ARI Final Report

Controls on CO2 Fluxes in the Marginal Ice Zone: Biological Productivity and Air-Sea Gas Exchange

Rachel H. R. Stanley (Assistant Scientist)
Brice Loose (formerly Postdoc at WHOI, now Assistant Scientist at URI)

Polar ice zones are important regions for transfer of CO_2 between the ocean and the atmosphere. However, CO_2 fluxes in the ice zones have been hard to quantify, in large part because of complicated physical and biological processes. During the winter, sea ice acts as a barrier to transfer of gas. In the spring, when the ice melts, this barrier is removed. At the same time, phytoplankton in the ocean thrive since light and nutrients are plentiful. These phytoplankton take up CO_2 from the surrounding water to form organic carbon, the same way that trees on land do. The interplay between CO_2 uptake by phytoplankton vs. release of CO_2 to the atmosphere in the melting ice zone is not well understood. With the support of the James M. and Ruth P. Clark Arctic Research Initiative, we developed a new methodology for simultaneously quantifying biological production by phytoplankton and air-sea gas exchange in melting ice zones. We used this methodology to study the interaction between ice melt, biological production, and gas exchange in a pilot study in the Bras D'Or Lakes, Nova Scotia. The lakes, an analog to the Arctic environment, provide an ideal "natural" laboratory for studying ice melting processes in an easily-accessible, fully supported field environment.

In the spring of 2011, we brought to Nova Scotia a field-capable mass spectrometer for measuring ratios of O_2 and Ar, which we use as a proxy for biological production, and a gas chromatograph, which we use to measure the air-sea gas exchange of the tracer gases SF6 and ^3He. We set these instruments up on a small commercial vessel and waited for the ice to melt. After almost two weeks of waiting, the ice finally melted and we happily started our experiment. We released the tracer SF6 into the water and tried to locate it finding the boat, all the while measuring O_2/Ar. We successfully found the tracer but then unfortunately, our boat got pushed by the wind and ice into a sand bar and we had to evacuate the ship in a dingy. Luckily all personnel and equipment were fine. However, the boat was not and by the time it was repaired, all the ice was melted. Thus we went home without data but with the resolve to try again. The following year was anomalously warm and there was no ice on the lake. Given that the purpose of our study is to look at the effect of melting ice on gas exchange and biological production, a lack of ice precluded the experiment.

Finally, in 2013, ice was again present and our field season was on. We made several significant improvements that led to a successful field season. Most notably, due to concerns about boats being able to navigate in the heavy ice environment which was crucial to our research, we set up our instruments on land and pumped seawater to them. We chose a small narrows as the site of our work – a region where one bay of the Bras D'Or Lakes narrowed considerably, since the narrow width ensured we would be able to "catch" our tracer as it flowed through. The Canadian ferry service kindly let us set up our equipment in the garage of a ferry building which was right near the shore of the narrows. Thus our expensive, state of the art instruments were nestled among snow blowers, motors for spare boats, and shovels. We pumped seawater using a submersible pump into the building and analyzed it for O_2/Ar, ^3He and SF6. Additionally, to further characterize biological production, we collected samples for triple oxygen isotopes (which provides a measure of total photosynthesis), chlorophyll, nutrients, and phytoplankton and bacteria community composition.

We set up in late March, 2013, well before the ice melted and thus was able to start our time-series under ice-covered conditions. Cara Manning, an MIT/WHOI graduate student advised by Rachel Stanley, remained in Nova Scotia for 6 weeks, making measurements, collecting samples, and maintaining the equipment. Rachel Stanley and Brice Loose spent several weeks each at the fieldsite. Overall we performed two tracer releases. The first, in early April, was an under the ice release – we drilled a hole in the ice upstream of the narrows and pumped tracer directly under. A few days later, we measured the tracer coursing through the narrows. The difference in ratios of 3He and SF6 from when we released the tracer to when we measured it will inform us of gas exchange under ice that was cracking and ponded. Several weeks later, just as the ice was breaking up, we released the tracer for a second time, this time from a zodiac since the ice was no longer safe to stand on. Once again, we were able to successfully measure the tracer as it flowed through little narrows, giving us this time an estimate of gas exchange under ice that was significantly broken up. Throughout the entire time, we measured biological productivity and associated parameters, giving us a detailed dataset of the response of biology in the spring bloom that occurs as the ice melts.

At present we are analyzing the data in order to obtain a detailed view of biological production and gas exchange as ice melts. The resulting data from this field experiment will be serve as the base for a chapter in the PhD thesis of Cara Manning. We expect what we learn will be interesting in its own right as well as provide proof that our novel methodology would be valuable in the Arctic. We are grateful for the support from the Clark Arctic Research Initiative for enabling us to perform this valuable research.

****

Two possible photos and captions follow:

MIT/WHOI graduate student Cara Manning at the ice edge in the Bras d'Or lakes, Nova Scotia, while scouting a suitable site for the tracer release.

WHOI scientist Rachel Stanley, along with collaborators from Cape Breton University, setting up a mooring with conductivity-temperature-depth sensor, current meter and light sensor in Little Narrows, Bra’s D’Ors Lakes, Nova Scotia.