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

Personnel - 14 science investigators, 10 institutions

Breadth of expertise - modelers and observationalists
Multiple subgroups working in parallel with an overall focus on model-data comparisons

Parallelism coupled with frequent communication

Builds diversity
Hofmann et al. (2008)
Circulation Model

Northeast North American shelf model (NENA)

Based on ROMS
10 km horizontal resolution
30 vertical levels
Nested in HYCOM

Haidvogel and Wilkin
Schematic of Biogeochemical Model

N shown here, but also includes C and O$_2$

Fennel et al. (2006)

Semi-labile DOM recently added
Fifty-two subregions

Profiles inshore of Sargasso:
- 460K T
- 110K S
- 20K O$_2$

(2005 WOD)

Hofmann et al. (2008)
MAB Sea-to-air oxygen flux

Air-sea Oxygen Flux (mol/m²/day)

Day

Inner Shelf
Mid-Shelf
Outer Shelf
Slope
Combined

Parameterization
1D modeling, Data assimilation

Circulation Model
Biogeochemical Model

Combined Model

Evaluation
Statistics, Plots

Budgets
Climate Scenarios
DOC & CDOM field measurements

From cruises in Southern MAB, including lower Chesapeake Bay.

Seasonal algorithms needed. Offset due to net community production of DOC and bleaching from spring to summer.
Space-based DOC estimates

DOC concentration (μM)
Primary production

\(^{14}\text{C}\)-based from MARMAP program

Satellite-based (VGPM2A)

Mean 1998 - 2005
Satellite Data Climatologies

East Coast Satellite Data Climatology 9-Year Mean 1998-2006

SST
Chl a
POC
DOC
Acdom
Kpar
Chl a
Euphotic
Primary Prod.

O'Reilly

PP algorithms do not work in SAB
Long Term Trends
1998-2006

Chl trend
-5% to 5%/yr

SST trend
-0.2° to 0.3°/yr
SAB
Chlorophyll dynamics

Correlation with discharge

0.84
0.73
0.60
0.53

Signorini and McClain (2006, 2007)
Central Gulf of Maine O₂ anomaly climatology
\[
H \frac{d\Delta[O_2]}{dt} = PP_I - R_I - F_S + F_B + E
\]

Annual, integrated mixed layer budget (mol O$_2$ m$^{-2}$):

\[ PP = 19.4 \]
\[ R = 13.6 \]
\[ NCP = 5.8 \]
\[ NCP \div PP = 0.30 \]
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 et al.
Impact of parameter optimization

![Graph showing the impact of parameter optimization with different lines representing SeaWiFS, Nena, 1D, and 1D assim.]
The variational adjoint method of data assimilation can be used to improve the model-data comparison:

- **max growth rate [d⁻¹]**
  - a priori: $\mu_0 = 1.0$  →  optimal: $\mu_0 = 0.38 \pm 0.20$

- **max Chl:C ratio [mgChl mgC⁻¹]**
  - a priori: $\text{Chl2C} = 0.0535$  →  optimal: $\text{Chl2C} = 0.030 \pm 0.009$

Data assimilation is used as an approach for improving model structure.
Evaluation of model physics—salinity
Evaluation of model physics—mixed layer depth

<table>
<thead>
<tr>
<th>Observations</th>
<th>Model</th>
<th>Observations</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>March</td>
<td></td>
<td>September</td>
<td></td>
</tr>
</tbody>
</table>
Evaluation of model biogeochemistry—oxygen anomaly

Model  Observations  Model  Observations

June  December

June  December

oxygen anomaly (μmol /l)

-50  0  50
Qualitative model-data comparisons are not enough!

We need to assess model skill quantitatively.
Model-data Fusion to Assess Skill

NENA model chlorophyll

SeaWiFS chlorophyll

O'Reilly, Wilkin, Fennel
Quantitative comparison by region with parameterization refinement

<table>
<thead>
<tr>
<th>Region</th>
<th>NENA chlorophyll</th>
<th>SeaWiFS chlorophyll</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. of Maine</td>
<td>Old $k_{PAR}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New $k_{PAR}$</td>
<td></td>
</tr>
<tr>
<td>Georges Bank</td>
<td></td>
<td></td>
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<tr>
<td>SE NScot Shelf</td>
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<tr>
<td>SAB Inner Shelf</td>
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</tr>
</tbody>
</table>

O'Reilly, Wilkin, Fennel
Normalized Target diagram for SST

Misfits of means and variability

Friedrichs et al.

MAB subregions

- SLOPE3
- SLOPE2
- MABSSF
- MABO
- L3
- N3
- D3
- L2
- N2
- D2
- data

\[
\text{model-data misfit} = \text{variability in data}
\]

\[
\text{model-data misfit} = \text{error in data}
\]
Changes over 21st century

$\Delta$Temperature [15 to -15°C]

$\Delta$Precipitation [8 to -8 mm/d]
Number of models that predict an increase in summer precipitation

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

- Integration of modeling and data analysis from outset is critical to addressing project goal
- Extensive collaboration of observationalists and modelers—more progress results than each component working independently
- Model advancement requires quantitative skill assessment coupled with data synthesis
• Interdisciplinary team focused on a single coupled circulation-biogeochemical is an effective way to address complex issues, such as carbon cycling in marine ecosystems
• Single model forces the team to resolve issues and reconcile differences of opinion—end product is stronger
Thank you
References


