Modeling the Ecosystem Response and Carbon Cycle to Iron Enrichment in the Equatorial Pacific

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Motivation of Modeling

- Test Response of Ecosystem Models
- Investigate Long-term Consequences
- Carbon Fluxes
- Design Experiments
- No Environmental Risks
Carbon, Silicate, Nitrogen Ecosystem Model
CoSiNE, Chai et al. 2002; Dugdale et al. 2002

- Small Phytoplankton [P1] → NO₃ Uptake → Nitrate [NO₃]
- Nitrate [NO₃] → NH₄ Uptake → Ammonium [NH₄]
- Ammonium [NH₄] → NH₄ Uptake → Small Phytoplankton [P1]
- Ammonium [NH₄] → Si-Uptake → Diatoms [P2]
- Diatoms [P2] → Si-Uptake → Silicate [Si(OH)₄]
- Silicate [Si(OH)₄] → Sinking
- Diatoms [P2] → Sinking

- Physical Model

- Air-Sea Exchange
- Biological Uptake
- NO₃ Uptake
- NH₄ Uptake
- N-Uptake
- Advection & Mixing
- G-Fe

Chai et al., 1996
3D Circulation-Ecosystem Modeling

Modular Ocean Model (MOM)
- Basin scale, coarse resolution (1°), 50 years simulation

Regional Ocean Model System (ROMS)
- Basin scale, finer resolution (1/2°), 50 years simulation
- Basin scale, finer resolution (12.5-km), 16 years simulation

Central California Upwelling System (ROMS)
- 15-5-1.5 Km resolution, 1998 - 2003, and 2006

West Coast of the North America (NCOM)
- 9 Km with physical data assimilation, 1998 - present

Gulf of Maine (POM)
- 3 Km resolution, 2002 - present
IronFx II  $P$ vs. $E$
Surface $\text{NO}_3$ Concentration - Annual Mean
Temporal Change of $\alpha$ and $P_{\text{max}}$

Chai et al, GBC, in review
Modeled Fe Fertilization

Integrated Chl a

Inside the Patch

Background - No Fe added

Integrated Primary Prod.

Background - No Fe added

IronEX II Results

Integrated Chl a

Inside the Patch

Outside the Patch

Integrated Primary Prod.

Outside the Patch

Chai et al, GBC, in review
Surface Anomaly Fields due to the Iron Addition (Iron - Normal)

Day 01  03  05  07  10  13  16  20  30  40  60

Lat(deg)
-6  -4  -2  0  2  4  6

Small Phyto.

SS1

0.0  0.1  0.2  0.3  0.4 (mmol N/m³)

Diatoms

SS2

Si(OH)₄

SiO

NO₃

NO3

Longitude(centered at 108°W)
-8  -6  -4  -2  0  2  4  6  8

-4  -3  -2  -1  0  (mmol/m³)
Data from K. Busseler, WHOI
### Comparisons of Productions and Ratios

<table>
<thead>
<tr>
<th></th>
<th>f-ratio</th>
<th>New Production (mmol C m(^{-2}) day(^{-1}))</th>
<th>Primary Production (mmol C m(^{-2}) day(^{-1}))</th>
<th>Export Production (mmol C m(^{-2}) day(^{-1}))</th>
<th>e-ratio</th>
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</thead>
<tbody>
<tr>
<td>No Iron</td>
<td>0.37</td>
<td>26.5</td>
<td>72.2</td>
<td>22.5</td>
<td>0.31</td>
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<tr>
<td>Iron Added</td>
<td>0.49</td>
<td>92.8</td>
<td>188.6</td>
<td>51.3</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Conclusions

- Need More Research on Iron Fertilization
  - Marine Ecosystem Response to Anthropogenic Perturbation
- Modeled Ecosystem Response to Iron Addition
  - Nutrients, Chl $a$, PP, and TCO$_2$
- Interaction Between Phytoplankton and Zooplankton
  - Diatoms Increase First, Small Phytoplankton Lasts Longer
- Increase of Vertical Carbon Fluxes
- The System Needs about 90 days to Recover