



**EXCOM/COs Meeting 2011**

**Edinburgh, 16,18,19<sup>th</sup> July 2011**

Agenda Item: 2.4.2

Person Responsible: Alberto  
Naveira  
Garabato

# **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](http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS.htm) - AGCS web site

**Introduction/ Background:** 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 growth in Antarctic sea ice observed during the past three decades to the identification of a causal link between the changing winds over the Southern Ocean and the warming of the Antarctic Bottom Water 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>). AGCS led the preparation of a brief update on the ACCE report in 2010. This will be a regular feature, with the update being presented to the Antarctic Treaty Consultative meeting.

**Recommendations/Actions and Justification:** We ask the Delegates to continue supporting AGCS for a further year so that the programme may carry its current activities in support of international Antarctic climate science to a successful conclusion and identify the scope and priorities of the next SCAR climate-focussed research programme.

**Expected Benefits/Outcomes:** The completion of significant 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, the development of key Antarctic data sets and portals, and the planning of the next SCAR climate-focussed research programme. 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](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 in the last two years, and thereby overlaps in part with the report presented to SCAR Delegates in July 2010. 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. AGCS led the preparation of a brief update on the ACCE report in 2010. This will be a regular feature, with the update being presented to the Antarctic Treaty Consultative meeting. A further legacy of the ACCE initiative has been the

creation of a SCAR Expert Group on Antarctic Climate Change and the Environment. It consists of most of the ACCE editors plus additional members to broaden the range of science covered.

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 21<sup>st</sup> century, as ozone levels recover (see Turner et al., 2009).
3. A surprisingly fast causal link between changes in winds over the Weddell Sea and the warming of the Antarctic Bottom Water filling the Atlantic Ocean abyss was identified on time scales of months to years through the analysis of repeat oceanographic section and long-term mooring data in the Weddell – Scotia boundary. The link suggests that Southern Annular Mode (SAM) –related changes in the winds over the Southern Ocean may be behind the interdecadal warming of Antarctic Bottom Water in the Atlantic basin (see Jullion et al., 2010; Meredith et al., 2011).
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). Evidence from West Antarctic ITASE ice cores indicates that recent strengthening of the austral westerlies is unique to at least the last 200 years further demonstrating a human induced Antarctic ozone hole depletion association (Dixon et al., 2011).
5. A collection of articles in *Deep-Sea Research II* (volume 58, issues 9-10) discusses Antarctic sea-ice zone research during the International Polar Year (see Worby et al., 2011). A highlight of this work is 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 2010 report occurred. Because of space restrictions only selected achievements are listed below, avoiding duplication of the work described in the above highlights.

- Themes 1 and 3. The first climatology of the Amundsen Sea Low was created from atmospheric reanalysis fields. The Amundsen Sea Low is the highly variable climatological low pressure system that has a profound impact on the meteorology between the Antarctic Peninsula and the Ross Sea. In recent years the Amundsen Sea Low has deepened as a result of the ozone hole resulting in more sea ice in the Ross Sea and giving a surface warming across the Antarctic Peninsula (see Turner et al., 2011).
- Themes 1 and 3. The mechanisms responsible for the large warming of the Antarctic winter troposphere previously identified in radiosonde data were investigated and shown to hinge

around an increase in the amount of polar stratospheric clouds. Globally, the stratosphere has been cooling as a result of greenhouse gas increases (see Lachlan Cope et al., 2009).

- Themes 1 and 3. Analysis of sea ice fields resulted in the discovery of a ‘polynya-like’ feature just to the west of Faraday / Vernadsky station on the western side of the Antarctic Peninsula. The loss of ice here has been responsible for the large warming that has been observed over recent decades at the station. The polynya has its origins in the loss of summer sea ice over the southern Bellingshausen Sea and the changing nature of the sea ice advance through the autumn and winter. The length of the sea ice season has increased in the area and the ice is now thinner than previously. A more rapid sea ice advance and subtle changes in the meridional component of the wind has resulted in the ice moving away from the coast near to Faraday / Vernadsky, creating the polynya-like feature.
- 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 CO<sub>2</sub>) 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 (see Meredith et al., 2011).
- Themes 3 and 4. 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 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).
- 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 first four cruises of the USA - UK 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 supported several scientific meetings and workshops targeted at advancing our knowledge of important elements of the Antarctic climate system. Some of the most salient examples are provided in the following. AGCS organized an International Workshop on Antarctic Sea Ice in IPY, held in Barga (Italy) with 47 participants, and supported the organization of the 4th Malaysian International Seminar on Antarctica (Legacy of IPY to the Tropics), which focussed on tropical-polar interactions. AGCS was also involved in leading the 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. AGCS supported 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. Further, a successful workshop was held on Antarctic Clouds at the Byrd Polar Research Center in July 2010. As has been highlighted by the Intergovernmental Panel on Climate Change (IPCC), the forcing by clouds is one of the biggest unknowns in understanding the climate system. This is especially the case in the Antarctic where there are relatively few *in situ* observations of cloud properties. This workshop brought together modellers and observationalists to assess our current understanding of Antarctic clouds and to plan future research. An AGCS-sponsored workshop was also held in Tromso in June 2010 to review the achievements of the ASPeCt project. Discussion of future plans highlighted the need to bring observations and modelling of sea ice in alignment, as modelling was not a specific goal of the original ASPeCt project. Future AGCS support of sea ice research will be focussed on that alignment task. A third, highly stimulating AGCS-sponsored workshop took place in Southampton in June 2010, focussed on the role of the Southern Ocean circulation on the changing global carbon cycle.
- 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).

### ***Future plans:***

With the AGCS programme drawing to a close in 2012, future AGCS activities will be focussed on leaving a valuable legacy for the continuation and expansion of SCAR's role in the field of Antarctic climate research. This will be done in parallel to the ongoing support of scientific advances in hot topics such as tropical – polar connections, the role of atmosphere – ice – ocean feedbacks in the ongoing Antarctic climate change, and the future evolution of the Southern Ocean circulation. AGCS will seek to affirm this legacy through (i) its support of the review and reconstitution of a new ASPeCt project focussed on sea ice observation – modelling alignment, and (ii) through the organization of a 3-day workshop in Melbourne in July 2011 to review AGCS' achievements, review recent advances in the field, and identify knowledge gaps and future priorities in Antarctic research.

### ***Recent and requested budget:***

The expenditure of AGCS in 2010 (including \$17K of 2010 budget plus \$22K carried over from 2009) was as follows: support of 2010 workshops described above (\$12K); early career scientist support (\$2.5K); ACCE book and flyer printing (\$4K); SASSI data management (\$2K); and arrangement of venue for 'End of AGCS / Next SCAR climate programme planning' workshop in Melbourne, via CSIRO (\$18K). We request continued support at the 2010 level with the following planned uses: sponsorship and organization of workshops on Antarctic sea ice and Antarctic climate dynamics (\$4K); support of early career scientists (\$3K); support of attendees to 'End of AGCS / Next SCAR climate programme planning' workshop in Melbourne (\$10K).

### **Outputs / Deliverables**

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

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.

Dixon, D. A., Mayewski, P.A., Goodwin, I., Freeman, R., Maasch, K.A., Sneed, S.B., and G. Marshall, in press 2011, An ice core proxy for northerly air mass incursions (NAMI) into West Antarctica, *International Journal of Climatology*

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.* 37, L09609, doi:10.1029/2010GL042822.

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.

Meredith, M. P., A. L. Gordon, A. C. Naveira Garabato, E. P. Abrahamsen, B. A. Huber, L. Jullion & H. J. Venables. Synchronous intensification and warming of the Antarctic Bottom Water outflow from the Weddell Gyre. *Geophys. Res. Lett.* 38, L03603, doi:10.1029/2010GL046265.

Meredith, M. P., A. C. Naveira Garabato, A. McC. Hogg & R. Farneti. Sensitivity of the overturning circulation in the Southern Ocean to changes in wind forcing. *J. Clim.*, submitted.

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.

Worby, A. P., K. M. Meiners & S. F. Ackley, 2011: Antarctic sea-ice zone research during the International Polar Year, 2007-2009. *Deep-Sea Res. II* 58 (9-10), 993-998.

Other AGCS-sponsored publications include:

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

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](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/](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.

Excellent progress has been made on the production of key field data sets which will be presented in the forthcoming months.

Recommendations/Actions and Justification:

We ask the Delegates to continue supporting AGCS for a further year so that the programme may carry its current activities in support of international Antarctic climate science to a successful conclusion and identify the scope and priorities of the next SCAR climate-focussed research programme.

Expected Benefits/Outcomes:

The completion of significant advances in the study of a range of aspects of the Antarctic coupled climate system (detailed above) 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, the development of key Antarctic data sets and portals, and the planning of the next SCAR climate-focussed research programme. 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 is regularly attending AGCS Steering Committee meetings.

**Budget Implications:**

Continued support at the current level is requested.