

An aerial photograph of Florida Bay, showing a complex network of waterways and green islands. The water is a deep blue, and the islands are lush green. The title text is overlaid in red at the top, and the authors' names and affiliations are overlaid in white at the bottom left.

Advection and Exchange in Florida Bay Inferred from Long-term Water Quality Data

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Florida International University, Miami, FL

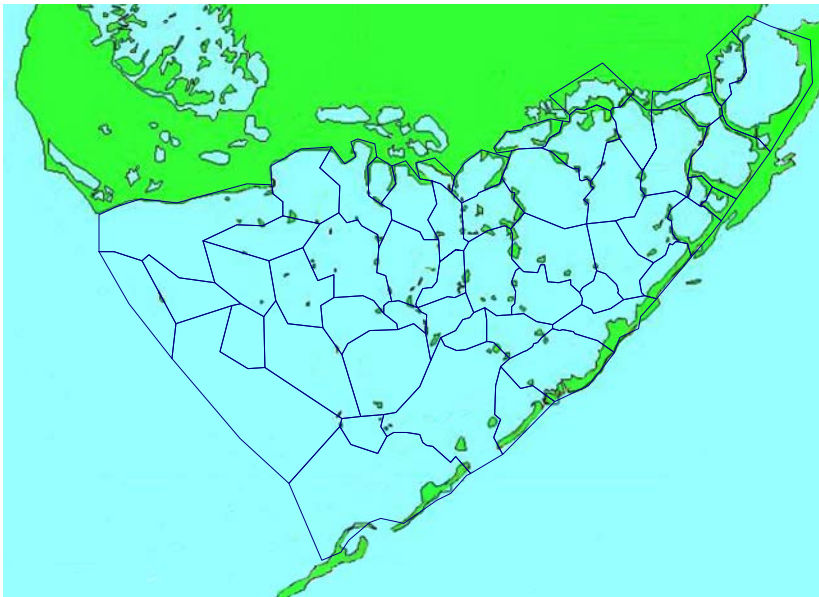
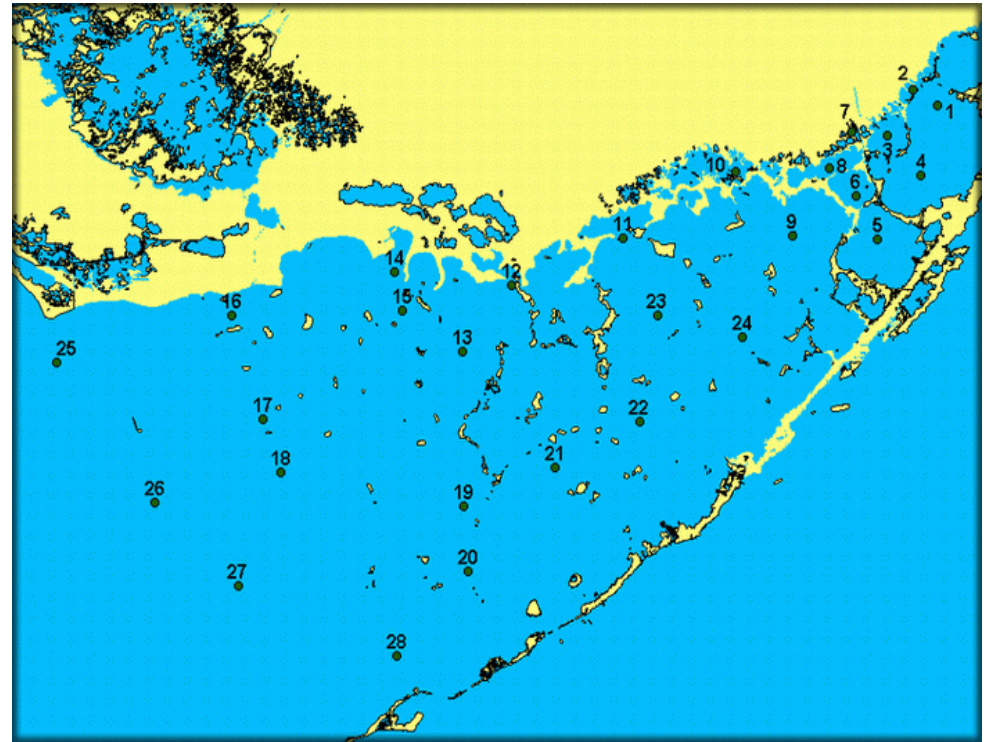
University of Virginia, Charlottesville, VA

Cetacean Logic Foundation, New Smyrna Beach, FL

Eco-hydrology, Ottawa, ON

Outline

- ⌘ Water Quality data from surface samples (25 cm) at SERC stations (28 and 24 sites) March 1991 to December 2007.
- ⌘ NO₃, NO₂, NH₄, TN, TON, TP, SRP, CHL_a, TOC, Salinity, Temperature, DO and Turbidity.
- ⌘ Factor Analysis on all data - identify Principle Components.
- ⌘ Cluster Analyses on PC scores - identify Similar Stations.



1. Analysis of spatial and temporal patterns of WQ parameters within and across clusters - inferences about WQ dynamics of identified regions of Florida Bay.
2. Use physical data (Bathymetry and Water Budgets) and a mass-balance model (FATHOM) to examine the dynamic characteristics of the identified regions - volume, cross-section exchange, water budgets, Turnover time estimates

Factor Analysis 1 - 28 stations

- NO3, NO2, NH4, TN, TON, TP, SRP, CHLa, TOC, Salinity, Temp, DO & Turbidity.
- Factor analysis with Varimax rotation.
- Six factor accounting for 79% of variance.
- PC scores for each station were retained.

PC1 - TN, TON, TOC

PC2 - NO3, NO2, NH4

PC3 - Chl-a, TP, Turb

PC4 - Temp, DO

PC5 - SRP

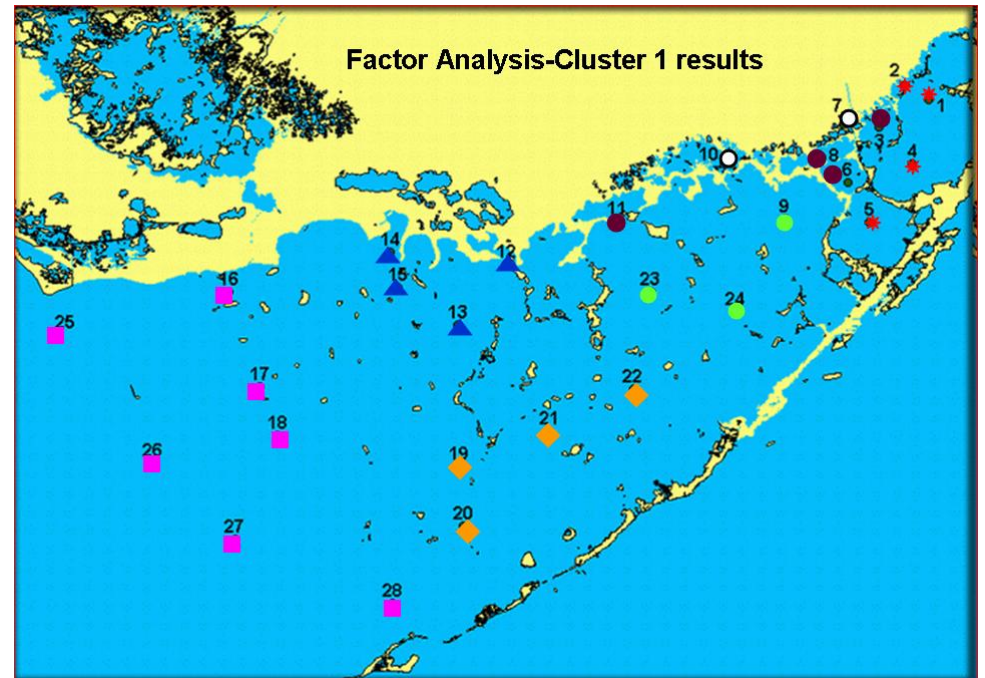
PC6 - Salinity

Oblique Solution Reference Structure

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
NO3	-.131	.550	.031	.080	.012	-.476
NO2	-.035	.836	3.812E-4	-2.358E-5	-.015	-1.438E-4
NH4	.178	.775	-.106	-.009	.021	.158
TN	.863	.192	-.021	.017	-.024	.053
TON	.878	-.037	.004	.017	-.032	.036
TP	.065	-.096	.735	-.042	.136	.080
SRP	4.307E-4	.009	.010	.009	.956	-.028
CHLA	.128	-.200	.698	-.029	-.021	-.002
TOC	.784	-.055	.009	.028	.031	-.113
SAL_S	-.076	.081	.025	.090	-.031	.843
TEMP_S	.100	-.087	-.122	.868	-.038	-.132
DO_S	.045	-.122	-.017	-.814	-.041	-.166
TURB	-.192	.197	.783	-.041	-.111	-.089

Cluster Analysis 1 - 28 stations

- Mean, Median, Standard Deviation, mean absolute deviation (MAD) from 6 PC scores for each site.
- Statistics input to hierarchical clustering analysis using Euclidian distances as metrics.
- Threshold set at approx 0.75



Factor Analysis 2 - 24 stations

Leave out sites 7,8,10,11

- NO3, NO2, NH4, TN, TON, TP, SRP, CHLa, TOC, Salinity, Temp, DO & Turbidity.
- Factor analysis with Varimax rotation.
- Six factor accounting for 79% of variance.
- PC scores for each station were retained.

PC1 - TN, TON, TOC

PC2 - NO3, NO2, NH4

PC3 - Chl-a, TP, Turb

PC4 - Temp, DO

PC5 - SRP

PC6 - Salinity

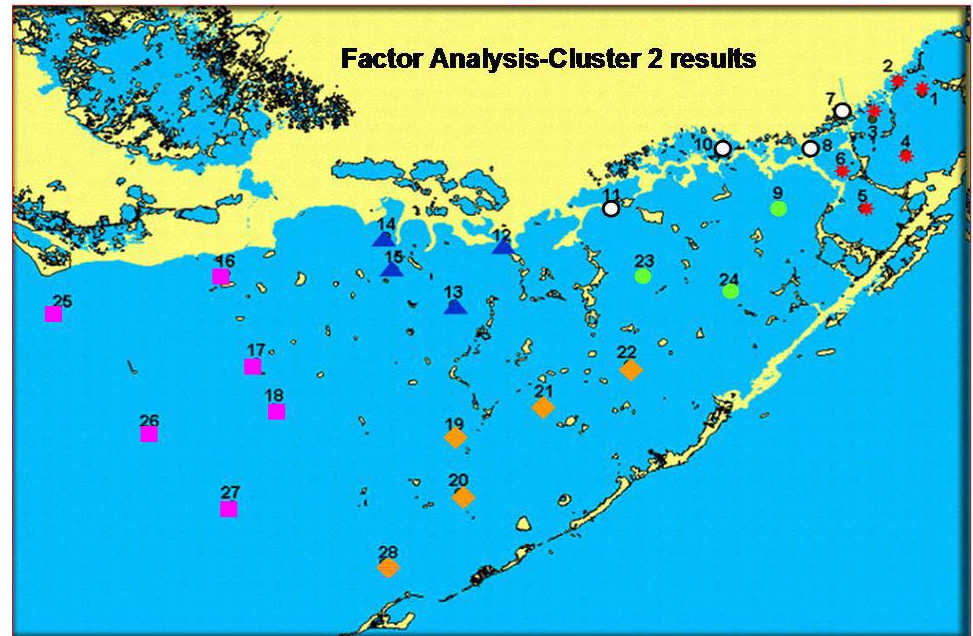
Oblique Solution Reference Structure

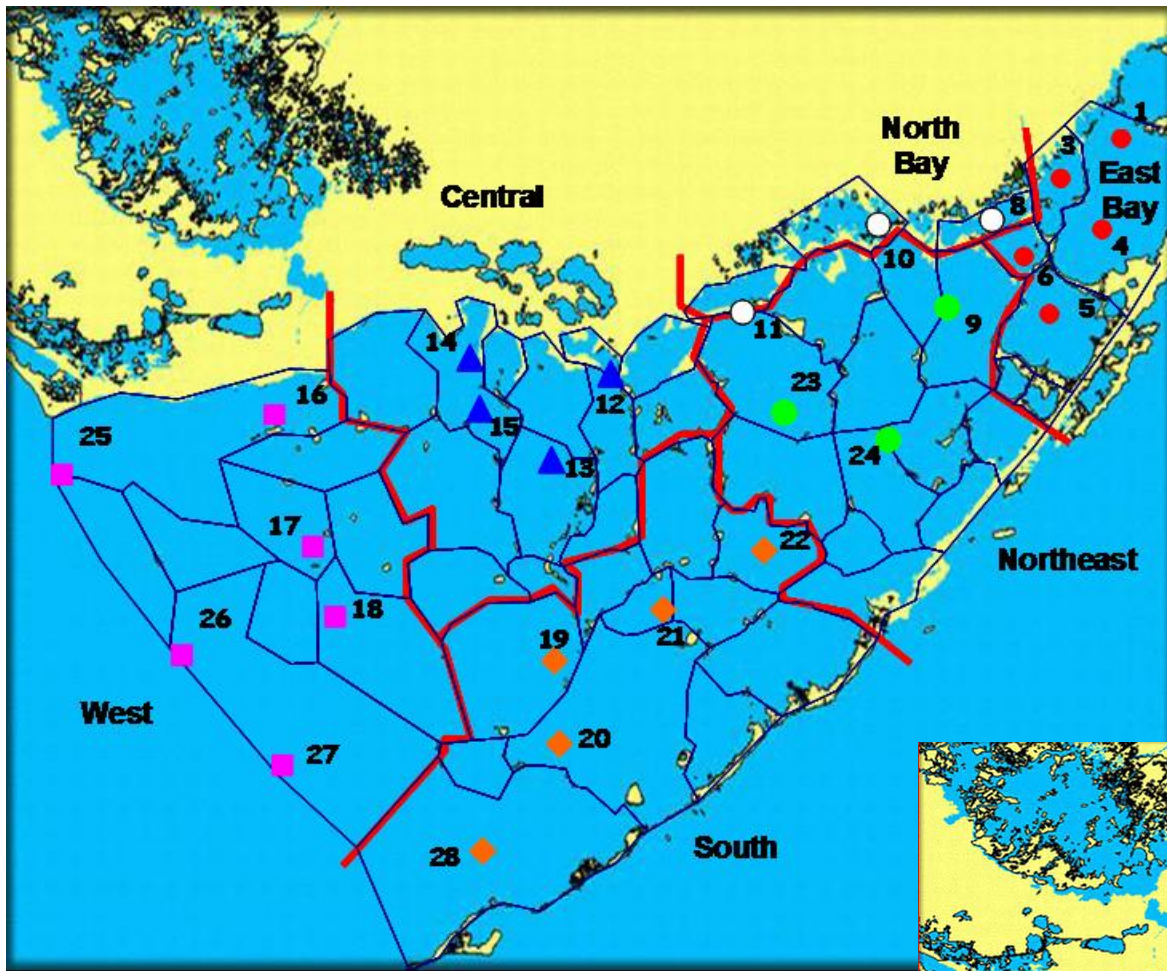
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
NO3	-.136	.590	.013	.080	.092	-.454
NO2	-.038	.845	.013	4.657E-4	-.009	1.642E-4
NH4	.188	.758	-.076	-.013	-.058	.112
TN	.864	.183	-.018	.018	-.016	.019
TON	.877	-.039	-5.553E-6	.019	-.006	.012
TP	.078	-.085	.738	-.030	.106	.097
SRP	.041	-.020	.003	.005	.972	-.023
CHLA	.161	-.214	.676	-.004	-.020	-.065
TOC	.795	-.046	.011	.013	.044	-.048
SAL_S	-.059	.021	.020	.156	-8.798E-5	.869
TEMP_S	.094	-.073	-.122	.845	-.024	-.046
DO_S	.056	-.105	-.055	-.836	-.025	-.135
TURB	-.201	.228	.795	-.038	-.087	-.024

Cluster Analysis 2 - 24 stations

- Mean, Median, Standard Deviation, mean absolute deviation (MAD) from 6 PC scores for each site.
- Statistics input to hierarchical clustering analysis using Euclidian distances as metrics.
- Threshold set at approx 0.75

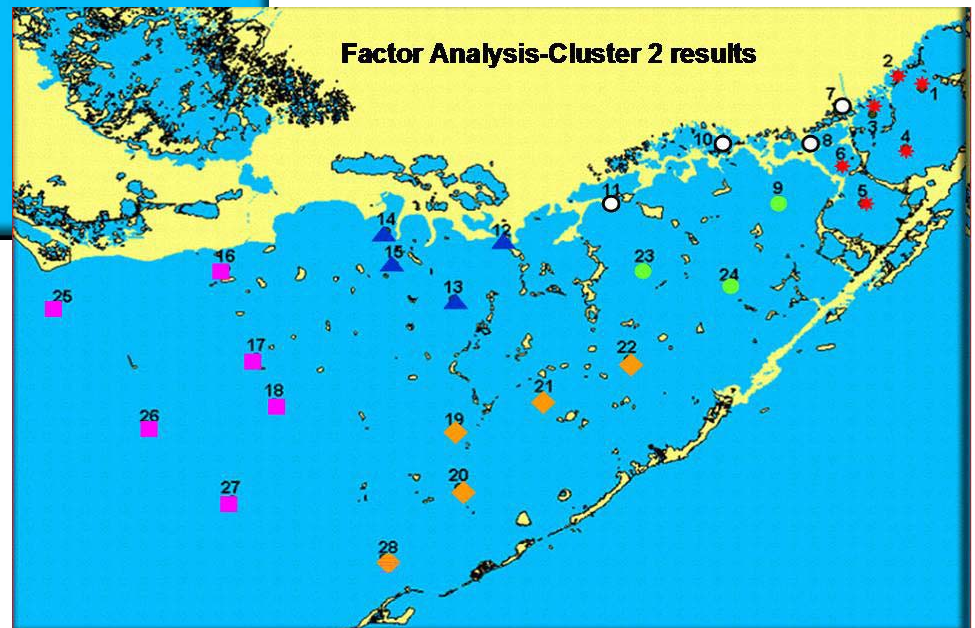
Leave out sites 7,8,10,11



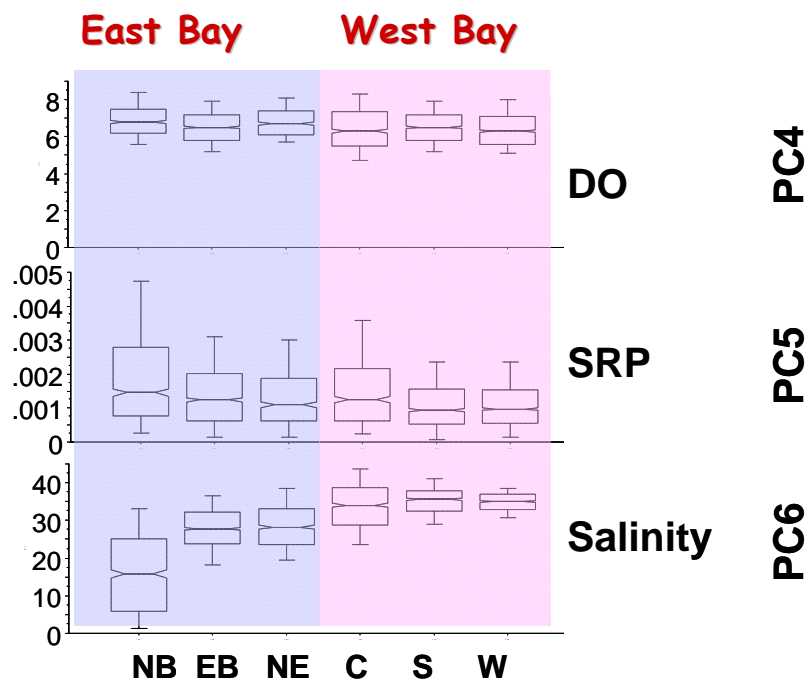
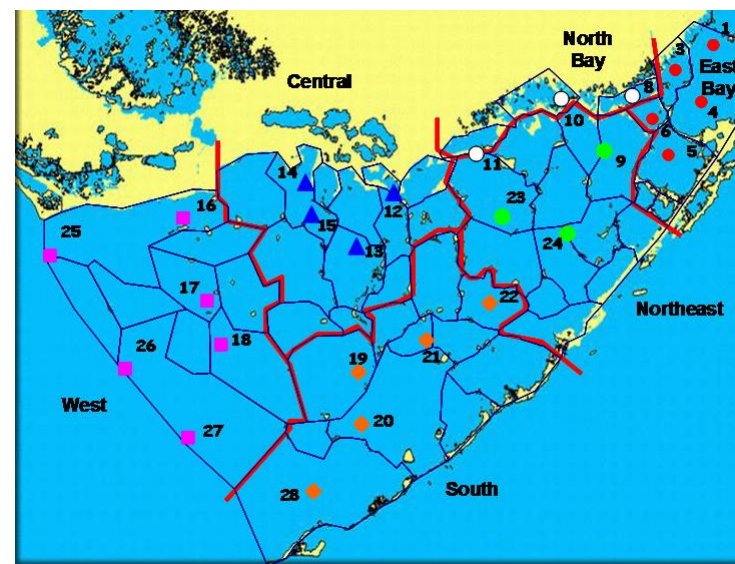
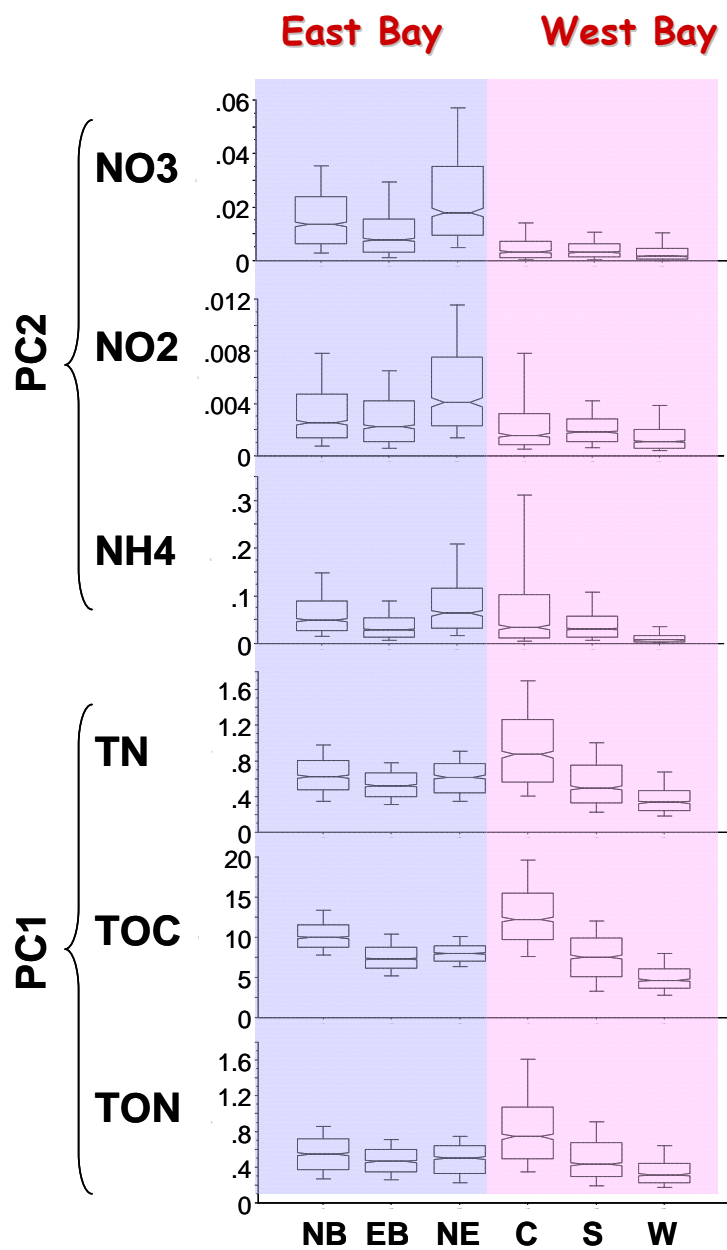


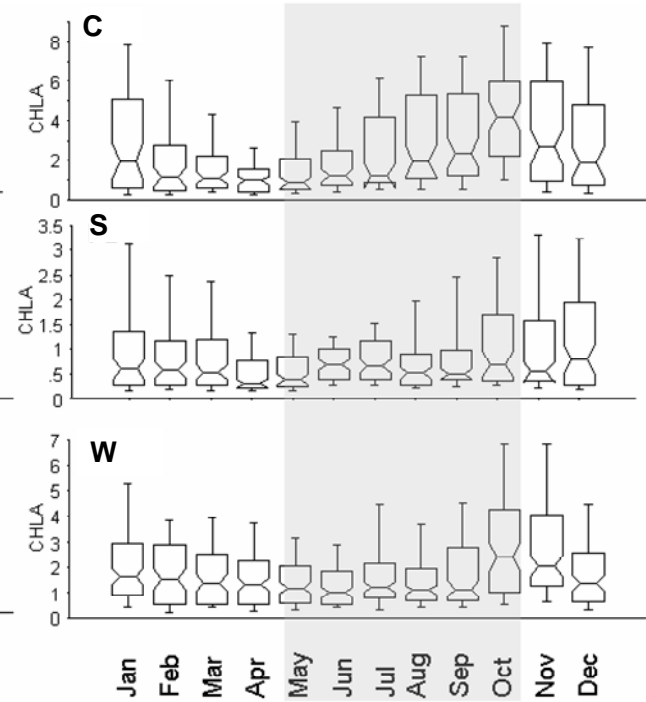
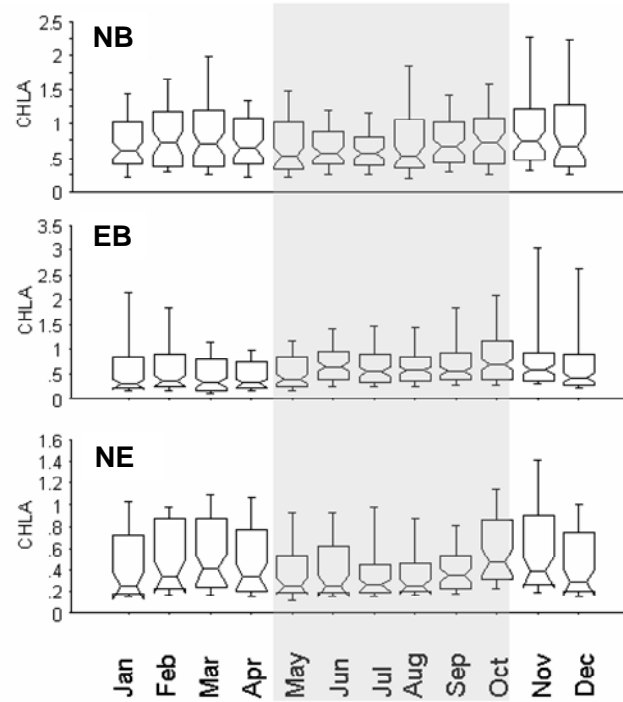
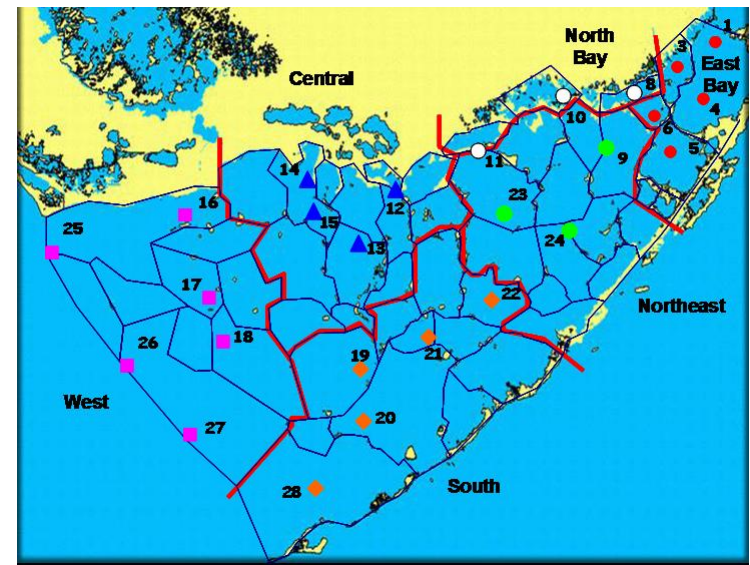
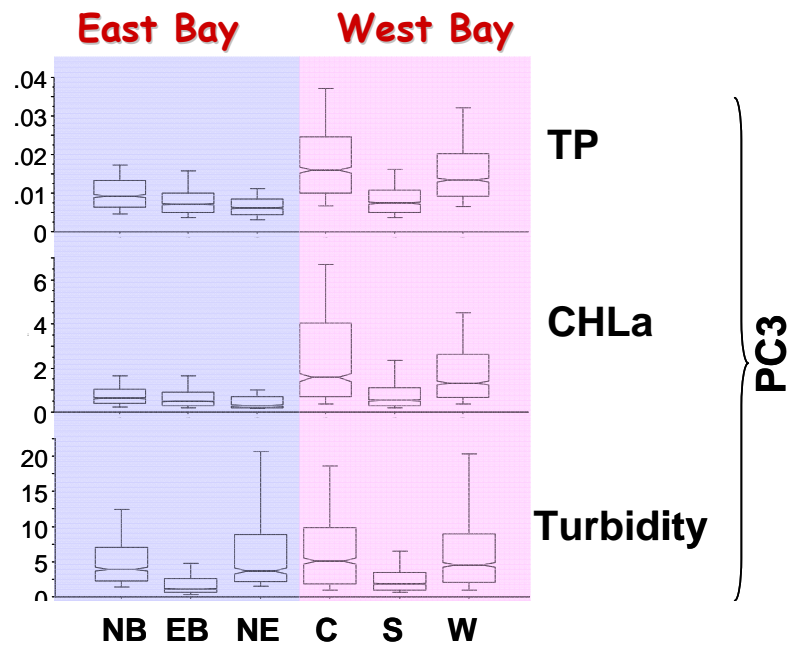
Florida Bay Water Quality Regions:

- NB - Northern Embayments (3)**
- EB - Eastern Bays (5)**
- NE - Northeast (3)**
- C - Central (4)**
- S - South (5)**
- W - West (6)**



18 Years of Monthly Water Quality Data in Florida Bay define 5 (or 6) discrete regions or Zones of Similar Influence (ZSI).





Now - What is responsible for the development of distinct zones of influence in Florida Bay?

Static - Physical isolation

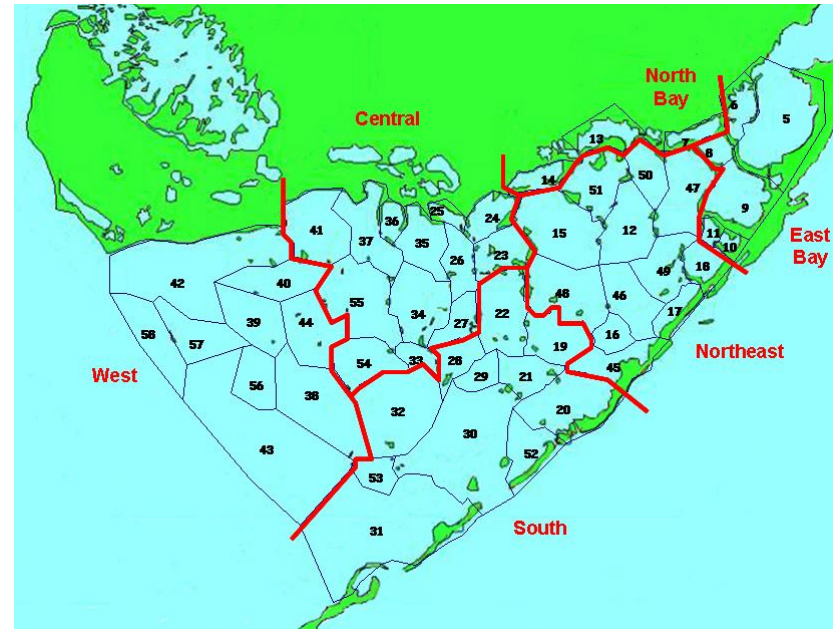
Barriers to flow

Channel and bank cross-sectional areas
(bathymetry of Florida Bay)

Dynamic - Circulation & rates of flushing

Turnover Times (V/Q)

Basin volumes and water budgets
(bathymetry, observed climate and runoff,
and channel and bank exchanges)

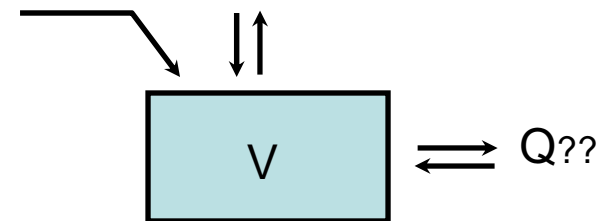
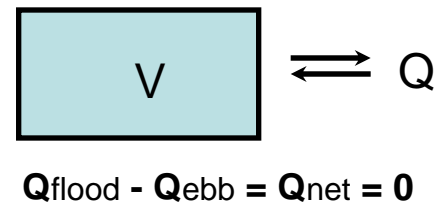
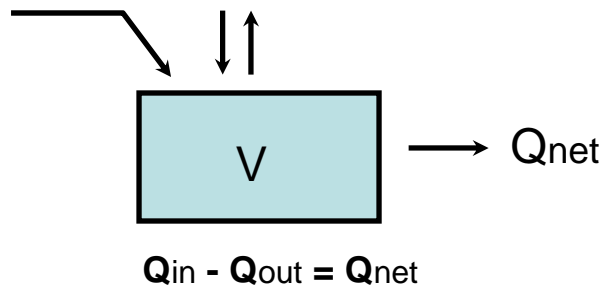


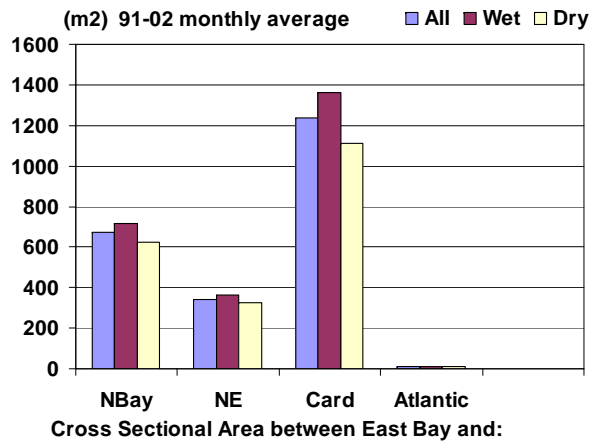
A note on defining turnover times as: $TO = V/Q$

Advective turnover times

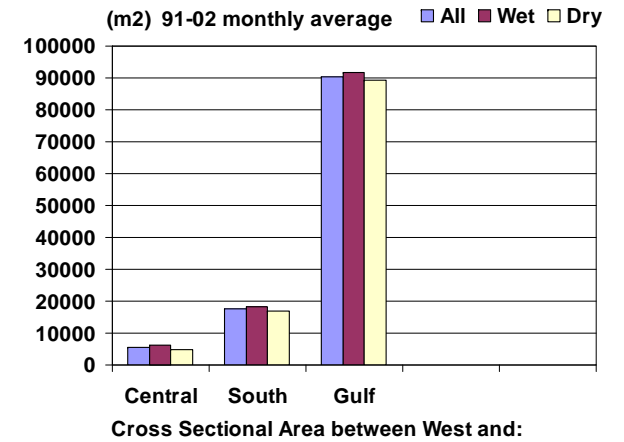
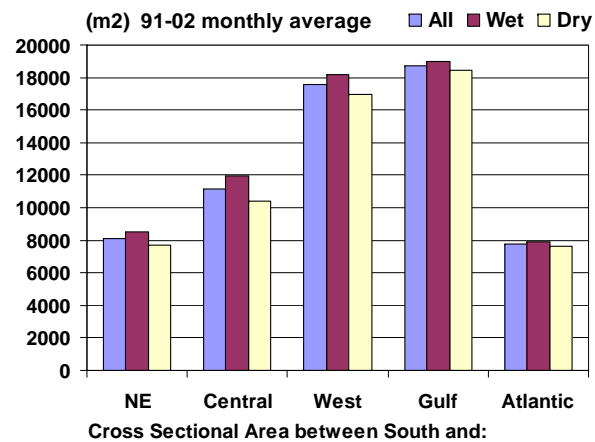
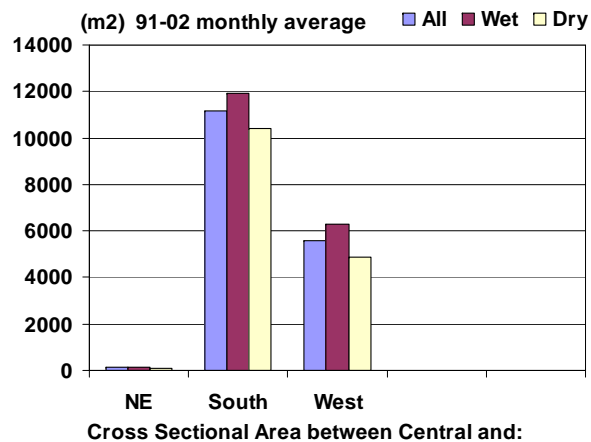
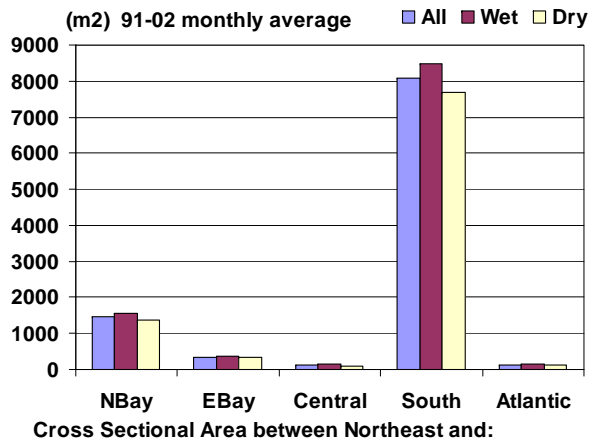
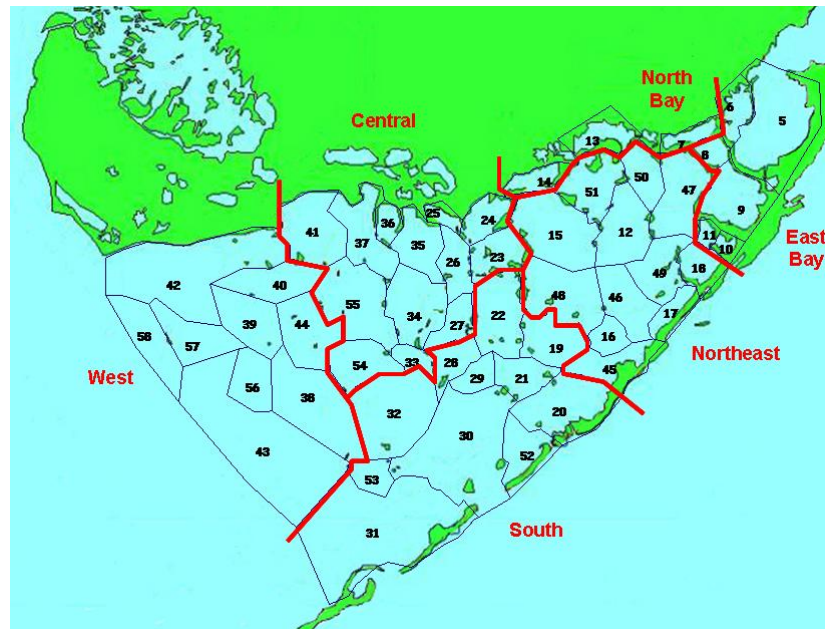
Dispersive turnover times

Turnover in the WQ regions



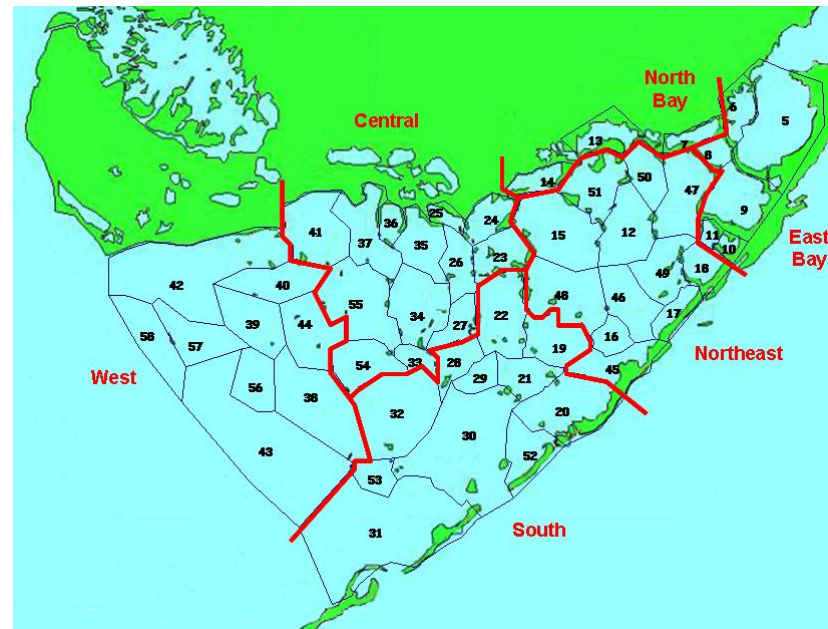
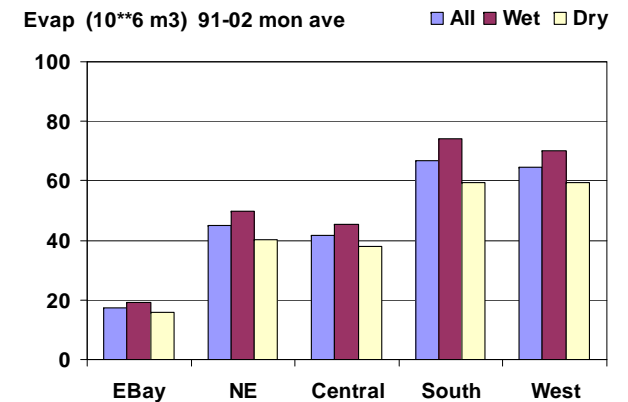
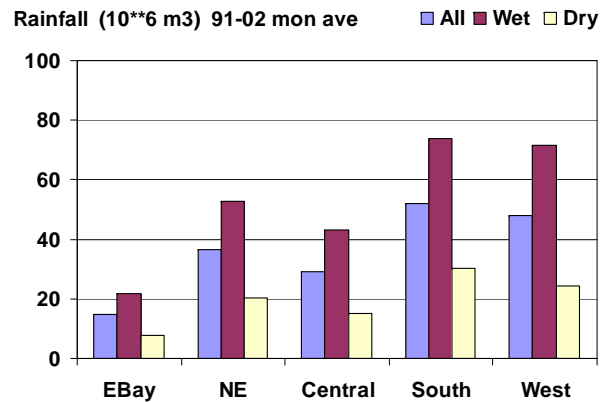
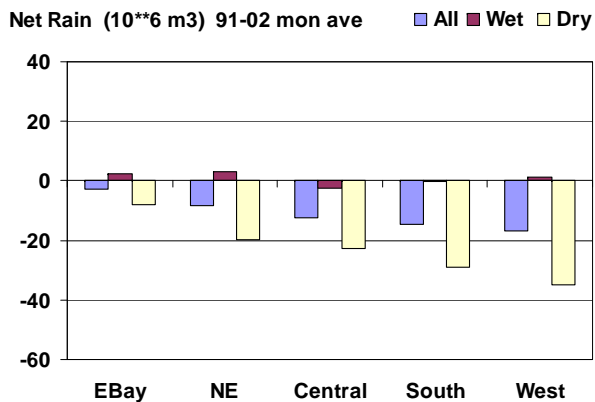
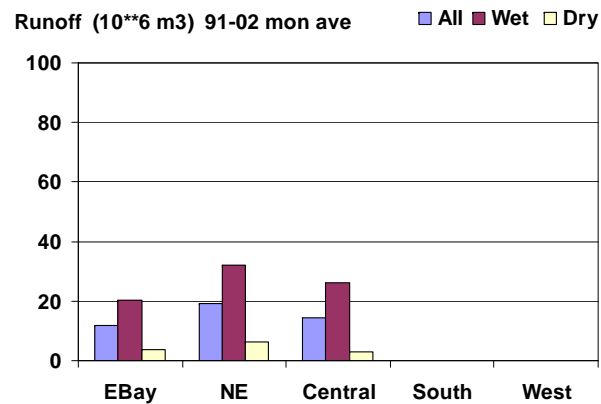
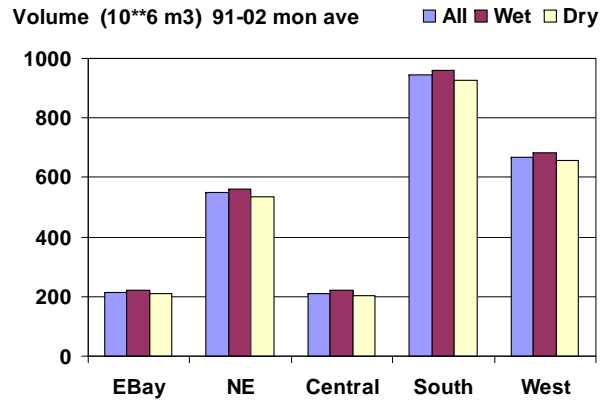


Cross-sectional area between each WQ region and its neighbor.
(Based on USGS and NPS bathymetry in Florida bay)



Basin Volumes and Freshwater Budgets.

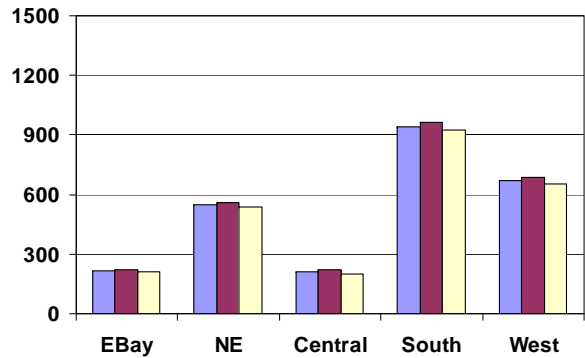
(Based on USGS and NPS bathymetry, observed rainfall and runoff, and estimated evaporation)



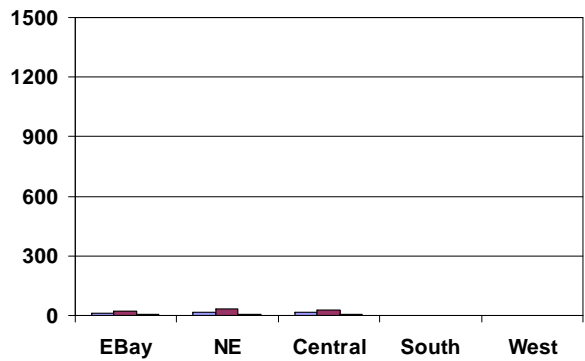
Basin Volumes and Total Water Budgets.

(Based on USGS and NPS bathymetry, observed rainfall and runoff, estimated evaporation, and channel and bank exchanges from FATHOM)

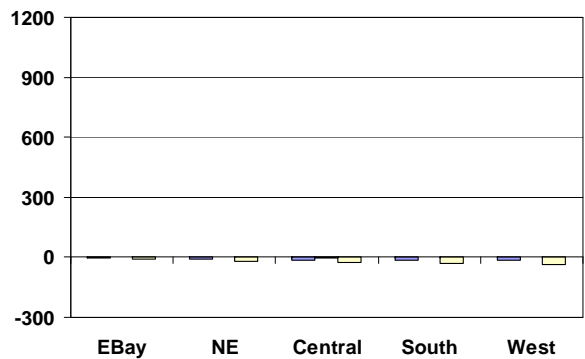
Volume (10**6 m3) 91-02 mon ave



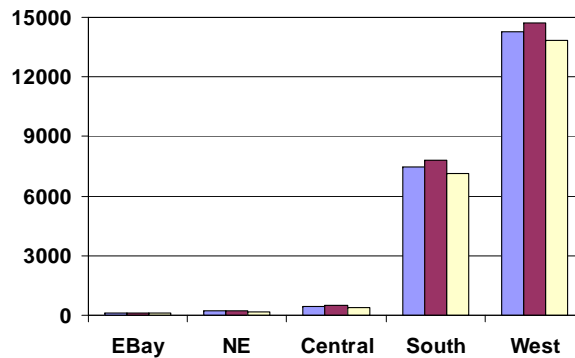
Runoff (10**6 m3) 91-02 mon ave



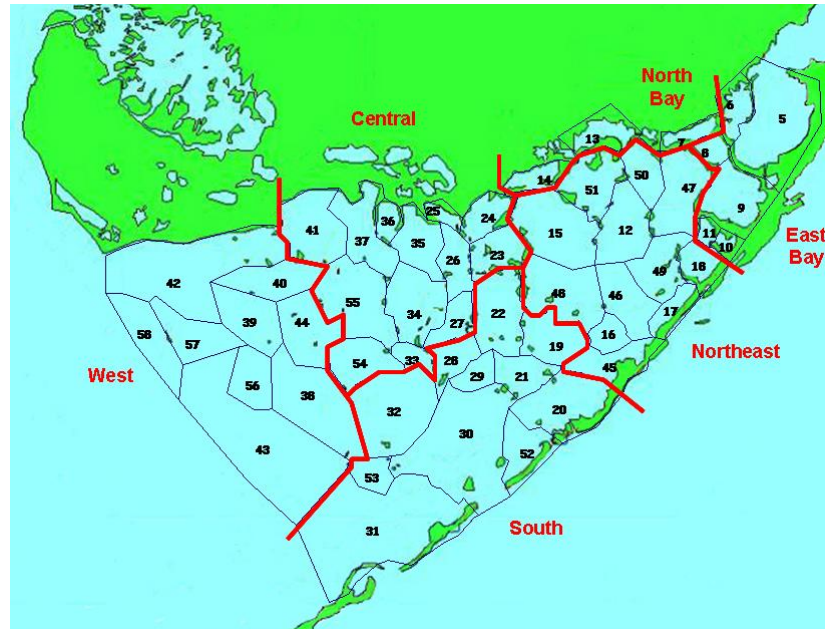
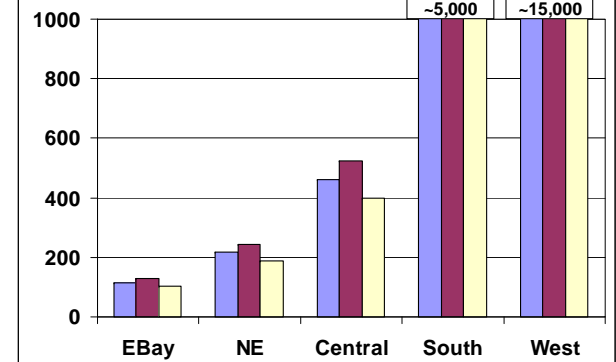
Net Rain (10**6 m3) 91-02 mon ave



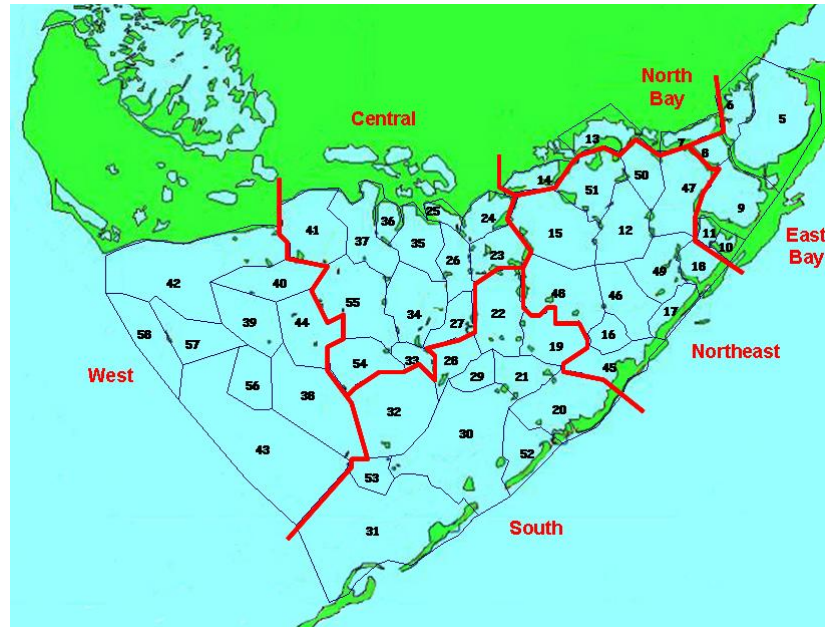
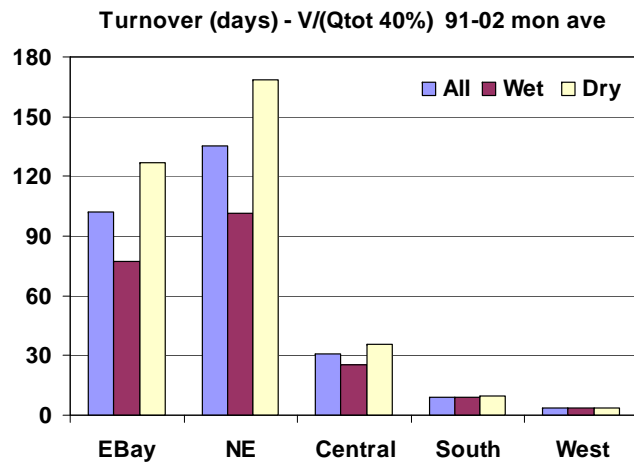
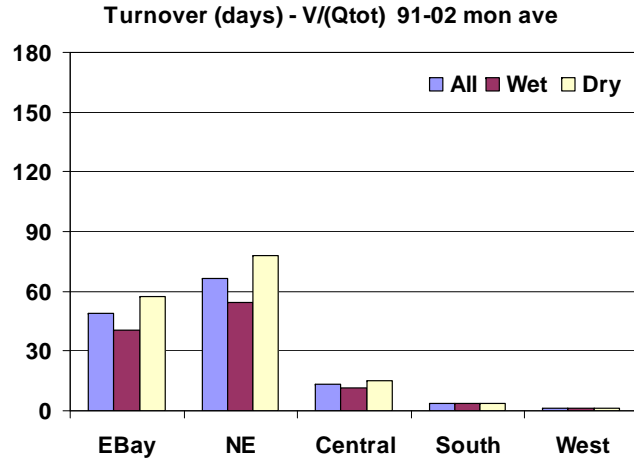
Tide Flood (10**6 m3) 91-02 mon ave



Tide Flood (10**6 m3) 91-02 mon ave



Estimated Turnover times in the WQ regions

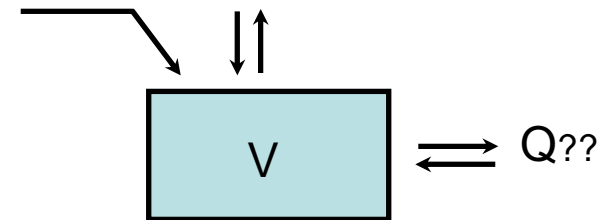


A note on defining turnover times as: $TO = V/Q$

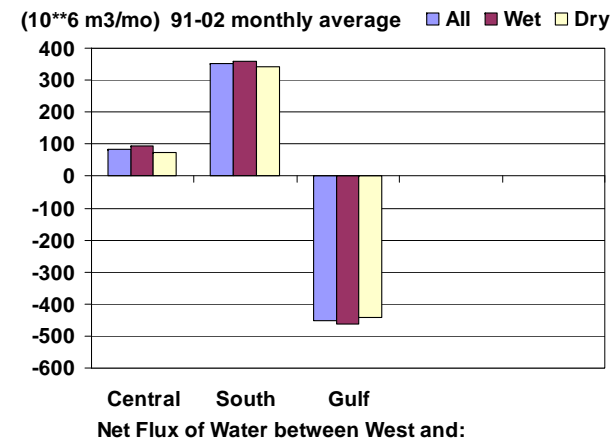
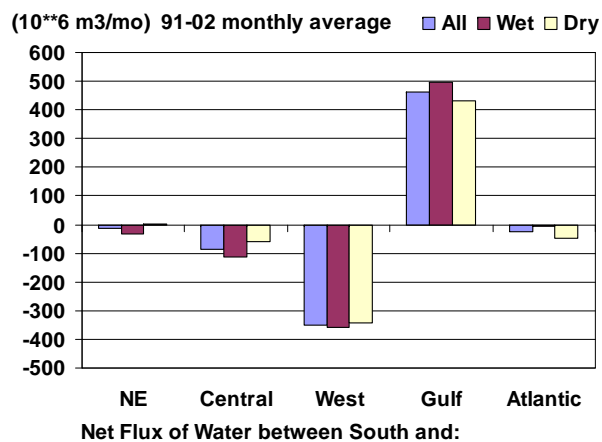
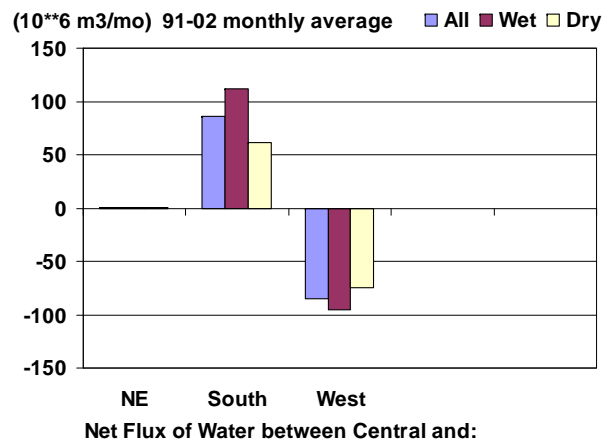
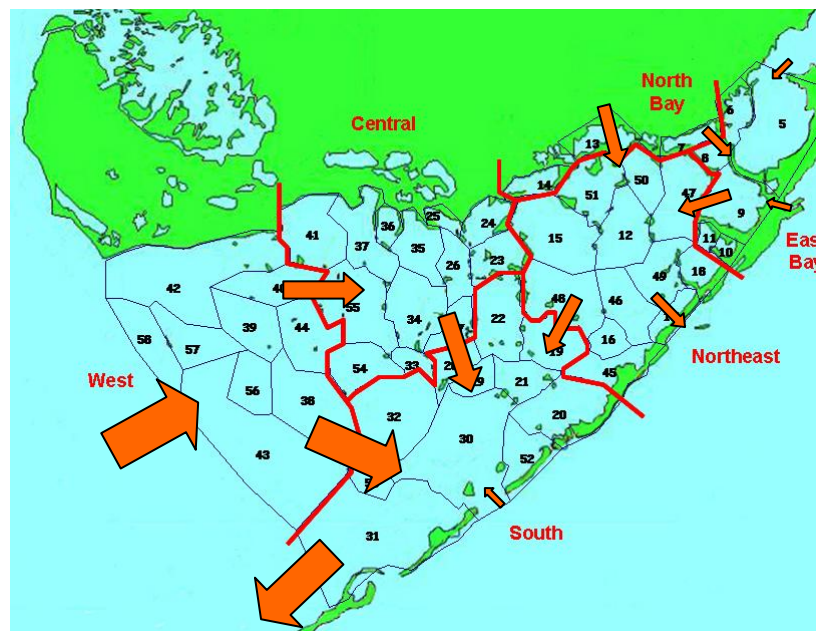
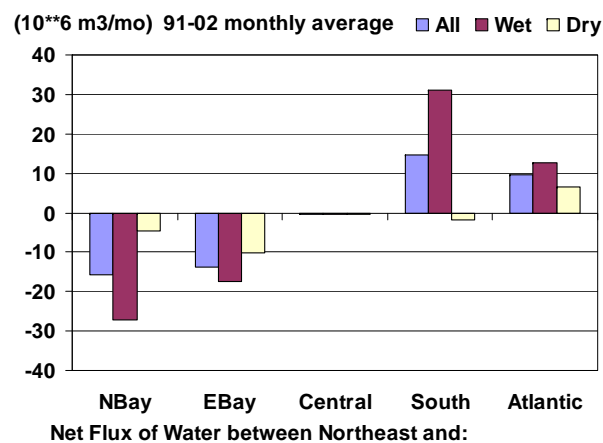
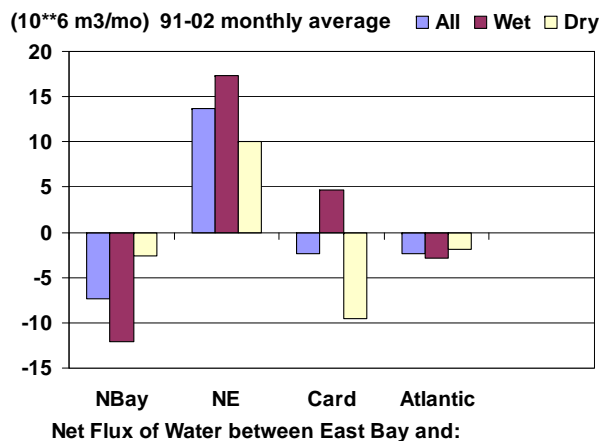
Turnover in the regions

$$Q_{in} + 0.4 * Q_{flood} = Q_{40\%}$$

$$Q_{in} + Q_{flood} = Q_{tot}$$



Patterns of circulation inferred from residual net water fluxes between the WQ regions

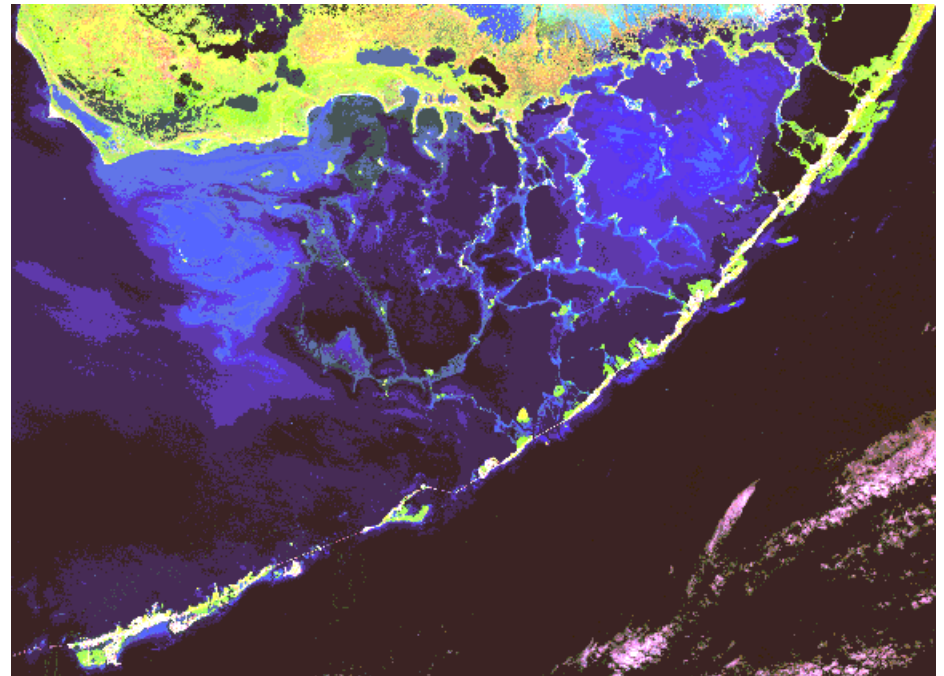



Conclusions

- Analysis of 18 years of water quality data in Florida Bay identifies 6 Water Quality Regions in the bay that differ significantly in biogeochemical characteristics.
- These Regions are essentially the same areas identified earlier in a similar analysis (using a shorter data record) suggesting the underlying pattern is robust and persistent.
- The Regions agree well with other empirical approaches for classifying discrete areas in the bay (benthos, seagrass, etc.)
- The physical characteristics of the Regions suggest that barriers to water exchange might be partially responsible for the discrete character of the water quality within each region.
- Field and modelling studies of water circulation patterns and water replacement rates are consistent with the concept that discrete water quality patterns can develop in the regions.

So what does all this tell us about our ability to move forward with models of water quality in the bay?

- Encouraging consistency among physical, biological, and geochemical patterns in Florida Bay.
- Convergence of perceptual and conceptual models.
- Emergent scale of resolution (and lack thereof).
- Occam



An aerial photograph of a vast wetland area, likely the Everglades. The landscape is a mosaic of deep blue water bodies and green, vegetated islands and peninsulas. The water appears to be a mix of light and dark blue, suggesting varying depths and possibly different water compositions. The green areas are dense with vegetation, likely sawgrass or similar wetland plants. The horizon is visible in the distance under a clear sky.

**Funding for this analysis provided through a CESI grant from the
National Park Service, Everglades National Park**

Acknowledgments: Thanks to the usual cast of FIU/SERC characters

Thank you for your attention !!