



**WP**

**12**

Agenda Item:

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Person Responsible:

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# **Antarctic Climate 21**



## Executive Summary

**Title:** AntarcticClimate<sup>21</sup>

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### Introduction/ Background:

Antarctica and the Southern Ocean have been an important modulator of global climate for the past 100 million years<sup>1-2</sup>. Due to anthropogenic modification of the climate system, aspects of Antarctica and the Southern Ocean are changing rapidly<sup>2-3</sup>, however, critical mechanisms, responses and potential feedbacks remain poorly understood<sup>4</sup>.

Climate model simulations predict that over the coming decades there will be declining sea ice extent, weakening bottom water formation, and an intensification of the zonal winds<sup>5-6</sup>. Observations confirm ice shelf collapse<sup>7</sup>, strengthening zonal winds<sup>8</sup>, a rapid increase in net contribution to sea level rise in particular from West Antarctica<sup>9-10</sup>, substantial warming of the mid troposphere over Antarctica<sup>11</sup>, and rapid warming of the Antarctic Peninsula and sub-Antarctic Islands<sup>12-13</sup>, an increase in temperature and acidification of the Southern Ocean<sup>14-15</sup>, regional decrease<sup>16</sup> and increase<sup>17</sup> in sea ice, a freshening of the Ross Sea<sup>18</sup>, and a decrease of bottom water formation<sup>18</sup>. However, these time series are short<sup>14-15,19</sup> and inter-model variability suggests physical processes are not yet fully captured or understood<sup>2,5</sup>.

Paleoclimate records extend observational data for past climates that provide relevant analogues to future projections<sup>4-5</sup>. The comparison of model performance with known past climate variability provides an important tool for validation of models and their ability to provide future projections<sup>20-22</sup>. For recent decades both observational data from Antarctic stations and satellite systems have allowed reconstruction of modern climate conditions<sup>12</sup>, in particular the establishment of meaningful reanalysis data sets, such as NCEP/NCAR, ERA-40, ERA-interim, Merra, CFSR, and JRA-55 data sets<sup>23-27</sup>. The improved re-analysis data sets allow for the development of transfer functions to convert proxy data into quantitative climate records<sup>28-29</sup>.

To reconstruct and understand climate and ocean variability with a frequency longer than seasonal to sub-decadal or to use past analogues of future climate conditions, paleoclimate archives provide critical information. In the Antarctic region, such records are principally derived from ice and marine sediment cores, and some terrestrial records from small pockets of ice-free areas. We will focus primarily on the reconstruction of the past 2,000 years, where the availability of high resolution (annual to sub-decadal) climate proxy records will allow us to extend observational data with near instrumental quality. In addition, we will take advantage of records and model outputs of earlier key periods as they may become available, in particular the mid-Holocene, glacial terminations, warm interglacials, and the mid-Pliocene.

Well dated, high resolution proxy data reconstruction will help to improve our understanding of natural climate variability, climate drivers, the onset and quantification of recent trends that are poorly captured in current climate models. Furthermore, we will utilise these records to provide data for climate model verification<sup>30</sup>. In addition to published work, we will synthesise data and results from existing initiatives to reconstruct high resolution climate data sets, such as the International Trans-Antarctic Scientific Expedition (ITASE)<sup>31</sup> and the 2,000 year array of the International Partnerships on Ice Coring Sciences (IPICS)<sup>32</sup>.

Reconstruction of time periods representing substantial climate transitions (for example the Medieval Warm Period – Little Ice Age, and potentially the mid-Holocene, and glacial terminations) provide an opportunity to investigate the magnitude of responses, feedback mechanisms, and model sensitivity to these drivers. Model outputs of past warm climates (Medieval Warm Period, and potentially Marine Isotope Stage 5 & 11, the mid-Pliocene) are useful analogues for possible futures. In Table 1, atmospheric carbon dioxide concentration and changes in temperature are summarised for these time periods:

Table 1: Atmospheric CO<sub>2</sub> concentration and temperature deviation during key past climate transitions

	Atmospheric CO <sub>2</sub>	Change in Temperature
<b>Little Ice Age</b>	~10ppm reduction <sup>33</sup>	~ -0.6 °C <sup>34</sup>
<b>Mid Holocene</b>	~260 to 285 ppm <sup>35</sup>	~ +1 to +2 °C
<b>Glacial transition</b>	~200 to 280 ppm <sup>36</sup>	+5.8 ± 1.4 °C <sup>36</sup>
<b>Mid Pliocene</b>	~400 ppm <sup>20</sup>	~+3 to +4 °C <sup>20</sup>

There are three important components involved in simulating future environmental changes, namely forcing scenarios, physical models, and biological models. Forcing scenarios are storylines of possible futures which cover a wide range of plausible anthropogenic emissions pathways. These depend on factors such as economic development, adoption of renewable energy and land use. In preparation for the upcoming IPCC AR5 a set of scenarios were produced. These comprises four Representative Concentration Pathways (RCPs), RCP2.6, RCP4.5, RCP6 and RCP8.5 (where the numbers represent the approximate change in radiative forcing in W/m<sup>2</sup>). RCP4.5 represents a “medium” mitigation scenario and RCP8.5 is a “high” emissions scenario. In addition to the new future scenarios, the IPCC has defined a set of baseline paleoclimate simulations. Paleoclimate simulations were not defined as part of the AR4 modelling effort and this represents one of the most significant new components in AR5. The paleoclimate simulations are designed to assess the response and performance of models under forcing conditions that differ significantly from the present day. The IPCC define three different run types: the Last Millennium (850-1850), the Mid-Holocene (6kyr BP), and the Last Glacial Maximum (18 kyr BP).

The physical models used for assessing future climate change vary in complexity. Most of the current generation of physical models are climate “simulators” in the sense that they attempt to represent the observed background climate as realistically as is practical (in this document the term climate model is used in reference to those that fall into this climate simulator category). The climate models that have been run for AR5 fit into this category and are global in scale. These mathematical representations of the atmosphere, ocean, ice and land surface use a large amount of computing resources and are therefore limited in spatial resolution.

The horizontal grid spacing in global climate models is generally in the range 100 km to 200 km in the atmosphere and around 50 km in the ocean. Regional climate models are used to “downscale” the low resolution data of global climate models to be more realistic at smaller grid sizes, which can be of particular importance in regions of steep mountains and complex coastlines such as the Antarctic Peninsula. Global climate models are also generally limited in their representation of ice sheets. In particular they do not represent the flow of glaciers and ice streams, which are a potentially important factor in future sea level change. Currently there is a large amount of work being carried out to address this issue by using regional climate models to force ice sheet models in regions of potentially large impact such as the Pine Island Glacier<sup>9-10</sup>.

A key aspect of producing reliable projections of future climate is the assessment of skill of the models. Model skill was not assessed rigorously in AR4 with regard to Antarctic climate<sup>4</sup> and this may continue with AR5 as more attention is likely to be directed towards the Arctic. Therefore it is unlikely that the IPCC report alone will provide the detailed best estimates of Antarctic climate change that are required by the SCAR community.

The new paleoclimate runs that are being made available as part of AR5 (and were not available as part of AR4) will provide an exciting opportunity to assess climate model and earth system simulations of a wide range of climatic conditions. This will facilitate a new possibility to assess models’ ability to capture responses to changes in orbital forcing and greenhouse gas concentrations. In addition to responses to “external” forcings, these longer-term runs will provide an opportunity to assess the ability of the models to reproduce climate variability, which is important for assessing the significance of changes over the 20<sup>th</sup> and 21<sup>st</sup> centuries.

Assessment of the ecosystem impacts of climate change requires output from the physical models on how key parameters are expected to change. For large-scale studies of the Southern Ocean the direct output from global climate models is adequate. However, for terrestrial, marine and benthic studies along

coastlines, fjords and valleys downscaling of the climate model output is required. This is a challenging area of Antarctic research that is in its infancy and requires significant multidisciplinary collaboration in the future. This initiative will collaborate with AntEco and Ant-ERA to synthesise advances made.

**Important Issues or Factors:**

The composition of the Steering Committee is characterized by an excellent range of scientific expertise. However, our national representation is rather limited. We are in the process of inviting and recruiting representatives from developing countries and new Antarctic nations to join the steering committee.

**Recommendations/Actions and Justification:**

We ask the SCAR Delegates and SSGs to provide continued support to **AntarcticClimate**<sup>21</sup>

**Expected Benefits/Outcomes:**

We believe that this proposed programme will strengthen SCAR's position as the leading authority on Antarctic climate change and its local and global impacts. Antarctica and the Southern Ocean do not have a high enough profile in IPCC, and SCAR is well placed to provide the detailed assessment that is required by policymakers and the broader scientific community.

**Partners:**

Important partners of **AntarcticClimate**<sup>21</sup> include: Ant-ERA, AntEco, ISMASS, PAIS, SOOS,. Relevant representatives of these groups have been identified. We are in negotiation with Ant-ERA on a combined mini-symposium and/or workshop. Outside SCAR we will engage in particular with IPICS, PAGES, ITASE, and the Arctic research community.

**Budget Implications:**

A total of \$24k (\$20k + \$4k of contingency funds) of SCAR funding are committed. No additional funds are requested.

# Antarctic Climate<sup>21</sup>

## 1. Rationale for the Programme

The overarching question of this proposal is: How will the Antarctic<sup>1</sup> environment change over the 21<sup>st</sup> Century? This is an important issue both within Antarctic region and globally. To achieve this goal, *AntarcticClimate*<sup>21</sup> will focus on three themes of research:

- Theme 1. Quantification of Antarctic climate variability.
- Theme 2. Climate model verification for the Antarctic region.
- Theme 3. Antarctic climate projection to 2100 AD

The Antarctic region has already experienced substantial changes with impacts on global sea level and ocean carbon uptake. To understand the significance of recent trends in the context of natural variability, it is important to consider change on a multi-century time scale. This proposal will focus on the past 2,000 years. In addition, we will take advantage of data and model outputs from earlier key time periods as they become available, such as the mid-Holocene, glacial terminations, warm interglacials, and the mid-Pliocene. Moreover, attribution of the causes of environmental change is a high priority. Assessment of how realistically climate models capture key forcings to help constrain climate model projections of future change. The overall aim is to provide improved projections of the magnitude and patterns of change to Antarctica's physical environment as a result of global change over the next 100+ years. The assessment will be based on Intergovernmental Panel on Climate Change (IPCC) Assessment Report Five (AR5) Representative Concentration Pathways (RCP) and updated scenarios as they become available.

## 2. Important Issues or Factors

### i) Suggested Steering Committee

We proposed that *AntarcticClimate*<sup>21</sup> be managed and directed by a Steering Committee, who consists of:

- Steering Committee Chair (Nancy Bertler, Victoria University and GNS Science, New Zealand), who oversees overall progress and takes responsibility for the final Synthesis Report
- Lead Authors (Prof. Paul Mayewski, University of Maine, USA (Theme 1), Dr. John Turner, British Antarctic Survey,, U.K. (Theme 1), Dr. Thomas Bracegirdle, British Antarctic Survey, U.K. (Theme 2), A/Prof. Joellen Russell, University of Arizona, USA (Theme 3),), who take responsibility each for one of the three Science Reports (one theme is jointly led)
- APECS Representative (Ms Alia Khan, University of Colorado, USA), who provide the linkage and access to the next generation of Antarctic researchers and will assist in identifying young experts to attend the workshops and contribute to the reports.
- Expert Advisors (6; 2 for each report, Shiobhan O'Farrell, University of Melbourne, Australia (Theme 3), others to be determined), who will assist the Lead Authors to identify key contributors and leading scientists essential to the research question, will assist in liaising with collaborating SCAR programmes and initiatives (Ant-ERA, AntEco, ISMASS, ITASE, PAIS, SOOS, IPICS, PAGES). We propose that the expert advisors are active contributors to the programmes listed above.
- The steering committee will meet several days each year to review progress on the programme and to refine the implementation plan. The next meeting is scheduled in advance of the first workshop from 20-21 Sep 2013.

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<sup>1</sup> We define 'Antarctica' in this context to include the sub-Antarctic Islands and the Southern Ocean.

- For the first workshop, the following invited researchers are confirmed: Dr. David Schneider (USA), Dr. Ian Goodwin (Australia), Dr. Isabella Velicogna (USA), Prof. Matthew England (Australia), Prof. Paul Kushner (Canada)

**ii) Outline of Implementation Plan including explicit milestones and expected scientific outcomes, and stating what is going to be achieved by when and if possible by whom**

The objectives of *AntarcticClimate*<sup>21</sup> are to produce improved projections of the magnitude and patterns of change to Antarctica's physical environment over the next 100+ years as a result of changes in forcings, such as an increase in the concentration of greenhouse gases and the recovery of the ozone hole. The assessment will be based on Intergovernmental Panel on Climate Change (IPCC) Assessment Report Five (AR5) Representative Concentration Pathways (RCP) and updated scenarios as they become available. To achieve this goal, *AntarcticClimate*<sup>21</sup> will focus on three themes of research:

1. *Quantification of Antarctic climate variability.* *This theme concentrates on quantifying and understanding natural and anthropogenically-forced climate change by utilising observational data, proxy records, and climate models. It will investigate rates of change, types of trends (linear, thresholds, accelerating), the onset of trends, and identification of contributing or alleviating feedback mechanisms. We will focus on key aspects of the Antarctic environment (e.g. temperature, circulation patterns and strength, mass balance, snow accumulation, sea ice extent, ocean circulation, sea surface temperature, ocean salinity).*

The analysis will be carried out on instrumental and paleoclimate modelling output. To discern natural oscillations from anthropogenic trends, the theme will focus on the recent Antarctic climate evolution of the past 2000 years, a time period when high resolution and continuous climate proxy records are available. In addition, we will also take advantage of key past time periods that provide analogues for future climates (e.g. Marine Isotope Stage 5, Mid Pliocene) and help to identify mechanisms of change (e.g. Last Glacial Termination). This theme will be built on the research outcomes of the concluded SCAR SRP *Antarctica in the Global Climate System (AGCS)* and will collaborate with ISMASS, SOOS, IPICS, ITASE, PAIS, and PAGES programmes.

2. *Climate model verification for the Antarctic region.* *This theme will use existing modelling results and instigate new modelling initiatives to evaluate and improve the ability of models to reconstruct past Antarctic climate conditions.*

Knowledge of the models' performance in past and present-day Antarctic climate will provide an estimate of their ability to reproduce future conditions. In addition, sensitivity tests will be used to explore the magnitude of responses and feedback mechanisms. Finally, correlation between paleoclimate data and model outputs will allow us to analyse the export of Antarctic signals of climate change (e.g. sea-level, ocean currents) and the import of global, tropical, and mid-latitude features/influences to Antarctica (e.g. ENSO, SAM, ozone, ocean currents, temperature gradients). The model verification will be focused predominantly on the past 2,000 years as outlined in Theme 1 and on relevant earlier time periods as such model outputs become available.

3. *Antarctic climate projection to 2100 AD.* *The aim of this theme is to provide model output for short term changes (decadal estimates) to longer term projections (50-100+ years). We will focus in particular on the four IPCC AR5 RCPs which bracket low to high emission scenarios using models that are identified in theme 2 to show high skill for the Antarctic region.*

The most reliable climate models identified in Theme 2 will be used to forecast Antarctic climate conditions to 2100 AD using at first the four IPCC AR5 RCPs and updated scenarios as they become available. Inter-model relationships between present-day climate bias and predicted change will be investigated, and where they exist will be used to produce more precise projections. Spatial resolution of model outputs will range from continental scale (e.g. mass balance, ocean currents) to micro scale (e.g. temperature gradient in the McMurdo Dry Valleys). Particular emphasis will be given to predicted change of global significance (e.g. ice sheet mass balance, ocean acidification, atmospheric and ocean circulation).

Each of the three themes will produce a science report that summarises its research results. A synthesis report will provide a summary for policymakers of all findings of **AntarcticClimate<sup>21</sup>** initiative.

#### Specific Milestones are:

##### 2012

- Appoint **AntarcticClimate<sup>21</sup>** Steering Committee (*achieved*)
- Appoint Expert Advisory Panel relevant for the three reports (*achieved*)
- Source AR5 model output (*achieved*)
- Acceptance of **AntarcticClimate<sup>21</sup>** as a SCAR programme in July 2012 (*achieved*)

##### 2013

- Workshop 1 'Quantification of Antarctic climate variability'. (*This workshop will be held from 22-25 September 2013, held in Castine, Maine, USA. It aims to produce the first draft of the report on 'Quantification of Antarctic climate variability'. All steering committee members are confirmed to attend. In addition, we have confirmation of six researchers, including an APECS representative, to attend the workshop. These researchers were specifically invited due to their expertise to contribute to the report draft. In addition, we are in communication with three additional researchers from emerging and/or new Antarctic nations to also attend the workshop. The draft report will then be circulated among the wider community to invite comments and contributions. All contributing researchers will be included as author*)
- Synthesis on existing climate model output for the Antarctic (*work in progress*)
- Conduct modelling studies in preparation of workshop (*work in progress*)
- Formalise the collaborations with ISMASS, SOOS, IPICS, PAGES, PAIS, Ant-ERA, AntEco (*work in progress*)

##### 2014

- Publication of Quantification of Antarctic climate variability' Report. The report will provide a synthesis of the current state of knowledge on contemporary and future trends in temperature, mass/balance and sea-level, SAM, ozone and other atmospheric chemistry and snow accumulation. The synthesis will incorporate the analysis of instrumental data as well as appropriate paleoclimate data (high resolution, well dated). This will be achieved during a 3-day workshop with invited contributors. The report will be assimilated in collaboration with ISMASS, 2,000 year array (IPICS and PAGES), ITASE and SOOS and will be included as a chapter in the **AntarcticClimate<sup>21</sup>** report.
- Workshop 2 Climate model verification for the Antarctic region'
- Conduct modelling studies as identified during workshop 2
- SCAR Open Science Conference – Session on "Antarctica 2100 AD – Response to and Initiation of Global Change"

### 3. Outputs/Deliverables

#### Deliverable Science Outputs

The fundamental outcomes of **AntarcticClimate<sup>21</sup>** will be syntheses of existing research and initiating new collaborations on critical science questions that will substantially improve our ability to predict the future role and response of Antarctica to global change. The knowledge will be obtained in three subsequent reports which will be combined to the final report **AntarcticClimate<sup>21</sup>** aimed at policymakers and a public audience. Moreover, a very important outcome will be a website that provides predictions of the Antarctic climate system out to 2100 AD. This will contain fields of data and also Antarctic-wide estimates of major climate parameters, such as temperature, precipitation, wind speed, sea surface temperature etc.

Best estimates of 21<sup>st</sup> century Antarctic climate change will be communicated to a range of stakeholders via a range of communication channels, which are outlined as follows.

- Scientific papers in peer-reviewed journals.
- Presentations at scientific conferences.
- Interim reports for the broader community based on the three themes:
  - Theme 1. Quantification of Antarctic climate variability.
  - Theme 2. Climate model verification for the Antarctic region.
  - Theme 3. Antarctic climate projection to 2100 AD

A final Synthesis **AntarcticClimate<sup>21</sup>** Report for policymakers and the broader community bringing together the main scientific findings and achievements of the programme.

#### Tangible Outputs:

- Publication of 'Quantification of Antarctic Climate variability' Report (2014)
- Publication of 'Climate Model Verification for the Antarctic Region' Report (2015)
- Publication of 'Antarctic Climate Projection to 2100 AD' (2017)
- **Major Publication of "AntarcticClimate<sup>21</sup>" report (2018)**
- SCAR Open Science Conference Session on "**AntarcticClimate<sup>21</sup>**" (2016)
- Attendance of policymakers to Antarctic Change – Important Adaptation Implications for Governments
- Providing input for the 6<sup>th</sup> IPCC report (2018)

#### Education and Outreach

- Workshop: "Antarctic Change – Results relevant to adaptation and mitigation responses". Planned as a two-day workshop focused on briefing policymakers on conclusions of the Synthesis **AntarcticClimate<sup>21</sup>** Report. The aim is for a venue at one of the UNFCCC COP meetings.
- Linkages with APECS to involve next generation of polar scientists
- **AntarcticClimate<sup>21</sup>** webpage, which will include updates on the research, copies of the reports and a comparison of predicted versus observed climate changes. It will also include images, important visualisation for media and public use. The webpage will be used as a portal to disseminate data to scientific community and for public use.

#### 4. Budgetary Implications

For the current financial year, the allocated funds (\$20k + \$4k of contingency allocations) are budgeted to support the first AntarcticClimate21 workshop, held from 22-25 Sep 2013, Castine, Maine, USA. The funds will support travel and accommodation expenses of invited contributors and the APECS representative. The remaining funds are budgeted for publication costs of the report and the creation of the **AntarcticClimate<sup>21</sup>** webpage, hosted by the University of Arizona.

#### 5. Future Plans

##### 2015

- Publication of Climate model verification for the Antarctic region' Report. The report will provide a synthesis on existing and new tests of earth system / climate models reproducing past known Antarctic climate conditions during relevant time slices (focus on the past 2,000 years with possible addition of Mid-Holocene, Last Glacial Maximum, Eemian, Mid-Pliocene) as reconstructed from paleoclimate data. This synthesis will also allow us to investigate mechanisms and feedbacks of climate forcings. The synthesis will be achieved during a 3-day workshop with invited contributors. The report will be assimilated in collaboration with PAIS, and will be included as a chapter in the **AntarcticClimate<sup>21</sup>** report.
- Workshop 3 Antarctic climate projection to 2100 AD.

**2016**

- Completion of model projections to 2100 AD for models identified in the “Climate Model verification for the Antarctic region’ Report.
- SCAR Open Science Conference – Session on “*Climate / Earth System Model performance in Antarctica*”

**2017**

- Publication of *Antarctic climate projection to 2100 AD* Report. The report will provide a synthesis on existing and new climate model outputs for Antarctic climate conditions to 2100 AD. Only models that passed the verification test above will be included in this ensemble. The synthesis will allow us to provide high resolution (spatial and temporal) model outputs for the Antarctic region using the IPCC AR5 RCP and quantify projection uncertainties. The synthesis will be achieved during a 3-day workshop with invited contributors. The report will be included as a chapter in the *AntarcticClimate*<sup>21</sup> report.

**2018 -**

- Publication of *AntarcticClimate*<sup>21</sup> Report. This report is the principle output from the proposed programme *AntarcticClimate*<sup>21</sup> and will be based on the three reports listed above in addition to two additional chapters – a) Summary for policymakers and b) Important Remaining Questions. We aspire for the report to be the Antarctic-specific equivalent of the IPCC report that it will provide the most up-to-date knowledge on future projections for both the science community as well as governments and other policy agencies (e.g. IPCC, Antarctic Treaty, CEP). The report will be achieved during a 3-day workshop with the steering committee and invited contributors.
- Succession planning – what are the next urgent, important science questions?
- SCAR Open Science Conference – Session on “*Antarctica Climate Projections – Global Challenges*”

**Appendices**

N/A