Paper No: 28 **Agenda item: 16.1**
SRP: AntClim21 SG: PS
Person Responsible: Tom Bracegirdle

SCAR Delegates Meeting 2020

Antarctic Climate Change in the 21st Century (AntClim21)

Final Report

Summary

Report Author(s)

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Introduction/background to the programme

AntClim21 has been focussed on the critical issue of estimating how the Antarctic climate system may change over the 21st century. Although the focus was on physical components of the system, specifically atmosphere, ocean and sea ice, strong links across disciplines led to some of the most exciting and high impact science. Key to making scientific progress has been the evaluation of climate models against observations and reconstructions of the past, ranging from the modern instrumental period to longer-term paleo-reconstructions.

Major achievements and legacies

AntClim21 led, and contributed to, major scientific advances. Improved estimates of Antarctic climate change to 2100 were achieved in a number of ways. A new method for combining information from many different climate models was developed to give more precise estimates of Antarctic temperature change. AntClim21 improved the climate model information used in collaborative inter-disciplinary studies of climate change impacts on the Antarctic ice sheet and Antarctic marine and terrestrial ecosystems.

The advances in climate projections were founded on improved knowledge how climate has behaved in the past (both recent and paleo) and on using this information to evaluate the reliability of climate models and the projections they produce.

Other major achievements and legacies are:

- Contribution of scientific literature to IPCC reports, both special and full assessment reports.
- The provision of extensive support for ECRs, in particular inclusion in running AntClim21, support for attendance at AntClim21 workshops and meetings,

support for attendance at major international conferences (both SCAR and non-SCAR) and through networking events at conferences.

- The development of a vibrant international community of Antarctic climate researchers connecting a range of disciplines.

Final procedural recommendations to Delegates *(see main text for an explanation)*

To help increase engagement of new participants to SRPs, AntClim21 recommends improvements to group webpages. Related to this, access for approved SRP members to make direct webpage edits would help improve efficiency of implementing updates.

Main report

Original rationale and objectives

The original rationale as set out in the 2012 proposal for AntClim21 is as follows:

> "It is envisaged 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.
>
> It is timely to launch AntarcticClimate21 since the climate model data have recently been released in preparation for the upcoming IPCC AR5 report. In particular, there are exciting new opportunities provided by the inclusion of paleoclimate model runs in AR5. More fundamentally, climate change is becoming an ever more urgent issue as mitigation to reduce emissions of greenhouse gases appears to be having little impact. Antarctic climate change will likely have global impacts on sea level, global ocean circulation, ocean carbon uptake and ecosystems. It is crucial that quantitative information on the impacts of climate change is produced in order to inform policy both locally and globally."

The main objective listed in the original proposal was "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." This overall objective was split into specific themes, which were as follows:

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

Main scientific achievements

Objective 1: Quantification of Antarctic climate variability

Linking modern observations with past reconstructions is key to quantify and understand natural climate variability and assess the emergence of anthropogenic influences. Key scientific papers addressing this are:

- Potential for climate surprises (Mayewski et al., 2015)
- Recent absence of Antarctic Peninsula warming (Turner et al., 2016)
- Ross Sea Dipole (Bertler et al., 2018)
- Back to the future (Bracegirdle et al., 2019)

Objective 2: Climate model verification for the Antarctic region

Information from many different climate models is available for quantifying how Antarctic climate may change in the future. There are large differences between these models in terms of their design and their ability to reliably represent the Antarctic climate system. Therefore verification (or evaluation) is a key step in using data from climate models to project future climate. AntClim21 made key advances in the evaluation of climate models for the Antarctic region, in particular the models developed as part of preparation for the IPCC Assessment Reports five and six (AR5 and AR6).

- Major workshop on climate model evaluation for the Antarctic region from a multi-disciplinary perspective, the #GreatAntarcticClimateHack.
- Metrics for the evaluation of climate models (Russell et al., 2018).
- Evaluation of models for use in ISMIP6 (Barthel et al., 2020).

Objective 3: Antarctic climate projection and impacts to 2100 AD

Achievements in research on Antarctic climate projections and impacts thereof where as follows:

- Publication of Antarctic climate projections from the state-of-the-art climate models and scenarios, which has been cited widely across IPCC reports (AR5, SROCC) and drafts of the upcoming AR6.
- Research into methods for combining climate information from multiple climate models to give more robust estimates of polar climate change (Bracegirdle and Stephenson, 2013).
- Implementation of above methods in collaboration with ecologists to assess 21st century change in Antarctic ice free areas (Lee et al., 2017).
- Provision of climate information for key assessment of Southern Ocean ecosystem stressors (Griffiths et al., 2017; Gutt et al., 2015).
- Model evaluation of atmospheric climate parameters for a major international assessment of future change in the Antarctic ice sheet in collaboration with ISMIP6 (Barthel et al., 2020).

Delivery against original implementation plan

Here we list, and comment on, the deliverables from the implementation plan for the second four-year phase of AntClim21.

Workshops and meetings:

- "Hold the "#The Great Antarctic Climate Hack" workshop. This will aim to provide training for senior and emerging scientists on the use of data products related both to AntClim21 and other initiatives (late 2017)."
    - This workshop was held in October 2017 and brought in researchers from more than 17 countries and a high proportion of early career scientists (29 from 92). It was successful in achieving its goals as documented in a report published in EOS (Khan et al., 2018).
- "Hold a workshop in 2018 on Antarctic climate projection to 2100 AD, which will aim to synthesise the outcomes of the previous AntClim21 workshops and plan a synthesis paper on Antarctic climate projections to 2100."
    - Two workshops were held to develop this aspect. The first in June 2018 at SCAR/IASC in Davos, Past2Projections, provided an assessment of how longer-term paleo climate data may be used to help improve climate projections (Bracegirdle et al., 2019). The second in July 2019 at BAS in Cambridge focussed specifically on climate projections and produced papers on climate projections to 2100 from the latest major climate model dataset which was prepared in advance of IPCC AR6 (CMIP6) (Bracegirdle et al., 2020a; Bracegirdle et al., 2020b; Roach et al., 2020). It was decided that the focus should be on using the new climate data to publish papers for potential citation in IPCC AR6 rather than a broader synthesis paper. A synthesis report of AntClim21 aimed at a general non-specialist

audience is currently in preparation, but has been delayed due to impacts of Covid-19.

Publications:

- "A peer review publication on proxy ice core and climate reanalysis analogues for understanding past, present and near future Antarctic climate, which follows on from the first AntClim21 workshop (submit 2016/2017)."
    - This was published in 2017 (Mayewski et al., 2017).
- "A peer review publication (or potentially multiple publications, since we are currently considering options for a journal special issue) will be a key output from "#The Great Antarctic Climate Hack" (submit in early 2018)."
    - Key publications relating to #GACH were (Khan et al., 2018) and (Russell et al., 2018).
- "A synthesis paper (peer review) on Antarctic climate projections to 2100 (submit in early 2019)."
    - See above comment that the focus was shifted to peer review publications for AR6 and a more general non peer-review synthesis report aimed at a more general audience.
- "A number of papers based on AntClim21 data products (see below) are anticipated and authors will be asked to acknowledge SCAR and AntClim21."
    - The above-listed papers have included acknowledgement to SCAR AntClim21.

Community products and outputs:

- "Link with the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project in providing a data portal for access to climate model estimates of 21st century climate change (2017-2018)."
    - The Southern Ocean Climate Model Atlas is hosted by SOCCOM (https://southernocean.arizona.edu/content/antclim21).
    - Maps of Antarctic temperature change have been made available on the AntClim21 website (https://www.scar.org/science/antclim21/data-surface-projections/)
- "Provide the Antarctic component of diagnostics being developed in parallel with the next set of IPCC-class climate / earth-system models (ESMValTool) (2017-2018)."
    - ESMValTool diagnostics have been developed as part of the paper on evaluation of the coupled Southern ocean climate system by (Russell et al., 2018).
- "Help disseminate regionally downscaled climate data from Antarctic CORDEX (a World Climate Research Programme initiative) across the SCAR community (initiate in 2017 and update as new data become available)."
    - AntClim21 members have attended Antarctic CORDEX meetings and Antarctic CORDEX activities have been highlighted at AntClim21 meetings. For example co-chair Andrew Orr attended and presented a poster at the 2019 AntClim21 workshop at BAS.

Main education, outreach and capacity building achievements

Support and mentoring of Early Career Researchers (ECRs) through the following:

- ECR representation on AntClim21 Steering Committee, a position held by Alia Khan. During a crucial stage in her career AntClim21 has provided support for attendance at major conferences and experience in international science coordination and networking.
- Opportunities for attendance at SCAR and other major conferences have been provided both as part of AntClim21 workshops and also through providing travel grants to relevant sessions at non-SCAR conference (for example grants were awarded to two ECRs to attend the 2018 AGU Fall Meeting).
- ECR presentation prizes were awarded at the 2019 AntClim21 workshop in Cambridge. An oral presentation prize supported by Nature Journals and a poster prize supported by SCAR.

Participation from emerging Antarctic nations has been supported at AntClim21 workshops. For example at the #GreatAntarcticClimateHack include particpants from four countries with emerging or initial-stage Antarctic programmes (Belgium, Canada, Chile and Denmark).

Many education and outreach activities have been conducted by AntClim21. Examples of such activities are as follows:

- School children: Eastbourne Kea Scouts visited Ice Core Facility: Nancy Bertler hosted 20 Scouts and their parents to the ice core facility to learn about Antarctic climate change research including international efforts such as AntClim21. 7 August 2017.
- General public: N. Bertler gave a public presentation at the War Memorial Hutt City Library (23 March, 2018) on 'Future Sea Level Rise and Implications for New Zealand' which highlighted the work by AntClim21, attended by ~50 participants.
- Media:
    - 1/2019 – "Searching for Certainty – Climate and the Deep Blue Sea"; Arizona Public Media; https://uascience.org/lectures/climate-and-the-deep-blue-sea/
    - TVNZ Breakfast, 12 July 2017, Interview by Jack Tame with Nancy Bertler on 'Climate Data Treasure Chest'.
    - National Radio, Interview Blog by Jacob McSweny with Nancy Bertler on 'Huge new climate database charts 2000 years of temperature', 12 July 2017, (http://www.radionz.co.nz/news/national/335001/huge-new-climate-database-charts-2000-years-of-temperatures)

Partnerships made and support received

A wide range of active and successful partnerships have been developed during the lifetime of AntClim21. There has also been significant support from many organisations and individuals through both up front and in-kind contributions. The main partnerships and support providers are listed in alphabetical order as follows:

- ICED (Integrating Climate and Ecosystem Dynamics), which is a programme focussed on Antarctic and the S. Ocean. AntClim21 provided input on the ICED-led peer-review paper (Cavanagh et al., 2017), which came from a ICED-sponsored workshop at BAS, Cambridge in 2013.
- ISMIP6 (Ice Sheet Model Intercomparison Project for CMIP6). AntClim21 collaborated in the activity of choosing climate models most appropriate for providing input data to studies of the response of the Antarctic ice sheet to 21st century climate change projections (Barthel et al., 2020; Nowicki et al., 2020; Nowicki et al., 2021).
- Nature Publishing Group. Nature provided support, including a student presentation prize, at the 2019 AntClim21 CMIP6 Workshop at BAS, Cambridge. They also participated at the #GACH.
- PAGES CLIVASH2k (Climate variability in Antarctica and Southern Hemisphere in the past 2000 years). AntClim21 and CLIVASH co-funded a workshop help at BAS Cambridge in September 2019 and CLIVASH2k contributed to the AntClim21 paper Bracegirdle et al. (2019).
- SCAR SRPs, Ant-ERA and AntECO, have been close partners with a number of joint workshops and scientific papers, including the joint workshop in Barcelona 2016 and key papers such as Gutt et al. (2018).
- SIMIP (Sea Ice Model Intercomparison Project for CMIP6). Collaboration on analysis for the Roach et al. (2020) study on Antarctic sea ice in the CMIP6 models, which was planned during discussions at the 2019 CMIP6 workshop in Cambridge.
- SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling). AntClim21 developed strong partnership with SOCCOM, who contributed to AntClim21 workshops, in particular #GACH, and provided the web infrastructure for the Southern Ocean Climate Model Atlas (https://southernocean.arizona.edu/content/socma).

Many funding bodies and institutions provided support for AntClim21 through supporting activities of AntClim21 members and logistical support for workshops. Notable organisations are (in alphabetical order):

- BAS (British Antarctic Survey), which is a research institute of NERC (the Natural Environment Research Council).
- University of Arizona.
- Victoria University of Wellington.

Other legacies

AntClim21 has created an active and inclusive international community of 71 Antarctic and Southern Ocean scientists and it is expected that many of the connections and networks will continue into the future. Other specific legacies include:

- Ongoing influence of IPCC reports, to which AntClim21 contributed peer-review science and expertise in terms of authorship. Notable examples are:

  - Three papers conceived at the AntClim21 2019 CMIP6 workshop (and written mainly by participants) are cited in the latest draft of the IPCC AR6 WG1 report.
  - The lead authors on the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) include AntClim21 members Nerilie Abram and Rob DeConto.
  - The lead authors on the IPCC AR6 WG1 include AntClim21 members John Fyfe, Nick Golledge and Gerhard Krinner.
- Strong links between physical and ecological Antarctic science communities, which are continuing in ongoing projects including the newly approved SRPs.
- Measures of how accurately climate models represent important aspects of the Antarctic and Southern Ocean climate system, or 'metrics' are an important part of developing models and choosing which models to use for making projections of future climate change. AntClim21 contributed to the development of, and made use of, metrics of atmospheric circulation (e.g. Bracegirdle et al., 2018), the coupled system (e.g. Bertler et al., 2018) and the Southern Ocean (e.g. Russell et al., 2018). An inter-disciplinary perspective of climate model metrics was developed at #GACH (Khan et al., 2018).

Draft final Budget summary

	2018	2019	2020
	Spent	Spent	Spent
Total (US$)	32,900	24,563	3,524
Budget to support ECRs	10,500	9,500	Above is journal page charges for Bracegirdle et al. (2020a, b)
Support for countries with developing programmes	400	None	

Final future research recommendations to Delegates

During the lifetime of AntClim21 new scientific questions have emerged as well as advances in capability in both observation and modelling of the Antarctic climate system. Suggested priority areas for future SCAR research are:

- Assess the role of freshwater input from melting ice sheets in the future evolution of Antarctic and global climate change.
- Decadal timescale climate variability, which is not well understood both in terms of observational data and modelling capability. New capabilities include improved proxy reconstructions, the wider availability of decadal climate forecasting systems and new data science (machine learning) approaches.

- Antarctic sea ice variability and trends, in particular recent dramatic swings in Antarctic sea ice area and relevance for projections of future change.
- The question of how the Southern high latitudes may evolve under low emissions scenarios.
- Improve the understanding of regional climate variability and change along coastal Antarctica, in particular locations of relevance to atmosphere-ocean-ice coupling, for example adjacent to the Amundsen Sea embayment. Also other regions of relevance to ecosystems or ice sheets.

Final procedural recommendations

In general the AntClim21 Steering Committee have found the SCAR Secretariat to be very efficient and helpful and ensuring the smooth running of events and general administrative matters. There are a number of procedural recommendations that could be considered to help make things run even more smoothly in the future.

- The procedure for joining, or becoming involved in, SCAR SRPs should be made clearer on SRP webpages. Indeed this could be one for the most prominent features of their homepages to help those who are interested to get involved.
- Providing more direct website editing access to SRP members (or a member approved for that role) could help improve the efficiency of simple edits such as membership lists or new published papers.

Notable Papers

Notable papers published in 2019 and 2020 in alphabetical order

1. Barthel, Alice, Agosta, Cécile, Little, Christopher M., Hattermann, Tore, Jourdain, Nicolas C., Goelzer, Heiko, Nowicki, Sophie, Seroussi, Helene, Straneo, Fiammetta, Bracegirdle, Thomas J. . (2020) CMIP5 model selection for ISMIP6 ice sheet model forcing: Greenland and Antarctica. *Cryosphere*, 14. 855-879. 10.5194/tc-14-855-2020.

ISMIP6 paper for which AntClim21 contributed to atmospheric metrics used for CMIP5 model selection.

2. Bracegirdle, Thomas J. , Krinner, Gerhard, Tonelli, Marcos, Haumann, F. Alexander, Naughten, Kaitlin A. , Rackow, Thomas, Roach, Lettie A., Wainer, Ilana. (2020a) Twenty first century changes in Antarctic and Southern Ocean surface climate in CMIP6. *Atmospheric Science Letters*, 21. 10.1002/asl.984.

An overview of 21st century projections from CMIP6. This is an outcome of the 2019 AntClim21 workshop in Cambridge (attended by the co-authors, many with travel funded by AntClim21).

3. Bracegirdle, T.J. , Holmes, C.R. , Hosking, J.S. , Marshall, G.J. , Osman, M., Patterson, M., Rackow, T.. (2020b) Improvements in Circumpolar Southern Hemisphere Extratropical Atmospheric Circulation in CMIP6 Compared to CMIP5. *Earth and Space Science*, 7. 12 pp. 10.1029/2019EA001065.

A paper showing a major advance in climate model capability for the Antarctic and Southern Ocean climate system. As above this is an outcome of the 2019 AntClim21 workshop in Cambridge (attended by the co-authors, many with travel funded by AntClim21).

4. Nowicki, Sophie, Goelzer, Heiko, Seroussi, Hélène, Payne, Anthony J., Lipscomb, William H., Abe-Ouchi, Ayako, Agosta, Cécile, Alexander, Patrick, Asay-Davis, Xylar S., Barthel, Alice, Bracegirdle, Thomas J. , Cullather, Richard, Felikson, Denis, Fettweis, Xavier, Gregory, Jonathan M., Hattermann, Tore, Jourdain, Nicolas C., Kuipers Munneke, Peter, Larour, Eric, Little, Christopher M., Morlighem, Mathieu, Nias, Isabel, Shepherd, Andrew, Simon, Erika, Slater, Donald, Smith, Robin S., Straneo, Fiammetta, Trusel, Luke D., van den Broeke, Michiel R., van de Wal, Roderik. (2020) Experimental protocol for sea level projections from ISMIP6 stand-alone ice sheet models. *The Cryosphere*, 14. 2331-2368. 10.5194/tc-14-2331-2020.

Ice Sheet Model Intercomparison Project Six (ISMIP6) paper for which AntClim21 contributed to developing the protocol.

5. Roach, Lettie A., Dörr, Jakob, Holmes, Caroline R. , Massonnet, François, Blockley, Edward W., Notz, Dirk, Rackow, Thomas, Raphael, Marilyn N., O'Farrell, Siobhan P., Bailey, David A., Bitz, Cecilia M.. (2020) Antarctic Sea Ice Area in CMIP6. *Geophysical Research Letters*, 47. 10.1029/2019GL086729.

This is an outcome of a collaboration between AntClim21 and the Sea Ice Model Inter-comparison Project (SIMIP), which was conceived at the 2019 AntClim21 Cambridge workshop. The lead author is an ECR who attended the workshop with travel support from AntClim21. SIMIP provided key sea ice data for the study.

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Barthel, A., and Coauthors, 2020: CMIP5 model selection for ISMIP6 ice sheet model forcing: Greenland and Antarctica. *Cryosphere*, **14,** 855-879.

Bertler, N. A. N., and Coauthors, 2018: The Ross Sea Dipole - temperature, snow accumulation and sea ice variability in the Ross Sea region, Antarctica, over the past 2700 years. *Climate of the Past*, **14,** 193-214.

Bracegirdle, T. J., and D. B. Stephenson, 2013: On the robustness of emergent constraints used in multi-model climate change projections of Arctic warming. *Journal of Climate*, **26,** 669-678.

Bracegirdle, T. J., P. Hyder, and C. R. Holmes, 2018: CMIP5 diversity in southern westerly jet projections related to historical sea ice area; strong link to strengthening and weak link to shift. *Journal of Climate*, **31,** 195–211.

Bracegirdle, T. J., C. R. Holmes, J. S. Hosking, G. J. Marshall, M. Osman, M. Patterson, and T. Rackow, 2020a: Improvements in Circumpolar Southern Hemisphere Extratropical Atmospheric Circulation in CMIP6 Compared to CMIP5. *Earth and Space Science*, **7**.

Bracegirdle, T. J., and Coauthors, 2020b: Twenty first century changes in Antarctic and Southern Ocean surface climate in CMIP6. *Atmospheric Science Letters*, **21**.

Bracegirdle, T. J., and Coauthors, 2019: Back to the Future: Using Long-Term Observational and Paleo-Proxy Reconstructions to Improve Model Projections of Antarctic Climate. *Geosciences*, **9**.

Cavanagh, R. D., and Coauthors, 2017: A Synergistic Approach for Evaluating Climate Model Output for Ecological Applications. *Frontiers in Marine Science*, **4**.

Griffiths, H. J., A. J. S. Meijers, and T. J. Bracegirdle, 2017: More losers than winners in a century of future Southern Ocean seafloor warming. *Nature Climate Change*, **7,** 749-754.

Gutt, J., and Coauthors, 2015: The Southern Ocean ecosystem under multiple climate change stresses - an integrated circumpolar assessment. *Global Change Biology*, **21,** 1434-1453.

Gutt, J., and Coauthors, 2018: Cross-disciplinarity in the advance of Antarctic ecosystem research. *Marine Genomics*, **37,** 1-17.

Khan, A., T. J. Bracegirdle, and J. L. Russell, 2018: Can we crack the climate code of the southern polar region? *EOS*, **99**.

Lee, J. R., B. Raymond, T. J. Bracegirdle, I. Chades, R. A. Fuller, J. D. Shaw, and A. Terauds, 2017: Climate change drives expansion of Antarctic ice-free habitat. *Nature*, **547,** 49-54.

Mayewski, P. A., and Coauthors, 2015: Potential for Southern Hemisphere climate surprises. *Journal of Quaternary Science*, **30,** 391-395.

Mayewski, P. A., and Coauthors, 2017: Ice core and climate reanalysis analogs to predict Antarctic and Southern Hemisphere climate changes. *Quaternary Science Reviews*, **155,** 50-66.

Nowicki, S., and Coauthors, 2020: Experimental protocol for sea level projections from ISMIP6 stand-alone ice sheet models. *Cryosphere*, **14,** 2331-2368.

Nowicki, S., and Coauthors, 2021: Future sea level under CMIP5 and CMIP6 scenarios from the Greenland and Antarctic ice sheets. *Geophysical Research Letters***,** submitted.

Roach, L. A., and Coauthors, 2020: Antarctic Sea Ice in CMIP6. *Geophysical Research Letters*, **in press**.

Russell, J. L., and Coauthors, 2018: Metrics for the Evaluation of the Southern Ocean in Coupled Climate Models and Earth System Models. *Journal of Geophysical Research-Oceans*, **123,** 3120-3143.

Turner, J., and Coauthors, 2016: Absence of 21st century warming on Antarctic Peninsula consistent with natural variability. *Nature*, **535,** 411-+.

Budget

Planned use of remaining funds

Year (YYYY)	Purpose/Activity	Amount (in USD)
2021	Synthesis report printing and associated promotion material	3500 (estimated maximum)

Membership

No changes to the leadership with the Steering Committee remaining as follows:

Role	First Name	Last Name	Affiliation	Country	Email	Date Started	Date Term is to End
Chief Officer	Tom	Bracegirdle	BAS	UK	tjbra@bas.ac.uk	From Oct-2016 (SC Theme Leader 2012-2016)	2020
Theme 1 leader	Paul	Mayewski	University of Maine	USA	Paul.Mayewski@maine.edu	2012	2020
Theme 2 leader	Nancy	Bertler	Victoria University of Wellington	New Zealand	Nancy.Bertler@vuw.ac.nz	From Oct-2016 (Chair 2012-2016)	2020
Theme 3 Leader	Joellen	Russell	University of Arizona	USA	jrussell@email.arizona.edu	2012	2020
SC member	Marilyn	Raphael	University of California	USA	Raphael@geog.ucla.edu	2017	2020
SC member	Gerhard	Krinner	CNRS	France	Gerhard.krinner@cnrs.fr	2017	2020
*Early-career / APECS Rep.	Alia	Khan	Western Washington University	USA	khana8@wwu.edu	2012	2020

*Please identify early-career researchers with * in first column*

Other members

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