Testing ocean biogeochemical models using combined measurements of atmospheric potential oxygen (APO) and Ar/N₂

Manfredi Manizza
Scripps Institution of Oceanography
University of California San Diego
mmanizza at ucsd.edu

In collaboration with:
Ralph Keeling - SIO/UCSD
Laure Resplandy SIO/UCSD
Cynthia Nevison - CU Boulder
Sara Mikaloff - Fletcher - NIWA, NZ
and
The Ocean Modelers
Seasonal Physical and Biogeochemical Variations – Ocean

North Pacific Ocean - Subtropics

Flux > 0 : O₂ Outgassing

Riser et al., 2008

Garcia & Keeling, 2001
Test 1 for BGC models: Ocean Processes

Latitudinal $fO_2/\Delta Q$ Flux Relationship

$$fO_2(lat) = a_1 \cdot \Delta Q(lat) + a_2$$

O$_2$ Flux

Heat Flux Seasonal Anomaly

Wind speed from ECMWF

Heat flux from ECMWF

How do current bgc models compared to this?

Garcia & Keeling, 2001
What can the atmosphere “see”? 

Latitudinal 

FO$_2$/Heat Flux Relationship

Ocean fluxes of heat and gases can be ALSO constrained by atmospheric obs.

BGC Models can be also tested

Transporting the fluxes in the atmosphere by an Atmospheric Transport Model

Garcia & Keeling, 2001
New Test for BGC models: APO & Ar/N₂

Oceanic Processes

O₂ tracks both Physics and Biology

Atmospheric observations

Ar and N₂ track heat (only)

Atmospheric Potential Oxygen
= O₂ + 1.1 * CO₂

Northern Extra-tropics

Southern Extra-tropics
Atmospheric Observations as Models Benchmark?

Scripps ( & more ) Network of atmos. stations

Seasonal Heat Fluxes

Ocean Gas Fluxes

Atmospheric Transport of ocean fluxes (TM3)

<table>
<thead>
<tr>
<th>Station</th>
<th>AMP(APO) / AMP(Ar/N₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Bay (CBA)</td>
<td>4.15 ± 0.41</td>
</tr>
<tr>
<td>La Jolla (LJO)</td>
<td>3.20 ± 0.27</td>
</tr>
<tr>
<td>Cape Grim (CGO)</td>
<td>4.89 ± 0.68</td>
</tr>
<tr>
<td>Palmer Station (PSA)</td>
<td>3.97 ± 0.54</td>
</tr>
</tbody>
</table>

A new benchmark for ocean bgc models ??
## Suite of forced Ocean Models to test

<table>
<thead>
<tr>
<th>Model</th>
<th>Ocean Physics Res.</th>
<th>Ocean BGC</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOM4</td>
<td>~ 1 by ~1</td>
<td>TOPAZ (GFDL)</td>
</tr>
<tr>
<td>CCSM</td>
<td>~ 1 by ~1</td>
<td>BEC (NCAR/UCI)</td>
</tr>
<tr>
<td>NEMO - CTRL</td>
<td>2 by 0.5 – 2</td>
<td>PISCES (IPSL)</td>
</tr>
<tr>
<td>NEMO - WS</td>
<td>2 by 0.5 – 2</td>
<td>PISCES (IPSL)</td>
</tr>
<tr>
<td>CESM</td>
<td>2 by 0.5 – 2</td>
<td>BEC (NCAR)</td>
</tr>
</tbody>
</table>

Models are **forced** by re-analyzed products (heat, water fluxes & wind stress)

Models compute $O_2$ and $CO_2$ fluxes $N_2$ and $Ar$ fluxes are HF fluxes derived (Keeling & Shertz, 1992)

\[
\text{Flux} = \frac{\partial S}{\partial T} \cdot \frac{Q}{C_p \cdot \rho}
\]

\[\delta S/\delta T = \text{Gas Solubility}\]
\[Q = \text{Heat Flux}\]
\[C_p = \text{Heat Capacity}\]
\[\rho = \text{SW Density}\]
\[\alpha = 1/1.3 \text{ (Jin et la. 2007)}\]
Ranking the models

Amplitude Ratio

APO Amplitude (Per Meg)

Ar/N₂ Amplitude (Per Meg)
Global Dataset Vs BGC Models

Models show **Different Sensitivity** on FO$_2$/Heat Flux

Same models also show **different sensitivity** in **different hemispheres**

**WHAT IF** now we combine:

Old Ocean metric : FO$_2$/Heat
New Atm. metric : Amplitude Ratio

Focus on extra-tropical systems
Ocean + Atmosphere

Both methods seem to converge!!

Manizza et al., in prep.
What’s Role for the Atmospheric Transport?

Amplitude Ratio

APO Amplitude (Per Meg)

Ar/N₂ Amplitude (Per Meg)

Atmospheric Stations

TransCom Models

O₂ fluxes (Garcia & Keeling 01)

N₂ fluxes (Blaine 2005)

Different physical transport

AMP. RATIO insensitive to transport model
Conclusions

Atmospheric obs. can be used as a new rigorous test for the performance of bgc models on air-sea gas fluxes at seasonal time scale.

The new method can help us to evaluate the performance of the ocean bgc models in the physical and biogeochemical components of O$_2$ fluxes via the use of Argon and then the ratio of seasonal amplitudes ($Amp_{APO}$ / $Amp_{Ar/N2}$).

The use of APO and other atmospheric gases can be adopted as new metric to constrain, in conjunction with satellite products as (e.g. C export production) to constrain the ocean bgc components of the CMIP5 Earth System Models (Nevison et al., 2015).