Everglades National Park

South Florida Natural Resources Center

National Park Service
U.S. Department of the Interior

Climate Variability and the Coastal Physical Environment (Florida Bay)

Presented by: Erik Stabenau - National Park Service

Contributions from: Christina Karamperidou, Laurant Cherubin, Joan Browder, Frank Marshall

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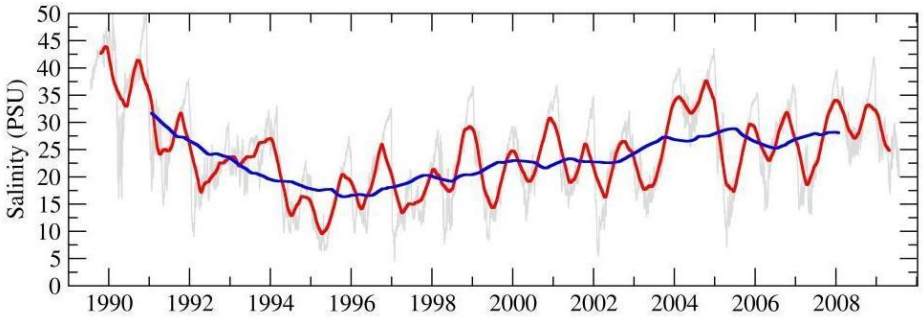
Overview

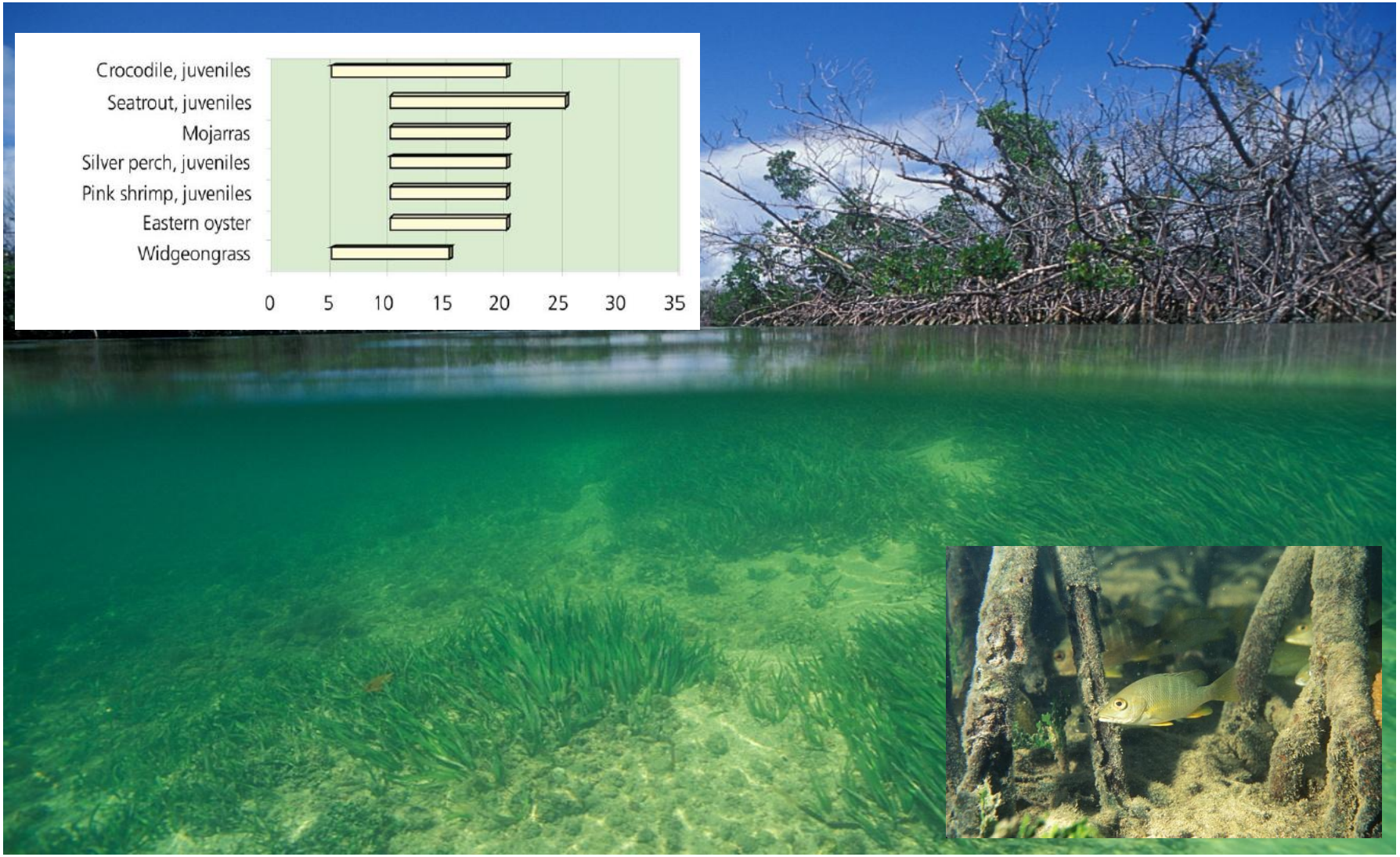


- Salinity regime sets the ecological environment in coastal systems
  - Extreme events lead to shifts in ecological communities
  - Salinity is variable and trending upward in Florida Bay
  - Salinity changes act in conjunction with other factors, including currents, temperature, and light with various feedback cycles

- 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



SCENARIO

1.5’ SLR by 2060 (~9.5 mm/yr)

± 10% precipitation

1.5^{o} C

DISCUSSION

SLR trend imposed on annual cycles

Teleconnection to global cycles through *hydrology* - changes in rain distribution and quantities leading to changes in salinity and resulting changes in mixing or water motion (include currents on west coast)

Teleconnection to global cycles through *heat* - seasonal and long term steric cycles and trends in sea level

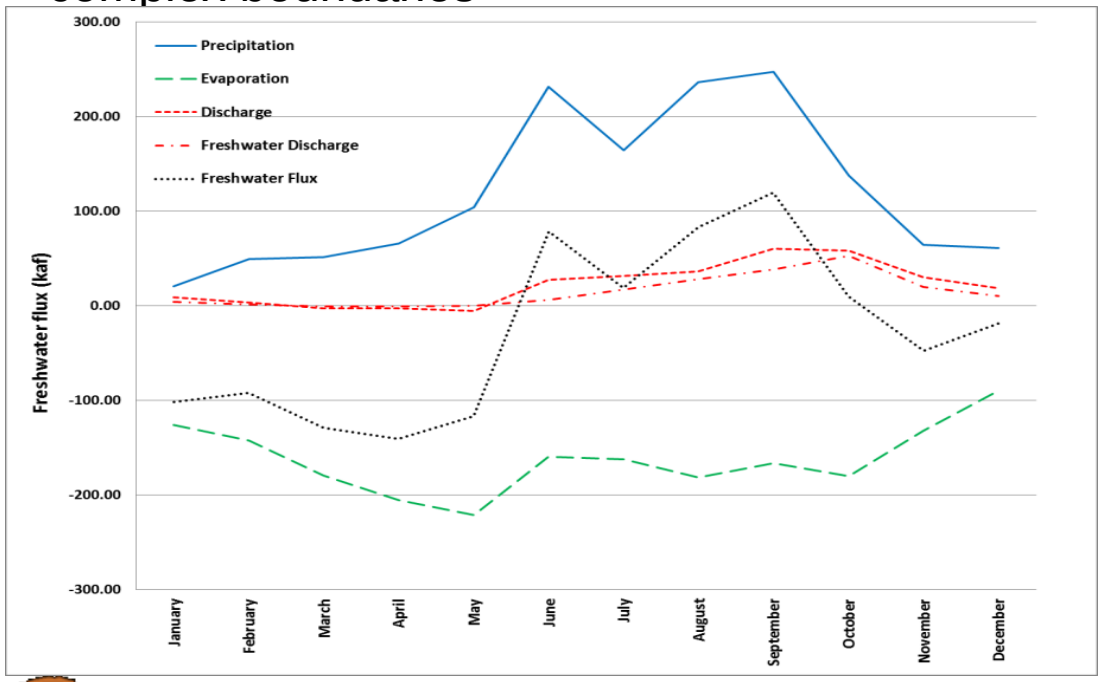
Regional to basin scale changes in currents causing changes in local sea levels - extreme tides with reduced Florida Current flow rates

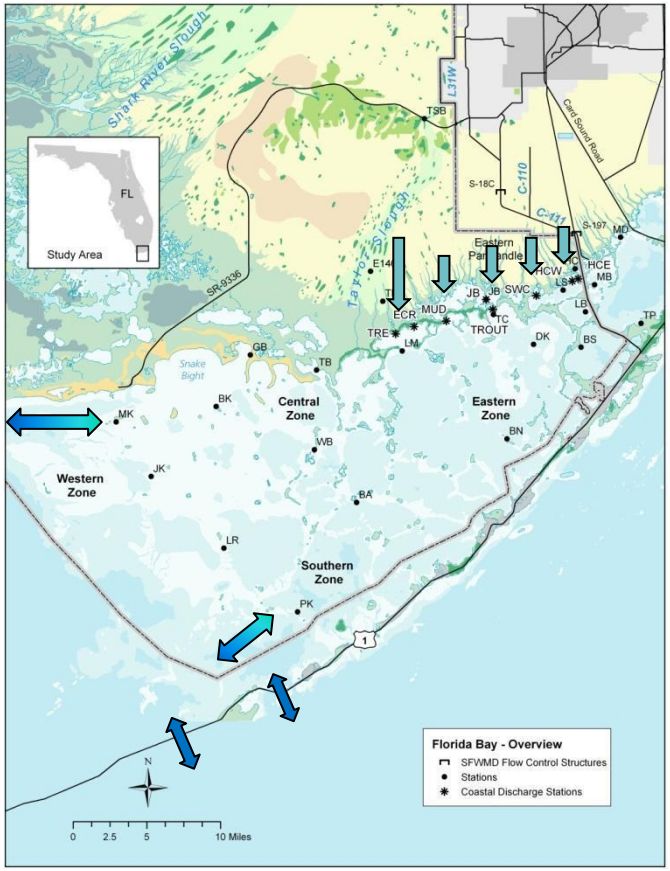
Tipping points such as opening Whitewater Bay to increased flushing

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





Tidal flow interannual variability and fresh water

By Cherubin, Browder, Crieales, and Paris
Presented to NPS, 2012

ROMS modeling exercise connecting currents and shrimp transport between Dry Tortugas and Florida Bay.

Key Points:

Water along the coast is both warmer and fresher therefore lighter than offshore.

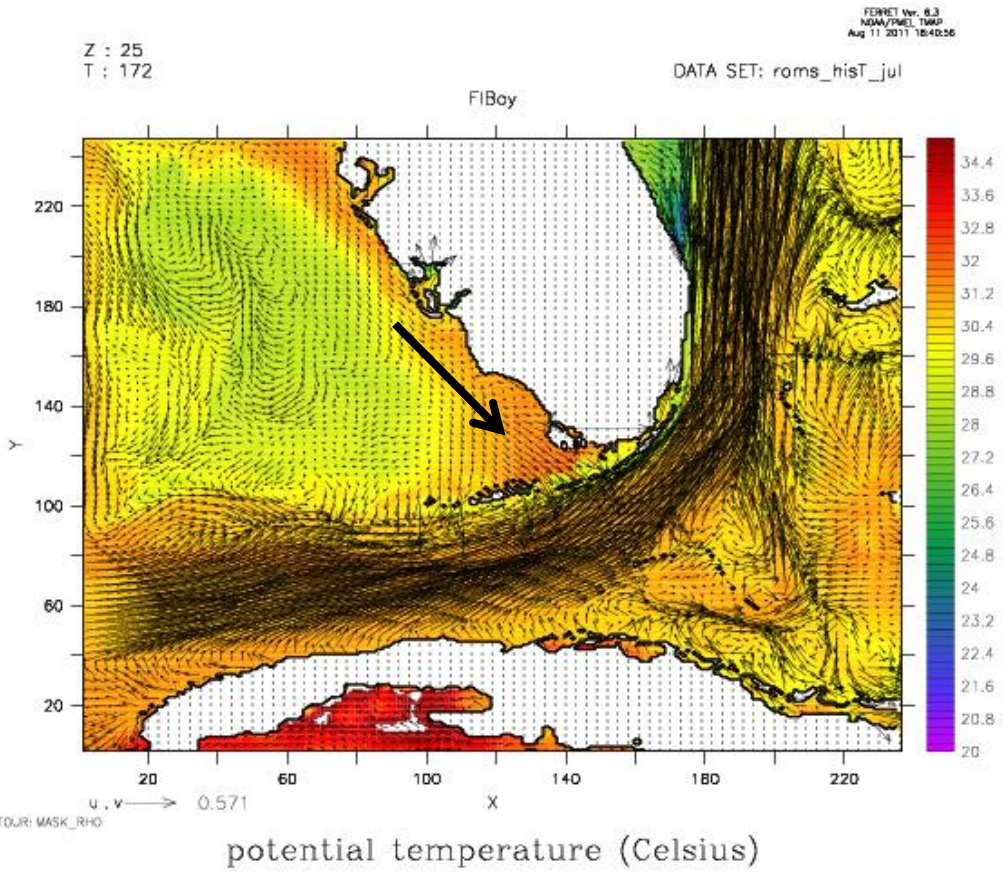
Mean geostrophic flow on the Southwest Florida Shelf is to the south and will increase with increasing amounts of freshwater deliveries

Large flow releases can act similar to coastal jets, breaking the flow, moving water offshore, and interrupting connectivity to Florida Bay.

Implication:

Precipitation and temperature will affect connectivity between western shelf and Florida Bay.

9h, beginning of outgoing tide



Florida Current Variability

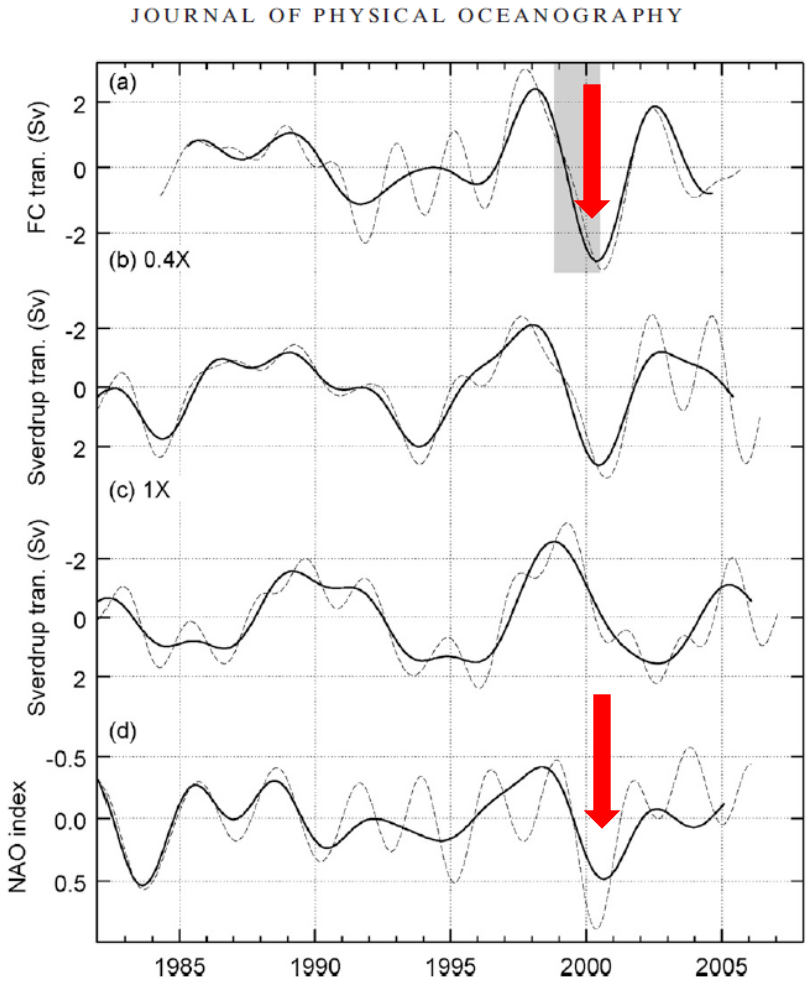
NAO and MOC interactions

NAO has a positive relationship with the wind-stress curl, explaining ~1/2 of the Florida Current variability (DiNezio et al. 2009)

*** Note inverted sign on axis

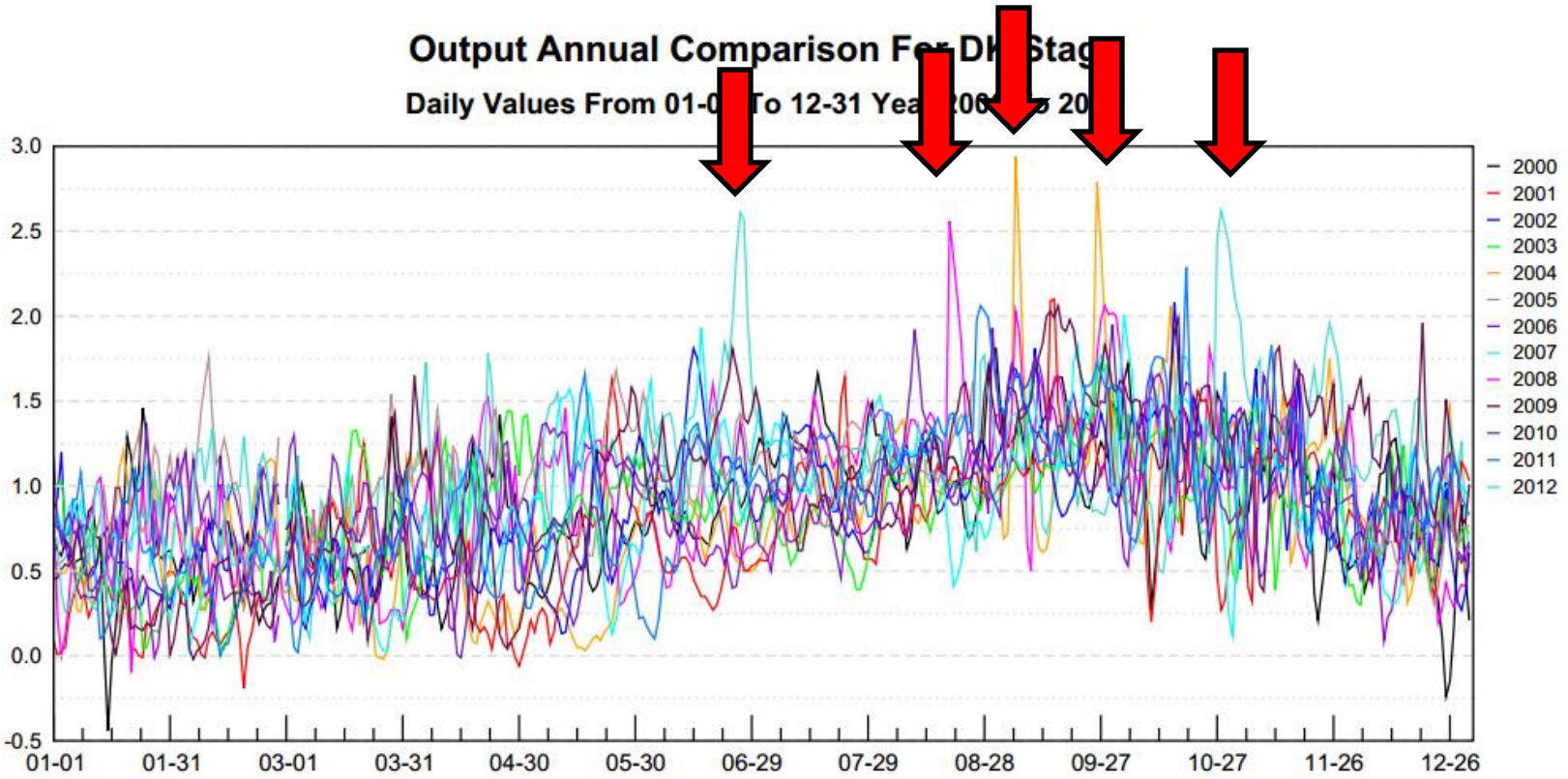
Florida Current is part of the returning flow for the MOC and so is link to variation in North Atlantic Circulation

On a smaller scale, eddies moving toward the west in the tropics can also interact with the Florida Current



Graph from DiNezio, et al., JPO, 2009.

Sea level extremes



History as a lesson: 5 events in the last 12 years where sea level has 'jumped' > 1'

October 2010 event led to flooding in South Beach
Causes of these events are varied but include
eddies, storms, and reductions in the Florida Current

Sea Level Rise in Florida Bay

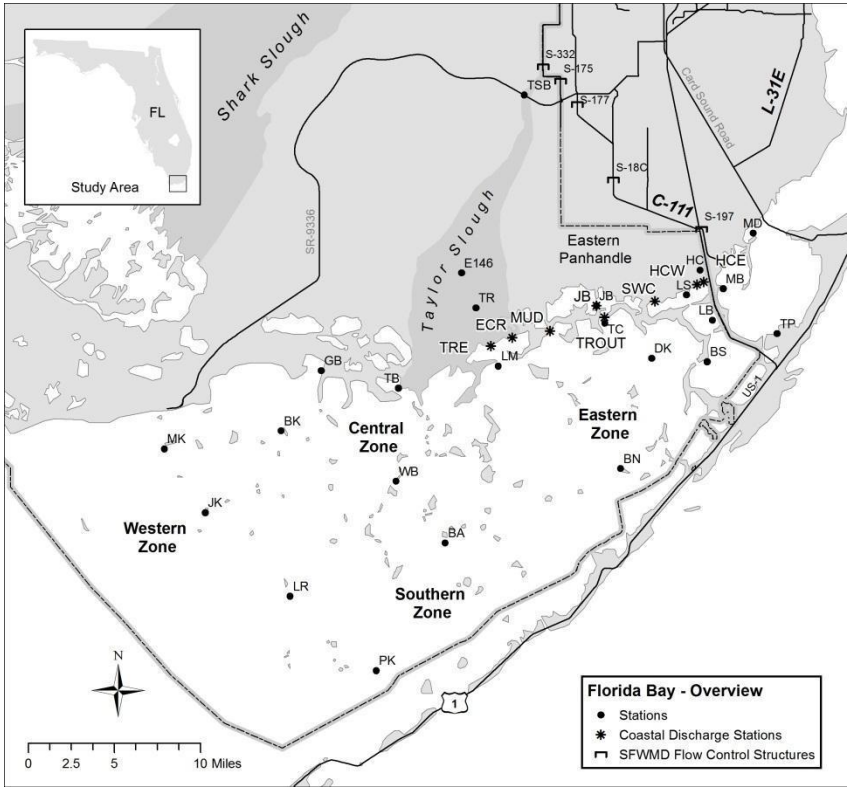
Impact primarily based on changes in mixing

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

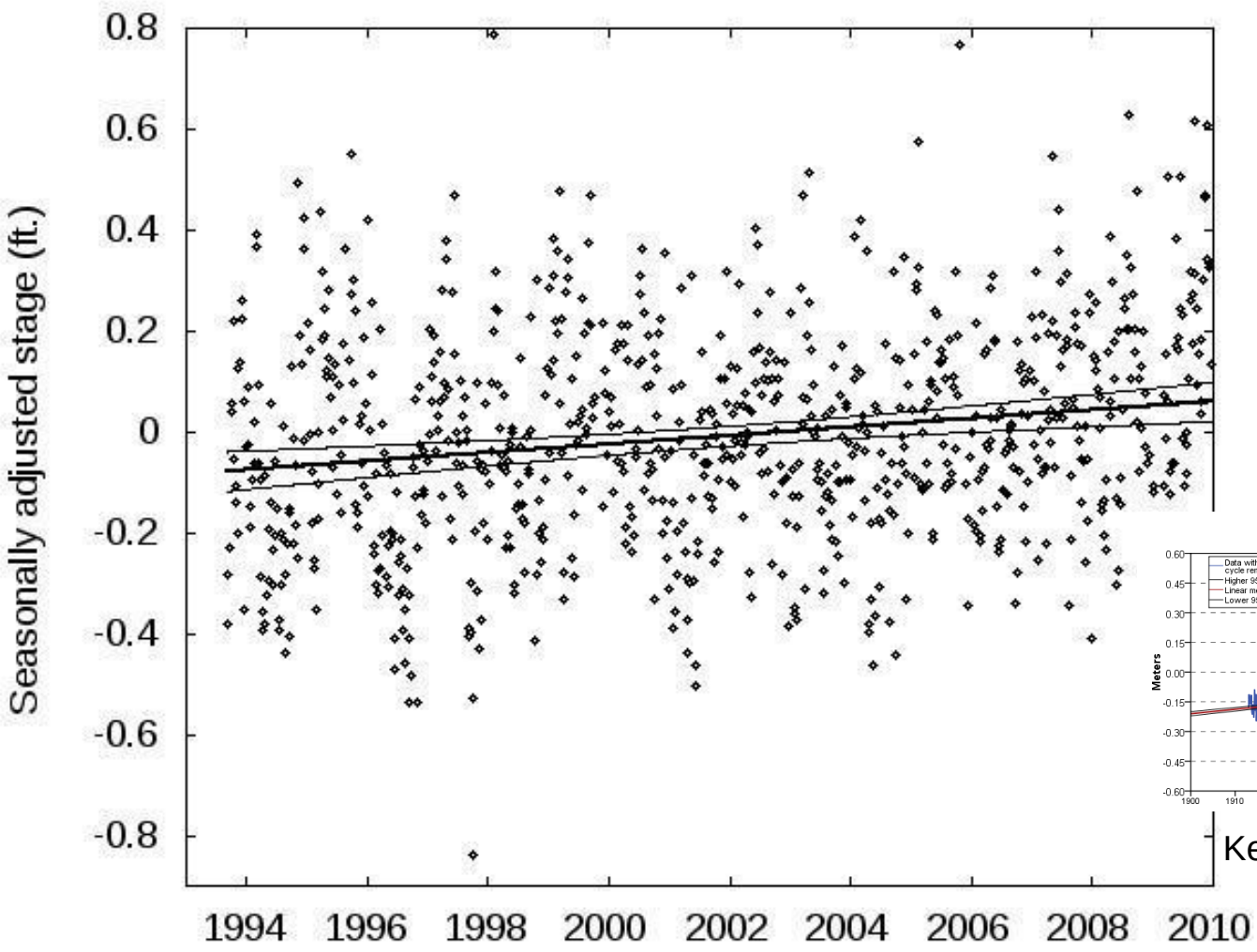
- Reduced frequency and extent of extreme high/low salinity conditions

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



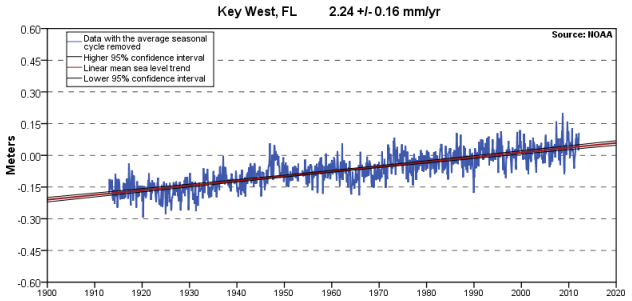
Sea-level rise



Station LM; 2.58 ± 0.47 mm/yr

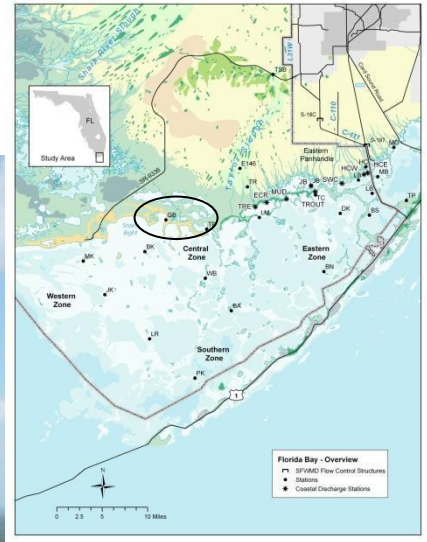
Data from Little Madeira Bay
+2.6 cm/decade
1994 - 2009

Key West observations
+2.2 cm/decade
~100 years



Key West; 2.24 ± 0.16 mm/yr

What's at Risk?



Is sea level rise already affecting salinity?

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

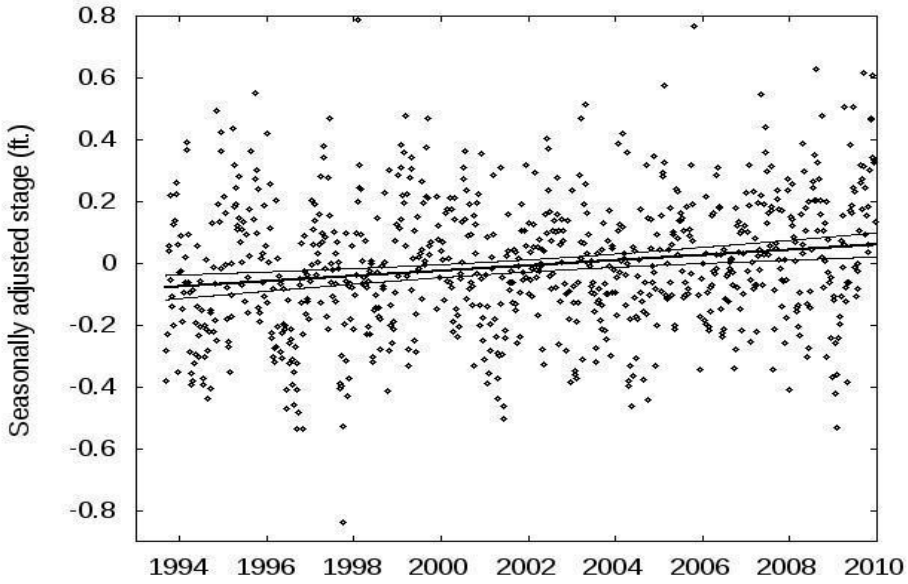
Salinity highly variable but has been increasing since 1995.

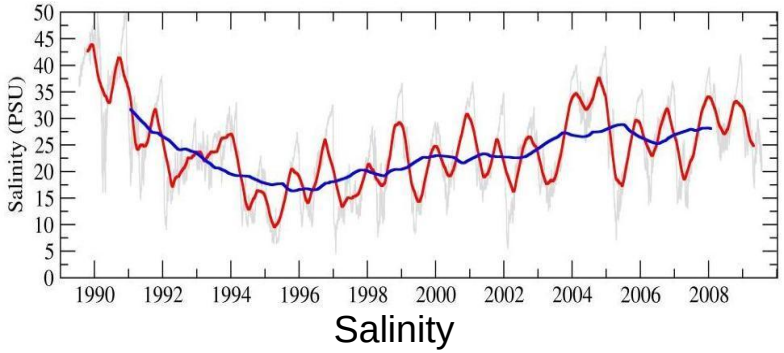
Conditions becoming more ‘marine-like’

lower variability

Average approaching 35 PSU

Station LM; 2.58 ± 0.47 mm/yr





Is this a trend or cycle?

Is salinity predictable?

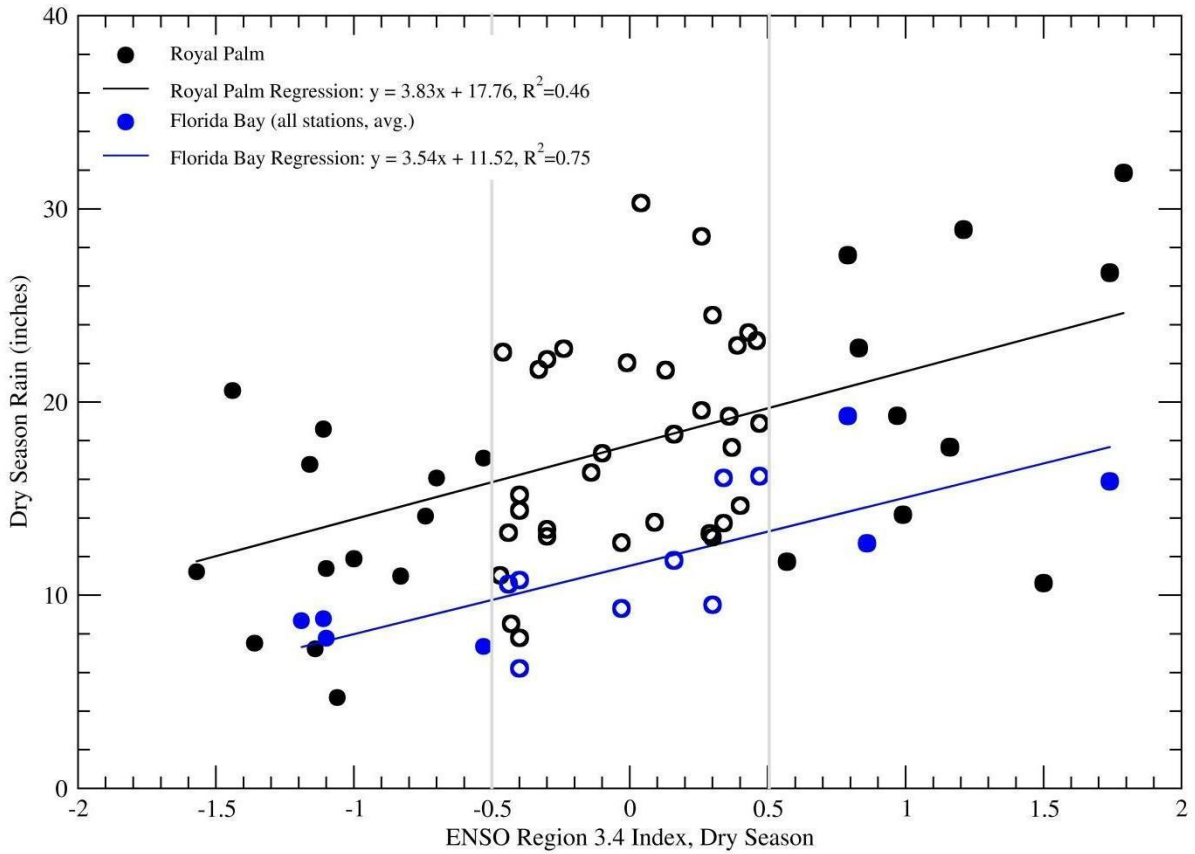
Observed: ENSO influences dry season rainfall

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

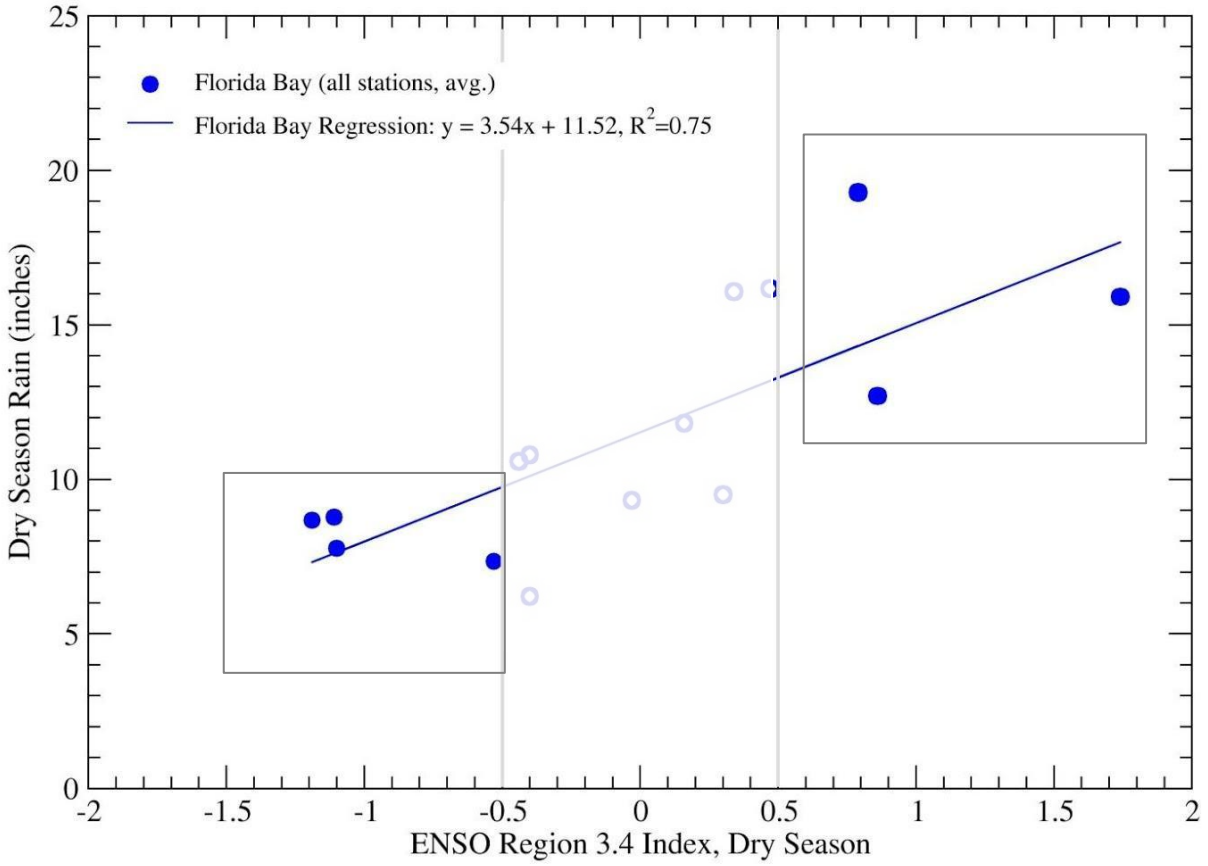
ENSO cycle length is variable
3 – 5 years on average



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

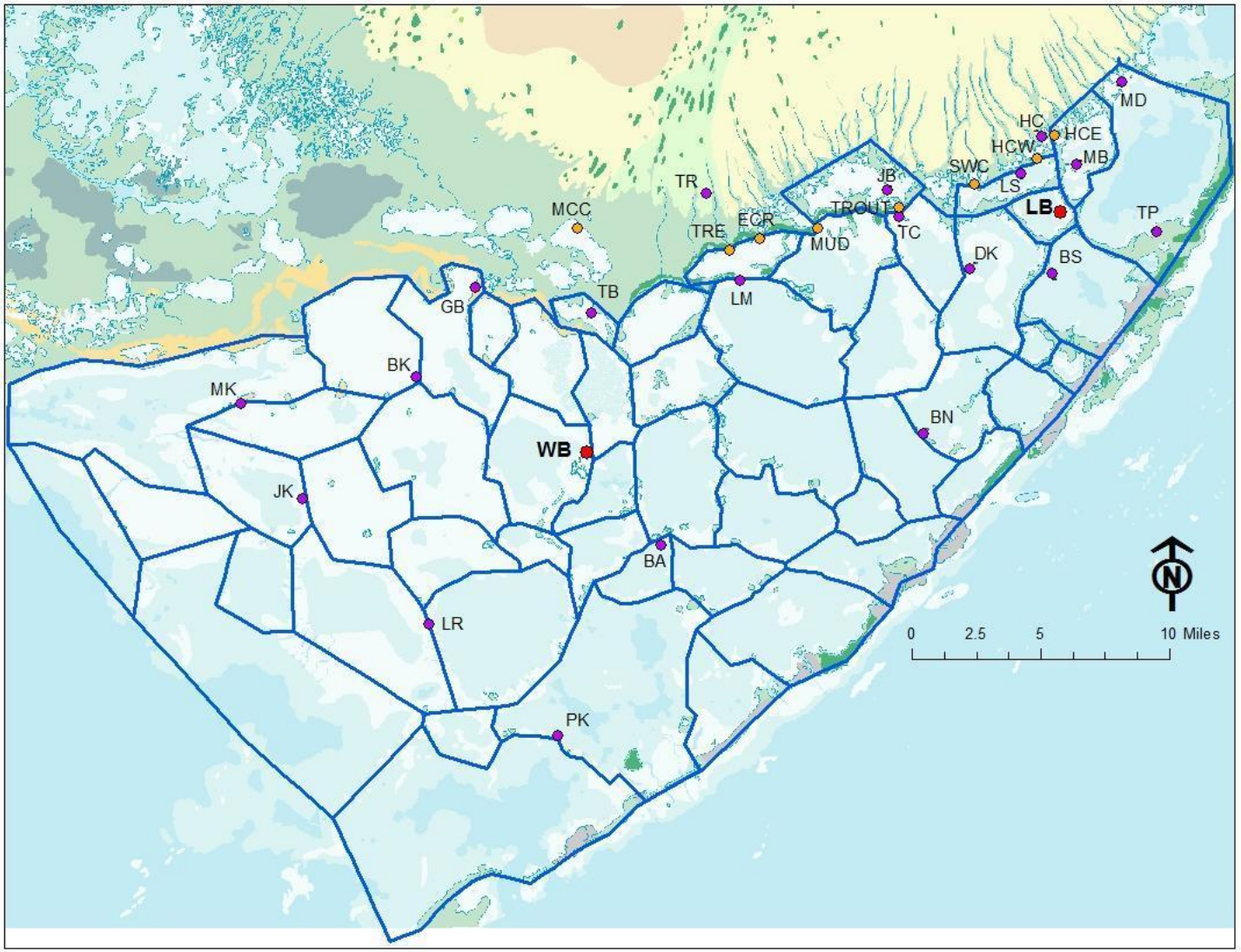


*Dry season rain analysis by Hagemeyer, NWS, produced for NOAA in 2006

FATHOM

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

Fathom basins and boundaries



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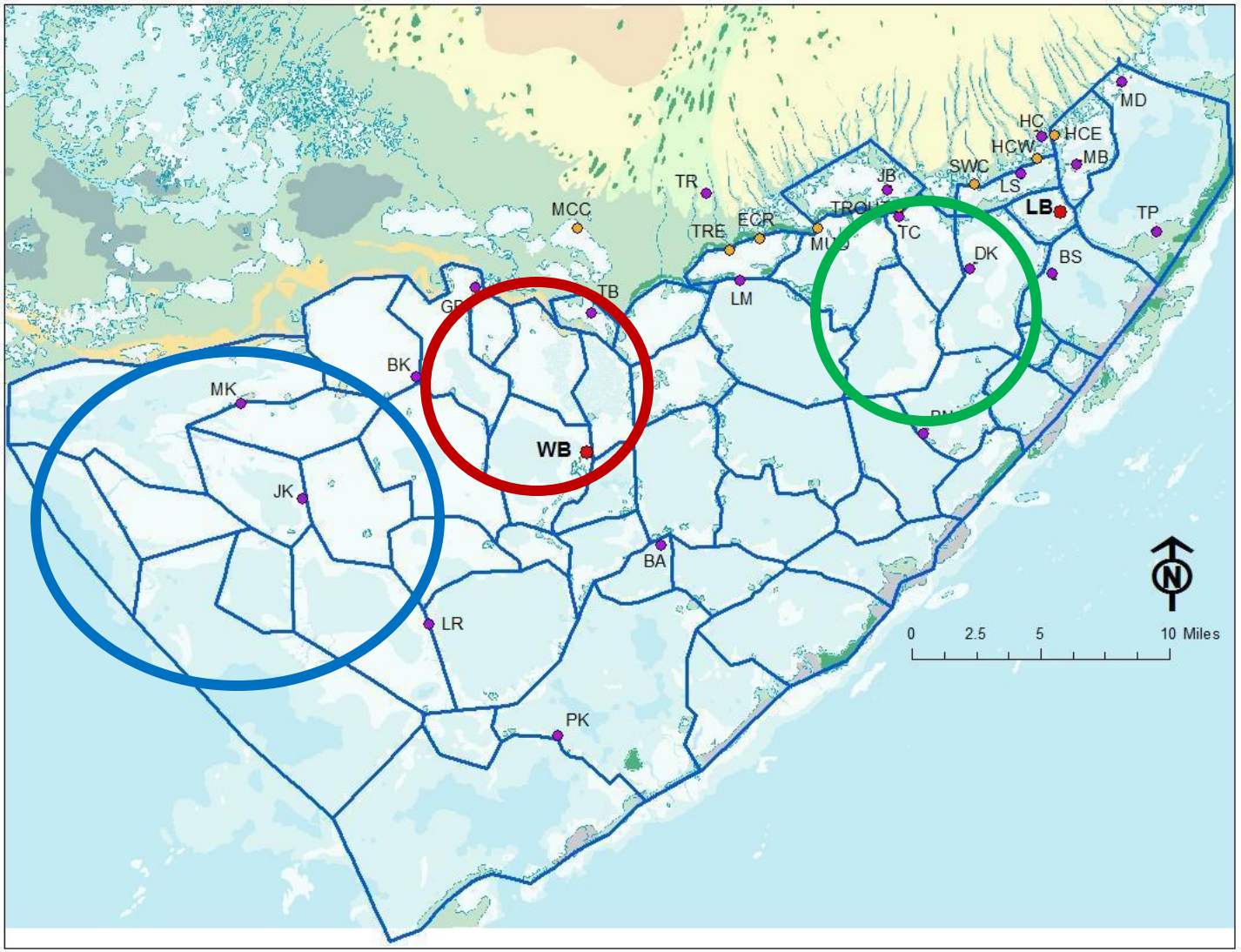
Fathom basins and boundaries



Western

Central

Northeastern

Fathom: Marine influence and variability

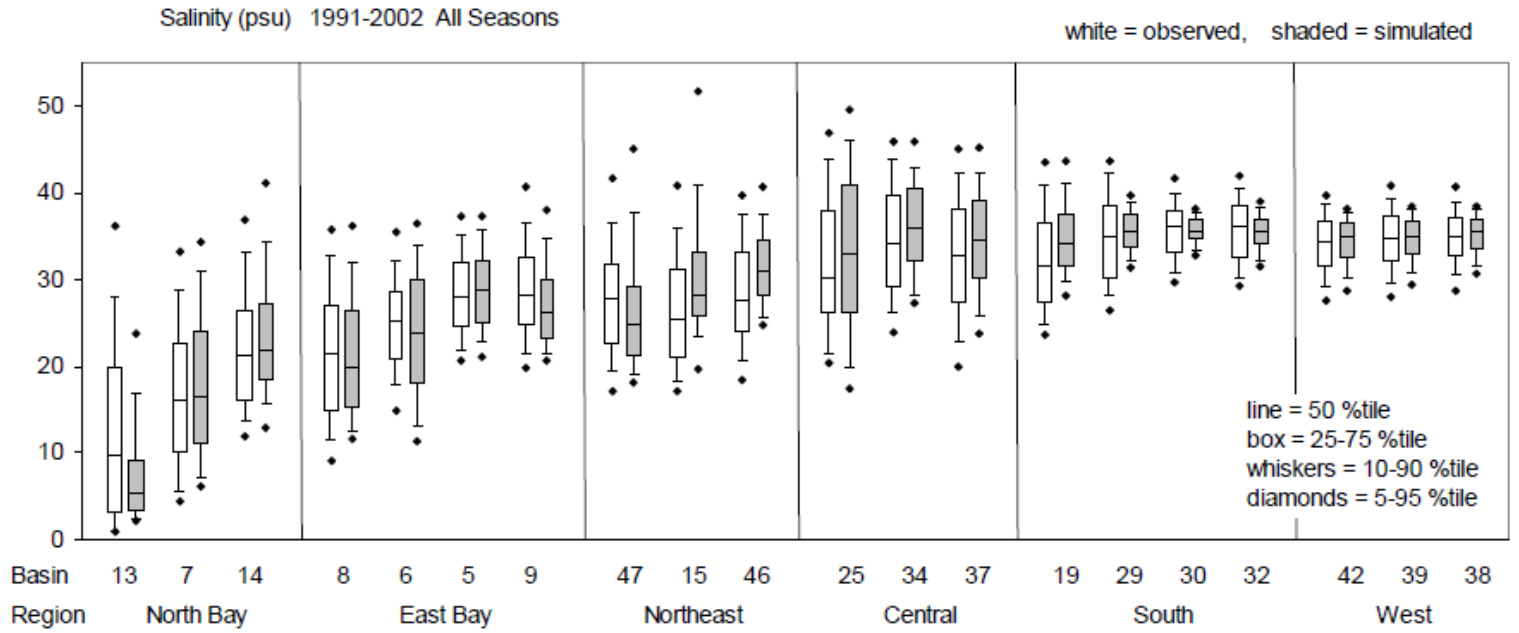


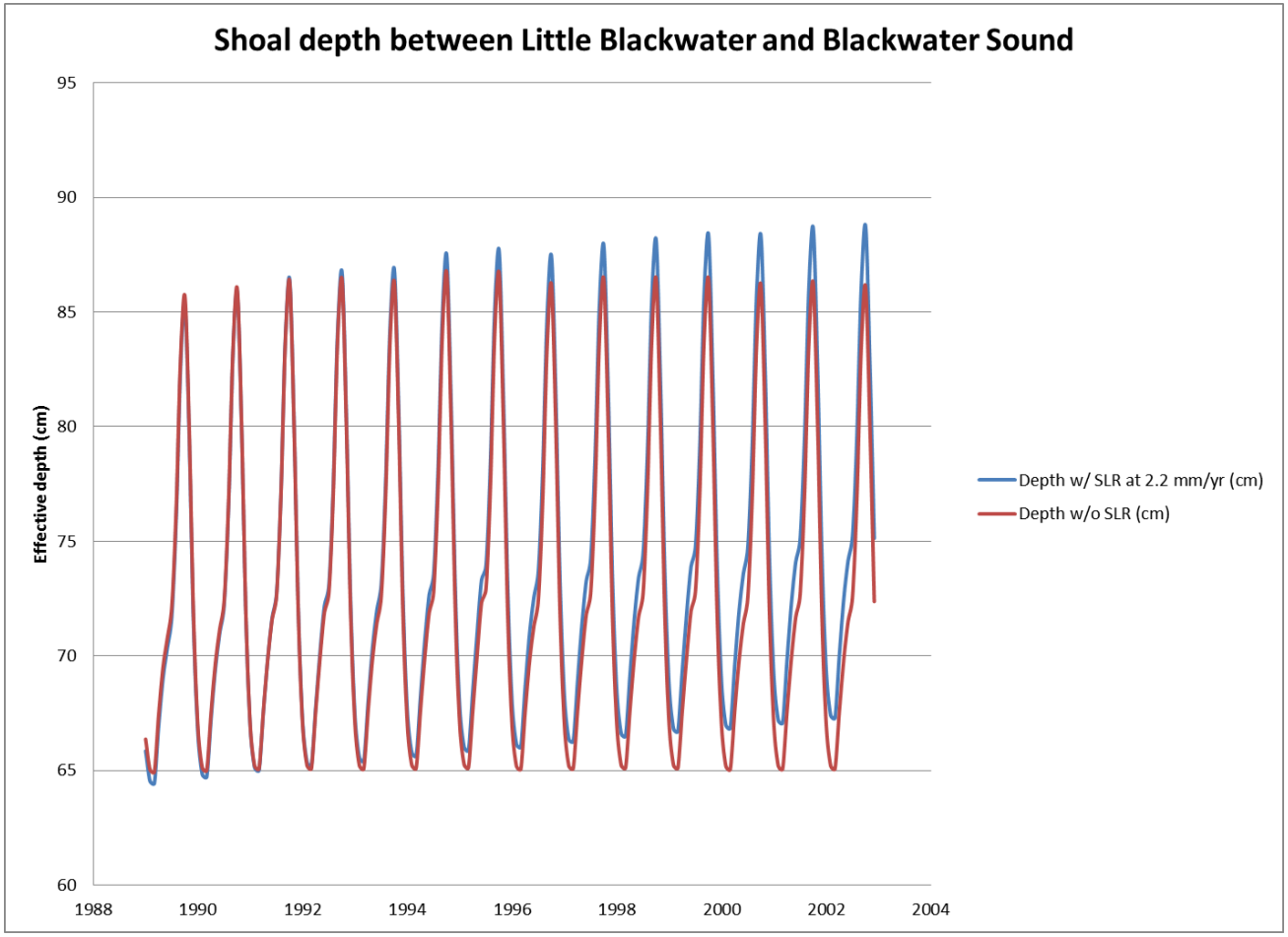
Figure 3-4 Comparison of the distribution of simulated (shaded) and observed (open) monthly salinity for the period 1991-2002. Distributions are based on all 12 months in each of the 12 years of observed data (all seasons).

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

As sea level rises we'd expect more marine like conditions across bay.

*Graphic from Fathom Model Structure and Salinity report

Fathom: Predicting Salinity Changes due to Sea Level Rise



Using CESI base conditions

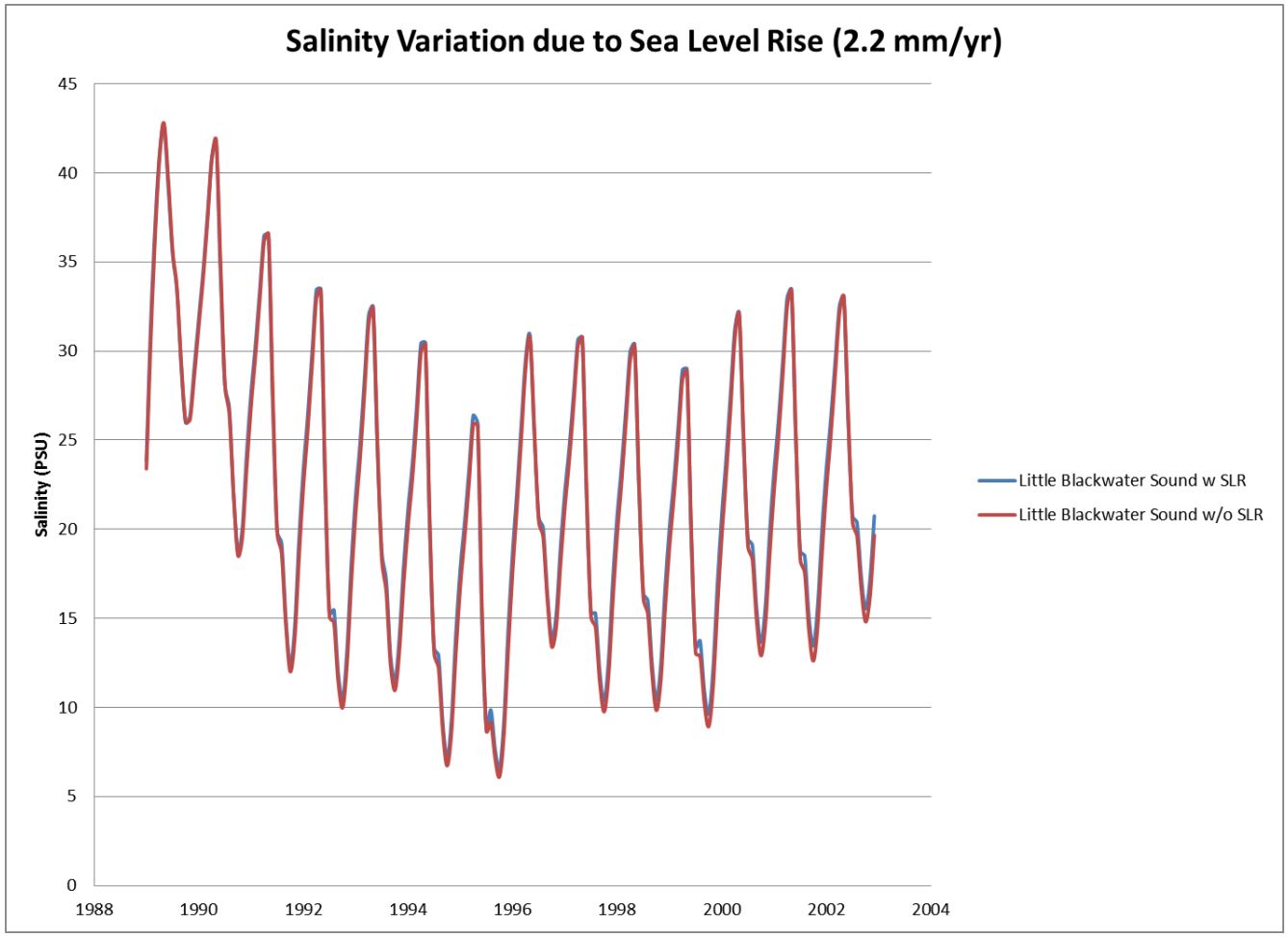
Set SLR at 2.2 mm/yr

Monthly Simulation
1989 – 2002

Model result:

- Sea levels increase in Eastern Florida Bay
- Range is constant but assumes bank height doesn't change

Fathom: Predicting Salinity Changes due to Sea Level Rise



Using CESI base conditions

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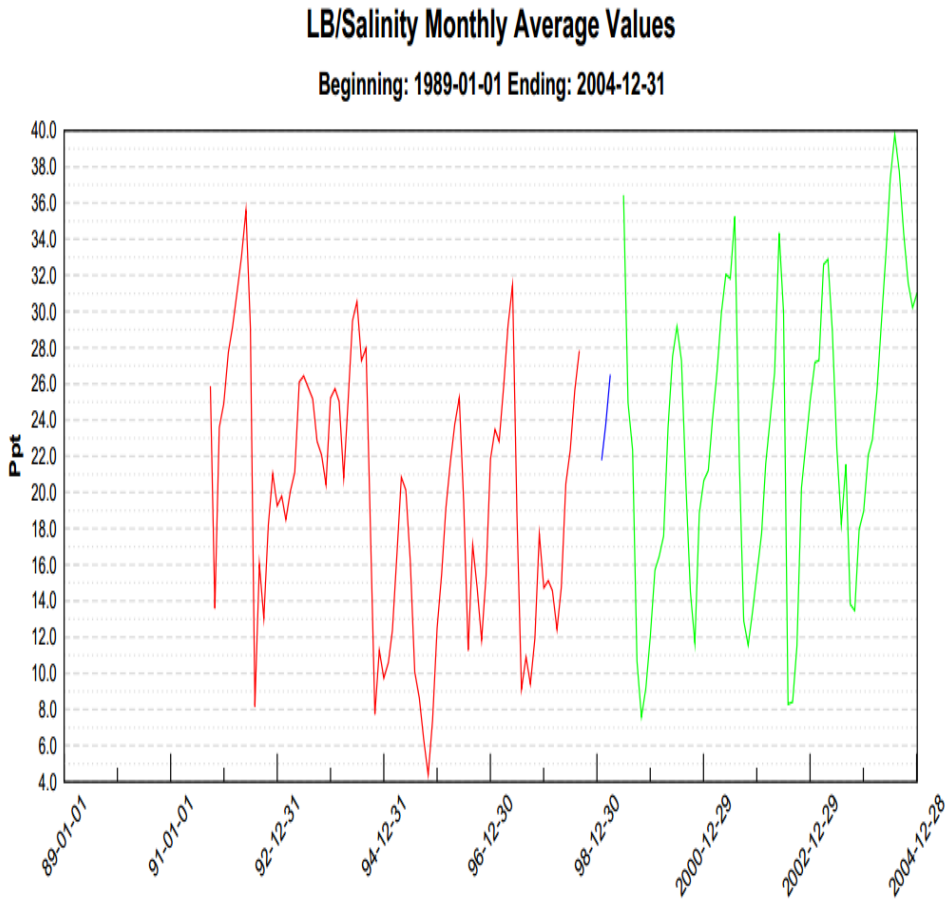
Monthly Simulation
1989 – 2002

Model results:

- Reduce seasonal variability
- Increase annual minimums
- Suggests that current rates of SLR are impacting salinity

Fathom: Predicting Salinity Changes due to Sea Level Rise



Using CESI base conditions

Set SLR at 2.2 mm/yr

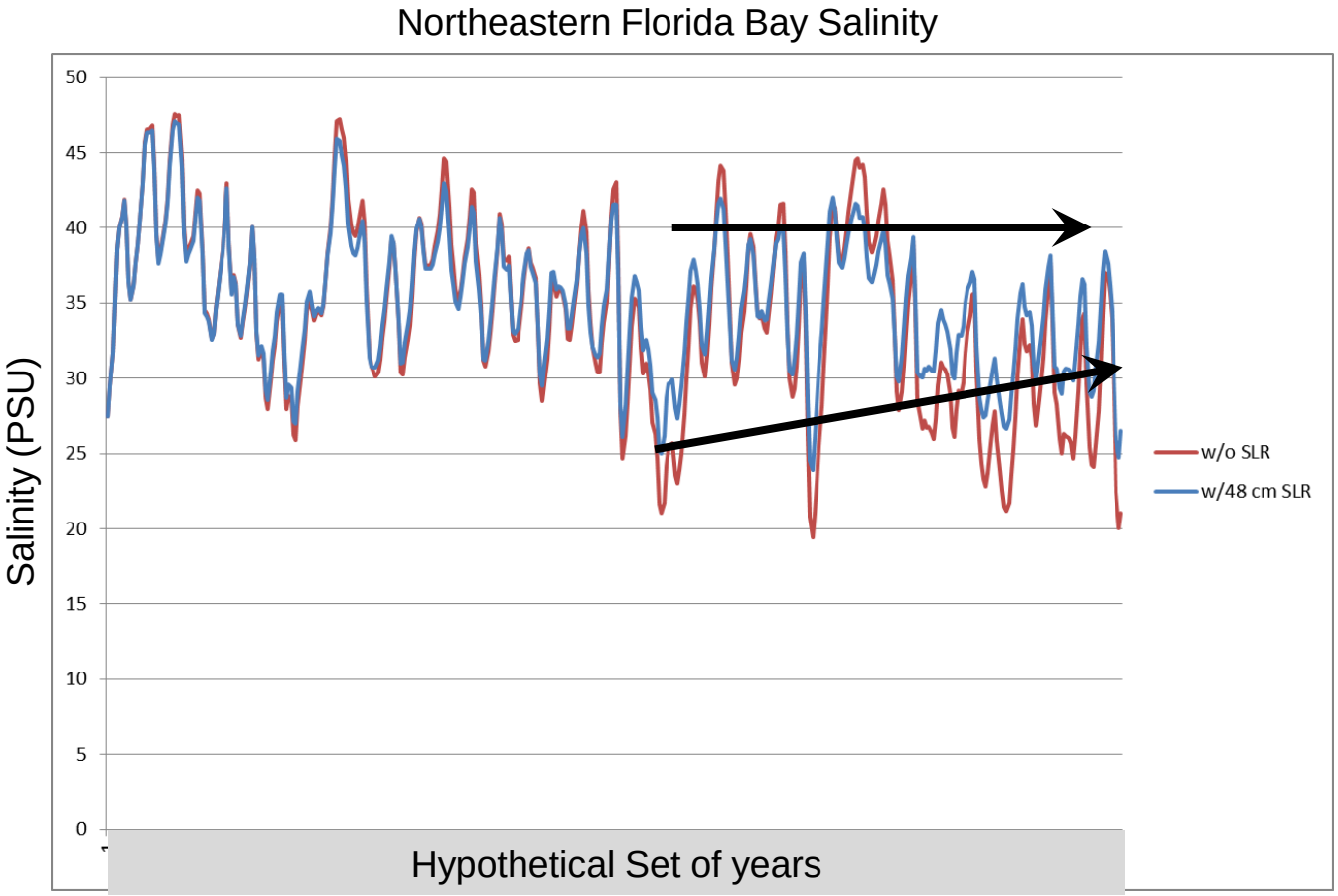
Monthly Simulation
1989 – 2002

Model results:

- Reduce seasonal variability
- Increase annual minimums
- Suggests that current rates of SLR are impacting salinity

Fathom: Salinity and Accelerated Sea Level Rise

Hypothetical – for evaluation purposes only



Using CESI base conditions

Set total SLR to reach 48 cm by end of simulated run

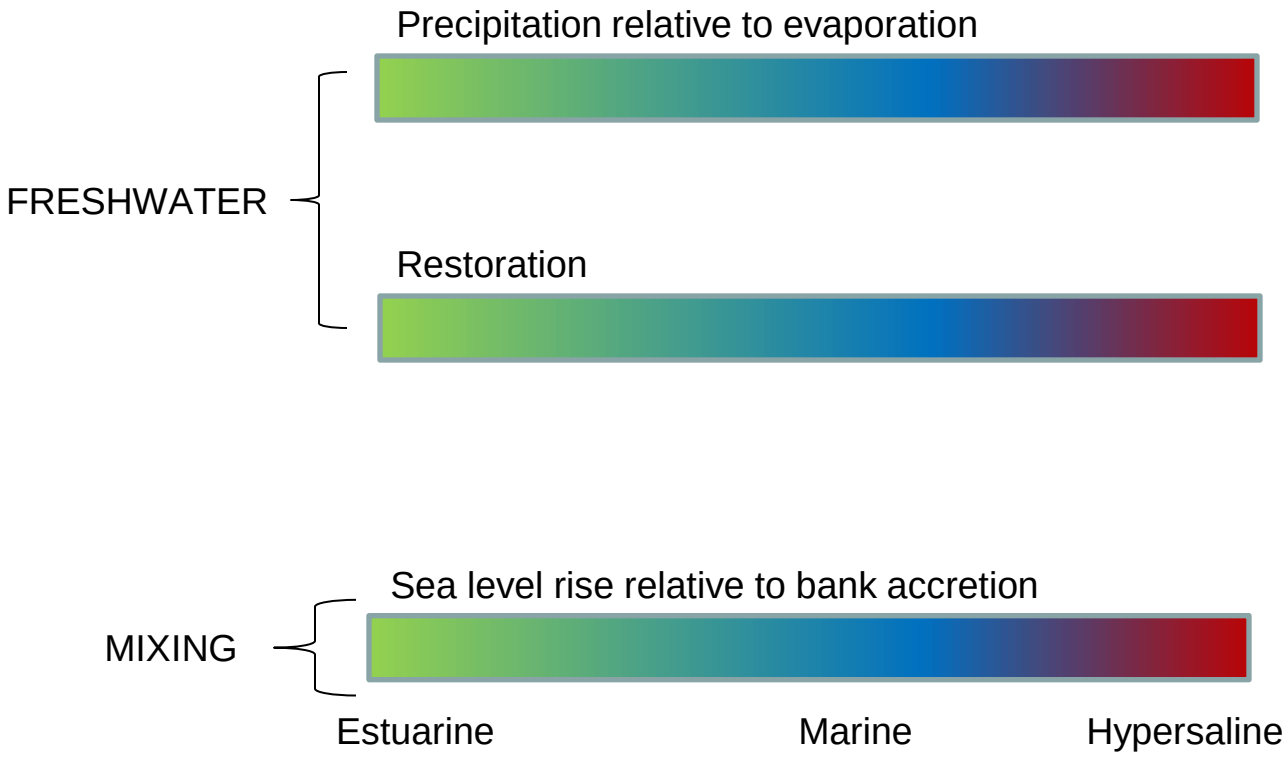
Simulation run strictly for comparison of end point

Model results:

- Reduce seasonal variability
- Increase annual minimums
- Eliminates mesohaline habitat in Eastern Florida Bay

Management objectives and climate change

Conceptual diagram for factors affecting salinity



Predicting the outcome when we expect both changes in freshwater delivery and changes in mixing is challenging.

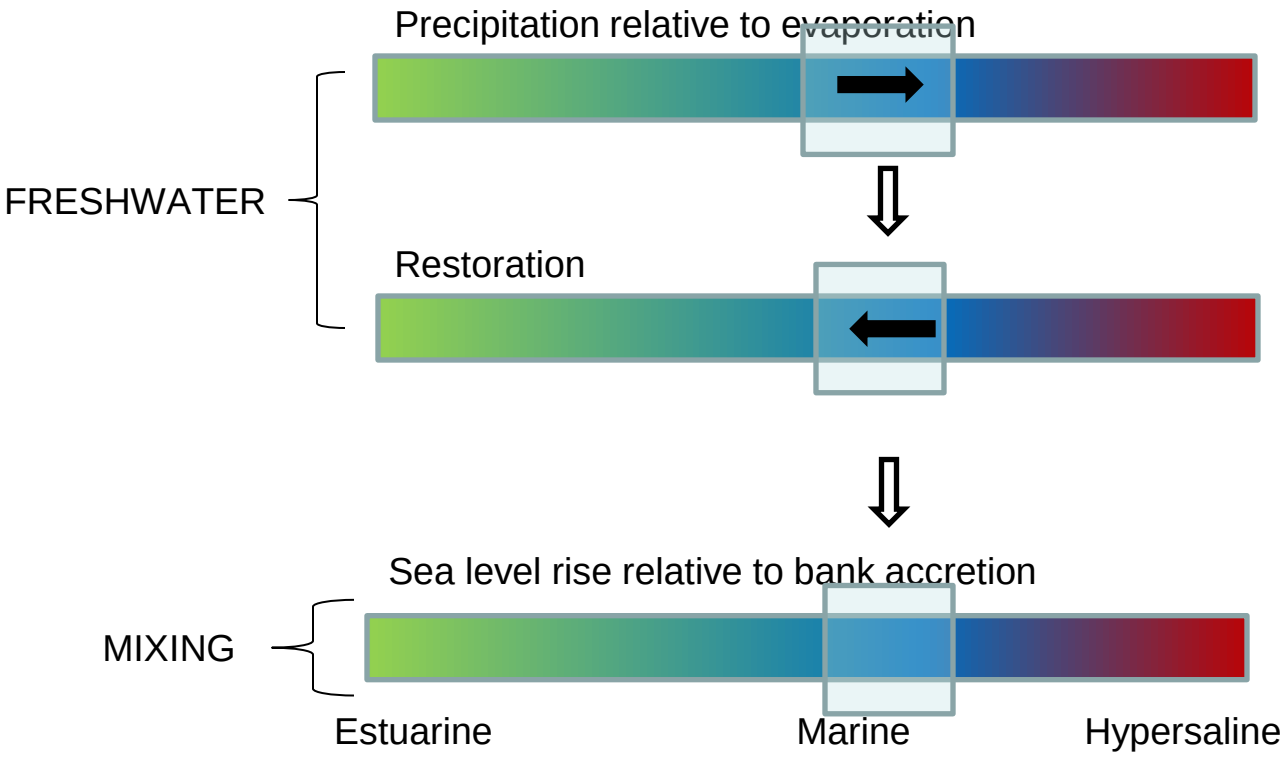
Graphic used for discussion.

Management objectives and climate change

Predicting the outcome when we expect both changes in freshwater delivery and changes in mixing is challenging.

Graphic used for discussion.

Conceptual diagram for factors affecting salinity
WESTERN FLORIDA BAY

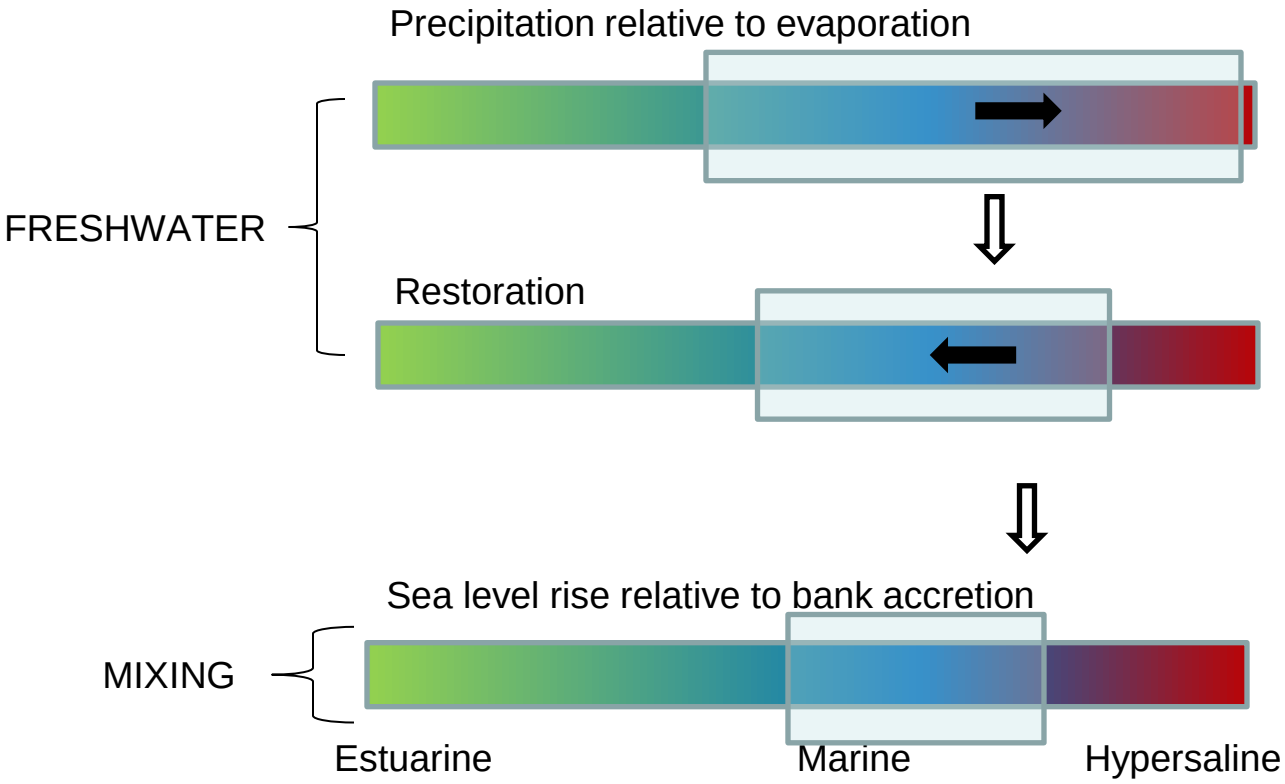


Management objectives and climate change

Predicting the outcome when we expect both changes in freshwater delivery and changes in mixing is challenging.

Graphic used for discussion.

Conceptual diagram for factors affecting salinity
CENTRAL FLORIDA BAY

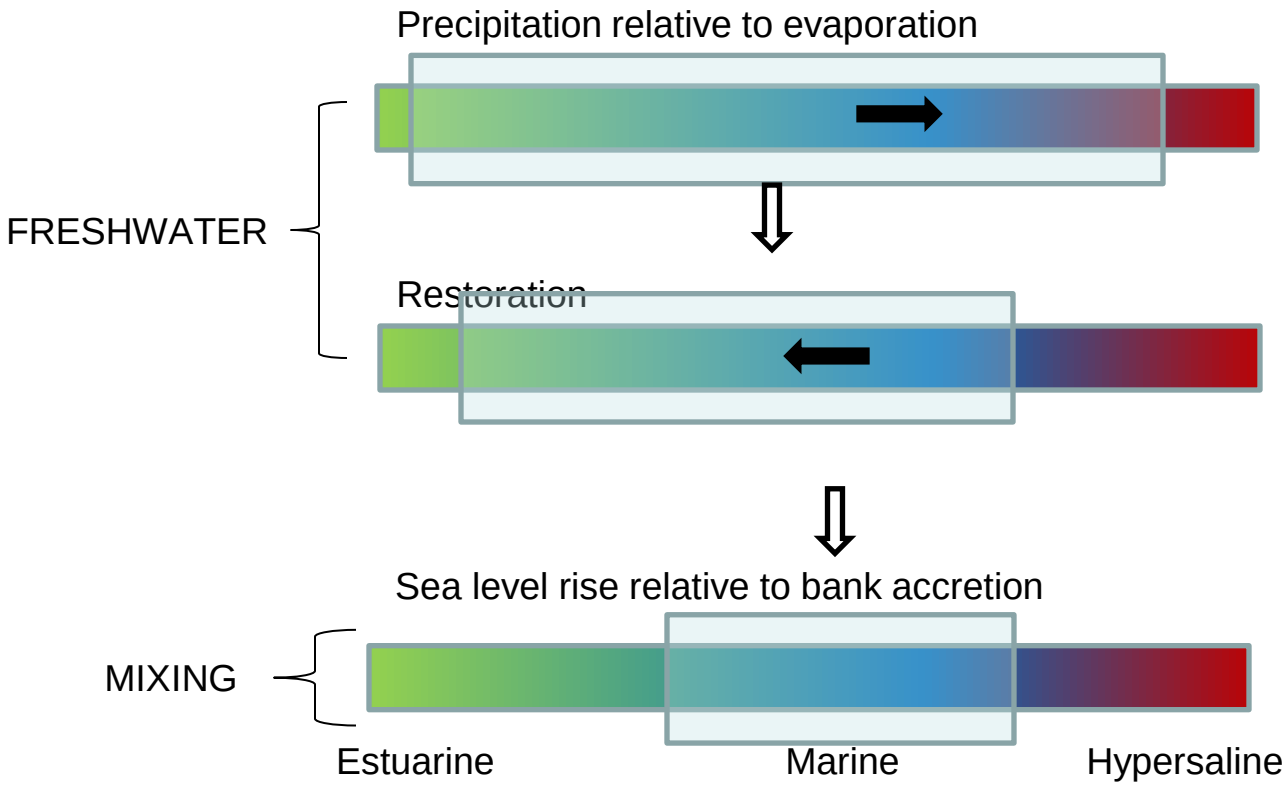


Management objectives and climate change

Predicting the outcome when we expect both changes in freshwater delivery and changes in mixing is challenging.

Graphic used for discussion.

Conceptual diagram for factors affecting salinity
NORTHEASTERN FLORIDA BAY



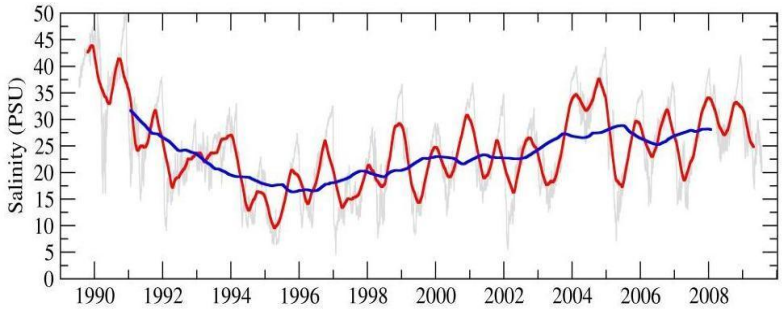
Discussion

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

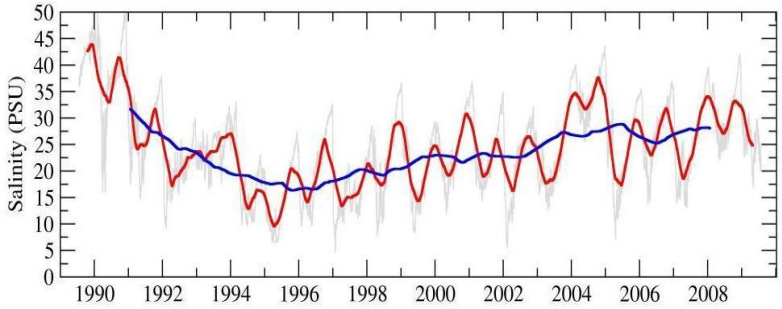
ENSO related cycles in salinity **were not observed**



Is this a trend or cycle?

Is salinity predictable?

Discussion



Prediction

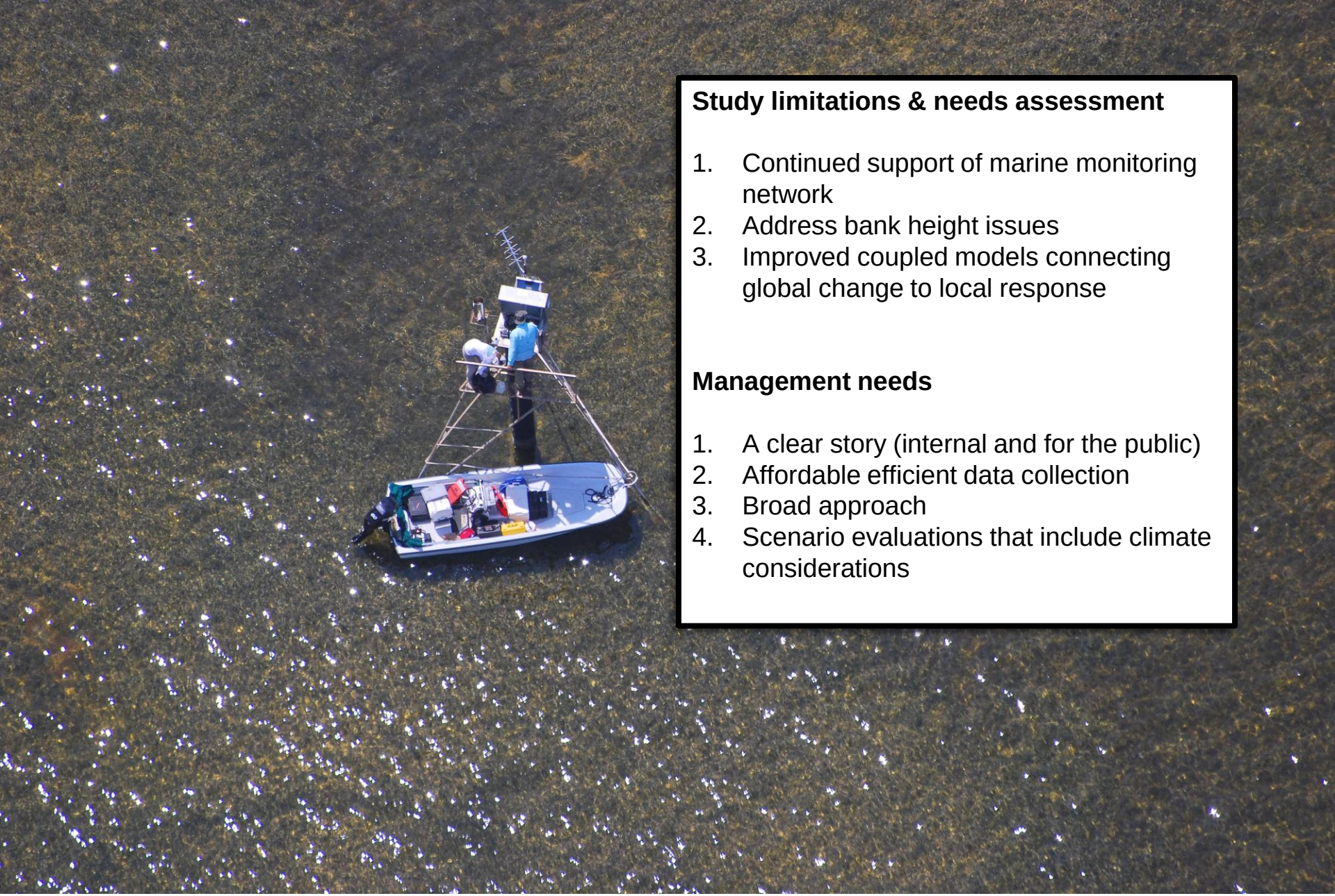
Temperature in synch. with atmospheric change, precipitation down but CERP flows up so net zero (!)

Salinity: increasingly marine-like conditions with largest difference observed in the more confined basins along the northern shore and eastern boundary

	Base	w/Sea Level Rise
Western	34.2 ± 3.8	34.2 ± 3.8
Central	34.1 ± 10.1	34.1 ± 5.5
Northeastern	29.5 ± 12.4	32.4 ± 9.5

Light: expect increased penetration (IMHO) and spectral slope coefficients to approach more bleached/marine like conditions.

Seasons: delayed onset of wet season (NCDC) but story is still out.



Study limitations & needs assessment

1. Continued support of marine monitoring network
2. Address bank height issues
3. Improved coupled models connecting global change to local response

Management needs

1. A clear story (internal and for the public)
2. Affordable efficient data collection
3. Broad approach
4. Scenario evaluations that include climate considerations

Acknowledgements:

This presentation contains Fathom model results (developed by B. Cosby, F. Marshall, and W. Nuttle), modeling information for the west coast of Florida (courtesy Laurent Cherubin), discussions of Florida Current variability (courtesy Christina Karamperidou), and data from the National Park Service's marine monitoring network. Credit is extended to the individuals mentioned and the teams of field personnel working tirelessly behind the scenes.

Data available at: EVER_data_request@nps.gov

Questions or further discussion: Erik_Stabenau@nps.gov

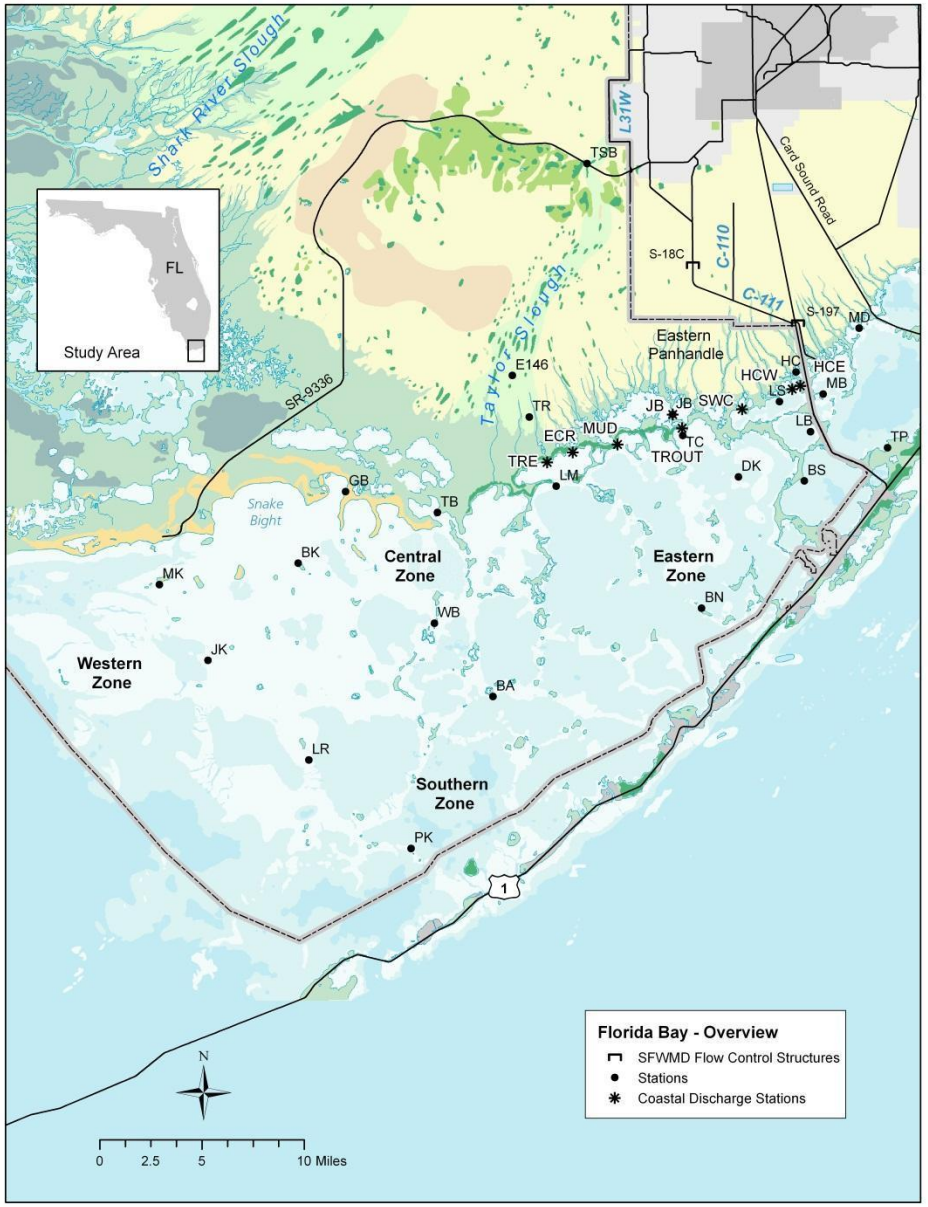
ADDENDUM

Marine monitoring network

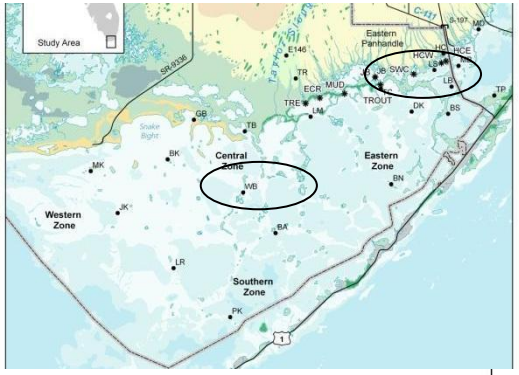
17 stations collecting hourly or higher resolution data in
- Stage
- Salinity
- Rain
- Water temperature

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

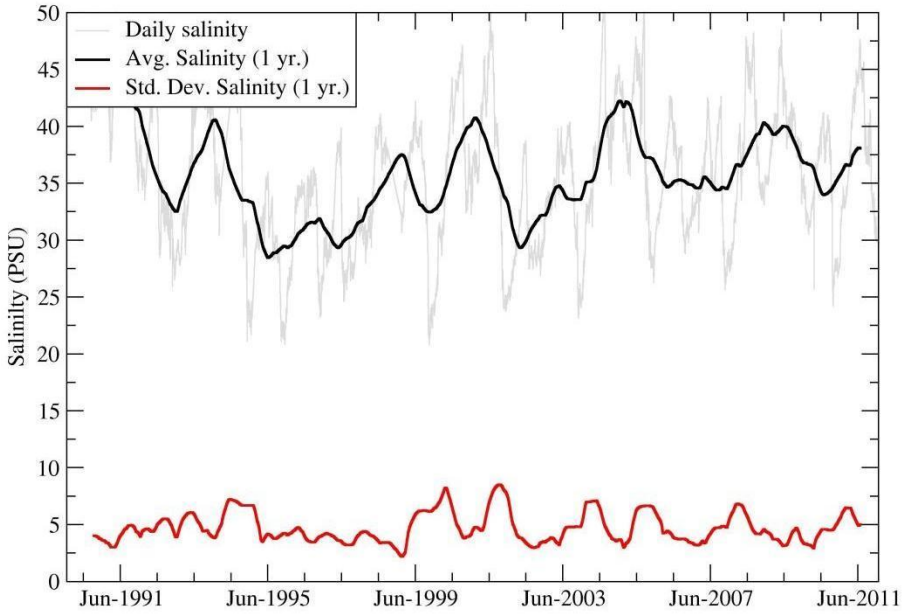
Data available
Live at: http://www.ndbc.noaa.gov
Validated: EVER_data_request@nps.gov



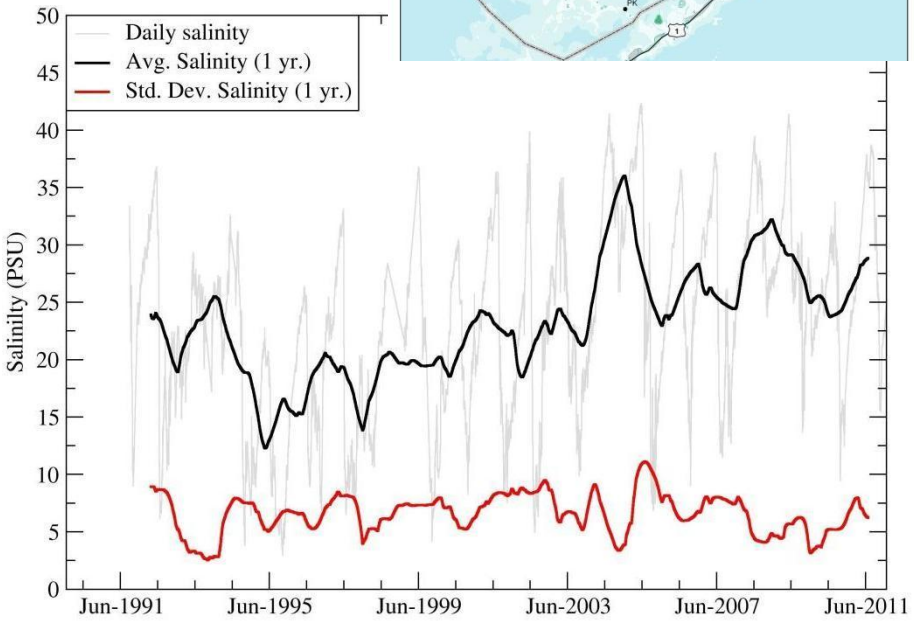
Salinity variability



Station WB



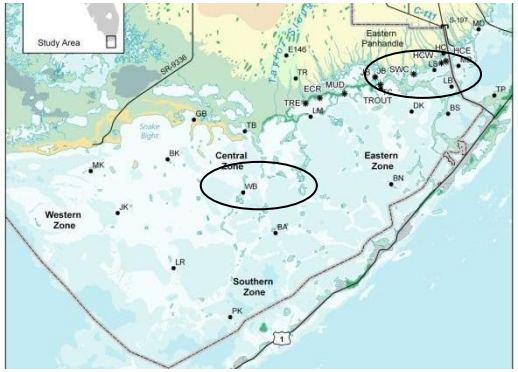
Station LB



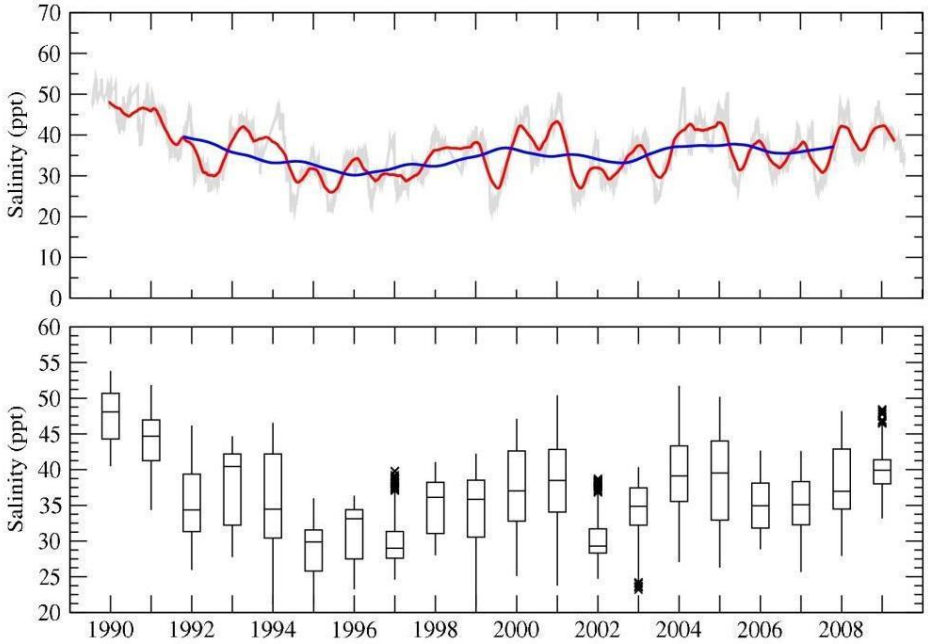
Mean salinity values change by season and year

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

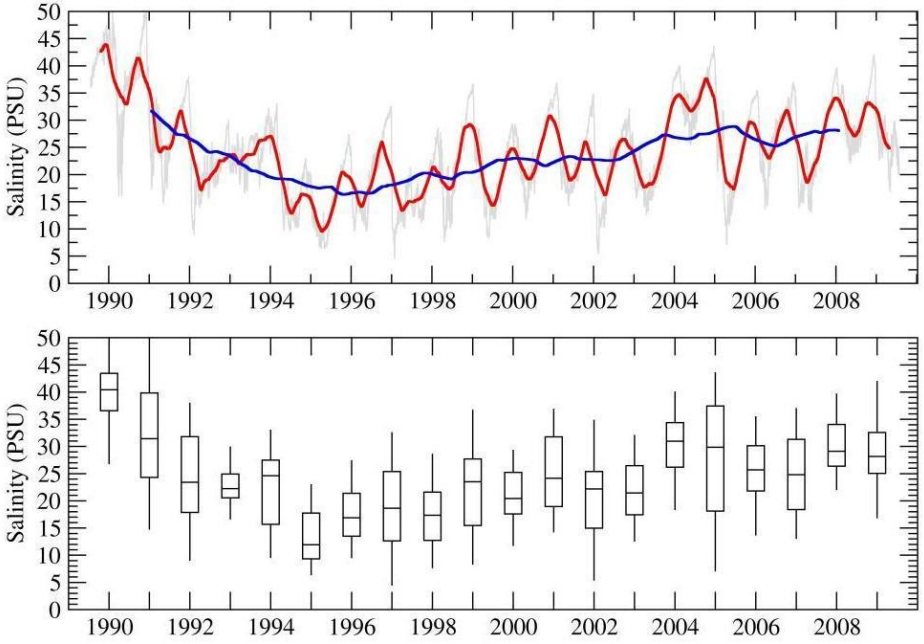
Observed: Salinity Time-series



Central Zone

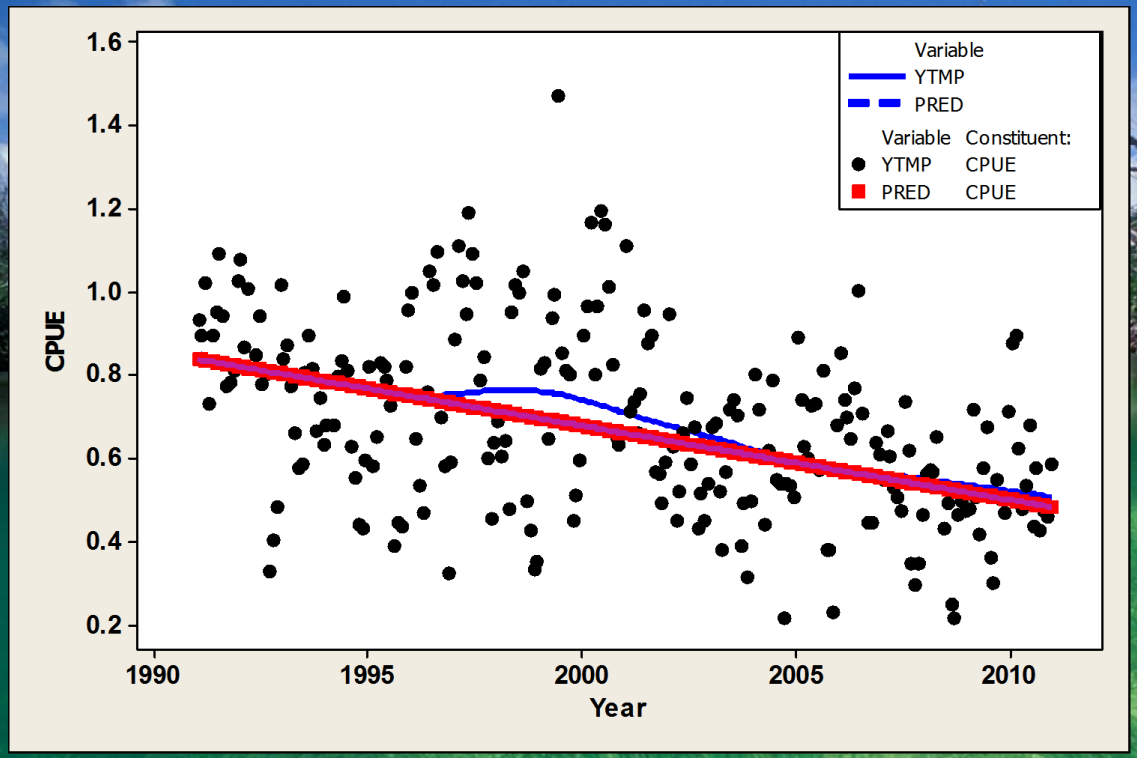


Eastern Zone



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

What's at Risk?



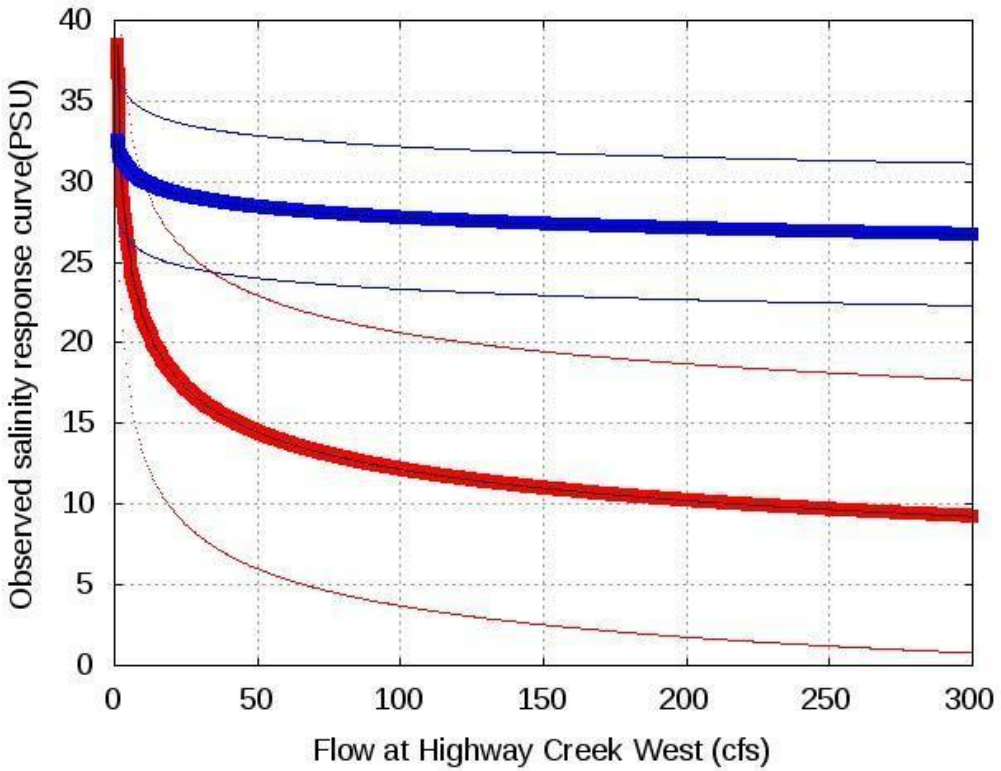
ENSO variation of rain & flow expected to influence salinity in coastal basins

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



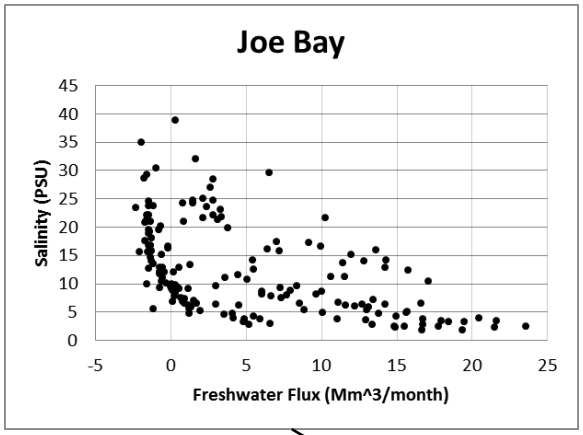
Fathom: Flow to salinity relationships

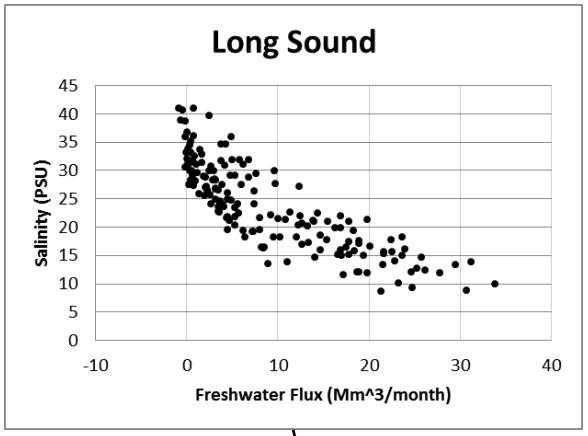
Model run: Existing conditions
Monthly 1989 – 2002

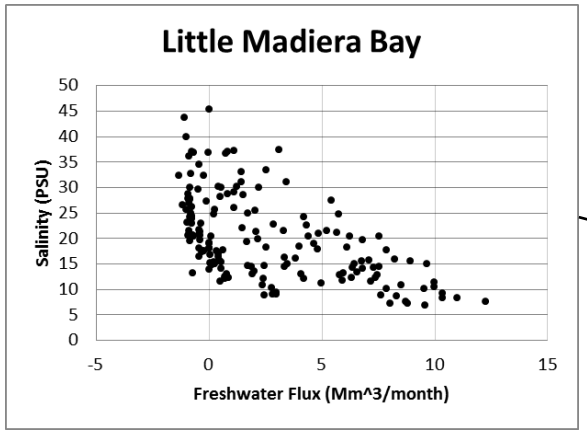
Salinity in coastal basins dependent on

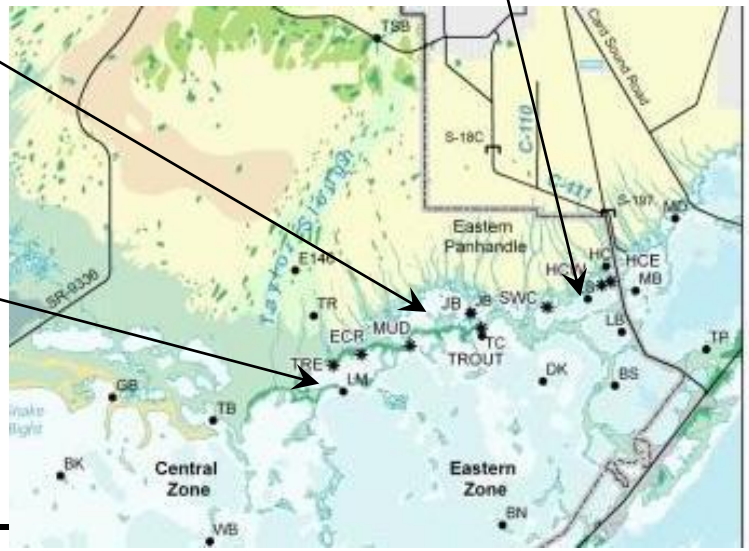
- flow rates and
- mixing
- Evaporation

Simulate trends and review results







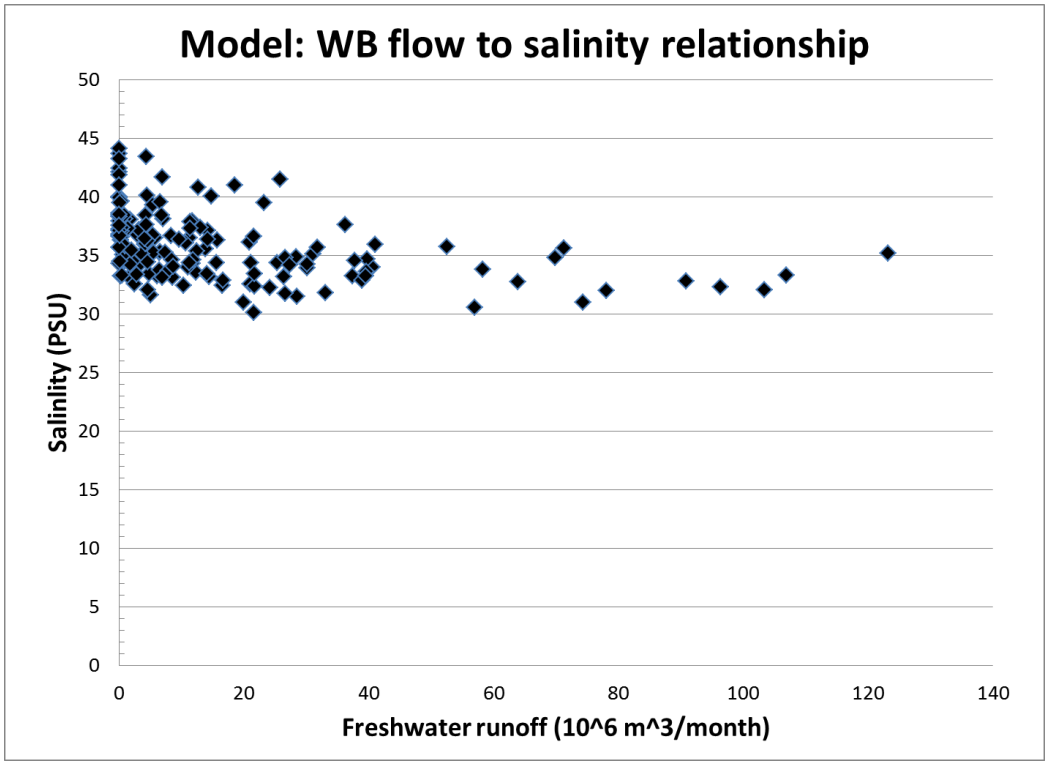


Everglades National Park

South Florida Natural Resources Center

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

Reasonable considering the semi-isolated conditions in the central region of the bay

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