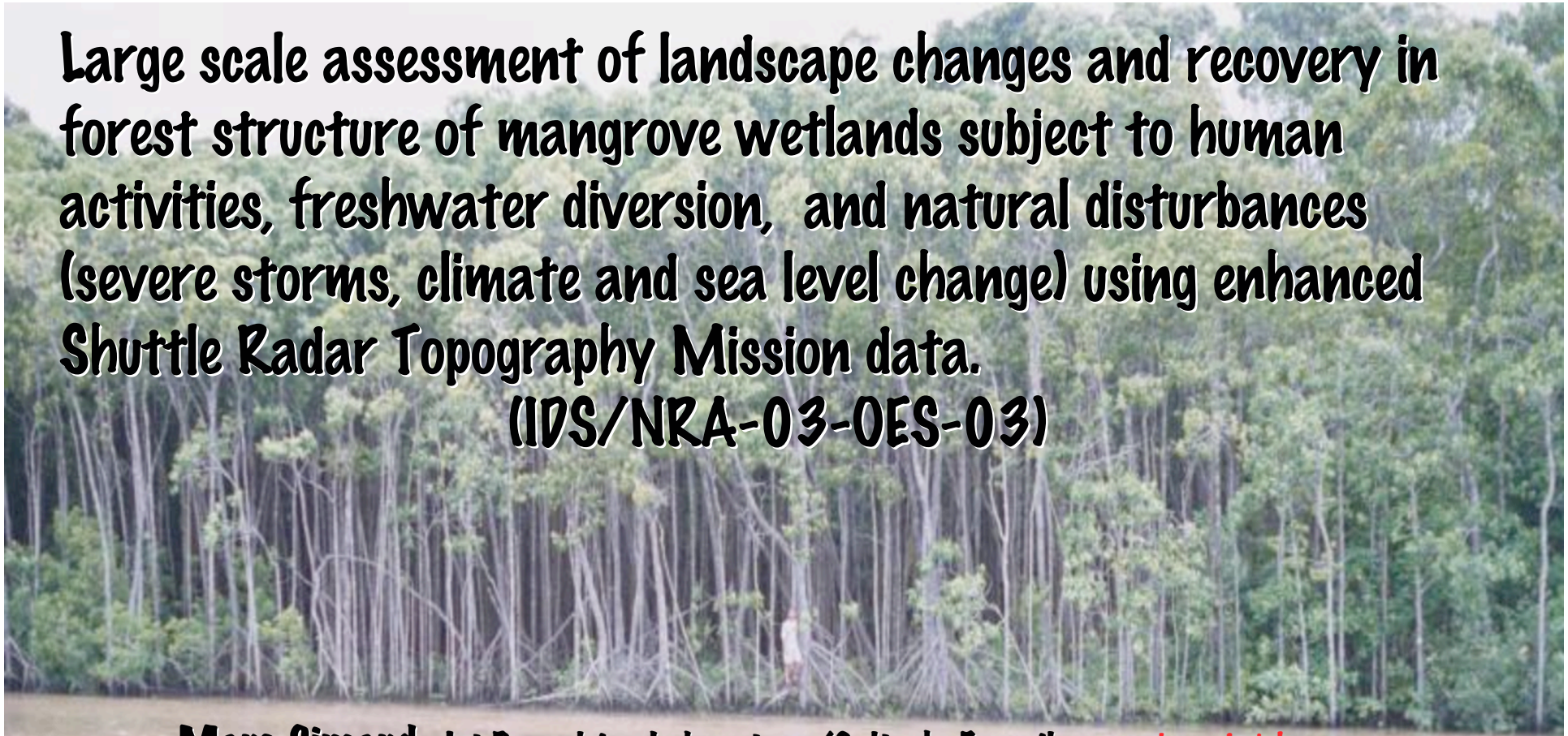
Large scale assessment of landscape changes and recovery in forest structure of mangrove wetlands subject to human activities, freshwater diversion, and natural disturbances (severe storms, climate and sea level change) using enhanced Shuttle Radar Topography Mission data.

(IDS/NRA-03-OES-03)



Marc Simard, Jet Propulsion Laboratory/Caltech, E-mail: marc.simard@jpl.nasa.gov

Victor H. Rivera-Monroy and Robert R. Twilley (Louisiana State University)
Michael Ross and Keqi ZhanG (Florida International University)
Norman Duke (The University of Queensland, Australia)
Catherine Ticehurst (CSIRO Land and Water, Australia)
Ernesto Rodriguez (JPL)

Jet Propulsion Laboratory
California Institute of Technology

NASA/LCLUC, Washington, February 2005

Objectives

- *to generate enhanced SRTM elevation data to estimate vegetation height in wetlands dominated by mangroves with;*
  - *a. concurrent LIDAR mapping;*
  - *b. semi-empirical modeling of radar scattering in mangroves to correct for the height bias;*
  - *c. differential height measurements.*
- *to estimate productivity within the complex mangrove mosaic, in the process improving our understanding of its underlying controls, and extend production models to regional scales.*
- *to develop a landscape-scale understanding of recovery from disturbance, which is of course related to the innate productivity of the site.*

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Relevance

- Carbon cycle and Ecosystem Roadmap
  - (T)Vegetation 3D structure (Biomass & Disturbance)
    - 3D (height) repeatedly emphasized by LCLUC science team (1/11/05).
    - "…a critical in this focus area." (Bill Emanuel, 1/11/05).
  - Coastal carbon
- Research associated to LTER (Long term Ecological Research)
  - Founded by NSF in 1980
  - Network of 26 sites
  - Over 1800 scientists
- Bridging scales, processes and disciplines

Why mangroves?

- Biodiversity
  - Habitats of 1300 species of animals of which 628 mammals, birds, reptiles, fish and amphibians
- Among the most productive ecosystems on earth (Jennerjahn & Ittekkot, 2002)
  - 100k-230k km^2 with mean 2.5g C m^{-2} per day
    - 25% accumulates in mangrove sediments
    - 25% is recycled
    - 50% is exported to the coastal zone
  - Annual input into ocean $46X10^{12}$ g C
    - Thus contributes 11% of global total export to ocean
  - Annual accumulation of carbon in modern sediments $23X10^{12}$g C yr^{-1}
    - Makes up for 15% of the C_{org} accumulation in modern sediments
- Endangered by urbanization, exploitation and sea level rise
- Between 33% to 50% coverage loss over the last 50 years
- Flat topography:
  - single band radar interferometry allows relative height measurement
  - e.g. Measuring tree height in Amazon requires detection of ground pixels and also assumption the local topo=0.

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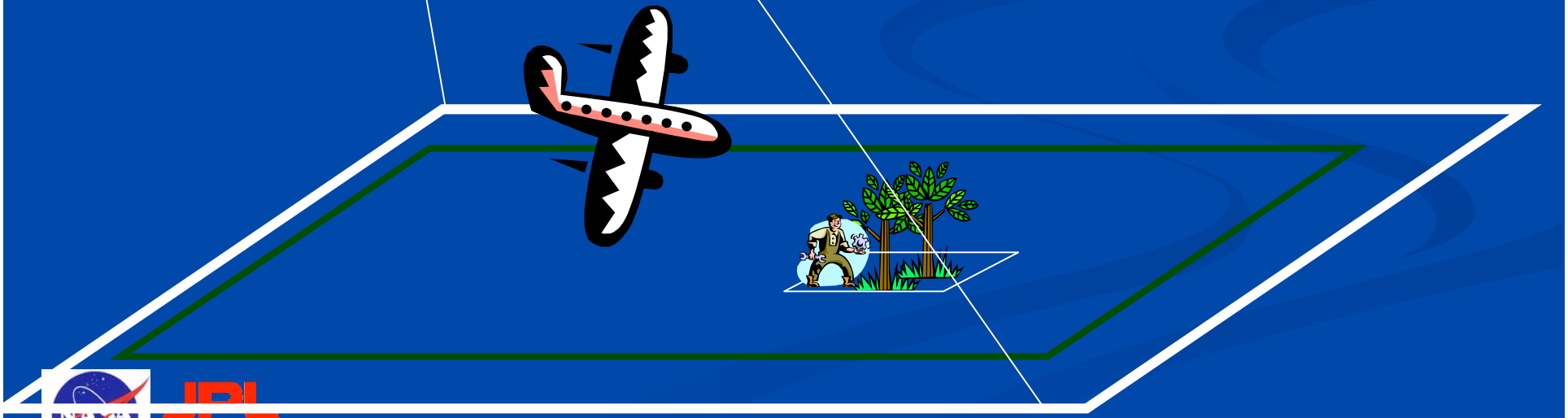
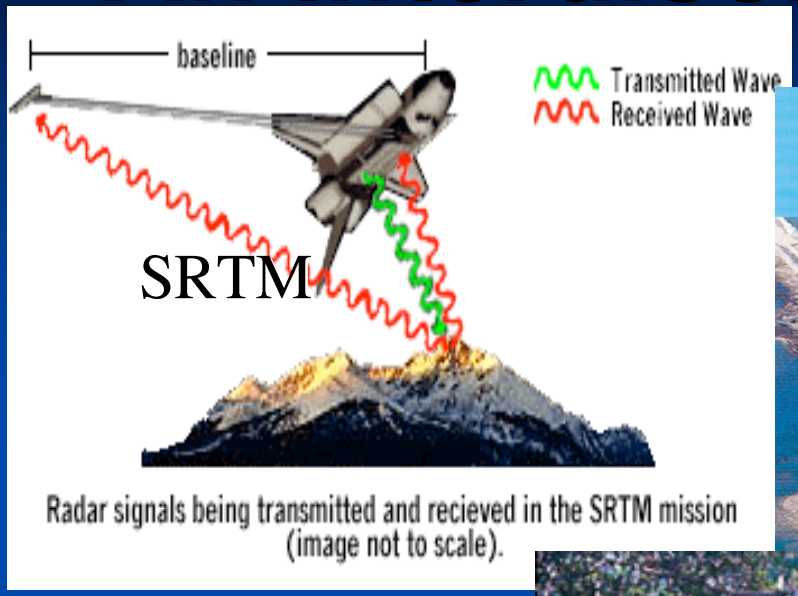
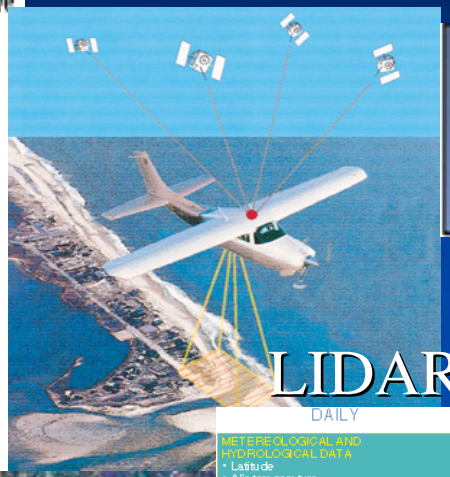
A Multiscale Approach…



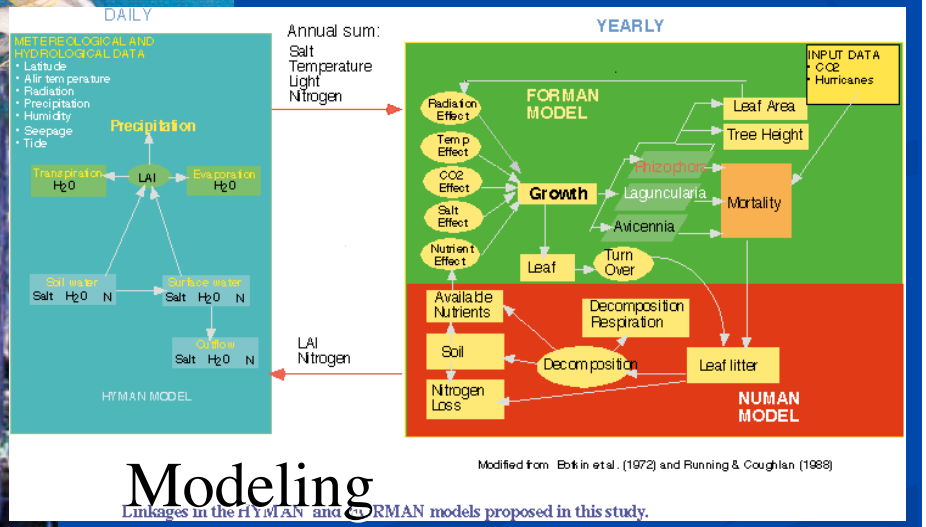
An Interdisciplinary Approach





LIDAR

NASA-DC 8 AIRSAR



Modified from Botkin et al. (1972) and Running & Coughlan (1988)

Modeling

Linkages in the HYMAN and FORMAN models proposed in this study.

We use interferometric radar data, LIDAR data, field data and ecosystem modeling

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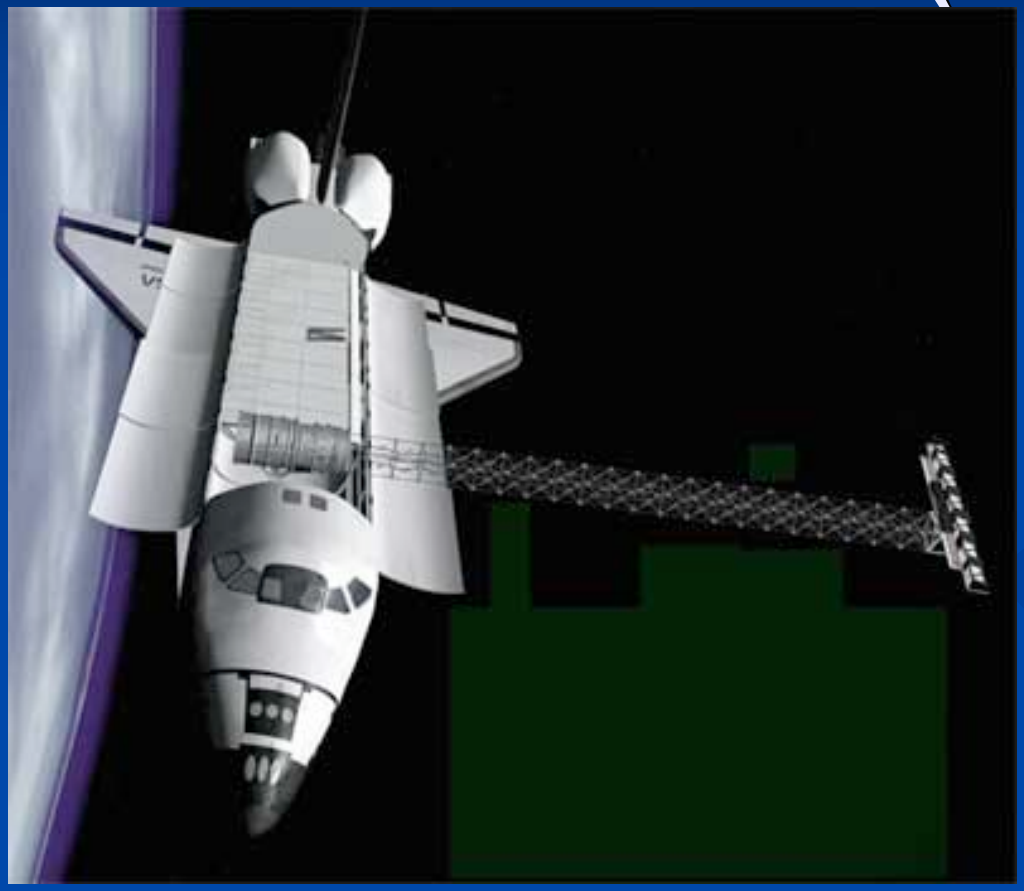
Shuttle Radar Topography Mission (SRTM)



1. Interferometer
2. 60m boom
3. C and X band
4. 11 days in February 2000.
5. 80% Earth Land
6. Latitude 56S to 60N
7. 30m US and World 90m

http://www2.jpl.nasa.gov/srtm/

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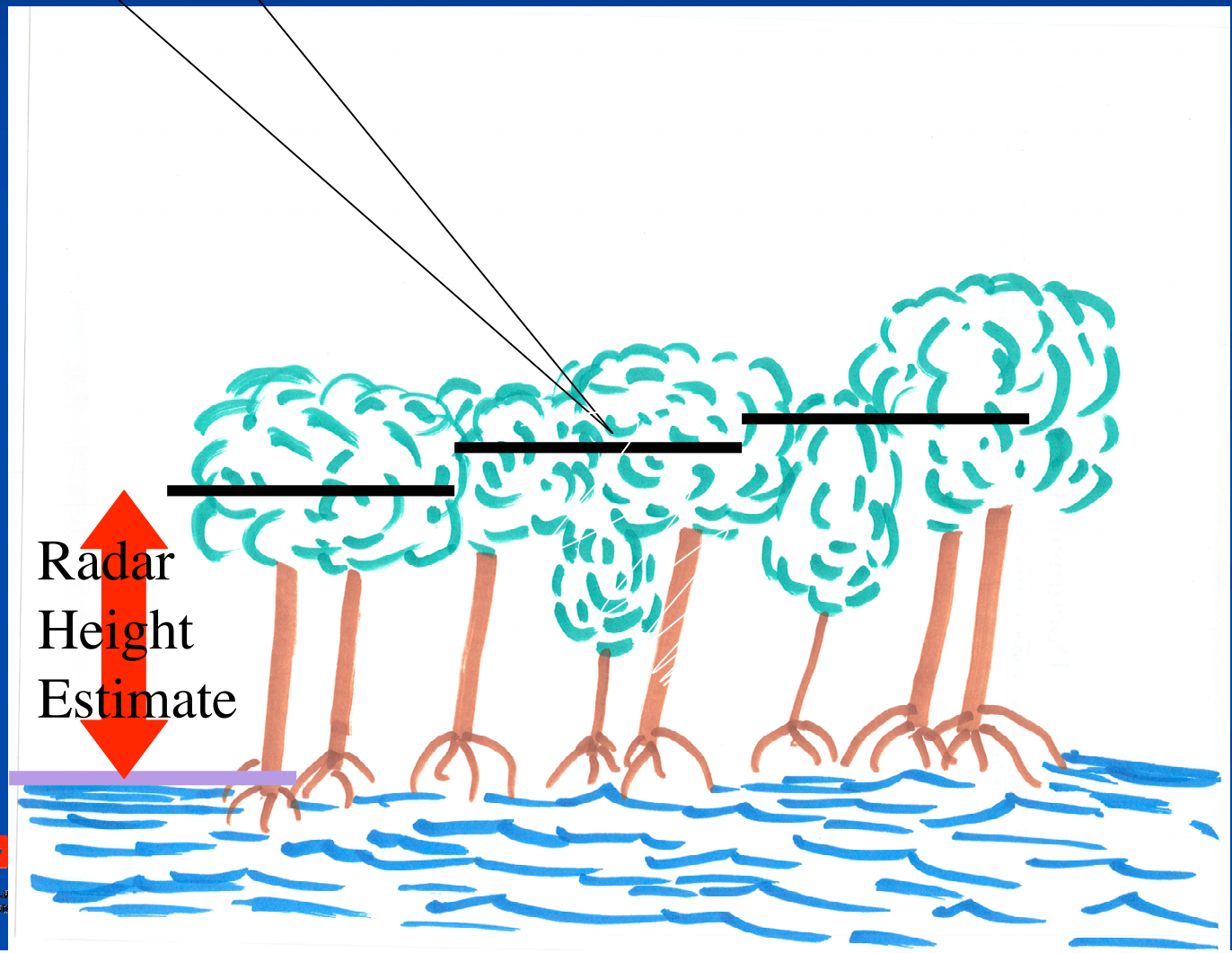
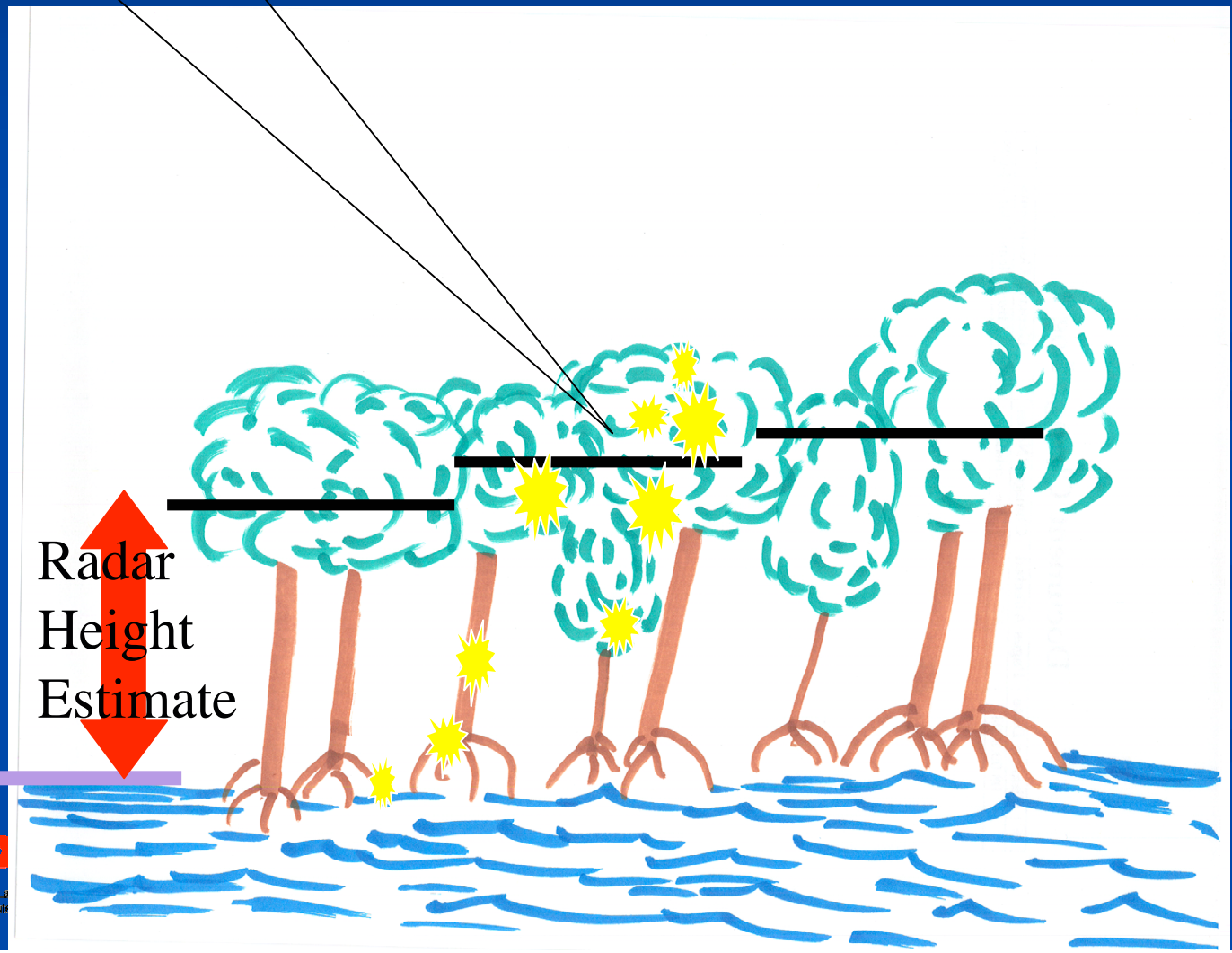
Relative Vegetation Height



Relative Vegetation Height



First study site:
Everglades National Park, Florida

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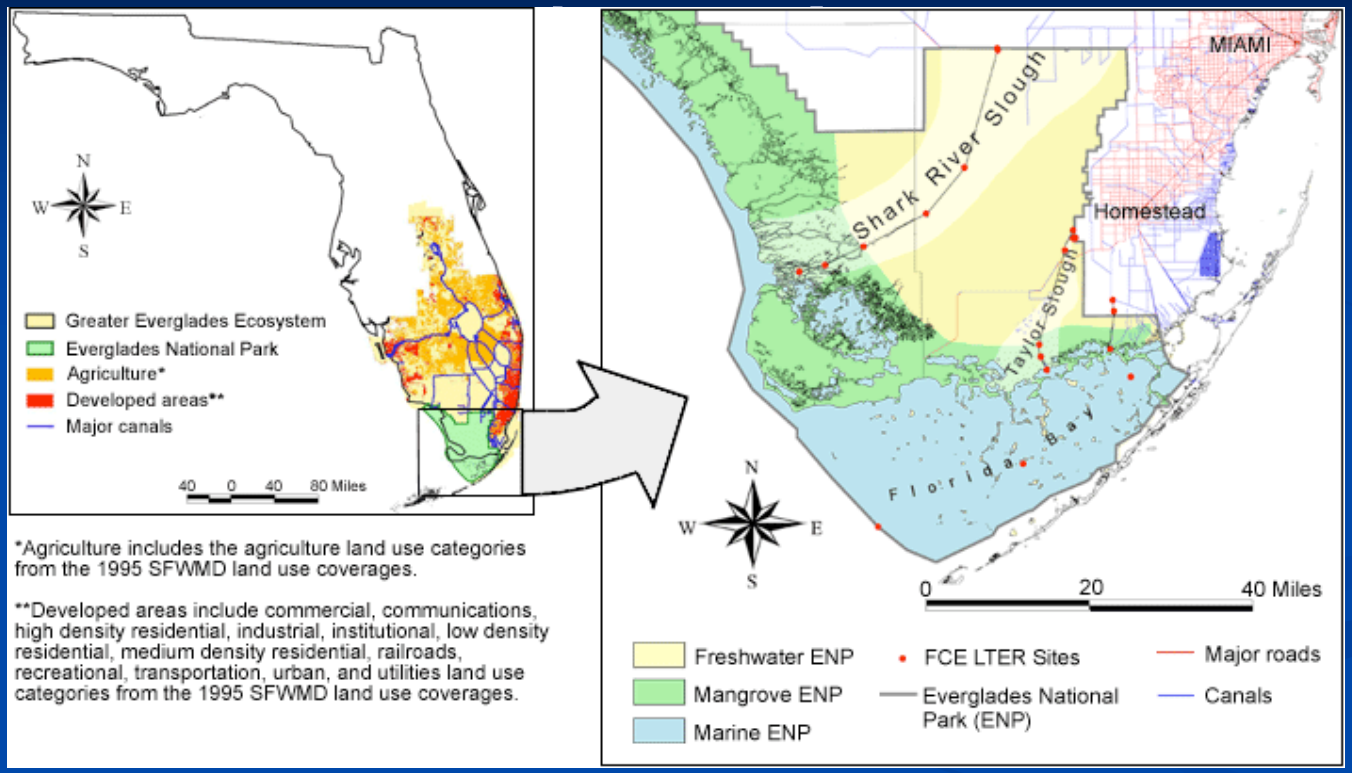
The Everglades National Park



- The majority of Florida Coastal Everglades LTER sites are located in freshwater marsh, estuarine mangroves, seagrass estuary ecosystems in Everglades National Park.
- Everglades National Park covers approximately 4300 km2 of south Florida and is part of the greater Everglades ecosystem which extends north to Lake Okeechobee and the Kissimmee River.
- Mangroves cover about 224, 500ha.

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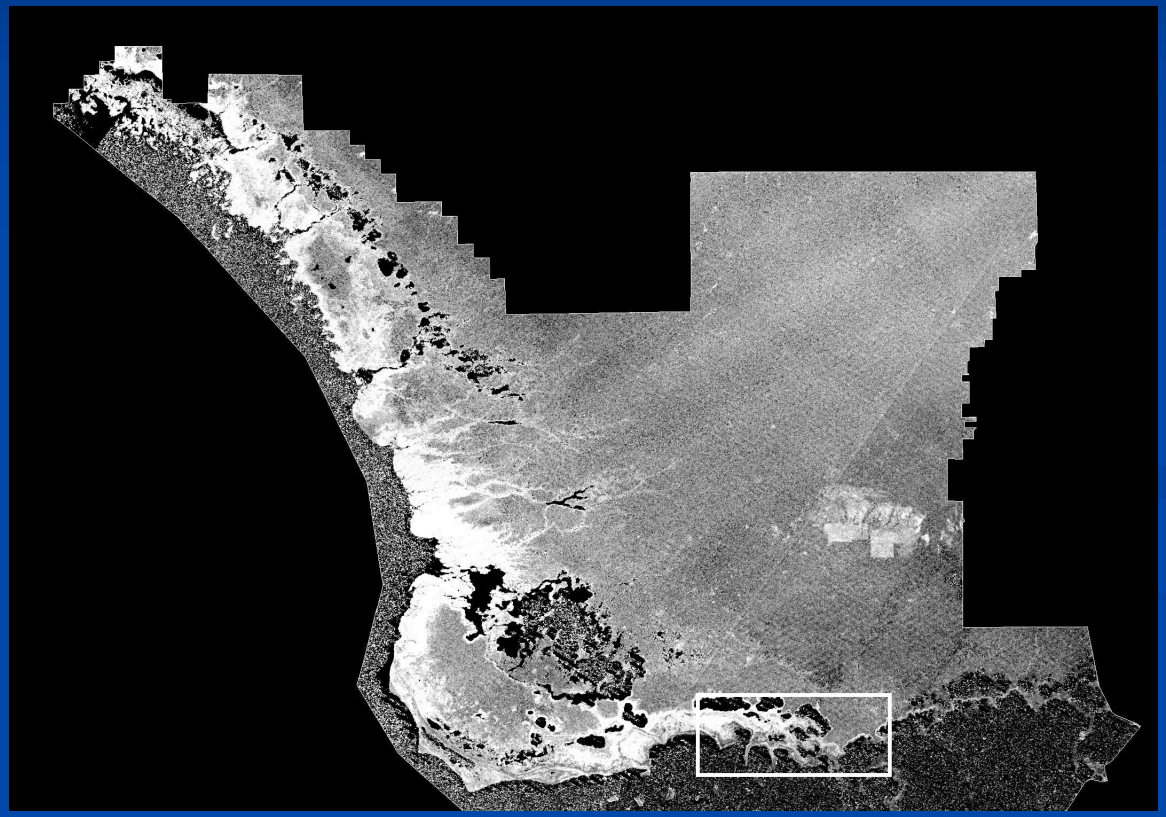
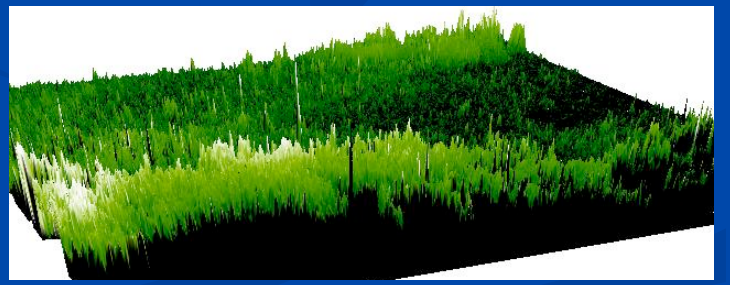
SRTM Elevation data



n.b. The brighter the higher



3D representation

LIDAR Data

- Optech 1233 Airborne Laser Terrain Mapper
  - Infrared 1.1um
- First and last reflection method
- Nominal Altitute of 500m
  - 360m swath
- May 13-15 2004
- 1.5m spacing with 13cm laser footprint
- 15 cm elevation accuracy

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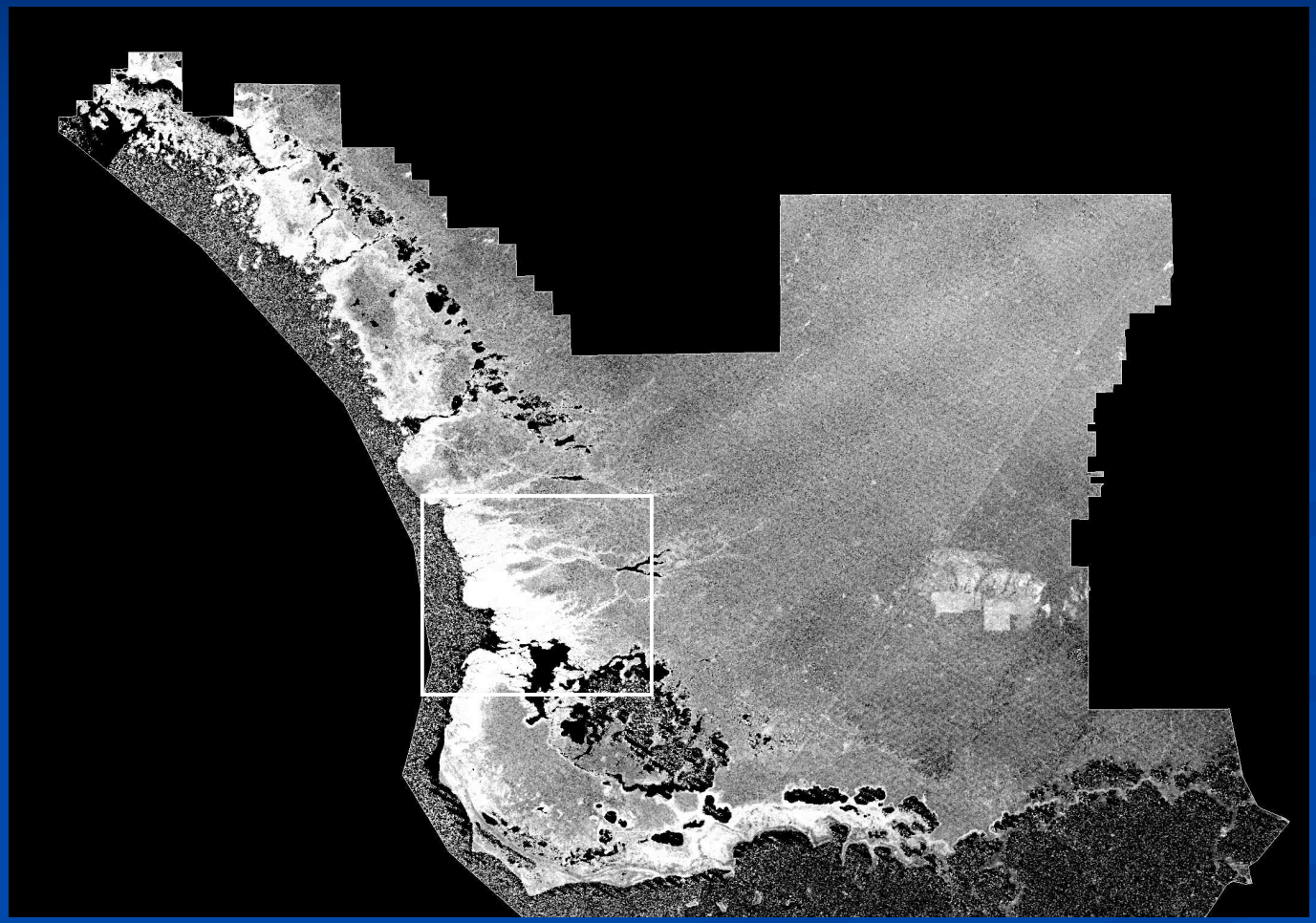
SRTM Elevation data



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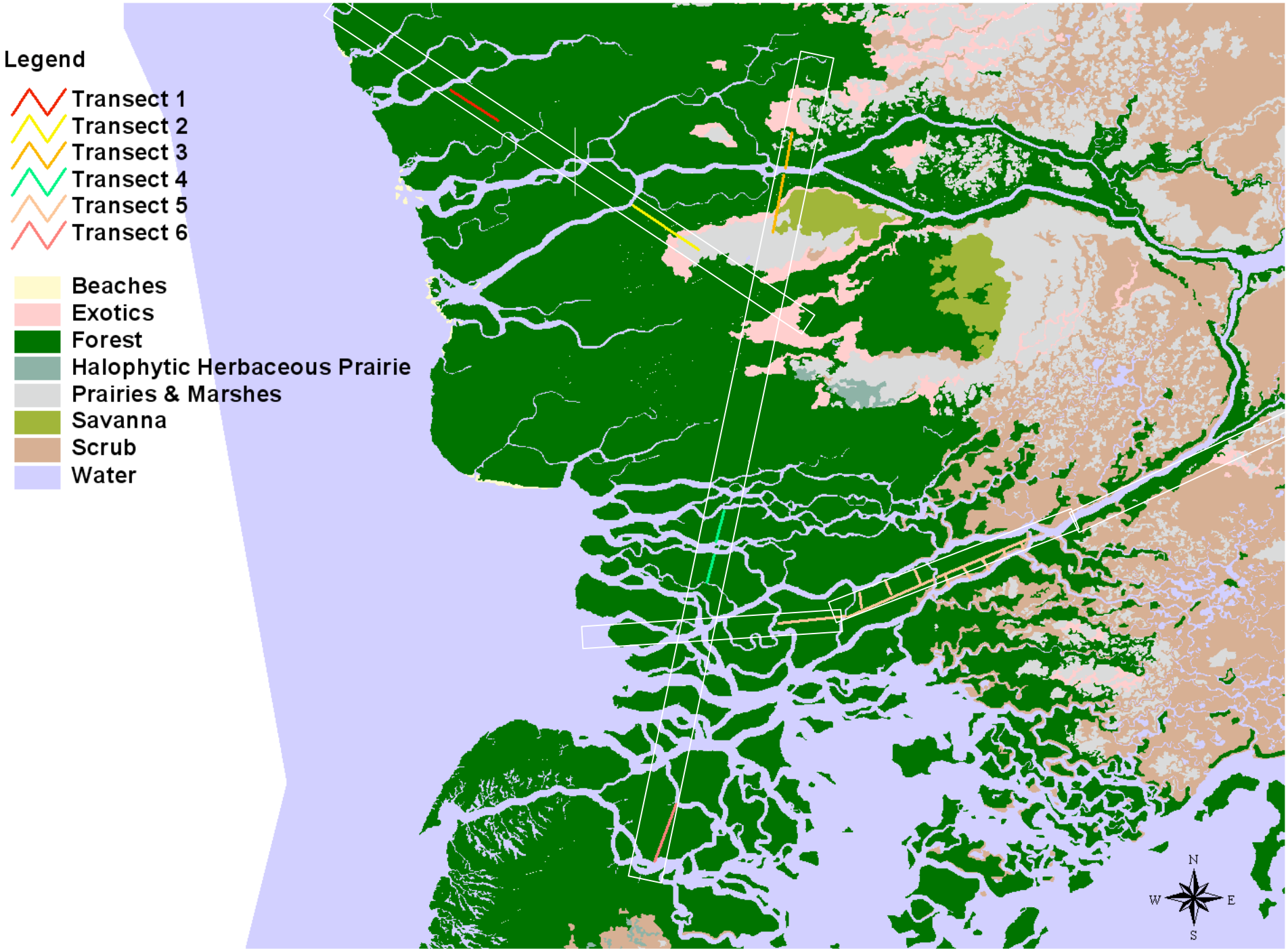
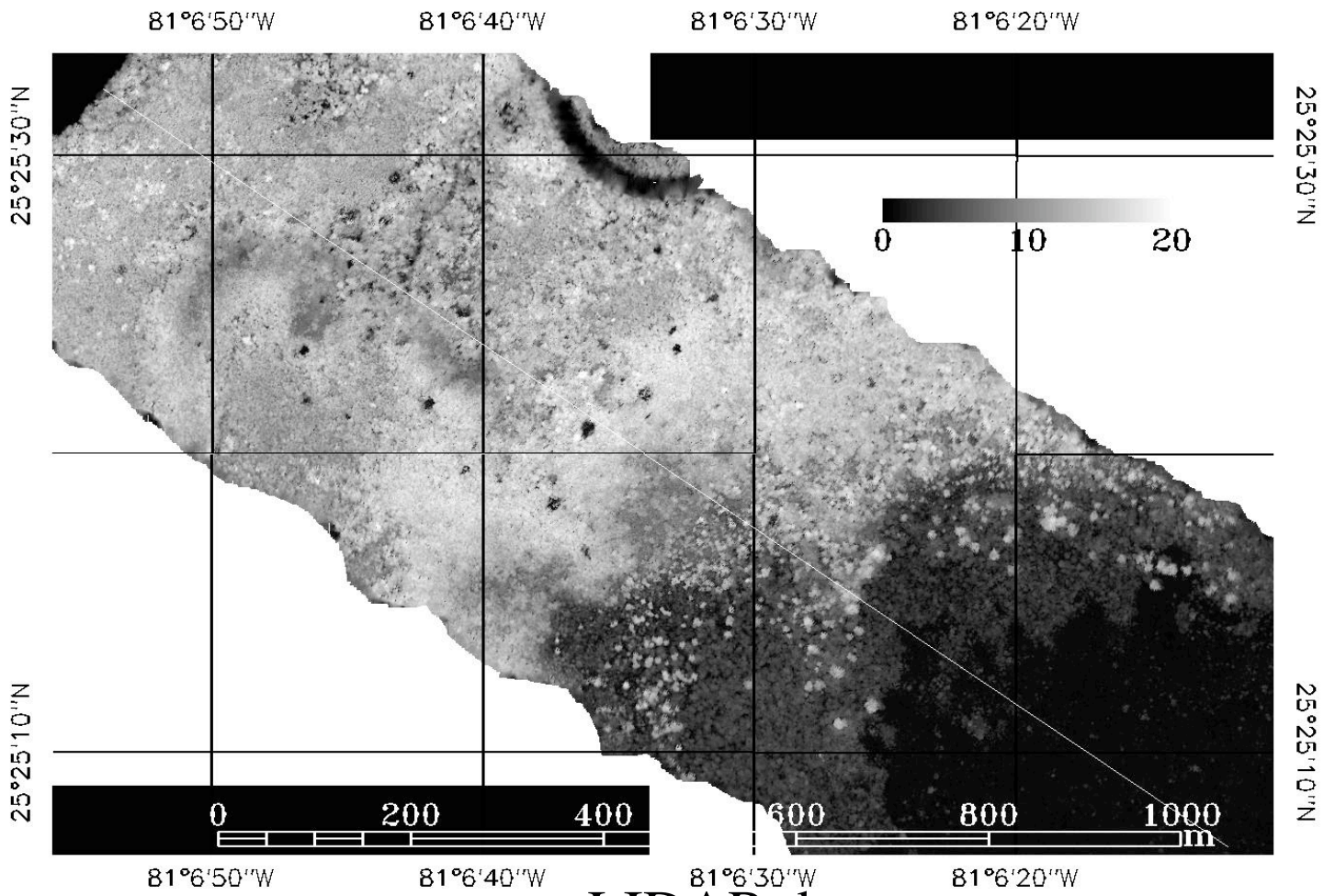
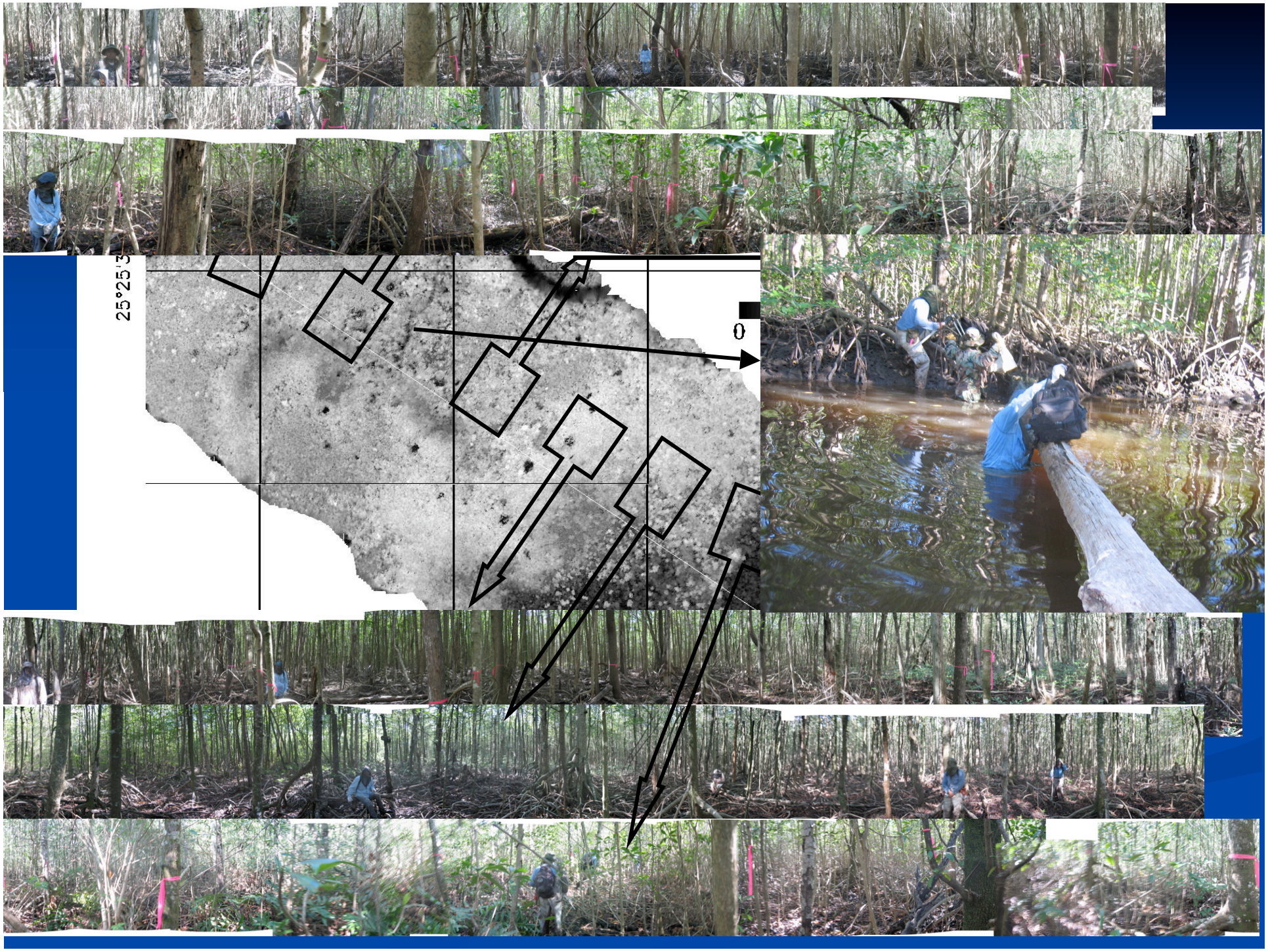

Legend
Transect 1
Transect 2
Transect 3
Transect 4
Transect 5
Transect 6
Beaches
Exotics
Forest
Halophytic Herbaceous Prairie
Prairies & Marshes
Savanna
Scrub
Water
N
W
E
S

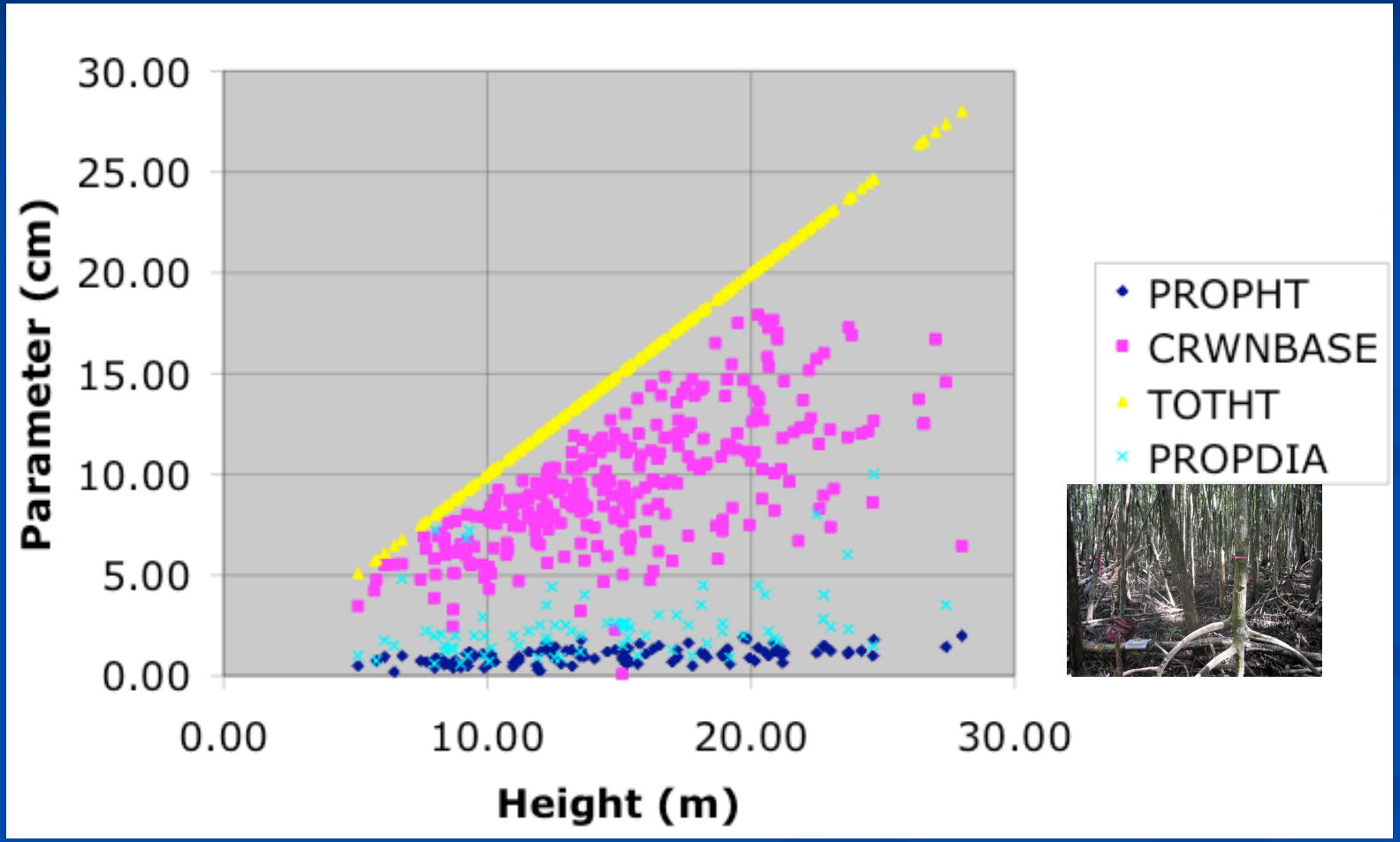
Transect Harney River



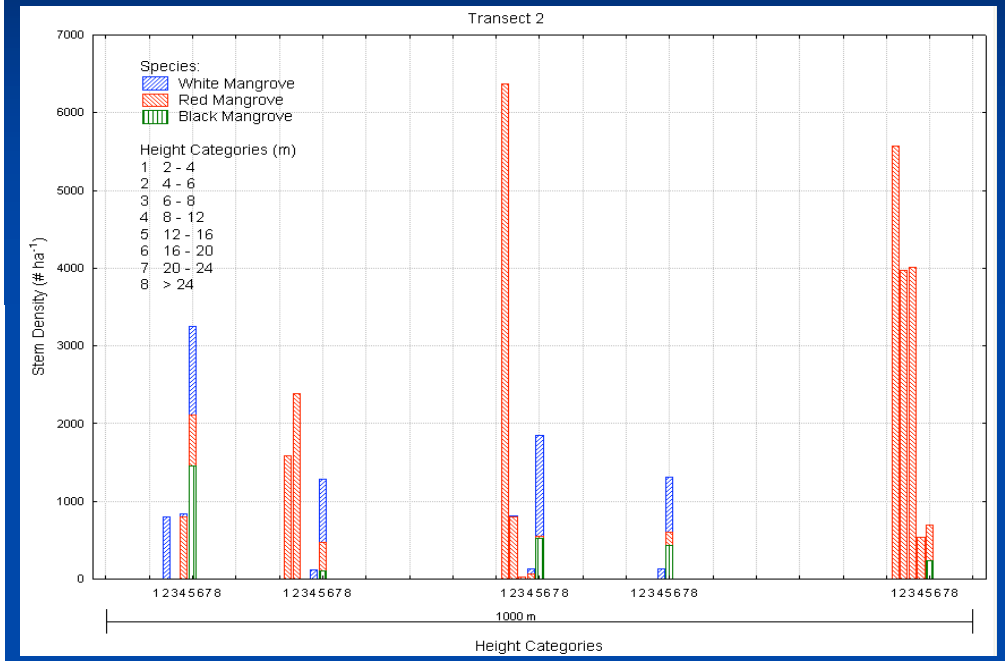
LIDAR data

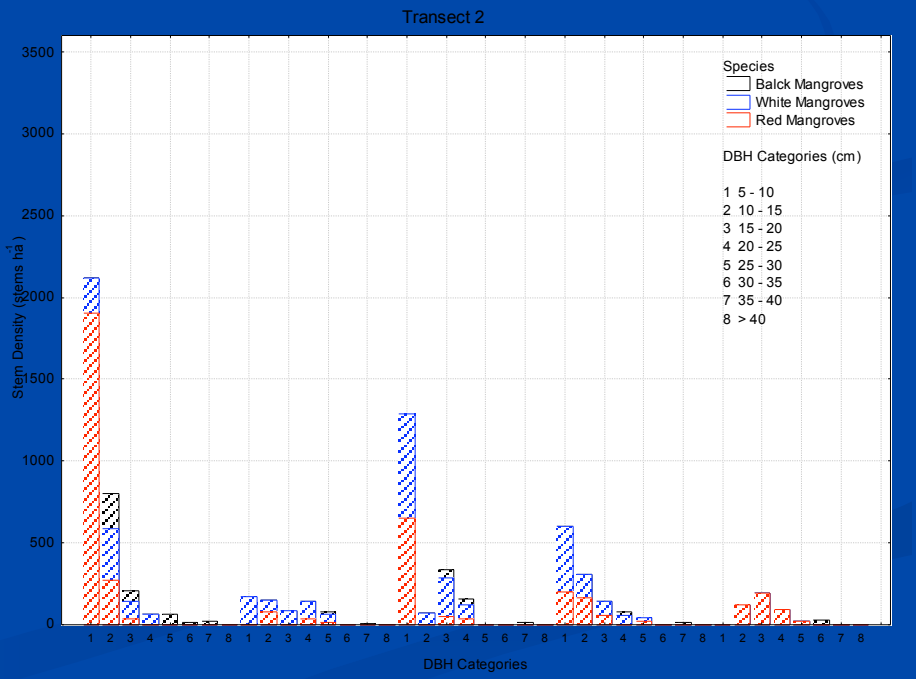

25°25'3
0

Field data: tree architecture



Field data: forest structure





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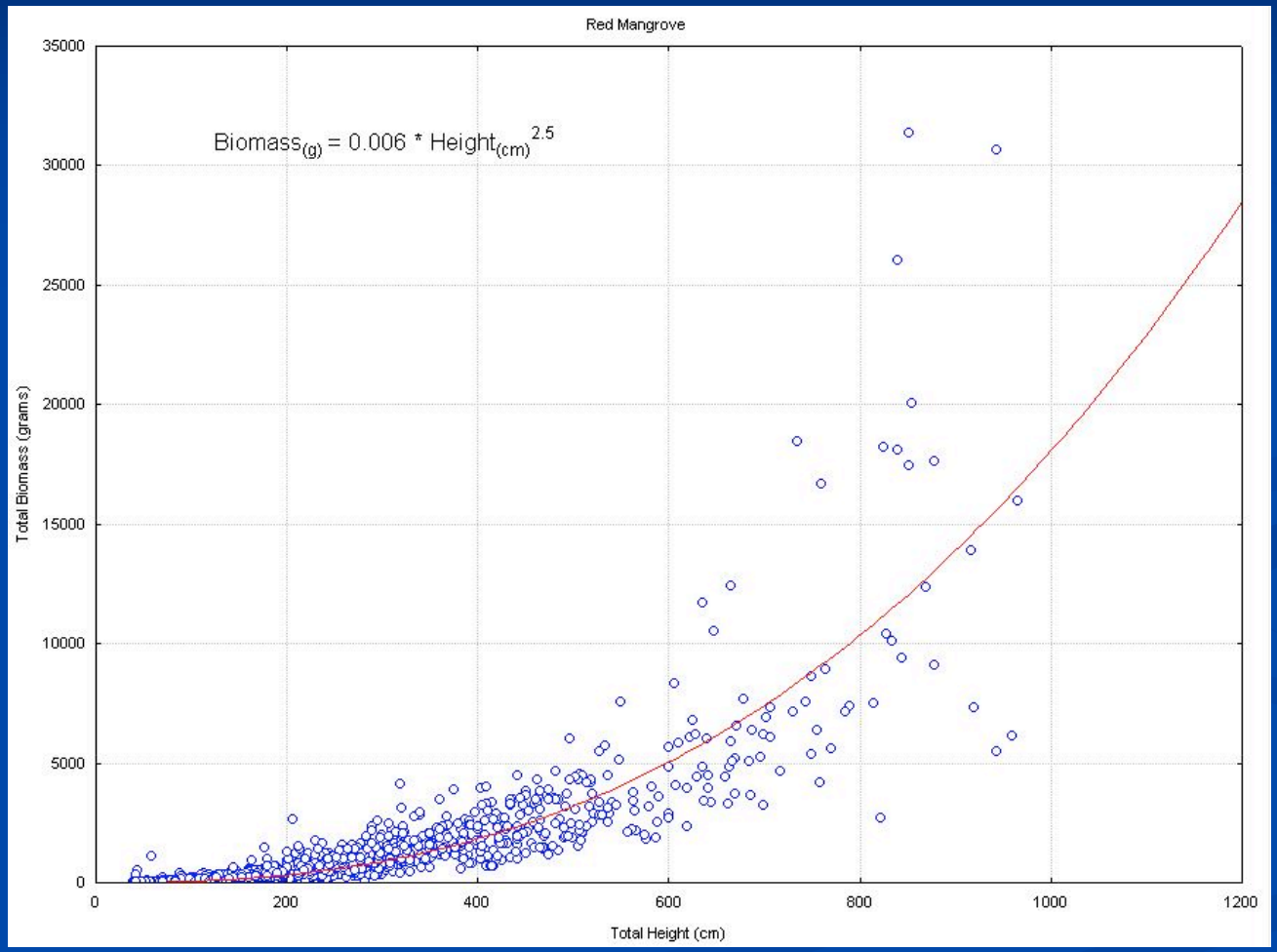
Biomass vs. Height



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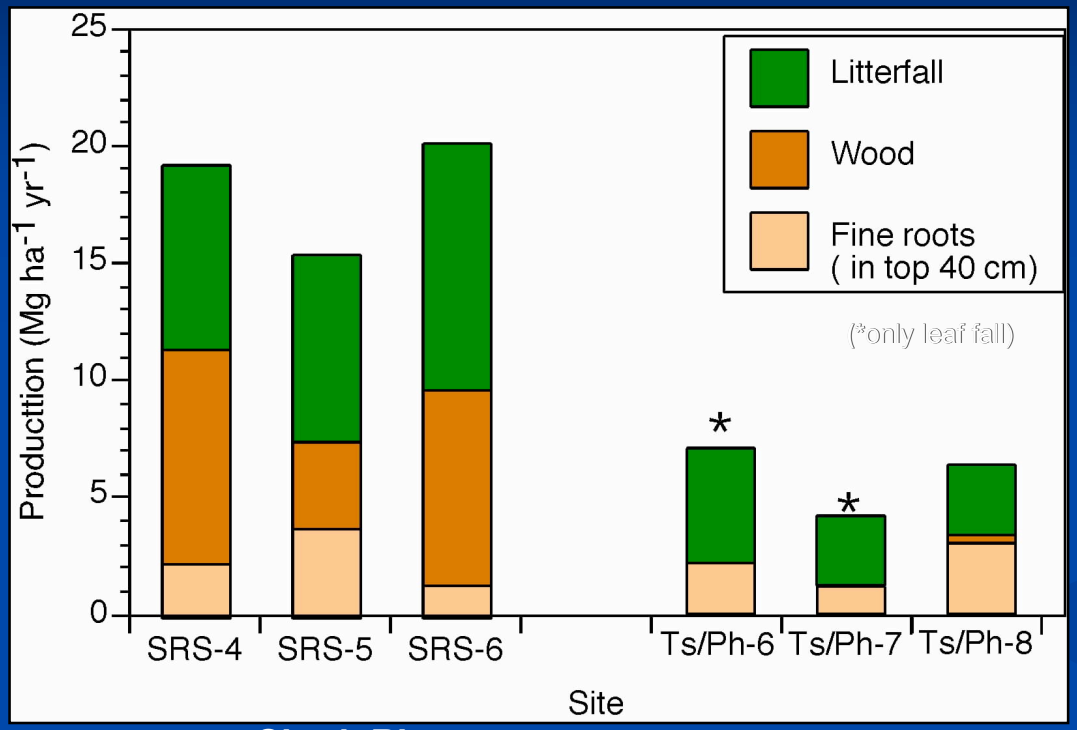
Mangrove productivity (Mg $ha^{-1}yr^{-1}$) Everglades National Park, FL

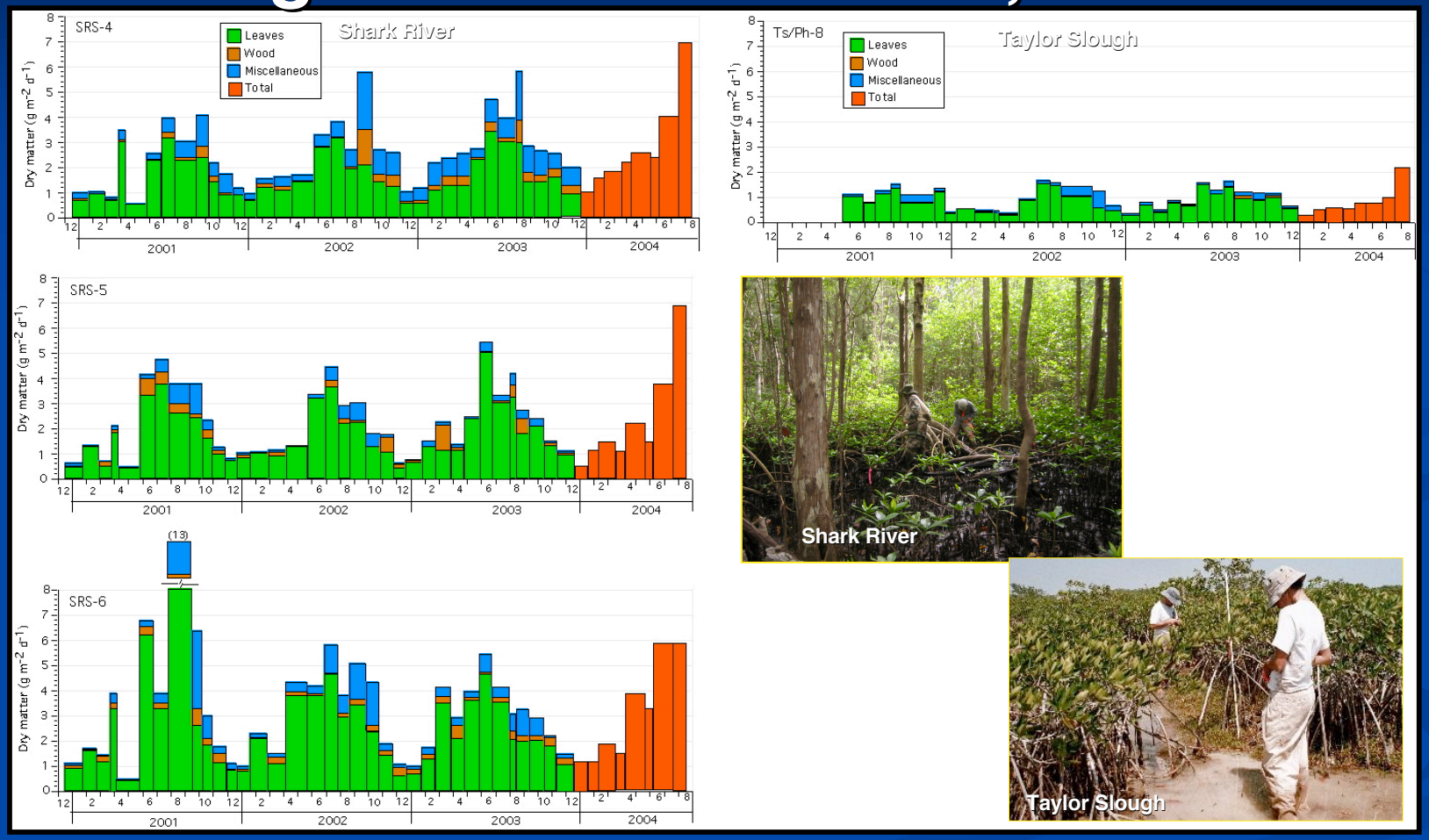


- Productivity is higher in Shark River sites than in Taylor River
- Although litterfall is higher in Shark River, fine root production is similar in both regions
- This suggests that large root production may play an important role in maintaining high wood production rates in Shark River

- There are significant differences in the relationship between DBH and tree height per species across sites.
- The conspicuous patterns for *R. mangle* and *L. racemosa* along Shark River underscores the importance of fertility differences among sites, particularly when comparing *R. mangle* DBH and tree height between Taylor River and Shark River.

(V. H. Rivera-Monroy, U. Louisiana at Lafayette)

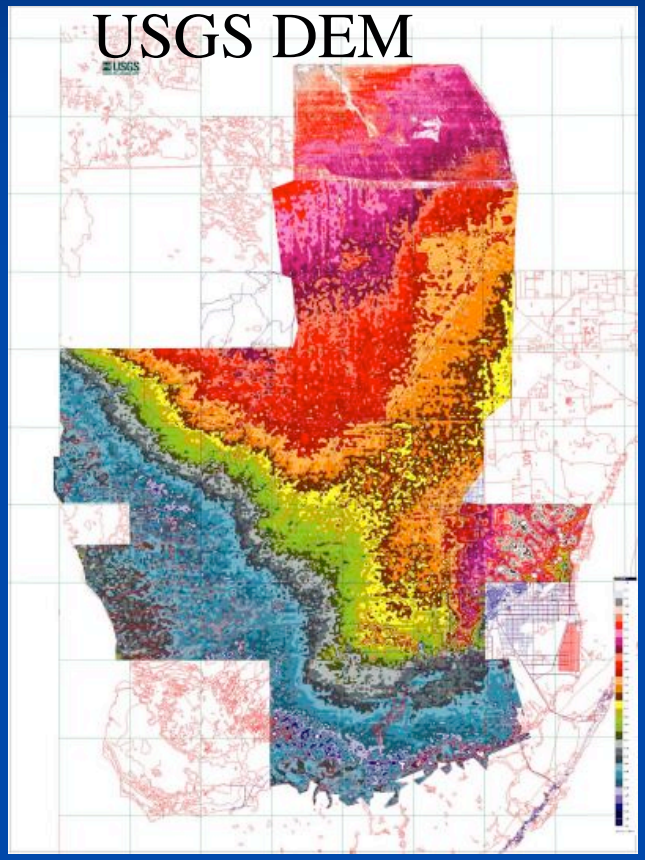
Litterfall productivity (g m^{-2} d^{-1}) Everglades National Park, Florida



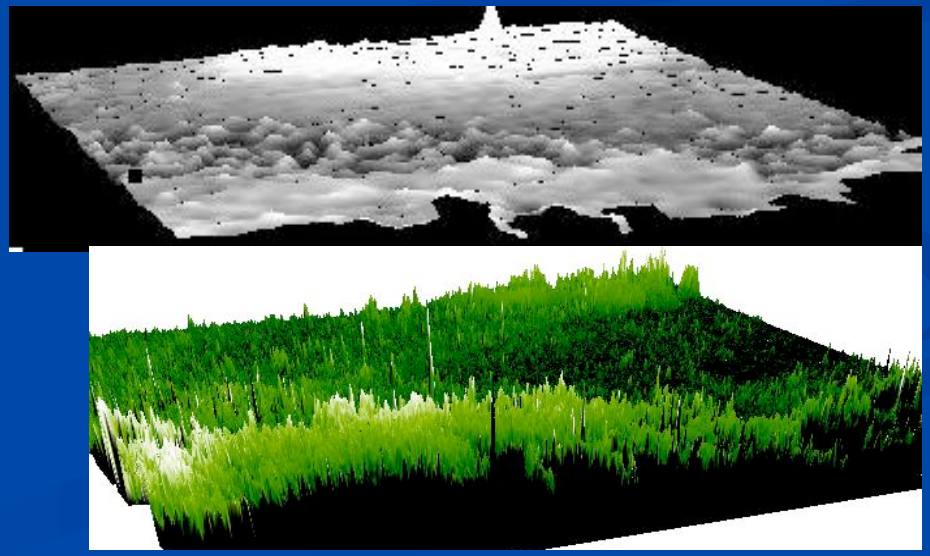
- Highest rate is observed in the rainy season (June-October)
- Productivity is highest in the Shark River region than in Taylor

(V. H. Rivera-Monroy, U. Louisiana at Lafayette)

SRTM data correction

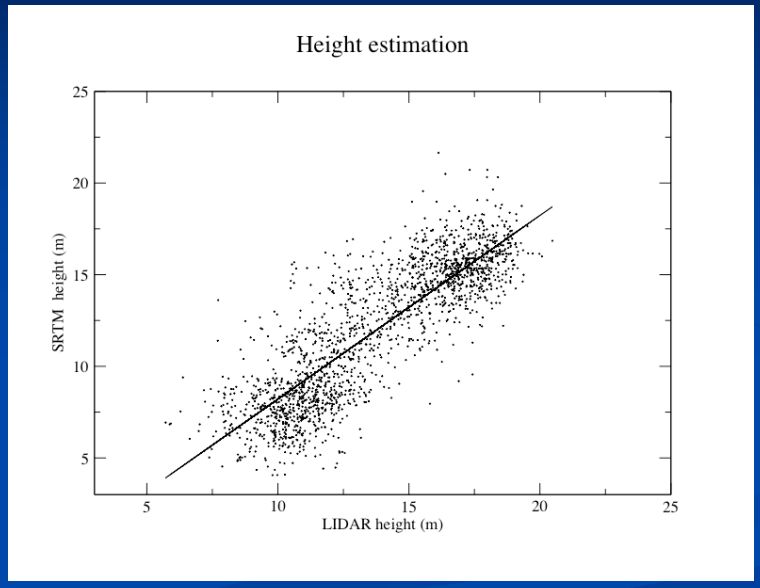


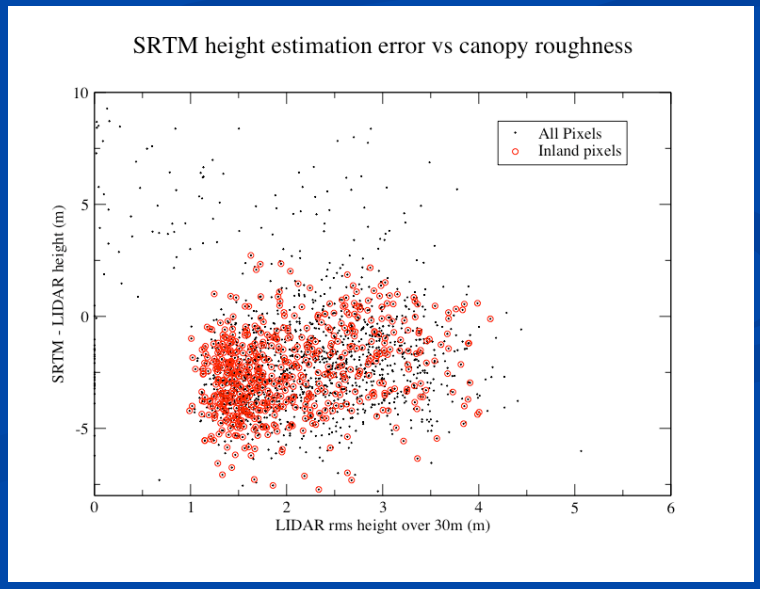
1. Fit planes with USGS DEM
2. Convert to orthometric height
3. Adaptive filtering
4. Masking water
5. Calibration Bias with LIDAR



SRTM Height Estimation

- Empirical Method
  - $H_{srtm} = 0.99\ H_{lidar} - 1.63$
  - Correlation 0.85
  - rms Height error 1.9m.
- No-Correlations
  - Canopy roughness
  - LIDAR height
  - SRTM height





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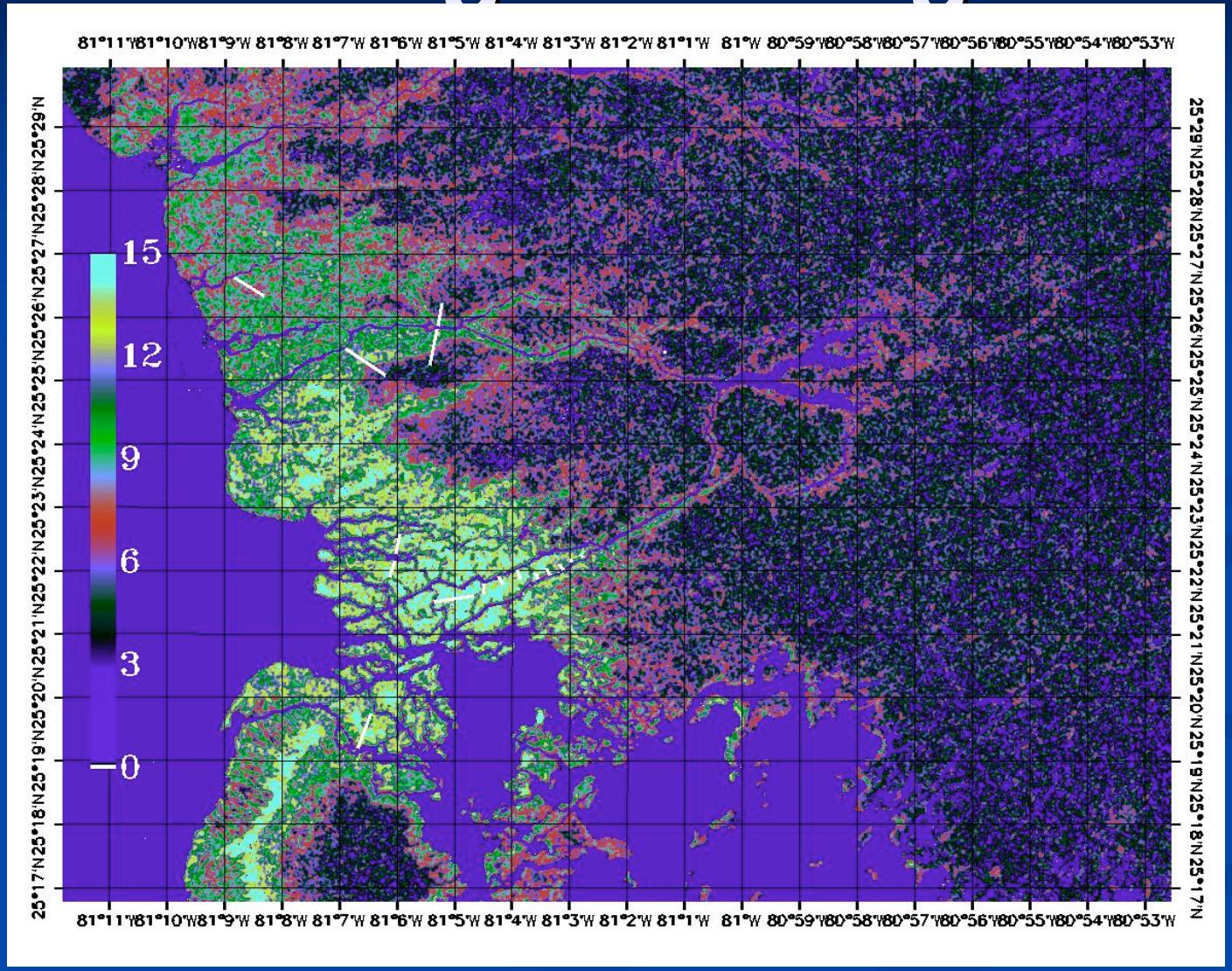
SRTM Mangrove Height Map



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Analysis and sources of Error

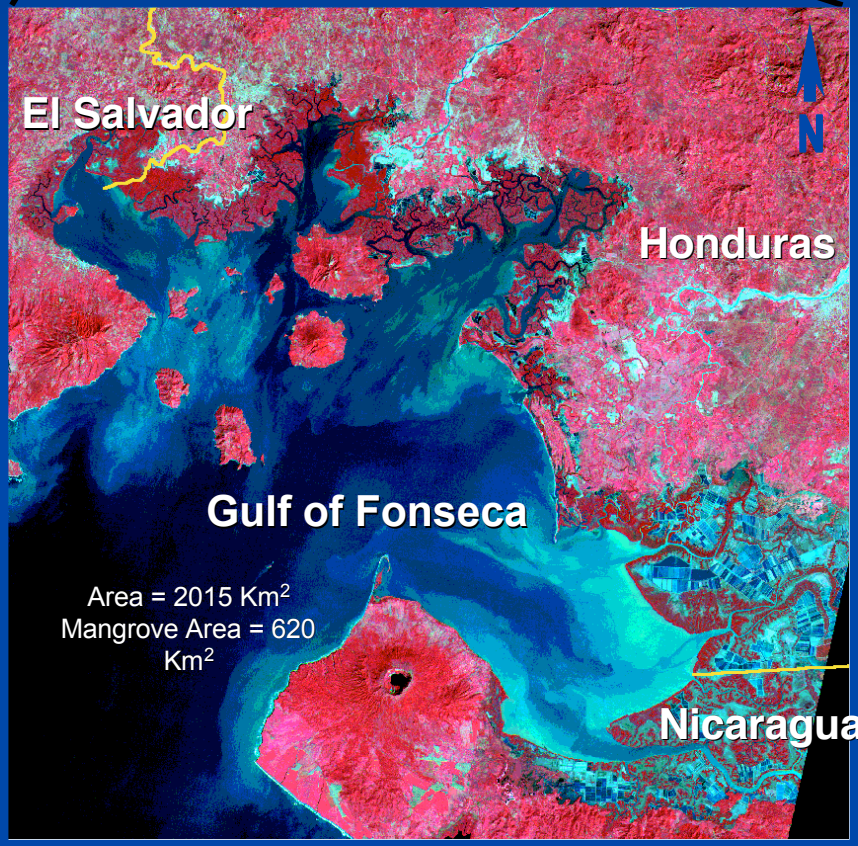
- Location of the ground
  - SRTM calibration
    - sea level around 0m
    - “Ground” (grassland) near mangroves around 1m
    - height stdev over grassland is 1.6m
      - Spatial filtering slightly improves
  - LIDAR data
    - ground between -0.5 and 1m
    - First stop data (no wave form)

Upcoming Analysis

- Averaging method for LIDAR data
  - underestimation of tree height
    - Spatial Weighing (e.g. intensity)
- Mixed pixels
  - The error near rivers and large tidal channels is large.
    - Geolocation
    - Masking

Gulf of Fonseca, Honduras

Simard & Rivera-Monroy



The Gulf of Fonseca is located in the Pacific coast of Central America and includes coastal areas of El Salvador, Nicaragua, and Honduras.

Mangrove forests composed by *R. mangle, A. germinans, A. bicolor, L. racemosa, and C. erectus* surround the estuaries and embayments.

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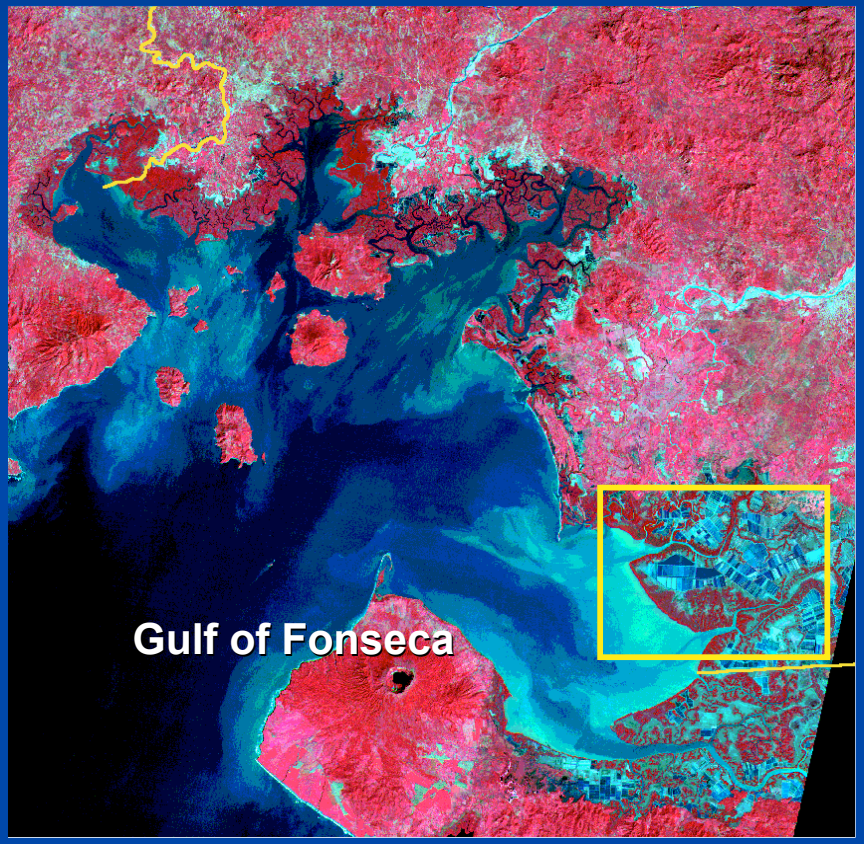
Shrimp Farming Development in Honduras

Shrimp Farming in the Southern Region of the Gulf of Fonseca



Estimated total area of shrimp ponds:

1985 = 845 ha

1999 = 15,580 ha

(V. H. Rivera-Monroy, U. Louisiana at Lafayette)

Granjas Marinas San Bernardo Shrimp Farm (7,000 ha); Largest shrimp farm in the Gulf of Fonseca.

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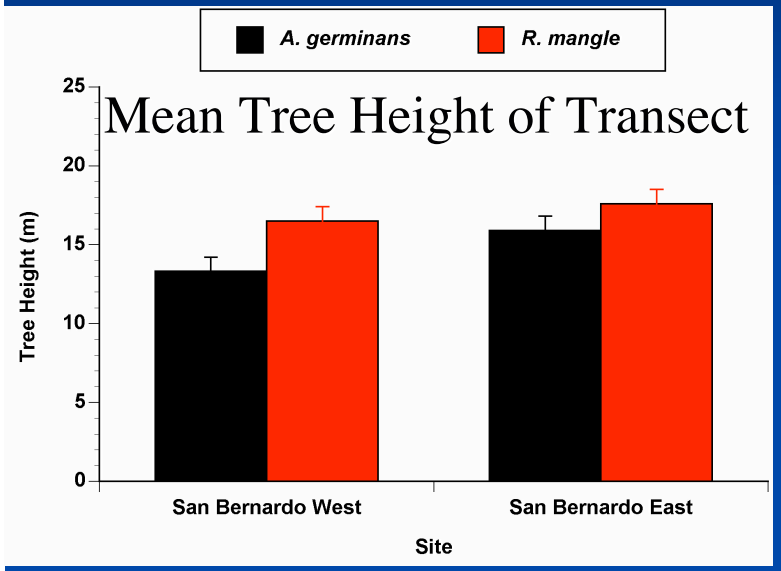
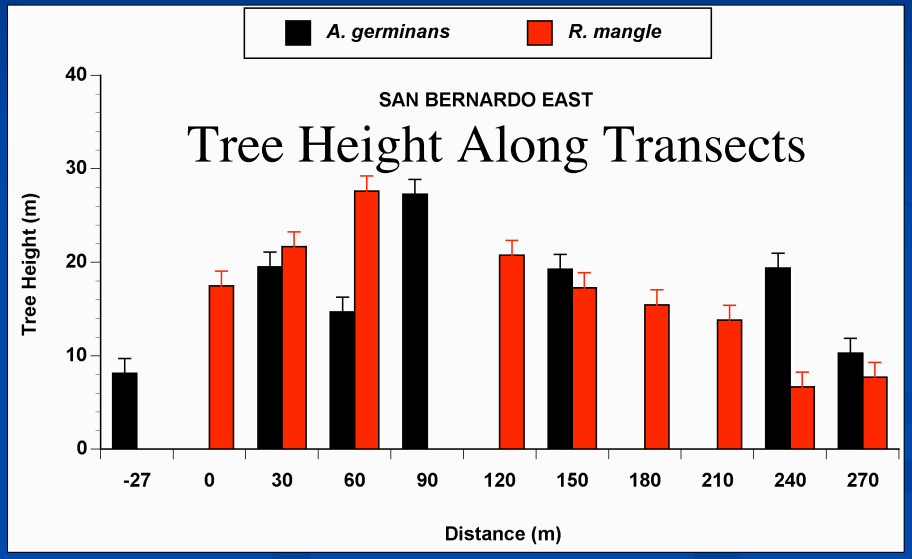
Field Data





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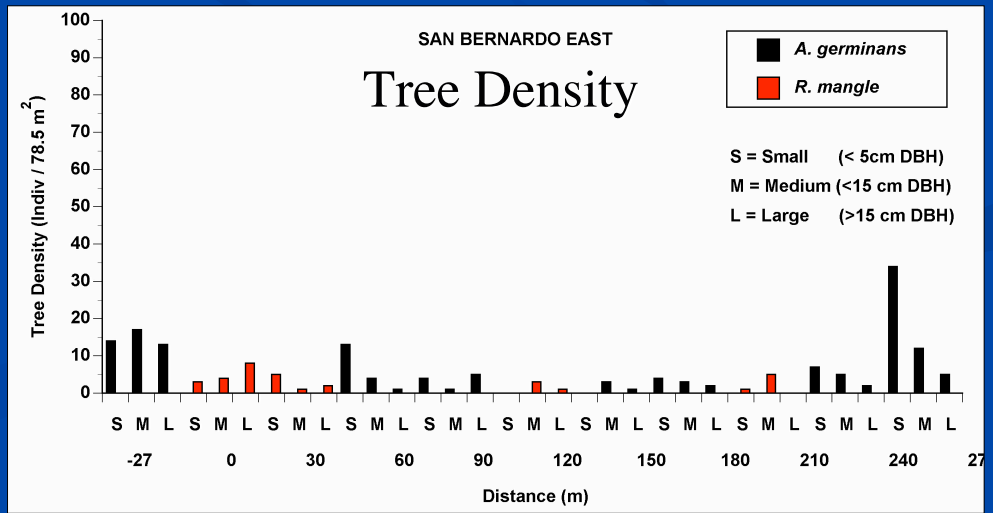
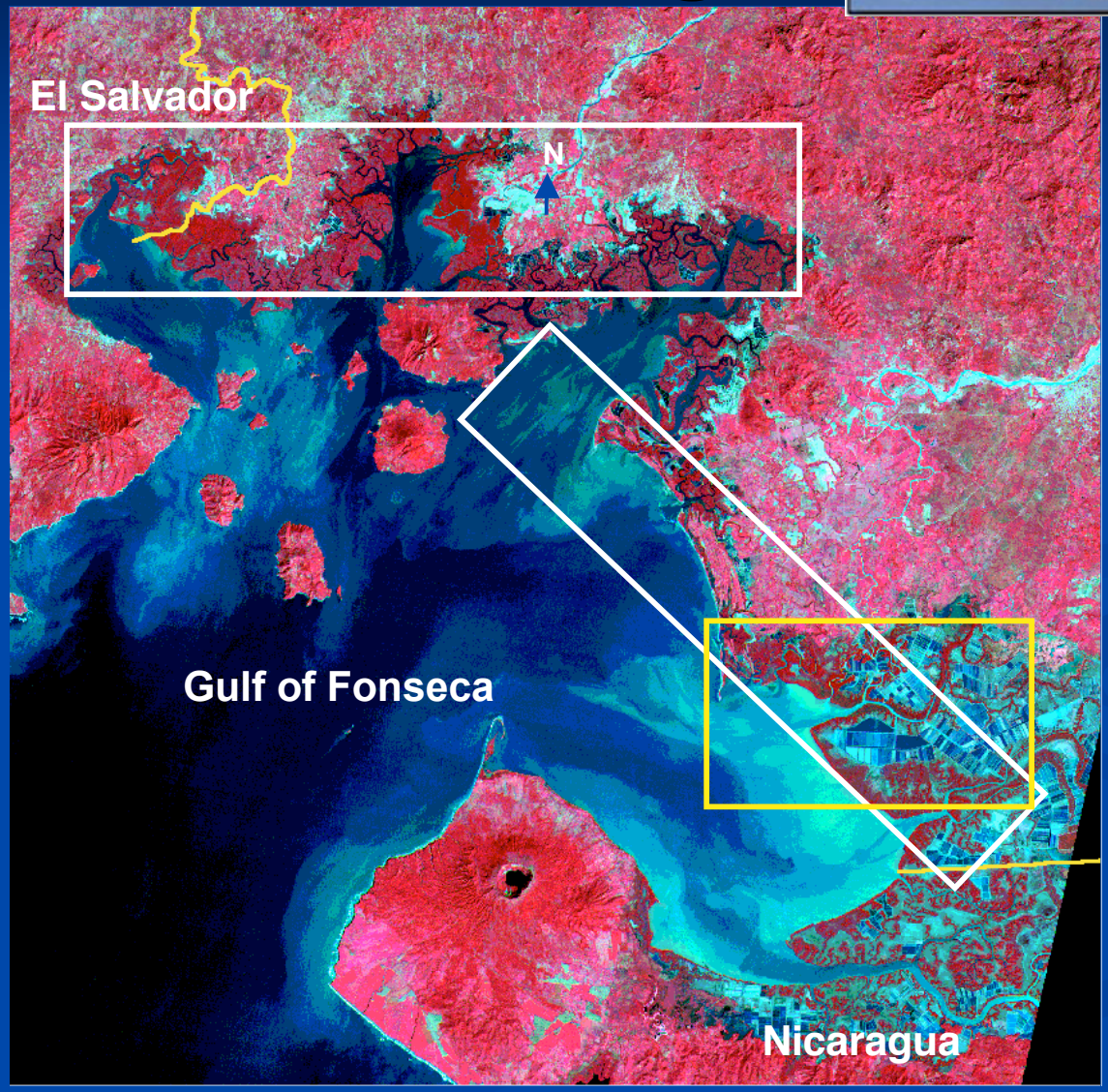


AIRSAR Coverage



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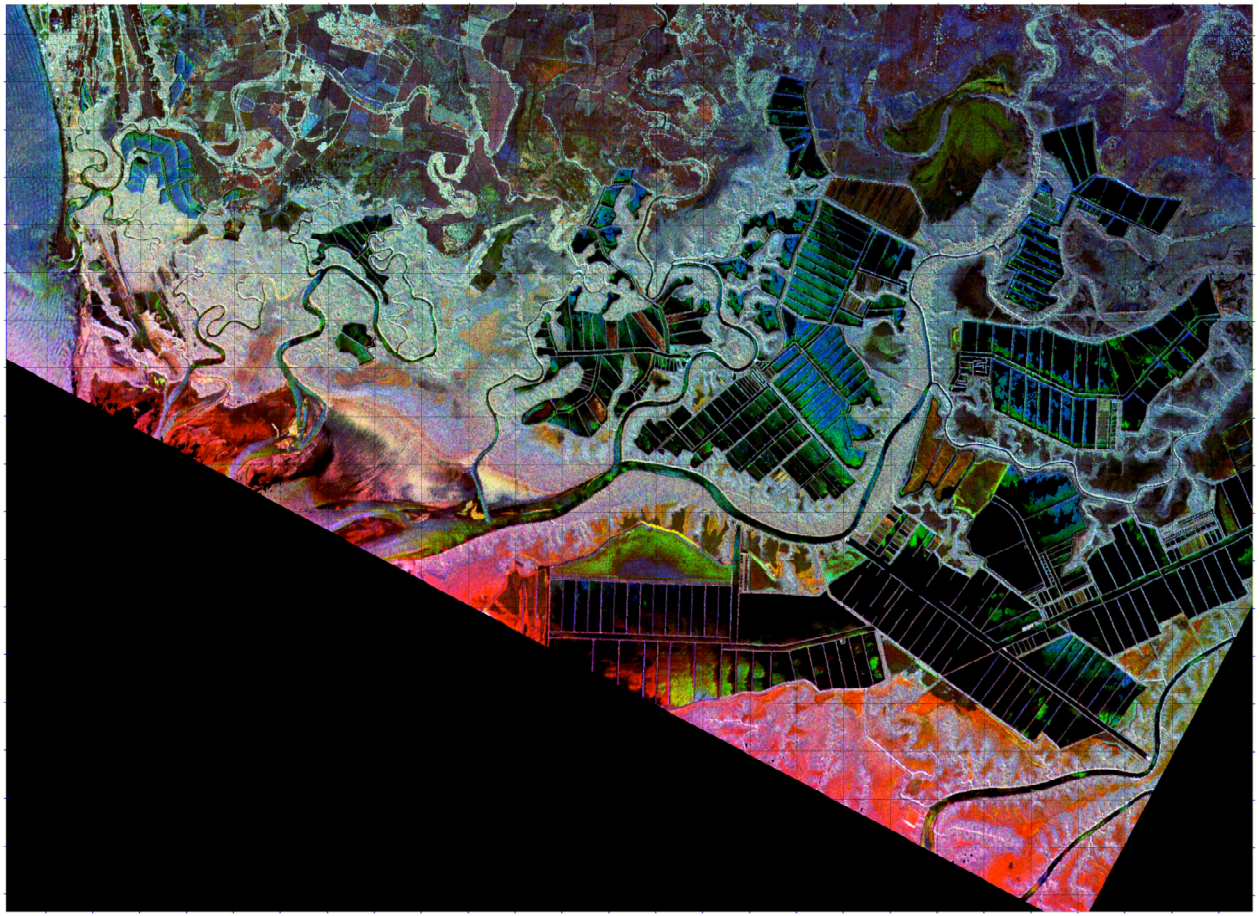
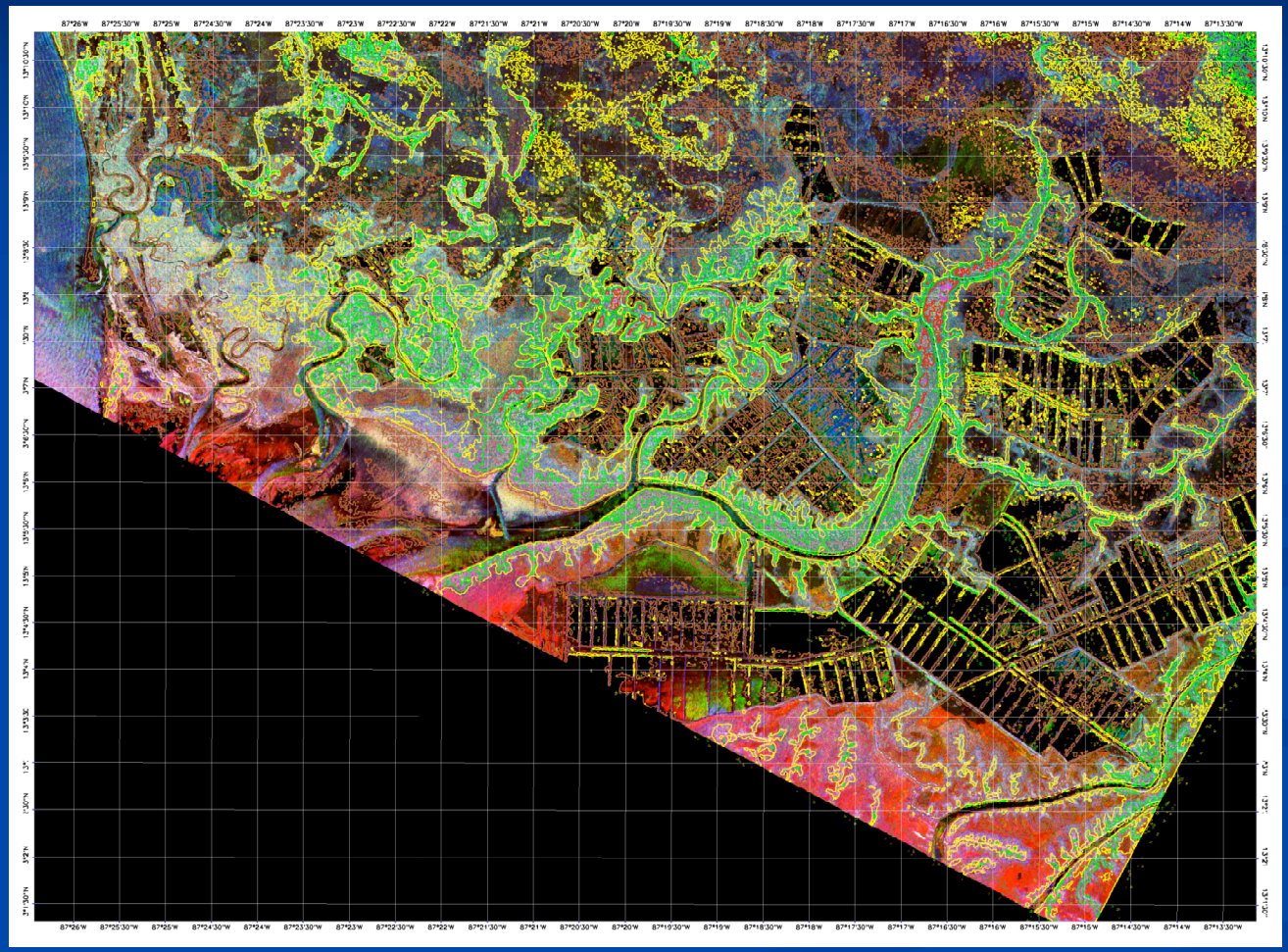
AIRSAR Backscatter data



AIRSAR Backscatter data



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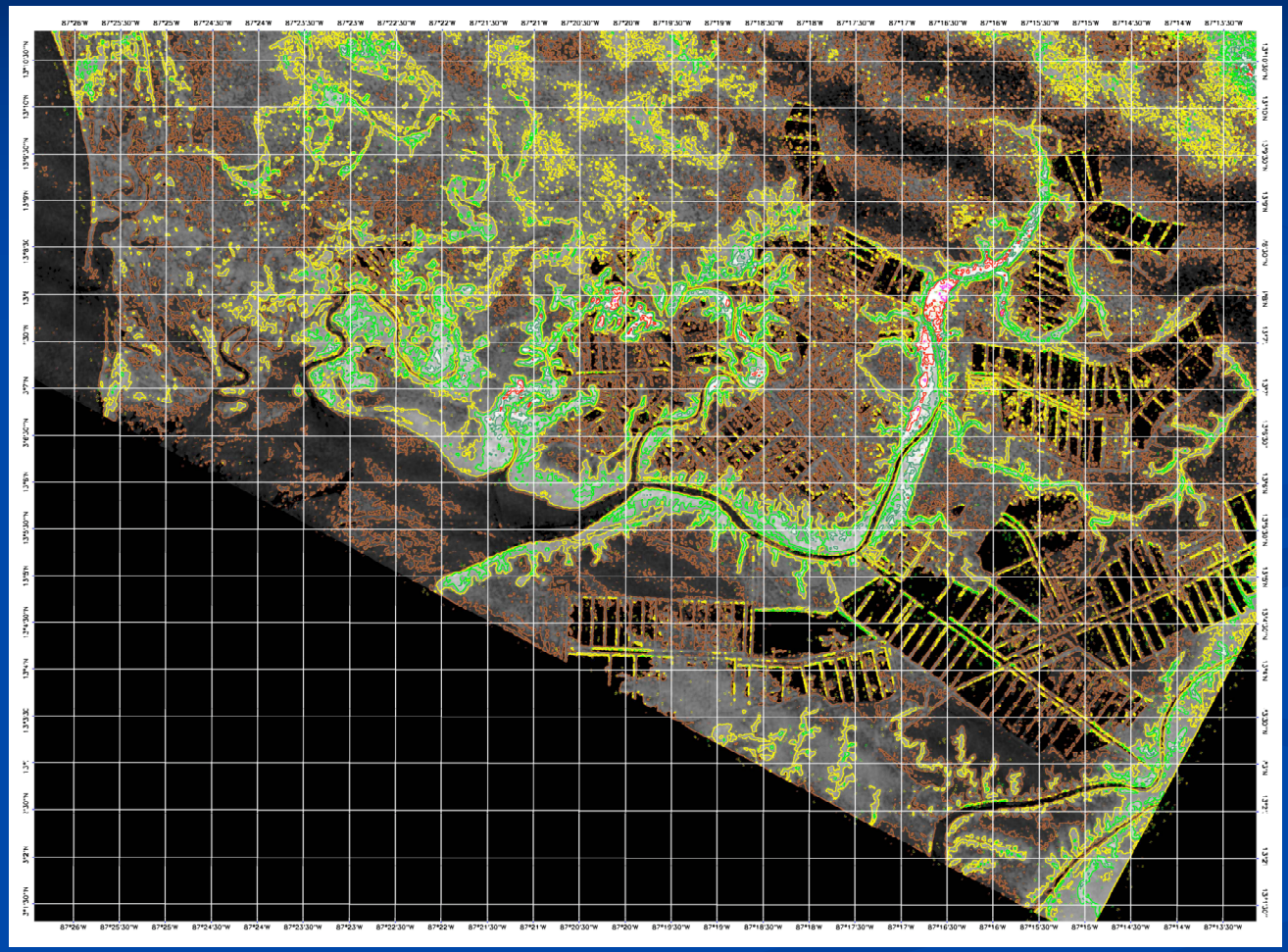
AIRSAR DEM (Pedregal)



The Current AIRSAR DEM needs reprocessing with phase screen

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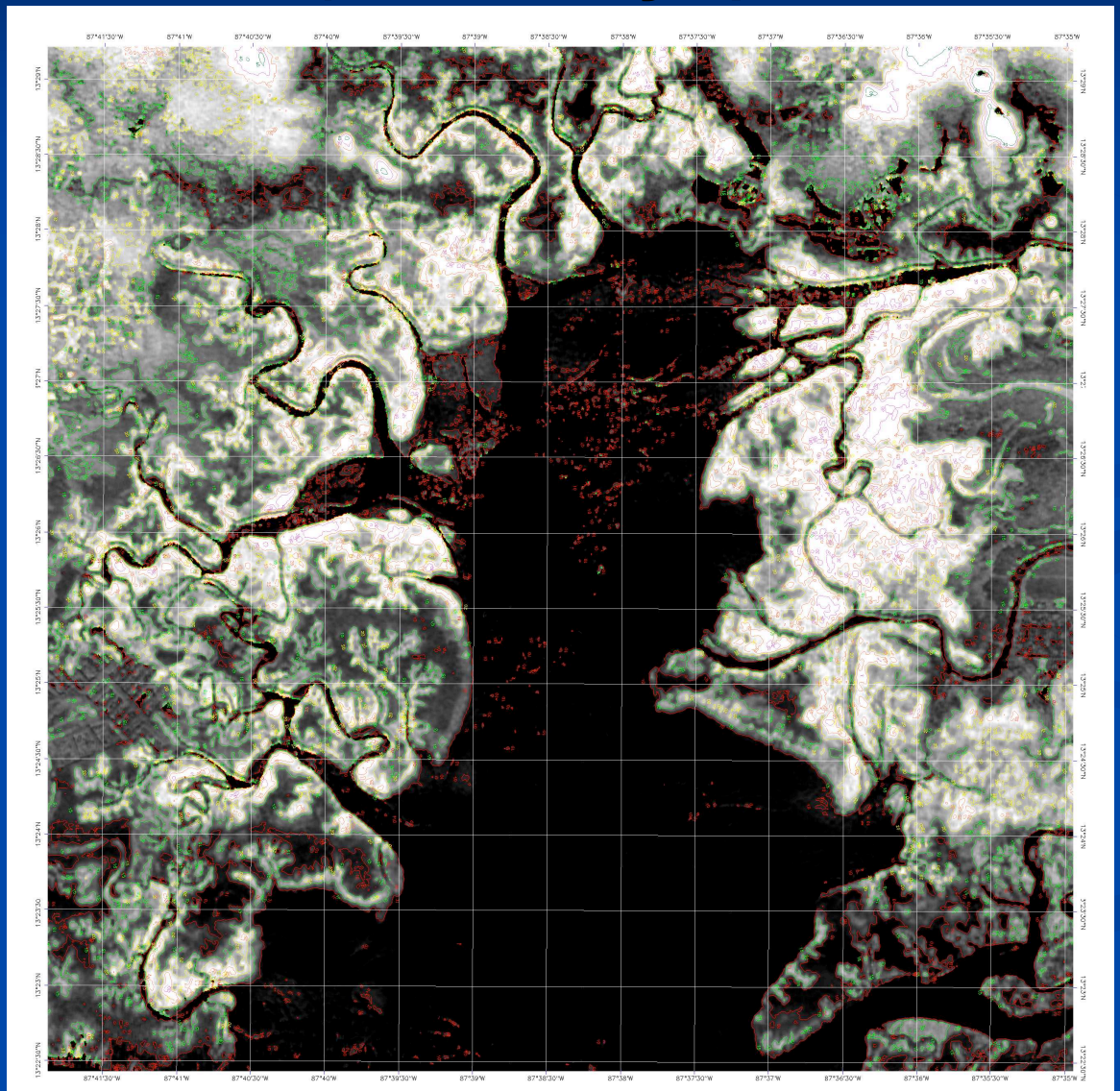
AIRSAR Vegetation Height Estimate (Chismuyo)



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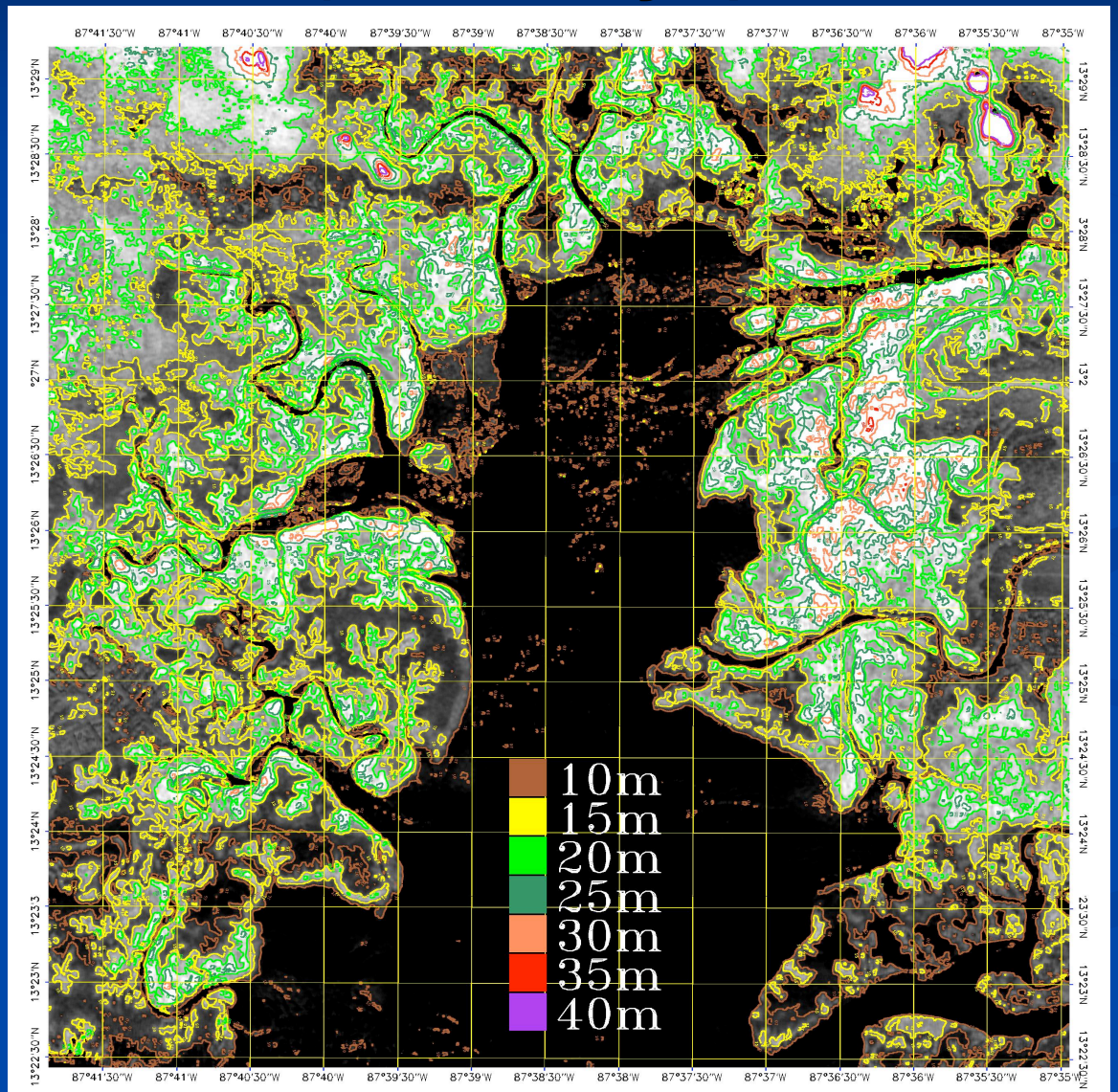
AIRSAR Vegetation Height Estimate (Chismuyo)



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2005

- Analysis of AIRSAR Data
  - Processing of AIRSAR data with phase screen
  - Mapping of Mangrove height in Golfo de Fonseca
  - Extent mangrove and productivity
  - Extent of Shrimp Farms and surrounding mangroves
- 2 Vegetation Model
  - 3D Structure of mangrove forest at landscape scale
    - Height
    - Biomass
    - species
    - Tree architecture
  - Radar backscatter
- Ecosystem Productivity Spatial Modeling

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