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Report on the SCAR**Antarctica and the Global Climate System (AGCS)****Scientific Research Programme****INTRODUCTION**

This document reports on progress with the implementation of the SCAR AGCS SRP since it was established at SCAR XXIII in Bremerhaven, Germany in October 2004. It provides details of progress with the science, lists outputs and identifies targets for the next two years. AGCS consists of four science themes concerned with:

1. Decadal time 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.

FIVE SCIENTIFIC HIGHLIGHTS

1. An undocumented major warming of the Antarctic winter troposphere was discovered that is larger than any previously identified regional tropospheric warming on Earth. The warming was identified by a careful analysis of the balloon-launched radiosonde data for the Antarctic extending back into the 1950s that forms part of the SCAR READER data base. The warming is largest close to 5 km above sea level where temperatures have increased at a rate of 0.5 – 0.7 deg C over the last 30 years. The results were published in Science in March 2006 (Turner et al., 2006)
2. An analysis of recent trends in Antarctic snow accumulation from ice core and model data showed that over the continent as a whole the annual trends are small and not statistically different from zero, suggesting that recent Antarctic snowfall changes do not mitigate current sea level rise. The work was carried out with the Polar MM5 climate model (Monaghan et al., In Press).
3. The climate of the Western Antarctic Peninsula (WAP) is the most rapidly changing in the Southern Hemisphere, with a rise in atmospheric temperature of nearly 3 deg C since 1951 and associated cryospheric impacts. It has been demonstrated for the first time, that the adjacent ocean showed profound coincident changes, with surface summer temperatures rising more than 1 deg C and a strong upper-layer salinification. Initially driven by atmospheric warming and reduced rates of sea ice production, these changes constitute positive feedbacks that will contribute significantly to the continued climate change. Marine species in this region have extreme sensitivities to their environment, with population and species removal predicted in response to very small increases in ocean temperature. The WAP region is an important breeding and nursery ground for Antarctic krill, a key species in the Southern Ocean foodweb with a known dependence on the physical environment. The changes observed thus have significant ecological implications (Meredith and King, 2005).
4. Modelling studies have shown for the first time that the major, near-surface increase in temperature on the eastern side of the Antarctic Peninsula has been caused, at least in part, by increases in greenhouse gases. Over the last few decades the Southern Hemisphere Annular Mode (SAM) has shifted into its positive phase during the summer, resulting in a drop (increase) in atmospheric pressure over the Antarctic (mid-latitudes). This has results in a strengthening of the westerly winds around the Antarctic and more mild, maritime air

masses crossing the Antarctic Peninsula. The warming has been instrumental in the disintegration of the ice shelves in this area (Marshall et al., In Press).

5. Ice core reconstructions of past atmospheric circulation suggest that modern atmospheric circulation intensity is within the range of variability of the last ~1000 years (Mayewski and Maasch, 2006). Ice core records also reveal increased penetration of marine air masses into the western coastal regions of West Antarctica as of the 1940s (Dixon et al., 2006).

PROGRESS AGAINST PRIOR WORK PLAN

What were the planned milestones and deliverables? What were the achievements against these during the 2-year cycle?

All the AGCS milestones and deliverables are listed in the AGCS Implementation Plan available at <http://www.scar.org/researchgroups/physicalscience/agcs/>. Because of space restrictions only selected achievements are listed below, but an expanded version is available on the web at http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS_Progress.htm

- Theme 1. Insight has been gained into changes in the Southern Hemisphere Annular Mode (SAM) over recent decades and especially its influence on Antarctic Peninsula temperatures.
- Theme 1. Model studies have shown that the horizontal precipitation variability across Dronning Maud land reflects the synoptic and topographic forcing. On the plateau, where these forcings become weak, a monotonous inland decrease in precipitation was not found. (U. Wacker, AWI).
- Theme 2. See item 5 under Scientific Highlights.
- Theme 3. The planned airborne campaign AGAMES “Antarctic Trace Gas and Aerosol Airborne Measurement Study” in 2005/06 have to postponed because of an accident with the POLAR 4 aircraft.
- Theme 3. In preparation for the IPY activity POLAR AOD (aerosol optical depth) Network in which ground-based measuring activities will take place in Antarctica, a special intercomparison campaign was held in Ny-Aalesund, Arctic.
- Theme 4. The AWI undertook a major cruise in the Weddell Sea over 20 Nov 2005 -12 Jan 2006 in which valuable oceanographic data were collected..
- Theme 4. Insight was gained into the maintenance of perennial sea ice cover from the Ice Station POLARstern drift experiment. During this cruise Helium isotope and neon measurements were made.
- Theme 4. Oceanographic measurements in the Weddell Sea have indicated that the bottom water temperature increased steadily during the last decades. E. Fahrbach (AWI)
- Theme 4. During FS Polarstern cruise ANT-XXII/3 in 2005, CO₂ system parameters were measured on two repeat sections through the Weddell Sea.
- Theme 4. In the framework of the Southern Ocean Observation System, 29 ice compatible floats have been deployed within the southern part of the Antarctic Circumpolar Current and the Weddell Gyre.
- Further understanding was obtained of how signals of the El Nino-Southern Oscillation are transferred into the Antarctic and the limits on how robust the ENSO can be in an area of high natural climate variability.
- A workshop was held (jointly with CliC and ICPM) to assess the quality of the reanalysis fields at high latitudes
- AGCS was instrumental in organising a workshop (jointly with POGO and CoML) on the design of a Southern Ocean Observing System, which will be held at the end of the SCAR OSC.

What deviations were made from the work plan, and why?

There were no major deviations from the work plan. The problems with the POLAR 4 aircraft are noted above.

What SCAR funds were allocated to the activity?

How were the SCAR funds spent?

AGCS had a budget of \$21K in 2005, of which \$8.2K was spent and \$12.7K carried forward to 2006. The 2005 spend was as follows:

AGCS Steering Committee meeting	\$4.2K
Ice READER data base development	\$4K
Total	\$8.2K

Planned spend for 2006

Development of the Ocean READER data base	\$4K
Development of the Ice READER data base	\$4K
ASPECT Workshop, Hobart, July 2006	\$6K
Last 2,000 year workshop Hobart, July 2006	\$6K
Reanalysis workshop, Cambridge, UK, April 2006	\$10K
Publication of ITASE paper in Annals of Glaciology	\$3K
Total	\$33K

(b) Proposed work plan for the next 2 years:

What are the new planned milestones and deliverables?

The targets for the next two years will be decided at the AGCS Steering Committee meeting in Hobart during July 2006. However, some possible targets will be:

1. Assessment of the Antarctic element of the IPCC Assessment Round 4 model predictions for the next century.
2. Investigation of the mechanisms responsible for changes in the SAM.
3. Research into mechanisms behind the mid-tropospheric warming above the Antarctic that occurred over the last 50 years.
4. Investigation of the current state of the Antarctic climate in the context of the last several hundred years for purposes of assessing natural vs anthropogenic impact.

What SCAR funds are required to support the activity and how will they be used?

We anticipate requiring level funding over the next two years of about \$21K per year. The exact usage of the funds will be decided in Hobart, but possibilities are:

- Further data recovery of early Antarctic climate records
- Development of the READER data bases
- Workshops on climate variability
- Further cross-SRP/SSG workshops

OUTPUTS/DELIVERABLES

(a) Publications in peer reviewed literature (including articles “in press”) – selected papers

Bertler, N. & et al (2005) Snow chemistry across Antarctica. *Annals of Glaciology*, 41, 167-179.

Blaker A. T., B. Sinha, V. O. Ivchenko, N. C. Wells, V. B. Zalesny (2006), Identifying the roles of the ocean and atmosphere in creating a rapid equatorial response to a Southern Ocean anomaly, *Geophys. Res. Lett.*, 33, L06720, doi:10.1029/2005GL025474.

Dixon, D., Mayewski, P.A., Kaspari, S., Sneed, S., and Handley, M., 2004, A 200 year sub annual record of the primary sources of sulfate in West Antarctica, *Annals of Glaciology* 39, 545-556.

- Fahrbach, E., Hoppema, M., Rohardt, G., Schröder, M., Wisotzki, A. (2006). Causes of deep-water variation: Comment on the paper by L.H. Smedsrud "Warming of the deep water in the Weddell Sea along the Greenwich meridian: 1977-2001", *Deep-Sea Research I*, 53(3), 574-577. DOI: 10.1016/j.dsr.2005.12.003
- Fogt, R.L., and D.H. Bromwich, 2005: Decadal variability of the ENSO teleconnection to the high latitude South Pacific governed by coupling with the Southern Annular Mode. *J. Climate*, accepted for publication.
- Hellmer, H. H., Dieckmann, G. S., Haas, C., Schröder, M. (2006). Sea ice feedbacks observed in western Weddell Sea, *EOS, Transactions, American Geophysical Union*, 87(18), 173, 179.
- Hoppema, M., Anderson, L. G. (2006). Biogeochemistry of polynyas and their role in sequestration of anthropogenic constituents, In: "Polynyas: Windows into Polar Oceans", W.O. Smith Jr., D. Barber (Eds.). Elsevier Oceanography Series, Amsterdam, in press.
- Klatt, O., Fahrbach, E., Hoppema, M., Rohardt, G. (2005). The transport of the Weddell Gyre across the Prime Meridian, *Deep-Sea Research II*, 52, 513-528. DOI: 10.1016/j.dsr2.2004.12.015
- Legeais, J.-F., Speich, S., Arhan, M., Ansorge, I., Fahrbach, E., Garzoli, S., Klepikov, A. (2005). The baroclinic transport of the Antarctic Circumpolar Current south of Africa, *Geophysical Research Letters*, 32, L24602. DOI: 10.1029/2005GL023271
- Makinson, K., Schröder, M., Osterhus, S. (2006). The effect of critical latitude and seasonal stratification on tidal current profiles along Ronne Ice Front, Antarctica, *Journal of Geophysical Research*, in press.
- Marshall, G. J., Orr, A., van Lipzig, N. P. M. and King, J. C. (In Press) The impact of a changing Southern Hemisphere Annular Mode on Antarctic Peninsula summer temperatures. *Journal of Climate*.
- Mayewski, P.A. and Maasch, K., in press 2006, Recent warming inconsistent with natural association between temperature and atmospheric circulation over the last 2000 years, *Climate of the Past (Discussions)*
- Mayewski, P.A. & et al (2005) The International Trans-Antarctic Science Expedition (ITASE): An Overview. *Annals of Glaciology*, 41, 180-185.
- Meredith, M.P. and A.McC. Hogg, "Circumpolar response of Southern Ocean eddy activity to changes in the Southern Annular Mode". Submitted to *Geophysical Research Letters*, 2006.
- Meredith, M.P., M.A. Brandon, M.I. Wallace, A. Clarke, M.J. Leng, I.A. Renfrew, N. van Lipzig and J.C. King. "Variability in the freshwater balance of northern Marguerite Bay, Antarctic Peninsula: results from $\delta^{18}O$ ". Submitted to *Deep-Sea Research*, 2006
- Meredith, M.P. & King, J.C. (2005) Climate change in the ocean to the west of the Antarctic Peninsula during the second half of the 20th century. *Geophysical Research Letters*, 32, L19606 doi:10.1029/2005GL024042.
- Monaghan, A.J., D.H. Bromwich, and S-H. Wang, 2006: Recent trends in Antarctic snow accumulation from Polar MM5. *Philosophical Trans. Royal. Soc.*, conditionally accepted, October 2005.
- Piel, C., Weller, R., Huke, M., Wagenbach, D. (2006). Atmospheric methane sulfonate and non-sea salt sulfate records at the EPICA deep-drilling site in Dronning Maud Land, Antarctica, *Journal of Geophysical Research-Atmospheres*, 111, D03304 DOI: 10.1029/2005JD006213
- Spikes, V.B., Hamilton, G.H., Arcone, S.A., Kaspari, S. and Mayewski, P.A., 2005, Primary causes of variability in Antarctic accumulation rates, *Annals of Glaciology* 39, 238-244.
- Turner, J., Lachlan-Cope, T.A., Colwell, S.R., Marshall, G.J. & Connolley, W.M. (2006) Significant warming of the Antarctic winter troposphere. *Science*, 311, 1914-7.
- Wacker, U. (2006). Nonlinear effects in a conceptual multilayer cloud model, *Nonlinear Processes in Geophysics*, 13, 99-107.

(b) Other Publications (e.g. institution reports, articles in the grey literature, maps, atlases, CDs, Newsletters or contributions to newsletters)

Several articles on AGCS science appeared in conference proceedings.

(c) Brochures, posters, press/media articles and similar PR material

A great deal of press coverage was generated by the discovery of the Antarctic mid-tropospheric warming. TV and radio interviews were carried out and many articles appeared in newspapers around the world.

The Meredith and King West Antarctic Peninsula warming paper was the subject of a full-page article in the UK Guardian newspaper, and also featured on a large number of news websites (including BBC news).

(d) creation of a web site, and number of hits per web site

An AGCS web site (http://www.antarctica.ac.uk/met/SCAR_ssg_ps/AGCS.htm) has been created that describes the research programme and our goals. At present we don't have any information on the number of hits.

(e) creation of database(s), and amount of use of database(s) (e.g. as measured by hits on a web version)

- 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 data. A new data base, known as ICE-READER (<http://www2.umaine.edu/itase/content/icereader/>), indicating the locations where Antarctic ice cores have been collected has been created. It is planned to add information on the data analysed in these cores and the papers that resulted.
- During 2006 a summer student will be employed to start work on the OCEAN-READER data base that will point to the key data sets on Southern Ocean oceanographic data.
- Important data sets have been created from the air chemistry (Neumayer Station) and aerosol (Konen station) observing programmes. The data are accessible under PANGAEA (<http://www.pangaea.de/PangaVista> ; search for "Neumayer Air Chemistry") and are also submitted to GAW (<http://www.empa.ch/gaw/gawsis/default.asp> ; submitted: surface ozone, condensation particle number concentration, aerosol scattering by integrating nephelometer).
- Data from Polarstern cruise ANT XXII/3 were processed and are in the AWI data base. It will also be released to the CLIVAR data centre.

(f) number and type of education/training and other capacity building activities;

Numerous public outreach talks were given by AGCS scientists.

Various UK labs/universities are spinning up a proposal to NERC to directly address some of the key questions under AGCS Theme 4

(g) new technology/model developments;

While making extensive use of climate models, our main involvement in model development has been through trying to improve the representation of Antarctic sea ice.

AGCS scientists have worked closely with the Physical Sciences SSG Expert Group on Ice Drilling in developing and exploiting the latest technology for drilling ice cores.

(h) contributions to IPY

AGCS is involved in the following full IPY proposals:

1. Antarctic Climate and Atmospheric Circulation (ID 180)
2. Antarctic Regional Interactions Meteorology Experiment (RIME) (ID 15)
3. Comprehensive Meteorological dataset of active IPY Antarctic measurement phase for Scientific and applied Studies (ID 267)
4. Climate of Antarctica and the Southern Ocean – Ocean Circulation Cluster (ID 132)
5. Trans-Antarctic Scientific Traverses Expeditions – Ice Divide of East Antarctica (ID152)
6. Dome A Observations and Multidisciplinary Exploring – Actions during IPY (ID 297)
7. International Polar Year GEOTRACES: An international study of the biogeochemical cycles of Trace Elements and Isotopes in the Arctic and Southern Oceans (ID 35)

(i) key achievements (short paragraphs on each)

- Publications in the peer reviewed literature (see above)
- Development of the READER data bases
- Preparation of IPY proposals

(a) number, gender and country of participating scientists

The AGCS Steering Committee consists of:

- Dr. John Turner, British Antarctic Survey, UK (Chair) (J.Turner@bas.ac.uk) M
- Prof. David Bromwich, Byrd Polar Research Center, Ohio State University, USA (bromwich.1@osu.edu) M
- Dr. Mike Meredith, British Antarctic Survey, UK (M.Meredith@bas.ac.uk) M
- Prof. Paul Mayewski, University of Maine, USA (paul.mayewski@maine.edu) M
- Dr. Alberto C. Naveira Garabato, National Oceanography Centre, UK (acng@noc.soton.ac.uk) M
- Dr. Tony Worby, University of Tasmania, Australia (a.worby@utas.edu.au) M
- Dr. Nancy Bertler, Victoria University of Wellington, New Zealand (nancy.bertler@vuw.ac.nz) F
- Dr. Cunde Xiao, Chinese Meteorological Administration, Beijing (cdxiao@cams.cma.gov.cn) M
- Dr. Gino Casassa, Centro de Estudios Científicos, Chile (GC@cecs.cl) M
- Dr. Shigeru Aoki, Low Temperature Institute, Hokkaido University, Japan (shigeru@lowtem.hokudai.ac.jp) M
- Ms Helen Campbell, British Antarctic Survey, UK (HCAMP@bas.ac.uk) (JCADM rep) F

The Implementation Plan explicitly names 64 scientists (52 male and 12 female) working on AGCS activities, but there are many other people involved in the project, including co-workers and students.

(b) number and type of meetings/workshops, and numbers, genders and countries represented in their attendees.

- Workshop on High Latitude Reanalyses, British Antarctic Survey, 10-12 April 2006.

Twenty participants from the UK (13), USA (6), France (1). Nineteen male and one female.

(c) links to other SCAR SRPs or Action or Expert Groups

A very valuable cross-SSG/cross-SRP workshop was held in Amsterdam in November 2005. Amongst other things, this meeting decided on the climate prediction variables covering the next century that would be provided to the EBA programme.

(d) links to other ICSU bodies or to other scientific groups

Close links have been established with the World Climate Research Programme Climate and Cryosphere (CliC) project and especially the CliC Project Area 4 on Linkages between the cryosphere and global climate.

(e) development and staffing of a project office or other administrative support

AGCS does not have a formal project office.

(f) sources and amounts of income for project activities

Besides the funds provided by SCAR, the activities of AGCS have been funded by national Antarctic programmes, research grants and university funds.

(g) expenditure on project activities

See the breakdown of the usage of SCAR funds.