# The Development of a Chesapeake Bay Physical-Biogeochemical Modeling System (ChesROMS) for Hindcast, Nowcast and Forecast: Achievements, Challenges and Outlooks

Wen Long, Jerry W. Wiggert, Jiangtao Xu

Lyon Lanerolle, Bala K. P. Prasad

Ragu Murtugudde, Christopher Brown

Raleigh Hood

University of Maryland Center for Environmental Science

HORN POINT LABORATORY

# Outline

- Where to get the model
- Physical model development and retrospective analysis
- Biogeochemical model development
- Operational system development
- Challenges
- Outlooks

# Where to get the model

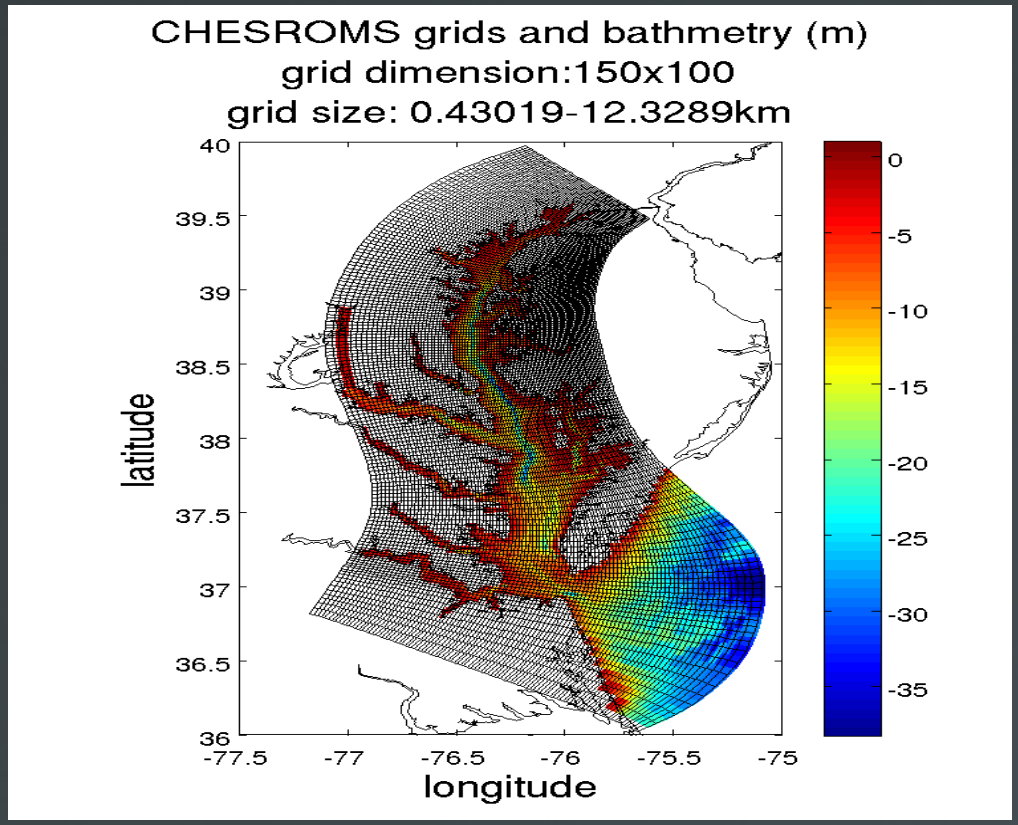
- ChesrROMS is based on Rutgers ROMS3.0
- ChesROMS is developing a ROMS model of the Chesapeake Bay to help in the prediction of Harmful Algal Blooms. We hope to catalyze a new method of community modeling with involvement beyond the core researchers of the ChesROMS project.
- Google CheROMS
- http://sourceforge.net/projects/chesroms/

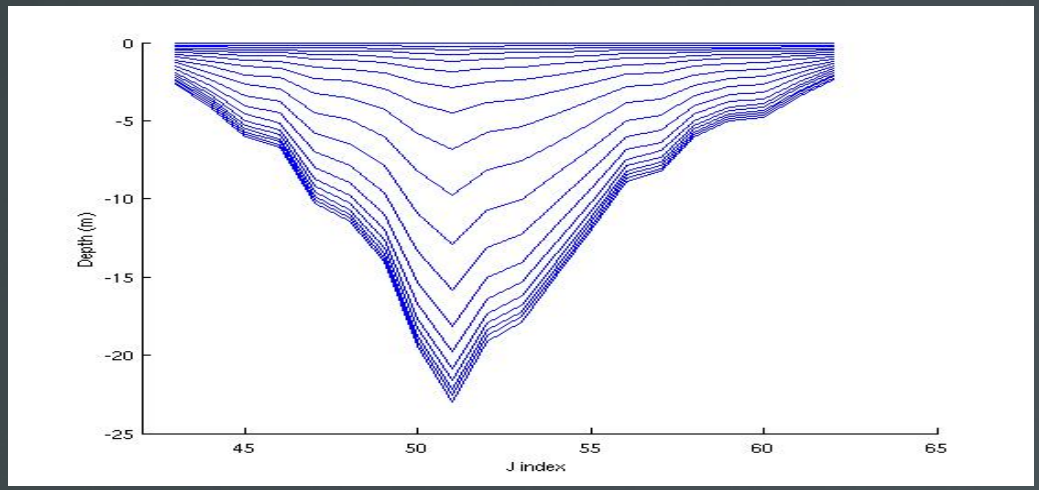
# Physical model development and retrospective analysis (1991-2006)

- Model configuration
- Data constraining the model
- Sensitivity analysis (drag, turbulence, time step …)
- Climatological model run
- Comparison with in-situ data
- EOF analysis of interannual variability
- Cross comparison with CH3D, EFDC and CBOFS2 (2004)

# Model configuration

- Initially ROMS2.2 (2006~2007)
- Updated to ROMS3.0 (2008)
- Intermediate grid density (150x100x20)
- Cover the whole Chesapeake Bay and lower tributaries
- Main drivers: rivers, tides, surface fluxes



# Data constraining the model

- Tides: 9 major constiuents form ADCIRC EC2001

  K1 O1 Q1 M2 S2 N2 K2 M4 M6

- Nontidal water level (Wachpreague and Duck station data detided, interpolated)
- OpenBoundary Temperature and Salinity:

World Ocean Atlas 2001/2005

- River discharge from USGS website
- Surface: North American Regional Reanalsis (NCEP)
- CnD canal: 350m^3/s inflow

# Sensitivity Analysis

- Turbulence schemes tried out:

MY2.5, KKL, KPP, GLS-K-omega

- CnD flux varied from outflow to inflow, 0~500m^3/s
- Backgroud vertical mixing coef (AKT, AKV, AKK, AKP)
- Linear vs quadratic drag
- Bottom roughness (0.005m~0.01m)
- OBC nudging+radiation vs clamping vs gradient

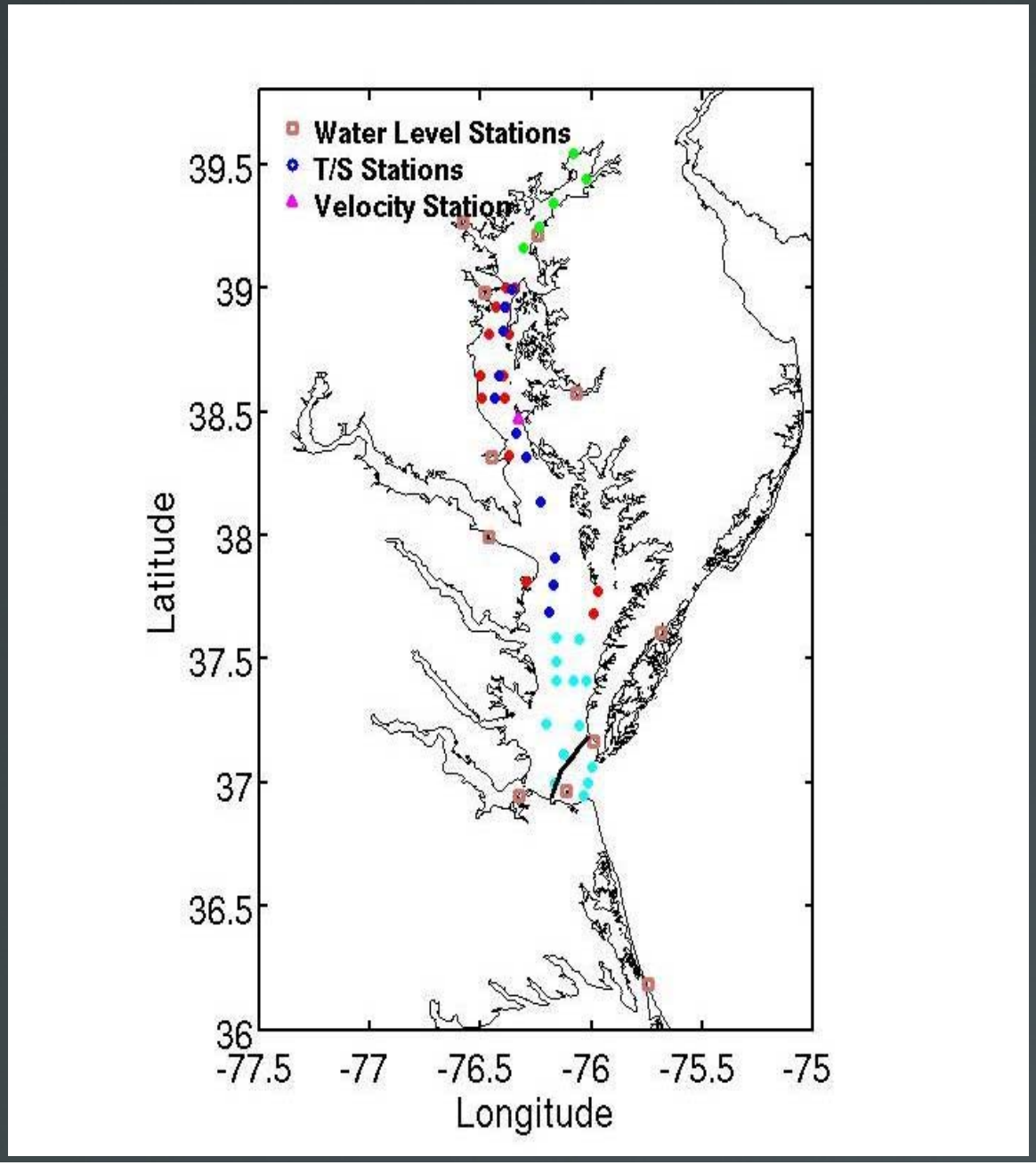
# Climatological run

- To test internal variability
- Repeated year 1999 for 15 years with tidal periods changed to beat 360 days precisely.
- All forcings cycled, year10 to 15 results analyzed.
- Found: system has very little internal variability

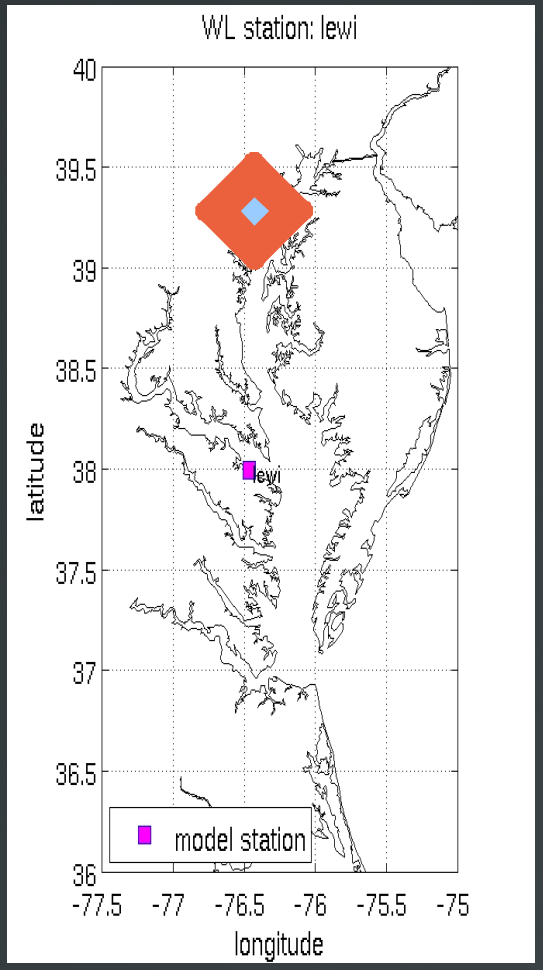
Chesapeake bay is strongly forced!!

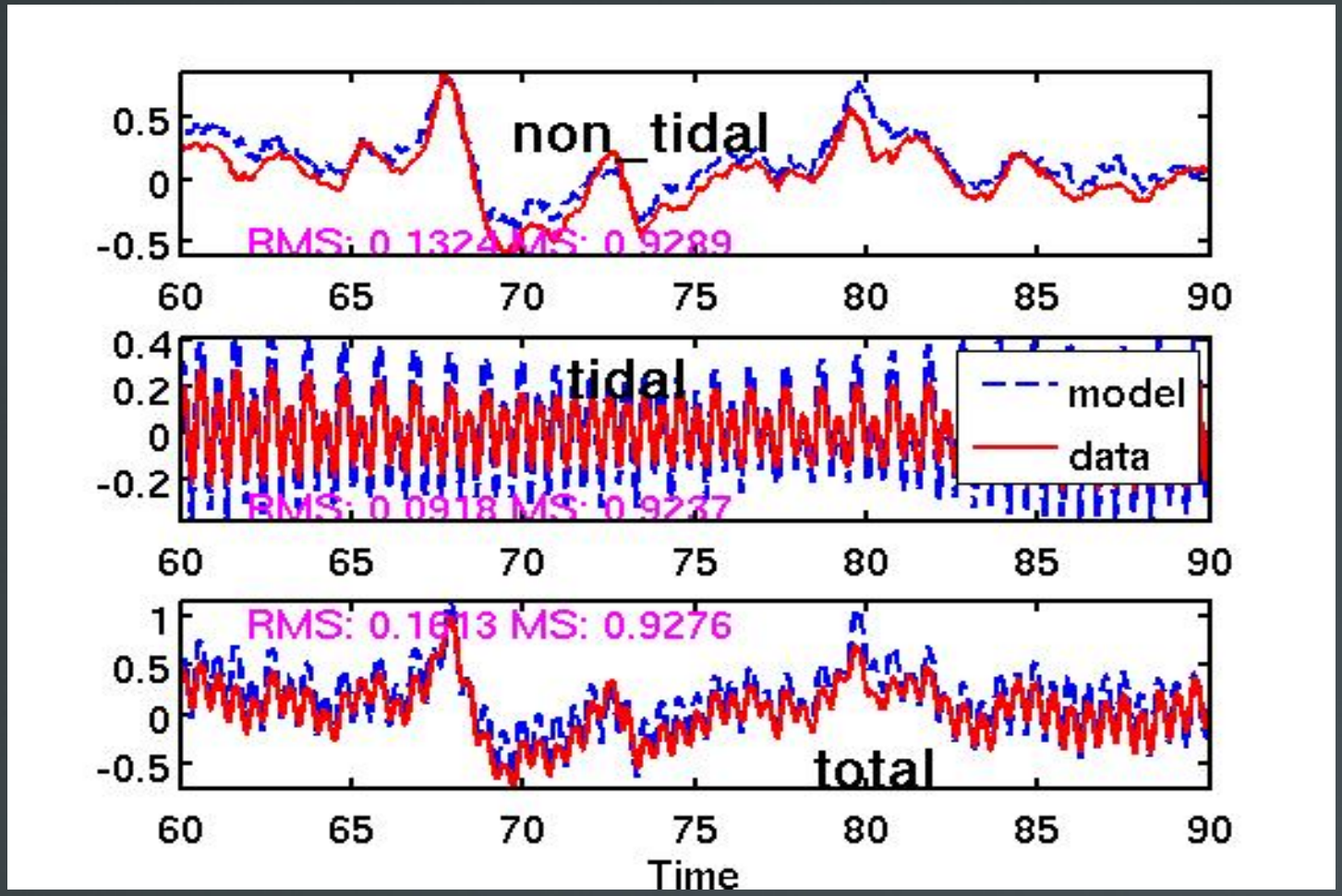
# Comparison with in situ data

- Waterlevel (tidal and sub-tidal)
- Temperature (EPA CBP monitoring)
- Salinity (EPA CBP monitoring)
- Current (CBOS, only a few measurements)
- Curises at Bay mouth

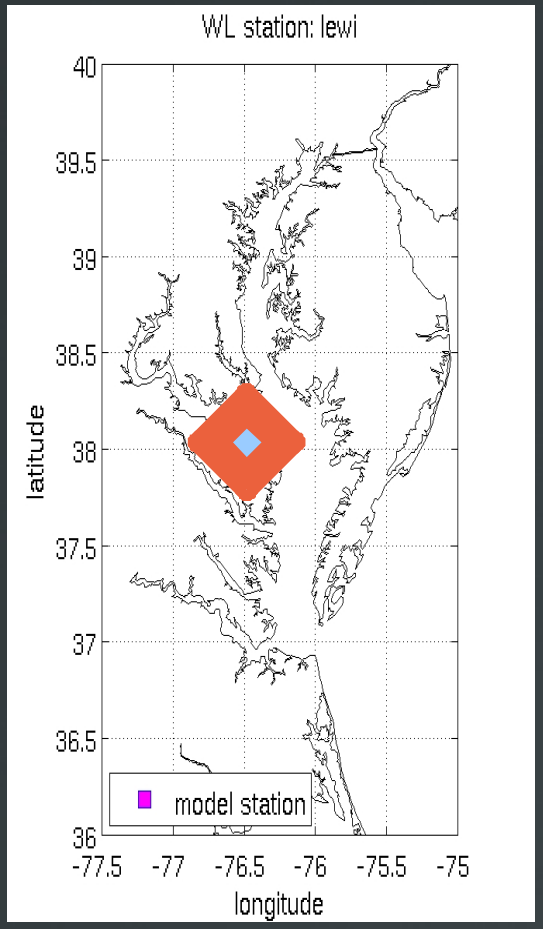


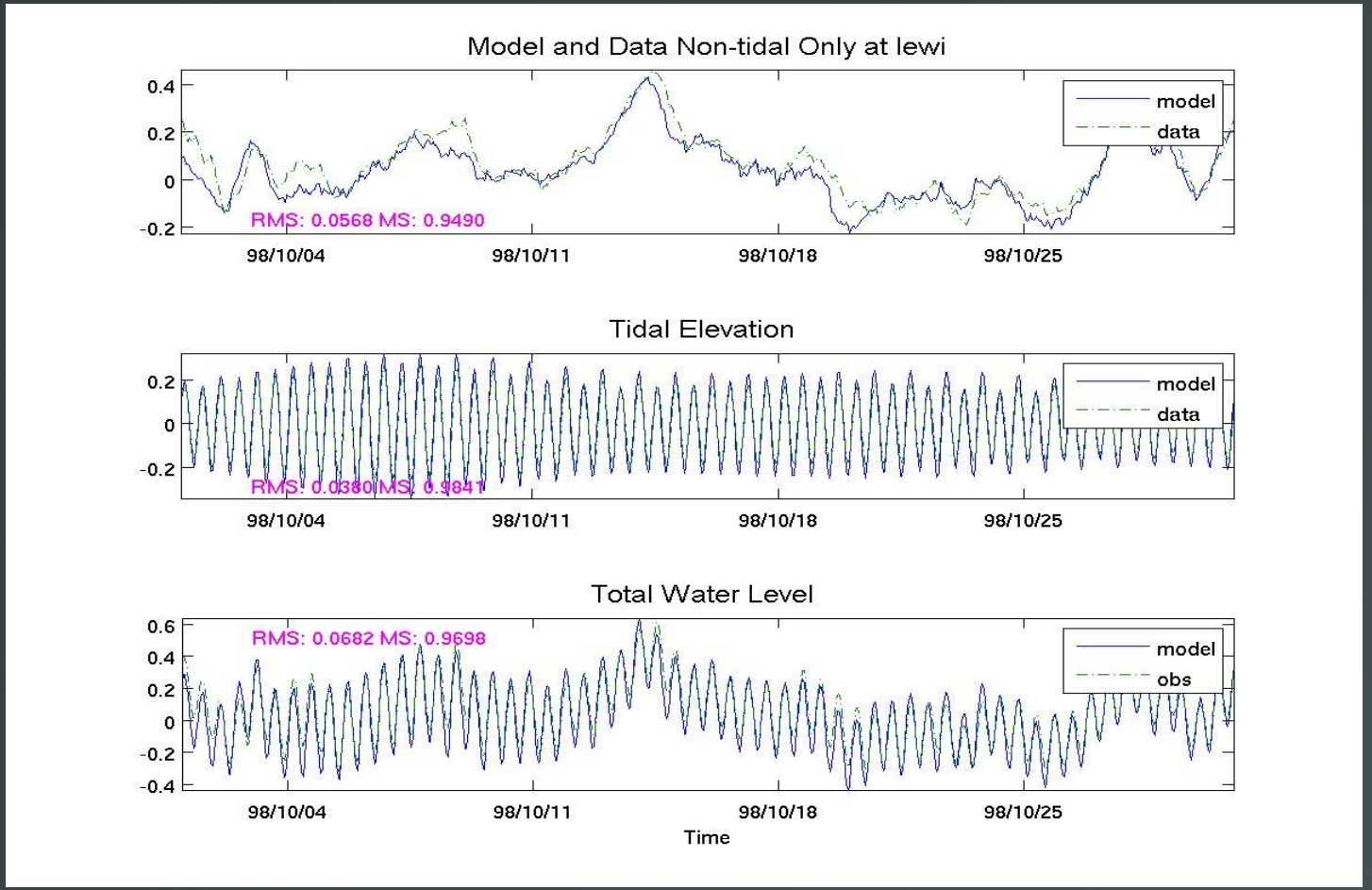
# Water Level (1998 Oct at Baltimore)



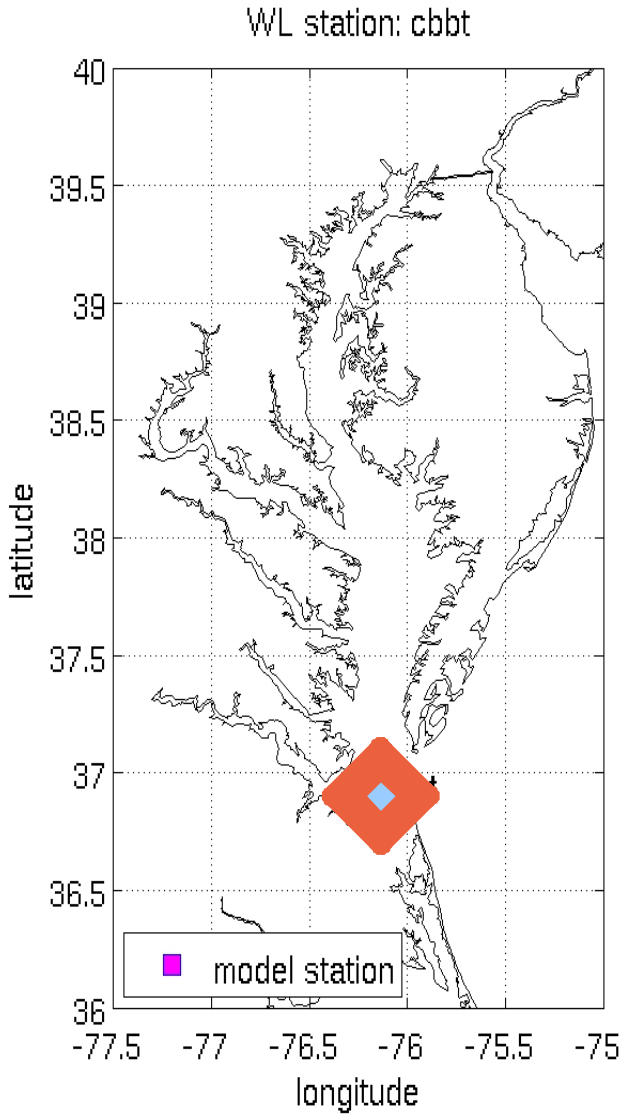



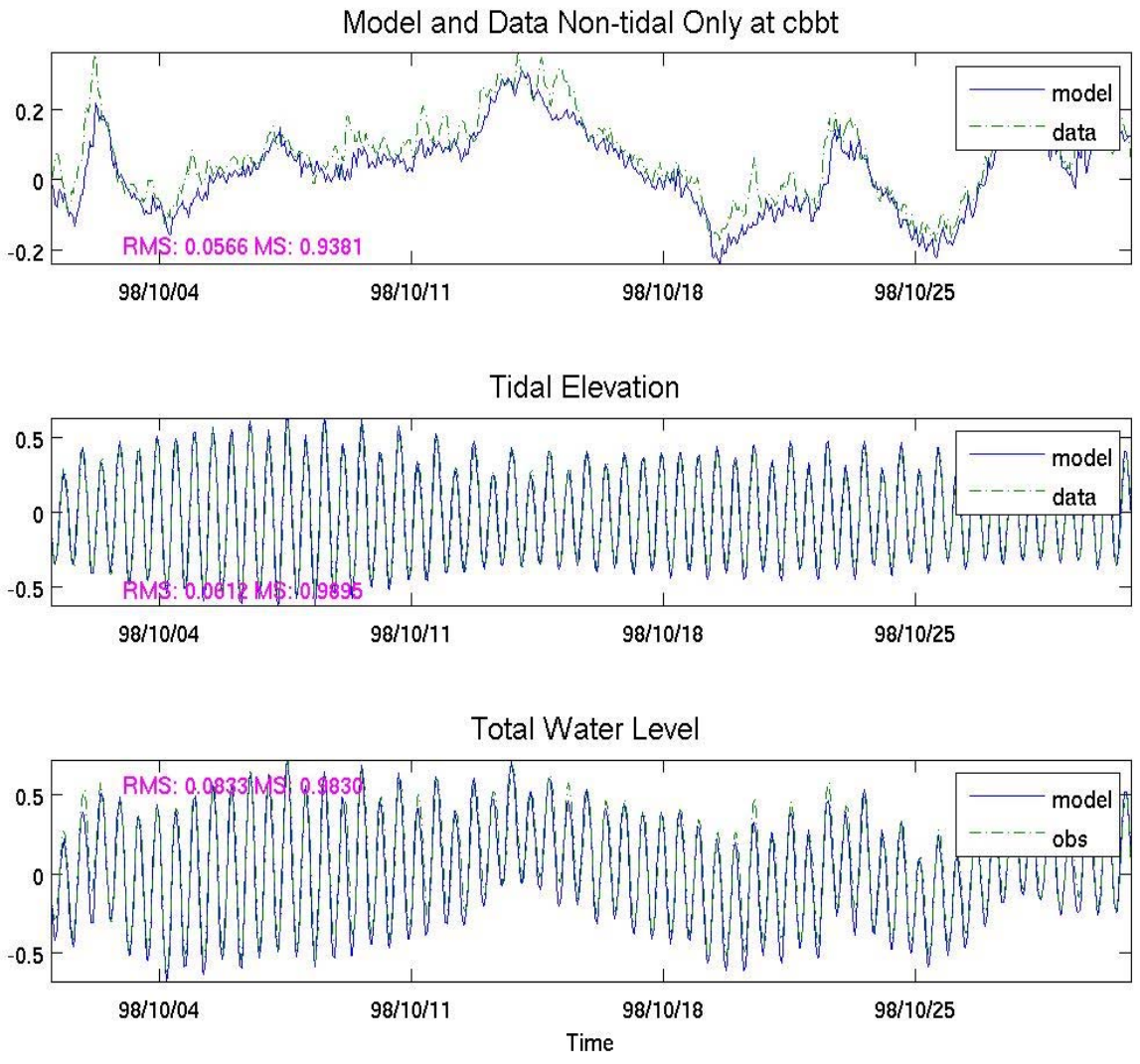
# Water Level (1998 Oct at Lewisetta)



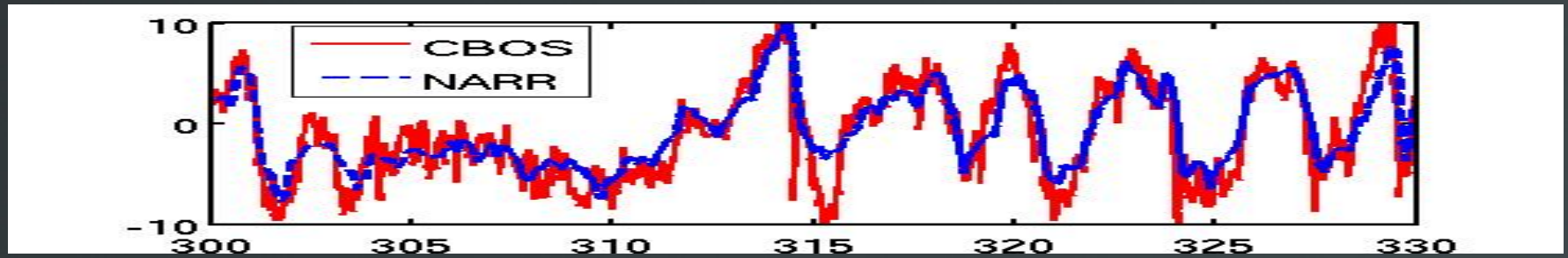



# Water Level (1998 Oct at CBBT)

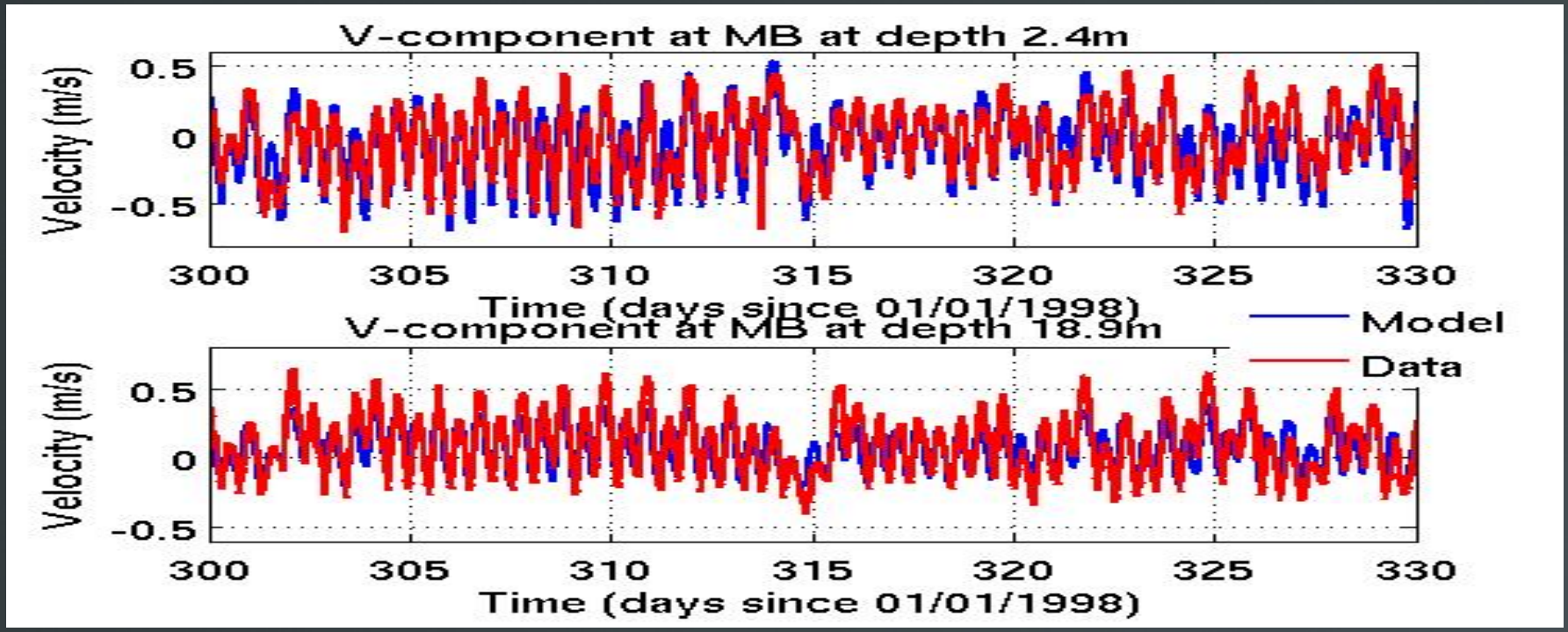


# Current at Mid-Bay (CBOS, northward positive, Oct 1998)



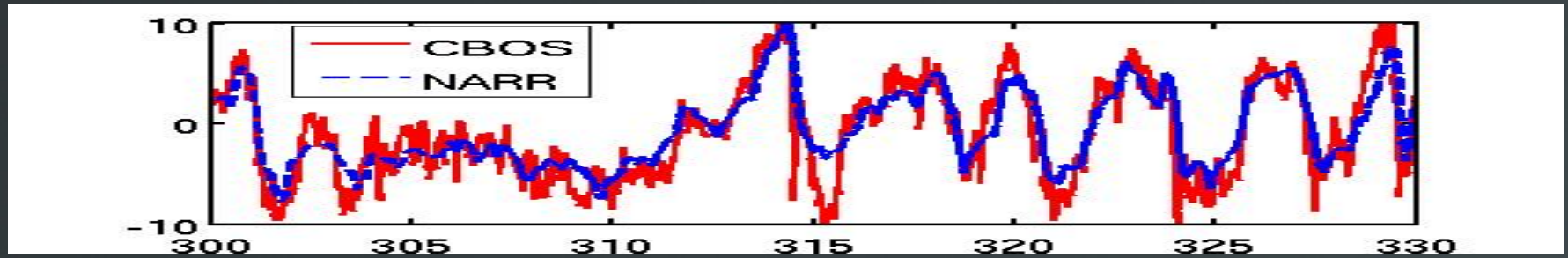

Wind

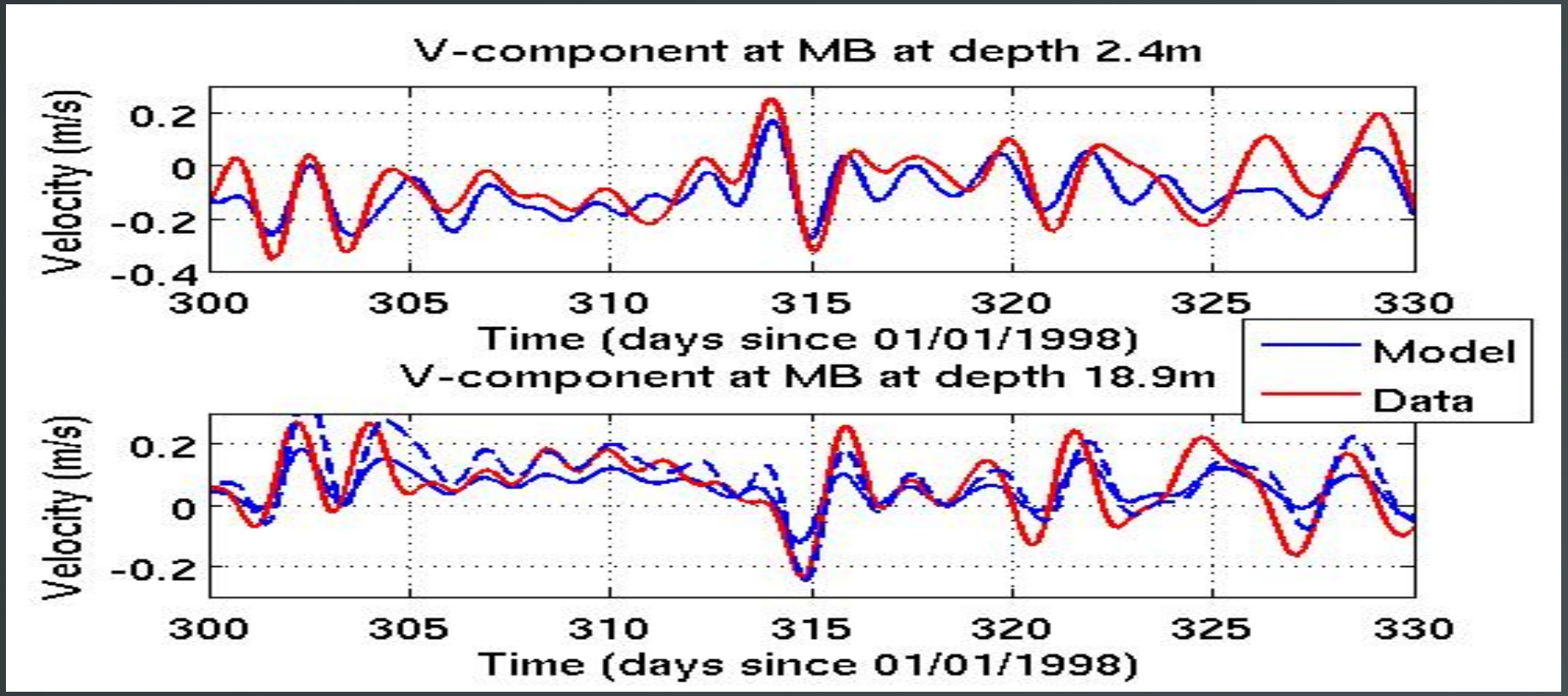



V_s

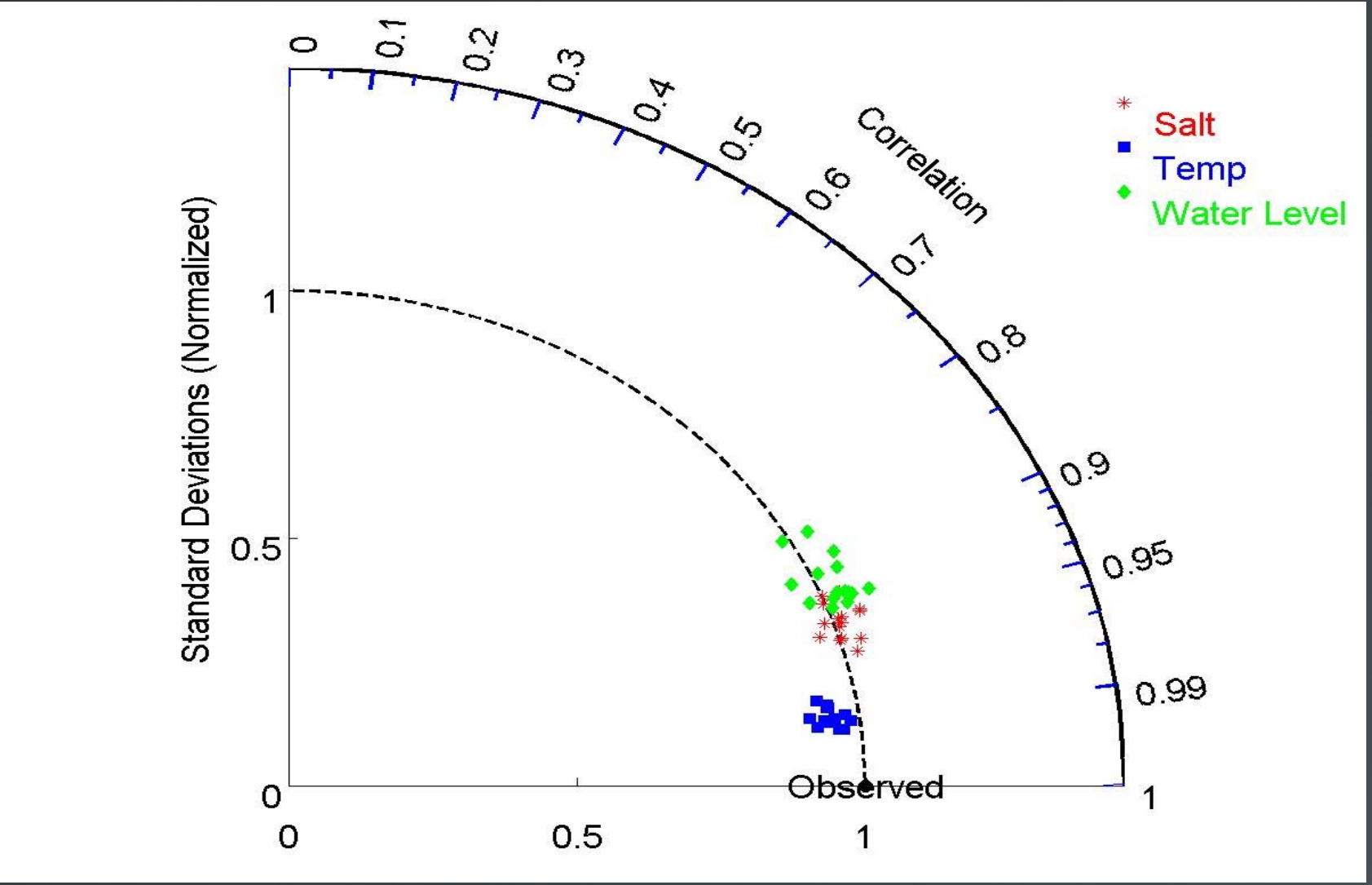
V_b

# Currents at MidBay (lowpass, Oct 1998)

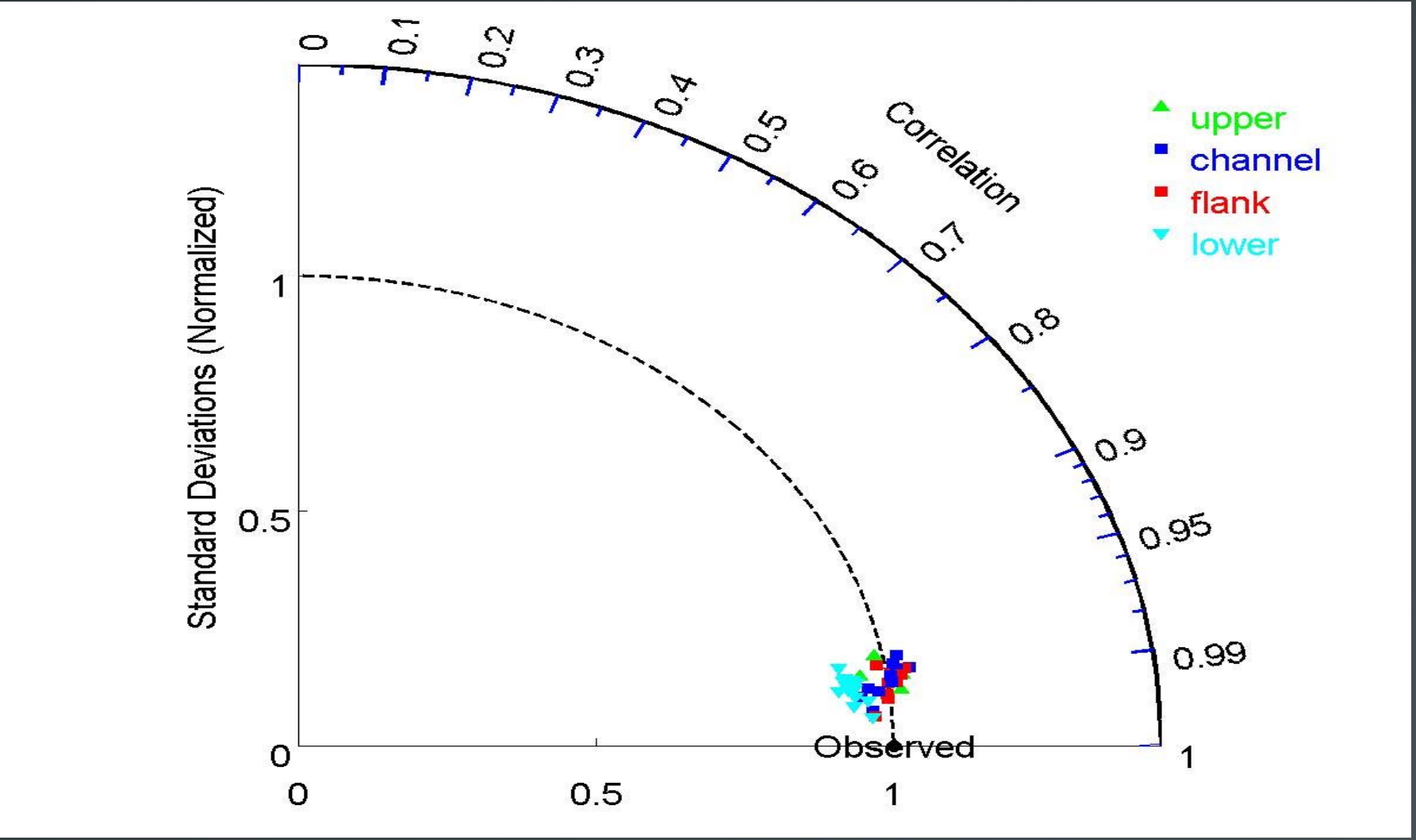


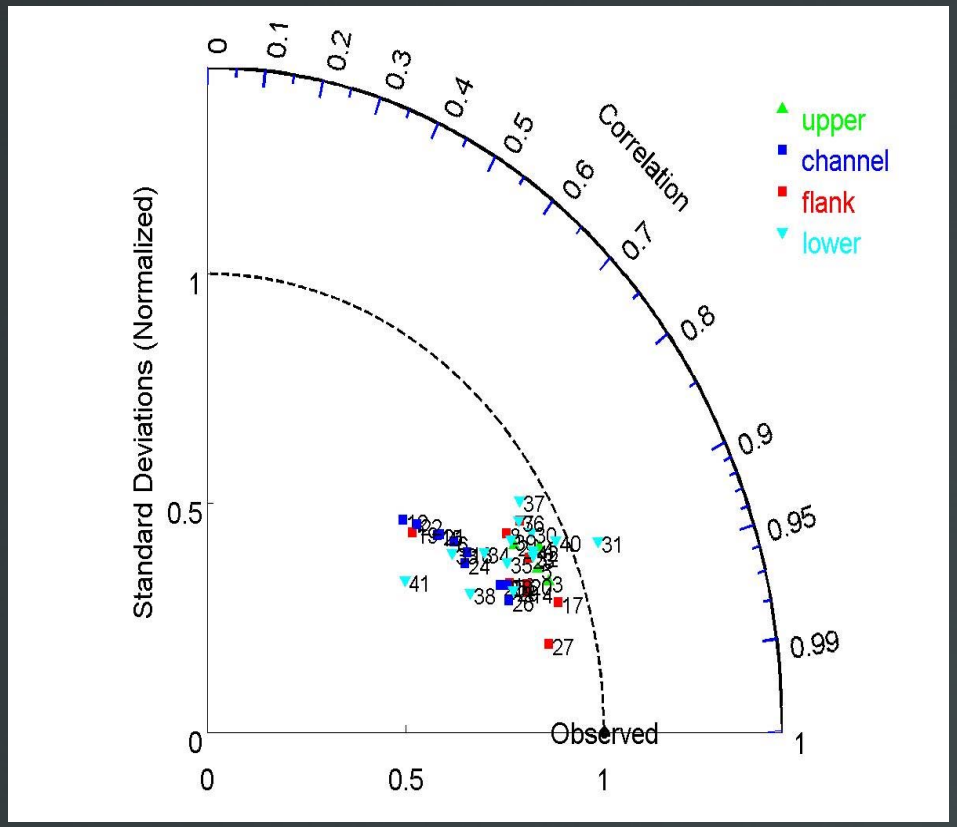
# 1991-2005 Taylor Diagam



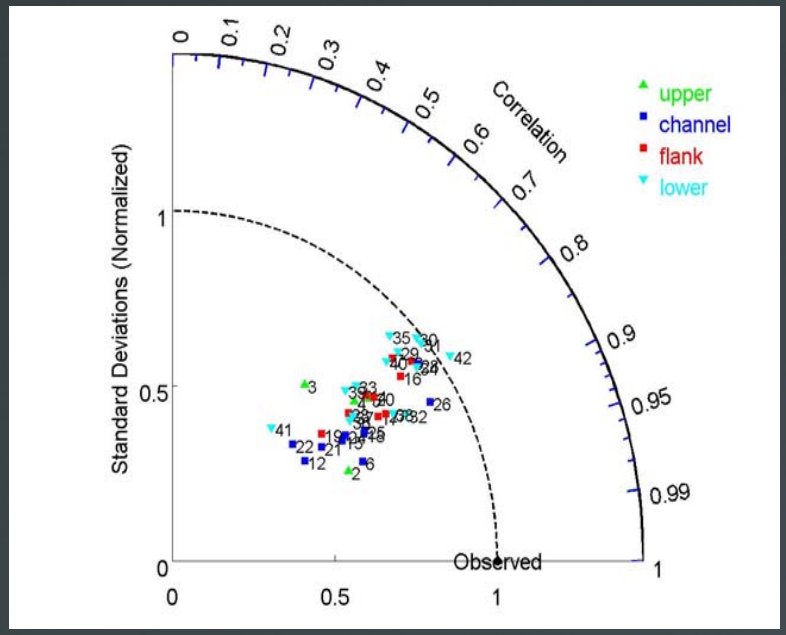
# 1991-2005 Taylor Diagram of Temperature



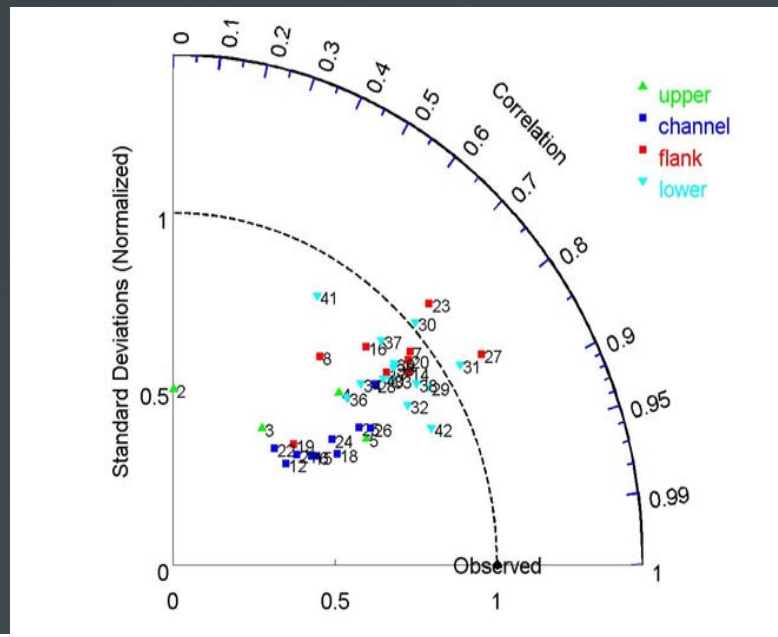
# Salinity Comaprison (1998, 2001, 2003)




1998-average

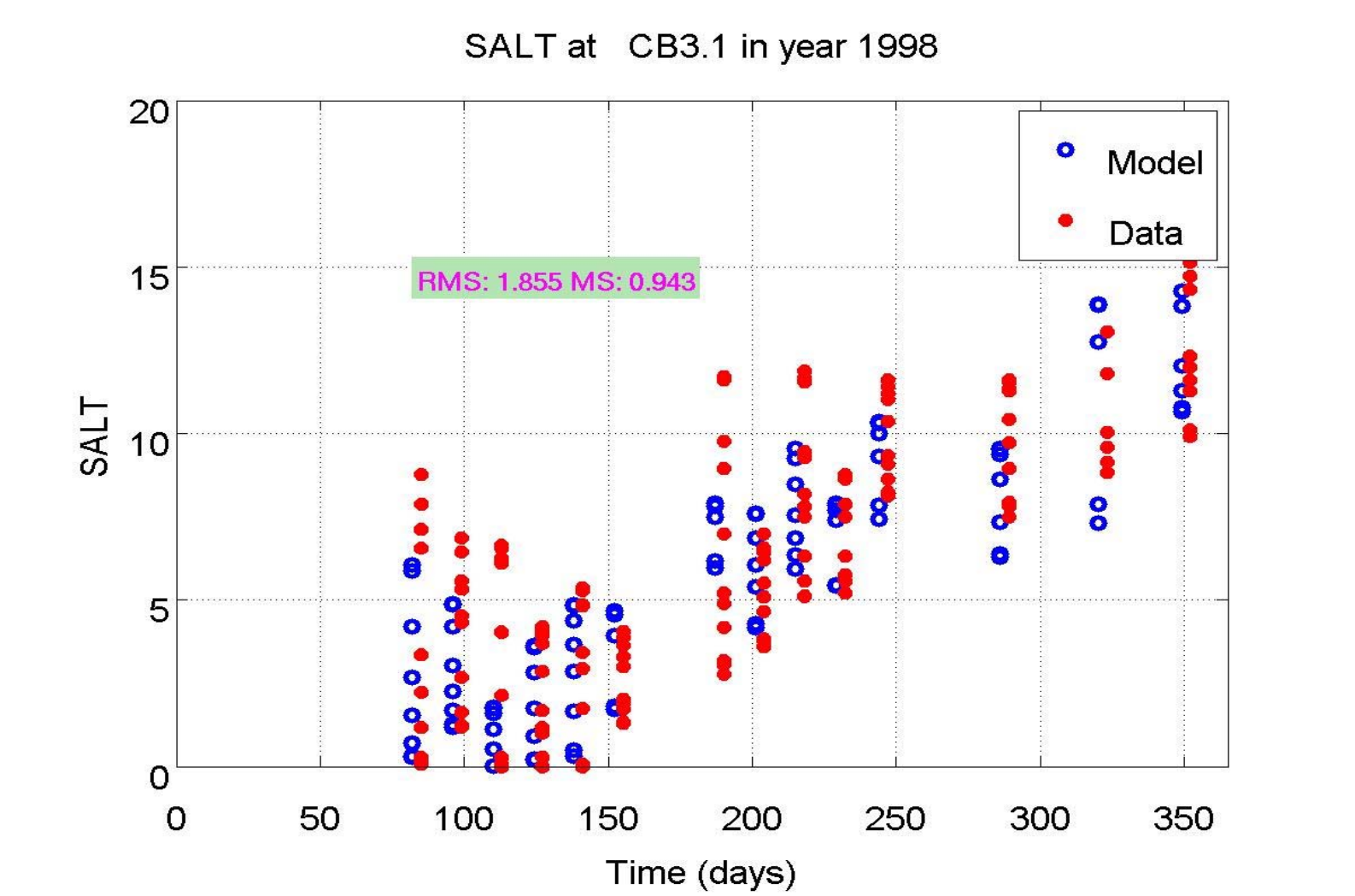



2001-dry

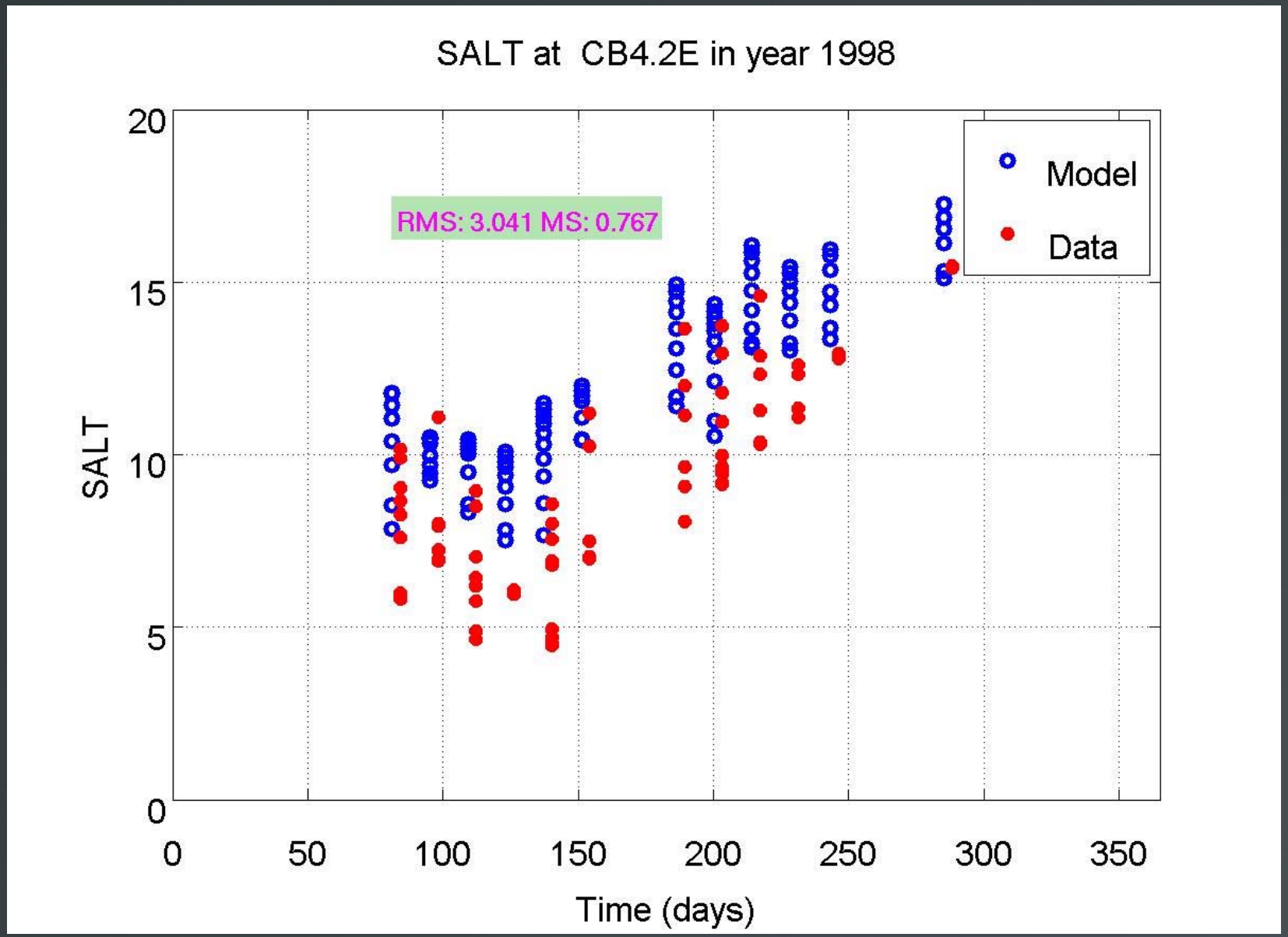



2003-wet

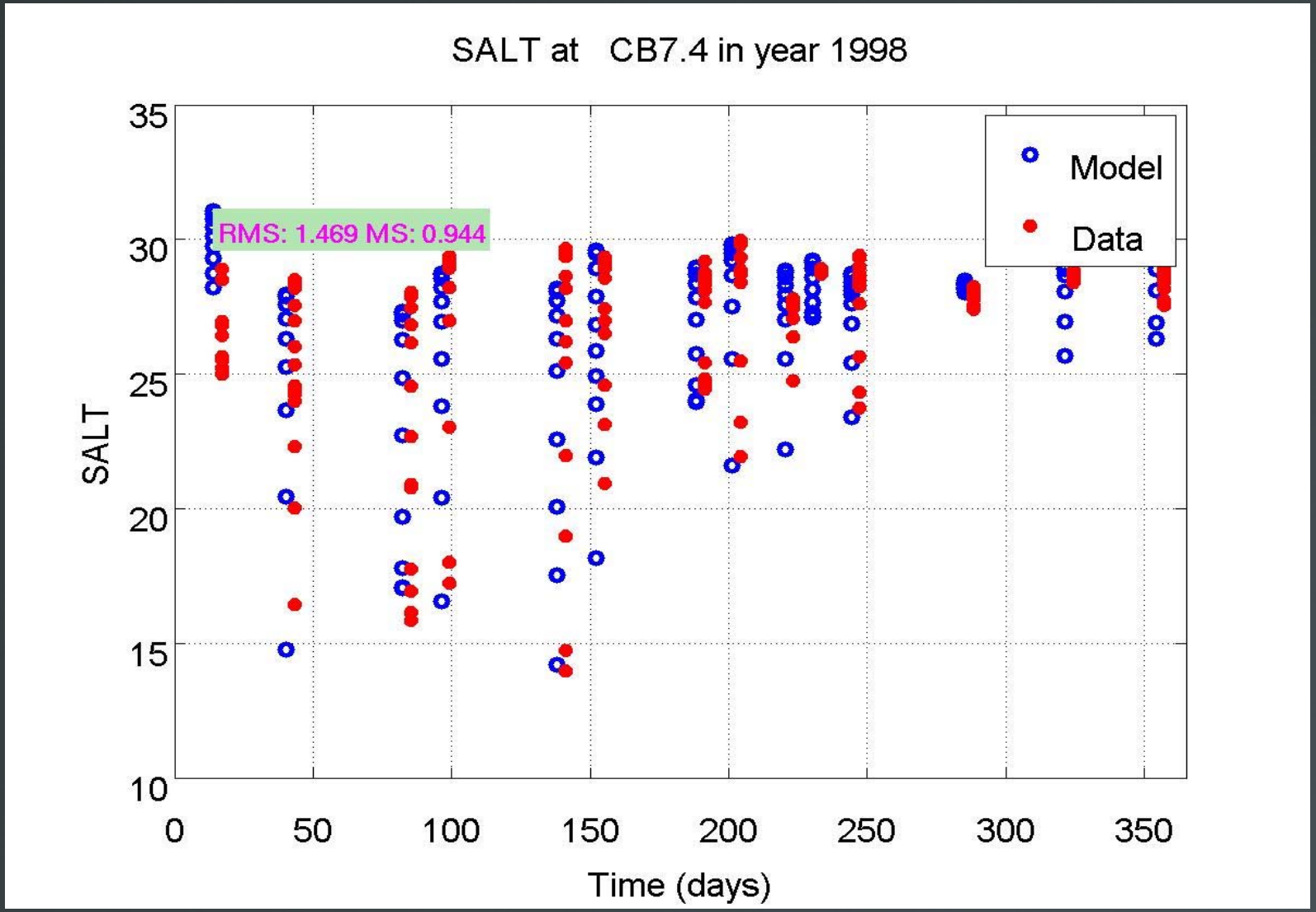
# Salinity Comparison (CB3.1,1998)



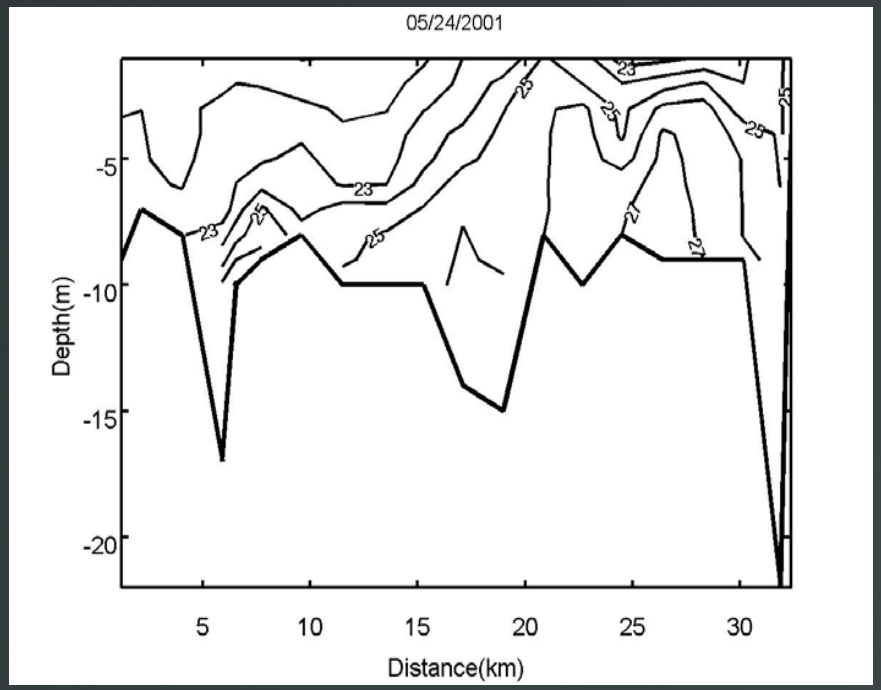
# Salinity Comparison (CB4.2E,1998)

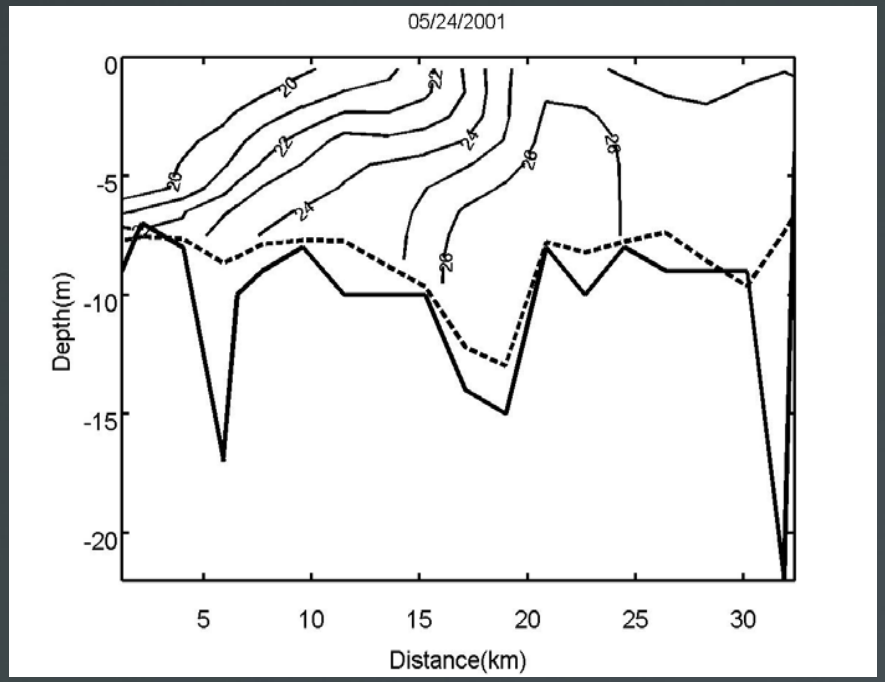


# Salinity Comparison (CB7.4,1998)

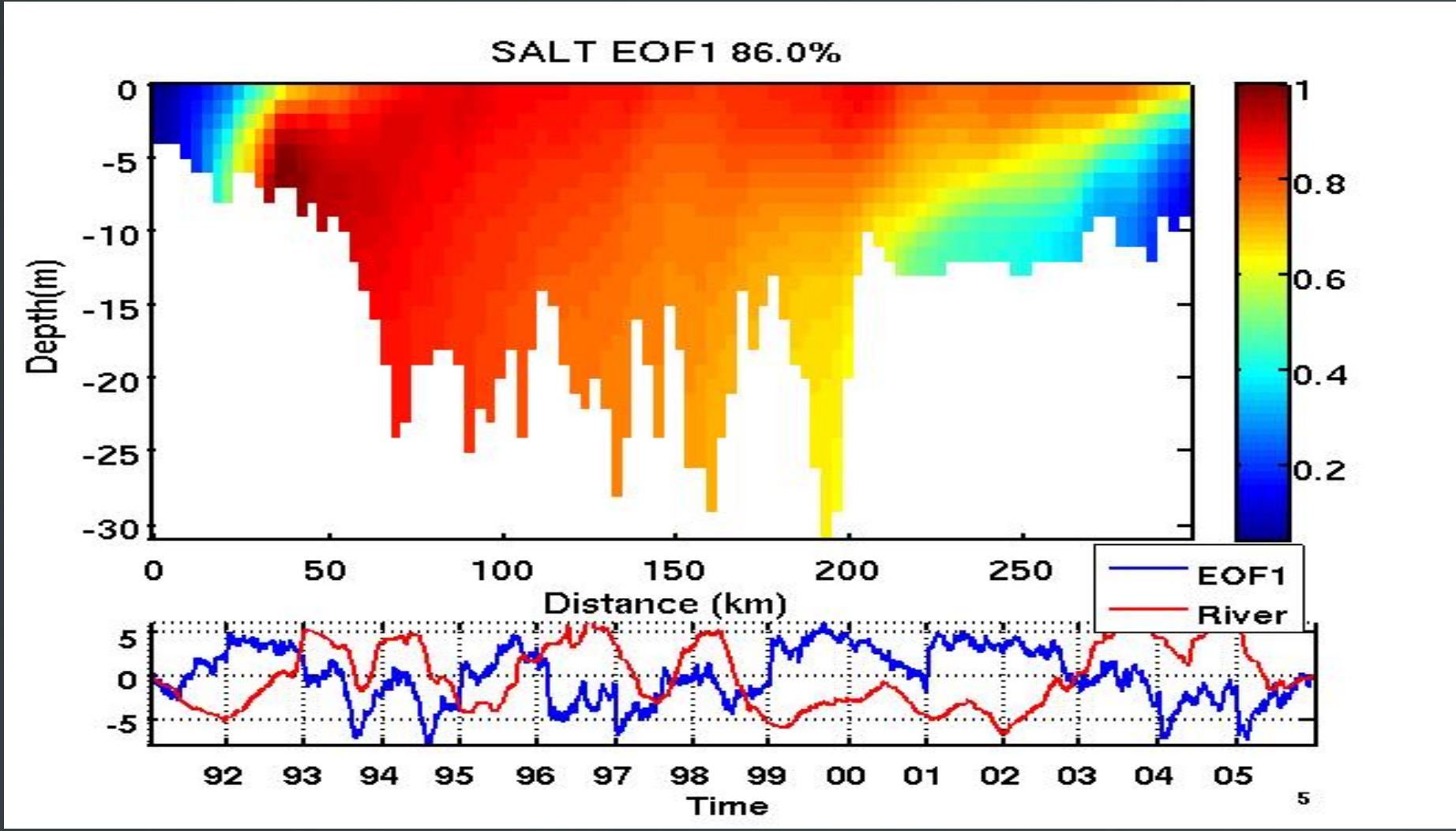


# Salinity Bay Mouth Cruise (2001)

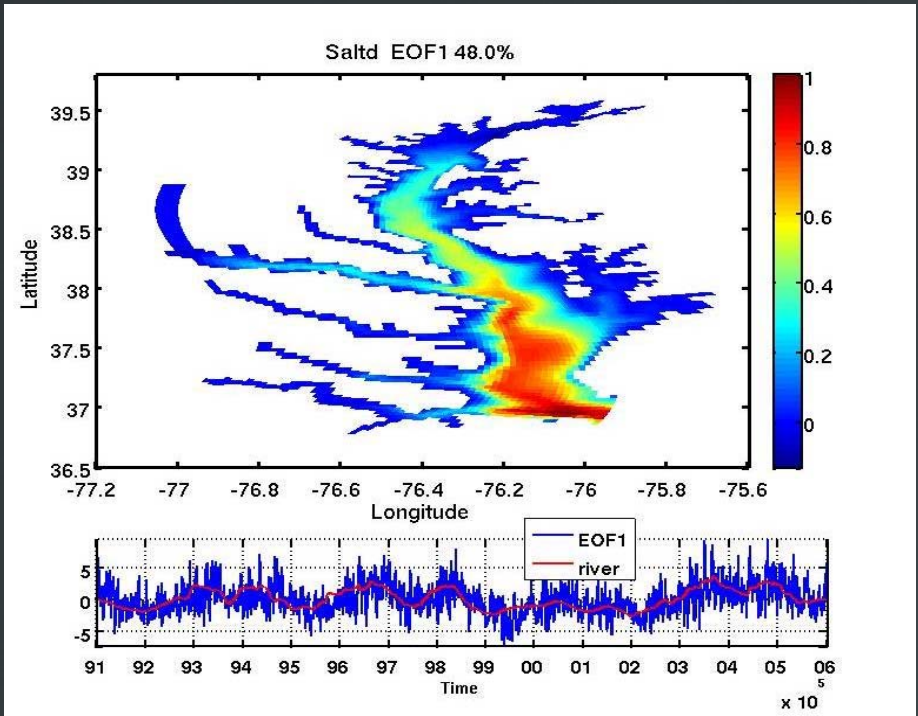


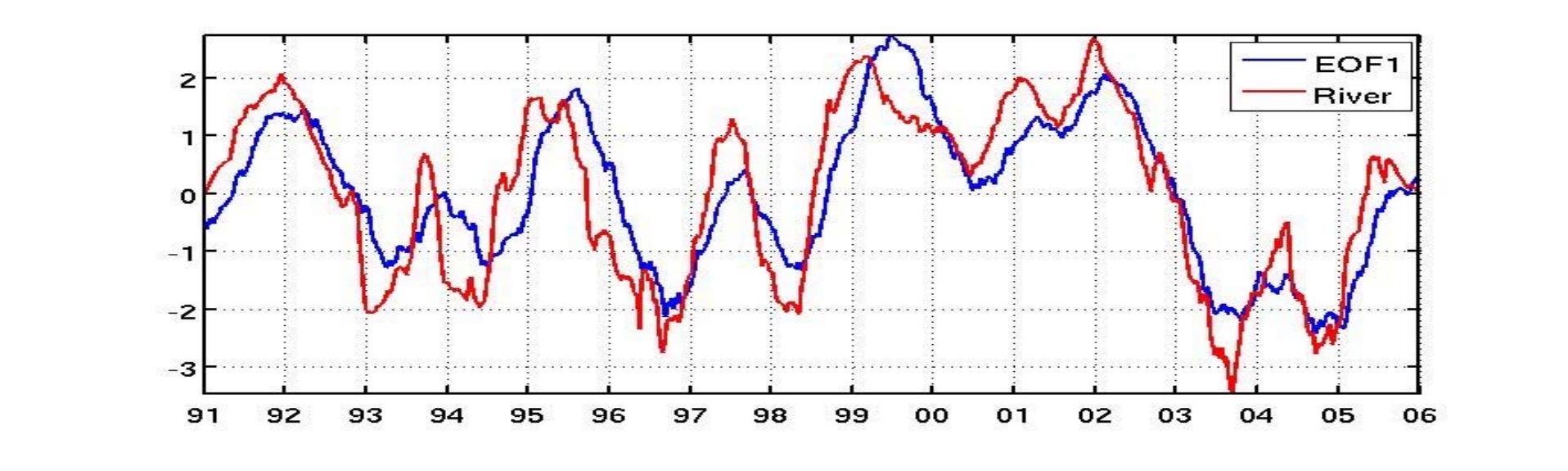



# Salt Along Center Line EOF1 (86%)

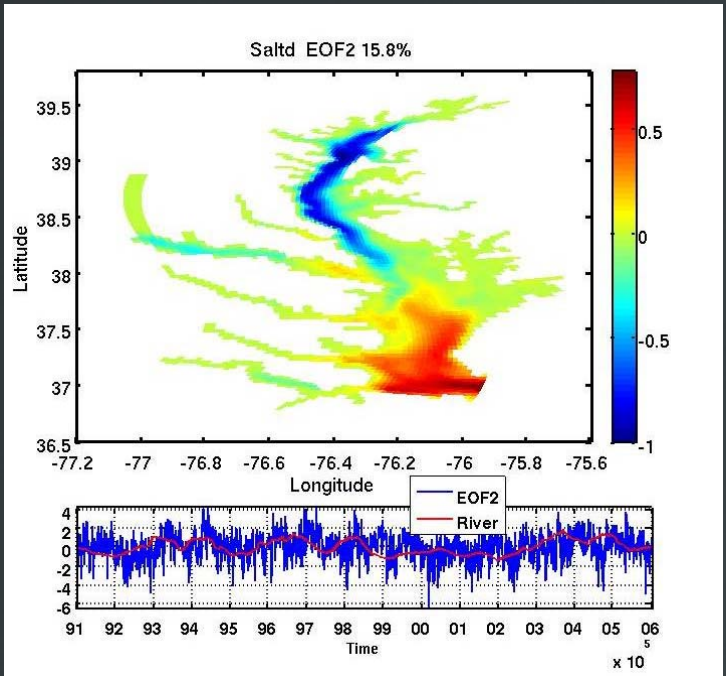


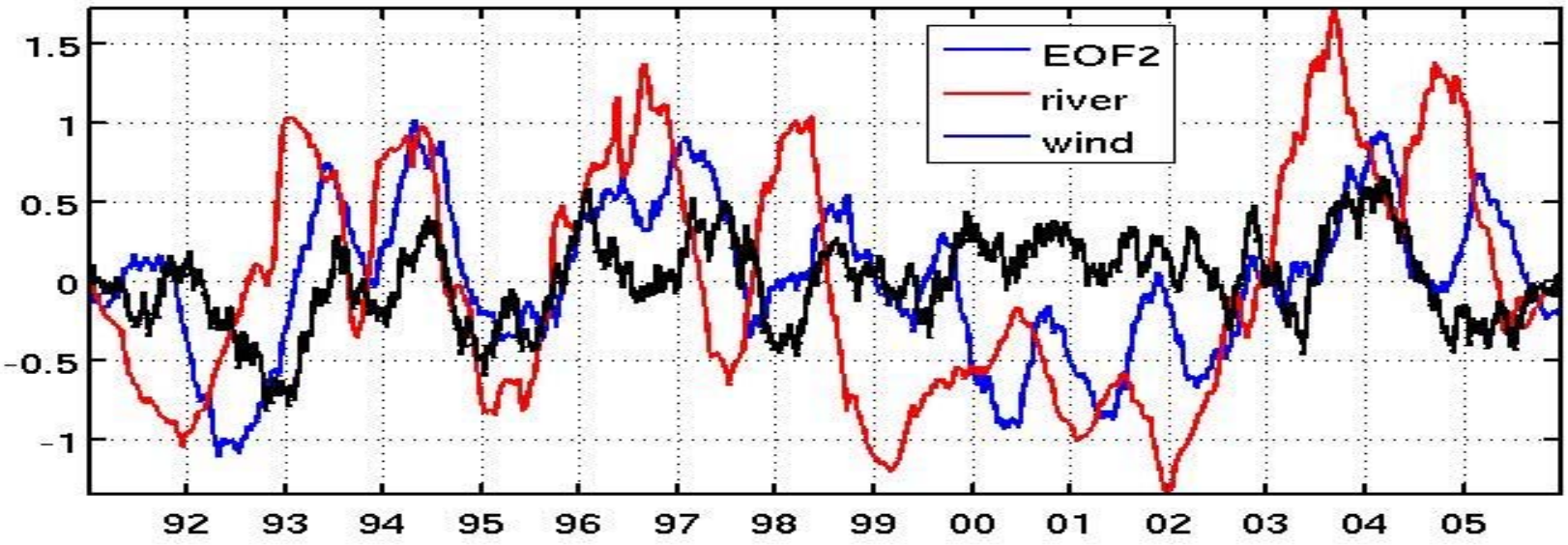
# Salinity stratification (Sb-Ss) EOF mode1 (48%)



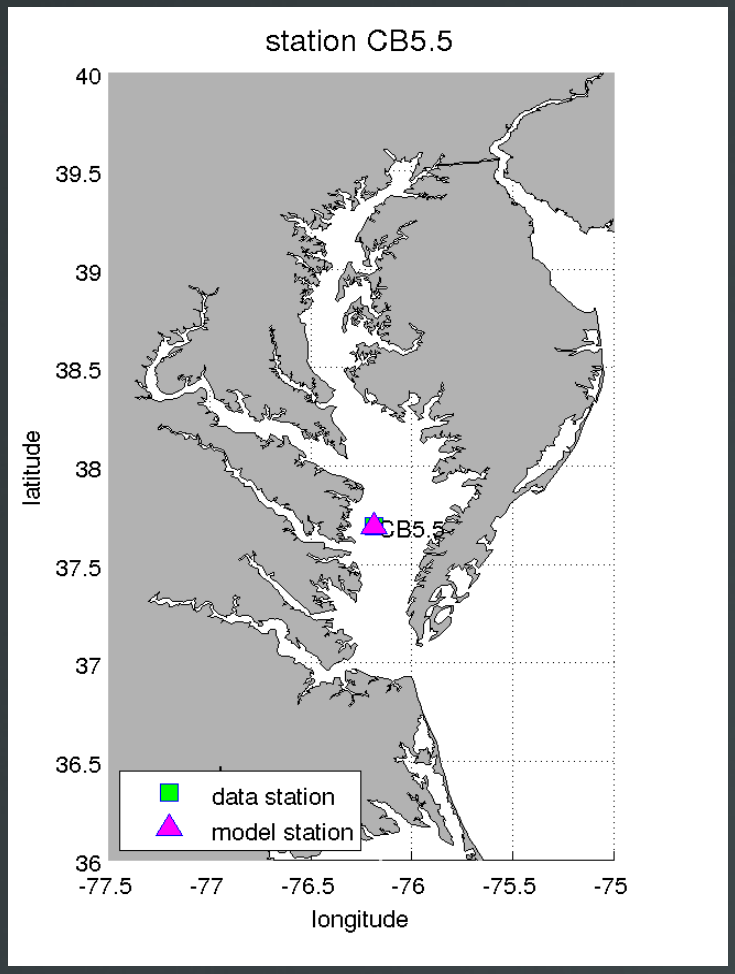
# Salinity Stratification (Sb-Ss) EOF mode2 (15.8%)

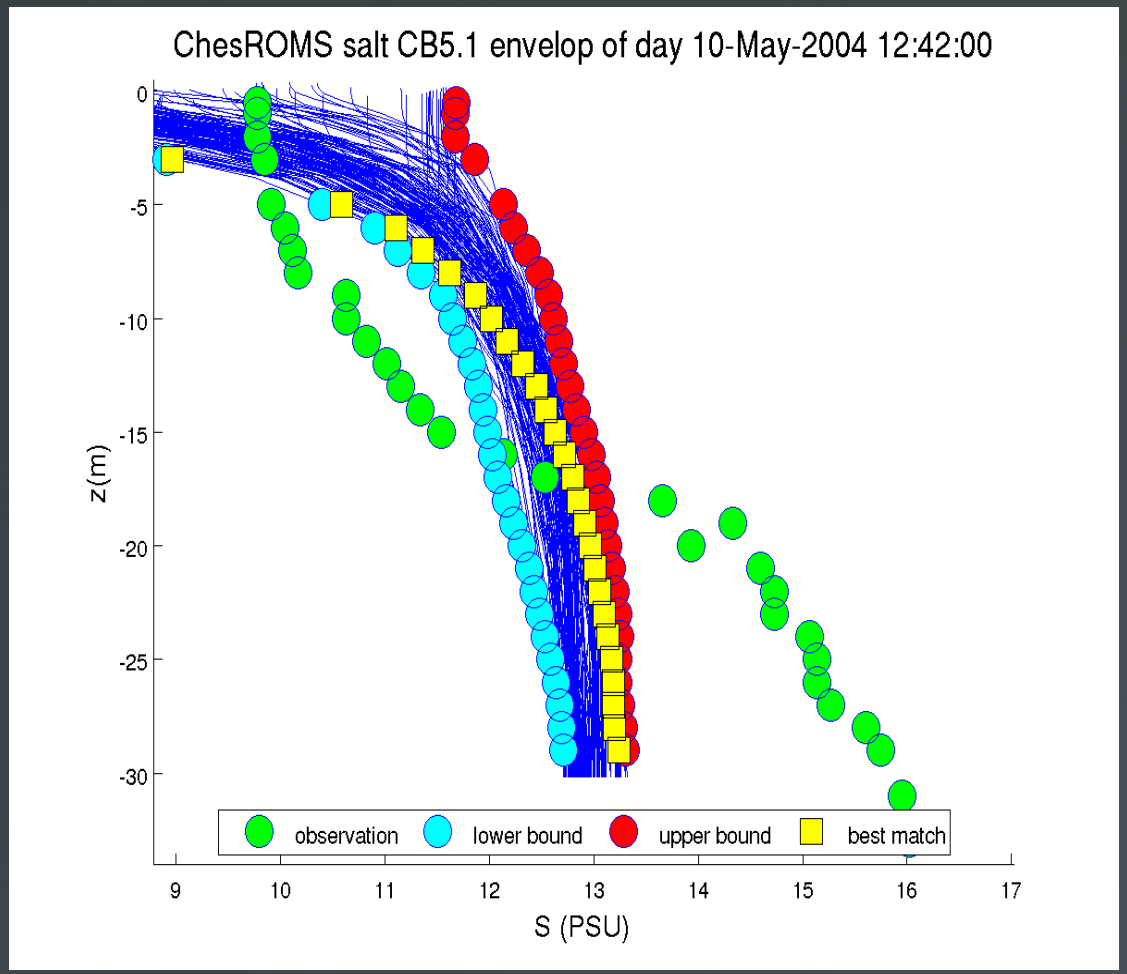


# Detailed Cross Comarison with CH3D, EFDC, CBOFS2

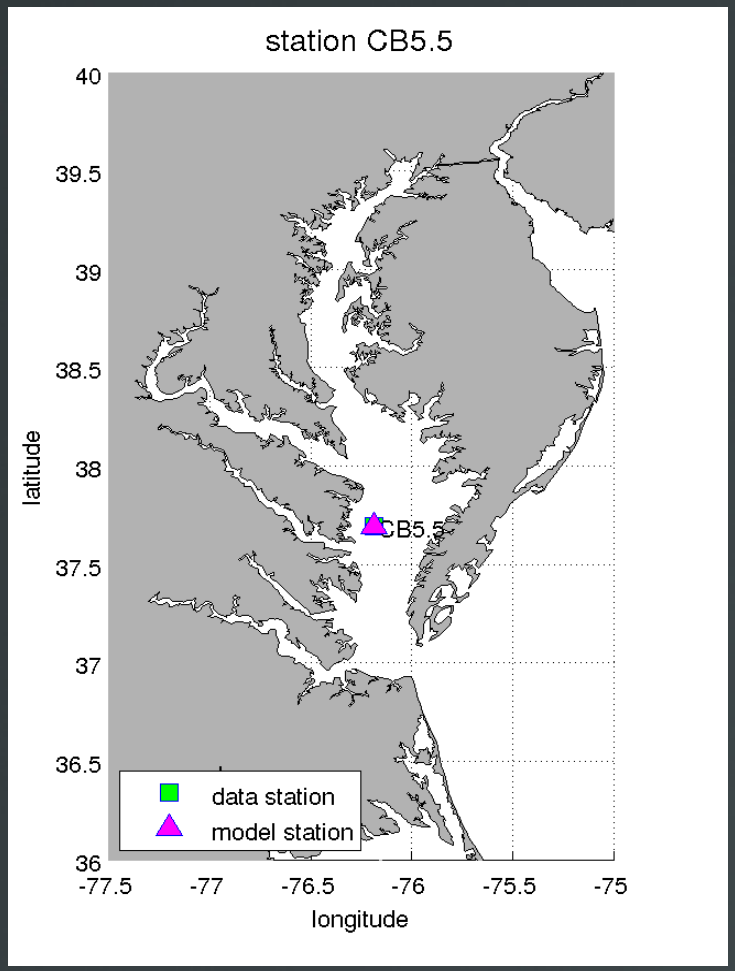
- CB5.1 ChesROMS

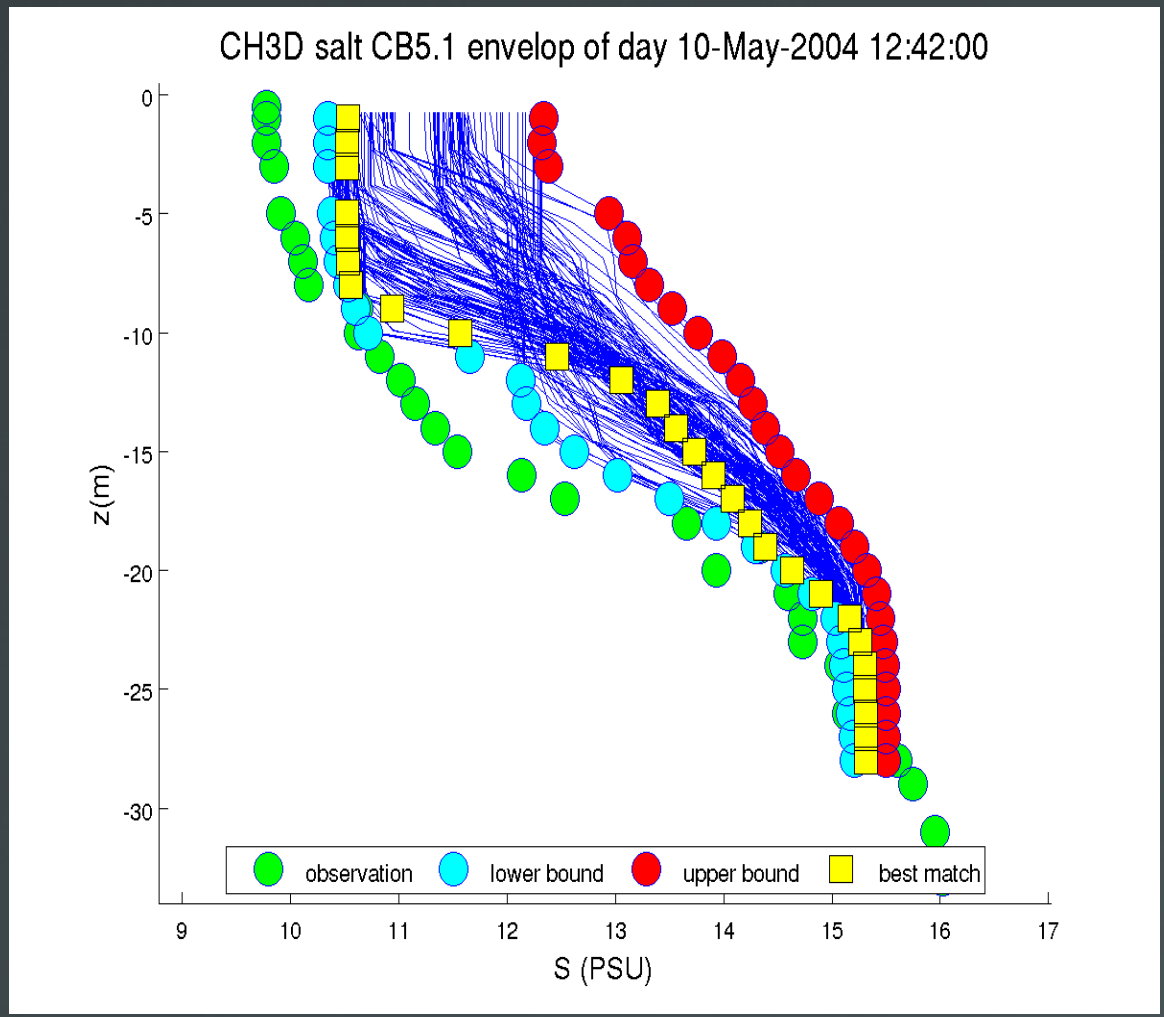


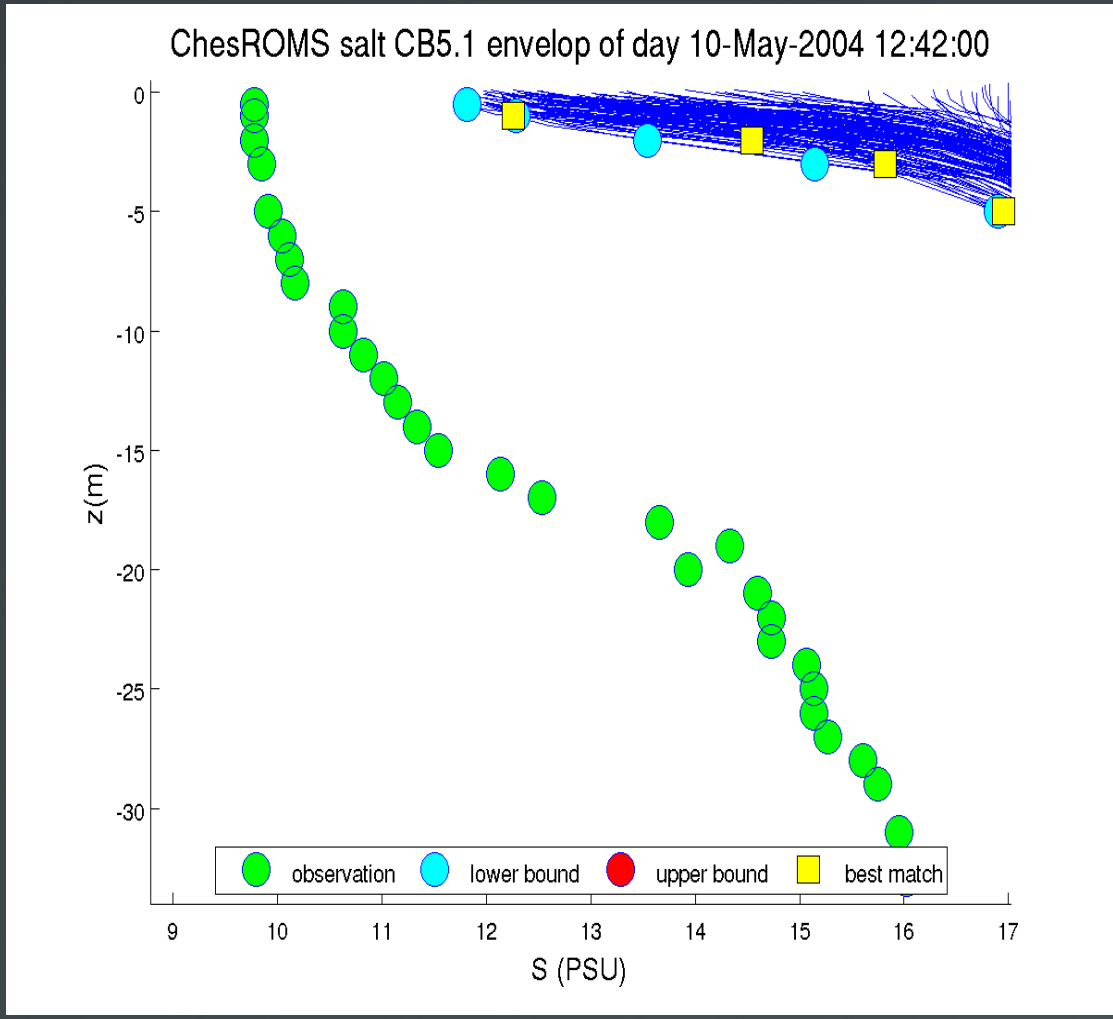
# CH3D model data comparison

- CB5.1 CH3D



# Crude Sensitivity to Depth Test (increase depth by 4 m)



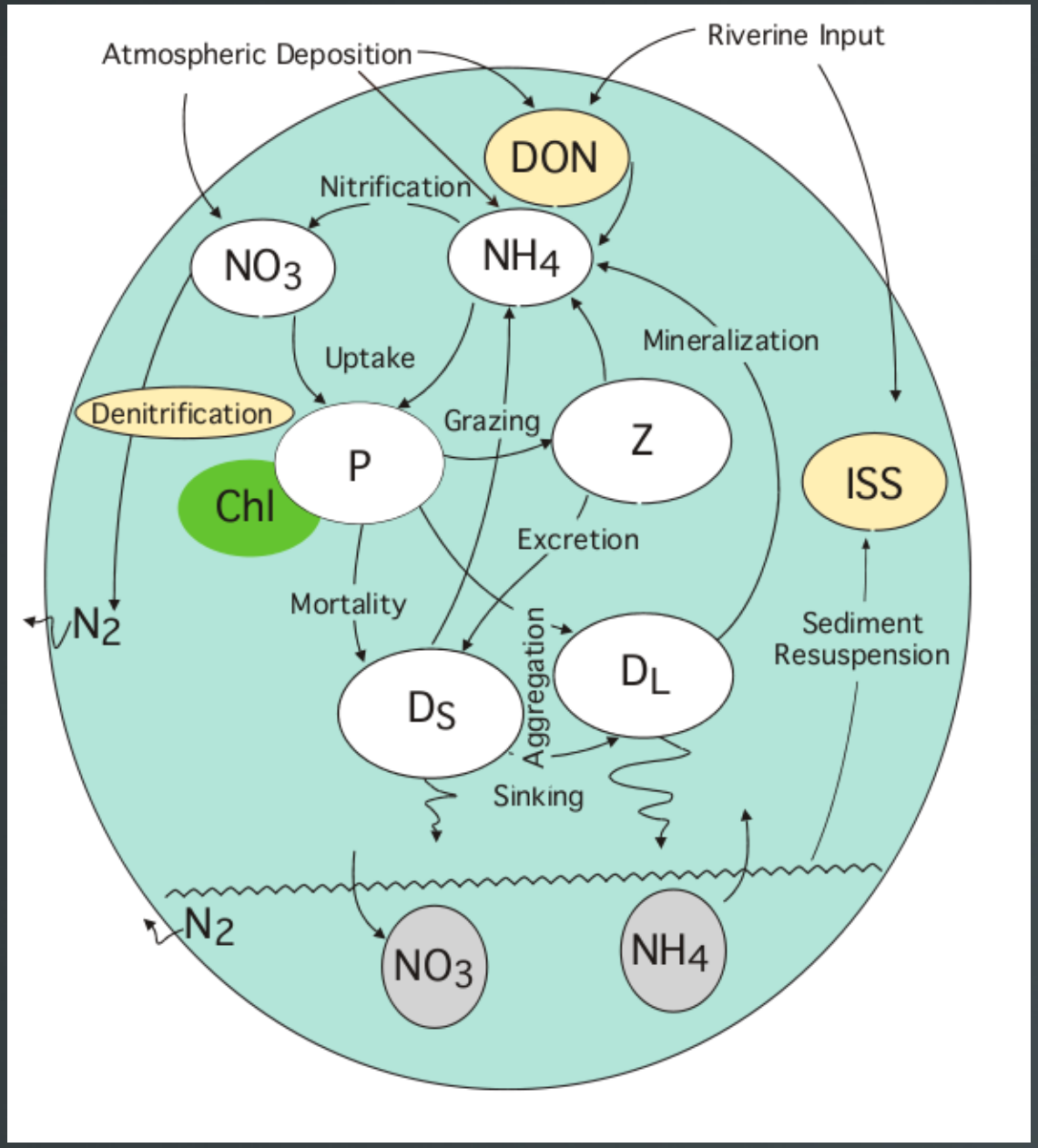
# Biogeochemical Model Development

- Initial development and tuning is based on 1999
- Fennel (2006) model, N-based
- Additions: ISS, DON, PO4, Oxygen regulation on denitrification based on Ryssgard (1994)

Atmospheric deposition of NO3, NH4, DON

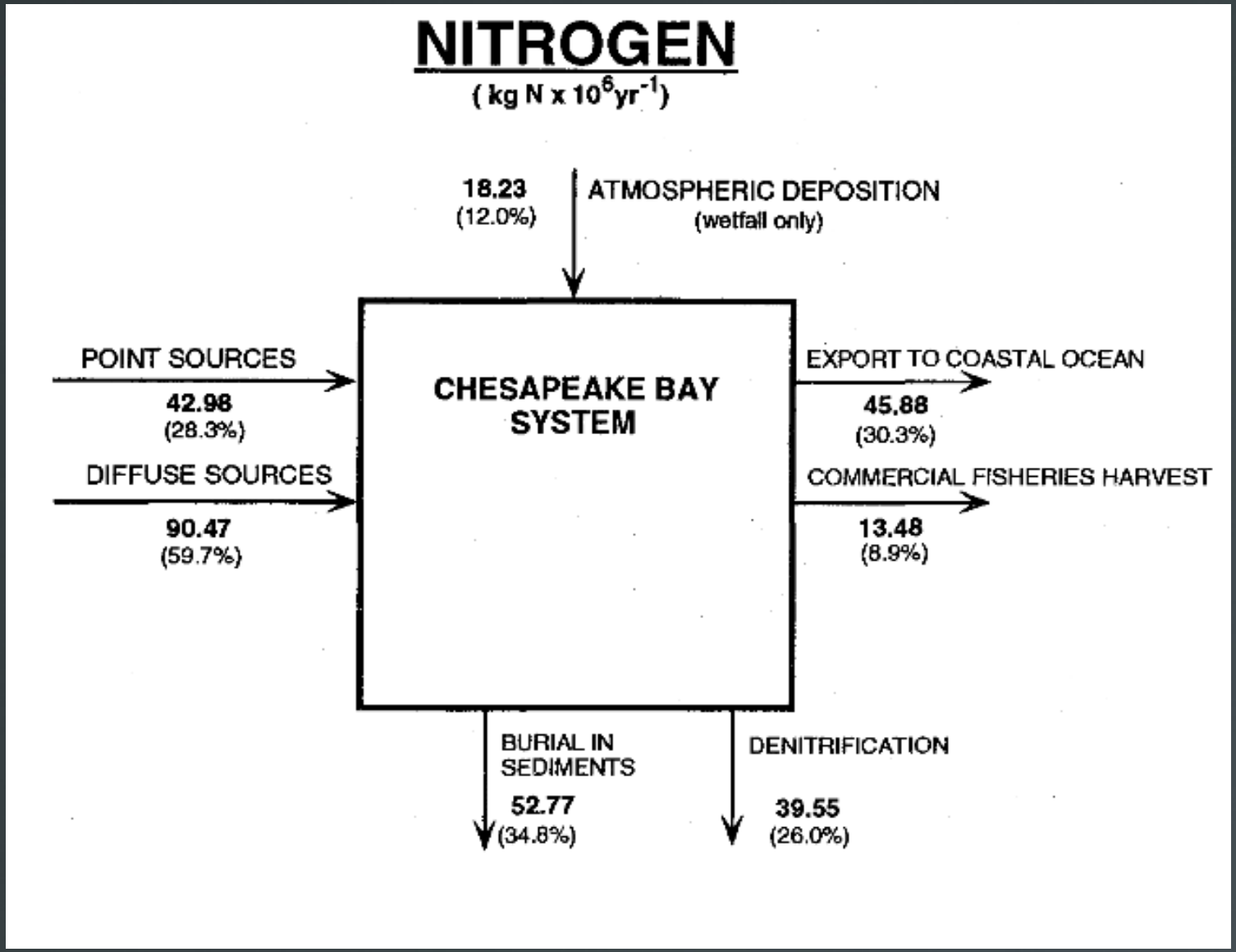
Non-point source along coastal lines

All bio equation including light diagnostics

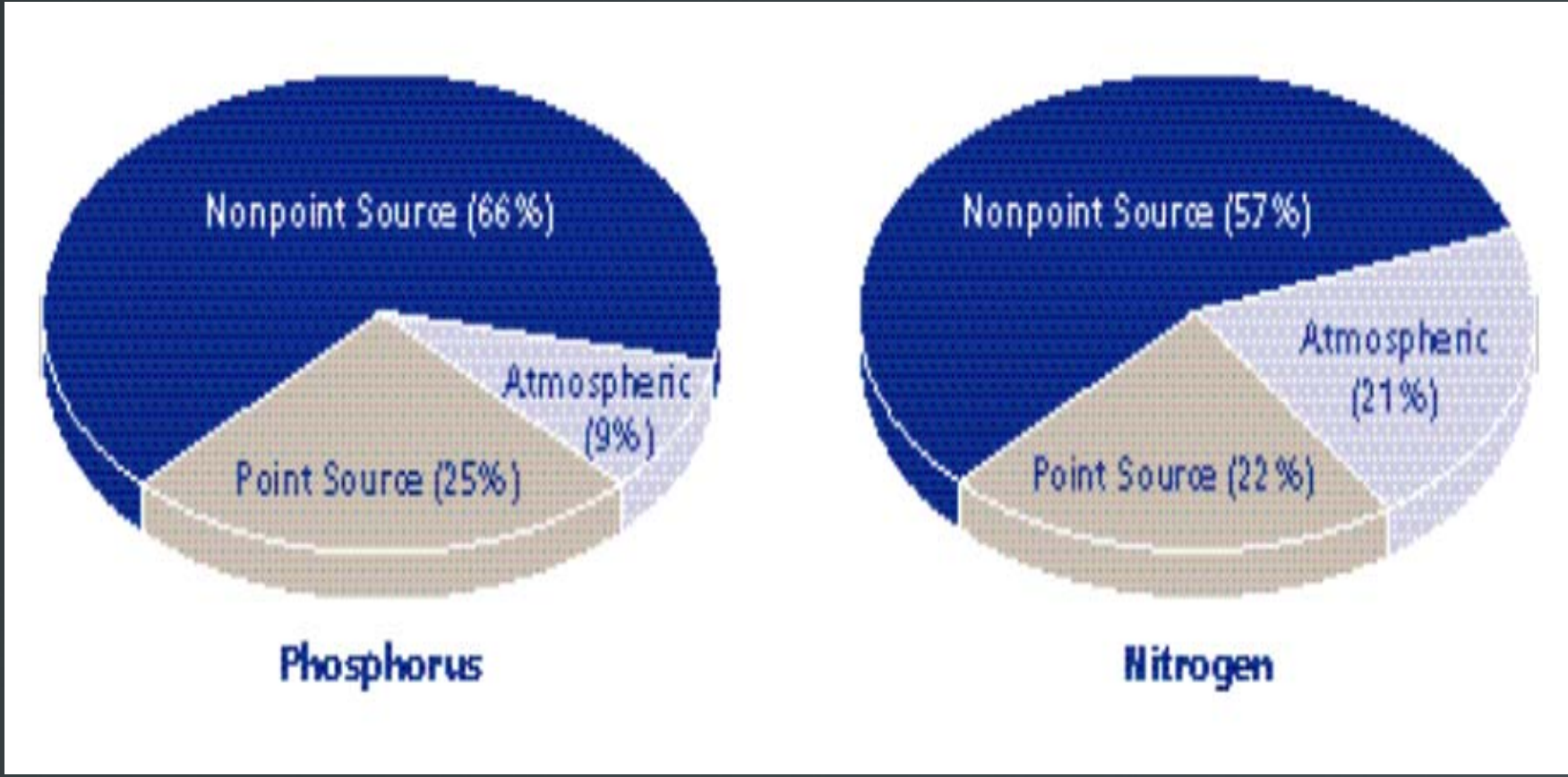



# BGC model structure

# N-Budget (Boyton, 1995)

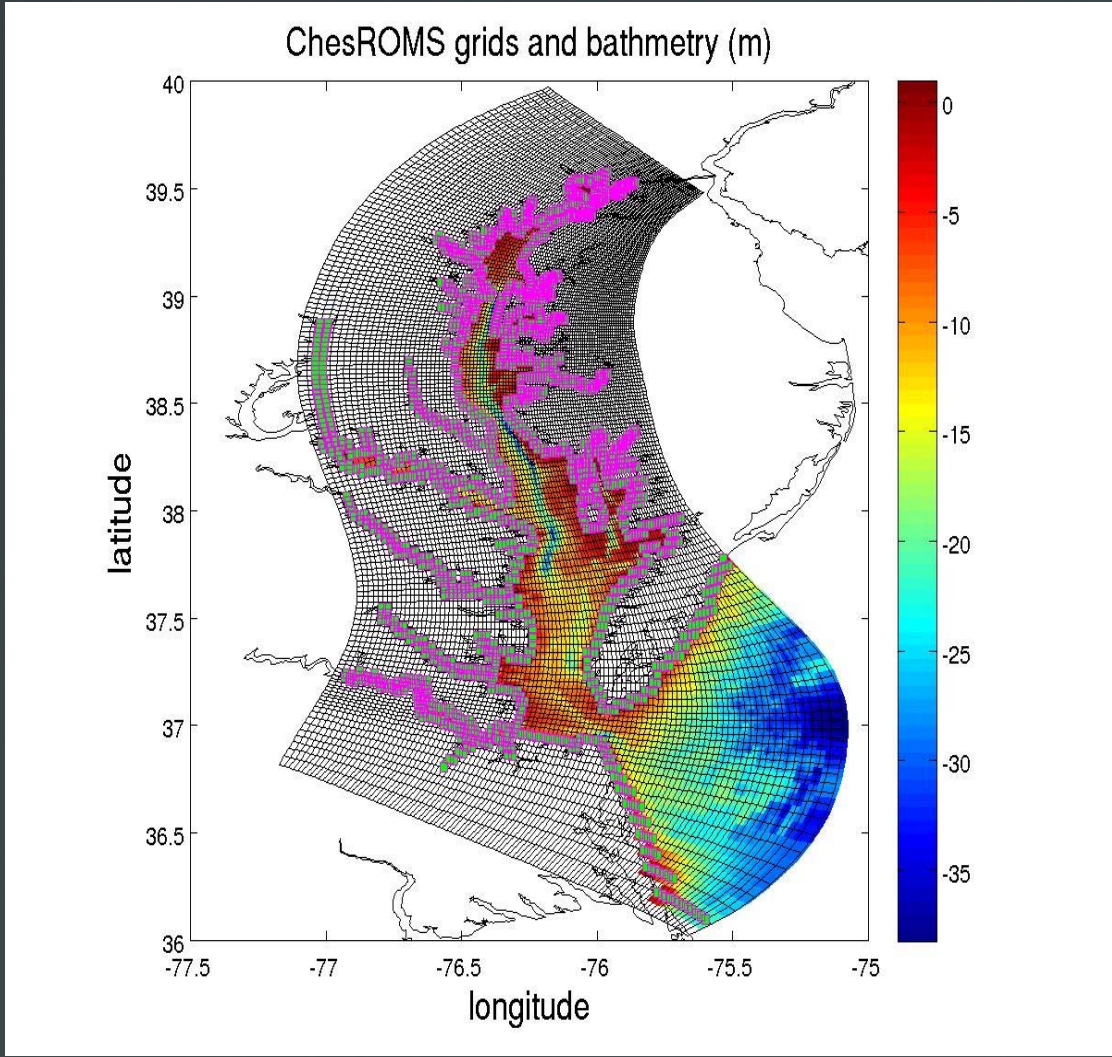


# Point Source vs Non-Point Source (year 1996)

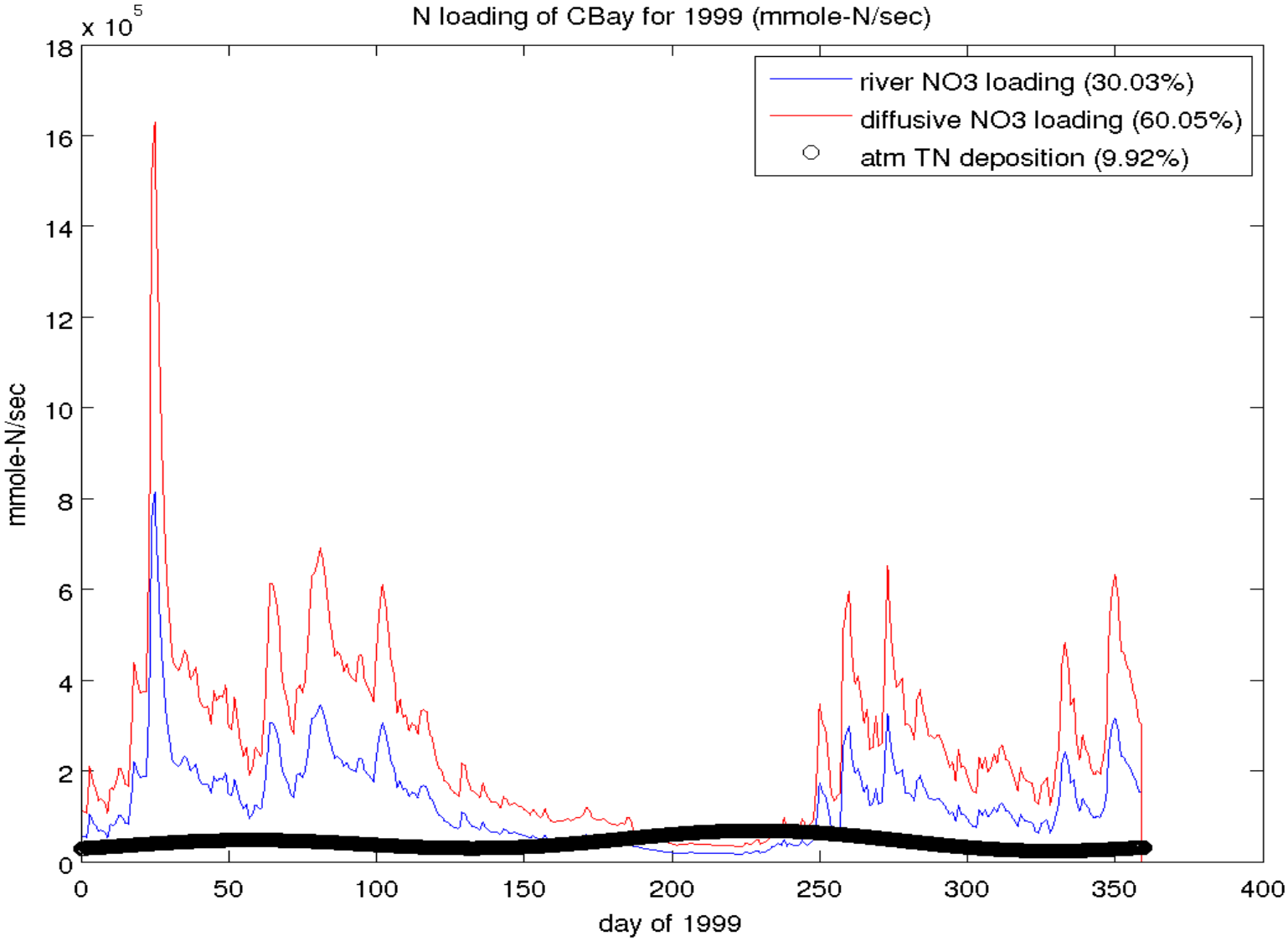


# Diffusive source implementation

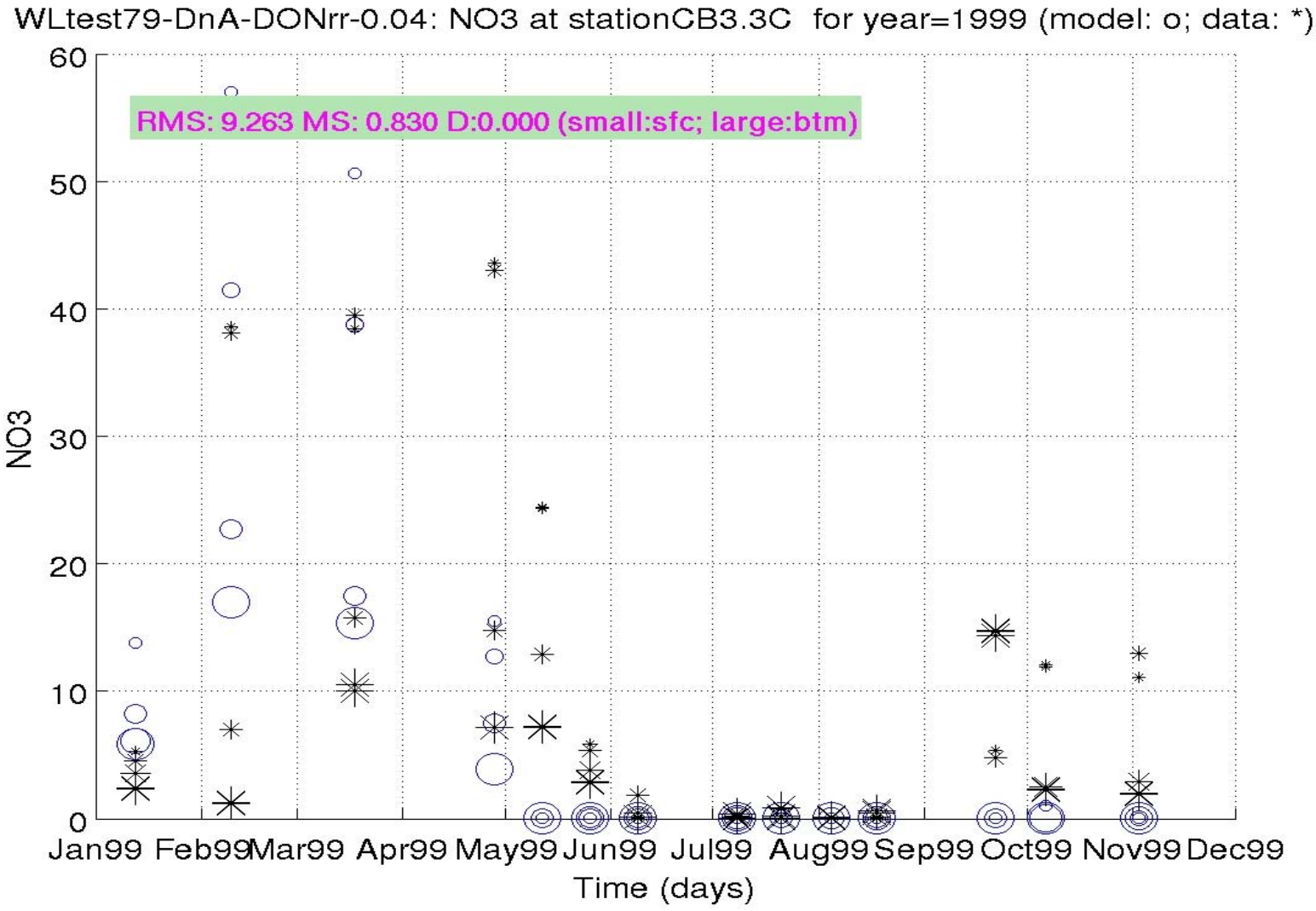
- Key-ed to river loading
- Factor applied and distributed along coastal grids as a source from surface deposition
- Implemented along with normal surface wet/dry deposition



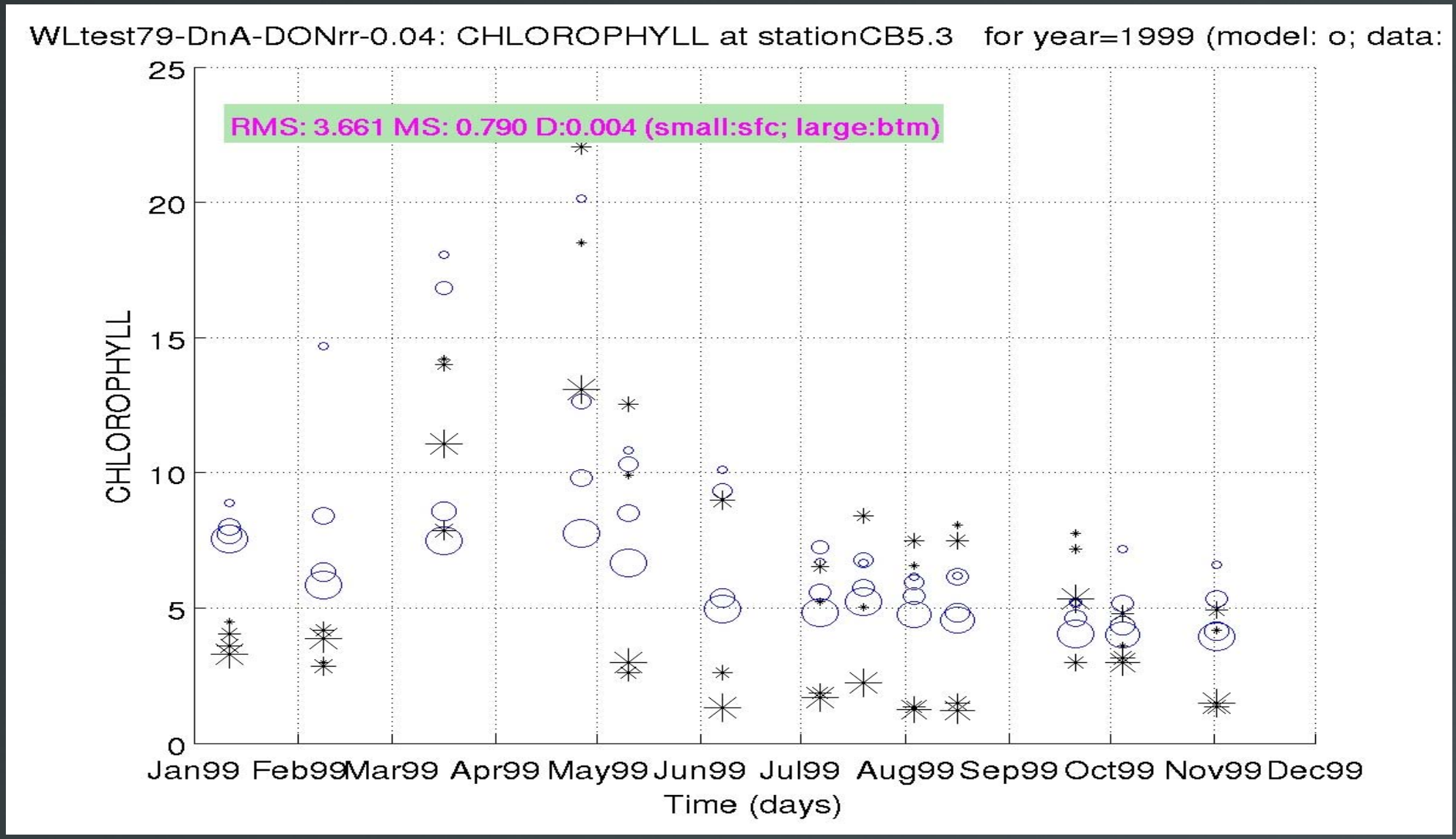
# Normal Atmosheric Deposition (N)



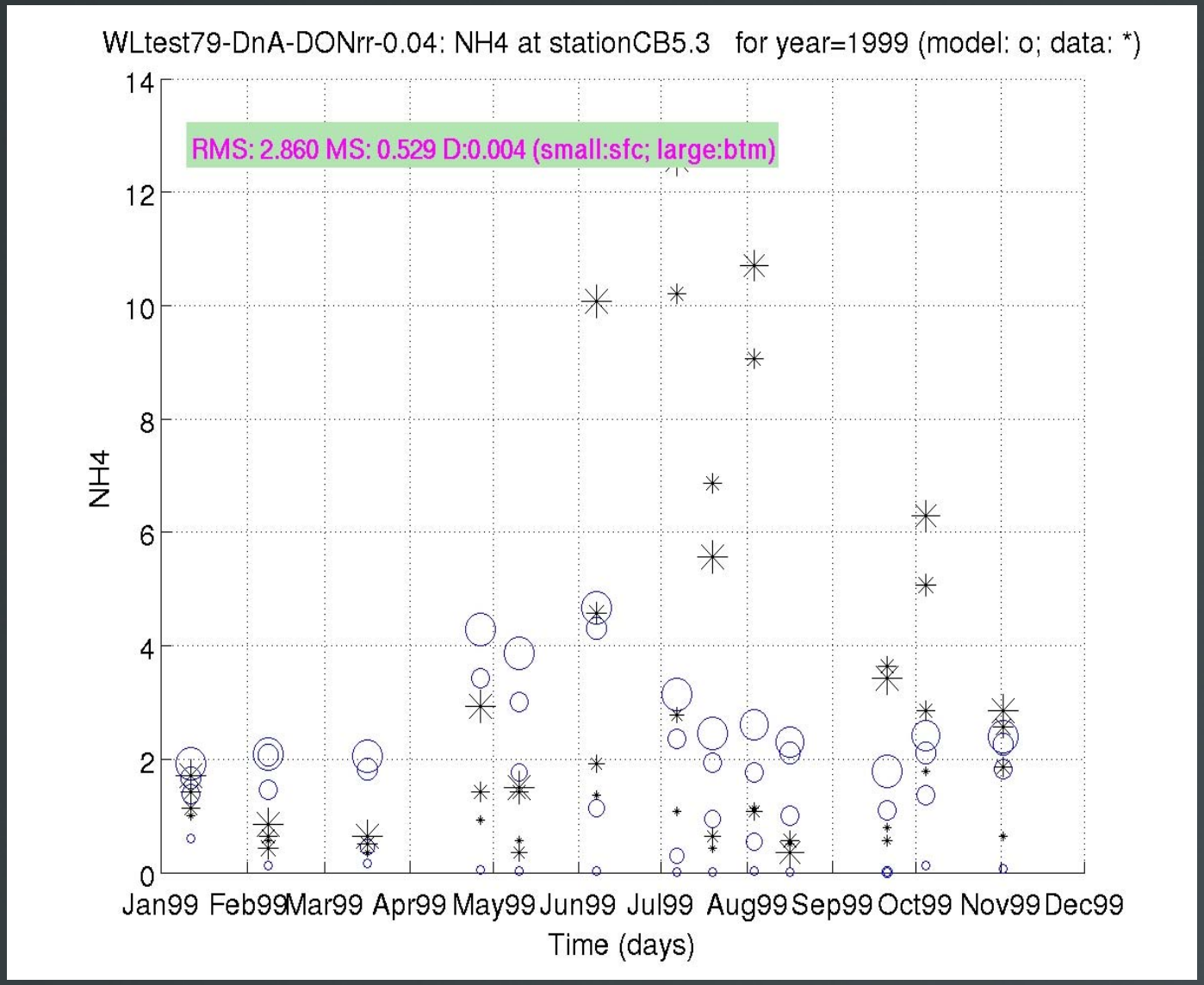
# Model-data comparison (NO3, CB3.3C)



# Model-data comparison (CHLA, CB5.3)



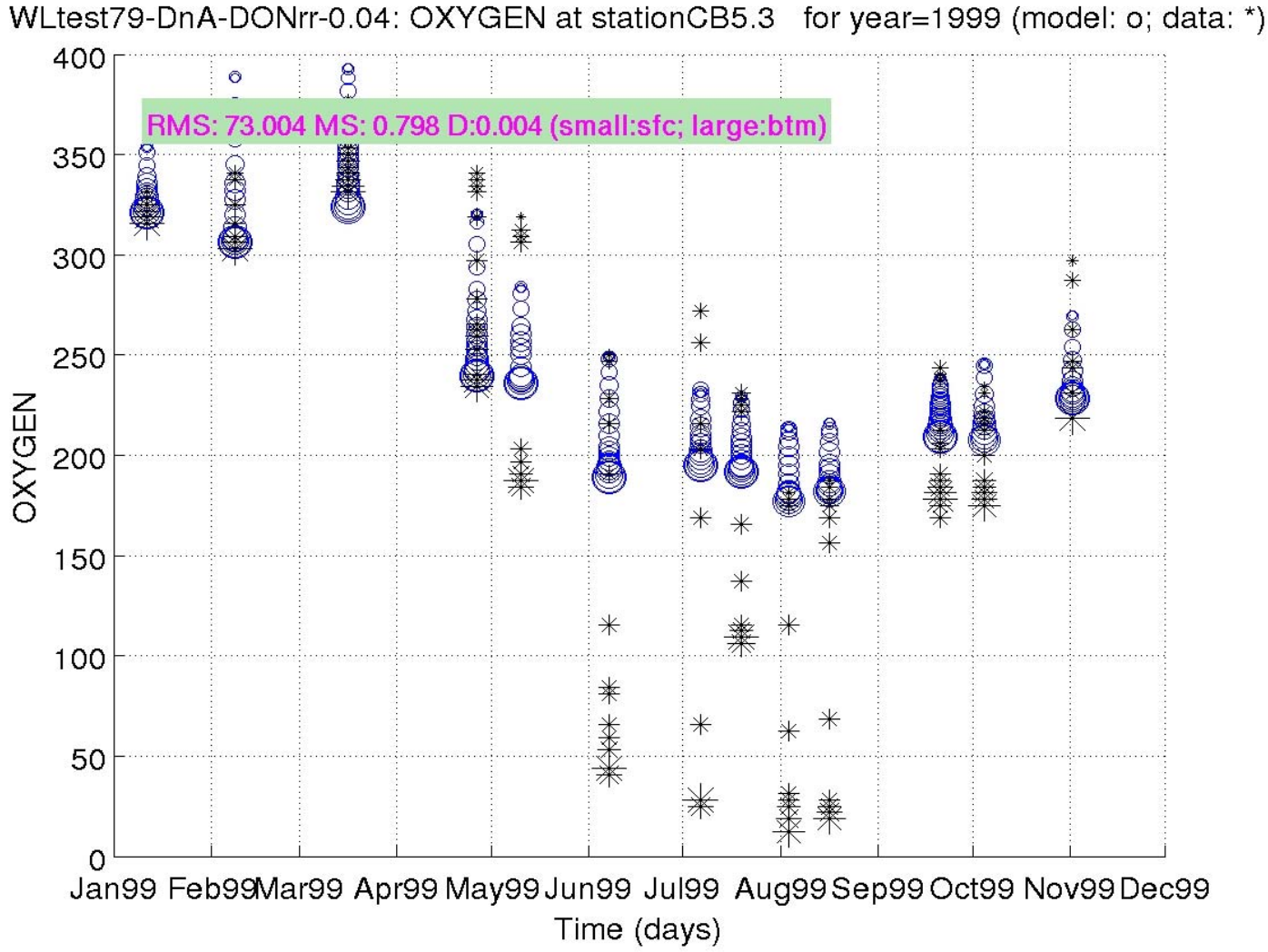
# Model-data comparison (NH4, CB5.3)




A challenge! Low bottom oxygen fueled NH4 return from sediments in summer is missed!

Chicken or Egg?

# Model-data comparison (DO, CB5.3)



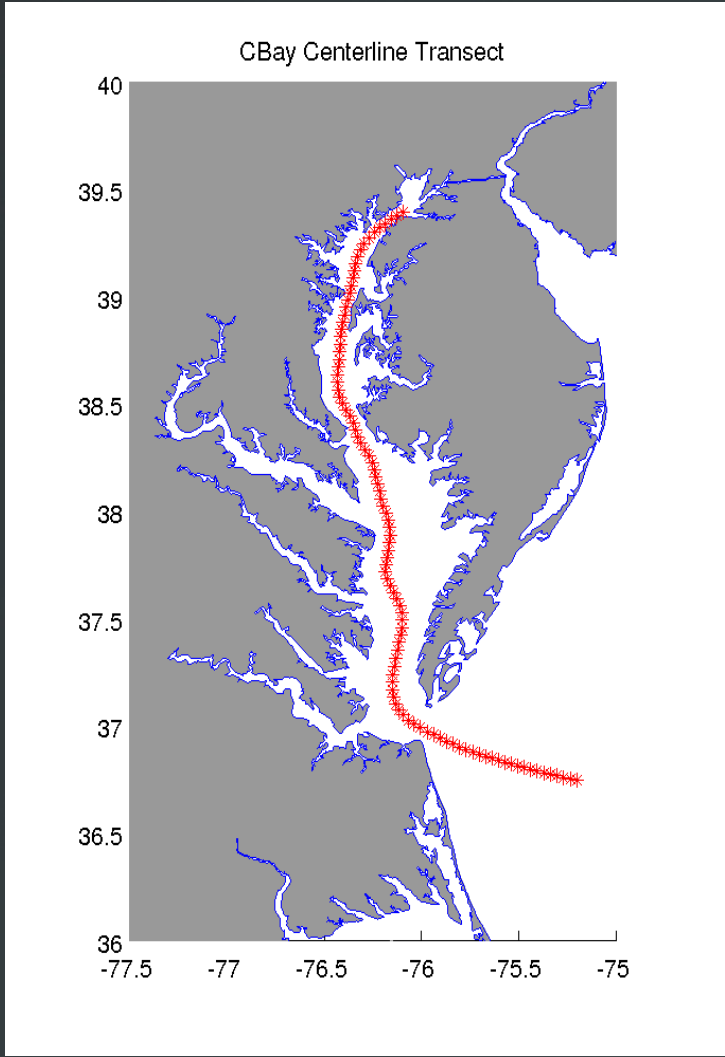

A challenge! Low bottom oxygen sediments in summer is missed! Fennel model is built for shelf isntead of estuary.

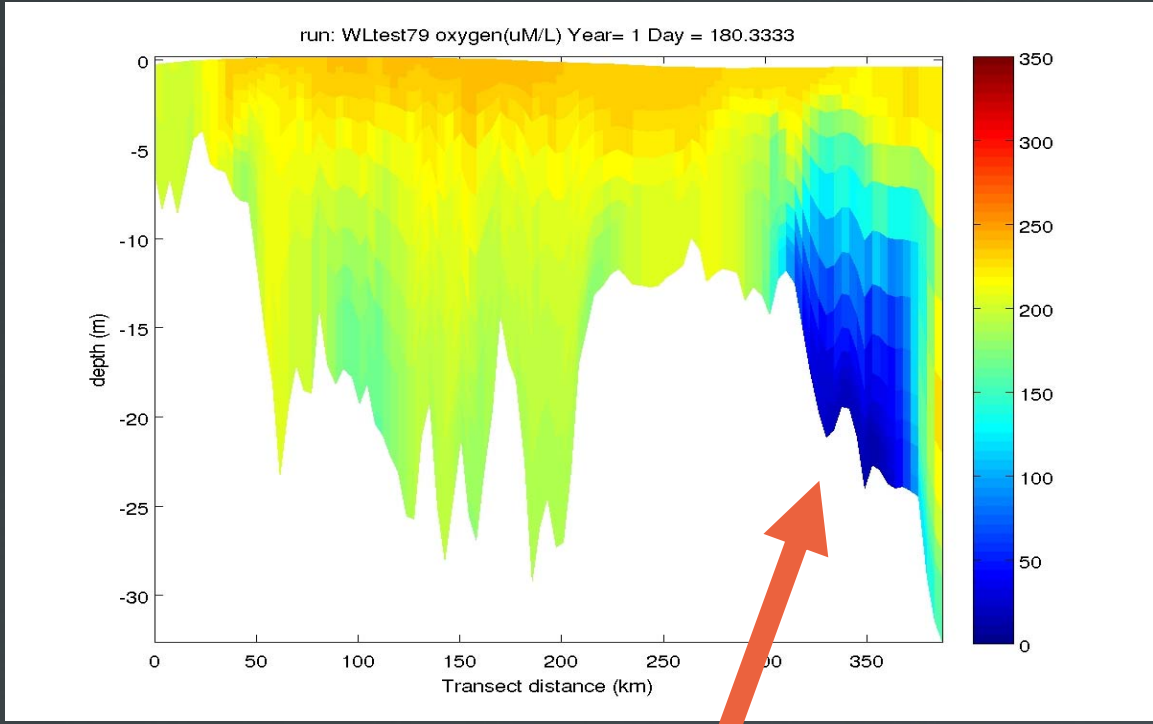
Chicken or Egg?

More comprehensive sediment flux model needed!

Need to hold bottom organic matter

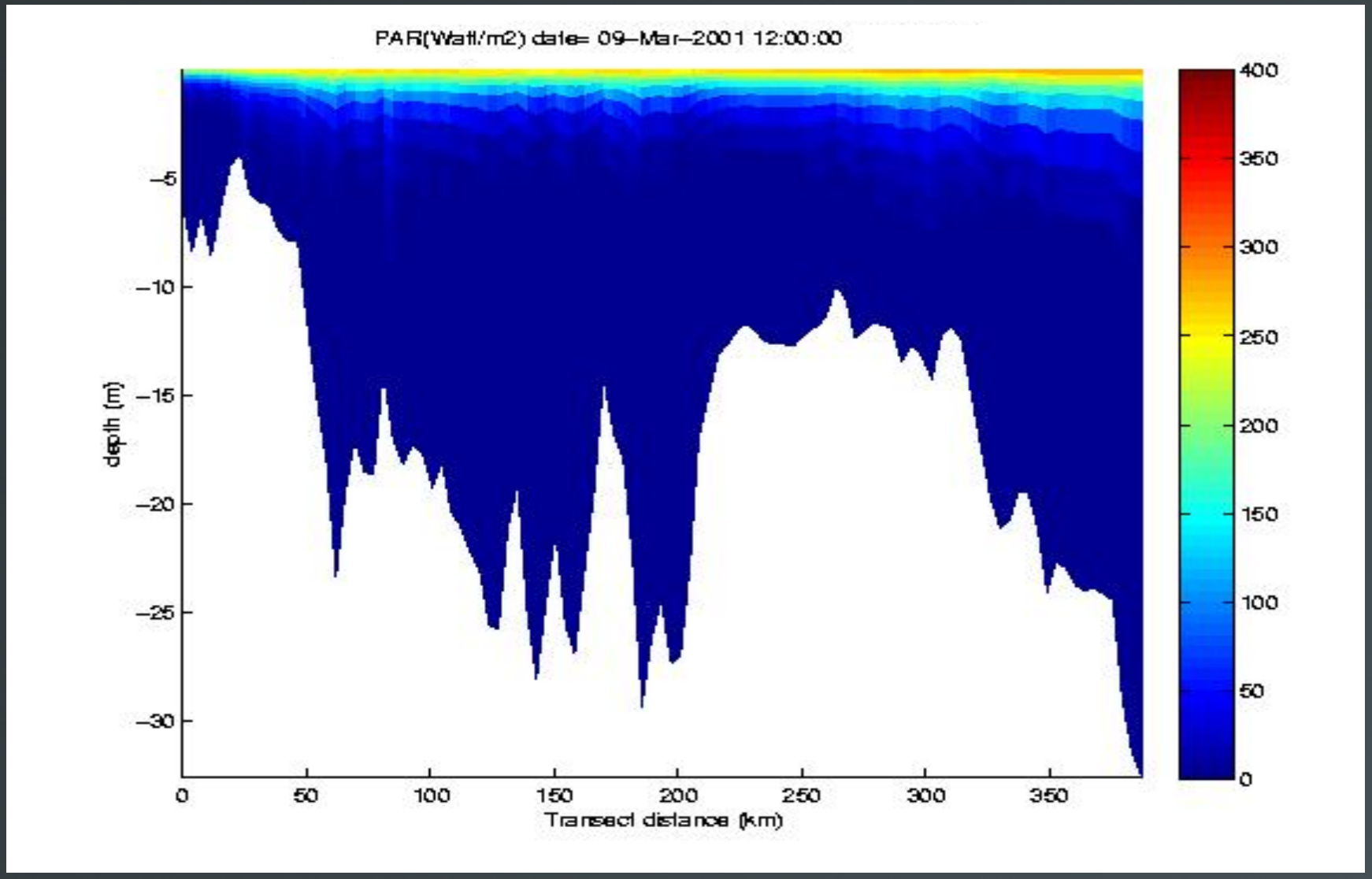
# DO along vertical transect




???? mistry here

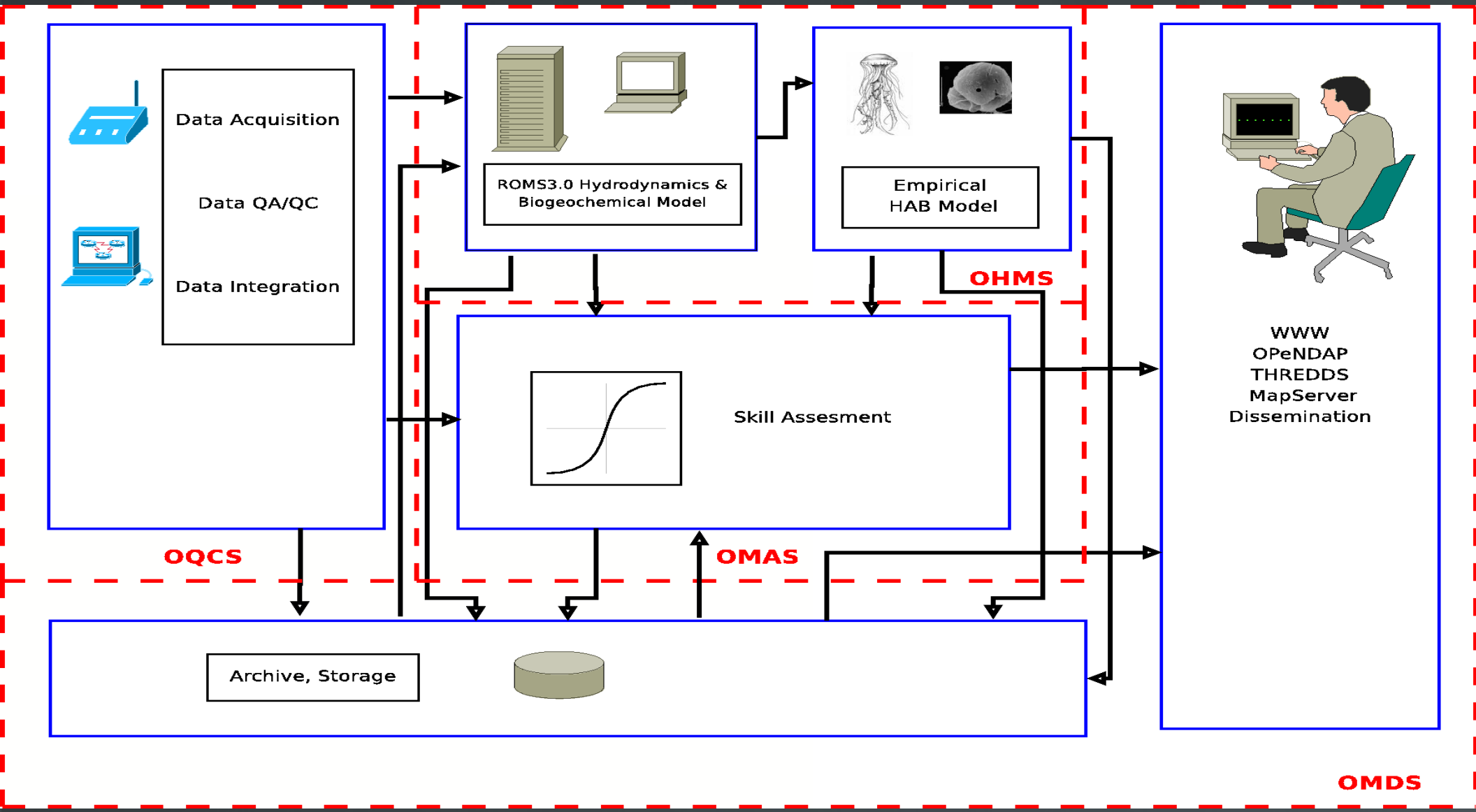
# Photosynthetically Active Radiation (PAR) (Watt/m^2)



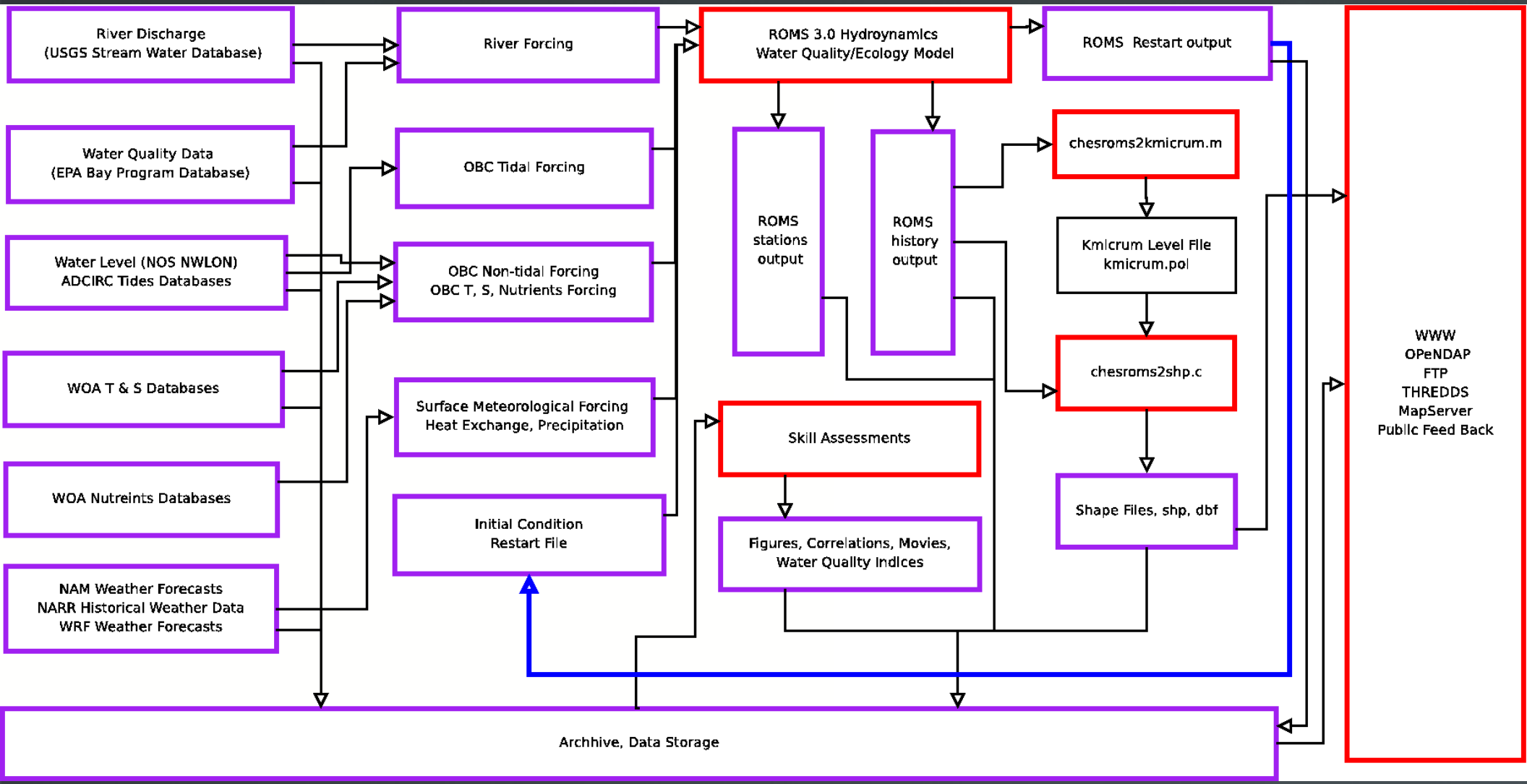
# Operational System Development

- Framework
- Physical model
- BGC model
- nowcast/forecast
- Empirical Habitat Models (Sea Nettle, V. Cholerae, V. Vulnificus, Striped Bass Habitate Suitability)
- Forcing switch from nowcast to forecast
- Templating system to allow easy portability

# Framework


Data Acquisition
Data QA/QC
Data Integration
OQCS
ROMS3.0 Hydrodynamics & Biogeochemical Model
Empirical HAB Model
OHMS
Skill Assesment
OMAS
Archive, Storage
WWW
OPeNDAP
THREDDS
MapServer
Dissemination
OMDS

# Dataflow


River Discharge
(USGS Stream Water Database)
Water Quality Data
(EPA Bay Program Database)
Water Level (NOS NWLON)
ADCIRC Tides Databases
WOA T & S Databases
WOA Nutreints Databases
NAM Weather Forecasts
NARR Historical Weather Data
WRF Weather Forecasts
River Forcing
OBC Tidal Forcing
OBC Non-tidal Forcing
OBC T, S, Nutrients Forcing
Surface Meteorological Forcing
Heat Exchange, Precipitation
Initial Condition
Restart File
ROMS 3.0 Hydroynamics
Water Quality/Ecology Model
ROMS stations output
ROMS history output
Skill Assessments
Figures, Correlations, Movies,
Water Quality Indices
ROMS Restart output
chesroms2kmicrum.m
Kmicrum Level File
kmicrum.pol
chesroms2shp.c
Shape Files, shp, dbf
WWW
OPeNDAP
FTP
THREDDS
MapServer
Public Feed Back
Archhive, Data Storage

# Datasets That Drive The System

- Nowcast

River: USGS realtime database discharge

Climatological nurtrient concentrations

Surface: NCEP NAM, IPCC, WRF

OBC: tides, NOAA tidal gage realtime data

OBC T/S:  WOA2005 climatology

OBC nutrient: WOA01 climatology

# Datasets That Drives The System

- Forecast

River: Regression based on precipitation forecast

or SWAT model forecast (not yet there)

Climatological nurtrient concentrations

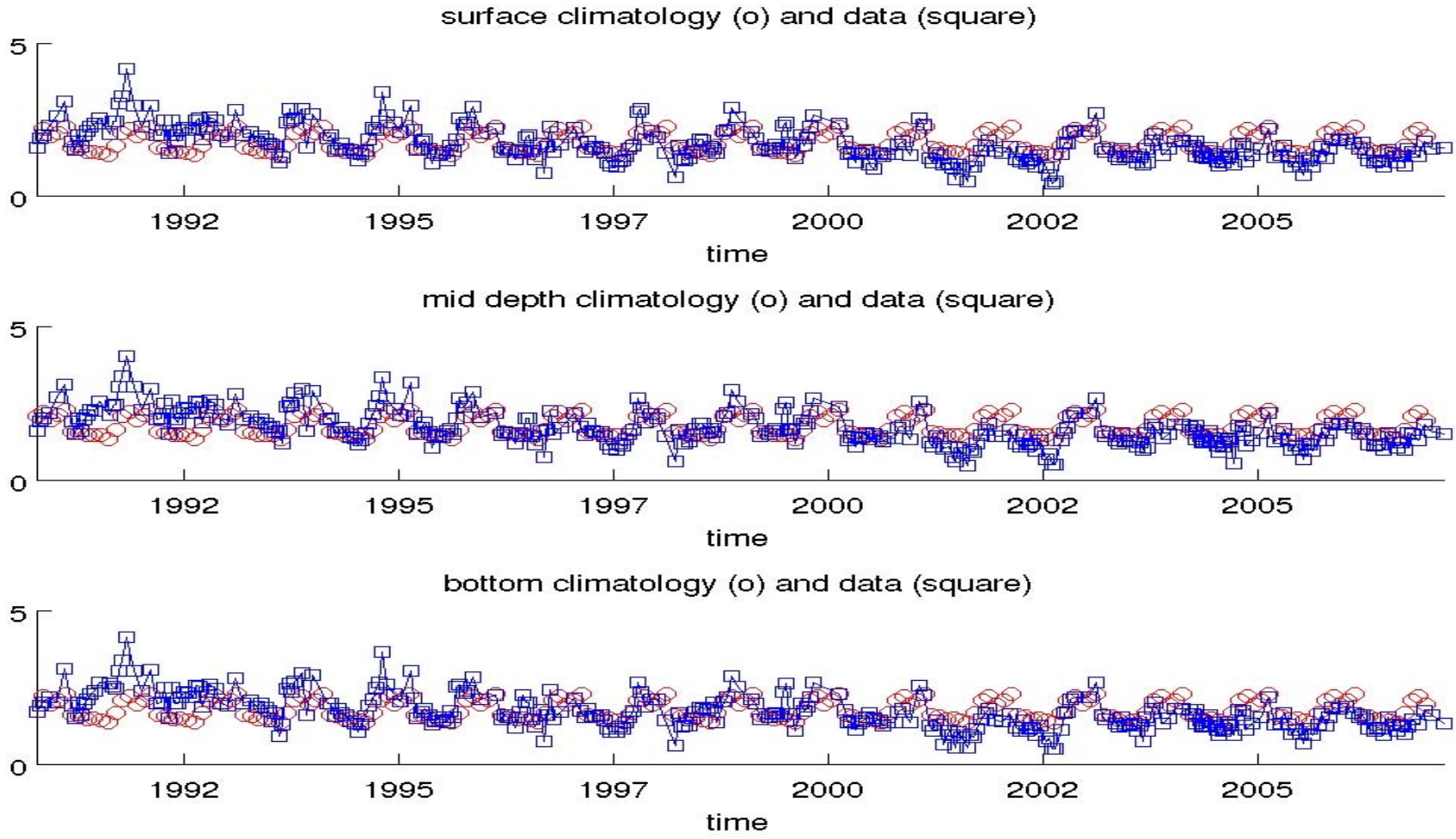
Surface: NCEP NAM, IPCC, WRF

OBC: tides  Persistent non-tidal water level (ehh!)

OBC T/S:  WOA2005 climatology

OBC nutrient: WOA01 climatology

# River loading concentrations climatology (e.g. NO3 at TF2.1)



# River loading (Potomac River)

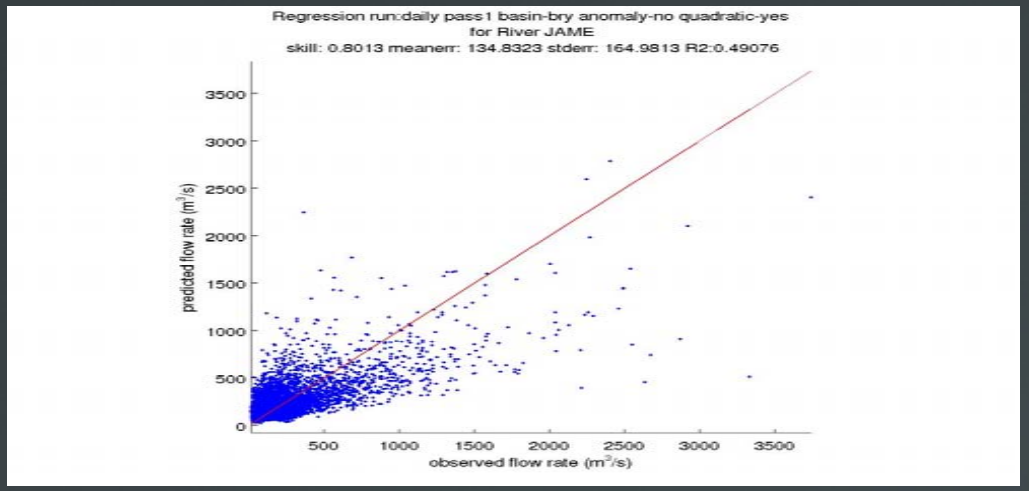
Have to work with constraints

Assumptions based on Redfield ratios made here

| | | | |
|---|---|---|---|
| Potomac | NO3 | TF2.1 | trib_NO3F_TF2.1_1990_2006.txt |
| | NH4 | TF2.1 | trib_NH4F_TF2.1_1990_2006.txt |
| | DON | TF2.1 | trib_DON_TF2.1_1990_2006.txt |
| | chlorophyll | TF2.1 | trib_CHLA_TF2.1_1990_2006.txt |
| | phytoplankton | eqn @8 | |
| | zooplankton | eqn @9 | |
| | TSS | TF2.1 | trib_TSS_TF2.1_1990_2006.txt |
| | detritus | eqn @10 | |
| | LDeN | eqn @11 | |
| | SDeN | eqn @12 | |
| | LDeC | eqn @13 | |
| | SDeC | eqn @14 | |
| | TIC | N/A | not available |
| | alkalinity | N/A | might deduce from TALK of RET2.4 |
| | oxygen | TF2.1 | trib_DO_TF2.1_1990_2006.txt |
| | PO4 | TF2.1 | trib_PO4F_TF2.1_1990_2006.txt |
| | ISS | eqn @15 | |
| | temp | TF2.1 | trib_WTEMP_TF2.1_1990_2006.txt |
| | salt | TF2.1 | trib_SALINITY_TF2.1_1990_2006.txt |

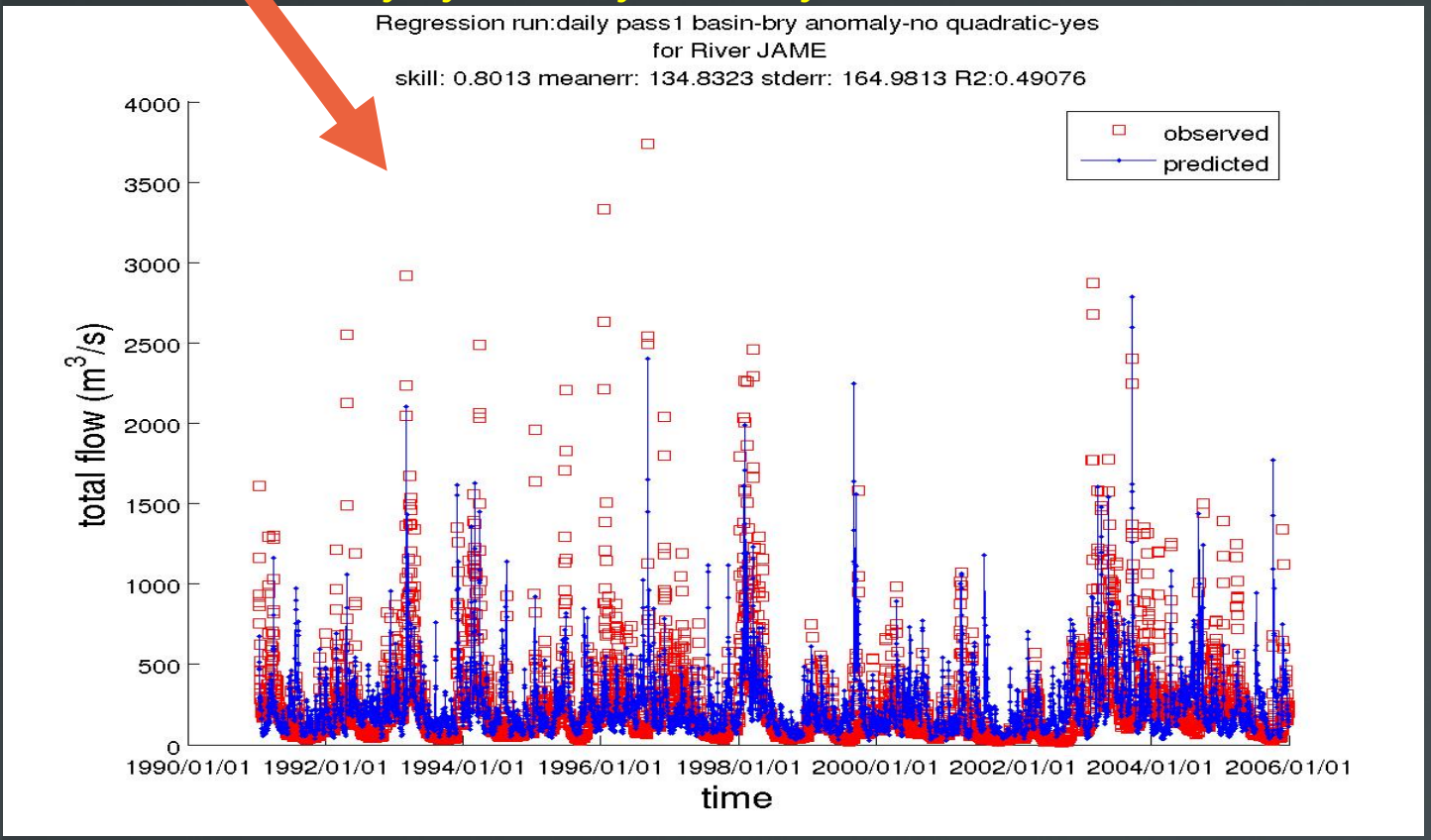
# River Discharege Regression: Q=f(P)

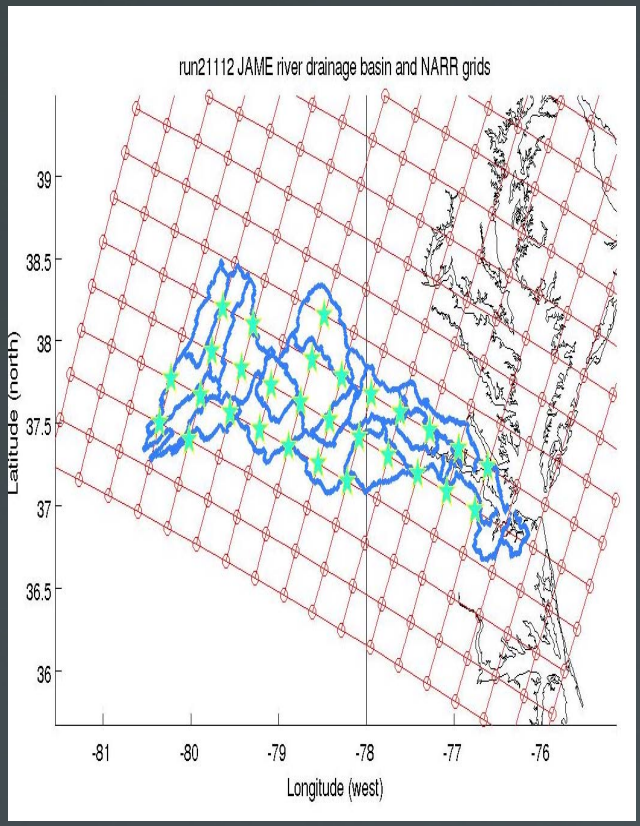
- Details omitted here (complicated scheme)
- inolves separation of quick flow/baseflow
- best time lag search, multiple smoothing




JAMES RIVER

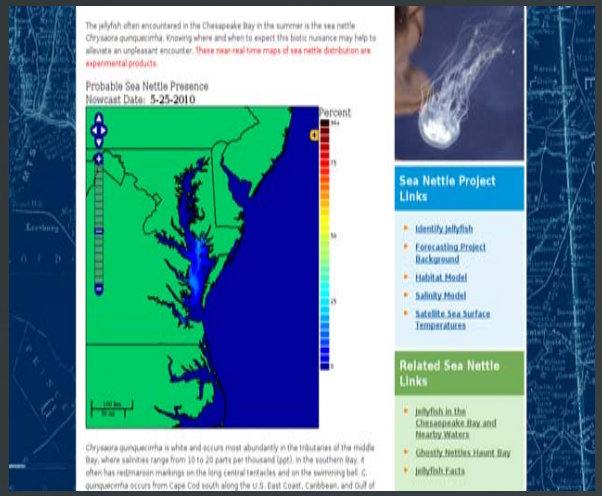
- Tributary by tributary, basin by basin

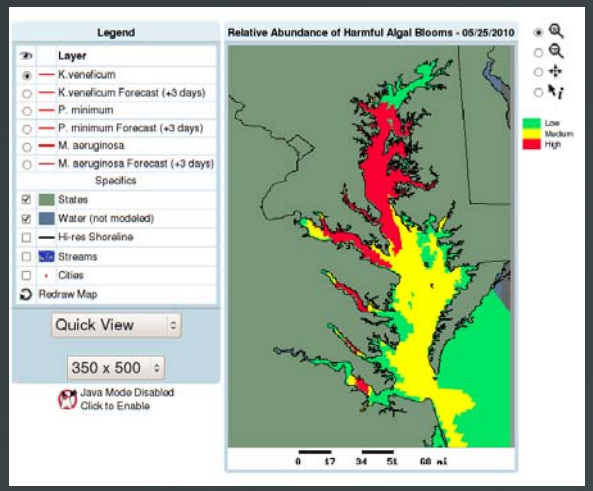


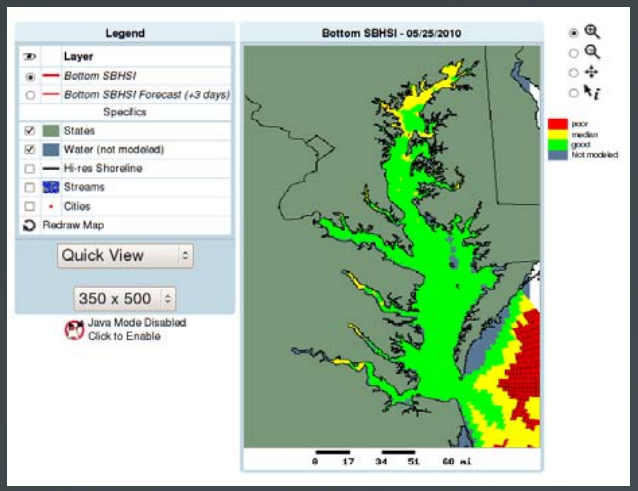



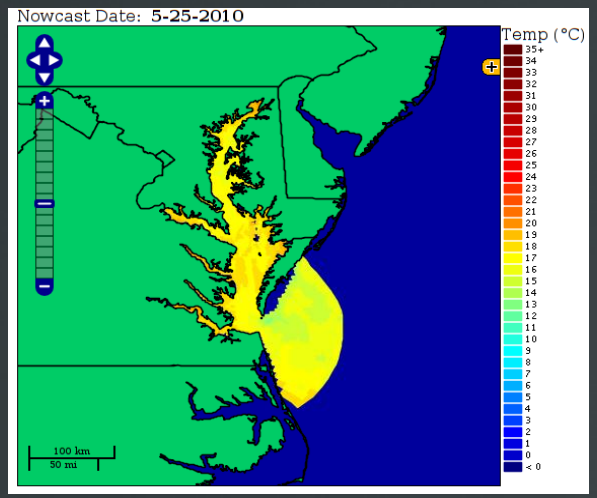
# Emprical Habitat Models

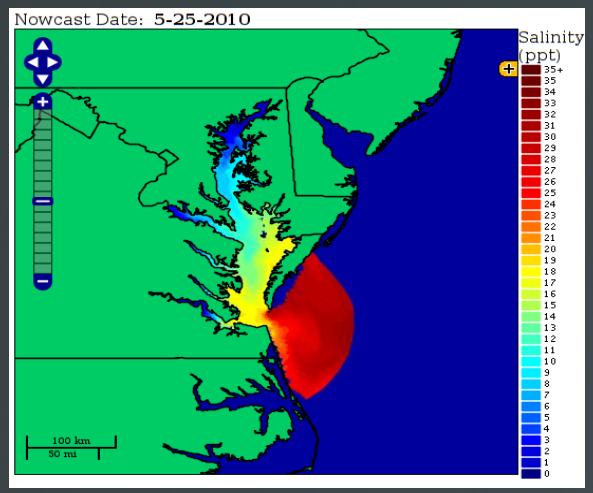
- Driven by T/S or BGC fields from ChesROMS

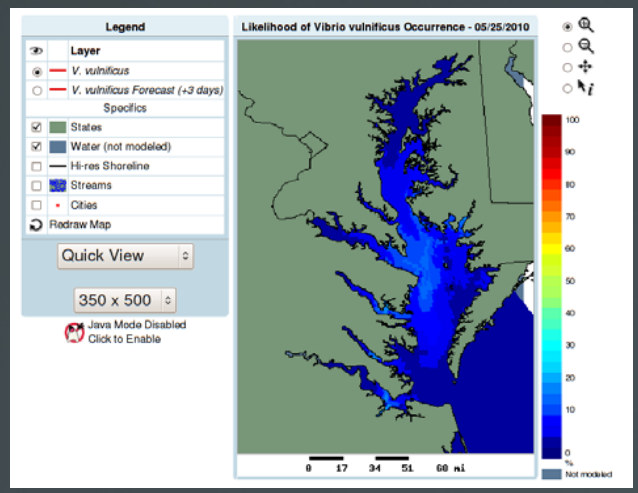


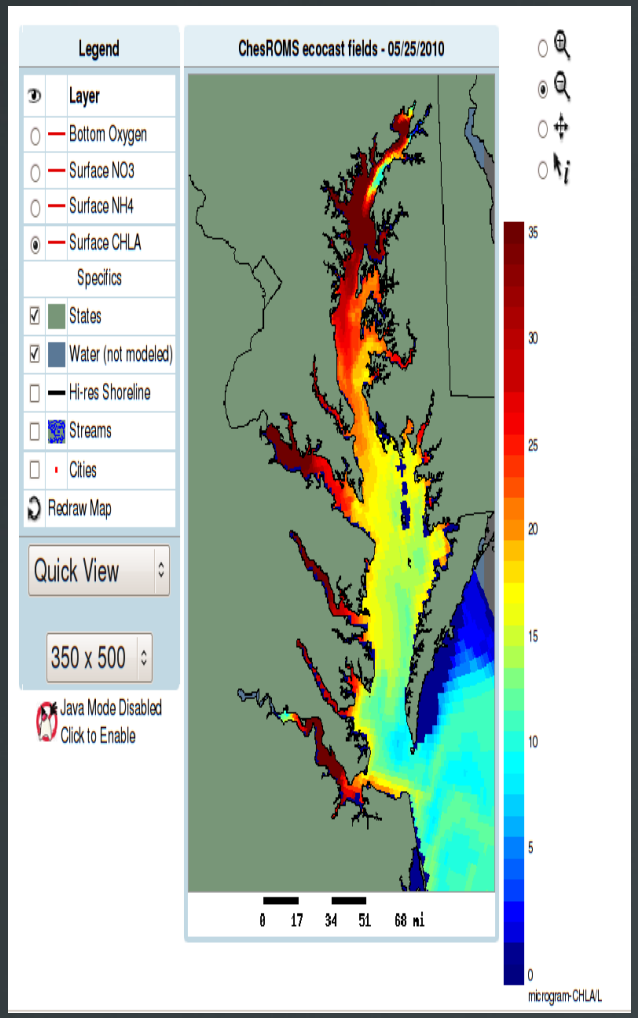



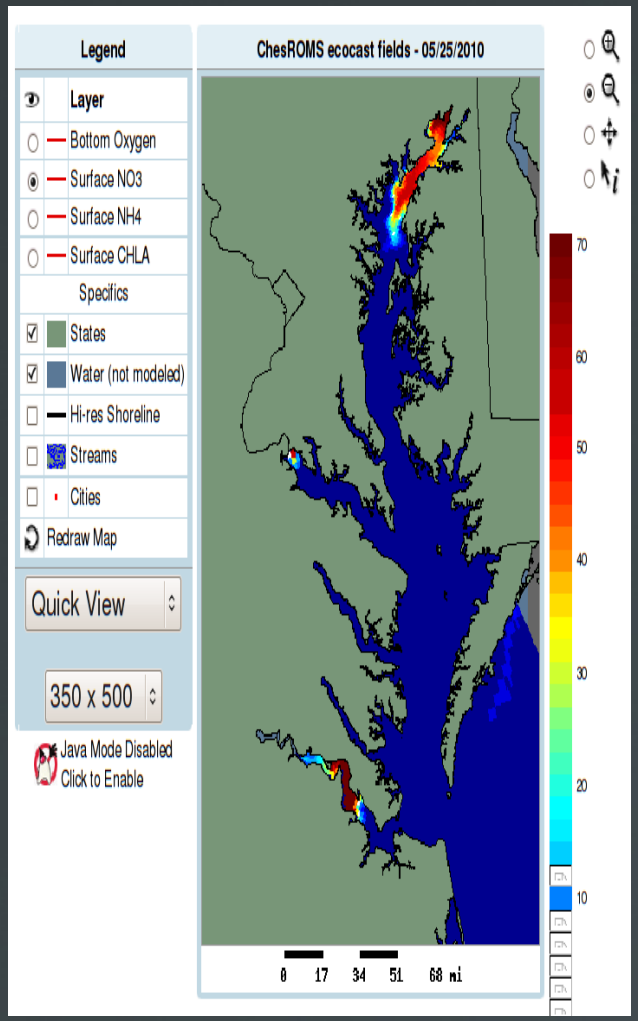



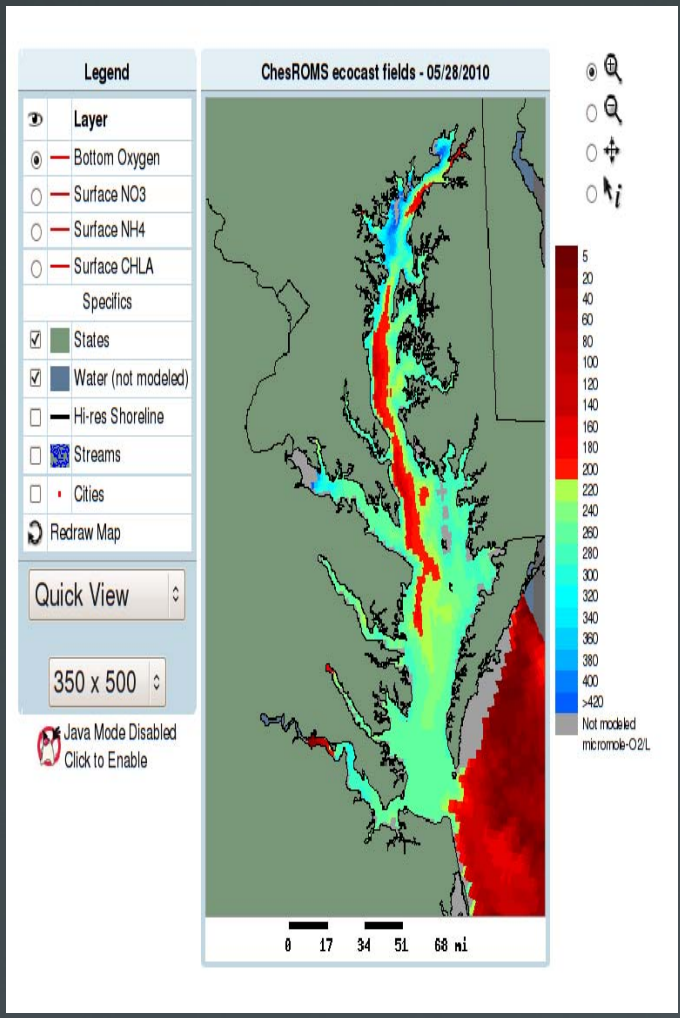
# ChesROMS Ecocast Sneak Preview

- Mechanistic BGC nowcast and forecast

http://155.206.18.162/chesroms_ecocast/



# Challenges

- Mixing and stratification; good bathymetry is definitely needed;

carry on cross comparison with other models. More research on turbulence scheme, mixing scheme of z-grid vs u grid.

- DO not low enough. ROMS is missing basic chemistry regarding sediment fluxes, a lot more tuning needed
- Plan to add 2-layer sediment flux model based on RCA model
- Need better data to constrain operational model (WWTP? )
- Need data to do near-real time model-data comparison not available

(example: eyesonthebay does not support realtime retrieval)

- Data assimilation scheme development (Matt Hoffman at JHU)

# Outlooks

- Refined grid version with wet and dry (challenge with the OBC)
- Fix BGC with DO and more comprehensive sediment flux model
- K. Veneficum model data match up (1991-2009) (to be published)
- More empirical HAB habitat model to appear (*P. Minimum*, *M. aeruginosa*)
- Operational physical model validation and tuning by reforecasting from 2007 to 2010
- Biogeochemical model validation and tuning by reforecasting from 2007 to 2010
- Ensemble nowcasting/forecasting modeling (with 8 menber WRF) and Kalman filter (40 members initial condition)
- Extend from 3 day to 16 day forecast (already doing it with CBFS)

# Thanks!