Derivation of Numeric Nutrient Criteria for South Florida estuaries and coastal waters

Team

Henry O. Briceño
Joseph N. Boyer
Peter Harlem

Joffre Castro

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Content

- **Methodology**
  - Monitoring programs and data selection
    - Period of Record (POR)
  - Segmentation of SoFlo Basins
  - Threshold analysis
    - Period of Calculation
- **Derivation of Numeric Nutrient Criteria**

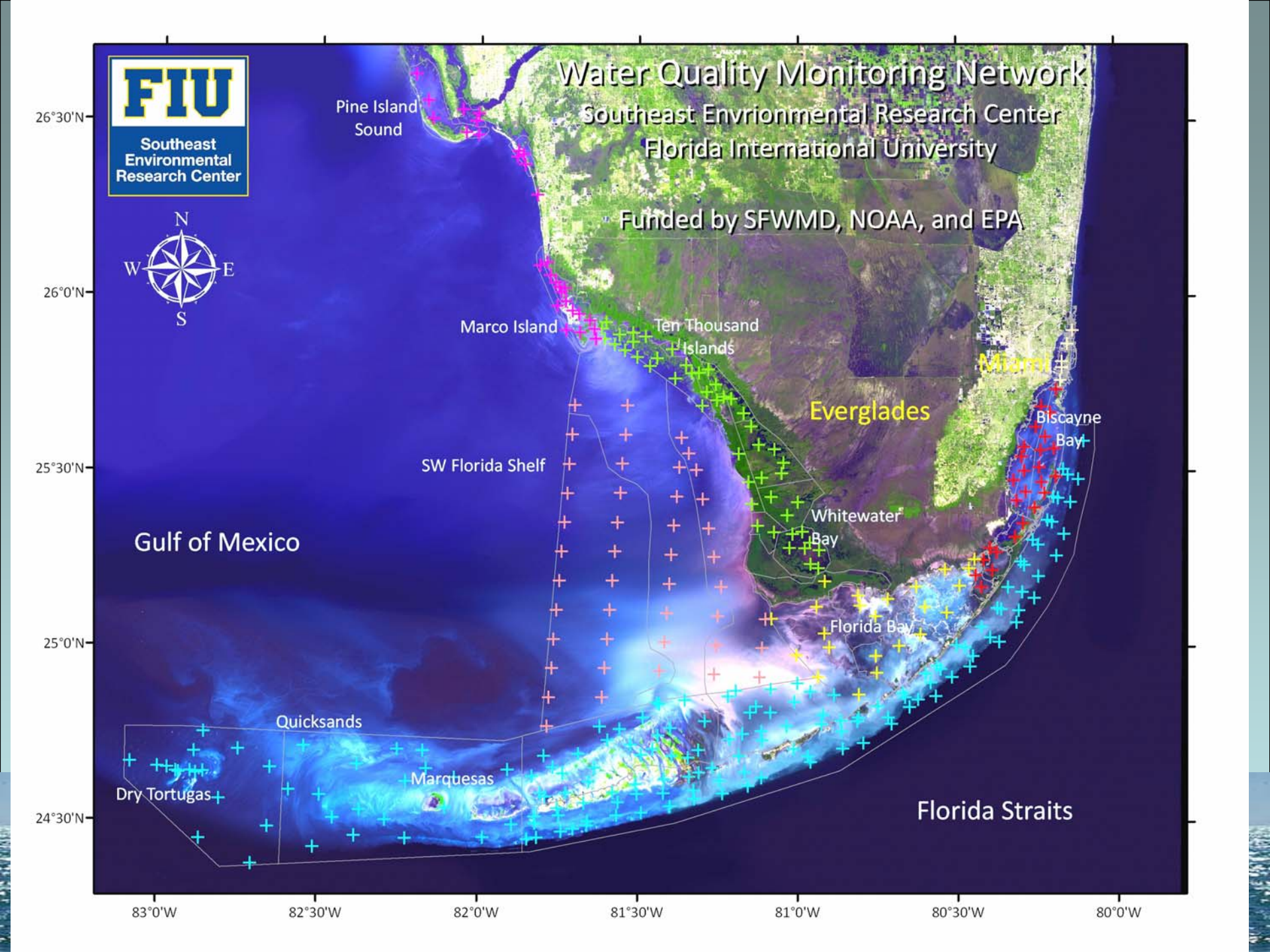
Data sources

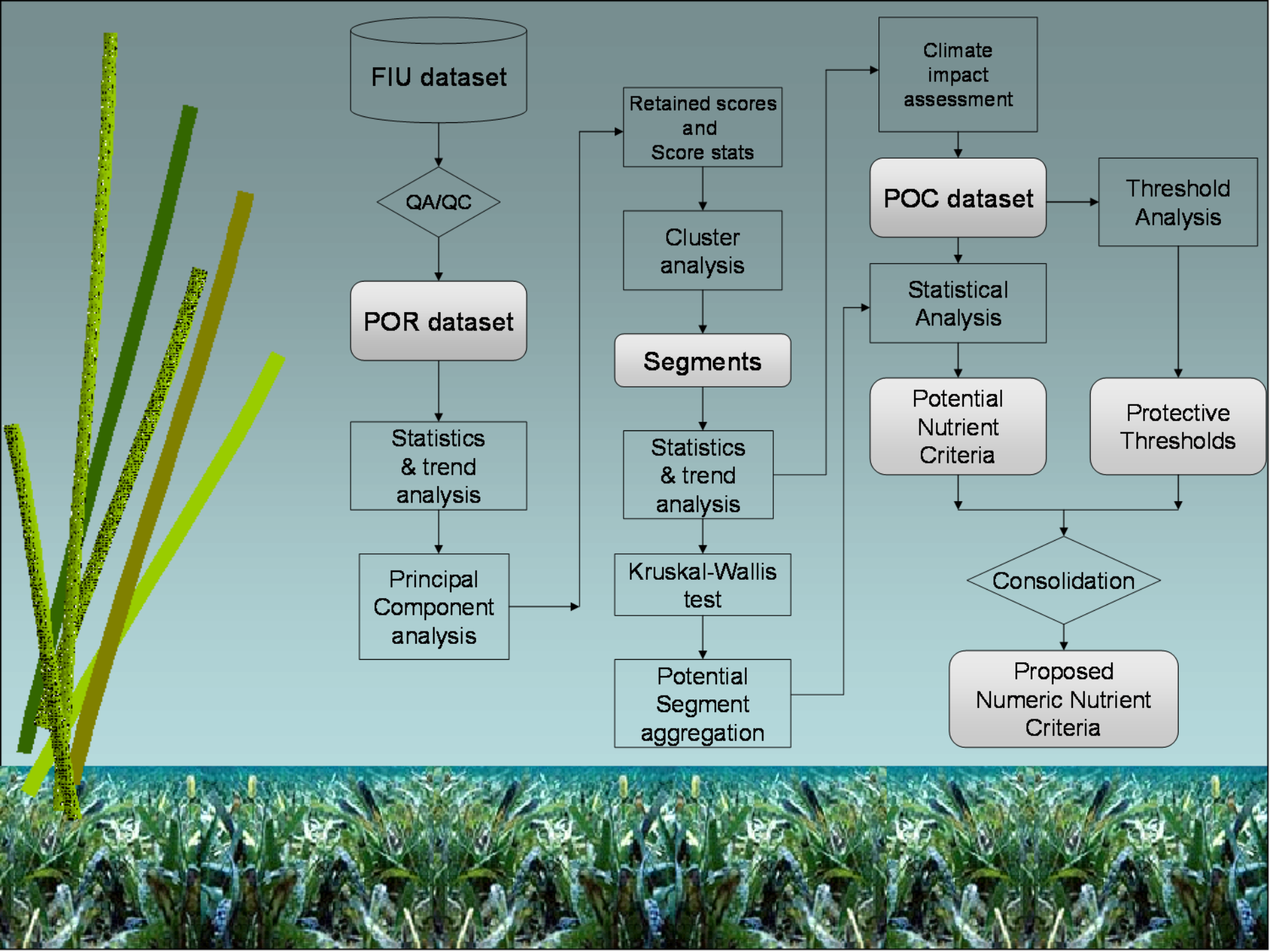
- NOAA/UM/RSMAS
  (http://www.aoml.noaa.gov/sfp/data.shtml)
- DERM
  (http://www.gcrc.uga.edu/wqmeta/app/organizations.asp)
  - Mr. Steve Blair
- USGS (http://sofia.usgs.gov/exchange/index.php)
- EPA (http://ww w.epa.gov/storet/)
- FIU/SERC (http://serc.fiu.edu/wqmnetwork/)
- FCE-LTER (http://fcelter.fiu.edu/data/)
- NPS
  - Mrs. Sarah Bellmund.

Dataset selection criteria

EPA's Guidance for the Data Quality Objectives Process
(EPA 2004; http://www.epa.gov/quality/qs-docs/g4-final.pdf)

- Long-term and sustained monitoring
- Regularity in sampling frequency
- Monitoring at fixed stations over the POR
- Spatial coverage to render representative and reproducible data
- Uniformity in field and laboratory protocols
- High quality results
- Include causal variables (i.e. nutrients), supporting variables (salinity, turbidity, DO, etc.) and ecosystem response variables (i.e. CHL-a)


Water Quality Monitoring Network
Southeast Envrionmental Research Center
Florida International University
Funded by SFWMD, NOAA, and EPA
FIU
Southeast Environmental Research Center
N
W
E
S
Pine Island Sound
Marco Island
Ten Thousand Islands
Miami
Everglades
Biscayne Bay
SW Florida Shelf
Whitewater Bay
Gulf of Mexico
Florida Bay
Quicksands
Marquesas
Dry Tortugas
Florida Straits
26°30'N
26°0'N
25°30'N
25°0'N
24°30'N
83°0'W
82°30'W
82°0'W
81°30'W
81°0'W
80°30'W
80°0'W


FIU dataset
QA/QC
POR dataset
Statistics & trend analysis
Principal Component analysis
Retained scores and Score stats
Cluster analysis
Segments
Statistics & trend analysis
Kruskal-Wallis test
Potential Segment aggregation
Climate impact assessment
POC dataset
Threshold Analysis
Statistical Analysis
Potential Nutrient Criteria
Protective Thresholds
Consolidation
Proposed Numeric Nutrient Criteria

SEGMENTATION

Factor Analysis

Principal Components

Score statistics (mean, SD, median, MAD)

Hierarchical Cluster

Segments

Geomorphology

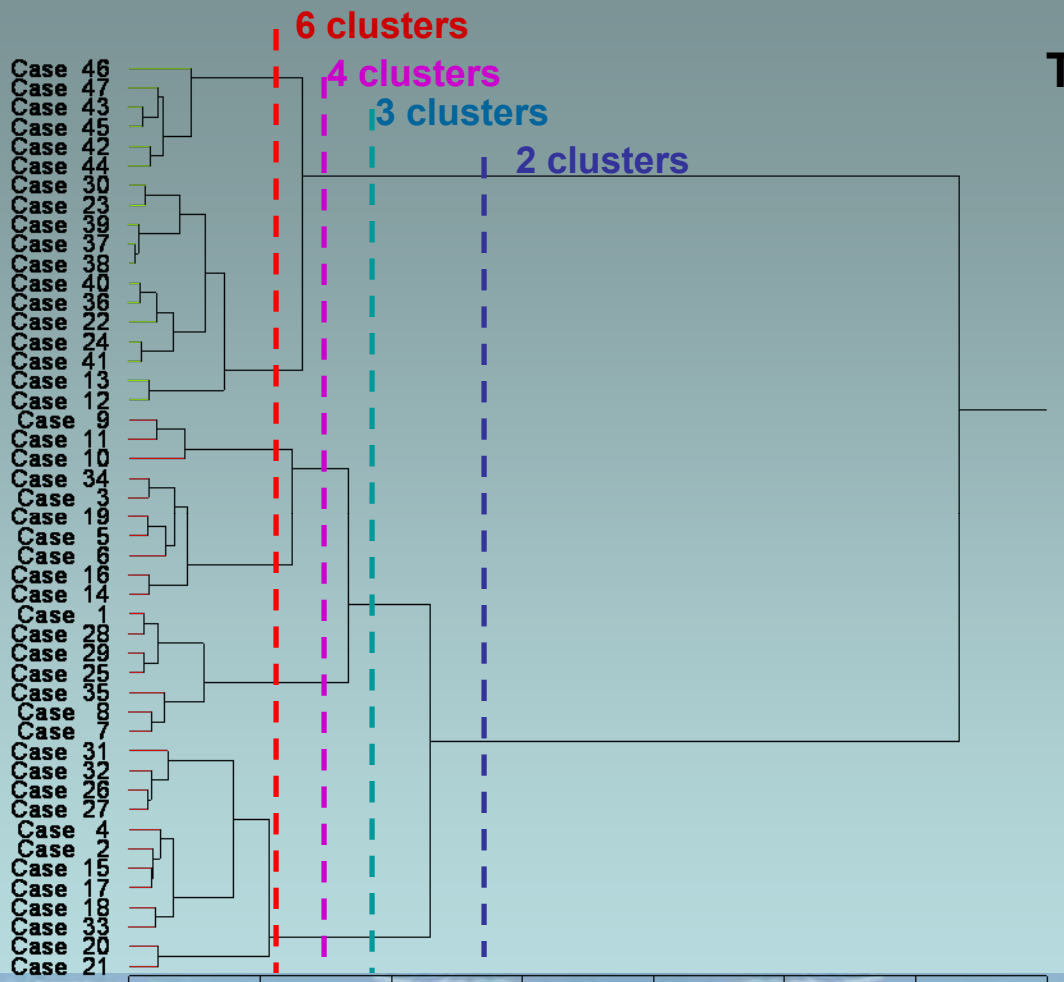
Circulation

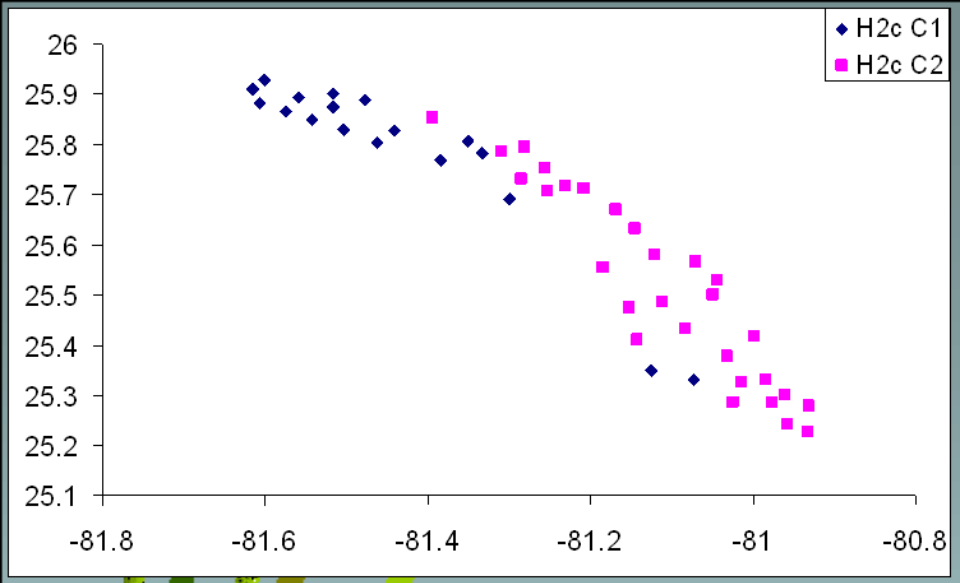
Bottom type

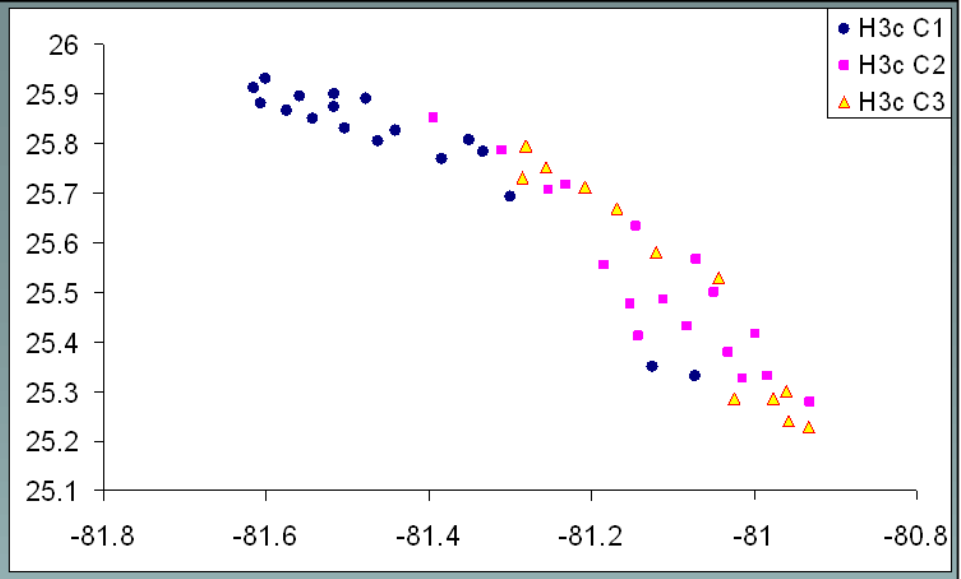
Benthic communities

Cluster Tree

Whitewater Bay
Ten Thousand Islands




H2c C1
H2c C2
26
25.9
25.8
25.7
25.6
25.5
25.4
25.3
25.2
25.1
-81.8
-81.6
-81.4
-81.2
-81
-80.8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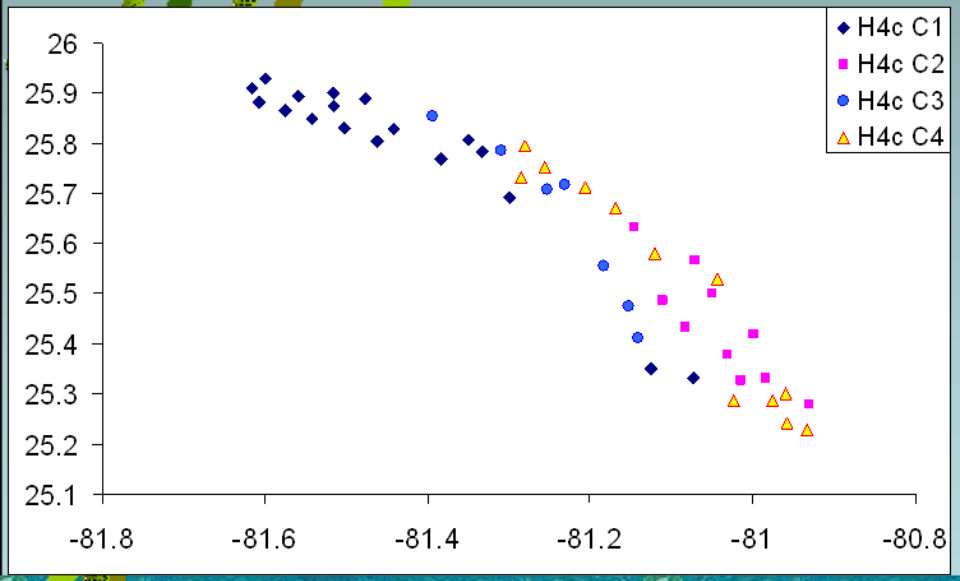
H3c C2
H3c C3
26
25.9
25.8
25.7
25.6
25.5
25.4
25.3
25.2
25.1
-81.8
-81.6
-81.4
-81.2
-81
-80.8


H4c C1
H4c C2
H4c C3
H4c C4
26
25.9
25.8
25.7
25.6
25.5
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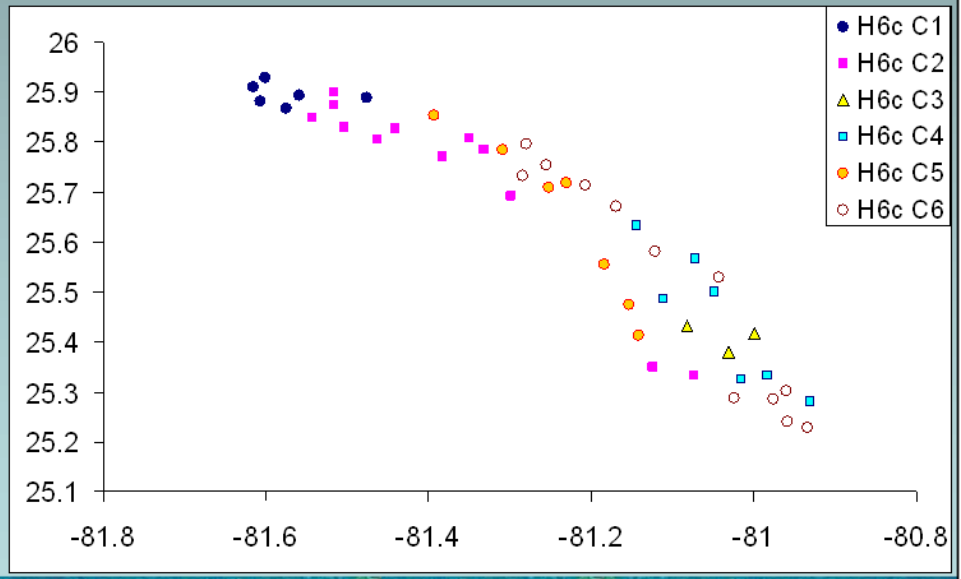
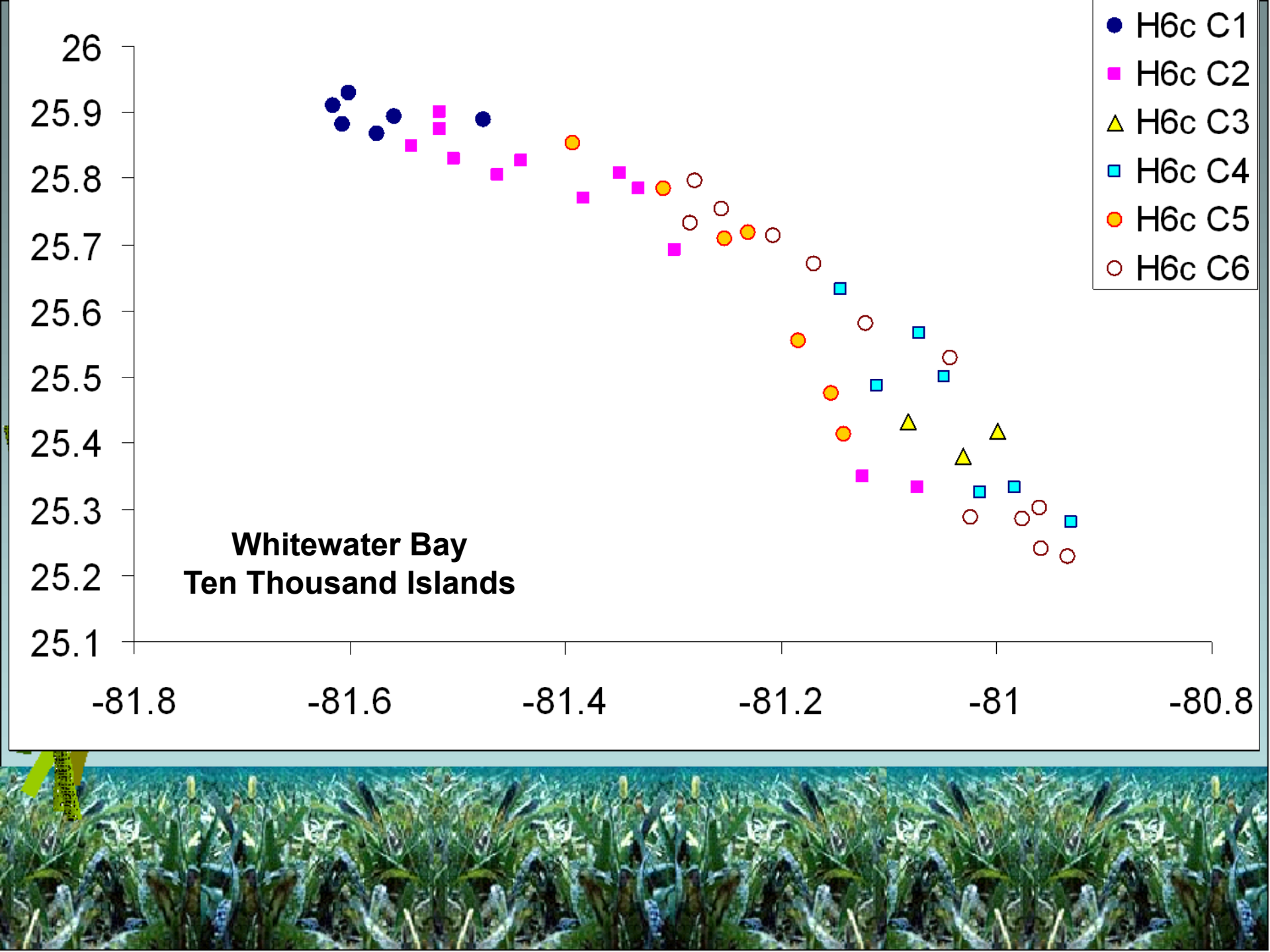
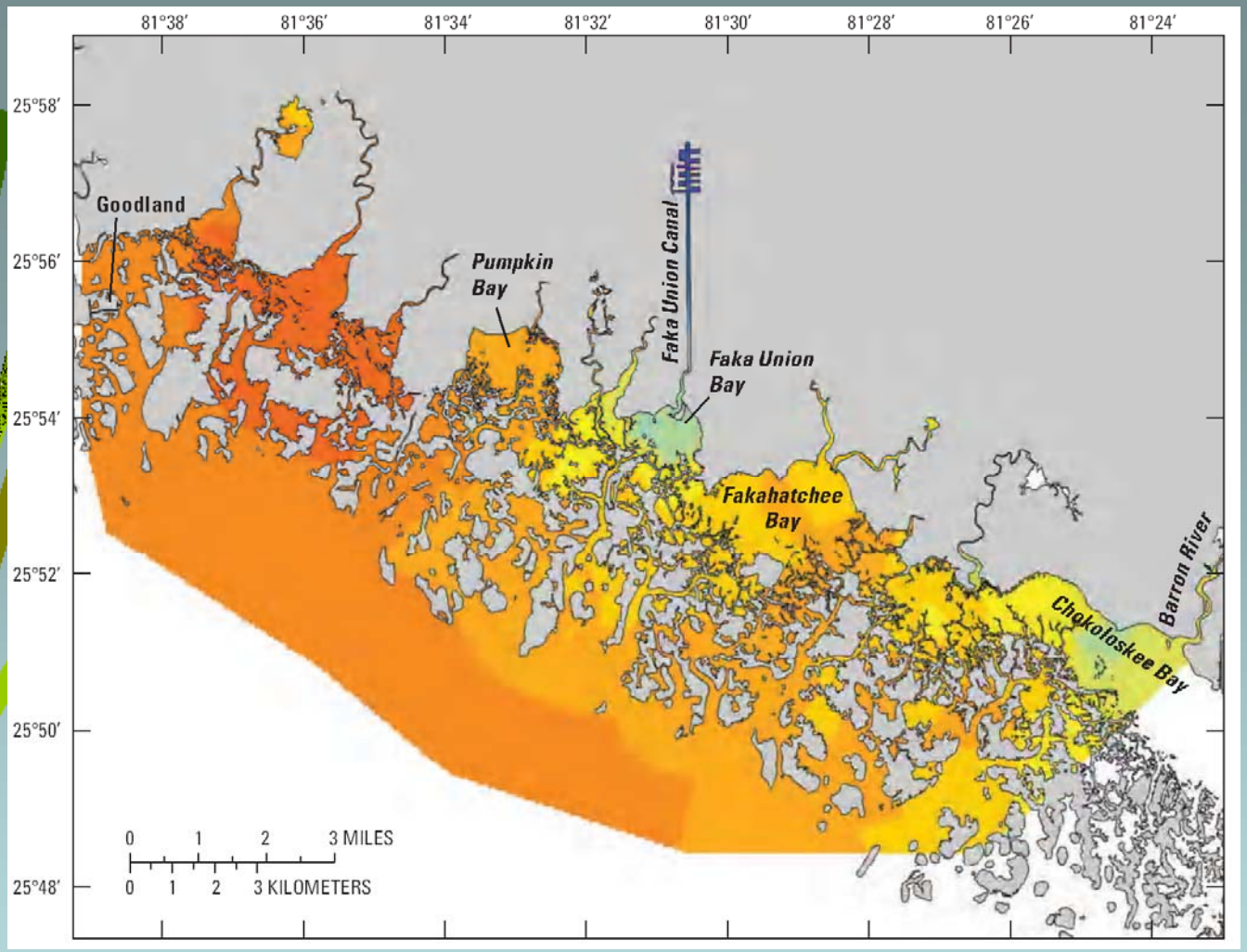
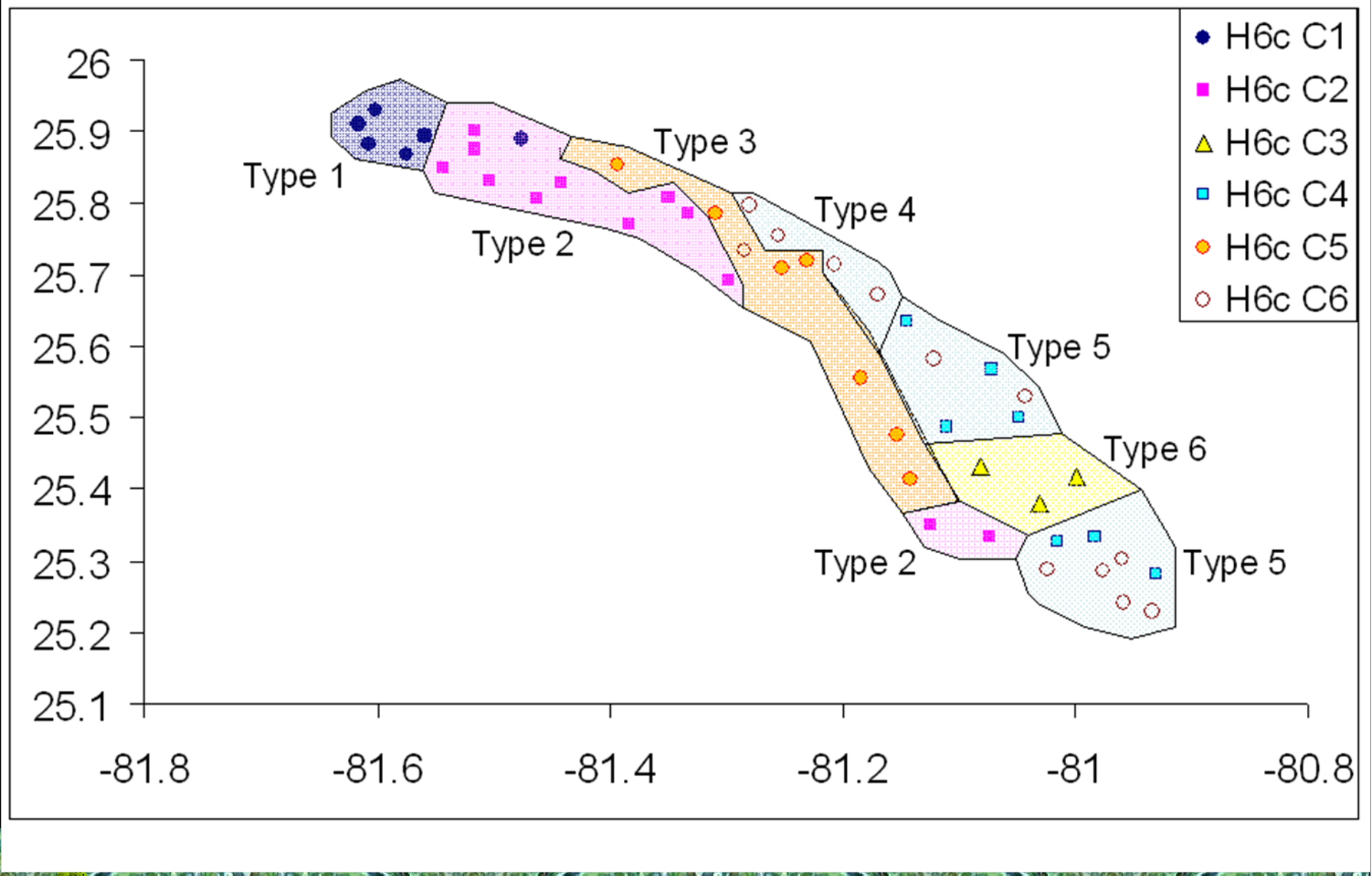
25.3
25.2
25.1
-81.8
-81.6
-81.4
-81.2
-81
-80.8


H6c C1
H6c C2
H6c C3
H6c C4
H6c C5
H6c C6
26
25.9
25.8
25.7
25.6
25.5
25.4
25.3
25.2
25.1
-81.8
-81.6
-81.4
-81.2
-81
-80.8


Whitewater Bay
Ten Thousand Islands


H6c C1
H6c C2
H6c C3
H6c C4
H6c C5
H6c C6
26
25.9
25.8
25.7
25.6
25.5
25.4
25.3
25.2
25.1
-81.8
-81.6
-81.4
-81.2
-81
-80.8
Whitewater Bay
Ten Thousand Islands

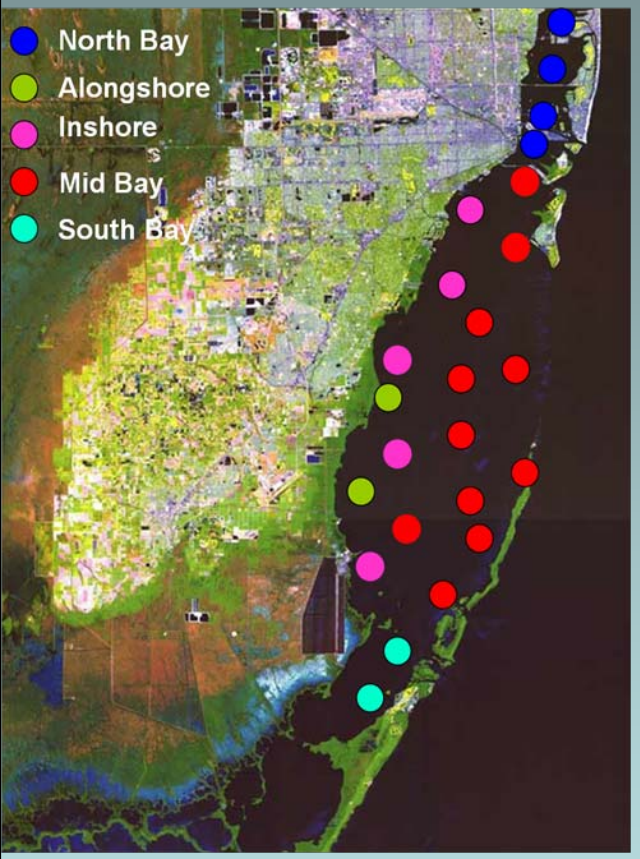

81°38′
81°36′
81°34′
81°32′
81°30′
81°28′
81°26′
81°24′
25°58′
25°56′
25°54′
25°52′
25°50′
25°48′
Goodland
Pumpkin Bay
Faka Union Canal
Faka Union Bay
Fakahatchee Bay
Chokoloskee Bay
Barron River
0 1 2 3 MILES
0 1 2 3 KILOMETERS



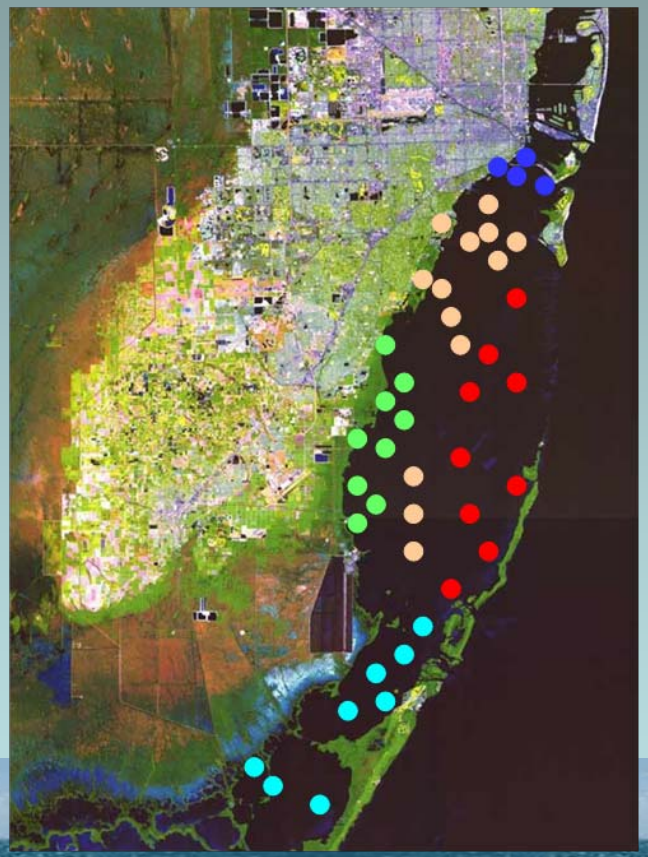
Final segmentation Whitewater bay-Ten Thousand Islands

Subdivision of Biscayne Bay waters

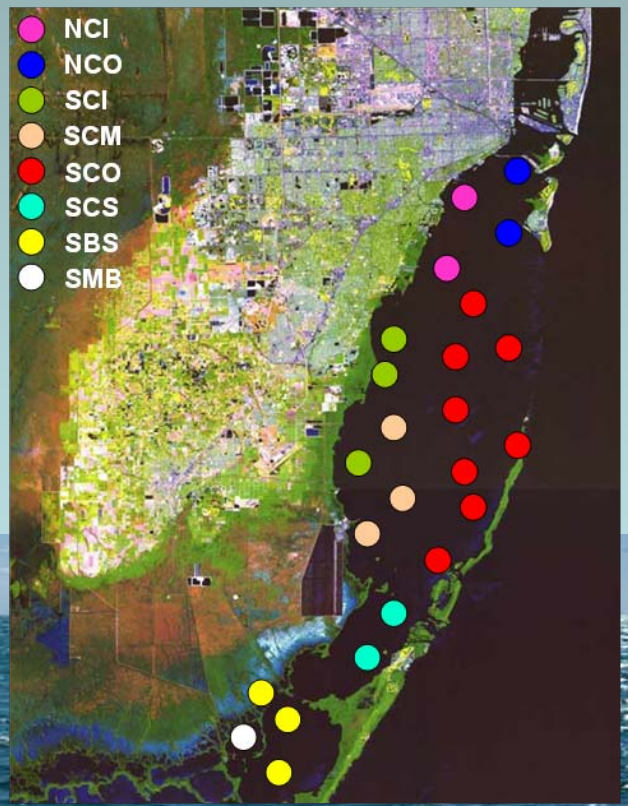
Caccia and Boyer (2005)



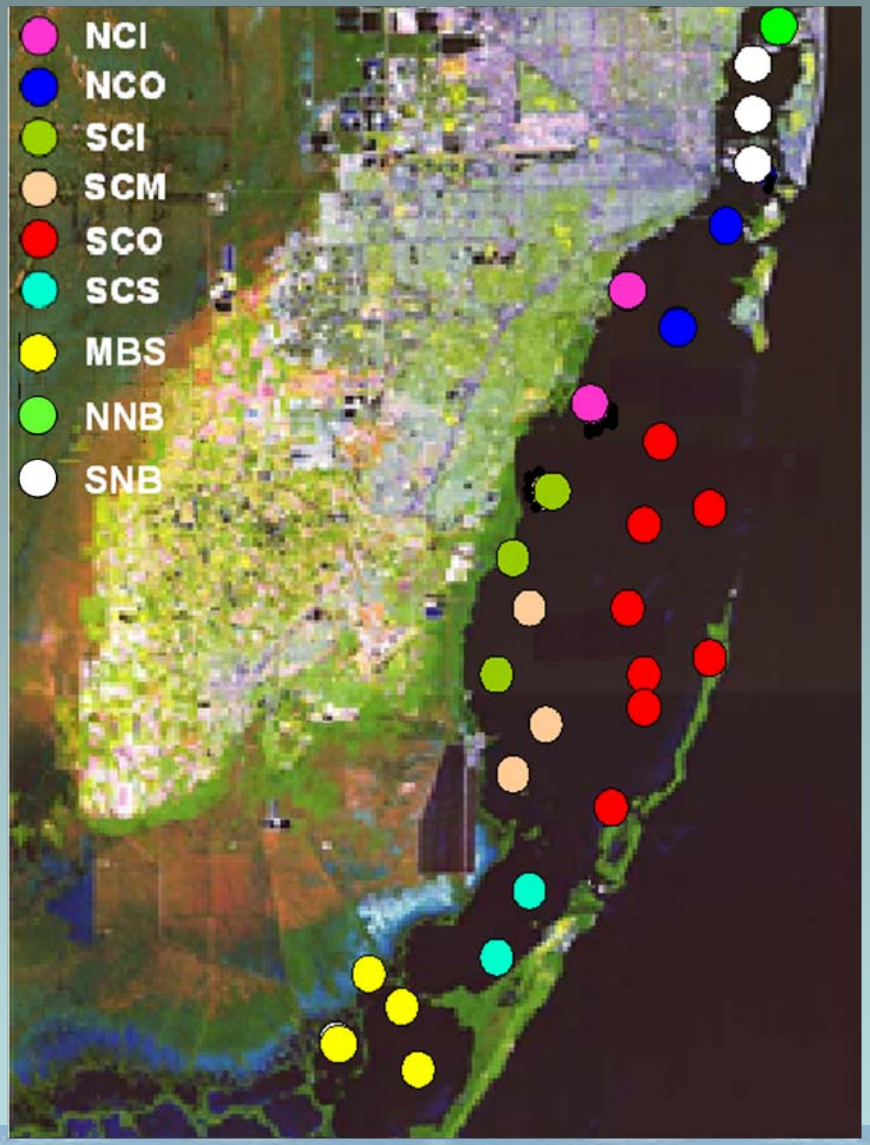
Hunt and Todt (2006)



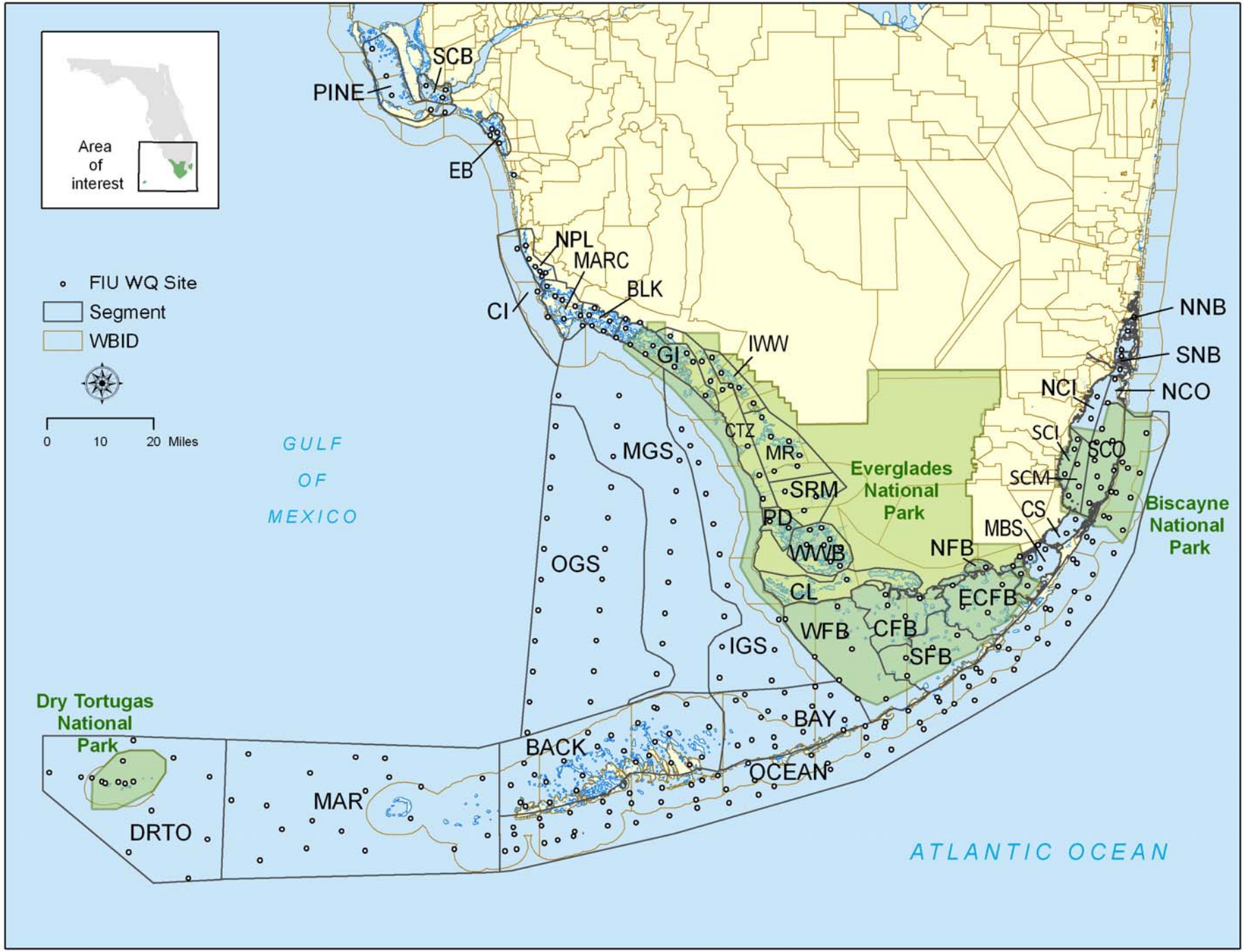
Briceño et al (in prep, 2010)

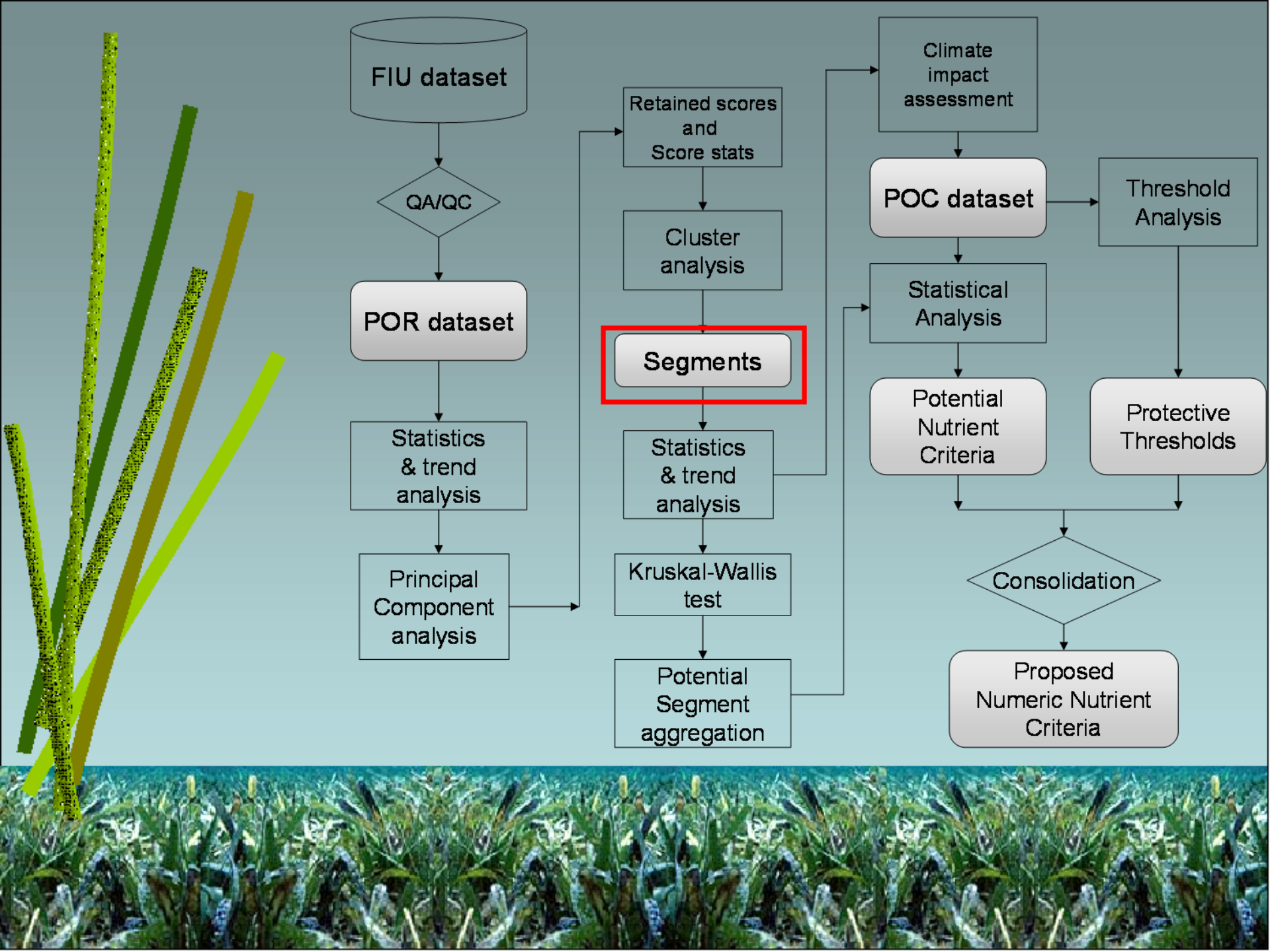


Biscayne Bay Segmentation



Region	FB	PIRB	BB1	BB2	SHELF	WWB-TTI	FK
POR	Mar 91-Dec 07	Jan 99-Sep 09	Sep 93-Sep 08	Jun 96-Sep 08	May 95-Sep 07	Sep 92-Sep 08	Mar 95-Oct 09
Input Variables for Factor Analysis	TN TP CHLA TOC SAL DO TURB NH4 NO3 NO2 SRP TEMP TON	TN TP CHLA TOC SAL DO TURB NH4 NO3 NO2 SRP	TN TP CHLA TOC SAL DO TURB NH4 NOx NO2 SRP	TN TP CHLA TOC SAL DO TURB NH4 NOx NO2 SRP	TN TP CHLA TOC SAL DO TURB NH4 NOx	TN TP CHLA TOC SAL DO TURB NH4	TN TP CHLA TOC SAL DO TURB TEMP
Stations	28	29	21	30	49	47	155
PC	6	5	5	5	4	4	4
Accounted Variance	79%	81%	76%	73%	63%	75%	66%
Segments	4 (+2)	6	6 (+1)	9	3	8	5


Area of interest
FIU WQ Site
Segment
WBID
0 10 20 Miles
SCB
PINE
EB
NPL
MARC
BLK
CI
GI
IWW
NNB
SNB
NCI
NCO
CTZ
MR
SCI
SCO
SCM
MGS
SRM
Everglades National Park
Biscayne National Park
PD
CS
MBS
WWB
NFB
OGS
CL
ECFB
WFB
CFB
IGS
SFB
BAY
Dry Tortugas National Park
BACK
OCEAN
MAR
DRTO
GULF OF MEXICO
ATLANTIC OCEAN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Potential Nutrient Criteria
Protective Thresholds
Consolidation
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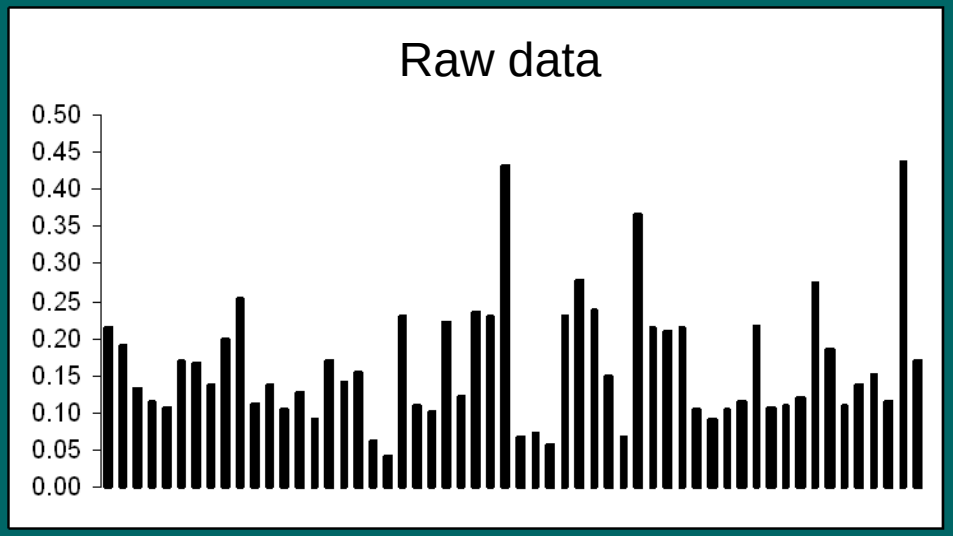
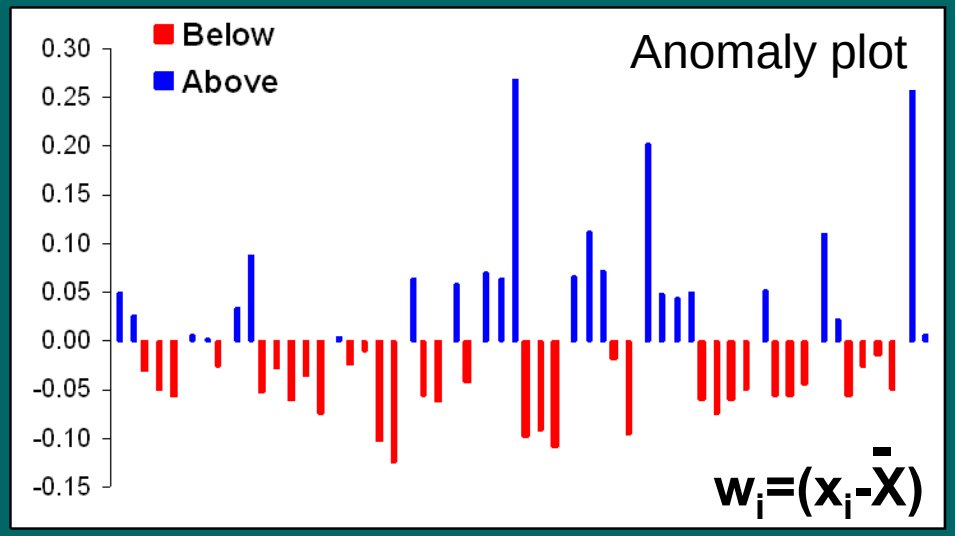
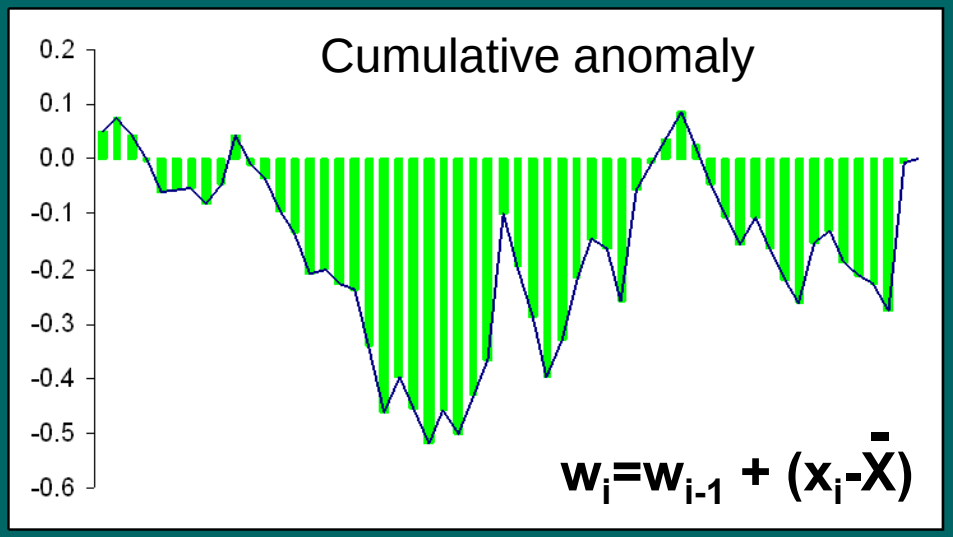
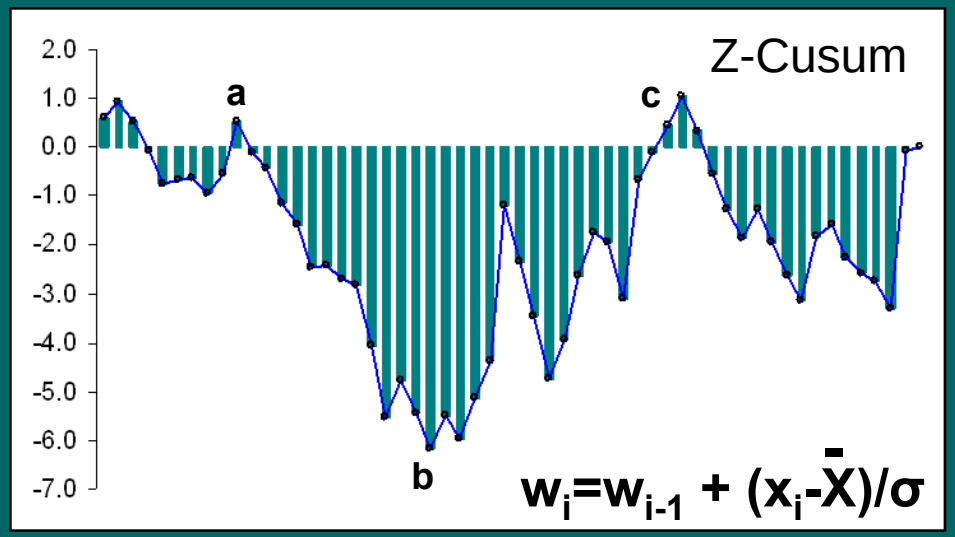
Modulation of WQ by multidecadal Climate Variability

Z-Cusum 101
Lecture 1



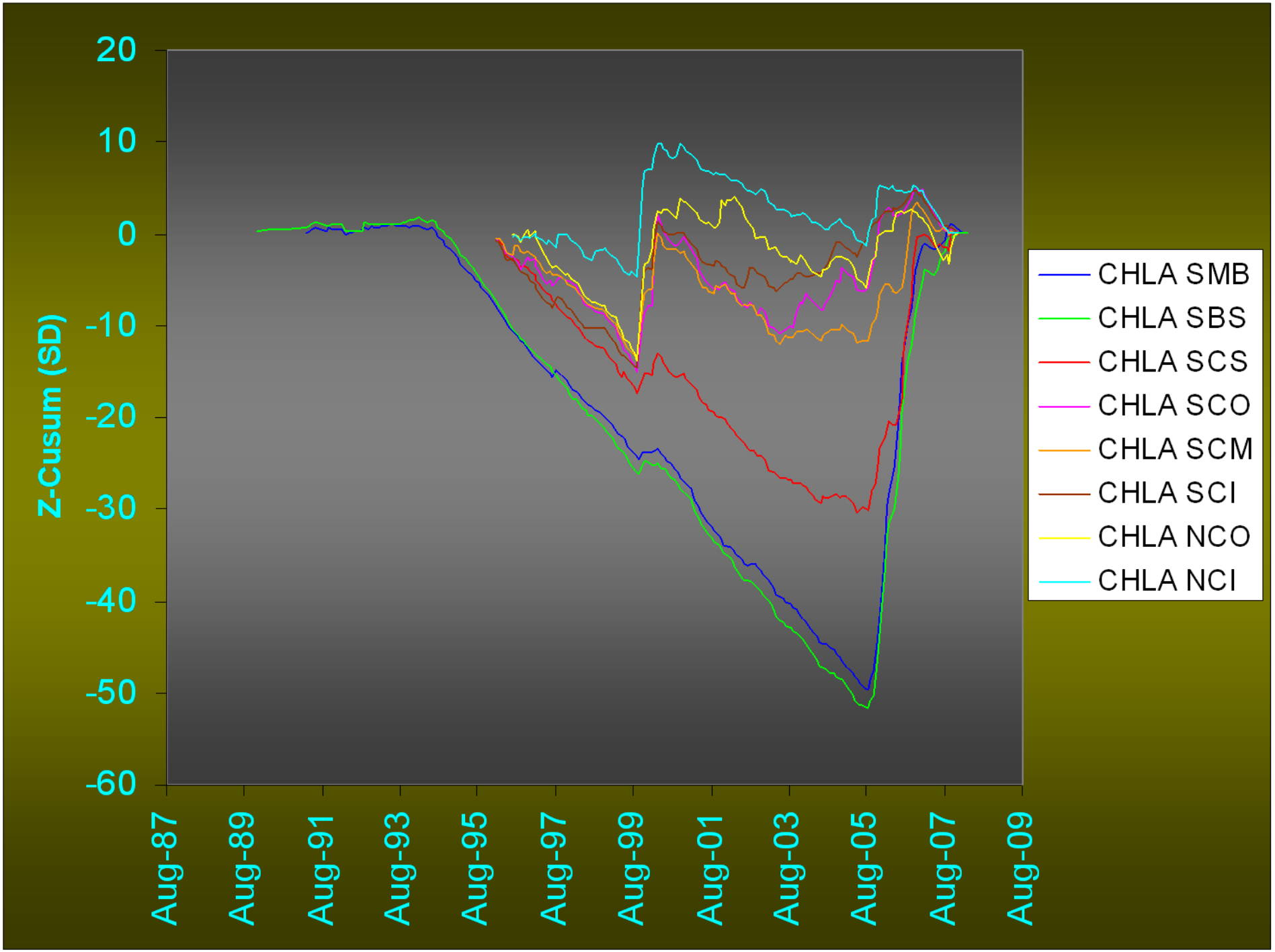




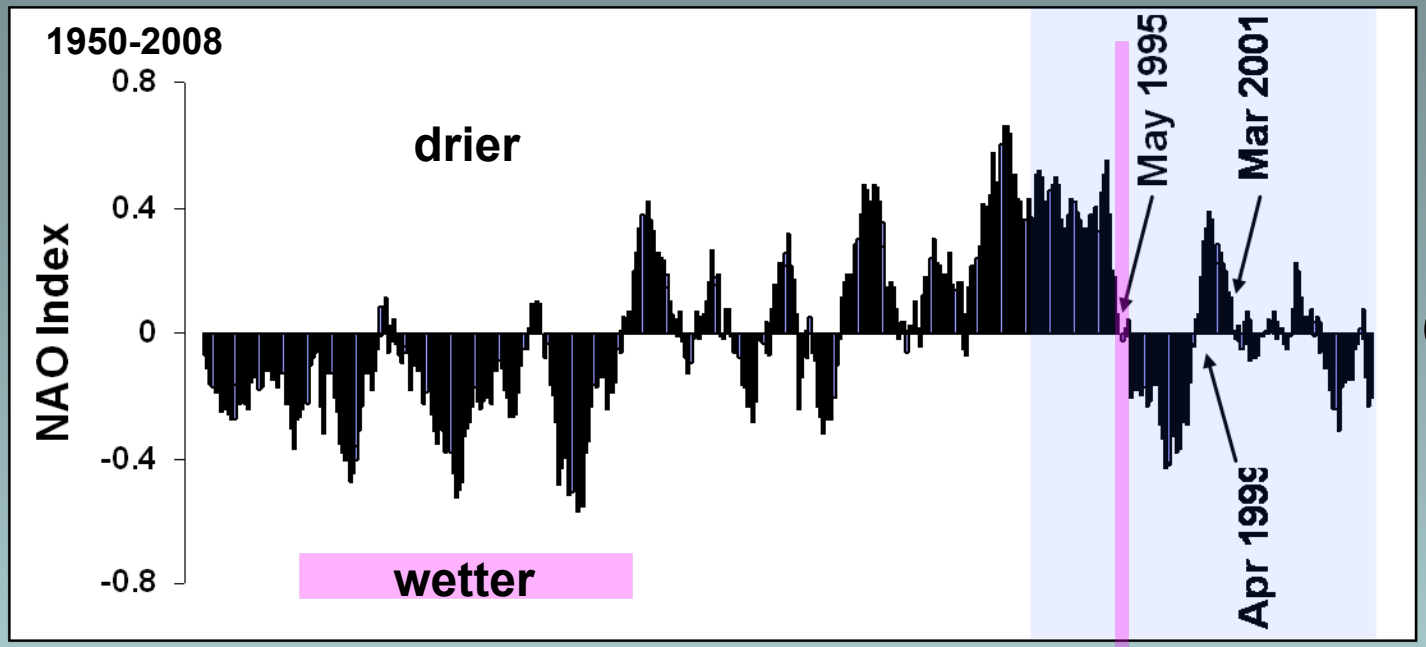


Running sum of anomaly data (deviation expressed in original units)

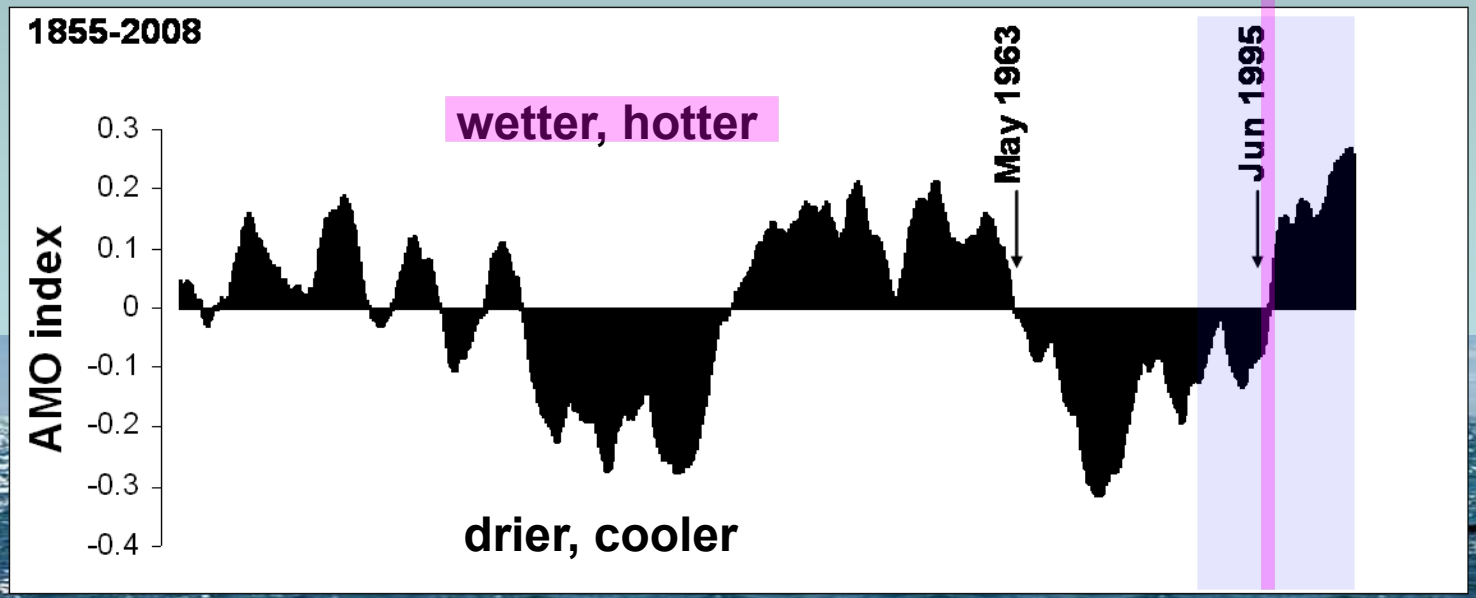
Running sum of z-scored data (deviation expressed as multiples of σ)


20
10
0
-10
-20
-30
-40
-50
-60
Z-Cusum (SD)
Aug-87
Aug-89
Aug-91
Aug-93
Aug-95
Aug-97
Aug-99
Aug-01
Aug-03
Aug-05
Aug-07
Aug-09
CHLA SMB
CHLA SBS
CHLA SCS
CHLA SCO
CHLA SCM
CHLA SCI
CHLA NCO
CHLA NCI

Coupled Global Atmospheric-Oceanographic forcing

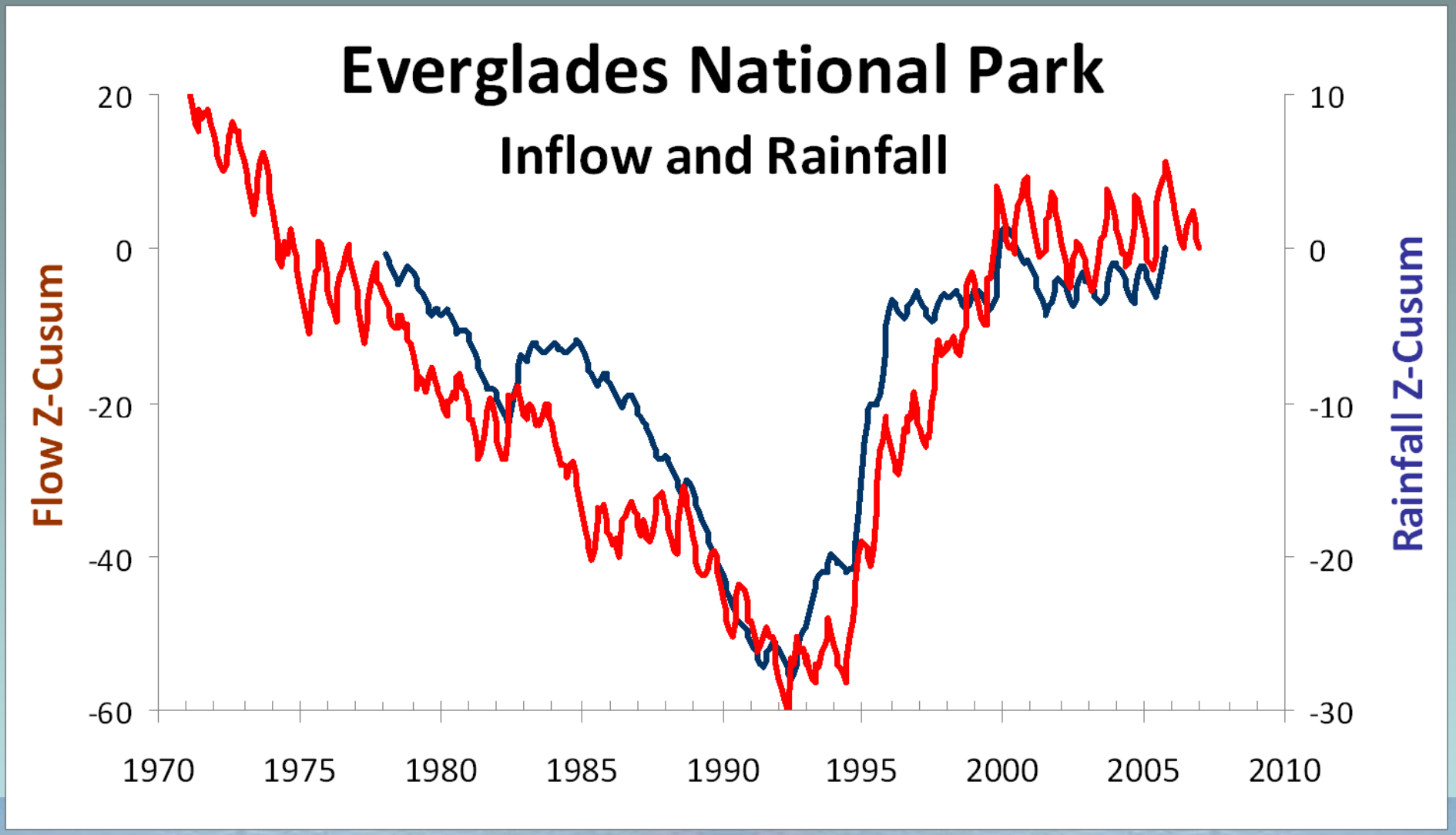


North Atlantic Oscillation

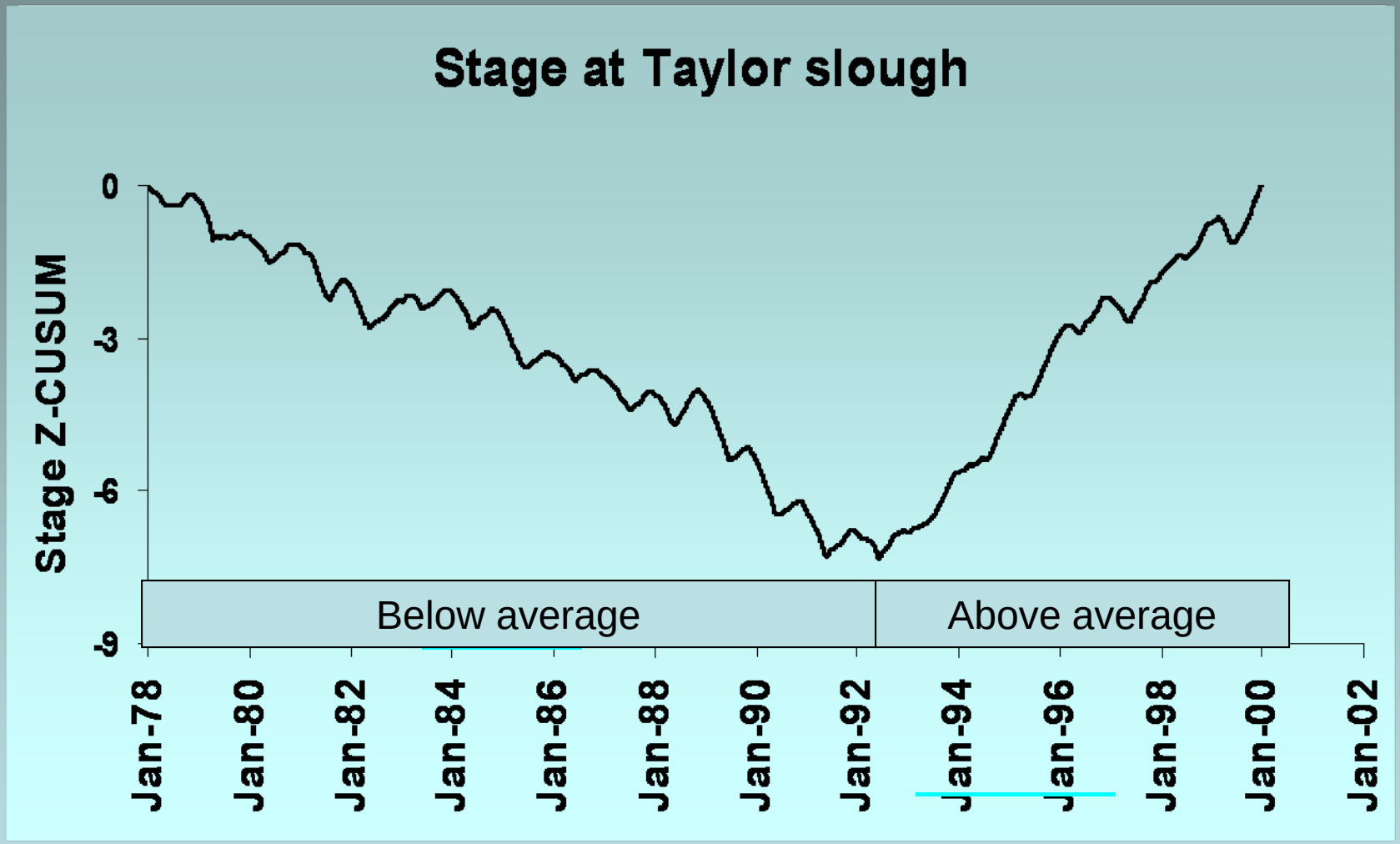


Atlantic Multidecadal Oscillation

Data source: NOAA CPC

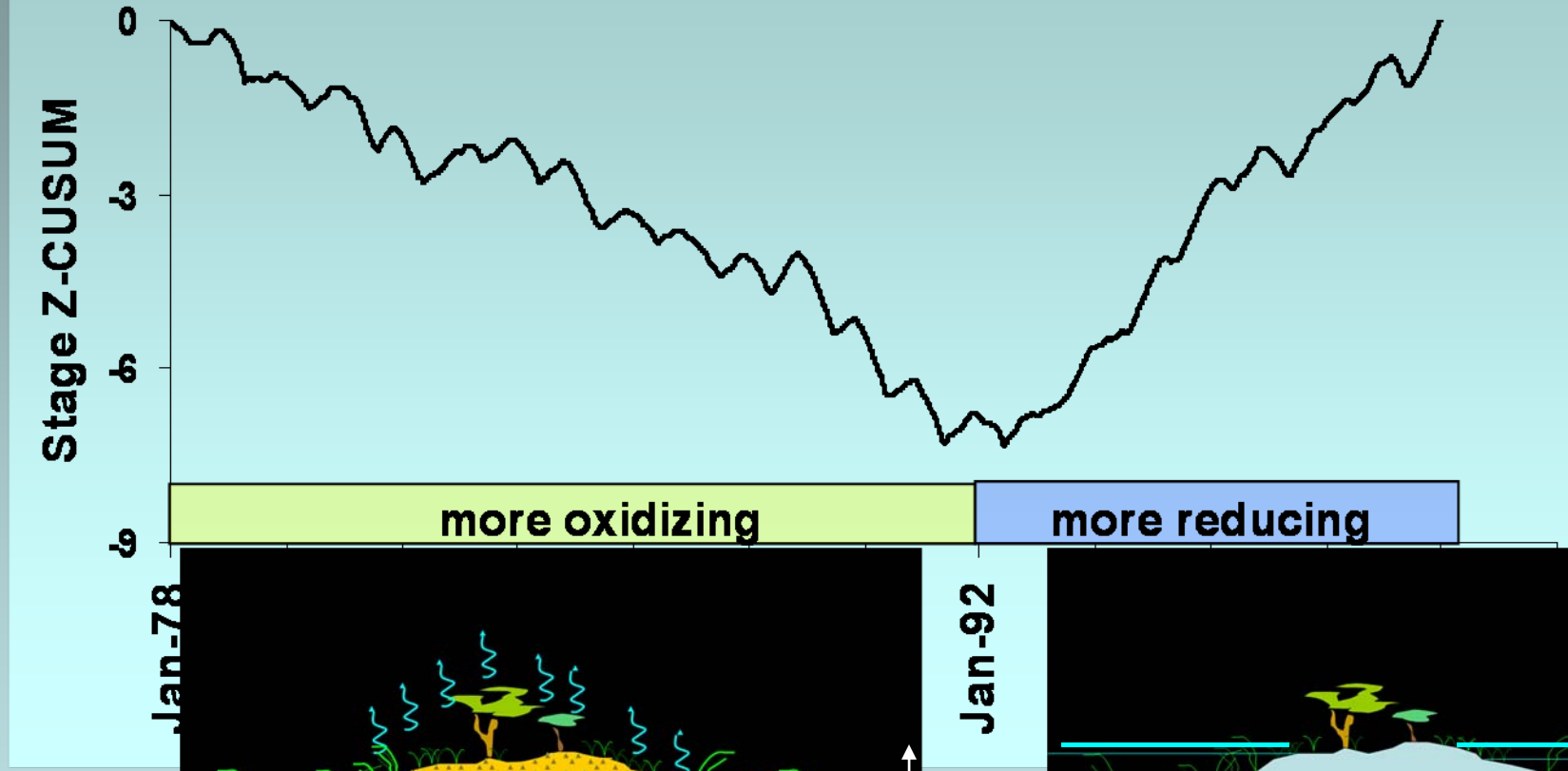

Everglades National Park
Inflow and Rainfall
Flow Z-Cusum
Rainfall Z-Cusum
20
0
-20
-40
-60
10
0
-10
-20
-30
1970
1975
1980
1985
1990
1995
2000
2005
2010

Source: NPS, Station TSB



Source: NPS, Station TSB

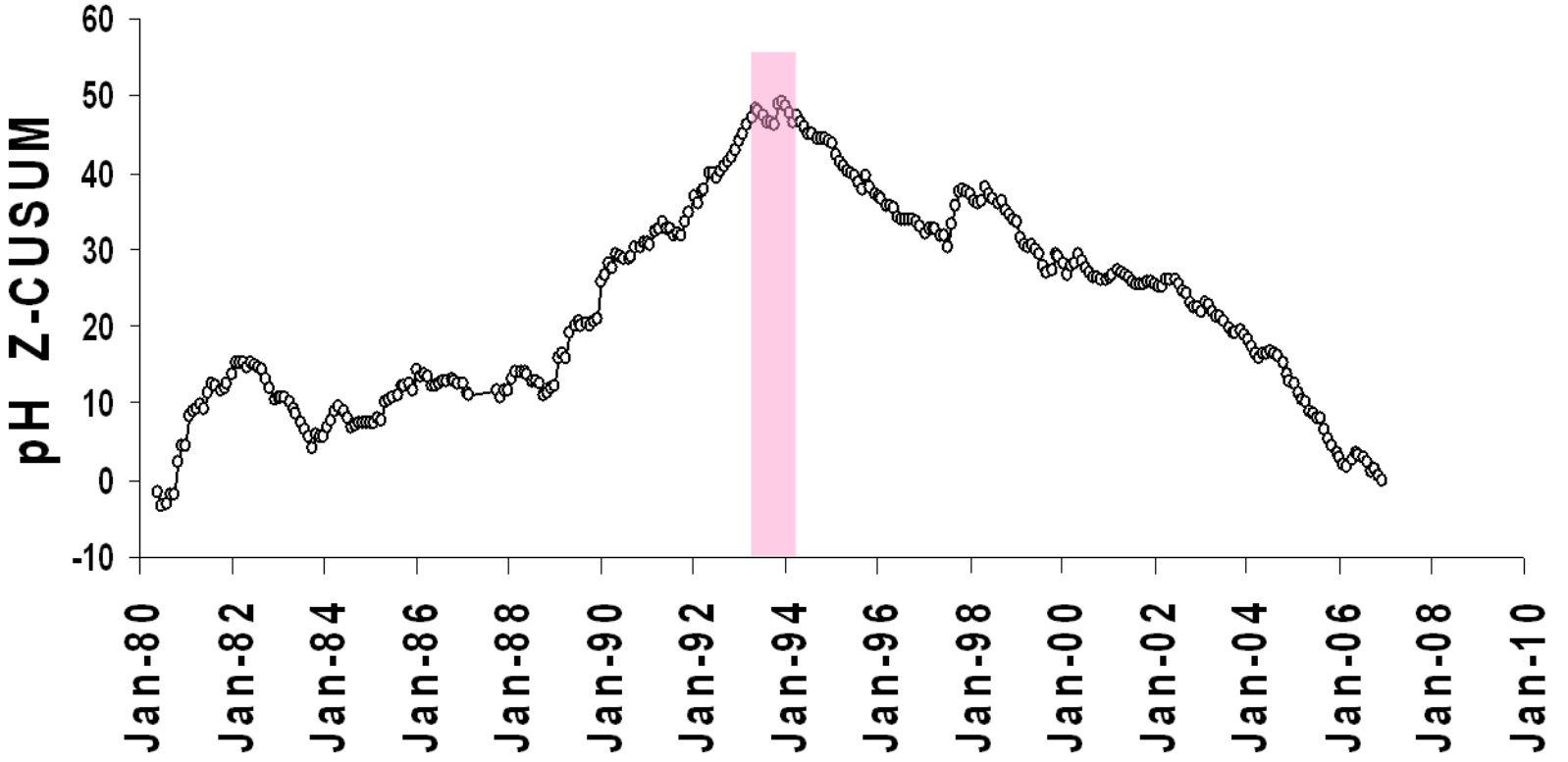
Stage at Taylor slough



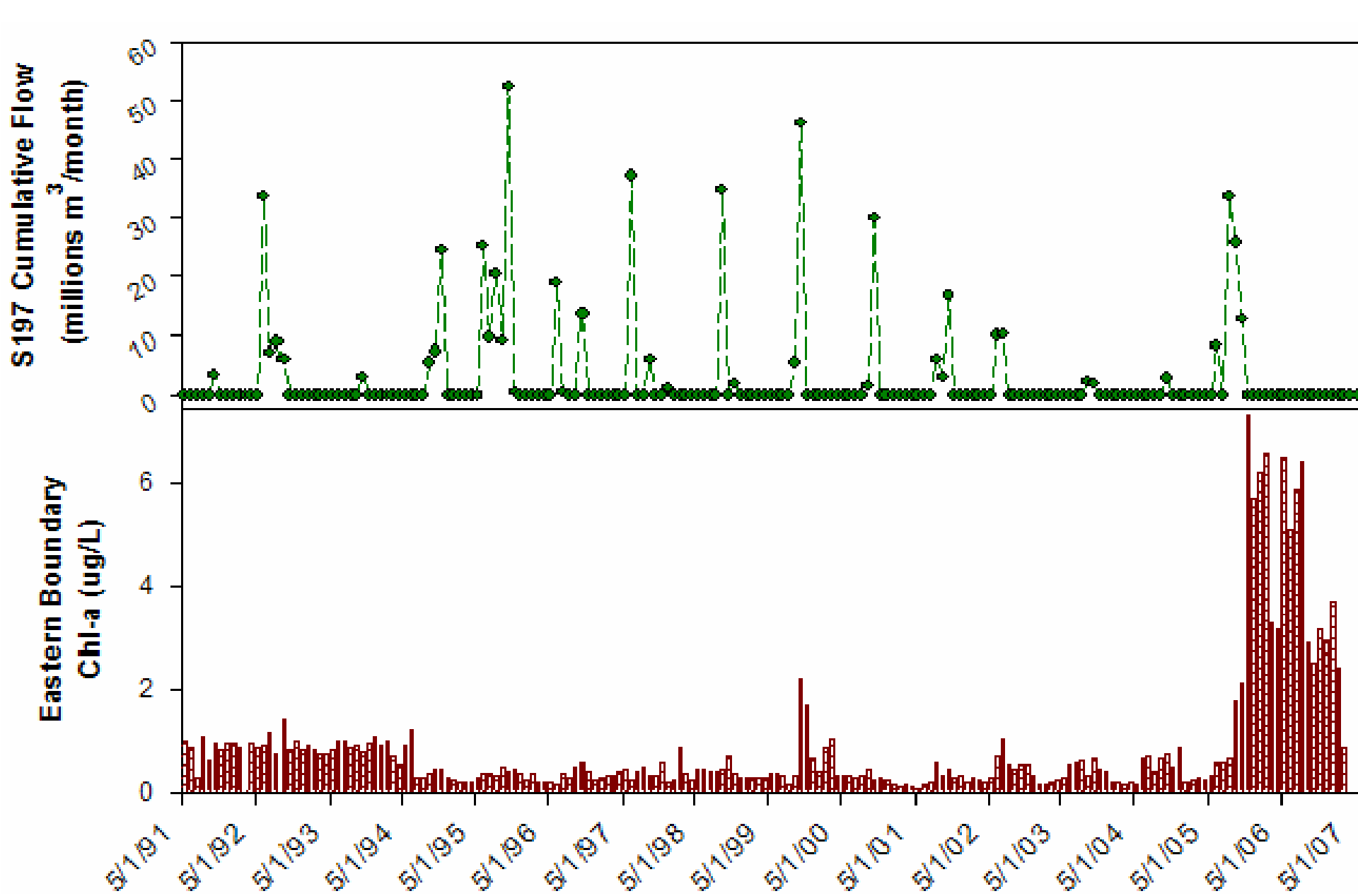
High nutrient contribution

Low nutrient contribution

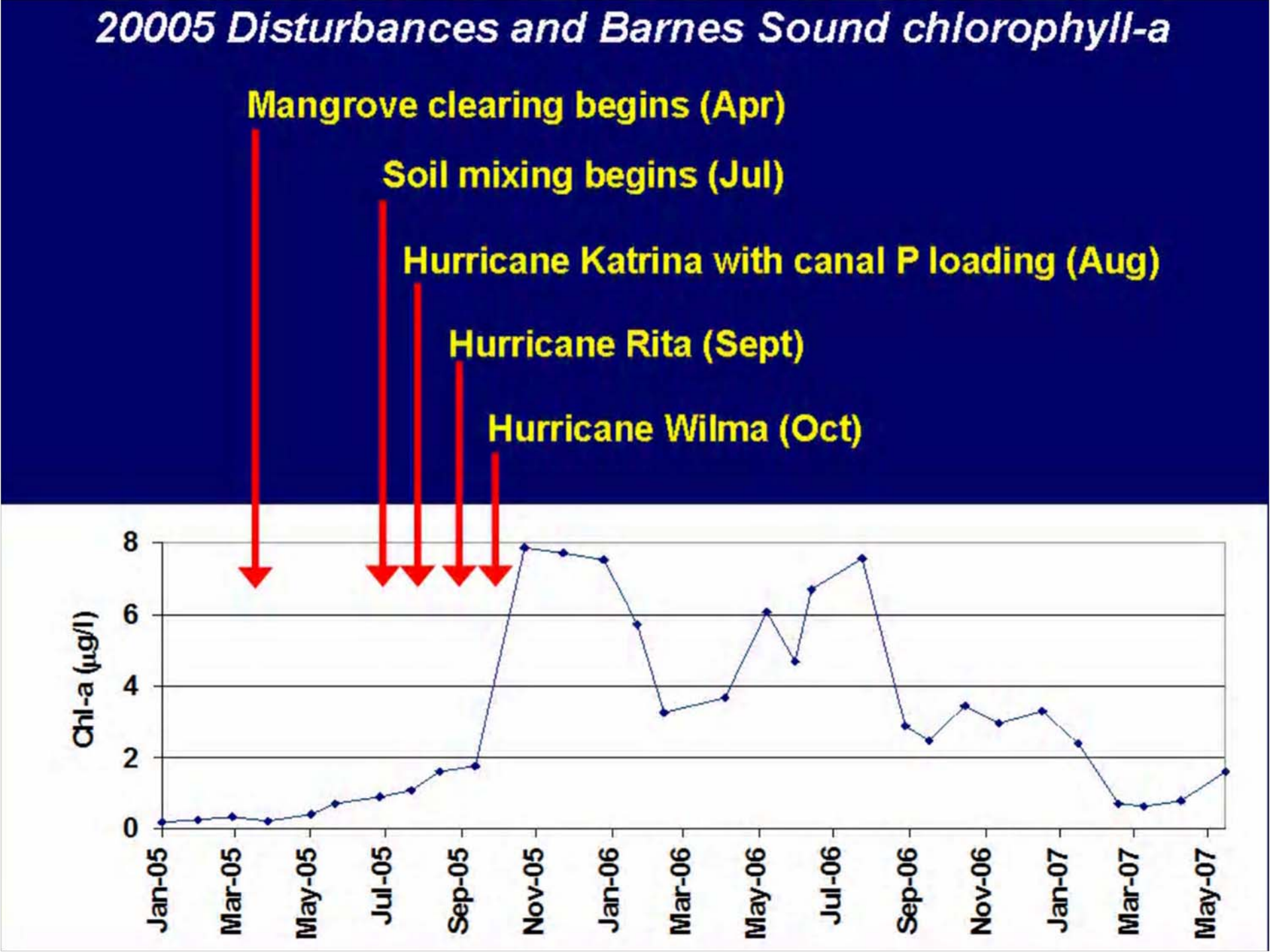
Atmospheric deposition pH



Hurricane Impact on Water Quality

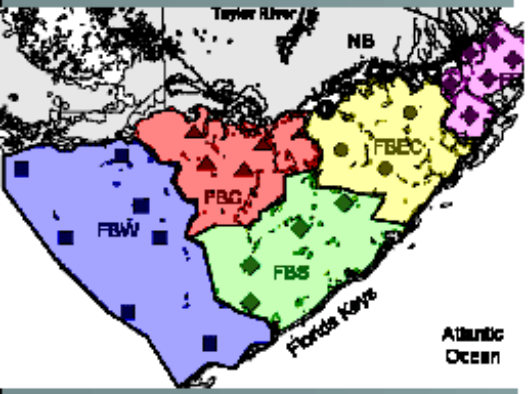

S197 Cumulative Flow
(millions m3/month)
0
10
20
30
40
50
60
Eastern Boundary
Chl-a (ug/L)
0
2
4
6
5/1/91
5/1/92
5/1/93
5/1/94
5/1/95
5/1/96
5/1/97
5/1/98
5/1/99
5/1/00
5/1/01
5/1/02
5/1/03
5/1/04
5/1/05
5/1/06
5/1/07

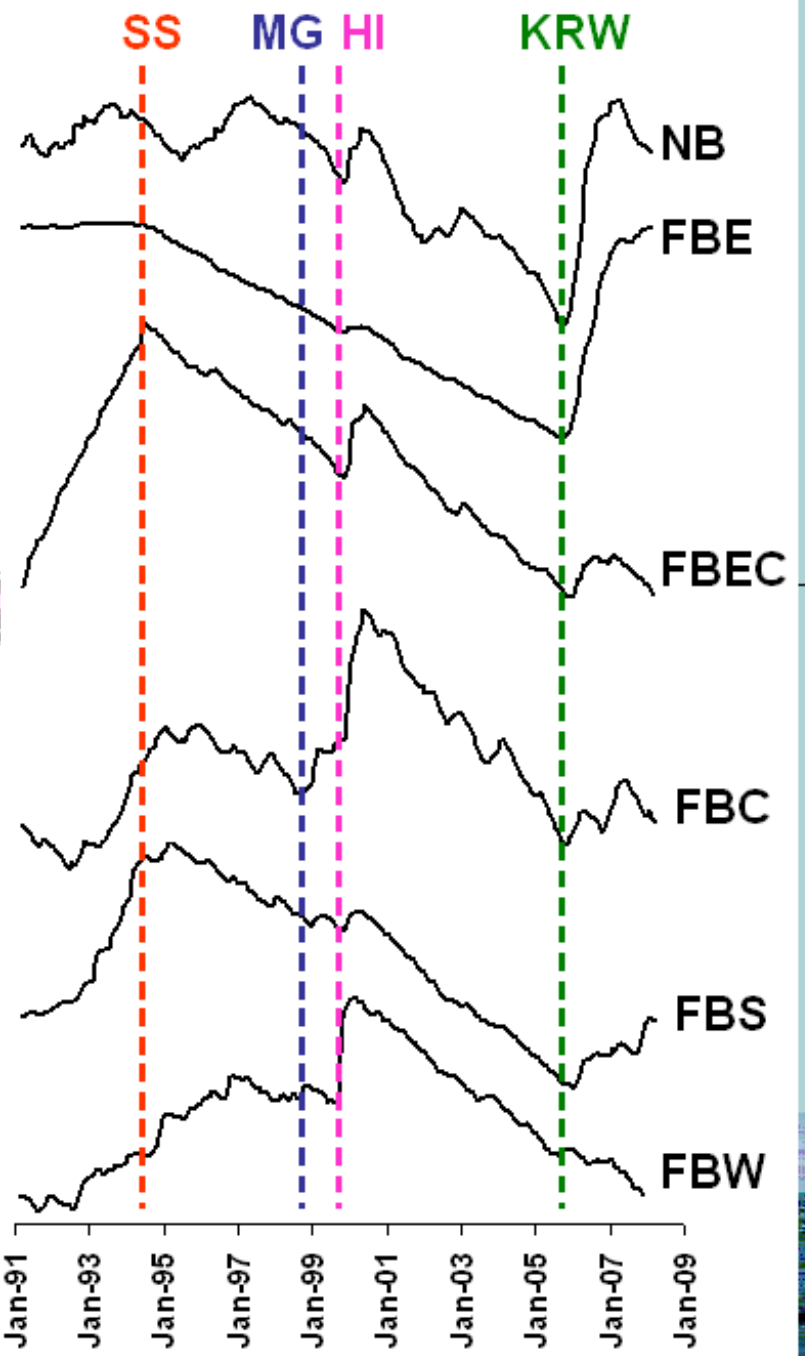
20005 Disturbances and Barnes Sound chlorophyll-a



COMBINE:
Hurricane impact
+
Large vol. water delivery
+
Disturbance due to Road construction
=
Algal bloom

Climate signals in Chlorophyll Time-series





GLOBAL+LOCAL DRIVERS

SS System Shift

HURRICANE DRIVEN

MG Mitch-Georges

HI Harvey-Irene

KRW Katrina-Rita-Wilma

Briceño & Boyer 2010

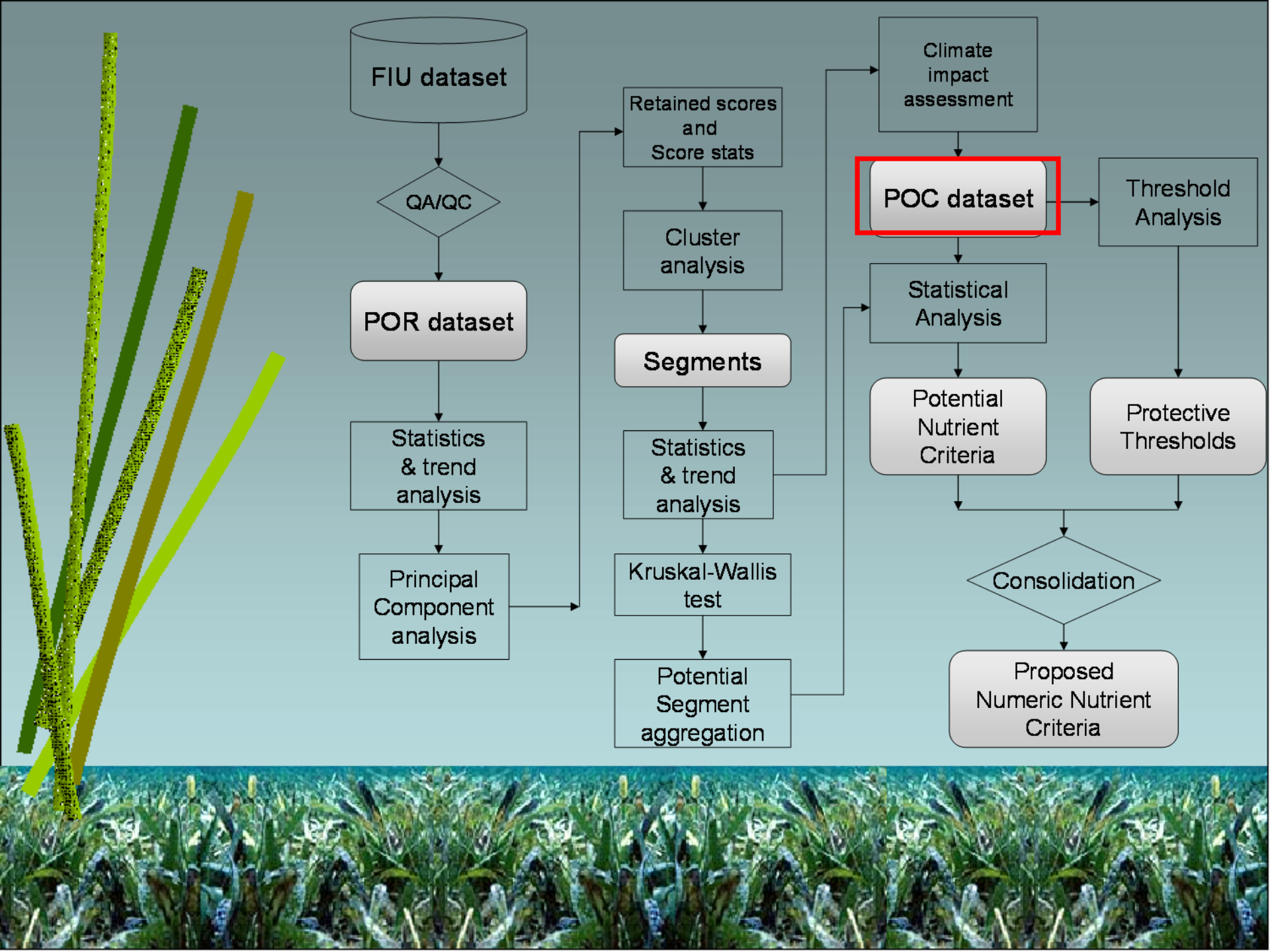
-Summary:

Period of Calculation should exclude pre-climate shift data and hurricane impacted data to better approach “normal” environmental conditions, supportive of its designated use.

Discarded impacted records corresponded in all instances to

1) pre-June 1995 data; and 2)sampling dates following extreme climatic events, especially after Hurricane Irene in 1999 and hurricanes Katrina, Rita and Wilma (KRW) in 2005

NOTE: Statistical outliers were not removed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Derivation of protective nutrient threshold

1- Selection of Biogeochemical Indicator

2- Calculation of indicator threshold for each segment

INDICATOR

Chlorophyll-a

KEY FINDINGS – SOUTHERN ESTUARIES

SUMMARY FINDING: Re-suspension of nutrients from the 2005 hurricane season resulted in algal blooms in many regions of the southern estuaries and may cause continued algal blooms in the bay for some time. However, this is expected to subside within a few additional years in lieu of further significant hurricane activity and if water flows to the southern estuaries is improved should return to predominantly green for all regions with the possible exception of BMB. If water flows do not improve the areas will probably remain yellow.

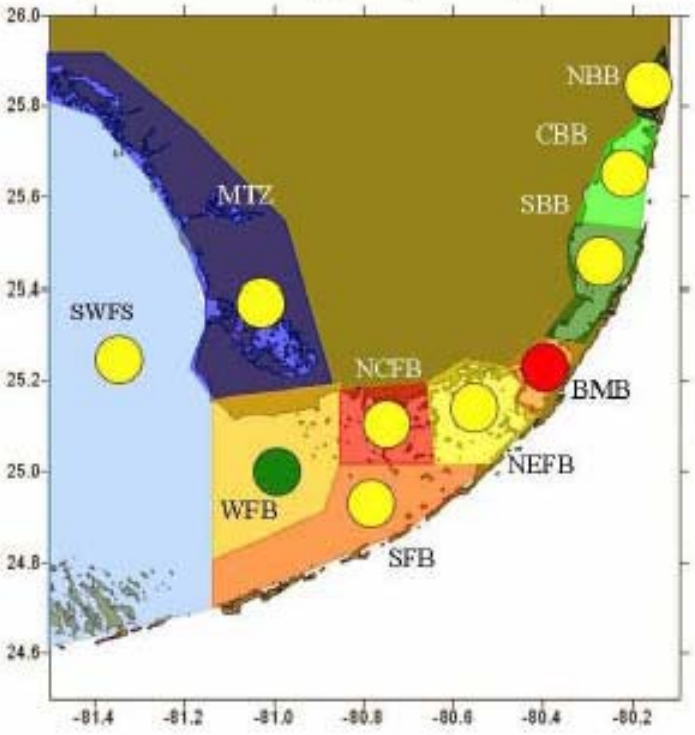


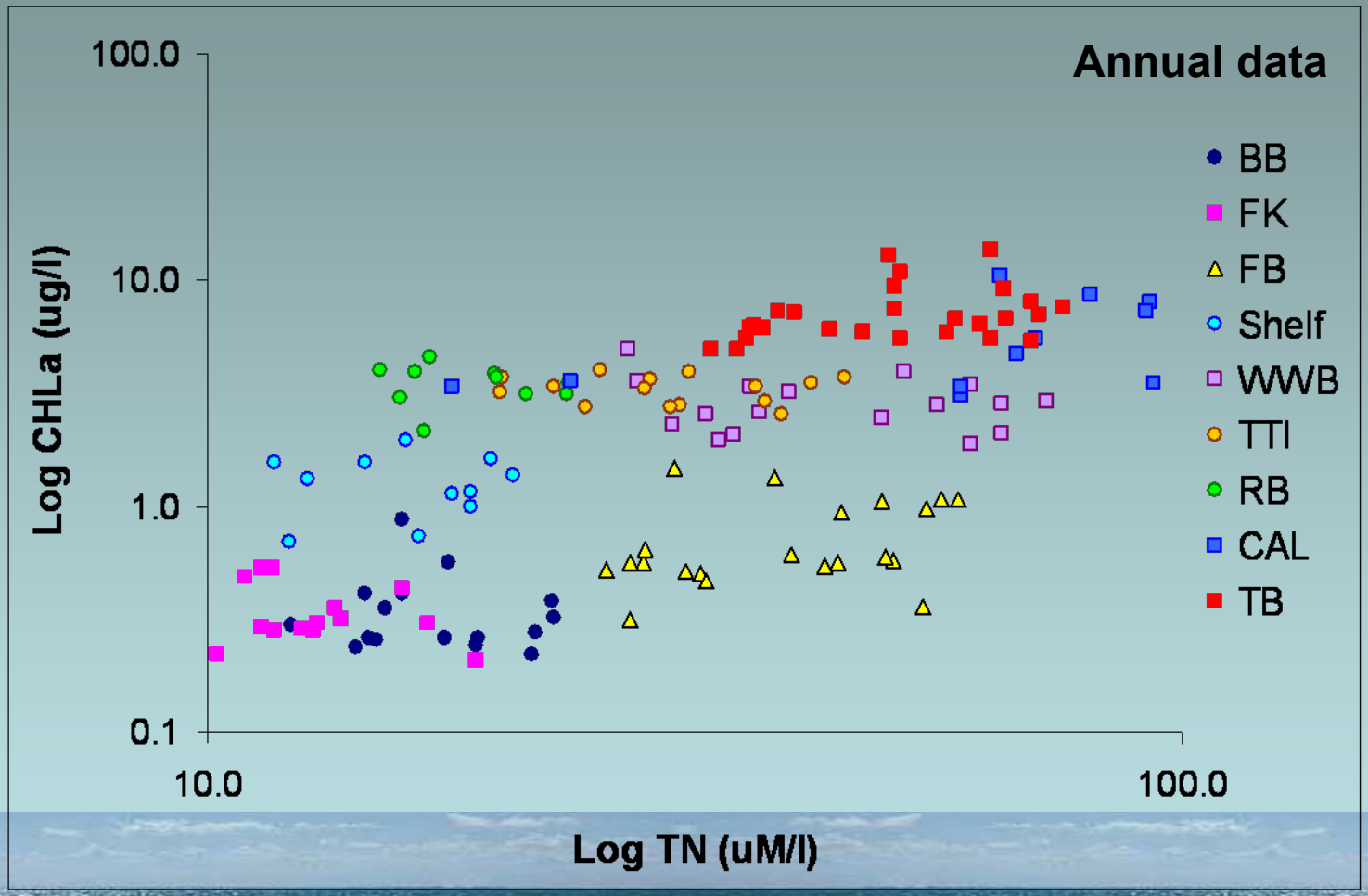
Figure 1. Map of Florida Bay regions with stoplight ratings by region

KEY FINDINGS:

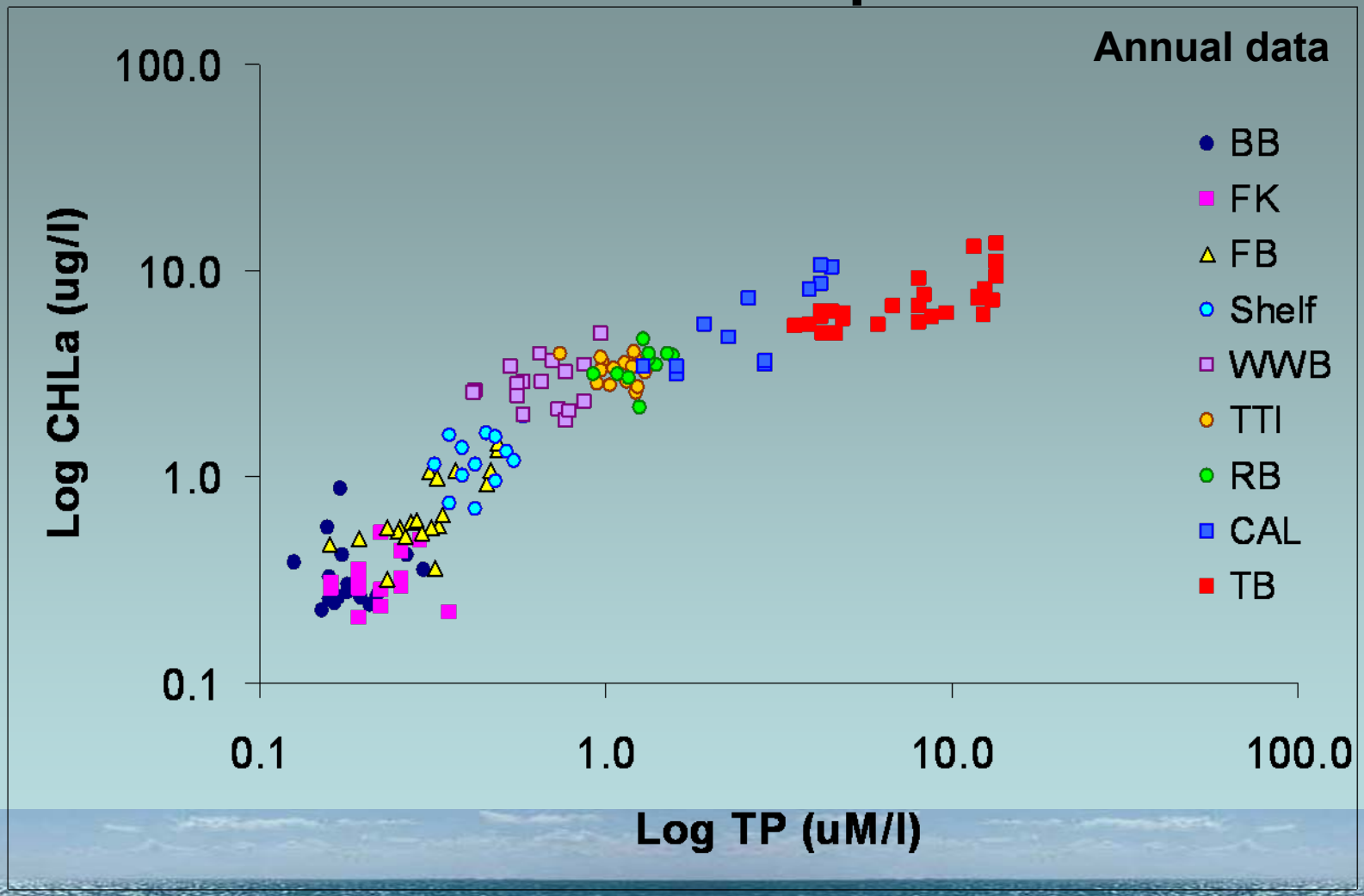
1. The majority of regions assessed had significant algal bloom activity that appears to have been predominantly influenced by the heavy 2005 hurricane season aggravated for the eastern bay by road construction on US 1.
2. The majority of regions assessed had chlorophyll-*a* and algal blooms rated as moderate (yellow).
3. The majority of regions assessed where the chlorophyll-*a* was higher than the median do not appear to be indicative of long-term negative trends.
4. The most commonly occurring condition was large spatial coverage of algal blooms and elevated chlorophyll-*a* concentrations.
5. Overall eutrophic symptom expressions were geographically variable and appear to be explainable from existing phenomenological conditions of hurricane activity overall exacerbated by road construction along US 1 in the eastern areas of the bay.

Boyer et al. 2009

Total Nitrogen : Chlorophyll-a Relationships



Total Phosphorous : Chlorophyll-a Relationships



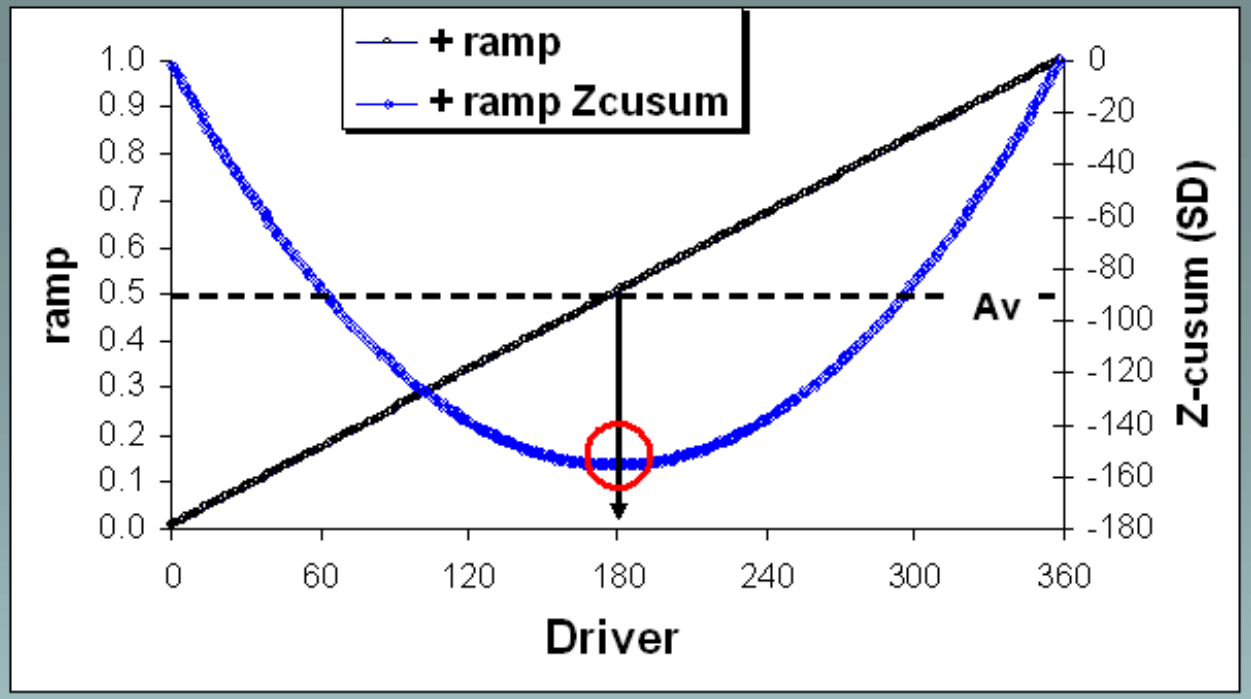
Threshold

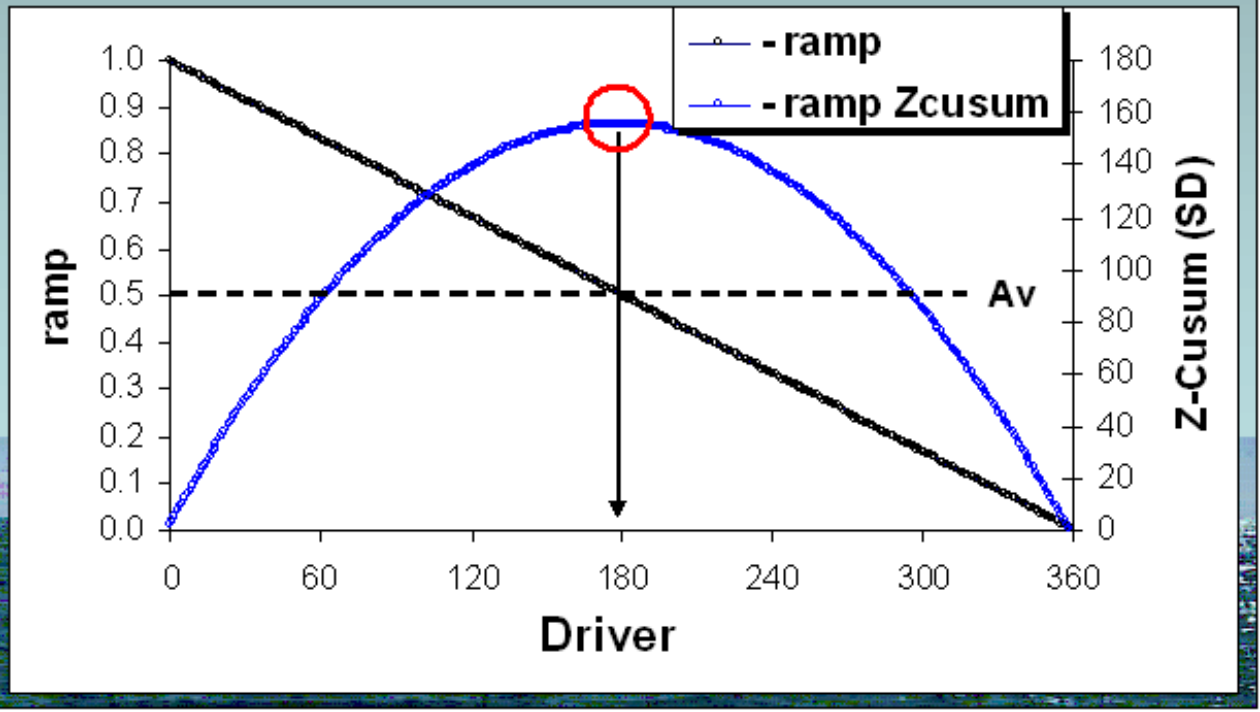
Nutrient level that if surpassed would trigger “anomalous” above average phytoplankton biomass responses, as measured by CHLa concentration

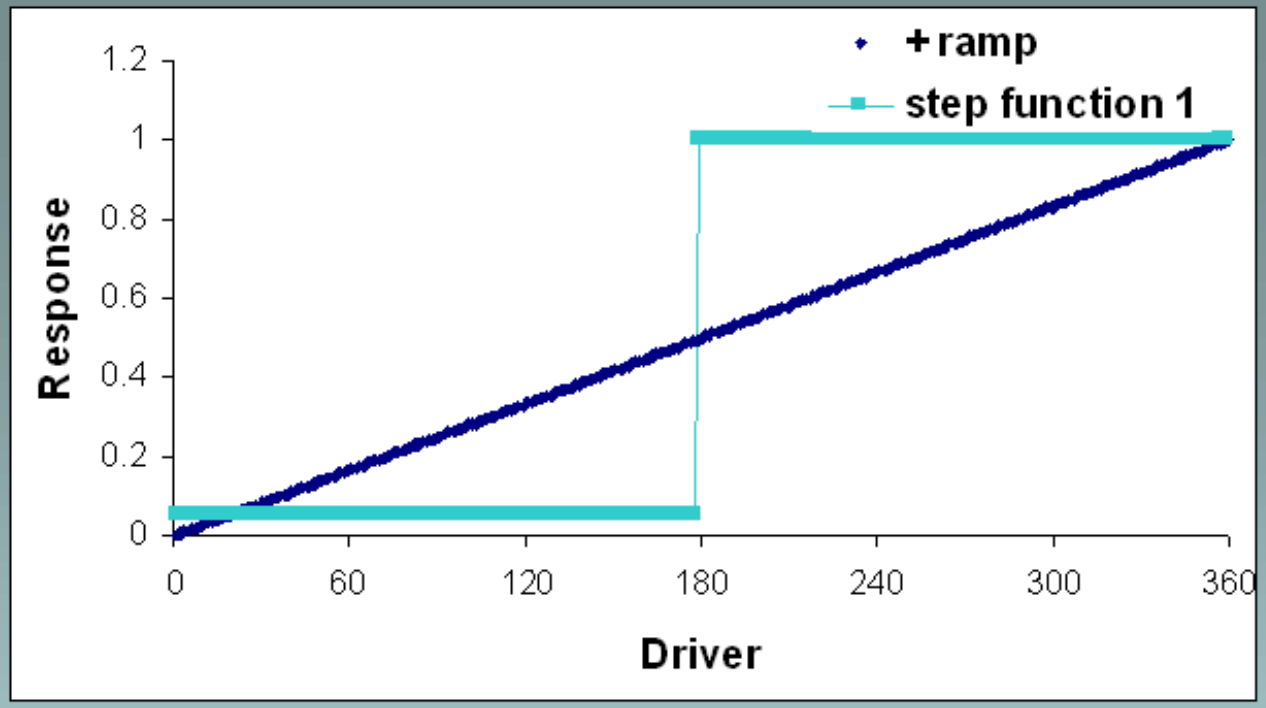
Z-Cusum 101

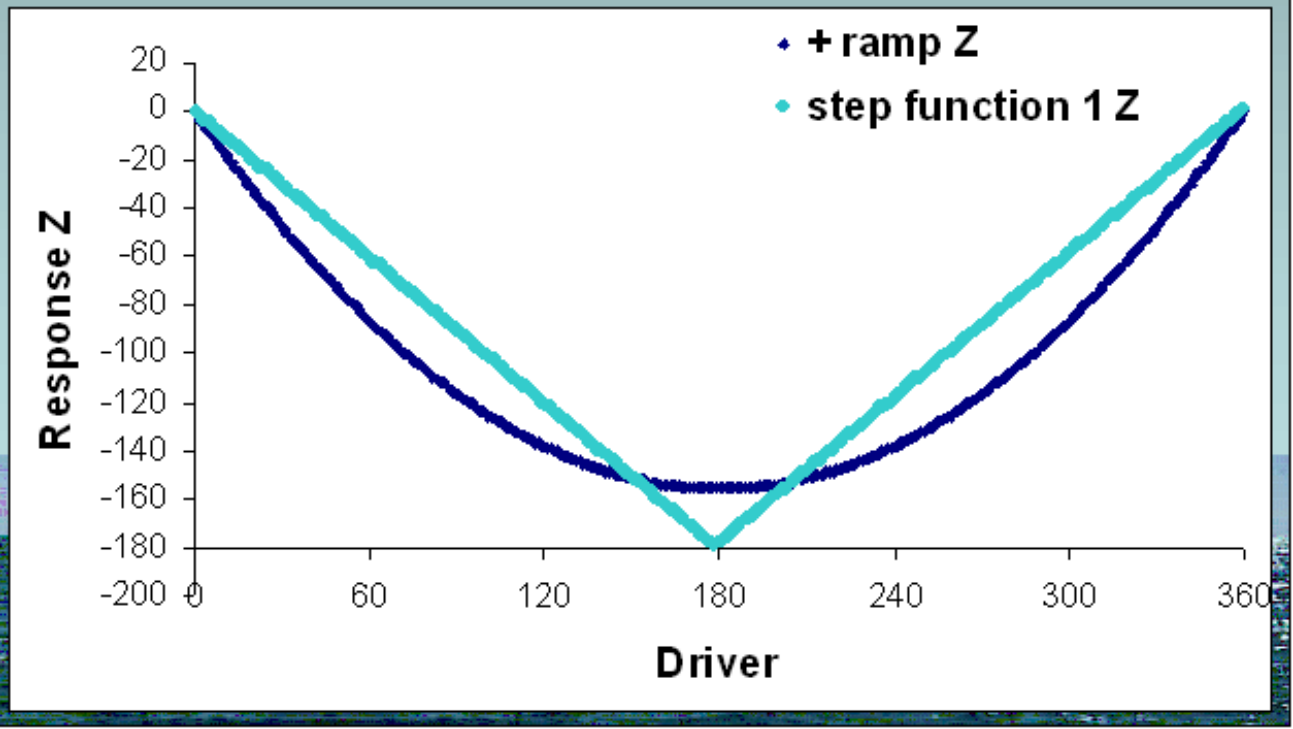
Lecture 2

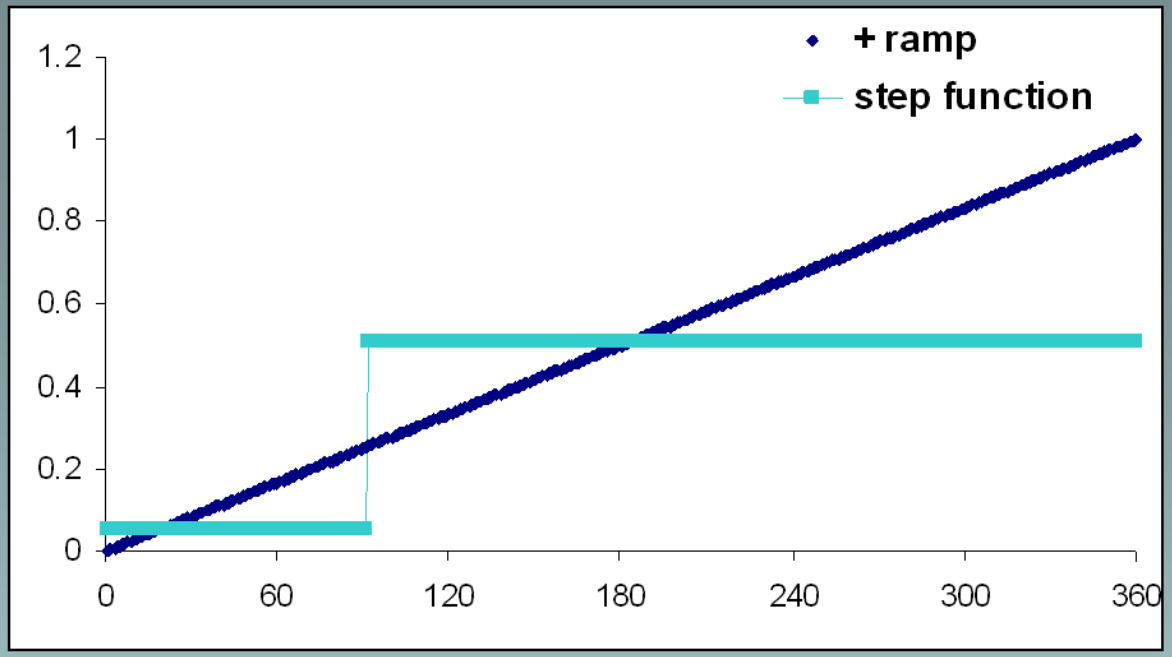
Z-Cusum data is a measure of cumulative deviation from a target value, in our case, the mean…

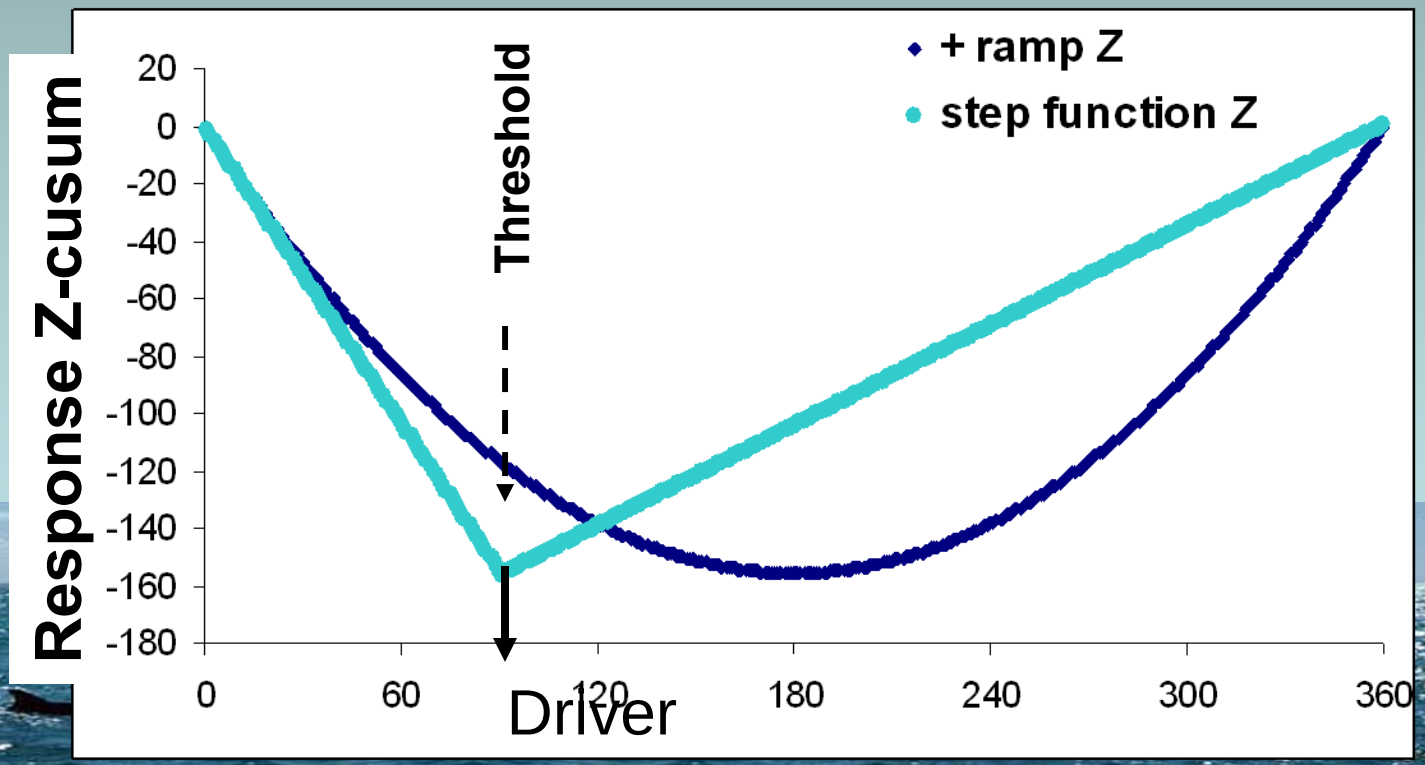

+ ramp
+ ramp Zcusum
ramp
Z-cusum (SD)
Av
Driver
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0
60
120
180
240
300
360

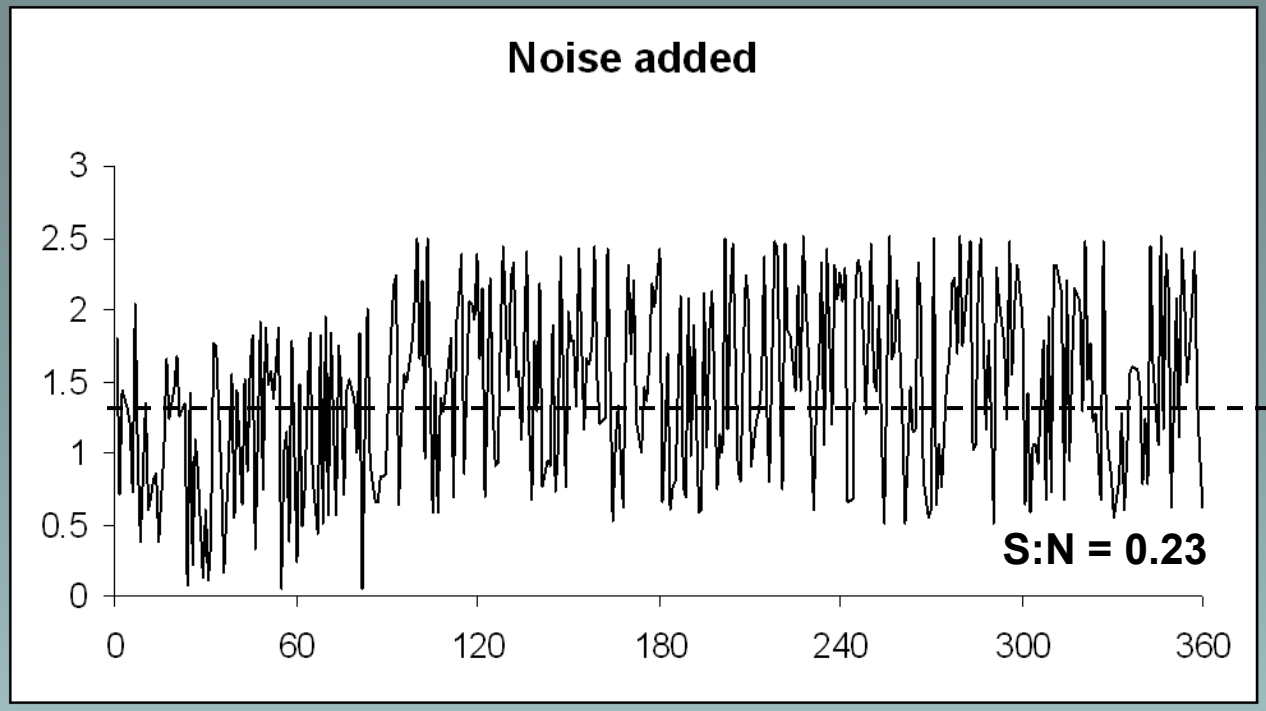

- ramp
- ramp Zcusum
ramp
Z-Cusum (SD)
Av
Driver
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
180
160
140
120
100
80
60
40
20
0
0
60
120
180
240
300
360


+ramp
step function 1
Response
1.2
1
0.8
0.6
0.4
0.2
0
0
60
120
180
240
300
360
Driver

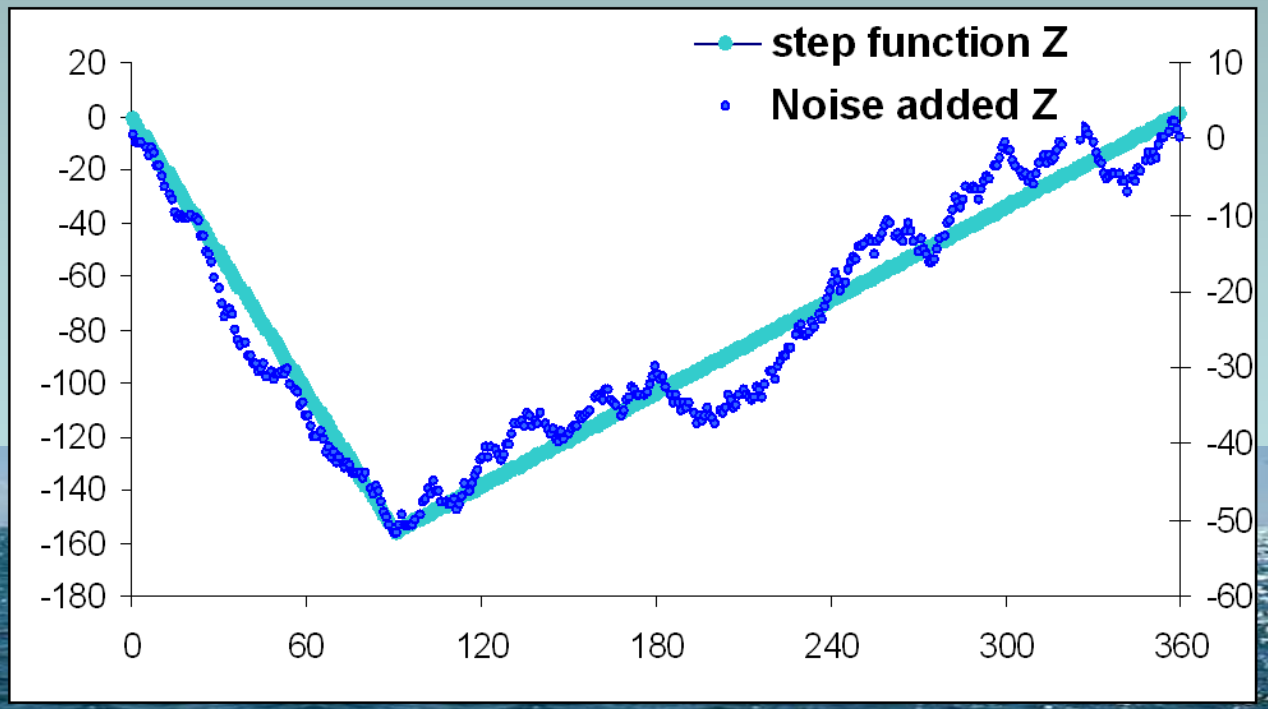

+ramp Z
step function 1 Z
Response Z
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
0
60
120
180
240
300
360
Driver


+ ramp
step function
1.2
1
0.8
0.6
0.4
0.2
0
0
60
120
180
240
300
360


+ ramp Z
step function Z
Threshold
Response Z-cusum
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0
60
120
180
240
300
360
Driver

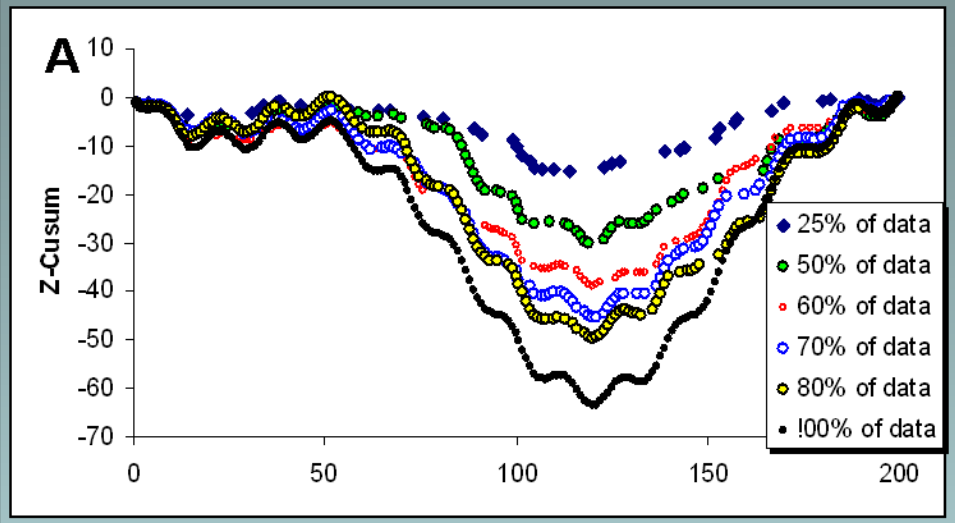


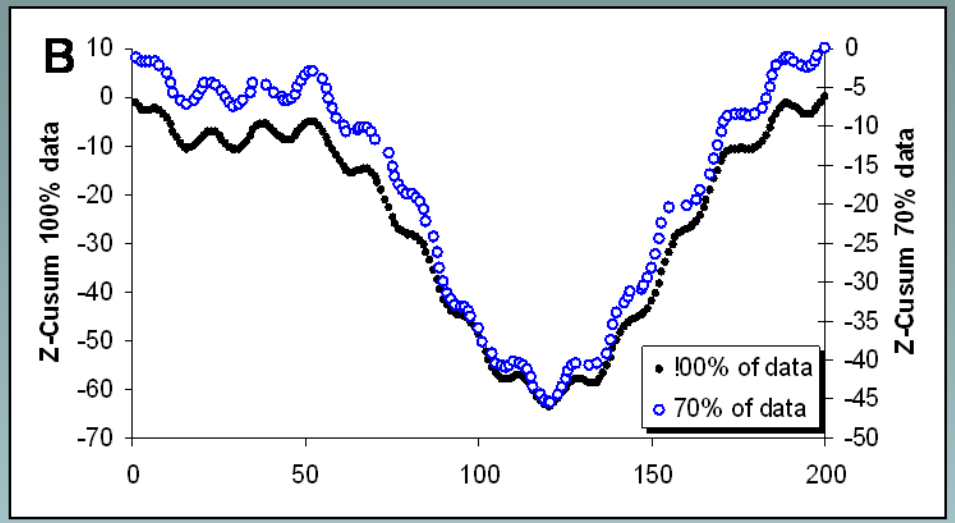
Z-Cusum transformation is a low-pass filter

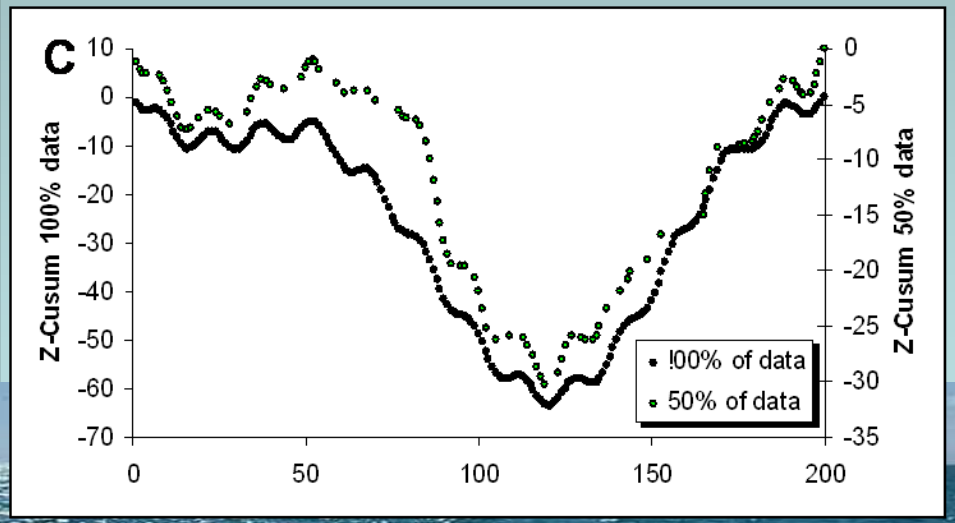


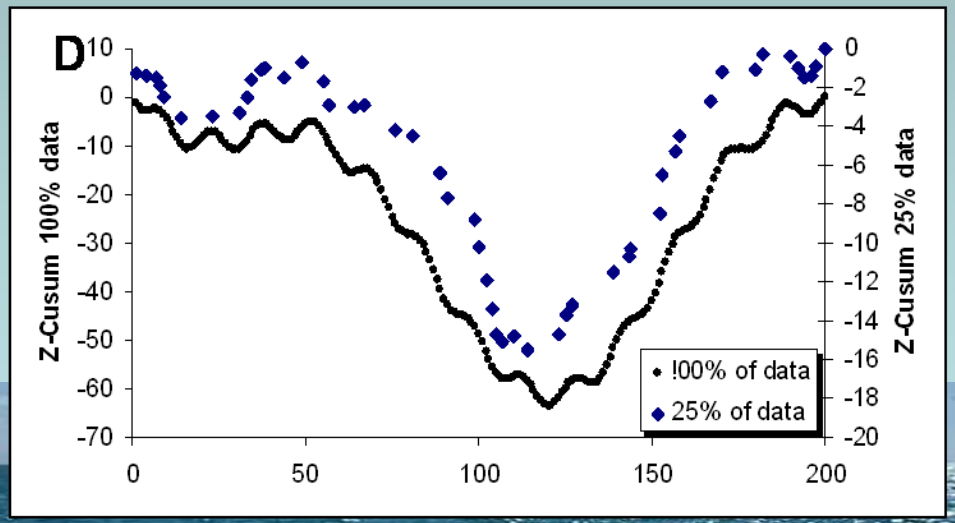
Resilience to data gaps

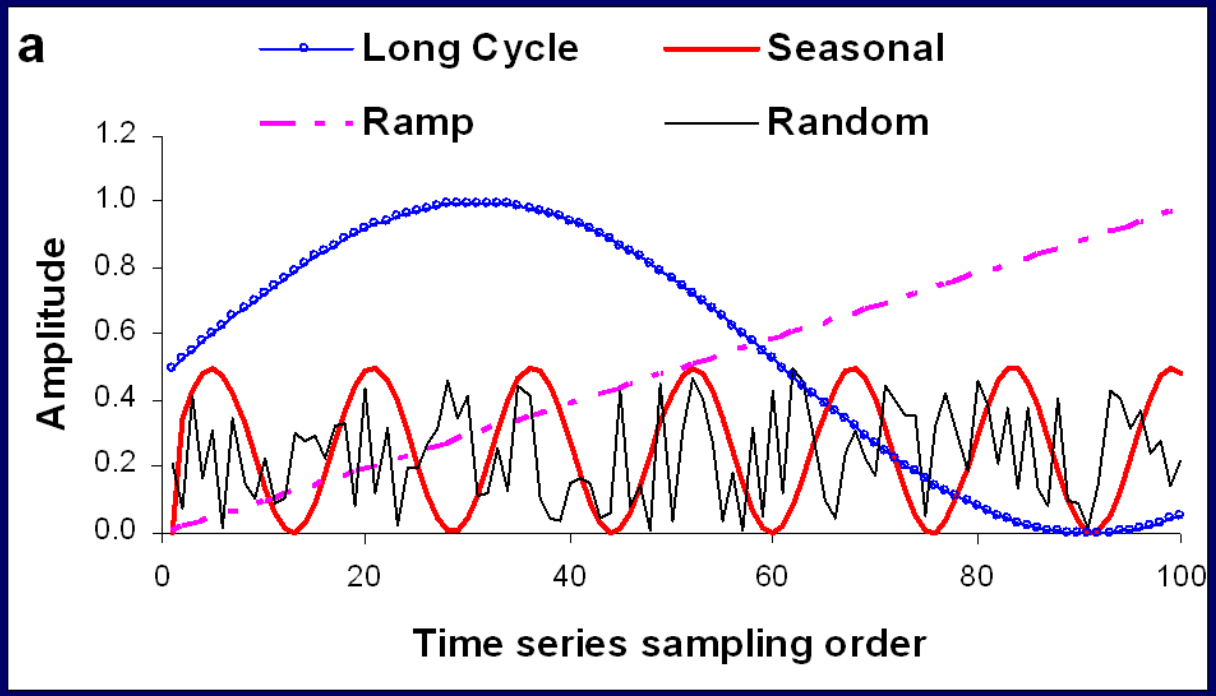
(hole-punching experiment)





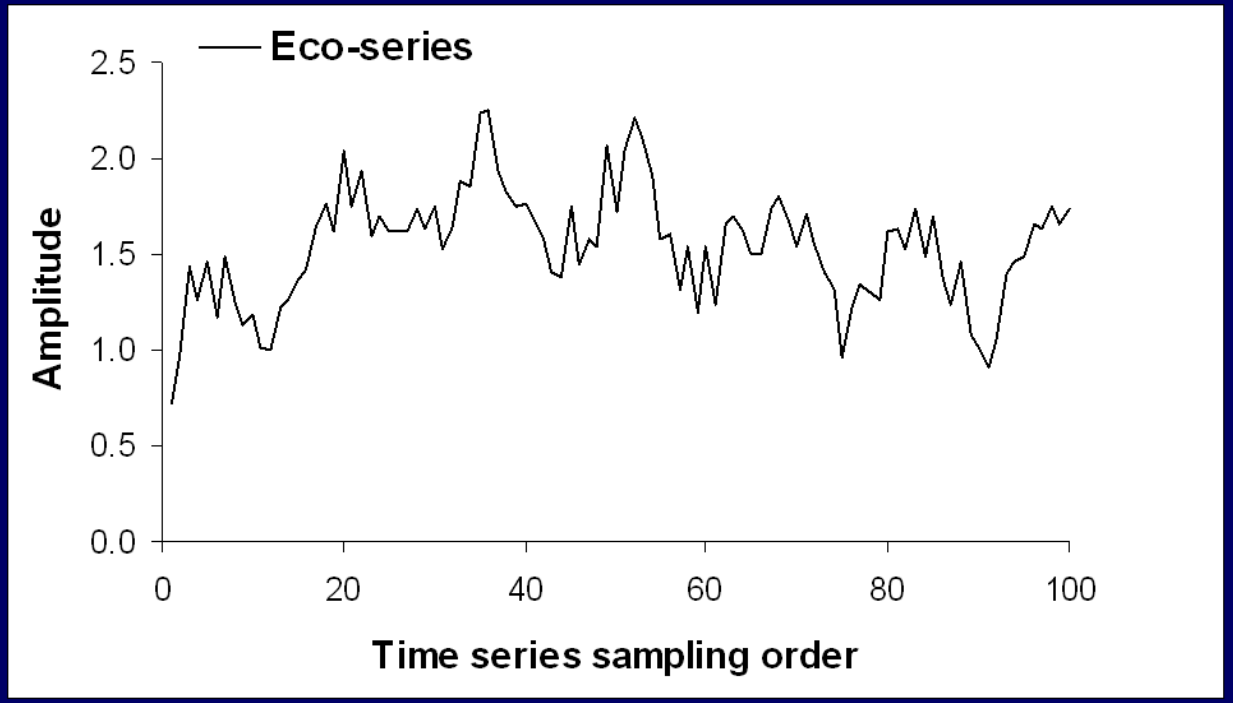


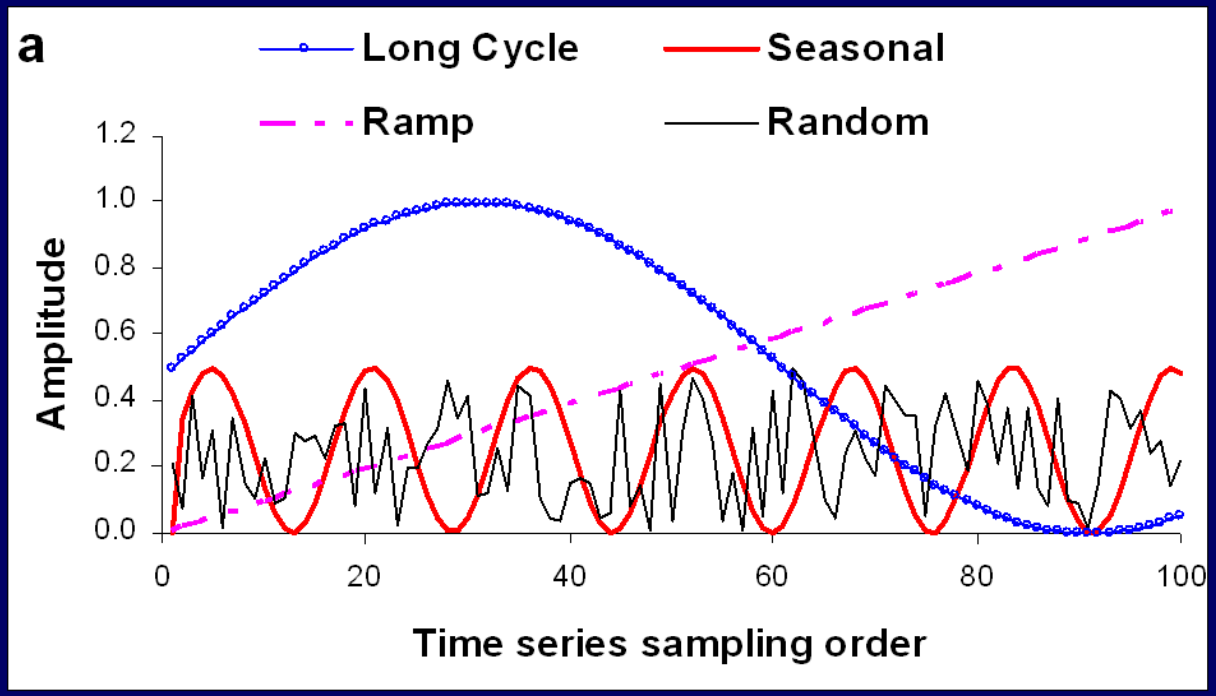




Time-series components

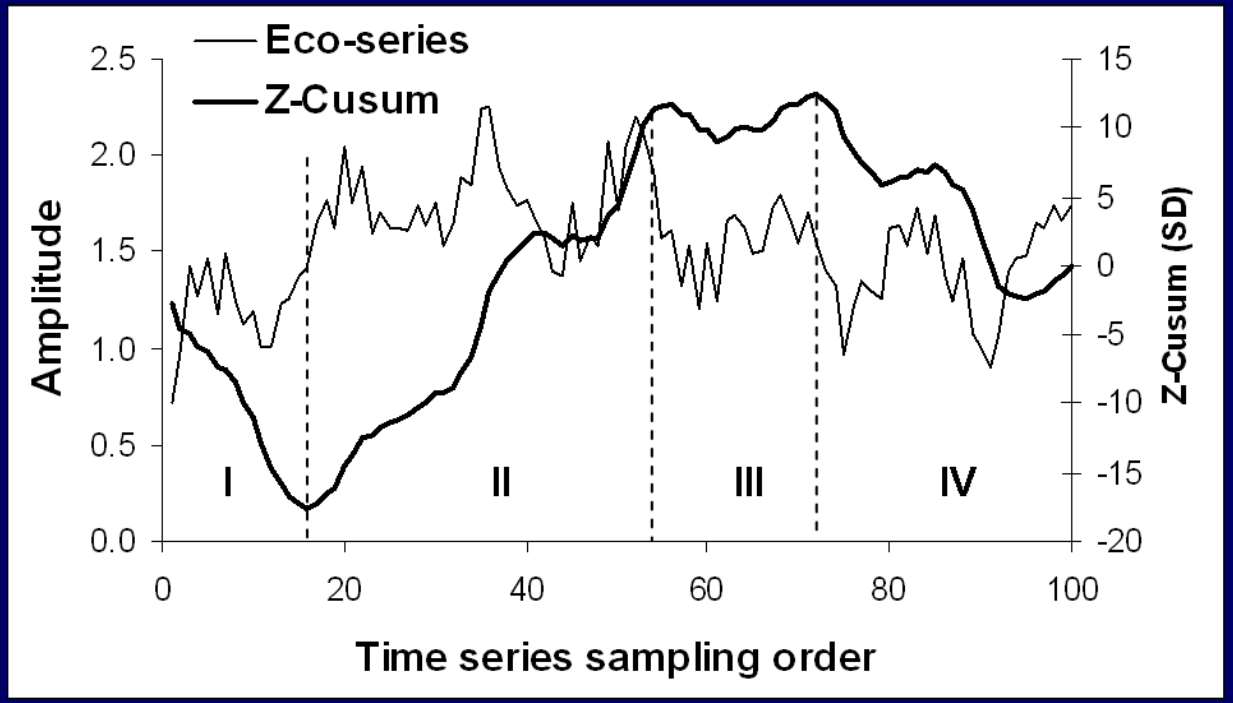
Resulting time-series





Time-series components

Resulting time-series and its Z-Cusum chart



End of Lecture 2

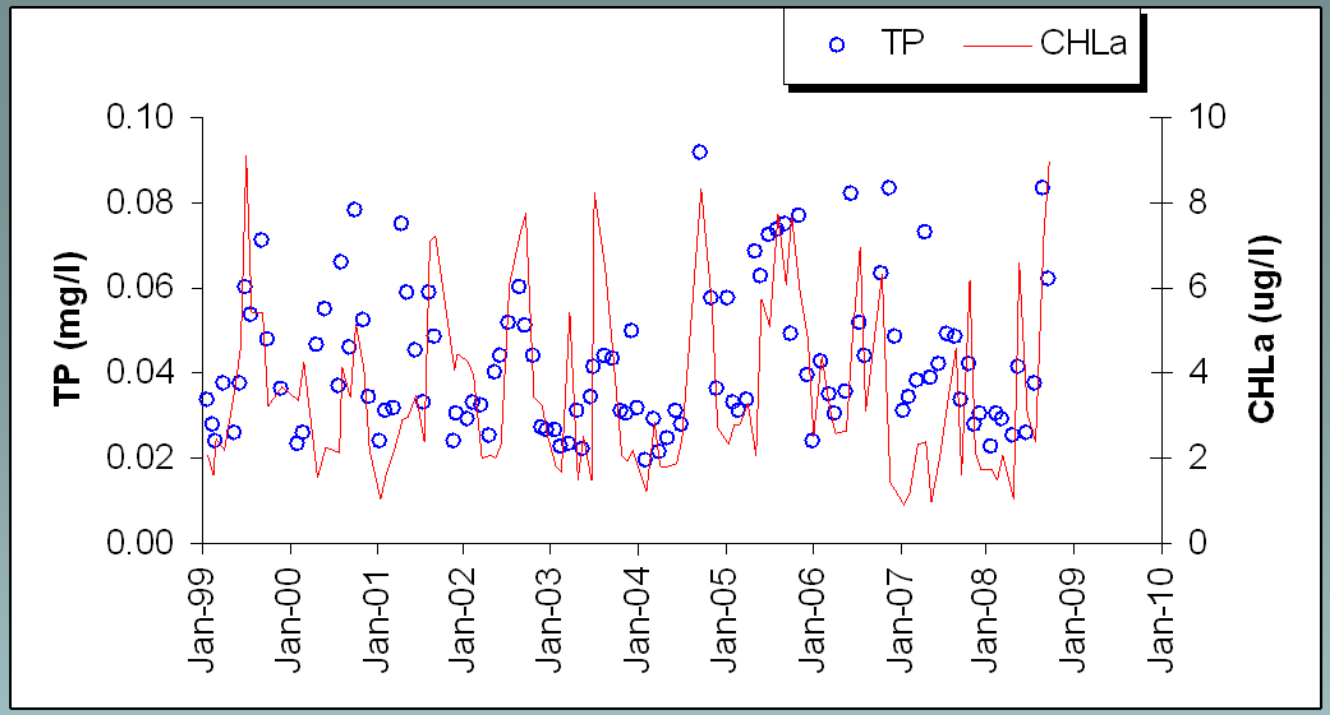
….and back to:

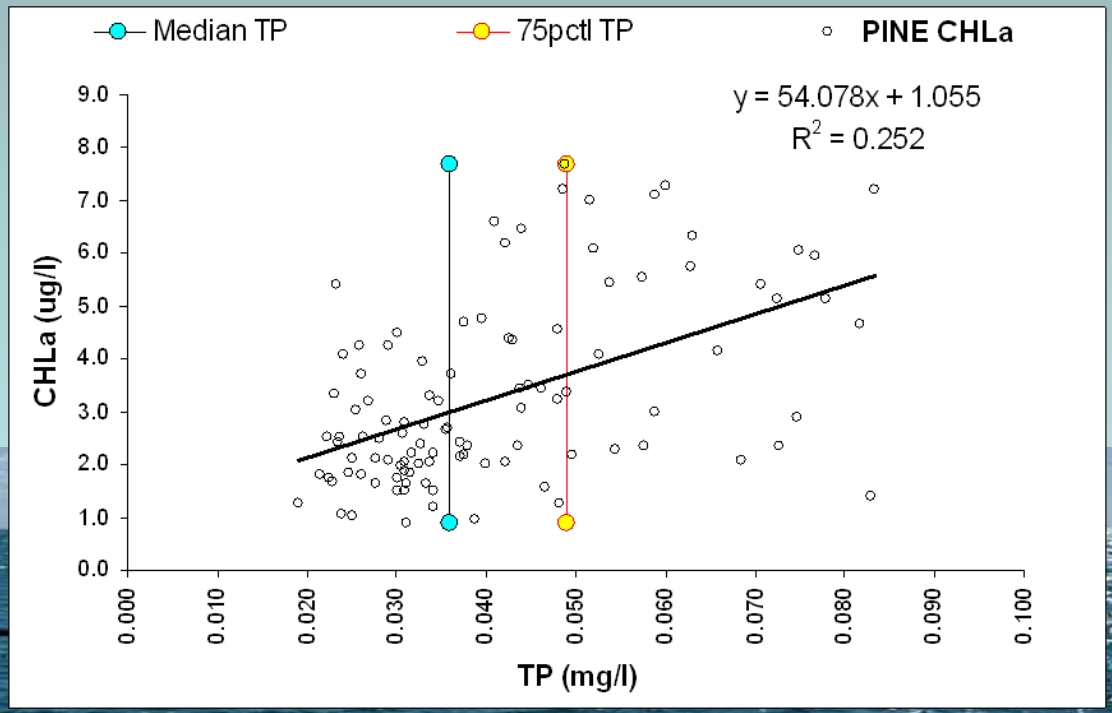
Threshold analysis

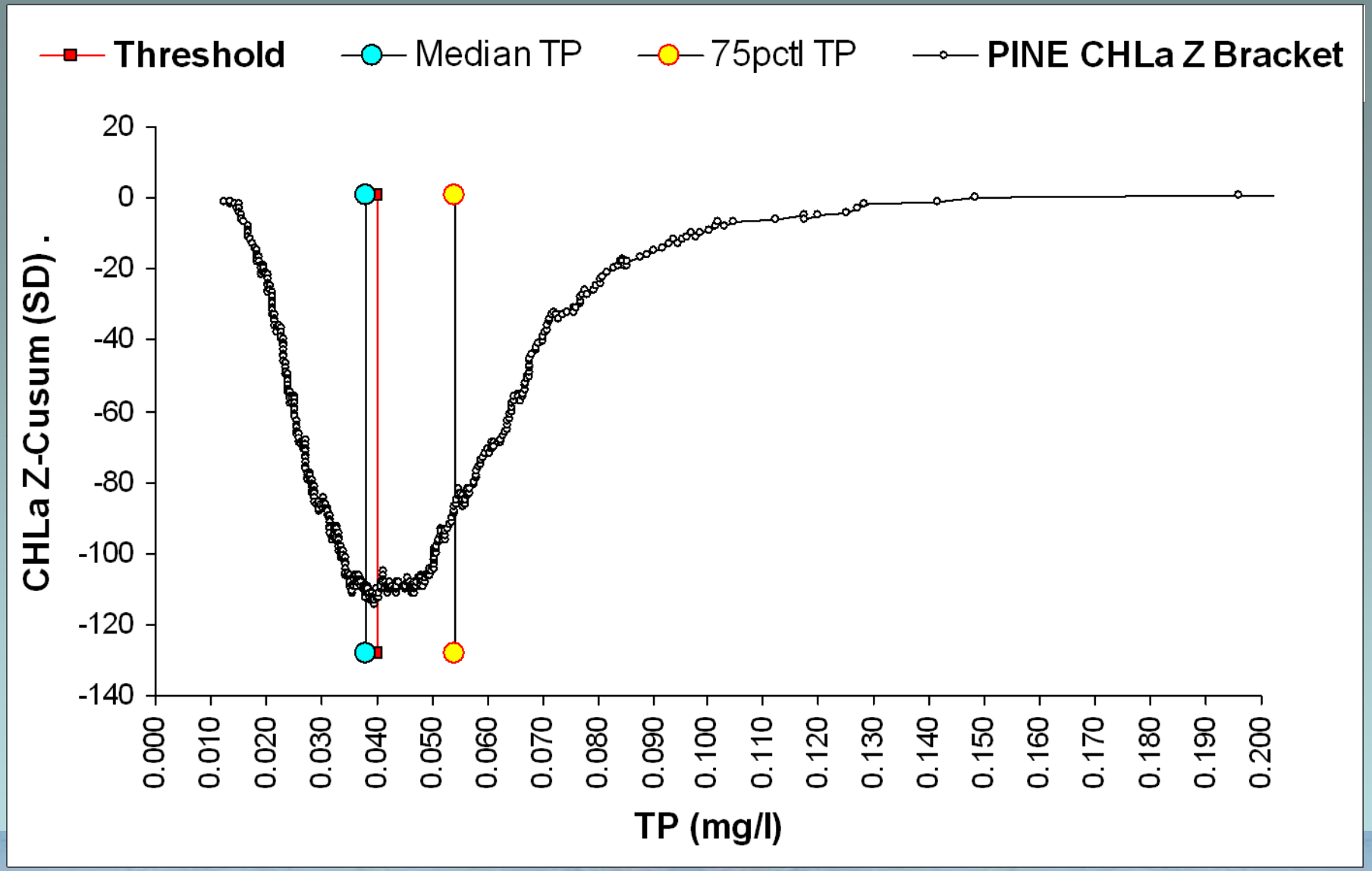
Our Objective:

To establish the **nutrient level** (threshold) corresponding to an inflexion in the CHLa Z-Cusum chart, which is preceded by a sustained below average portion of the CHLa time-series (negative slope in Z-Cusum chart) and is followed by sustained above average CHL-a values (positive slope in Z-Cusum chart).

Pine Island Segment

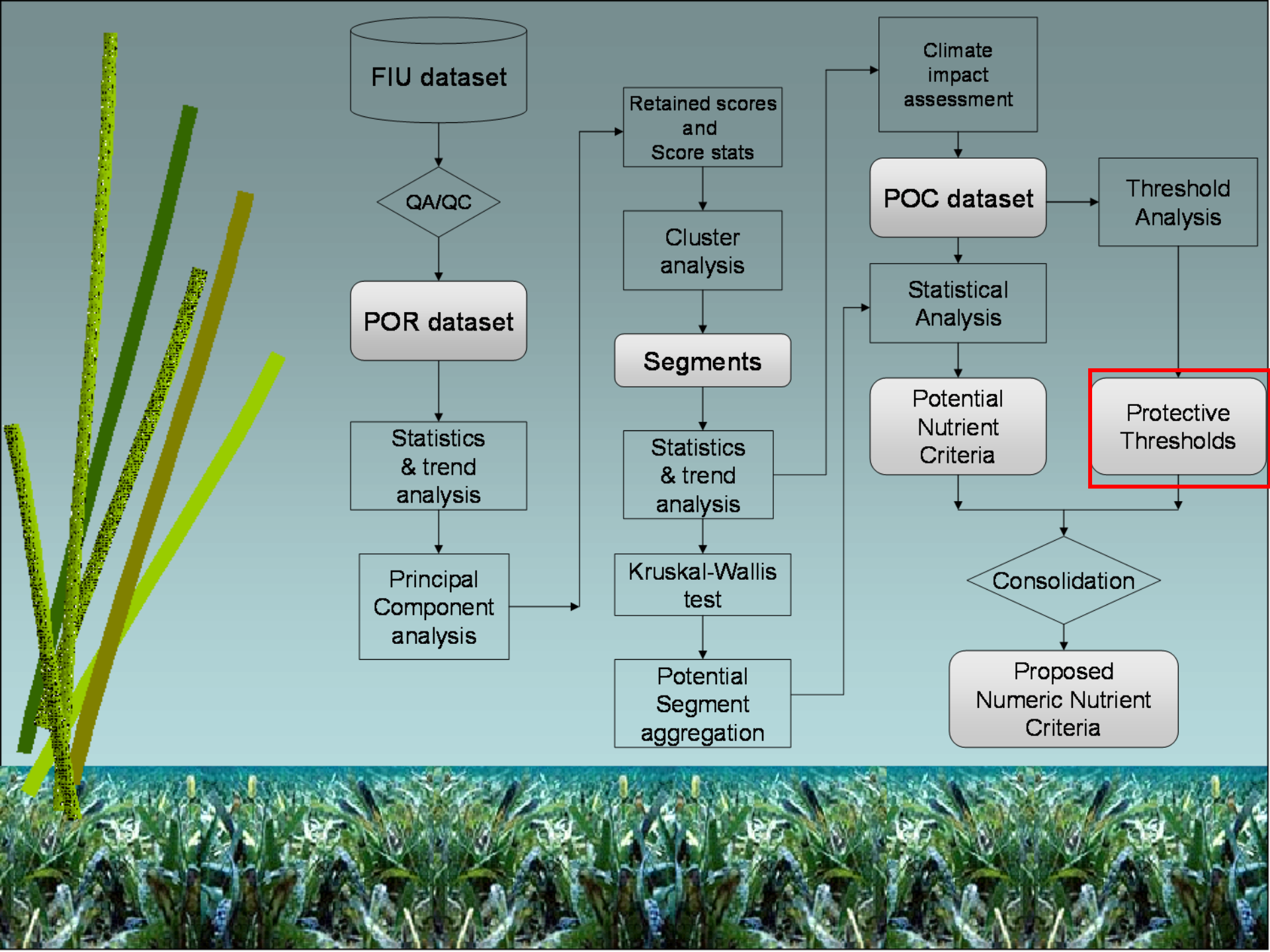





Threshold
Median TP
75pctl TP
PINE CHLa Z Bracket
CHLa Z-Cusum (SD) .
20
0
-20
-40
-60
-80
-100
-120
-140
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100
0.110
0.120
0.130
0.140
0.150
0.160
0.170
0.180
0.190
0.200
TP (mg/l)

Threshold

Nutrient level that if surpassed would trigger “anomalous” above average phytoplankton biomass responses, as measured by CHLa concentration


FIU dataset
QA/QC
POR dataset
Statistics & trend analysis
Principal Component analysis
Retained scores and Score stats
Cluster analysis
Segments
Statistics & trend analysis
Kruskal-Wallis test
Potential Segment aggregation
Climate impact assessment
POC dataset
Threshold Analysis
Statistical Analysis
Potential Nutrient Criteria
Protective Thresholds
Consolidation
Proposed Numeric Nutrient Criteria


LYDIA E. PINKHAM'S
Lydia E. Pinkham
HERB MEDICINE
Z-CUSUM