Observing changes in sea-air CO$_2$ fluxes in the tropical and subtropical Pacific during the strong 2015-2016 El Niño event

Session 4: Societal Challenge #2 Ocean Extremes

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Global Carbon Balance

The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean.


<table>
<thead>
<tr>
<th>Year</th>
<th>Sources</th>
<th>Sinks</th>
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</thead>
<tbody>
<tr>
<td>2006-2015</td>
<td>9.3 ± 0.5 PgC/yr</td>
<td>0.9 ± 0.5 PgC/yr</td>
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<tr>
<td></td>
<td>3.1 ± 0.8 PgC/yr</td>
<td>4.5 ± 0.1 PgC/yr</td>
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<td></td>
<td>2.6 ± 0.5 PgC/yr</td>
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Schematic Diagram of the impact of Strong Eastern Pacific El Niños on the Sea-Air CO₂ Exchange in the Equatorial Pacific

Winter/Spring 1997

HNLC Region
Low SST, High SSS, High Nutrients, ΔCO₂ ~ 0

Summer/Fall 1997

Warm Pool Region
High SST, low SSS, Low Nutrients, ΔCO₂ ~ 0

Winter/Spring 1998

- 0° to 20° N
- 20° S
- 180° E to 120° W
- 75° W to 60° W
- 150° E to 120° E
- 160° W to 100° W
- 140° W to 80° W
- 140° E to 120° E
- 130° W to 100° W
- 120° W to 100° W
- 110° W to 80° W
- 100° W to 80° W
- 90° W to 60° W
- 80° W to 60° W
- 70° W to 40° W
- 60° W to 20° W
- 50° W to 0° W
- 0° to 20° E
- 160° W to 140° W
- 140° W to 120° W
- 120° W to 100° W
- 110° W to 90° W
- 100° W to 80° W
- 90° W to 70° W
- 80° W to 60° W
- 70° W to 50° W
- 60° W to 40° W
- 50° W to 20° W
- 20° W to 0° W
- 0° to 20° E
- 160° W to 140° W
- 140° W to 120° W
- 120° W to 100° W
- 110° W to 90° W
- 100° W to 80° W
- 90° W to 70° W
- 80° W to 60° W
- 70° W to 50° W
- 60° W to 40° W
- 50° W to 20° W
- 20° W to 0° W
- 0° to 20° E

La Niña
El Niño

0°C
20°C
28.6°C
20°C

δCO₂ [µatm]
A new type of El Niño: maximum warming in the central-equatorial Pacific (CP)


Question: How will climate change will impact physical, chemical, biological, or ecosystem dynamics in the Equatorial Pacific?

Types of El Niño “Flavors”
Overview of carbon observing system

Shipboard and mooring data (1968-2016)

Mooring and underway CO₂ data available at NCEI and incorporated into Version 4 of SOCAT (see Bakker et al., 2016, ESSD)
2014-2016 $p\text{CO}_2$ observations and CO$_2$ flux from TAO buoys

CO$_2$ concentration plots available at www.pmel.noaa.gov/co2/
Corroboration of oceanic signal

Abhishek Chatterjee et al (Science, in press)

TAO buoy shows decreasing $\Delta pCO_2$ during onset phase

OCO-2 suggests a negative $X_{CO2}$ anomaly over the same time period
2014-2016 $p$CO$_2$ observations and CO$_2$ flux from TAO buoys

The tropical Pacific CO$_2$ flux decrease in this region during El Niño (~0.2 - 0.3 PgC yr$^{-1}$) amounts to an overall CO$_2$ flux decrease of approximately 40-60%.
Conclusions

- The tropical Pacific is the major natural source of CO$_2$ from the ocean to the atmosphere, contributing more than 70% of the global flux to the atmosphere.

- The interannual variability of the sea-air CO$_2$ flux in the tropical Pacific is also the major source of CO$_2$ flux variability in the Pacific Ocean (~0.2 - 0.3 PgC yr$^{-1}$), which is a an overall CO$_2$ flux decrease of approximately 40-60% in the tropical Pacific during El Niño events.

- With the high-resolution observations available from OCO-2 and TAO moorings, we are able to directly: 1) observe the strong correlations that exist between atmospheric CO$_2$ concentrations and the El Niño forcing, and 2) track the development of the atmospheric CO$_2$ anomaly as it switches from a negative phase due to a reduction in CO$_2$ outgassing from the tropical Pacific Ocean, to a strong positive phase due to a reduction in biospheric uptake and increased fire emissions.
The instrument measures the intensity of three relatively small wavelength bands (Weak CO2, Strong CO2 and Oxygen O2) from the spectrum, each specific to one of the three spectrometers. By simultaneously measuring the gases over the same location and over time, OCO-2 will be able to track the changes over the surface over time. The OCO-2 spectrometers will measure sunlight reflected off the Earth's surface. The sunlight rays entering the spectrometers will pass through the atmosphere twice - once as they travel from the Sun to the Earth, and then again as they bounce off from the Earth's surface to the OCO-2 instrument.