WP 16

Agenda Item: 5.3.2

Person Responsible: Maurizio Candidi

SCAR Business and XXXII Delegates' Meeting

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Antarctica in the Global Climate System (AGCS)

Executive Summary (1 page)

Title: Antarctica in the Global Climate System (AGCS)

Authors: AGCS Steering Committee

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 supplements 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 major advances in the understanding of Antarctic clouds to significant new insights into how turbulent flows shape the climatically key Southern Ocean overturning circulation. AGCS has produced regular annual updates to the ACCE report (http://www.scar.org/publications/occasionals/acce.html). In June 2011, AGCS organized a 3-day symposium in Melbourne to review our current state of understanding of the Antarctic and Southern Ocean climate system, to identify the major gaps in present knowledge, and to lay out the scientific issues that a future climate-focussed SRP must address to maximize scientific progress and societal impact. AGCS has continued to strongly support symposia and data management activities focused on Antarctic climate science.

Recommendations/Actions and Justification: AGCS is coming to an end in 2012. We ask the Delegates to consider supporting the AGCS-sparked proposal of a new climate-related SRP (AntClim21) focussed on the understanding and prediction of how the Antarctic environment will change over the 21st century.

Expected Benefits/Outcomes: The adoption of AGCS's recommendation will lead to improved projections and mechanistic understanding of the magnitude and patterns of change to Antarctica's physical environment and of the likely consequences for biological ecosystems over the next century (see AntClim21 SRP proposal for further details).

Partners: In its final year, AGCS will continue to work (often in a leading role) with the SSGs and several other SRPs, the Southern Ocean Observing System Steering Committee, and the CLIVAR / CliC / SCAR Southern Ocean Implementation Panel, amongst others, to ensure that AGCS-sponsored research and associated 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: No support is requested further to the present allocation for 2012.

Antarctica and the Global Climate System

1. 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 2010. It provides details of progress with the science and lists outputs.

2. Important Issues or Factors

Five Scientific Highlights

1. The Amundsen Sea Low (ASL) is the climatological area of low atmospheric pressure that occurs between the Antarctic Peninsula and the Ross Sea. Changes in the low have a profound impact on the climate of the Antarctic Peninsula, the Marie Byrd land area of West Antarctic and the Ross Ice Shelf/Ross Sea region. The ASL has a large variability because of the shape of the Antarctic continent, but is also strongly affected by tropical climate variability via a teleconnection from the central Pacific Ocean. We produced the first climatology of the ASL covering the period 1979-2008 using ECMWF operational and reanalysis fields. The low exhibits an annual cycle in its zonal location moving from close to 110° W in January to near 150° W in June as planetary waves 1 to 3 amplify and their phases shift westwards. The ASL has deepened over the last 30 years, especially during summer and autumn, giving stronger northerly flow over the Bellingshausen Sea, and playing a part in the marked reduction of sea ice in that area (Turner et al., 2012).

2. 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 (Jullion et al., 2010; Meredith et al., 2011).

3. The present state of knowledge of tropospheric clouds over Antarctica and the Southern Ocean, a key factor in the radiation budget and surface mass balance of the regional cryosphere, was reviewed and critiqued in a recent review paper (Bromwich et al., 2012). A new climatology of tropospheric clouds in the Antarctic region was derived as part of the same study from combined

measurements of the CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation satellites, and used to assess the forecast cloud amounts in 20th century global climate model simulations.

4. A new theory for the rate at which mesoscale eddies stir and transport water masses across the Antarctic Circumpolar Current (ACC) was developed and tested against observations (Naveira Garabato et al., 2011). The theory was then used to demonstrate that the overturning circulation of the Southern Ocean is sensitive to decadal changes in wind stress over the ACC such as those known to have occurred in association with the evolving state of the SAM since the 1950s (Meredith et al., 2012). This finding has important implications for the problem of how the global carbon cycle is responding to changes in Southern Ocean climate.

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 was 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. A pioneering illustration was provided by the work of Xie et al. (2012), who applied the aforementioned relationships to IceSAT data from the Bellingshausen - Amundsen pack ice in 2003-2009 to produce the first regional-scale and interannual comparisons of sea ice thickness for Antarctic sea ice. The major finding is that, over the 7-year record, there have been surprisingly large variations in sea ice thickness, but no trend. It was shown that such variations are primarily caused by interannual wind-driven changes in ice deformation. This body of work fills a major gap in knowledge identified by the last IPCC Assessment.

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.

- Following the leading in 2009 by AGCS of 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 (see http://www.scar.org/publications/occasionals/acce.html), AGCS has produced brief annual updates on the ACCE report via the newly created SCAR Expert Group on Antarctic Climate Change and the Environment. We are currently updating the 80 'key points' of the ACCE report and will present this to the Treaty meeting in the spring.
- 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 (Turner et al., 2012). 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 1 and 3. Different climate models give different answers under greenhouse gas increases. This presents a major challenge when faced with combining data from a

collection (ensemble) of models. A new method has been developed (ensemble regression) that takes model bias into account when combining multi-model ensembles (Bracegirdle and Stephenson, 2012). This gives different and more precise surface temperature projections over both polar regions in all seasons apart from summer. Current work is focussed on extending the method to other variables and assessing the latest climate model output in advance of the Fifth IPCC report.

- Themes 1, 2 and 3. The AGCS-sponsored ITASE Synthesis Workshop in Castine in September 2008 requested a synthesis of the ice core reconstruction tools used to develop sea ice extent proxies. This has now been published (Sneed et al., 2011).
- Themes 1, 2, 3 and 4. Polar-Tropical Connections and CASA, both stemming from ITASE, are focusing on emerging results from an ice core recovered from Detroit Plateau through a joint Brazil-Chile-US effort (several papers near review). Ice cores have been recovered from New Zealand (joint NZ-US-China) and the Andes (joint Chile-US), and results are forthcoming. See e.g., Bertler et al. (2011), Dixon et al. (2011), Sneed et al. (2011) and Stager et al. (2012).
- Theme 4. The US-UK Diapycnal and Isopycnal Experiment of the Southern Ocean (DIMES) has concluded much of its fieldwork phase, consisting of 8 research expeditions. New insights into the role of turbulent processes in shaping the large-scale circulation in the Southern Ocean are beginning to emerge (Ledwell et al., 2011; St. Laurent et al., 2012).
- 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 supported the data management element of the IPY-era international SASSI programme, dedicated to the study of air-sea-ice interactions at the Antarctic margins.
- 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. An AGCS-sponsored successful workshop on Antarctic Clouds was held at the Byrd Polar Research Center in July 2010. This workshop brought together modellers and observationalists to assess our current understanding of Antarctic clouds and to plan future research on the subject. AGCS also supported the organization in 2011 of the 5th Malaysian International Seminar on Antarctica, which concentrated on tropical-polar interactions. 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. An AGCS-sponsored workshop was also held in UCLA, Los Angeles in March 2011 to review the achievements of the ASPeCt project and redefine its future structure and objectives. Finally, AGCS organised a 3-day symposium in Melbourne in June 2011 to review our current state of understanding of the Antarctic and Southern Ocean climate system, to identify the major gaps in present knowledge, and to lay out the scientific issues that a future climate-focussed SRP must address. This has sparked a proposal for a future climate-focussed SRP (AntClim21). 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.

- 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).

3. Outputs/Deliverables

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

Bertler, N.A.N., P. A. Mayewski, P.A. & L. Carter, 2011. Cold conditions in Antarctica during the Little Ice Age - Implications for abrupt climate change mechanisms. Earth and Planetary Science Letters 308, 41-51.

Bracegirdle, T. J. & D. B. Stephenson, 2012. Higher precision estimates of regional polar warming by ensemble regression of climate model projections. Climate Dynamics, published online, doi:10.1007/s00382-012-1330-3.

Bromwich, D. H., J. P. Nicolas, K. M. Hines, J. E. Kay, E. Key, M. A. Lazzara, D. Lubin, G. M. McFarquhar, I. Gorodetskaya, D. P. Grosvenor, T. A. Lachlan-Cope & N. van Lipzig, 2012: Tropospheric Clouds in Antarctica. Reviews of Geophysics 50, RG1004, doi:10.1029/2011RG000363.

Dixon, D. A., P. A. Mayewski, I. Goodwin, R. Freeman, K. A. Maasch, S. B. Sneed & G. Marshall, 2011. An ice core proxy for northerly air mass incursions (NAMI) into West Antarctica. International Journal of Climatology, online doi:10.1002/joc.2371.

Jullion, L., S. C. Jones, A. C. Naveira Garabato & M. P. Meredith, 2010. Wind-controlled export of Antarctic Bottom Water from the Weddell Sea. Geophysical Research Letters 37, L09609, doi:10.1029/2010GL042822.

Ledwell, J. R., L. C. St. Laurent, J. B. Girton & J. M. Toole, 2011. Diapycnal mixing in the Antarctic Circumpolar Current. Journal of Physical Oceanography 41, 241-246.

Mahowald, N., S. Kloster, S. Engelstaedter, J. K. Moore, S. Mukhopadhyay, J. McConnell, S. Abani, S. Doney, A. Bhattacharya, M. Curran, M. Flanner, L. Hoffman, K. Lindsay, P. Mayewski, J. Neff, D. Rothenberg, E. Thomas, P. Thornton & C. Zender, 2010. Observed 20th century desert dust changes: implications for climate and biogeochemistry. Atmospheric Chemistry and Physics 10, 10875-10893, doi:10.5194/acp-10-10875-2010.

Meredith, M. P., A. L. Gordon, A. C. Naveira Garabato, E. P. Abrahamsen, B. A. Huber, L. Jullion & H. J. Venables, 2011. 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., P. L. Woodworth, T. K. Chereskin, D. P. Marshall, L. C. Allison, G. R. Bigg, K. Donohue, K. J. Heywood, C. W. Hughes, A. Hibbert, A. McC. Hogg, H. L. Johnson, L. Jullion, B. A. King, H. Leach, Y.-D. Lenn, M. A. Morales Maqueda, D. R. Munday, A. C. Naveira Garabato, C. Provost, J.-B. Sallée & J. Sprintall, 2011. Sustained monitoring of the Southern Ocean at Drake Passage: past achievements and future priorities. Reviews of Geophysics 49, RG4005, doi:10.1029/2010RG000348.

Meredith, M. P., A. C. Naveira Garabato, A. McC. Hogg & R. Farneti, 2012. Sensitivity of the overturning circulation in the Southern Ocean to decadal changes in wind forcing. Journal of Climate 25, 99-110.

Naveira Garabato, A. C., R. Ferrari & K. L. Polzin, 2011. Eddy stirring in the Southern Ocean. Journal of Geophysical Research 116, C09019, doi: 10.1029/2010JC006818.

Sneed, S. B., P. A. Mayewski & D. Dixon, 2011, Multi-ice core sodium, nss sulfate, and methlysulfonate correlations with Antarctic sea ice extent - an enhanced ice core sea ice extent proxy. Annals of Glaciology 52, 347-354.

St. Laurent, L. C., A. C. Naveira Garabato, J. R. Ledwell, A. M. Thurnherr, J. M. Toole & A. J. Watson. Turbulence and diapycnal mixing in Drake Passage. Journal of Physical Oceanography, in press.

Stager, J.C., P. A. Mayewski, J. White, B. M. Chase, F. Neumann, M. E. Meadows, C. King & D. A. Dixon, 2012. Rainfall variability in South Africa and Australia during the last millennium linked to meridional shifts in the austral westerlies. Climates of the Past 7, 4375–4399.

Turner, J., T. Maksym, T. Phillips, G. J. Marshall & M. P. Meredith, 2012. The impact of changes in sea ice advance on the large winter warming on the western Antarctic Peninsula. International Journal of Climatology, in press.

Turner, J. & G. J. Marshall, 2011. Climate Change in the Polar Regions. Cambridge University Press., Cambridge, 434pp.

Turner, J., T. Phillips, S. Hosking, G. J. Marshall & A. Orr, 2012. The Amundsen Sea Low. International Journal of Climatology, submitted.

Weissling, B. & S.F. Ackley, 2011. Antarctic Sea Ice Altimetry: Scale and Resolution Effects on derived ice thickness distributions. Annals of Glaciology 52, 57A093, 225-235.

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, 993-998.

Xie, H., A. Tekeli, S.F. Ackley & D. Yi, 2012. Sea Ice thickness estimations from IceSAT Altimetry over the Bellingshausen and Amundsen Seas, 2003-2009. The Cryosphere, submitted.

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 in the subsequent two years. AGCS has produced brief annual updates on the ACCE report via the newly created SCAR Expert Group on Antarctic Climate Change and the Environment. We are currently updating the 80 ‘key points’ of the ACCE report and will present this to the Treaty meeting in the spring.

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 data bases and portals:

- The frequently used MET-READER data base 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/) data base 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 has actively supported.

4. Budgetary Implications

	AGCS (USD)
2011+12 Expenses to date	18402
2012 Budget Allocations	20000
2011 Budget Allocations	21000
TOTAL Remaining funds TO DATE	22598

No further support is requested.

5. Future Plans

The SRP is drawing to an end in 2012. Please see 'Recommendations' section for an outlook on how AGCS-related scientific issues are to be progressed within SCAR.

Appendices

Membership of AGCS Steering Committee: Azizan Abu Samah (University of Malaya), Steve Ackley (University of Texas), Nancy Bertler (Victoria University of Wellington), David Bromwich (Ohio State University), Andrew Lenton (CSIRO), Mike Meredith (British Antarctic Survey), Paul Mayewski (University of Maine), Alberto Naveira Garabato (University of Southampton, Chair), Siobhan O'Farrell (CSIRO), John Turner (British Antarctic Survey), Tas van Ommen (CSIRO), Tony Worby (CSIRO), Cunde Xiao (Chinese Academy of Meteorology)