Magnitude and Drivers of the Seasonal Cycle and Interannual Variability of pCO_2 in the Washington Coast OOI Endurance Array

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Introduction

- Carbon flux is negative when carbon is drawn into the ocean (carbon sink) and positive when released from the ocean into the atmosphere (carbon source).
- Understanding the drivers that cause the ocean to act as a source or sink is important for future predictions and models regarding climate change and ocean acidification.
- Previous research by Takahashi et al. (2002) suggests that the coastal northwestern U.S. is a carbon sink. However, there is debate about the magnitude and the role of biological and physical drivers.
- This project studies the seasonal cycle and drivers of the partial pressure of CO_2 (pCO_2) off the Washington coast, a region with little documentation on this topic.

Methods

- Data was taken from the Washington Offshore Surface Mooring of the Ocean Observatories Initiative (OOI) Coastal Endurance Array.
- Instruments used: 3-wavelength fluorometer, air-sea pCO_2 instrument, and meteorological sensors.
- Suspect and failed data was flagged by the OOI and removed in Google Colaboratory using the Pandas Data Analysis Library to ensure quality control.

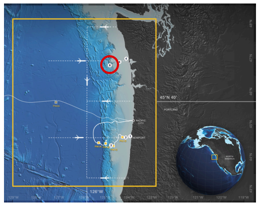

Photo from oceanobservatories.org

Figure 1. The OOI Coastal Endurance Array off the Washington and Oregon coasts. The Washington Offshore Surface Mooring is denoted by a number 6 and a red circle.

Calculations and Analysis

- Flux was calculated using the following equation:

$$\mathbf{flux = k\,K_0\,(pCO_{2,water} - pCO_{2,air})}$$

where K_0 is the solubility coefficient and k is piston velocity from measured wind speed at the mooring.

- Thermal decomposition calculations come from Takahashi et al. (2002):

$$pCO_2\ therm = \overline{pCO_2}\, e^{0.0423(T_{obs} - \overline{T})}$$

$$pCO_2\ nontherm = pCO_{2,obs}\, e^{0.0423(\overline{T} - T_{obs})}$$

where pCO_2 *therm* is expected pCO_2 with only thermal drivers, pCO_2 *nontherm* is expected pCO_2 when temperature is held constant, a bar indicates annual mean, and the *obs* subscript indicates observed values.

Results

Seasonal Cycle

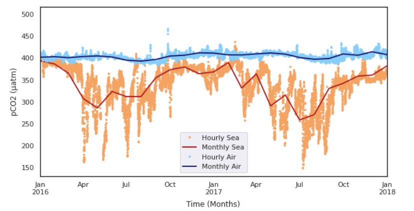

Figure 2. 2016-2017 seasonal cycle and variability of air and seawater pCO_2. Ocean pCO_2 tends to decrease during late spring and summer, then increases for fall and winter, when it approaches equilibrium with the air. There is more variability of values during late spring and summer, with more constant levels during fall and winter. This seasonal cycle is relatively consistent between the two years; however, the lowest pCO_2 levels are found in late spring for 2016 and mid-summer for 2017.

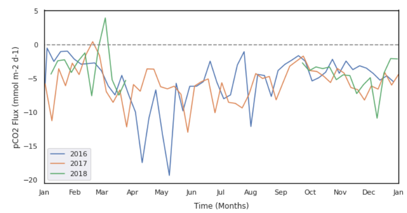

Figure 3. Comparison of weekly pCO_2 flux data from 2016-2018. Most of the data are below zero, meaning that the area generally acts as a sink. The annual flux value for 2016 was -1.9 ± 2.1 mol m^{-2} yr^{-1}, and -2.1 ± 1.9 mol m^{-2} yr^{-1} for 2017 (negative values are flux into the ocean). However, the region can act as a source in late winter and early spring. There is a high flux value between February and March of 2018, which could be due to an upwelling event.

Drivers

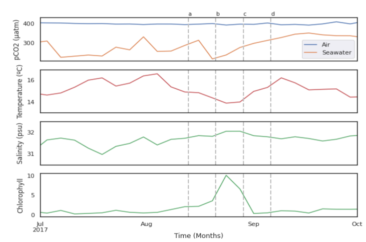

Figure 4. 2017 weekly data showing a low pCO_2 event in late August. Chlorophyll levels spiked, while pCO_2 levels decreased. Salinity increased slightly and temperature decreased, which would be consistent with coastal upwelling. Dashed gray lines and associated letters denote the dates used for satellite data (see Fig. 5).

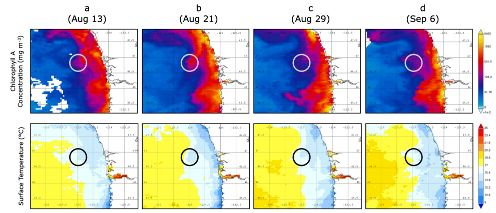

Figure 5. Satellite images of a low pCO_2 event in 2017. Images are from NASA Giovanni MODIS 8-daily average. Circles denote the location of the mooring. Letters correspond to those in Fig. 4. The increase in chlorophyll and decrease in temperature at letter 'b' are consistent with upwelling along the coast, after which cold, chlorophyll-rich water is advected toward the Offshore Mooring. These effects are still seen in 'c' and 'd' along the coast, but the water at the mooring becomes warmer and less productive in the last two sets of images.

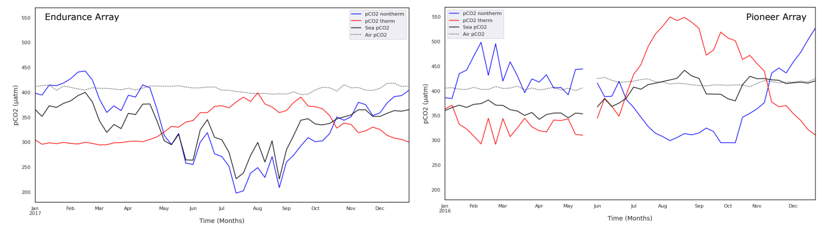

Figure 6. Comparison of the decomposition of the pCO_2 curve at the Endurance Array and Pioneer Array. Average weekly pCO_2 is lower at the Endurance Array (left) than it is at the Pioneer Array (right). The 2017 Washington Offshore Surface Mooring closely follow non-thermal drivers. However, temperature decreases the overall magnitude of pCO_2 in the winter, effectively stopping the area from becoming a carbon source. In contrast, the 2016 Pioneer Offshore Surface Mooring loosely follows thermal drivers, though non-thermal factors dampen the effects of temperature on the curve to establish a weaker seasonal cycle. Trends were relatively constant from year to year, so the most complete annual data for each station was used.

Conclusions

- The region is a net carbon sink, but can occasionally become a carbon source in the winter. The annual flux value for 2016 is **-1.9 ± 2.1 mol m^{-2} yr^{-1}**, and **-2.1 ± 1.9 mol m^{-2} yr^{-1}** for 2017.
- The pCO_2 values for 2016 and 2017 range from 148 µatm to 436 µatm.
- The seasonal cycle is strongly driven by non-thermal factors, such as upwelling and algal blooms.
- Temperature works to decrease the magnitude of pCO_2 during the winter, keeping the region from becoming a carbon source.
- Evans et al. (2011) estimated annual flux off the Oregon shelf to be −0.3 ± 6.8 mol m^{-2} yr^{-1}, suggesting that the Washington shelf is potentially a larger sink despite the close proximity of the stations. This indicates that this study would likely not yield a completely accurate estimate of the entire northwestern U.S. coastal region.
- The drivers of the seasonal pCO_2 cycle differ from the Endurance Array to the Pioneer Array. The Washington Mooring is most influenced by non-thermal factors, while the Pioneer Mooring weakly follows thermal factors.
- Despite differences in drivers, the Pioneer Offshore Surface Mooring has a similar annual flux value of -1.2 ± 2.2 mol m^{-2} yr^{-1}.

References and Acknowledgements

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