Influence of primary productivity and carbon export on dissolved oxygen in the Ross Shelf sea.

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Many thanks to Antarctic Science Ltd. for their funding that enabled me to participate in this project.

1 Introduction

The project "Glider Observations of Variability in the Antarctic - Ross Sea (GOVARS): Nutrients and Seasonal Production (OPP/NSF)", led by Prof. Walker Smith (Virginia Institute of Marine Science) ran from November to January 2010/11. This bursary provided funding to contribute one Seaglider from the University of East Anglia (Prof. Karen Heywood) and gave me the great opportunity to participate in the field mission based at the American base on Ross Island (McMurdo Station). This UEA Seaglider added an extra dimension to the observations: while one Seaglider performed a long transect to map spatial variations in ocean chemistry and biology, the other surveyed a smaller region to see how it evolved over time. The University of Washington's Applied Physics Lab refurbished the Seagliders and provided modified control systems for missions under sea-ice. The presence of Prof. Craig Lee (Applied Physics Lab, University of Washington) in the team, one of the Seaglider's principal developers, brought many years of experience relating to their use under sea-ice to the project. Also present during the deployment were Dr. Vernon Asper (University of Southern Mississippi) and Michael Dinniman (Old Dominion University). Piloting was done by Dr. Jason Gobat from the Applied Physics Lab (UW).

Seagliders are autonomous underwater vehicles with a maximum mission length of over 10 months and a maximum operating depth of 1000 m. Each is equipped with CTD, dissolved oxygen, chlorophyll fluorescence and turbidity sensors, as well as the capacity to determine current directions and speeds. This provides high spatial and temporal resolution data, over large distances and periods. Typically, our Seagliders sample every 5 seconds while covering distances reaching 30 km per day and can oscillate between the surface and 1000 m in 6 hours.

The Antarctic is critical in regulating the global marine carbon cycle through its interactions with the atmosphere and its export of deep water. In particular, the Ross Sea is known to be one of the most productive regions of the Southern Ocean; this is partly due to the persistent large areas of open water, or polynyas, present there (Smith Jr and Gordon, 1997). In such regions of upwelling, the increased primary productivity often leads to reduced oxygen concentration mid-water in what is known as the oxygen minimum zone (Gordon, 1966; Jacobs et al., 1970). With this project we aimed to observe variations in phytoplankton primary productivity and trophic impacts; in particular, my intention was to investigate impacts of currents in the Ross Sea polynya on biochemical mechanisms in the water column.

As the polynya opens throughout the austral summer, light penetrates into the nutrient rich surface waters. The melt-water and the increased surface temperature cause strong stratification near the surface encouraging the growth of phytoplankton. Several different phytoplankton communities are observed during these blooms and appear in different areas and at different times. It is the interannual variability in the biomass, timing and distribution of these blooms that we aim to observe.

The particular novelty of this project was our intention to observe the initiation of the spring bloom. This had previously not been possible as all other surveys had previously been shipped based and therefore restricted to later periods of the austral summer once the polynya opened up (Fig. 1). By flying down to Ross Island and deploying our Seagliders from the ice edge, we were able to obtain data while the majority of the polynya was still frozen over.

2 Mission Outcome

My main role on this mission was to provide technical support with the seaglider aspect of the mission. The NSF antarctic contractor (Raytheon polar services) provided flights from Christchurch, New Zealand to McMurdo on the 8^{th} of November. Once on the base, both survival gear and accommodation were provided. Return flights at the end of the mission (26^{th} of November) were also provided by the NSF. This bursary covered my subsistence costs in New Zealand, travel from the UK to Christchurch, New Zealand

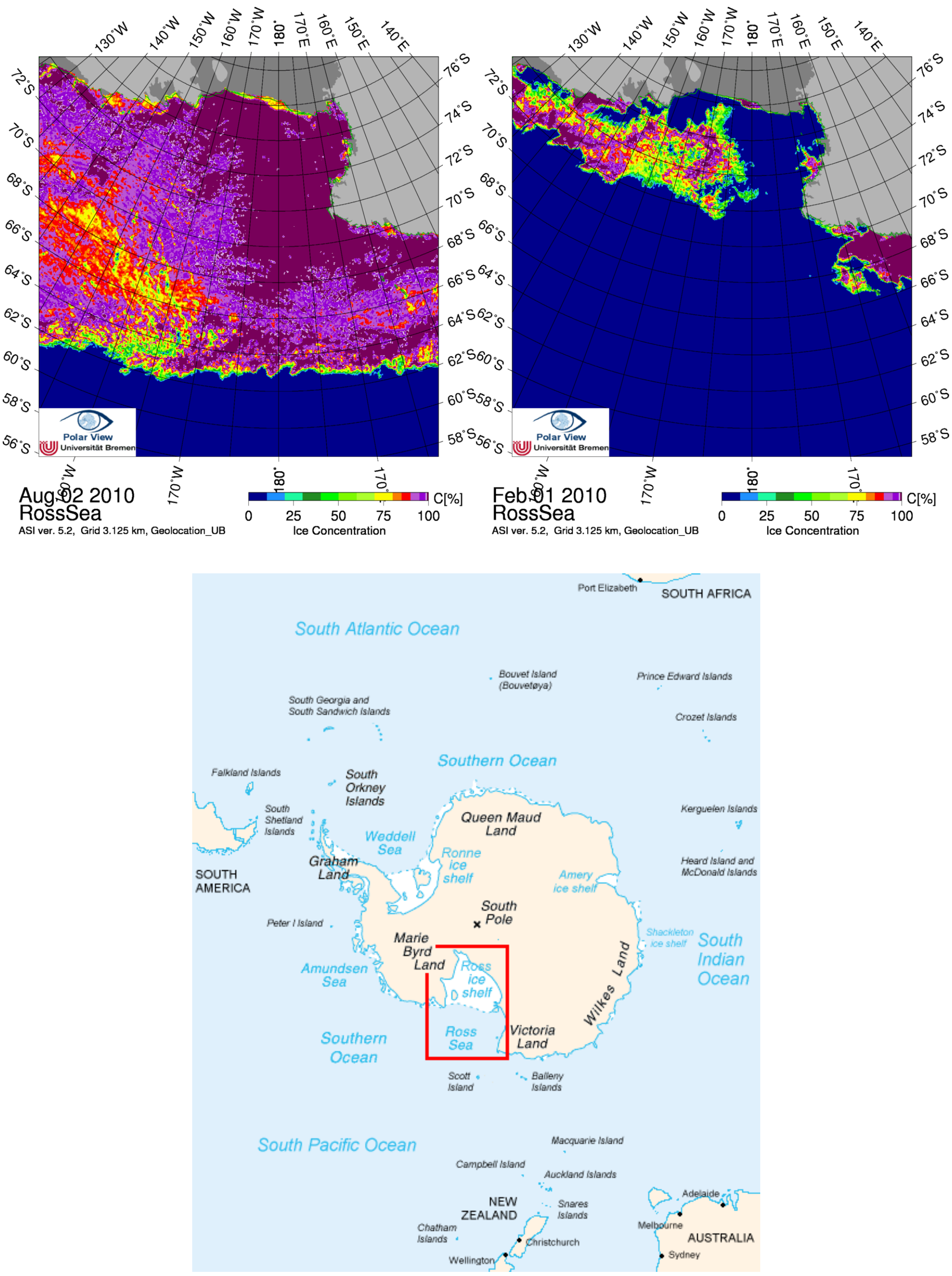

Figure 1: State of the Ross polynya during the austral winter and austral summer. The ice melts from the continent outwards, creating a large area of open water blocked off by ice further north (top). Location of the Ross Sea (bottom).

Figure 2: Launch of Seaglider 502 from the ice edge.

as well as all the necessary medical checks and iridium communications for the seaglider data transfers.

Both Seagliders were launched from shore-fast ice. Seaglider 502, dubbed "Minke", was deployed on the 22^{nd} of November 2010 in McMurdo Sound. This location was far from ideal as we wished to deploy the Seagliders in the Ross polynya located on the other side of Ross Island; unfortunately, ice conditions were much worse in the area of interest and time was pressing. The launch site in the McMurdo polynya also presented dangers of its own, not only were the currents unknown and could have pushed the Seaglider under ice that does not usually melt but the polynya had begun to freeze over slightly due to the exceptional weather. During the summer, good weather leads to the formation of ice whereas storms and windy weather push the ice offshore. This thin layer of "grease ice" prevented the glider from communicating for the first 36 hours. As the ice cleared away, communications improved. We kept Minke in the McMurdo polynya until the ice bridge broke down slightly and then sent it across to the Ross polynya on the 12th of December. This journey over to the area of interest covered over 160 km, 60 of which were under the ice bridge. This was the longest ever under-ice journey without using an external positioning system as the ice blocked all

GPS signals. Once in the Ross polynya, Minke performed 2 repeats of a long zonal transect.

Seaglider 503 was launched on the 29^{th} of November 2010 directly into the Ross polynya from the north side of Ross Island. Because of the extensive and thick ice covering, the Seaglider had to be launched from a breathing hole created, and shared, with minke whales. This required the Seaglider to travel 34 hours north to finally reach open water where it travelled in a butterfly pattern with the centre point midway through Seaglider 502's transect.

Both Seagliders were eventually recovered for the RVIB Nathaniel B. Palmer after 59 days (Seaglider 502) and 63 days (Seaglider 503) having covered 1341 and 1671 km in 701 and 923 dives respectively.

One of the major issues we had to contend with before the deployment was recalibrating the compass. As the deployment site was very near to the magnetic south pole, we were concerned this would disrupt the Seaglider's ability to determine the direction it was facing. To recalibrate the Seagliders, we were required to go out onto the ice, far away from the iron-rich rock which makes up Ross Island.

Data and maps for the entire mission are available on our Seaglider website: http://ueaglider.uea.ac.uk.

3 Preliminary Results

Selected results are displayed in Figures 7 to 11.

4 Expenses

Iridium:	£1788.90
Travel:	£1211.95
Shipping:	£770.58
Subsistence:	£381.05
Insurance and Medicals:	£204.30
TOTAL:	£4356.78

Funding was also provided by a NERC CASE Studentship and NSF grant ANT-0838980.

Figure 3: Seaglider 503 being deployed through a whale hole (top) and surfacing of a minke whale pod minutes afterwards (bottom).

Figure 4: Seaglider equipped with a ComNav Vector G2 satellite compass being calibrated away from hard iron.

Figure 5: The field team in front of Scott's hut. Craig Lee, Mike Dinniman, Bastien Queste, Walker Smith, Vernon Asper.

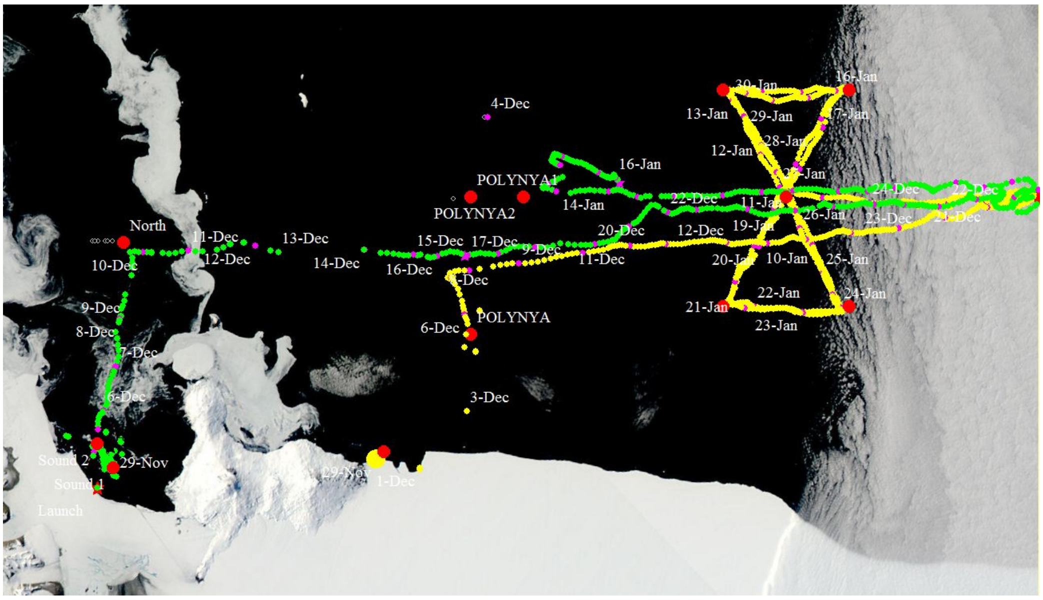

Figure 6: Final Seaglider tracks and positions.

5 Presentations and posters

SAMS SOFI Glider workshop. January 2011, Oban, UK

Seaglider deployment in the Ross Sea : advantages of glider platforms and preliminary results. (talk)

EGO 2011. March 2011, Las Palmas de Gran Canaria, Spain

Seaglider deployment in the Ross Sea: advantages of glider platforms and preliminary results. (talk)

CEFAS Student Presentation. June 2011, Lowestoft, UK

Seaglider deployment in the Ross Sea: advantages of glider platforms. (poster)

References

Gordon AL (1966) Potential temperature, oxygen and circulation of bottom water in the Southern Ocean. Deep Sea Research and Oceanographic Abstracts 13(6):1125–1138, DOI 10.1016/0011-7471(66)90704-2

Jacobs S, Amos A, Bruchhausen P (1970) Ross sea oceanography and antarctic bottom water formation. Deep Sea Research and Oceanographic Abstracts 17(6):935–962, DOI 10.1016/0011-7471(70)90046-X

Smith Jr WO, Gordon LI (1997) Hyperproductivity of the Ross Sea (Antarctica) polynya during austral spring. Geophysical Research Letters 24(3):233, DOI 10.1029/96GL03926

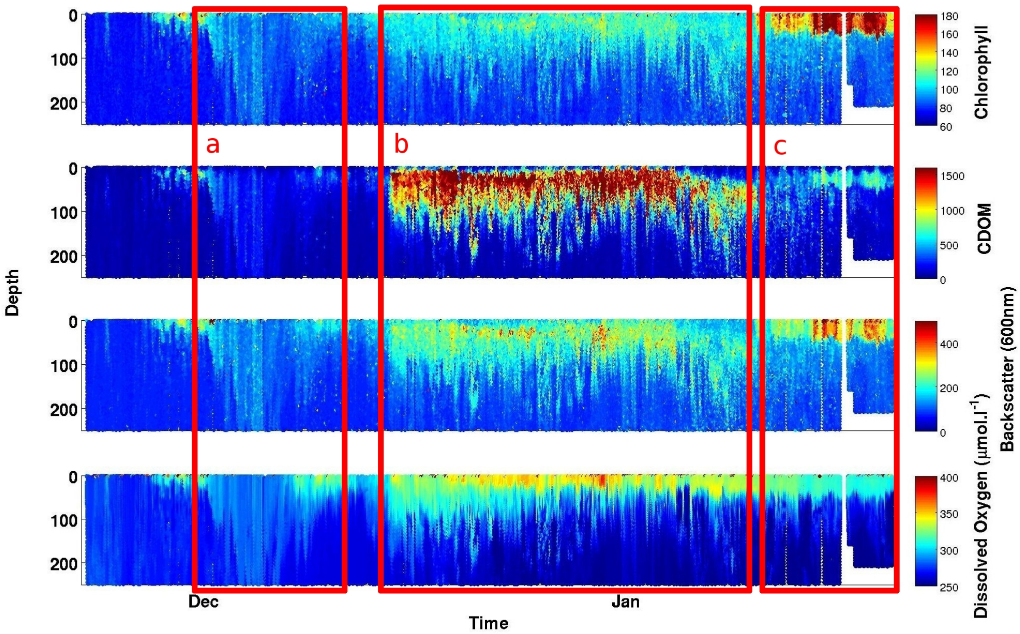

Figure 7: Optical and oxygen data from Seaglider 502. The three different wavelengths on the optical sensor show a succession of different phytoplankton communities. a. Phytoplankton community in McMurdo Sound and around the ice bridge. b. The major bloom event, most likely composed of Phaeocystis spp. due to the high CDOM signature relating to the polysaccharide gel matrix they generate. The elevated oxygen concentration indicates elevated primary production. c. Third community identified by the high backscatter count, this could indicate either a high proportion of Diatom spp. or an increase in zooplankton.

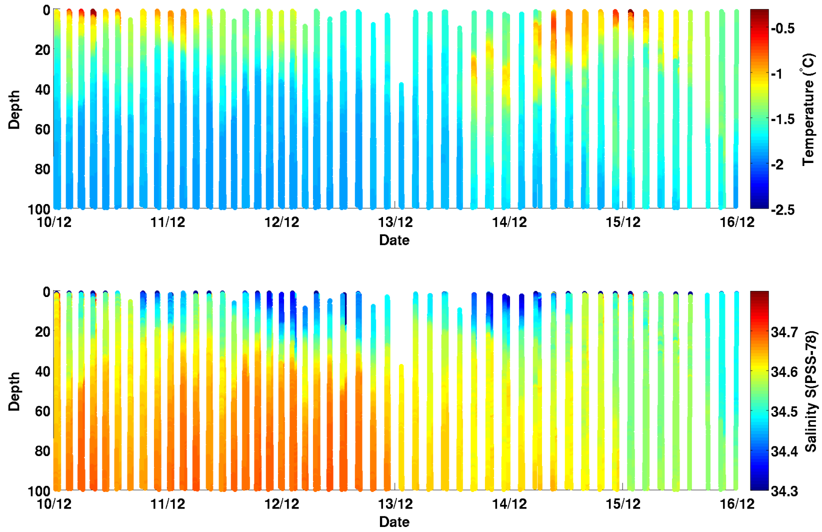

Figure 8: The 60 km passage under the ice-bridge by Seaglider 502. This was the longest ever under ice seaglider flight without an external positioning systems. A strong temperature inversion is visible on the eastern edge of the bridge created by very fresh ice melt at the surface.

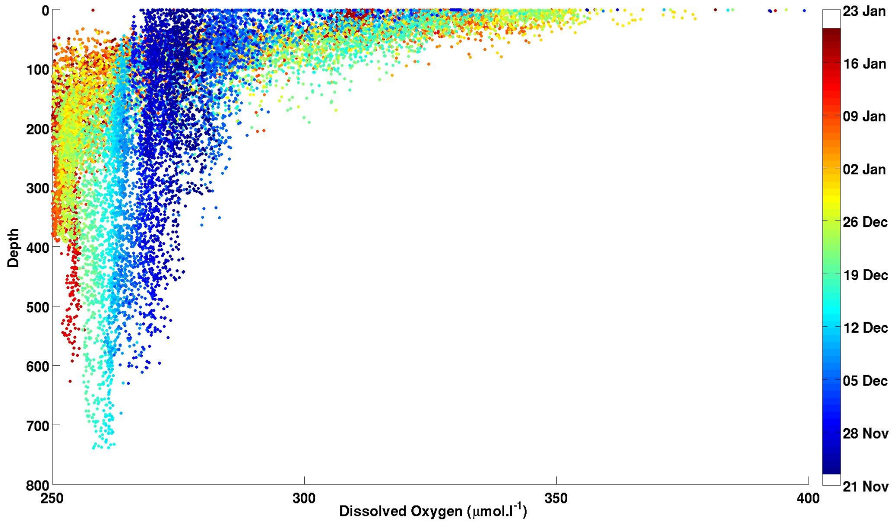

Figure 9: Evolution of dissolved oxygen throughout the austral summer. An increasing difference is visible between surface fresh waters and deeper waters. As the season progresses, surface waters increase in concentration despite their increasing temperature which reduces oxygen solubility; this is due to the very high photosynthesis by phytoplankton. Deeper waters show an opposite trend with gradually decreasing concentrations, most likely due to the consumption of sinking organic matter by bacteria and zooplankton.

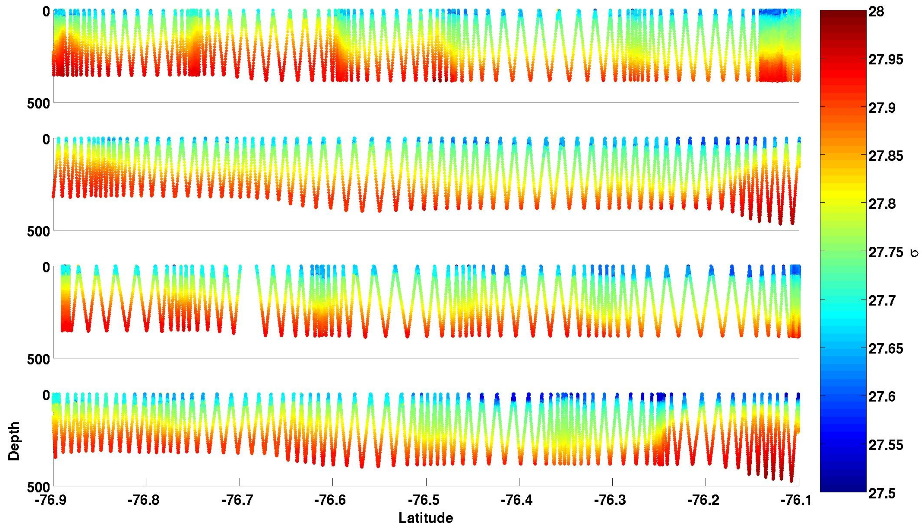

Figure 10: Repeat North-South transects by Seaglider 503 showing the change of mixed layer depth throughout the deployment.

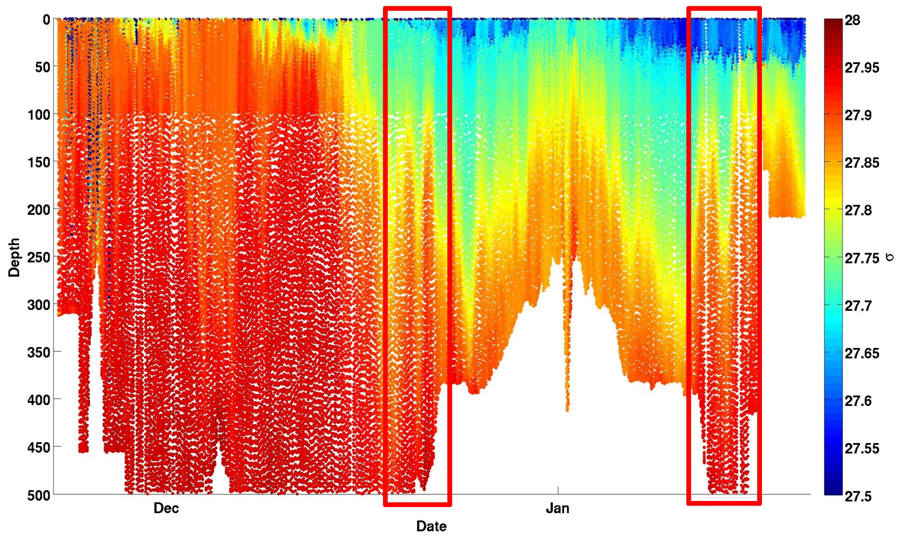

Figure 11: Potential density as measured by Seaglider 502. Highlighted in red is an eddy observed twice. The first time heading eastward, the second while returning on the repeat of the transect.