Observing the carbon cycle in the Southern Ocean from biogeochemical floats with pH sensors

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Overview of SOCCOM

The Southern Ocean plays a major role in the global carbon cycle by accounting for around half of the overall ocean carbon sink yet it is relatively undersampled and not well-represented in climate models. The Southern Ocean Carbon and Climate Observations and Modeling (SOCOCOM) project aims to fill this observational gap by deploying 200 autonomous biogeochemical profiling floats in the Southern Ocean over 5 years. Now in year 3, there are over 75 floats in the water and reporting data back every 10 days (green dots in the Southern Ocean in the map to the left). These data are publicly available and are quality controlled in near-real time.

What is a SOCCOM float?

A SOCCOM float, pictured at left, is an autonomous profiling float that measures temperature [T] and salinity [S] and carries the following additional biogeochemical sensors:

- Deep Sea DurafET (Johnson et al. 2016)
- ISUS UV Nitrates (Johnson et al. 2013)
- WET Labs FLBB backscattering and chlorophyll (Boo et al., 2008)
- Aanderaa or Okean oxygen optode (Tengberg et al., 2006)

A SOCCOM float is generally set to “park” at 1000 m depth, drifting with the currents until, every 10 days, it descends to 2000 m turns on its sensors, and then ascends to the surface taking measurements along the way. When the float reaches the surface it transmits the profile data back to a data center via satellite before descending back to its park depth. These floats are ice-enabled, meaning that they can safely sample under seasonal sea ice and report their data when the ice opens in spring.

How well can we calculate pCO2 from float pH?

To calculate the flux of carbon dioxide between the atmosphere and the ocean we need to calculate the ΔpCO2:

\[ \Delta pCO_2 = pCO_{\text{atmosphere}} - pCO_{\text{in water}} \]

A positive ΔpCO2 implies that the ocean will release carbon to the atmosphere. A float-based estimate of pCO2 from the float pH measurements and an estimate for total alkalinity (Carter et al., 2016). The uncertainty in the float run from 2014 to 2.7% as compared to a 1% uncertainty in a traditional ship-based underway measurement. This uncertainty was estimated using a careful analysis of uncertainties from three main sources: the float pH measurement, the alkalinity estimate, and the calculation of pCO2 from pH and TA, as summarized in the fishbone diagram below.

Results

While float-based calculated pCO2 from in situ pH sensors is inherently more uncertain than most ship- or mooring-based pCO2 measurements, a well-calibrated array of biogeochemical floats can complement the existing global dataset by providing a seasonal context to regions where wintertime measurements are sparse. The figure below shows ΔpCO2 from four floats each representing one of four major Southern Ocean frontal zones. In the Polar Antarctic Zone (panel c) and the Southern Ocean Sea Ice Zone (panel d) the floats (black dots) are significantly higher ΔpCO2 (leading to more carbon flux out of the ocean) than either the Takahashi et al. (2014) or the Landschützer et al. (2014) climatology (blue and green lines, respectively).

The climatologies tend to agree with the floats within their respective uncertainties during the austral summer when there are significantly more underway pCO2 measurements data to create the climatology. Large disagreements arise when there is no suitable data to constrain the climatology, such as austral winter (see lack of measurements in panel b in the figure to the right) and in ice-covered waters. This disagreement is not surprising, considering (1) the limited availability of austral winter and under ice observations to compute the climatologies and (2) the pCO2 climatologies are based on climatological sea ice cover, which may differ from float observations.

Conclusions

Ongoing shipboard and moored observation programs show that the pCO2 from floats is increasing globally as a result of anthropogenic emissions. Nonetheless, our current understanding of the seasonal cycle and interannual variability, and thus the mechanisms controlling pCO2 and air-sea CO2 flux, is lacking over many parts of the world ocean. Despite the estimated 2.7% relative standard uncertainty in current biogeochemical float-based pCO2 estimates, it is clear from the differences between existing climatologies and new float-based pCO2 estimates (pH, TA) estimates that incorporating information from these novel carbon observational platforms can improve climatologies, climate models, and future projections. While true space/time crossovers between biogeochemical floats and shipboard pCO2 systems are rare, and spatial and temporal heterogeneity make direct comparisons difficult, we have shown that a well-calibrated biogeochemical float provides meaningful data that strengthen the current body of pCO2 observations.

References


2. SOCCOM项目的目标
3. SOCCOM浮标的工作原理
4. 如何计算浮标pCO2
5. 浮标数据的应用

这些内容将帮助你理解南大洋碳循环的研究，以及SOCCOM项目如何通过浮标技术来监测和分析这一过程。