IN DEEP

AUSTRALIAN RESEARCH IN THE SOUTHERN OCEAN

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In deep: Australian research in the Southern Ocean

This edition of the *Australian Antarctic Magazine* features the Southern Ocean. Formed 130 million years ago when the supercontinent Gondwana broke up and Africa, South America, India and Australia moved northwards, the Southern Ocean surrounds Antarctica. Its major current, the Antarctic Circumpolar Current, rotates clockwise around the continent and mixes the waters from the southern parts of the Earth's three great oceans – the Atlantic, Pacific and Indian. Its cold waters hold much oxygen, and the rich nutrients of the surrounding oceanic abyss, coupled with the short but intense spring and summer growth periods, support vast populations of krill, fish, seabirds, penguins, seals and whales.

The Southern Ocean touches the lives of us all.

Despite its remoteness, the Southern Ocean has been overexploited on a truly vast scale. As Steve Nicol showed in his article in the last edition of *Australian Antarctic Magazine* 3:6 first seals then whales, fish and krill were subject to intense and unregulated harvesting with many species being brought to the brink of extinction *(Figure 1)*. Andrew Constable reviews the key international instruments that are now in place to govern the sustainable management of the region, and talks about our recently established Southern Ocean Taskforce and our attempts to develop strategic approaches to the conservation of Antarctic marine living resources and their sustainable use, as well as to the growing problem of illegal, unreported and unregulated fishing. There is much to be done, and little time remaining.

The Southern Ocean touches the lives of us all. The rotation of the Earth generates air movements that travel to the north east from the edge of the Antarctic continent. The steady march of cold fronts that flick across southern Australia indicates how much our weather is influenced by what is going on down south. Our work in the Cooperative Research Centre for the Antarctic and Southern Ocean, based at the University of Tasmania, has taught us much about how ice, water and atmosphere interact in the generation of the world's weather. Steve Rintoul and John Church point out that the Southern Ocean functions as a huge heat sink, storing and transporting heat from one part of the Earth to another. The release of heat into the atmosphere influences temperature and rainfall far to the north. Nathan Bindoff and Helene Banks show us that change is happening in the Southern Ocean and that it is warming and becoming less salty in parts. These changes affect the sinking of cold, dense salty water and influence not only our climate and weather patterns but also the circulation patterns of the Earth's ocean currents.

It is not only heat that the Southern Ocean stores. Carbon dioxide – the greenhouse gas given off during combustion of organic materials – is stored in huge amounts by the ocean. It is incorporated by marine plants into their tiny skeletons (see pictures by Harvey Marchant on p. 21) and eventually finds its way to the sea bed. Here it can remain for thousands of years, locked away in the ooze and detritus that coats the ocean floor. As humans produce increasing quantities of carbon dioxide we need to better understand how the oceans can help to strip this gas from the atmosphere. Bill Budd and Roland Warner from the Antarctic Cooperative Research Centre have developed models incorporating carbon dioxide levels higher than we currently experience into long-term models of the stability of Antarctic ice-shelves. They suggest that the great ice-shelves of Filchner-Ronne and the Ross Sea will disappear within a few centuries under an enhanced warming regime. By the time two millennia have passed it may be possible to navigate a ship from the Ross Sea into the Weddell Sea! Our models are only as good as our data, and the Southern Ocean has been less studied than the Earth's other oceans, but the predicted changes to ice abundance and sea-level rise are of great concern to the future management of coastal Australia and elsewhere in our region.

The Southern Ocean is a living, breathing, organic body of water that embraces us and nurtures us in ways we cannot yet fully appreciate. The articles in the pages that follow reveal some of its challenges and delights.

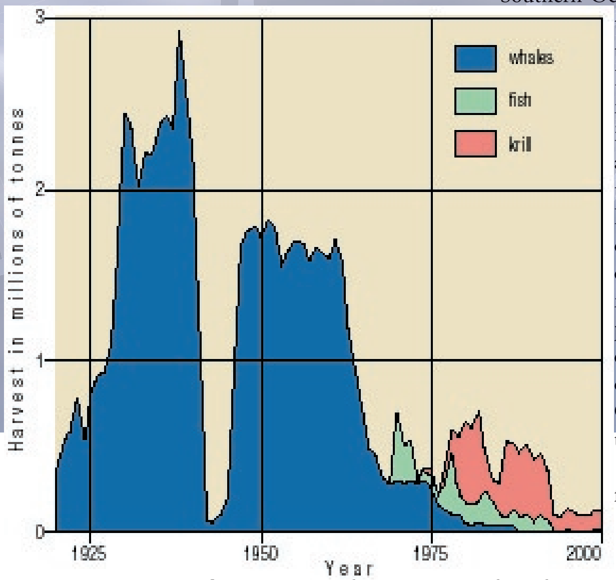

Figure 1. Harvesting of Antarctic marine living resources in the 20th century

Fittingly, we begin this 2002-03 Antarctic season with a major marine research voyage. Deep ocean moorings with automated sediment traps will be deployed and the contents analysed to help us understand the role of the Southern Ocean in controlling atmospheric CO_2 levels. Scientists will also be studying the primary productivity of sea ice microbial communities – a vital link in the Southern Ocean food web – in the region of the Mertz Glacier polynya, and the melt rate of giant iceberg B9B. Later in the season another major marine program will investigate the distribution and abundance of krill in the part of the ocean where our Béchervaise Island Adélie penguins feed, and continue the study on the effects of UV radiation on aquatic micro-organisms. On the latter part of that voyage scientists will examine the structure and flow of the Antarctic Circumpolar Current, a key to understanding the global climate system.

Also in this edition you will find news of the current season's field-based activities, and of a number of interesting developments that have occurred during the past six months. We have a big season to manage this year: the work in the Southern Prince Charles Mountains, being conducted jointly with Germany's Bundesanstalt für Geowissenschaft und Rohstoffe (Geological Survey) is a major undertaking that will provide valuable information about the geological and glaciological histories and past climates of eastern Antarctica. At Casey we are continuing with work on cleaning up the Thala Valley tip site, and at Mawson we are building a wind turbine farm. Davis should see the installation of a VHF radar array, and upgrades to the LIDAR. Again at Casey, we are undertaking preliminary work on a blue-ice runway. At Cape Denison we will continue vital conservation work on the wooden huts used by the Australasian Antarctic Expedition 1911-1914 led by Douglas Mawson. And in addition we have very many other terrestrial and marine projects in many places to complete!

I wish you and your families well for Christmas and I hope your New Year will be as rich and fulfilling as ours promises to be.

The Southern Ocean's global reach: a crucial cog in Earth's heat engine

The ocean influences the Earth's climate by storing and transporting vast amounts of heat, moisture and carbon dioxide. Heat absorbed by the ocean in one location may be carried

The Southern Ocean is a crucial cog in this global heat engine, in part because of its unique geography: the Southern Ocean occupies the only band of latitudes on Earth where ocean waters circle the globe. This simple fact turns out to have profound implications for the global ocean circulation and the Earth's climate system.

thousands of kilometers before being released to the atmosphere. This release of heat in turn drives motions in the atmosphere that determine the large-scale, slowly evolving temperature and rainfall patterns that make up our climate.

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The circumpolar channel of the Southern Ocean allows a vast ocean current, the Antarctic Circumpolar Current (ACC), to circle from west to east around Antarctica (*Figure 1*). Because the ocean basins are almost surrounded by land except at their southern boundaries, the ACC is the primary means by which water, heat, and other properties are exchanged between the ocean basins. For example, the ACC carries about 145 million cubic metres of water per second from the Indian to the Pacific basins south of Australia, a flow equivalent to about 150 times the flow of all the world's rivers combined. The ACC connects the Atlantic, Pacific and Indian Oceans to form a global network of ocean currents that redistributes heat around the Earth and so influences climate. The inter-basin connection provided by the ACC also means that what happens today in the South Atlantic, for example, may flow downstream to influence Australian climate some years later.

The flow of the ACC is concentrated into a number of narrow jets, or fronts. The two most important fronts, the Subantarctic and Polar Fronts, are shown in Figure 1. Water properties like temperature, salinity, oxygen and nutrients tend to change rapidly as one passes from north to south across the ACC fronts. As a result, the fronts coincide with boundaries between distinct biological communities. In fact, early oceanographers could determine which side of the fronts they were on by the presence or absence of particular species of krill.

The massive flow of the ACC is driven by some of the strongest winds on the planet. The persistent westerly winds, punctuated by frequent gales, led sailors to christen the southern latitudes the 'Roaring Forties' and 'Furious Fifties.' The strong winds also create some of the largest waves encountered in the ocean, as many ANARE expeditioners would recall all too well.

The circumpolar connection in the Southern Ocean also permits a global-scale overturning (or thermohaline) circulation to exist. The overturning circulation carries layers of warm near-surface water and cold deep water in alternate directions, resulting in a net transport of heat (and other properties). The Southern Ocean plays a unique role in the overturning circulation as well.

Water found at intermediate and abyssal depths at low latitudes rises towards the surface in the Southern Ocean. Where these layers reach the sea surface, the water characteristics are modified by intense interactions between the ocean, the atmosphere, and sea ice (Figure 2). Some of the upwelled water is warmed by the atmosphere and freshened by rainfall and melting sea ice, and becomes less dense. The modified water is driven north in the wind-driven surface layer and ultimately sinks to return to lower latitudes. Deep water that upwells closer to Antarctica is cooled by the cold air blowing off the continent and its salinity is increased by brine released during sea ice formation. The dense water produced in this way sinks near the continental margin of Antarctica and returns to the north in deep currents flowing along the sea floor.

The water masses formed in the Southern Ocean spread throughout the world ocean; in fact, the characteristics of more than 50% of the ocean volume reflect the ocean-atmosphere-ice interactions taking place in the Southern Ocean. When these new water masses sink from the sea surface, they carry oxygen and carbon dioxide into the deep sea, to 'renew' or 'ventilate' the sub-surface ocean. In the absence of dense, oxygen-rich water sinking near Antarctica, the deep ocean would have very low oxygen levels. In this sense, the Southern Ocean acts as the 'lungs' of the deep sea.

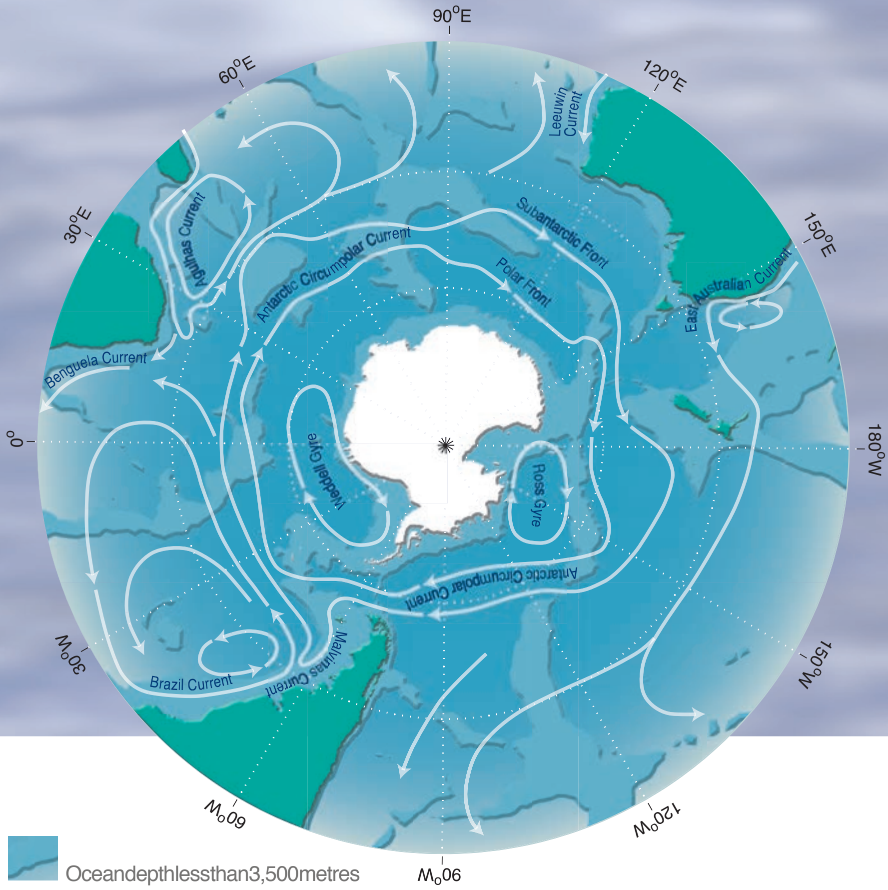

Figure 1. The major ocean currents south of 20°S are shown by the arrows. The largest current in the world ocean, the Antarctic Circumpolar Current, circles from west to east around Antarctica.

As well as gases like oxygen and carbondioxide, the Southern Ocean absorbs heat from the atmosphere. The overturning circulation carries the excess heat from the surface down into the interior of the ocean, causing sea-level rise through thermal expansion. The formation, sinking and circulation of Southern Ocean water masses will contribute to the regional distribution and rate of sea-level rise in the southern hemisphere as the Earth warms in response to the enhanced greenhouse effect.

The water sinking in the Southern Ocean also carries carbon dioxide into the ocean. About one third of the carbon dioxide produced by human activities is accumulating in the ocean, slowing the rate of climate change due to the enhanced greenhouse effect. Of this, 40% is being sequestered in the Southern Ocean by water masses sinking from the sea surface as part of the overturning circulation. (The role of the Southern Ocean in the Earth's carbon cycle is described in more detail 'The Southern Ocean and the carbon cycle: unfinished business' on p.6).

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The existence of sea ice is another important factor contributing to the Southern Ocean's influence on climate. Each winter, enough sea ice forms around the continent

What is the Southern Ocean?

The Southern Ocean refers to the ring of ocean that circles Antarctica. While the Antarctic continent provides a clear southern boundary, the northern limit of the Southern Ocean is not so clearly defined. Oceanographers usually consider the Subtropical Front - a transition zone between cool, fresh, nutrient-rich subantarctic waters and warm, salty, nutrient-poor subtropical waters – to indicate the northern extent of the Southern Ocean. Although the position of the Subtropical Front varies with longitude, it lies roughly along 40°S for much of the Southern Ocean. Defined in this way, the Southern Ocean occupies about 20% of the surface area of the global ocean.

The Southern Ocean is notorious for having some of the strongest winds and largest waves on the planet. It is also home to the largest current in the world ocean, the Antarctic Circumpolar Current. The Circumpolar Current carries between 135 and 145 million cubic meters of water per second from west to east along a 20,000 km long path around Antarctica. While the speed of the current is not extraordinary (about 0.5 m/sec, or 1 knot, at the surface), the great depth (4 km) and breadth (100-200 km) of the current results in a massive transport of water. The flow of the Circumpolar Current is equivalent to about 150 times the flow of all the world's rivers combined, or 500 billion cans per second of your favourite cold beverage.

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Opposite page: Peter Boyer
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to double the area of Antarctica. Even in summer, sea ice remains around many parts of the continent. In addition to providing habitat for Antarctic animals, the sea ice is a significant player in the Earth's energy balance. Snow and ice are bright and reflect light (i.e. they have a high albedo). The more ice present, the more energy from the sun that gets reflected back into space rather than

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absorbed by the earth. As the Earth warms in response to the enhanced greenhouse effect, we expect the amount of sea ice to decrease. The change in the Earth's albedo would act as a positive feedback, tending to further increase the rate of climate change.

The sea ice also influences the ocean. Sea ice is mostly made up of freshwater, so the salt in the seawater is left behind as the ice freezes, increasing the salinity of the water beneath the ice. Seawater gets denser as its salinity increases and as its temperature falls. In some locations, the cooling by the atmosphere and the salt released from sea ice together make the water near Antarctica dense enough to sink from the sea surface to the deep ocean, as illustrated in Figure 2. The sinking near Antarctica forms one branch of the global overturning circulation.

Over the last decade, Australian scientists have made significant advances in understanding how the Southern Ocean influences the climate system. For example:

- Oceanographers have used ships, moorings, and satellites to measure the transport of the Antarctic Circumpolar Current south of Australia for the first time.
- The Adélie Land coast of Antarctica has been identified as a significant source of dense Antarctic Bottom Water, counter to the conventional notion that the Weddell and Ross seas were the only important sources of this water mass.
- The first midwinter expedition to a coastal polynya (an area of open water within the sea ice pack) near the Mertz Glacier has helped explain why this region acts as a 'sea ice factory' and hence a productive source of bottom water.
- A number of multi-disciplinary voyages have provided new insights into the complex interactions between physics, biology and chemistry that together determine how much carbon is absorbed by the Southern Ocean and how biologically productive the region is.
- By combining simple dynamical models with ocean observations, Australian scientists have quantified the Southern Ocean overturning and demonstrated the region's role in the global thermohaline circulation.

What does the future hold? How will the Southern Ocean respond to or drive climate change? Climate models indicate that the Southern Ocean overturning circulation will slow down as the Earth warms. The decrease in the overturning circulation results in a decrease in the amount of carbon dioxide absorbed by the Southern Ocean and a reduction in sea ice extent around Antarctica: both of these changes represent a positive feedback, tending to increase the rate of climate change. A reduction in sea ice would also likely have an impact on Antarctic marine ecosystems. Our limited observations suggest the Southern Ocean is already changing, and the pattern of change is at least broadly consistent with the climate model projections. On the other hand, our climate models are still crude. Many of the Southern Ocean processes that influence climate are not yet well represented in the models. The challenge for Southern Ocean scientists in the coming years is to develop the understanding of the Southern Ocean needed to refine, test, and improve the climate models, and hence provide reliable information to guide policy, adaptation, and sustainable management of marine resources.

Stephen Rintoul and John Church, CSIRO Marine Research

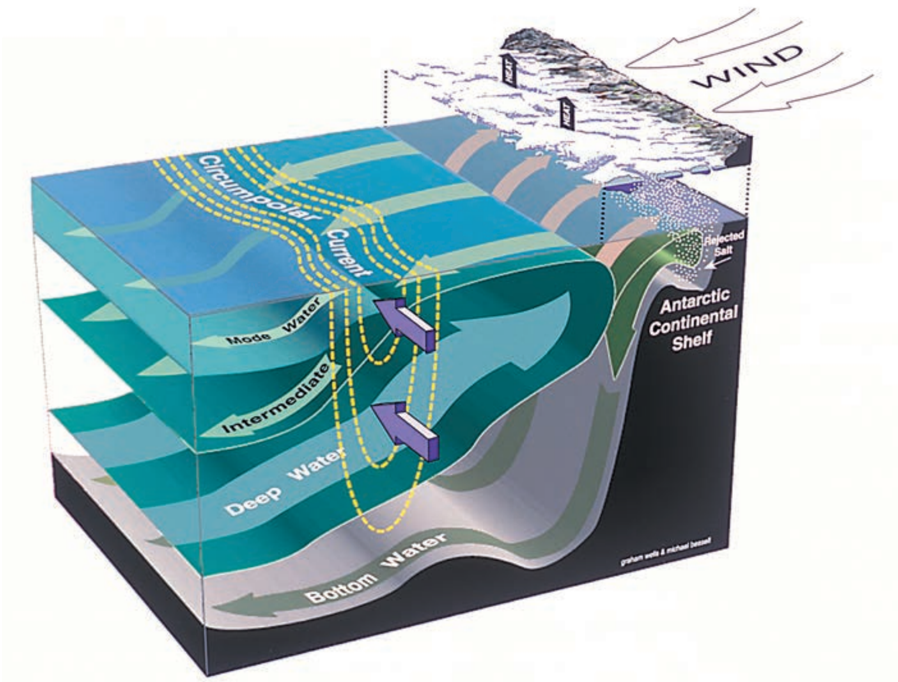

Figure 2. Deep water upwells to the surface south of the Antarctic Circumpolar Current. Part is freshened by precipitation amd melting sea ice, becoming less dense, flows equatorward and sinks as Mode and Intermediate Water. The remainder flows onto the shelf, is cooled and salt added from brine rejected during sea ice formation. This denser water sinks down the continental shelf as Bottom Water and flows north. By connecting the ocean basins, the Antarctic Circumpolar Current allows a global-scale overturning circulation of water masses to exist. The heat carried by this overturning circulation is one of the main ways the ocean influences the Earth's climate.

Observing and detecting climate change in the Southern Ocean

Much of the debate about climate change has been about the evidence for climate change within the limited data sets that are available, and the skill of the coupled ocean-atmosphere models used to create scenarios of future climate. The World Ocean Circulation Experiment (WOCE) has produced new high quality oceanographic data that enables more detailed comparison with coupled ocean-atmosphere models in the Southern Ocean and has established modes of variation or 'fingerprints' of change that can be attributed only to climate change.

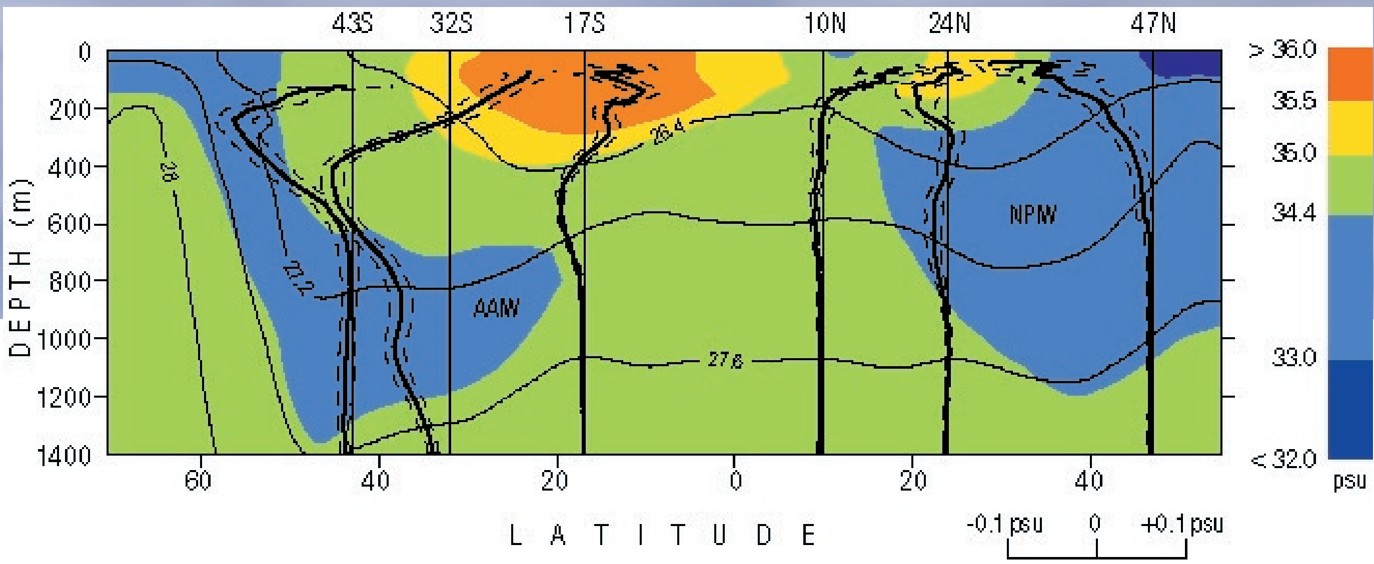

Figure 1. Salinity change on density surfaces for six east-west sections taken in the Indian Ocean (32°S), Tasman Sea (43°S) and South Pacific (17°S) and also in the North Pacific from the 1960s to the 1990s. These differences are overlaid on the average salinity of the ocean, showing fresh Antarctic Intermediate Water (AAIW) below the more salty Subantarctic Mode Waters (SAMW) which lie south of the surface salinity maximum in the tropics (~15°S). The observations show that the waters in the salinity minimum have freshened, suggesting fresher surface waters over the Southern Ocean, and that the SAMW has cooled on density surfaces, which is paradoxically consistent with warmed surface waters. The increase in surface water salinity at 17°S suggests increased evaporation (and warming). PSU is the practical salinity scale for the measurement of salinity.

The oceans are an important component of the overall earth system. The ocean has an extraordinary capacity to absorb heat – approximately one thousand times that of the atmosphere. A direct consequence of the oceans' capacity to store heat (and gases) is that under climate change conditions the ocean can add very long delays to the climate system before coming into equilibrium. Depending on the particular water masses (and depth) the time delay may be decades to centuries to millennia.

The Southern Ocean is one of the least sampled oceans around the world. In particular there are very few surface observations of temperature and salinity that allow trends to be established. However, the International Geophysical Year of 1957–58 inspired oceanographic programs that sampled much of the Southern Ocean with good quality top-to-bottom hydrographic data during the early sixties. Since the large-scale programs in the sixties there have been very few systematic hydrographic programs that have measured the full water column with the exception of the World Ocean Circulation Experiment (WOCE) during the nineties.

Comparison of top-to-bottom measurements from the historical data with modern WOCE sections (43°S, 32°S, 17°S) and recent historical data in the Southern Ocean (Aoki et al., 2003) has shown that there are significant differences between the sixties and the nineties. In particular, Subantarctic Mode Water (SAMW), the water that lies above the salinity minimum and north of 50°S, has freshened (and cooled) on density surfaces (*Figure 1*). Paradoxically this is consistent with warmed surfaces waters sinking into the ocean interior just north of the Subantarctic Front (SAF, or sometimes called the Antarctic Convergence) at about 55°S (*Figure 1*). The water in the salinity minimum, called Antarctic Intermediate Water, has freshened on density surfaces (*Figure 1*) consistent with fresher surfaces waters south of the Polar Front. South of the SAF we find that the waters beneath the mixed layer, and above the oxygen minimum have warmed and freshened on density surfaces. The overall pattern is broadly consistent with the changes expected from climate change scenarios for the next century.

Work with the Hadley Centre using their state-of-the-art coupled atmosphere and ocean model has shown that this broad signal found in the relatively sparse observations (spatially and temporally) is also present in the model for precisely the same period of the observations (*Figure 2*). This model is for the observed changes in atmospheric CO^2 (and other gases) since pre-industrial times through to the 1990s. The model shows that over the 30 year period from the sixties to the nineties the SAMW has freshened (and cooled) on density surfaces just like the observations. AAIW water (the water around the salinity minimum) is also fresher, and that south of the SAF (where the salinity minimum intersects the surface of the ocean) the waters are saltier (and warmer) on density surfaces. The pattern of changes is strikingly similar to the observed changes at depth (*Figure 1*) and with more recent work (Aoki et al., 2003).

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The amplitudes of the signal in the model and data when compared directly are also quite similar, suggesting the expected changes

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from the coupled ocean atmosphere model is consistent with the observed changes.

The predicted changes are not constrained to just temperature changes. The hydrological cycle is expected to be enhanced, leading to a decrease in the difference between precipitation and evaporation in the sub-tropics (increased salinity in the subtropic surfaces waters, *Figure 1* and *Figure 2*) and increased precipitation over the Southern Ocean. In addition, these models also predict strengthened westerlies over the Southern Ocean north of the Antarctic Trough (about 60°S) and increased easterlies south of the Antarctic Divergence. The Antarctic Trough has now been observed to have deepened over the last 30 years, implying stronger westerlies over most of the Southern Ocean and strengthened easterlies near the Antarctic continent.

Although the observed changes are broadly consistent with the coupled ocean-atmosphere models, it is possible that the observed response to increasing greenhouse gases (*Figure 2*) is also a natural fluctuation. This issue has been tested in the coupled ocean-atmosphere model by projecting the climate fingerprint pattern over thirty years from the rising atmospheric CO_2 model on the natural variability in the model. It is found that over an 800 year period the climate change fingerprint (*Figure 2*) was only found to be significant at the 95% level in just a few years, whereas in the climate change scenario for 20th and 21st centuries the fingerprint was found to statistically significant about 30% of the entire period, and particularly from 2000 onwards.

Because the Southern Ocean is circumpolar in extent and has greater surface area relative to the Northern Hemisphere, and is the source region of some of the key water masses, the Southern Ocean has a greater capacity to store heat and to mask the surface signatures of climate change. The Southern Ocean (and Southern Indian and Pacific Oceans) is likely to have a greater climate signal (over noise) at depth and therefore have significant advantages for detecting and monitoring climate change.

New programs for measuring the temperature and salinity within the water column using autonomous profiling floats (the ARGO Program) combined with satellite observations of sea-surface height, with more systematic measurements of precipitation and surface temperatures will greatly enhance these tantalising first results.

Nathan Bindoff, Antarctic CRC &
Helene Banks, Hadley Centre for Climate Prediction and Research, Bracknell, U.K.

Reference

Aoki, S., N.L. Bindoff and J.A. Church, 2003, 'Interdecadal watermass changes in the Southern Ocean between 30E and 160E', *Geophysical Research Letters*, submitted.

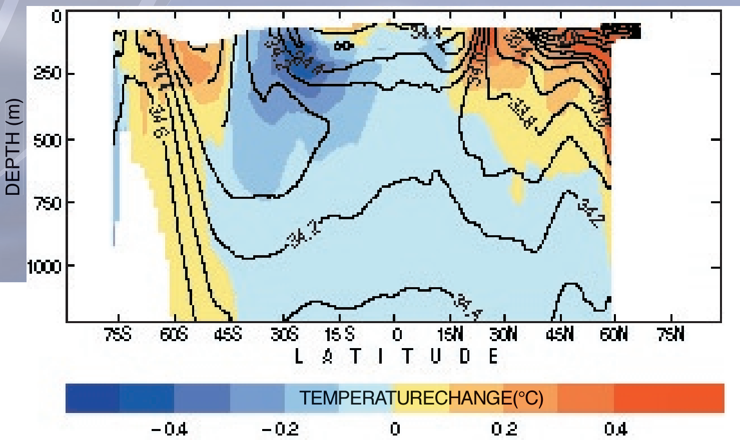

Figure 2. Indo-Pacific zonal average potential temperature change on density surfaces from the state-of-the-art HADcm3 model anthropogenic climate change experiment between 1989-1998 and 1959-1968. Contours show the zonal average salinity field similar to Figure 1. The observations and the model show the same overall pattern, cooling of Antarctic Intermediate Water, cooling of Subantarctic Mode Water and increased salinity near 15°S. Statistical tests show that the signature of change in the model (and data) results from anthropogenic change and not from natural variability. Temperature change on density surfaces has the same pattern as salinity change on density surfaces. (From Banks and Bindoff, copyright J. Climate 2003)

The Southern Ocean and the carbon cycle: unfinished business

Over the past ten years we have unravelled much of the major mystery that surrounded the role of the Southern Ocean in the global carbon cycle. We have made major advances in quantifying Southern Ocean uptake of anthropogenic carbon dioxide, and the role of Southern Ocean biological productivity in the transfer of carbon to the deep sea. But important puzzles remain.

Global carbon cycle models estimating the amount of anthropogenic carbon dioxide

Model	Uptake (Gt C)
Princeton	2.2
Hadley	2.1
IPSL	1.5
MPI	1.6
CSIRO	1.6
Average	1.8

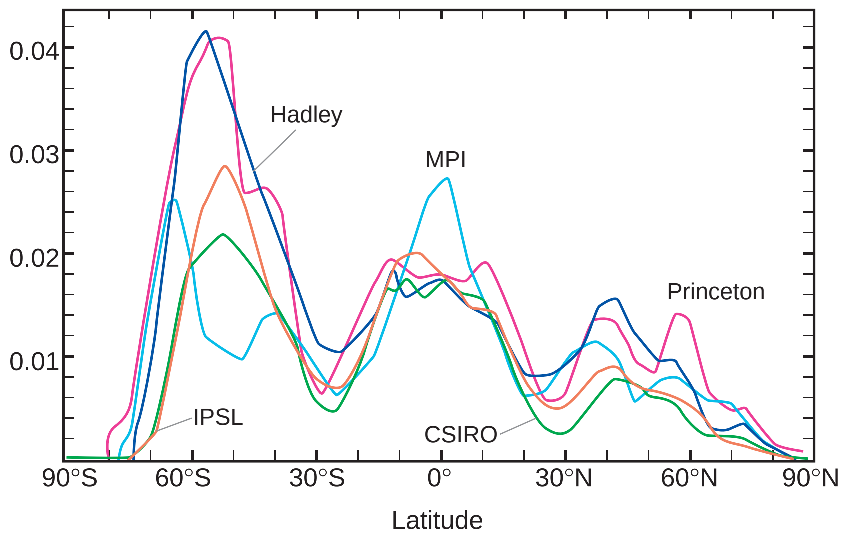

Figure 1. For the 1980s, the oceanic uptake of anthropogenic CO_2 versus latitude from a range of ocean carbon models. Table 1 (left). Global ocean uptake for the 1980s from a range of models used in the OCMIP-1 (Orr, Maier-Reimer et al. 2001) and from the CSIRO ocean carbon model.

absorbed into the ocean from the atmosphere show a wider variation for the Southern Ocean than anywhere else. Even the observations are not in full agreement – atmospheric data suggests a smaller uptake than that estimated from ocean data. The effectiveness of biological processes in moving carbon from the surface to the deep sea is now recognised as high, but the reasons remain unclear, and thus the possible role of biological carbon transfers in past variations in atmospheric carbon dioxide levels remains unknown. Until these issues are resolved, we cannot predict the future of Southern Ocean contributions to the control of global atmospheric carbon dioxide levels.

The recent results from the Ocean Carbon Model Inter-comparison Project illustrate the range in model estimates of the oceanic uptake of anthropogenic carbon dioxide. *Figure 1* shows the latitudinal flux of anthropogenic carbon dioxide into the ocean simulated by the models. The uptake peaks occur in the high latitude Southern Ocean, the equatorial ocean and the high latitude North Hemisphere. From the models, the global uptake of anthropogenic carbon dioxide for the 1980s varied between 1.5 and 2.2 gigatonnes of carbon (Gt C) annually *(Table 1)* which is about 30% of anthropogenic carbon dioxide emissions during this period. The Southern Ocean accounts for approximately 40% of the ocean uptake and 50% of the variability between the models. Observational analysis of the accumulation of anthropogenic carbon dioxide from repeat oceanographic measurements *(Figure 2)* suggests that the lower bound estimate of the uptake is more consistent with observations (Matear 2001).

Model-based predictions indicate the Southern Ocean is a major global sink for anthropogenic carbon dioxide, but sparse data and limitations in measuring techniques have made observational tests of the models difficult. High quality data now emerging from the internationally coordinated Joint Global Ocean Flux Study/World Ocean Circulation Experiment (JGOFS/WOCE) carbon dioxide ocean survey are providing information on how much and where anthropogenic carbon dioxide is accumulating in the ocean. These data are a vital test of the carbon dioxide uptake predictions from models and combined with atmospheric data are leading to a major improvement in our understanding of global and regional carbon budgets for both the oceans and land.

An example of the pattern of carbon dioxide accumulation along a hydrographic section in the Southern Ocean south of Australia is shown in *Figure 2*. The pattern of accumulation is intricately linked to the uptake shown in *Figure 1* and to the large-scale circulation of the Southern Ocean. Old deep water that has a low anthropogenic carbon dioxide rises up in the offshore region around Antarctica and takes up carbon dioxide from the atmosphere. Some of this water mixes with other water before sinking to the seafloor, carrying with it anthropogenic carbon dioxide, to form Antarctic Bottom Water. The southern end of the section in *Figure 2* is one of the few locations around Antarctica where surface waters become dense enough to sink to the seafloor and carry anthropogenic carbon dioxide.

A component of the water which originally welled up off Antarctica is carried north in the surface ocean. As the waters move north they exchange with the atmosphere taking up more anthropogenic carbon dioxide. Eventually, they contribute to the formation of Subantarctic Mode Water and Antarctic Intermediate Water. The mode and intermediate waters are subducted into the ocean interior taking anthropogenic carbon dioxide away from contact with the atmosphere. The formation and subduction of these water masses provide major pathways for anthropogenic carbon dioxide uptake by the ocean and help sustain the large uptake by the Southern Ocean.

Another major advance has been the recognition of the importance of iron to Southern Ocean ecosystems. Use of new measurement techniques and open ocean iron fertilisation experiments have shown that the lack of this essential micro-nutrient limits phytoplankton production in much of the Southern Ocean. Combining these observations with ice-core based estimates of increased dust supply during the time of the last major period of glaciation on Earth (the last glacial maximum, about 25,000 years ago), suggests that increased iron deposition from continentally derived dusts could partially explain the ~80ppm lower carbon dioxide levels of the glacial era in comparison to the pre-industrial era of a few hundred years ago.

Figure 3 shows a SeaWiFS ocean colour satellite image of a large 'bangle' shaped area, about 80 km across, of abundant phytoplankton in the Antarctic Treaty region south of Tasmania (near 61°S). The enhanced growth, known as a 'bloom', was artificially induced during the NZ-UK-Australian organized Southern Ocean Iron Release Experiment (SOIREE) by the addition of about 10 tons of ferrous sulfate heptahydrate over an area of around 55km^2, and persisted for at least six weeks during which an eddy in the Antarctic Circumpolar Current stretched it out and curled it around into the bangle shape (Boyd et al., 2000).

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Following SOIREE in 1999, additional iron fertilisation experiments have been carried out by US and European research consortiums, and more are planned. The primary goal of these studies is to advance understanding of the controls on phytoplankton communities and their role in the global carbon cycle, but they have also raised the possibility of intentional fertilisation for carbon dioxide management or even fisheries enhancement. Knowledge of marine ecosystems is still too rudimentary to permit the efficacy or risks of these ideas to be fully evaluated.

Iron limitation, cold waters, and low light levels (as a result of deep mixing driven by high winds) keep phytoplankton production at low to moderate levels in the Southern Ocean. But the amount of carbon transferred to the deep sea in settling particles appears to be surprisingly high – close to the global median, and higher than regions such as the North Atlantic where phytoplankton abundances are much higher. In *Figure 4* the Southern Ocean results are shown in pink, and have all

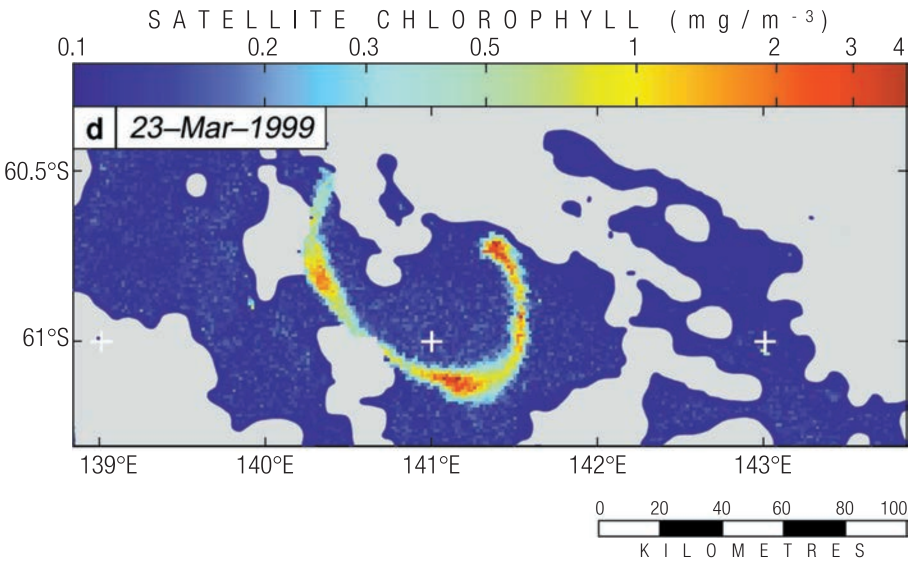

Figure 3. Bangle-shaped area of abundant phytoplankton in the Southern Ocean, in units of the major plant green pigment, chlorophyll-a, with red representing levels about 2ug/l and blue the normal late summer background levels of less than 0.1ug/l.

been obtained since 1997 by Australian, U.S., Japanese and French research groups.

The increase in Southern Ocean anthropogenic carbon dioxide contents has been determined from repeat observations along the WOCE SR3 section.

These carbon transfers to the deep sea are based on the particles collected in no more than a few square metres of sediment trap funnels, extrapolated to the millions of square kilo metres which make up the Southern Ocean. Each trap has a large funnel and a set of about 20 cups which rotate beneath the funnel at fixed intervals during a year long deployment. The traps and the yellow floats that keep them upright after deployment are strung out in a line of equipment 3 km long behind the ship before the final release of the 3 tonne mooring weight.

Sediment trap being deployed

The ecosystem controls on these vertical particulate carbon transfers are not understood – we do not know which types of phytoplankton communities play the major role in this carbon 'export' from the top 100 metres of the sea, much less the role of the food-webs of the next 1000 metres in altering this 'exported' material. This includes the key issue of whether iron fertilisation leads to increased carbon transport to the deep sea, and not just increased surface phytoplankton production. No artificial iron fertilization has lasted long enough to assess export, and we are still developing methods (such as stable isotope compositions, biomarkers, and shell assemblages) to permit this possibility to be assessed from the deep ocean sedimentary records from the time of the last glacial maximum.

Planned future programs to further advance our knowledge of the Southern Ocean carbon cycle include:

- remeasurement of ocean carbon inventories to determine how climate variations affect atmosphere to ocean transfers,
- comparison of particulate carbon export between the iron-poor regions south of Tasmania and the relatively iron-rich regions near Heard, McDonald and Kerguelen Islands and
- development and deployment of automated moorings which can make biogeochemical measurements and collect biogeochemical samples to augment our growing but still very sparse observations from ships and satellites.

These programs are core objectives of the proposed Cooperative Research Centre for Antarctic Climate & Ecosystems, a proposal currently being evaluated for possible funding. If approved, this will take the place of the existing Antarctic CRC, due to wind up in June 2003.

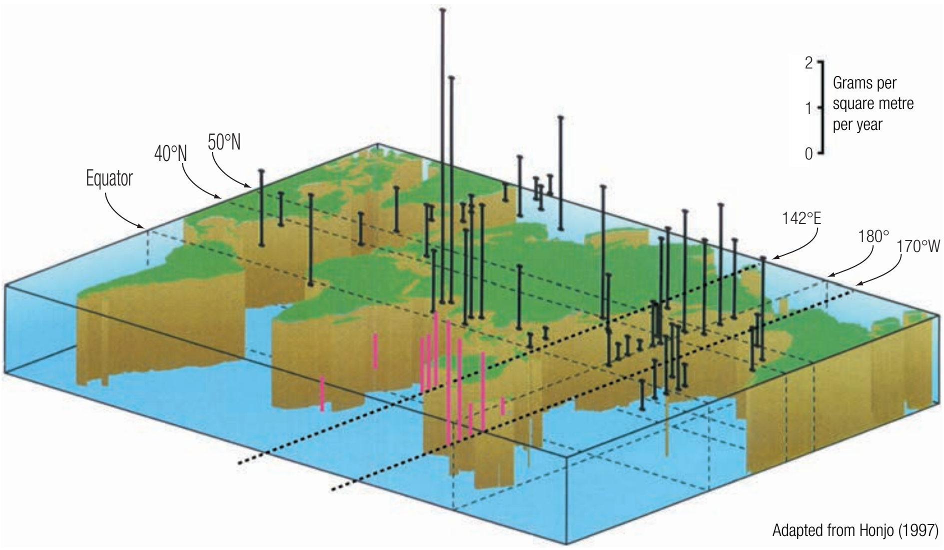

Figure 4. Export flux of organic carbon: Northern and Southern hemispheres.

Tom Trull, Antarctic Cooperative Research Centre, and Richard Matear & Bronte Tilbrook, Antarctic Cooperative Research Centre & CSIRO Marine Research

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Sea-level changes: reducing the uncertainty

One of the projected outcomes of climate change is a rise in sea level. A rise in sea level will be felt through more intense and frequent storm surges, increased erosion, loss of wetlands and mangroves, impact on coastal ecosystems, and flooding of human settlements (100 million people live within about a metre of present-day sea level).

Global sea level is largely determined by how much water is stored on land (in ice sheets, glaciers, reservoirs and aquifers) and how warm the oceans are (water expands as it warms, so sea levels rise as ocean temperatures increase). As the Earth warms because of the enhanced greenhouse effect, melting glaciers and warming oceans will cause sea level to rise.

Sea levels have responded to naturally-varying climates for many thousands of years, shaping life on the Australian continent. As major ice sheets melted after the peak of the last ice age – about 20,000 years ago – sea levels rose by about 120 m, flooding present-day continental shelves and creating Australia's coastal islands and inlets. Geological data indicate that over the past 3,000 years global averaged sea level has risen at the rate of only 0.1 to 0.2 mm a year.

Recent sea-level change has been recorded by a sparse network of coastal and island tide gauges. During the 20th century the rate of global averaged sea-level rise is estimated to be 1-2 mm a year, an order of magnitude larger than the average rate over the previous several millennia. This higher rate is linked, at least in part, to global temperature rises caused by increases in greenhouse gases. More specifically, the rise in sea-level reflects:

- ocean warming and the resultant thermal expansion,
- widespread melting of non-polar glaciers,
- increased melting of ice in Greenland (partially offset by increased snowfall),
- increased snowfall over Antarctica (partially offsetting sea-level rise from other components),
- a long-term contribution from the Antarctic ice sheet, which is still responding to changes since the last glacial maximum, and
- changes in terrestrial storages (such as aquifers and man-made dams).

The most recent projections by the Intergovernmental Panel on Climate Change (IPCC) are for a sea-level rise of between nine and 88 cm between 1990 and 2100 and a global average surface temperature rise of between 1.4 and 5.8°C. These estimates are made by simulating how the ocean and atmosphere respond to increases in atmospheric greenhouse gas concentrations. The rate and magnitude of sea-level change in the next century is likely to vary from region to region around the globe, but there is at yet little agreement as to the pattern of sea-level rise.

The Southern Ocean plays an important part in determining the rate and pattern of sea-level rise. Water sinking from the sea surface in the Southern Ocean carries heat into the deep ocean where the heat is re-distributed by ocean currents. The heat uptake and transport by the Southern Ocean in this way influences the rate and pattern of thermal expansion in the global oceans.

Even if greenhouse gases are stabilised today, sea-level rise will continue for hundreds of years. For example, after 500 years, sea-level rise from ocean thermal expansion may have reached only half of its eventual level.

If greenhouse gas concentrations doubled, sea-level rise from thermal expansion is likely to be in the range of 0.5–2 m (1–4 m for a quadrupling of greenhouse gas concentrations and even more in some recent results).

Glaciers will also be affected. Some glaciated areas could reduce and others could become ice free.

Warming over Greenland of 5.5°C, which is consistent with mid-range greenhouse gas stabilisation scenarios, would result in the Greenland ice sheet continuing to melt, with a projected contribution to global sea-level rise of about 3 m in 1,000 years. A collapse of the West Antarctic Ice Sheet would result in a sea-level rise of several metres, but this is very unlikely during the 21st century. However, there is insufficient understanding to make reliable projections for longer time scales.

The current wide range of estimates of future sea-level rise limits our ability to develop strategies to adapt to climate change. To narrow this wide range, we need to refine our estimates of each of the factors contributing to sea-level rise. New measurements of changes in ocean temperature – such as from the Argo float array (see 'Argo: a revolution in ocean observations', p.10) and repeat oceanographic transects – will improve estimates of ocean heat uptake.

One of the contributions to rising sea levels is the melting of mountain glaciers. The Jacka Glacier on Heard Island (pictured above in 1997) has retreated about 0.7 km since the early 1950s when it extended to the sea.

By combining sparse direct sea-level observations with global satellite measurements we will be able to estimate more accurately the global and regional pattern of sea-level rise. These observed changes in sea level will provide an increasingly robust test of the climate models used to make projections of future sea-levels. The impact of a rising sea level in many regions will be felt through changes in extreme events, like storm surges, which makes it all the more necessary to develop the ability to estimate changes in the frequency of extreme events.

John Church and Stephen Rintoul,
CSIRO Marine Research

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PHOTO CREDITS
L Robertson

Opposite page:
Tom Trull

FEATURE

Argo: a revolution in ocean observations

> Argo floats will completely revolutionize our ability to measure – and understand – the oceans. For the first time, we can measure the global-scale ocean circulation in real time. Because the floats drift with the currents, they are ideal for obtaining measurements in remote regions away from shipping routes (like the Southern Ocean).

The world's oceans are being taken over by a fleet of robots with an ambitious mission: to measure ocean temperature and salinity throughout the globe, providing the information needed to understand and predict climate change.

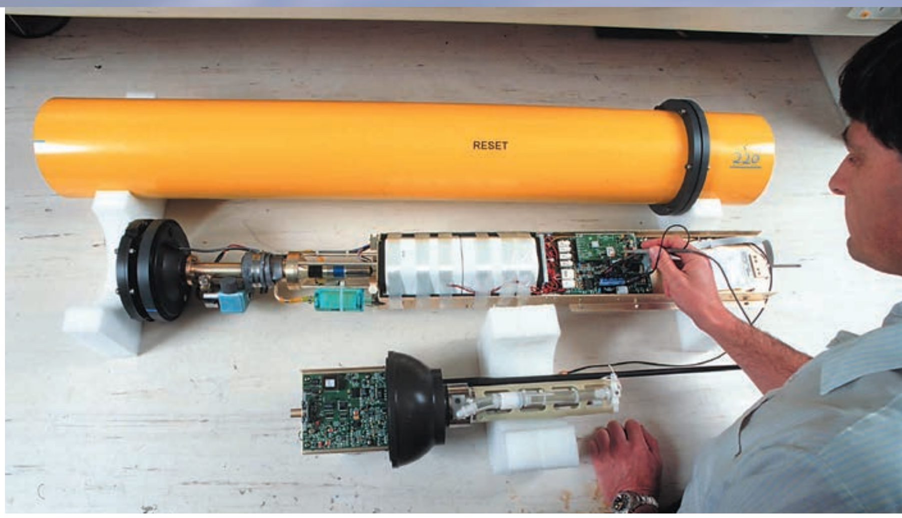
The Argo 'robots' are autonomous floats that drift with the ocean currents, usually at a depth of 2000 m. Every ten days, a small pump inflates a bladder with oil, increasing the buoyancy of the float. As the float rises, it records the water temperature and salinity. Once the float reaches the sea surface, the information is relayed via satellite to researchers on land. The pump then deflates the bladder and the float sinks back to its 'park depth' to begin another cycle. Each float lasts for about four or five years, sending back up to 150 vertical profiles of ocean conditions.

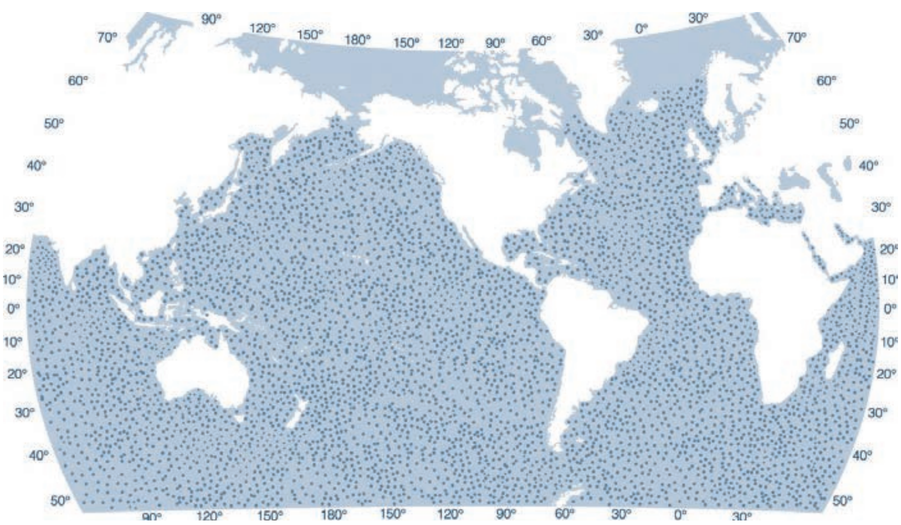
Argo floats will completely revolutionise our ability to measure – and understand – the oceans. For the first time, we can measure the global-scale ocean circulation in real time. Because the floats drift with the currents, they are ideal for obtaining measurements in remote regions away from shipping routes (like the Southern Ocean). Argo floats are also extremely cost-effective: for the cost of a single day on a ship, during which up to four or five profiles might be made, two or three floats could be purchased, capable of providing 300 to 450 profiles.

The Argo data will be used for a wide range of studies. The drift of the floats will provide a direct measurement of deep ocean currents. The temperature and salinity profiles will allow us to measure how rapidly the ocean is changing and to relate these changes to climate variability experienced on land. The floats also provide essential data for testing climate models, leading to improved climate predictions. Measurements of ocean variability obtained from Argo will help scientists understand how variations in the physical environment are linked to changes in biological populations and hence contribute to conservation and sustainable management of marine resources.

About 500 floats are currently in the water. When fully implemented in 2005, 3,000 floats will form a global network covering all the world's oceans. While Australia is so far a small participant in Argo, we are seeking support to expand our contribution (e.g. through the proposed Antarctic Climate and Ecosystems Cooperative Research Centre). The likely pay-off to Australia from participating in Argo is huge. For the first time, we would be able to obtain the ocean measurements we need in order to understand, predict, and respond to future changes in the marine and terrestrial environment.

Stephen Rintoul,
CSIRO Marine Research





TOP to BOTTOM: • Every ten days, the Argo floats return to the sea surface to transmit data on their location and profiles of temperature and salinity to a satellite. A pump inside each float inflates a diaphragm with oil when it is time to return to the surface, slightly increasing the volume, and hence the buoyancy, of the float. • When fully deployed, the global Argo array of profiling floats will provide regular observations of all the world's oceans. LEFT: • Argo floats are cylinders about 150 cm long and 20 cm in diameter. The temperature and salinity sensors are near the top of the float, next to the antenna that transmits the data to the satellite.

Fun without touching: satellite remote sensing of sea ice

The sheer magnitude of Antarctic sea ice extent lends itself perfectly to measurement from space. Each year Antarctica's sea ice cover puts on the greatest geophysical show on Earth, expanding and contracting between an area of about 3 million km^2 in February and about 19 million km^2 in September–October. In so doing, it has a profound and immensely complex yet highly variable impact on high-latitude air-sea-ice physical and biogeochemical interaction processes, ocean water-mass modification and circulation, marine ecology and the global climate system. The seasonal sea ice cycle also has a profound effect on human activities.

The magnitude and variability of these impacts depends on a number of characteristics of the ice cover, including its areal extent, concentration (degree of compaction), thickness distribution, motion/deformation, and snow cover thickness. On longer time scales, modeling studies suggest that global change may be readily detectable through changes in Antarctic sea-ice extent and thickness (or volume).

Antarctica's sea ice cover puts on the greatest geophysical show on Earth, expanding and contracting between an area of about 3 million km^2 in February and about 19 million km^2 in September–October.

Fortunately, sea ice research is no longer limited to point measurements that are greatly limited in space and time. Over the past 30 years polar-orbiting satellites have revolutionised our ability to monitor the vast and data-sparse 'Great White Hell' on climatically-relevant temporal and spatial scales. Over that time, they have given us great insight into the complex large-scale interactions of air, ocean and atmosphere in the Southern Ocean, and the variable role of sea ice as a habitat for species from microscopic phytoplankton to whales. Only satellites can cost-effectively provide systematic, repetitive, continuous and reliable coverage for large-scale monitoring studies. With satellite sensor technology has come great advances in ground segment and computing technology. With the advent of the internet, this allows rapid access and dissemination of data.

Passive microwave radiometers

The first Earth-observing satellites launched in the early 1960s gave us tantalising glimpses of Antarctic sea ice through breaks in the cloud cover, but it was not until the launch of a microwave instrument (the Electrically Scanning Microwave Radiometer, or ESMR) in 1972 onboard NASA's Nimbus-5 satellite that we gained the first overview of the incredible seasonal waxing and waning cycle of sea ice encircling Antarctica (shown in later satellite image in *Figure 1*). These were also our first images showing significant interannual variability in areal sea ice extent, enabling routine extraction of another key geophysical parameter from the data – sea ice concentration.

By sensing the Earth's surface at centimetre-scale wavelengths through atmospheric 'windows', passive microwave radiometers have the key ability to penetrate both cloud cover and polar darkness. As a result, they have become a workhorse of sea-ice research. In this case, 'passive' describes the fact that the sensor detects radiation thermally-emitted from the surface, the intensity of which depends on both the temperature and the 'emissivity' of the radiating portion of that surface material. Emissivity is the ratio of the radiation emitted by a surface to the radiation emitted by a perfect (blackbody) radiator at the same temperature. Importantly, a large microwave-emissivity contrast exists between open ocean and sea ice, allowing the latter to be readily detected from space.

Subsequent sensors, such as the current Special Sensor Microwave-Imager, or SSM-I, added a multi-spectral capability, enabling more accurate measurements. Collecting data over a wide swath, such sensors offer complete coverage of the entire Antarctic sea ice cover once daily, albeit at a fairly coarse spatial resolution (pixels 12.5-25 km). Swath refers to the width of the ground track covered by the sensor, and spatial resolution is the smallest object or narrowest line that a sensor can detect.

Extending back 30 years, passive microwave data enable monitoring of trends in the sea ice cover, and have highlighted on a regional basis significant interannual variability in sea-ice extent. The data have also recently been used by studies relating anomalies in regional sea-ice concentration and extent to El Niño–Southern Oscillation events and the eastward propagation of the Antarctic Circumpolar Wave around the continent.

Time series of sea-ice concentration and extent data are critical for identifying possible decadal fluctuations resulting from significant changes in high-latitude oceanic and atmospheric circulation. This vitally important time series continues today with data from the Advanced Microwave Scanning Radiometer (AMSR-E) onboard NASA's Aqua satellite, launched in May 2002. With additional channels, this sensor will routinely

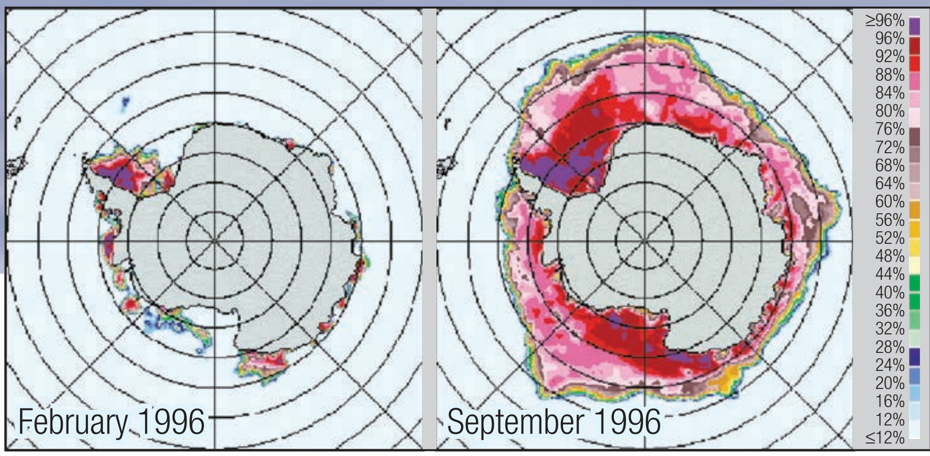


Figure 1. Monthly mean images of sea ice concentration (%) from February (minimum ice extent) and September (maximum extent) 1996, derived from the Special Sensor Microwave/Imager onboard the US Defense Meteorological Satellite Program satellites. With reliable data dating back to 1978, daily passive microwave images of sea ice concentration and extent have become a 'bread-and-butter' tool of Southern Ocean climate research. Image courtesy of the NASA Earth Observing System Distributed Active Archive Center, National Snow and Ice Data Centre, University of Colorado.

Over the past 30 years polar-orbiting satellites have revolutionised our ability to monitor the vast and data-sparse 'Great White Hell' on climatically-relevant temporal and spatial scales. Over that time, they have given us great insight into the complex large-scale interactions of air, ocean and atmosphere in the Southern Ocean, and the variable role of sea ice as a habitat for microscopic phytoplankton to whales.

PHOTO CREDITS

Opposite page:
CSIRO Marine Research

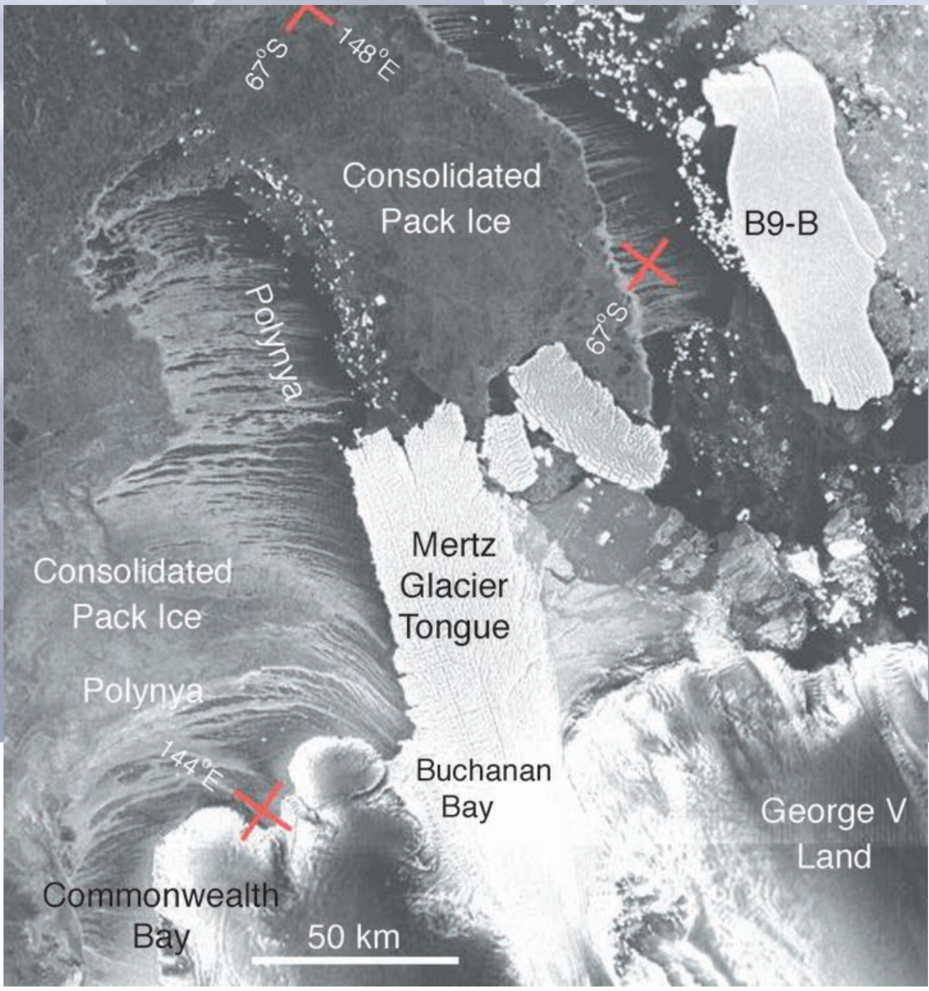


Figure 2. Part of a Radarsat ScanSAR image of the Mertz Glacier tongue region, August 4 1999, showing new (frazil) ice formation in the Mertz Glacier Polynya. Also prominent are grounded icebergs. This region is an important site for the formation of very dense and cold Antarctic Bottom Water, which is a key component of the global ocean circulation system. ©Radarsat International/NASA, 1999.

provide additional key information on snow-ice interface temperature and snow-cover thickness.

Active microwave sensors

Active microwave sensors, which include synthetic aperture radars (SAR), radar altimeters and wind scatterometers, transmit a centimetre-wavelength signal and measure the strength of its return, or backscatter, from a target surface. This backscatter contains information about the nature of that target. The SAR is a high data rate sensor that allows us to observe the surface at a spatial resolution of tens of metres. Current SARs are aboard Radarsat-1 *(Figure 2)* and Envisat, and collect data over a 400-500 km-wide swath – again uninterrupted by clouds and darkness.

Unlike their passive microwave cousins, SARs can resolve morphological features such as leads and floes, and provide information on the structure of the pack. As geolocation of SAR imagery can be relatively accurate, sequential images can be superimposed to determine the relative movement of sea ice in the intervening period. Maps can be constructed of sea-ice motion vectors using cross-correlation techniques to identify and track floes. (Note that sea-ice motion is also derived from passive microwave and visible-thermal IR images.)

Better understanding of large-scale ice motion is a key to enabling us to obtain a more accurate parameterisation of the relative roles of ice motion and interaction (dynamics) and thermodynamics in determining the thickness distribution of Antarctic sea ice. Rapid ice formation occurs in leads during divergent conditions, with pressure ridge building occurring during subsequent ice convergence.

SAR data are also being used to map the fast-ice cover around Antarctica's coastal margins, determine the effect of grounded icebergs on sea ice distributions, and estimate the extent of open water and thin ice types in the study of coastal polynyas (areas of open water within the sea ice cover). The latter is expected to result in more accurate estimates of ocean–atmosphere heat fluxes and sea-ice production rates – key climate-related processes.

Another important, though largely under-utilised, sea ice research tool is the radar scatterometer. Designed to measure wind speed and direction over open ocean, it also has the potential to deliver low resolution (25-50 km) but important hemispheric sea ice information on a daily basis. Products from these data include daily maps of ice-type (age) classification, extent, motion, and the timing and progression of regional sea ice melt. These data are currently research and development only, but show great potential.

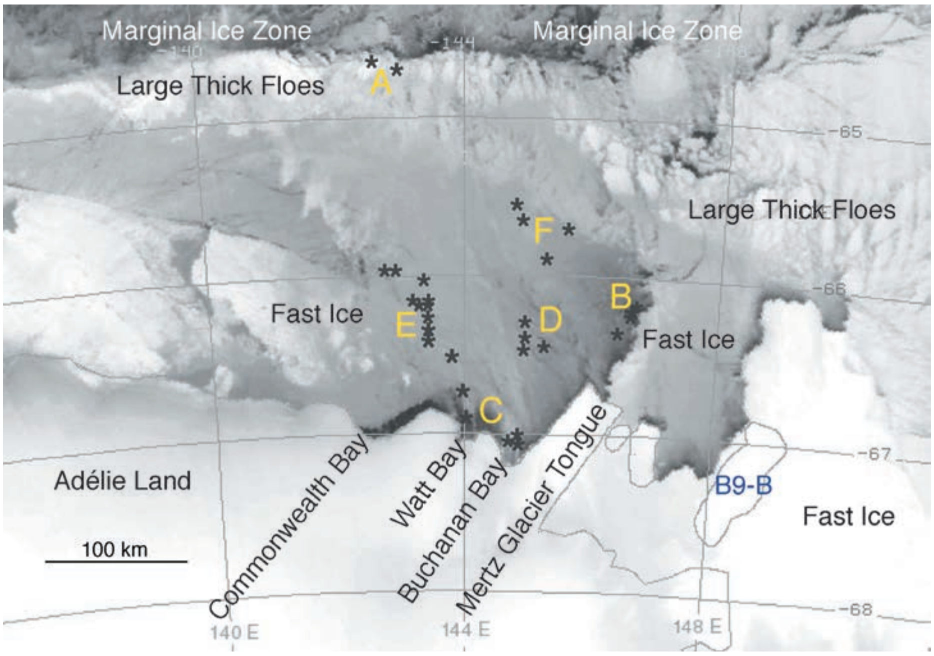


Figure 3. An example of a NOAA AVHRR thermal IR image collected at Casey Station, June 14, 1999. When cloud free, such images give excellent broad-scale information on the distribution of different sea-ice regimes, albeit at a medium resolution (about 1 km). In this case, the image shows ice conditions at sites where Crabeater seal groups (*), in assemblages marked A-F, were located by field survey during the July-August 1999 cruise of the RV Aurora Australis. *In this image, thicker ice is lighter in colour. Grounded berg B9-B is also marked.*

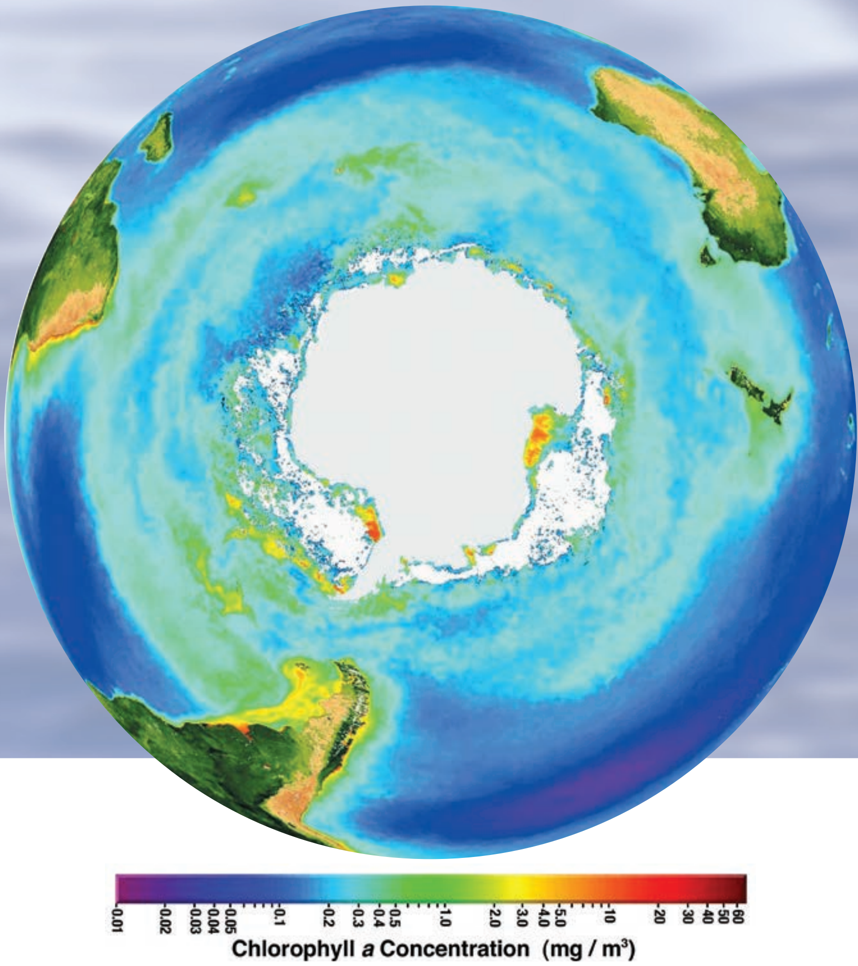


Figure 4. A composite ocean colour image of the Southern Ocean produced from data from the SeaWiFS sensor onboard the SeaStar satellite, for the period September 1997 to August 2000. The colours relate to chlorophyll a concentration in the upper ice-free ocean, with red being the highest concentration. Sea ice and ice sheet are masked out in white. Courtesy of NASA.

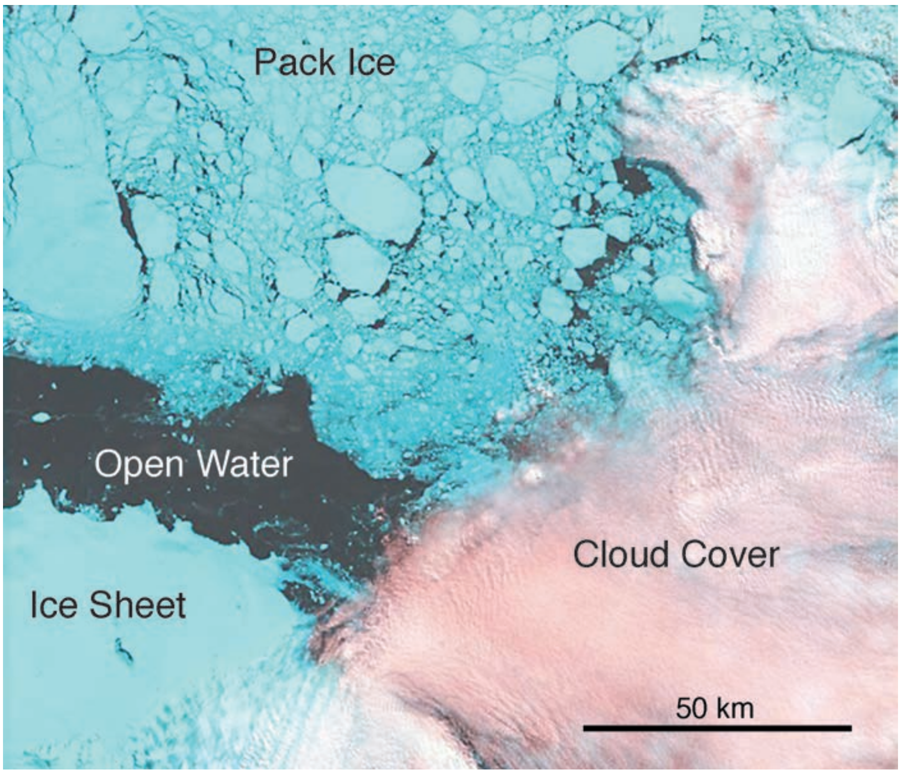


Figure 5. Landsat 7 Enhanced Thematic Mapper image of the Cape Adare region (image centred on 70.92°S, 171.62°E), December 12, 1999 (about 21:00 UTC). The ETM simultaneously collects high-resolution data in 8 bands (0.45-12.5 microns) across a 170 x 183 km scene. Note that individual floe assemblages are resolved. Courtesy of US Geological Survey and Eosat International.

Visible-thermal infrared radiometers

Microwave sensors cannot provide information on sea ice albedo and surface temperature. Albedo is defined as the ratio of electromagnetic (EM) radiation reflected from an object to the total amount incident upon it (for a given portion of the EM spectrum), and is an important climate variable. Measuring albedo and surface temperature is the realm of radiometers operating at visible to near-IR (about 0.4-1.4 microns) and thermal IR (about 3.0-12.0 microns) wavelengths respectively (1 micron = 1 x 10^{-6} m).

The medium-resolution radiometer is another workhorse, and offers excellent spatial coverage each time the satellite passes overhead. Examples are the NOAA Advanced Very-High Resolution Radiometer (AVHRR, resolution about 1-4 km, swath about 2000 km – see *Figure 3*) and the new Moderate Resolution Imaging Spectrometer (MODIS, resolution 0.25-1.0 km, swath about 2,300 km) onboard NASA's Terra and Aqua satellites. Unfortunately from a sea ice perspective, these sensors are severely limited by cloud cover and, in the case of visible-near-infrared sensors, polar darkness. However, such is the regularity of coverage that gaps can usually be found in the cloud cover; and cloud cover is itself an important climate variable.

Other visible to near-IR sensors are important because they can detect and monitor ocean colour related to the presence of phytoplankton in open water. Once calibrated, these data yield estimates of ocean primary production, and are providing insight into the patchy distribution of phytoplankton blooms in the Southern Ocean

Another illustration of recent technological advances is the improved spectral resolution of MODIS operating in 36 discrete bands, compared to 5-6 relatively broad bands for the NOAA AVHRR. This increased sensitivity should potentially enable the detection of subtle differences in the surface signature related to ice thickness, for example.

Other visible to near-IR sensors are important because they can detect and monitor ocean colour related to the presence of phytoplankton in open water. Once calibrated, these data yield estimates of ocean primary production, and are providing insight into the patchy distribution of phytoplankton blooms in the Southern Ocean *(Figure 4)*. Current ocean colour sensors are the MODIS and the SeaWiFS onboard the SeaStar satellite – all give excellent coverage, are wide-swath (>1000 km), and medium resolution (0.25-4.5 km).

Another current trend is towards higher spatial and spectral resolution. The commercial QuickBird and IKONOS satellites can, for example, produce visible-near IR data at a an ultra-high spatial resolution of 0.61-1 m, albeit at the expense of good coverage (i.e. the swath is <15 km). Among today's other high-resolution sensors, the SPOT HRG can deliver data at a 2.5-20 m resolution (swath 60 km), while the Landsat Enhanced Thematic Mapper (ETM) has a resolution of 15-60 m and includes a night-time (thermal infrared) imaging capability (Figure 5). Big Brother can indeed be watching – on a cloud-free day, that is!!

Parameter	PMW	SAR	Low-Res. Visible-TIR#	Hi-Res. Visible-TIR#	Radar Scatt.
Sea Ice Extent	X	S	S	S	X
Sea Ice Concentration	X	S	S	S	-
Surface 'Skin' Temp.	-	-	X	S	-
Snow-Ice Interface Temp.	X/R	-	-	-	-
Sea-Ice Motion	X	X	X	S	X
Polynya Size	X	X	X	X	-
Fast Ice Extent	-	X	X	X	-
Sea-Ice Classification	X	X	S	S	S
Floe-Size Distribution	-	X	S	X	-
Wave-Ice Interaction	-	R	-	-	R
Cloud Distrib./Type	S	-	X	S	-
Broadband Albedo	-	-	X	S	-
Snow cover Thickness	X/R	-	-	-	-
Regional Melt Progression	-	-	-	-	R
Iceberg Size/Tracking	-	X	X	X	S
Primary Production	-	-	X	-	-

Table 1. Summary of sea ice-related applications of major satellite sensor classes. TIR is thermal infrared; # = cloud-affected (visible to near-infrared sensors are also darkness-affected); X = primary data source; S = secondary data source; and R = research and development. PMW is passive microwave. Icebergs are included as they have a significant effect on sea-ice distribution, and primary production because it is closely linked to sea-ice distribution and melt.

Modelling and operational uses

Satellite data are now of key importance in providing initial data to drive coupled ocean-ice-atmosphere models and also different data to validate the latter. Model simulations of future climate are highly sensitive to the manner in which the high latitudes are represented, and improved satellite data support improved model performance. Moreover, the resolutions of both passive microwave satellite data and sophisticated models have converged to the stage where assimilation of satellite data into operational sea-ice forecasting models is becoming a reality.

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This exciting trend is aided by developments in the ground sector, including higher-performance computers, which have resulted in the near real-time availability of high-level geophysical products from many of these data.

Satellite remote sensing plays an important role in operational activities in the sea-ice zone. Vessels operating in Antarctic sea ice can now receive high-quality satellite data in real time. Polar-orbiting satellites also play a key role in transmitting data from remote sensor packages, such as automatic weather stations, drifting buoys or instruments attached to wildlife.

Conclusions

Satellite remote sensing, though a wonderful research tool, is not a panacea. Uncertainties remain in interpreting more complex data. Satellite data require calibrating and validating, ideally with dedicated surface measurements, a need driving next year's first voyage of the *RV Aurora Australis*. Sea ice thickness, a key climate parameter, can be inferred from satellite data or estimated by combining satellite observations with models, but its direct measurement from space remains an elusive 'holy grail'. Future missions are addressing this issue, including the sophisticated dual radar altimeters on board the European Space Agency's 2004 CryoSat. Developed to determine the (high) freeboard of multiyear sea ice in the Arctic, the accuracy of this instrument in determining ice thickness in the Southern Ocean remains to be seen.

An important 'take-home' message is that no one perfect, multi-purpose satellite sensor exists for sea-ice research. Due to technological trade-offs (for example, between spatial–temporal coverage and spatial resolution), each sensor possesses inherent strengths and weaknesses. A combination of data from different yet complementary sensors is a powerful research tool, particularly when added to contemporary surface observations and models. The imminent launch of new and improved sensors bodes well, not only for continuing key time series such as ice concentration and extent but also providing improved and additional data.

Satellite remote sensing is still about the best way to stay informed by being out of touch. Or to put it another way, it's the most fun you can have without touching.

Satellite remote sensing will never entirely replace surface measurements. Rather, it will always serve to greatly extend them, both spatially and temporally. Satellites cannot, for example, directly measure ocean properties under an ice cover. Intermediate-scale measurements from helicopters and fixed-wing aircraft will continue to be important, and data collection from autonomous unmanned vehicles (both airborne and underwater) will play an increasing role in sea-ice research. But, as John Mobbs of the Australian Defence Force Academy put it, satellite remote sensing is still about the best way to stay informed by being out of touch. Or to put it another way, it's the most fun you can have without touching.

Rob Massom,
Polar Waters Program,
Antarctic CRC

Sea ice data sets help build the big picture

Top: Newly forming sea ice in Antarctica. The ice starts to form when the surface of the ocean cools to its freezing point of –1.8°C. Above: Sea ice can thicken rapidly as a result of wind and waves deforming the ice and stacking ice floes on top of each other. Sea ice can thicken to 10 metres or more by this process.

At the southernmost limit of the Southern Ocean, in a broad band around Antarctica, the ocean freezes to form sea ice. At its maximum extent in September the frozen ocean covers 20 million square km, approaching three times the area of Australia.

This frozen skin on the ocean plays a critical and intriguing role in how the ocean and atmosphere interact and how they circulate and transport heat. The sea ice rejects salt as it forms and this drives a vertical overturning of the ocean. It also reflects a large proportion of solar radiation back to space that would otherwise be absorbed by the ocean. Sea ice maintains a tenuous existence at the interface of the ocean and atmosphere, and is highly sensitive to temperature changes. This makes it a particularly important indicator of any change to the climate system.

Sea ice maintains a tenuous existence at the interface of the ocean and atmosphere, and is highly sensitive to temperature changes. This makes it a particularly important indicator of any change to the climate system.

We do not know the total volume of sea ice forming each year, and this is a strong focus of Australia's glaciological research program. Internationally, ASPeCt – the Antarctic Sea Ice Processes and Climate program – has as one of its main aims development of a climatology of sea ice thickness around Antarctica. To achieve this, ASPeCt have embarked on parallel programs to make the necessary observations from research vessels operating in the Antarctic.

Ship data being gathered by Australian, Russian, German and US Antarctic programs are vital to our understanding of the thickness and properties of Antarctic sea ice because there is no reliable way of determining these parameters from satellite data. An intensive effort is seeking as much information as possible from field measurements made aboard research vessels such as Australia's *Aurora Australis*. The photographs above show the large differences that can occur in sea ice thickness, from newly forming thin ice in the autumn, to much thicker ice that forms by ridge building by the spring.

Australian sea ice scientists have played a leading role in developing these programs, particularly in establishing protocols for making sea ice observations from ships, that are now in use by scientists around the world. A CD-ROM, Observing Antarctic

To page 17

PHOTO CREDITS
Tony Worby

FEATURE

Sea ice formation in the Mertz Glacier Polynya

Antarctic coastal polynyas – areas of open water within pack ice – are thought to be winter-time sources of 'Antarctic bottom water'. Cold and windy conditions encourage rapid ice formation, while persistent winds remove the ice cover. Previous estimates of polynya ice production rates have largely been based on satellite remote sensing data and meteorological data from numerical models. Here, we report on measurements collected in August 1999 in the Mertz Glacier polynya (MGP) on the Antarctic coast about 145°E 67°S, west of the Mertz Glacier tongue. We used the data to determine directly the rate of ice growth in winter and the processes occurring as the ice forms.

Air temperature, air pressure, windspeed and wind direction were measured continually from the ship during the voyage and from an automatic weather station on Eder Island to the west of the polynya. For most of the experiment, air temperatures ranged from about minus 15°C to minus 23°C, although they dropped as low as minus 28°C for a short period. The exception to this was from 11 to 15 August, when a low pressure system brought a brief period of northeasterly winds during which temperatures reached as high 0°C (*Figure 1*). These warm northerlies occur often around Antarctica, even in the middle of winter. Apart from this warm spell, winds were generally south or southeasterly with speeds frequently exceeding 70 km/h.

The photograph above shows the early stages of sea ice formation and consolidation. Snow can be seen blowing off the glacier cliffs at bottom left. Wind speeds were frequently high enough for blowing snow; these same strong winds also increased the heat transfer from the open water of the polynya, and increased the ice formation rate. Under these turbulent conditions, the ice initially forms as frazil ice, or individual ice crystals, seen as white streaks. As these ice crystals form they reject salt into the water column. The ice is then blow away from the coast by the persistent winds.

We observed frazil ice and grease streamers forming near the upwind end of the polynya, the frazil being thicker in the middle of the long streams of grease ice and thinning towards the edges. The ice drifted generally north-northwest, often forming small pancakes or thin sheets of nilas before consolidating into a solid sheet of ice. Unconsolidated frazil ice was often observed beneath consolidated ice while travelling through the ice, with any new cracks or openings created as the ship broke through the ice rapidly filling with frazil.

As this frazil ice accumulates, it eventually forms a continuous cover of ice crystals, called 'grease ice' because of its matt texture and the resemblance to oil floating on top of the ocean. This ice could then take several days to consolidate into a solid ice cover – during a period of warmer weather this took over four days. Even after the surface was relatively solid, frazil was still abundant under the surface, rapidly filling any newly-drilled holes or recently-opened leads.

During the experiment, 15 buoys in three different arrays were deployed in open water or newly forming frazil ice along the Mertz Glacier tongue or near polynya's southeast boundary in Buchanan Bay. These buoys transmitted their position via satellite, and were used to track the ice as it drifted through the polynya. While travelling between each of the buoys we collected detailed, standardised ice observations from the ship based on the method developed by Allison and Worby in 1994. These observations recorded ice and snow thickness, ridging statistics, and ice concentration every half hour. During the experiment the ship travelled between the buoys three different times. Using these data, we have calculated the average ice thickness between buoy locations, and ice growth rates. The estimates provide an area-averaged value for ice thickness, including any open water areas.

Evidence of snow incorporation into the upper layer of ice was found in 16 of the 22 ice samples, or 13 percent of the total ice thickness sampled. Of the 42 days in the ice, snowfall was recorded on 23 days, and drifting snow on 13 days.

The undeformed new ice growth rate averaged about 4 cm a day for the first five days of formation. Ridging and rafting doubled the total growth rate to an average of 8 cm a day. Blowing and falling snow was incorporated into the surface of the newly forming ice, with 16 of 22 ice cores having some snow in the top few centimeters.

Evidence of snow incorporation into the upper layer of ice was found in 16 of the 22 ice samples, or 13 percent of the total ice thickness sampled. Of the 42 days in the ice, snowfall was recorded on 23 days, and drifting snow on 13 days. In addition, observations from helicopters flying near the coast regularly noted considerable snow blowing off the coast into the open water. Four of the six cores with no snow were from ice which had quickly consolidated under cold conditions, with little or no snowfall recorded. Therefore, although there is considerable blowing snow, it is possible for ice to form with no snow incorporation when the initial consolidation occurs rapidly when there is no falling or drifting snow.

This is a novel approach to estimating ice production rates within the polynya. These growth rate estimates are based on direct measurements of ice thickness and do not rely on any heat flux estimates or parameterisation which is often used to estimate ice growth and hence salt flux. The average ice growth rates reported here are for the first few days of ice formation. They are averages from the time of initial frazil formation through ice consolidation, and are also a sort of spatial integration as ice drifts north-northwest through the polynya. Higher ice formation rates (12 and 25 cm a day) such as those reported in Roberts and others are applicable over a smaller area of open water.

About half of the ice thickness results from dynamic processes including both rafting and ridging, while the other half is thermodynamic in origin. Consequently, any model estimates need to consider both processes in estimating ice growth. Midwinter air temperatures can reach 0°C, reducing ice formation rates. This reduces or delays consolidation of frazil ice, affecting timing and location of salt rejection into the upper ocean, as the ice may drift farther before complete consolidation occurs. The timing and frequency of these warm storms could have a large influence on the annual ice growth rate and hence the ocean salt flux. Although it is difficult to assess the relative importance of snow in the overall ice formation with these data, it is clear that snow is frequently incorporated into the ice, probably as blowing snow or snowfall during the initial frazil formation and before the ice is consolidated. ■

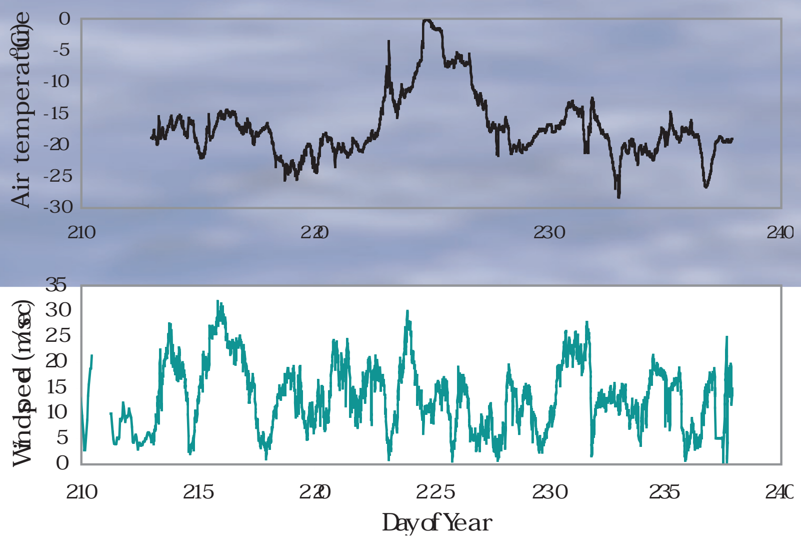
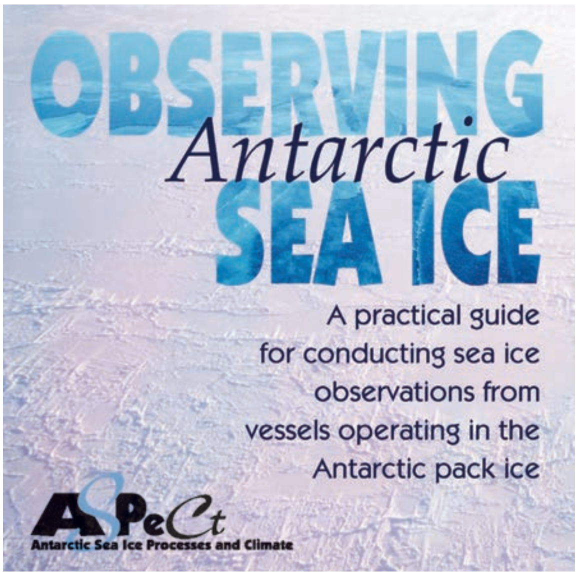


Figure 1. Daily measurements of air temperature and windspeed in the Mertz Glacier polyna in August 1999.

VICTORIA LYTLE,
GLACIOLOGY PROGRAM,
ANTARCTIC CRC AND AAD

FROM PAGE 15



Sea Ice, has been compiled to help train sea ice observers (at right). Each year scientists now make observations of the thickness, concentration, floe size and topography of Antarctic sea ice and contribute them to a central database at the Australian Antarctic Data Centre. These data are now used by scientists all around the world.

The historical data, translated from records made as early as the 1970s (some of which were found decaying in old warehouses), have come from a number of different countries. Russian scientists have provided a wealth of historical data – invaluable for providing snapshots of past conditions and for compiling with more contemporary observations to provide a time series of data.

The combined data sets now provide a circumpolar picture of sea ice conditions around Antarctica based on about 20,000 individual observations from 74 voyages over the past several decades. While much more analysis will be done on these data, preliminary results show regional variability of sea ice thickness around the continent. This data set will be useful for comparisons with the output of sea ice models and as a baseline data set for assessing future climate change. ■

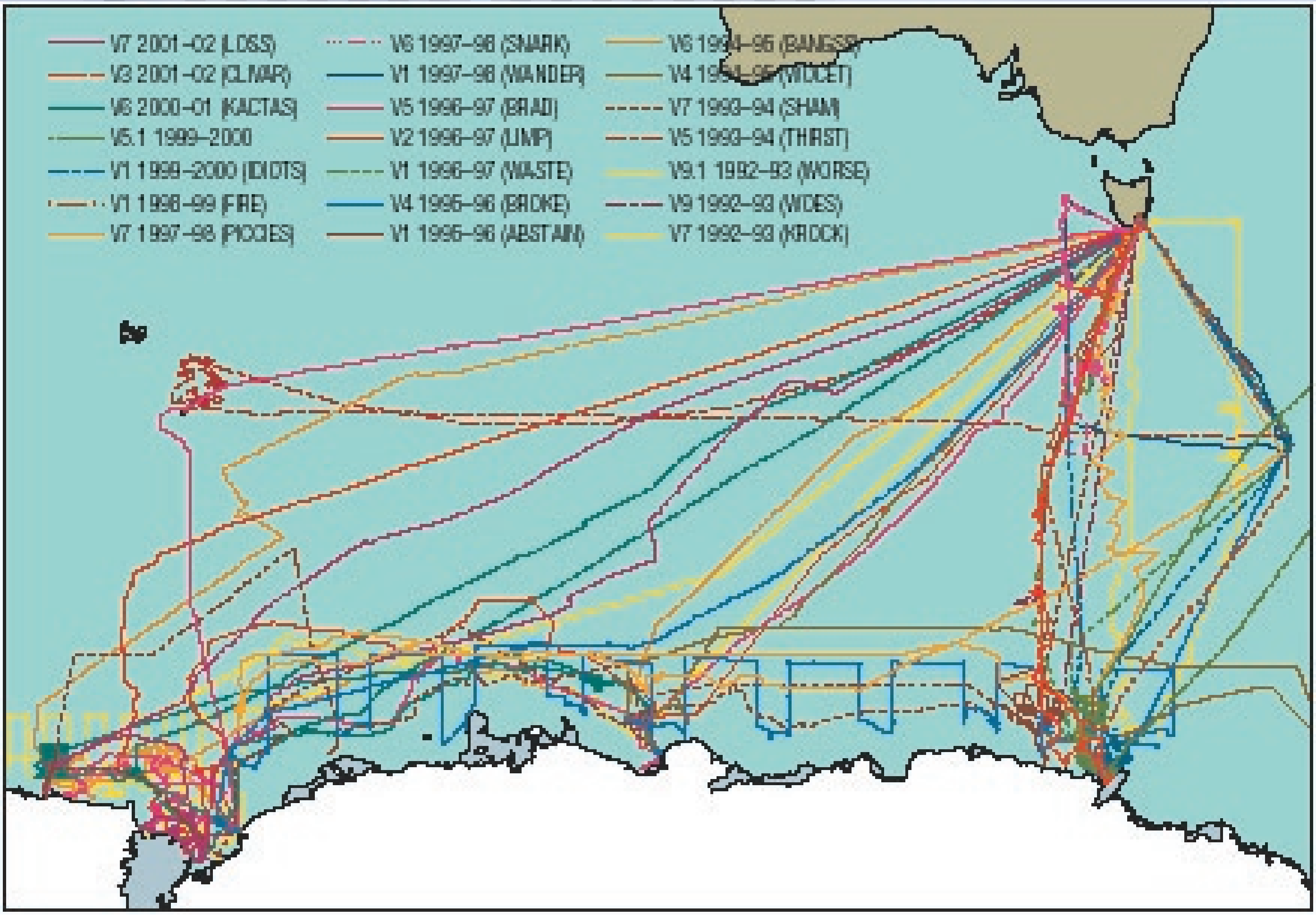
The combined data sets now provide a circumpolar picture of sea ice conditions around Antarctica based on about 20,000 individual observations from 74 voyages over the past several decades.

TONY WORBY,
GLACIOLOGY PROGRAM,
ANTARCTIC CRC & AAD

PHOTO & DIAGRAM CREDITS
Victoria Lytle

Opposite page:
Victoria Lytle

Marine science tackles big resource questions



Map showing the tracks of the major marine research voyages conducted by the Australian Antarctic program over the last ten years.

From tentative first steps in the late 1970s, Australian research in Antarctic marine biology is now participating in international programs aimed at ensuring that harvesting of Southern Ocean living species can be sustained without harming this vital resource.

From tentative first steps in the late 1970s, Australian research in Antarctic marine biology is now participating in international programs aimed at ensuring that harvesting of Southern Ocean living species can be sustained without harming this vital resource. The task is as herculean as it is important.

The task is as herculean as it is important.

Australian research into Antarctic marine biology began in the late 1970s, spurred on by the establishment of the international BIOMASS (Biological Investigations into Marine Antarctic Systems and Stocks) Program. Driven by the development of a fishery for krill, BIOMASS looked at the distribution and abundance of Antarctic krill, seeking information on the interrelationships between krill and the other elements of the marine ecosystem.

Australian Antarctic marine research was made feasible by the conversion of the supply ship *Nella Dan* into a functional research vessel, in which the Australian Antarctic Division made its first concerted forays into open ocean research. Australia was a participant in the highly successful 1981 First International BIOMASS experiment (FIBEX) – the first attempt to survey the distribution and abundance of Antarctic krill using acoustic techniques. The results from this huge effort, using 13 ships from 11 nations, were translated 10 years later into catch limits for the krill fishery in the Atlantic and South West Indian sectors of the Southern Ocean. The Second International BIOMASS Experiment (SIBEX) was fraught with logistic difficulties.

In parallel with the scientific focus on the waters around Antarctica, diplomatic efforts in the late 1970s and early 1980s concentrated on developing a regime to manage the harvesting of krill, fish and squid in the Southern Ocean. The ground-breaking 1982 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) took an 'ecosystem approach' to management. It recognised the central importance of krill in the Antarctic food web and the need to protect the recovery of seals and whales from past over-exploitation.

The Convention is overseen by the Commission for the Conservation of Antarctic Marine Living Resources (also known as CCAMLR) which first met in Hobart in 1981 and has since met there annually. The Commission uses the advice of its Scientific Committee to set catch regulations on the fisheries in Antarctic and subantarctic waters. The major fisheries in the region have been those for krill in Antarctic waters and for a number of fish species, such as icefish, Antarctic rock cod and Patagonian toothfish in the Subantarctic.

Australia's research program has become the prime source of information to CCAMLR on the harvested species and on the wider marine ecosystem off East Antarctica. It has included:

- A CCAMLR Ecosystem Monitoring Program established near Mawson station in 1989.
- An AAD krill research program, including a series of krill surveys in the Prydz Bay region in the early 1980s to the early 1990s and a single large-scale krill survey off East Antarctica in 1996. These surveys were used by CCAMLR to set precautionary catch limits in the waters off the Australian Antarctic Territory.
- Fish surveys in the Prydz Bay area in the early 1990s and then around Heard

Island, where scientific surveys in the early 1990s were used by CCAMLR to establish management procedures for this region.

The krill fishery is unique amongst the worlds' fisheries in that the current catch (~100,000 tonnes per year) is so much lower than the conservatively estimated precautionary catch limit (~5 million tonnes a year). It is highly likely that this fishery will increase as new uses and processes are developed and this increase will require careful management. Squid are also thought to be abundant in Antarctic waters but no viable fishery has yet been established.

From 1997 an Australian-based fishery for Patagonian toothfish in the Heard Island area has led to an increased focus on fisheries research by the AAD.

In 1999 Australia established a new Antarctic Marine Living Resources (AMLR) Program specifically to provide information that can be used by CCAMLR, and by the Australian Fisheries Management Authority (AFMA), to regulate fisheries in Antarctic and subantarctic waters. This science program conducts strategic research into issues such as stock assessment of fish and krill, incidental mortality of seabirds in long-line fisheries, ecosystem monitoring, the development of novel techniques to examine ecosystem interactions, ecosystem modeling and research into the life history parameters of harvested and dependent species.

Although harvesting of fish is unlikely to increase into the future because of a lack of further significant stocks to exploit, fish remain a controversial research subject because of illegal, unregulated and unreported fishing on the valuable populations of Patagonian and Antarctic toothfish.

The krill fishery is unique amongst the worlds' fisheries in that the current catch (~100,000 tonnes per year) is so much lower than the conservatively estimated precautionary catch limit (~5 million tonnes a year). It is highly likely that this fishery will increase as new uses and processes are developed and this increase will require careful management. Squid are also thought to be abundant in Antarctic waters but no viable fishery has yet been established.

The existence of these fisheries and the continued demand for quality scientific information on harvested species, dependent species and on the Southern Ocean ecosystem will ensure that Australia will require a scientific program focused on Antarctic fisheries into the foreseeable future. ■

STEPHEN NICOL,
ANTARCTIC MARINE LIVING RESOURCES PROGRAM

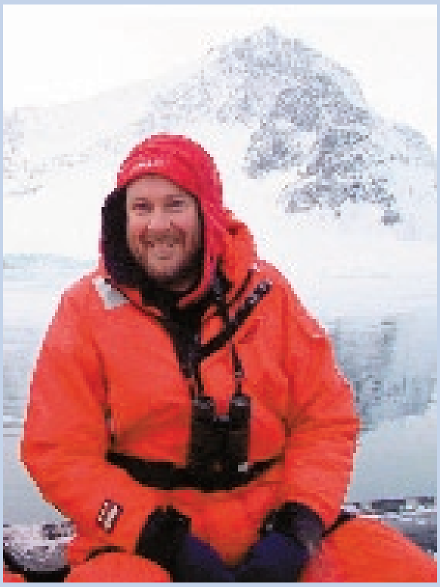
Top to bottom: Marine research vessels used by the Australian Antarctic program over the last 20 years include RV Aurora Australis, *MV* Nella Dan, *RV* Tangaroa *and RV* Southern Surveyor.

PHOTO & MAP CREDITS
Left: Jennifer Burns
Right top to bottom:
Wayne Papps
Peter Boyer
NIWA New Zealand
CSIRO Marine Research

Opposite page:
Australian Antarctic Data Centre

STOP PRESS

Outstanding seal conservation research picks up major Australasian science award



Dr Mark Hindell from the Antarctic Wildlife Research Unit at the University of Tasmania has been awarded the Australasian Science Prize for his outstanding research on the conservation of elephant seals.

The award recognises world-class science being conducted by Australia's leading scientists.

Mark Hindell has been studying southern elephant seals (Mirounga leonina), the world's largest seals, for two decades. The population of this species on Macquarie Island has more than halved since the AAD's first survey in 1949.

Dr Hindell's research aims to give early warning of the very real threats to mammal populations. The team from the Antarctic Wildlife Research Unit has most recently been studying the possibility that the elephant seals' decline is due to a flow-on effect starting with a reduction in food available to females, which culminates in reduced juvenile survival and ultimately in a decline in population size.

Who does all the work in the Southern Ocean?

The whales, seals, penguins and flying birds of Antarctica are well known and the subject of evocative images. They are Antarctic icons – the charismatic megafauna. However, by far the most abundant and globally important living things in Antarctica are the single-celled organisms - the phytoplankton (the single-celled floating plants), the protozoa (the single-celled animals), and bacteria that live in the sea. These microscopic critters hugely outnumber the macroscopic organisms (the ones you can see with the naked eye) in terms of species and abundance. They play a key role in the health, not just of the Southern Ocean, but of the planet.

These microscopic plants and animals range in size from around one micrometre (a thousandth of a millimetre) to about one tenth of a millimetre in size. Bacteria range in size from around a quarter of a micrometre to about a micrometre. Although they are very tiny there are a lot of them – what they lack in size they make up for in number. Every litre of seawater contains about one billion bacteria and around one million phytoplankton cells.

We know that the biomass of whales in the Southern Ocean is about five million tonnes. There are about 10 million tonnes of the six species of Antarctic seals and slightly less than one million tonnes of penguins. The krill population, on which these predators feed, is estimated to be between 60 and 155 million tonnes. In contrast, the biomass of the single-celled plants, the phytoplankton is estimated at around 5,000 million tonnes in the Southern Ocean. In addition, there are some 1,200 million tonnes of bacteria and about 600 million tonnes of protozoa. In comparison, if all of us human beings on planet Earth stood on a weighbridge we would weigh in at around 160 million tonnes. In short, in the Southern Ocean the mass of microscopic plants, animals and bacteria is dramatically greater than that of the total all the macroscopic organisms.

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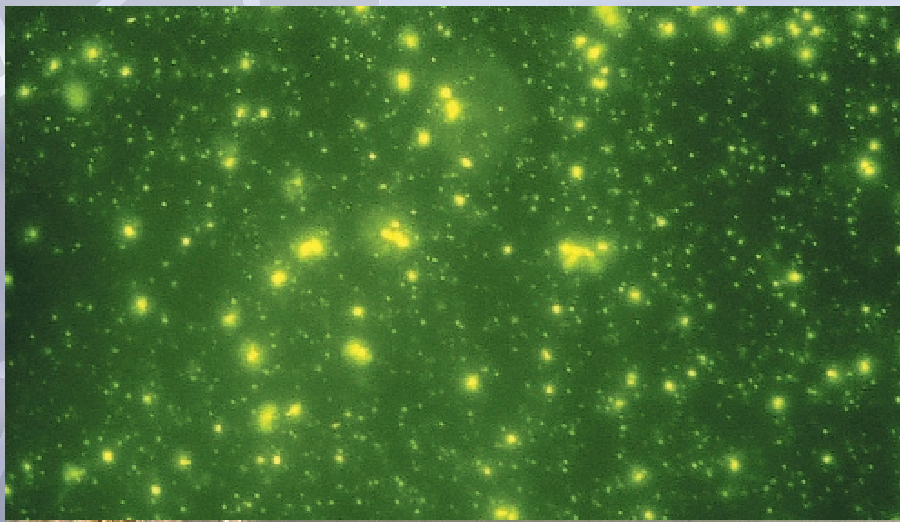
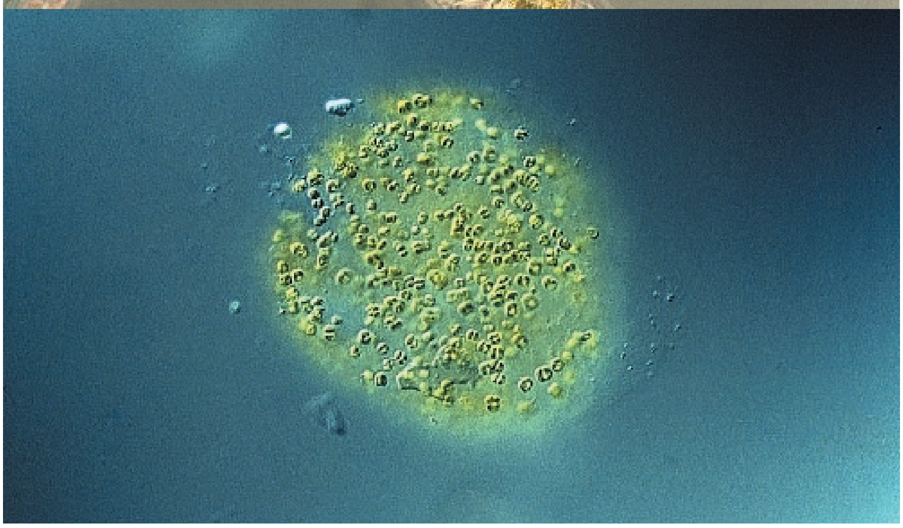
Not only are the marine microorganisms very tiny and numerous, but they are highly diverse. We recognize around 400 species of phytoplankton and over 100 species of protozoa from the Southern Ocean.

We generally group the phytoplankton and protozoa together and call them protists because at the level of the single cell the differences between animals and plants get blurry. Many different kinds of phytoplankton





TOP to BOTTOM: • Bacteria (large green/yellow dots) and viruses (small, pale green dots) are critical components of the food web, functioning as both predators and prey. • The large chain-forming diatom Entomoneis sp. *is typical of springtime Antarctic sea-ice communities, and cells are eventually released into the water column; their photosynthesis produces food and oxygen which are then available to other life forms. •* Phaeocystis antarctica *is arguably the most abundant of Antarctic protists. Cell concentrations can reach 6 x 10^7 cells per litre, giving the sea a brownish oily appearance and releasing sulphur compounds.*

can graze like protozoa, especially under low light conditions, and several different types of protozoa digest phytoplankton cells, except the chloroplasts (the site of photosynthetic activity) which they retain. These chloroplasts produce sugars which are used by their protozoan host.

Each species of microorganism, like the species of plants and animals that we can see with our naked eye, differs in size and shape and does different things in the ecosystem. Just as emperor penguins and Adélie penguins are different species, differ in size and shape and have very different strategies for feeding, breeding and generally going about their lives, so do different species of single celled animals. Similarly, just as different species of macroscopic plants differ in size, shape, means of reproduction, and food value to grazers, we find similar differences between microscopic plants.

Their main functions are:

- First, they're the food on which just about everything else in the sea ultimately depends. The single-celled plants are justifiably called the pasture of the ocean. They live in the top 100 metres or so of the ocean and just like their counterparts on land they use the energy of sunlight to produce carbohydrates in the process of photosynthesis. They are the direct equivalents in the sea of the trees, the bushes and the grass on land on which grazing animals depend. In the Southern Ocean, krill, copepods, salps and other grazers feed on phytoplankton and are they themselves prey for birds, mammals, fish and squid. No phytoplankton, then no krill, and no whales.
- Secondly, phytoplankton trap atmospheric carbon dioxide. Carbon dioxide from the atmosphere dissolves in the sea and is used by them. Most of this carbon dioxide that is turned into organic carbon by the algae is respired straight back to carbon dioxide again by the algae themselves and bacteria that use their excreted products. Only about 2% of the photoassimilated carbon is transported to the deep sea where it is out of circulation for centuries to thousands of years. The utilization of carbon dioxide by single-celled plants, the modification of this carbon by the marine micro-organisms and its vertical flux to the deep sea and sea floor is called the biological carbon pump. In these days of concern about the greenhouse effect and climate change, understanding how this biological carbon pump works and how hard this pump is working is of global significance. The process of photosynthesis by phytoplankton produces oxygen. We, and all the other oxygen-breathing animals, couldn't survive without them.
- The third major function of marine microorganisms is a feedback to climate. Many of them produce sulphur-based chemicals which, when ventilated to the atmosphere, are modified to form sulphate aerosol particles. These aerosols can act as cloud condensation nuclei. The more cloud condensation nuclei the greater the cloudiness; the greater the cloudiness the greater the amount of solar radiation reflected back into space. A negative feedback loop has been proposed whereby the production of the sulphur compounds is enhanced by high light and increased temperature but increased cloudiness shades and lowers the temperature, reducing production of the sulphur based compounds.

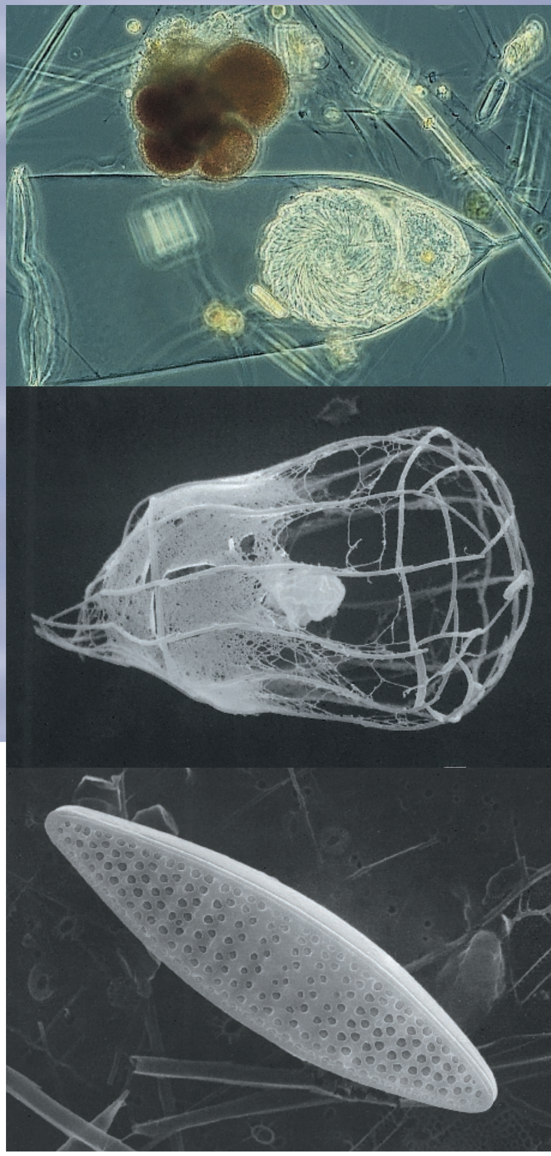
The microscopic single-celled animals do all the sorts of things their larger macroscopic, visible, counterparts do. The herbivores eat plant material, the carnivores eat other animals and there are others that clean up the microscopic equivalents of carrion and detritus. So, just as is the case with large animals there are those that quietly graze and those that are voracious predators. In every drop of water there is a jungle with a similar struggle for survival. You just need a microscope to witness it. And yes, they do have sex.

The filter feeding group of protozoa called choanoflagellates illustrates the impact tiny, but very abundant, critters can have on the environment. They feed over a wide size range of particles. For them large food items are bacteria, about a quarter of their own size. They also ingest dissolved organic material, particles only a few tens of nanometres (One nanometer is a millionth of a millimetre) in size. In the Southern Ocean and off the coast of California choanoflagellates filter up to 10% of the surface water per day. In Danish coastal waters they filter about 25% of the surface waters. They play a vital role in trapping and repackaging carbon which will either be grazed by other animals or sink to great depths in the sea.

Next time you see Antarctic wildlife enjoy it, marvel at it and learn. But spare a thought for the microscopic creatures on which the whales, seals and birds ultimately depend. Picture in your mind's eye a microscopic jungle teeming with life. The plants are doing all the sorts of things plants do – photosynthesizing, competing among themselves for light and space, and being grazed by animals. And among the plants lurk microscopic animals – some quietly grazing, others filtering goodies out of the water, and still others leaping out to devour the unwary. There is a jungle in every drop. Think about it too next time you go for a swim and get a mouthful.

HARVEY MARCHANT,
BIOLOGY PROGRAM LEADER, AAD

So, just as is the case with large animals there are those that quietly graze and those that are veracious predators. In every drop of water there is a jungle with a similar struggle for survival. You just need a microscope to witness it. And yes, they do have sex.



TOP to BOTTOM: • Ciliates and Foraminifora feed on other protists and bacteria, re-packaging some of the carbon of the Southern Ocean. • Diaphanoeca grandis *is a choanoflagellate with a mesh-like lorica, used to trap small food particles from surrounding waters. •* Fragilariopsis kerguelensis *is a heavily silicified diatom that contributes to silica deposits on the ocean floor after cell death.*

Antarctica Online

For further information on Antarctic marine protists, including some wonderful QuickTime movies of microbes swimming, go to the AAD's website at <http://www.aad.gov.au/science/AntarcticResearch/Biology/MME/movement.asp>

PHOTO CREDITS
Harvey Marchant (all)

Opposite page top to bottom:
Andrew Davidson
Harvey Marchant
Harvey Marchant

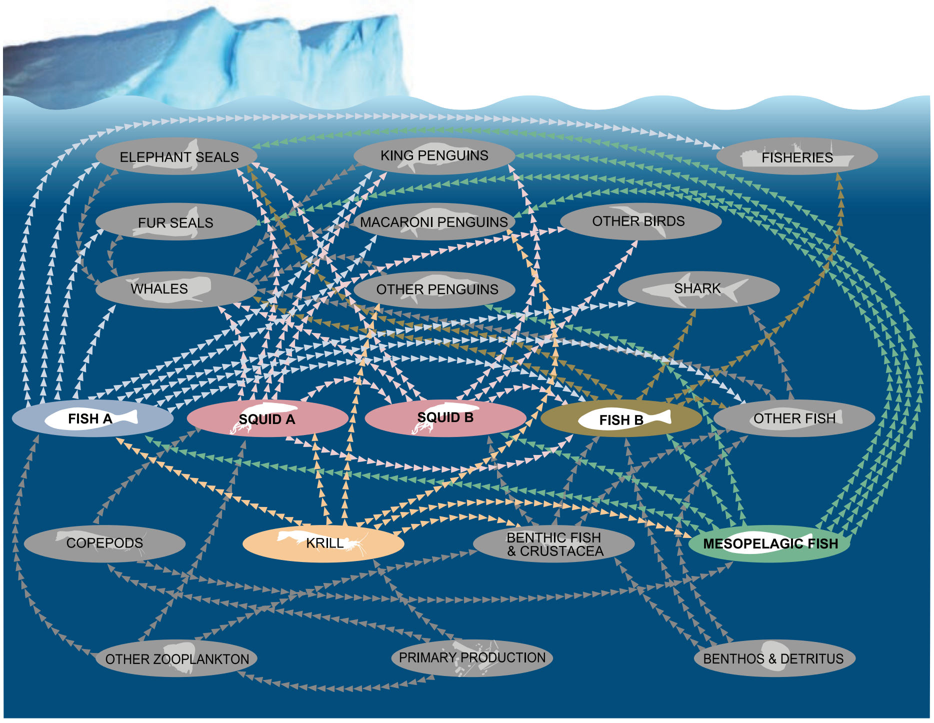
Whales eat fish!

Why is it that a statement of rather obvious logic like 'whales eat fish' has come to represent a pivotal debate about the way we manage and conserve our fisheries? The answer to this lies in the international politics and science that play out in the International Whaling Commission (IWC). In this, and other forums, several pro-whaling nations have raised the case that resourses consumed by whales affect global food security, and that the resumption of whaling would result in more resources being available for commercial fisheries. The consequences of this, and similar debates about other predators (such as seals), have major socioeconomic implications.

We have witnessed the early stages of recovery of a number of whale stocks, whilst others remain seriously threatened. The gradual re–emergence of some of these highly visible species has been used by some of the pro-whaling nations to stimulate the long-standing, polarised debate about the way in which marine predators such as whales might limit or influence fisheries, and to further the case in favour of the resumption of commercial whaling.

Whales are a highly diverse group of marine mammals that exist in all our oceans. Their diet is varied, and whilst the baleen whales in the Southern Ocean feed almost exclusively on krill, fish – not surprisingly – can also be a dietary component of some whales. Poor regulation of whale hunting during the whaling era drove most of the great whale species close to extinction. Over the past few decades we have witnessed the early stages of recovery of a number of whale stocks, whilst others remain seriously threatened. The gradual re-emergence of some of these highly visible species has been used by some of the pro-whaling nations to stimulate the long-standing, polarised debate about the way in which marine predators such as whales might limit or influence fisheries, and to further the case in favour of the resumption of commercial whaling. A case is gradually being developed to consider ecosystem manipulation, whereby predator numbers, such as whales, are reduced with a view of making additional biomass available to commercial fisheries.

The type of interactions in question here are not the operational ones such as killer whales taking fish from a commercial long-line, but rather, the more complex interaction at the level of the food-web, whereby predators, including man and whales, might be competing directly for a food species. The fundamental premise behind the idea of manipulating a food web, or ecosystem, is that if you were to cull a number of whales, then the food that is not consumed by those whales will be available to commercial fisheries. How likely is this?



The scientific debate on this has been, and continues to be, controversial and polarised. To a great extent this reflects the complexity of ecosystem structure and function and our limited capacity to measure and predict it. At its most simple, a food web model consists of a series of boxes, each representing a species in that food web, with arrows indicating who eats who. At its next level of complexity the size of the arrows between predators and prey might be scaled, so that the size of the arrow represents the relative importance of a particular prey species to a particular predator. An example of a highly simplified food web is given in the figure below. In this system, which is one that might operate in the Southern Ocean, you can see that there is an arrow between Fish B and whales. This reflects the likely fact that Fish B contributes towards some part of the diet of animals such as killer whales, sperm whales and beaked whales. What is also evident is that elephant seals, sharks, other fish and fisheries also 'eat' Fish B. This consumption is of course not only at the stage of mature fish, but may be at any stage of the fish's life cycle. Thus, it may be that some relatively small fish are eating masses of juvenile Fish B. Indeed, where data of this type have been assessed previously in relatively well studied ecosystems, it is usual that 'other fish' contribute enormously more to the mortality of a commercial prey species than do marine mammals.

If we imagined that we were to remove the whales from our simplified food web model, then their contribution to the mortality of Fish B would also be removed. From the point of view of the fisheries the best outcome of this would be that this hypothetical surplus of fish would now be available for us to catch. There are several things that make this outcome unlikely. Firstly, the other predators of Fish B are likely to want a share of this possible surplus, so at best only a portion remains for the fishery. Secondly, you will notice that there is also a line from 'other fish' to whales. This means that there will also be more of these 'other fish' left in the water after the hypothetical demise of our whales, and these additional 'other fish' will require more Fish B to sustain them. This again depletes the potential surplus for our fishery. More generally the obvious complexity of even this simplified food web means that the adjustment of the relationship between just one predator and one prey is likely to change the myriad of other relationships in the food-web in a way that is likely to be subtle and extremely difficult to predict. Finally, the figure is like a snap-shot of relationships. In reality we know that these relationships are highly dynamic and subject to large scale changes, dependent upon a complex interaction of competing influences.

The Australian Antarctic Division is required to provide scientific advice to organisations like CCAMLR to support the sustainable utilisation of fisheries in the Southern Ocean. To this end, much of the research we undertake aims to improve our knowledge of how marine predators, such as whales, and their prey interact within their complex food webs, and how we might improve our ability to predict changes from processes such as fisheries or climate change. Given the difficulty of this task, and the high possibility of making erroneous predictions, CCAMLR invokes the precautionary principle in any management action that results from this, or other research.

Nick Gales,
Antarctic Marine Living Resources Program, AAD

Long-term study analyses seabird communities

Antarctic petrels, one of the most frequently observed seabirds in Prydz Bay.

Since observations of seabirds at sea within Prydz Bay began in 1980–81 with the start of the BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks) program, almost 32,000 observations of seabirds and associated environmental variables (such as sea ice, sea surface temperature and wind speed) have been made. Forty species of seabirds have been reported from the Prydz Bay region.

Of the 26 most frequently observed species, nine breed within Prydz Bay (emperor and Adélie penguins, southern giant petrels, southern fulmars, cape, Antarctic and snow petrels, Wilson's storm petrels and south polar skuas) and 17 visit Prydz Bay from their breeding grounds farther north, such as albatrosses and shearwaters. There have been no winter observations (June to August, inclusive) of seabirds within Prydz Bay over the 22 years, so the analyses were confined to spring, summer and autumn observations.

Since observations of seabirds at sea within Prydz Bay began in 1980–81 almost 32,000 observations of seabirds and associated environmental variables have been made. Forty species of seabirds have been reported from the Prydz Bay region.

A recently completed study has used this extensive data set to identify and examine three species assemblages, or communities, of seabirds within Prydz Bay (*Figure 1*). Observations of assemblage 1, comprising all

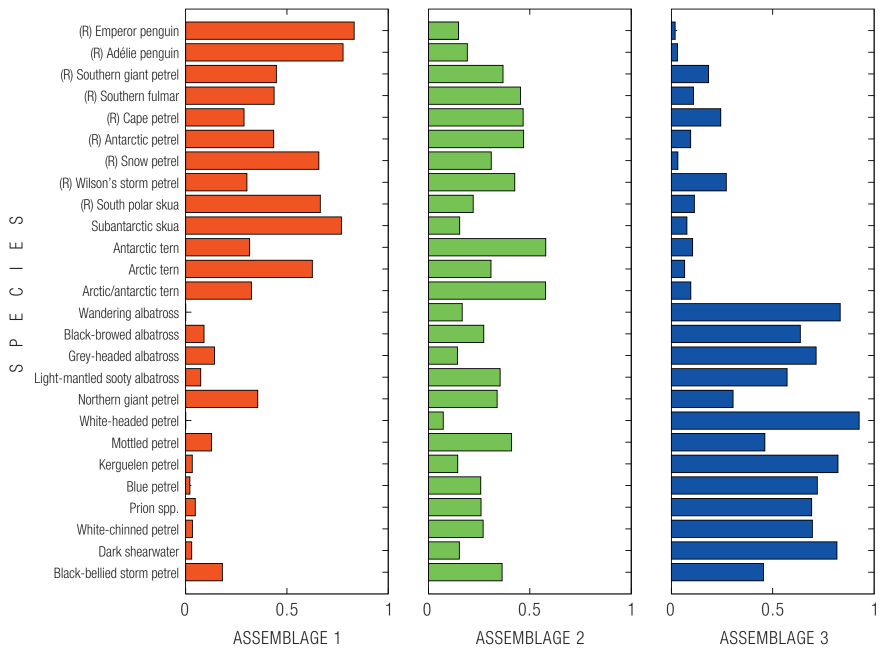


Figure 1. Species composition for the three seabird assemblages within Prydz Bay identified in this study. R = species breeding within Prydz Bay. The values shown are the numbers of observations of each species associated with each assemblage (as a fraction of the species' total).

PHOTO & DIAGRAM CREDITS
Eric Woehler

Opposite page:
Nick Gales / de Vos design

nine breeding species, were consistent with the influx, presence, and departure of breeding birds to their colonies around Prydz Bay – a major breeding area for all nine breeding species, with large breeding populations during summer months. In midsummer this assemblage was observed in the southeast of Prydz Bay, adjacent to known Vestfold and Larsemann Hills breeding areas.

Assemblage 1 is similar to pack ice associated seabird assemblages identified elsewhere around Antarctica, with minor differences in species composition due to different seabird breeding distributions. For example, the sea ice assemblage in the South Atlantic sector of the Antarctic includes chinstrap penguins that do not breed in the Australian sector.

Assemblage 2 comprises all 26 commonly observed seabird species from Prydz Bay and represents an overlap (in time and space) assemblage, being observed in late summer in central Prydz Bay.

Assemblage 3 consists principally of the non-breeding species that visit Prydz Bay each summer from subantarctic and temperate breeding localities, including some species from as far afield as southeast Australia, such as shearwaters. This assemblage was observed most frequently in mid- to late summer and well offshore (see *Figure 2*).

Two species (cape petrels and Wilson's storm petrels) were found to be members of assemblages 1 and 3. This is believed to be a result of their widespread breeding distributions, with colonies in the Antarctic and subantarctic. Individual cape and Wilson's storm petrels forage within Prydz Bay before returning to their colonies. This behaviour produces broad ranges in their 'at -sea' distributions in the Southern Ocean.

The study provides the foundation for further investigations such as predicting seabird distributions from physical environmental parameters at localities elsewhere in East Antarctica.

Eric J Woehler, Ben Raymond & David J Watts, AAD

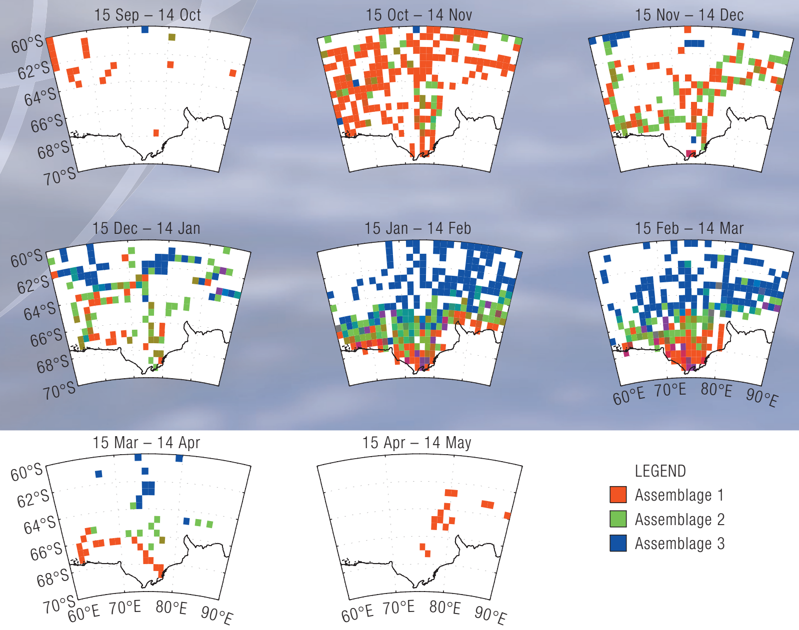


Figure 2. The distributions of the three seabird assemblages within Prydz Bay by month, using the assemblage colours of Figure 1. Data from all years are shown; areas with no data are white.

Southern Ocean data: what's out there?

What do seabirds, fishing activities, water currents, sea surface temperatures and sea ice all have in common? The Southern Ocean? While that is certainly true, they are just a few examples of datasets held by the Australian Antarctic Data Centre (AADC). The AADC was created in 1995 to help meet the AAD's obligation towards Article III.1.c of the Antarctic Treaty – the free and ready exchange of Antarctic scientific data. The AADC maintains a large repository of publicly available Antarctic data, obtained from all disciplines of scientific research, such as atmospheric physics, glaciology and oceanography. The data are indexed with a metadata system – a catalogue that contains such information as when the data were collected, how, where and by whom.

So is the AADC merely archiving all this data? No. Some of the data, such as fish catches, and fast ice thickness, is fed back into the System for Indicator Monitoring and Reporting (SIMR – see *Australian Antarctic Magazine 3:16*), in order to monitor the state of the Antarctic and Southern Ocean environment. Other Southern Ocean data have been collated by the AADC's data miner, and examined for potential relationships (see the article 'Long-term study analyses seabird communities' above). The responsibility of a data miner is to trawl through datasets, sometimes wildly different in nature, and analyse them for any linkages or patterns. When you combine the curious and inquisitive nature of a data miner with a large repository of data, such as the AADC has, then suddenly you have quite a powerful research tool at your fingertips.

So when you consider the multidisciplinary nature of the data held by the AADC, and the possibility that said data may have a much broader application than the purpose for which it was originally collected, who knows what else could be lurking beneath the depths of the Southern Ocean?

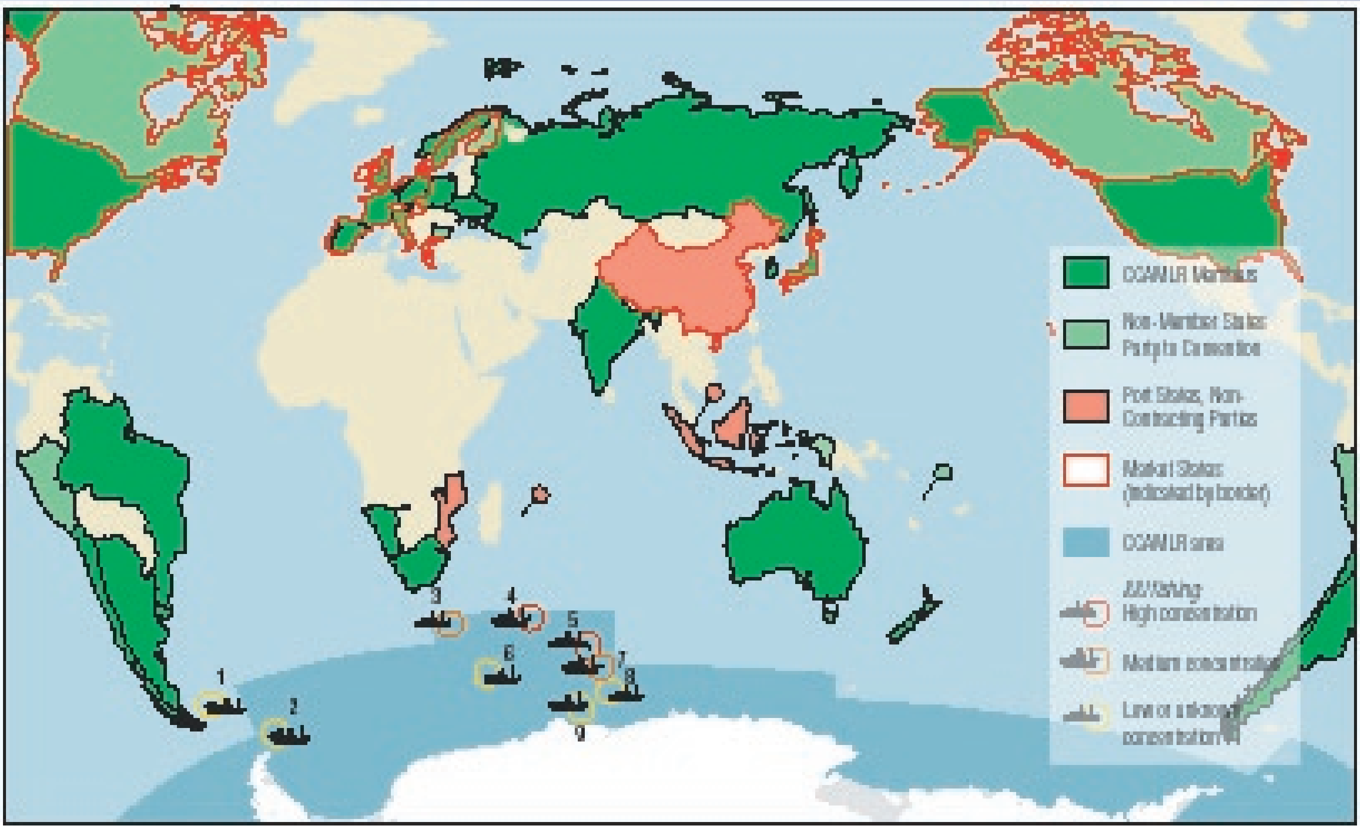
Dave Connell,
Scientific Data Coordinator,
Australian Antarctic Data Centre, AAD

From sea surface temperatures to diving penguins ...

The following are some examples of datasets that the AADC maintains:

- Sea ice biota of coastal eastern Antarctica
- Marine science underway data
- Prydz Bay current meter data
- Antarctic drifting buoys
- Regional dialects and herd formation aspects of Weddell seal (*Leptonychotes weddellii*) underwater vocalisations

Conserving Southern Ocean ecosystems: chequered past, difficult future



Map highlighting the different states involved in toothfish fisheries in the Southern Ocean, including Members to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) (dark green), States party to CCAMLR but not members (light green), non-contracting parties involved in toothfish fishing as port states (orange) and market states (red border). Fishing vessels with circles indicate locations of illegal, unregulated and unreported (IUU) fishing (red means greater levels of IUU fishing, orange medium levels and yellow low levels).
*• **Key to fishing areas:** 1 Falkland Islands (Islas Malvinas); 2 South Georgia; 3 Prince Edward and Marion Islands; 4 Crozet Island; 5 Kerguelen Island; 6 Ob and Lena Seamounts; 7 Heard and McDonald Islands; 8 BANZARE Bank; 9 Mawson Coast. • **CCAMLR Members:** Argentina, Australia, Belgium, Brazil, Chile, European Community, France, Germany, India, Italy, Japan, Korea, New Zealand, Namibia, Norway, Poland, Russian Federation, South Africa, Spain, Sweden, Ukraine, United Kingdom, USA, Uruguay. • **States Party to the Convention but not Members of the Commission:** Bulgaria, Canada, Finland, Greece, Netherlands, Peru, Vanuatu. • **Non-Contracting Parties Port States:** Indonesia, Mauritius, Mozambique, Singapore, Hong Kong, China. • **Market States:** USA, Canada, China, Japan, European Community.*

The Southern Ocean has suffered the ravages of over-exploitation since the late 18th century, including sealing, pelagic whaling, and overexploitation of fish species. The collapse of many fisheries throughout the world, particularly in the northern hemisphere, has meant that the relatively unexploited Southern Ocean is now seen as the last frontier for global fisheries.

The chequered history of the Antarctic marine ecosystem is similar to that of other large-scale marine ecosystems. What sets it apart is the political and decision-making regime covering Antarctic waters, developed over the past twenty years, which has given us the opportunity to determine what we need to manage Antarctic fisheries in an ecologically sustainable way. If successful, this could be a pattern for managing marine ecosystems elsewhere in the world.

Exploitation of Southern Ocean species is managed primarily under three different conventions: the International Convention for the Regulation of Whaling (1946), the Convention for the Conservation of Antarctic Seals (1978) and the Convention on the Conservation of Antarctic Marine Living Resources (1980) (CCAMLR). The latter two conventions are part of the Antarctic Treaty System.

The International Whaling Commission (IWC) agreed in 1982 to impose a moratorium on whaling beginning in the 1985–86 austral season, although despite opposition Japan has continued whaling under a special permit for scientific whaling. The work of the IWC's Scientific Committee – a pre-eminent forum for evaluating methods for assessing the status and yield of exploited populations and developing management procedures – has been a major precursor for approaches developed in CCAMLR.

The Antarctic Seals Convention, a 1978 instrument to protect seals and manage any commercial exploitation within the Antarctic Treaty area, south of 60° South, provides for a permissible catch between September and February in each year of crabeater, leopard and Weddell seals and forbids the killing or capture of Ross, southern elephant and

The chequered history of the Antarctic marine ecosystem is similar to that of other large-scale marine ecosystems. What sets it apart is the political and decision-making regime ... If successful, this could be a pattern for managing marine ecosystems elsewhere in the world.

fur seals. However, there has been no sealing at all since its inception.

CCAMLR, in force from 1982, was negotiated to ensure that the needs of the whole marine ecosystem were taken into

DIAGRAM CREDITS
Peter Boyer

Opposite page:
Eric Woehler

account in managing, among others, the expanding krill fishery (*Australian Antarctic Magazine* 1:57). The convention was a major advance in the conservation and management of marine species in the Southern Ocean, not least because it extended beyond the Antarctic Treaty area to encompass the whole of the Southern Ocean south of the Antarctic Convergence (Antarctic Polar Front) – predominantly high seas but also including four undisputed national territories – Heard Island and McDonald Islands (Australia), Kerguelen and Crozet Islands (France), Prince Edward and Marion Islands (Republic of South Africa), and Bouvet Island (Norway).

The Commission established under CCAMLR (currently with 24 members and seven acceding states) has invited all countries involved in fishing for or trading in Southern Ocean species to attend its annual meetings. Namibia, as a port State, has recently become a member of the Commission and Vanuatu, a flag State, has become a contracting party.

With its broad mandate to address the conservation of the Antarctic marine ecosystem, CCAMLR also has the attributes of a regional fisheries management organisation. Its innovative ecosystem approach to managing fisheries places it at the vanguard of international instruments. This approach is governed by the three conservation principles in Article II of the Convention.

The first principle for target species is to ensure stocks are maintained close to levels that ensure greatest potential recruitment (birth and survival) of young to the harvested population. Methods derived from this approach, called 'maximum sustainable yield' – the catch expected to keep the stock at this level – were applied in early years but failed, and the approach is no longer applied to CCAMLR stock assessments. Nevertheless, current CCAMLR models rely on similar kinds of information, including knowledge of the dynamics of populations (birth and death rates), productivity of individuals including growth and reproduction, and the interaction between the fishery and the population (the ages or sizes of fish being exploited).

The second principle is conservation of the marine ecosystem, which fishing affects both directly – through by-catch of species including bottom-dwellers, finfish and seabirds – and indirectly through impact on food webs. In requiring the conservation of 'dependent and related species', the Convention implies that food webs should remain largely unaltered as a result of fishing. This makes research on the potential for competition between fisheries and Antarctic predators an important element of CCAMLR work.

Lastly, the principles of the Convention include rational use of marine living resources in the region, the need to allow the recovery of depleted species, such as seals and whales, and the need to avoid irreversible changes – changes that cannot be reversed within two to three decades.

All fisheries in the Convention area are subject to management controls (conservation measures). The main controls apply to total allowable catches, fishing methods, and seasons in each statistical area. Harvest controls are derived from the best scientific evidence available, based on assessments by the Scientific Committee's two working groups: fish stock assessment (developing management advice on toothfish, icefish and other fisheries except krill) and ecosystem monitoring and management (mainly concerned with assessment of krill fisheries and integration of data from the CCAMLR Ecosystem Monitoring Program).

CCAMLR now takes a precautionary approach to managing fisheries (see the CCAMLR website at <http://www.ccamlr.org>), which means that the absence of information does not prevent action being taken to ensure ecological sustainability is achieved. Under this approach, uncertainty is a factor in ensuring that risks to the environment are kept to a low level. In so doing, development of high seas fishing is prevented from escalating more rapidly than the ability to manage and mitigate against environmental impacts. Catch limits are set to keep stocks at or above target levels relative to an average level prior to fishing. Measures are also being established to mitigate the incidental mortality of seabirds in longline fisheries and minimise bycatch of non-target, finfish and other species.

The CCAMLR Ecosystem Monitoring Program (CEMP), initiated in 1986 to detect significant changes to the ecosystem resulting from fishing, was deliberately restricted to monitoring a few selected predators (feeding mainly on krill) in a few areas. Working out how the CEMP data will be utilised in formulation of advice is still being resolved.

A full management procedure for the krill fishery is to be developed over coming years (*Australian Antarctic Magazine* 2:47).

The Commission has established systems for making scientific observations of harvesting activities and inspecting licenced vessels' compliance with conservation measures, as well as measures to help ensure that CCAMLR members comply with conservation measures. CCAMLR's Standing Committee on Observation and Inspection recently established a catch documentation scheme to help restrict trade in Patagonian toothfish, *Dissostichus eleginoides*, to that caught in a manner that does not undermine CCAMLR (*Australian Antarctic Magazine* 1: 56).

Measures to combat illegal, unregulated and unreported (IUU) fishing have been established under United Nations agreements. IUU fishing for Patagonian toothfish (see map on previous page) remains a serious problem for CCAMLR, and further control measures are being pursued.

Progress through CCAMLR's innovative advances in achieving ecologically sustainable harvesting of Southern Ocean species has been tarnished by the rapid rise and sustained activities of IUU fishing for toothfish species. The success of CCAMLR and other regional organisations managing high seas fisheries and the conservation of high seas biodiversity depends on management measures being successfully enforced at regional levels. ■

CCAMLR now takes a precautionary approach to managing fisheries. In so doing, development of high seas fishing is prevented from escalating more rapidly than the ability to manage and mitigate against environmental impacts. Catch limits are set to keep stocks at or above target levels relative to an average level prior to fishing. Measures are also being established to mitigate the incidental mortality of seabirds in longline fisheries and minimise bycatch of non-target, finfish and other species.

ANDREW CONSTABLE
MANAGER, SOUTHERN OCEAN TASK FORCE

CCAMLR XXI

The twenty-first meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was held in Hobart from 20 October to 1 November 2002. The Scientific Committee's Working Group on Fish Stock Assessment met in the two weeks prior to the Commission meeting and the Commission's informal working group on Catch Documentation Scheme for toothfish also met on 17 and 18 October 2002. The Australian delegation was led by Dr Tony Press, Director of the Australian Antarctic Division.

Arguably the most important issue at CCAMLR XXI was illegal, unreported and unregulated (IUU) fishing for toothfish and how to combat it. CCAMLR estimated that IUU catches of toothfish inside the Convention Area continued to increase, up from 8,802 tonnes in the 2000–01 season (December to November) to 10,898 tonnes in the 2001–02 season. The IUU catch for the 2001–02 season inside Australia's Exclusive Economic Zone around Heard and McDonald Islands was 2,500 tonnes, up from 2,004 tonnes in the previous season.

Toothfish catches on the high seas outside the Convention Area fell from 19,299 tonnes to 14,659 tonnes, due mainly to the decline of 4,097 tonnes to 11,213 tonnes in catches claimed to have come from statistical areas 51 and 57. The large majority of the Commission accepted that virtually all catches attributed to Areas 51 and 57, which lie immediately to the north of the Convention Area in the Indian Ocean region, are IUU catches taken inside the Convention Area, in contravention of CCAMLR's conservation measures, and misreported as having come from outside the Area.

The Commission was presented with strong evidence from Australia and some other Members that IUU fishing had become a form of international, organised crime with the nationals and vessels of several CCAMLR Members heavily involved. Of particular concern, given the fears of some Members' involvement expressed at CCAMLR XX, was the clear failure of the same Members to implement existing CCAMLR obligations to combat IUU fishing, especially those relating to monitoring of their fishing vessels.

A number of stronger measures to combat IUU fishing were proposed, including by Australia, with the Commission agreeing:

- to strengthen the toothfish Catch Documentation Scheme in several ways and to trial an electronic version of the Scheme, a change which should offer reduced opportunity for fraud and facilitate movements of fish in trade;
- to establish a 'black list' of vessels involved in IUU fishing;
- to update the satellite-based, vessel monitoring system (VMS) requirements, although, critically and disappointingly, there was not consensus for a centralised VMS; and
- to strengthen conservation measures aimed at improving compliance by Contracting Party and non-Contracting Party vessels with CCAMLR's measures.

Australia's proposal to nominate toothfish to Appendix II of the Convention on International Trade in Endangered Species (CITES) was strongly opposed by the large majority of CCAMLR Members.

CCAMLR XXI agreed to a number of proposals to conduct exploratory fishing for toothfish, including those from Australia. It also set new catch limits for established fisheries, including those around Heard Island where the annual allowable catch in the 2002–03 season for toothfish (for trawling and longlining combined) was set at 2,879 tonnes and 2,980 tonnes for mackerel icefish.

In other scientific developments, CCAMLR XXI agreed to hold an intersessional workshop to explore and develop the estimation of biomass of icefish using acoustic techniques. Australia will participate in this. There was also agreement to subdivide the main krill fishing grounds into small scale management units that take better account of the needs of krill predators and the krill fishery, and more accurately reflect the distribution of krill. The adoption of such ecologically appropriate units for managing the region's largest fishery is the culmination of a series of initiatives advanced, mostly by Australia, since 1987. The next step is to subdivide the catch limit on krill into these small scale units. The Commission also adopted standardised data reporting from the krill fishery, a move which should provide for better understanding of the relationships between the distribution of the fishery and krill stocks.

Ian Hay
Southern Ocean Task Force

TOP to BOTTOM: • Antarctic Marine Living Resources Program Leader Dr Steve Nicol shows CCAMLR XXI delegates the AAD's new research facilities. • Director Dr Tony Press addresses CCAMLR XXI delegates at the reception held at the Australian Antarctic Division's headquarters.

Southern Ocean Taskforce formed

The Southern Ocean Taskforce was established by the Director of AAD, Dr. Tony Press, to advise him on approaches to the conservation of marine species in the Southern Ocean. This includes managing AAD policy work relating to the Commission for the Conservation of Antarctic Marine Living Resources, as lead agency in the Commonwealth Government for CCAMLR issues, as well as associated key issues, including working with other agencies to combat IUU fishing in the Southern Ocean. The major purpose of the taskforce is to develop strategic approaches to these issues for the future, in collaboration and consultation with other agencies. The Taskforce has six staff. They will be reporting on the outcomes of their work during 2003.

Andrew Constable
Manager, Southern Ocean Taskforce

PHOTO CREDITS
Matthew McKee

Opposite page:
Eric Woehler

FEATURE

Gardens under the ice

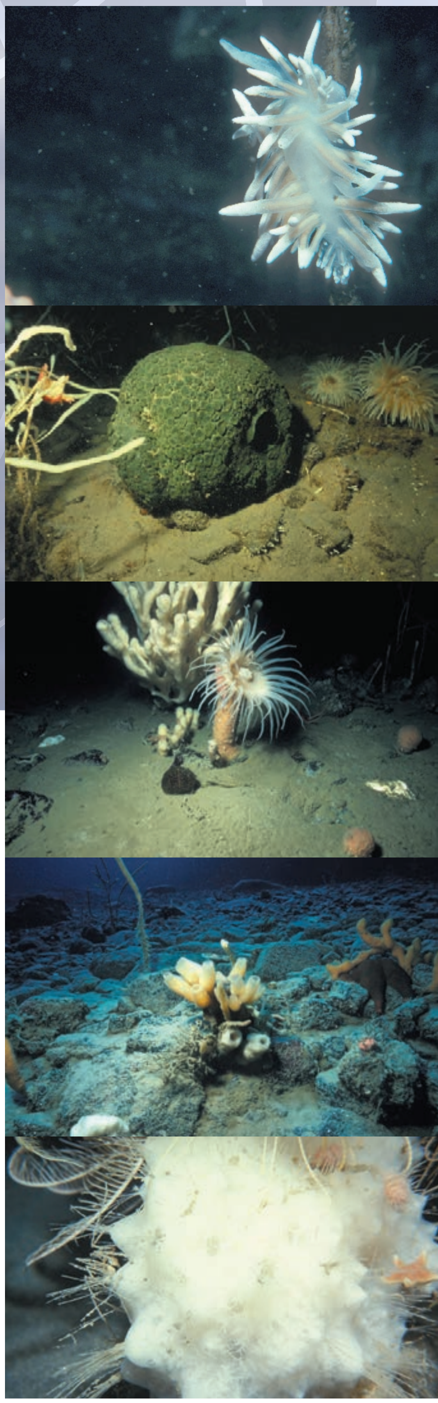
Locked away under the Antarctic sea ice is a rarely seen underwater world teeming with life and colour. The diversity of form and hue in these seabed communities is in stark contrast to the sparse plant and animal communities found on land in Antarctica. Despite our perceptions that the Southern Ocean is a harsh environment, conditions in the sea around the coast of Antarctica are remarkably constant, so although it is cold, with an average temperature only a few tenths of a degree above the freezing point of seawater (-1.85°C), the environment is predictable and hence quite benign for those life forms that have evolved to live there.

They are only found adjacent to the small ice-free areas which make up less than 0.4% of Antarctica, because elsewhere, as the ice of the plateau meets the sea, the seabed is scoured to great depths.

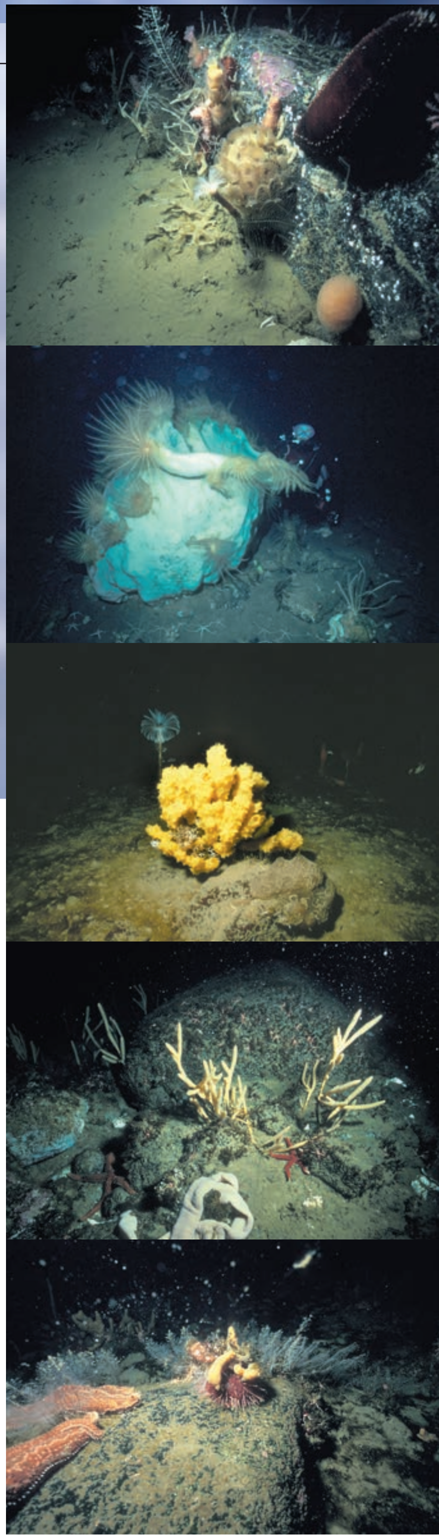
The shallow sea floor communities of Antarctica have been studied in detail in only a few locations, mainly on the Antarctic Peninsula to the north and in the southern part of the Ross Sea at McMurdo Sound. Neither is representative of the great majority of the coastline of continental Antarctica. Despite the enormous size of Antarctica there are surprisingly few places where shallow waters are accessible for study. They are only found adjacent to the small ice-free areas which make up less than 0.4% of Antarctica, because elsewhere, as the ice of the plateau meets the sea, the seabed is scoured to great depths.

At Casey these sea bed communities are being studied by the Human Impacts Program because they are the best indicator of environmental impacts from abandoned waste disposal sites. In contrast to the rich natural communities found at other locations, the seabed adjacent to the Old Casey tip in Thala Valley is littered with rubbish and supports very few species. These communities will be monitored during clean-up to ensure that the effort invested in removing the tips results in real environmental improvements and a return to natural conditions.

Martin Riddle,
Human Impacts Program Leader, AAD



TOP to BOTTOM: • The white nudibranch Austrodoris kerguelensis *feeds on hydroids as it crawls along the stalk of a tube-worm. • Both the green knobbly sphere* Latrunculia apicalis *and the white branches to the left,* Homaxinella balfourensis, *are sponges. The anemones to the right are predators waiting to engulf passing food in their tentacles. • Although they look like plants both the white branching sponge and the flower-like anemone are animals. • When sea ice is present there is not enough light for plankton; as a consequence the water can be crystal clear with horizontal visibility of several hundred metres not uncommon. • Sponges can become the home for other species such as the pink starfish on the right. The tufts sticking out to the side are glass-like strands of silicate that form the skeleton of hexactinellid sponges.*

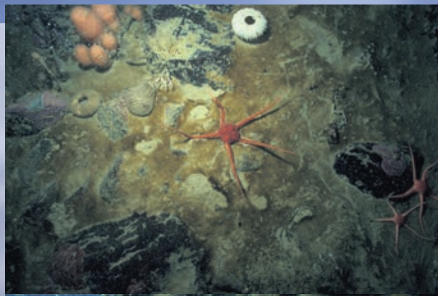
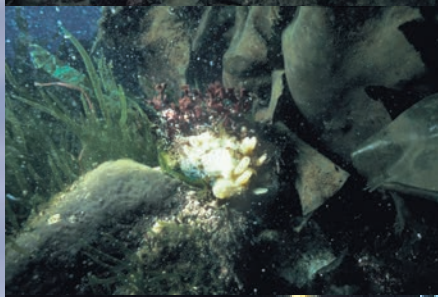
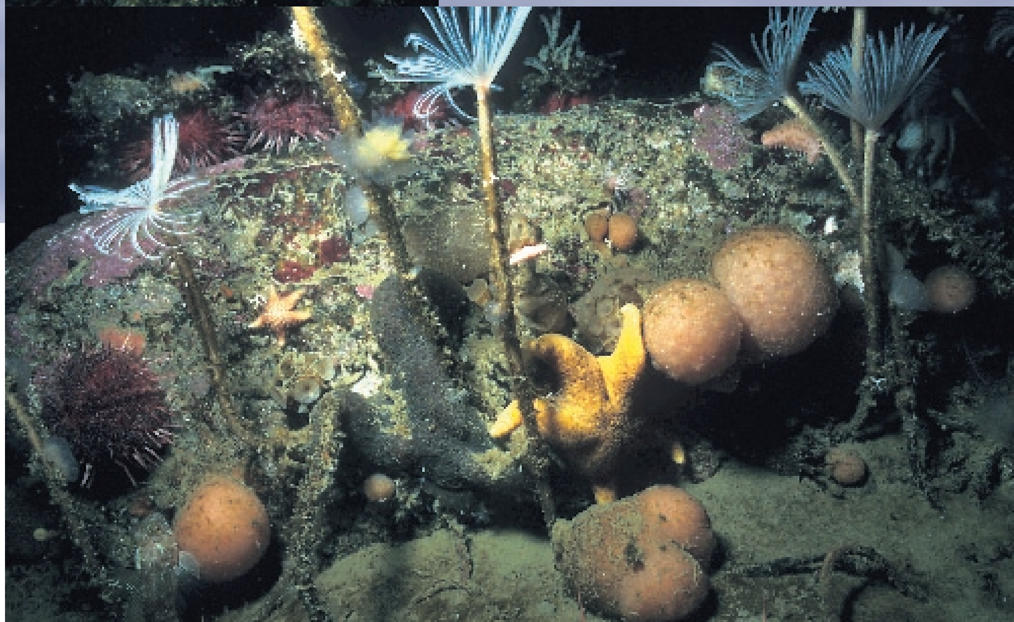
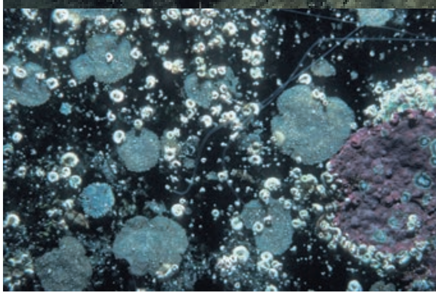


TOP to BOTTOM: • The strange sphere in the centre is another form of sponge. It feeds by filtering particles from the surrounding water. • Giant hexactinellid sponges such as this take hundreds of years to grow to this size and are found in shallow waters only in the Antarctic; elsewhere they are confined to the deep ocean. • This yellow sponge is superficially very similar to species found on tropical reefs in Australia. • The white branching sponge Homaxinella balfourensis *is characteristic of shallow Antarctic seabed communities. It is relatively fast growing and quick to recolonise disturbed areas. • The sea–urchin* Sterechinus nuemayeri *(centre) is thought to carry around bits of sponge and seaweed to protect it from predation by anemones.*






TOP to BOTTOM: • Every available space on this rock is occupied. • The starfish in the centre feeds by engulfing its prey; it then everts its stomach and digests the meal externally. • This large starfish Perknaster sp. *grows to more than 30 cm diameter and can be various colours including white, yellow, red and brown. • At some places the Antarctic scallop,* Adamussium colbecki, *is found in very large numbers. • Nemertean worms in other parts of the world normally grow to only a few centimetres in length; the Antarctic nemertean* Parborlasia corrugatus *commonly grows to 2-3 metres. • Sea-spiders or pycnogonids grow much larger in Antarctica than elsewhere. This specimen is about 20 cm in diameter, more than ten times the size of sea-spiders from other regions.*

TOP to BOTTOM: • Even the muddy areas are rich with life. The brittle star in the centre feeds by sorting through the sediment. The brown on the surface of the sediment is caused by colonies of microscopic plants (diatoms). • In some areas where the sea ice is lost early in the summer enough sunlight reaches the sea floor to allow the growth of dense beds of seaweed. • Even a single rock can support an enormous diversity of life; seen here are sea-urchins, starfish, sea-cucumbers, tube-worms, sponges and colonial ascidians. • In shallow waters the sea ice grinds everything off the rocks except a few small species such as tube worms, bryozoans and encrusting red algae that can live in protected crevices.

PHOTO CREDITS
Left top to bottom:
Andrew Tabor
Andrew Tabor
Martin Riddle
Martin Riddle
Martin Riddle
Martin Riddle
Right: Martin Riddle (all)

Opposite page:
Martin Riddle (all)

Captive krill to get a new home

Vital questions about an organism central to the Southern Ocean ecosystem – Antarctic krill, *Euphausia superba* – would remain unanswered without the ability to study them alive in captivity. The Australian Antarctic Division has maintained a live krill aquarium continuously since 1981 to enable year-round experiments on the animal's behaviour and physiology. Numbers are maintained with wild specimens caught each year from the Southern Ocean.

The old aquarium system, located in a 0°C cold-room, recirculates 4000 litres of sea water daily between the holding tanks and a variety of water filters. Two factors limit the holding capacity of this system to about 5000 krill: the limited space available for tanks and filtration systems, and the slow rate at which the biological filter can remove toxic ammonia waste (due to the low operating temperatures).

To alleviate these problems a dedicated marine research facility is being installed in a new science building at the AAD's Kingston headquarters. This will include two research

The facility will probably be the most advanced laboratory for the study of Antarctic marine biology in the world. It will greatly improve the ability of AAD scientists to study critical aspects of the life history of Antarctic marine organisms and enhance the AAD's reputation as a key international centre for the study of experimental marine biology of Antarctic organisms.

Titanium heat exchangers and an array of biological filters and de-gassing units being installed in the plant room.

labs, a holding lab for krill and other marine species, a plant room for filtration equipment, a preparation room for production of food and monitoring of water quality, a toxicology lab for determining the potential effects of various man-made pollutants on Antarctic marine organisms and connection points to enable container labs from research vessels to be maintained alongside the facility.

The ambient air temperature of the facility will be 18°C, providing a more favourable environment for both staff and for experimental equipment. The sea water will be chilled through heat exchangers to maintain the tanks at 0°C and recirculated every hour through an array of filtration devices.

Before being filtered, the water will be warmed in a counter-current heat exchanger to raise its temperature to 20°C. At this temperature the rate of biological filtration will be considerably higher than has been possible in the existing facility, allowing the more efficient removal of ammonia.

These improvements will enable the new system to maintain more krill at higher feed rates, allowing research into aspects of reproduction and larval biology that was impossible before.

The facility will probably be the most advanced laboratory for the study of Antarctic marine biology in the world. It will greatly improve the ability of AAD scientists to study critical aspects of the life history of Antarctic marine organisms and enhance the AAD's reputation as a key international centre for the study of experimental marine biology of Antarctic organisms.

The new research facility is expected to be operational by December 2002.

Rob King,
Antarctic Marine Living Resources Program, AAD

GLOBEC looks south

The Global Ocean Ecosystem Dynamics (GLOBEC) is an international scientific program whose primary objective is to understand how marine populations vary in response to changes in their environment. The program has identified the unique characteristics of the Antarctic marine food web in the Southern Ocean region as ideal for addressing GLOBEC's main objectives.

Southern Ocean GLOBEC (SO-GLOBEC) has been designed to study the year round life cycle of Antarctic pelagic animals, particularly Antarctic krill. It involves Germany, the United States, Australia, Japan, Korea, South Africa, the United Kingdom and the International Whaling Commission (IWC).

A single key species, Antarctic krill, *Euphausia superba*, provides the mechanism for linking environmental variability and primary production processes with predator species, such as penguins and seals. An environmental linkage is also made by the fact that many components of this food web depend on sea ice during some or all of their life history.

These unique characteristics make the Antarctic marine ecosystem potentially vulnerable to changes in environmental conditions, or to resource exploitation. However, predictions of how this system will respond to environmental variability and climate change first require understanding of the cycles of natural population variability, especially in those that occur in response to physical variability.

An intensive US SO-GLOBEC research program in 2001–02 has focused on Marguerite Bay in the Western Antarctic Peninsula region. Two research vessels, *Nathaniel B. Palmer* and *Lawrence M. Gould*, have made consecutive autumn–winter cruises. The Australian contribution of a marine research voyage, curtailed in 2000–01 for logistic reasons, is now scheduled for January–February 2003.

The voyage involves a detailed examination of the structure and movement of krill swarms near Mawson station, where an Adélie penguin colony has been intensively studied for the past 12 years as part of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Ecosystem Monitoring Program (CEMP). The study, in a small survey area important to krill-feeding predators, aims mainly to determine the fine scale abundances and temporal variation in the horizontal and vertical distribution of krill and other key pelagic species, in relation to water column structure and water mass movements.

Stephen Nicol, Program Leader, Antarctic Marine Living Resources

* The author is a member of GLOBEC's Southern Ocean and Scientific Steering Committees.

The Roaring Forties sometimes purr

The 'Roaring Forties' and the 'Furious Fifties' are terms often applied to the strong westerly winds which are experienced over the mid-latitudes of the Southern Hemisphere. But while this image of raging gales is accurate for much of the time the strength of these winds varies greatly from day to day, across the seasons and also from year to year.

When *Aurora Australis* sailed into the Southern Ocean in July of 1995 (Voyage 1, 1995–96) many expected very difficult weather conditions. However, on the voyage south, reports received from the vessel indicated that despite traversing approximately 2000 km of ocean between Tasmania and the coast of Antarctica in winter, the weather was remarkably kind with relatively light winds and unexceptional sea conditions. Expeditioners did eventually encounter some intense storms near the Antarctic coast, but the question remains: How can a ship experience gentle wind and sea conditions at a time of year when southern Australia is lashed by rain and cold changes from Southern Ocean depressions and cold fronts?

Measuring the actual wind in remote areas such as the Southern Ocean is very difficult. It can be achieved by making measurements on isolated ships and from some instrumented buoys. More recently it has been accomplished over larger areas from satellites equipped with an instrument known as a scatterometer, which measures average wave height – closely related to wind speed.

But estimating wind speeds and directions over the ocean has traditionally meant making inferences from carefully constructed atmospheric pressure charts. This involves assumptions that the analysed distribution of pressure is realistic and that the airflow above the friction layer (about the lowest kilometre of atmosphere) is in geostrophic balance. That is, the force due to the pressure gradient (as indicated by the isobars) is balanced by the apparent force due to the rotation of the earth (the coriolis force).

Application of a simple mathematical formula gives the wind speed at a given latitude for a specified pressure gradient. The wind is normally resolved into two components, one

When 'Aurora Australis' sailed into the Southern Ocean in July of 1995 (Voyage 1, 1995–96) many expected very difficult weather conditions. However, on the voyage south, reports received from the vessel indicated that despite traversing approximately 2000 km of ocean between Tasmania and the coast of Antarctica in winter, the weather was remarkably kind with relatively light winds and unexceptional sea conditions.

in the west-east direction and the other in the south-north sense. The wind direction above the lowest few hundred metres (the friction layer) is parallel to the isobars with low pressure to the right of the wind vector in the Southern Hemisphere. Close to the surface, the wind is slowed by the effect of friction and the wind vector turns slightly across the isobars towards lower pressure.

To understand the seasonal variation of wind over the Southern Ocean we compare

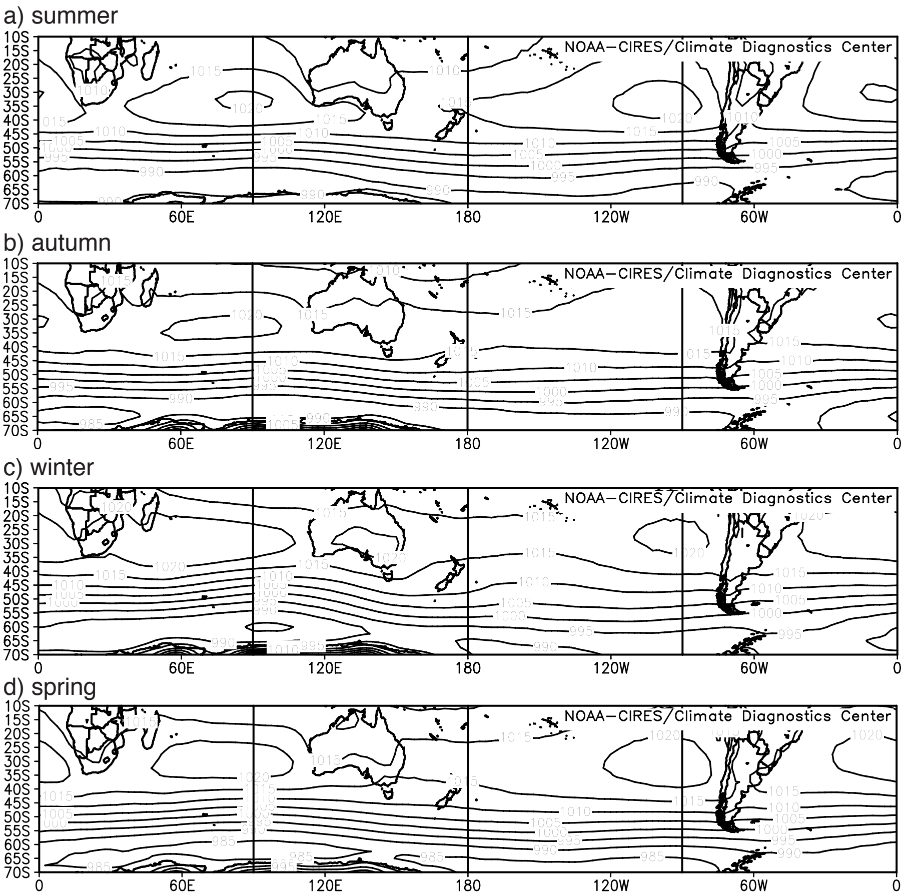


Figure 1. Average pressure at mean sea level (hPa) for (a) summer (December/January/February), (b) autumn (March/April/May), (c) winter (June/July/August), and (d) spring (September/October/November) from the NCEP Reanalysis Program for the period 1948 to 2002. (Isobars are at intervals of 5 hPa)

PHOTO CREDITS
Wayne Papps

Opposite page:
Wayne Papps

the seasonal pressure patterns over the Southern Hemisphere. *Figure 1* shows the average pattern of pressure at mean sea level (MSLP) over the Southern Ocean in the four seasons from the NCEP (National Centres for Environmental Prediction) reanalysis program (Kalnay *et al.*, 1996). The most obvious variation in the appearance of the maps from season to season relates to the north-south migration of the subtropical ridge of high pressure. In summer, the ridge is at its maximum southwards extent and in winter it moves northwards over Australia.

A more subtle change occurs in the trough of low pressure encircling the Antarctic coast south of 60°S, known as the Circumpolar Trough – the region of minimum barometric pressure where the effects of the intense depressions over the Southern Ocean are most felt. It reaches peak intensity and moves closer to the coast in autumn and spring, intensifying the pressure gradient and strengthening the westerly winds to its north. Hence strong winds are associated with the equinoxes (misleadingly called equinoctial gales – great variations in wind speed can happen at any location within these seasons as well as from year to year).

In *Figure 1c* the average MSLP for winter indicates that the westerly winds are on average established across southern Australia but the orientation and spacing of the isobars over the Tasman Sea and New Zealand region suggest that there is a 'split' in the westerly winds in this area. This divergence of the westerly flow occurs because there is a high incidence of anticylonic activity in winter, the so-called 'blocking highs' which are found well to the south of the subtropical ridge. It was such a situation in July and August of 1995 that resulted in the spell of light winds enjoyed by Voyage 1. *Figure 2* reveals the average mean sea level pressure over five days in late July 1995. It features an extensive high pressure ridge extending southwards of Tasmania between major depressions to its east and west.

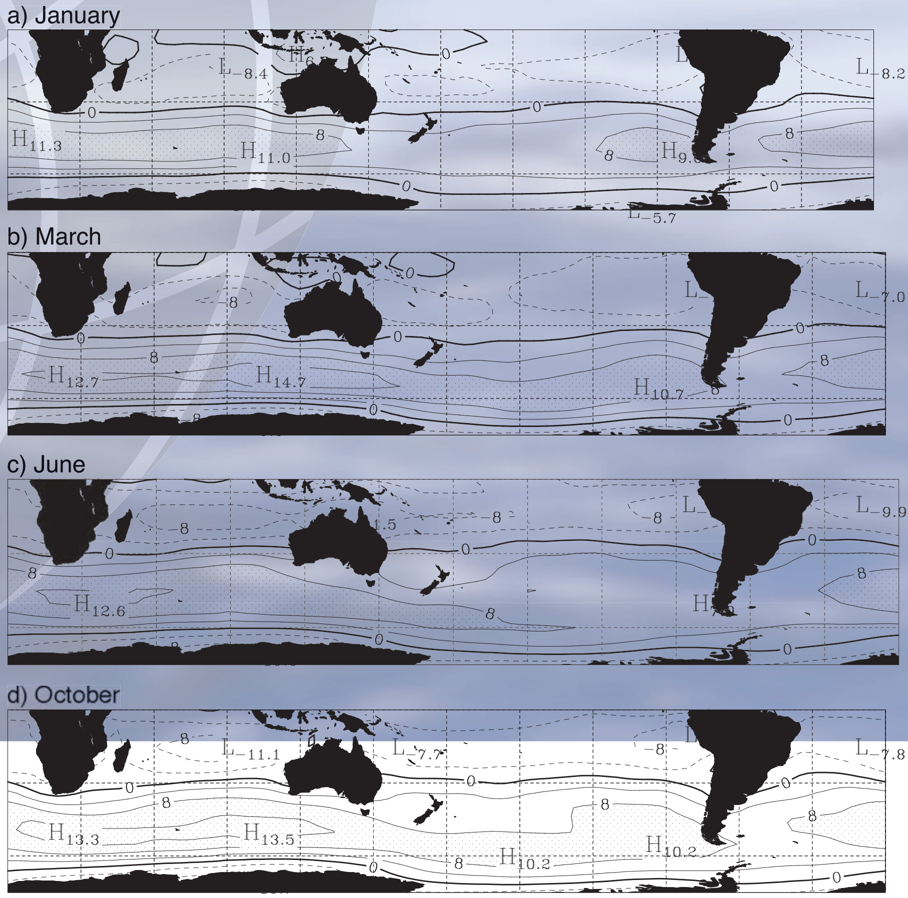


Figure 3. The mean westerly component of the wind at the 1000 hPa level for the months of (a), January, (b) March, (c) June and (d) October for the ten year period from 1980 to 1989 (inclusive) from the Australian Hemispheric Analysis data set. Regions of mean speed of at least 8 m/s are stippled and negative values represent mean winds from the east. (Contours are at intervals of 4 m/s)

The seasonal variation of the strength of the westerly component of the wind is demonstrated in *Figure 3* which plots the wind speed at the 1000 hPa level for the months of January, March, June and October. On average, the belt of strongest winds over the Southern Ocean is found between 50°S and 60°S at all times of the year, but within that zone maxima occur in autumn and spring. The strongest westerly winds occur in the Indian Ocean sector. The area of lightest westerly winds is apparent in the Tasman Sea and New Zealand region in winter, but relatively light winds also extend across the South Pacific Ocean at this time of year *(Figure 3c)*.

In summary, although there is a well understood seasonal variation of the 'westerlies' there is great variability in the day to day strength of the wind over the Southern Ocean in response to the position and movement of the pressure systems. There is also variation in the strength and frequency of systems within seasons and from one year to the next.

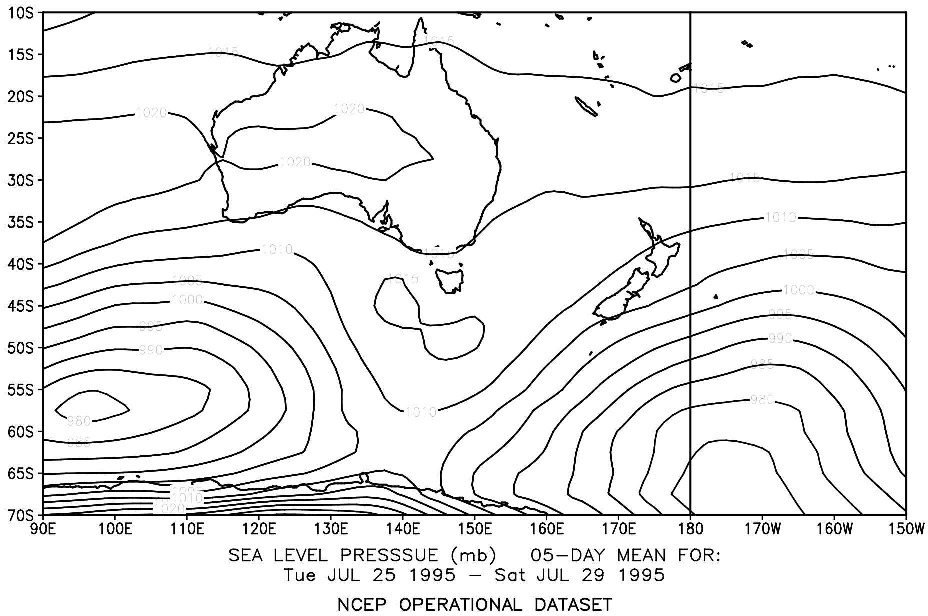


Figure 2. Average sea level pressure (hPa) for the five-day period from 25 July 1995 to 29 July 1995 (inclusive) from the NCEP Reanalysis Program. (Isobars are at 5 hPa intervals)

MICHAEL POOK,
ANTARCTIC COOPERATIVE RESEARCH CENTRE

Reference

Kalnay, E., and co-authors (1996). 'The NCEP/NCAR 40-year reanalysis project', *Bull. Amer. Met. Soc.*, 77, 437-71.

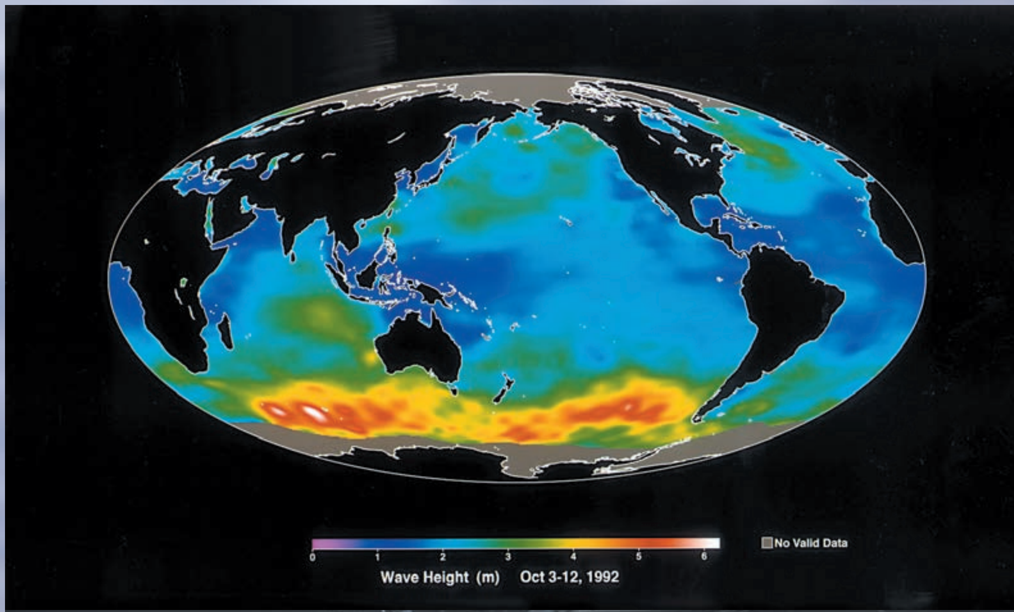
The Southern Ocean factor

Scheduling a shipping program for working in the Southern Ocean is a vexed business. Long term plans become obsolete the first time the vessel encounters the conditions that have given it the reputation as the stormiest sea in the world. Whether it be lowering instruments to the sea bed or towing them behind, or retrieving them from submerged buoys where they were deployed a year ago, it is almost certain that the outcome and timings will not match the original plan.

Towering seas, snow and wild winds ensure that Mother Nature rules in the Southern Ocean. Ships' Masters spend many hours observing, recording and plotting, using their experience to distill the array of information from satellite weather charts and photographs in a quest to make opportunities for the conduct of research when the sea and wind and swell permit safe operations.

It requires dedication and determination, often with repeated attempts, to achieve a component of the program. One task at a time, a variety of approaches perhaps, until, after weeks of working on the most unstable platform, the work is achieved and the ship returns to smooth waters to re-stock and re-fuel before heading south into the maelstrom once more.

The following account by the Master of the Aurora Australis, *Captain Les Morrow, of one storm on one marine science voyage (Voyage 7, January–February 2002) gives some insight into the challenges of conducting scientific research in the Southern Ocean.*



Top to bottom: • This map shows the variation in sea-surface height measured by TOPEX/POSEIDON and estimated by a high resolution global model. The red areas correspond to the most turbulent zones of the oceans, regions of strong currents and high eddy variability. • In following seas, over a metre of water floods the trawl deck of Aurora Australis. *Nets and other equipment were washed overboard.*

We have had some severe weather as an intense low passed close south of us on the 31st January.

Using satellite data, we had seen the likely path of that system for a few days previously, and I had contemplated trying to avoid the worst of it. But the speed at which it appeared to be moving convinced me that to get out of the way, I really needed to be driving an Incat fast ferry.

Conditions freshened up from about 11 am on the 30th, as the wind veered from west to north and increased to 45 knots by 11 pm.

One hour later, the wind was 50 knots with 10 metre swell waves, and it was then that we decided to heave-to.

The wave period was very short, and this made the ship motion very uneasy and caused water to be shipped over the bow, quite an unusual thing for us as our broad beam well forward means that she normally throws the water away in heavy seas.

Down aft, the pitching motion of the ship meant that the trawl deck was frequently awash to considerable depths. One wave that came up the stern ramp, came over the mezzanine deck as well. I know because that was where I was standing with the boatswain checking things, and we were buried !

Those conditions worsened a little through to about 11 am on the 31st, by which time the wave height was around 11 to 12 metres. From then until 2 pm, the winds increased at times to 60 knots, and I estimated wave heights to be averaging 12 metres with quite a number being nearer 14 metres!

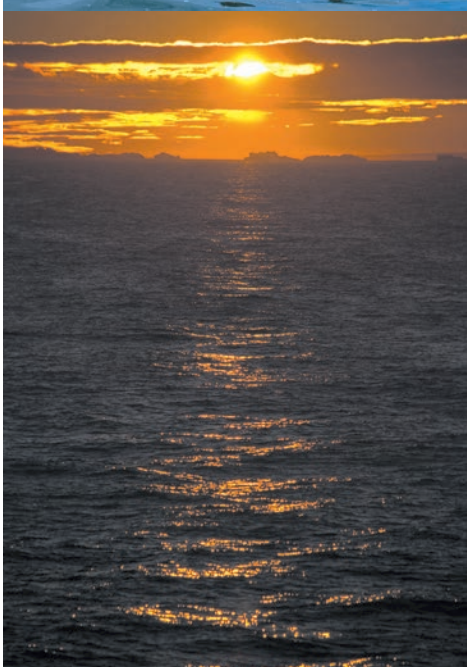
Fortunately this period remained very short. Around 1 pm, a number of waves reached 16 metres. But after 2 pm, there was a very gradual easing so that by later that day (31 January), the wind was 35 knots from the west and wave heights had dropped down below 8 metres.

We are all in agreement here that it was a first class storm !

Les Morrow,
Master, Aurora Australis

PHOTO CREDITS
Top to bottom:
Map: NASA Jet Propulsion Laboratories
Lyn Irvine

When the wind screams...



Only rarely is the Southern Ocean calm. On such days work is easy and spirits high. But usually there is little time to acclimatise to your ocean environment – the ship begins rolling as soon as it enters exposed waters and varying levels of seasickness pervade the ship. As wind strengths increase life becomes more difficult. With winds around 50 knots and seas of seven to 10 m the vessel can no longer maintain the desired heading and hoves-to, heading into the wind at just enough speed to maintain steerage.

Seas sometimes reach 20 m or more in height, tossing the vessel like a toy in a bathtub, and the ship can roll more than 50 degrees either side of vertical as it is dwarfed by menacing walls of dark, forbidding water with foam-capped crests. The ship bucks, rolls

Seas sometimes reach 20 m or more in height, tossing the vessel like a toy in a bathtub, and the ship can roll more than 50 degrees either side of vertical as it is dwarfed by menacing walls of dark, forbidding water with foam-capped crests.

and shudders, impossibly making it over the crest, followed by a sense of weightlessness as it falls into the trough below. The bow buries into the base of the following wave, throwing spray high in the air that is whisked away on the screaming wind and causing the entire ship to flex and vibrate from stem to stern. Astern, great waves careen across the aft deck threatening to tear away or disintegrate fittings and equipment.

You soon learn to keep one hand available to cling to passing objects and avoid being catapulted into fixed objects like bulkheads, tables and doors. Life becomes an endless set of callisthenic exercises as you compensate for the ship's roll, and people attain crazy angles negotiating the corridors. Non-skid matting over meal tables does not always ensure your food stays with your plate. Cups, glasses, jugs and sauce bottles have an unerring ability to become missiles as they cascade from tabletops.

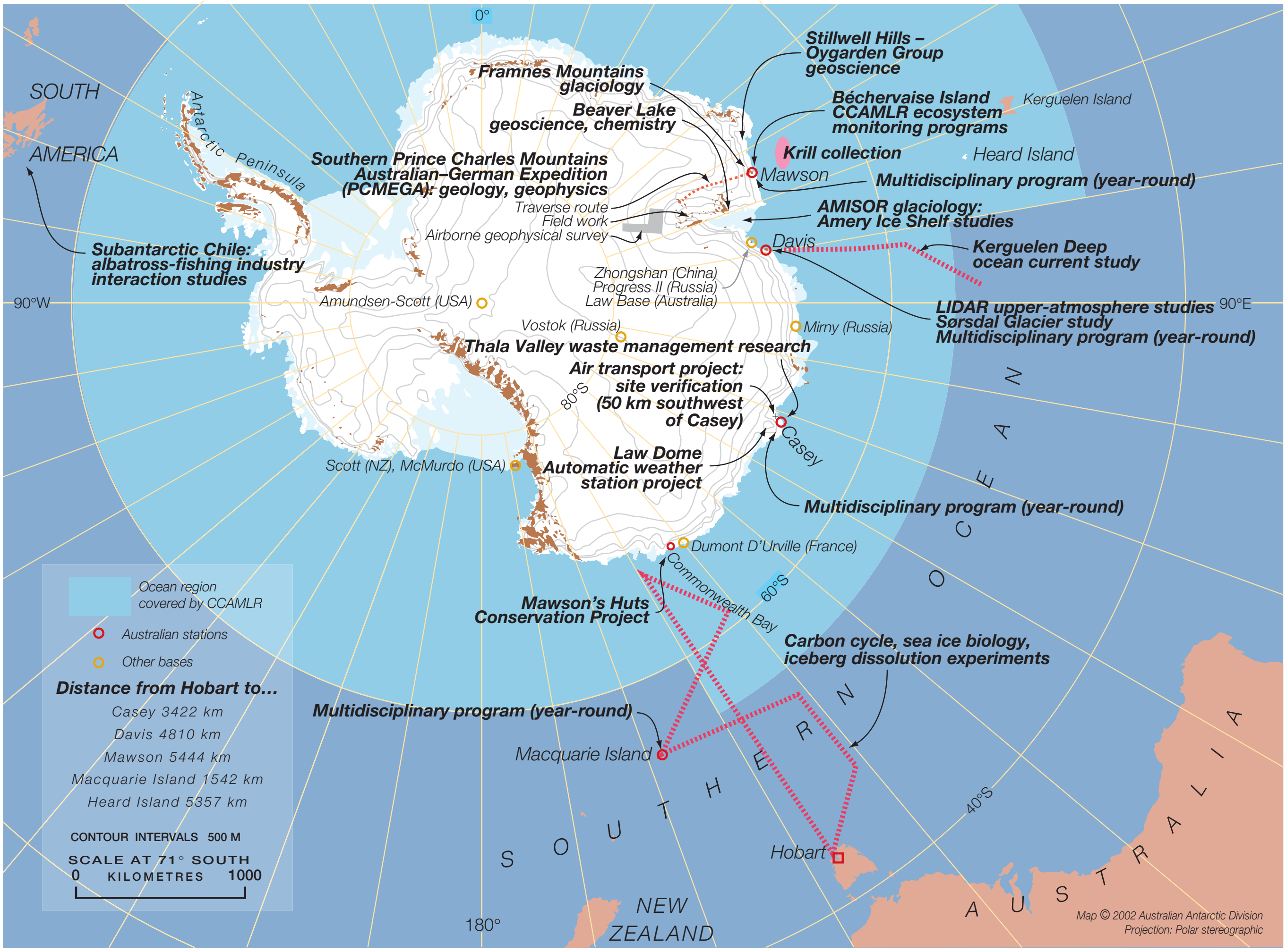
Simple tasks like pouring a glass of water become a juggling act. Working on computers includes chasing the mouse around the desk and gripping the bench to avoid falling off your seat. Taking a shower involves grimly clasping the safety rail in one hand and intermittently soaping yourself with the other while making constant adjustments to the shower rose which swivels wildly as the ship gyrates. Soaping your feet becomes a high-risk occupation.

Sleeping is intermittent if not impossible. Lying in your bunk may at least allay the worst of the seasickness for many but is anything but restful. First you stand in bed as the vessel rolls one way, then, as the vessel lurches in the opposite direction, you are scraped across your sheets to then find yourself standing on your head. In mountainous seas, normal life ceases completely. You can only hang on grimly or jam yourself in your bunk with kit bags, pillows and any other available materials, hoping against hope that the awfulness will soon end.

The trauma of the vessel and its occupants is unrelenting. Inability to sleep results in losing all sense of the passage of time which leads to the perception that the storm has gone on interminably. But eventually the seas subside, accompanied by a collective sigh of relief from expeditioners and crew alike as life returns to a semblance of normality. ■

Andrew Davidson,
Biology Program, AAD

Spanning the Antarctic: a busy research season



Australian Antarctic field research activities 2002-2003

This season in Antarctica is characterised by full programs of scientific research and operational activities, including a major expedition to the southern Prince Charles Mountains range and construction trials on an ice runway for the proposed Antarctic air link. In addition there are two marine science voyages examining features of climate change, phytoplankton bloom, iceberg melt, krill swarm behaviour and plankton studies.

To get the season under way at the first possible opportunity the Russian ice-breaker *Kapitan Khlebnikov* departed from Cape Town in late September to deliver personnel to Mawson, Davis and Casey stations. The early arrival should enable Human Impacts researchers to work on rehabilitation of the Thala Valley tip site at Casey before the spring melt begins. Engineering crews at Mawson will start work on building an extension to the cosmic ray laboratory, and continue their work on the erection of a wind turbine power generation system. At Davis work will continue on the construction of a VHF radar facility to further strengthen the Space and Atmospheric Sciences instrument concentration at that location. To progress the proposed air-link to Antarctica construction trials will begin on a blue-ice runway near Casey station.

After years of planning and careful logistic analysis this season will see the deployment of a field party of Australian and German scientists into the southern Prince Charles Mountains. Thirty-four personnel will undertake geophysical and geological research in several locations in this remote and spectacular region, some 500 km south of Mawson station. The study, which is jointly funded by the AAD and the German Bundesanstalt für Geowissenschaft und Rohstoffe (equivalent to the geological survey), will be supported by a Twin Otter aircraft equipped with aeromagnetic and aerogravity instrumentation. The objective of the study is to better understand geological and glaciological histories and past climates of the region. Staff at Mawson station have been working on this project for almost a year and have successfully deployed fuel and equipment caches at strategic locations around the study site.

Major marine science voyages this season will continue long-term studies on the spring phytoplankton bloom, the changing quality of the Southern Ocean, and initiate a study on the melt rate of icebergs. These studies will help us to understand the rate and significance of environmental change. In February the RV *Aurora Australis* will undertake a hydroacoustic study of the behaviour of krill swarms off the Mawson coast, its centre of operation being dictated by the feeding behaviour of Adélie penguins that are bringing up their chicks on Béchervaise Island. This voyage will also gather data on the structure and flow of the Antarctic Circumpolar Current, as part of our climate and environment change research.

Altogether 500 scientists and support staff will travel south this season, on five different vessels conducting 14 voyages, making 2002–2003 one of the busiest seasons on record!

Michael Stoddart,
Chief Scientist, AAD

PHOTO & MAP CREDITS
Peter Boyer

Opposite page left: Tom Trull
Opposite page right top to bottom: Stephen Rintoul, Wayne Papps, Wayne Papps, Nick Gales, Lyn Irvine

Airlink: runway construction trials this season

Australia's Casey station will be the centre of field work to provide the basis for full runway construction in 2003–04 (subject to environmental and other regulatory approvals) for a new Australia–Antarctica air link. The field program includes confirmation of a runway site, preliminary construction trials and establishment of additional automatic weather stations.

The project is designed to provide much greater flexibility in deploying scientists and support people in Antarctica. Up to 25 planned flights are planned each summer, using a 16-seat Dassault Falcon 900EX wide body passenger jet, between Hobart and a compacted snow runway near Casey.

Designed to complement the long haul sea voyages to Antarctica, the jet flights would enable direct return travel between Hobart and Casey. If prevented from landing at Casey by weather or other factors, the long-range jet can return to Australia without landing, reducing the need for refuelling in the sensitive Antarctic environment, minimising the potential for fuel spills, and increasing passenger safety.

Recent Australian work has included meetings between the Australian Antarctic Division, the Bureau of Meteorology, the Civil Aviation Authority and the preferred supplier of the air service, SkyTraders. SkyTraders has been pleasantly surprised by the level of interest by other nations in the proposed service, raising the potential for cost-sharing by extending access to the flights to other national science programs.

A September 2002 stakeholders' workshop at the Australian Antarctic Division headquarters at Kingston to refine the proposal was attended by George Blaisdell, a world expert in ice runway construction from the Cold Regions Research and Engineering Laboratory in the United States.

Charlton Clark,
Air Transport Project Manager, AAD

Flying around Antarctica

Once passengers arrive at the Casey runway, those bound for other Antarctic stations and remote destinations would change to CASA 212 twin turbo-prop aircraft fitted with both skis and wheels. The capability offered by these aircraft provides further exciting new opportunities for the conduct of field science. In addition to moving scientists between stations, the C212 can move 2,000 kg of cargo up to 1,400 km. For aerial surveying the aircraft's range extends to 2,500 km.

Dimensions		
Length	16.15 m	53 ft
Wing Span	20.27 m	63 ft, 6 in
Cabin Length	6.55 m	21 ft, 6 in
Cabin Height	1.80 m	5 ft, 11 in
Cabin Width	2.10 m	6 ft, 11 in
Weights		
Maximum Take-Off Weight	8,100 kg	17,857 lb
Maximum Landing Weight	8,100 kg	17,857 lb
Maximum Payload	2,950 kg	6,503 lb
Maximum Fuel	2,000 l	528USGall
Maximum Fuel (with underwing tanks)	3,000 l	792USGall
Number of Fully Equipped Expeditioners	16	
Performance		
Maximum Speed	360 km/h	195 ktas
Take-Off Distance to 50 ft (S/L,ISA,MTOW)	402 m	1,318 ft
Landing Distance from 50 ft (S/L,ISA,MTOW)	273 m	895 ft
Maximum Range (with external fuel tanks)	2,550 km	1,375 nm
Range with 2.000 kg payload (4,400 lb)	1,522 km	822 nm

Southern rendezvous

At Mawson station, year-long preparations culminated in the departure of the final of three traverses to support the remote PCMEGA base camp at Mt Cresswell, 500 kilometres to the south.

The Prince Charles Mountains Expedition of Germany and Australia is a combined geological and geophysical program using helicopters and a Twin Otter for an extensive aerial survey of the region.

Essential supplies including over 500 drums of aircraft fuel, tents and safety equipment as well as food for 35 expeditioners for four months have been loaded on sleds with each of the three Caterpillar D7 tractors set to tow 80 tonnes.

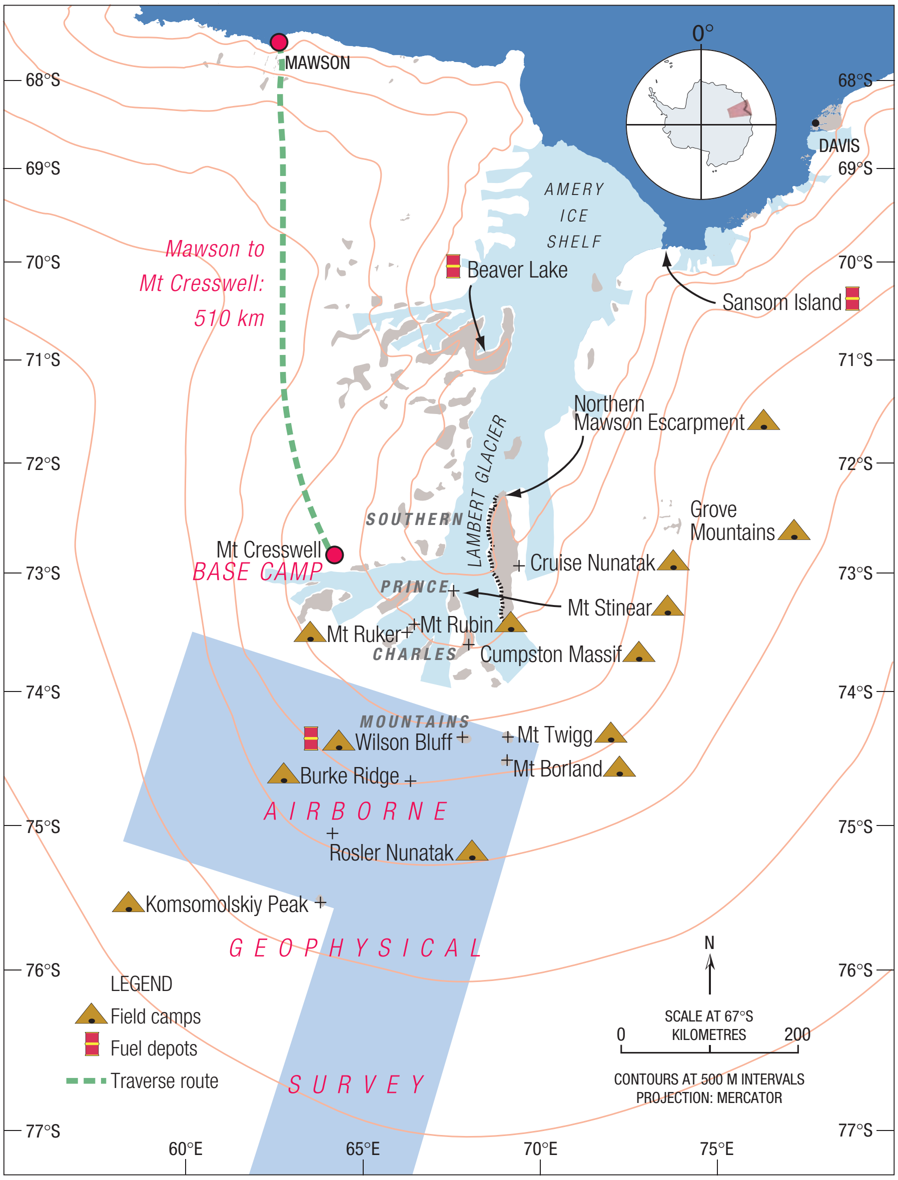
The traverse departed Mawson on 26 October and will take over a month to reach Mt Creswell, the last two hundred kilometres of the journey being over unexplored territory. Arrival of the five-member traverse team at their barren, windswept destination will be timed to rendezvous with a Twin Otter aircraft flown into the region from Canada via South America and the South Pole. Reliant on the fuel carried on the sleds, the aircraft and two helicopters will be used to deliver field geologists to outlying camps.

Some members of the traverse team will then return to Mawson in the Twin Otter. Geophysical equipment will then be fitted in the aircraft prior to its return to the southern Prince Charles Mountains for a month of survey work several hundred kilometres further south of Mt Cresswell.

At the base camp, the tractor train will be used to house the scientists, pilots and support staff. A communications operator will maintain a watch over the field camps and aircraft, relaying up to date weather reports and forecasts prepared at Davis station 500 kilometres to the north-east.

Satellite equipment will be used by the Field Leader, Robb Clifton and Coordinating Scientists Chris Wilson and Norbert Roland, to send progress reports back to Australia and Germany.

By early February, the weather in the area will become unworkable for the field parties and they will be withdrawn to Davis to meet the resupply vessel *Polar Bird* for their return to Hobart. With two replacement crew flown in from Mawson, the tractor train will set out for the return journey carrying the equipment, empty fuel drums and waste from the expedition, arriving at the coast in time for four members of the traverse team to board the *Aurora Australis* for the voyage home.



Rob Easther,
PCMEGA Project Manager, AAD

Antarctica Online

Follow the progress of the traverse and the scientific program and view the photos and the stories of PCMEGA on the AAD website at <http://www.aad.gov.au/pcmega>.

Vans and sleds are prepared at Mawson before being towed by tractors onto the plateau and south 500 kilometres to Mt Cresswell, PCMEGA Base Camp.

PHOTO CREDITS
Top to bottom:
Peter Boyer
Malcolm Arnold

Opposite page top to bottom:
EADS
Chris Paterson
Chris Paterson

Mawson's Huts protected

Sir Douglas Mawson's home in the blizzard – at Cape Denison, in the eastern sector of the Australian Antarctic Territory – will receive some much-needed repairs this season with the arrival of a team of heritage specialists at the site in late October.

Built and occupied by Mawson's Australasian Antarctic Expedition (AAE) of 1911-14, the wooden living quarters

Ferocious katabatic winds have further worn away the boards, blasting snow and ice into the Hut. During warmer spells the accumulated snow and ice in the ceiling cavity has melted and run down the walls and onto the floor, saturating AAE artefacts including equipment, books, magazines, bedding, clothing and other personal items. In winter the refrozen melt water entombed the timbers and artefacts in ice as hard as concrete.

and conjoined workshop have national and international heritage significance as one of just six complexes surviving from the 'heroic era' of Antarctic exploration, and as the foundation of the modern Australian Antarctic science program.

Over the years the Main Hut has borne the brunt of the extreme climate. Its Baltic pine tongue-and-groove roof was not adequately sealed during its construction, and ferocious katabatic winds have further worn away the boards, blasting snow and ice into the Hut. During warmer spells the accumulated snow and ice in the ceiling cavity has melted and run down the walls and onto the floor, saturating AAE artefacts including equipment, books, magazines, bedding, clothing and other personal items. In winter the refrozen melt water entombed the timbers and artefacts in ice as hard as concrete.

The Mawson's Huts buildings are on the Register of the National Estate and their inclusion on the Antarctic Treaty list of Historic Monuments means that the AAD, as owner of the site, is obliged to ensure that the historic structures are not destroyed. This season's expedition to Cape Denison comprises a heritage architect, two specialist carpenters, a materials conservator and an archaeologist, who will conduct vital conservation works including:

- structural investigation of the building foundations;
- excavation of some compacted snow and ice from the interior of the living quarters and workshop;
- patching of the living quarters' roof and south-facing walls to stop snow, ice and melt water from entering;
- repair of broken rafters and collar ties in the workshop roof;
- installation of a variety of sensors inside the hut to monitor the internal environment, including temperature, relative humidity, salt ingress and corrosion;
- documentation of historical artefacts inside and outside the living quarters and workshop; and
- preservation of those artefacts currently under threat of destruction by the effects of snow ingress and the freeze/thaw cycle.

TOP to BOTTOM: • Mawson described the trail of objects scattered by the katabatics as 'flotsam' and 'a rubbish heap'. Time has transformed this 'rubbish' into a cultural landscape, a rich repository of information about the lives of Australia's early Antarctic explorers. • Expeditioners come to grips with the assignment at their pre-departure seminar held at Liawenee, in Tasmania's Central Highlands, in early September.

All work will be conducted in accordance with the site's Conservation Management Plan, endorsed by the Federal Government in February 2002, and a Conservation Works Plan specially developed for this expedition by heritage consultants Godden Mackay Logan. The Works Plan was referred to the Minister for the Environment and Heritage in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (see 'Conservation work program approved' opposite). The Works Plan is designed so that the living quarters and workshop will be stabilised to a point that no major work will be required for several years.

Returning to Hobart in late December, the expedition marks the latest in a series of programs to ensure the stability and integrity of the Huts. Since 1996, four expeditions (organised by the AAP Mawson's Huts Foundation and the AAD) have achieved structural repairs, re-clad the workshop roof, and repaired the skylights, roof capping and valley gutters between the two roofs to reduce the ingress of snow and ice. In 1997 the Foundation sponsored the installation of monitoring equipment which has produced enough temperature and humidity data to enable specialists to assess the likely effects of the environment on the aging structure and artefacts. The 2000-01 expedition removed non-heritage waste left by work parties since Mawson's last visit in 1931, helping to re-establish the setting of this historic landscape. Throughout all of the expeditions an archaeologist has continued to document the rich collection of artefacts Mawson and his men left behind.

The 2002-03 expedition will travel to and from Cape Denison on the French re-supply vessel *l'Astrolabe*. The improved access to the site, located approximately 2560 km south of Hobart, is due to a new cooperative agreement with the Institut Polaire Français Paul Émile Victor (IPEV) and will allow closer monitoring of the Huts. Nevertheless, the isolation and extreme weather conditions means the management of Australia's most valuable Antarctic heritage asset remains a costly and challenging exercise.

The nine-member expedition team, led by experienced station leader Diana Patterson, will have about eight weeks in which to carry out the program in what will at times be hurricane conditions. Eight expeditioners will be deployed and retrieved by helicopters jointly chartered by the AAD and IPEV, while a ninth will be delivered in early December by the Russian icebreaker *Kapitan Khlebnikov* – weather permitting – to complete an environmental assessment of the site for its nomination as an Antarctic Specially Protected Area. The team will live in a prefabricated hut specially erected to support maintenance teams and scientists, but at least four members will stay in tents in the lee of the hut to protect them from the katabatics.

The expedition's busy program will be supplemented by the arrival of tourists from the *Kapitan Khlebnikov*. Team members will guide the tourists around the site and through Mawson's living quarters and workshop, providing them with an unusual and invaluable opportunity to understand expedition life not only of the AAE but also their modern-day equivalents. Knowledge of the site and its inhabitants will be further developed in the months after the expedition with the creation of an archaeological database. This, together with the environment monitoring data, will provide a vital resource for continuing research and effective conservation management of this icon of Antarctic heritage.

Rob Easther,
Mawson's Huts Program Manager, & Stephanie Pfennigwerth,
Environmental Management and Audit Unit, AAD

Antarctica Online

The plan for the expedition, a weekly diary from one of the expedition members, and progress reports of the conservation program can be viewed on the AAD's website at<http://www.aad.gov.au/mawsons_hut>.

The hut is almost engulfed by the elements.

Conservation work program approved

Mawson's Huts are on Commonwealth land, requiring the expedition to observe relevant Commonwealth laws including the *Antarctic Treaty Environment Protection Act 1980* and the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*. In accordance with the EPBC Act, the expedition Works Plan was referred to the Minister for the Environment and Heritage to decide whether a proposed action is likely to have a significant impact on a matter of national environmental significance. Public comment about the AAD's referral was also taken into account by the Minister. On October 11 the Minister formally approved the program of conservation works.

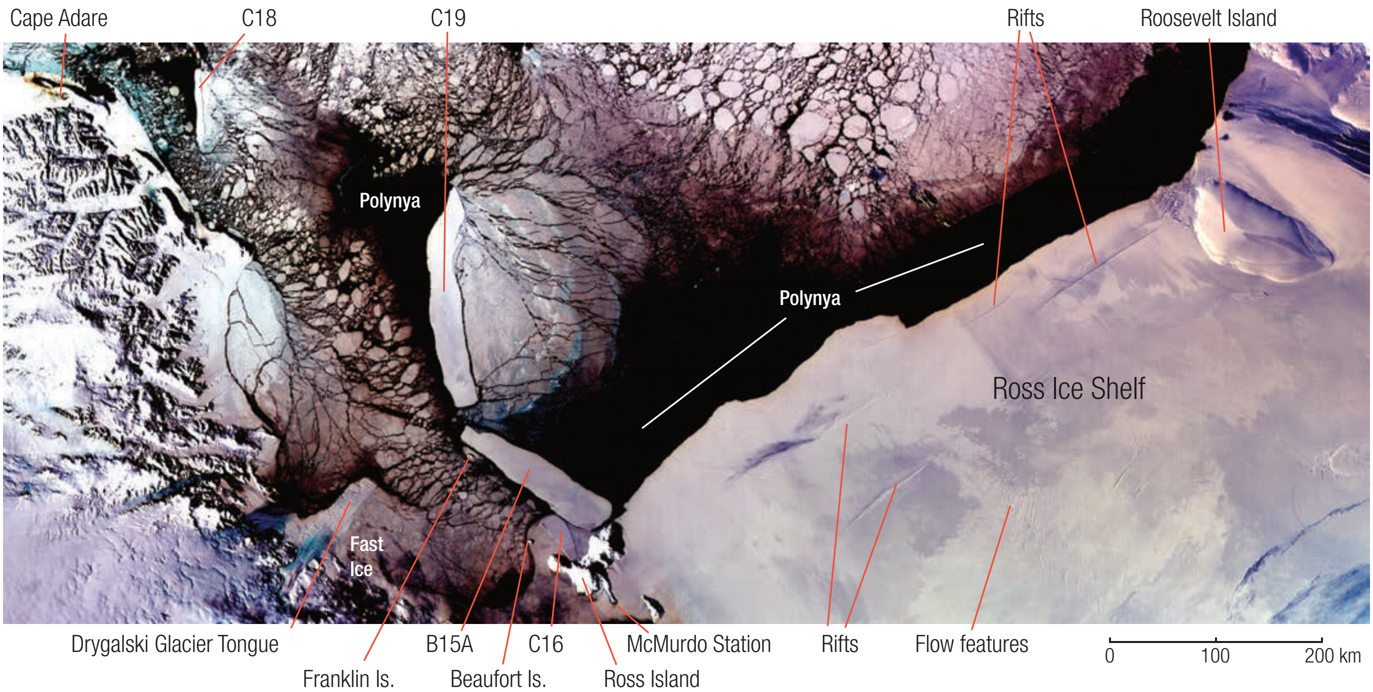
The historical value of Mawson's Huts means that the site is also entered on the Register of the National Estate, maintained by the Australian Heritage Commission (AHC). As a Commonwealth agency, the AAD was obliged to seek advice under section 30 of the *Australian Heritage Commission Act 1975* and will take the AHC's advice into account during the conduct of the works.

The conservation program is also consistent with Australia's international obligations under the Antarctic Treaty and the Madrid Protocol. Under Annex V of the Madrid Protocol, the AAD has responsibility to ensure that the structure shall 'not be damaged, removed or destroyed' (Annex V, Article 8, Clause 4). The aim of the conservation project is to prevent this damage from occurring. The AAD is also planning to nominate the site as an Antarctic Specially Protected Area under Annex V in order to secure more comprehensive protection for this site of outstanding historic significance. The nomination will put forward at the next Antarctic Treaty Consultative Meeting, in Madrid in 2003.

PHOTO CREDITS
Dave Killick

Opposite page top to bottom:
Ian Godfrey
Rob Easther

Another massive iceberg is born



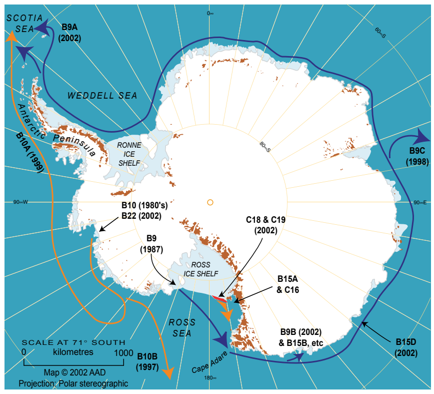
This almost cloud-free view of the entire front of the Ross Ice Shelf and southern Ross Sea with its collection of massive icebergs is part of a satellite image acquired by the MODIS instrument on NASA's AQUA satellite at 04:25 UT on Friday 11 October 2002. The low sun elevation angle highlights the Transantarctic Mountains along the western side, Ross and Roosevelt Islands, and many features within the Ross Ice Shelf, including the giant rifts that will form the calving fronts of future massive icebergs, and other fracture features associated with the flow and merging of the many ice streams that form the shelf. The large dark area bordering the ice shelf is a huge polynya formed by persistent offshore winds blowing newly formed sea ice away from the shelf front. The gradation in tone of the sea ice to almost white with increasing distance indicates thicker older ice with varying amounts of snow cover. The illumination conditions mean that the new ice forming in the polynya appears black in this high contrast view. There are also polynyas in the lee of icebergs C19, and C18 (approaching Cape Adare) and very high ice concentration on the windward side of the bergs. The image spans 1290 km by 540 km.

In May 2002, another massive iceberg calved from the western section of Ross Ice Shelf to become the third largest that has been observed. Iceberg C19 is about 200 km long and 32 km wide. Shortly before that event, iceberg C18 calved from the front of the Ross Ice Shelf immediately to the east. Together with the calving of icebergs B15 and others in 2000, these events have resulted in the loss of a significant area of ice from about 90% of the length of the ice shelf front. There is only a small section of about 60-70 km near the middle of the front has not suffered a major calving event in the past two years, and indeed not for at least 45 years.

When added to the amount of ice in the massive icebergs that calved from the Ronne Ice Shelf in 2000, and from the Thwaites Glacier, Pine Island Glacier, and Larsen 'B' Ice Shelf over these past two years, taken together they represent several times the annual average turnover of ice through the whole of the Antarctic ice sheet. However, because the icebergs come from the floating sections of the ice cover, the calving events alone do not have an impact on sea level.

The movement of massive icebergs is primarily influenced by ocean currents in the upper few hundred metres of the ocean, and so their movements act as tracers of those currents. So far, the recently formed icebergs have drifted distances that range from only a few kilometres to over a thousand kilometres. B22 (*Australian Antarctic Magazine* 3:36) has remained close to Thwaites Glacier. The locations of B15A, C16, C18 and C19 can be seen in the MODIS image of the Ross Ice Shelf above.

The map (*right*) shows the positions and approximate drift tracks of a selection of current massive icebergs. The tracks of icebergs B9 and B10 that calved over 15 years ago give us an insight into the likely future drift tracks. For instance iceberg B9 calved from the east end of Ross Ice Shelf in 1987. It drifted slowly out of the Ross Sea and broke into three sections as it passed Cape Adare. The three sections became grounded for various periods around the sector of Antarctic coast south of Australia. Sections B9A and B9C began drifting again in the late 1990s, and moved westwards around the coast. B9C moved north through Prydz Bay, whereas B9A continued westwards, circumnavigating about two-thirds of Antarctica. It has passed through the southern part of the Weddell Sea, north along the Antarctic Peninsula, then headed eastwards. It has recently turned sharply north and west round the South Orkney Islands into Scotia Sea. Other icebergs that calved from Ronne Ice Shelf (*Australian Antarctic Magazine* 1: 24) and Larsen Ice Shelf (*Australian Antarctic Magazine* 3:4) have followed a similar path up the east coast of the Peninsula, but many passed through the gap between the tip of the Antarctic Peninsula and the South Orkneys. From their various locations in the Scotia Sea they may drift northwards into the South Atlantic, or yet join the southern part of the Antarctic Circumpolar Current and once again drift eastwards towards waters south of Australia. Iceberg B10, on the other hand remained near the Thwaites Glacier for about 15 years, before drifting west into the Ross Sea, splitting into B10A and B10B. B10A headed north, then east, ultimately passing through Drake Passage and breaking up in the South Atlantic late in 1999. B10B headed northeast through the Ross Sea.



Where are all those icebergs going?

NEAL YOUNG,
CONTINENTAL ICE SHEET PROGRAM,
ANTARCTIC CRC
& GLACIOLOGY PROGRAM, AAD

Planning begins for Heard Island 2003-04

In the summer of 2003–04 the AAD will conduct a scientific expedition to Heard Island. A party of scientists including glaciologists, animal, bird and terrestrial biologists, and support staff will spend approximately two months on the island living in tents and huts while *Aurora Australis* conducts a marine science program in the waters around the island.

An important planning workshop was held in Hobart on 8–9 June 2002 for scientists to discuss the work to be achieved on the expedition and to consider the level of support required to ensure the work is done safely and in accordance with the strict environmental guidelines in the management plan for the World Heritage Area.

Operational support for the program will be coordinated by a planning project team in the AAD's Operations Branch. As the plans are developed, details will be posted on the AAD's website at <http://www.aad.gov.au/goingsouth/expeditioner/projects/heard.asp>

Heard Island predator-prey study

One ambitious and exciting project planned for the summer of 2003–04 will seek to better define the relationships between land-based predators of Heard Island and their prey. An understanding of these relationships is one of the essential steps towards the determination of ecologically sustainable levels of fishing activity in the Heard Island vicinity.

The study focuses on what we determined to be the most important consumers of prey in the nearby shelf waters around Heard and MacDonald Islands; king penguins, macaroni penguins, Antarctic fur seals and juvenile elephant seals. Black-browed albatross and light-mantled sooty albatross will be included in the research because of their propensity to be drowned in long-line fisheries. A carefully selected group from each of these species will have specialised tracking and data-logging instruments glued to their fur or feathers and as they feed in the waters around Heard Island they will be tracked in almost real time. For 50 days scientists aboard *Aurora Australis* will conduct intensive marine research in the areas the animals use. Potential prey will be sampled with echo-sounders and trawl nets and details of the physical oceanography of the area collected.

As well as the predator-prey study, scientists aboard *Aurora Australis* will also conduct research to map benthic communities and sediments to assist in the designation of marine protected areas.

A suite of new techniques will be applied to this large, ecosystem-scale experiment and the results will add greatly to our knowledge of, and ability to protect, this important area.

Nick Gales,
Antarctic Marine Living Resources Program, AAD

Heard Island terrestrial research

At the recent development workshop, significant interest was shown in future terrestrial biology and earth science research on Heard Island. Over 20 applications for research have been received and are currently being assessed by the Antarctic Research Assessment Committee.

Some projects have already received multi-year approval. These include a study which is looking at the impact of UV light on Antarctic plants, to see if such plants have good sunscreens or, if their DNA has been damaged by high UV exposure, if they have effective DNA repair mechanisms. Another project is establishing baseline information on the current distribution and abundance of seabirds on Heard Island with a view to establishing population trends. Another ambitious project being planned will simultaneously look at variation in size, structure and developmental timing (such as flowering) in plants and insect on four subantarctic island groups (Heard, Kerguelen, Crozet and Marion). These islands have similar geological structures but currently different climates. This project will require carefully arranged logistics between the Australian, French and South African programs.

Dana Bergstrom,
Biology Program, AAD

Working and surviving on Heard

Scientists engaged in field work on Heard Island will experience some of the most extreme climatic conditions on Earth. Strong winds and freezing rain, sleet and snow make the achievement of productive work particularly challenging. Drawing on the experience of the 2001–02 field season, scientists will use tents with a thick waterproof outer protective cover fitted. The two base camps at either ends of the island will use the plastic converted water tanks successfully trialled on the previous expedition for accommodation, laboratory and communications facilities.

Approximately 30 scientists will be delivered by inflatable rubber boats which will also be used to permit transfer between coastal field sites when the weather and sea conditions permit. Although *Aurora Australis* will be working in the vicinity, it will only rendezvous with the land-based field parties in an emergency. ■

Rob Easther,
Heard Island 2003-04 Project Manager, AAD

Heard Island now world's biggest marine reserve

The Australian Government has proclaimed the world's largest fully protected marine reserve in Australia's remote subantarctic waters.

The new 6.5 million hectare Heard Island and McDonald Islands Marine Reserve is 4500 kilometres south-west of the Australian mainland and 1000 kilometres North of Antarctica. It falls within Australia's 200 mile Exclusive Economic Zone surrounding Heard and McDonald Islands. Heard and McDonald Islands was inscribed on the World Heritage List in 1997 for its outstanding natural universal values

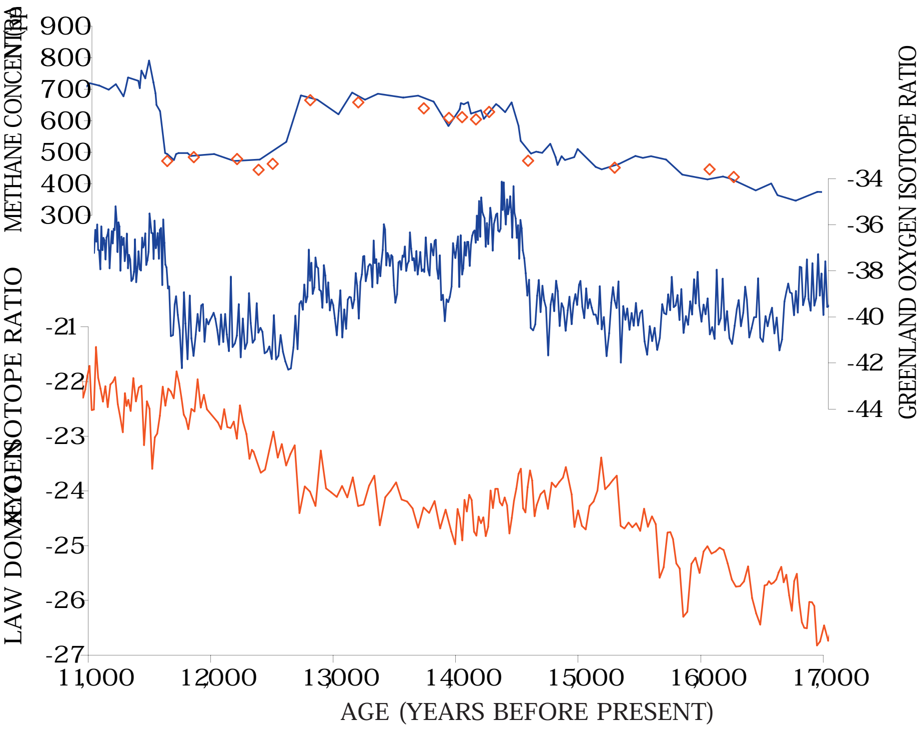
The new park surpasses another Australian marine reserve, the 5.8 million hectare Macquarie Island reserve, as the world's largest.

In making the announcement, Federal Minister for the Environment and Heritage, Dr David Kemp, said the declaration would protect the conservation values of the region and provide an effective conservation framework to manage the region in an integrated and ecologically sustainable manner. ■

PHOTO & MAP CREDITS
Karl Rollings

Opposite page top to bottom:
MODIS data provided by NASA/GSFC/DAAC (Image by N. Young, AAD & Antarctic CRC)
Map Peter Boyer / Neal Young

A tale of two hemispheres



This figure compares climate changes in Greenland and Antarctica from 17,000 to 11,000 years ago, as the ice age was coming to an end. The bottom (red) graph shows the temperature at Law Dome (actually it shows the oxygen isotope ratio, which is closely related to temperature). Temperatures at Law Dome are increasing throughout this period, except for a period of about 1000 years, starting around 15000 years ago.

The middle (blue) graph shows the temperature at the GRIP site in Greenland. This study focuses on the abrupt warming 14,500 years ago. Previous comparisons had indicated that this abrupt warming came ahead of the cooling in Antarctica, but this work shows that not to be the case. Antarctic cooling is seen up to 500 years before Greenland warming.

The top blue graph shows atmospheric methane from bubbles in the Greenland ice core. Since the atmosphere is well mixed, this global signal is basically the same in both hemispheres, so that measurements in the Law Dome core (red diamonds) show the same changes at the same time. It is these methane changes that were the key to synchronising the temperature records, making this research finding possible.

Recently published research based on studies of Antarctic ice cores by Australian and French scientists has provided new information about the way rapid climate changes occur, and how the climates of the Northern and Southern Hemispheres are connected.

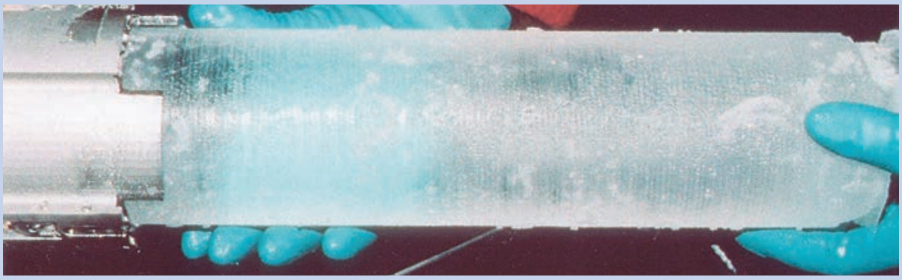
The research used the Australian deep ice core from Law Dome, near Casey Station. This core extends from the surface of the ice cap to the bedrock 1200 metres below and provides a record of climate variations over the last 80,000 years or more.

This latest study, published in the international journal *Science* (volume 297, September 13, 2002, pp. 1862-1864), focuses on the end of the last ice age, around 14,500 years ago. The work compared temperature changes at Law Dome (which are recorded by isotopes of oxygen in the ice) with those in Greenland. The Greenland record shows a very abrupt climate warming that is well documented, and was widely thought to be triggered by changes in North Atlantic ocean circulation. The conventional view of this, and other abrupt warmings during the last ice age, has been that reorganized ocean circulation carries more heat northward, leading to a subsequent cooling in the Southern Hemisphere – an effect known as the 'bipolar see-saw'.

Comparisons with the Law Dome record were a surprise, however, because they show that cooling occurred in the south around 15,000 years ago, about 500 years ahead of the abrupt Greenland warming. This finding poses a challenge to discover climate processes that might explain these observations. It is unclear whether the changes are being driven from the south, or whether, on these timescales, the changes are not even related. Computer models of climate need to be able to reproduce these past changes for their predictions of climate change to be accurate and reliable.

The abrupt Greenland climate change 14,500 years ago that was the focus of this work was one of several similar events during the last ice age. Together they give a picture of a climate system that is not necessarily as stable as recent experience might suggest. Some computer models indicate that greenhouse warming of the climate system might push it once again into an unstable state, where a major reorganization of ocean circulation brings large and rapid changes to some regions. This study and others like it which explore the detail of global responses to past abrupt changes, lead to a better understanding of the climate system and will hopefully help assess the likelihood of abrupt changes in the future.

Tas van Ommen, Glaciology Program, Antarctic Cooperative Research Centre & AAD



What's in an ice core and what does it tell us?

The ice sheets of Antarctica, Greenland and alpine glaciers are composed of snow that has accumulated for up to hundreds of thousands of years. In such glaciated regions, snow survives each summer season and is buried by subsequent snowfalls, eventually becoming compressed into solid ice. As the snow is buried, it carries with it information which forms an archive of past climate and environmental changes.

To unlock this archive, scientists use coring drills to bore holes into the ice sheets. Cores are typically recovered in sections 1-3 m long (depending upon the drill), and have diameters between 5 and 50 cm. The cores are extracted and generally returned from the field for analysis in laboratory facilities, although some analysis is frequently undertaken in the field.

The information in the ice is carried in dust, chemical impurities, trapped air bubbles, and in the isotopes of hydrogen and oxygen of the ice itself. The mix of these isotopes in the snow is a good measure of past climatic temperatures. The other parameters provide information on atmospheric composition, precipitation amounts, volcanic activity, atmospheric chemistry, atmospheric circulation and even biological activity. This rich record of information makes ice cores one of the best tools for the study of past climate and environment.

Antarctica Online: well worth exploring

Have you discovered the other Antarctica? Those of us who may never set foot there and seasoned expeditioners alike can navigate vast floes of information and resources at Antarctica Online, the website of the Australian Antarctic Division (AAD) at <http://www.aad.gov.au>.

The AAD has a proud history of maintaining Australia's 'virtual Antarctic territory' with its original website being one of the first to be created by an Australian government agency. The site is consistently among the most visited Australian sites on the web averaging 48,500 'hits' from 3,170 unique visitors daily.

As you would expect the site is rich in photographs of the region's unique environment and varied biological life. But the site is primarily a working resource providing crucial information for researchers, expeditioners, and the family members and friends of those wintering at our research stations and those venturing south during the shipping season.

With such a vast subject to cover, the site focuses on the core functions of the AAD's role in administering the Australian Antarctic program – with emphasis on the science program, environmental management, expedition and station operations, Australia's role in the Antarctic Treaty system, and the broad cultural legacy of Australia's presence in the region. To achieve this the site content is structured into six thematic channels: Experience Antarctica; Protecting the Environment; Science; Antarctic Law & Treaty; Going South; and Antarctic Communities.

Experience Antarctica is a good starting point for new visitors, providing an exciting selection of links that place Australia's Antarctic science effort in a context of global environmental research. Looking South is a major information resource providing an introduction to the aims and scope of the Australia's involvement in the region. There are FAQs about a wide range of subjects, and regular updates covering the challenges of expedition logistics, sea and air transport, science support, people and events at This Week in Antarctica. Looking Up: Atmospheric Sciences and Antarctic Ice Fields explore what the polar atmosphere can tell us about tomorrow's weather and how the secrets of our planet's climate are drilled from thousands of years of compacted snow in the continental ice fields. Current Projects showcases major initiatives such as new expeditions, the installation of wind turbines at our stations and progress with the restoration of Mawson's Hut. Life at a Station takes you to three continental stations and subantarctic Macquarie Island with a snapshot of life in the 'freezer'. Getting there is an experience itself. Life on a Ship takes you on board Australia's research and resupply ship *Aurora Australis* and other vessels, with links to voyage diaries and the history of ANARE shipping.

Find out about the science research and grants application process, the humanities program, tenders and employment opportunities for technical and support staff at Want to go South? . With the expansion of Tourism into Antarctica and the Subantarctic the site provides links to government policy, research and developments in the sustainable management of this new polar industry.

If you want an immersive internet experience go directly to What's Happening Now? for the virtual reality (VR) panoramas created by AAD photographer, Wayne Papps. Using your keyboard or mouse you can zoom into a scene to investigate details and pan left or right through a full 360° circle around the location. Each of these stunning images is created from a sequence of individual photographs 'stitched' end to end using digital imaging technology. They are enabled for viewing on the internet using the Quicktime media player (you can download the software direct from the site). For visitors without ADSL (broadband) internet connections the image files will take some time to download, but they're well worth waiting for. This is what the web is all about.

If VR is too much for your system you can souvenir conventional (but no less spectacular) photographs from Antarctic Images. Here you can download your own desktop wallpapers selected from the rich photographic archive of the AAD's Multimedia Unit. The Australian Antarctic Magazine is also well represented. Download printable .pdf files of each edition (with complete text and full colour graphics). Eventually we plan to have every edition fully enabled for browsing on the website.

Protecting the Environment links you to resources such as the Environmental Toolbox and the mini-portal Classroom Antarctica where you'll find comprehensive teaching units that can be built into literacy and science curricula, plus decorative book covers and other visual resources to inspire primary and secondary students – and parents.

Science is the central theme of the site. You'll find links to key science concepts and policy objectives. The Science Strategic

Explore the virtual reality panoramas at <http://www.aad.gov.au/explore>

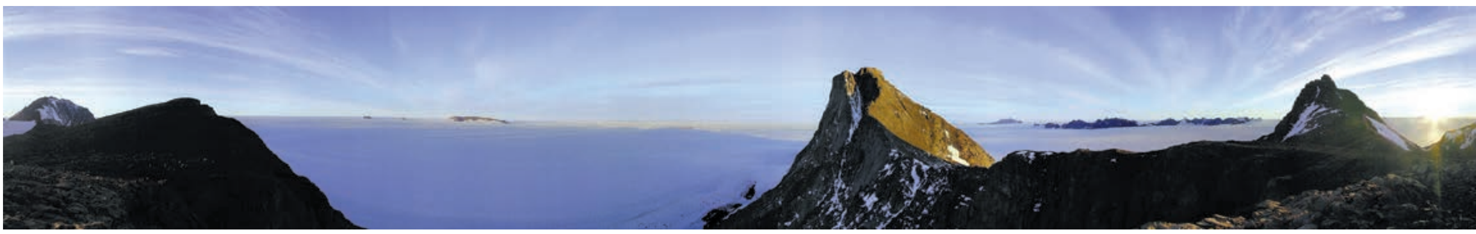
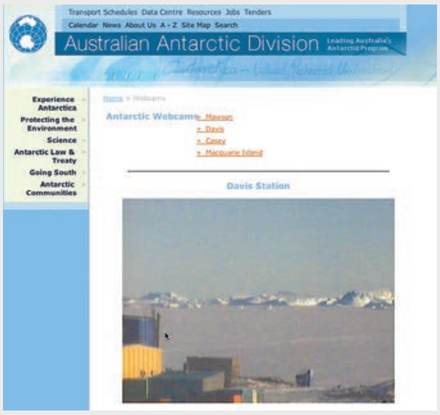


PHOTO CREDITS
Wayne Papps

Opposite page:
Vin Morgan



Antarctica Online facts

Sitestatisticsasat7October2002

Hits
Entire site (successful): 22,127,896
Average per day: 60,624
Page Views
Page views: 5,047,219
Home Page: 602,260
Average per day: 13,827
Average per unique visitor: 8
Document views: 5,001,007
Visits
Visits: 1,440,029
Average per day: 3,945
Average visit length: 00:10:50

Most Used Search Phrases:

"Antarctica" (1st); the misspelt "Antartica" (11th); "webcam" (3rd); "penguins"; "emperor penguin"; "krill" (5th); Macquarie Island (9th); "seals" (17th); Antarctic Treaty (20th)

Most Frequent Referrers:

(1) Google search engine (59% of referrals)
(2) Environment Australia (website of the Antarctic Division's parent Department)
(3) Various independent webcam portals and weather sites

Most popular features:

- Mawson station web cam (114,5000 unique visitors in the last 12 months), followed by the Davis, Macquarie Island and Casey station web cams, (separated by approx 10,000 unique visitors each)
- Employment (peaked at 16,579 visitors in Feb/March 2002)
- Going South
- *Australian Antarctic Magazine*
- Classroom Antarctica

Visitor Country of Origin:

(1) USA (2) Australia

Plan sets out how each of Australia's ten Antarctic science programs meet expressed Government goals. Antarctic research into environmental issues sets the major theme for Australia's Antarctic science programs. Scientists wishing to conduct projects in Antarctica must apply using the online forms for Research & Project Applications. A database of publications arising from scientific research projects can be searched at the Publications site.

Science in Antarctica reveals how the region generates much of Australia's weather, powers currents in the world's great oceans, and acts as a sentinel for ecological and climatic change. Fact Files cover a wide range of topics and Science Technical Support profiles the technology and scientific facilities needed to answer the big questions. Scientific Resources links you to key information about science program support through ANARE, including laboratory facilities, communications, transport and site services at Australian research stations.

Antarctic Law & Treaty deals with all aspects of Antarctic Treaty (including the full text), the Madrid Protocol resolutions on the Antarctic environment, other international agreements such as the Law of the Sea, the 45 international Treaty Partners and the Information Exchange arising from the annual Antarctic Treaty Consultative Meetings.

Going South is a virtual tour, providing an inside view of the complete cycle of a research and resupply cruise to Antarctica and subantarctic Macquarie Island. This invaluable resource for prospective ANARE expeditioners also provides key information for family members about communication with ships and research stations, coping with separation, and preparation for the eventual homecoming. You can view the Voyage Tracks and Transport Schedules for current and past seasons, browse the Expeditioner Handbook, read the Voyage Diaries, and Personal Stories of icy adventures.

Antarctic Communities recognises that the majority of 'Antarcticans' live and work far from the continent. You'll find useful links to research institutions, government agencies, international and intergovernmental bodies and non-government organisations, plus social groups of past expeditioners, and families. This channel also links you to the most popular feature of the website – the web cams at each of the research Stations. Video cameras capture periscope views of station surrounds, updating their images every ten minutes to provide the closest thing we have to a 'real time' video link to our remote bases. Throughout the year you can access the web cams to monitor the changing weather and light conditions experienced by expeditioners as they emerge from winter darkness into the 24 hour daylight of summer — often obscured by white-outs during the withering Antarctic blizzards.

Virtual Antarctica has a dynamic life of its own with news and information updated regularly to keep pace with new developments across the AAD and the global Antarctic community. While the station web cams currently show only still video images, there are plans to provide full motion video and sound clips of other interesting research and operational activities. With digital video cameras being used during the 2002-03 expeditions to the Prince Charles Mountains and Heard Island, there will be plenty of reasons to revisit the site in coming years to see what rare and exciting material becomes available. ■

WHAT'S HAPPENING

How the Casey station orthophoto map was made

An orthophoto is an aerial image that has been corrected for the effects of camera lens tilt and other aberrations, image scale variations and displacement of objects due to ground relief. Images are seamlessly joined to make a map. They can be regenerated at any scale and have their colour or contrast enhanced so that the user has the double benefit of a map's positional accuracy and the detailed visual information of a photograph.

Making an orthophoto involves five basic steps: (1) aerial photography using sensors aboard aircraft or on satellites, (2) rectifying the image using ground control points, (3) joining images in a mosaic and removing seams, (4) compiling the orthophoto with title block, imagery source diagram and origin of the imagery, and (5) printing on high quality printers.

Antarctic weather, availability of logistics and personnel, and the short time span when rocky areas are free of snow severely limit opportunities for Antarctic aerial photography. Aerial photographs of Australia's Antarctic stations are obtained as regularly as possible to ensure current records of station surroundings and buildings.

This Casey station orthophoto map was compiled from aerial photography on 30 December 2000, when rocky areas were relatively snow-free. The photography anticipated the need for a large scale map for remediation of the Thala Valley tip site, which was also mapped in detail from the same aerial photography. The flight coincided with a ground survey of Thala Valley and the road linking the station with 'old Casey' and the wharf area. ■

Henk Brolsma,
Mapping Officer, AAD

INTERNATIONAL

Antarctic Treaty Parties meet in Warsaw

Poland hosted the 25th Antarctic Treaty Consultative Meeting (ATCM) in Warsaw from 10 to 20 September. The 2002 meeting addressed a number of improvements to the Treaty's operations.

Apart from the annual meeting of the Committee for Environmental Protection, the Parties also addressed establishment of the permanent secretariat to the Treaty, further negotiations on a regime on liability for environmental damage, and management of Antarctic tourism. In addition, the Parties commenced a review of past recommendations of Treaty meetings and considered ways to improve the efficiency of the annual meetings.

To improve the way it handles its work, the meeting moved away from the established twin working group arrangements and established four groups to deal with Secretariat, Liability, Legal and Institutional Matters, and Operational Matters.

The ATCM was attended by representatives of all 27 Consultative Parties, and most of the 18 acceding states. This year there were 253 delegates including the observer and expert bodies. The meeting dealt with 50 working papers, and 111 information papers.

The volume of documents and the size of the delegations indicated the amount of business confronting the Treaty Parties. The working sessions of the meeting were provided with simultaneous interpretation into the four official languages of the Treaty (English, Spanish, French and Russian) and all working papers were translated.

The US, as depositary state, circulated a long anticipated update of the Antarctic Treaty handbook, which will greatly assist understanding of the scope of the Treaty system's obligations.

The Australian delegation was led by the Department of Foreign Affairs and Trade, with other delegation members from the Australian Antarctic Division, the Tasmanian Office of Antarctic Affairs and the Antarctic and Southern Ocean Coalition.

Next year's meeting will be in Spain, followed by South Africa and Sweden in subsequent years. ■

Andrew Jackson,
Manager, Antarctic Treaty and Government, AAD

The Australian delegation to ATCM XXV. From left: Tom Maggs (AAD), Professor Michael Stoddart (AAD), Constance Johnson (DFAT), Dr Tony Press (Director AAD), Richard Rowe (Head of Delegation), Quentin Hanich (ASOC), Simon Smalley (AAD), Ben Galbraith (Tasmanian Government).

PHOTO CREDITS
Top to bottom:
Australian Antarctic Division Data Centre
Andrew Jackson
Andrew Jackson

Australian heads environment body

Australian Antarctic Division Director, Dr Tony Press, has been elected to chair the Committee for Environmental Protection (CEP). This was agreed at the 5th meeting of the CEP, held in conjunction with the Antarctic Treaty Consultative Meeting (ATCM) in Poland.

The Chair is elected from members of the CEP for a two year period. The inaugural Chair of the Committee, Dr Olav Orheim of Norway, stepped down at the end of the Warsaw meeting having completed two terms as Chair. Dr Orheim had previously chaired the Transitional Environmental Working Group and thus had a lead role in establishing the CEP's role within the Antarctic Treaty system.

The CEP was established by Article 11 of the Madrid Protocol and has a number of critical functions to undertake in advising the ATCM. The Treaty's environmental decision-making is based on the advice of the CEP, and addresses issues such as environmental impact assessment, conservation of flora and fauna, waste management and marine pollution. An increasingly important part of the CEP's agenda is the development of measures to protect areas of special significance.

The role of the Chair of the Committee is an important one, and will involve Australia, through the AAD, in facilitating intersessional communication between the Parties on environmental issues, and providing various information services to support the group's work. In the AAD, this will be coordinated by Tom Maggs of the Environmental Management and Audit Unit, who has extensive experience in the CEP.

Dr Press and the Committee expressed warm thanks to the outgoing Chair for his skills and enthusiasm, which have been a significant factor in the effectiveness of the CEP during its formative years. In appreciation of Dr Orheim's contribution, Australia hosted a reception to honour his personal and professional efforts during his two terms as Chair. ■

Andrew Jackson, Manager, Antarctic Treaty and Government, AAD

Newly elected Chair of the CEP, Australian Dr Tony Press, with outgoing Chair, Norwegian Dr Olav Orheim.

Treaty secretariat closer to reality

A priority issue for the 25th Antarctic Treaty Consultative Meeting was negotiation of the instruments and documents necessary for the Antarctic Treaty Secretariat to be established.

> Australia has a long-standing position that the early establishment of the Secretariat is fundamental to efficient operation of the Treaty.

Members of the Australian delegation involved in negotiating the establishment of an Antarctic Treaty Secretariat. From left: Warren Papworth (AAD), Constance Johnson (DFAT), Richard Rowe (DFAT) and Andrew Jackson (AAD).

These discussions occupied five days and followed the welcome decision in 2001 to establish the Secretariat in Argentina. When operating it will lead to immediate efficiencies in the way the Treaty conducts its business. However, the Secretariat cannot start until a number of legal instruments enter into force.

The parties have agreed that a legally binding instrument will be necessary for the Secretariat to conduct its business and to secure funding by the Parties. However, it is also necessary to negotiate a means for the Secretariat to undertake its functions on an interim basis.

While progress was made on most of the issues, all the instruments must be adopted as a package. Accordingly, further negotiations are required.

As time for the negotiations in Warsaw was limited, it was not possible to examine a number of the technical issues such as the financial regulations, staff regulations, budget, and cost sharing mechanisms. These issues can be advanced in the lead up to and at the 2003 Treaty meeting.

Australia has a long-standing position that the early establishment of the Secretariat is fundamental to efficient operation of the Treaty. Since the adoption of the Madrid Protocol in 1991 the Treaty system has had an increasingly complex environmental agenda and a proliferation of working papers. The need for a mechanism to assist with organising the annual meetings and to properly manage the documents has become urgent.

The Antarctic Treaty is unique among international agreements of this stature in not having a permanent body to support it. Australia hopes that the Secretariat can be established in 2003. ■

Andrew Jackson, Manager, Antarctic Treaty and Government, AAD

Liability for environmental damage

The Warsaw meeting saw useful progress on the vexed question of developing rules for liability for environmental damage – an obligation arising from Article 16 of the Madrid Protocol.

The need is to have rules to decide responsibilities if an environmental disaster were to occur in Antarctica. Like elsewhere in the world, environmental liability rules are difficult to settle — a problem exacerbated by the unique operational and jurisdictional situation of Antarctica.

In the past, Parties have been split between a single annex (the so-called comprehensive approach) or a step-by-step approach starting with response action in environmental emergencies. Parties have now agreed to the latter approach on the expectation that broader concerns can be addressed at a later time. Accordingly, excellent progress was made on issues which in the past have highlighted the differences of approach.

COMNAP contributed practical advice on worst-case scenarios and the outcomes of a survey of recent Antarctic incidents.

The Warsaw meeting will lead to a further revision of a draft annex to form the basis of further negotiations in 2003. ■

Andrew Jackson, Manager, Antarctic Treaty and Government, AAD

Malaysia attends Treaty meeting

YBhg. Dato' Dr Salleh Mohd Nor, Chair of the Malaysian Task Force on Antarctica, and Dr Tony Press, Director of the Australian Antarctic Division, sign a bilateral cooperation agreement on 5 August 2002.

The Treaty meeting in Poland was pleased to have, for the first time, a representative of Malaysia present to observe the Treaty meeting.

In recent years Malaysian scientists have begun to develop an interest in Antarctic research and have been sending scientists to Antarctica as guests of the Australian and New Zealand Antarctic programs (see story in *Australian Antarctic Magazine* 3:.46). In addition, the Malaysian Prime Minister, Dr Mahatir, visited the Antarctic Peninsula in the 2001-02 summer, further stimulating Malaysian interest in Antarctica. Malaysia has also foreshadowed cooperative research with the Argentine Antarctic program in the 2002-03 summer.

In August 2002, the Malaysian Academy of Sciences convened an international seminar on Malaysia's future scientific opportunities.

Because of the growing Malaysian interest in Antarctic research and possible interest in accession to the Treaty, the Treaty Parties decided to invite Malaysia to observe the recent Treaty meeting to assist their understanding of how the Treaty operates. Dr Azizan Abu Samah, head of the Malaysian Antarctic Research Program, attended the Warsaw meeting. This is the first time that any state not party to the Treaty has been invited to observe proceedings and reflects the importance that the Parties place on doing what they can to encourage States with an interest in Antarctica to become party to the Treaty.

Australia has indicated to Malaysian scientists that we are pleased to continue cooperation with Malaysia and will continue to encourage their accession to the Treaty. To mark the close relationship that is developing, the occasion of the August seminar was used to sign a bilateral cooperation agreement between the AAD and the Malaysian Academy of Sciences.

ANDREW JACKSON,
MANAGER, ANTARCTIC TREATY AND GOVERNMENT, AAD

Malaysian scientists head south with Australia

AAD microbiologist Fiona Scott demonstrates microscope repair to Ms. Sazlina Md. Salleh, Mr Mahadi Mohamad, Dr Wan Maznah Wan Omar, Dr. Aileen Tan Shau Hwai, Prof. Mashhor Mansor and Prof. Zulfigar Yasin.

With the encouragement of Prime Minister Dr Maharthir, Malaysia is initiating a program of Antarctic research. Last season, Professor Siti Alias and the late Dr Omar Pozan participated in Voyage 5 and collected microbial samples from Casey. This coming season, six Malaysian scientists will participate in the Australian Antarctic program.

A/Professor Irene Tan and student Wong Chiew Yen, from the University of Malaya, Kuala Lumpur, will round-trip to Casey on Voyage 3, studying the microbial content of the ocean and sea-ice as well as snow and soils at Casey.

In addition, four Malaysian scientists will be participating in Voyage 4. During this cruise they will measure the distribution, abundance and composition of microbial populations as part of the AAD's Marine Microbial Ecology Program. Six scientists (Voyage 4 participants and two backup participants) from the Universiti Sains Malaysia (the science university in Penang) visited the AAD from 6 to 14 October to receive training in the microbiological techniques that they will be using on Voyage 4.

The Vice Chancellor of Universiti Sains Malaysia, Prof. Dato Dzulkigli Abdul Razak, will meet the scientists on their return from Antarctica, and will then sign a Memorandum of Understanding establishing research links with the University of Tasmania.

SIMON WRIGHT,
BIOLOGY PROGRAM, AAD

PHOTO CREDITS
Top to bottom:
Tony Press
Wayne Papps

Opposite page top to bottom:
Andrew Jackson
Holger Martinsen

Committee for Environmental Protection meets

The Committee for Environmental Protection (CEP) held its 5th annual meeting in parallel with the 25th ATCM in Warsaw, Poland in September. The Committee provides advice to the ATCM on environmental matters, particularly in relation to the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol).

Both Romania and the Czech Republic advised that they were close to completing domestic arrangements to ratify the Madrid Protocol, bringing the number of Treaty parties which have ratified the Protocol to 31.

There was a substantial agenda for the CEP with items largely based around each Annex of the Madrid Protocol: (I) Environmental Impact Assessment (EIA); (II) Conservation of Antarctic Fauna and Flora; (III) Waste Disposal and Waste Management; (IV) Prevention of Marine Pollution (no matters were raised on the agenda); and (V) Area Protection and Management. The CEP also discussed State of the Antarctic Environment reporting, tourism, and biological prospecting; these latter two issues will be given more detailed consideration at CEP VI.

Work of the Committee was substantially assisted by the use of intersessional contact groups established at the last meeting to ensure that Antarctic Treaty parties could consider matters in detail in order to be better able to discuss the many substantive issues at CEP V.

Intersessional consultation will develop policy and position papers such as the review of Annex II, discuss Russia's Comprehensive Environmental Evaluation for drilling into the sub-glacial Lake Vostok, and consider draft protected area plans.

Environmental Impact Assessment (Protocol Annex I)

There were no Comprehensive Environmental Evaluations (CEEs) submitted for consideration at CEP V in Warsaw, but delegations indicated that three CEEs are scheduled for submission at CEP VI which will address:

- penetration to enable water sampling of the sub-glacial Lake Vostok, the largest known sub-glacial lake in Antarctica and the first to be penetrated (Russian Federation);
- the ANDRILL stratigraphic drilling program in McMurdo Sound to investigate Antarctica's role in global climate change over the last 65 million years (New Zealand); and
- a proposed summer research station at Brandy Bay, James Ross Island (Czech Republic).

The Council of Managers of National Antarctic Programs (COMNAP) presented a review of Initial Environmental Evaluations (IEEs) for the construction of Antarctic station living facilities, bulk fuel storage, and scientific ice core drilling. The review was conducted to achieve a better understanding of how environmental impact assessment is being used by national programs, and to identify the strengths and weaknesses of past assessments. The analysis noted that the identification of impacts was often a weakness in IEEs. Further details of the analysis will be discussed at the next meeting of the CEP in Madrid next year.

Work by the Scientific Committee on Antarctic Research (SCAR) reviewed the literature on marine acoustic technology and the Antarctic environment. Australia's domestic guidelines for marine acoustic technology associated with the Environmental Protection and Biodiversity Conservation Act 1999, may provide a useful benchmark for consideration of this and future work on this matter.

Conservation of Antarctic Fauna and Flora (Protocol Annex II)

Substantial progress was made on improving the working of Annex II of the Madrid Protocol on Environmental Protection, and in agreeing to commence assessments of the conservation status of Antarctic species based upon the International Union of Nature Conservation (IUCN) criteria, starting with birds and seals.

The CEP has sought to encourage further work on the conservation of marine species through a common approach with the Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR), the Commission on the Conservation of Antarctic Seals (CCAS), and other relevant bodies.

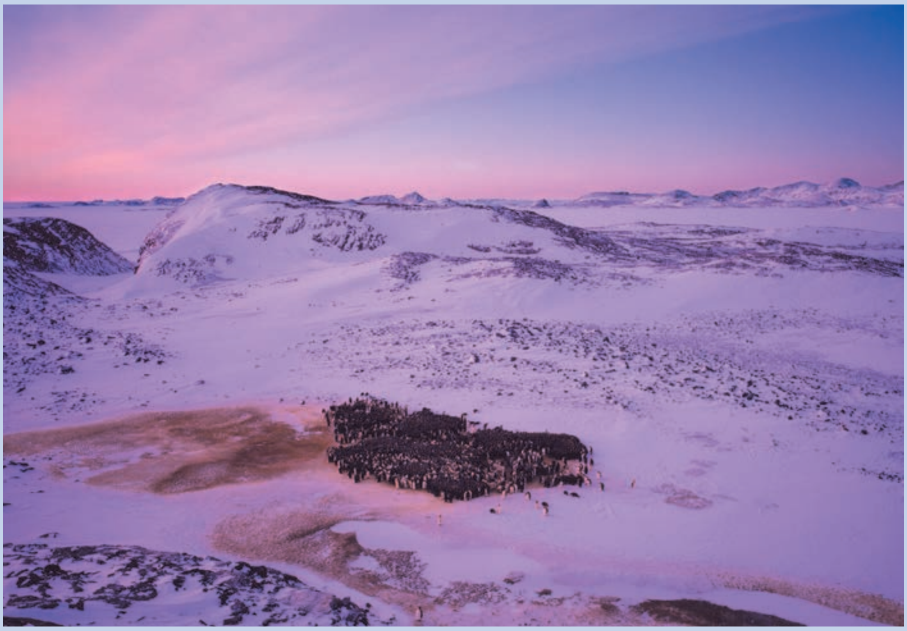
Waste Disposal and Waste Management (Protocol Annex III)

Australia's information paper on the clean-up of waste from Heard Island was well received and complemented similar papers from the UK and Russia on clean-up activities at two of their Antarctic stations. These papers presented a variety of clean-up activities, which were undertaken in different ways.

Australia intends to present at CEP VI papers describing the clean-up of the abandoned Thala Valley tip site at Casey station, and Australia's approach to the clean-up provisions of Annex III through a comprehensive waste management strategy. The AAD will be undertaking further research into clean-up and remediation techniques at Thala Valley this summer.

Area Protection and Management (Protocol Annex V)

As with other matters of Antarctic Treaty work, much inter-sessional activity enabled



Antarctic Specially Protected Area 101 (previously SPA 1): Taylor Rookery, Mac.Robertson Land. The ~0.4 km^2 Taylor Rookery is among the few, and probably the largest, of the known colonies of emperor penguins located entirely on land.

Annex V comes into force

With India's approval of Annex V, the Annex came into force on 24 May 2002. As a consequence Specially Protected Areas (SPA) and Sites of Special Scientific Interest (SSSI) are renamed and renumbered as Antarctic Specially Protected Areas (see <http://www.era.gs/resources/apa/index.html> for detailed lists of the Antarctic special areas).

Since the Madrid Protocol entered into force in 1991 parties have revised and rewritten SPA and SSSI management plans in the Annex V format as Antarctic Specially Protected Areas. Parties agreed to seek completion of this work of updating management plans. ■

13 management plans for Antarctic Specially Protected Areas to be forwarded for adoption by the ATCM. A further nine revised or new management plans will be considered in intersessional work reporting to CEP VI. These include Australia's draft management plan for the Frazier Islands and the revised plans for ASPA 135 (Bailey Peninsula, Casey) & 143 (Marine Plain, Davis).

Antarctic Specially Managed Areas (ASMA) are intended to facilitate cooperation amongst parties with a view to minimising environmental impacts. Three management plans are in draft for ASMAs; by Brazil and Poland (Admiralty Bay), the USA and New Zealand (Dry Valleys), and Australia, China and Russia (Larsemann Hills).

The CEP took note of Australia's planned 2002-03 conservation expedition to Mawson's Huts at Cape Denison, and our proposal to bring a Protected Area Management Plan for this important historic site to the CEP VI meeting in Madrid in 2003.

Guidelines for consultation on management plans (previously agreed at CEP III) will be revised intersessionally to clarify the process for seeking approval from the Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR) for any relevant proposed Antarctic Specially Protected Area and its management plan.

State of the Antarctic Environment Report

The Committee considered three papers on state of the environment reporting, including an Australian paper on the recently launched System for Indicator Monitoring and Reporting (SIMR). The Committee endorsed Australia and New Zealand as joint convenors of intersessional work to develop the concept towards a continent-wide application, and report to CEP VI.

Simon Smalley & Tom Maggs,
Environmental Management and Audit Unit, AAD

AAD achieves international environmental standard

The AAD received certification on 4 September 2002 for its environmental management system (EMS) to the international standard ISO14001. Certification – with no nonconformances – is a major milestone in Australia's impressive history of protecting the Antarctic environment.

Australia is the first national operator amongst the Antarctic Treaty parties to implement a certified EMS. News of our certification to the international standard was warmly received by Treaty Parties at the meeting of the Committee for Environmental Protection in Warsaw in September, and Australia will be taking forward an EMS progress report to the next meeting.

In recommending certification, the EMS auditors (NATA Certification Systems International) praised the extraordinarily high awareness of environmental issues and commitment to environmental protection evident amongst all AAD staff, both in Australia and at the Antarctic stations.

ISO14001 was established in 1996 to answer the growing need worldwide for a systematic approach to the management of an organisation's environmental responsibilities, with a focus on continual improvement.

The process of implementing an EMS began in earnest for the AAD in 2000 with an initial environmental review, which described the AAD's activities at its various sites and the policies and procedures that were already in place to address the associated environmental issues. Then followed a detailed analysis of the activities to determine possible environmental impacts, a risk analysis to assess their likelihood and consequences, and a process of ranking their significance.

Responsibility for groups of activities at specific sites was assigned to 'key section managers', who developed a suite of environmental management programs under broad objectives, including tasks, deadlines and responsible officers.

The AAD officially launched its Environmental Policy in December 2001, the first major tangible output of the EMS process. The Policy sets out the AAD's charter and its environmental commitments with respect to the conduct of its operations.

The EMS is underpinned by a software system, ISOSoft 14001, which collates essential background information, provides a register of environmental management program details, and includes an automatic email reminder system which notifies officers when an EMS task falls due.

Implementing the EMS required that the AAD develop a register of legal and other requirements. Project staff compiled a list of 44 environmental laws and agreements under Commonwealth and Tasmanian jurisdictions, and developed a protocol under which the AAD's achievement of compliance with these instruments could be tested. The AAD's documented procedures and instructions, developed over some 50 years, were collated, updated, and registered.

The EMS has also focused attention and resources on other organisation-wide improvements, including the development of a pilot 'e-learning' program – an interactive web-based environmental awareness program which all staff will complete as part of the AAD's induction program. Document control, records management, and incident reporting procedures developed for the EMS will mesh with those being developed for the organisation as a whole.

In order to ensure that the system continues to function effectively, a formal review by AAD senior management is conducted every six months, followed by an external surveillance audit to ensure continued compliance with the standard.

From left: Phil Crosby (NCSI), Martyn Summers (NCSI), Tom Maggs (AAD), Ewan McIvor (AAD).

A copy of the AAD Environmental Policy and the respective ISO14001 EMS certificate is proudly displayed at the Kingston Headquarters, the Hobart wharf Cargo Facility, and at each Antarctic station.

Tom Maggs,
Environmental Management and Audit Unit, AAD

Antarctica Online

Further information on the AAD's environmental management system is available at <http://www.aad.gov.au/environment/policy/policy_intro.asp>.

PHOTO CREDITS
Phil Crosby

Opposite page:
Graham Robertson

MIDWINTER

Warm glow from Midwinter Festival

Antarcticans have a long history of celebrating midwinter's day. Falling on the winter solstice when sunshine is at its minimum, it provides a milestone to mark the darkest time of the year after which the sun's light and warmth return. It's the southern equivalent of the northern hemisphere's Christmas and is traditionally celebrated with food, wine, and original (and highly imaginative) entertainment.

Tasmanians – especially those of its capital, Hobart – have had Antarctic connections since the early days of Southern Ocean exploration and industry, and in a place where seasons are clearly defined, feel an empathy with those experiencing Antarctica's dark winter. In 2002 they celebrated the second – and by the far the biggest – *Antarctic Tasmania Midwinter Festival*. Last year's one-day pilot, which focused on Antarctic education for school children, was expanded into a nine-day, state-wide event.

The 2002 festival inspired people to venture out in the middle of the Tasmanian winter, often at night. The activities ranged from displays and educational activities to a community barbecue and a traditional dinner, where hundreds of Hobartians celebrated the season the Antarctic way. *The Longest Night Film Festival* helped to create an atmosphere by displaying an international collection of films on all things cold and polar.

In a place where seasons are clearly defined, Tasmanians feel an empathy with those experiencing Antarctica's dark winter.

The Australian Antarctic Division contributed a photographic exhibition, lectures on Antarctic science and demonstrations of Antarctic operations which included diving, zodiac boat operations and a crevasse rescue. Crevasses are rare in Hobart so a suitable blank wall was substituted.

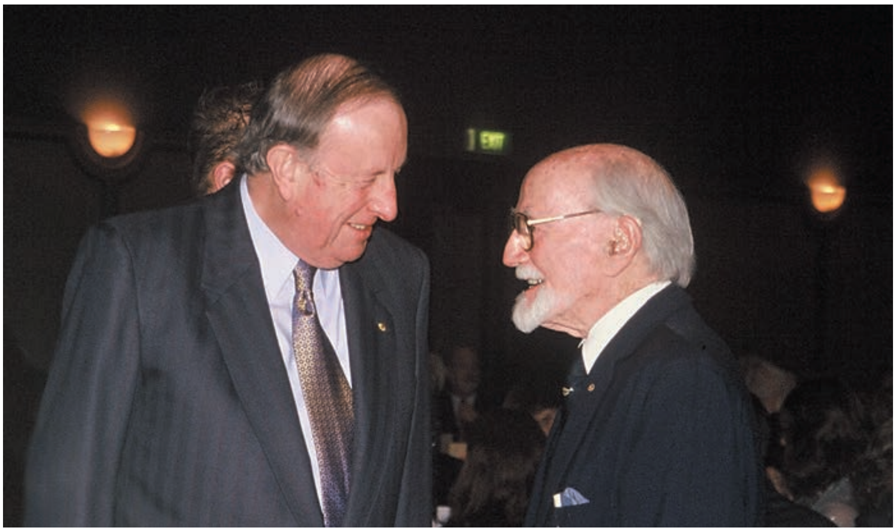
Tasmania's diverse range of polar organisations was well represented, with events organised by the Australian Antarctic Division, Hobart City Council, CSIRO, Antarctic Adventure and the Tasmanian Polar Network. The Hotel Grand Chancellor provided a venue for formal events and the festival's events were strongly supported promoted in local and interstate media.

The future of the festival, overseen and coordinated by the Department of State Development, seems assured. Held over eight days from June 15 to 23, attendance far exceeded the organising committee's expectations. Planners of next year's event are seeking to attract many more interstate and international visitors and to make connections with complementary northern hemisphere polar celebrations. ■

Cathy Bruce,
Information Services, AAD

Antarctic Treaty, science under scrutiny in inaugural Phillip Law Lecture

The Governor of Tasmania, Hon. Sir Guy Green AC KBE CVO, presented the inaugural Phillip Law Lecture as part of the Antarctic Tasmania Midwinter Festival in Hobart on 22 June 2002. Text of the original lecture has been reduced here for space reasons. Original text is in roman type; editor's summaries in italics.



The Governor of Tasmania, Hon. Sir Guy Green AC KBE CVO, with Phillip Law at the inaugural Phillip Law Lecture in Hobart on 22 June 2002

This Tasmanian Midwinter Festival celebrates some wonderful and unique qualities of Tasmania as a place and a society. A place whose geology and flora evoke ancient memories of its *[Gondwana]* origins …and … *[whose most southerly part]*, Macquarie Island, is actually located in the subantarctic itself. As a society Tasmania's culture and history have been rooted in the history of Antarctic and Southern oceanic science and exploration for 175 years and today Tasmania is arguably the most significant centre of Antarctic endeavour in the world. This festival is a most fitting and exciting way of celebrating those special aspects of Tasmania's history, geographic location and culture.

[Fitting that festival marks winter solstice, traditionally celebrated for tens of thousands of years. Imaginative variety of events comprising Tasmanian festival embody spirit of ancient observances. Would seem appropriate for Tasmania to have its own structure, positioned, like Stonehenge, to mark moment of sunrise on shortest day.

Inauguration of Phillip Law Lecture an especially appropriate event for this festival. Would like to join in welcoming Dr Law here this evening. Wonderful that someone who has made such a magnificent defining contribution to the history of human endeavour in Antarctica has been able to join us for these celebrations and this lecture.

Antarctica: 'remarkable place' – driest continent containing 68 percent of world's fresh water as ice; world's most powerful sustained winds, temperatures down to minus 90 degrees – leading to emotional, poetic responses from explorers such as Mawson and Scott.]

But overwhelming and remarkable as Antarctica is, it is about the magnificent history of human endeavour which that continent has seen… that I wish to speak tonight… in particular … the significance which that history has had for the world at large. Human endeavour in connection with Antarctica falls into two distinct domains – international law and policy on the one hand and science on the other.

On 1 December 1959 in Washington representatives of 12 nations including Australia signed the Antarctic Treaty… a remarkable international instrument which for more than 40 years has succeeded in fulfilling its objectives that Antarctica be used for peaceful purposes only, that scientific research be undertaken freely and in a spirit of cooperation and that existing territorial claims be frozen and that no new claims shall be made.… The Treaty …*[has]* ensured that the last continent on earth to be settled has not followed the tortuous path of conflict and unthinking exploitation which has characterised the history of all the other continents.

…The way in which the Treaty was negotiated is instructive and inspiring … In June 1958 *[during meetings to negotiate the Treaty,]* the prospects were, to say the least, not promising. The Ambassador of Chile, Oscar Pinochet de la Barra later recorded (1) that 'Some of the delegates were in favour of freedom of science, others were against it; some supported the freezing of sovereignty, some did not; some wanted a treaty for 30 years, others a permanent treaty; some said yes and some said no to observers; and so on.'…

But then came a remarkable series of breakthroughs. Argentina was against freedom of science in Antarctica but accepted a proposal from South Africa that the principles of the International Geophysical Year should be applied. All delegations then went on to accept a total prohibition of nuclear explosions and an accommodation was reached whereby all countries agreed that whilst military bases should not be established in the Antarctic continent it would be acceptable to use military personnel for logistic work and the support of scientists. But … the crucial issue of sovereignty could still have defeated the whole exercise. The concept of freezing sovereignty claims was accepted but the question was for how many years. …A number of countries refused to accept *[suspension of claims in perpetuity]* on the ground that it would … represent a complete renunciation of their claims. In the end, a proposal from Chile was accepted that after 30 years there would be a special meeting of review with a decision to be taken by a majority of delegates. 'United in diversity,' Ambassador de la Barra concluded, 'we created in those autumn days in Washington a product of simple commonsense, helped by a secret key: consensus.'

I think that those who are engaged in difficult international negotiations should take heart from the example of the negotiation of the Antarctic Treaty which showed that sometimes it is possible to overcome apparently intractable differences through honest open discussion informed by principle and good sense.

[Treaty's success inspiring and instructive; provides new perspective on and better understanding of nature of international relations and United Nations role. In UN in 1983 Treaty System said to be exclusive, not accountable, 'neo-colonial; push for its replacement by universal UN-controlled regime. Australia and other Treaty nations saw strong arguments for status quo. Richard Woolcott, former Australian UN Ambassador, said (2) that Treaty is open to any UN member, is consistent with UN Charter, encourages open scientific research and has reduced international tension by dealing effectively with sovereignty claims. Richard Rowe, leader of Australian delegation to Treaty Consultative Meeting, observed (3) that Treaty system is 'robust framework for action in Antarctica'. Inclusive spirit of Treaty continues today with Australia's help to Indonesia and Malaysia to participate in Antarctic science.

PHOTO CREDITS
Peter Laws

Opposite page:
Top right Wayne Papps
Peter Laws (all others)

Treaty system is model for effective, principled international arrangement in accord with UN philosophy. Treaty has extraordinary record as vehicle for civilised discussion in difficult times, such as meeting recalled by Woolcott (4) between Russian and US ambassadors in which agreement was reached on vital tactics and procedures despite personal insults. Woolcott observed that at Cold War's height, Antarctica was main area of effective Soviet–US cooperation.]

And I have my own memory of receiving at Government House on 2 June 1982 delegations from Argentina and the United Kingdom who had been working together at a meeting of an Antarctic Treaty organisation just two months after … *[the start of]* a war between the two countries.

The Antarctic Treaty System has made an inspiring and instructive contribution to international law and policy which extends well beyond merely the governance of Antarctica itself. And Antarctic science has similarly made a very substantial contribution to many other scientific fields and to the doing of science generally.

The … Antarctic Treaty System has also been … *[adopted]* as a model in other fields… The principles upon which the 1967 Outer Space Treaty was based were in essence identical with the philosophy of the Antarctic Treaty System.

…The other major area of human endeavour in Antarctica … is the doing of science. Originally this was seen as being primarily concerned with discovering, describing and understanding the properties of the continent and the region below, above and around it. And that still remains a major function of Antarctic science. But what has changed is that much of the science which is being done is now understood to have far wider ramifications so that Antarctic science has now become truly global science.

[Examples: air trapped in Antarctic ice cores are archive of past climates to guide climate prediction; Antarctic seismic and ozone study enlarging understanding of global patterns; study of Antarctic ice sheet and Circumpolar Current increase understanding of phenomena influencing fisheries, coastal industries and climate everywhere; world studies in meteorology, oceanography, geospace depend on Antarctic science.]

But … some countervailing influences have emerged which have a chilling or inhibiting effect on the advancement of science. The first is the tendency to specialisation. All scientific disciplines are subject to an escalating process of specialisation and subdivision, an inevitable result of which is that the science curriculum, scientific endeavour and the knowledge of individual scientists tend to become more and more narrowly focused and as a result less accessible to those without a comparable specialist training. …*[This trend also militates against scientific advances resulting from insights transcending traditional discipline boundaries.]*

Antarctic science is different. Whilst individual scientists and their projects are just as narrowly specialised in Antarctic science as they are in any other field they still maintain a broad perspective extending well beyond their own particular fields. …The multidisciplinary character of Antarctic science is partly because a 'dependence on common logistics has demanded cooperation and joint planning between scientists of different disciplines'. (5) It is also a function of the nature of the science which is being done, much of it being concerned with understanding how interactions between geological, physical, chemical and biological phenomena can inform our understanding of the global environment.

[To illustrate:] just last month … the light detection and ranging instrument (LIDAR) at Davis Station stopped operating because of a failed capacitor. In any other facility the scientists would have simply ordered up a replacement component. But in the best traditions of Antarctic ingenuity and cross-disciplinary cooperation, the scientists decided to build a replacement themselves. Naturally enough they started by seeking the assistance of the most important person on any Antarctic station, the chef, who provided plastic cling wrap and aluminium foil. Two physicists, the communications officer, the electrician and the station diesel mechanic then together set about building a new capacitor which is operating most successfully enabling the instrument to work as it should.

In short Antarctic science has a generalised and multidisciplinary character which is in sharp contrast to the tendency to narrowness and specialisation found in much of the rest of science.

Another trend which is inimical to the advancement of science *[over recent decades is]* a distinct decline in the standard of conduct observed in scientific debate, especially when it is about environmental issues. Positions are taken which are informed by self interest or dogma rather than by intellectual conviction and discussion is sometimes personal, intemperate or partakes of the nature of propaganda rather than rational argument.

…Consider the reaction to a work entitled *The Skeptical Environmentalist* written by a Danish scholar, Bjørn Lomborg. Published for the first time in English last year the work deals with environmental concerns about the depletion of natural resources, the effects of human population growth, the loss of biodiversity and the pollution of water and the atmosphere. In a 500 page analysis of the evidence, Lomborg argues that these fears are either unfounded or exaggerated.

I express no opinion as to whether Lomborg's thesis is valid or not. What I wish to comment on is the way in which his thesis has been debated. The response to *The Skeptical Environmentalist* has been very disturbing indeed. Much of it consists of attacks on Lomborg personally …*[which]* are gratuitous, irrelevant and of course quite unscientific. But even when it is the book rather than the man which is being addressed the way in which the issues he raises have been discussed has been just as unedifying and unhelpful.

A review of the book was published in the journal *Nature* (6). In that review which was later fairly characterised by correspondents to the journal as 'peevish' and 'part of a rush to rubbish Lomborg's book', the authors expressed the conclusion that Lomborg's survey 'reads like a compilation of form papers from one of those classes from hell where one has to fail all the students'. It is a troubling indication of the depths to which debate about environmental issues has descended when it is thought appropriate to include puerile material like that in what purports to be a serious review of a serious book in one of the most prestigious scientific journals in the world.

Similarly… *Scientific American* decided to depart from its usual mode of publishing *[detached, expert]* one-page book reviews … and instead published a special eleven page section on the book written by four academics known to be closely associated with environmental advocacy (7). Their articles were … polemical attacks which were accurately summarised by *The Economist* as 'strong on contempt and sneering, but weak on substance'.

…I repeat that I do not express any opinion at all about the quality of Lomborg's work or about the validity of *[his]* conclusions… *[but]* the personal attacks on him and the partial and intemperate reviews of his book are a serious departure from the norms of scientific discussion and objectivity. And unfortunately the Lomborg case is not an isolated example; it is typical of much environmental debate today.

In strong and refreshing contrast Antarctic science, including in particular those parts which deal with climatology and global change, is still being conducted and debated in accordance with the traditional norms of scientific discourse. Whilst Antarctic scientists are as … concerned about the environment and its biota as anyone else and … *[vigorously debate]* environmental issues, the personal attacks and low-grade debate which characterise environmental discussion elsewhere … are completely alien to the atmosphere in which Antarctic science is conducted.

Consider for example the position taken by the *[Antarctic]* Cooperative Research Centre … on … polar ice sheets, climate and sea level rise. In 1997 and 2000 the CRC published position statements about the popular speculation that within a relatively short time greenhouse warming might trigger sea level rises of 60-100 metres… *[which]* politely suggest that scientific analyses do not support such extreme possibilities and … present a detached non-polemical report of the current state of knowledge about the various factors involved and some of the possibilities for the future.

Another example of the more responsible and rigorous quality of Antarctic science in relation to environmental issues … is to be found in the way it approaches the precautionary principle… frequently invoked in discussions and regulatory regimes governing environmentally sensitive activities. …*[The principle]* is routinely referred to as if it had a single universally accepted meaning. But it does not. When it first gained currency the principle was generally understood to mean that where proposed activity might cause irreversible environmental harm a lack of full scientific certainty is not a sufficient reason for not taking measures to guard against that harm. But over the years the principle has been given other more extended meanings – the most stringent being that no activity may be undertaken unless it can be positively demonstrated that it will not cause environmental harm. And between those extremes the precautionary principle has been given scores of different formulations in international agreements and the legislation and policy statements of individual countries. Some make the principle applicable where harm is possible whilst others make it applicable where harm is probable – two very different tests; and other formulations including the well known Rio declaration introduce the notion of cost effectiveness into the application of the principle.

[Precautionary principle not invalidated because it has many formulations but must be defined in terms of context. Is routinely being used without being defined, making discussions sterile and even counterproductive. Some meanings ascribed to principle make it impossible to apply and hence impracticable. Principle's stringent form precludes activity which can't positively be shown not to cause environmental harm, but until everything in universe is known it can't be proved conclusively that a particular action won't have adverse consequence somewhere sometime. Hence this form of precautionary principle precludes us from doing anything.]

Compare that situation with the way in which Antarctic science approaches the precautionary principle. Article II of the Convention on the Conservation of Antarctic Marine Living Resources requires … that a precautionary approach be taken to the harvesting of resources in the southern oceanic area to which the convention applies. …*[Much effort put into giving practical effect to this approach, in form of application of sophisticated mathematics to decide catch limits.]* That careful, disciplined program really amounts to an extended definition of the precautionary principle and stands in marked contrast to the casual application of the principle in programs of environmental management outside the Antarctic field.

…In this lecture I have wanted to demonstrate two things. First that the Antarctic Treaty System has made an inspiring and instructive contribution to international law and policy which extends well beyond merely the governance of Antarctica itself. And secondly that Antarctic science has similarly made a very substantial contribution to many other scientific fields and to the doing of science generally. Let me conclude by referring to an additional contribution which those two domains have made through the extraordinary success they have had in working productively with each other.

As Professor Michael Stoddart, Chief Scientist, Australian National Antarctic Research Expeditions (ANARE), points out (8), the Antarctic Treaty has its origins in the International Geophysical Year (1957-58)… an international scientific collaborative endeavour organised by a non-governmental organization,… *[and since then]* Antarctica has been the domain of science and scientists… *[where]* scientific collaboration *[is fostered]* in a manner not seen elsewhere in the world.

…Underpinning all this has been the professionalism and hard work of all those who have been responsible for the negotiation of the Antarctic Treaty System and its successful operation …*[creating]* the political, legal, economic and logistic environment which has enabled that great co-operative scientific endeavour to be undertaken. A remarkably successful partnership between those working in diplomacy, government, law, non-government organisations and science and technology.

The Antarctic Treaty System and Antarctic science are unique historic achievements which have endured to the benefit of all mankind. We have the right to feel proud of the centrally important contribution to these achievements which Australia, through people such as Dr Phillip Law, has made and continues to make. And we can also feel proud of the centrally important role which Tasmania as one of the most significant Antarctic centres in the world is also playing in that great saga.

Hon. Sir Guy Green AC KBE CVO
The Governor of Tasmania

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PHOTO CREDITS
Wayne Papps

Antarctic Medal award acknowledges quiet achiever

A Tasmanian electronics engineer and head of the Australian Antarctic Division's science support section, Mr Jon Reeve, of Taroona, is the sole recipient of the Australian Antarctic Medal in 2002.

The award was a public acknowledgment of Mr Reeve's outstanding commitment and service to Australia's Antarctic work over many years – a public acknowledgment of a quiet achiever, Dr Sharman Stone, Parliamentary Secretary responsible for the Antarctic, said.

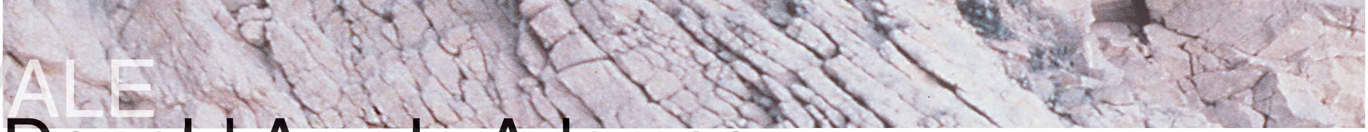
The award was announced on Midwinters Day 2002 by the Governor-General, His Excellency the Right Reverend Dr Peter Hollingworth AC, OBE.

Mr Reeve, whose work has underpinned major Australian Antarctic marine science projects, has spent many months at sea on the world's roughest oceans in support of research into the Southern Ocean and its resources – a central part of Australia's Antarctic program.

His award citation noted his dedication to the maintenance of sophisticated ship electronics and scientific equipment and his major contribution to the achievements of Australian science in

Antarctica and the Southern Ocean, covering the full breadth of marine science activities.

A recent success of Mr Reeve was the organisation of a major Southern Ocean voyage involving a research group of 70 from 13 countries.



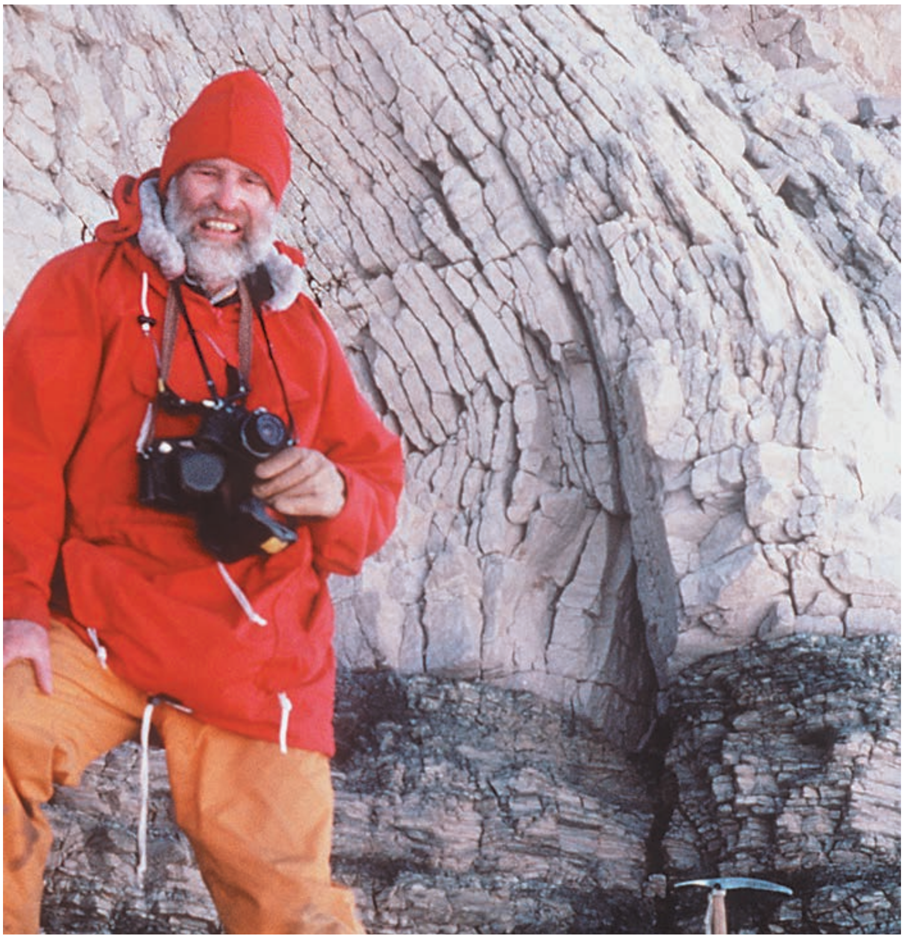
VALE

Donald Argyle Adamson

Early in 2002 the Australian Antarctic scientific community was saddened to learn of the death of Don Adamson, a person who was in his heaven fossicking around in southern regions during many a summer season either in mainland Antarctica or on Macquarie Island. Don was a son of the Australian bush where he lived his early childhood before moving with his parents to Sydney. Don was educated at Sydney University in biological sciences where he received his doctorate. He was appointed to a lectureship in the School of Biological Sciences at the then relatively new Macquarie University from where for many years he taught, researched and positively influenced the lives of many students and colleagues. He was well known throughout Australia and overseas for his work in biological sciences, in archaeology and geomorphology in Africa, and his work on various aspects of the environment of Antarctica. For this work Macquarie University rewarded him with an Associate Professorship, a well-deserved accolade for a life spent endeavouring to resolve scientific problems.

Apart from previous incidental meetings, I first got to know Don in 1986 when we joined forces to work together on the ANARE expedition that established the Sir Edgeworth David summer field base in the Bunger Hills. During two months working daily with Don in the field I learnt a lot about him and his achievements in Antarctica. It is not that he would have told me, as Don was a modest person, but that during the course of our scientific discussions his past contributions became evident. At various times Don worked in the Vestfold Hills, Larsemann Hills, Stillwell Hills, Bunger Hills, at Beaver Lake and on Macquarie Island. His most important scientific contributions were the finding of the diatomite deposits at Marine Plain in the Vestfold Hills where the world famous cetacean fossils were later found. Together with John Pickard he found the fossil clam *Clamys tuftsensis* that dated the deposits as of Pliocene age and showed that the sea had transgressed the Vestfold area around three million years ago. The Pagodroma Tillite at Pagodroma Gorge also fascinated Don, and he made observations on its possible age. Notable amongst his numerous publications was a considerable contribution to *Antarctic Oasis* (edited by John Pickard, Academic Press, 1986).

Don had a love of the outdoors and a concern for the environment – not a shallow concern but one that required him to satisfy his own mind on problems through scientific explanation. Working with Don one soon discovered that he was a very acute observer, often seeing details of the landscape that others would have missed. One also realised that he was full of ideas, ideas that had to be tested fully with the gathering of facts.



Don Adamson in the Prince Charles Mountains, 1989

Don would not just accept current views. He was like a terrier with a bone. If the current view did not fit the observed facts as he saw them then the view would have to be revised.

Don was a strong man both physically and mentally. I remember being with Don at the end of the Edisto Glacier when the weather 'clagged in' and the helicopter pilot advised he could not land and we would have to make it back to camp. After some exhortation from Don for the pilot to land the wind began to blow as it can only do in Antarctica. Nothing for it but to 'trog' as Don would say for about 5 km across the land and sea ice back to Edgeworth David base. During that walk the wind was so fierce that it caught Don's pack and spun him around on the sea ice before flattening him. When I asked him was he OK the answer was 'sure I'm OK' as I helped him to his feet. We returned to camp just in time to catch one of the tents taking off with the wind.

During the time at Bunger I had been focused mainly on studying the raised beaches. Don was anxious to spend quite a bit of time on the 'ice-edge' where the continental ice sheet abuts the hills. When we went to the ice-edge I realised that these excursions really summed up 'Don the scientist' who always wanted to test the edges of theory and was sometimes slightly impatient with those taking a more cautious approach. However, during his career he pushed back frontiers of knowledge in biology, archaeology and geomorphology, and showed himself as a remarkable interdisciplinary scholar not dissimilar to a well-versed natural philosopher of late Victorian times.

Don was also a generous man. Apart from the knowledge that he gave so willingly to all who learned from or worked with him, I remember a small event that indicated his extreme generosity. During the summer of 1986 at Edgeworth David base two skuas strutted around the 'melon' hut that we called the mess. They were such regular visitors that we named one Edgeworth and the other David. One day when Don and I were about four kilometres from the camp we realised that Edgeworth and David had followed us towards Lake Figurnoe. When we sat down briefly in the sunshine behind a rock for lunch the skuas were still present. It was not long before Don was sharing his limited lunch of cheese and rather dry biscuits with Edgeworth and David.

With the death of Don Adamson the Australian Antarctic scientific community has lost a good friend, a man of ideas, a man who has made outstanding scientific contributions, and a strong, humble and generous person. ■

DON'S FRIEND AND COLLEAGUE
ERIC A. COLHOUN
NEWCASTLE UNIVERSITY

Station Leaders appointed for 2003

Jeremy Smith – Davis
Jeremy was for many years an Associate Professor in biogeography at the University of New England, Armidale, NSW, where in addition to teaching he undertook investigations of mountain floras, seed dispersal, and invasive weeds. He is the author of nearly 100 publications in these and other fields. His research interests have taken him to mountains in New Guinea, Borneo and Venezuela, and he has participated in several expeditions including to Heard Island in 1983. He was the Station Leader at Macquarie Island in 1996, and at Davis in 2001. When not with ANARE, he lives on a small rural property near Armidale where he enjoys growing trees, raising poultry and bird-watching.

Ivor Harris – Casey
Ivor comes from Brisbane and is married with three adult sons. He has worked for most of his career as a veterinarian, including large and small animal practice and TAFE teaching. For many years he specialised as a laboratory animal scientist and also developed a research interest in microbiology. In this role he has managed biomedical research support facilities in the Commonwealth Department of Health and the University of Queensland. He had also been in the Army reserve for 17 years, and for the last three years has been in the regular Army as Major, administrative/scientific officer at the Army Malaria Institute in Brisbane. This included deployment to East Timor in 2000–01 as coordinator of a major antimalarial drug trial. He is currently on leave without pay from the Army and anticipates returning to his position in 2004.

Sarah Bolt – Mawson
Sarah is a solicitor who has worked with the South Australian Equal Opportunity Commission for the past five years. Her current position with the Commission covers legal, conciliation and training and education as it relates to the Commission's complaint handling process. Prior to joining the Equal Opportunity Commission Sarah held a variety of legal positions specialising in Industrial, Civil and Employment law.

Louise Crossley – Macquarie Island
Louise has had a varied career as an academic, museum director, science broadcaster and environmental consultant. She lives in Hobart when she isn't travelling to far flung destinations like Siberia and Mongolia. Since spending 16 months in Antarctica in 1991–92 as Station Leader at Mawson and Field Leader in the Prince Charles Mountains, she has developed an addiction to the deep south, and has made about 20 voyages to the ice as a guide/lecturer on Russian icebreakers carrying tourists to many different parts of Antarctica. She was Station Leader at Macquarie Island in 2000, and is looking forward to returning to the Green Sponge.

Being prepared

Expeditioners working in the Australian Antarctic Program need a wide range of skills from navigating their way in the field using a map and compass, to fighting fires in an emergency, to being an effective member of an isolated community. It is an important requirement that all members of Australian Antarctic Division expeditions undergo pre-departure training.

The Bronte Park Highland Village was the venue again this year for station and field training for over 100 expeditioners prior to the departure of the first voyage of the season. Tasmanian spring weather produced a light cover of snow and heavy rain during the four-

day program, ensuring the one night in tents was challenging, especially for those departing for Macquarie Island.

Training in the use of four wheel drive Honda quads was conducted on a disused runway and expeditioners had the opportunity to use fire extinguishers as part of a program of practical skills training.

The program also included classroom sessions on environmental management, coping with separation from family and friends, occupational health and safety, and issues in community living.

Several more training camps are scheduled for the 2002–3 season.

PHOTO CREDITS
Left: Wayne Papps, Wayne Papps
Centre: Wayne Papps, Glenn Jacobson
Right: Rob Easther, Rob Easther

Opposite page:
Rod Ledingham

Evaluation of Australia's Antarctic science program

An Evaluation of Australia's Antarctic Science Program is currently in progress. The evaluation is being carried out for the Antarctic Science Advisory Committee (ASAC) by a Steering Committee (Chaired by Professor John White, FAA, FRS) with input from four discipline-based subcommittees.

The Terms of Reference for the evaluation are:

- to evaluate the quality of the science output against the current Strategic Plan;
- to evaluate the relevance of the scientific output to the goals of Australia's Antarctic program as measured against the Strategic Plan;
- to evaluate the quality and relevance of the scientific output resulting from research projects supported by Australian Antarctic Science Grants (AASG);
- to evaluate the quality and relevance of the scientific output resulting from research projects ineligible for AASG funding; and
- to provide advice on areas of science that require either a greater or lesser emphasis and/or on new research endeavours to be undertaken.

The Steering Committee will meet in December 2002. It is due to finalise a report to ASAC by February 2003.

AAD e-Procurement Initiatives

In April 2000 the Commonwealth Electronic Procurement Strategy document set two goals for Commonwealth agencies:

1. to pay all suppliers electronically by the end of 2000; and
2. to be able to trade electronically with all simple procurement suppliers that wished to do so, using open standards, by the end of 2001.

The AAD has come as close as is practical to achieving the first goal of paying all suppliers electronically, given the large number of diverse suppliers servicing the AAD.

The Accounting Services group started payments by Electronic Funds Transfer (EFT) in July 1999. A simple strategy of producing and delivering a remittance advice with each payment, via post, fax or email was implemented and has been well received by both staff and suppliers.

Over 12,000 EFT payments have been made since the system went into production. In the 2001-2002 financial year over 83.5% of all payments to suppliers (92% by value) were paid by EFT. This is a very good result considering that the AAD deals with up to 1,000 suppliers per year. A rigorous routine of following up all cheque payments with requests for EFT bank details by the AAD's Accounting Services group has ensured that EFT payment levels have remained high.

The AAD has also made significant progress towards achieving the second goal of trading electronically with all simple procurement suppliers that wish to do so. The AAD is one of only two Commonwealth agencies that had made significant progress with e-Procurement.

The Finance & Supply group has been working on implementing e-Procurement since 1999. Trial projects have been run with two e-commerce service providers over two and a half years. In 2001 the AAD signed an agreement with Tasmania Business Online (TBO) as our e-commerce service provider. TBO is based in Tasmania and is aimed at developing trading communities within the state, especially amongst small to medium enterprises (SMEs).

Since July 2001 the AAD has been making steady progress with the first live orders going to a supplier via TBO in September 2001. About 130 purchase orders representing over 1400 order lines have been transmitted through TBO so far. There are now a dozen AAD suppliers enabled for e-Procurement through the TBO electronic market place. Two of those suppliers (for food and medical supplies) represent nearly thirty percent of all annual purchase order lines generated by the AAD. Both of those suppliers will be actively in use through TBO for the first time this Antarctic shipping season (September 2002 to March 2003).

The National Office for the Information Economy has recognised the AAD's lead in implementing e-Procurement and is working together with us on two proposals. One proposal is to address the barriers for SME suppliers to engage in e-Procurement. The other proposal is to scope and design a general e-commerce gateway to simplify suppliers communicating electronically with government that could have application amongst a wide range of Commonwealth agencies.

Improvements in the implementation of e-Procurement will be incremental and continuous. Internal processes have had to gradually change as the implementation has progressed over the last year. There is still a way to go with extending the e-Procurement system to the rest of the supply chain.

John Chrisoulakis, A/Finance & Supply Manager, AAD

New Kingston facilities nearing completion

Substantial progress has been made on a major building construction and refurbishment project which commenced in February at the AAD's Kingston headquarters. When completed, the $6.2 million project – with its upgraded laboratories, aquarium and new building to house office planning and research facilities – will greatly enhance Australia's Antarctic research capability.

On 23 August inspections were completed for the partial handover of the first floor of the refurbished building for occupancy by the Biology and Human Impacts Programs. The area was fully stripped and refurbished with new ceilings, energy efficient lighting, sunshades, relocatable partitioning, carpets, workstations, desks, storage cabinets and mechanical services. The inclusion of a skylight through the length of the building has achieved good natural light levels. Accommodation for around forty staff has been achieved.

Handover of the ground floor laboratories took place on 18 September. All facilities within the laboratories meet current standards and provide specialised work environments for the Australian Antarctic Division's research programs.

The newly constructed building, which links existing structures, has also proceeded ahead of schedule and the first floor has now been occupied by scientists of the Antarctic Marine Living Resources Program following inspections completed on 27 September. Accommodation for around forty-four personnel has been achieved. The same fitout criteria were used in this building, including a skylight. A much needed conference room is provided within the building along with tea making and recycling facilities.

The ground floor provides accommodation for the Space and Atmospheric Sciences Program, and houses a herbarium and state of the art aquarium.

Changes to AAD publications procedures

The Australian Antarctic Division publishes Reports, Research Notes and other selected publications both in print and electronically on our website at <http://www.aad.gov.au/science/publications>.

The AAD also maintains a searchable database of titles of Australian Antarctic publications or published articles – which covers over 10,600 recorded scientific papers. This database has recently been streamlined. While still maintaining the 14 programs within which each published article resides and the five categories under which each scientific publication is classified for measuring output, the database is now a one-point entry system.

A downloadable PDF available at <http://www.aad.gov.au/science/publications/download/pdfs/Entry_Form.pdf> is now to be used when submitting newly published articles for inclusion on the Australian Antarctic Division's publications database. Publications staff are happy to enter or edit your publication. Contact them at <publications@aad.gov.au> for assistance.

The AAD is no longer keeping excess reprints. Authors who would like surplus copies returned to them should contact Publications staff before 17 January 2003.

The surface of the ice sheet has ablated away while the rocks have protected the ice beneath from the sun's heat, thus forming these ice pillars. At the same time the ice is flowing so that the rock is transported away from where it was originally deposited. Rocks transported in this manner are called erratics.

FREEZEFRAME

The Silent Sentinels

The shot came to me during a field trip to Mt Rumdoodle. The sun was setting over the David Range and cast a wonderful light over these huge boulders precariously balanced on pedestals of ice on their laggard march to the coast. The composition fell into place, the scene begged for a half stop under at full depth of field on the Bronica 6x 4.5. An eight second exposure on Velvia 50 film captured the image I saw through the lens.

James Dragisic

James Dragisic is the Plant Inspector wintering at Mawson Station in 2002. His love of Antarctica is second only to his passion for photography. The highlight of his involvement as leader of three PCMEGA traverses this season (which are described on p37 in this issue of Australian Antarctic Magazine) will be the opportunity to capture the grandeur of the remote Prince Charles Mountains on film.