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Physical and biological forcing of mesoscale variability in the carbonate system of the Ross Sea (Antarctica) during summer 2014

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ABSTRACT

Water samples (0–200 m) were collected in a coastal area of the Ross Sea in January 2014 to evaluate the physical and biological forcing on the carbonate system at the mesoscale (distance between stations of 5–10 km). Remote sensing supported the determination of the sampling strategy and helped positioning each sampling station. Total alkalinity, pH, dissolved oxygen, phytoplankton pigments and composition were investigated in combination with measurements of temperature, salinity and current speed. Total inorganic carbon, sea water CO_2 partial pressure and the saturation state (Ω) for calcite and aragonite were calculated from the measured total alkalinity and pH. In addition, continuous measurements of atmospheric CO_2 concentration were completed. LADCP measurements revealed the presence of a significant change in current speed and direction that corresponded to a clearly defined front characterized by gradients in both temperature and salinity. Phytoplankton biomass was relatively high at all stations and the highest values of chlorophyll-a were found between 20 to 50 m, with the dominant taxonomic group being haptophyceae. The carbonate system properties in surface waters exhibited mesoscale variability with a horizontal length scale of about 10 km. Sea-ice melt, through the input of low salinity water, results in a dilution of the total alkalinity and inorganic carbon, but our observations suggest that phytoplankton activity was the major forcing of the distribution of the carbonate system variables. Higher CO_3^-, Ω and pH in the surface layer were found where the highest values of chlorophyll-a were observed. The calculated ΔpCO_2 pattern follows both MODIS data and in situ chlorophyll-a measurements, and the estimated CO_2 fluxes ranged from −0.5 ± 0.4 to −31.0 ± 6.4 mmol m^{-2} d^{-1}. The large range observed in the fluxes is due to both the spatial variability of sea water pCO_2 and to the episodic winds experienced.

1. Introduction

The Ross Sea is one of the most productive regions of the Southern Ocean, exhibiting high levels of biomass and primary production, and high flows of biogenic material accumulations on the continental shelf (Armand et al., 2005; Arrigo et al., 2008; Catalano et al., 2010; Saggiomo et al., 1998, 2002; Smith and Comiso, 2008; Smith and Gordon, 1997). Ocean color imagery shows that the phytoplankton blooms are spatially extremely variable in the Ross Sea, even when the surface waters are ice free (Reddy and Arrigo, 2006). In fact, the Ross Sea is characterized by a complex array of ecosystems, each contributing differently to the primary production processes at the basin scale (Peloquin and Smith, 2007). Many differences are known to exist between coastal/offshore waters and thickness of the upper mixed layer (UML) relative to the composition of phytoplankton, as well as in the origin and development of the blooms and transfer of C within the food web (Mangoni et al., 2004; Saggiomo et al., 2002; Smith et al., 2010).

Phytoplankton blooms occur during the austral spring and summer, especially in the waters next to marginal ice zones, within polynyas, and on continental shelves (Garrity et al, 2005; Mangoni et al., 2009a; Moore and Abbott, 2000; Reddy and Arrigo, 2006; Saggiomo et al., 2002; Sullivan et al, 1993). Furthermore, a restricted number of functional groups contribute to this productivity and dominance varies at different temporal and spatial scales (Mangoni et al., 2004; Smith et al., 2010). The two dominant functional groups in the Ross Sea, diatoms and haptophytes (mainly *Phaeocystis antarctica*) have different temporal and spatial distributions, with *P. antarctica* generally dominating in spring in water columns with deeper vertical mixing and diatoms dominating in more stratified summer conditions (Arrigo et al., 1999; Di Tullio et al., 2003; Goffart et al., 2000; Smith et al., 2014). The

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