Ocean carbon sink response to ENSO and impacts on atmospheric CO2

Enhui Liao; Laure Resplandy; Julius Busecke
Princeton University

Abstract

ENSO is the main source of inter-annual fluctuations in atmospheric O2 and CO2. During the 2015/2016 El Niño event, glint OCO-2 data detected a strong decrease of 1 ppm in column CO2 over the central Equatorial Pacific, which is attributed to an increase in the ocean sink. The model (MOM6-COBALT) from GFDL and observations of atmospheric CO2 and O2 data are used to quantify the magnitude and investigate the driving process of this increase in the ocean sink. Preliminary model simulations show significant interannual variability in the global tropical ocean carbon flux. Most of the variabilities are attributed to the equatorial Pacific Ocean and correlate well with Niño3.4 index. This variability indicates an anomalous ocean uptake of CO2 during El Niño which are related to thermal, biological, and ventilation processes. Detailed analysis of these three driving processes and magnitude estimation are ongoing and will be discussed later. The magnitude estimation and driving processes analysis have far reaching implications for our understanding of the land-ocean carbon sink estimation and carbon cycle response to climate variability.

1. Motivation and Introduction

Fig. 1 NASA’s OCO-2 mission observes atmospheric CO2 globally (left) and CO2 anomaly in the Niño3.4 region (5N-5S, 170W-120W) during El Niño 2015/2016 (Chatterjee et al., 2017).

During the 2015/2016 El Niño event, glint OCO-2 data (Fig. 1) detected a strong decrease of ~1 ppm in column CO2 over the central Equatorial Pacific and this decrease is related to an ocean drawdown in the Equatorial Pacific.

Fig. 2 Ocean processes (ventilation, biology and thermal fluxes) controlling CO2 and O2 fluxes in the Equatorial Pacific in normal condition (left) and El Niño events.

Atmospheric potential oxygen (APO) combines records of atmospheric CO2 and O2/N2 content (APO=O2+1.1CO2) and is insensitive to exchanges with the land biosphere and can be used to track the imprint of ocean fluxes.

2. Methodology

Model: MOM6 and COBALT in GFDL

Fig. 3 Objectives and workflow in the project (left) and cobalt state nitrogen variables (right, Stock et al., 2013).

3. Preliminary Results

Fig. 4 Modeled (left) and Observed (middle) composite SST anomaly and time series of Niño index

The preliminary results from MOM6 and COBALT model show an anomaly O2 outgassing and CO2 uptake. This anomaly air-sea flux corresponds to an anomaly mixing layer depth, heat flux, and chlorophyll which represents ventilation, thermal, and biological processes.

Table 1 Model experiments and global tropical APO and CO2 changes

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Specifications</th>
<th>Process</th>
<th>APO changes</th>
<th>CO2 changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Realistic forcing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G110</td>
<td>Phyto. Growth rate +10%</td>
<td>Bio</td>
<td>-1.43%</td>
<td>+0.56%</td>
</tr>
<tr>
<td>G90</td>
<td>Phyto. Growth rate -10%</td>
<td>Bio</td>
<td>+3.95%</td>
<td>+3.11%</td>
</tr>
<tr>
<td>W110</td>
<td>Wind stress +10%</td>
<td>Vent/Therm</td>
<td>+7.79%</td>
<td>-5.57%</td>
</tr>
<tr>
<td>W110</td>
<td>Wind variability +10%</td>
<td>Vent/Therm</td>
<td>+0.37%</td>
<td>-1.81%</td>
</tr>
</tbody>
</table>

Fig. 5 Modeled and Observed N03, P04, and Si04

3. Model Evaluation

Fig. 6 Composite pattern of APO, O2, and CO2 fluxes and mixing layer depth (MLD), heat flux, and chlorophyll during El Niño events

Fig. 7 Time series of O2 and CO2 in the global tropical, Pacific tropical, and Equatorial Pacific oceans

Fig. 8 Lag Regressions of Niño3.4 index verse O2 and CO2 fluxes (left, units: mmol/year/sigma). Map of zero lag regression of Niño3.4 index verse anomalies of O2 (middle) and CO2 (right) fluxes (units: mmol/m^2/year/sigma).

4. Conclusion

- The equatorial Pacific ocean is the major source for the variabilities of O2 and CO2 fluxes in the global tropical ocean.
- The wind influence on the O2 and CO2 fluxes is larger than the phytoplankton.
- This study is funded by NASA OCO2 project. We thank the GFDL model developing groups for providing the model.