Predicting Coastal Landscape Changes by Modeling Long-Timescale Impacts of Hydrodynamic Fluctuations on Salinity and Hydroperiods

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Past and Future Impacts of Sea Level Rise on Coastal Habitats and Species:
Long-term hydrologic effects on coastal landscapes influenced by:

- Tidal fluctuations
- Wind driven seiches
- Storm events

Static representations and simplified flow equations cannot represent these factors

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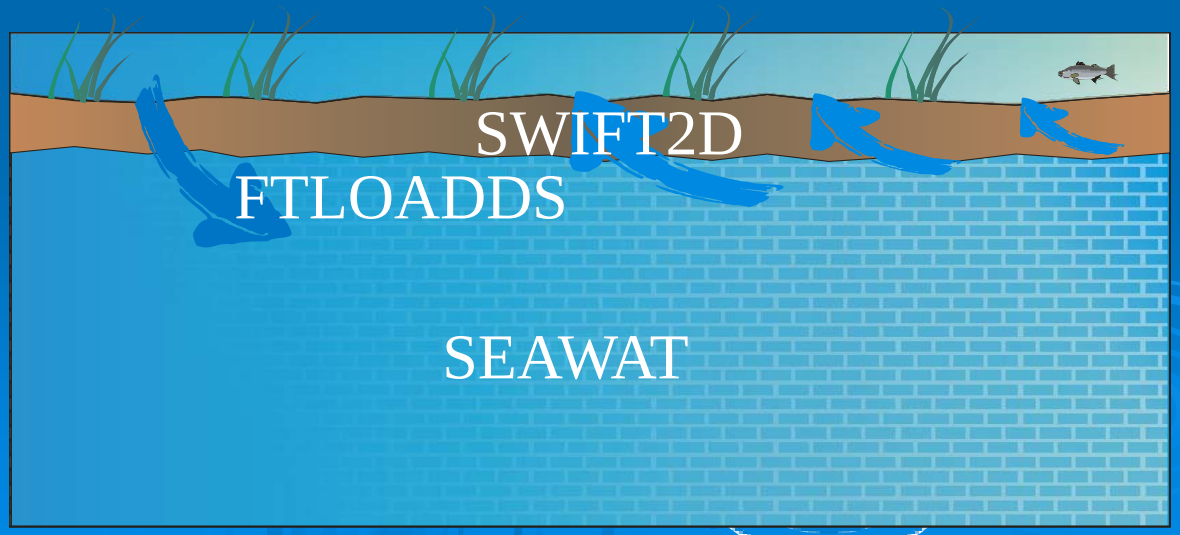
USGS numerical model

- FTLOADDS (Flow and Transport in a Linked Overland/Aquifer Density Dependent System) Useful to look at water management because:
  - **SWIFT2D is a two-dimensional hydrodynamic surface-water model**
  - **SEAWAT is a three-dimensional ground-water flow model**
  - **Salinity transport is accounted for in both surface water and ground water**



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$$\frac{\partial z_1}{\partial t}+\frac{\partial (HU)}{\partial x}+\frac{\partial (HV)}{\partial y}=0$$

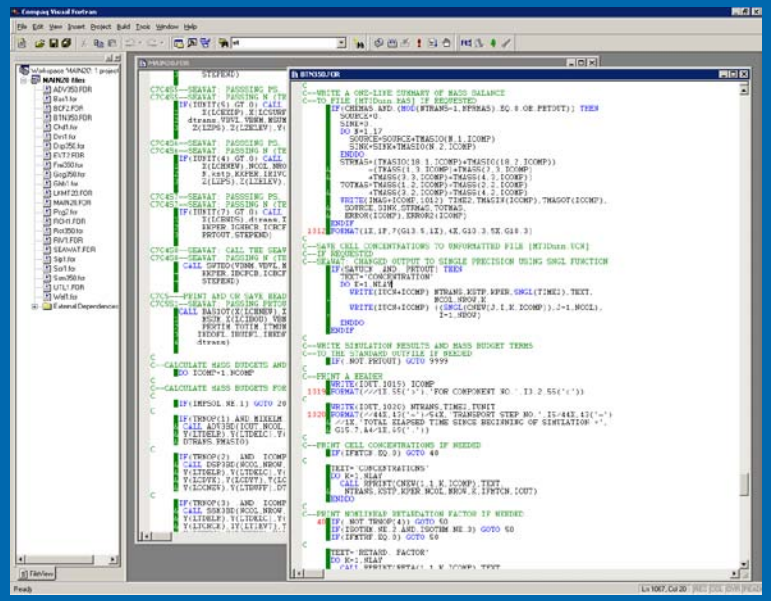
$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}-fV=$$
$$-g\frac{\partial z_1}{\partial x}-\frac{g}{2}\frac{H}{\rho}\frac{\partial \rho}{\partial x}-RU+\frac{C_d\rho_a W^2\sin\theta}{\rho H}+k_x\left[\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}\right]$$

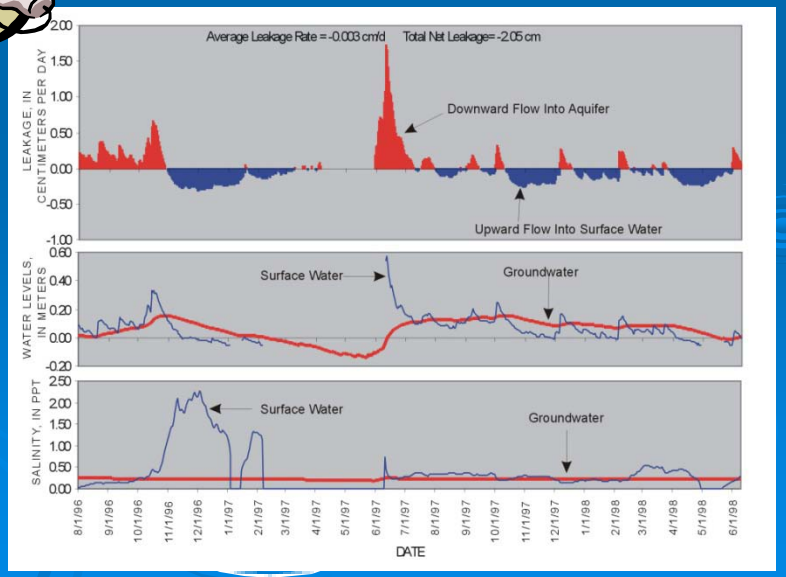
$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}-fU=$$
$$-g\frac{\partial z_1}{\partial y}-\frac{g}{2}\frac{H}{\rho}\frac{\partial \rho}{\partial y}-RV+\frac{C_d\rho_a W^2\cos\theta}{\rho H}+k_y\left[\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}\right]$$

$$\frac{\partial (HS)}{\partial t}+\frac{\partial (HUS)}{\partial x}+\frac{\partial (HVS)}{\partial y}+\frac{\partial}{\partial x}\left(HD_x\frac{\partial S}{\partial x}\right)+\frac{\partial}{\partial y}\left(HD_y\frac{\partial S}{\partial y}\right)+G=0$$

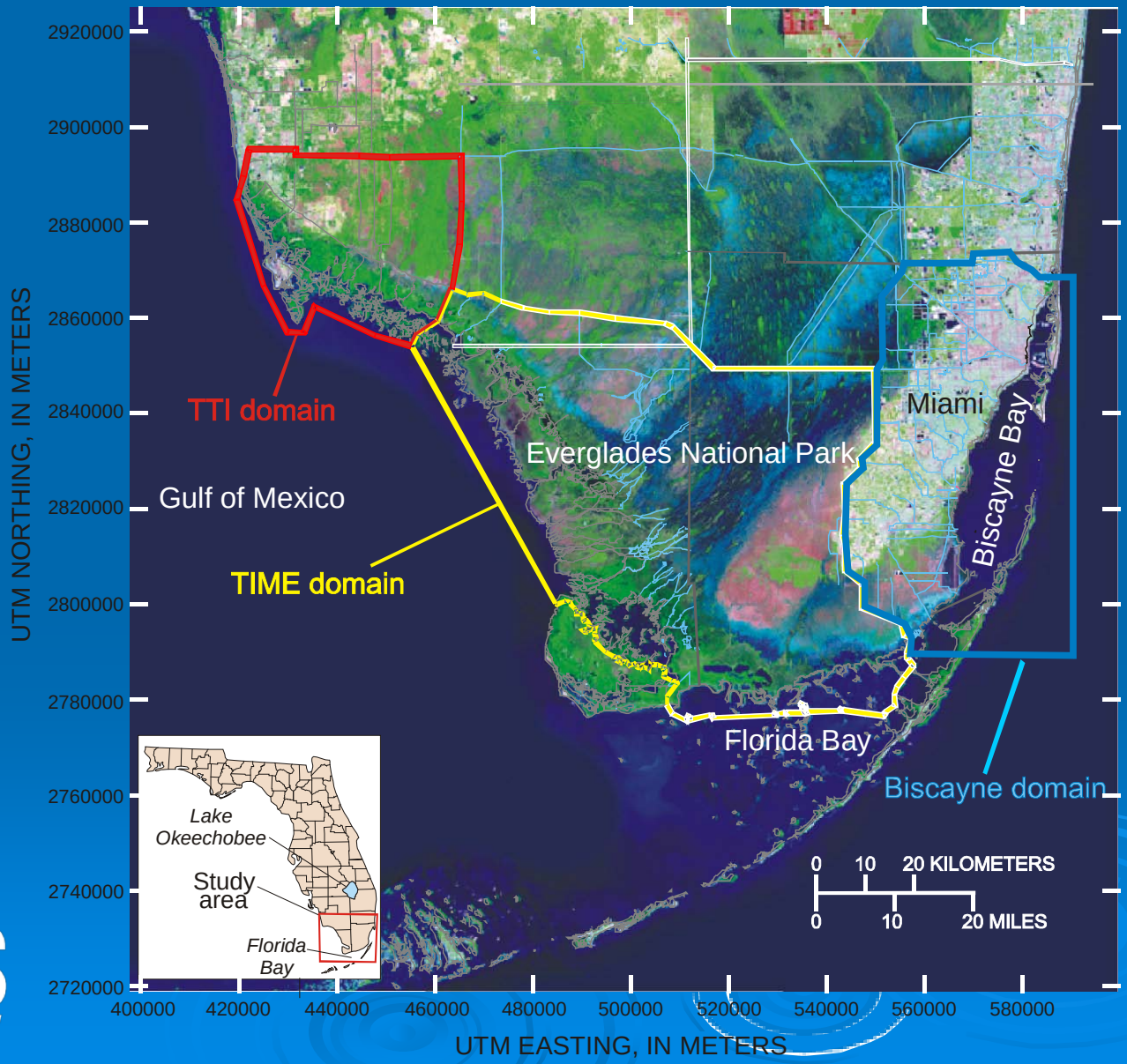
$$\frac{\partial}{\partial x}\left[\rho K_{fx}\left(\frac{\partial h_f}{\partial x}\right)\right]+\frac{\partial}{\partial y}\left[\rho K_{fy}\left(\frac{\partial h_f}{\partial y}\right)\right]+\frac{\partial}{\partial z}\left[\rho K_{fz}\left(\frac{\partial h_f}{\partial z}+\frac{\rho-\rho_f}{\rho_f}\right)\right]=\rho S_f\frac{\partial h_f}{\partial t}+n\frac{\partial \rho}{\partial C}\frac{dC}{\partial t}-\overline{q}_s$$

$$\frac{\partial C}{\partial t}=\nabla(D\nabla C)-\nabla\cdot(\vec{v}C)-\frac{q_s}{n}C_s$$





South Florida and Model Areas



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Hindcast Simulations

- Simulate historical period with FTLOADDS model to determine water levels, salinity, and flows
- Utilize model results for comparison with historic aerial photography and supply information for ecologic models

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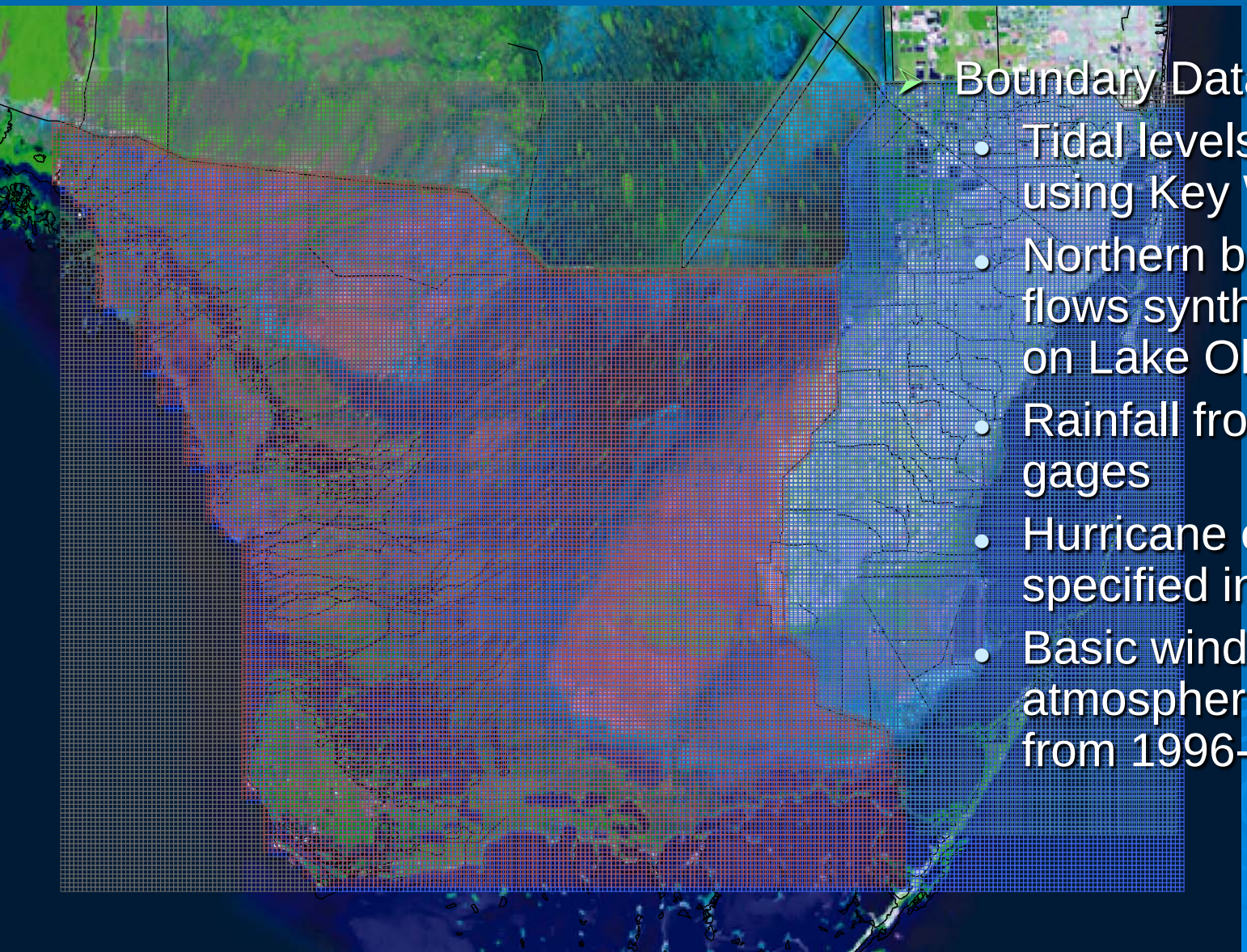
Data Input for Hindcast BISECT MODEL

Representing historical periods 1926-1932, 1934-1940, 1946-1952



- Boundary Data
  - Tidal levels adjusted using Key West record
  - Northern boundary flows synthesized based on Lake Okeechobee
  - Rainfall from historic gages
  - Hurricane events specified individually
  - Basic wind and atmospheric data used from 1996-2002

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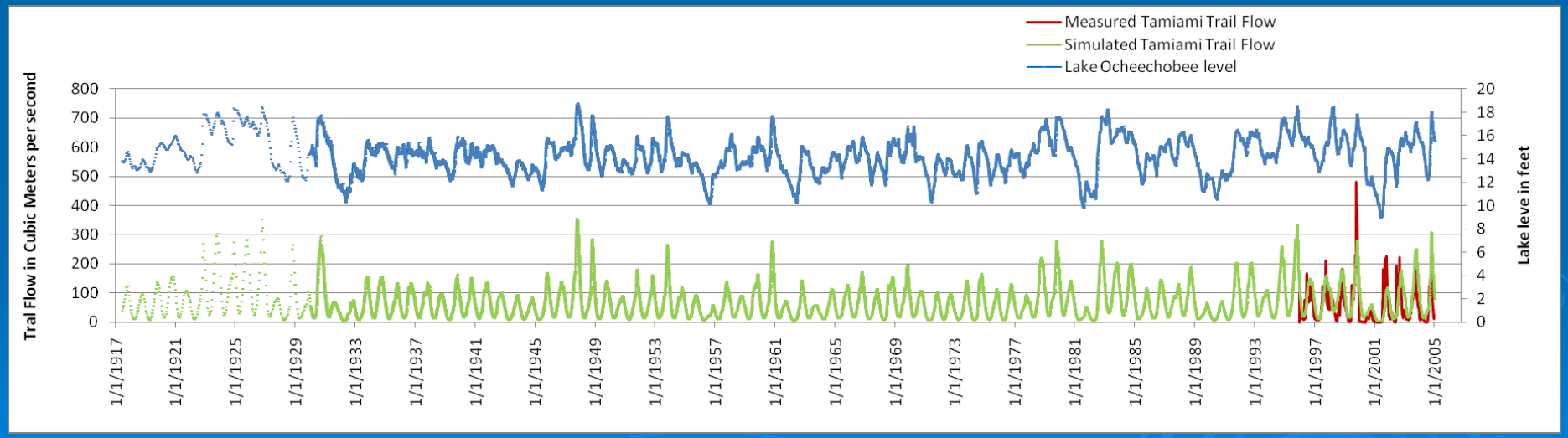
Tamiami Trail flows related to Lake Okeechobee levels

- Lake Okeechobee water-level record back to 1917
- Best fit function uses a Fourier series for the seasonal fluctuations and amplitude a function of Lake levels



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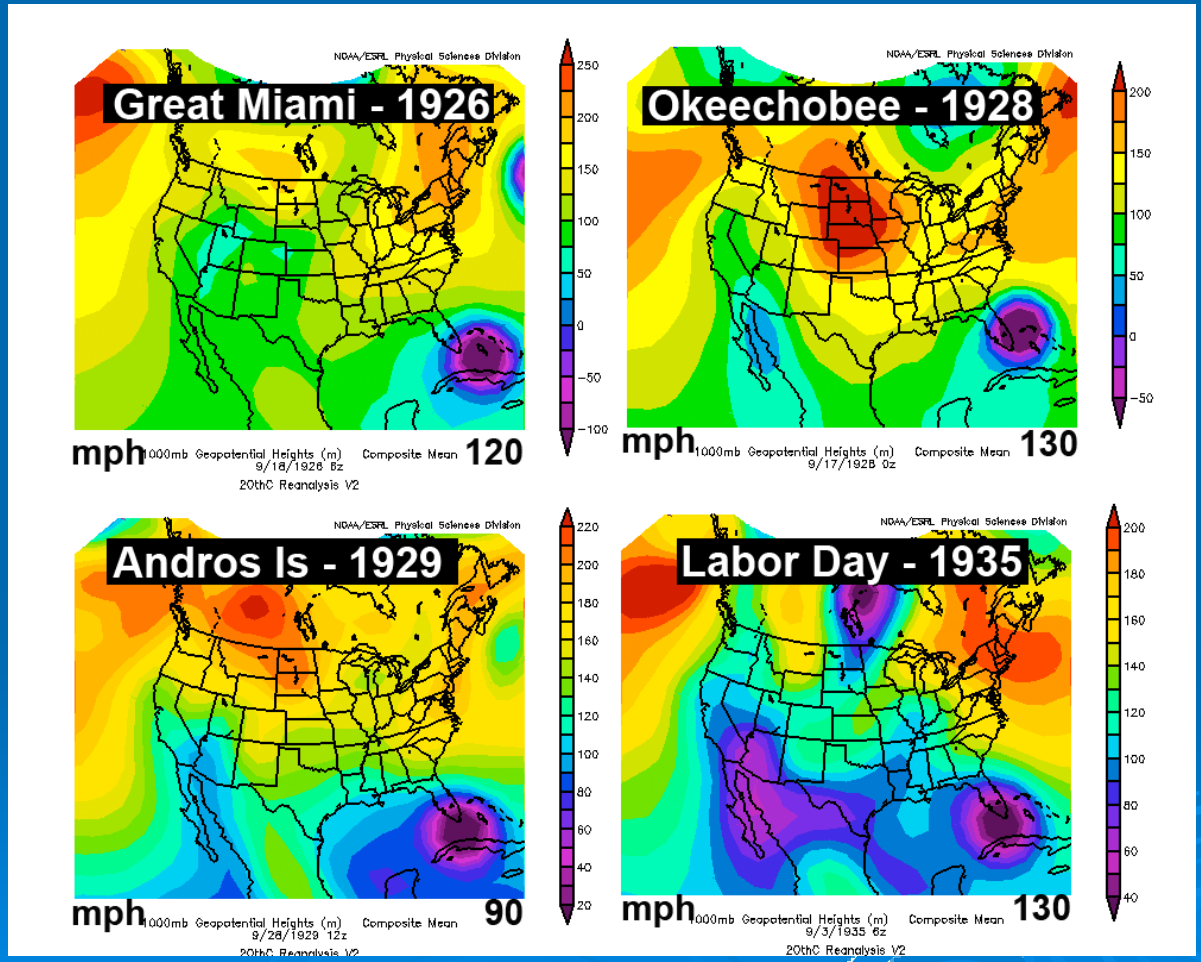
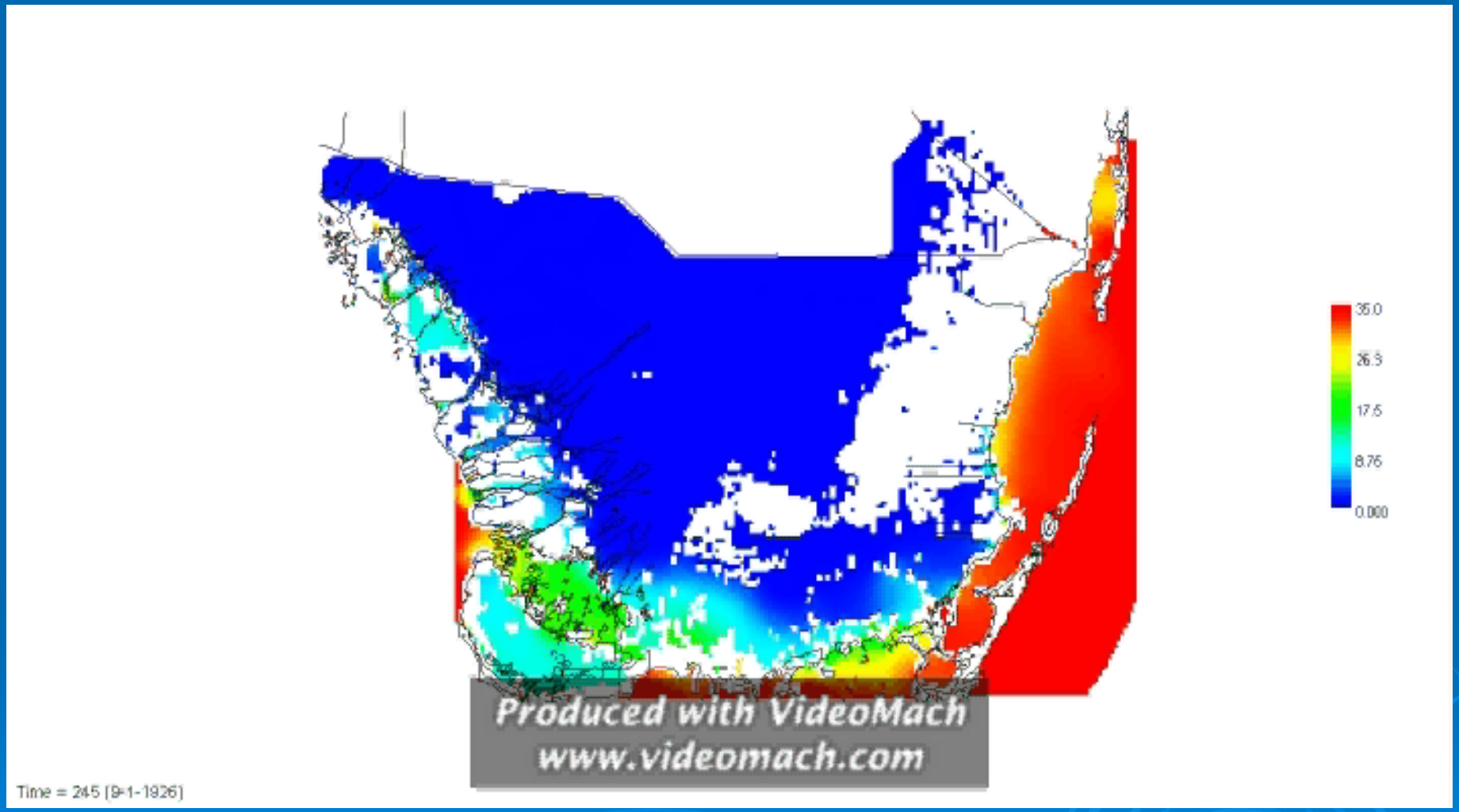
20th Century Reanalysis: Wind speed from Hurricane Tracks



Great Miami Hurricane of 1926



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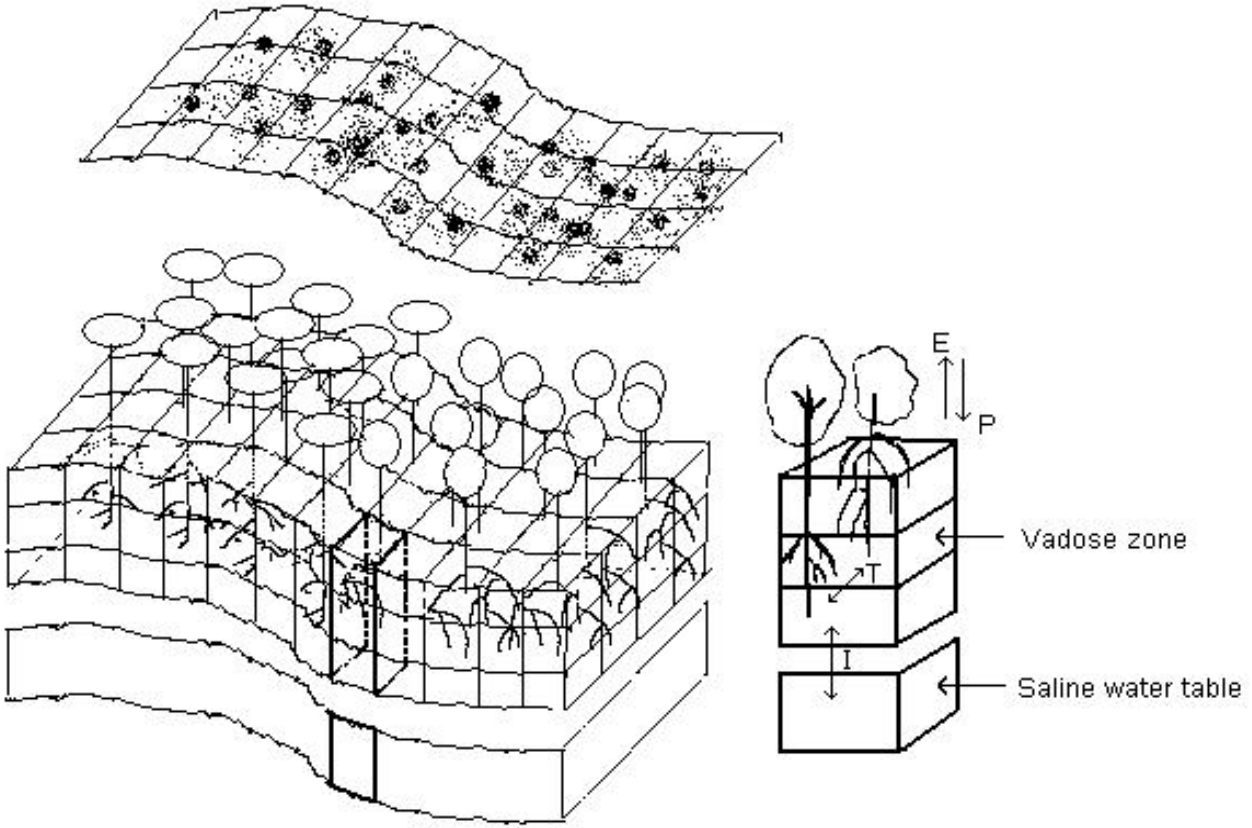
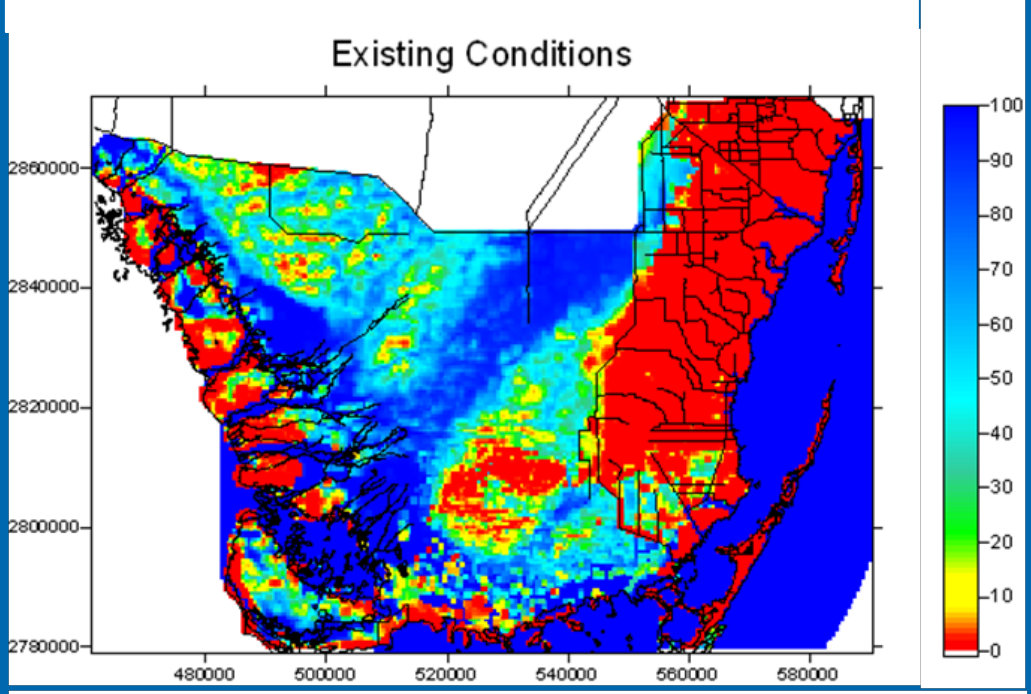
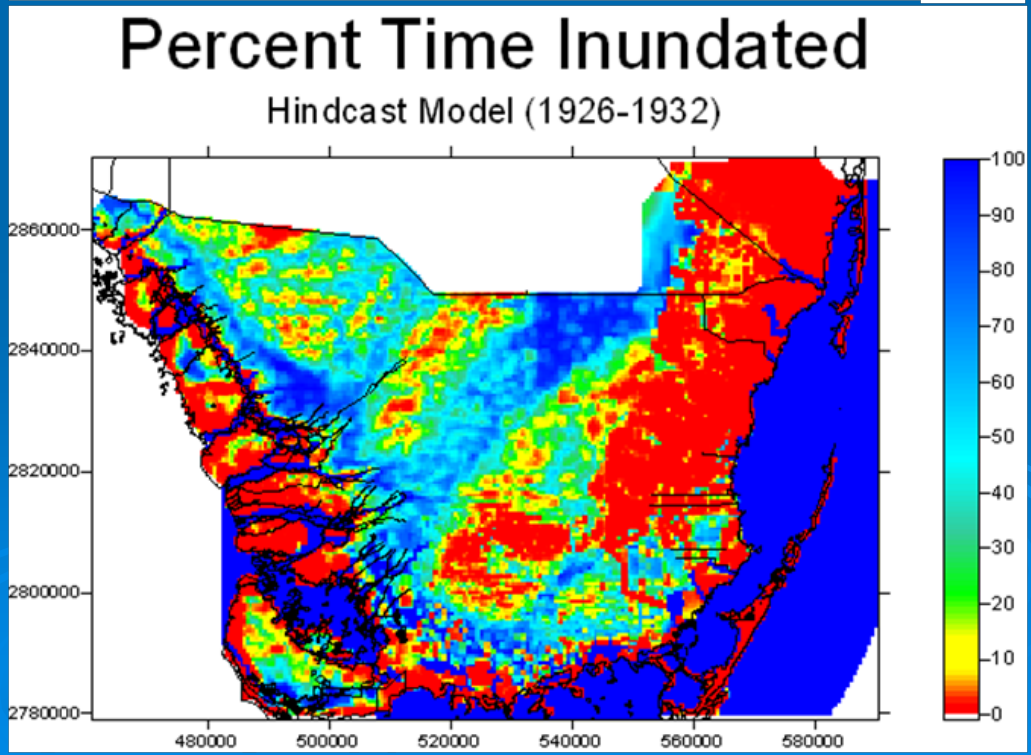
- September 18, 1926

Salinity washed on shore important to Mangrove-Hammock Model



Comparisons of the percent of time inundated indicate changes in hydrology





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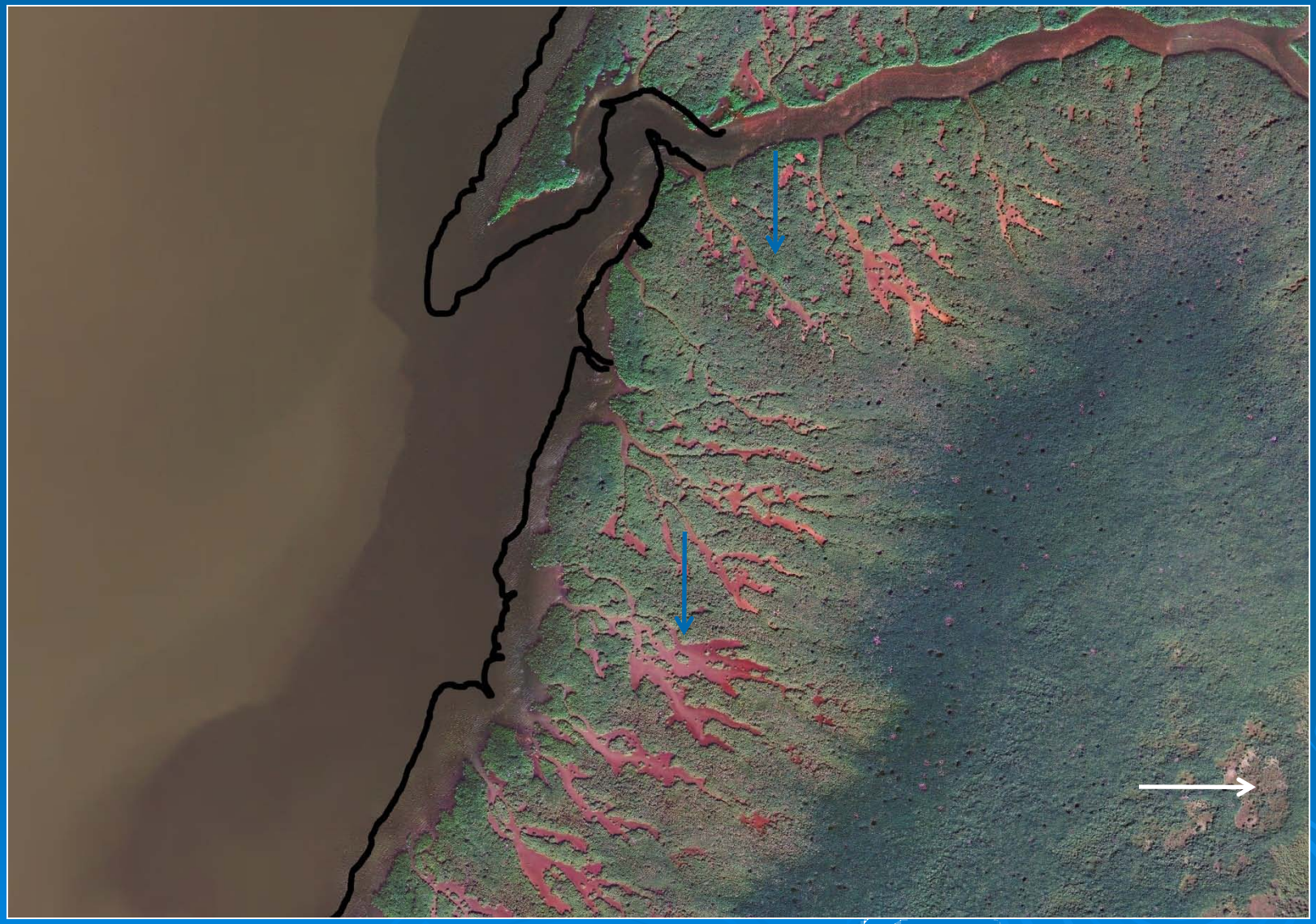
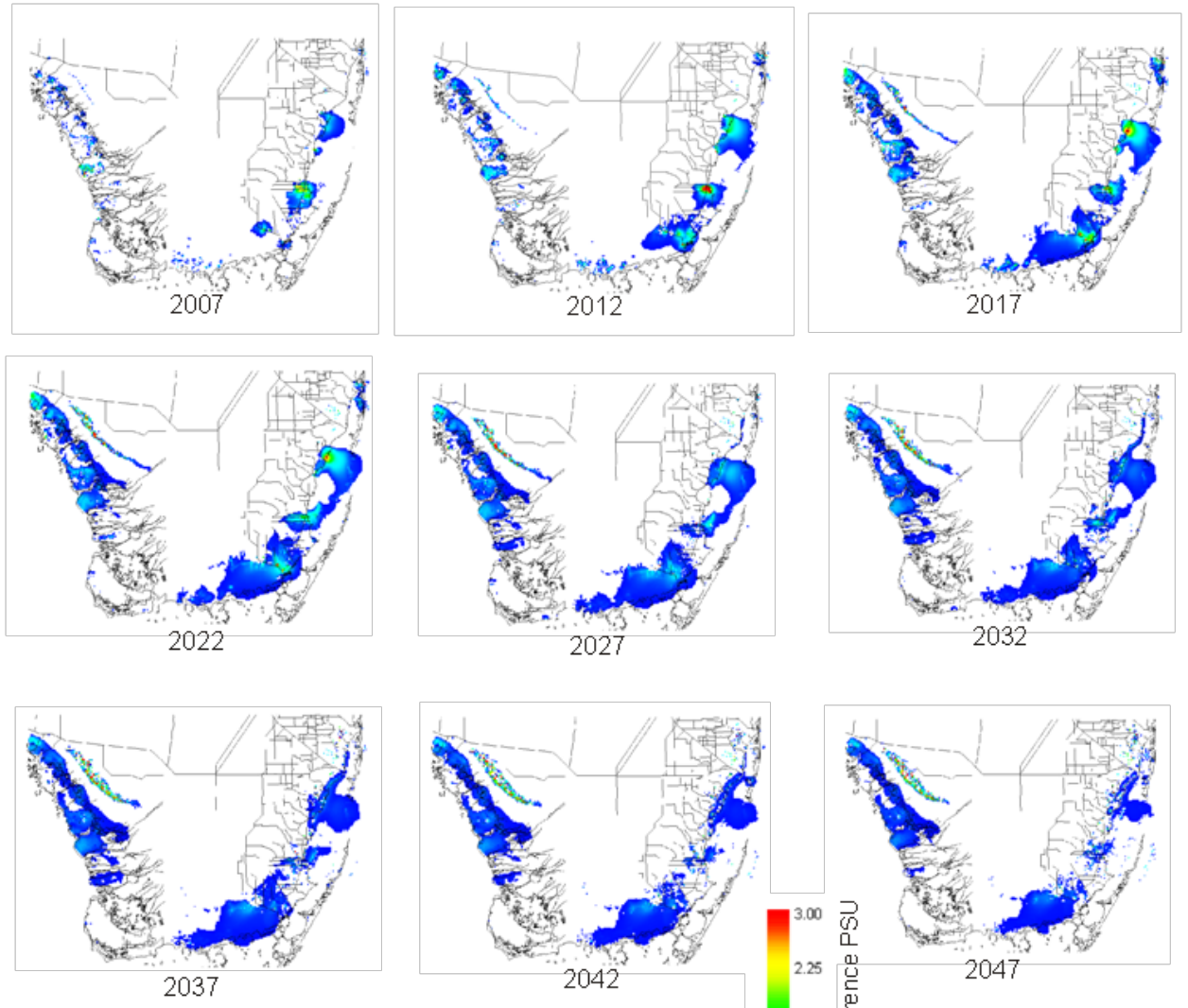
Mouth of the Little Shark River from 2004 aerial imagery

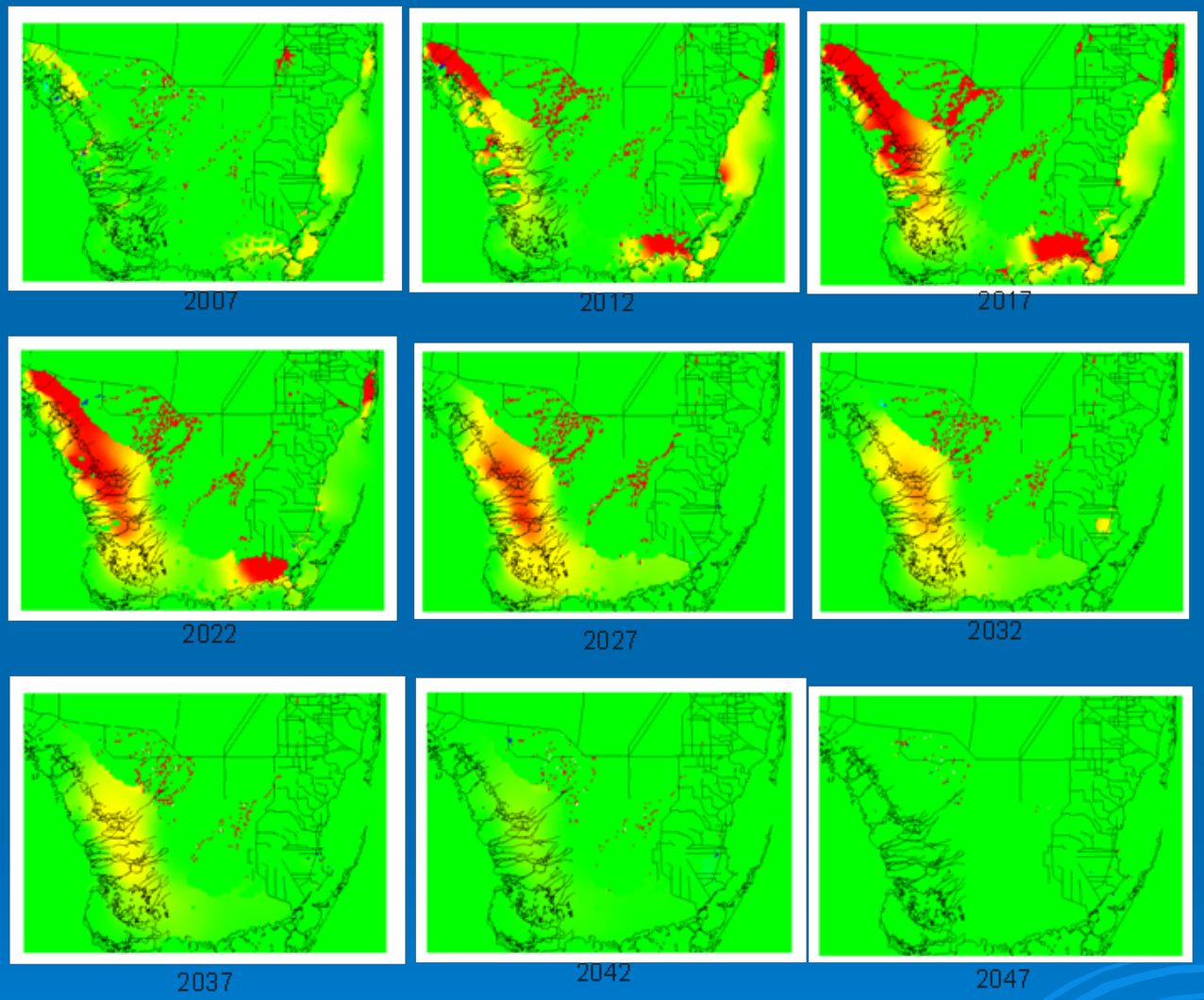


Simulation of incremental CERP implementation and sea-level rise

PERIOD	Sim A	Sim B	Mean Sea Level
(1) 1996-2002	Existing conditions (EC)	Existing conditions (EC)	-0.20 m NAVD88
(2) 2003-2007	0.67EC + 0.33CP	0.8EC + 0.2CA	-0.13 m NAVD88
(3) 2008-2012	0.33EC + 0.67CP	0.6EC + 0.4CA	-0.07 m NAVD88
(4) 2013-2017	2015CP (CP)	0.4EC + 0.6CA	0.00 m NAVD88
(5) 2018-2022	0.83CP + 0.17CA	0.2EC + 0.8CA	0.07 m NAVD88
(6) 2023-2027	0.67CP + 0.33CA	CERPA (CA)	0.13 m NAVD88
(7) 2028-2032	0.5CP + 0.5CA	CA	0.20 m NAVD88
(8) 2033-2037	0.33CP + 0.67CA	CA	0.27 m NAVD88
(9) 2038-2042	0.17CP + 0.83CA	CA	0.33 m NAVD88
(10) 2043-2047	CERPA (CA)	CA	0.40 m NAVD88

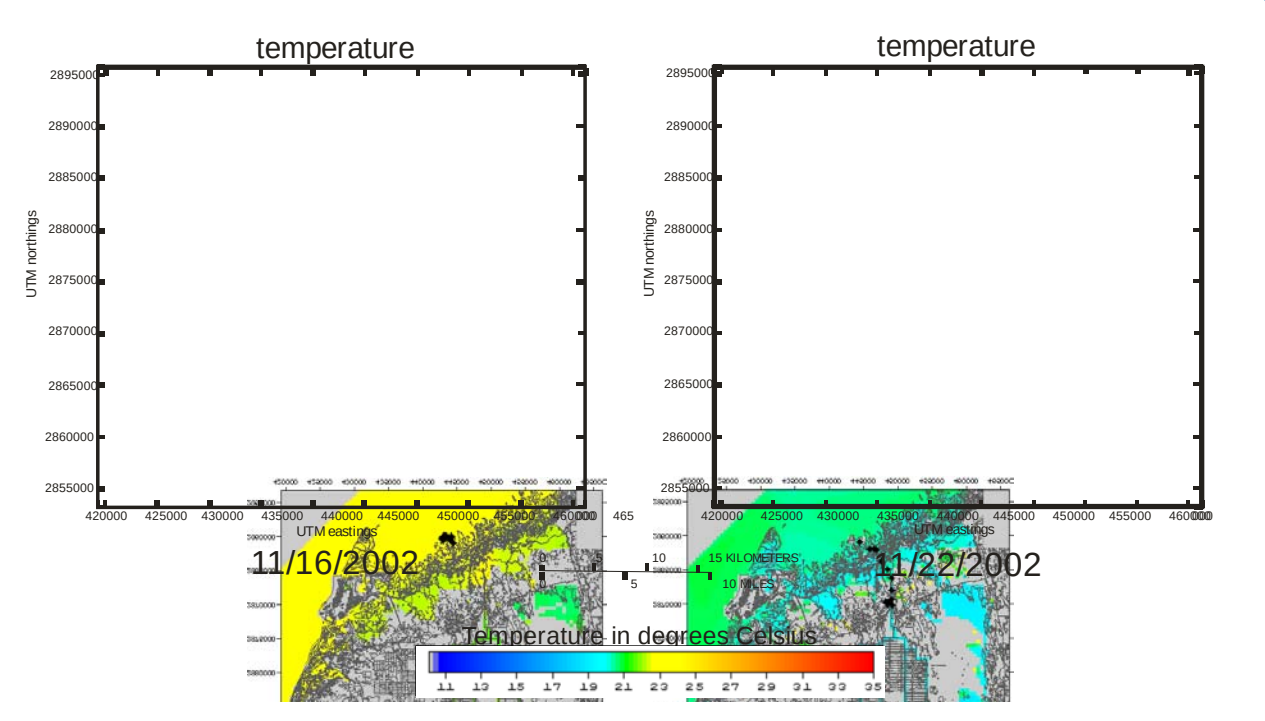


Groundwater salinity differences between scenarios A and B



Surface water salinity differences between scenarios A and B

Heat Transport and Manatee Movement



Heat transport computations require accurate heat flux terms. Current physical experiments are developing better soil heat storage and albedo terms for modeling wetlands.

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FUTURE USES OF THE MODELS & RESEARCH

- **Water Supply Issues**
- **Understanding climate change and effects to organisms**
  - *Sea level rise*
  - *Temperature increases*
  - *Seawater encroachment effect on wellfields*
- **Delineating manatee critical habitat use and carrying capacity in the Greater Everglades.**
  - *Population growth*
  - *Immigration from northern areas when power plants shut down.*
- **Understanding hurricane damage to habitats and the effects to hydrological processes and parameters that impact organisms**
  - *Before and after models to identify mechanisms and assess resilience of populations to storm events.*

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USGS Modeling Team and Collaborating Scientists

- **USGS Fort Lauderdale**
  - Eric Swain
  - Melinda Lohmann
  - Jeremy Decker
  - Don DeAngelis
- **USGS Gainesville**
  - Brad Stith
  - Catherine Langtimm
- **USGS St. Petersburg**
  - Dennis Krohn
  - Tom Smith

- **Collaborating Scientists**
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  - Jon Cline, University of Tennessee
  - Rafa Munez and Stuart Miller, UF
  - John Hamrick, Tetratech
  - Jerry Lorenz, Audubon
  - Michael Kohler and Momo Chen, SFWMD
  - Kiren Bahm, Robert Fennema, Ed Kearns, Dewitt Smith, ENP

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