

## SCAR COMMENTS ON THE IPY 2007-2008

### EXECUTIVE SUMMARY

SCAR is keen to participate at the highest level in providing advice on carrying out the IPY.

SCAR's five main Scientific Research Programmes offer the IPY the opportunity to develop several of the long-term observatories called for in the IPY Science Plan, because the programmes require continuity of measurement beyond the IPY time frame. The programmes plan to develop subsets of their activities that require Special Observations during the IPY. For example IPY could be used:

- (i) to get complete coverage with radars for observing geospace as a contribution to SCAR's ICESTAR programme;
- (ii) to undertake a Circum-Antarctic Census of Marine Life (CoML) programme, contributing to the marine biological studies required for SCAR's Programme on Evolution and Biodiversity in the Antarctic, and providing the Southern Ocean element of the global CoML programme (which ends in 2010);
- (iii) to develop an integrated Southern Ocean observing system that includes synoptic, multidisciplinary transects; time series measurements; enhanced atmospheric measurements; and new paleoclimate data sets, to help understand the role of Antarctica in the Global Climate System;
- (iv) for a major bi-polar ice drilling programme to collect a large number of shallow ice cores to enable us to understand annual to multi-decadal scale regional variability and its links to large scale atmospheric circulation and topography, and to provide essential input to climate models;
- (v) to improve coordination and coverage of measurements of the cryosphere, thereby generating the data and information needed by the research and operational forecasting and climate forecasting communities;
- (vi) to take a geological perspective on climate change, on time scales approaching the time resolution of ice cores but extending much further back into the past;
- (vii) to begin exploring subglacial Antarctic lake environments.

SCAR also recommends that the IPY be used:

- (viii) to explore the subglacial highlands of the Gamburtsev Mountains, hidden beneath the East Antarctic Ice Sheet. No continent other than Antarctica has a huge central mountain range for which there is no plate tectonic explanation;
- (ix) to develop a benchmark series of geological and geophysical maps;
- (x) to create a network of autonomous geological and/or geophysical observatories across Antarctica and the Southern Ocean, to investigate systems-scale polar geodynamics and interactions with the cryosphere, hydrosphere and atmosphere;
- (xi) to create a comprehensive data and information management strategy that facilitates easy access to data collected during the IPY, and its use in geographical information systems.

## **MAIN POINTS OF ADVICE**

On the basis of advice from the SCAR Advisory Committee on the IPY (see Annex 1), the SCAR Executive Committee, and the Chief Officers of the SCAR Standing Scientific Groups, SCAR would like to make the following comments on the development of the International Polar Year (IPY).

### **SCAR and the IPY Structure**

The ideal position for SCAR in the management of the IPY would be alongside IASC as part of the proposed ICSU-WMO Joint Committee that will be set up to steer the IPY process. The presence of both SCAR and IASC at this high level would ensure the highest quality of scientific steering for the IPY process. It was envisaged that SCAR would also play a role in the proposed IPY Consultative Forum. SCAR would also contribute to the activities of the proposed IPY International Programme Office. In providing its advice SCAR should liaise closely with COMNAP to ensure, to the extent possible, that COMNAP's concerns were taken on board in the IPY planning process. SCAR should also liaise with IASC and FARO.

### **SCAR's Scientific Research Programmes**

In deciding on the kinds of science to be supported during the IPY, every effort should be made to build on existing developments rather than creating new and competing developments. In this context, just as IASC has a set of ongoing major science programmes that should be exploited, so too SCAR is developing from within its broad-based science community a set of major new programme initiatives that will be its flagship projects for the next 5-10 years. These flagship projects address the Grand Challenges of Antarctic science. The 5 programmes are:

- Antarctica and the Global Climate System (AGCS)
- Antarctic Climate Evolution (ACE)
- Evolution and Biodiversity in the Antarctic (EBA)
- Inter-hemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR)
- Subglacial Antarctic Lake Environments (SALE)

These are described in Appendix 1. SCAR Delegates approved them in October 2004, for start-ups in 2005.

Within each of the SCAR Programmes a selection of the overall activities will be emphasized during the IPY, which SCAR Programmes will treat as a Special Observing Period. The SCAR Standing Scientific Groups have begun identifying the specific activities that will be emphasized during the IPY, and will inform the IPY Planning Office of their intentions.

SCAR's major programmes offer the IPY the opportunity to develop several of the long term observatories that are called for in the IPY Science Plan, because the SCAR programmes have a longer time frame than the IPY and require continuity of measurement beyond the IPY time frame.

**AGCS: Recent Climate Change:** SCAR sees the need for synoptic to quasi-synoptic physical oceanographic and atmospheric observations that will establish base-lines against which variability with time can be measured. There is a pressing need for (i) measurements of ocean properties from beneath the sea ice, without which it will be difficult if not impossible to ascertain precisely the ways in which Antarctica is connected to the global climate system; (ii) arrays of drifting buoys in the ocean and on the sea ice, to better ascertain surface meteorological fields and the patterns of surface circulation; (iii) more automated weather stations; and (iv) more radiosondes for upper atmospheric measurement. It will be useful to develop programmes with a wide geographical scale, which will enable the community subsequently to ascertain where best to locate monitoring systems to provide data on long term variability. Synoptic observations should be connected to the use of advanced models to improve understanding of processes, and to determine the extent to which the behaviour of the system is predictable.

Under this heading the IPY offers an opportunity to develop an integrated IPY Southern Ocean observing system that includes synoptic, multidisciplinary transects; time series measurements; enhanced atmospheric measurements; and new paleoclimate data sets. Extensive use of new technologies such as autonomous floats, gliders and aircraft would be required to sample regions, seasons and variables that have eluded us in the past. Establishing such an observing system will enable us to:

- i. obtain the first circumpolar snapshot of the Southern Ocean environment, including physical, ecological and biogeochemical properties;
- ii. measure the circumpolar volume (extent and thickness) of Antarctic sea ice through an annual cycle for the first time; and
- iii. observe the sub-ice ocean circulation, water mass properties and biological distributions.

This initiative would enable us to obtain an integrated bipolar view of ocean circulation in relation to climate, through partnership with the AOSB/CliC initiative “The Northern Seas at a time of Global Change”. A Southern Ocean observing system would leave a legacy of a targeted, affordable, sustained observations; a circumpolar snap-shot to serve as a benchmark for the assessment of past and future change; models capable of simulating interactions between climate, ecosystems and biogeochemical cycles, providing vastly improved projections of future change; a well-integrated interdisciplinary polar research community; and a new generation of polar researchers.

Under this heading, SCAR also considers that there should be a major bi-polar ice drilling programme in which a large number of shallow ice cores are drilled in many places in both the Arctic and the Antarctic to enable us to understand annual to multi-decadal scale regional variability and its links to large scale atmospheric circulation and topography. The shallow cores would provide an invaluable look at climate change in the recent past (say over the past 1000 years). This approach is one aspect of SCAR’s AGCS programme, and could easily be extended to the Arctic, with equally beneficial results.

Both the bipolar ice drilling programme and the Southern Ocean observing system (integrated with Arctic ocean observing efforts) could form high profile flagship projects for the IPY.

The cryosphere is an important element of the Earth’s climate system, but probably its most undersampled part. Through several feedbacks it has a large effect on the predictability of weather and climate change. It plays an important role in generating and mediating the conditions for possible abrupt climate change. It is one of the factors of largest uncertainty in

determining contributions to mean sea level rise. A framework is needed for improved coordination of cryospheric observations, and for improving the generation of the data and information needed by the research and operational forecasting and climate forecasting communities. The community needs, in particular: (i) validated remote sensing and in situ observations of the land-based cryosphere that are capable of providing a complete picture of precipitation and accumulation; (ii) comprehensive observations of sea-ice characteristics; and (iii) a significantly enhanced monitoring system for ice sheets, ice caps and glaciers. These are the goals of the Cryosphere Theme of the Partnership for an Integrated Global Observing Strategy (IGOS), which involves all of the space agencies. The IGOS Partners, led by SCAR and the WCRP (CliC) programme, are developing a Cryosphere Theme that will outline the major challenges for research on the cryosphere from space and in situ. The Cryosphere Theme will be finalised in 2005 for a start up in 2006, and will therefore be fully active during IPY. It will make a major contribution to the goals of the IPY in both hemispheres and should be seen as an integral part of the IPY Plan.

With climate change the water cycle will intensify. The way in which this happens in the Arctic and the Antarctic will differ because one has an ocean surrounded by land, and the other a land surrounded by ocean. What signals occur at the same time? Can we understand these through modeling? What data do we need to calibrate the models? This should be a focus for the IPY.

**ACE: Long-Term Climate Change:** SCAR also considers that understanding the polar response to global warming demands that the IPY should take a geological perspective on climate change, on time scales approaching the time resolution of ice cores but extending much further back into the past. A three-phase approach can be adopted.

A first requirement is to understand the interactions of climate and the polar cryosphere in the Antarctic in order to resolve global linkages between sea level, oceanic circulation and atmospheric systems. Geological and geophysical databases should be integrated with ice sheet and climate models in order to understand processes on different time scales, from millions of years to centuries and decades. Important foci include: the fundamental climate transition from a greenhouse to ice house world, and the birth and evolution of the Antarctic ice sheet; the scale and rapidity of the response of large ice masses and associated sea ice to climatic forcing, particularly warming; and external influences on the Antarctic cryosphere including tectonics, orbital cycles and solar forcing. These are the targets of SCAR's CACE programme, outcomes of this which will provide geological constraints on modeling the future response of the Antarctic ice sheet to climatic change and global consequences.

A complementary requirement is to examine the interplay of northern and southern polar processes in driving and amplifying global climate variability, as recorded in paleoclimate archives. The Bipolar Climate Machinery (BIPOMAC) project will combine: (i) "ground truthing" based on well synchronized northern and southern polar high-resolution ( $10^2$ - $10^3$  y) palaeoceanographic, palaeolimnological, palaeoatmospheric and continental ice volume/extent records (time window: mid-late Pleistocene climate cycles, Holocene), and (ii) numerical modelling of ice-atmosphere-ocean processes to decipher the complex pathway and timing of climate development, its internal amplification and propagation mechanisms (ice/ocean/atmosphere), and the effect of external forcing (insolation/solar activity). These initiatives will be the basis for the generation of models for realistic estimates of future climate and sea level development under different anthropogenic impact scenarios.

It will also be necessary to address the role of polar ocean gateways in controlling exchanges of energy and matter in polar water between the Arctic Ocean, the world oceans, and around Antarctica (Antarctic Circumpolar Current). Understanding the geological development of

these polar ocean gateways is essential for understanding the consequences of water mass exchange on the global climate, from long geological time-scales to the present. Establishing the detailed histories of the shallow and deep-water seaways will enable a close correlation with palaeo-climate observations collected across the globe. Focussed studies of tectonic, magmatic, sedimentary, biostratigraphic and biological evolutionary processes, as well as investigations of the past and present oceanographic conditions in the polar gateways, will provide the constraints for numerical simulations of palaeo-current systems and palaeo-climate. A gateway programme could provide a focus for the IPY.

These three activities are in various stages of development. Drilling projects are already planned (e.g. ANDRILL) and will yield significant data and results during the IPY period, but other large projects, such as examining the physical and biological processes in polar oceans, will require dedicated ship and air support provided by national operators. The overall goal within each program is to provide high quality datasets that will provide the necessary constraints for numerical modelling of ice-land-ocean-atmosphere interactions.

**EBA: Biodiversity:** A survey of marine life is the basis for understanding the variability in Antarctic diversity. The global Census of Marine Life (CoML) is currently taking place, and a Circum-Antarctic CoML programme during the IPY will ensure that the Southern Ocean is represented in the CoML within the global CoML time frame (which ends in 2010). Such a survey will not only be valuable in its own right as a contribution to global understanding, but also will provide an excellent base-line for the marine biological studies proposed as part of SCAR's Programme on Evolution and Biodiversity in the Antarctic. SCAR has created an Action Group to take forward a Circum- Antarctic contribution to the CoML as the main contribution to the IPY from the SCAR Life Sciences Group. In effect the Circum-Antarctic CoML programme during the IPY will constitute a Special Observing Element of EBA.

Under SCAR's umbrella, terrestrial and limnetic biologists plan to use the IPY as a period during which to focus on remote areas and on quantifying all human-carried propagules into Antarctica. They also plan to liaise with groups like ITEX to develop a significant bipolar activity during the IPY. Visiting remote areas may be possible through participation on traverses proposed by other disciplines.

SCAR's Life Sciences Group has identified the need for a Marine Biodiversity Information Network (MarBIN). This network, which should be operational at the start of the IPY, will provide a key database to optimize the compilation, integration and dissemination of Antarctic marine biodiversity data, and will make an Antarctic contribution to global biodiversity initiatives such as the Global Biodiversity Information Facility (GBIF) and the Ocean Biogeographical System (OBIS) being developed as part of the CoML.

**ICESTAR (Geospace):** Some large arrays of observatories are already in place for upper atmosphere and geospace measurements. These should be effectively exploited. The arrays of geospace instruments have grown in Antarctica to the point where we can now make very effective comparisons between the two hemispheres; this should be a goal of IPY. IPY could be used to get complete coverage of the Antarctic with radars as a contribution to SCAR's ICESTAR programme.

**SALE: Subglacial Lakes:** A great deal of planning has been done on how to study subglacial lakes, and the community is poised to move forward. IPY would be an opportune

time to accelerate these initiatives. Many of the technical and scientific questions can be addressed by tackling analogous settings and smaller lakes in an experimental way now.

Subglacial Antarctic lake environments are emerging as a premier, new frontier for exploration during the IPY 2007-2009. Several coordinated campaigns by various nations are in the early stages of planning and implementation. These efforts can be coordinated under the auspices of the SCAR Scientific Research Program (SRP) - Subglacial Antarctic Lake Environments (SALE). Under the leadership of the SCAR SRP SALE, these programs would join together to promote and advance common scientific, technological, and logistical issues in close consultation with COMNAP. The coalition approach recognizes that the ambitious interdisciplinary objectives of SALE, as internationally agreed during a series of workshops, and extensive discussions of the SCAR Group of Specialists (SALEGOS), can only be realized by multiple exploration programs that will investigate exemplars of the diverse subglacial environments over the next decade or more. The IPY provides an opportunity for an intensive period of initial exploration that will advance scientific discoveries in glaciology, biogeochemistry, paleoclimate, biology, geology and tectonics, and ecology to a new level that could not otherwise be achieved by a single nation or program.

A common effort will be the development, implementation and promotion of environmentally benign procedures for subglacial lake environment exploration and research programs properly vetted through national and ATCM procedures. With proper planning and careful and methodical technology development and testing, SALE can be an exemplar of environmental stewardship.

The concerted multi-target approach will assure the widest possible characterization of subglacial lake environments beneath the East and West Antarctic Ice Sheets. This will advance our understanding of the range of possible lake evolutionary histories; the character of the physical, chemical, and biological niches; the interconnectivity of subglacial lake environments; the coupling of the ice sheet, climate and the evolution of life under the ice; the tectonic setting; and the interplay of biogeochemical cycles. Research and exploration programs spanning the continent will allow for complementary investigations of subglacial lake environments of differing ages, evolutionary histories, and biogeochemical settings providing a holistic view of these environments over millions of years and under changing climatic conditions. While early discoveries and exciting findings are expected during the IPY 2007-2009, a long-term sustained program of research and exploration will continue far beyond 2009.

### **Additional Topics for IPY**

**1. Human Biology and Medicine:** IPY 2007-2008 offers the opportunity to develop and coordinate an innovative international Human Biology and Medicine research programme utilising synergies of existing national polar research programmes, activities and data collection. SCAR proposes that a multinational, multidisciplinary, collaborative dataset will be collected to validate and analyse current physiological, public and occupational health and psychosocial observations, and to provide an ongoing standardized dataset that can be referenced against prior and future research endeavour. Efficient and innovative e-Health and telemedicine technologies could be used and enhanced in the collection and support of this snapshot of human health in polar regions during the IPY.

**2. Mountain Building:** The IPY offers the opportunity to focus geological attention on areas that are still unknown, like the subglacial highlands of the Gamburtsev Mountains that are 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. Why are these high mountains situated in the centre of a large plate? What tectonic processes were responsible for their formation? Are they related to the amalgamation of Gondwana at the start of the Phanerozoic Era and the rapid diversification of life forms? Do they represent a hot spot in the Earth's mantle and as such may influence the long term stability of the ice sheet? When did they form? Were they present before the formation of the ice sheet, in which case they may have controlled the formation and nucleation of the ice sheet, or did they form after the formation of the ice sheet, in which case they may ultimately control the disintegration of the East Antarctic ice sheet?

SCAR geoscientists propose during IPY to investigate the Gamburtsev Mountains through satellite remote sensing, airborne geophysical survey, overland traverses and ice drilling. This challenge will not be met without the pooling of resources, international collaboration and impetus provided by IPY.

**3. Autonomous Remote Geophysical Observatories:** The IPY offers the opportunity to create a network of autonomous geological and/or geophysical observatories across Antarctica and the Southern Ocean, to investigate systems-scale polar geodynamics and interactions with the cryosphere, hydrosphere and atmosphere. Principal observatory components would be GPS and seismometer, possibly augmented with a geomagnetic measuring device, tide gauge (coastal) or bottom pressure gauge (offshore), and relative and absolute gravity measurements. These stations could be augmented in addition with a meteorology and/or oceanography packages. The goals would be to provide higher resolution maps of crustal structure, tomographic maps of the Earth's interior, regional views of bedrock motions, improved models of glacial isostatic adjustment, better understanding of secular variations in the Earth's magnetic field and its dynamics, improved validation of satellite signals, improved tidal models, and the basis for a permanent observatory network.

SCAR would be able to provide "science management advice" for new stations, including automated robotic ones.

**4. A Benchmark Map Series:** Understanding Earth's evolution and environmental processes and their changes through geological time demands the creation of geoscience maps and supporting databases (geographical, potential field, bedrock topography/bathymetry, geological, tectonics). Taking into account new broad initiatives in data acquisition during IPY, geological and geophysical data sets will be required for the Antarctic geoscience community in the form of grids, maps, original information and metadata. Ideal products will include (inter alia) an updated Antarctic Digital Gravity Anomaly map; an updated Tectonic Map of the Earth's Polar Regions; revised Gondwana reconstructions; an International Bathymetric Chart of the Southern Ocean; and enhanced Ice Thickness and Bedrock Elevation Maps.

**5. Astronomy:** Though SCAR does not have a major programme in astronomy, it does have an active Astronomy community through which SCAR has been encouraged to promote the use of Antarctica as a platform for astronomical observation. Activities contributing towards this development that could be emphasized during the IPY include traverses to assess the viability of Antarctic domes for an eventual large diameter telescope.

### **6. Data and Information – an Important IPY Legacy**

An integral and essential part of the IPY legacy should be a comprehensive data and information management strategy that facilitated easy access to data collected during the IPY, and its use in geographical information systems. This will enable many different kinds of data

to be linked in an interactive on-line fashion. Ideas on data and information management for the IPY overall have been submitted separately by SCAR on behalf of JCADM, the SCAR/COMNAP Joint Committee on Antarctic Data Management.

SCAR will assist in the development of an Antarctic Spatial Data Infrastructure (ANTSDI), comprising fundamental reference data, policies, and enabling technologies.

It is essential that scientists from different disciplines be able to access data across the disciplines (which is not easy with the present network of World Data Centres). We need an additional mechanism of data dissemination. IPY projects should be required to provide high level products in standard based formats accessible across the disciplines. This will help in the creation of an SDI, and will facilitate development of the Cybercartographic Atlas of Antarctica (CAA) proposed by SCAR's Geosciences SSG. The CAA will provide a key means of informing the general public and schoolchildren about Antarctica.

**7. Communication of Results:** SCAR would be interested in working with the IPY community on a major international synthesis event (or events) to report on the main results of the IPY, and to point the way forward. Presumably the best time for this would be after the end of the field phase (i.e 2009-10). The SCAR Open Science Conferences for 2008 and 2010 could be suitable vehicles. Collaborative events could be organised with other agencies active in the Antarctic region, such as WCRP (CLIVAR and CliC), IGBP (GLOBEC and IMBER), IGOS Partners, etc, to illustrate the benefits of inter-agency dialogue and cooperation. Given the growing importance of satellites for observing the Antarctic region as a whole, thought should be given to organising a symposium on "Space Observations and the Antarctic Region". This could be done in concert with the IGOS Partners and CEOS (Committee on Earth Observing Satellites). Give the growing importance of modelling, IPY might consider a meeting comparing the performance of climate models (global and regional) in polar regions.

**8. High Value Incremental Activities:** Small incremental activities can be encouraged that may add significant data benefiting larger programmes. For example - it will be useful

- (i) to encourage the making of bird counts from ships, to provide the data needed for a comparison with the 20-year old BIOMASS data set, as the basis for a study of the variability of diversity with time.
- (ii) ship operators should be encouraged to use continuous plankton recorders widely to obtain comprehensive coverage of upper ocean plankton around Antarctica.
- (iii) it will be useful to encourage ships to drop disposable bathythermographs, and deploy drifting buoys, Argo and under ice floats.
- (iv) ship operators should be encouraged to turn on single beam and multi-beam echosounders so that the widest possible collection can be made of the bathymetric data essential for marine geological studies and for defining the shape of the seabed for ocean modelling; all too often well-equipped ships sail with expensive survey equipment turned off.
- (v) on land, multiple use should be made of proposed trans-Antarctic traverses, where geological, glaciological, geophysical, atmospheric and biological data can be collected given appropriate forward planning.

**Annex 1:****SCAR Advisory Committee**

SCAR has formed a SCAR Advisory Committee on the IPY, which had *ad hoc* status until approved by the Delegates in October 2004. Its terms of reference are:

- i. to advise the Executive Committee on the SCAR input to the IPY Science Plan;
- ii. to advise the Executive Committee on the SCAR role in IPY Implementation, and on the content of the IPY Implementation Plan;
- iii. to ensure that IPY is represented in the SCAR Scientific Research Programmes;
- iv. to work with COMNAP to realize IPY objectives for the southern hemisphere;
- v. to monitor the IPY process as it unfolds, and advise SCAR on how its contribution to the IPY should develop.

The Advisory Committee will consult widely within the SCAR family to solicit advice on the way forward throughout the IPY process.

**Membership:**

- i. Chairperson (Colin Summerhayes)
- ii. Standing Scientific Group Chairs for Life Sciences (Ad Huiskes), Physical Sciences (John Turner) and Geosciences (Alessandro Capra) [Members of programme planning groups should be consulted by SSG heads]
- iii. selected experts (Eberhard Fahrback (Germany); In-Young Ahn (R.Korea); Chuck Kennicutt (USA); Pedro Skvarca (Argentina)
- iv. Ian Allison, the SCAR rep on the IPY Planning Group;
- v. COMNAP representative (Anders Karlqvist);
- vi. JCADM to advise on data management (Taco de Bruin)

Communication will take place by e-mail and meeting in the margins of other meetings (e.g. Open Science Conference; Delegates meeting).

The group met in Bremen on 30 July 2004, following the IPY discussion sessions arranged for 19 and 30 July 2004.

**Annex 2:****Outline descriptions of the purposes, scope and overall objectives of SCAR's five main programme proposals.****Antarctica and the Global Climate System (AGCS)**

This proposal outlines a programme of research to investigate the nature of the atmospheric and oceanic linkages between the climate of the Antarctic and the rest of the Earth system. The linkages between the different elements of the Antarctic climate system are highly non-linear and it is necessary to understand the behaviour of and interactions between the atmospheric, oceanic and cryospheric elements of the system if past change is to be explained and we are to have confidence in future predictions. A study of this kind has only recently become feasible with the advent of sufficient high-resolution in-situ data and ice core records and the development of modelling tools to the point where they can represent realistically the closely coupled atmosphere-ocean processes that are important in long-term climate variability.

This work requires a combination of modern, instrumented records of atmospheric and oceanic conditions, and the climate signals held within ice cores to understand fully past and future climate variability and change in the Antarctic as a result of natural and anthropogenic forcings. The primary time period to be considered will be approximately the last 6,000 years, since the mid-Holocene warm period to 100 years in the future, but records that capture abrupt climate change over the past few glacial/interglacial cycles will also be included.

The programme will make use of 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 the means by which signals of tropical and mid-latitude climate variability reach the Antarctic, and high latitude climate signals are exported northwards. The emphasis will be on synthesis and integration of existing data sets and model output, although some new ice core and oceanographic data will be collected.

There will be four major, closely linked themes of research reflecting significant gaps in our knowledge:

1. *Decadal time scale variability in the Antarctic climate system*, to investigate ocean-atmosphere coupling and the role of the El Niño-Southern Oscillation in modulating the Antarctic climate;
2. *Global and regional climate signals* in shallow and deep ice cores, to establish better quantitative relationships between ice core data and measures of tropical, mid- and high latitude climate variability;
3. *Natural and anthropogenic forcing on the Antarctic climate system*, including the production of regional-scale estimates of expected climate change over Antarctica during the next 100 years, to be able to distinguish natural variability from anthropogenic activity and to understand how global climate change will be expressed in the Antarctic; and
4. *The export of Antarctic climate signals*, to examine the means by which climate changes in the Antarctic can influence conditions at more northerly latitudes.

The programme will contribute to the International Polar Year planned for 2007-2008. The programme will use the IPY as a Special Observing Period to test models and high-low latitude climate signal transfer functions.

The research will be carried out in an interdisciplinary way through a close collaboration between meteorologists, climatologists, glaciologists, oceanographers and ice chemists, who will integrate observational and modelling activities.

The results of this programme will be of value to the Fifth Assessment Intergovernmental Panel on Climate Change (IPCC), which will need input by 2010, towards the end of the programme. A key deliverable at that time will be the production of regional and Antarctic-wide climate predictions for the Antarctic covering the next 100 years.

AGCS will incorporate several former Action and Expert Groups, including:

Action Group on “Reference Antarctic Data for Environmental Research” (**READER**): to create a high quality, long term dataset of mean surface and upper air meteorological measurements from *in-situ* Antarctic observing systems, for use in climate research and climate change investigations;

Action Group on “Antarctic Tropospheric Aerosols and their Role in Climate” (**ATAC**): to determine the influence of Antarctic tropospheric aerosols on the radiation budget, and characterise and classify the nature of Antarctic aerosols;

Expert Group on “International Trans-Antarctic Scientific Expedition” (**ITASE**): to collect and interpret a continental-wide array of environmental parameters assembled through the coordinated efforts of scientists from several nations, as the basis for monitoring biogeochemical cycles and local-to-global scale climate change, so as to assess Antarctica's role in and response to environmental and climate change.

Expert Group on “Antarctic Sea-Ice Processes and Climate” (**ASPeCT**): to understand and model the role of Antarctic sea ice in the coupled atmosphere-ice-ocean system.

### **Antarctic Climate Evolution (ACE)**

ACE is a new research initiative to study the climate and glacial history of Antarctica through palaeoclimate and ice sheet modelling investigations, integrated with terrestrial and marine geological and geophysical evidence for past climate change. Changes in climate have led to spatial temporal fluctuations in ice volume over the past 34 million years that have been the driving forces for changes in global sea-level throughout the Cenozoic Era. Determining the scale and rapidity of the response of ice masses and associated sea ice to climate forcing is essential to understanding the processes of climate change in the region, and to underpin the understanding of likely directions of future change.

ACE promotes the exchange of data and ideas between research groups focusing on the evolution of Antarctica's climate system and ice sheet. It will facilitate scientific exchange between modellers and data gatherers, facilitating the development of relevant projects and the testing of hypotheses. The broad outcomes will be:

1. quantitative assessment of the climate and glacial history of Antarctica;
2. identification of the processes that govern Antarctic climate change and those that feed back around the globe;
3. improvements in the ability to model past climate changes in Antarctica; and
4. documented case studies of past changes against which models of future change can be tested. ACE will be complementary to AGCS, by providing a distant past dimension to climate studies.

The programme will link geophysical surveys and geological studies on and around Antarctica with ice-sheet and climate modelling experiments, to determine climatic

conditions and climate change during the Holocene, the Pleistocene glacial period, and the pre-Quaternary, when temperatures were several degrees warmer than today. The cross-disciplinary approach will lead to a substantial improvement in knowledge and understanding of climate change in the region, and of the factors that have guided its evolution. This will allow the building of hypotheses, testable by numerical modelling, about how Antarctic climate may be likely to change in future.

The main function of the programme is to acquire and compile “ground truth” geoscience data and to use these to develop a suite of palaeoclimate models for significant periods of climate change throughout Cenozoic times up to and including the Holocene. Data access and data sharing will be encouraged to facilitate the data syntheses needed for enhancing palaeoclimate models. Numerical modelling is an essential component, and will address:

1. ice sheet modelling;
2. coupled ice-sheet, climate and ocean modelling; and
3. coupled ice sheet and sediment modelling to address the interaction between ice sheets, water and deformable sediment at the interface between ice and bedrock.

ACE will also promote new drilling programmes to expand the necessary database. These will include the activities of the International Ocean Drilling Program (IOPD) in deep water, the shallow drilling (SHALDRIL) programme on land, and the ANDRILL programme on the ice shelves. Among other things the programme will examine the terrestrial record of landscape evolution; the influence of tectonics on the behaviour of the ice sheet; and the influence of palaeo-seaways, such as the opening of the Drake Passage, on climate.

#### **Evolution and Biodiversity in the Antarctic (EBA): the response of life to change.**

This programme will use a range of modern techniques and a multidisciplinary approach to explore the evolutionary history of the modern Antarctic biota, examine how modern biological diversity in Antarctica influences how present-day ecosystems function, and thereby attempt to predict how the biota may respond to future environmental change. For the first time it will integrate the major realms of Antarctic biology into a cohesive picture and contribute to evolutionary theory and understanding of global ecology and biological diversity. More specifically, this programme will examine:

- The evolutionary history of the Antarctic biota.
- Evolutionary adaptations to the Antarctic environment.
- Patterns of gene flow within, into and out from the Antarctic, and their consequences for population dynamics.
- Patterns and diversity of organisms, ecosystems and habitats in Antarctica, together with the ecological and evolutionary processes that control these.
- The impact of past, current and predicted environmental change on biodiversity and the consequences for Antarctic marine, freshwater and terrestrial ecosystem function.

This programme explicitly involves an integration of work on marine, freshwater and terrestrial ecosystems in a manner never before attempted within SCAR. The science in this program thus extends over an entire biome on Earth, and by comparing the outcome of similar evolutionary processes in freshwater, terrestrial and marine systems, fundamental insights can be obtained into evolutionary processes and the ways in which life responds to change, from the molecular to the whole organism level. Furthermore the Antarctic political environment offers a unique opportunity to address a series of globally significant scientific questions. Most national programmes cannot attempt a study on such a bold scale by

themselves, whereas the collaborative spirit of the Antarctic science community will provide a mechanism for achieving outstanding scientific success.

A key observational element of EBA during the International Polar Year will be the proposed Circum-Antarctic Census of Marine Antarctic Life.

### **Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR).**

ICESTAR strives for international coordination of interhemispheric research in the areas of solar-terrestrial physics and polar aeronomy, promoting exchange of research ideas, and sharing experimental data from various arrays of geophysical instrumentation deployed over the polar regions and in near-Earth space. ICESTAR addresses the fact that important gaps remain in our understanding of the solar wind-magnetosphere-ionosphere interaction. We do not know enough about the changes and dynamics of the Earth's magnetosphere under extreme solar wind conditions, i.e., during strong geomagnetic storms. Much remains to be learned about how the solar forcing can affect neutral atmosphere, especially at high latitudes where the solar wind-driven processes are most influential. Possible influences of the changing Sun (i.e., its irradiance and magnetic moment) and geospace environment on polar climate and weather are also poorly understood.

The programme aims:

- i. to identify and quantify various mechanisms that control interhemispheric regional differences and commonalities in the electrodynamics and plasmadynamics of the Earth's magnetosphere-ionosphere coupling system, and in the aeronomy of the upper atmosphere over the Arctic and Antarctic; and
- ii. to create a data portal that will link together a large number of geophysical databases including both data serving applications and visualization tools, so as to enable a systems view of the polar upper atmosphere.

In order to obtain a deep understanding of various mechanisms responsible for energy transfer from the solar wind into the geospace environment, simultaneous consideration is needed of various geophysical phenomena occurring over both the Northern and Southern polar regions.

ICESTAR will create an integrated, quantitative description of the upper atmosphere over Antarctica, and its coupling to the global atmosphere and the geospace environment. The reasons to embark on the endeavour now are:

- i. the emergence of new data sets;
- ii. the emergence of Grid technology (which will allow the seamless sharing of data, and the convergence of data and models);
- iii. easy access to distributed data, to feed the demands of data assimilation tools;
- iv. the uniqueness of Antarctica as a vantage point for examining the near-Earth space environment, spanning from the top of the troposphere, through the stratosphere, mesosphere, thermosphere and ionosphere, and into the magnetosphere.

ICESTAR will both enable and conduct focused scientific research on the upper atmosphere above the Antarctic and on how that region of space ties in with the global system. No other programme is focused specifically on the quantitative understanding of the upper atmosphere above the Antarctic continent.

Creation of the ICESTAR data portal to facilitate the sharing and interpretation of global geospace datasets will encourage the collaboration of researchers by sharing data and the interpretation of the results.

ICESTAR will incorporate several former Action Groups and Expert Groups of SCAR, including:

Action Group on “Middle Atmosphere Dynamics and Relativistic Electron Precipitation” (**MADREP**): to facilitate collaboration between atmospheric physicists and chemists and ionospheric and magnetospheric scientists, and to quantitatively determine the degree to which atmospheric ozone is affected by the precipitation of relativistic electrons;

Action Group on “Antarctic Peninsula Tropospheric-Ionospheric Coupling” (**APTIC**): to explore the responses of the ionosphere to the many deep depressions that cross the Antarctic Peninsula, and identify energy transfer mechanisms;

Expert Group on: “Solar-Terrestrial Processes and Space Weather” (**STEPS**): to facilitate collaboration between groups collecting upper level Antarctic measurements at different stations;

### **Subglacial Antarctic Lake Environments (SALE)**

SALE serves as the international focal point of SCAR’s activities to promote, facilitate, and champion cooperation and collaboration in the exploration and study of subglacial environments in Antarctica.

The overarching scientific objectives of SALE are:

1. to understand the formation and evolution of subglacial lake processes and environments;
2. to determine the origins, evolution and maintenance of life in subglacial lake environments; and
3. to understand the limnology and paleoclimate history recorded in subglacial lake sediments.

To understand the complex interplay of biological, geological, chemical, glaciological, and physical processes within subglacial lake environments an international, interdisciplinary plan for coordinated research and study is essential. The three objectives can only be accomplished by integrated and coordinated phases of discovery and hypotheses driven research over at least a ten-year period. The scientific objectives will be addressed through a series of projects that form a comprehensive research program for the exploration of subglacial lake environments. Each research project will be defined by its own scientific objectives and requirements for logistics and technology. Together the portfolio of projects advances the overall program. The timing of individual projects, while interrelated, will ultimately be determined by the resources and technologies available and the priorities of individual national Antarctic programmes. The projects are not necessarily sequential and several may be pursued in parallel. However, some later objectives are dependent on the information, results, and technological advances provided by earlier phases of research.

Major areas of research will be:

1. Functional Genomics and Phylogenetics (e.g. to determine the genetic diversity in the water columns and benthic sediments of subglacial lakes);

2. Limnology (e.g. to establish the geochemical and isotopic composition of selected lake water constituents to determine their role in biological processes, water column stability, and to establish the age of subglacial lake water);
3. Geophysics (e.g. to understand the tectonic and ice sheet setting of subglacial lakes through geological analysis of geophysical data);
4. Glaciology (e.g. to understand the interrelation between ice sheet processes and lake water circulation);
5. Geology and Cenozoic Paleoclimate (e.g. to use paleoenvironmental data to determine lake and ice sheet histories, and evaluate temporal changes in Cenozoic paleoclimate relative to those histories determined from Antarctic marginal sequences and global Cenozoic proxy records).

The technological challenges and environmental stewardship issues of under ice drilling cannot be underestimated, so SALE will also advise the international community not only on scientific issues but also on technology issues relevant to subglacial lake exploration, including environmental concerns and safeguards.

SALE will actively contribute to the goals of the IPY, in which subglacial lake environments are proposed as a major theme.