



A History of SCAR, 2004-2010

by

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Note: This History was originally drafted as a chapter of the SCAR 50th Anniversary Book (Walton and Clarkson, 2011), for which a much condensed text was required. To facilitate future studies of SCAR history it was felt that it would be beneficial to make the full version of the text available to the SCAR community, hence the decision to make it a SCAR Occasional Publication. The review covers the period January 1 2004 to April 2010, so does not include activities involved in the SCAR presentations to the Antarctic Treaty Consultative Meeting of 3-14 May 2010 (Punta del Este, Uruguay) or in the biennial XXXI SCAR meeting of July 30-August 11 2010 (Buenos Aires, Argentina).

The text (and any opinions it may contain) is the product of the author; it does not constitute an officially approved SCAR document, nor does it represent an endorsed SCAR position. At the time of writing the author, SCAR's first Executive Director, had retired from SCAR (April 2010) and was operating as an Emeritus Associate of the Scott Polar Research Institute.

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1. Introduction

By 2004 it was plain that continued global warming was having its most significant effects on the polar regions, where ice was melting and biodiversity was increasingly under threat – especially in the case of organisms adapted to narrow temperature ranges. The prospect of melting ice and rising seas and their attendant effects on people, animals and plants had led to plans being set in train for an International Polar Year (IPY) for 2007-2008 during which baselines could be established, change could be monitored or detected, predictions could be made of future change, and new frontiers could be explored. The IPY would be the largest internationally coordinated research programme in 50 years, and was a direct descendent of the International Geophysical Year (IGY) (1957-58) in which SCAR was created to coordinate Antarctic scientific research.

With its recent reorganisation, which had been stimulated by a comprehensive review in the year 2000, SCAR was well positioned in 2004 to make exciting and important new contributions to the study of the polar regions and to the IPY through its ability to pull together teams of researchers to work on programmes of pan-Antarctic scale that were beyond the scope of any one country. SCAR had, of course achieved great things in the course of its almost 50 year history to that date (e.g. SCAR 2007), but something more was needed to keep it at the forefront of scientific discovery. The review had advised, and SCAR had agreed, that significant focus was needed – efforts must not be spread so thinly in the future as they had been in the past if SCAR was to maintain and enhance its position as the authoritative leader of scientific research in and around Antarctica. With the growth of interdisciplinary Earth System Science it was time for SCAR to show how Antarctic processes contribute to the working of the Earth System, and vice versa; how the south polar environment is influenced by human activities originating both within and outside the region; and what needed to be done to safeguard the environment.

It was not only SCAR's review that had called for change. SCAR is an Interdisciplinary Body of the International Council for Science (ICSU), and in reviewing the performance of all of its environmental bodies, ICSU's 2003 *“Report on Environment and its Relation to Sustainable Development”* concluded that *“The importance of SCAR has increased over the years with greater understanding of the pivotal role of the Antarctic in the Earth system and its numerous connections with other physical and biological elements including space weather and Sun-Earth interactions. Antarctic science therefore has global relevance, whether in tracking the history of the atmosphere through ice-core analysis over the last half-million years, in determining levels of pollution (e.g. heavy metals, organic compounds) and their impacts, and ultimately in exploring life forms in subglacial Lake Vostok.”* The Report went on to note that SCAR was in the process of a reform, and recommended that *“These reforms should lead to better cooperation with other groups and institutions, particularly those within the ICSU family.”*

One of the first responses to the review had been to restructure the organisation into three Standing Scientific Groups (SSGs) - for the Life Sciences (SSG-LS), the Geosciences (SSG-GS) and the Physical Sciences (SSG-PS), under each of which would be a suite of Action Groups to address issues demanding fast attention over a short time span, Expert Groups to address issues of a more permanent nature, and a small number of substantial Scientific Research Programmes (SRPs), which would

carry out scientific research on major strategic scientific questions of global scientific interest, some of them with considerable socio-economic significance. These programmes would be major flagship projects lasting 6-8 years and would get the bulk of the scientific funding.

The basic groundwork had thus been set, but a fully comprehensive response to the review demanded the development in 2004 of a Strategic Plan to set out the vision, mission and objectives of the organisation for the next 3 SCAR cycles, from 2004-2010, to guide decision making and to define SCAR's new operating procedures, which would include employment of an Executive Director to steer the organisation, and a biennial Open Science Conference to reach out to the wider community. Outlining that Strategic Plan would be a primary task for the Executive Director called for by the review committee.

Following interviews in Cambridge in August 2003, I was appointed to the new post of Executive Director. I was due to retire in April 2004 from the post of Director of the Global Ocean Observing System (GOOS) Project Office within UNESCO's Intergovernmental Oceanographic Commission (IOC) in Paris. It was hoped that my broad science background in marine geology and oceanography in government, academia and industry could be valuable in developing SCAR's scientific research programmes, and that my experience of presenting marine science to policy makers at the intergovernmental level in UNESCO could help SCAR present its scientific advice to Antarctic Treaty Parties in a favourable way. I began working for SCAR part-time from 1 January 2004, and full-time on 1 April 2004.

Given my oceanographic background it should be no surprise that I focused initially on developing SCAR's re-engagement with oceanography (SCAR had handed over responsibility for oceanography to SCOR in 1980). It should also be no surprise, given my involvement at the intergovernmental level in the development of systems for observing and detecting climate change, that I began to promote research between SCAR and its potential partners on climate change and its effects in the Antarctic, and on the development of observing systems related to that change.

A first task was to draft the Strategic Plan for 2004-2010 (SCAR, 2004), which was produced for the Delegates at XXVIII SCAR (Bremerhaven, October 2004). They agreed that the Vision, Mission and Objectives of the organisation were as follows:

The Vision: *"To establish through scientific research and international cooperation a broad understanding of the nature of Antarctica, the role of Antarctica in the Earth System, and the effects of global change on Antarctica."*

The Mission: *"To be the leading independent organization for facilitating and coordinating Antarctic research, and for identifying issues emerging from greater scientific understanding of the region that should be brought to the attention of policy makers"*.

The five Main Objectives for achieving the mission were agreed to be:

- *to initiate, develop, and co-ordinate high quality international scientific research in the Antarctic region, and on the role of the Antarctic region in the Earth system;*
- *to provide objective and independent scientific advice to the Antarctic Treaty Consultative Meetings and other organizations on issues of science and conservation affecting the management of Antarctica and the Southern Ocean.*

- *to facilitate free and unrestricted access to Antarctic scientific data and information;*
- *to develop scientific capacity in all SCAR Members, especially with respect to younger scientists, and to promote the incorporation of Antarctic science in education at all levels;*
- *to communicate scientific information about the Antarctic region to the public.*

In developing the processes and structures to reach these main objectives, two further cross-cutting objectives would underpin the way forward:

- *to improve the effectiveness, efficiency and flexibility of the structure, working mechanisms and practices of SCAR.*
- *to increase funding to match requirements, and to maintain a healthy funding stream.*

To meet these goals Delegates agreed that SCAR should take the following strategic approach:

- (i) To generate and coordinate innovative high quality international science programmes addressing key issues of global importance;
- (ii) To provide a forum for excellence in Antarctic science, and for debate on the big issues to which Antarctic science can contribute (climate change, ozone hole etc);
- (iii) To promote the establishment of regional and international scientific networks;
- (iv) To encourage multi-disciplinary cooperation in relevant fields;
- (v) To maintain a high level of collaboration within ICSU and with other international organisations, enhancing and where appropriate developing joint programmes to address specific topics, so as to increase the involvement of the wider scientific community in SCAR's work.

In addition, to meet the objective of facilitating free and unrestricted access to Antarctic scientific data and information, SCAR would:

- (i) encourage that maximum use is made of all available data;
- (ii) encourage the development and operation of appropriate mechanisms to facilitate the collection, storage, retrieval and dissemination of data and information for the common good; and
- (iii) encourage the community to ensure that these mechanisms are effective.

Delegates agreed through the Strategic Plan that to ensure that the scientific (user) community gets what it needs in the way of data and information would require the development of a SCAR data and information strategy.

As a final departure from the past, Delegates agreed in the plan to expand SCAR's geographical remit to include the Southern Ocean from the Antarctic coast north to the Subantarctic Front, to recognise the important role of the Antarctic Circumpolar Current in controlling Antarctic climate.

In the following text I explore the development of SCAR through the lens of the 5 main objectives of the strategic plan – science; advice; data; capacity building; and communication.

2. Background to Development of the Science Programme

Despite a century of scientific investigation of Antarctica and its surrounding Southern Ocean, in 2004 our knowledge of Antarctic processes and their role in the Earth System was still in its infancy, due in large part to the remoteness of the region and the hostile conditions that prevail there, which make observation difficult. Increasing knowledge of what is there and understanding of why it is so are necessary first steps in being able to develop and apply advanced numerical models of the kind that will enable us to predict with increasing accuracy how the region may change in the future in response to global warming, and what the effect of change in Antarctica may be on the rest of the world. SCAR's strategy for scientific research to raise our understanding of Antarctic processes to a new level was based on the following analysis of key scientific issues.

A pressing scientific and societal requirement was the full understanding of the Earth's climate system, which is needed to underpin accurate forecasts of climate change. This required understanding Antarctica's role in the global climate system, which in turn required comprehensive observation and analysis of the roles of the Antarctic atmosphere, ocean and cryosphere (comprising snow, ice and permafrost) in that system both now and in the past. Antarctica's crucial role was highlighted by the observation that the many rises and falls of sea-level that have characterised the past few millions of years have been controlled largely by the melting or growth of the Antarctic ice sheet, which locks up 70% of the world's fresh water. Currently all aspects of the climate system in Antarctic are grossly under-sampled. Yet it is clear that the global warming that is affecting most of the surface of the Earth is affecting at least parts of Antarctica, as could be seen from the break up of ice shelves and the shrinkage of sea ice in West Antarctica and the Antarctic Peninsula region in recent years. Despite the importance of observations of climate parameters from the region, many more measurements of the atmosphere, ocean and cryosphere were required to provide the basis for accurate forecasts of both regional and global climate change, and for assessments of the state of the climate system by the Intergovernmental Panel on Climate Change (IPCC).

The Southern Ocean plays a key role in the global climate system, being the medium through which critical exchanges of heat, salt, carbon, oxygen and nutrients take place between the Antarctic region and the rest of the world. Along its northern margin, the Antarctic Circumpolar Current (ACC) – the world's largest ocean current, with a transport of around 130 million cubic meters per second (four times as much as the Gulf Stream) - acts as a thermal barrier between Antarctica and the tropics and helps to keep Antarctica cold. Forcing by westerly winds brings to the surface old deep water that originated in northern seas, which contains dissolved CO₂ and abundant nutrients and stimulates high productivity. Water sinking in the ACC carries nutrients north in Antarctic Intermediate Water to influence the biological productivity of the global ocean. At the coast, cold surface waters sink to form the Antarctic Bottom Water that oxygenates and cools the deep global ocean. These various processes link the poles together as well as the three main oceans – Atlantic, Pacific and Indian. Knowledge of these processes is now seen as critical to an understanding of global climate.

The Southern Ocean marine ecosystem is a complex product of the interaction of many key aspects of evolutionary history. Knowing how this ecosystem evolved will help to understand evolutionary pathways in many other parts of the world, especially the possible connection between the Antarctic deep-sea benthos and the benthic species in the other deep oceans. Understanding the Earth's biodiversity will be incomplete without comprehensive studies of the ways in which plants and animals have adapted to living in the cold environments of the south polar region, where the extreme conditions provide extra selection pressure leading to unique features of biochemistry and biology in endemic species.

Monitoring sea-ice is important not just because it plays a role in the climate system. Annual changes in sea-ice do much to control the extent of biological activity around Antarctica. The crevices and channels in sea ice house a multitude of small organisms, which contribute substantially to Southern Ocean productivity and interact with the pelagic and benthic subsystems.

Deep beneath the ice sheet, water has accumulated over millennia to form more than 200 subglacial lakes, one - Lake Vostok – the size of Lake Ontario. These lakes now appear to be part of an immense interconnected hydrological system that had previously gone unrecognised. Although the full extent and the interconnectedness of this major system are not yet fully known, the potential drainage systems identified are as extensive as large continental river basins. These environments are virtually unexplored and unknown. Sealed from free exchange with the atmosphere for possibly 10 to 35 million years, the sub-ice lakes may be analogues for the icy domains of Mars and Europa that hold the greatest promise for the presence of life beyond Earth.

Evidence from studies of the overlying ice sheet indicates that unique life-supporting ecosystems are likely locked within subglacial lake environments. Such life must have adapted to unique combinations of temperatures, pressures, gases, and carbon and energy sources. These settings may harbour specially adapted organisms and ecosystems. Lake sediments may contain unique records of ice sheet variability over the last few hundred thousand years, which could critically advance our understanding of ice sheet stability.

Much still remains to be learned about the geological history of Antarctica. There was a need to focus geological attention on particular areas that were still largely unknown, like the subglacial highlands of the Gamburtsev Mountains hidden beneath the East Antarctic Ice Sheet. There is no continent on Earth other than Antarctica that has a huge central mountain range for which an explanation in terms of plate tectonics does not exist. How did these features come to be there, and how did they influence the growth of the ice sheet?

Studies like these are essential to understand the history of motion of the Earth's lithospheric plates, and the tectonic processes taking place in and around Antarctica that are integral to our understanding of whole Earth evolution. In much the same way, geophysical observatories on Antarctica, such as those engaged in earthquake location, are integral parts of a global network of stations recording Earth properties. That network must be as complete as possible to provide maximum benefit.

Studies of the Antarctic atmosphere are essential for the forecasting of weather conditions, and to understand the chemical processes taking place high in the stratosphere above Antarctica that result in the ozone hole, creating conditions

potentially harmful to life in those and surrounding areas, and depleting stratospheric ozone levels globally.

Antarctica is one of the best places to study “geospace” the region where the Earth’s atmosphere interacts with the solar wind, a supersonic stream of charged particles emitted from the sun’s corona. Electrons and ions in the solar wind collide with atoms and molecules in the upper atmosphere, causing them to emit photons, forming the *aurora australis* and heating the upper atmosphere. The interaction of the solar wind with the Earth’s magnetic field also creates a wide range of other effects including geomagnetic storms, disruptions in short-wave radio communications, and power surges in long electricity transmission lines. Important gaps remain in our understanding of the interaction of the solar wind with the Earth’s protective outer layers – the magnetosphere and the ionosphere - especially under extreme solar wind conditions associated with geomagnetic storms and with mass ejections from the sun’s corona. Full understanding of the physics of “geospace” requires coordinated observations in both the Arctic and the Antarctic.

Antarctica is also one of the best places in the world from which to study the cosmos, because the skies above the Antarctic plateau are the coldest, driest and most stable on the Earth. This permits observations of extraordinary sensitivity to be made across the electromagnetic spectrum from the near ultra-violet to the millimetre wavebands. The combination of great sensitivity and clarity of vision makes Antarctic observatories strong candidates for exploring one of the most challenging and exciting frontiers in science, the detection of Earth-like planets in the Galaxy. In addition, conditions are favourable for the construction of telescopes capable of detecting neutrino emissions from individual astrophysical objects. Antarctica is a prime location for the observation of cosmic rays, because proximity to the magnetic pole allows rays of lower energy to penetrate to the ground more readily than at mid-latitude locations.

3. The SCAR Science Programme

Everything SCAR does, and how SCAR is perceived as an organization, is rooted in the quality and timeliness of SCAR's scientific portfolio. Even SCAR's advice to the Antarctic Treaty System can only be effective if SCAR is scientifically strong. To ensure that SCAR maintains a high quality scientific portfolio, its Scientific Research Programmes (SRPs) are peer-reviewed every 4 years by the wider community. Internal assessments of SCAR's scientific portfolio are carried out annually by SCAR's Executive Committee (EXCOM) – comprising the SCAR President, Vice-Presidents and Executive Director, with advice from the Chief Officers of SCAR's various Standing Committees - and biennially by the SCAR Delegates, as the basis for planning and budgeting and to ensure continuous improvement. Renewal is essential to the continuing health of SCAR, and mechanisms are in place to ensure the generation of exiting new projects as old ones come to their end. For example, as detailed below, in July 2008, the SCAR Delegates approved the phasing out of one major SRP and its replacement by another at the end of 2009, along with development of a further major programme for approval in 2010. A regular Cross-Linkages workshop involving the Chief Officers of the Standing Scientific Groups and the leaders of the SRPs provides an incubator for the generation of new programme proposals.

All of SCAR's science programmes are 'bottom-up', being invented within the Standing Scientific Groups. And all of SCAR's scientific planning, reporting and review is carried out by volunteers. The willingness of the community to participate in these processes for assuring success is another metric of the health of SCAR, especially when people have competing demands on their time.

Planning for the first five SRPs had begun at XXVII SCAR in Shanghai in 2002, and their initial design plans, vetted by peer review, were ready for approval by the SCAR Delegates meeting at XXVIII SCAR in Bremerhaven in October 2004. The five approved programmes were:

- Antarctica and the Global Climate System (AGCS), a study of the modern ocean-atmosphere-ice system;
- Antarctic Climate Evolution (ACE), a study of climate change over the past 34 million years since glaciation began;
- Evolution and Biodiversity in the Antarctic (EBA), a study of the response of life to change;
- Subglacial Antarctic Lake Exploration (SALE), a study of the chemistry and biology of lakes long buried beneath the ice sheet;
- Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR), a study of the response of the Earth's outer atmosphere to the changing impact of the solar wind at both poles.

As a next step, the SRPs were asked to develop implementation plans and plans for scientific steering committees for approval by the Executive Committee (EXCOM) meeting in mid 2005. The SRPs depend for their success on partnerships and cooperation. Members of each are funded through their national programmes to conduct the science. The achievements of each are a collaborative set of advances produced by a cohort of national efforts.

Delegates meeting at XXVIII SCAR in 2004 decided that the Standing Scientific Groups (SSGs) should receive around \$17,000 per year for their various Action and Expert Groups, and hoped to provide \$25,000 per year for each of the large Scientific Research Programmes. Unfortunately the budget has never quite measured up to expectations, but funding levels have been as close as possible to these ideal targets over the past 6 years (to 2010).

In the following section the 5 SRPs are described as parts of the 3 SSGs, from within which they originate. They report to the EXCOM and Delegates through the SSGs, but they operate their budgets independently of the SSGs. In evaluating the progress of the SRPs it should be borne in mind that they are not just about producing leading edge pan-Antarctic science; much of the activity of SCAR groups of all kinds comes down to arranging meetings for planning field activities or for reviewing progress in science and agreeing on what, where and when to publish. In addition the SRPs use some of the budget as seed-corn to attract much larger funds.

A key element of the Strategic Plan 2004-2010 was recognition that the key to solving the complex environmental problems of today is through partnerships with organisations having complementary skills, technologies and interests. The most important partnership for SCAR is the linkage between science and logistics, which comes about through the close relationship that exists between SCAR and the Committee of Managers of National Antarctic Programmes (COMNAP). SCAR coordinates its activities with COMNAP through: (i) meetings of the SCAR and COMNAP Executives; (ii) joint meetings of the full memberships of both organisations in even numbered years; and (iii) liaison in the margins of the annual Antarctic Treaty Consultative Meeting (ATCM).

Partnerships have also become increasingly necessary with those scientific organisations of global reach that also have Antarctic interests, like the World Climate Research Programme (WCRP), or the International Geosphere-Biosphere Programme (IGBP), which grew up in the 1980s. For that reason SCAR's programme teams and specialist groups are encouraged to form partnerships with other organisations relevant to the achievement of particular objectives. In some cases, SCAR may decide that the relationship with certain partners warrants formal co-sponsorship of an activity; co-sponsorship implies a sharing of responsibility for programme management, and some commitment of resources.

As a constituent body of ICSU, SCAR is called upon to develop strong links with other ICSU environmental bodies. The extent and pattern of these links is substantial, and SCAR's SSGs are encouraged to maintain, strengthen and diversify their links with other ICSU bodies.

SCAR has formal Letters of Agreement or Memoranda of Understanding for scientific collaboration with the WCRP, with the Global Ecosystems Dynamics (GLOBEC) programme of the IGBP, with the International Arctic Science Committee (IASC), the International Permafrost Association (IPA), and the International Association of Cryospheric Sciences (IACS). These and many other less formal project-to-project links are mentioned in the appropriate places in the following text.

3.1 The SSG on Life Sciences (SSG-LS)

The SSG-LS was led by Chief Officer Steven Chown (South Africa) up to the Delegates meeting in 2004, Ad Huiskes (Netherlands) from 2004-2008, and Kathleen Conlan (Canada) from 2008 on.

One of the main tasks for the SSG-LS is organizing SCAR's quadrennial International Biology Symposia (IBS). The 9th IBS took place in Curitiba, Brazil, in July 2005, with the theme of "Evolution and Biodiversity in Antarctica". Edith Fanta, subsequently deceased, led the Local Organising Committee. There were 246 oral and poster presentations from 29 countries, with 70 from Brazil. Many young South American scientists were able to attend. A selection of the presentations will be published in a special issue of *Antarctic Science* (Volume 19, issue 2, 2007). In 2006, planning began for the 10th IBS, held at Hokkaido University in Sapporo, Japan, on July 26-31, 2009. This was the first IBS in Asia. Mitsuo Fukuchi of the National Institute for Polar Research led the Local Organising Committee. The symposium focussed on the early outcomes of the IPY and was opened by the Chair of the Census of Antarctic Marine Life, Michael Stoddart. There were over 110 oral presentations and 130 posters, with 40% of the papers by early career scientists. Many of the presentations have been published in a special issue of *Polar Science* (e.g. Fukuchi and Conlan, 2010). New to the symposium was a special outreach event and awards for the best ten presentations by young researchers.

3.1.1 the SRP on Evolution and Biodiversity in the Antarctic (EBA)

Antarctica is a natural evolutionary laboratory for studying the impacts of climate change on molecular evolutionary rate, dispersal, speciation and to some extent, extinction.

EBA (www.eba.aq/) is the flagship programme of SCAR's Life Sciences activities (www.scar.org/researchgroups/lifescience/). It aims to examine the evolutionary history of Antarctic organisms, the evolutionary adaptation of organisms to the Antarctic environment, the patterns of gene flow and consequences for population dynamics, the diversity of organisms, ecosystems and habitats in the Antarctic, and the impact of past, current and predicted future environments. Among other things EBA assists in the production of scientific advice to the Antarctic Treaty parties and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). EBA works by its scientists organizing or participating in workshops and conferences to review scientific progress, to facilitate collaboration, and to maximise international and multidisciplinary involvement, all of this leading to outputs in the form of key scientific papers in top quality journals.

As EBA spun up during 2004 and 2005, its two major biological predecessor programmes were wound down. One of these was EVOLANTA (Evolutionary Biology of Antarctic Organisms), a primarily marine biological programme that would continue in modified form in EBA, and which published the proceedings of one of its workshops as a special issue of *Antarctic Science* (Eastman et al., 2004). The other was RiSCC (Regional Sensitivity to Climate Change in Antarctic Terrestrial and Limnetic Ecosystems), a terrestrial programme which would also be incorporated into EBA, and which completed three successful field campaigns during this period: the three island study (Marion, Kerguelen, and Heard islands); the

Antarctic Peninsula transect (Netherlands – United Kingdom), and the Latitudinal Gradient Project in Victoria Land (New Zealand – Italy – United States). To mark the end of its prior efforts, in 2006 the RiSCC team produced a synthesis volume – ‘Trends in Antarctic Terrestrial and Limnetic Ecosystems, Antarctica as a Global Indicator’ establishing how Antarctic land, lake and pond life respond to climate change, and identifying the processes determining community response to stress (Bergstrom et al., 2006).

The EVOLANTA team produced a number of publications to complement their 2004 special issue of Antarctic Science (volume 16). In addition, the Latitudinal Gradient Programme (LGP), which is linked to EBA, published a special issue of Antarctic Science (volume 18) in December 2006, with a further special issue (volume 22) of Antarctic Science published in late 2010, and EBA members completed the publication of a synthesis volume from the final meeting of the EASIZ (Ecology of the Antarctic Sea Ice Zone) programme, on understanding the diversity, ecology and population dynamics of the organisms beneath the Antarctic sea ice, and their sensitivity to change (Arntz and Clarke, 2002; Clarke et al., 2006).

From the start, then EBA was something of an experiment in that it brought together under one umbrella the formerly quite separate marine and terrestrial research elements of SCAR. The merger created tensions that were eventually resolved at a workshop near Eindhoven airport in the Netherlands, enabling the construction of the EBA science plan. During 2004 and 2005 considerable effort went into developing the EBA Implementation Plan, a draft of which was discussed in depth during the 9th International SCAR Biology Symposium in Curitiba, Brazil, in July 2005. The Symposium also saw a workshop on the Census of Antarctic Marine Life (CAML) (below), which was a key field component of EBA during the IPY period. In due course, SCAR’s EXCOM approved the implementation plan and membership of the Steering Committee, which would be led by P Convey (UK) and G Di Prisco (Italy). The EBA plan had five different work packages: (i) Evolutionary history of Antarctic organisms; (ii) Evolutionary adaptation to the Antarctic environment; (iii) Patterns of gene flow and consequences for population dynamics: isolation as a driving force; (iv) Patterns and diversity of organisms, ecosystems and habitats in the Antarctic, and controlling processes; (v) Impact of past, current and predicted future environmental change on biodiversity and ecosystem function.

Despite its difficult start, EBA has been a success. Even so, there was and still is little collaboration between the terrestrial and marine biologists, although now both groups study similar topics via the five work packages. In a way this reflects not simply a discipline approach but also the difference between the two realms, the marine Antarctic biota having a huge biomass, high species diversity and a narrow temperature tolerance, the terrestrial and limnetic biotas having low biomass, the lowest diversity on Earth, and tolerance for large temperature ranges of up to over 50°C seasonally and even daily as well as exposure to large fluctuations in solar radiation and changes in hydration. Particular successes are evident in the Census of Antarctic Marine Life (CAML) and in the spinning up of a major effort on microbial life. Significant progress has been made on the terrestrial side in biodiversity and paleobiogeography. Perhaps most important has been the development and enhanced use of the marine and terrestrial databases described below.

In 2006, EBA scientists established that the terrestrial biota of the Antarctic Peninsula is very different from that of the rest of the continent - there is a striking

biogeographical ‘divide’ between the two, suggesting that the biota does not have a ‘recent’ origin. There must have been ice-free ‘refugia’ in which species survived the severe glacial conditions between the warmer interglacials like that we are experiencing today (Convey and Stevens 2007, Convey et al. 2008). In the marine realm diversity is much higher than expected, and dramatically higher than in the Arctic, with some phyla represented at levels above global averages (e.g. 17.5% of known pycnogonid species; 12.2% of polychaetes; and 8.3% of amphipods) (e.g. Clarke and Johnston 2003). Evolution of organisms in Antarctica and the Southern Ocean has been influenced first by the creation of an ocean barrier between Antarctica and other continents around 10-15 million years ago, and second by the formation of the Antarctic Circumpolar Current and its associated frontal systems, especially the Polar Front between 50° and 60°S. Colonisation has been quite different from that in the Arctic where warm conditions brought colonisers from warmer regions. Threats to Antarctic life now come from direct impacts of warming and other environmental changes (particularly on the Antarctic Peninsula), the invasion of non-indigenous species encouraged by a combination of warming, and the risks of accidental transport through human activity, and the effect of ocean warming on cold-adapted marine animals. Later developments within the EBA research community have expanded the initial implications of this ‘paradigm shift’ in understanding of Antarctic evolutionary history both into the marine realm (Convey et al. 2009a) and the world of microbial diversity (Vyverman et al. 2010).

Two EBA-coordinated biodiversity databases met the needs of EBA and affiliated programmes as well as those of the international research community. One is the RiSCC-created terrestrial / freshwater database held at the Australian Antarctic Division. The other was the Marine biodiversity portal – MarBIN (www.scarmarbin.be/), which, with generous help from the Belgian government and the Alfred P. Sloan Foundation, had been established at the Royal Belgian Institute of Natural Sciences. Both now link to the Global Biodiversity Information Facility (GBIF); MarBIN also links to the Ocean Biogeographical Information System (OBIS). As a current development, both are being integrated within a single facility – ANTABIF (see below) – with the intention of bringing increased accessibility and analytical potential to data from both the marine and terrestrial realms, as well as integrating increasing quantities of microbial and molecular data, as these fields expand rapidly.

EBA was both a SCAR and an IPY programme. Several other projects that contributed to EBA were also IPY endorsed projects such as CAML (Census of Antarctic Marine Life), MarBIN (Marine Biodiversity Information Network), Aliens, TARANTELLA, MERGE, the Latitudinal Gradient Project, and ICED (Integrating Climate and Ecosystem Dynamics in the Southern Ocean). Of these, CAML, MarBIN and ICED were either SCAR activities or sponsored by SCAR, and part of the list of some 40 national and international programmes contributing to EBA.

The SCAR-Marine Biodiversity Information Network (SCAR-MarBIN) set up the first authoritative Register of Antarctic Marine Species (RAMS), which feeds larger taxonomic systems such as the World Register of Marine Species, the Catalogue of Life, or the Encyclopaedia of Life. RAMS included information on 13,000+ taxa and is updated and checked by a board of specialists. MarBIN also gives access to occurrence and abundance data from 115 interoperable databases, reaching over 913,000+ records, which are also published through the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information System (GBIF).

Main ongoing developments included a new data portal to give access to new features, including access to genetic data, expeditions and experts databases, interactive identification keys, field guides and a new intuitive interface including a powerful search engine. MarBIN was funded wholly by the Belgian Science Policy until September 2009, and has subsequently successfully gained other additional sources of support to sustain its future.

Progress under Work Package 2 included work on genes and proteins in polar fish and bacteria, which enable molecular studies of thermal adaptation, to understand their evolutionary adaptation to Antarctic conditions. The ability of cold-adapted organisms to survive implies that they have overcome constraints imposed by a permanently cold environment through genomic, biochemical and physiological adaptations, which preserve the flexibility of DNA, RNA and proteins. Similar to other bacteria, the genome of the cold-adapted bacterium *Pseudoalteromonas haloplanktis* contains multiple genes encoding three monomeric hemoglobins exhibiting a 2/2 α -helical fold. EBA scientists have cloned, over-expressed and characterised one of these 2/2 haemoglobins. Results indicate high protein structural flexibility, probably in response to the constraints of the cold environment. Papers have been published in e.g. International Innovation, Biophys J, IUBMB Life, Marine Genomics, and the J Fish Biol.

EBA, with SCAR's Antarctic Treaty System committee, is also funding terrestrial biodiversity analyses based on existing databases so as to provide information and advice for the Antarctic Treaty Consultative Meetings (ATCM). Scientific publications are also being developed from this work, emphasising the increasing synergy between science and policy input in some areas of EBA supported research. This is further illustrated by a recent publication analysing the efficacy of protection measures provided by the current system for Antarctic Specially Protected Areas (Hughes and Convey 2010).

EBA provided funding to assist the continuation of data analyses within the IPY-Aliens programme. Publications are expected to come online from that programme during 2010, with a major effort associated with its organising a session at the 2010 IPY conference in Oslo.

In 2008 SCAR obtained Associate Participant status in the Global Biodiversity Information Facility (GBIF). SCAR will be involved in the governing of GBIF and in implementing GBIF's goals and work plan. Bruno Danis (Belgium), manager of the SCAR-MarBIN data network, will represent SCAR in the GBIF Governing Board, and Dave Watts, (Australia), in charge of the management of the EBA Antarctic Biodiversity Database, will represent SCAR in the GBIF Participant Node Managers' Committee.

Through SCAR-MarBIN, and as of early 2010, the ANTOBIS geodatabase (forming the Antarctic node of the Ocean Biogeographic Information System, OBIS) had reached 1,054,676 records from 145 distributed databases. This information is also accessible through other web portals such as those for OBIS and GBIF. Since its inception, the SCAR-MarBIN website has reached over 700,000 visitors and had 5,000,000 hits and over 32,000,000 downloaded records.

Together, SCAR-MarBIN and CAML (see below) meet the need to establish the current state of Antarctic marine communities and their diversity, so that we can understand the impact of future climate change, and the changes wrought by human

activities such as overfishing and pollution. SCAR-MarBIN had managed to attract additional funding from Australia, Germany, The Netherlands, the TOTAL Foundation and the ArcOD consortium; these contributions represent an important first step into making SCAR-MarBIN an internationally supported initiative. Networking activities are ongoing thanks to a new Belgian-funded project, the Antarctic Biodiversity Information Facility (ANTABIF), mentioned above, which will give access to all Antarctic Biodiversity information (marine, terrestrial and limnetic) on a single web portal, thanks to a tight collaboration with the Australian Antarctic Data Center.

EBA's success is reflected in part in publications emerging from its scientific community, and totalling at least 159 peer-reviewed papers in 2007; more than 150 EBA-related publications published in 2008; and a similar number in 2009. From time to time EBA science leads to publication of a special issue of a journal, such as the one in *Polar Science* arising from the EBA-sponsored workshop on polar microbiology held in Canada in 2008. In addition, EBA kept its community apprised of progress through the EBA Newsletter. EBA participants made important contributions to the ACCE report (Turner et al., 2009a) and an associated review publication for Antarctic Science Journal (Convey et al., 2009b). EBA committee and programme members were central to the organisation of the Xth SCAR Biology Symposium in Sapporo in July 2009, attracting over 250 participants, and leading to the publication of a special issue of *Polar Science* in 2010.

3.1.2 SSG-LS Action and Expert Groups

Census of Antarctic Marine Life (CAML) Expert Group:

During 2005, SCAR launched CAML, a five-year international project funded by the Alfred P. Sloan Foundation as part of the Foundation's global Census of Marine Life, and led by Michael Stoddart of the Australian Antarctic Division. CAML (www.caml.aq/) formed part of EBA as well as being a SCAR Expert Group in its own right. It aimed to investigate the distribution and abundance of Antarctica's marine biodiversity, to see how biodiversity is affected by environmental change, and how change will alter the nature of the ecosystem services provided to the planet by the Southern Ocean. It aimed to include all groups of organisms, from microbes to whales. In addition to traditional taxonomy, the use of powerful new tools for genetic sequencing would determine the extent to which the Antarctic marine fauna and flora were responding to change. Research was planned for the pelagic, sea-ice, and benthic realms in as many locations around Antarctica as the provision of research vessels would allow. At its start, CAML had the prospect of coordinating research on over a dozen ships from a similar number of nations, with the potential to be the largest project yet undertaken in Antarctic marine biodiversity. The fieldwork occurred mainly in 2007-08, during the IPY. Sloan funding provided for a CAML Office, hosted by the Australian Antarctic Division, with Victoria Wadley as the project manager

The Scientific Steering Committee (SSC) for CAML held a planning workshop with about 20 invited experts in Brussels during May 2005 to prepare a comprehensive science plan. Logistic and scientific coordination were discussed at an SSC meeting in Bremerhaven in June 2005. CAML also held meetings in 2005 at the 9th SCAR Biology Symposium (July, Curitiba, Brazil) and the Dynamic Planet assembly (August, Cairns, Australia).

In 2006 the first CAML cruise began in December, aboard *Polarstern*, around the Antarctic Peninsula. A complementary IPY project “System-Coupling” (SYSTCO) took a vertical snapshot through the water column to examine atmospheric-pelagic-benthic coupling processes. EBA representatives organised an IPY-SYSTCO workshop at the Alfred Wegener Institute (Bremerhaven, Germany) in September 2006.

By 2007, the Census of Antarctic Marine Life (CAML) was in the midst of an extensive fieldwork phase, with coordination of research on 18 Antarctic voyages during IPY. Each addressed the central CAML and EBA themes of biodiversity and evolution in Antarctica. *Polarstern* was conducting the “SYSTCO” project to examine benthic pelagic coupling of the ecosystem to 5,000 m depth in the Weddell Sea. *Aurora Australis*, *L’Astrolabe* and *Umitaku Maru* synchronised investigations for the East Antarctic survey “CEAMARC”. *Humboldt* and *Ary Rongel* from South America were active around Admiralty Bay. *Tangaroa* planned work in the Ross Sea. Other vessels would be involved in due course. All biodiversity data would be submitted to SCAR MarBIN, and an Education and Outreach scientist on each ship would send material daily to websites.

By 2007, seabird and mammal observations from tourist ships were being fed to CAML, following agreement with the International Arctic and Antarctic Tour Operators organisation (IAATO). The World Conference on Barcoding in Taipei in September 2007 provided directions and contacts for CAML’s special DNA barcoding project, based at the British Antarctic Survey and Scott Polar Research Institute. Barcoding of Antarctic species was connected to the new POLARBOLI group based in Trondheim.

As CAML was part of the global Census of Marine Life (CoML), CAML representatives attended the CoML All Programmes meeting in Auckland in November 2007 to strengthen collaboration with related projects on Arctic biodiversity, zooplankton, seamounts, and near-shore and abyssal environments. CAML began preparing an Encyclopedia of Antarctic Marine Life as a contribution to CoML.

The IPY programme ICEFISH (International Collaborative Expedition to collect and study Fish Indigenous to Sub-Antarctic Habitats) contributed to both EBA and CAML. It planned to study the dominant suborder Notothenioidei, to help understand the evolution, population dynamics, eco-physiology and eco-biochemistry of these sub-Antarctic fish and their Antarctic relatives. ICEFISH started with a cruise in the South Atlantic sector in 2004.

By 2008 CAML was seen as one of the major achievements of the IPY, having coordinated 18 major research voyages in the Southern Ocean. It had pioneered new understandings of the evolution and diversity of life, and provided comprehensive baseline information on Antarctic marine biodiversity that will be a benchmark against which future change in marine communities around Antarctica can be assessed. Scientific results were being made available via SCAR-MarBIN. As one example of the CAML approach, in early 2008, CAML scientists participated in the Collaborative East Antarctic Marine Census aboard Japan’s *Umitaka Maru*, France’s *L’Astrolabe* and Australia’s *Aurora Australis*. They studied seabed communities and the deep pelagic (open ocean) zone of the region adjacent to Terre Adélie and George V Land. This and parallel studies showed that the Southern Ocean is unexpectedly rich in marine life, and that the seafloor around Antarctica is a single benthic

bioregion. Molecular techniques showed Antarctica to be the birthplace of many species, driven by glacial cycles over millions of years. For example, eight genera of octopus were present in Antarctica 30 million years ago. Since then, different octopus types repeatedly colonised the deep sea, radiating northwards when the ice retreated. Similar patterns are observed with other species, including asellote isopods (crustaceans) and pycnogonids (sea spiders). Melting ice shelves have exposed seafloor communities to light for the first time; during the first CAML expedition, on *Polarstern*, the disintegrating Larsen A and B ice shelves revealed areas of the continental shelf attracting life from deeper waters on the slope, including sponges that rapidly colonised the seafloor disturbed by ice scour.

In partnership with Canada's Guelph University, CAML was 'barcoding' (analysing DNA sequences) for some 2,000 Antarctic species, with SCAR-MarBIN creating related data storage, analysis and visualization tools. Analysis of genetic variation in Antarctic and subAntarctic seas will then be possible and will help identify new species and 'cryptic' species (species difficult to distinguish from each other). The data will contribute to the Barcode of Life data system.

During CAML voyages, a team coordinated by the Equipe Cousteau (www.cousteau.org), sent words and pictures around the world via blogs, and online and print articles. The CAML team participated in the Scientific Steering Committee meeting of CoML in Antarctica in mid February 2008.

By 2009 CAML had established a benchmark of over 16,000 taxa of biota in the Southern Ocean, and CAML researchers had discovered new pathways of evolution, dispersal and colonization by Antarctic organisms. A comparison of the species in Antarctic and Arctic waters was possible for the first time, inspired by the IPY. When CAML ends in December 2010, a legacy will remain in the strong international network that has been fostered, with 350 participants from 33 countries, including a consortium of the seven South American countries with Antarctic programmes. Training the next generation of researchers has been a priority, implemented by funding young scientists to join voyages and attend conferences.

In the last five years, CAML had coordinated the largest-ever survey of biota in the Southern Ocean, including 18 major voyages to Antarctica (and as many minor voyages). The survey had contributed data to SCAR-MarBIN; coordinated intensive Continuous Plankton Recorder sampling, shown changes in zooplankton communities; discovered hundreds of new species; published barcodes for 2,500 species (from over 11,000 DNA sequences); posted web-based media from each voyage and three major international press events; and produced a video on YouTube with another in progress. Lasting legacies from CAML are the 30-year benthic dataset from Admiralty Bay; a biological contribution to the Southern Ocean Observing System, including biologist data from marine mammals; writing taxonomic monographs, Antarctic Field Guides and pages for the Encyclopedia of Life; publication of over 1,000 scientific papers; and providing evidence for CCAMLR's bioregionalisation programme and designation of two Vulnerable Marine Ecosystems. CAML had published a regional descriptive paper (Griffiths, 2010) and a synthesis chapter (Gutt et al., 2010) for the CoML. The main findings would be published in a special volume of *Deep-Sea Research II* (e.g. Bowden, D.A., et al., 2010). These achievements during the IPY have provided a robust benchmark against which future change in the Antarctic marine ecosystems may be measured.

Initiatives like the barcoding project and the Encyclopaedia of Life are expected to continue beyond 2010 if funding is available. CAML's international network of researchers in marine biodiversity will also continue, under the auspices of SCAR, addressing the central EBA themes of biodiversity and evolution in Antarctica.

In terms of evolution it became evident through CAML and EBA results that the isolation of the Antarctic biota is really clear only in the upper water column, due to the separation of water masses at the polar front, and not so obvious at the seafloor. Some species (limpets, bivalves, sea-urchins, brittle stars) are split into northern and southern groups, other species (octopods, isopods (= crustaceans), sponges, feather stars, sea-cucumbers) invaded Antarctic waters from the deep-sea, and yet others (other octopods, other isopods, other amphipods (crustaceans), and molluscs) moved north from Antarctica into the deep sea. Many examples from modern genomic studies confirm earlier hints based on traditional systematic findings. These new results bring into question the 'old' notion that the formation of the circumpolar current was the main evolutionary driving force generating high Antarctic species richness.

In terms of ecology, at a very coarse (circumpolar) spatial scale there seems to be only one single benthic faunistic province. There are similar results for the plankton. For instance no clear longitudinal differences were found between Antarctic sectors on the basis of surveys with the continuous plankton recorder over decades, signifying that there can be only one community. At smaller spatial scales, ranging from several 100 km to single metres (or less), there is widespread patchiness among many benthic species groups in many areas and in different habitats. The benthos can reach world records in biomass for both highest and lowest values, the latter being found beneath recently disintegrated ice shelves. In some cases the reasons for such extreme patchiness results from variations in iceberg disturbance, food supply, and sediment characteristics. Diversity is not everywhere high on the Antarctic seafloor, as was formerly thought. It can be very high at unique places, (e.g. Admiralty and Scott Sea Mounts); it can differ greatly from one unique site to another; and it can be low, for instance where there has been explosive growth of pioneer species such as sea squirts. The first macroecological survey of a former ice shelf covered area (the Larsen A/B ice shelf) in 2006/2007 provided the basis for some of these findings. In addition the species-specific response to climate-change can be complex. For example warming initially affects the behaviour (e.g. digging) rather than the metabolic performance of infaunal bivalves. Despite that, some species show differing behaviour in the wild and in experiments, like the fish *Pagothenia borchgrevinki*, which seems to be quite tolerant in its natural habitat, occurring in a range between -2 and +6°C, whereas single specimens show in experiments a much narrower temperature tolerance. Deciphering such complexity is a prerequisite for successful application of a bioregionalisation approach as the basis for spatial and temporal predictions. Such ecological complexity also exists in the open water habitat. As shown by analyses of satellite imagery, the shrinking ice margin and a decreasing sea-ice cover west of the Antarctic Peninsula do not necessarily lead to increased phytoplankton growth. Additional (physical?) factors (perhaps weather) must help to decide whether primary production will increase or decrease in a changing environment. Changes registered in the plankton composition in recent decades include a shift from larger organisms (krill) to smaller organisms (e.g. the copepod *Oithona*), but thus far it does not seem possible to attribute this shift in the environmentally quite stable East Antarctic region to climate change.

The Southern Ocean programme of GLOBEC, the Global Ecosystems Dynamics Programme of the International Geosphere-Biosphere Programme (IGBP):

SCAR became a co-sponsor of this marine biological programme in 2004. It focussed on the year-round lifecycle of Antarctic zooplankton, particularly krill and the predators of krill, such as marine mammals and seabirds. Southern Ocean GLOBEC (SO-GLOBEC) was concerned with the development and testing of ecosystem models that can explain the data and be used as the basis for forecasting trends and patterns in the krill. SO-GLOBEC was due to end by 2007, but analyses continue. In 2009, initial results of SO-GLOBEC were reported at the third GLOBEC Open Science Meeting (22-26 June 2009, Victoria, BC, Canada)(www.globec.org/).

The Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) Programme of the IGBP:

With the end of SO-GLOBEC, efforts to understand the operation of the Southern Ocean ecosystem continued through this new Southern Ocean component of a newly emerging IGBP programme, IMBER (Integrated Marine Biogeochemistry and Ecosystem Research). SCAR became a co-sponsor of ICED in 2006. ICED makes a contribution to EBA.

The challenge for ICED (www.iced.ac.uk), led by Eugene Murphy, of BAS, was to predict how the diverse Southern Ocean ecosystems may respond to climate change, and the impacts of marine ecosystem change on the Earth System. Climate related changes were already having a profound effect on the marine ecosystems (especially krill), parts of which are also commercially exploited. ICED brings together oceanographers, biogeochemists, climatologists, and ecosystem and fisheries scientists to generate unique circumpolar datasets, undertake coordinated field activities and develop models to address three key questions:

1. How do climate processes affect the dynamics of circumpolar ecosystems?
2. How does ecosystem structure affect circumpolar ocean biogeochemical cycles?
3. How should ecosystem structure and dynamics be included in sustainable approaches to fisheries management?

ICED developed its science plan in 2006 and 2007. It plans to approach its challenges through historical data synthesis, fieldwork, and model development. A project had begun with EUR-OCEANS to retrieve biological information from past Southern Ocean cruises, especially on the abundance and distribution of pelagic species - to build a more complete picture of the changing circumpolar ecosystem. ICED plans to use international fieldwork to address gaps in coverage and knowledge. As a first step, a picture of Southern Ocean fieldwork was provided through the interactive ICED IPY fieldwork map on the ICED website. This was designed to encourage communication and cooperation, and to help to develop coordinated field activities in future.

In 2008 The ICED Science Plan and Scientific Steering Committee were formally approved by the IGBP's GLOBEC and IMBER programmes, and ICED held several meetings to develop the science, starting with a multidisciplinary modelling workshop (Old Dominion University, Virginia, in April 08) to begin to characterise the Southern Ocean food web across a range of species (microbes to cetaceans), trophic levels and geographical areas, so as to identify major gaps in knowledge and data availability,

and to explore the issues in modelling the Southern Ocean ecosystem. Results from the ICED modelling workshop were given at the Advances in Marine Ecosystem Modelling Research meeting (Plymouth, UK, in June 08). ICED scientists attended the annual science meeting of Ecosystem Studies of Sub-Arctic Seas (ESSAS) (Nova Scotia, in September 08) enabling discussion of potential areas for collaboration on polar ecosystem issues. An ICED/ESSAS session on Climate Influences and Biological Controls in High Latitude Marine Ecosystems had been part of the IGBP Conference in Cape Town in May 08, facilitating discussion and synthesis of current research on control mechanisms and feedbacks in the marine ecosystems of the Southern Ocean. A joint session on Polar Marine Ecosystems: Status and Change was convened by ICED and CAML for the Open Science Conference in St Petersburg, in July 08. And several ICED-related presentations were made at the EUR-OCEANS final meeting in Rome, Italy, in November 08.

Two EUR-OCEANS funded projects (EUR-OCEANS Southern Ocean System and ICED data rescue projects) contributed to the data synthesis aims of ICED. Southern Ocean species distribution and abundance data were retrieved from historic cruises spanning 1925-85. Data were submitted to EUR-OCEANS WP 2.2 and included in the PANGEA database. For the ICED-IPY project, a web-based system was developed for collating information on relevant field activities. This information is fed to a live virtual globe layer (Google Earth). This is the first stage developing a useful tool for coordinating existing fieldwork and targeting potential future fieldwork. The map layer is linked to a database to ensure integration with other relevant IPY ocean projects. Developing a Google Earth layer to display long-term ecosystem monitoring sites in the Southern Ocean will contribute to the Southern Ocean Observing System (SOOS) (see below).

In 2009, ICED participated the Southern Ocean Sentinel Workshop (Hobart, in April), to consider how to measure, assess and provide early-warning detection of climate change impacts on the Southern Ocean and how these could be used to signal future impacts on marine and other ecosystems elsewhere in the world. The Sentinel programme is developing as part of ICED (www.iced.ac.uk/documents/Sentinel%20report.pdf). In June 09, ICED held a workshop at Princeton University on New Frontiers in Southern Ocean Biogeochemistry and Ecosystem Research. The objective was to facilitate interaction between the physical, biogeochemical, and ecosystem research communities to develop research strategies to resolve current limitations, gaps and discrepancies in our understanding and prediction of the Southern Ocean ecosystems, biogeochemical cycles and carbon uptake. A further ICED session was held as part of the IPY Polar Conference in Oslo in June 2010.

The Continuous Plankton Recorder Programme (CPR):

Recognising the growing importance of the continuous plankton recorder as a tool for marine biological studies, the Delegates at XXIX SCAR in Hobart (July 2006) established a new Action Group on Continuous Plankton Recorder research, led by Graham Hosie (Australia) and endorsed the already existing CPR data set as a SCAR data set. It was envisioned that extensive CPR data would be collected during the IPY, and that the CPR-AG would work closely with CAML, EBA and SCAR-MARBIN. The new Action Group (CPRAG) started its activities in 2007. It supports and develops the SCAR Southern Ocean CPR Survey based at the Australian Antarctic Division. The CPR Survey maps the biodiversity and distribution of

plankton, including euphausiid (krill) life stages, and then using the sensitivity of plankton to environmental change as early warning indicators of the health of Southern Ocean. CPRAG's members include representatives of CCAMLR and the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), which leads the northern hemisphere CPR surveys. By the end of 2007 the data set held more than 100,000 records for about 200 zooplankton species from the Scotia Arc east to the Ross Sea. The SO-CPR Survey would contribute to the Census of Antarctic Marine Life with a circum-Antarctic CPR survey conducted from at least 10 vessels.

At XXX SCAR in St Petersburg in July 2008, the CPR Action Group was elevated to an Expert Group (www.scar.org/researchgroups/lifescience/) in recognition of the expansion of this work, its long-term nature, and its linkages and successes. The SO-CPR Survey is now an official SCAR Product (<http://data.aad.gov.au/aadc/cpr/index.cfm>). The Group continued with the Southern Ocean CPR Survey (SO-CPR), and the 2007/08 season was the most successful to date, with 90 tows around Antarctica using eight vessels from seven countries. This included tows in the Amundsen Sea and Bellinghousen Sea, areas that have received little attention in the past. 25,000 nautical miles or 5000 sample records were added to the CPR data set and to CAML (Census of Antarctic Marine Life). New Zealand's Ministry of Fisheries had secured funding for the next five years to run CPRs on toothfish fishing vessels operating between NZ and the Ross Sea. This will improve sampling in the western Pacific region. The South American LA-CAML consortium proposed to join the SO-CPR Survey with tows planned across Drake Passage. CPR data were being used in a global study that has observed a general shift in dominance from large to smaller copepod species. The SO-CPR Survey observed a change from krill to small copepods in the sea ice zone around year 2000. In 2004/05, a massive increase occurred in foraminiferan numbers from a long-term average of 2% to >50% numerical dominance. CCAMLR uses the data in its bioregionalisation research, a first step towards the possible development of Marine Protected Areas.

The Southern Ocean CPR Survey (SO-CPR) had a relatively quiet sampling season in 2008/09. Forty-four tows were completed from 4 vessels. Nonetheless, the 2008/09 season and the year following was marked with a number of important milestones. Successful tows were conducted between New Zealand and the Ross Sea from a commercial toothfish vessel. This will continue each Antarctic summer, greatly improving the monitoring of plankton in the western Pacific region. The South American CAML consortium LA-CAML officially joined the SO-CPR Survey with tows across Drake Passage from Brazilian and Chilean vessels. This is an important region in relation to the krill fishery and also the proximity of the rapidly warming western Antarctic Peninsula. Tows will be conducted annually there. In preparation for the New Zealand and LA-CAML tows, CAML sponsored a training workshop at the Australian Antarctic Division (AAD) for Ms Karen Robinson (NZ plankton analyst) and Dr Manuela Bassoi (Brazil) who coordinates the CPR work in South America. Dr Bassoi also represents South America on the Expert Group. This workshop was followed by a more extensive CPR workshop in Rio de Janeiro in November 2009, to train 14 people from Brazil, Argentina, Chile, Peru, Ecuador and Venezuela. Other notable milestones included the completion of the first zooplankton atlas using the CPR data, and the submission to SCAR-MarBIN of all data collected during the 2007/08 circum-Antarctic CPR. The atlas was presented at the SCAR Biology Symposium in Sapporo in July 2009 and will be published in the symposium's Polar Science special issue in 2010. Preliminary results of the analysis

of the 2007/08 data shows that while there is distinct north-south zonation of zooplankton assemblages across the Antarctic Circumpolar Current (ACC), the zooplankton species composition remained relatively consistent within the ACC around Antarctica suggesting there is just one community.

The Expert Groups on Birds and on Seals:

In 2006, the Expert Group on Birds, led by Eric Woehler (Australia) continued to provide advice regarding the nomination of Specially Protected Species status to Southern Giant Petrels. The Group continued to work with BirdLife International to define Important Bird Areas in the Southern Ocean region, and continued its assessment of the potential impact of flipper banding on penguins. The Expert Group on Seals, led initially by Arnoldus Blix (Norway) and subsequently by Marthán Bester (South Africa), completed the final report of the Antarctic Pack Ice Seals (APIS) project. A new research programme was being designed to understand the role(s) of top predators in the Southern Ocean. It planned to integrate long-term studies with new animal-borne instrument technologies for the study of water masses, behaviour and movement patterns. The Life Sciences SSG began considering the options for a potential merger of these two Expert Groups to form a new Expert Group on Higher Predators, and planned to report on progress to the Executive Committee in 2007.

The Chief Officer of the Birds Group resigned in 2007. Appointment of a successor was postponed pending the outcome of discussions on the possibility of merging with the Expert Group on Seals. With the resignation of the Chief Officer, SCAR's representation on the Advisory Committee on Albatrosses and Petrels (ACAP) became temporarily vacant. The Expert Group on Seals produced an update on the progress and products of the Antarctic Pack Ice Seals (APIS) programme, which was presented at the 2007 ATCM Meeting. In addition, a White Paper was tabled on the status of knowledge of the biology, distribution and abundance of the Ross Seal, which militated against the removing of the species from the list of Specially Protected Species in Appendix A to Annex II of the Environmental Protocol.

The Delegates at XXX SCAR in St Petersburg in July 2008 approved the merger of the Expert Groups on Seals and Birds to become the Expert Group on Birds and Marine Mammals. The new group's performance was to be evaluated at XXXI SCAR in 2010. The new group, initially chaired by Donna Patterson (USA) and subsequently by Mark Hindell (Australia), met in July 2009 at the 10th SCAR Biology Symposium (see below) and identified some long-term research objectives, including the compilation of all existing bird and mammal tracking data. These data will form the basis of multi-species 'hot-spot' analysis as well as a gap analysis to indicate species and regions where tracking efforts should be focused in future. A long-term objective would be to build on this retrospective analysis to launch a new Southern Ocean predator community study. Delegates meeting at XXXI SCAR in Buenos Aires approved continuation of the new group.

The Biological Monitoring Action Group:

The Biological Monitoring Action Group hosted a workshop in Texas, USA in March 2005, to develop a biological protocol updating and combining existing biological, physical and chemical monitoring protocols for the Antarctic. A workshop on Antarctic Conservation in the 21st Century was held at Stellenbosch in South Africa in

May 2005, with the purpose of updating conservation protocols in the Antarctic Treaty. Following initial discussions it became clear that in order to address this issue adequately, the scope of the effort should be expanded to include the World Conservation Union (IUCN). The Action Group produced the report “Practical Biological Indicators of Human Impacts in Antarctica” in 2006, and was disbanded in 2008.

Codes of Practice:

Following extensive consultation within SCAR and COMNAP, the SSG-LS produced a unified code of conduct for fieldwork anywhere in the Antarctic, including protected areas, to help scientists avoid introducing alien propagules into the Antarctic. It was published on the SCAR website in autumn 2008, and submitted as an Information Paper to the ATCM and CEP in April 2009. That same year, a new Cross-SSG Action Group was formed on the Code of Conduct for the Exploration and Research of Subglacial Aquatic Environments (AG-CCER-SAE), led by Warwick Vincent (Canada). It reported to the SSG in Buenos Aires in 2010.

The Human Biology and Medicine Expert Group:

This group of medical researchers, led initially by Claude Bachelard (France), meets annually, and in 2006 began having annual meetings jointly with the Medical Network (MEDINET) group of COMNAP (Council of Managers of National Antarctic Programmes). These meetings were seen as possible first steps towards a potential merger.

Action Group on Antarctic Fuel Spills (AGAFS):

In 2007, in the aftermath of the sinking of the MV Explorer on 23 November 2007, the SCAR EXCOM decided to create an Action Group on Antarctic Fuel Spills (AGAFS) to address issues that might arise related to the fate and effects of fuel releases in Antarctica. The group is tasked with responding when specific advice is requested. It will operate as an executive committee directing, facilitating and coordinating responses. Its activities will be largely quiescent until a specific need arises. Responses might include a white paper on selected topics, compilations of biological resource data for an affected geographic location, convening of a workshop of experts, and/or provision of contact information for experts as examples.

Cross-SSG Action Group on Prediction of Changes in the Physical and Biological Environments of the Antarctic:

This new group, co-chaired by John Turner (BAS) and Julian Gutt (AWI), was created at XXX SCAR in July 2008 and met first at BAS in November 2008 and at AWI in September 2009 to discuss how to develop a research programme to capitalise on the results of the study of Antarctic Climate Change and the Environment.

Cross-SSG Action Group on King George Island (KGI):

At XXX SCAR in July 2008, the terms of reference and membership for this group were revised, and new members were appointed under the leadership of Sergio Marensi (Argentina). It was agreed that efforts should be focused on encouraging national operators and station managers working on KGI to work in such a way that their activities contributed as much as possible to the research activities of SCAR, such that KGI activities formed a useful subset of wider-ranging

SCAR programmes. To draw this plan to the attention of national operators a paper (“King George Island and SCAR Science”) was prepared for presentation by Sergio Marensi to the COMNAP meeting in Punta Arenas in August 2009 (www.scar.org/researchgroups/physicalscience/). Additional support to this initiative was provided by the SCAR President’s visit to King George Island courtesy of the Uruguayan polar programme in February 2009.

3.2 The Standing Scientific Group on the Physical Sciences (SSG-PS)

The SSG-PS was led by Chief Officer John Turner (UK, BAS) in 2004, followed by Maurizio Candidi (Italy) in 2006-2010. It comprised two major Scientific Research Programmes (AGCS at 3.2.1; and ICESTAR at 3.2.2), and a number of smaller programmes (at 3.2.3).

3.2.1 The SRP on Antarctica in the Global Climate System (AGCS)

AGCS was set up to investigate the linkages between the climate of the Antarctic and the rest of the Earth system over the past 10,000 years, with particular reference to the behaviour of and interactions between the atmospheric, oceanic and cryospheric elements of the climate system, in part in order to provide data to improve confidence in the outputs of numerical forecasts of climate change for the next 100 years. AGCS proposed to use existing deep and shallow ice cores, satellite data, the output of global and regional coupled atmosphere-ocean climate models, and in-situ meteorological and oceanic data to understand how signals of tropical and mid-latitude climate variability reach the Antarctic, and how high latitude climate signals are exported northwards. It would work closely with the ACE programme (see SSG-GS, below), which is looking deeper into the past. Results would be of use to governments in developing national inputs to the Intergovernmental Panel on Climate Change and the UN Framework Convention on Climate Change, and national responses to climate change.

Like EBA, AGCS would work through workshops and conferences to encourage production of papers on key topics in top journals. Led initially by meteorologist John Turner (UK, BAS), and from 2008 by oceanographer Alberto Naveira-Garbato (UK), its activities were divided between four major, closely linked themes dealing with (1) Decadal time scale variability in the Antarctic climate system (leader Dave Bromwich, USA), (2) Global and regional climate signals in ice cores (leader Paul Mayewski, USA), (3) Natural and anthropogenic forcing on the Antarctic climate system (leader John Turner, UK) and (4) The export of Antarctic climate signals (leader Mike Meredith, UK, and subsequently Alberto Naveira-Garbato, UK).

AGCS incorporated two SCAR Expert Groups - International Trans-Antarctic Scientific Expeditions (ITASE), led by Paul Mayewski (USA), and Antarctic Sea Ice Processes and Climate (ASPeCt), led by Anthony Worby (Australia), which nevertheless retained their identity and operating structure.

In 2005, EXCOM approved the AGCS implementation plan and Scientific Steering Committee, but work on the programme had begun much earlier. AGCS scientists reported that balloon-launched radiosonde data for the Antarctic extending back into the 1950s had revealed a major warming of the Antarctic winter troposphere that was larger than any previously identified regional tropospheric warming on Earth. Peak

warming was close to 5 km above sea level, where temperatures had increased at a rate of 0.5 – 0.7° C per decade over the last 30 years (Turner et al., 2006).

Recent trends in Antarctic snow accumulation were investigated using the Polar MM5 climate model. Averaged over the continent the annual trends were small and not statistically different from zero, suggesting that recent Antarctic snowfall changes did not mitigate current sea level rise.

The west Antarctic Peninsula (WAP) was known to be undergoing one of the most rapid atmospheric warmings of any region in the world, with temperatures having risen by nearly 3°C in the past 50 years and 5°C in winter, while air temperatures in East Antarctica had remained steady or cooled. A long-term decrease in sea ice in the adjacent Bellingshausen Sea had been linked to that, but little understanding had been obtained of the ocean's role in these climatic changes. To address this, a long series of oceanographic measurements (temperature and salinity) was compiled and examined, covering the second half of the twentieth century. A significant warming had occurred in the summertime surface and near-surface ocean, of greater than 1°C – greatly exceeding general rates of warming in the world ocean, and one of the most rapid regional ocean warmings noted to date. Concurrent with this warming was a surface-intensified summer salinification, of greater than 0.25. Although initially counter-intuitive, this salinification appears linked to oceanic mixed layer processes driven by the reduction in sea ice. These profound changes reveal the strong atmosphere/ocean/ice coupling involved in the climate change at the WAP (Meredith and King, 2005). The ocean changes are positive feedbacks, acting to promote further decreases in ice production and further atmospheric warming. They also suggest that the initial cause of the climate change here may be atmospheric in origin, rather than oceanic, as some people have suggested. The changes are also significant for the operation of the marine ecosystem, which has evolved to be unusually sensitive to changes in ocean temperature. If the warming progresses further, population and species level losses might be expected.

Since the mid-1960s rapid regional summer warming has occurred on the *east* coast of the northern Antarctic Peninsula, with near-surface temperatures increasing by more than 2°C. This warming contributed significantly to the collapse of the northern sections of the Larsen Ice Shelf in 2002. The explanation is that over the last few decades the Southern hemisphere Annular Mode (SAM) shifted into a more positive phase, with surface pressures dropping over the Antarctic and rising in mid-latitudes, causing the westerly winds to increase, especially in summer. These strong westerly winds were able to take warm maritime air across the mountain barrier of the Antarctic Peninsula to melt the ice shelves. Model experiments showed that the observed shift in the SAM to its positive phases in recent decades was larger than anything occurring in long simulations of the present climate. For that reason the shift was thought to be predominantly a response to anthropogenic forcing, and provided the first evidence that increasing levels of greenhouse gases contributed, at least in part, to the observed rapid warming on the Antarctic Peninsula.

AGCS scientists started work on production of a review of Antarctic Climate Change and the Environment (ACCE), which had been formally called for by the 2005 EXCOM meeting (SCAR Bulletin 159), following my proposal to the EXCOM meeting in Bremen in July 2004 to produce an equivalent of the Arctic Climate Impact Assessment.

The ASPeCT Expert Group continued to develop its database of sea ice parameters from in-situ ship observations. Data from 81 voyages were added in 2005. The data archive was used in a number of studies, including comparisons with satellite ice edge location to determine seasonal variability in the reliability in the satellite estimates, comparisons with sea ice-ocean models and the development of a circumpolar climatology of area-averaged albedo.

The ITASE Expert Group collected more than 240 firn cores (for a total of 7,000 m) and about 20,000 km of snow radar, resulting in numerous publications. In addition ITASE developed multi-centennial scale proxies for sea ice, winds and regional temperature.

In 2006, a study using output from the latest generation of climate models found that they reproduce the observed mid-depth Southern Ocean warming of 0.2°C that has occurred since the 1950s if they include time-varying changes in anthropogenic greenhouse gases, sulphate aerosols and volcanic aerosols in the Earth's atmosphere. The agreement between observations and climate models suggested significant human influence on Southern Ocean temperatures. Climate models that did not include volcanic aerosols produced mid-depth Southern Ocean warming that was nearly double that produced by climate models that did include volcanic aerosols. This implies that the full impact of human-induced warming of the Southern Ocean has yet to be realised (Fyfe, 2006).

Ice core reconstructions of past atmospheric circulation suggested that modern atmospheric circulation intensity was within the range of variability of the last 1000 years (Mayewski and Maasch, 2006). Ice core records also revealed increased penetration of marine air masses into the western coastal regions of West Antarctica in the 1940s.

Analysis of the output from the 20 climate models used in the 4th Assessment of the Intergovernmental Panel on Climate Change (2007) were used to examine how the climate of the Antarctic may evolve in the 21st Century (Bracegirdle et al., 2008). The model fields were weighted according to their level of skill in reproducing the climate changes observed over the last few decades. The projections suggested that near surface temperatures in the sea ice zone will increase in winter by up to 0.6°C/decade, resulting in a decrease of 25% in sea-ice cover; central Antarctica will warm at 0.4°C/decade in all seasons; precipitation will increase by 3.3mm/decade on average over the continent, mostly around the edges; westerly winds will strengthen over the ocean, mostly in autumn, but coastal easterlies will decrease; katabatic winds will decrease slightly as polar plateau temperatures rise by several degrees.

AGCS had also been actively coordinating cross-disciplinary Antarctic science and the preparation of data sets and research tools. In April 2006 a workshop was held in Cambridge, UK to consider the strength and weaknesses of the high latitude elements of the atmospheric re-analysis data sets, which are proving a very powerful tool for the investigation of recent climate change. Means were also considered for the collection and digitisation of historical Antarctic meteorological observations for the next round of reanalyses that are to be produced. The first issue of the AGCS Newsletter 'Notus' was issued in October 2006.

In 2007, the Bracegirdle et al paper mentioned above was accepted for publication in the Journal of Geophysical Research. Another paper accepted by the same journal, was the first assessment of the circumpolar distribution of sea ice and snow thickness

on the sea ice around Antarctica. It was derived from the SCAR Antarctic Sea Ice Processes and Climate (ASPeCt) climatology, which was based on ship observations from 1980 to 2005 (Worby et al., 2008).

Regional changes in bottom water production were discovered that have the potential to affect the ventilation of the global ocean abyss. The densest layers of the ocean's overturning circulation form in the Southern Ocean. An oceanographic section across the eastern Scotia Sea revealed significant variability in the deep and bottom waters. Warming ($\sim 0.1^{\circ}\text{C}$) of the warm mid-layer waters in the Scotia Sea between 1995 and 1999 reversed through to 2005, reflecting changes seen earlier upstream in the Weddell Sea. The volume of deep waters with potential temperature less than 0°C decreased during 1995-2005. Entry of the abyssal waters to the eastern Scotia Sea changed from the south to the northeast between 1995 and 1999, then back to the south by 2005. These changes reflect inter-annual variations in the deep waters exiting the Weddell Sea, that are due to changes in the strength of the Weddell Gyre, in turn reflecting large-scale atmospheric variability that may include the El Niño/Southern Oscillation phenomenon. These signals promulgate into the world ocean.

Exciting new data on snow accumulation, temperature and ice thickness were obtained from Dome A. Excess deuterium data from Dome A shallow ice cores showed an increasing trend during the past ~ 4000 years, implying that the average moisture sources of Dome A in the southern hemisphere are moving equatorwards. A deep ice core collected here could provide a climate record extending back more than a million years.

A 136 m ice core drilled in a high accumulation site on the southwestern Antarctic Peninsula revealed a doubling of accumulation since the 1850s, from a decadal average of 0.49 m (water equivalent) per year in 1855–1864 to 1.10 m per year in 1997–2006, with acceleration in recent decades (Thomas et al., 2008). This rapid increase is the largest observed across the region. It is strongly associated with changes in the regional meteorology – especially SAM.

Good progress had been made in 2007 in preparing the SCAR ACCE review document, a draft of which would be presented to the SCAR Delegates meeting in Moscow in July 2008.

The Australian Antarctic Data Centre had made good progress in establishing a sea ice data portal for *in situ* sea ice data, as recommended by the International Workshop on Antarctic Sea Ice Thickness, co-sponsored by SCAR in Hobart in July 2006. SCAR funded a student to source and enter data from almost 150 files from various national programmes. This stimulated funding from the Australian programme to develop the data portal.

AGCS led the organisation of the Second Workshop on Recent High Latitude Climate Change (Seattle, USA; 22-24 October 2007), a joint effort with IASC and the WCRP/SCAR/IASC Climate and the Cryosphere (CliC) project that considered atmospheric, oceanic and cryospheric changes that had taken place during the last 50 years in the Arctic and Antarctic (SCAR Report 32). A workshop, jointly organised with CliC, on Global Prediction of the Cryosphere, was held at the British Antarctic Survey in October 2007. It reviewed our ability to predict the evolution of various aspects of the cryosphere over the coming century. A symposium on Antarctica and

the Global Climate System was held at the European Geosciences Union General Assembly in Vienna, Austria in April 2007.

In 2008, AGCS scientists devoted considerable efforts to completing the ACCE report, synthesizing knowledge on past present and possible future changes in Antarctica and the Southern Ocean and their impact on the biota. The first part, a review of the physics of the climate system, was already in press as ‘State of the Antarctic and Southern Ocean Climate System (SASOCS)’ in ‘Reviews of Geophysics’ (Mayewski et al., 2009).

An AGCS-authored paper in press in the Journal of Climate showed that the interdecadal warming and freshening of mode and intermediate water masses in the Southern Ocean since the 1960s has likely been driven by changes in the major modes of Southern Hemisphere climate variability (Southern Annular Mode, El Niño-Southern Oscillation and Interdecadal Pacific Oscillation). The work was based on oceanographic observations in the Drake Passage region (Naveira-Garabato et al., 2009).

Analysis of air temperatures over Antarctica from 1960-2007, using data from SCAR’s READER database, showed that near-surface warming on the Antarctic Peninsula had spread into West Antarctica, reaching as far east as the Pine Island Bay-Thwaites Glacier region. It was most marked in recent years, with 2007 being the warmest. While the western Antarctic Peninsula warming was maximal in winter, and the eastern Peninsula warming was maximal in summer, the West Antarctic warming was maximal in spring. Weak near-surface warming was found over East Antarctica (Steig et al., 2009).

Work on the ACCE review provided the basis for determining the mass balance of the Antarctic Ice Sheet. West Antarctica is losing mass; East Antarctica remains largely stable, ACCE also helped to create an unprecedented spatio-temporal array of information about the ice sheet as the basis for exploring the variability and recent evolution of Antarctic climate, and using new geological data and numerical modelling to explain the history of the ice sheets and climate since extensive glaciation began 34 million years ago.

By now, AGCS scientists had realised that the warming of the Antarctic winter troposphere, previously identified in radiosonde data, was due to an increase in the amount of polar stratospheric clouds (PSCs) made of ice crystals. The stratosphere had been cooling as an expected result of tropospheric warming induced by increases in greenhouse gases, stimulating the production of PSCs.

AGCS routinely recovered and archived Antarctic data, and had updated the Met-, Ice- and Southern Ocean- READER databases. The Australian Antarctic Data Centre contributed by archiving data on Antarctic sea ice and snow thicknesses collected over the past 30 years from ship expeditions; 80% of the known data was now archived. In future information on physical, chemical and biological properties of Antarctic sea ice cores will be archived. Development of a climatology of Antarctic sea-ice will be an aid to understanding sea-ice formation, validating satellite data, and feeding coupled ocean-ice-atmosphere models.

AGCS organised the ITASE Synthesis Workshop (Castine, USA; 2-5 September), to identify climate changes that impacted the Antarctic over the past 200-1000+ years, as a basis for assessing likely future change. Workshop results will assist collaboration between ice core researchers, meteorologists, oceanographers, and climate modellers.

In 2009, together with colleagues from ACE and EBA, AGCS completed the ACCE review, which was published in October 2009 and formally launched at a press conference in London on November 30 (Turner et al., 2009a). The report was made available via the SCAR website, but hard copies were provided ahead of time to the national delegations attending the UN Framework Convention on Climate Change conference held in Copenhagen in December 2009, which I attended and at which I gave two talks on ACCE. A review summarising the results of the ACCE work and with the same title was published in December 2009 in the journal ‘Antarctic Science’ (Convey et al., 2009b).

A paper in press in the Journal of Physical Oceanography presented unprecedented observational evidence of the way in which mesoscale eddies mix tracers across the Southern Ocean (Ferrari and Nikarushin, 2010). An article submitted to Nature Geoscience showed, using a theory that fits those observations, that the overturning circulation of the Southern Ocean was sensitive to decadal-scale changes in the Southern Ocean westerlies, contrary to recent propositions (Meredith et al., in press). This had implications for the role of the Southern Ocean in the global carbon cycle. A paper published in Geophysical Research Letters showed that the increased growth in Antarctic sea ice during the past three decades was a result of the strengthening of surface winds around Antarctica associated with stratospheric ozone depletion. The presence of the ozone hole had delayed the impact of greenhouse gases on Antarctic climate, and the study predicted that Antarctic sea ice would retreat considerably by the end of the 21st century, as ozone levels recovered (Turner et al., 2009b). An article in press in Nature Geoscience presented evidence from an East Antarctic ice core indicating a link between drought conditions in Western Australia and increased snowfall in Antarctica (Van Ommen and Morgan, 2010). The link was established via evolving atmospheric circulation patterns off southern Australia, with the change in the last three decades appearing to be outside the range of natural variability. Papers in press in Deep-Sea Research II (e.g. Xie et al., 2010) discussed the development of novel regional empirical relationships between ice thickness and satellite-derived snow freeboard, and their application to IceSAT altimetry. This development will allow the prompt determination, for the first time, of an adequate baseline of ice thickness distribution for future monitoring of climatic changes in the Antarctic sea ice cover.

3.2.2 The SRP on Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR)

ICESTAR planned to create an integrated, quantitative description of the upper atmosphere over Antarctica, and of its coupling to the global atmosphere and the geospace environment. It was designed as a bipolar programme that would coordinate its bipolar activities with the Polar Research working group of IAGA (International Association of Geomagnetism and Aeronomy). A scientific benefit would be that global-scale coordination of observing networks would allow study of conjugate and multi-scale geospace phenomena in fundamentally new ways. A practical benefit would be improved prediction of space weather phenomena that adversely affect spacecraft operations, humans in space, satellite-based positioning systems and electrical and communication systems on Earth and in space.

ICESTAR planned to operate with four Thematic Action Groups: (i) quantification of the coupling between the polar ionosphere and neutral atmosphere from the bottom-

to-top and the global electric circuit; (ii) quantification of the inner magnetospheric dynamics using remote sensing techniques; (iii) quantification of the state of the upper atmosphere, ionosphere, and magnetosphere over the Antarctic continent and how it differs from the northern hemisphere during a wide range of geophysical conditions; and (iv) creation and management of a data portal. The Implementation Plan was completed close to the end of 2005, and an ICESTAR Steering Committee was appointed. ICESTAR held a “Data Portal and Virtual Observatory” Workshop on 23 July 2005 in Toulouse, France, in conjunction with the IAGA 2005 Scientific Assembly. At the workshop data sharing issues were discussed for the first time among a community including representatives of some of the most widely used existing geospace data servers. The group agreed to focus initially on three of them: VGMO (for magnetometer data), GAIA (for auroral precipitation data), and Madrigal (for incoherent scatter radar data), and to build or upgrade these systems so that they have easily adoptable interfaces for both users and data providers. A more ambitious goal will be to make the systems communicate electronically. The GAIA Virtual Observatory (VO) was being developed, and a prototype of the VO for optical data was quickly released, along with a prototype of the VO for magnetometer data (VGMO.NET) (Papitashvili et al., 2006). A data portal was released for the multi-instrument data sets at South Pole Station.

By 2006, ICESTAR research was able to demonstrate that: (i) conjugate studies of aurora showed that the onsets of simultaneous Arctic and Antarctic substorms are not symmetric, which has implications for predicting space weather events that could have deleterious technological impacts; and (ii) satellite observations suggested that the global rate of merging between interplanetary magnetic fields and Earth's magnetosphere drives near-Earth space weather, which implies that - contrary to prevailing wisdom - space weather cannot best be predicted by the behaviour of solar wind electric fields.

By this time an ICESTAR proposal “Heliosphere Impact on Geospace” had been accepted for the IPY, to be shared with the International Heliophysical Year (IHY). Its science fell into three main themes: (i) coupling processes between the different atmospheric layers and their connection with the solar activity; (ii) energy and mass exchange between the ionosphere and the magnetosphere; and (iii) inter-hemispheric similarities and asymmetries in geospace phenomena. Work on linking the IHY, IPY and ICESTAR research activities took place in October 2006.

In 2007, there were several ICESTAR workshops and conferences including:

- (i) a session on “Solar Influence on Geospace as Determined by Hemispherically Conjugate Observations”, in the Greenland Space Science Symposium (in May). Proceedings were to be published, in 2008, in a special issue of *Journal of Atmospheric and Solar-Terrestrial Physics*, with the title “Transport in the Coupled Solar Wind - Geospace System seen from a High-Latitude Vantage Point”.
- (ii) participation in a workshop in Åland (Finland) to discuss results from the system of EISCAT incoherent scatter radars; the workshop was accompanied by a two-week summer school to teach students to use the radar facilities. Papers from the workshop appear in a special issue of *Annales Geophysicae* in 2008.

At this time ICESTAR began collaborating with the POLENET IPY project to build

and maintain an extensive Antarctic network of dual-frequency GPS receivers. Data from this network will be invaluable for the ICESTAR-IPY community, which also maintained several GPS receiver stations in the Antarctic for ionospheric research.

ICESTAR scientific highlights in 2007 included:

Geospace-atmosphere coupling: Lightning during strong thunderstorms launches electromagnetic waves that propagate both in the wave-guide between the earth surface and ionosphere (spherics) and along geomagnetic field lines (whistlers). Whistlers can interact with radiation belt electrons and cause their precipitation into the atmosphere. Combined observations from VLF-antennas, lightning detection systems, and the DEMETER satellite showed a causal relationship between lightning and electron precipitation events. Both data and models confirmed the connection between the intensity of the electromagnetic waves and the fluxes of electrons in precipitation events (Inan, et al., 2007)

Interhemispheric comparison studies: Tests of the extent to which auroral events in both hemispheres are joined together (inter-hemispheric conjugacy) have long shown that some auroral structures are synchronous and may even pulsate in tune (i.e. are conjugate). Recent observations with ground-based all-sky TV-cameras confirmed this conjugacy but also showed some non-conjugate auroras: (i) pulsating auroras in both hemispheres with different spatial appearance and period, and (ii) pulsating auroras in one hemisphere only (Watanabe, et al., 2007).

Arctic and Antarctic polar winter NO_x: GOMOS satellite night-time observations of middle atmosphere NO₂ and O₃ profiles during recent polar winters in the Arctic and Antarctic had been used to study the relation between energetic particle precipitation and downward transport of polar NO_x. NO_x are commonly enhanced when there are high levels of high-energy particle precipitation and/or geomagnetic activity. In the Arctic winter of 2005–2006 the NO_x enhancement was higher than expected from the geomagnetic conditions, indicating the importance of changing meteorological conditions (Seppälä, et al., 2007).

In January 2008, the ICESTAR/IHY team convened the 2008 Polar Gateways Arctic Circle Sunrise conference at Barrow, Alaska, to address Earth, planetary, and heliophysical science and future exploration of polar and icy worlds in the solar system. The event held satellite sessions in NASA Centers, US universities, and research institutes around the Arctic Circle in Norway, Sweden and Russia and in Antarctica, communicating between sites through video- and teleconferences. Discussions addressed the advantages of polar icy regions for testing instrumentation for different planetary missions and outer solar system exploration. Several educational sessions arranged in Barrow Point were also made available for the US participating schools through the NASA Digital Learning Network.

Riometers are emerging as an important tool in both space science and space weather. They measure the ionospheric opacity for radiomagnetic noise that comes from distant stars and galaxies. The intensity of this noise depends on the ionization level in the ionosphere and thus riometers can be used to monitor solar activity effects in the upper atmosphere. Global networks of imaging and single beam riometers support studies of high energy central plasma sheet and radiation belt electron

precipitation, dynamic magnetospheric processes such as dispersionless injections, the effect of geospace processes on high latitude atmospheric composition and dynamics, and the effects of polar cap high energy proton precipitation on communications. The growing global network of riometers facilitates studies of processes involving the production, transport, and loss of high-energy magnetospheric particles at all spatial scales. Many of these cheap instruments could be deployed in dense continent-wide networks. Agreements between data providers, under the auspices of the IPY-ICESTAR and GLORIA (GLObal RIometer Array) initiatives, and facilitated by the GAIA Virtual Observatory, are on the verge of enabling ready access to these data. The Third International Workshop on Riometry was held in June 2008 at the Zermatt Resort in Midway Utah.

The ICESTAR team helped to develop the Global Auroral Imaging Access (GAIA) data portal. This virtual observatory deals with data from geospace optical and riometer systems. While the optical and riometer instruments differ in observational technique, both remotely sense auroral precipitation. GAIA is a network-based set of tools for browsing summary data from All-Sky Imagers (ASIs), Meridian Scanning Photometers (MSPs), and riometers worldwide. It provides indexes for direct access to data. Over 10,000,000 summary images are registered in the GAIA database. They and the associated metadata provide a link to hundreds of “imager years” of data from observational programs in at least seven countries. Version 2 of GAIA was rolled out before summer 2008, with at least an order of magnitude more summary data, mirror sites at Lancaster, the Finnish Meteorological Institute, and Natural Resources Canada, tools for creating value added data products (e.g., movie making tools, and calibration information), ingestion of data in real-time, and direct access to some full-resolution data (NORSTAR, for example). This programme is the virtual observatory component of the IPY Auroral Optical Network (AON) and GLORIA projects, and falls under the ICESTAR IPY umbrella.

In 2009, ICESTAR scientists conducted a statistical study that revealed new information about the linkage between solar activity and surface temperatures in polar regions. During periods of enhanced geomagnetic activity the surface temperatures in certain high-latitude regions are on average 4-5°C higher or lower than during quiet conditions. It is thought that solar activity and consequent precipitation of energetic charged particles to upper and middle atmosphere can affect the ozone balance there, and in this way geospace variations can have an effect also on surface temperatures. Modelling efforts to testify this concept are underway.

ICESTAR researchers reported observations that clearly contradict the common assumption about symmetric aurora. It is commonly assumed that the aurora borealis (Northern Hemisphere) and aurora australis (Southern Hemisphere) are mirror images of each other, because the charged particles causing the aurora follow the magnetic field lines connecting the two hemispheres. The particles were believed to be evenly distributed between the two hemispheres, from the source region in the equatorial plane of the magnetosphere. Although it has been shown that similar auroral features in the opposite hemispheres can be displaced tens of degree in longitude and that seasonal effects can cause differences in global intensity, the overall auroral patterns were still similar. The new research shows intense spots were seen at dawn in the Northern Hemisphere summer, and at dusk in the Southern Hemisphere winter. The asymmetry is interpreted in terms of inter-hemispheric currents related to seasons, which have been predicted but not seen hitherto.

The ICESTAR team convened a scientific session at the 2009 Fall American Geophysical meeting in San Francisco. Papers on high-latitude electromagnetic fields, currents, and auroras in the conjugate hemispheres revealed latitudinal, longitudinal and hemispheric asymmetries. Such global-scale coupling effects can be predicted by global models, yet many fundamental questions remain. For example, can asymmetries in auroral intensity and morphology be accounted for by tilt angle and the influence of the sun's magnetic field on the magnetosphere? Or is the energy input from the solar wind to the magnetosphere different in the two hemispheres? What is the role of seasonal conductivity differences and inter-hemispherical currents? ICESTAR will play an important role in answering these questions by organizing and helping to develop data portals, such as GAIA (see above). The ICESTAR SRP comes to an end in 2010.

3.2.3 SSG-PS Action and Expert Groups

In 2004, SCAR signed a 5-year Memorandum of Understanding with the WCRP agreeing to co-sponsor the Climate and Cryosphere programme (CliC), the Southern Ocean Implementation Panel (already co-sponsored by CLIVAR and CliC), which was devoted to establishing a Southern Ocean observing system, and the International Panel for Antarctic Buoys (IPAB), which deploys drifting buoys on the sea ice. In turn, WCRP agreed to co-sponsor AGCS and its subgroups – ITASE and ASPECT.

The Action Group on Modelling and Observational Studies of Antarctic Katabatic winds (MOSAK):

Led by Azizan Samah (Malaysia), in 2004-5 MOSAK carried out a modelling study that produced a new, improved high resolution near surface wind field for the Antarctic, of value in studies of blowing snow, sea ice advection and the investigation of katabatic winds. In March 2006, MOSAK held a workshop to further improve understanding of the Antarctic wind field and our ability to represent it in climate models, and produced a report assessing our understanding of the near-surface flow across the continent. The group was then absorbed into AGCS.

Reference Antarctic Data for Environmental Research (READER) Action Group:

Led by John Turner (UK, BAS), this group aimed to develop high quality data sets of key variables for investigating climate variability and change, and produced a new, improved database of mean Antarctic tropospheric/stratospheric temperatures, winds and heights from surface observations and radiosonde ascents. Having started with meteorological data, in 2005, the team began developing a database of physical oceanographic data from the Southern Ocean (OCEAN-READER) to assist in understanding how the ocean works, and the influence of the physical system on the chemistry and biology of the region. The various READER databases can be seen at www.scar.org/researchgroups/physicalscience/.

The Expert Group on Operational Meteorology.

Led by Jon Shanklin (UK, BAS) until 2008, and then by S Colwell (BAS), this group provides a point of contact between many groups undertaking meteorological work in the Antarctic. Through liaison with the World Meteorological Organisation (WMO) it ensured that the amount of real-time data available from Antarctic sites increased, with data from several new Automated Weather Stations (AWS) now available on the

WMO Global Telecommunications System (GTS). During the year the Group worked with COMNAP to produce an International Antarctic Weather Forecasting Handbook (Turner and Pendlebury, 2004). WMO provided funding for a hardcopy version for distribution to all nations active in the Antarctic. During 2008, this Group continued to extend the Met-READER database (see READER, above), and provided news and information about Antarctic meteorological activities through its web page. There is evidence that many ships operating in Antarctic waters do not make meteorological reports. SCAR and the International Maritime Organisation (IMO) should co-operate to improve the situation to the benefit of mariners, tourists and science. Through liaison with the World Meteorological Organisation (WMO) the group has ensured that the amount of real-time data available from Antarctic sites has increased, with only two of the GCOS Surface Network (GSN) stations now not sending out a CLIMAT message on the WMO Global Telecommunications System (GTS). In 2009, the group continued to extend the Met-READER database, and to provide news and information through its web pages about Antarctic meteorological activities. The International Antarctic Weather Forecasting Handbook was updated in 2009, has been converted into web pages and can be accessed at (www.antarctica.ac.uk/met/momu/International_Antarctic_Weather_Forecasting_Handbook/index.htm).

Astronomy and Astrophysics Groups:

Capitalising on the use of Antarctica as a vantage point, SCAR had two astronomy groups in 2004-5: the Expert Group on Antarctic Astronomy and Astrophysics (AAA), and the Action Group on Plateau Astronomy Site Testing in Antarctica Action Group (PASTA), both led by John Storey (Australia). Although neither group met during 2005, there were several important international astronomy meetings at which members of these SCAR groups were present, giving the opportunity for informal interactions, e.g. the "Wide Field Survey Telescope at Dome C/A conference" in Beijing, China, in June. This was the first conference on Antarctic astronomy to be held in China, and included a report from the Chinese traverse team on their successful expedition to Dome A. Another astronomical highlight of 2005 was the first winter-long operation of the French-Italian "Concordia" Station at Dome C. Both Dome C and Dome A showed promise of offering exceptionally good conditions to astronomers.

In 2006 PASTA was dissolved, having achieved its objective in demonstrating that the Antarctic Plateau is the best place on Earth for surface-based astronomy – future plans call for possible installation of a terahertz telescope at Dome A, and a 2.4-metre optical/infra-red telescope at Dome C. Delegates at the SCAR meeting in Hobart in July 2006 agreed that the AAA Expert Group should develop plans for a Scientific Research Project on Astronomy and Astrophysics. Delegates at XXX SCAR in 2008 approved the plans for the Astronomy and Astrophysics from Antarctica (AAA) Scientific Research Programme. The next step would involve establishing four task groups: (i) Site testing, validation and data archiving; (ii) Arctic site testing; (iii) Science goals; (iv) Major new facilities. The full SRP would start at the beginning of 2010.

During 2008, China began constructing a permanent station at Dome A, which will join Dome C and the South Pole as one of the best sites on earth for astronomical observations. With the declaration by the United Nations that 2009 was to be the International Year of Astronomy, it was fitting that the International Astronomical

Union (IAU) was admitted to membership of SCAR as an ICSU scientific union member. During 2009, the Planning Group held two meetings coinciding with major international astronomical meetings - the Third ARENA Conference in Frascati, Italy, in May, and the International Astronomical Union General Assembly in Rio de Janeiro, Brazil, in August, to establish its four working groups. China continued the construction of the permanent "Kunlun" station at Dome A. Site testing continued at Dome C and Dome A throughout the year, and astronomical science was conducted at both these stations and at the South Pole.

The joint SCAR/SCOR Oceanography Expert Group:

Co-chaired initially by Eberhard Fahrback (AWI, Germany) and Eileen Hofmann (USA), the Oceans Group held its first formal meeting, in Venice, in October 2005. The Group aimed to encourage an inter-disciplinary approach to Southern Ocean observations, modelling and research, recognizing the inter-dependence of physical, chemical and biological processes in the ocean at present and in the past; to facilitate coordination between the physical oceanographic research groups currently active and those planning research in the Southern Ocean; to identify historical and reference data set of value to researchers, focusing initially on physical oceanography data; and to encourage the exchange of information with operational agencies. The development of databases of physical oceanographic data from the Southern Ocean (see OCEAN-READER, above) will assist in understanding how the ocean works, and the influence of the physical system on the chemistry and biology of the region. The group held its second meeting, in Hobart, in July 2006, and agreed to focus on developing plans for a Southern Ocean Observing System (SOOS). A workshop on that topic, organised by SCAR, CAML and the Partnership for Observations of the Global Ocean (POGO), took place on July 15 2006 in Hobart, and led to a SOOS workshop to be held in Bremen in October 2007. By 2007, the sponsors of the SOOS plan included SCAR, SCOR, CAML, POGO, the Global Ocean Observing System (GOOS), and WCRP. The US National Oceanic and Atmospheric Administration (NOAA) provided significant funding for meetings. The group continued developing the SOOS design plan throughout 2008, and held a planning meeting during XXX SCAR in July to agree on key actions to move the process forward. The group prepared a white paper on SOOS for the OceanObs09 meeting in Venice (Rintoul et al., 2009), and held a group meeting in Venice, on September 26th 2009, following the OceanObs09 meeting. The group meeting identified the main gaps in the SOOS Design Plan and people to fill those gaps, and discussed how the plan should be implemented. Redrafting was completed in time for the SOOS Plan to go out for wide consultation by the time of the XXXI SCAR Meeting in 2010. Australia subsequently agreed to host a SOOS Secretariat in Hobart to implement the plan. The new Ocean Expert Group co-chair, Mike Meredith (UK, BAS), agreed to act as the SCAR representative on the OceanObs09 Working Group on Ocean Observations.

Other Southern Ocean Research Activities:

In 2004-5 SCAR also co-sponsored with SCOR the ***international Antarctic Zone (iAnZONE) Project***, chaired by Karen Heywood (UK), which undertakes physical oceanographic investigations around the Antarctic margins. During 2005, both iAnZONE and the SCAR co-sponsored ***Southern Ocean Implementation Panel (SOIP)*** (chaired by Steve Rintoul, Australia), developed successful proposals for projects to be carried out during the IPY. The SOIP met at the Scott Polar Research

Institute in Cambridge in June 2005, to investigate Modes of Variability in the Southern Ocean and to develop their IPY proposal. The SOIP and the International Programme for Antarctic Buoys (IPAB), also met in Hobart in July 2006, and the SOIP held a full meeting in Buenos Aires in November to discuss progress and plans for Southern Ocean observations. Both groups were involved in developing IPY projects. The SOIP and IPAB contributed to the physical climate side of SOOS development, and so complement the work of the Oceans Expert Group (above). IPAB partners deployed more than 15 buoys in February, March, September and October 2007 in the Bellingshausen Sea, Ross Sea, and East Antarctic to study small scale ice deformation and large scale ice drift. The 5th meeting of the SOIP took place in Sydney, Australia, on 16-18 of February 2009. It aimed to evaluate progress with the design plan for SOOS, identify priority research questions in the region, and identify key gaps in Southern Ocean climate modelling and in atmosphere and ocean reanalysis and fluxes in the Southern Ocean/ice system. One of the SOIP's main achievements was the production of a vision document "A Vision for Climate Variability Research in the Southern Ocean-Ice-Atmosphere System" the results of which are feeding in the design of a Southern Ocean Observing System (the 'vision' document is on the SOIP website at www.clivar.org/organization/southern/southern.php). This document fed in to the OceanObs99 meeting in Venice in September. The IPAB, which last met in 2008, planned to meet again in 2010 to discuss implementing an array of drifting buoys on the Antarctic sea-ice.

Cryosphere Observations:

In 2004-5, SCAR had agreed with the World Climate Research Programme (WCRP) to co-sponsor the development of a Cryosphere Theme for the Integrated Global Observing System Partnership (IGOS-P). The Theme would take the form of the design plan for a Cryospheric Observing System (CryOS) for eventual review by the Committee on Earth Observing Satellites (CEOS) and the IGOS partners in May/June 2006 after which it would be implemented as part of the Global Earth Observing System of Systems (GEOSS). The CryOS team was led by J Key (NOAA) and met in Kananaskis, Canada in March 2005. Work continued in 2006 on the CryOS design; a blueprint was developed of requirements for the cryospheric observations from space and in situ that would be needed to document cryospheric change. The group's CryOS plan was published in 2007 on the SCAR website and forms a contribution to the IPY (www.eohandbook.com/igosp/cryosphere.htm).

Pan-Antarctic Observing Network Action Group (PantOS):

This group was created at the SCAR meeting in Hobart in 2006, recognising that separating natural from human induced variability in the Antarctic is a major challenge that requires sustained observation of multiple parameters. It was thought at the time that some aspects of sustained observations already being addressed by ongoing ocean and cryosphere activities (above) could be coordinated by such a group, though the group was eventually disbanded since such coordination was already occurring.

International Partnership in Ice Core Science (IPICS):

As another means of accessing information about climate change, Delegates in Hobart endorsed SCAR's co-sponsorship of IPICS (co-chaired by Eric Wolff (BAS, UK) and

Ed Brook (USA)), which plans new paleoclimate scientific research based on drilling long ice cores from the polar ice caps (www.pages.unibe.ch/ipics/). During 2007, IPICS gained sponsorship from the IGBP's PAGES programme on past global change, and the International Association of Cryosphere Sciences (IACS). The IPICS team drafted science and implementation or coordination plans for its four priority projects. The drafts for "The oldest ice core: A 1.5 million year record of climate and greenhouse gases from Antarctica" and "The IPICS 40,000 year network: a bipolar record of climate forcing and response" were completed. The plan for the IPICS 2K project – "A network of ice core climate and climate forcing records for the last two millennia" - was being drafted, along with a plan for Greenland drilling. Twenty nations were currently members of IPICS, and the IPICS agenda was endorsed in Europe with the formation of the EuroPICS project under the European Polar Board. In 2008, IPICS became a SCAR Expert Group, and held a steering committee meeting in April. Work continued to refine the science plans for the four start-up projects. In July 2009, IPICS held a major workshop in Oregon on "Science and Technology for the Next Generation of International Ice Coring". For the IPICS 2k and 40k networks, the workshop agreed on the production of initial synthesis products, and the definition of which sites should and will be drilled in the future. IPICS agreed to expand its project on the last interglacial to include Antarctica. Suitable sites for the oldest ice project were identified. IPICS will organise a major open science ice core conference in 2012.

Ice Sheet Mass Balance and Sea Level (ISMASS) Expert Group:

From 2006, this group was led by Kees Van der Veen (USA). It aimed to revitalise approaches to assessing methods and uncertainties in estimating Antarctic Ice Sheet mass balance and its relation to sea level. Many recent events suggestive of rapid ice-sheet change could not be reproduced by the current generation of whole ice-sheet models on which the predictions issued by the IPCC are primarily based. Developing the next generation of more realistic ice-sheet models requires a comprehensive and integrated approach based on targeted data collection and interpretation, and theoretical and numerical developments. ISMASS began developing plans to work on these issues with the NSF-supported Center for Remote Sensing of Ice Sheets (CReSIS), led by the University of Kansas, and the Center for Interglacial Climate at the Niels Bohr Institute at the University of Copenhagen. During 2007, ISMASS developed a strategy to improve existing prognostic ice-sheet models. Following an informal meeting during the 2006 Fall Meeting of the American Geophysical Union, ISMASS developed the case for "A need for more realistic ice-sheet models", published in 2007 as SCAR Report 30. The report documented key gaps in our knowledge that prevent development of more realistic models for the polar ice sheets and was intended to form the starting point for focussed discussion during a three-day workshop as part of XXX SCAR in St. Petersburg in July 2008. The workshop on Improving Ice Sheet Models was organised by ISMASS and co-sponsored by SCAR, CReSIS, WCRP/CliC, and the IASC working group on glaciology, and made possible with support from several agencies. Its object was to develop a community strategy on how best to: (i) improve the physical understanding of ice sheet processes responsible for rapid change; (ii) incorporate improved physical understanding into numerical models; (iii) assimilate appropriate data into the models for calibration and validation; and (iv) develop prognostic whole ice-sheet models that better incorporate non-linear ice-sheet response to environmental forcings (such as change in surface mass balance, loss of buttressing from floating ice shelves and ice tongues, and rising

sea level). Attendees participated in drafting a Science Plan (published as SCAR Report 38 in 2010) outlining a community strategy for the next 5-10 years to address current inadequacies in prognostic ice-sheet models. A paper outlining the ISMASS Science Plan was presented at the International Symposium on Glaciology in the International Polar Year, organised in Newcastle UK in July 2009 by the International Glaciological Society. The ISMASS group also ran a successful Summer School, in Portland, Oregon, in August 2009, with funding assistance from ICSU and NSF, to explore how to improve ice-sheet models used to predict sea level change, and to train young researchers (SCAR Report 36).

Environmental Contamination in Antarctica (ECA) Action Group:

This new group, led by Roger Fuoco (Italy) and Gabriele Capodaglio (Italy), was formed at the 2006 Hobart meeting. It aimed (i) to understand the mechanisms and processes controlling distribution and transport of microcomponents in polar environments, and their environmental effects; (ii) to assess the effects of global climatic changes on processes controlling the dispersion and transport of micro-components and to estimate the contribution of micro-components on climate and environmental changes in polar regions; and (iii) to monitor the environmental characteristics in Antarctica and set up a database of environmental parameters to follow the environmental evolution in Polar Regions. ECA held its first workshop in Venice in June 2007. Preliminary groups were formed for initial data collection on the themes of: Atmosphere and aerosols; Biological contamination; Hg; Inland waters and soils; Minor and trace elements in biota; Persistent Organic Pollutants (POPs) in general; Seawater; and Trace elements in snow and ice. In 2008, the ECA group met in St Petersburg to discuss contamination in terrestrial water and soil environments; heavy metal occurrence in snow and ice; the presence and distribution of Persistent Organic Pollutants (POPs) in environmental matrices; and trace elements in the water and sediment of the Southern Ocean. The workshop identified the need to integrate the ECA data base into JCADM (now SCADM, see below) through a dedicated portal; to recognise and separate local sources (bases, aircrafts, ships, traverses) from global contaminant signatures by identifying proxies of the potential sources; to optimise the use of samples collected for environmental characterization purposes and guarantee reliable data by defining the role of specimen banks (international collaboration) and organizing proficiency tests for trace contaminant determination in environmental matrices; and to organise the third ECA workshop, in Venice (June 2009) to complete datasets for environmental contaminants and define topics for joint research projects. ECA also agreed to prepare a comprehensive review of POPs in Antarctica, for presentation to the ATCM in 2009 (Fuoco et al., 2009). Due to organizational problems the 3rd ECA workshop was not held as planned in 2009, but the group continued following the priorities identified during its 2nd workshop. Analysis of the available data showed that despite the collection of a lot of data in recent years, a coordinated approach to contaminant studies across Antarctica is still lacking, and most studies have been restricted to the Antarctic Peninsula and the Ross Sea; circum-polar collaboration should be encouraged. ECA recommended that SCAR should consider establishing an internationally coordinated Antarctic Monitoring and Assessment Programme (AnMAP) (the equivalent of the Arctic Council's AMAP project); making an inventory of all Antarctic Environmental Specimen Banks (AESBs) as the basis for setting up an information system; and encouraging faster processing from sampling to publishing.

Polar Atmospheric Chemistry at the Tropopause (PACT) Action Group:

This new group was formed at XXX SCAR in July 2008, under the leadership of Andrew Klekociuk (Australia) and Gennadi Milinevsky (Ukraine). It aims to improve understanding of the distribution and variability of ozone in the polar upper troposphere – lower stratosphere (UTLS) region, and the feedbacks of ozone changes to polar climate. It will produce a database consisting of information derived from existing high latitude ozone-sonde measurements, including: high resolution profiles of ozone mixing ratio and partial pressure in the vicinity of the tropopause; the height of the chemical tropopause; and ten-day forward and backward trajectory information at selected potential temperature surfaces intersected by the ozone-sonde profiles. The information will aid model studies of the UTLS region, particularly validating heating and cooling rates and trace gas transport fluxes. Data will be made available through the Australian Antarctic Data Centre and the International Global Radiosonde Archive (IGRA). In 2009, a workshop was held in August 17-22, 2009, Kiev, Ukraine, in the framework of the 36th Annual European Meeting on Atmospheric Studies by Optical Methods, enabling PACT participants to agree on their tasks and work plan. The group created a website (<http://data.aad.gov.au/aadc/pact/>) along with a database of the tropopause and ozone distribution information derived from existing high latitude ozone-sonde measurements, and proposed a session on “Processes at the Polar Tropopause and their Association with Climate Variations” for the 2010 IPY Oslo Science Conference.

Action Group on GPS For Weather and Space Weather Forecast (joint with SSG-GS):

This new group was formed at XXX SCAR in 2008 to assist the POLENET and ICESTAR communities working on the IPY project for Upper Atmosphere Monitoring with their cooperation to achieve (i) ionospheric imaging over Antarctica; (ii) exchange of data and expertise for the application of tomography to other fields of interest (e.g. 3D water vapour reconstruction); (iii) exchange of technologies to install and manage remote GPS stations; and (iv) the possibility of hosting instruments in the polar stations. Initial work had been dedicated to first attempts to exchange data and expertise on ionospheric imaging and on the mitigation of ionospheric effects on Global Navigational Satellite System (GNSS) signals. A feasibility study was in process on the use of Antarctic measurements for estimating water vapour. Global tropospheric models for water vapour retrieval were implemented in the analysis of geodetic observations to improve the estimation process of zenith total delay with GPS data. Comparisons with old models were being carried out with alternative techniques such as radio-sondes, for estimating water vapour content. Common data sets from different techniques and overlapping observations periods had been identified and adopted as benchmarks on which cross checking could be performed and integrated water vapour be computed. Papers and posters had been presented at workshops and meeting during the year. Representatives of the group met during the AGU Fall Meeting in San Francisco in fall 2008, and the group held its first meeting in September 2009 at INGV (Rome, Italy). Discussions focused on the need to establish a permanent network of GNSS receivers for a multi-purposes investigation over the Arctic and Antarctica (e.g. for 3-D water vapour reconstruction and ionospheric imaging), and on international collaboration for bi-polar investigations particularly at conjugate regions. Next steps will be: (a) establishment of a common portal where data and products will be available for scientific communities, and (b)

organization of special sessions at international meetings for dissemination and awareness activities.

Action Group on Prediction of Changes in the Physical and Biological Environment of the Antarctic (PCPBEA) (Cross SSG Group):

This new group, formed at XXX SCAR in 2008, held its second meeting, at AWI, from 30 September to 2 October 2009. It aims to make a significant contribution to the forthcoming 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). It will encourage: integration between biological and physical data gatherers and modellers; the development of long-term biological records that can be matched with long-term meteorological and oceanographic databases; and development of biological models that can be combined with physical models of the Antarctic environment. It aims to produce a comprehensive paper comparing climate variability with biological variability, and recognises the need to examine biological tolerance to change, and the effects of extreme events.

3.3 The Standing Scientific Group on the Geosciences (SSG-GS)

The SSG-GS was led by Chief Officer Phil O'Brien (Australia) in 2004, followed by Alessandro Capra (Italy) in 2004-2010. It comprised two major Scientific Research Programmes (ACE at 3.3.1; and SALE at 3.3.2), and a number of smaller programmes (at 3.3.3).

One of the major activities of the SSG-GS is the organisation of the quadrennial meeting of the SCAR International Symposium on Antarctic Earth Science (ISAES). The 10th ISAES was held at the University of California, Santa Barbara, USA, in August 2007. The Proceedings "*Antarctica: A Keystone in a Changing World*" can be ordered from the National Academies Press (USA). In 2009, planning began for the 11th ISAES, which will take place in Edinburgh on 10-16 July 2011.

3.3.1 The SRP on Antarctic Climate Evolution (ACE):

ACE coordinates the integration of enhanced geological data and improved Antarctic palaeoclimate models for a series of time periods from the onset of glaciation around the Eocene-Oligocene boundary 34 million years (Ma) ago, to the last glacial maximum (LGM) 20,000 years ago, in order to establish the origin of the present configuration of the ice sheet. ACE results will be of use to governments in developing national inputs to the Intergovernmental Panel on Climate Change and the UN Framework Convention on Climate Change, and national responses to climate change. Prior to 2004, the ACE community had been active for a couple of years, organising meetings and publishing the results of its workshops in the international literature. ACE is following up the work of the SCAR ANTIME project (part of the former SCAR GLOCHANT programme) that focused on the Antarctic environment during the Last Glacial Maximum. ACE was led initially by Martin Siegert (UK) and Rob Dunbar (USA), and from 2008 by Carlota Escutia-Dotti (Spain) and Rob De Conto (USA).

In 2005, EXCOM approved the ACE Implementation Plan and Steering Committee. ACE published a special issue of an international journal on the topic of "Long-term changes in southern high-latitude ice sheets and climate: the Cenozoic history" (Florindo, et al., 2005). ACE also organised several meetings on climate change:

- (i) ‘Glacial Sedimentary Processes and Products’ (August 2005, Aberystwyth, Wales). This international symposium was co-sponsored by ACE, the International Association of Sedimentologists, the International Commission of Snow and Ice, the International Glaciological Society, the International Quaternary Association, the Quaternary Research Association and the British Geological Survey. It promoted dialogue between researchers in the fields of contemporary glacial processes, glacial sedimentology and ice sheet modellers in order to advance these fields in an integrated way. Contributions came from researchers working on all aspects of glacial sedimentary processes and products in glaciomarine, glaciolacustrine and terrestrial settings, from Archaean times to the present day. A special volume will appear in 2006 as a consequence of this meeting.
- (ii) ‘The Last Great Global Warming: Proxy Reconstructions and Modelling the Pliocene Climate’ (August 2005, Calgary, Canada). The Pliocene was the most recent period in Earth history in which temperatures were as warm as they are likely to be within the next century. The session addressed fundamental questions concerning our knowledge of the Pliocene world, including what the biota, climate and environments of the Pliocene were really like, why the climate was warmer than today, how variable Pliocene climate was, and the relevance of the period to the ongoing climate change debate.
- (iii) ‘Cenozoic onshore and offshore stratigraphic record from the East Antarctic margin: recent results and future directions’ (September 2005, Spoleto, Italy). This international workshop, co-sponsored by ACE with Italian and Spanish organisations, discussed the state of knowledge of Cenozoic East Antarctic ice sheet evolution, and aimed to define future research activities in the east Antarctic margin, including activities related to proposed Wilkes Land drilling by the Integrated Ocean Drilling Program (IODP).
- (iv) ‘Antarctic Ice Sheet Evolution from the Last Glacial Maximum to the Holocene: Recent Advances From Modelling and Field Investigations’ (December 2005, fall AGU, San Francisco). This special session brought together modellers and field-based researchers to discuss new results that advance our understanding of the development of the ice sheet during this period and the implications for regional and global climate change and ice retreat. The session attracted contributions from: terrestrial glacial geology and geomorphology; marine geology and geophysics; high-resolution ice core and sediment core records; glaciological modelling; climate modelling; and modelling of glacial isostatic adjustment.

By 2006, through the efforts of ACE and its predecessor programme ANTOSTRAT, it was understood that the onset of glaciation was not simply a response to the thermal isolation of Antarctica by the opening of the Southern Ocean between Antarctica and adjacent continents. Instead, recent numerical modelling suggested that declining atmospheric CO₂ was a more important factor in cooling Antarctica. Ice was, however, around before the mid-Cenozoic; marine sediments from Seymour Island provide indirect evidence, from what appear to be drop stones from icebergs, for extensive ice cover in Antarctic near the Cretaceous-Tertiary boundary 65 million years ago. In the Lambert-Amery glacier-ice shelf region, the field evidence favoured a much thinner ice sheet than models showed for the last glacial maximum 20,000 years ago. Drilling through the Ross Sea ice shelf showed that the shelf has come and

gone repeatedly over the past few hundred thousand years in response to climate change. Both Ross Sea drilling and Lambert Glacier studies confirmed that the ice margin advanced and retreated many times during late Cenozoic times and into the Quaternary, confirming suspicions that fluctuations in the ice sheet reflect changes in insolation driven by changes in the Earth's orbit. Careful examination of the timing of events associated with the Last Glacial Maximum 20,000 years ago showed that the ice sheet retreated rapidly over a period of around 800 years, apparently contributing to a global melt-water pulse as well as to a rapid rise in sea level. ACE members undertook a field campaign led by BAS to map, describe, sample and photograph glacial sedimentary sequences and associated fossils on James Ross Island. The rock and fossil samples will be analysed to create realistic environmental reconstructions and new data on environmental change, particularly Antarctic ice sheet history, over the past 7-10 million years, for input to climate models. ACE members also helped refine the International Ocean Drilling Programme (IODP) Wilkes Land drilling proposal, eventually scheduled for Austral summer 2009-10, and to develop the IODP Ancillary Program for obtaining a Holocene ultra-high resolution record of climate variability from the Adelie Drift (Wilkes Land).

During the year, ACE published another special issue of an international journal on the topic of 'Antarctic Climate Evolution - view from the margin' (Barrett et al., 2006). This was the third in three years on the theme of Antarctic Climate Evolution, and covered a wide range of techniques and timeframes concerning the evolution of the Antarctic continental margin, ranging from detailed sedimentary analyses of the Cape Roberts Project core to numerical modelling investigations of ice sheet growth and decay. ACE also organised two international meetings:

- (i) 'Deep Time Perspectives on Climate Change: Marrying the Signal from Computer Models & Biological Proxies' (April 2006, EGU, Vienna). This session discussed the relevance of pre-Quaternary data to scenarios for future climate change; and
- (ii) 'Post IPY geophysical exploration of Antarctica' (December 2006, fall AGU, San Francisco). This special session brought together experts from the area of radio-echo sounding, to speak about the development and use of this technique in the exploration of Antarctica over the last 50 years. The session detailed new ways in which the technique can be developed, which is of central interest to ice sheet modellers as it provides the only feasible means by which sub-ice bed topography can be measured.

By 2007, ACE was formally co-sponsored by IGBP's PAGES programme, and was also an IPY project. Aside from many papers in journals, ACE produced a new Special Issue of *Palaeogeography, Palaeoclimatology, Palaeoecology* on Antarctic Climate Evolution (Florindo et al., 2008). This was the fourth such ACE contribution, and contained papers from presentations at the ACE sponsored EGU meeting in Vienna (April 2006), and at the XXIX SCAR open Science meeting, Hobart, Tasmania (July 2006). ACE also published an overview of its work in the journal *Antarctic Science* and Florindo and Siegert were editing a book on Antarctic Climate Evolution for publication in 2008.

ACE continued to be much involved in scientific meetings. It supported many activities in the 10th SCAR International Symposium on Antarctic Earth Sciences (ISAES) (Santa Barbara, California, August 2007), including a short course on Geoscience Modelling for Novices, and ten individual sessions and meetings. ACE

also held a Special Session on Antarctic Climate Evolution at the 2007 INQUA meeting. In addition to the many ACE-themed sessions at the 2007 Fall meeting of the American Geophysical Union, ACE organised a Town Hall Meeting there attended by 65 people.

ACE also continued to stimulate or be involved in geological drilling. It supported a workshop to refine a proposal to the International Ocean Drilling Programme (IODP) for drilling in the Ross Sea, where focus is on the Cenozoic evolution of the West Antarctic Ice Sheet from Eocene to present. Plans for the IODP Wilkes Land drilling were moving ahead, with Carlota Escutia from ACE and Henk Brinkhuis nominated as Co-chief scientists. They attended a pre-cruise meeting with the Operators at College Station, Texas between 17 and 19 December 2007. During the year, the ANDRILL (Antarctic Drilling) Project (IPY Project #256), which ACE supports, made a major contribution to increasing the geological data set of Antarctic climate and ice sheet history for the past 20 million years. The project completed its first drill hole beneath the McMurdo Ice Shelf in January 2007, reaching a record depth of 1284.87 metres below sea floor. The recovered strata provided a record of ice shelf and climate history for the past 14 million years. The initial report was completed and was in press as Volume 14, No. 3 of *Terra Antarctica*. ANDRILL's second season of drilling was completed in November 2007 with another record depth of 1138.54 m drilled beneath the sea ice of Southern McMurdo Sound. The recovered strata overlapped with those from the first drill hole, and extended the record back to 20 million years.

Plans to undertake deep-field airborne radar surveying of the structure of the East Antarctic ice sheet progressed during the year, with a new ACE-focused programme emerging between the US, UK, Australia and New Zealand. The project planned to survey the ice sheet base across Dome C to the surrounding coastal regions in 2008. In addition plans were consolidated for the airborne surveying component (joint US-UK-Germany) of the IPY Project AGAP (Antarctica's Gamburtsev Mountains Province Project), which would take place around Dome A in the 2008/09 field season.

In 2008, ACE produced five key publications:

- (i) A Special Issue on 'Antarctic cryosphere and Southern Ocean climate evolution (Cenozoic–Holocene)' including papers on palaeoenvironments and palaeoclimates around Antarctica, based on seismic research, drilling and coring (Florindo et al., 2008).
- (ii) The book 'Antarctic Climate Evolution' including 13 chapters exploring the state of knowledge concerning the ice and climate history of the Antarctic continent and its surrounding seas throughout the Cenozoic (Florindo and Siegert, 2009).
- (iii) A peer-reviewed review article 'Recent advances in understanding Antarctic climate evolution' (Siegert et al 2008).
- (iv) A special issue, dedicated to Professor Bruce Sellwood, entitled 'The Pliocene: a vision of Earth in the late 21st Century' with 10 papers exploring what we know of the Pliocene Earth, and use of Pliocene analogues in considering future climate change (Haywood, et al., 2009).

- (v) ‘Cenozoic East Antarctic Ice Sheet Evolution from Wilkes Land Margin Sediments’, as Integrated Ocean Drilling Program Expedition 318 Scientific Prospectus (Escutia Dotti et al, 2008).

ACE also organised several meetings and/or funded scientists and students to attend them:

- (i) European Geophysical Union, Vienna;
- (ii) SCAR Open Science Conference, St. Petersburg;
- (iii) International Geological Congress, Oslo;
- (iv) AGU Fall Meeting, San Francisco.
- (v) Circum-Antarctic Stratigraphy and Palaeobathymetry (CASP) Project workshop (1-4 July, Granada) to make palaeobathymetric maps of the East Antarctic continental margin from 40 Ma to the present, using digital seismic reflection data and rock samples. Such maps set boundary conditions for ocean circulation models and coupled atmosphere-ocean Global Climate Models (GCMs).
- (vi) Pliocene Climate Model Intercomparison Project (4-6 June, New York).

During the year, ACE supported a workshop (29-30 June, Granada) for the scientific planning of the drilling by IODP of the Wilkes Land margin, Expedition 318, scheduled for January-March 2010. Following the successful McMurdo drilling (see above) an ANDRILL core workshop was held at Florida State University in April; the initial drilling report was in press; and a synthesis of the scientific results was published in the ISAES-X volume (US National Academy Press). New results were under review in a special issue of *Global and Planetary Change*, and the first set of linked data-model manuscripts were in review with *Nature*. Papers had been submitted to *GSA Bulletin* and to *Geology*. Site surveys for future potential drilling continued in Granite Harbour in the 07/08 and 08/09 field seasons. A new proposal was submitted to NSF for drilling on Coulman High beneath the Ross Ice Shelf. A drilling strategy and technical development report was prepared to define the needs for drilling through thicker, faster moving ice and in shallower water depths. The EuroANDRILL consortium proposal advanced to the full proposal stage with the European Polar Board.

Plans to undertake deep-field airborne radar surveying of the structure of the East Antarctic ice sheet progressed, with a new ACE-focused programme emerging between the USA, UK, Australia and New Zealand to survey the ice sheet base between Dome C and the coast in 2008/09. Plans were also made for the 08/09 USA-UK-Germany-China airborne survey for the IPY Antarctica’s Gamburtsev Province Project (AGAP) on Dome A.

To reach scientists beyond the Antarctic community and convey the significance of Antarctic data to palaeo-oceanographers and palaeo-climatologists worldwide, ACE and PAGES co-hosted a special session at the International Geological Congress, focusing on bi-polar records and linkages. ACE funded young scientists to attend the 2008 Urbino Summer School in Paleoclimatology, and aligned itself with the education and outreach activities of ANDRILL, which includes developing K-12 teaching resources on Antarctic Climate Evolution.

In 2009, planning was underway for site surveys for the next ANDRILL Coulman-High Project. In addition plans began to drill into subglacial environments (see SALE report, below), which will as a spin off provide useful data for ACE. For example, the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) project will study the subglacial environments of a West Antarctic ice stream by using a range of new technologies in three integrated projects:- LIZZARD: (Lake and Ice Stream Subglacial Access Research Drilling), RAGES: (Robotics Access to Grounding-zones for Exploration and Science), and GBASE: (Geomicrobiology of Antarctic Subglacial Environments).

2009 saw the US-UK-Australian-French ICECAP team deployed twice in East Antarctica. ICECAP aims to measure the ice and crustal evolution of the Central Antarctic Plate, using a DC3 airborne geophysics platform. In January 2009, ~30,000 km of geophysics data (radar, gravity, magnetics, altimetry, GPS) was acquired over the Aurora basin (flying from Casey Station), and a small amount over the Wilkes Basin (flying from McMurdo). In October 2009 ICECAP redeployed to McMurdo to continue data acquisition of the southern Wilkes basin, to Casey via Dome C for further Aurora transects, and to Durmont d'Urville for measurements of the Astrolabe basin and other outlets in the surrounding coast. Several ICESat II lines were flown in this second season, with an aim to bridge altimetric data from ICESat I. In total over 90,000 km of flight track have been acquired. 2010 will see the processing of these data, and the deployment for a third time of the DC3 later in the year. The data provide the basis for stratigraphic analysis of ice sheet history essential for ACE objectives.

ACE's main activity was the organisation of the First Antarctic Climate Evolution Symposium in Granada, Spain (7-11 September), attended by nearly 200 scientists from the fields of climate, ocean, and ice modelling, geology, geophysics and geochemistry. A summary of the symposium and its outcomes was published in EOS (DeConto and Escutia, 2010). In addition to co-funding the Symposium, ACE supported the following workshops in Granada:

- (i) Reconstruction of Antarctic Paleotopography (ANTscape) (preceded by one on 15-17 April, in Leeds (UK));
- (ii) Circum-Antarctic Stratigraphy and Palaeobathymetry (CASP) Project;
- (iii) Antarctic Ice-Volume Proxies: High and Low Latitude Sequence and Seismic Stratigraphy and Deep-Sea Records;
- (iv) Seismic Data Library System (SDLS);
- (v) Amundsen Sea Embayment: Tectonic and Climatic Evolution (Larter, Gohl and Bentley, 2010);
- (vi) Developing an Integrated Strategy to Recover Paleoclimate Records from the Antarctic Margin and Southern Ocean. This workshop outlined a sediment drilling strategy for submission to the IODP New Ventures in Exploring Scientific Targets (INVEST) meeting as a contribution to the planning of IODP beyond 2013.

ACE was also active in organizing special sessions in major scientific meetings such as the European Geophysical Union, Vienna; and AGU Fall Meeting, San Francisco. ACE continued to be committed to the training of the next generation of Antarctic scientists. For this, ACE provided travel expenses, student housing and low

registration fees for students for the First ACE symposium. ACE also co-funded an Association of Polar Early Career Scientists (APECS) workshop, 7 September, Granada, Spain.

In the January 2009 PAGES Newsletter, ACE and PAGES highlighted new paleoclimatic research being conducted at both poles, and a number of key papers were published (Naish, et al., 2009; Pollard and DeConto, 2009; Sun Bo, et al., 2009; Harwood, et al., 2009; Wilson and Luyendyk, 2009). ACE also contributed to the text of the SCAR Review of Antarctic Climate Change and the Environment (ACCE) (Turner et al., 2009a).

3.3.2 The SRP on Subglacial Antarctic Lake Environments (SALE)

Subglacial water is central to many processes that have shaped the Antarctic continent and its ice sheets today and in the past. Wet subglacial environments are isolated from the weather, the seasons, and celestially controlled climatic changes that establish fundamental constraints on the structure and functioning of most other Earth-bound environments. The processes that affect subglacial environments are mediated by the flow of the overlying ice, by the flux of heat and possibly fluids from the underlying rocks, and by hydrological processes that deliver water, materials, and heat to and through subglacial systems, dictating the residence times of water in lakes. This complex hydrological system constitutes one of Earth's last great unexplored frontiers and can be expected to contain clues to fundamental Earth and life processes. Its study will advance our understanding of how life, climate, and planetary history have combined to produce the Antarctic continent as we know it today.

SALE's main objective was to promote, facilitate, and champion cooperation and collaboration in the exploration and study of sub-glacial environments in Antarctica. It aimed to understand the formation and evolution of sub-glacial lake processes and environments; to determine the origins, evolution and maintenance of life in sub-glacial lake environments; and to understand the limnology and paleoclimate history recorded in sub-glacial lake sediments. SALE would also provide scientific advice for use by governments on scientific and technology issues including addressing environmental concerns and proposing safeguards, and encourage adherence to the agreed guiding principles for sub-glacial environmental stewardship, exploration, research, and data management.

The SALE Implementation Plan was completed and approved during 2005, along with the membership of its Steering Committee, and a SALE Programme Office was officially established at Texas A&M University. The first SALE meeting was held in Vienna, Austria in April 2005. SALE was led by John Priscu (USA).

By the end of 2005, 145 subglacial lake features had been recognised, demonstrating that subglacial lake environments were widespread beneath Antarctica's ice sheets (Siegert et al. 2005). Geophysical surveys identified additional large subglacial lakes that suggested an important role for these features in controlling ice movement and flow. Evidence was mounting that subglacial accumulations of water were an important agent of geomorphological change of the earth's surface over geological history. Biogeochemical studies of Lake Vostok accretion ice demonstrated that the lake environment varied over time frames of thousands of years suggesting these systems are dynamic and not stagnant. The age of Lake Vostok suggested that its water has been cycled over 30 times yielding total dissolved gas concentrations high enough to have important implications for drilling into the lake. The high oxygen

concentration (50 times more than air-equilibrated water) may pose a severe biological stress.

By the end of 2006, we knew that Antarctica had a complex, continental-scale hydrological system comprising interconnected subglacial lakes and streams under thick ice sheets. Satellite observations of changes in the height of flat-spots on the ice were used to deduce that one lake had discharged downstream into another. The existence of sub-ice water was confirmed when drilling to the base of the ice at the Kohnen Station in the EPICA project in January 2006 led to an injection of water into the base of the drill hole from the ice-rock interface – something also seen in Greenland drill holes.

Major scientific advances were summarised at the second SCAR SALE workshop (Grenoble, France, in April 2006). The workshop laid out plans for future SALE exploration and study, calling for a continent-wide campaign at multiple locations to systematically map subglacial lake systems and their environs, and to enter, instrument, and sample ice, water, sediments, and potential microbiological residents.

SALE was accepted as an IPY programme - SALE-UNITED (Unified International Team for Exploration and Discovery), and continued to develop its plans for the IPY. And SALE was a featured programme at the American Geophysical Union IPY session in December 2006, where SALE investigators also organised a session on sub-ice water.

During 2007, observations of phenomena related to Antarctic subglacial aquatic environments advanced our understanding on a number of fronts. For example, subglacial accumulations of water are now known to be common features beneath thick ice sheets; several new lakes had been identified, bringing the total identified features to over 160. A third inventory was planned for 2010. It is expected that as aerial coverage by various types of survey techniques planned during the IPY improves, the number of recognised subglacial features will increase.

Outburst discharges of subglacial water have repeatedly occurred over geologic time and are part of an on-going process that influences the dynamics of the overlying ice. Satellite altimetry of the ice sheet surface has shown that a portion of the central East Antarctic ice sheet lowered by 2-3 m between 1996 and 1997, at the same time the ice sheet was elevated 1-2 m some 250 km away. The only feasible explanation for this observation is the rapid loss of 1.8 km³ of water from a subglacial lake, which flowed along the base of the ice sheet and into a series of other lakes. Similar observations have been made near the margins of West Antarctica. Significant fluxes of water are flowing beneath the Antarctic ice sheet producing an interconnected system of subglacial lakes. The consequences for subglacial lakes as habitable environments and for modifications to large-scale ice flow conditions are considerable. The expected pathways of subglacial water drainage were been calculated, revealing a coherent network of channel systems, feeding water from large upstream catchments into several large outlets. Through these hydrological systems it is plausible that subglacial water can flow from the interior of ice-sheets to the ocean. The landforms created by paleo-outbursts have been documented suggesting that these processes have been an important agent of morphologic change over geologic history.

By now it appeared that a spectrum of subglacial aquatic environments exists. Subglacial aquatic environments occur in a range of geological settings suggesting that individual lakes may have differing origins and evolutions. Subglacial aquatic

environments are not randomly distributed across the Antarctic continent occurring in preferred locations. This suggests that the limnological conditions, the age, the source of founder microbes, the time of isolation and the extant microbiological inhabitants will vary from location-to-location. More than one classification system has been proposed. The recognition of a spectrum of subglacial lake types provides a framework for comparing and contrasting lake environments across the Antarctic continent, greatly enhancing our ability to test fundamental hypotheses about the origins, evolution, and significance of subglacial aquatic environments to the evolution of the Antarctic continent, its ice sheets and microbiota.

During the year, SALE built its community through workshops, meetings, and sessions at scientific meetings; identified major scientific and technological goals for SALE research and exploration through active engagement of the community; provided a framework for the US National Academies report on environmental stewardship of subglacial aquatic environments; held regular meetings that served as forums for the discussion of science and technology amongst national programmes; and educated the public through extensive and sustained coverage of SALE science in the lay and scientific press.

Antarctica's Gamburtsev Province Exploration programme included subglacial lake characterisation. Subglacial aquatic environments were also a target for exploration by the US-Norway Traverse proposed for 2008-09. The number of SALE related publications in peer-reviewed journals was increasing each year, with lists being maintained at the SCAR SALE website. The SALE Workshop organisers published an EOS front-page article in 2007 (Kennicutt and Petit, 2007).

By 2008, knowledge of subglacial aquatic environments had reached a level where major proposals were being submitted for funding by individual national programmes to directly sample the subglacial environment. These projects proposed to sample subglacial systems in compliance with current environmental protocols. The data obtained would provide the basis for future research and discovery. The three proposals were:

- (i) **Subglacial Lake Ellsworth:** In December 2008, the UK's Natural Environmental Research Council (NERC) awarded £6.7 million for sampling Subglacial Lake Ellsworth in 2012/2013, in a combined UK-USA programme. The team will use hot water drilling to penetrate the lake's ice roof without contaminating the water body below. A probe will then enter the lake and collect measurements and samples. A gravity core will collect a 2-3 m sediment core from the lake's bed. Instrument development and testing, and a comprehensive environmental evaluation, will be completed in the next three years.
- (ii) **West Antarctic Ice Streams:** Proposals to the National Science Foundation include:
 - "Lake and Ice Stream Subglacial Access Research Drilling" (LISSARD) – to study lakes beneath Mercer and Whillans ice streams;
 - "Robotic Access to Grounding-zones for Exploration and Science" (RAGES) - to study nearby hydraulically linked ice stream grounding zones.
 - "GeomicroBiology of Antarctic Subglacial Environments" (GBASE) - to study biodiversity and biogeochemical transformations within these

systems.

Sampling in 2010/2011 will yield data on the glaciological, geological and microbial dynamics of these environments and test the idea that their hydrology exerts a major control on ice sheet dynamics, geochemistry, metabolic and phylogenetic diversity, and the biogeochemical transformations of major elements.

- (iii) Subglacial Lake Vostok:** In 2007/08 the Russian Antarctic drilling programme at Lake Vostok included drilling in borehole 5G-1, radio-echo sounding, and seismic studies. From radio-echo sounding completed in January 2008 maps were made of the coastline of the lake and of the water layer thickness. Seismic studies of the water layer and of sediment rock thickness were also completed. During 2008-09, radio-echo sounding was conducted beyond the lake limits and preparations were underway to conduct seismic measurements of the geological structure of the Earth's crust. The plan was to extract the stuck drill in January 2009 so that drilling operations can continue with a modified drill.

The US National Aeronautics and Space Administration (NASA) funded development of a sub-ice robot ("Endurance") to characterise the physical and chemical environment of subglacial lakes. Endurance was deployed in late 2008 in Lake Bonney (McMurdo Dry Valleys), collecting the first 3-dimensional data on a permanently ice-covered lake. The robot also mapped the intersection of the Taylor Glacier with the water of Lake Bonney.

During the year, SALE provided a framework for developing a code of conduct for Antarctic subglacial exploration, and SCAR formed an action group to finalise this plan.

The number of SALE-related papers in peer-reviewed journals continued to increase. Two major review papers were published in 2008, summarising much of what is known about subglacial ecosystems.

By 2009, through the efforts of SALE, the international scientific community now recognised these environments as frontiers for scientific study across disciplines. SALE science had gone from a curiosity to a focus of scientific research with three national projects funded to sample subglacial lakes in both east and west Antarctica within the next five years. Geophysical exploration of Subglacial Lake Ellsworth took place in the 2007/08 and 2008/09 field seasons, when scientists used seismic and radar surveys to map the outline of the lake, measure the depth of the water (150 m at its deepest) and establish that sediments suitable for coring, which could contain a record of ice sheet history, are present. The WISSARD (Whillans Ice Stream Subglacial Access Research Drilling) project had made plans to test the cleanliness of its drill on the Ross Ice Shelf in 2011-2012, sample Lake Whillans in 2012-2013, and sample the lake's outflow at the grounding zone in 2013-2014. At Lake Vostok, the Russian crew made an unsuccessful attempt in the 2008/9 field season to recover from 3,367 metres a drill that had been damaged during an accident in October 2007. They deployed a new drill and managed to deviate around the stuck drill. They now plan to enter the lake in the 2010-2011 drilling season. Radio-echo sounding was conducted beyond the lake limits and preparations were underway to conduct seismic measurements of the geological structure of the Earth's crust. Japanese scientists continued their work at Dome Fuji and confirmed that liquid water was present at the

base of the Dome Fuji ice core and that bacteria and other organic matter was present throughout the core. These biogenic particles were not correlated with the temperature or dust records in the core. They have begun examining the possible connection between subglacial water in the Dome Fuji region with coastal lakes. Belgian scientists continued focusing on developing numerical models of ice flow over subglacial lakes, and studying the force and mass balance of large Antarctic glaciers and ice streams in combination with satellite radar interferometry, the influence of basal conditions on the dynamic behaviour of Antarctic glaciers and ice streams, and the paleo-reconstruction of the glacial history of ice sheets.

During 2009, SALE continued to develop workshops and promote sessions at scientific meetings, and worked with a SCAR action group to develop a code of conduct for subglacial exploration (the code was finalised for submission to the SCAR Delegates for approval in 2010).

3.3.3 SSG-GS Action and Expert Groups

Antarctic Neotectonics Expert Group (ANTEC):

This group formed in 2004 from a former Group of Specialists formed in 1998. It aimed to promote and coordinate multidisciplinary, multinational research relevant to Antarctic neotectonics; to identify ‘target sites’ where there is a need for deployment of geodetic and seismic stations and arrays, and airborne, marine and field campaigns; to encourage and coordinate the installation of instruments at permanent sites and in regional networks (GPS, gravity, seismic) for focused studies in target areas; and to promote and coordinate sharing of instrumentation, logistics, and data. In 2004/5 the Airborne Mapping Task Group encouraged development of coordinated international airborne campaigns over Antarctic regions that looked promising targets for neotectonic research. A web-based resource of information on technological components required for autonomous remote observatories had been started as the Technological Information Resources project. A start had been made on compiling data for the integration of data sets to study neotectonics of selected regions and an Antarctic Seismology Web Resource (AnSWer) had been developed. In conjunction with the ISMASS programme (see SSG-PS, above), the Expert Group presented a thematic set of 21 papers on “Ice Sheets and Neotectonics” that was published in a Special Issue of *Global and Planetary Change* 42 (pages 1–326) in 2004. In conjunction with a joint IRIS-UNAVCO meeting, Washington State, in June 2005, ANTEC held a workshop on Autonomous Remote Observatories for IPY, to finalise a science and implementation plan for deployment of a network of remote autonomous observatories for the International Polar Year. ANTEC was also involved in the GSA-sponsored Earth System Processes II meeting on Geodynamics, Ice Sheets and Climate, in Calgary, in August 2005. In April 2006 ANTEC organised an EGU symposium on short and long-term observations in the polar regions. But at XXX SCAR in July 2008 ANTEC ceased to exist; its activities were absorbed into the IPY POLENET Programme and SERCE (see below).

Geodetic Infrastructure of Antarctica Expert Group (GIANT):

This group provides a common geodetic reference system for all Antarctic scientists and operators. It also contributes to global geodesy for studying the physical processes of the earth and the maintenance of the precise terrestrial reference frame, and provides information for monitoring the horizontal and vertical motion of

Antarctica. Together with ANTEC (above) GIANT is a leader in the bipolar IPY POLENET (Polar Earth Observing Network) project, to which GIANT contributes the Antarctic GPS component. GIANT organised a POLENET workshop in Dresden in October 2006, and another in Santa Barbara, California, in August 2007. Discussions began there on plans to propose POLENET as a SCAR Scientific Programme Planning Group (SPPG) for 2008-10 at the XXX SCAR meeting, with the intention of it becoming a Scientific Research Programme in 2010. This prospect was replaced by the development of SERCE (below).

Solid Earth Response and influences on Cryospheric Evolution Scientific Programme Planning Group (SERCE):

This new group, formed in 2008, was intended to capitalise on GIANT, on ANTEC, and on developments made by the IPY POLENET programme in 2007-2009. SERCE aims to improve understanding of the solid Earth response to cryospheric and tectonic forcing, recognizing that neotectonic motion across Antarctica will occur due to displacements on active structures, deformation associated with active volcanism, and glacio-isostatic adjustment (GIA) of the Earth in response to changes in ice mass load. Predicted vertical motions due to GIA exceed 4 mm/year over large areas of the continent and range up to 20 mm/year - rates that can be measured with precision by GPS. Discovering modern structural displacements (for example across the West Antarctic rift system) and testing different GIA models requires a distributed array of GPS stations across the continental interior. GIA is the response of the Earth to past and present-day changes in ice sheets and glaciers. In most parts of Antarctica it is the main process causing neotectonic crustal motions. GIA models combine an ice sheet history with an assumed Earth rheology to predict past and present crustal motion, sea-level change, and changes to the Earth's gravitational field. To obtain more accurate Earth models for GIA predictions, we need to know how the physical properties and thermal structure vary laterally and with depth in the East and West Antarctic crust and mantle. Many of the needed GPS measurements of crustal motion are being made by POLENET for the IPY period. Deployment of GPS stations in optimal positions with respect to historical and modern ice mass changes, and at sufficiently high spatial resolution, will provide robust constraints on ice models, improving our ability to predict sea-level change. SERCE will provide the internationally coordinated approach to data analysis and synthesis necessary to optimise the science outcomes of these new data sets. That will enable the GIA component to be removed from satellite signals that include a GIA component, so providing a more accurate picture of ice mass balance. The SERCE programme planning group proposed to convene a multidisciplinary workshop to establish priority research themes and groups for the SERCE programme.

International Bathymetric Chart of the Southern Ocean Expert Group (IBCSO):

This new group was launched in 2005. High quality bathymetric maps are needed for safe navigation, as a first order control for modellers trying to understand the role of ocean currents, as a habitat indicator for depth-related ecosystems, and as a first clue to geological processes. IBCSO forms the steering group for production of a revised chart of the bathymetry of the Southern Ocean, in conjunction with the International Hydrographic Office (IHO), UNESCO's Intergovernmental Oceanographic Commission (IOC), and the General Bathymetric Chart of the Oceans (GEBCO). The project was discussed in detail at the GEBCO meeting in Aguascalientes in July 2005,

where it was agreed that the largest data gaps are in the South Pacific. Efforts on IBCSO increased in October 2006 with employment of an IBCSO scientific editor at the Alfred Wegener Institute (AWI). During 2006, multi-beam bathymetric data were collected and processed on four *Polarstern* cruises in Antarctic waters, and a bathymetry proposal (POBACE) was submitted to the IPY Project Office.

Both SCAR and the Scientific Committee on Oceanic Research (SCOR) strongly support efforts to gather and make available bathymetric data from sparsely surveyed areas of the Southern Ocean. At a meeting in London, in December 2006, SCOR recommended (i) that Principal Investigators (PIs) should incorporate into their proposals requests to collect and process multi-beam bathymetric data, especially data that fills present gaps; (ii) that funding agencies should fund multi-beam bathymetry data acquisition and processing on all research vessels equipped with multi-beam echo-sounders, whether on transit or on location; and (iii) that PIs should submit their data to the appropriate World Data Centre (US National Geophysical Data Centre – NGDC).

During 2007, IBCSO expanded international collaboration in data collection and exchange. New multi-beam data were collected and processed by AWI during two *Polarstern* cruises in Antarctic waters. IBCSO developed collaboration and exchanged data with the RADARSAT Antarctic Mapping Programme (RAMP), Antarctic Bedrock Topography (BEDMAP2), Antarctic Digital Magnetic Anomaly Project (ADMAR), Earth Topography (ETOPO2), and GEBCO. The first IBCSO meeting took place in Santa Barbara in August. By then the IBCSO Editorial Board comprised 15 experts from the fields of hydrography, oceanography, and ocean mapping. Presentations on IBCSO and its relevance to other projects were given to the GEBCO Sub-Committee on Digital Bathymetry (New York, in September), the Southern Ocean Observing System (SOOS) planning meeting (Bremen, in October), the Standing Committee on Antarctic Geographic Information (SC-AGI) (Buenos Aires, in October), and the GEBCO Guiding Committee (Paris, in November).

During the year, SCAR and SCOR distributed Circulars to their Members and Principal Investigators regarding the importance of bathymetric data acquisition in Polar Regions and their transfer to project databases (SCAR Circular Letter 768). The SCAR/SCOR Expert Group on Oceanography made an explicit request to national members for bathymetric data for completing Bathymetric Charts in Antarctica. And SCAR Circular Letter 770 called upon SCAR Members to nominate a wide range of scientists to the IBCSO Steering Committee, so as to increase its effectiveness. In 2008, the group collected and processed new single and multi-beam data from R/V *Polarstern* cruises in the Weddell Sea/Drake Passage and the Lazarev Sea. Other contributions were made by Australia (South Indian Ocean), New Zealand (Ross Sea and adjacent Southern Ocean), Ukraine (Antarctic Peninsula), and the United States (Amundsen Sea). Additional bathymetric data or grids were provided by Russia (South Indian Ocean), Spain (Scotia Sea), the United Kingdom (South Atlantic) and international research programmes (Bellinghousen and Amundsen Sea). A preliminary inventory of ship tracks with existing *N B Palmer*, *Polarstern*, and *J C Ross* multibeam data was now available from the Marine Geoscience Data System (MGDS) at Lamont-Doherty Earth Observatory. Presentations on IBCSO and its relevance to other projects were given to the GEBCO Guiding Committee (Tokyo, in May), the SCAR Standing Scientific Group on Geosciences (St Petersburg, in July) and the Hydrographic Commission on Antarctica (Rio de Janeiro, in October). In 2009, IBCSO organised a one-day meeting in November at AWI to discuss: the status

of the bathymetric database provided by numerous institutions, data centres and individuals; the need to enlarge the network for a continuous data exchange; and the international collaboration needed in regions of poor bathymetry but high interest, such as the Amundsen Sea. To address these questions, IBCSO proposed to provide gridded products for the relevant scientific communities, and to organise special sessions and workshops at international meetings. Unfortunately funding for the position of IBCSO Coordinator ceased in 2010, and the programme was put on hold.

Antarctic Digital Magnetic Anomaly Project Expert Group (ADMAP):

This group was created in 1995 under the auspices of SCAR and IAGA (International Association of Geomagnetism and Aeronomy) to compile national near-surface and satellite magnetic anomaly data into a digital map and database for the Antarctic continent and surrounding oceans. The unified data set will be a powerful tool for determining the structure, processes and tectonic evolution of the continent, together with providing information valuable in the reconstruction of the Gondwanaland and Rodinia supercontinents. The resulting merged potential field anomaly maps enable the geological mapping studies of the various national programmes to be better connected, providing a regional framework for the interpretation of smaller scale areas and enabling a more effective selection of areas for further investigation. ADMAP also coordinates protocols for data distribution; serves as a reference for future survey planning; and archives and maintains the magnetic anomaly database of Antarctica. In 2004/5 ADMAP was developing a DVD of the compilation of data up to 1999 for release to the World Data Centers; had updated the near-surface anomaly predictions from Magsat in the ADMAP database with the significantly more accurate observations from the Ørsted and CHAMP satellite missions; improved modeling of the Antarctic core field and its secular variations, and external fields for better definition of crustal anomalies in magnetic survey data; compiled rock magnetic and other physical properties into a database to support geological applications of the ADMAP data; developed and promoted regional and continental scale interpretation efforts of ADMAP data to provide new insight into global tectonic and geologic processes in the Antarctic context; and supported the World Magnetic Anomaly Map initiative of IAGA. The work programme continued through 2006.

In 2007, the group updated the DVD of the data compiled up to 1999 for release to the World Data Centers; developed an Antarctic Reference Model for improved magnetic anomaly determination in the Antarctic; and worked on establishing a spherical harmonic cap model for the database to facilitate analytical manipulations of the Antarctic magnetic anomaly grid for geological applications. ADMAP continued compiling all available terrestrial, marine, and satellite magnetic survey data collected since the IGY 1957-58 for the region south of 60°S, incorporating new magnetic surveys into the ADMAP digital database. The ADMAP team met in Santa Barbara in August. In 2008, ADMAP approved release of a CD to the World Data Centers with the latest completed ADMAP compilation. Work on the next compilation was underway with the intention of publication in 2010 as a contribution to the legacy of the IPY. More than 2 million line kilometres of new aeromagnetic and ship survey data since 2000 were becoming available for inclusion in the database, as well as new survey results from IPY projects, along with CHAMP satellite magnetic observations collected at altitudes of 300-325 km. Work on the next compilation continued in 2009. ADMAP is cooperating with Antarctic Geoid Project, which aims to support

gravity measurements in Antarctica to close the gaps in terrestrial gravity data coverage.

Expert Group on Antarctic Permafrost and Periglacial Environments (EGAPPE):

This group aimed to provide coordination, communication and exchange of data amongst Antarctic permafrost researchers within SCAR and the International Permafrost Association (IPA) and promote interaction and collaboration with SCAR and IPA working groups; to collect and collate spatial data on permafrost and cryosols and contribute to databases for Antarctic soils, permafrost and ground ice conditions including the active layer; to develop and promote monitoring/observation protocols and networks; to promote international cooperation and facilitate collaborative field research; and to address key science questions pertaining to permafrost. During 2004/5 EGAPPE prepared a white paper on the State of Antarctic Permafrost Science; prepared a map showing permafrost and ground ice features in the southern circumpolar region; and prepared maps showing soils of the southern circumpolar region. It was involved in the meetings of CliC-IASC (Beijing, in April); EUCOP II (Potsdam, in June); IAG (Zaragoza); and ICARP II (Copenhagen in November).

In 2006, the group continued to work through ANTPAS, the Antarctic Permafrost and Soils group. During 2006 EGAPPE prepared and was awarded an IPY project, Antarctic Permafrost and Soils (ANTPAS), for coordinating national and individual research. The aim was to create a database for permafrost within the framework of the Thermal State of Permafrost (TSP) and the Global Terrestrial Network-Permafrost (GTN-P), and for active-layer monitoring within the framework of the Circumpolar Active Layer Monitoring-South (CALM-S) and a Geographic Information System (GIS) for storing and analysing these data. A network of data centres was identified for managing ANTPAS data; soil maps were being prepared for Antarctic dry valleys; and a set of latitudinal environmental gradients was identified for monitoring change. In July 2006, ANTPAS held its second meeting, in Hobart. The Expert Group hosted a workshop in Santa Barbara, in August 2007. In December a special issue of *Geoderma* produced by EGGAPE was published with the title “*Antarctic Soils and Soil-Forming Processes in a Changing Environment*”. During 2007 EGAPPE continued developing legends for soil and permafrost map units, and prepared provisional soil and permafrost maps of (i) Transantarctic Mountains, and (ii) Antarctic Peninsula and islands, and a permafrost map of the Andes (Trombotta, Argentina). EGAPPE developed the LATITUDE60 project in Portugal, which includes (i) a 18' film about Antarctic Permafrost research distributed to over 200 schools in Portugal; (ii) 30 talks about Antarctic Permafrost research in high schools all over Portugal, including the Azores; and (iii) held the 1st Iberian Workshop on Antarctic Peninsula Permafrost and Climate Change (Lisbon, Portugal, in December). It also monitored the active layer depth, permafrost temperatures in boreholes, and soil climate in the McMurdo Dry Valleys, North Victoria Land, and South Shetland Islands, and maintained the EGGAPE database at Waikato University. EGAPPE published more than 50 papers in refereed journals pertaining to soils and permafrost in Antarctica, in the period 2005-2008. In 2008, EGAPPE hosted a workshop at the 9th International Conference on Permafrost (Fairbanks, Alaska, in June), and another at the SCAR Open Science Conference (in July). It continued developing legends for soil and permafrost map units, and prepared provisional soil and permafrost maps of the TransAntarctic Mountains, and King George Island. EGAPPE published more

than 50 papers in refereed journals pertaining to soils and permafrost in Antarctica, in the period 2006-2009.

In 2009 several members of EGAPPE helped prepare SCAR's ACCE report. The group aims to establish a network of permafrost and active layer monitoring sites as a contribution to the Standing Committee for Data Information and Communication (SCDIC) of the International Permafrost Association (IPA), and to prepare a permafrost map of Antarctica. Map upgrades will be presented in 2010 at a Cryosol session at the World Soils Congress of the International Soil Science Society, Brisbane, Australia; at a session on Permafrost and Periglacial Antarctic Environments at the Open Science SCAR meeting in Buenos Aires; and at the IPY science conference in Oslo in June.

Action Group on Acoustics in the Marine Environment:

This group was formed to consider the effects on marine mammals of noise created by marine scientific activities such as echo-sounding and airgun surveys. The group made its initial report for the Antarctic Treaty in 2002. To make use of new scientific results in understanding how marine noise impacts on the Antarctic environment, SCAR sponsored a second workshop on 12–13 May 2004 at the British Antarctic Survey, results of which were communicated to the Antarctic Treaty Consultative Meeting in Cape Town in June as Information Paper 78. The report described a structured risk evaluation of examples of scientific instruments deployed in Antarctic research programmes, and a comparison with other acoustic activities known to impact marine life. The group met again in Cadiz, Spain in January 2006 for its third workshop. It reviewed progress in understanding the effects of anthropogenic noise on marine species, and a COMNAP survey of shipping activity in the Antarctic. It revised the risk analysis conducted in 2004 by simplifying some categories and including shipping noise as a separate matrix. The group concluded that ship noise levels in the Antarctic Peninsula needed consideration because of the increase in tourist vessel traffic. The report of the meeting was presented to the ATCM in Edinburgh in June 2006 as Working Paper 41. These reports also provide scientific background information for national regulators responsible for issuing permits for marine surveys, and have been used widely by groups involved in the issues beyond the Antarctic (e.g. by the US Marine Mammal Commission).

Sub-Ice Geological Exploration Action Group (SIGE):

This new Action Group was formed in 2006 to look into ways of developing a collective SCAR-wide pan-Antarctic approach to drilling into the rocks beneath the ice to improve our understanding of Antarctica's geological history. In 2008, SIGE was converted to an Expert Group with the acronym SIEGE. Its goals were to: evaluate and synthesise potential geological targets for subglacial sampling; determine areas of high scientific interest to define targets for future surveying for geological sampling; provide a forum (a) to exchange ideas on potential geological targets and communicate plans of national and multinational campaigns for surveying and sampling, and (b) for reviewing existing ice drilling and geological sampling technology and establishing plans for developing new technologies to achieve the desired surveying and sampling. SIEGE will collaborate closely with ACE and SALE (above). One key topic area is Fast Access Drilling and Ice Sheet Bed Sampling. During 2008, US scientists held a workshop on this topic, focusing on the technology required for recovering basal ice and sub-ice geological materials. Among other

things, the workshop considered the NAS/NRC report on “Exploration of Antarctic Subglacial Aquatic Environments: Environmental and Scientific Stewardship.” Another key topic was the West Antarctic Ice Sheet Divide Basal Science and Implementation Plan. The US ice-coring programme WAISDivide aims to recover basal debris-rich ice and subglacial material including water, sediment and bedrock. The plan, produced in September 2008, laid out science and sampling objectives. The US ice core drilling office will be tasked to build the required sampling equipment if approved by NSF. Various other ice coring and drilling initiatives are being planned and are likely to include recovery of geological materials. These include Subglacial Lake Ellsworth (lake sediment core), Dome A (bedrock sample of the Gamburtsev Mountains), the International Partnerships in Ice Core Sciences (IPICS) (several planned sites), and US initiatives to access near-grounding-line lakes on Whillans Ice Stream (lake sediment and till recovery). Efforts also include programmes designed to recover subglacial sediment from below ice shelves, including the international ANDRILL programme, the Pine Island Glacier (PIG) programme, and a US Siple Coast programme that plans to recover short cores of sediment from below ice shelves.

Seeps and Vents ANTarctica Action Group (SAVANT):

This group was created at XXX SCAR in July 2008 to investigate biological communities associated with seamounts, cold seeps and hydrothermal vents, cold water coral and sponge communities. These are of interest to CCAMLR, which is charged with developing management practices for Vulnerable Marine Ecosystems (VMEs) in Antarctic waters; VME’s may include submarine cold seep or hot vent communities. Seamounts can be mapped using global data sets such as satellite gravity, and local compilations of ship-based bathymetry being made by IBCSO (see above). Location of cold seep and hydrothermal vent communities is more difficult and will require a range of ship-based techniques. Existing geophysical data can be used to identify areas likely to contain such features. SAVANT will identify areas within the CCAMLR region likely to contain Vulnerable Marine Ecosystems around cold seeps and hydrothermal vents. A pilot study reviewing echo sounder data for evidence of gas flares in the water column has begun. In August 2009, SAVANT presented a paper on “Detection of Cold Seeps and Hydrothermal Vents” to the CCAMLR Workshop on Vulnerable Marine Ecosystems (La Jolla, California) (CCAMLR paper WS-VME-09/9). The workshop accepted the four-level classification of seep and vent indicators from Class 4 areas, which are geomorphic features associated with seeps and vents, to Class 1 areas where Vulnerable Marine Ecosystems living on a seep or vent, have been confirmed. The workshop also identified the need for a guide to vent and seep organisms so that fisheries observers are able to recognise them when they are part of by-catch. Two pilot studies examined echo-sounder and seismic data from the East Antarctic margin to determine if indicators of seepage were present. The echo-sounder data did not produce any possible indicators; however, some seismic lines did have signs of shallow gas and fluid escape.

4. Scientific Advice

SCAR's second key objective, aside from but dependent on science, is to identify issues emerging from greater scientific understanding of the region that should be brought to the attention of policy makers. SCAR has been officially recognised as an Observer to the Antarctic Treaty since its formation in 1959, and in that role has the privilege of supplying both Working Papers and Information Papers containing objective and independent scientific advice for the consideration of the (now annual) Antarctic Treaty Consultative Meeting (ATCM). Since 1982, SCAR has held the same position in relation to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

In 2008, SCAR also elected to provide scientific advice to the Intergovernmental Panel on Climate Change (IPCC) on the role of the Antarctic in global climate change. In designing observing systems like the Cryosphere Observing System (CryOS) and the Southern Ocean Observing System (SOOS), SCAR is providing dual-use advice on the one hand to the academic scientific research community, and on the other hand to operational agencies (hence indirectly to policy makers), and to intergovernmental agencies like the IOC and WMO responsible for operational entities like the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS), which together contribute to the Global Earth Observing System of Systems (GEOSS) and the UN Framework Convention on Climate Change. SCAR currently reports to the IPCC through membership of the delegation of ICSU, which is recognised as an observer to the IPCC. SCAR was accredited as an observer in its own right to the UNFCCC meeting in Copenhagen in December 2009.

4.1 Advice to the Antarctic Treaty Consultative Meeting (ATCM) and Committee on Environmental Protection (CEP)

In 2004, as part of its reorganisation, SCAR replaced its Group of Specialists on Environmental Affairs and Conservation (GOSEAC), which was primarily responsible for the provision of scientific advice to the ATCM and its Committee on Environmental protection (CEP), with a new Standing Committee on the Antarctic Treaty System (SC-ATS) having the same remit but fewer resources, both financial and human. David Walton (BAS, UK), the former chairman of GOSEAC, chaired SC-ATS until 2006, when he retired and was replaced by Steven Chown (South Africa).

The reduction in effort from GOSEAC to SC-ATS had been predicated on the likelihood that the newly created CEP would take on much of the work formerly carried out by GOSEAC. This turned out to be a forlorn hope. The steadily expanding work of the CEP, which had held its first meeting in 1998, was leading to a significant increase in the number of requests to SCAR for advice and information. It became clear that SC-ATS needed to be strengthened with the help of the Life Sciences SSG to ensure that SCAR could deal with the growing demand for scientific advice, as discussed later.

Note that all SCAR papers to the ATCM can be downloaded from www.scar.org/about/standingcommittees/antarcticreatysystem/meetingpapers/. Also note that SCAR continues to provide a science lecture to each ATCM (see Table 4.1, below).

Turning to the advice provided, it had long been part of SCAR's agenda to persuade Treaty Parties to apply IUCN criteria to determining whether or not species needed to remain designated as Antarctic Specially Protected Species, and a paper on that topic was presented at the ATCM meeting in Cape Town in May-June 2004, along with a paper evaluating risks to cetaceans from noise created by seismic surveys (see Acoustics, in 3.3.3 above). SCAR's proposal to provide a "straw man example" for designating a Protected Species was well received and provided a forum for discussing selection criteria and thresholds for designation. In response to enquiries, SCAR suggested that Fur Seals did not require special protection as the population now numbered in the millions. However, a final population census was not yet available for Ross Seals. SCAR was asked to propose criteria for delisting a species (e.g. Fur Seal and Ross Seal).

At the ATCM in Stockholm, in June 2005, SCAR used the IUCN approach to show what criteria and processes could be used to designate species as meriting special protection, suggesting that consideration might be given to the Macaroni Penguin and Southern Giant Petrel. The CEP endorsed the use of the IUCN criteria for assessing endangerment, agreed that any species assessed as Vulnerable or above should be assessed for listing, and accepted the new submission process and the guidelines for an appropriate Action Plan. SCAR was requested to submit cases for the Southern Giant Petrel and the Macaroni Penguin for consideration. SCAR used the IUCN approach in a companion paper to present the case for delisting Fur Seals, using the latest data from the Expert Group on Seals. Following discussion, SCAR was asked to resubmit the case at the next ATCM using the newly agreed process and taking comments into account. SCAR was keen to provide advice on how Biological Monitoring could help determine human impacts in the Antarctic, and presented a paper on Biological Diversity drawing attention to shortfalls in current approaches. This paper attracted considerable interest and SCAR was asked to revise it to include comments on microbial introductions and resubmit it the following year as a Working Paper to allow more substantive discussion.

At the ATCM in Edinburgh in June 2006, SCAR provided four Working Papers and six Information Papers; this compares with three Information Papers and two Working Papers in Stockholm, and five Information Papers in Cape Town, a measure of the increasing workload on the SC-ATS. Included were papers on the Giant Petrel and on Fur Seals. The advice to de-list fur seals was accepted, but more work was needed on the Giant Petrels paper given new information arising from a recent meeting of the Advisory Committee on Albatrosses and Petrels. In addition, SCAR agreed to provide an assessment of status and trends for the Ross Seal. SCAR had also followed up its 2004 report on Marine Acoustics in the Southern Ocean in a further paper addressing the likelihood of damage to cetaceans from geophysical scientific surveys, which concluded that the likelihood of such damage was extremely small from the systems currently in use (see Acoustics, in 3.3.3 above). At this meeting SCAR announced its proposal to undertake an assessment of Antarctic climate change and its effects. The plan met with almost universal endorsement. Discussions with Bob Correll (USA), the prime mover behind the recently published Arctic Climate Impact Assessment, which was profiled at the ATCM, helped to define how to deliver an outcome that would be both scientifically sound and valuable for policy makers. In response to questions about the status of existing SCAR guidelines for terrestrial biological fieldwork, which were circulated for information, SCAR agreed to update them in consultation with SSG-LS and COMNAP.

SCAR provided three Working Papers and nine Information Papers for the ATCM in Delhi in 2007. Unfortunately, SCAR's advice on Giant Petrels had to be withdrawn when it was disclosed shortly before the meeting that a new and substantial source of data had been identified by the UK. SCAR disclosed the problem and outlined a solution in a "Non-Paper". As an immediate result the ATCM agreed a Resolution on the need for Parties to improve and exchange data on this species. SCAR offered to hold a workshop of the relevant experts in early 2008 so as to provide a complete picture on the status of the Southern Giant Petrel for the next ATCM. SCAR's comprehensive review of the current status of the Ross Seal, which was listed as 'Lower Risk, Least Concern' by the IUCN, but for which there were insufficient data to reach a sound conclusion, led to the CEP accepting SCAR's recommendation that the Ross Seal remain a Specially Protected Species under Annex II to the Protocol. The CEP also thanked SCAR for its paper on the Application of IUCN Endangerment Criteria at the Regional level of the Antarctic Treaty Area, noting the several important differences between regional and global listing procedures, the potential utility of the regional criteria for designation of Specially Protected Species under Annex II to the Protocol, and the information required to undertake such a regional listing, and proposed that the guidelines from the SCAR paper be added to the CEP's own guidelines for managing specially protected species. Several papers were presented on non-indigenous (invasive) species. SCAR's paper on hull fouling indicated that this provides an important route for the transport of marine non-native species to the Antarctic region, and drew attention to the need for research to understand the sources of and species contributing to hull fouling and the extent to which hull fouling could be reduced to prevent the introduction of non-native species. Australia and SCAR presented a paper on the IPY Aliens in Antarctica project, which required the collection of samples from visitors to Antarctica, and from cargoes, so as to identify the flux of spores, seeds and other propagules into the continent from elsewhere. SCAR provided a paper on the "State of the Antarctic and Southern Ocean Climate System", which was Phase I of the review of Antarctic climate that SCAR had introduced at the previous ATCM, and which addressed what was known of the physics of the climate system. These reviews help to decide what observations need to be made in future in the systems that are currently being designed to monitor the behaviour of the climate system and its effects, as the basis for understanding processes and underpinning forecasts of future change. In response, the Parties supported a Resolution calling for observations of the environment and the climate system to be sustained and enhanced.

On October 1-4, 2007, I attended a conference on "Polar Regions: Challenges and Possibilities", organised by the UK Foreign Office at Wilton Park Conference Centre, Sussex, UK. In the light of the rapid changes affecting the polar regions, the workshop examined the effects and implications in terms of human impacts and governance structures. In the course of the meeting it became clear that some of the criticism SCAR had been receiving at previous ATCM/CEP meetings stemmed from misinformation about SCAR's role in the Treaty system. I was able to counter this by explaining that SCAR is not a governmental body, but is made up of experts nominated by national academies who, even if they work for government agencies, are not there to represent their governments but to represent the science community in their country. The science carried out or fostered by SCAR scientists is for the most part about knowledge, understanding, and prediction: creating new knowledge by finding out what is there, determining the processes that drive the system, and using that knowledge and understanding in models to predict how the system may change in

the future. It is not about monitoring, for which SCAR has no remit (though some around the table thought we did), although at times SCAR science may monitor change over time as a means of determining the variability in the system. This made SCAR quite different from CCAMLR, another observer to the ATCM.

In response to these observations, the SCAR Executive Committee decided that SCAR's interrelations with the Treaty Parties deserved careful examination to see how they might be improved. An *ad hoc* Action Group on SCAR and the ATS in the 21st Century was formed under the chairmanship of Clive Howard-Williams (NZ) to review the matter, in consultation with the chairman of the CEP (Neil Gilbert) and representatives of Treaty Parties along with Tito Acero, a representative of the Antarctic Treaty Secretariat. The group met in Cambridge on 22-23 May 2008, and concluded that misperceptions of SCAR's capabilities in relation to the Treaty had come about because SCAR's role as an observer and independent source of scientific advice was not widely understood by the continually changing representatives of the national delegations to the ATCM and CEP. A number of actions were agreed to improve coordination between SCAR and the CEP and ATCM, among them the need to produce a paper explaining SCAR's Role in the Antarctic Treaty System to Antarctic Treaty Consultative Parties. The paper was presented as Information Paper IP07 to the ATCM in Baltimore in April 2009. It explained SCAR's mission and its independence from government, and reminded Parties that SCAR does not conduct routine monitoring and reporting for regulatory or compliance purposes, but does encourage the collection of long-term observations of the environment for scientific reasons, such as establishing trends and variability, to enable better understanding of underlying processes. The report made plain that SCAR followed a set of guiding principles to ensure that its advice was accurate, robust and defensible. The principles required that SCAR provide the best, most accurate and up-to-date advice, noting that assessments of scientific data and information are works in progress and that conclusions are tempered and qualified as being to the "best of our knowledge" at the time, and that incomplete or insufficient knowledge was grounds for delaying a report. Advice would rely primarily, if not exclusively, on peer-reviewed, publicly available science and information as an assurance of quality, and would be based to the extent possible on broad, inclusive, and open consultation. The report also noted that SCAR also provided a number of products potentially of interest to Treaty Parties, and kept them informed of new developments in key areas by means of the annual SCAR lecture. It was clear from the Baltimore meeting in 2009, where the paper was presented, that it went a long way towards disabusing Parties of the notion that SCAR was in some way a servant of the Antarctic Treaty System. One immediate consequence of these interactions was an invitation to the CEP Chair to attend meetings of the SCAR Delegates.

SCAR provided two Working Papers and five Information Papers to the ATCM in Kiev in June 2008. Early in 2008 SCAR had convened a workshop of experts on the Southern Giant Petrel so as to bring together all of the available data, both published and unpublished, as the basis for a final paper to the ATCM/CEP. According to the IUCN global criteria, the regional population south of 60°S is of Least Concern. That is, it does not qualify as Critically Endangered, Endangered, Vulnerable or Near Threatened. The ATCM agreed that the data do not support the designation of the Southern Giant Petrel as a Specially Protected Species under Annex II to the Protocol on Environmental Protection. As part of its Working Paper on this topic, SCAR called for additional censuses and demographic work on the species; researchers

should be encouraged to submit their data on this species to ACAP. SCAR's review of "Human Disturbance to Wildlife in the Broader Antarctic Region" noted that the effects of human disturbance on Antarctic wildlife are highly variable and that no 'one size fits all' solution can be applied to managing human disturbance effects on wildlife. SCAR also noted with concern the decline in the numbers of long-term studies being undertaken and recommended that parties encourage long-term work that will help improve management of wildlife populations in the region. SCAR also recommended that studies that are site-, timing-, and species-specific are required to produce results that are of use in the management of human activities near wildlife aggregations, and that investigations of interactions between human disturbance and other factors affecting wildlife populations are urgently required. The report was well received. Following a discussion on the question of bioprospecting in the Antarctic Treaty Area, SCAR was asked to review recent published research that may involve bioprospecting, and to provide a survey of ongoing bioprospecting research within the SCAR community. Following an ATCM workshop on hydrographic surveying, the ATCM agreed on a Resolution calling for Parties to collect hydrographic and bathymetric data on all voyages, to forward data to the appropriate chart producer, and to improve charting and surveying in the region (this supports SCAR's efforts in the same direction – see IBCSO in 3.3.3, above).

SCAR provided one Working Paper and nine Information Papers to the ATCM in Baltimore in April 2009. These included SCAR's revised Environmental Code of Conduct for Terrestrial Scientific Field Research in Antarctica, a summary of its Antarctic Climate Change and the Environment (ACCE) review, and papers on the IPY Aliens in Antarctic Project (from the Dutch perspective), the Alien Species Data Base, biological prospecting, and persistent organic pollutants (POPs) (the latter as a major report for ATCM to transmit to the office for the Stockholm Convention on POPs). In addition SCAR presented its paper on SCAR's Role in the Antarctic Treaty (see above). In the discussion on a work programme for CEP action on non-native species, SCAR pointed out that during its ongoing evaluation of terrestrial biodiversity – as part of the evaluation of the environmental domains analysis approach (which was reported in 2010) – it had become clear that there were major gaps in our knowledge of terrestrial biodiversity. Without knowing what is indigenous, identifying non-native species and their impact will be problematic. To obtain the requisite data, a similar approach on land is needed to that adopted for the Southern Ocean by the Census of Antarctic Marine Life. In 2011 SCAR plans to hold a conference on biodiversity to develop plans to tackle this problem. SCAR's advice on biodiversity resulting from that meeting will help Parties to rationalise the process of systematic conservation management. In relation to biological prospecting, the ATCM recognised that the issue was complex and urged Parties to respond to SCAR's questionnaire so that SCAR could complete its survey of bioprospecting activities and report back to the next ATCM.

SCAR's climate report was very well received, and Parties decided to forward the SCAR climate paper to the Executive Secretary of the UNFCCC for consideration at the 51st UNFCCC meeting in Copenhagen (3-4 December 2009). Parties accepted a proposal from Norway and the UK that the ATCM convene a formal climate change meeting of experts to consider how the ATCM could and should respond to climate change trends in the Antarctic. The meeting took place in Svolvær, Norway, on 6-9 April 2010, where I gave a talk on the results from the ACCE report, which was the primary guidance document for the meeting. The meeting led to preparation of a

paper on climate change, led by the UK and Norway, for the May ATCM. SCAR agreed in Baltimore to bring regular updates on Antarctic climate change to future ATCM/CEP meetings.

The CEP meeting in Baltimore in 2009 welcomed the paper on SCAR's Role in the Antarctic Treaty System, recognizing that over the years the framework within which SCAR conducts its Treaty advisory role had become increasingly complex, with the creation of new organizations, large increases in the numbers of nations participating, and the adoption of various new conventions and legal instruments. As the Antarctic Treaty System has evolved, so has SCAR and its advisory role. The Information Paper helped to establish a common understanding among Parties for setting realistic expectations in relation to SCAR's role in the Antarctic Treaty System.

Aside from these various papers, SCAR – in its role as an Interdisciplinary Body of ICSU – had presented at each ATCM meeting from 2004 onwards, on behalf of the International Project Office for the International Polar Year (IPY), a paper on progress with planning and implementing the IPY, and stressed the importance of making sure that the IPY legacy works effectively in the south polar region. In the context of the IPY, SCAR had stressed the importance of developing and implementing a Southern Ocean Observing System (SOOS) as an IPY legacy, and encouraged Parties to submit data to their National Antarctic Data Centres or equivalents, because only by sharing data across national boundaries will a pan-Antarctic view of how Antarctica works as an integrated component of the Earth system be attained. At the Baltimore meeting, Parties recognised that one of the outstanding successes of IPY was the Census of Antarctic Marine Life programme, sponsored by SCAR and organised by the Australian Antarctic Division.

At the 2009 meeting, the UK made a call for the development of environmental data services to inform environmental impact assessments (EIAs). In response it was agreed that SCAR should present to a future ATCM a paper on the work of SCAR's Standing Committee on Antarctic Data Management (see section 5, below) and the Antarctic Master Directory.

One of the major tasks of GOSEAC was to review protected area Management Plans for the ATCM. Those reviews had proved impossible for the much smaller SC-ATS created by the SCAR reorganization. Yet those plans did contain some elements for which a review of the science by SCAR was deemed appropriate (reviewing a plan's science would be a much smaller task than GOSEAC had had in reviewing an entire management plan). Recognising the difficulties that SC-ATS was having in tackling the science of Management Plans, SCAR's EXCOM agreed in 2009 to assist SC-ATS by forming an Expert Group on Protected Area Management Plans (EG-PAMP) within the SSG for Life Sciences. That group had not been fully formed, so had not made any contribution, by the time of the XXXI SCAR meeting in Buenos Aires (August 2010).

Table 4.1 The SCAR Lectures to the ATCM (text and associated slides can be downloaded from the SCAR communications web page).

2003: Anna Jones (UK): "Antarctic science: global relevance"

2004: Robin Bell (USA): "The Secret Life of Lake Vostok"

2005: Steven Chown (S.Africa): "Biodiversity: Antarctic moves in life's grand game"

2006: Valerie Masson-Delmotte (France): Climate change: an Antarctic perspective”

2007: Chris Rapley (UK): “Climate change and the Antarctic: what next?”

2008: Lou Lanzerotti (USA): “Space weather”

2009: Karin Lochte (Germany): “Marine life and change in the Southern Ocean”

2010: Charles Gerday (Belgium): “Psychrophiles: a challenge for life”

4.2 Interactions with CCAMLR

SCAR is also an Observer to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), although the relationship tends mainly to comprise an exchange of information – mainly between SCAR and the Scientific Committee of CCAMLR. There would be a strategic advantage to both organizations in a stronger linkage and SCAR has already been making efforts to strengthen the relationship. These efforts will increase following the appointment of the new Executive Secretary to CCAMLR in 2010.

To ensure a close relationship between the two organisations, SCAR appoints a representative to take the SCAR observer’s seat at CCAMLR meetings in Hobart each October. By agreement with CCAMLR this person has usually also been asked to be the CCAMLR observer to biennial SCAR meetings, though from 2006 onwards the CCAMLR Executive Secretary was invited to attend SCAR Delegates meetings. In 2004 the SCAR observer to CCAMLR was Edith Fanta (Brazil). Following her election to chair the CCAMLR Scientific Committee, she was replaced from 2005-2008 by Graham Hosie of the Australian Antarctic Division, and in 2009 by Mark Hindell of the University of Tasmania.

In 2005, CCAMLR was developing a proposal for an IPY project, a survey of Antarctic krill, and Graham Hosie was asked to coordinate between SCAR’s CAML IPY project and the CCAMLR one. This offered the prospect of discussions to develop common sampling protocols for Antarctic krill and other pelagic species that would meet the objectives of both CCAMLR and CAML/EBA, and of using standard CCAMLR sampling protocols for krill during CAML surveys. CCAMLR noted that SCAR’s Marine Biodiversity Information Network (SCARMarBIN) and Southern Ocean Continuous Plankton Recorder (SO-CPR) survey database could help to address the objectives of CCAMLR’s Ecosystem Monitoring Programme (CEMP). With regard to SCAR’s provision of bird and seal data, CCAMLR recognised that it needed to hold a workshop to determine what it actually needed in the way of seal and bird data for its ecosystem monitoring and management programme. This would help SCAR to see what was needed in the provision of bird and seal data.

Recognising SCAR’s interests in developing a closer relationship with CCAMLR, both Hosie and I attended the 25th meeting of CCAMLR, in October 2006. CCAMLR’s data manager was invited to join the SCAR MarBIN scientific steering committee, CCAMLR was invited to nominate a representative to SCAR’s Continuous Plankton Recorder Action Group. Dr Volker Siegel, a CCAMLR scientist, had already attended a meeting of the CAML Scientific Steering Committee, and Dr Stephen Nicol had joined the SCAR/SCOR Expert Group on Oceanography, where the development of a Southern Ocean Observing System (SOOS) would be useful to CCAMLR. CCAMLR was invited to send representatives to the SOOS planning meetings, to the 2008 SCAR Delegates meeting and open science

conference in 2008, and to the SCAR Biology Symposium planned for Sapporo in 2009. In return, Graham Hosie represented SCAR at the CCAMLR workshop on Southern Ocean bioregionalisation in September 2006.

Further developments to cement relations between SCAR and CCAMLR took place in 2007. Hosie attended a meeting in Cambridge in May 2007 to help to develop the CCAMLR-led IPY programme on the use of acoustics to map krill and other species in the Southern Ocean, and Hosie and Bruno Danis of MarBIN attended a CCAMLR bioregionalisation meeting in Brussels in August. At the CCAMLR meeting in October, a Resolution was adopted encouraging Members to contribute to SCAR's CAML programme. It was agreed that Dr Andrew Constable would be the CCAMLR representative on the SCAR Continuous Plankton Recorder Action Group. CCAMLR's Data Manager, Dr David Ramm, had already been appointed to the Scientific Steering Committee of SCAR MarBIN and attended its meeting in Poland in June, and Dr Volker Siegel had joined the Scientific Steering Committee of CAML. Hosie presented SCAR's ATCM paper on climate change, which elicited considerable interest from CCAMLR, especially in terms of possible impacts on krill, fish and high predators. CCAMLR's attention was also drawn again to the development of the design plan for a Southern Ocean Observing System (SOOS).

No significant further developments occurred in 2008, when Graham Hosie retired from the observer position. It took a while to find an appropriate replacement, but in due course Mark Hindell, as new Chief Officer of the newly formed Birds and Marine Mammals Expert Group, agreed to take on the task shortly before the 2009 CCAMLR meeting, when, again, there were no significant further developments. Nevertheless, SCAR is expecting to make a contribution to CCAMLR's development of protected areas labelled Vulnerable Marine Ecosystems (VMEs) through SAVANT, the new SCAR Expert Group on Seeps and Vents.

5. Data and Information

One of SCAR's main objectives was to facilitate free and unrestricted access to Antarctic scientific data and information in accordance with Article III-1c of the Antarctic Treaty. SCAR has traditionally achieved this in three ways. Scientific data was the responsibility of the Joint SCAR-COMNAP Committee on Antarctic Data Management (JCADM), which became the SCAR Standing Committee on Antarctic Data Management (SCADM) in 2008. When SCAR was restructured, geographical information became the responsibility of the Expert Group on Geospatial Information (EGGI), which changed to the Standing Committee on Antarctic Geographic Information (SC-AGI) in Hobart in 2006. In addition, over the years a number of SCAR data products had developed to meet particular scientific needs; each product (for example the Seismic Data Library System, and the Marine Biodiversity Information Network, MarBIN) was managed by a selected institution responsive to the needs of its particular scientific user or national operator community. All three of these mechanisms had arisen independently over the years, but not in any coherent and integrated fashion; at my urging it was agreed in the Strategic Plan for 2004-2010 that SCAR would *“work with JCADM and EGGI and the scientific community to develop a strategy for data and information management.”*

There is no single centralised database in Antarctica. Instead, there are several distributed systems, information about which can be obtained from the Antarctic Master Directory (AMD), which operates as a one-stop-shop. Together the NADCs and the AMD comprise the Antarctic Data Directory System (ADDS), development of which is coordinated by SCADM. The ADDS is intended to provide an index for access to all Antarctic data, no matter where or how they are stored.

5.1 Standing Committee on Antarctic Data Management (SCADM) (formerly JCADM)

SCADM's members are the managers of National Antarctic Data Centres (NADCs) or their equivalents, which are places where one can go to find out what scientific data exist at the national level. SCADM aimed to get all NADCs working together in a pan-Antarctic way, to encourage the establishment of NADCs where they did not exist, and to help to enhance the capabilities of NADCs that were not yet well developed. This is entirely consistent with ATCM Resolution 4 of 1988, which addressed the question of how to best implement Article III-1c. Despite that urging, some countries still do not have NADCs. Of those that do, the number of people serving the NADC may range from half a person to a dozen people. SCADM now has 30 member countries, and meets in the margins of the biennial SCAR meetings and, where possible, also in the intervening years. Owing to the resource constraints of individual members it is seldom possible to get full attendance, but by holding meetings in different parts of the world SCADM is able to connect face-to-face with each of its members from time to time. At each meeting there is an element of capacity building in which those from more advanced NADCs pass on their expertise to those from less advantaged bodies. The data management capacity of existing NADCs had also been strengthened by valuable nation-to-nation support from the Australian Antarctic Data Centre.

At that start of this period (2004) SCADM was managed and sponsored jointly by SCAR and COMNAP as JCADM. Aside from the tasks listed above, the main task was to encourage the submission of metadata (descriptions of available data sets) to the Antarctic Master Directory (AMD) managed by NASA through its Global Master Change Directory (GCMD) using a defined set of fields known as the Directory Interchange Format (DIF). Each submission was known colloquially as a DIF, and - to quote the jargon - JCADM aimed to increase the number of DIFs in the AMD. In effect the AMD is a web-based metadata catalogue populated with contributions from NADCs. A DIF could mean anything from one data set (say the physical oceanographic data from a research cruise to the Weddell Sea) to a collection of data comprising several national data subsets (e.g. data from several national oceanographic cruises all bundled together). Continued work by existing NADCs and the implementation of new NADCs led to a steady increase in the number of submissions (DIFs) by 18% from 2966 in June 2004 to 3503 in July 2005. By then, each NADC had its own 'portal' into the AMD, through which to provide its own DIF entries under its own national heading, so providing a national view of its metadata. NADCs were also submitting data to relevant World Data Centres and making data freely available on the Internet as data files, as databases and using Web Services to international science portals, such as the Global Biodiversity Information Facility and the Ocean Biogeographic Information System. By mid 2005, over 30 million data records had been placed online by NADCs.

Despite all this activity there were some questions over the management and direction of JCADM. To address these issues the joint meeting of the SCAR and COMNAP Executive Committees in 2004 called for an external review of JCADM, which took place in the spring of 2005 with Dr Lesley Rickards of the British Oceanographic Data Centre in the chair; Lesley, an international data management expert, was at the time Chair of the IOC's International Oceanographic Data and Information Exchange (IODE) programme. The Review applauded progress made to date, and identified a list of actions for improvement, notably for formalising the interactions between JCADM and the SSGs so that the scientific community became more aware of what JCADM had to offer, and JCADM became more aware of the needs of that community.

Much of the questioning of the value of JCADM came from COMNAP and was expressed at the annual joint meetings of the SCAR and COMNAP Executive Committees. To allay COMNAP's fears about the value of JCADM, I presented the JCADM review to the joint meeting of EXCOMs in Sofia in 2005, and the Chief Officer of JCADM, Taco de Bruin (Neth) made a presentation to them on JCADM's progress and plans. I advised COMNAP that SCAR would soon begin developing a data and information management strategy for Antarctic scientific data, but COMNAP declined to join this effort, considering it outside the COMNAP remit.

A further external (and favourable) review of JCADM took place early in 2006 and was reported to Delegates meeting in Hobart and to the joint meeting of the SCAR and COMNAP EXCOMs. Following its two reviews, JCADM had made significant improvements and was now liaising much more effectively with the SCAR science groups. Much more metadata was being loaded by NADCs onto the Antarctic Master Directory, though it was clear that some nations were far more engaged in the process than others were. Having evaluated its own terms of reference, COMNAP decided that the management of scientific data was outside its remit. Although COMNAP and many of its members supported development of JCADM and the Antarctic Master

Directory for some 10 years, it considered that JCADM was mature enough to sustain itself and so proposed to cease its financial support (amounting one third of the \$10,000 annual contribution to the GCMD) after June 2008.

In 2007, SCAR's EXCOM agreed to my proposal that when COMNAP's support ceased JCADM should be renamed the Standing Committee on Antarctic Data Management (SCADM). This would put it on the same footing as the Standing Committee on Antarctic Geographic Information (SCAGI), whose new status had been agreed in Hobart (see below). A further positive review of JCADM in early 2008 demonstrated that it now had 31 member nations and had led to around 5000 data descriptions being deposited in the Antarctic Master Directory. Two new initiatives were launched in 2008 to improve communication between data management and science practitioners: (i) a periodic newsletter; (ii) a dedicated metadata/data portal for the SCAR Evolution and Biodiversity in the Antarctic (EBA) research programme. This style of dedicated portal could be easily replicated for other key SCAR science research programmes.

Delegates at the XXX SCAR meeting in St Petersburg agreed that JCADM should be renamed SCADM from 1 January 2009. They also considered the draft of the SCAR Data and Information Management Strategy that had been called for in the Strategic Plan and prepared by the SSG Chief Officers and teams of JCADM (Kim Finney, Australia) and SCAGI (Henk Broksma, Australia) with my assistance. Delegates formed an intersessional action group to prepare a final version of the plan, and the revised strategy was approved by EXCOM in 2009 and published as SCAR Report 34. It set the direction for SCAR data management activities over the next five years and emphasised the need to leverage established regional, global and thematic data-centric networks to improve data management capability within SCAR science programmes.

To further enhance collaboration and integration with other data networks and facilities, SCAR obtained membership of the ICSU Strategic Coordinating Committee on Data and Information (SCCID), established in 2009 as a consequence of ICSU's review of global scientific data management and the ICSU World Data Centre System (WDCS). The next step for SCADM was the production of a draft SCAR Data Policy for the consideration of Delegates at XXXI SCAR in 2010.

5.2 Standing Committee on Antarctic Geographic Information (SCAGI) (formerly EGGI)

All work in Antarctica relies on a consistent geographic framework, and the main function of the SCAGI is to manage and improve the geographic framework not only for Antarctic scientific research but also for other activities including operations, environmental management and tourism. Among other things, SCAGI's work will help to provide geographic limits to Antarctic Specially Protected Areas (ASPAs) and Antarctic Specially Managed Areas (ASMAs), locations of Historic Sites and Monuments, and geospatial web services that might be needed for scientific, logistic, or tourism related applications. Nomination of a point of contact by each SCAR Member is a pre-condition for ensuring that SCAGI is effective for the benefit of all.

At the time of SCAR's reorganisation, geographic advice came from the Working Group on Geodesy and Geographic Information. SCAR decided to divide that group into the Expert Group on Geospatial Information (EGGI), and the Expert Group on

the Geodetic Infrastructure for Antarctica (GIANT) Programme (described under 3.3.3 above), and to group both under the SSG for Geosciences. Because the geospatial information group (a direct descendant of the Working Group on Cartography formed in 1958) was now one step down in the hierarchy and expected to operate through an SSG, it began to lose touch with its constituency of representatives of members, which were from all SCAR science disciplines and external bodies (Treaty Parties and operators) – a lesson in the application of the law of unintended consequences. Delegates at XXIX SCAR in Hobart in 2006 agreed that to be fully effective EGGI needed to have the status of a Standing Committee reporting to the Delegates Committee on Administration and Outreach. SCAGI was duly formed with that reporting line, and National Committees were requested via Circular Letter 766 to nominate appropriately qualified experts with a working knowledge of geographic information systems, or geographical nomenclature, or surveying and mapping.

SCAGI held its first workshop in Buenos Aires in September 2007 (SCAR Bulletin 165), and another, jointly with SCADM, in Amsterdam in July 2009 (SCAR Report 37). A core project is the SCAR Composite Gazetteer of Antarctica (CGS). This brings together in one volume all national place name information. Following development by Italy, it is now hosted on the Australian Antarctic Division website. Data providers are responsible for the accuracy of the coordinates, and can be informed of errors by users. SCADM is also responsible for managing the Antarctic Digital Database of topographic information; the SCAR Map Catalogue, which contains all available national Antarctic maps; and the SCAR Feature Catalogue, which will enable interoperability between geographical databases across the Antarctic community. In addition SCAGI is responsible for the King George Island Geographical Information System (KGIS), which is intended to facilitate the work of SCAR members who maintain bases on the Island. At the time of writing, the KGIS was not functional and needed a new server host. Initial plans to develop a Cybercartographic Atlas were dropped on the arrival of Google Earth, which made aspects of the atlas project redundant. The EGGI is also the body responsible for adopting and developing spatial standards for use in Antarctica. It provides the SCAR representative to ISO TC211, and liaises with the OpenGeospatial Consortium; these are the two primary bodies for international standards in Geographic Information.

5.3 SCAR Products

As mentioned above, SCAR also supports the activities of the scientific community through the development of a range of essential products that are established and maintained by groups of enthusiasts (Box 1). These are available on-line to the scientific community, the national science and logistics operators, the Treaty Parties and the public. SCAR has long seen the need to give these Products a higher profile on the SCAR website and to ensure that they are well developed and functioning for the benefit of all. This is a task for the future along with the perceived need to make data fields available on the SCAR website. In 2009 EXCOM asked SCADM to work with the managers of the various SCAR products to assess their viability for incorporating them into the implementation plan of the data and information management strategy, and to develop a corporate SCAR web image for them.

Box 1: SCAR Products (available from www.scar.org)

The REference Antarctic Data for Environmental Research (READER) project has created databases for meteorological data, ice core data and ocean data.

The Antarctic Digital Database (ADD) provides topographic data for Antarctica, and provides access to maps of Specially Protected Areas, Historic Sites and Monuments, and Seal Reserves.

SCAR maintains a web-accessible Antarctic Biodiversity Database whose contents contribute to the Global Biodiversity Information Facility (GBIF), and the Ocean Biodiversity Information System (OBIS).

SCAR's Marine Biodiversity Information Network (MarBIN), compiles and manages information on Antarctic marine biodiversity through a distributed system of interoperable databases.

The Composite Gazetteer of Antarctica is a comprehensive compilation of the various national lists of place names in Antarctica.

The Seismic Data Library System (SDLS) makes Compact Disc copies of seismic data over 4 years old available for joint projects and distributes them to regional libraries.

Those interested in geodesy can consult SCAR's Master index for Antarctic positional control, and SCAR's Geodetic Control Database, which provides access to high precision positional data from 7 countries, and which is useful for aerial photography, mapping and satellite imaging projects.

The Australian Antarctic Data Centre maintains SCAR's Antarctic Map Catalogue, which contains information on all maps published by SCAR Members.

BEDMAP comprises Antarctic Bedrock Mapping Data collected on surveys undertaken over the past 50 years, and describing the thickness of the Antarctic ice sheet.

Tide gauge data on sea level measured around Antarctic are managed by the Permanent Service for Mean Sea-level (PSMSL).

The IBCSO programme is producing a new bathymetric chart of the Southern Ocean.

The Antarctic Digital Magnetic Anomaly Project (ADMAG) maintains the magnetic anomaly database of Antarctica.

A Geographical Information System for King George Island (KGIS) facilitates the work of the several SCAR Members who maintain national bases there.

The SCAR Feature Catalogue will enable geographic database interoperability in the Antarctic community.

The Continuous Plankton Recorder programme compiles data from all oceanographic cruises in the Southern Ocean that collect plankton samples from a towed Continuous Plankton Recorder device.

6. Capacity Building, Education and Training (CBET) and Awards

6.1 CBET

As agreed by the Delegates at the XXVIII SCAR meeting in Bremerhaven in 2004, and in the Strategic Plan for 2004-2010, SCAR needed to develop a strategic approach to CBET to meet its objective “*to develop scientific capacity in all SCAR Members, especially with respect to younger scientists, and to promote the incorporation of Antarctic science in education at all levels.*” The strategy was published in 2006 as SCAR Report 27.

SCAR's main contribution to Capacity Building, Education and Training is through its Fellowship Programme, which began with the award of the prestigious Prince of Asturias (Spain) Prize of \$50,000 in 2002. That enabled SCAR to support five PhD/post doctoral level students part-time in 2003-2004, enabling them to visit and work with polar institutions in countries other than their own, so as to broaden their networks, exchange ideas and develop new concepts. This objective forms the core of the \$30,000 per year SCAR Fellowship Programme, which was endorsed by the Delegates at XXVIII SCAR, and which has funded on average four students per year from the 2005-6 season onwards. Each student provides a scientific and financial report for the SCAR website on completing a project. In recent years, individual countries have provided extra funds to enhance the fellowship programme. SCAR plans to expand the programme in future with funds from an educational Foundation.

As a body of ICSU, SCAR is eligible to bid for ICSU grants. In 2007 SCAR was awarded 30,000 Euros from ICSU in a joint bid with IASC, IACS and WCRP to fund a summer school on ice sheet modelling, which took place in Portland, Oregon, on 3-14 August 2009 (SCAR Report 36). In 2009, SCAR was awarded a further 30,000 Euros in a joint bid with IASC, to develop a set of 'lessons learned' from the IPY experience in engaging the public. The analysis will lead to discussions of the roles of IASC, SCAR and other key partners in how best to contribute to future ICSU education programmes, especially those with a polar focus.

Since 2008, SCAR has been a co-sponsor with IASC of the Association of Polar Early Career Scientists (APECS), which is a worldwide association for undergraduate and graduate students, postdoctoral researchers, early faculty members, educators and others with interests in polar regions and the wider cryosphere. APECS grew out of the International Youth Steering Committee of the 4th International Polar Year 2007-08, in recognition of the need to stimulate and nurture the next generation of polar researchers so as to ensure a legacy of continued polar science. The association represents people with a wide range of scientific expertise and interests including glaciology, geology, anthropology, sociology, atmospheric science, oceanography, polar biology, culture and heritage studies, linguistics, space studies, biogeochemistry, and paleontology. APECS' mission is to raise the profile of polar scientists by providing a continuum of leadership that is both internationally focused and interdisciplinary, and to stimulate the development of collaborative projects. Primary objectives include - creating a network of polar researchers across disciplines and national boundaries to meet, share ideas and experiences, and develop new research directions and collaborations; providing opportunities for career

development; and promoting education and outreach to attract future generations of polar researchers. Membership is free and open to all early career researchers interested in the natural and social sciences of the polar regions. APECS encourages senior researchers to register on the APECS website (www.apecs.is/) and serve as mentors. SCAR provides advice to APECS and co-sponsors initiatives such as workshops and brochures on topics relevant to SCAR. APECS has been invited to send an observer to XXXI SCAR, and has nominated local representatives to attend SCAR science meetings where appropriate.

SCAR is also an Associate Member of the International Antarctic Institute (IAI), which is a "virtual" university comprising the Antarctic science courses of a number of universities and institutes around the world, led by the University of Tasmania.

SCAR's CBET web pages (<http://www.scar.org/about/capacitybuilding/>) now include a large number of national Antarctic Education Websites, separated into different categories and languages.

In 2009, the SCAR CBET committee was revamped with new Terms of Reference. It will take on tasks such as the design of a Visiting Professor Scheme, as agreed by EXCOM in 2009.

6.2 Awards

At its 2005 meeting, the Executive Committee agreed to establish a SCAR medal scheme to award excellence. It was decided that there should be three different SCAR Medals:

- (i) ***"The President's Medal"*** for outstanding achievement in Antarctic science, to be awarded every four years (or once in each SCAR Presidency) to a candidate chosen by the President;
- (ii) ***"The SCAR Medal for Excellence in Antarctic Research"***; and
- (iii) ***"The SCAR Medal for International Scientific Coordination"***.

The candidates for the last two would be chosen by the Delegates and SCAR scientists through a process of consultation, with awards being decided by the Executive Committee on the recommendations of an Awards Committee every two years. Awards would be presented during the biennial SCAR meetings.

The first three SCAR Medals were awarded during the opening ceremony of the Open Science Conference (OSC) in Hobart in 2006. Peter Barrett (NZ) was awarded the President's medal for his work on the geological history of Antarctic climate change. Paul Mayewski (USA) was awarded the Research Medal for his work on ice cores and the ITASE programme. David Walton (UK-BAS) was awarded the Coordination Medal for his extensive work with the Antarctic Treaty System. Unfortunately, the stock of medals was not available in time for the meeting, but President Jörn Thiede took pleasure in awarding the three winners with chocolate medallions in gold wrappers as an interim measure until the real medals could be awarded at a later date!

The second three SCAR medals were awarded during the opening ceremony of the OSC in St Peterburg in 2008. Vladimir Kotlyakov (Russia) won the President's Medal for his contribution to glaciology, Angelika Brandt (Germany) was awarded the medal for Excellence in Antarctic Research for her work on deep water benthic organisms, and Claude Lorius (France) received the medal for International Scientific

Coordination for his work with ice coring teams over the years. Both Kotlyakov and Lorius were young scientists in Antarctica during the IGY.

In 2004 SCAR had begun the practice of awarding Certificates of Appreciation to individuals who had provided SCAR with outstanding service over long periods. These went to Bob Rutford, Chris Rapley and Roland Schlich in 2004, to Peter Clarkson in 2005, to Jörn Thiede (Germany), Jeronimo Lopez-Martinez (Spain), and Clive Howard-Williams (NZ) in 2006, and to Chris Rapley (UK), Zhanhai Zhang (China) and Des Lugg (IUPS representative and leader or member of the Human Biology and Medicine group for 30 years+) in 2008. Past Presidents continue to be made Honorary Members of SCAR.

In 2009, thanks to the behind-the-scenes efforts of Chuck Kennicutt, SCAR won a contract to manage the award of the Martha T. Muse Prize for Science and Policy in Antarctica, on behalf of the Tinker Foundation (USA). This prestigious \$100,000 unrestricted yearly prize is given to a mid-career individual who has demonstrated potential for sustained and significant contributions that will enhance the understanding and/or preservation of Antarctica. A high-powered international scientific selection committee chooses the successful candidate. The first recipient was Professor Steven Chown (South Africa), Chief Officer of SCAR's SC-ATS programme, a former Chief Officer of the SSG for Life Sciences, and the SCAR Lecturer at the ATCM in Stockholm in 2005 in the presence of the King of Sweden.

7. Communication

Antarctic science in many fields is now at the forefront of global science and highly relevant to policy development and decision-making for governments. While some countries are significantly increasing their investments in Antarctic research, others are cutting back in response to pressures on funding. The growing global population is increasing demands for oil, while oil reserves are at or approaching their peak, which means that the costs of getting to and working in Antarctica and the Southern Ocean will inevitably increase. Given increasing competition for research funds, all SCAR scientists will need to make their voices heard even more in national fora, whilst SCAR itself must redouble its efforts on the international stage to make its own voice heard. Recognising the importance of both internal and external communication, SCAR's Strategic Plan 2004-2010 called for a strategy for communication, which was published in 2006 as SCAR Report 25. This communications plan is consistent with ICSU's strategic plan for communications, which aims "*to ensure a greater awareness of the valuable contribution of science to society, and improved mutual understanding between science and other sectors of society, with a particular focus on ICSU's scientific priorities.*" In concert with this drive, one of SCAR's five primary goals is "*to communicate scientific information about the Antarctic region to the public.*"

Communication is not a subject just for the SCAR Secretariat. What is needed is a 'culture of communication', in which all SCAR scientists and staff see themselves as having a responsibility to communicate both between themselves and with the outside world, to ensure the success of SCAR's primary goals and objectives.

A core element of the Communications Plan is the biennial Open Science Conference (OSC), which attracted roughly 1000 people, most of them to present papers or posters, in Bremen in July 2004, in Hobart in July 2006, and in St Petersburg in 2008; signs are good for the OSC in Buenos Aires in August 2010, despite competition from the IPY polar science conference in Oslo in June 2010 (the BA meeting has more southern hemisphere registrants). The OSC provides a wonderful opportunity for polar scientists to meet, to exchange ideas, to form new programmes and to develop networks, as well as a chance to explain polar science to the media.

The biennial SCAR meetings in which the OSC is embedded provide further opportunities for communication, notably through the 2-3 day science business meetings of the SSGs and their subgroups, which now take place immediately prior to the OSCs, and the now 3-day long SCAR Delegates meeting, which follows each OSC. SCAR's many smaller meetings, seminars and workshops, organised from time to time by scientific or data and information subgroups, provide further mechanisms for communication, and include the major 4-yearly meetings of the Earth Scientists and the Biologists, which attract around 300 participants each. The portfolio of SCAR meetings now includes those of the SCAR Action Group on the History of Antarctic Research, formed in 2004, and will in future include meetings of the new SCAR Social Sciences Action Group formed in 2009.

Each biennial SCAR meeting is organised voluntarily by the host country, and now includes an OSC. The first OSC, in Bremen in 2004, was organised and managed internally by AWI. Hosts of subsequent SCAR meetings have chosen to use professional conference management organizations to assist in managing the OSCs. Not surprisingly, as these are profit-making concerns, this has pushed up the cost of

registration. Equally, it has meant that each of the OSCs to date, including the forthcoming one for Buenos Aires in 2010, will have been organised and managed in a different way. In 2008, I proposed to Delegates that SCAR would benefit from standardizing the approach to managing these meetings, and be able to cut costs by managing them to a large extent in-house; this would also decrease the growing burden on the local host. The costs of providing in-house management would have to be recouped from the registration fee. Delegates would address this issue again at their meeting in August 2010.

Electronic means of communication are essential in the modern day and age, and SCAR has invested considerable time and effort into developing and maintaining an attractive and user-friendly website. The new website was launched in July 2004, and got 22,000 hits and 20,000 requests for downloads (pages) that month; the monthly total rose steadily through 2009, when there was an average of 143,000 hits and 81,600 downloads per month, excluding December 2009, the month of the Copenhagen climate conference, when there were 548,000 hits and 99,000 downloads; the increase was likely due to the publication of SCAR's Antarctic Climate Change and the Environment (ACCE) report on the SCAR website at the end of November. Despite the success of the web page, web capabilities have moved on and it is now time to revamp the SCAR website to make it yet more attractive and to lead with information on key issues, such as climate change, biodiversity, and ocean acidification.

Each SCAR Standing Scientific Group has its own web page, maintained by the SCAR Secretariat, and each Scientific Research Programme maintains its own web page, accessible through the SCAR website. Most Expert Groups and some Action groups also maintain their own websites.

Starting in 2004, SCAR rapidly moved to become a paperless operation, with almost all correspondence being handled by e-mail, and papers for meetings being provided electronically on the SCAR website rather than sent by mail. SCAR Bulletins and Reports are now also provided only on the website, making the Secretariat virtually a paperless office environment. Cessation of the flow of paper meant that the former full time post of Administrative Assistant could be reduced to half time, thus cutting both personnel and printing and mailing costs. Over time, more SCAR documents have been moved from the password-protected Members page to the public pages on the SCAR website.

Starting in 2004, SCAR began providing news via the website on Antarctic and polar science and related matters. From 1 January 2005, news items were assembled into a quarterly electronic SCAR Newsletter to keep the community abreast of current developments. SCAR's main science programmes (AGCS, EBA, ACE, SALE) have each established electronic newsletters, as have the SSG for Geosciences, SCADM and MarBIN).

Also starting at the end of 2004, SCAR began providing an annual report of its activities. Annual reports are also provided to the ATCM and to the hosting organisation for the Secretariat (Scott Polar Research Institute) but are no longer required by SCAR's parent body, ICSU. The annual report features highlights of research results. From time to time these are now compiled into a report on SCAR's achievements. Achievements to 2006 are documented in SCAR Report 29. Reports on national activities have been streamlined and are posted on the SCAR web page.

Starting in July 2008, the incoming President, Mahlon “Chuck” Kennicutt, inaugurated a series of monthly ‘Notes from the President’, to inform the SCAR community about particular developments. These are supplemented by SCAR Circular Letters, which inform or request action from National Committees and Delegates.

For general information, SCAR now has a brochure, and various posters, and PowerPoint presentations on SCAR have been prepared and are available via the SCAR website at www.scar.org/communications/ – including the ones for the SCAR lectures to the ATCM.

To improve communications internally, Chief Officers of SSGs, SCADM and SCATS are now invited to attend Executive Committee meetings, as *ex officio* members. They also attend Delegates meetings. To improve communication and coordination between the SSGs and SRPs, Chief Officers of SSGs, SCADM and SCATS attend Cross-Linkages meetings with the leaders of the Scientific Research Programmes. Cross-Linkages meetings, initiated at the instigation of President Jörn Thiede, were held in Amsterdam in November 2005, Rome in November 2006, and Modena in February 2009. The Cross-Linkages meetings, reported on the SCAR Science and Data web page, have greatly improved the development of interdisciplinary approaches to Antarctic science, including the development of the ACCE report.

Outcomes of SCARs major meetings are recorded in SCAR Bulletins. Action sheets from each meeting are combined to form the work programmes for the Secretariat, Delegates and EXCOM. These action sheets form the basis for the annually modified Implementation Plan posted on the SCAR website.

Media contacts are made when there is something exciting to report (such as the launch of the ACCE report), and during the OSC meetings.

8. SCAR, IASC (International Arctic Science Committee) and the IPY (International Polar Year 2007–08)

8.1 SCAR and IASC – a Bipolar Approach

IASC was formed in 1990 and started operations in 1991. In 1999 it established the Arctic Science Summit Week (ASSW), usually held in March each year, and providing opportunities for coordination, collaboration and cooperation in all areas of Arctic science, and combining science and management meetings to save on travel and time. Recognizing the growing importance of the Arctic Science Summit Week, and given the bipolar nature of much polar research, especially where ice is concerned, at its meeting in Brest in 2003 SCAR's EXCOM decided that SCAR should seek to have a formal representative at IASC meetings with a reciprocal invitation for IASC to be represented at SCAR meetings. This wish was reiterated at the January 2004 meeting of the EXCOM in Bremerhaven, but SCAR's reorganisation and the first Open Science Conference absorbed the Secretariat's time. I initiated formal discussions between SCAR and IASC in January 2005, with a view to improving collaboration in areas of common interest, holding a joint SCAR-IASC forum in association with SCAR's proposed 2008 meeting in St Petersburg, and considering the implications of the IPY for both organisations. I met Odd Rogne (Norway), the IASC Executive Secretary, in the margins of the IPY Planning Meeting in Paris in March 2005. Given that both bodies have polar interests, and both are associated closely with ICSU (SCAR as one of ICSU's Interdisciplinary Science Bodies, and IASC as an International Scientific Associate of ICSU), there were strong grounds for supposing that a closer linkage between the two organisations should bring benefits to both parties, not least in an exchange of views and experience on important scientific topics. A SCAR and IASC Letter of Agreement was developed, and duly signed in July 2006. Through it, SCAR and IASC agreed to combine their efforts in selected fields and activities so as to raise the level of impact of both organizations in terms of making scientific advances and of advising policy makers, as well as to avoid duplication. The development of the IPY was an important driver for the two organisations coming together, though not the only one; the partnership would have developed anyway.

The association has proved successful, notably due to the cooperative responses of the IASC Directors Odd Rogne and his successor Volker Rachold, with both of whom it was a pleasure to work. SCAR and IASC have worked hard together to ensure a higher profile for the polar sciences in the post-IPY world. Both organisations have found it disappointing that there is no lasting mechanism within ICSU to enable polar issues to be brought to the attention of the ICSU Executive Board or General Assembly once the IPY Joint Committee is disbanded in 2010. Polar issues should be on the agenda of the ICSU governing bodies for the simple reason that it is in the polar regions that global warming is happening fastest and having its greatest effect on the environment, on ecosystems, and on people.

SCAR and IASC also have a common interest in having a higher profile within ICSU's global programmes (Earth System Science Partnership – ESSP, and International Geosphere-Biosphere Programme - IGBP), which previously have largely ignored the polar realms. The future of these large programmes is currently

the subject of an ICSU consultation. SCAR and IASC do have a high profile within the World Climate Research Programme, of which ICSU is a co-sponsor, and in July 2008 IASC joined SCAR as a co-sponsor of the WCRP Climate and Cryosphere programme (CliC).

SCAR and IASC now co-sponsor the biennial High Latitude Climate meetings that take place every 2 years or so. They also co-sponsored the ice sheet modelling workshop in St Petersburg (July 2008), and with funding from ICSU and NSF subsequently co-sponsored its follow up, an ice sheet modelling summer school (Portland, Oregon, August 2009). In July 2008 they co-signed a Letter of Agreement on cooperation with the new International Association of Cryospheric Sciences (IACS) and a Memorandum of Understanding agreeing to cosponsor the Association of Polar Early Career Scientists (APECS). In March 2009 they co-signed a Letter of Agreement with the International Permafrost Association (IPA), which was already co-sponsor of SCAR's Permafrost science group. These agreements effectively bind together the main polar bodies of ICSU.

SCAR and IASC worked closely together as members (*ex officio*) of the IPY Joint Committee (see 8.2, below). Both organisations are encouraging the development of the ocean observing systems called for by the IPY (an international Arctic Ocean Observing System (iAOOS) and a Southern Ocean Observing System (SOOS). They jointly sponsored the Open Science Conference in St Petersburg, Russia (8-11 July 2008), which was adopted and co-sponsored by ICSU and WMO as the 1st IPY conference. And they continued to work together as co-sponsors (with others) of the 2nd IPY science conference (Oslo, June 2010), and are working in a similar fashion in relation to the 3rd IPY conference (Montreal, Canada, April 2012).

The ending of the IPY begs the question of how SCAR and IASC may maintain the IPY legacy. To address that question, in January 2008 the two organisations formed the Joint IASC/SCAR Bipolar Action Group (BipAG), chaired by Heinz Miller (AWI, Ger) to advise both bodies on (a) how best to develop collaborative bipolar activities in the future, and (b) how best to nurture the IPY 2007/2008 legacy. BipAG met in St Petersburg on July 8, 2008, and in Oslo, on October 15-16, 2009, and prepared advice for the management bodies of its two parents. From 2010, BipAG will handle bipolar issues, and joint efforts of the SCAR and IASC EXCOMs will handle IPY legacy issues.

8.2 SCAR and the IPY

SCAR began thinking about an IPY at its Tokyo meeting in July, 2000, where Karl Erb (USA) told Delegates that the COMNAP XII Meeting held during the previous week had agreed “*to prepare for recognition of the 50th Anniversary of the International Geophysical Year in 2007-08*”. Next year, the joint meeting of the SCAR and COMNAP Executive Committees in Amsterdam (22 August 2001) discussed what activities might be promoted to celebrate the 50th Anniversary of the IGY in 2007–08, and it was agreed to investigate what plans ICSU might have. At XXVII SCAR, in Shanghai in 2002, Delegates supported the proposal that there should be an IPY programme to celebrate the 50th anniversary of the IGY. Chris Rapley (UK) agreed to make enquiries to ICSU and IUGG. In due course he and Robin Bell (USA) presented to ICSU a proposal for an IPY that was duly accepted by the ICSU governing bodies. Meanwhile the 14th WMO Congress in May 2003 had independently approved the idea of holding an IPY in 2007–08, and eventually the

ICSU and WMO proposals came together. Much of the history is in papers by Bell (2007) and Summerhayes (2008).

At SCAR's 2002 Shanghai meeting, Heinz Miller (AWI, Germany) suggested that SCAR investigate the Ice Divide of Eastern Antarctica (IDEA), which would involve a surface traverse of the ice sheet of Eastern Antarctica over a four-year period (2007–11) as the basis for glaciological, geological, geophysical and climatological studies. Miller was asked to lead a small group to consider how the plans for IDEA could best be elaborated and advanced, and to report to EXCOM in July 2003. In addition, Delegates were reminded that 2008 was also the 50th anniversary of SCAR. People had begun to ask what SCAR would do to commemorate this. Michael Stoddart (Australia) suggested that it was the right time for a written history of SCAR and the Delegates in Hobart unanimously agreed! This report is one result. Another was the Gala Dinner to celebrate SCAR's 50th Anniversary, hosted for the SCAR Delegates at the Academy of Sciences in Moscow in July 2008 and attended by Mr Artur Chilingarov of the Russian Duma.

The arrival of the IPY, which aimed to achieve an intensive burst of internationally coordinated, interdisciplinary, scientific research and observations focused on the Earth's polar regions from 1 March 2007 until 1 March 2009, was a fantastic opportunity for SCAR to work to strengthen international coordination of research and enhance international collaboration and cooperation in the Antarctic. Concealed in the opportunity was the challenge to SCAR to work out how it would manage the eventual legacy of new or enhanced observational systems, facilities and infrastructure arising from the IPY. SCAR faced the further challenge of responding to the IPY initiative with no extra resources of manpower or money. The planners of the IPY were spurred on by the need to clarify with some urgency the contribution of the polar regions to the global climate system through the effect of melting ice on rising sea levels.

As mentioned under 4, above, as a body of ICSU, one of the co-sponsors of the IPY, SCAR offered a means of presenting IPY plans and progress reports to the ATCM, the first of them being to the XXVI ATCM, in Madrid in June 2003. In response, the ATCM adopted a Resolution calling for Parties to support planning and implementation of the IPY. At its meeting in Brest (July 2003), SCAR's EXCOM welcomed the news that ICSU had approved the establishment of a Planning Committee for the IPY, with SCAR Vice President Chris Rapley (UK) as Co-chairman. Aside from Rapley, there were nine active SCAR scientists in ICSU's IPY planning group of 2003–04: Co-Chair Robin Bell (USA) along with Ian Allison (Australia), Bob Bindschadler (USA), Gino Cassassa (Argentina), Steven Chown (South Africa), Vladimir Kotlyakov (Russia), Olav Orheim (Norway), Pram Pandey (India), and Zhanhai Zhang (China). In June 2004, Ian Allison agreed to be the official SCAR representative on the planning group.

At its meeting in Bremerhaven in January 2004, SCAR's EXCOM endorsed the active involvement of SCAR in the IPY process and tasked me with representing SCAR's interests in IPY planning, and with ascertaining how to maximise SCAR's role in coordinating and implementing Antarctic components of the IPY. I attended the IPY Open Forum in Paris, 31 March 2004, which coincided with the 3rd meeting of ICSU's IPY Planning Group. There I described SCAR's mission, and explained that SCAR could help to make the IPY a success by building on the already successful SCAR initiatives in the Antarctic. SCAR could help to achieve the goals

of the IPY by providing access to Antarctic Treaty Parties and to the network of SCAR scientists.

In May 2004 the leaders of the SCAR Science Research Programmes agreed to adapt their programme plans to indicate the extent to which these would contribute to the IPY. They decided to treat the IPY as a ‘special observing period’ within their larger programmes, and submitted IPY proposals tailored accordingly. Their proposals were approved along with proposals led by other SCAR activities such as the sea ice programme ASPeCt, CAML, ITASE and several others. Of the approved IPY science programmes, 97, or just under half of the total, were relevant to SCAR. Of this 97, 75 were in the natural sciences, 40% of them focused on the Antarctic and the rest being bipolar. 24 were SCAR-led, and another 27 involved SCAR science groups.

At its meeting in Bremen in July 2004, the SCAR EXCOM decided to form an *ad hoc* SCAR Advisory Committee on the IPY, chaired by me: (i) to advise it on the SCAR input to the IPY Science Plan, on SCAR’s role in IPY Implementation, and on the content of the IPY Implementation Plan; (ii) to work with COMNAP to realise IPY objectives for the Southern Hemisphere; (iii) to ensure that SCAR’s Scientific Research Programmes were contributing to the IPY; and (iv) to monitor the IPY process and to advise SCAR how its contributions to the IPY should develop. The *ad hoc* group met on 30 July 2004 in Bremen. COMNAP formed a complementary Coordinating Group for IPY preparations, chaired by Anders Karlqvist (Sweden), with which the SCAR group would liaise.

At the IPY Open Forum in Paris in September 2004, I presented papers on “SCAR Comments on the IPY 2007-2008” and “Recommendations on data management for the International Polar Year 2007-2008”. The SCAR ‘Comments’ paper was subsequently presented to the Delegates at XXVIII SCAR in Bremerhaven in October 2004. Delegates agreed with its recommendations that:

- (i) a comprehensive data and information management should be an integral and essential part of the IPY legacy;
- (ii) major SCAR programmes should be allocated a high priority for investment, with the highest priority being for subsets of these programme activities that require Special Observations during the IPY;
- (iii) SCAR’s Circum-Antarctic Census of Marine Life (CAML) programme would make a valuable IPY contribution;
- (iv) the IPY offered an opportunity to develop an integrated Southern Ocean Observing System (SOOS);
- (v) the IPY offered an opportunity for a major bi-polar ice-drilling programme to provide essential input to climate models;
- (vi) the IPY should take a geological perspective on climate change;
- (vii) the IPY should support the Cryosphere Theme of the IGOS Partners;
- (viii) the IPY offered the opportunity to focus geological attention on the subglacial highlands of the Gamburtsev Mountains;
- (ix) the IPY provided an opportunity for initial exploration of subglacial Antarctic lake environments.

When the call for expressions of intent in IPY activities was distributed by ICSU and WMO (9/11/2004), SCAR ensured that all of its science groups were made aware that they should consider submitting proposals for IPY activities. On November 10, SCAR suggested to the Chairman of the Global Ocean Observing System's Scientific Steering Committee (J. Baker) that GOOS should consider developing proposals for an Arctic and a Southern Ocean Observing System (SOOS), to meet the IPY Planning Group's requirement. This was supported by WMO but to no effect. Independently, SCAR directly stimulated the development of two IPY programmes serving the eventual needs of a SOOS – these were CASO (Climate of Antarctic and the Southern Ocean) and SASSI (Synoptic Antarctic Shelf-Slope Interactions Study), and, with its sister ICSU body, SCOR, began developing a design plan for a SOOS. On November 12, SCAR also encouraged the Cryosphere community and WCRP to submit an expression of interest focused on the bipolar Cryosphere plan being developed by SCAR, CliC and WCRP, which duly emerged as an IPY programme.

ICSU and WMO invited SCAR to provide a representative to be a member *ex-officio* of the ICSU-WMO Joint Committee for the IPY (the IPY-JC), which would steer the IPY process on behalf of the two sponsors. SCAR appointed me to take on this role. COMNAP was not invited to join the Joint Committee, so SCAR offered to provide an avenue through which COMNAP could communicate its thoughts to the Committee. The IPY-JC held its first meeting in Paris (7–9 March 2005), in association with an IPY Open Forum (10–11 March 2005). Several SCAR scientists were appointed to be members of the IPY-JC, including Chris Rapley (UK), Robin Bell (USA), Eberhard Fahrback (Germany), Jeronimo López-Martínez (Spain), Ian Allison (Co-Chairman, Australia), Vladimir Kotlyakov (Russia), Takahashi Yamanouchi (Japan) and Edith Fanta (Brazil, later deceased). The Chief Officer of SCAR's data committee (JCADM), Taco de Bruin, took on the role of Co-Chairman of the IPY Data Sub-Committee. On my retirement (April 2010), I would be reappointed to the JC *ad hominem* and SCAR would be represented *ex officio* by the President, Chuck Kennicutt, until the JC came to its end in June 2010 after the 2nd IPY Science Conference in Oslo that month.

The IPY-JC agreed that the proposed SCAR-IASC Open Science Conference in St Petersburg (2008) should be the first of a series of three IPY science conferences. The conference was co-sponsored by ICSU and WMO and organised by SCAR and IASC, who created an international scientific organising committee for the task, chaired by Chuck Kennicutt (USA) for SCAR and Louwrens Hacquebord (Netherlands) for IASC. A similar organising committee, under the chairmanship of Olav Orheim (Norway) was created to organise and manage the 2nd IPY science conference, which took place in Oslo in June 2010. In late 2009 a follow-on organising committee under the chairmanship of Peter Harrison (Canada) and Karl Erb (USA) was formed to arrange the 3rd and final IPY science conference, which would take place in Montreal in 2012. As Executive Director of SCAR, I served on all three of these organising committees, the last of which included the incoming SCAR Director, Mike Sparrow.

In recognition of the impact of the four IPYs on polar science, SCAR decided to launch its Open Science Conferences with the prestigious “*Weyprecht Lecture*” in recognition of Karl Weyprecht, the inspiration behind the first IPY (1882-83). The first Weyprecht lecture was delivered in St Petersburg in July 2008 by Robin Bell (USA) on the topic of the Gamburtsev Mountains beneath the East Antarctic Ice Sheet.

SCAR thus played a key role in the inception of the IPY, its science was very well represented in the science programmes approved by the IPY Joint Committee, it wielded appropriate influence in the way in which the IPY was steered, and it played a prominent role in organizing the IPY science conferences. SCAR's involvement in IPY affairs did not end there, as following the IPY SCAR was expected to take a major role in managing the Antarctic legacy of the IPY, in much the same way that it had successfully managed the Antarctic legacy of the IGY of 1957-58 (SCAR was formed by ICSU in 1958 to carry out that task). The key elements of the IPY legacy appropriate for management by SCAR are scientific cooperation, the development of observing systems, data and information management, and the development of early career scientists and public outreach. All of these were already part of the SCAR Strategic Plan 2004-2010, and will be key entities in the Strategic Plan for 2011-2016. Under the heading of observing systems, the focus will be on completing and implementing the design plan for a Southern Ocean Observing System (SOOS), considered an essential operational requirement by WMO. SCAR will also contribute to implementation of the Cryosphere Observing System (CryOS) (see section 3.2.3 above). Improving Antarctic data and information management is an ongoing objective, and the SCAR Data and Information Management Strategy for the Antarctic is an essential first step to managing the IPY data legacy in the Southern Hemisphere. Through the medium of the IPY, ICSU has also recognised the need for improved management of polar data and has created what it calls a Polar Information Commons (PIC) to develop this further. Kim Finney (Chief Officer of SCADM) has been elected as a SCAR member on the PIC committee. Development of early career scientists is happening through the Association for Polar Early Career Scientists (APECS), jointly sponsored by SCAR and IASC (see 6, above), and public outreach should improve through currently planned improvements to the SCAR website (see 7, above). Finally, I contributed several sections to the book describing the IPY, which will be the landmark reference volume for those planning the next such endeavour (Krupnik et al., 2011).

9. Improvements in Performance

We could tell our own story of success, but it is better to use the words of the Performance Review carried out in February 2009 by an external peer group chaired by Phil Smith, who chaired the review of 2000:- *“All of these developments, in the judgment of the Review Group, have re-established SCAR as the principal authority on scientific research in Antarctica, its role as a facilitator of collaboration in the conduct of Antarctic science and its voice on ways science can usefully inform policy makers on critical issues. The Review Group believes that a central issue in the next decade will be managing the science initiatives that SCAR has launched and ensuring that they remain vigorous, are regularly reviewed in depth by the Delegates Committee on Scientific Affairs and that there is full deliberation of these initiatives at SCAR plenary sessions. Importantly, a second and perhaps even greater challenge for the Delegates Committee on Scientific Affairs will be to give due attention to emerging scientific information about Antarctica’s natural systems that suggest policy recommendations and applied research that should be coordinated with the Standing Committee on the Antarctic Treaty System, COMNAP, and others. SCAR has made significant headway in its provision of important policy advice to the ATCM. This is noted in two ways. First, the numbers of policy papers submitted to the ATCM, including CEP, have risen dramatically since 2000. Second, SCAR’s revamped and modernized administrative practices have enabled timely submittals, which is a critical aspect of policy making.”*

“The Review Group applauds SCAR’s progress in...” capacity building, education and training. *“Capacity building – in the nations with smaller Antarctic communities and among early career polar researchers in all SCAR member research communities – must remain central SCAR initiatives.”*

“Since 2000 SCAR has made enormous progress in the total revamping of all aspects of its internal and external communication systems. SCAR, under the leadership of the Executive Director, has transformed itself from a paper-driven institution into one that conducts virtually all of its administrative work, communications and outreach electronically. The efficiencies gained cannot be appreciated fully unless one was familiar with the pre-2000 SCAR and its administration. Thus the pace of SCAR’s work and its effectiveness in the planning and coordination of Antarctic science has quickened and the conduct of its internal administrative business has moved to an effectiveness that was not imaginable in 2000; much else that the Review Group favourably notes in this report benefits from the total transformation that has taken place in SCAR’s move from a printed to an electronic record. Of equal importance is the fact that the shift to 21st Century information technologies has made SCAR much more relevant to the practicing polar scientist and to the interested public whose appetite for Antarctic information is growing with world awareness of the polar regions in Earth’s changing climate grows. A sign of this success is the register of 130,000 hits per month on the SCAR website during 2008; in January 2004 when the website was launched there were 16,000 hits. The Review Group, therefore, gives SCAR high marks for these developments; they have greatly transformed SCAR and made it a relevant and active player through electronic communication. SCAR had made substantial progress in “opening up” its internal organization and administration by placing much information about these matters on its website thus making it easily accessible to national committees adhering to SCAR, scientists working in Antarctica, and the interested public. The SCAR website now contains a

large amount of useful information concerning SCAR operations, including annual member subscriptions. This openness and transparency is to be applauded.”

“SCAR will make continuing updates of ‘Antarctic Climate Change and the Environment’, and will report the findings to ATCM, COMNAP, and other organizations. The Review Group noted this proactive role in Antarctic climate assessment with satisfaction.”

Regarding the link between SCAR and IASC, *“The Review Group applauds these developments.”* Regarding the link to COMNAP, *“SCAR-COMNAP relations have improved considerably. SCAR has developed a paper on the future of Antarctic science to present at the August 2009 COMNAP meeting which hopefully will stimulate a dialogue about longer term infrastructure needs along with the aforementioned paper on collaboration among national programs on King George Island. However, the Review Group also noted that COMNAP and SCAR no longer work together on data management, which is discussed elsewhere in this report. With this exception the Review Group finds that SCAR and COMNAP have greatly increased their partnership.”*

Regarding SCADM, *“the groups within the SCAR community who are responsible for establishing, managing and contributing to the SCAR Antarctic Master Directory System (hosted by NASA) have by international measures achieved considerable success, particularly in the area of standardization and in the development of content. The SCAR community is one of very few that can claim to subscribe to a unified, multidisciplinary metadata system, which is to be roundly applauded. The Review Group is heartened by SCAR’s progress in facilitating data management and archiving.”*

Regarding general management, *“the Review Group noted with pleasure that the organizational developments have led to a revitalization of SCAR at the Delegate level, in the work of the SCAR Executive Committee, the oversight roles that vice presidents now play, and in the activities of SCAR’s subsidiary committees.”* Regarding the Secretariat, *“the SCAR Secretariat is working extremely well at this time.”*

Regarding funding, *“We congratulate the SCAR leadership on its recent successful fund-raising efforts, with funds secured from a number of sources, including grants from ICSU, the Sloan Foundation, the Total Foundation, the Tinker Foundation and Memorial University of Newfoundland. This excellent activity should continue, and must remain focused because of limited human and financial resources.”*

Regarding the transformation in general, *“The recent and current Presidents of SCAR and the Executive Director should be congratulated for their effective leadership that has been crucial for delivering the transformation of SCAR as recommended by the Ad Hoc Group.”* The Review Group was – *“favourably impressed by the reform process that SCAR initiated in 2000 in response to the recommendations of the Ad Hoc Group. It is a record of change that few national or international voluntary science associations can equal. SCAR has prepared itself well to address emerging challenges through the reforms undertaken during 2000-2009. By building on these developments through the recommendations presented here, SCAR can continue to play a central role in facilitating and coordinating science and advising governments working together in the Antarctic Treaty System.”*

So, here we are, at the end of a re-organisation that began in 2000 and re-energised SCAR's community. A revitalised SCAR now takes responsibility for an expanded area – including the whole of the Southern Ocean up to the SubAntarctic Front (the northern boundary of the Antarctic Circumpolar Current), and is making significant contributions to environmental science, for example with the publication in 2009 of “Antarctic Climate Change and the Environment”, with the tremendous contribution of the multi-nation Census of Antarctic Marine Life to the global Census of Marine Life programme, which concludes in 2010, and with a major contribution to the International Polar Year and ensuring the IPY legacy.

Strategic planning and performance reviews are now key management aids. More advice than ever is being provided to the ATCM, and SCAR is working more closely and in a more structured way with a larger group of international partners. SCAR is more efficient, more effective, and now has its own independent legal status, having become a UK Company Limited by Guarantee (14 April 2008) and, from 4 July 2008, a Charity under UK law - a status that brings certain financial benefits. As another sign of success, SCAR has gained four new national members and two new ICSU union members since 2000. Biennial meetings are now much shorter (largely by having science and administration groups meet in parallel) and have been reorganised to give National Delegates greater contact with the science through the biennial open science conference. It has vastly improved and enhanced its communications, both internally and externally.

There is no doubt that many of the changes can be attributed to SCAR's implementation of the 2000 Review Group's recommendation that it appoint an Executive Director to push things along. As the first Director, my roles were defined by the EXCOM in January 2004 as follows:-

1. To play a leading role in the development of SCAR by:
 - a. forming a new vision for SCAR and Antarctic science;
 - b. guiding the development and implementation of the SCAR programme of activities by:
 - i. working with the SCAR Standing Science Groups, Standing Committees and Scientific Programme Groups to achieve appropriate scientific and organizational integration;
 - ii. ensuring effective links between SCAR and other relevant international research activities, especially IGBP, WCRP and SCOR;
 - iii. maintaining strong links with COMNAP, appropriate governmental organizations, and the international policy community;
2. Raising additional funding for SCAR's scientific activities;
3. Improving SCAR's communications internally and with the outside world;
4. Representing SCAR at international meetings; and
5. Managing the SCAR Secretariat efficiently and effectively.

To implement these tasks, I proposed to EXCOM in January 2004 the preparation of a Strategic Plan, along with plans for communication and outreach, for capacity building, and for data and information management. Having a background in ocean and climate science, and recognising that for climate science purposes Antarctica and the Southern Ocean were intimately linked, I persuaded Delegates that SCAR should

extend its geographical remit to include the Antarctic Circumpolar Current, that SCAR should expand its Action Group on Oceanography to be an Expert Group co-sponsored with SCOR, and that SCAR should undertake an Antarctic equivalent of the Arctic Climate Impact Assessment (EXCOM discussed my proposal for this at its meeting in Bremen in July 2004). At my instigation it was agreed that SCAR should form bilateral partnerships with global organisations having an Antarctic interest, so as to expand SCAR's influence: with the IGOS Partners for the cryosphere observing system; with the Southern Ocean component of the IGBP's Global Ecosystems Dynamics programme (GLOBEC); with the Southern Ocean Implementation Panel (SOIP) of the WCRP's Climate Variability (CLIVAR) programme; with SCOR for developing the joint SCAR-SCOR Southern Ocean programme; with IASC, for bipolar studies; with the International Association for Cryospheric Sciences (IACS) and with the International Permafrost Association (IPA). Even before joining SCAR, I had begun proposing development of the Southern Ocean Observing System (SCAR Oceanography Group meeting, Rome, September 2003) (Summerhayes, 2004), and the development of the cryosphere observing system (IGOS-P-10b report, 20 November 2003). I also initiated the SCAR Newsletter and Annual Report.

Nevertheless, it is also true that a great many people contributed to SCAR's success, not least the many volunteers working in the many different SCAR programmes, and the SCAR Officers and Secretariat. This is a collaborative effort. During my first year I was ably assisted and learned a great deal from the outgoing Executive Secretary, Peter Clarkson (UK), who retired in June 2005 to be replaced by Marzena Kaczmarek (Poland) as Executive Officer. She in turn was replaced by Mike Sparrow (UK) in June 2007. Peter helped to train both officers. With Mike's appointment to replace me in mid April 2010, he was replaced in turn, as Executive Officer, by Renuka Badhe (India). These officers in turn depend heavily upon the skills of the SCAR Administrative Assistant – at the moment the indefatigable Mrs Rosemary Nash.

At the instigation of SCAR President Jörn Thiede (Germany), my 'training' included a visit to Dronning Maud Land, accompanied by Peter Clarkson as an advisor, in November 2004, courtesy of AWI. Under the leadership of Hartwig Gernandt (AWI), we and Henry Valentine (South Africa) visited the bases of Germany, India, Norway, Russia and South Africa. Peter Clarkson and David Walton (Chief Officer of SCATS) brought me up to speed on the business of ATCM and CEP meetings, starting with the XXVII ATCM in Cape Town, South Africa, 24 May to 4 June 2004. Roland Schlich (France, Vice President responsible for Finance) and Peter Clarkson educated me in the complexities of the SCAR budget, enabling me to prepare with Roland a Financial Strategy for the Delegates to XXVIII SCAR in Bremerhaven that led to a 30% increase in membership subscriptions in 2006. EXCOM in 2005 also approved my attendance at the ICSU General Assembly (Suzhou, China, October 2005) to help to raise the profile of SCAR within ICSU, and to use that trip as an opportunity to visit the National Committees of Malaysia, Korea, China and Japan, to encourage their greater involvement in SCAR activities. Visits to National Committees have been part of my deliberate strategy of taking SCAR to the regions. I have visited and held discussions with the National Committees of Germany, Russia, USA, Norway, UK, India, Italy, Chile, Argentina, Australia and Spain, and visited the research stations of Germany, India, Norway, Russia and South Africa. Mike Sparrow has visited the National Committees of the UK, Argentina, Brazil, Ecuador and Peru. Chuck Kennicutt has visited those of Bulgaria, Belgium, Chile,

Argentina, Uruguay, Korea, Japan, China, the UK, the USA and Italy (and the stations of Korea, Chile, China, and Russia on King George Island).

The Executive Director's task of raising external funds to enable things like the Fellowship programme to grow was never going to be easy. I felt that it would not be appropriate to start a large-scale approach to potential funding agencies before certain basic documents were in place to demonstrate SCAR's credibility as a 'professional' organization; these included:

- (i) The strategic plan (published July 2005);
- (ii) A new brochure (done for XXX SCAR in St Petersburg, July 2008);
- (iii) A statement of SCAR's achievements (published on the website in May 2006);
- (iv) Implementation plans for the five SCAR Scientific Research Programmes (completed January 2006);
- (v) Finalisation of SCAR's scientific plans for the IPY (approved April 2006);
- (vi) Establishing SCAR as a not-for-profit Limited Company registered as a Charity in the UK to facilitate the receipt of gifts (effected in April and July 2008).

These various documents and developments put SCAR in a good position to attract external funds in future, especially for fields attractive to donor organisations, such as education (e.g. the Fellowship programme). As mentioned above, some SCAR Members (India, South Africa, Italy) themselves provided additional funds for the Fellowship Programme (not forgetting the Prince of Asturias funds from Spain). The Executive Committee agreed that it would be desirable to create a Development Committee to assist in identifying potential funding sources, but at the time of writing this body was not yet in place.

SCAR's credibility had grown sufficiently following the reorganisation to attract grants from the Sloan Foundation - for the Census of Antarctic Marine Life (CAML); from the TOTAL Foundation and national sources – Belgium, Australia, Germany - for the Marine Biodiversity Information Network (MarBIN); and from the Tinker Foundation to administer the Martha T Muse Award, as well as grants from ICSU. Apart from ICSU's, these grants provided management fees to compensate for the Secretariat time required to manage the financial reporting and payments for the many project meetings generated. This overhead must be properly funded so as not to drag down the Secretariat's productivity. Additional sources of revenue can be generated by acquiring new national Members, or by current Members upgrading their status and contributions.

It was a significant challenge to the Secretariat to implement all of the recommendations of the 2000 Review Group. That challenge was compounded by the addition of the workload imposed by managing the new biennial Open Science Conferences, by administering the new programmes for Fellowships and Medals, by distributing the new external funds for such large new programmes as CAML and the Martha Muse Award, and by SCAR take a new leading role in the development and implementation of the IPY, as well as managing the external grants. In spite of the added workload, these challenges have been met by a Secretariat now reduced to two full time officers and a part-time administrative assistant Mrs Rosemary Nash

(appointed in October 2007 to follow in the footsteps of Mrs Mandy Dalton and Mrs Karen Smith).

SCAR continues to be beholden to the Scott Polar Research Institute, Cambridge, and its Director, Julian Dowdeswell, for hosting the Secretariat, which it has done for the past 50 years. SPRI is a wonderful base for SCAR operations, containing as it does the world's greatest polar science library, and being the location of choice for visits to the UK by polar scientists from around the world.

Much remains to be done under the new Executive Director, Mike Sparrow, not least to address the recommendations of the Review Group of 2009 and to ensure management of the IPY legacy in the south. SCAR's future is now being planned in the shape of the SCAR Strategic Plan for 2011-2016, which will be presented to the SCAR Delegates for approval at their meeting in August 2010. It is generally agreed that more needs to be done, for example, to encourage all national operators to share scientific results and contribute to SCAR science programmes, to encourage the sharing of major facilities in support of science, and to get more international collaboration while at the same time cutting fuel costs. At the same time there is a need to expand SCAR's science horizons even further, for example ocean acidification will appear on the agenda, recognising that the Southern Ocean is likely to suffer first and most from it, and to integrate SCAR's several initiatives in climate change research. The Delegates and the SSG meetings need to take a more strategic view of the science and its development. There is the promise of developing stronger links with COMNAP and CCAMLR. But above all, there is now a strong platform to build on. I wish my successors a safe and profitable voyage in the future in the good ship SCAR.

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