The role of model structure in simulating changes in oceanic new production over the 21st century

Jay Brett, University of Hawaii Manoa
Manoa collaborators Kelvin Richards, Kate Feloy
NCAR collaborators Dan Whitt, Matt Long, Frank Bryan
Funded by NSF

April 15, 2020
Under global climate change, new production decreases overall, but mechanisms and amount vary between locations and models.
Questions

- Under a climate perturbation, how do physical changes drive changes in new production rates?
- How well can an idealized model project new production?
- What is the role of the model structure for production in the spatial patterns of projected change?
1. Tracers
2. Climate perturbation timeslice
3. General Behavior
4. Results from two contrasting models
5. Conclusions
A pair of idealized tracers is the minimum for entrainment, production, and export.

NUTRI: idealized nutrient, fixed value below 1km.

PARTI: idealized organic particulate (phyt. and detritus)
Idealized Tracers

NUTRI: idealized nutrient, fixed value below 1km.
PARTI: idealized organic particulate (phytoplankton and detritus)

\[
\frac{dN}{dt} = -\mu_0 QL + S_1,
\]
\[
\frac{dP}{dt} = \mu_0 QL - \text{decay + sinking},
\]
\[
Q = \frac{N}{(k_N + N)},
\]
\[
L = 1 - e^{\alpha I}, \quad I = I(z, MLD),
\]
\[
S_1 = \begin{cases} 
0 & \text{if } z > -1\text{km} \\
20 - N & \text{if } z < -1\text{km}
\end{cases}
\]
### Production parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>0.125</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>$k_N$</td>
<td>0.25</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Highlighted members (0.05, 0.125, 0.25) and (0.2, 2, 1). Set of 12 have all $k_N$ for $(\alpha, \mu_0) = (0.0125, 0.5) (0.05, 0.125) (0.2, 0.125) (0.2, 2)$. 
Outline

1. Tracers
2. Climate perturbation timeslice
3. General Behavior
4. Results from two contrasting models
5. Conclusions
Uses Large Ensemble to perturb T, S, forcing based on the difference between 2000 and 2100. Changes in HMXL and SHF_QSW are most important.
1. Tracers
2. Climate perturbation timeslice
3. General Behavior
4. Results from two contrasting models
5. Conclusions
New production magnitudes are reasonable.
Production patterns are reasonable

Annual production, top 100m, mean of 12 parameter cases.
Production change
Outline

1. Tracers
2. Climate perturbation timeslice
3. General Behavior
4. Results from two contrasting models
5. Conclusions
Production patterns

Global decreases in new production of 11% and 19%.

\((0.05, 0.125, 0.25, 0.2, 2, 1)\)

\((\alpha, \mu_0, k_N)\)
South Pacific
Conclusions

- Idealized tracers behave reasonably well
- When one consistent limiting factor is the main change, projection not sensitive to bgc model (parameters)
- When limiting factor changes or multiple factors change, projections are sensitive

Continuing work: connecting bgc changes back to the physics
PAP high-res studies
The role of model structure in simulating changes in oceanic new production over the 21st century

Jay Brett, University of Hawaii Manoa
Manoa collaborators Kelvin Richards, Kate Feloy
NCAR collaborators Dan Whitt, Matt Long, Frank Bryan
Funded by NSF

April 15, 2020
Seasonal production

Global rates, 6-month offset N/S hemispheres

Production above 100m Nutrient flux at 100m

gC/m² yr

Availability

slow Q_{2100}/Q_{2000}
fast Q_{2100}/Q_{2000}
slow L_{2100}/L_{2000}
fast L_{2100}/L_{2000}
Production patterns

![Maps comparing production patterns in different years](image-url)
Range of production

**Ensemble range/mean of annual production 2000**

**Ensemble range/mean of annual production 2100**
Production limitations

months production limited by $Q$

2000 slow

2000 fast

2100 slow

2100 fast
Vertical velocity changes at 100m

Climate perturbation, annual-mean $w$

Vertical Velocity, 100 m

min -870.688 max 1114.9 m/day
Production change in multi-model context
Global annual new production changes

gC/yr vs varied parameters

- Total
- Positive
- Negative
South Pacific production change ensemble

South Pacific production changes

- increase
- decrease
- total

$gC/yr$ vs varied parameters

$10^{14}$
Arctic production change ensemble
North Atlantic production change ensemble
Ensemble global production rates
Production decreases in all but Arctic
Ensemble basin production changes

Percent change in annual new production

Change in annual new production

Jay Brett
Climate, physics, bgc
Parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0.0125</td>
<td>0.05</td>
<td>0.2</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>0.125</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>$k_N$</td>
<td>0.25</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>$w_s$</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>1/365</td>
<td>1/60</td>
<td>1/30</td>
</tr>
</tbody>
</table>

27 runs with $w = 0$ and $\sigma = 1/60$.
Highlighted members (0.05, 0.125, 0.25, 5, 1/365) and (0.2, 2, 1, 10, 1/30).
Set of 12 have all $k_N$ for $(\alpha, \mu_0) = (0.0125,0.5) (0.05,0.125) (0.2,0.125) (0.2,2)$. 