Antarctica and Climate Change

The Antarctic scientific community is well aware of the possibility that rising CO_2 levels may be accelerating global warming, perhaps leading to the disintegration of ice shelves and their associated ice sheets, and a consequent rise in sea-level. Sea level would rise 6 meters if the West Antarctic Ice Sheet were to melt.

The international body responsible for the co-ordination of scientific research in Antarctica (SCAR – the Scientific Committee on Antarctic Research) has just reorganised its scientific research programme to focus on climate change and its effects. The scientific community agreed to focus its attention and effort for the next few years on five major scientific research programmes, all directed in one way or another on determining the effects of climate change on Antarctica, and on elucidating Antarctica's role in the global climate system. The five programmes were just approved by the national delegates representing the 32 SCAR Member countries meeting in their 28th session during the week of October 3-8, 2004, in Bremerhaven, Germany. Funding for these programmes will begin early in 2005. They will all make significant contributions to achieving the goals of the International Polar Year in 2007-2008.

Details of the programmes follow. Paragraphs in bold describe the 5 programmes. Other paragraphs provide background detail.

1. The Antarctica and the Global Climate System (AGCS) programme will investigate how the atmosphere and the ocean connect the climate of the Antarctic to that of the rest of the world. It will use records of atmospheric and oceanic conditions, and the climate signals held within ice cores, along with satellite data and the output of global and regional coupled atmosphere-ocean climate models, to understand how the present climate system works, and how it is affected by human activities, and to develop forecasts to 100 years in the future. It will tell us how signals of tropical and mid-latitude climate variability reach the Antarctic, and how polar climate signals are exported northwards.

Background Information
Fifty years ago, at the time of the International Geophysical Year (1957-58) the Antarctic was thought of as rather isolated from conditions at more northerly latitudes, but studies using the new observational data sets and sophisticated Atmosphere-Ocean General Circulation Models show that Antarctica is closely coupled to the global climate system. Heat arriving at the equator from the sun moves north and south towards the poles. The main sink for this heat in the southern hemisphere is Antarctica and its surrounding Southern Ocean; 80% of the heat is carried by the atmosphere, 20% by the ocean. The Antarctic Circumpolar Current (ACC), which is four times as big as the Gulf Stream, inhibits the poleward flux of heat via the ocean and so plays an important role in keeping the continent cold.

Antarctica is connected to the global climate system through important long-range links known as teleconnections. Warm North Atlantic Deep Water moving south at depths of 2000-3000 meters, is 'balanced' by the northward flow of cold Subantarctic Mode Water near the surface, and Antarctic Intermediate Water further down, and Antarctic Bottom Water at the bottom. The North Atlantic Deep Water and the Antarctic Bottom Water are major constituents of the so-called 'thermohaline conveyor belt' that keeps the ocean oxygenated and regulates the Earth's temperature. Understanding how the 'conveyor' works globally demands that we understand ocean processes in the Antarctic.

Investigating the links between Antarctica and the rest of the world has shown recently that the El Niño events that arise in the tropical Pacific bring cold, dry conditions to the Antarctic Peninsula, and warmer, temperatures and higher levels of precipitation over the coastal region of the southern Amundsen Sea off West Antarctica.

It is not obvious why there is rapid winter season warming on the western side of the Antarctic Peninsula, where temperatures are rising faster than anywhere else in the southern hemisphere. This region has also experienced the disintegration of a number of floating ice shelves. This programme aims to investigate the causes.

2. The Antarctic Climate Evolution (ACE) programme is a complementary cross-disciplinary investigation of the ancient climate and glacial history of Antarctica. It will collect information on past climate change, and integrate it with ice sheet and climate models to identify the processes that govern Antarctic climate change, and those which feed this change back around the globe. In addition it will provide detailed case studies of past climate changes, against which models of future change in Antarctica can be tested. The end result will be forecasts of how Antarctic climate is likely to respond to future global change.

Background Information

Antarctica has been glaciated for some 34 million years, but its ice sheets have fluctuated considerably, driving changes in global sea level and climate throughout the Cenozoic Era. Variations in ice-volume can change global sea levels by tens of meters or more, and alter the capacity of ice sheets and sea ice to act as major heat sinks or insulators. So it is important for us to determine the scale and rapidity of the response of large ice masses and associated sea ice to climatic forcing. For that reason the Intergovernmental Panel on Climate Change (IPCC) has called for an assessment of the stability of the cryosphere (the ice, snow and permafrost system) in the face of rising CO_2 levels.

This programme will link geophysical surveys and geological studies on and around the Antarctic continent with ice-sheet and climate modelling experiments. It will determine both climate conditions and climatic changes at selected times in the past. These will include periods of unusual warmth and cold during the glaciations of the last 2 million years, and other periods

in the more distant past when global temperatures were several degrees warmer than today, along with older cooling events.

The programme will also examine (i) the evolution of the Antarctic landscape, to provide climatic and environmental constraints at different times; (ii) the influence of tectonics on the behaviour of the ice sheets; and (iii) the influence of plate tectonics on the opening of gateways for ocean currents and their role in climate change.

3. The Evolution and Biodiversity in the Antarctic (EBA) programme aims to determine how environmental change influences the properties and dynamics of Antarctic and Southern Ocean ecosystems, and to predict how organisms and communities may respond to current and future environmental change. This ambitious programme integrates work on marine, terrestrial and freshwater ecosystems in a manner never before attempted. By comparing the outcome of parallel evolutionary processes over the range of Antarctic environments, fundamental insights can be obtained into evolution and the ways in which life responds to change, from the molecular to the whole organism level and ultimately to the level of an entire biome.

Background Information
Geographic isolation is a feature that makes the Antarctic an important natural laboratory for evolutionary work. The extreme nature of the physical environment there allows us to probe evolutionary adaptation in rare detail. Important Antarctic discoveries such as the biosynthesis and evolution of antifreeze compounds in fish and terrestrial and freshwater invertebrates are now part of standard textbooks. The combination of isolation and climate change has lead to a biota rich in endemic taxa, and to a strong contrast between marine and terrestrial and freshwater biotas, from apparently simple ecosystems on land to highly diverse marine benthic systems on the continental shelves and in the open waters of the Southern Ocean. We seek to understand the reasons behind these striking differences.

Warming on the western side of the Antarctic Peninsula is affecting its ecosystems, and so will influence future biological diversity. Many Antarctic species are susceptible to this change, especially offshore. Examining these changing ecosystems will contribute to an understanding of evolutionary processes relevant to all life on Earth.

Powerful insights into the evolutionary history of the Antarctic biota are now being gained from modern molecular techniques, allowing divergence times between taxa to be dated, and enabling biological changes to be related to climatic or tectonic events. Results reveal a number of cryptic species, hinting at a vast reservoir of undetected diversity. The programme will use molecular techniques for potent insights into the evolutionary history of the Antarctic biota.

Molecular studies will also help to establish the patterns of gene flow into and out of the Antarctic, and the consequences for population dynamics.

They will enable us to examine among other things the role of humans as vectors; the differences between the genetic structure of populations of Antarctic organisms and those elsewhere; to what extent such differences reflect past evolutionary history; and the role of advective processes in the gene flow and population structure of Southern Ocean organisms.

Work on biodiversity in the Antarctic region has concentrated in certain geographical areas, and many important areas and habitats remain almost completely unexplored, such as the Amundsen and Bellingshausen Seas and many areas of east Antarctica, including continental nunataks and some ice-free oasis on land. The programme will focus on these almost completely unknown areas. It's marine activities will contribute to the Circum-Antarctic Census of Marine Life, which will make a significant contribution to global Census of Marine Life.

4. The programme on Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR) focuses on that part of outer space near-Earth (known as geospace), where the solar wind interacts with the Earth's outer atmosphere, ionosphere and magnetosphere. Manifestations of that interaction, like the aurorae, are apparent primarily through the Polar Regions. Since the International Geophysical Year of 1957-58, we have been able to describe many of the component parts of geospace. But important gaps remain in our understanding of the interactions. We need a deeper understanding of how energy is transferred from the solar wind into the geospace environment; this is impossible without simultaneous consideration of various geophysical phenomena occurring over both the north and south Polar Regions. Among other things we need to know more about the dynamics of the Earth's magnetosphere during geomagnetic storms caused by extreme solar wind conditions. Much remains to be learned about how the solar forcing can affect the neutral atmosphere, especially at high latitudes where the solar wind-driven processes are most influential. We also need to understand more about the possible influences of the changing sun on polar climate and weather. The goal is to specify and predict the global state of geospace and, hence, "space weather". "Space weather" poses a potential hazard to the space-borne and ground based electronic and communication technologies on which society depends.

Background Information
It is because the Earth's magnetic field focuses the effects of solar-terrestrial interactions into the polar regions, and Antarctica has a land mass on which to base instruments at high latitudes, that Antarctica offers an excellent platform from which to observe the vast region of geospace (extending over millions of kilometres from the planet). Yet Antarctica has been under-exploited for this purpose relative to the Arctic. Recently there has been substantial investment by a number of countries in sophisticated instrumentation providing a grid of instruments over much of the South Polar Region. Further instruments are to be installed in the near future that will provide coverage equal to and in some cases better than that in the

north polar region. There is now the capability to investigate conjugate relationships between the two hemispheres at an unprecedented level of detail. ICESTAR is designed to exploit this capability. One of the main results will be the enhanced visibility, accessibility, and usability of the Antarctic geospace data to enable whole-system geospace research, including interhemispheric and ground-space studies, and new cross-disciplinary research on teleconnections between the upper and lower levels of the atmosphere – in which ICESTAR will link up with SCAR's climate programmes.

Taking a bi-polar approach is important to eliminate the effects of seasonal variations and north-south asymmetries that are not yet accurately understood, and to enable us to asses the total energy input into the upper atmosphere from the solar wind–magnetosphere coupling. Most of the current geospace models are developed only from northern hemisphere observations, and assume an (unlikely) symmetrical response of both the northern and southern Polar Regions to magnetospheric disturbances. Knowing the similarities and differences between the northern and southern polar upper atmospheres will enable us to fully understand how the entire planet responds to the varying influence of the solar electromagnetic radiation and of the solar wind, thereby helping to improve forecasts of their effects on the Earth's surface.

5. The Subglacial Antarctic lake Environments (SALE) programme will provide exciting opportunities to examine biodiversity and evolutionary responses in the subglacial lakes that are now known to be common in Antarctica. These isolated systems are analogues for life on early Earth and on other planetary bodies. Novel responses to the environment are likely to be found in these lake systems, which are important end-members for biodiversity and polar community dynamics. SALE will thus provide one end member system for the EBA programme. In addition, SALE will contribute to the goals of SCAR's climate research programmes. The palaeoclimatic record contained in subglacial lake sediments will provide new information on climate history from the interior of the continent. In addition, the ice sheet history quantified through numerical modelling in the SCAR climate programmes will offer important constraints on the formation and development of subglacial lake environments.

SCAR's contribution:
SCAR is the leading independent organisation for facilitating and coordinating Antarctic scientific research, and for identifying issues emerging from greater scientific understanding of the region that should be brought to the attention of policy makers. Its primary goal is to initiate, develop, and coordinate high quality international scientific research in the Antarctic region and on the role of the Antarctic region in the Earth system. SCAR is well placed to lead these 5 research programmes, as it brings together scientists from all the nations with major Antarctic research programmes. SCAR's new structure of Standing Scientific Groups provides a forum in which scientists with the necessary skills to undertake such cross-

disciplinary programmes of research can come together and make plans. SCAR also provides strong links into the planning of Antarctic operations through its close association with the Council of Managers of National Antarctic Programmes (COMNAP).

Through its Scientific Research Programmes and related activities SCAR will increasingly endeavour to support and encourage the next generation of Antarctic scientists in a variety of ways. SCAR's new biennial Open Science Conference, which attracted 1000 attendees at its unveiling in Bremen (July 26-28, 2004), provides an important avenue through which young scientists can share their results. Results of SCAR's scientific activities are largely available through the SCAR web site or SCAR contact points, in keeping with the principle that data and information should be shared to ensure maximum utility. SCAR's main Scientific Research Programme leaders will encourage young scientists to take part in their workshops and to participate in exchanges between relevant institutions.

For further details see the SCAR web site at http://www.scar.org