Reading climate signatures in the Southern Ocean

The polar regions are sensitive barometers of environmental change – what we see at both the poles foreshadows what we can expect elsewhere on the globe in a changing climate, and right now they are experiencing some of the most rapid rates of environmental change in the world. Jess Tyler explains how pooling resources in an ambitious polar oceans program, called CASO, will be a watershed in our understanding of the relationship between ocean, atmosphere, ice and climate.

When the icebreaker *Aurora Australis* left Hobart in March this year, the voyage heralded a step-change in science's ability to explore the Southern Ocean – a vast area of the roughest and wildest waters on the planet.

The sailing was part of the Climate of Antarctica and the Southern Ocean project (CASO), the lead in an international cluster of similar projects in the Antarctic Ocean Circulation program of the International Polar Year (IPY).

The science of IPY has been driven by researchers from 63 nations, motivated by urgency and a need to understand the poles and their relation to the rest of the planet. With more than 250 projects, IPY is giving the world an opportunity to harness the collective resources of oceanographic organisations, to take a snapshot of the polar regions in unprecedented detail during a single season.

CASO aims to obtain the first-ever circumpolar snapshot of the Southern Ocean, using the latest technology in a collaboration by oceanographic institutes around the world. It is also complemented by a raft of other IPY programs targeting the biology and chemistry of the Antarctic oceans.

This summer's voyage was led by the Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC), the final sailing in a schedule of more than a dozen expeditions by 18 nations to put together the most comprehensive picture of the region yet taken. The season saw the largest-ever fleet of scientific vessels converge on the Southern Ocean and marked the start of the first international polar ocean–climate study in over a decade.

The *Aurora Australis* was one of the vessels taking part in the international Climate of Antarctica and the Southern Ocean (CASO) project involving more than a dozen expeditions by 18 nations. CASO aims to create the first circumpolar 'snapshot' of the Southern Ocean. ACE CRC

Observing the ocean

The ocean and its relationship with the polar regions plays a key role in global climate by storing and transporting vast amounts of heat and carbon dioxide – if the ocean was not so effective at soaking up heat and carbon, the rate of greenhouse warming would be much greater than the world has experienced so far. Better observations of the polar regions are critical to forecast the implications of this warming for future climate change. In global terms, the Southern Ocean is especially important: it absorbs more heat and carbon than any other part of the ocean and it is the only place where large amounts of water can be exchanged between the other major oceans – the Indian, the Pacific and the Atlantic.

In particular, the belt of ocean circling Antarctica – the Antarctic Circumpolar Current – is an important driver of the Earth's climate. The largest and deepest current in the world ocean, it rings the Antarctic unimpeded by land and influences climate and ocean circulation patterns over much of the globe. The current is in turn driven by a similarly influential and unobstructed circumpolar atmospheric flow, the notorious Roaring Forties and Furious Fifties that blow from west to east around the Antarctic continent largely without obstacle. Together, these tempestuous winds and driving seas have been a long-term barrier to detailed scientific exploration, making the current IPY circumpolar snapshot particularly notable and important.

Detailed knowledge of the isolated and forbidding Southern Ocean continues to be hampered by a lack of observations, even though scientists have been measuring in the south since the epic voyage of the *Challenger* in 1872. Many of the region's key processes are therefore not represented well in today's climate models.

The CASO team was drawn south by an imperative to simultaneously take stock of the Southern Ocean in all its dimensions: physical, chemical and biological. Like other CASO voyages from other nations, the Australian expedition deployed a variety of high-tech instruments to study the ocean circulation and properties, managing to collect in a single season what had taken decades to do in the past.

Satellites and ocean surface drifting recorders provide a single view of the ocean surface, but the most valuable data is within the bodies of water formed and circulating at many levels from the surface to the sea floor. Their chemical signatures are clues to the history of water formation.

Argo floats that have a 10-day cycle profiling between the surface and a depth of 2 km were deployed to measure temperature and salinity in the upper

Focus

2000 m of the ocean. The global array of Argo floats, now numbering more than 3000, is particularly valuable in remote regions like the Southern Ocean, where in a few years the floats have already collected more profiles than the entire history of ship-based oceanography. The Argo program is providing an unprecedented view of the inner workings of the Southern Ocean.

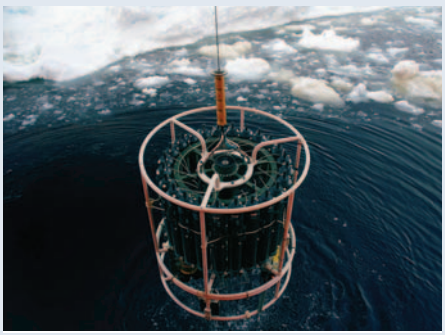
The CASO team also deployed moorings to provide long records of ocean currents, temperature and salinity, including instruments to make the first accurate measurements of how much dense water sinks near the Antarctic coast south of Australia.

ACE CRC Program Leader Dr Steve Rintoul, co-Chair of the international CASO program, was also the Voyage Leader and Chief Scientist on the trip. Dr Rintoul is a Fellow at CSIRO Marine and Atmospheric Research and is deeply immersed in investigating the role of the Southern Ocean in the Earth's climate system.

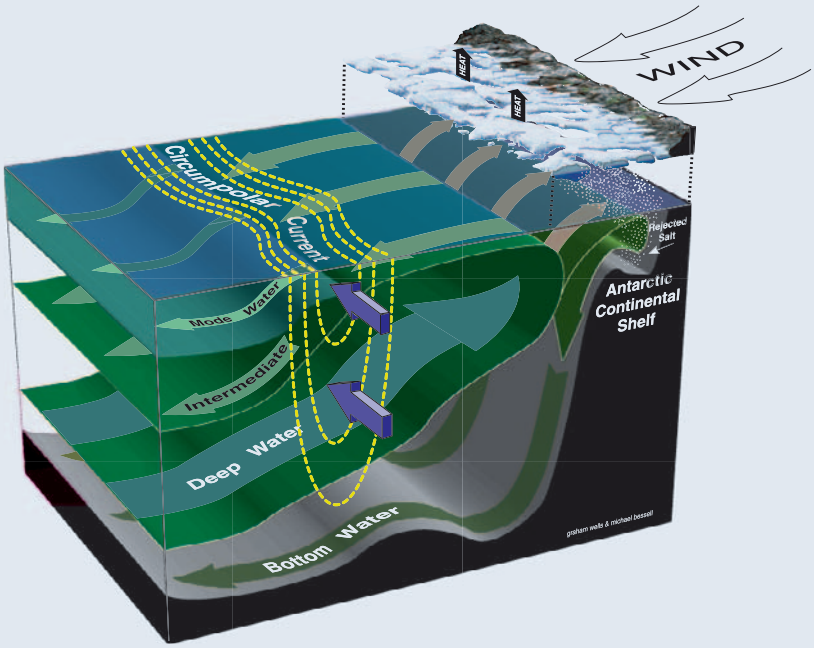
He says the critical questions motivating the immense collective effort are: Is the Southern Ocean changing? And if so, what are the consequences for climate and biological productivity?

'The dense water sinking near Antarctica is part of a global system of ocean currents that determines how much heat and carbon dioxide the ocean can store. Changes in these currents could therefore have implications for the rate of future climate change.'

'We targeted a crossroads of two of the three major sources of dense bottom water, allowing us to assess how rapidly this important part of the ocean is changing,' says Dr Rintoul.



The Australian expedition led by Dr Steve Rintoul deployed a range of high-tech sensors to study ocean circulation, managing to collect in a single season what had taken decades to do in the past. ACE CRC



The Antarctic Circumpolar Current is an important driver of the Earth's climate, circling the Antarctic, unimpeded by land. Cold, dense water sinking near Antarctica is part of a global system of ocean currents that determines how much heat and carbon dioxide the ocean can store. ACE CRC

Going global

Oceanographer Dr Eberhard Fahrbach from the Alfred Wegener Institute of Polar & Marine Research (AWI) in Germany, also a Chair of the CASO program, led a separate CASO expedition on board the German research vessel *Polarstern* with 58 scientists from 10 countries. AWI is a partner in the ACE CRC and is involved in both CASO and a sister project in the Arctic called DAMOCLES. Together, CASO and DAMOCLES provide the important bipolar perspective on the role of the polar regions in the global climate system.

According to Fahrbach, the CASO project is the basis for understanding the opposing – yet inextricably linked – developments in the Arctic and Antarctic.

'If we look on the time-scales of climate, there is only one inter-connected global system,' Dr Fahrbach says. 'If our climate models are wrong in one hemisphere, their results will be wrong globally after some time. To trust model results, it is necessary to validate them globally with appropriate observations.'

'The pattern of change is not the same in both hemispheres. For example, the amount of sea ice in the Arctic has declined dramatically in recent years, while the Antarctic sea ice appears not to have changed much, [although] … the part of Antarctica extending north towards South America has experienced some of the most rapid warming on the planet,' he says.

'Comparing the behaviour of the two polar regions is a good way to test our understanding of the important physical processes. We are far from understanding why the northern and southern hemispheres behave so differently, and so we are far from understanding regional climate change.

'We need observation systems that allow us to track changes, then we need to improve the models so that they are able to reproduce the observations. Only then will we be able to provide robust regional climate scenarios.

'The circumpolar view is critical, and this is only possible with efforts like CASO.'

Oceanic changes are often visible only over several years, and the ambitious CASO program aims to help close the gap in the longer term for improved climate predictions from models. A better understanding of southern polar input to climate can be incorporated. Importantly, it will leave a legacy of a sustained, cost-effective and high-tech observing network for Antarctica and the Southern Ocean critical to provide the information and understanding needed to detect, forecast and adapt to future changes in climate.

More information:
International Polar Year, www.ipyeducation.org.au

CASO, www.acecrc.org.au/drawpage.cgi?pid=voyages&aid=797563