Overview of Salinity Occurrence and Distribution in Biscayne Bay

South Miami-Dade Water Issues Coordination:
Biscayne Bay
November 22, 2010

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Outline

I. Background
   - A. Peer Review (2008)
   - B. Overview Water Budget (2008)

II. Evaluation Objectives (2010)
   - A. Existing Monitoring
   - B. Data Representations

III. Approach (2010)
   - A. Salinity Patterns and Freshwater Signal
   - B. Updated Rainfall Analyses
   - C. Elevated and Hyper-Salinity

IV. Summary

Peer Review October 2008

- Public workshop
- Broad-scale assessment and summary of previous inflow studies:
  - hydrology
  - biological resources
  - Inflow - salinity - resource link needed for rule making
- No salinity-sensitive resource identified on which to base Rule
- Mass balance model and water budget 1965-2000

Lagoonal Systems: Wetland /Tidal Creek Transition Zone

Everglades supports large transition salinity zone between the fresh and marine environment

Highly modified watershed - Compressed transition salinity zone is limited to mangrove fringe and near-shore

Peer Review Comments Existing Salinity Condition

- Establish system patterns, evaluate east to west salinity gradient

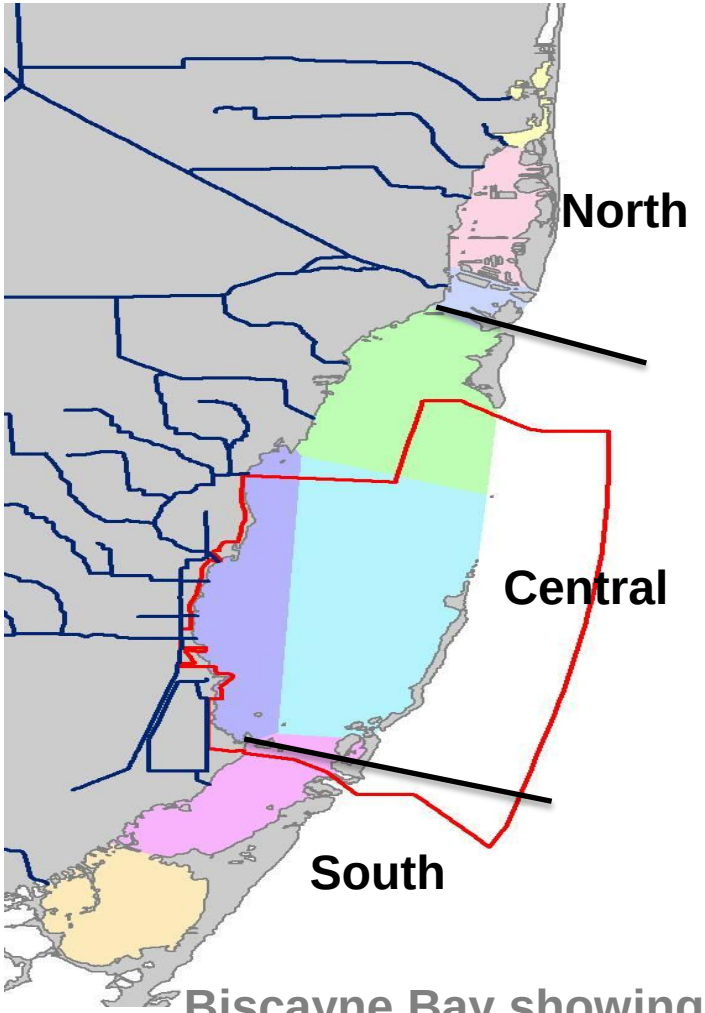
  Mass balance tool limitations - need additional tool or salinity observations

- Hyper-salinity a key concern

  Where, when, or how often does it occur?- salinity observations

Water Budget Tool (2008)

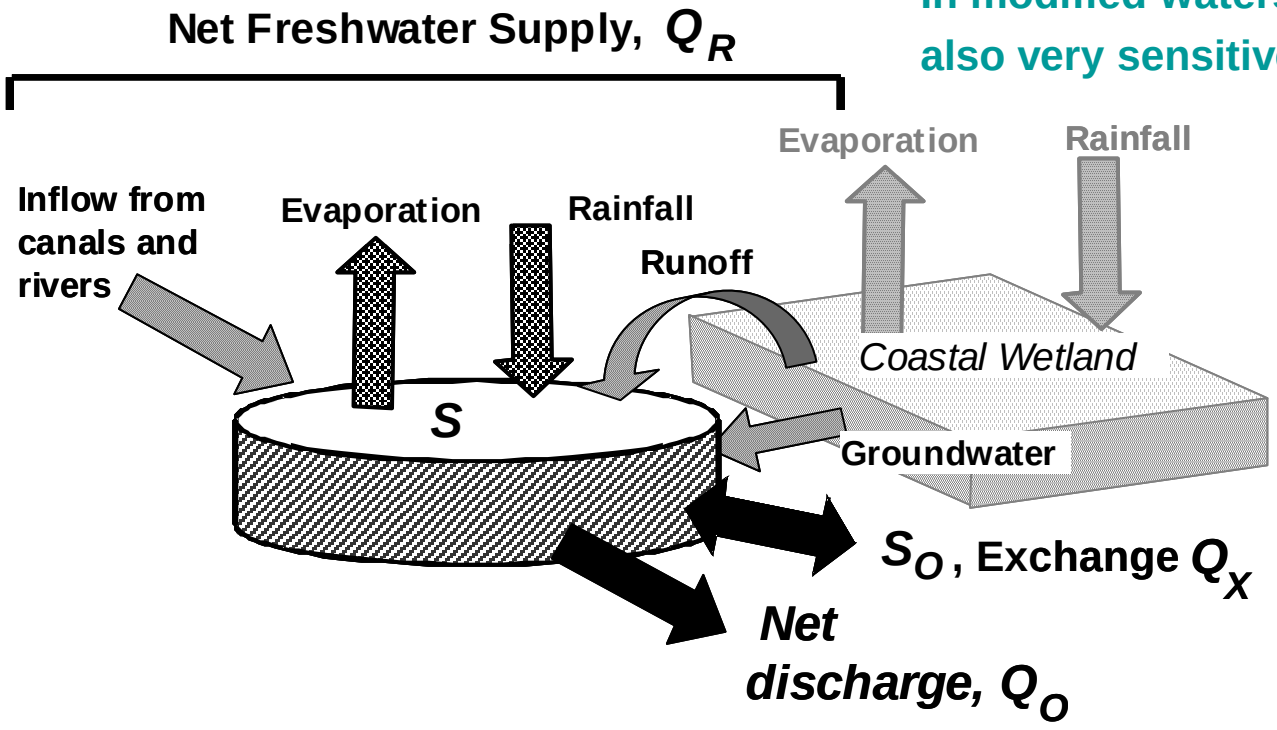
- ECT, Sept. 2008: Bay-wide water budget for 1965-2000
- 8 sub-regions
- Components
  - Evaporation,
  - Rainfall; inflows- canal, overland, groundwater
- Fresh water displacement
- Salinity predictions within each sub-region



Biscayne Bay showing 8 sub-regions

Freshwater Budget Connection to Salinity

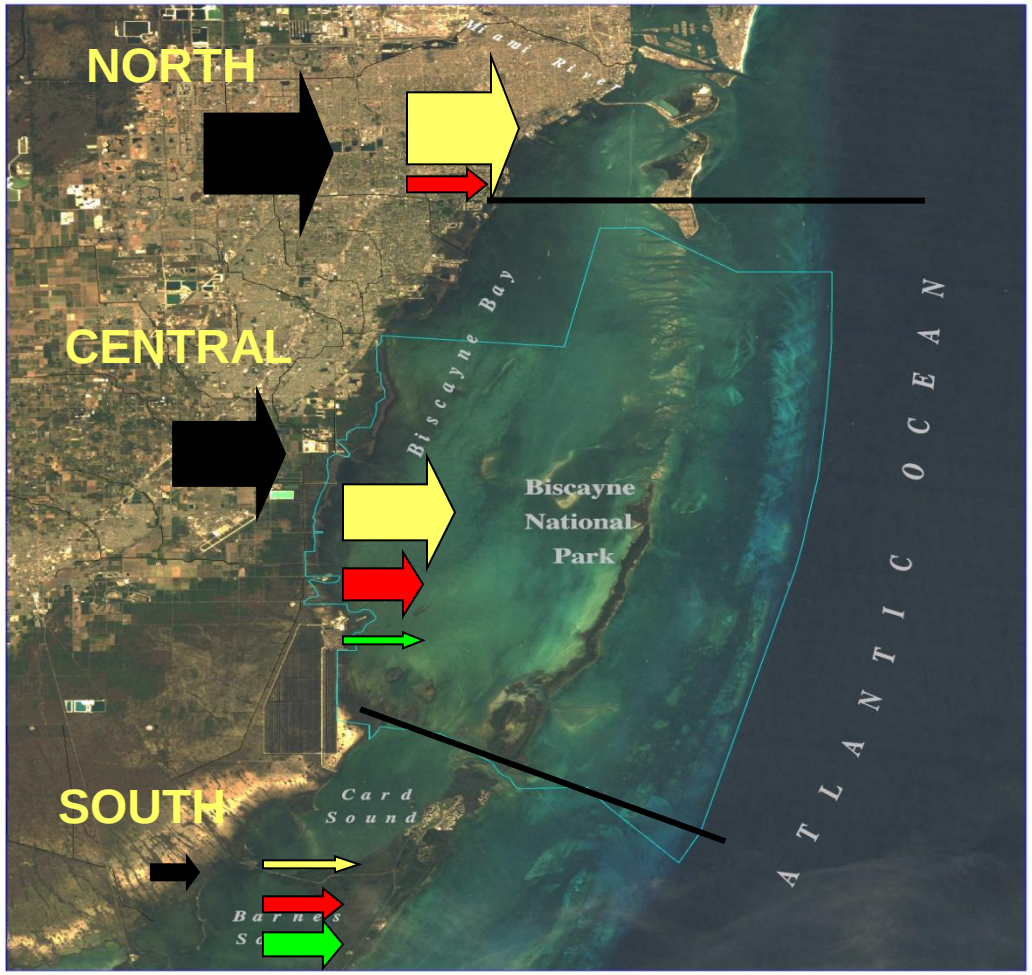
In modified watersheds Inflows also very sensitive to rainfall



Source: ECT, 2008; Marshall, Nuttle, and Cosby

Net Supply of Freshwater = Rainfall - Evaporation + Canal Flow + Un-Gauged Wetland Flow + Ground Water Inflow

Inflow Summary 1965-2000



NORTH
Canal: 567
Groundwater: 32
Overland: NA

CENTRAL
Canal: 413
Groundwater: 107
Overland:15

SOUTH
Canal: 2
Groundwater: 28
Overland: 51

Based on “Average Rainfall ” Year (1965-2000) 1000 acre-ft/year

Additional Feature Freshwater Displacement

- North: 2 months
- Central: 26 months
- South: 60 months

Water Budget Tool Limitations

Identified by Peer Review

- Salinity prediction are underestimated at high salinities
- East-west salinity gradients not well represented using 8 sub-regions

Additional Considerations

- Salinity observations and climate did not include current decade
- Tool has been updated to 10 sub-regions

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Evaluation Objectives 2010

1. Compile bay-wide salinity observations from monitoring observations
2. Address fundamental salinity-related questions

Primary Questions

- System patterns observed?
- Hyper-salinity occurrences?

Secondary Questions

- How often? Where? When?

Existing Monitoring Programs

- **Monthly Grab Sampling:**
  Bay-wide, since 1979

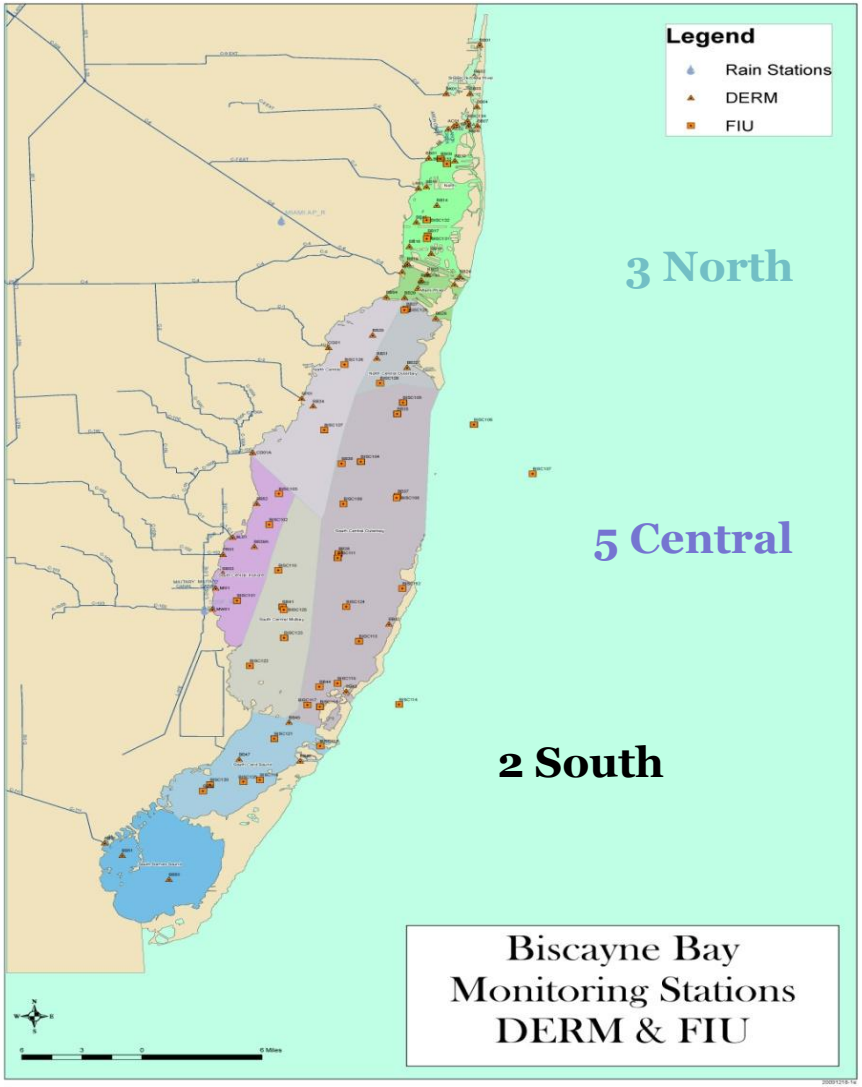
- **Continuous Sampling:**
  Concentrated in Central and South Regions; some co-located with monthly sites, since 2004

Existing Monitoring Evaluation Considerations

- Multiple programs / objectives
- Different data collection and reporting protocols
- Stations have records over different time spans
- Station modifications & location changes
- Non-uniform spatial representation
- Incomplete database entry
- Incomplete QA/QC

Data Representations

- Water year (May 1 - April 30)
- Data Summaries used updated 10 sub-regions
- Monthly Data Record 1988-2009: most consistent record available, 75 stations
- Continuous Data Record 2004-2008: available record, 35 stations



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Approach: Overview of Data Evaluation

- Broad-scale analyses
- High level summaries
- Based on observations for whole system
- Summarize bay-wide patterns and salinity conditions over period of monitoring record and within sub regions
- Build upon Bay-wide water budget information from 2008 effort

Approach: Outline of Steps

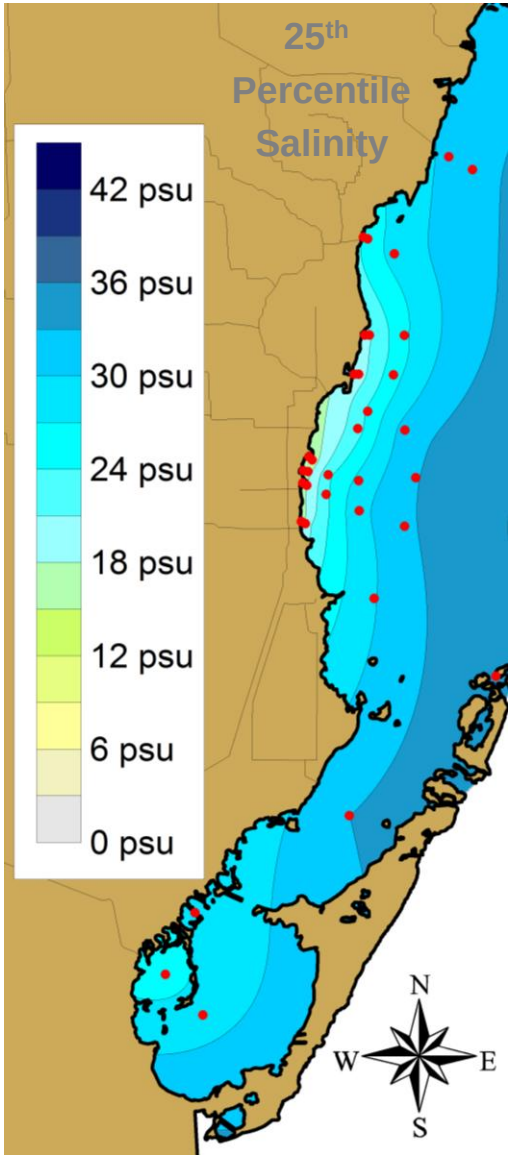
1) Create database for salinity using monitoring data
   a) QA/QC
   b) Queries/ tables for export to other software
2) Spatial representation – GIS mapping
3) Statistical analyses
4) Compile and create graphical summaries
5) Hydrologic information - supplemented existing water budget information to extend rainfall information consistent with period of salinity observation

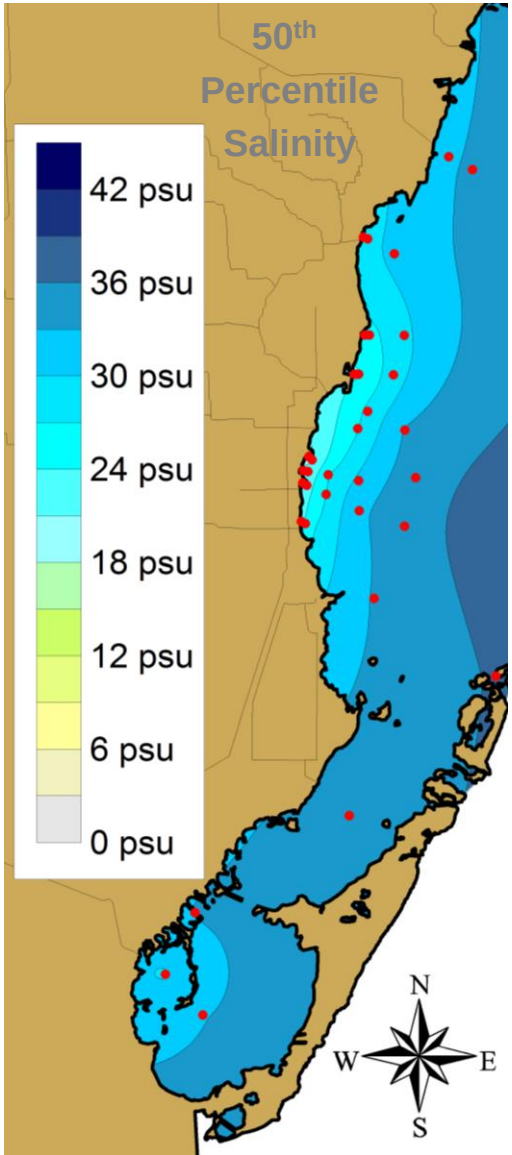
Bay-Wide Salinity Patterns: Summary Contour Maps

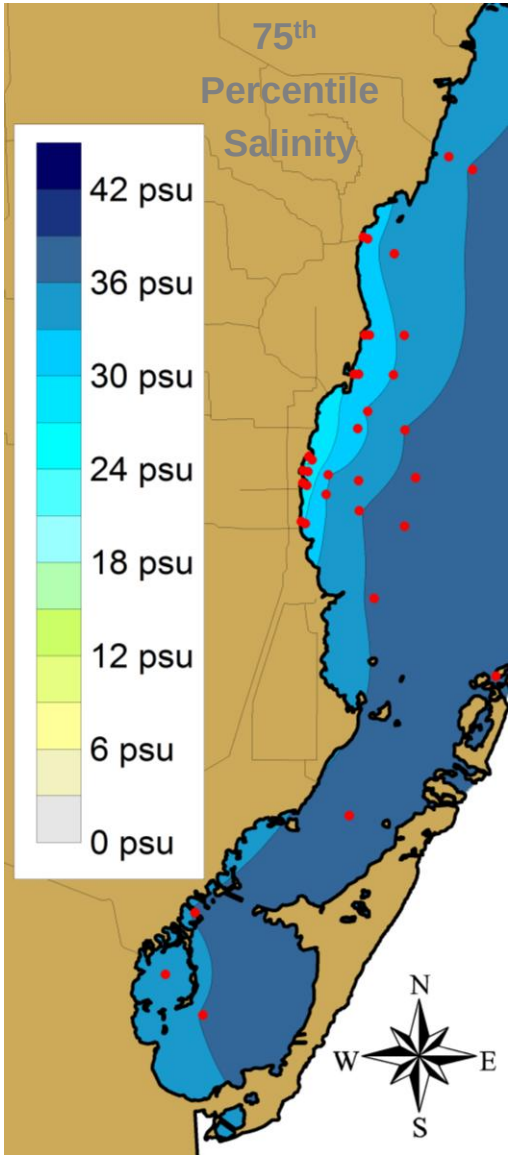
- East-west salinity gradient in all regions; both monthly and continuous data
- Regional Patterns
  - Small areas of lower to intermediate salinity conditions in near-shore central and north regions
  - All regions areas with salinities < less marine

Salinity Contours (Water Years 2004 - 2008)

Continuous Monitoring

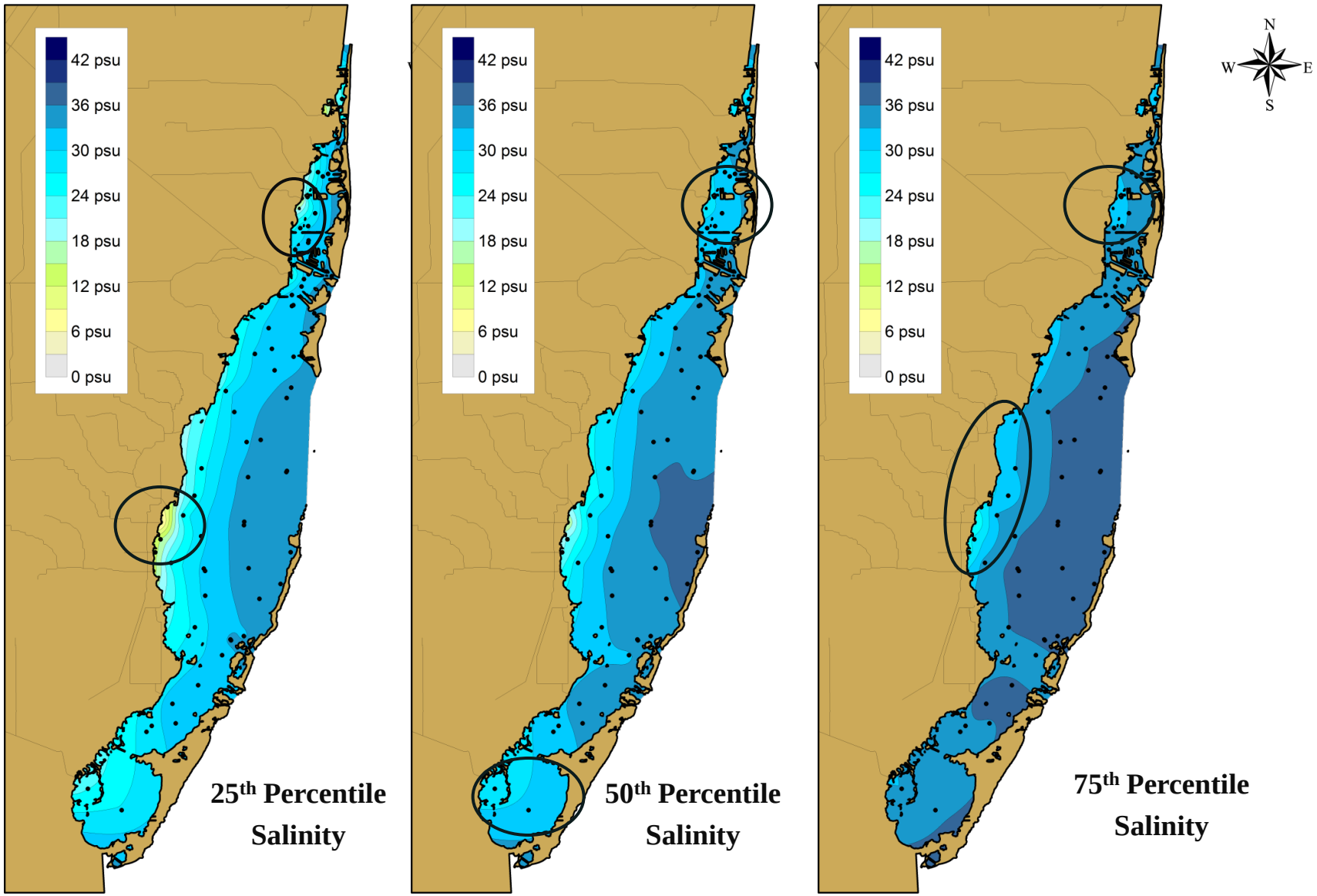






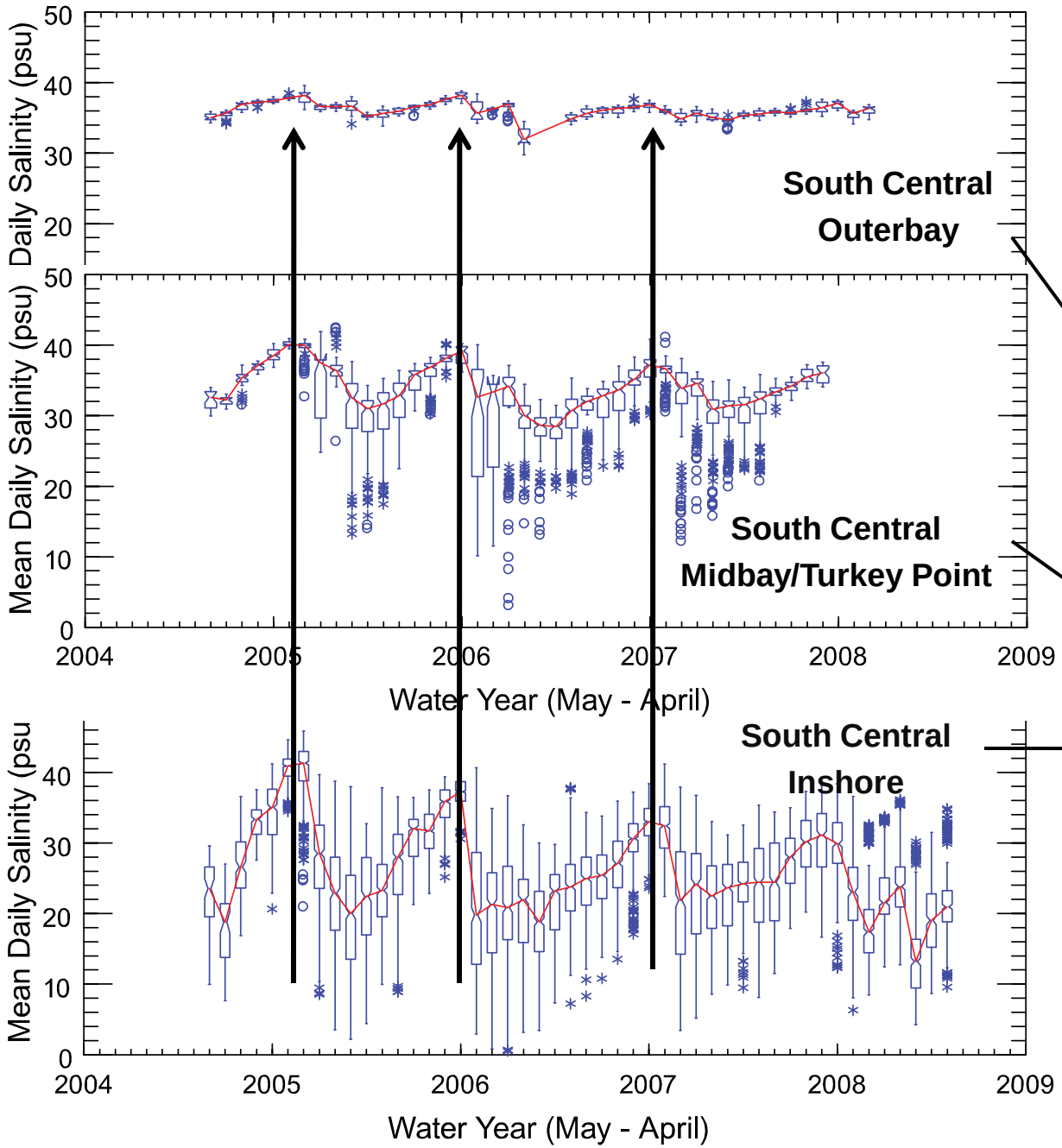
Salinity Contours (Water Years 1988 - 2009)

Monthly Monitoring



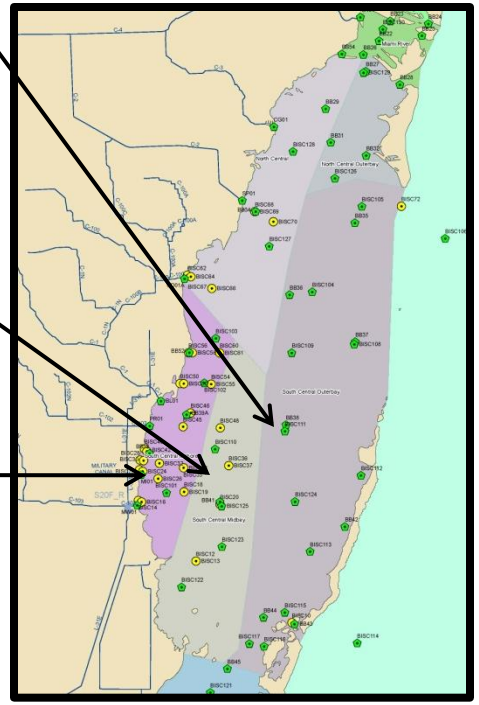
Bay-Wide Salinity Patterns: Salinity Contour Maps (cont.)

- Shows importance of bay-wide assessment and the influence of freshwater inflow
- Small areas within near-shore central and south have lower salinity relative to other parts of Bay
  - Ecological implications
- At the 50 percentile most of the south and north regions are less than marine
- Region differences attributed to combination of
  - Distribution and quantity of inflow
  - Freshwater displacement



Inflow Signal:

Near-shore to Outer Sub-Region



Continuous Data

Seasonal Salinity Pattern

- Continuous data shows salinity increase and decrease consistent with seasonal (wet and dry) inflow from near shore sub-region to outermost sub-region
  - Seasonal freshwater inflow signal from east to west

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Rainfall Analyses: Importance

- Integral component of water budget
  - Direct input
  - Reflected in the inflow response of watershed inputs
  - Modified system with rapid inflow responses from watershed - salinity is sensitive rainfall variability and seasonal variation

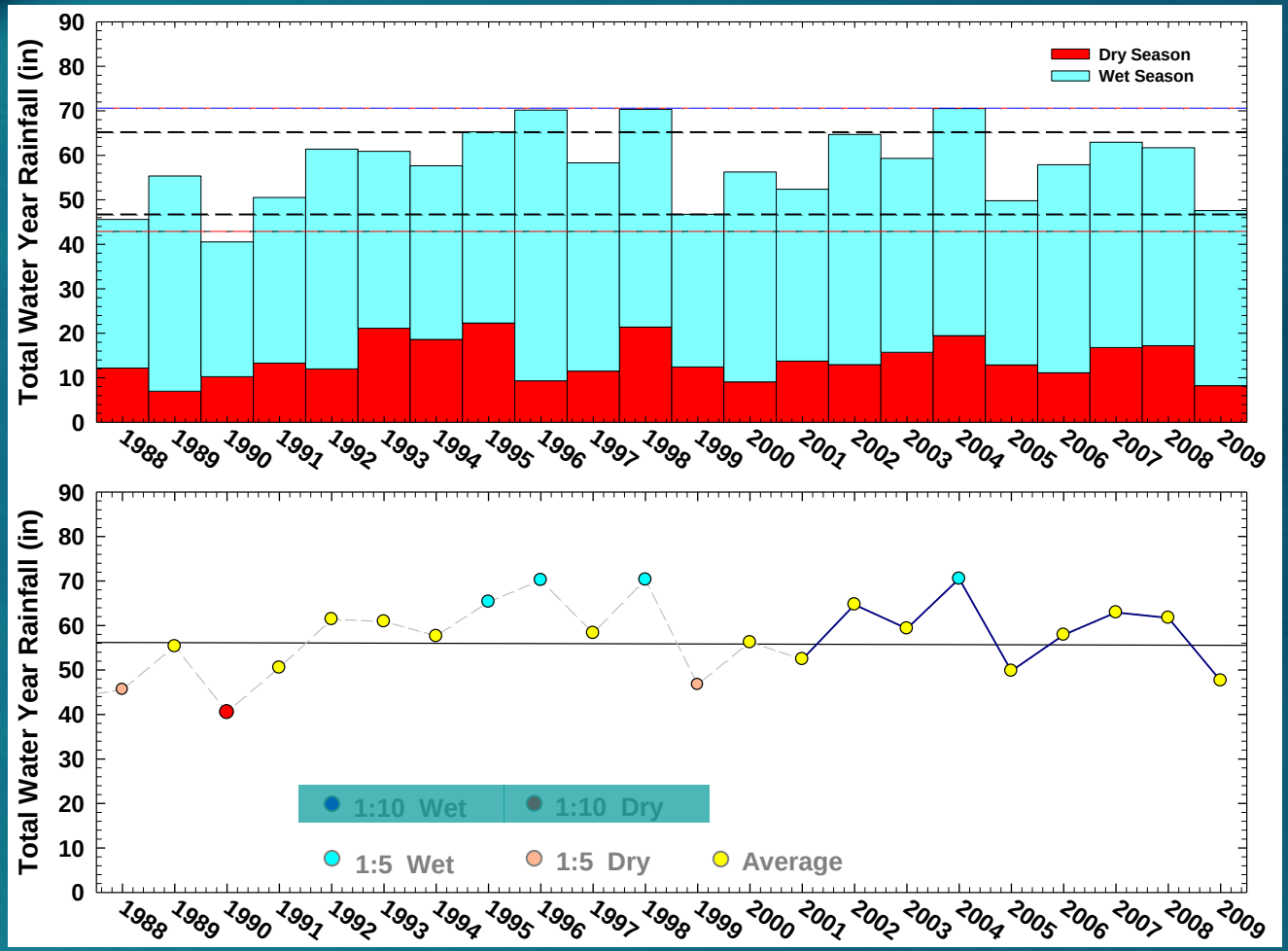
Rainfall Analyses: Objectives

- Evaluate local patterns
  - Long-term annual climatic variations
  - Seasonal variation
  - Establish classifications in years of salinity observations
    - dry
    - average
    - wet

Rainfall Analyses: Approach

- Water Year representations
- Extend rainfall data
  - Encompass monitoring period to present (existing water budget 1965 - 2000)
  - Utilize long observation record (allows better classifications for period of interest)
- Construct rainfall time series spanning 1914 - present
- Classify Years: Average, Dry, Wet

Annual Rainfall 1988 - 2009

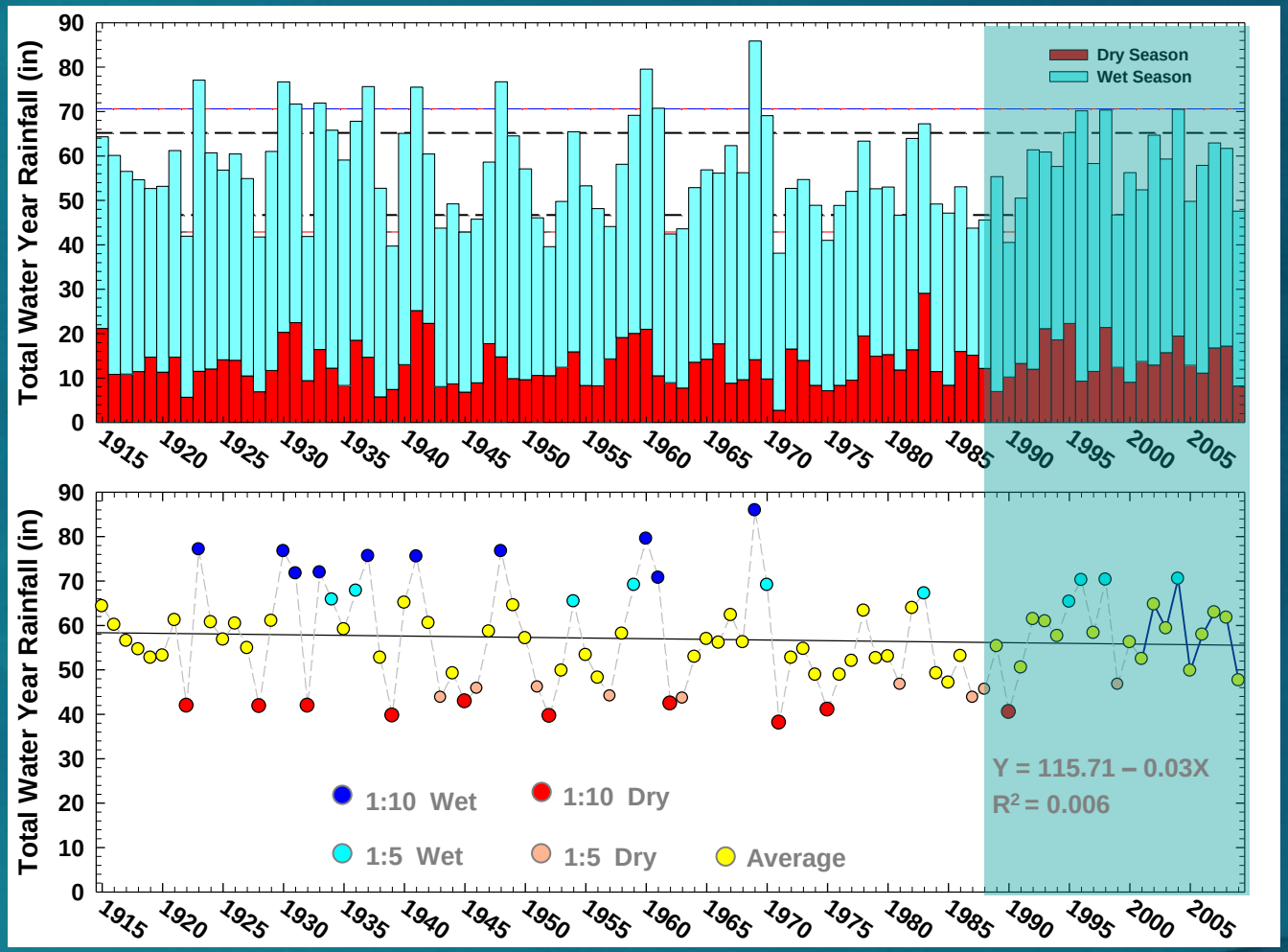


Inter-annual and seasonal variability

Average Range 48”- 66” /year

56” Mean

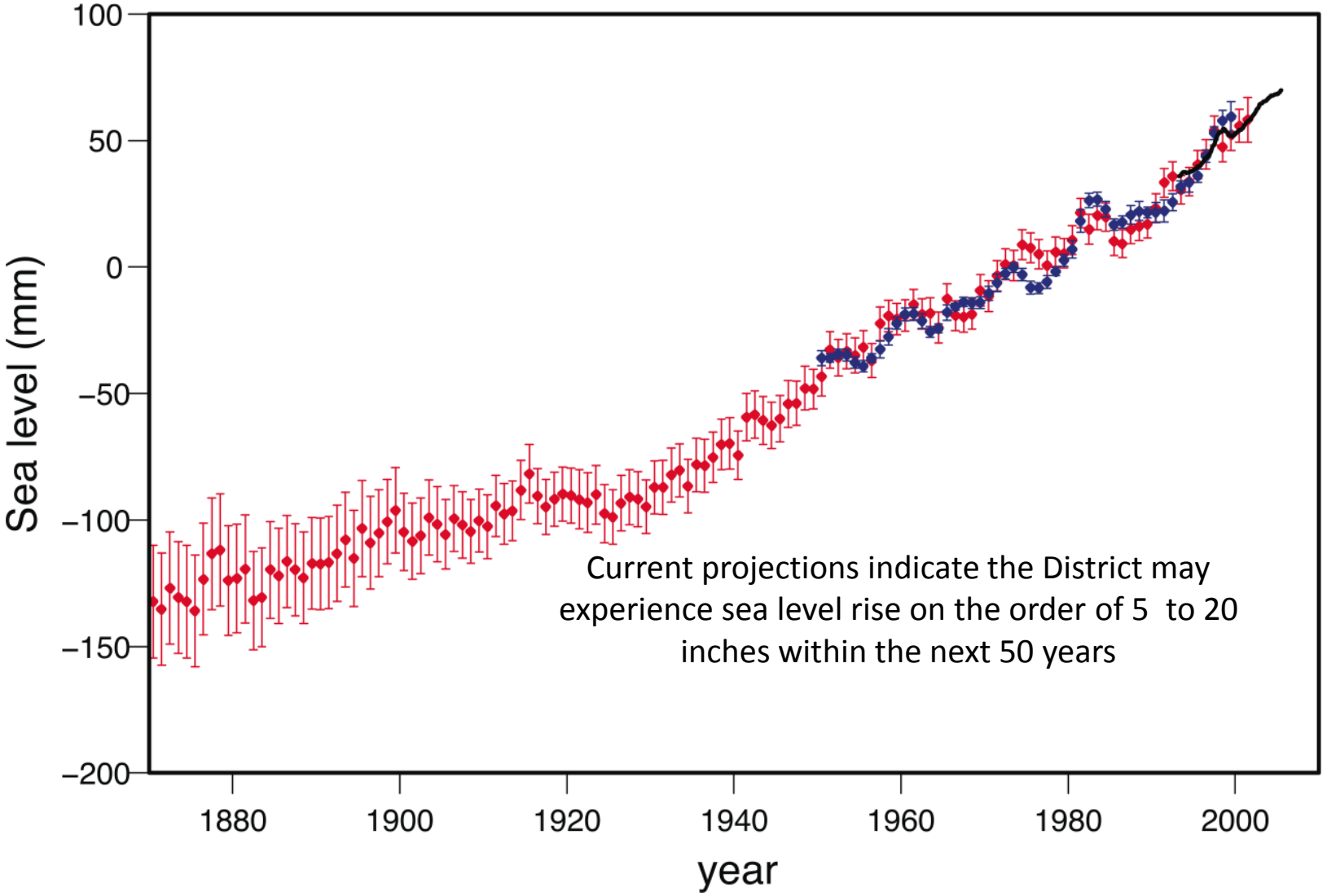
Annual Rainfall Water Years 1914 – 2009



1988-2009

Moderate variability 1 drought, no extreme wet

Sea Level Rise



from SFWMD, 2009, Climate Change and Water Management in South Florida

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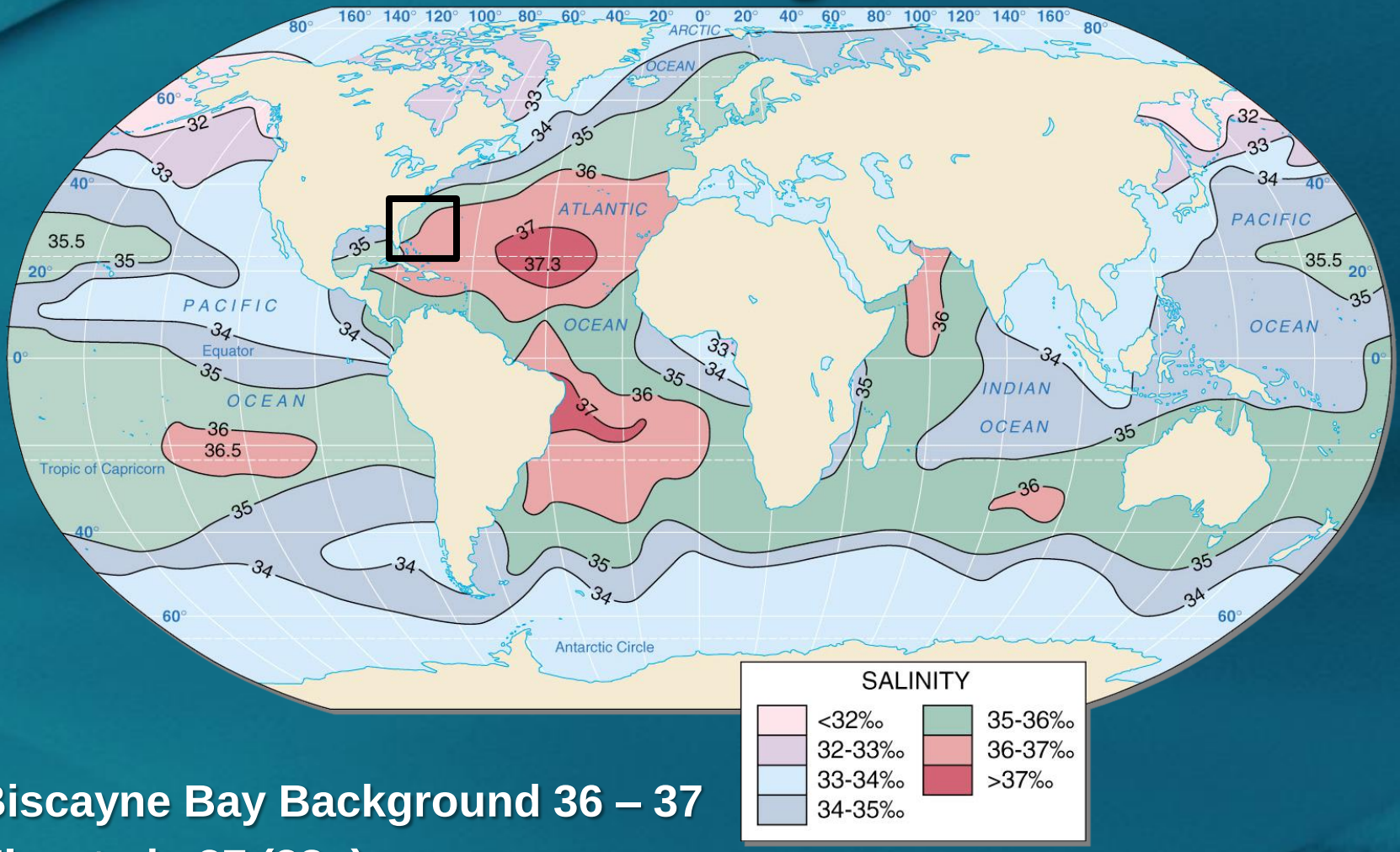
Elevated and Hyper-Salinity

- Working Definitions
- General Occurrences
- Concerns

Global Salinity Patterns



Biscayne Bay Background 36 – 37

Elevated >37 (38+)

Hyper-Salinity >39 (40+)

Source: Scientific American

Hyper-Salinity Occurrences

Evaporation > Rainfall + Inflows

- When near this balance small changes in flow can have large impact on salinity conditions
- Not common
  - Enclosed shallow lagoons
  - Primarily associated with Mediterranean climates (cool wet season, hot dry season)
  - Florida Bay; Texas; Baja; Africa; Australia

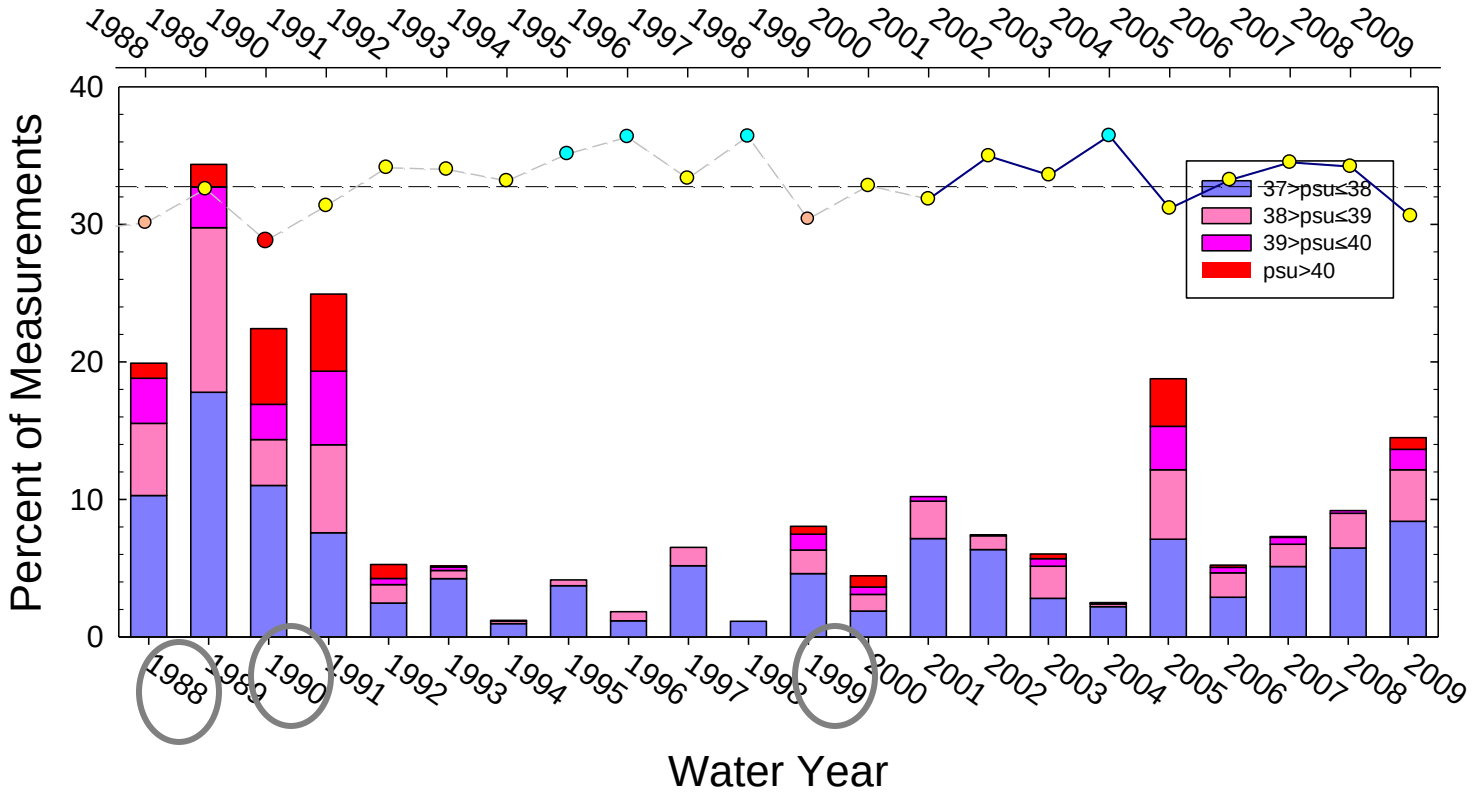
Hyper-Salinity
What Are The Concerns?

1. Resources under stress, sub-lethal impacts
2. Impacts of other stressors magnified
3. Low diversity of species

Creates instability

environment at risk for a sudden, rapid regime shift taking a decade or more to re-stabilize

Elevated & Hyper-Salinity Bay-Wide Annual Occurrences

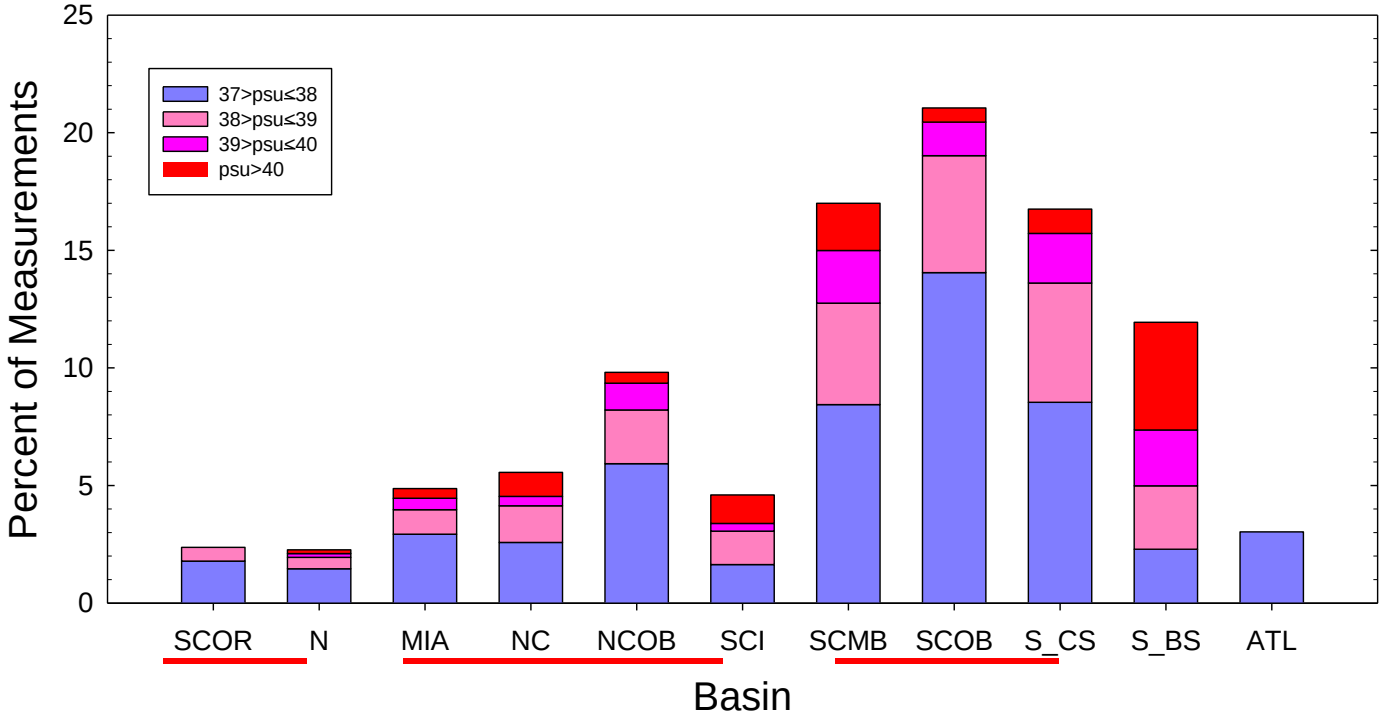


Based on monthly monitoring data

Average range rainfall range in most years

Note effect of falling just below mean rainfall

Elevated Salinity Patterns: Sub Regions 1988-2009



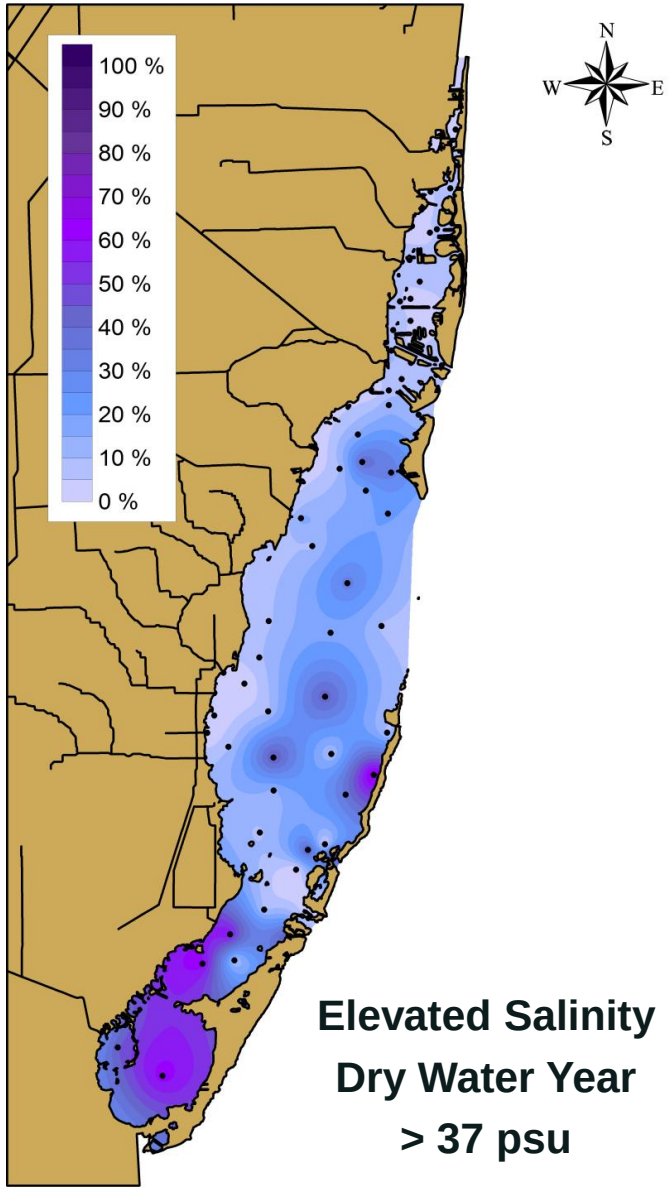
Hyper-salinity in all regions increasing from North to South

Elevated and Hyper-Salinity Bay-Wide Annual Patterns

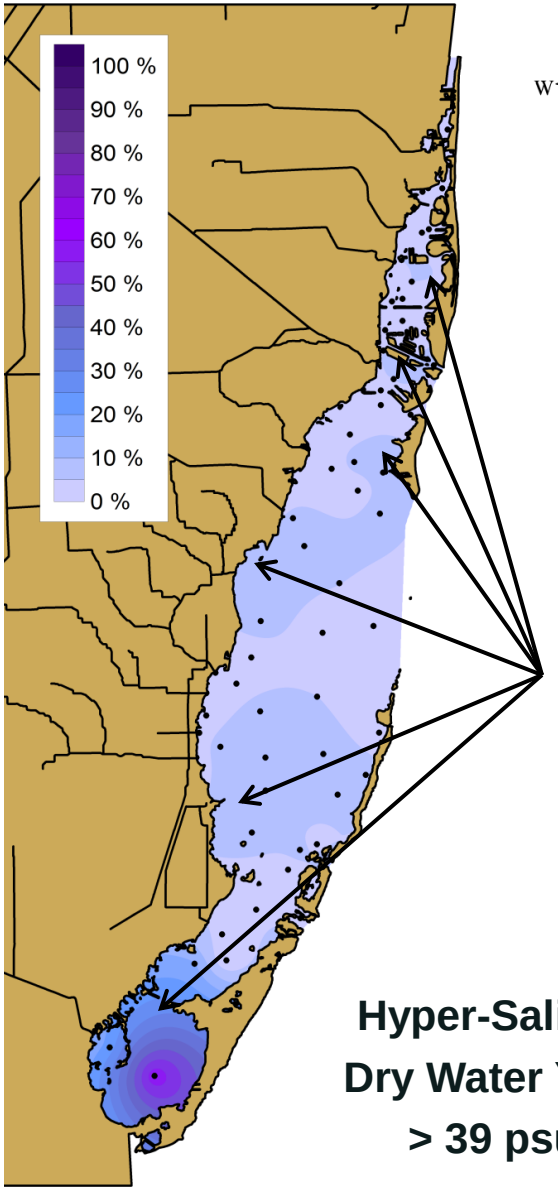
- Occurrence sensitive to rainfall
  - Dry years
  - Slightly below average years see increase.
  - Timing of wet season onset (2005)
- Elevated salinities observed in all sub-regions
- General sub-region groupings of elevated and hyper-salinity

Elevated and Hyper-Salinity: Probability Contour Maps

- Dry years: Monthly
- Average years: Monthly and Continuous Monitoring
- Wet years



Elevated Salinity
Dry Water Year
> 37 psu

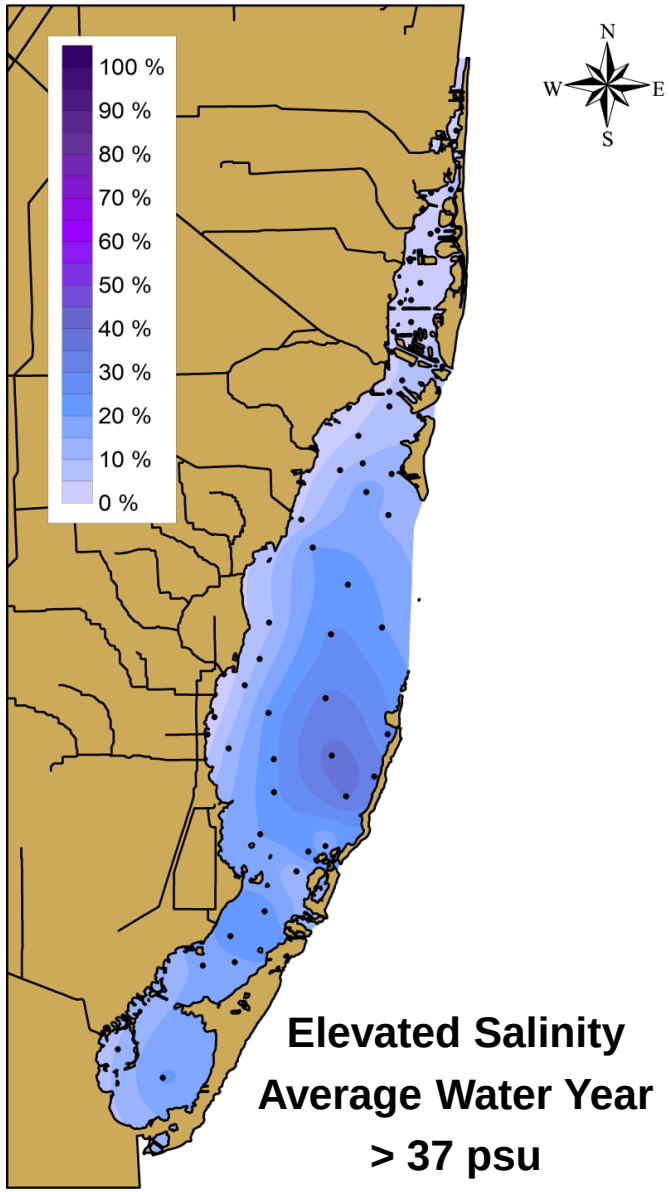


Hyper-Salinity
Dry Water Year
> 39 psu

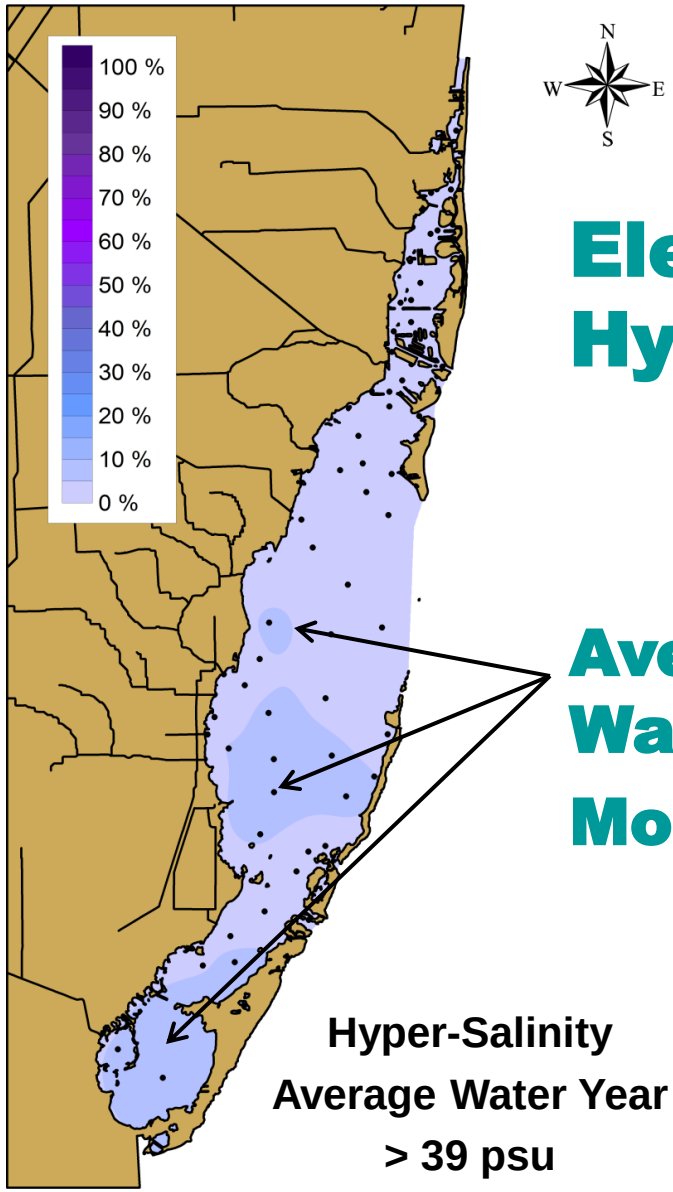
Elevated and Hyper-Salinity:

Dry Water Years 1988,1990,1999

Monthly Data



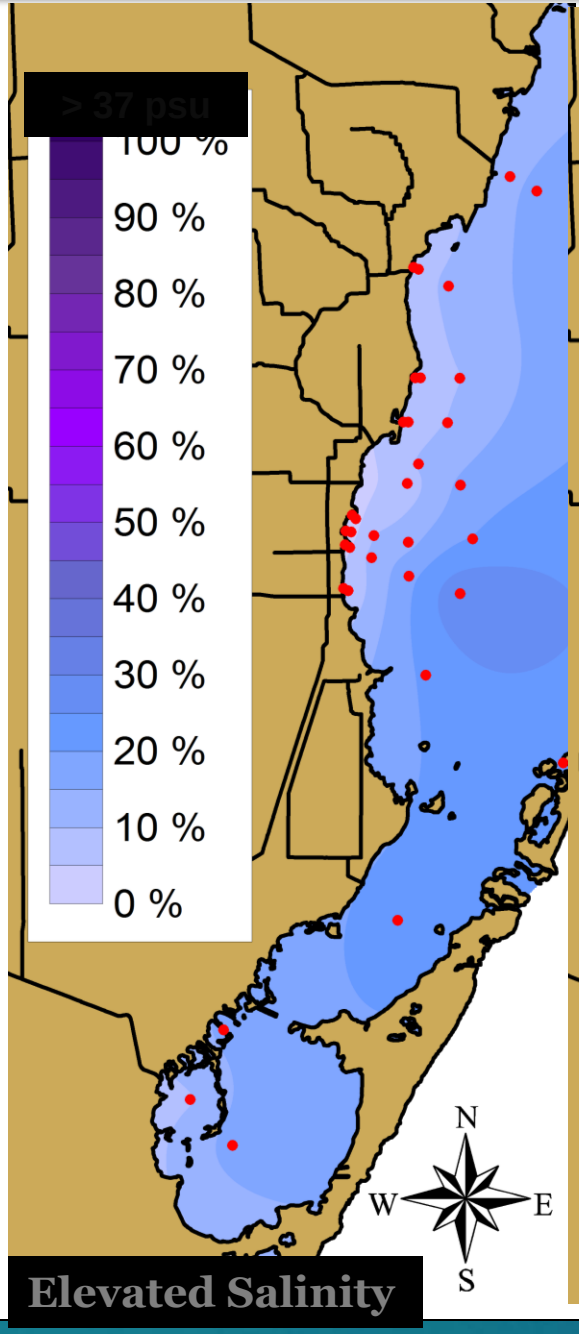
Elevated Salinity
Average Water Year
> 37 psu

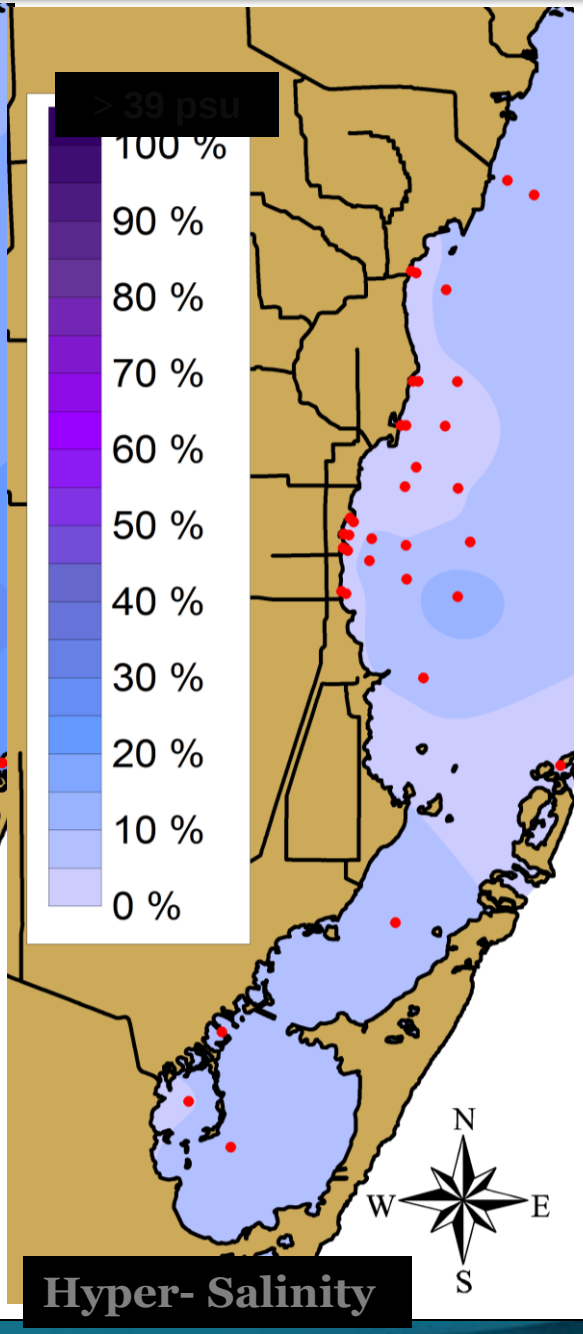


Hyper-Salinity
Average Water Year
> 39 psu

Elevated and Hyper-Salinity:

Average Rainfall Water Year Monthly Data





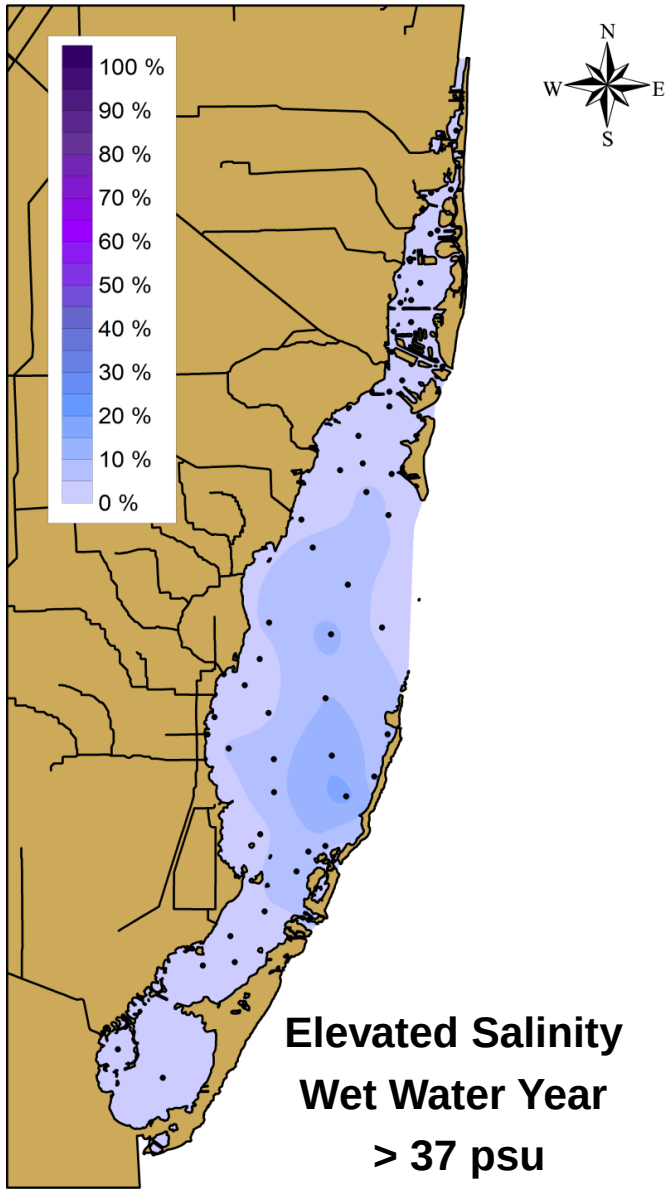
Elevated and Hyper-Salinity

Continuous Data

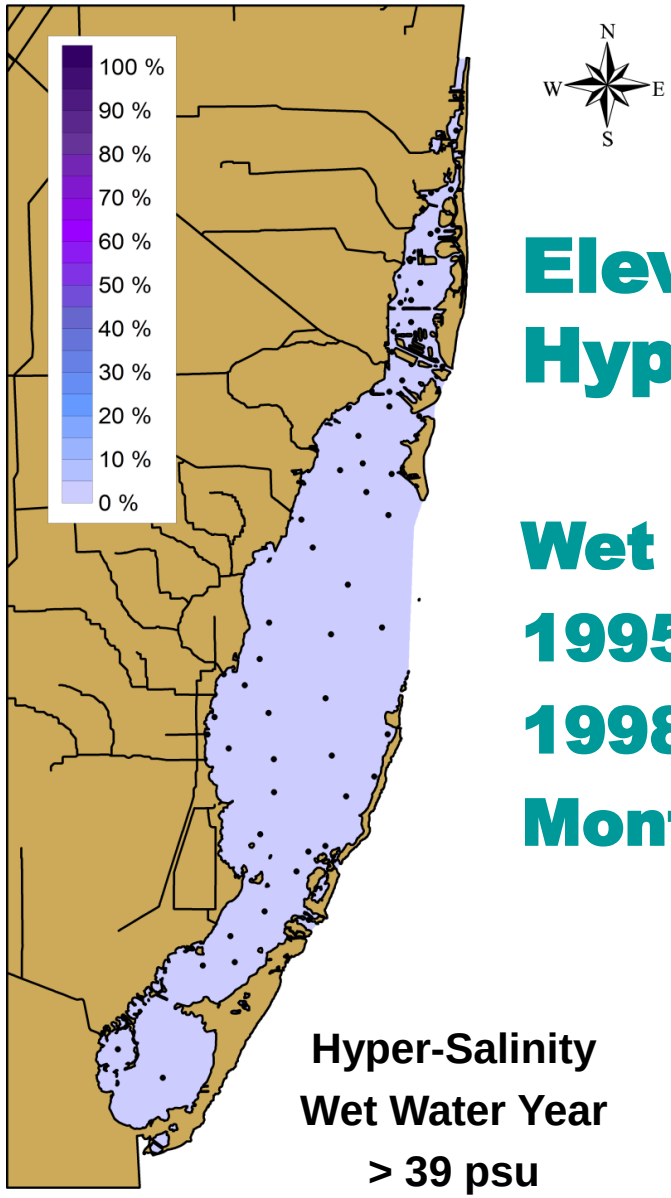
2004 - 2008

Average Rainfall Years (slightly above)

- Different station distribution
- Limited number of years



Elevated Salinity
Wet Water Year
> 37 psu



Hyper-Salinity
Wet Water Year
> 39 psu

Elevated and Hyper-Salinity:

Wet Water Years 1995,1996, 1998, 2004 Monthly Data

Elevated and Hyper-Salinity: Probability Contour Maps

- All Regions - dry and average years
- Dry years - highest probability in South
- Average years
  - Highest elevated salinity in Central mid and outer regions
  - Same probability in South and parts of Central
- Wet years – elevated only in Central
- Hyper-salinity concentrated in areas consistent with occurrence of elevated salinity

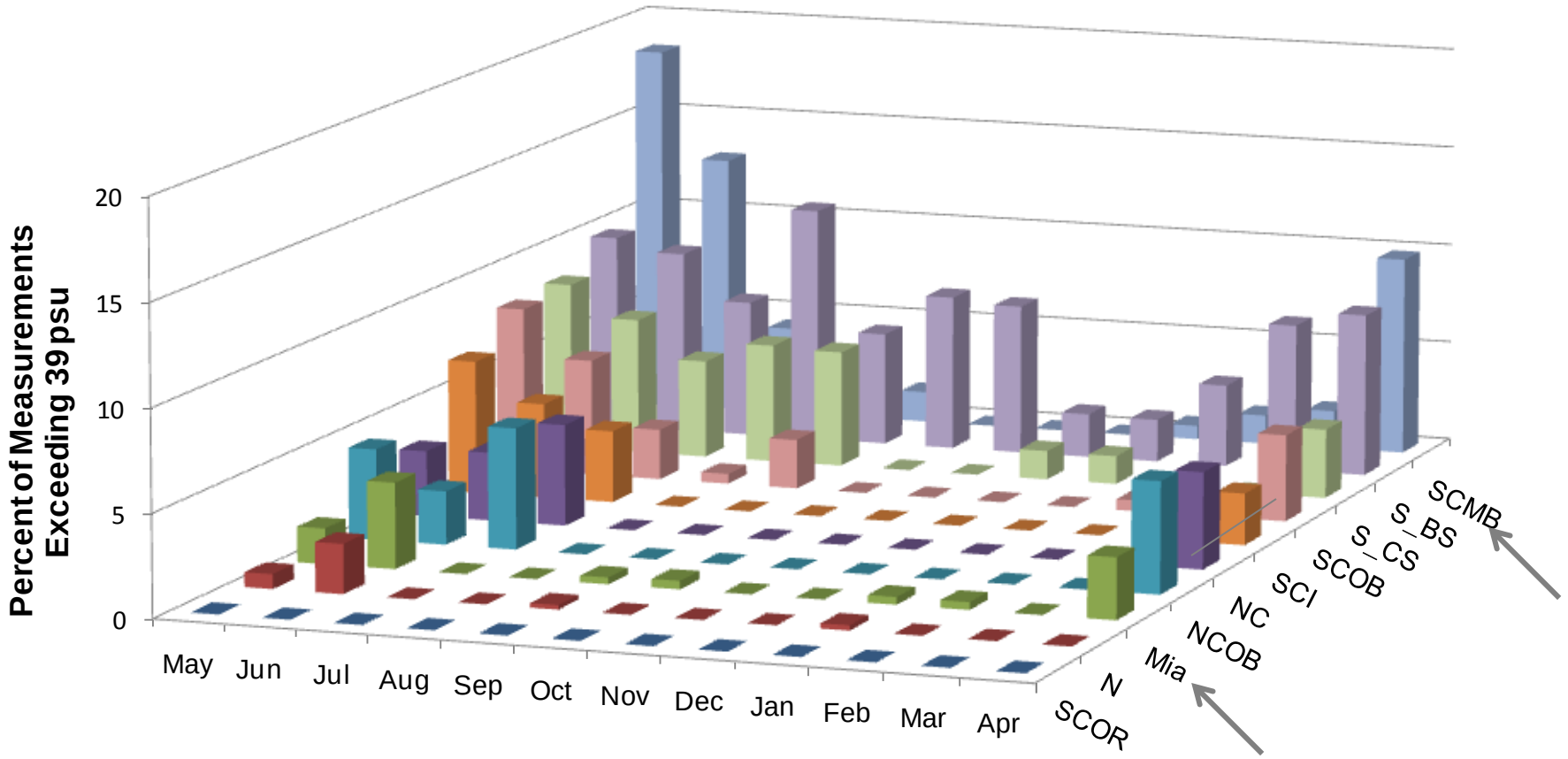
When Does Hyper-Salinity Occur?

3-D Plots showing % occurrences for each month

- Hyper-salinity
- Elevated salinity

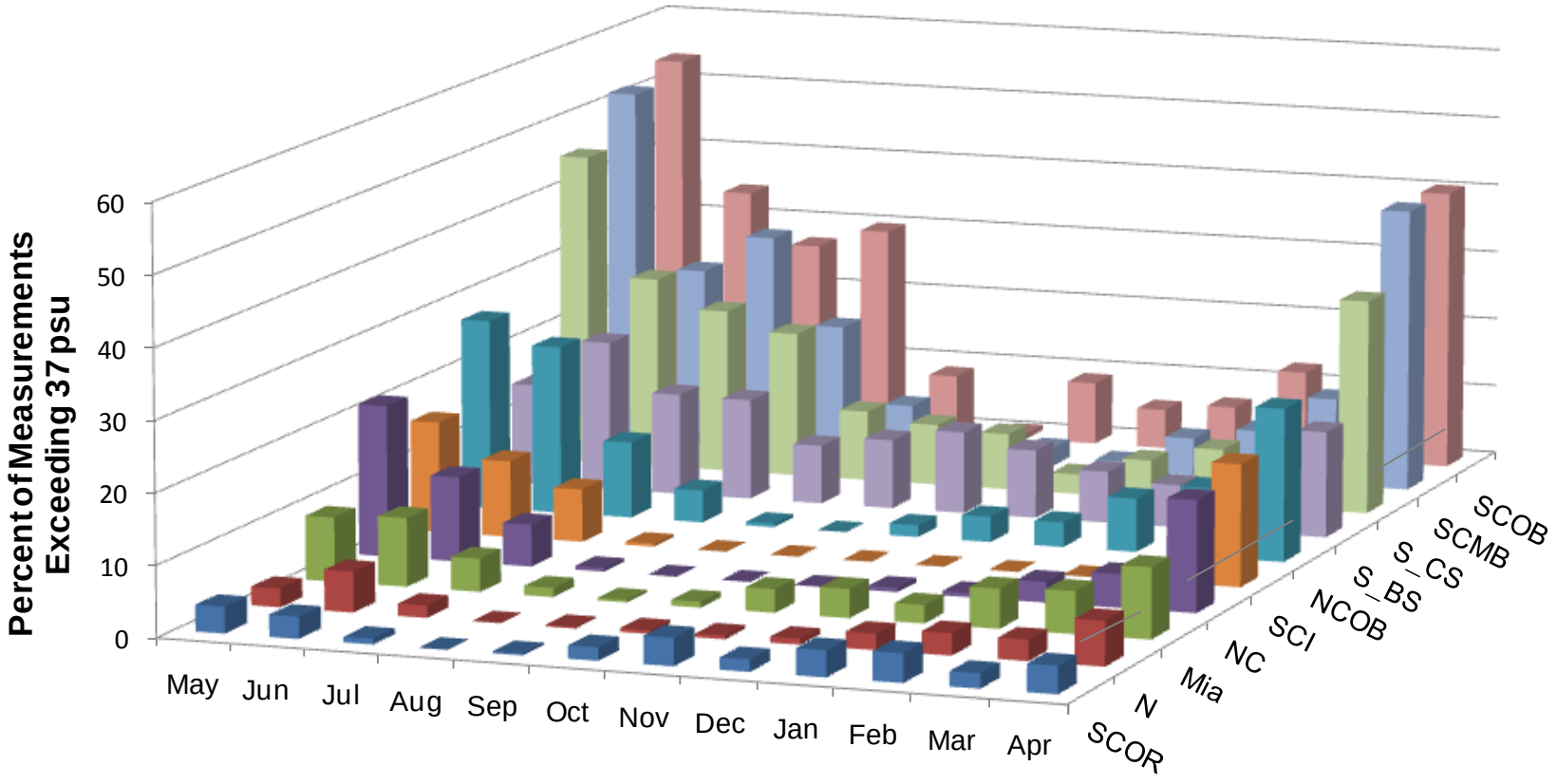
Overall April, May, June have highest %, but can occur in all months in some basins

Regions and Months: Hyper-Salinity



Regions and Months: Elevated Salinity Conditions

Scale different than hyper-salinity graph



When Does Hyper-Salinity Occur?

Months of occurrences

- North - lowest incidences of hyper-salinity & elevated salinities can occur throughout the year
- Central (North) - April through July; May highest
- Central (South) - April through September: May highest; elevated throughout wet season mid-bay/Turkey Point and Card Sound
- South - throughout the year in Barnes Sound

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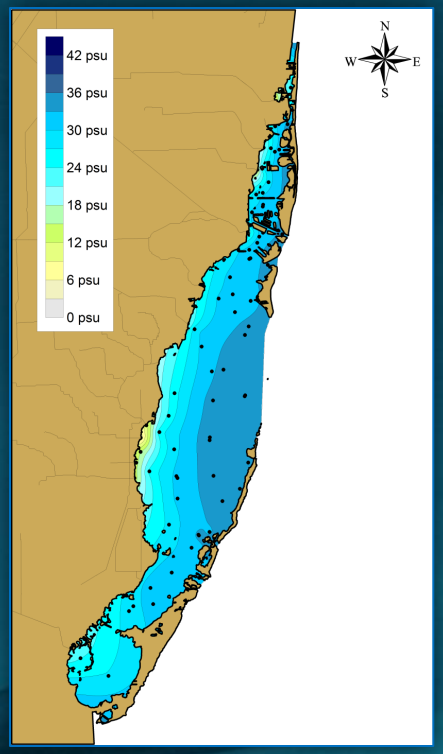
Summary Objectives and Approach

- ☑ **Assess potential use of salinity as indicator using observations**
  - Existing conditions

- ☑ **Evaluations are based on a whole system approach:**
  - Salinity patterns
  - Extent of elevated and hyper-salinity occurrences
  - Updated rainfall conditions

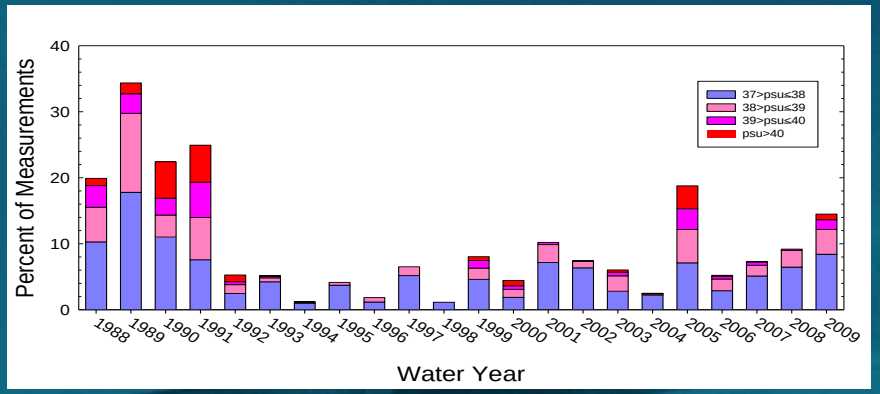
Summary
Bay-Wide Salinity Patterns

- **East-west gradient: all regions**
  - Regions have different gradients, influenced by inflow quantity and fresh water displacement
- **Influence of freshwater inflow**
  - Lowest salinity areas in North and Central Regions
  - Seasonal freshwater inflow signal east to west



Summary: Occurrence Elevated and Hyper-Salinities

- ☑ Elevated salinity throughout the Bay
- ☑ Hyper-salinity throughout the Bay
  - Most late dry season
  - Throughout the year in some areas
  - Average rainfall years
  - Near-shore areas
  - Increase from North to South



Summary: Rainfall

- **Limited extreme conditions in last 22 years**
- **Water budget is important**
  - Small change in inflow can impact budget (resulting in elevated or hyper- salinity)
  - Sensitivity to slightly below average rainfall

Conclusions

- ☑ Salinity Observations
  - Establish existing conditions
  - Establish performance measures or to meet rule development criteria (MFL, reservations)
- ☑ Bay-Wide Assessment
  - Indicates two areas in central and north with lowest salinities
  - Indicates all regions are prone to elevated and hyper-salinity
- ☑ Salinity conditions
  - Sensitive to small differences in rainfall (freshwater)

Next Steps for Inflow Analyses

Some additional assessment would be needed to proceed with rule development (MFL or Water Reservation) or establish restoration performance measures

- Some further QA/QC needed salinity data
- Evaluate the average range (48”- 66”/year) in context of inflow quantities
- Expand seasonal analyses
- Examine inflow data 1988 - 2009

Next Steps for Inflow Analyses cont.

- Expand the years of water budget information
- Use water budget to calculate quantities of water needed for specific salinity conditions (e.g., as required by specific Rule or needed for performance measures)
- Consideration of other factors (sea level rise)
- Link salinity condition to biological resources
  - ✓ Hyper-salinity
  - Inflow signal
  - Estuarine conditions

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Questions?

Overview of Salinity Occurrence and Distribution in Biscayne Bay

Melody Hunt
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