”Geotiff” for convenience



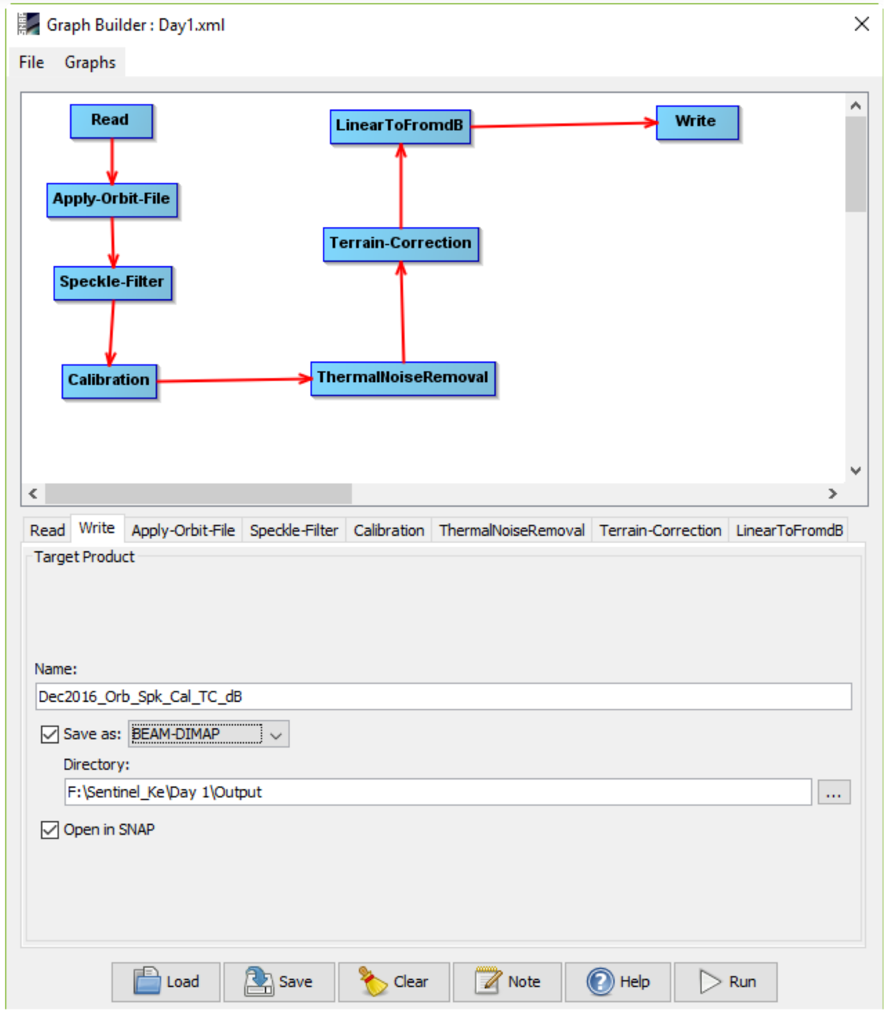




Using SNAP to process raw radar data - automation

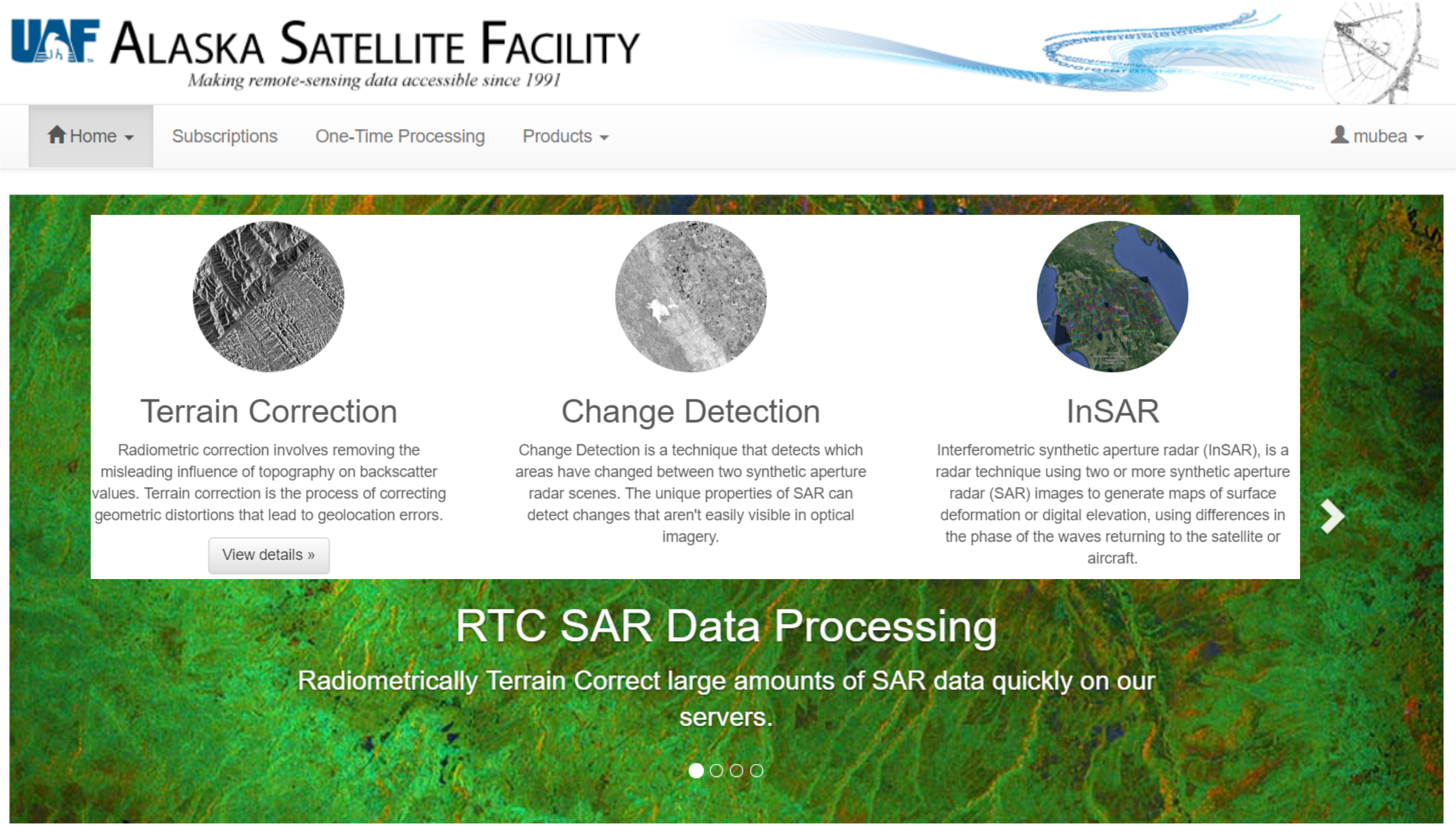
- ❑Read
- ❑Calibrate
- ❑Apply terrain correction
- ❑Filter radar image (e.g. Lee Filter)
- ❑Project to ground range
- ❑Convert linear to decibels (dB)
- ❑Write output

1. Select "Graph Builder"
2. Inset processing steps using right-click
3. Insert and connect all processing graphs
4. Processing step parameters can be set by clicking on the respective box
5. Output can be specified as GeoTIFF or BEAM-DIMAP
6. Save graph in a folder.
7. The graph can be used with other images
8. Replace the input and output paths with $infile and $outfile, respectively



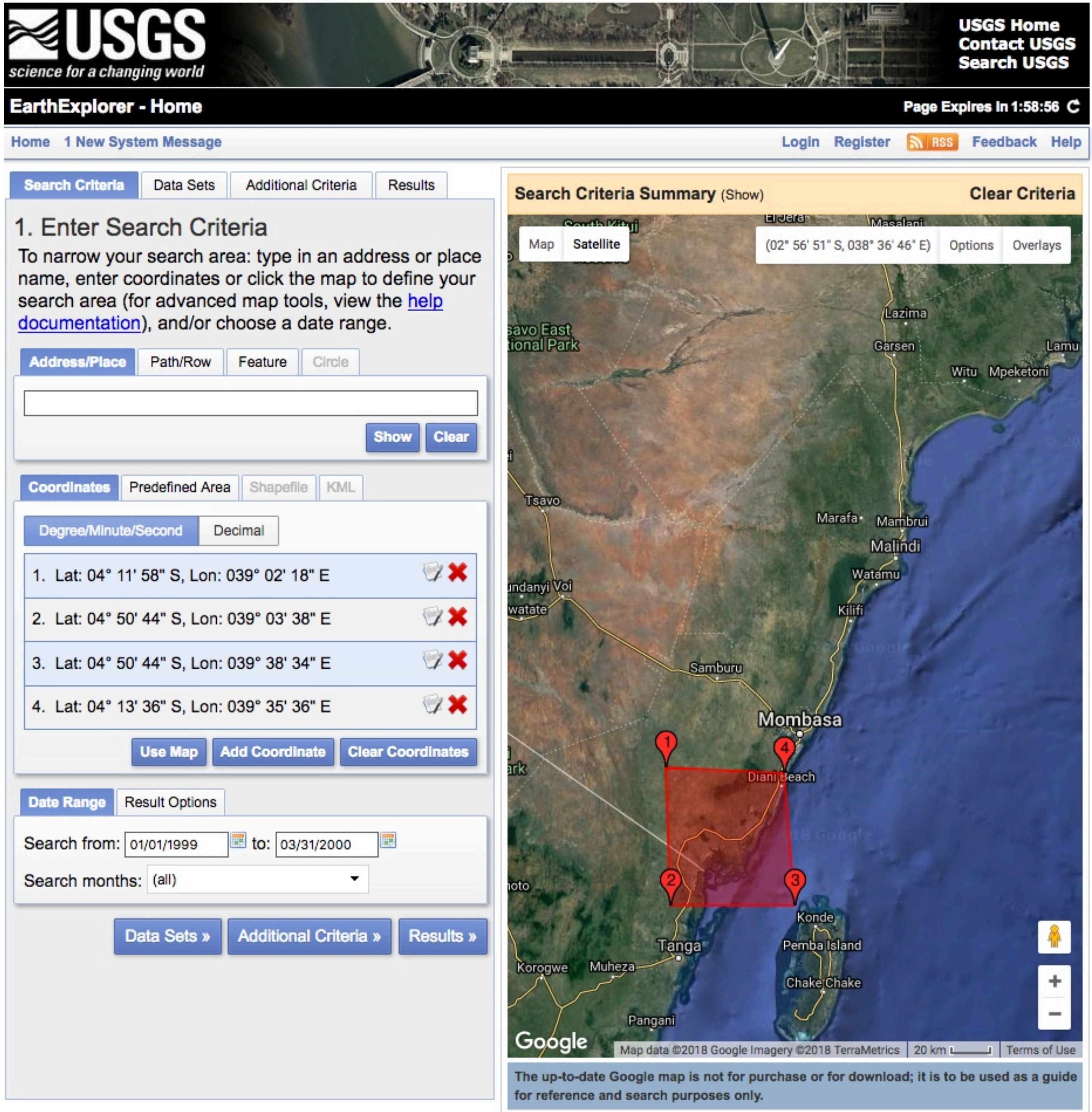
Sentinel processing - Alaska Satellite Facility

http://hyp3.asf.alaska.edu/



Obtain SRTM Digital Elevation Model (DEM) - USGS Explorer

- Go to: https://earthexplorer.usgs.gov/
- Register to be able to download data
- In ”Search Criteria” tab clicke “Use Map”
- Click “Clear Coordinates”
- Generate polygon on map with clicks.
- Go to ”Data Sets” tab.
- Select type of data needed. SRTM in “Digital Elevation” than “SRTM” Use the “SRTM 1 Arc-Second Global”. Note the future NASADEM will not work for that purpose.
- Click “Results” and select files for download.



SRTM1S05E039V3
Coordinates: -5, 39

Break..!

Mapping mangrove canopy structure

- Forest structure can be described: spatial extent, tree cover, canopy height and above ground biomass (AGB).
- Tree cover, canopy height and above ground biomass (AGB) are correlated.
- Different Radar parameters are used to estimate AGB and forest canopy height.
- A generic formulation relating radar backscatter to AGB is:

$$\sigma^{o}(dB) = a + b \times Log\ (AGB)$$

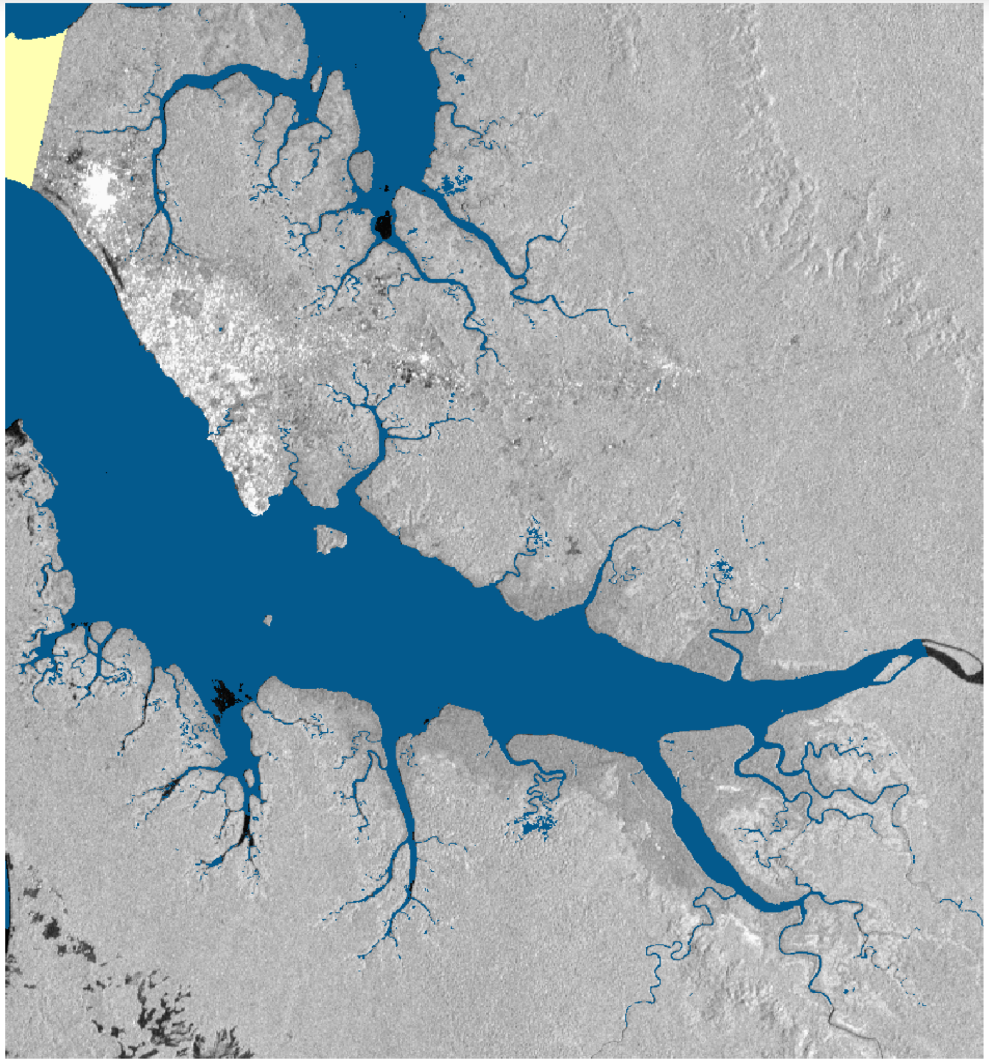
Where a and b are determined by the user from in situ data

- In wet tropical forests, values are about -22.5 and 3 for a and b respectively.
- The values for mangrove forests can change significantly: large variation in structure, species and the inundation state
- The longer the wavelength (equivalent to lower frequency), the larger is the biomass saturation point.
- Approximate mangrove backscatter values (σo) range from 200, 100, 50, 25 for P, L, C and X respectively.

Mapping mangrove canopy structure

- The observed backscatter (σo) reduces dues to absorption by the dense aerial root especially for HV polarization.
- Observation of scrub mangroves at HH and VV display high backscatter (σo) due to increased penetration within the canopy and double-bounce interaction with the water surface
- It is recommended to use a combination of datasets from different sensing technologies to map mangroves.
- Land cover classification can be performed with the radar backscatter as one of the layers along with data from optical instruments such as Landsat.
- One can build upon existing global maps of mangrove extent

Mapping mangrove canopy structure

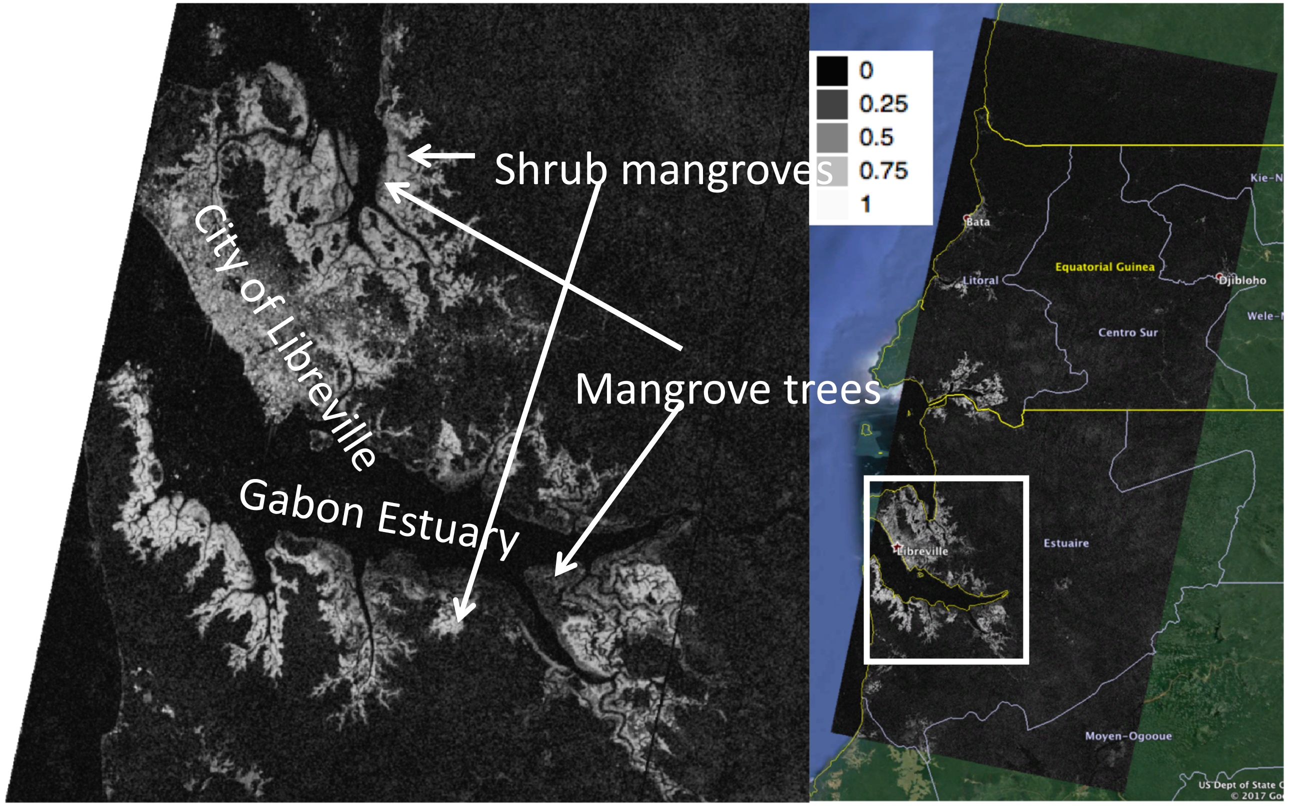


- Radar backscatter at L band HH acquired by ALOS-2 over the Gabon Estuary, Gabon. Bright areas to the North West result from strong double bounce effect in urban structures of the city of Libreville.
- Large medium backscatter (mid-gray tones) are due to volume scattering in forests. Water was easily masked based on darker backscatter (in particular at LHV).
- Interestingly, due to strong attenuation from roots, tall mangrove forest with red mangrove trees reaching several tens of meters exhibit lower backscatter along the South Eastern portion of the Estuary.

Mapping mangrove canopy structure

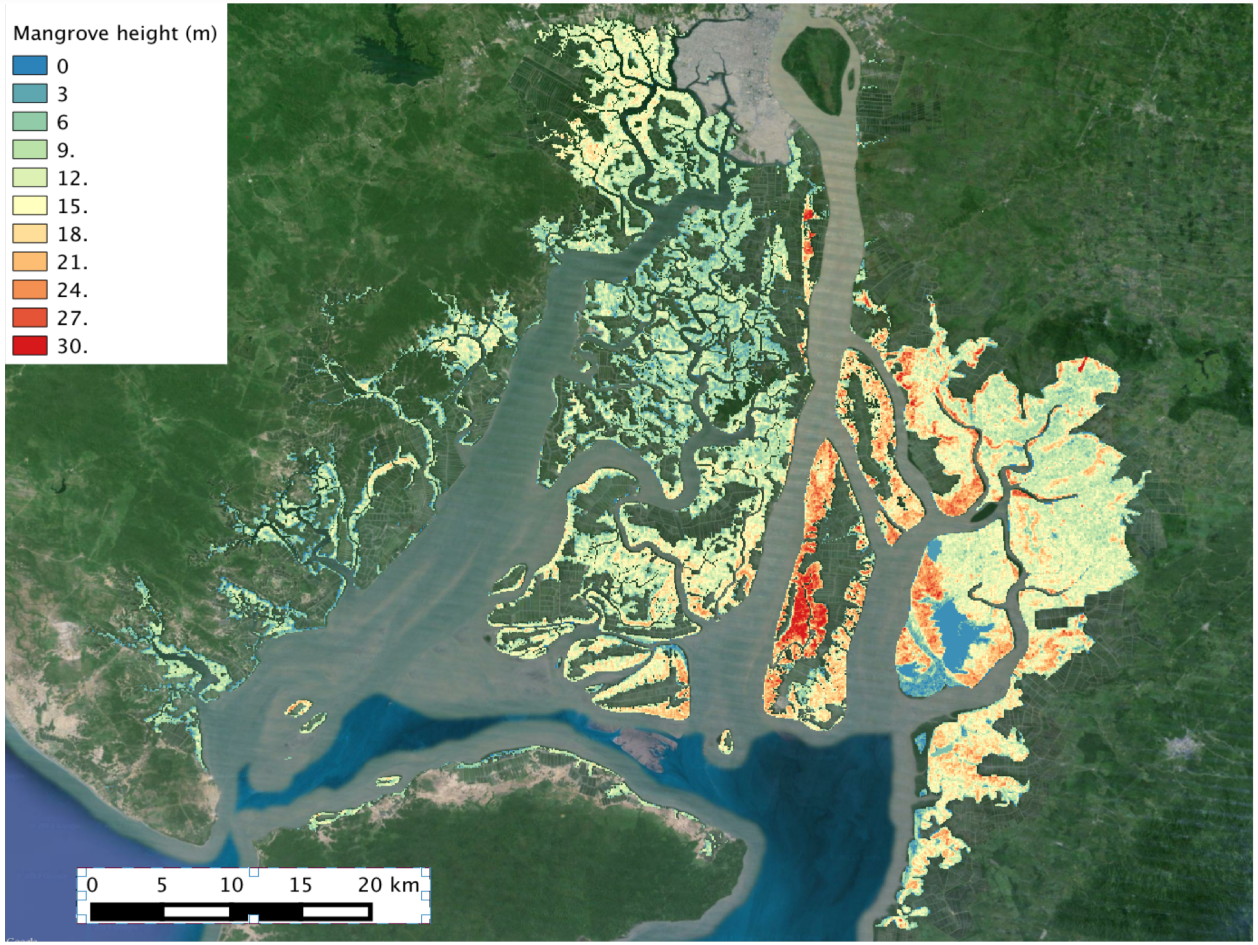
- Significant advances in the use of Radar interferometry to map mangrove canopy height.
- Data from the Shuttle Radar Topography Mission has been used to measure canopy height
- SRTM was designed to measure elevation, but due to the interaction of the radar microwave with the canopy volume, the SRTM elevation measurement is biases for forest height and density.
- SRTM helps determine patterns of mangrove height at the landscape to global scales
- New elevation measurements derived with interferometric data acquired by **TanDEM-X** (e.g. World DEM) providing a second and more recent dataset.
- TanDEM-X elevation datasets are currently available through a proposal process or can be purchased. https://tandemx-science.dlr.de/

Mapping mangrove canopy structure



- Interferometric radar coherence obtained from ALOS-2 LHH.
- The bright areas represent coherence close to 1 indicating strong similarity between images collected successively after 24 days.
- These are observed in shrub mangrove as well as in urban areas.
- Tall mangrove trees exhibit lower coherence due to temporal decorrelation caused by scattering in the canopy which changes between the two radar acquisition (i.e. 24 days in this case).
- Open water surface also displays low coherence due to waves constantly changing surface scattering.

Mapping mangrove canopy structure



- Map of mangrove canopy height in the Guayas Estuary of Ecuador obtained from SRTM elevation data, calibrated with in situ field data.

Above Ground Biomass Allometry

Tree Allometry for Aboveground Biomass Estimation

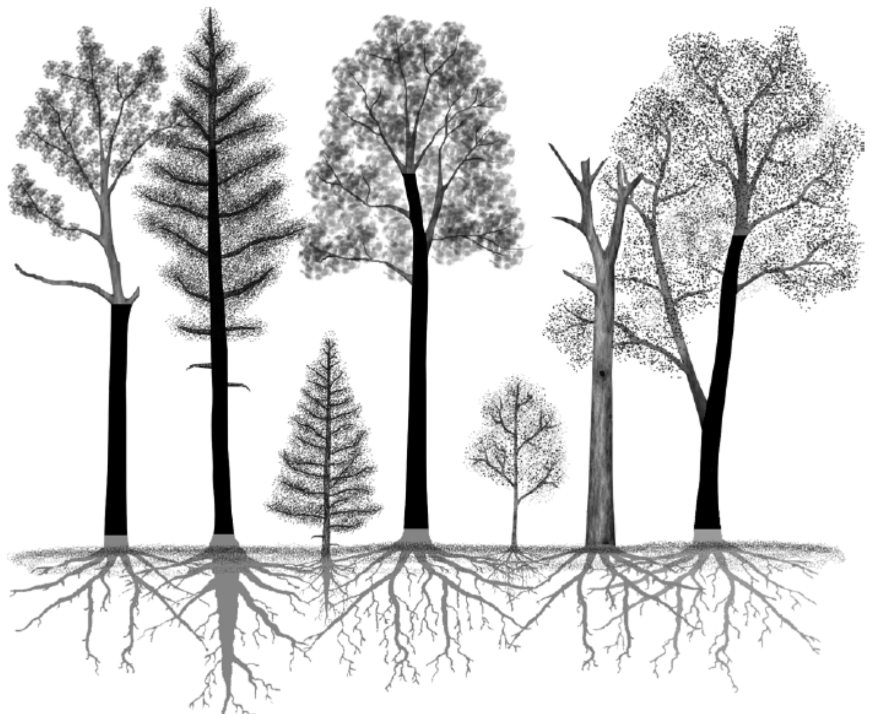
Above Ground Biomass Density (AGBD) = Vol_{wood} x W

$$AGBD = \frac{1}{A}\sum_i \frac{pD_i^2}{4} H_i T_i W_i$$

$$Vol = \frac{1}{A}\sum_i \frac{pD_i^2}{4} H_i$$

$$BA = \frac{1}{A}\sum_i \frac{pD_i^2}{4}$$

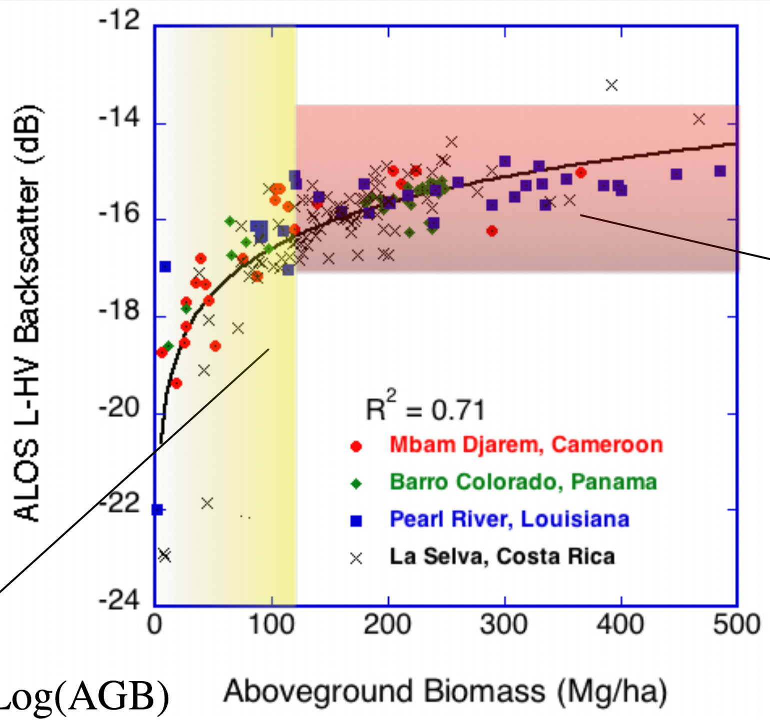
A: Area sampled
D: Diameter at Breast Height, DBH
H: Tree Height
T: Tapering Factor (species dependent)
W: Wood Density (species dependent)



Wood density decreases as a function of tree height

Water content(dielectric constant) increases as a function of tree height

Radar Sensitivity to Biomass



High Priority Fusion Region
Lower to no sensitivity of radar
Domain of data fusion and synergism with GEDI and BIOMASS

$$\text{LHV (dB)} = -22.5 + 3.0\text{Log(AGB)}$$

Biomass < 100 Mg/ha
Low Priority Fusion Region
Higher sensitivity of radar
Domain of NISAR Performance

Global Biomass Product must be derived from Fusion Approach

For low biomass density (100 Mg/ha) radar sensitivity is high but impacted by structure & environment

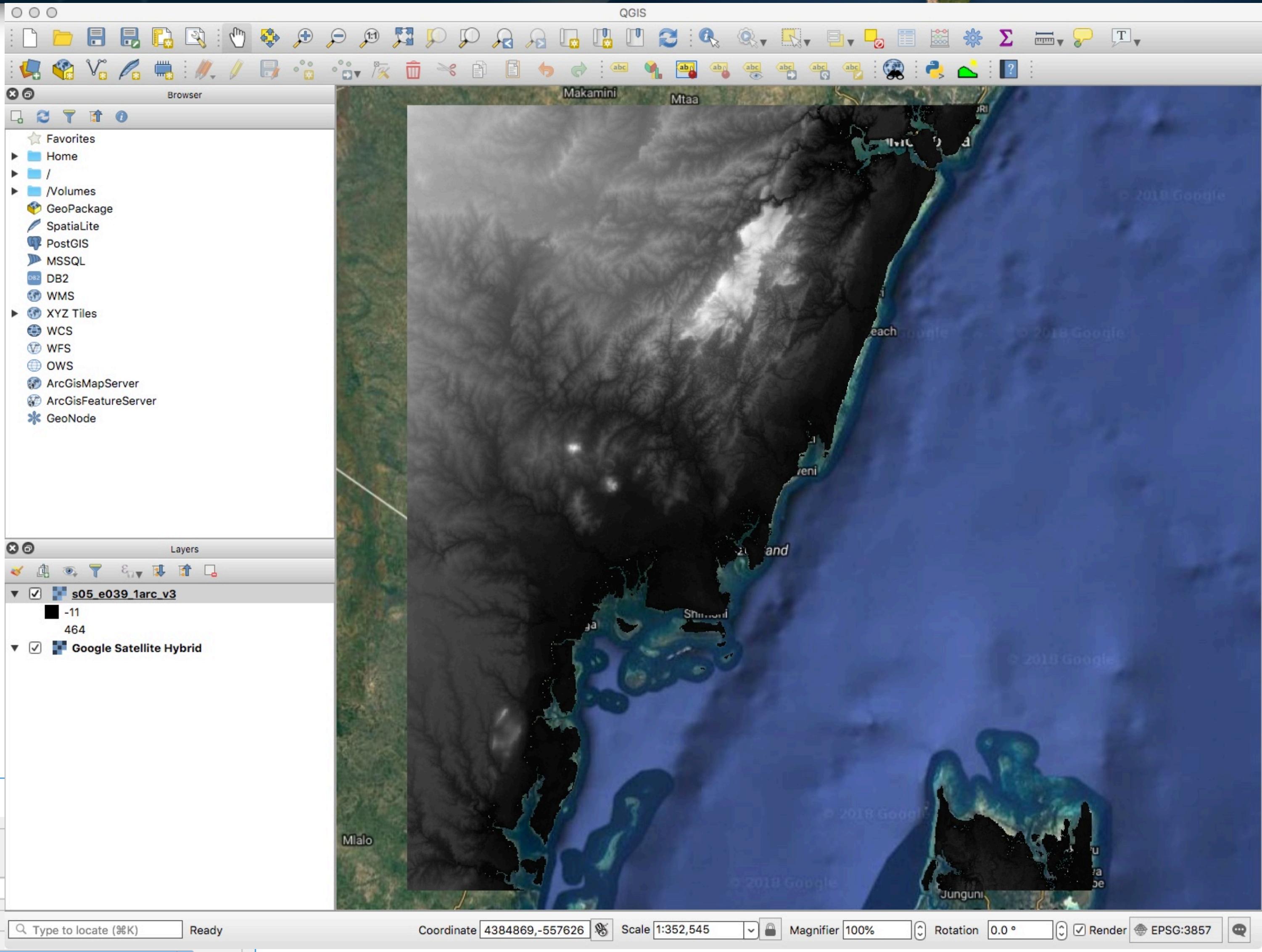
For high biomass density (>100 Mg/ha) data fusion with GEDI and/or BIOMASS required

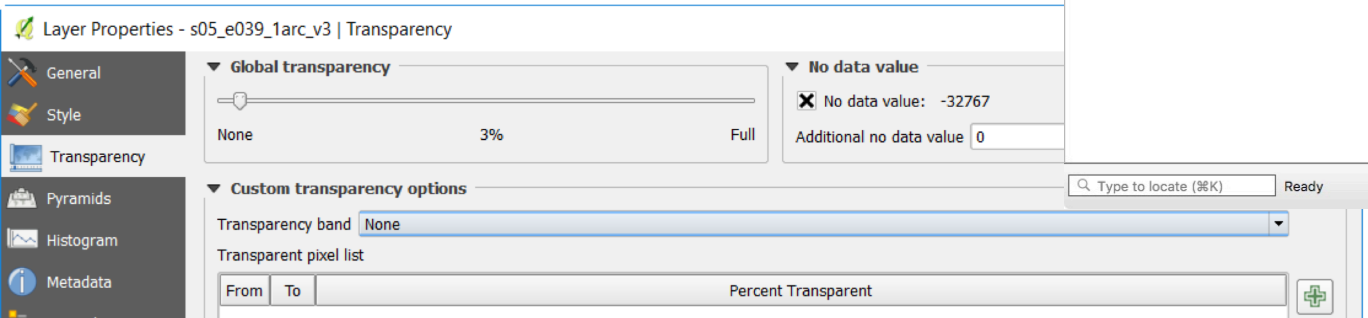
Using QGIS to estimate mangrove biomass

- Two methods
  - Using Canopy height from SRTM
    - Could also be TanDEM-X or lidar data or stereophotogrammetry
  - Using radar backscatter
    - From previous exercise

Read and Display SRTM DEM in QGIS

- Drag and drop the DEM (default .tif format) into QGIS.
- Go to “properties” by right clicking on DEM file name in QGIS->”Transparency”->”Additional value”=0
- Set background as Google Satellite using the “XYZ Tiles“ setup.
- Drag and drop available bands in QGIS to set which is on top or below.
- To select an area of mangroves, open vector file.





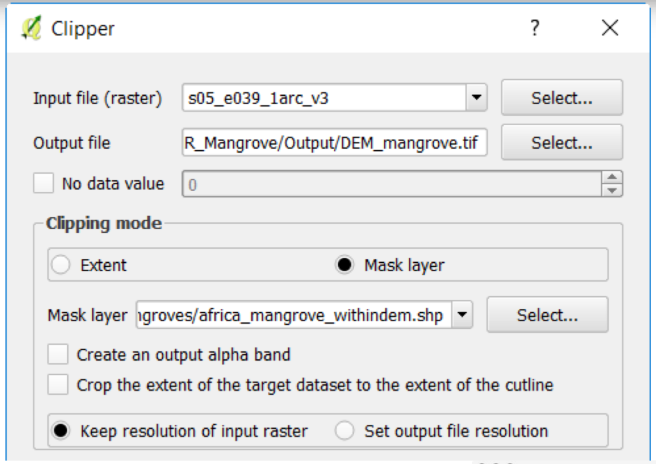
Break..!

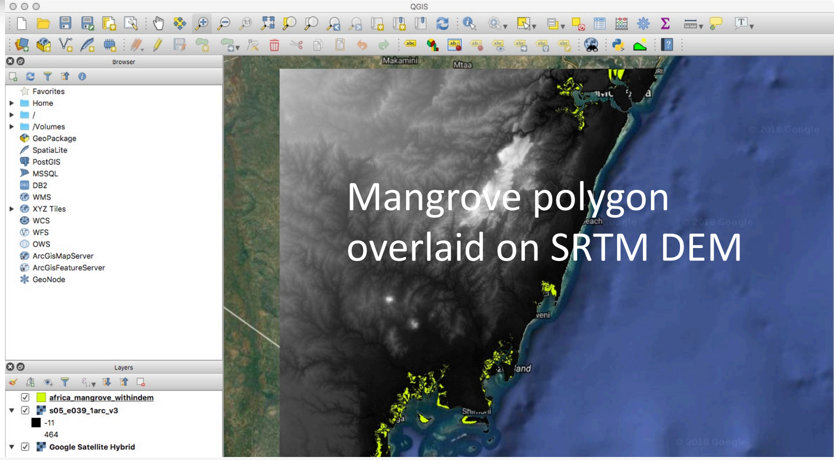
Course outline: Day 2

09:00 – 10:00	Session 3b Biomass estimation
10:00 – 10:30	Tea/Coffee Break
10:30– 12:30	Session 3c Biomass estimation
12:30 – 14:00	Lunch Break
14:00 – 16:00	Session 4 Monitoring mangrove loss and gain
16:00 – 16:10	Tea/Coffee Break

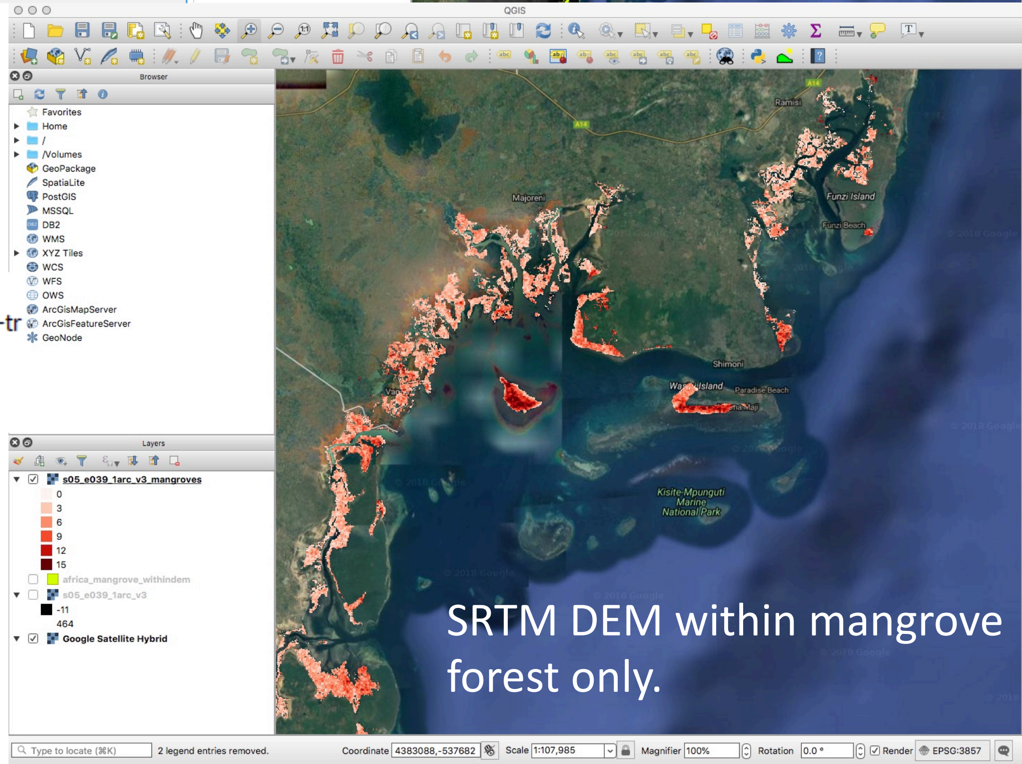
Read, load and use polygons to cut a raster in QGIS

1. Drag and drop shapefile into QGIS
2. Change colors within polygons with a right click->"Properties
3. Cut SRTM DEM with polygon
   - Top menu "Raster"->"extraction"->"Clip Raster by Mask Layer"
   - If QGIS fails in cutting the SRTM DEM, you may need use a command line such as (copy from QGIS into terminal. The shapefile directory did not come up right in this execution): *gdalwarp -ot Float32 -of GTiff -tr 0.00027778 -0.00027778 -tap -cutline /YourDirectoryWithShapeFile/africa_mangrove_withindem.shp -crop_to_cutline -dstnodata 0.0 / YourDirectoryWithSRTM /s05_e039_1arc_v3.tif / YourDirectoryWithOutputs /s05_e039_1arc_v3_mangroves.tif*





gdalwarp -q -cutline C:/SAR_Mangrove/Mangroves/africa_mangrove_withindem.shp -tr 0.000277777777777778 0.000277777777777778 -of GTiff C:/SAR_Mangrove/DEM_SRTM/s05_e039_1arc_v3.tif C:/SAR_Mangrove/Output/DEM_mangrove.tif



4. *You now have a canopy height map. It is SRTM, the height correspond to basal area weighted height (also called Lorey's height). The maximum height is generally 1.6X this value. (Simard et al., 2018)*

Estimation of Above Ground Biomass with Generic Allometric Equations

1. Generic equation relating SRTM to canopy height and aboveground biomass (Simard et al., 2018):
   - Basal area weighted height $H_{ba} \sim 1.08*SRTM$
   - Maximum canopy height $H_{max} \sim 0.93*1.7*SRTM$
   - Aboveground Biomass – AGB, $B \sim 3.25*H_{ba}^{1.53}$
2. Generic equation relating aboveground biomass B in tons per hectare (t/ha) to backscatter in decibels (dB):
   - $s^o_{HV}(dB) \sim -22.5 + 3.0 * \ln(B)$
   - $s^o_{HV}(dB) \sim A.B^a (1-e^{-B.D}) + C$, with A=0.013682, a=0.21116, D=0.051846, C=0.02192 (Yu & Saatchi, 2016). To simplify: $B = \exp(0.038\, s^o_{HV}{}^3 + 1.6089\, s^o_{HV}{}^2 + 23.007\, s^o_{HV} + 112.28)$
   - $s^o_{HV}/ 0.013682$
   - Note: There is no definite relationship for mangrove because of water presence and also increased absorption by roots at high biomass levels, but the shape of the logarithmic shape remains.

Applying the Generic Height-Based Allometric Equation

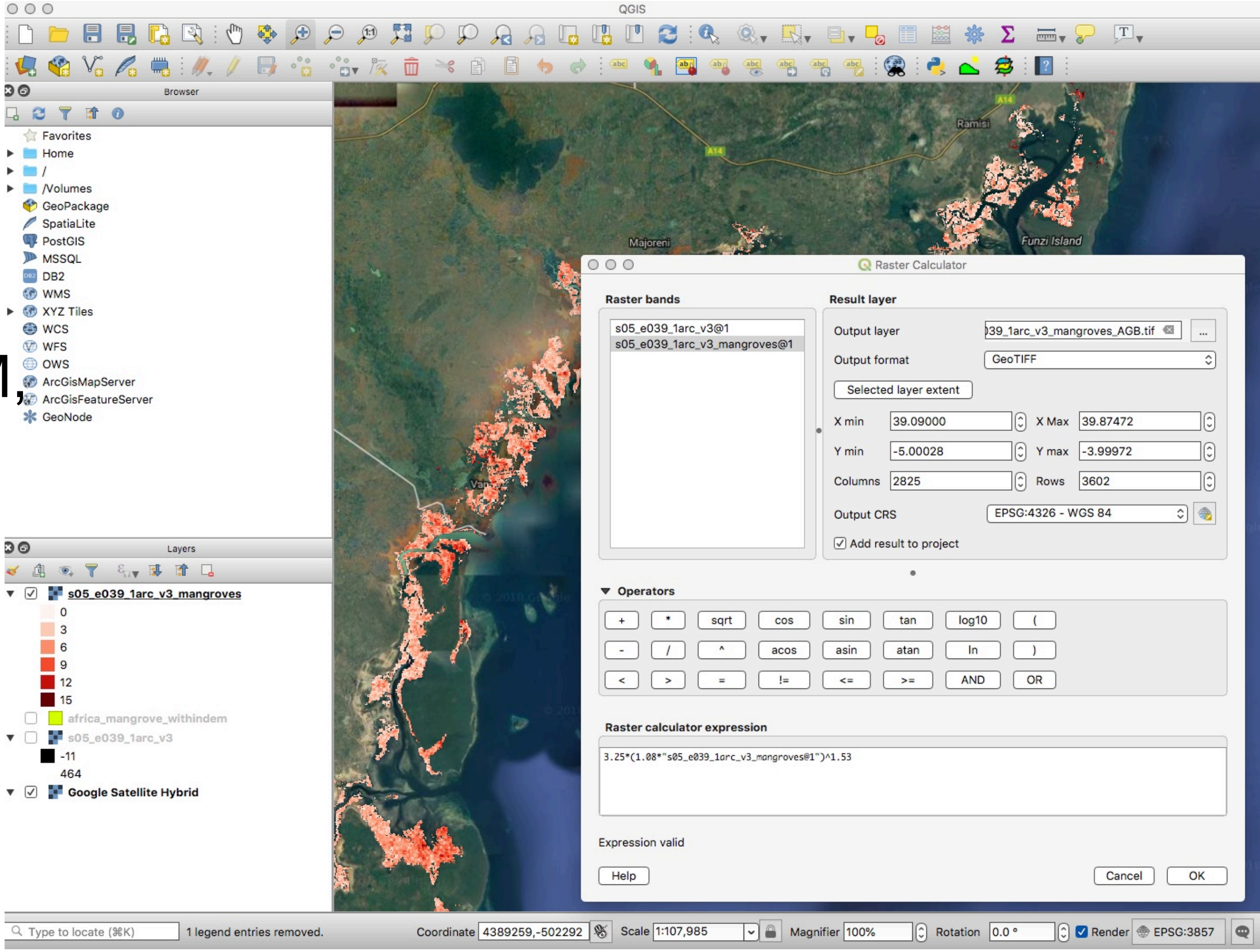
- In QGIS, click on “Raster” in the top menu, then ”Raster Calculator”
- Define output layer filename, location and format (Geotiff is a favorite)
- Enter allometric equation for SRTM

$B=3.25*H_{ba}{}^{1.53}$, where $H_{ba} = 1.08*SRTM$,

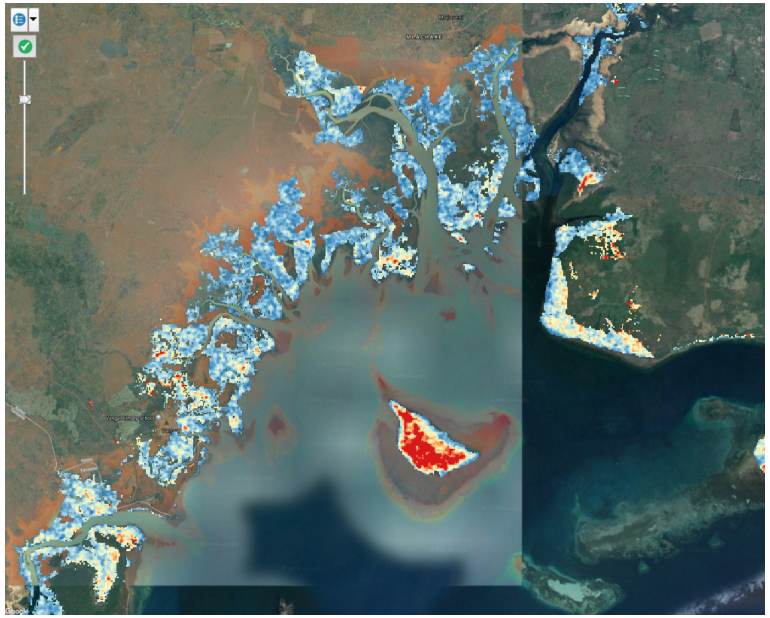
The equation becomes

$3.25*(1.08*SRTM)^{1.53}$

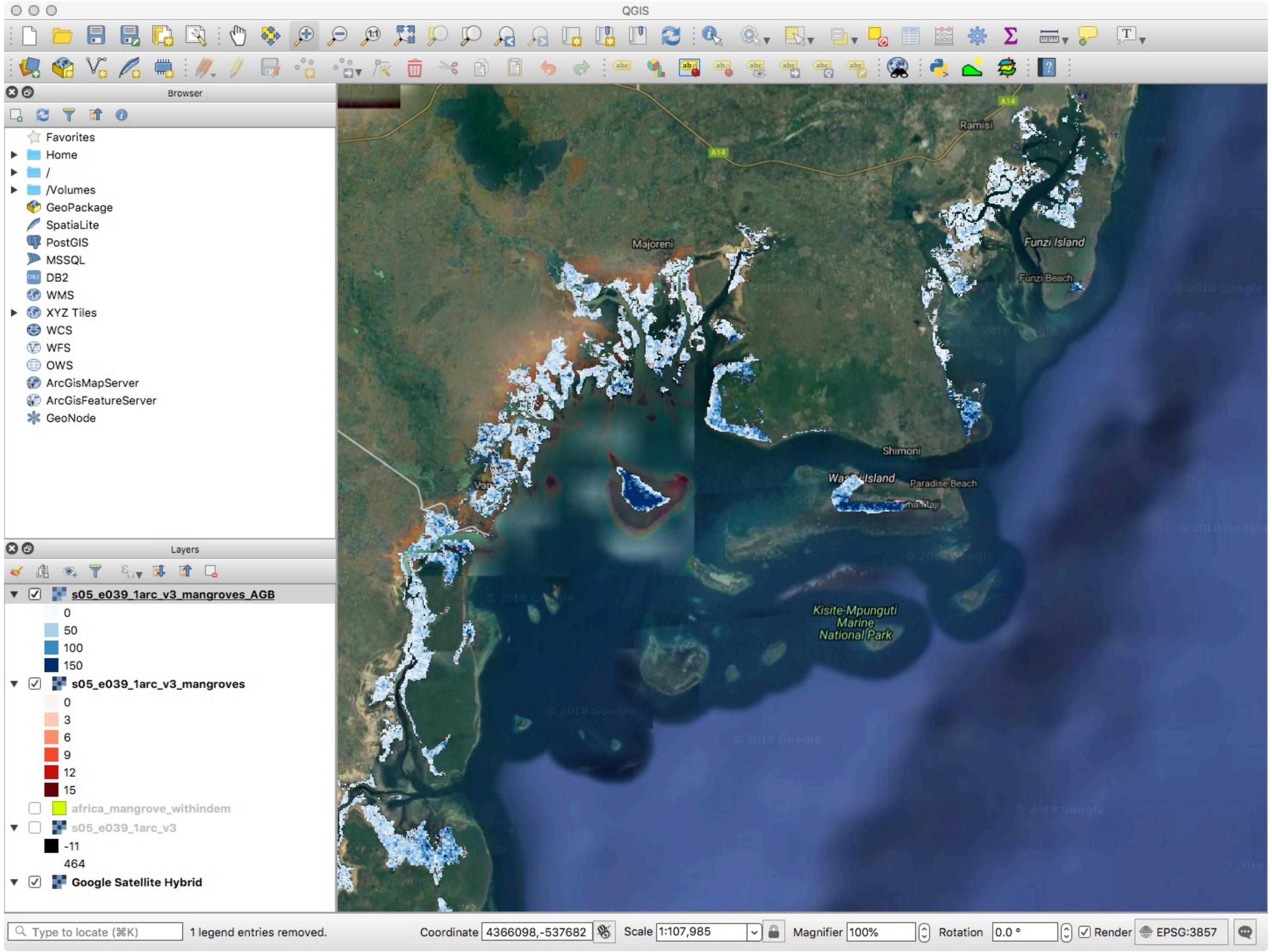
DEM_mangrove_AGB



Applying the Generic Height-Based Allometric Equation



Value	Color	Label
4.03		4.03
49.1		49.1
94.3		94.3
139		139
185		185

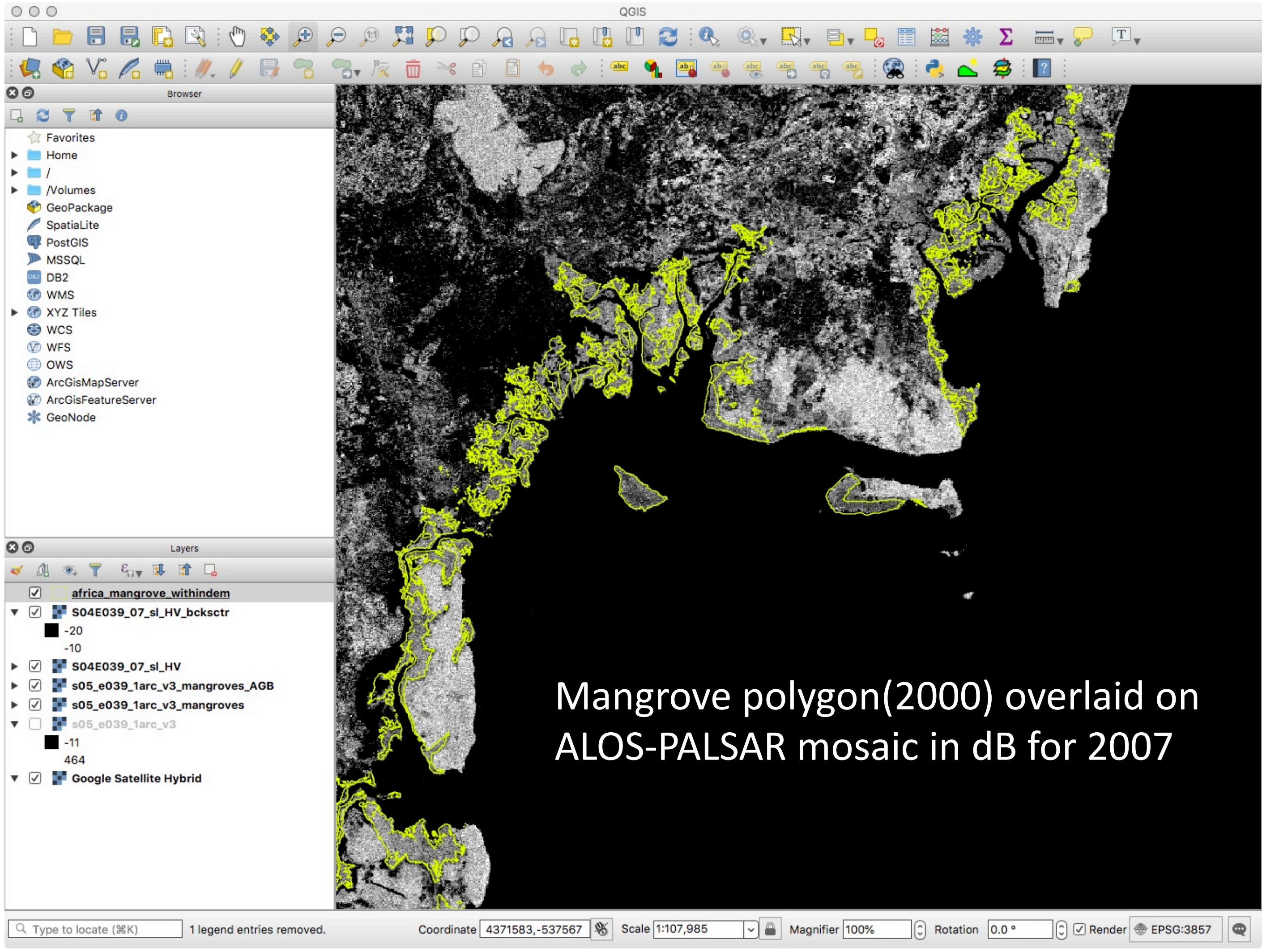


Applying the Generic Backscatter-Based Allometric Equation

1. Upload either the Radar images generated with through SNAP processing in dB, or the ALOS-PALSAR mosaics.
   - Note that in the mosaics, the digital number (DN) value of the pixel must be transformed to dB using the following JAXA-provided formula:
     - $s^{o}_{HV}(dB) = 20*\log_{10}(DN) – 83$
2. In top menu, click ”Raster”, then “Raster Calculator”.
3. Enter formula in ”Raster Calculator Expression”. Double-click on band name to insert in expression.

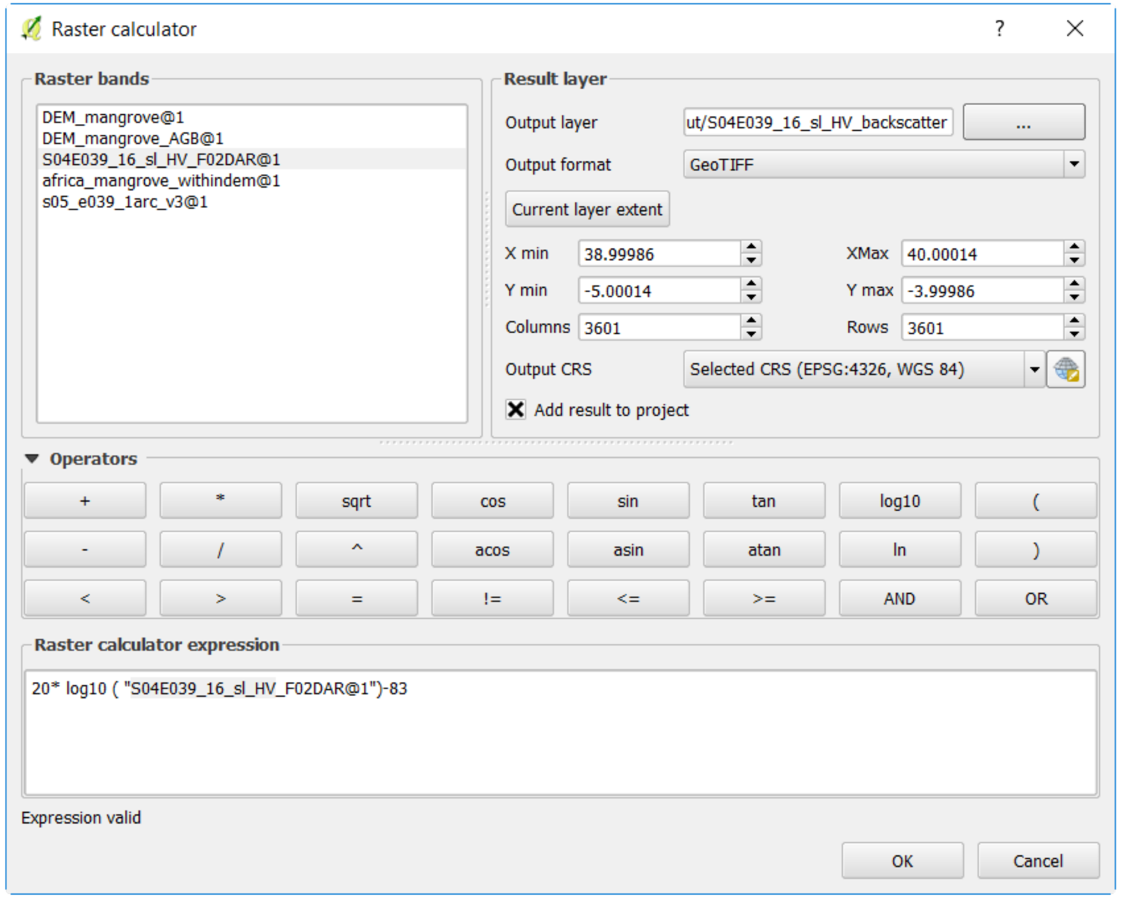
ALOS PALSAR mosaic S04E039_16_MOS_F02DAR

Dar es Salaam, Tanzania



Applying the Generic Backscatter-Based Allometric Equation

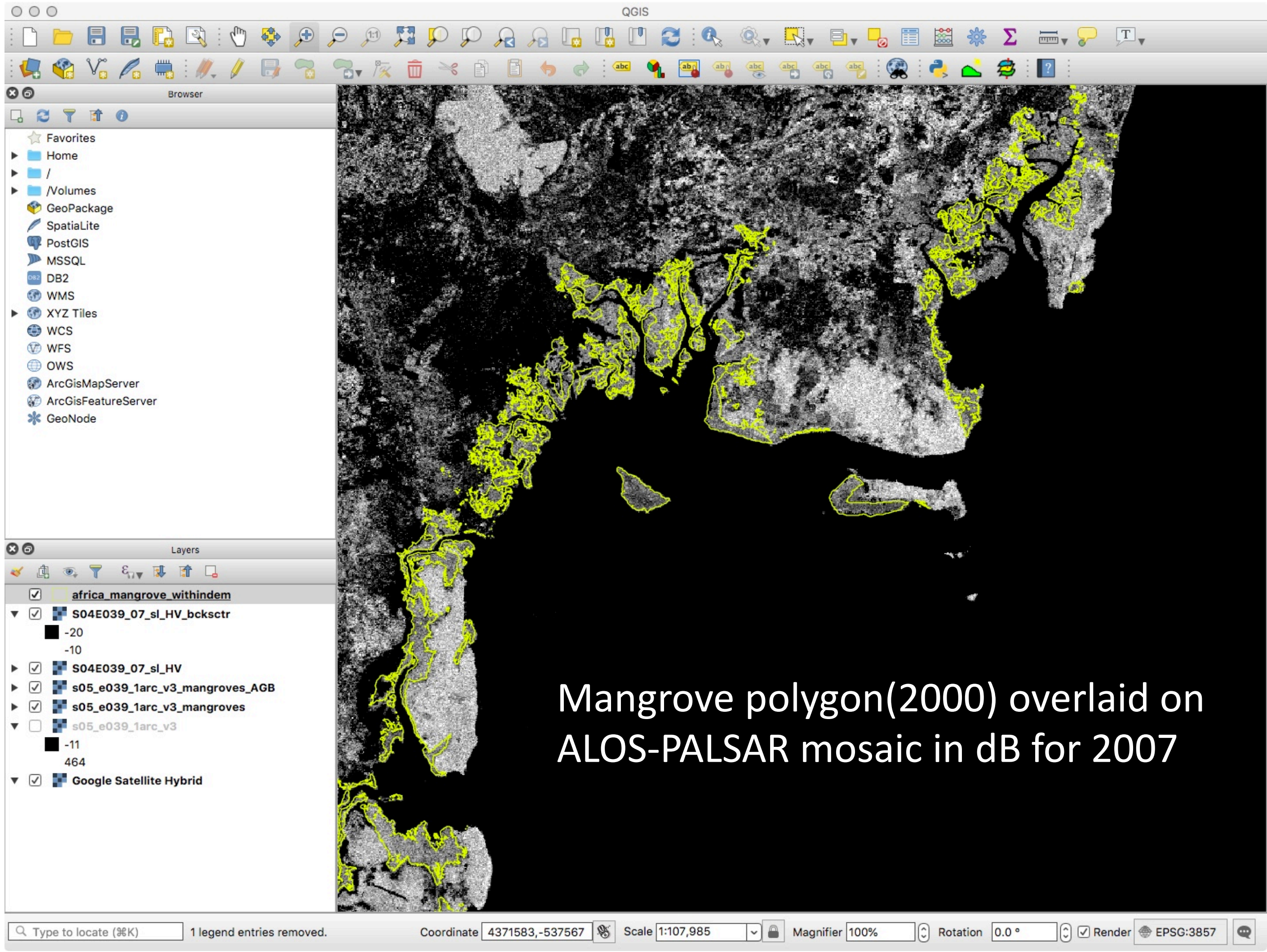
Convert digital number (DN) value to dB - backscatter



Formula: $20*\log_{10}(DN) - 83$

ALOS PALSAR mosaic S04E039_16_MOS_F02DAR

Dar es Salaam, Tanzania

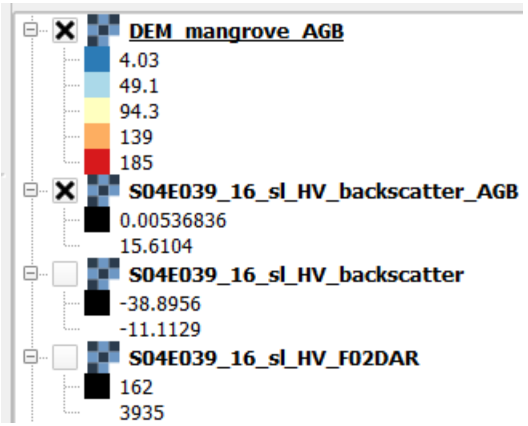


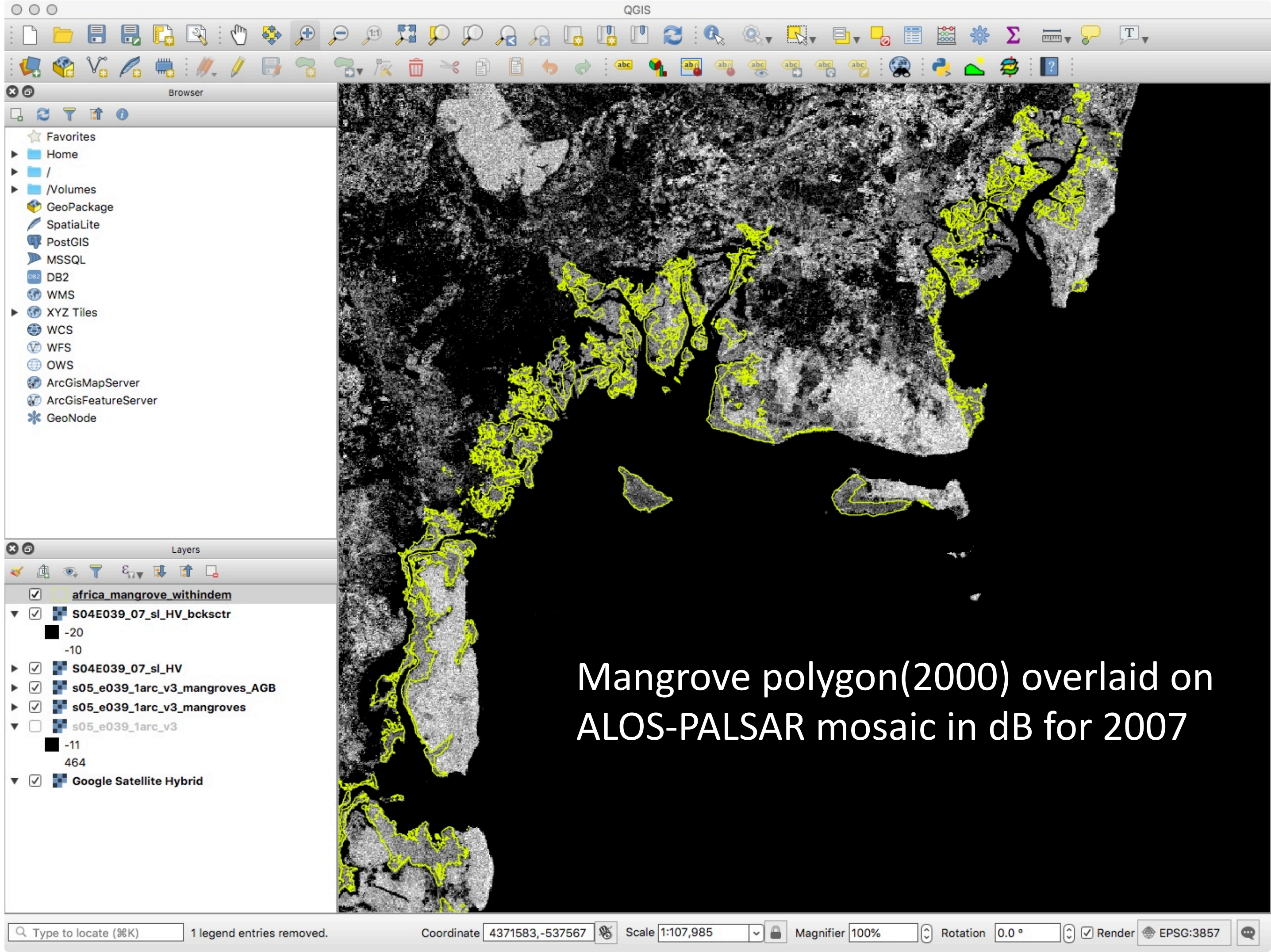
Mangrove polygon(2000) overlaid on ALOS-PALSAR mosaic in dB for 2007

Applying the Generic Backscatter-Based Allometric Equation

4. In top menu, click on "Raster" and then "Raster Calculator". Enter allometric equation in "Raster Calculator Expression", i.e. $0.5*10^{(40.2*\text{"RasterImage"})}$ with "RasterImage" in linear unit (m^2/m^2). That means if your equation, if using a dB image, becomes: $0.5*10^{(40.2*10\text{^}(\text{"RasterImage"}/10))}$

0.5*10*(40.2*10^("S04E039_16_sl_HV_backscatter"/10))



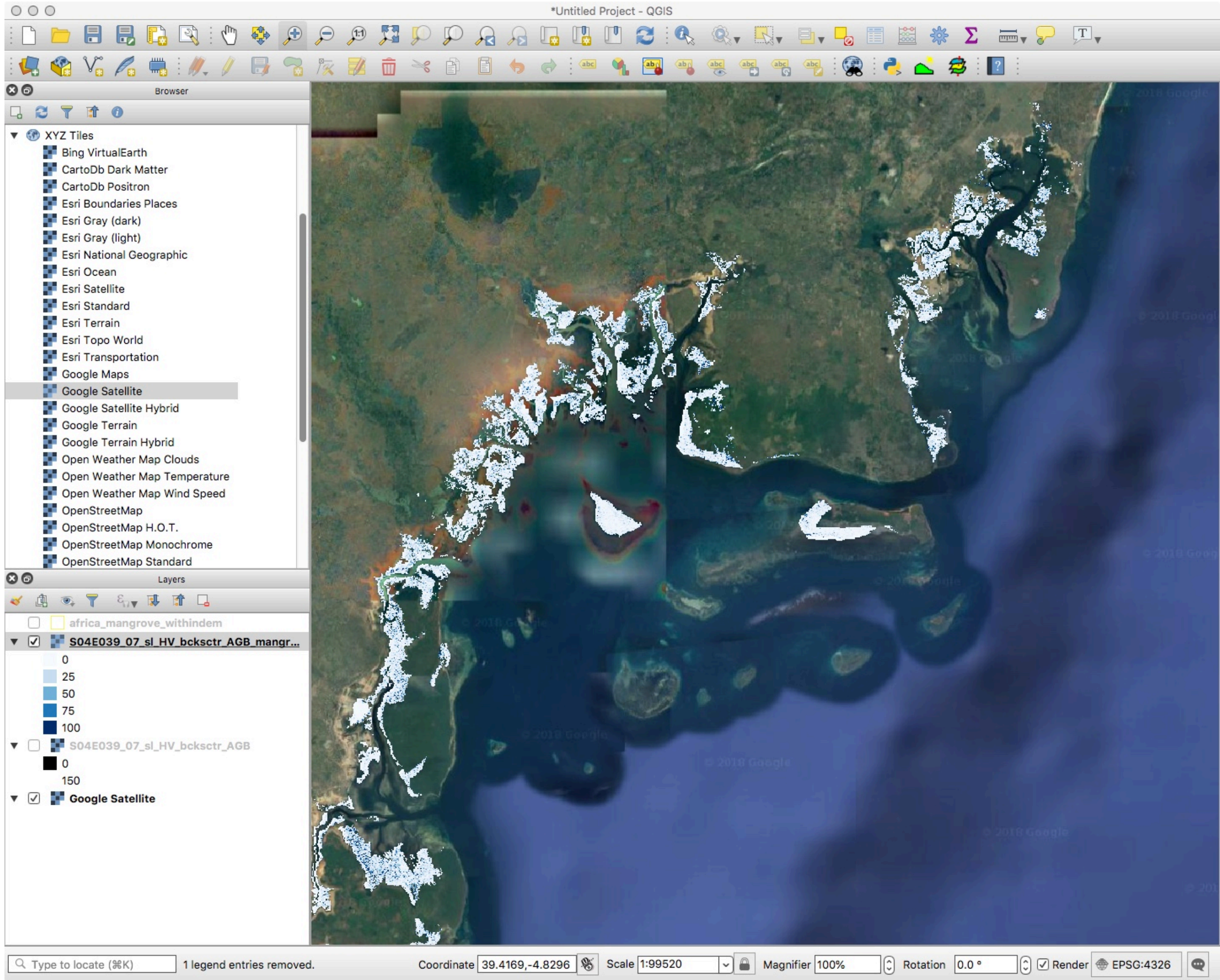


Mangrove polygon(2000) overlaid on ALOS-PALSAR mosaic in dB for 2007

Applying the Generic Backscatter-Based Allometric Equation

5. Use same mangrove polygon file used with SRTM to extract the mangrove extent. Use QGIS (currently not working in 3.0 and 3.2) or copy/paste to your terminal window. E.g. *gdalwarp -ot Float32 -of GTiff -tr 0.0002222 -0.0002222 -tap -cutline /DIrectoryWherePolygonLocated/africa_mangrove_withindem.shp -crop_to_cutline /DirectoryWhereBiomassTransformedImageIsLocated/S04E039_07_sl_HV_bcksctr_AGB.tif /YourOutputDirectory/S04E039_07_sl_HV_bcksctr_AGB_mangroves.tif*

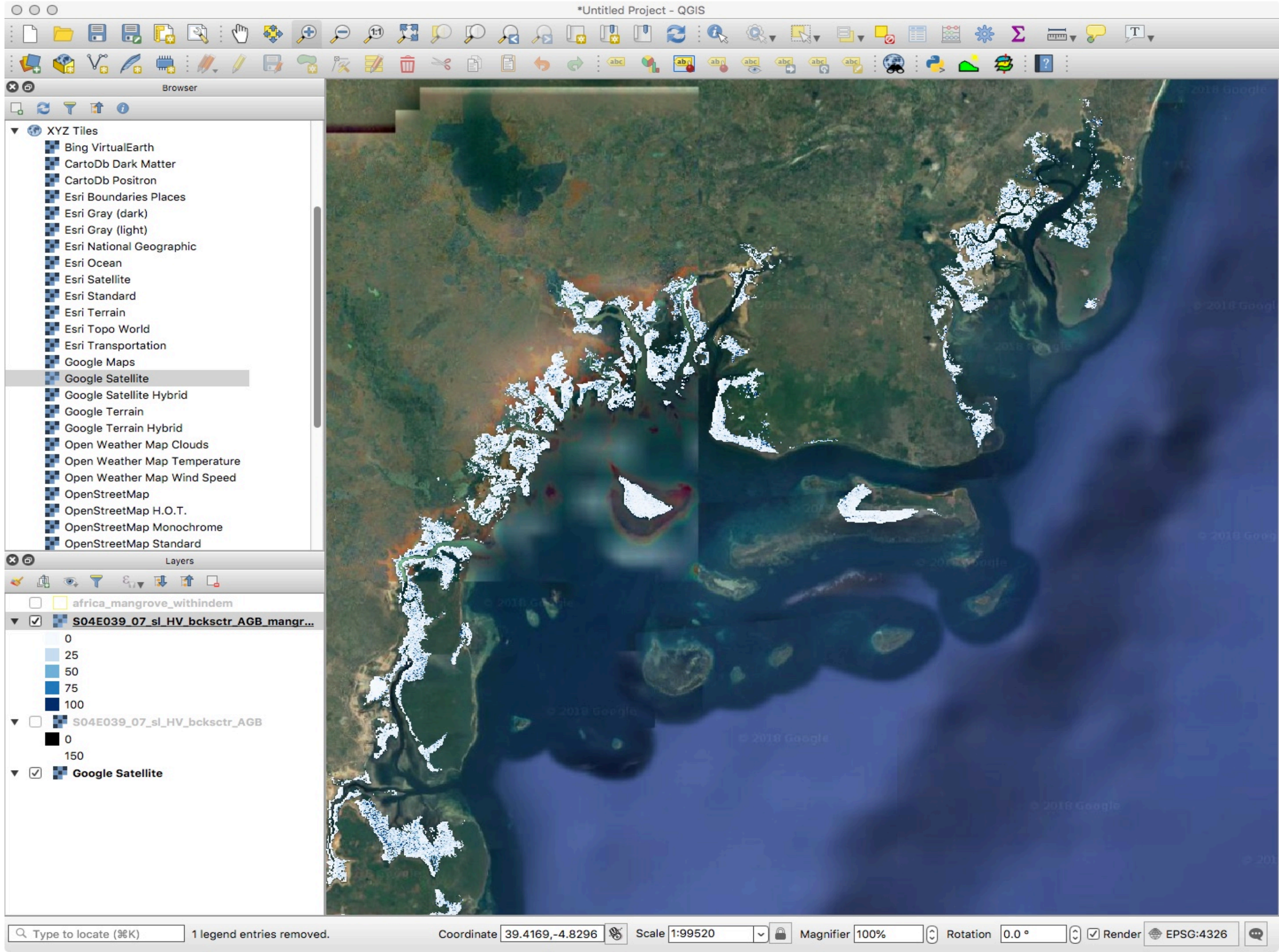
Mangrove polygon(2000) overlaid on ALOS-PALSAR mosaic in dB for 2007



Applying the Generic Backscatter-Based Allometric Equation

- This is the resulting aboveground biomass map for mangrove areas, based on the backscatter curve.
- The retrieved biomass is much lower than that obtained with SRTM.
- Backscatter is known to be limited in mangrove forest, changing with water level and mangrove types, sometimes decreasing at biomass above 100t/ha in red mangroves.

S04E039_07_sl_HV_bcksctr_AGB_mangroves.tif overlay on Google satellite



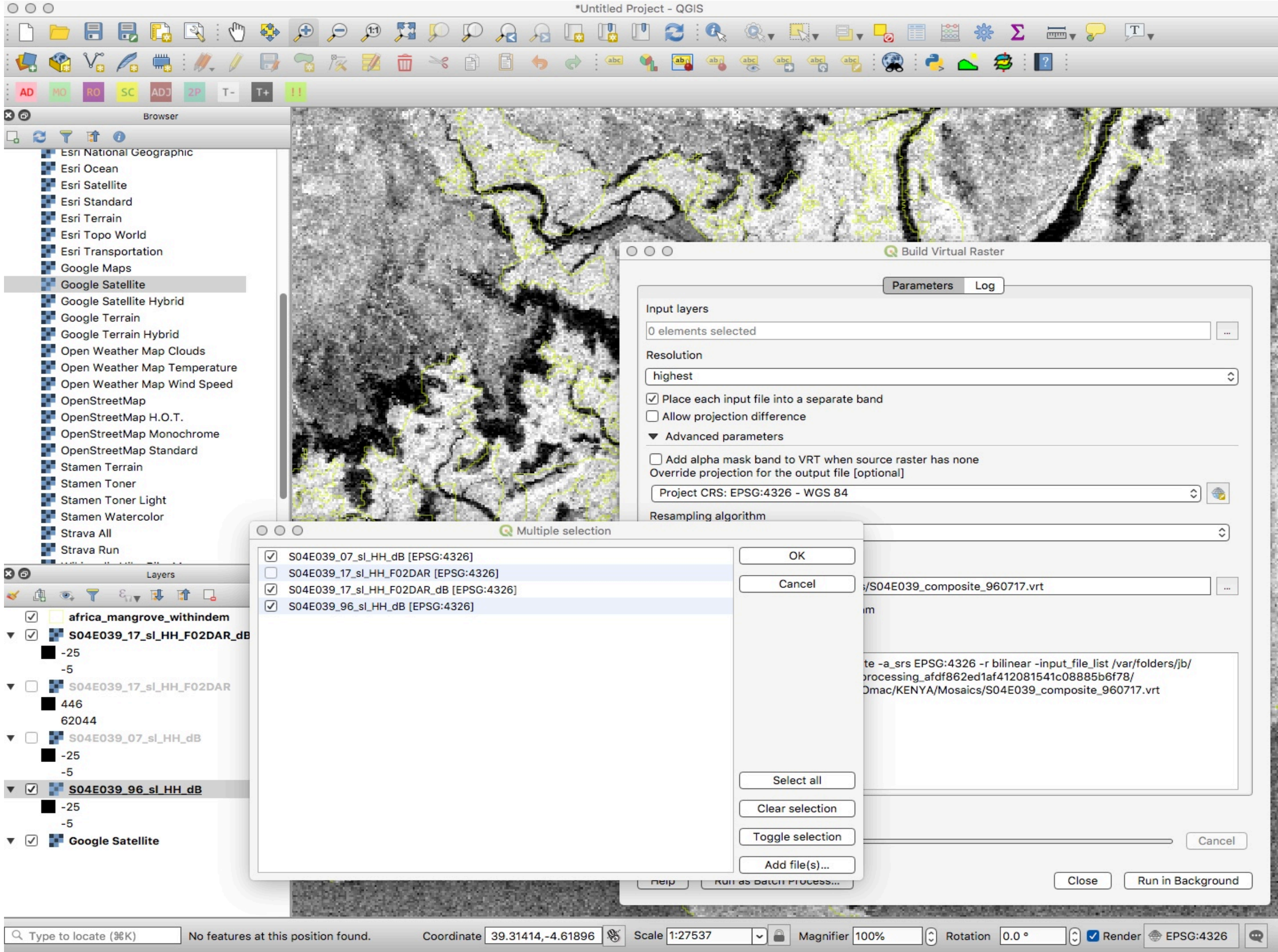
Optional: Deriving your own allometric equations

- Obtain field data with latitude, longitude and biomass.
- Make a CSV file.
- Read into QGIS:
  - In the top menu: click “Layer”->”Add Layer”-> ”->”Add Delimited Text Layer”. Then search your CSV file and follow instruction. Your may need to specify the projection in “Geometry”.
- If you have installed the QGIS “Point Sampling Tool” plugin, click on its icon and select your CSV layer.
  - Select the attributes you want to preserve in the output file.
    - These must, of course, include for example biomass and backscatter.
  - Define your “Output point vector layer”.
  - With the pop-up window, select “Comma Separated Values (*.csv)” as output format.
- Open your new CSV file in Excel and fit equation.
- In QGIS, apply new equation to radar backscatter image using the “Raster Calculator”.
- At this point, your can independently generate your own biomass map.
- Using this same method, you can also validate your biomass maps using available field data.

Break..!

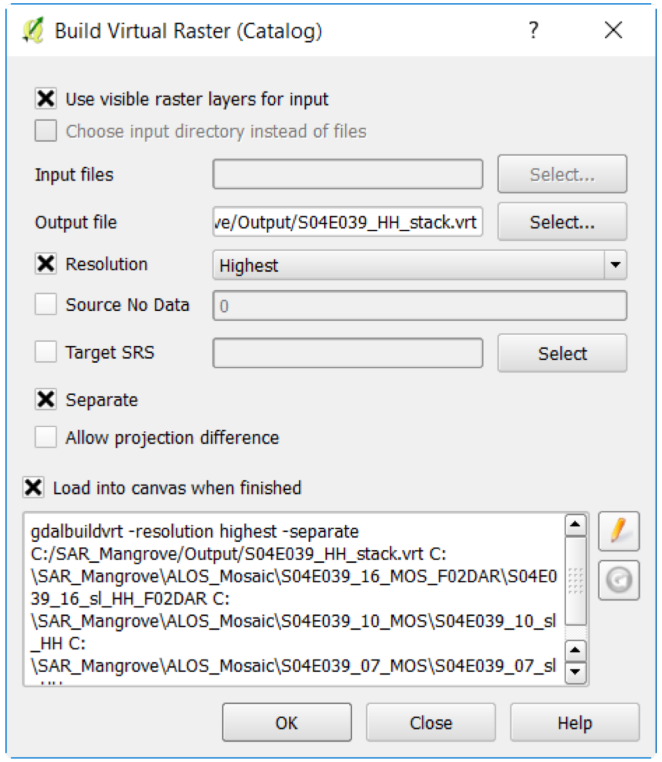
Monitoring mangrove forests loss and gain

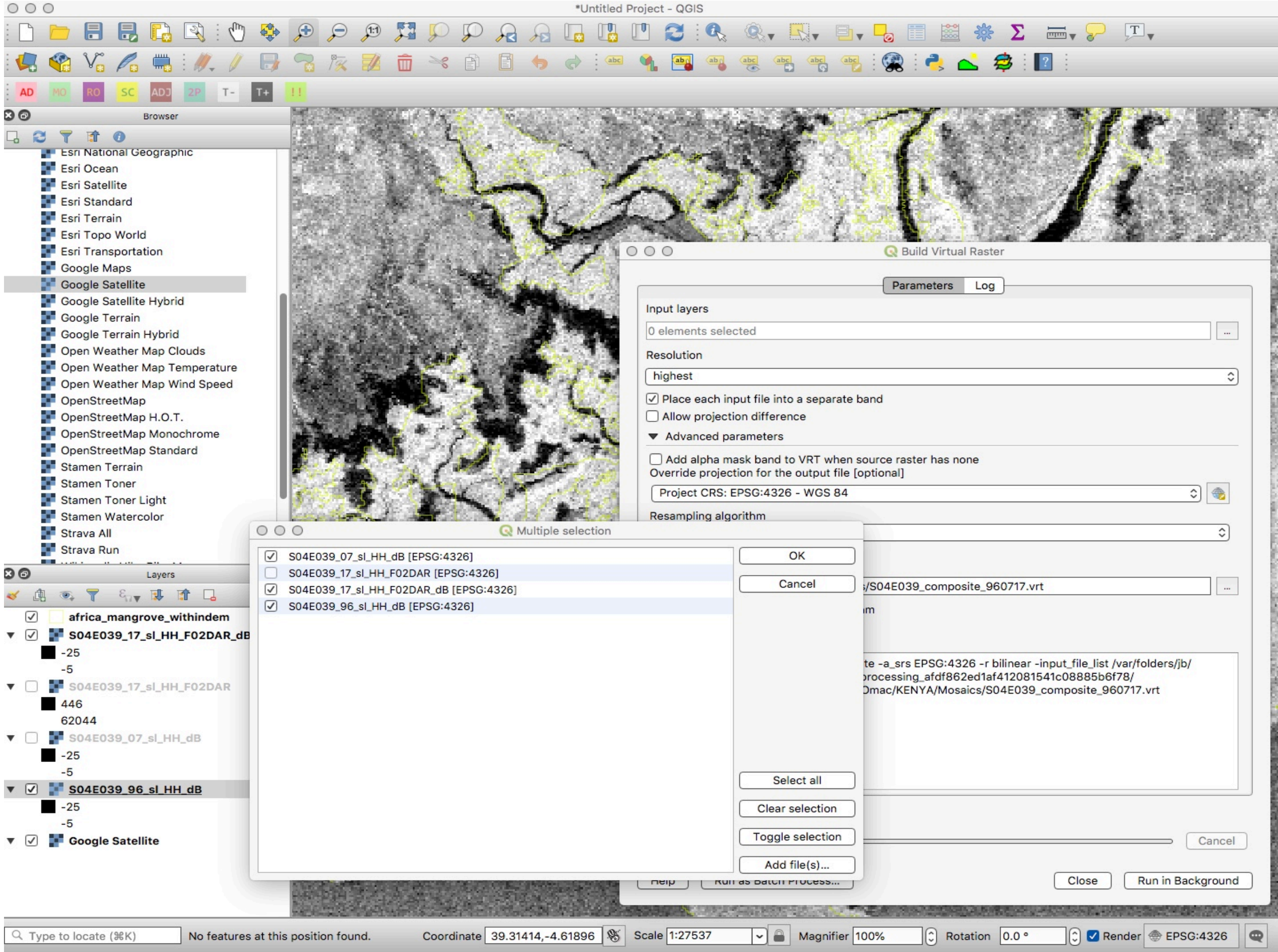
- While radar backscatter is not the best measurement to estimate biomass in mangrove forests, one can use it to monitor mangrove forest loss and gain through time.
- Use color composite to visualize changes:
- Load 3 images from different times into QGIS
  - e.g. JERS-1 (1996), ALOS-1(2007) and ALOS-2 (2017) mosaic tiles.



Monitoring mangrove forests loss and gain

- ALOS-2 (2017) mosaic tiles.
- Navigator: Click Raster - > Miscellaneous -> Build Virtual Raster

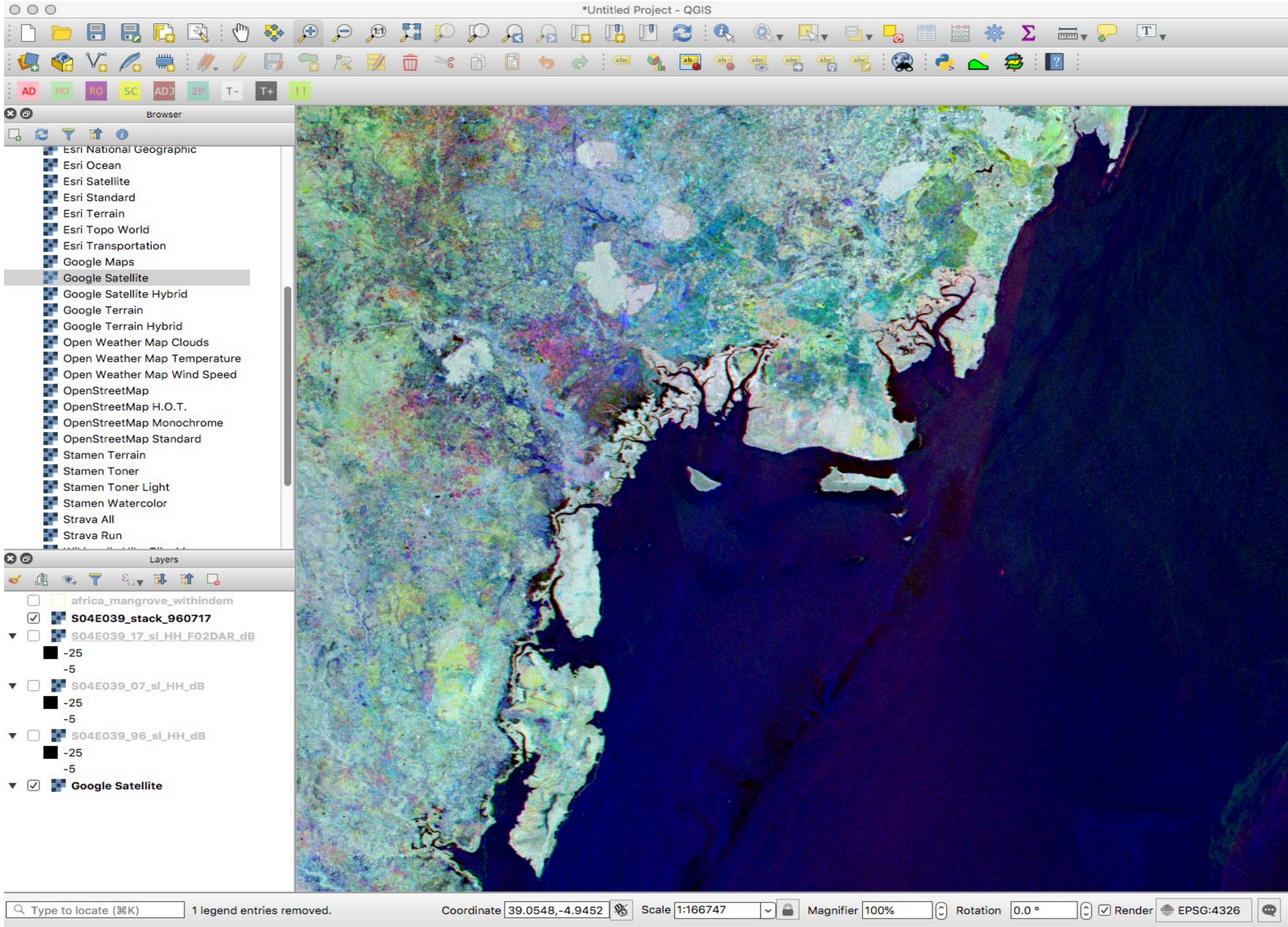




Monitoring mangrove forests loss and gain

SERVIR

- Load the virtual raster into QGIS.
- Change colors using “Properties” by right clicking on the virtual raster.
- If red, change occurred between you first input band and the others
- If green, change occurred only for the 2nd band. i.e. change occurred between band 1 and 2 but change again, may be returning to original land cover between image 2 and 3.
- If blue, there may have been some regeneration.



Monitoring mangrove forests loss and gain

Exercise – detect changes in a virtual stack

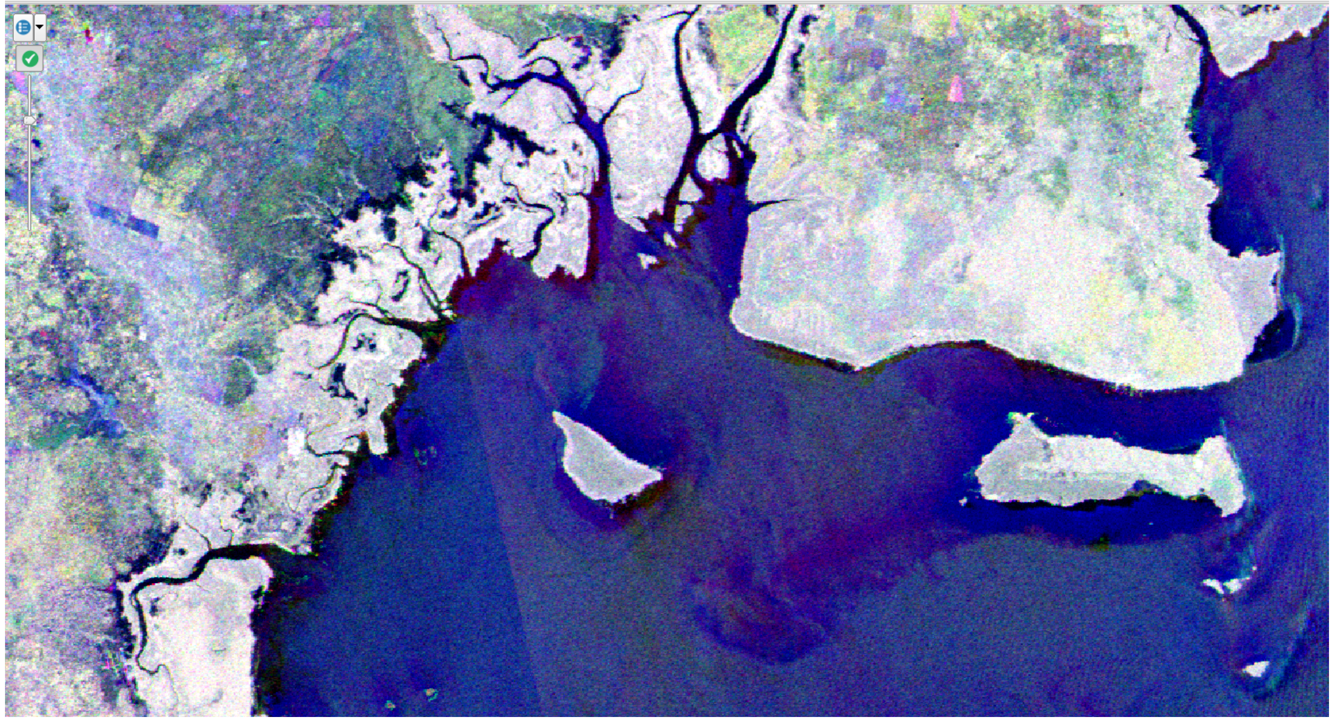
- Monitor changes, generate your time-series from either ALOS mosaics or Sentinel-1 time-series, processed through SNAP. You can choose the acquisition dates to correspond to plant phenology and climatic trends.
- Convert the images to backscatter values

  Hint : Convert DN to db

  $s^{o}_{HV}(dB) = 20*\log_{10}(DN) – 83$

  In dB values; -20 and -5, and -25 and -10 for HH and HV respectively
- Have you found significant changes in mangrove forests for the study region?

ALOS Mosaic – back scatter values: S04E039_HH: 07, 10, 16

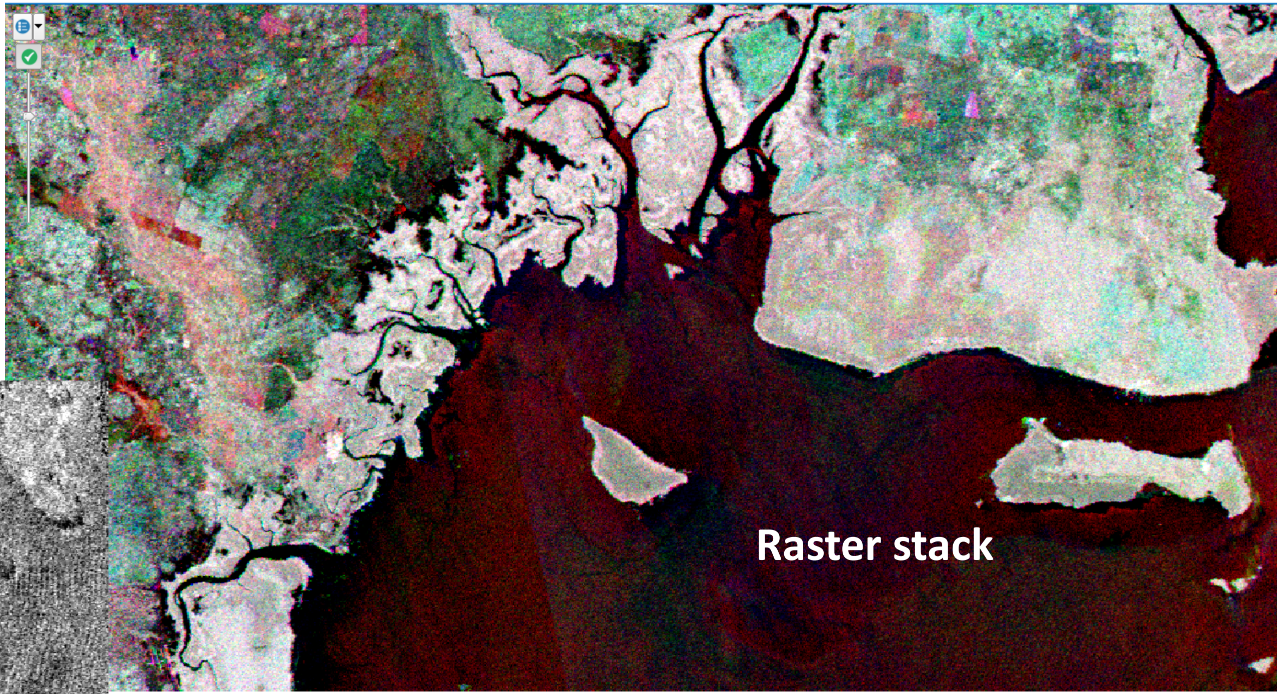


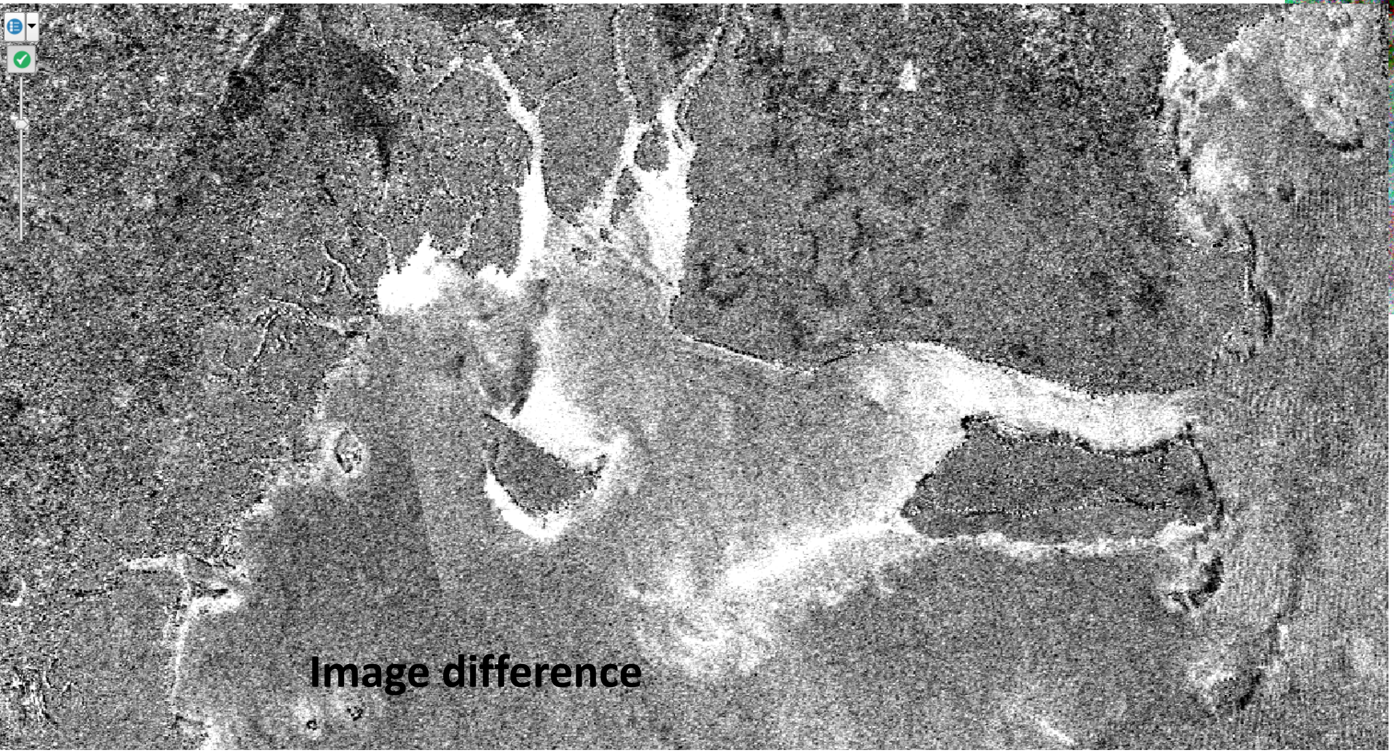
In the example above, we used ALOS mosaics of HH: S04E039_07_MOS, S04E039_10_MOS, S04E039_16_MOS_F02DAR

Monitoring mangrove forests loss and gain

- Determine change areas with simple thresholds
- In QIGS, use ”Raster”->”Raster Calculator” to compute the difference between two bands from different years.

ALOS Mosaic – back scatter values: S04E039_HH: 07, 10, 16



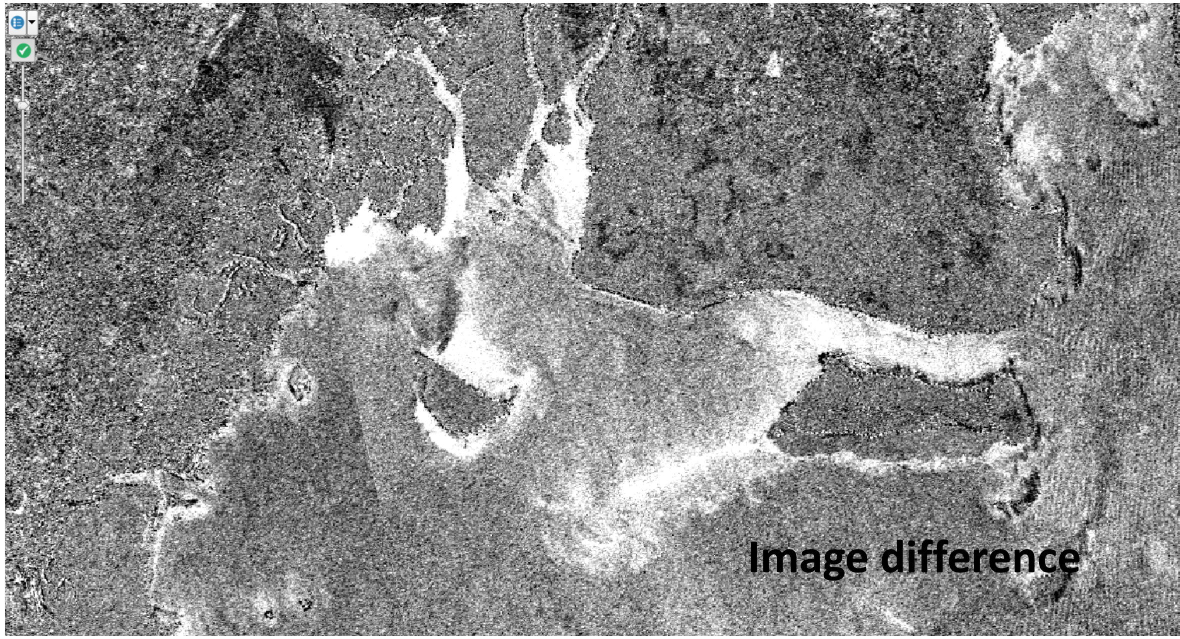


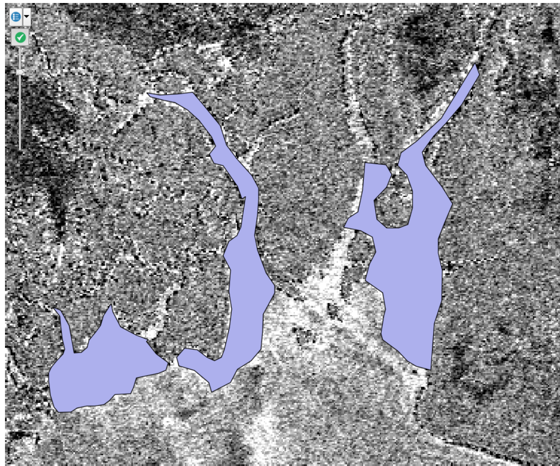
You will notice some changes between the two images. This is the same location over the coast of Kwale, Kenya. Coordinates: -4.66, 39.279

Make a polygon of observed change

- In top menu click “Layer”->”Create Layer”->”New Shapefile Layer”
- Define “Geometry Type” as “polygon”.
- Define output filename in “File Name” and in “New Field” use whole number. We’ll use 1 for change.
- In the “layers” window, click on this new layer
- In top menu click ”Layer”->”Toggle Editing”. You can now add features within the file by clicking in the top menu “Edit”->”add polygon feature”
- Draw polygon around observed changes in difference map with mouse click on vertices of polygon. To close polygon, right click. Don’t forget to save after you are done (by clicking “Toggle Editing” again.

ALOS Mosaic – back scatter values: S04E039_HH: 07, 10, 16





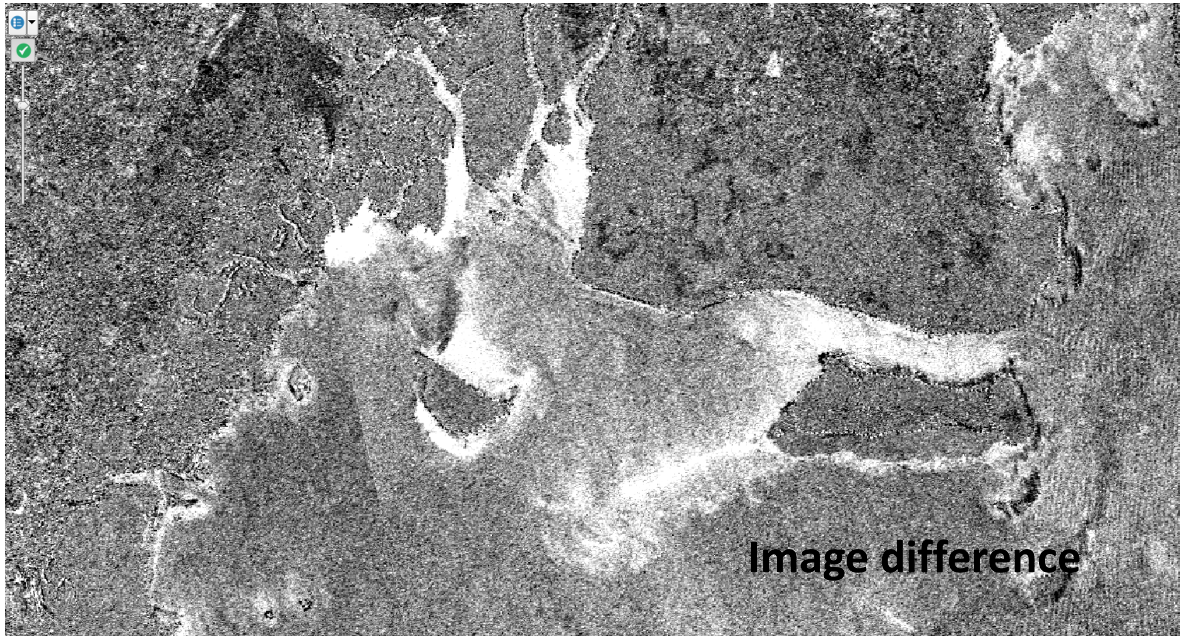
Monitoring mangrove forests loss and gain

Make a polygon of observed change

- To populate the polygons with attribute values containing statistics from the difference image, use “SAGA” in the toolbox. To see the the toolbox, click “Processing” in the top menu and then “Toolbox”. Navigate to “SAGA”->”Vector-Raster”->”Raster Statistics for polygons”.
- Compute zonal statistics of the polygon

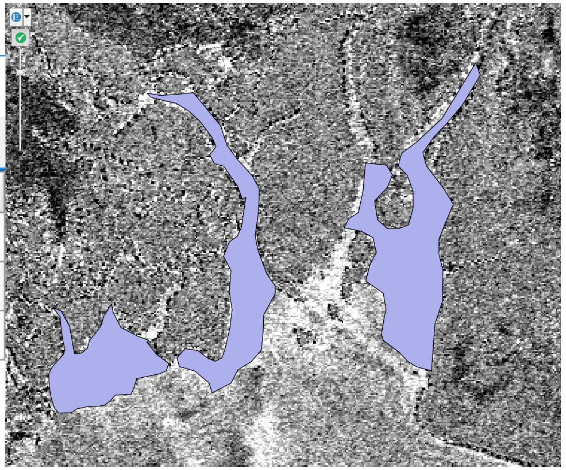
    Click “Processing” in the top menu and then “Toolbox”.
    Type Zonal Statistics and it will appear under Raster tools.

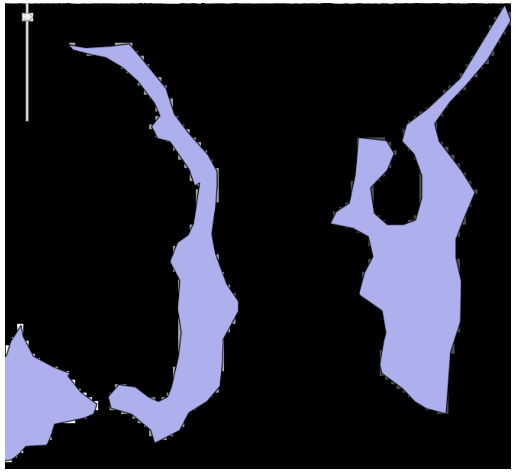
ALOS Mosaic – back scatter values: S04E039_HH: 07, 10, 16



Zonal statistics :: Features total: 3, filtered: 3, selected: 0

	id	Change	Areas	_min	_max	_sum	_count	_mean
1	2	1		2.000000	2.000000	1226.000000	613.000000	2.000000
2	3	1		3.000000	3.000000	1464.000000	488.000000	3.000000
3	1	1		1.000000	1.000000	925.000000	925.000000	1.000000



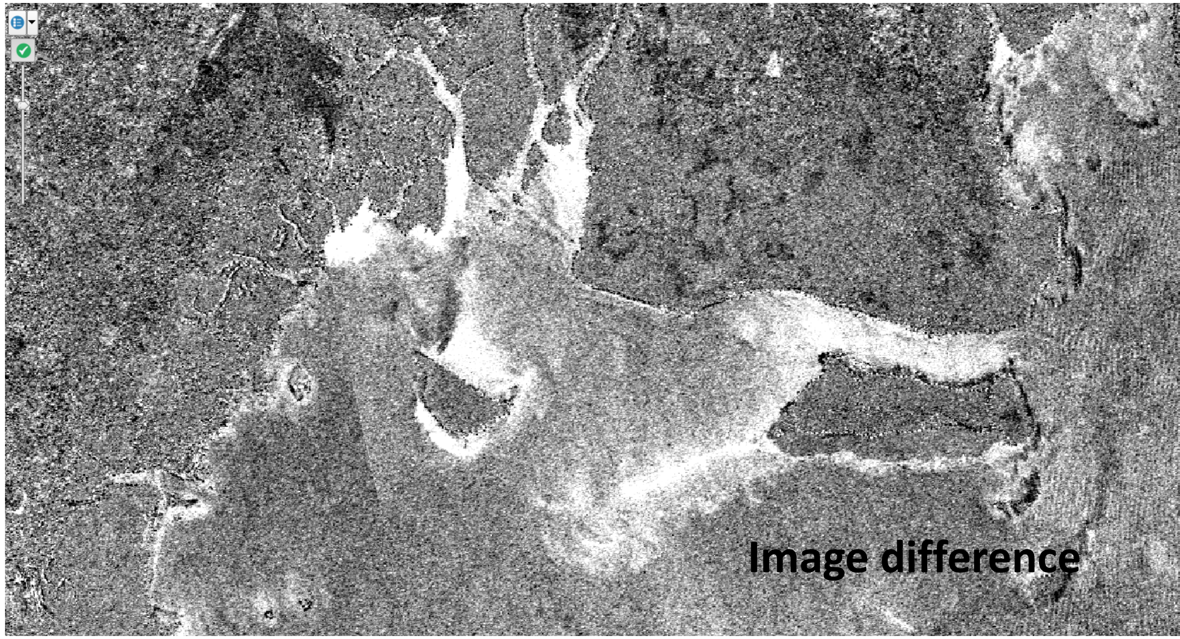


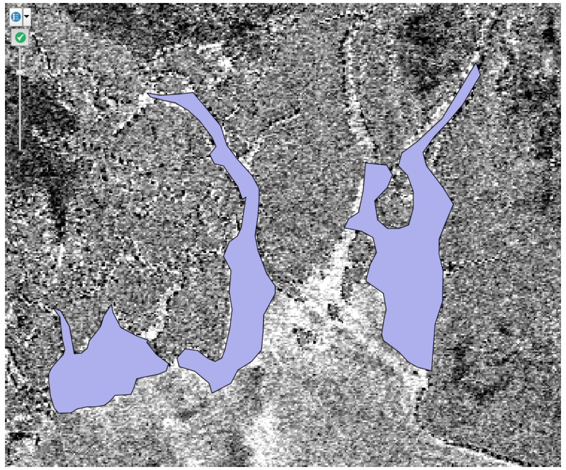
Monitoring mangrove forests loss and gain

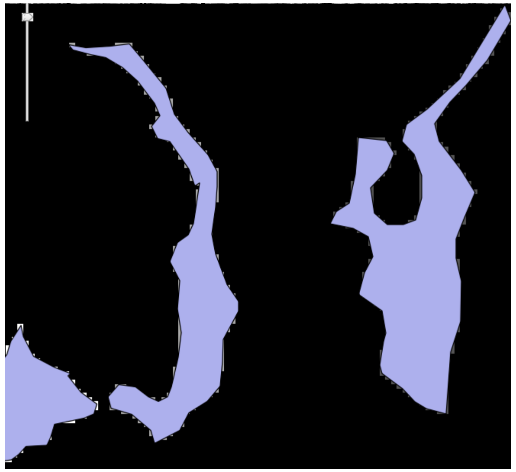
Use “Raster”->”Raster Calculator” to make a change map

- The equation can, for example, have the following form ("S04E039_07minus96@1"<-7.0) and ("S04E039_07_sl_HH_dB@1">-15)
    - The logical operators select all values smaller than -7 (i.e. change) that are above -15 in 2007. The latter condition removes some water surfaces when using HH. You can build you own water mask and use it instead.
- To clean-up the *change map,* use the “Majority Filter” found in “SAGA”->”Raster Filter”. A filter of radius 1 is sufficient to remove false changes that may results from radar speckle noise.
- Try again but filter the radar images with the “Multidirectinal Lee Filter” found in “SAGA”->”Raster Filter”

ALOS Mosaic – back scatter values: S04E039_HH: 07, 10, 16



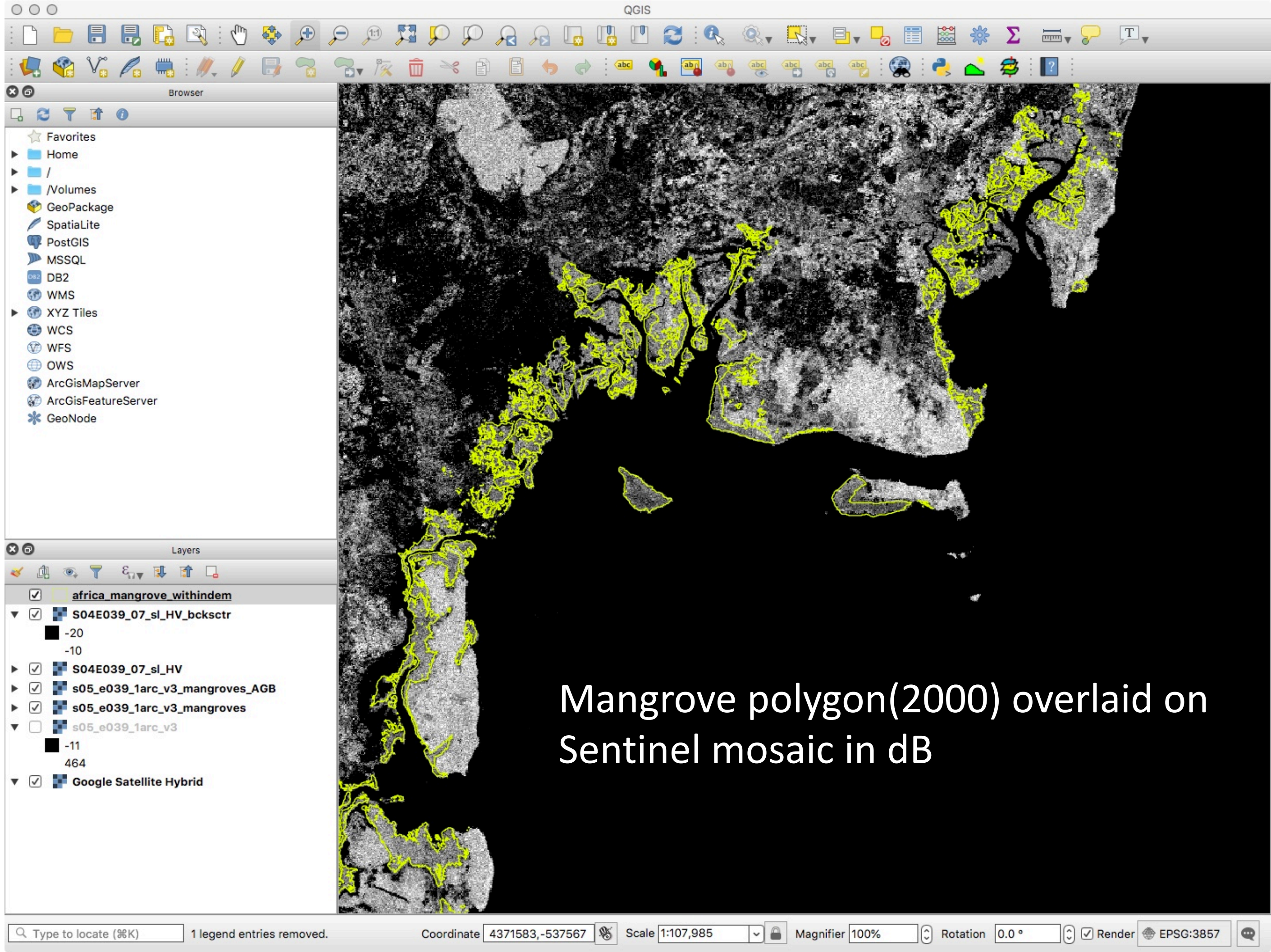




Exercise: Monitoring mangrove forests – Sentinel data

1. Upload the Radar images generated with through SNAP processing in dB from Sentinel 1 in **QGIS**.
   - Note that in the mosaics, the digital number (DN) value of the pixel must be transformed to dB using the following JAXA-provided formula:
     - $\sigma^{o}_{HV}(dB) = 20*\log_{10}(DN) - 83$
2. In top menu, click ”Raster”, then “Raster Calculator”.
3. Enter formula in ”Raster Calculator Expression”. Double-click on band name to insert in expression.

Sentinel 1 data– back scatter values



Thank you

SERVIR

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