Integrated Modeling of Estuarine and Coastal Ecosystem Dynamics

Y. P. Sheng

Coastal & Oceanographic Engineering

University of Florida

January 22, 2003

National Ocean Service

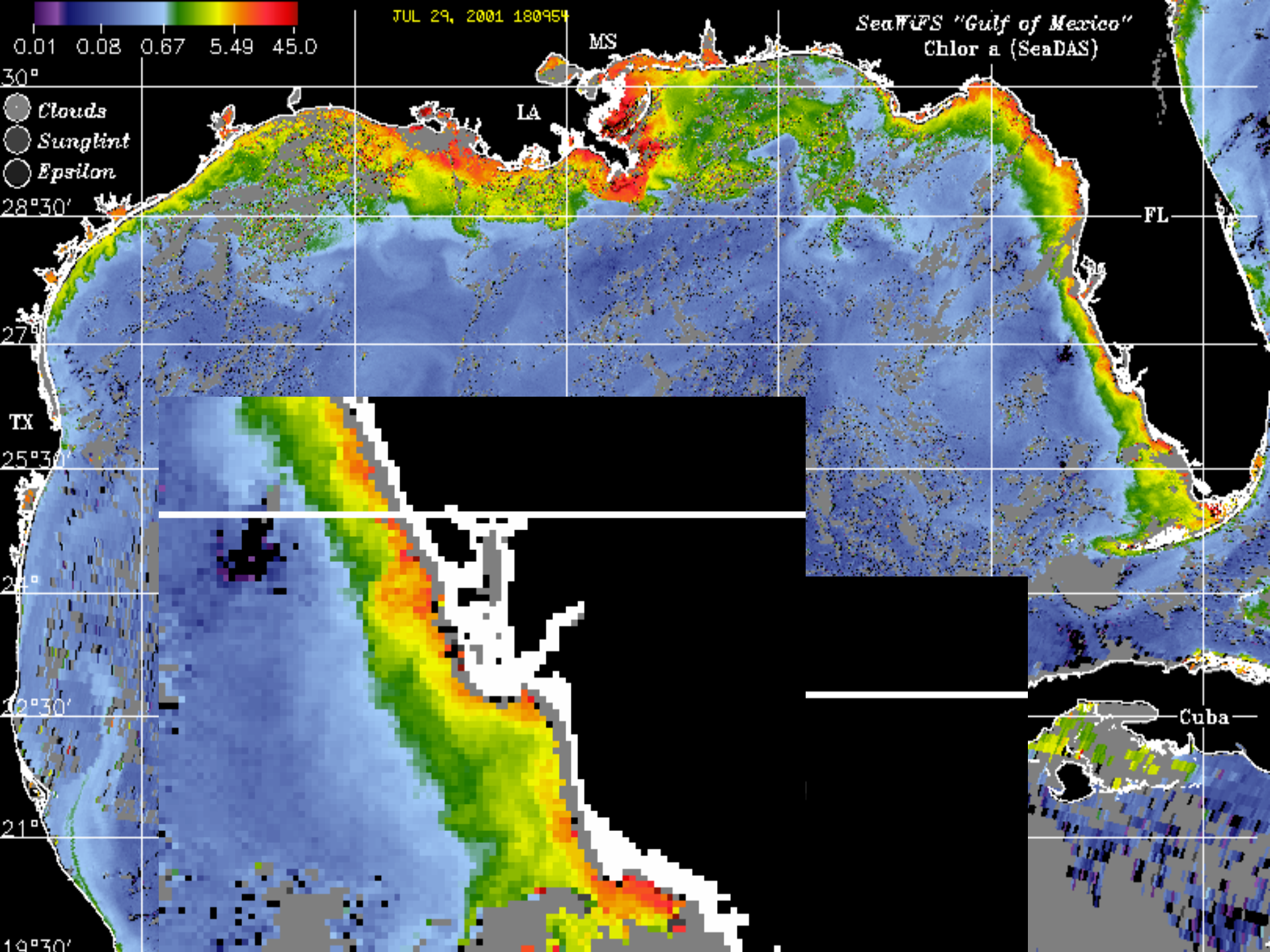
- Yes, we have a lot of PROBLEMS in Florida
- No, I am not talking about the Hanging Chad
- I am talking about the Everglades, Florida Bay, Charlotte Harbor, and

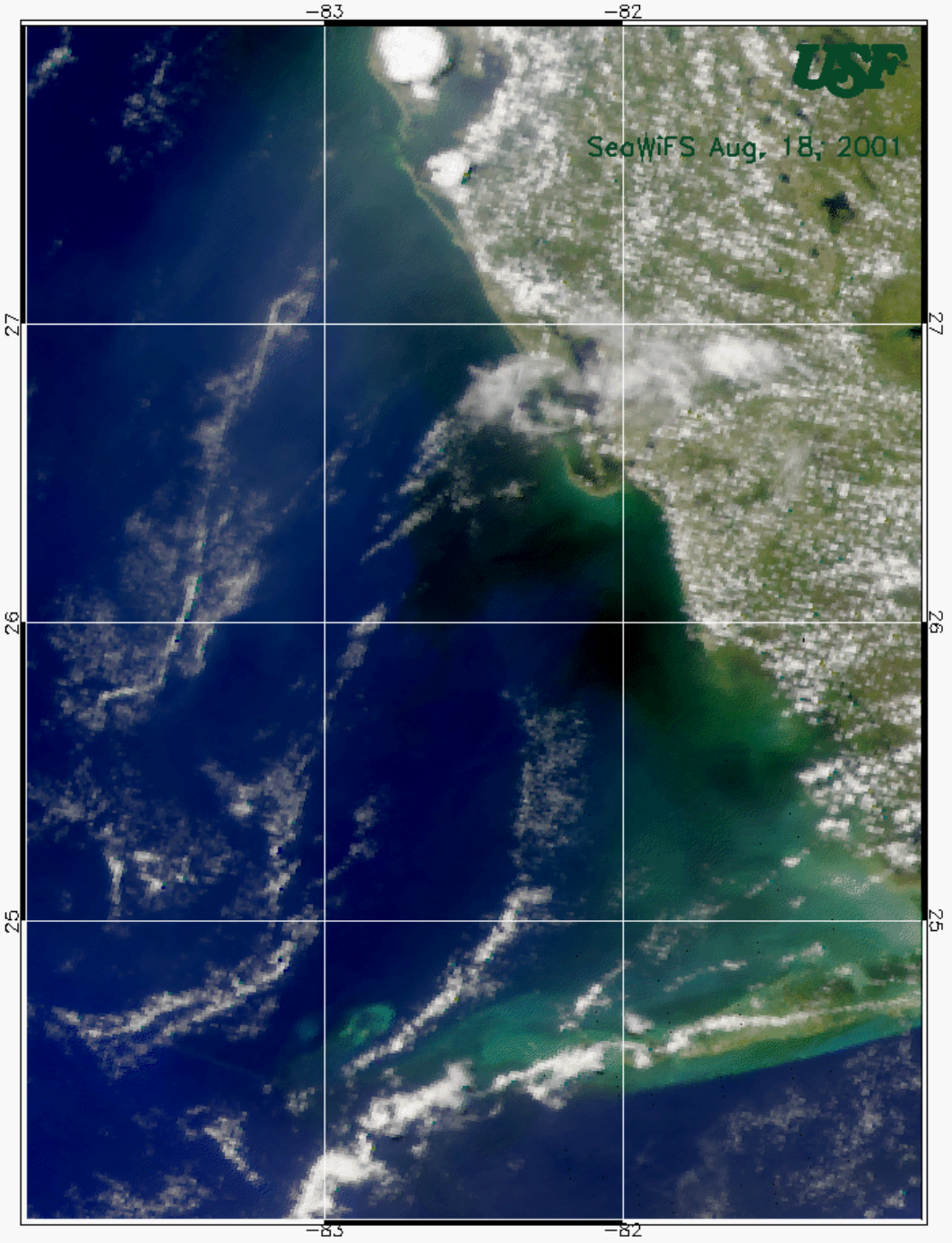
  Indian River Lagoon, St. Lucie Estuary,……
- I am talking about seagrass dieoff, black water, & loading of nutrients, sediments, and **copper**,……
- NOS has been actively involved in solving Florida problems
- **Integrated Modeling System** can assist

  Coastal Monitoring and Assessment

Integrated Estuarine & Coastal Studies

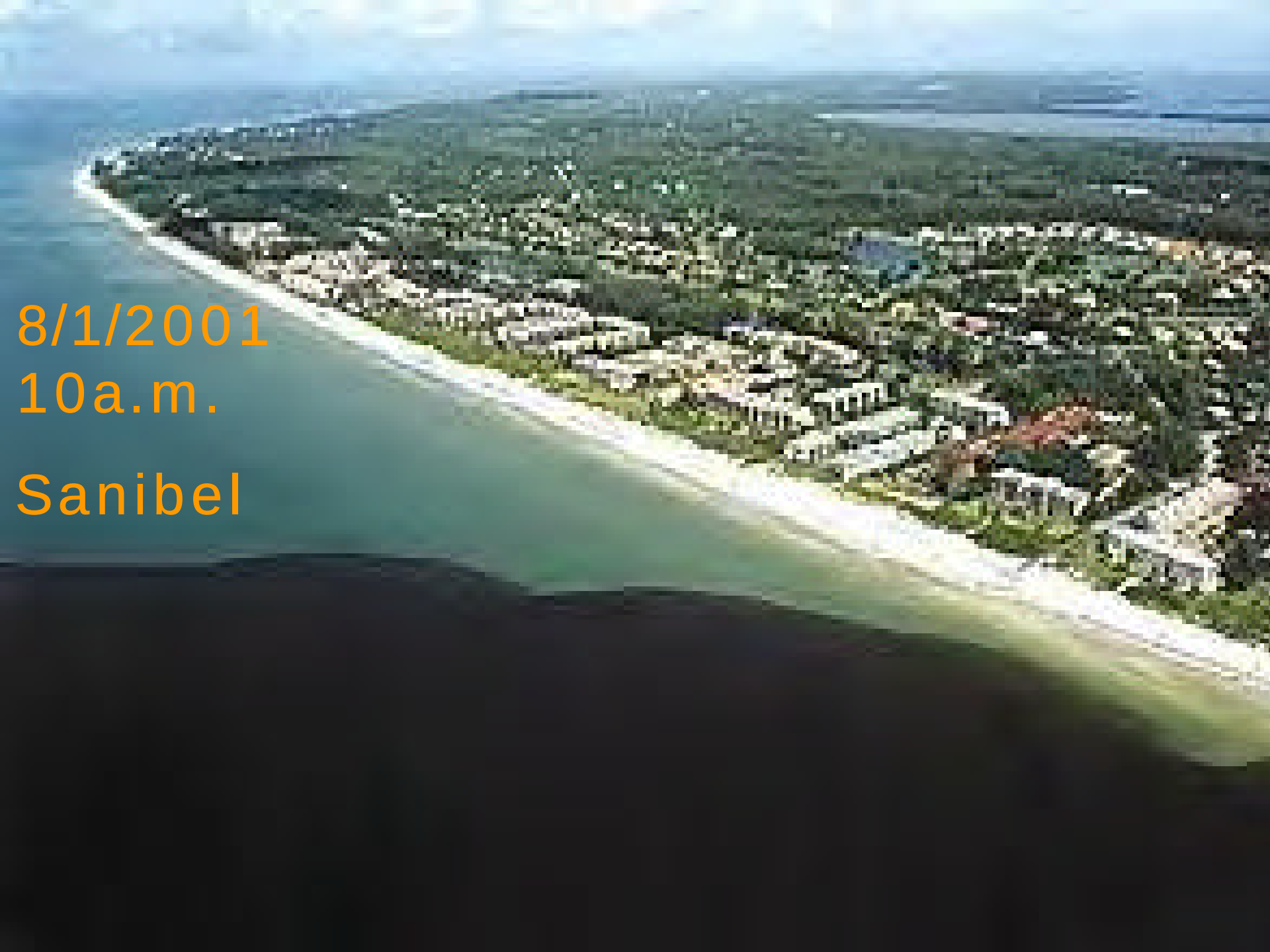
- To develop understanding of physical, chemical, and biological processes, and particularly their interactions;
- To predict the short-term and long-term responses of estuarine-coastal systems to anthropogenic and natural changes.


0.01 0.08 0.67 5.49 45.0
JUL 29, 2001 180954
SeaWiFS "Gulf of Mexico"
Chlor a (SeaDAS)
Clouds
Sunglint
Epsilon
MS
LA
FL
TX
Cuba
30°
28°30'
27°
25°30'
21°
19°30'



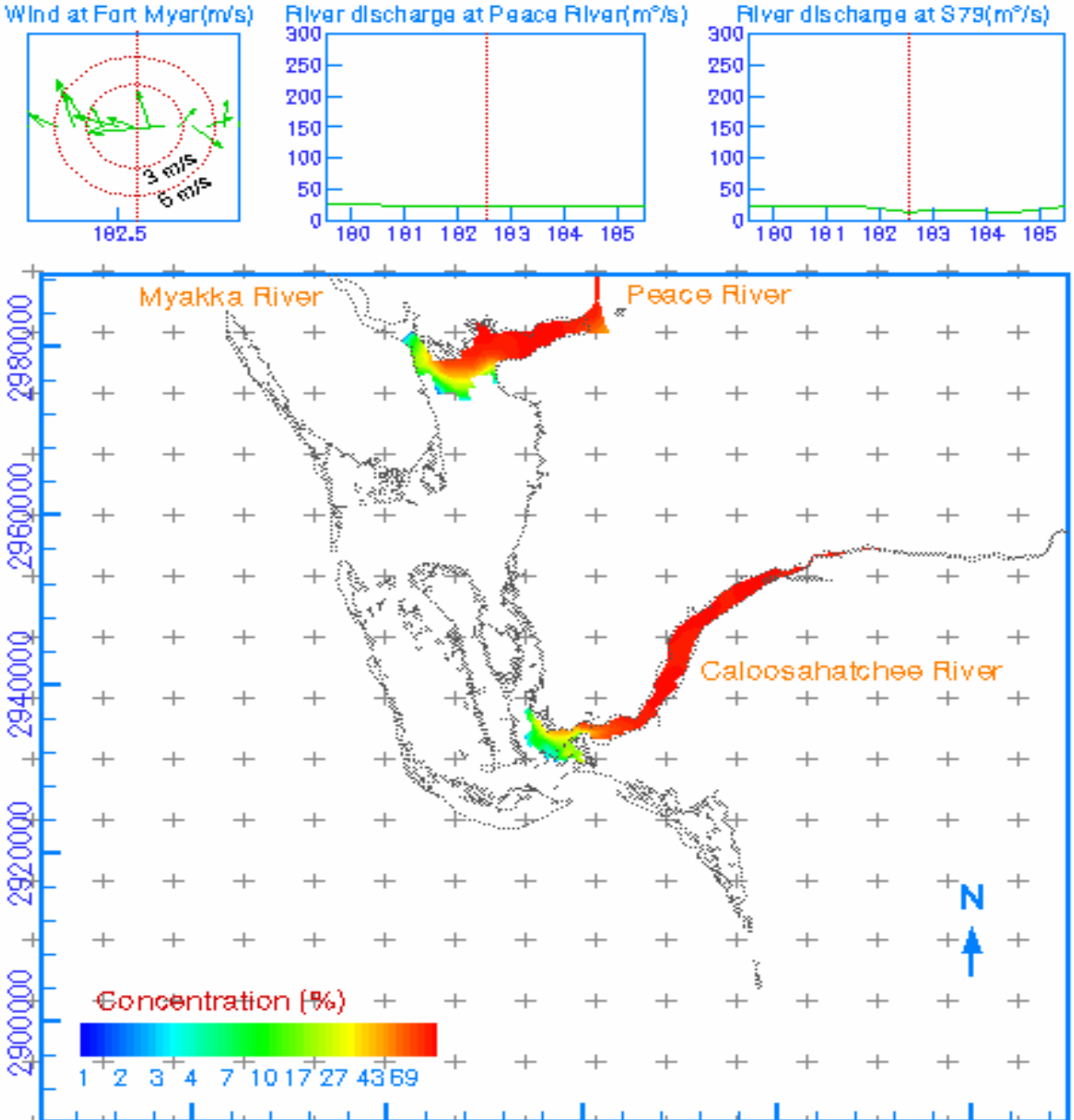
SeaWIFS

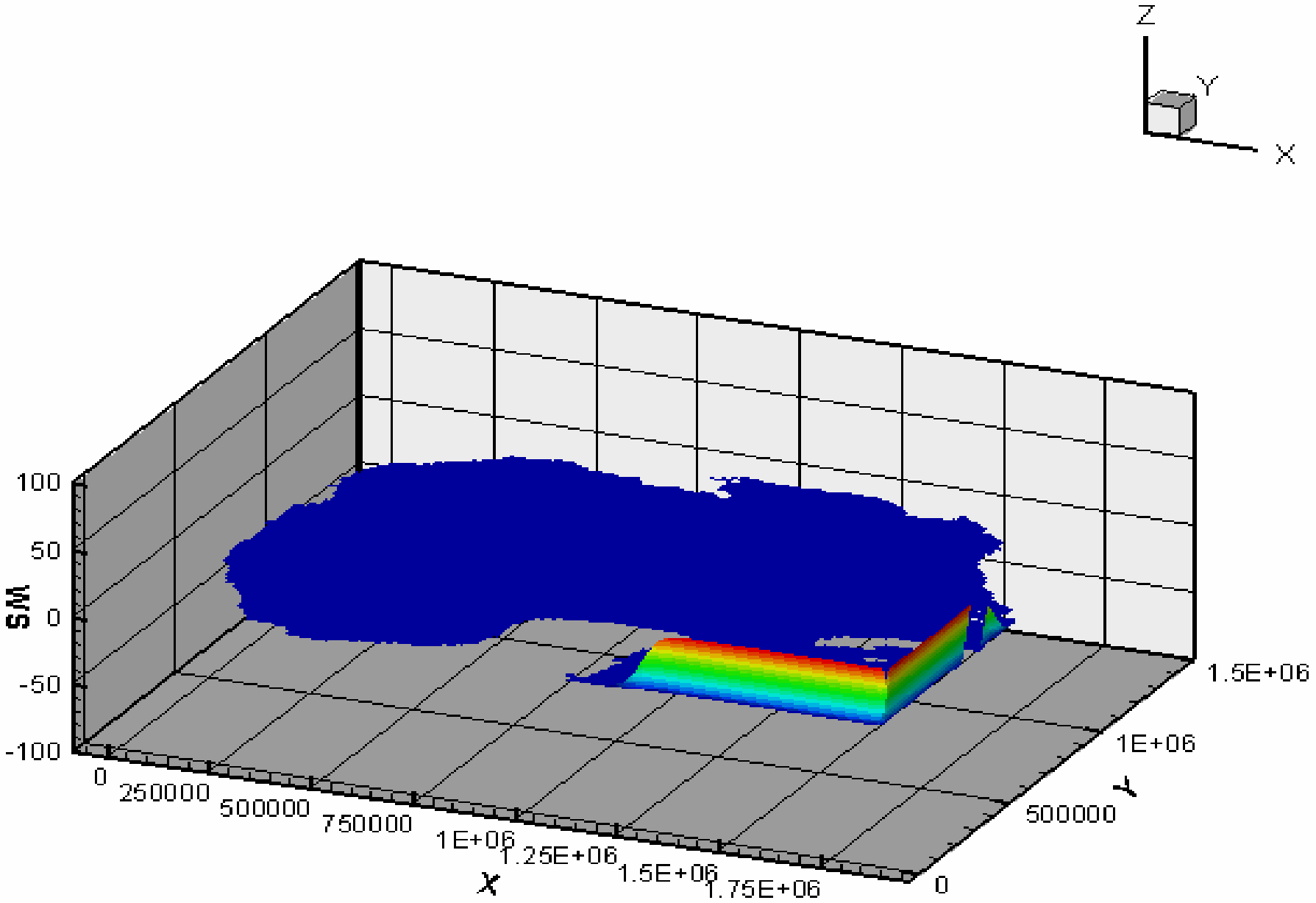
8/18/2001

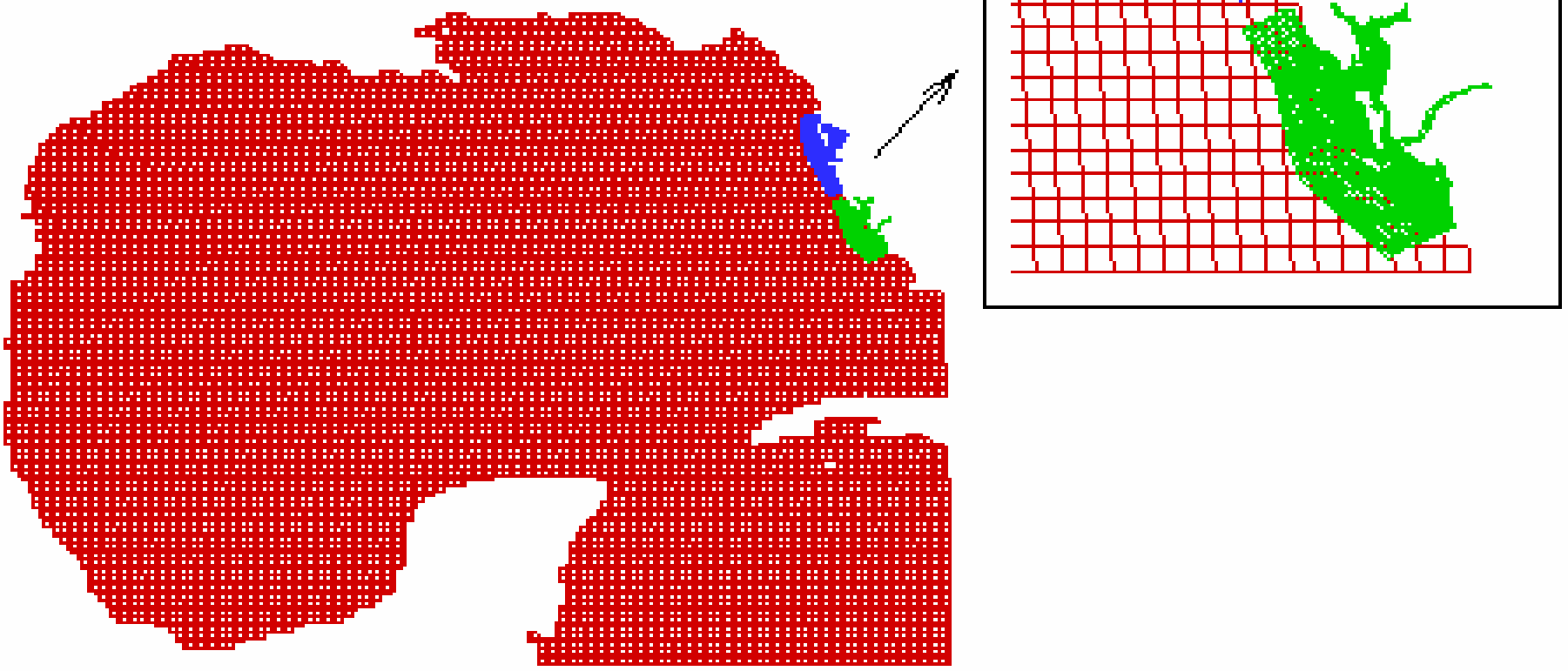

8/1/2001
10a.m.
Sanibel

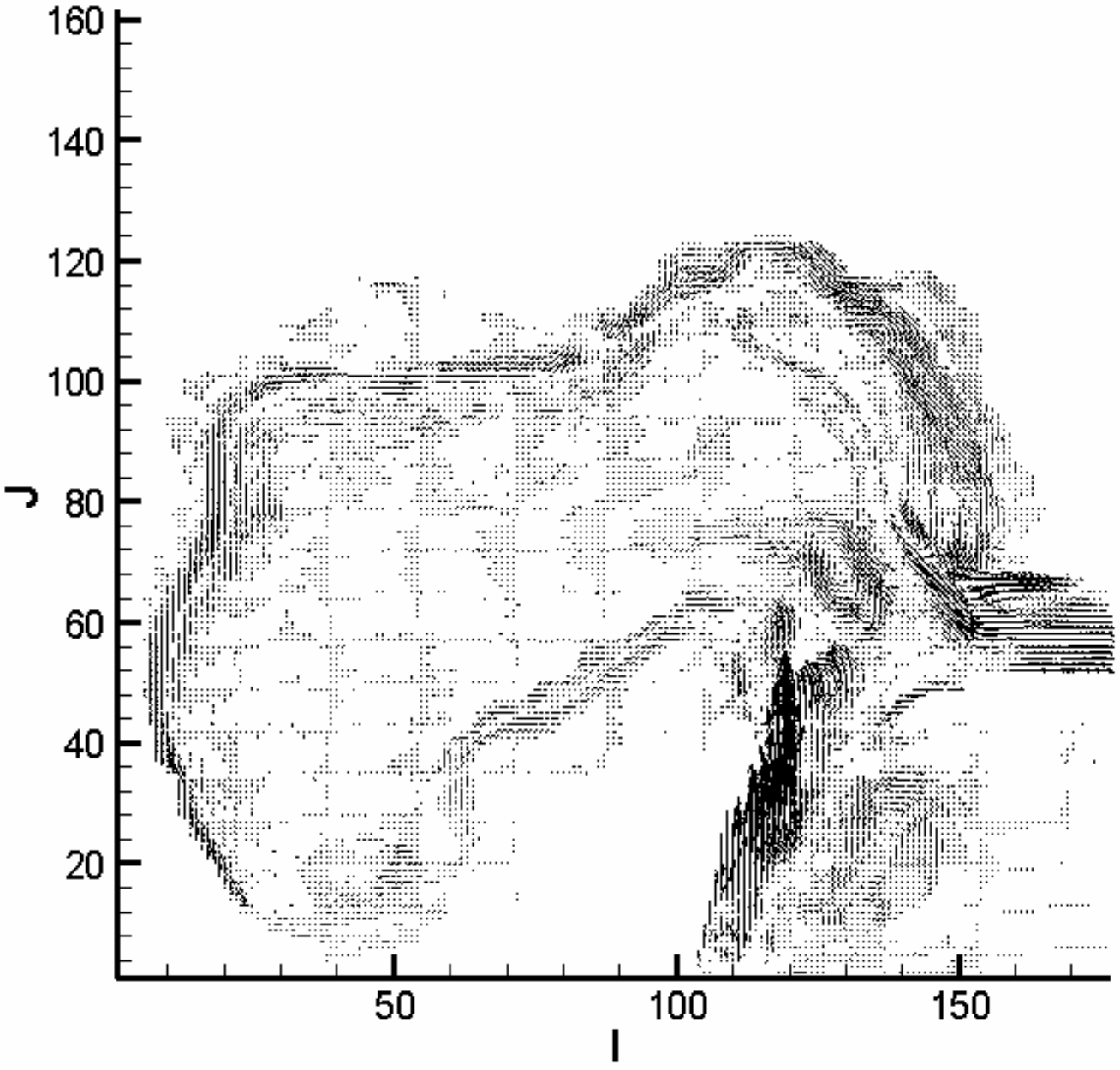
Prof. Peter Sheng and Kijin Park
University of Florida
Civil & Coastal Engineering

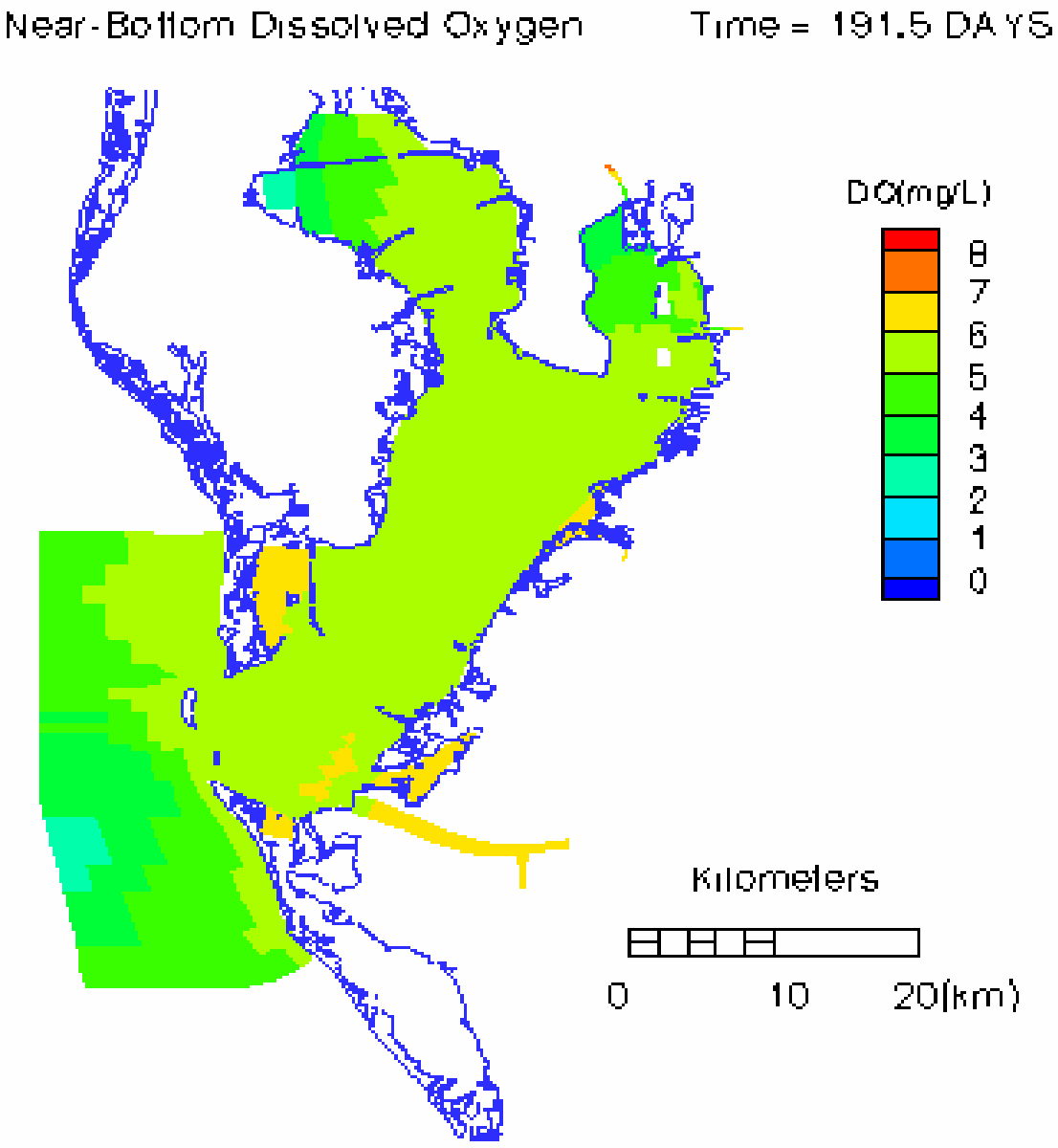
Simulation Time
13:00 07/01/2001

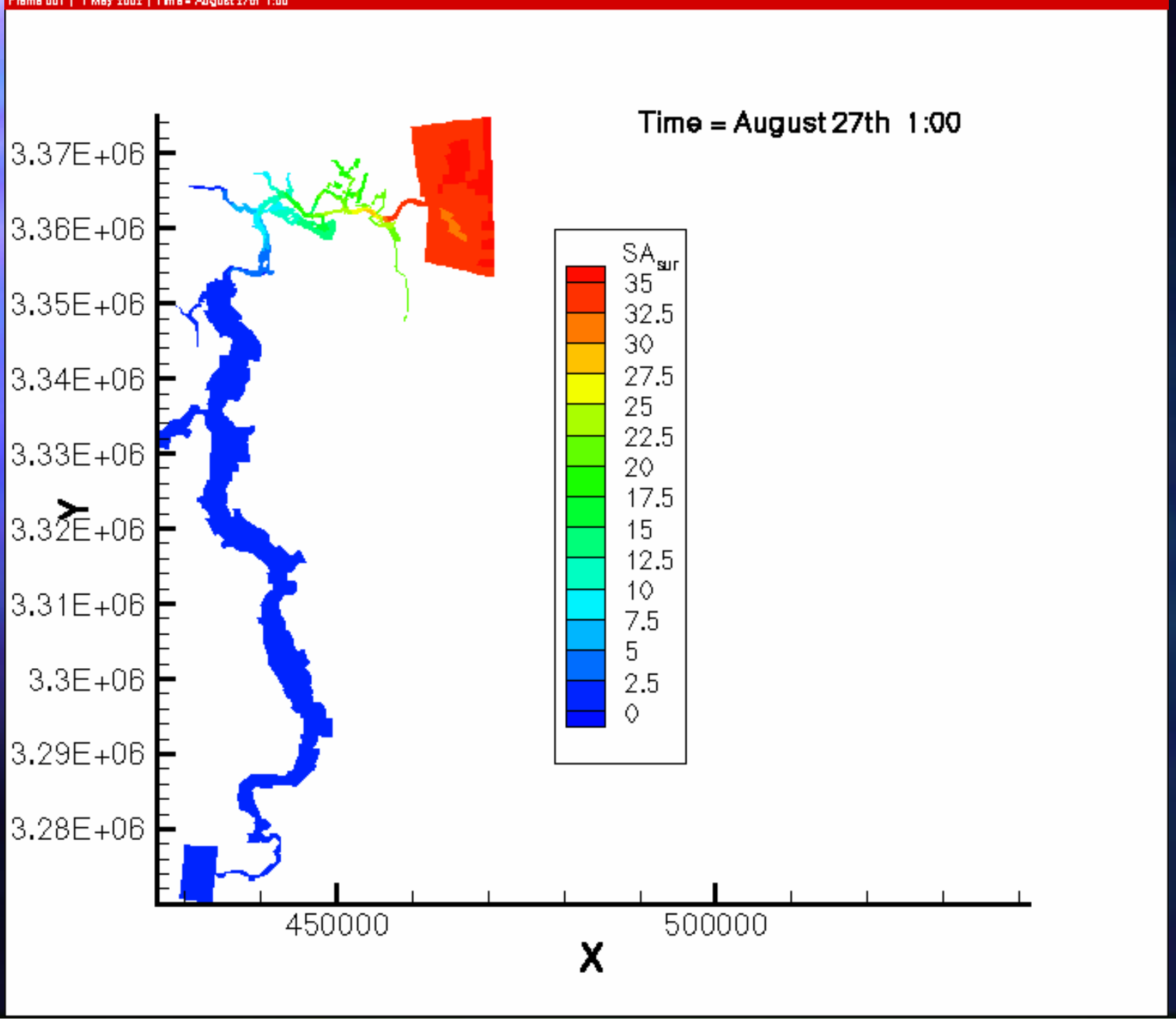



Z
Y
X
100
50
0
-50
-100
SM
0
250000
500000
750000
1E+06
1.25E+06
1.5E+06
1.75E+06
X
0
500000
1E+06
1.5E+06
Y

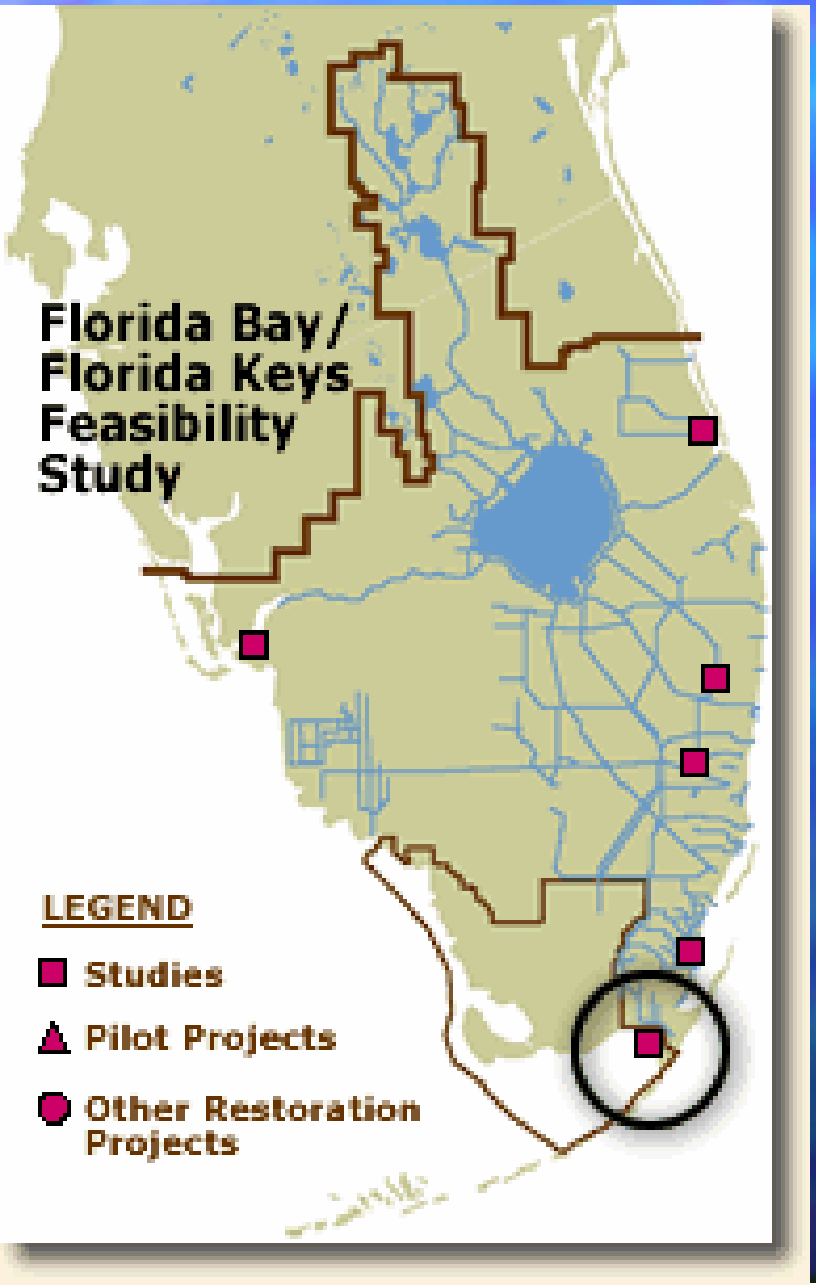


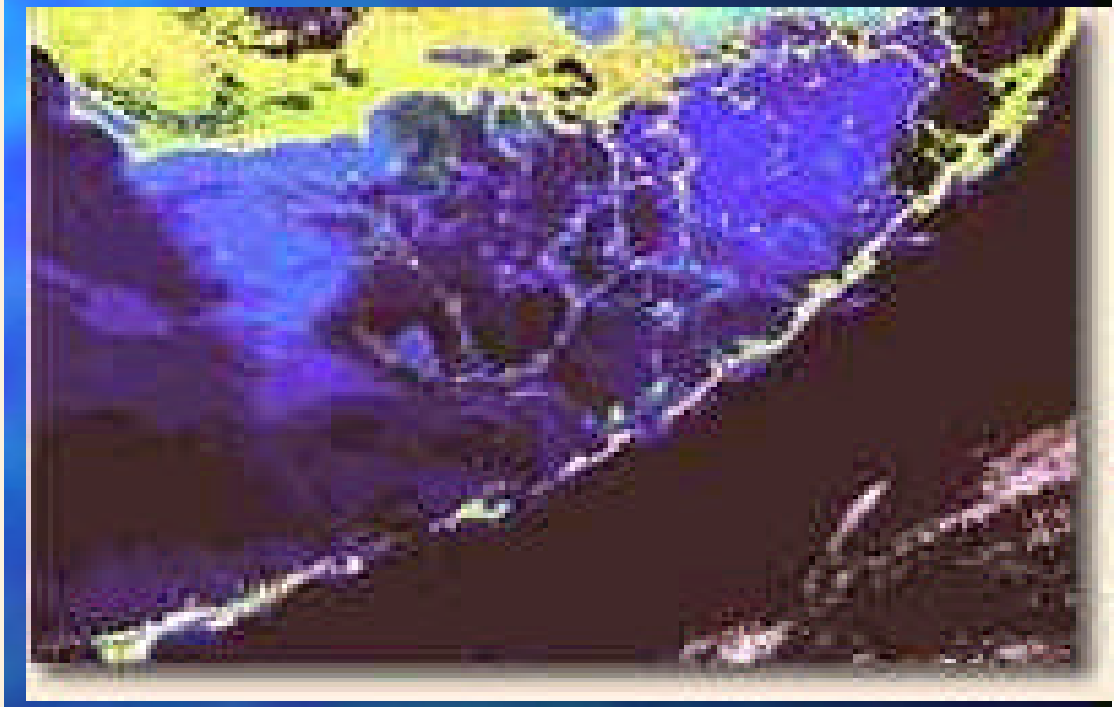

160
140
120
100
80
60
40
20
J
50
100
150
I


Near-Bottom Dissolved Oxygen
Time = 191.5 DAYS
DO(mg/L)
8
7
6
5
4
3
2
1
0
Kilometers
0
10
20(km)


Time = August 27th 1:00
SA sur
35
32.5
30
27.5
25
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
3.37E+06
3.36E+06
3.35E+06
3.34E+06
3.33E+06
3.32E+06
3.31E+06
3.3E+06
3.29E+06
3.28E+06
Y
450000
500000
X

Florida Bay

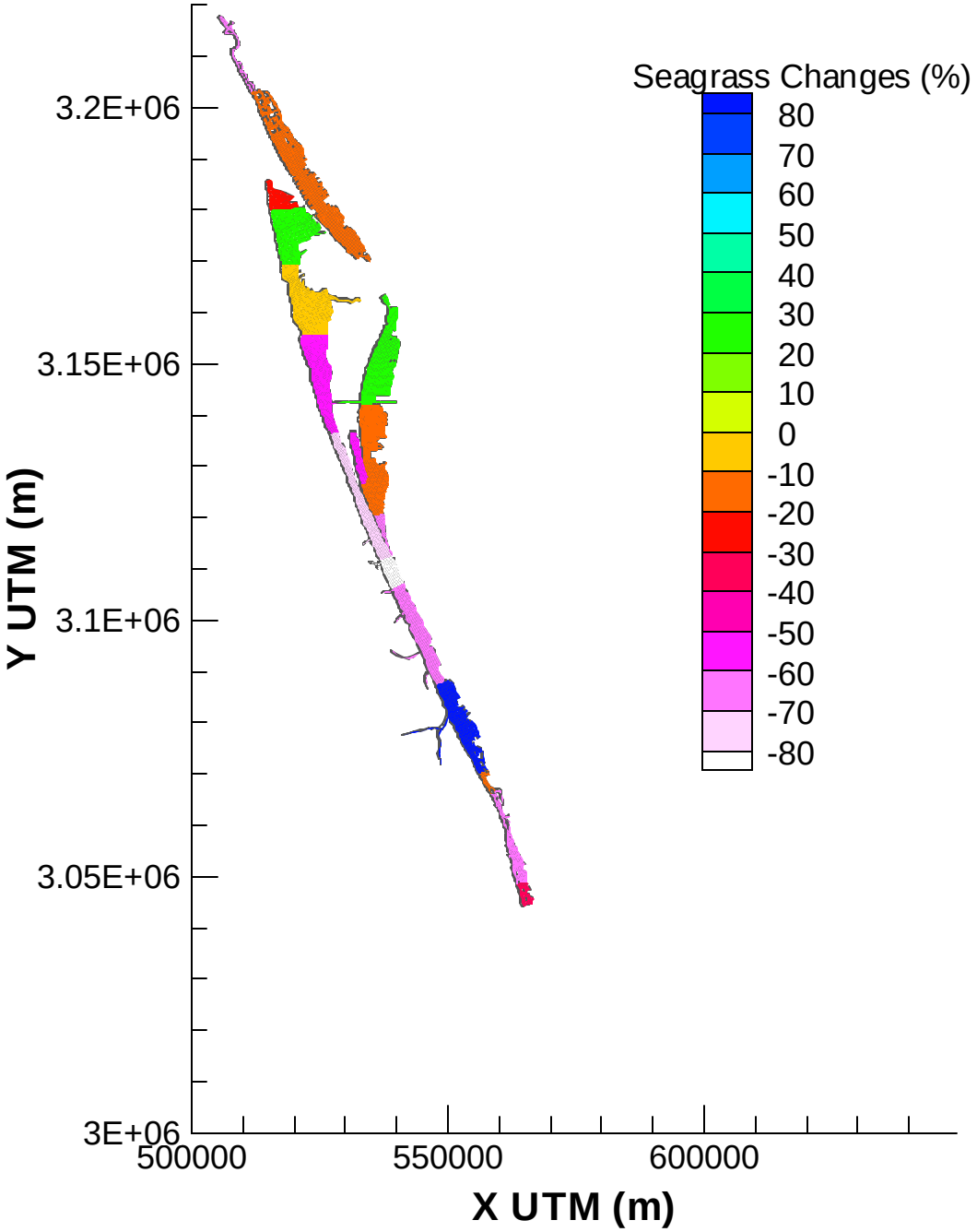

Florida Bay/
Florida Keys
Feasibility
Study
LEGEND
Studies
Pilot Projects
Other Restoration
Projects



Spatial distribution of IRL seagrass changes

What caused the changes?

- Light attenuation
- Nutrient load
- TSS load
- Salinity, temp.
- Flushing



IRLPLR Model Development Project

- Sponsored by SJRWMD
- UF-SJRWMD Partnership
- Develop and Validate IRLPLR Model

Next Step:

- Develop Pollutant Load Reduction Goal (PLRG)

Field and Lab Data

- Hydrodynamic
  - Bathymetry, wind and tidal forcings
- Sediment
  - Mean diameter, settling velocity, erosion rate, and critical shear stress
- Water Quality
  - Dissolved oxygen, nitrogen, phosphorus, chlorophyll's, salinity, pH, temperature, & TSS data
- Light and Seagrass Data

WQMN Stations

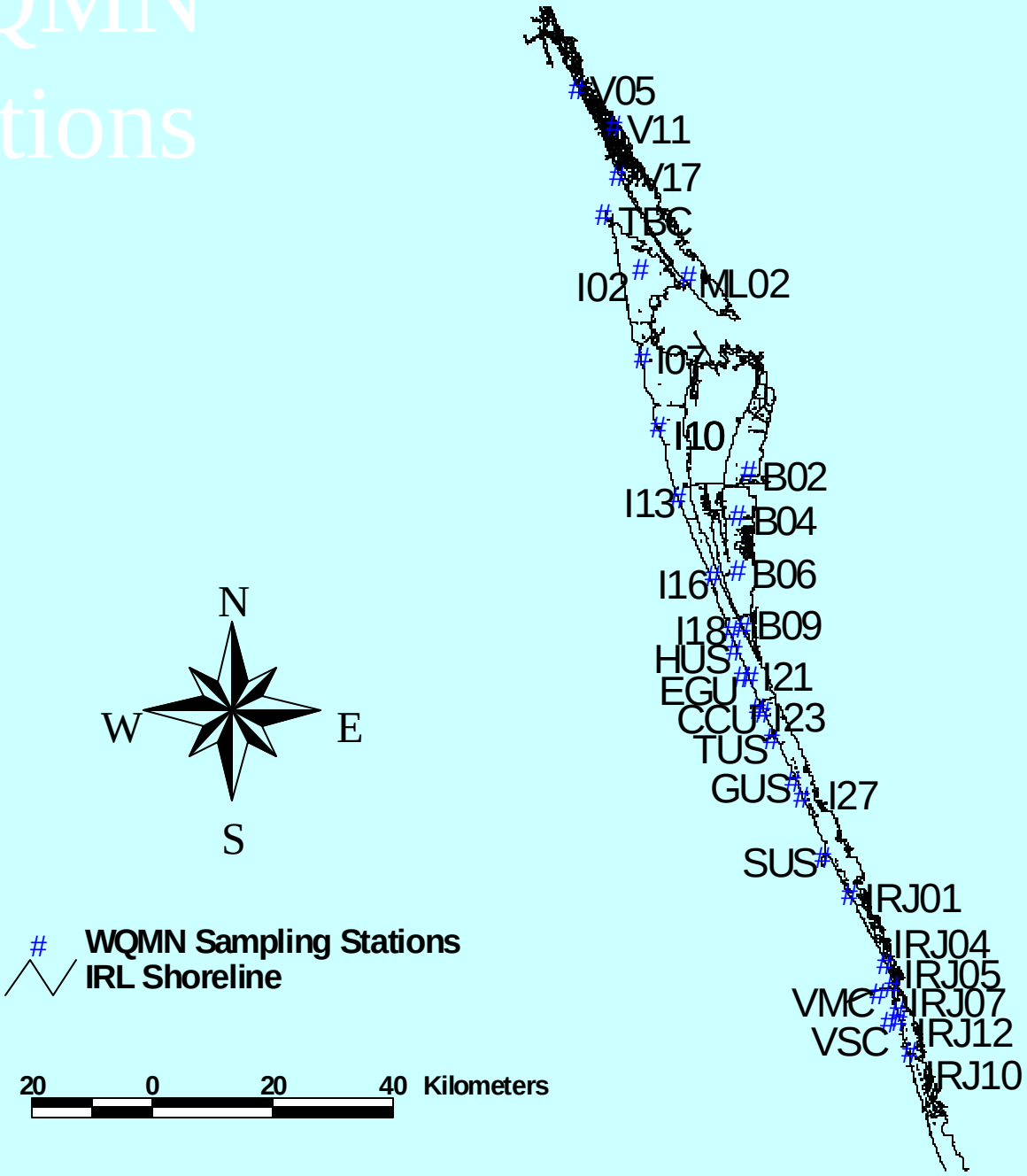


Figure 5. Indian River Lagoon Light Attenuation During Synoptic Events

Feburary, 1998

March, 1998

April, 1998

CH3D-IMS

Circulation Model : CH3D

Wave Model : SMB, SWAN, REF/DIF

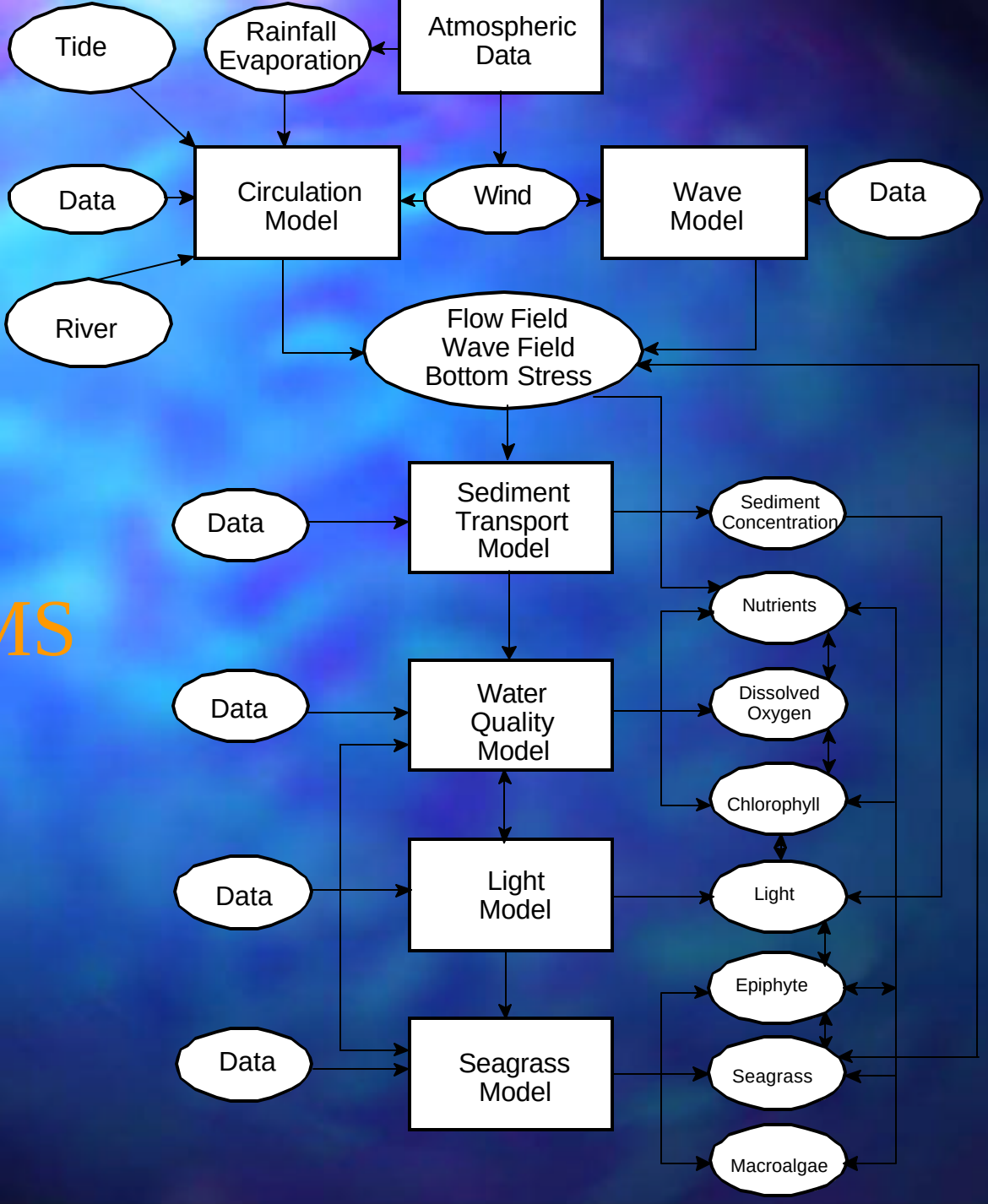
Sediment Transport Model : CH3D-SED3D

Water Quality Model : CH3D-WQ3D

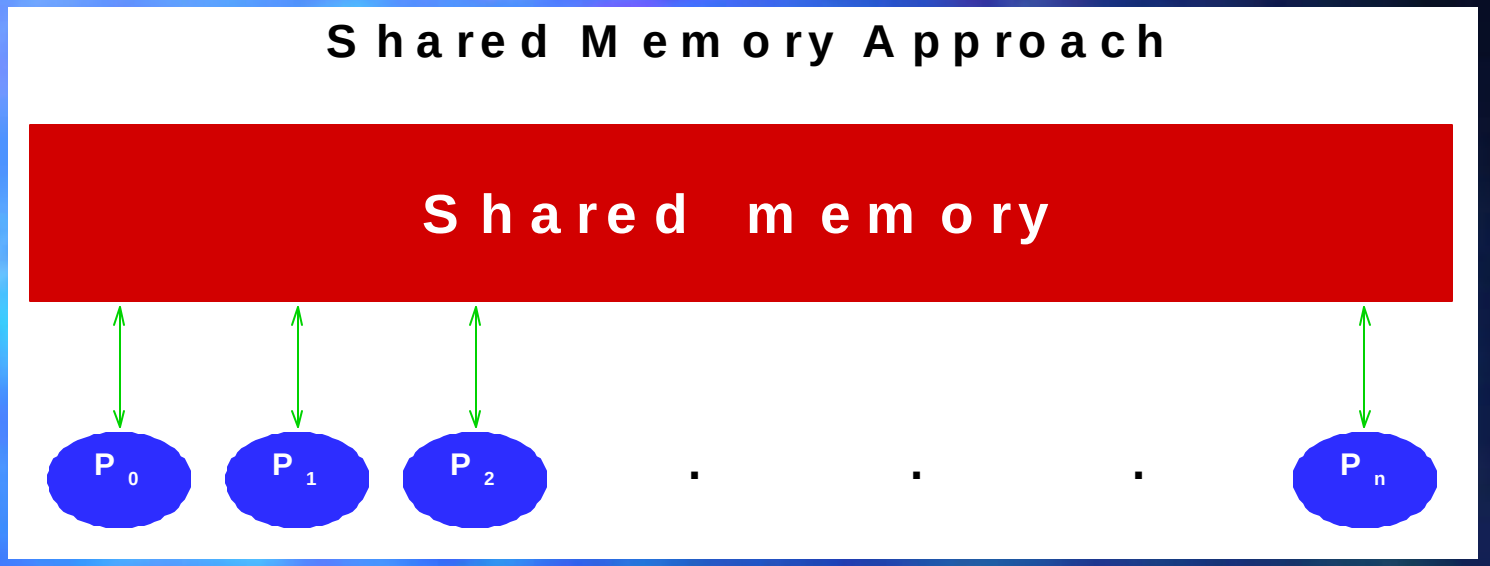
Light Attenuation Model : CH3D-LA

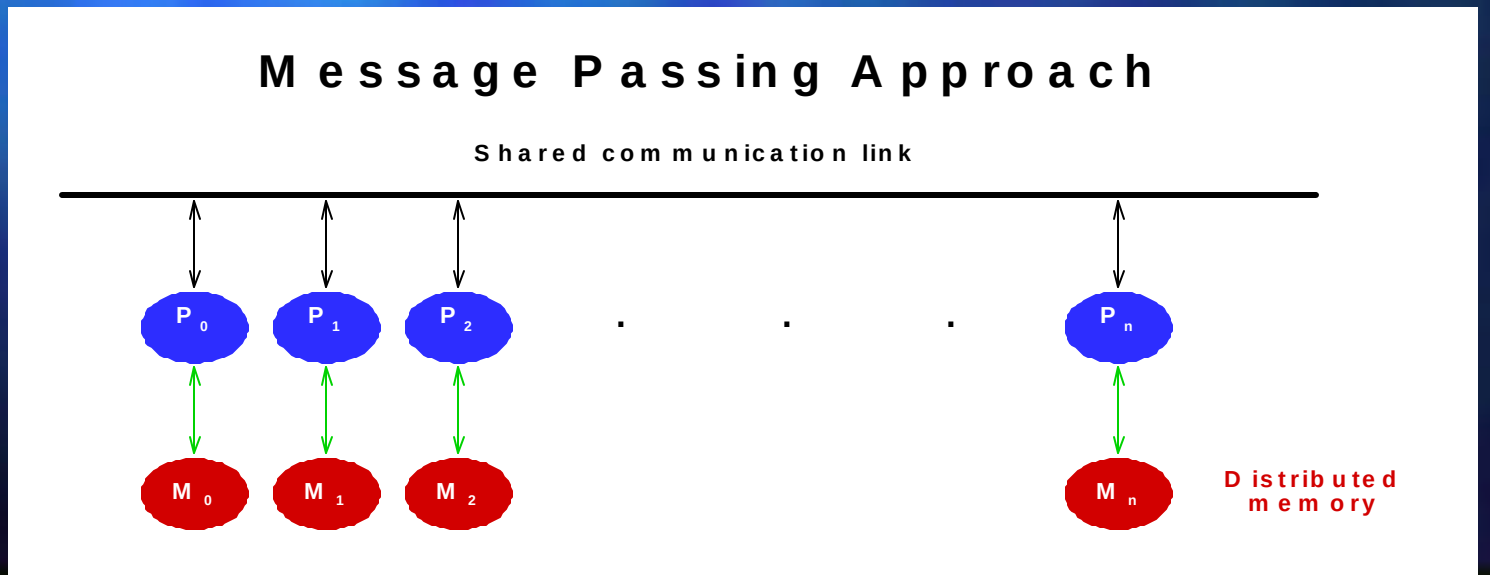
Seagrass Model: CH3D-SAV

CH3D-IMS


Tide
Rainfall
Evaporation
Atmospheric
Data
Data
Circulation
Model
Wind
Wave
Model
Data
River
Flow Field
Wave Field
Bottom Stress
Data
Sediment
Transport
Model
Sediment
Concentration
Nutrients
Data
Water
Quality
Model
Dissolved
Oxygen
Chlorophyll
Data
Light
Model
Light
Epiphyte
Data
Seagrass
Model
Seagrass
Macroalgae

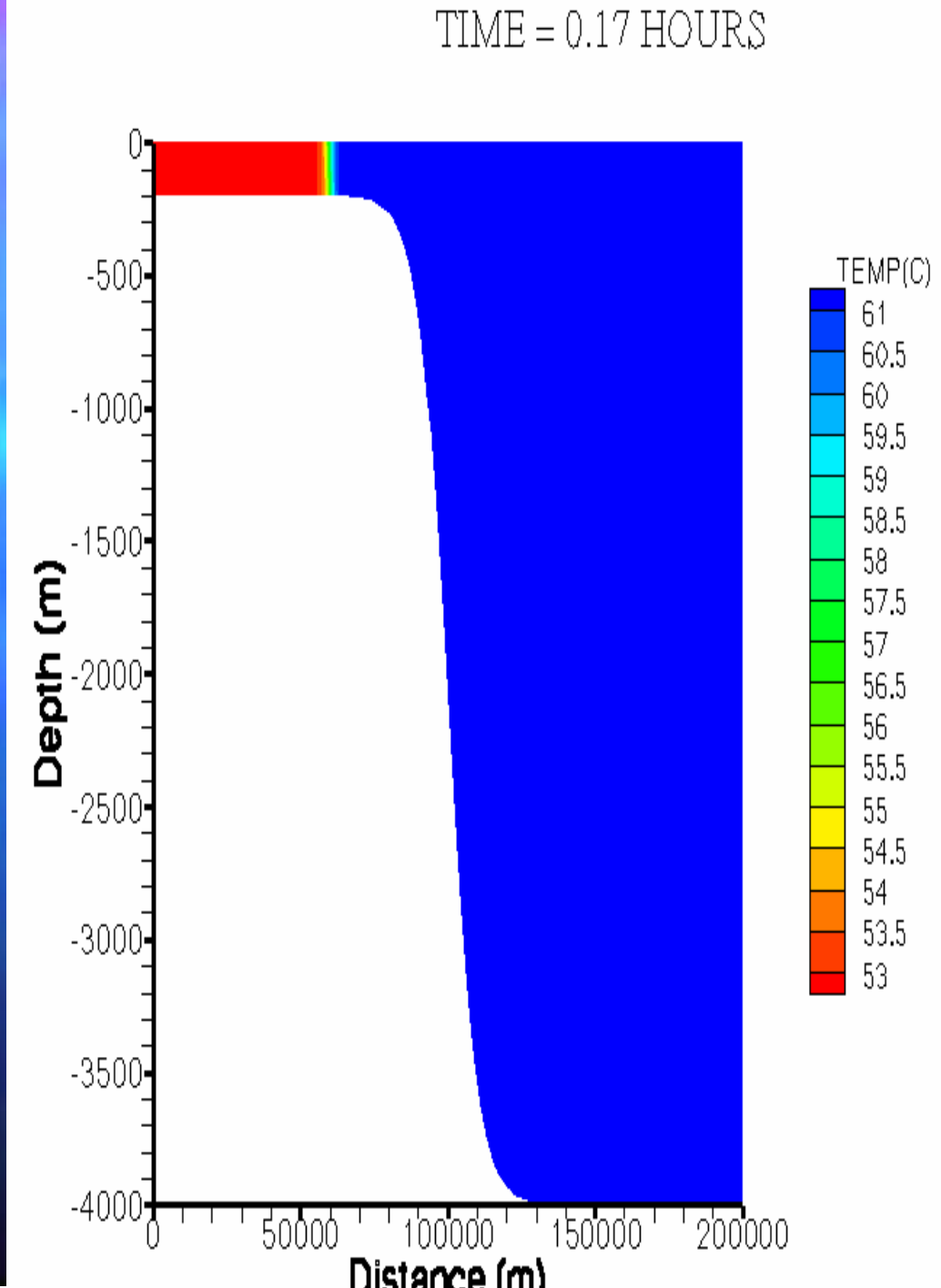
High Performance Computing (HPC)





NEW CH3D

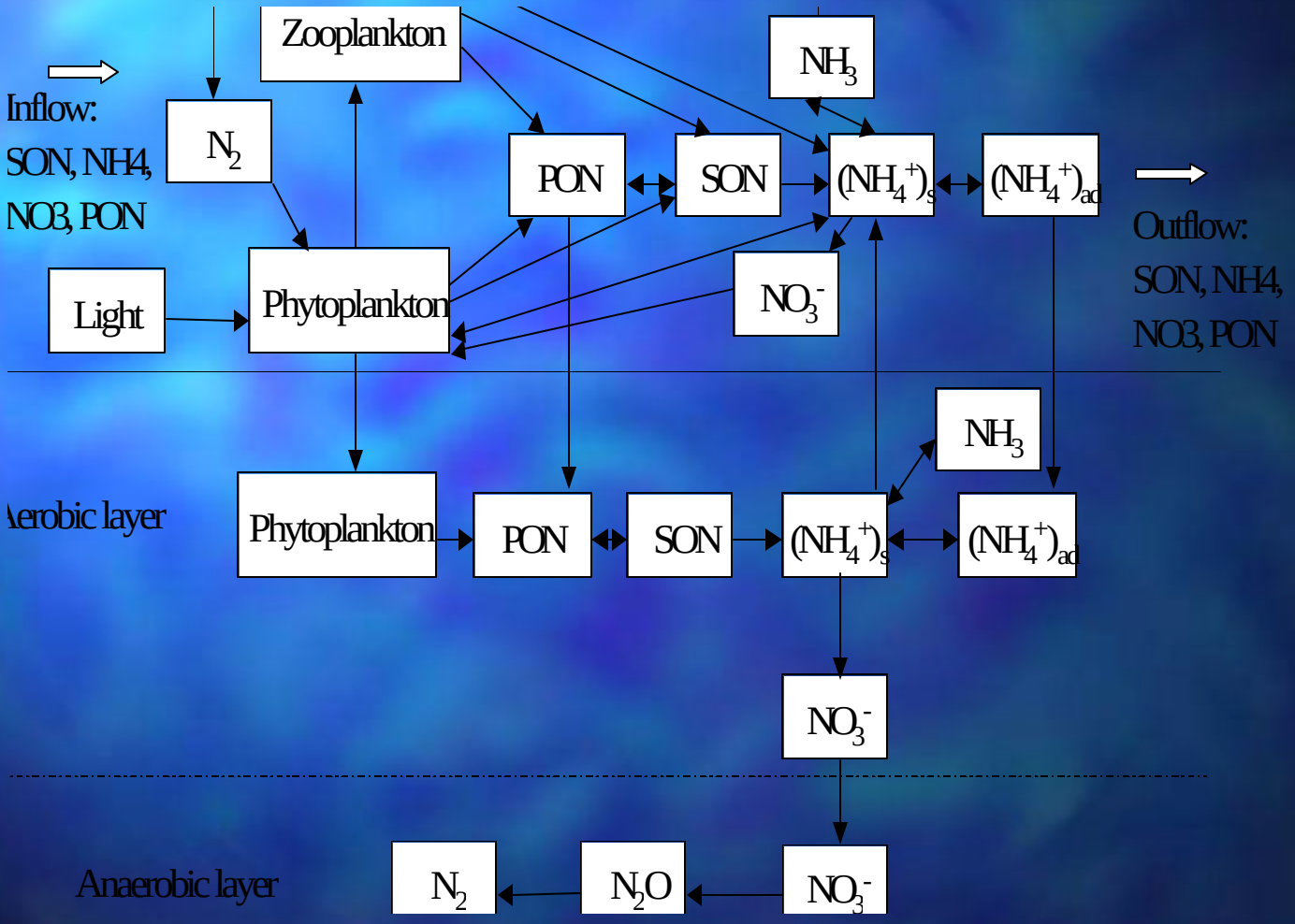
- Non-Orthogonal Boundary-Fitted Curvilinear Grid in Horizontal Direction
- Sigma-Grid in Vertical Direction
- Robust Model for Vertical Turbulence: Equilibrium Closure
- Contravariant Velocity
- Accurate Advective Schemes
- Strictly Conservative
- Can Handle Sharp Bottom Slopes
- New Features: Wetting & Drying, Parallel Versions, Non-hydrostatic Pressure, Un-structured Grid

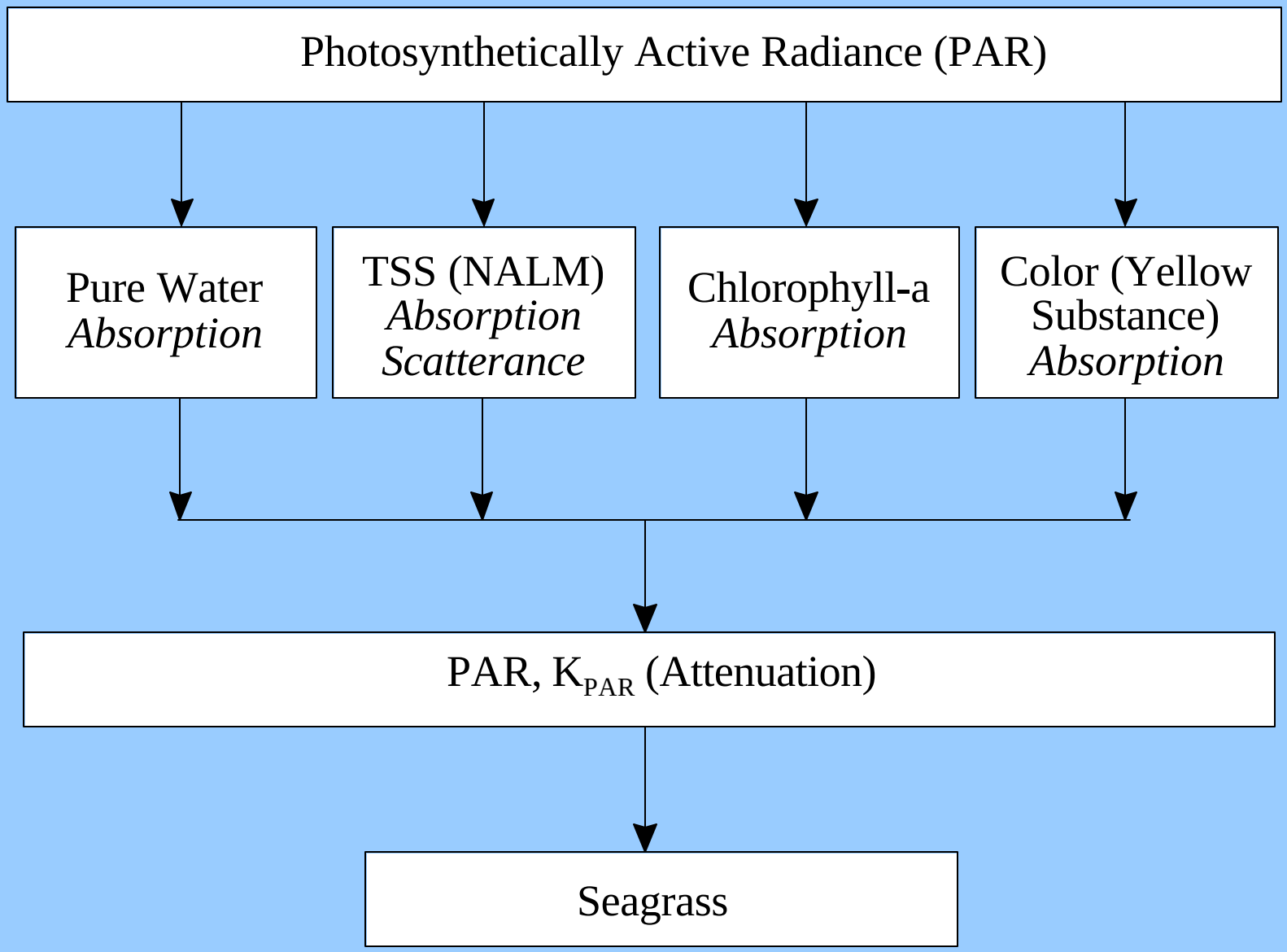

TIME = 0.17 HOURS
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Depth (m)
0
50000
100000
150000
200000
Distance (m)
TEMP(C)
61
60.5
60
59.5
59
58.5
58
57.5
57
56.5
56
55.5
55
54.5
54
53.5
53

CH3D-SED3D

- **Advection**
  CH3D
- **Two Size Groups**
  Fine & Coarse
- **Vertical Mixing**
  TKE Closure
  Equilib. Closure
- **Horizon. Mixing**
  LES
- **Settling/Flocculation**
  Stokesian
  Function of SSC, TKE
- **Deposition**
  1/Layers'Resistances
- **Resuspension**
  Func. of Shear, Sed.
  Lab/Field/Num. Exp.

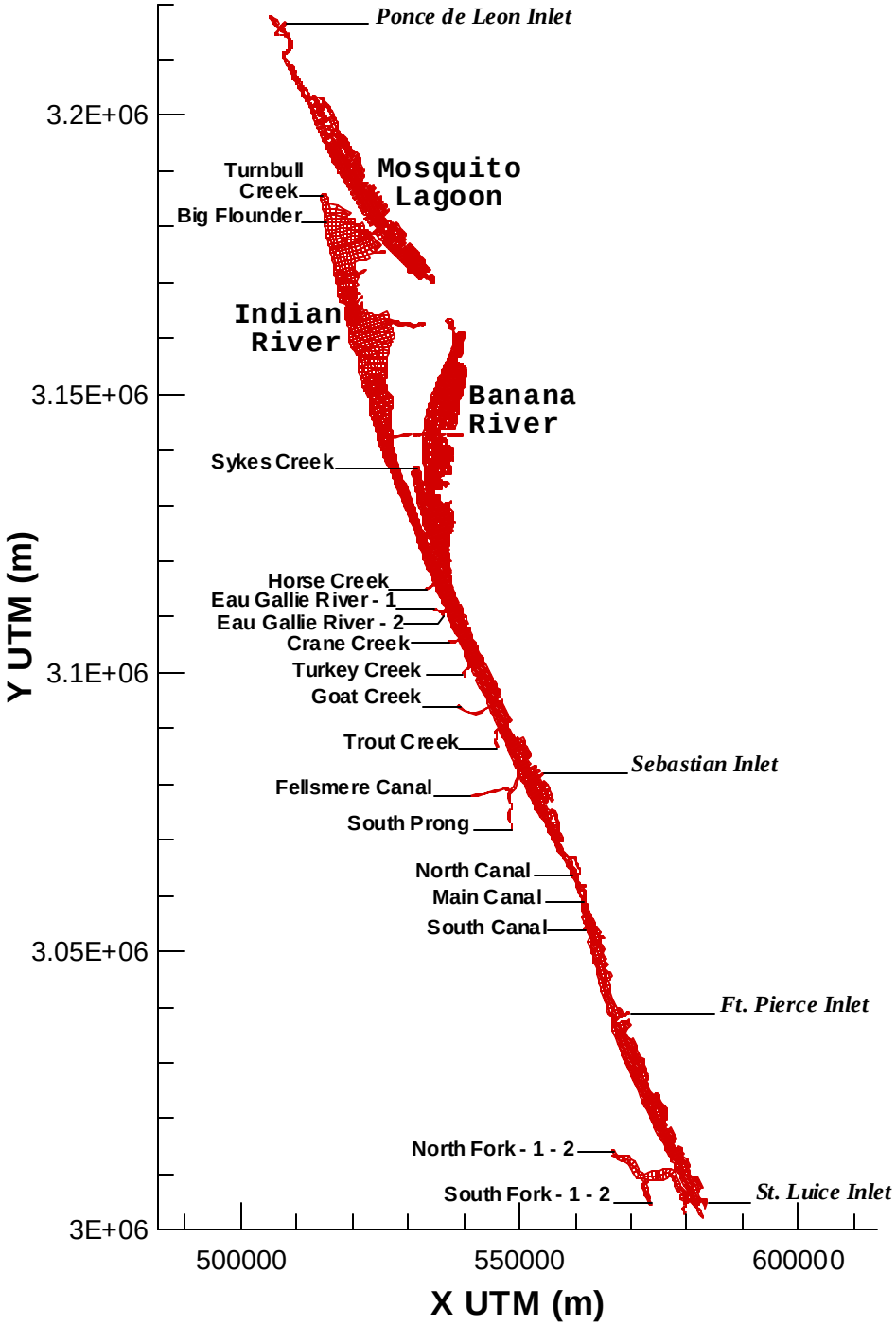
Nitrogen cycling

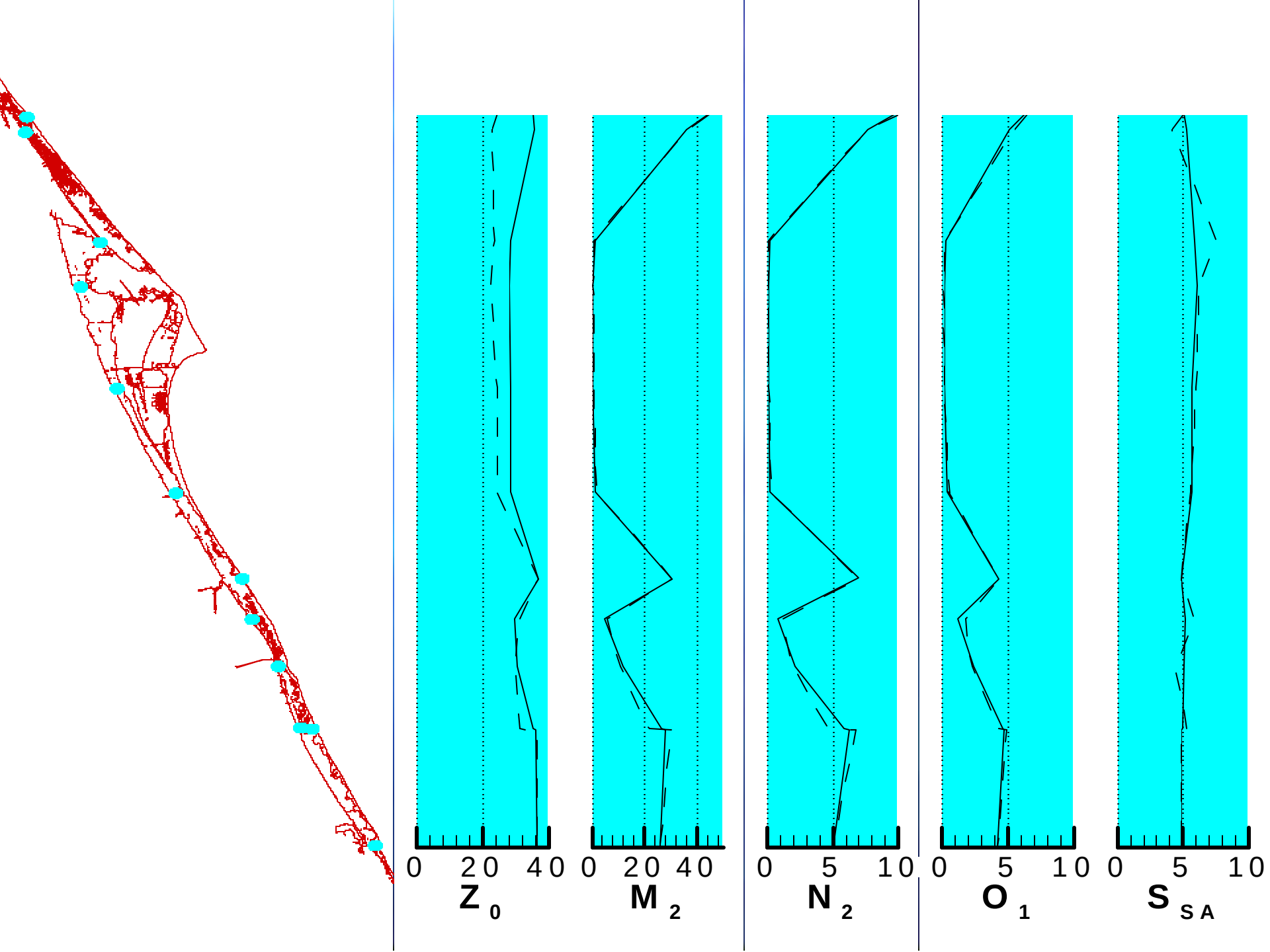


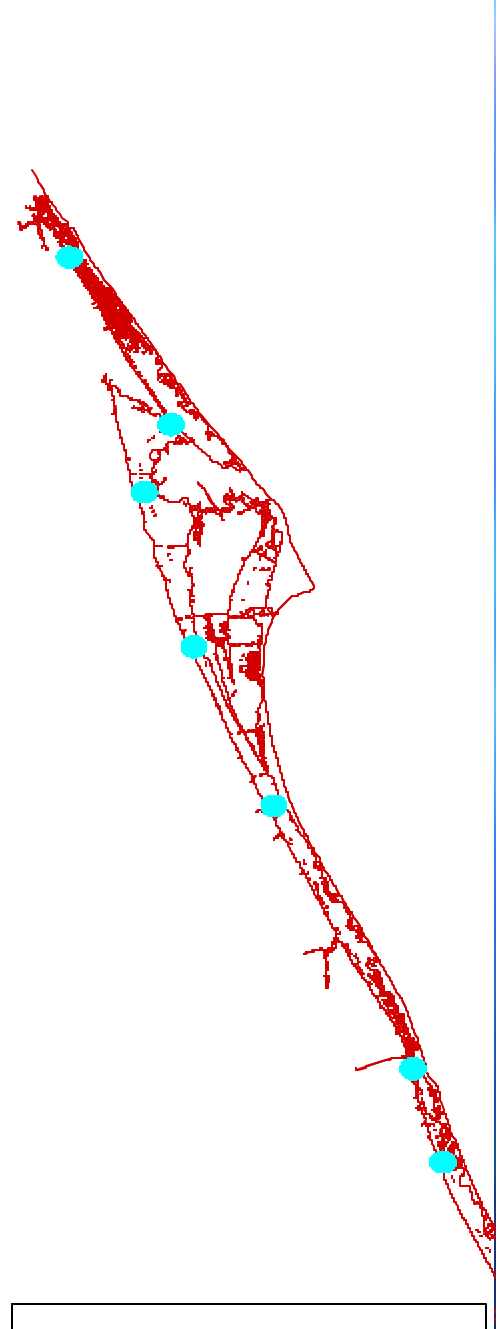

Photosynthetically Active Radiance (PAR)
Pure Water
Absorption
TSS (NALM)
Absorption
Scatterance
Chlorophyll-a
Absorption
Color (Yellow
Substance)
Absorption
PAR, K_PAR (Attenuation)
Seagrass

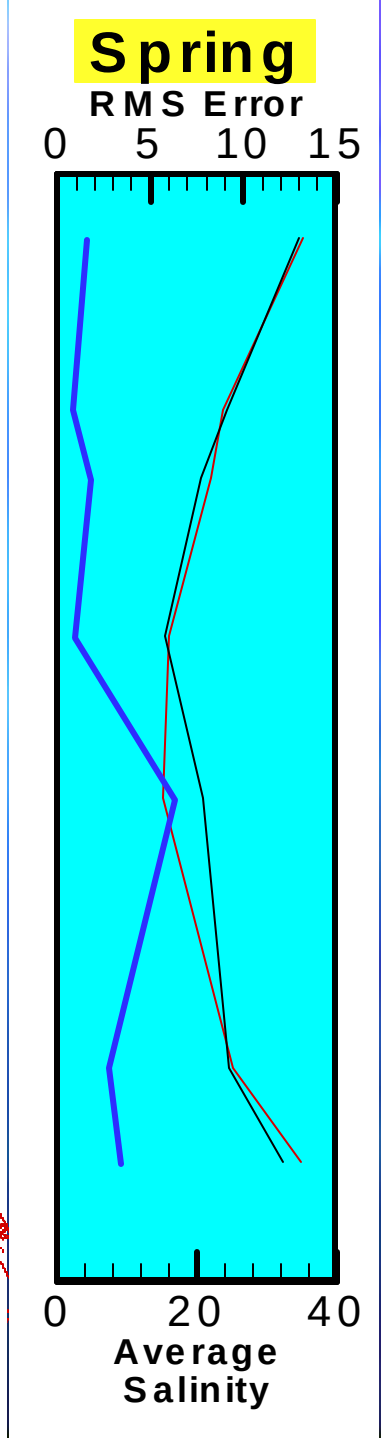
IRL Grid

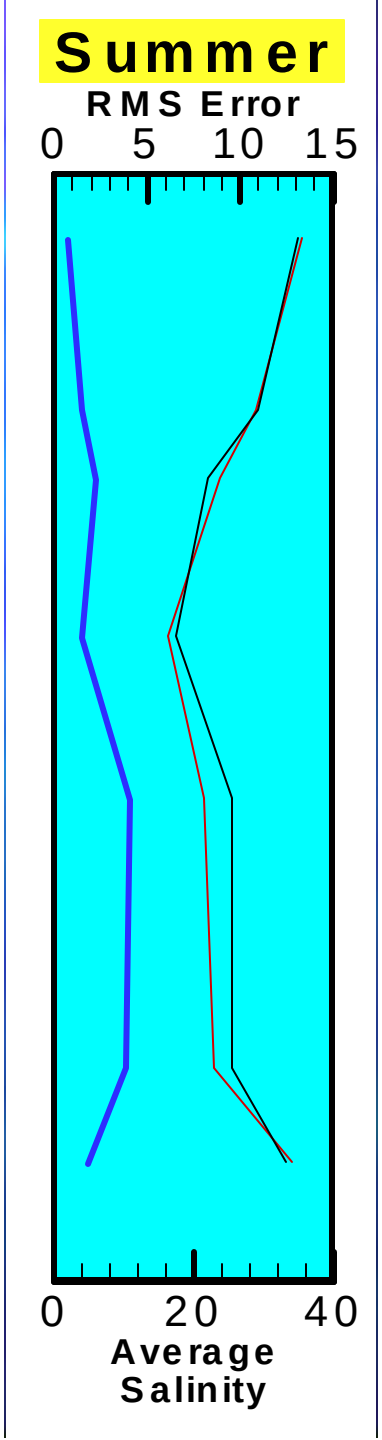
- Very fine:
  477 X 43 X 4
- Horizontal:
  non-orthogonal curvilinear
- Vertical: σ-stretching

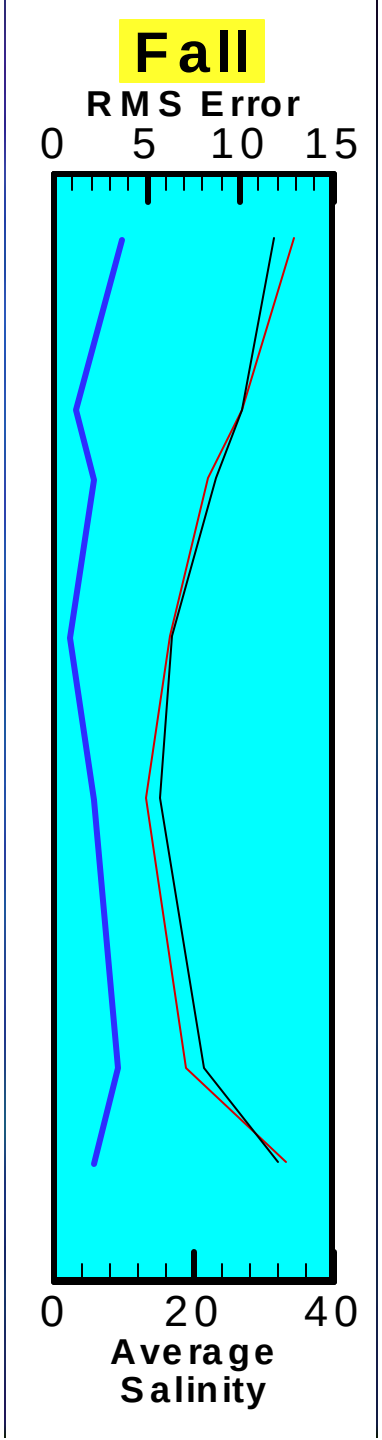


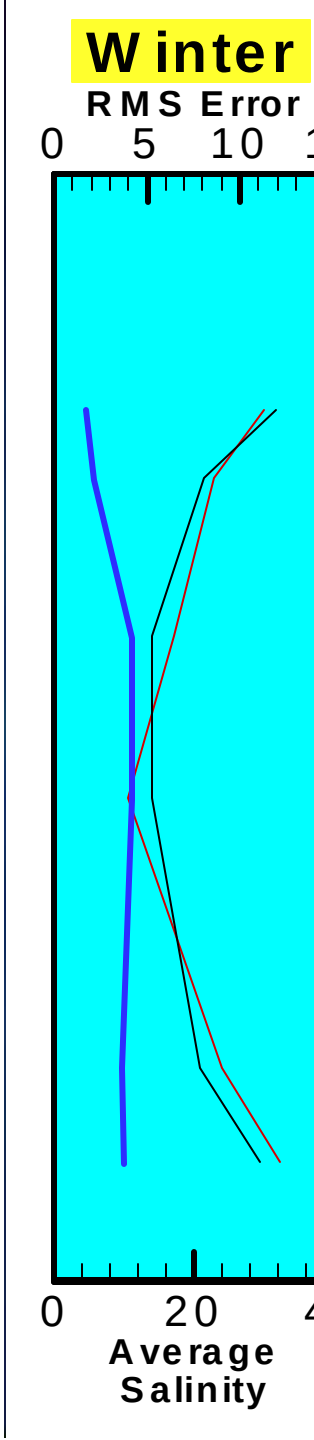

0 20 40
Z 0
0 20 40
M 2
0 5 10
N 2
0 5 10
O 1
0 5 10
S SA

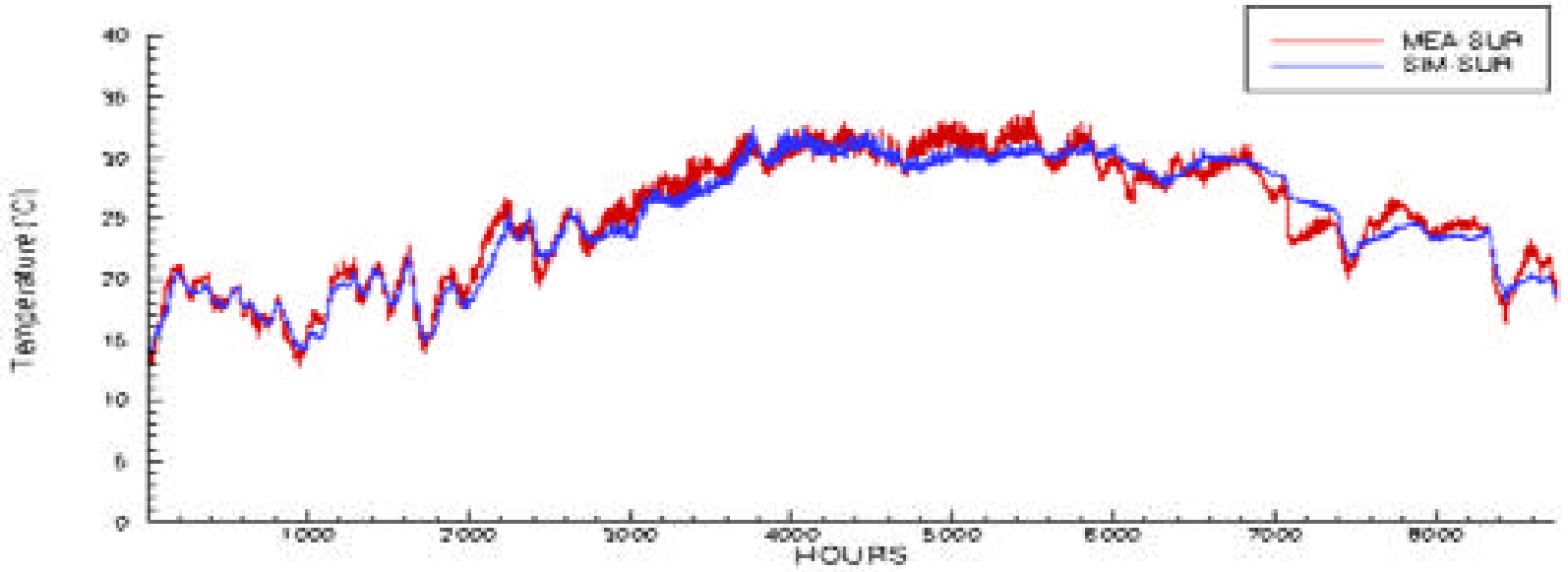

Simulated Average Salinity
Measured Average Salinity
RMS Error

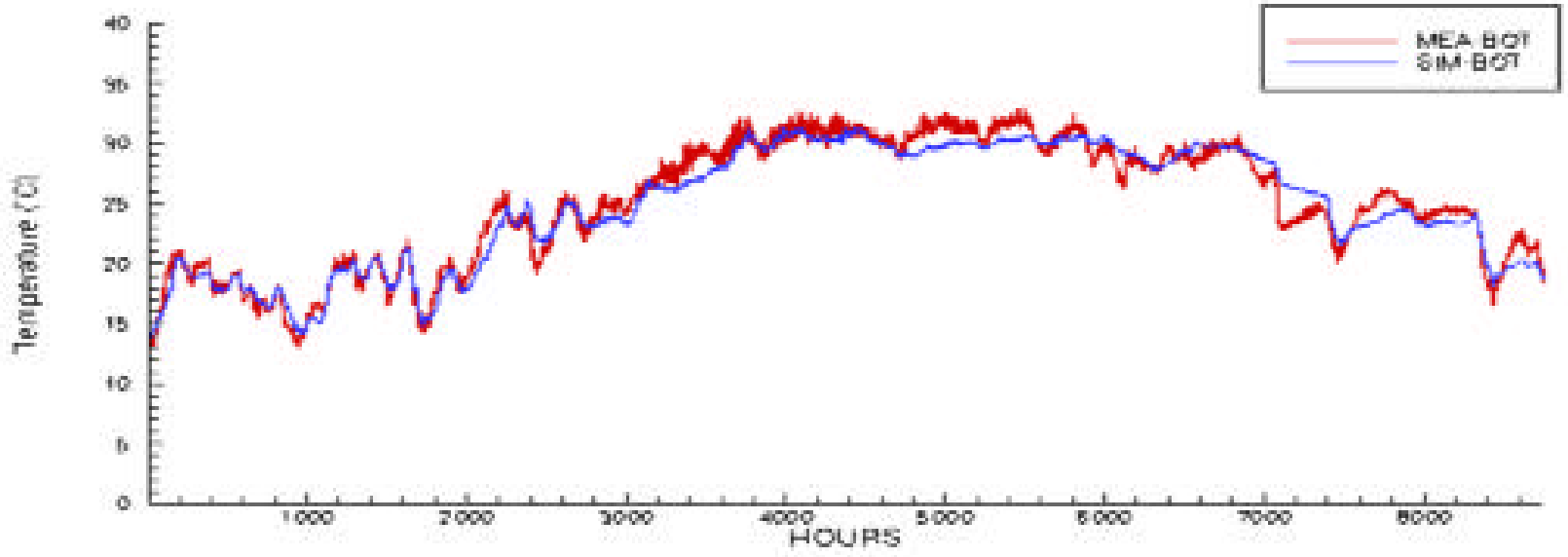

Spring
RMS Error
0 5 10 15
0 20 40
Average Salinity


Summer
RMS Error
0 5 10 15
0 20 40
Average Salinity

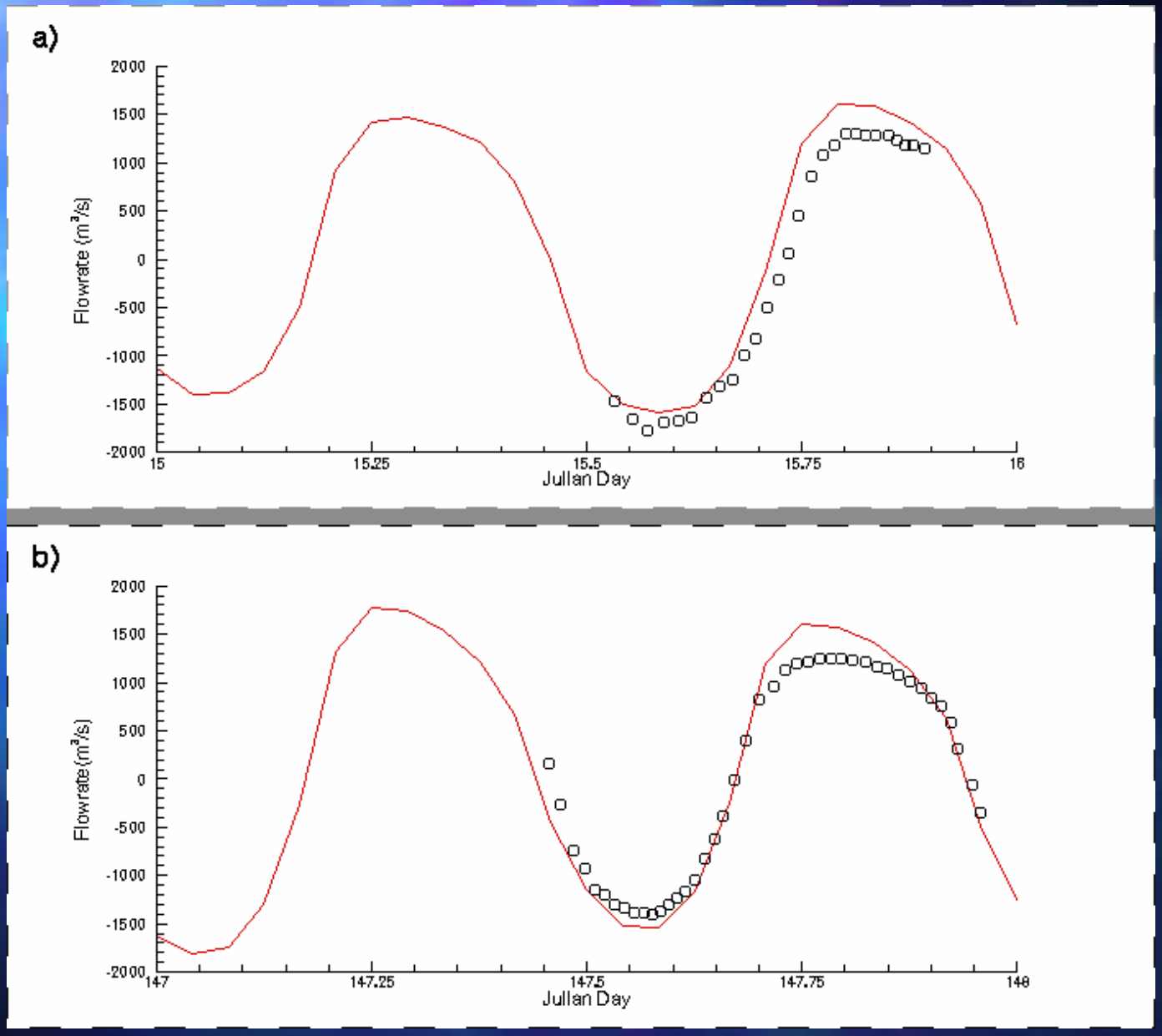

Fall
RMS Error
0 5 10 15
0 20 40
Average Salinity

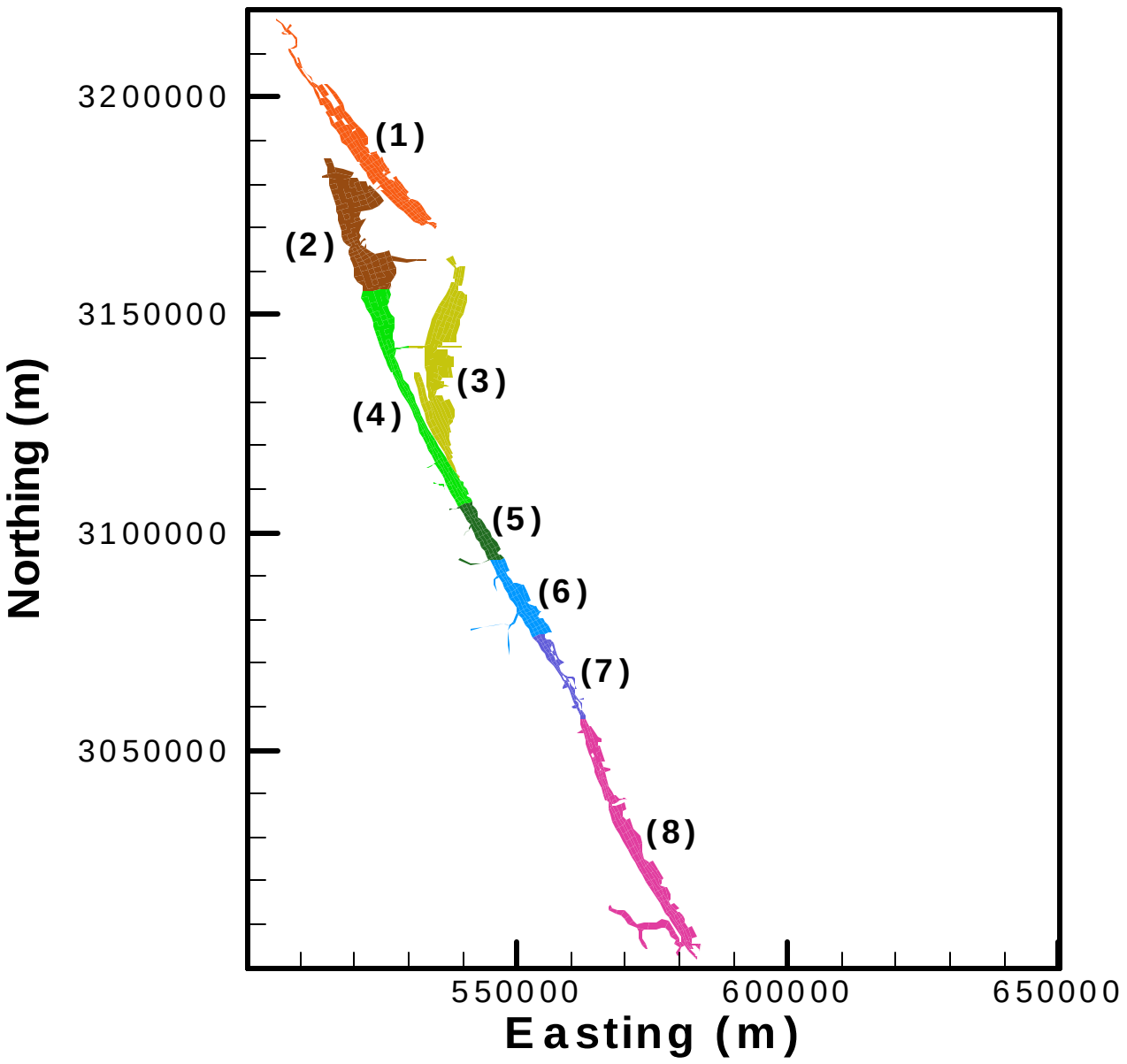

Winter
RMS Error
0 5 10
0 20
Average Salinity

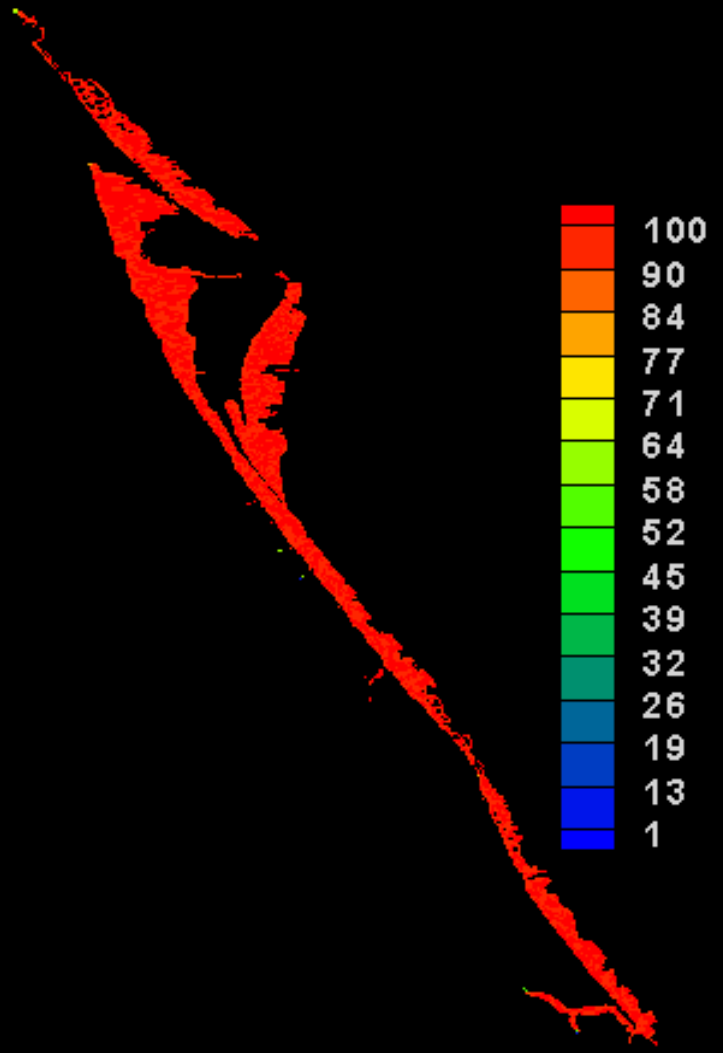




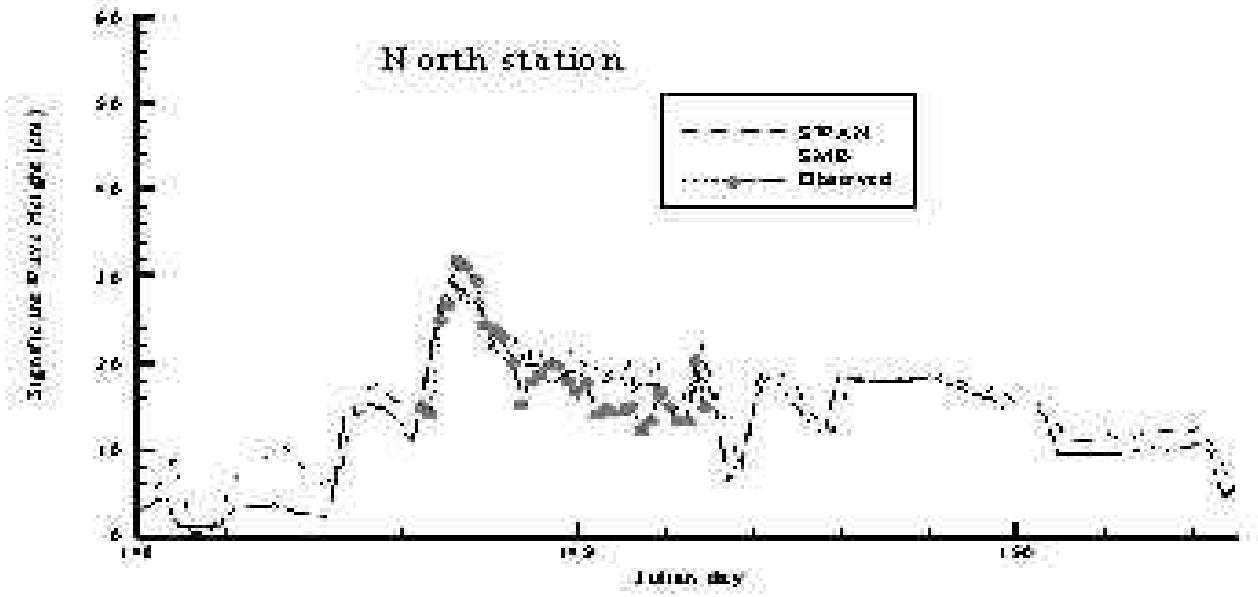
Surface and Bottom Temperature Time Series at Station One

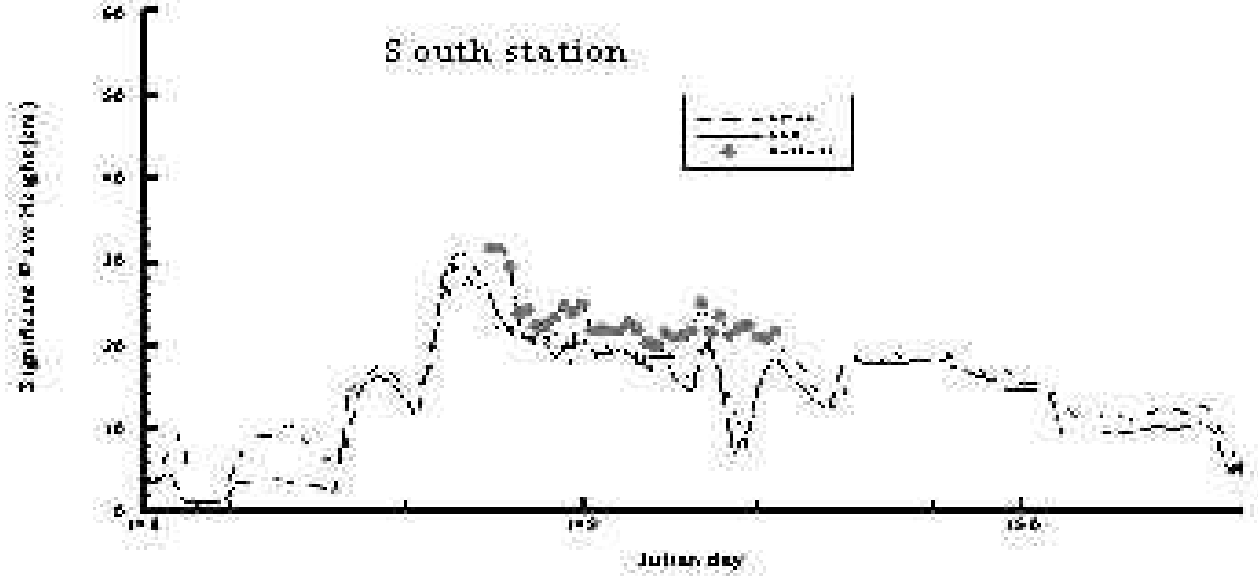

a)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
Flowrate (m³/s)
15
15.25
15.5
15.75
16
Julian Day
b)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
Flowrate (m³/s)
147
147.25
147.5
147.75
148
Julian Day

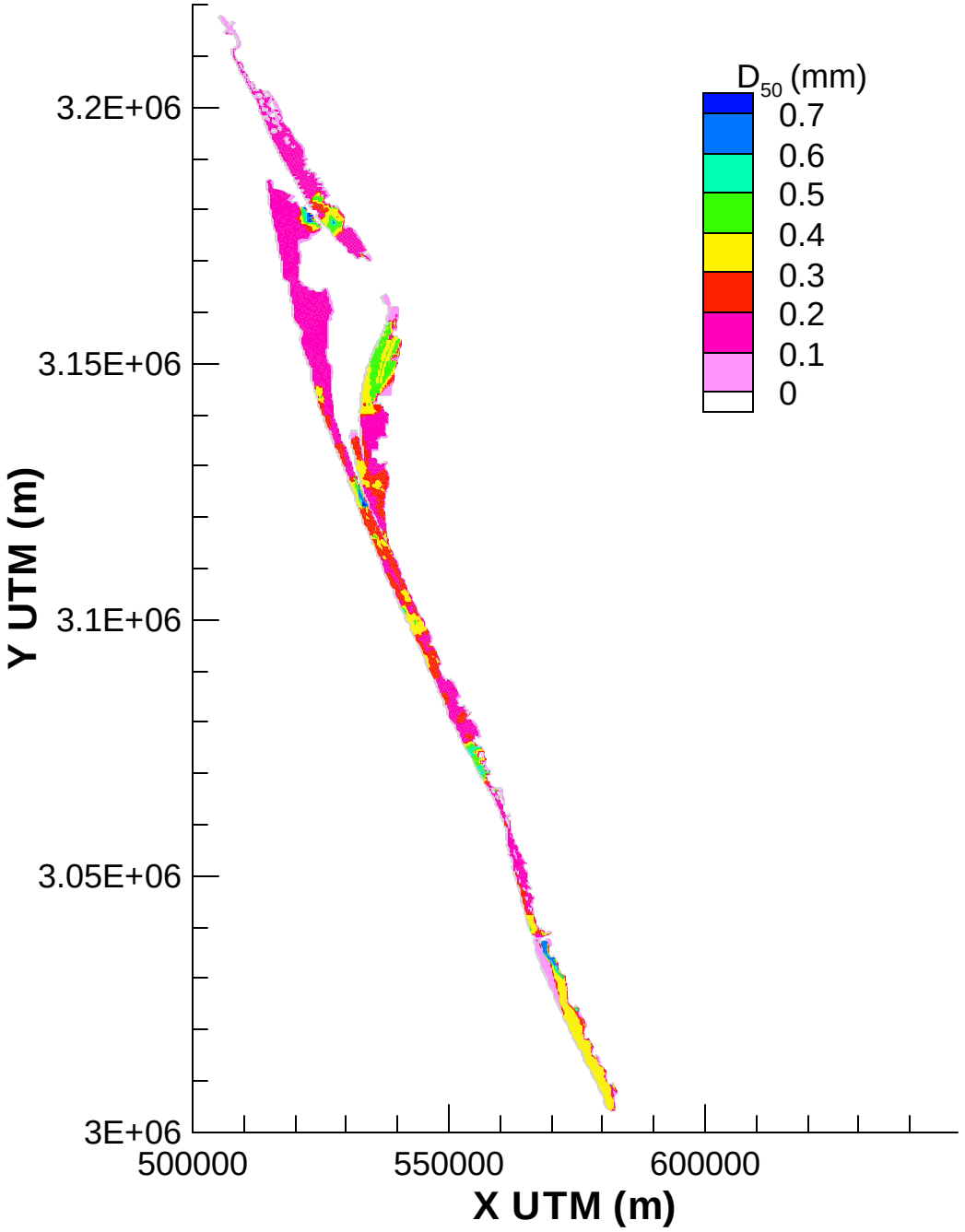

3200000
3150000
3100000
3050000
Northing (m)
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
550000
600000
650000
Easting (m)



January, 1998

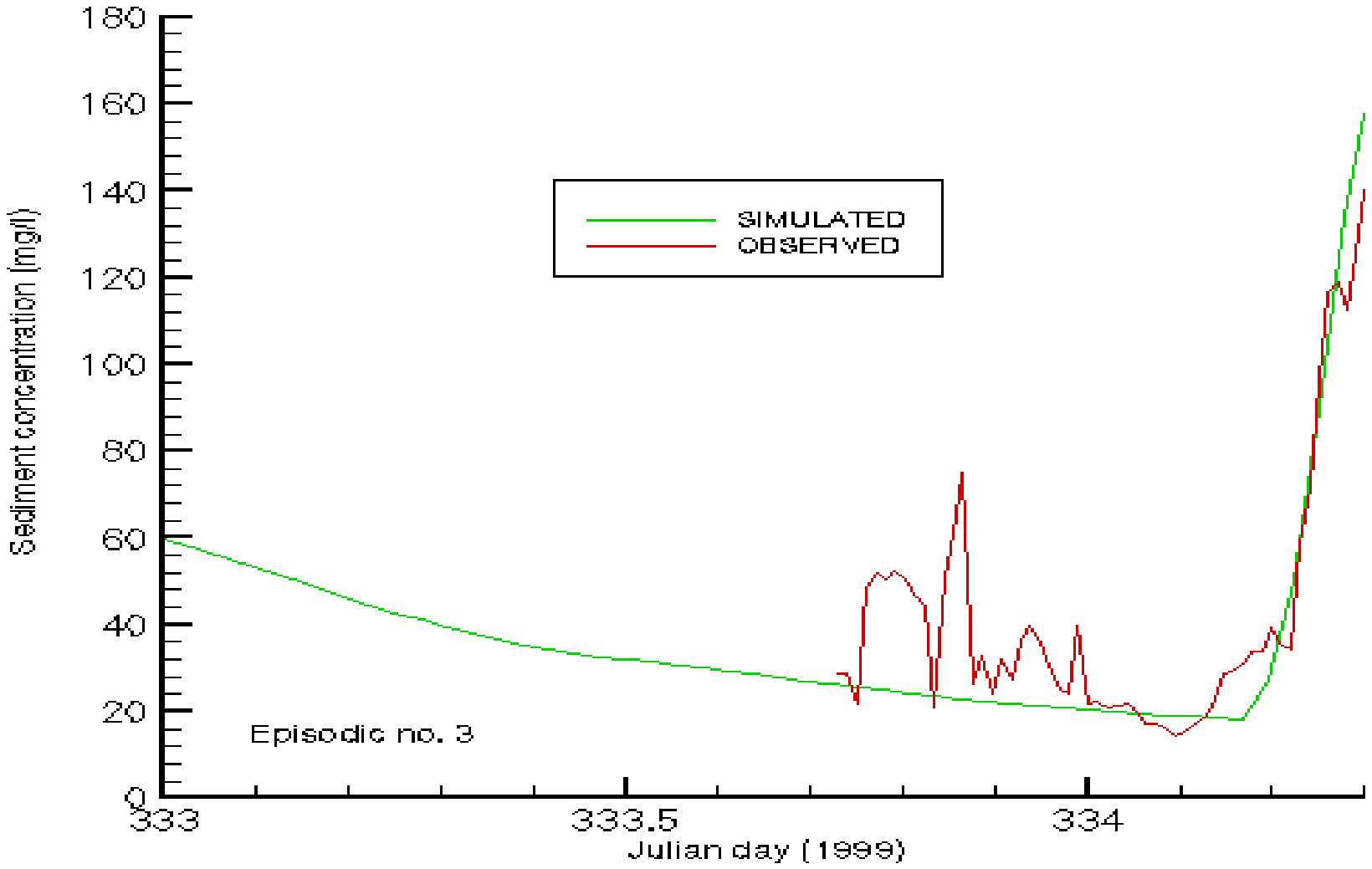

North station
SWAN
SMB
Observed
Julian day

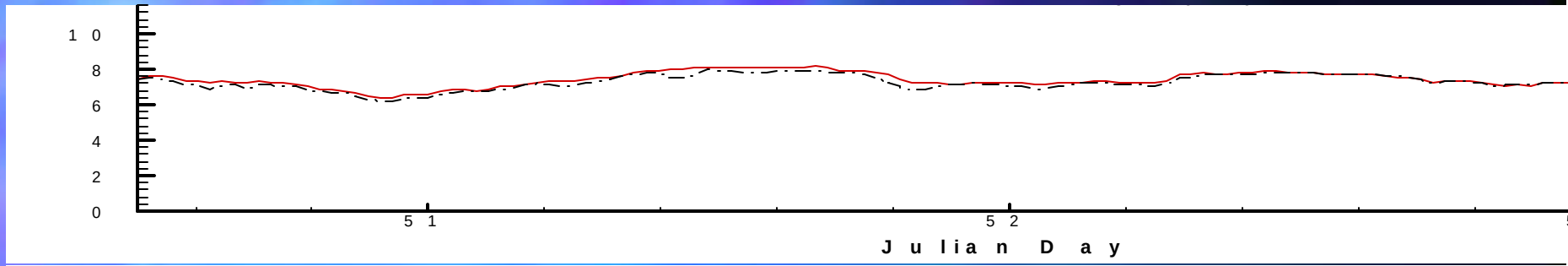

South station
Julian day

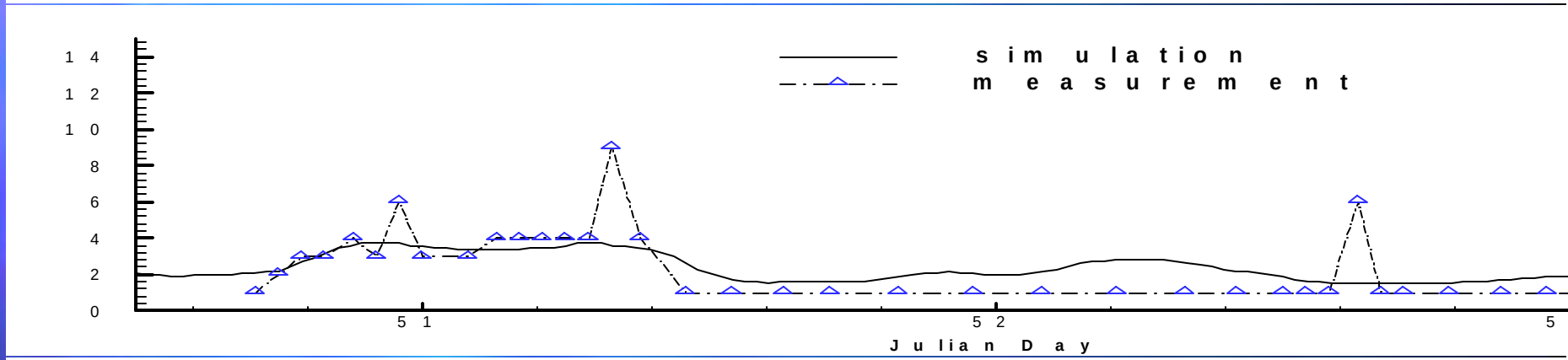


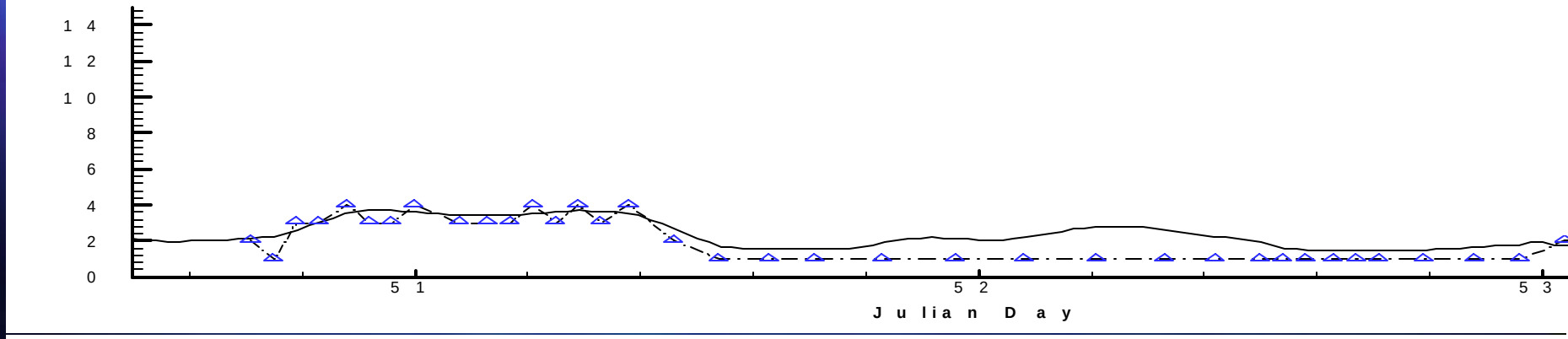
IRL sediment distribution map

Sediment Resuspension during an episodic event

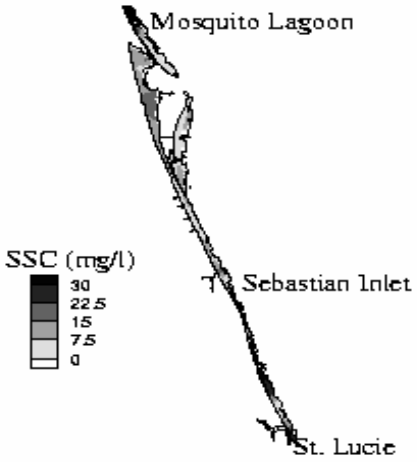



1 0
8
6
4
2
0
5 1
5 2
J u l i a n D a y

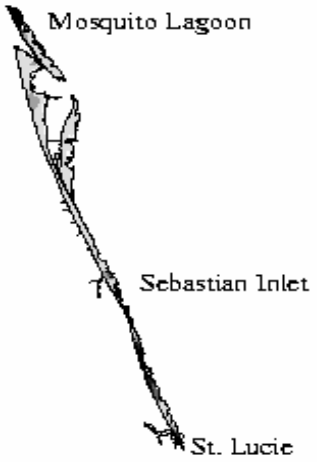

1 4
1 2
1 0
8
6
4
2
0
s i m u l a t i o n
m e a s u r e m e n t
5 1
5 2
J u l i a n D a y


1 4
1 2
1 0
8
6
4
2
0
5 1
5 2
5 3
J u l i a n D a y

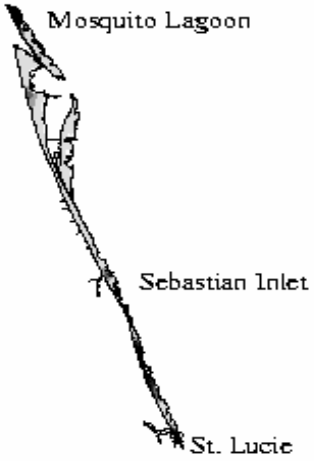

8 0
7 0
6 0
5 0



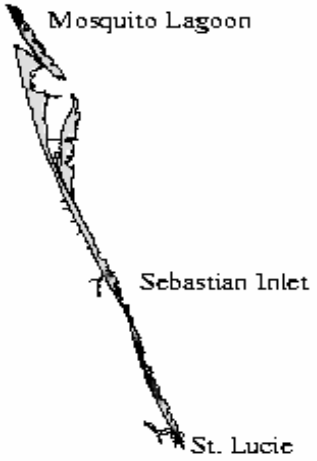
March



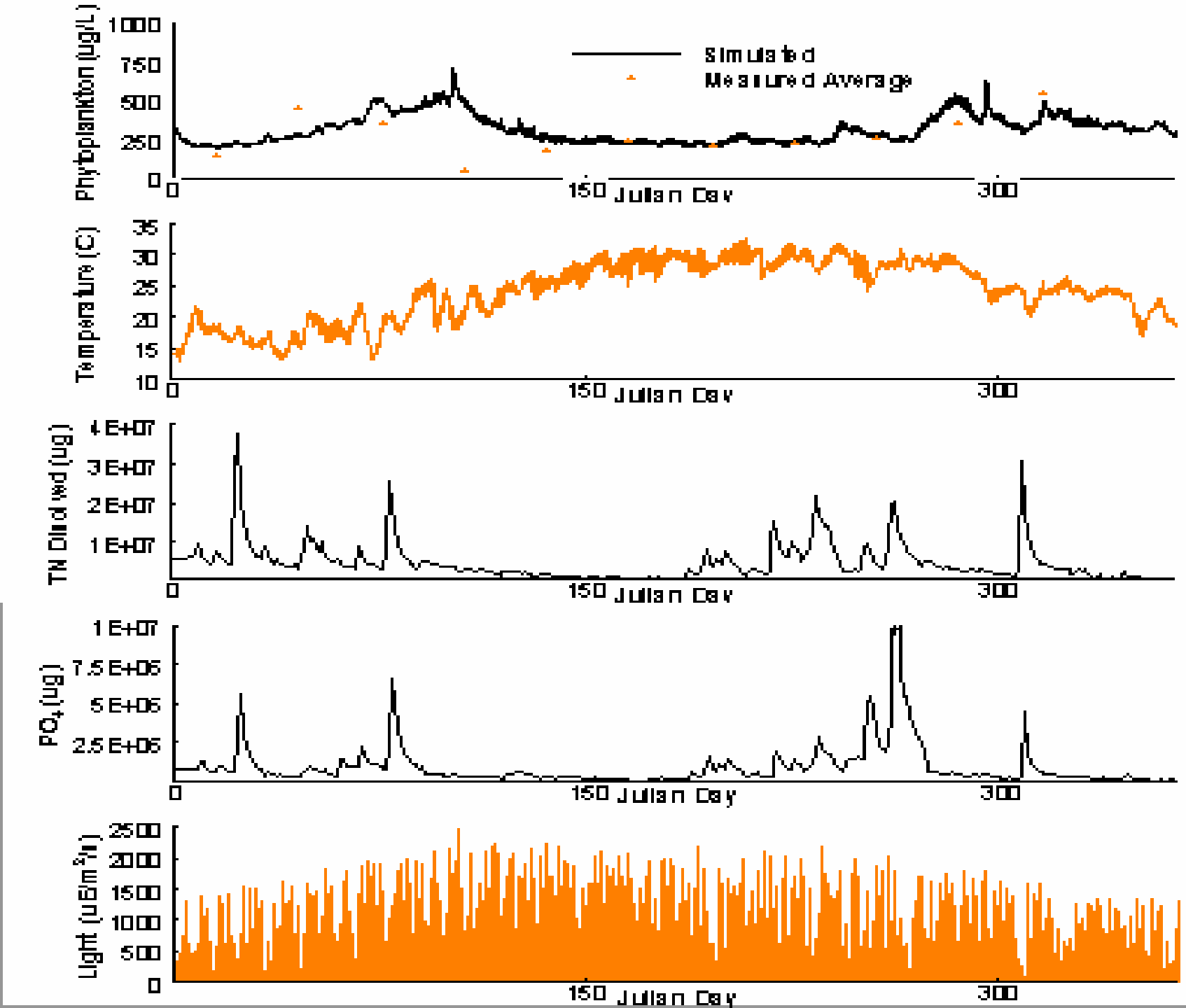
June



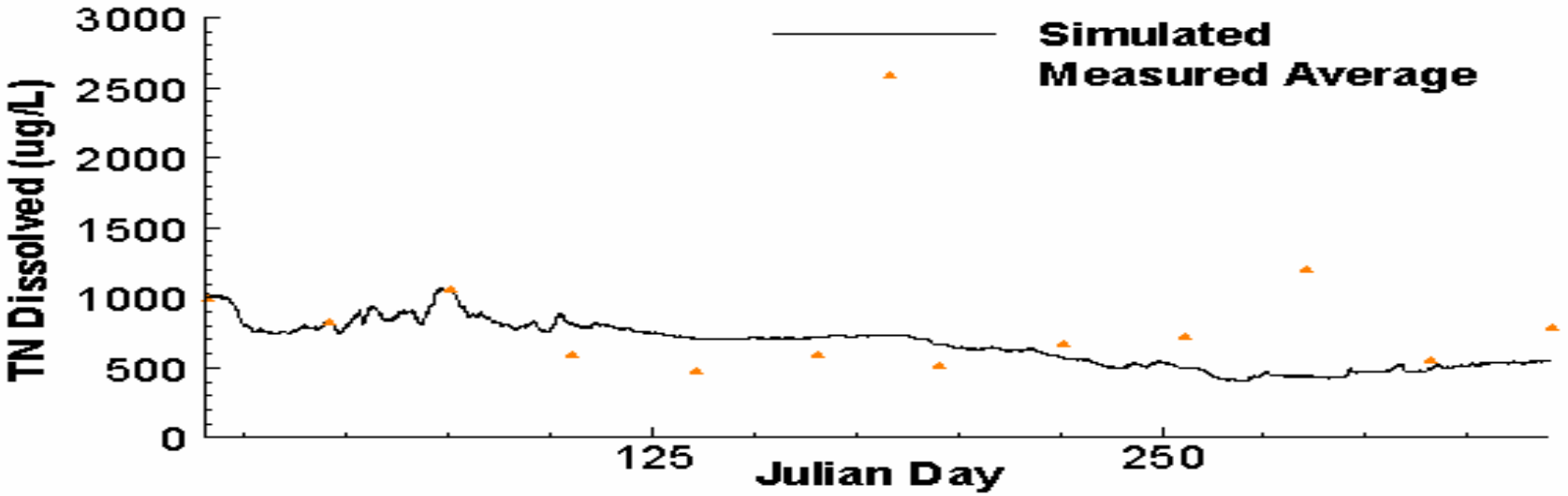
September

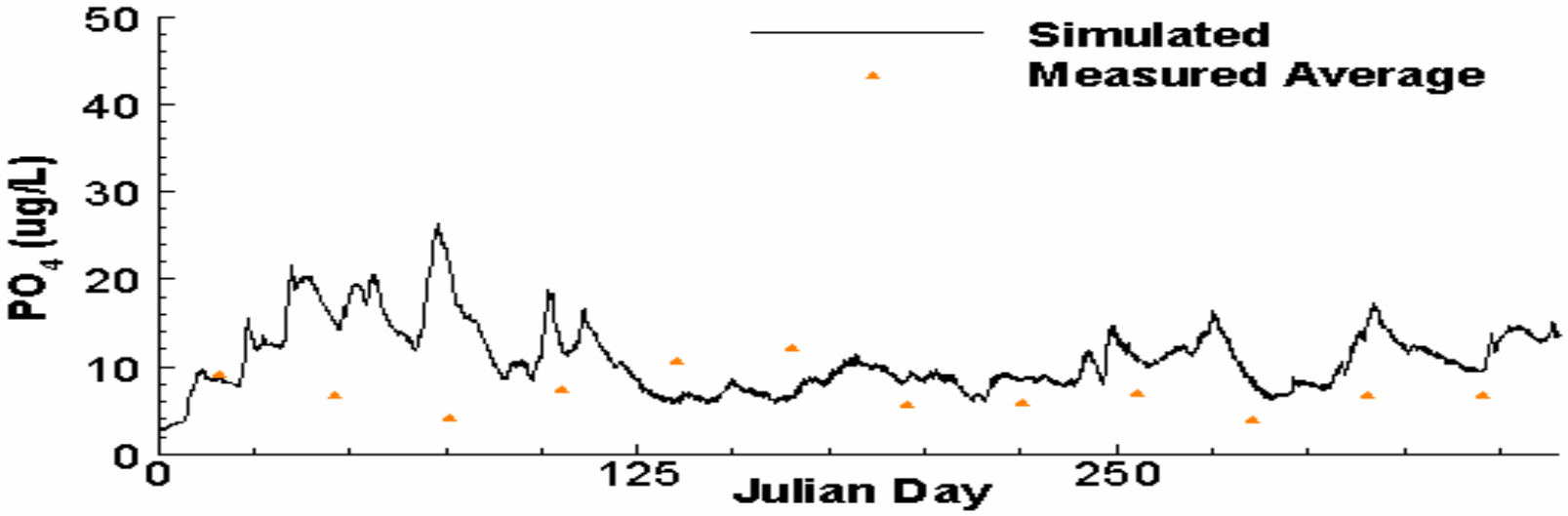


December

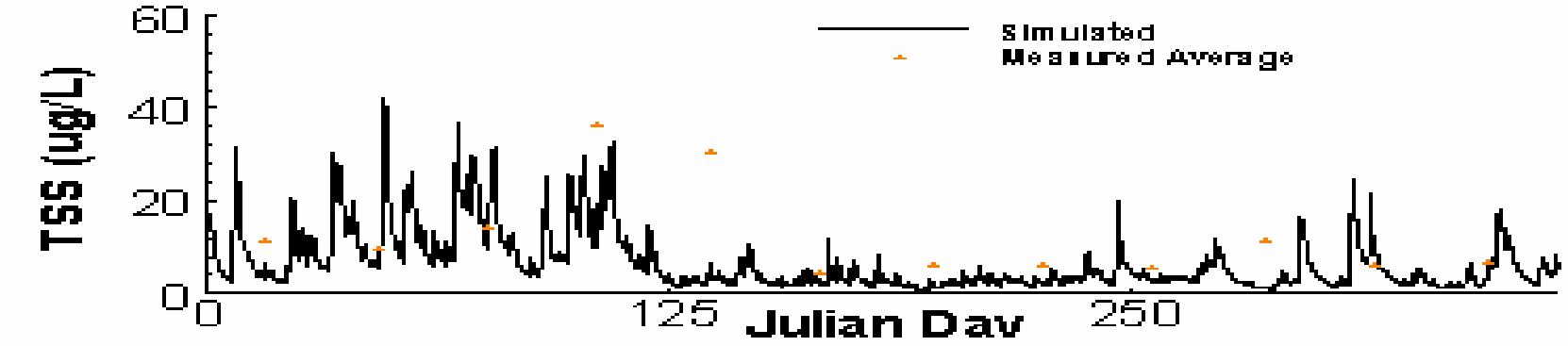

Phytoplankton (ug/L)
1000
750
500
250
0
Simulated
Measured Average
0
150
Julian Day
300
Temperature (C)
35
30
25
20
15
10
0
150
Julian Day
300
TN Dissolved (ug)
4 E+07
3 E+07
2 E+07
1 E+07
0
150
Julian Day
300
PO4 (ug)
1 E+07
7.5 E+06
5 E+06
2.5 E+06
0
150
Julian Day
300
Light (uEim^2/s)
2500
2000
1500
1000
500
0
150
Julian Day
300

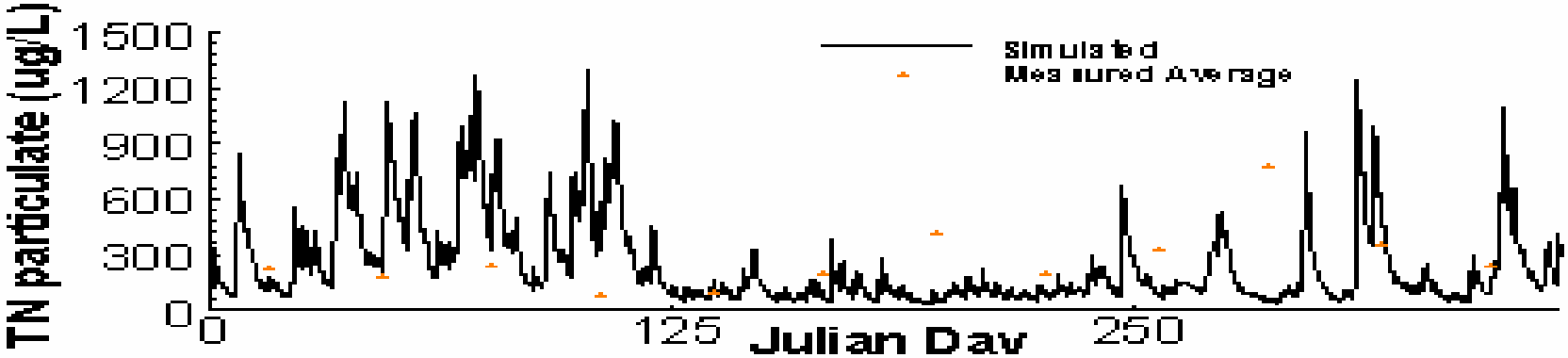
Segment Averaged TND & SRP

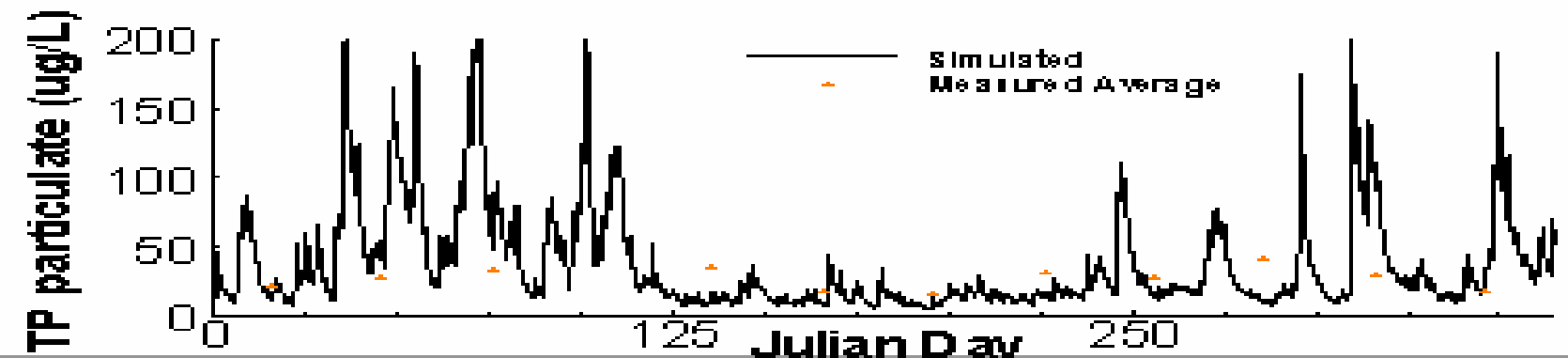




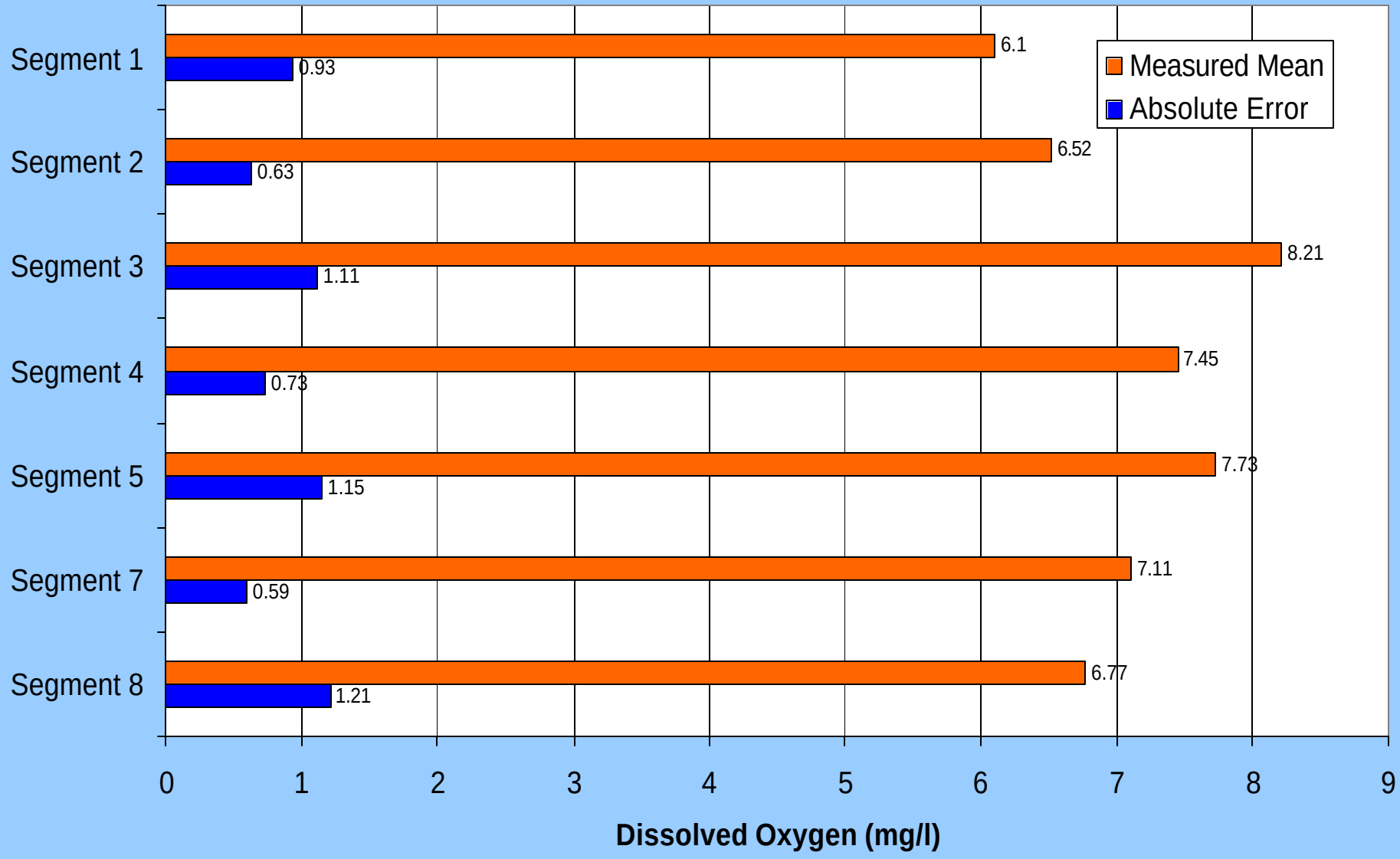
Segment Avg. TSS, TNP, TPP



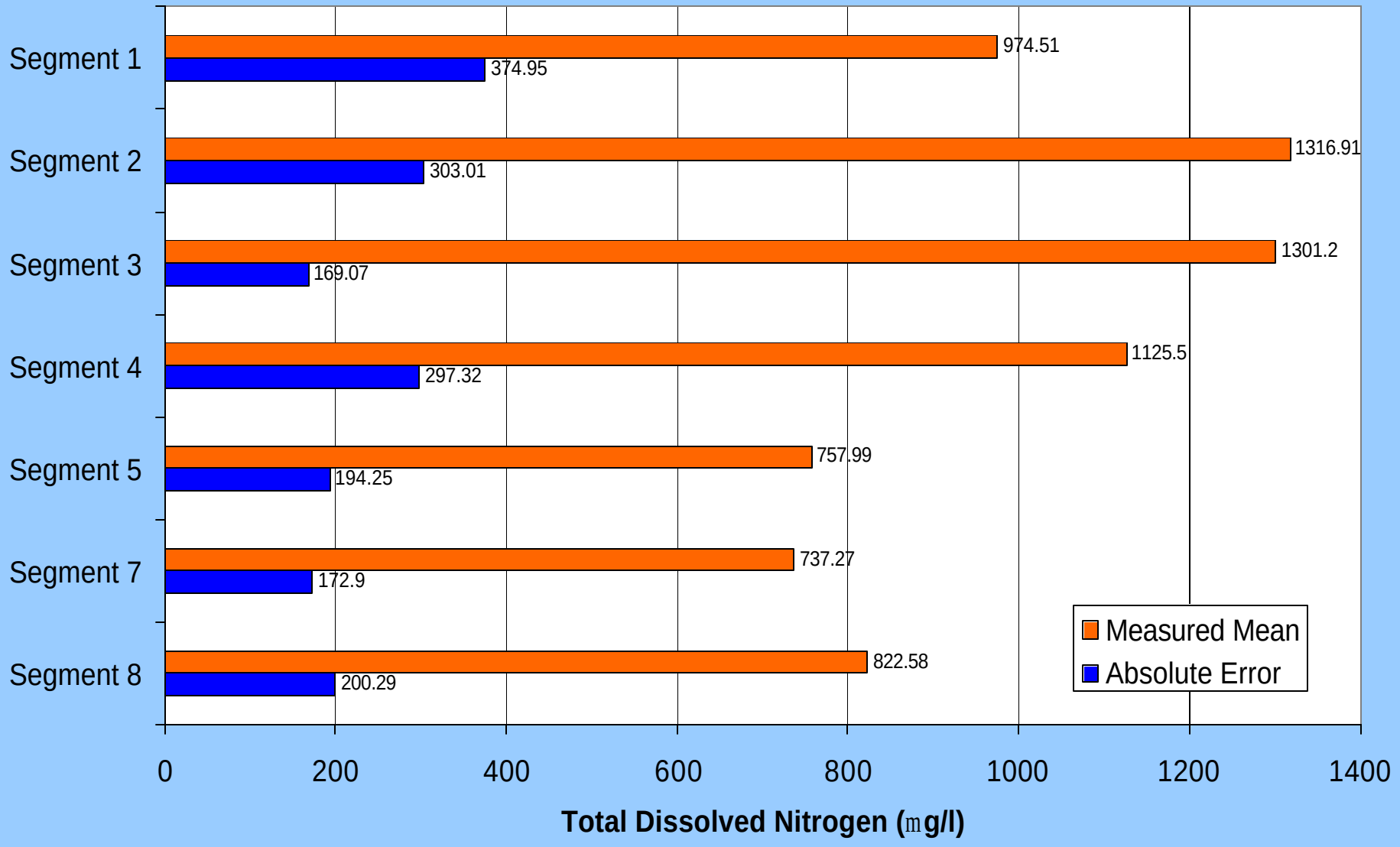




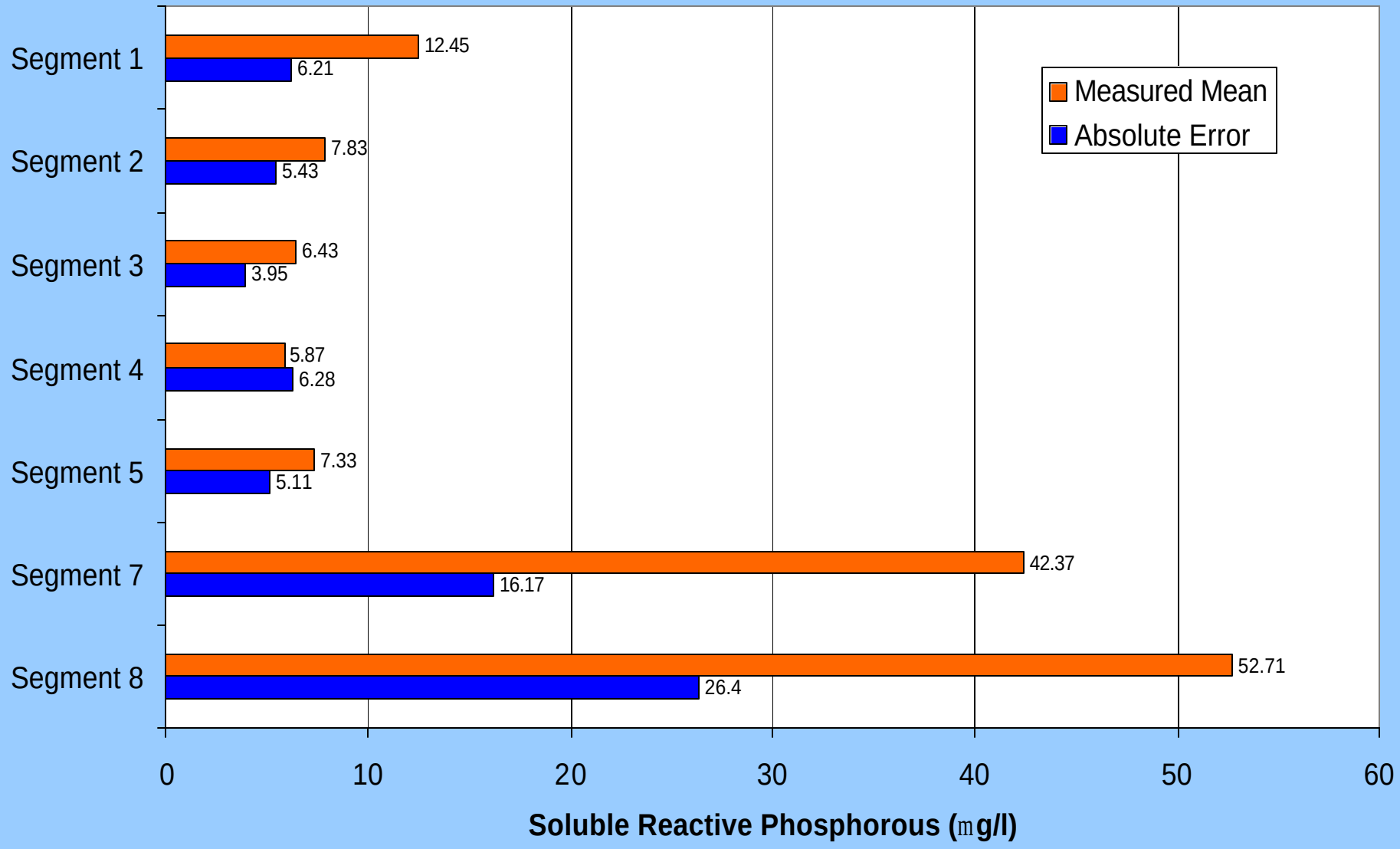
Error of Simulated Dissolved Oxygen Concentration



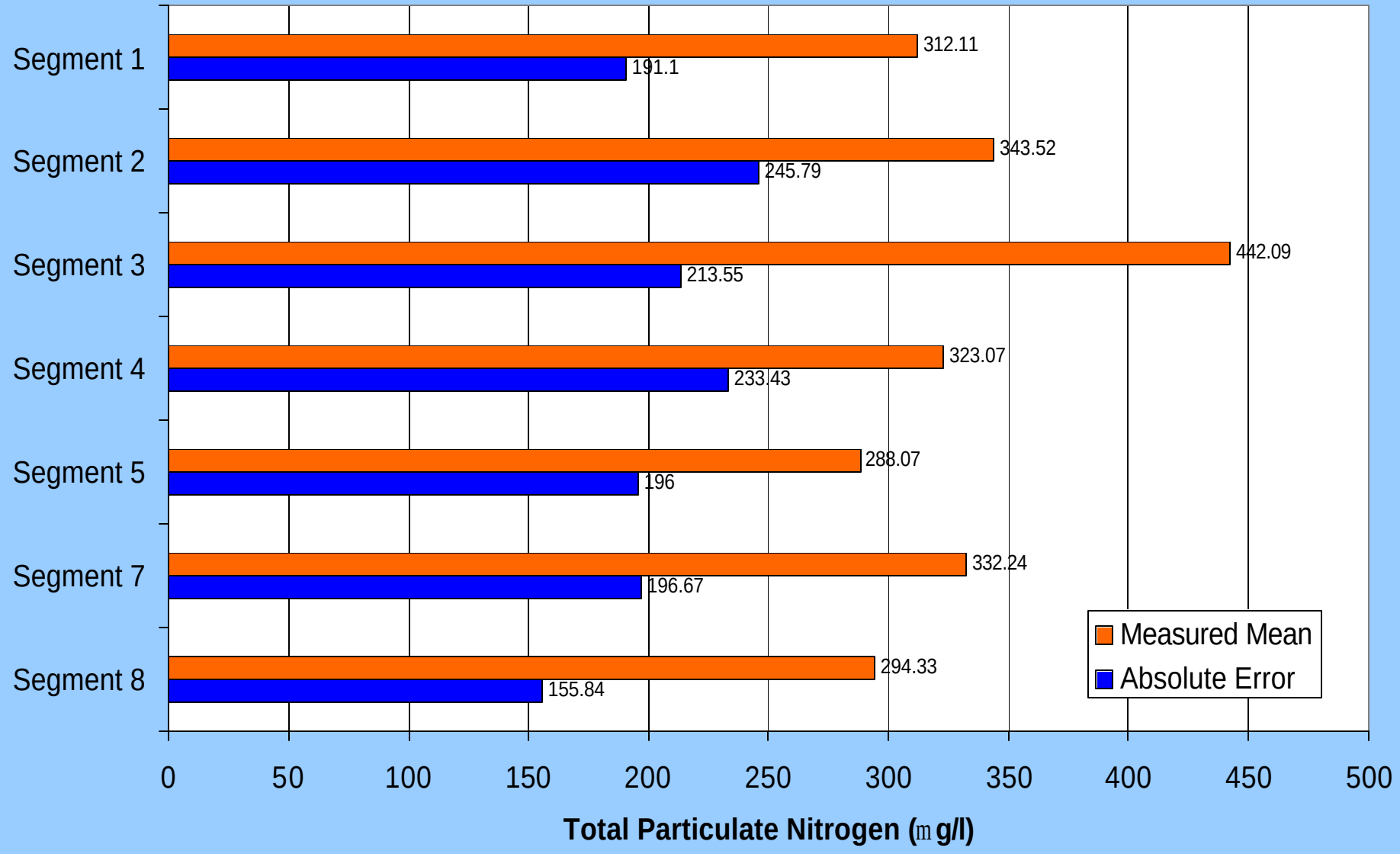
Error of Simulated Total Dissolved Nitrogen



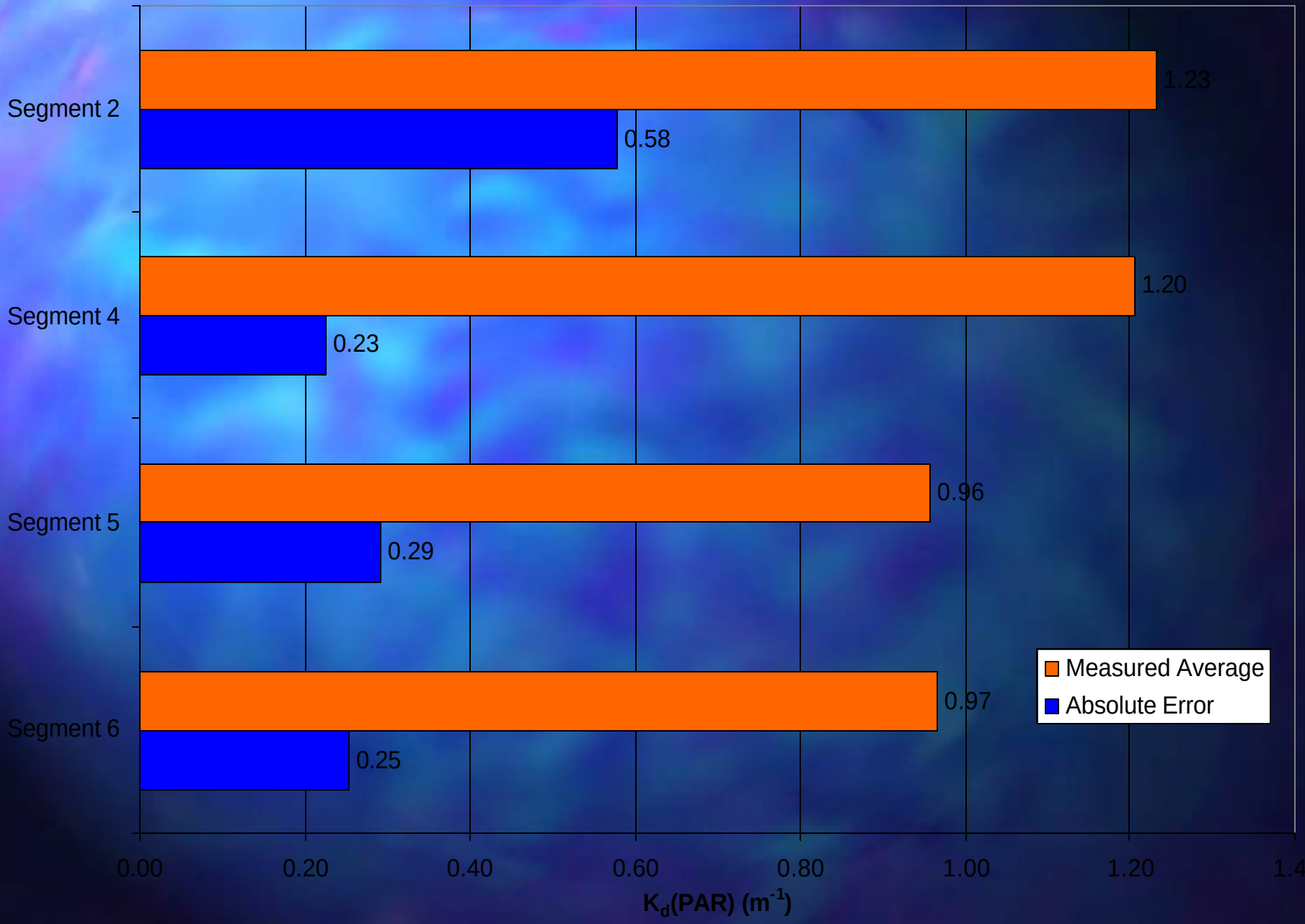
Error of Simulated Soluble Reactive Phosphorus

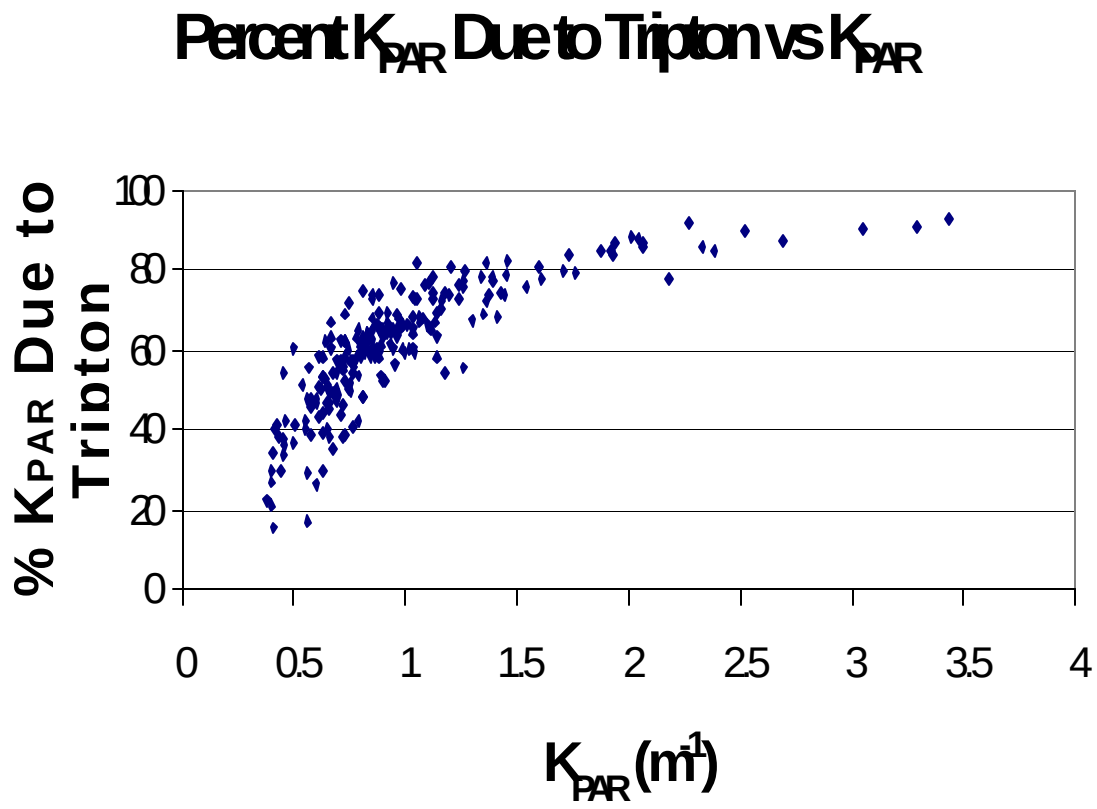


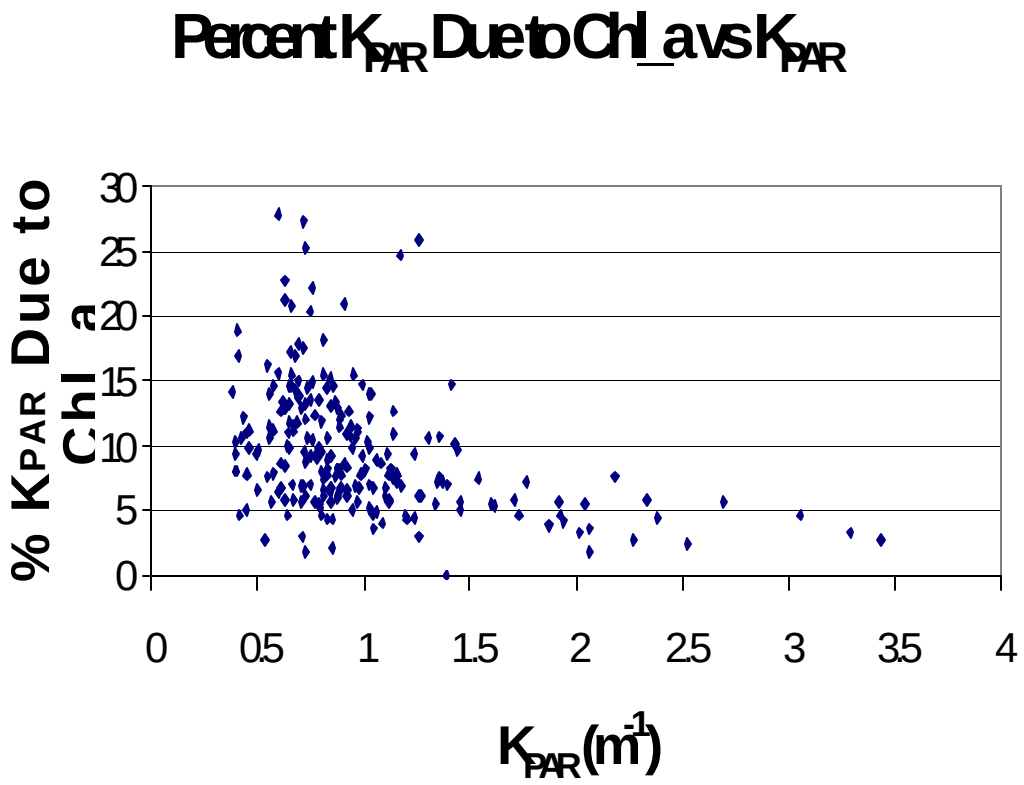
Error of Simulated Total Particulate Nitrogen

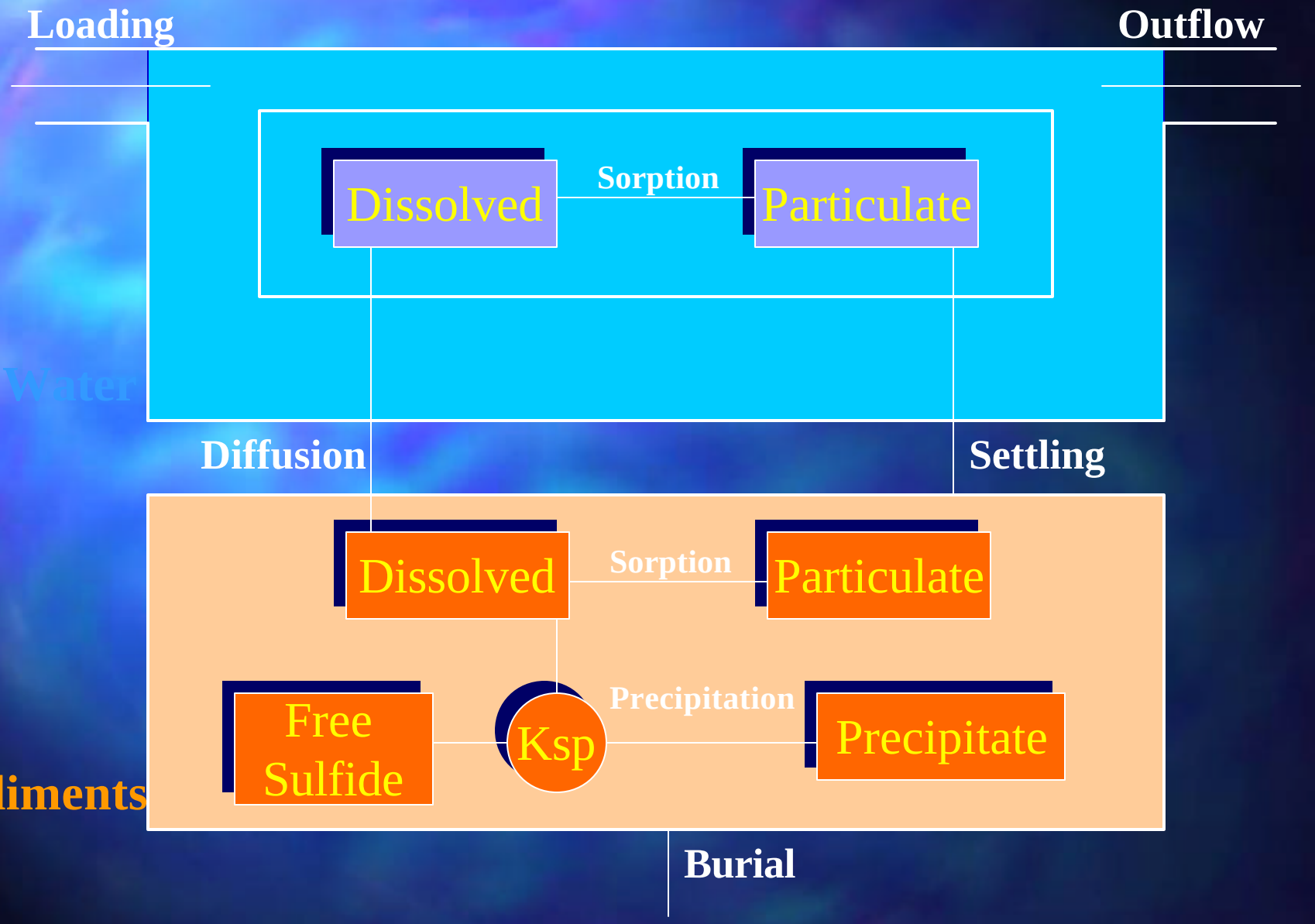


Synoptic 11


Segment 2
Segment 4
Segment 5
Segment 6
1.23
0.58
1.20
0.23
0.96
0.29
0.97
0.25
Measured Average
Absolute Error
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
K_d(PAR) (m^{-1})


Percent K_{PAR} Due to Tripton vs K_{PAR}
% K_{PAR} Due to Tripton
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
K_{PAR} (m^{-1})


Percent K_{PAR} Due to Chl_a vs K_{PAR}
% K_{PAR} Due to Chl_a
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
K_{PAR} (m^{-1})


Loading
Outflow
Dissolved
Sorption
Particulate
Water
Diffusion
Settling
Dissolved
Sorption
Particulate
Free Sulfide
Ksp
Precipitation
Precipitate
Sediments
Burial

a)
b)
Depth (cm)

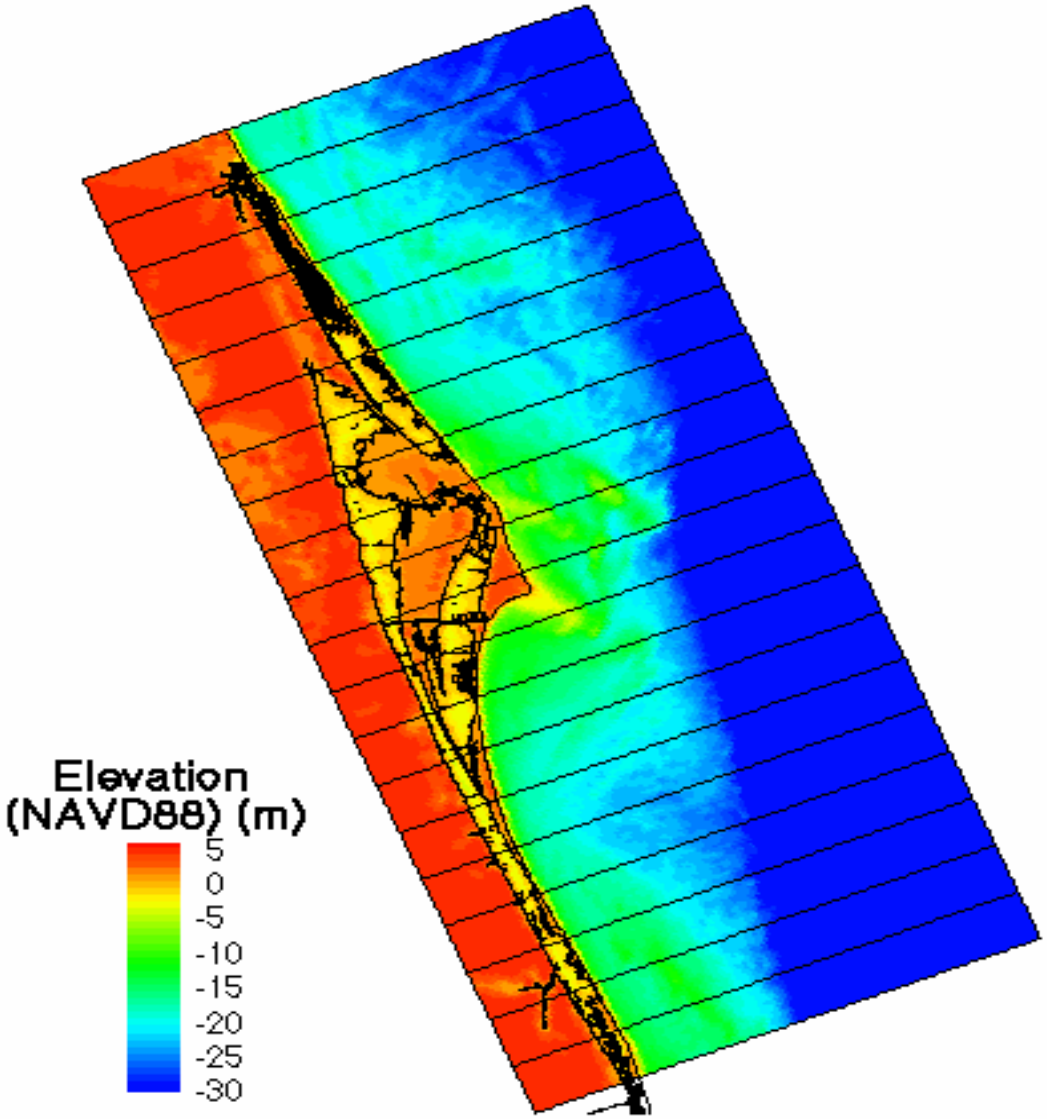
a) July (dry) - 4 Layers

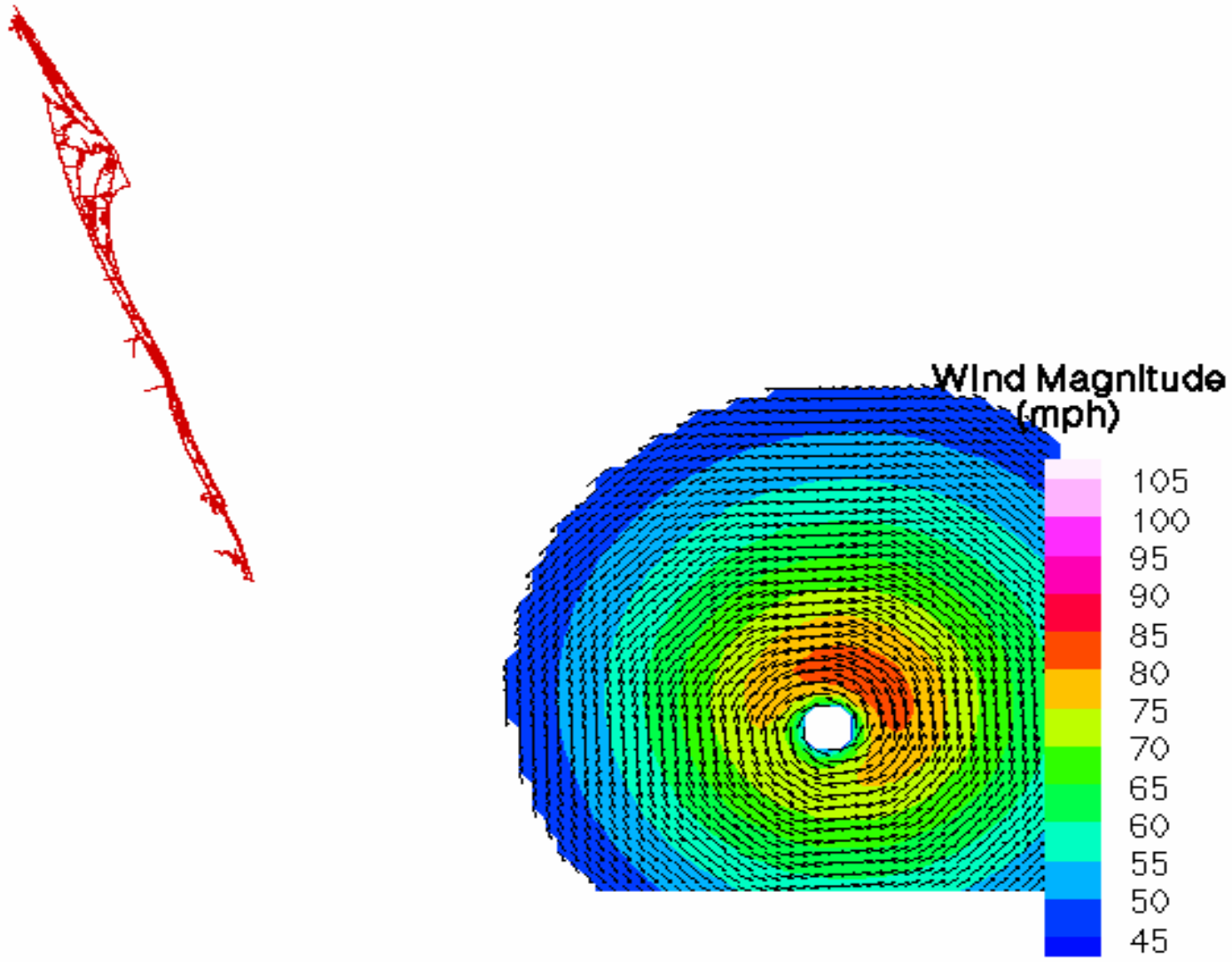
a) August (wet) - 4 Layers

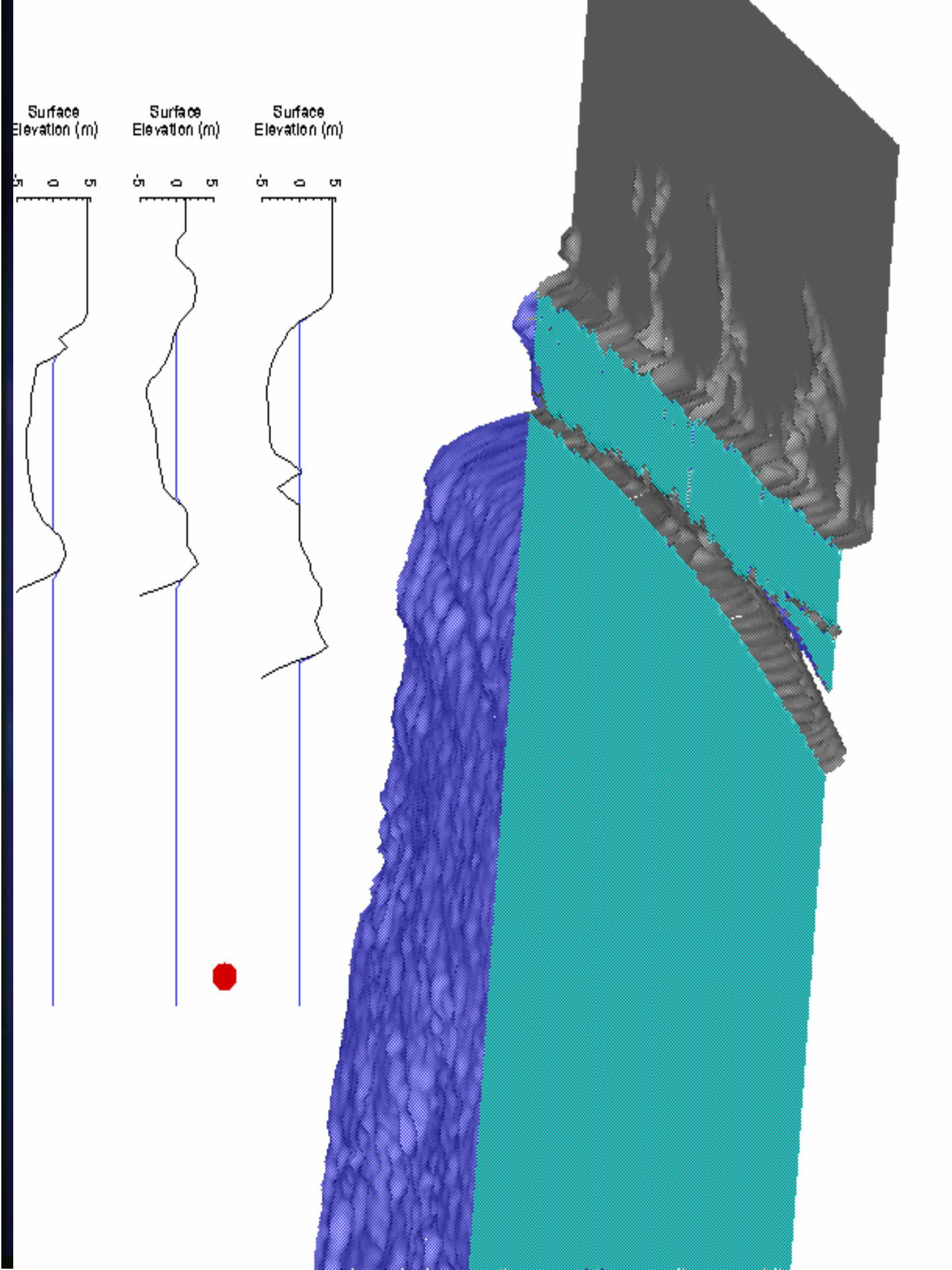
c) July (dry) - 8 Layers

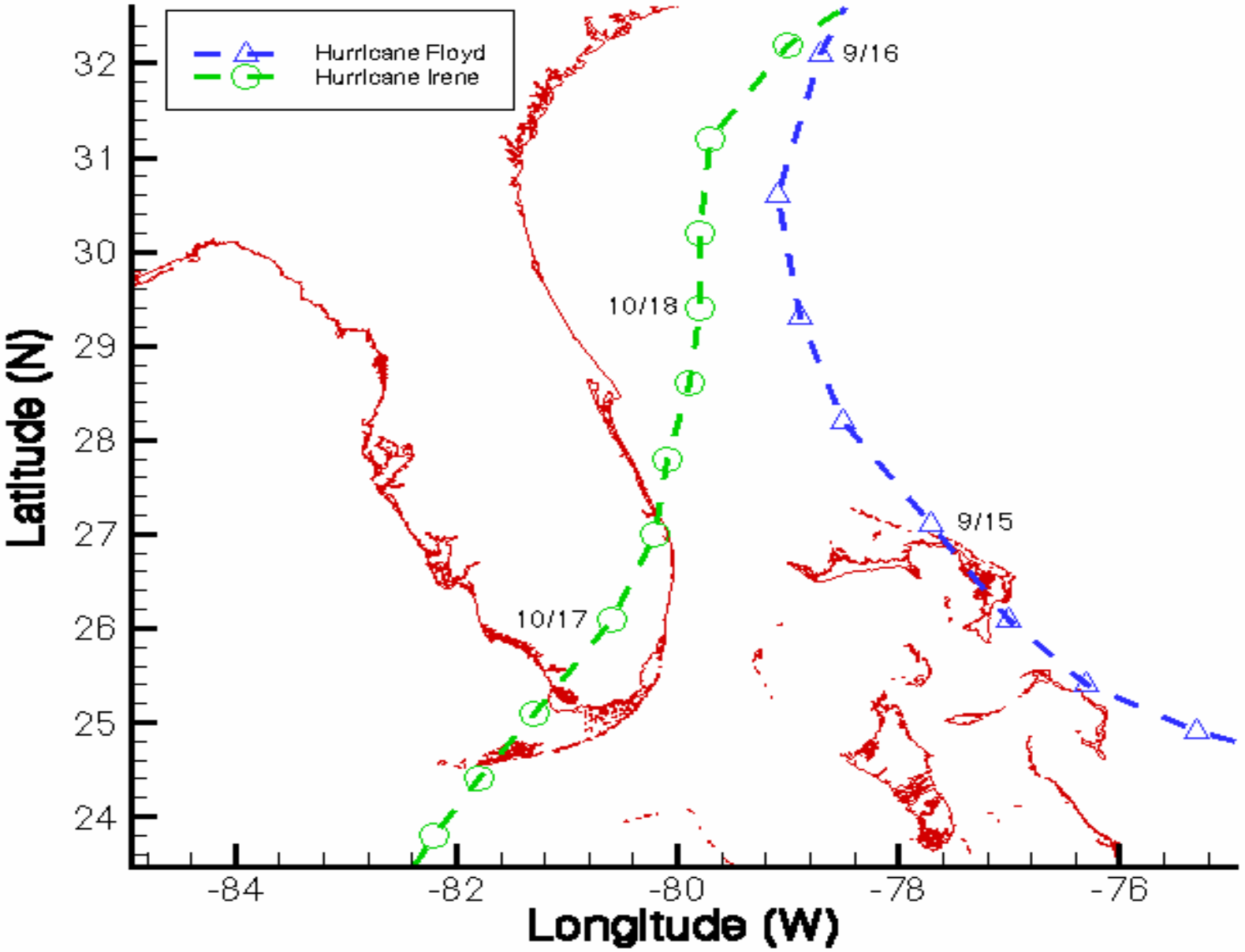
d) August (wet) - 8 Layers

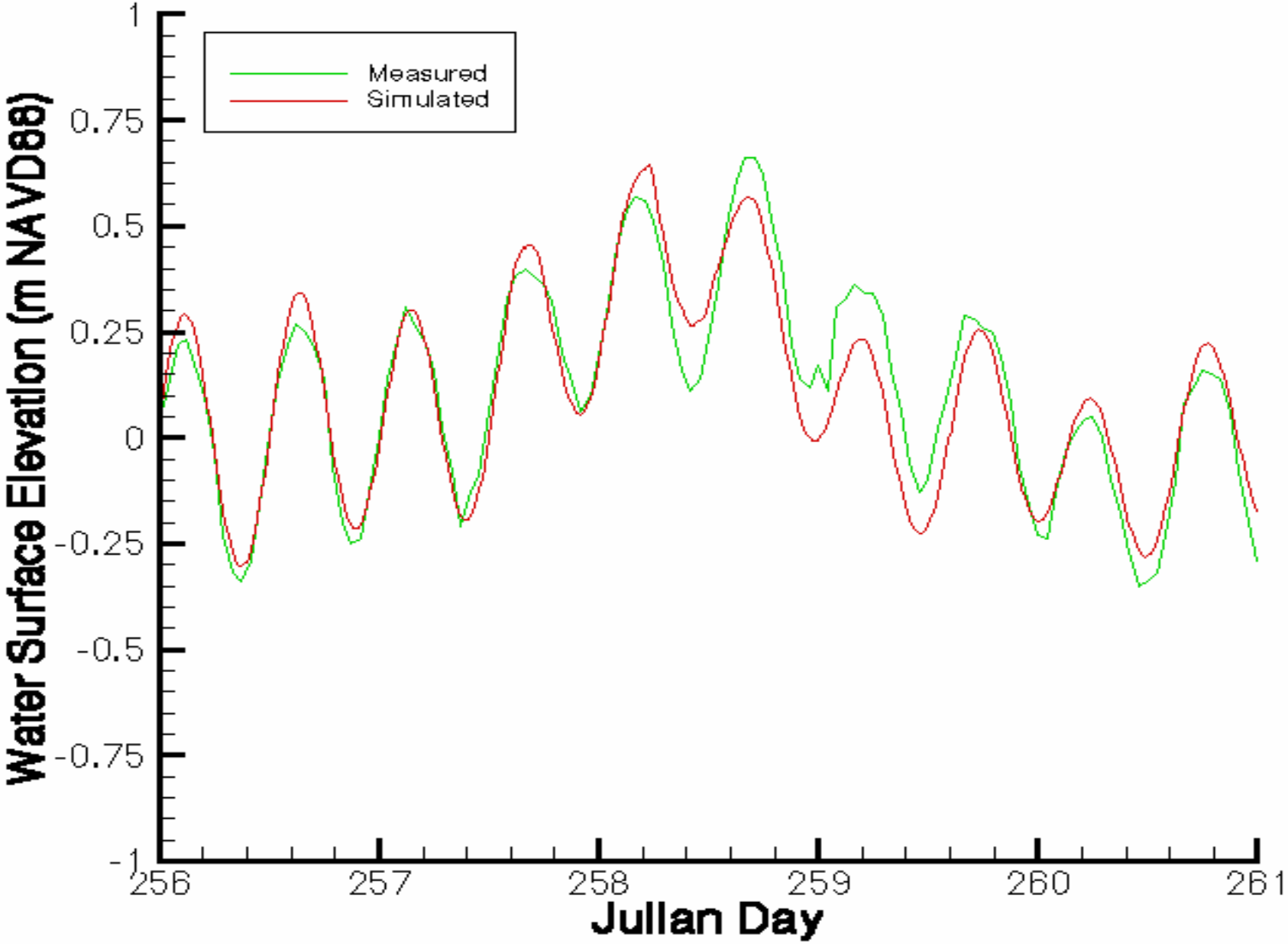
Salinity Stratification (ppt)

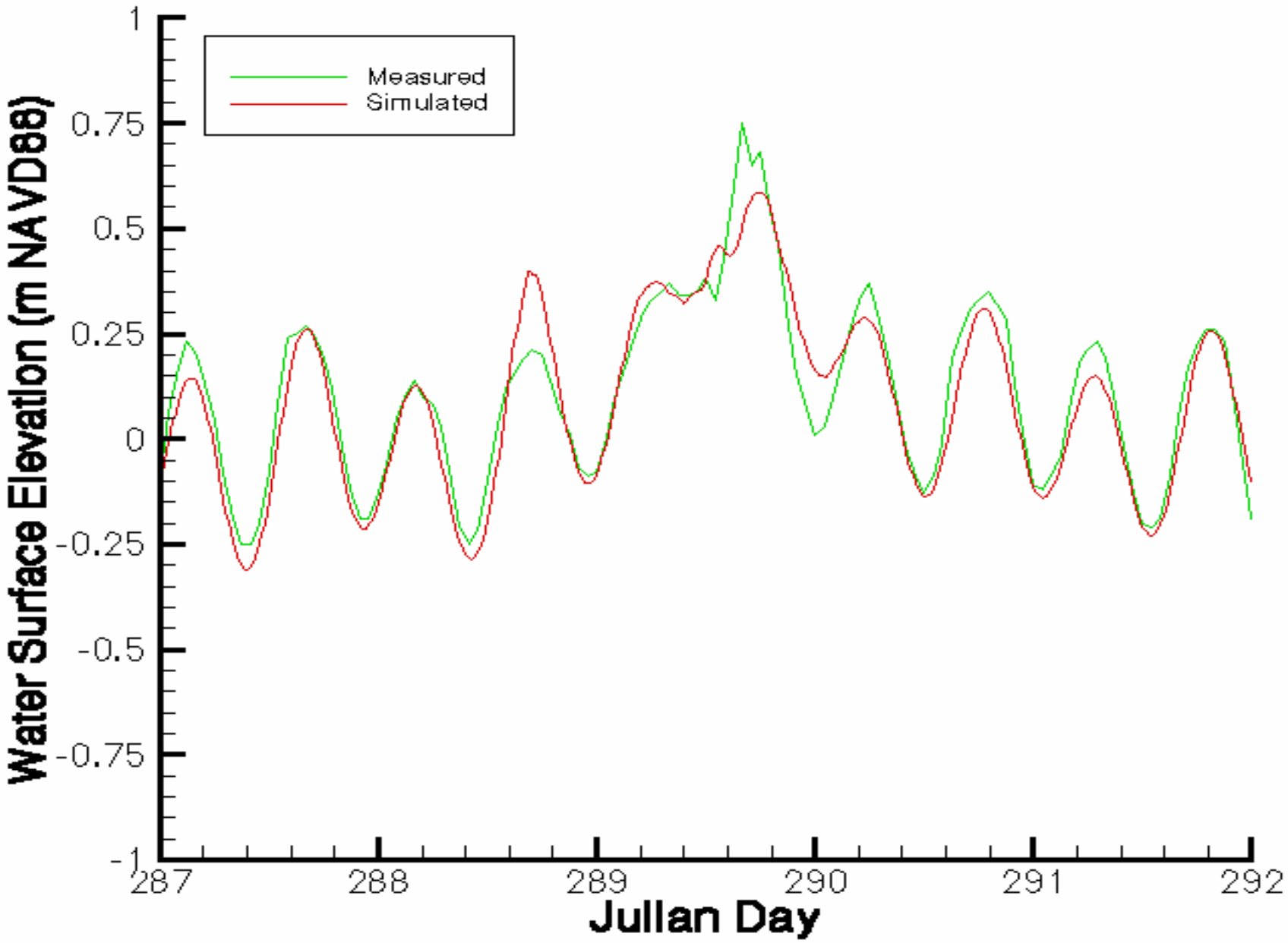

Elevation
(NAVD88) (m)
5
0
-5
-10
-15
-20
-25
-30


Wind Magnitude
(mph)
105
100
95
90
85
80
75
70
65
60
55
50
45

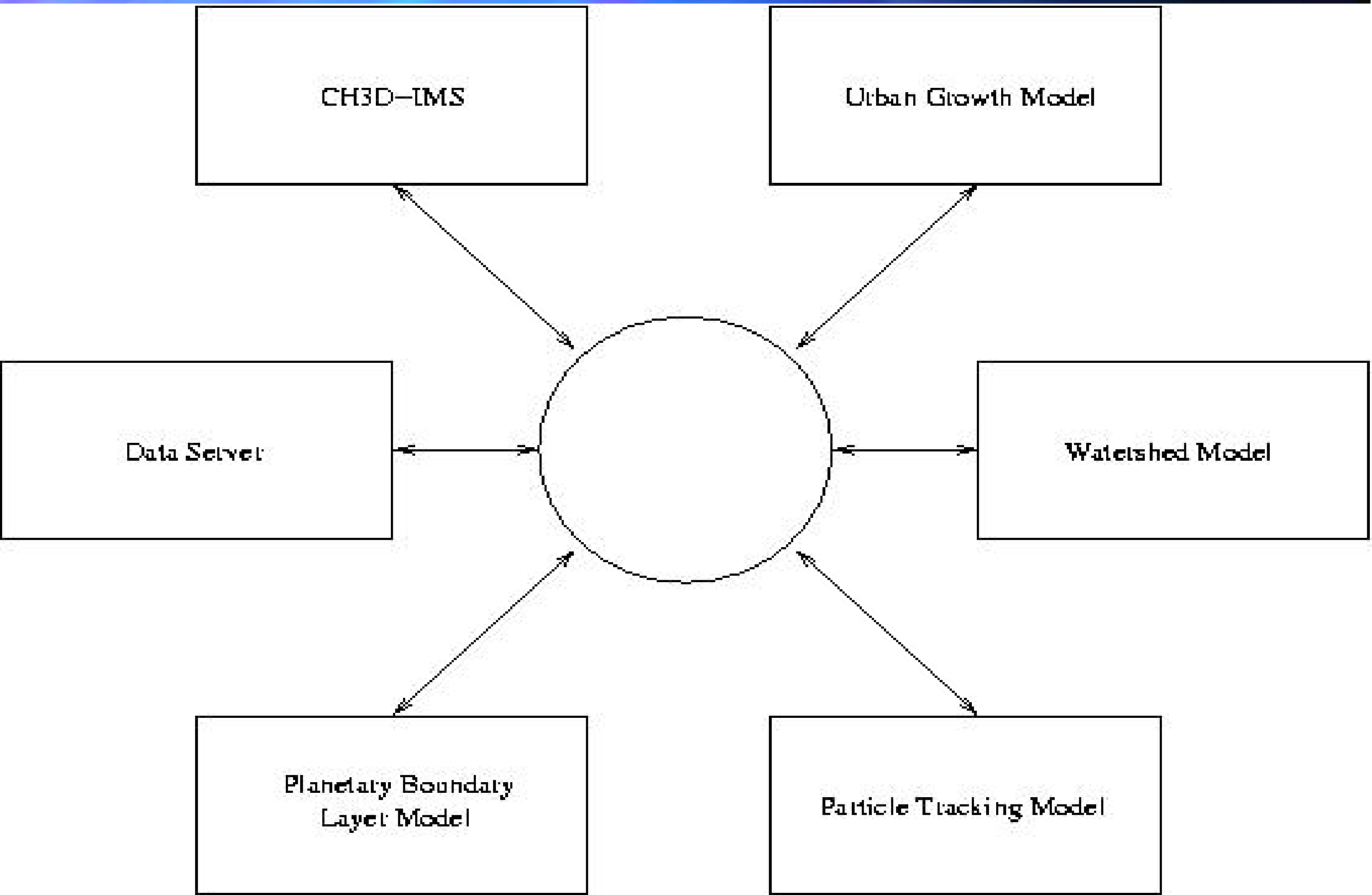

Surface Elevation (m)
Surface Elevation (m)
Surface Elevation (m)


Hurricane Floyd
Hurricane Irene
9/16
9/15
10/18
10/17
32
31
30
29
28
27
26
25
24
-84
-82
-80
-78
-76
Latitude (N)
Longitude (W)

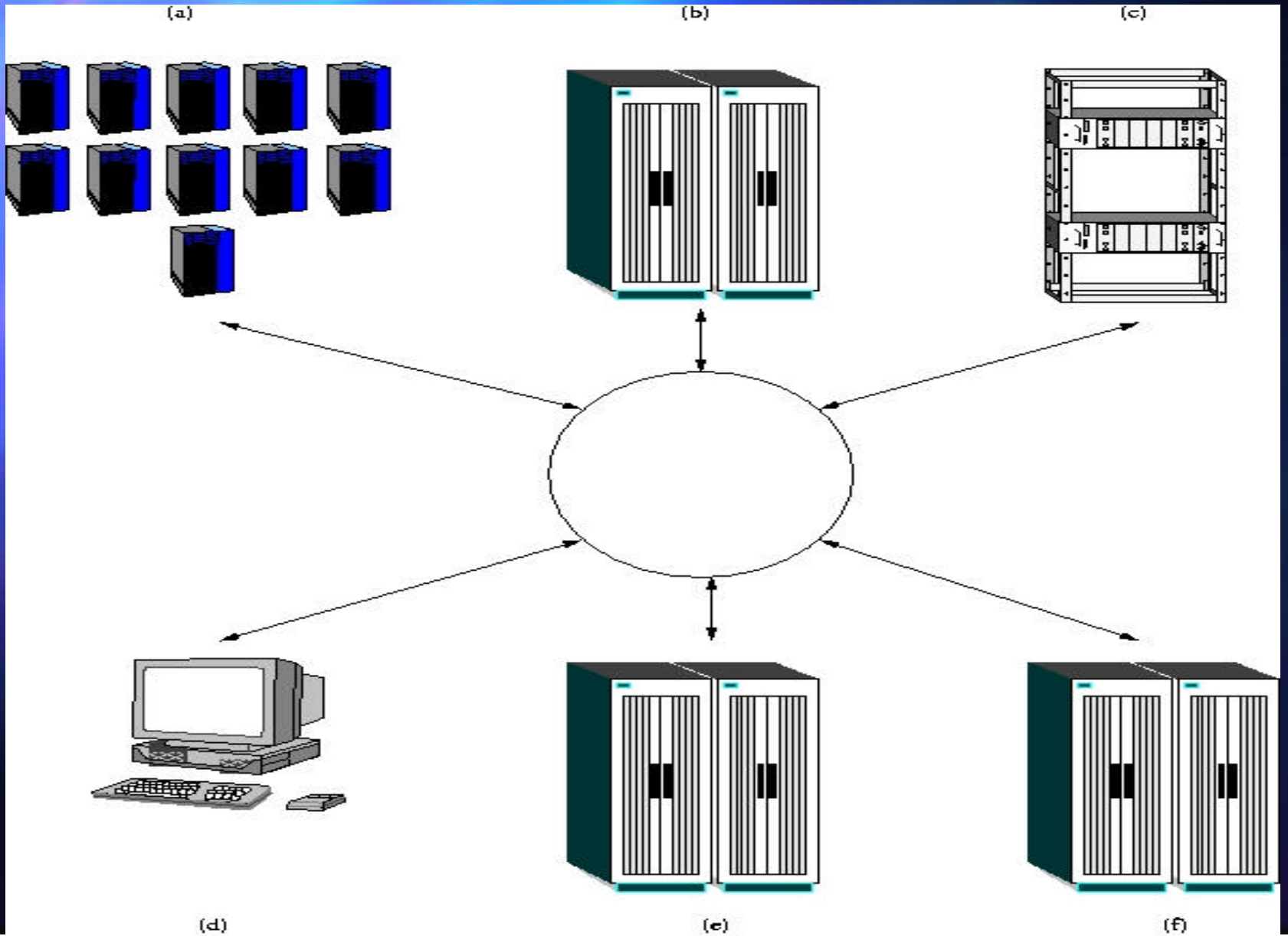

Measured
Simulated
Water Surface Elevation (m NAVD88)
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
256
257
258
259
260
261
Julian Day


Measured
Simulated
Water Surface Elevation (m NAVD88)
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
287
288
289
290
291
292
Julian Day

CH3D-DIMES


CH3D-IMS
Urban Growth Model
Data Server
Watershed Model
Planetary Boundary Layer Model
Particle Tracking Model

DIMES Infrastructure



CONCLUSIONS

- CH3D-IMS, which consists of the following component models: Hydrodynamic/Salinity Model, Wave Model, Sediment Transport Model, Water Quality Model, and Light Model, has been quantitatively validated with 1998 IRL data.
- CH3D-IMS can be expanded to include metal processes to aid the monitoring and assessment of Copper in IRL/St. Lucie Estuary.