Annual Report

2006-2007

British Antarctic Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL

Above and cover: *Black-browed albatrosses nesting on Bird Island, South Georgia, are carefully monitored by British Antarctic Survey scientists.*

Our vision

British Antarctic Survey aspires to become, by 2012, the leading international centre for global science in the Antarctic context.

Our mission

To undertake a world-class programme of scientific research and to sustain for the UK an active and influential regional presence and a leadership role in Antarctic affairs.

Director's introduction

Five years ago we adopted the British Antarctic Survey (BAS) vision: 'To become by 2012 the leading international centre for global science in the Antarctic context'. We defined success as the impact of our contributions to global science, our effectiveness at working across disciplines, our ability to attract the best people, our care for the environment, and our recognition as an authoritative source of information and data by scientists and the public alike.

Prof Chris Rapley CBE
Director British Antarctic Survey
(Jan. 1998 to Aug. 2007)

Recent successes across the whole of BAS mean we are already well on our way to achieving that vision. Central to this are the excellent results of the second year of our core science programme 'Global Science in the Antarctic Context' (GSAC), which are set out in this report. They provide a glittering array of new insights across a vast domain of science. Here are some that I believe will be seen as especially important in years to come:

- the development of a unified theory of Southern Ocean ecology, demonstrating the dominant force of the Antarctic Circumpolar Current
- the discovery of deep subglacial trenches beneath the coastal East Antarctic Ice Sheet – which implies that huge regions of the ice sheet, thought until now to be stable, may not be
- new evidence of the link between rapid climate changes in the northern hemisphere and slow warming in the Antarctic preceding these changes
- the discovery of a hotspot of marine biodiversity in the Scotia Sea – which may be an evolutionary 'crucible' feeding life into the deep ocean
- the unexpected biodiversity of microscopic soil communities on exposed rocky areas in the deep Antarctic interior. This challenges our understanding of the colonisation of such remote spots and the received wisdom concerning past extremes of Antarctic glaciation.

I am pleased at the growing catalogue of results from the Natural Complexity Programme, including the apparent universality of the way in which materials fracture. The CACHE Programme (Climate and Chemistry: Forcings, Feedbacks and Phasings in the Earth System) is currently dating grains of desert sand drawn from the base of the ice core on Berkner Island. To know when the sand last saw daylight, before the Antarctic ice sheet extended over it and locked it away, will be thrilling and thought provoking!

An independent view of the GSAC programme has been provided by our Integrated Programme Review Committee (IPRC). This is chaired by Lord Oxburgh, and consists of distinguished scientists from the UK and overseas. After a rigorous three-day review at BAS in April 2007, the IPRC concluded the following:

It is no exaggeration to state that on becoming fully aware of the BAS programme for the first time, members were astonished at:

- the 'dazzling' breadth of BAS science
- the success in integrating diverse disciplines in interdisciplinary programmes
- the ability to mount timely and unique interdisciplinary programmes that conventional reviewing and funding procedures customarily find difficult to accommodate
- the world-class quality of all eight BAS research programmes and the long-term monitoring and survey work
- the essential, but rare, ability of BAS to avoid short-termism in its science.

BAS was seen as having an internal structure that allowed it to punch well above its weight internationally. This was attributed to the quality of its staff, their morale and their enthusiasm, and to the clear managerial encouragement to think widely and to think of 'Antarctic science in a global context'. BAS was regarded as having made interdisciplinarity a reality, to an extent that, as far as the Committee knew, was being achieved nowhere else in the world.

Images: Top Right: *HRH Princess Anne visited Rothera Research Station in January 2007.* **Centre Right:** *ITN news anchor Mark Austin and the ITN team successfully broadcast a series of live news programmes from Rothera Research Station.* **Bottom Right:** *Logo of the 29th Antarctic Treaty Consultative Meeting, held in Edinburgh in June 2006.*

Another major success this year was the pivotal role BAS played in supporting the Foreign and Commonwealth Office (FCO) in hosting the 29th Antarctic Treaty Consultative Meeting (ATCM), in Edinburgh in June 2006. In addition to our contributions on scientific and environmental issues to the business meetings, we gave key presentations addressing International Polar Year 2007-08 (IPY). We also organised the media coverage of the proceedings, and led a public outreach campaign – 'Discover Antarctica!' – consisting of 24 events over the two weeks of the ATCM, which were attended by 12,000 members of the public. This included 5,000 visitors to RRS *James Clark Ross* and the Royal Navy's ice patrol vessel HMS *Endurance*, both docked at Leith.

Operating in the Antarctic is a fickle business. This year we lost unexpectedly 25% of our flying season because of an aircraft regulatory issue. I record my thanks to the air unit staff and others involved in the onerous and frustrating task of resolving the matter. Our aircraft and their operation have been shown to meet the highest standards of safety and professionalism.

This year we received several awards, including:

- certification to ISO 14001 standard of our environmental management system, and our achievement of the ISO 18001 standard for occupational health and safety management
- Public Sector People Managers Association recruitment awards: 'Best Recruitment Advertisement in Sustainability/Regeneration/Environment' and 'Best Recruitment Advertisement in IT' (both for the GSAC recruitment campaign)
- a BAFTA nomination and an international Webby Award nomination for our 'Discovering Antarctica' educational website, developed with the Royal Geographical Society and FCO
- a CorpsComms Award with the FCO – 'Best Public Sector Corporate Communications' for 'Discover Antarctica!' at the ATCM
- Polar Medals were awarded to six BAS staff.

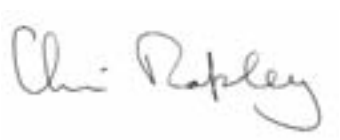
As a follow-up to her inauguration of the ATCM, HRH the Princess Royal visited Rothera Research Station in January 2007. During the two-day visit, she had an opportunity to see our science first-hand. I introduced the Princess to 100 science and support staff, as well as briefing her on the importance of Antarctica's role in global environmental issues such as climate change and ozone depletion. Shortly after, I hosted a visit to Rothera by the Right Honorable Malcolm Wicks, Minister of Science and Innovation.

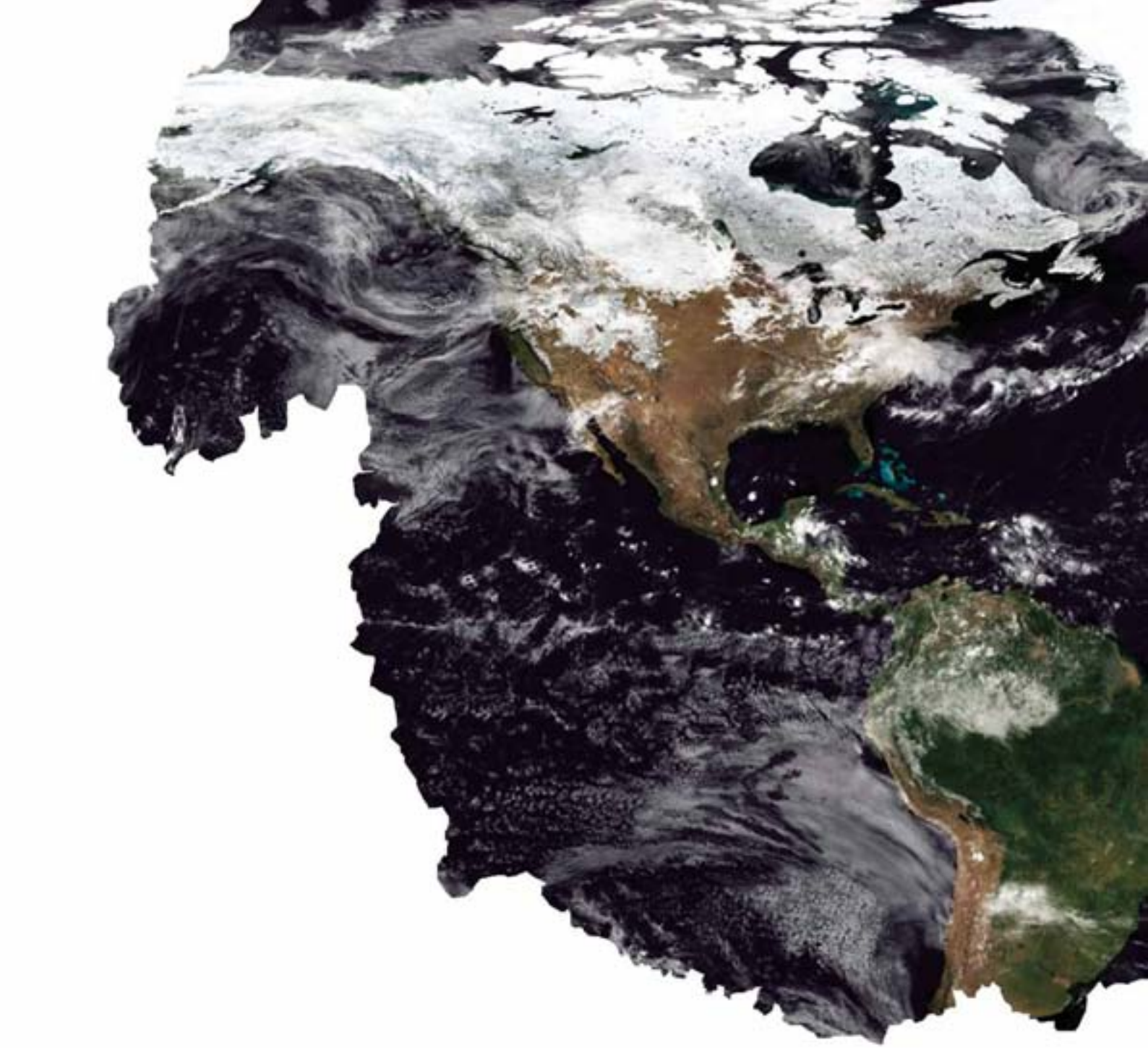
On 26 February 2007, Princess Anne also inaugurated the UK launch of International Polar Year 2007-08 at the Royal Society in London. A few days later I attended the international launch in Paris. IPY aims to transform our knowledge and understanding of the polar regions and the role they play in the state of the planet. The IPY International Programme Office is hosted by BAS. Scientists from BAS are involved in 50 IPY-endorsed projects, half of which are bi-polar, contributing to around 25% of the global programme. This contribution makes BAS by far the biggest UK player in IPY.

If you have a good story to tell you should use a megaphone, and BAS does. This year we organised a successful briefing day for key parliamentarians, presentations on climate change for senior industrialists, support for the Prince of Wales Business and Environment Group, and a three-day training event by Al Gore in Cambridge.

In addition, we achieved television history with the first-ever live broadcast from the Antarctic – by ITN's news anchor Mark Austin and science editor Lawrence McGinty from Rothera. A series of broadcasts included a live interview with Tony Blair in Number 10 Downing Street. The viewing figures were over eight million in the UK, and more than 200 million worldwide.

This was the busiest of my ten years as BAS Director. Now I move on to become Director of the Science Museum. It has been a privilege and honour to lead BAS, which is undoubtedly one of the gems of the UK. I will miss the people and the Antarctic. However, I am proud of what we have achieved together, and I wish Nick Owens, my successor, as much fun and satisfaction in his time as Director as I have had in mine.

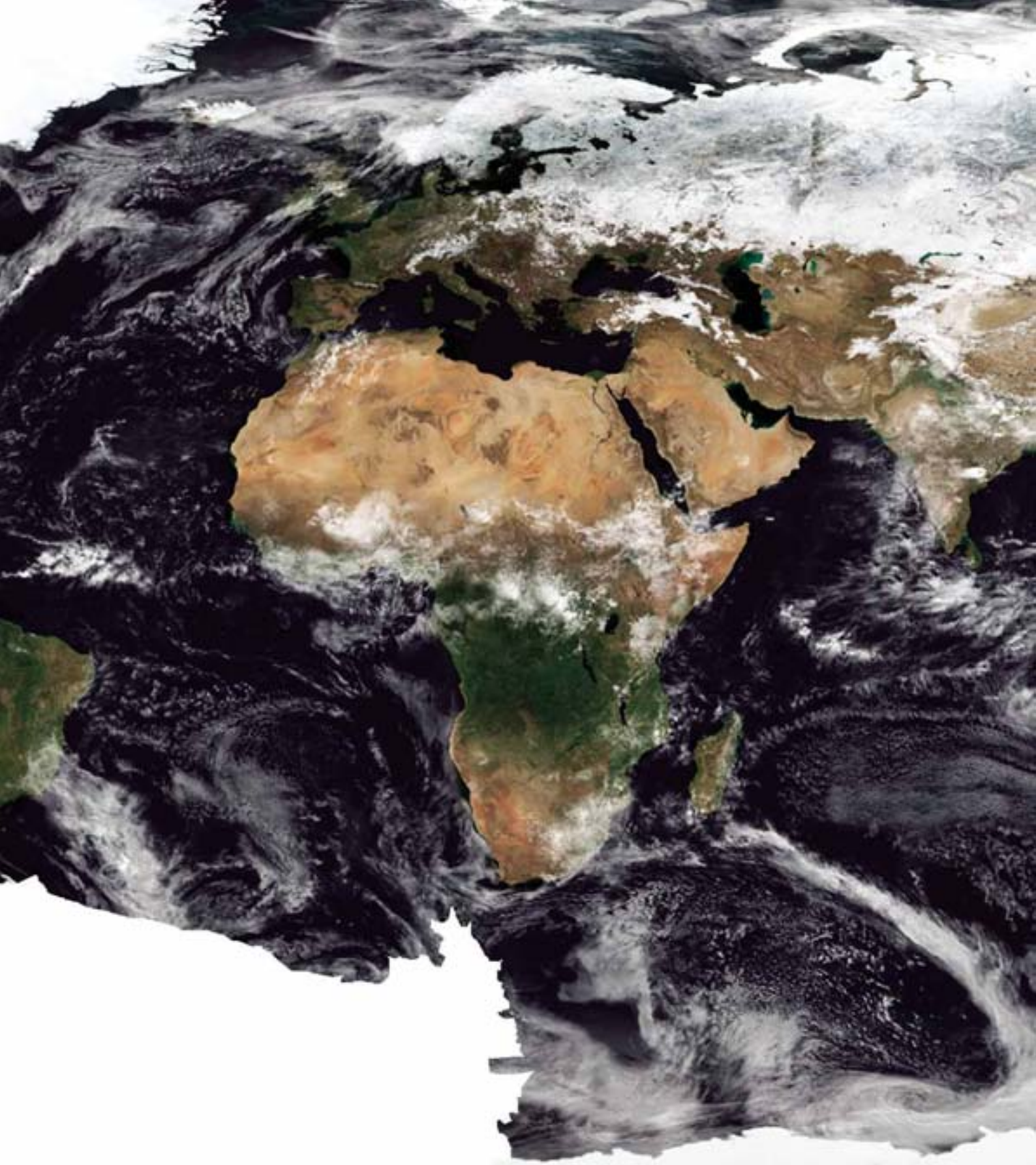




Global Science in the Antarctic Context

Global Science in the Antarctic Context (GSAC) comprises eight interconnected research programmes totalling 18 projects, plus long-term monitoring and survey. It addresses Antarctica as a pivotal component of the Earth system and a unique source of environmental knowledge. It covers the period from 30 million years in the past to 300 years in the future and focuses on issues of climate, sea level, and biological evolution and adaptation. GSAC aims to increase humanity's skill in predicting the future behaviour of the planet and the effects of environmental change for the benefit of society, policy-makers and business. GSAC involves over 120 national and international collaborations. BAS undertakes commissioned research on behalf of the Government of South Georgia and the South Sandwich Islands as well as receiving grants for complementary UK and European research projects.

Image: *A simulated view of the Earth based on the latest NASA Blue Marble dataset and composite cloud imagery from polar orbiting meteorological satellites.*



GRADES Glacial Retreat in Antarctica and Deglaciation of the Earth System

Principal Investigator: **Prof David Vaughan dgv@bas.ac.uk**

Introduction

The 2007 report from the Intergovernmental Panel on Climate Change identified changes in the flow of ice sheets as the greatest uncertainty in predicting global sea-level rise for the coming centuries.

GRADES will improve understanding of global deglaciation events and reduce uncertainty about sea-level rise by focusing several integrated research efforts on the most rapidly changing parts of the Antarctic ice sheet. This involves learning more about key processes promoting and limiting changes in ice flow, developing more accurate histories of past deglaciations, and creating realistic and reliable simulations of the ice-sheet response to changing environmental conditions.

Tidal influences on an Antarctic ice stream

Global Positioning Satellite (GPS) measurements reveal that ocean tides drive a fortnightly cycle in the flow of an Antarctic ice stream. The data show the unexpected result that Rutford Ice Stream varies its speed by as much as 20% as the ocean tide changes between springs and neaps. This is the first indication that the tidal range has a direct impact on ice-stream flow and has two important implications. First, to make a measurement of mean ice-stream flow that could be used to detect long-term change, the period of observation must correctly allow for the fortnightly cycle – measurements based solely on satellite images taken over a short interval would be prone to error.

Secondly, the fortnightly change in ice-stream speed indicates a non-linear relationship between the resistance to ice-flow and tidal height. A numerical model that describes this relationship has been developed and shown to reproduce the observations. This model will provide a basis for predicting the potential for ice streams to respond to future sea-level change.

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Technical terms: **Antarctic ice streams:** *Fast-flowing streams of ice that drain the Antarctic ice sheet.* **Drumlin:** *A streamlined mound formed by a moving glacier, with the 'tail' in the direction of ice-flow.* **Global deglaciation event:** *The widespread reduction of glacial ice as a result of climate change, sea-level rise and ice-sheet dynamics.* **Hydrological changes:** *Changes in the distribution and movement of water.* **Ice-penetrating radar:** *A system using radar pulses to detect layers and features within the ice.* **Non-linear relationship:** *Where two aspects of a system are related in such a way that a minor change in one produces a more significant change in the other.* **Seismic observations:** *A method of determining the geological structure beneath the ice using sound waves generated by explosives.* **Spring and neap tides:** *Spring tides are the large tides that occur around new and full moon. Neap tides are the smallest tides, which occur between spring tides.*

Images: **Above:** *Retrieving GPS data from a transmitter on the Rutford Ice Stream, Antarctica.* **Top Right:** *Velocity changes were measured in over 300 Antarctic Peninsula glaciers.* **Centre Right:** *Radar data shows the shape of the bed underneath the ice sheet and the clear development of the drumlin feature between 1997 and 2004.* **Far Right:** *Radar data shows the many internal layers within the ice sheet and how they interact with subglacial features.*

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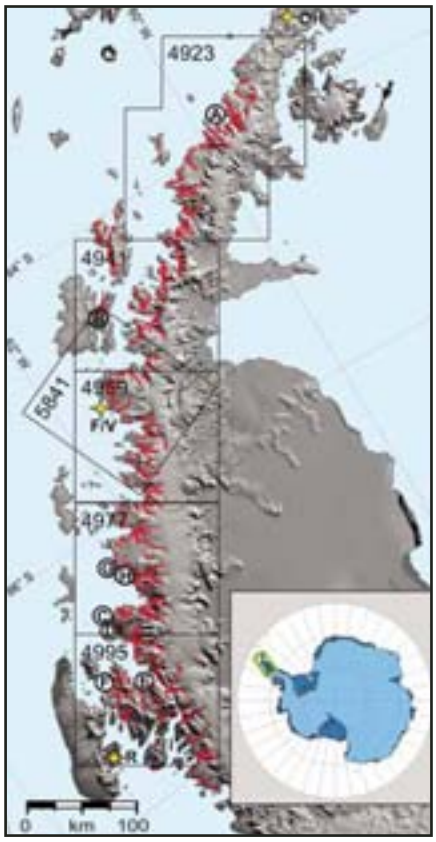

Acceleration of Antarctic Peninsula glaciers

The northern Antarctic Peninsula is unlike the rest of the Antarctic continent – it is warmer, has high rates of snowfall, is drained by hundreds of glaciers, and has been subject to rapid rates of atmospheric warming (around 3°C in the last 50 years). Compared with the rest of the Antarctic ice sheet, the Antarctic Peninsula could make a contribution to sea-level rise out of proportion to its size. However, until now, quantifying this contribution has remained a matter of speculation. By tracking glacial features in 75 pairs of satellite images, we measured the change in speed in over 300 glaciers. The results reveal the effect of climate warming – a 12% increase in glacier speed from 1993 to 2003.

The study allows the first assessment of how much the northern Antarctic Peninsula contributes to a rise in sea level (0.16 ± 0.06mm per year in 2000), which is similar to that of glaciers in Alaska, where the climate is also warming rapidly. The study also addresses the debate about how sub-polar glacier systems respond to climate change. Many Greenland glaciers have been shortening and accelerating in recent years, but it is not known whether the shortening or the acceleration comes first. By correlating the changes in glacier speed on the Antarctic Peninsula with changes in atmospheric temperature and glacier terminus position, we have shown that the shortening and steepening of glaciers is the primary cause of acceleration. This should improve predictions in many polar and sub-polar systems, such as Alaska, Svalbard and Greenland.

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Drumlin formation beneath an ice stream

Subglacial processes significantly influence ice-stream flow, but direct observations from beneath glaciers are rare and these processes are normally inferred from landforms left behind after the ice has retreated. Repeated seismic observations on Rutford Ice Stream have shown more clearly what is happening beneath a contemporary glacier. We have observed much faster erosion than was expected (around 1m per year) followed by formation of a drumlin from mobilised sediment.

We also observed hydrological changes within the glacier bed. All these changes occurred over periods of only a few years. This variability suggests that an ice stream can reorganise its bed rapidly, which present models of ice dynamics cannot simulate. The work also suggests that the features that remain after deglaciation represent only a snapshot of the glacial conditions immediately before the loss of the ice.

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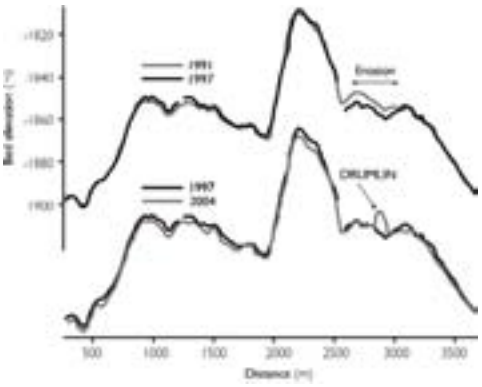

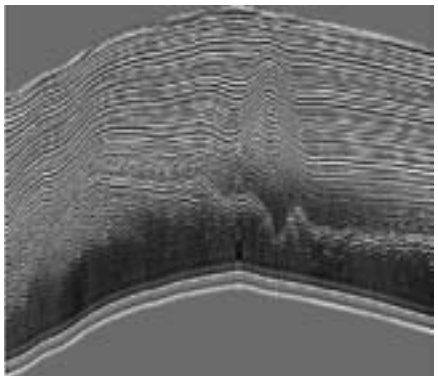

Internal architecture of ice sheets

Internal layers within ice sheets, which can be detected using ice-penetrating radar, are an under-used archive of information on current and past ice-flow. To use this information more widely, we need a better understanding of the relationship between radar-detected layers and ice-flow. Two recent studies that systematically examine this relationship show predictable correlations between the internal layers and features beneath the ice.

In particular, we have investigated where radar layers should drape around subglacial hills, and where they should override them. The studies also show that, for interpreting radar layers, some simple high-order evaluations can adequately predict layer architecture, and we do not always need a more detailed analysis.

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CACHE Climate and Chemistry: Forcings, Feedbacks and Phasings in the Earth System

Principal Investigator: **Dr Eric Wolff** ewwo@bas.ac.uk

Introduction

CACHE uses ice cores, with marine and lake sediment records collected in Antarctica, to examine past climates. These reveal complex interactions between different parts of the Earth system, and very large natural swings in global climate.

Present-day atmospheric chemistry and models help us interpret past data, so that we can understand how climate and atmospheric composition were linked in the past, and suggest how they may interact in the future.

Coupling of Antarctic and Greenland climate changes during the last glacial period

A major international ice-core collaboration has shown that climate variability during the last glacial period involved links between Antarctica and the North Atlantic. The most important climate changes during this period (~110,000 to 11,000 years ago) are the so-called Dansgaard-Oeschger (D-O) events, seen most clearly in Greenland ice cores as rapid warmings of 10°C or more, and occurring at millennial-scale intervals. It was already known that the longest of these events were preceded by slow warmings in Antarctica. This was consistent with the idea that changes in the oceans would alter the distribution of heat between the North Atlantic and the Southern Ocean. Using a new high-resolution ice core drilled in Dronning Maud Land in Antarctica, scientists from the European Project for Ice Coring in Antarctica (including several from BAS) have shown that every D-O event has an Antarctic counterpart, although the relative timing is difficult to pin down. This adds weight to the idea that changes in global ocean circulation played a major role in the climate dynamics of cold periods.

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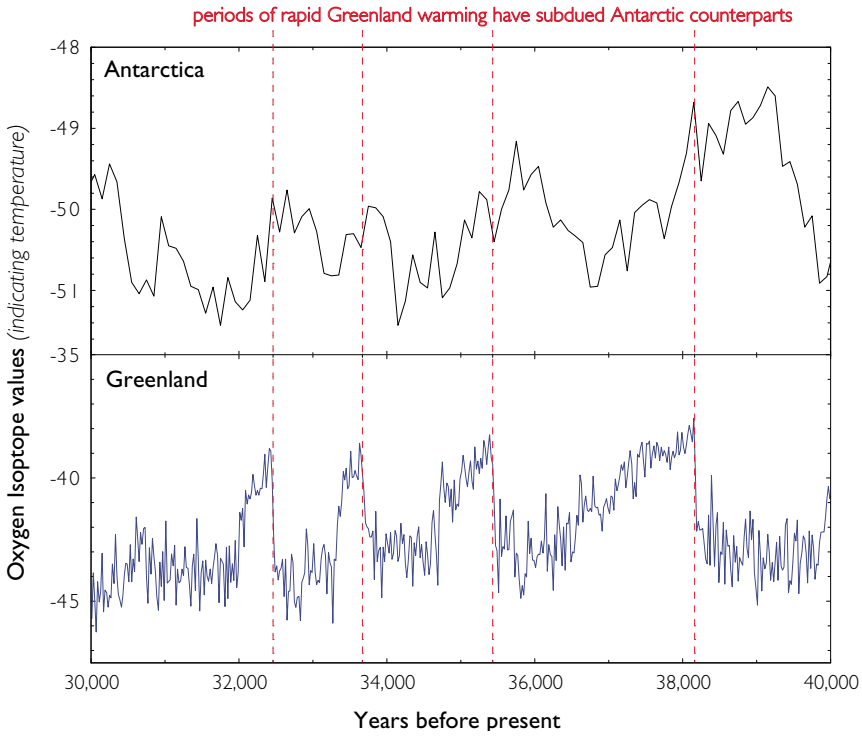

Technical terms: **Boundary layer:** *The lowest layer of the atmosphere, below 1km, where wind is influenced by the Earth's surface and objects on it.* **Holocene:** *A geologic epoch extending from the present back approximately 10,000 years.* **Hydrological information:** *Data referring to the movement and distribution of water.* **Macrofossils:** *Fossils that are large enough to be seen with the naked eye.* **Proxy:** *A variable from which data about another variable can be inferred.* **Radiocarbon dating:** *An absolute dating method based on the radioactive decay of Carbon-14 contained in organic materials.* **Sublimation:** *Ice or snow changing directly into water vapour without melting.* **Tropospheric chemistry:** *The chemistry of the troposphere, the lowest layer of the atmosphere, where most weather occurs, from the surface to approximately 10km altitude.*

Images: **Above:** *Oxygen isotope values (representing temperature) for Antarctic and Greenland ice cores show that each rapid warming in Greenland has a less pronounced Antarctic counterpart.* **Top Right:** *The relationship between methanesulphonic acid (MSA), recorded in coastal ice cores, and winter sea-ice extent around Antarctica.* **Centre Right:** *An overview of the Halley V site on the Brunt Ice Shelf shows the Clean Air Sector Laboratory sited 1km away from the main station.* **Far Right:** *Forlidas Pond in the Pensacola Mountains, Antarctica. Former water levels can be seen in the darker snow-free area of the valley floor.*

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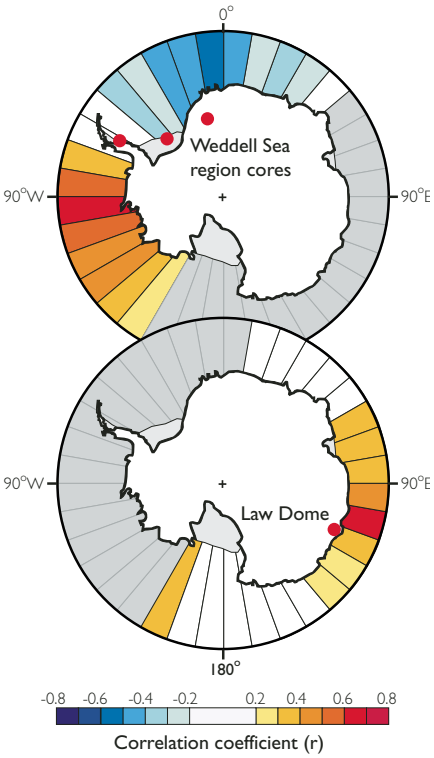

Ice core proxies for past sea-ice conditions

Ice core records from the Weddell Sea region of Antarctica have shown that methanesulphonic acid (MSA) is not always a reliable proxy for reconstructing past sea-ice conditions. MSA originally derives from biological activity at the sea-ice margin. In the western Pacific region of Antarctica, years with more extensive sea ice show increased MSA in nearby ice cores. An ice core record from Law Dome in Antarctica has been used to infer a 20% decrease in Antarctic sea ice since 1950.

However, in the Weddell Sea region, MSA displays an inverse relationship with sea-ice conditions – less MSA means more sea ice. This is due to unusual conditions where cold air flows offshore across the Weddell Sea, which increases sea ice while also carrying less MSA to the nearby ice core sites. The potential for ice core records from different regions to reflect sea-ice conditions or atmospheric transport strength (or some combination of both) means that further development of the MSA proxy for sea ice will depend on similar detailed studies at other sites around the Antarctic coast.

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Nitrogen oxides and the link with ice core data

Atmospheric measurements made in the Clean Air Sector Laboratory at Halley Research Station open up the possibility of using ice cores to reconstruct the chemistry of the past Antarctic lower atmosphere. Nitrogen oxides (NO_x) play a key role in tropospheric chemistry, but there have been no comprehensive studies of their sources, concentrations and associated chemistry at high latitudes. At Halley we measured a wide range of oxidised nitrogen gases through a six-month period. Data show a strong correlation between nitrate measured in surface snow and the inorganic nitrogen compounds in the atmosphere, while organic nitrogen shows a different seasonal trend. However, our data tell us that emissions from the snowpack are the most important source for NO_x in the air, suggesting that we can determine sources of Antarctic boundary layer NO_x for certain times in the past using ice-core nitrate data.

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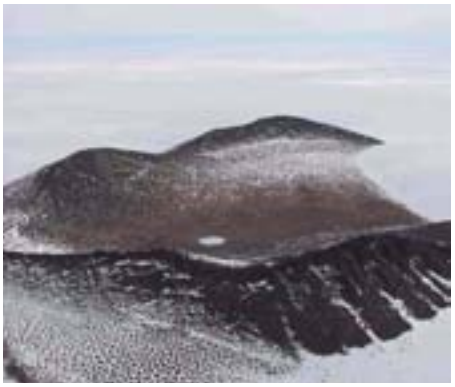

Increased warmth in inland Antarctica

New evidence from lakes provides the first evidence from the interior of Antarctica for a period of increased warmth about 4,000 to 2,000 years ago. Changes in the hydrological cycle can be tracked by studying past lake shorelines. In closed-basin lakes, water levels are the result of the balance between snowfall and the evaporation and sublimation of water, snow and ice from lakes and their catchments. With accurate dating, past water levels can provide important information on climate changes, from local to regional scales, in more detail than may appear in ice cores.

We surveyed and dated the former shorelines of two remote lakes in the Pensacola and Shackleton Mountains. These are among the most southerly lakes in the Antarctic and are from an area where, until now, we have had little information on climate and hydrology. Radiocarbon dating of 33 lake-derived macrofossils showed that a sustained period of higher water levels, 18m and 16m above the present level, occurred between 4,250 and 2,200 years ago. This is the first evidence that the well-documented Holocene warm period, measured in lake and marine sediments around the coast of Antarctica, extended into the interior of the continent, and will help us predict better the nature and extent of future climate change in Antarctica.

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COMPLEXITY Natural Complexity Programme

Principal Investigator: **Dr Mervyn Freeman mpf@bas.ac.uk**

Introduction

Nature exhibits many varied structures, which go to make up its beauty, but are these structures complicated or complex?

The distinction lies in whether the structures are specific to the details of the system in which they arise, or whether they are generic properties of a system with many interacting parts in which the interactions are more important than the details of these parts.

The Natural Complexity programme has been exploring these distinctions – identifying the generic complex behaviours of the fracturing of rocks and of turbulence in the upper atmosphere, but also revealing that the seemingly complex behaviour of animal foraging may be complicated but relatively mundane.

What we didn't know about the birds and the bees… and the deer

How animals search for food is of great practical ecological importance. It is also part of a much wider problem of how best to find things. One possible search strategy is the Lévy flight, which is a random journey whose stages have no typical size. Eleven years ago, a study concluded that wandering albatrosses perform Lévy flights when searching for prey on the ocean surface. This widely reported finding was followed by similar ones concerning deer, bumblebees, reindeer, microzooplankton, grey seals, spider monkeys and fishing boats. Scientists at BAS, in Brazil and in the USA re-visited this problem using new, high-resolution data on the movements of wandering albatrosses.

We found no evidence for Lévy flight behaviour. Closer examination revealed that, in the original study, the lengthy stages that had been thought to indicate Lévy flight behaviour actually included time that the birds spent on their nests rather than out searching. Using a new method, no evidence of Lévy flights was found in the deer and bumblebee data either. The results question whether the Lévy flight paradigm is a suitable model of ecological search behaviour.

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Technical terms: Ionosphere: *The region of Earth's atmosphere that extends from about 80 to 500km above the surface and is made up of multiple layers containing electrically charged particles.*
Microzooplankton: *Tiny animals (20-200 microns across) carried with the motion of the currents.* **Paradigm:** *A model used to explain a concept or theory.*

Images: Above: *BAS scientists study the foraging patterns of the wandering albatross.* **Top Right:** *The SuperDARN radar monitors the dynamics of the ionosphere from Halley Research Station, Brunt Ice Shelf.*
Bottom Right: *Studies of how rocks fracture may help predict how areas of rock will respond to future earthquakes.*

Smile please!

Turbulence is a ubiquitous process in nature known since the time of Leonardo da Vinci, but is still difficult to measure and study, with some aspects remaining as enigmatic as Mona Lisa's smile. However, turbulence is universal as well as ubiquitous, in that many of its properties appear similar whether in the atmosphere, ocean, or space. Advances in understanding turbulence in one area may thus spur developments in another. Recently, BAS scientists have led the first attempts to analyse the spatial structure of turbulence in the upper reaches of the Earth's atmosphere, using radar at Halley Research Station to remotely sense the motion of the atmosphere 300km up, in a region known as the ionosphere.

Besides identifying the likely physical model of turbulence in this region, we also found that the spatial structure of upper atmospheric motion was different in polar regions compared to lower latitudes. This is probably because the polar regions acquire their turbulence more directly from the Sun. The results have generic interest in showing that the nature of turbulence is altered as energy flows through different linked regions of the Sun-Earth system. They also have practical application in numerical models of the upper atmosphere to improve their description of atmospheric heating.

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Rocking all over the world

How materials fracture is of enormous technological interest because of its economic and human cost. Despite a large amount of experimental data, many questions about fracture have not yet been answered. A BAS scientist and colleagues in Germany found that the statistics of waiting times between fractures in a wide range of rock systems are remarkably universal. The study involved a detailed statistical analysis of laboratory rock fracture, obtained from different experiments on different materials. In all considered cases, the waiting times between fractures could be described by the same mathematical formula. This formula is identical to that for earthquakes so may apply generally to all fracture processes, whatever the material and size of the system.

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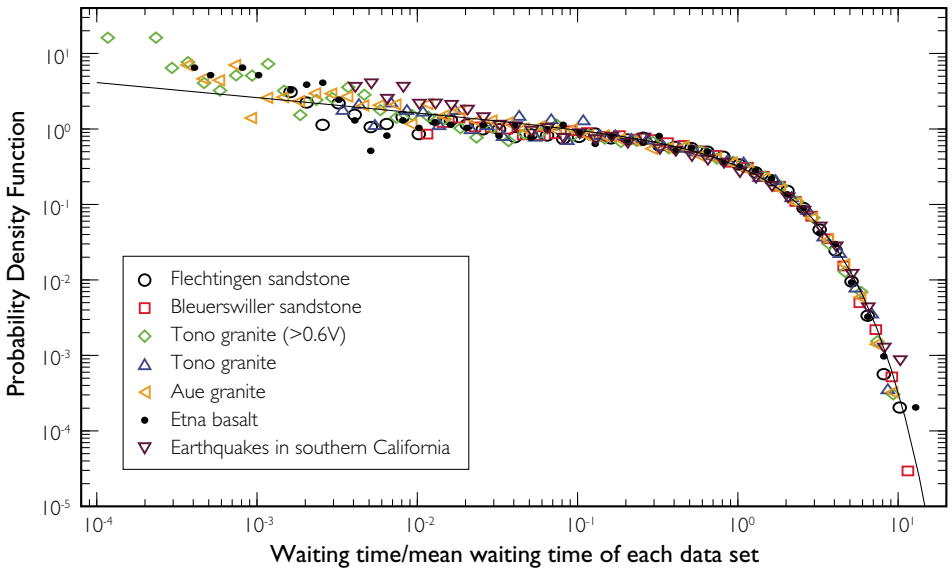

ACES Antarctic Climate and the Earth System

Principal Investigator: **Dr John King** jcki@bas.ac.uk

Introduction

Predicting how the Earth's climate may vary in response to natural or man-made changes is one of today's greatest scientific challenges. It requires an understanding of the workings of the climate system, both in its components and in the ways that these interact.

ACES integrates studies of the Antarctic atmosphere, ocean and sea ice to provide a new perspective on the Antarctic climate system and its coupling to the global atmosphere and ocean. By quantifying the role of polar processes in controlling global climate, the programme helps reduce uncertainty in predictions of climate change.

The response of ice-shelf basal melting to variation in ocean temperature

We have studied the response of ice shelves to a series of ocean-warming scenarios using a three-dimensional ocean General Circulation Model. The model predicts that melting at the base of the ice shelf increases quadratically as the offshore ocean warms. This occurs because the melt rate is proportional to ocean flow speed multiplied by the temperature in the water directly beneath the ice shelf, and both of these factors are found to increase proportionally with ocean warming.

The results of this study confirm and unify several previous examinations of the relationship between melt rate and ocean temperature. The hypothesised warming does not depend on additional heat input to the ocean, as warmer waters (or larger volumes of warm water) may reach ice shelves purely through a shift in ocean circulation. Since ice shelves link the Antarctic ice sheet to the climate of the Southern Ocean, this finding is important to our understanding of ice-sheet evolution and sea-level rise.

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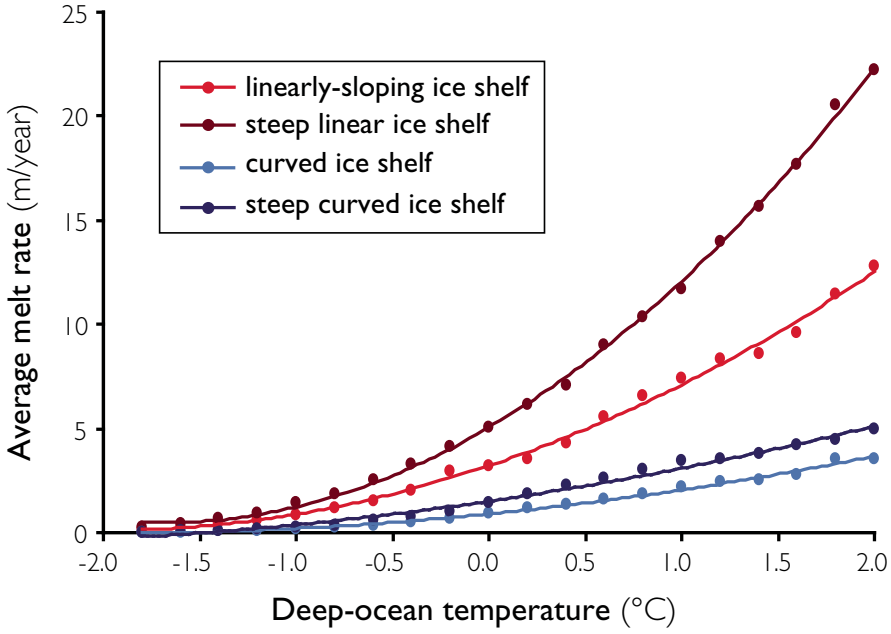

Technical terms: **Antarctic Bottom Water:** *A cold, dense water mass formed at locations around Antarctica occupying a depth range below 4,000m.* **Basal melt:** *Melting at the bottom of an ice shelf, ice sheet or glacier.* **Boundary layer:** *The lowest layer of the atmosphere, below 1km, where wind is influenced by the Earth's surface and objects on it.* **Coupled climate model:** *A model of the interactions between the atmosphere and other environmental factors that affect it, such as the oceans.* **Global thermohaline circulation:** *The global, density-driven circulation of the oceans.* **High-latitude overturning circulation:** *The high-latitude part of the global density-driven circulation of the oceans.* **Ice-sheet mass balance:** *The relationship between accumulation (snowfall) and melting/sublimation of the ice sheet, determining the rate of growth or decay of the ice sheet.* **Quadratic increase:** *An increase to the power of two.*

Images: **Above:** *Model predictions of ice-shelf basal melt rate as a function of ocean temperature.* **Top Right:** *Near-surface currents as predicted in the HadCM3 climate model and the more complex reality of recorded observations.* **Centre Right:** *Instruments for measuring turbulence and atmospheric boundary layer structure at Halley Research Station, Brunt Ice Shelf, Antarctica.* **Bottom Right:** *Predictions of surface temperature change in the Antarctic from the present day to 2100.*

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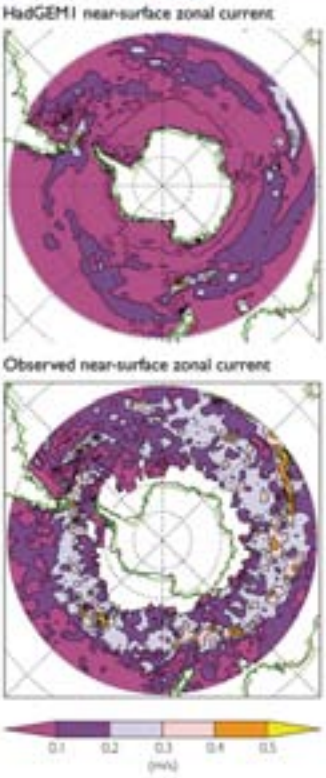

Simulating Southern Ocean circulation

The oceans of the southern hemisphere play a crucial role in the global climate system. The scarcity of oceanographic data from the southern hemisphere has prevented detailed, systematic assessment of the behaviour of the ocean component in coupled climate models. We used the best available ocean velocity data to measure the ocean currents and assess the role of ocean circulation in determining ocean temperature and salinity in two Hadley Centre climate models: HadCM3 and its higher resolution successor HadGEM1.

HadCM3 has a large proportion of fresh water at the surface as a result of a weak high-latitude overturning circulation and excessive rainfall. HadGEM1 has higher surface salinity since the high-latitude overturning and tropical upwelling of sea water are stronger. This overly strong upwelling brings large areas of cold water to the surface. These results show the difficulty of simulating the complex balance between ocean temperature, salinity, and circulation. However, we need to correctly simulate these factors if we are to understand recent and future climate variability.

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Sensitivity of modelled climate to the representation of stable boundary layers

Stable boundary layers (SBLs) occur in many parts of the climate system but are particularly common in the polar regions. The transport of heat and momentum through such layers have to be accurately represented in large-scale models. BAS observations have demonstrated weaknesses in the way SBLs are currently represented in climate models. We have carried out experiments with a global climate model to assess how misrepresenting SBL processes could lead to uncertainties in modelled climate.

The results of these experiments show that modelled surface conditions over Antarctica are very sensitive to changes in the way SBLs are represented. However, the largest impacts on broad-scale atmospheric circulation are not seen in the polar regions but over the northern hemisphere oceans in summer. These changes appear to be associated with persistent SBLs that form over the western margins of the oceans as warm, continental air moves out over a cooler ocean. Our results confirm the need to represent SBLs more accurately in climate models and highlight the importance of maritime SBLs in the climate system.

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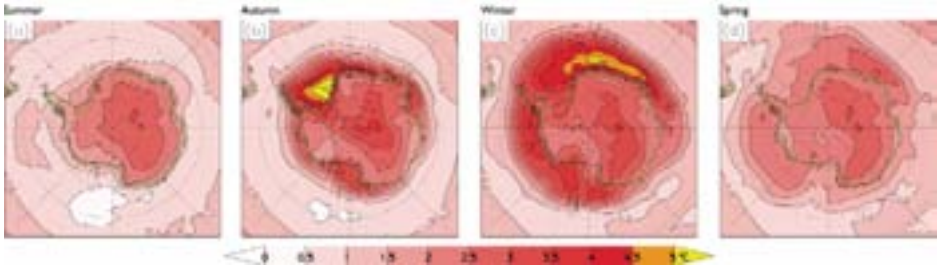

Improved projections of Antarctic climate change over the 21st century

Antarctica is important to assessments of future climate change and their global impacts since it is a key regulator of factors such as ice-sheet mass balance, sea level and ocean circulation. We have improved projections of Antarctic climate change by weighting the output from climate models based on their ability to reproduce the climate of the late 20th century.

We have used output from coupled ocean-atmosphere models submitted to the Intergovernmental Panel on Climate Change in considering the projections that showed a doubling of CO_2 by 2100. Over the 21st century, projections show a widespread surface warming across high southern latitudes, with peaks on the Antarctic plateau and in the sea-ice zone during winter of 0.3-0.5°C per decade. The weighting gives a temperature increase that is 20% larger than the unweighted trend in the sea-ice zone. The warming over the Southern Ocean will result in a loss of about 33% of the sea-ice area by 2100, potentially affecting the production of Antarctic Bottom Water, and the global thermohaline circulation.

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DISCOVERY 2010 Integrating Southern Ocean Ecosystems into the Earth System

Principal Investigator: **Prof Eugene Murphy** ejmu@bas.ac.uk

Introduction

The Southern Ocean is home to large and diverse ecological communities that have been subject to exploitation over the last two centuries, the consequences of which are still ongoing. These activities are not the only threat to Southern Ocean wildlife. Antarctica is experiencing climate change, as evidenced by rising air temperatures and melting ice shelves.

The challenge for environmental scientists is to predict how climate changes and fishing will affect Antarctica's unique species and ecosystems. To address this, DISCOVERY 2010 is doing research to build computer models that can simulate biological and physical processes on a range of scales, from the local to the entire ocean.

The programme has already generated major new insights into the operation of large-scale ecosystems that are directly relevant to understanding the response of the Earth System to climate change. This programme will also underpin the management of Southern Ocean fisheries for long-term sustainability and protection of the region's wildlife.

Towards a unified theory of Southern Ocean ecology

The Scotia Sea, home to half the world's population of Antarctic krill, contains the richest and most productive biological communities in the Southern Ocean. After more than two decades of detailed study of the component parts, BAS scientists have brought together all this information to provide fundamental new insights into how this whole system works. The Antarctic Circumpolar Current is the dominant force, as it mixes the nutrients that fertilise the huge algal blooms during summer and moves zooplankton to areas where they are consumed by vast numbers of predators such as penguins and seals.

This current also plays a key role in transporting the climate oscillations of El Niño from the Pacific, producing warm or cold periods lasting two or three years that have profound effects on ecosystems. In the Scotia Sea, for example, these climate processes affect the dynamics of krill populations, which are a key species in the food web. Some krill-dependent predators adapt by switching to alternatives, such as squid and fish, during years when few krill are available. A rapidly changing climate and the historical harvesting of seals, whales, fish and krill are combining to place critical stresses on the balance of the system. As the climate-driven physical change continues, our analyses indicate that we can expect rapid shifts in entire biological communities that will fundamentally change the way the whole marine ecosystem works.

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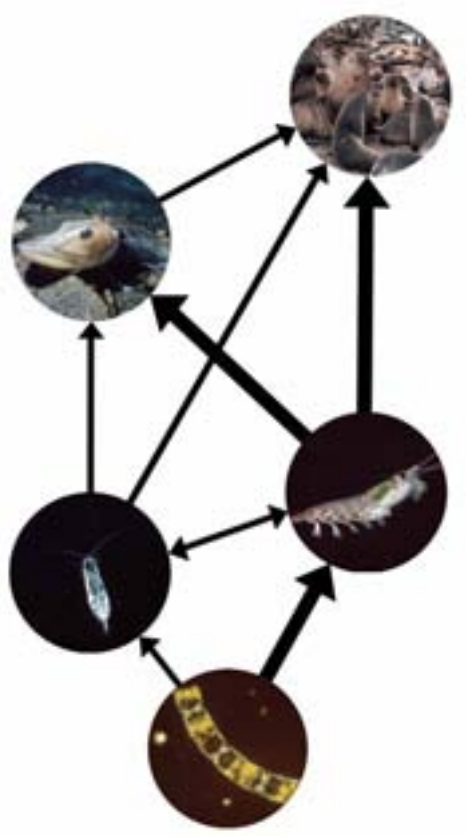

Technical terms: El Niño Southern Oscillation (ENSO): *A global phenomenon linking the oceans and atmosphere. It was first identified as cyclic warming and cooling of the eastern and central Pacific over periods of 4-12 years, associated with changes in marine biomass.* **Krill:** *Shrimp-like crustaceans that form a key part of the Antarctic food web.* **Microbial organisms:** *Microscopic life-forms.* **Moults:** *In the case of krill, exoskeletons that are shed to allow body growth.*

Images: Above: *A foodweb diagram highlights how changes in key species populations can affect the entire system.* **Top Right:** *Green-coloured algae, the primary food source of krill during the Antarctic spring, can be seen here in the stomach of a male krill.* **Centre Right:** *Charts showing increasing intensity of eddy activity in the Southern Ocean from 1993 to 2004.* **Bottom Right:** A grey-headed albatross flying out to sea after feeding its chick.

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How krill meet their energy challenge

The Southern Ocean is a 'boom and bust' environment for many predators, where short periods of extreme food supply are followed by many months of hardly anything at all. Despite this particularly harsh regime, Antarctic krill prosper in large numbers. We examined their feeding habits to reveal the key to their success. By gathering in large, mobile swarms, krill can scan sizeable areas of the ocean at a time to find their preferred food – algae – that occur in extensive blooms during the Antarctic spring. When krill encounter algal blooms they efficiently consume them.

During the 'bust' periods, when algal concentrations are low, krill exploit alternative food sources such as microbial organisms, material from the sea floor and even their own moults. This diet may mean rather lean pickings, but we calculated that it could easily sustain krill through the harsh times and provide them with enough energy to fuel egg production in early spring. These strategies ensure that the next generation of krill can take advantage of the ensuing spring bloom and so survive another cycle in the Southern Ocean.

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Strengthening winds make Southern Ocean eddies more vigorous

The Antarctic Circumpolar Current is the world's largest current system, and flows uninterrupted around the Southern Ocean, encircling the Antarctic continent. The strong westerly winds that blow over the Southern Ocean are known to be important in driving this current. It is also known that these winds have been dramatically increasing in strength during recent decades. However, there has been much uncertainty about whether the Antarctic Circumpolar Current will speed up in response to the stronger winds.

Our findings, based on satellite measurements of the ocean surface and high-resolution computer modelling, indicate that the Antarctic Circumpolar Current shows only a small acceleration in stronger winds, but shows a large increase in ocean eddy activity. These eddies are the ocean equivalent of atmospheric weather systems, and in the Southern Ocean they play a key role in moving heat southward toward the Antarctic continent. The Southern Ocean is known to be warming at a rapid rate, and our findings suggest that the role of these ocean eddies is important in explaining this.

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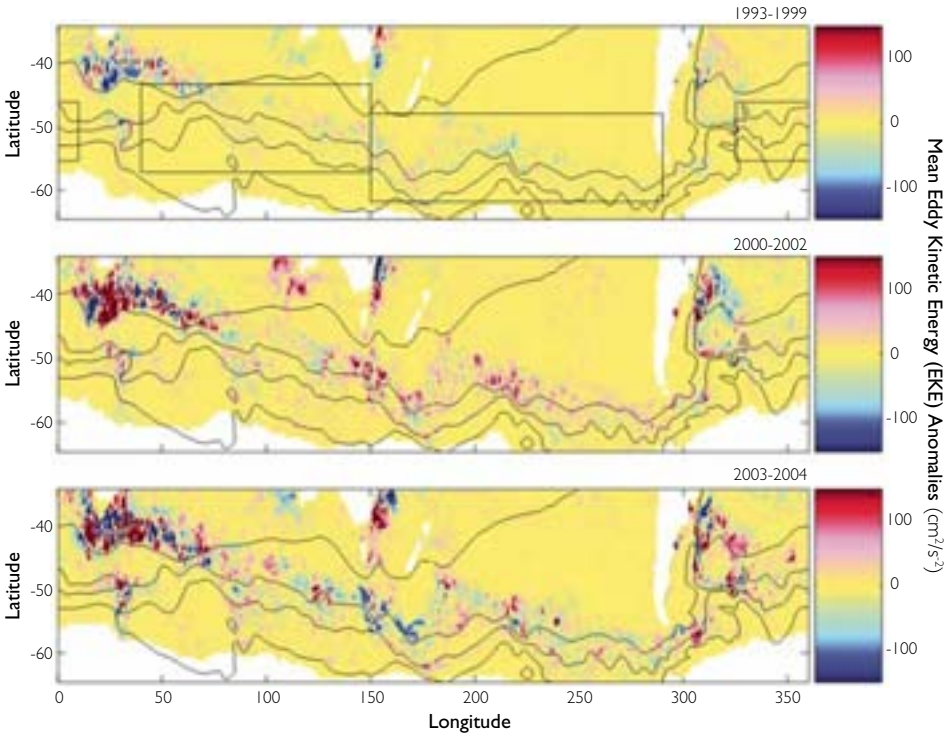

Albatross foraging performance declines in old age

In a competitive environment, experience counts for a lot, but there comes a point when it is no longer enough. As a body ages beyond a certain point, old age takes hold and performance starts to decline. Albatrosses, it seems, go through a similar story. Grey-headed albatrosses are one of the longest-lived bird species, with a potential lifespan of over 40 years.

Their performance on foraging trips was found to peak in their late twenties, when the birds were at mid age and had sufficient foraging experience. Beyond the age of 35, however, they spent a lot longer searching and were less successful at finding food. Although similar effects have been noticed in many other species, most are the result of individuals being terminally ill, which becomes increasingly common with age. This was not the case here and is the first time that general physical deterioration in long-lived birds has been shown to occur well before their final demise.

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SEC Sun-Earth Connections

Principal Investigator: **Dr Richard Horne rh@bas.ac.uk**

Introduction

Solar eruptions are a source of high-energy radiation that damages satellites and spacecraft, disrupts communications, navigation and power supplies, and increases radiation doses to aircraft passengers and astronauts.

This radiation also affects the composition and dynamics of the atmosphere and may affect the Earth's climate system. SEC studies how Earth's atmosphere responds to solar variation so that we can assess the hazards and mitigate their effects, and distinguish between natural and human contributions to climate change. To achieve this, SEC combines observations and models to investigate the way that solar energy is linked vertically by dynamics and chemistry through the atmosphere from space to the ground.

Changes in stratospheric chemistry linked to auroral dynamics

Nitrogen oxides (NO_X) cool the upper atmosphere and help destroy ozone. During the northern hemisphere winter of 2003-04, satellites observed significant levels at about 40km that appeared to be gradually descending from about 60km. The origin of the NO_X was unclear, either being produced at ~60km by very energetic particle precipitation, or produced at much higher altitudes ~120km by softer particle precipitation in the auroral zone, and then descending to lower altitudes.

Working closely with collaborators from New Zealand and Finland, we used AARDDVARK data from the NERC base at Ny Ålesund, Svalbard, to show that the NO_X was more consistent with being produced at high altitudes by auroral precipitation. We found that the key factor controlling the amount of NO_X at 40km was not the amount of auroral precipitation itself, but the presence of a strong polar vortex, which enabled the NO_X to descend more effectively. This shows that there is a strong link between auroral dynamics, the polar vortex and the chemistry of the stratosphere, which can translate the effects of solar activity into the lower atmosphere.

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Technical terms: **AARDDVARK:** *Antarctic-Arctic Radiation-belt (Dynamic) Deposition – VLF Atmospheric Research Konsortia.* **Atmospheric gravity waves:** *Buoyancy waves created by the action of gravity on density variations in the atmosphere.* **Auroral zone:** *The region around the poles in which there is auroral activity.* **Electromagnetic waves:** *A propagating wave in space with electric and magnetic components.* **Geomagnetic activity:** *Changes in the Earth's magnetic field.* **Ionosphere:** *The region of Earth's atmosphere that extends from about 80 to 500km above the surface and is made up of multiple layers of electrically charged particles.* **Mesosphere:** *The layer of the atmosphere above the stratosphere, at 50-95km altitude.* **Particle precipitation:** *The deposition of charged particles from the Earth's radiation belts into the atmosphere, usually as a result of heightened solar activity.* **Polar vortex:** *A persistent, large-scale, circumpolar wind circulation around Antarctica, which is most pronounced in winter.* **Solar irradiance:** *The amount of solar radiation reaching Earth.* **Solar wind:** *The outward flow of electrically charged particles from the Sun.* **Stratosphere:** *The layer of the atmosphere ranging, in polar regions, from approximately 10km up to 50km, where temperature increases with height. The ozone layer is situated in the stratosphere.* **Troposphere:** *The lowest layer of the atmosphere, where most clouds are located and where most weather occurs. In the polar regions, it typically extends to about 8km above the surface.* **Van Allen radiation belts:** *A doughnut-shaped region around the Earth in which electrically charged particles are trapped by the planet's magnetic field.*

Images: **Above:** *Aurora, caused by energetic charged particles in the upper atmosphere, above Halley Research Station, Brunt Ice Shelf.* **Top Right:** *Comparison between variation in solar output and Earth's mid-latitude tropospheric temperature response.* **Centre Right:** *The upper panel shows flux of radiation belt energetic electrons from satellite data. Our model (bottom panel) shows good agreement with the data.* **Bottom Right:** *The Imaging Riometer for Ionospheric Studies (IRIS) at Halley Research Station, Brunt Ice Shelf.*

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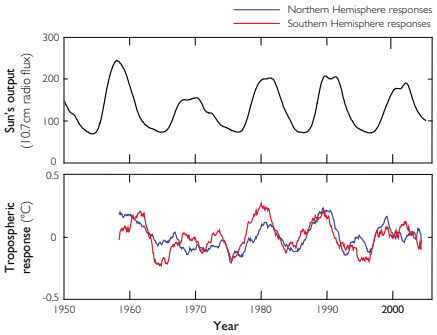

Detecting solar signatures in atmospheric temperature

Climate change occurs on various timescales because of natural variability and man-made effects. One major source of natural variability is the Sun, where changes in solar irradiance and the solar wind can influence atmospheric circulation by changing heating and cooling rates, and may subsequently affect weather systems and climate patterns. Solar irradiance heats the atmosphere directly and follows an 11-year cycle, while the solar wind affects the atmosphere indirectly via the Earth's magnetic field (charged particle precipitation) and changes in atmospheric chemistry. To determine the relative contributions from solar irradiance and geomagnetic activity, we conducted statistical analyses using global temperature data from the Hadley Centre. We found that both solar irradiance and geomagnetic activity have short and longer-term effects on atmospheric temperature and that solar influences are systematically modulated by variability in the atmosphere. Atmospheric temperature responds to solar irradiance in both the stratosphere and troposphere, but mainly responds to geomagnetic activity in the stratosphere. These results show that the stratosphere responds to solar variability via at least two different pathways: changes in solar irradiance, which has been well established, and geomagnetic activity, for which there has only been tentative evidence.

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Modelling the Earth's radiation belts

The Earth's magnetic field traps energetic charged particles in the Van Allen radiation belts. When some of these energetic electrons are deposited into the atmosphere they change atmospheric chemistry, leading to the destruction of ozone and alterations to the radiation balance of the atmosphere. Since the radiation belts depend on geomagnetic activity driven by the Sun, they pass on solar variability to the atmosphere, which may have an important effect on climate. However, there is no general model that links changes in the radiation belts to the atmosphere.

BAS scientists have now taken the first step to rectify this by developing a model of the outer radiation belt (the further of the two areas of trapped magnetic particles), that uses satellite data and a database of electromagnetic waves to calculate losses to the atmosphere. Using a time series of geomagnetic activity, the model can reproduce particle concentration variations during geomagnetic storms very well, although the peaks are somewhat lower than observed. It can also determine where and when losses to the atmosphere are most intense. The model will provide a vital link to global atmospheric circulation models to determine how the Sun affects the atmosphere via energetic particle precipitation.

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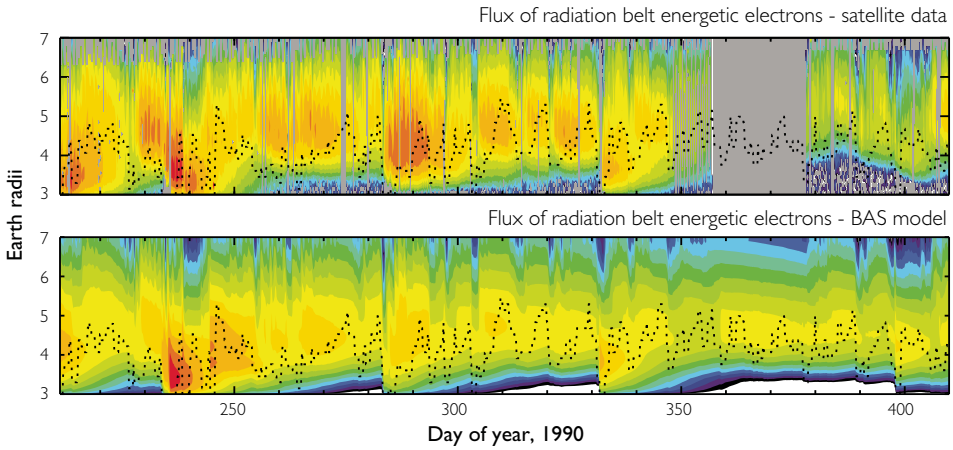

New method of detecting atmospheric gravity waves

Atmospheric gravity waves are produced at low altitudes, propagate upwards, and dissipate energy between 60km and 100km up, in the mesosphere. They drive atmospheric circulation between the northern and southern polar regions at high altitudes. General atmospheric circulation models cannot resolve gravity waves directly, but since their effects are so important for circulation, they are represented in the models by other means. However, we infer from differences in the observed and modelled stratospheric temperatures that the representation of gravity waves over Antarctica may be incorrect.

BAS scientists have developed a new analysis technique to detect gravity waves from instruments known as imaging riometers. An imaging riometer measures the amount of cosmic radio noise absorbed in the ionosphere, at an altitude of 90km. By detecting modulations in the absorption they are able to identify gravity waves passing through the region with wavelengths greater than 15km. Since there are networks of imaging riometers in both polar regions, the new analysis technique opens up opportunities for atmospheric and climate change research, which can help to improve the accuracy of general circulation models.

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BIOFLAME Biodiversity, Function, Limits and Adaptation from Molecules to Ecosystems

Principal Investigator: **Prof Lloyd Peck lspe@bas.ac.uk**

Introduction

BIOFLAME is a cross-disciplinary programme which takes a holistic approach to studying Antarctic biology across levels of adaptation from the gene to regional biodiversity.

It aims to answer major global questions such as 'Why are there such enormous differences in numbers of animals living in different places?' and 'What specific characteristics are needed for animals to live in Antarctica's extreme environments, especially in the context of change?' BIOFLAME blends traditional biodiversity, ecology and physiology with molecular biology methods to answer these questions on microbial and animal groups in Antarctica. This helps us find out how climate change influences biodiversity and ecosystems in Antarctica and globally.

Terrestrial habitats existed throughout Antarctic glacial cycles

Research on the diversity of nematodes has identified unexpected levels of biodiversity in the southern Antarctic Peninsula region. No previous studies had taken place on this group of microscopic soil animals south of Rothera Research Station in Marguerite Bay. We expected less diversity, consistent with the higher latitude and more extreme environment. However, we have now identified sites on southern Alexander Island with nearly twice the nematode diversity previously known from the maritime Antarctic as a whole. A large proportion (~40%) of this diversity is new, consisting of undescribed species currently known only from this island. Such high levels of diversity and endemism show this is a regional biodiversity hotspot. They are inconsistent with the current view among glaciologists that these terrestrial habitats have only existed since the Last Glacial Maximum, indicating a much longer evolutionary history. We can hypothesise that elements of this fauna survived the Pleistocene glaciations, indicating the availability of terrestrial habitat during glaciations, a result that challenges current glacial models.

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Technical terms: **Endemism:** *The existence of species found only in one particular region.* **Hydra:** *A tiny, tubular freshwater marine animal.* **Last Glacial Maximum:** *The time of maximum extent of the ice sheets during the last glaciation, approximately 20,000 years ago.* **Magellanic:** *From the region around the southern tip of South America, south to the Antarctic Circle.* **Molecular biological analyses:** *The analysis of the structure, function, and make-up of biologically important molecules.* **Nematodes:** *Microscopic worms which have smooth, unsegmented, cylindrical bodies with pointed ends.* **Paradigm:** *A model used to explain a concept or theory.* **Phylum:** *An animal or plant group related by a direct line of descent. In taxonomies of biological organisms, the phylum is the basic unit of differentiation within kingdoms.* **Pleistocene:** *A geologic period, usually thought of as the Ice Age, which began 1.6 million years ago and ended about 11,500 years ago with the melting of the continental glaciers.*

Images: **Above:** *Alexander Island, close to the terrestrial habitat study area.* **Top Right:** *Map showing the high phylum diversity for the different areas in the Scotia Sea.* **Centre Right:** *Heat shock response in an Antarctic limpet* (Nacella concinna). **Bottom Right:** *Antarctic clams,* Laternula elliptica, *in the Bonner Laboratory at Rothera Research Station.*

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Turning up the heat: Antarctic marine animals do have a heat shock response

The classical animal response to environmental stress is to dramatically increase the production of biochemicals that protect the cell proteins from damage – the heat shock proteins (HSP). This is termed the heat shock response (HSR) and has been demonstrated in all animals more complex than hydra so far studied, with the exception of Antarctic fish. Antarctic marine organisms have not been thought to possess an HSR. We subjected the clam (*L. elliptica*) and limpet (*N. concinna*) to acute heat shocks over a range of temperatures.

In contrast to the previous work on fish, the clam showed massive response at +15°C and above, whilst the limpet displayed an increased regulation of HSP genes at temperatures over +8°C. Therefore, these species do possess the classical HSR. However, the temperatures needed to activate this response in experiments are far above those that either species would experience naturally. This surprising result shows that some Antarctic marine animals can use the HSR to protect themselves, and experiments using single stressors should be interpreted with caution.

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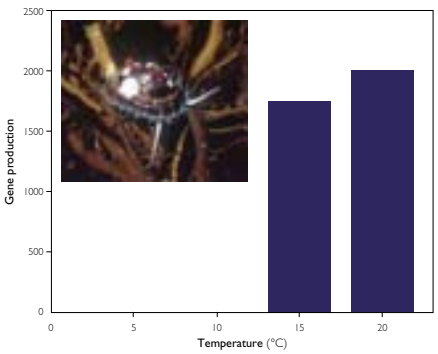

The Scotia Sea is a hotspot of marine biodiversity

The Scotia Sea region covers the transition between the Magellanic and Antarctic regions and their islands, which might act as stepping-stones for the dispersal and colonisation of marine seafloor-living (benthic) species. A research cruise on RRS *James Clark Ross* sampled benthos from vertical sections of water, ranging from 200m to 1,500m depth, off seven islands of the Scotia Sea. This comprehensive sampling allowed us to assess community structure and biodiversity at local and regional scales and from phylum to species level. The diversity in our samples was exceptionably high, with up to 12 phyla of the 36 phyla known worldwide collected at any one station. The most diverse samples were mostly at depths between 500m and 1,000m. These data are surprising because there are more phyla present in one sample than found in similar samples from temperate and tropical high-diversity areas, such as coral reefs.

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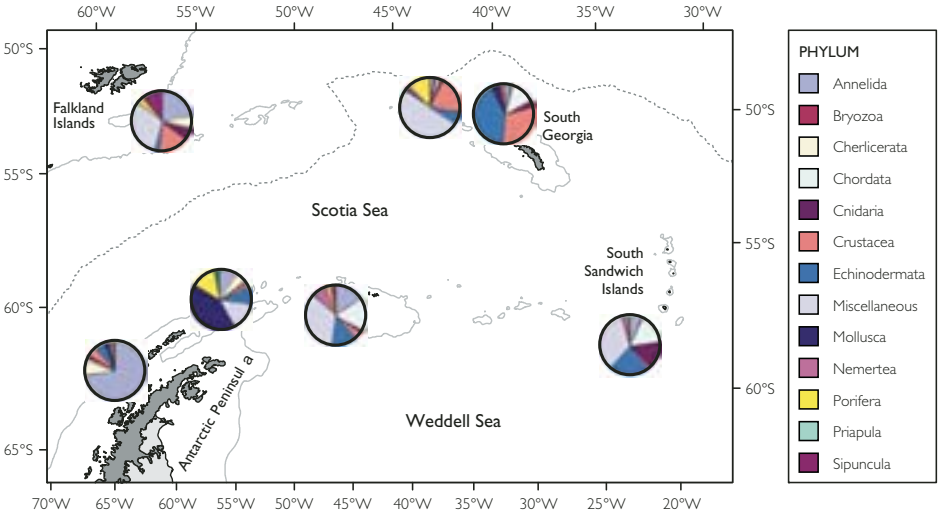

Extreme sensitivity of Antarctic marine species to temperature change

Previously, we had shown that some Antarctic marine species die with relatively short-term temperature rises of 5°C to 10°C. We extended this to show that critical activities (e.g. burying in clams and swimming in scallops) are compromised when the temperature rises by only around 2°C above current summer maximum temperatures. Recently, we have developed this work to show that larger individuals fail before smaller ones. We have confirmed that this is linked to oxygen availability and supply, by demonstrating that if oxygen concentration in the immediate environment is raised or lowered, upper lethal limits rise or fall correspondingly. We have also compared the temperature sensitivity of Antarctic clams with that of closely-related species from temperate and tropical latitudes and shown the tropical and Antarctic species are much more temperature sensitive than the temperate species.

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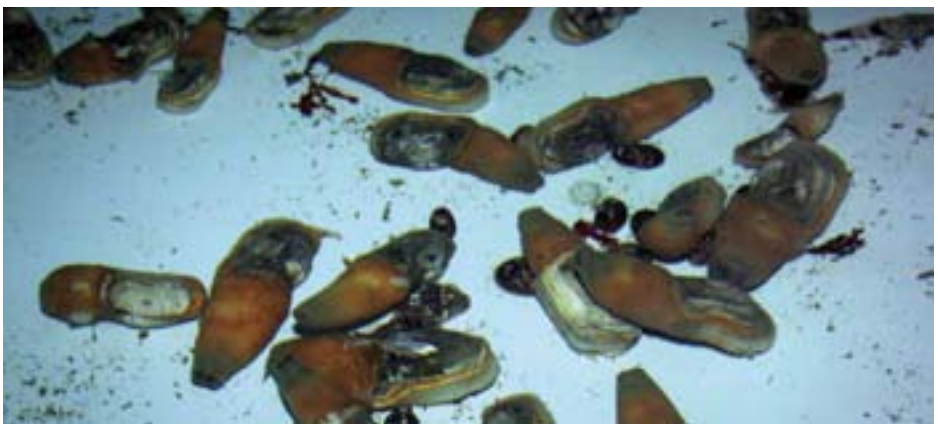


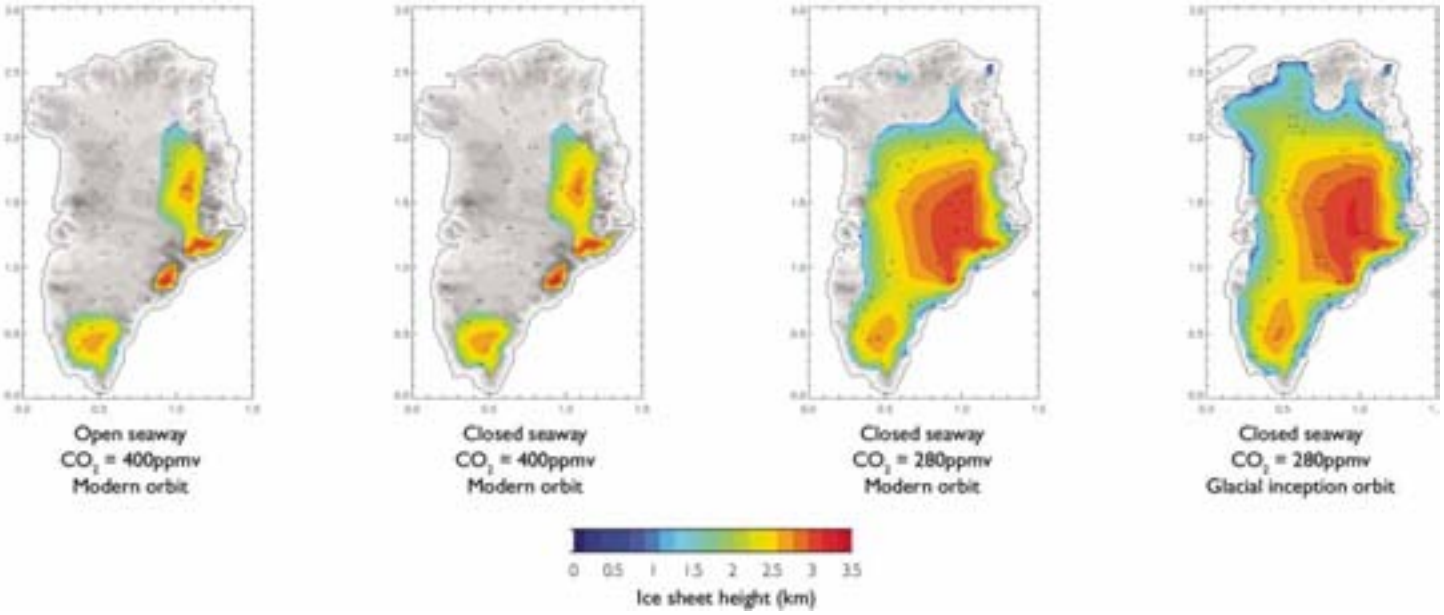
GEACEP Greenhouse to Ice-House Evolution of the Antarctic Cryosphere and Palaeoenvironment

Acting Principal Investigator: **Dr Alan Vaughan** **apmva@bas.ac.uk**

Introduction

Through collecting geological data and combining them with advanced computer models of Earth as an integrated system, GEACEP investigates the evolution of the Antarctic ice sheet and the changing global environment over the last ~30 million years.

The programme explores the nature of warm climates in Earth history, investigating the mechanisms associated with the initiation of glaciation on Antarctica, as well as examining the stability of the Antarctic ice sheet in the recent geological past. This helps us assess the ability of climate models to reproduce previous large-scale climate changes and consequently their ability to accurately predict future climate change.



Ocean gateways and the onset of northern hemisphere glaciation

North and South America have not always been joined. They became connected approximately three to five million years ago, forming the Panama Isthmus. This was during the time period known as the Pliocene, when the climate was generally warmer than today. It was also at approximately that time when the first ice sheets began to appear in the Northern Hemisphere, in particular over Greenland. For many years, scientists have wondered whether these two events were linked.

They have generally assumed that the formation of the Panama Isthmus led to the creation of the Gulf Stream. This ultimately brought wetter weather to the polar regions, which fell as snow over Greenland and allowed the build-up of the ice sheet we see today. However, recent work carried out at BAS, using supercomputers to predict the Pliocene climate, has demonstrated that changes in carbon dioxide concentration in the atmosphere were more likely to have triggered the formation of the Greenland ice sheet.

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Technical terms: **Aerogeophysical survey:** *Ground/ice survey using sophisticated instruments mounted on the wings of, and inside, a Twin Otter aircraft.* **Biome:** *A major portion of the living environment of a particular region.* **El Niño Southern Oscillation (ENSO):** *A global phenomenon linking the oceans and atmosphere. It was first identified as cyclic warming and cooling of the eastern and central Pacific over periods of 4-12 years, associated with changes in marine biomass.* **Gulf Stream:** *A warm ocean current flowing from the Gulf of Mexico, across the North Atlantic and along the coast of north-west Europe.* **La Niña:** *La Niña refers to the appearance of colder than average sea surface temperatures in the central or eastern equatorial Pacific region (the opposite to conditions during an El Niño event).* **Palaeobotanical data:** *Data on the vegetation and plant life from past environments.* **Palaeoclimate modelling:** *Reconstructing the climates of past environments using computer models.* **Pliocene:** *Epoch of geologic time 1.8 to 5 million years ago.*

Images: **Above:** *Model predictions for Greenland ice sheet volumes in the Pliocene.* **Top Right:** *Airborne radio-echo sounding of the Dome C area of the East Antarctic Ice Sheet. Layering is clearly visible. Possible subglacial lakes are bracketed in red.* **Centre Right:** *Global biome map combining vegetation reconstruction from palaeobotanical proxies with BIOME4 model simulations.* **Bottom Right:** *More extreme weather in the distant past could indicate a similar pattern for the future.*

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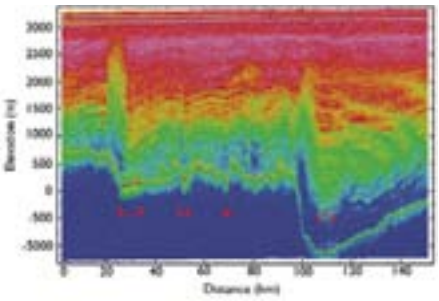


East Antarctic Ice Sheet: stable or dynamic?

Could global warming eventually trigger the collapse of the East Antarctic Ice Sheet (EAIS)? Although it is traditionally considered as stable, recent satellite observations are detecting changes, in particular over George V Land, where the Wilkes Subglacial Basin lies. A major aerogeophysical survey flown by BAS and the Italian Antarctic programme targeted this largely unknown region. Airborne radar identifies ice layers, ice thickness, bedrock topography and subglacial lakes, while aeromagnetic and aerogravity data create images of sub-ice geology. Hence new constraints are now available to put into ice sheet and palaeoclimate models addressing the stability of the EAIS during warm periods in the geological past, which may provide a template to predict future changes.

Our new sub-ice topography map, for example, radically changes existing views of the region. Deep subglacial trenches are revealed, flanked by mountain blocks and plateaus, in striking similarity to the topography underlying dynamic and potentially unstable parts of the West Antarctic Ice Sheet. Ice-sheet collapse in any part of the EAIS would have a significant impact on global sea level.

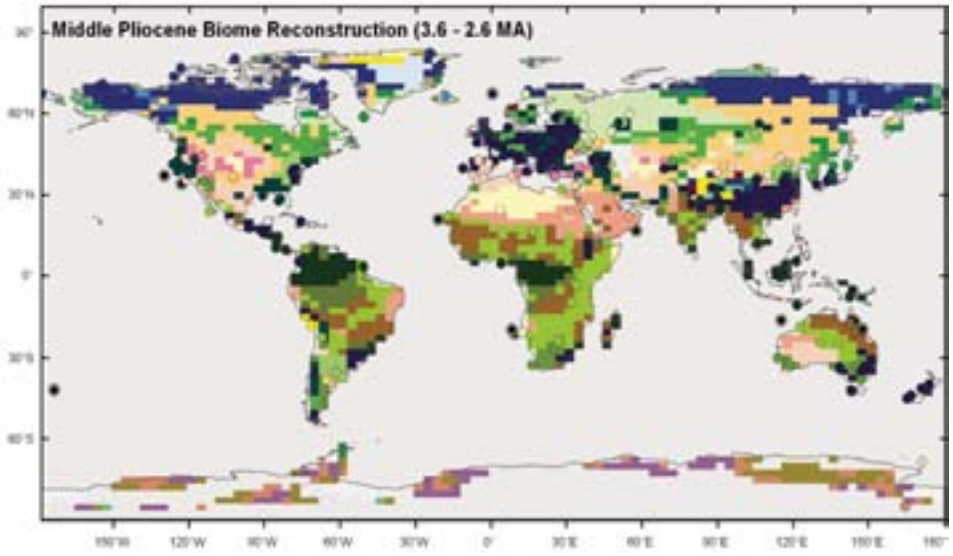
Contact: **Dr Fausto Ferraccioli ffe@bas.ac.uk**

A new global biome reconstruction for the Mid-Pliocene

The importance of links between vegetation and climate has been highlighted by several palaeoclimate modelling exercises. However, the role of these links in Tertiary period modelling (65 to 1.6M years ago) has not been fully recognised. To this end, we have developed a comprehensive GIS database TEVIS (Tertiary Environment and Vegetation Information System). This integrates global marine and terrestrial vegetation data, taken from fossil pollen, leaf or wood, into a consistent classification scheme.

Our new biome reconstruction for the Mid-Pliocene synthesises global palaeobotanical data from 202 sites. The model results compare favourably with available palaeo-data. The Mid-Pliocene biome reconstruction indicates a warmer and moister climate than today. It shows a northward shift of boreal forest in the Northern Hemisphere, a spread of warm-temperate forests in middle and eastern Europe, and expansion of savannas and woodland at the expense of tropical deserts. Our combined data-modelling approach and biome reconstruction provides new boundary conditions for future Global Climate Model simulations. It will be used in the future to test fully-linked ocean-atmosphere and vegetation model simulations.

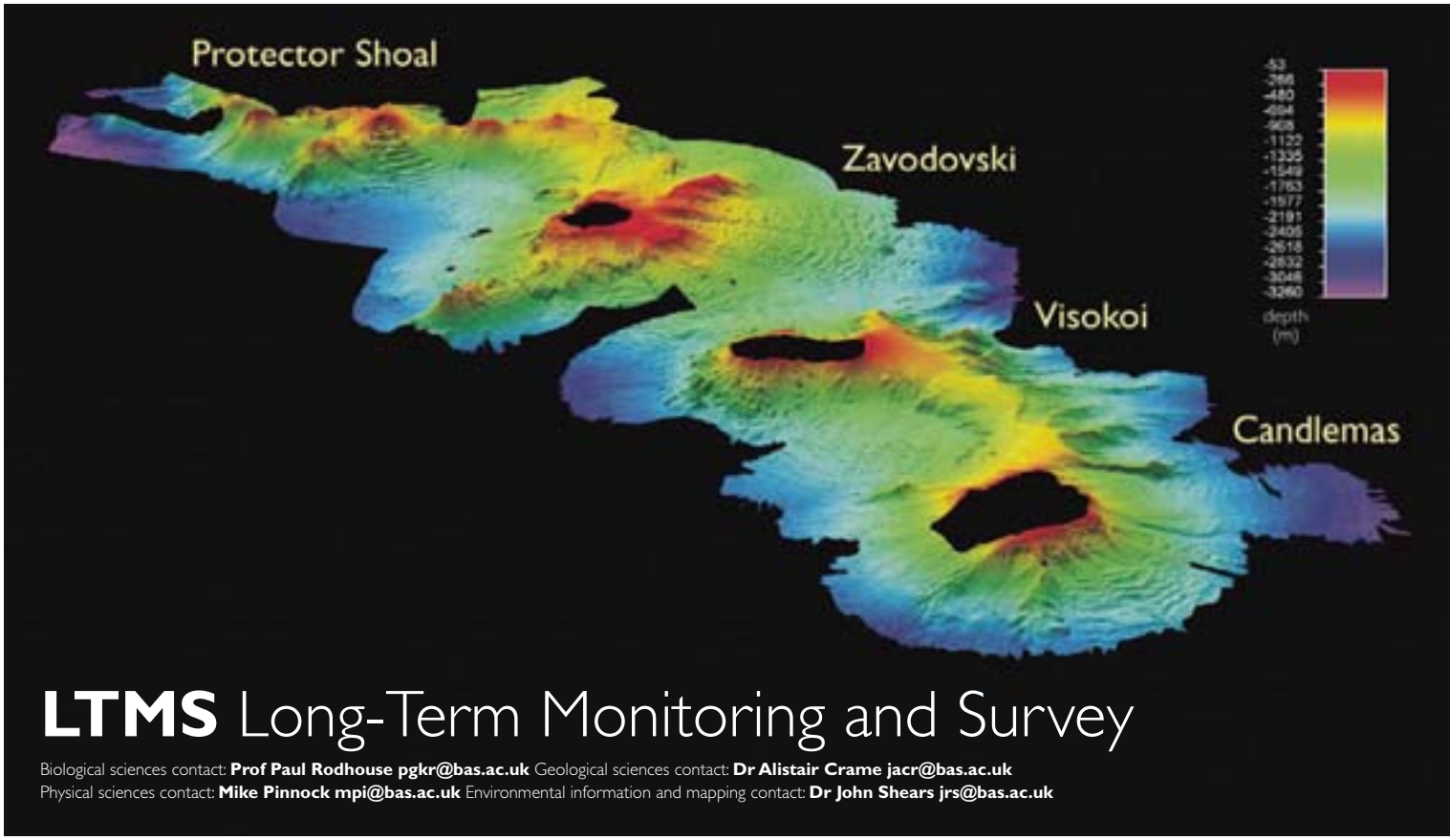
Contact: **Dr Ulrich Salzmann usa@bas.ac.uk**



Reconstructing palaeo El Niño Southern Oscillation

Three to five million years ago, during the Pliocene period, the world was a warmer place. Palaeoceanographers previously held different views about the behaviour of the El Niño Southern Oscillation (ENSO) during that period. One argument suggests that permanent La Niña-like conditions prevailed; the other that the Pliocene was characterised by permanent El Niño-like conditions. To tell which view was correct, we have produced sophisticated computer-generated climate reconstructions for the Pliocene using the UK Meteorological Office's General Circulation Model. The results reveal a number of interesting findings. Firstly, the pattern of change of sea surface temperature and surface air temperature in the tropical Pacific suggests alternating El Niño and La Niña conditions, just like today. Secondly, the model suggests that the variability is greater (~20%) in the Pliocene experiment than it is for the equivalent present-day experiment. This means that El Niño and La Niña events were more intense or more frequent or both in the past. This translates into more frequent and more extreme droughts and floods in the South American and Indonesian regions in the past, and potentially in the future too.

Contact: **Dr Alan Vaughan apmva@bas.ac.uk**



LTMS Long-Term Monitoring and Survey

Biological sciences contact: **Prof Paul Rodhouse pgkr@bas.ac.uk** Geological sciences contact: **Dr Alistair Crame jacr@bas.ac.uk**
Physical sciences contact: **Mike Pinnock mpi@bas.ac.uk** Environmental information and mapping contact: **Dr John Shears jrs@bas.ac.uk**

Introduction

BAS undertakes a range of long-term monitoring and survey activities that underpin national and international research, and government and international policies. We are building on a legacy of more than 50 years of observations and measurements.

Underwater structure of an Antarctic island arc revealed

New underwater mapping has revealed for the first time the morphology (structure) of the predominantly undersea South Sandwich Arc in the South Atlantic. The survey extends between 55°45'S and 57°20'S and includes Protector Shoal and the areas around the islands of Zavodovski, Visokoi and Candlemas. The entirely submerged Protector Shoal area is close to the northern limit of the arc and forms a chain of seamounts (undersea mountains) aligned east-west.

The seamounts rise to 50m below sea level and at least some are associated with summit craters and imaged lava flows. Zavodovski, Visokoi and the Candlemas Island group are the summits of three large underwater ridges. The images show clearly that the structures are dominated by slope failure and generation of debris flow deposits. All three show clear evidence for migrating to the west. Older, eastern parts of the volcanoes are not covered by younger deposits, and the progressive collapse of the edifices due to debris flows is clearly seen.

Contact: **Dr Phil Leat ptl@bas.ac.uk**

Technical terms: **Arthropod:** *Invertebrate animals with jointed legs and segmented bodies such as insects, crustaceans, and arachnids.* **Bathymetry:** *The measurement of depths of water in oceans, seas and lakes.* **Biodiversity:** *The variety and abundance of species.* **Biogeochemical cycle:** *The movement of chemicals between living and non-living components in the Earth System.* **Lithosphere:** *The layer of solid, brittle rock making up the outer shell of the Earth.* **Macro-organisms:** *Animals large enough to be seen with the naked eye.*

Images: **Above:** *Bathymetry of the South Sandwich Islands showing many new underwater ridges and features.* **Top Right:** *The autonomous instrument platform in the Du Toit Mountains, Palmer Land.* **Centre Right:** *The new BAS produced Arctic and Antarctic double-sided map, created for International Polar Year 2007-08.* **Bottom Right:** *Marine samples were collected for DNA analysis from RRS* James Clark Ross.

For more information please visit our website: **www.antarctica.ac.uk**

New biodiversity survey of terrestrial macro-organisms

To determine the biological consequences of rapid climate change, we are undertaking baseline assessments of terrestrial and marine biodiversity at several carefully-selected sites on and around the Antarctic Peninsula and sub-Antarctic islands.

Terrestrial macro-organisms

A six-week field trip to South Georgia resulted in samples from ten sites, including over 400 arthropod samples. Initial sorting has provided samples for molecular analyses. We have found a shoreline fly from the family *Empiidae,* previously unknown in South Georgia, and this is presently undergoing formal species identification.

Contact: **Dr Pete Convey pcon@bas.ac.uk**

Microbial communities

Microbial communities are the least understood component of the Earth's ecosystems. This is particularly so in the polar regions, where their role in moderating productivity and in the biogeochemical cycles of both land and sea are still poorly understood. We are using the latest DNA-based molecular technology to generate an environmental DNA 'blueprint' (metagenome) for Antarctic terrestrial and marine ecosystems. Small DNA fragment or 'clone' libraries have now been constructed from more than 25 sites, resulting in over 5,000 DNA sequences. Large DNA fragment or 'metagenomic' libraries have also been constructed from water around the Scotia Arc and in the terrestrial environment at Mars Oasis.

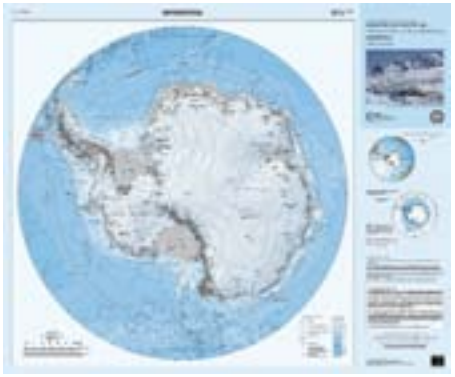
Contact: **Dr David Pearce dpearce@bas.ac.uk**

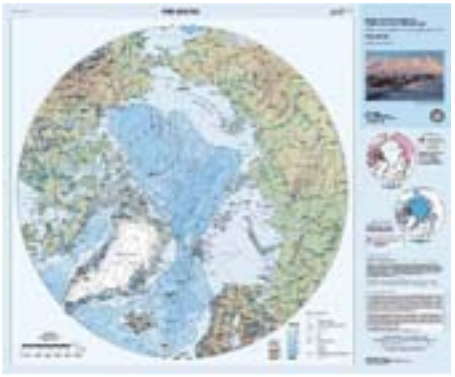
New instrumentation to study Antarctic sea-level rise

As ice has retreated since the Last Glacial Maximum, the Earth's crust has risen in response to losing the overburdening ice. Long-term monitoring of this vertical motion of the lithosphere on the Antarctic Peninsula is needed to understand the role of Antarctica in current sea-level change. It is also required to reduce the errors in determining ice mass balance by satellite missions, such as GRACE (Gravity Recovery And Climate Experiment). BAS's existing GPS survey station at Rothera was augmented by the installation of an autonomous instrument platform in the Du Toit Mountains, Palmer Land in February 2007.

These instruments complement the USA's West Antarctic GPS Network (WAGN), forming a link between WAGN and more northerly stations. The power supply for the Palmer Land instrument (a year-round, continuous-operation GPS station) was a significant technical challenge, due to the remoteness of its location, and was made possible by the autonomous instrument capability that has been developed in BAS over 15 years.

Contact: **Mike Pinnock mpi@bas.ac.uk**





New polar map for International Polar Year 2007-08

The Mapping and Geographic Information Centre (MAGIC) in BAS has prepared a new 1:10,000,000 scale map of the polar regions, which has been produced specially for International Polar Year 2007-08 (IPY). IPY is the largest and most ambitious internationally co-ordinated scientific effort for 50 years.

The map shows both Antarctica and the Arctic north of 60°N and is designed give an overview of the polar regions and the context for IPY activities, both for scientists working in the area and more widely for the media, students and the public. The map includes bathymetry, a shaded elevation backdrop and contours for ice-cap areas. Insets show seasonal sea-ice extent and key boundaries such as the limit of vegetation in the Arctic.

Contact: **Dr Adrian Fox ajfo@bas.ac.uk**

Delivering the Science

Image: *BAS geologist examines rocks close to Fossil Bluff, Alexander Island, Antarctic Peninsula.*

Infrastructure and operations

Contact: **John Pye** ajpye@bas.ac.uk

Introduction

To deliver world-class science 16,000km away, BAS needs modern technology for science and infrastructure, up-to-date facilities and effective operational management.

We have long-term planning horizons, a flexible and innovative approach, and an ongoing programme to introduce new facilities and technology. Success depends on excellent teamwork across many disciplines, a continuous search for better ways of working, and collaboration with other NERC programmes and national Antarctic operators.

Halley VI project

The Halley VI project involves the design and construction of a new scientific research station on the Brunt Ice Shelf in Antarctica and the demolition and removal of the existing Halley V research station. Halley V has to be replaced due to an increased risk that the section of the Brunt Ice Shelf on which it is located will break away after the year 2010. The project was launched with an international, multi-stage design competition to deliver innovative ideas and concepts. The result is a low-maintenance, energy-efficient station that can be relocated in future years as and when required. Throughout the development of the project, BAS has worked in partnership with the construction contractor Morrison Construction Ltd, the design team Hugh Broughton Architects, and engineers Faber Maunsell.

In September 2006, BAS and Morrison signed a £22 million construction and demolition contract for the project. Fabrication of all elements of the station is now progressing steadily in Cape Town, South Africa, and the UK. During the 2006-07 season, the relocation concept was successfully tested by towing a 150-tonne sledge across the ice. A scale model of the new station demonstrated that its aerodynamic shape will minimise snow build-up. Preparations were made for construction to start in 2007-08. Over the next two Antarctic seasons, construction will be fully completed before science equipment is installed during the 2009-10 Antarctic summer.

Vehicles are required for all phases of the Halley VI project. The most challenging time is 'relief' when we need to transport stores and materials across miles of floating sea ice from the supply ship to the station. Halley V research station is normally re-supplied with 1,500m^3 of cargo. The new Halley VI station requires a cargo volume of 15,000m^3 during the construction phase. This tenfold increase means that we have had to increase the speed, power and cargo capacity of the Halley vehicle fleet. To do this we have bought Agco Challenger and John Deere tracked tractors. These units, with additional sledges, will enable the Halley VI project to be delivered to schedule.

Contact: **Karl Tuplin** ketu@bas.ac.uk

Images: Above: *A newly aquired BAS Challenger tractor pulls a load across the ice in front of RRS* Ernest Shackleton *during testing for the Halley VI building phase.* **Bottom Right:** *Bransfield House, one of the new buildings being constructed at Rothera Research Station, Adelaide Island.* **Centre Right:** *The SOUTH travel database gives staff immediate access to their travel itineraries.* **Far Right:** *The fully automated remote weather station on Signy Island.*

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Redevelopment of Rothera Research Station

Rothera is BAS's largest Antarctic research station and is the key node in our Antarctic operations. It has scientific laboratory facilities, an aircraft runway and hangar, a ship's wharf, workshops and accommodation for staff. The station is a forward base for field activities as well as providing facilities for near-shore marine, terrestrial and atmospheric sciences. Many of the structures at Rothera are old and use a lot of energy compared to modern structures. We are committed to reducing the use of energy in Antarctica and so replacing old structures is essential. As well as being poorly insulated, many of the existing structures are sited in areas where snow deposition is high, leading to a heavy demand for snow clearing early in the Antarctic season.

A programme has started to redevelop Rothera Station over several years; removing, refurbishing or replacing buildings where appropriate. A snow model has been run to ensure that the overall site plan minimises the build-up of snow. Construction of the first of the new buildings began during the 2005-06 season, and was largely completed during the 2006-07 season. This new building provides accommodation, recreational facilities and food storage space. It has been designed to be highly insulated, simple to construct, and with minimal environmental impact. Solar collectors provide hot water, and a building management system ensures that all services are used efficiently. Initial indications are that the new structure is very successful, with only very limited build-up of snow downwind.

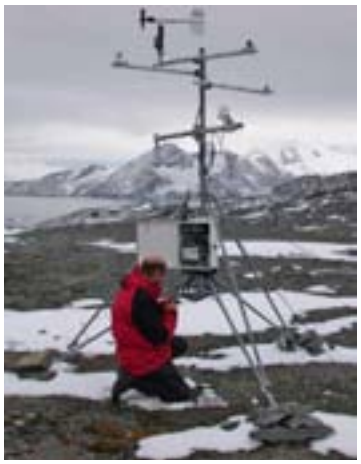
Contact: **Dave Ingham** di@bas.ac.uk

Planning and tracking Antarctic travel

BAS moves about 350 people to and from Antarctica each year, mainly through the Falkland Islands and Chile, although the number of destinations in Antarctica and variety of routes taken grows each year. While Halley VI is built, visitors to Halley and the crew of RRS *Ernest Shackleton* will travel via South Africa. As the complexity of the operation has increased, so has the need for a simple, robust and visible planning and tracking database.

We have developed an in-house, web-based system known as SOUTH (Successfully Out and Home). It allows us to record and co-ordinate all elements of Antarctic travel, from leaving the UK to arriving in Antarctica and home again, taking in the many operational changes that occur each season and allowing the planners to co-ordinate alterations with revised timetables. SOUTH is accessible to everyone in BAS, showing individual travel details, ships' itineraries and aircraft movements. It provides real-time information detailing who is travelling, who is on the ships and stations and which projects they are working on. The database is now being extended to include other aspects of BAS Antarctic travel. SOUTH already provides useful statistics and an easy way to monitor Antarctic travel costs. During the next year, this information will become directly accessible to project leaders and managers throughout BAS.

Contact: **Caroline Lewis** cjml@bas.ac.uk



Remote data collection and communications

Collecting data in the Antarctic is essential for science projects. Being able to collect data in an electronic form and transmit information in near-real time to the UK enables us to deliver scientific studies more quickly and effectively than by relying on site visits and a person to measure and acquire data.

The communications link between the UK and Antarctica remains a challenge as the choice of satellite telemetry technology in polar regions remains limited. Argos, Inmarsat and Iridium are the only satellite providers covering Antarctica that provide a viable service for data collection. We selected a dial-up system from Iridium to transfer data from a data collection system at Signy Station. Dial-up was chosen as it allows greatest flexibility and is most economical for transfers of greater than 10 kilobytes.

The system designed for Signy Station is fully automatic, almost 'off the shelf' and ideally suited to automatic weather stations and other low-to-medium data rate logging applications. The system is based around an Iridium Subscriber Unit (ISU) and a Campbell Scientific CR1000 logger. A watchdog circuit is also included to minimise any possible problems and to allow remote reprogramming of the logger.

Since installation in December 2006, the system has worked reliably, achieving data rates of up to 10 kilobytes per minute. The data acquisition logger software has been remotely updated several times. We intend to build on the success of the design and install more remote, automated systems in the future.

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UK and international collaborations

Contact: **Prof Alan Rodger** **asro@bas.ac.uk**

Introduction

Many of the important science questions posed in the GSAC programmes cannot be answered by BAS alone.

Therefore we collaborate extensively with the UK environmental science community, including the Antarctic Funding Initiative, and maintain international links at the scientist-to-scientist level and through involvement in internationally co-ordinated science activities, such as International Polar Year 2007-08.

Volcanoes tell a story of ice-sheet evolution

Few proxies give information on the former elevation, thickness and extent of the East Antarctic Ice Sheet. A new technique pioneered at BAS uses the interaction between erupting volcanoes and existing ice sheets to extract key information about ice-sheet history.

During the past two southern summer seasons a BAS volcanologist, in collaboration with Italian and US scientists, examined ancient volcanic sequences along 800km of the East Antarctic Ice Sheet margin, between Cape Adare and Mount Discovery. The period investigated encompasses most of the past 13 million years. These results provide a range of critical new ice-sheet parameters, and will give key insights into how ice sheets in East Antarctica may respond to a warming world.

Contact: **Prof John Smellie** **jlsm@bas.ac.uk**

Technical terms: **Pelagic:** *In the open sea, away from the sea bottom.* **Photolysis:** *Chemical decomposition induced by light or other radiant energy.* **Proxies:** *Variables from which data about other variables can be inferred.*

Images: **Above:** *British and American geologists descend a steep slope after examining multiple volcanic sequences formed variably under former ice sheets.* **Top Right:** *Frost flowers forming on sea ice in the Antarctic Peninsula.* **Far Right:** *Logo of the Integrating Climate and Ecosystem Dynamics Programme (ICED).* **Bottom Right:** *King penguins have been tracked to depths in excess of 250m as they forage for food.*

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Air-Ice Chemical Interactions

A BAS-led initiative has resulted in a major international workshop and a special journal issue highlighting the important atmospheric chemistry occurring in the lowest parts of the polar atmosphere. In recent years, some very interesting chemical processes have been found over snow and ice surfaces. The photolysis of chemicals, such as nitrate, within the top few centimetres of snow, turns out to dominate the chemistry of the polar boundary layer. New sea-ice surfaces, including the fragile crystals known as frost flowers, have been found to host reactions that increase levels of active bromine compounds, which can cause a complete loss of ozone from the near-surface during spring in both polar regions.

Air-Ice Chemical Interactions (AICI) is a task endorsed by the International Global Atmospheric Chemistry Project, and led by BAS. We organised and sponsored a workshop in summer 2006 at Grenoble (France) at which 44 people from 13 nations discussed these phenomena and their effects. As a result of the meeting, a special issue of the journal 'Atmospheric Chemistry and Physics' is in preparation, to contain major review papers on these topics, along with tutorials on relevant issues in snow and boundary layer physics.

Contact: **Dr Eric Wolff** **ewwo@bas.ac.uk**

ICED: think global – act global

Understanding how large oceanic ecosystems work is fundamental to addressing key scientific questions of the importance of climate-ecosystem interactions and feedbacks, including the impacts of harvesting. The size of the area covered and sampling involved requires an integrated approach at an international level. To achieve such circumpolar and multidisciplinary analyses of Southern Ocean ecosystems, DISCOVERY 2010 scientists have taken a lead role in developing the Integrating Climate and Ecosystem Dynamics Programme (ICED), which brings together scientists from 20 nations across a range of research disciplines. Within the European Union's EUR-OCEANS Network of Excellence, ICED is a major focus for Southern Ocean scientists.

International Polar Year 2007-08 (IPY) provides the catalyst for the launch of ICED in the shape of the ICED-IPY project, which forms the umbrella for a range of studies around the Antarctic during 2007-08. The vision for ICED is a decade-long programme of Southern Ocean research that contributes to the ocean programmes (GLOBEC and IMBER) of the International Geosphere-Biosphere Programme. Just as an ecosystem represents much more than the sum of its component parts, so the international co-ordination of ICED will provide scientific insights that national programmes alone could not achieve.

Contact: **Dr Rachel Cavanagh** **rcav@bas.ac.uk**

New technology – new insights

BAS scientists continue to use the latest technology to revolutionise studies of the foraging behaviour of land-based predators such as Antarctic fur seals, albatross and king penguins. These new-generation instruments are tiny and have no significant effect on the animals.

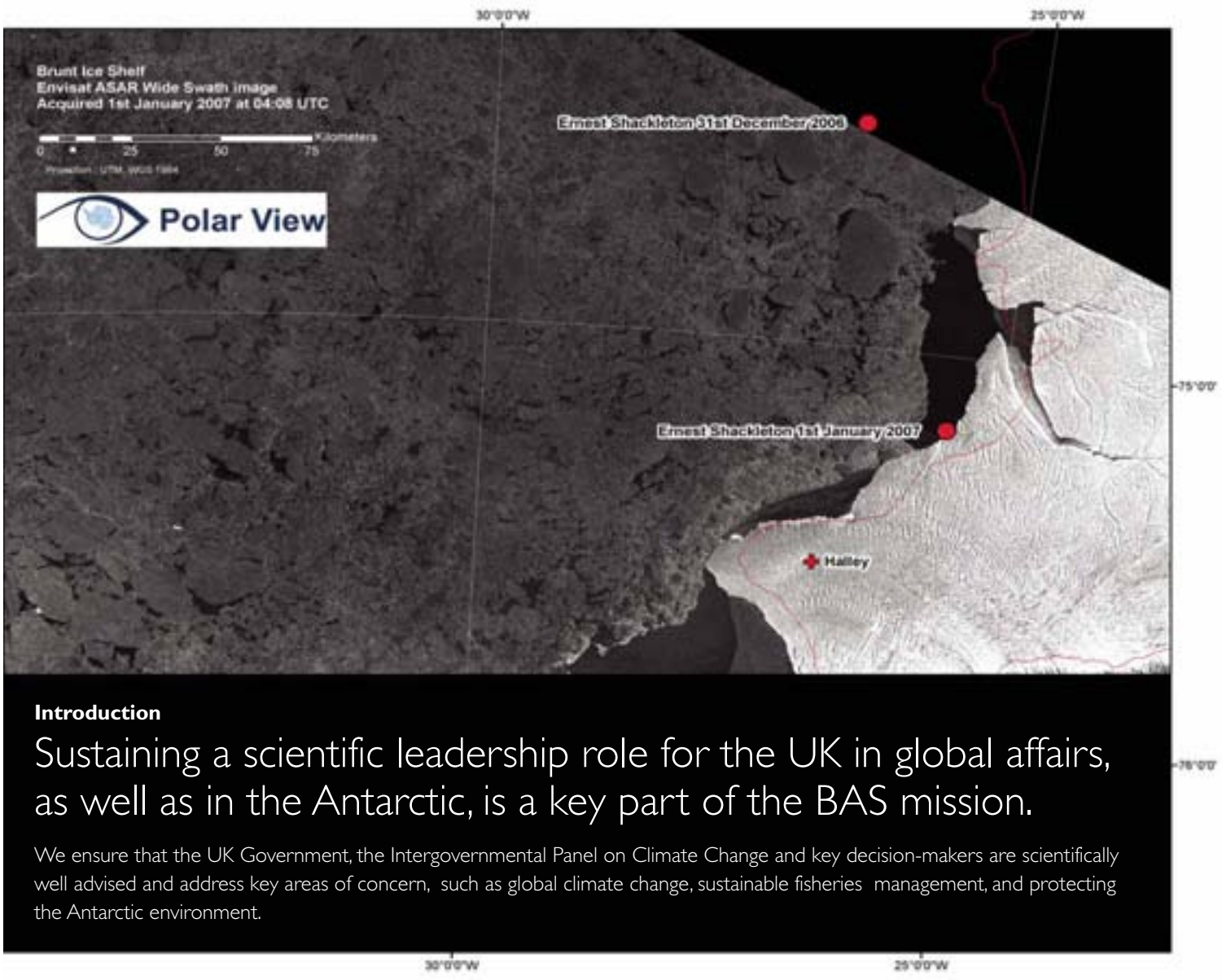
Using novel rapid GPS tags developed at the University of Bangor, we can study the fine-scale foraging patterns of diving predators for the first time. These new devices store GPS-derived position data. This allows us to locate animals and birds with much greater frequency and accuracy than traditional satellite tags. Recently deployed on king penguins, the tags have shown that the birds forage mainly in areas with surface temperatures of 5-5.5°C. King penguins, which dive to over 250m, probably use temperature to help locate the Polar Front, where their main prey (pelagic fish) gathers.

In collaboration with Texas A&M University, we used prototype telemetry devices on adult male fur seals at Bird Island. These unique devices combine records of three-dimensional diving behaviour with high-resolution video from a camera mounted on the animal's head. A successful trial has captured amazing footage of seals feeding within krill swarms in the waters around South Georgia. Such data allow us to measure foraging success and rates of encountering prey, and help clarify fine-scale predator-prey interactions.

Contact: **Dr Phil Trathan** **pnt@bas.ac.uk**

UK influence in global affairs

Contact: **Dr John Shears** jrs@bas.ac.uk



Introduction

Sustaining a scientific leadership role for the UK in global affairs, as well as in the Antarctic, is a key part of the BAS mission.

We ensure that the UK Government, the Intergovernmental Panel on Climate Change and key decision-makers are scientifically well advised and address key areas of concern, such as global climate change, sustainable fisheries management, and protecting the Antarctic environment.

Polar View

BAS was awarded a major contract by the European Space Agency (ESA) to manage the Southern Ocean component of a new polar environmental information programme – Polar View. The programme operates in the Antarctic and Arctic, delivering a range of remote-sensing products and services free of charge as part of the Global Monitoring for Environment and Security programme being developed by ESA and the European Commission.

BAS manages a consortium of organisations from Canada, Denmark, Germany, Italy, Norway and the UK, which deliver the Antarctic services for Polar View. These initially focus on near real-time, satellite-based information about sea-ice conditions to assist ship operations. Initially, users of these services are national Antarctic science programmes and tour ships, with future potential interest from commercial shipping and fishing vessels operating in the Southern Ocean. In the current climate of high fuel prices and increasing concerns about operational safety, better information helps improve efficiency and safety for vessels navigating in sea ice. Following a very successful first season of operation, we are now improving the scope and delivery of services and expanding the range of users. Further information about the Antarctic services is available at www.polarview.aq.

Contact: **Dr Andrew Fleming** ahf@bas.ac.uk

Images: Above: *This European Space Agency Envisat radar image was processed by the Polar View programme to assist RRS* Ernest Shackleton *navigate in sea ice during its approach to Halley Research Station in 2006.* **Top Right:** *A wandering albatross and chick nesting on Bird Island, South Georgia.* **Centre Right:** *The 29th Antarctic Treaty Consultative Meeting was held in the UK for the first time in nearly 30 years.* **Far Right:** *Climate change threatens species in both the Arctic and Antarctic. These polar bears were photographed from* RRS James Clark Ross *during a NERC Arctic science cruise.*

The wandering albatross – a world-class conservation success

As part of our long-term monitoring programme, BAS scientists have counted the number of breeding pairs of wandering albatrosses at South Georgia annually since 1972. Over this time the population has declined by around 50%. Our data have shown that the problem lay not with breeding success but with incidental deaths as birds scavenge for food behind long-line fishing vessels. Satellite tracking data showed that albatrosses (males in particular) were foraging in the same areas as the fishery for Patagonian toothfish around South Georgia during the chick-rearing period.

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which regulates fishing around Antarctica, decided that the by-catch of albatrosses had to be addressed. BAS scientists worked closely with CCAMLR, fishers and fisheries managers to establish the scientific basis needed to implement workable solutions. As a result, albatross by-catch in the CCAMLR fishery has decreased from almost 6,000 in 1997 to 0 in 2006. Such outstanding success sets CCAMLR apart as a model for other fisheries commissions to follow, particularly as further tracking of albatrosses has revealed the areas under the control of other fisheries commissions where they are still being killed in large numbers.

Contact: **Dr Keith Reid** kre@bas.ac.uk

BAS plays key role in Edinburgh Antarctic Treaty Consultative Meeting

For the first time since 1977, the UK hosted the international Antarctic Treaty Consultative Meeting (ATCM), held in Edinburgh during June 2006. The annual ATCM provides the opportunity for the Treaty nations to discuss and agree how to manage activities in Antarctica, promote scientific research and protect the environment. Over 400 people from 50 nations attended the meeting in Edinburgh. BAS assisted the Foreign and Commonwealth Office (FCO) in all aspects of the planning, organisation and delivery of the ATCM.

The Edinburgh ATCM gave BAS the opportunity to showcase its world-leading science and logistics. Over 50 BAS staff were involved in the meeting in some way, many taking important roles in discussing major scientific policy issues. The Foreign Office Minister, Lord Triesman, paid particular tribute to BAS for our work in Edinburgh, which he considered fundamental to the success of the conference.

The ATCM was used as an opportunity to showcase International Polar Year 2007-08 (IPY). To commemorate and communicate IPY, one day of the ATCM was set aside to focus on its aims and objectives. After presentations and discussions, the Edinburgh Declaration on the International Polar Year was adopted. Senior BAS scientists working closely with diplomats from the Foreign and Commonwealth Office (FCO) drafted the Declaration and led the negotiations, which secured the historic agreement.

Contact: **Dr John Shears** jrs@bas.ac.uk

Present and future climate change

The Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical and socio-economic information relevant to the understanding of climate change, its potential impacts, and options for adaptation and mitigation. The Fourth Assessment Report 'Climate Change 2007' has now been published.

Professor David Vaughan of BAS was one of two co-ordinating lead authors on the chapter on Polar Regions (Arctic and Antarctic), an important part of the Working Group II report, 'Climate Change 2007: Impacts, Adaptation and Vulnerability'. In addition, many BAS staff contributed as authors or expert reviewers, particularly to the Working Group I Report, 'Climate Change 2007: The Physical Science Basis'.

A key conclusion of the IPCC report was that most of the observed increase in globally-average temperatures since the mid-20th century is very likely due to the observed increase in man-made greenhouse-gas concentrations. The report also pointed out the contribution of Antarctica and Greenland to future sea-level rise was very uncertain – a key focus of the current research programmes.

Contact: **Prof Alan Rodger** asro@bas.ac.uk

Protecting the environment

Contact: **Rachel Clarke racl@bas.ac.uk**

Introduction

BAS is committed to delivering the GSAC science programme and its associated logistics with the minimum environmental impact.

We achieve this through the use of an environmental management system and environmental impact assessment and monitoring. We also maintain a leadership role in Antarctic environmental affairs through taking part in Antarctic Treaty Consultative Meetings and in Antarctic Treaty inspections.

Certification to ISO 14001 Environmental Management System

In March 2007, BAS was awarded certification to ISO 14001, the internationally recognised standard for environmental management systems. The accreditation covers our Cambridge site and the ships RRS *James Clark Ross* and RRS *Ernest Shackleton*. The standard requires an organisation to demonstrate its commitment to continuous improvement by identifying its most significant impacts, setting targets to improve environmental performance, and carrying out regular senior management reviews of its environmental performance. The accreditation process was undertaken over a period of nine months, and included four audits from the British Standards Institute (BSI). BAS received certification without any non-conformities.

Contact: **Rod Downie rhd@bas.ac.uk**

Certificate of Registration

ENVIRONMENTAL MANAGEMENT SYSTEM - ISO 14001:2004

This is to certify that:

British Antarctic Survey
High Cross
Madingley Road
Cambridge
CB3 0ET
United Kingdom

Holds Certificate No: EMS 503966

and operates an Environmental Management System which complies with the requirements of ISO 14001:2004 for the following scope:

The operations at the BAS site at Cambridge and the R.R.S. Ernest Shackleton and the R.R.S James Clark Ross. These include administration, operational planning, logistics, IT, communications, laboratories, freezer facilities, garages and the mechanical and electrical workshops.

For and on behalf of BSI:

Managing Director, BSI Management Systems (UK)

Originally registered: 26/02/2007 Latest issue: 26/02/2007 Expiry Date: 25/04/2010

Page: 1 of 2

BSI Management Systems

Images: Above: *The ISO 14001 Environmental Management System certificate.* **Top Right:** *A BAS Twin Otter at a fuel depot in the Antarctic Peninsula.* **Centre Right:** *This dead rat was washed up at Bird Island, sparking an urgent response from the BAS environmental team and Bird Island staff.* **Bottom Right:** *Plankton and other marine species may be being transported from other regions to the Antarctic in ships' ballast water.*

Innovation in waste management

During his visit to Rothera in January 2006, Professor Howard Dalton (Chief Scientist, DEFRA) said he was 'seriously impressed' by the BAS waste management strategy. Managing waste at remote locations requires innovative solutions. The Environment Office, together with BAS Operations Group, have worked with an engineering firm in Cambridge to develop a portable hydraulic drum crusher that can be broken down into its component parts, loaded onto a Twin Otter and flown to remote field depots to crush empty drums.

A Twin Otter would normally carry 20 intact empty drums or 50 to 60 drums if crushed. As an example, the removal of 110 crushed waste fuel drums from a typical fuel depot could save 17,000 litres of aviation fuel from aircraft operations (costing about £50,000). In successful trials in January and February 2007 at Berkner Island and at Bluefields Depot, 80 empty drums were crushed by a four-person team in six hours using the prototype drum crusher.

Contact: **Rod Downie rhd@bas.ac.uk**

Bird Island remains rat-free

Although rats are common on the South Georgia mainland, they have never been found on Bird Island, where they could have a disastrous impact on the local bird population. BAS has implemented extensive measures to prevent rats getting onto Bird Island.

In July 2006, a dead female rat was found near the jetty on Bird Island. Bait stations and chew sticks deployed around the station did not show any sign of rats. An autopsy showed the rat was a non-pregnant female with tussock grass in its stomach, suggesting it was from the local area. But had the rat been washed ashore from the mainland, 500m away across Bird Sound, or had it come from Bird Island itself? To answer this crucial question the whole island was checked for rats during a nine-week monitoring programme, which fortunately showed no evidence of their presence. Monitoring will continue indefinitely.

Contact: **Dr Kevin Hughes kehu@bas.ac.uk**

Antarctic Treaty nations accept guidelines on ships' ballast water management

There are widespread concerns about invasive marine species being transported into Antarctic waters, and between biologically distinct regions within the Antarctic Treaty Area, through ships' ballast water. Experts from BAS, together with the Maritime and Coastguard Agency (MCA), have drawn up draft guidelines on ballast water management for all vessels entering Antarctic waters, based on scientific research.

These were accepted by the Antarctic Treaty Committee on Environmental Protection in June 2006 and have been passed to the International Maritime Organisation (IMO) to be extended to all shipping activities through IMO resolution.

Contact: **Dr Kevin Hughes kehu@bas.ac.uk**

Science in society

Contact: **Linda Capper MBE** lmca@bas.ac.uk

Introduction

Explaining our science in accessible language is vital to enable informed public dialogue about global environmental issues.

Media relations, publications, events, exhibitions, educational resources, the internet and a public information service are the main means of achieving public engagement and dialogue about BAS science.

Hitting the headlines

Many people get information about science and technology from newspapers, TV and radio. The BAS press team regularly manage media visits to Cambridge and, during 2005-06, held discussions with 13 television documentary producers to develop programmes featuring Antarctic research – mainly on climate change.

Each year, as part of its overall science communication public engagement activities, BAS supports Antarctic media visits. In January 2006, television history was made with the first live news programmes broadcast from Antarctica. Over eight million UK viewers watched three daily special reports by ITN News science editor Lawrence McGinty and news reader Mark Austin. 'The Big Melt' series focused on the science of climate change from BAS's Rothera Research Station. In addition, selected reports shown on CNN international reached over 200 million viewers worldwide.

Contact: **Athena Dinar** amdi@bas.ac.uk

Images: Above: *ITN News anchor Mark Austin presented a series of live news broadcasts from Rothera Research Station.* **Top Right:** *Posters to promote 'Discovering Antarctica' were sent to all UK secondary schools.* **Centre Right:** *Over 5,000 people visited RRS* James Clark Ross *and HMS* Endurance *during the weekend of the Edinburgh Antarctic Treaty Consultative Meeting.* **Bottom Right:** *Logo for International Polar Year 2007-08.*

For more information please visit our website: **www.antarctica.ac.uk**

Antarctica in the classroom

A new online, interactive teaching tool was launched in June 2006. Aimed primarily at teachers and students of Key Stages 3 and 4 Geography (GSCE), the resource covers the main Antarctica-based curriculum topics, including science and geopolitics.

www.discoveringantarctica.org.uk was developed jointly by BAS, the Royal Geographical Society and the Foreign and Commonwealth Office (FCO) Polar Regions Unit. Designed to be as interactive as possible, 'Discovering Antarctica' has a host of interactive activities, video and audio clips, images to download, factsheets and links. A rigorous teacher-testing process during its development kept the content relevant for teachers, and the site is structured around lesson plans and its usefulness in the classroom. With thousands of visitors and downloads each month, the site has received excellent feedback from the educational press and teacher forums. It was nominated for a Childrens' BAFTA award for secondary education and an international Webby award for education. It also received special commendations from the Geographical Association and Scottish Association of Geography Teachers.

Contact: **Jamie Oliver** jaol@bas.ac.uk

Discover Antarctica!

In June 2006, the UK hosted the Antarctic Treaty Consultative Meeting in Edinburgh. To celebrate, the Foreign and Commonwealth Office asked BAS to co-ordinate an engaging programme of public events entitled 'Discover Antarctica!'

'Discover Antarctica!' represented a major opportunity to communicate key messages about the excitement and importance of Antarctic science, and the UK's leading role in Antarctica. By building an effective network of 25 partners in Edinburgh and beyond, and supporting them with BAS in-house PR and marketing, 'Discover Antarctica!' succeeded in attracting more than 12,000 visitors from various target groups to the two-week festival of 24 events.

Visitors experienced Antarctica through film, art, performances, public lectures and hands-on activities at museums, galleries and science centres across Edinburgh. Two 'ice ships', BAS's Royal Research Ship *James Clark Ross* and the Royal Navy's HMS *Endurance* were berthed at Leith and transformed into a floating Antarctic exhibition during the middle weekend of the programme.

Contact: **Linda Capper MBE** lmca@bas.ac.uk

International Polar Year

As Co-Chair of the International Polar Year 2007-08 (IPY) Planning Committee, Professor Chris Rapley CBE was instrumental in pulling together leading scientists for the largest co-ordinated international scientific effort for 50 years. He engaged the International Council for Science (ICSU) and the World Meteorological Organisation (WMO) as co-sponsors. The UK launch of IPY, one of a series of launch events around the world, took place on 26 February 2007, at the Royal Society, London, in the presence of HRH the Princess Royal.

From ice sheets and space science to Arctic communities and the deep-sea animals of the Southern Ocean, IPY includes more than 200 Arctic, Antarctic and bi-polar projects and harnesses the skills of 50,000 people – including scientists, teachers, students and support staff – from 63 nations. In addition to our own core science programme, scientists from BAS are involved in 50 IPY-endorsed projects, half of which are bi-polar, contributing to around 50% of the UK effort. This contribution makes BAS by far the biggest UK player in IPY.

Working together with national and international partners, BAS scientists will help create a unique snapshot of the state of our planet at the start of the 21st century. Most importantly, we will help IPY leave a legacy with profound implications for the future. The observing networks and international partnerships we have established will continue to broaden and deepen our understanding of how the Earth functions.

Contact: **Dr Cynan Ellis-Evans** jcel@bas.ac.uk

Health and safety

Contact: **Robert Culshaw MVO** rocu@bas.ac.uk

BAS attaches the utmost importance to managing the health and safety aspects of all its operations. We remain committed to eliminating or reducing health and safety risks to meet our legal obligations and to ensure the welfare of our staff. We have continued to refine the safety management system introduced three years ago; this year we incorporated environmental management.

During the year, we gained certification to OHSAS 18001, the occupational health and safety management standard. We created a Safety, Health and Environment (SHE) Management Team and trained a team of internal auditors to support the continuing certification to both the health and safety and the environmental standards. We met all the targets we set last year, including a significant reduction in slips, trips and falls, which were the biggest cause of accidents in the previous year. We recorded no accidents serious enough to be reported to the Health and Safety Executive. The BAS Board thoroughly reviewed our safety management system and also monitored our health and safety policy and performance in detail through a standing item on the agenda of the monthly Board meetings.

We have continued to consult our staff on changes to the management of health and safety through consultative committees on all our stations and ships. We encourage staff to become involved in health and safety and welcome constructive comments. We operate an open system of health and safety management so that the minutes of all SHE Management Team meetings and consultative committee meetings are published on our internal website with our policy, procedures, guidance and summaries of accident reports and investigations.

Images: Above: *Loading cargo into the hold of RRS* Ernest Shackleton *at Mare Harbour, Falkland Islands.*
Right: *BAS featured on the cover of 'People Management' magazine in July 2006.*

For more information please visit our website: **www.antarctica.ac.uk**

Recruitment and career development

Contact: **Fiona Brazil** **fibra@bas.ac.uk**

2006 was a busy and challenging year for the BAS Personnel team. An initiative to set up a joint Research Council Service Centre for 'back office functions' involved a lot of input to the NERC Human Resources (HR) project team.

This work will carry on in earnest for the next year or so and will also include development of a new HR function. In 2006, there were also important changes in UK employment legislation on age discrimination and public sector retirement, which meant training for staff involved in recruitment and selection, and changes to internal policies. BAS is benefiting from more fluid retirement periods by being able to retain key skills and experience in specialist roles.

Successes and initiatives of the year included a new participatory bonus scheme for Antarctic staff, a staff survey with the highest level of coverage and response across all divisions achieved to date, and the launch of our fully online recruitment management system. This system has transformed how we manage the recruitment of around 90 staff a year. 95% of our applications are now sent electronically and can be assessed and processed online. 5,000 people have also signed up to a new BAS 'jobs by email' service – a significant source of potential candidates. The new system is flexible, allowing campaigns to be tailored according to need, and much greener as it uses 90% less paper.

The BAS Personnel team continues to raise its profile in the HR community. BAS was featured on the front cover of 'People Management' magazine (published by the Chartered Institute of Personnel and Development – CIPD) in July 2006 and we were invited speakers at the national CIPD conference in October on the issues surrounding remote management.

INVESTOR IN PEOPLE

British Antarctic Survey today

Contact: **Linda Capper MBE** lmca@bas.ac.uk

Understanding Antarctica is an ever more important part of understanding Earth's changing environment.

Antarctica is a remote and frozen wilderness, yet offers a unique opportunity for science that addresses key global issues, such as changing climate, sea level and ecosystems. British Antarctic Survey (BAS), part of the Natural Environment Research Council, is a world leader in Antarctic research. Based in Cambridge, BAS is the UK's national Antarctic operator and maintains an active and influential role in Antarctic affairs.

The current BAS science programme is planned on a five-year timetable and offers an unrivalled inter-disciplinary approach to polar science. Details of this programme, Global Science in the Antarctic Context 2005-2010 (GSAC), can be downloaded from the BAS website and are available in hard copy. The quality of the programme's content was assured through open competition and by independent, rigorous, international peer review. GSAC involves over 120 national and international collaborations.

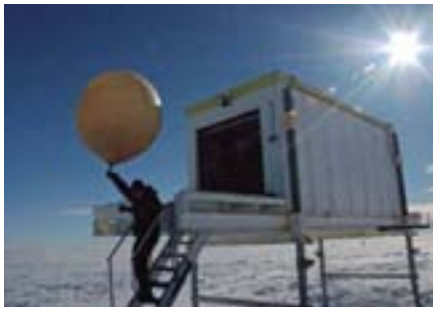
BAS operates five research stations in and around Antarctica (four year-round and one summer-only), has five aircraft and two ice-strengthened ships, RRS *James Clark Ross* and RRS *Ernest Shackleton*. BAS ships and aircraft are equipped with sophisticated technology and a range of specialist equipment, enabling them to carry out scientific research as well as logistical operations.

Each year BAS sends more than 350 staff, collaborators, contractors and visitors to Antarctica to work on over 70 science projects; at sea, on research stations or in the field. The logistics of undertaking science in the Antarctic in a safe and cost-effective way are challenging and complex. Detailed operational planning for each science season starts two years before, and is managed from BAS Cambridge.

To maintain and run self-contained research stations, ships and aircraft, as well as delivering world-class science and technology, our workforce has an exceptionally wide range of skills. We apply national standards of best practice in selecting staff through open competition, and then in managing and supporting their performance and development. Details of vacancies at BAS are listed on the BAS website.

Images: Above: *A remote BAS field camp on the Rutford Ice Stream, Antarctica.* **Top Right:** *BAS marine biologist during a dive close to Rothera Research Station, Adelaide Island, Antarctic Peninsula.* **Top Far Right:** *Bird Island Research Station in winter, Bird Island, South Georgia.* **Bottom Right:** *Releasing a weather balloon at Halley Research Station, Brunt Ice Shelf.* **Bottom Centre Right:** *Transporting skidoos via Sno-cat during relief of Halley Research Station, Brunt Ice Shelf.* **Bottom Far Right:** *RRS* James Clark Ross *berthed at Rothera Research Station.*

For more information please visit our website: **www.antarctica.ac.uk**



Facts and figures

UK staff, based at BAS Cambridge

- 189 scientists contributing to the BAS science programme
- 49 scientific support staff, including Directorate
- 212 staff in the Administration and Logistics Division, technical, aircrew and ships

Overwintering Antarctic staff

- 22 at Rothera Research Station
- 18 at Halley Research Station
- 9 at King Edward Point Research Station
- 4 at Bird Island Research Station

Ships

- Two complements of 27 crew on RRS *James Clark Ross*
- Two complements of 21 crew on RRS *Ernest Shackleton*
- 93 scientific and technical staff working on RRS *James Clark Ross*, RRS *Ernest Shackleton*
- 197 staff carried to and from Antarctic destinations on RRS *James Clark Ross*, RRS *Ernest Shackleton* and HMS *Endurance*

Summer participants in Antarctic operations

- 143 at Rothera, including those in transit to Halley
- 33 at Halley
- 15 at Signy
- 13 at Bird Island
- 8 at King Edward Point
- 29 contractors at Rothera
- 22 in the field and on various projects off HMS *Endurance* and on South Georgia

Antarctic Funding Initiative

- 76 scientists supported

Publications

- 204 peer-reviewed research papers listed in the ISI database of high-quality journals

Education and Training

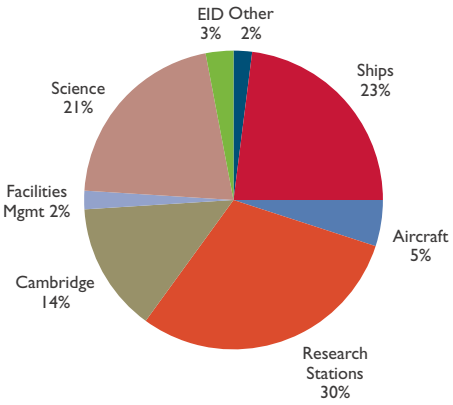
- 54 registered for higher degrees (co-supervised by BAS staff)

Expenditure

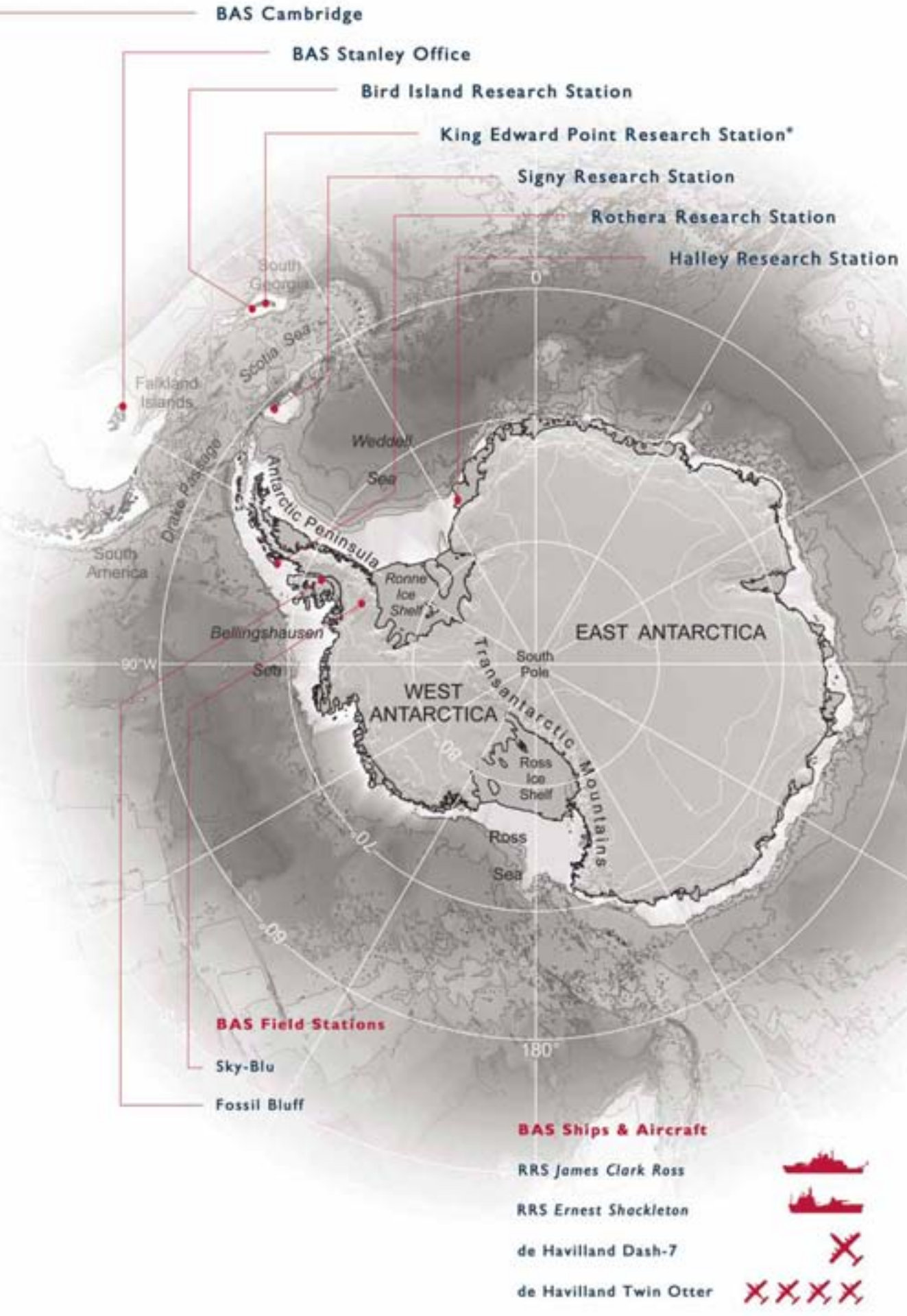
- Total budget 2006-07: £54 million (£41 million running costs, £13 million capital spend).

Expenditure

Analysis of Expenditure 2006-2007



BAS offices and research stations



*Run on behalf of the Foreign and Commonwealth Office and the Government of South Georgia and South Sandwich Islands.

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Feedback and further information

We welcome your feedback and comments on this document. These should be addressed to:

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