



XXXI SCAR Delegates Meeting
Buenos Aires, Argentina, 9-11 August 2010

Agenda Item: 6.2
Person Responsible: John Turner

Antarctica in the Global Climate System (AGCS)

Executive Summary

Title: Antarctica in the Global Climate System (AGCS)

Authors: AGCS Steering Committee

Relevant URLs or references to other reports:

http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS.htm - AGCS web site

Rationale for the Programme: AGCS is a cross-disciplinary science programme that focuses on the atmospheric, oceanic and cryospheric linkages between the Antarctic and the rest of the Earth system. It uses a very wide range of observations from the Antarctic continent and the Southern Ocean to investigate natural climate variability and possible anthropogenic signatures of change. The in situ meteorological and oceanic observations provide high quality data for recent decades, but these are supplemented with proxy data from deep and shallow ice cores that extend the records back into the pre-instrumental period. The programme also uses a range of satellite data and the output of climate and numerical weather prediction models to investigate the mechanisms of change and how climate signals are transferred to and from mid-latitudes and the tropics to the Antarctic. Our focus is on climate change over roughly the last 10,000 years, although we work closely with the ACE programme, which is looking deeper into the past.

Important Issues or Factors: AGCS has produced several important scientific highlights in the last two years (see this document), ranging from the evaluation of the causes of the increased growth in Antarctic sea ice that has occurred during the past three decades to the identification of climatic changes in the Antarctic water masses renewing the deep layers of the global ocean. Possibly AGCS's most significant achievement in this period has been its leading of a major review on Antarctic Climate Change and the Environment (ACCE), synthesizing knowledge on past, present and possible future changes in Antarctica and the Southern Ocean and their impact on the biota. The ACCE report was published in October 2009 and formally launched at a press conference in London on November 30. Copies are available at (<http://www.scar.org/publications/occasionals/acce.html>).

Recommendations/Actions and Justification: We ask the Delegates to continue supporting AGCS for a further two years so that the programme may carry its current activities in support of international Antarctic climate science to a successful conclusion.

Expected Benefits/Outcomes: The accomplishment of key advances in the study of a range of aspects of the Antarctic coupled climate system (detailed in this document) is expected from present progress. AGCS is centrally engaged in the design and implementation of the Southern Ocean Observing System, the coordination of international activities and workshops targeted at Antarctic climate science, and the development of key Antarctic data sets and portals. The success of these activities will be greatly facilitated by the requested support.

Partners: AGCS will continue to work (often in a leading role) with the SSGs and several other SRPs, the SCAR Oceanography Expert Group and the CLIVAR / CliC / SCAR Southern Ocean Implementation Panel, amongst others, to ensure that the above activities are carried out to a successful conclusion. AGCS will continue to support the development of the next generation of Antarctic scientists via its close association with APECS.

Budget Implications: Continued support at the current level is requested.

Antarctica and the Global Climate System

Authors: AGCS Steering Committee

Relevant URLs or references to other reports:

http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS.htm - AGCS web site

Rationale for the Programme:

AGCS is a cross-disciplinary science programme that focuses on the atmospheric, oceanic and cryospheric linkages between the Antarctic and the rest of the Earth system. It uses a very wide range of observations from the Antarctic continent and the Southern Ocean to investigate natural climate variability and possible anthropogenic signatures of change. The in situ meteorological and oceanic observations provide high quality data for recent decades, but these are supplemented with proxy data from deep and shallow ice cores that extend the records back into the pre-instrumental period. The programme also uses a range of satellite data and the output of climate and numerical weather prediction models to investigate the mechanisms of change and how climate signals are transferred to and from mid-latitudes and the tropics to the Antarctic. Our focus is on climate change over roughly the last 10,000 years, although we work closely with the ACE programme, which is looking deeper into the past.

AGCS consists of four science themes concerned with:

1. Decadal-scale variability in the Antarctic climate system
2. Global and regional climate signals in ice cores
3. Natural and anthropogenic forcing on the Antarctic climate system
4. The export of Antarctic climate signals.

This document reports on progress with the implementation of the programme since our report to the SCAR Delegates in July 2008. It provides details of progress with the science and lists outputs.

Important Issues or Factors:

Five Scientific Highlights

1. AGCS led the cross-SCAR development of a major review on Antarctic Climate Change and the Environment (ACCE), synthesizing knowledge on past, present and possible future changes in Antarctica and the Southern Ocean and their impact on the biota. It was published in October 2009 and formally launched at a press conference in London on November 30. Copies are available at (<http://www.scar.org/publications/occasionals/acce.html>). 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 was attended by the SCAR Executive Director, who gave two talks there 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* by Convey et al. A more limited version of the foregoing provided the basis for ACCE and appeared as an article entitled “State of the Antarctic and Southern Ocean Climate System (SASOCS)” in *Reviews of Geophysics* (Mayewski et al., 2009)

2. A new assessment of the changes in Antarctic sea ice in recent decades, published in *Geophysical*

Research Letters, shows that the increased growth in Antarctic sea ice during the past 30 years is a result of the strengthening of surface winds around Antarctica associated with stratospheric ozone depletion. The presence of the ozone hole has delayed the impact of greenhouse gases on Antarctic climate, and the study predicts that Antarctic sea ice will retreat considerably by the end of the 21st century, as ozone levels recover (see Turner et al., 2009).

3. An analysis of four decades of oceanographic observations in the Drake Passage region, published in the *Journal of Climate*, showed that the interdecadal warming and freshening of mode and intermediate water masses detected across large sectors of the Southern Ocean since at least the 1960s has likely been driven by decadal-scale changes in the major modes of Southern Hemisphere climate variability — such as the Southern Annular Mode (SAM), El Niño / Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation. A recent analysis of dissolved oxygen measurements in the global ocean indicated that a widespread reduction in the oxygen content of the same water masses has occurred across the Southern Ocean over the last 3-4 decades, suggesting a decline in the rate of ventilation of the Southern Ocean's intermediate layers in that period (see Naveira Garabato et al., 2009).

4. Evidence from an East Antarctic ice core indicates a link between drought conditions in Western Australia and increased snowfall in Antarctica. The link is 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 in the previous 7 centuries. The study has been published in *Nature Geoscience* by van Ommen et al. (2010).

5. A collection of articles in *Deep-Sea Research II* discuss 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.

Progress against Prior Work Plan

All the AGCS milestones and deliverables are listed in the AGCS Implementation Plan available at <http://www.scar.org/researchgroups/physicalscience/agcs/>, and in the minutes of the AGCS Steering Committee. No major deviations from the work plan outline in the 2008 report occurred. Because of space restrictions only selected achievements are listed below, avoiding duplication of the work described in the above highlights.

- Theme 1. A reconstruction of near-surface and mid-tropospheric air temperatures over Antarctica for 1960-2007, using manned station observations and radiosonde records from the READER database, yielded important new insight into recent Antarctic climate change. It was found that the Antarctic Peninsula near-surface warming on an annual basis has spread into West Antarctica, reaching as far as east as the Pine Island Bay-Thwaites Glacier region. The warming is most marked in recent years with 2007 being the warmest year in the 1960-2007 interval. In contrast to the western (eastern) Antarctic Peninsula warming, which is maximized in winter (summer), the warming over West Antarctica is maximized in the spring, a season in which warming stretches across all of West Antarctica and into northern Victoria Land. Weak near-surface warming is found over East Antarctica and the continent as a whole on an annual basis (see Monaghan et al., 2008).
- Themes 1 and 3. A related study investigated the mechanisms responsible for the large warming of the Antarctic winter troposphere previously identified in radiosonde data and showed that an increase in the amount of polar stratospheric clouds likely played a part. Globally, the stratosphere has been cooling as a result of greenhouse gas increases (see Lachlan Cope et al., 2009).

- Themes 1 and 3. A paper published in Geophysical Research Letters investigated the internal melting of Antarctic sea ice, revealing the physical causes for the formation of “gap layers” during the melting season. Gap layers are partially melted, honeycomb-like ice matrices filled with seawater that form below a surface layer of snow and ice that are common within Antarctic summer ice, and should be considered when analyzing melting scenarios (see Ackley et al., 2008).
- Themes 3 and 4. New observational evidence of the way in which mesoscale eddies (oceanic weather systems) flux water masses and climatically important tracers (such as CO₂) across the Southern Ocean has motivated the development of theoretical models of eddy-induced mixing. Using one of these theories, it has been shown that the overturning circulation of the Southern Ocean is sensitive to decadal-scale changes in the Southern Ocean westerlies, contrary to recent propositions. This has implications for the role of the Southern Ocean in the global carbon cycle.
- Themes 3 and 4. Monitoring of the properties of the Antarctic Bottom Water (AABW) exported from the Weddell Sea into the global ocean abyss has led to significant progress in understanding the mechanisms controlling the variability of that water mass. A causal link has been found between the SAM-modulated, wind-forced intensity of the Weddell gyre and the exported AABW properties. This suggests a connection between the steady warming of AABW across the Atlantic Ocean in recent decades and the concurrent trend in the SAM (see Jullion et al., 2010).
- AGCS has been centrally involved in many successful field campaigns contributing to the International Polar Year (IPY), including:
 - Multi-national traverses across Antarctica as part of the International Trans-Antarctic Scientific Expedition (ITASE) to measure ice thickness, snow and ice chemistry, snow accumulation rates and ice flow, thereby reconstructing climate;
 - Brazilian-Chilean-USA ice core drilling and airborne radar survey on the Detroit Plateau, Antarctic Peninsula, for the Climate of the Antarctic and South America (CASA) programme;
 - Oceanographic transects across the Southern Ocean and the Antarctic margins as part of the Climate in Antarctica and the Southern Ocean (CASO); and Synoptic Antarctic Shelf-Slope Interactions Study (SASSI) programmes.
 - The two first two cruises of the UK-USA Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean (DIMES), which seeks to test and, if necessary, redefine the present paradigm of Southern Ocean mixing and its grip on the ocean's overturning circulation.
- AGCS has continued to support the recovery and archiving of Antarctic data. The Met, Ice and Southern Ocean READER databases have been updated regularly throughout the last 2 years. A further, ongoing effort is the archiving by the Australian Antarctic Data Center of data on Antarctic sea ice and snow thicknesses collected over the past 30 years from ship expeditions. AGCS now has a new portal for accessing information about data sets related to the programme - it is part of the Antarctic Master Directory and provides searchable information on projects and data associated with AGCS - <http://gcmd.gsfc.nasa.gov/KeywordSearch/Home.do?Portal=agcs>.
- AGCS has led or supported several major programmes of Antarctic research through the sponsoring of focussed workshops, special issues in refereed journals and other activities, such as:
 - the ITASE Synthesis Workshop (Castine, USA; 2-5 September 2008), which focussed on identifying the characteristics of climate change that have impacted the Antarctic and surrounding ocean over the past 200-1000+ years, in order to provide a basis for assessing the dramatic changes expected as a consequence of the ~4-6°C warming projected for this region by the IPCC (report available).

- the International Workshop on Antarctic Sea Ice in IPY, held in Barga (Italy) with 47 participants (report available).
 - the 4th Malaysian International Seminar on Antarctica (Legacy of IPY to the Tropics) which focussed on tropical-polar interactions.
 - a special issue of Deep-Sea Research II on the results from the Sea Ice Physics and Ecosystem Experiment (SIPEX) and the Sea Ice Mass Balance in the Antarctic (SIMBA) projects conducted during IPY, with over 20 papers submitted.
 - a range of activities of the Working Group on Southern Ocean Physical Oceanography and Cryosphere Linkages (SOPHOCLES), which focusses on understanding how well the current generation of models represent the interaction between the cryosphere and the Southern Ocean.
- Members of AGCS have been involved in many education and outreach activities through public lectures, schools visits, the preparation of popular articles and broadcasts on radio and television. We are also actively seeking to engage scientists from the new Antarctic nations in AGCS activities and broaden the membership of the AGCS Steering Committee.
 - AGCS supports early career researchers through its partnership with the Association of Polar Early Career Scientists (APECS).

The above list of scientific advances and activities were achieved with the following budget in 2009:

Activity	Spent
ASPeCt	\$4,000
Malaysian Int. Sem. On Antarctica	\$2,039.82
Page charges for SASOCS paper	\$154.60
Currency conversion	\$282.85
Total	\$6,477.32

We have a carry forward of \$22,737 to 2010, which when combined with the 2010 allocation of \$17,000, gives a budget of \$39,737. We anticipate spending the bulk of this sum as follows:

	Allocation
ASPeCt	\$3.5K
Southern Ocean Observing System	\$5.5K
Tropical Polar Interactions	\$3.5K
SOPHOCLES	\$5K
IPCC Ice Sheet & Sea Level workshop	\$1K
Antarctic Mesoscale Prediction workshop	\$1K
Support for Early Career Scientists travelling to SCAR conference	\$3K
Outreach	\$4K
Data recovery	\$4K
Page charges for AGCS-related articles	\$4K

Total	\$34,500
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Outputs / Deliverables

The following selected publications in the peer-reviewed literature were led by AGCS:

Ackley, S. F., M. J. Lewis, C. H. Fritsen & H. J. Xie, 2008. Internal melting in Antarctic sea ice: Development of “gap layers”. *Geophys. Res. Lett.*, 35 (11), L11503.

Convey, P., R. Bindshadler, G. di Prisco, E. Fahrbach, J. Gutt, D. Hodgson, P. A. Mayewski, C. P. Summerhayes & J. Turner, 2009. Antarctic climate change and the environment. *Ant. Sci.* 21 (6), 541-563.

Jullion, L., S. C. Jones, A. C. Naveira Garabato & M. P. Meredith. Wind-controlled export of Antarctic Bottom Water from the Weddell Sea. *Geophys. Res. Lett.*, in press.

Lachlan-Cope, T. A., W. M. Connolley, J. Turner, H. Roscoe, G. J. Marshall, S. R. Colwell, M. Hopfner & W. Ingram, 2009. Antarctic winter tropospheric warming - the potential role of polar stratospheric clouds, a sensitivity study. *Atmos. Sci. Lett.*, 10 (4), 262-266.

Mayewski, P. A., M. P. Meredith, C. P. Summerhayes, J. Turner, A. Worby, P. J. Barrett, G. Casassa, N. A. N. Bertler, T. Bracegirdle, A. C. Naveira Garabato, D. Bromwich, H. Campbell, G. S. Hamilton, W. B. Lyons, K. A. Maasch, S. Aoki, C. Xiao, T. van Ommen, 2009. State of the Antarctic and Southern Ocean climate system. *Rev. Geophys.* 47, RG1003, doi:10.1029/2007RG000231.

Monaghan, A. J., D. H. Bromwich, W. Chapman & J. C. Comiso, 2008. Recent variability and trends of Antarctic near-surface temperature. *J. Geophys. Res.*, 113, D04105.

Naveira Garabato, A. C., L. Jullion, D. P. Stevens, K. J. Heywood & B. A. King, 2009. Variability of Subantarctic Mode Water and Antarctic Intermediate Water in the Drake Passage during the late-twentieth and early-twenty-first centuries. *J. Clim.* 22 (7), 3661-3688.

Turner, J., J. C. Comiso, G. J. Marshall, T. A. Lachlan-Cope, T. Bracegirdle, T. Maksym, M. P. Meredith, Z. Wang & A. Orr, 2009. Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent. *Geophys. Res. Lett.*, 36, L08502, doi: 10.1029/2009GL037524.

van Ommen, T. D. & V. Morgan, 2010. Snowfall increase in coastal East Antarctica linked with southwest Western Australia drought. *Nature Geosci.*, 3 (4), 267-272.

Other AGCS-sponsored publications include:

Antarctic Climate Change and the Environment, Turner, J., Bindshadler, R.A., Convey, P., Di Prisco, G., Fahrbach, E., Gutt, J., Hodgson, D.A., Mayewski, P.A., and Summerhayes, C.P., Eds., SCAR Report, 2009.

The third issue of the AGCS Newsletter ‘Notus’, issued in June 2009. It is available at http://www.antarctica.ac.uk/met/SCAR_ssg_ps/NOTUS_Jun2009.pdf. It was edited by Dr. Nancy Bertler, Victoria University of Wellington, New Zealand.

AGCS scientists have been involved in numerous press activities. Foremost amongst these is the launching of the ACCE report at a press conference in London on November 2009. Hard copies of the report 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 was attended by the SCAR Executive Director, who gave two talks there on ACCE. The SCAR Executive Director has disseminated the findings of the report in a number of other public lectures.

AGCS has maintained a web site (http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS.htm) that describes the research programme and our goals.

AGCS has maintained the following databases and portals:

- The frequently used MET-READER database of monthly-mean Antarctic climate data (<http://www.antarctica.ac.uk/met/READER/>) has continued to be developed and kept up to date with recent observations.
- The ICE-READER (<http://www2.umaine.edu/itase/content/icereader/>) database has been updated to include additional ice core records.
- A portal for Southern Ocean data (OCEAN-READER) continues to be maintained by AGCS (http://www.antarctica.ac.uk/met/SCAR_ssg_ps/OceanREADER/). In due course, it is intended that this will be replaced by a “Southern Ocean Observatory”, to be created to handle data flowing from the Southern Ocean Observing System (SOOS), the design of which AGCS is supporting.

Recommendations/Actions and Justification:

We ask the Delegates to continue supporting AGCS for a further two years so that the programme may carry its current activities in support of international Antarctic climate science to a successful conclusion.

Expected Benefits/Outcomes:

The accomplishment of key advances in the study of a range of aspects of the Antarctic coupled climate system (including the understanding of tropical – polar interactions and their links to West Antarctic warming, the sensitivities of the Southern Ocean circulation and carbon cycle to climate change, the evolution of Antarctic sea ice thickness, and coupled climate processes at the Antarctic shelf / slope) is expected from present progress. AGCS is centrally engaged in the design and implementation of the Southern Ocean Observing System, the coordination of international activities and workshops targeted at Antarctic climate science, and the development of key Antarctic data sets and portals. The success of these activities will be greatly facilitated by the requested support.

Partners:

AGCS has membership on the SCAR Oceanography Expert Group and the CLIVAR / CliC / SCAR Southern Ocean Implementation Panel, to ensure that these groups’ activities are fully aligned with the science requirements of AGCS. Through this, AGCS is centrally engaged in the design of the Southern Ocean Observing System. AGCS is sponsoring the establishment of ASPeCt as a Southern Ocean sea ice working group servicing both SCAR and CliC. AGCS is currently seeking representation in the SCAR Aerosol / Trace Gas Group.

AGCS has worked closely with the SSGs and several other SRPs over the drafting of the ACCE report.

Following the tri-lateral agreement between SCAR, IASC and APECS, signed during the SCAR

open science conference in St Petersburg 2008, APECS representatives have been included in each of the SCAR working groups and scientific standing committees. Dr Liz Thomas was selected as the APECS representative for AGCS and will be attending the meeting in Buenos Aires in August.

Budget Implications:

Continued support at the current level is requested.