Oceanographic fieldwork in the Amundsen Sea: An overview of cruise JR141

Deb Shoosmith and **Adrian Jenkins**

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, CB3 0ET, UK

Introduction

This report provides an overview of a 2006 cruise to the Amundsen Sea, the oceanographic data collected, and how we intend to use these data to further our understanding of the physical oceanography of this region. The Amundsen Sea, located in the eastern Pacific sector of the Southern Ocean, is a region where ice shelves are rapidly thinning (Shepherd et al., 2004). The widespread, coherent nature of the thinning suggests a reaction to external forcing. Given that air temperatures are below freezing year-round, the most likely instigator of rapid change is the ocean.

The Amundsen and Bellingshausen Seas have water properties unlike anywhere else around Antarctica. Circumpolar Deep Water (CDW), which elsewhere is found only within the Antarctic Circumpolar Current (ACC), floods the continental shelves, resulting in the highest water temperatures to be found around the continent. CDW is characterised by temperatures in excess of 1ºC, which is around 3°C warmer than the surface freezing point. When this water mass has access to the base of an ice shelf, melting is one to two orders of magnitude higher than it would otherwise be. Previous studies have shown the link between rapid melting and the presence of CDW beneath ice shelves (Potter and Paren, 1985; Jacobs et al., 1996), and sub-ice shelf melt rates have been found to be sensitive to relatively minor changes in water temperature (Hellmer et al., 1998).

Understanding the mechanisms of the on-shelf transport of CDW and quantifying the associated heat fluxes are clearly key to understanding the oceanographic impact on the ice shelves.

Cruise Overview

In January and February 2006, the *RRS James Clark Ross* spent several weeks in the Amundsen Sea on cruise JR141. This was the first cruise of BAS's ACES-FOCAS[1] program in the eastern Pacific sector of the Southern Ocean. It was, however, primarily a geophysics cruise[2], with just 48 hours of ship time being dedicated to FOCAS physical oceanography. FOCAS objectives relevant to JR141 were:

- Determine primary locations of CDW delivery to the Amundsen continental shelf;
- Quantify the associated heat flux;
- Investigate modification of seawater below floating glacier ice;
- Determine the role of the regional circulation in melting the floating ice shelves.

Planned activities for the physical oceanography included Conductivity-Temperature-Depth (CTD) sections and Acoustic Doppler Current Profiler (ADCP) transects in Pine Island Bay, especially in front of Pine Island Glacier, and on the neighbouring continental shelf. Of

[1] ACES is a BAS core program, **A**ntarctic **C**limate and the **E**arth **S**ystem. FOCAS is a component project, **F**orcings from the **O**cean, **C**louds, **A**tmosphere and **S**ea-Ice.
[2] JR141 was a principal cruise of BAS's GRADES program.

particular importance was a shelf-edge trough at ~114ºW that was previously sampled on JR84 in 2003. This trough was found to be a conduit for CDW to access the continental shelf (Walker et al., in press), and questions that have since been raised mainly concern how representative the section was and how much variability there might be in the on-shelf transport.

Unfortunately, sea ice and icebergs prevented us getting into Pine Island Bay, and our work was confined to a large polynya between approximately 111ºW and 117ºW. Luckily for FOCAS's objectives, it was a shore polynya and we were able to take the ship right up to the fronts of two ice shelves. On trying to access the continental shelf through heavy sea ice, we were only able to complete one CTD station in the shelf-edge trough. Nearly three weeks later when we headed north out of the polynya, the sea ice had shifted southwards and the trough was fully accessible. The first individual station in addition to the full section provides us with a chance to look at short term variability within the trough, albeit only at one location.

During the course of the cruise, a total of 29 stations were occupied. The majority of these were arranged in three sections; one in front of the Getz Ice Shelf, one in front of the Dotson Ice Shelf, and one across the shelf-edge trough (Figure 1). In addition to temperature and salinity measurements from the CTD, samples were taken for oxygen-18 and helium/neon. These will allow us to distinguish between sea ice melt, glacial ice melt and precipitation, refining our estimates of meltwater concentration near the ice shelves. *RRS James Clark Ross* has recently been fitted with a 75 kHz RD Instruments Ocean Surveyor shipboard ADCP, which is capable of profiling to approximately 1000 m depth. In ideal conditions it therefore retrieves data throughout the entire water column over most of the continental shelf, it is only the deepest parts of the troughs near the ice shelves where we will have to use indirect methods to determine velocities.

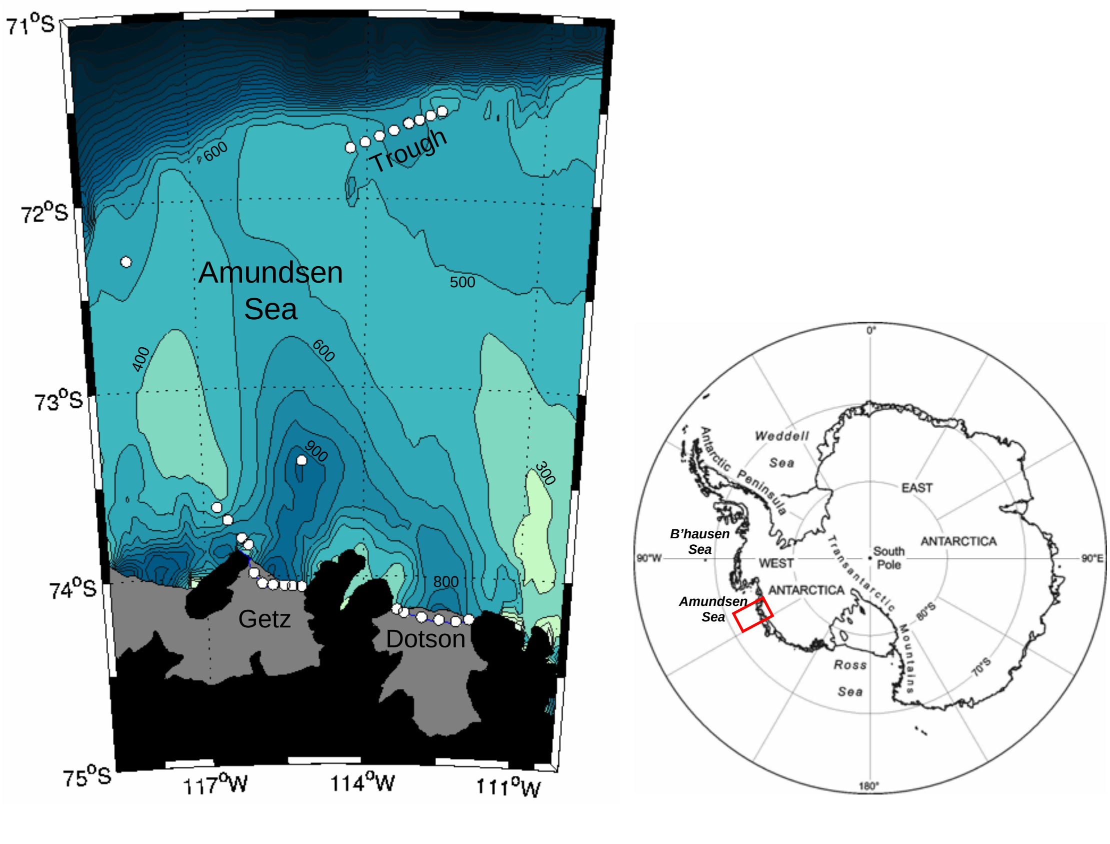

Figure 1. Locations of JR141 CTD stations (white circles), the Getz and Dotson Ice Shelves, and the shelf-edge trough. Red box on Antarctica map (right) shows approximate extent of CTD location map (left).

Oceanographic Observations

Data from 24 CTD stations, making up the three main sections occupied during the cruise, are shown in Figure 2. The warm CDW can be seen at depth on each section, although it has obviously undergone modification by the time it reaches the ice shelves. This modified CDW is still significantly warmer than water on any other of the Antarctic continental shelves which have near freezing conditions throughout the water column. The surface water properties are very variable away from the ice shelves, mainly due to the occurrence of sea ice, which was very patchy during the survey.

The Dotson Ice Shelf is bounded by land and therefore the CTD section at its front fully encloses the cavern of water beneath the ice, allowing transports across the section to be constrained using statements of mass and tracer conservation. These will allow us to determine the warm water inflow to the sub-ice shelf cavity and the melt-water outflow, leading to a calculation of the basal melting rate. Warm modified CDW can be seen at depth throughout the section. Highest temperatures, concentrated on the eastern boundary, are around 0.5ºC warmer than found on an R/V Nathaniel B. Palmer cruise in 2000 (Jacobs et al., 2002).

The Getz Ice Shelf has a number of fronts and we were only able to reach the easternmost of these. The Getz section therefore continues from the front north-westwards across a secondary trough (Figure 1), which should allow us to calculate the total amount of CDW reaching the ice shelf via the main trough. From the bathymetry contours, which it should be noted are based on very sparse data coverage, it appears that the main trough splits to feed both the Dotson and Getz ice shelves. Comparison of the water mass properties on the two ice shelf sections may help to determine whether there is one main route the CDW follows from the shelf edge into this region.

Water properties on the shelf-edge trough section were similar to those found during cruise JR84 in 2003. Almost unmodified CDW with temperatures in excess of 1.4ºC reaches onto the shelf. The CDW extends higher in the water column than in 2003, although whether this means a greater on-shelf transport will have to await further analysis. The single repeat trough station shows that this is quite a variable region, with timescales of variability as short as a few weeks, and thus care should be taken when drawing conclusions from a comparison of just two occupations.

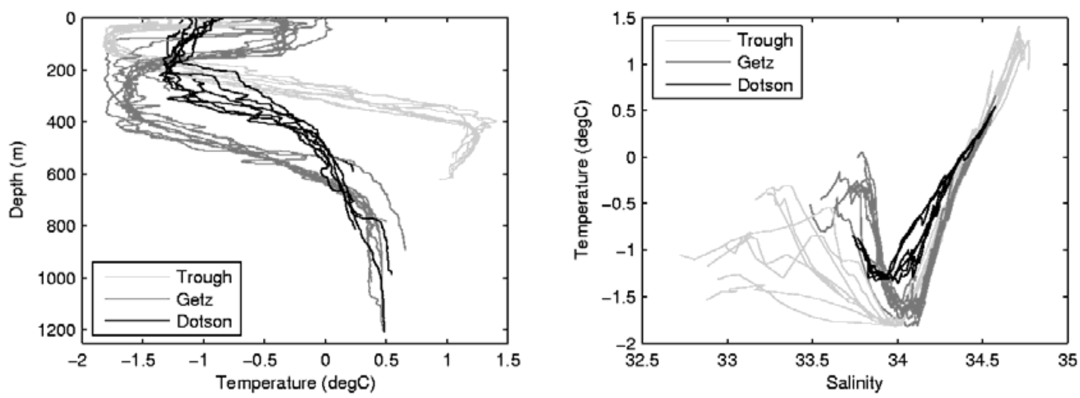

Figure 2. Temperature profiles (left) and temperature-salinity plot (right) of data from the three CTD sections: shelf-edge trough (pale grey); Getz Ice Shelf front (dark grey); Dotson Ice Shelf front (black).

Future Work

Data analysis from cruise JR141 is at an early stage, with work progressing towards providing answers to the following questions:

- How much CDW is transported onto the Amundsen Sea continental shelf within the shelf-edge trough and what is the associated heat flux?
- How variable is the transport and what are the mechanisms that could cause this variability?
- How much CDW reaches the ice shelves and how has it been modified?
- How much melting is occurring at the base of the Dotson Ice Shelf as a result of CDW flowing underneath it?
- To what extent is the ocean driving the rapid ice shelf thinning that has been observed by satellites?

Answers to these questions will significantly further our understanding of ocean circulation on the Amundsen Sea continental shelf and the ocean's impact on ice shelves in this region.

Acknowledgements

We are grateful to the officers and crew of the *RRS James Clark Ross* and participants in cruise JR141, especially Dziga Pozzi Walker, for their assistance in the collection of the data presented in this report.

References

Hellmer, H.H., S.S. Jacobs and A. Jenkins, 1998. Oceanic erosion of floating Antarctic glacier in the Amundsen Sea. In: *Ocean, Ice, and Atmosphere: Interactions at the Antarctic Continental Margin*, edited by S. S. Jacobs and R. Weiss, Antarctic Research Series, 75, AGU, Washington D.C., 83-99.

Jacobs, S.S., H.H. Hellmer, and A. Jenkins, 1996. Antarctic ice sheet melting in the Southeast Pacific, Geophys. Res. Lett., 23(9), 957–960.

Jacobs, S.S., P.A. Mele, G. Krahmann and W.M. Smethie, Jr., 2002. Coastal Ocean Measurements in the Amundsen and Ross Seas, NB Palmer Cruise 00-01, February-March 2000, TR LDEO-2002-2a, Palisades, NY, 370pp.

Potter, J.R. and J.G. Paren, 1985. Interaction between ice shelf and ocean in George VI Sound, Antarctica. In: *Oceanology of the Antarctic Continental Shelf*, edited by S.S. Jacobs, Antarct. Res. Ser., 43, 35-58.

Shepherd, A., D. Wingham and E. Rignot, 2004. Warm ocean is eroding West Antarctic Ice Sheet, Geophys. Res. Lett., 31, L23402, doi:10.1029/2004GL021106.

Walker, D.P., M.A. Brandon, A. Jenkins, J.T. Allen, J.A. Dowdeswell and J. Evans, in press. Oceanic heat transport onto the Amundsen Sea shelf through a submarine glacial trough, Geophys. Res. Lett.