Everglades National Park

South Florida Natural Resources Center

National Park Service
U.S. Department of the Interior

Water Budget, Climate Variability, and Predicting Salinity for Eastern Florida Bay

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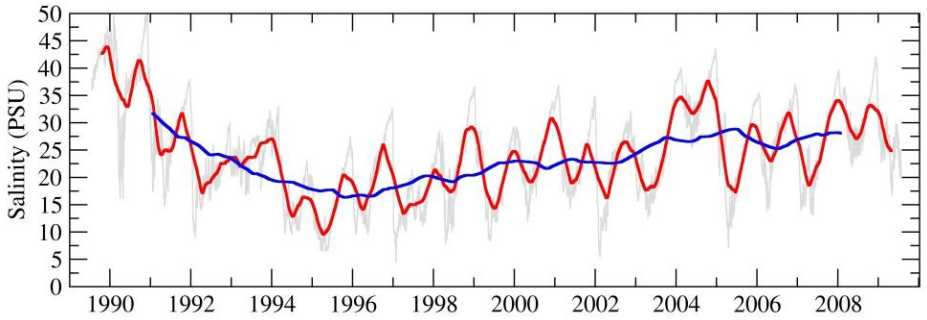
Overview

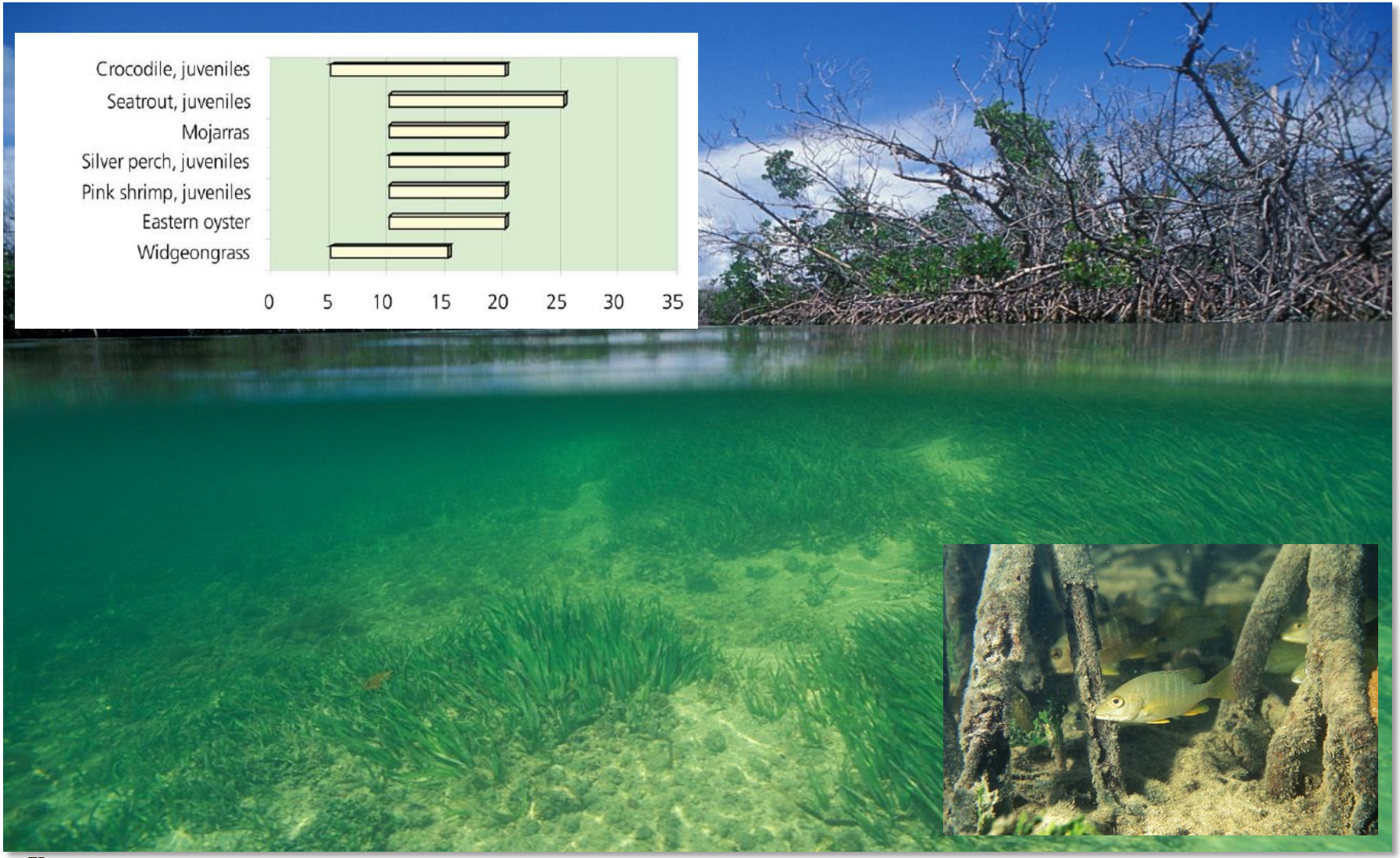


- Salinity regime sets the ecological environment in Florida Bay
  - Extreme events lead to shifts in ecological communities
  - Salinity is variable and trending upward in Florida Bay

- Sea level rise (SLR) is expected to play an increasingly important role in coastal ecosystems
  - In Florida Bay, the rate of SLR relative to changes in bank height has an effect on mixing between basins
  - Salinity responds to other climate factors (rain, temperature) as well

- Monitoring data is available but the period of record is short for climate related analysis

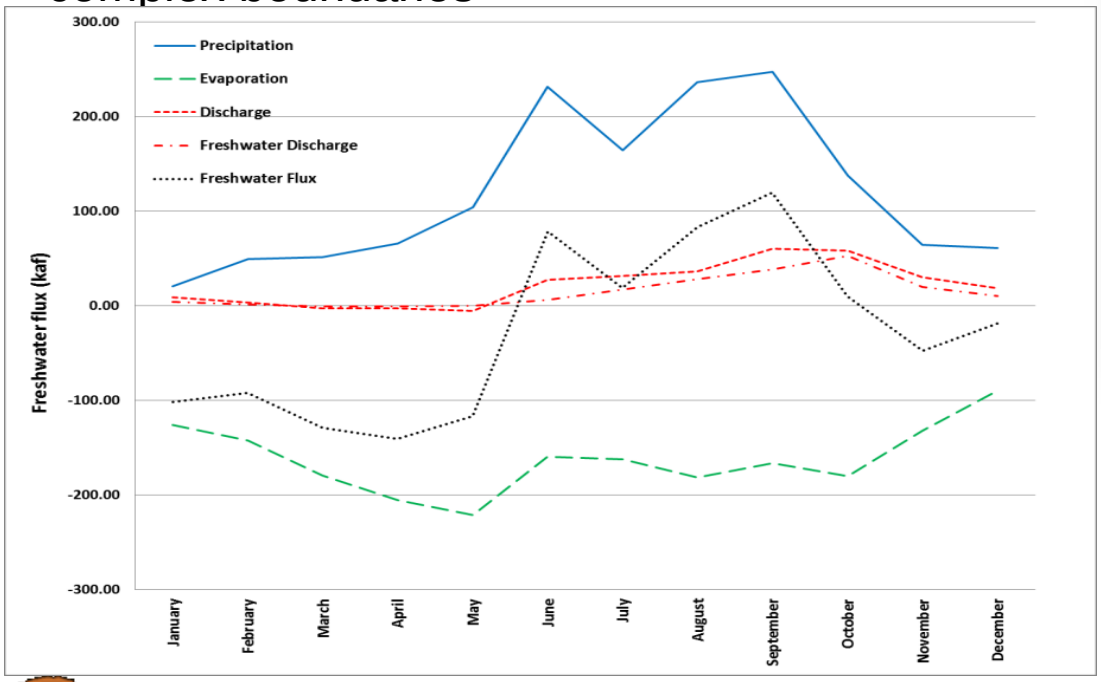
Salinity management for maintaining critical habitats

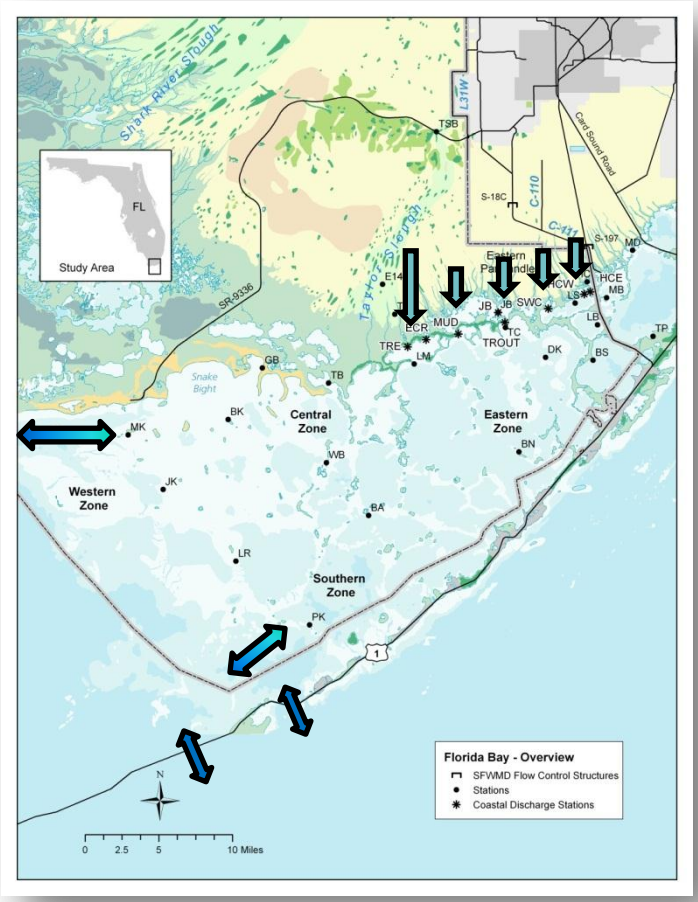


Factors affecting salinity in Florida Bay

Freshwater budget

- **Sources:** precipitation, freshwater flow from coast (stream, sheet, ground)
- **Sinks:** evaporation
- **Mixing**: tide and wind driven across complex boundaries





Sea Level Rise in Florida Bay

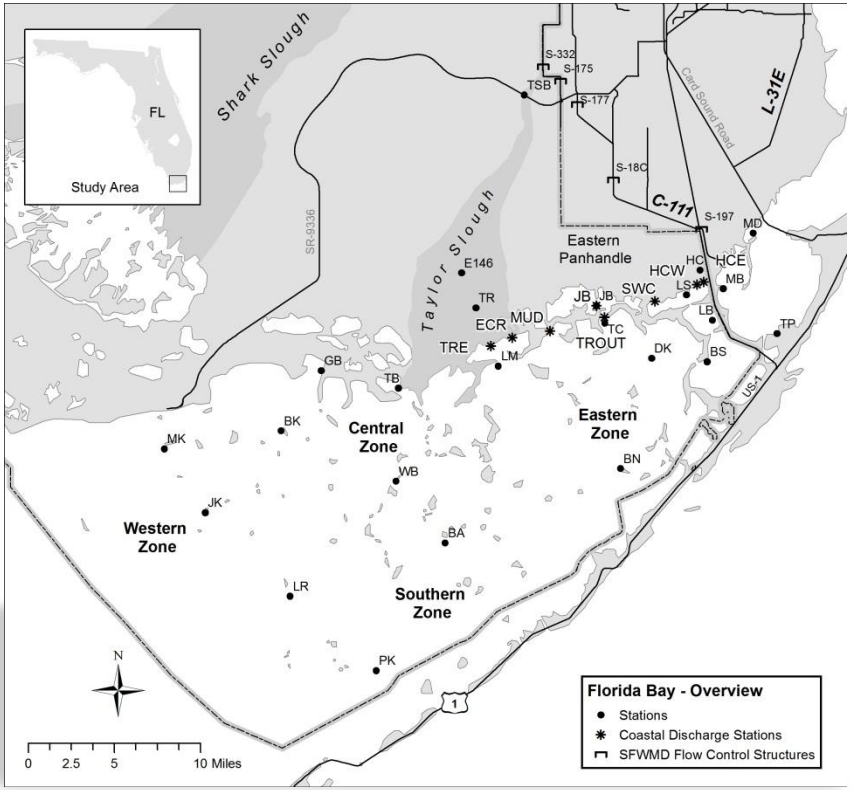
Impact primarily based on changes in mixing

Hypothesis: salinity regime will become more marine-like with reduced variance

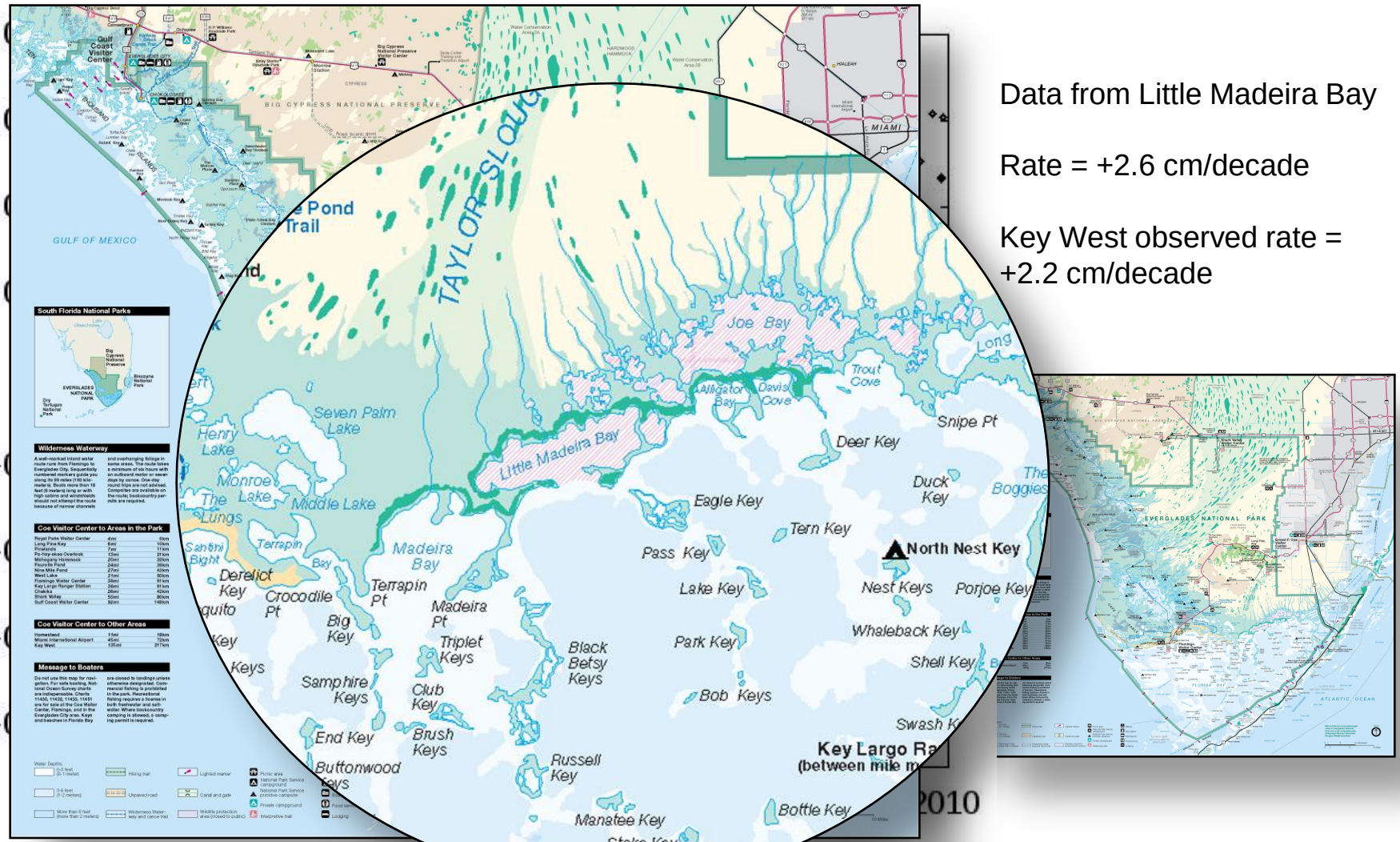
- Reduced frequency and extent of extreme high/low salinity conditions

Tipping points are unknown but could include;

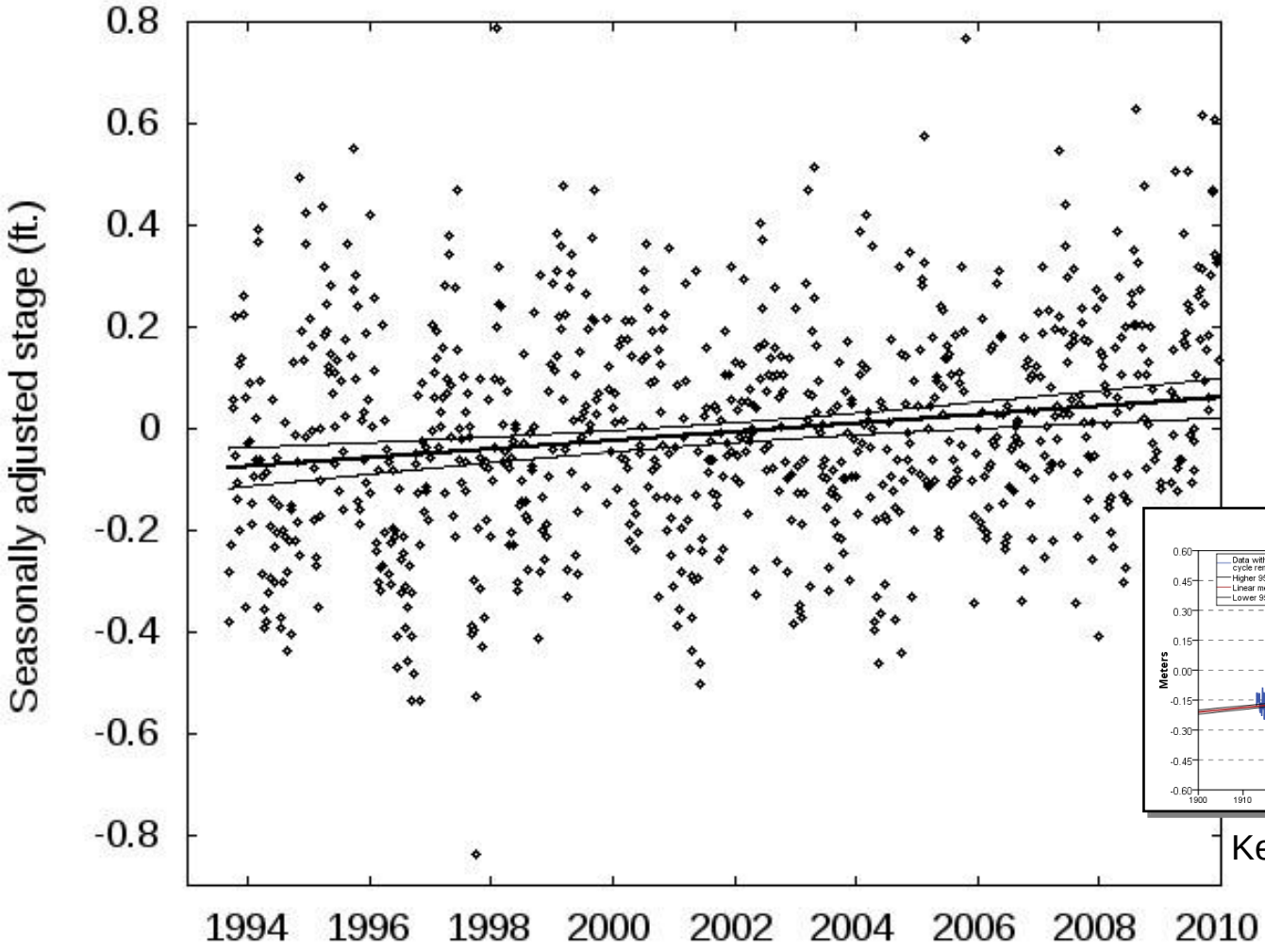
  - Changes in freshwater discharge if sea level breaches the coastal ridge.
  - Changes in connectivity across basins
  - *Event based* changes related to tropical storms causing mass movement of coasts or sediments



Sea-level rise



Sea-level rise

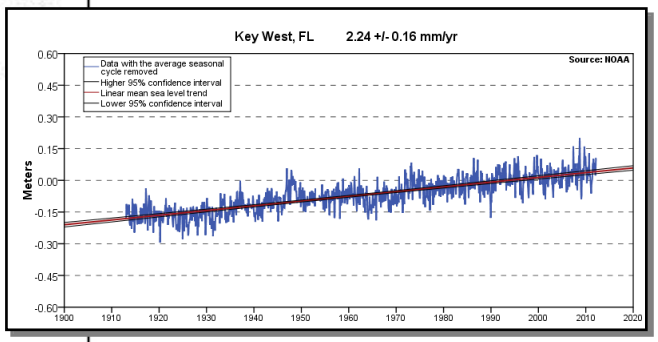


Station LM; 2.58 ± 0.47 mm/yr

Data from Little Madeira Bay

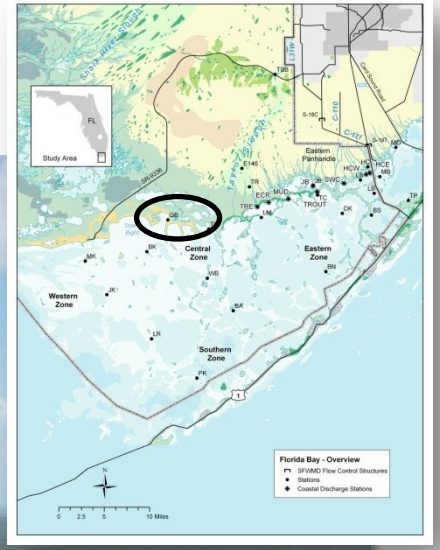
Rate = +2.6 cm/decade

Key West observed rate = +2.2 cm/decade

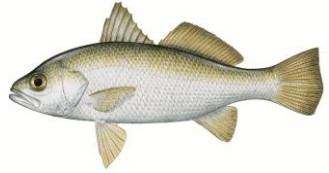


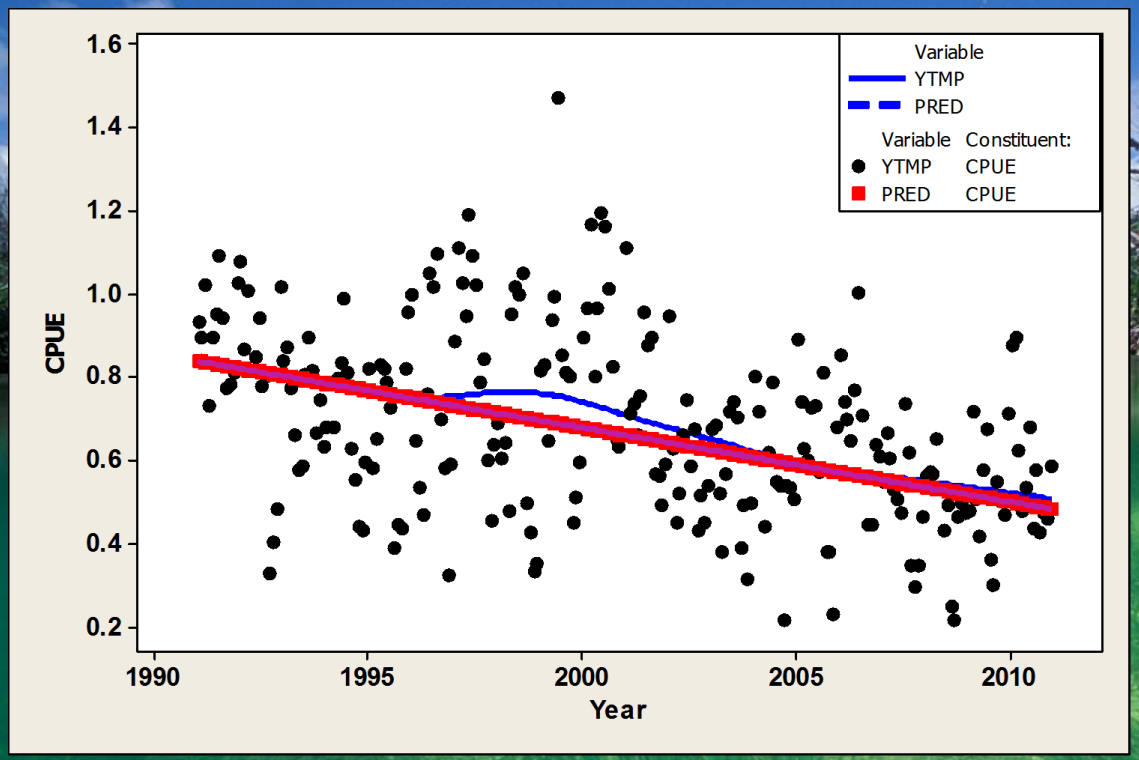
Key West; 2.24 ± 0.16 mm/yr

What's at Risk?



What's at Risk?



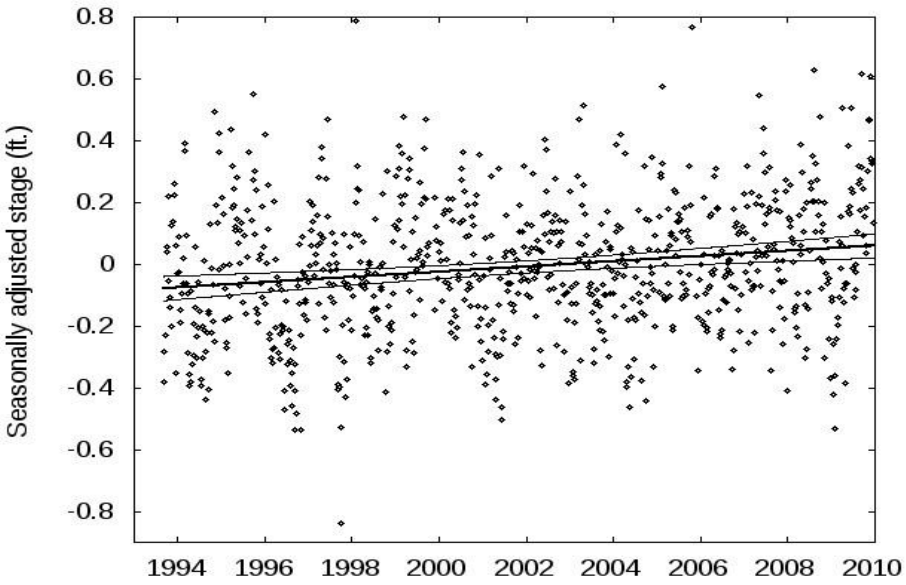


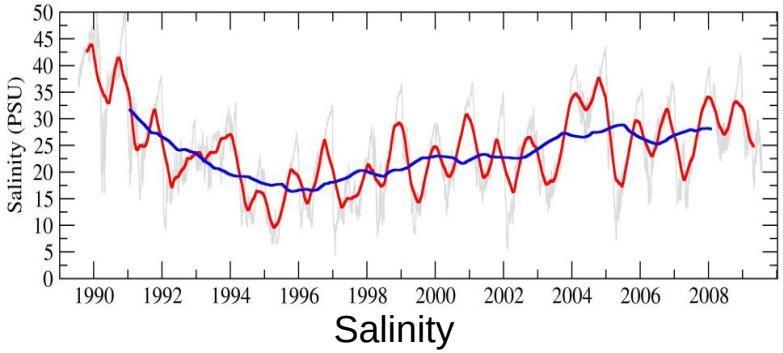
Is sea level rise affecting salinity?

Clear signal of sea level rise in the coastal zones of Florida Bay

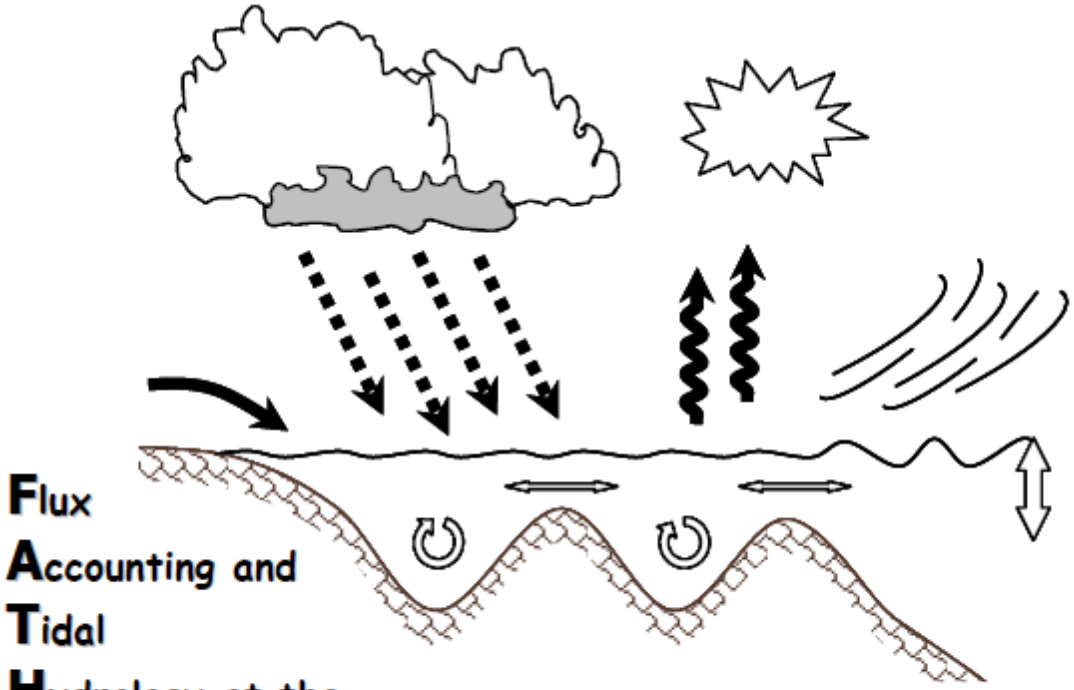
Salinity highly variable but has been increasing since 1995.

Station LM; 2.58 ± 0.47 mm/yr



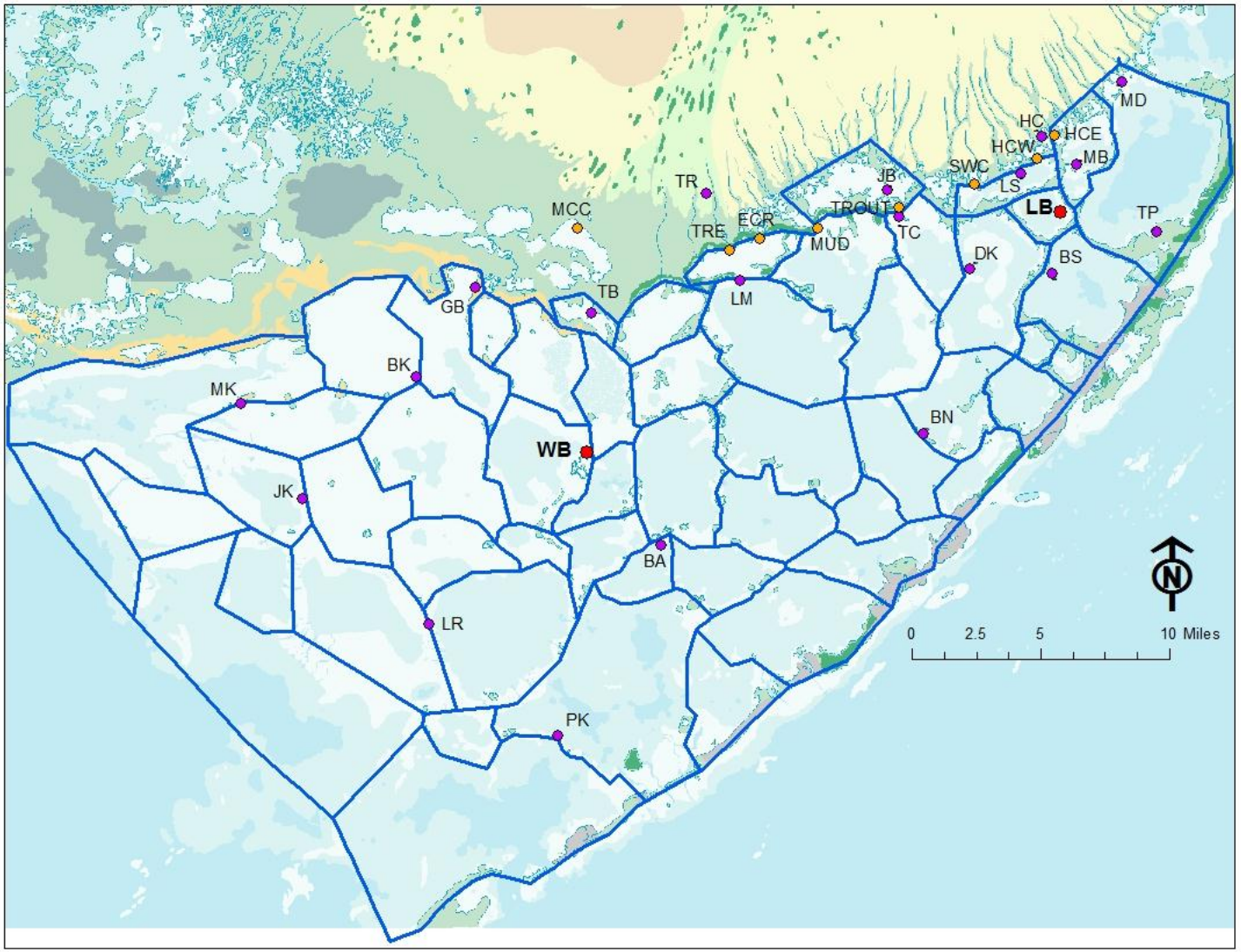


Is this a trend or cycle?
Is salinity predictable?



Developed by B. Cosby, W. Nuttle & F. Marshall with other contributors

Fathom basins and boundaries



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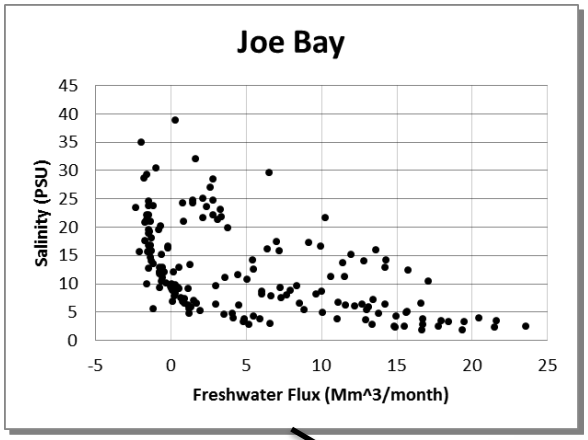
Fathom: Flow to salinity relationships

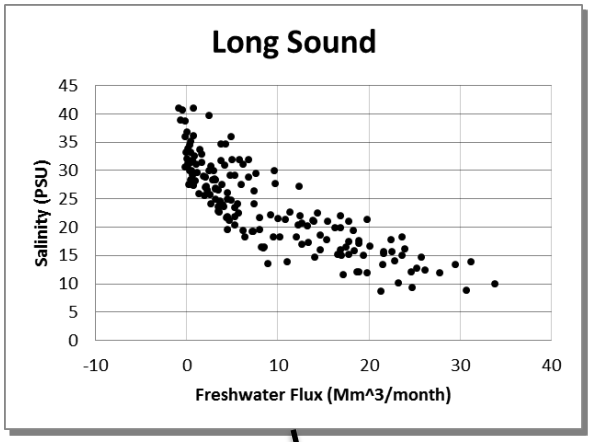
Model run: Existing conditions
Monthly 1989 – 2002

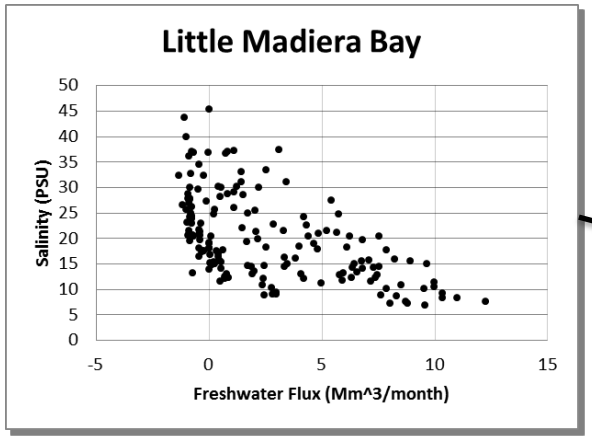
Salinity in coastal basins dependent on

- flow rates and
- mixing
- Evaporation

Simulate trends and review results







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Fathom: Marine influence and variability

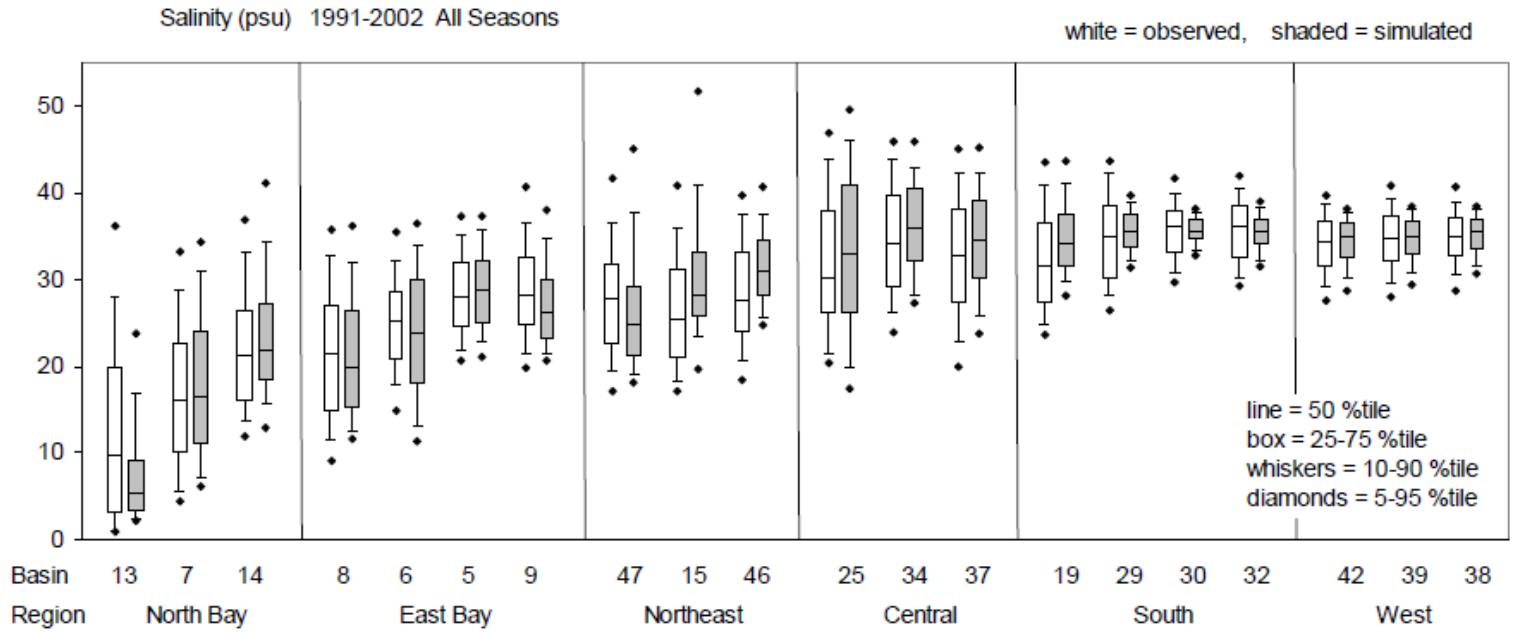
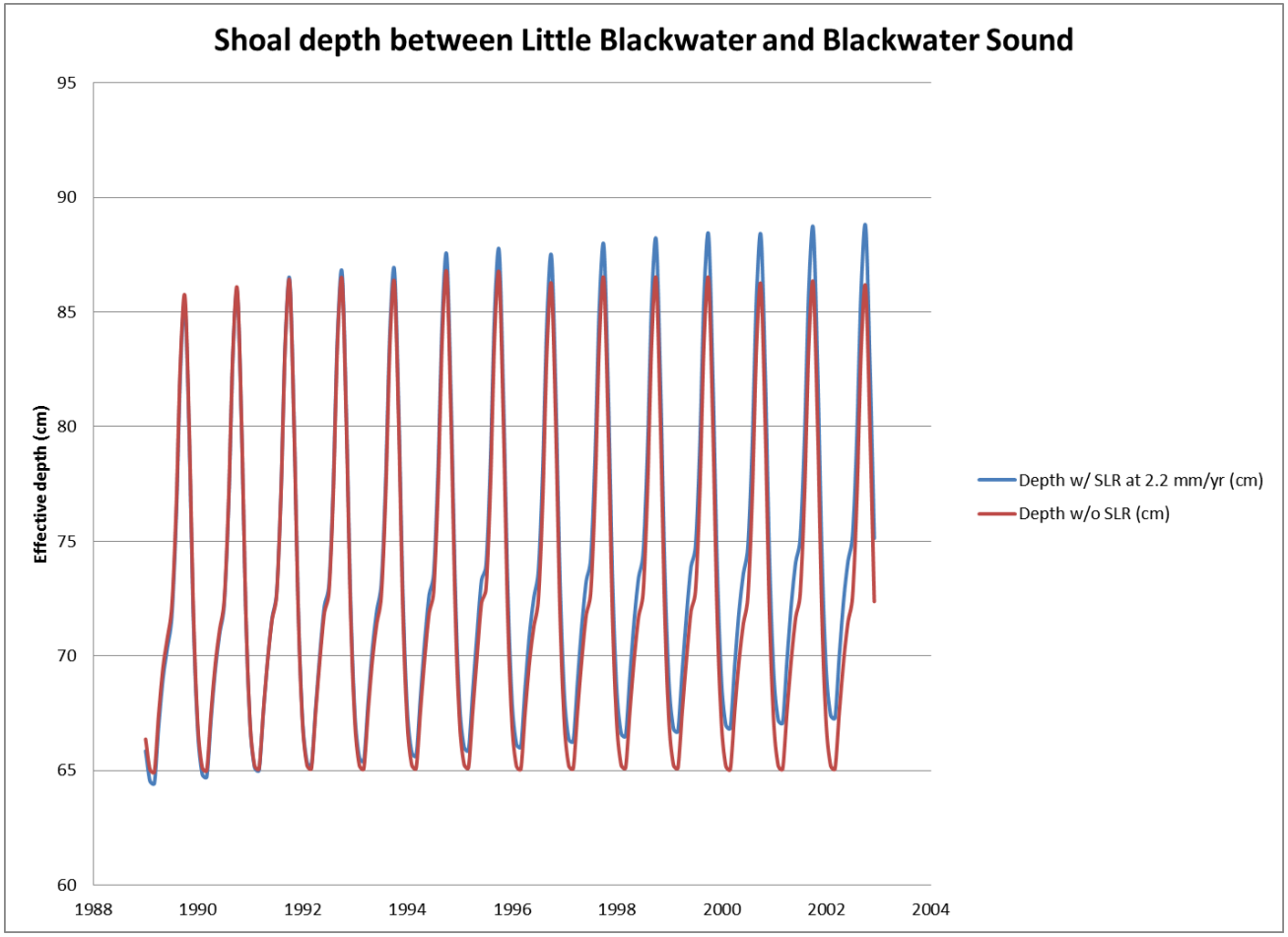


Figure 3-4 Comparison of the distribution of simulated (shaded) and observed (open) monthly salinity for the period 1991-2002. Distributions are based on all 12 months in each of the 12 years of observed data (all seasons).

Marine influenced regions have smaller range and increased mean relative to freshwater influenced stations

*Graphic from Fathom Model Structure and Salinity report

Fathom: Predicting Salinity Changes due to Sea Level Rise



Using CESI base conditions

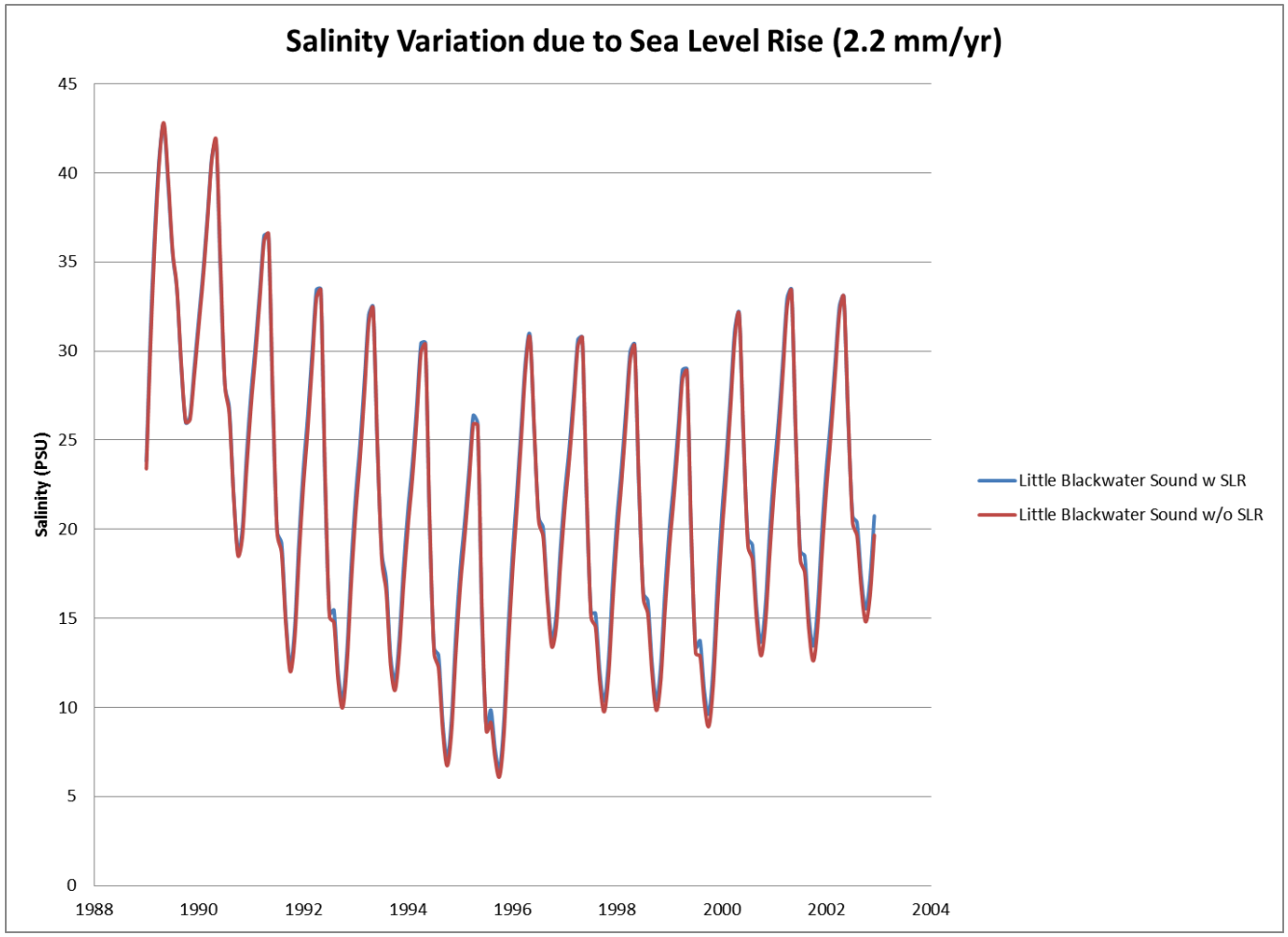
Set SLR at 2.2 mm/yr

Monthly Simulation
1989 – 2002

Model result:

- Sea levels increase in Eastern Florida Bay

Fathom: Predicting Salinity Changes due to Sea Level Rise



Using CESI base conditions

Set SLR at 2.2 mm/yr

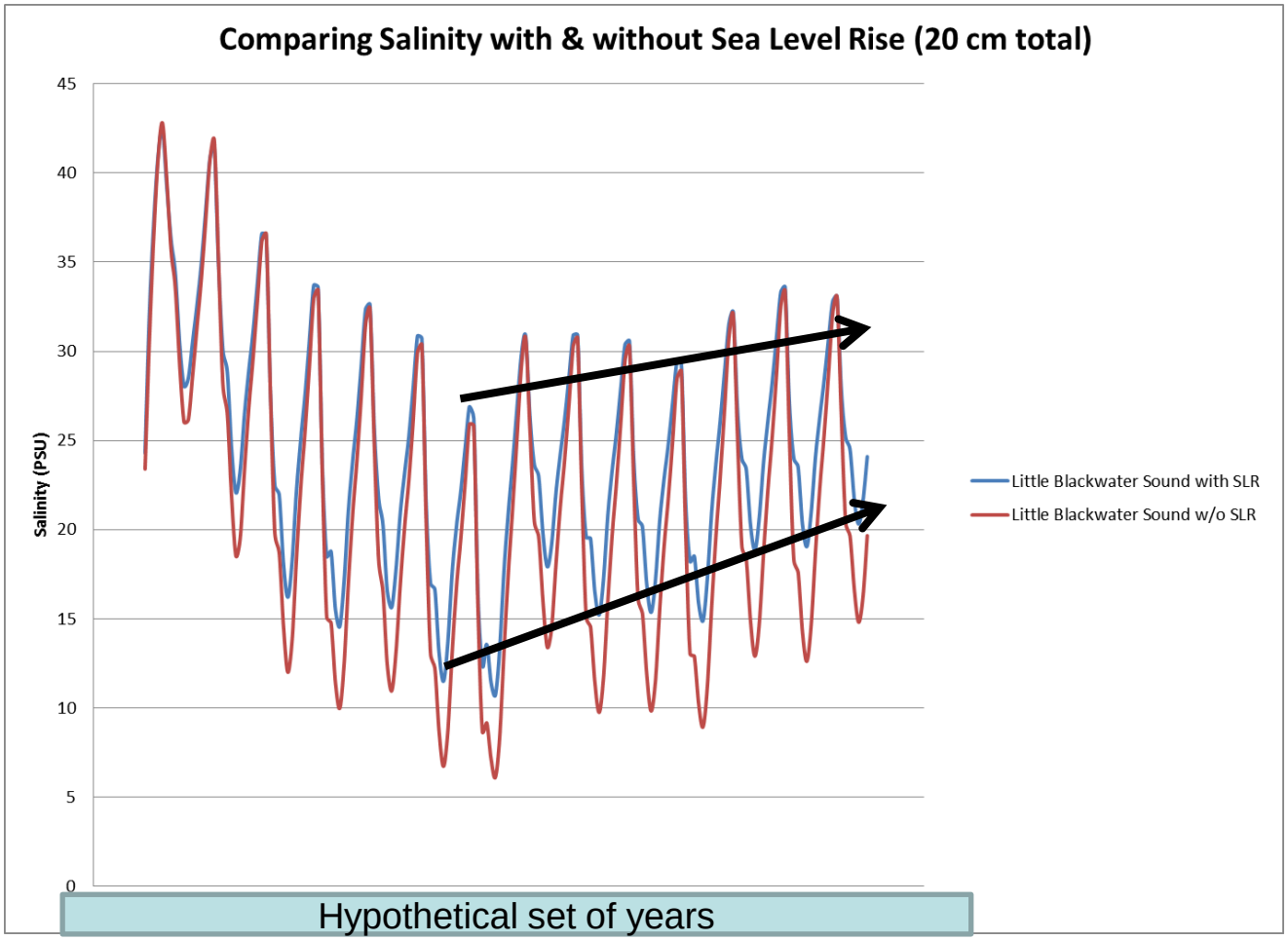
Monthly Simulation
1989 – 2002

Model results:

- Reduce seasonal variability
- Increase annual minimums

Fathom: Salinity and Accelerated Sea Level Rise

Hypothetical – for model evaluation purposes only



Using CESI base conditions

Set total SLR to reach 20 cm by end of simulated run

Similar to SLR observed at Key West since 1910

Simulation run strictly for comparison of end point

Model results:

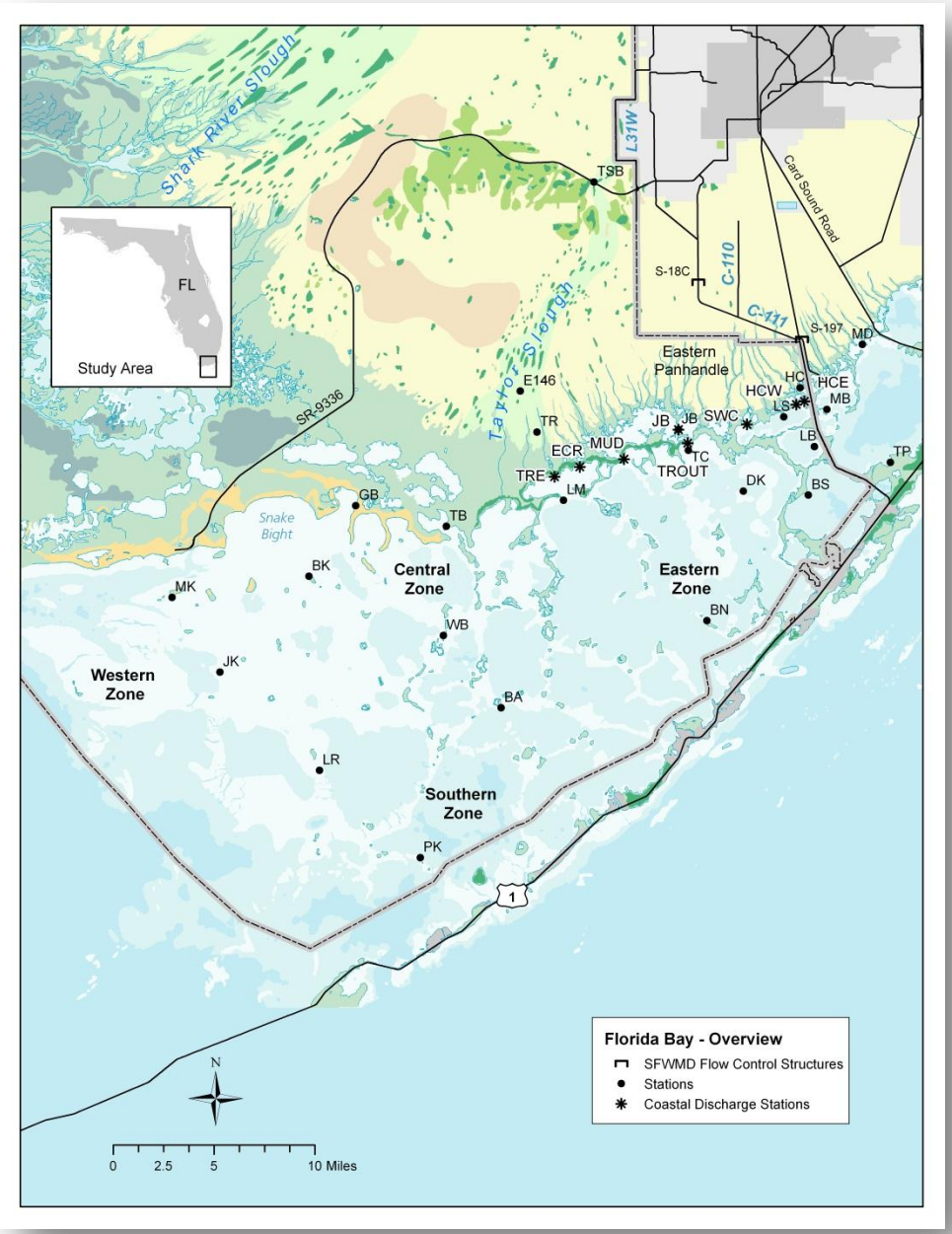
- Reduce seasonal variability
- Increase annual minimums
- Conditions moving away from estuarine goals for Florida Bay

Marine monitoring network

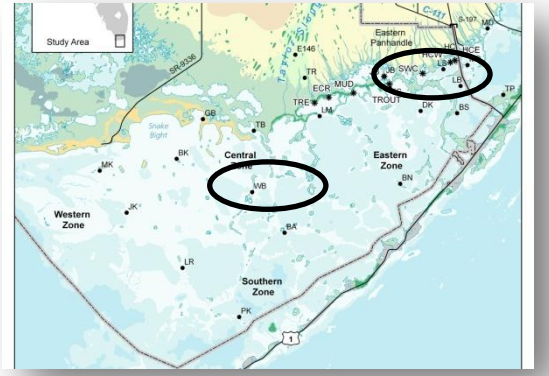
17 stations collecting hourly or higher resolution data in
- Stage
- Salinity
- Rain
- Water temperature

Subset of those stations collect:
- Chlorophyll A
- Turbidity
- Dissolved oxygen
- Wind speed & direction

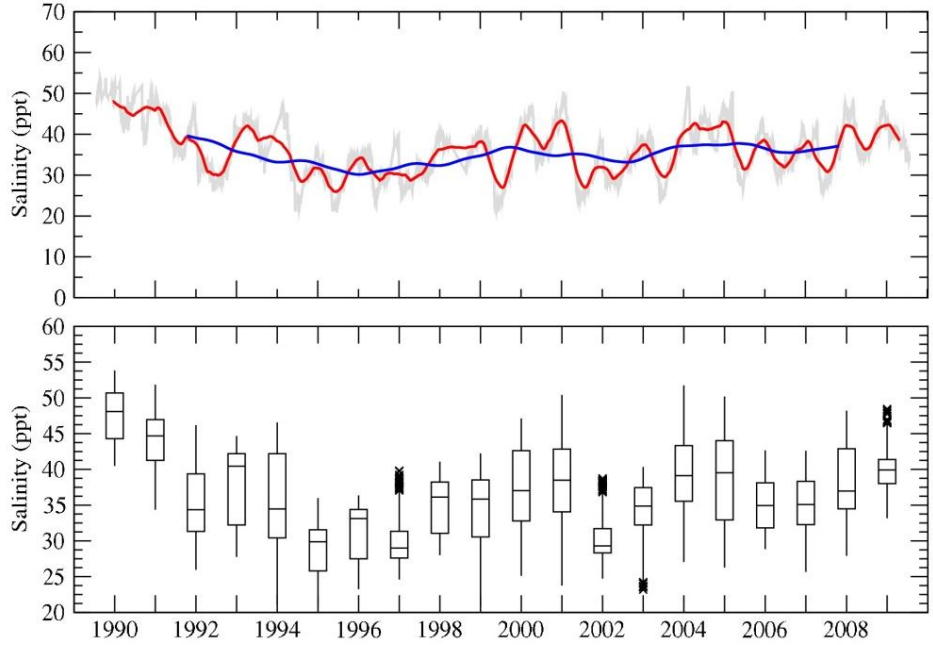
Data available
Live at: http://www.ndbc.noaa.gov
Validated: EVER_data_request@nps.gov



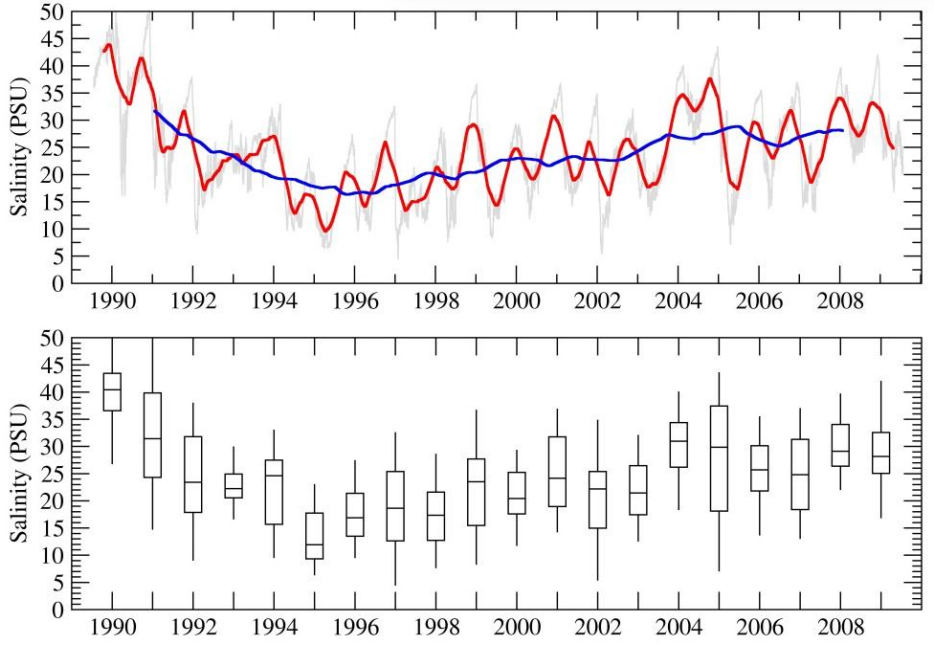
Observed: Salinity Time-series



Central Zone

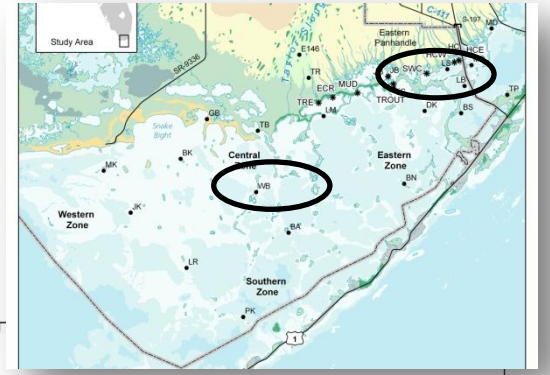


Eastern Zone

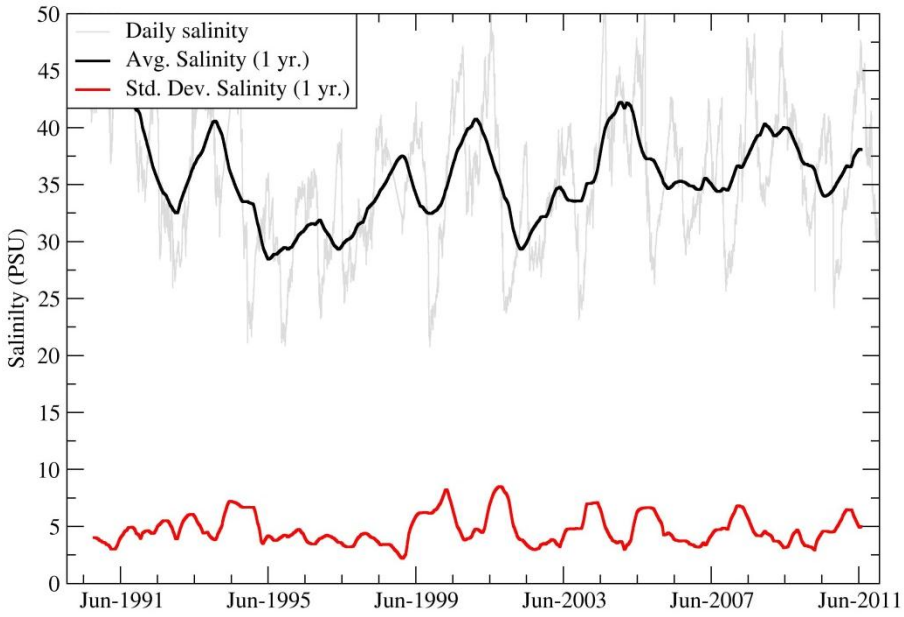


Year-to-year variability in salinity reflecting changes in precipitation, management, other long-term trends including climate.

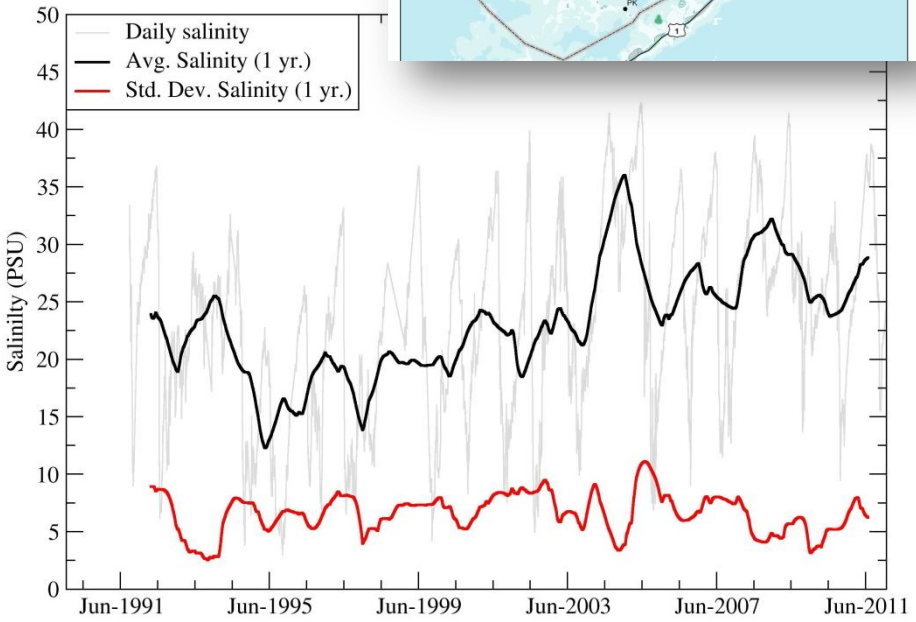
Salinity variability



Station WB



Station LB



Mean salinity values change by season and year

No trend in salinity variability -** what about cycles?

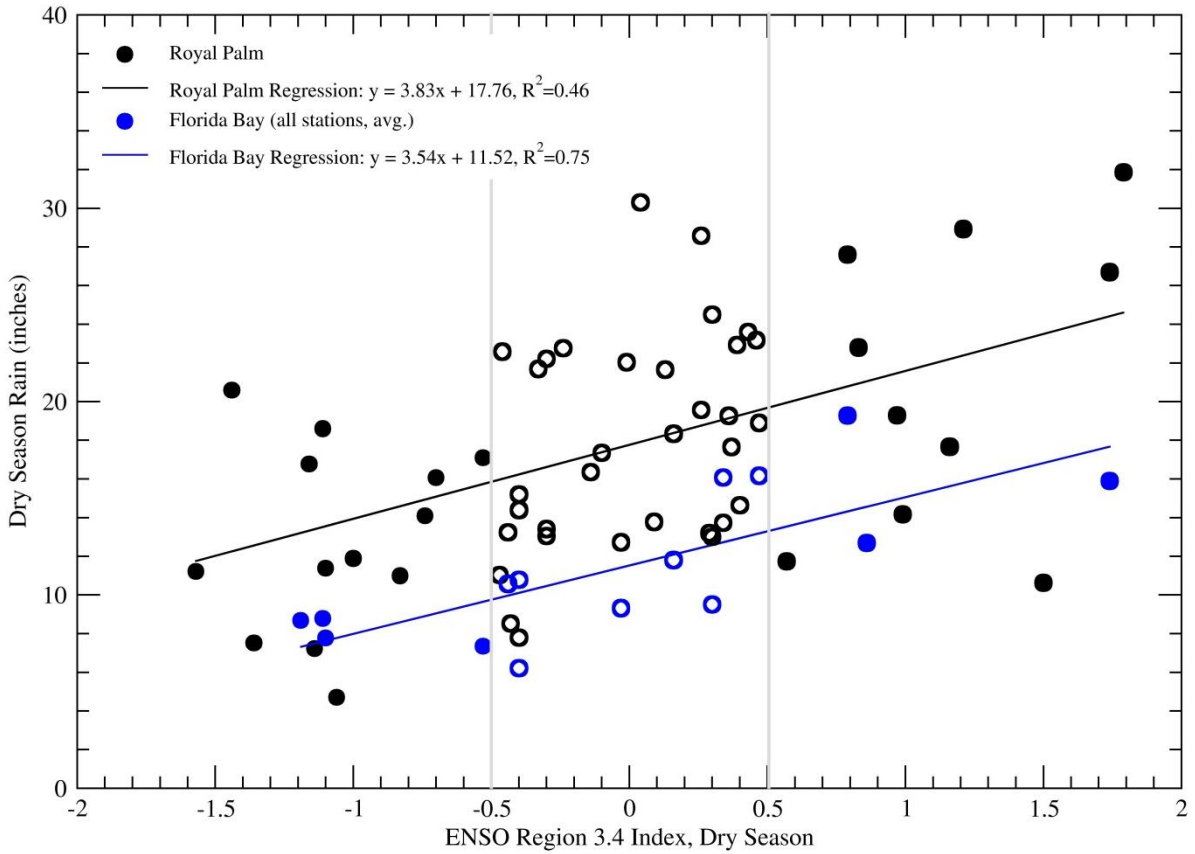
Observed: ENSO influences dry season rainfall

Data from Royal Palm station (marsh) or Florida Bay stations (marine) shows similar trend

- higher dry season totals in marsh
- ENSO index is categorized as being in a positive or negative phase when;
  (X < -0.5) or (X > +0.5)

ENSO duration is variable
9 – 12 months

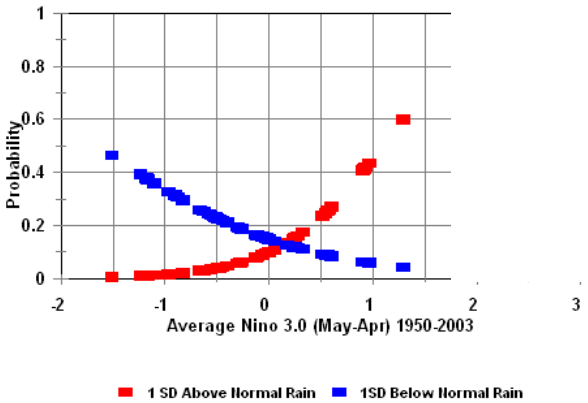
ENSO cycle length is variable
3 – 5 years on average

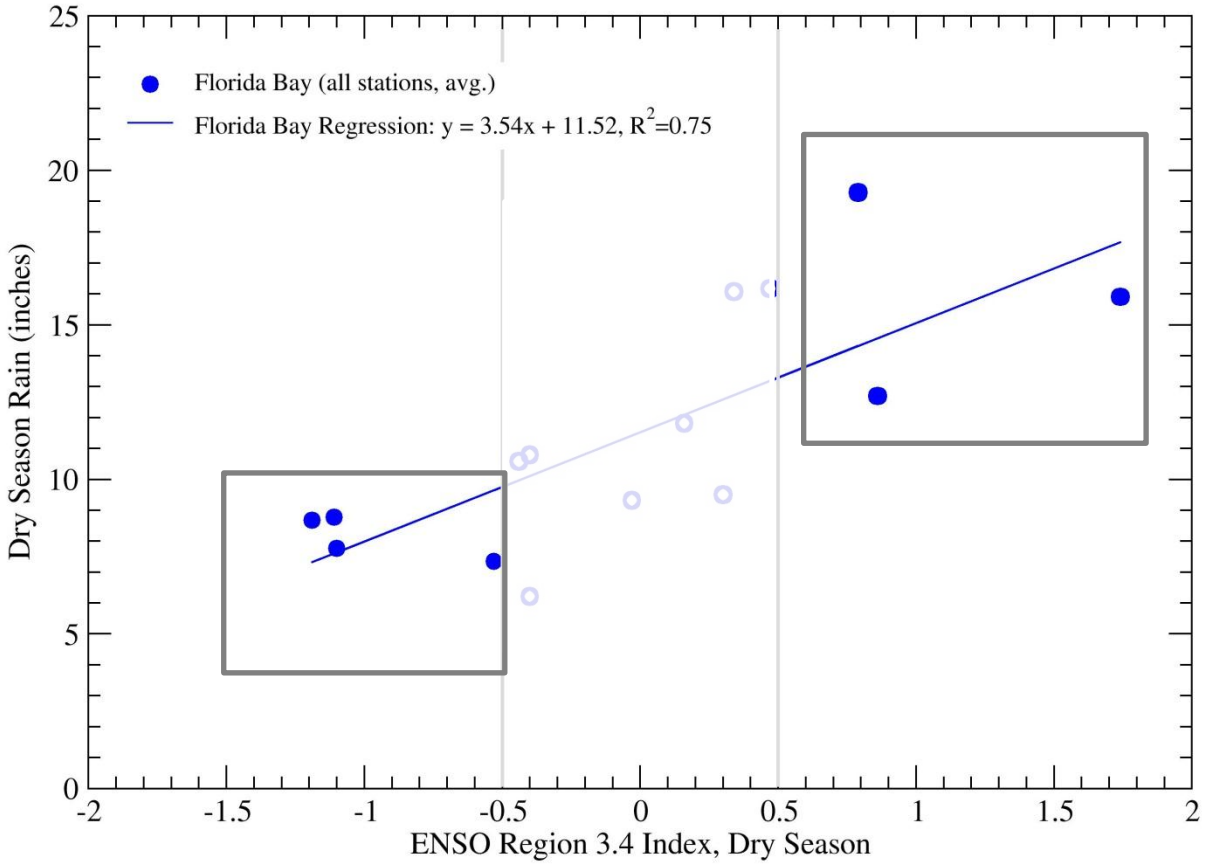


ENSO influences dry season rainfall in Florida Bay

ENSO phase effects relative amount of dry season rain

Changes in dry season rainfall should affect salinity





*Dry season rain analysis by Hagemeyer, NWS, produced for NOAA in 2006

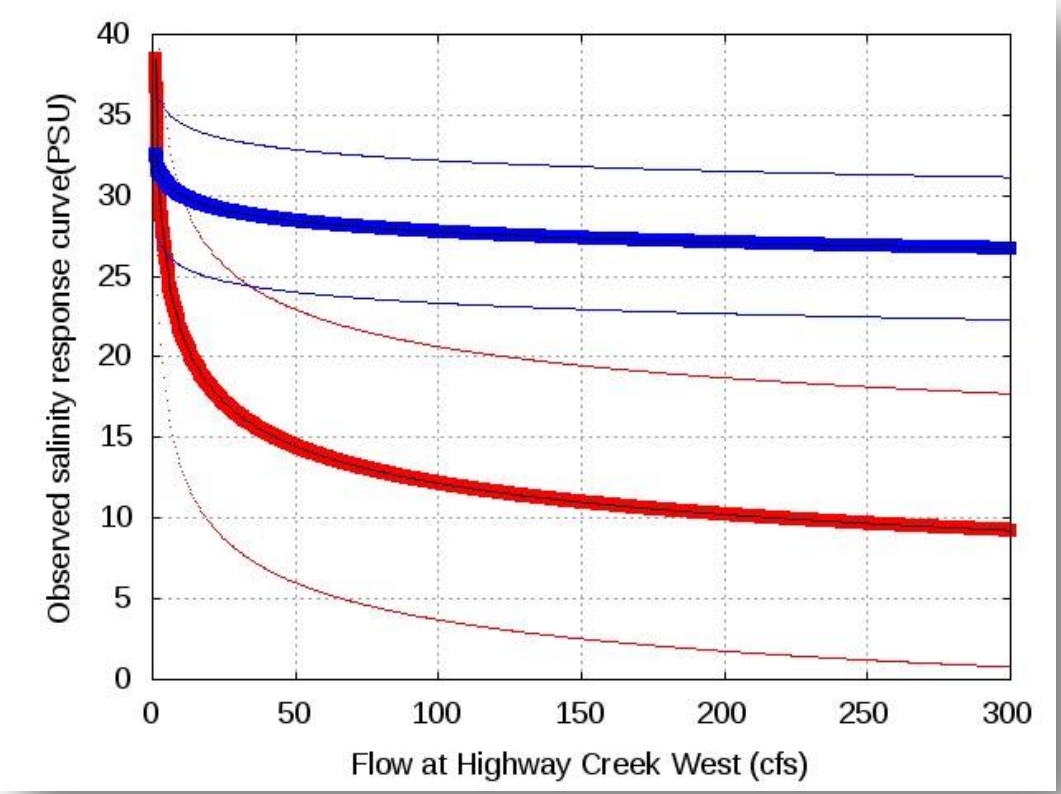
ENSO variation of rain & flow expected to influence salinity in coastal basins

Graph shows relationship between flow rate and salinity response

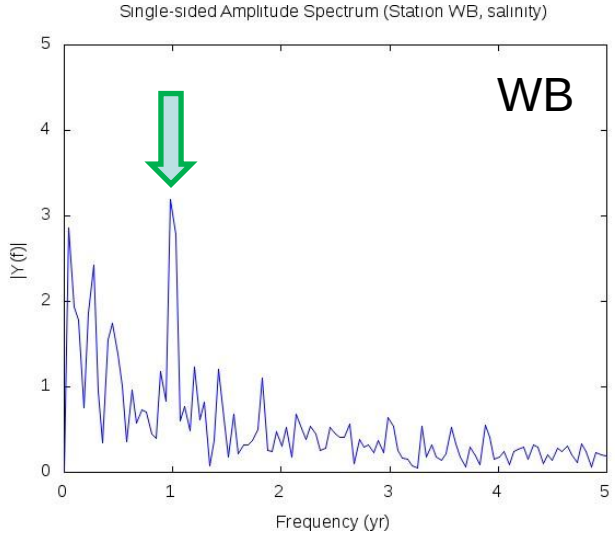
- Station LS (red)
- Station BS (blue)

Result: Indicates salinity in coastal basins is very sensitive to relatively low flow rates during peak salinity time periods

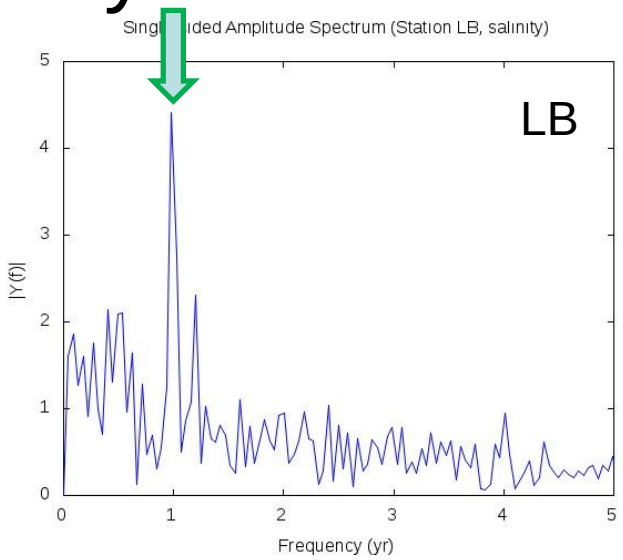
ENSO influences dry season rain, influencing flow during peak salinity periods

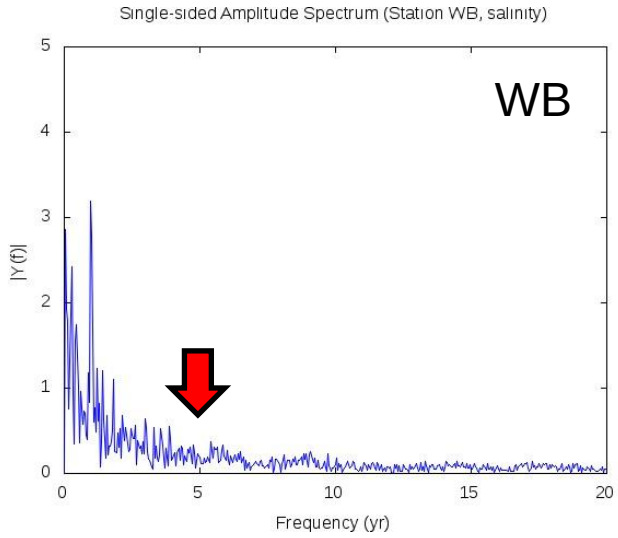


Frequency analysis on salinity observations

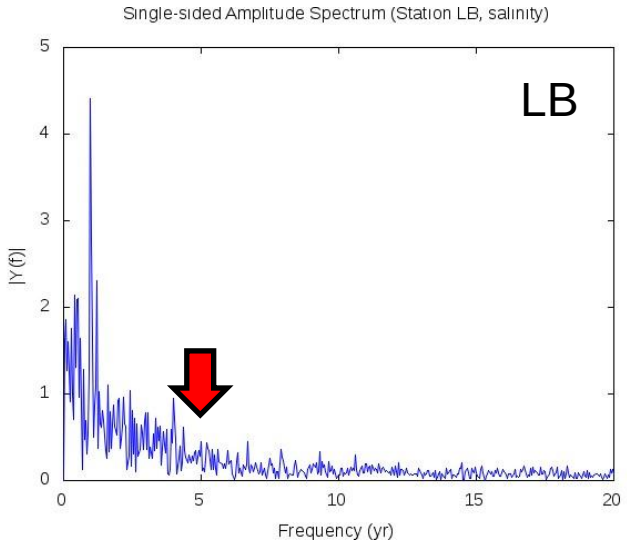


Annual cycle present





ENSO cycle was not detected in salinity data.



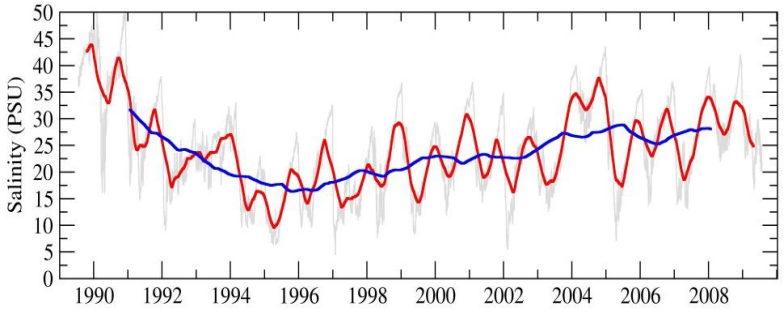
Discussion

Detected sea level rise at rates equivalent to those observed in Key West

ENSO related changes in dry season rain **were observed**

Did not detect more marine-like conditions, with reduced salinity variation, in the bay

ENSO related cycles in salinity **were not observed**



Is this a trend or cycle?

Is salinity predictable?

Discussion

Detected sea level rise at rates equivalent to those observed in Key West

ENSO related changes in dry season rain **were observed**

Did not detect more marine-like conditions, with reduced salinity variation, in the bay

ENSO related cycles in salinity **were not observed**

Next steps:

Targeted monitoring and modeling efforts to predict climate and management affects on salinity in Florida Bay.

Continue: Time series of flow, rain, salinity, temperature, and wind

Improve: Evaporation and groundwater data

Fathom: Efforts aimed at understanding impact of sea level rise and changing bank heights on mixing and salinity

Analysis of impact of climate cycles on salinity

Acknowledgements:
This presentation contains coastal discharge data from the USGS (M. Zucker, J. Ward), Fathom model results (developed by B. Cosby, F. Marshall, and W. Nuttle), and data from the National Park Service's marine monitoring network.

Data available at: EVER_data_request@nps.gov

Questions or further discussion: Erik_Stabenau@nps.gov

ABSTRACT

Water Budget, Climate Variability, and Predicting Salinity for Eastern Florida Bay
Erik Stabenau[1], Kevin Kotun[1]
[1]National Park Service, Homestead, FL, USA

An increase in upstream freshwater flow to the marine transition zone of Florida Bay to reduce salinity levels in the coastal basins is an important goal of the Comprehensive Everglades Restoration Plan (CERP). CERP salinity performance measures for the coastal system are useful to evaluate the impacts of upstream flow restoration on seasonal salinity levels within the basins of Florida Bay. However, predicting the success of such projects is challenging, since cycles and trends in salinity in the natural system may be larger than salinity changes attributed to restoration alternatives being evaluated. The goal of this analysis is to determine the drivers of the seasonal variation and long-term trends in salinity and predicting how those drivers may influence salinity through the projected timeframe for CERP implementation.

Since 1990, salinity values in eastern Florida Bay have shown wide variations on annual to interannual time scales. Prior to 1995, salinity ranged from euhaline to hypersaline conditions, while in 1995-1996, eastern Florida Bay experienced mesohaline conditions likely due to greater precipitation and freshwater discharge. While salinities were higher on average in 1990 than today, from 1994 through the present there has been an increasing trend in mean salinity. In addition, there is larger interannual variation in the range of salinity observed during the tropical wet or dry season cycles.

Extensive monitoring in the region has allowed the development of a water budget which was then used to investigate the relative importance of the individual components on salinity in eastern Florida Bay. One critical issue is to determine if the increase in salinity is a secular trend or part of a cyclical process, and the likely outcome of each scenario. Trend related features, such as long-term changes in canal operations in the C-111 and related structures in the marsh or sea level rise in the marine environment may affect residence time within and exchange rates between basins and affect salinity. Cyclical features, such as annual cycles in precipitation and freshwater flow, experience changes in magnitude and timing due to connections with multi-year climate cycles. Recent advances in the understanding of these global drivers of local sea-level and regional precipitation patterns may improve our ability to understand the relative importance of the individual drivers of salinity variation. We will present predictions for the future salinity conditions in eastern Florida Bay, identify features that may be used to improve those predictions, and discuss their limitations.

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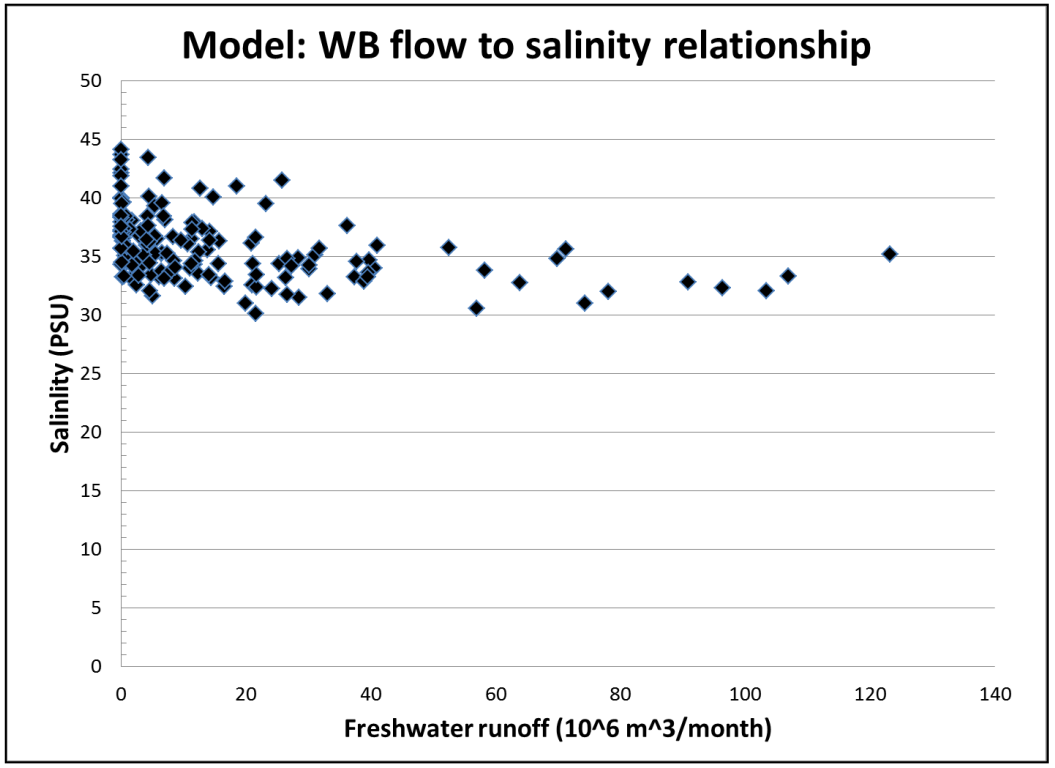
Fathom: Freshwater flow to salinity relationship – paleosalinity flow targets

- Paleosalinity estimate* circa 1900→ 28.3 ± 5.5 PSU
- Current observations → 36.6 ± 7.8 PSU



Result: variable flow yet monthly salinity at WB is never less than 30 PSU

Relationship between salinity and flow isn't well defined

Model reflects observed conditions in the semi-isolated central region of the bay

* Paleo target data from USGS Open File Report (Marshall & Wingard, 2012)