



WP 13

Agenda Item: 4.3.4

Person Responsible: N. Bertler

XXXIII SCAR Delegates Meeting

Auckland, New Zealand, 1-3rd September 2014

Antarctic Climate²¹

Executive Summary

Title: *AntarcticClimate*²¹

Authors: Nancy Bertler, Thomas Bracegirdle, Paul Mayewski, John Turner

Introduction/ Background: The overarching question of this research initiative is: How will the Antarctic / Southern Ocean environment change over the 21st Century? To achieve this goal, *AntarcticClimate*²¹ focuses on three themes of research:

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

The Antarctic region 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, we consider changes on a multi-century time scale that are relevant to improve climate projections, the attribution of the causes of environmental change, and the skill of earth system models in the Antarctic / Southern Ocean region. The overall aim of *AntarcticClimate*²¹ is to provide improved projections of the magnitude and patterns of change to Antarctica's physical environment over the next 100+ years.

Important Issues or Factors: The *AntarcticClimate*²¹ team has made significant progress in accordance with proposal schedule. Since many of the *AntarcticClimate*²¹ team members have been intimately involved in the Antarctic Climate Change and the Environment (ACCE) report, the group already had a successful track record in synthesis efforts and was quick to develop a research strategy and to recruit relevant experts as lead authors, including members of key partner initiatives. The report for objective 1 is well advanced and we anticipate timely submission to the Proceedings of the National Academy of Sciences. In addition, the ground-work for objective 2 is well on the way, with the second workshop coordinated for Dec 2014 (adjacent to the 2014 AGU Fall Meeting) and participants are near finalized (see annex 1). One aspect the *AntarcticClimate*²¹ team seeks to improve is our profile and public outreach. The *AntarcticClimate*²¹ webpage and facebook page are high priorities to be developed further.

Recommendations/Actions and Justification: We request the SSGs and SCAR Delegates to approve continued support for *AntarcticClimate*²¹. The outcome of this SCAR initiative will provide important leadership to improve modeling capability for future projections in time for inclusion in the IPCC AR6, it seeks multidisciplinary collaboration between existing SCAR initiatives, encourages new international research efforts, engages proactively in the development of the new generation of CMIP6 experiments, and promotes the integrates early and mid career scientists.

Expected Benefits/Outcomes: The principle aim of *AntarcticClimate*²¹ is to provide realistic, data-constrained future projections for the next century and beyond, and to support SCAR's leadership in Antarctic research and policy advice.

Partners: *AntarcticClimate*²¹ seeks to serve and collaborate in particular with PAIS, SERCE, AntEco, AnTERA, APECS, ACCE, ISMASS, ASPeCT, SOOS, PAGES, IPICS, CliC, CMIP, PMIP, WCPR, and PCIP.

Budget Implications: In addition to the proposed budget, we note the excellent support of SCAR of hosting the SRP webpage.

Report on Antarctic Climate21

1. Rationale for the Programme

Antarctic / Southern Ocean climate model projections of the atmospheric/oceanic changes for the coming decades include accelerating ice sheet mass loss¹⁻², declining sea ice extent³, weakening AABW formation⁴, and an intensification of the zonal winds⁵, with the potential to lead to accelerated mass transfer of ice into the ocean and thus sea level rise⁶⁻⁷, enhanced CO₂ ventilation and reduced sequestration causing increased atmospheric CO₂ concentrations⁸⁻⁹, and compounding impacts on the ecosystem¹⁰⁻¹¹. Observations confirm ice shelf collapse¹², accelerated ice net loss¹³, strengthening zonal winds⁵, an increase in temperature and acidification of the Southern Ocean¹⁴⁻¹⁵, and a decrease of AABW formation^{4,16}. However, observations are spatially limited and short^{14,17}, some being controversial¹⁸, and inter-model variability suggests physical processes are not yet fully captured or understood⁸. An emerging array of high resolution paleoclimate records extending observational data back to analogous periods that are relevant times for future projections support model refinement and process diagnostics⁸, yet large uncertainties remain¹⁹⁻²⁰.

The objectives of *AntarcticClimate*²¹ 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*²¹ focuses 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 investigates rates of change, types of trends (linear, thresholds, accelerating), the onset of trends, and identification of contributing or alleviating feedback mechanisms. We 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).
2. **Climate model verification for the Antarctic region**. This theme uses existing modeling results (i.e. CMIP5) and informs/stimulates new modeling initiatives (i.e. CMIP6) to evaluate and improve the ability of models to reconstruct past Antarctic climate conditions.
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 *AntarcticClimate*²¹ SRP proposal was conceived by research needs identified in the SCAR report – *Antarctic Climate Change and Environment* (ACCE) which highlighted the need for improved skill of earth system models in the Antarctic / Southern Ocean region. Considering the important and significant global consequences of change in the Antarctic / Southern Ocean region, this SRP specifically aims to assess the modelling skill in the Antarctic / Southern Ocean region, reduce uncertainties of key parameters, improve future projections in time for inclusion in the IPCC AR6.

2. Important Issues or Factors

i) Five Scientific Highlights

Reconstruction of Westerly wind influence on West Antarctica shows current situation is unprecedented in past 100,000 years: A reconstruction of atmospheric circulation around Antarctica revealed that the recent southward migration of the westerly winds as expressed in the positive trend of the Southern Annular Mode (SAM) due to increases in greenhouse gases and ozone depletion has caused unprecedented marine air masses transport into West Antarctica which led to increased precipitation and a rise in temperature.

Mayewski, P. A. et al. (2013) West Antarctica's sensitivity to natural and human-forced climate change over the Holocene. *Journal of Quaternary Science* 28, 40-48

Emergence of significant wind changes takes until the early-to-mid 21st century in CMIP5: The intensification of the Westerly winds along the Amundsen / Bellinghausen Seas have been suggested as principle forcing for upwelling of warm, circum polar deep water, leading to rapid loss of ice from beneath ice shelves. A comparison of the CMIP5 modelling experiments for the IPCC representative concentration pathways RCP4.5 and RCP8.5 scenario projections distinguishes between model uncertainties and internal climate variability. The results indicate that due to large internal climate variability, the intensification of winds is statistically significant in the CMIP5 model ensemble at one (two) sigma standard deviations only at 2030 (2065) following RCP8.5. *Bracegirdle, T.J., Turner, J., Hosking, J.S., Phillips, T. (2014) Sources of uncertainty in projections of twenty-first century westerly wind changes over the Amundsen Sea, West Antarctica, in CMIP5 climate models, Climate Dynamics, in press, doi: 10.1007/s00382-013-2032-1.*

Increase in Antarctic Sea Ice not captured in CMIP5 modelling experiments: A comparison of trends and annual variability of 18 models used in the CMIP5 ensemble runs shows unsurprisingly large inter-model variability. More importantly though, all models produce a negative sea ice trend, which is forced by an earlier trend. This suggests that the forcing mechanism causing the currently observed increase in the Ross Sea Region are not captured and simulated incorrectly. *Turner, J., Bracegirdle, T., Phillips, T., Marshall, G., Hosking, J.S. (2013) An initial assessment of Antarctic Sea Ice Extent in the CMIP5 Models. Journal of Climate, 26, 1473-1484*

Reconstruction of modern sea ice trends reveal longer term decline: An exceptionally high resolution reconstruction of seasonal sea ice variability over the past 130 years in the Ross Sea region suggests stable sea ice area until the mid 1950s, which is followed by a period characterised by significant sea ice reductions. However, since early 1990s a sea ice area increase of 5% is observed which masks the underlying declining trend. The strengthening of southerly wind flow across the Ross Sea polynya has been suggested as driving mechanism for the observed sea ice area increase. *Sinclair, K., Bertler, N., Bowen, M., Arrigo, K. (2014) Twentieth century sea ice trends in the Ross Sea from a high resolution coastal ice core record. Geophysical Research Letters, 41:10, 3510-3515*

Source of iron fertilisation in the Ross Sea region from ocean upwelling: Observations show that the Ross Sea polynya has low concentration of bio-available iron (Fe). Extensive algae blooms during summer indicate either an oceanic (upwelling) or atmospheric (dust from the Tran Antarctic Mountains) contribute significantly to the Fe budget in the Ross Sea and area of Antarctic Bottom Water formation. Analysis of Fe concentrations in sea ice and snow samples suggests that the Fe from atmospheric sources accounts for ~15% of the observed primary productions. This suggests that ocean upwelling is the major driver of Fe delivery and thus primary productivity. Thus changes in ocean currents (and to a lesser degree of atmospheric circulation) could influence the carbon uptake efficiency in the Ross Sea. *Winton, V., Dunbar, G., Bertler, N., Millet, M.-A., Delmonte, B., Atkins, C., Chewings, J. and Andersson, P. (2014): The contribution of Aeolian sand and dust to iron fertilisation of phytoplankton blooms in the southwestern Ross Sea, Antarctica. Global Biogeochemical Cycles, 28: 4, 423-436*

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

Since its establishment, the *AntarcticClimate*²¹ Steering Committee met twice yearly in face to face meetings and about three monthly via video conferencing with the exception of the Antarctic field season period. Overall the group is on target to deliver on scheduled milestones as outlined below with some minor delays.

Scheduled Milestones in 2013

- Workshop 1 ‘Quantification of Antarctic climate variability’.
A successful and highly productive workshop was held during September 2013 in Castine, Maine, USA. This workshop facilitated the multidisciplinary discussions required to identify and quantify past and present atmosphere/ocean/ice interactions. In a next step we endeavour to include ecosystem responses in this discussion, a process that is already initiated successfully by AnT-ERA.
- Synthesis on existing climate model output for the Antarctic
Through liaison with relevant groups (in particular CMIP, PMIP) existing model ensemble experiments

have been evaluated and individual publications (see science highlights) initiated. In addition, SC members (in particular T.Bracegirdle and J.Russell) are involved in the discussion of the next generation ensemble experiments.

- Conduct modelling studies in preparation for workshop

While currently now new modelling studies have been conducted, the CMIP3 and CMIP5 model experiments offer a wealth of information which is yet to be fully explored. Significant progress has been made in differentiating model uncertainty from internal climate variability. One of the key requirements for improvement is the standardisation of reportable parameters so that outputs can be fully assessed.

Scheduled Milestones in 2014

- Publication of *Quantification of Antarctic climate variability*' Report.

A draft of the publication has been compiled and we expect submission of the report within the next 2 months. It provides 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 incorporates the analysis of instrumental data as well as appropriate paleoclimate data (high resolution, well dated).

- Workshop 2 *Climate model verification for the Antarctic region*'

The organisation of this workshop is well advanced with 19 invited, confirmed participants. The workshop will run from the 11-12 December, prior to the 2014 AGU Fall Meeting in San Francisco, close to the convention centre. A draft publication is currently being prepared to be circulated prior to the meeting. This will focus the discussion of the workshop efficiently on the topic and also permit all participants to arrive highly prepared.

- Conduct modelling studies as identified during workshop 2

Initially, we scheduled the second workshop to be held during the 2014 SCAR Open Science Conference. However, due to the commitments of many participants in pre and post OSC meetings, it was not feasible to add the workshop to the existing agenda. For this reason, the workshop was shifted to the 2014 AGU Fall Meeting. Thus, identified modelling studies will now be initiated during 2015. We anticipate however, that we can progress with the third workshop as planned in late 2015.

- SCAR 2014 Open Science Conference – Session on “*AntarcticClimate21*”

A highly successful *AntarcticClimate²¹* session was held during the SCAR 2014 Open Science Conference. We were particularly encouraged by the fact that contributions ranged from atmosphere/ocean/ice observations to reconstructions and modelling studies. A joint session between AnT-ERA and *AntarcticClimate21* successfully attracted contributions that investigated ecosystem responses and feedback to environmental change.

3. Outputs/Deliverables

The fundamental outcomes of *AntarcticClimate²¹* 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 *AntarcticClimate21* 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.

- First *AntarcticClimate²¹* Workshop: ‘Quantification of Antarctic Climate Variability’

From 22-24th September 2013, we held the first *AntarcticClimate²¹* workshop. The goal of the workshop was to quantify and understand natural and anthropogenically-forced climate variability and change over the last few hundred years by utilising observational data, proxy records, and climate models. Experts of the respective fields were invited to investigate rates of change, types of trends (linear, thresholds, accelerating), the onset of trends, and identification of contributing or alleviating feedback mechanisms. We focused 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, ozone depletion). During the final two days of the workshop a draft report was developed. The synthesis incorporates the analysis of instrumental data as well as paleoclimate data. The report will be prepared in collaboration with ISMASS, IPICS and PAGES (2,000 year array), ITASE, SOOS, ASPeCT, and CliC. The results of the workshop report are expected to contribute to the update the recently established ACCE wiki and a summary will be made available for public outreach and information for local government agencies.

- ***AntarcticClimate*²¹** Publication: ‘Antarctica is science’s biggest hole in understanding current and predicting future climate’

Based on the conclusions from the first workshop, the *AntarcticClimate*²¹ lead authors (Objective 1, see annex 1) drafted a manuscript which focuses on important uncertainties and surprises. In particular it discusses themes such as: what is the possibility of abrupt sea level rise, could the Antarctic Peninsula cool again, what is the future of the Westerly winds (location, intensity, non-zonal behaviour), was is the uncertainty of ozone recovery (rate and magnitude), and what surprises could be produced by internal variability. This publication will be circulated to an extended science community for additional input prior to submission for publication in the Proceedings of the National Academy of Sciences.

- ***AntarcticClimate*²¹** – APECS Cruise

This event was sponsored by *AntarcticClimate*²¹ to facilitate discussion and interactions between various SCAR SRP representatives. Alia Khan, SC Member and APECS representative organised the event with the help of the SCAR office and included a quiz competition which featured science questions that are highly relevant to *AntarcticClimate*²¹ goals and the SCAR community overall with the aim to foster interest and initiate additional participating in the SRPs. The feedback from emerging researchers as well as participating senior scientists and representatives were very positive.

4. Budgetary Implications

2014 Budget	Expenditure	Budget
2014 Budget Allocation		\$ 20,000.00
2013 carry over		\$ 2,852.40
APECS Cruise	\$ 4,701.40	
Support for APECS Representative to attend SC Meetings and Workshops	2,000	
APECS Quiz Prices	\$ 560	\$ 275
ACCE	\$ 1,000	
AntClim21 Workshop	\$ 14,100	
AntClim21 Webpage	\$ 1,000	
Total	\$23,361.40	\$23,402.40

2015 Budget	Expenditure	Budget
2015 Budget Request		\$ 20,000.00
Support for APECS Representative to attend SC Meetings and Workshops	\$ 3,000	
AntClim21 Workshop	\$ 14,000	
AntClim21 Webpage	\$ 1,000	
Publication Fees	\$2,000	

2016 Budget	Expenditure	Budget
2016 Budget Request		\$ 20,000.00
Support for APECS Representative to attend SC Meetings and Workshops	\$ 3,000	
AntClim21 Symposium	\$ 10,000	
AntClim21 Webpage	\$ 1,000	
Publication Fees	\$6,000	

5. Future Plans

Milestones for 2015

- Promote modelling studies as identified during workshop 2
- Publication of *Climate model verification for the Antarctic region* Report.
- Workshop 3 *Antarctic climate projection to 2100 AD*.

Milestones for 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*”

Milestones for 2017

- Publication of *Antarctic climate projection to 2100 AD* Report.
- Succession planning – what are the next urgent, important science questions?

Milestones for 2018

- Publication of *AntarcticClimate²¹* Report. This report is the principle output from the proposed programme *AntarcticClimate²¹* 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.
- SCAR Open Science Conference – Session on “*Antarctica Climate Projections – Global Challenges*”

Appendix

The *AntarcticClimate*²¹ Team comprises:

Steering Committee

Nancy Bertler (Chair, NZ)
 Thomas Bracegirdle (Leader, Objective 2 – Climate model verification for the Antarctic Region, UK)
 Alia Khan (APECS Representative, USA)
 Paul Mayewski (Co-Leader, Objective 1 – Quantification of Antarctic Climate Variability, USA)
 Joellen Russell (Leader, Objective 3 – Antarctic Climate Projection to 2100 AD, USA)
 John Turner (Co-Leader, Objective 1 – Quantification of Antarctic Climate Variability, UK)

Lead Authors for Publication ‘Quantification of Antarctic Climate Variability’

Nancy Bertler (NZ)
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 Ian Goodwin (Australia)
 Jung-Ho Kang (Korea)
 Alia Khan (USA)
 Paul Kushner (Canada)
 Paul Mayewski (USA)
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 David Schneider (USA)
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Confirmed Lead Authors to date for Publication “Climate Model Verification for the Antarctic Region”

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 Eric Larour (France)
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 Lorenzo Polvani (USA)
 Joellen Russell (USA)
 Samantha Stevenson (USA)
 John Turner (UK)
 Ilana Wainer (Brazil)
 Melchior van Wessern (Netherlands)