

## **CO<sub>2</sub> IN THE WESTERN ARCTIC OCEAN: A COMPARISON OF DATA FROM THE YEARLONG SHEBA TIME-SERIES STATION, AND TWO SPRINGTIME DATA SETS FROM THE CHUKCHI SHELF**

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The goal of this research was to evaluate seasonal patterns of biological production and respiration in the Western Arctic Ocean with an emphasis on predicting the direction and extent of air-sea carbon exchange. One key objective was to compare the carbon cycle of seasonally-ice-covered Arctic seas to that of perennially-ice-covered seas, with an eye toward predicted changes in future sea-ice coverage due to climate change. Previous work in seasonally-open Arctic polynyas suggested that they are net-autotrophic, with the potential for being one-way sinks for atmospheric carbon. Questions remained about whether seasonally ice-covered Arctic shelves were also net-autotrophic, and about the balance of autotrophy and heterotrophy in the perennially ice-covered Arctic Ocean. Here we report results from research at the yearlong SHEBA field station, established in the perennial ice pack along the eastern edge of the Beaufort Sea between October 1997 and October 1998. We also report results from two U.S. Coast Guard Science of Opportunity expeditions to the Chukchi Shelf during Spring of 1996 and 1998.

At the SHEBA field station, oceanographers observed, for the first time ever with modern methods, most major components of the central Western Arctic Ocean carbon cycle with approximately weekly resolution over an entire year. While perennially ice-covered seas have been historically considered "net heterotrophic," these estimates have typically relied on summertime measurements. With a data set covering an entire annual cycle, we (myself and my collaborators) tested the following hypotheses: that 1) autotrophy exceeds heterotrophy during parts of the year, 2) a seasonal offset exists between autotrophic and heterotrophic production, 3) wintertime heterotrophy is supported by dissolved organic carbon produced locally during the spring and early summer, and 4) local production and respiration balance on an annual basis.

We collected samples for weekly depth profiles (20 samples between 0-240 m) of total dissolved inorganic carbon and alkalinity to detect the biological transformations of carbon between the dissolved inorganic (DIC) and organic carbon (OC) pools, specifically the extent of net primary production during the summer photic period, respiration rates during the dark wintertime, and the effect of springtime ice algae on near-surface DIC concentration. Our work complemented that of other principle investigators, Wheeler et al. and Welch et al., who measured dissolved oxygen and nutrients, particulate and dissolved organic carbon, autotrophic and heterotrophic biomass, and primary and secondary production and respiration. By providing the link between biological processes and pCO<sub>2</sub>, our data allowed us to test additionally whether this region of perennially-ice covered Arctic seas (net heterotrophic, net autotrophic, or balanced) is, on an annual basis, a source or sink for atmospheric CO<sub>2</sub>. These measurements were made in the context of a larger surface heat budget experiment (NSF-SHEBA, DOE-ARM, NASA-FIRE, ONR-HLP) where many biogeochemically-relevant physical parameters were monitored throughout the year.

Over 1200 seawater samples for DIC and alkalinity were collected and transported to UGA for analysis. Samples were analyzed using a SOMMA (Johnson et al., 1993) for high-precision total DIC measurements in seawater. Late delivery of the instrument delayed sample analysis until this year, but the DIC analyses are now complete. Estimates of short-term repeatability on duplicate DIC samples (DOE, 1996) are excellent (0.6 μmol/kg). Accuracy for this new SOMMA is also good, giving an average of  $2008.8 \pm 0.6$  μmol/kg ( $n > 100$ ) for reference material certified at  $2006.6 \pm 0.6$ . This small offset from the standard was constant over 6 months and is likely due to an internal calibration error, so samples can be corrected with confidence. Alkalinity samples are still being analyzed using an auto-mated open-cell potentiometric titrator. Control samples, for checking potential storage effects, were collected from the Arctic during Sept. 1999 and will be processed over the next 2 years.

Results from the perennially-ice-covered SHEBA time series show the strong seasonal effects of sea-ice melt and biological activity on surface DIC, as well as a subsurface maxima in DIC that shallows steadily from 200 m to 100 m between January and October of 1998 (Fig. 1). DIC concentrations generally show a strong correlation with salinity, although a distinct transition in this relationship occurs when the SHEBA ice camp moved from the Beaufort Sea into the Chukchi borderlands in January. This effect can be observed in the relatively high salinity-scaled DIC values (Fig. 2) near the surface before Julian Day 30, 1998. Summertime net-photosynthesis also causes

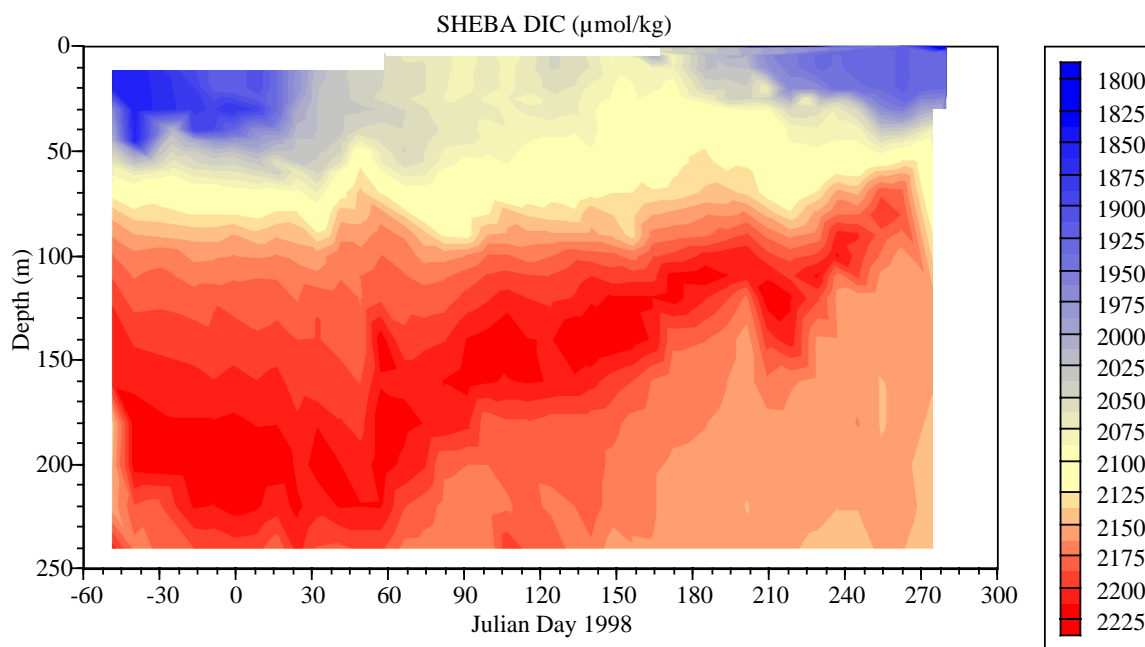


Figure 1: Contour plot of total dissolved inorganic carbon (DIC;  $\mu\text{mol kg}^{-1}$ ) concentration through time at the SHEBA ice station. Time is plotted as Julian Day of 1998, so January 1, 1998 is at 0, and the axes are divided roughly into months and weeks. Data density is 20 samples per profile with ca. weekly resolution.

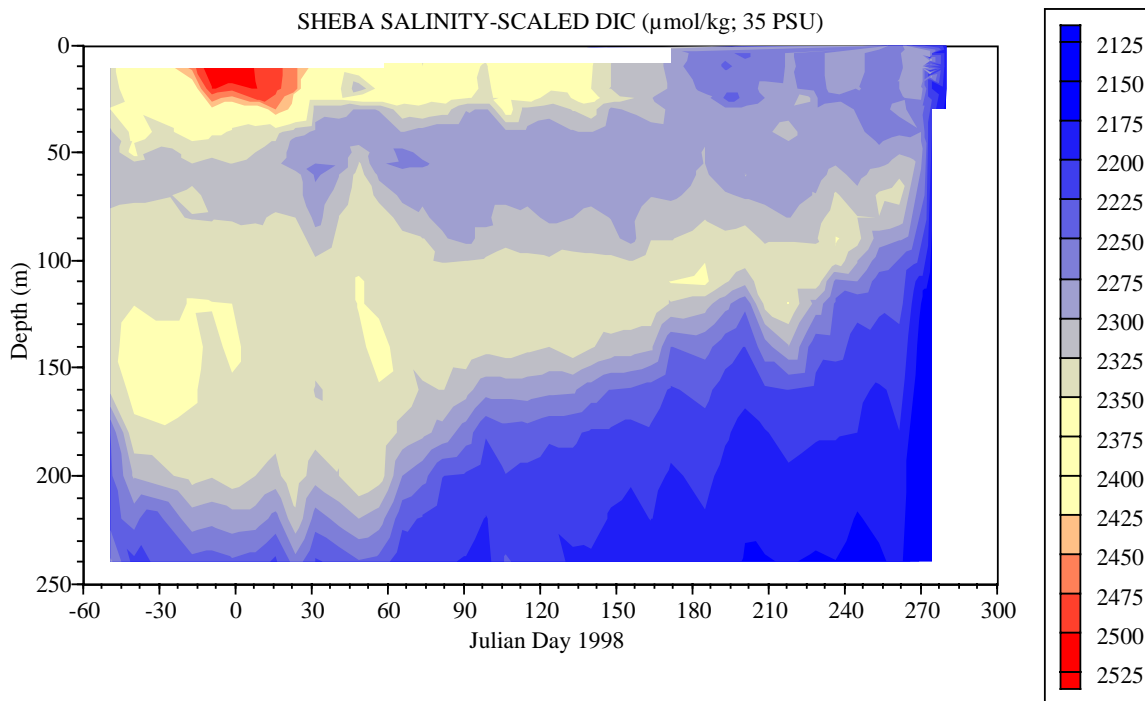


Figure 2: Contour plot (as in Fig. 1) of total DIC concentration scaled to a uniform salinity of 35 psu.

a deviation from the correlation, as seen in the relatively low concentrations in the salinity-scaled DIC between July and September (Julian Day 180-270). Wintertime near-surface pCO<sub>2</sub> estimates were supersaturated with respect to the atmosphere, but summertime pCO<sub>2</sub> was undersaturated. Seasonal changes in salinity-scaled DIC concentrations (Fig. 3) concur with other net community production estimates suggesting that the annual carbon cycle in the perennially-ice-covered Arctic is balanced over the upper 50 m (Sherr et al., submitted). Salinity-scaled concentrations of DIC at SHEBA show very little seasonal change between 50 - 100 m (Fig. 3), suggesting that the system may not be as heterotrophic as previously thought, although the effects of alkalinity sources must still be taken into account. Results from the seasonally ice-covered Chukchi Sea show that springtime under-ice algal blooms can draw pCO<sub>2</sub> concentrations below equilibrium with the atmosphere before the ice melts. This result confirms the springtime component of the rectification hypothesis (Yager et al., 1995) suggesting that seasonally ice-covered shelves are also net autotrophic.

