EFFECTS OF SEA-LEVEL RISE AND WATER MANAGEMENT ON THE HYDROLOGIC IMPACT OF HISTORIC STORMS

- By
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GEER- Greater Everglades Ecosystem Restoration

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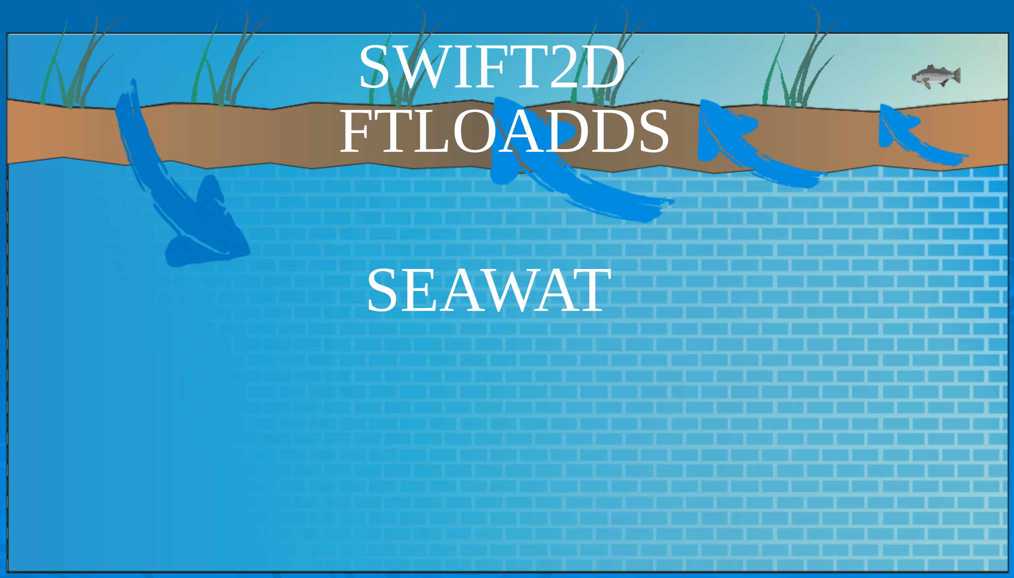
Numerical Modeling Code

- FTLOADDS (Flow and Transport in a Linked Overland/Aquifer Density Dependent System) Combines:
  - **SWIFT2D** hydrodynamic surface water code
  - **SEAWAT** variable density ground-water flow and transport code
- Satisfies requirements for modeling South Florida
  - Hydrodynamic representation of surface water in two-dimensions
  - Three dimensional representation of groundwater
  - Salinity transport is represented in each model and passed with leakage
- Modifications
  - Heat Transport
  - Interfaces with other models



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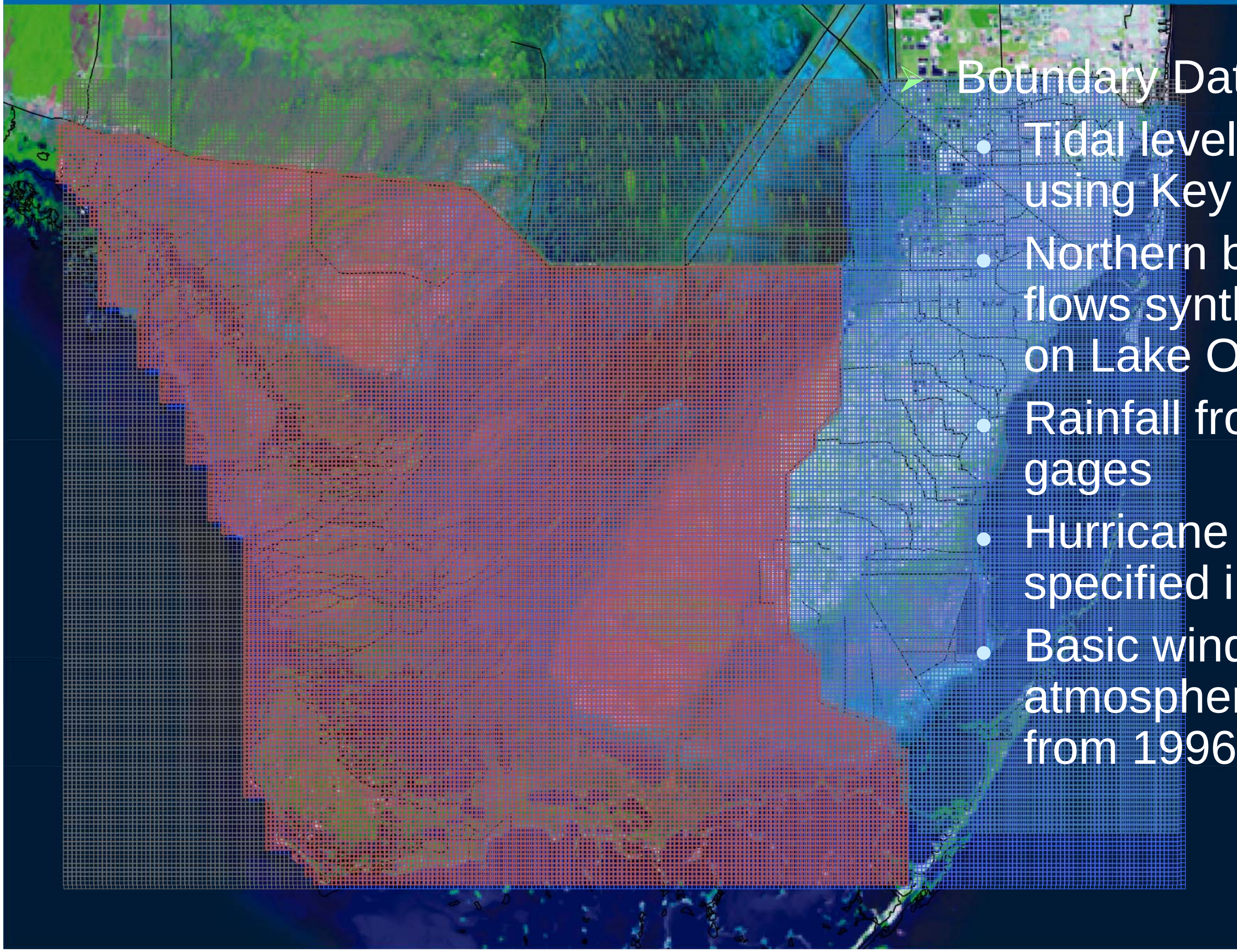
To simulate historic storms: Hindcast BISECT MODEL

Representing historical period 1926-1932, 1926-1940



- 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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Hindcast

- Simulate historical period with FTLOADDS model to determine water levels, salinity, and flows and compare with historic aerial photography
- Represent historic storms and effects on coastal regimes
- Use results to develop insight into future

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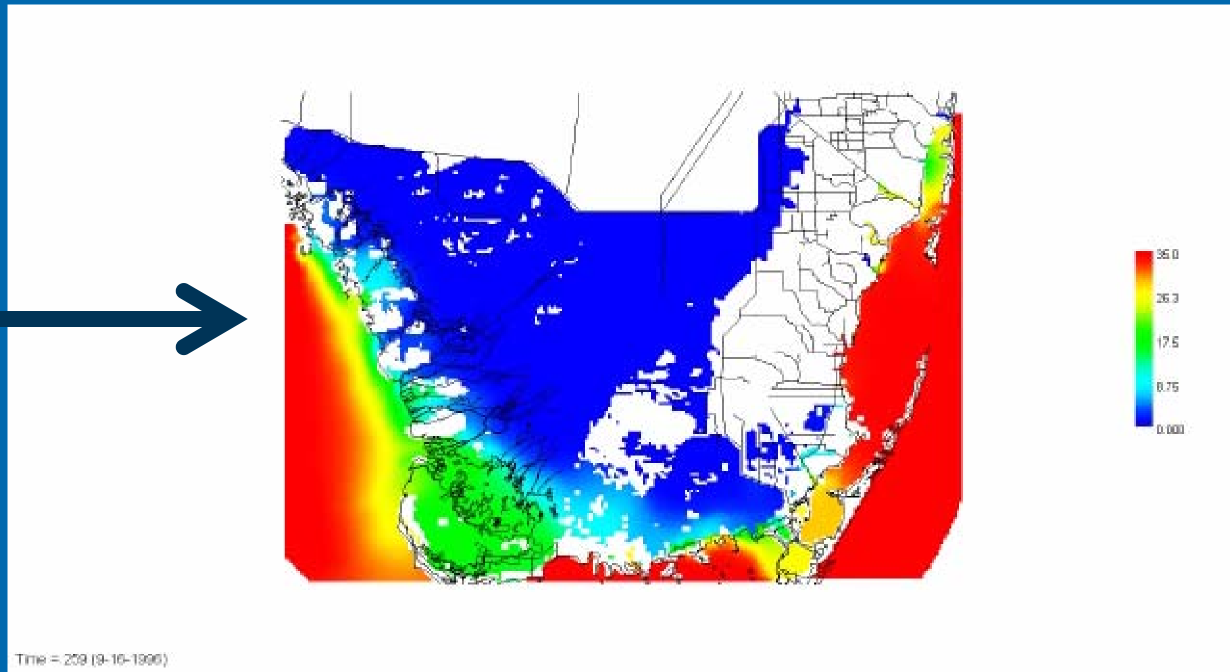
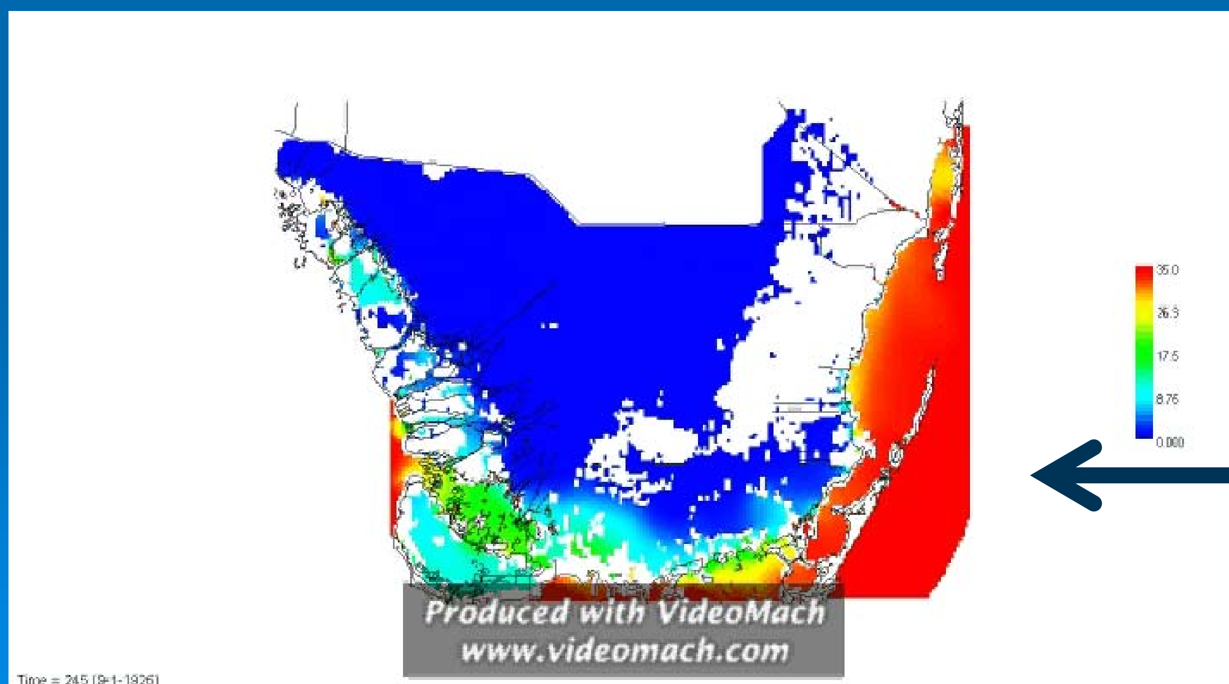
When is a hydrodynamic simulation coupled with groundwater most useful?

- During **major storm events**, dynamic inundation brings water and salinity ashore
- Long-term simulation capabilities allow representation of salinity intrusion effects on surface water and groundwater

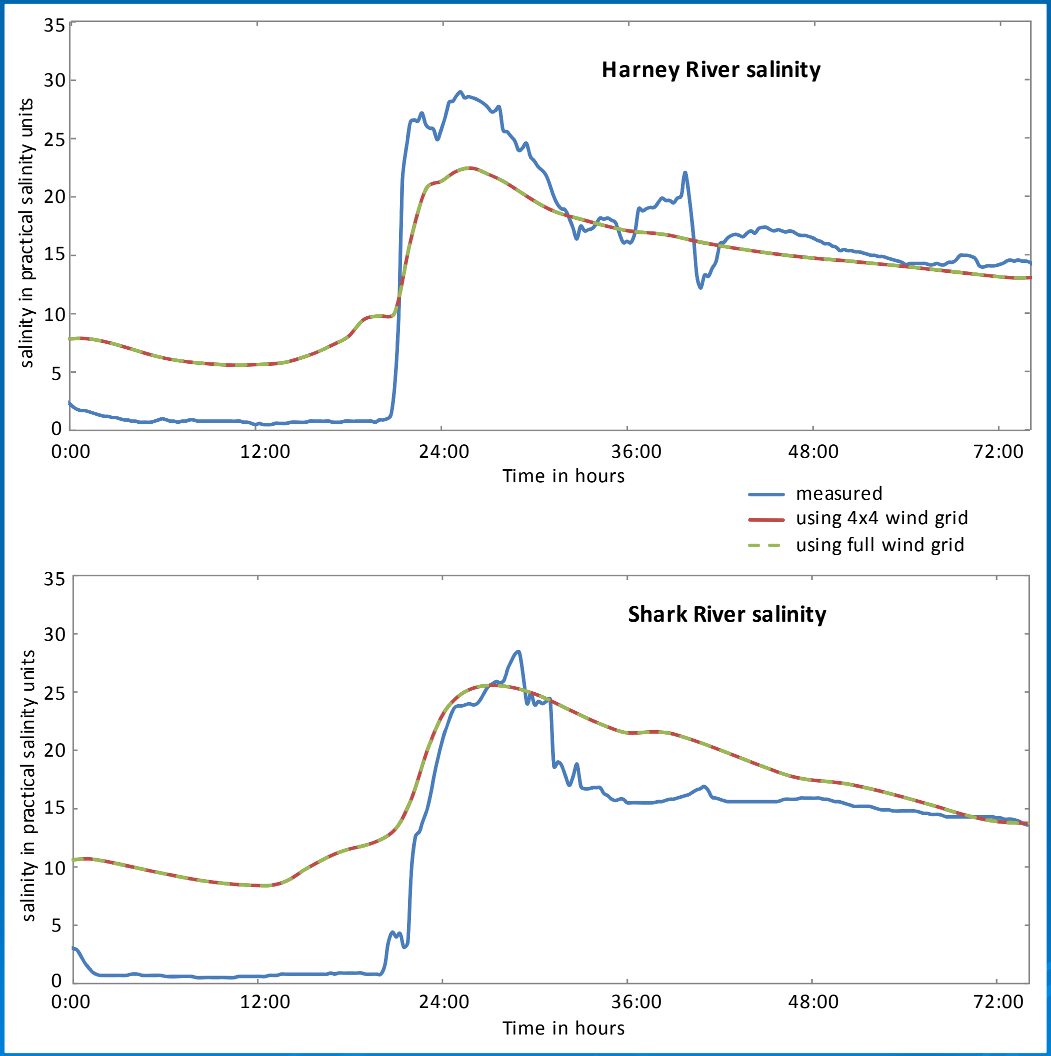
Hurricane Wilma



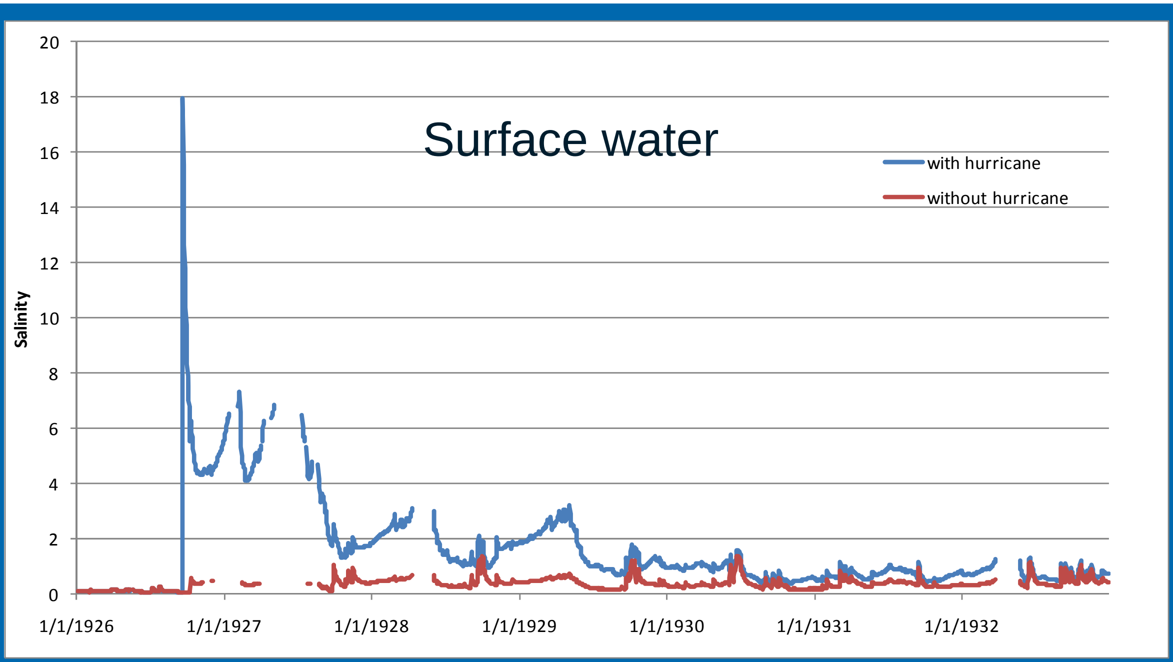
Great Miami Hurricane



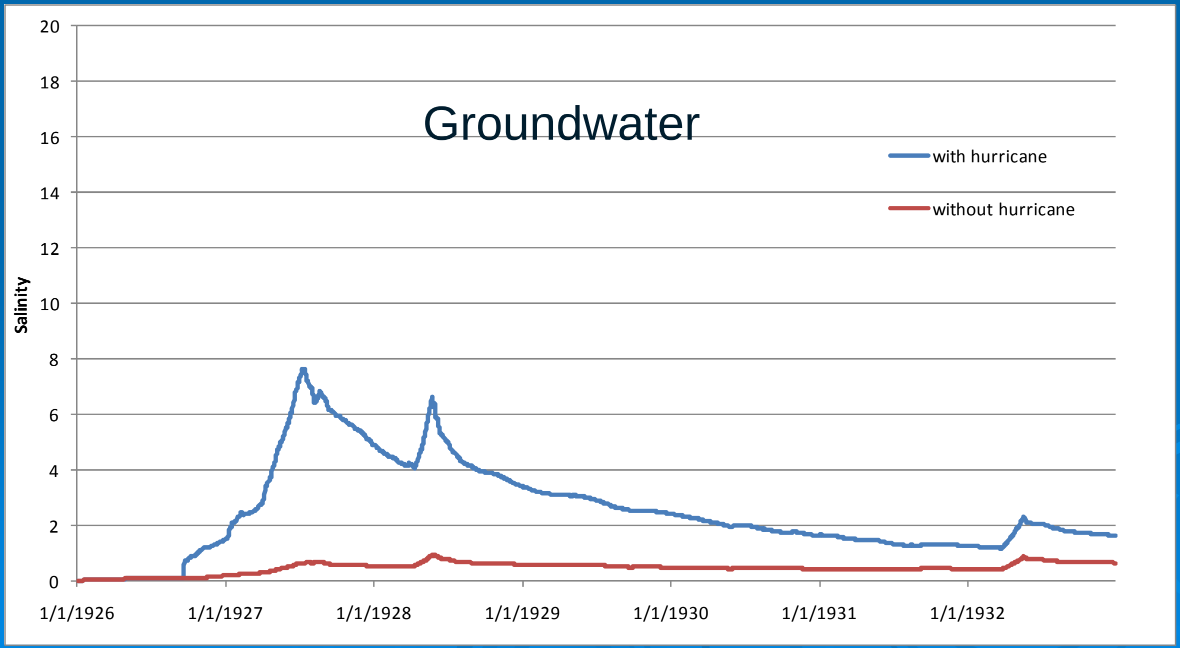
Salinity surge and washout matches with field data at coastal creeks.



Comparison of "1996 Wilma simulation" of salinity surges to actual 2005 Wilma field measurements



Surface water
with hurricane
without hurricane
Salinity
20
18
16
14
12
10
8
6
4
2
0
1/1/1926
1/1/1927
1/1/1928
1/1/1929
1/1/1930
1/1/1931
1/1/1932



Groundwater
with hurricane
without hurricane
Salinity
20
18
16
14
12
10
8
6
4
2
0
1/1/1926
1/1/1927
1/1/1928
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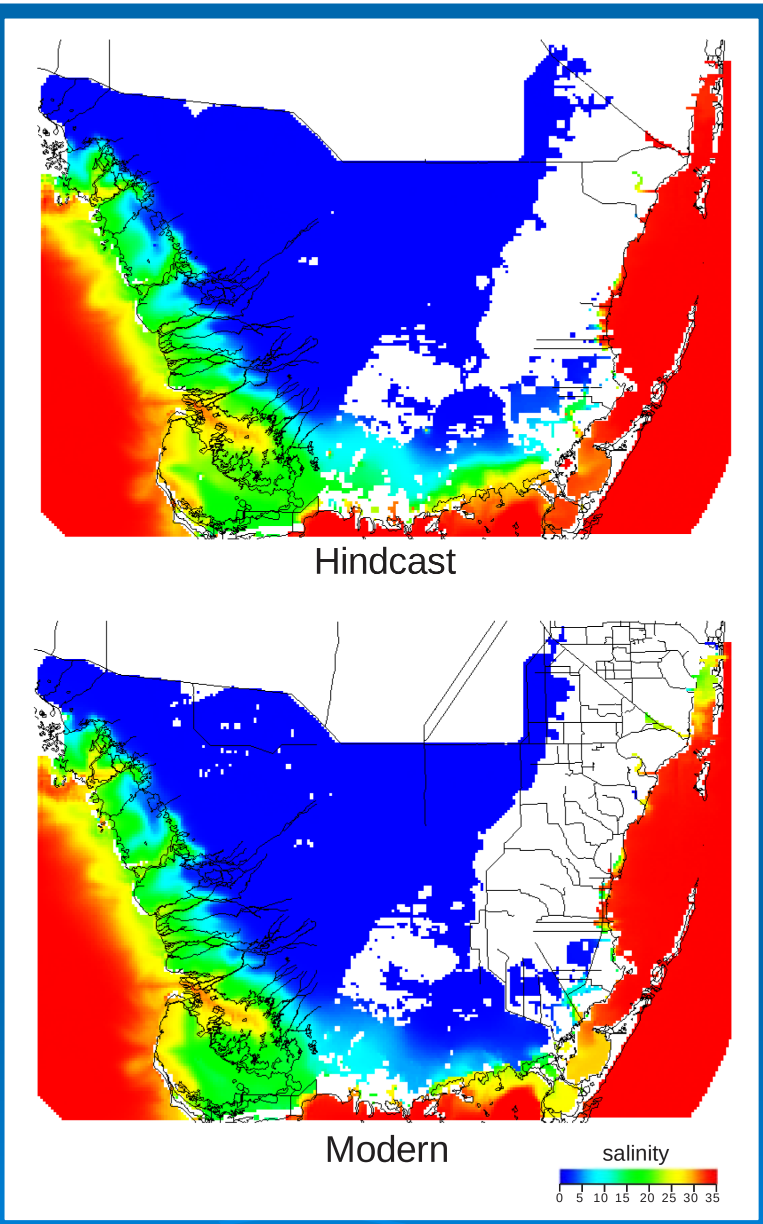
1/1/1931
1/1/1932



Simulating effects of Wilma-type storm on hindcast hydrology (1926) and recent hydrology (1996).

Simulations to determine variables in storm effects

- Windfield, storm surge, and rain from day of Great Miami Hurricane applied to September 18, 1996
- Comparison of hydrologic effects made to Hindcast simulated Great Miami Hurricane
- 1926 simulation with Great Miami Hurricane repeated with 1996 sea levels

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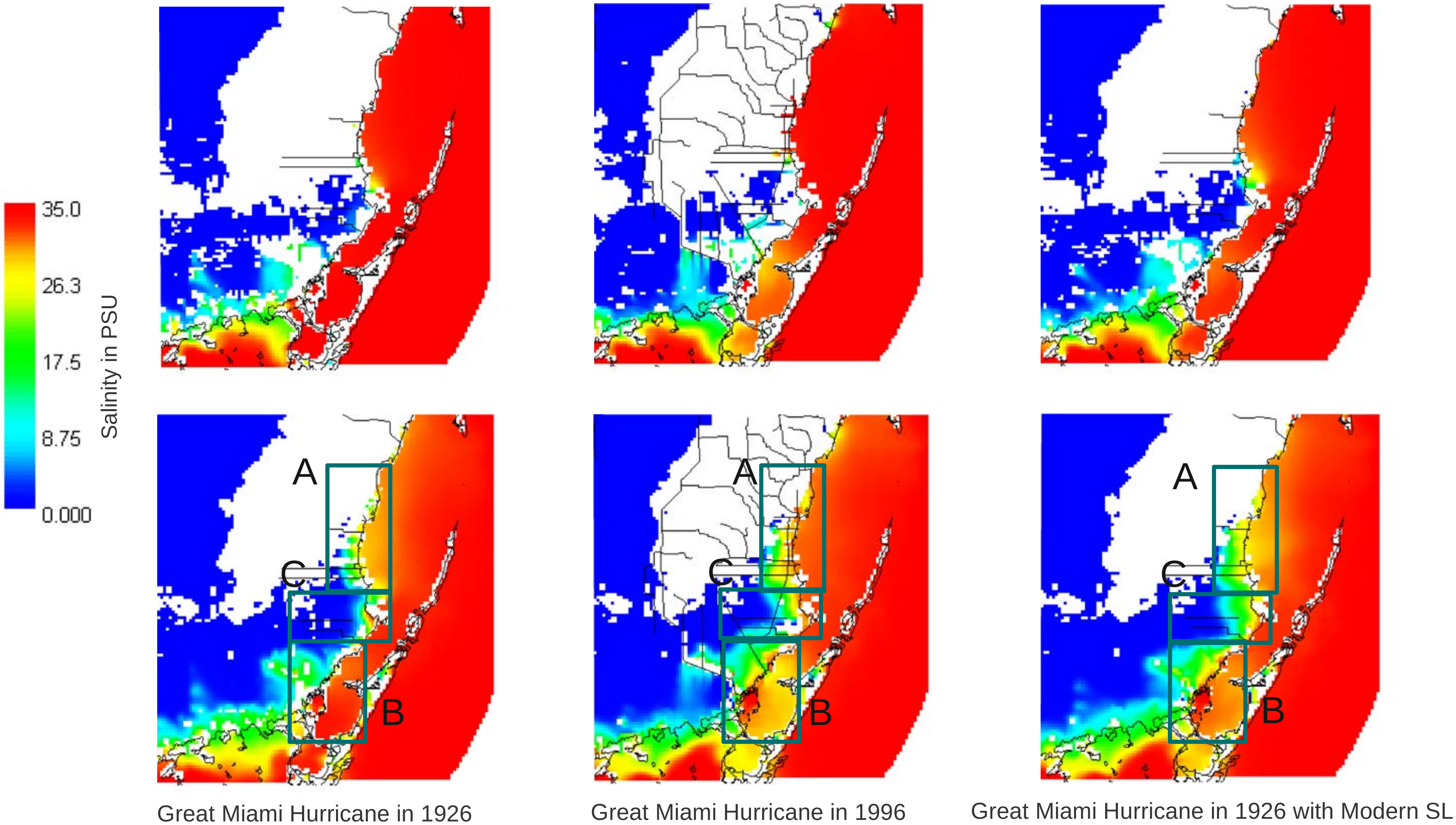

Salinity and inundations before and after hurricane

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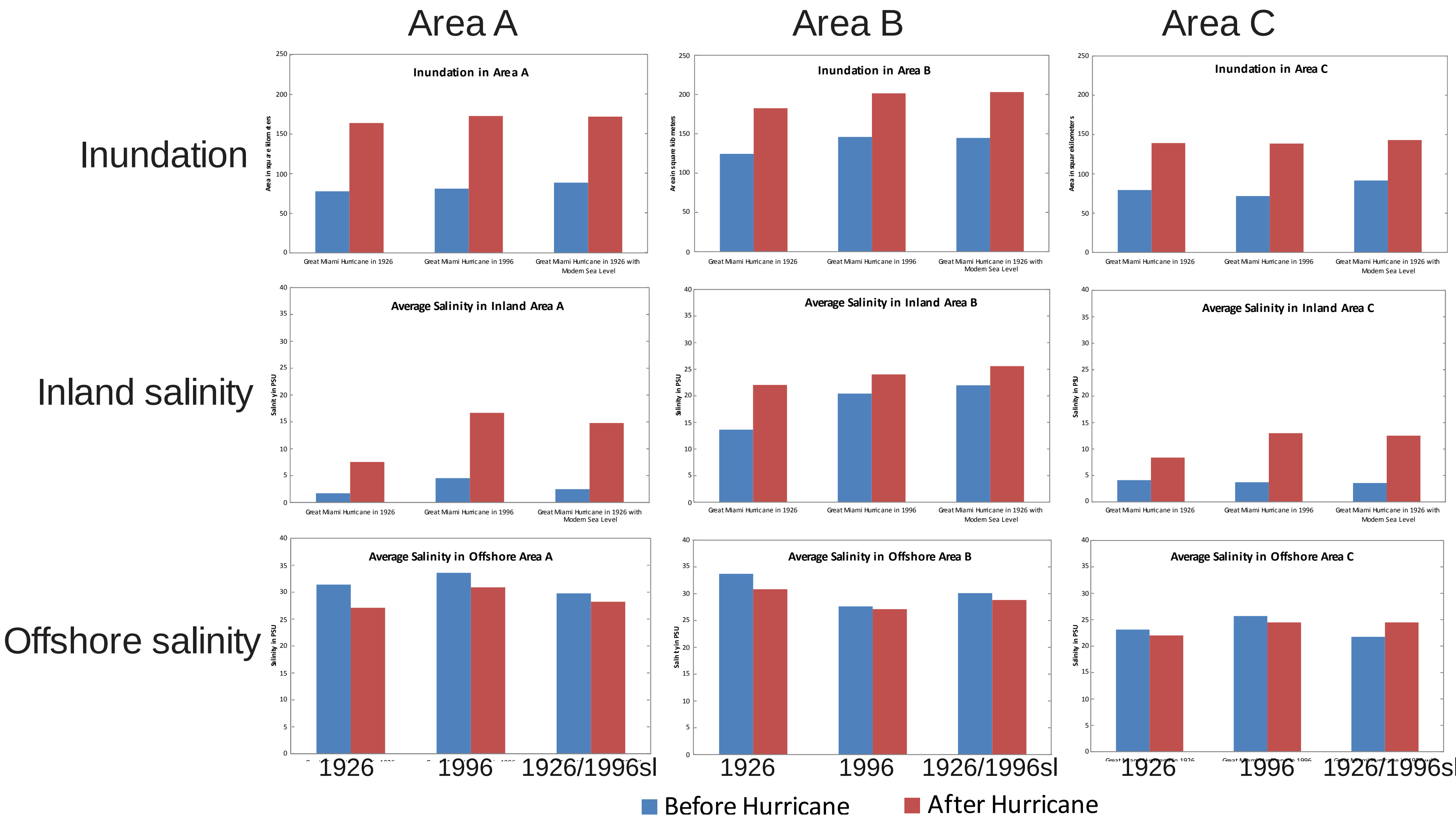

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Area A	Great Miami Hurricane in 1926	Great Miami Hurricane in 1996	Great Miami Hurricane in 1926 with Modern Sea Level
Inundation change in square kilometers	86.25	91.75	83.25
Inland salinity change in PSU	5.84	12.12	12.29
Offshore salinity change in PSU	-4.29	-2.71	-1.56

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Area B	Great Miami Hurricane in 1926	Great Miami Hurricane in 1996	Great Miami Hurricane in 1926 with Modern Sea Level
Inundation change in square kilometers	58.00	55.50	58.25
Inland salinity change in PSU	8.38	3.59	3.61
Offshore salinity change in PSU	-2.87	-0.53	-1.29

Area C	Great Miami Hurricane in 1926	Great Miami Hurricane in 1996	Great Miami Hurricane in 1926 with Modern Sea Level
Inundation change in square kilometers	59.75	66.75	51.50
Inland salinity change in PSU	4.26	9.29	8.93
Offshore salinity change in PSU	-1.12	-1.18	2.74

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Future work includes a Integrated Proposal with the tasks:

- Optimize wellfield operations based on environmental and operational criteria, including potential future scenarios
- Delineate drainage structure characteristics that affect rainfall-runoff process
- Determine potential effects of storm events and storm surge on coastal canals and county facilities

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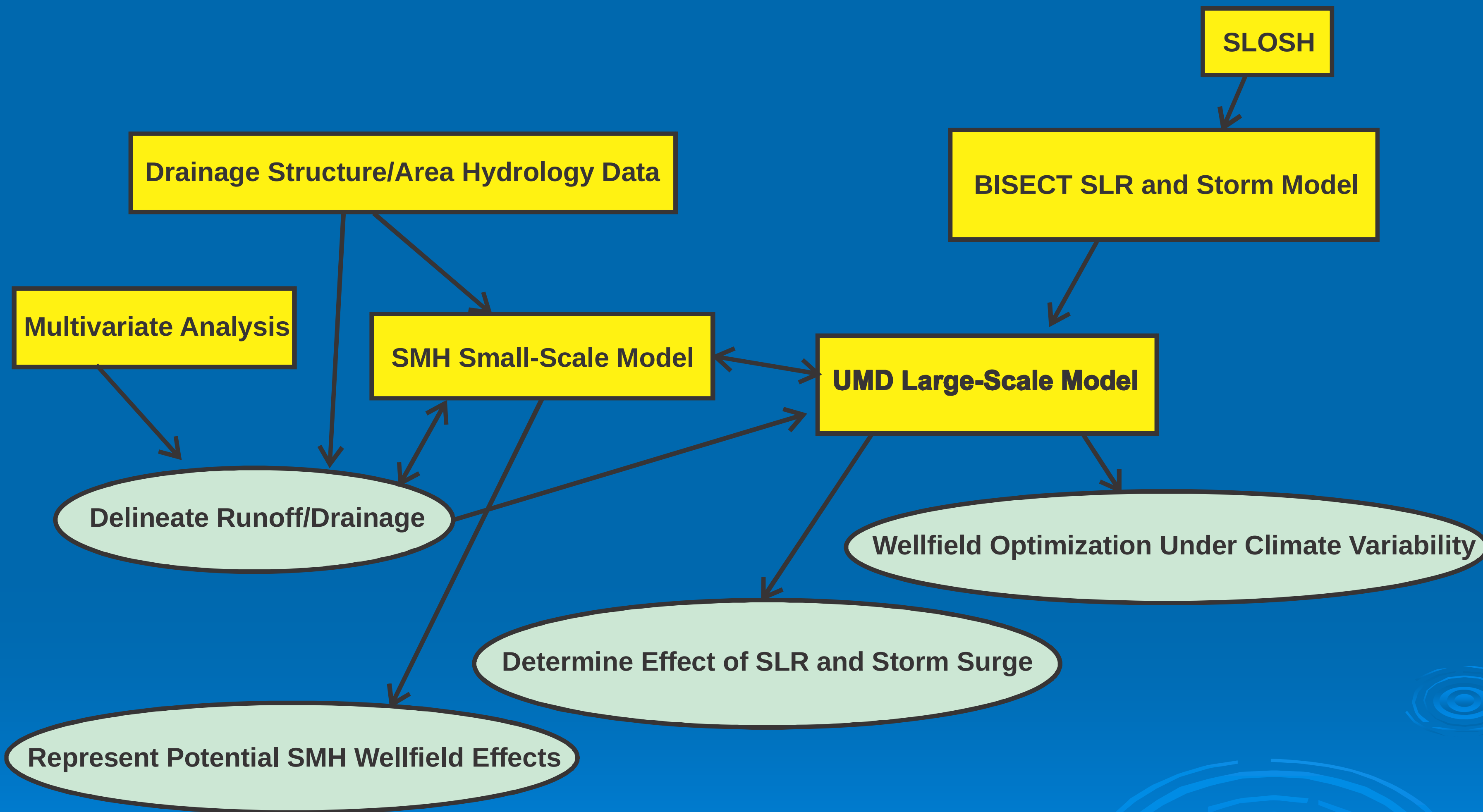
Integrated project flowchart



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Development of storm surge model using BISECT and SLOSH

- Current hydrodynamic representations of storm surge in BISECT can use SLOSH-generated surge-wave momentum
- BISECT simulation determines long-term impact on surface-water and groundwater salinity
- Combination of SWR for the canal effects and SWIFT2D for the overland hydrodynamics of the storm surge

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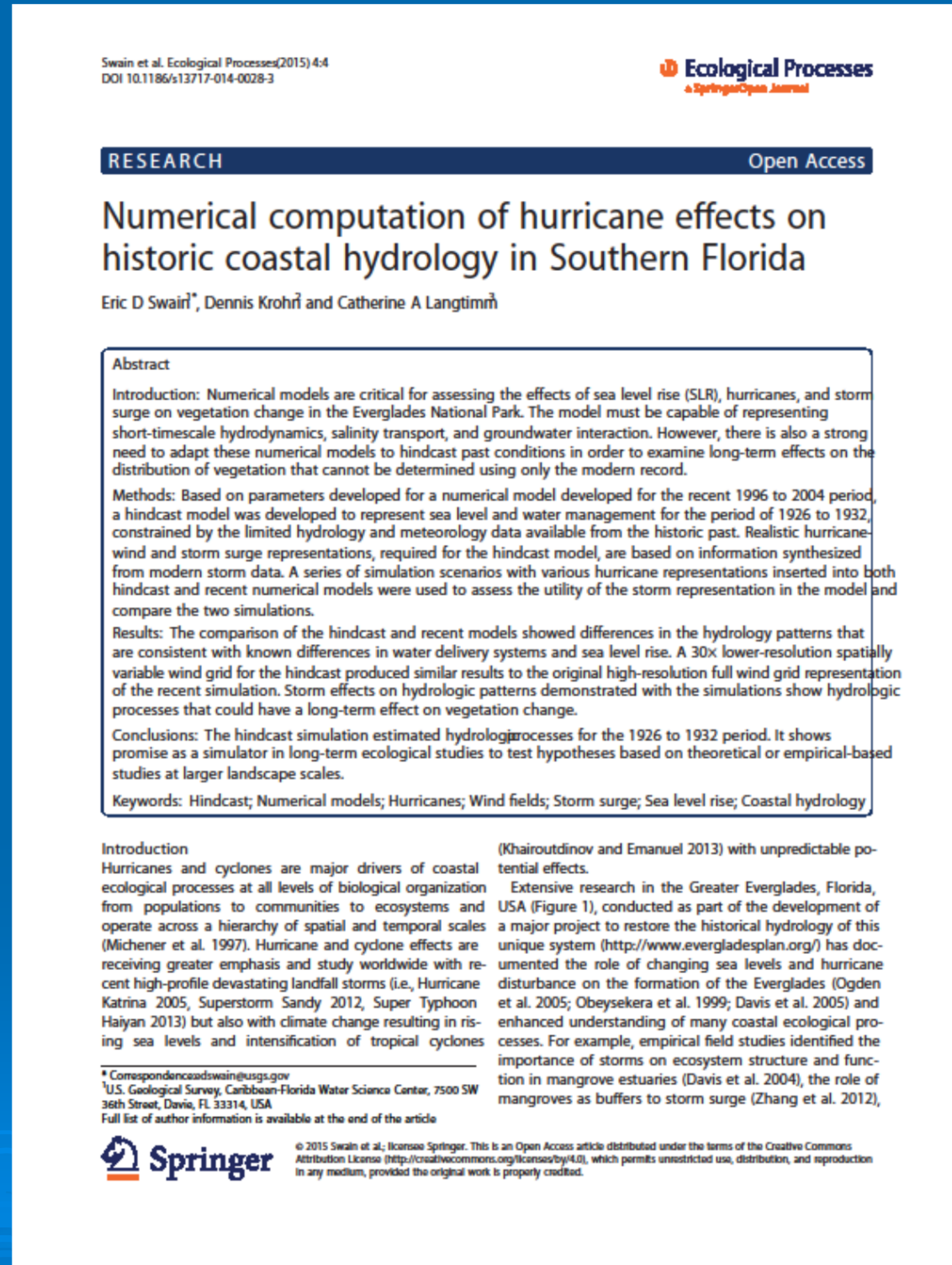
Swain, E. D., Krohn D., and Langtimm C.A., 2015, Numerical Computation of Hurricane Effects on Historic Coastal Hydrology in Southern Florida: Ecological Processes 4:4, 1-20.



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Ecological Processes
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Numerical computation of hurricane effects on historic coastal hydrology in Southern Florida

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Abstract

Introduction: Numerical models are critical for assessing the effects of sea level rise (SLR), hurricanes, and storm surge on vegetation change in the Everglades National Park. The model must be capable of representing short-timescale hydrodynamics, salinity transport, and groundwater interaction. However, there is also a strong need to adapt these numerical models to hindcast past conditions in order to examine long-term effects on the distribution of vegetation that cannot be determined using only the modern record.

Methods: Based on parameters developed for a numerical model developed for the recent 1996 to 2004 period, a hindcast model was developed to represent sea level and water management for the period of 1926 to 1932, constrained by the limited hydrology and meteorology data available from the historic past. Realistic hurricane-wind and storm surge representations, required for the hindcast model, are based on information synthesized from modern storm data. A series of simulation scenarios with various hurricane representations inserted into both hindcast and recent numerical models were used to assess the utility of the storm representation in the model and compare the two simulations.

Results: The comparison of the hindcast and recent models showed differences in the hydrology patterns that are consistent with known differences in water delivery systems and sea level rise. A 30× lower-resolution spatially variable wind grid for the hindcast produced similar results to the original high-resolution full wind grid representation of the recent simulation. Storm effects on hydrologic patterns demonstrated with the simulations show hydrologic processes that could have a long-term effect on vegetation change.

Conclusions: The hindcast simulation estimated hydrologic processes for the 1926 to 1932 period. It shows promise as a simulator in long-term ecological studies to test hypotheses based on theoretical or empirical-based studies at larger landscape scales.

Keywords: Hindcast; Numerical models; Hurricanes; Wind fields; Storm surge; Sea level rise; Coastal hydrology

Introduction

Hurricanes and cyclones are major drivers of coastal ecological processes at all levels of biological organization from populations to communities to ecosystems and operate across a hierarchy of spatial and temporal scales (Michener et al. 1997). Hurricane and cyclone effects are receiving greater emphasis and study worldwide with recent high-profile devastating landfall storms (i.e., Hurricane Katrina 2005, Superstorm Sandy 2012, Super Typhoon Haiyan 2013) but also with climate change resulting in rising sea levels and intensification of tropical cyclones (Khairoutdinov and Emanuel 2013) with unpredictable potential effects.

Extensive research in the Greater Everglades, Florida, USA (Figure 1), conducted as part of the development of a major project to restore the historical hydrology of this unique system (http://www.evergladesplan.org/) has documented the role of changing sea levels and hurricane disturbance on the formation of the Everglades (Ogden et al. 2005; Obeysekera et al. 1999; Davis et al. 2005) and enhanced understanding of many coastal ecological processes. For example, empirical field studies identified the importance of storms on ecosystem structure and function in mangrove estuaries (Davis et al. 2004), the role of mangroves as buffers to storm surge (Zhang et al. 2012),

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Questions?

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