Ocean carbon sink response to ENSO and impacts on atmospheric CO2

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Abstract

ENSO is the main source of inter-annual fluctuations in atmospheric O_2 and CO_2. During the 2015/2016 El Niño event, glint OCO-2 data detected a strong decrease of 1 ppm in column CO_2 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 CO_2 and O_2 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 CO_2 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

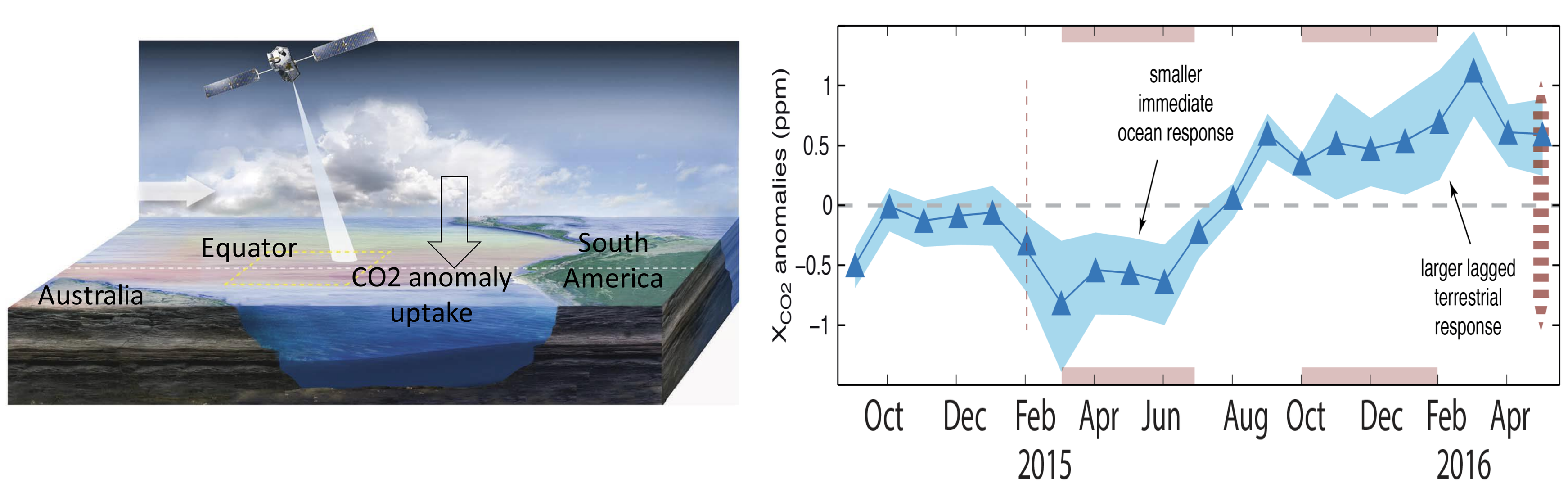

Fig. 1 NASA's OCO-2 mission observes atmospheric CO_2 globally (left) and CO_2 anomaly in the in Niño3.4 region (5N-5S, 170W-120W) during El Niño 2015/2016 (Chatterjee et al., 2017)

During the 2015/2016 El Niño event, glint OCO-2 data (Fig. 1) detected a strong decrease of ~1 ppm in column CO_2 over the central Equatorial Pacific and this decrease is related to an ocean drawdown in the Equatorial Pacific.

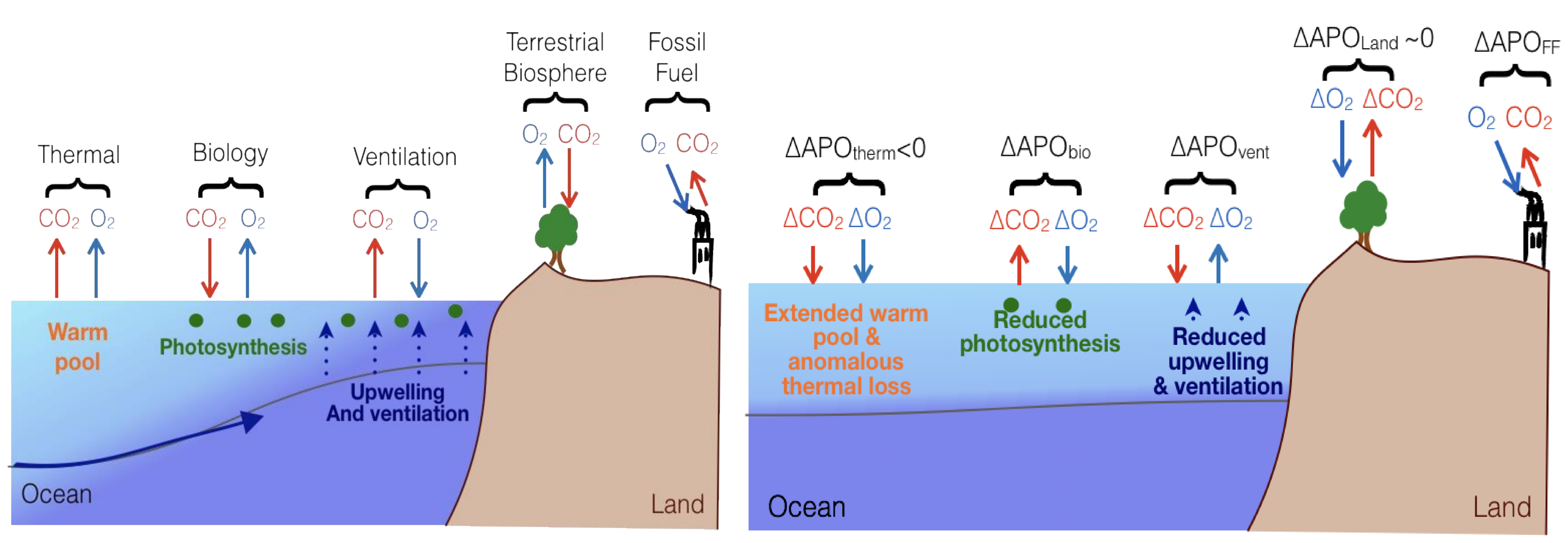

Fig. 2 Ocean processes (ventilation, biology and thermal fluxes) controlling CO_2 and O_2 fluxes in the Equatorial Pacific in normal condition (left) and El Niño events.

Atmospheric potential oxygen (APO) combines records of atmosphere CO_2 and O_2/N_2 content ($APO=O_2+1.1CO_2$) and is insensitive to exchanges with the land biosphere and can be used to track the imprint of ocean fluxes.

2. Methodology

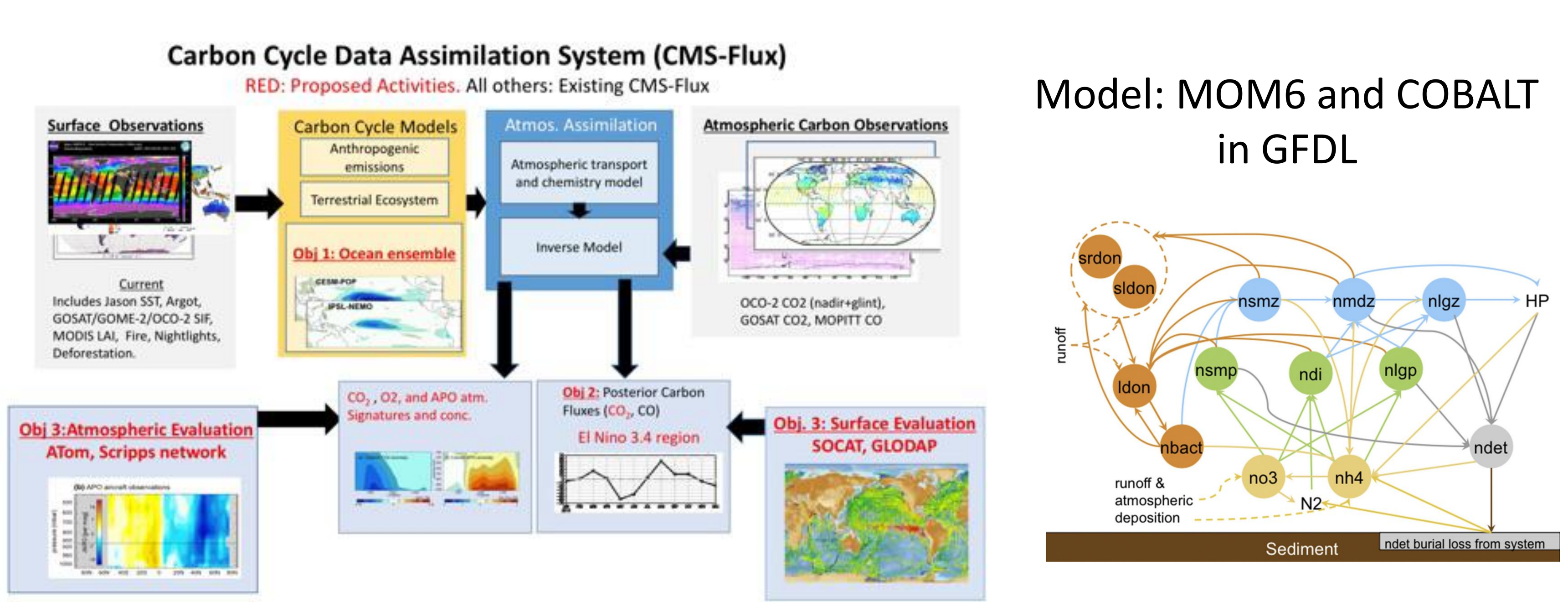

Fig. 3 Objectives and workflow in the project (left) and cobalt state nitrogen variables (right, Stock et al., 2013).

3. Model Evaluation

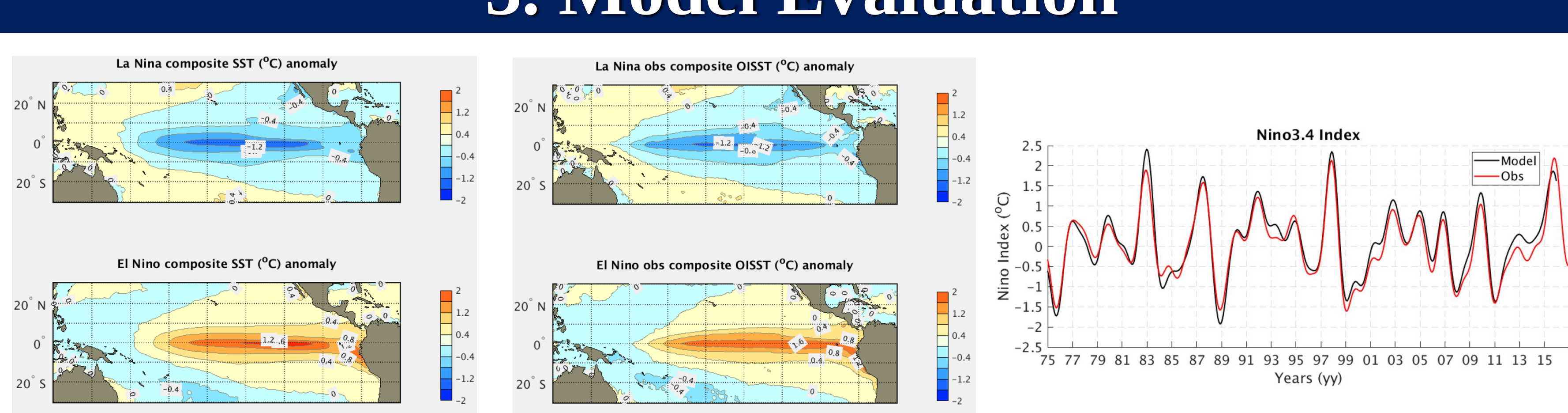

Fig. 4 Modeled (left) and Observed (middle) composite SST anomaly and time series of Niño index

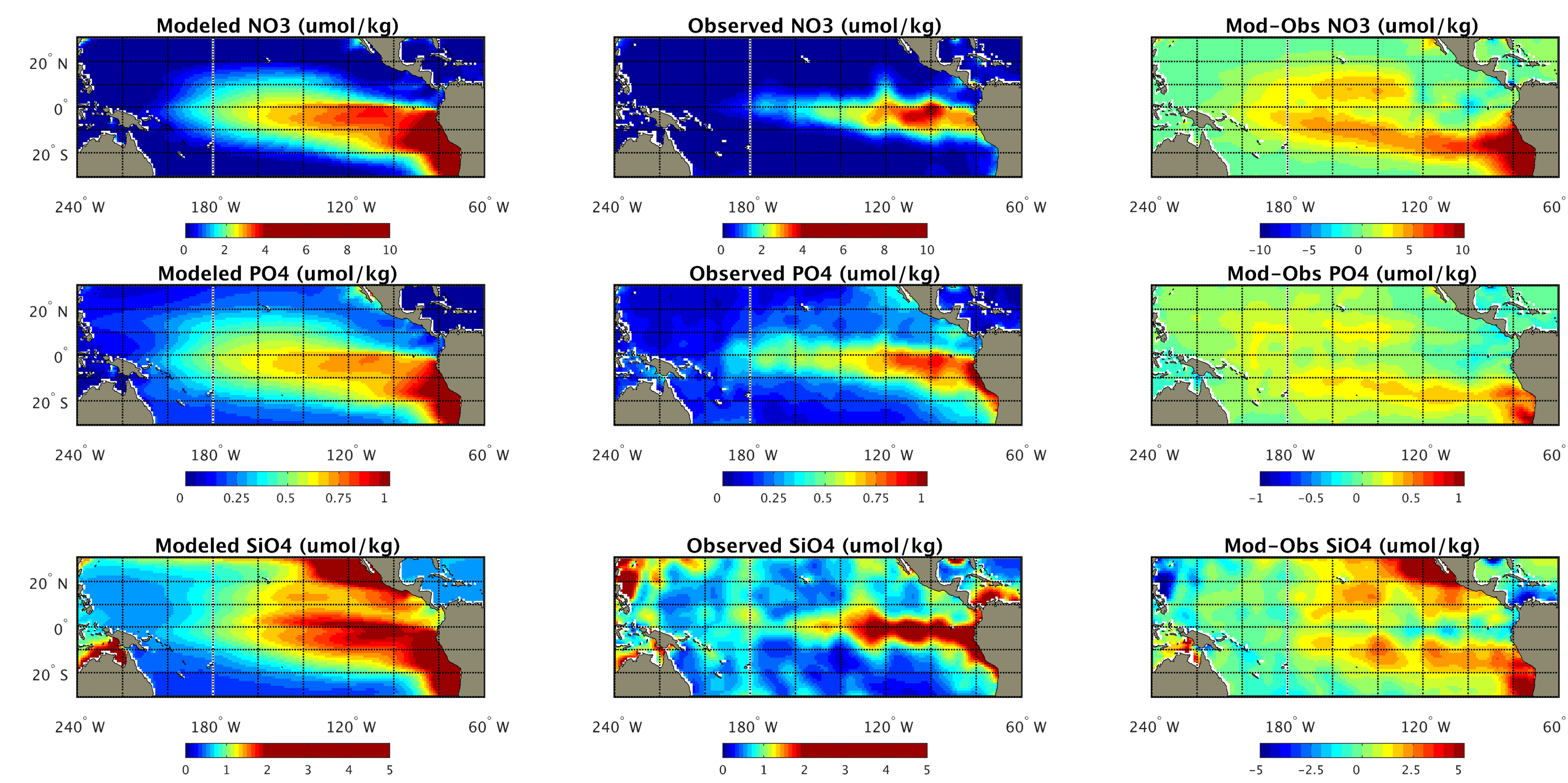

Fig. 5 Modeled and Observed NO3, PO4, and SiO4

3. Preliminary Results

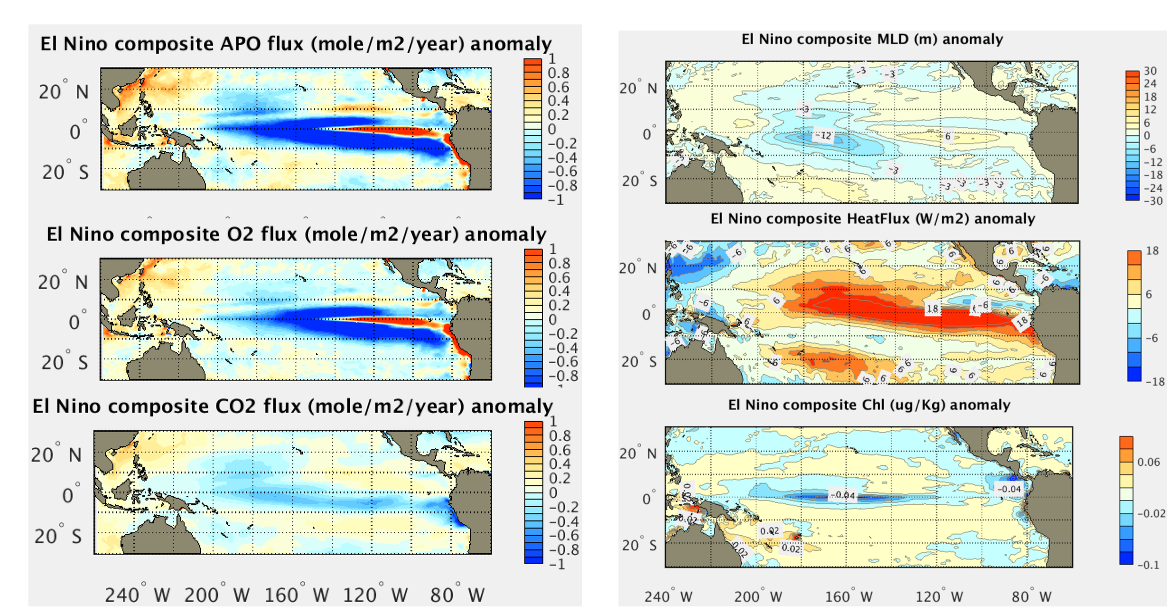

Fig. 6 Composite pattern of APO, O_2, and CO_2 fluxes and mixing layer depth (MLD), heat flux, and chlorophyll during El Nino events

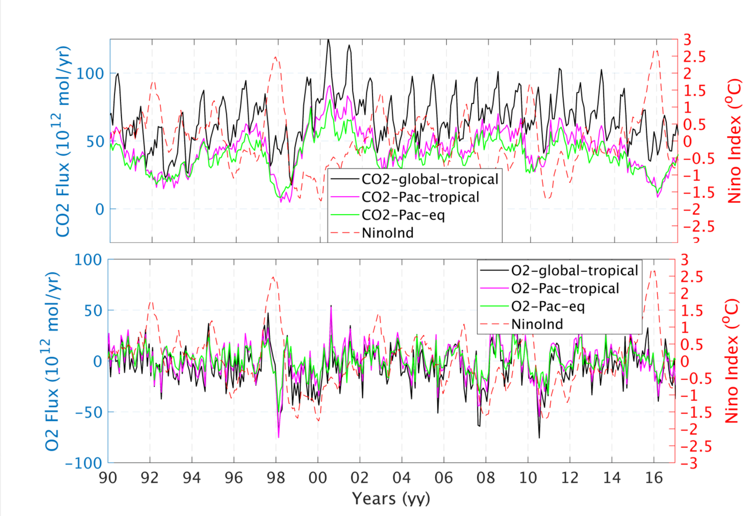

Fig. 7 Time series of O_2 and CO_2 in the global tropical, Pacific tropical, and Equatorial Pacific oceans

The preliminary results from MOM6 and COBALT model show an anomaly O_2 outgassing and CO_2 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 CO_2 changes

Experiments	Specifications	Process	APO changes	CO2 changes
Control	Realistic forcing			
G110	Phyto. Growth rate +10%	Bio	-1.43%	+0.56%
G90	Phyto. Growth rate -10%	Bio	-3.95%	+3.11%
W110	Wind stress +10%	Vent/Therm	+7.79%	-5.57%
Wvar	Wind variability +10%	Vent/Therm	+0.37%	-1.81%

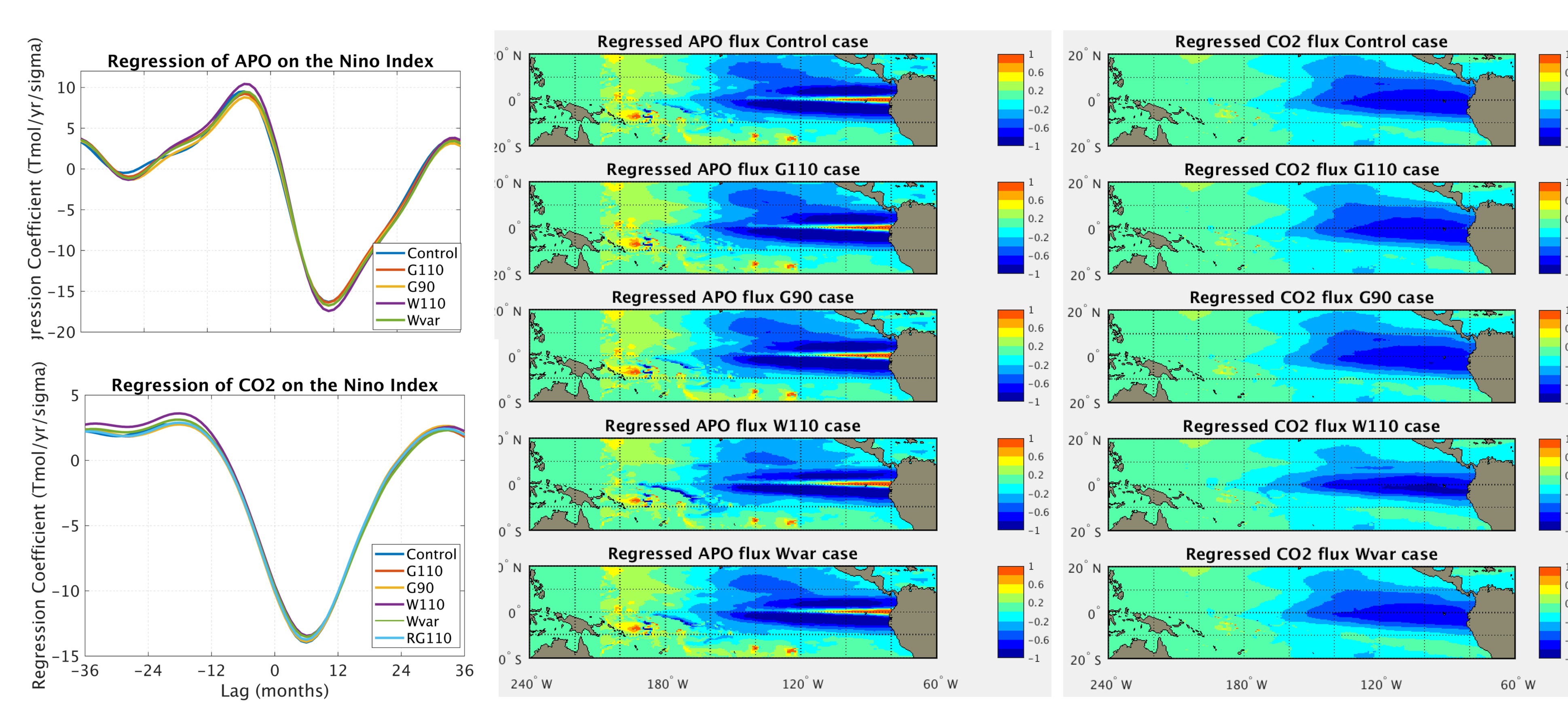

Fig. 8 Lag Regressions of Niño3.4 index verse O_2 and CO_2 fluxes (left, units: Tmol/year/sigma). Map of zero lag regression of Niño3.4 index verse anomalies of O_2 (middle) and CO_2 (right) fluxes (units: mol/m^2/year/sigma).

4. Conclusion

- The equatorial Pacific ocean is the major source for the variabilities of O_2 and CO_2 fluxes in the global tropical ocean.
- The wind influence on the O_2 and CO_2 fluxes is larger than the phytoplankton.

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