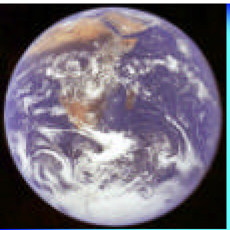

Interannual Variations in Biogeochemical Variables in the Southern Ross Sea

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Abstract

Interannual variations of a number of physical (e.g., ice cover) and biological (e.g, penguin abundance) variables have been documented within various regions of the Southern Ocean for a number of years, but assessment of the long-term variations in nutrient and phytoplankton concentrations is much more difficult. However, an understanding of this variability is essential in order to understand and predict any changes that occur in the future due to anthropogenic forcing. We have begun a study of the interannual variations in the nutrient concentrations and phytoplankton standing stocks in the southern Ross Sea. Three approaches are being used. The first analyzes data collected from a series of cruises conducted from 1970 to the present. These data are compiled to assess the spatial variations within a restricted time period, and also objectively analyzed to produce a biogeochemical climatology of the entire Ross Sea. The second uses moorings to continuously collect chemical and biological data from two locations in the southern Ross Sea, which then are used to estimate the short-term and seasonal net community production. The third collects data from a grid of stations to assess the spatial variations in net community production of the region, as well as the proximate causes for the variations. Initial results suggest that interannual variations in nutrient concentrations, phytoplankton biomass, vertical flux of organic matter and net community production are substantial and are similar in magnitude to those of ice cover and concentration. Annual variability also is confounded by differing seasonal temporal patterns. Assessing anthropogenic changes may be difficult given the substantial interannual variations observed in the past 30 years.

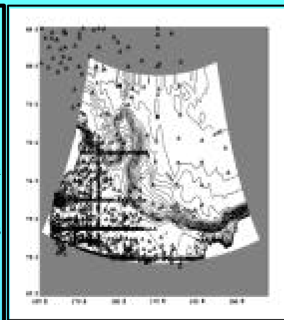

Figure 4. Location of stations used in climatology

The climatology (an objectively analyzed time/space interpolation of all data) of nitrate (Figure 1), silicic acid (Figure 2), and chlorophyll (Figure 3) in the Ross Sea. The data included in the generation of this climatology is shown in Figure 4. In all panels a, b, c and d represent November, December, January and February, respectively. Climatological minima for nitrate and silicate were ca. 12 and 42 μM, whereas the maximum for chlorophyll was approximately 6.0 μg L^{-1}. Chlorophyll and nutrients were inversely related, and biological removal of nutrients was responsible for much of the changes in spring in summer. Physical processes strongly influenced the horizontal distribution of nutrients and the changes in concentration during winter. Substantial spatial variability within the seasonal progression occurs, with phytoplankton growth initially being greatest in the area of the Ross Sea polynya, but by February these differences in large part have been reduced by loss processes. Differences in nitrate concentration of 5 μM remain in February.

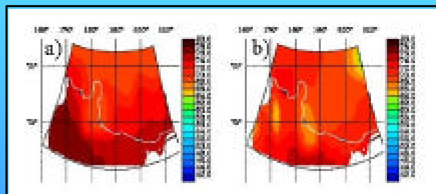

Figure 2. Silicate climatology

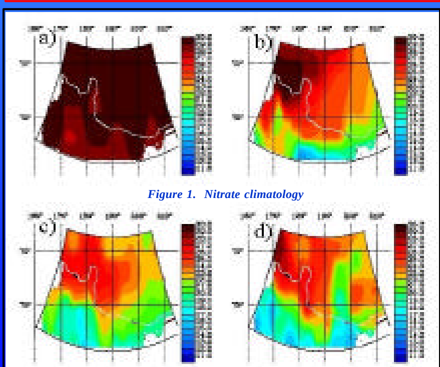

Figure 1. Nitrate climatology

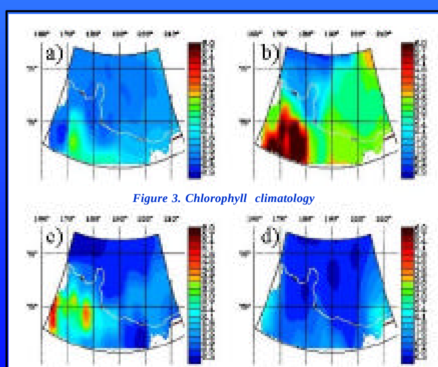

Figure 3. Chlorophyll climatology

Field efforts to assess the interannual variations in seasonal production and nutrient removal began in austral summer 2001-2002 as part of IVARS (Interannual Variations in the Ross Sea). The goals of the project are a) to measure the nutrient deficits across a specified transect over five consecutive years, b) to measure the continuous nutrient concentrations during the austral summer to elucidate the controls of production, and c) to simultaneously measure the vertical flux of organic matter to assess the coupling of production and vertical flux. Results from the first cruise showed that much of the biological removal of nitrate occurred in November and December (Figure 5) and continued through February (Figure 6). The net depletion for the entire growing season was approximately 10 μM nitrate. Silicic acid decreased from > 70 μM (Figure 7) to ~56 μM (Figure 8), a change of about 14 μM. Thus the silica:nitrate uptake ratio over the entire season was about 16, and for the spring growth period it was about 4. This suggests that the early nitrate removal was driven by uptake by *Phaeocystis antarctica*-dominated assemblages, and the modest nitrate removal that occurred after late December was largely by diatoms.

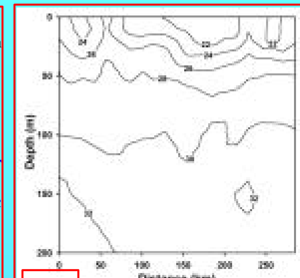

Figure 5.

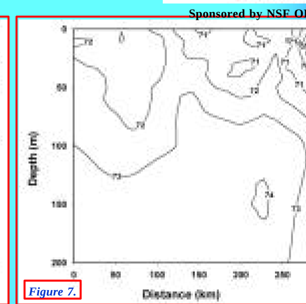

Figure 7.

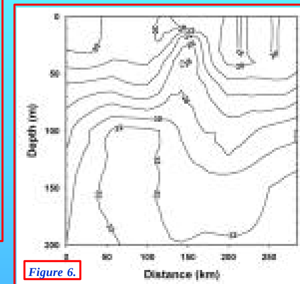

Figure 6.

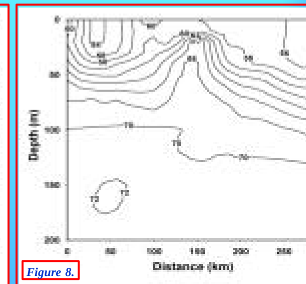

Figure 8.

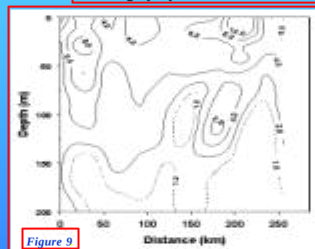

Figure 9

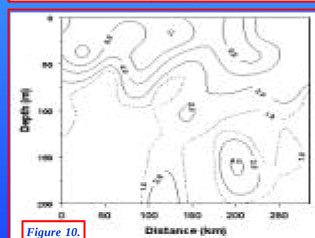

Figure 10.

Chlorophyll concentrations in December were elevated, with the mean surface value exceeding 6 μg L^{-1}, with one station having more than 12 μg L^{-1} (Figure 9). Pigment levels had not dramatically decreased by mid-February, unlike the climatology, and still were 6 μg L^{-1} in the surface layer (Figure 10). Most of the chlorophyll (> 50%) was found in the > 20 μm size fraction during both periods.

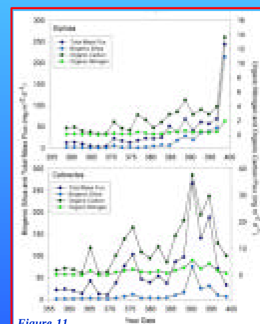

Figure 11.

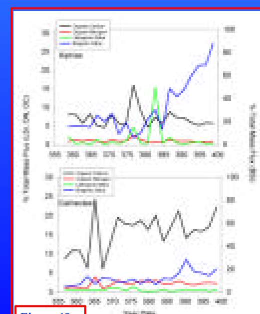

Figure 12.

Sediment trap data suggest that the production and vertical flux of organic material was largely uncoupled during the duration of this experiment. Vertical flux was measured at two sites: Calinectes (77°S, 171°30' E) and Xiphius (77°S, 178°W). The eastern site (Calinectes) was characterized by a much lower contribution of siliceous material and a peak flux around January 19 (Figures 11, 12). The western site (Xiphias) had a peak flux at the end of the deployment (February 7) and up to 85% of the flux being siliceous. Maximum mass fluxes were 290 and 250 mg m^{2} d^{-1} in the east and west, respectively.

Conclusion

The magnitude of interannual variations is difficult to ascertain in polar systems, but it is clear that large spatial and temporal variations do occur, with poorly known biogeochemical and food web consequences. We hope in the coming years to help assess the significance of these changes in the southern Ross Sea and to further understand the controls on these variations.

We thank all those who provided us nutrient and chlorophyll data from previous cruises, especially Drs. Giulio Catalano, Doug Biggs and Kevin Arrigo. Mike Dinniman (Old Dominion University) conducted the objective analysis. IVARS 2001-02 was conducted using the USCGC Polar Star.