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UNIVERSITY OF MIAMI
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SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

Biomass Estimation in the Everglades using Synthetic Aperture Radar and Ground-based LiDAR

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Background

- Wetland ecosystems, such as the Everglades have greater carbon/biomass storage and sequestration capabilities than tropical forests .

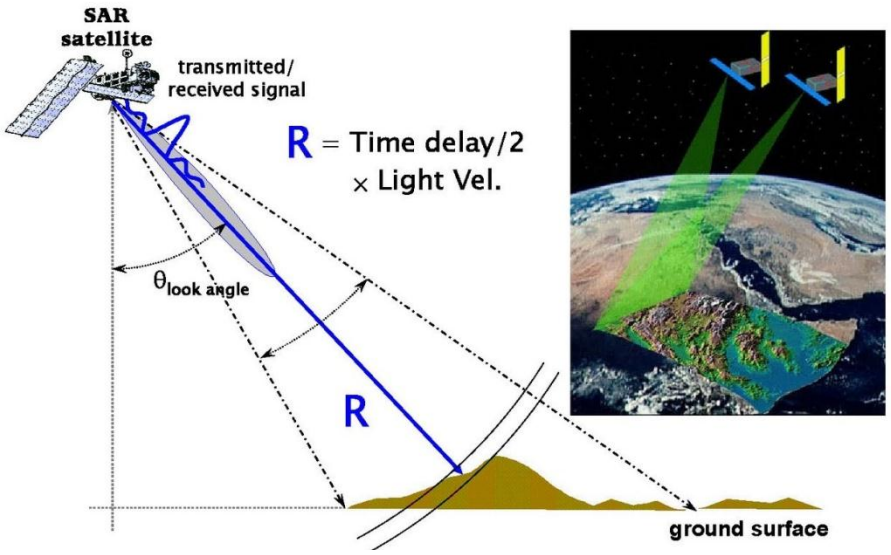
- Anthropogenic activities and climate change have disturbed many wetland ecosystems, including the Everglades.

- Wetlands are difficult to access - a combination of remote sensing techniques will give us a tool to monitor wetlands vegetation and changes over time.

- Application to other wetland ecosystems.

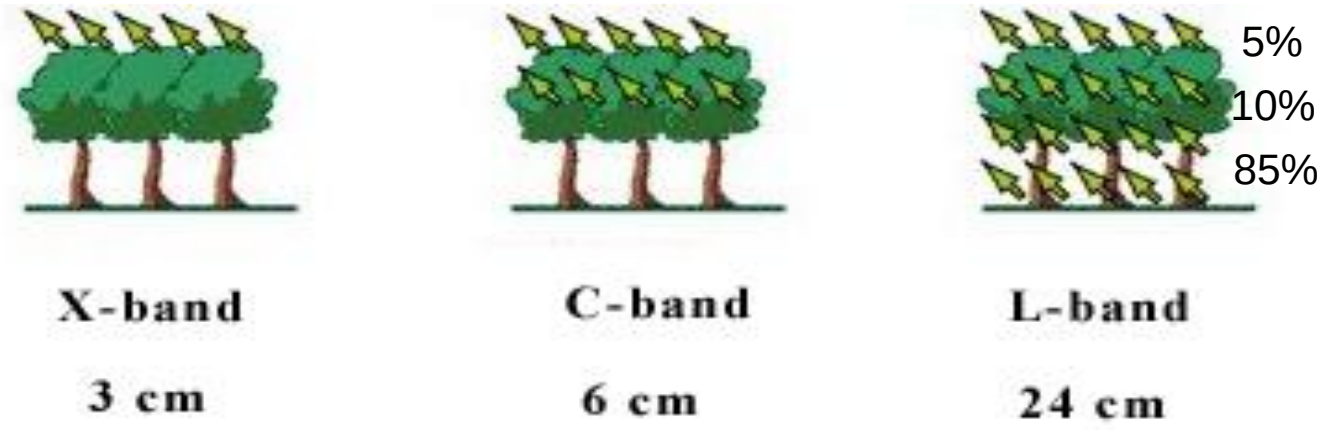
Synthetic Aperture Radar (SAR)

- Radar - active illumination system.
- Reflected signal or echo, is backscattered from the surface and received a fraction of a second later at the same antenna.



- Coherent radar system - amplitude and phase of the received echo are recorded.

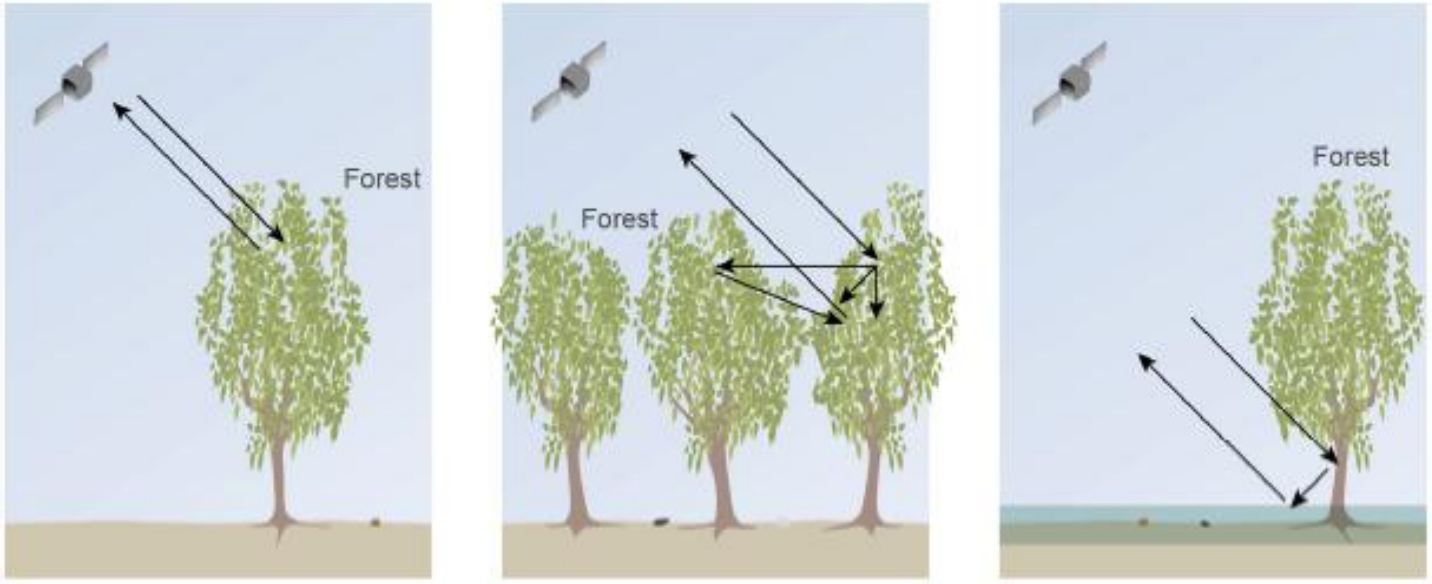
SAR Wavelength



by (ESA)

- *X-band (3.2 cm)*: canopies.
- *C-band (5.6 cm)*: canopies and branches.
- *L-band (24 cm)*: surface and lower portion of the vegetation.

SAR Polarization: Vegetation Scattering Theory



by Gondwe (2010)

<u>Current assumption:</u>

Single bounce = HH+VV

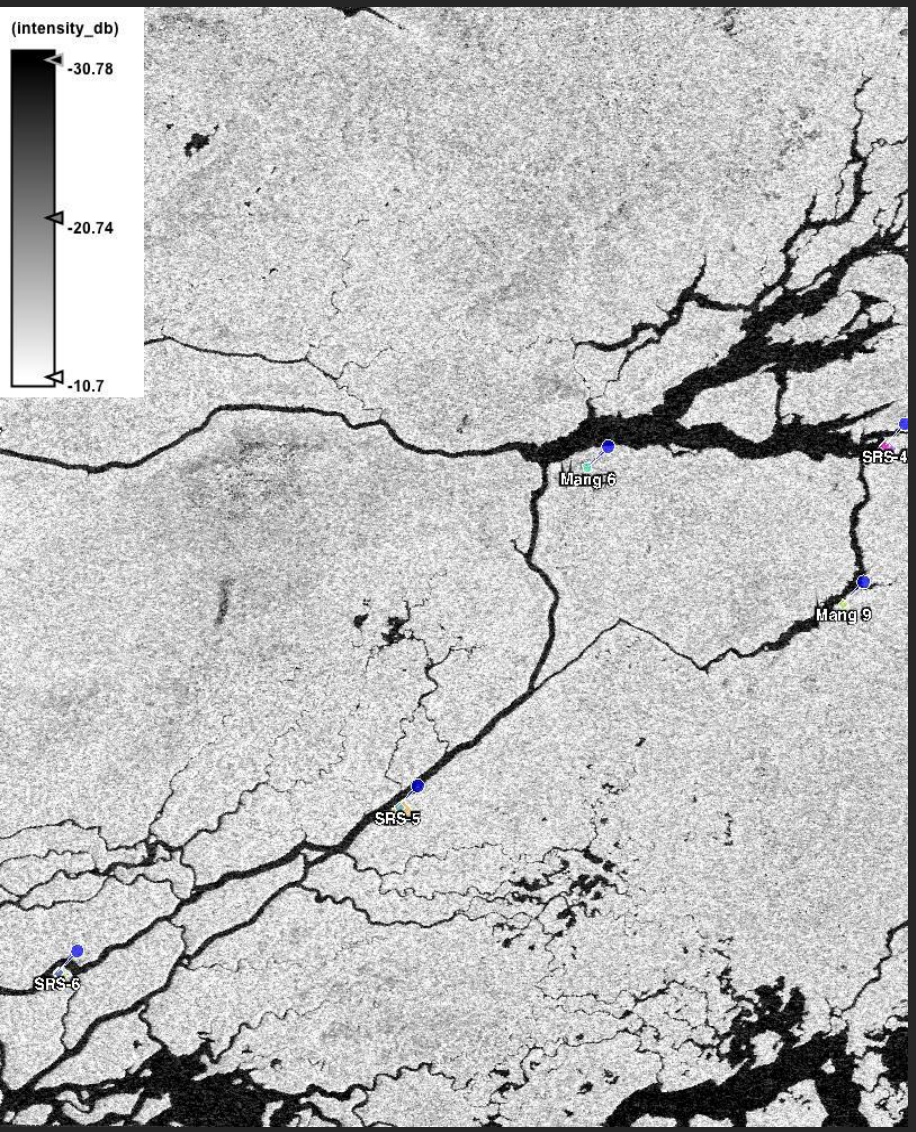
Double bounce = HH-VV

Volume scattering = HV

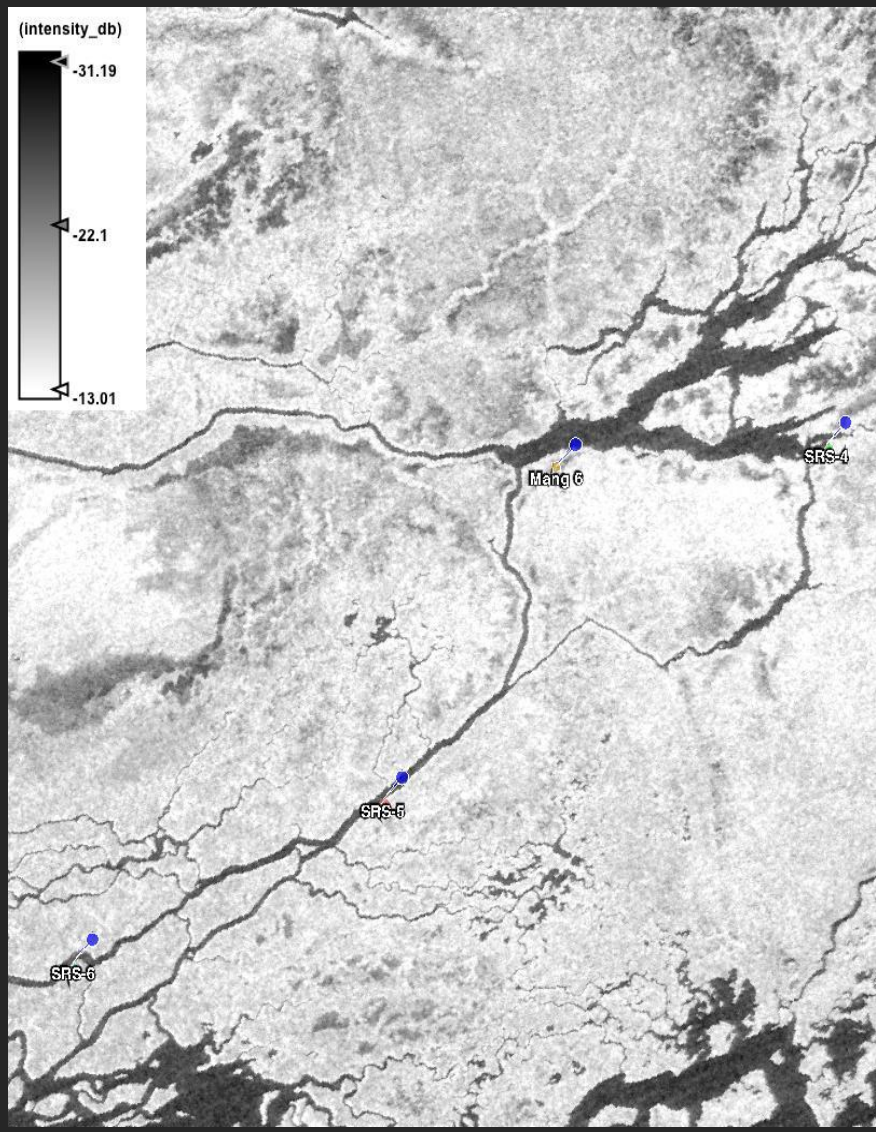
=> *HV has a double bounce component*

SAR

RADARSAT 2 - HV



ALOS PALSAR - HV



SAR Data Calibration

- SAR vegetation structure and biomass estimates **rely on calibration with ground-based estimates for more precise measurements.**

- Conducted 2 field measurement campaigns in various vegetation communities:

  1st : **Hammock, Pine and Cypress** (2010).

  2nd: **Tall mangrove, Intermediate and Small size mangrove** (2011).

- Field measurements included:

1) State-of-the-art Terrestrial Laser Scanning (TLS).

2) Traditional forestry surveys.

Terrestrial Laser Scanning - LiDAR

- **LiDAR** = Light Detection And Ranging

- Range is determined by measuring the time delay between transmission and detection of the reflected signal

- Ground-based LiDAR
  - Terrestrial Laser Scanning (TLS)
  - Laser scanner mounted on tripod
  - Surface models generated from point clouds

Everglades Field Campaign

SRS-5

SRS-4

Cypress

Hammock

Everglades Field Campaign

Site Name	Common Species Name	Specific Species Name
SRS-6	Red mangrove, White Mangrove, Black Mangrove	*Rhizophora mangle, Laguncuria racemosa, Avicennia germinans*
SRS-5	Red mangrove	*Rhizophora mangle*
SRS-4	Red mangrove	*Rhizophora mangle*
Cypress	Bald Cypress	*Taxodium distichum*
Pine	Pine tree	*Pinus elliottii*
Hammock	Various types vegetation	*n/a*

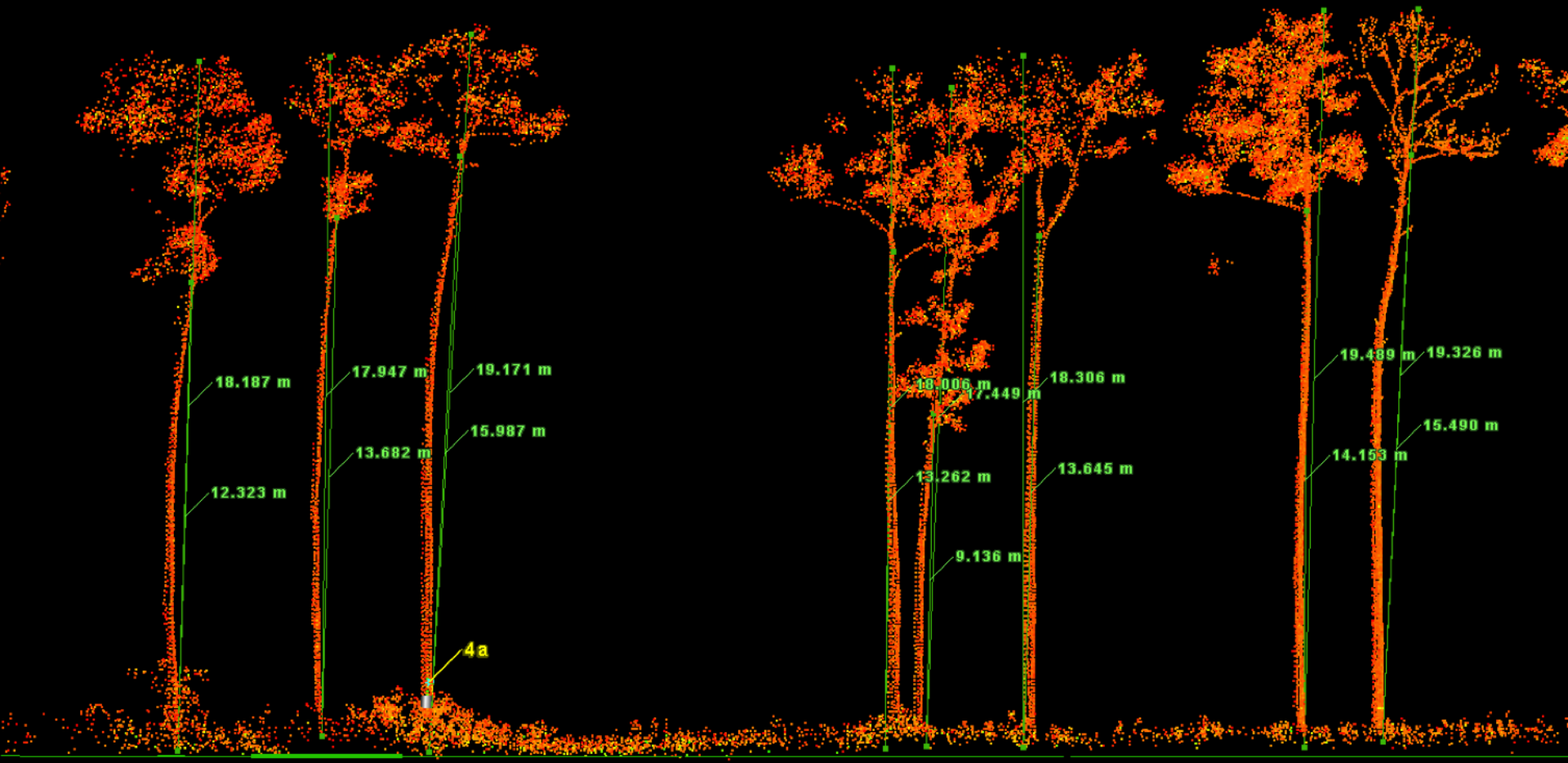
Site	Year	Scans	Plot Area (m)
SRS-6	2011	8	100 x 50
SRS-5	2011	8	50 x 50
SRS-4	2011	9	50 x 50
Cypress	2010	5	40x40
Pine	2010	7	150x150
Hammock	2010	17	50x50

Pine Site

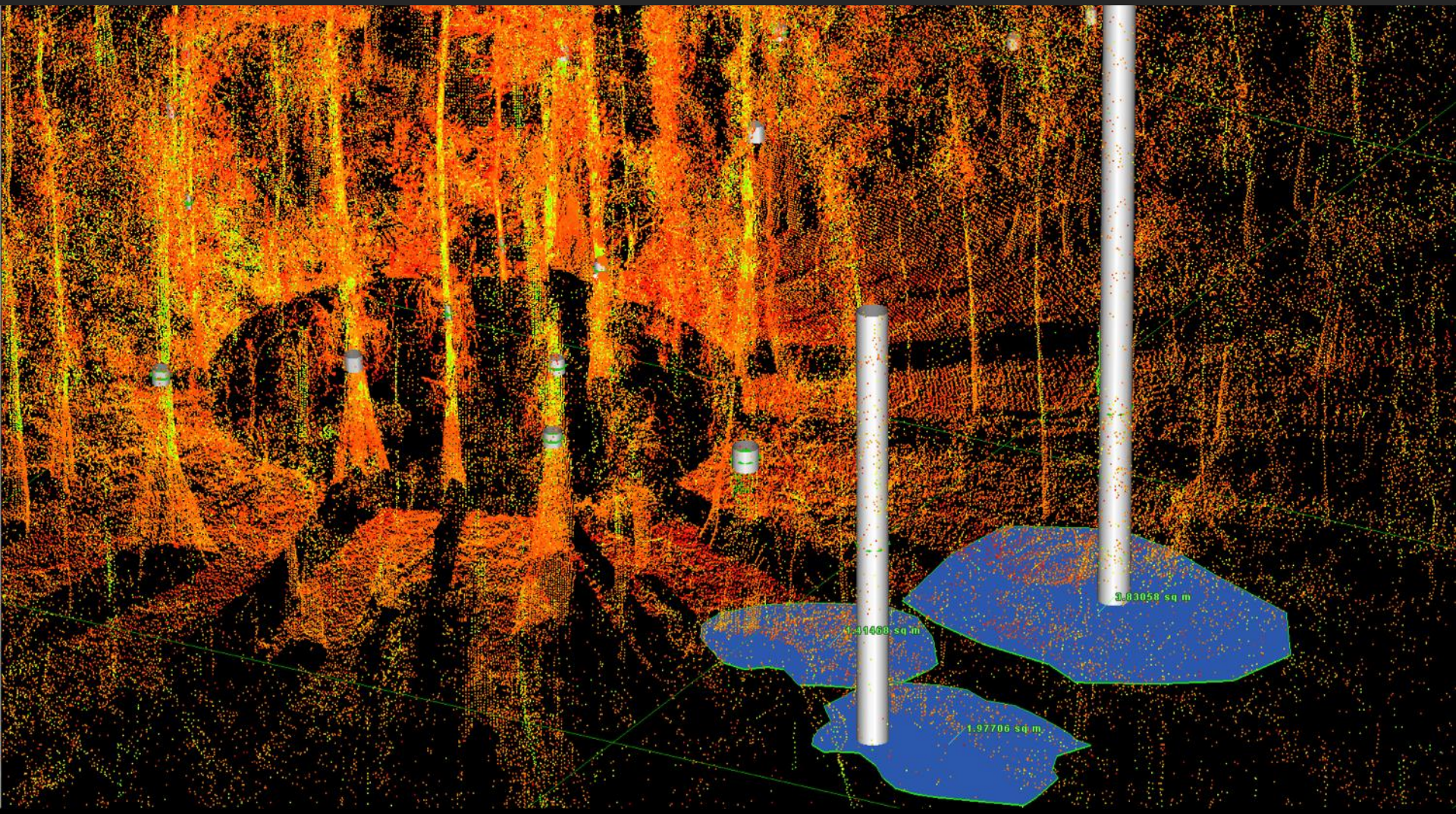
1.Height

2.Diameter

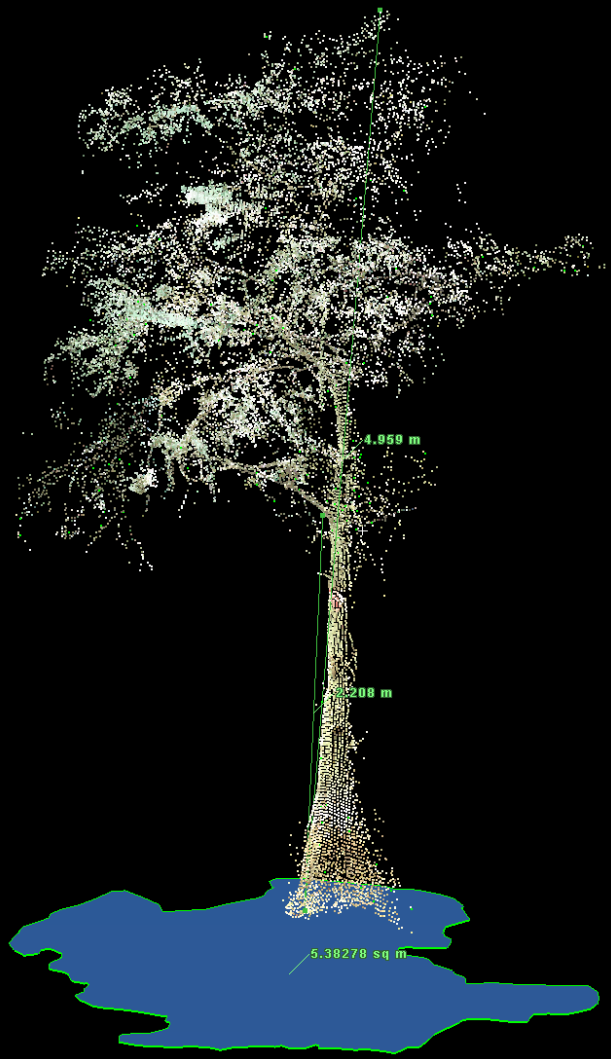
Pine Site

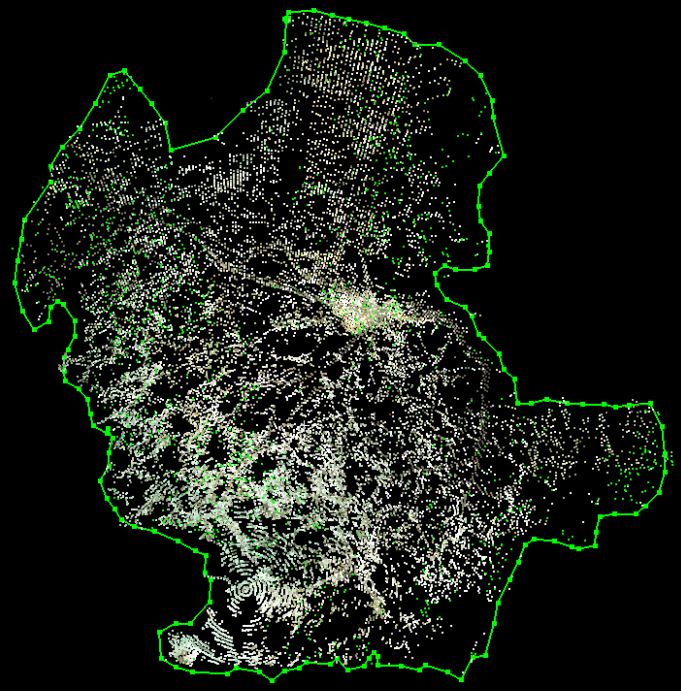

18.187 m
17.947 m
19.171 m
15.987 m
13.682 m
12.323 m
4a
18.306 m
13.645 m
9.136 m
19.489 m
19.326 m
15.490 m

Bald Cypress Site

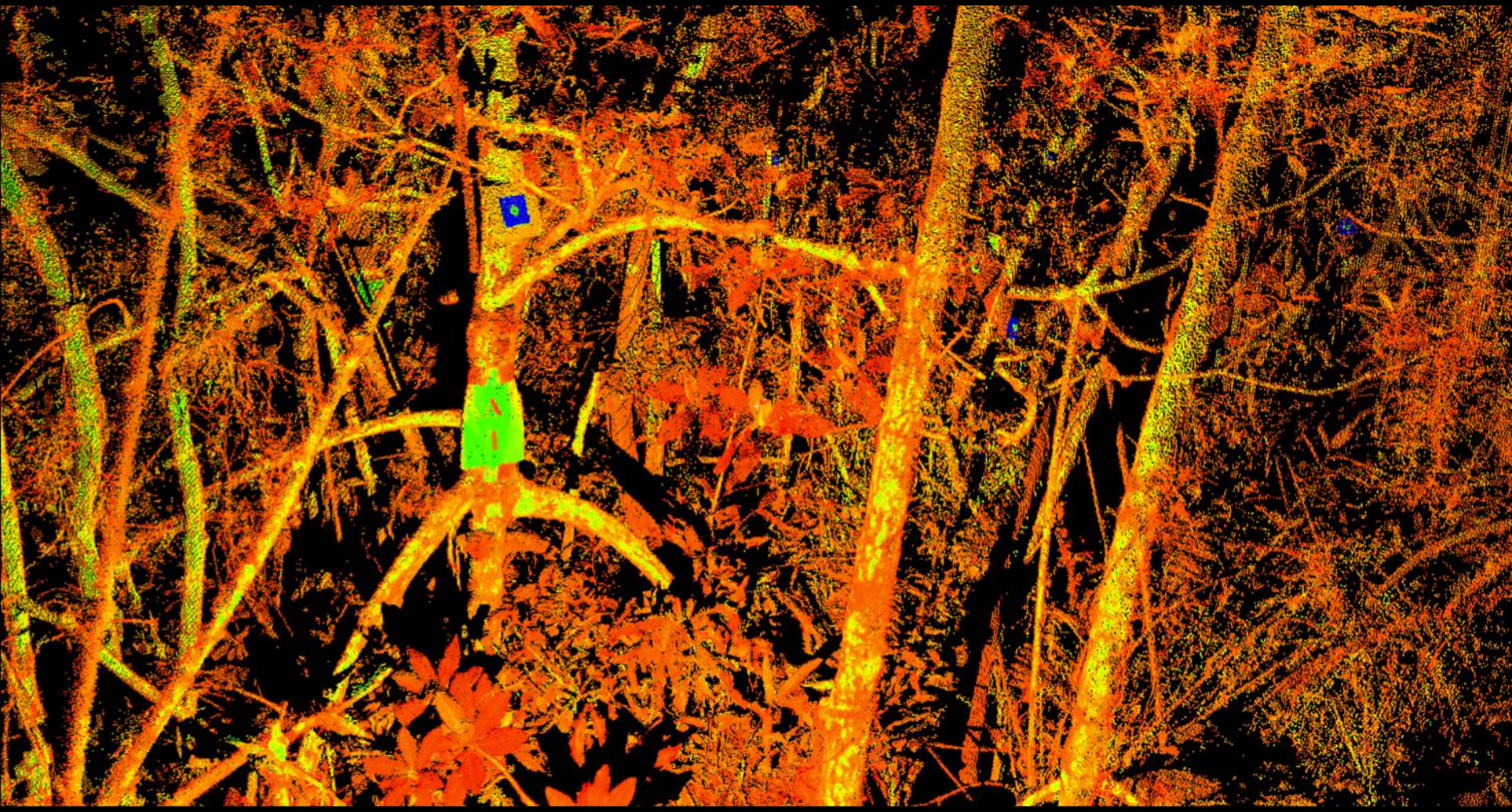


Cypress Site





Intermediate Mangrove Site: SRS 5

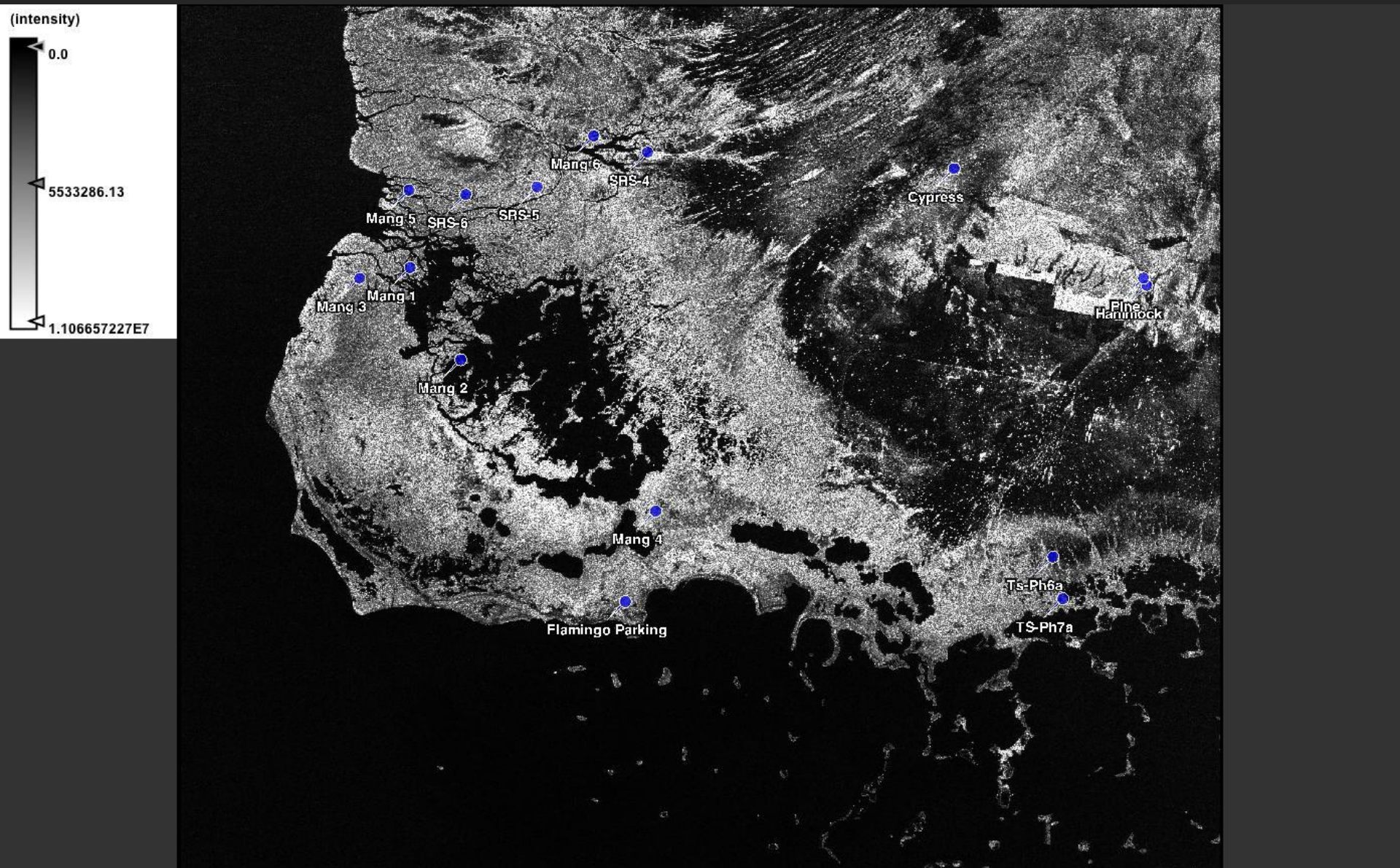


Intermediate Mangrove Site: SRS 5

Preliminary Biomass Estimations

Site	Biomass (Mg/ha)	Method/Formula	Source	RMS Error(%)
SRS-6	150	10*Canopy Height (m)	Simard et al., 2006	37
SRS-5	70	10*Canopy Height (m)	Simard et al., 2006	37
SRS-4	38	10*Canopy Height (m)	Simard et al., 2006	37
Cypress	108	bm = Exp(-2.0336 + 2.2592* In dbh)	Jenkins et al., 2003	20
Pine	63	bm = Exp(-2.5356 + 2.4349 * In dbh)	Jenkins et al., 2003	20
Ts-Ph6a	15	bm = 3.4980 * crown ^ -0.5083	Coronado-Molina et al., 2004	/
Ts-Ph7a	25	bm = 3.4980 * crown ^ -0.5083	Coronado-Molina et al., 2004	/

ALOS PALSAR - HV Raw Intensity Scene

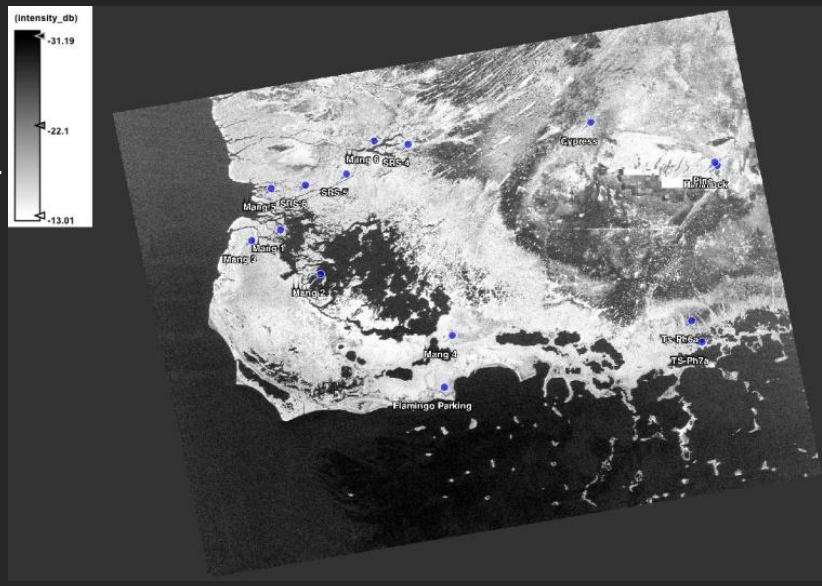


SAR Data Pre- and Post- Processing

1) Radiometric calibration:

Pixel Digital Number converted Sigma Naught (σ0)

Backscatter Coefficient in decibels (dB)



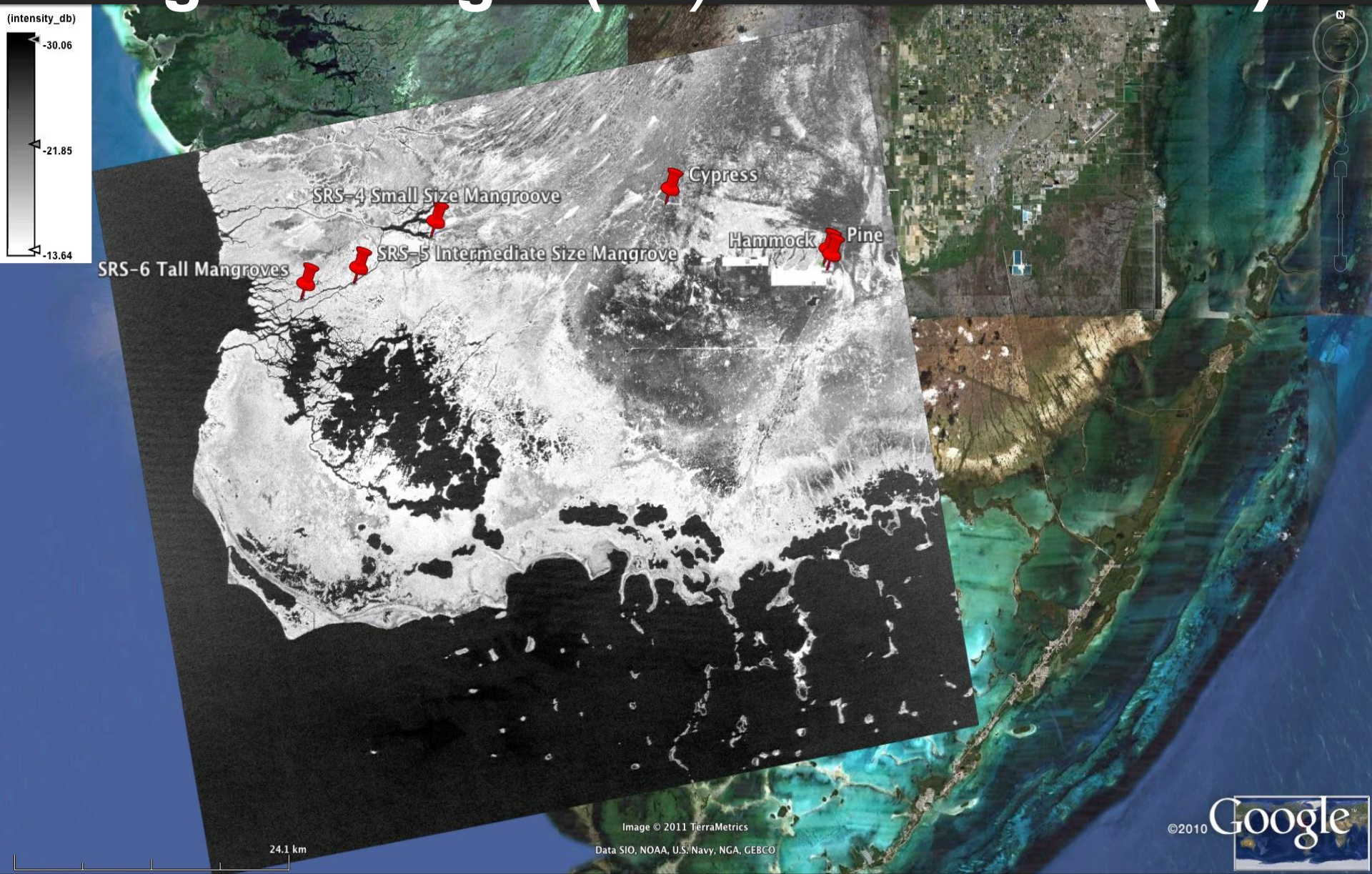
2) Coregistration of Multi-Temporal Data

3) Multi-Temporal Speckle Noise

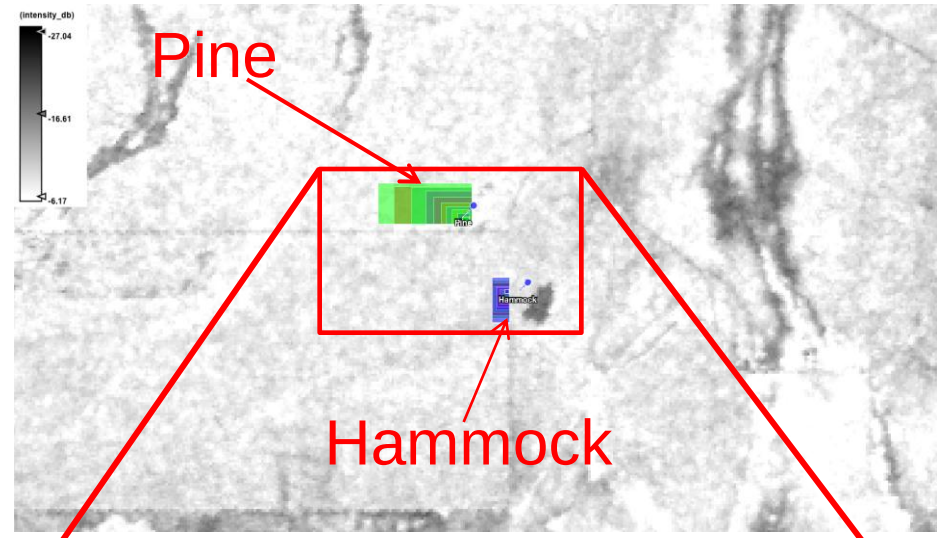
4) Geocoding and Reprojection

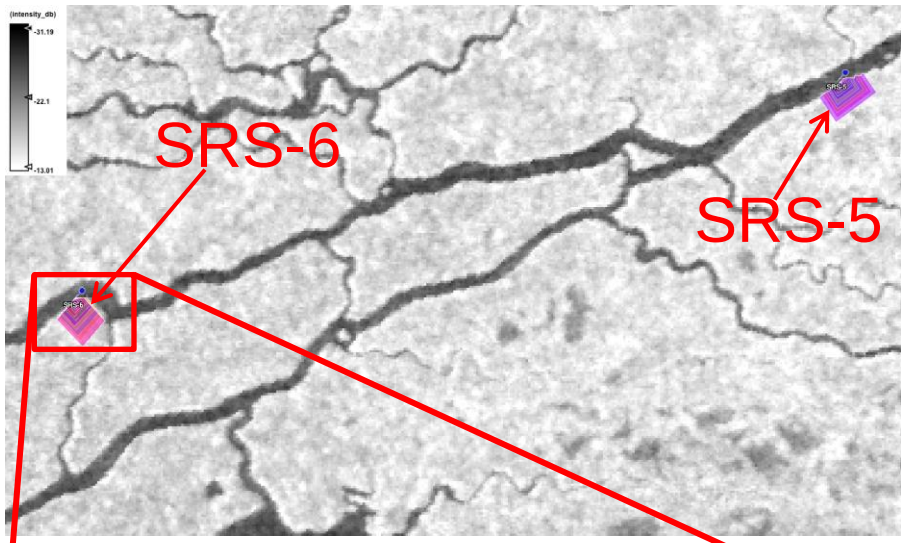
5) Backscatter (dB) polygon sensitivity study

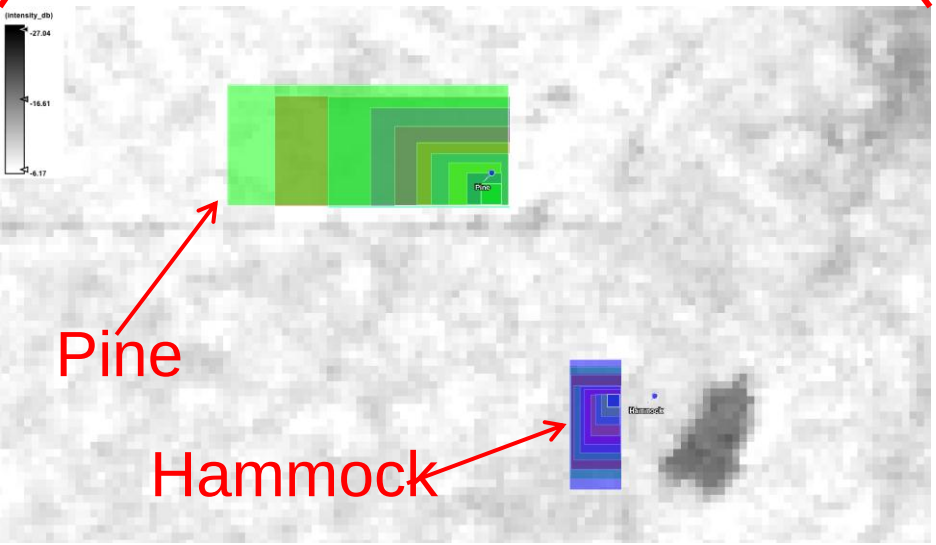
ALOS PALSAR - HV Processed Scene for Sigma Nought (σ0) Backscatter (dB)

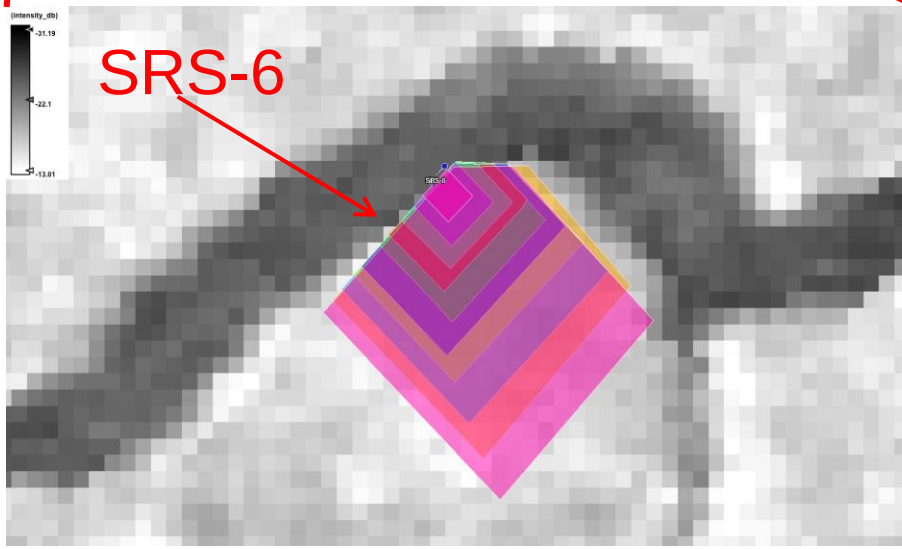


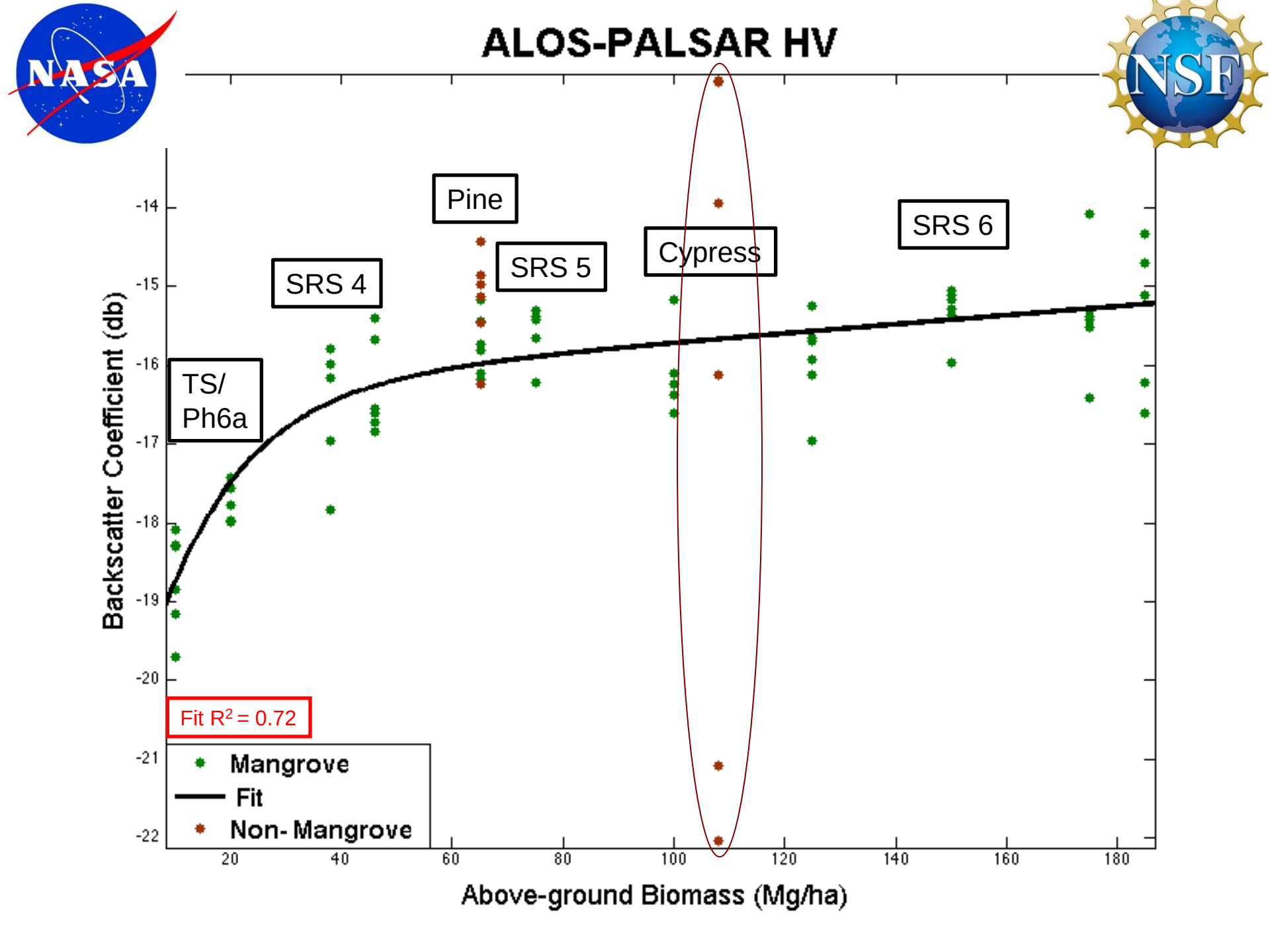
Preliminary Analysis

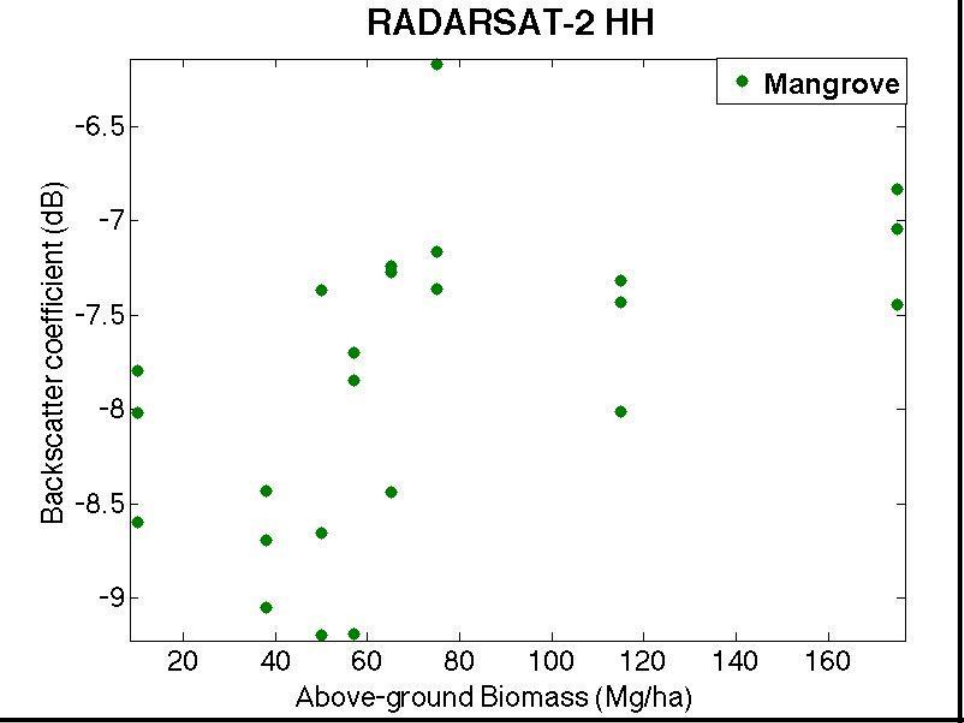


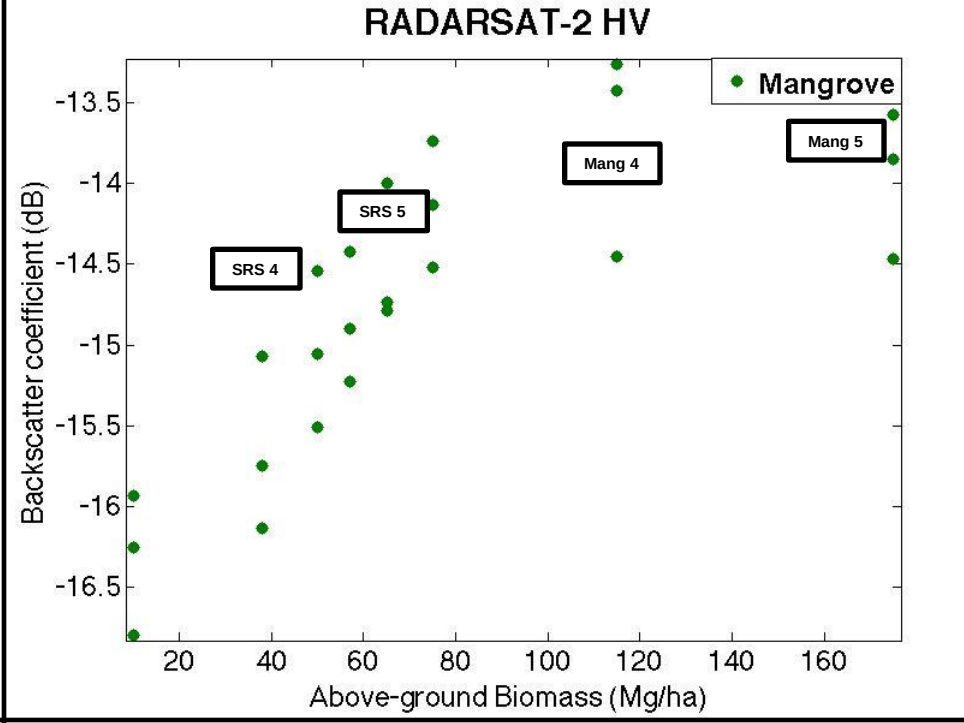


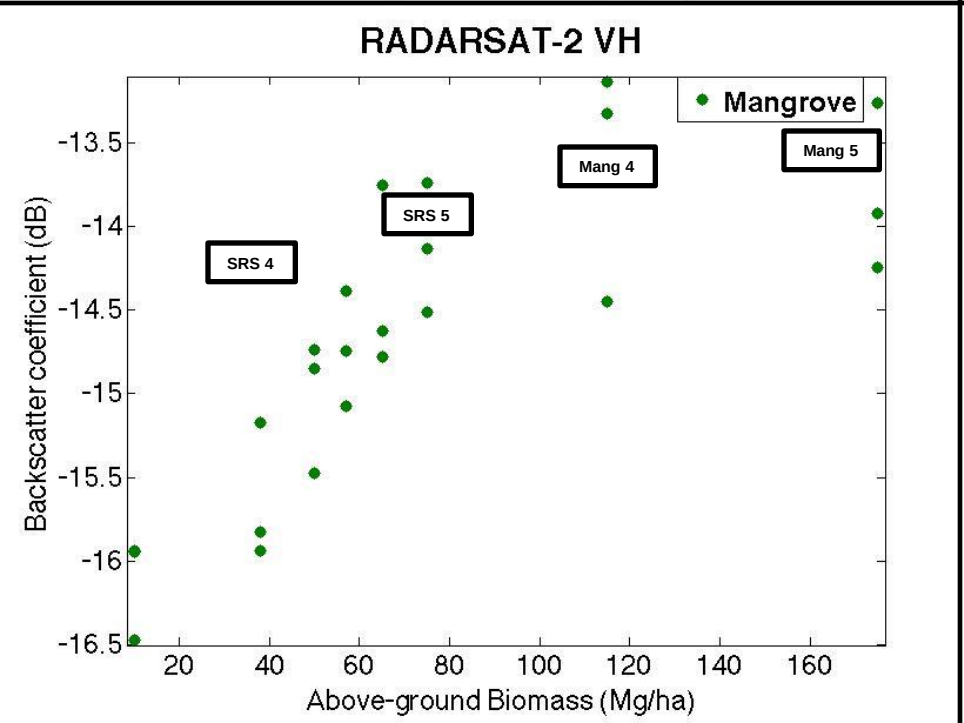


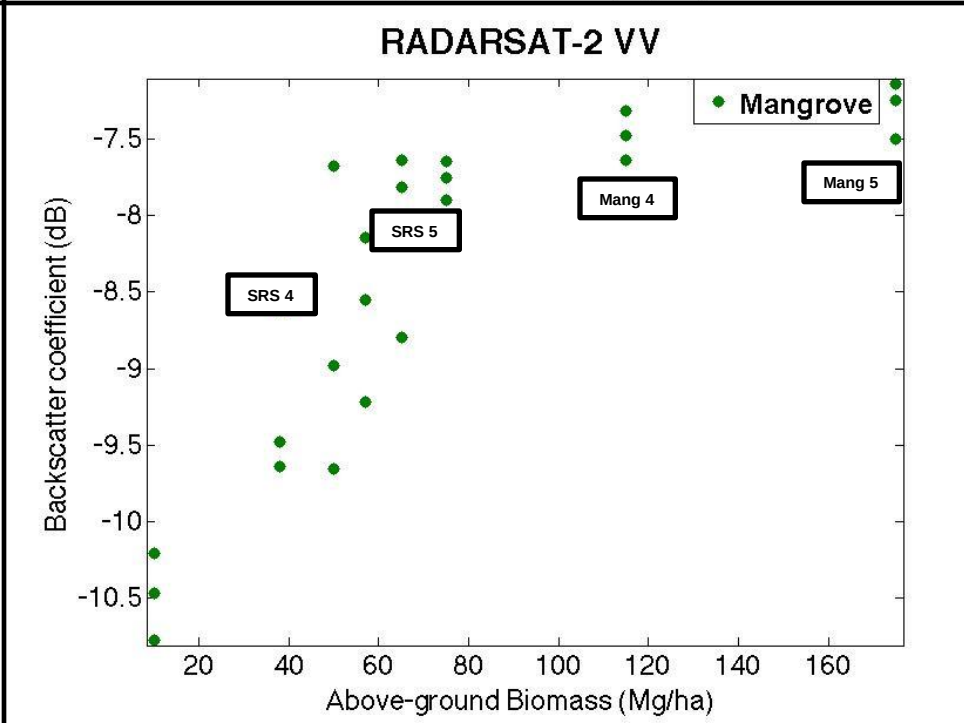



ALOS-PALSAR HV
Backscatter Coefficient (db)
Above-ground Biomass (Mg/ha)
TS/ Ph6a
SRS 4
Pine
SRS 5
Cypress
SRS 6
Fit R2 = 0.72
Mangrove
Fit
Non- Mangrove
-14
-15
-16
-17
-18
-19
-20
-21
-22
20
40
60
80
100
120
140
160
180


RADARSAT-2 HH
Mangrove
Backscatter coefficient (dB)
-6.5
-7
-7.5
-8
-8.5
-9
20
40
60
80
100
120
140
160
Above-ground Biomass (Mg/ha)


RADARSAT-2 HV
Mangrove
Mang 5
Mang 4
SRS 5
SRS 4
Backscatter coefficient (dB)
-13.5
-14
-14.5
-15
-15.5
-16
-16.5
20
40
60
80
100
120
140
160
Above-ground Biomass (Mg/ha)


RADARSAT-2 VH
Mangrove
Mang 5
Mang 4
SRS 5
SRS 4
Backscatter coefficient (dB)
-13.5
-14
-14.5
-15
-15.5
-16
-16.5
20
40
60
80
100
120
140
160
Above-ground Biomass (Mg/ha)


RADARSAT-2 VV
Mangrove
Mang 5
Mang 4
SRS 5
SRS 4
Backscatter coefficient (dB)
-7.5
-8
-8.5
-9
-9.5
-10
-10.5
20
40
60
80
100
120
140
160
Above-ground Biomass (Mg/ha)

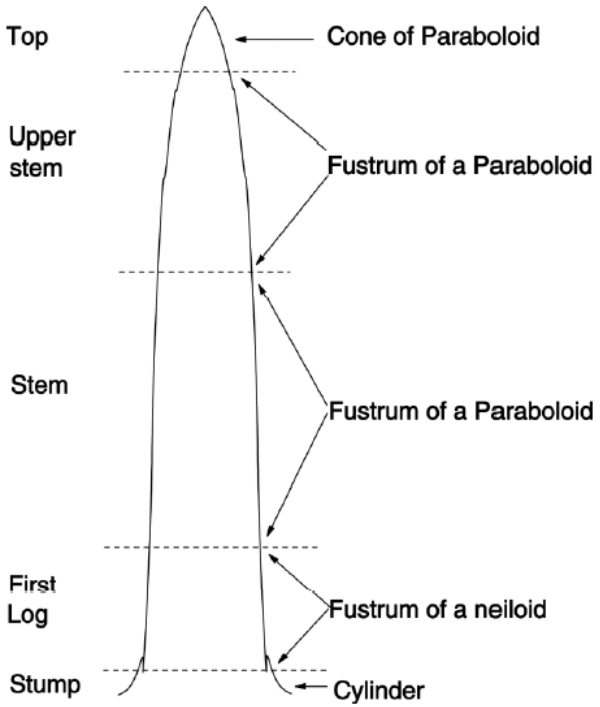
Preliminary Results

	Radarsat-2 (C-band)	ALOS PALSAR (L-band)
Sensitive to AGB	HV, VH, VV	HV
Not sensitive to AGB	HH	HH

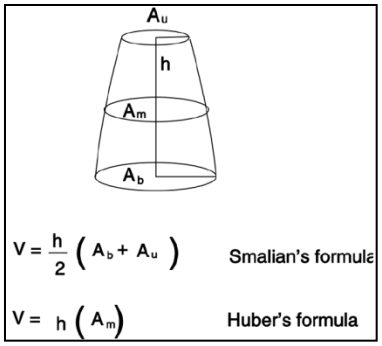
- Higher biomass sites (SRS-6, SRS-5) might be affected by the double-bounce SAR effect, because of a major tidal influence.
- Saturation begins approximately at 80-100 Mg/ha in both bands.
- ALOS PALSAR-HV shows more sensitivity for AGB. This is shown by previous biomass studies in tropical forests.

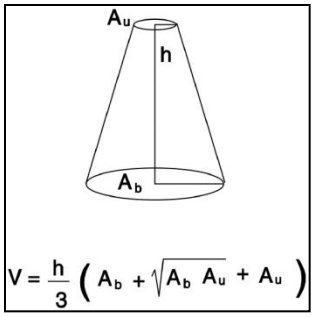
Tree Volume/Biomass Calculation

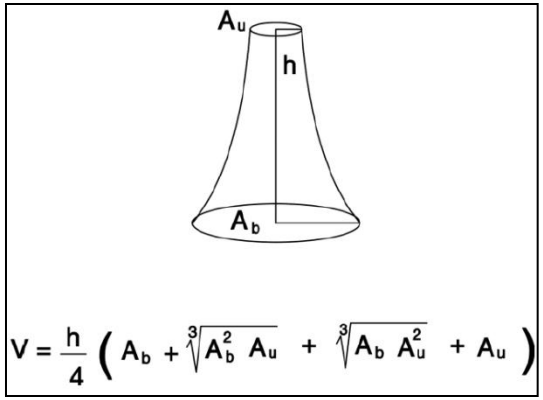
- Solids of Revolution – approximation of volume using a combination of frustum formulas of various geometric solids.

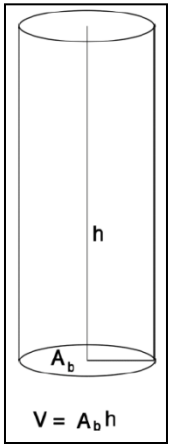


(Husch et al; 2003)

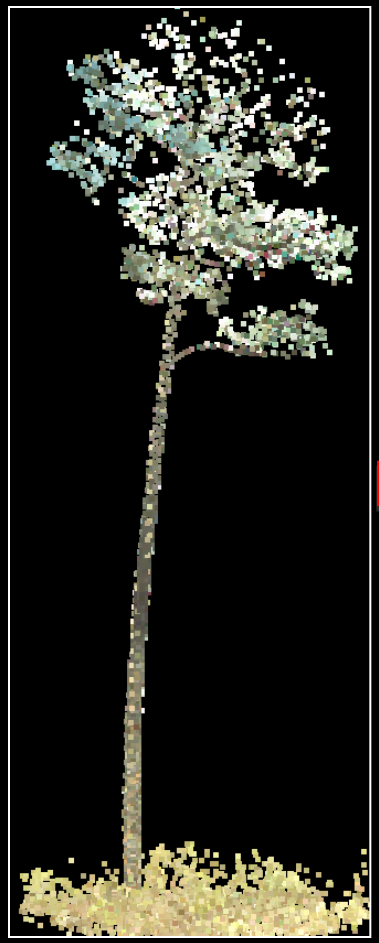




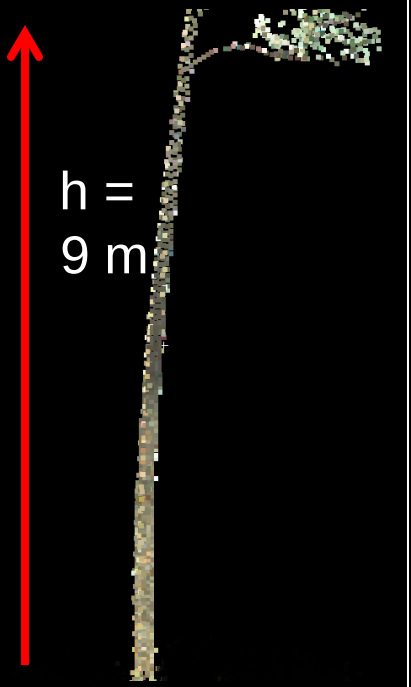




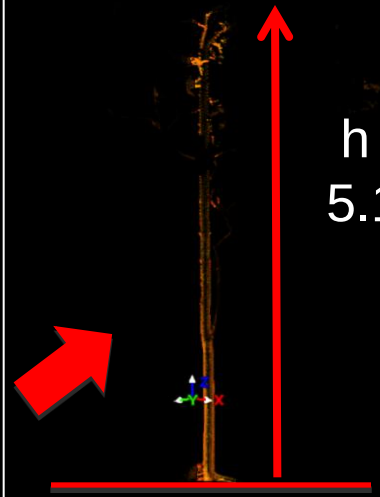
Tree Volume Calculation



Frustum of a Paraboloid



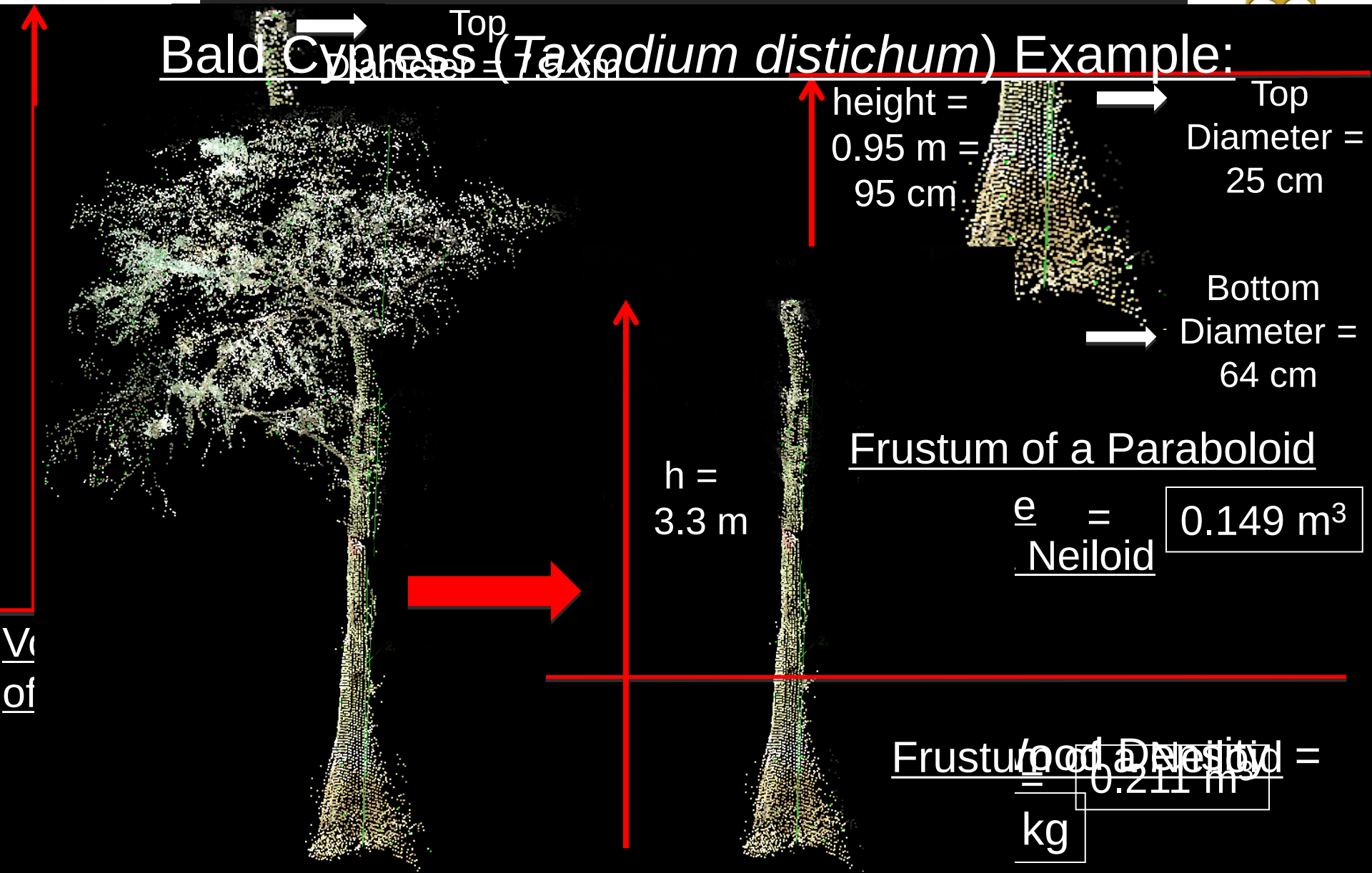
Frustum of a Paraboloid



Frustums of Multiple Paraboloids/Pipe Modelling

Tree Volume/Biomass Calculation

Bald Cypress (*Taxodium distichum*) Example:



Frustum of a Paraboloid

Neiloid = 0.149 m³

Frustum of a Neiloid = 0.211 m³

Wood Density = kg

Upcoming Goals

TLS:

- Better tree volume/AGB estimation using the frustum-based or “small cylinders” approach using the LiDAR data.
- Automation of tree volume calculation. MATLAB or similar software.

SAR:

- Additional SAR data acquisition. (Radarsat-2)
- Explore the combination of C- and L- bands for more accurate biomass estimates.

Airborne:

- Implementation of Airborne LiDAR (NCALM Seed Proposal)

Acknowledgments

- NASA WaterSCAPES and National Science Foundation (NSF)
- UNAVCO
- Everglades National Park Staff
- University of Miami
- Florida International University
- SAR Data Provided by:

Questions?


NASA
NSF


NASA
NSF

Questions?