Draft Strategic Plan for the SCAR Standing Scientific Group Physical Sciences

July 24, 2009

Introduction.

Understanding the earth-system, its components and the connections and feedbacks is a major endeavour of our time. This is driven largely but not entirely by the critical problem of climate change. Antarctica is a key component of the global system, and yet there remain large gaps in our understanding of the physical system that will be the focus of research to come.

Many of the outstanding research challenges relevant to SSG/PS lie at interfaces between bio-geo-physical domains that require cross-disciplinary approaches within and beyond the physical sciences. Within the physical realm, processes at the interfaces between ice, ocean, land and atmosphere are critical to our ability to describe and predict the response to climate change. Outstanding uncertainties will require continued research directed at improving understanding of ice sheet dynamics, extracting climate records from the ice sheet, exploring processes and changes in sea-ice and ocean circulation and improving understanding of atmospheric dynamics and chemistry.

A distinct component of physical sciences research in Antarctica is based on the unique properties of the continent which favour astronomical and solar-terrestrial observations. Much of this research is of wider human interest and not directly applicable to earth-system questions, although the solar-terrestrial component has obvious applicability to climate-related research.

Beyond the physical system, the need to understand ecosystem impacts and biological feedbacks will continue to drive research of even broader cross-disciplinary scope. Biological responses to environmental change need to be informed by the physical changes, and increasingly we are aware that biological processes play a role in the physical system.

SCAR Physical Sciences Standing Group will play an important role in identifying needs, and coordinating the research effort, along with the Geosciences and Life Sciences areas. The emerging earth system questions will be addressed by fostering and increasing cross-linkages between the physical sciences and other groups.

Scientific Content

The Antarctic region plays significant roles in physical scientific research in several areas.

1. the Antarctic continent and the Southern Ocean play key roles in global climate change, and observations of climate parameters and their evolution over time are crucial to understand and predict change.

2. Antarctica is a key environment for studies of all aspects of the cryosphere, including deriving the history of climate change from ice cores.

3. the position of the magnetic south pole makes Antarctica (like the Arctic in the north) a region where interactions between a variable star, our Sun, and the Earth can be best monitored from the ground.

4. the characteristics of the site (dry, cold, and wind free at some locations, especially on the high domes of the polar plateau) make Antarctica one of the places on Earth where astronomical research is expected to be best conducted.

5. Lack of human habitation makes Antarctica a pristine environment in which slight contamination from human activities and from distant volcanic eruptions can readily be observed and related to global physical processes.

SSG/PS is designed to coordinate international scientific research in these and related fields.

SSG/PS will assist in the development and management of SRP's designed to conduct major efforts in research addressing these and related topics. Currently there are three such SRPs:

AGCS is concerned with the modern climate system and climate change. AGCS research includes observational and modeling studies of atmospheric processes, Southern Ocean characteristics, sea ice, and ice, air, and ocean interactions. This work examines climate variability and change in the ice core record over timescales in the 200-2000 year time frame as part of ITASE and, in conjunction with IPICS, on timescales as long as the ice sheet will permit, potentially over 1 million years. This work is complementary to the long time scale geological records of climate change dating back millions of years that are studied by the ACE SRP under SSG/GS.

AAA will coordinate and promote the definition of optimal site conditions for different astronomical instruments. Definition of the appropriate astronomical observations to be conducted at given locations will take into account similar research conducted at different temperate sites, and in space.

ICESTAR will conclude its activity as an SRP, and continue as an expert group, in the coordination of bipolar approaches to solar terrestrial physics. Space Weather at the time of the upcoming solar maximum will be one of the important subjects.

Other expert and action groups will develop as required to address specific activities peripheral or complementary to these main areas of investigation, and in some instances to facilitate interaction between SSG/PS and other SSGs.

The synergy among SRP's and expert/action groups will be promoted, in the same spirit as interaction among SSGs has been sought through the cross-linkages meetings of SCAR.

The effect of solar terrestrial inputs to the upper atmosphere, and their possible influence on atmospheric phenomena, and their change, will be more deeply investigated, especially with reference to the exchange of NOx between the ionosphere and lower layers of the upper atmosphere. The definition of site properties for astronomical research will involve astronomers and atmospheric physicists in common work.

The SSG will also vigorously promote the continued development of systems for observing planetary behaviour, such as CryOS (for the cryosphere), SOOS (for the oceans) and others under the umbrella of PAntOS.

Geographic Focus

SSG-PS covers the Antarctic continent and the southern ocean. Arrays of instruments are deployed throughout the continent and the surrounding islands; chains of instruments at sea are serviced systematically. Site characteristics for astronomy will be more deeply analyzed at existing sites (South Pole, Dome-C, Dome-A), and extended to new sites (Dome-F, ridge B).

Proposed Scientific Foci

SCAR Scientific Research Programme AGCS

One of the major challenges as regards the climate aspects of physical sciences is to understand the couplings of the physical ice-ocean-atmosphere system in the cryospheric region where records are shortest and knowledge is most limited. Antarctica and Southern Ocean are regions of key importance to the global climate system and the mechanisms and patterns of variability over decadal to centennial time scales are not well understood.

To date, the view of Antarctic / Southern Ocean region climate variability has been largely atmosphere-centric, with relatively little being understood of oceanic and ice feedbacks onto the atmosphere. SCAR should take a lead in the promotion of research in this interface area, and in coordinating observational and modelling efforts that contribute toward this major challenge, by helping to set up or consolidate the basic elements of an Antarctica and Southern Ocean observing system and by coordinating model intercomparisons.

Another (hitherto understated) key strand that SCAR should take a lead on is bringing biogeochemistry (particularly the carbon cycle) into this effort, perhaps by establishing a new cross-discipline task force.

The interface of AGCS with the upper atmosphere should be analysed with greater attention. Interaction with ICESTAR and the related SCAR groups GPS and PACT, should be enhanced. The group on Operational Meteorology is naturally connected with the AGCS program.

Strong partnership should also be established with SCOSTEP, the ICSU body devoted to Solar Terrestrial Physics, at this favourable time when they are starting their multiannual research program CAWSESII.

Prediction of Changes in the Physical and Biological Environment of the Antarctic (PCPBEA) (Cross SSGs Group)

This group is tasked with addressing interface areas among physical and biological research in Antarctica. They will:

Assess current ability to predict how the physical and biological environments of the Antarctic will evolve over the next century; Identify the extent to which the physical and biological approaches to prediction can be integrated; Determine the parameters needed from climate models to predict changes in the biosphere; Consider the issues involved in downscaling from the resolution of climate models to those required for prediction of biological systems; Investigate the means of improving prediction of selected physical parameters and their impacts on aspects of marine and terrestrial biota.

Ice Sheet Mass Balance and Sea Level (ISMASS)

As acknowledged by the Intergovernmental Panel on Climate Change, "dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise."

The importance of ice sheet modeling efforts has been magnified by recent reports suggesting that sea level rise remains the most poorly constrained and potentially catastrophic impact of climate change.

The questions to be addressed in the coming years concern:

1. Will climate change lead to irreversible (non-linear, rapid) ice-sheet response?

2. Does a rapid change lead to a large mass change?

3. Are observed rapid changes "natural variability" or responses to warming?

International Partnership in Ice Core Sciences (IPICS)

Ice cores provide information about past climate and environmental conditions on timescales from decades to hundreds of millennia, and direct records of the composition of the atmosphere. As such, they are cornerstones of global change research. For example, ice cores play a central role in showing how closely climate and greenhouse gas concentrations were linked in the past, and in demonstrating that very abrupt climate switches can occur.

The Antarctic ice sheet holds promise of significant advances in understanding that are driving at least four strands of research for the next decade. Firstly, the network of Antarctic ice cores covering the last 2,000 years needs to be developed in

order to provide high resolution regional and global climate reconstructions, as used by IPCC. Secondly, a sparser but longer network covering the last 40,000 years is required in order to understand the southern expression of rapid climate changes related to ocean heat transport, and of major climate transitions, including the last deglaciation. Thirdly, on longer timescales still, a high-resolution record covering the penultimate interglacial period, in conjunction with a similar record from Greenland would allow a better understanding of ice-sheet configuration, hemispheric connections and climate in a period of similar warmth to that anticipated in the coming century. Fourthly, ice core records beyond the existing 800 ka record are needed in order to understand the origin of the current 100 ka periodicity of interglacials.

In addition to these record-recovery goals, there is ongoing need for better understanding and utilization of ice core proxy data and reconstruction of high-temporal and spatial resolution climate histories from multi-proxy sources. This work requires detailed meteorological, modeling and ice core proxy calibration efforts to gain the maximum benefit from the cores.

Further understanding of existing ice core data is required in order to provide critical information about issues such as carbon cycle feedbacks, ocean circulation changes under different climates, and aerosol-climate feedbacks.

Expert Group on Oceanography

By connecting the ocean basins and the upper and lower limbs of the ocean overturning circulation, the Southern Ocean plays a critical role in the global ocean circulation, biogeochemical cycles and climate. The Ocean Expert Group will encourage an inter-disciplinary approach to Southern Ocean observations, modeling and research, recognizing the interdependence of physical, chemical and biological processes in the ocean.

As part of the IPY legacy, the group is taking the lead in developing a plan for an interdisciplinary Southern Ocean Observing System (SOOS) in partnership with SCOR, CAML, POGO, GOOS, WCRP and other organizations.

Future foci of the group will include implementation of the SOOS plan in order to keep track of the ongoing changes and investigating the question of Ocean Acidification jointly with ICED.

SCAR Scientific Research Programme ICESTAR

-Improving our understanding about the boundary layer between the atmosphere and near-Earth space. Now the general trend is to improve the atmospheric models in their lower boundary conditions (i.e. atmosphere-biosphere interactions, sea-atmosphere interactions, anthropogenic influences). With the progress in this work it becomes increasingly important to advance our understanding on the upper boundary as well. Incoherent scatter radars (ISR) provide unique opportunities to monitor the transition region between atmosphere and geospace.

Support should also be provided to those modelling efforts which address the interpretation of bi-polar ISR observations (e.g. the development of the TRANSCAR model).

-The next sunspot maximum is approaching and consequently the space weather issues will again gain more attention. The Australian WDC for space weather has done valuable work during the recent years in providing space weather services also for the southern hemisphere.

These services should be raised roughly on the same visibility level as the northern hemispheric space weather services. The POLENET mission to monitor ionospheric conditions above both polar areas could be a flagship in this work. The electron content maps that Polenet will hopefully produce will be useful to support various navigation and communication services.

Coordination between ICESTAR and specialized groups within SCAR is to be improved; groups like GPS for Weather and Space Weather Forecasting (GWSWF) (Cross SSGs Group) and Polar Atmospheric Chemistry at the Tropopause (PACT) will need to coordinate and operate in concert with ICESTAR.

In this areas as well as for AGCS, strong partnership should be established with SCOSTEP, the ICSU body devoted to Solar Terrestrial Physics, at this favourable time when they are starting their multiannual research program CAWSESII.

SCAR Scientific Research Programme AAA

Astronomy is already well developed in Antarctica; the South Pole experiments have produced breakthrough results and promise further scientific successes, with the neutrino experiments. Other sites may prove superior in several wavelength bands, and further opportunities for dedicated observations in selected areas of astronomical research may open up at sites where the local conditions prove to be superior to the South Pole site. The moderate “launch costs” for Antarctic plateau observatories make them an extremely attractive alternative to space, that may still offer observing conditions of the same quality as space.

Progress in astronomy will be brought about by continued site testing at various places, especially domes and ridges. Understanding the basic meteorology, stable boundary layer, atmospheric turbulence characteristics, atmospheric transmission at all wavelengths, contributions to sky brightness including airglow and aurorae. Measurement campaigns and models to allow detailed, quantitative comparison of sites. Understanding what kind of science is best done from Antarctica, and developing appropriate science cases. This is one example of research at the boundary among different disciplines.

Technology: developing common instrumentation and robotic facilities to facilitate site characterization, developing common technologies such as towers and icing-mitigation schemes.

Cross-cutting Issues

Research within SSG/PS is already interdisciplinary in itself; atmosphere, ocean science, astronomy, solar terrestrial interactions, and other scientific objectives make SSG/PS scientific objectives cross cutting. Some cross disciplinary subjects even across SSG's have been identified, and are being addressed by SSG/PS scientists together with their LS and GS colleagues. The cross SSG groups provide examples of such interrelation: PCBEA, GPS

Potential Collaborators

SSSG-LS and SSSG-GS and their SRPs (e.g. EBA, SALE and ACE), COMNAP, CEP, IASC, IPY legacy, CliC, SCOSTEP, IAU, URSI, SCOR.