



**SCAR Business and XXXII Delegates' Meeting**

**Portland, USA, 13-25 July 2012**

Agenda Item:

5.3.1

Person Responsible:

Carlota  
Escutia

**“Antarctic Climate Evolution”  
Final Report to the Delegates, 2012**



## Executive Summary

**Title: Antarctic Climate Evolution (ACE)**

**Authors: C. Escutia and R. DeConto**

**Introduction/ Background:** The SCAR Antarctic Climate Evolution (ACE) Programme represents the interests of a large land and marine geoscience research community focusing in deciphering the record of the onset and the response of the Antarctic ice sheets to past climate changes across a range of timescales. ACE coordinates the integration between geophysical and geological records of past ice sheet behavior and coupled climate, ocean, and ice sheet models. The Programme has a planned lifetime of 2005-2013.

**Important Issues or Factors:** (what do the SSGs and Delegates need to be aware of) The present Antarctic ice sheet has existed for approximately 34 million years. Understanding the response of the Antarctic ice sheet to climatic forcing is essential because changes in the ice sheet can have major impacts on global sea level and can impact the entire climate system through a wide range of physical and chemical feedbacks. Since ACE's last Report to Delegates during the SCAR OSC 2010, ACE continues to be very active in its primary coordination role, promoting interactions amongst geologists, geophysicists, modelers and other polar scientists from the climate, ocean and ice coring communities. ACE continues to promote work within its subcommittees to address gaps in our knowledge about the role of Antarctic ice sheets in the global climate system. ACE subcommittees synthesize the state of the art of our knowledge and define the future questions and challenges that are critical for providing science-based advice to major scientific programmes (i.e., IODP, ERICON-AB) and policy makers (i.e., IPCC). To address some of these outstanding questions ACE has been active in guiding the community and is sponsoring a workshop on Antarctic Drilling during the SCAR OSC 2012 for the coordinated submission of a series of drilling proposals (ANDRILL, IODP, and subglacial sampling) in key areas around Antarctica and the Southern Ocean. In this last 2 years of the Programme, ACE is also playing an active and central role in the development of a proposal to SCAR for the new SRP Past Antarctic Ice Sheet Dynamics (PAIS) to succeed ACE. In addition, and as it has been done in the past, ACE has continued to be active in proposing dedicated sessions and workshops in all international meetings, including AGU, EGU, ISAES and the 2012 SCAR OSC, and in the publishing of its results in high impact journals.

**Recommendations/Actions and Justification:** (what actions are you requesting of the SSGs and Delegates and why they should agree) Support for ACE plans for the remaining life of the Programme and input from the Delegates on ACE plans based on the new SCAR Strategic Plan.

**Expected Benefits/Outcomes:** (if the actions are taken what outcomes are expected) Significant publication output (both content and numbers), Publications and science relevant to "Big- science" programmes and policy makers, enhancement of SCAR profile

**Partners:** (will this involve others both within and outside of SCAR?) IPICS; PAGES of the IGBP; IASC on APEX; ANDRILL, SHALDRIL, IODP and ERICON-AB.

**Budget Implications:** Request for confirmation of SCAR science programme funding at current level for planned remainder of the Programme's operation to 2013.

# Antarctic Climate Evolution (ACE)

## 1. Rationale for the Programme

ACE is one of the approved Scientific Research Program (SRP) of the Scientific Committee on Antarctic Research (SCAR). The mission of ACE is to facilitate the study of Antarctic climate and glacial history through integration of numerical modeling with geophysical and geological data. ACE is designed to determine both climate conditions and climatic changes and their impact on ice sheet and sea ice behavior during the recent past (i.e., the Holocene prior to anthropogenic impacts, as well as at the last glacial maximum and other Quaternary glaciations, when temperatures were cooler than at present) and the more distant past (i.e. the pre-Quaternary, when global temperatures were several degrees warmer than today).

Antarctica has been glaciated for approximately 34 million years, but its ice sheets have fluctuated considerably and are one of the major driving forces for changes in global sea level and climate throughout the Cenozoic Era. The spatial scale and temporal pattern of these fluctuations is subject to considerable debate. Understanding the response of large ice masses to climatic forcing is of vital importance because ice-volume variations impact global sea level and also alter the capacity of ice sheets and sea ice to act as major heat sinks/insulators. It is particularly important to assess the stability of the cryosphere in the face of rising CO<sub>2</sub> levels, as modeling of the climate shift from a warm, vegetated Antarctica to a cold, ice-covered state 34 Myrs ago suggests a powerful greenhouse gas influence. As Antarctica is a major driver of Earth's climate and sea level, much effort has been expended in deriving models of its behavior. Some of these models have been successfully validated against modern conditions. Modeling the past record of ice-sheet behavior in response to changes in climate (inferred from ice cores for example), paleoceanographic conditions (inferred from paleoecology and climate proxies in ocean sediments) and paleogeography (as recorded in landscape evolution) is the next step and will allow for modeling of the large and dynamic changes observed in geologic history.

The cross-disciplinary approach within ACE, involving climate and ice sheet modelers, geologists, and geophysicists leads to a substantial improvement in the knowledge of past Antarctic climate, and our understanding of the factors that have guided its evolution. This in turn allows us to build hypotheses, examinable through numerical modeling, as to how Antarctic climate is likely to respond to future global change. Equally important, the development of data-driven models for Antarctic climate will allow us to extend our results to the analysis and forecasting of global climate variability.

### **ACE is structured in subcommittees:**

ACE subcommittees provide the overall leadership, direction and management for their respective topics. They contribute to the overall understanding of the Antarctic's climate evolution by encouraging and facilitating communication and collaboration among research scientists working on any aspects of Antarctic climate evolution pertinent to the respective topic. The subcommittees also ensure that activities within each committee are communicated and wherever possible integrated with those of other time-based, modelling and process-based themes of the ACE programme. Ace subcommittees include:

- 1) LGM/Deglacial/Holocene (Active since 2004)
- 2) Pleistocene (Active since 2004)
- 3) Middle Miocene-Pliocene (Active since 2004)
- 4) Oligocene-Miocene (Active since 2004)
- 5) Eocene-Oligocene (Active since 2004)
- 6) Radio-echosounding (Active since 2005)
- 7) Circum Antarctic Stratigraphy and Paleobathymetry (CASP) (Resulting from the merge between ROSSMAP and CASP (Active since 2008)

- 8) ANTScape: Antarctic Paleotopography (Active since 2009)
- 9) Paleoclimate Records from the Antarctic Margin and Southern Ocean” (PRAMSO) (Active since 2010)

## **2. Important Issues or Factors**

### **i) Five Scientific Highlights**

ACE has been instrumental in resolving a number of previously unanswered palaeoclimate science questions at critical “times-slices” in the evolution of the Antarctic cryosphere. These range from determining the mechanisms responsible for the onset of the first major Cenozoic glaciation of the continent ~34 million years ago, to the more recent West Antarctic Ice Sheet (WAIS) retreat and readvance events during the Pliocene and Pleistocene. ACE’s success came largely by promoting and facilitating major initiatives and field programmes that championed the “data-model paradigm”, including: ANDRILL, IODP programmes, airborne geophysical surveys such as AGAP and ICECAP, work within ACE sub-programmes and working groups including ANTScape, and CASP, among others.

Through this careful combination of geological and geophysical data with numerical ice sheet modeling ACE has demonstrated the potential for past ice sheet history and behavior to be reconstructed (e.g., DeConto and Pollard, 2003; Naish et al., 2009; Pollard & DeConto, 2009; Stocchi et al., submitted). It has mobilised fundamental advances in our knowledge regarding: the influence of atmospheric CO<sub>2</sub> levels, rather than other factors such as plate tectonics and changes in ocean circulation on the first appearance of the ice sheet as we know it today; ice sheet stability over the last 5 million years, in particular the dramatic variability of the West Antarctic Ice Sheet and its impact on sea level; climate variability over the past 10,000 years including sediment records at tree-ring-like resolution; constraints on paleo-topography; and the paleo-bathymetry of the Antarctic continent and surrounding continental margins in relation to geological controls on ice sheet evolution and stability.

Scientific achievements of ACE are published in numerous publications in the primary scientific literature, including *Science* and *Nature*. In addition to ACE’s indirect contribution to these publications, ACE as it stands has produced five major edited books and special volumes (Florindo, Cooper and O’Brien, 2004; Florindo, Nelson, and Haywood, 2008; Florindo and Siebert, 2008; Florindo, Harwood and Levy, 2009; Escutia, Florindo, Bentley, and DeConto, 2012).

ACE achievements are having impacts on larger international science programmes and capacity building. This impact is seen in the new IODP 2013-2023 science plan, which adopted a similar data-model philosophy with increased focus on polar regions and with the potential to make substantial contributions to the Intergovernmental Panel on Climate Change (IPCC). In this regard, two members of the ACE community were amongst the writing team for the IODP, and also the icebreaker Aurora Borealis, Science Plans. ACE has been active in making the case for a more developed paleoclimate section for the next IPCC report with T. Naish, as part of the ACE community, contributing to the next IPCC report in the section of pre-Quaternary paleoclimate.

### **ii) Progress against prior work plan, including metrics of performance**

Since 2010 ACE has made substantial progress in programmes that cover some of the original objectives for ACE, for example:

- The IODP Expedition 318 drilled the Wilkes Land margin, one of the programmes in the ACE implementation Plan, and recovered cores containing ~53 m.y. of Antarctic history: from an ice-free “greenhouse Antarctica”, to the first cooling, to the onset and erosional consequences of the first glaciation and the subsequent dynamics of the waxing and waning ice sheets, all the way to thick, unprecedented “tree-ring style” records with seasonal

resolution of the last deglaciation that began ~10,000 y ago. Preliminary results from this Expedition are published in Escutia, Brinkhuis, Klaus et al. (2011).

- The Antarctic Geological Drilling programme (ANDRILL) continues to develop results from its SMS and MIS Projects. These projects have resulted to date in more than 100 publications in peer review journals, including *Nature* (Naish et al., 2009; DeConto and Pollard, 2009), and in 17 theses and dissertations. The 2010-2011 field season saw a major step forward for the next planned ANDRILL project, the Coulman High Project. Oceanographic equipment and a ROV were deployed through 270 m-thick ice and short sediment cores and new seismic data were obtained. These achievements help establish the case for deep drilling.
- The US-UK-AUS ICECAP (Investigating the Cryospheric Evolution of the Central Antarctic Plate) programme completed its third season of airborne geophysics of the Aurora and Wilkes basins in East Antarctica. The new 25 km grid sheds new insights into former ice sheet dynamics and size. In addition, the UK completed the first airborne survey of the Institute and Moller ice streams in West Antarctica that help us understand modern flow processes and how these have changed in the past.
- The UK-led programme to undertake the direct measurement and sampling of Lake Ellsworth in West Antarctica remains on track for exploration in December 2012 when a team of British scientists and engineers will drill through 3 km of solid ice into a buried lake to search for life forms in the water and clues to past climate in the lake-bed sediments. A comprehensive environmental evaluation of the programme was submitted to the Antarctic Treaty Committee on Environmental Protection.

### 3. Outputs/Deliverables

Selected publications; databases; workshops and meetings; Education and Outreach; Data and Information activities

#### ACE Publications

In addition to ACE's indirect contribution to numerous publications in the primary scientific literature, including *Science* and *Nature*, ACE as it stands has produced key peer reviewed publications, which include:

- 2004 Special issue of *Palaeogeography, Palaeoclimatology, Palaeoecology: Antarctic Cenozoic Palaeoenvironments: Geologic Record and Models*, F. Florindo, A.K. Cooper and P. E. O'Brien (Editors). *Palaeogeography, Palaeoclimatology, Palaeoecology*, Volume 198, issues 1-2,
- 2005 Special Issue of *Global and Planetary Change: Long-term changes in Southern high-latitude ice sheets and climate: the Cenozoic history*. Florindo, F., Harwood, D.M., Wilson, G.S. (Editors), *Global and Planetary Change* 45, 1-264.
- 2008 Special Issue of *Palaeogeography, Palaeoclimatology, Palaeoecology: Antarctic cryosphere and Southern Ocean climate evolution (Cenozoic–Holocene)*, F. Florindo, A. Nelson and A. Haywood (Editors). *Palaeogeography, Palaeoclimatology, Palaeoecology*, Volume 260.
- 2009 ACE Book: *Developments in Earth and Environmental Sciences: Antarctic Climate Evolution*. F. Florindo and M. Siegert (Editors). *Developments in Earth and Environmental Sciences* Volume 8, 2009. The Netherlands: Elsevier, 2009, DOI 10.1016/S1571-9197(08)00005-0.

- 2012 Special Issue in Palaeogeography, Palaeoclimatology, Palaeoecology: Cenozoic Evolution of Antarctic Climates, Oceans and Ice Sheets, C. Escutia, F. Florindo, M. Bentley, R. DeConto (Editors).

### **ACE Community building/coordination activities**

As in the past, ACE has been very active in major conferences and international meetings, such as AGU, EGU, IPY, ISAES and SCAR OSC. During the ISAES 2011, in addition to ACE related scientific sessions, ACE coordinated and financed a series of workshops and business meetings:

- meetings of the ACE Steering Committee
- Seismic Data Library System Meeting
- Joint CASP-ANTscape Meeting
- Amudsen Sea Meeting
- IODP Expedition 318 post-cruise science meeting

For the SCAR Open Science Conference 2012 in Portland, an ACE session is planned as well as a workshop (Antarctic and Southern Ocean Drilling), and several business meetings (ACE SC, ANDRILL SC, CASP-ANTscape and SDLS meetings). The Antarctic and Southern Ocean Drilling workshop is funded by ACE and will take place 13-14 July in Portland. The workshop aims to guide existing and new submissions for a coordinated set of proposals and pre-proposals to IODP, ANDRILL, ICDP, that address key questions y key locations around Antarctica.

ACE has continued its activities coordinating cross-linkages across programmes (e.g., with the paleoceanography community and through ESF EuroPOLAR Project HOLOCLIP: integration of the Holocene paleoclimate record from very high resolution sediment cores with the ice core records)

Since 2011 ACE has been active in coordinating and guiding the submission of new SRP proposal to succeed ACE. The outcome is the proposed SCAR SRP PAIS (Past Antarctic Ice Sheet Dynamics), submitted in April 2012, which aims to improve understanding of the sensitivity of East, West, and Antarctic Peninsula Ice Sheets to a broad range of climatic and oceanic conditions during past warm times. PAIS builds on the success of SCAR-ACE (Antarctic Climate Evolution), but with a new focus on the ice sheet rather than palaeoclimate reconstructions, and for this incorporates a challenging new strategy: continent-to-abys transects.

### **Education and Outreach**

ACE continues its education and outreach (E&O) activities through the different science programmes they are part of. Since 2012 two of the major E&O efforts relate to the ANDRILL programme (<http://www.andrill.org/education/>) and the IODP Expedition 318 Programme. Through its “Project Iceberg” and “Antarctica’s Climate Secrets”, the ANDRILL programme has produced numerous education materials (posters, podcasts, books, etc) for teachers and students that are available in their website. The “Arise” project provides for opportunities for Research Immersion for Science Educators. During the IODP Expedition 318, seven episodes portraying the science conducted on the Expedition were released in YouTube. These were designed to bring science on the ship understandable to the public and featured “Penguin TV” specially designed for the youngest audience (<http://www.youtube.com/user/OceanLeadership>). In addition, numerous life conferences with middle school to college level students reached several thousands of students. Life conferences were also conducted with science museums (i.e., the San Francisco Exploratorium and the Science Museum in Granada).

Outreach ACE publication include two International Innovation - Research Media Publication:

- Integration of climate modeling gathers pace (C. Escutia) 2010.
- Back to the Future (C.Escutia and R. DeConto), 2011.

## Training the new generation of Antarctic Scientists

Training of the new generation of Antarctic scientists is achieved through the active participation of early career scientist in all field programmes that relate to ACE. In addition, ACE funds were allocated for early career scientists to attend the ISEAS in Edinburgh. Members of the ACE community continue to be active in the organization and teaching in the Urbino Summer School in Paleoclimatology “*Past Global Change Reconstructions and Modelling Techniques*” (USSP) (<http://www.urbinosp.it/>), which this year will have its 9<sup>th</sup> edition.

## Data Archiving – Data Bases

ACE database for multichannel seismic reflection data is the SCAR-ACE Seismic Data Library System (SDLS) (<http://scar-sdls.org/>), managed by the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) and the US Geological Survey (USA).

In addition, for the research conducted within ACE other databases supported by other large International programmes are used such as:

ANDRILL: PANGAEA <http://www.pangaea.de/>

For IODP ACE work relies in the following databases:

Riserless Core data and log data: <http://iodp.tamu.edu/database>

Riserless Downhole log data: <http://iodp.ldeo.columbia.edu/DATA/index.html>

Antarctic and Southern Ocean Data existing coring expedition can be checked at the Google earth link: <http://campanian.iodp-mi-sapporo.org/google/data/iodp.kml>

## 4. Budgetary Issues

Since 2010, the expenditure by ACE has mainly focussed on coordination activities (workshops and meetings) in the ISAES and the SCAR OSC 2012, cross-linkages meetings, and meetings for the writing of the SRP to succeed ACE. In addition, ACE has provided for travel support for key scientists and early career scientists to attend meetings and workshops. ACE has set aside 2012 funds to: 1) provide support major participation of the ACE community (key scientists and early career scientists) in the IODP Southwest Pacific Drilling workshop that will take place 9-12 October, in Sydney, Australia; and 2) provide support for writing meetings of the drilling proposals that will be planned at the ACE Antarctic and Southern Ocean Drilling Workshop, 13-14 July, Portland (USA).

## 5. Future Plans

Future plans over next two years, in particular any deviations from original work plan.

### 2012:

- Guiding the submission of the new SRP PAIS proposal to SCAR.
- Planning for the Antarctic and Southern Ocean Workshop 13-14 July, Portland, USA.
- SCAR Open Science Conference in Portland: ACE sessions, Drilling workshop, and business meetings.
- Guiding & coordinating the writing and submission of a coordinated set of proposals and pre-proposals to IODP (deadline 1<sup>st</sup> October), ANDRILL, and other drilling programs (i.e., ICDP).
- ACE participation in the IODP Workshop Southwest Pacific Drilling workshop that will take place 9-12 October, in Sydney, Australia.

- Continue to coordinate cross-linkages across programs, including the publication of results from some of the cross-linkages projects (e.g., ANDRILL and IODP Wilkes Land; ESF EuroPOLAR Project HOLOCLIP: integration of the Holocene paleoclimate record from very high resolution sediment cores with the ice core records).
- Continue to provide science-based advise to major scientific programs (i.e., IODP, ICDP) and policy makers (i.e., IPCC).
- Planning for a 2<sup>nd</sup> ACE Symposium.
- Preparation leading to the 2012-2013 field season for Lake Ellsworth drilling.
- Field seasons for major Projects (e.g., ICECAP, WIZZARD, LIZZARD).
- Preparations for the drilling of the ANDRILL Coulman High Project.
- ACE sessions in major international meetings (AGU 2012).
- ACE participation in the Urbino Paleoclimate School, July 2012.

### 2013:

- 2012-2013 Field seasons for major Porjects (e.g., ICECAP, WIZZARD, LIZZARD).
- 2012-2013 Lake Ellsworth drilling.
- Preparations for the drilling of the ANDRILL Coulman High Project.
- Continue coordination and integration, through subcommittees, of past field work results.
- Continue development of process-based multidisciplinary subcommittees to formulate future research directions .
- Continue fostering the submissions of the coordinated set of proposals / pre-proposals to IODP, ANDRILL, and other drilling programs (i.e., ICDP, the use of Lake Ellsworth drilling technology, etc).
- Continue to coordinate cross-linkages across programs, including the publication of results from some of the cross-linkages projects.
- Continue to provide science-based advise to major scientific programs (i.e., IODP, ICDP, ERICON-AB) and IPCC.
- Organization of the 2<sup>nd</sup> ACE Symposium.
- ACE sessions in major international meetings (EGU and AGU).
- ACE participation in the Urbino Paleoclimate School.
- Provide SCAR with reports.

## Appendix

### 1. ACE Steering Committee

\* co-chair since 2008

<b>Name</b>	<b>Role</b>	<b>Gender</b>	<b>Country</b>	<b>Term From</b>
Dr Carlota Escutia	<i>Co-Chair</i>	Female	Spain	2004*
Dr Robert DeConto	<i>Co-Chair</i>	Male	United States	2004*
Bob Arko	<i>JCADM liaison</i>	Male	United States	2008
Dr Mike Bentley	Member LGM Subcommittee leader	Male	United Kingdom	2008
Sun Bo	<i>Member</i>	Male	China	2005
Dr Fabio Florindo	<i>Member</i>	Male	Italy	2004
Dr Andrzej Gazdzicki	<i>Member</i>	Male	Poland	2005
Dr Alan Haywood	<i>Member</i> Miocene-Pliocene Subcommittee leader	Male	United Kingdom	2008
Dr Robert Larter	<i>Member</i>	Male	United Kingdom	2004
Dr Andrew Mackintosh	<i>Member</i>	Male	New Zealand	2008
Dr Sandra Passchier	<i>Member</i>	Female	United States	2005
Dr Ross Powell	<i>Member</i>	Male	United States	2004
Dr Gary Wilson	<i>Member</i>	Male	New Zealand	2005
Dr Eric Wolf	<i>Member</i>	Male	United Kingdom	2005
Dr Detlef Damaske	<i>Member</i> Radio-echo sounding Subcommittee leader	Male	Germany	2005
Dr Martin Siegert	Ex-Officio	Male	United Kingdom	2004
Dr Robert Dunbar	Ex-Officio	Male	United States	2004
Dr Tim Naish	Pleistocene Subcommittee leader Member (2004-2008)	Male	New Zealand	2004
Dr Jane Francis	Eocene.Oligocene Subcommittee leader Member (2005-2008)	Female	United Kingdom	2005
Dr Karsten Gohl Dr Stuart Henrys	CASP Subcommittee	Male Male	Germany New Zealand	2007
Dr Peter Barrett	ANTScape	Male	New Zealand	2009
Dr Alan Cooper	Seismic Data Library System	Male	United states	2004