



SCAR Scientific Research Programme
External Performance Review



PAST ANTARCTIC ICE SHEET DYNAMICS (PAIS)



<http://www.scar.org/srp/pais>

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Introduction

The overarching goal of PAIS is to improve confidence in predictions of ice sheet and sea-level response to future climate change and ocean warming. For this, PAIS aims to improve understanding of the sensitivity of East, West, and Antarctic Peninsula Ice Sheets to a broad range of climatic and oceanic conditions. Study intervals span a range of timescales, including past “greenhouse” climates warmer than today, and times of more recent warming and ice sheet retreat during glacial terminations. The PAIS research philosophy is based on data-data and data-model integration and intercomparison, and the development of data transects, extending from the ice sheet interior to the deep sea. The data-transect concept will link ice core, continental, ice sheet-proximal, offshore, and far-field records of past ice sheet behaviour and sea level, yielding an unprecedented view of past changes in ice sheet geometry, volume, and ice sheet-ocean interactions. These integrated data sets will enable robust testing of a new generation of coupled Glacial Isostatic Adjustment-Ice Sheet-Atmosphere-Ocean models that include new reconstructions of past and present ice bed topography and bathymetry. PAIS will accomplish its objectives by: 1) facilitating the planning of new data-acquisition missions using emerging technologies; 2) encouraging data sharing and integration of spatially targeted transect data with modelling studies; and 3) initiating/expanding cross linkages among Antarctic research communities. The PAIS Scientific Programme is led by a Steering Committee ([Appendix I](#)) with wide knowledge of thematic issues, and appropriate regional (field), technical and logistical experience. Additionally, four subcommittees have been established to implement the scientific objectives of PAIS: 1) *Palaeoclimate Records from the Antarctic Margin and Southern Ocean (PRAMSO)*; 2) *Palaeotopographic-Palaeobathymetric Reconstructions*; 3) *Subglacial Geophysics*; and 4) *Ice Cores and Marine Core Synthesis*. The subcommittees provide the overall leadership, direction and management for their respective topics. Membership of these committees allows PAIS to widen involvement in the programme in terms of expertise, gender and nationality.

Deliverables and Milestones

Antarctic greenhouse environments under >600 ppm CO₂ scenarios The early Eocene provides insights into the response of Earth’s climate and biosphere to the higher range of atmospheric carbon dioxide (CO₂) levels predicted for the future as a result of relatively un-restricted anthropogenic carbon emissions. Climate during the early Eocene ‘greenhouse world’ are poorly constrained in Antarctica. Sediments collected off the east Antarctic Wilkes Land coast during Integrated Ocean Drilling Programme (IODP) Expedition 318, provide quantitative, seasonal temperature reconstructions for the early Eocene pointing to extremely mild frost-free winters capable of supporting the growth of diverse, near-tropical forests (*Pross et al., Nature 2012*). At around 50 Ma, a regional surface water and continental cooling (2–3 °C) (*Pross et al., Nature 2012*), coeval with earliest throughflow of a westbound Antarctic Counter Current through a southern opening of the Tasman Gateway (*Bjil et al., PNAS, 2012*), corresponds with the loss of the tropical forest in favour of temperate vegetation. This information provides critical new constraints for the validation of global climate models and for understanding the response of high-latitude terrestrial ecosystems to increased CO₂ forcing. Climate and carbon cycle modeling (*DeConto et al., Nature 2012*) points to the importance of Antarctic terrestrial ecosystems in global carbon cycle dynamics, prior to widespread Antarctic glaciation at the Eocene-Oligocene Transition (EOT, 34 Ma). It was shown that enough soil organic carbon could have been stored in Eocene Antarctic permafrost environments to trigger sudden, extreme warming events if the permafrost was lost. These Antarctic climate-

carbon dynamics provide an alternative mechanism for the cause of global events like the Paleocene-Eocene Thermal Maximum (PETM) and subsequent Eocene hyperthermals, and reinforce the importance of Antarctica in the global climate system, even before the development of its massive ice sheet-sea ice system.

The stepwise expansion of ice on Antarctica during the EOT induced crustal deformation and gravitational perturbations around the continent rising (in the order of 10s of m) sea level close to the ice sheet, despite an overall reduction in the mass of the ocean caused by the transfer of water to the ice sheet (*Stocchi et al., Nature Geosciences 2013*). Sediment cores from around Antarctica and at the vicinity of the Antarctic ice sheet, are in agreement with the spatial patterns of relative sea-level change indicated by GIA models. These results are consistent with the suggestion that near-field processes such as local sea-level change influence the equilibrium state obtained by an ice sheet grounding line.

Once the Antarctic Ice Sheet grew, the highly diverse Eocene rainforest evolved to an Oligocene cold temperate forest and an impoverished Miocene sub-Antarctic shrubland (*Salzmann et al., EGU abstract 2016*). Temperatures on the Wilkes Land margin were higher than in the Ross Sea region (i.e. Andriill, Cape Roberts) and Seymour Island (Antarctic Peninsula), implying that Wilkes Land was possibly one of the last refugia for temperate forest taxa on Antarctica during the Late Oligocene. These studies point to the need for records from other Antarctic sectors to understand regional differences and continental gradients, which PAIS will continue to support, encourage, and facilitate.

East Antarctic Ice Sheet (EAIS) stability or instability in 400-600ppm CO₂ world?

The warm-Pliocene period (5-3 Ma) is recognized to be an important analogue to near-future conditions and for understanding the long-term response of the Earth System to 400ppm atmospheric CO₂ (see section below on IPCC contribution). Reconciling near field records of the ice sheet with, far-field sea-level records and models has been a major challenge facing the paleoclimate research community. Work conducted under the SCAR Antarctic Climate Evolution (ACE) Programme (predecessor of PAIS) provided evidence for a complex behaviour of the Neogene EAIS. However, complete deglaciation was not demonstrated with geological data. Neither was an entirely stable EAIS defensible. A recent summary of this history and state of knowledge was produced by Barrett (*Earth and Environmental Science Transactions of the Roy. Soc. Edinburgh, 2013*), However, most climate and ice sheet models were not able to simulate significant loss EAIS required by the far-field sea-level records (*Miller et al., Geology, 2012*) given that atmospheric CO₂ levels were relatively low throughout this period. Work conducted under PAIS, has now provided geological evidence for marine EAIS retreat into the Wilkes Subglacial Basin during the early Pliocene implying that the EAIS is capable of contributing as much sea-level rise, if not more, than the West Antarctic Ice Sheet (WAIS) (*Cook et al., Nature Geosciences 2013; Patterson et al., Nature Geosciences 2014; Reinardy et al., Paleo3, 2015*). These results have triggered the revision of ice sheet models (*Dolan et al., 2011; de Boer et al., 2015; DeConto et al., 2012; Pollard and DeConto, 2012; Pollard et al., 2015*) which, when incorporating melt-driven hydrofracturing of ice shelves and ice-margin cliff failure (*Pollard et al., 2015*), now reproduce a rapid Pliocene collapse of West Antarctic ice, and retreat into East Antarctic subglacial basins. The total Antarctic ice loss corresponds to ~+17m sea-level rise, in good agreement with far-field geologic sea-level records and near-field ice extent records. Modelling studies are now ongoing to understand how the uncertainty in the Bedmap2 Antarctic topographic data set effects model derived estimates of past (and future) ice-sheet retreat (*Gasson et al., GRL 2015*). Using the warm mid-Pliocene as a test case, it is found that estimates of Pliocene sea-level rise vary from 12.6 to 17.9m, simply due to unknown topographic boundary conditions.

This study clearly points to the need for additional, targeted geophysical surveys, which PAIS will continue to support, encourage, and facilitate.

PAIS and its focus on the Pliocene also helped spark the development of the U.S. NSF supported PlioMAX project (www.pliomax.org), with the mission of linking Pliocene sea-level indicators with GIA modelling and ice sheet modelling, to further improve constraints on the Pliocene sea-level, and hence Antarctic ice sheet sensitivity (e.g., *Raymo et al., 2011; Rovere; 2014*).

Attention is now turning to the Miocene where work conducted under PAIS, includes two important new papers based on the Antarctic Geological Drilling Program (ANDRILL) 2A record (*Levy et al., Gasson et al., PNAS 2016*). This work reveals that all the marine based ice in the EAIS (equivalent to +22m sea-level rise) was likely lost at times in the Miocene when atmospheric CO₂ approached or exceeded ~500ppm, similar to CO₂ levels that will be reached in middle of this century. The ANDRILL 2A sediment record (*Levy et al., 2016*) shows strong orbitally-paced variability of the ice margin in a Ross Sea up to 6°C in the Ross Sea, and the ice-modelling companion paper (*Gasson et al., 2016*) shows that a combination of including new ice-shelf hydrofracturing physics and climate-ice sheet feedbacks can produce ice volume changes consistent with benthic oxygen isotope records, resolving a longstanding problem of EAIS hysteresis.

The contribution of Antarctica to abrupt sea-level rise during the Last Deglaciation

In recent years new geological and bathymetric constraints of the ice extent during the Last Glacial Maximum (LGM) and the patterns of retreat during the Holocene deglaciation have been provided (*Bentley et al., Quaternary Science Reviews 2014; Weber et al., Science 2014, Rebesco et al., Science 2014*). These records provide evidence for episodic mass loss of the Antarctic ice sheet between 20 and 9 kyr. Older events are related to the deglaciation of the Antarctic Peninsula Ice Sheet and the EAIS in the SE Weddell Sea, with the onset of the Antarctic-wide deglacial warming marked by an IRD peak at around 17 kyr when the Northern Hemisphere was cold during Heinrich event 1. New constraints have been provided for the Antarctic contribution Meltwater Pulse 1A from an ice sheet model (*Golledge et al., Nature Communications 2014*) and a well-dated iceberg rafted debris record in the Scotia Sea (*Weber et al., Nature, 2014*). The agreement between these two entirely independent studies is remarkable and shows that ice mass discharge primarily from WAIS contributed at rates of up to 1m/century to sea-level rise during meltwater pulse 1A. This work points to the importance of ocean warming in the timing of ice-sheet retreat during the last deglaciation, with clear implications for possible future response to a warming ocean.

Policy relevant PAIS research informs the IPCC 5th Assessment Report

A number of PAIS outputs mentioned above were influential in Assessment Report 5 of the Intergovernmental Panel on Climate Change (*IPCC, 2013*), and contributed to Chapter 5 “Information from Paleoclimate Archives” (*Masson-Delmotte et al., 2013*), Chapter 13 “Sea-level Change” (*Church et al., 2013*), the Technical Summary and Summary for Policy Makers. PAIS members also contributed as authors. PAIS researchers specifically contributed to AR5 topics, including carbon-cycle feedbacks, polar ice-sheet dynamics and contribution to sea-level rise, high-latitude temperature response to high CO₂, polar amplification, and anthropogenic greenhouse gas attribution in the context of ice cores. Examples of some specific policy relevant statements from AR5 are listed below.

- 1. There is high confidence that the volumes of the Greenland and WAIS were reduced during periods of the past few million years that were globally warmer than present.** Ice sheet model simulations and geological data suggest WAIS retreat if atmospheric CO₂ concentration stays within or above the range of 350 ppm to 450 ppm for several millennia. *Chapter 5 executive summary*

- 2. New temperature reconstructions and simulations of past climates show with *high confidence* polar amplification in response to changes in atmospheric CO₂ concentration.** For high CO₂ climates *Chapter 5 executive summary*.
- 3. There is *high confidence* that global mean sea level was above present during some warm intervals of the mid-Pliocene (3.3 to 3.0 million years ago), implying reduced volume of polar ice sheets.** The best estimates from various methods imply with high confidence that sea level has not exceeded +20 m during the warmest periods of the Pliocene, due to deglaciation of the Greenland and WAIS and areas of the EAIS. *Chapter 5 executive summary*.
- 4. With very *high confidence*, the current rates of CO₂, CH₄ and N₂O rise in atmospheric concentrations and the associated radiative forcing are unprecedented with respect to the highest resolution ice core records of the last 22,000 years.** *Chapter 5 executive summary*.
- 5. The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.** *Summary for Policymakers*.

II. Primary publications in peer-reviewed journals (use appendices if necessary)

References to citations in the previous section and other selected PAIS publications are listed in **Appendix II**. In addition, PAIS has produced three special volumes and has contributed to Policy relevant reviewed publications (i.e., *Kennicutt et al., Nature and Antarctic Science, 2014*).

III. Major reports, including linkages to major SCAR activities (e.g. advice to the Treaty or IPCC)

Active involvement of members of the PAIS scientific community in international programmes and networks has provided science-based advice to: 1) SCAR activities (e.g., Antarctic Treaty, HorizonScan, Strategic Plan, etc.); 2) other major scientific programs (e.g., IODP, EU PolarNet); and 3) Policy makers (IPCC, United Nations Climate Change Conferences; Antarctic Portal). A detailed list of reports to which members of the PAIS have contributed are listed in **Appendix III**. PAIS will continue to provide reports on its activities to SCAR and contribute to reports for international and national programmes and government bodies, as required.

IV. Workshops and other key meetings organized and activities associated to major SCAR meetings (Open Science Conferences, International Symposia on Biology, Earth Sciences, etc.)

PAIS work on facilitating coordination and collaborations between different multidisciplinary and interdisciplinary international groups is largely conducted through community workshops and meetings. Some of the completed activities funded/co-funded by PAIS are listed in **Appendix IV**. In addition to these activities, PAIS convenes scientific sessions and additional meetings of the Steering Committee and subcommittees during large international meetings such as AGU and EGU, SCAR OSC (2012, 2014 and 2016), ASLO 2015, and XII ISAES 2015. PAIS plans to organize a PAIS Symposium in 2017 in Trieste (Italy). It is expected to be similar in size and format to the 1st ACE Symposium held in Granada in September 2009.

V. Capacity building and education outreach activities; detail any difficulties encountered

PAIS endeavors to support and encourage the next generation of Antarctic scientists by: 1) including young scientists in the leadership of sub-committees and the SC (see **Appendix I**); 2) encouraging young scientists to take part in PAIS meetings and workshops by offering bursaries for travel and subsistence; 3) participation and funding, when possible, of graduate students to attend the Urbino Palaeoclimate School, the Karthaus Summer School on Ice Sheets and Glaciers in the Climate System, and other training schools in topics that are relevant to PAIS. PAIS members also serve as instructors at these summer schools. **Appendix V** lists some of the activities conducted by PAIS since 2012.

VI. New data and/or meta-data (including plans for archiving)

PAIS supports continued development of the **Antarctic Data Library System** for Cooperative Research (SDLS) under the auspices of Scientific Committee on Antarctic Research (SCAR) and the Antarctic Treaty (ATCM XVI-12). The SDLS provides open access to all multichannel seismic-reflection data collected south of 60° S. The new website is operated and administered at the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) and provides open access to Antarctic multichannel seismic-reflection data online is <http://sdls.ogs.trieste.it/> While PAIS does not directly support other data archiving infrastructure, it maximizes the effectiveness of its limited budget by encouraging responsible archiving of data and samples to established data centres and repositories. Among these databases the most relevant to the data to be generated by PAIS are: 1) PANGAEA the data Publisher for Earth & Environmental Science- <http://www.pangaea.de/> which holds all ANDRILL Program data, and a wealth of data from marine sediment cores from the Southern Ocean. 2) The IODP data bases and core repositories <http://www.iodp.org/access-data-and-samples> holds all Antarctic and Southern Ocean cores and data obtained by the Ocean Drilling Programmes since the 70s (i.e., DSDP, ODP, IODP). 3) The IPEV IMAGES Programme Sub-Antarctic and Antarctic portal - http://gcmd.gsfc.nasa.gov/KeywordSearch/Home.do?Portal=amd_fr, which contains data from both marine and ice core records. Other databases include NOAA NCDC/NSIDC, and national programmes metadata systems.

VII. Communication activities (eg website contents and stats, social media stats, brochures, speaking engagements, etc.) and how these contribute to the promotion of SCAR and its mission.

PAIS has been involved in numerous *community service and outreach activities*. In terms of public interest in PAIS research, PAIS members have been interviewed in numerous occasions in TV and radio, disseminating research findings and information about research projects to the general public. PAIS members have been quoted in numerous articles in newspapers concerning scientific results, research plans and expert opinions. PAIS also collaborates in science museums exhibits (e.g., <http://icestories.exploratorium.edu/dispatches/en-espanol-video-del-joides-resolution/>). Finally, through programmes of relevance to PAIS, video journals, video animations and blogs have been produced (e.g., <http://andrill.org/static/media.html>; <http://www.youtube.com/watch?v=uvzrK24YJyQ>). In addition, PAIS leadership has been invited to provide *science policy, keynote, and public outreach talks* such as: 1) The SCAR Lecture at XXXVII Antarctic Treaty Consultative Meeting, Brasilia, Brasil, April 2014; 2) The United Nations COP19 – Day of the Cryosphere: Climate Change Today in Polar and Mountain Regions, Varsaw, November 2013, 3) The S.T. Lee Lecture series on Antarctic Studies, 4) The WAIS Initiative, Julian, CA USA, 2014; and 5) The International Conference on Paleoceanography (ICP), Barcelona, 2013.

VIII. Linkages to other SCAR groups, international programmes and other activities

PAIS is well aligned with the other SCAR SRPs, particularly with SERCE, Ant-eco and AntClim21. With SERCE we share the study of ice dynamics and sea level but they involve very different scientific communities, and different time scales (i.e., post LGM vs 60 Ma). Linkages with Ant Eco involve the study of paleoenvironments, biota evolution, land bridges, and refugia. Linkages to AntCLIM21 relates to climate variability since the LGM. PAIS also has linkages with SCAR Expert Groups such as ADMAP, ISMASS, ATHENA, IBSCO and ANTVOLC; as well as SCAR Action Groups (CGG, Multibeam Data Acquisition, SAVant). Result of these cross linkages is the SCAR-OSC 2016 Mini-Symposium “The Antarctic ice sheet from past 2 future” co-organized by PAIS, SCERCE, AntClim 21 and ISMASS. Outside SCAR, and given that the nature of PAIS science is international and global in scope, we have established partnerships with: IODP, ANDRILL, SHALDRIL (Shallow Drilling Program), ICECAP (International Climate and Environmental Change Assessment Project), AGAP (Antarctica’s Gamburtsev Province Project), PLIOMAX (Pliocene Maximum Sea Level Project), PALSEA (Sea Level and Ice Sheet Evolution), and WAIS among other national Antarctic research centres and multinational research projects.

IX. Expenditure on project activities and plans for unspent funds

Expenditure to date is related to the funding of workshops; the funding of early career and senior scientists to attend SCAR conferences, PAIS meetings and proposal-writing workshops considered in the PAIS Implementation Plans; and providing support for open access to articles relevant to PAIS. In addition, PAIS has committed funding for training schools. These activities are listed in [Appendices IV and V](#). Planning is ongoing for a PAIS Symposium to be held in Trieste in 2017. Therefore PAIS 2016 and 2017 funding will be largely used to support this symposium.

Future Plans

Future plans for the next 4 years (2016-2019) include (see also [Appendix VI](#) for updates on the programmes in the original implementation plan):

- shallow drilling project on the Amundsen Sea Embayment shelf and in Pine Island Bay with MeBo is scheduled to take place in February to March 2017 on an RV Polarstern cruise (Gohl et al.);
- Field seasons for Totten Glacier (Armand et al) seismic and coring cruise 2017 on the Australian vessel Investigator.
- Field season to the Scotia Sea-Ona Basin (Escutia et al.) seismic and coring cruise 2017 on Spanish vessel BIO Hespérides.
- Field seasons for Ross Sea (Stocchi et al) seismic and coring cruise 2017 on the Italian vessel OGS Explora (EU-Eurofleets 2 project).
- IODP-MSP expedition 831 in the George V Land margin (T. Williams and C. Escutia co-chiefs) scheduled for January-February 2018 with the NBP Palmer (USA) and the shallow Rock driller (BGS,UK).
- Provide input to IODP to schedule of the IODP expeditions in the Ross Sea (proposal 751), Amundsen Sea (prop. 839), Antarctic Peninsula (prop.732)
- Continue the coordination of the scientific community to implement active and encouraging the submission of new shallow and deep drilling proposals from the Antarctic margin and from the ice shelf (using the ANDRILL platform)

- Progress on paleobathymetric mapping and ice sheet modelling
- Involve physical oceanographic community to develop collaborative work on understanding the role of Antarctic and Southern Ocean waters in ice sheet dynamics
- Organize the PAIS 2017 meeting in Trieste, Italy, to highlight main results achieved and scientific/technical questions still to be solved
- Organize PAIS sessions workshops and business meetings in major international meetings (SCAR OSC, AGU, EGU, ISAES)
- Continue outreach activities via National/International Programmes.
- Submit a proposal to the EU - SKŁODOWSKA-CURIE INNOVATIVE TRAINING NETWORKS for organizing an advanced school on polar stratigraphy
- Work on cross-linkages with other programmes (i.e., ice-core & marine core integration, develop links with SERCE and PAIS);
- Provide input to IPCC in a coordinated action with the other SCAR programs

Appendix I - Membership

Steering Committee

Last Name, First Name	Affiliation	Country	Email	Gender	Term	Expertise
Escutia Carlota	IACT-U. Granada	Spain	cescutia@ugr.es	F	2012-2016 chief-office 2016-ex-officio PAIS proponent	Paleoclimate-glacial processes-Ice Sheets
Robert DeConto	U. Massachusetts	USA	deconto@geo.umass.edu	M	2012-2016 chief-office 2016-ex-officio PAIS co-proponent	Ice Modeling
Tim Naish	Victoria U. of Wellington	NZ	Timothy.Naish@vuw.ac.nz	M	2016-chief-officer	Cyclostratigraphy -ice sheets and sea level
Laura De Santis	OGS	Italy	ldesantis@ogs.trieste.it	F	2012- PAIS co-proponent	Geophysics-glacial evolution
Robert Larter	British Antarctic Survey	UK	rdla@bas.ac.uk	M	2012- PAIS co-proponent	Geology and Geophysics – paleo ice-sheets
Karsten Gohl	AWI	Germany	karsten.gohl@awi.de	M	2012- PAIS co-proponent	Geophysics-rustal and sedimentary processes
Ross Powell	Northern Illinois U	USA	r.powell@mchsi.com	M	2012- PAIS co-proponent	Sedimentology-subglacial geology and marine ending glaciers
Mike Bentley	Durham U	UK	m.j.bentley@durham.ac.uk	M	2012- PAIS co-proponent	Glacial geomorphology dating-Ice sheets and sea level
Barbara Stenni	U. Trieste	Italy	barbara.stenni@univie.it	F	2012-	Ice cores
Julia Welner	U. of Houston	USA	jswellne@Central.UH.EDU	F	2012-	Sedimentology-glacial processes
Paolo Stocchi	NIOZ	NL	Paolo.Stocchi@nioz.nl	M	2012-	GIA modelling
Jongkuk Hong	KOPRI	Korea	jkhong@kopri.re.kr	M	2014-	Seismic and radar
Yusuke Sugamuna	NIRP	Japan	suganuma.yusuke@nipr.ac.jp	M	2013-	Paleomagnetism-Geochronology
Sun Bo	Polar Research Institute of China	China	sunbo@pric.gov.cn	M	2013-	Glaciology
Marcelo Reguero	Instituto Antartico Argentino	Argentina	regui@fcnym.unlp.edu.ar	M	2015-	Paleontology Vertebrates
Marcelo Leppe	INACH	Chile	mleppe@inach.cl	M	2015-	Paleontology Botany
Peter Bjil	U. Utrecht	NL	P.K.Bjil@uu.nl	M	2015-	Paleoceanography dinocists
J. Abel Flores	U. Salamanca	Spain	flores@usal.es	M	2015-	Paleoceanography nannofossils
Anton Van Putte	Royal Belgium I for Nat. Sci	Belgium	antonarctica@gmail.com	M	2013-	Databases SCADM

Members

Membership of the four established subcommittees allows PAIS to widen involvement in the programme in terms of expertise, gender and nationality. The mailing list at this time includes more than 208 scientists from all SCAR countries.

Appendix II - Primary publications in peer-reviewed journals

PAIS Selected publications to illustrate the breath of Science and Programs conducted under the PAIS umbrella:

2016

- Galeotti, S., DeConto, R., Naish, T., Stocchi, P., Florindo, F., Pagani, M., Barrett P., Bohaty, S., Lanci, L., Pollard, D., Sandroni, S., Talarico, F., Zachos, J., in press, Antarctic Ice-Sheet variability across the Eocene-Oligocene boundary climate transition. **SCIENCE (in press)**.
- Gasson, E., DeConto, R., Pollard, D., Levy, R., 2016, Dynamic Antarctic ice sheet during the early to mid-Miocene, **PNAS**. 10.1073/pnas.1516130113.
- Levy, R., Harwood, D., Florindo, F., Sangiorgi, F., Tripathi, R., von Eynatten, H., Gasson, E., Kuhn, G., Tripathi, A., DeConto, R., and Fielding, C., Field, B., Golledge, N., McKay, R., Naish, T., Olney, M., Pollard, D., Schouten, S., Talarico, F., Warny, S., Willmott, V., Acton, G., Panter, K., Paulsen, T., Taviani, Marco T., and SMS Science Team. 2016. Antarctic ice sheet sensitivity to atmospheric CO₂ variations in the early to mid-Miocene. **PNAS**. 10.1073/pnas.1516030113.

2015

- Barron, J.A., Stickley, C.E., and Burkry, D., 2015. Paleooceanographic and paleoclimatic constrains on the global Eocene diatom and silicoflagellate record. *Palaeogeography, Palaeoclimatology, Palaeoecology* 422: 85-100.
- De Boer, B., Dolan, A., Bernales, J., Gasson, E., Goelzer, N.R., Sutter, J., Huybrechts, P., Lohmann, G., Rogozhina, I., Abe-Ouchi, A., Saito, F., Van De Wal, R.S.W., 2015. Simulating the Antarctic ice sheet in the late-Pliocene warm period: PLISMIP-ANT, an ice-sheet model intercomparison Project. *Cryosphere* 9 (3):881-903.
- Feakins, S., Warny, S., and DeConto, R. 2015. Snapshot of cooling and drying before onset of Antarctic Glaciation, *Earth and Planetary Science Letters*, 404:154-166.
- Pollard, D., DeConto, R.M., Alley, R.B. 2015. Potential Antarctic Ice Sheet retreat driven by hydrofracturing and ice cliff failure. *Earth and Planetary Science Letters*, 412: 112-121
- Gasson, E., DeConto, R. M., and Pollard, D. 2015 Antarctic bedrock topography uncertainty and ice sheet stability, *Geophysical Research Letters*, Vol 42: 5372-5377.
- Barrett, P.J., 2013. Resolving views on Antarctic Neogene glacial history and the Sirius debate, *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, 104, 31–53, 2013.
- Griener, K.W., and Warny, S., 2015. Nothofagus pollen grain size as a proxy for long-term climate change: An applied study on Eocene, Oligocene, and Miocene sediments from Antarctica. *Review of Paleobotany and Palynology* 221:138-143.
- Lavoie, C., Domack, E. W., Pettit, E. C., Scambos, T. A., Larer, R. D., Schenke, H.-W., Yoo, K. C., Gutt, J., Wellner, J., Canals, M., Anderson, J. B., and Amblas, D., 2015. Configuration of the Northern Antarctic Peninsula Ice Sheet at LGM based on a new synthesis of seabed imagery. *The cryosphere*, 9:613-619.

- Lewis, A & Ashworth, A, 2015, An early to middle Miocene record of ice-sheet and landscape evolution from the Friis Hills, Antarctica, Geological Society of America, 128, doi: 10.1130/B31319.1.
- Teitler, L., Florindo, F., Warnke, D.A., Fillippelli, G.M., and Taylor, B., 2015. Antarctic Ice Sheet response to a long warm interval across Marine Isotope Stage 31: A cross-latitudinal study of iceberg-rafted debris. *Earth and Planetary Sciences*, 409:109-119.
- 2014
- Christner, B.C., Priscu, J.C., Achberger, A.M., Barbante, C., Carter, S.P., Christianson, K., Michaud, A.B., Mikucki, J.A., Mitchell, A.C., Skidmore, M.L., Vick-Majors, T.J. and the WISSARD Science Team, 2014. A microbial ecosystem beneath the West Antarctic Ice Sheet. **Nature** 512, 310–313, doi:10.1038/nature13667.
- Cowan, E.A., Christoffersen, P., Powell, R.D. and Talarico, F.M., 2014. Dynamics of the late Plio-Pleistocene West Antarctic Ice Sheet documented in subglacial diamictites, AND-1B drill core. *Global and Planetary Change*, 119: 56-70. doi: 10.1016/j.gloplacha.2014.05.011.
- Escutia, C., Brinkhuis, H., and the Expedition 318 Science Party. 2014. From Greenhouse to Icehouse at the Wilkes Land Antarctic margin: IODP 318 synthesis of results. In *Developments in Marine Geology 7: Earth and life processes discovered from seafloor environment*. Stein, R. (AWI/Paleoclimate), Blackman, D. (Scripps/Solid Earth), Inagaki, F. (JAMSTEC/Biosphere), and Larsen, H.-C. (IODP-MI) (Eds.): 295-328.
- Golledge, N.R., Menviel, L., Carter, L., Fogwill, C.J., England, M.H., Cortese, G. and Levy, R.H., 2014. Antarctic contribution to meltwater pulse 1A from reduced Southern Ocean overturning. **Nature Communications** 5: 5107. doi:10.1038/ncomms6107.
- Huang, X., Gohl, K., Jokat, W. 2014. Variability in Cenozoic sedimentation and paleo-water depths of the Weddell Sea basin related to pre-glacial and glacial conditions of Antarctica. *Global and Planetary Change*, 118, 25-41, doi:10.1016/j.gloplacha.2014.03.010.
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- Kennicutt, M.C., et al., 2014, Polar Research: Six Priorities for Antarctic Science, Nature, 512, 23-25, doi:10.1038/512023a.
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Appendix III: Major reports, including linkages to major SCAR activities (e.g. advice to the Treaty or IPCC)

- Lead authors for the International Ocean Drilling Program (IODP) Science Plan 2013-2023.
- Lead and contributor authors for the ERICON Science Perspective 2015-2030: Scientific Research in Polar Seas.
- Lead and Contributing Authors of 5th Assessment Report (AR5 - 2013): The Physical Science Basis. Intergovernmental Panel of Climate Change (IPCC).
- Lead and Contributing Authors of the European Science Foundation (ESF) Science Position Paper 2015 “Sailing through Changing Oceans: Ocean and Polar Life and Environmental Sciences on a Warming Planet” <http://www.esf.org/publications.html>
- Invited participation in the COP19 “Day of the Cryosphere: Climate Change Today in Polar and Mountain Regions” (7 November, 2013, Warsaw, Poland). A side activity to the United Nations Framework Convention on Climate Change.
- SCAR Lecture in PAIS topics to the Antarctic Treaty ATCM XXXVII-CEP XVII meetings (30 April, 2014, Brasilia, Brasil).
- Invited participants in the SCAR Horizon Scan retreat (21-23 April, 2014, Queenstown, New Zealand).
- Professors Martin Siegert and Tim Naish awarded the Martha T Muse Prize for Science and Policy in Antarctica in 2013 and 2014, respectively.
- Members of the Antarctic Portal Editorial Group since 2015.
- Members of the SCAR Structure Review Group (April 2015).
- A PAIS Whitepaper submitted to the Council of Managers of National Antarctic Programs (COMNAP) Antarctic Roadmap Challenges (ARC) Project considered during the ARC workshop in Tromso at the end of August 2015.
- Invited participation to the COMNAP ARC Workshop, 22-24 August 2015, Tromso (Norway).

- Scientific reviewer to the Ice Sheets - Awakening Giants chapter of the “Thresholds and Closing Windows – Risks of Irreversible Cryosphere Climate Change” Report of the International Cryosphere Climate Initiative (<http://iccinet.org/thresholds>) - ICC at COP20 Paris.
- Review of the U.S. NAS/Polar Research Board report on A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research (2015).
- PAIS membership in the EU-PolarNet External Expert Advisory Board (EEAB) (www.eu-polarnet.eu).
- Future planning for a U.S.-NERC focus on WAIS, in progress.

Appendix IV: Workshops and other key meetings organized and activities associated to major SCAR meetings (Open Science Conferences, International Symposia on Biology, Earth Sciences, etc.)

- Antarctic and Southern Ocean Drilling (PRAMSO) workshop, July 2012 (Portland, USA). Kick-off meeting for community to organize projects in the PAIS latitudinal transect strategy.
- Scotia Arc Symposium: Geodynamic Evolution and Global Implications. May, 2013 (Granada, Spain).
- Eastern Ross Sea IODP Drilling proposal writing workshop, June 2013 (St. Petersburg, USA)
- Wilkes Land Eocene Greenhouse and Greenhouse-Icehouse transition workshop, Fall 2013 (NIOZ, NL)
- MOCA Joint Model-data workshop for the Late Pleistocene evolution of the Greenland and Antarctic ice sheets LGGE, Grenoble, May 22-24, 2014
- Multiproxy approach to the reconstruction of climate of the Pliocene Workshop, Barcelona, Spain, September 2014.
- PAIS Subcommittee meetings during the SCAR OSC, Auckland, New Zealand, 2014. PRAMSO and SDLS (23 August, 2014).
- PAIS open community and Steering Committee meetings during the SCAR OSC, Auckland, New Zealand, 25 and 27 August 2014, respectively.
- PAIS Subcommittee (PRAMSO) and Town Hall meetings during the XII ISAES, Goa, India, July 2015.
- Wilkes Land & Ross Sea Oligocene ice sheet dynamics, April 2015 (NIOZ, NL).

Appendix V: Capacity building and education outreach activities; detail any difficulties encountered

- Participation in the Association of Polar Early Career Scientists (APECS) Networking Cruise for early career researchers. 26 de August 2014, Auckland, New Zealand.
- Participation in the Smart Talk speaker panel of the IceFest: Bringing Antarctica to the World. Auckland, New Zeland, 27 de Agosto 2014.
- PAIS support and participation in the “Polar Marine Diatom Workshop” Salamanca, Spain, 19th-24th July 2015. This is a training course for PhD and Master students. The workshop was attended by 45 persons of which 25 were PhD students and five were early career researchers with no permanent position. The participants represented 15 countries, with 26 from European institutions and 19 others from Australia, Japan, Republic of Korea and the USA.
- PAIS contributed funding for students and early career researchers to attend the SCAR OSC 2014 in Auckland, New Zealand.
- PAIS provided US\$10,000 funding for four students and two keynote speakers to attend the XII International Symposium on Antarctic Earth Sciences. In addition, PAIS provided US\$6000 to the XII ISAES organizers for student travel support.

- PAIS contributed co-funding and participated in the “Advanced course in organic-walled dinoflagellate cysts”, September 13-19, 2015 in Heidelberg, Germany.
- Members of the Scientific Committee for the SCAR Open Science Conference (OSC) in Auckland (NZ) 2014 and SCAR-OSC in Kuala Lumpur, Malaysia, 2016; and the XII International Symposium on Antarctic Earth Sciences ISAES 2015, Goa, India.
- Chair of the Science Support and Advisory Committee of ECORD (the European Consortium of Ocean Research Drilling) (October 2010- December 2013) and Vice-chair of ESSAC (2014).
- Co-chair of the Scientific Committee for the SCAR Open Science Conference in Buenos Aires, Argentina, 3-6 August 2010.
- Chairs of the First Antarctic Climate Evolution (ACE) Symposium, Granada, Spain, 2009.
- The Urbino Summer School for Paleoclimatology (USSP), where Antarctic climate and ice sheet dynamics has become a major segment of this highly competitive and renowned graduate-training workshop.

Appendix VI – Updated PAIS Implementation Plan. This table is updated from the original Implementation Plan.

Projects	Location	Objectives	Year	Implementation Since 2013
Current				
ANDRILL SMS & MIS	Ross Sea	Pleistocene-Miocene glacial history	2007-2008	Continue review of sedimentary cores from SMS & MIS programmes. Comparison-integration with Exp 318, ODP Legs & CRP, and available onshore data. Provide data to numerical GIA-ice sheet modelling community. 2 new papers in PNAS (Feb 2016) on Miocene ice sheet response to 400-600 ppm CO ₂ .
IODP Leg 318	Wilkes Land	Holocene to Eocene Greenhouse palaeoclimate and glacial history	2010	Continue review of sedimentary cores from Exp 318. Comparison-integration with ANDRILL, CRP, ODP Legs, and available onshore data. Work on Holocene ice-core and marine-core integration. Provide data to numerical GIA-ice sheet modeling community.
Subglacial WISSARD (LISSARD & RAGES) Drilling	Whillans Ice Stream	Marine Ice Sheet Stability and Subglacial Life Habitats in West Antarctica	2009-2015	Analyze water, sediment and geophysical data and samples collected during the 2012-2013 and 2013-2014 field seasons. Papers being submitted and others still in the pipeline (e.g.

				we have one just recently accepted for EPSL).
WAIS Divide	WAIS ice flow divide	Climate, ice sheet history and cryobiology	2010-2013	2013 field season ended: Ice cores record of past climate and greenhouse gases in the atmosphere that extends back 68,000 years. Current planning for future proposal
AGAP	Gamburtsev Mountains	Initial ice sheet formation, subglacial hydrological processes	2008-2009	Continue review of data obtained and provide data to numerical ice sheet modeling community.
Approved				
Amundsen Sea shelf - MeBo	Amundsen Sea Embayment shelf	Basic shelf stratigraphy, glacial onset, LGM retreat ages	Scheduled for early 2017	Implementation of MeBo drilling in the Amundsen Sea
Totten Glacier seismic and coring cruises (US, Italy, Spain, Australia)	Totten Glacier	Basic shelf stratigraphy, Pleistocene ice sheet dynamics, LGM retreat.	NSF cruise achieved in early 2015 Australian cruise Scheduled for early 2017	Analysis of data collected during the NSF cruise from eastern Wilkes Land dredging & Totten Glacier surveys Planning and implementation of Australian led international coring and seismic cruise to the Totten Glacier
Ross Sea seismic and coring cruises (NL, UK, Italy, NZ, South Korea) – EU/EUROFLEETS 2	eastern Ross Sea slope and rise	Basic slope and rise stratigraphy, Miocene-Pleistocene ice sheet dynamics, LGM retreat, Ross Sea Gyre along slope current, and Antarctic Bottom Water present and past dynamics.	Approved 2014 Scheduled for early 2017	Planning and implementation of the cruise to collect seismic data for IODP prop. 751 site survey
IODP 813-Full	Eastern Wilkes Land; Adélie Land & George V Land shelf	Greenhouse to Icehouse Antarctic paleoclimate and ice history from George V Land and Adélie Land shelf sediments	Scheduled for 2018 by ECORD FB	Planning and implementation of the IODP expedition
IODP 732-Full2	West of Antarctic Peninsula and Bellingshausen Sea	Sediment drifts off the Antarctic Peninsula and West Antarctica; Late Miocene to Quaternary paleoceanography & ice sheet history	At JR-FB to be scheduled	Continue fostering IODP proposal for Bellingshausen Sea drift drilling. New site survey data were collected by BAS (UK) in early 2015
IODP 751-Full2	Western-central Ross Sea	Ocean-ice sheet interactions and West Antarctic Ice Sheet vulnerability: clues from the Neogene and Quaternary record of the outer Ross Sea continental margin	At JR-FB to be scheduled	Continue fostering IODP proposal for western-central Ross Sea IODP drilling. New site survey data were collected by PNRA (Italy) and KOPRI (S. Korea) in 2014 and 2015. A new cruise is scheduled in 2016-17 with EU-Eurofleets funds.
IODP 839-Full	Amundsen Sea Embayment	Development and sensitivity of the West Antarctic Ice Sheet tested from drill records of the Amundsen Sea Embayment	At JR-FB to be scheduled	Continue fostering IODP proposals for Amundsen Sea Embayment.
Proposed				
IODP 812-Pre	Eastern Ross Sea continental shelf	“Shallow drilling in the far southeastern Ross Sea Antarctica for records of the early West Antarctic Ice Sheet”.	After review of the pre proposal, SEP has requested a full proposal to be submitted.	Continue fostering IODP proposal for Eastern Ross Sea shelf
ANDRILL Coulman High	Central-southern Ross Sea	Palaeogene to lower Miocene ice sheet behaviour &	Coulman High	Investigating other future sites

		environments during greenhouse gas levels	proposal rejected by NSF, but supported by ICDP And deactivated by IODP	to employ the ANDRILL platform (Siple Coast, Neumayer Station) Current status is that the Coulman High drilling project has been abandoned. ANDRILL Program has been closed down.
IODP 847-Full	Drake Passage	Plio-Pleistocene reconstruction of ocean, atmosphere and ice-sheet interactions through the Drake Passage	submitted Oct. 2013; deactivated by SEP in July 2015 but with strong encouragement to resubmit	Continue fostering IODP proposal for Drake Passage/Scotia Sea
IODP 848-Full	Weddell Sea	Late Neogene ice-sheet and sea-level history of the Weddell Sea	Submitted Oct. 2015 – SEP recommended revision	Continue fostering IODP proposal for Weddell Sea
IODP 861-Pre	W Antarctic Peninsula	Cenozoic formation of the Antarctic glacial landscape investigated by low-temperature thermochronometry (W Antarctic Peninsula)	deactivated by SEP in June 2014 but with encouragement to resubmit	Continue fostering IODP proposal for West Antarctic Peninsula
IODP 873-Pre	SE Pacific & southern Chilean margin	Plio-Pleistocene paleoceanography of the Subantarctic Southeast Pacific linked to Drake Passage throughflow	deactivated by SEP in Jan 2015 but with strong encouragement to resubmit	Continue fostering IODP proposal for SE Pacific; new site survey data are collected in early 2016
Planned				
IPICS "Beyond Epica: oldest ice"	Dome C, Dronning Maud Land	Deep ice core drilling to obtain the oldest ice climate record from the Antarctic Ice Sheet	-2016	A new proposal for co-funding site surveys for identifying future new drilling sites to sample oldest ice (> 1 Ma) is going to be submitted to the EU H2020 in 2016
IODP southern Indian Ocean (former IODP 824-Pre)	Conrad Rise, Del Caño Rise, South Indian Ocean	Antarctic Cryosphere and Southern Ocean Responses to Glacial-Interglacial Climate Change: Transect drilling across the Indian Ocean sector of the (ACC)	Re-submission planning	Discussion on resubmission plan will be held in Kuala Lumpur (SCAR-OSC) during the PRAMSO meeting
Rapid Access Ice Drill (RAID)	Antarctic Ice Sheet	Development of rapid access ice drill for deep drilling of basal ice sheets and sub-ice bedrock in Antarctica	First tests in 2015; expected scientific projects from 2017/18	Moving forward with testing in 2016-17. If successful it may be funded to carry on with the first scientific drilling



SCAR Scientific Research Programme
External Performance Review



Evaluation Form

for

SCAR Scientific Research Programmes (SRPs)

Note to reviewers:

When reviewing an SRP's capabilities, activities and outputs, please keep in mind that SRPs are managed by volunteers from the SCAR community and that they receive between 20,000 to 25,000 USD per year to facilitate/coordinate the activities that will allow them to fulfil their goals. Please also be aware that your reviews will be shared with the SRP chairs and the SCAR Delegates, and be made public on the SCAR website after September 2016. Your name will be kept confidential, unless you specify otherwise.

Reviewers should complete this page, expanding the text boxes where necessary, but should be kept to 3 A4 pages max. Reviews will be made public.

Name of SRP: Past Antarctic Ice Sheet Dynamics (PAIS)

Name of Reviewer (optional): _____ Ho Il Yoon _____

Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

Excellent science. The programme stimulated new important findings such as Antarctic climate condition under high CO₂ condition, importance of Antarctic ecosystem in global carbon cycle, new constrains for climate and ice sheet models, instability of EAIS and its potential to sea level change, role of Antarctic glacier in global sea level change during the last deglaciation, etc.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (<http://www.scar.org/about/futureplans/>)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. Science is excellent, and deals with important issues in upcoming high CO₂-world. PAIS-relevant works have provided scientific knowledge for the use of policy making (e.g. IPCC 5th assessment report).

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

Yes. Antarctic multichannel seismic data, provided by the SDLS, are managed well. A data library for Antarctic sediment core data is yet to be established, and it would be great if PAIS would start a discussion on how to build that kind of data library.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes. PAIS members have been involved in numerous communication activities.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes, it is. The programme supports student to participate in conferences and training courses.

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Modestly. It is appreciated that the programme has invested a lot to help young scientists participate in Antarctic research community. It is less clear if the programme contributed to build the capacity of countries with less well developed Antarctic programmes.

Value for Money. Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

Excellent. PAIS helped international collaboration and publication of excellent papers by supporting key meetings. Antarctic drilling projects would have been less well-organized without PAIS meetings.

Terms of Reference. To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

I feel the SRP meet the criteria very well.

Reviewers should complete this page, expanding the text boxes where necessary, but should be kept to 3 A4 pages max. Reviews will be made public.

Name of SRP: Past Antarctic Ice Sheet Dynamics (PAIS)

Name of Reviewer (optional): Eugene W. Domack, PhD

Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

I have a difficult time evaluating a list of publications which are simply efforts that would have taken place anyway, the quality of the science in these publications is very high to excellent, but that perhaps is not the point for evaluation. What should be assessed is what role PAIS played in fostering the publications—synergizing the effort. A difficult parameter to quantify but some thought needs to go into this by the SCAR so that it is clear what is being produced by PAIS and what is simply being cataloged. This concern is relevant for the following reasons:

- 1) Several papers listed under primary publications actually have no members on the PAIS committee-- so it is difficult to see how these can be termed as PAIS contributions, most of the papers were initiated as observational concepts and planning well before PAIS was even established.
- 2) The NBP14-02 cruise is listed as a PAIS initiative, yet none of the PIs on this NSF funded expedition were ever contacted or consulted about the relevance of the work to the PAIS – nor are they listed in any of the committees or programs,, so it is hard for me as a reviewer to accept this as proof of an actual PAIS project—it may indeed be relevant but how can PAIS be credited for it?
- 3) Totten 2017 Australian cruise more a collaborative effort with the USAP Totten project than PAIS, although I note two participants are on the PAIS team.
- 4) Most of the activities in the projects list are basically repeating efforts of IODP system but plugged into SCAR? Seems like repeating efforts.
- 5) LARISSA is one of the more integrated ice sheet shelf studies yet undertaken with international (KOPRI, UKRAINE, UK, AUST) partners yet there is absolutely no mention of this program,, which is still on going at least till 2017. Yet some publications by this group are included under the PAIS publications list. Why is this?

A clearer record of actual deliverables is needed by this group actual accomplishments need to be demonstrated.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (<http://www.scar.org/about/futureplans/>)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

See above comments on deliverables and relevance.

Yes

Yes very relevant, to goals of SCAR, but the recommendations for “way forward “ are written by the very committee chairs that serve SCAR so it is a bit self-serving in that regard, goals should focus on actual national programs recommendations.

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

Yes

Although I do not think that this is relevant since the projects under the PAIS initiative have their own data archiving requirements.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

No

The PAIS committee needs to do a better job of reaching out to non-committee members for input and recognition of contributions,, many folks out there produce the primary data and this group seems like a sweep of that data to the overarching of these more basic hard fought field and laboratory programs.

If PAIS wishes to include projects under their umbrella then they need to reach out to the folks that actually do all the heavy lifting in these peripheral projects.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Fine no issues here.

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Not sure about this it seems to have reached those programs that are basically established or with deep resources but has ignored those nations that are basically struggling along.

Value for Money. Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

Good value,

Terms of Reference. To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

They have met the Terms of Reference

Reviewers should complete this page, expanding the text boxes where necessary, but should be kept to 3 A4 pages max. Reviews will be made public.

Name of SRP: Past Antarctic Ice Sheet Dynamics

Name of Reviewer (optional): _____

Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

Excellent. The quality of the research by members of the PAIS community is reflected in the stature of journals and diversity of publications around common themes, as well as topics more broadly related to Antarctic ice sheet history and dynamics. A review of the author lists of the publications listed in their report shows a high proportion with contributing authors from multiple SCAR member nations. These publications range from review papers summarizing the state of current understanding based on efforts by individual researchers from many countries, to results from field-based efforts focused around multinational coring projects. Additionally, it is clear that there is a strong and productive connection between modeling and field/lab based researchers that has pushed both groups to test new hypotheses/approaches and drive the science forward to address societally relevant questions. Undoubtedly, there is room for improvement to include valuable contributions from more individuals from more member nations, particular countries with emerging Antarctic research programs. This can likely be promoted through the range of activities already supported by PAIS including meetings, sessions, fellowship programs and student training programs.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (<http://www.scar.org/about/futureplans/>)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. The research focus areas highlighted in the PAIS report are important, relevant *and* timely. As we see Earth's environment diverging from patterns of recent history (last million years) into a different climate regime outside of the norm for the Quaternary, it is imperative to look to times in the more distant geologic past that are most comparable. Such research efforts provide critical context to create a framework of understanding what environmental changes are possible in the coming centuries-millenia. Similarly, the consequences of rapid sea level rise are extraordinary in their potential impact on humans and so developing additional constraints and predictions on rates of sea level rise is vital. It would seem to benefit PAIS to continue cooperative international efforts around the continent, emphasizing the clear need for both terrestrial and marine data that can constrain models for both the most recent deglaciation, as well as times of higher CO₂. Previous research focus on the last glacial period has taught the community many lessons on the exceptional value of a dynamic connection between field and modeling-based studies. It may be useful to create a subcommittee to identify and promote research in areas of critical data-modeling gaps. Additionally, it may be valuable to build connections with the Arctic research community with knowledge of topics such as permafrost to promote understanding of analogues of a warmer time. Finally, and importantly, PAIS contributions to the IPCC AR5 report highlight the value of focusing on Antarctic ice sheet reconstructions (data and models), particularly for the context they provide in understanding future warming scenarios and ice sheet sensitivity.

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

Yes. The seismic data library (SDLS) is an excellent archive and resource. I would encourage

ongoing efforts to engage with the scientific community using these resources to continually improve functionality. The PAIS community may also consider exploring opportunities to link to new databases for terrestrial records & chronology.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes, but it seems that this area needs continued effort to keep it current. PAIS has been involved with excellent outreach activities (i.e., Exploratorium, ANDRILL & IODP fieldwork blogs), but these projects seem to be finished and it's unclear what new efforts are underway to communicate ice sheet science beyond media interviews related to specific projects and presentations at conferences. It may be useful for a subgroup of the Steering Committee to identify educational opportunities related to approved field-based programs or other media-friendly research efforts.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes. Significant funding has been provided to support travel for students and early career scientists to attend both courses and conferences. This seems to reach students from a wide variety of countries, and as such helps meet the strategic mission of SCAR. Does PAIS co-sponsor the SCAR Fellowship Scheme or could it sponsor one additional fellowship to specifically promote ice sheet research?

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Yes, PAIS has contributed toward capacity building, primarily by supporting travel to meetings/workshops. It would have been helpful to see some statistics on how funds have historically been utilized by member countries to determine whether there is a need to improve the balance of spending. My rating is here is 'modestly', as I suspect there is room for improvement in this area. Many of the activities detailed in the report are carried out by a subset of the community and it would be useful to explore ways to expand opportunities for and contributions by more scientists. Does PAIS have a clear mechanism to promote the SCAR Fellowship and Visiting Professor schemes? Additionally, it seems there could be improvements to encouraging involvement by more scientists with PAIS. The report states there are 208 scientists on the mailing list, but a visit to the PAIS website doesn't indicate that there is a mailing list, nor provide any information on how one might add their name to it. Hopefully such simple changes can encourage more inclusive participation.

Value for Money. Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

It is unclear exactly how the total funds have been spent each year to get a sense of how the money has been distributed (by event, by career stage and by country), but based on the items detailed in appendices IV and V, it seems that the choices the PAIS steering committee is making are excellent investments. PAIS is supporting a variety of activities to promote the exchange of ideas by organizing meetings/workshops and by supporting individual travel to meetings/courses. This is in keeping with the SCAR strategic plan and objectives of PAIS.

Terms of Reference. To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

Some of the items in the Terms of References are difficult to evaluate (i.e., response to requests from the Exec. Committee) because of a lack of information related to those topics in the report. Based on the terms which can be evaluated based on the report, it appear that PAIS has satisfactorily fulfilled its obligations.

Reviewers should complete this page, expanding the text boxes where necessary, but should be kept to 3 A4 pages max. Reviews will be made public.

Name of SRP: PAST ANTARCTIC ICE SHEET DYNAMICS (PAIS)_____

Name of Reviewer (optional): **Professor Dominic A Hodgson (BAS, UK)**_____

Science quality. Recognising that the national/international science on which the research was based has already been peer-reviewed, do the scientific highlights and published papers indicate that the internationally collaborative research stimulated by the programme has produced science that is excellent, good, or fair? (please provide a brief justification for your choice).

The science quality of ACE has been maintained and developed through PAIS and remains excellent with publications in top discipline and leading science journals. The steering committee contains a good mix of very senior and experienced leaders and mentors and energetic mid-career researchers. The interaction between the modeling and geological data components is particularly encouraging, and has led to the formation and testing of well developed hypotheses.

The policy relevance of the PAIS research is best demonstrated at an international level by its contributing authors on the IPCC and the examples given of statements in AR5 underpinned by PAIS activities.

Suggestions: Include additional early career researchers on the steering committee to ensure a leadership succession plan is in place.

Science importance/relevance/timeliness. Has the work advanced scientific understanding and been in accordance with the SCAR Strategic Plan (<http://www.scar.org/about/futureplans/>)? (Yes or no; please provide a brief explanation for your choice). Are there important gaps currently not considered by the SRP? (If yes, please provide a brief description)

Yes. The work done by PAIS is highly relevant and of critical importance to society. It encompasses two grand challenges: (1) Understanding how the Earth will operate in a higher CO2 world and (2) predicting the magnitude and rate of global sea level change from ice sheet loss over the coming decades to centuries. Leading researchers are engaged and most National Antarctic Programmes recognise these challenges as central to their mission. National funding agencies are responding varying degrees and members of PAIS are lobbying hard to ensure a more coordinated international funding effort.

Suggestions:

1. Work with CONMAP to ensure research access to key marine-based areas of the Antarctic Ice Sheet is within scope for the next decade.

2. Continue to lobby funding agencies (including IODP) to develop multinational research efforts on the most vulnerable parts of the ice sheet (e.g. Thwaites, Totten).
3. Seek to replicate and validate recent studies that have potentially wide implications (e.g. Weber, et al. 2014, Golledge et al., 2014), and find geological analogues for threshold states in ice sheet response (e.g. ice margin cliff failure; Pollard et al., 2015).
4. Develop an aspirational horizon-scan of transformational geoscience priorities over the next 10-20 years (e.g. McKay et al 2016). Start to develop the geophysics campaigns that will underpin these (e.g. Byrd subglacial basin, former transantarctic seaways, continental shelf and deep ocean records).

Data archival and access. Is the programme adequately addressing the issues of data archiving and data access, and are its data accessible to the wider community? (Yes or no; please provide a brief explanation of your choice).

Yes – the report shows that PAIS researchers are committed to depositing data in open access portals and repositories. Investment by NAP's in data management and data managers (in particular) remains variable in the present financial climate and continued vigilance by the SCAR community is required.

Communication activities. Are the communication activities of the SRP contributing to the promotion of SCAR and its mission? (Yes or no; please provide a brief explanation of your choice).

Yes – the PAIS SRP includes a number of excellent communicators. There is an appropriate mix of outreach and within discipline activities in the report.

The PAIS symposium in Trieste will be a valuable opportunity for early career researchers to bring their research and ideas forward, and engage the emerging Antarctic programmes.

Education. Is the work contributing to education about Antarctic science? (Yes or no; please provide a brief explanation of your choice).

Yes – plenty of good examples provided in the report. Not included, but reaching a wide younger audience are activities such as the 'Antarctica: Explorers Heroes Scientists' exhibition at Durham University (UK) which highlighted PAIS activities.

Building capacity across all SCAR Member countries. Has the programme contributed to building the capacity of countries with less well developed Antarctic programmes and/or early career scientists a lot, modestly, little, or not at all? Keeping in mind that there are various difficulties in this area, e.g. depending on the current interest of science topics in certain countries, please provide a brief explanation of your choice.

Yes – my impression is that PAIS is very inclusive. The PAIS symposium will offer an additional opportunity to invite and provide bursaries for new researchers to join the PAIS research effort.

Value for Money. Considering that SCAR is only able to invest ~20,000-25,000 USD per year in each SRP, do the results indicate excellent/good/fair/poor value for money (please provide a brief justification for your choice)?

One can only conclude that PAIS represents excellent value for money for SCAR – demonstrating a remarkable leverage of the SCAR investment into grants from the national funding agencies.

Terms of Reference. To what extent do you feel the SRP has met the Terms of Reference (provided on the following page).

The PAIS SRP is meeting these objectives and is rising to the challenge of operating in the current restricted financial climate. In most cases NAP's are no longer able to address the grand challenges other own and PAIS and the other SCAR SRPs are engaged in promoting renewed international cooperation.



Past Antarctic Ice Sheet Dynamics (PAIS)

The science quality of PAIS remains excellent with publications in top discipline and leading science journals. Plans address two important grand challenges: (1) Understanding how the Earth will operate in a higher CO₂ world and (2) predicting the magnitude and rate of global sea level change from ice sheet loss over the coming decades to centuries. It is clear that there is a strong and productive connection between modeling and field/lab based researchers that has pushed both groups to test new hypotheses/approaches and drive the science forward to address societally relevant questions.

The steering committee contains a good mix of very senior and experienced leaders and mentors and energetic mid-career researchers. The interaction between the modeling and geological data components is particularly encouraging, and has led to the formation and testing of well developed hypotheses.

PAIS contributions to the IPCC AR5 report highlight the value of focusing on Antarctic ice sheet reconstructions (data and models), particularly for the context they provide in understanding future warming scenarios and ice sheet sensitivity.

The linkage through PAIS with the IODP and its future plans is important for SCAR and continued collaboration between PAIS and IODP is encouraged.

The PAIS presence in organising meetings and sessions in relevant SCAR and external international meetings is commendable, and contributes to the external visibility and opportunities for involvement of new scientists.

The PAIS symposium in Trieste will be a valuable opportunity to bring research achievements and move ideas forward, and engage the emerging Antarctic programmes. It will be a particularly good opportunity for early career scientists to be involved in.

PAIS represents excellent value for money for SCAR – demonstrating a remarkable leverage of the SCAR investment into grants from the national funding agencies.

PAIS Recommendations:

- PAIS may want to consider including additional early career researchers on the steering committee to ensure a leadership succession plan is in place.
- PAIS should consider working closely with CONMAP, through SCAR, to ensure research access to key marine-based areas of the Antarctic Ice Sheet is within scope for the next decade.
- PAIS should continue to lobby funding agencies (including IODP) to develop multinational research efforts on the most vulnerable parts of the ice sheet (e.g. Thwaites, Totten).
- PAIS may want to consider replicating and validating recent studies that have potentially wide implications (e.g. Weber, et al. 2014, Golledge et al., 2014), and find geological analogues for threshold states in ice sheet response (e.g. ice margin cliff failure; Pollard et al., 2015).
- PAIS may want to lead a follow up on the Horizon Scan, focused on transformational geoscience priorities for the next 10-20 years (e.g. McKay et al 2016) and then start to develop the geophysics campaigns that will underpin these (e.g. Byrd subglacial basin, former transantarctic seaways, continental shelf and deep ocean records).

- PAIS may want to consider adding outreach activities such as the 'Antarctica: Explorers Heroes Scientists' exhibition at Durham University (UK) which highlighted PAIS activities, to their report.
- PAIS should continue its cooperative international efforts around the continent, emphasizing the clear need for both terrestrial and marine data that can constrain models for both the most recent deglaciation, as well as times of higher CO₂.
- It may be useful for PAIS to create a subcommittee to identify and promote research in areas of critical data-modeling gaps.
- PAIS might consider building connections with the Arctic research community with knowledge of topics such as permafrost to promote understanding of analogues of a warmer time.
- PAIS should continue its efforts in contributing to the seismic data library and may want to consider exploring opportunities to link to new databases for terrestrial records & chronology.
- PAIS may want to explore continuing some of the great outreach efforts that seem to have ended (ANDRILL, Exploratorium, etc.) or finding new partners who are doing similar outreach activities.
- PAIS and SCAR may want to consider finding sponsors for an Ice Sheet Fellowship for early career researchers.
- PAIS should update its website to include information on how to join the mailing list.
- PAIS should review their publications list to make sure that what is listed would not have happened without PAIS / SCAR support.
- There is scope for improvement in communications and engagement of scientist in countries with small Antarctic research programmes.
- PAIS may want to consider reaching out to the broader scientific community, particularly to those who collect the data that is used in PAIS analyses to help strengthen the efforts of both groups.
- PAIS may want to consider starting discussions to establish an Antarctic sediment core database.
- PAIS should recommend to its members to mention in their publications that a paper is a contribution to the SCAR PAIS SRP.
- PAIS should consider adding information on how the SRP funding was distributed in terms of countries, career levels, and events.



Recommendations for all SRPs and/or SCAR

The following are recommendations arising from the 2016 SRP External Review Process that apply to all SRPs and/or SCAR as a whole:

- Given that SRPs are intended to be finite in duration, it would be useful to identify some key outputs that can be put forward to summarize progress achieved, for example “We now have sufficient information on x to support robust conservation and management of this component of the Antarctic ecosystem. Document y assembles all the relevant information. SCAR can now focus on other priorities”. Along this line, all SRPs should consider putting an emphasis on synthesis of the information collected thus far and have such a paper/product result in the completion of their programme.
- All SRPs should consider assessing the impact of their research by having some additional summary statistics, such as a list of paper citations, or impact factors of the journals where publications have been accepted which could be a useful metric to assess science quality in future reviews.
- All the SRPs should recommend to their members to mention in their publications that the paper is a contribution to the SCAR xxxxx SRP.
- All SRPs should somehow document which of their achievements are directly resulting from the SRP and would not have happened otherwise.
- All SRPs should improve their engagement with scientists from less well-developed Antarctic programmes. Collaborations in Asia, Scandinavia, Africa and South American are particularly important to increase. To help assess current engagement, SRPs should create a graph of the distribution of people involved from various SCAR member countries.
- It is recognized that the SRPs establishment was prior to the SCAR Science Horizon Scan. However, SRPs might want to consider mapping their activities to Horizon Scan questions and including this information on their websites and make sure it is included in all Horizon Scan follow-ups/accomplishment reports.
- Support for early career scientists should involve some kind of ‘feed-back’ to their home countries, the larger early career and science community and/or other ‘outreach’ efforts. This could include a presentation to their home department when they return, a report to their National Committee, a webinar, or another activity to share their experience with the wider community
- The SRPs are encouraged to contribute to reinforce the linkages of SCAR with the IPCC and the future Special Reports.
- The SCAR Social Sciences groups could potentially consider doing case studies detailing how the science community was coordinated through the SRPs, if goals were met, what lessons might be learned, and detail examples of management/policy outcomes that were based on work arising from the SRP.
- SCAR should do better at showcasing the results of the SRPs and recognizing the amazing voluntary efforts of their many participants and the amount of in-kind contributions from participating institutions.
- SCAR as a whole, should have a real communication strategy for major publications and scientific outputs, including the outputs of the SRPs. This includes a more standardized format for the SRPs

that meet the needs of the programmes and help to showcase their efforts. Including metrics of hits for various programmes on webpages and social media channels would be useful to assessing reach of content.

- All SCAR groups, including the SRPs, should be reminded that acknowledging SCAR in publications is important. SCAR may wish to develop a standard statement that groups could use to help showcase publications that would not be possible without SCAR support. In a similar vein, when groups report publications they should highlight how papers advance the objectives of the programme, or listing them under the objectives to which they are targeted may also be useful for tracking progress.
- SCAR needs to define how publications can be attributed to a SCAR SRP, and which publications would have not been possible without SCAR involvement/endorsement. In the same vein, SCAR should set up a reference collection 'facility' to showcase all publications attributed to SCAR activities. This should also include non-technical publications.
- SCAR may wish to have a more detailed list of where all its data are stored and a contingency plan for maintaining the data in case current funding decisions are reversed.
- There is great value in SCAR's small contribution to these SRPs, which can often provide incentive funds to bring scientists together and it is essential that this be continued. SCAR Members are asked to continue to advocate for the support of SCAR efforts, particularly because few national funding sources allow for international collaborations such as those offered through SCAR activities.



Scientific Research Programmes

Antarctic data management evaluation

General comments

The Antarctic Treaty System offers a clear statement on data. “*Scientific observations and results from Antarctica shall be exchanged and made freely available (Art. III).*”

Even at the level of ICSU the need for free and open access is becoming increasingly recognized. See “Open data in a big Data world”. SCAR through the Standing Committee on Antarctic Data management has developed the SCAR Data and Information Management Strategy (DIMS). A principal component of this is the Antarctic Data Management System (ADMS) which is composed of The Antarctic Master Directory (AMD) and The National Antarctic Data Centres (NADCs). The Antarctic Master Directory is part of NASA’s GCMD.

While overall the different research programs show good intent on making data and metadata available (through the AMD), this is not achieved in a consistent manner. Showing ample room from improvement.

It is clear all SRP’s could be more aware of the SCADM and the ADMS. In regards to the overall reporting on data activities It would be good to have a more detailed description of how data feeds into the AMD as well as an overview of the records that belong to a specific SRP. This is a task that needs to be addressed by the SRP’s and SCADM in collaboration.

For this purpose it would be good if all SRP could interact with SCADM during the upcoming SCAR OSC conference in Kuala Lumpur.

The SCADM joint meeting takes place on the 19th and 20th August. SRP’s are invited to participate in this meeting (the 20th is probably of most interest). The meeting is open but notification of who will participate is mandatory. For this the SCADM Chief Officer can be contacted (avandeputte@naturalsciences.be or antonarctica@gmail.com). We believe that participation to this meeting would held SRP’s better understand SCAR DIMS and how to use it for improving the visibility of the research and data of their SRP.

Evaluation of the individual reports.

SERCE (score: B)

No section on data management, no mention of the AMD. Nevertheless Data archiving & exchange is mentioned for instance in a 2015 workshop.



PAIS (score: A)

PAIS has a section on data management and they provide an overview of a number of domain specific data repositories. Metadata is not always put into the AMD directly by these repositories (Pangaea, IODP). But for instance IPEV IMAGES is part of GCMD and will as such feed into the GCMD. No concrete overview of which metadata was made available and national repositories are just briefly mentioned.

***AntarcticClimate21* (score: A)**

AntClim21 has a section on data management. It seems metadata and data is not yet made available but would be in future. No Mention of the AMD specifically but they would be using SOCCOM. SOCCOM contributes to SOOS (which is a SCAR data product), and as such this also to the AMD.

AntEco (score: A)

AntEco has a section on data and metadata, no mention of the AMD specifically, but data is fed into the biodiversity.aq, a SCAR data product that feeds into the AMD. However there is no outlined protocol. Some specific contributions are listed.

AnT-ERA (score: A)

AnT-ERA has a section on data management and they provide an overview of a number of domain specific data repositories. Not all of these feed into the AMD though.

Kind Regards

Dr Anton P. Van de Putte On behalf of SCADM

Dear Jenny,

The current (and ex-officio) PAIS co-chairs have read the SRP reviews and the overall recommendations to all SRPs. As you know, the referee's overall response to PAIS activities was very positive, but they did make a few excellent recommendations. We offer the following responses to the points/recommendations raised. Comments from the review are in black and our responses are in blue. Let us know if you have any further questions or need anything else from us.

Best,

Laura, Tim, Carlotta, and Rob

- PAIS may want to consider including additional early career researchers on the steering committee to ensure a leadership succession plan is in place.

PAIS is currently planning an international conference, to be held in Trieste, Italy in early September, 2017. This will be a great place to recruit new talent. Rob McKay (New Zealand) has recently joined the PAIS leadership team, which is a great addition. We have identified additional early career talent that will be recruited as potential steering committee members. These names represent good national and gender balance and include: Molly Patterson (US), Lara Perez (DEN), Nick Gollidge (New Zealand), Tina Van der Flierdt (UK), Frank Nitsche (US), Paolo Stocchi (NED, IT), Lauren Simkins (US), and Florence Colleoni (IT).

- PAIS should consider working closely with CONMAP, through SCAR, to ensure research access to key marine-based areas of the Antarctic Ice Sheet is within scope for the next decade.

PAIS leadership is currently discussing this issue. The EUROFLEETS project provides one possible model <http://www.eurofleets.eu/np4/14>, but applied to the Antarctic margin and including non-European vessels. We will ask COMNAP to discuss this within the national agencies that are managing the polar vessels and ice breakers. One option might include the sharing of ship time for international initiatives, every year for the next 5-10 years. PAIS can develop a map showing areas of key interest, in light of the PAIS concept of continent-to-deep ocean transects, to help identify key science opportunities where ice-breakers are likely to be operating. For example, this might include: Ross Sea (NBP Palmer, ARAON, ODEN, Chinese vessels); Amundsen Sea (NBP Palmer, ARAON, ODEN, Polarstern); Weddell Sea and Scotia Sea (Polarstern, ODEN, new UK polar vessel, new Norwegian ice breaker, and possibly a Spanish vessel); Totten margin (NBP Palmer, Investigator Australian vessel, French military polar vessel, and possibly others from Japan). An example of this model would be the use of the ARAON for supporting the IODP expeditions in the Ross Sea (in 2018) and in the Amundsen Sea (in 2019). Furthermore, shallow drilling using the rockdriller or the MeBo on these vessels would further support PAIS science.

Through its subcommittee PRAMSO, PAIS has been instrumental in identifying key sites for future drilling requiring access to both the continental rise and margin as well as through ice shelf and ice sheet. PRAMSO has helped co-ordinate a series of proposals within IODP to access open ocean sites in the Ross Sea, Amundsen Sea, Wilkes Land margin and Peninsula. Three of these have been scheduled for drilling between 2018 and 2019. The suggested co-ordination with ice breakers through national Antarctic programmes and agencies will be key to enable the Joides Resolution to undertake its Antarctic expeditions, and will limit risk of these expeditions being jeopardized through lack of costly ice breaker support. PAIS leadership have also had input into the CONMAP process of identifying logistical requirements to support the science priorities in the SCAR Horizon Scan. These include over-snow traverse capability, ice breakers, research vessels and logistical and drilling technologies to recover geological records at the base of the ice sheet and sedimentary records beneath the ice shelves (e.g. Siple Coast). Additionally, a co-ordinated logistics effort between NERC and NSF is focusing international

efforts in the Thwaites region of West Antarctica. PAIS will endeavour to continue supporting and coordinating international community research efforts there- including opportunities for coastal ice coring and sub ice geological records.

- PAIS should continue to lobby funding agencies (including IODP) to develop multinational research efforts on the most vulnerable parts of the ice sheet (e.g. Thwaites, Totten).

Agreed. This is already happening through the workshop “Antarctica’s Cenozoic ice and climate history: New Science and new challenges of drilling in Antarctic waters”, held at IODP-Texas A&M University College Station (TX, USA) on May 9th-11th, 2016. The workshop was organized by T. Williams (TAMU, USA) and some of the proponents of the IODP proposals that are approved or in review by IODP. Funds came from USSSP, MagellanPlus and ANZIC and also PAIS contributed to cover some expenses of one student and one scientist to attend the workshop. The participants were 84 (65 from USA, 15 from Europe, 4 from the rest of the world) of which 52 were senior scientists, 8 early career scientists, and 24 students. The workshop was also aimed at producing a report to the Joides Resolution facility board, that met the week after the workshop for deciding the 2018-19 scheduling. The report highlighted the scientific relevance of the three IODP drilling proposals (Ross Sea, Amundsen Sea and Antarctic Peninsula-Bellingshausen Sea) that are at the facility board. The report also contained information about the best weather/sea ice windows for each proposed expedition. The workshop was hugely successful- the three proposals are now scheduled for 2018 (Ross Sea), 2019 (Amundsen Sea) and 2020 (Antarctic Peninsula-Bellingshausen Sea).

Furthermore PAIS’ participation in the “How Much, How Fast” science plan recently submitted to NSF and facilitation of a possible US-NERC partnership, targeting Thwaites (also with PAIS input via DeConto/Bentley/Siegert).

The Australian cruise in 2017 on the Totten Glacier margin will involve Italian and Spanish scientists/technicians. PNRA has also established specific calls for proposals (every ~two years) that allow Italian scientists to participate as partners on international projects (already funded by other countries). These types of proposals are funded up to the ~200k Euro level, and the funds can be used for all sort of expenses, including logistics. We may ask other countries to adopt this model, to help stimulate new international projects. The PAIS conference in Trieste will undoubtedly generate new ideas, and the next step will be to lobby for funding.

Geological drilling from ice platforms (ice shelf ice sheet e.g. ANDRILL and RAPID) are also required to constrain minimum extents of ice retreat during warmer than present interglacials (e.g. MIS 5e). PAIS has been asked to help oversee residual funds and assets from the ANDRILL Program as it helps develop new research consortia.

- PAIS may want to consider replicating and validating recent studies that have potentially wide implications (e.g. Weber, et al. 2014, Golledge et al., 2014), and find geological analogues for threshold states in ice sheet response (e.g. ice margin cliff failure; Pollard et al., 2015).

This science is already underway and PAIS will continue to encourage and support those involved. The topic of “thresholds” could be the focus of future PAIS sessions at international symposia (AGU/EGU) and of course Trieste.

The rationale for initiatives discussed above is driven very much by the need to validate the processes and dynamic responses of the Antarctic ice sheet implied by the latest model simulations. It is recognized that the models are well ahead of the data community asking questions that will guide future drilling and geophysical campaigns.

- PAIS may want to lead a follow up on the Horizon Scan, focused on transformational geoscience priorities for the next 10-20 years (e.g. McKay et al 2016) and then start to

develop the geophysics campaigns that will underpin these (e.g. Byrd subglacial basin, former transantarctic seaways, continental shelf and deep ocean records).

This continues to happen through the active PRAMSO subcommittee and will be the focus of workshops associated with the Trieste meeting.

- PAIS may want to consider adding outreach activities such as the 'Antarctica: Explorers Heroes Scientists' exhibition at Durham University (UK) which highlighted PAIS activities, to their report.

This is a great idea. We fully acknowledge that some education/outreach infrastructure has been lost with the end of ANDRILL. New Zealand in particular is developing new outreach activities (e.g., Antarctic Time Travel Exhibition), that have the potential to travel to other international venues.

- PAIS should continue its cooperative international efforts around the continent, emphasizing the clear need for both terrestrial and marine data that can constrain models for both the most recent deglaciation, as well as times of higher CO₂.

This is happening, as evidenced by PAIS input in the recent US NAS report on "A Strategic Vision for NSF Investments in Antarctic and Southern Ocean Research", and the recent Texas A&M IODP workshop report (May, 2016) outlining the importance of these scientific targets. In fact a small US-NZ-Italian permafrost drilling project will be undertaken this summer to link key records of middle Miocene terrestrial glacial and climate variability from the Transantarctic Mountains (Friis Hills) with the marine records (e.g. ANDRILL 2A, IODP) and models (e.g. Gasson et al; Levy et al. papers in PNAS 2016). The relationship between the terrestrial and marine Neogene records has long been a source of controversy and is critical for resolving Antarctic ice-sheet sensitivity to CO₂ concentrations in the range of 400-600ppm.

- It may be useful for PAIS to create a subcommittee to identify and promote research in areas of critical data-modeling gaps.

PAIS was founded on the concept of data-model linkages. This is the foundation of all PAIS activities, but this could certainly be the topic of a special breakout group at Trieste.

- PAIS might consider building connections with the Arctic research community with knowledge of topics such as permafrost to promote understanding of analogues of a warmer time.

This is also beginning to happen, for example through connections to Lake Elgygytgen science. Julie Brigham-Grette (Lake Elgygytgen PI) and other Arctic scientists will be invited to Trieste to lead a session or breakout on bi-polar linkages. There are also some recent findings/studies about permafrost below the ice sheet that we hope to have represented at the conference. Gas hydrates in slope areas of the margin (well known in the Norwegian margin for example) also remain understudied. Their stability and relationship with past changes in sea-level, could be a good target for PAIS. In addition, two IODP MSP expeditions, one in the Arctic and one in the Antarctic margin, are scheduled for 2018. We will invite the co-chiefs of both expeditions in the PAIS 2017 Trieste conference, to give talks and lead a plenary discussion on scientific linkages between the two projects, expected results, and their follow up.

- PAIS should continue its efforts in contributing to the seismic data library and may want to consider exploring opportunities to link to new databases for terrestrial records & chronology.

The lack of consistency of countries and programmes submitted data to the ASDL is currently an issue that the ASDL group are grappling with. This is potentially a huge resource to PAIS, but

over recent years the library has suffered from resource issues, and nations not paying their annual fees. The ASDL group will meet in Kuala Lumpur in 2016 (before the SCAR-OSC) and then also in Trieste in 2017 and PAIS will be well represented in discussions of its future.

- PAIS may want to explore continuing some of the great outreach efforts that seem to have ended (ANDRILL, Exploratorium, etc.) or finding new partners who are doing similar outreach activities.

This is great in principle, but the required financial resources might be beyond the scope of a SCAR SRP. Collaboration with New Zealand's "Antarctic Time Travel Exhibition" might be a good place to start building new partnerships.

- PAIS and SCAR may want to consider finding sponsors for an Ice Sheet Fellowship for early career researchers.

This is an excellent idea, and will be discussed by PAIS leadership. In the meantime, PAIS will continue to support a few competitive fellowships for attendance at the Urbino Summer School, and perhaps Hans Oerleman's Karthaus Summer School and/or the International Summer School in Glaciology.

- PAIS should update its website to include information on how to join the mailing list.

Agreed. This will be done.

- PAIS should review their publications list to make sure that what is listed would not have happened without PAIS / SCAR support.

This is a tricky issue, because the indirect, trickle-down, intellectual impact of ACE and PAIS over the years has helped to push the community to think about the science in a new, PAIS framework (model-data-continent-deep sea). It can sometimes be difficult to draw the line in terms of which research outcomes were "influenced" by the legacy of ANTOSTRAT, ACE and PAIS. With that said, we agree that PAIS should (and will) reappraise its list of publications. Conversely, some researchers and programmes, while not necessarily a consequence of PAIS, find it very useful to be aligned or associated with PAIS. PAIS is open to all Antarctic paleoclimate research groups, and certainly does not want to take credit for their outputs, but were possible PAIS facilitates and promote their efforts.

- There is scope for improvement in communications and engagement of scientist in countries with small Antarctic research programmes.

Agreed. PAIS will allocate some travel funds to scientists from "under-represented countries" to attend the Trieste conference in 2017. In addition, there are current negotiations with ICTP <https://www.ictp.it/> to be involved in the organization of the conference. Another idea is to organize a short course at ICTP training (during the week before and/or after the PAIS conference) for students and early career scientists from those under-represented nations. ICTP funding can be used to pay for scientists (who already plan to attend the PAIS conference) to arrive and stay in Trieste for a few extra days to teach polar science. The students and early careers scientists attending the ICTP short course will also attend the PAIS conference and workshops, with undoubtedly many new ideas to bring back to their home institutions.

PAIS may want to consider reaching out to the broader scientific community, particularly to those who collect the data that is used in PAIS analyses to help strengthen the efforts of both groups.

Our tight links with the IODP community is a good example of the importance of this, but we recognize a need for better integration with other communities, particularly the ice-core, physical oceanographic, climate dynamics, subglacial geophysics and remote sensing communities. One

way to improve this will be through changes in the make up of the PAIS steering committee, possibly including the addition of Massimo Frezzotti (ice cores), and Anna Whalin (oceans). A major focus of the Trieste meeting will be to invite representatives from other communities in order to improve cross fertilization. This was a particular success of the previous ACE conference held in Granada, Spain, where the paleoceanographic community become much better integrated with the Antarctic paleoclimate community.

- PAIS may want to consider starting discussions to establish an Antarctic sediment core database.

PAIS is discussing this issue with Maureen Raymo (director of the core repository at Lamont).

- PAIS should recommend to its members to mention in their publications that a paper is a contribution to the SCAR PAIS SRP.

Easily done and an excellent suggestion. Some language will be added whenever financial support is given to a group/student/scientist, etc. for travel, fellowships, etc., that they should consider acknowledging SCAR-PAIS support.

- PAIS should consider adding information on how the SRP funding was distributed in terms of countries, career levels, and events.

This is a straightforward recommendation and will be a future “book-keeping” activity for the new PAIS co-chairs.