Modeling Hydrodynamic Effects and Salinity Intrusion

Presented by Dr. Eric Swain, USGS Water Science Center, Fort Lauderdale Florida

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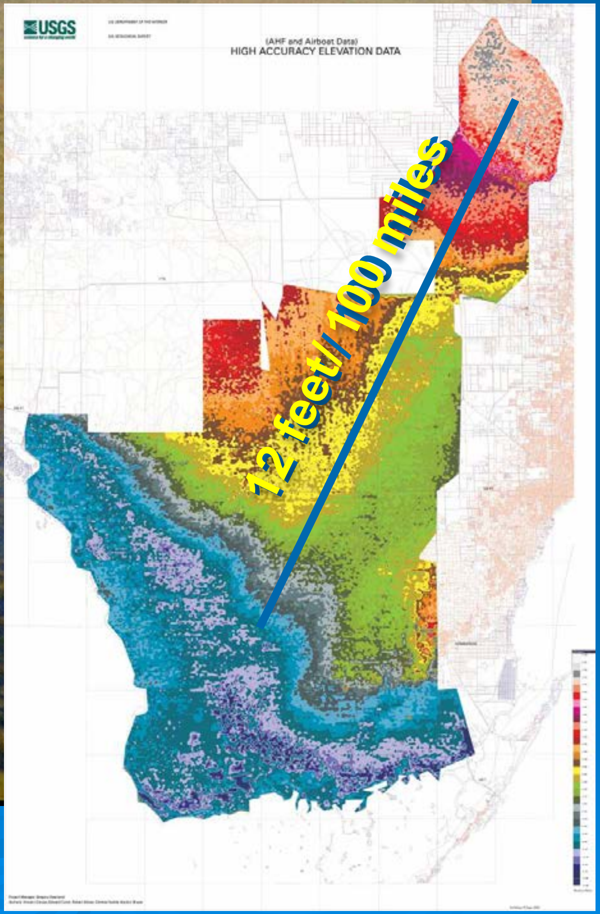
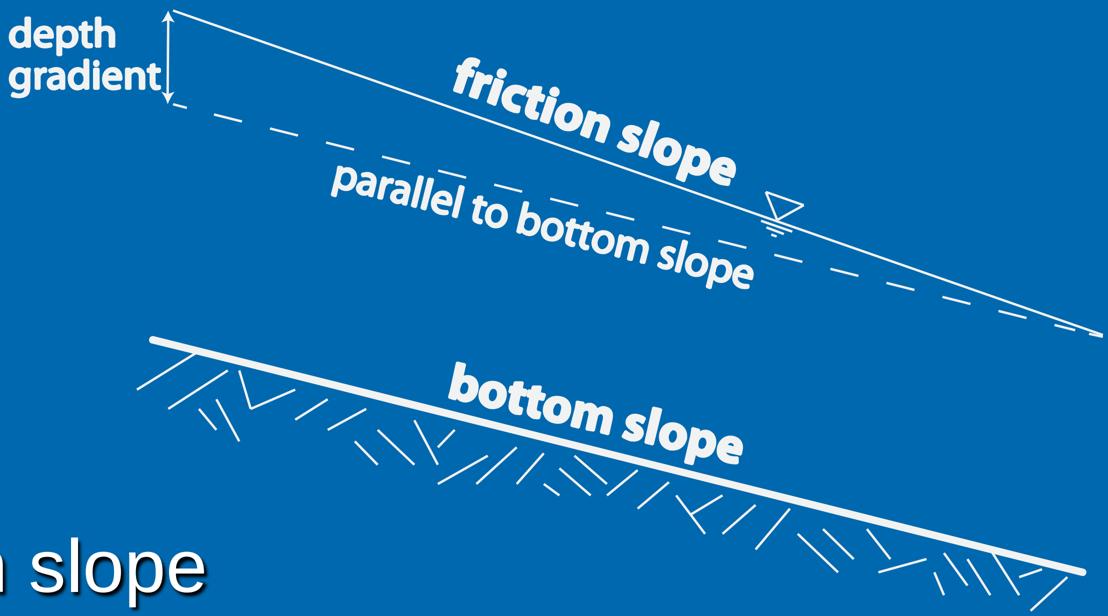
Requirements

Because coastal South Florida has unique features such as low gradients and high surface-water/groundwater connectivity:

- Surface-water represented by hydrodynamic formulation to account for transient momentum changes
- Linkage to groundwater formulation to account for close interaction
- Salinity transport with density effects to account for coastal interactions



Surface Water Momentum Formulations



Kinematic Wave

friction slope = bottom slope

Diffusive Wave

friction slope - depth gradient = bottom slope

Hydrodynamic

friction slope - depth gradient + temporal acceleration + spatial acceleration = bottom slope

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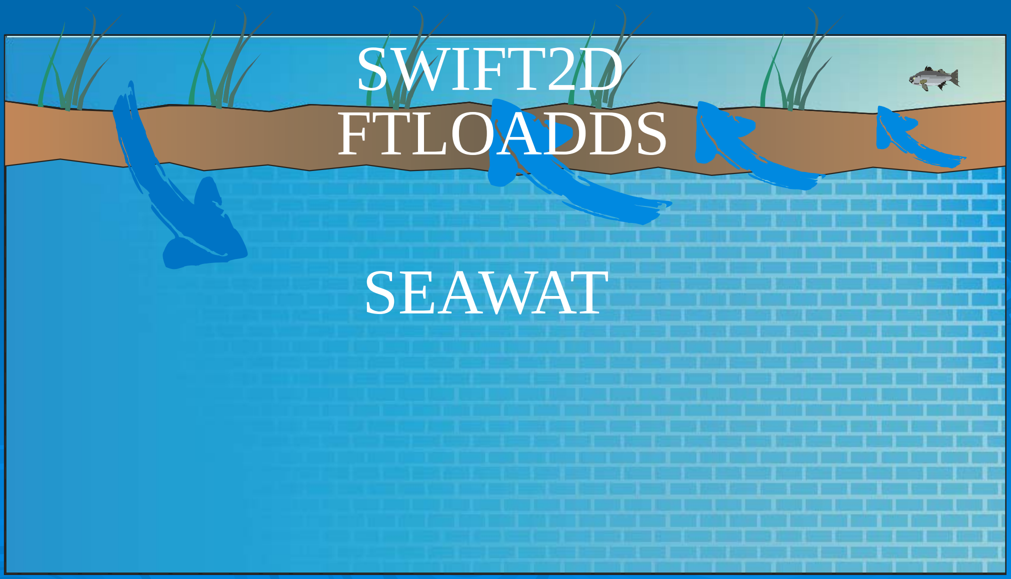
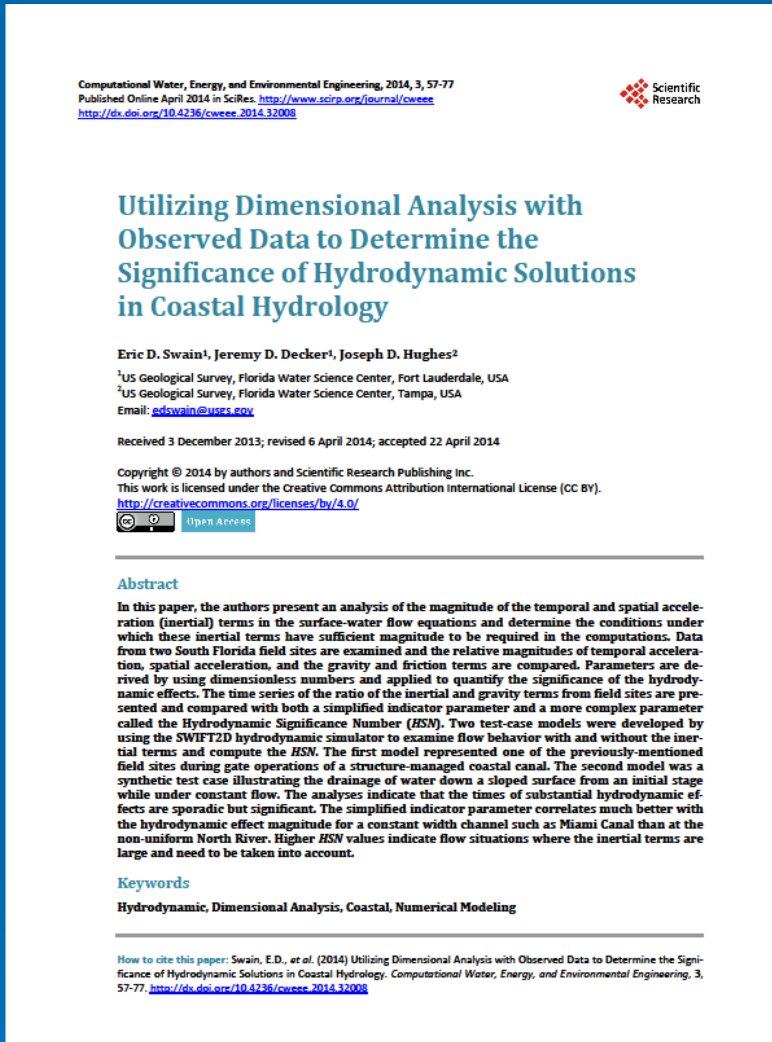
Challenges

- Hydrodynamic formulation requires short timesteps and is computationally intensive
- The combined sw/gw code with transport has a multitude of interrelated parameters
- Hydrodynamic formulation required when short-timescale transients occur, but often a simpler scheme suffices

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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Scientific Research

Utilizing Dimensional Analysis with Observed Data to Determine the Significance of Hydrodynamic Solutions in Coastal Hydrology

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Abstract

In this paper, the authors present an analysis of the magnitude of the temporal and spatial acceleration (inertial) terms in the surface-water flow equations and determine the conditions under which these inertial terms have sufficient magnitude to be required in the computations. Data from two South Florida field sites are examined and the relative magnitudes of temporal acceleration, spatial acceleration, and the gravity and friction terms are compared. Parameters are derived by using dimensionless numbers and applied to quantify the significance of the hydrodynamic effects. The time series of the ratio of the inertial and gravity terms from field sites are presented and compared with both a simplified indicator parameter and a more complex parameter called the Hydrodynamic Significance Number (*HSN*). Two test-case models were developed by using the SWIFT2D hydrodynamic simulator to examine flow behavior with and without the inertial terms and compute the *HSN*. The first model represented one of the previously-mentioned field sites during gate operations of a structure-managed coastal canal. The second model was a synthetic test case illustrating the drainage of water down a sloped surface from an initial stage while under constant flow. The analyses indicate that the times of substantial hydrodynamic effects are sporadic but significant. The simplified indicator parameter correlates much better with the hydrodynamic effect magnitude for a constant width channel such as Miami Canal than at the non-uniform North River. Higher *HSN* values indicate flow situations where the inertial terms are large and need to be taken into account.

Keywords

Hydrodynamic, Dimensional Analysis, Coastal, Numerical Modeling

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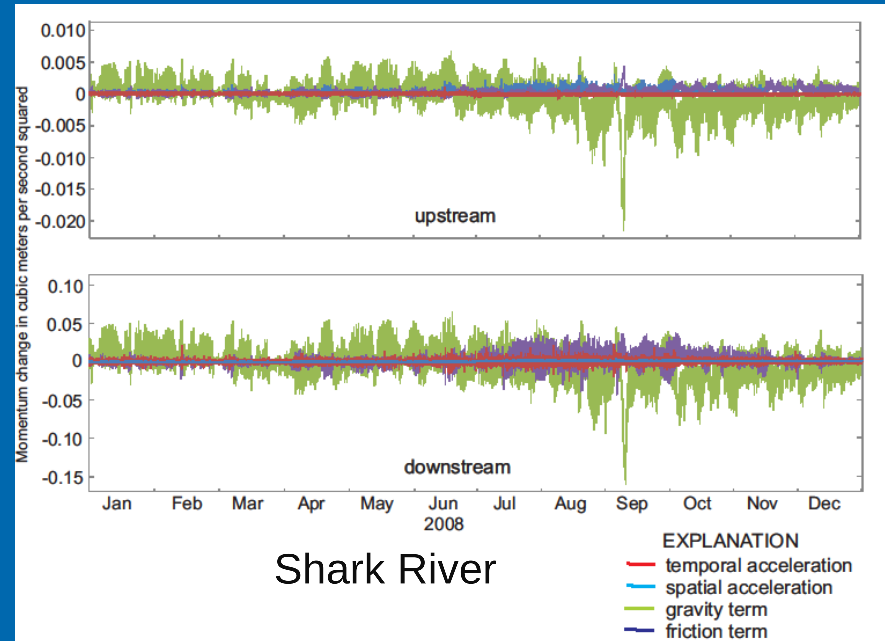

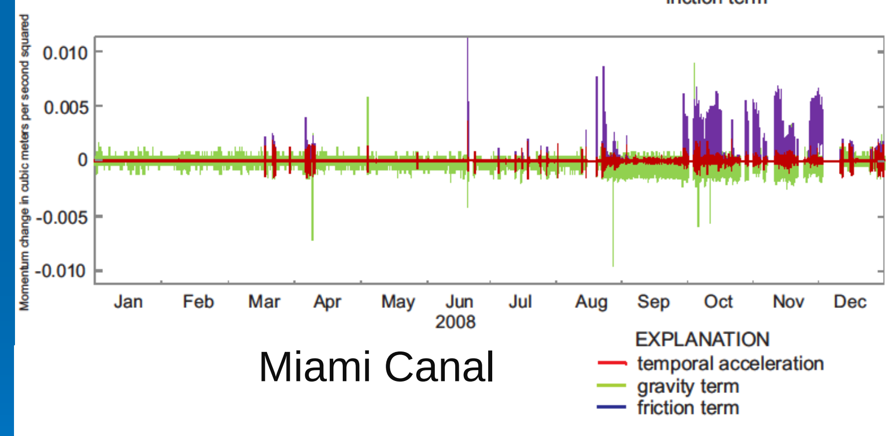

Recent publication surveys field conditions under which hydrodynamic terms are important

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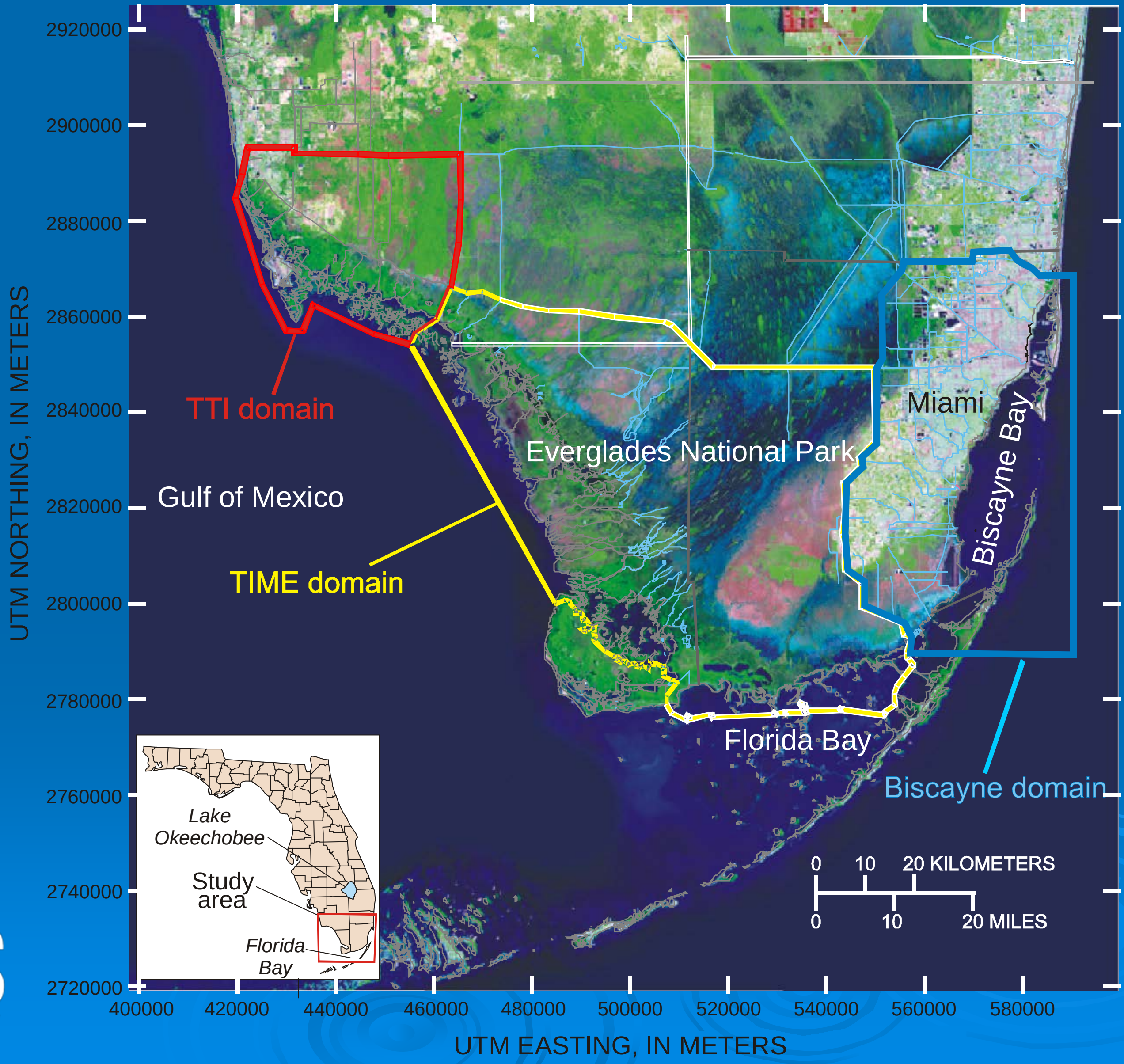
South Florida and Model Areas



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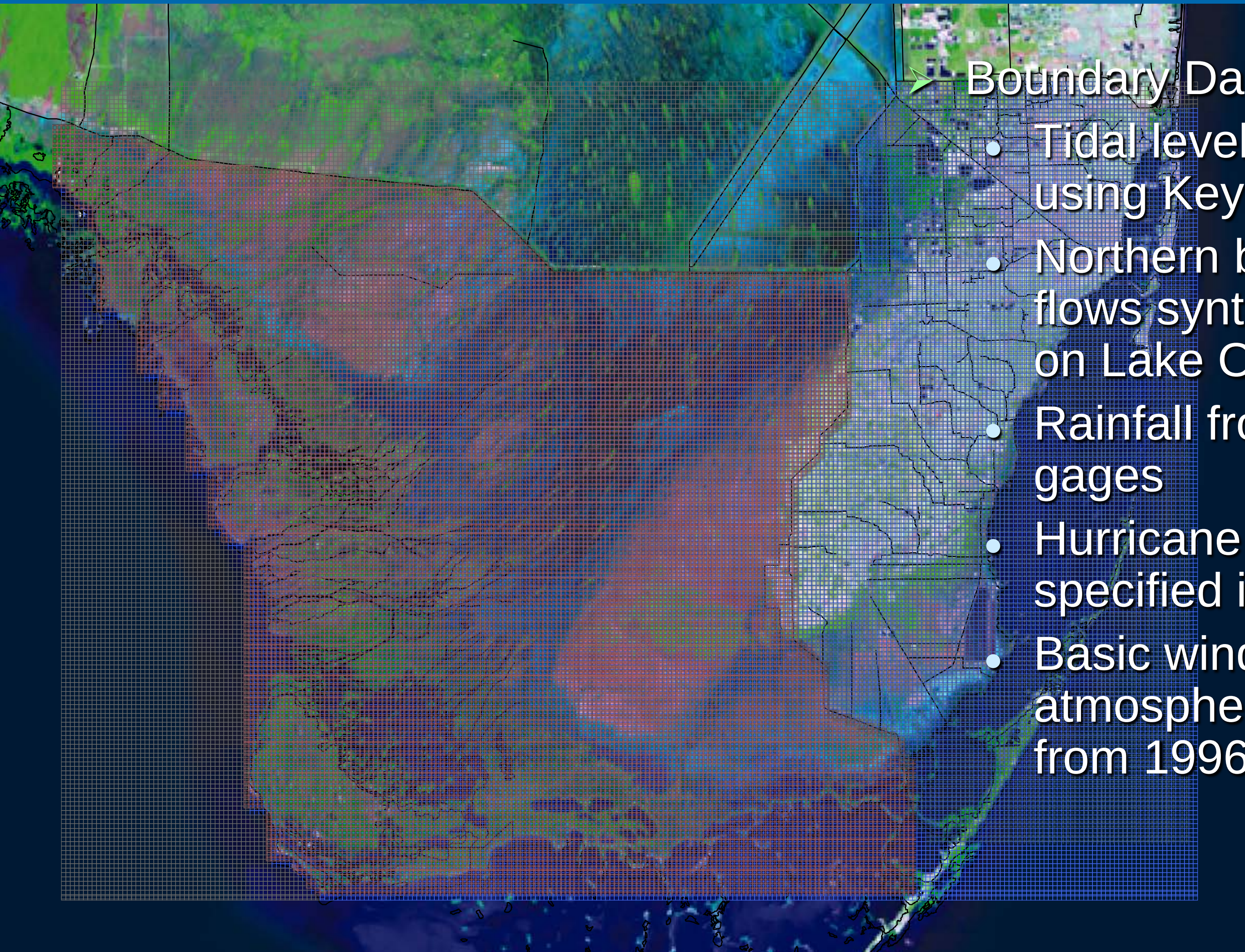
When is a hydrodynamic simulation coupled with groundwater most useful?

- 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

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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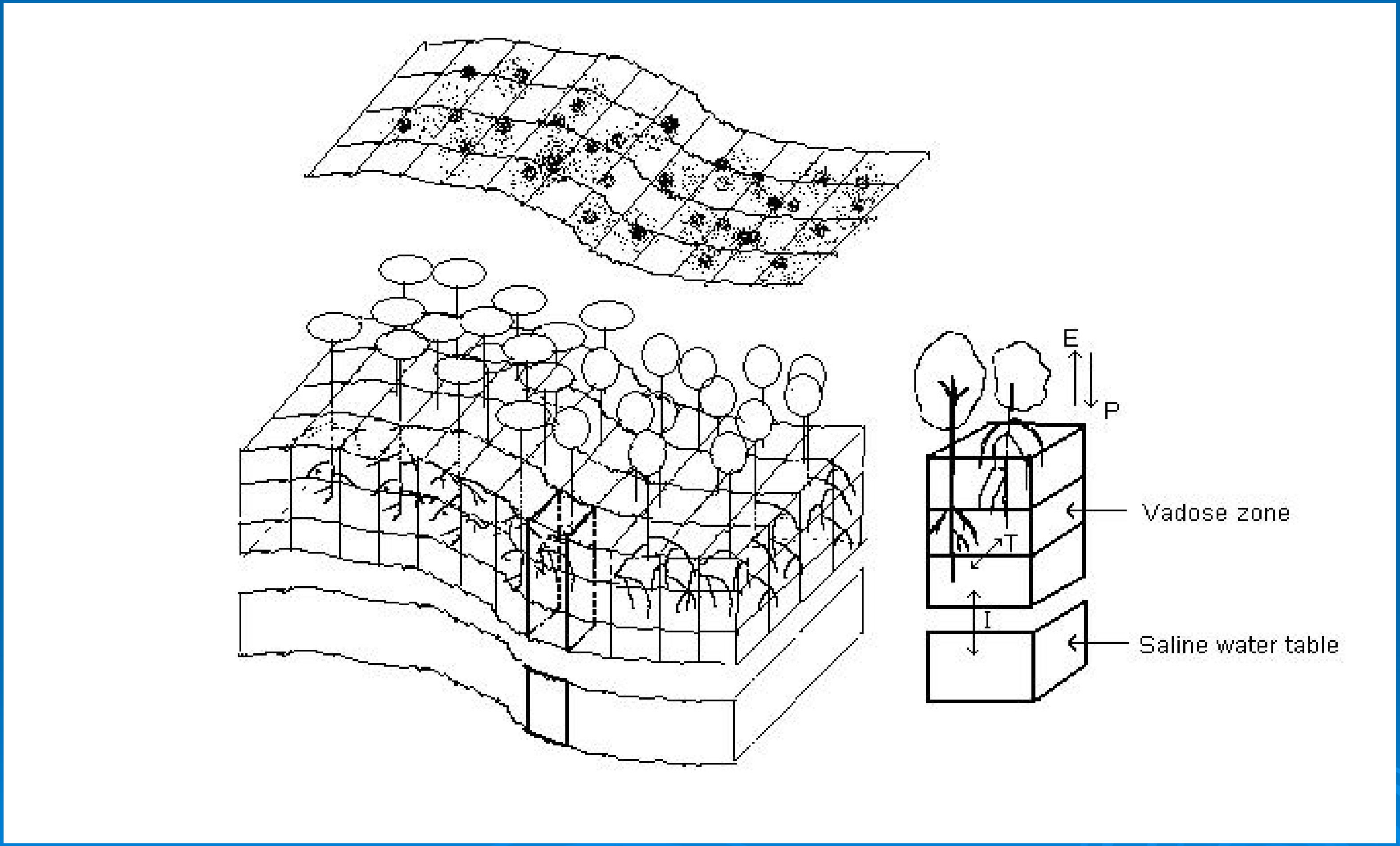
Hindcast

- 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

Salinity washed on shore important to Mangrove-Hammock Model



To Examine Future Conditions: Incorporating Sea-Level Rise

- Represent existing period with increased tidal levels
- Can be combined with estimated future conditions such as rainfall, water management
- Needed conditions for future storm effects

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To Examine Future Conditions: Downscaled Climate Data

- Rainfall data from Global Climate Models and reanalysis is downscaled for hydrology model input
- Comparison is made between existing conditions and downscaled input
- Effects of future rainfall scenarios can be examined

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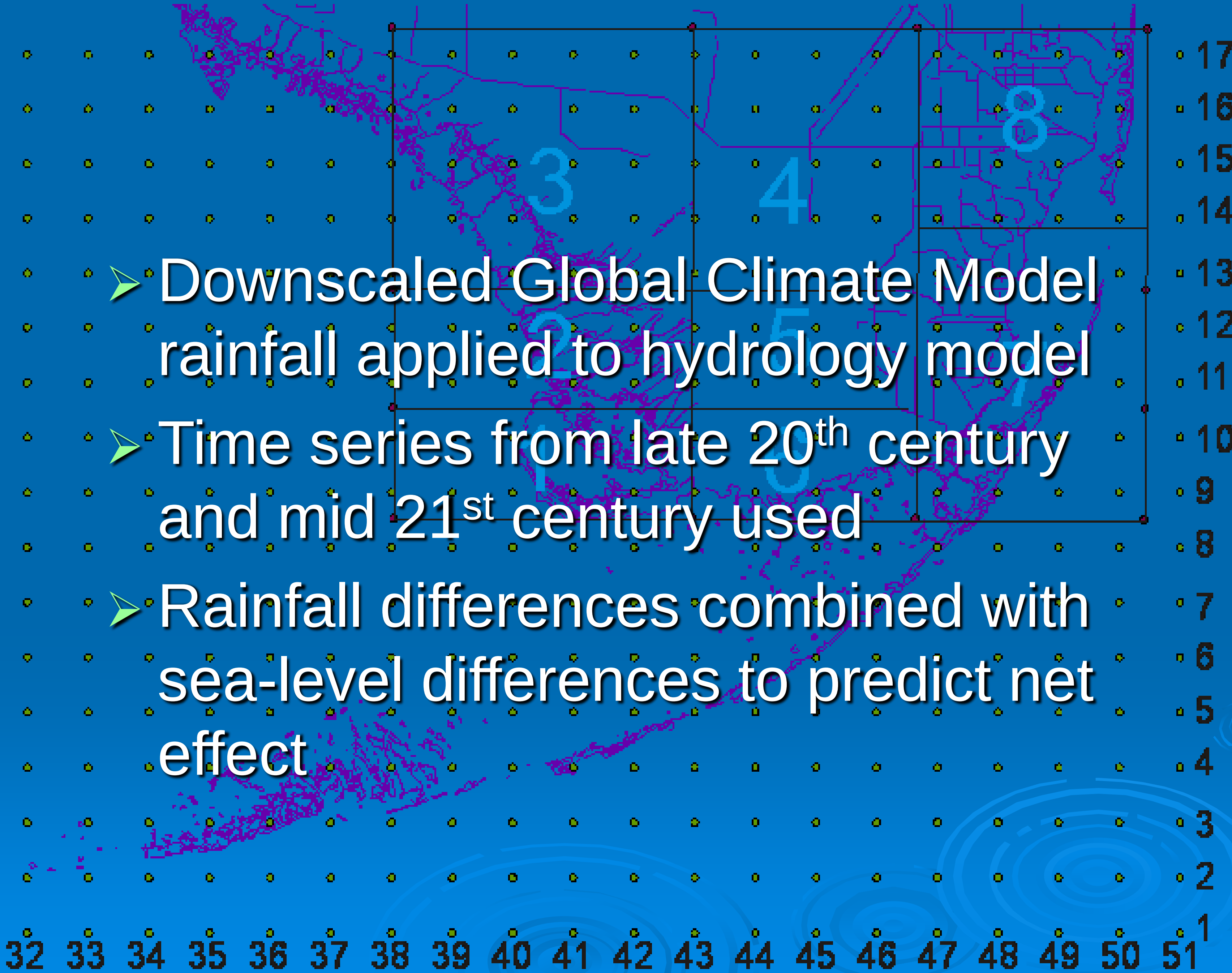
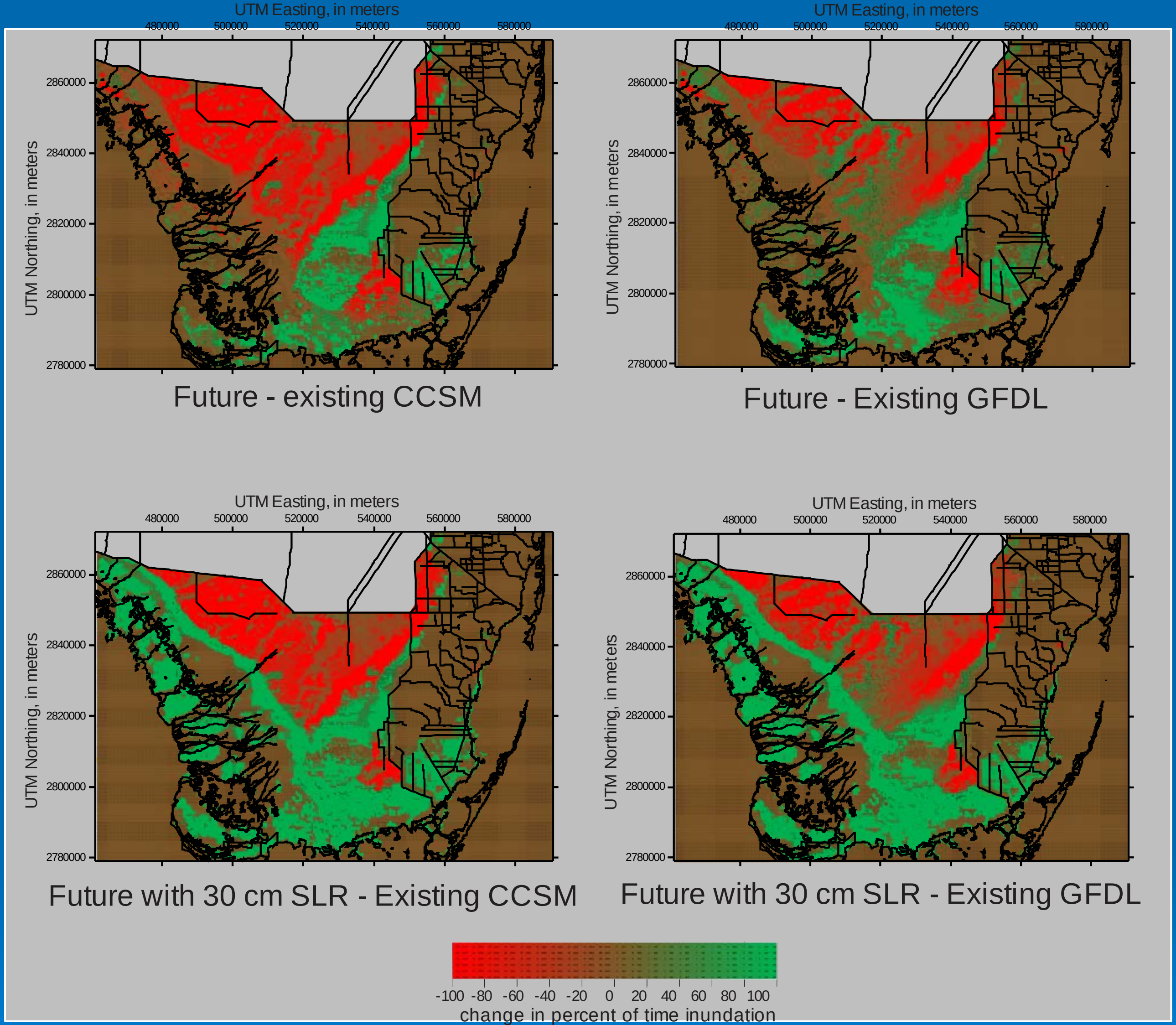
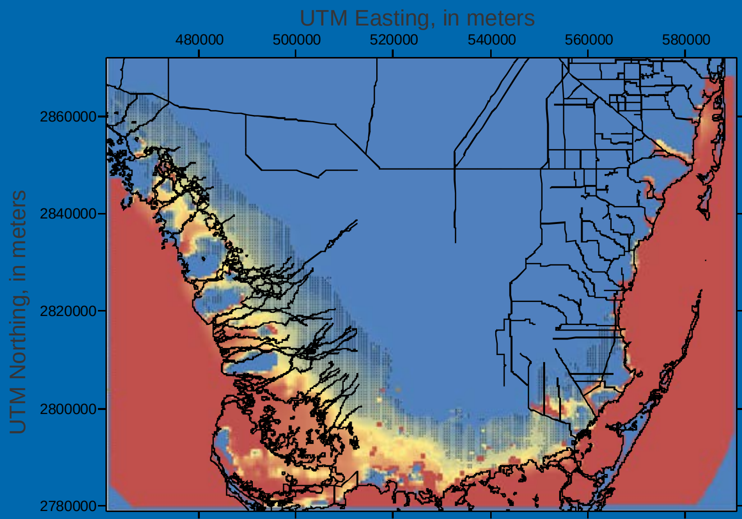
- Downscaled Global Climate Model rainfall applied to hydrology model
- Time series from late 20th century and mid 21st century used
- Rainfall differences combined with sea-level differences to predict net effect



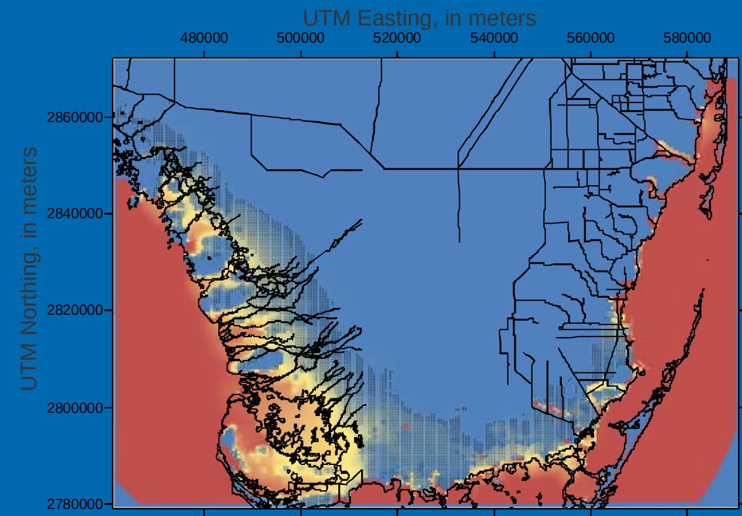


Swain, E., Stefanova, L., and Smith, T., 2014. Applying Downscaled Global Climate Model Data to a Hydrodynamic Surface-Water: American Journal of Climate Change, Vol. 3 No. 1, 2014, pp. 33-49.

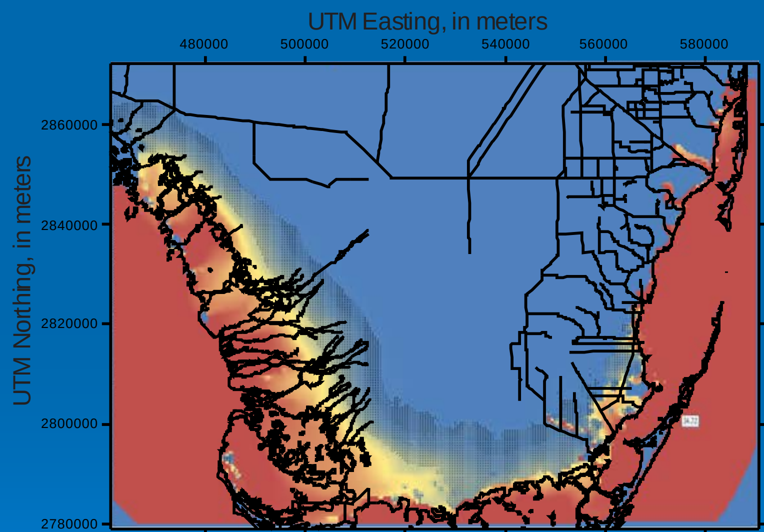
Differences in time inundated with future rainfall from global climate models

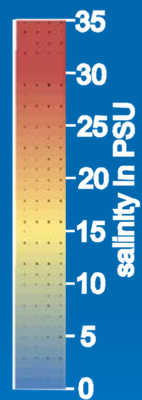


1996-1999 rainfall



2038-2057 rainfall

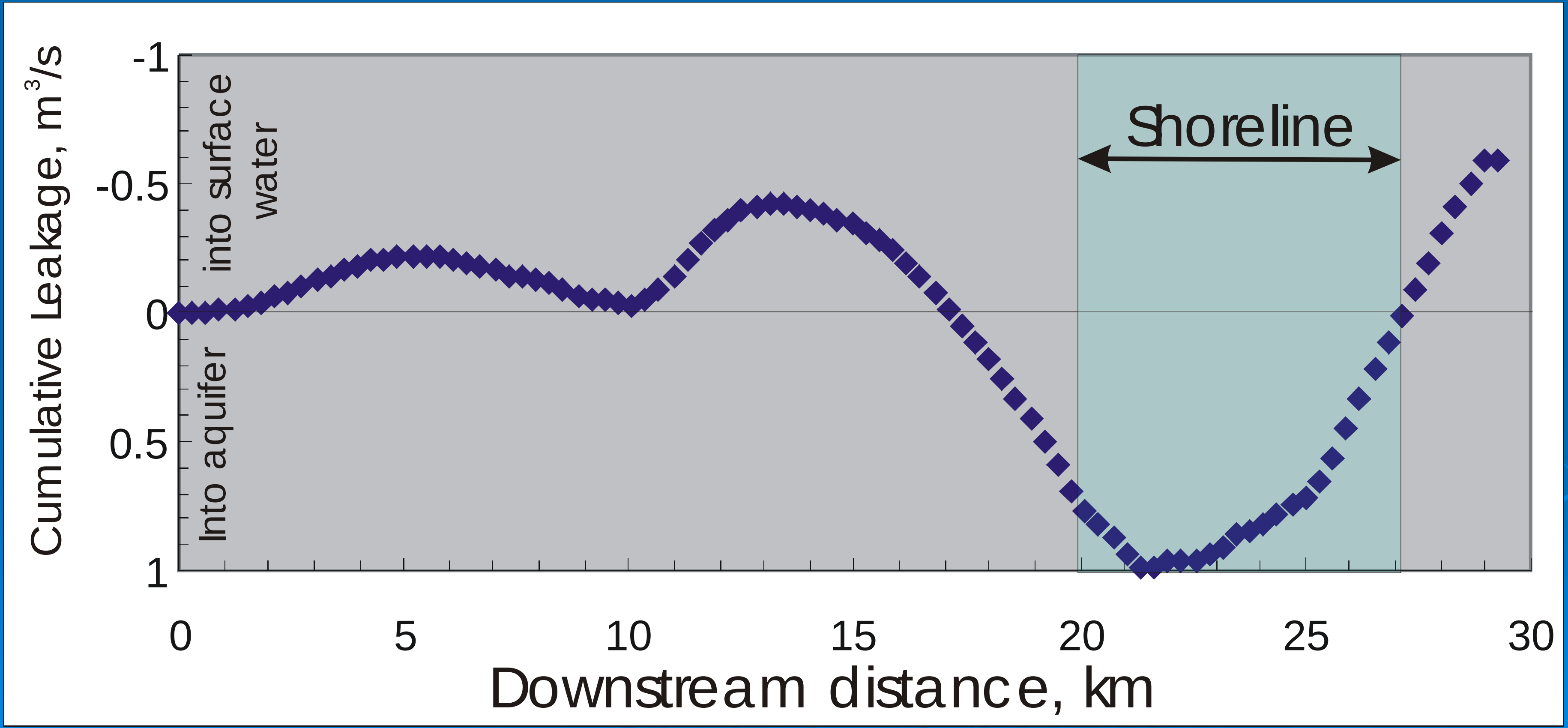


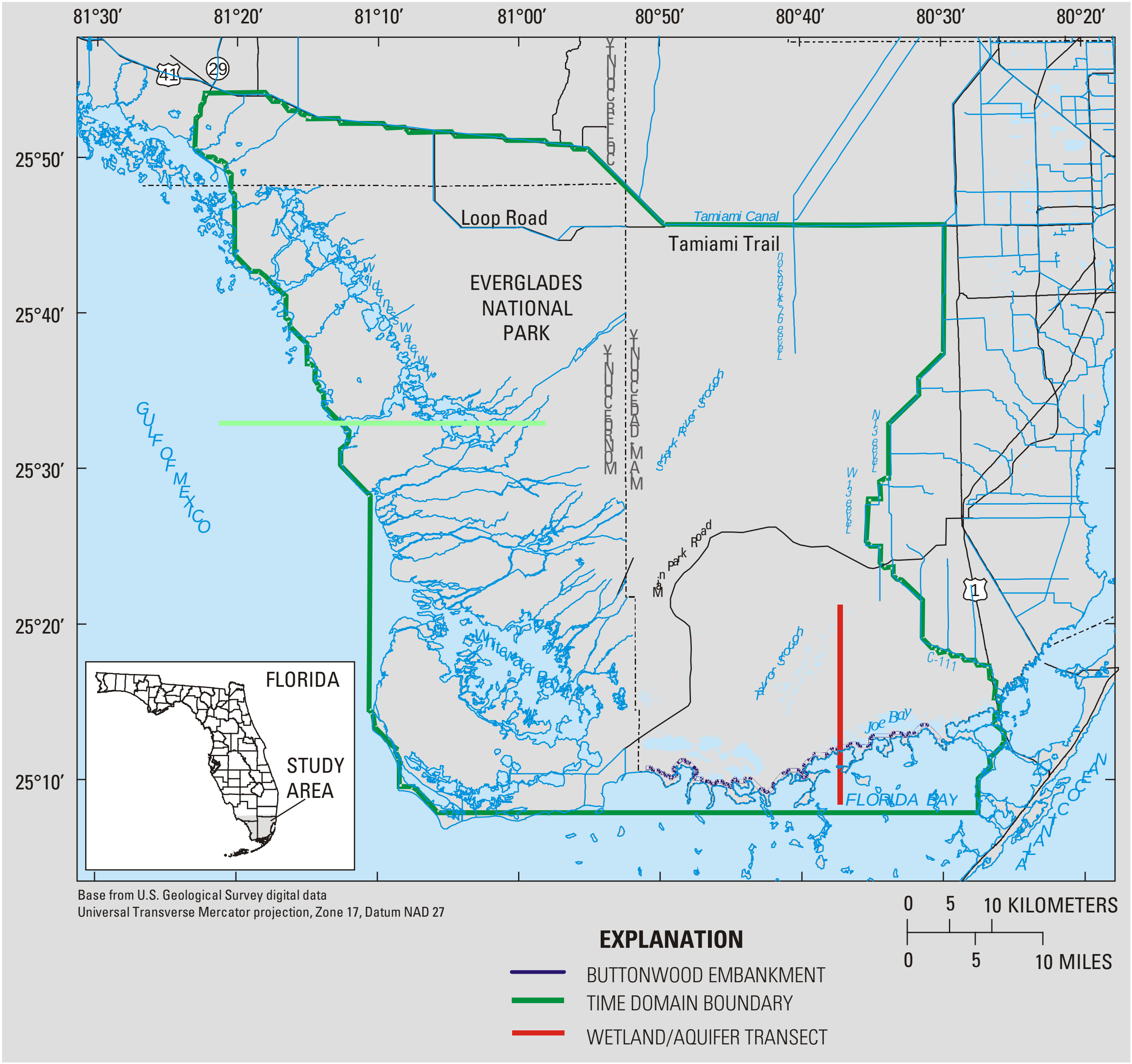


2038-2057 rainfall, 1 foot sea-level rise

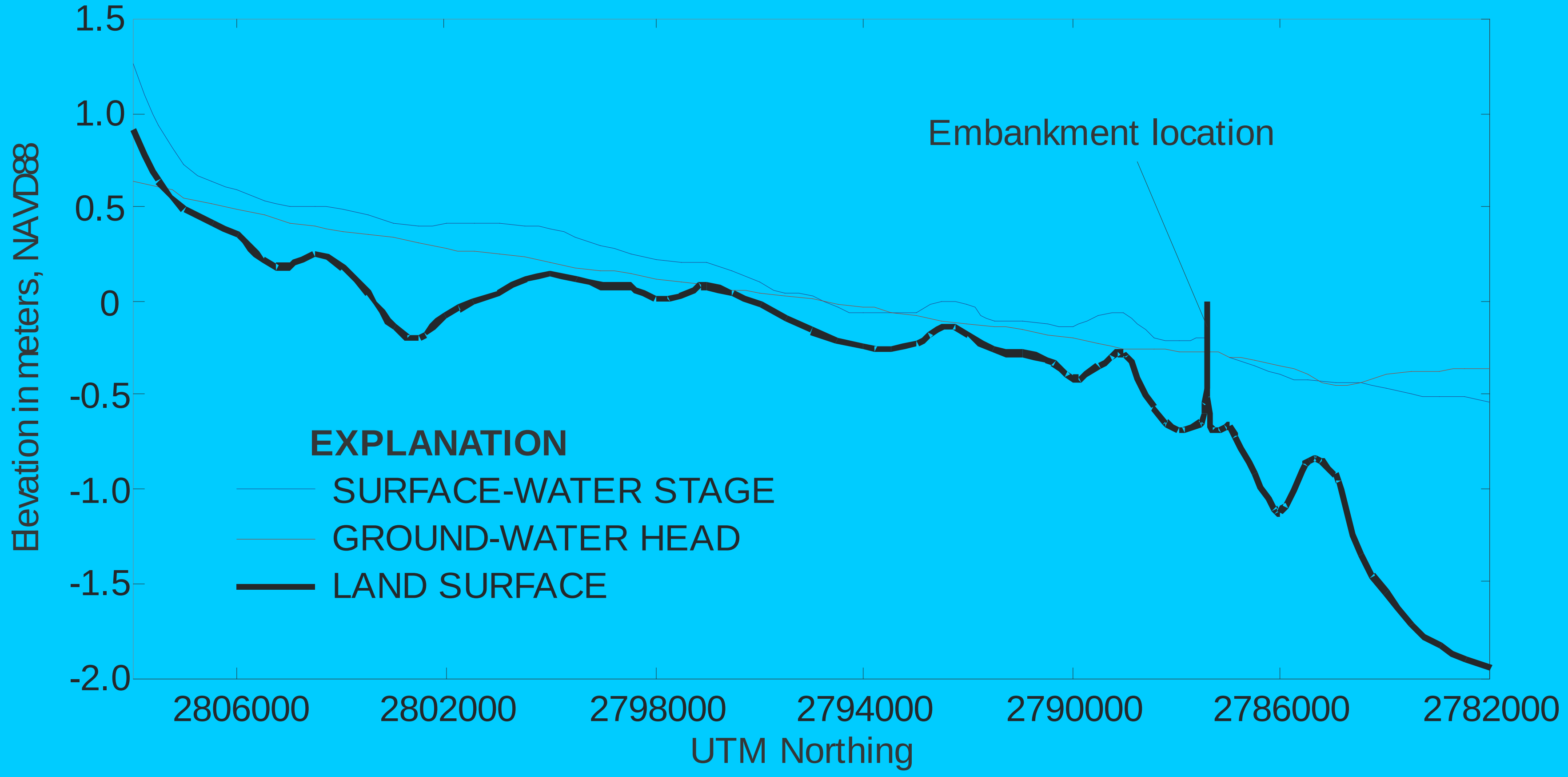
Comparison of average salinity between late 20th century scenario and future rainfall and sea-level rise scenario.

Defining the salinity interface - cumulative leakage from north to south





Location of transects through model domain



Average water levels along north-south transect

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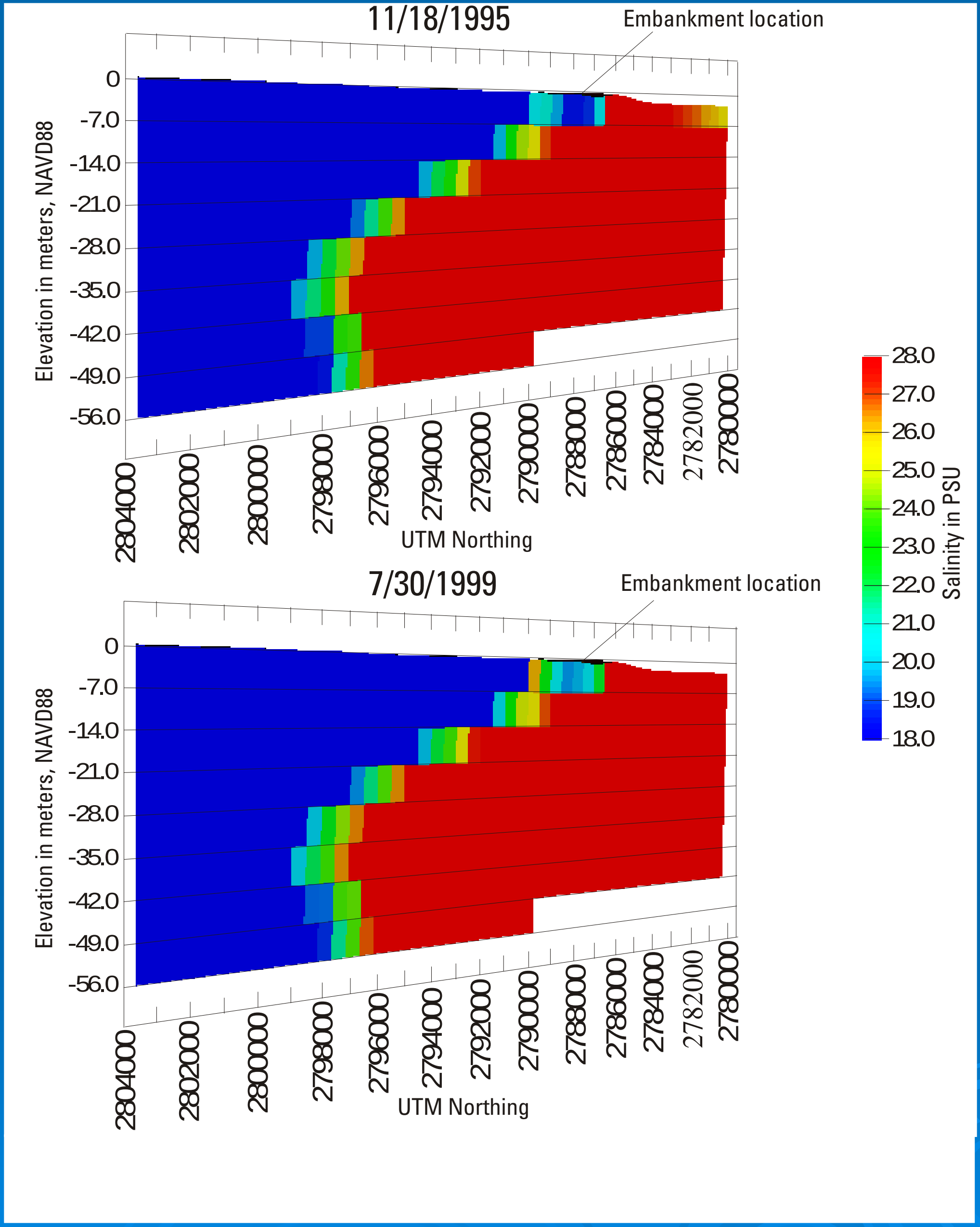
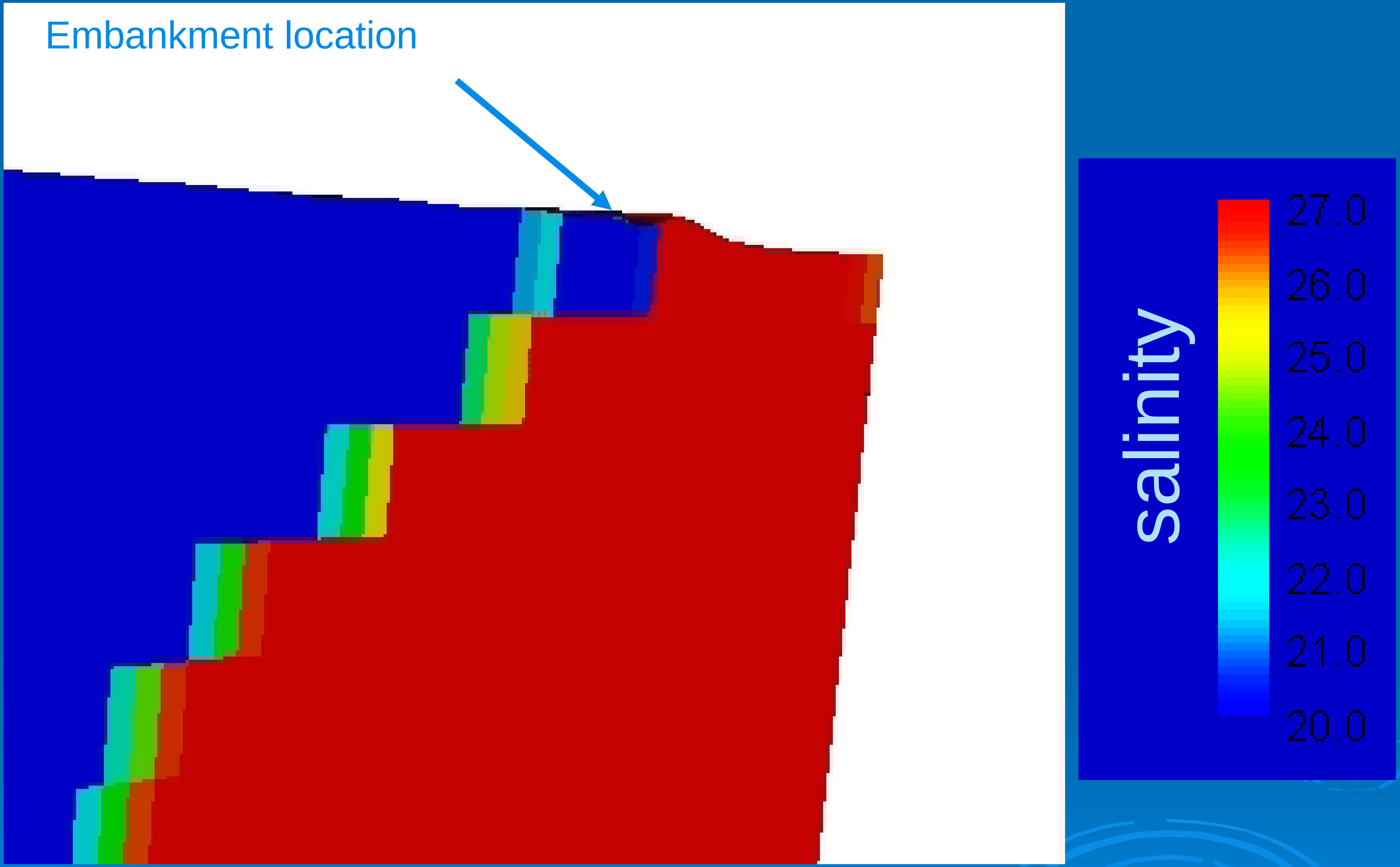
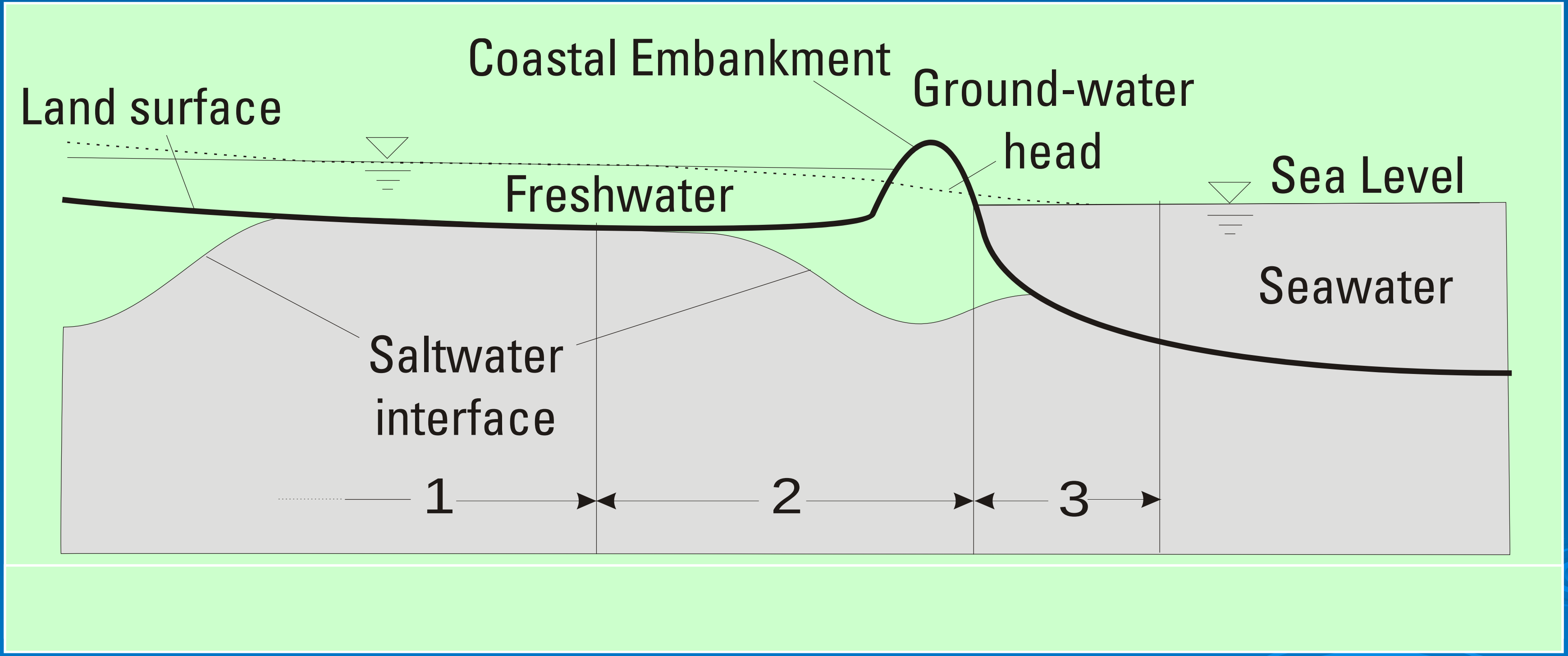


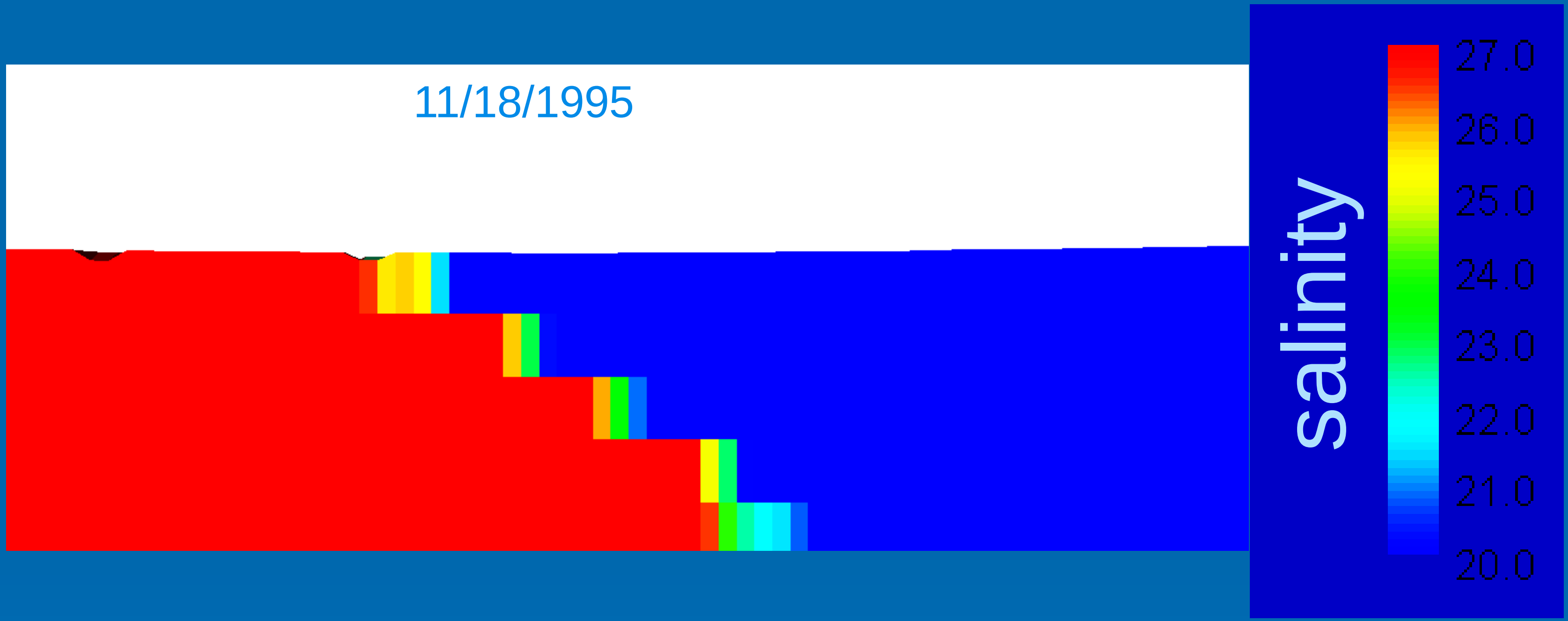
Aquifer salinity along north-south transect



1997-1999 simulation shows changes only in top layer

Coastal Everglades salinity interface as indicated by model

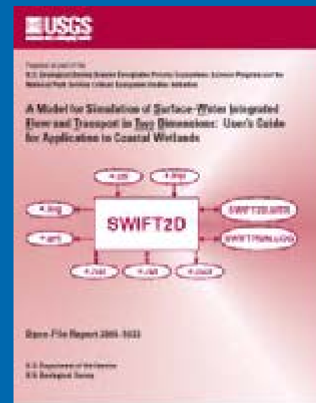




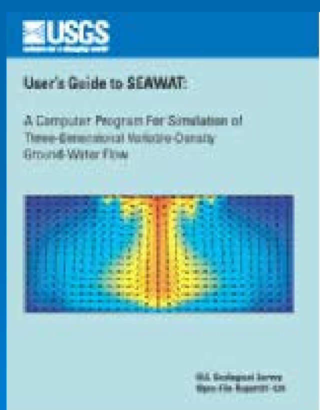
East-west transect shows a saltwater interface representation closer to classical model

Publications – Codes and Models

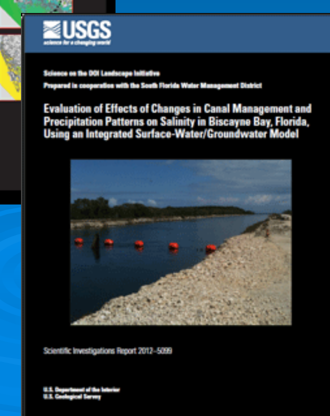
SWIFT2D



SEAWAT



FTLOADDS



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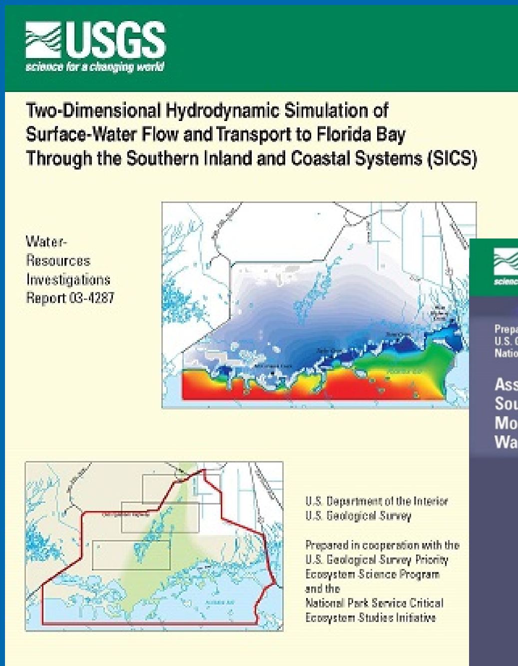
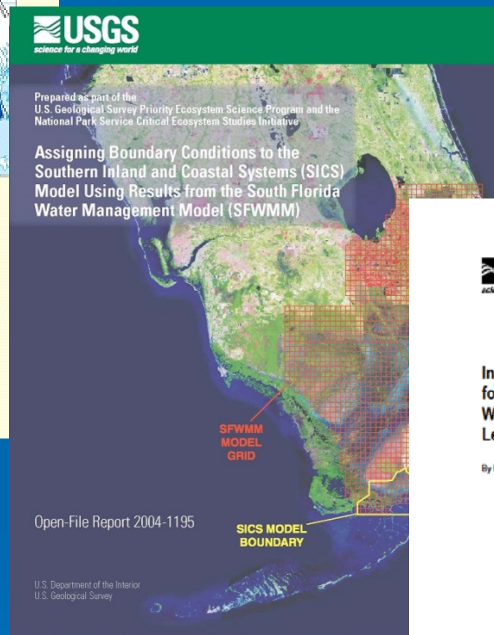
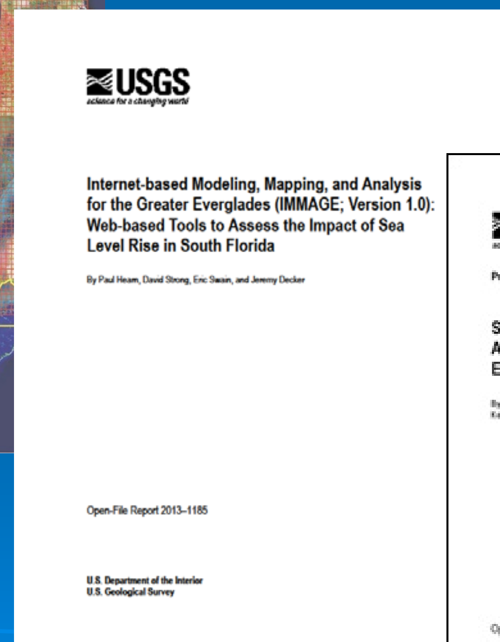
Publications – Additional USGS Reports







Publications – Additional Peer-reviewed

American Journal of Climate Change, 2013

Applying Downscaled Global Climate Model Data to a Hydrodynamic Surface-Water and Groundwater Model

Eric Swain, Lydia Stefanova, and Thomas Smith

Wetlands — HYDROLOGIC RESTORATION

Evaluating Effects of Everglades Restoration on American Crocodile Populations in South Florida Using a Spatially-Explicit, Stage-Based Population Model

Timothy W. Green · Daniel H. Slone · Eric D. Swain · Michael S. Cherkiss · Melinda Lohmann · Frank J. Mazzotti · Kenneth G. Rice

Wetlands (2010) 30:635–648 — ORIGINAL PAPER

Measurement-derived Heat-budget Approaches for Simulating Coastal Wetland Temperature with a Hydrodynamic Model

Eric Swain · Jeremy Decker

Critical Reviews in Environmental Science and Technology

Use of Hydrologic and Hydrodynamic Modeling for Ecosystem Restoration

The Role of Hydrology in Water Resources Management (Proceedings of a symposium held on the island of Capri, Italy, October 2008). IAHS Publ. 327, 2009.

Hydrological simulations of water-management scenarios in support of the Comprehensive Everglades Restoration Plan

Eric D. Swain, Melinda Lohmann & Jeremy Decker

Journal of Hydrology (2008) 351, 188–202

Inverse modeling of surface-water discharge to achieve restoration salinity performance measures in Florida Bay, Florida

Eric D. Swain, Dawn E. James

Journal of Coastal Research 24 6 1418–1429 West Palm Beach, Florida November 2008

Utilizing Spectral Analysis of Coastal Discharge Computed by a Numerical Model to Determine Boundary Influence

Eric D. Swain, Christian D. Langevin, and John D. Wang

Hydrological simulations of water-management scenarios in support of the Comprehensive Everglades Restoration Plan

Eric D. Swain, Melinda Lohmann & Jeremy Decker

Other FTLOADDS Publications

- Cline, Jon C., Lorenz, Jerome J., and Swain, Eric D., 2004, Linking Hydrologic Modeling and Ecologic Modeling: An Application of Adaptive Ecosystem Management in the Everglades Mangrove Zone of Florida Bay: International Environmental Modelling and Software Society iEMSs 2004 International Conference, June 14-17 2004, University of Osnabrück, Germany.
- Swain, E.D., Langevin, C.D., and Wolfert, M.A. 2002. Cooperative linking of numerical models for coastal wetland planning: American Water Resources Association's Spring Specialty Conference on "Coastal Water Resources," May 13-15, 2002, New Orleans, Louisiana.
- Langevin, C.D., Swain, E.D., and Wolfert, M.A. 2002. Numerical simulation of integrated sur-face-water/ground-water flow and solute transport in the southern Everglades in Florida: Second Federal Interagency Hydrologic Modeling Conference, Las Vegas, Nevada, July 28 - August 1, 2002.
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- Swain, E.D., 2000, Dynamic numerical wetland modeling to determine destinations of surface water: AWRA 2000 Annual Water Resources Conference, Miami, Florida, November 6-9, 2000.
- Swain, E.D., 2000, Development of numerical tools for integrating wetland hydrologic processes: SICS and TIME: in U.S. Geological Survey Open-File report 00-449, p. 54-56.
- Swain, E.D., 1999, Two-dimensional simulation of flow and transport to Florida Bay through the Southern Inland and Coastal Systems (SICS): in U.S. Geological Survey Open-File Report 99-181, p. 108-109.
- Swain, E.D., 1999, Numerical Representation of Dynamic Flow and Transport at the Everglades/ Florida Bay Interface: Third International Symposium on Ecohydraulics, Salt Lake City, Utah, July 13-16, 1999.
- Swain, E.D., 1998, Using a Two-Dimensional Surface-Water Model to Integrate Coastal Wetland Data From Multiple Process Studies: Proceedings of the American Geophysical Union Spring Meeting, Boston Massachusetts, May 26-28 1998.

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- John Hamrick, Tetratech
- Glenn Landers, Russ Weeks, Jessica Files, USACE
- Jayantha Obeysekera, SFWMD
- Kiren Bahm, Robert Fennema, Ed Kearns, Dewitt Smith, ENP
- Michael Swain, University of Miami

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