Antarctic Climate Evolution (ACE) Research Initiative


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**SCIENCE AIMS AND OUTCOMES**

The Antarctic Climate Evolution (ACE) project is a new international research initiative to study the climate and glacial history of Antarctica by linking climate and ice sheet modeling studies with geophysical surveys and geological studies on and around the Antarctic continent (Fig. 1). The rationale for the ACE programme, outlined herein, was developed and refined, before, during and after the Antarctic Earth Science Symposium in Erice, Italy, in September 2001 (Cooper et al., 2002, Florindo et al., 2003).

Although the Antarctic continent has been in a polar position since the early Cretaceous, the first records of a continental ice sheet there are not found until around 34 Ma. From that time, Antarctic ice sheets have fluctuated considerably and have been 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 has been the subject of considerable debate. Determination of the scale and rapidity of the response of large ice masses and associated sea ice to climatic forcing is of vital importance, because ice-volume...
variations lead to (1) changing global sea levels on a scale of tens of metres or more, and (2) alteration to the capacity of ice sheets and sea ice as major heat sinks/insulators. It is thus important to assess the stability of the cryosphere under a warming climate (Intergovernmental Panel on Climate Change, IPCC, 2001), particularly as ice-core records have yielded evidence of a strong correlation between CO2 in the atmosphere and palaeotemperatures (Fig. 2). This concern is justified when CO2 levels are compared with those of the past. Since Antarctica is a major driver of Earth’s climate and sea level, much effort has been expended in deriving models of its behaviour. Some of these models have been successfully validated against modern conditions. Modelling the past record of ice-sheet behaviour in response to changes in climate (inferred from ice cores, sedimentary facies, and seismic data), palaeoceanographic conditions (inferred from palaeoecology and climate proxies in ocean sediments) and palaeogeography (as recorded in landscape evolution) is the next step.

The ACE programme is designed to determine past climate conditions and change in both the recent past (i.e. during the Holocene, prior to anthropogenic impacts as well as at the last glacial maximum, which culminated around 20 000 years ago) and the more distant past (i.e. tens of millions of years ago when global temperature was several degrees warmer than it is today).
today). This new cross-disciplinary approach, involving climate and ice sheet modellers, geologists and geophysicists, will lead to a substantial improvement in the knowledge base on past Antarctic climate, and our understanding of the nature and extent of events associated with the onset and subsequent history of Antarctic glaciation. This in turn will allow us to build hypotheses, examinable through numerical modelling, for how the Antarctic climate is likely to respond to future global change.

A previous SCAR (Scientific Committee on Antarctic Research) programme, named ANTOSTRAT (ANTarctic Offshore STRATigraphy) project focused principally on developing a stratigraphic framework for the Cenozoic Antarctic margin through seismic stratigraphy and direct sampling through offshore drilling and coring. During the lifetime of ANTOSTRAT (its mandate ended at the SCAR meeting in Shanghai, China, July 2002), significant advances were made to ice sheet and climate models, in terms of their ability to replicate the modern environment and to reconstruct former conditions. As yet, there has been no concerted effort to employ such models to investigate the Cenozoic climate evolution of Antarctica. The ACE programme will build on the achievements of ANTOSTRAT by integrating palaeoenvironmental records from current and future drilling and coring with new ocean-ice sheet-climate modelling efforts in order to provide both constraints and tests for this new generation of models.

The science plan we propose will necessarily depend on outcomes from a range of regional programmes for gathering field data (Fig. 3). Some of these have been completed, are now in progress, or are still in the planning stage. Programs for which data useful for ACE research will be collected are summarised in table 1.
The role of ACE will be to organise theme-based meetings and workshops to review past work and develop volumes for publication, and to promote planning and international collaboration for future field programmes.

Most Antarctic earth science research is necessarily regional in character, with different countries normally operating in relatively limited sectors of the continent. Even multinational programmes typically focus on one particular area of the continent. Understanding climate evolution calls not only for a continent-wide view of past records of Antarctic climate change, but also for an understanding of the connections between continental margin and deep-sea processes and their separate but related histories. Progress in making these connections can only succeed through international collaboration that SCAR has mandated. The SCAR has now set up a Scientific Programme Planning Group to develop a programme for ACE to operate as a sanctioned, international research initiative, operating under the SCAR umbrella (http://www.ace.scar.org).

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### APPROACH TO IMPLEMENTATION

It has been proposed that the programme be led by a 10-member committee, large enough to cover the range of disciplines, scientific and technical expertise and experience that we consider necessary for the successful implementation of the programme, but small enough to ensure that each member has a significant and clearly identified role. Two people in the committee have been identified as convener and deputy convener.

The committee should have knowledge of thematic issues and have appropriate regional (field) and technical/logistical experience. Eight members would focus principally on thematic issues (to cover the areas of palaeoclimate modelling, ice-sheet and sea ice modelling, ice-sheet...

<table>
<thead>
<tr>
<th>Programme (and year)</th>
<th>Location</th>
<th>Type of data</th>
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<tbody>
<tr>
<td>Ocean Drilling Program Leg 178 (1997)</td>
<td>Pacific margin of Antarctic Peninsula</td>
<td>Cores and down hole logs for last 15 Ma from outer shelf and rise</td>
</tr>
<tr>
<td>Cape Roberts Project (1997-1999)</td>
<td>Coastal southern Victoria Land</td>
<td>Cores and down-hole logs for 34 to 17 Ma from inner shelf</td>
</tr>
<tr>
<td>Ocean Drilling Program Leg 188 (2000)</td>
<td>Prydz Bay</td>
<td>Cores and down hole logs from outer shelf (50 and 36 30 Ma), slope (2-6 Ma) and rise (22-00 Ma)</td>
</tr>
<tr>
<td>Ocean Drilling Program Leg 189 (2000)</td>
<td>Tasman Sea</td>
<td>Cores and down-hole logs for the Eocene and Oligocene</td>
</tr>
<tr>
<td>ANDRILL (2005-2010)</td>
<td>McMurdo Sound (initially)</td>
<td>Several cores up to 1000 mbsf from Quaternary to Paleogene stages</td>
</tr>
<tr>
<td>SHAH DRL (2003-?)</td>
<td>Weddell margin of Antarctic Peninsula (initially)</td>
<td>Many cores to 200 mbsf for sampling thick drilling sedimentary sections and expanded Holocene sections</td>
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<tr>
<td>SAFe (2000-?)</td>
<td>Central Antarctica</td>
<td>One or two continuous sediment cores to depths of several hundred m in subglacial lakes beneath EAG</td>
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<tr>
<td>IMAGINE (2003-2006)</td>
<td>Continental rise around Antarctic margin Drake Passage</td>
<td>Many glacial (up to 80 m) piston cores from late Quaternary drift deposits, basin fill, and older sediments in outcrop, My become part of IODP</td>
</tr>
<tr>
<td>IODP (2005-?)</td>
<td>Ross Sea and Wilkes Land</td>
<td>Proposals to drill in these areas are being developed and, if funded, would contribute to the database useful for AMI research</td>
</tr>
<tr>
<td>ANTEC (2000-?)</td>
<td>Antarctica</td>
<td>Determine Antarctic neovolcanicity and understand the nature of coupling between tectonics, climate and erosion</td>
</tr>
<tr>
<td>WAIN (incl. WAINsavors) (1999-?)</td>
<td>West Antarctica</td>
<td>West Antarctic ice sheet initiative to study rapid climate change and future sea level</td>
</tr>
<tr>
<td>ERICA (1996 ?)</td>
<td>Dome C and Dronning Maud Land, East Antarctica</td>
<td>Establishing palaeoclimate records for the last few glacial interglacial cycles in East Antarctica.</td>
</tr>
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Tab. 1 - List of programmes generating data useful for research within the science plan of ACE.
The main function of the programme lies in the acquisition and compilation of “ground truth” geoscience data from geophysical surveys and drilling, and the use of these data in developing a suite of palaeoclimate models (both continent-wide and sectorial) for the Antarctic region for significant periods of climate change through Cenozoic times. These periods include:

- late Eocene-early Oligocene cooling,
- middle-late Miocene cooling,
- Pliocene warm periods,
- Pliocene-Pleistocene cooling,
- Quaternary periods of unusual warmth and extreme cold,
- warming since the Last Glacial Maximum,
- Holocene “stable” period.

While these activities will concentrate on periods subsequent to the Palaeocene, it should be noted that ACE will also encourage and support palaeoenvironmental data collection from earlier periods that allow us to understand the immediate pre-glacial history of Antarctica.

Specific functions of ACE include:

1) encourage and facilitate communication and collaboration among scientists working on any aspect of the evolution of Antarctic climate. This would be achieved by organizing workshops and symposia to present new results, exchange ideas, share/compile information and coordinate/plan laboratory and field operations. These would be coordinated with the activities of autonomous programmes such as ANDRILL and SALE (and its successor), and designed to complement them;

2) advise the research community on the types of geoscience data required for palaeoclimate modelling and effective model-data intercomparison, and critical locations (and ages) for which such data are needed;

3) provide advice/assistance as needed on technical issues related to geoscience field and laboratory programs and to palaeoclimate modelling studies;

4) promote data access and data sharing (and data-contributions to the SDLS, Antarctic data centres, and cognizant World Data Centres [WDC]) to facilitate and expedite data
syntheses needed for developing new field programs and enhancing palaeoclimate models. This function includes direct guidance of the ATCM-mandated SDLS; and
5) summarize and report results of these efforts to the scientific and wider community on an ongoing basis through workshops, symposia, websites, etc.
6) a formal report would be made and presented to SCAR every 2 years.

TIME-LINE AND MILESTONES

Advance scheduling of workshops and symposia, and special sessions at major conferences, is important for fostering collaboration, exchange of ideas and further planning. The ACE steering committee will develop and maintain a schedule of such meetings extending forward at least 3 years. Such a schedule might include:
1) June 2002; ANTOSTRAT/ACE workshop on palaeoclimate modelling – Amherst, USA;
2) July 2002; Antarctic palaeoclimate session at Western Pacific AGU meeting, Wellington, New Zealand;
3) July 2002; Poster session at SCAR XXVII in Shanghai, China;
4) December 2002; ACE session at Fall AGU meeting in San Francisco, USA;
5) May-July 2003; ACE regional working group meetings at various venues for the purpose of developing syntheses on regional data, and/or time and process-oriented problems;
6) August/September 2003; ACE workshop (1-day) at a time close to the Antarctic Earth Sciences Symposium in Potsdam, Germany;
7) December 2003; Antarctic session at Fall AGU meeting in San Francisco, USA;
8) May-July 2004; ACE symposium – Siena, Italy;

REFERENCES