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Plans for an Antarctic Climate Assessment – Trends and Impacts

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The Plan

Following the production of the Arctic Climate Impact Assessment early in 2005, the SCAR Executive Committee agreed at its meeting in Sofia (July 11-13, 2005) that a comparable and complementary assessment of the Antarctic should be produced for the guidance of policy makers in the Antarctic Treaty System and to inform the public. SCAR's Executive Director and the Chief Officers of SCAR's Standing Scientific Group on Physical Sciences and of SCAR's Standing Committee on the Antarctic Treaty System were charged with developing an appropriate document, for presentation in due course to the Antarctic Treaty Consultative Meeting. It was agreed that the bulk of the work would take place through SCAR's Scientific Research Programme on Antarctica in the Global Climate System (AGCS), led by Dr. John Turner of the British Antarctic Survey. The final draft of the report will be sent out for peer review prior to publication in the refereed scientific literature.

This plan is brought to the attention of the XXIX ATCM in the expectation that some Parties may wish to contribute to the Assessment in one way or another, and to stimulate debate about the possible direction that such an Assessment may take. We intend to form an international scientific steering committee, and would welcome suggestions for scientific participation in that committee.

Antarctic Climate Change – a Brief Background

Modern climate science observes that the lower atmosphere has warmed by around 0.6ºC in the past 100 years, at a rate of less than 0.1ºC per decade (reference 1). Analysis of natural variations caused by the sun, volcanoes and sulphate particles suggests that variations in these components of the climate system are not enough to explain the recent warming trend, which may therefore be attributed to the emission of greenhouse gases like carbon dioxide (see the figure on page 199 of ref. 1)(also see ref. 2). It is assumed that the trend will continue if emissions continue to rise, and it is argued that this is a problem about which something should be done. This is more or less the position of the Intergovernmental Panel on Climate Change, of the US National Academy of Sciences, and of the American Geophysical Union, among others.

Warming in the Antarctic can be a serious problem if it leads to the melting of grounded ice (the melting of floating ice has no direct effect on sea-level) (ref. 1). The West Antarctic Ice Sheet has retreated significantly since the Last Glacial Maximum (ref. 3). BAS scientists have shown recently that since 1950 86% of glaciers in the Antarctic Peninsula show significant signs of retreat suggesting that melting continues (ref. 4). It is predicted that if the West Antarctic Ice Sheet were to melt completely, sea level would rise by 4-6 m (ref. 5). However, such melting is not expected within the next 1000 years (ref. 6). There is evidence that the East Antarctic Ice Sheet is thickening (ref. 7, 8). This may reflect increases in the accumulation of snow induced by warming (ref. 9).

Certainly there is abundant evidence of global warming. The effects are particularly marked in the Arctic, and also on the Antarctic Peninsula. There is no disputing that temperatures and greenhouse gas concentrations in the atmosphere have risen. However, correlation is not causation. The relationship between carbon dioxide and temperature is modified by a variety of feedbacks – for example the aforementioned effects of aerosols (such as aeolian dust swept into the atmosphere from deserts, and airborne particulates emitted by industry and vehicles), dust and gas from volcanic eruptions, and the eleven-year fluctuation in sunspot activity.

Then again there is the geological dimension to consider. Looked at from the geological perspective, many times in Earth's history climate has changed more and faster than the change now observed, without any help from mankind. That is particularly true of the past 2 million years during which the Earth has experienced multiple 'ice ages'. The characteristic signal of the 'ice age' is short warm periods (inter-glacials), one of which we are now living through, separated by much longer glacial periods during which large ice caps covered significant parts of Europe and North America, and in which the Antarctic sea ice doubled in area from its maximum present extent in winter (ref. 3).

Detailed studies of ice cores from Greenland and Antarctica show that the last inter-glacial (123,000 years ago) was 5ºC warmer than today (ref 10); sea-level was also 4-7 m higher then than it is today. While these studies raise the possibility that the present inter-glacial may become warmer naturally, regardless of man's input of greenhouse gases, it has to be borne in mind that during the last inter-glacial the Earth's orbit was such that the summers occurred when the Earth was closer to the sun than it is today, enhancing seasonal radiation. Nevertheless, it is clear that a warmer Earth and higher sea levels are not unique; the changes forecast by global warming models predict similar conditions within a few centuries from now to those seen 123,000 years ago.

The fact that the Earth has been warmer than it is today in the not too distant past is confirmed also by other detailed studies in ice cores that show that the Earth experienced a climatic optimum about 8000-9000 years ago that was warmer than the present, and had higher sea-levels (ref. 10, 11). It is not clear whether that was an isolated event or part of a pattern that might recur naturally; understanding such changes is critical to our ability to model future climate change.

Ice-core studies suggest that during the Holocene (the past 10,000 years) the climate has varied with a periodicity of between 70-240 years, due to unexplained variability in the ocean-ice-atmosphere system, which presents a challenge for climate modeling (ref.11).

Finally, ice core studies also suggest that climate varied during the 'ice-age' initially in response to changes in the amount of radiation received from the sun, as the Earth's orbit varied through time, and that carbon dioxide followed rather than led temperature in warming intervals (ref. 12). Thus carbon dioxide amplified climate change induced by changes in Earth's relation to the sun. The picture is complex because initial warming melted ice, thereby changing both the albedo and the input of greenhouse gases to the atmosphere by plants – in other words the initial thermal signal due to radiation was amplified by positive feedbacks within the climate system. These relationships tell us that one cannot simply assume a temperature rise based on a carbon dioxide increase by analogy with ice cores.

The difficulty in evaluating the causes of climate change with absolute confidence lies primarily in the fact that the signal (0.1ºC per decade) is tiny compared with the noise of seasonal and inter-annual variability. The difficulty is further complicated by the dearth of past climatic data, and the lack of knowledge of past variability in solar output.

It should also be noted that most of the current debate about climate change centers on future predictions and not on observed trends. The validity and accuracy of the current generation of models of the non-linear climate system lie at the core of current controversy regarding future change. Such models need to be tested more rigorously in the Antarctic context, where at present they perform rather poorly.

Despite these various caveats and our lack of certainty regarding ultimate causes, by coordinating research results from the many national scientific research programmes across Antarctica SCR scientists are now in a position to evaluate with specified levels of confidence how climate is changing and has changed in Antarctica on long, medium and short time scales. And with the massive increases in computing power that have come about in recent years, we are now in a good position to model numerically how the ocean-ice-atmosphere system works in the Antarctic, and to forecast what changes might be expected in the future on a variety of timescales in response to a range of different forcings. Many of the necessary studies have been completed recently or will take place during the IPY.

Even though the present rise in temperature is less in both magnitude and rate than some that have been seen in the Earth's recent past, the fact that mankind is living now and will find the shift difficult to deal with in certain regions makes it imperative that we assess what is happening and try to forecast what might happen next, especially in the polar regions where change is taking place faster than elsewhere on the planet.

SCAR's Role in Climate Assessment

SCAR has been coordinating climate and global change research at the forefront of the science for well over a decade. Three of its five major current Scientific Research Programmes are directed at observing and modeling climate change and its effects:-

- Antarctica in the Global Climate System (AGCS);
- Antarctic Climate Evolution (ACE);
- Evolution and Biodiversity in the Antarctic (EBA);

These programmes are described in detail on the SCAR web site (www.scar.org). In addition SCAR obtains data on climate change from SCAR programmes such as:-

(i) the International Trans Antarctic Scientific Expedition (ITASE), which has the potential to explore temporal variability and recent evolution of Antarctic climate utilizing an unprecedentedly dense spatio-temporal array of samples;

(ii) Ice Sheet Mass Balance and Sea-Level (ISMASS), which aims to determine the growth or shrinkage of the great ice sheets; and

(iii) Antarctic Sea Ice Processes and Climate (ASPecT), which aims to improve understanding of the Antarctic sea ice zone through field programs, remote sensing and numerical modeling, and to rescue valuable historical sea ice zone data, as the basis for understanding and modeling the role of Antarctic sea ice in the coupled atmosphere-ice-ocean system

SCAR's research on the workings of the climate system in Antarctica and on the interrelation of the Antarctic climate system with the global system is carried out in conjunction with the World Climate Research Programme (WCRP). SCAR co-sponsors with the WCRP: (i) the Climate and Cryosphere (CliC) programme devoted to studies of the role of the cryosphere in the climate system; (ii) the joint CLIVAR/CliC/SCAR Southern Ocean Implementation Panel, which seeks to observe and understand the role of the Southern Ocean in the climate system; and (iii) the International Programme for Antarctic Buoys, which deploys drifting and other buoys for collecting information on oceanography, meteorology and ice drift in the Southern Ocean.

SCAR's recent analysis of the balloon-launched radiosonde data for the Antarctic extending back into the 1950's has revealed a major warming of the Antarctic winter troposphere that is larger than any previously identified regional tropospheric warming on Earth (ref. 13). The largest warming has been close to 5 km above sea level where temperatures have increased at a rate of 0.5 – 0.7° C per decade over the last 30 years. The cause of this warming is not yet understood, but should emerge from a climate assessment.

SCAR has established the linkages between the El Niño-Southern Oscillation (ENSO) and the climate of the high latitude South Pacific (ref. 14). A sharp annual contrast was found between the 1980s and the 1990s, with the link in the 1990s being significantly amplified. In the1980s the connection between the topics and Antarctica was weaker due to the interference between the Pacific South American pattern associated with ENSO, and the Southern Hemisphere Annular Mode (SAM) typical of the Southern Hemisphere atmosphere around Antarctica.

Recent trends in Antarctic snow accumulation have been investigated using the Polar MM5 climate model. Averaged over the continent the annual trends are small and not statistically different from zero, suggesting that recent Antarctic snowfall changes do not have a significant effect on current sea level rise (Ref. 15).

The west Antarctic Peninsula (WAP) is undergoing one of the most rapid atmospheric warmings on the planet, temperatures having risen by nearly 3ºC in the past 50 years. The warming appears to be linked to a long-term decrease in sea ice in the adjacent Bellingshausen Sea, but there is little understanding of the ocean's role in these climatic changes. To address this, a long time series of oceanographic measurements (temperature and salinity) was compiled and examined, covering the second half of the twentieth century (Ref. 17). It was found that a very significant warming of greater than 1ºC had occurred in the summertime surface and near-surface ocean– this greatly exceeds general rates of warming of the world ocean, and is one of the most rapid regional ocean warmings noted to date, and much greater than the 0.2ºC warming shown for the deep water of the Southern Ocean. Concurrent with this warming was a surface-intensified summer salinification, of greater than 0.25 parts per thousand. Although initially counter-intuitive, this salinification is 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 Peninsula. The ocean warming and salinification both provide positive feedbacks that act to decrease ice production and to further warm the atmosphere. The data 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 very 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 losses might be expected (Ref. 18).

There is also the observation that a continuing rise in ocean uptake of atmospheric carbon dioxide may lead to acidification of the Southern Ocean, with consequent losses of calcareous planktonic organisms (Ref 19).

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 has contributed significantly to the collapse of the northern sections of the Larsen Ice Shelf. The explanation is that over the last few decades the Southern hemisphere Annular Mode (SAM) has shifted into its positive phase, with surface pressures dropping over the Antarctic and rising in mid-latitudes (Ref. 20). This has caused the westerly winds to increase, especially in summer. Faced with these stronger westerlies, the barrier effect of the Antarctic Peninsula has been reduced. As a result, the ice shelves on the eastern side of the peninsula have become less isolated from relatively warm, maritime air masses. 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 is thought to be predominantly a response to global warming, and provides the first evidence for that on the Antarctic Peninsula.

Determining the extent of environment change across the Antarctic in recent decades is a high priority activity, and SCAR's Standing Scientific Group on Physical Sciences has contributed to this work via the creation of a number of new data sets of key environmental variables. The conventional surface and upper air meteorological data have been brought together within the READER (Reference Antarctic Data for Environmental Research) project. The READER data set of monthly and annual mean near-surface climate data (temperature, surface and mean sea level pressure (MSLP) and wind speed) for the Antarctic has been created using historical observations. Where possible, 6 hourly surface synoptic and automatic weather station observations were used to compute the means. The ability to quality control the data at the level of individual observations has produced a more accurate series of monthly means than was available previously. Analyses of the READER data set has resulted in assessments of climatic change over the Antarctic since the IGY in 1957/58. The data show that there has been a complex pattern of change across the Antarctic over the last 50 years, with the Antarctic Peninsula warming more near the surface than anywhere else on Earth (3ºC in the past 50 years) while the rest of the continent has shown little change (Ref. 21).

From the geological perspective SCAR'S ACE programme is coordinating the integration of enhanced geological data, and the improvement of Antarctic paleoclimate models for a series of time periods from the onset of glaciation around the Eocene-Oligocene boundary 34 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. ACE workshops have resulted in compilations of the state of the science, and recommendations for future work (Refs. 22, 23, 24). A clear understanding is emerging of the role of climate change in controlling the development and variability of the Antarctic ice sheet through time.

The Assessment Process

A possible outline of the eventual Assessment document, with potential chapter headings is provided as Annex 1, which is taken from Annex 3 to the Report of the SCAR Cross-Linkages Workshop, 22 – 24 November, 2005, Free University, Amsterdam, The Netherlands.

The process will take place under the leadership of an International Scientific Steering Committee. Leaders for each section will bring together teams of experts to provide objective inputs broadly following the model used for the Arctic Climate Assessment. Protocols and templates will be devised to ensure a uniform style of input from the different teams.

The extent to which face-to-face as opposed to virtual meetings will be needed remains to be decided. Opporunities will be taken to hold small group meetings in the margins of other larger scientific meetings such as the American Geophysical Union, to keep costs down. Several of the potential authors will meet in the margins of the XXIX SCAR meeting in Hobart, Tasmania, during July 2006. The need for substantial meetings will emerge as plans firm up, at which point funding will be solicited from appropriate agencies.

It is envisaged that the process will be simpler, smaller, and less costly than the Arctic one, not least because of the smaller size of the Antarctic scientific community and the fact that nobody lives in Antarctica.

The study will be interdisciplinary, including information on the atmosphere, ocean, earth history and ice systems, and on the interaction of these with Antarctic ecosystems. It will explore the uncertainties in the climate system, and the extent to which the system is predictable. The full report will be a SCAR report. A distilled version will be prepared for publication in a journal such as Nature or Science.

Aside from providing information for policy makers, the public, and the scientific community, the assessment should provide inputs to the activities of the Intergovernmental Panel on Climate Change (IPCC), which is currently preparing its next report, to the planners of activities for the International Polar Year, which begins in March 2007, and to the Parties to the UN Framework Convention on Climate Change.

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Annex 1: "Antarctic Climate Assessment - Trends and Impacts": Outline Plan

Subtext:- Antarctica and the Southern Ocean - The Next 100 Years in the Context of the Past 10,000 Years

Three main sections:-

- **Evolution: since 10,000 yrs**
- **The past 50 years**
- **The next 100 years**

Evolution since -10,000 yrs

a) Ice core data (e.g. Taylor Dome, Siple Dome)
b) Marine sediment data
c) Glacial geology data
d) Lake sediments data - take home message: last 1000 years cooler, stormier
e) Past sea level data
f) Atmospheric chemistry data (acidity, trace elements, dust)
g) Biological evolution

Current (last 50 yrs)

a) Atmospheric circulation
b) Atmospheric chemistry
c) Southern Ocean: (i) warming; (ii) circulation; (iii) Ross Sea ;(iv) Weddell Sea (under ice)
d) Teleconnections
e) Peninsula warming and glacier retreat
f) Sea ice retreat
g) Ice shelf retreat (Antarctic Peninsula vs. Ross Sea)
h) East Antarctic and West Antarctic temperatures (stable, cooling) (thickening/ thinning?)
i) Ocean ecosystems and biogeochemistry
j) Terrestrial Animals and plants response to change
k) Biological evolution: adaptations in marine vertebrates
l) Lakes and islands (who??)

Next 100 yrs

a) IPCC Scenarios
b) Models such as HadCM3
c) Sea ice
d) Atmospheric circulation
e) Precipitation,
f) Sea level and Sea level response (continuing but not dramatic until +500yrs?)
g) Ocean models such as OCCAM, thermohaline, coastal seas
h) Changes in ice shelves and ice streams
i) Atmospheric + Biogeochmical + Teleconnections
j) Biological response
k) Adaptive evolution in action in marine vertebrates
l) Terrestrial response (Life history changes, physiological stress/upper limits/marine stenothermy, changes in primary production and decomposition, dispersal and colonization)
m) Human impact on ecosystems – non-indigenous species and transfer
n) Nearshore marine disturbance (icebergs, other forms of sea ice)