Climate change in the United States and South Africa: Lessons for irrigation and drainage management at the catchment scale

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Outline

1. Motivation: decisions and uncertain information
2. Water resources in the southern USA: O way down south in Dixie … there's a water war …
3. Sea Level Rise: because nothing focuses a person's attention like the ocean moving toward their house…
4. Summing Up

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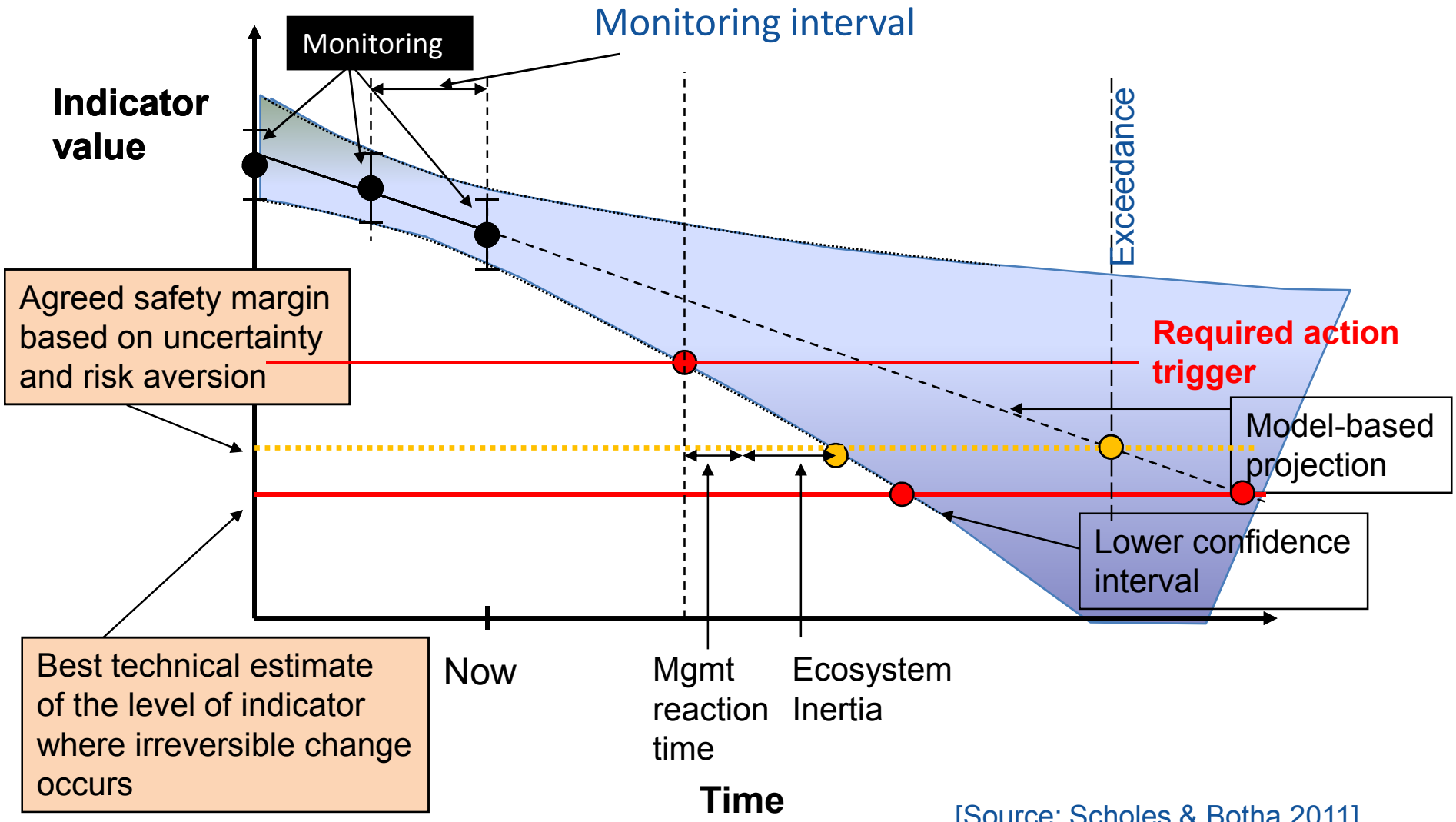
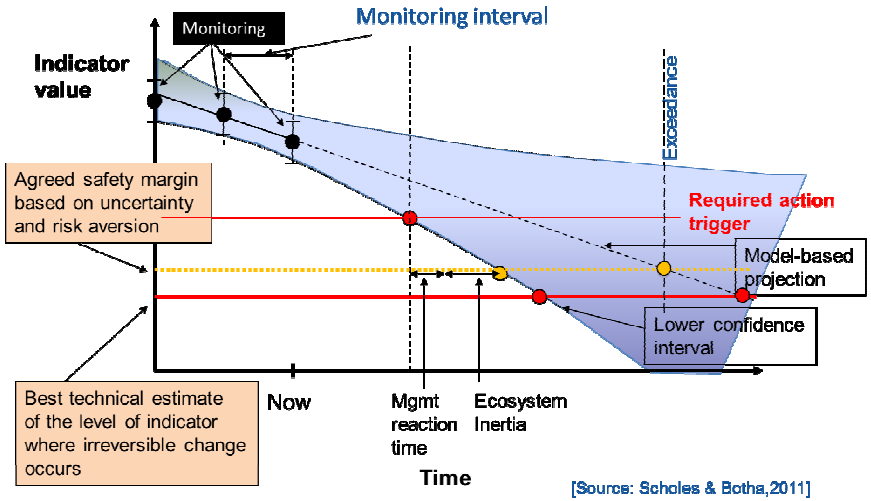
The Challenge:
To integrate many types of information to help inform decisions



[Source: Scholes & Botha,2011]

An Additional Challenge:
What are the assumptions embedded in this figure?

- We agree on the model and its predictions…
- We agree about the metrics and their levels…
- We agree about what needs to be done…
- Management and ecosystem reaction times are known…(and they are relatively short)



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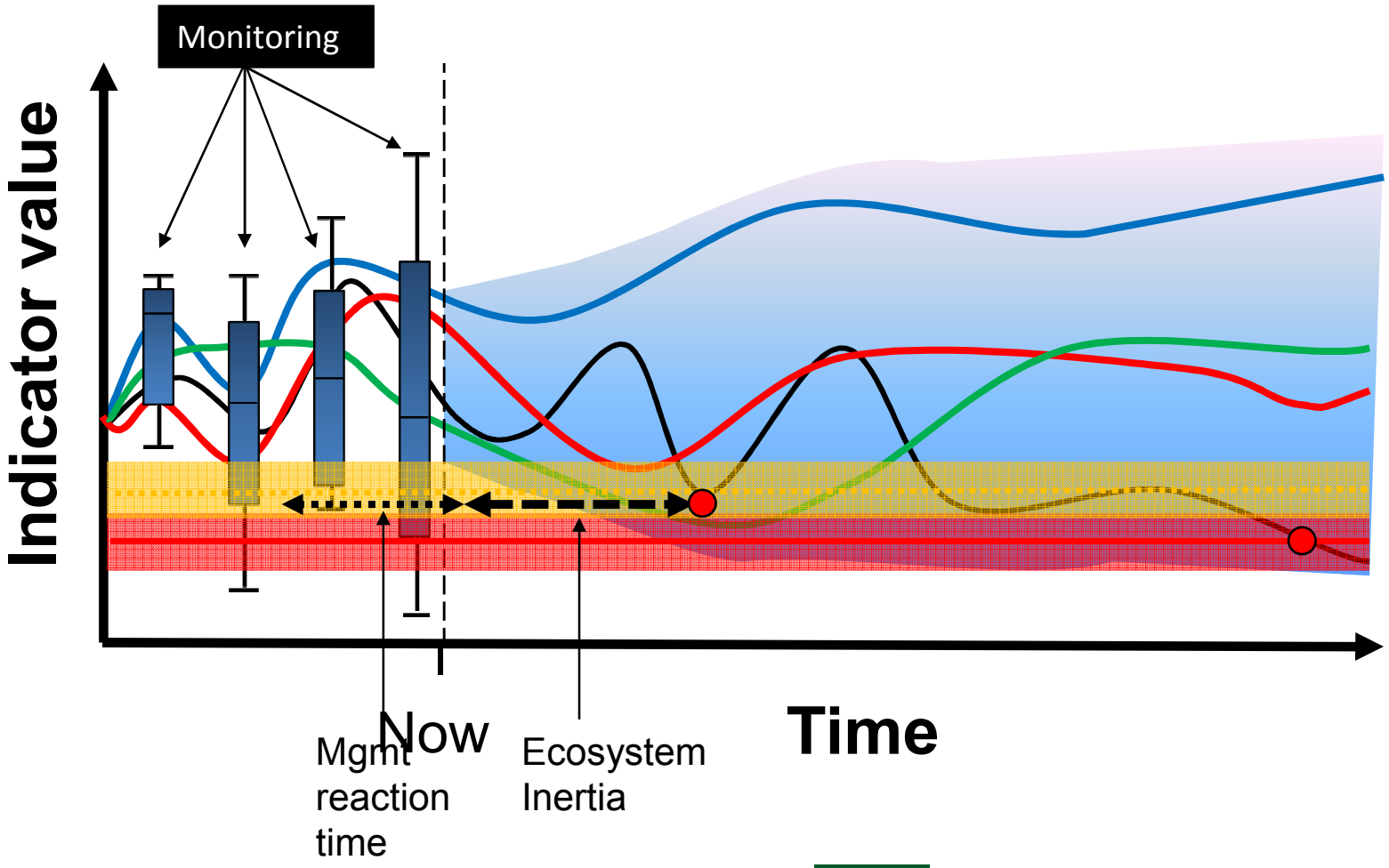
The Reality? Multiple models showing uncertain futures with significant disagreement on metrics and institutional reaction



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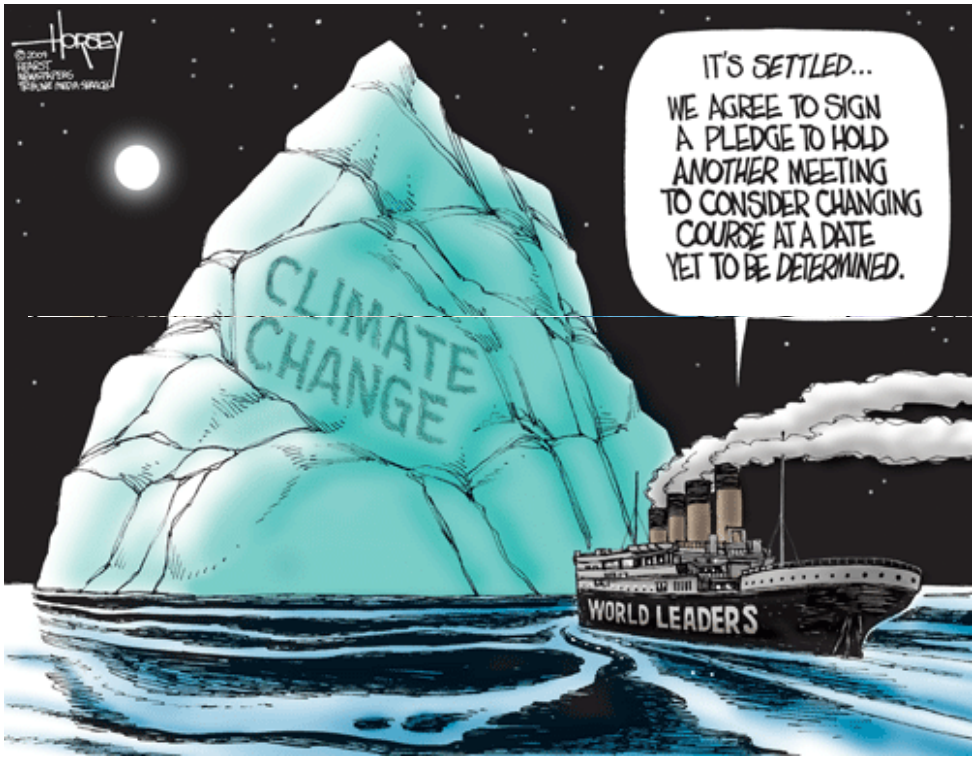
Decision making in complex, coupled human-natural systems…

- We (USA) are not much of an example…
- 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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A MODELING "TRILEMMA": UNCERTAINTY, COMPLEXITY AND RELEVANCE

- Models are built in the presence of **uncertainty**
  - Input factors (parameters, initial and boundary conditions)
  - calibration data (error, scale, etc.)
  - equations/model structure…
- This is a source of growing **anxiety** among developers and users of dynamic, complex simulation models
- In particular, there is anxiety about the effects of various sources of uncertainty on **model output**

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"The danger in creating fully detailed models of complex systems is ending up with two things you don't understand – the system you started with and your model of it."

P. England, as ref. by Paola, C. *Nature* 469, p38. 2011

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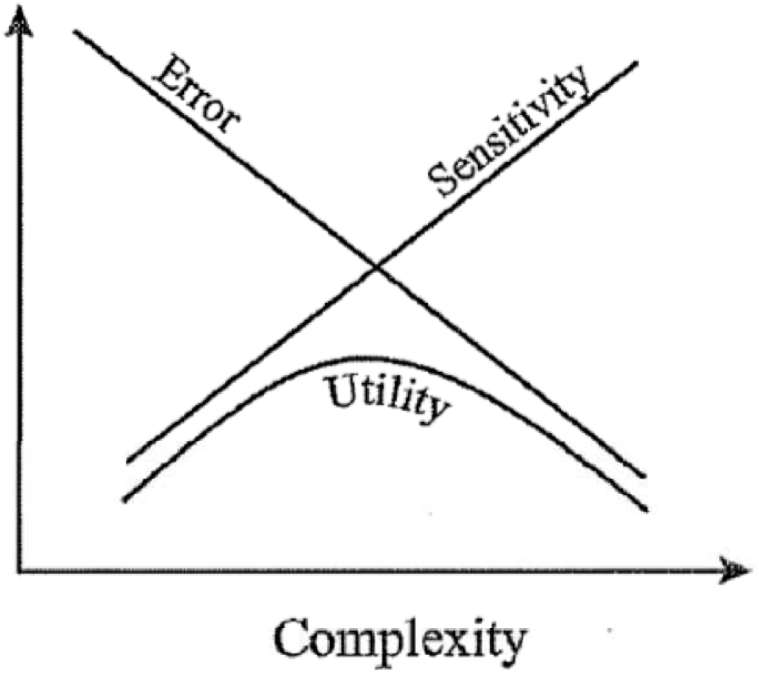
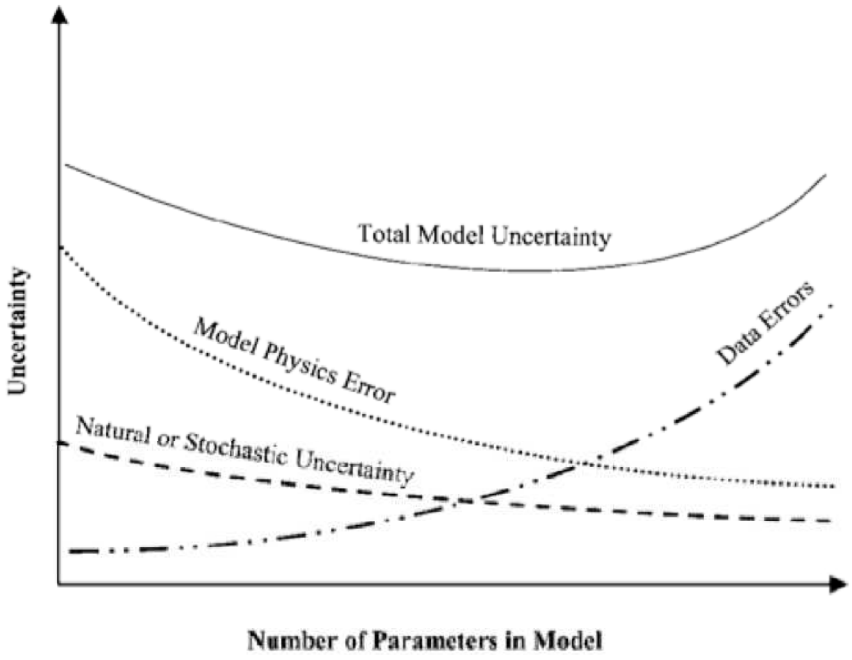
Model Complexity vs. Uncertainty: A Tug of War?



(Snowling and Kramer,1991)



(Hanna, 1993)

Model RELEVANCE: significance with respect to the output(s) of interest (objective functions)

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Complexity vs. Relevance Conundrum

As model complexity increases it leads to:

- Over-parameterization
- Hard/impossible to parameterize
- Equifinality, non-uniqueness
- …
- Loss of **RELEVANCE**

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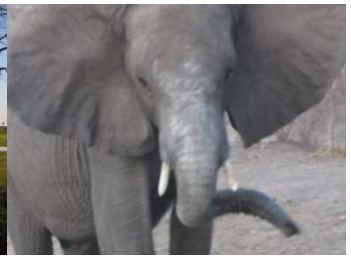

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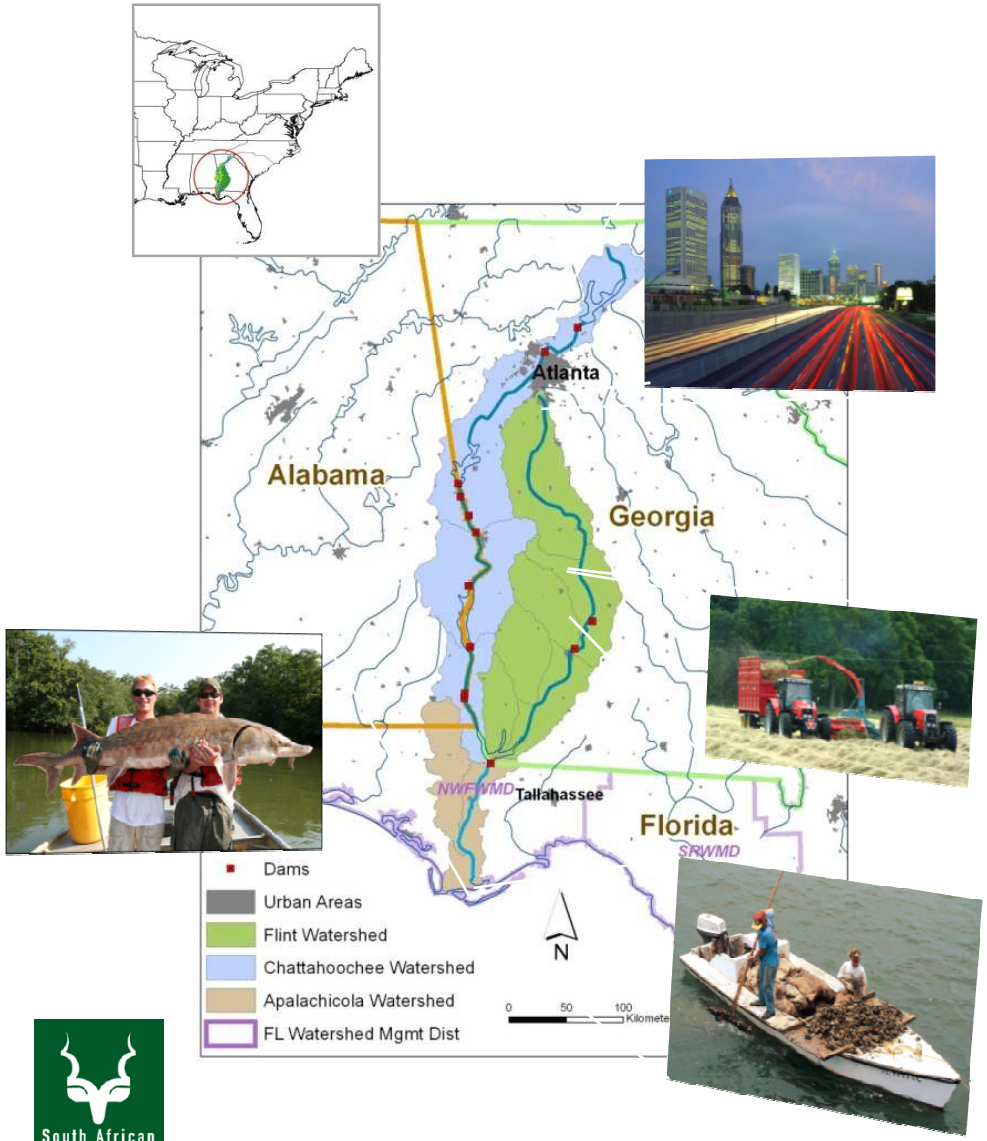
APALACHICOLA CHATTAHOOCHEE FLINT

1. Watershed north and west Georgia and north Florida.

2. Area Famous for “Water Wars”, nearly three decades of negotiation of water allocation.

3. Major stakeholders are:
   - Atlanta Metropolitan area
   - Southern Georgia agriculture
   - Apalachicola seafood industry (oysters)
   - Navigation
   - Alabama Power
   - Environmental rights agencies (gulf coast sturgeon, 4 species of mussels)



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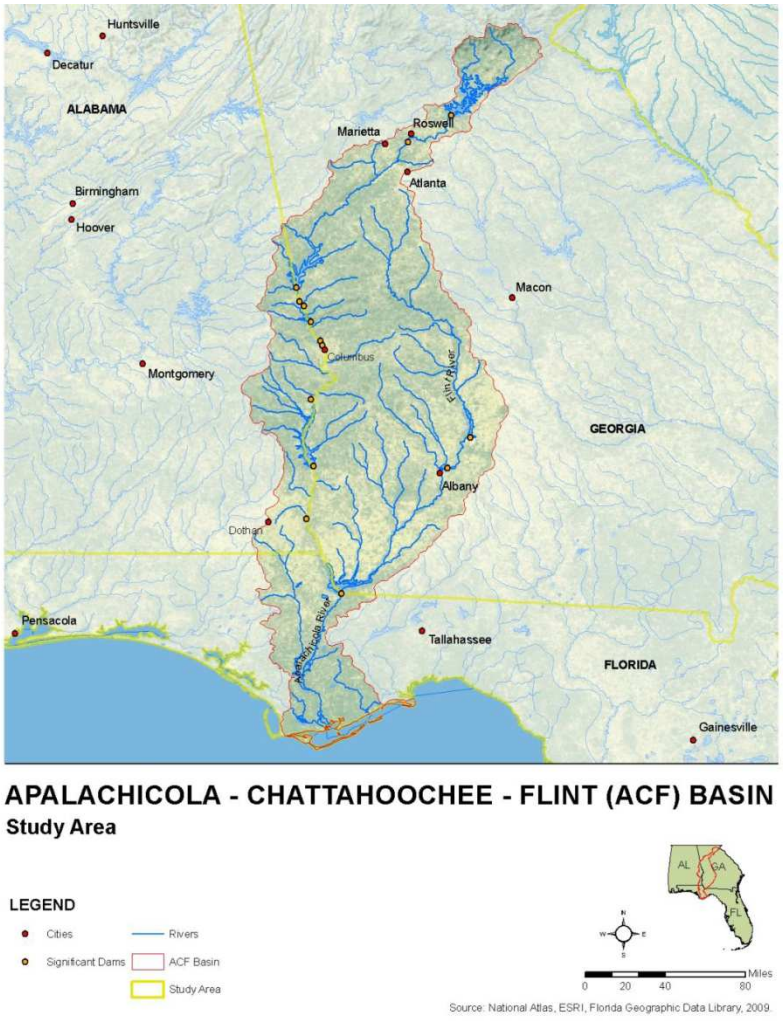
ACF basin snapshot

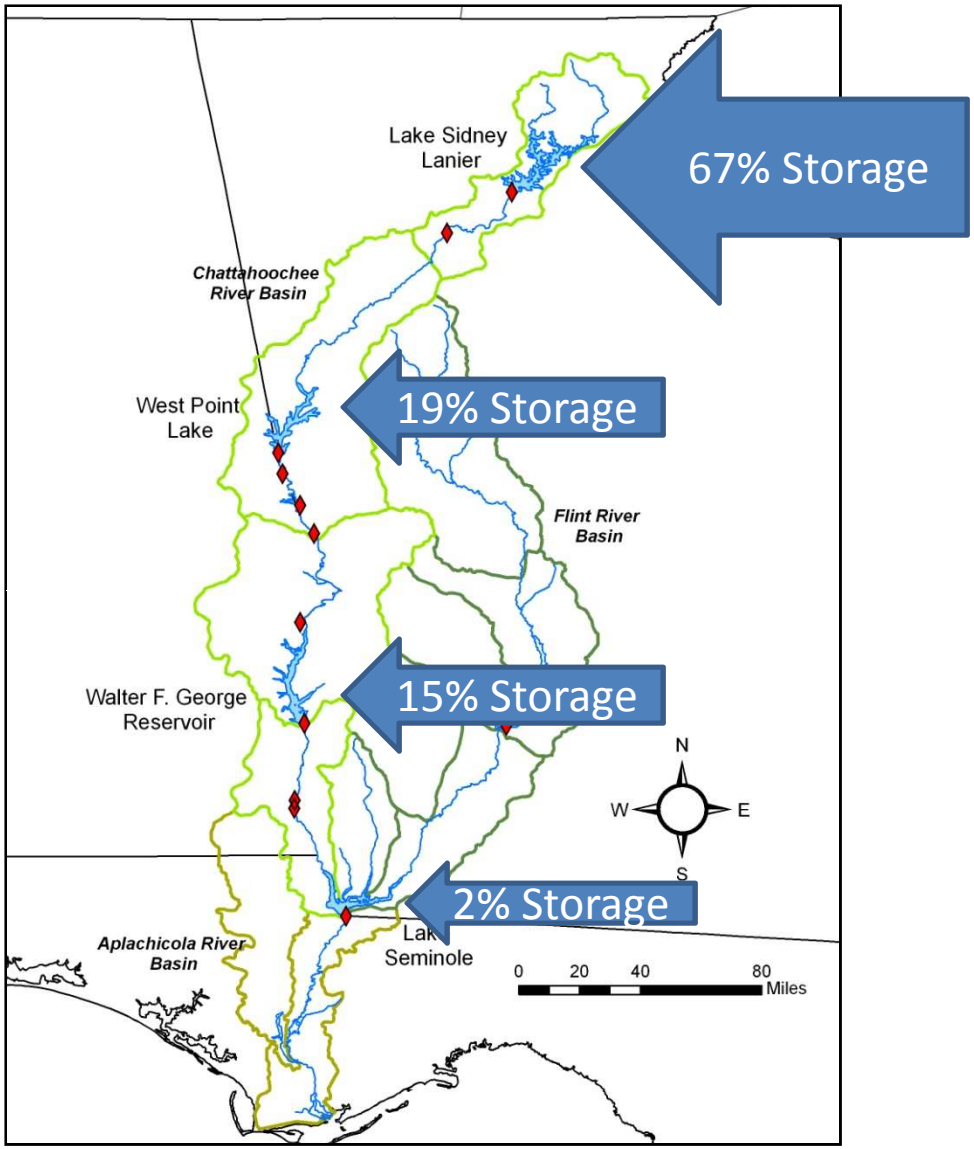


Area: 50,764 sq. km. or 5 million hectares
Population: 1995 -4 million
2050 estimated -7 million
Land use: 6% residential; 2% commercial; 25% agricultural; balance is mainly undeveloped forested
Reservoirs: hundreds of reservoirs, 16 on the three principal river main stems (11 non-federal and 5 federal)

Basin	Georgia	Alabama	Florida
Population	90%	7%	3%
Basin Area	74%	15%	11%
Withdrawals	82%	11%	7%

Source: Presentation to USDA-CSREES, National Water Conference Savannah, GA by Robert Haskell Abrams, Professor of Law, Florida A & M University (January 31, 2007)

ACF – SURFACE WATER STORAGE



- Federal government controls the dams on the ACF
- Managed in the federal interest
- No state controls the releases or the storage levels from the reservoirs...
- The states do control abstractions from the rivers and more local reservoirs

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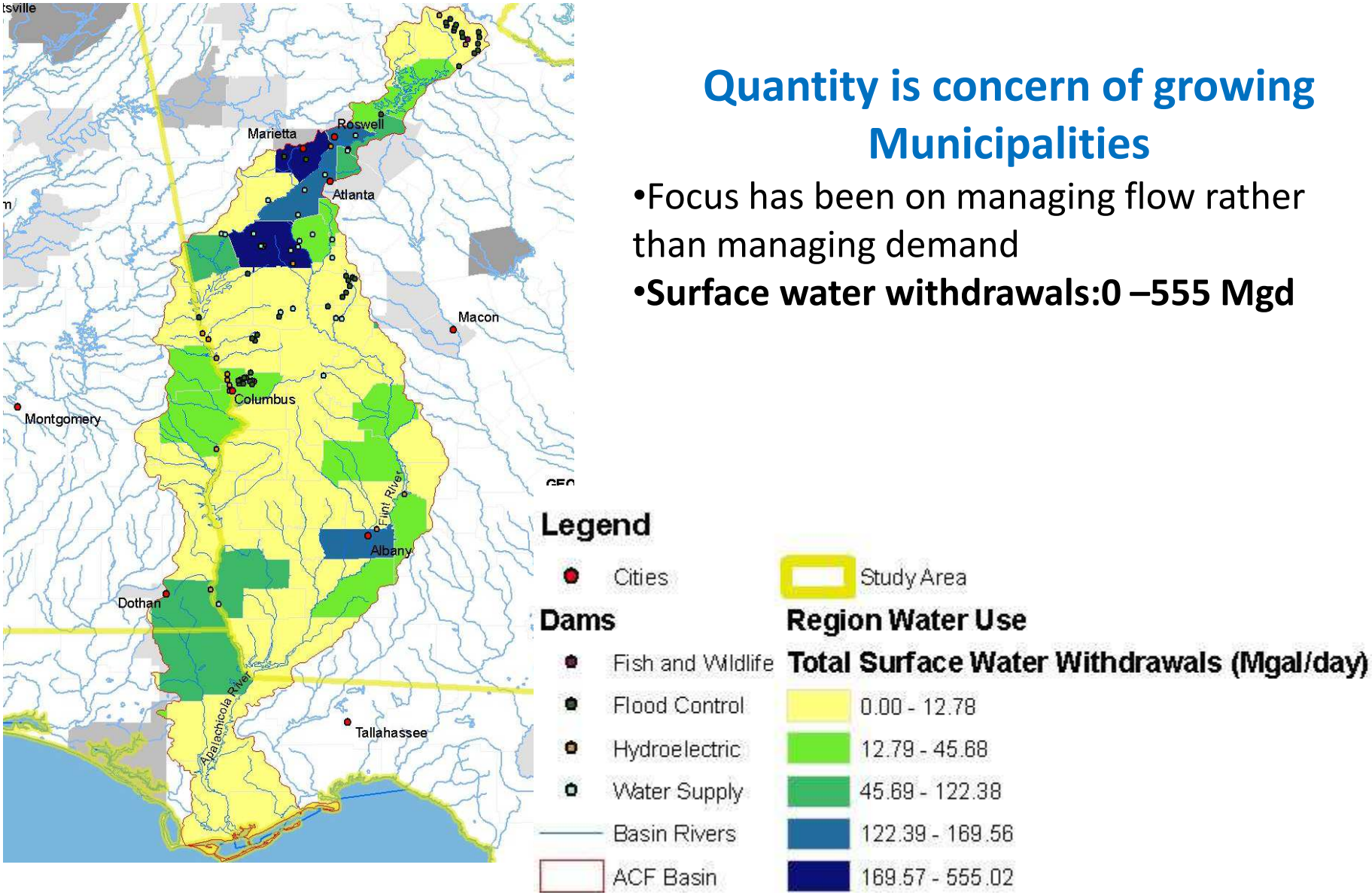

Quantity is concern of growing Municipalities

- Focus has been on managing flow rather than managing demand
- **Surface water withdrawals:0 –555 Mgd**

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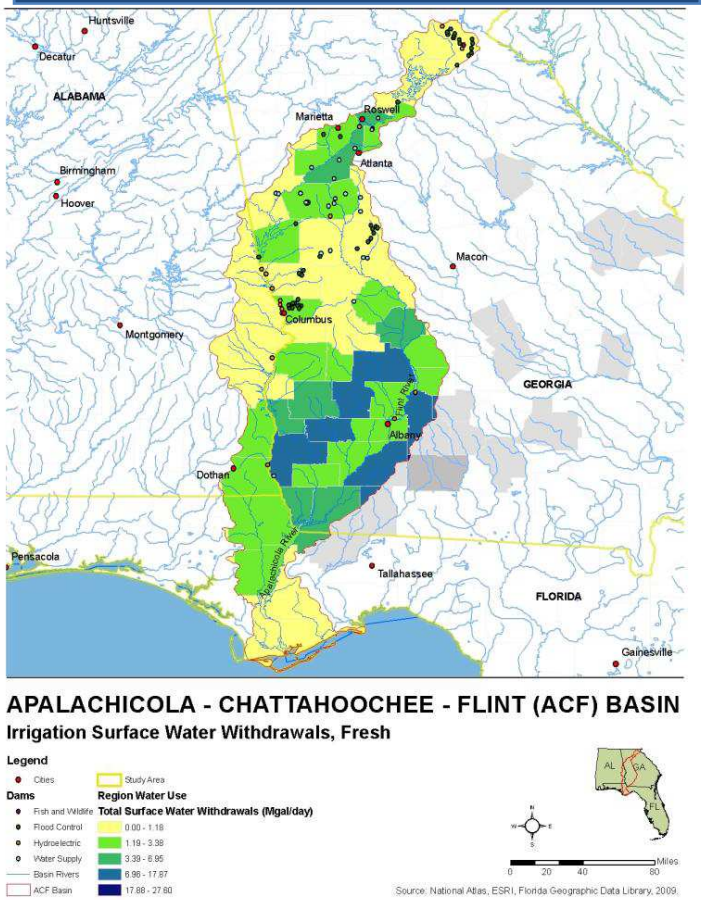
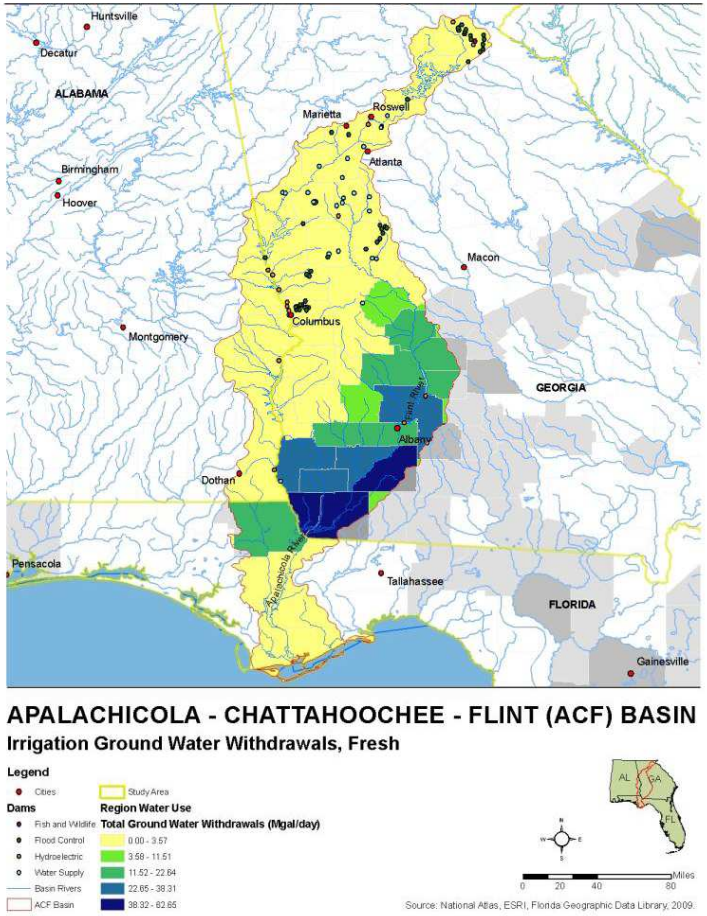
Significant irrigation demand for both surface and ground water

Surface Water Irrigation



Ground Water Irrigation

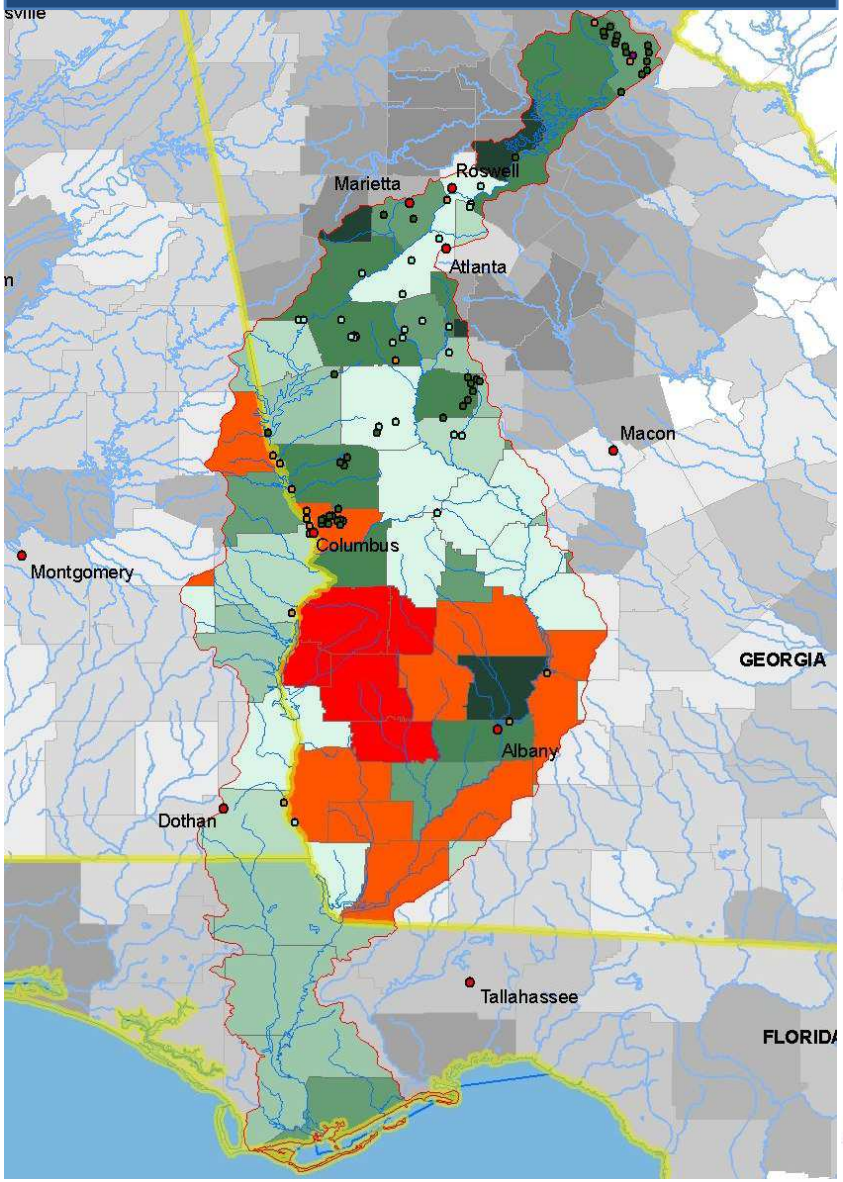


Withdrawal by type:

Surface water (0-30 Mgd): highest withdrawals in the Atlanta, GA region and the southern Chattahoochee and Flint (cotton, timber, peanuts, nurseries, etc.)

Groundwater (0-65 Mgd): highest withdrawals along the Flint and in the Alabama region (King cotton, peanuts, vegetable and fruits)

Projected Population growth 2000 -2015



Future availability of water is the primary concern of metropolitan Atlanta

- Significant growth in the northern ACF basin
- Significant contraction of the area of the southern ACF

SOURCE: USGS POPULATION DATA

To address basin wide water quantity issues in a multi-state basin in the U.S., there are four options:

1. *A lawsuit through the U.S. Supreme Court,*
2. *Federal legislation requiring interstate management,*
3. *Creating an Interstate Water Compact, and*
4. *Pretend you have no problems and pass them on to unsuspecting future generations.*

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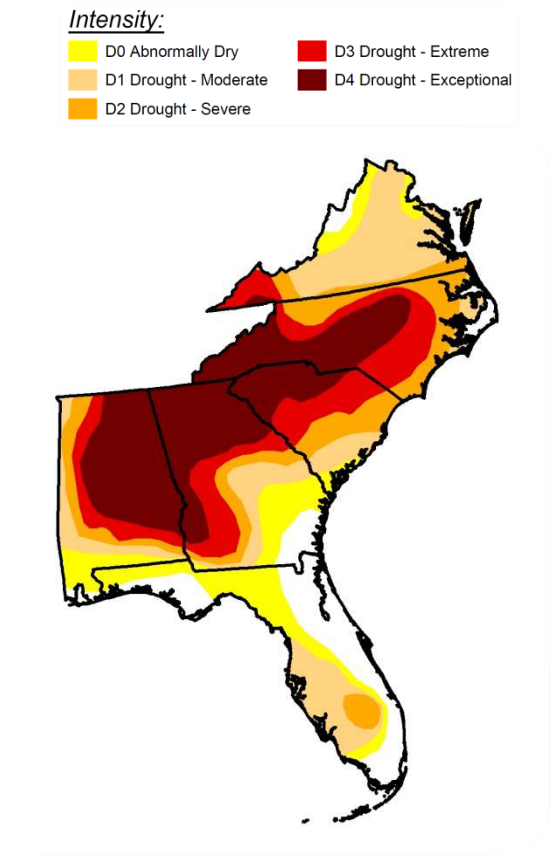
2007-2008 Drought Causes Urgency



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“WATER WARS” EPISODE 1: A NEW HOPE”

- **1989:** Atlanta applies to the Corps for increased water withdrawals and Alabama sues the Corps. States already had contentious relationship over federal navigation project for over a decade.
- **1992-1997:** Comprehensive Study of water use in the basin conducted after negotiated agreement.
- **1998:** ACF Compact approved by Congress and three states requires development of a Water Allocation Formula by December 1998. **First such Compact in the southeast and first in US since passage of major environmental laws in the 1970s.**
- In the compact legislation, the states were required to negotiate an allocation formula to provide the details for managing the basin.
- **1999 – 2003:** Compact negotiation extended 14 times when agreement could not be reached by three States.
- **2003:** Memorandum of Understanding between States on principles of Water Allocation Formula and then the termination of ACF Compact.

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“WATER WARS” EPISODE 2: THE LAWYERS STRIKE BACK

- **2004-2005:** Multiple lawsuits relating to the ACF water management proceed through courts in Washington, D.C., Birmingham and Atlanta.
- **2006:** Corps of Engineers and U.S. Fish and Wildlife present Interim Operating Procedures (IOP) for managing ACF reservoir system.
- **2007:** Severe drought requires modifying IOP to include Emergency Drought Operations (EDO) as the Apalachicola River experiences record low flows and endangered species are threatened. Court case consolidated to single court.
- **2008:** District Court of Appeals rules in favor of Florida and Alabama on case relating to water supply withdrawals from Lake Lanier. Georgia appeals decision. Corps of Engineers announce preparation of new Water Control Plan for ACF basin.
- **2009:** Magnuson Ruling. Maintains that city of Atlanta has no right to water from Lake Lanier (federal reservoir). In 3 years, all rights return to early 1970s, leaving Atlanta without access to Lake Lanier. Atlanta appeals.
- **2011:** 11th Circuit Court overrules Magnuson ruling, restores Atlanta’s right to withdraw from Lake Lanier. Gives US Army Corps one year to decide how to allocate the water. Florida and Alabama appeal to Supreme Court…
- **2012:** The US Supreme Court declines to hear Florida and Alabama’s appeal, thus affirming Atlanta’s right to withdraw and we all start over again… rewind to 1989...

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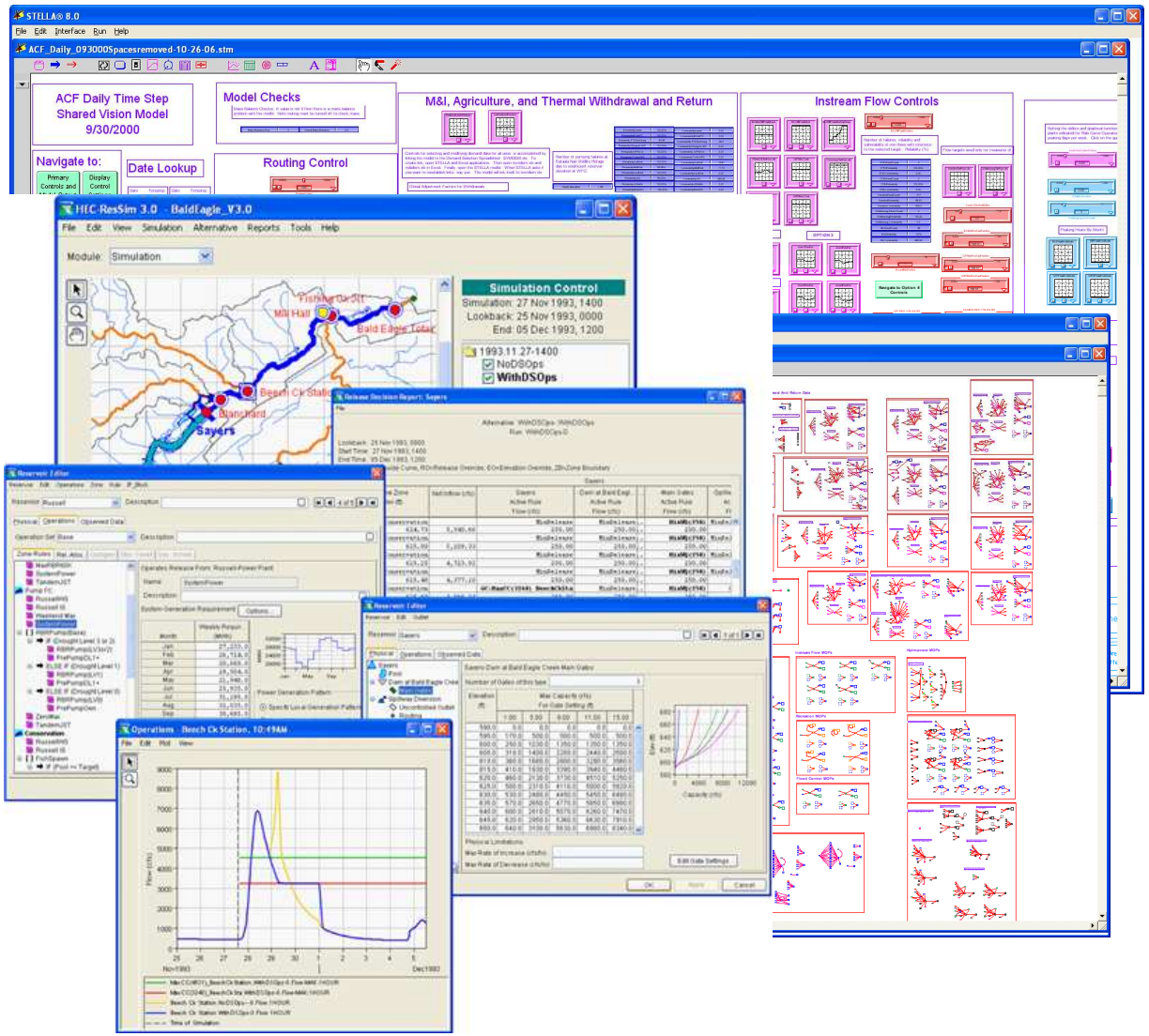
ACF MODELS -

- ACF-Stella – generated from the ACF Compact Negotiations
- HEC 5 : RES-SIM USACE Mobile District
- For the most part, the models match each other quite closely
- The forecasts are not in dispute..



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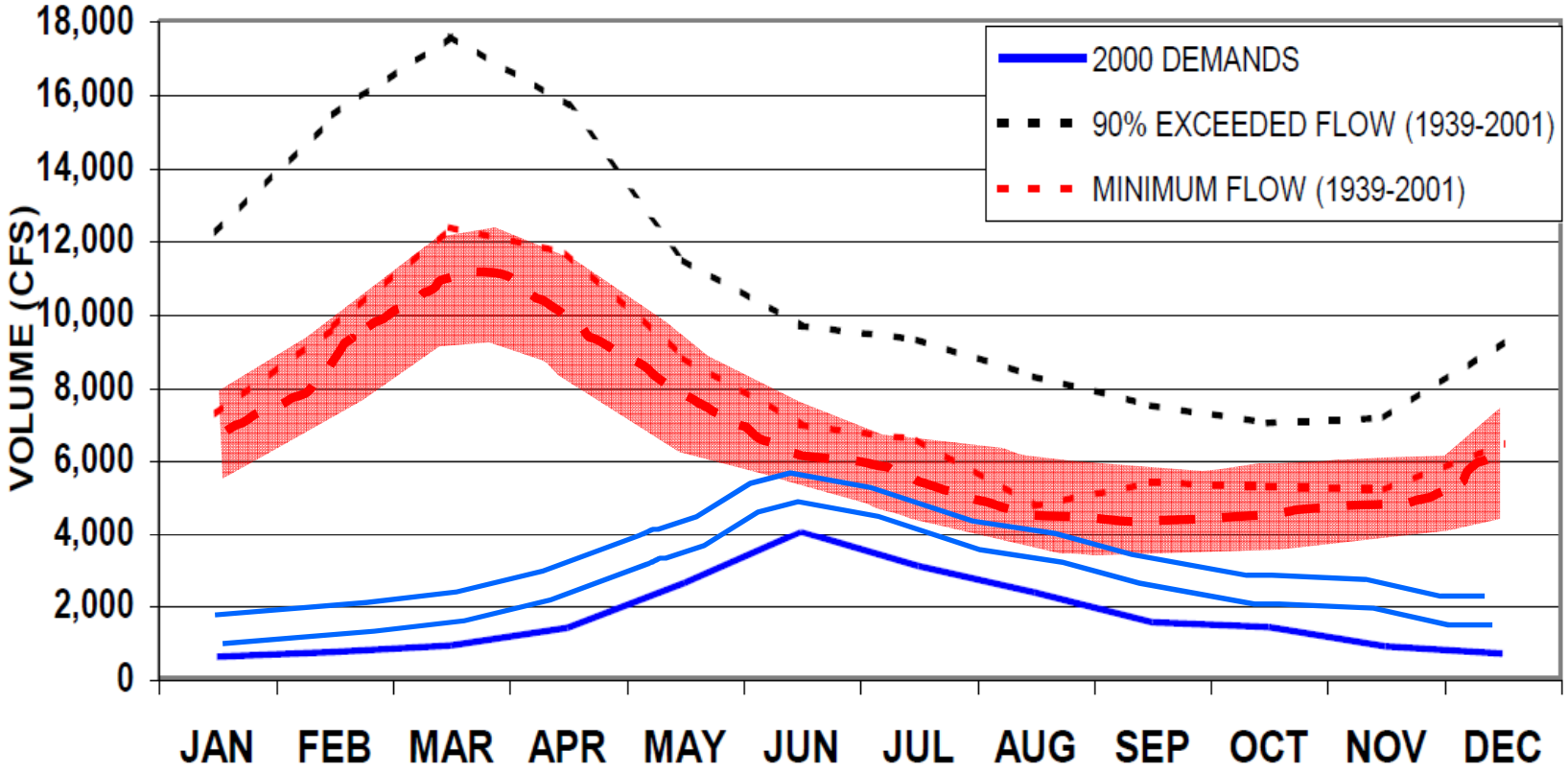
Total consumptive withdrawals from the Flint and Chattahoochee



SOURCE: ACF COMPREHENSIVE STUDY DATA BASE

The Chattahoochee makes a greater contribution to peak flows in the Apalachicola. However, during extreme dry periods, the greater contribution to flow in the Apalachicola comes from the Flint, where base flow is sustained by groundwater discharges (Elder et al. 1988).

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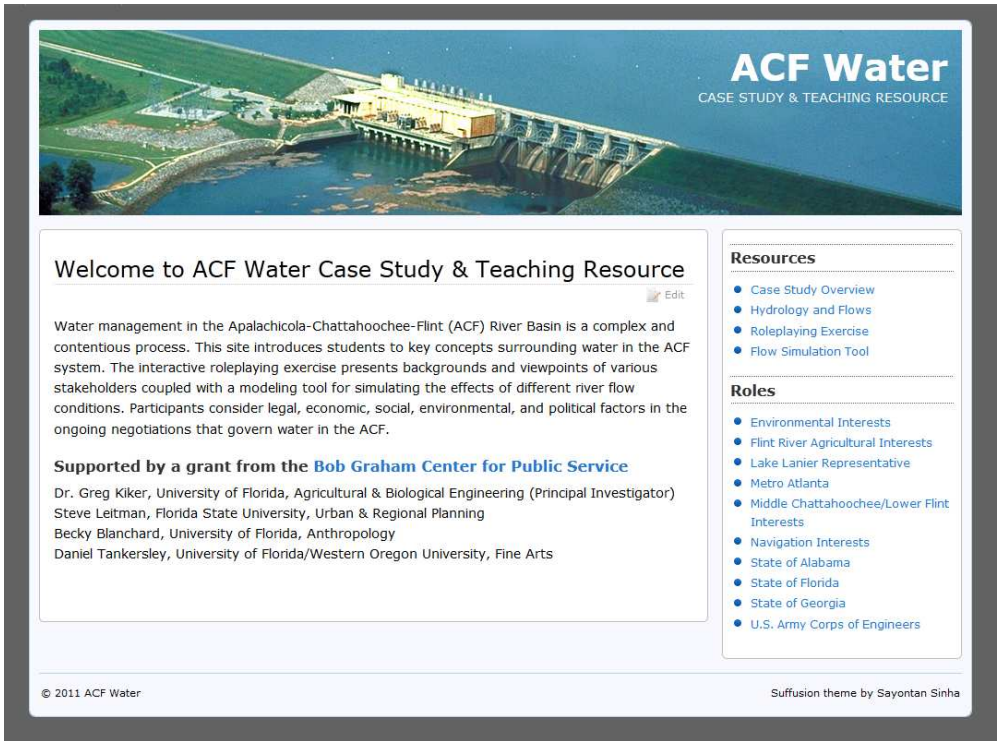
Educating future water resource managers: Role play and computer aided negotiation



- States of Florida, Georgia and Alabama
- Environmental interests
- Agricultural interests
- Lake Lanier Association
- City of Atlanta
- Middle Chattahoochee Association (Power companies & Municipal uses)
- Flint River Agricultural Association
- Fed Agencies: US Army Corps of Engineers/USFWS
- Tri Rivers Navigation Association

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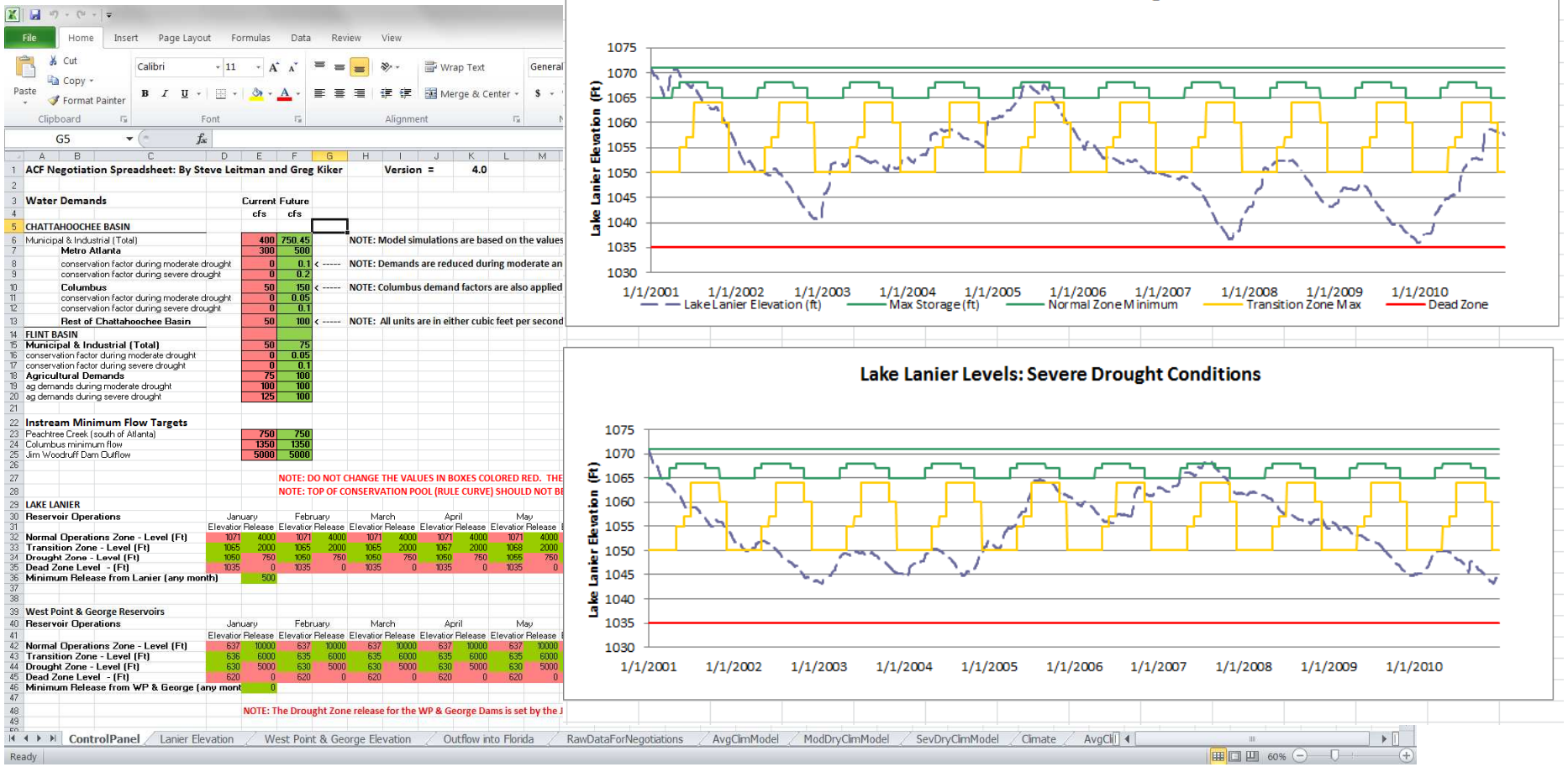
Coordinated courses at four ACF universities: Role play and computer aided negotiation



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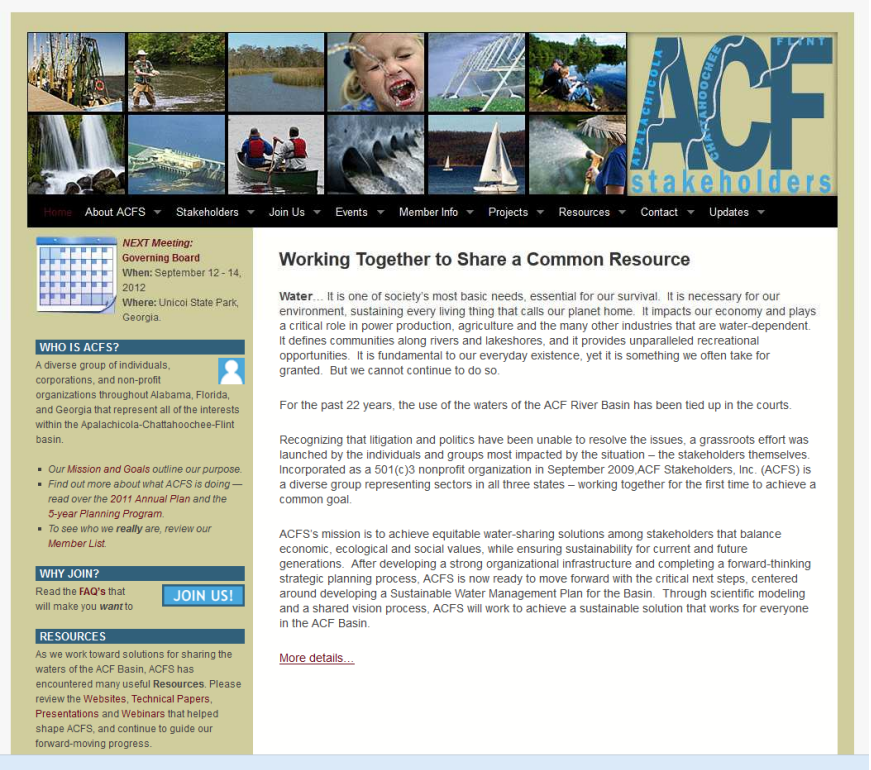
The ACF Stakeholders get organized



- The GA, AL and FL stakeholders formed and funded their own group
- Membership? Live in the catchment
- Industry, Agriculture, Municipalities, Environmental interests
- A DeFacto CMA? … in search of authority…
- http://acfstakeholders.org

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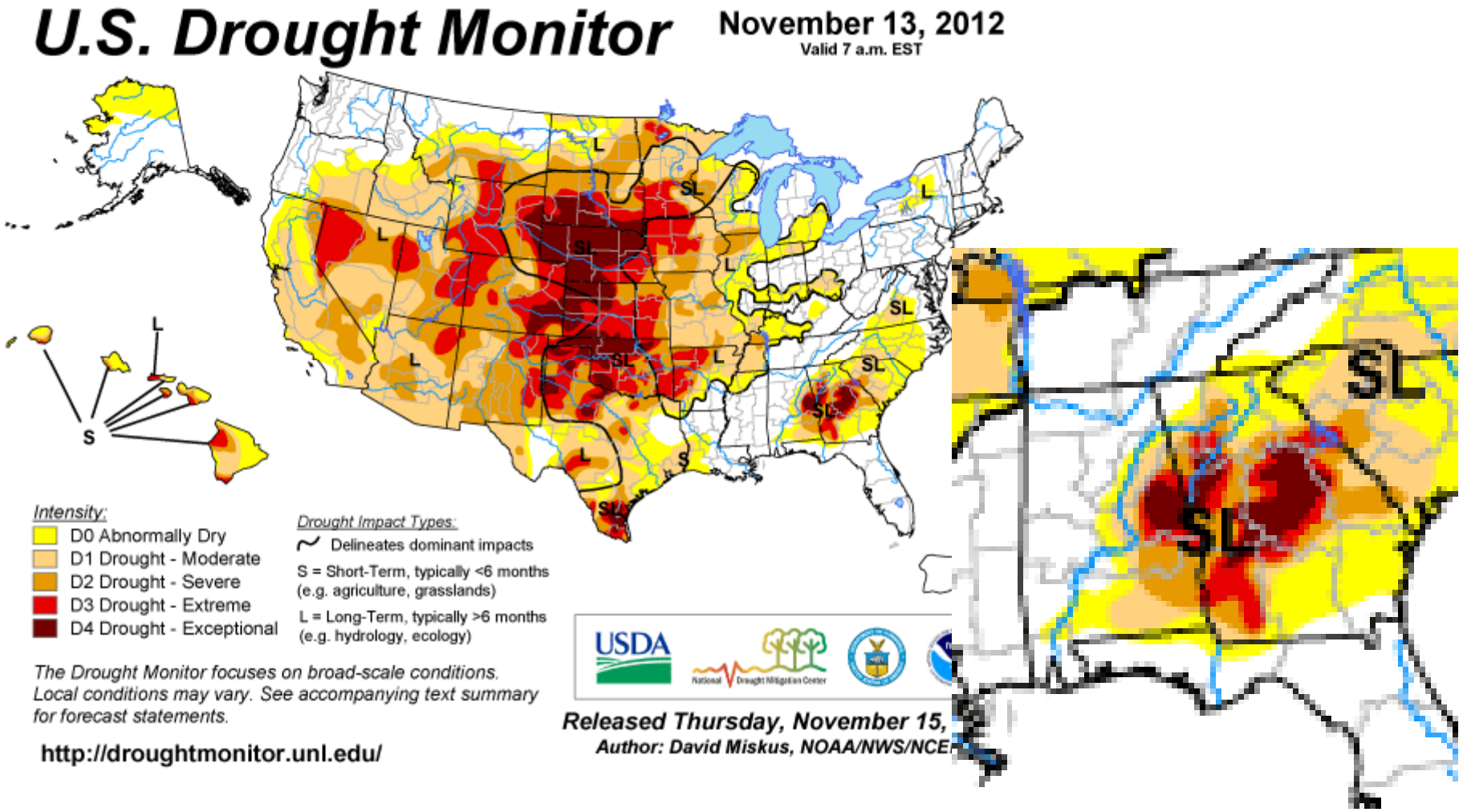
Getting organized for now and the future



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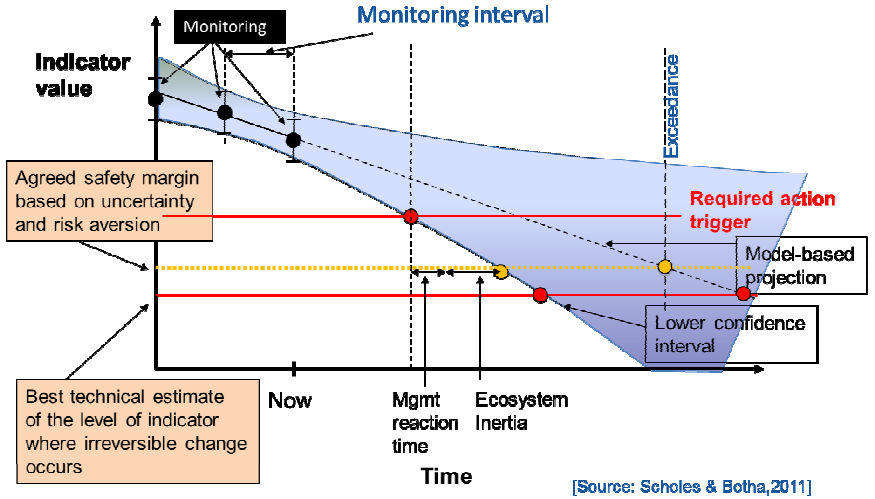
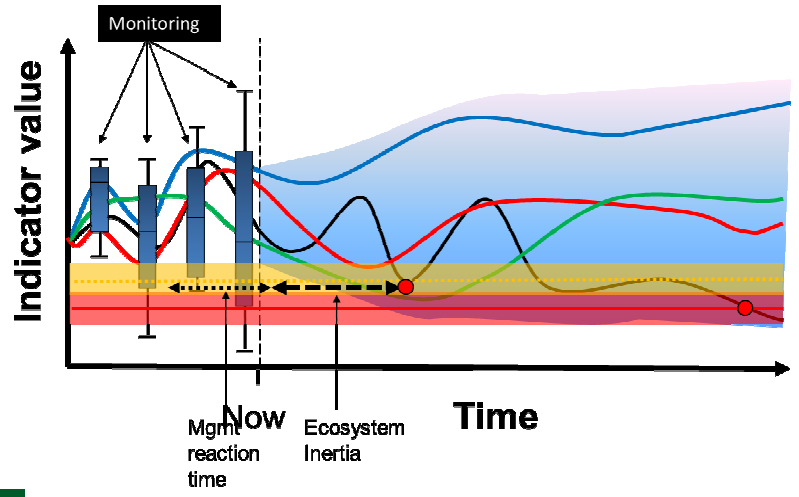
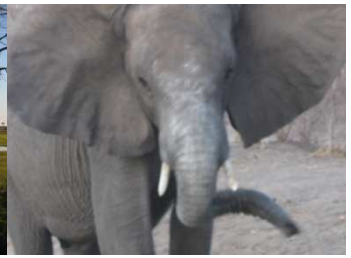
Lessons from the ACF:

- General agreement on the Models and their predictions…
- Some agreement about the metrics and their levels…
- Very little agreement about what needs to be done
  - Sometimes values are the primary conflict point
  - Trust and long-term connections become critical factors
  - Attempts to understand each other and each other's metrics and data can pay big dividends provided one is patient
- Management and ecosystem reaction times are still unknown, because a multistate governance has not been established
- Climate change is pushing the issue forward through ever more frequent and powerful droughts.





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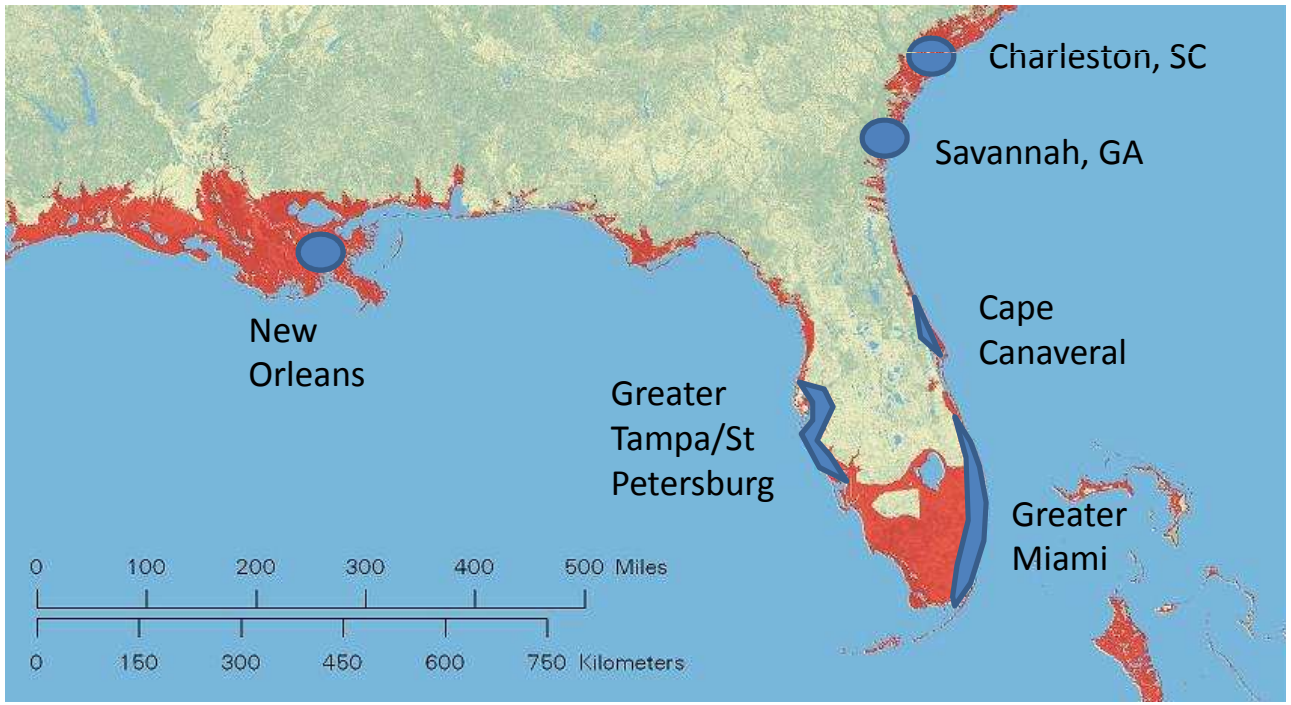
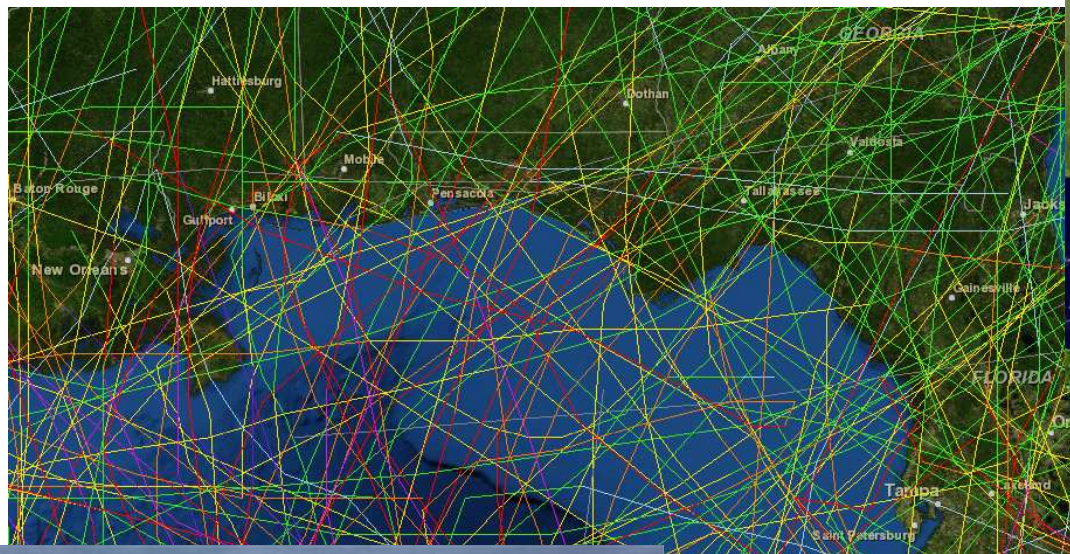
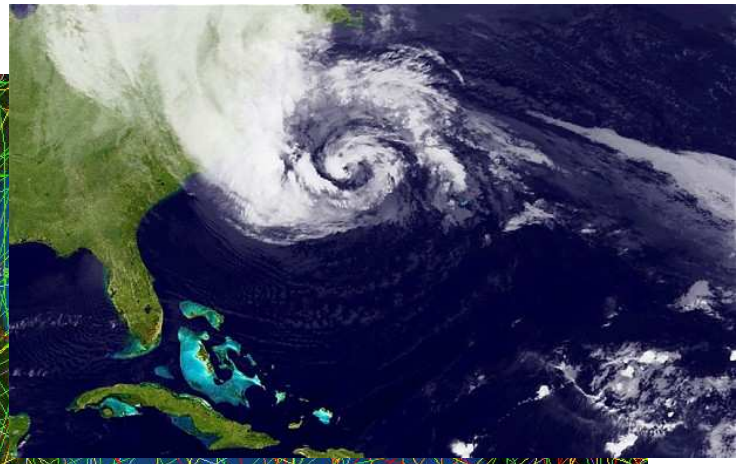
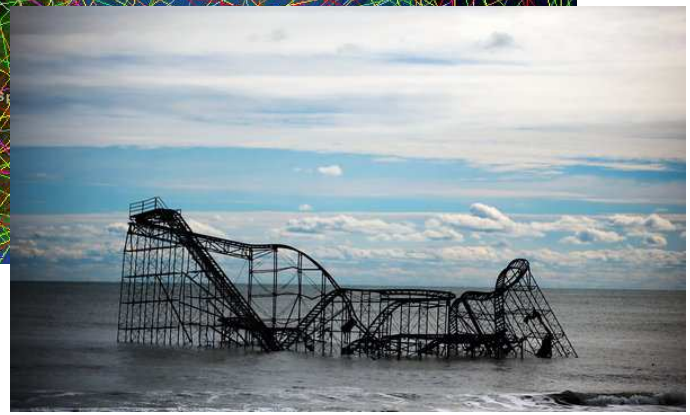
Sea Level Rise and Potential Wetland Migration in Florida



Hurricanes, Tropical Storms and Tropical Depressions are not exactly a surprise to most Floridians

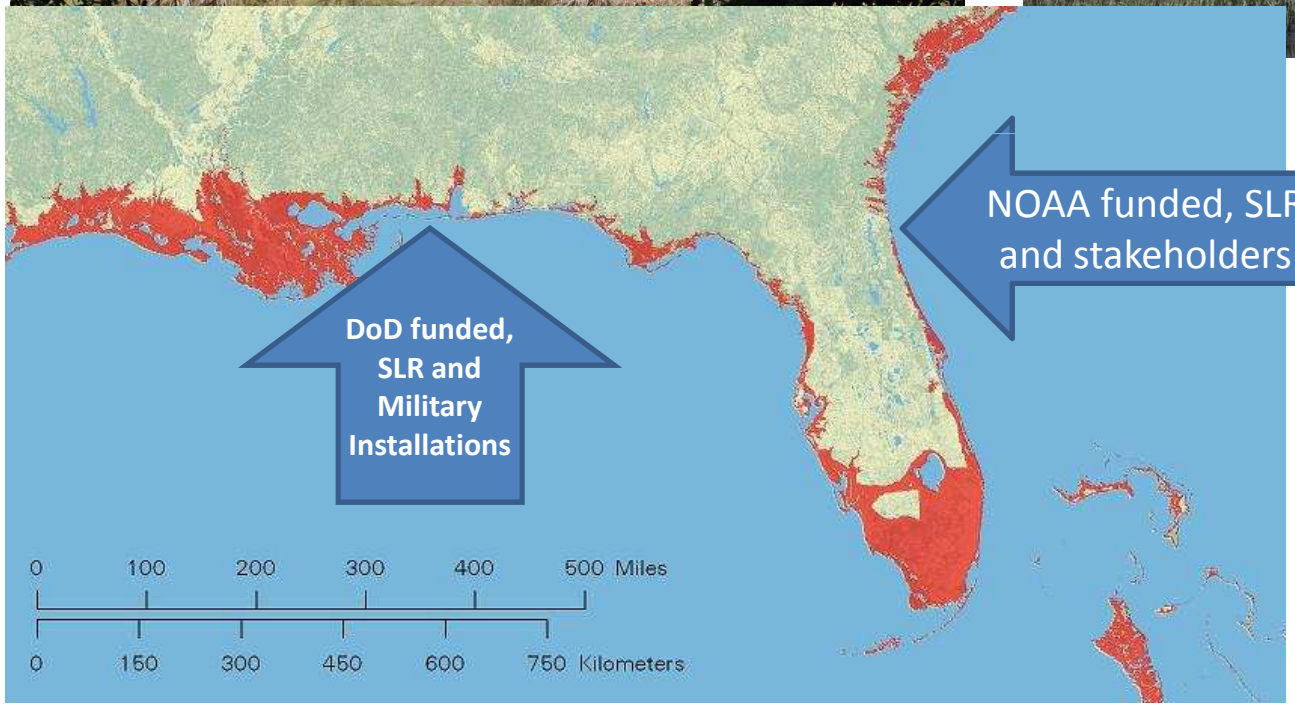






Sources: NOAA, NY Times, Telegraph UK

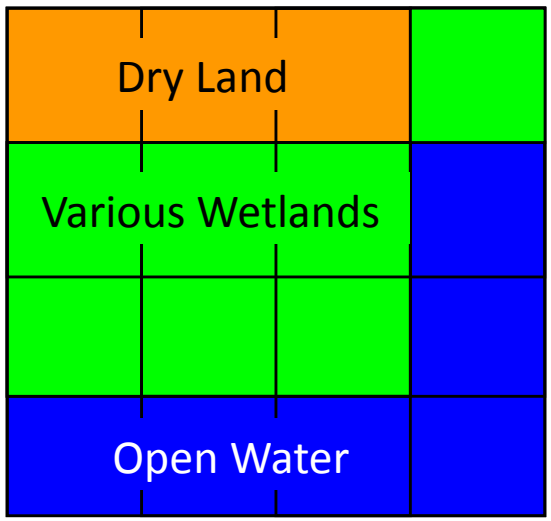
Sea Level Rise and Potential Wetland Migration in Florida: Two studies



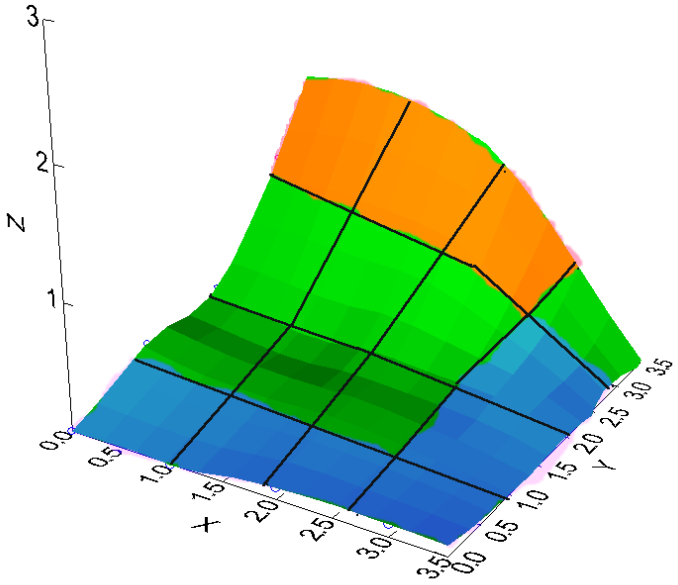
- Significant coastal infrastructure
- Increasing human populations
- Intense interest in the vulnerable areas

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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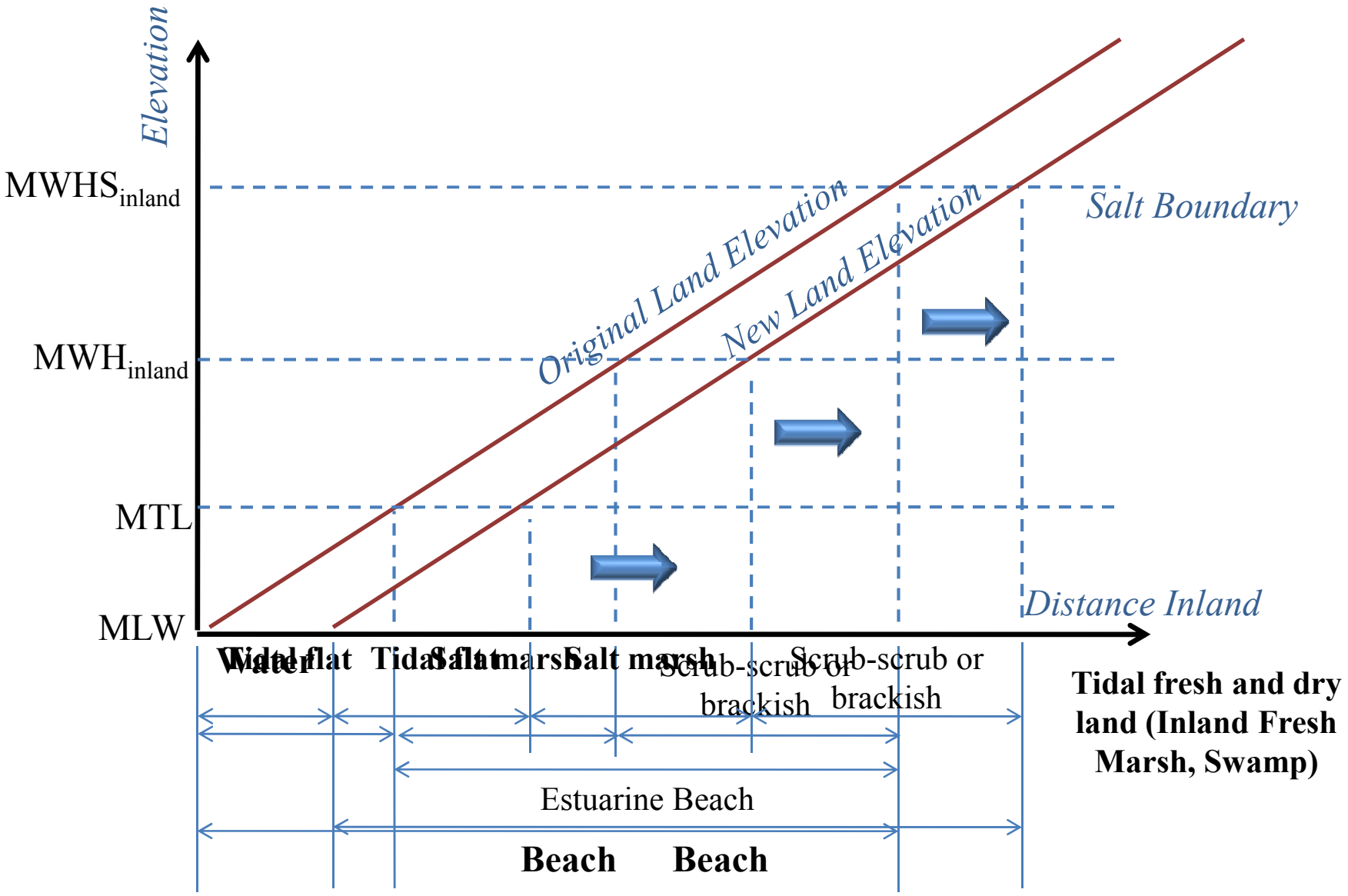
SLAMM Inundation Model

(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.

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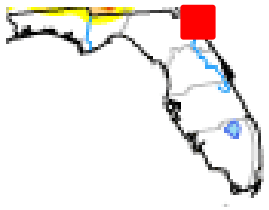
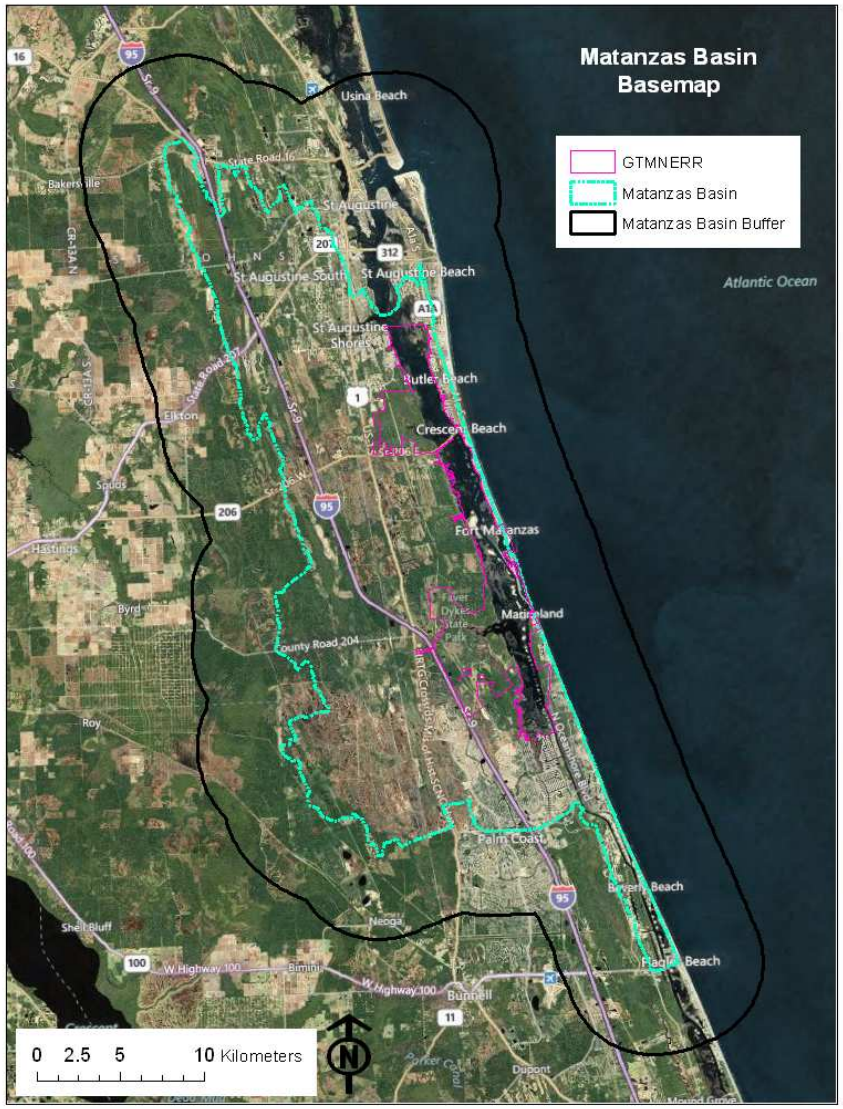
Jonathan Clough

National Estuarine Research Reserve System Science Collaborative:



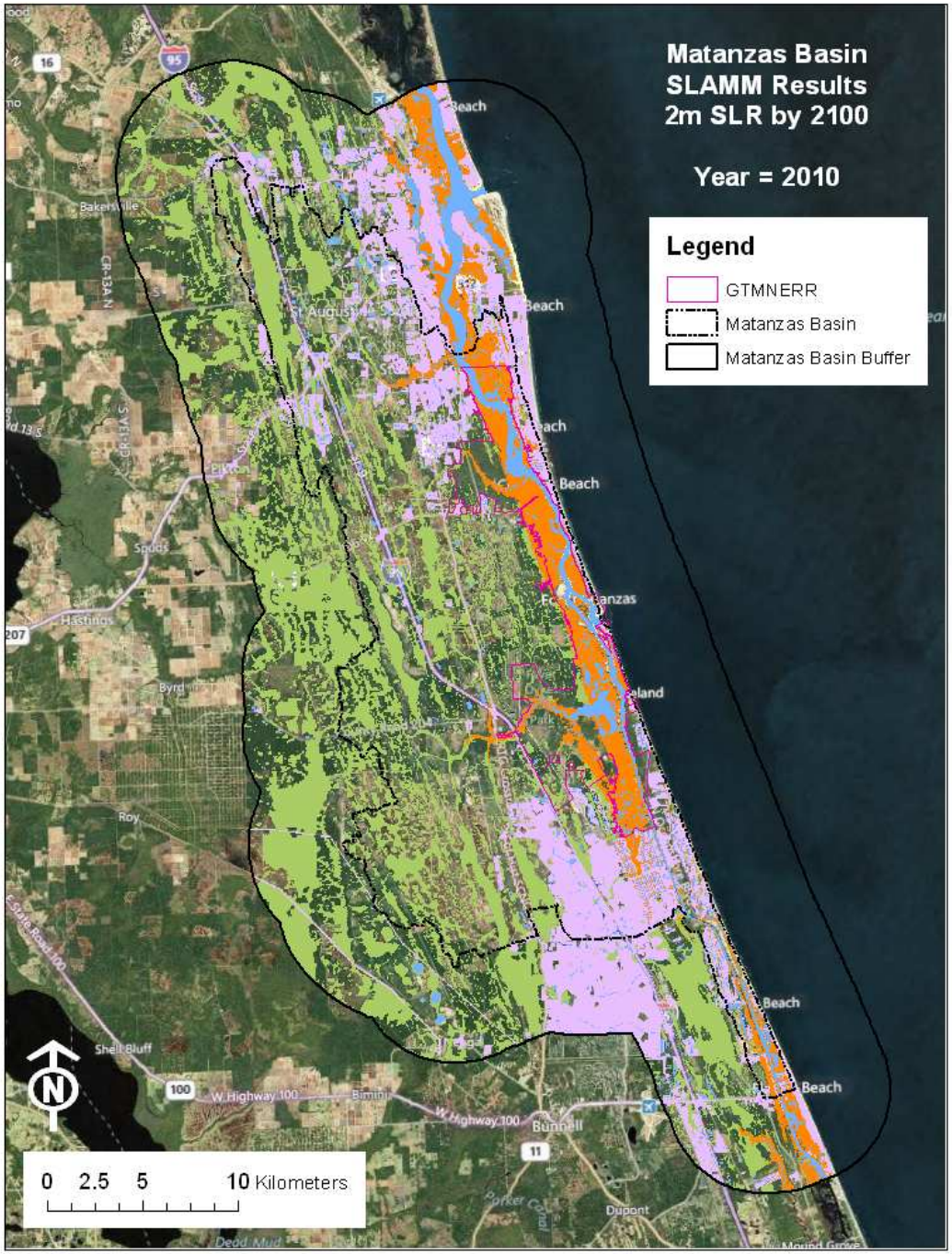


- Guana Tolomato Matanzas National Estuary Research Reserve (GTMNERR)
- Low elevation estuary between St Augustine, FL (America's oldest city) and the Palm Coast (rapidly growing retirement community)

SLAMM results
2m SLR by 2100

2010

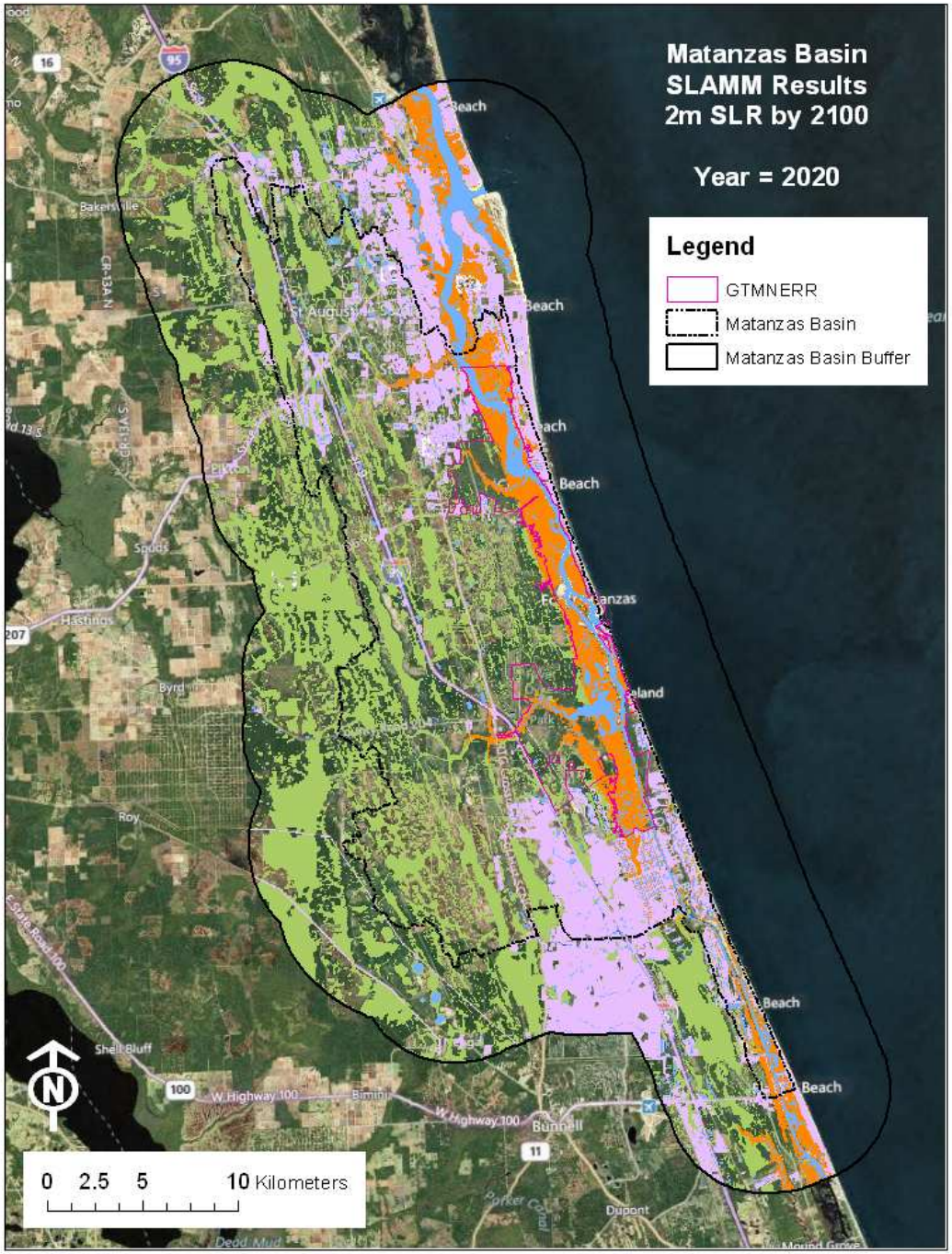
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2020

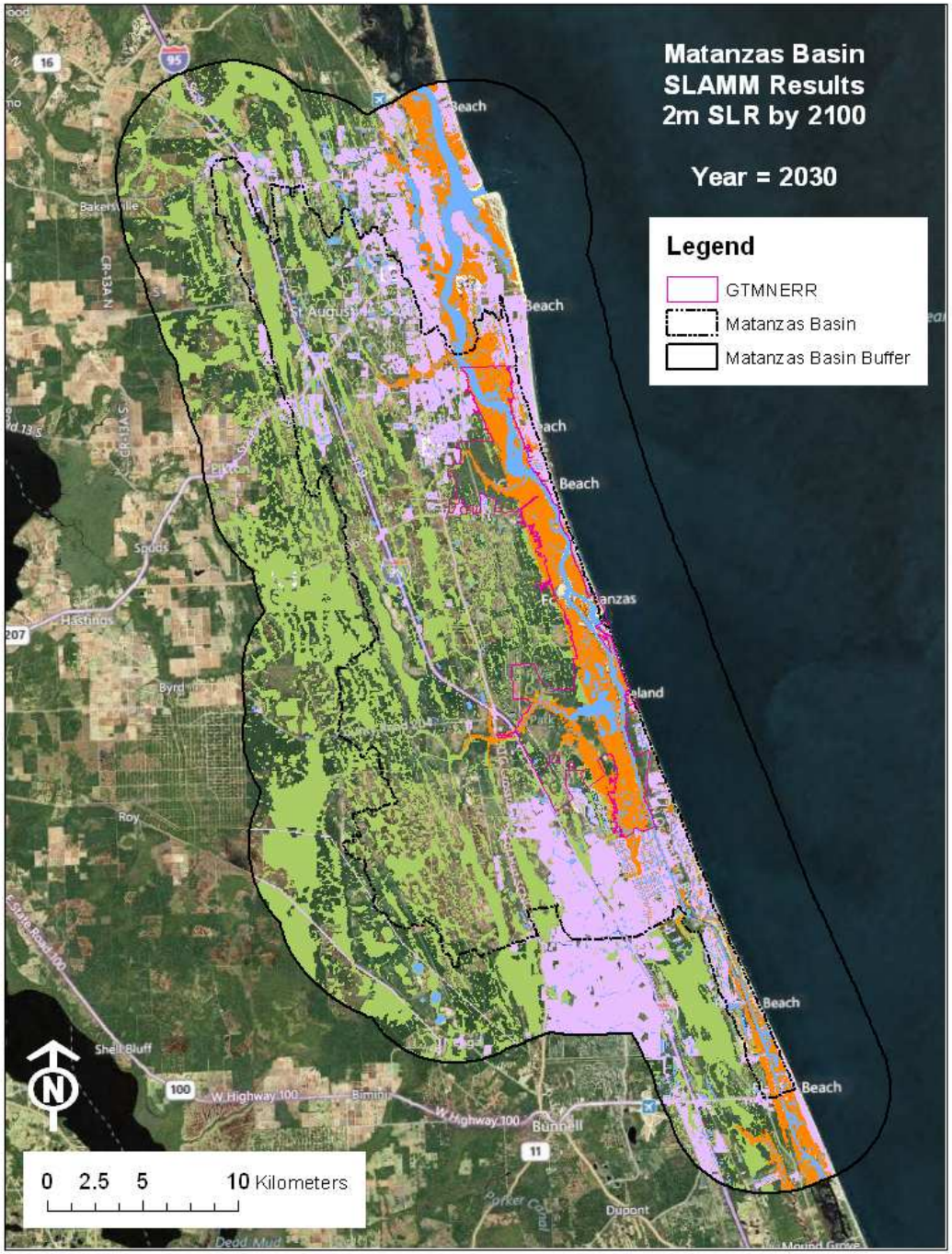
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2030

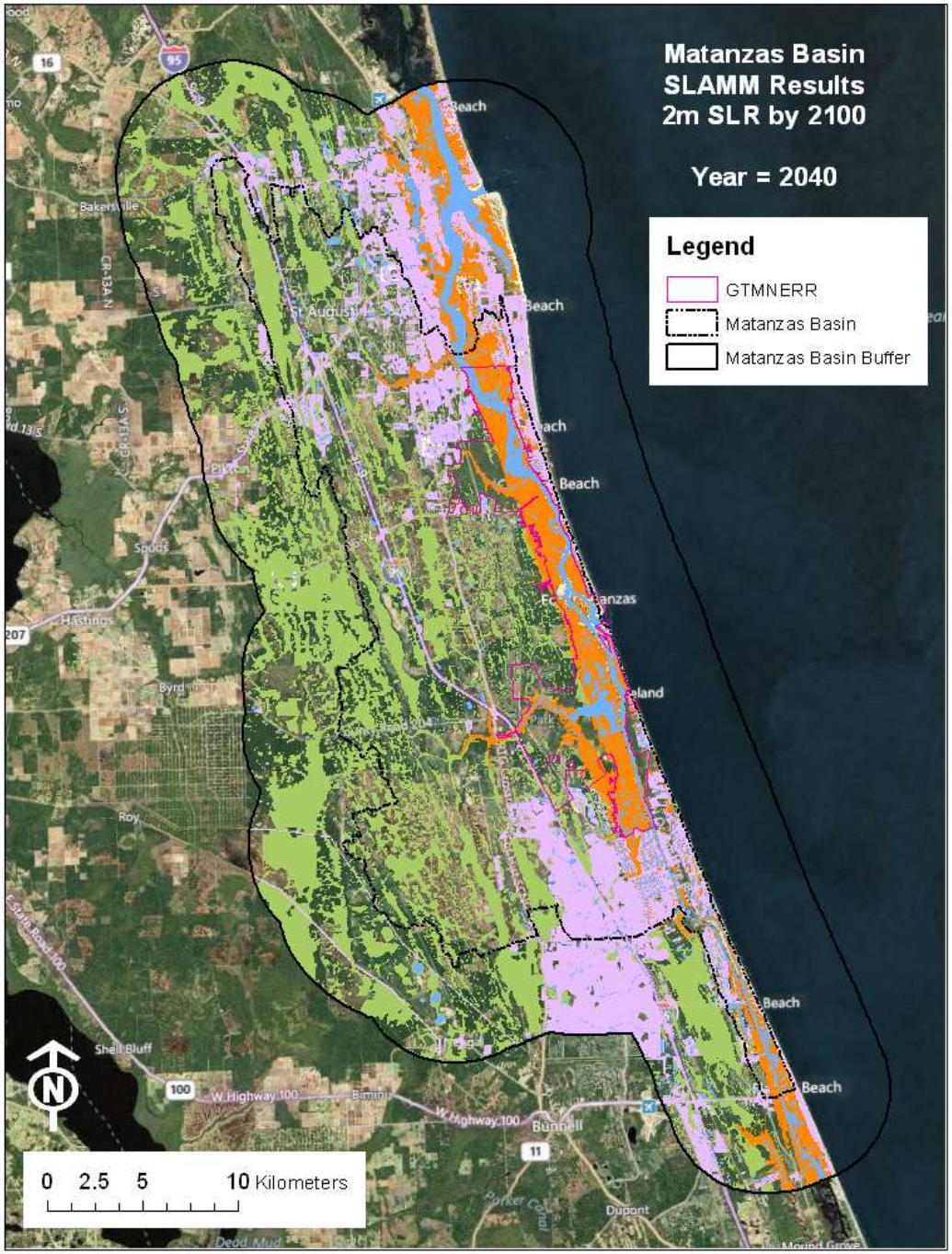
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2040

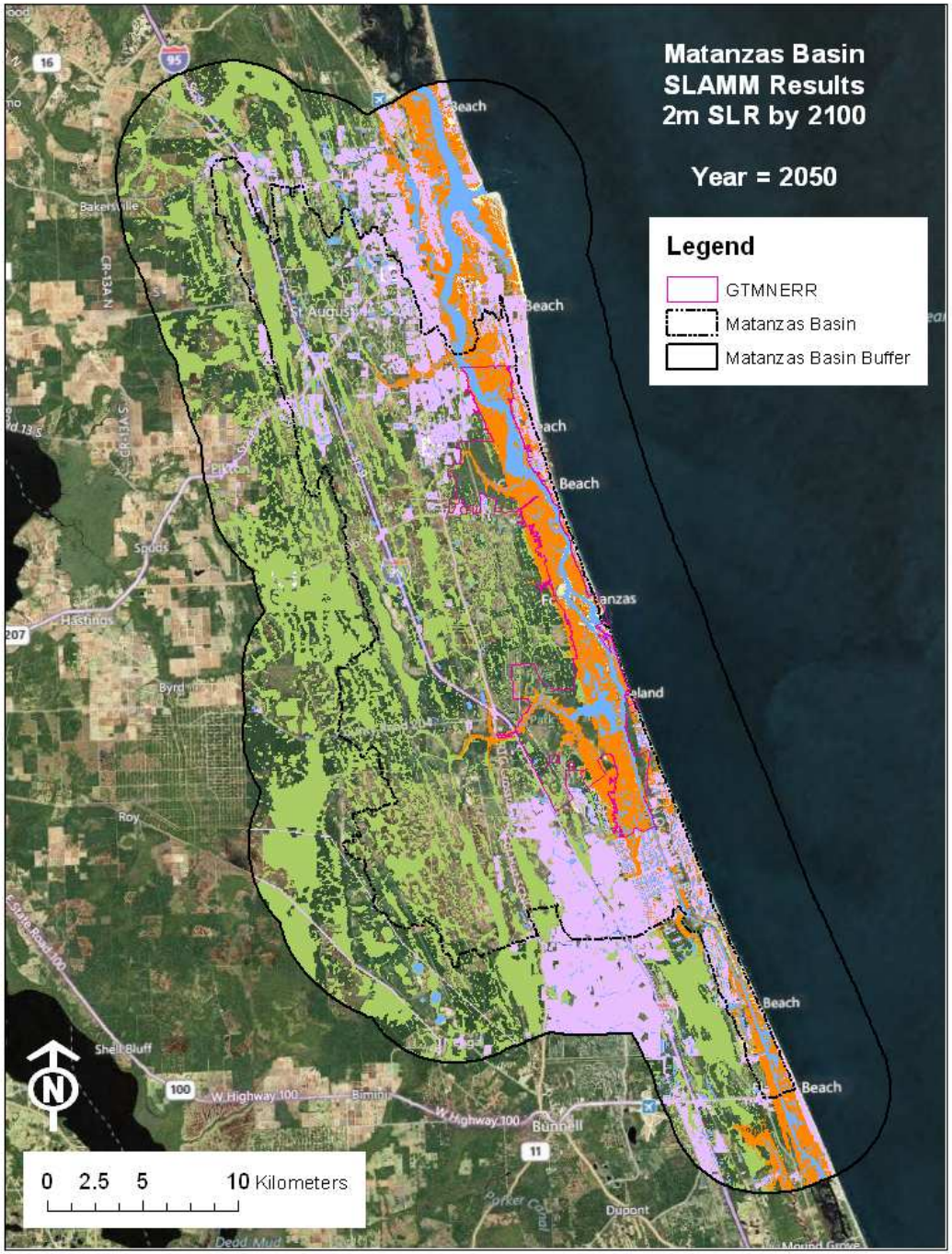
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2050

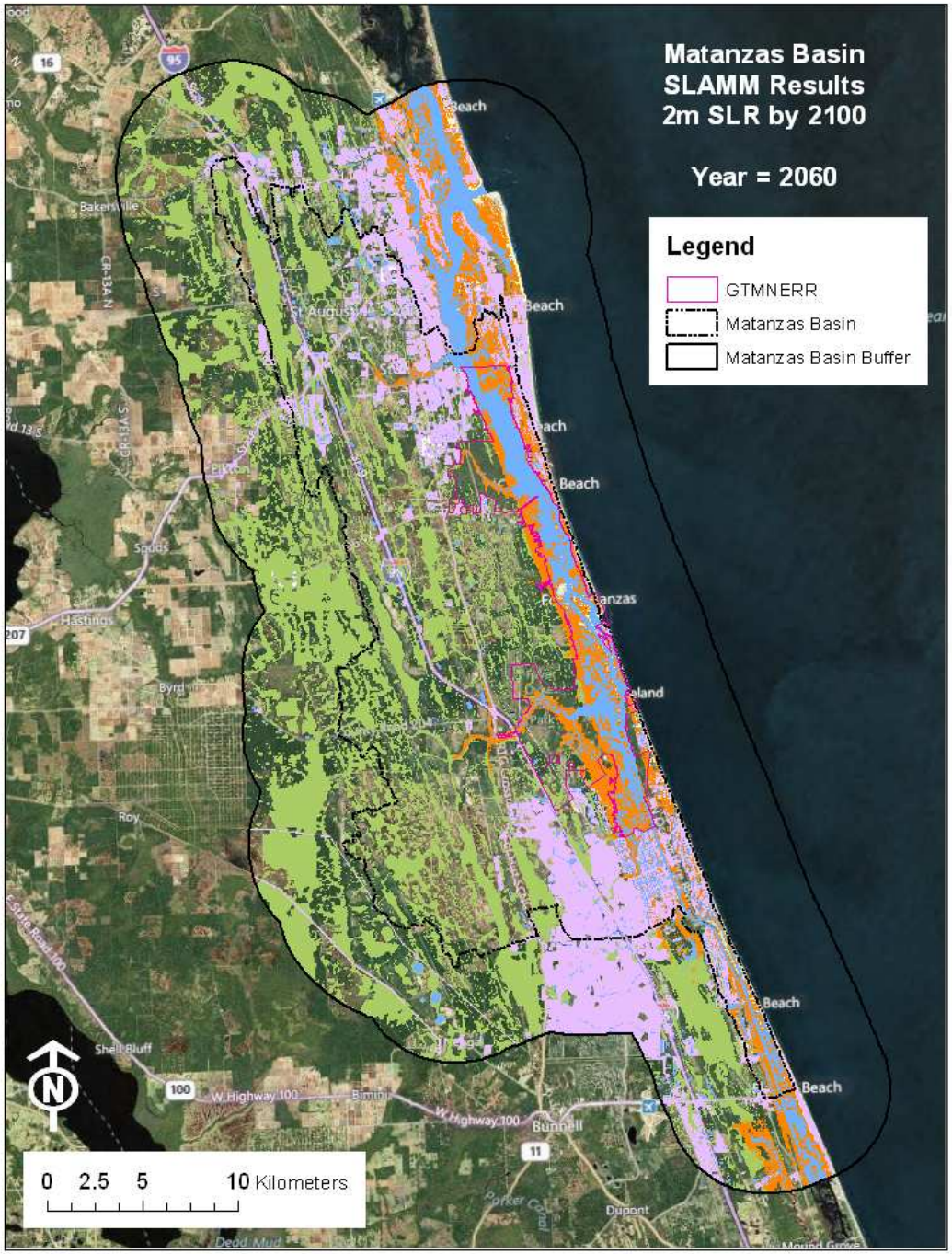
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2060

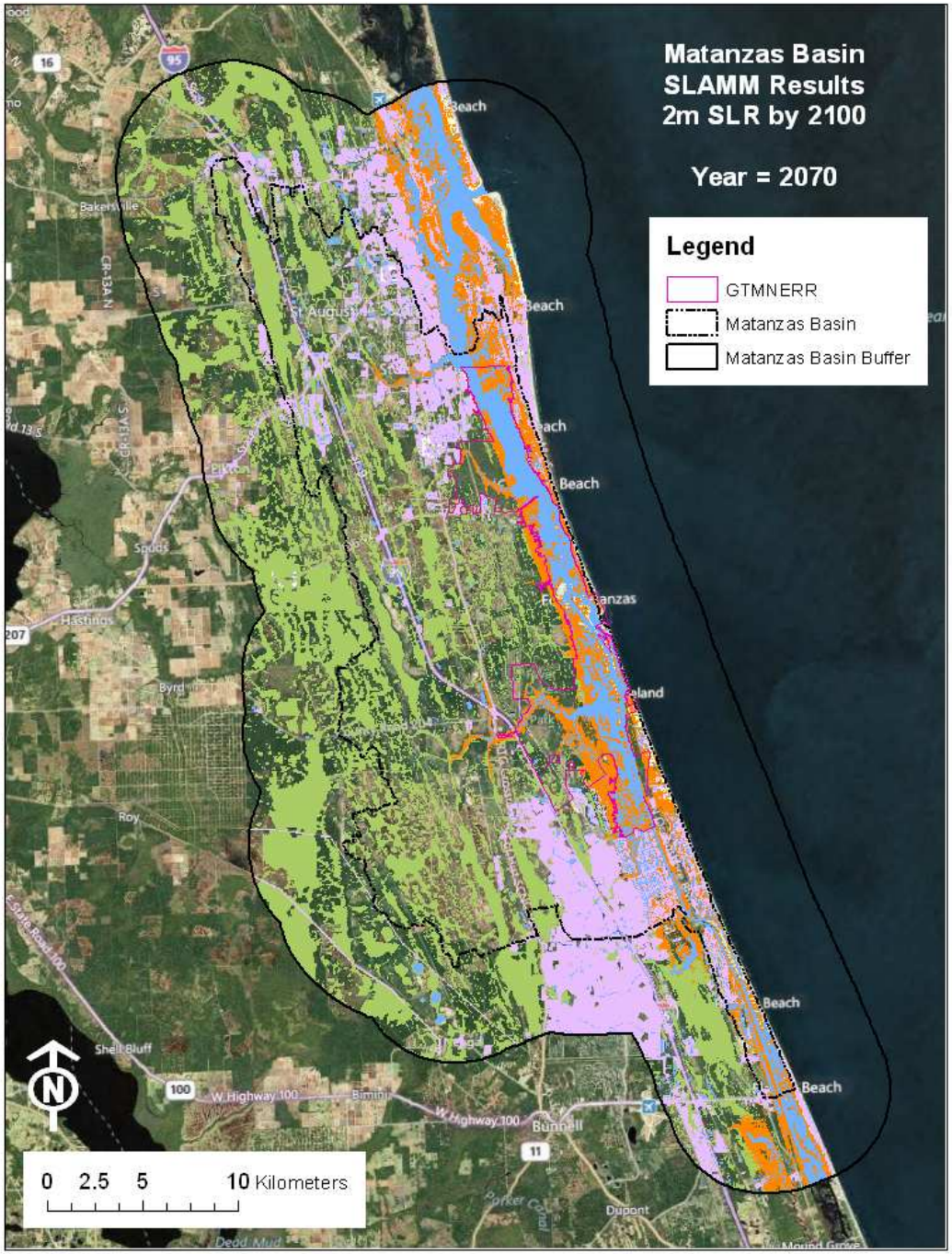
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2070

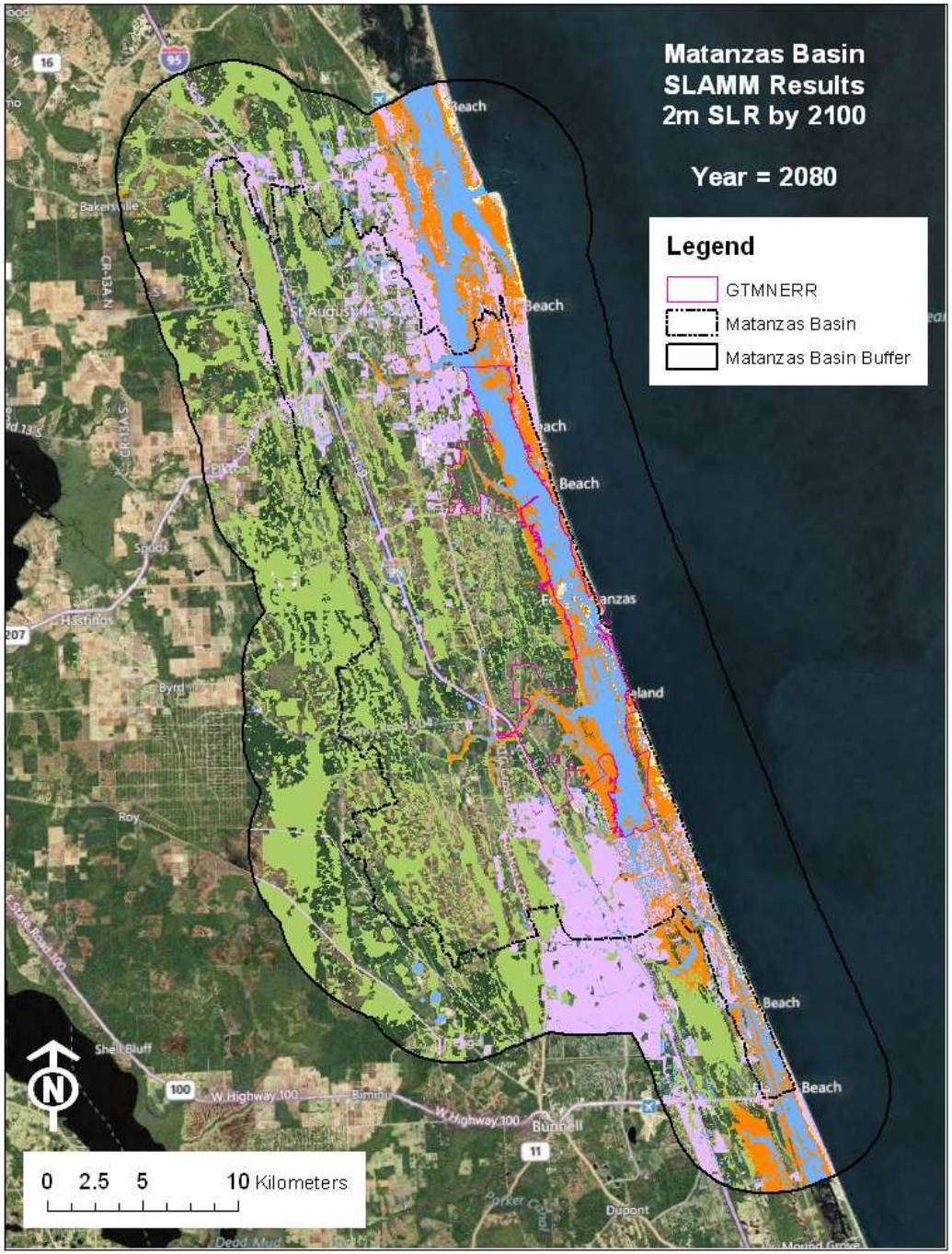
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2080

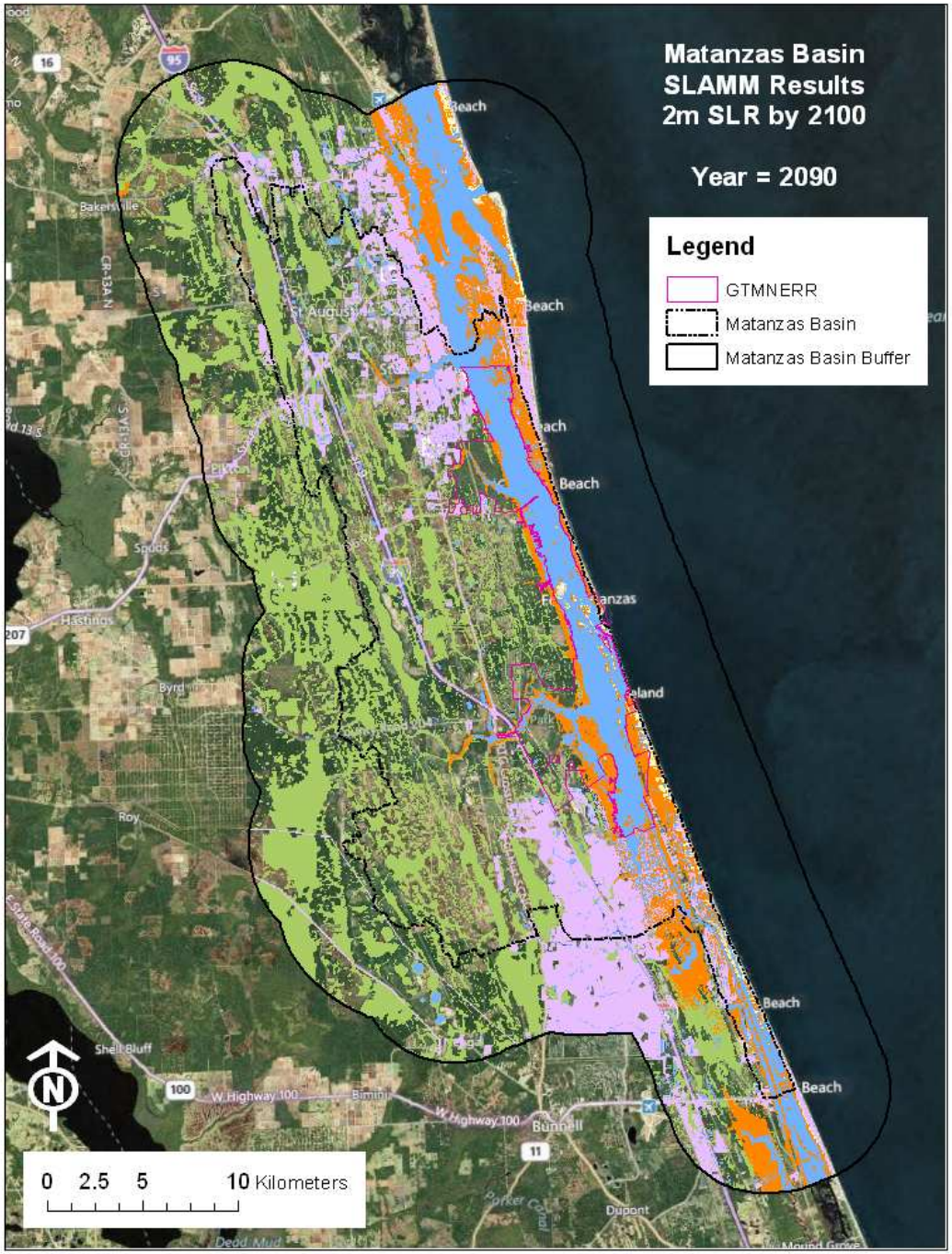
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

2090

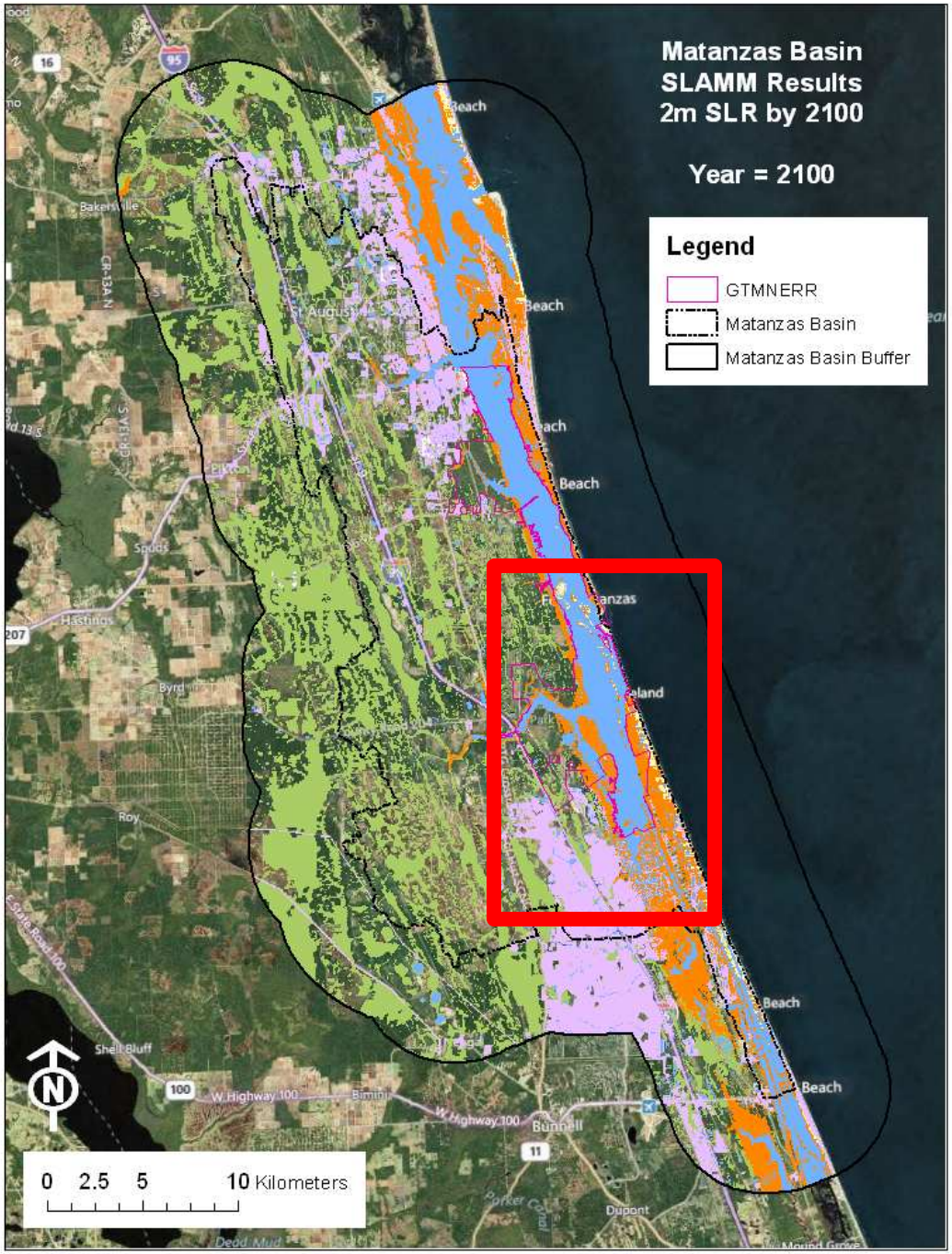
- Developed Land
- Freshwater Marsh
- Saltwater Marsh
- Beach
- Water



SLAMM results
2m SLR by 2100

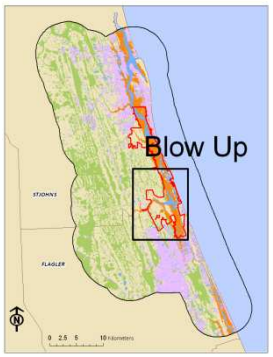
2100

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



SLAMM results
Pellicer Creek
2m SLR by 2100

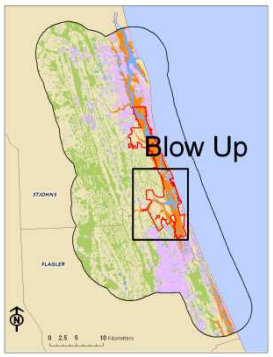
2010



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

SLAMM results
Pellicer Creek
2m SLR by 2100

2020



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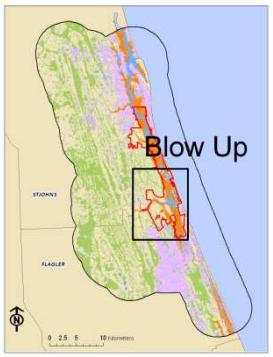
SLAMM results
Pellicer Creek
2m SLR by 2100

2030



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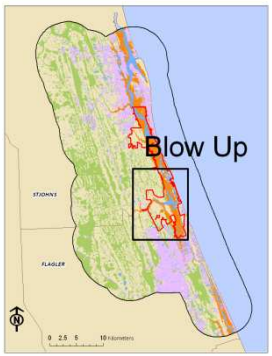
SLAMM results
Pellicer Creek
2m SLR by 2100

2040



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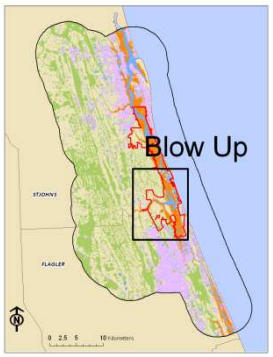
- Tidal Flat

SLAMM results
Pellicer Creek
2m SLR by 2100

2050



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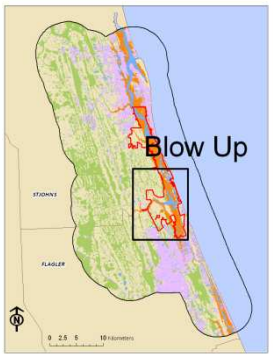
SLAMM results
Pellicer Creek
2m SLR by 2100

2060



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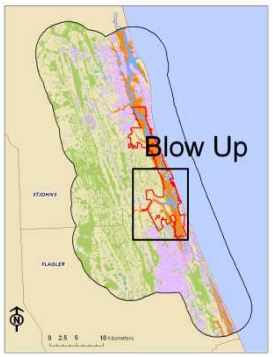
SLAMM results
Pellicer Creek
2m SLR by 2100

2070



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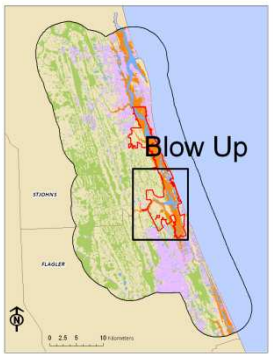
- Tidal Flat

SLAMM results
Pellicer Creek
2m SLR by 2100

2080



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- Water
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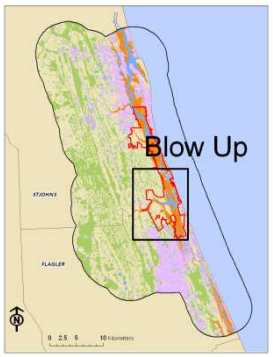
- Tidal Flat

SLAMM results
Pellicer Creek
2m SLR by 2100

2090



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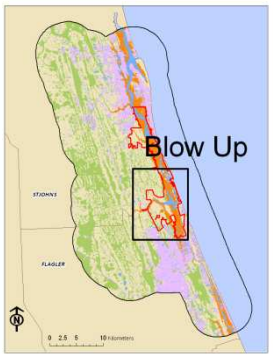
SLAMM results
Pellicer Creek
2m SLR by 2100

2100



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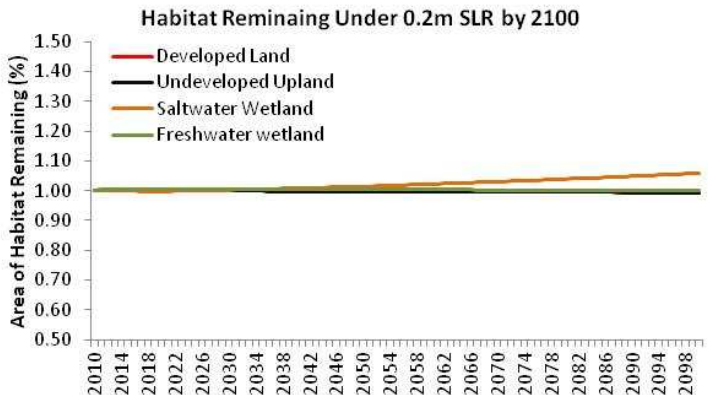
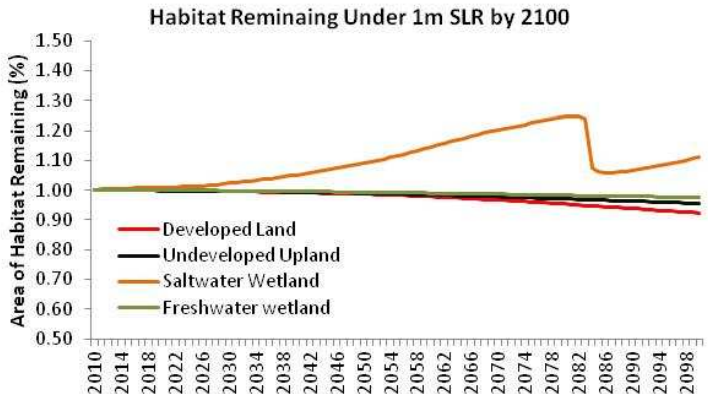
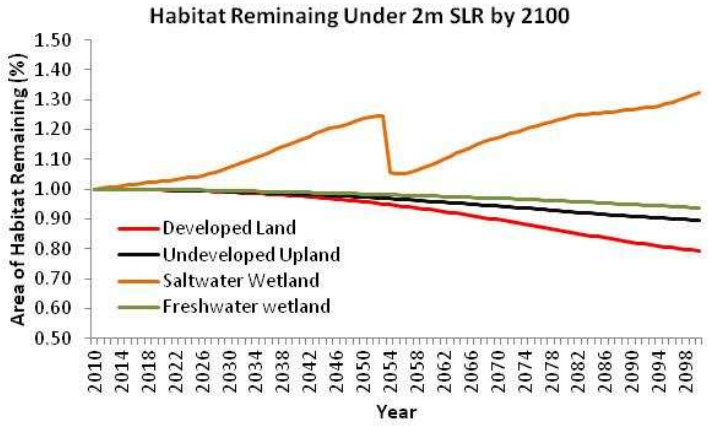
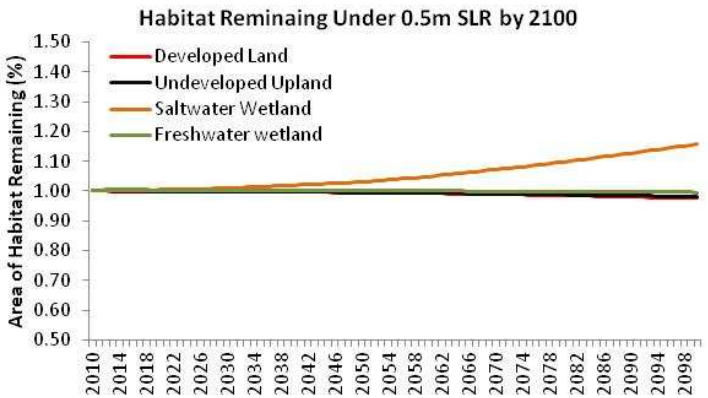
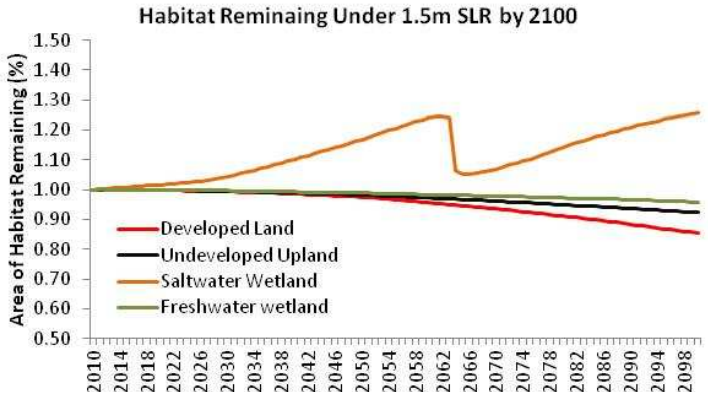
How much difference is there between the sea level rise scenarios?

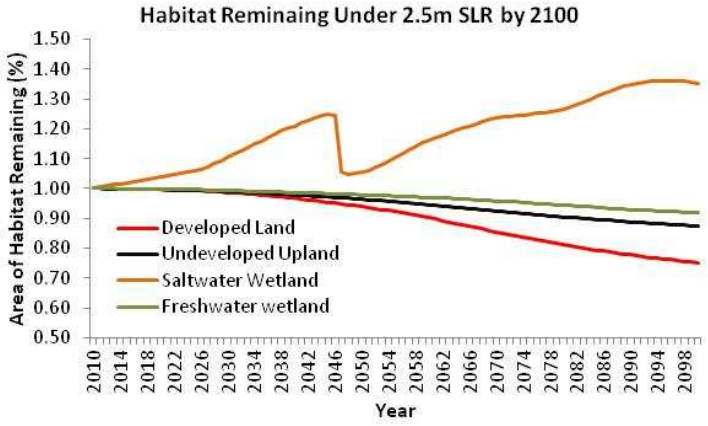


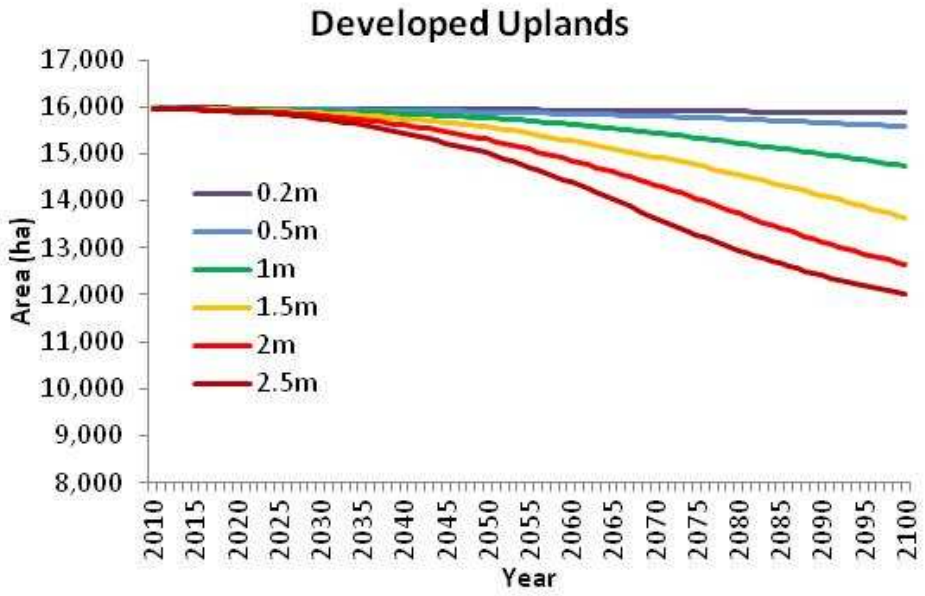


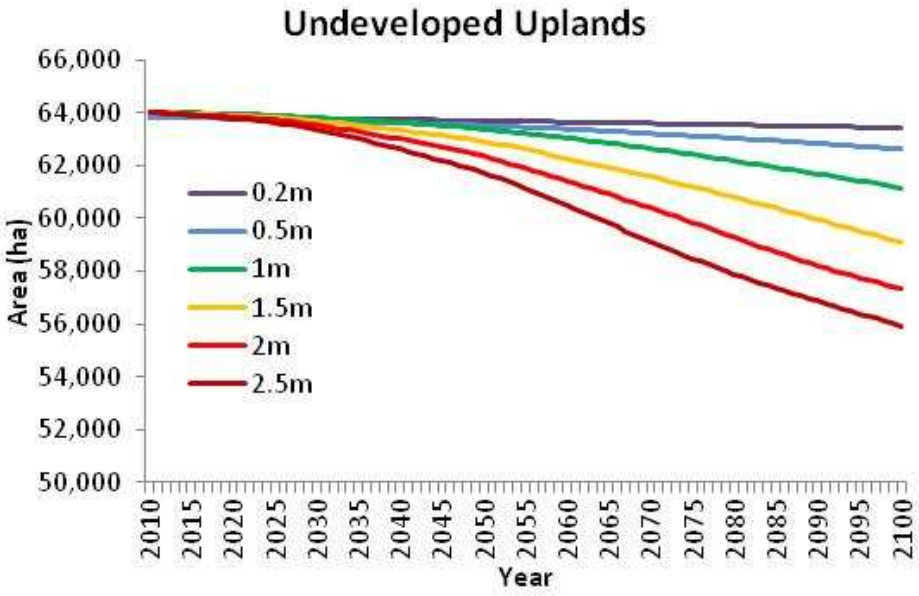


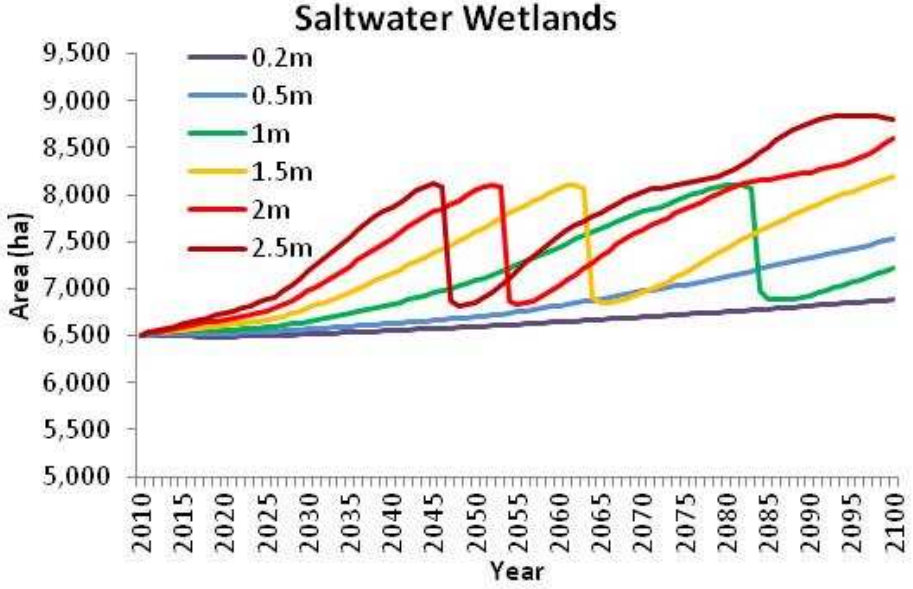


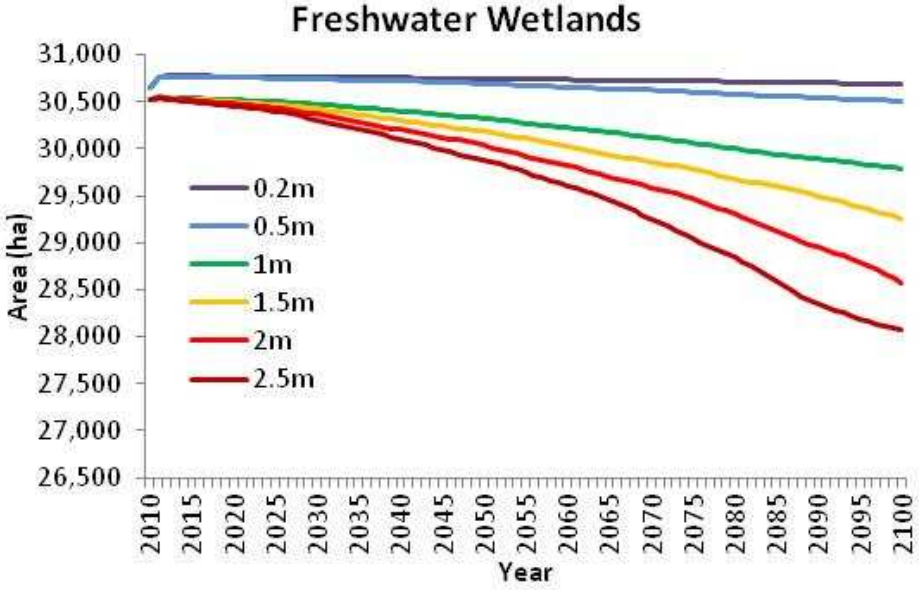


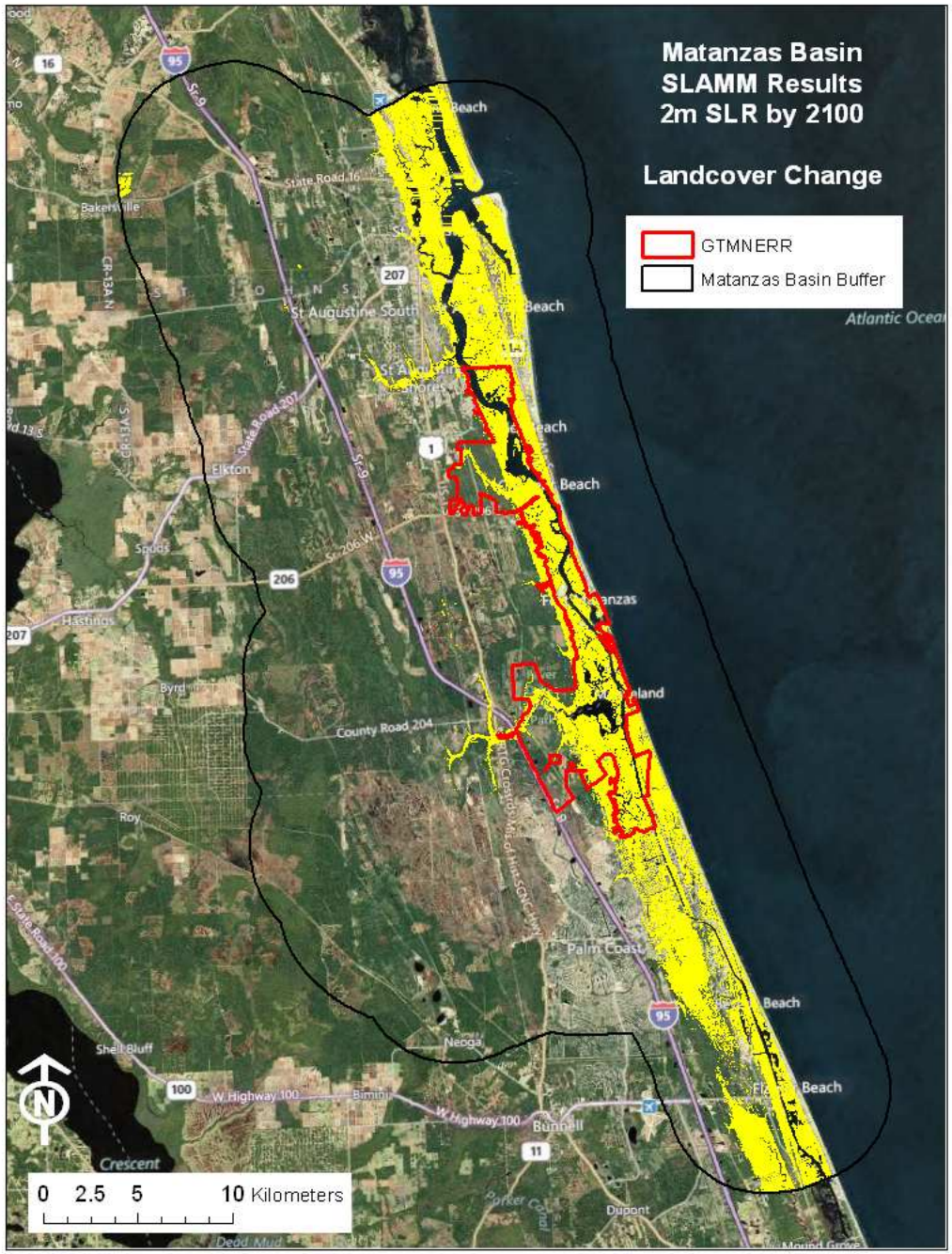



Developed Uplands
Area (ha)
Year
0.2m
0.5m
1m
1.5m
2m
2.5m

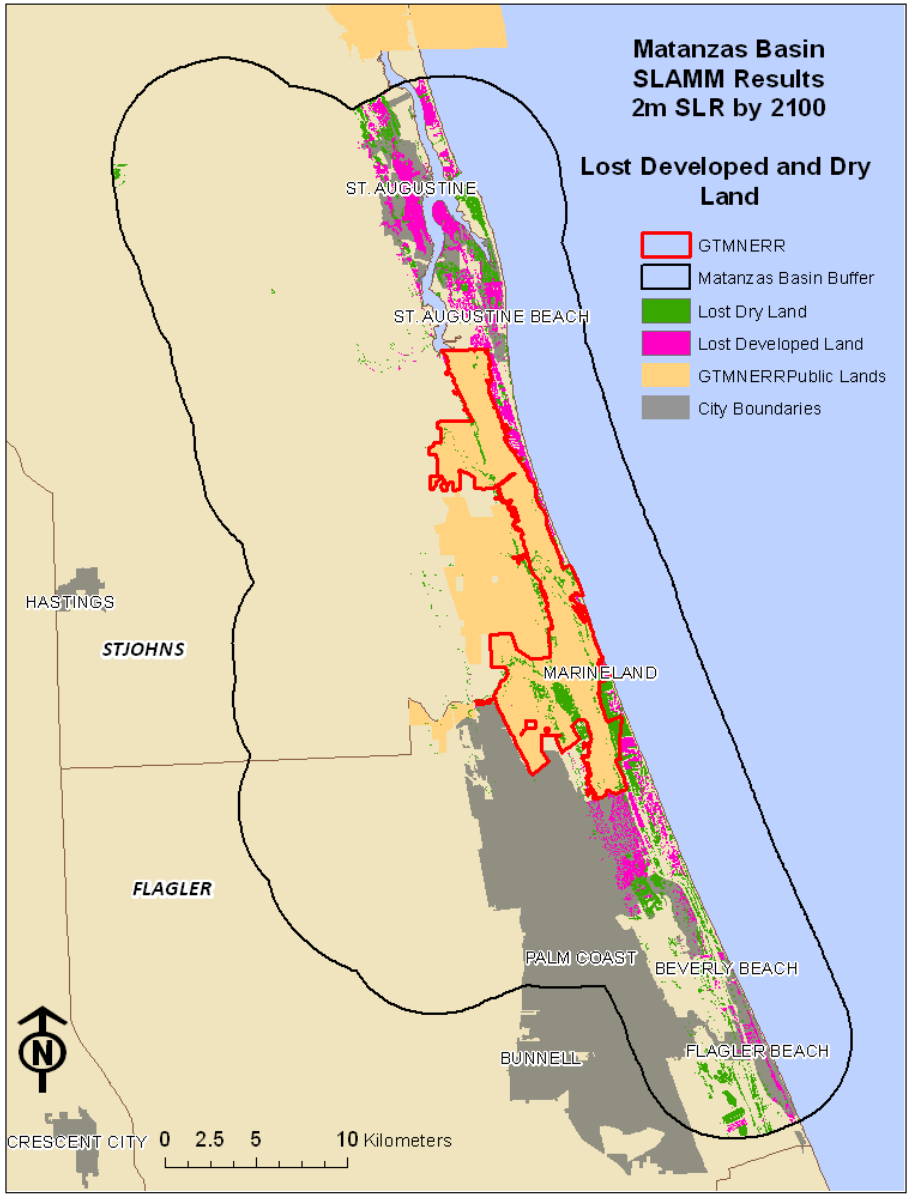

Undeveloped Uplands
Area (ha)
Year
0.2m
0.5m
1m
1.5m
2m
2.5m

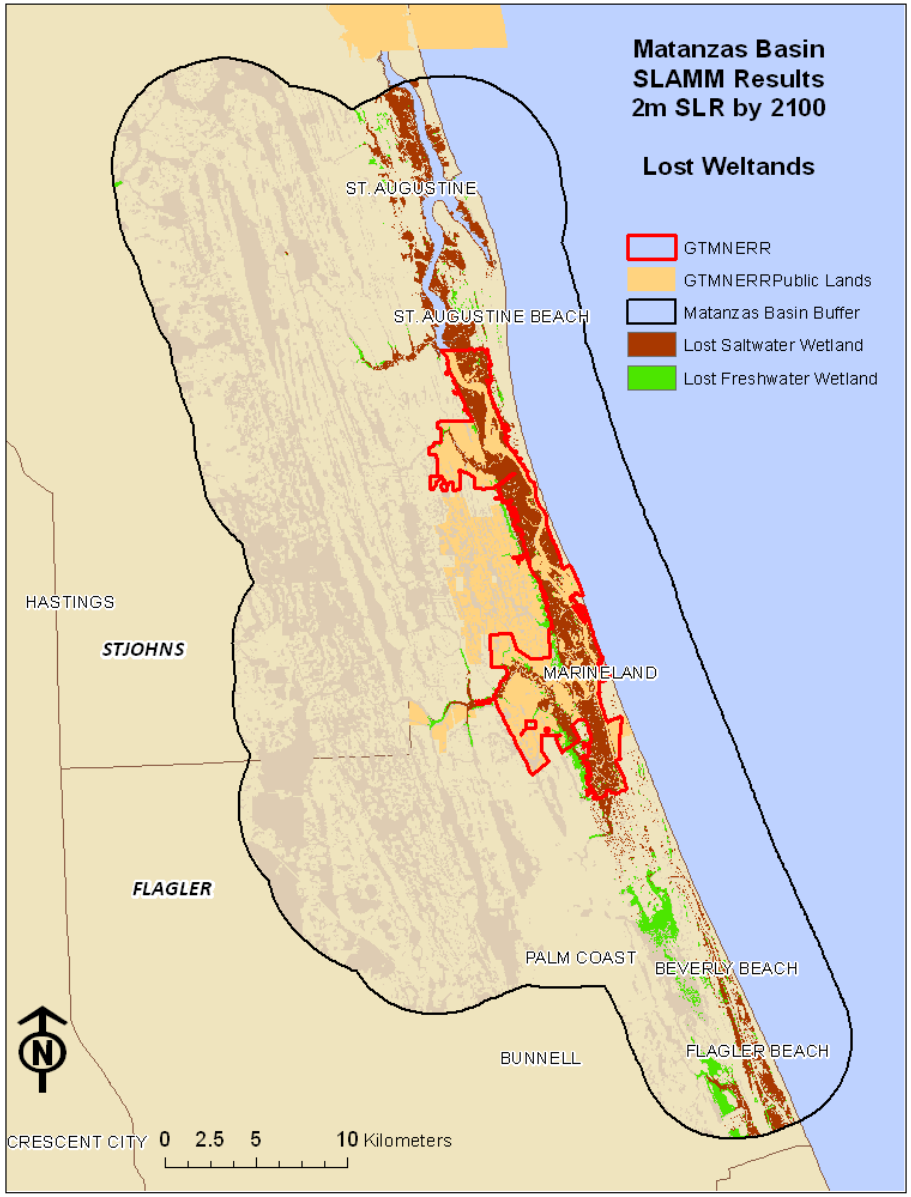

Saltwater Wetlands
Area (ha)
Year
0.2m
0.5m
1m
1.5m
2m
2.5m


Freshwater Wetlands
Area (ha)
Year
0.2m
0.5m
1m
1.5m
2m
2.5m

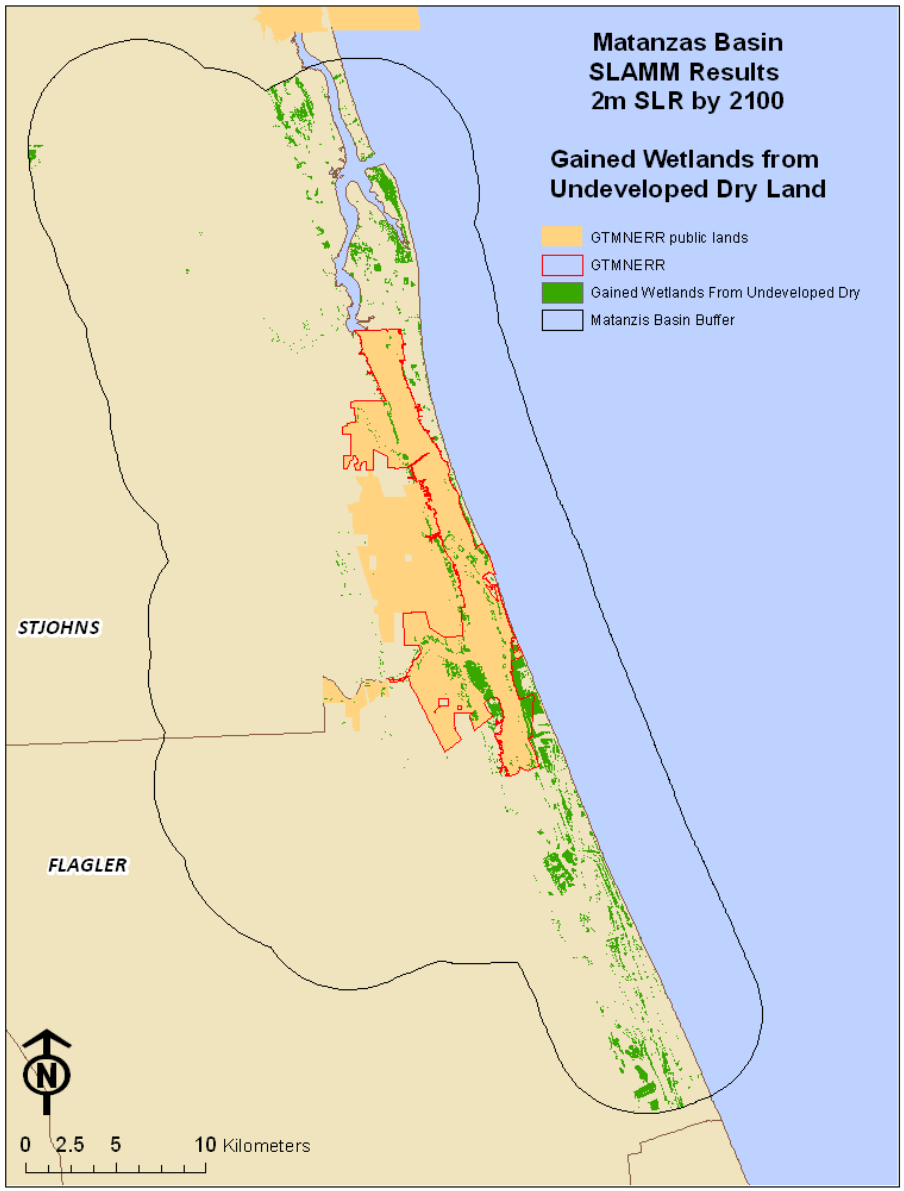

Matanzas Basin
SLAMM Results
2m SLR by 2100
Landcover Change
GTMNERR
Matanzas Basin Buffer
Atlantic Ocean
St Augustine South
Elkton
Hastings
Bakersville
Palm Coast
Bunnell
Dupont
Crescent
Shell Bluff
Neoga
Roy
Byrd
County Road 204
State Road 16
State Road 207
W Highway 100
0 2.5 5 10 Kilometers

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





Where might we gain wetlands outside of developed areas?



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**
- 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)

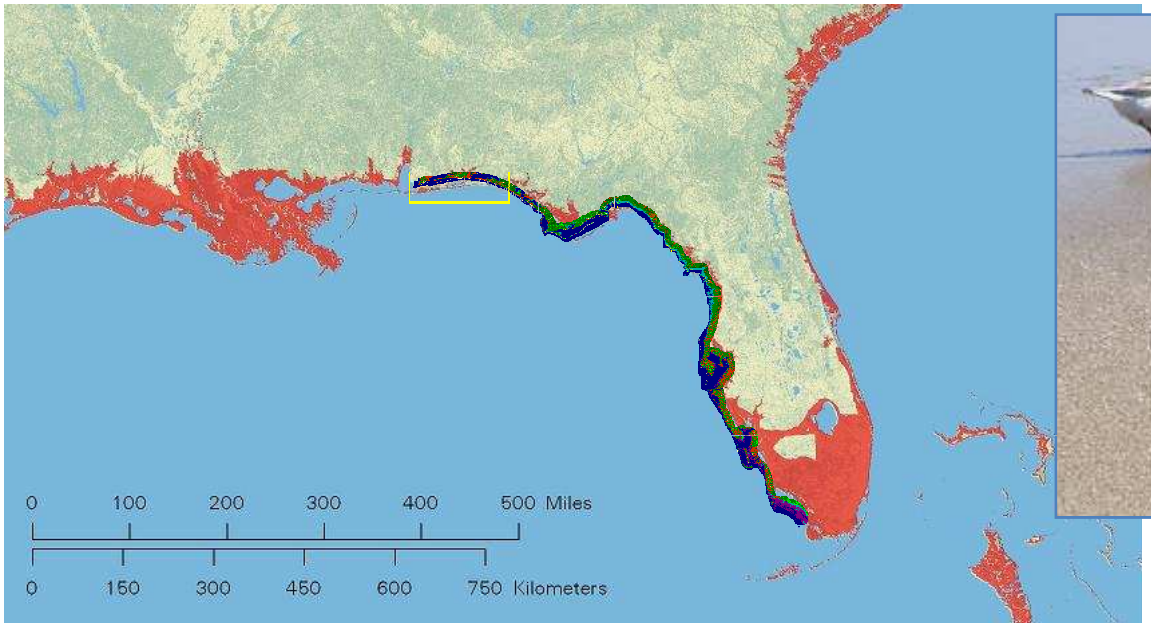
UF UNIVERSITY of FLORIDA

UNIVERSITY OF KWAZULU-NATAL

South African NATIONAL PARKS

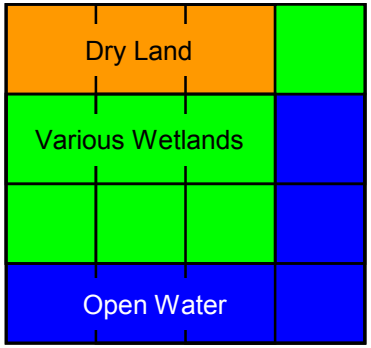
Strategic Environmental Research and Development Program (SERDP): Linking models to management outcomes - Florida Snowy Plover Populations and Sea Level Rise

(Partners: US Army Corps of Engineers, Univ of Florida, SUNY Stoney brook



Global Sensitivity/Uncertainty Analysis
Multi-Criteria Decision Analysis

Sea Level Affecting Marshes Model (SLAMM)



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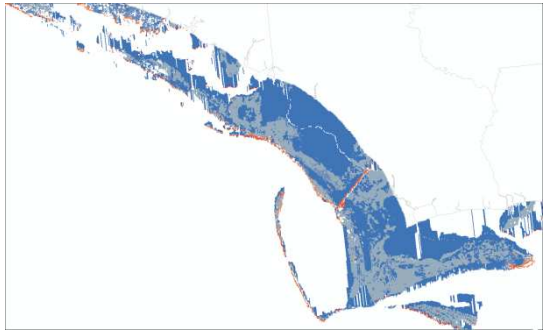
MaxEnt – Species Distribution Model



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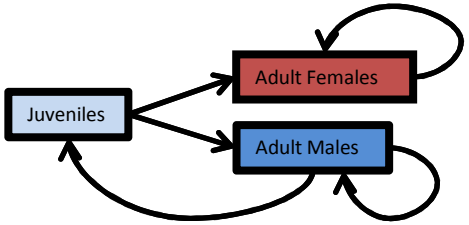
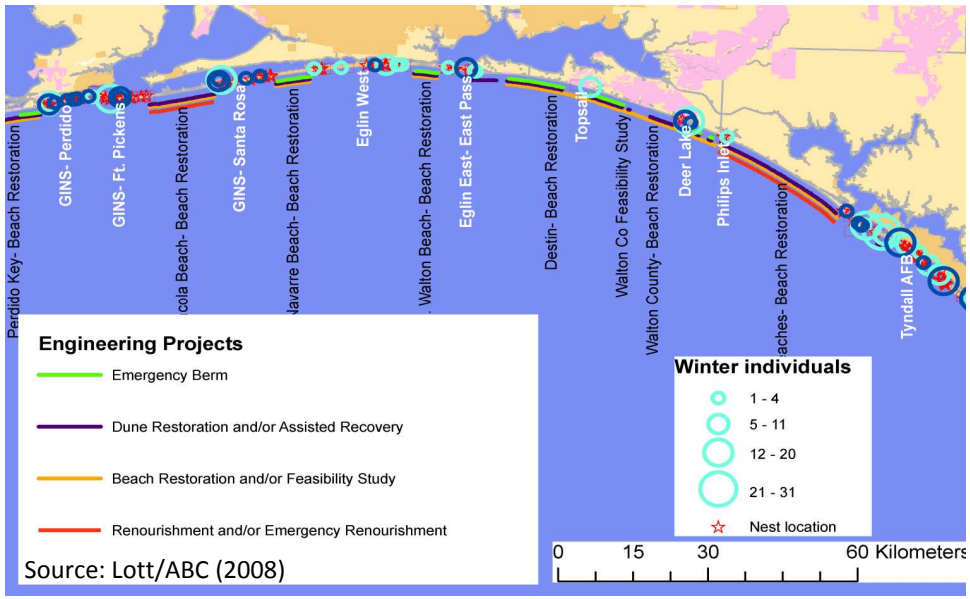
RAMAS MetaPopulation Model

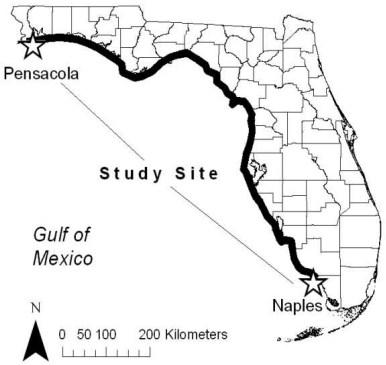


Why are military areas important habitats?

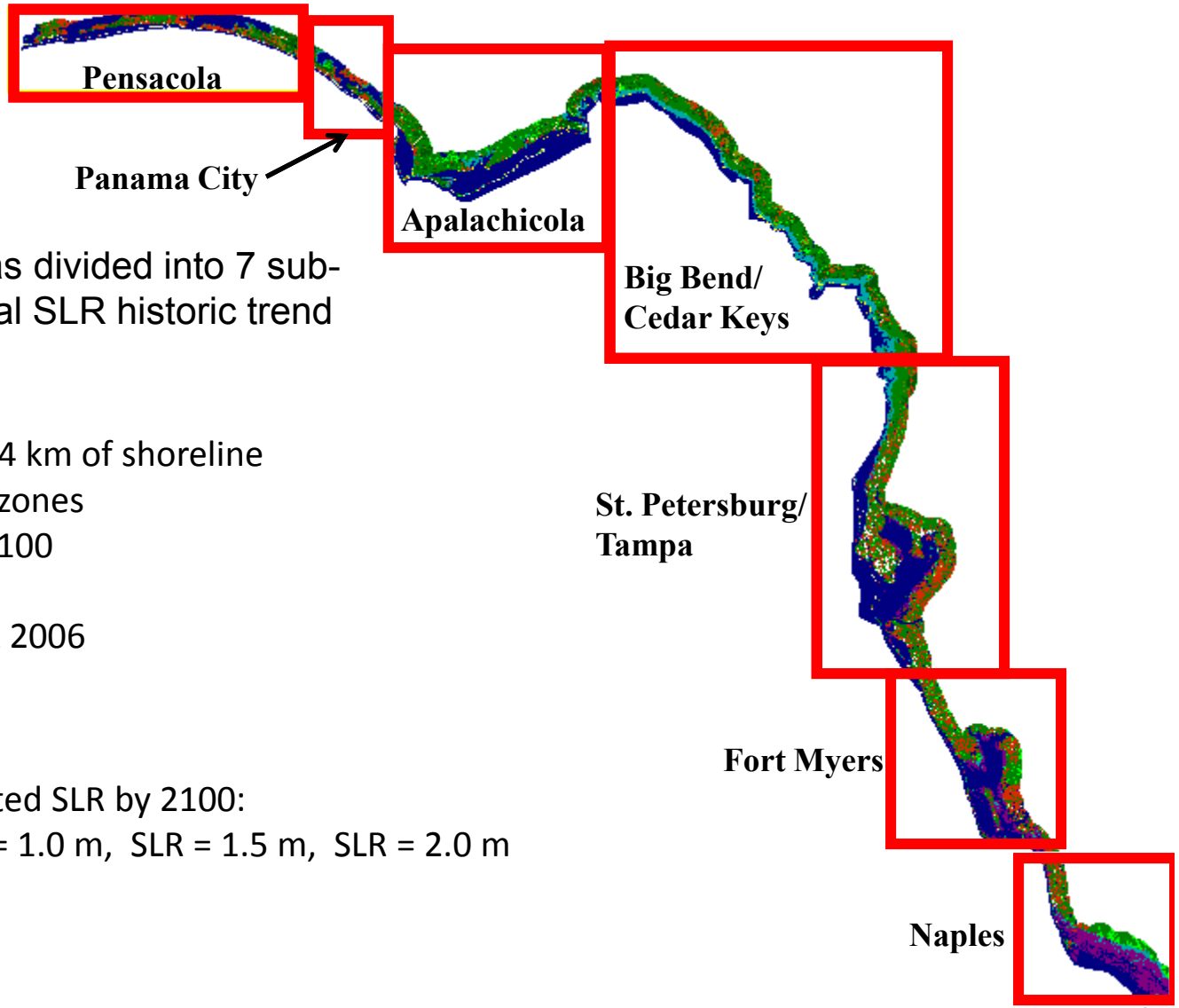
- Important forage areas and nesting habitats for shoreline birds



Source: Lott/ABC (2008)



Florida-Scale SLAMM v6 Simulations

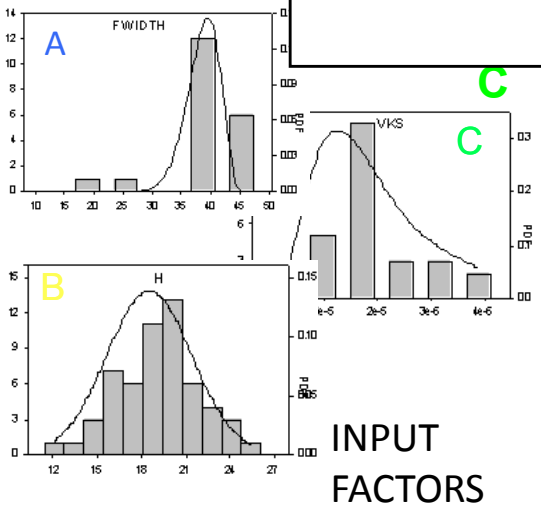


The Gulf coast of Florida was divided into 7 sub-sites based on available local SLR historic trend measurements

- 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

Global Sensitivity/Uncertainty Analysis



INPUT FACTORS

WHY/WHEN?

Apportions output variance into input factors

GLOBAL SENSITIVITY ANALYSIS

MODEL

? ? ?

OUTPUTS

UNCERTAINTY ANALYSIS

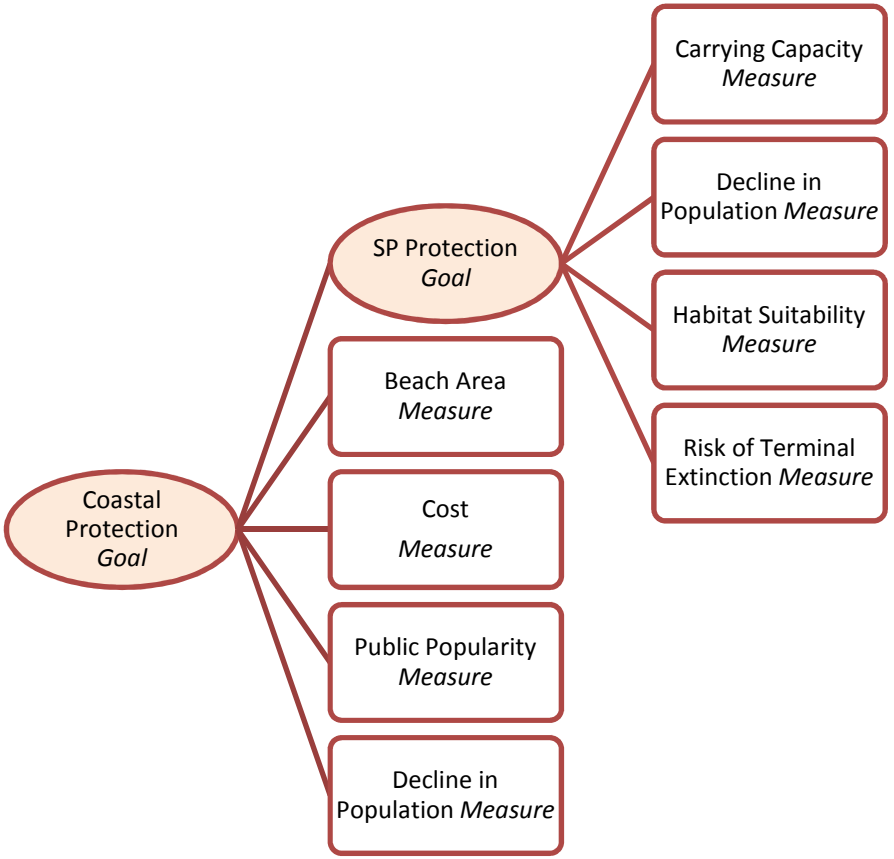
HOW MUCH?

Propagates input factor variability into output

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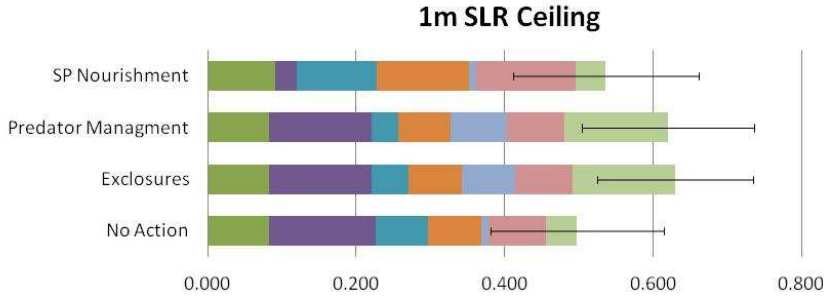
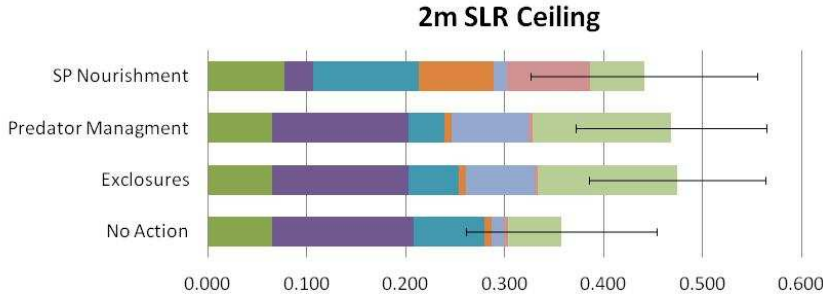
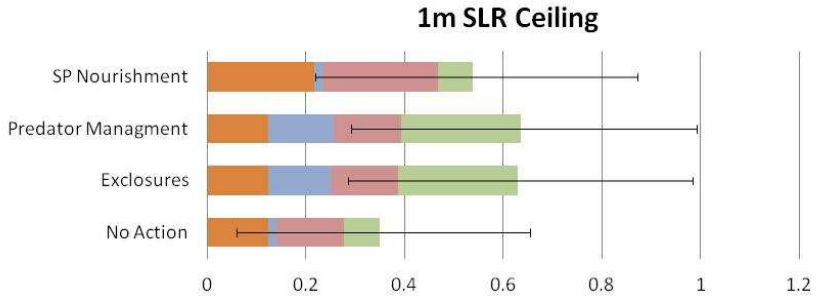
Decision Analysis allows the combination of model uncertainty with different stakeholder valuations

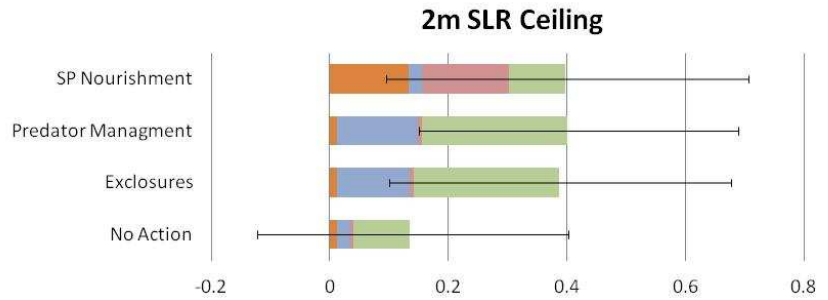
Goal: Coastal Protection

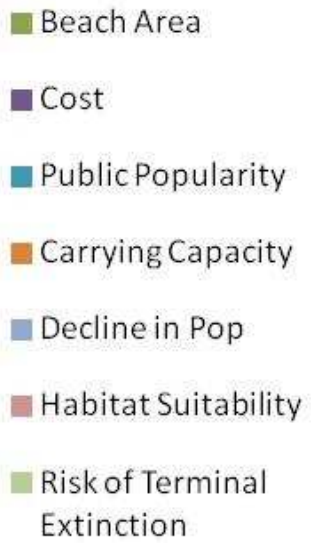




Goal: Plover Protection





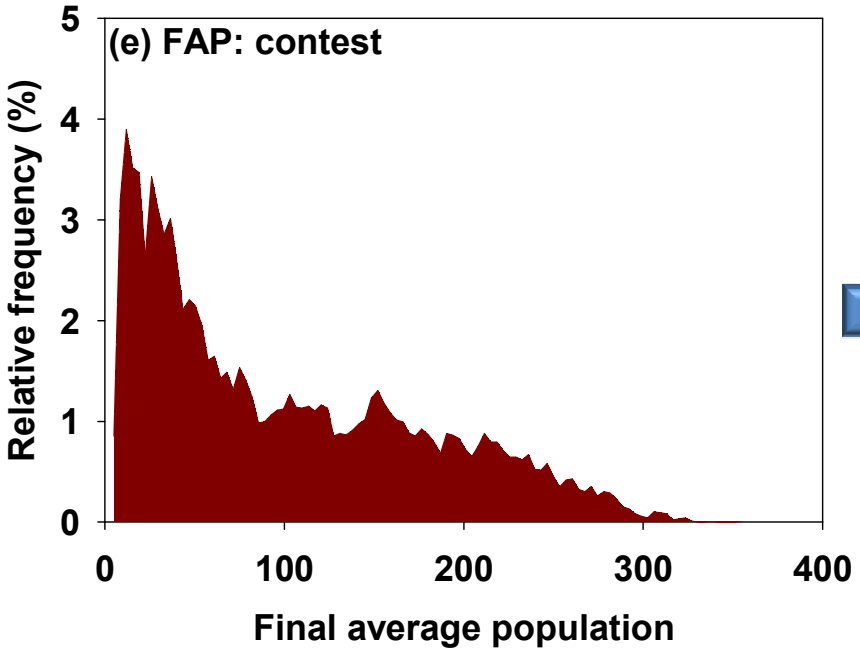


Exploring the conditions for success: Linking GSA/UA to management outcomes- Florida Snowy Plover Populations and Sea Level Rise

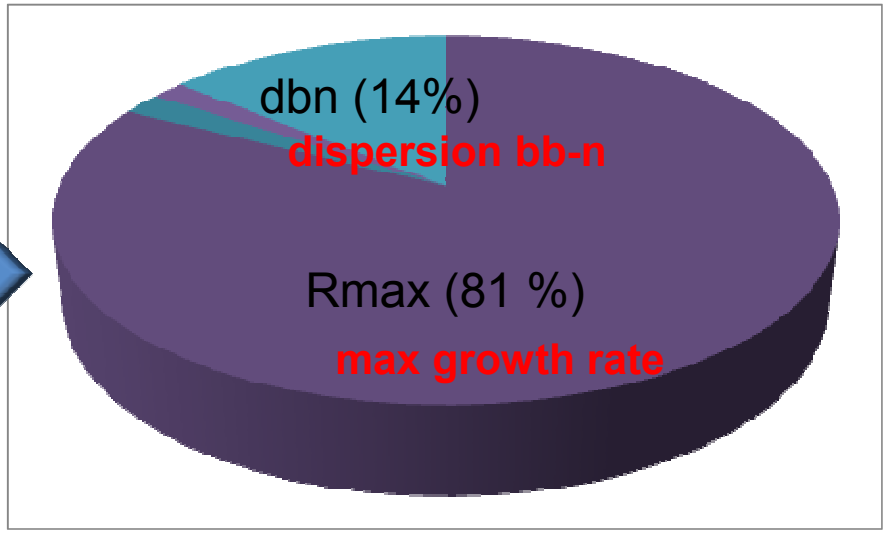
Final Average Snowy Plover Population in 2100 over the entire FL Gulf coast

(RAMAS model)

Uncertainty analysis tells you this



Sensitivity analysis

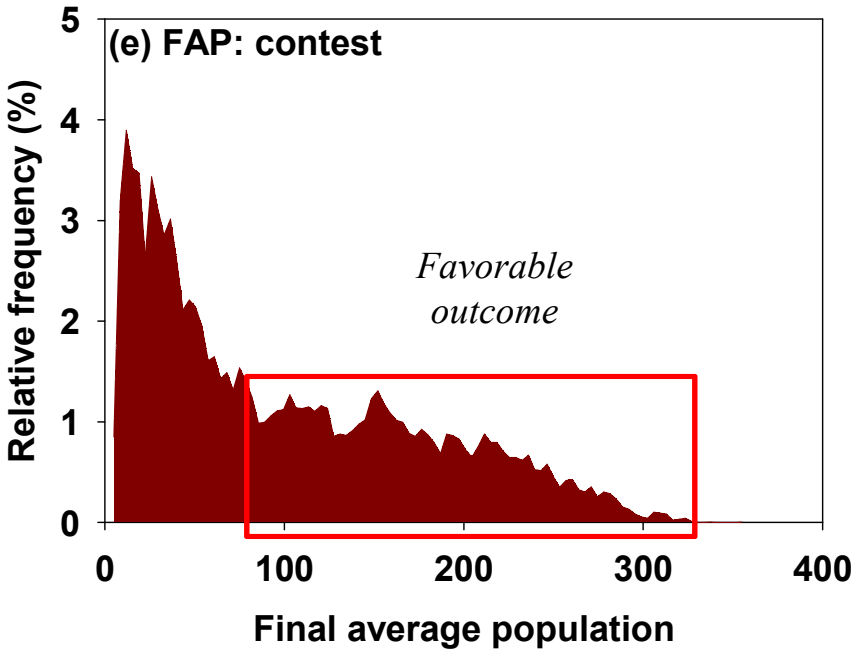


So, this tells us that growth rate and dispersion are critical, but can we control them with management?

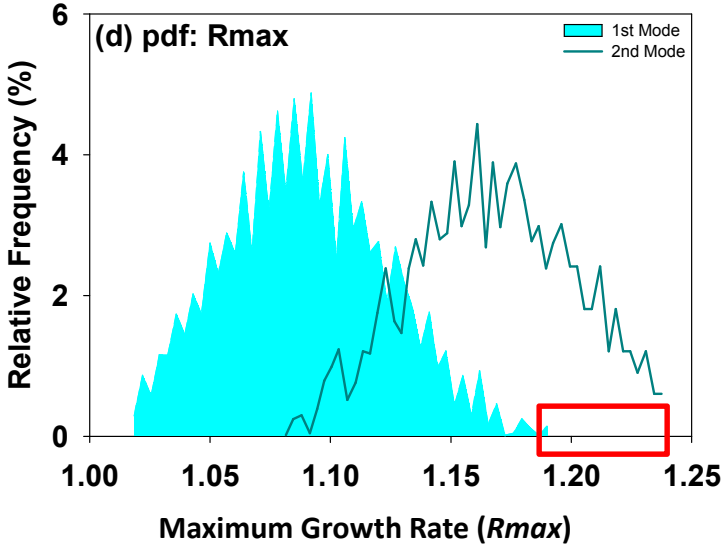
What are the conditions for success and can we control them?

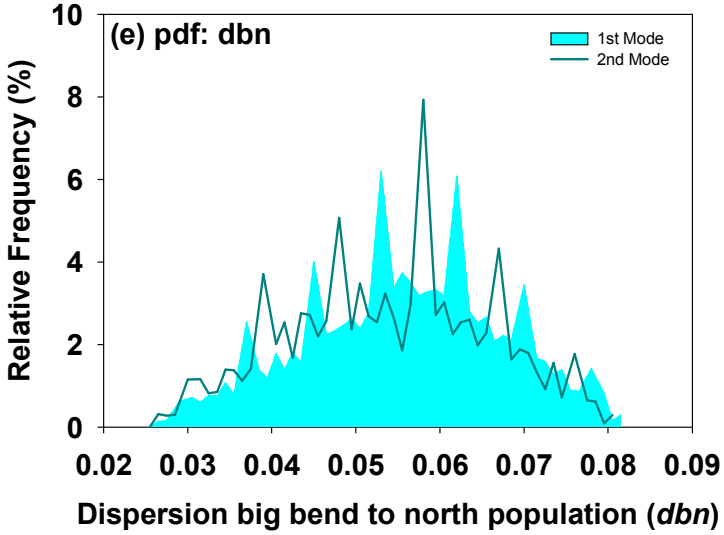
Output: Final Average Population

TPC: Final Average Population > 80



Ranges of Inputs

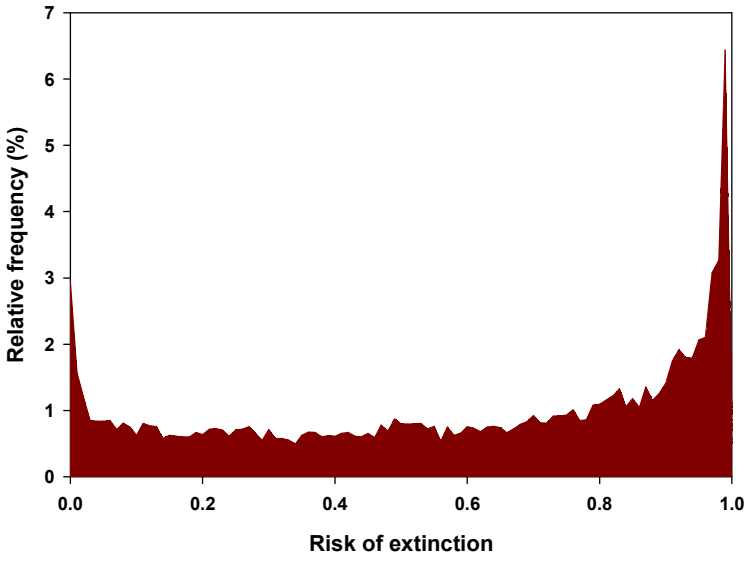




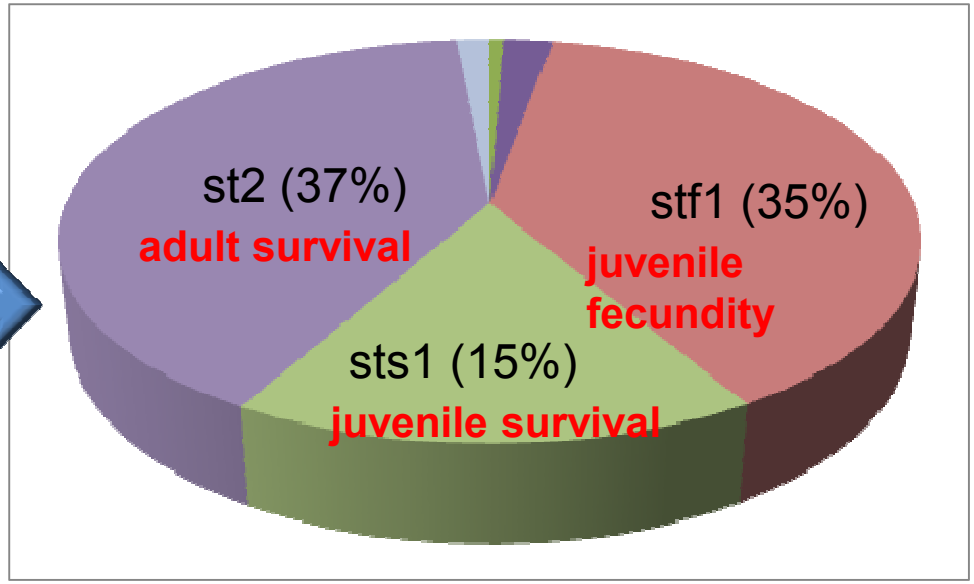
Let's look at another metric of management interest: Snowy Plover Risk of Extinction

Risk of Extinction

Uncertainty analysis

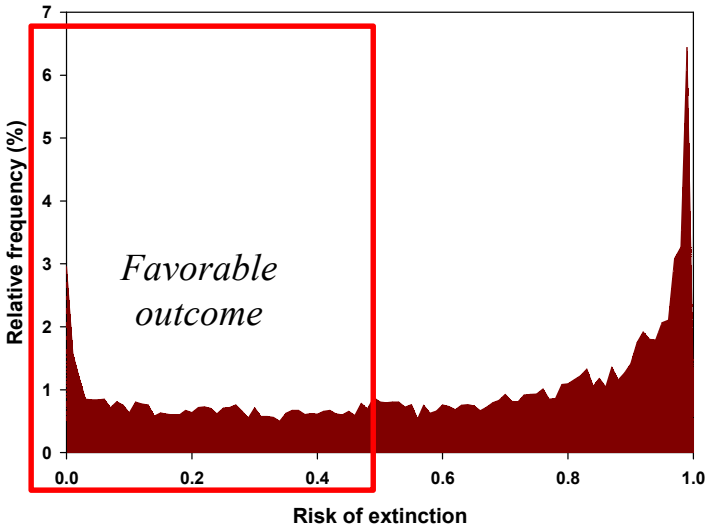


Sensitivity analysis

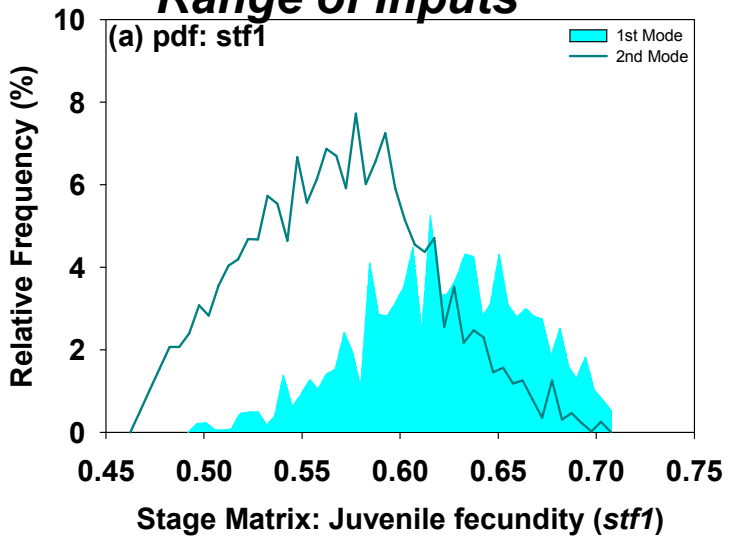


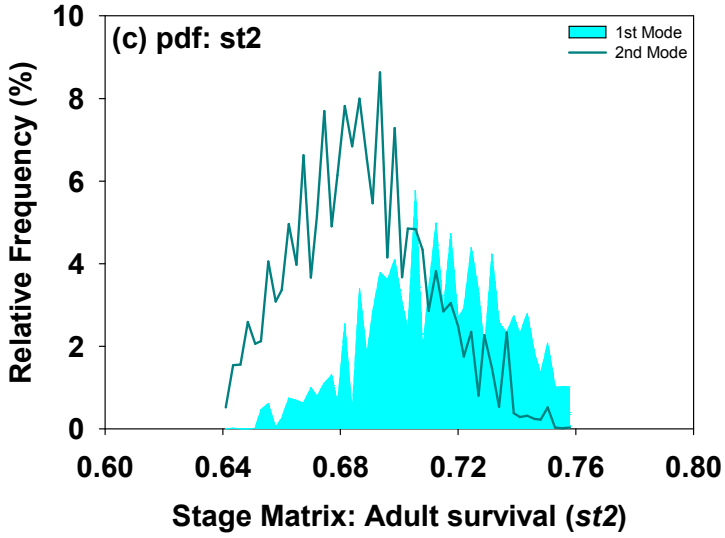
System uncertainty and management outcomes: Snowy Plover Risk of Extinction

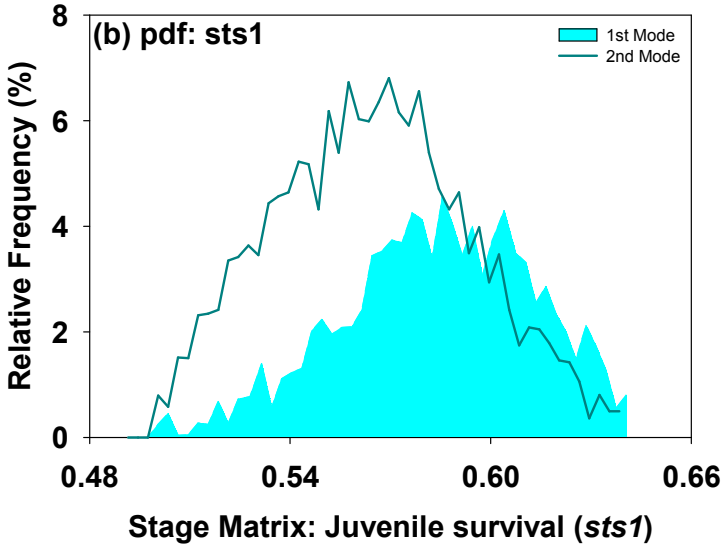
Output: Risk of Extinction
TPC: Risk < 50%



Range of Inputs







Decision Analysis Results

- The ranking of the alternatives is the same between 1 and 2 m SLR
- The ranking of the alternatives is different between contest and ceiling type density dependence
  - Ceiling Ranking: (1) Exclosures, (2) Predator Management, (3) Nourishment, and (4) No Action
  - Contest ranking: (1) Nourishment, (2) No Action, (3) Exclosures, and (4) Predator Management
- 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.
- JSMAA and Logical Decisions rank the alternatives the same.

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Conclusions and Implications for Future Research/Implementation

- The alternatives rank the same between the 1 and 2 m SLR scenarios but different between the contest and ceiling type density dependence.
  - Density dependence describes how a population grows relative to its population size.
    - In ceiling density dependence, the population grows exponentially until it reaches its carrying capacity.
    - In contest density dependence growth is a function of the current population size and the carrying capacity.
    - This MCDA shows that more information on density dependence is necessary to be able to select an optimal management alternative.
- SLAMM runs do not account for future armoring. This will decrease beach area and snowy plover habitat further

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Lessons 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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Outline

1. Motivation: decisions and uncertain information
2. Water resources in the southern USA: O way down south in Dixie … there's a water war …
3. Sea Level Rise: because nothing focuses a person's attention like the ocean moving toward your house…
4. Summing Up

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Lessons for the RSA and the USA

- Climate change/variation will not only change things…
- It will change how we think about things…
- Lessons from the USACE
  - Be the bearer of your own bad news
  - Keep engaging even when they yell at you
- Lessons for anyone
  - Have some numbers before someone gives them to you…
  - Short term fixes are exactly that… at what cost?

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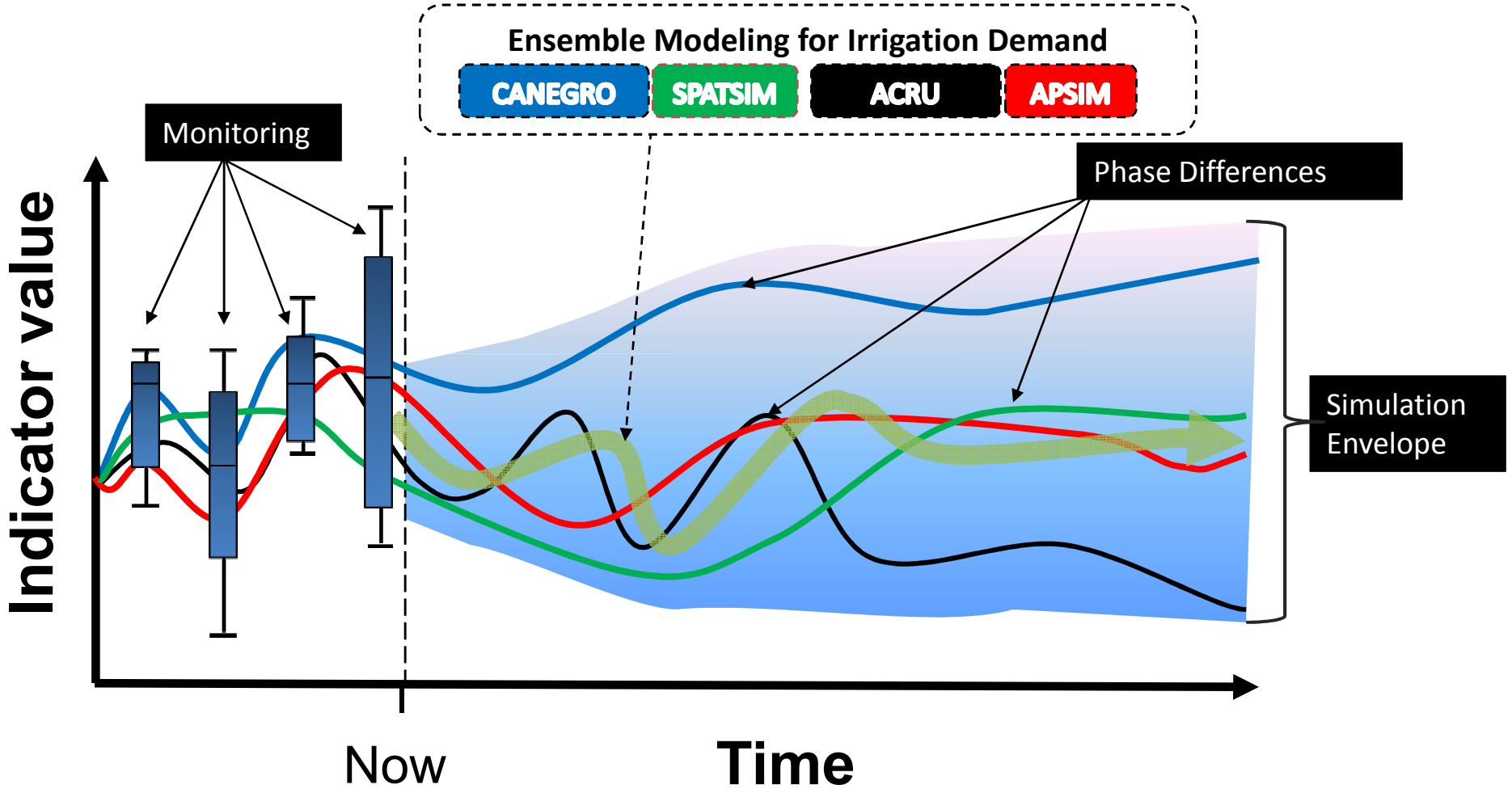
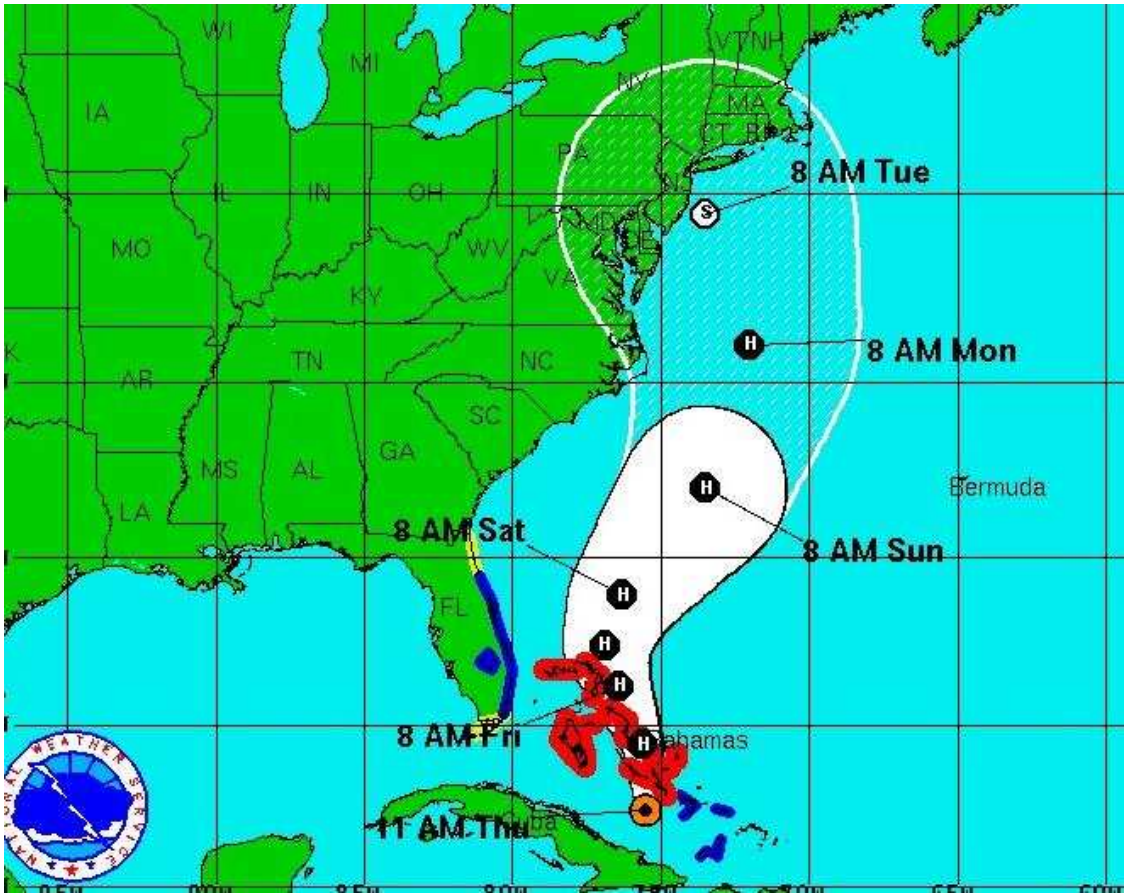
So, What About the Future? Ensemble modeling allows simulation and combination of models in uncertain futures

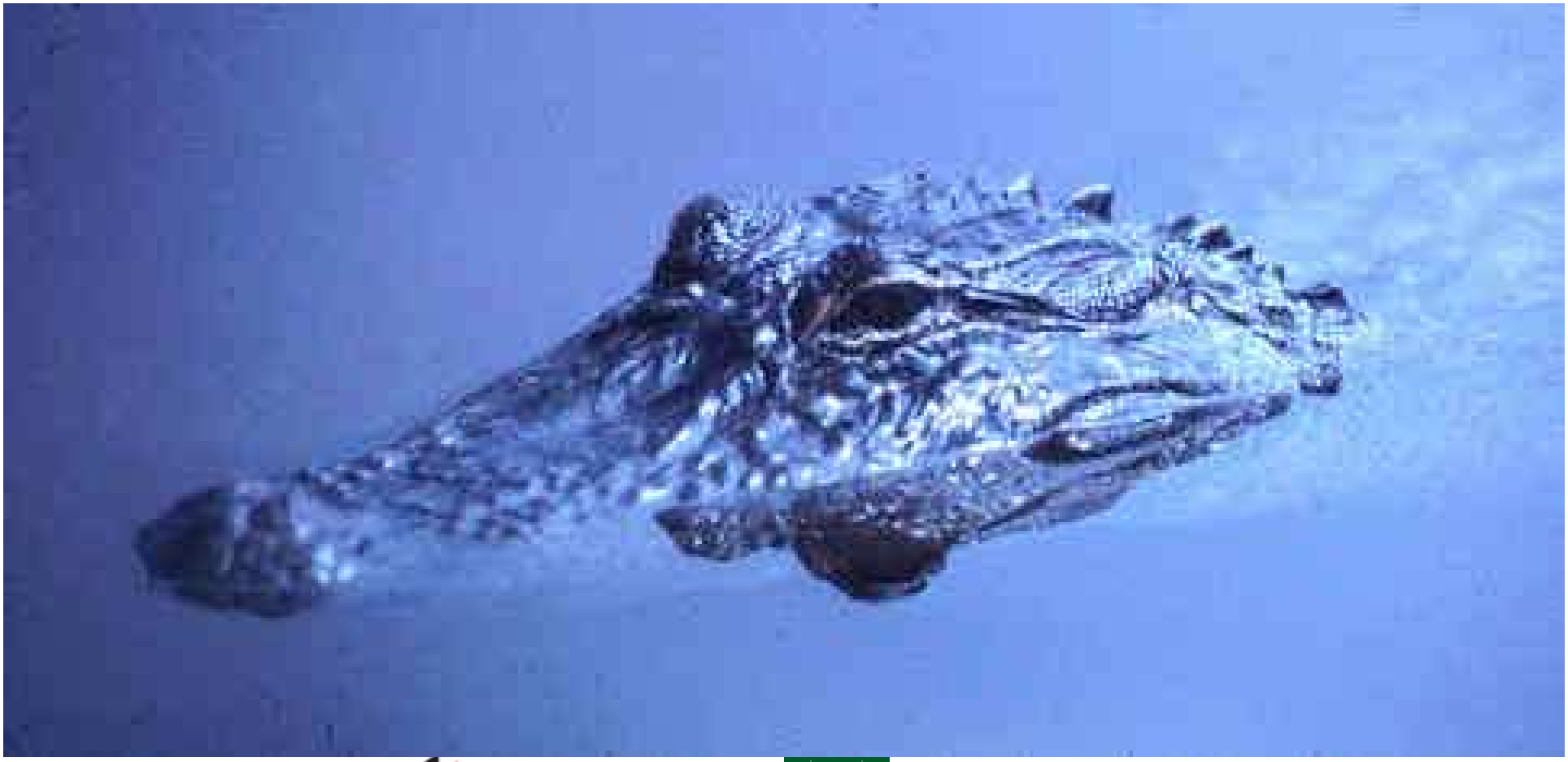


Discussion - How does society handle uncertainty/complexity?

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



Thank you for your attention



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