Between the Devil and the Deep Blue Sea: Florida's Vulnerability To Sea Level Rise

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Acknowledgements

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- Predicting and Mitigating the Effects of Sea-level Rise and Land Use Changes on Imperiled Species and Natural Communities in Florida
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  - **Reed Noss** and Joshua Reese, University of Central Florida
  - **Jon Oetting**, Florida Natural Areas Inventory

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Agenda

1. Motivation: What devil? What deep blue sea?
2. Canaries in a coal mine: Florida style
3. Getting local and personal: Sea Level Rise predictions meet stakeholders
4. The Way Forward: Where to go? How to grow?

What devil? What deep blue sea?

Source: After (Florida 2060 Report http://www.1000friendsofflorida.org/connecting-people/florida-smart-growth-advocates-2/

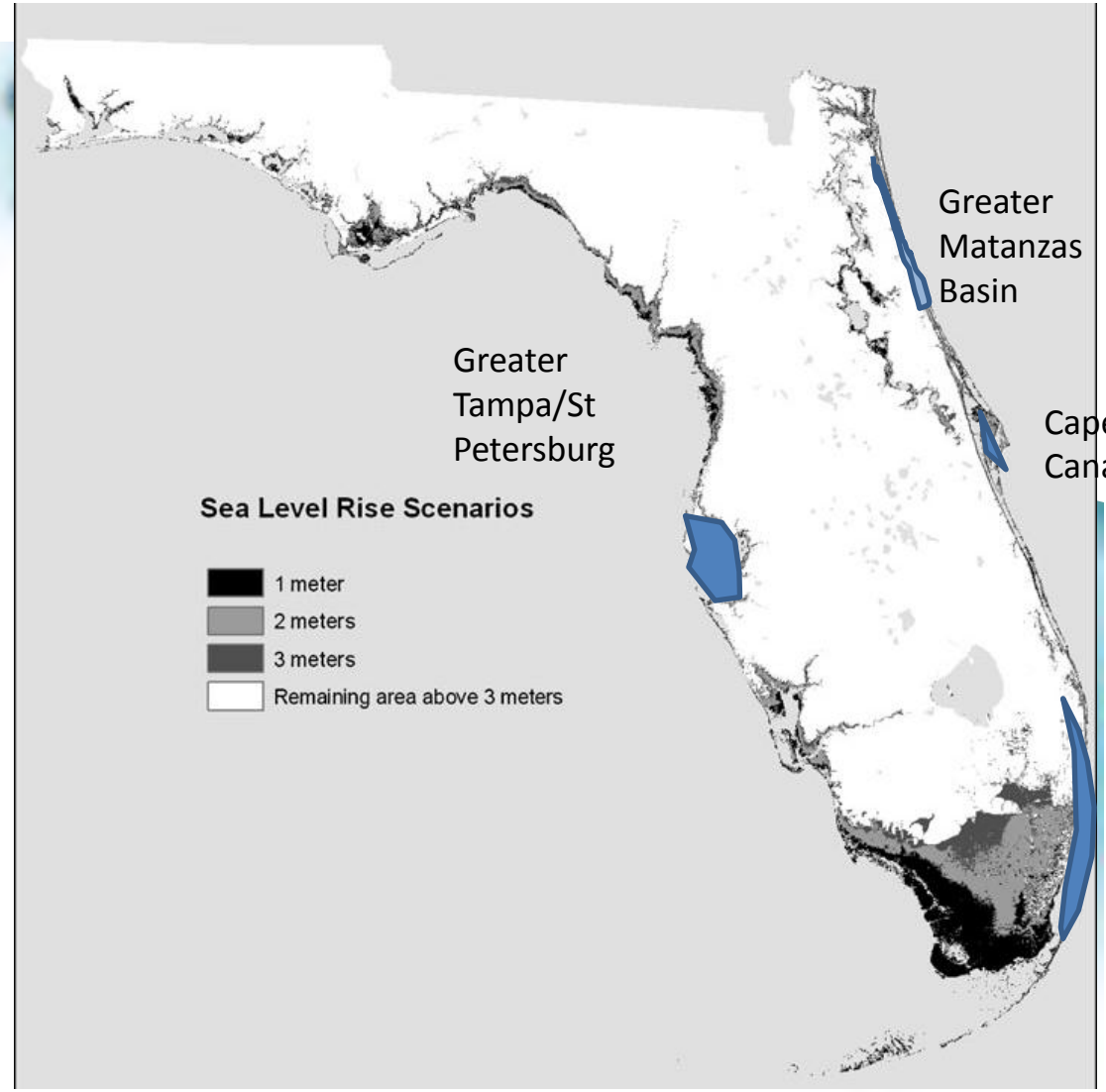
- *Noss (2011) Climatic Change*
- *Harris and Cropper (1992)*
- *19.318 million* (July, 2012)
  - Within 200k of NY state (U.S. Census Bureau)
  - Within ≈ 3 years, Florida will be the third most populous state in the USA (CA, TX, FL)
- Florida has 3,660 km of tidal shoreline (Donoghue 2011),
- No point in the state is more than 120 km from the coast (CSO 2010)
- Fifteen of the state's major population centers and more than 75% of the population are in coastal counties, and 86% of the GDP is derived from the coastal economy (CSO 2010;Wilson and Fischetti 2010).

The devil we know: growth and development

- How to grow?
- Where to grow?
- Should we grow denser/taller/smarter?
- How we can avoid gridlock and land use conflicts?
- Urban vs Agr vs Conservation?
- What does a livable Florida look like?

Source: Florida 2060 Report http://www.1000friendsofflorida.org/connecting-people/florida-smart-growth-advocates-2/

…Devil… meet blue sea..



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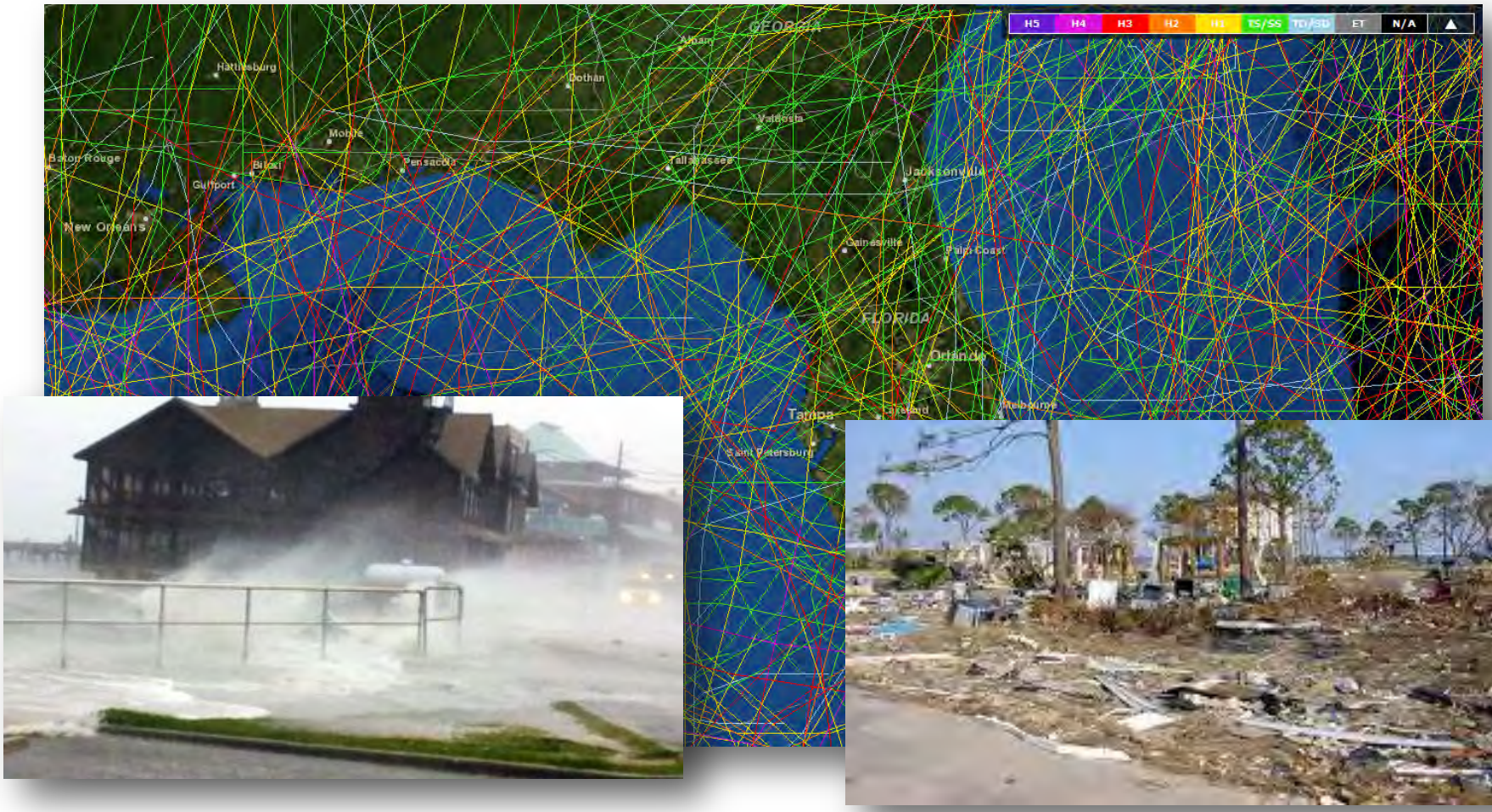
Source: Noss,R. Climatic Change (2011) 107:1–16

Because it's not the heat or the humidity or the sea level rise… It's the storms…

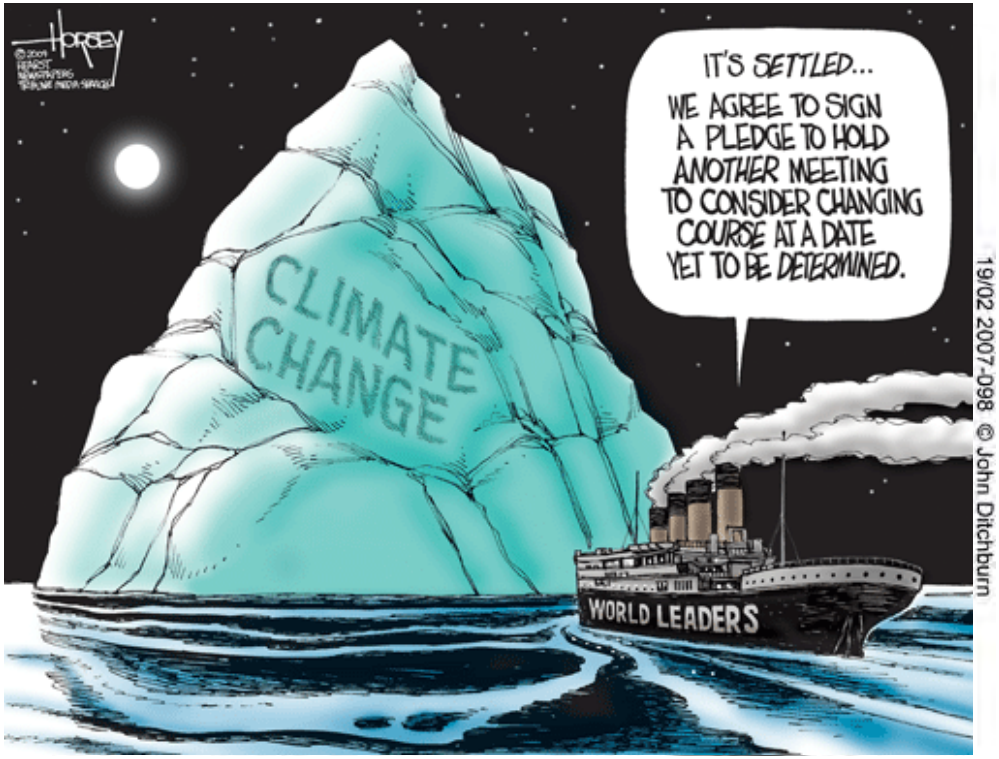


Hurricanes, tropical storms and tropical depressions are not exactly a surprise to most Floridians

Decision making in complex, coupled human-natural systems…

- People don't believe models (or information) that clash with their worldview…
  - "Do you believe in Climate Change?"
  - IIABDFI-"if it ain't broke, don't fix it…"
  - "Cherry picking: good for pies, bad for analysis" (M Shepherd FSU Prof /AMS President)
  - Obama reelection – one side "…operating at a self-imposed information disadvantage". (Nov 7, 2012) Conor Friedersdorf *The Atlantic*

- Human challenges
  - We tend to underestimate probabilities and consequences of "left-tailed events."
  - Heuristics and biases (12+)
  - Crisis-driven …



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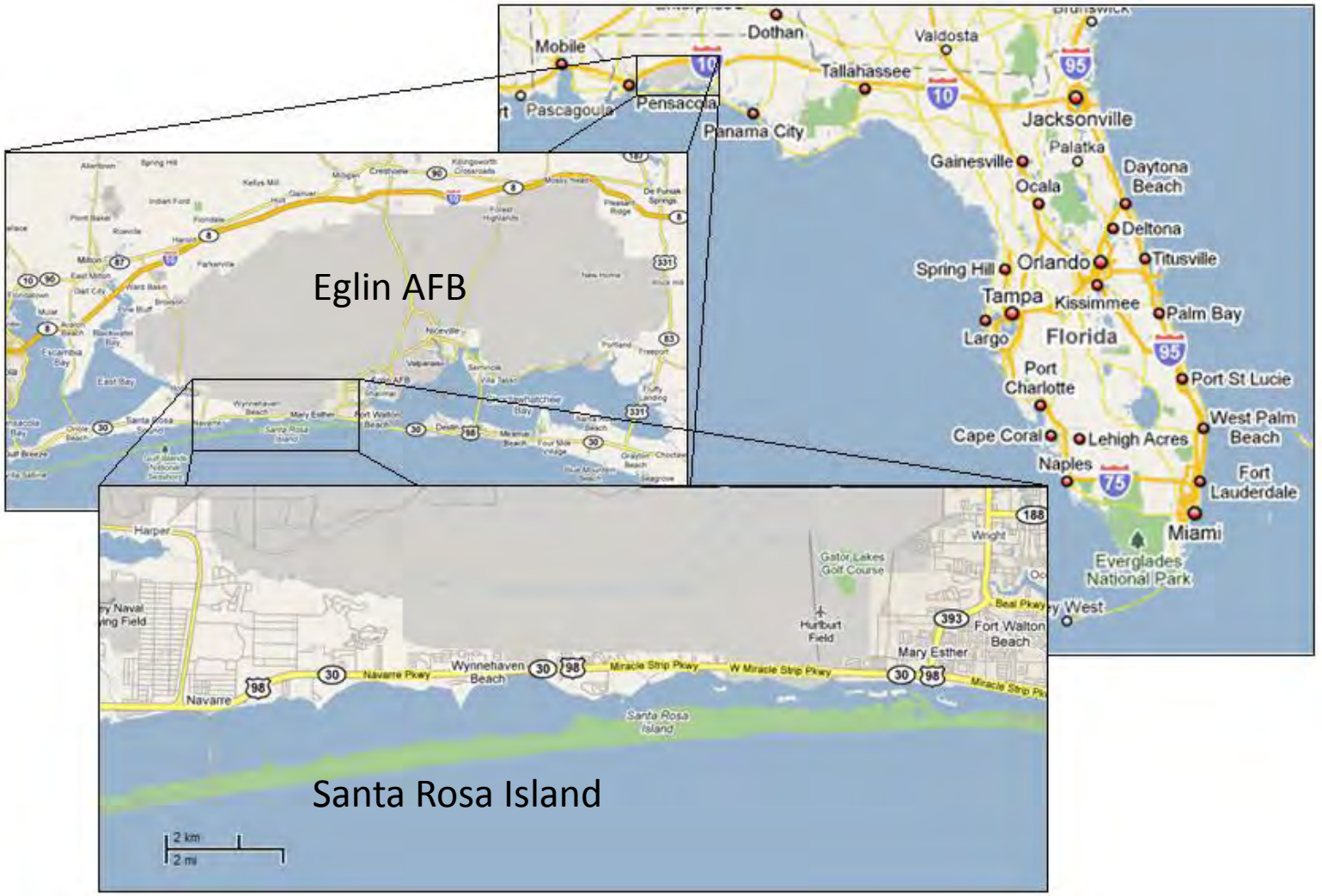
Agenda

1. Motivation: What devil? What deep blue sea?
2. **Canaries in a coal mine: Florida style**
3. Getting local and personal: Sea Level Rise predictions meet stakeholders
4. The Way Forward: Where to go? How to grow?

Study Area: Eglin Air Force Base



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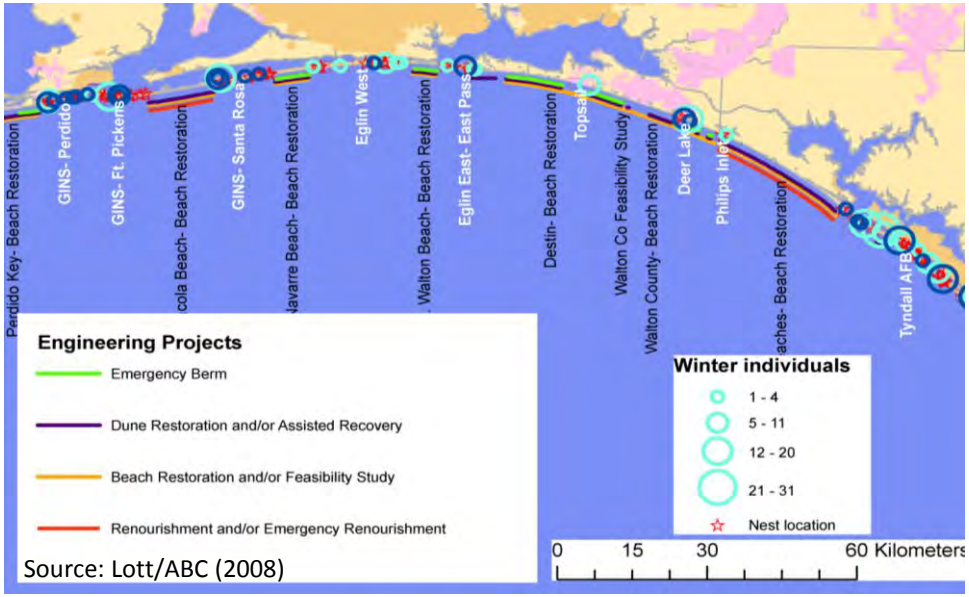
Why are military areas important habitats?

- Important forage areas and nesting habitats for shoreline birds



Source: Lott/ABC (2008)

Focal Species - Snowy Plover (SNPL) *Charadrius alexandrinus* –

A beach-nesting and wintering species found year-round in FL

- **Status**

  State Threatened Species - FL Fish and Wildlife Conservation Commission

  "Extremely High Priority for Conservation" - US Shorebird Conservation Plan

  Potential Federal Candidate Species for Listing - USFWS

- **Importance of DoD Lands**

  Eglin AFB and Tyndall AFB, along with State Park and NPS shorelines accounted for 80% of all estimated nesting Snowy Plover pairs in the Florida Panhandle during recent statewide surveys.

- **Justification for Selection**
  - **Species is easily surveyed; population data and estimates of population parameters are available.**
  - **SNPL is a good sentinel for detecting climate change effects on coastal habitats. Habitat changes are relatively easily detected and birds respond rapidly to these alterations.**

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Additional Species of Interest

Piping Plover (PIPL) (*Charadrius melodus)*

- The Piping Plover (SNPL), is federally listed as 3 separate sub-populations
- Birds from all populations winter in high numbers on Florida's barrier islands during the non-breeding season
- DoD has high stewardship responsibility for this species

Red Knot (REKN) (*Calidris canutus)*

- Red Knots have declined dramatically during the past decade
- Species may be Federally listed in the near future
- This species "stops over" in Florida during spring and fall migration at various locations along the Atlantic and Gulf Coasts

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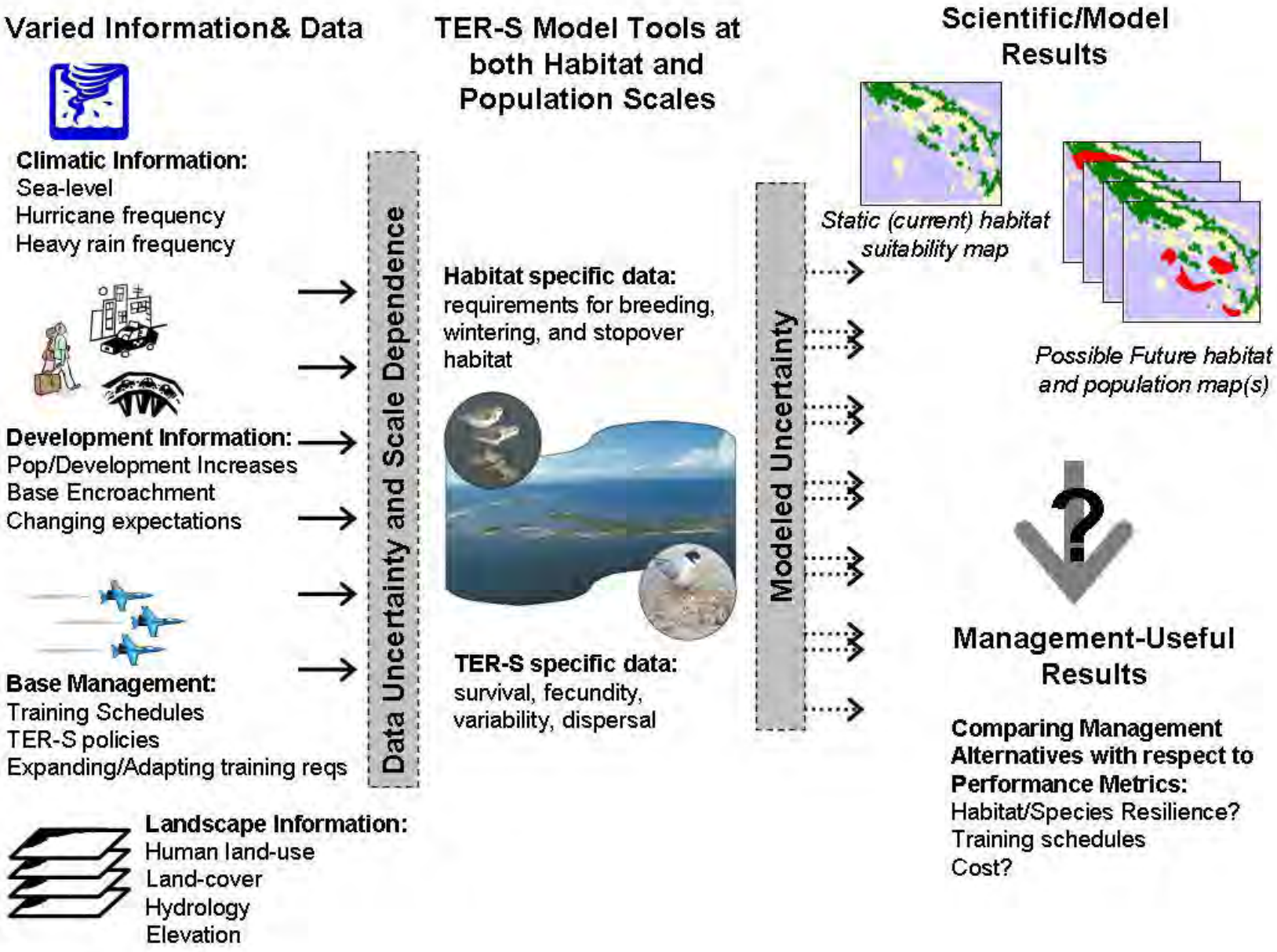
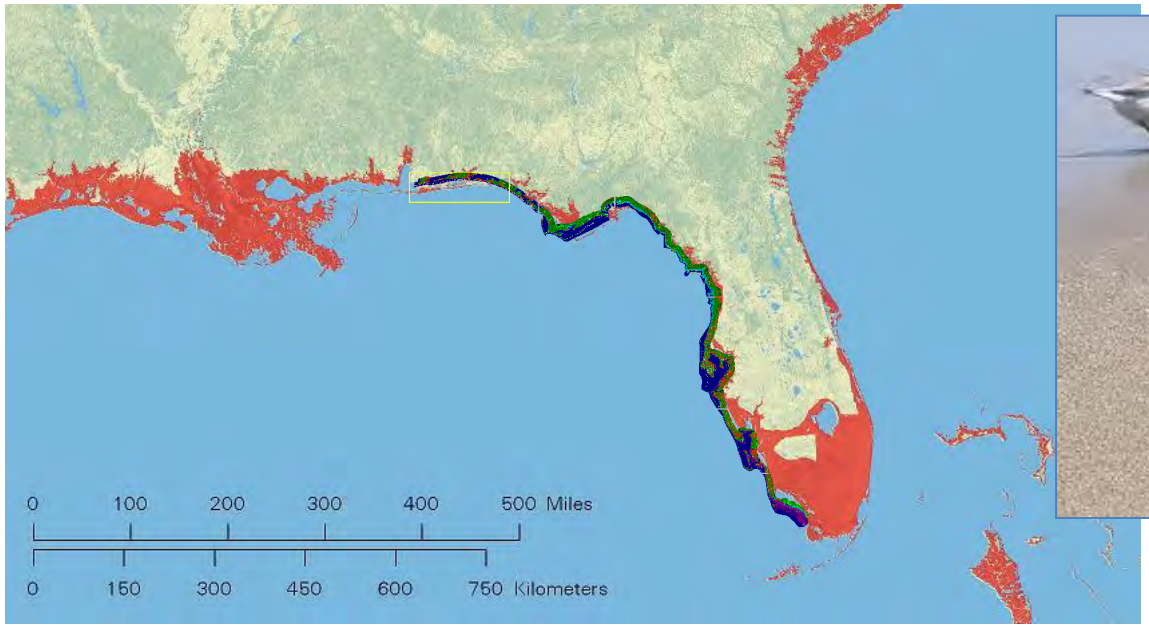
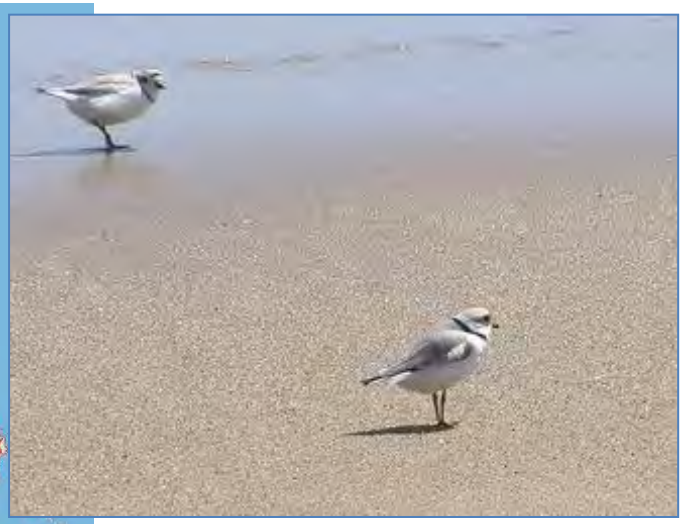
Conceptual Model: Integration of Data, Models, Uncertainty and Decision Analysis



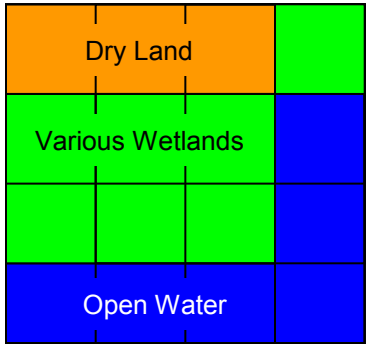
Linking models to management outcomes - Florida Snowy Plover Populations and Sea Level Rise





Global Sensitivity/Uncertainty Analysis
Multi-Criteria Decision Analysis

Sea Level Affecting Marshes Model (SLAMM)



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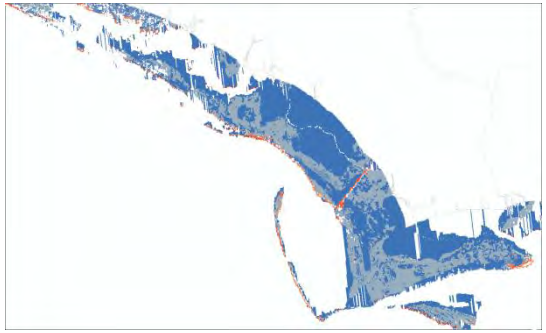
MaxEnt – Species Distribution Model



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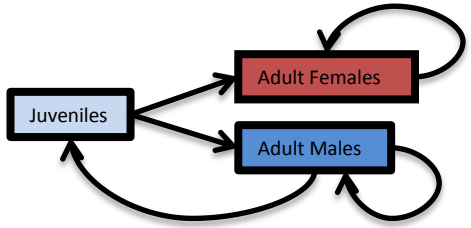
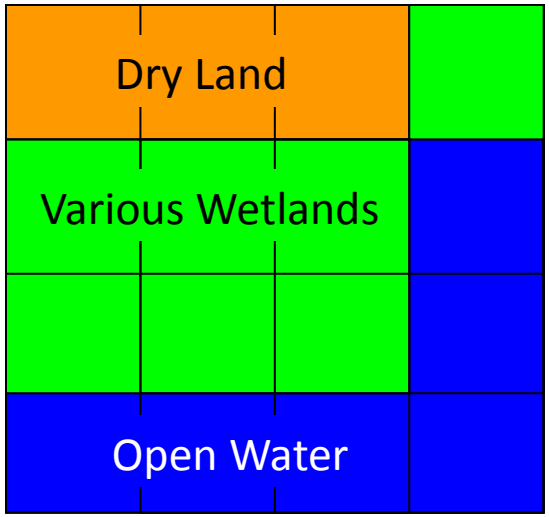
RAMAS MetaPopulation Model

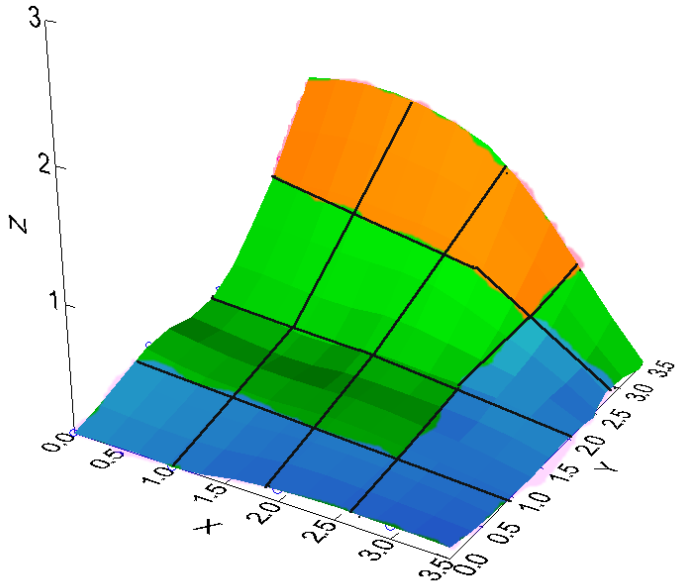


SLAMM: Sea Level Affecting Marshes Model

- Simulates the dominant processes involved in wetland conversions and shoreline modification due to long term-sea level rise.
- The study area is divided into cells and each cell is simulated separately



2D representation



3D representation

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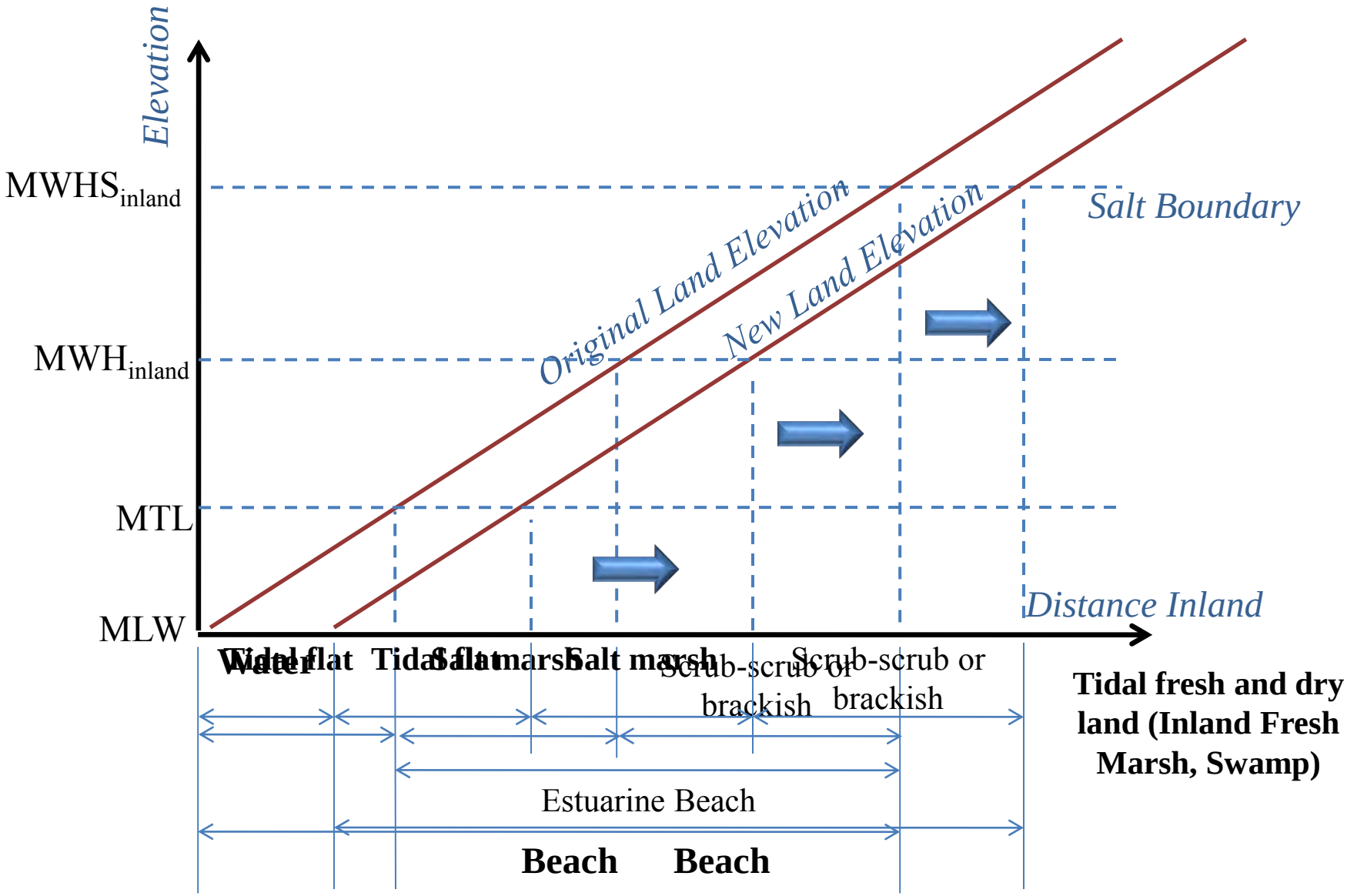
SLAMM Inundation Model

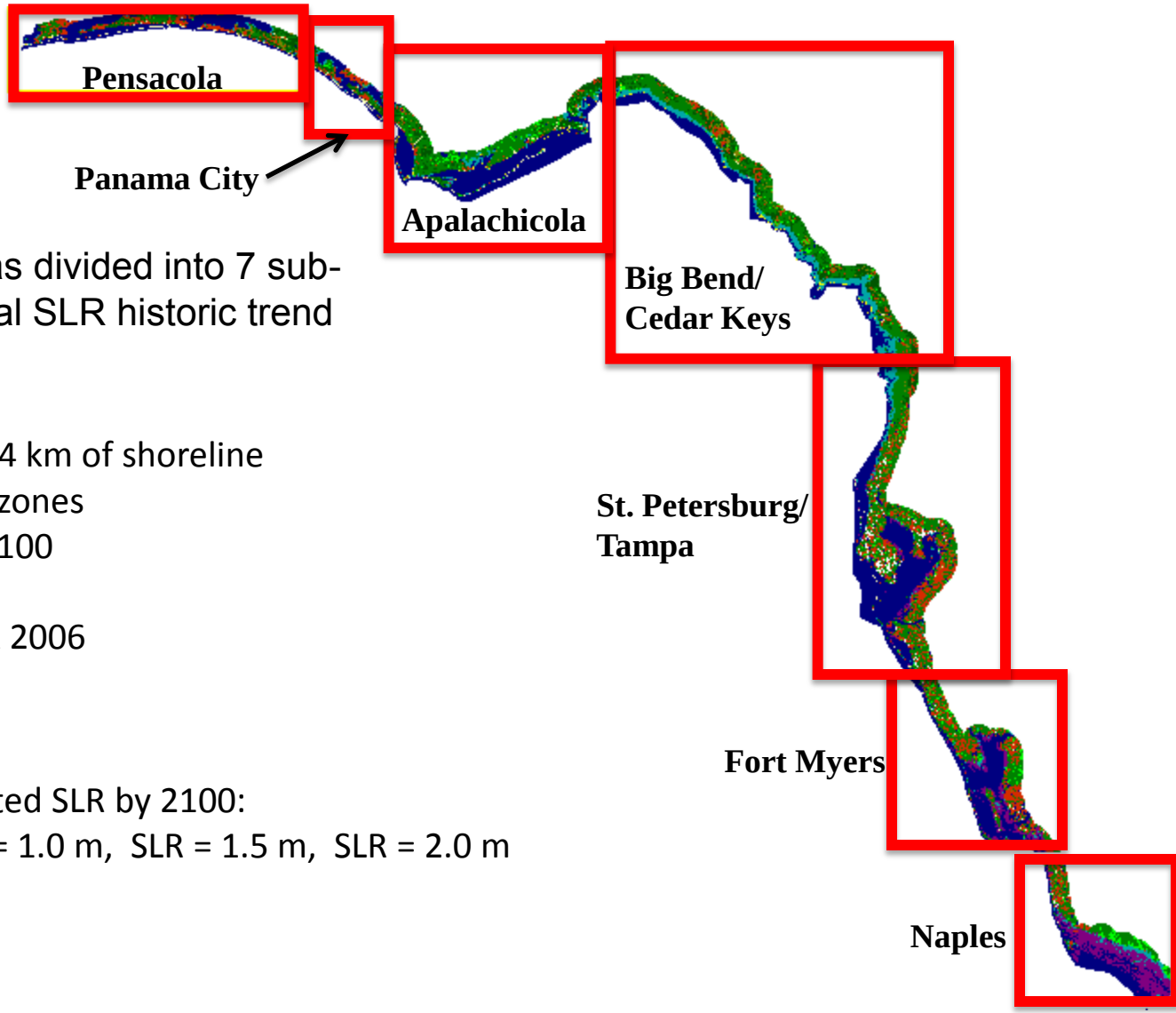
(Migration of Wetlands Boundaries due to Sea Level Rise)



Model Process Overview

- Inundation: Bathtub style model, based on cell elevation and slope.
- Erosion: Triggered when a maximum fetch threshold is reached and cell is in proximity of the marsh to estuarine water or open ocean.
- Overwash: Barrier islands experience overwash from storms at a fixed interval. Calculates beach migration and movement of sediments.
- Saturation: Simulates the response of the water table to rising sea level. Allows marshes to migrate onto adjacent uplands.
- Accretion: Simulates the vertical rise of elevation due to the buildup of organic and inorganic matter. Rate may differs by marsh type.

Florida-Scale SLAMM v6 Simulations

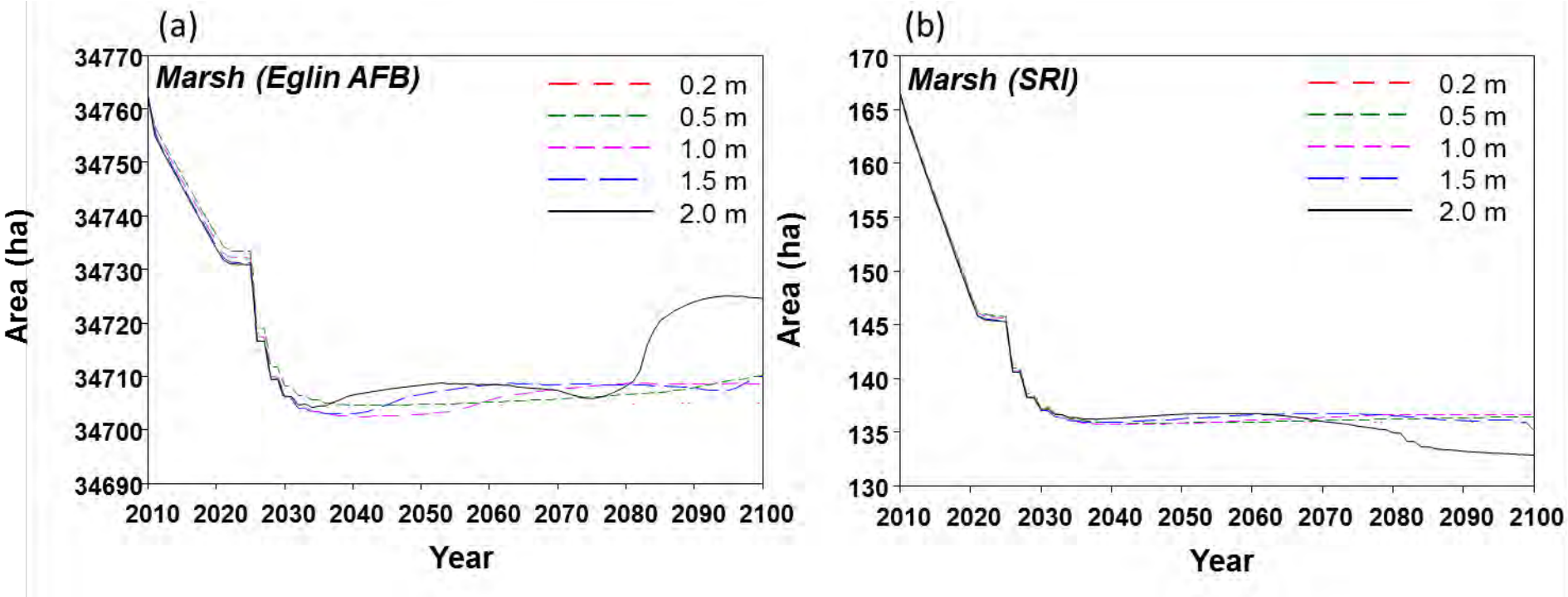


The Gulf coast of Florida was divided into 7 sub-sites based on available local SLR historic trend measurements

- Eglin AFB was simulated as 74 km of shoreline
- 10-km distance inland on all zones
- Simulation period: 2010 to 2100
- Time step: 10 years
- Land Cover map used: NOAA 2006
- DEM map used: USGS 2003
- Resolution: 120x120 m

Change in land cover at projected SLR by 2100:
SLR = 0.2 m, SLR = 0.5 m, SLR = 1.0 m, SLR = 1.5 m, SLR = 2.0 m

Habitat Change: Eglin Base vs its Barrier Island (SRI)



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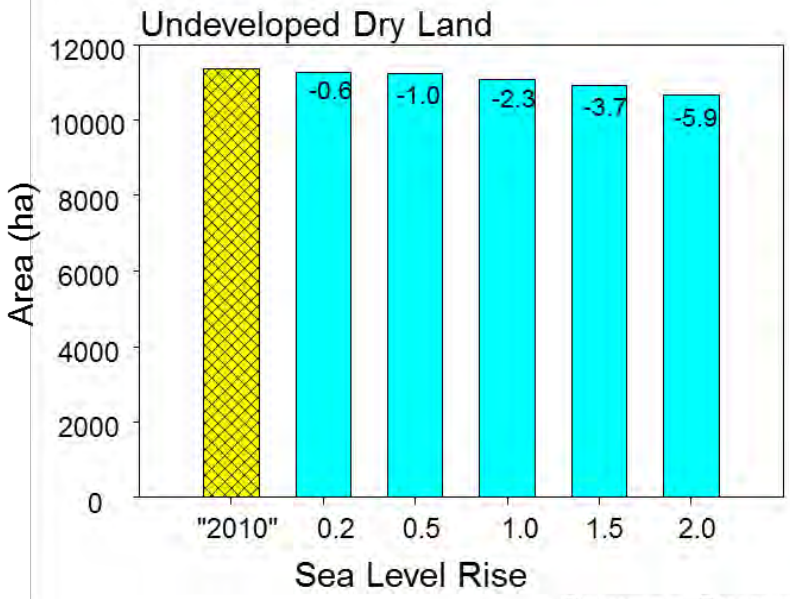
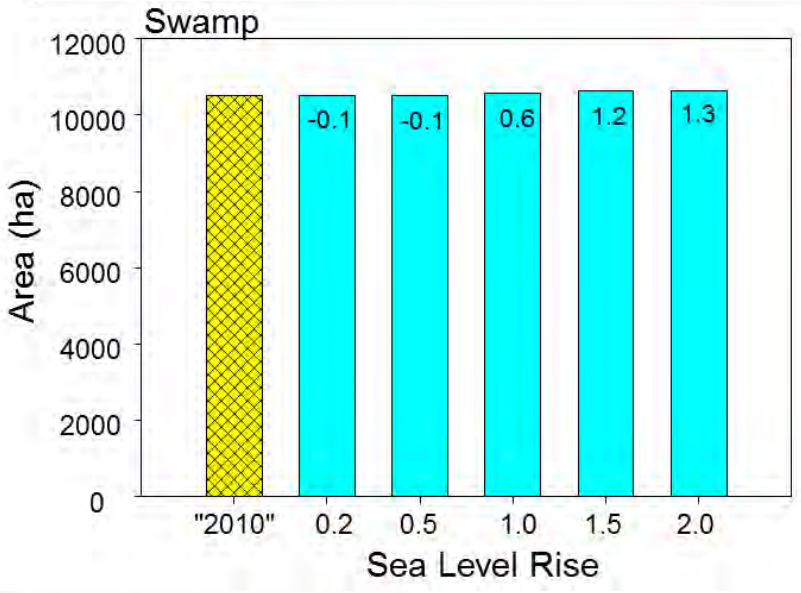
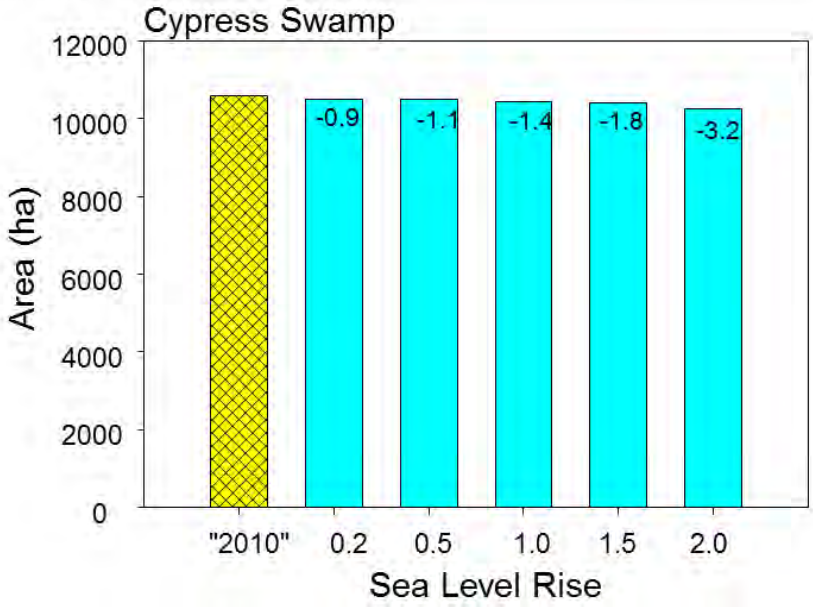
So how does the Eglin Change?







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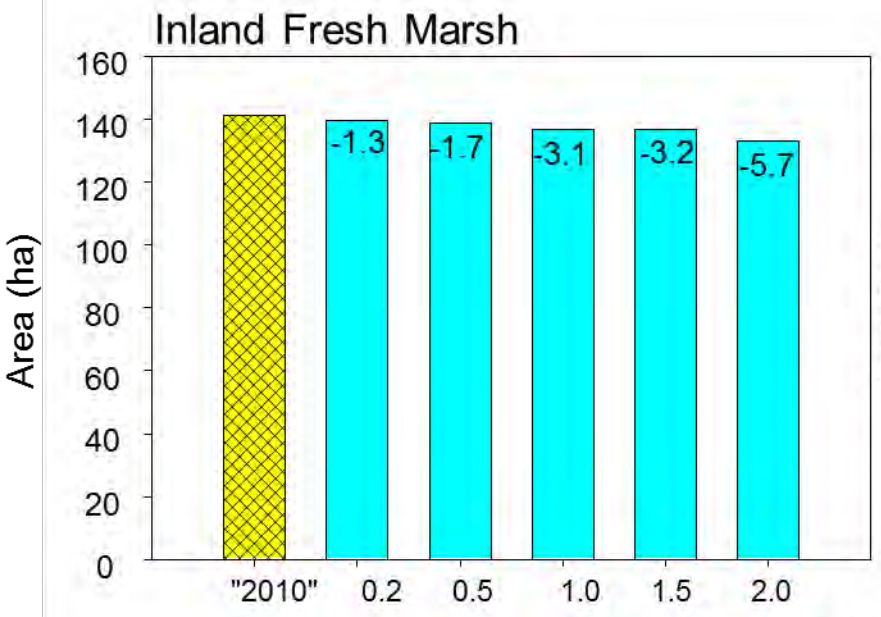
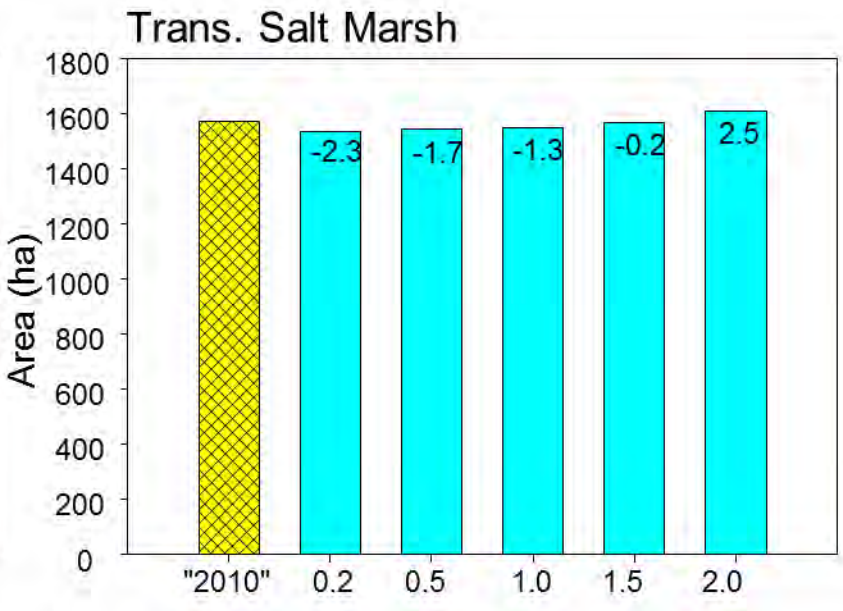
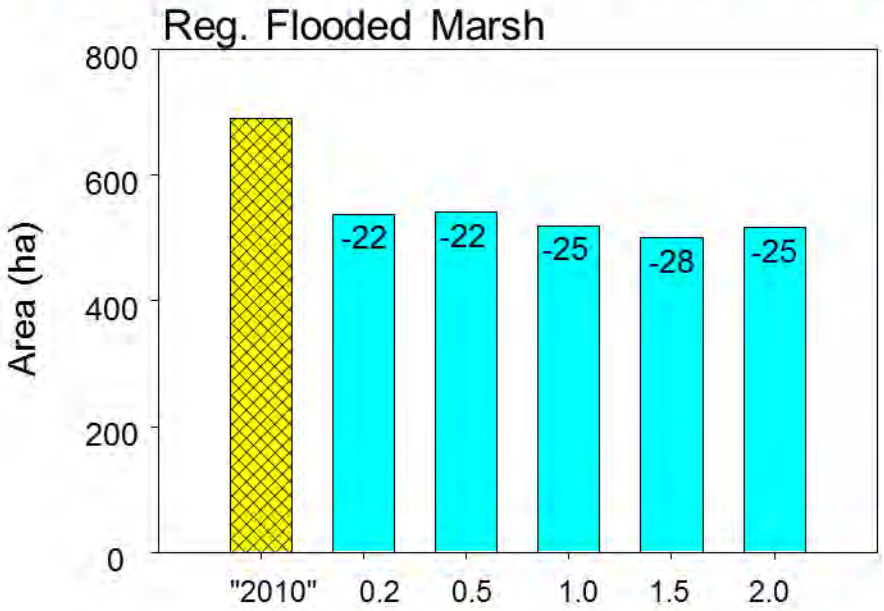
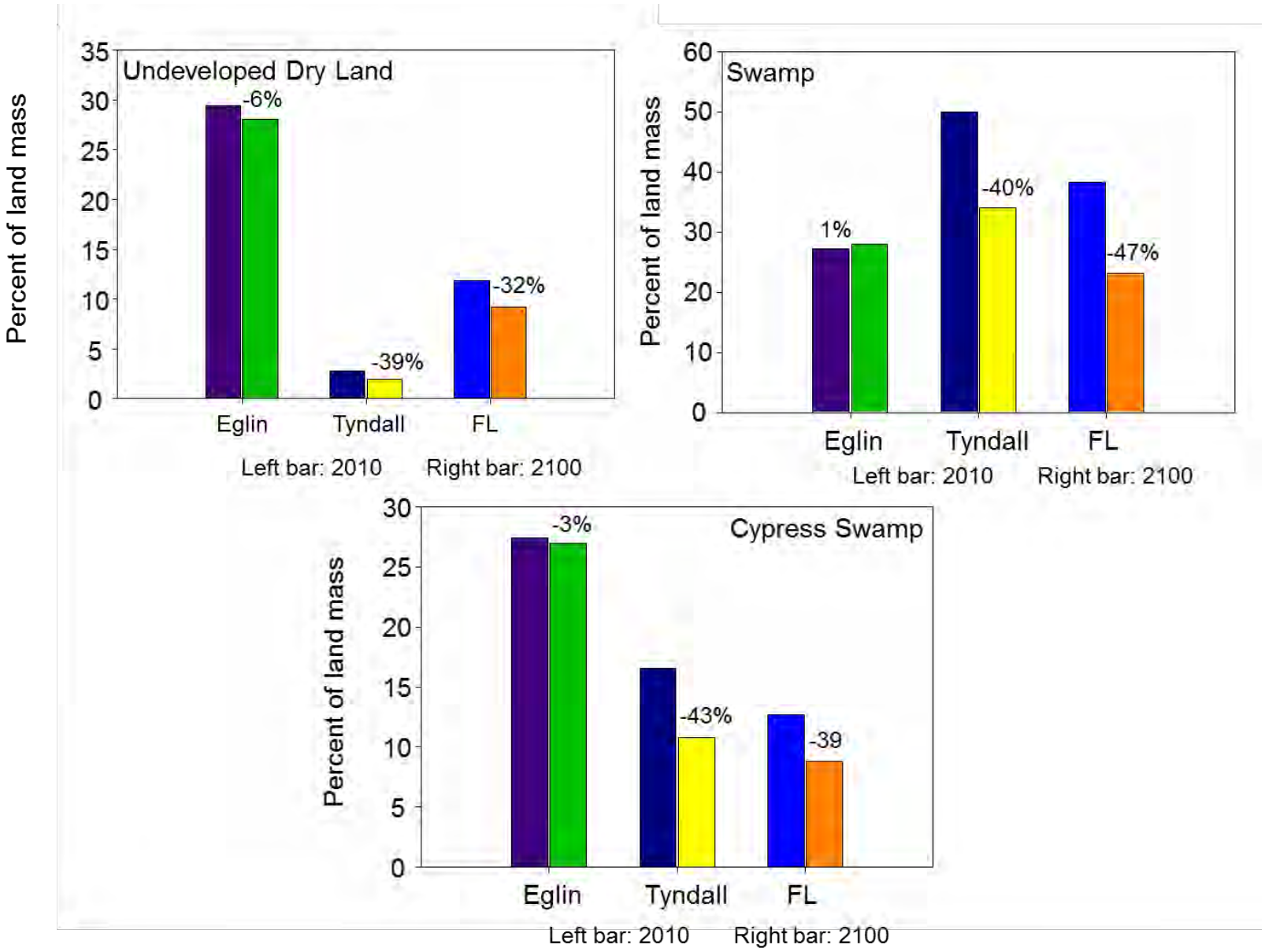
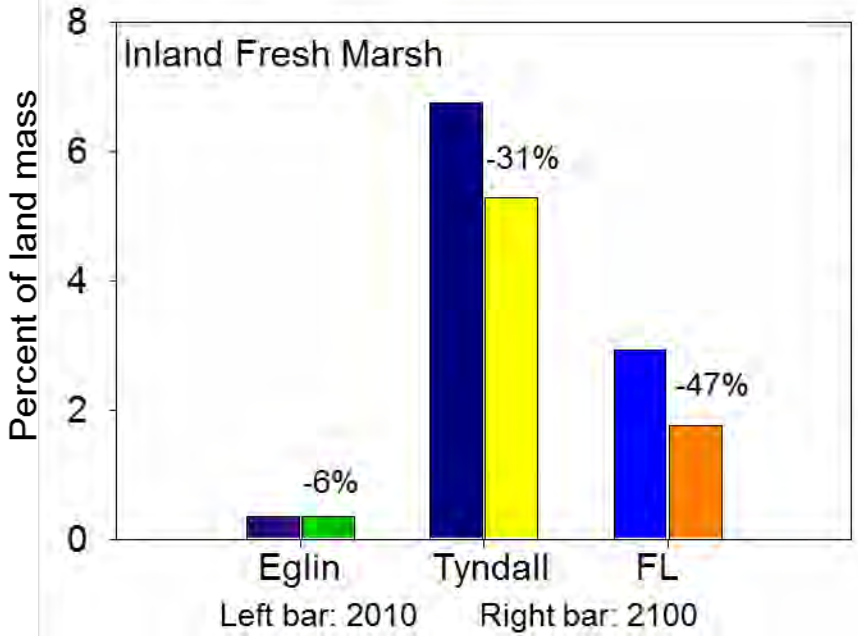


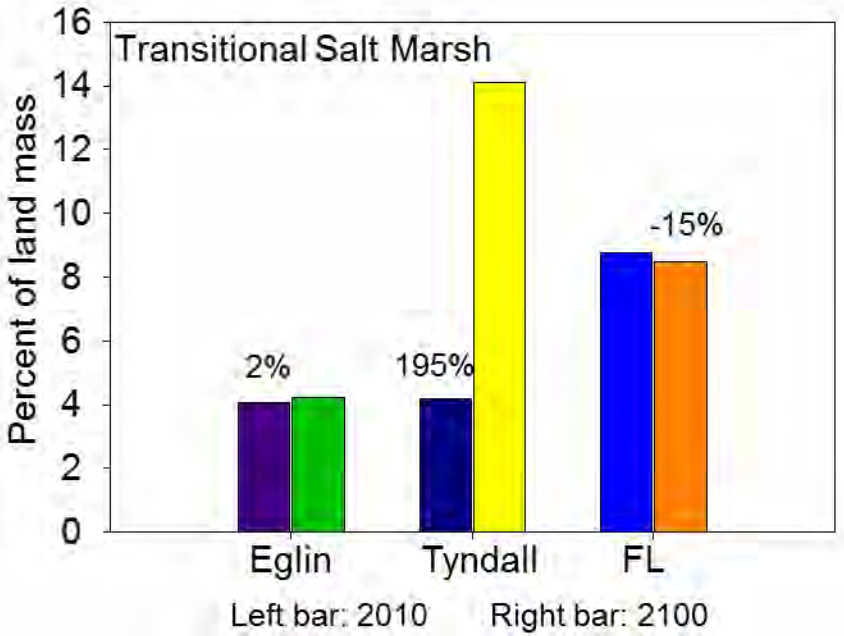


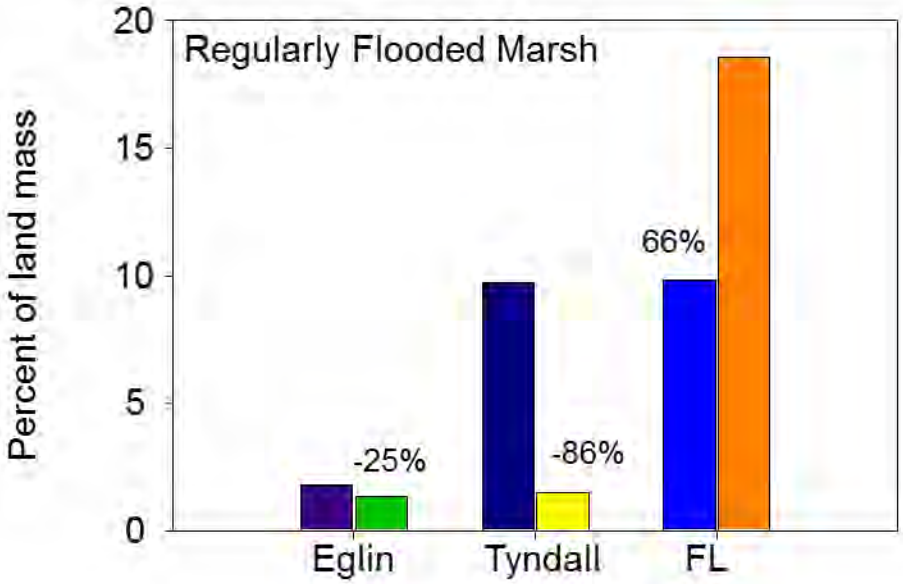


Land Cover Change: Eglin vs Tyndall vs Gulf Coast Florida

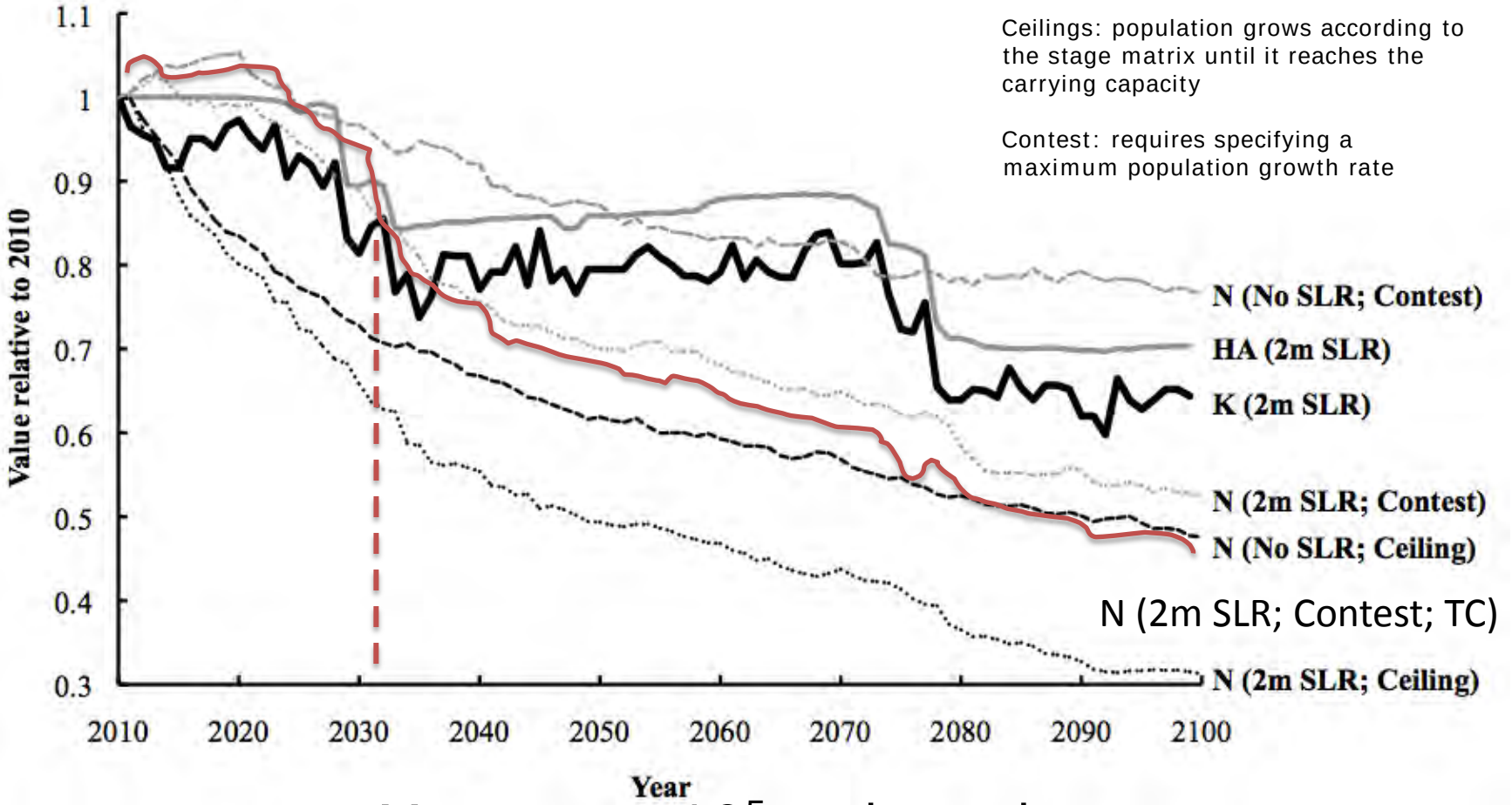



Inland Fresh Marsh
Percent of land mass
8
6
4
2
0
-6%
-31%
-47%
Eglin
Tyndall
FL
Left bar: 2010
Right bar: 2100


Transitional Salt Marsh
Percent of land mass
16
14
12
10
8
6
4
2
0
2%
195%
-15%
Eglin
Tyndall
FL
Left bar: 2010
Right bar: 2100


Regularly Flooded Marsh
Percent of land mass
20
15
10
5
0
-25%
-86%
66%
Eglin
Tyndall
FL
Left bar: 2010
Right bar: 2100

Snowy Plover Populations in many futures…



Mean over 10^5 trajectories

Aiello-Lammens et al., 2011, Global Change Biology

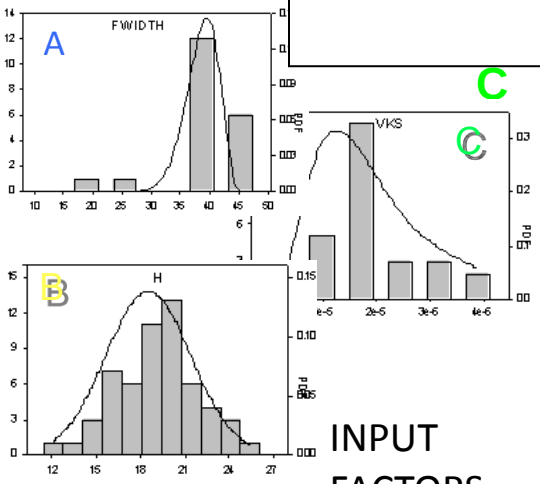
Convertino et al., 2011, in ``Global Change and Local Adaptation'', Springer

Global Sensitivity/Uncertainty Analysis

WHY/WHEN?

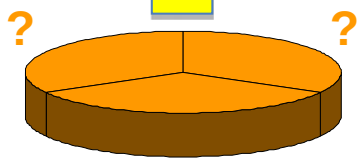
Apportions output variance into input factors

GLOBAL SENSITIVITY ANALYSIS



INPUT FACTORS

MODEL



OUTPUTS

UNCERTAINTY ANALYSIS

HOW MUCH?

Propagates input factor variability into output

So what are we managing here?

- SLAMM model alterations to allow coastal management
- Extreme erosion events from storms
- Beach nourishment

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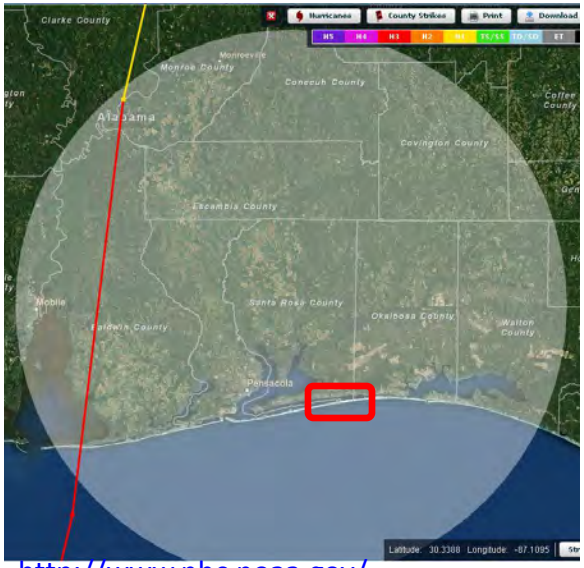
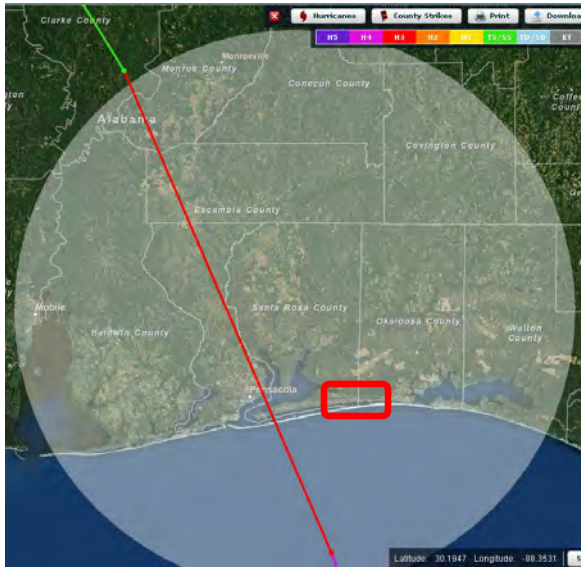
Storms considered

a) **Ivan (2004)**: storm surge return period of 100 yrs (10-11.5 ft in Navarre Beach)
b) **Dennis (2005)**: storm surge return period of 20 yrs (6-7 ft in Santa Rosa Island)
c) **Katrina (2005)**: storm surge return period of less than 10 yrs (3.1-4.2' ft in Pensacola). Katrina brought in more deposition than erosion on the seaward side of the barrier island.

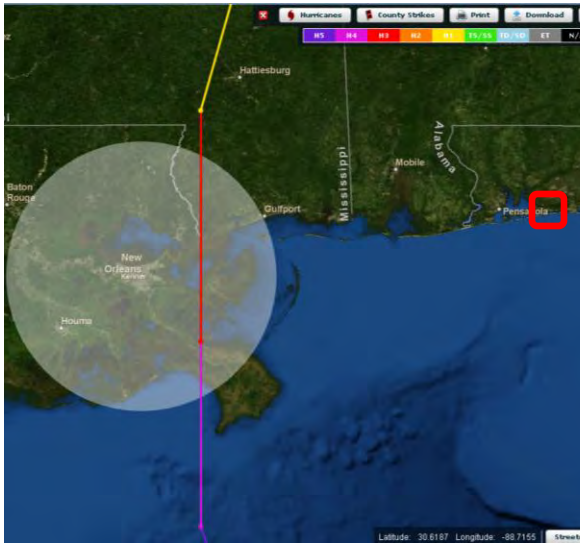
(a) Ivan (H5)



(b) Dennis (H4)



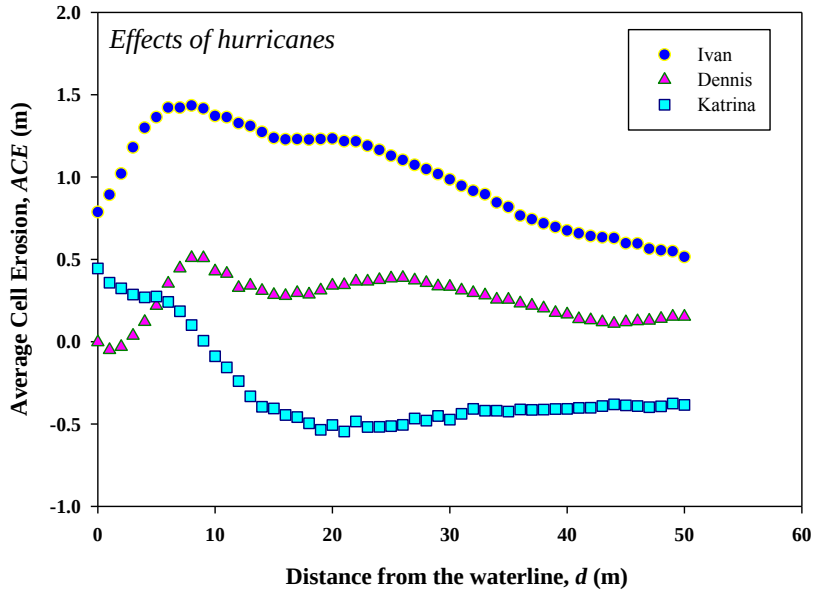
(c) Katrina (TS)



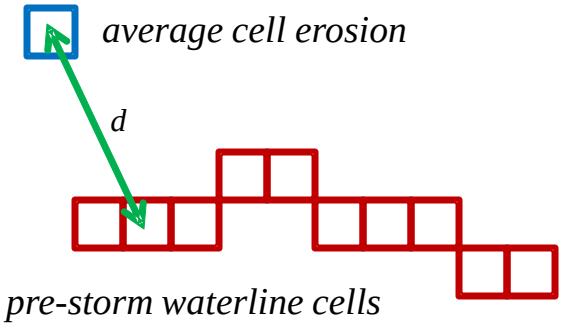
http://www.nhc.noaa.gov/

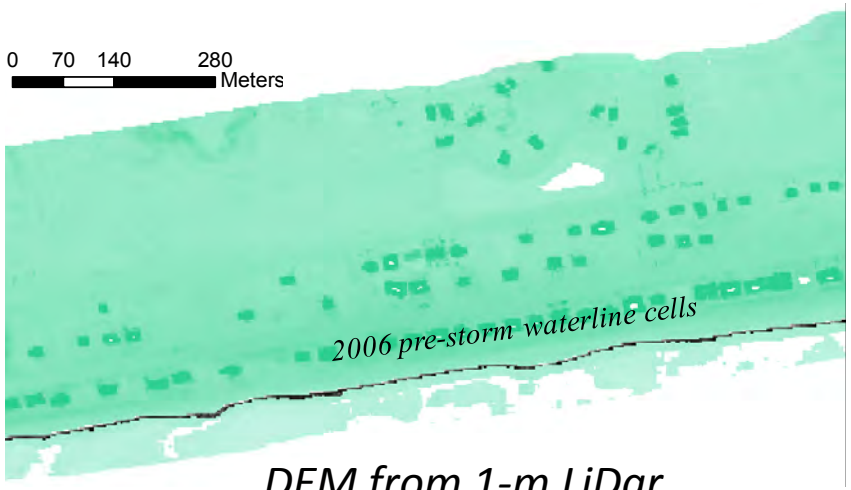
Erosion by historic storms

Erosion Function based on measured erosion using LiDar



- Erosion function: relationship between cell erosion and its distance from waterline
- Predicting future erosion based on derived function





DEM from 1-m LiDar

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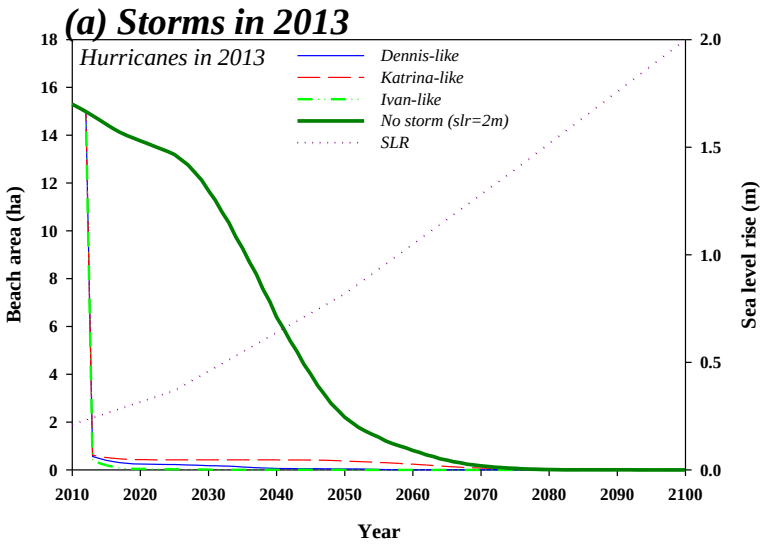
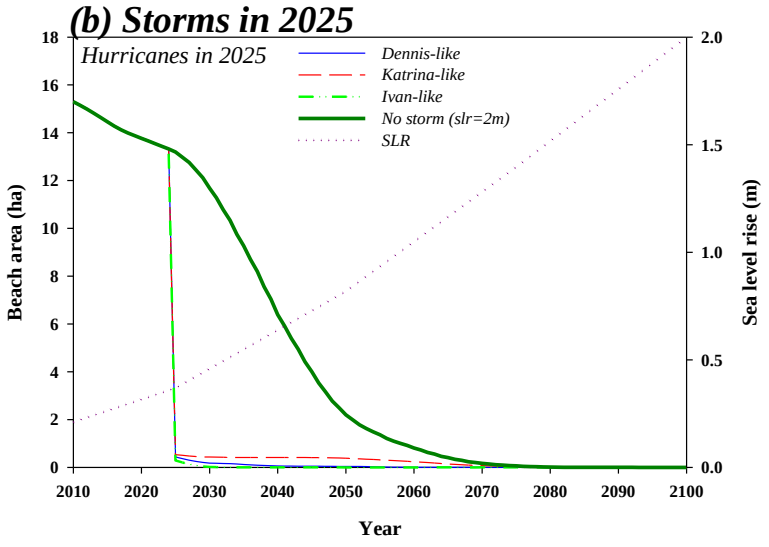
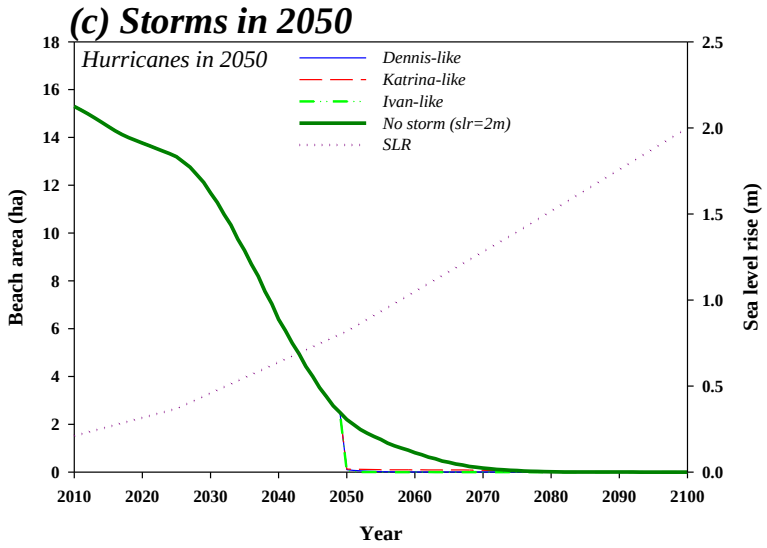
http://www.csc.noaa.gov/digitalcoast/index.html

Individual Storms: immediate effects

(without re-nourishment)







Loss in area after the storm = 97-100%

Over time effects of the same storm are worse due to SLR

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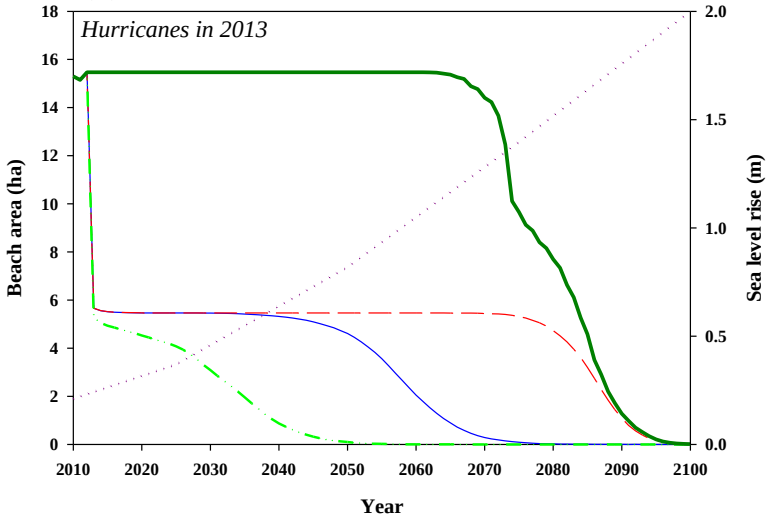
Agricultural & Biological Engineering

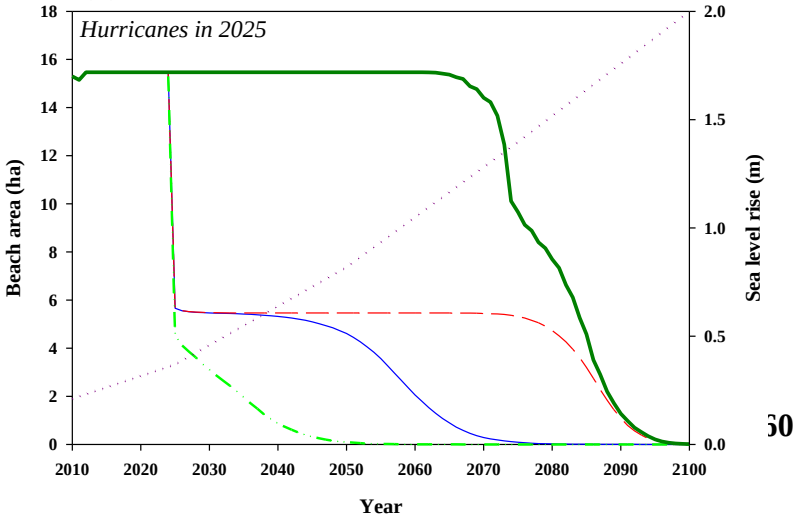
Individual Storm

(with re-nouris

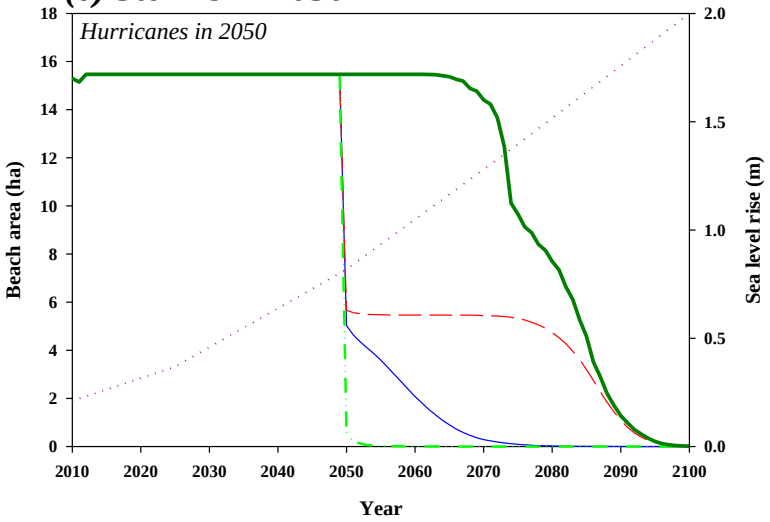
(a) Storms in 2013



(b) Storms in 2025



(c) Storms in 2050



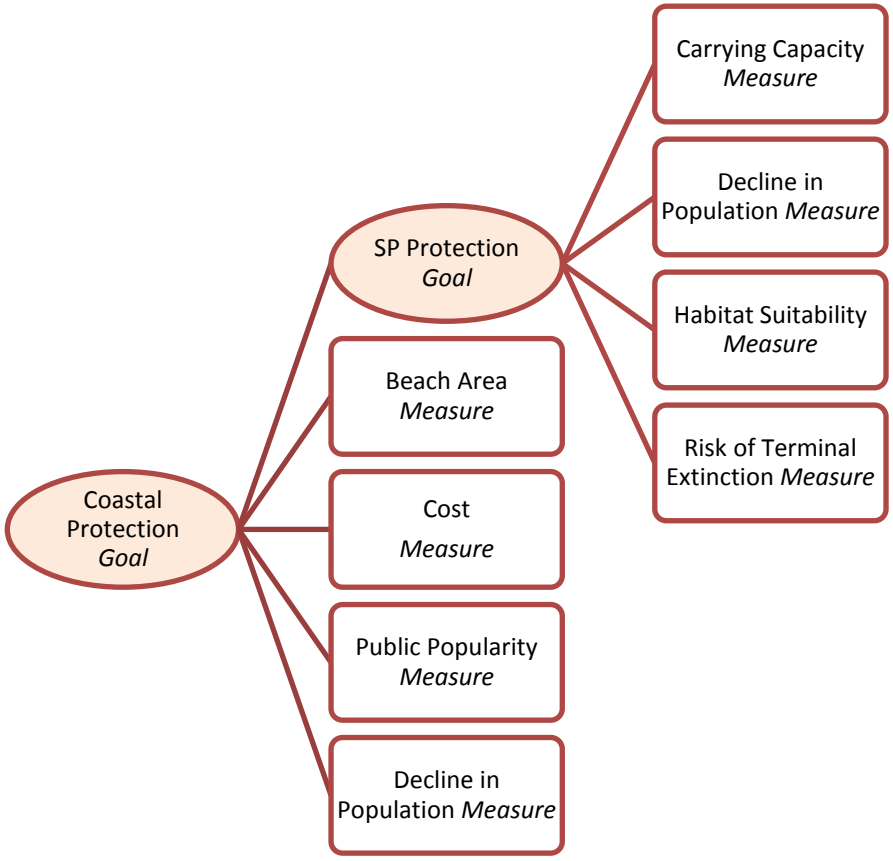
Dennis-like
Katrina-like
Ivan-like
No storm (slr=2m)
SLR

- *Loss in area after storm = 60%*
- *Length of time the remaining 40% stays depends on storm category*

Translating Integrated modeling results into Decision Information

Incorporates:

- Scenarios
  - 1m and 2m SLR by 2100
  - Ceiling and contest density dependence
- Management alternatives
  - No action
  - Species focused beach nourishment ($38m/yr)
  - Predator management ($1.8m/yr)
  - Predator exclosures ($1.8m/yr)
- Measures
- Levels of risk
- Uncertainty



Decision Structure

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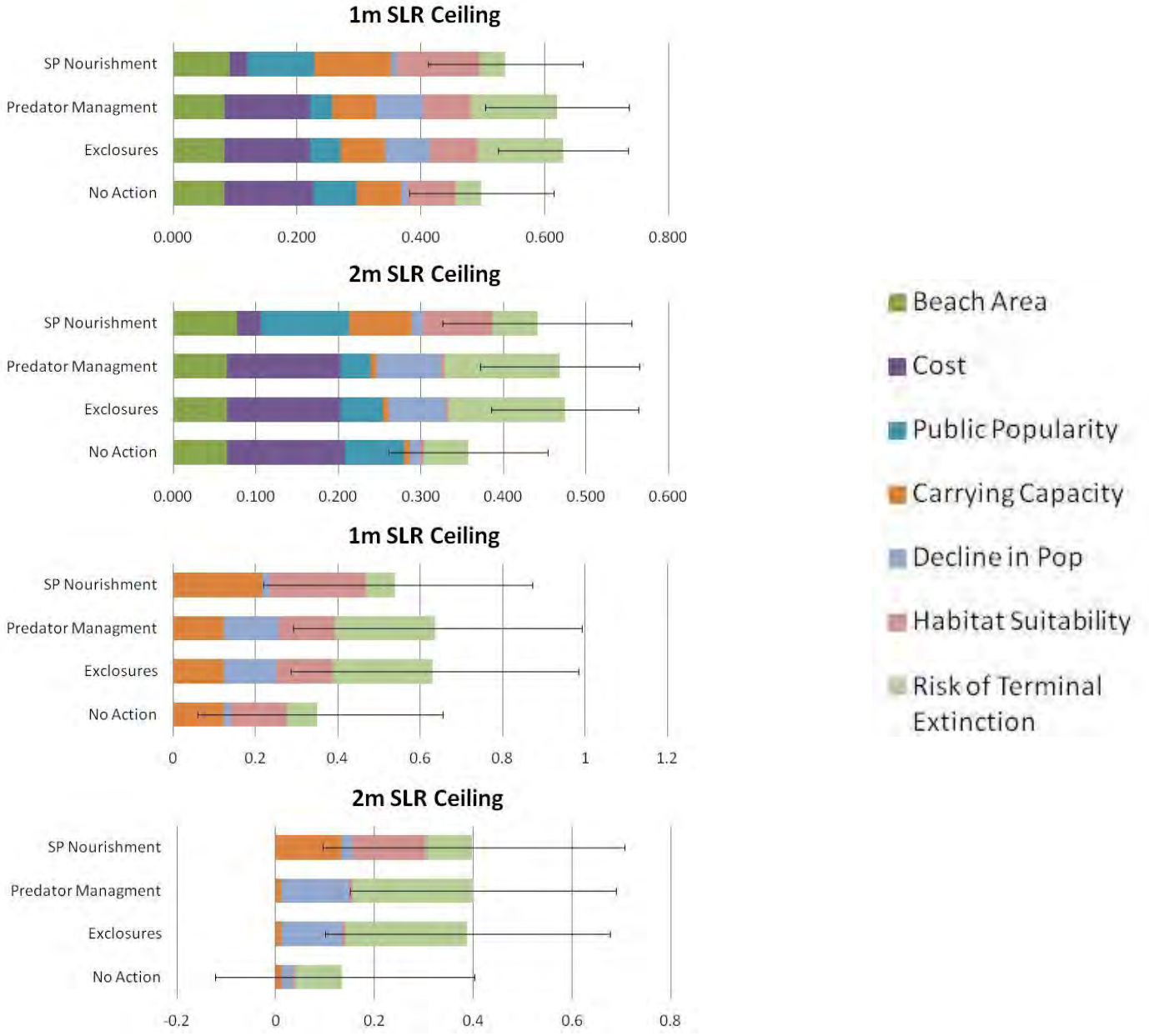
Decision Analysis allows the combination of model uncertainty with different stakeholder valuations

Goal: Coastal Protection

Goal: Plover Protection



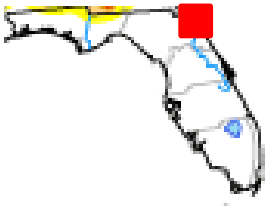
Decision Analysis Results

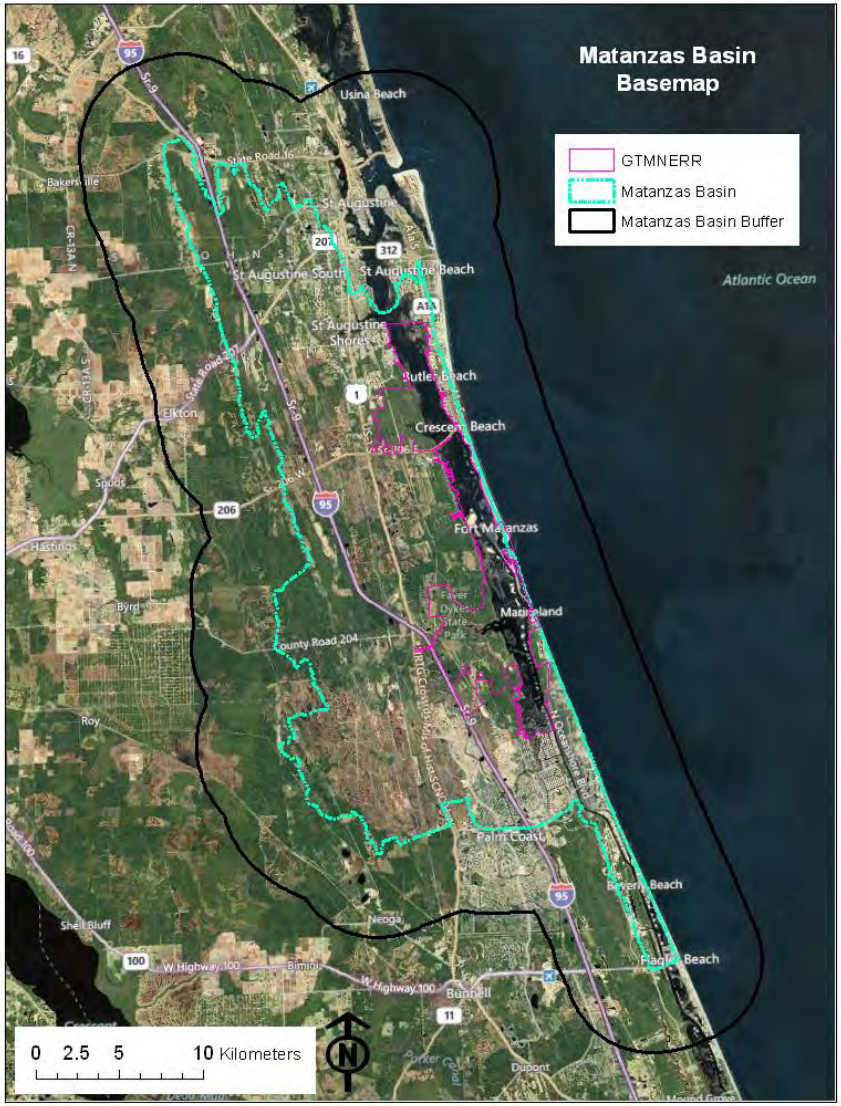
- **The ranking of the alternatives is the same between 1 and 2 m SLR**
- **Information about the Snowy Plovers makes a big difference**. The ranking of the alternatives is different between contest and ceiling type density dependence
- In all of the model scenarios Exclosures ranks higher than Predator Management
- **The level of uncertainty is higher in the 2 m SLR scenarios than in the 1 m SLR scenarios**
- **The uncertainty in each of the scenarios and in each of the management alternatives makes a definitive selection of an optimal alternative unclear.**

Agenda

1. Motivation: What devil? What deep blue sea?
2. Canaries in a coal mine: Florida style
3. **Getting local and personal: Sea Level Rise predictions meet stakeholders**
4. The Way Forward: Where to go? How to grow?

National Estuarine Research Reserve System Science Collaborative:



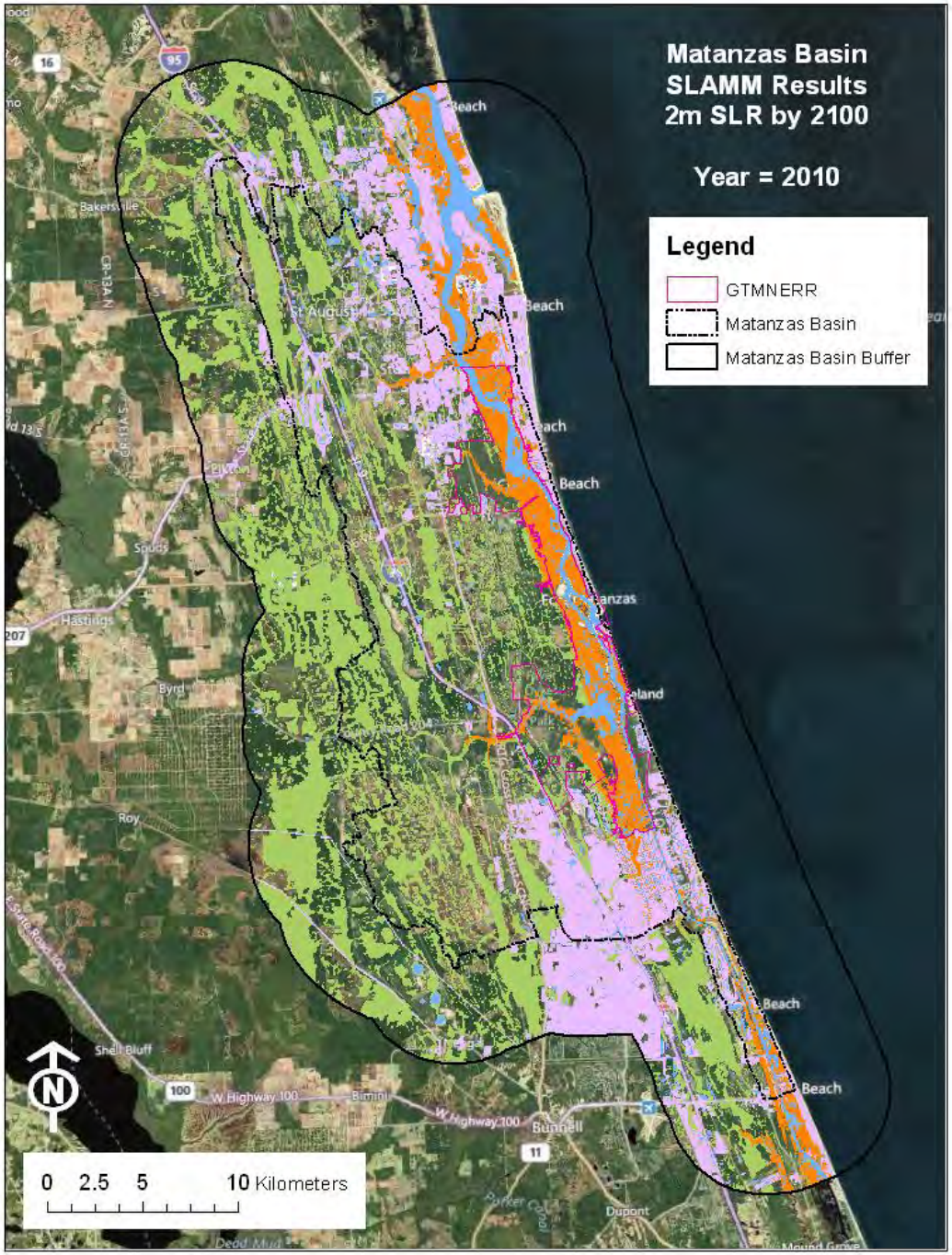


- Guana Tolomato Matanzas National Estuary Research Reserve (GTMNERR)
- Low elevation estuary between St Augustine, FL (America's oldest city) and the Palm Coast (rapidly growing retirement community)

SLAMM results
2m SLR by 2100

2010

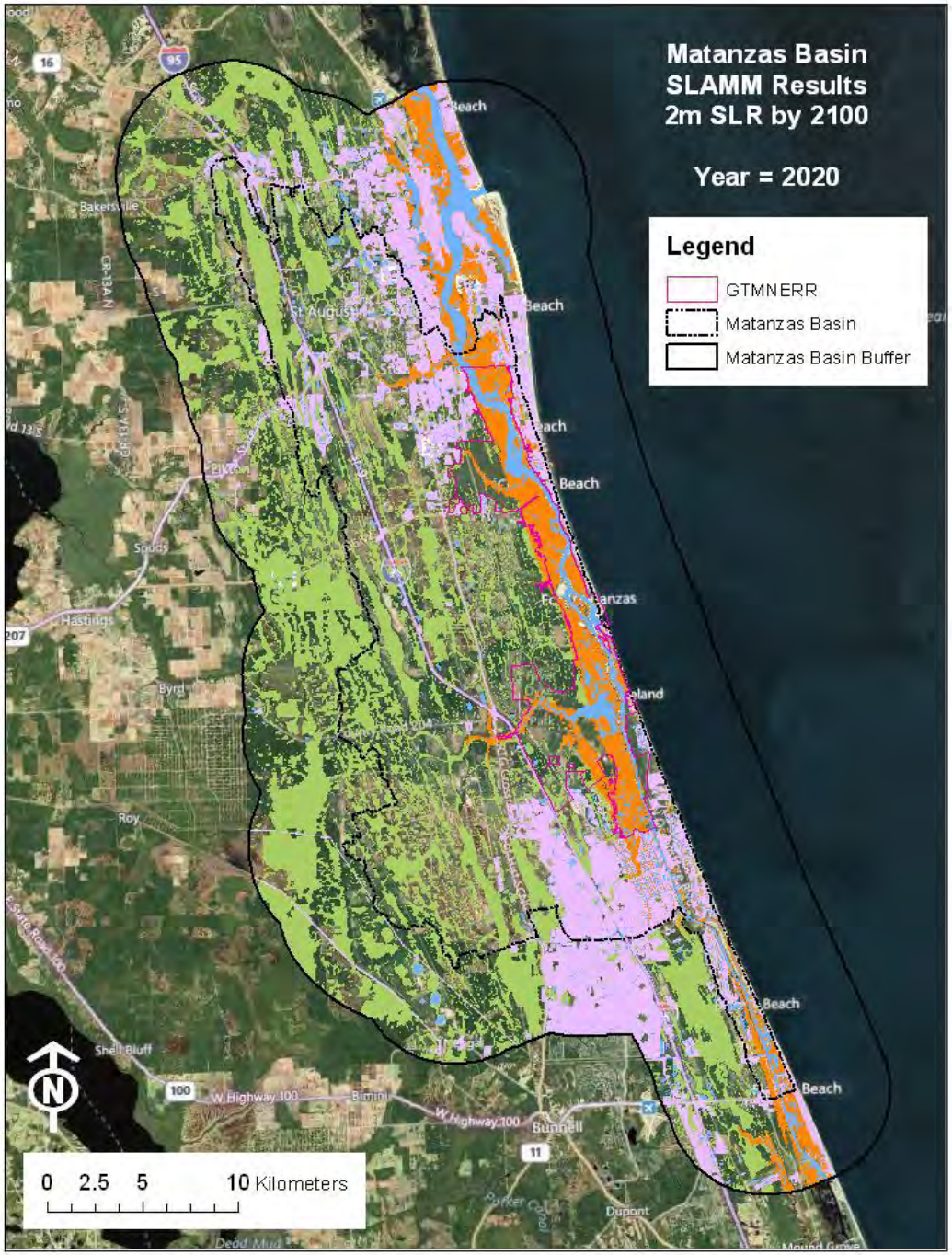
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2020

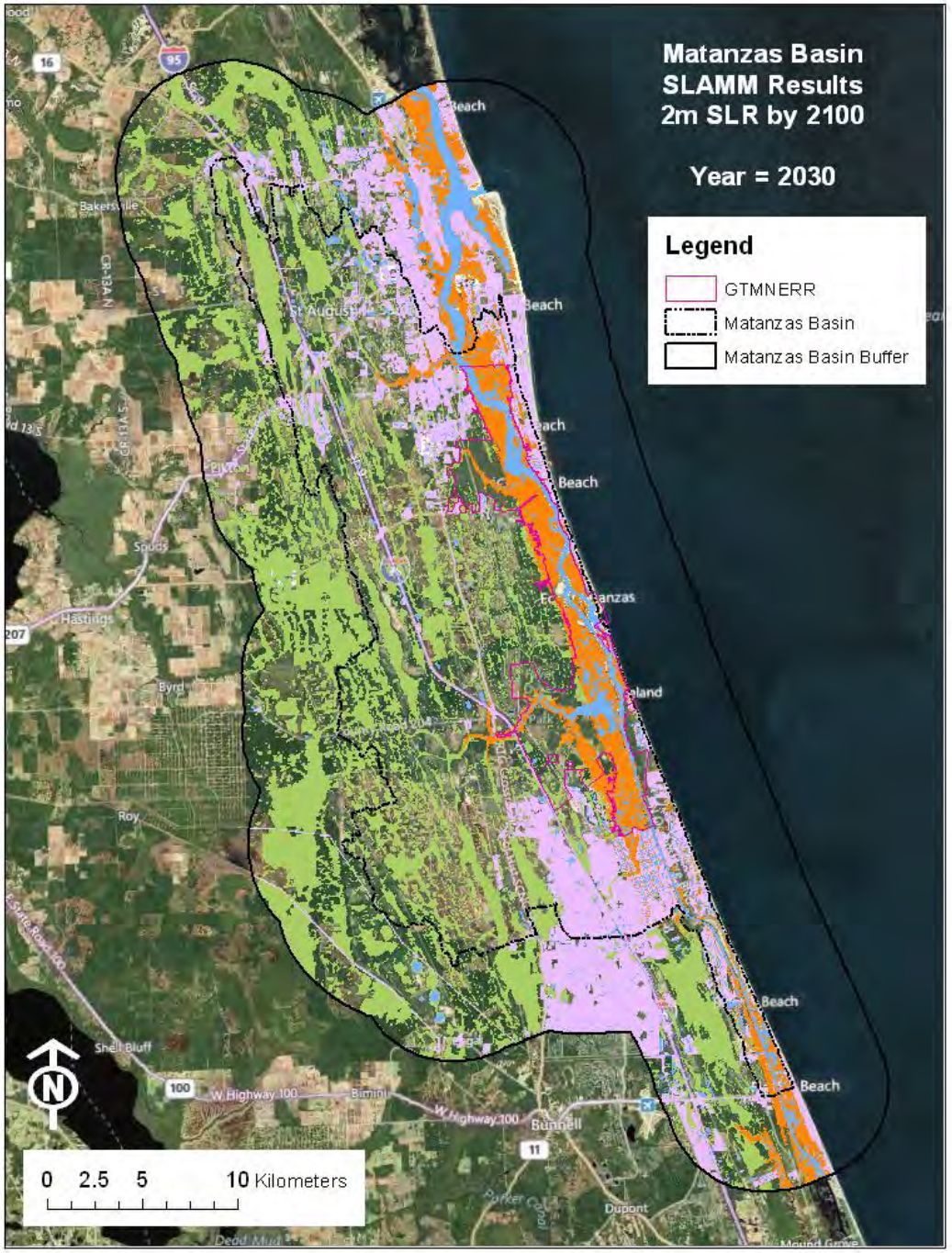
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2030

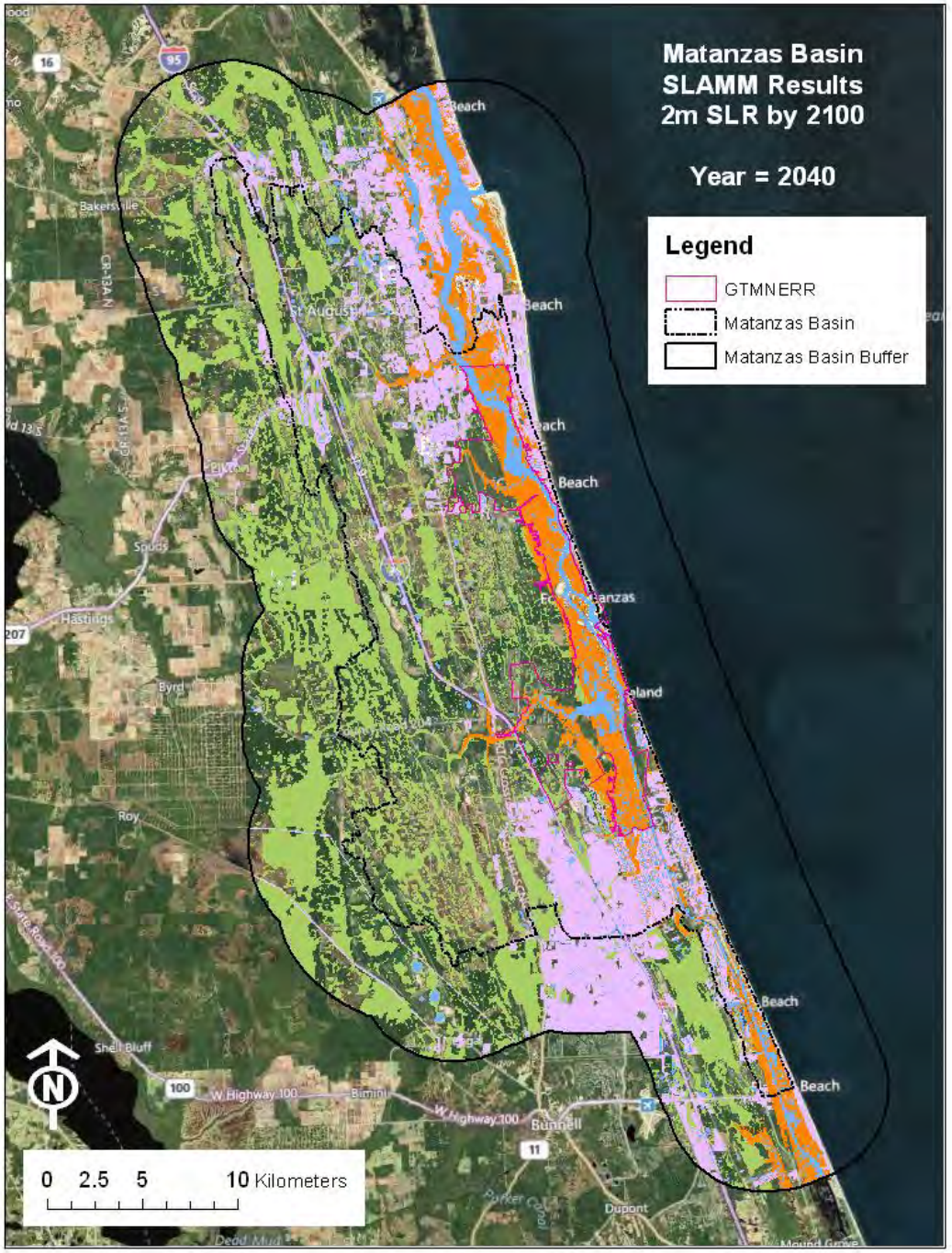
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

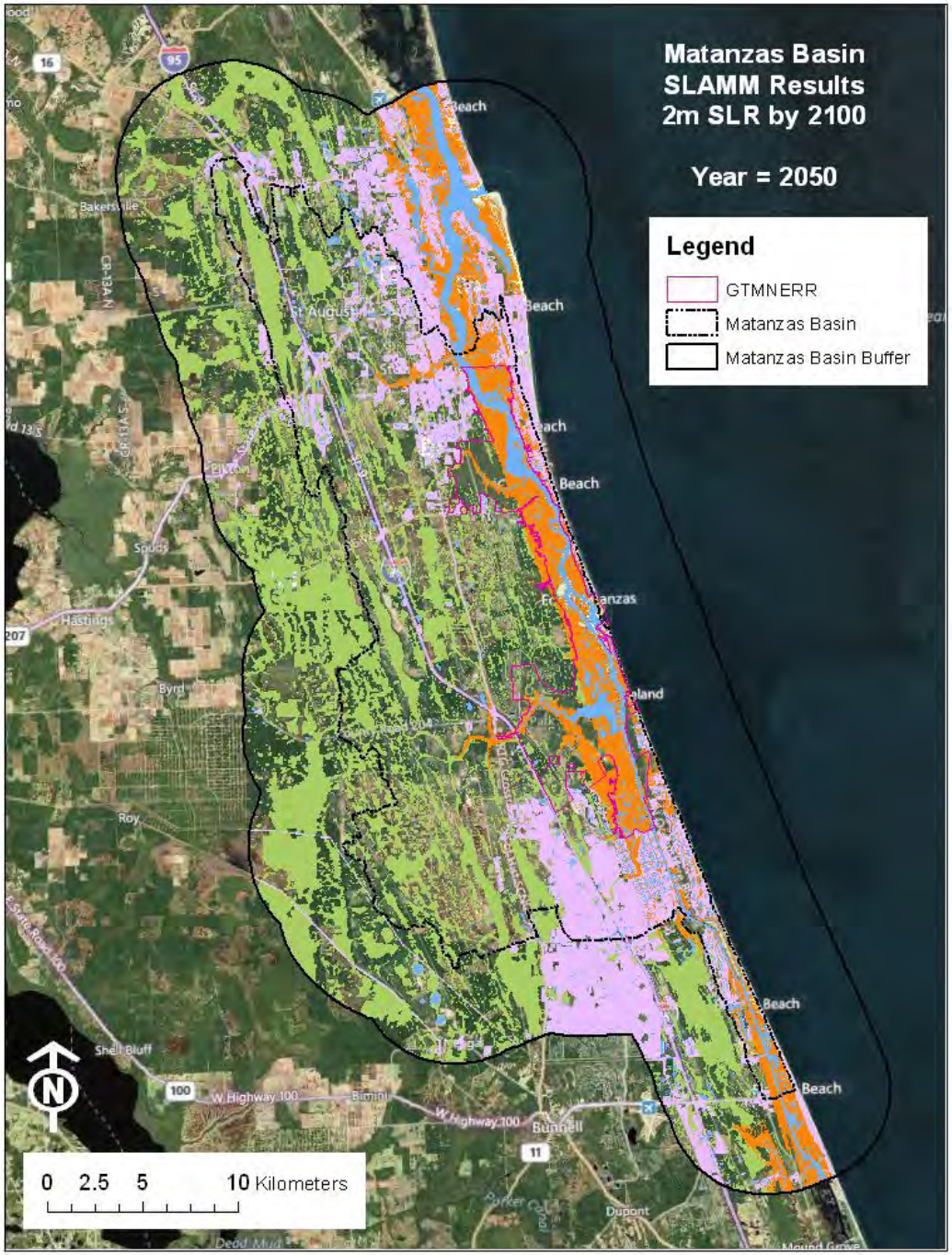
2040

- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

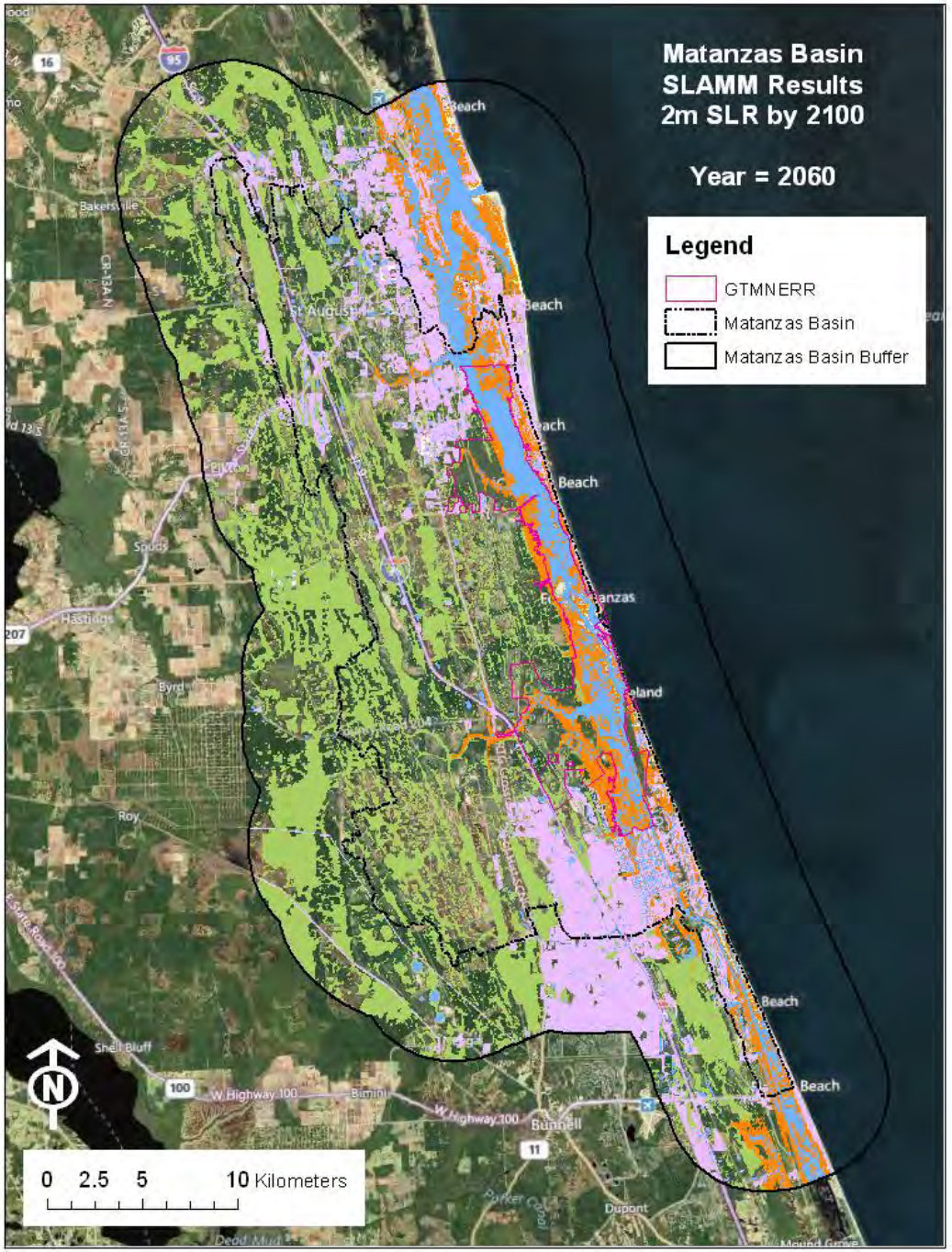
2050



SLAMM results
2m SLR by 2100

2060

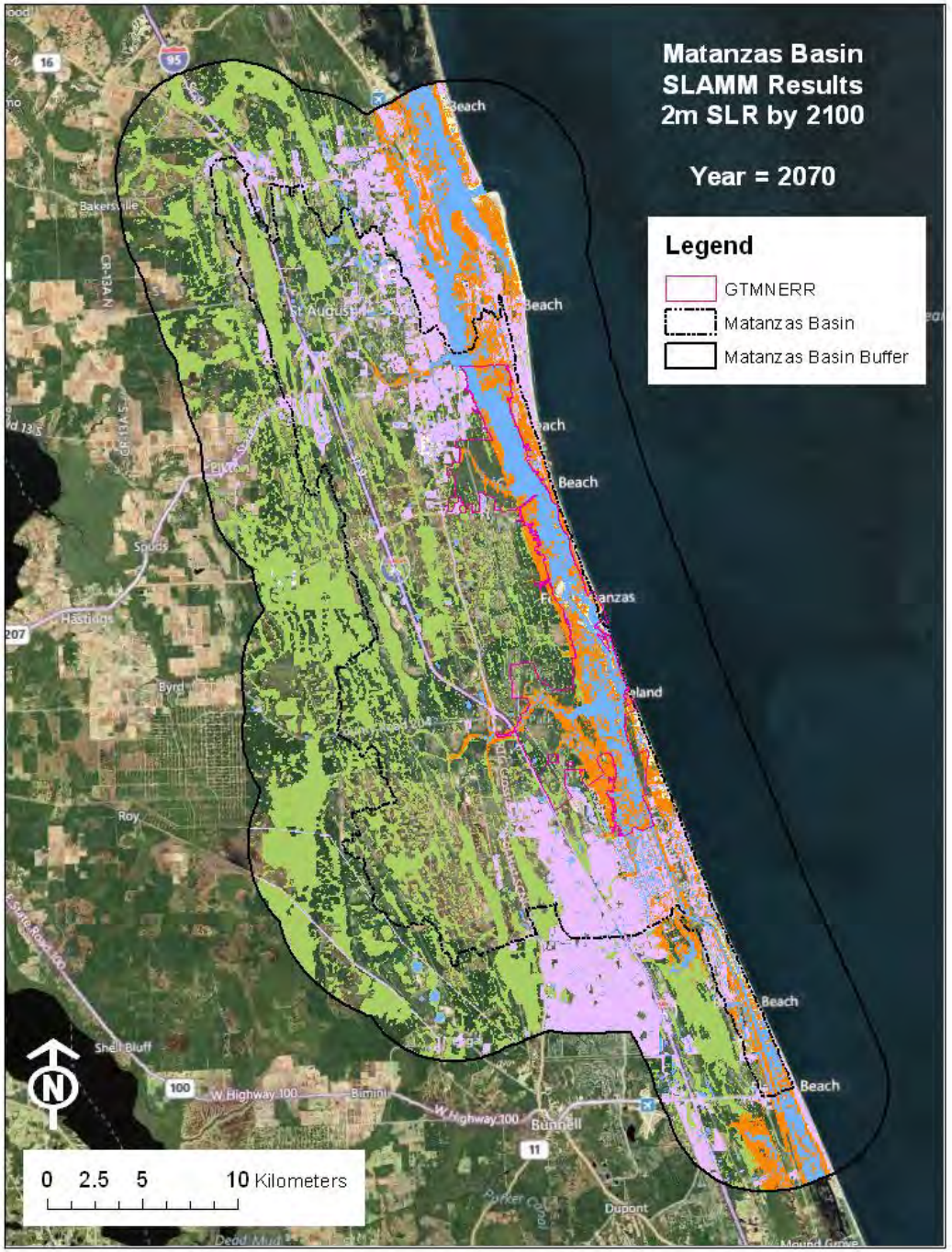
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

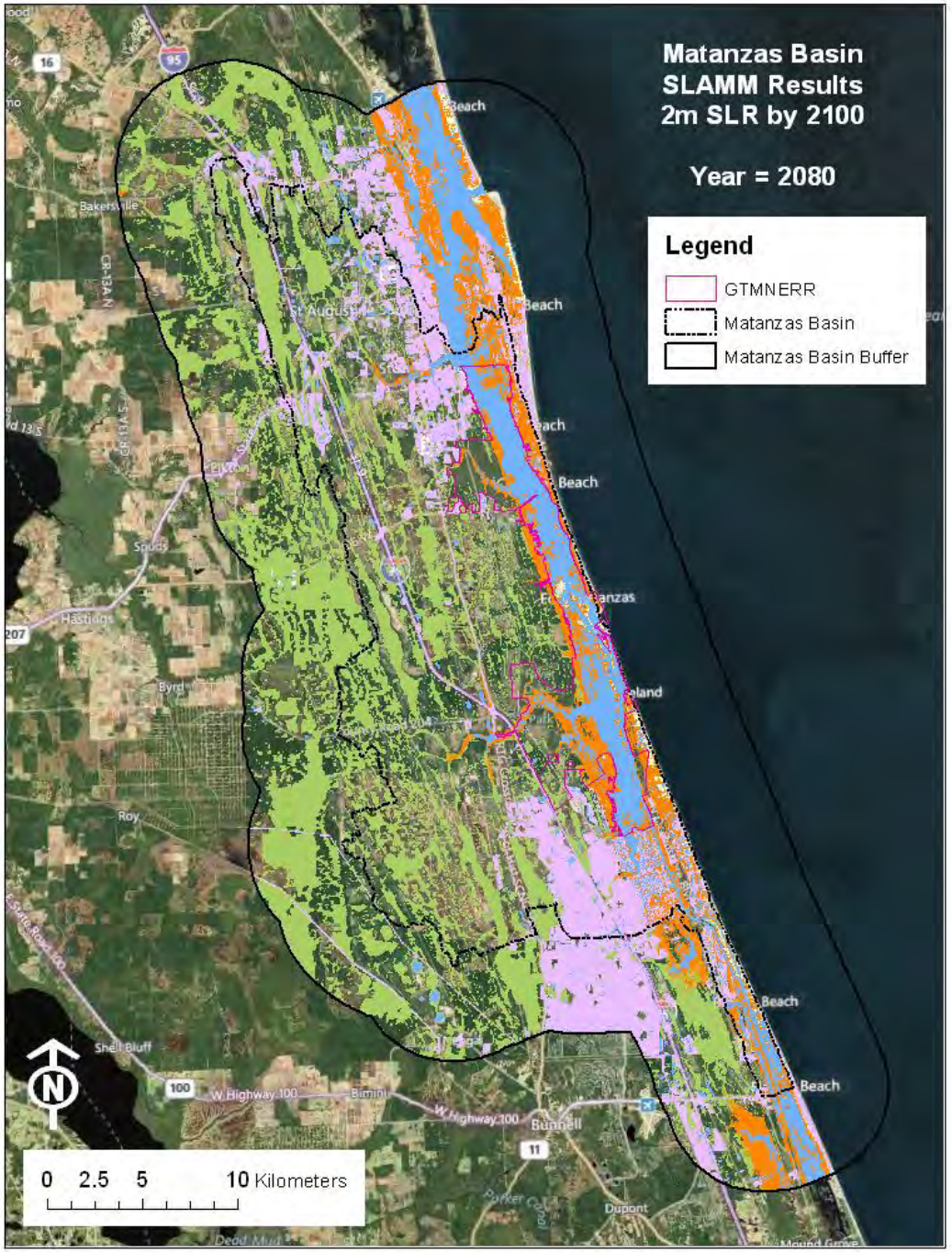
2070

- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

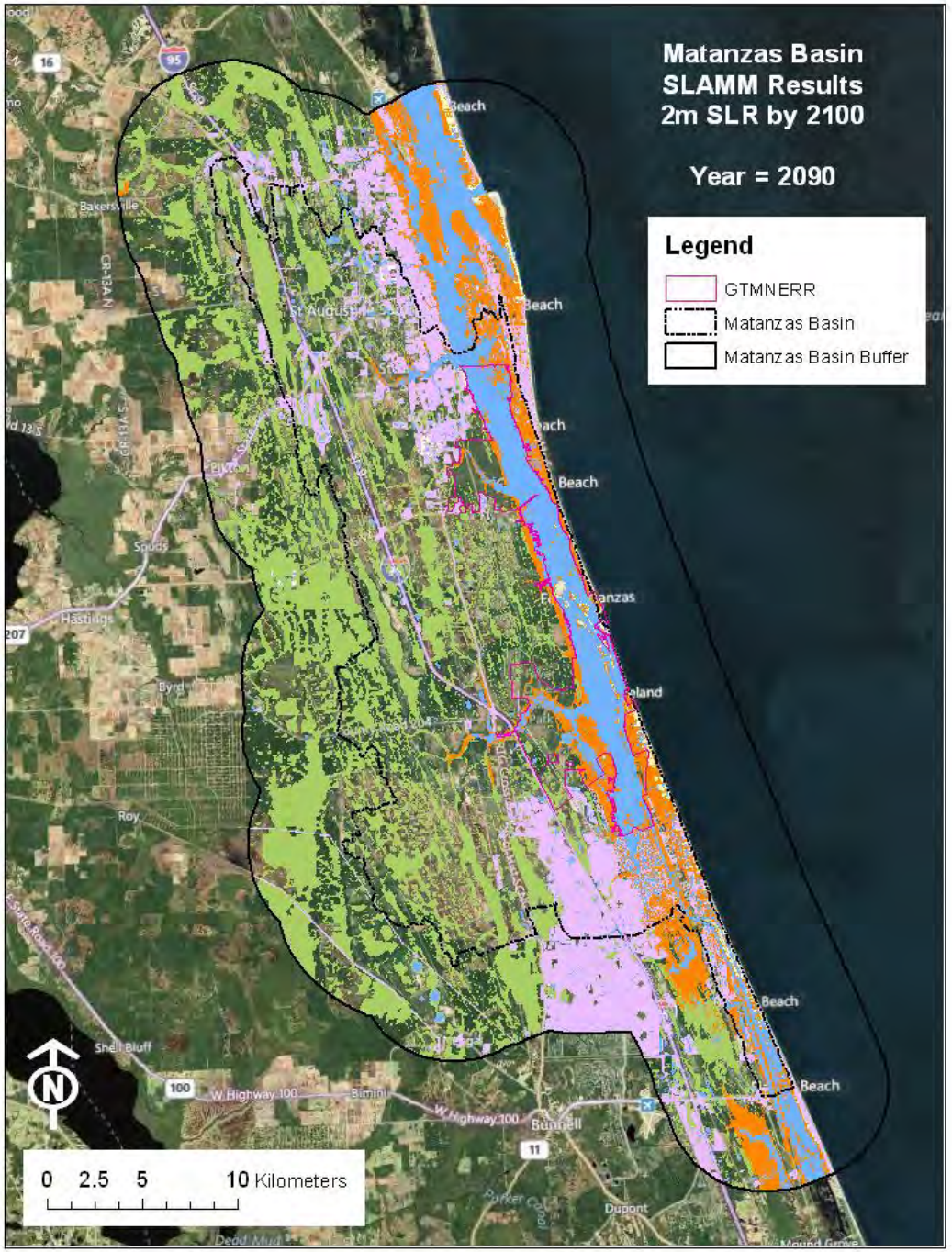
2080



SLAMM results
2m SLR by 2100

2090

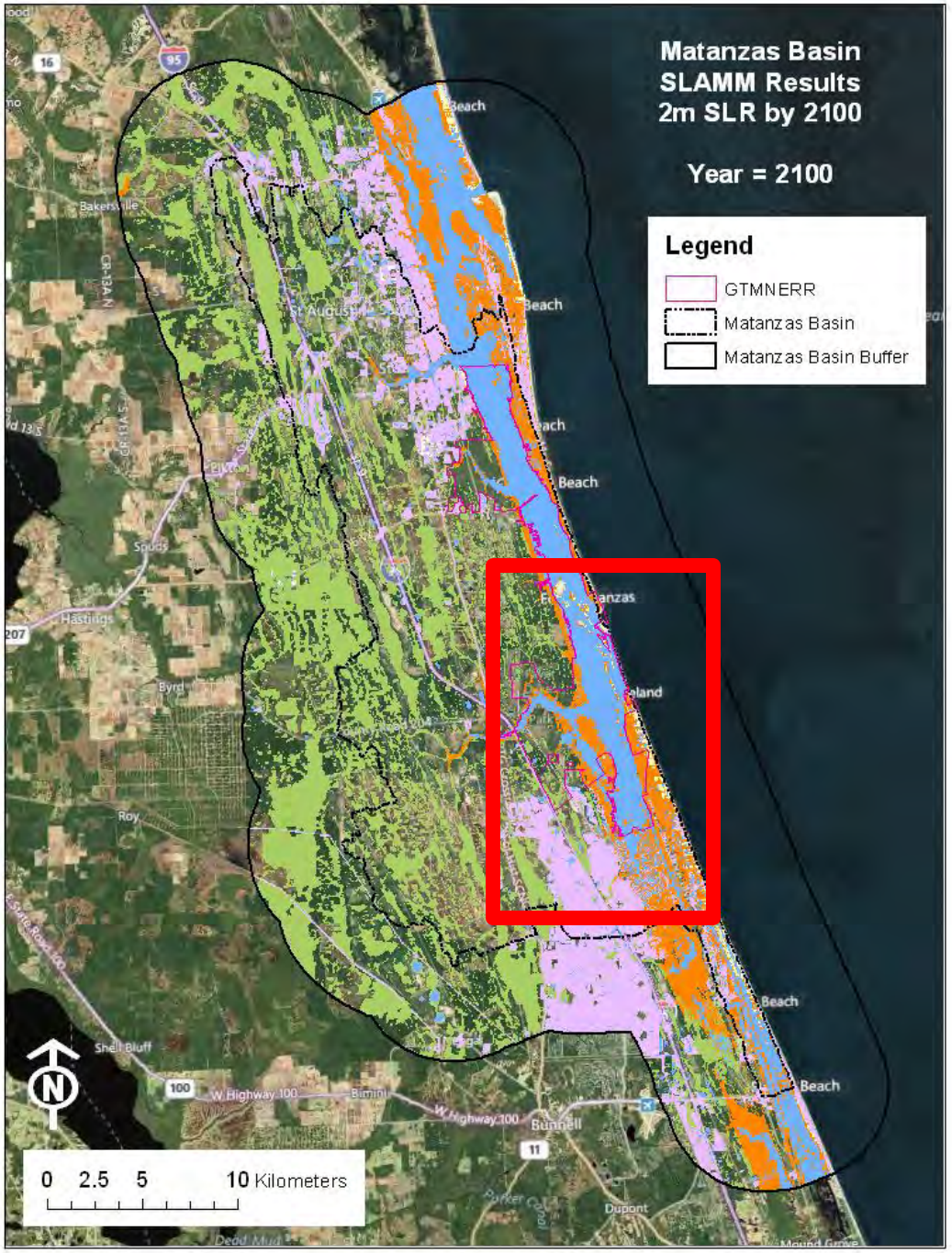
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

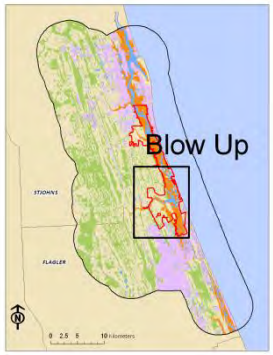
2100

- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
Pellicer Creek
2m SLR by 2100

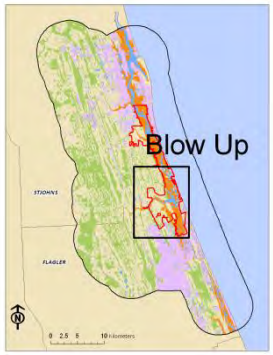
2010



Value
Developed Dry Land
Swamp
Cypress Swamp
Inland Fresh Marsh
Transitional Salt Marsh
Regularly Flooded marsh
Mangrove
Beach
Water
Irregularly Flooded Marsh
Tidal Flat
Estuarine Water
Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2020



Developed Dry Land

Swamp

Cypress Swamp

Inland Fresh Marsh

Transitional Salt Marsh

Regularly Flooded marsh

Mangrove

Beach

Water

Irregularly Flooded Marsh

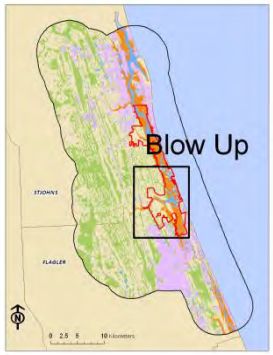
Tidal Flat

Estuarine Water

Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2030



Value

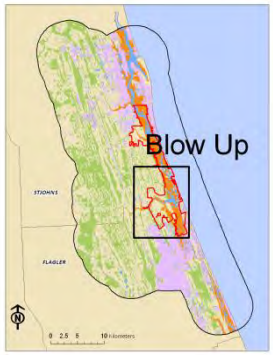
- Developed Dry Land
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Transitional Salt Marsh
- Regularly Flooded marsh
- Mangrove
- Beach
- Water
- Irregularly Flooded Marsh
- Tidal Flat

Estuarine Water

Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2040



Value

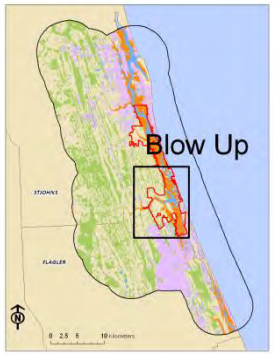
- Developed Dry Land
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Transitional Salt Marsh
- Regularly Flooded marsh
- Mangrove
- Beach
- Water
- Irregularly Flooded Marsh
- Tidal Flat

Estuarine Water

Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2050



Developed Dry Land

Swamp

Cypress Swamp

Inland Fresh Marsh

Transitional Salt Marsh

Regularly Flooded marsh

Mangrove

Beach

Water

Irregularly Flooded Marsh

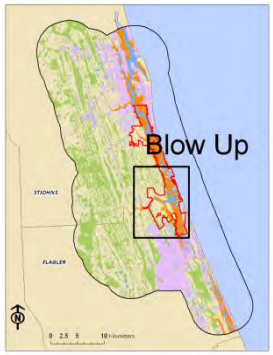
Tidal Flat

Estuarine Water

Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

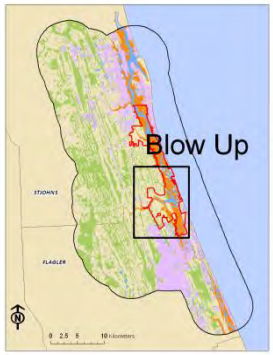
2060



Developed Dry Land
Swamp
Cypress Swamp
Inland Fresh Marsh
Transitional Salt Marsh
Regularly Flooded marsh
Mangrove
Beach
Water
Irregularly Flooded Marsh
Tidal Flat
Estuarine Water
Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2070



Value

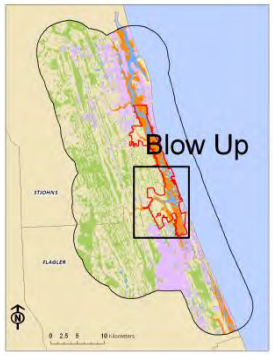
- Developed Dry Land
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Transitional Salt Marsh
- Regularly Flooded marsh
- Mangrove
- Beach
- Water
- Irregularly Flooded Marsh
- Tidal Flat

Estuarine Water

Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

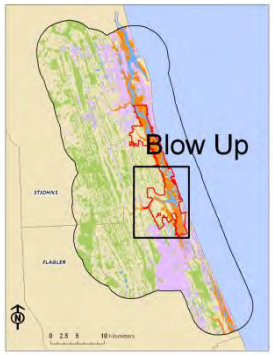
2080



Value
Developed Dry Land
Swamp
Cypress Swamp
Inland Fresh Marsh
Transitional Salt Marsh
Regularly Flooded marsh
Mangrove
Beach
Water
Irregularly Flooded Marsh
Tidal Flat
Estuarine Water
Tidal Creek

SLAMM results
Pellicer Creek
2m SLR by 2100

2090



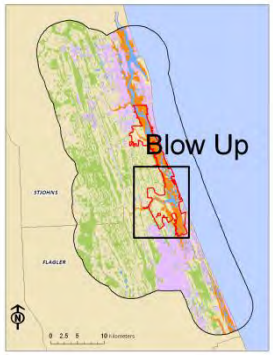
Value
- Developed Dry Land
- Swamp
- Cypress Swamp
- Inland Fresh Marsh
- Transitional Salt Marsh
- Regularly Flooded marsh
- Mangrove
- Beach
- Water
- Irregularly Flooded Marsh
- Tidal Flat

Estuarine Water

Tidal Creek

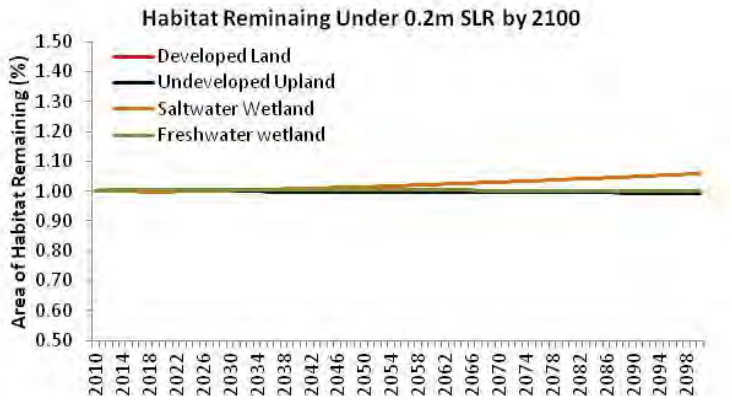
SLAMM results
Pellicer Creek
2m SLR by 2100

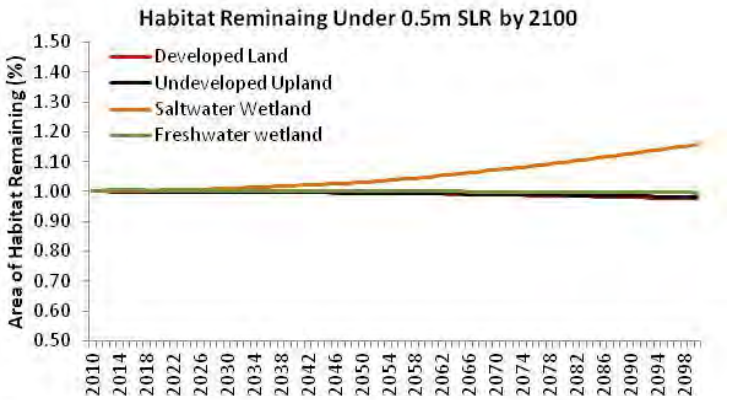
2100

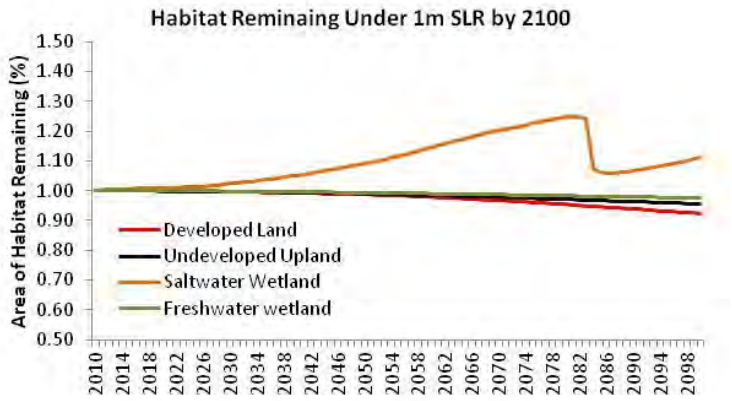


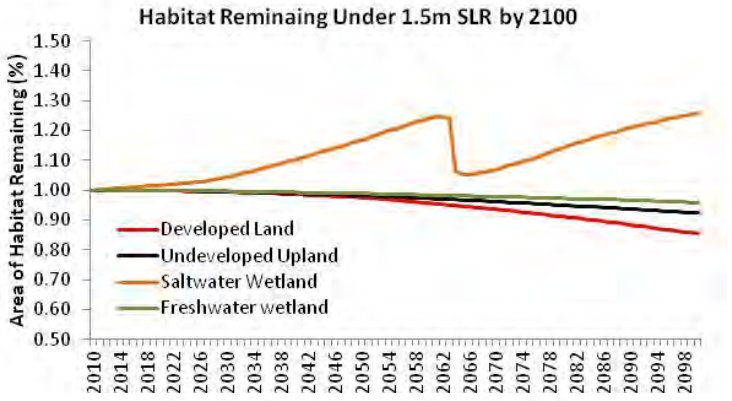
Developed Dry Land
Swamp
Cypress Swamp
Inland Fresh Marsh
Transitional Salt Marsh
Regularly Flooded marsh
Mangrove
Beach
Water
Irregularly Flooded Marsh
Tidal Flat
Estuarine Water
Tidal Creek

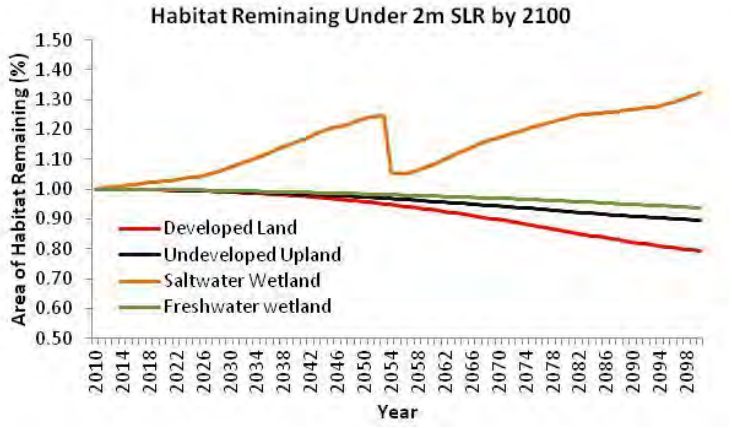
How much difference is there between the sea level rise scenarios?

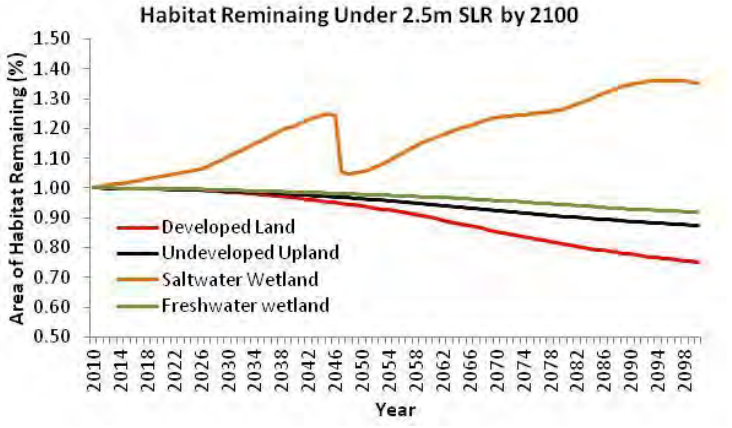


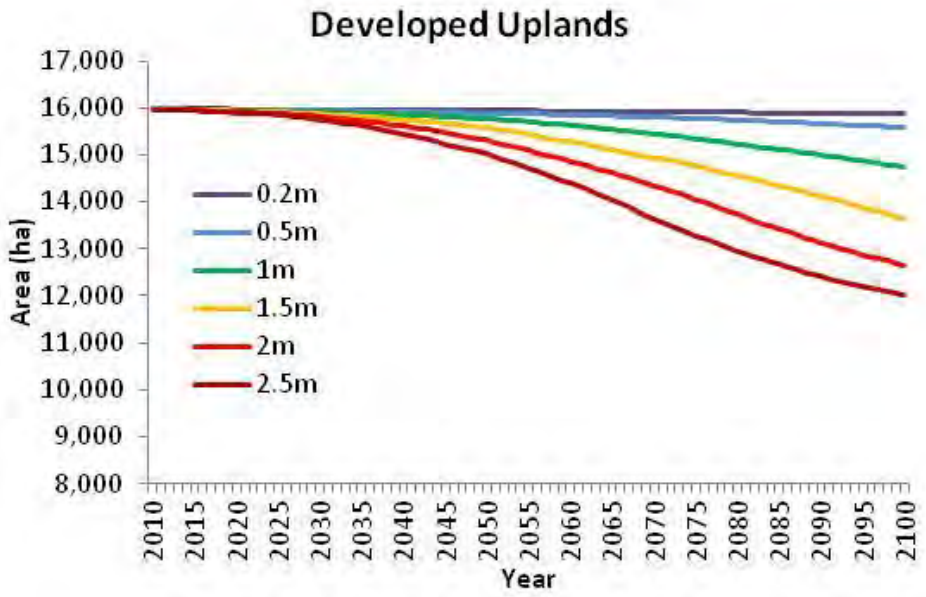


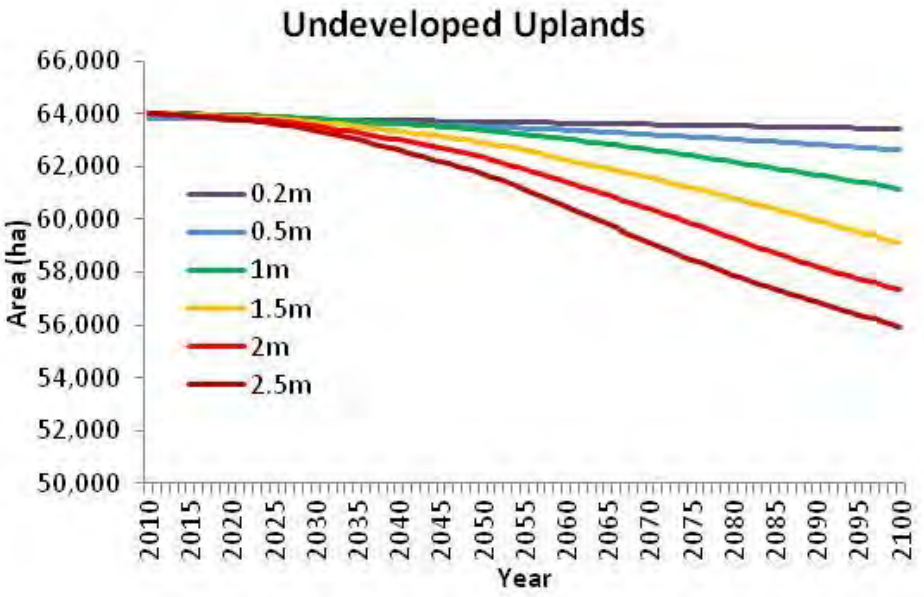


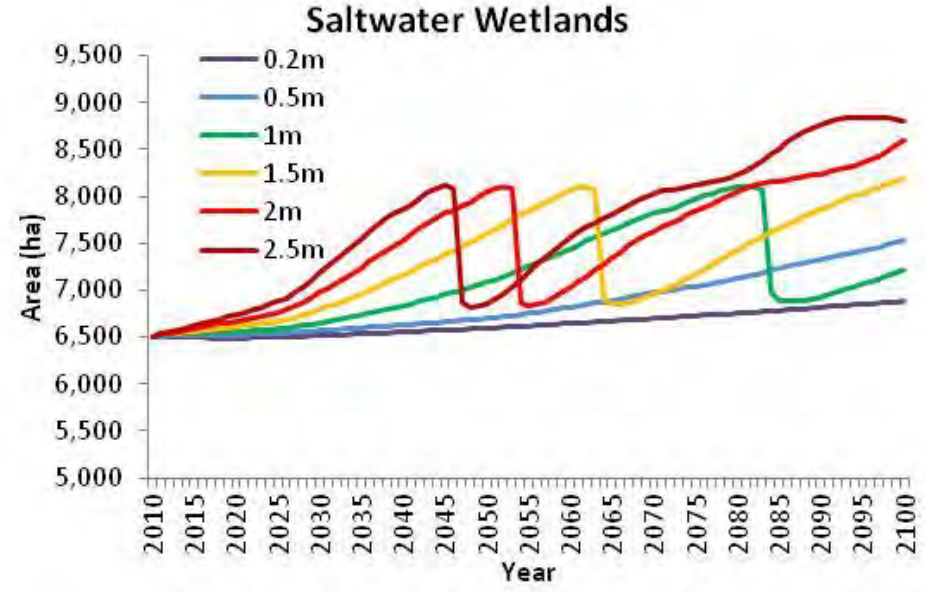


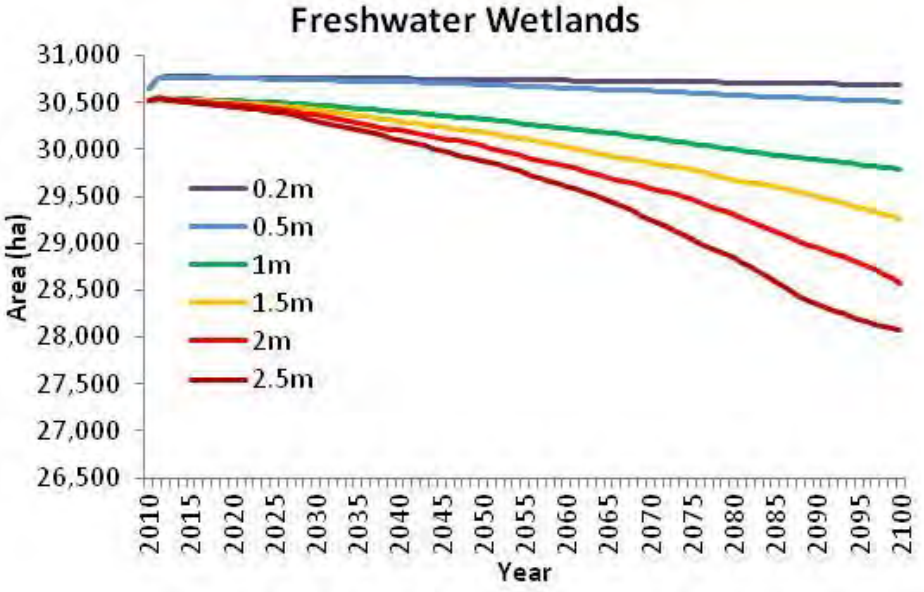




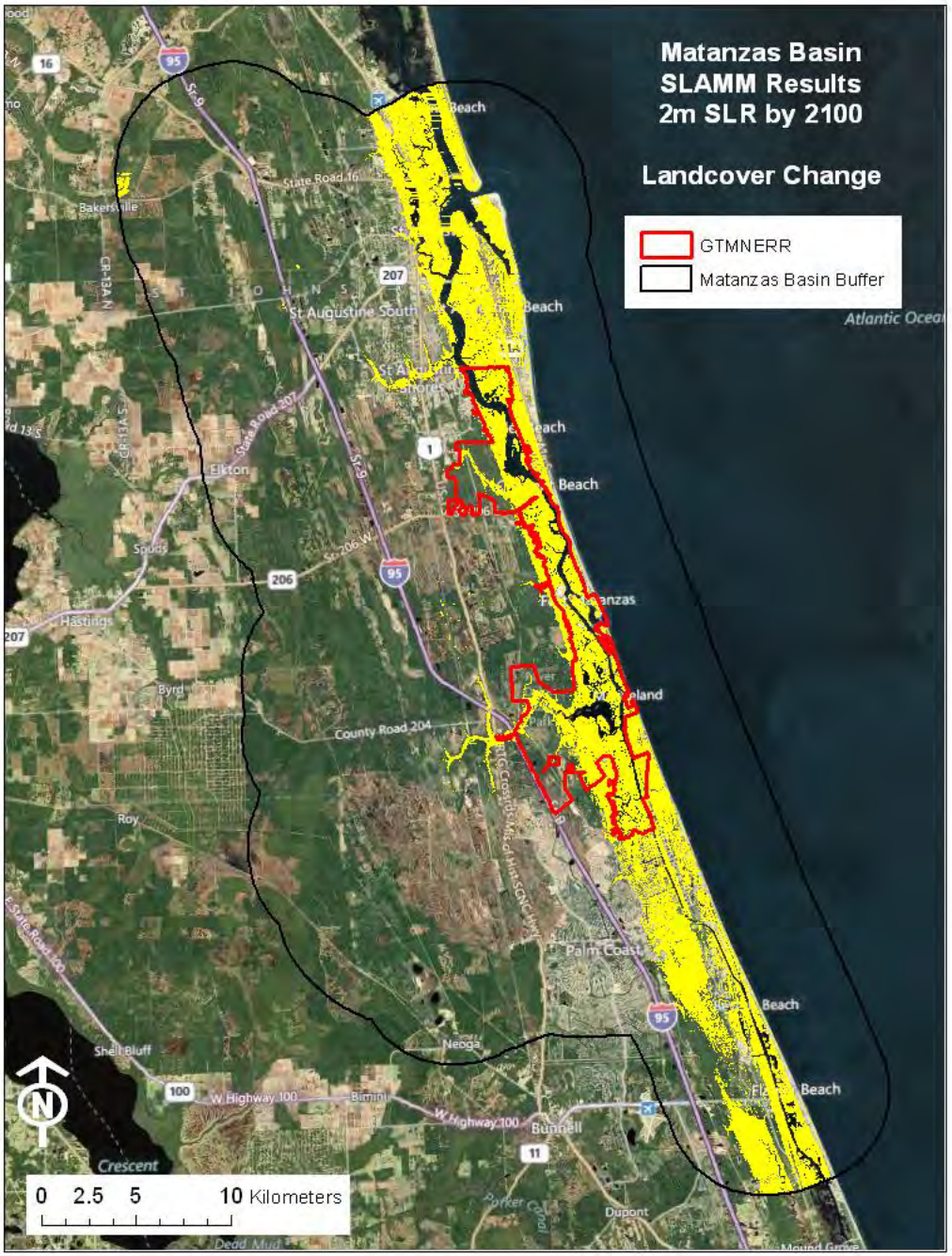

Developed Uplands
Area (ha)
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
0.2m
0.5m
1m
1.5m
2m
2.5m
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
Year


Undeveloped Uplands
Area (ha)
66,000
64,000
62,000
60,000
58,000
56,000
54,000
52,000
50,000
0.2m
0.5m
1m
1.5m
2m
2.5m
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
Year

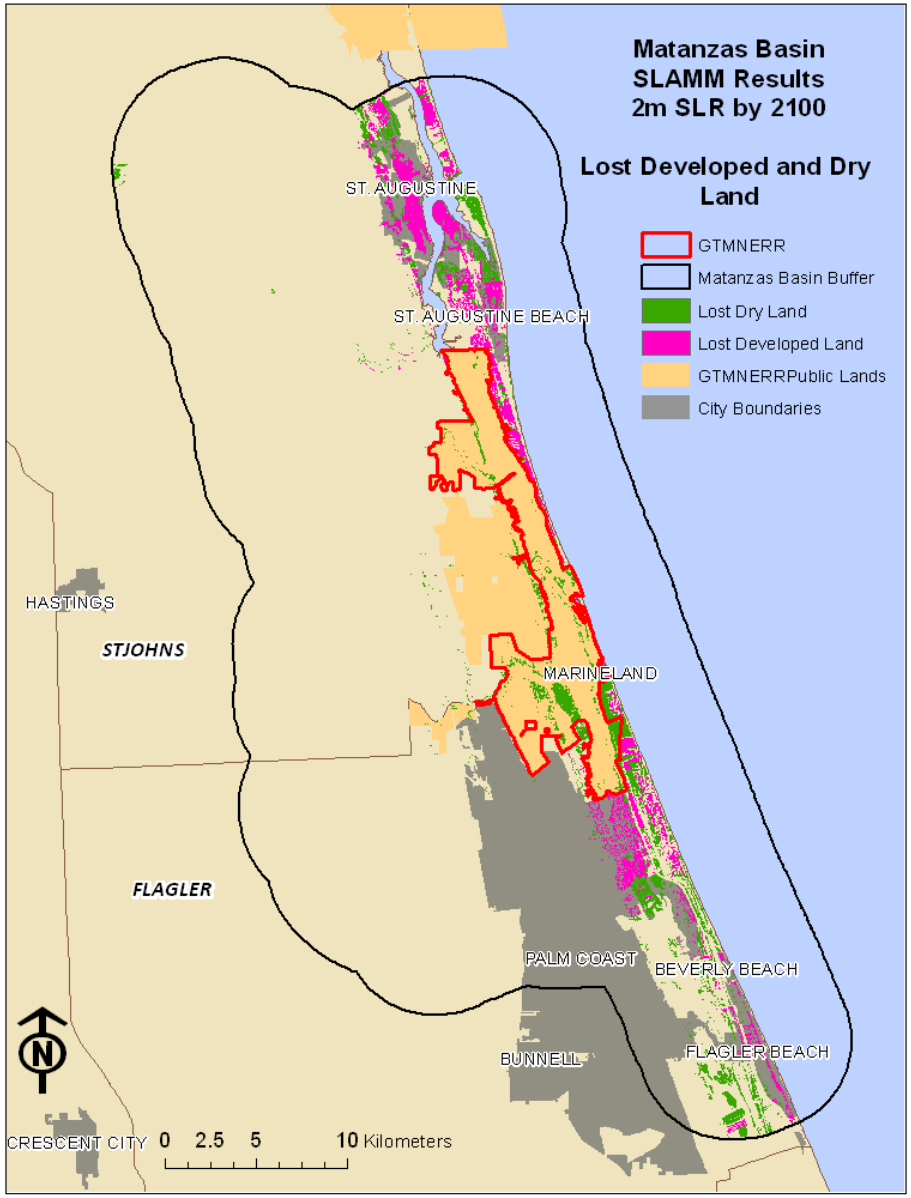

Saltwater Wetlands
Area (ha)
9,500
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
0.2m
0.5m
1m
1.5m
2m
2.5m
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
Year

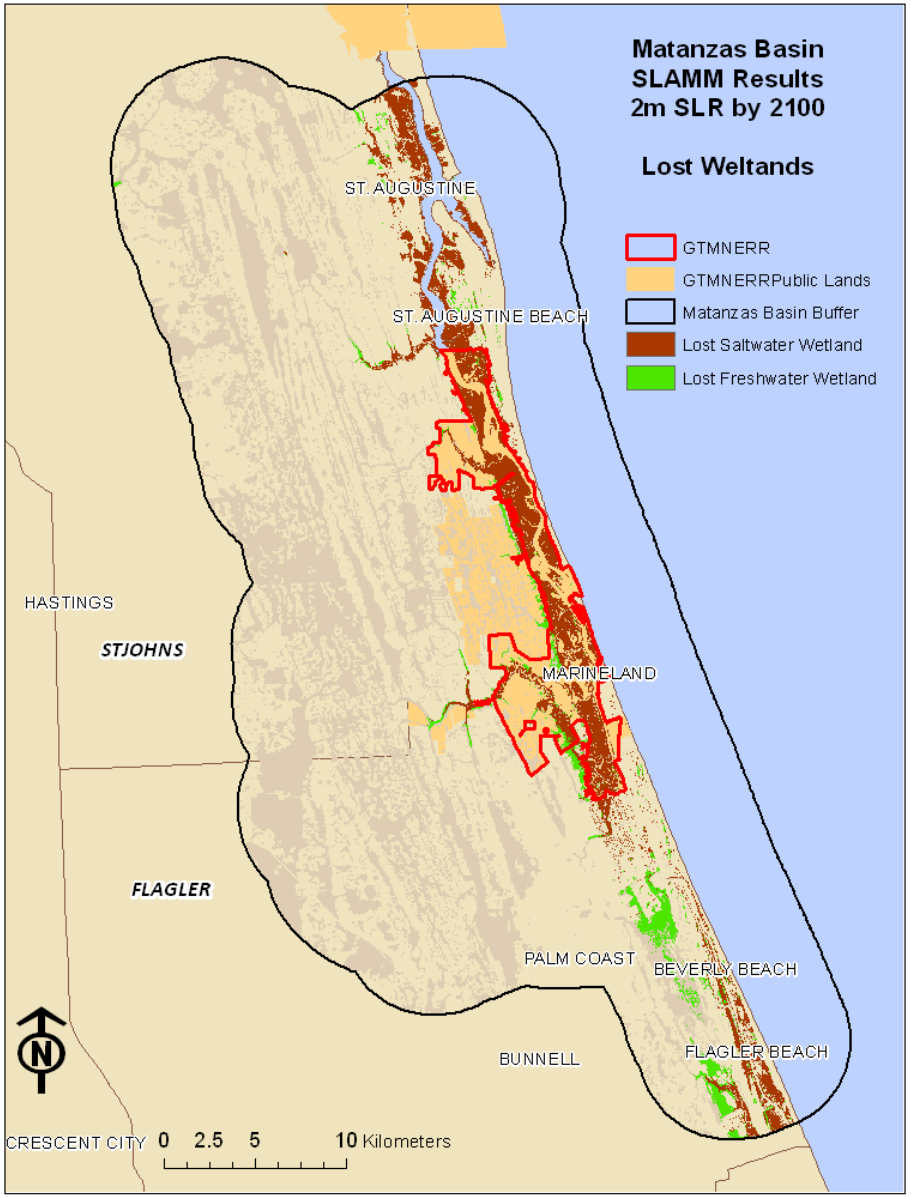

Freshwater Wetlands
Area (ha)
31,000
30,500
30,000
29,500
29,000
28,500
28,000
27,500
27,000
26,500
0.2m
0.5m
1m
1.5m
2m
2.5m
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100
Year

What ***general*** areas are vulnerable to change and habitat migration?

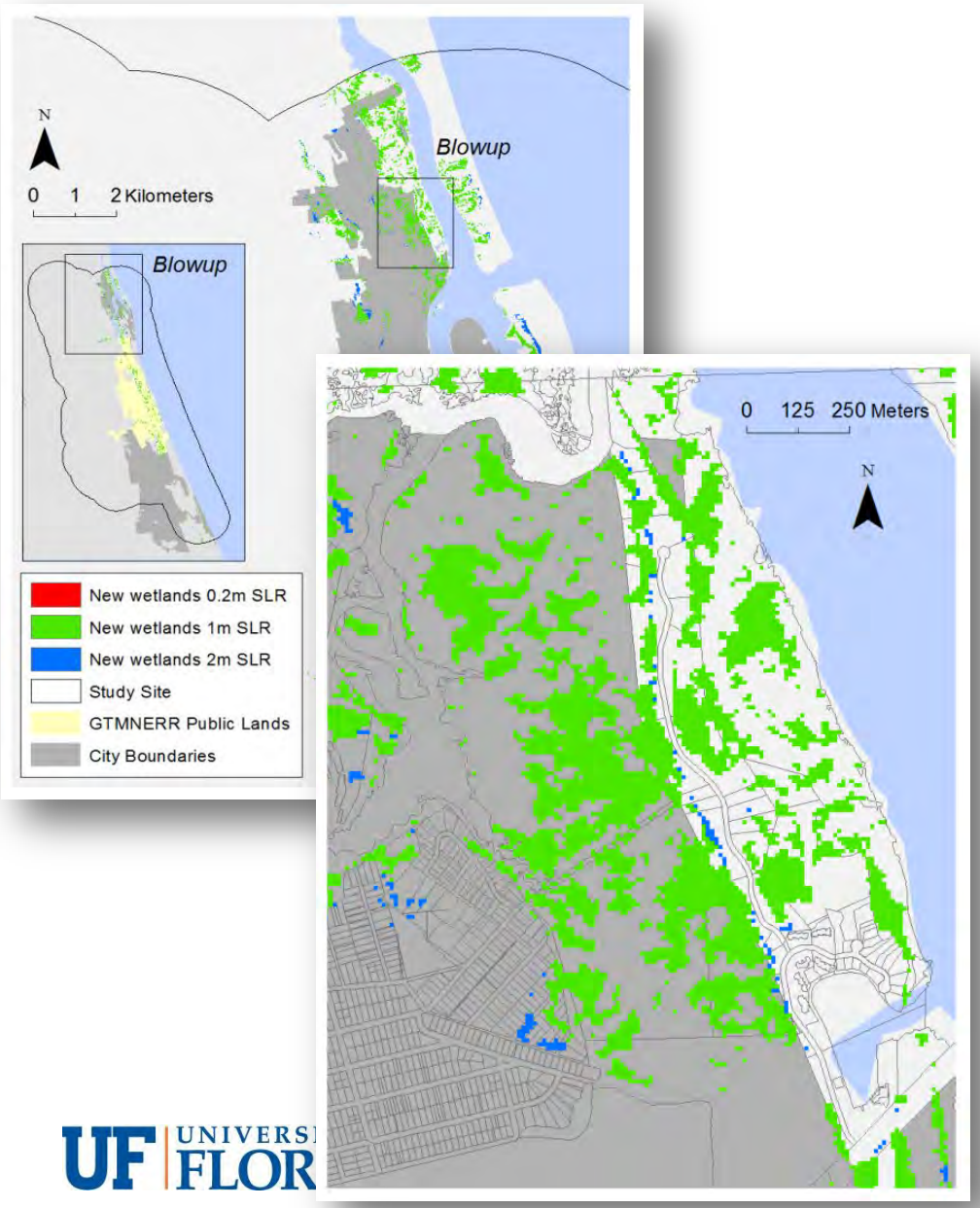


What areas are vulnerable to the loss of dry land and wetland?





So How Much Will This Cost Us?



- Simple flood/value rules – 10% flood means 10% taxable value lost… (very conservative…)
- Under a scenario of 1 m sea level rise by 2100, we project that 2,639 ha and $1 billion in land value will be lost to inundation
- If you want to replace wetlands as they are lost then we will need 2,758 ha of new wetland area costing about $3.8 billion in land value

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The way forward… SLR in the GTMNERR

- Areas within 2.5 to 5km of the ocean are generally affected
- Changes in landcover area (0.2 to 2.5m SLR)
  - Developed Areas: loss of 10 to 400 ha
  - Undeveloped Area: loss of 40 to 800 ha
  - Because it is largely located within 5km of the ocean, St. Augustine is particularly vulnerable to the loss of developed and dry land
  - **Estimated losses are in the tens of millions to billions**
- Ecological Losses: Vulnerable habitats throughout study area
  - Regularly Flooded Marshes loose 45% (1,100 ha) under the 2m SLR scenario.
  - Tidal Flats loose 25% (650 ha) under the 2m SLR scenario.
  - Swamps loose 7% (1,800 ha) under the 2m SLR scenario.
- A significant part of this project is over 30 stakeholder meetings (just beginning)
- More info and videos! www.planningmatanzas.org

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Lessons (so far) from Coastal Florida:

- The models and their predictions make people nervous and suspicious…
- Strong agreement and interest about the metrics and their levels…
- Decision makers are beginning to notice..
- Stakeholders are just now “getting their heads around” the implications…
- Management and ecosystem reaction times are still unknown, because a multistate governance has not been established
- Hurricanes are pushing the issue forward …

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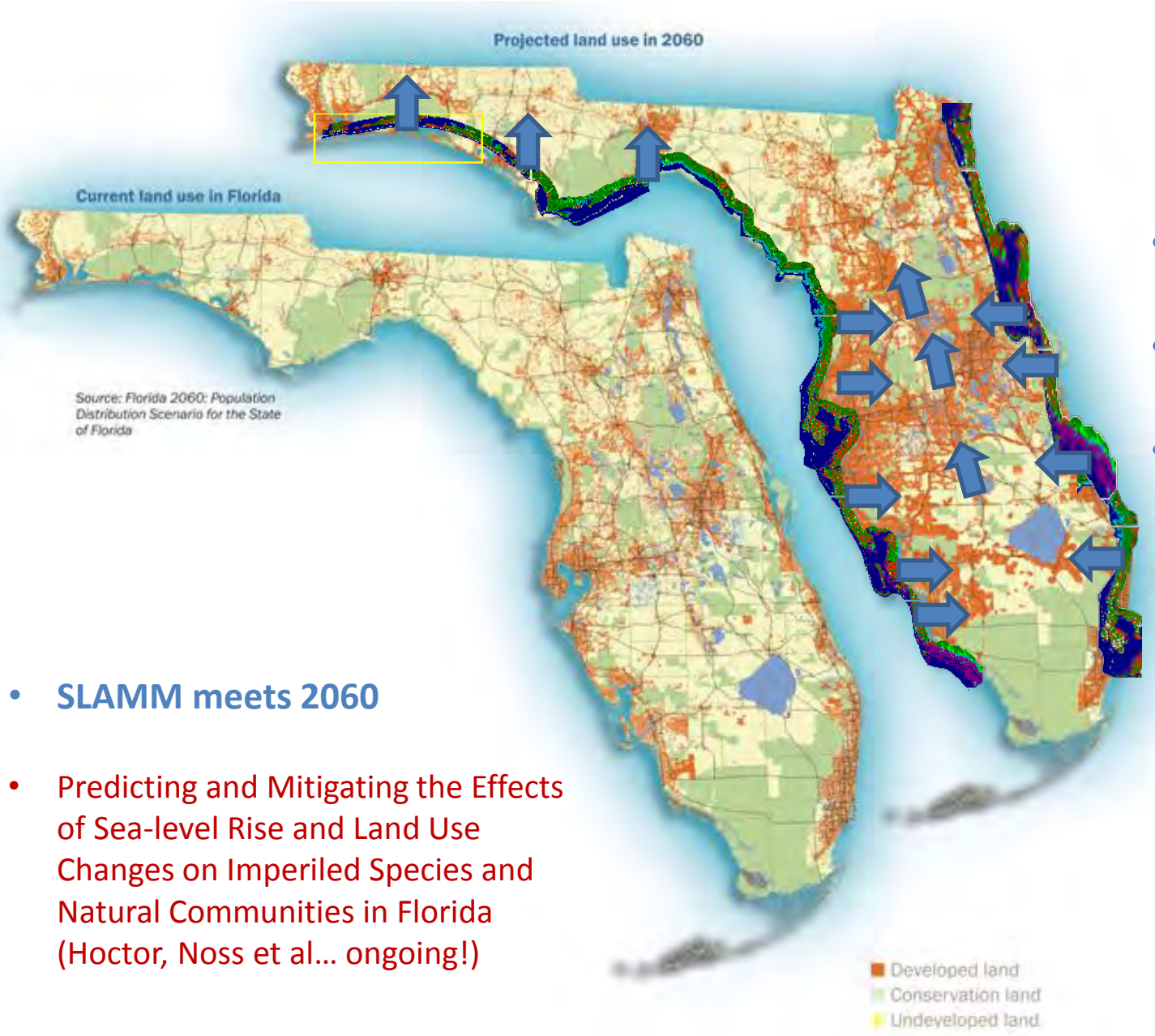
Agenda

1. Motivation: What devil? What deep blue sea?
2. Canaries in a coal mine: Florida style
3. Getting local and personal: Sea Level Rise predictions meet stakeholders
4. **The Way Forward: Where to go? How to grow?**

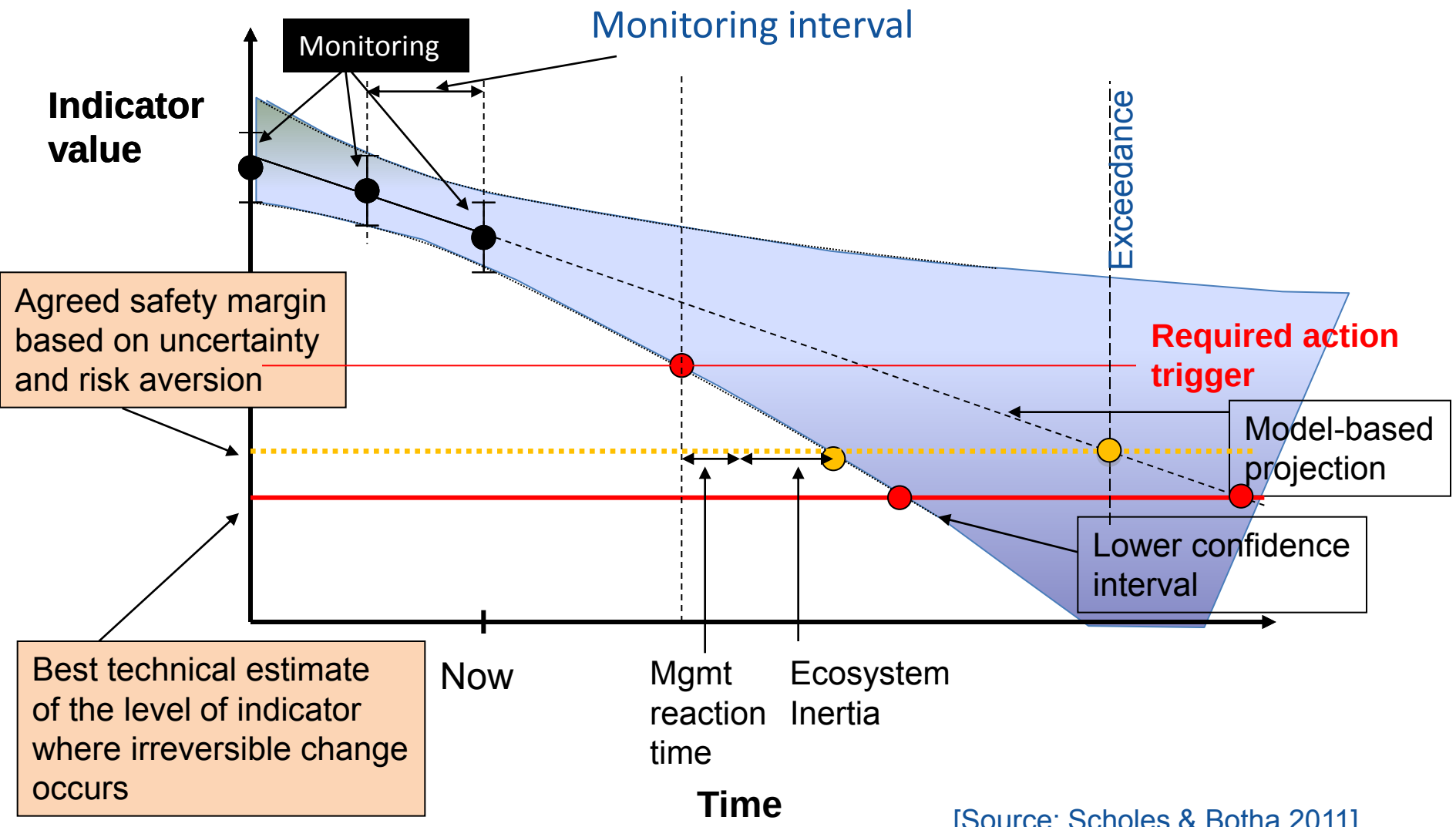
The devil is in the details… and… location, location, location



- Where will people move?
- Where will wildlife move?
- How can both thrive?

- **SLAMM meets 2060**
- Predicting and Mitigating the Effects of Sea-level Rise and Land Use Changes on Imperiled Species and Natural Communities in Florida (Hoctor, Noss et al… ongoing!)

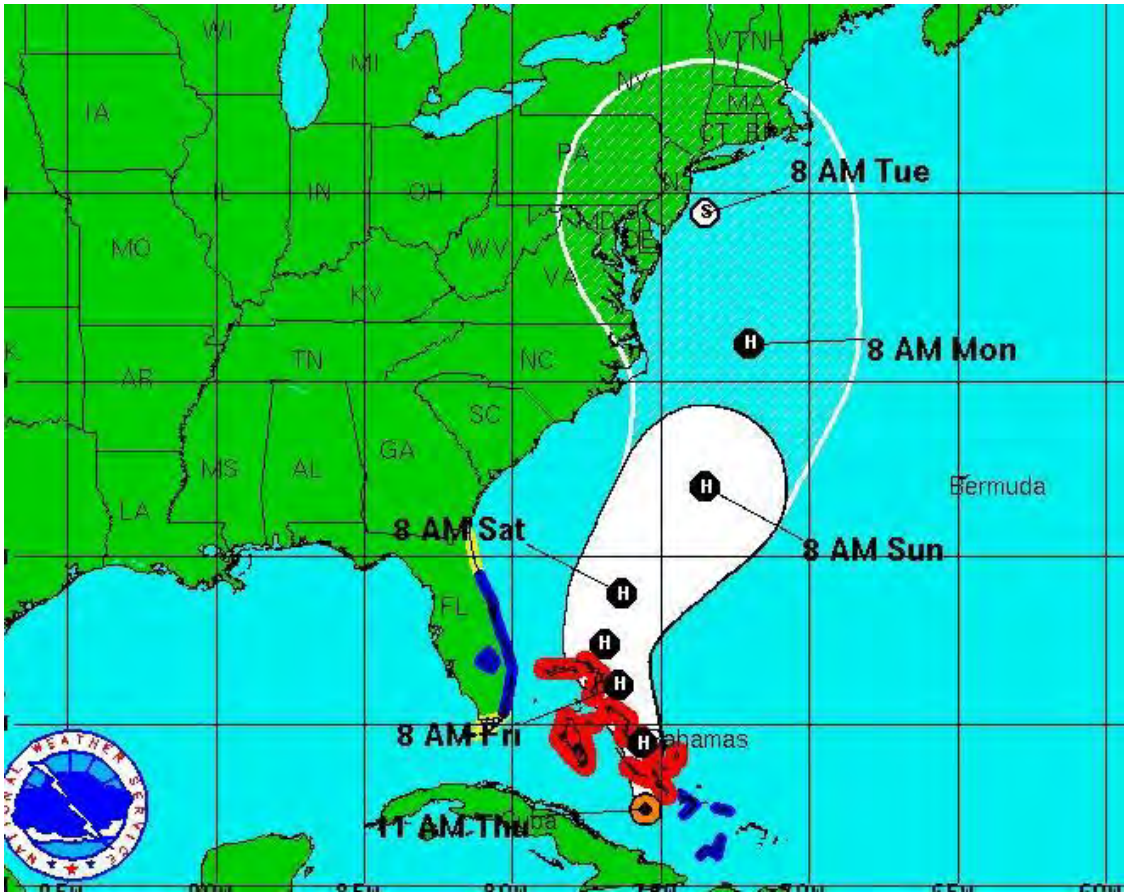
The Way Forward:
To integrate many types of information to help inform decisions



[Source: Scholes & Botha,2011]

Discussion - How does society handle uncertainty/complexity?

- Acceptable limits of Uncertainty?
- Multiple models, multiple independent sources?



Thank you for your attention

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