U.S. ECoS

U.S. Eastern Continental Shelf Carbon Budget: Modeling, Data Assimilation, and Analysis

A project of the NASA Earth System Enterprise Interdisciplinary Science Program

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J. Druon, S. Seitzinger, S. Signorini, D. Pollard

U.S. ECoS

Science Team:

Eileen Hofmann (ODU):	project oversight, 1D modeling
Chuck McClain (GSFC):	project oversight, remote sensing data
Marjorie Friedrichs (VIMS):	1D modeling and data assimilation
Sergio Signorini (GSFC):	satellite data analysis
Antonio Mannino (GSFC):	carbon cycling, DOC algorithms
Jean-Noel Druon (GSFC):	DOM modeling
Cindy Lee (SUNY-SB):	carbon cycling
Jay O’Reilly (NOAA):	satellite-derived data sets
Dale Haidvogel (RU):	ROMS circulation modeling
John Wilkin (RU):	ROMS circulation modeling
Sybil Seitzinger (RU):	food web and nutrient dynamics
Katja Fennel (Dal.U):	biogeochemical modeling
Ray Najjar (PSU):	oxygen data, climate modeling
David Pollard (PSU):	climate modeling

U.S. ECoS

Goal: To develop carbon budgets for the U.S. east coast continental shelf (Mid-Atlantic Bight and South Atlantic Bight)

Research Questions:

1. What are the relative carbon inputs to the MAB and SAB from terrestrial run-off and *in situ* biological processes?
2. What is the fate of DOC input to the continental shelf from estuarine and riverine systems?
3. What are the dominant food web pathways that control carbon cycling and flux in this region?
4. Are there fundamental differences in the manner in which carbon is cycled on the continental shelves of the MAB and SAB?
5. Is the carbon cycle of the MAB and SAB sensitive to climate change?

Project Structure/Management

Personnel

Breadth of expertise: modelers and observationalists

Multiple subgroups working in parallel:

model-data comparison via Rutgers OpenDap server

Communication

Semi-annual group meetings

Monthly conference calls

Parallelism and frequent communication

$\Rightarrow$ builds diversity

Outline

1. Data Analysis

- Historical *in situ* measurements
- Satellite-derived data
- Limited field measurement effort

2. Development/Implementation of Models

- Circulation model
- Coupled biogeochemical-circulation model
- Coupled biogeochemical-circulation model with DOM

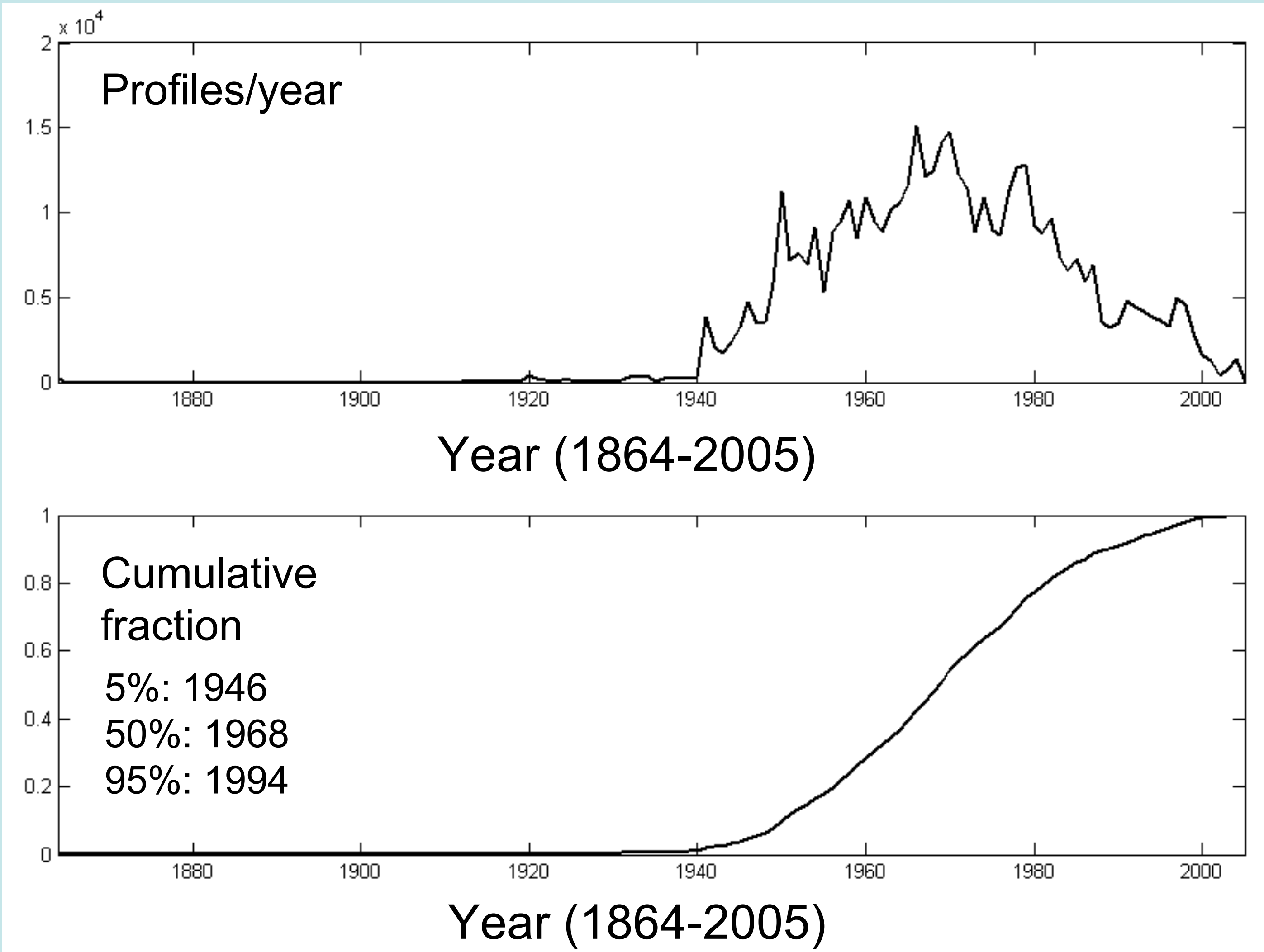
3. Models+Data

- Quantitative skill assessment
  - Scatter, Taylor, Target, Variational data assimilation

4. Process/Climate Studies

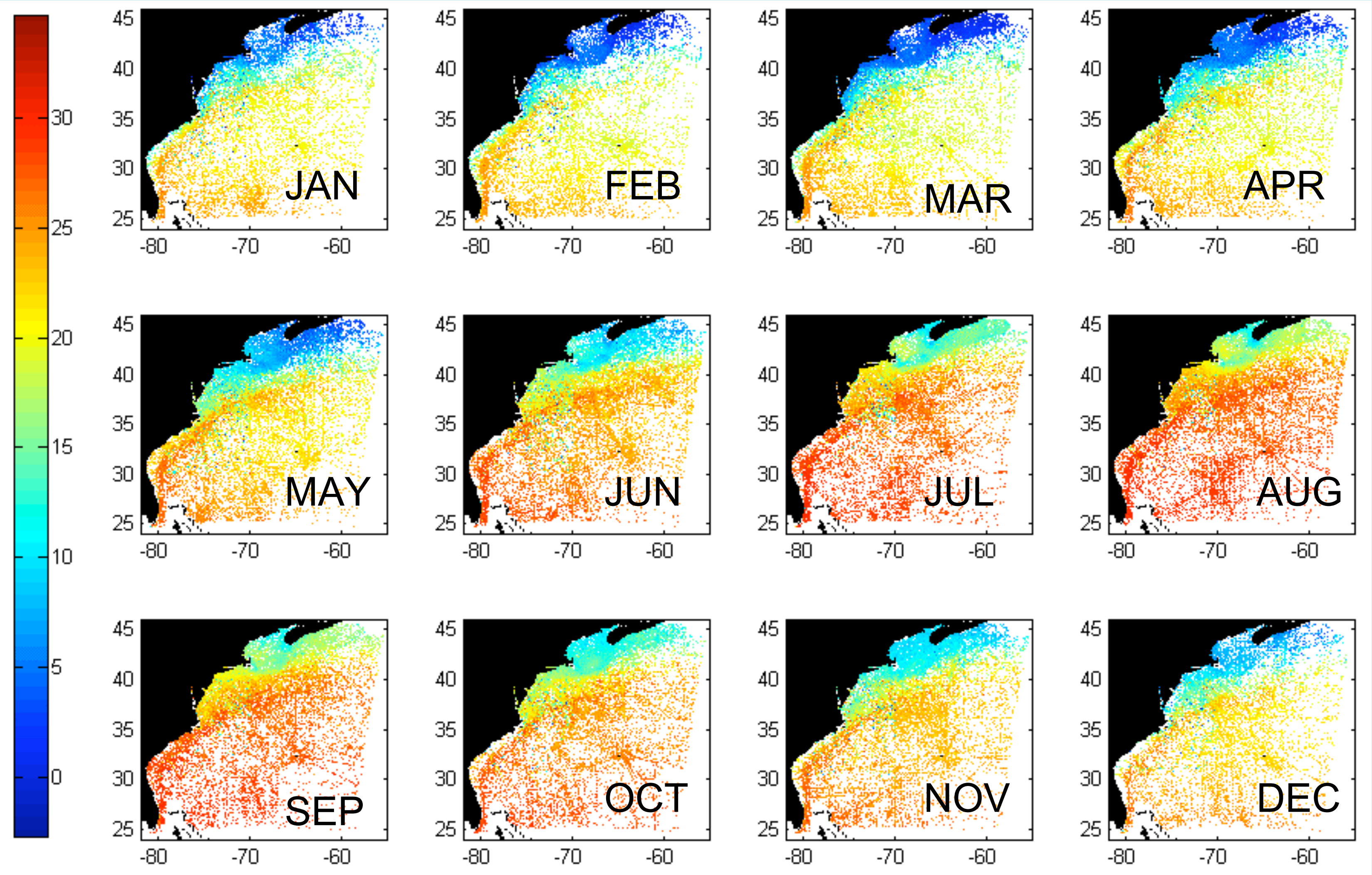
1a. Historical data

Total number of NODC Temperature profiles: 462,348



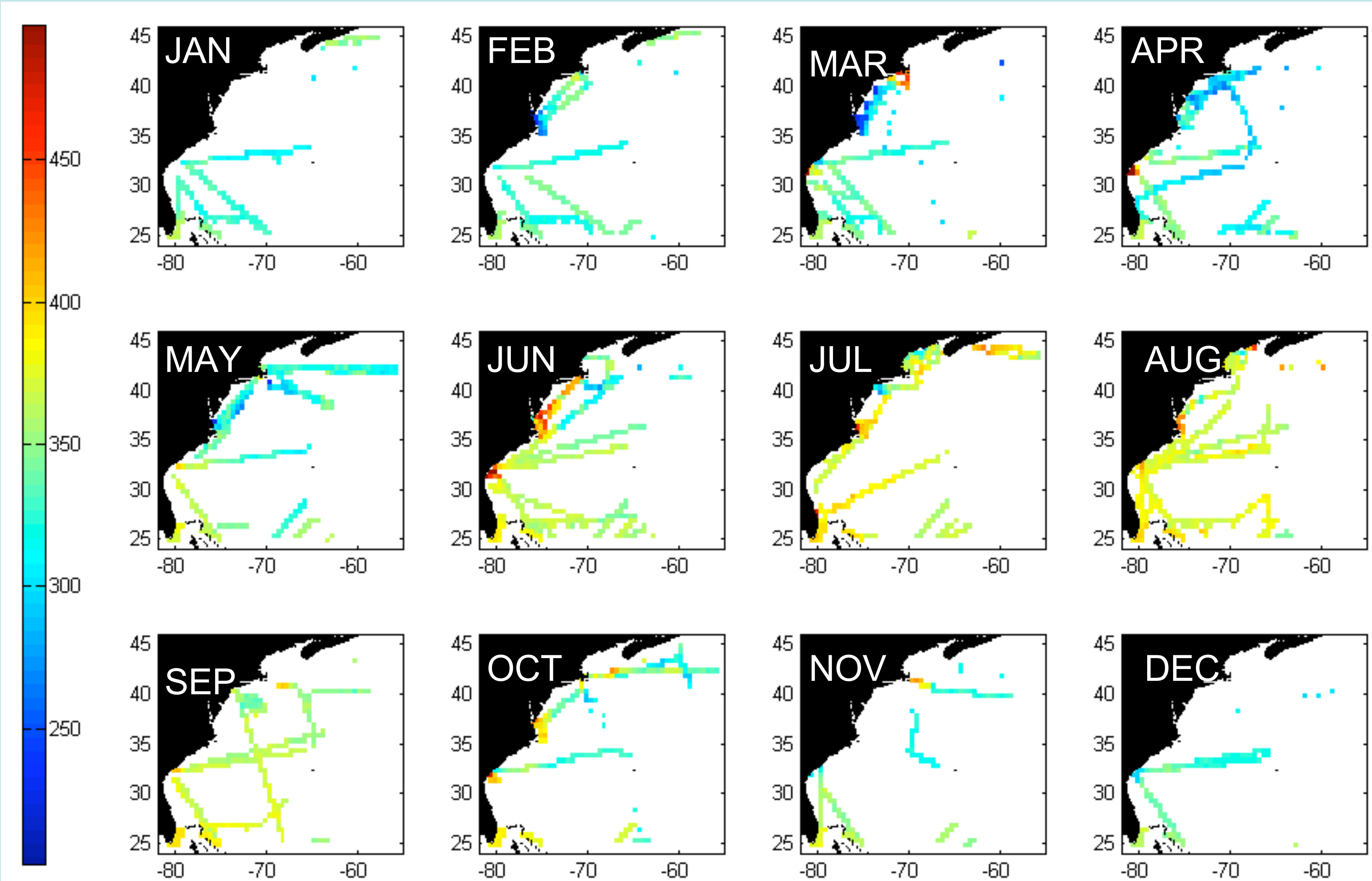
Najjar

Temperature (ºC)



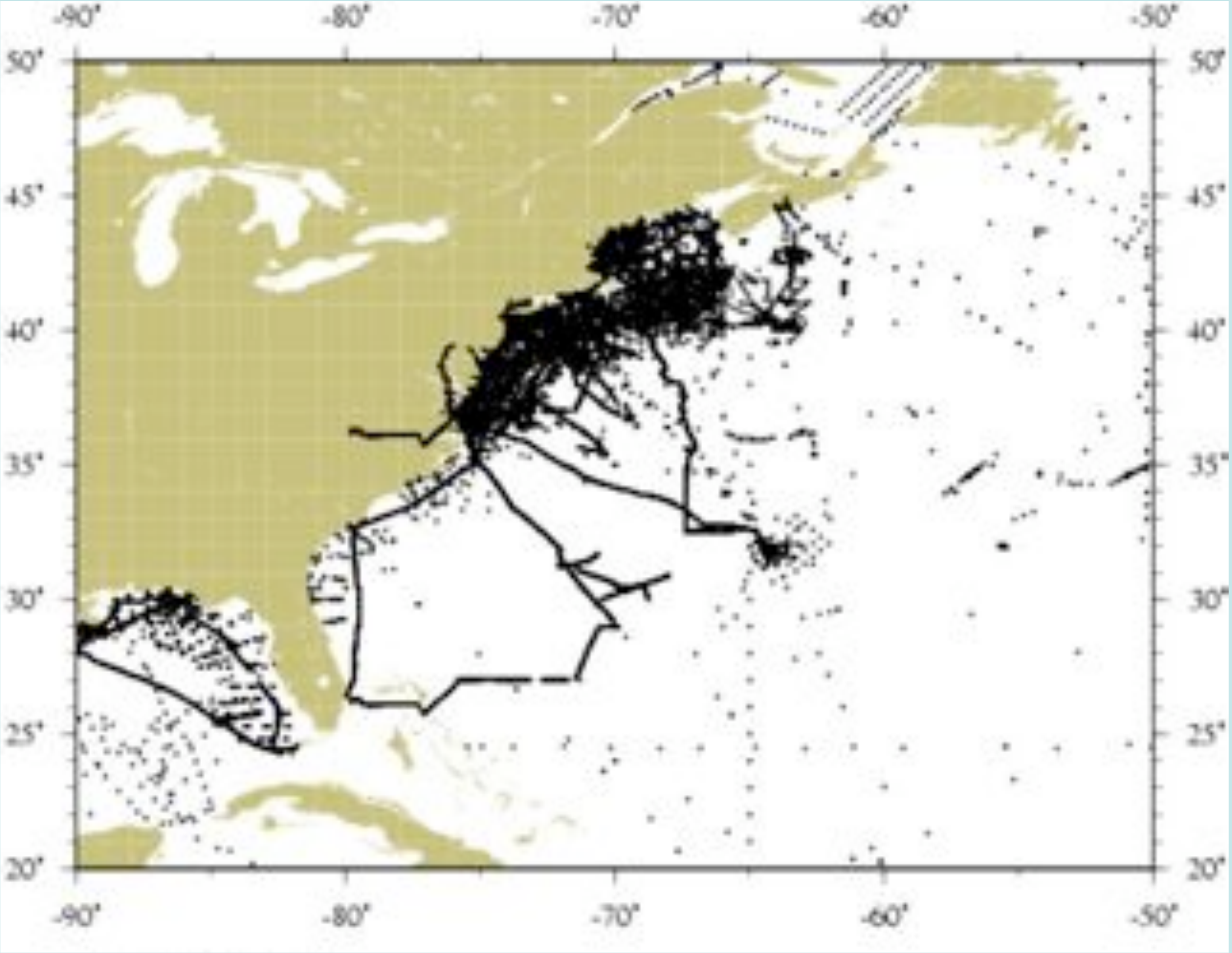
Najjar

pCO_2 (μatm)



Najjar

NODC chlorophyll-a profiles



• Disparity in data density between SAB and MAB

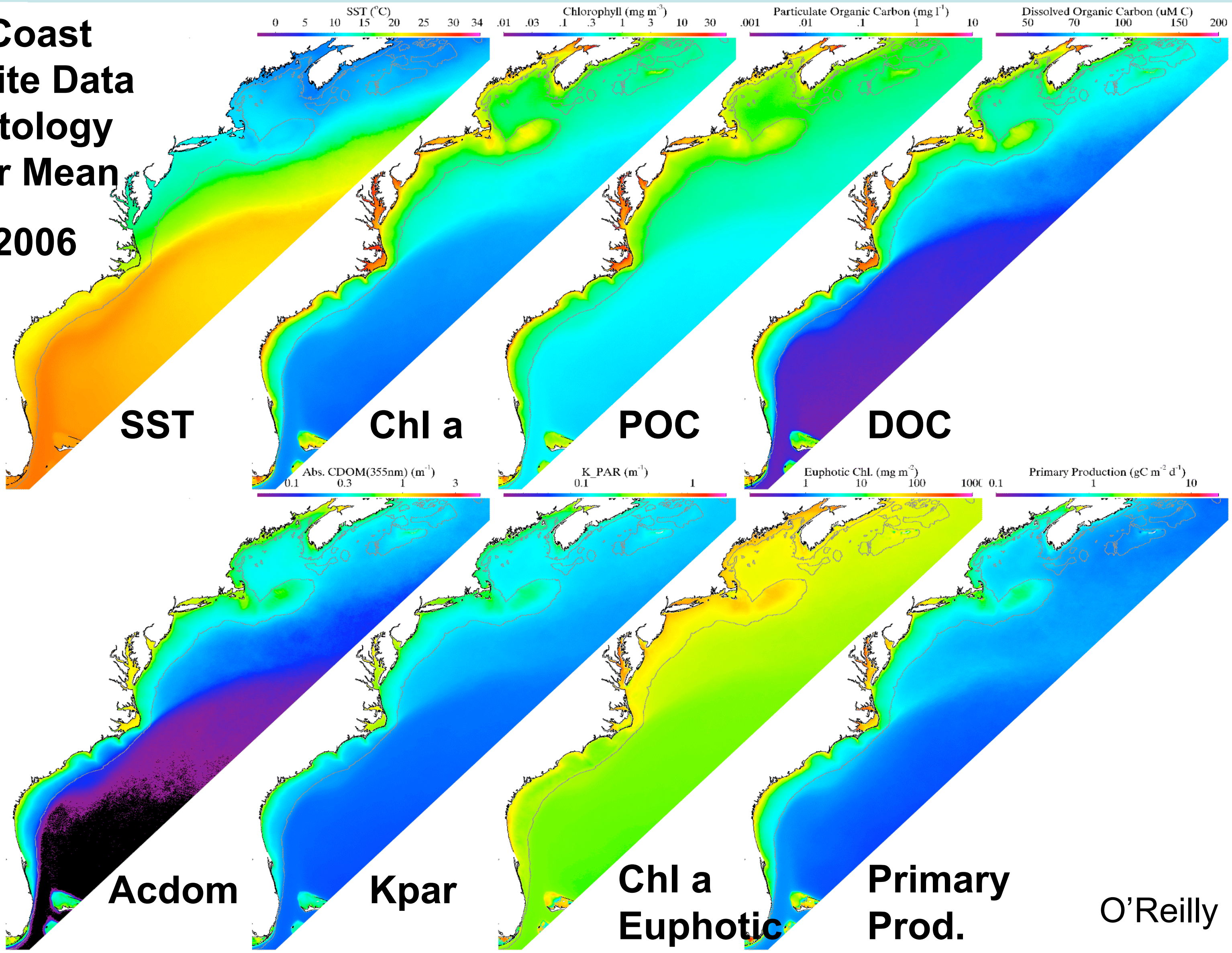
• More burden on satellite data in south

Hofmann

1b. Satellite data

East Coast Satellite Data Climatology 9-Year Mean

1998-2006

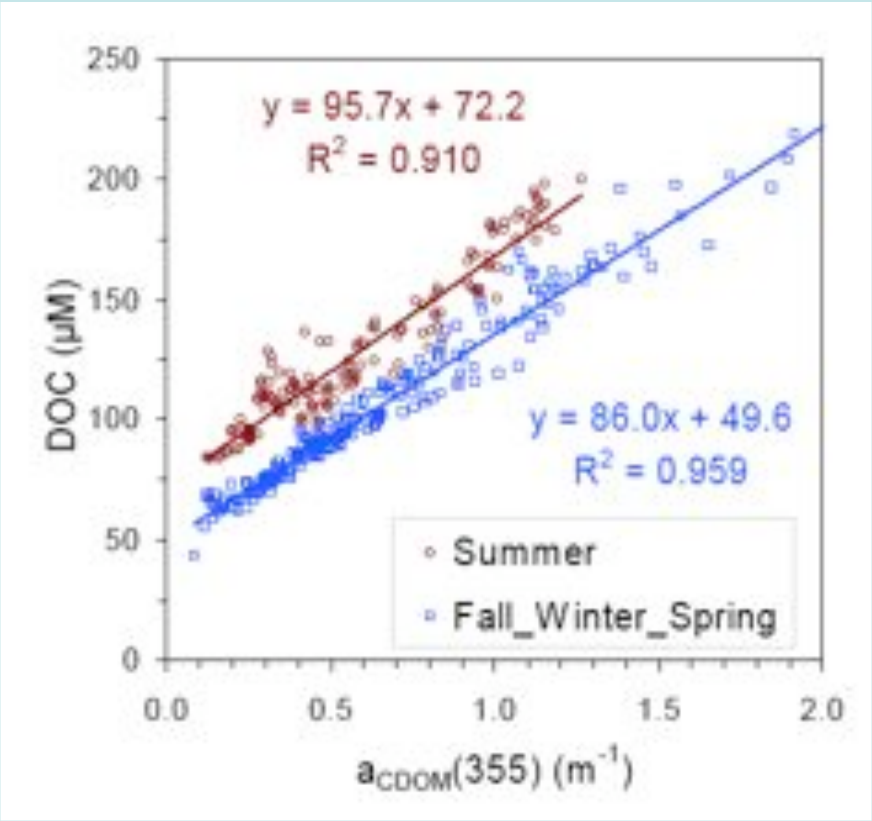


O'Reilly

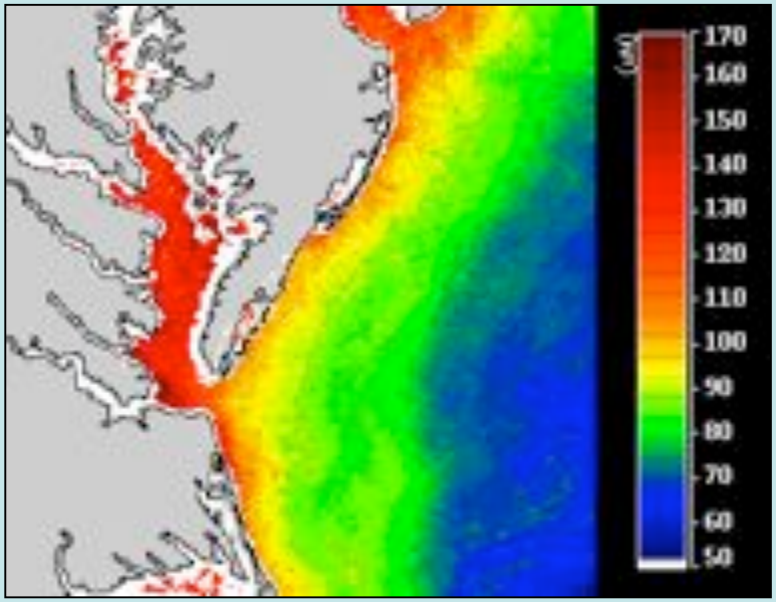
1c. Satellite+*in situ* data analyses

Chesapeake Bay Mouth and adjacent coastal waters

- in situ DOC, CDOM, POC, pigments, TSP
- satellite derived CDOM, DOC, POC algorithms



SeaWiFS Feb. 2005 - DOC (uM)



DOC Reservoir for Winter 2004 & 2005 = 1.13 ±0.036 Tg C

Mannino

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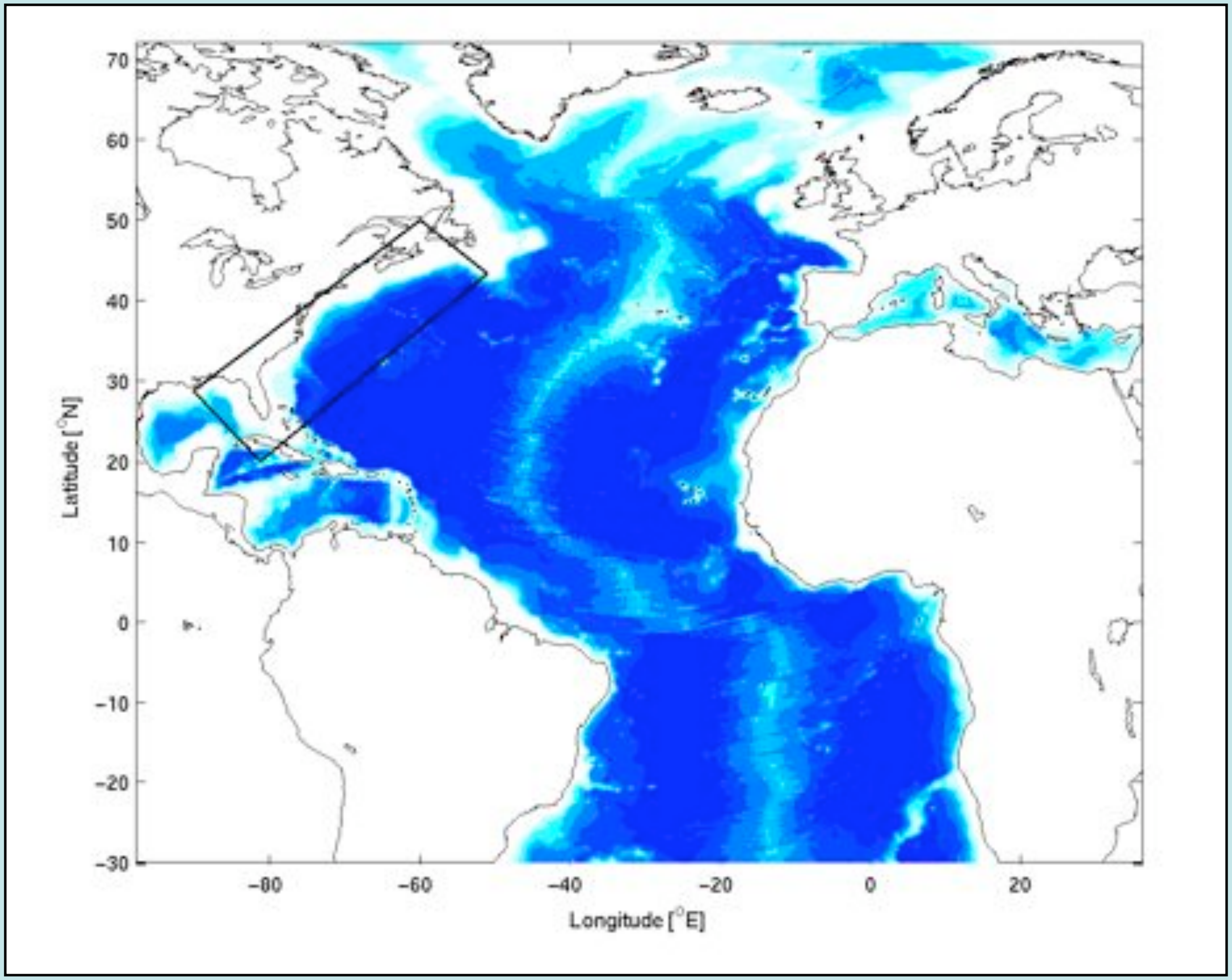
4. Process/Climate Studies

2. Coupled circulation-biogeochemical-DOM model

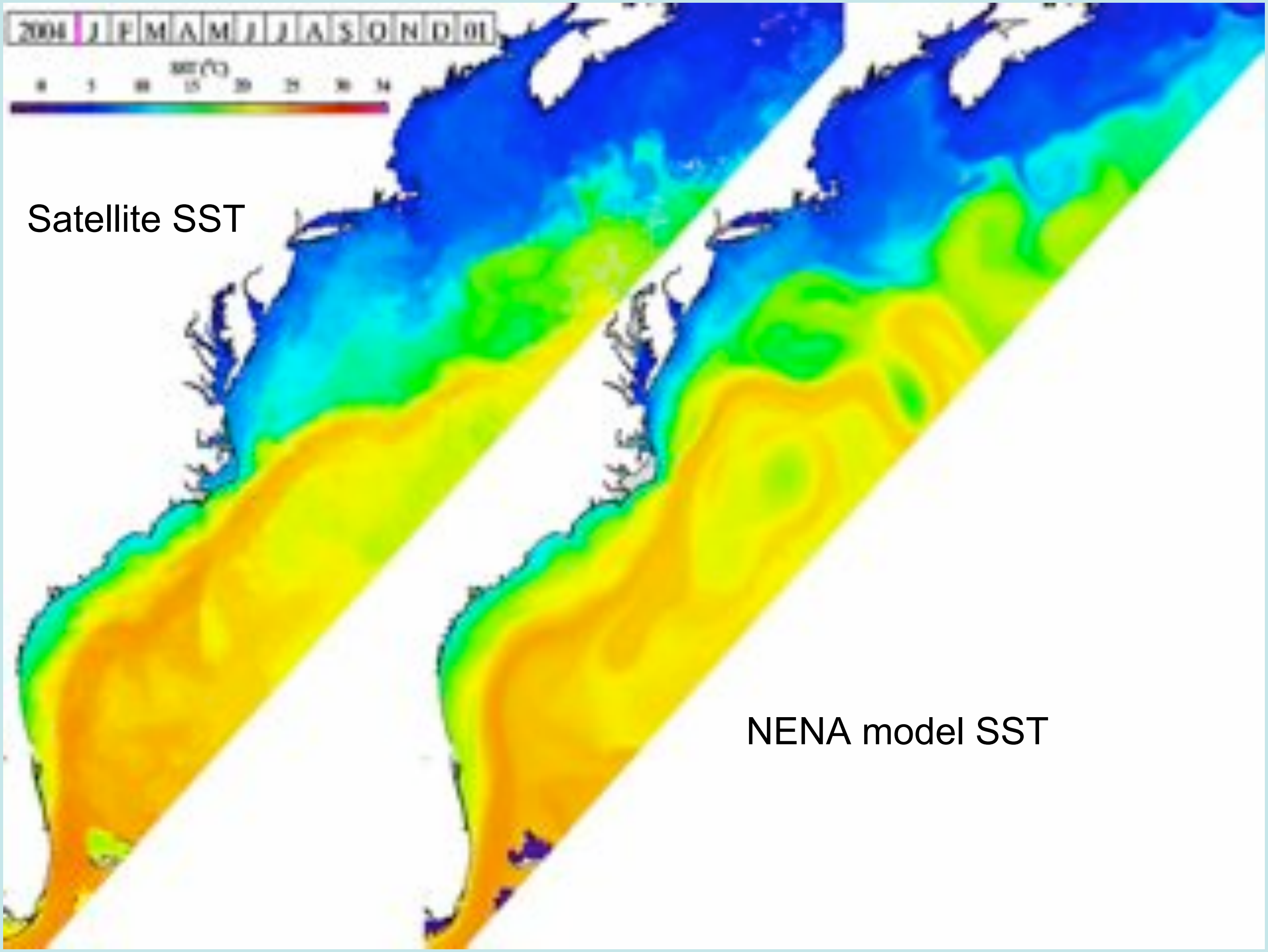
Northeast North American shelf model (NENA)



10 km horiz res
30 vertical levels
Nested in
HYCOM

Wilkin
Haidvogel
Fennel
Druon

SST satellite-model comparison for 2004

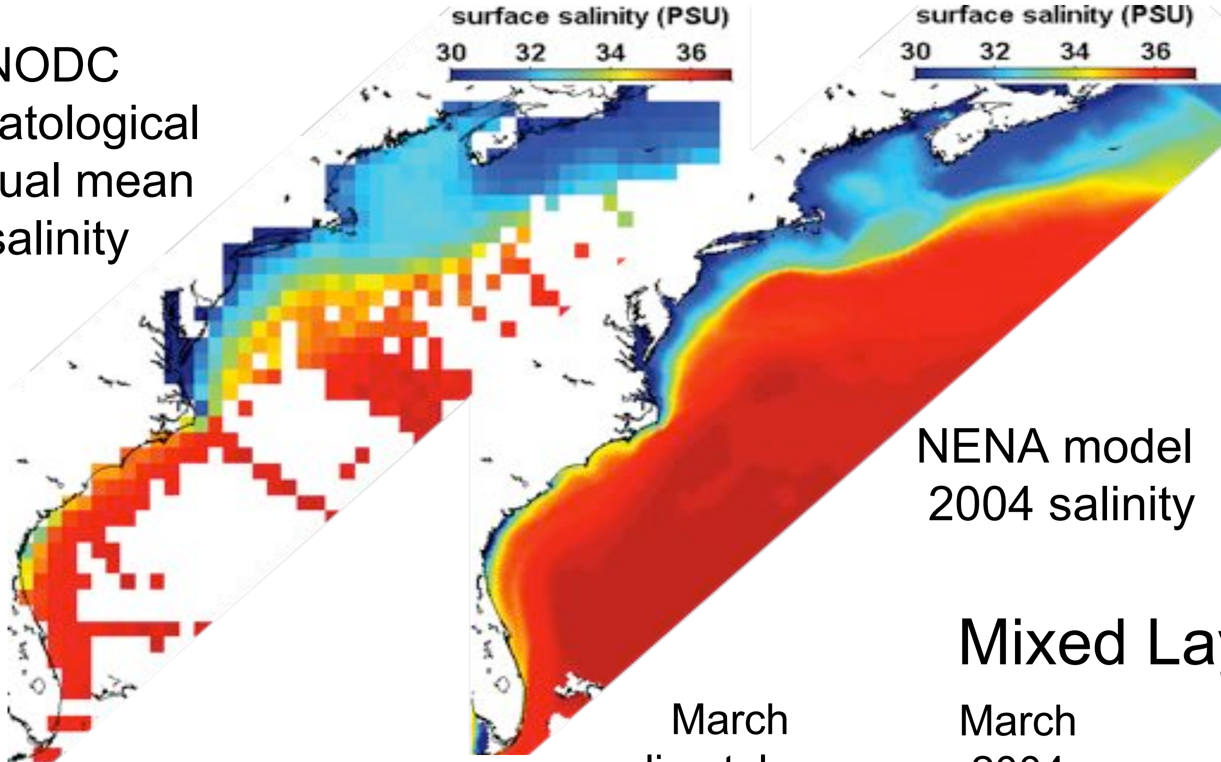


Wilkin

In situ NODC model-data comparisons

NODC climatological annual mean salinity

NENA model 2004 salinity



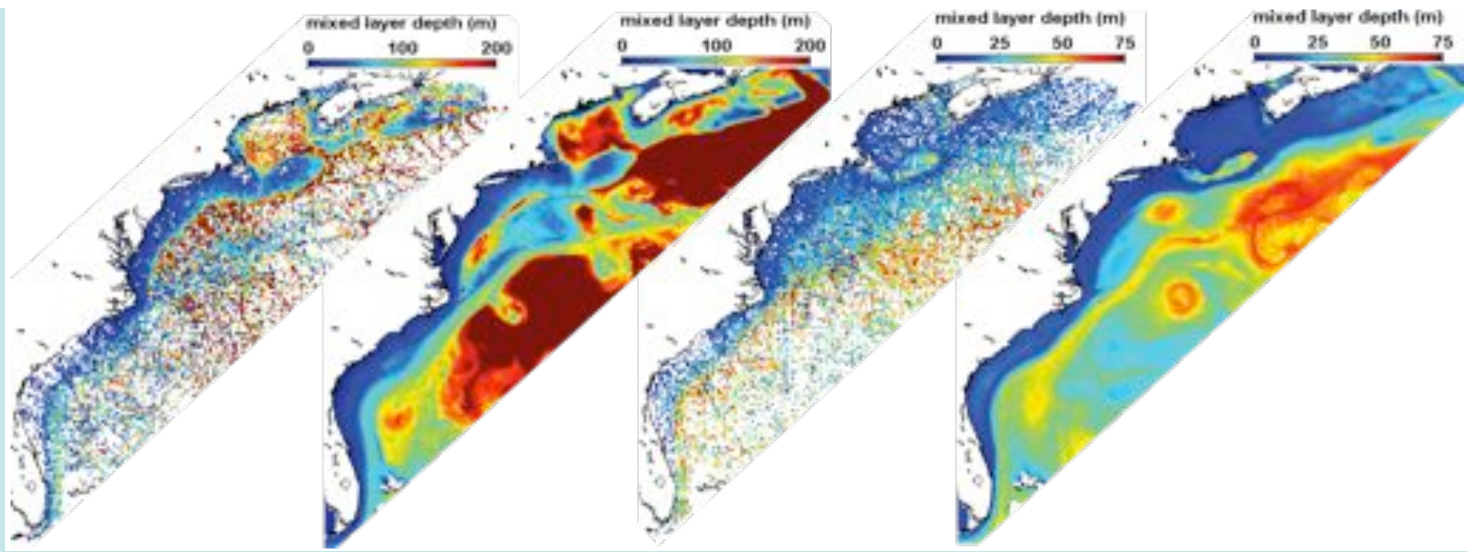
Mixed Layer Depths

March climatology data

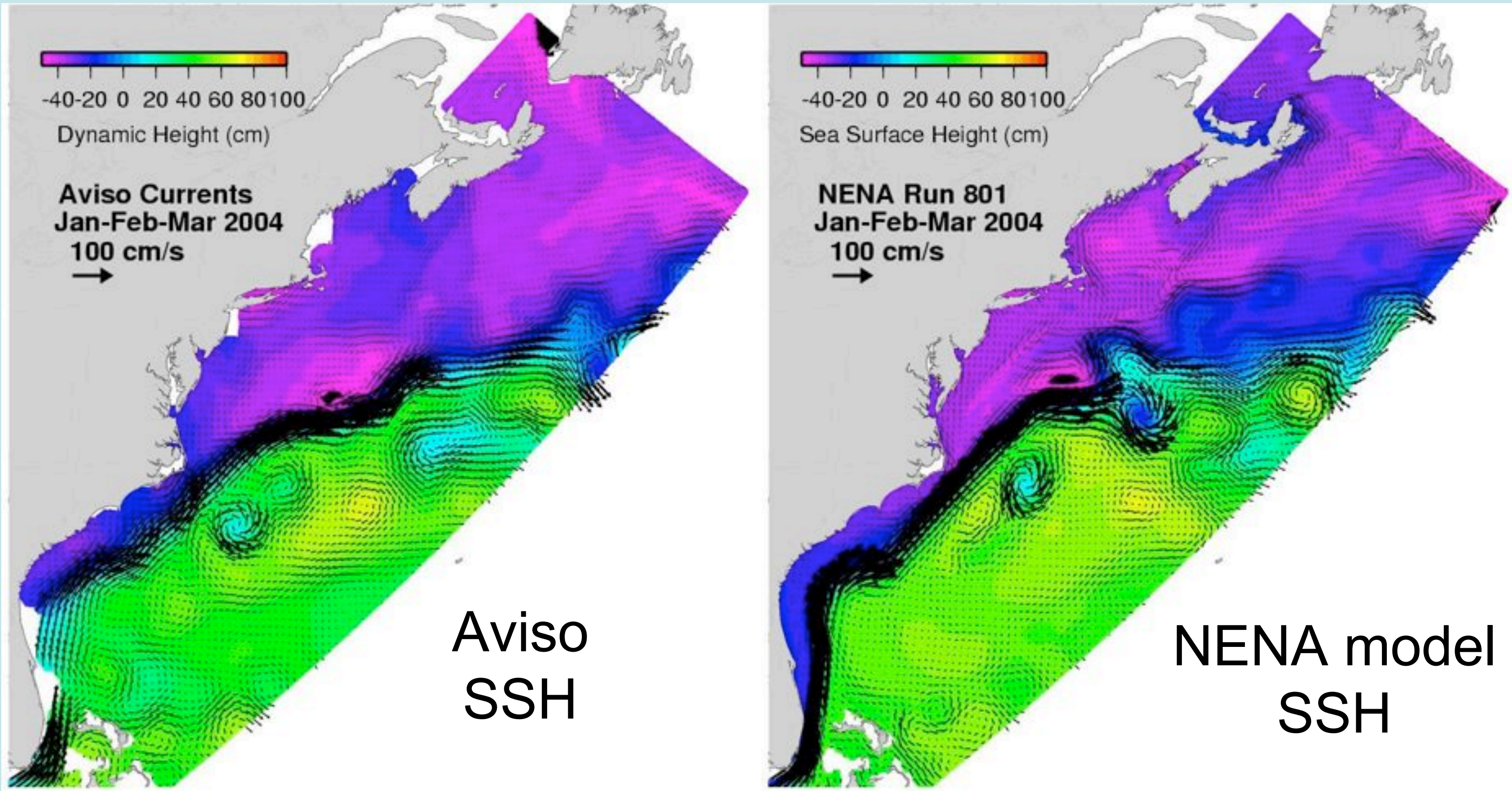
March 2004 model

September climatology data

September 2004 model

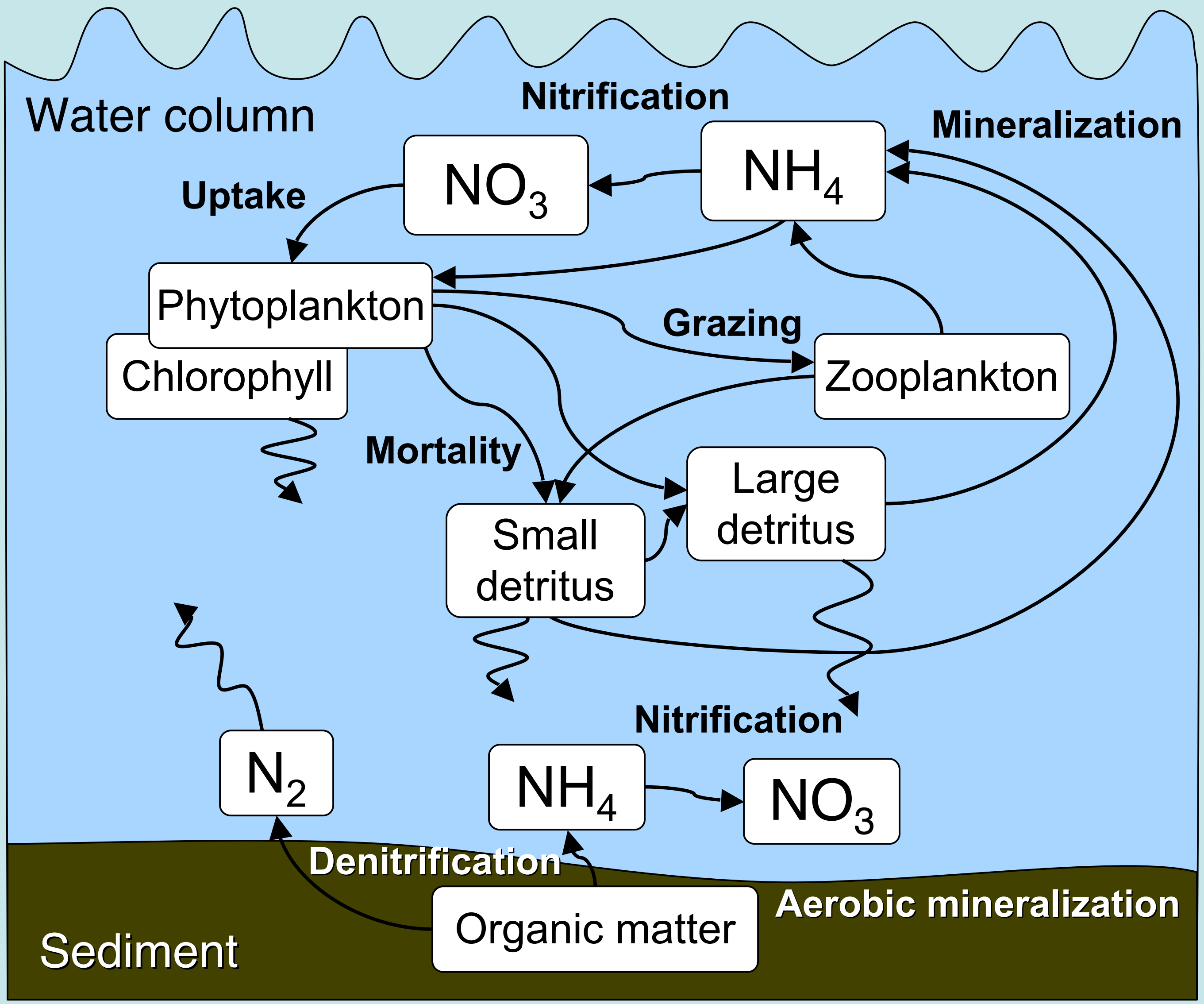


SSH & surface current comparison: NENA vs. Aviso*



*AVISO =Archiving, Validation and Interpretation of Satellite Oceanographic data
Absolute Dynamic Topography from all altimeter missions:
Jason-1,T/P, ENVISAT, GFO, ERS1/2, GEOSAT)

2b. Biogeochemical-circulation modeling

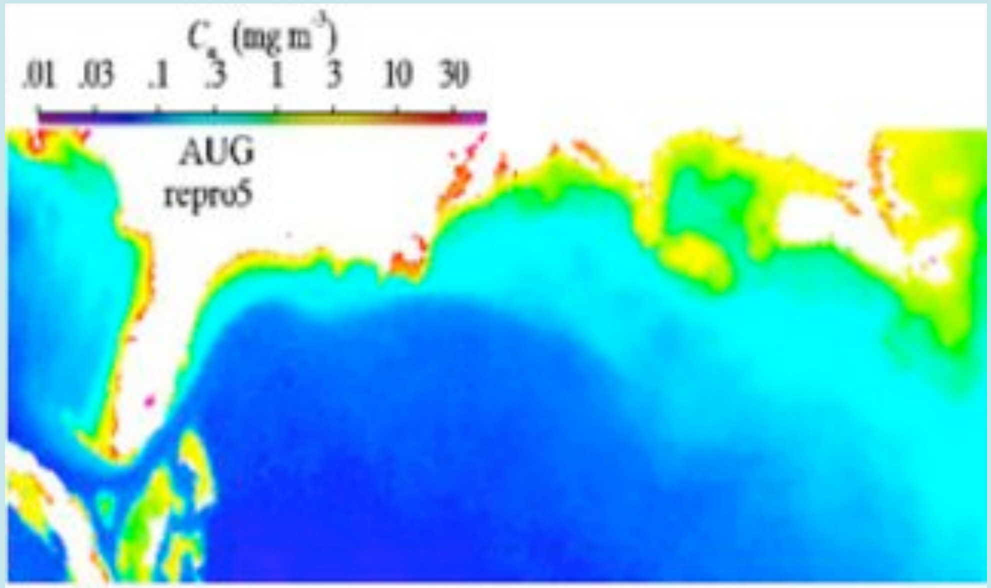


Fennel et al., 2006

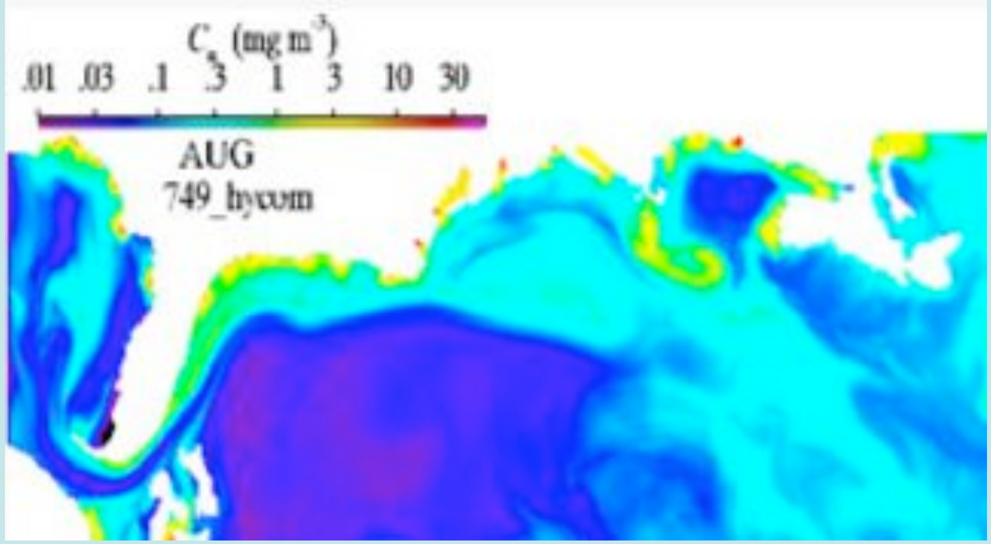
No DOM

Surface chlorophyll comparison: model vs. SeaWiFS

SeaWiFS



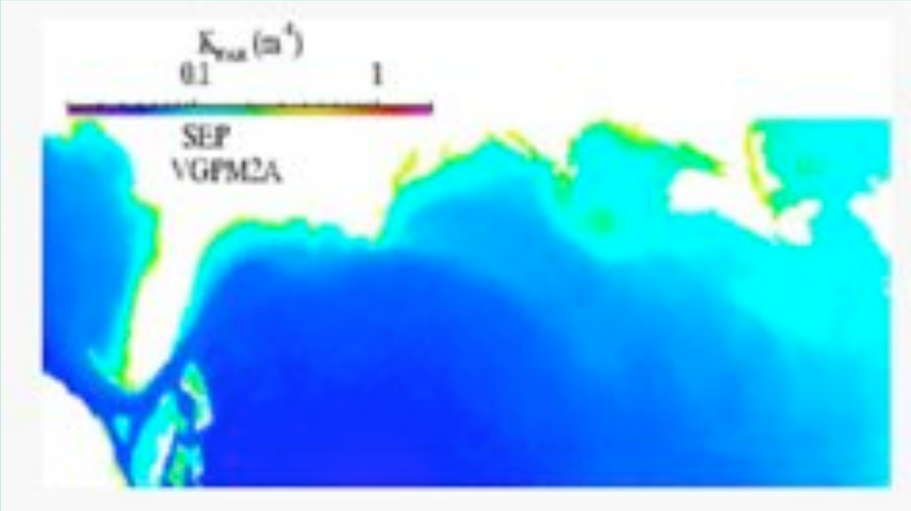
NENA
model

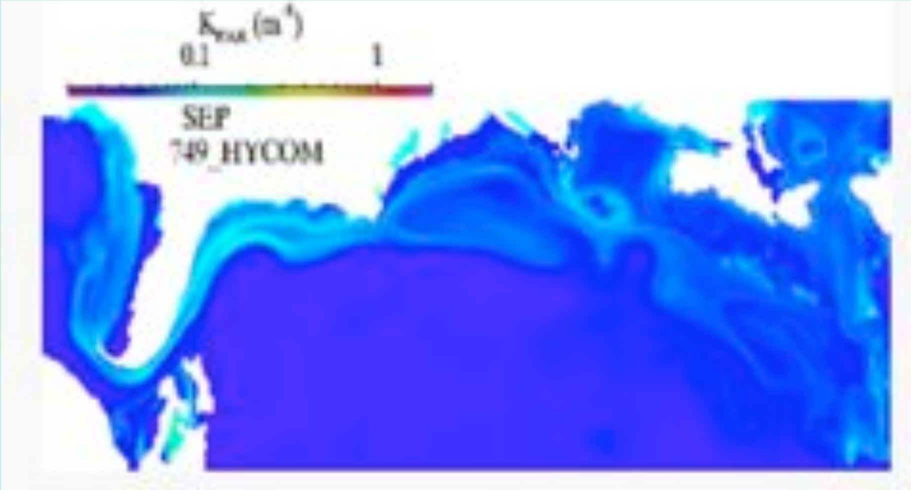


Fennel

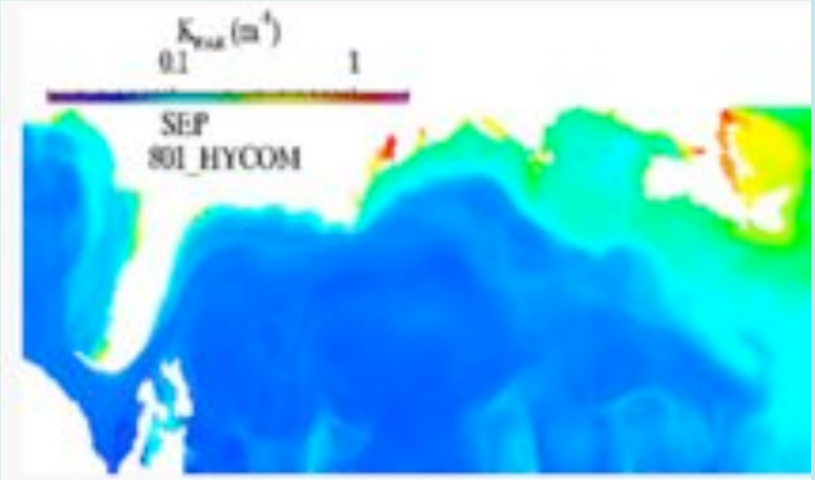
k_PAR: derived from VGPM2A vs. NENA

k_PAR
derived from
VGPM2a





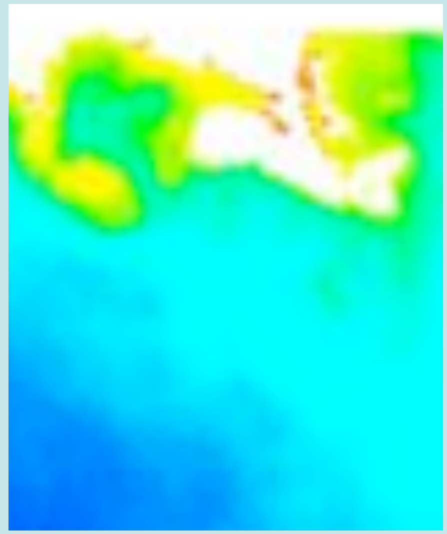
k_PAR: original simulation

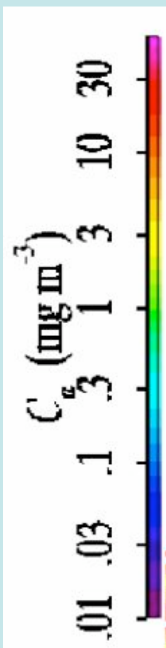


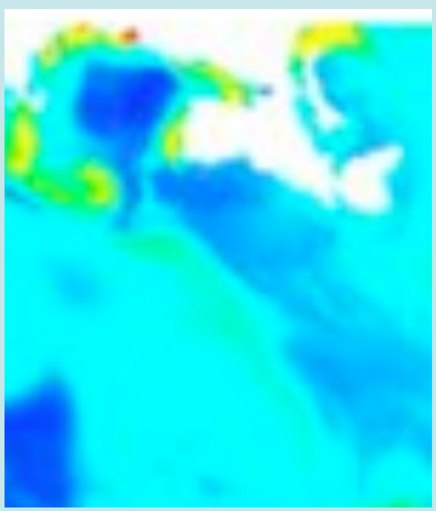
k_PAR: after addition of k_CDOM

chlorophyll comparison: with/without k_CDOM

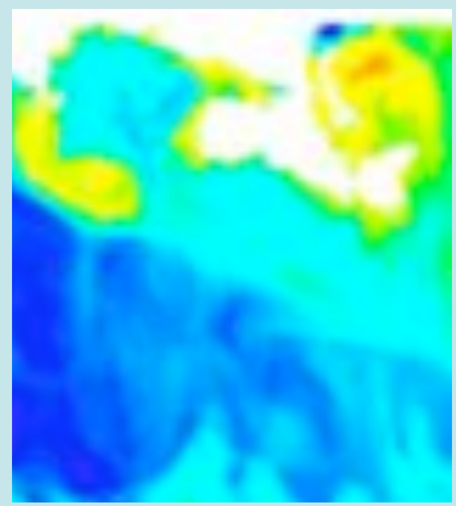
SeaWiFS
chlorophyll
September







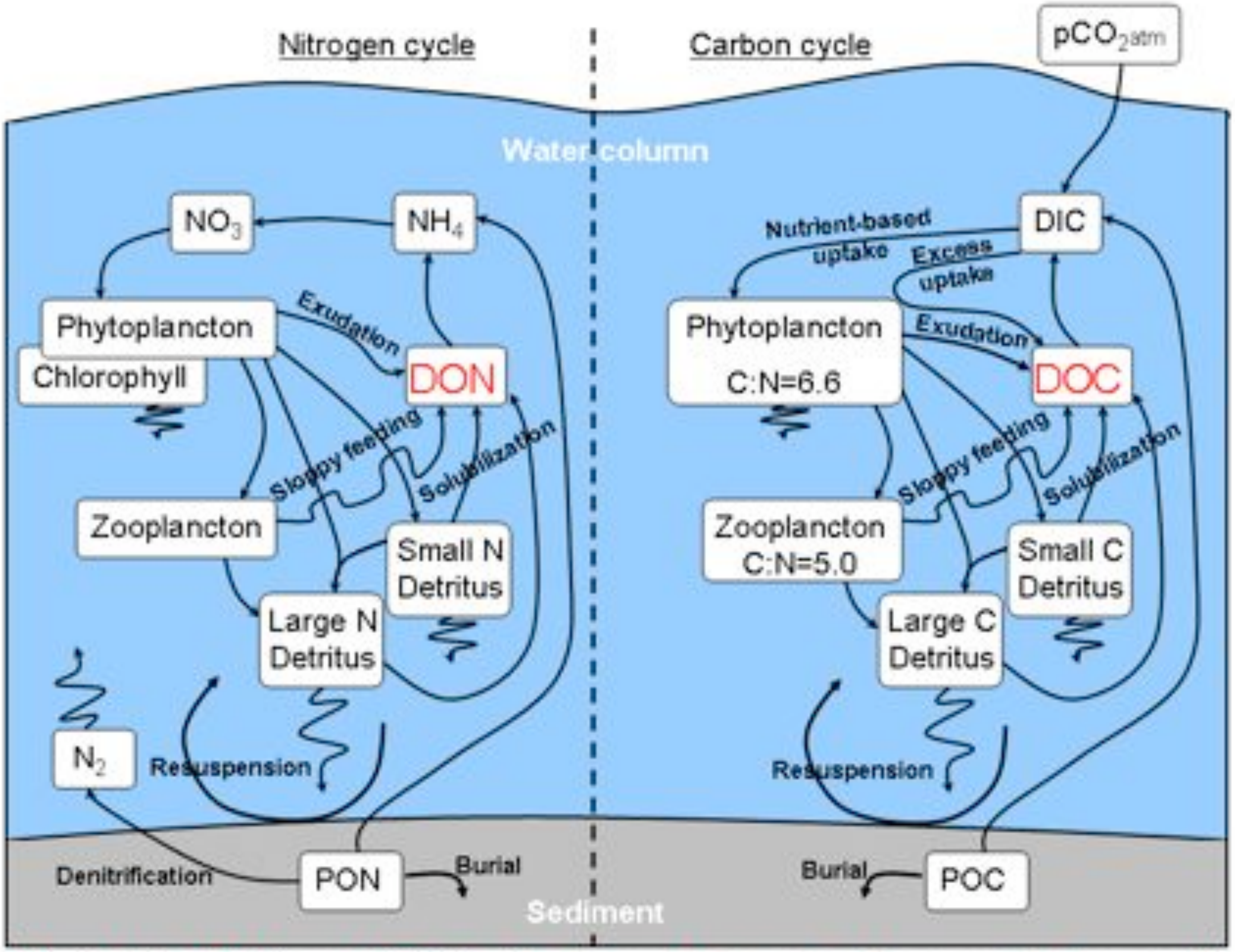
original simulation (no_k_CDOM)



after addition of k_CDOM

Fennel

2c. DOM modeling

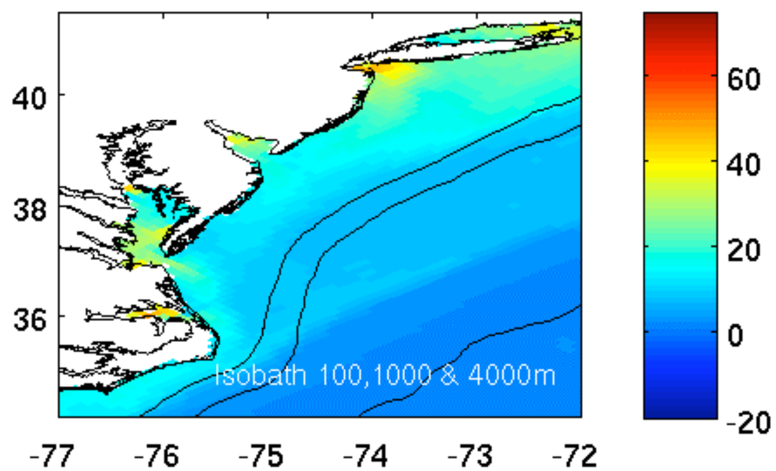


Semilabile DON and DOC with degradation rates from weeks to months

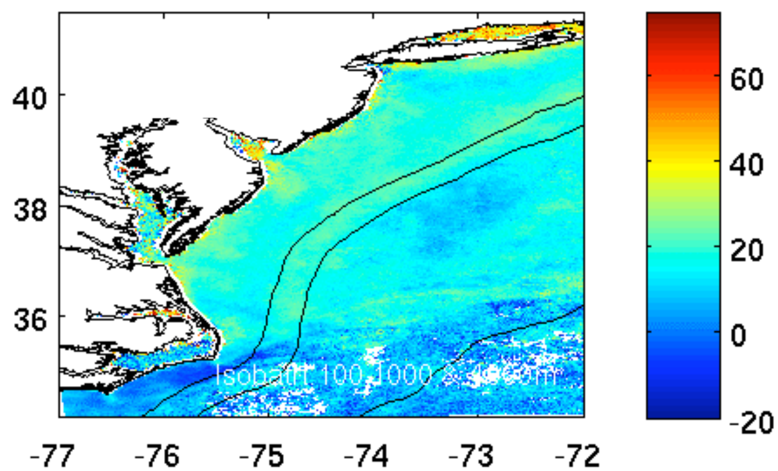
Druon

Semi-labile DOC
July 2004

Model semi-labile DOC



SeaWiFS-derived semi-labile DOC



ΔDOC=TotalDOC(July)-TotalDOC(March)

[Refractory+semi-labile] *[Refractory]*

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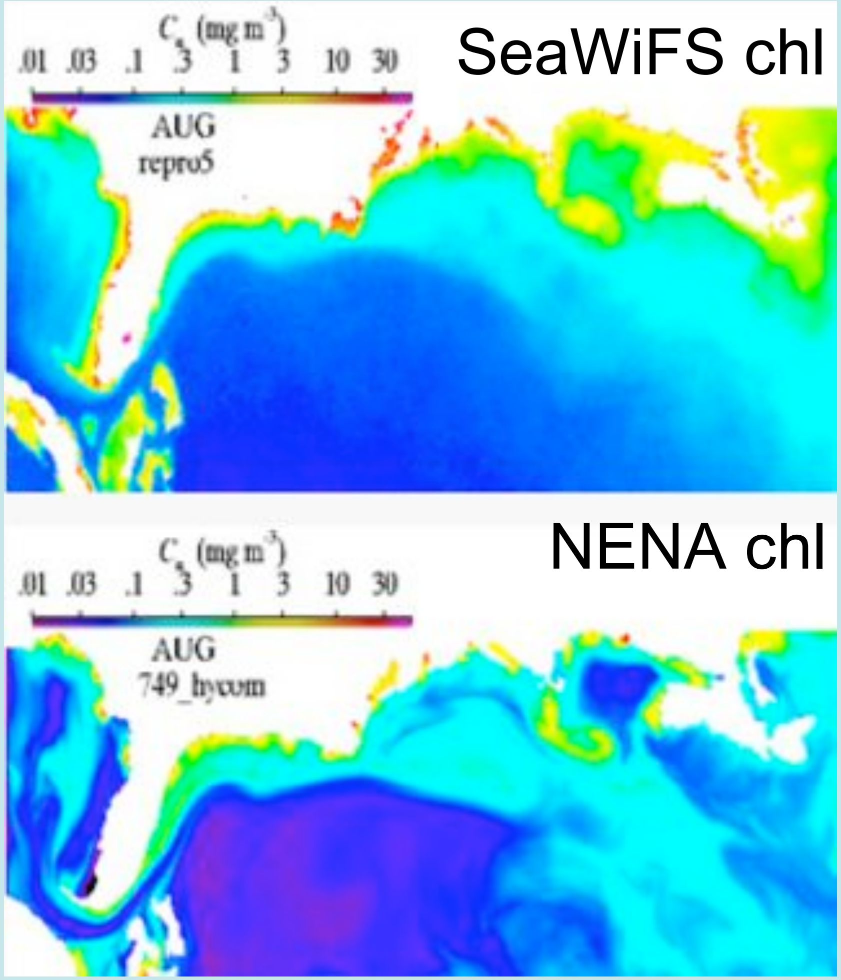
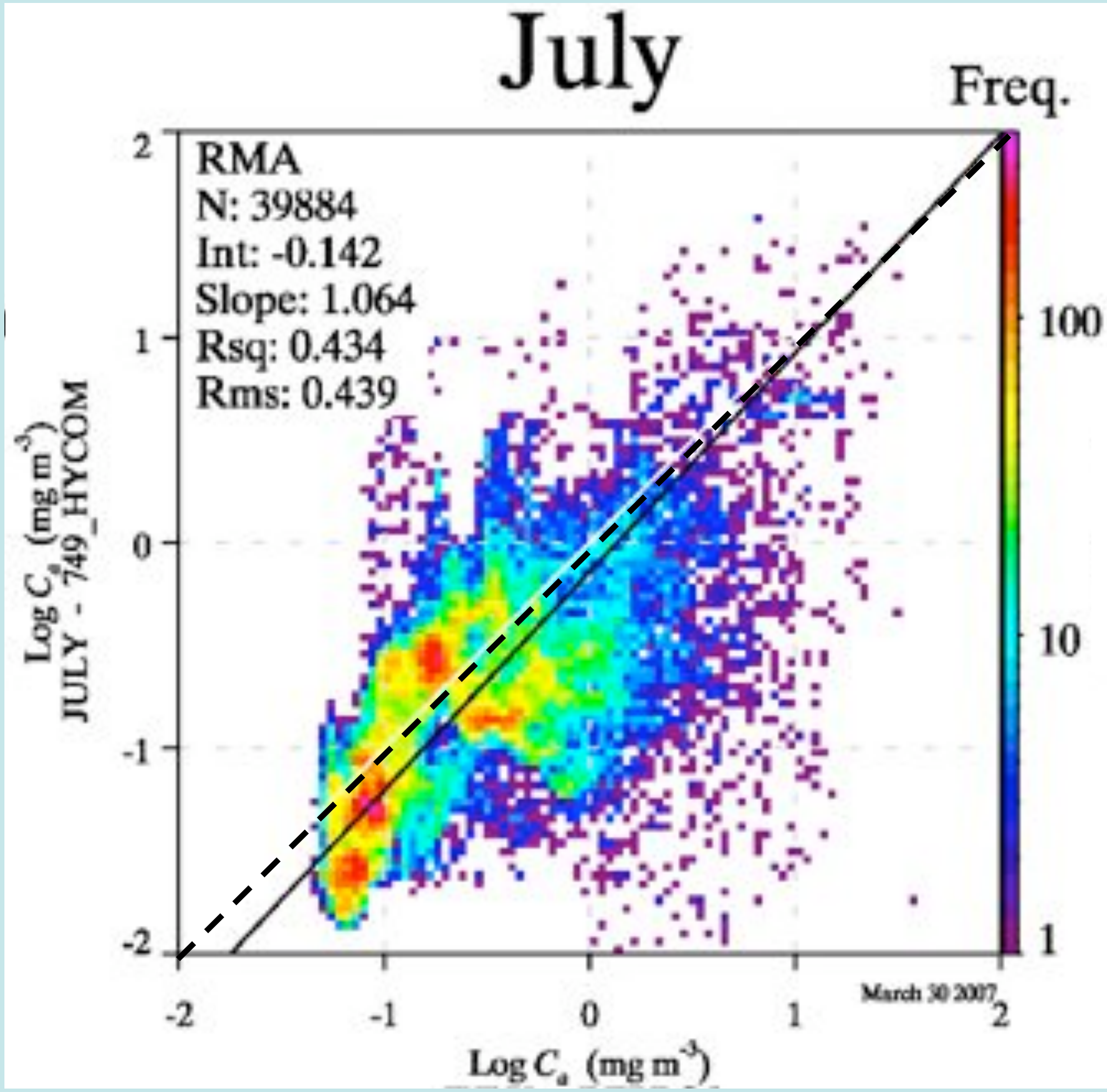
Qualitative model-data comparisons are not enough!



We need to assess model skill **quantitatively**

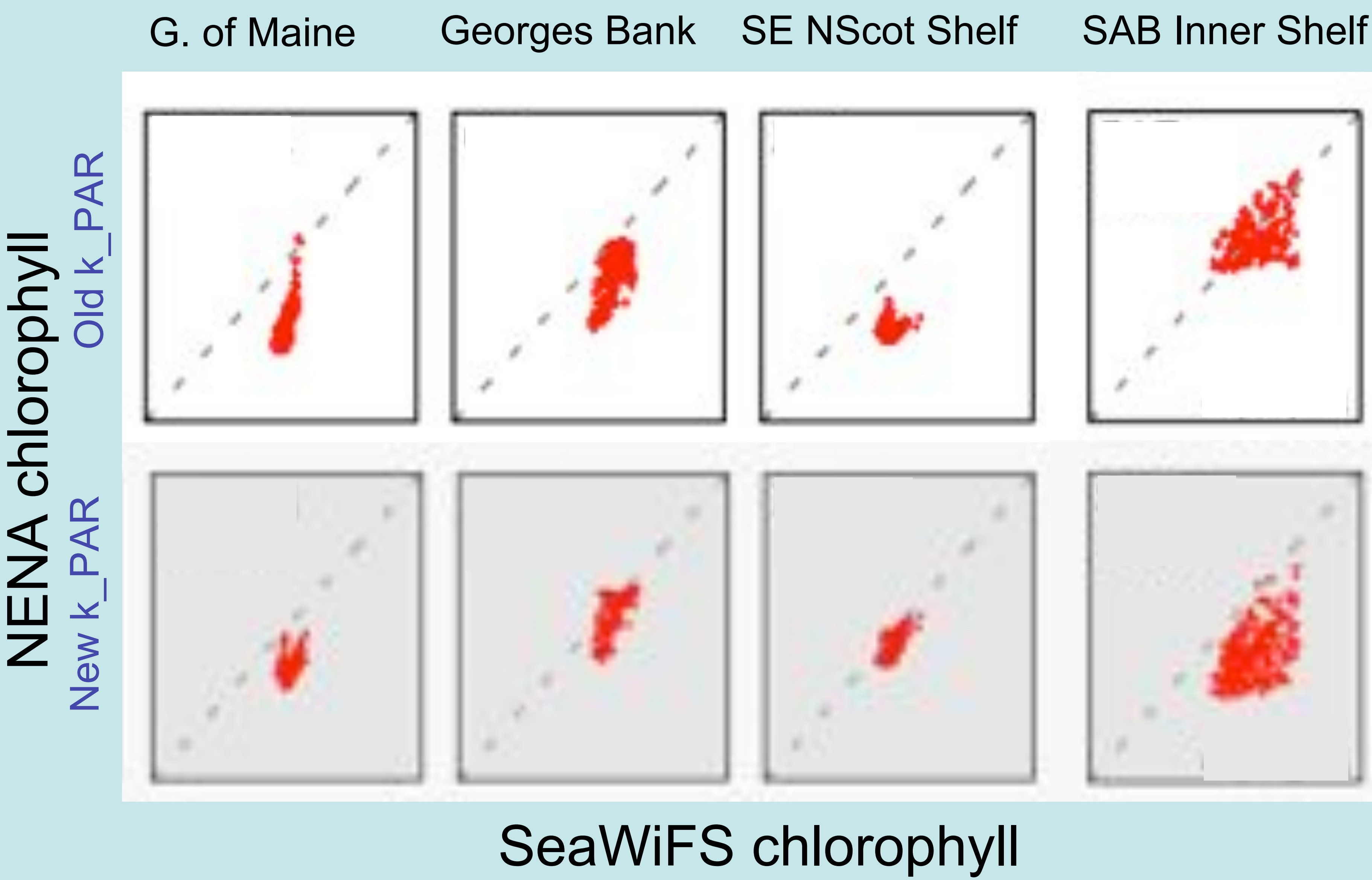
3. Quantitative Model Skill Assessment

NENA model chlorophyll

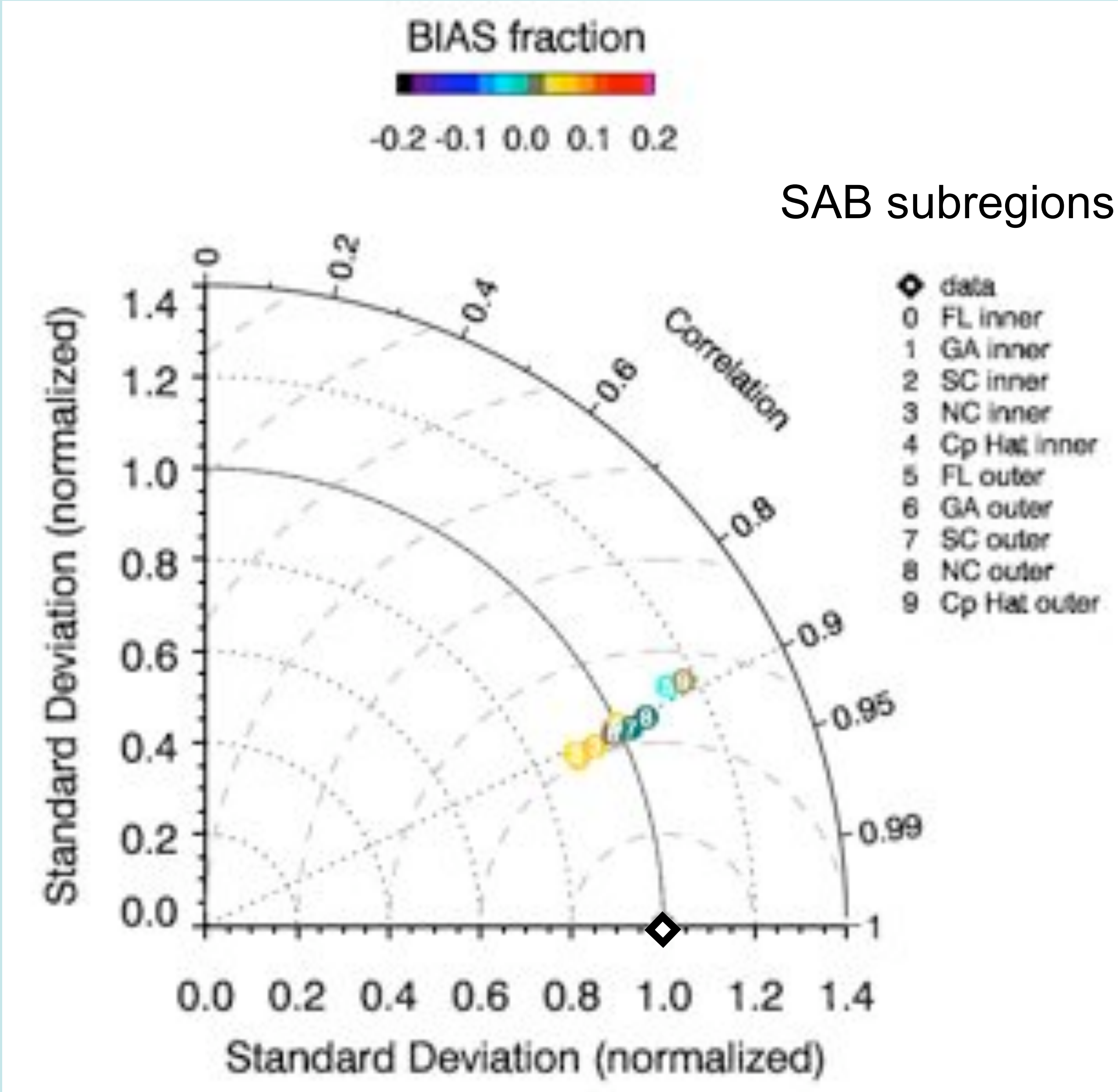


SeaWiFS chlorophyll

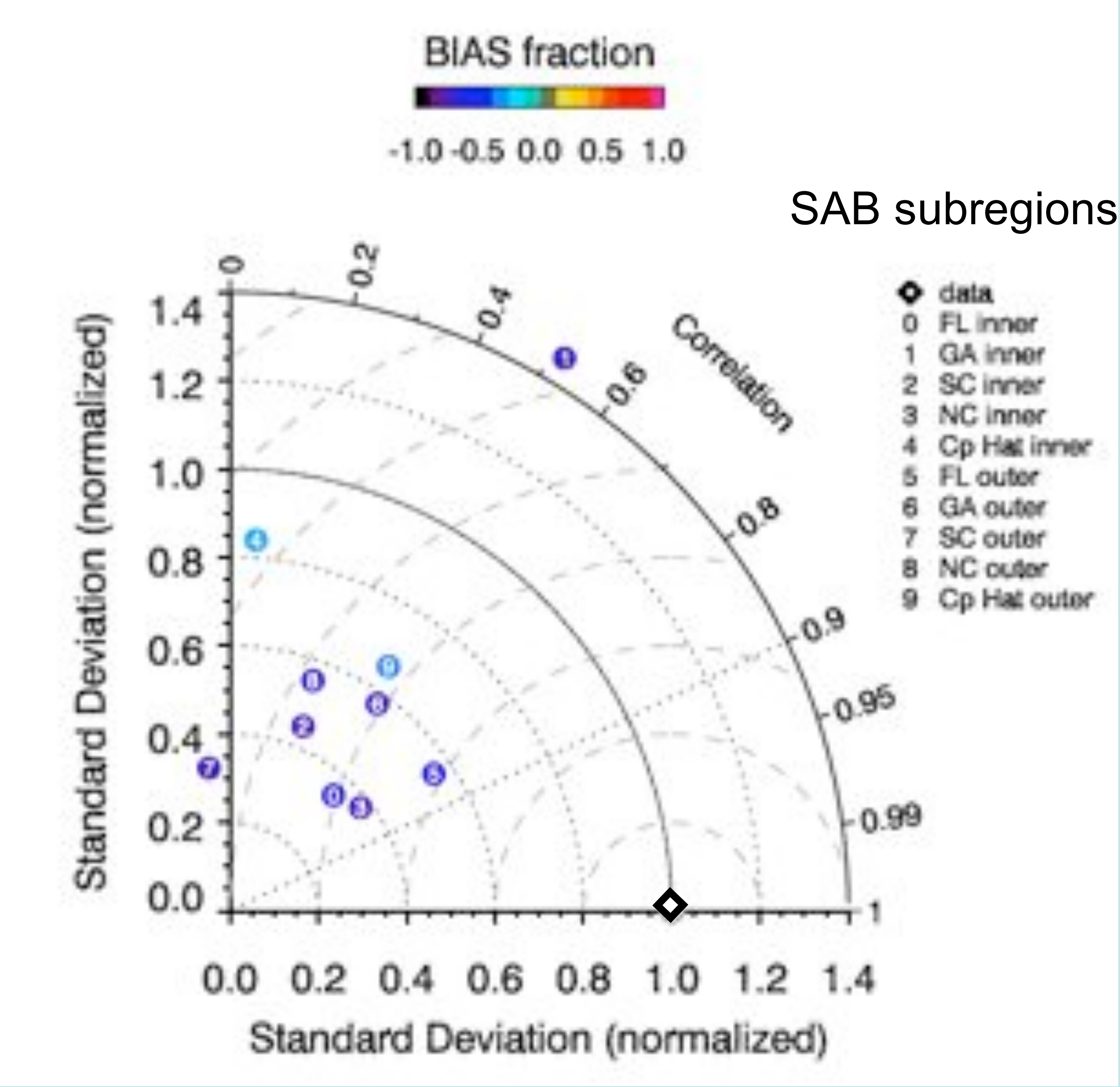
Quantitative comparison by region



Normalized Taylor diagram for SST

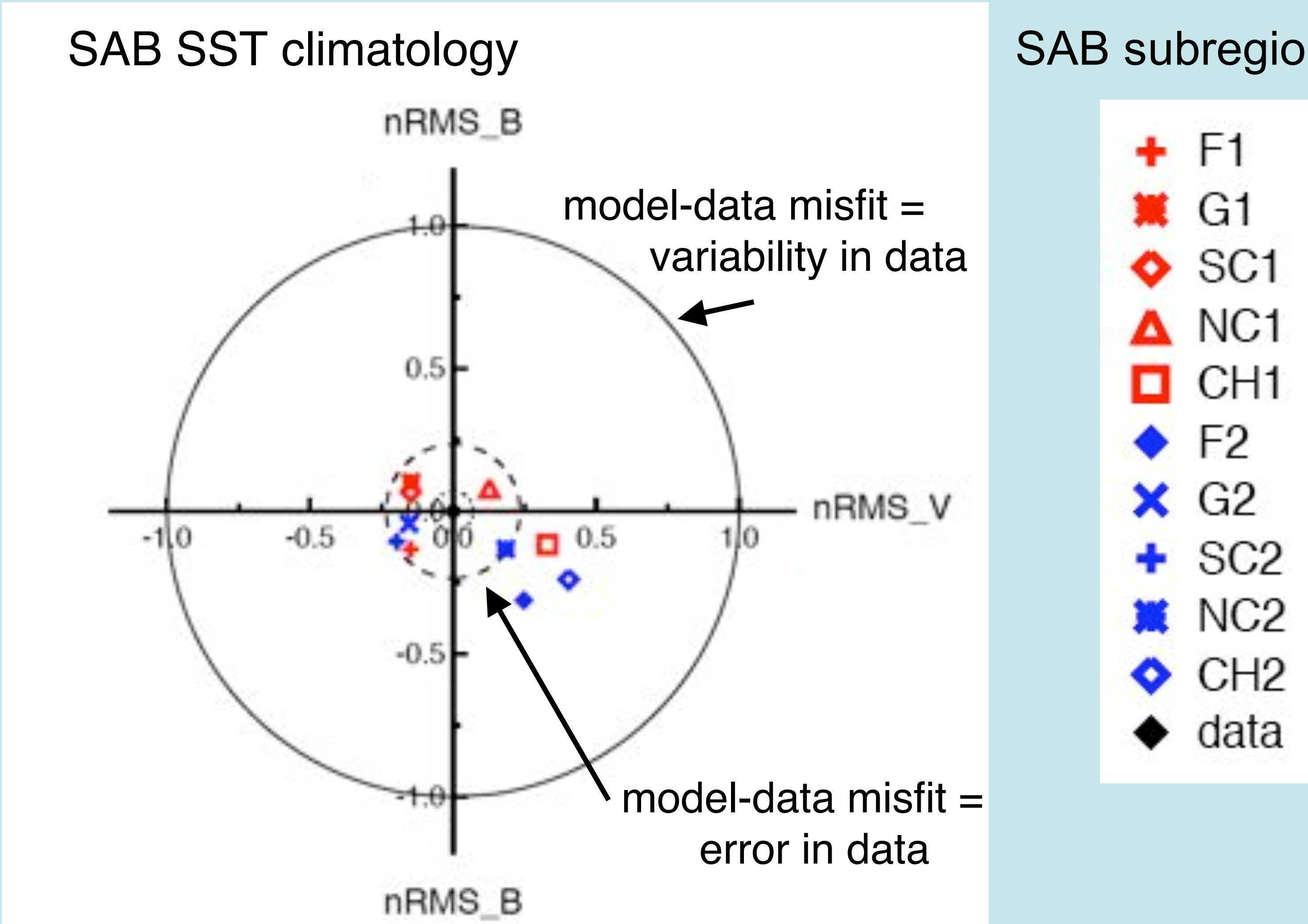


Normalized Taylor diagram for chl



Normalized Target diagram for SST

$RMS\_T^2 = RMS\_B^2 + RMS\_V^2$



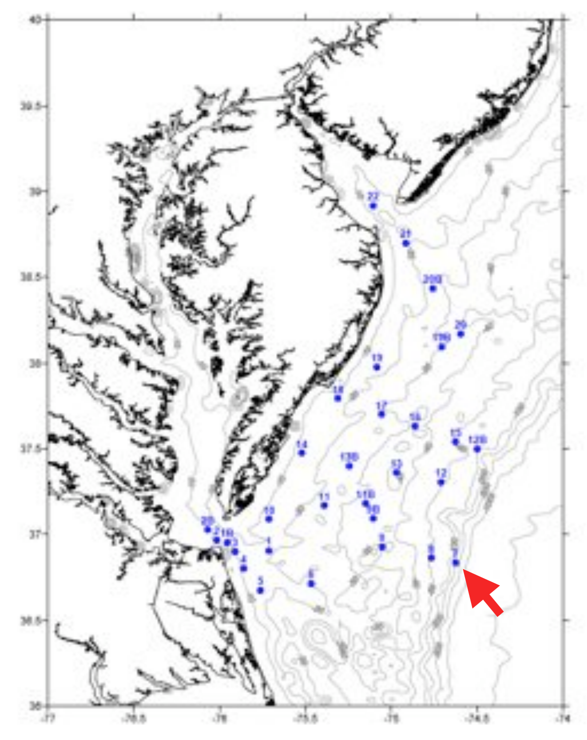
Data assimilation framework: 1D implementation

Approach:

1-D physics + horizontal advection terms from 3D model
Same biogeochemical model as is running in 3D;
reproduces 3D model results very well!
Assimilate ocean color or in situ data (variational adjoint method)
for optimization of biogeochemical parameters
(e.g. max. growth rate; C:chl ratio)
Runs quickly!

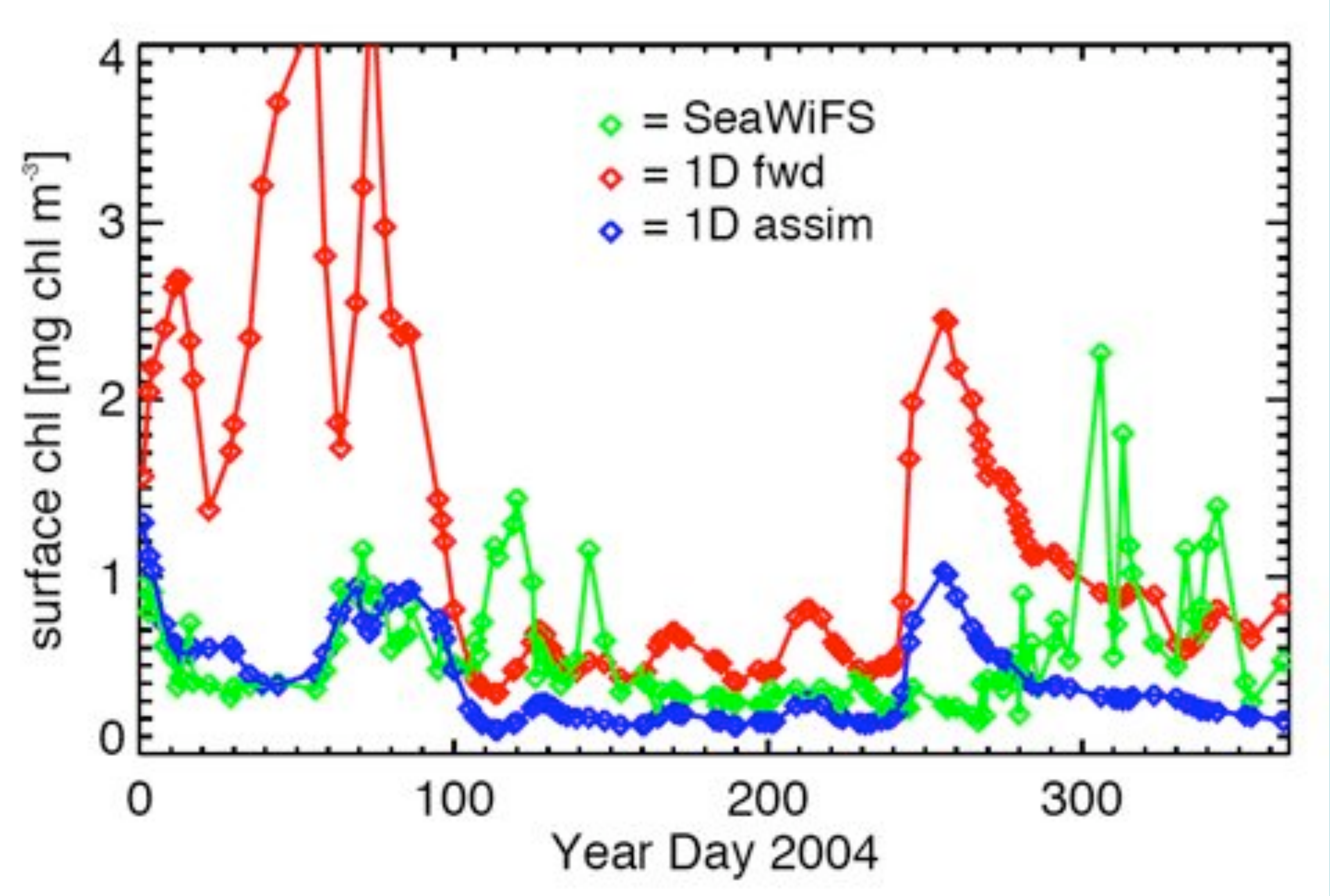
Goals:

Test new parameterizations and formulations
Perform parameter sensitivity/optimization
analyses
Quantitatively assess optimal model-data fit
via cost function



Friedrichs, Hofmann

SeaWiFS Assimilation Results



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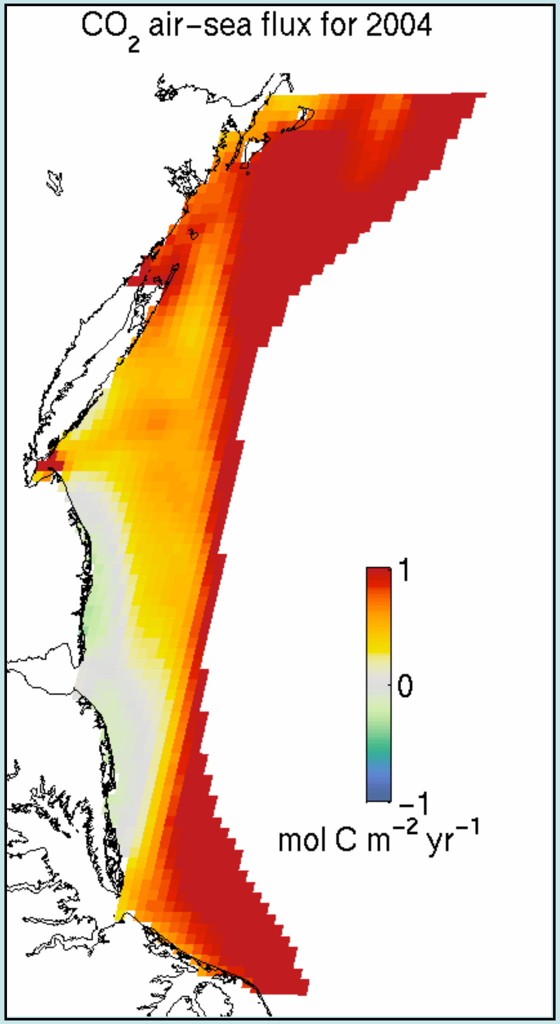
4. Process Studies



Fennel

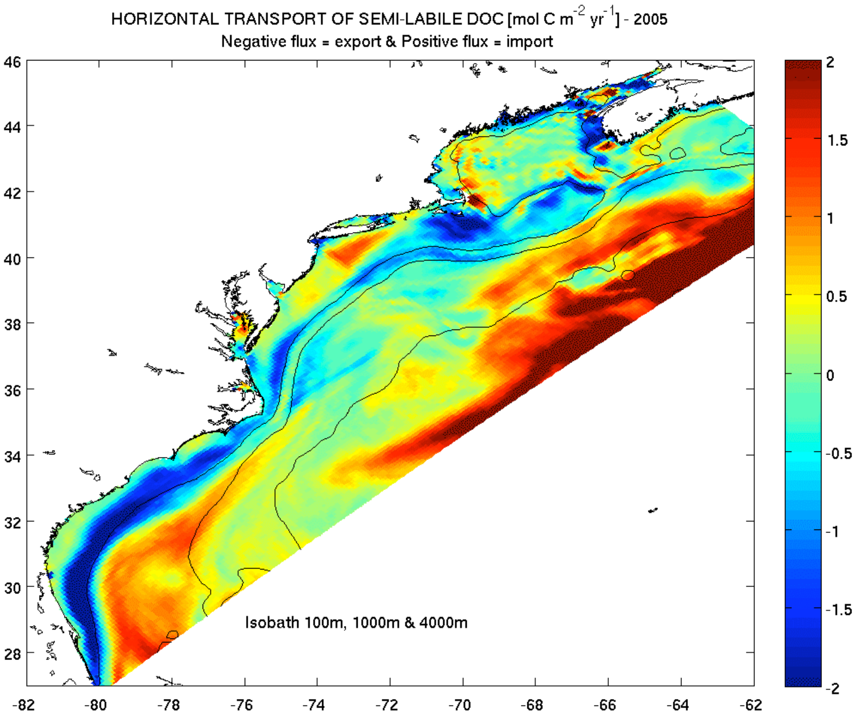
Simulated annual air-sea flux of CO_2
Explicit inorganic carbon cycling

Positive values indicate uptake by ocean

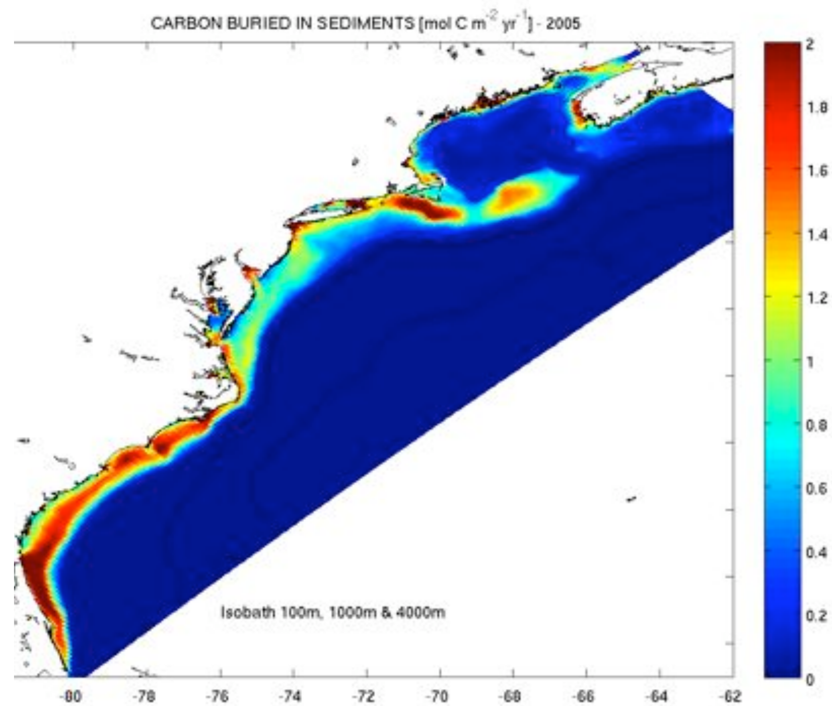
Outer Mid-Atlantic Bight continental shelf is a sink for atmospheric CO_2

No net uptake off NJ due to outgassing during summer from upwelling

Semi-labile DOC export



POC burial



Simulated **semi-labile DOC net horizontal fluxes** for 2005 (mol C.m-2.yr-1). Negative values correspond to areas of production and export, and positive values to areas of import.

Simulated **POC burial** for 2005 (mol C.m-2.yr-1).

Climate Studies

How will coastal regions respond to climate change, and what are the feedbacks on the carbon cycle?

Force the BGC-circulation model with climate change scenarios from a Regional Climate Model (RegCM3):

Present day scenario: 1980-2000

100 years later scenario: 2080-2100

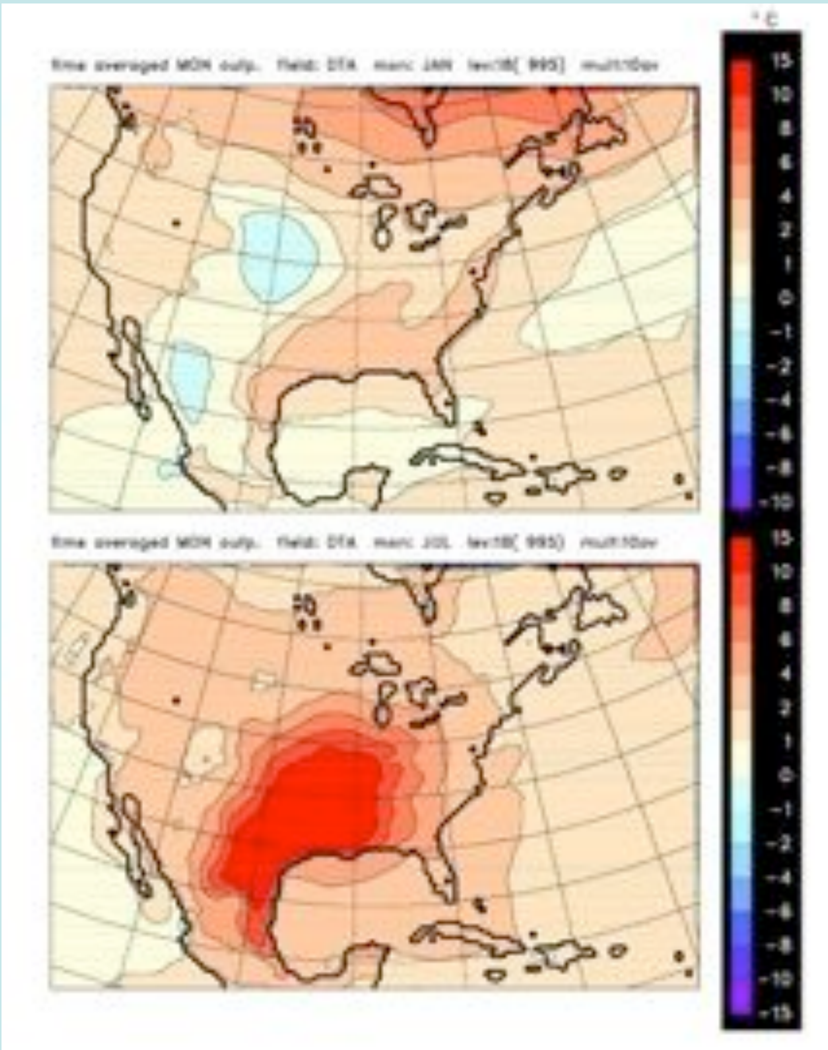
Pollard, Najjar

Changes over 21st century

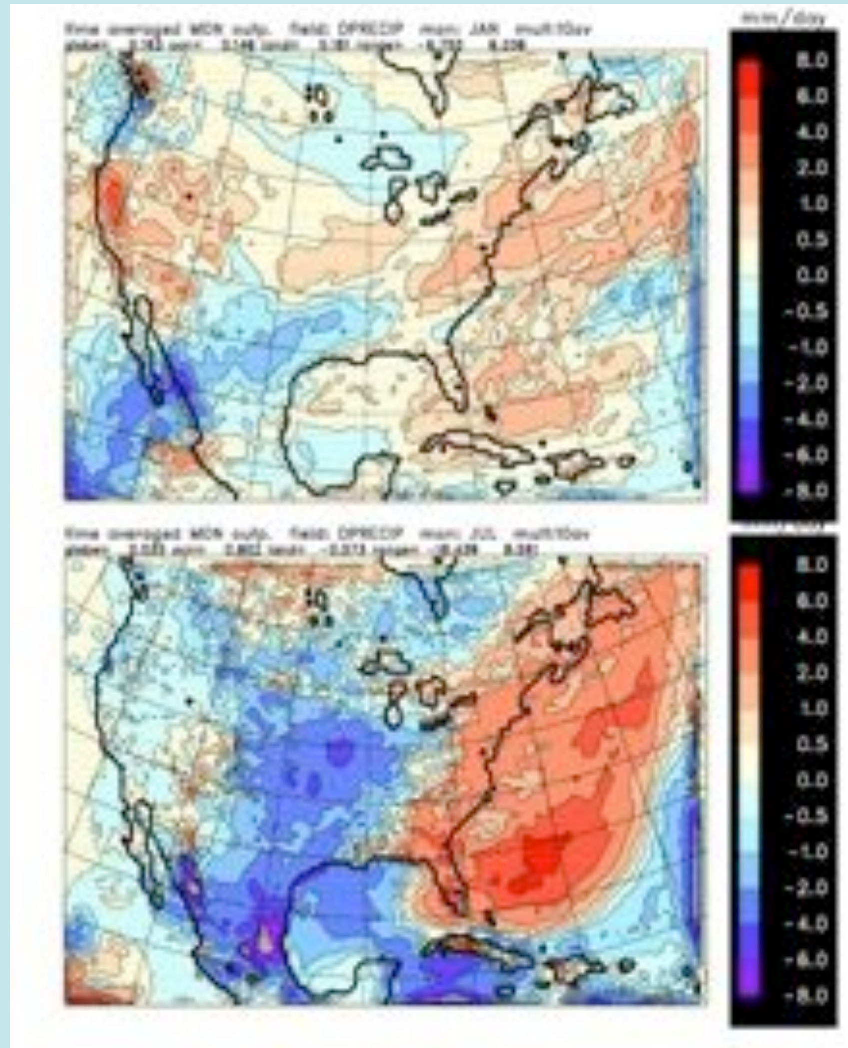
January

July

ΔTemperature [15 to -15ºC]



ΔPrecipitation [8 to -8 mm/d]



Summary

U.S. ECoS Goal: To increase our understanding of carbon cycling in U.S. east coast continental shelf waters

- Requires modeling effort coupled with satellite and *in situ* data analysis
- Requires observationalists and modelers to work together
- Requires quantitative skill assessment
- Ongoing effort