K&C Phase 3 – Brief project essentials

Mangrove extent, change and structure in Africa and the Americas

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(Presenting: Naiara Pinto, University of Maryland College Park)

Project objectives and schedule

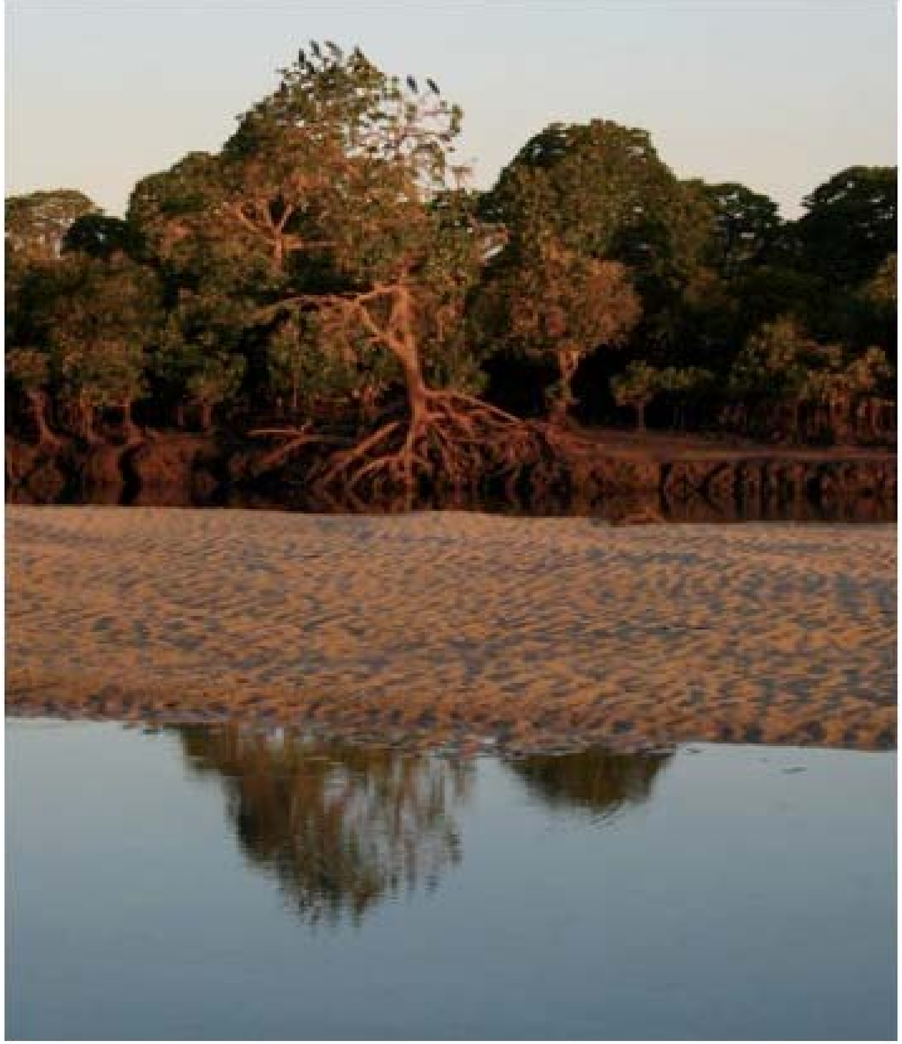
We propose to produce detailed maps of land cover and forest structure change in mangrove forests of the Americas and Africa using the K&C PALSAR data.

Objectives：

1) Improve current global maps of mangrove cover,
2) Produce annual land cover change products for key sites in the Americas and Africa, and
3) Produce tree height, biomass and carbon storage estimates for these sites

- This project responds to the original K&C objective of “developing of a regional scale application” by producing annual land-use change and forest structure products for regional sites in the Americas and Africa.
- We have chosen sites based on our access to field and remote sensing data (PALSAR, UAVSAR, GLAS, airborne lidar, SRTM).
- These mangrove systems are also chosen for the importance in terms of biodiversity, ecosystem function, local-regional livelihoods and landscape change, as well for their locations across distinct yet representative regional and bio-geographic contexts.

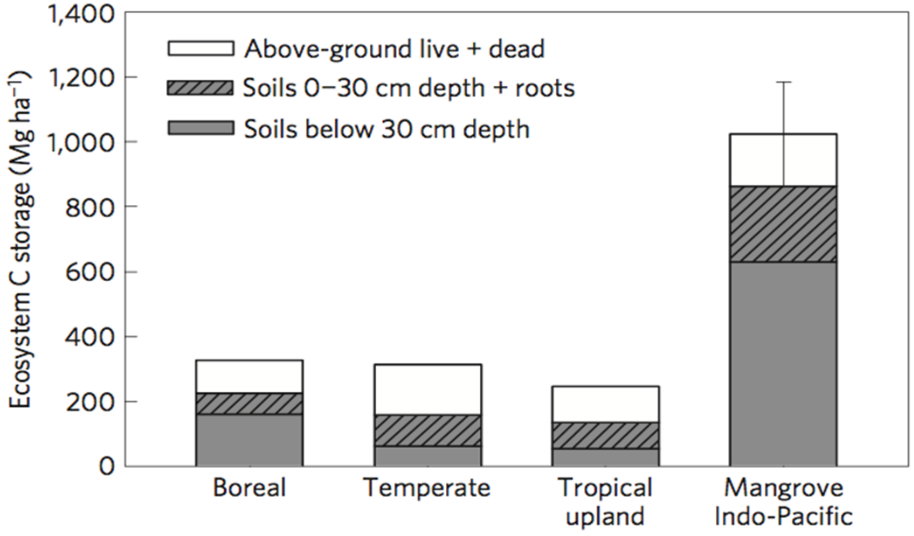
Mangroves 101



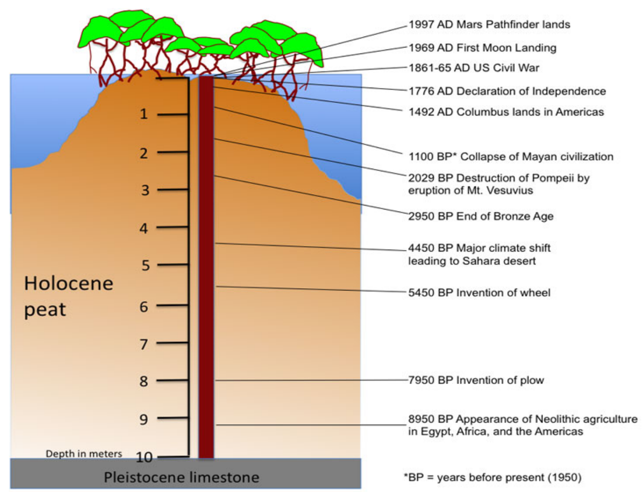
- Mangrove forests are coastal wetlands that contribute to biodiversity and act as major biogeochemical links between upland and coastal regions.
- Biodiversity: Habitats for over 1300 species of animals, including many economically important fish and shrimp species.
- Biogeochemistry: Among the most productive ecosystems on Earth with 2.5g C m^2 per day
  - 25% accumulates in mangrove sediments
  - 25% recycled
  - 50% exported to oceans and contributes 10% of C to Global Dissolved Organic Carbon
- They act as a protection of shoreline against topical storms, hurricanes and Tsunamis

Mangroves and Carbon

- Mangroves are among the most carbon-rich forests in the tropics, containing on average 1,023 Mg carbon per hectare in above and belowground C .
- Organic-rich soils range from 0.5 m to more than 3 m in depth and account for 49–98% of carbon storage in these systems.
- The estimated economical of mangrove services value varies between $200k to $900k per km^2 per year (UNEP report 2006)
- New Initiatives such as Reduced Emissions from Deforestation and Degradation (REDD+) and the UN Blue Carbon Initiative are developing frameworks to compensate states for their C storage.



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

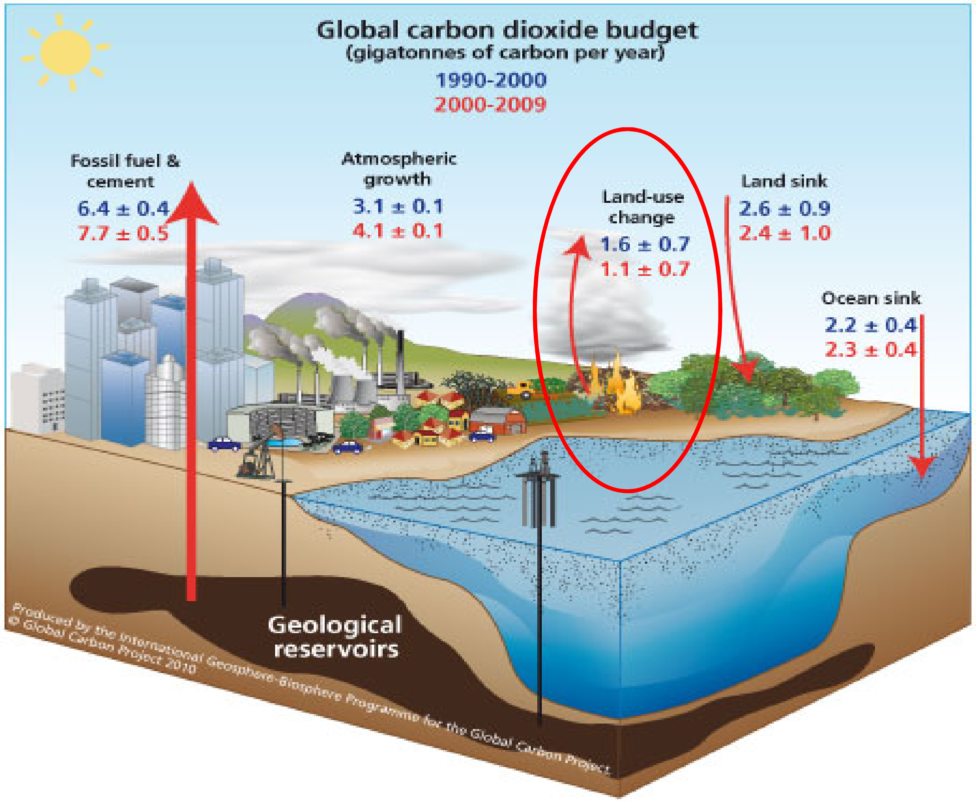


Mangroves are endangered

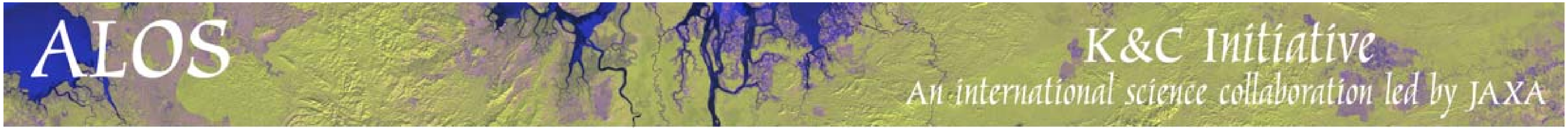
But as a result of their location and economic value, they are among the most rapidly changing landscapes.

- 35% to 50% of mangrove forests have disappeared in the past 60 years, although no systematic baseline data is available;
- The greatest current threats to mangroves derive from human activities: aquaculture, freshwater diversions, overharvesting and urban and industrial development.
- The effects of climate change, such as sea-level rise and increased extreme climatic events (e.g. hurricanes), may also increase the vulnerability of this ecosystem

How do mangroves fit into the Global C cycle?

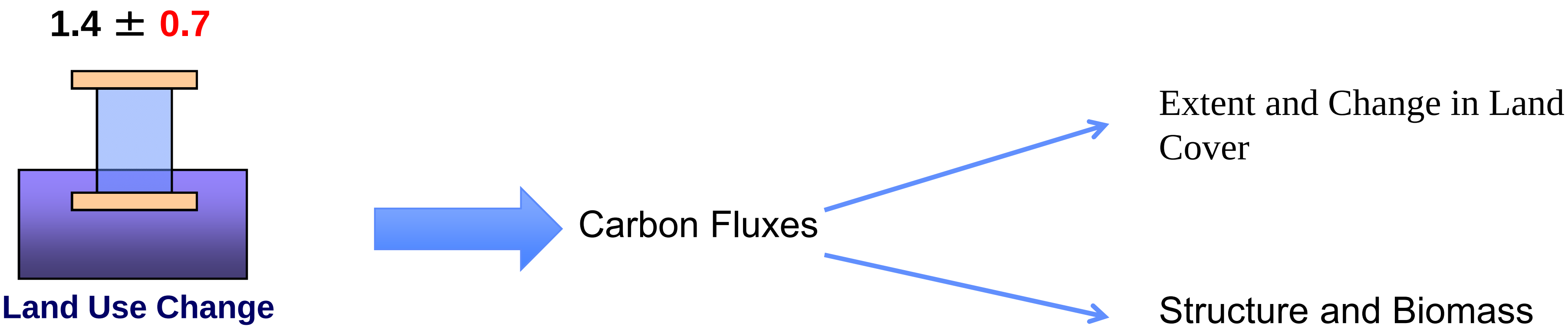


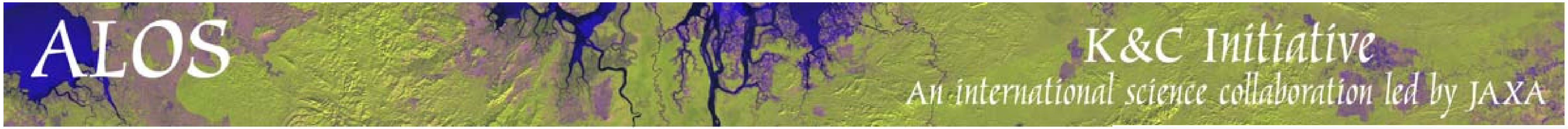
Mangrove deforestation generates emissions of 0.02–0.12 Petagrams carbon per year—potentially **as much as around 10% of emissions from deforestation globally**, despite accounting for just 0.7% of tropical forest area (Donato et al, 2011).



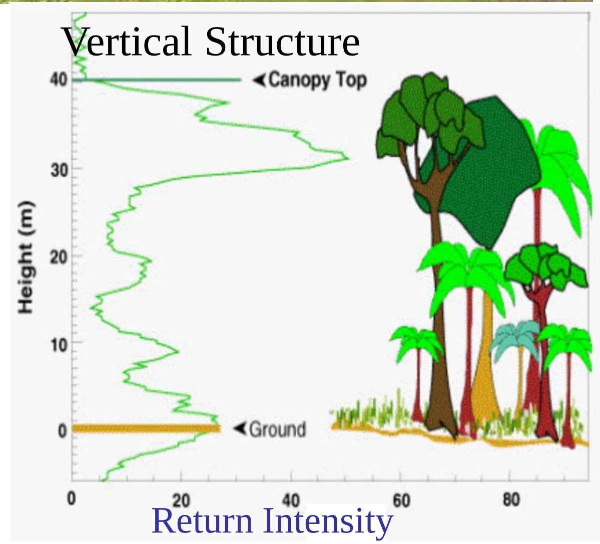
Uncertainties of biomass measurements

- Currently, the uncertainty in the magnitude of carbon emissions from land use changes is 66% of the input.
- Most of this uncertainty is due to errors in biomass estimation





Vegetation structure measurements

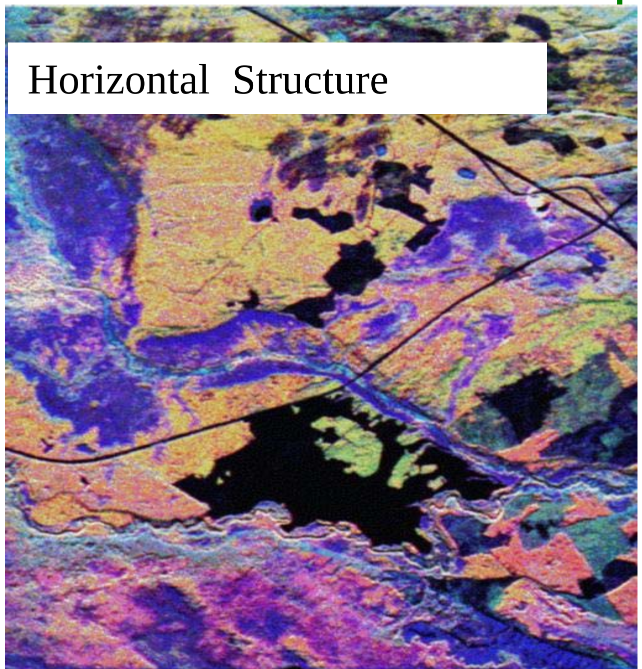


To better understand C emissions and ecosystem structure from mangroves and other ecosystems we need to accurately quantify ecosystem biomass, extent and change by measuring horizontal and vertical heterogeneity

- Horizontal structure: in terms of land cover and land cover change
- Vertical structure: in terms of forest height and biomass

•Three complementary technologies meet these science requirements:

- Lidar
- Interferometric Synthetic Aperture Radar (InSAR)
- Polarimetric SAR (PolSAR)

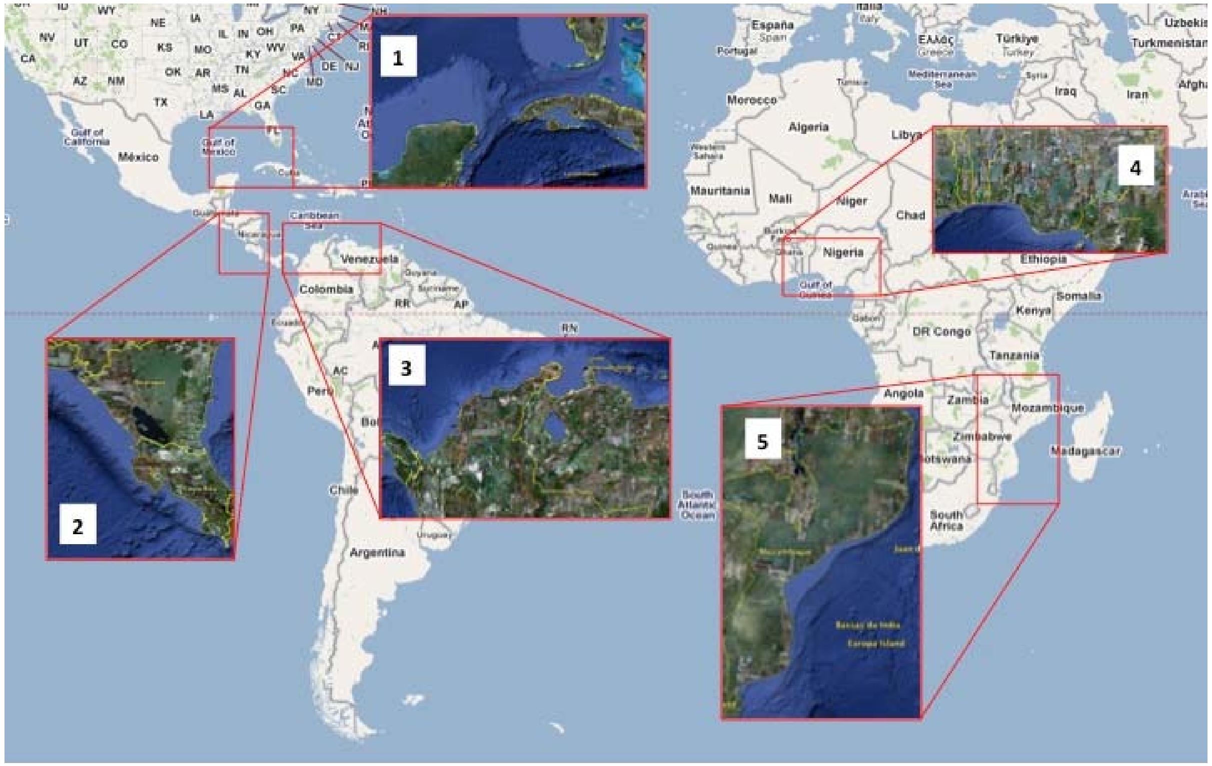


This is what we are doing as part of our K&C project

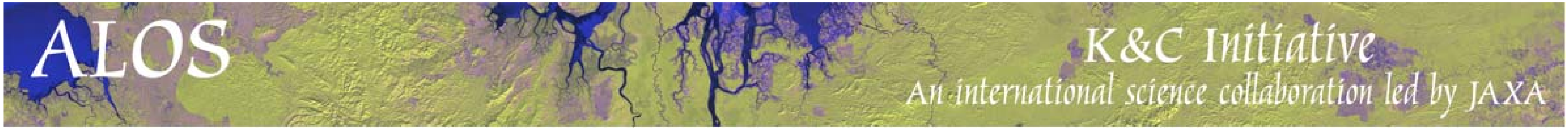
K&C Project areas

Project area(s)

- Gulf of Mexico:
  - Yucatan Peninsula, Mexico;
  - Southern Florida, USA)
- Central American Pacific Coast:
  - Gulf of Fonseca, Honduras;
  - Sierpe, Costa Rica
- Caribbean Coast of South America:
  - Cienaga Grande de Santa Marta, Colombia;
  - San Juan estuary, Venezuela
- Gulf of Guinea:
  - Togo-Benin-Nigeria Lagoons
- Mozambique:
  - Maputo Bay,
  - Zambezi Delta



1. Gulf of Mexico
2. Central American Pacific Coast
3. Caribbean Coast of South America
4. Gulf of Guinea
5. Mozambique



Project objectives and schedule

This project responds to all three of the K&C “3C” thematic drivers:

- **International Conventions:**
  - the data products of land cover and change, forest height and biomass are crucial for the UN Reduced Emissions from Deforestation and Degradation (REDD) initiative, the UN Blue Carbon Initiative and the Ramsar Convention as they provide background and repeat data needed for the MRV (measuring, reporting and verification) process.
- **Carbon cycle science**:
  - The proposed data products will improve current estimates of carbon storage in forest and coastal ecosystems.
- **Environmental Conservation**:
  - the proposed products will also help in determining high conservation priority areas based on threats to and the health of the forest.

Project objectives and schedule

Foreseen deliverables/products:

- Annual mangrove cover and change maps for regional sites in the Americas and Africa for 2007 through 2011.
- Mangrove Tree height maps from K&C mosaics and ancillary field and GLAS data for the regional sites using a decision tree approach.
- Mangrove Biomass maps and changes from K&C mosaics and ancillary field and GLAS data for regional sites using a decision tree approach.

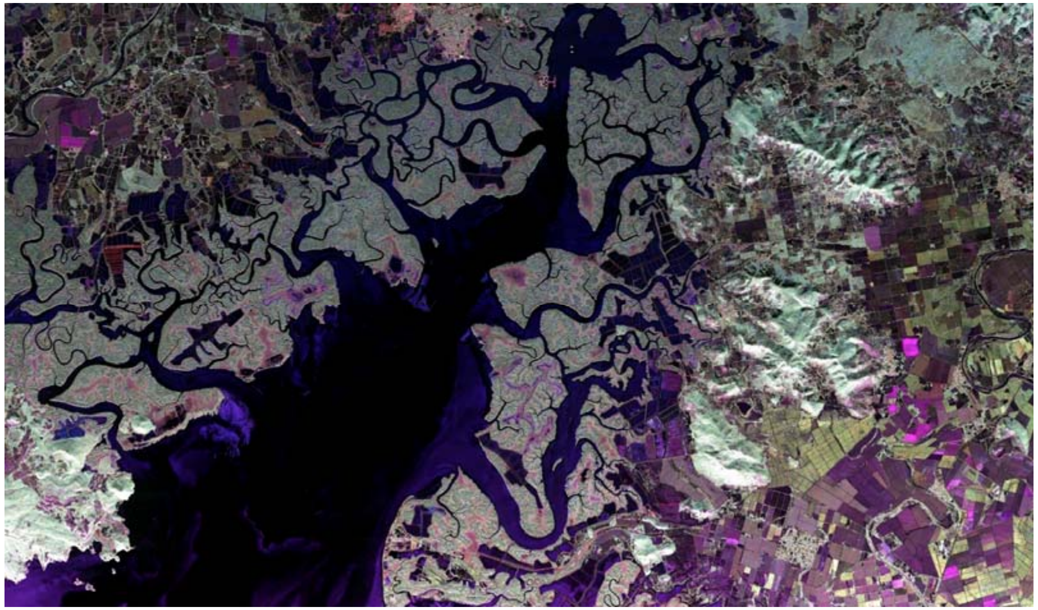
Milestones and Target dates

- 6/2011: Mangrove cover product for the regional sites in America and Africa for 2007
- 6/2013: Mangrove cover change product for the proposed regional sites from 2007-208
- 12/2013: Mangrove Above Ground Biomass, Tree height and cover change products for the regional sites through 2010
- 12/2014: Updates of all products with new data (up to 2011)

Support to JAXA's global forest mapping effort

The project can support JAXA's global forest mapping effort and help improve and validate the JAXA forest cover maps by:

- Improving the classification and algorithm development of the K&C annual map of global mangrove cover and changes in Africa and the Americas. Specifically, we will develop annual maps of mangrove cover and change in the five regions.
- Validating the K&C annual mangrove map from field data and other available remotely sensed data such as Landsat and UAVSAR.
- Validate the development of above ground biomass estimates in mangrove forests and help support the calibration and validation of the global mangrove biomass estimates developed by JAXA.



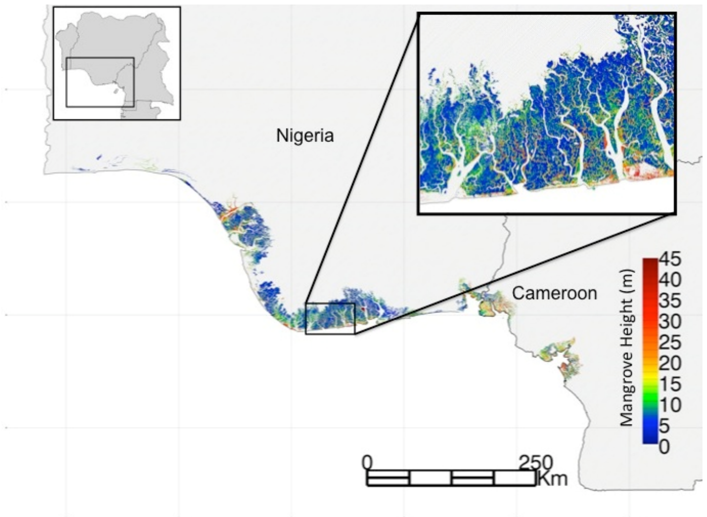
High resolution UAVSAR image of the Gulf of Fonseca, Honduras

- Type of data:
  - Gulf of Mexico: Field plot measurements, field photos, high resolution SAR data, 30 m height and biomass maps for 2000, GLAS tree height measurements
  - Central American Pacific Coast: Field plot measurements, field photos, high resolution SAR data, 90 m height and biomass maps for 2000, GLAS height measurements
  - Caribbean Coast of South America: Field plot measurements, field photos, 90 m height and biomass maps for 2000, GLAS tree height measurements
  - Gulf of Guinea: Field plot measurements, field photos, 90 m height and biomass maps for 2000, GLAS tree height measurements
  - Mozambique: field plot measurements, field photos, 90 m height and biomass maps for 2000, GLAS height measurements

- Restrictions: Current field data will be available to K&C team after publication expected early 2012. The data for Mozambique, Florida and Colombia has already been published and is available for distribution. New field data collected specifically for the proposed K&C project, will be made available within 2 months to allow for database analysis and verification of dataset.

Ground Truth Data

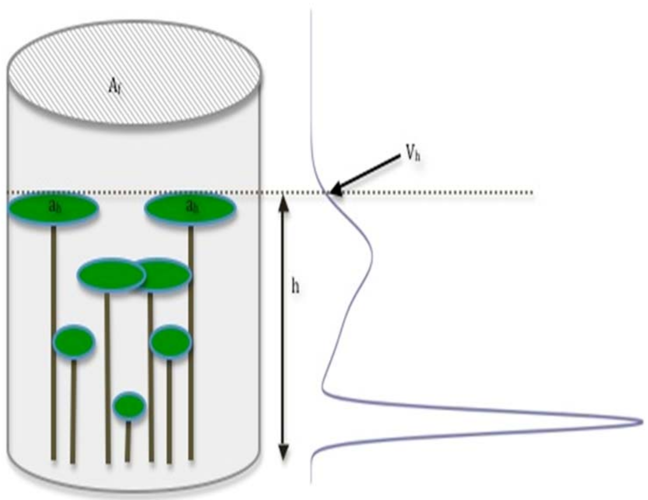
Site	Plot data	Field Photos	High Res SAR	30m Height and Biomass for 2000	GLAS canopy height
Gulf of Mexico	✔	✔	✔	✔	✔
Central America	✔	✔	✔	✔	✔
Carribbean	✔	✔	x	✔	✔
Gulf of Guinea	✔	✔	x	✔	✔
Mozambique	✔	✔	x	✔	✔

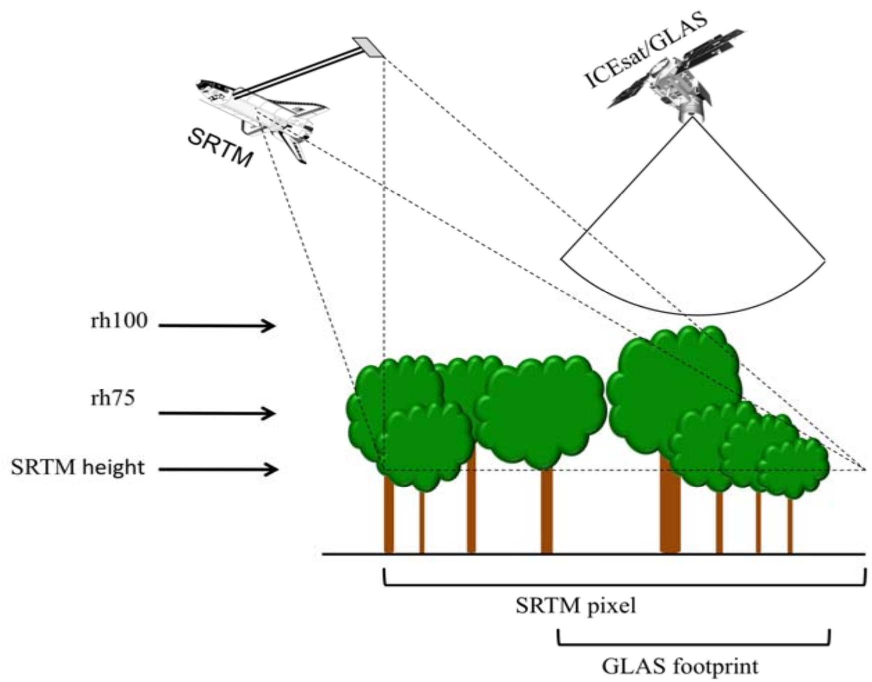


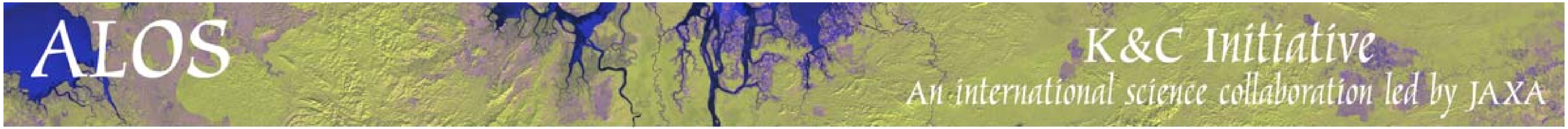
Our K&C project benefits from significant heritage

Vertical Structure from InSAR

- The C-band Radar signal penetrates into the canopy to scatter with all forest components and the ground.
- The radar height estimate (i.e. radar phase center) lies somewhere within the canopy volume, which can be used to estimate canopy height.
- Mangrove height estimates work well because mangroves grow at sea level

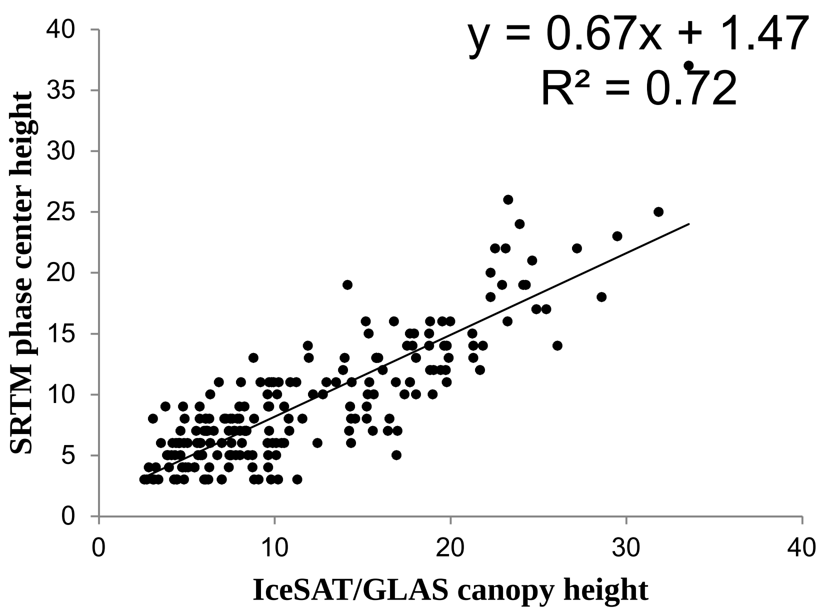


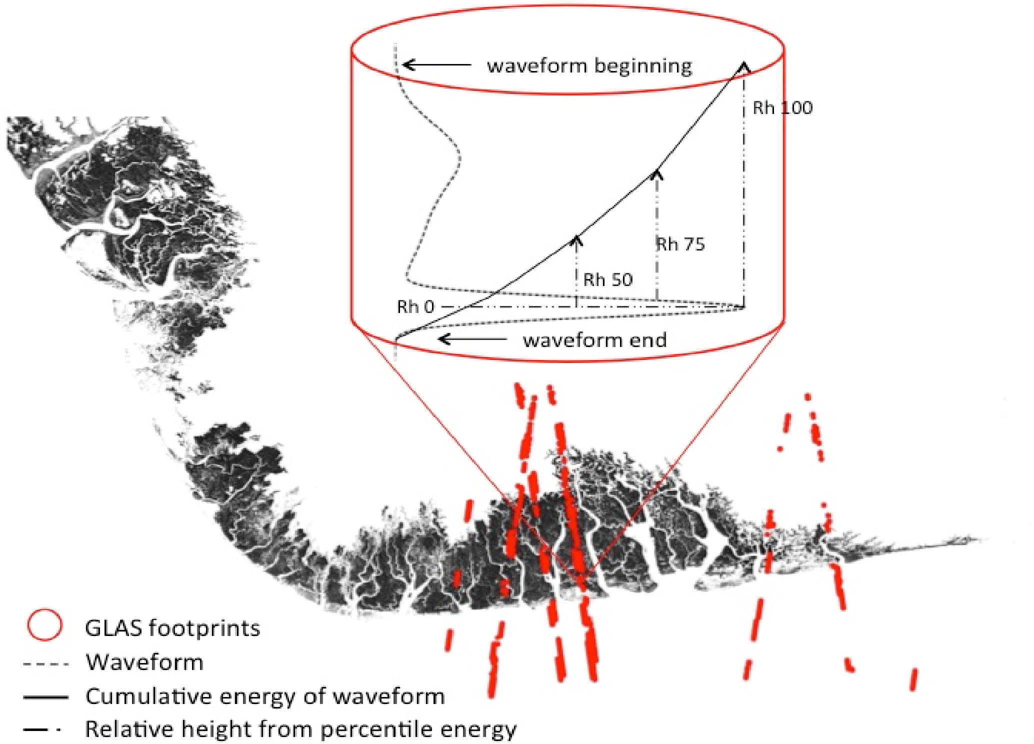




InSAR-Lidar Fusion

- The SRTM values corresponding to the GLAS shots were extracted
- Assuming that rh75 represents the canopy height, we derived linear regressions between the GLAS point's rh_{75} values, and DEM height values to determine the regression equation.



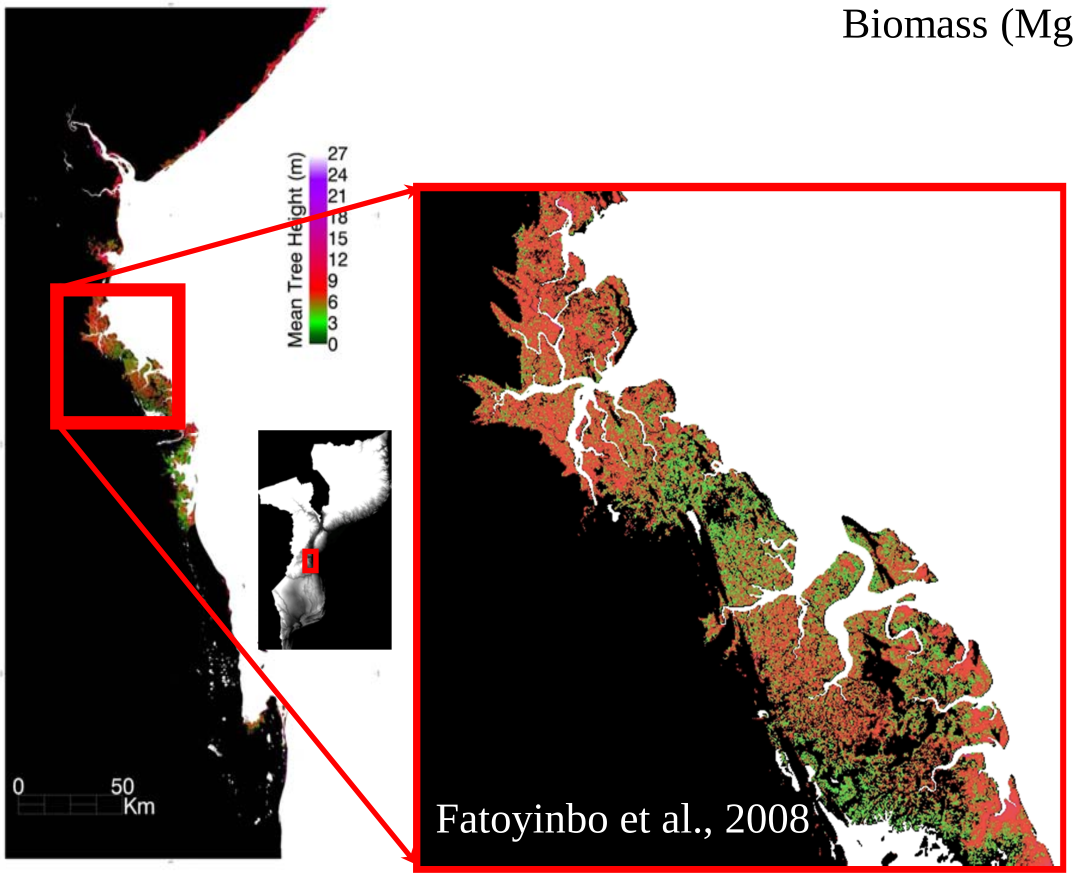


Height and Biomass estimation

- Studies of forest biomass worldwide have shown that there is a strong correlation between tree size (diameter and height), and tree biomass.

- For mangrove forests, a global stand height-biomass allometric equation was calculated by Saenger and Snedaker (1993):

$$\text{Biomass (Mg ha}^{-1}\text{)}, = 10.8 * \textit{Height (m)} + 35$$



Fatoyinbo et al., 2008

- We were able to produce height and biomass maps for Mozambique based on field data and SRTM alone, with an RMSE of 1.6 m and 65 Mg/ha.

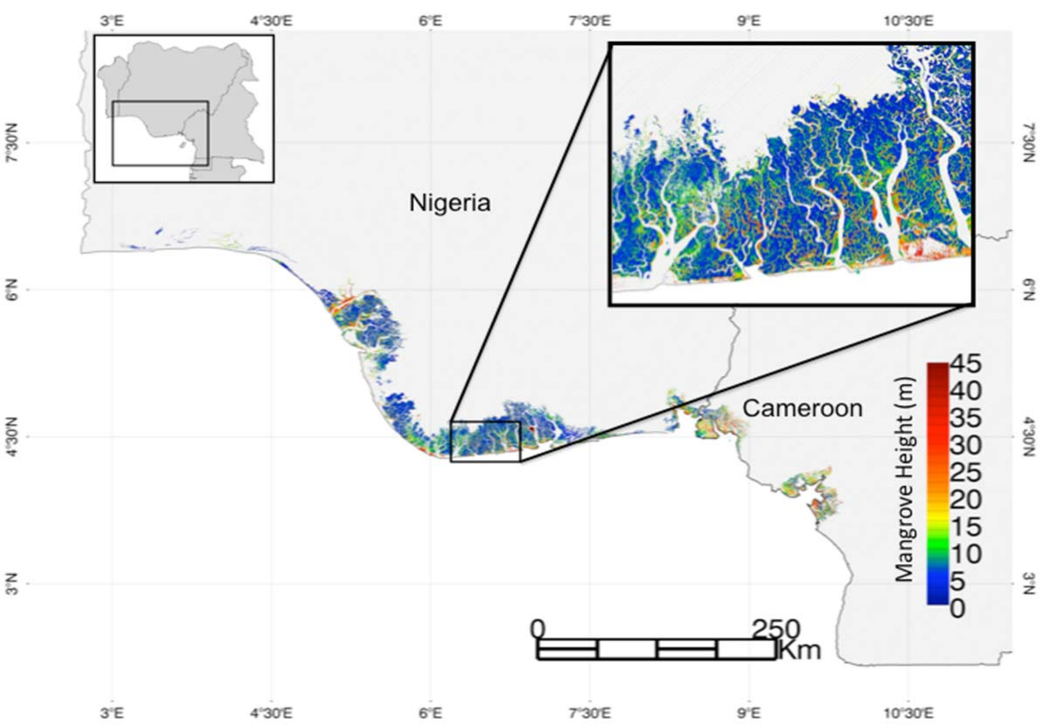
- Then we expanded our work to the entire African continent where we used GLAS height as calibration with an RMSE of 3.5 m

ALOS

K&C Initiative

An international science collaboration led by JAXA

Height and Biomass Map of All Mangrove Forests of Africa



Country	Area in km²	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

Fatoyinbo & Simard, IJRSE 2012

Google earth files: http:www-radar.jpl.nasa.gov/coastal

ALOS

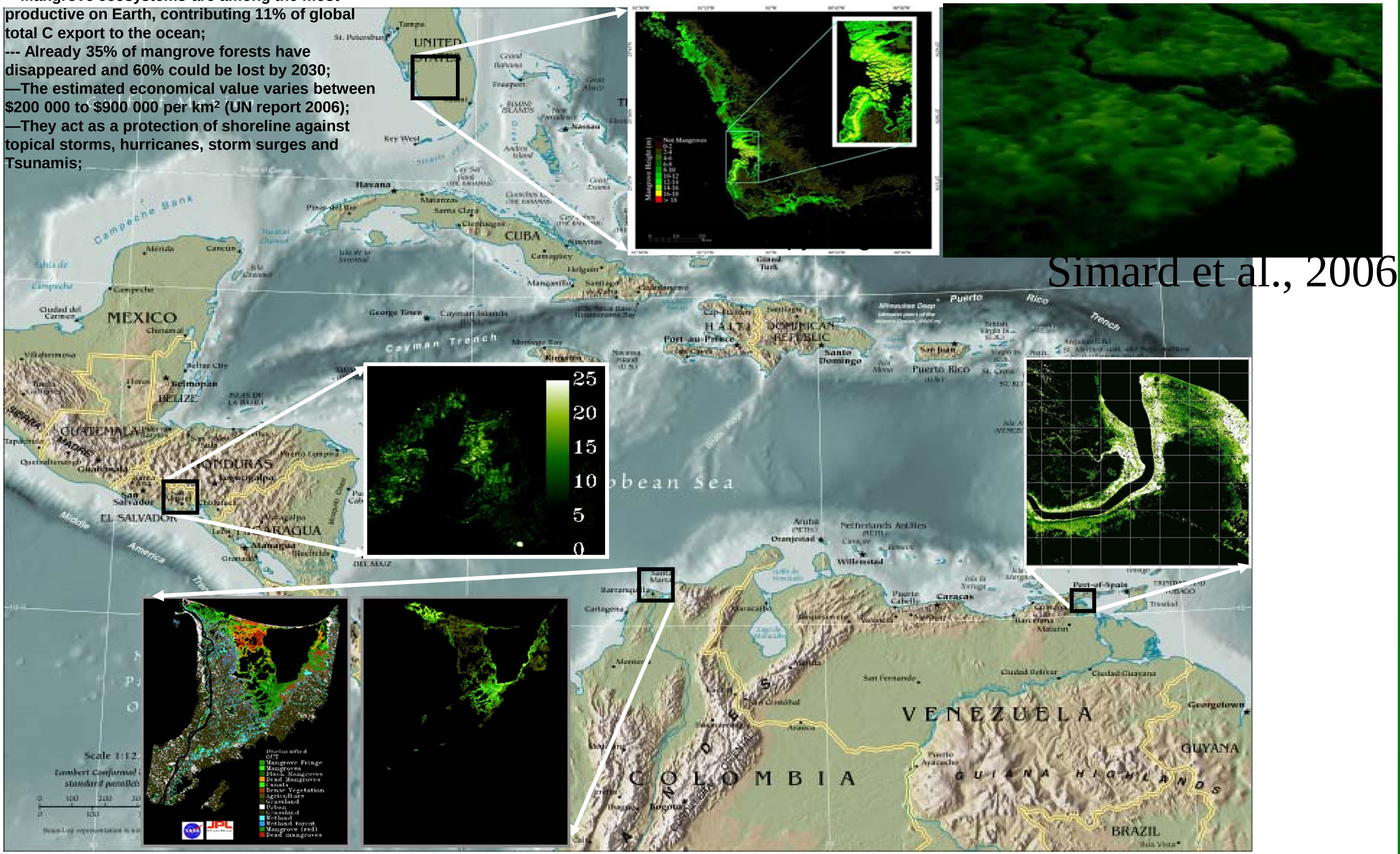
Americas

K&C Initiative

An international science collaboration led by JAXA

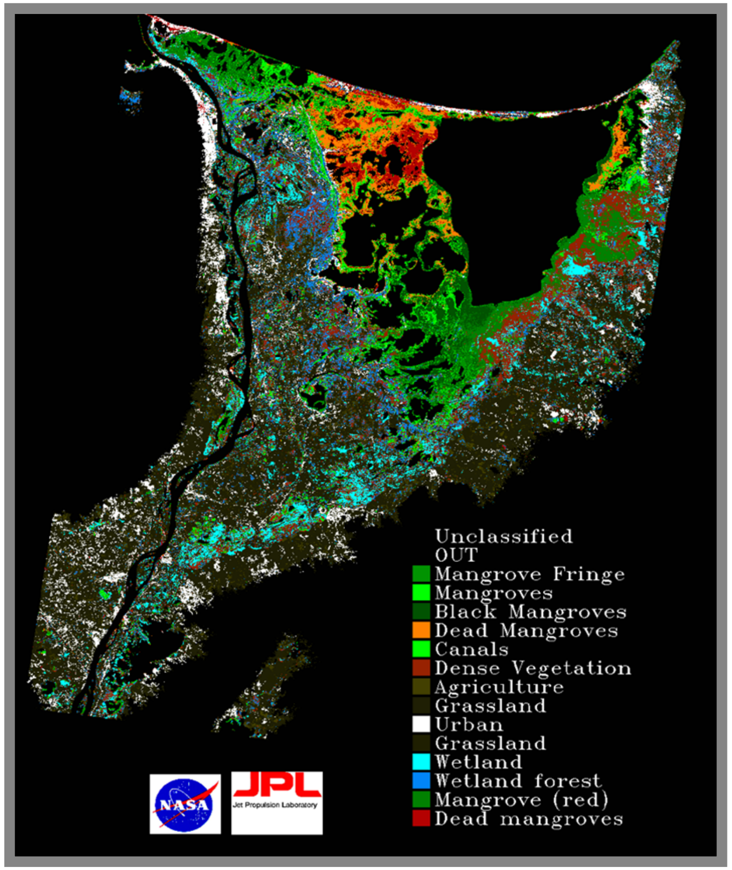
Marc Simard (marc.simard@jpl.nasa.gov)

—Mangrove ecosystems are among the most productive on Earth, contributing 11% of global total C export to the ocean;
--- Already 35% of mangrove forests have disappeared and 60% could be lost by 2030;
—The estimated economical value varies between $200 000 to $900 000 per km² (UN report 2006);
—They act as a protection of shoreline against topical storms, hurricanes, storm surges and Tsunamis;

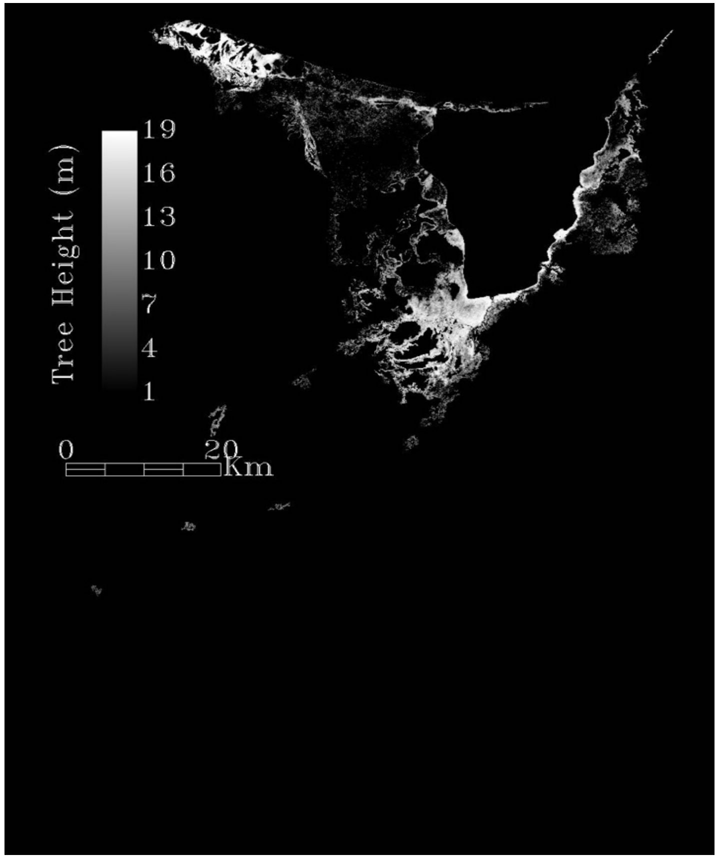


Simard et al., 2006

Cienaga Grande de Santa Marta, Colombia



Landsat Land Cover Classification

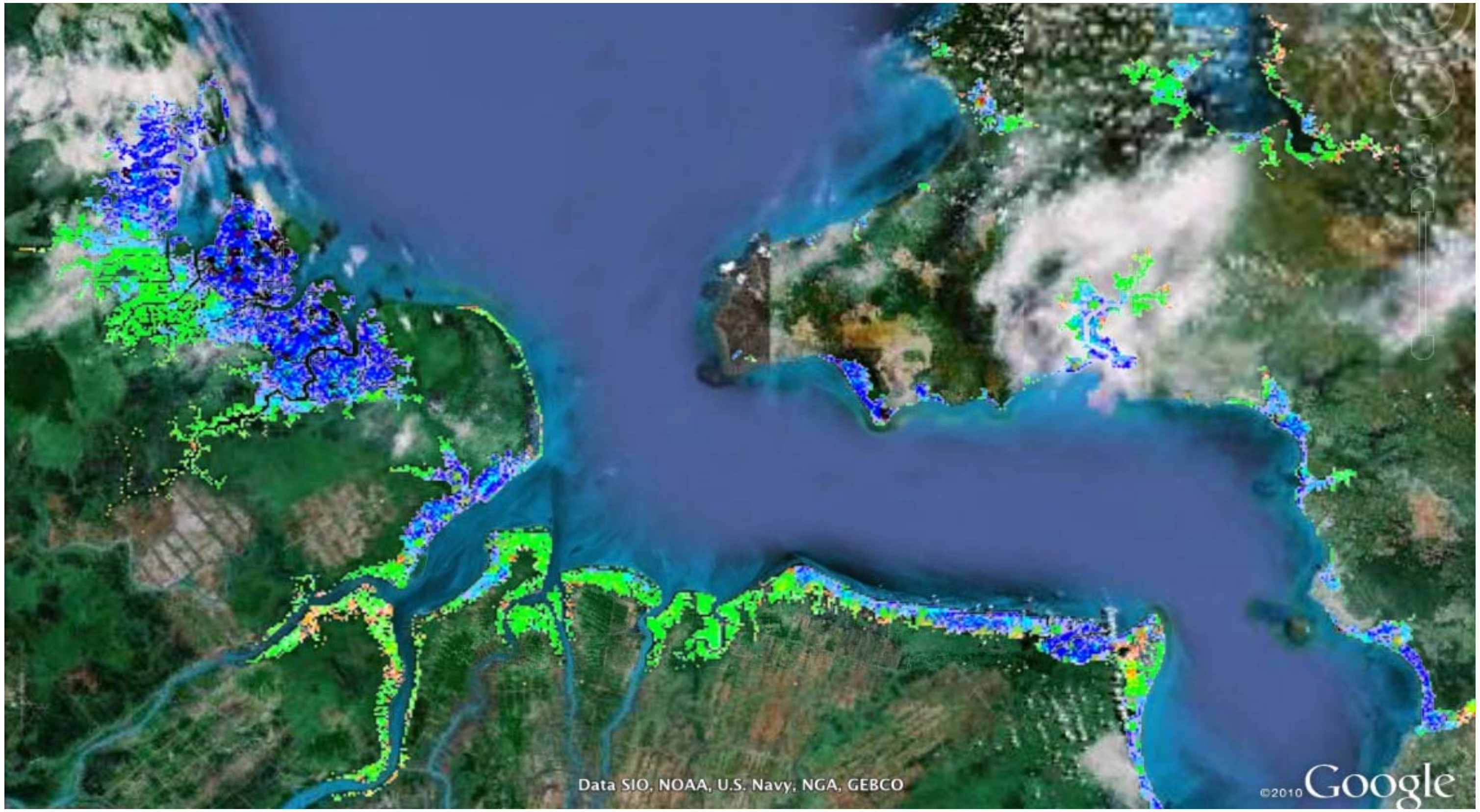


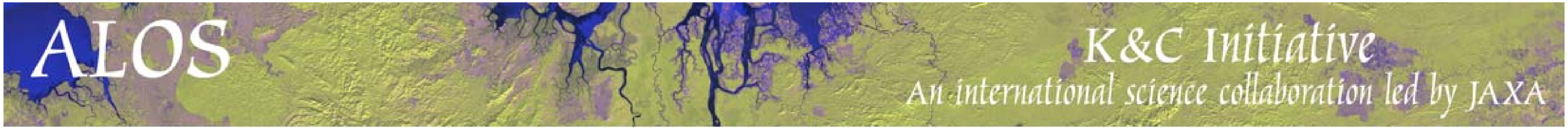
Mean Mangrove Tree Height

Simard et al. Remote Sensing of the Environment, 2008.

Next Steps: Global Map of Mangrove height and biomass

- Expand mangrove height and biomass measurements from SRTM and GLAS to the entire globe
- This is possible thanks to new global maps of mangrove cover (Giri et al 2011), improvements from ALOS/PALSAR landcover mapping and field data in South and Central America.





Related Projects:
Vulnerability assessment of mangroves in the Americas (NASA's Land Cover Land Use Change program 2012-1015)

PI: Marc Simard (Caltech Jet Propulsion Laboratory)

Co-I's:

Rinku Roy-Chowdhury (Indiana University);

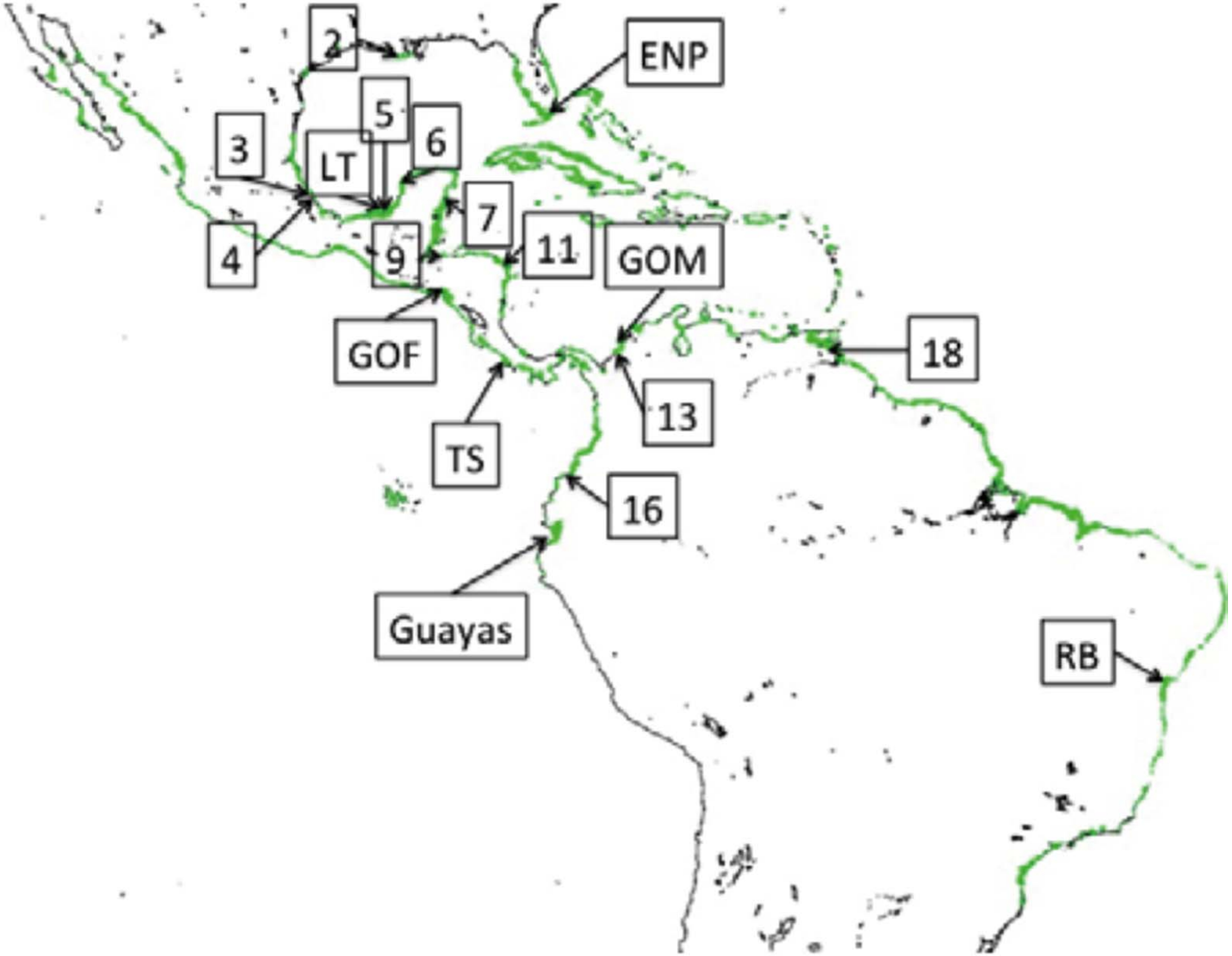
Temilola Fatoyinbo (Goddard Space Flight Center);

Victor- H. Rivera-Monroy (Louisiana State University)

OBJECTIVES:

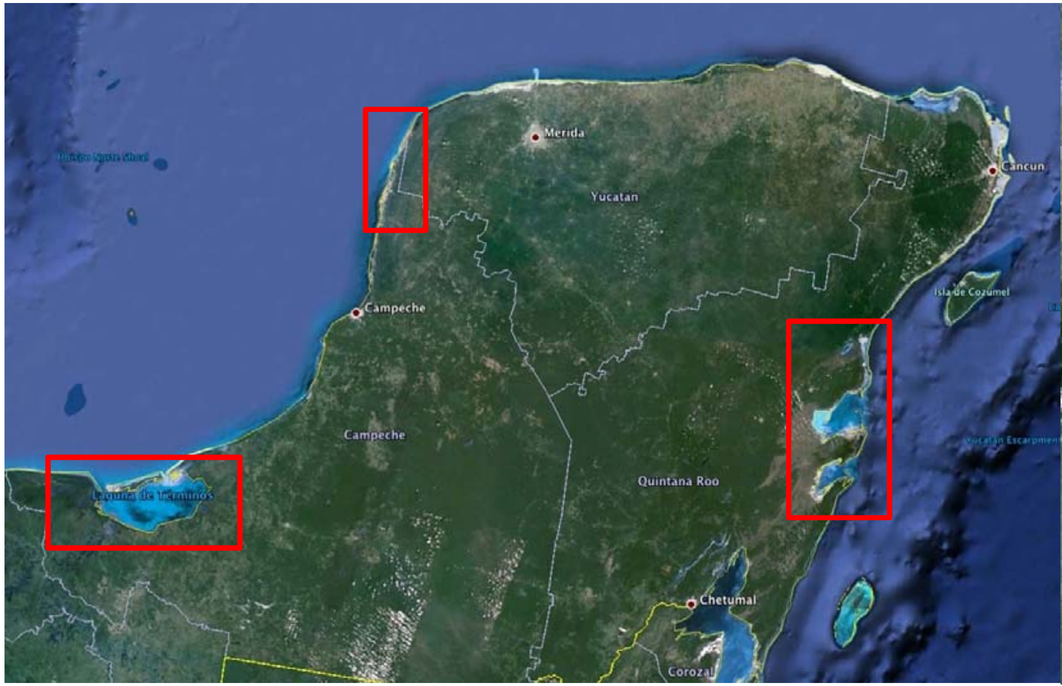
- **Produce land cover, 3-dimensional mangrove forest structure, and ecogeomorphology** maps of all coastal regions with mangrove forests throughout the Americas using multi-sensor data fusion (radar, lidar, passive optical)
- Identify and map the spatial distribution of anthropogenic activities that act as **proximate sources of land use/change** in mangrove regions including shrimp farming, timber extraction, water diversions, urban and agricultural expansion.
- Produce user-friendly regional-local models to assess mangrove forest vulnerability to **human and climate change drivers** that can be adapted to diverse socio-demographic, economic, policy as well as ecogeomorphic contexts of the Americas.

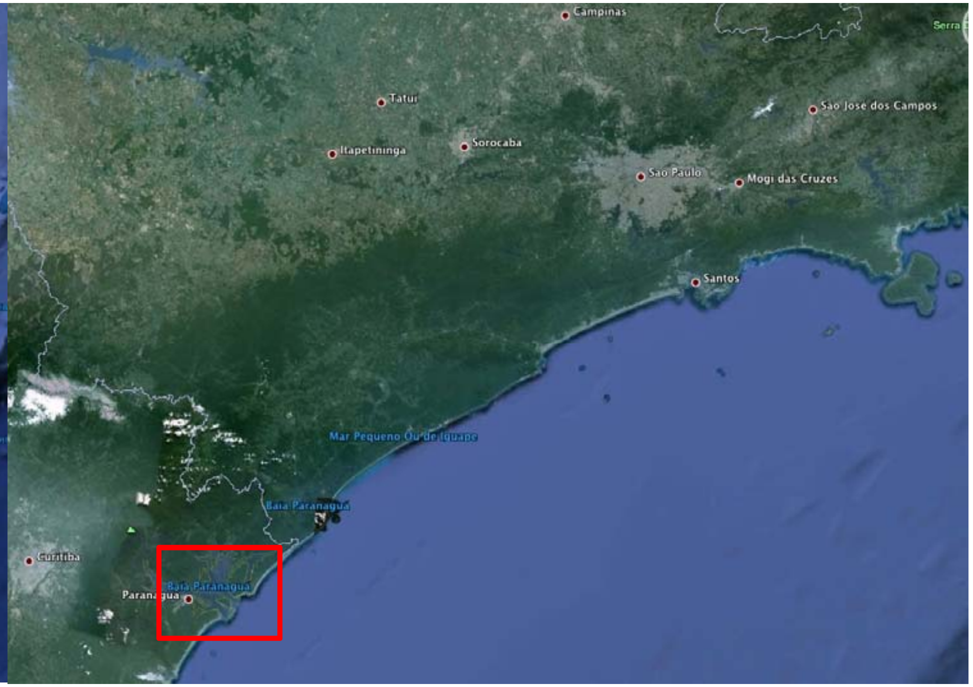
NASA LCLUC sites



- **Field work for the LCLUC project will start this summer (2012):**
    - **August Field campaign to Campeche and Yucatan, Mexico**
    - **November Field campaign to Paranagua, Brazil**

  The field data will also be made available to the K&C



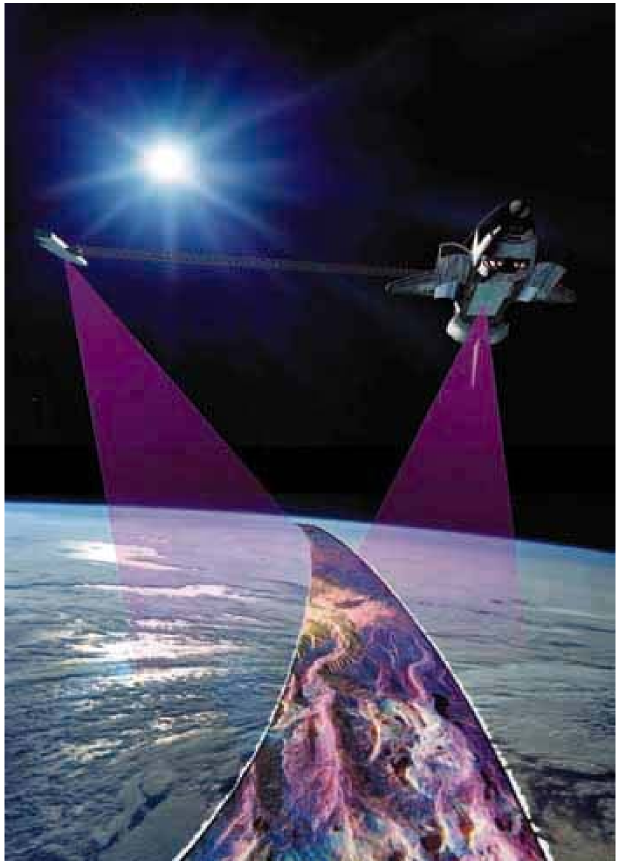


THANK YOU

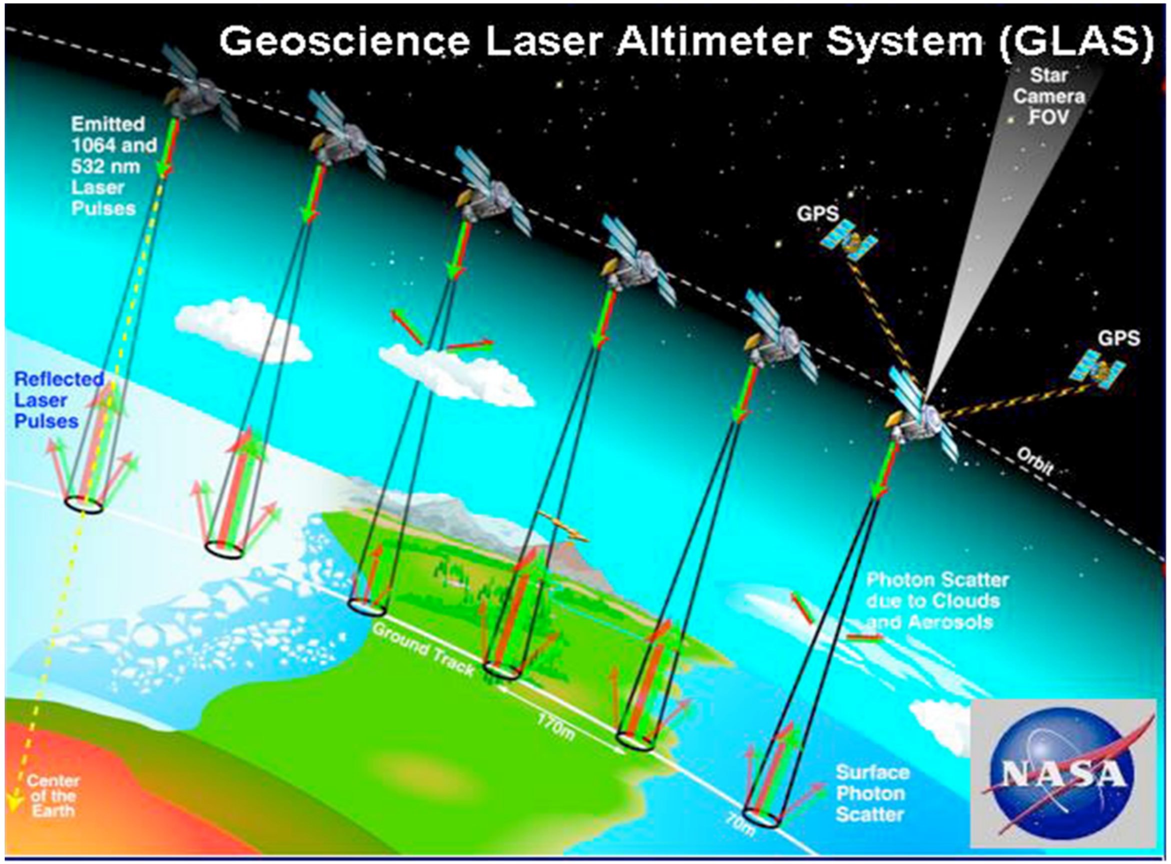
Vertical Structure from Radar & Lidar data

Using SRTM, Field and GLAS for mangrove 3-D structure in Mozambique, then across Africa

SRTM



IceSat GLAS



Vertical Structure from ICESat/GLAS

- We used the GLA14 (Global land altimetry) data product to estimate canopy height.
- 327 waveforms, as GLAS footprints were not available in all mangrove areas.
- The GLA14 product was produced by fitting up to six Gaussian distributions to the GLAS LiDAR waveform (Zwally *et al*. 2003).
- The shape and position of the Gaussians distributions describe the canopy vertical structure within the LiDAR footprint.
- We only used data from cloud-free profiles
- We excluded waveforms with a single Gaussian peak

Deliverables

Planned output of the project.

- Annual mangrove cover and change maps for regional sites in the Americas and Africa for 2007 through 2011.
- Mangrove Tree height maps from K&C mosaics and ancillary field and GLAS data for the regional sites using a decision tree approach.
- Mangrove Biomass maps and changes from K&C mosaics and ancillary field and GLAS data for regional sites using a decision tree approach.