

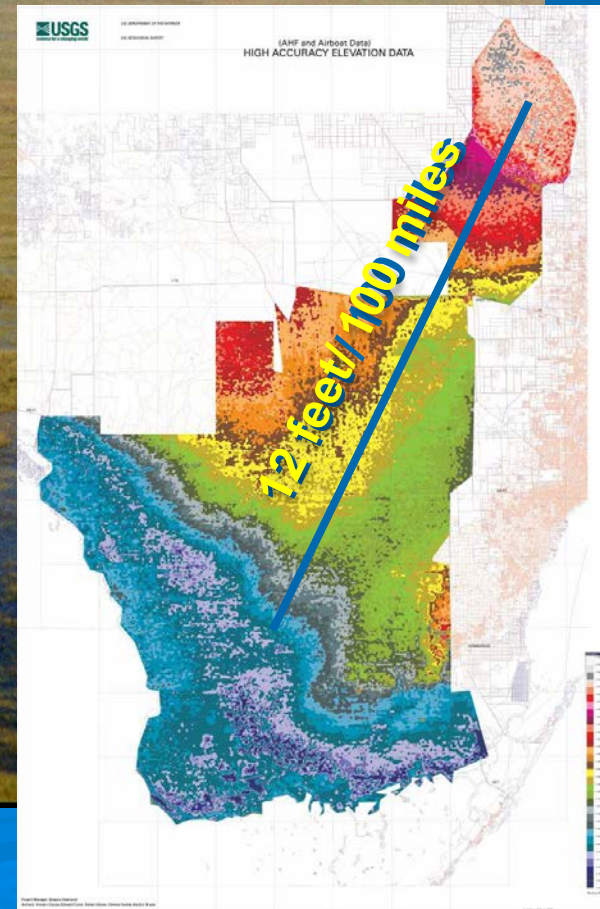
Modeling Hydrodynamic Effects and Salinity Intrusion

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

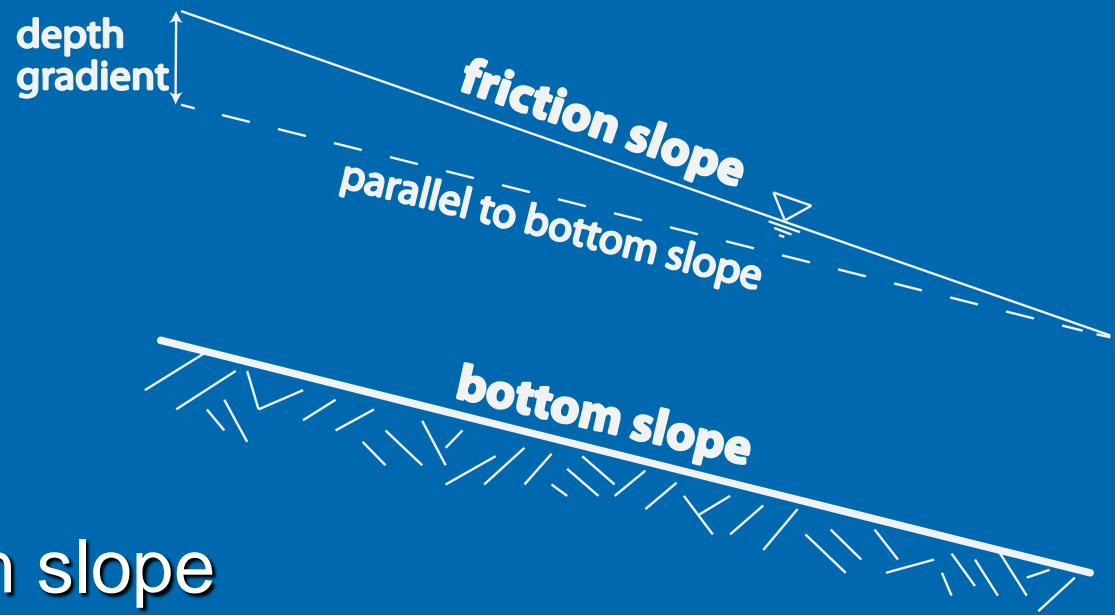
Requirements

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

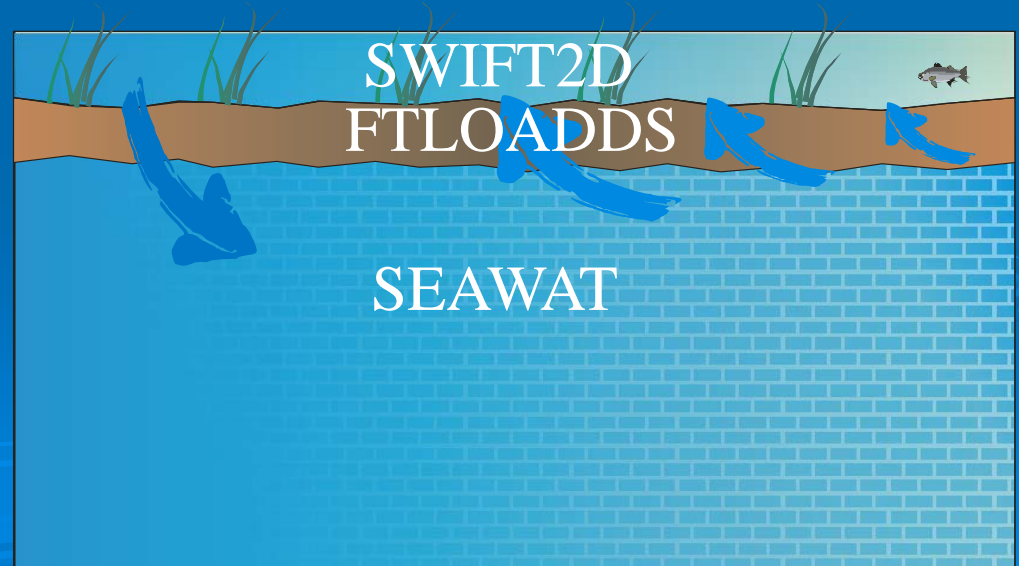
friction slope - depth gradient + temporal
acceleration + spatial acceleration = bottom slope

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



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

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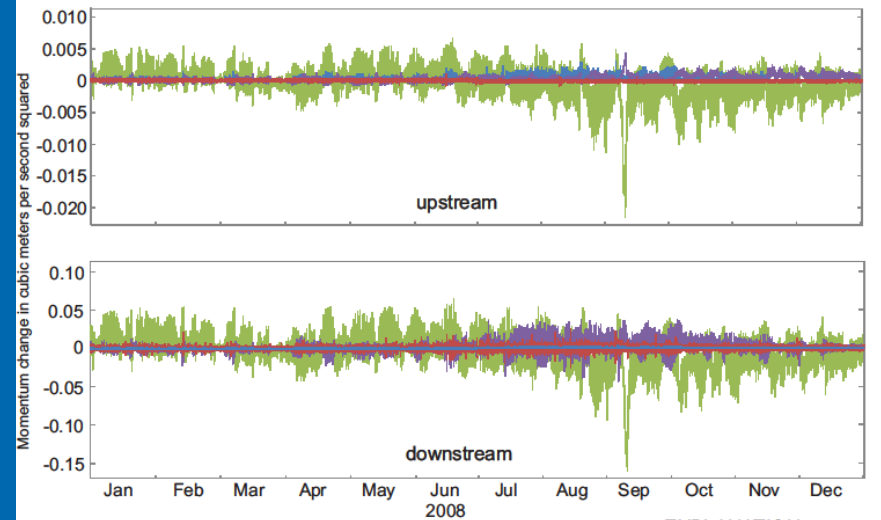
Abstract

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

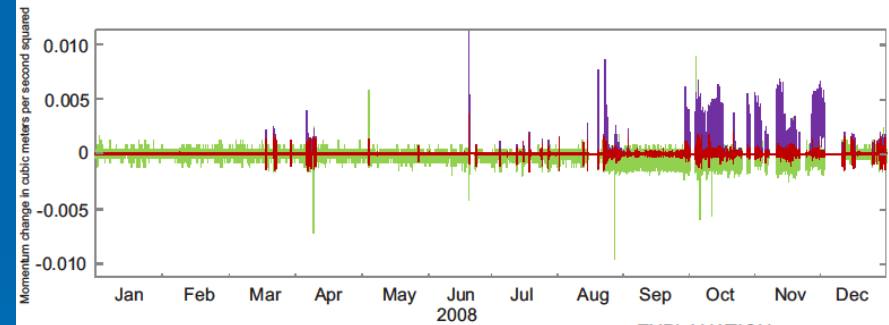
How to cite this paper: Swain, E.D., et al. (2014) Utilizing Dimensional Analysis with Observed Data to Determine the Significance of Hydrodynamic Solutions in Coastal Hydrology. *Computational Water, Energy, and Environmental Engineering*, 3, 57-77. <http://dx.doi.org/10.4236/cweee.2014.32008>



Shark River

EXPLANATION

- temporal acceleration
- spatial acceleration
- gravity term
- friction term



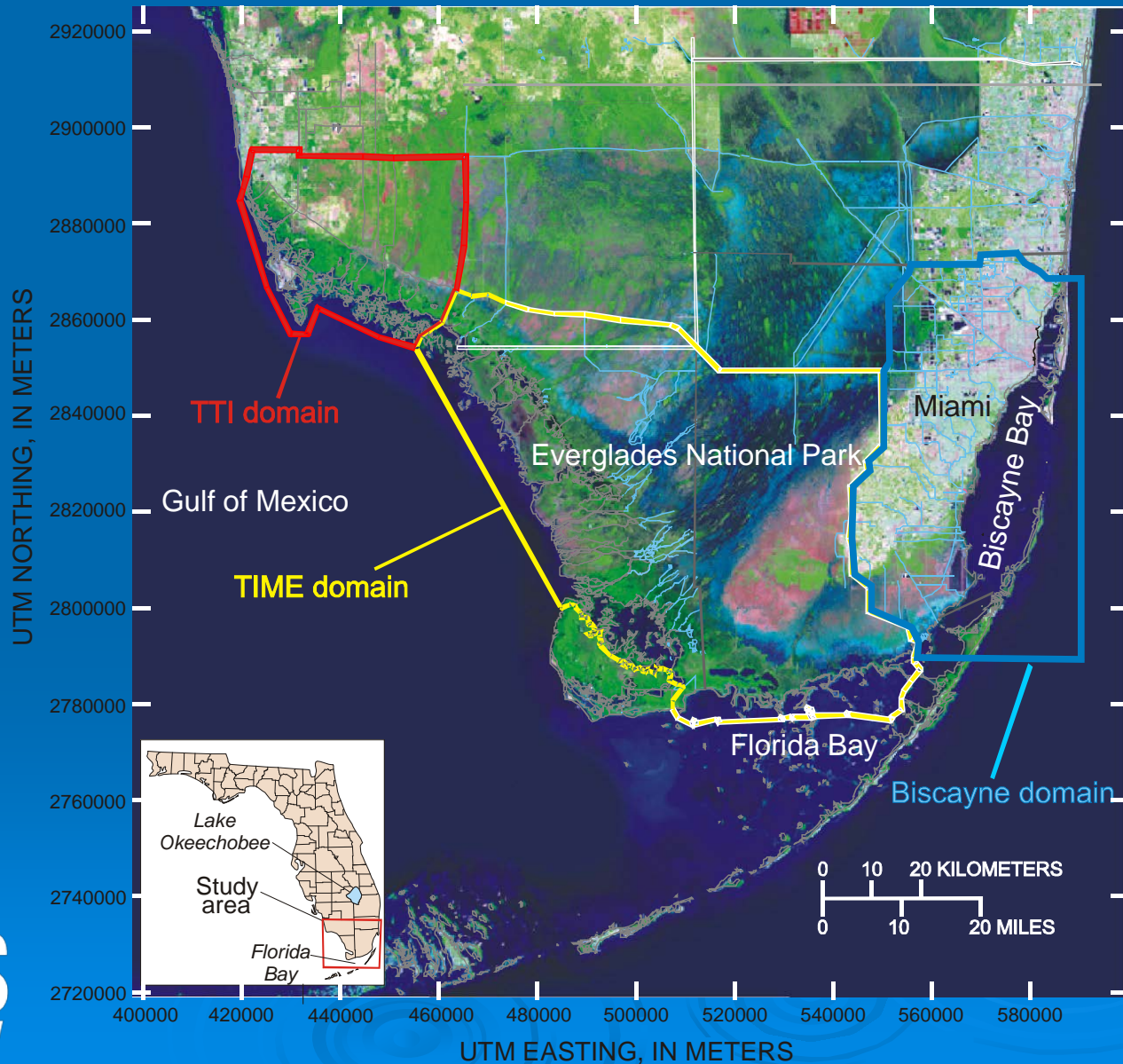
Miami Canal

EXPLANATION

- temporal acceleration
- gravity term
- friction term

Recent publication surveys field conditions under which hydrodynamic terms are important

South Florida and Model Areas



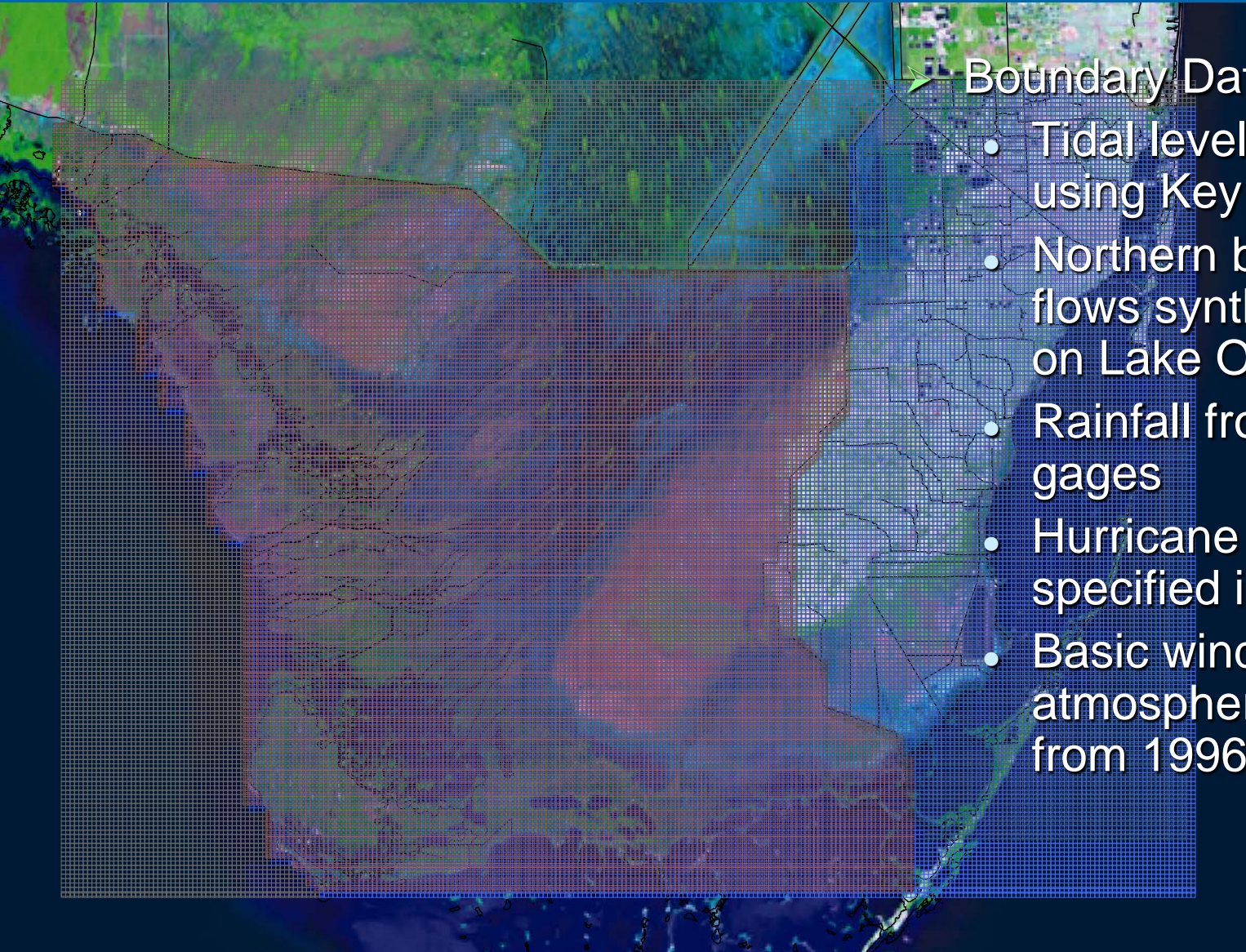
When is a hydrodynamic simulation coupled with groundwater most useful?

- 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



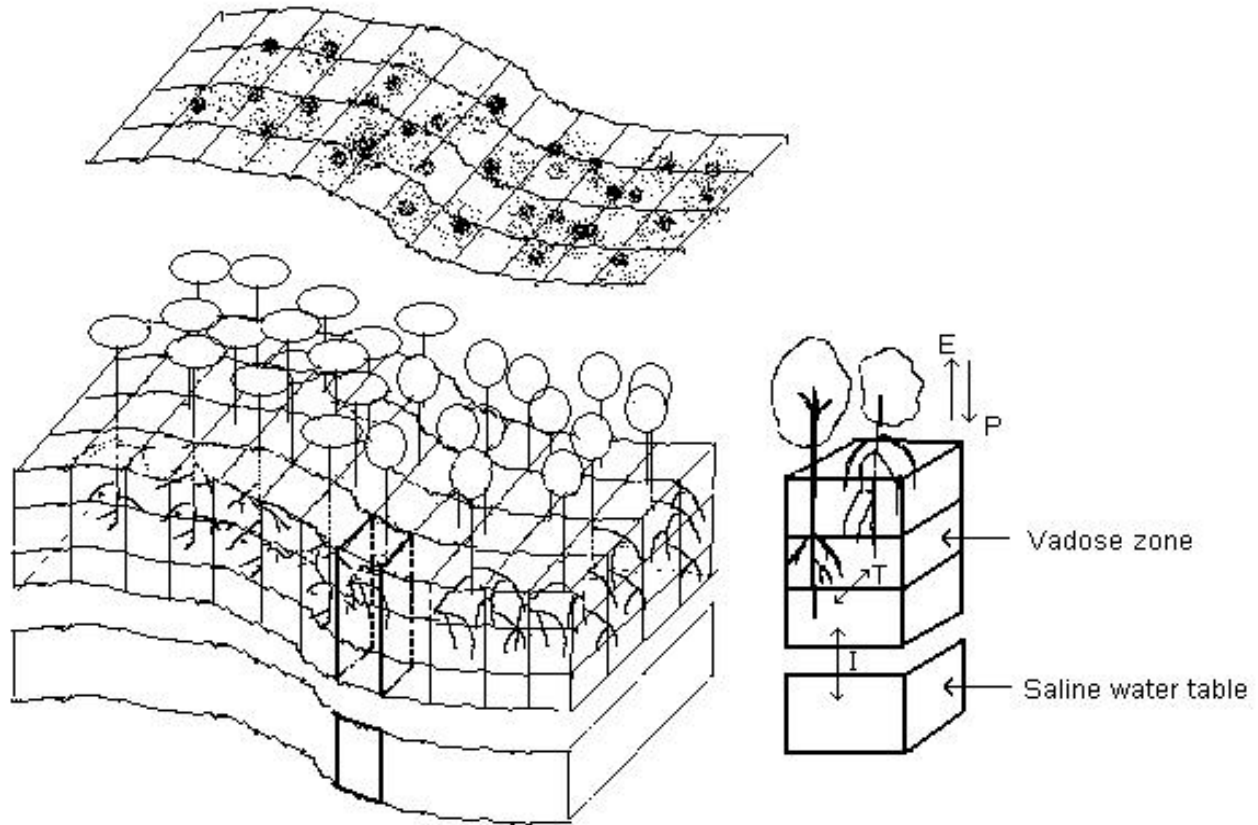
Boundary Data

- 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

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

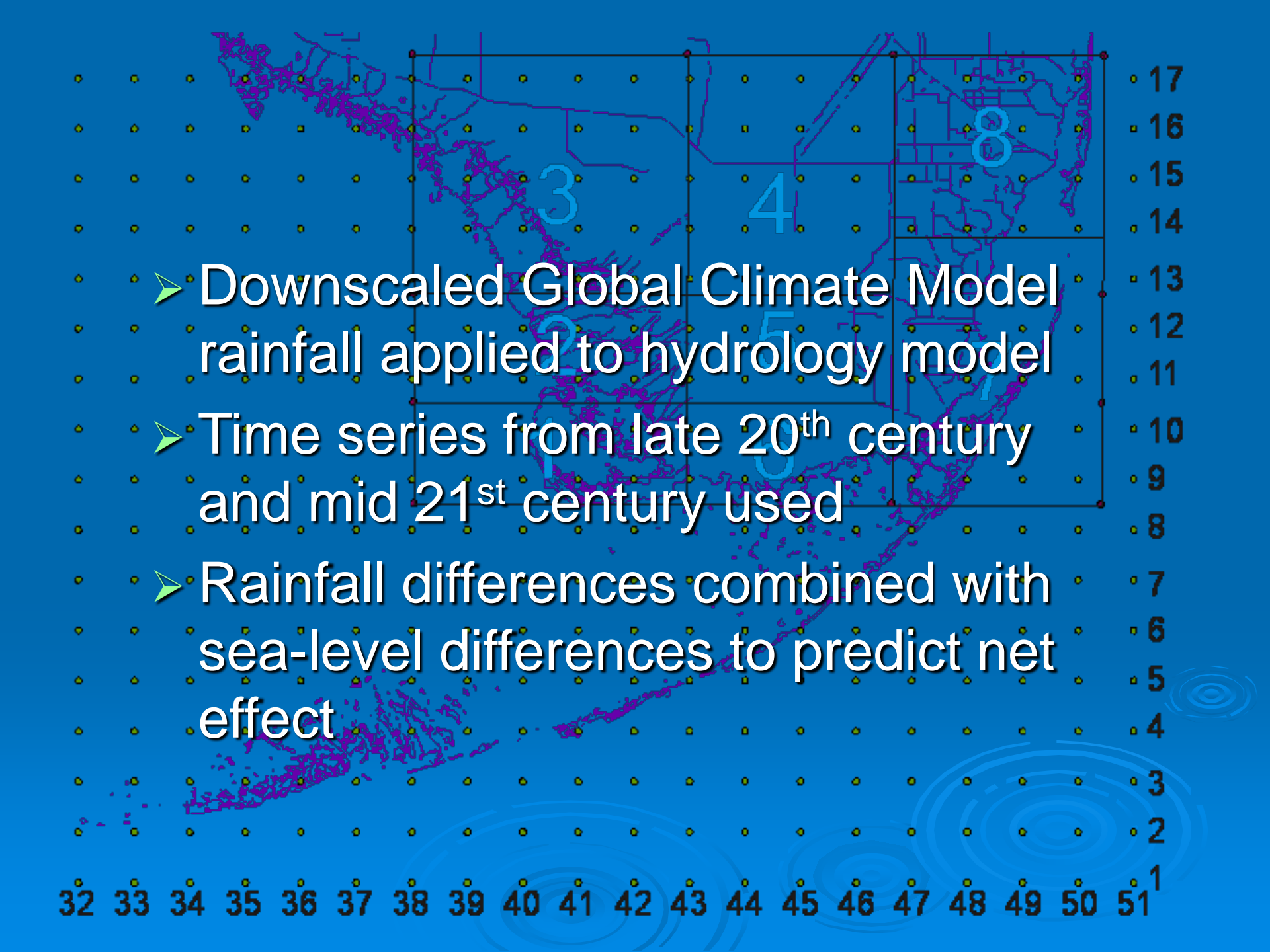


To Examine Future Conditions: Incorporating Sea-Level Rise

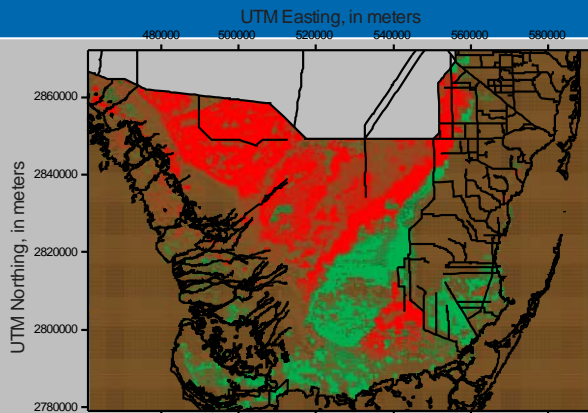
- Represent existing period with increased tidal levels
- Can be combined with estimated future conditions such as rainfall, water management
- Needed conditions for future storm effects

To Examine Future Conditions: Downscaled Climate Data

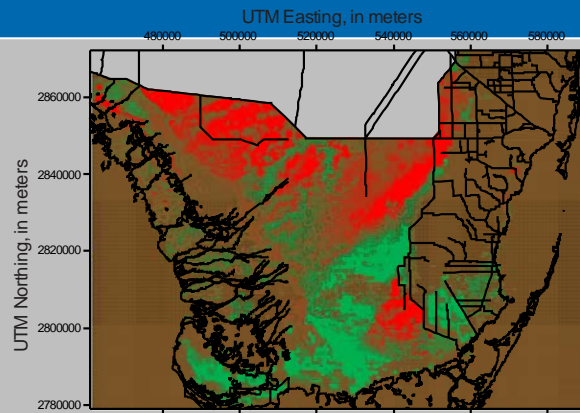
- Rainfall data from Global Climate Models and reanalysis is downscaled for hydrology model input
- Comparison is made between existing conditions and downscaled input
- Effects of future rainfall scenarios can be examined

- 
- A map of the United States overlaid with a grid. The grid has columns numbered 32 to 51 and rows numbered 1 to 17. Eight regions are outlined in red and numbered 1 through 8 in blue. Region 1 is in the southwest, 2 in the central-west, 3 in the north-west, 4 in the north-central, 5 in the central, 6 in the south-central, 7 in the southeast, and 8 in the northeast. A list of bullet points is overlaid on the map.
- 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

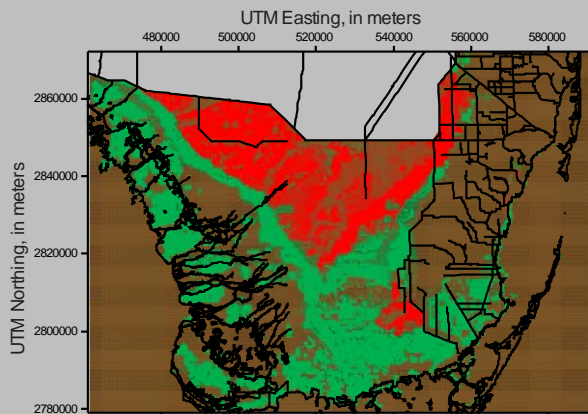
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51



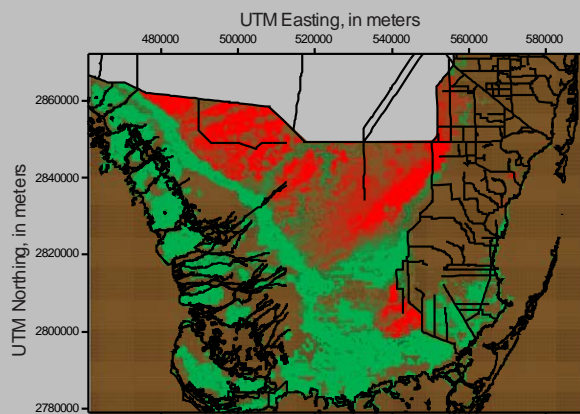
Future - existing CCSM



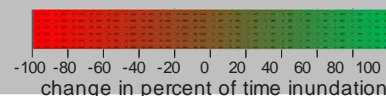
Future - Existing GFDL



Future with 30 cm SLR - Existing CCSM

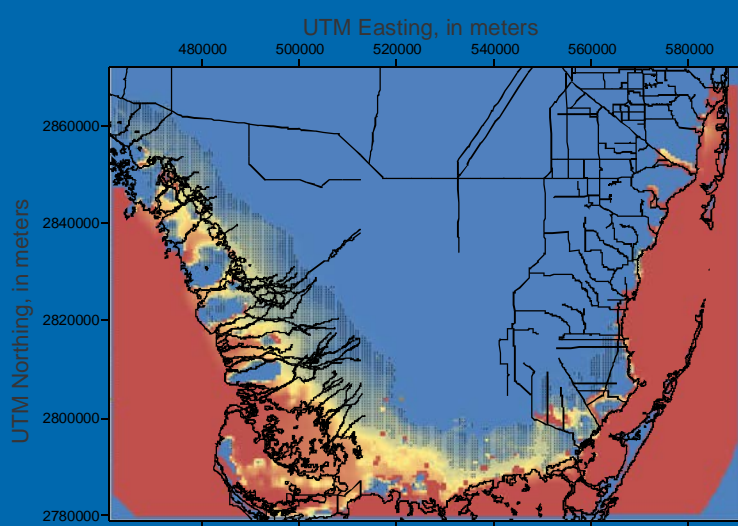


Future with 30 cm SLR - Existing GFDL

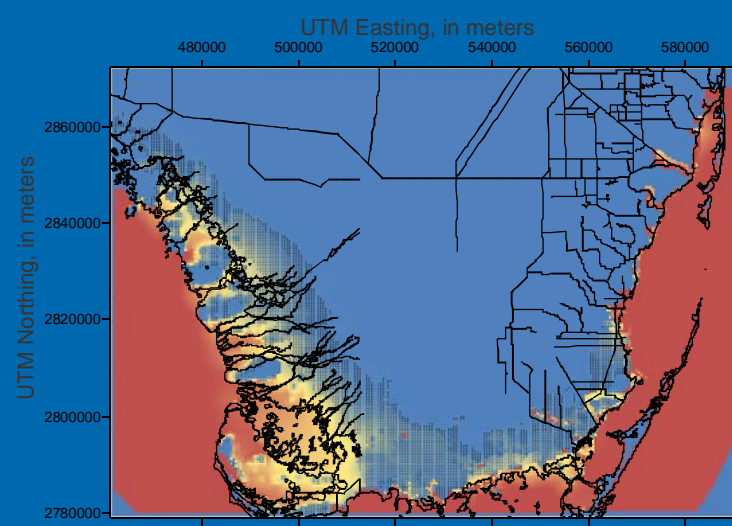


Swain, E., Stefanova, L., and Smith, T., 2014. Applying Downscaled Global Climate Model Data to a Hydrodynamic Surface-Water: American Journal of Climate Change, Vol. 3 No. 1, 2014, pp. 33-49.

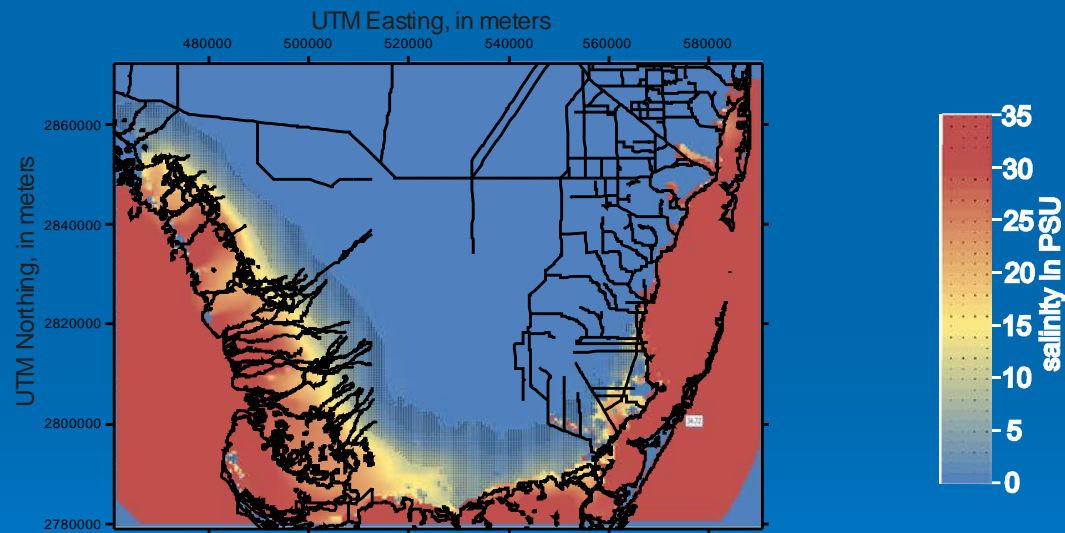
Differences in time inundated with future rainfall from global climate models



1996-1999 rainfall



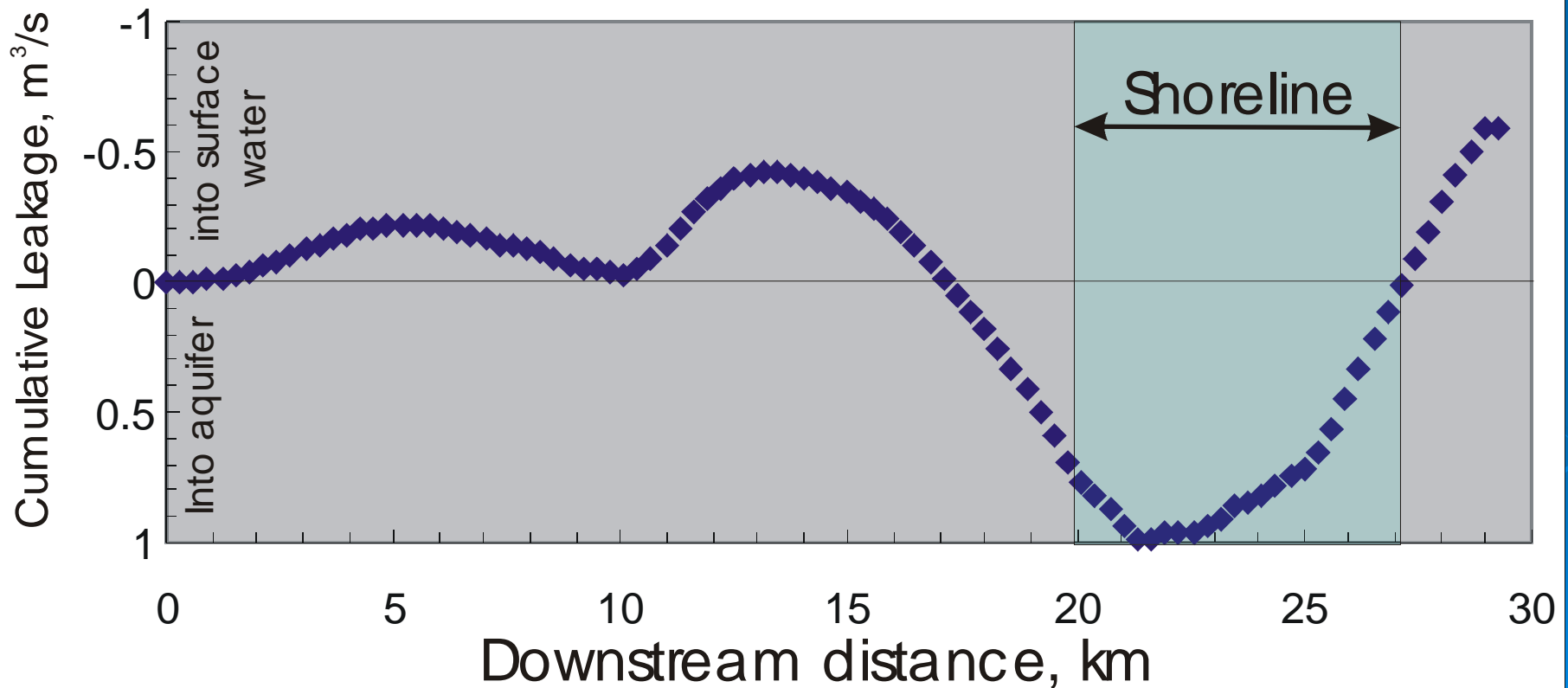
2038-2057 rainfall

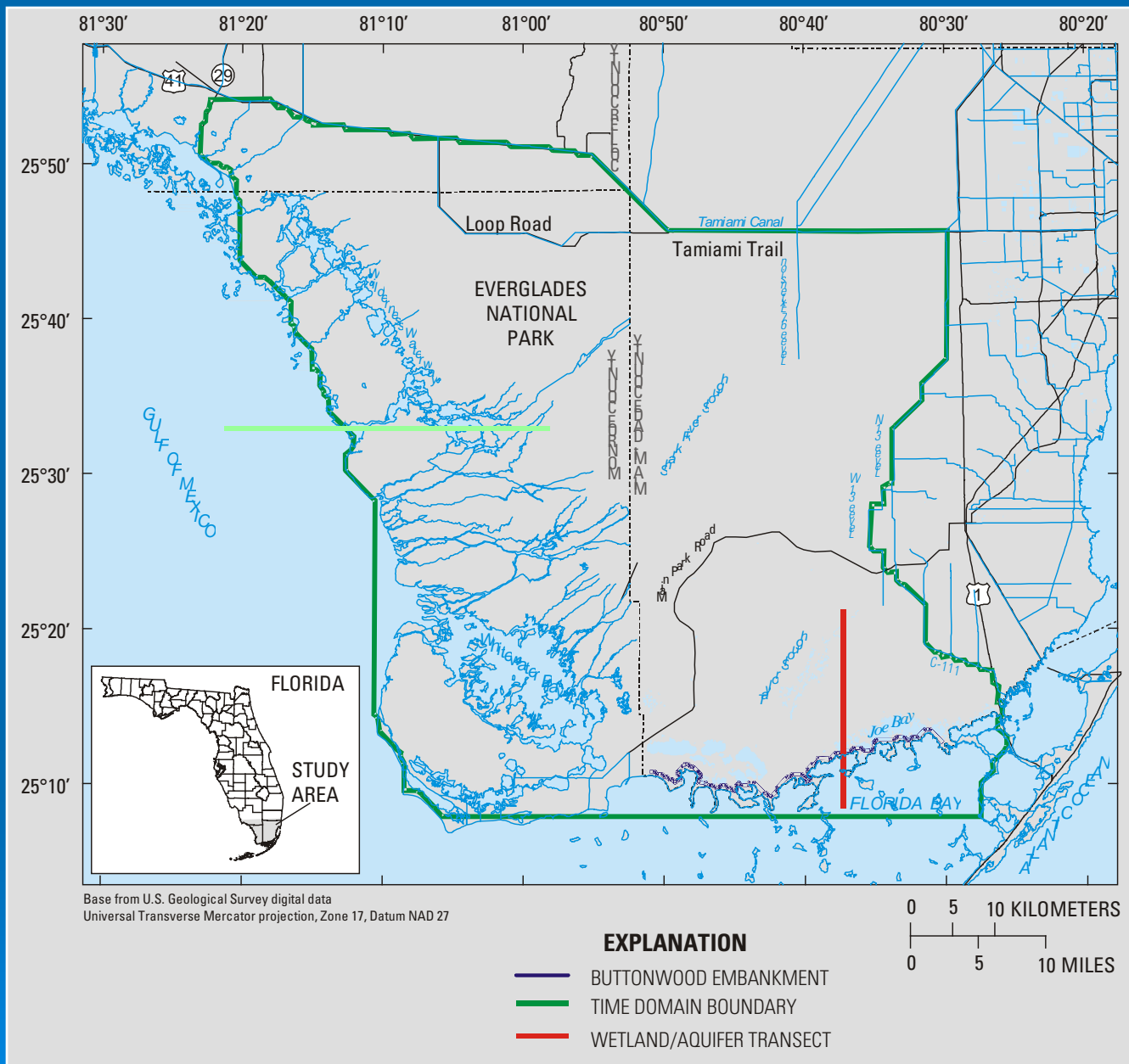


2038-2057 rainfall, 1 foot sea-level rise

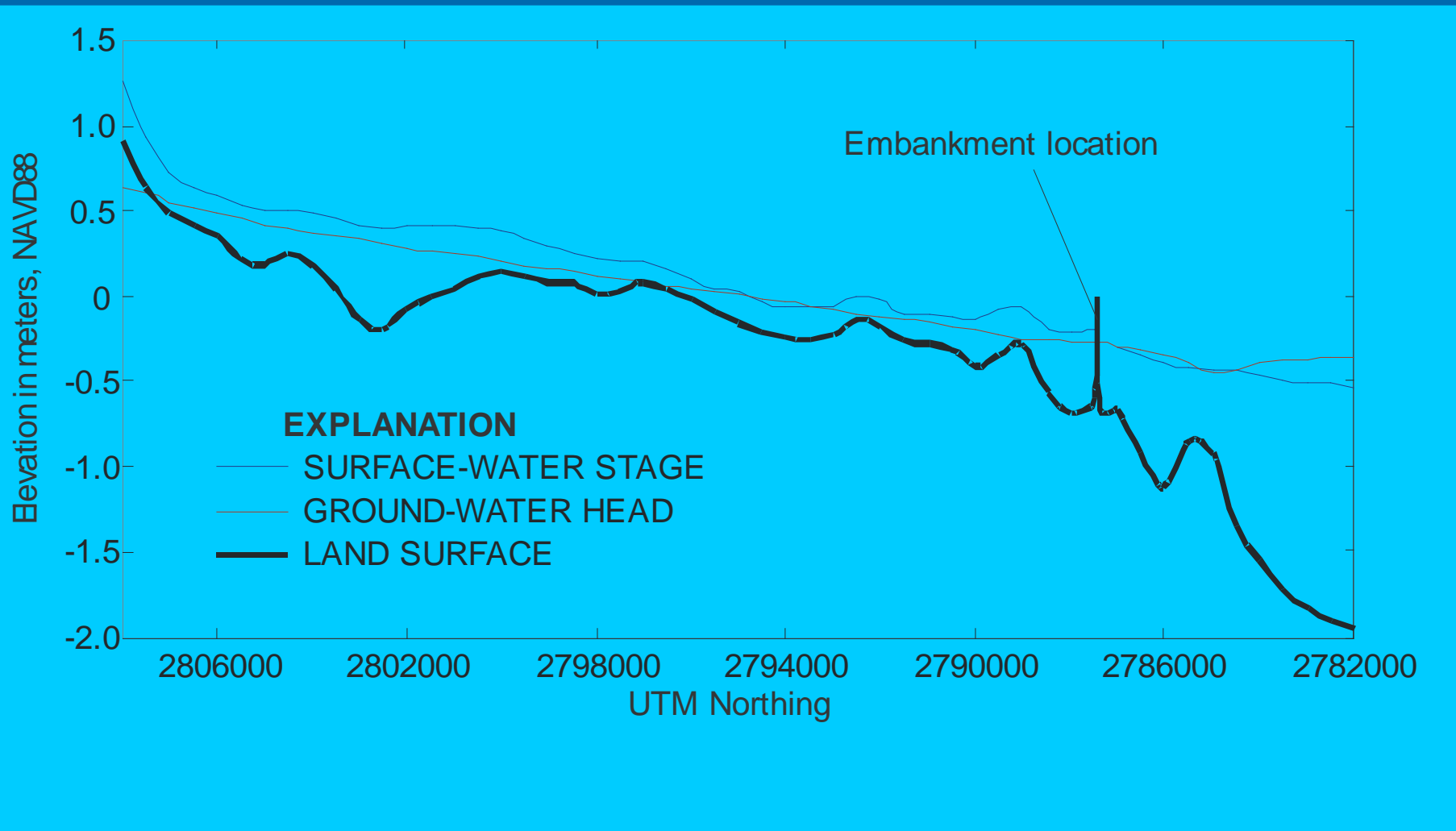
Comparison of average salinity between late 20th century scenario and future rainfall and sea-level rise scenario.

Defining the salinity interface - cumulative leakage from north to south

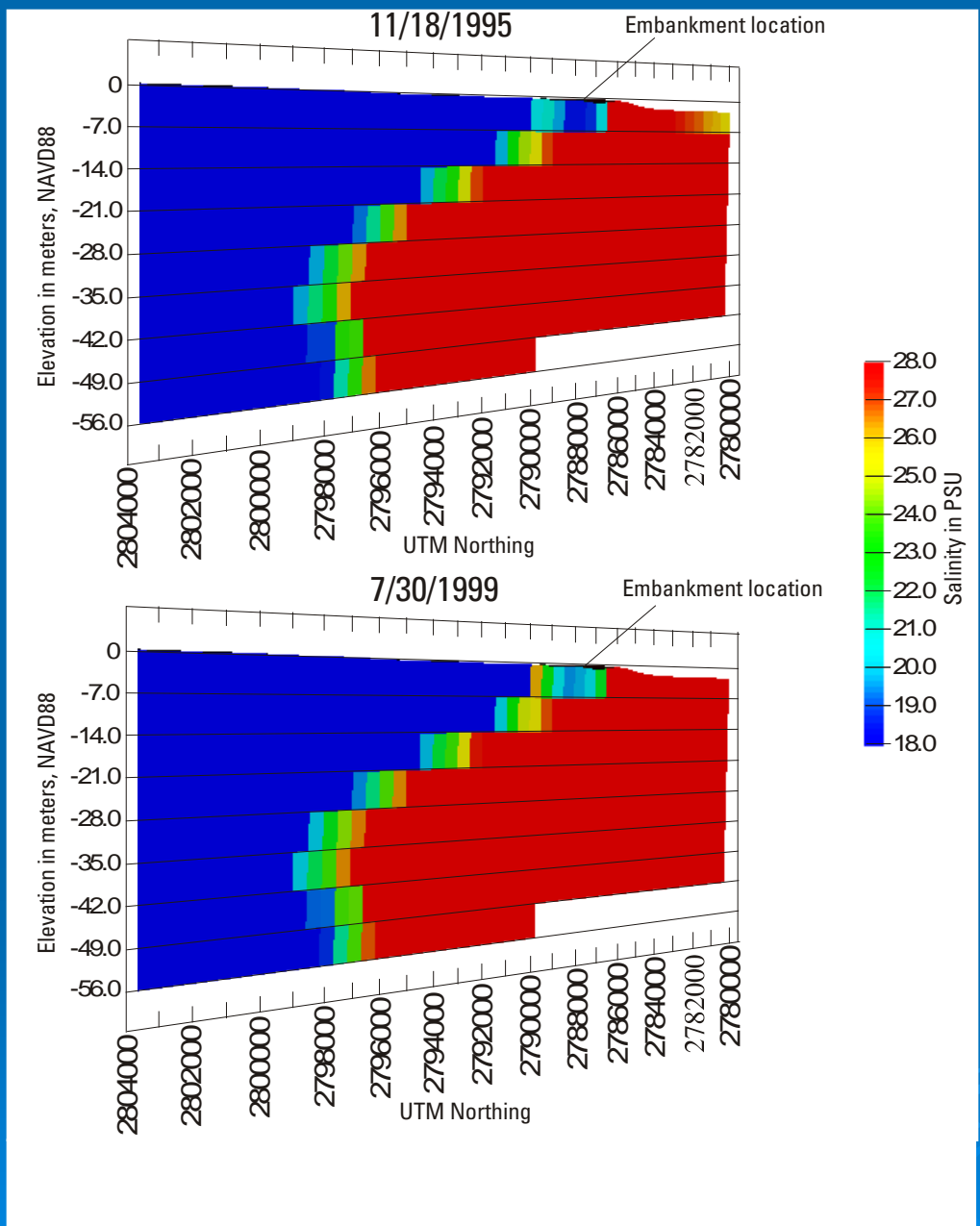




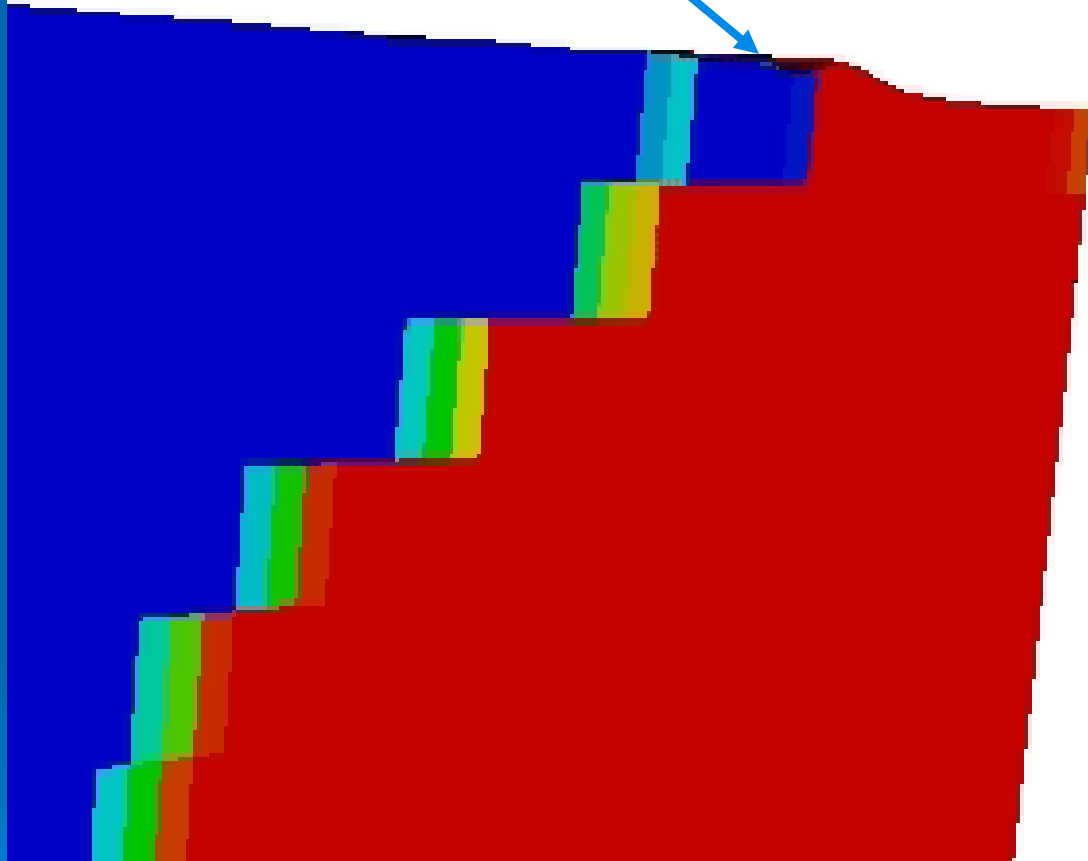
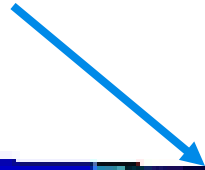
Location of transects through model domain



Average water levels along north-south transect



Embankment location

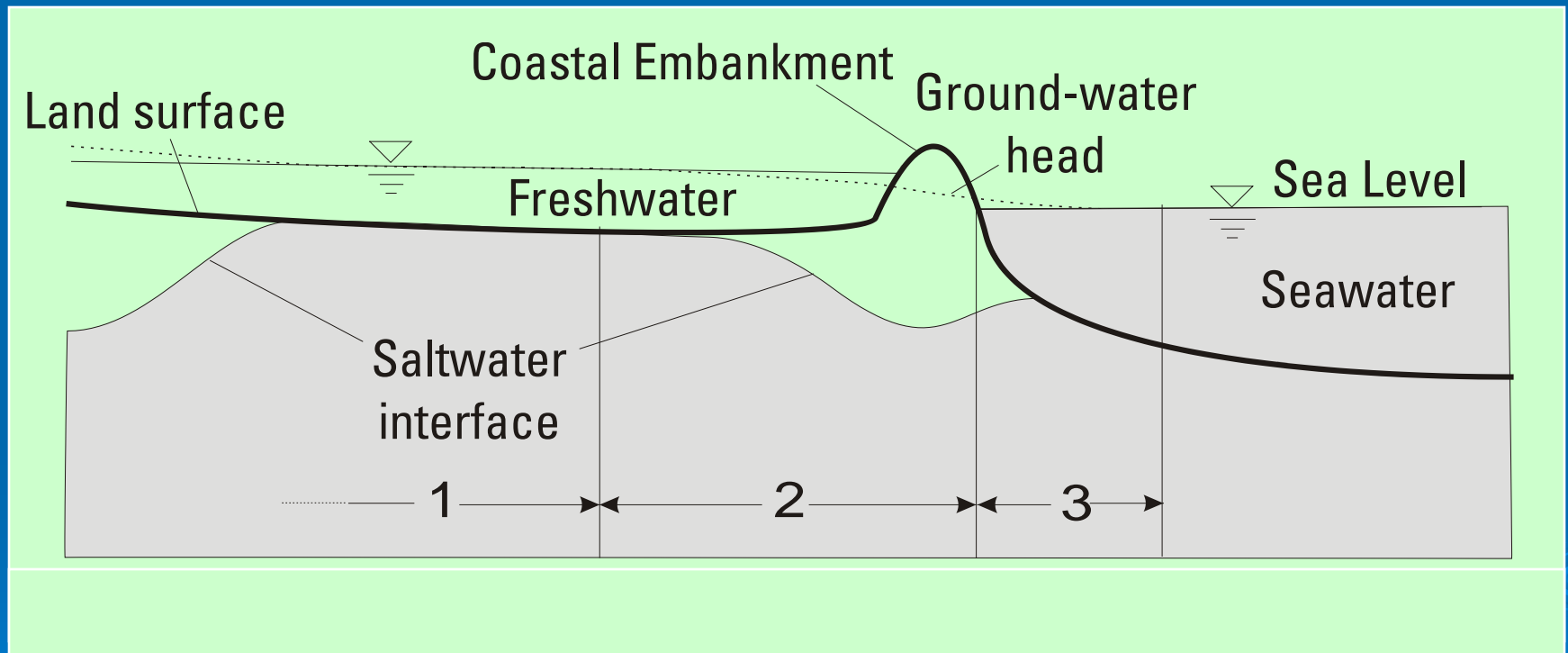


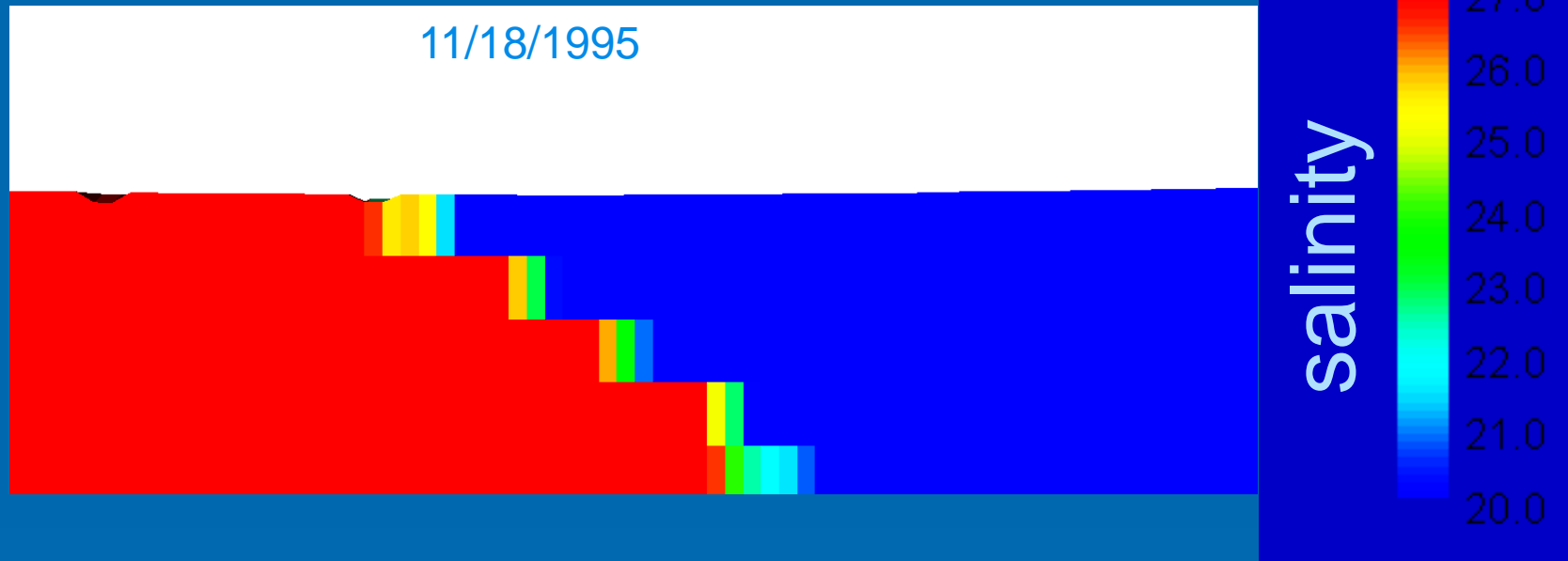
salinity



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

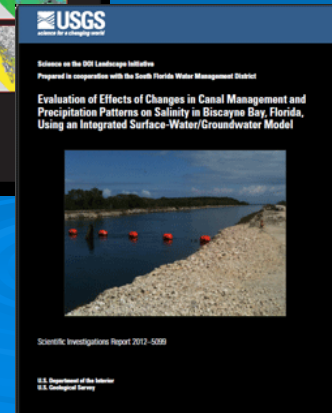
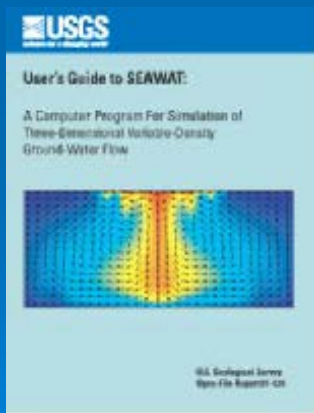
SWIFT2D



FTLOADDS



SEAWAT

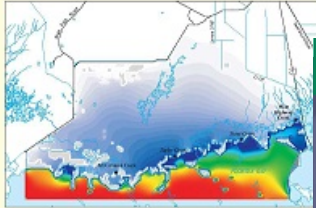


Publications – Additional USGS Reports



Two-Dimensional Hydrodynamic Simulation of Surface-Water Flow and Transport to Florida Bay Through the Southern Inland and Coastal Systems (SICS)

Water-Resources Investigations Report 03-4287



U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
U.S. Geological Survey Priority
Ecosystem Science Program and the
National Park Service Critical
Ecosystem Studies Initiative



Prepared as part of the
U.S. Geological Survey Priority Ecosystem Science Program and the
National Park Service Critical Ecosystem Studies Initiative

Assigning Boundary Conditions to the Southern Inland and Coastal Systems (SICS) Model Using Results from the South Florida Water Management Model (SFWMM)

Open-File Report 2004-1195

U.S. Department of the Interior
U.S. Geological Survey



Internet-based Modeling, Mapping, and Analysis for the Greater Everglades (IMMAGE; Version 1.0): Web-based Tools to Assess the Impact of Sea Level Rise in South Florida

By Paul Heam, David Strong, Eric Swan, and Jeremy Decker

Open-File Report 2013-1185

U.S. Department of the Interior
U.S. Geological Survey



Prepared as part of the U.S. Geological Survey Priority Ecosystems Science Initiative

Spatial and Stage-Structured Population Model of the American Crocodile for Comparison of Comprehensive Everglades Restoration Plan (CERP) Alternatives

By Timothy W. Green, Daniel H. Stone, Eric D. Swain, Michael S. Cherkiss, Melinda Lohmann, Frank J. Maccotti, and Kenneth G. Rice

Open-File Report 2010-1284

U.S. Department of the Interior
U.S. Geological Survey

Articles – Additional Peer-reviewed

Annals of the American Geophysical Union, 2010, 91, 10, 10, 10
DOI: 10.1029/2010JD014111



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

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Received 01/14/2010

Abstract

Precipitation data from global climate models have been downscaled to smaller regions. Adapting this downscaled precipitation data to a coupled hydrodynamic surface-water-groundwater model of southern Florida allows an examination of future conditions and their effect on groundwater levels, infiltration systems, surface water stage and flow, and salinity. The downscaled rainfall data includes the 1960–2010 time series from the ECHAM5 GCM-20 simulation and both the 1960–1999 and 2016–2077 time series from two global climate models, the Community Climate System Model (CCSM) and the Geophysical Fluid Dynamics Laboratory (GFDL). Hydrodynamic surface-water datasets were developed for the 2016–2077 simulation. The resulting hydrologic simulations, with and without a 30-cm sea-level rise, were compared to each other and field data under a range of projected conditions. Simulations performed generally higher future stage and groundwater levels and surface-water flows, with an elevated rise resulting higher coastal salinity. A consistent rise in sea level, precipitation, and surface water flows resulted in a narrower inland aquifer freshwater zone. The inland areas were affected more by the rainfall difference, with the sea-level rise and the rainfall difference model both difference in coastal salinities, but a larger difference in coastal salinities.

Keywords: hydrologic models; climate change; rainfall; hydrologic simulation

1. Introduction

Global models are being used to simulate and predict the effects of natural and anthropogenic stresses on the world's fresh water resources. The development and use of advanced models that couple groundwater with surface-water hydrologic simulation, hydrodynamic surface-water salinity transport has culminated in the Flow and Transport in a Linked Overland-Aquifer-Dammy-Dependent System (FTLADOADS) simulator [12]. In FTLADOADS, the two-dimensional hydrodynamic surface-water flow and transport simulator SWIFT2D [13] is coupled with the two-dimensional groundwater flow and transport simulator SEAWAT [14]. Vertical linkage and salt flux between the surface water and groundwater are computed in FTLADOADS, making a complete simulation of the two-dimensional surface-water-groundwater system.

The hydrodynamic surface-water simulation in SWIFT2D allows the FTLADOADS simulation to represent over eight regions associated with tidal, diurnal and precipitation events [15, 16, 17, 18]. Treatment of precipitation such as surface-water flooding and drying, are represented along with surface-water processes such as infiltration, evaporation and groundwater recharge. The evaporation/infiltration is computed based on the Penman-Monteith method [19] and the freshwater availability. The FTLADOADS simulator has been applied to several Florida regions that have significant coastal interactions. The model developed was used to evaluate the Mangrove and Biscayne domain coastal area of Miami-Dade county and Biscayne National Park. In a subset of the TIME domain, the USCOAD parameter estimation code was used to derive salinity to water management implications and plans [20, 21]. Two models that have been run are associated with FTLADOADS are the TIME model of the Biscayne domain, and the USCOAD parameter estimation code.



Figure 1. Location of TIME and FTLADOADS model areas in Florida. A number of Global Climate Models (GCMs) have been downscaled previously to simulate future.

31043

DOI: 10.1029/2010GL043794

HYDROLOGIC RESTORATION

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