Assessment of Mangrove Vulnerability in the Americas

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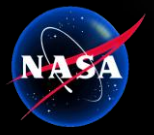

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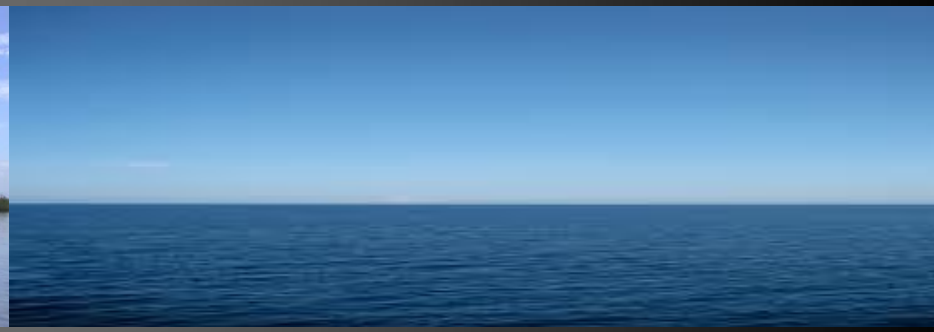
Mangrove continuum

Salt-tolerant plants thriving in the intertidal area of tropical coasts

Marshes-Mangroves



Coastal Ocean

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Global distribution of Mangrove forests

(Giri et al., 2010)

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Objectives

- Produce land cover, 3-dimensional mangrove forest structure, and eco-geomorphology 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.

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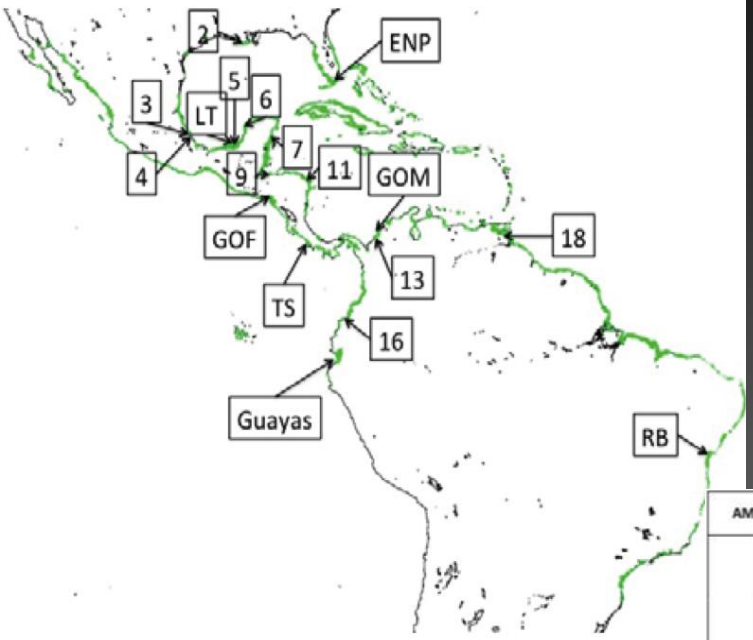
NASA LCLUC sites

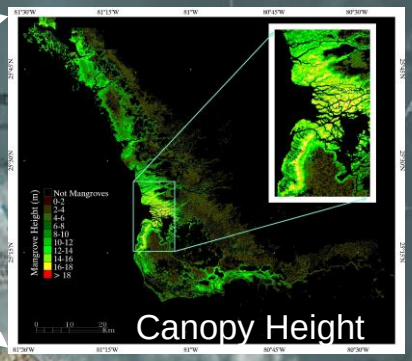


AMERICAS				Lat	Long	Geophysical Mangrove System Type						Remote sensing			Field		Socio-economics and RAMSAR	
						mudflat	Delta	karstic	River-dom	lagoons	Fringe/coast	UAVSAR	ALOS	Landsat	Veg 3D	Productivity	Local problematics	RAMSAR
North	USA	1*	Everglades-FL (ENP)	25	-81			x	x		x	X	x	X	X	X	water management, levees+canals	X
		2	Port Fourchon-LA	29	-90						X	X	x	X		X	levee, canals	
	Mexico	3	Tamiahua, Veracruz	19	-96	x							x	X		X	Agriculture, Livestock, pasture, wood	X
		4	La Mancha, Veracruz	19	-96					x			x	X		X	Agriculture, Livestock, pasture, wood, hudrological impacts	X
		5	Tabasco	19.9	-91		X						x	X			Freshwater Diversions, Urban development, oil industry, coastal erosion	
		6	Celestun	21	-90.3					x			x	X		X	Tourism, road construction, pollution	
		7	Sian Ka'an reserve, Yucatan	20	87			x					x	X			Tourism, pollution	X
		8*	Laguna de Terminos (LT)	18	-91		X			X			x	X		X	Oil Industry, road construction, freshwater diversions, deforestation	
Central	Honduras	9	Kawas National Park	15.8	-87.5		X		X				x	X			Pollution, freshwater diversions	X
		10*	Gulf of Fonseca (GOF)	13	-87.3				X		x	X	x	X	X	X	Shrimp farming, pollution, levees, deforestation	X
		11	Sistema de Humedales de Caratasca	15.3	-83.8					X			x	X			hydrological changes, pollution	
	Costa Rica	12*	Terraba-Sierpe (TS)	8.85	-83.5				X		X	X	x	X	X		Hydroelectric damn, new airport	X
South	Colombia	13	Cispata-Sinu	9.4	-75.8		X		X				x	X			excess sediment load, pollution, shirmp farming, levees, road construction	
		14*	Golfo de Morrosquillo (GOM)	9.5	-75.5				X	x			x	X			Pollution, deforestation, road construction	
	Ecuador	15*	Guayas River estuary (Guayas)	-2	-80				X		X		x	X		X	Shrimp farming, pollution, urban development, deforestation	
		16	Esmeraldas	0.9	-79				X		X		x	X			Deforestation, pollution, coal production, shirmp farming	X
	Brazil	17*	Todos os Santos, Reconcavo basin (BB)	-13	-36.7	X	X	X	X	X			X	X			urban development, oyster andd shrimp farming	
	Venezuela	18	San Juan River	10.2	-62.6				X		X		X	X	X	X	Lumber	

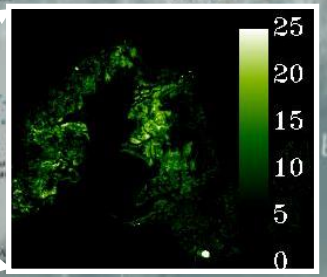
Table 1: Summary of the 18 study sites including the 7 intensive local validation sites marked with an asterisk (*). All site locations are shown in Figure 2.

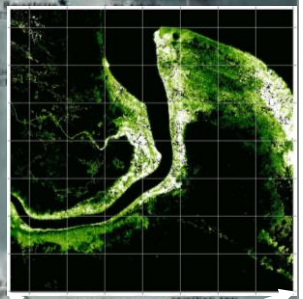
NASA LCLUC Legacy

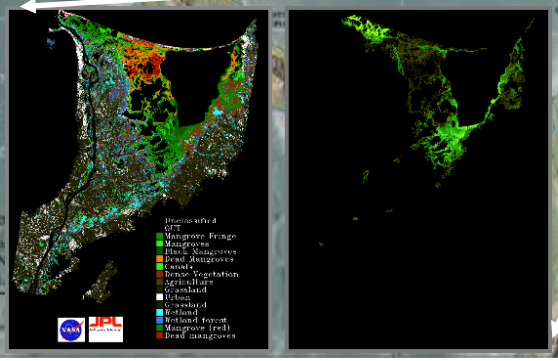
—Mangrove ecosystems are among the most productive on Earth, contributing 11% of global total C export to the ocean;
--- Already 35% of mangrove forests have disappeared and 60% could be lost by 2030;
—The estimated economical value varies between $200 000 to $900 000 per km^2 (UN report 2006);
—They act as a protection of shoreline against topical storms, hurricanes, storm surges and Tsunamis;



Simard et al., 2006







Simard et al., 2008

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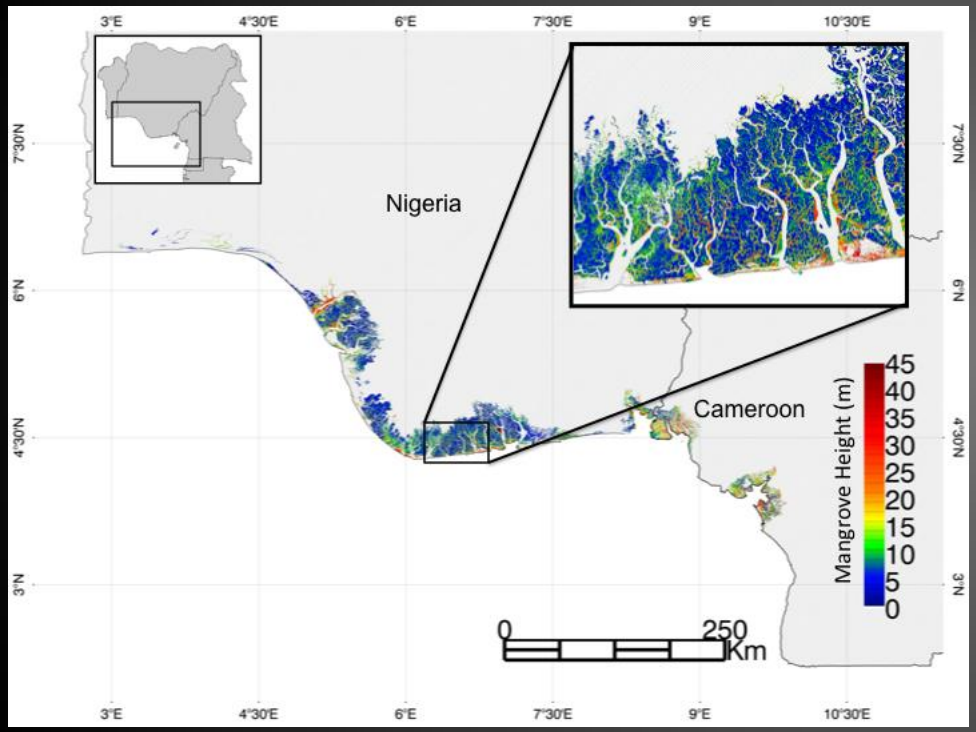
Height and Biomass Map of All Mangrove Forests of Africa



Fatoyinbo & Simard, IJRSE 2012

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

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

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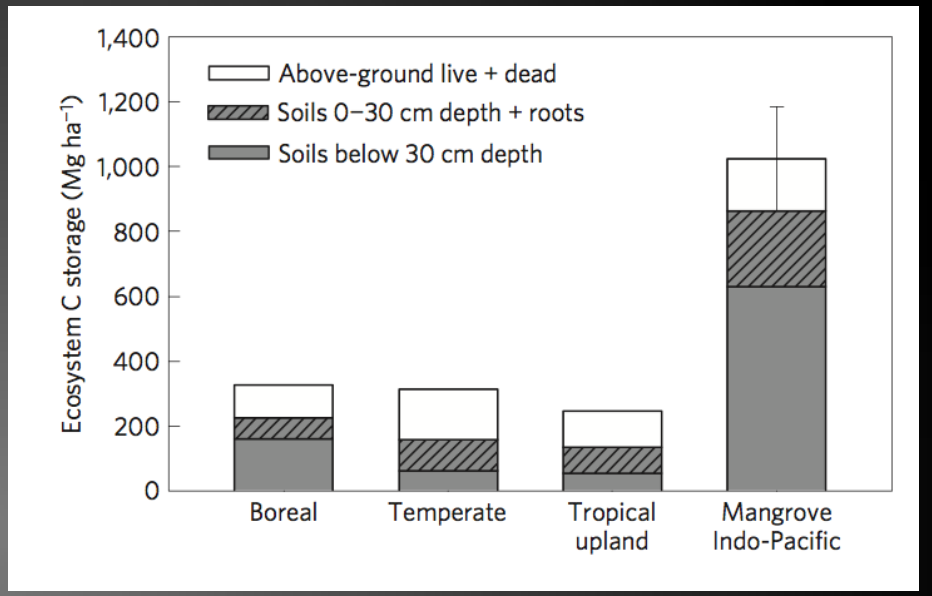
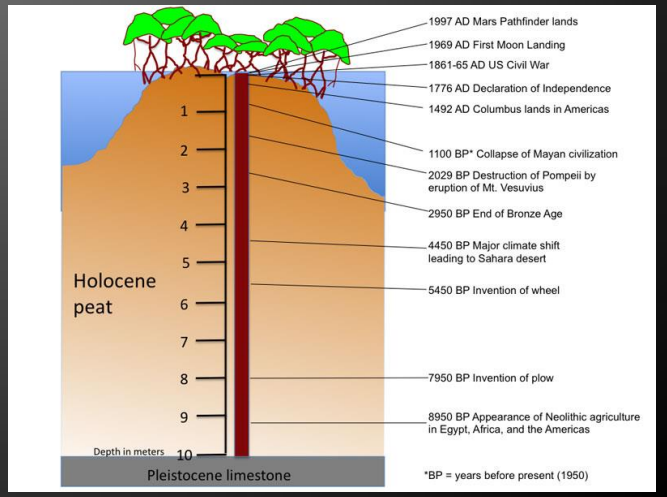
Mangroves and Carbon

- 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)
- They act as a **protection** of shoreline against topical storms, **hurricanes** and **Tsunamis**
- 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.
- Endangered by Urbanization, exploitation and sea level rise
- Already **35%** of mangrove forests have **disappeared** and **60%** could be lost by **2030;**



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



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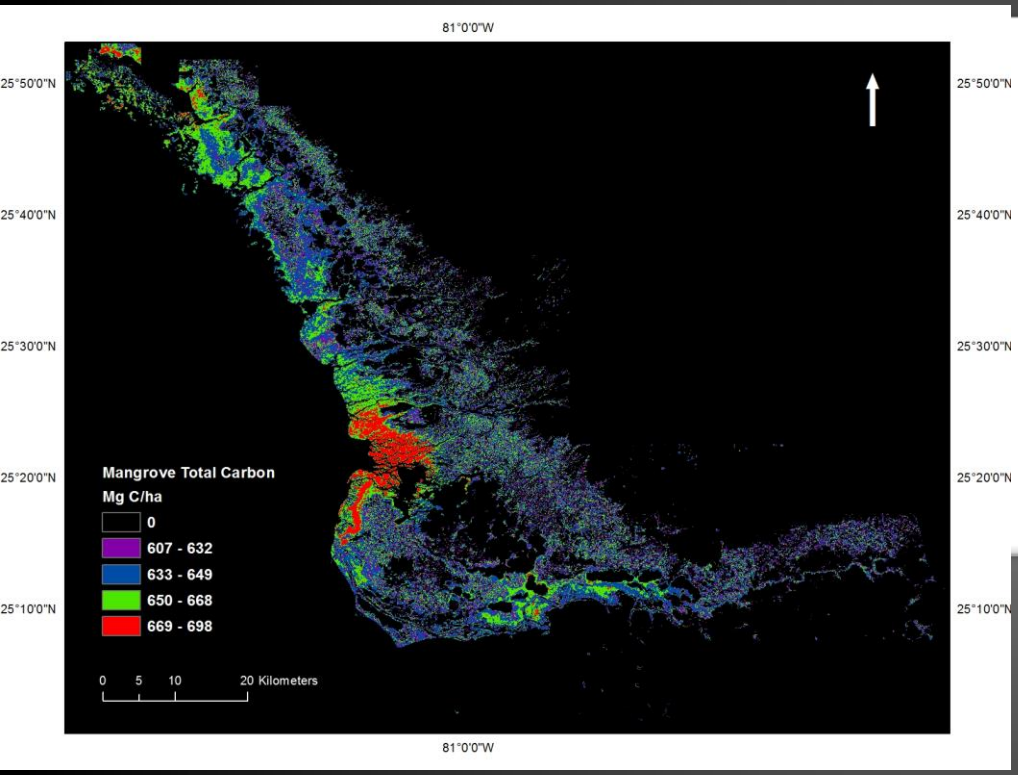
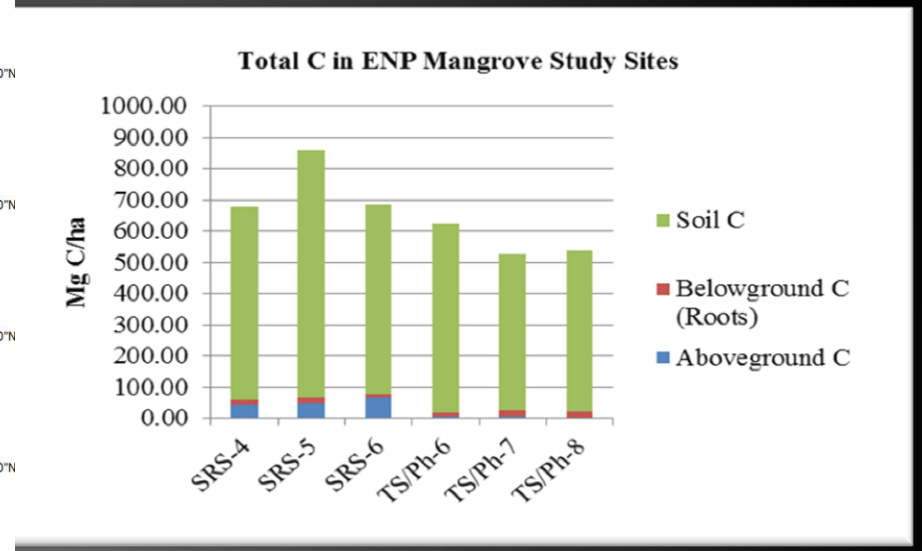
Carbon Storage in ENP Mangroves

Florida Coastal Everglades LTER Study Sites





Total Carbon Storage in ENP mangroves = 990,724 ,732 Mg C

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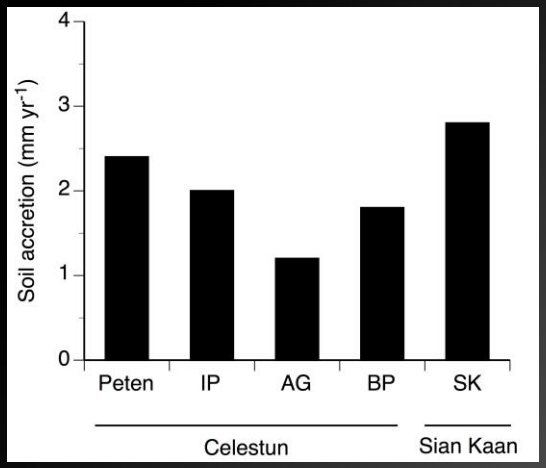
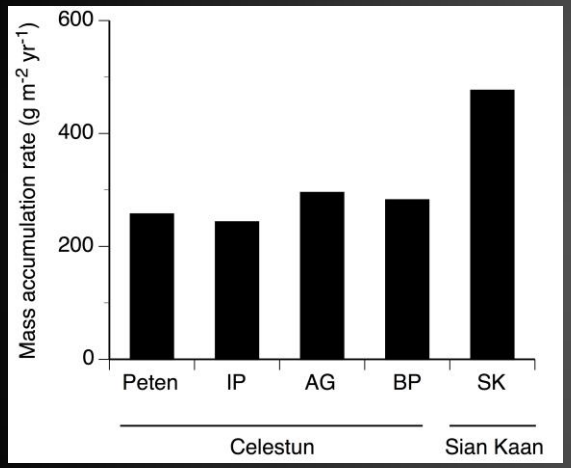
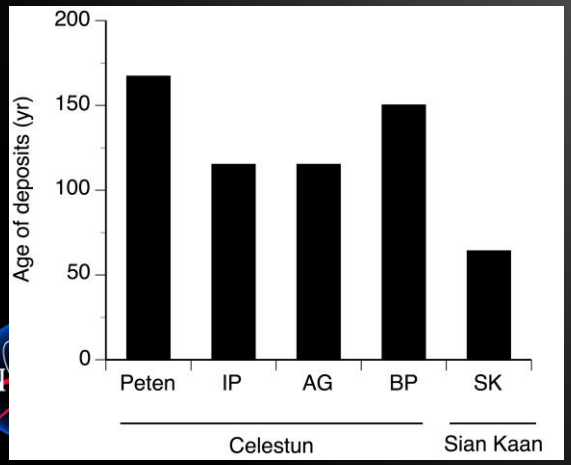
Soil Accretion, Mass Accumulation, and Age of Deposits







- Soil accretion rates ranged from 1.2 mm yr^{-1} (AG) to 2.8 mm yr^{-1} (SK) across all sites.

- The SK site showed the highest (476 g m^{-2} yr^{-1}) mass accumulation rate of all sites and the youngest (64 yr) soil deposits.

- Mangrove forests in the Peten site showed the oldest (167 yr) organic deposits and have one of the highest forest development relative to other sites.

- The higher accretion and mass accumulation rates observed in scrub mangroves of Sian Kaan is associated with higher root biomass accumulation. This demonstrates an adaptation of these forests to allocate more resources to belowground (i.e., roots) relative to aboveground compartments in response to soil stress conditions such as nutrient limitation or higher salinity.

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Economic Valuation of C storage in ENP mangroves

Valuation Methodology	Examples	Cost of Carbon ($/tC)	Total Value of C in ENP mangrove forests (million $)	Mean estimate (million $)	Value of ENP mangroves per ha ($/ha)	Mean estimate ($/ha)
Social Cost of Carbon	Peer Reviewed[a]	80	79,258	64,397	571,520	464,360
	US Interagency Report[b]	86	85,202		614,384	
	Tol[c]	59	58,453		421,496	
	Nordhaus[c]	35	34,675		250,040	
Marginal Abatement Cost	Globalized MAC[d]	233	202,108	131,767	1,457,376	950,152
	IPCC, Fourth Assessment Report[e]	129	123,841		893,000	
	Cost of forest based sequestration[f]	103	69,351		500,080	
Market Prices[g]	EU ETS[h]	79	78,267	35,006	564,376	252,421
	CERs[i]	46	45,573		328,624	
	secondary CERs	40	39,629		285,760	
	RGGI[j]	7	6,935		50,008	
	VERs[k]	22	21,796		157,168	
	REDD[l]	18	17,833		128,592	

With collaborators: Meenakshi Jerath & Mahadev Bhat, Florida International University

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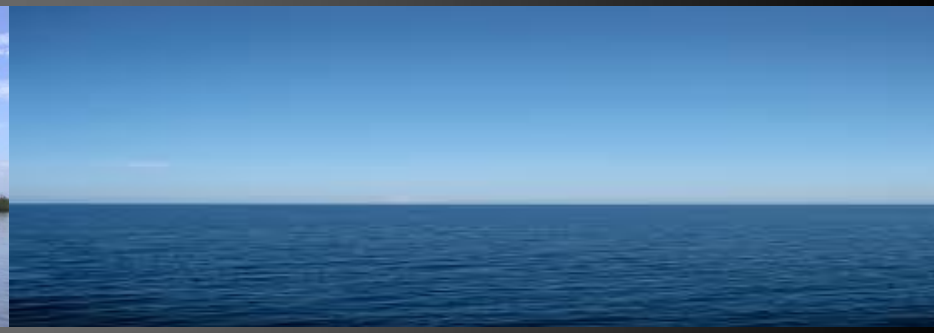
Mangrove continuum is threatened by sea level rise



Marshes-Mangroves

Ocean

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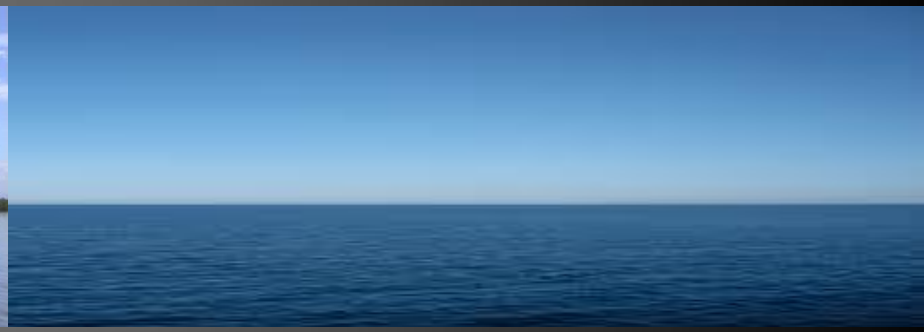
Mangrove continuum is threatened by sea level rise

Anthropogenic

Marshes-Mangroves



Ocean

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Human Dimensions & Modeling Objectives

Where we are right now

- **Identify and map** the spatial distribution of anthropogenic land uses that act as proximate sources of change in mangrove regions, including shrimp farming, timber extraction, water diversions, urban and agricultural expansion.

- **Quantify spatially explicit variables** representing social, economic and political-institutional drivers of land use/change, and analyze main spatial trends in relation to changes in mapped land cover.

- **Produce user-friendly regional-local models** to assess mangrove forest vulnerability to human and climate drivers that can be adapted to diverse socio-demographic, economic, policy as well as ecogeomorphic contexts of the Americas, and used to produce future scenarios of change.

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Human Dimensions & Modeling Objectives
(nested extensive-intensive approach)

- **Extensive** social (census & ancillary) datasets for 18 regions coupled with remote sensing products and ecological data to develop regional-scale **spatial econometric models** of mangrove change.
- **Intensive** assessments in the 7 coastal mangrove study site for **calibration and validation of the regional-scale models**, relating socioeconomic activity with local changes in mangrove and adjacent land use and cover. These intensive assessments will include **stakeholder, resource manager and expert interviews** and **in-depth, semi-structured surveys**.
- Use above multi-scale assessments for **upscaling** of regionally calibrated models and the generation of continental scale, **spatially explicit scenarios** of mangrove-social system vulnerability.

Anthropogenic Drivers	Main Data Sources
Policies and institutions (land tenure, resource governance, political process, etc.)	Census, State and Local institutions/ agencies, local interviews
Socio-demographic change (population growth and decline, seasonal/long-term migration, gender, education and social structure)	Census, State and Local institutions/ agencies, local interviews
Economic & technological drivers (local, regional and international commodity markets, labor and tourism markets, technological factors)	Census, State and Local institutions/ agencies, local interviews
Resource and climate dynamics (Resource availability, seasonality & spatial distribution, perceptions of climate variability and change)	Remote sensing, climate station and other data, local interviews

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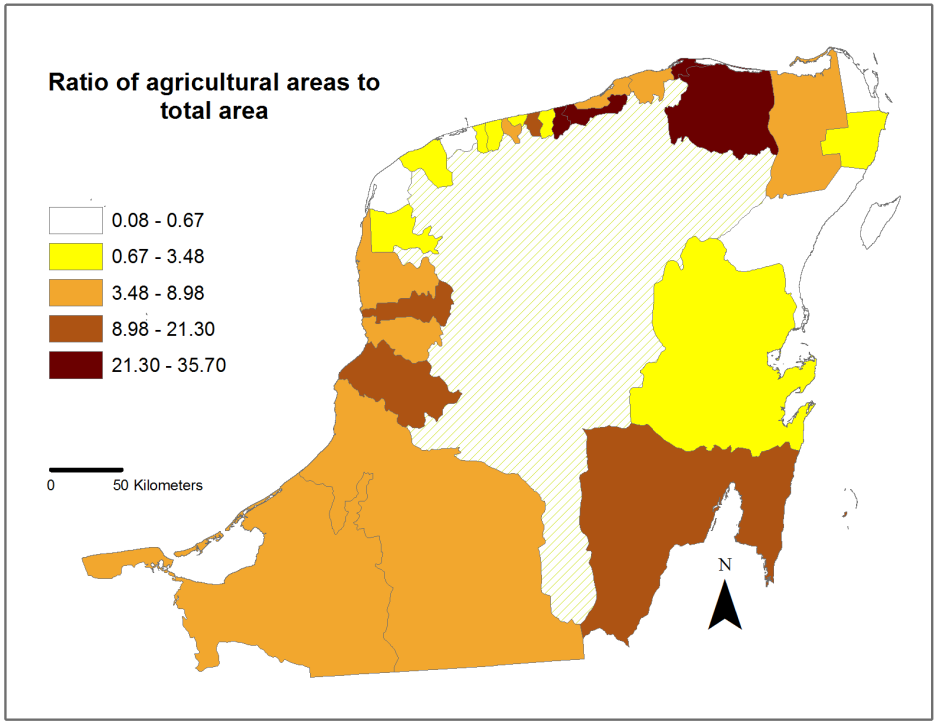
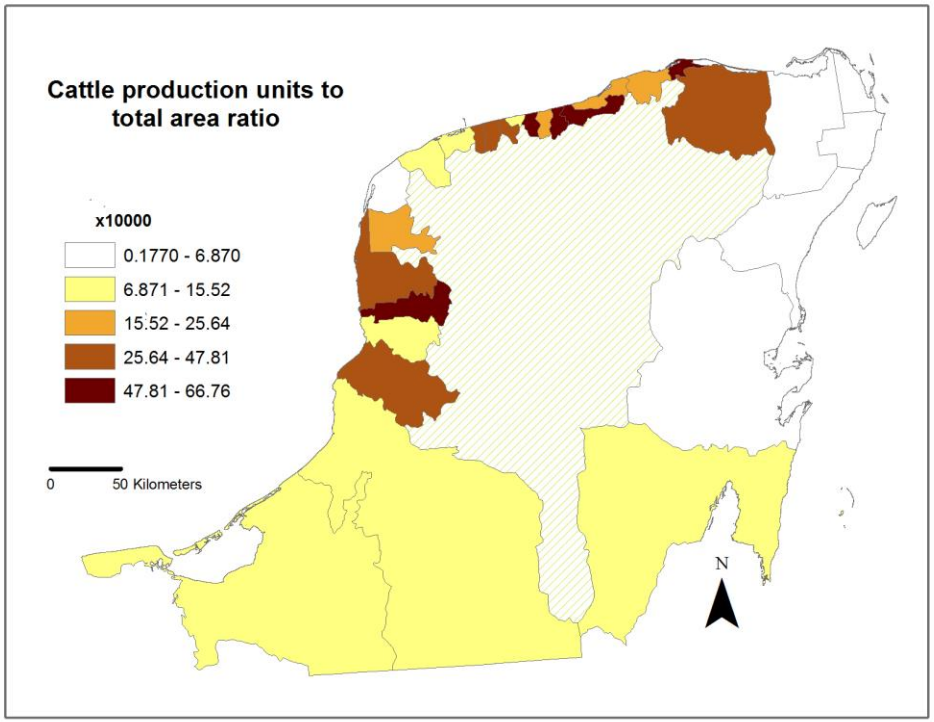
Compilation of socioeconomic variables, (coastal municipalities)



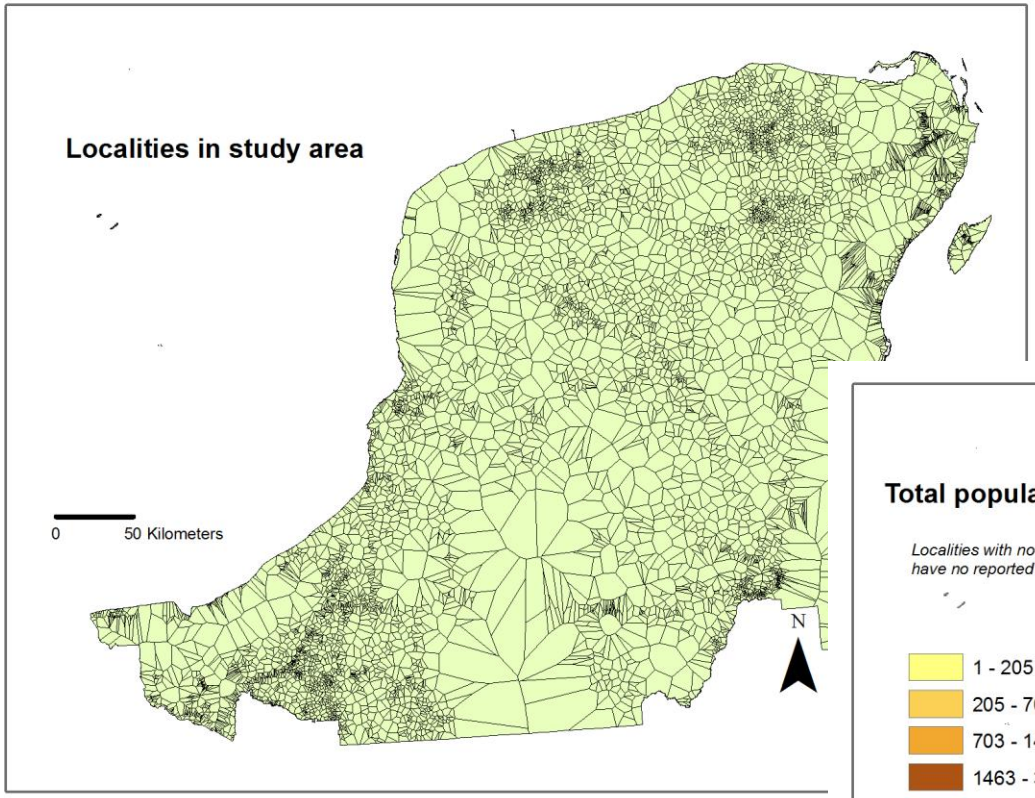
Calibrate regional models of land cover (mangrove) change and test hypotheses about the role of various socioeconomic drivers



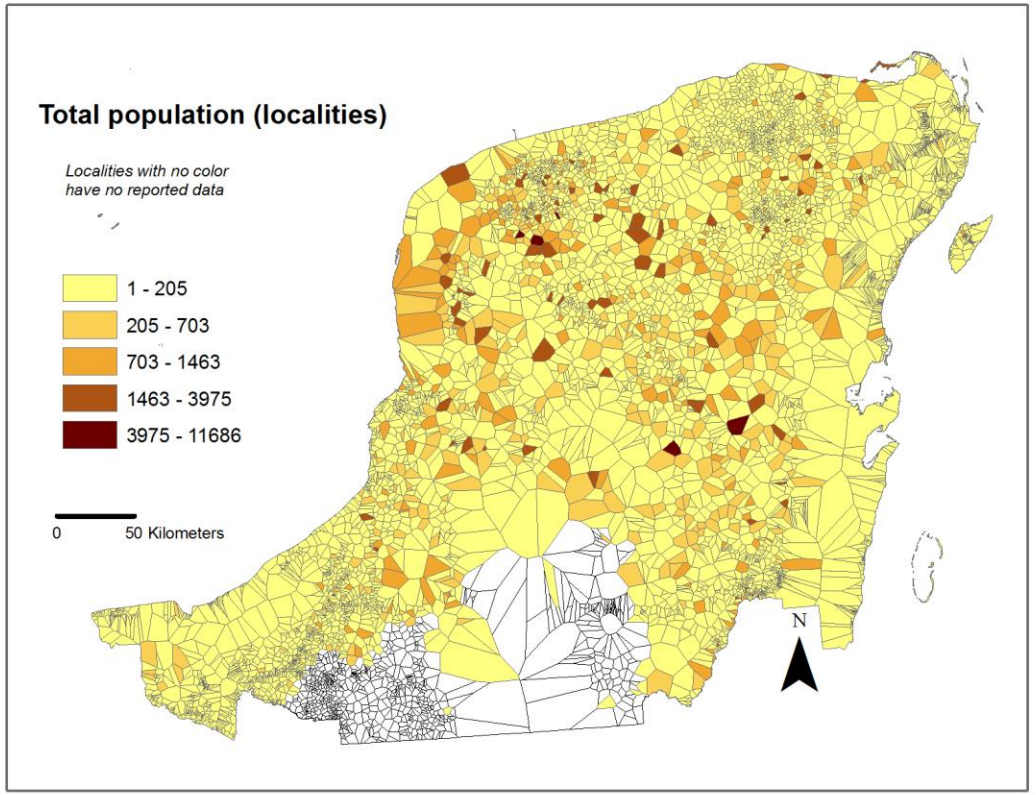
LAND USE/ECONOMIC SECTORS

Relative emphasis on economic/land use activities such as agriculture and ranching structures livelihood options in coastal communities and influences pressure on mangroves

Compilation of socioeconomic variables, (localities)



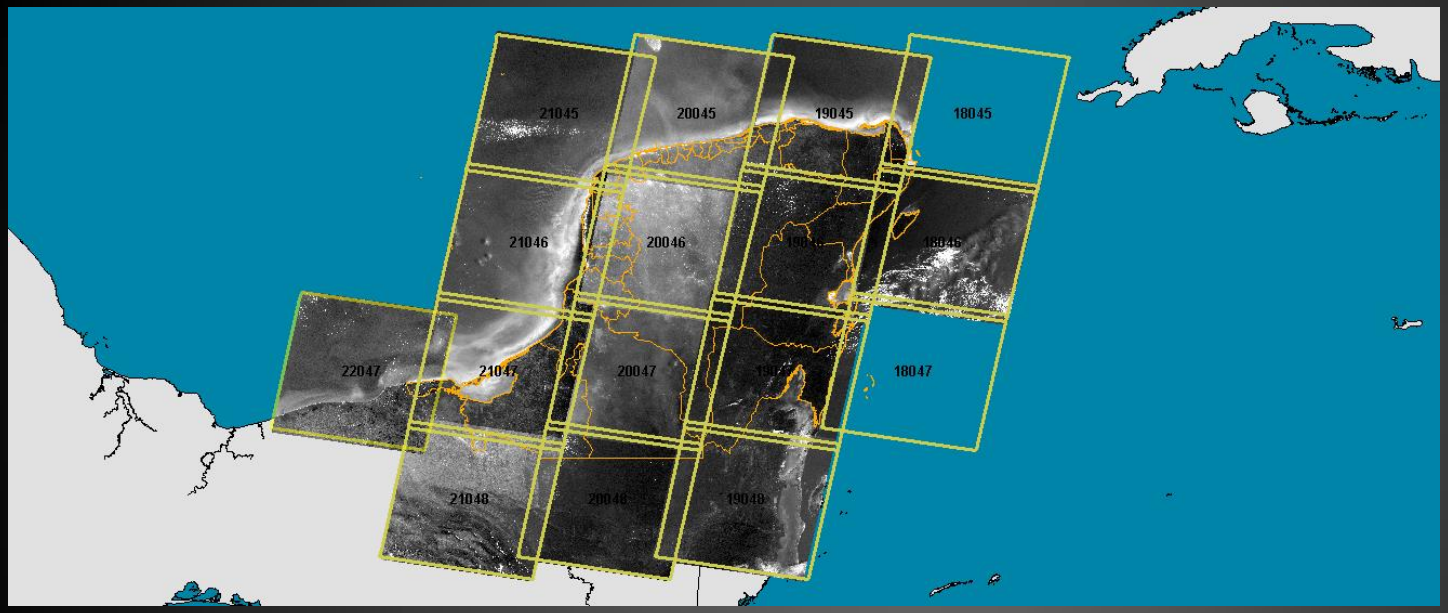
A continuous Thiessen tessellation was generated from locality point data, in the absence of polygonal GIS layers at this scale.



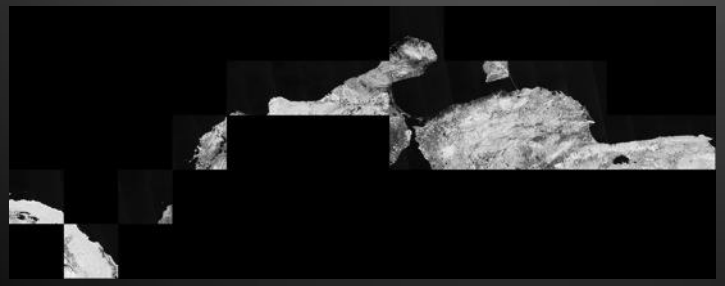
The produced locality polygon file was then spatially joined to locality-specific attribute data from the Mexican census.

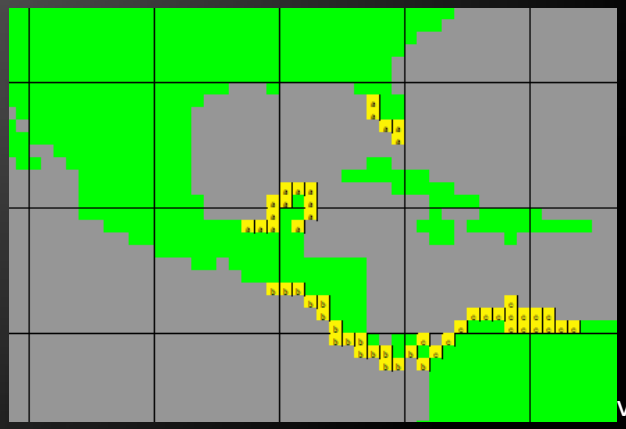
Remote Sensing Datasets

Landsat Path/rows

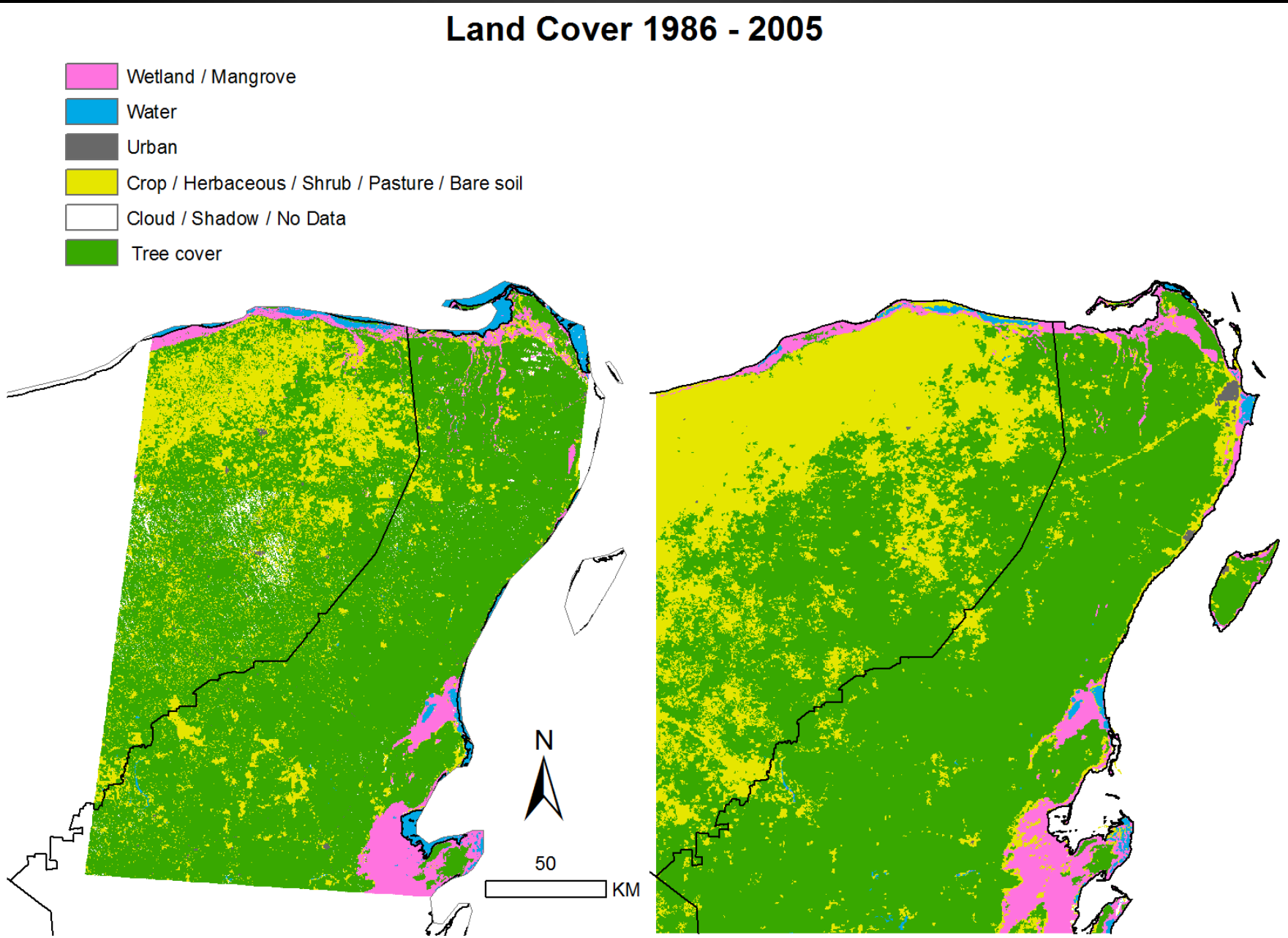


ALOS KC tiles





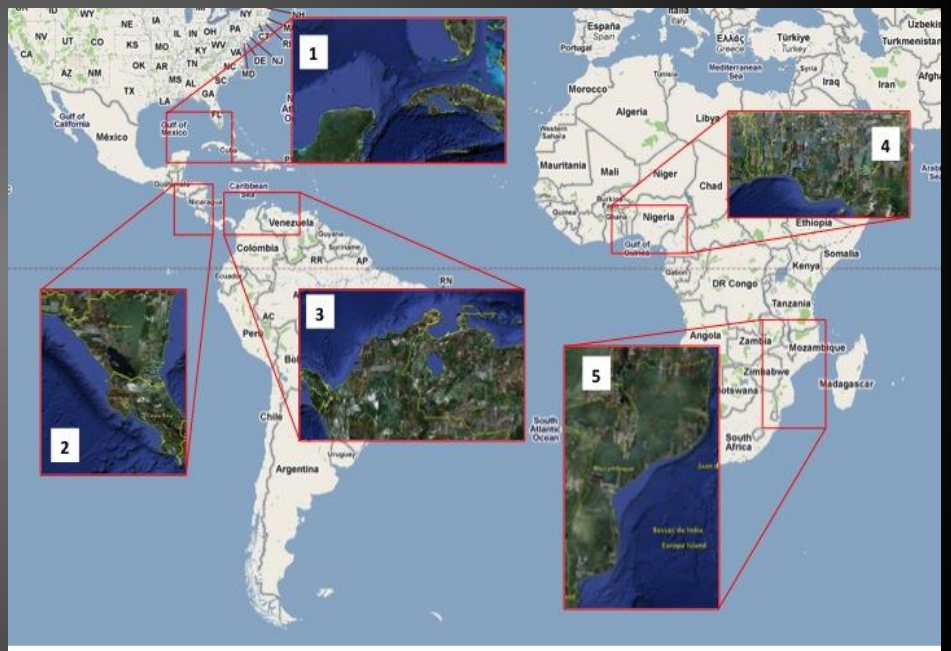
Change analysis



ALOS Kyoto and Carbon Initiative

- Launched in 2006, worked until April 2011
- Programmed for repeat data acquisition over global wetland sites through the Kyoto and Carbon Initiative in support of the Ramsar convention.
- Current research on using ALOS/PALSAR for mapping of land cover, degradation and biomass in mangroves

- 25 m ALOS K&C mosaics and
- High resolution Dual Polarimetric (HH and HV) and fully Polarimetric (HH, HV, VV and VH)
- To produce annual land use change and biomass maps of mangrove forests in the Americas and Africa.



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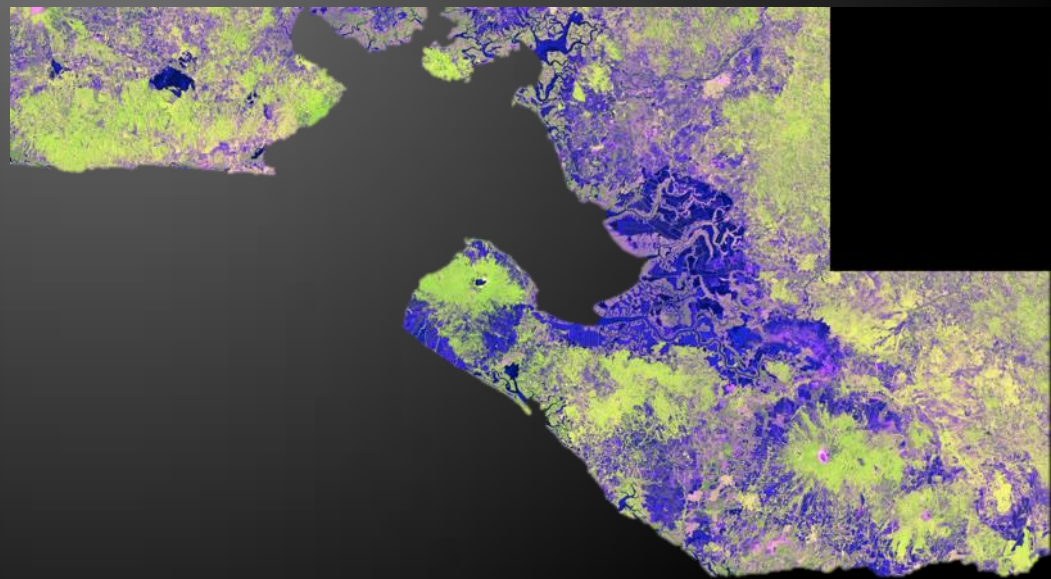
ALOS Kyoto and Carbon mosaics

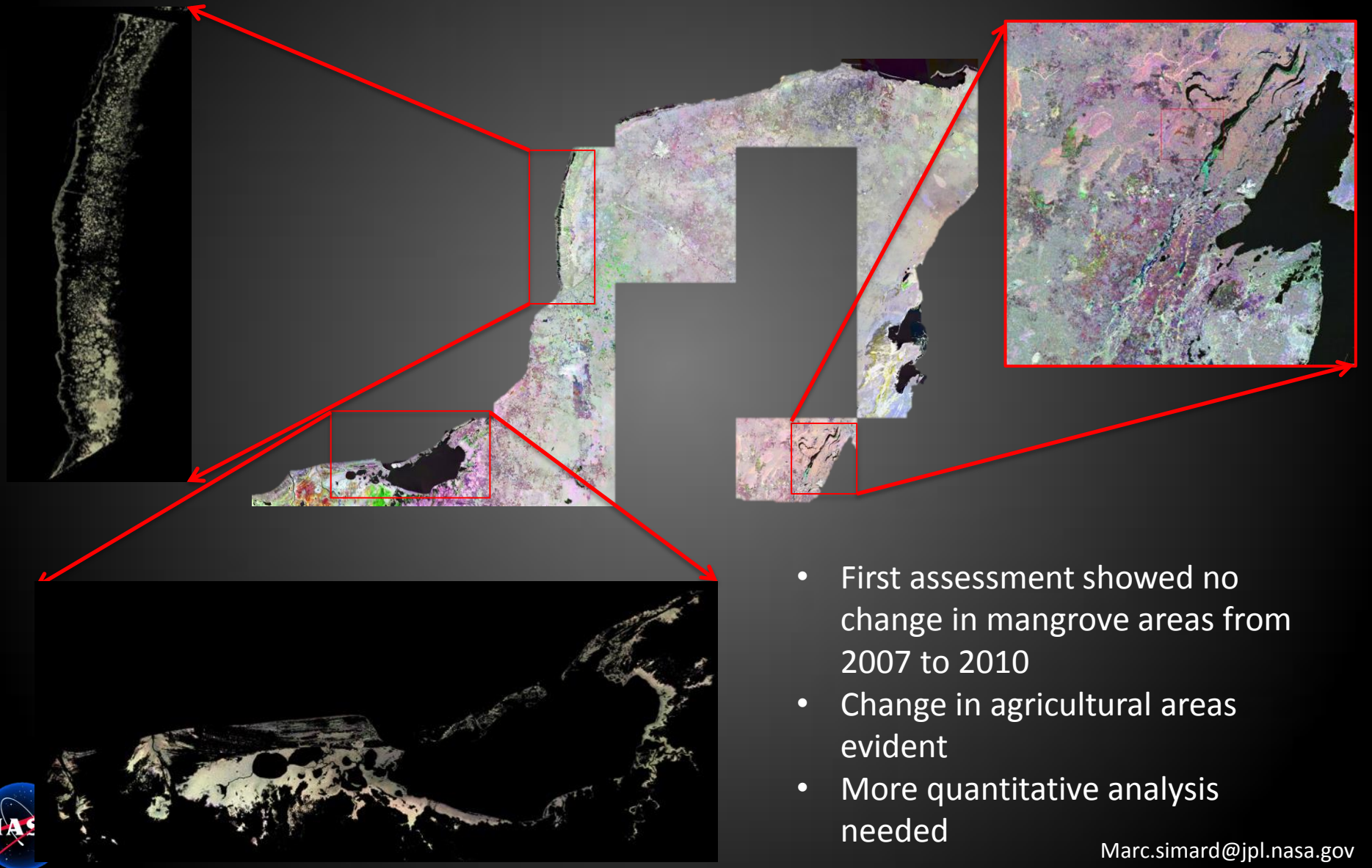
Red: 2007 HV
Green: 2009 HV
Blue: 2010 HV

- Mosaic of ALOS/PALSAR 25 m data
- 4 years (07/08/09/10)



- ALOS for forest/non forest maps
- R: HH; G:HV; B:HH/HV

LUC from Radar in Yucatan



- First assessment showed no change in mangrove areas from 2007 to 2010
- Change in agricultural areas evident
- More quantitative analysis needed

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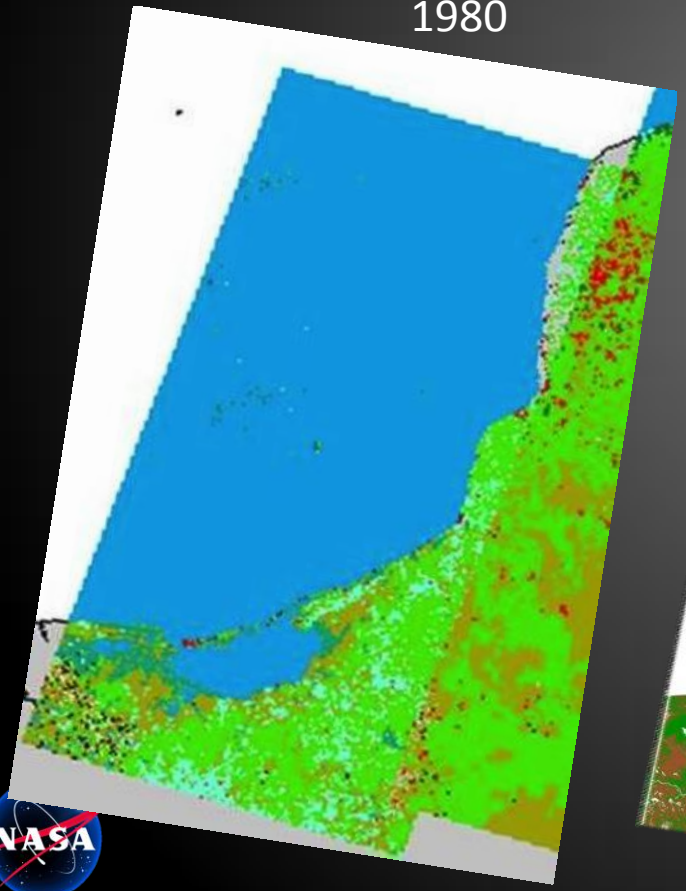
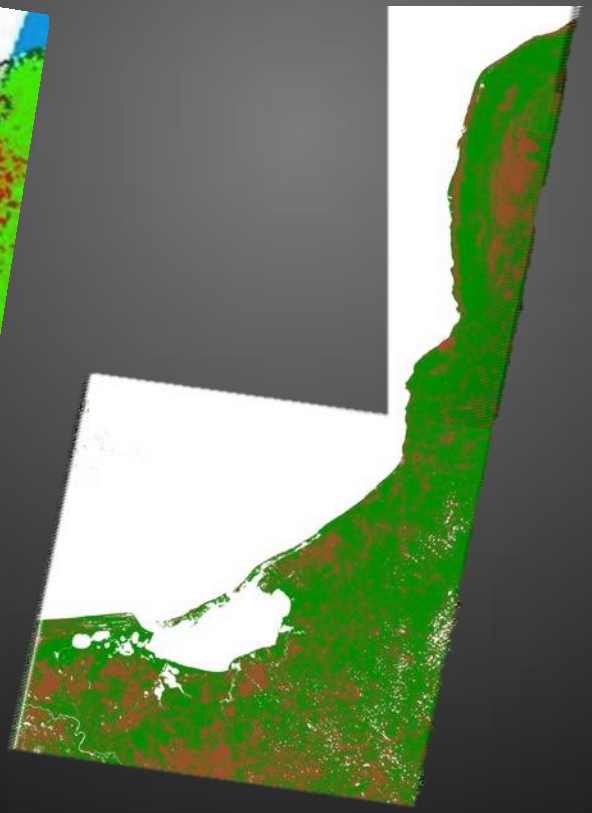
Forest/non forest maps

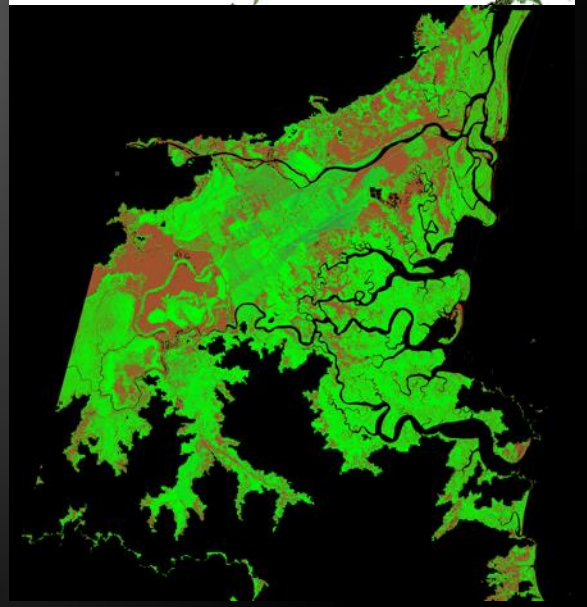
- In addition to Full land cover classification, we are also producing Forest/Non Forest maps from Landsat and SAR data

1980

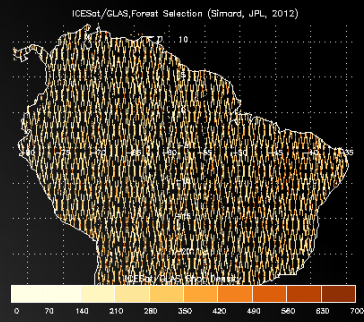


2010





ICESat/GLAS coverage



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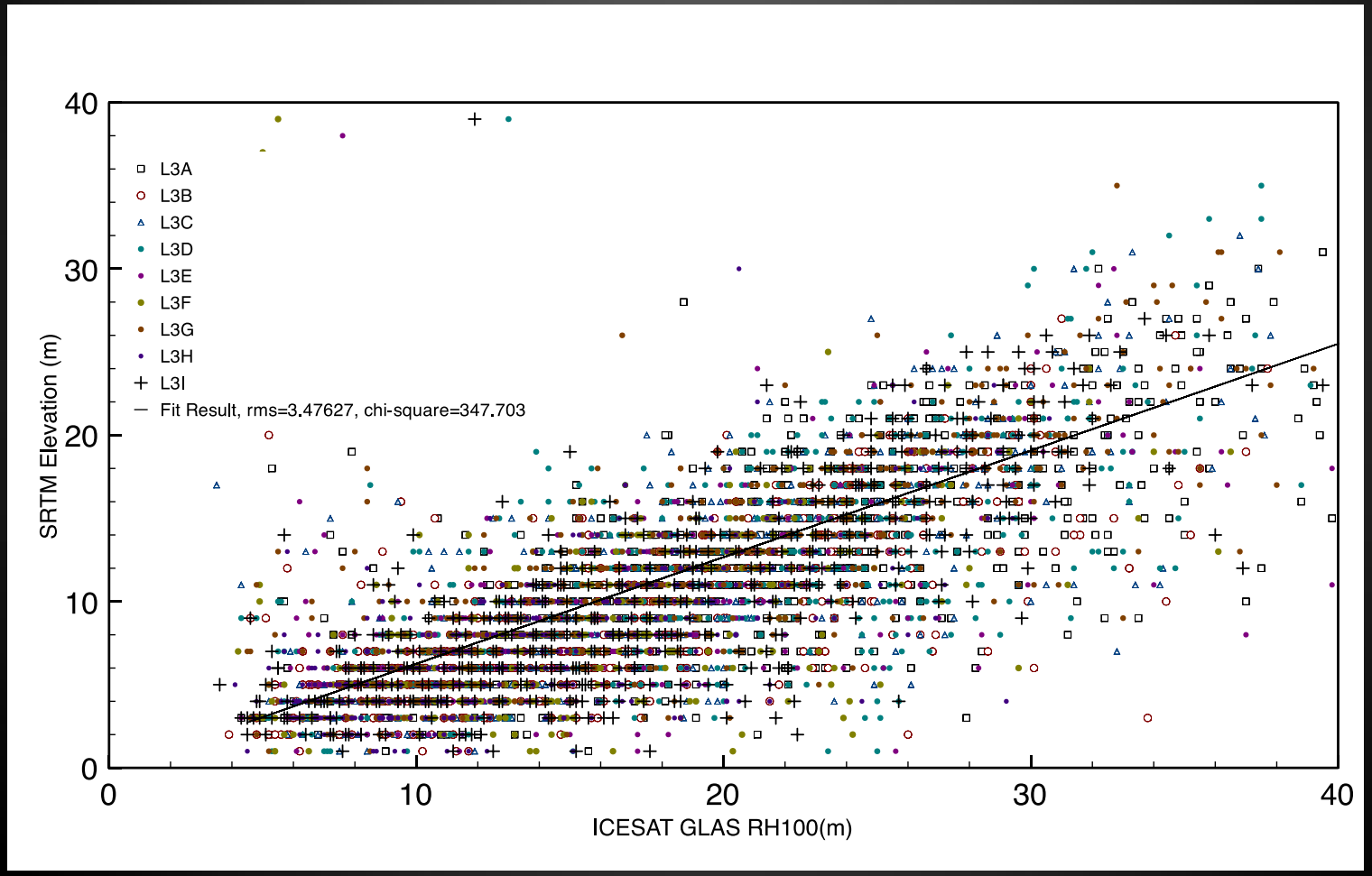
SRTM calibration using ICESat/GLAS and field work



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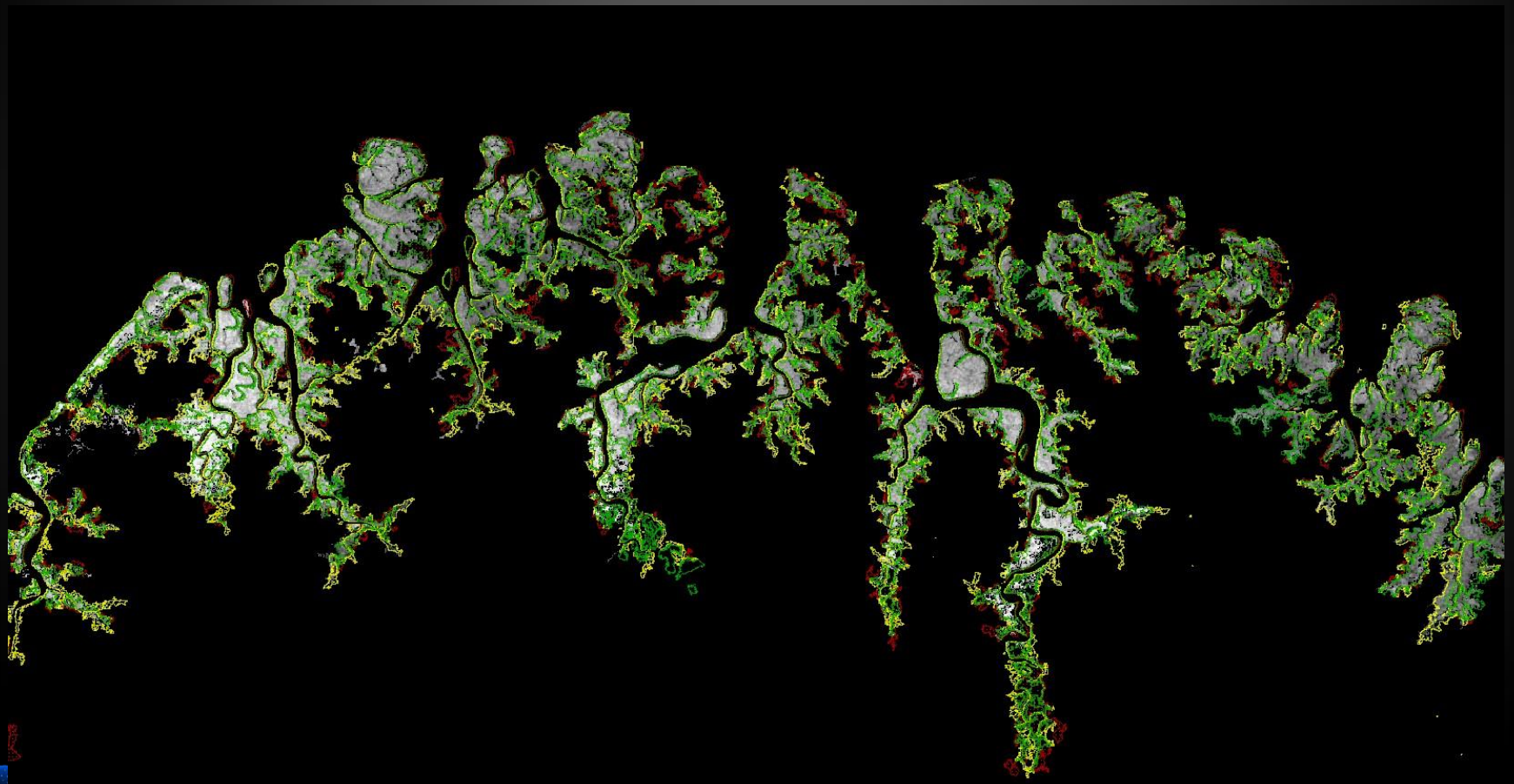
Time-series analysis with JAXA's ALOS/PALSAR dataset (K&C initiative, Mangrove Watch) and SRTM



With Collaborators: Souza-Filho, Nascimento, Lucas, Fatoyinbo

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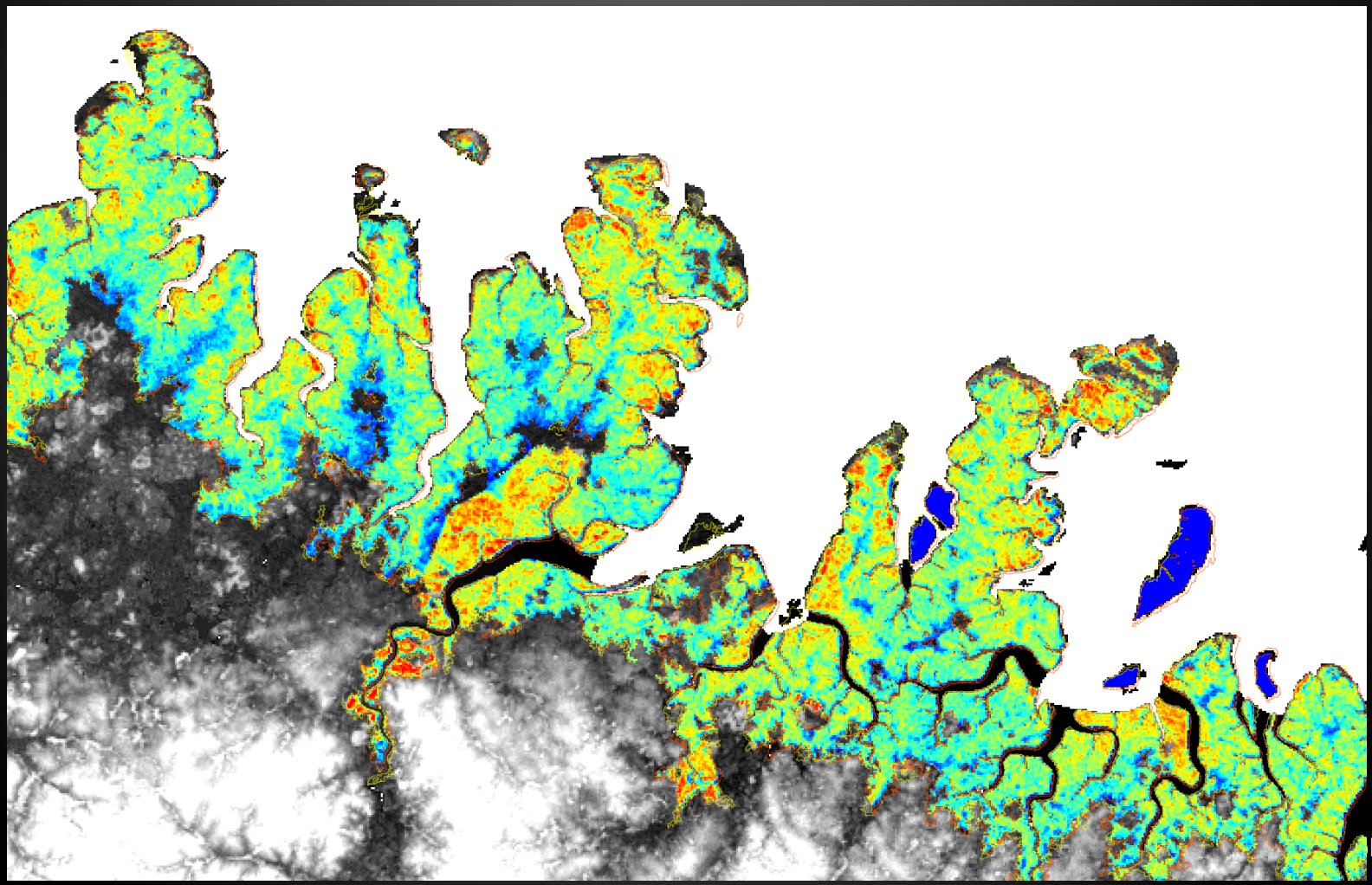
Mangrove Vulnerability to:

- sea level rise
  - Geomorphology
  - Human activity
- socio-economic activity
  - Carbon Value
  - Services = f(structure)



Need higher resolution

- Scale of erosion and accretion and;
- most importantly human and project scale.

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UAVSAR mangrove monitoring campaign in Central and South America

Térraba-Sierpe, Costa Rica

Gulf of Fonseca, Honduras

Chocó, Colombia

Guayas, Ecuador

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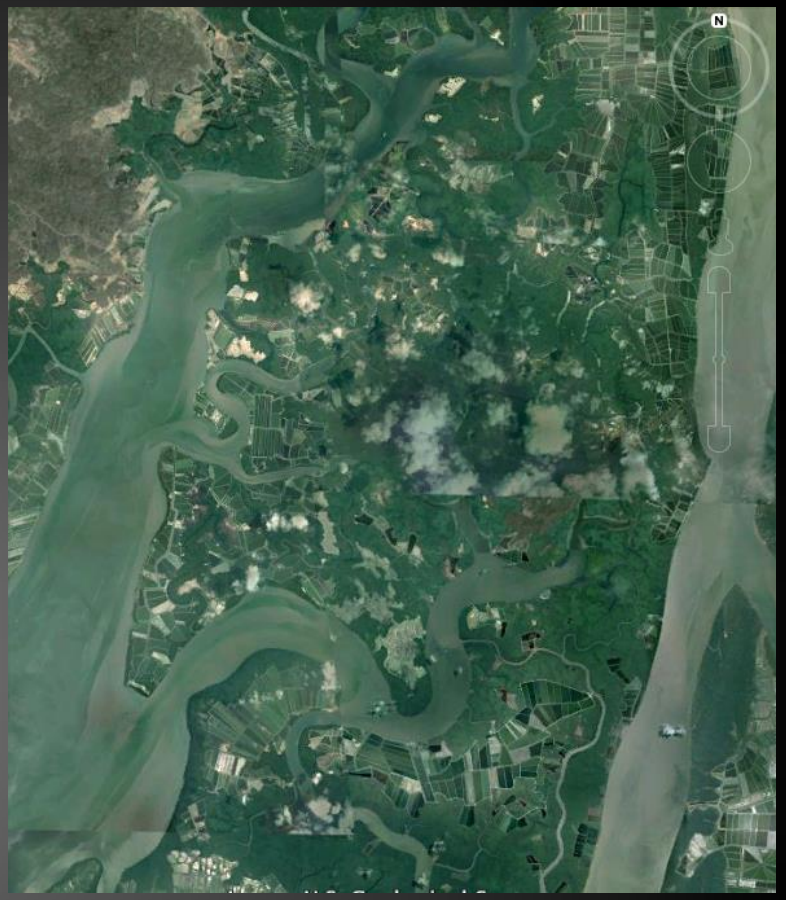
Chocó, Colombia
Sunday March 31st, 2013



Guayas, Ecuador
March 29th, 2013

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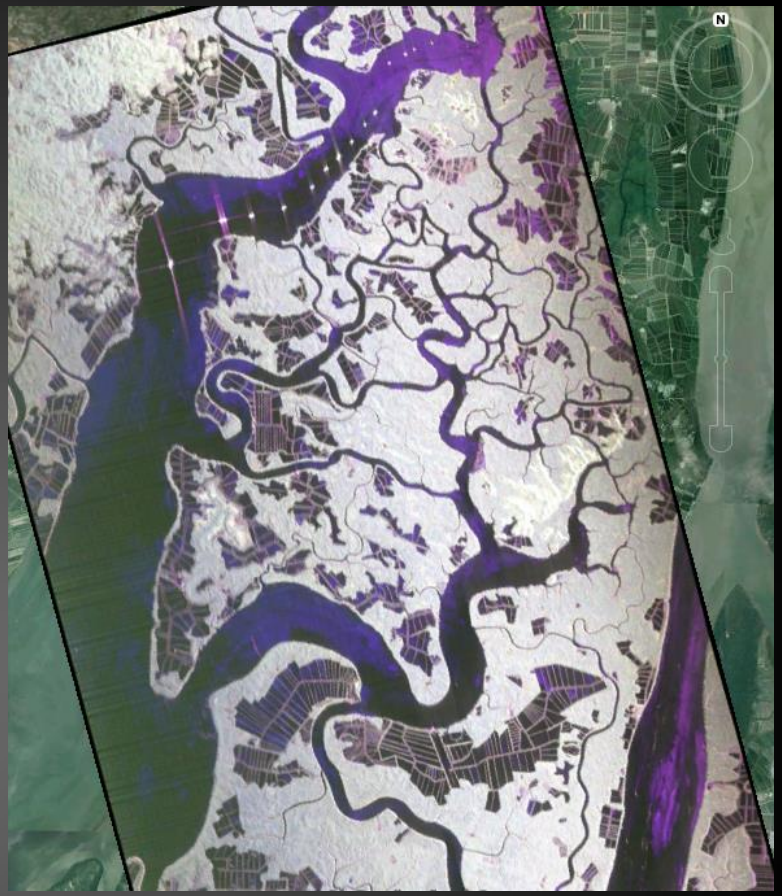
Chocó, Colombia
Sunday March 31st, 2013



Guayas, Ecuador
March 29th, 2013

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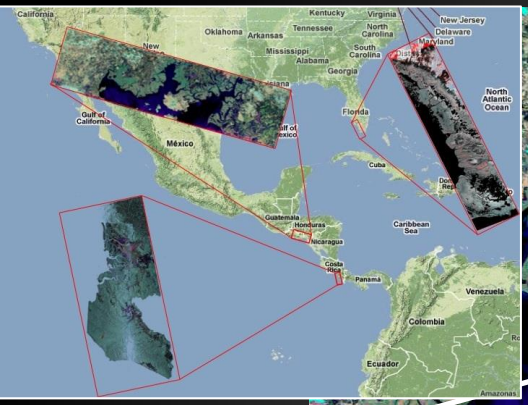
Mangrove Vulnerability Assessment to Climate Change and Socio-Economic Pressure.



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