SCAR Executive Committee Meeting 2019

Plovdiv, Bulgaria, 29-31 July 2019

Past Antarctic Ice Sheet Dynamics (PAIS)

2018-19 Report

Report Author(s)

Tim Naish (NZ)
Laura De Santis (Italy)

Summary

The Past Antarctic Ice Sheet (PAIS) programme aims to improve understanding of the sensitivity of East, West, and Antarctic Peninsula Ice Sheets to a broad range of climatic and oceanic conditions and to improve confidence in predictions of ice sheet and sea level response to future climate change and ocean warming.

PAIS has delivered above expectation with respect to the implementation plan, and is now completing final products, which are outlined further in this report. Following a very successful strategic planning workshop in Trieste, Italy, in 2017 the PAIS community have produced a strategic White Paper (http://www.scar-pais.org/index.php/documents/13-pais-conference-2017-white-paper/file) that identifies priorities for future research. The white paper recognises the importance of transdisciplinary approach incorporating geoscience, physical sciences and biological sciences in understanding and quantifying the Antarctic ice sheet contribution to past and future global sea-level change, from improved understanding of climate, ocean and solid Earth interactions and feedbacks with the ice. It also recognizes the importance of understanding the global consequences and impacts of Antarctic change so that decision-makers can better anticipate and assess the risk in order to manage and adapt to sea-level rise and evaluate mitigation pathways. Consequently, the PAIS white paper has been influential in the development of a new SRP – Antarctic Ice Dynamics and Sea Level (AIDSL; https://www.scar.org/science/aissl/aissl/).

Since SCAR Delegates Meeting in 2018 at Davos, Switzerland, PAIS reports the following highlights.

1. High-profile scientific papers (9 of the 11 highlighted papers were published in Nature journals) and show:
    - New evidence for the (in)stability of the marine margins of East Antarctic Ice Sheet under 300-500ppm atmospheric CO_2
    - Antarctic futures under high and low emissions pathways and implications for global sea-level rise, ocean change and biological systems.
    - The importance of solid Earth responses and feedbacks in controlling ice sheet dynamics

- A new integrated model of Antarctic ice sheet evolution over the last 50 million years reconciling the roles of orbital forcing and atmospheric carbon dioxide with implications for future change
- A review of the complex processes that occur at the boundaries of ice sheets (bedrock, ocean and atmosphere) and integrated data-model approaches that need to be the focus of future research.

2. Two integrated ocean discovery programme (IODP) drilling expeditions successfully completed (valued at ~$60M USD) to the Amundsen and Scotia seas were co-ordinated and led by the PAIS community. The sediment cores will provide an unprecedented level of insight on how the marine-based sectors of the Antarctic ice sheet responded to climates and atmospheric CO_2 levels predicted for this century including model simulations of the possibility of a tipping point being crossed at about 2 degrees C of global warming (the Paris IPCC agreement's Target) that could lead to irreversible ice sheet loss.
3. The PAIS community have been active in outreach, engagement and ECR development. A highlight has been the IODP-PAIS Antarctic marine sediment core school at the IODP Gulf Coast Repository at Texas A&M University in June which has co-funded 24 students and ECRs (12 non USA and 12 USA), to learn how to characterise, sample and interpret marine sediment cores form the Antarctic margin.

SRP updates since 2018 Delegates Meeting

What has been achieved?

Date	Activity
Jan-Mar 2019	**IODP Expedition 379 to the Amundsen Sea.** International Ocean Discovery Program (IODP) Expedition 379, led by Julia Wellner and Karsten Gohl, accomplished two successful drill sites on the continental rise of the Amundsen Sea, the first from this sector, despite significant logistical limitations, including persistent sea ice that prevented access to all proposed continental shelf sites and abundant mobile icebergs that forced loss of ~50% drilling time. The Amundsen Sea sector of Antarctica has long been considered the most vulnerable part of the West Antarctic Ice Sheet because of the great water depth and retrograde slope at the grounding line, incursion of warm Circumpolar Deep Water onto the shelf, and the lack of substantial buttressing ice shelves. Notably, ice flowing into the Amundsen Sea embayment is undergoing rapid changes, including substantial grounding line retreat over recent decades. The cores contain unique records to study the cyclicity of West Antarctic ice sheet advance and retreat processes as well as ocean-bottom circulation and water mass changes during warmer than present periods during the Pliocene and Pleistocene (5-1 million years ago).
April-May 2019	**Iceberg Alley IODP Expedition 382 to the Scotia Sea.** Mike Weber and Maureen Raymo led an expedition to core Plio-Pleistocene sediments (1-5 million years) to get history of Antarctic Ice Sheet variability. The area aggregates ice discharge from the entire continent as ice bergs pass through here deposit ice berg rafted debris. Quite a number of scientists that contribute actively to PAIS goals joined this project, either onboard or shore-based post cruise. They retrieved cores from multiple sites spanning the Plio-Pleistocene in a continuous, high-resolution fashion with potential to reconstruct ice-sheet and climate dynamics. Initial reports have exceeded expectations
Jan-Feb 2019	**Marine seismic survey for proposed IODP drilling of the Indian Sector of the Southern Ocean** R/V Hakuho-maru KH-19-1 led by Minoru Ikehara, Kochi University. Japan in association with NIPR.
Dec 2018	**Oversnow seismic survey for the Kamb Ice Stream** grounding line on the Ross Ice Shelf for future geological drilling led by Gary Wilson and the NZ programme
3-4 September 2018	**Workshop on Climate variability in Antarctica and the Southern Hemisphere over the past 2000 years (CLIVASH 2k)** held at British Antarctic Survey, Cambridge UK, CLIVASH 2k is a PAGES 2k working group investigating Climate Variability in Antarctica and the Southern Hemisphere over the past 2000 years. Forty researchers from over twenty nations attended the 2-day workshop hosted at the British Antarctic Survey. The workshop consisted of talks, posters and discussion sessions centred around three main scientific questions: 1) What is our current understanding of sea ice variability? 2) What are the best proxies or regions for capturing changes in westerly winds? 3) How can paleoclimate data inform predictions of future climate change? Generous support from PAIS,

	and our other sponsors (PAGES and AntClim21), ensured participation from members of the PAIS community. The money supported the travel and accommodation for one PhD student from the USA and paid for the accommodation and registration (lunches and evening meal) for a further four early career researchers from Peru, USA, France and Australia.
2018-2019 summer	**Over 200,000 km of geophysical line surveying by the CHINARE airborne geophysics programme and the ICECAP** consortium across Princess Elizabeth Land and a variety of other locations across East Antarctica. These data will contribute to the next iteration of the BEDMAP depiction of subglacial Antarctica.
9–14 June 2019	**IODP-PAIS Antarctic marine sediment core school at the IODP Gulf Coast Repository at Texas A&M University.** The school trains early career scientists (mostly PhD students and post-docs) to document and interpret lithological, geochemical, and physical properties of Antarctic marine sediment cores to understand stratigraphy and depositional environments in the contact of ice, climate, and source-to-sink processes. It included lectures and classroom activities in the mornings and hands on core characterization activities in the afternoon using a selection of DSDP, ODP, IODP, and ANDRILL sediment cores from a variety of Antarctic depositional environments. 24 scientists have participated (12 from U.S. and 12 international attendees representing Argentina, China, India, Ireland, Italy, Korea, Netherlands, New Zealand, and United Kingdom) to attend the school, with PAIS funds supporting travel for 10 of the international attendees as well as one international instructor. There were 8 U.S. instructors, as well as Trevor Williams and Denise Kulhanek. At the conclusion of the school they will create an educational package of lectures and activities that can be used for both formal and informal training.

What lies ahead?

Date	Activity
ongoing	PAIS members are contributing to the IPCC 6th Assessment Report and Special Report on the ocean and cryosphere (Nick Golledge, Rob DeConto, Andrew Mackintosh)
ongoing	Completion of 1 more IODP expedition and write up of results from the 3 completed.
July 2019	PAIS-PRAMSO workshop in Incheon to develop future drilling proposals (e.g. Ekstrom Ice Shelf), but specifically to write ICDP proposal for Kamb Ice Stream Siple Coast international drilling consortium
ongoing	Development of 2 IODP proposals to recover geological drill core records near the Totten Glacier (EAIS) and the Sabrina Coast (EAIS)
ongoing	Continued support of early career researchers to summer schools, workshops and meetings.

SRP planned final products (including related to OSC2020)

Date	Output/product
July 2019	PAIS sponsored sessions at ISAES Incheon, Korea to highlight latest scientific achievments.
July 2020	PAIS has already developed a white paper for future research priorities which are being incorporated into the Science and Implementation Plan for the new AISSL SRP. A workshop will be held in Korea to further develop the SRP.
2020	PAIS will sponsor a session at the OSC marking the end of the Programme to highlight its outcomes.
	PAIS has achieved everything from the original implementation plan and more
2020	PAIS co-chiefs are co-editing the 2nd edition of the book "Antarctic Climate Evolution", by Elsevier, involving many scientists working on different field related to PAIS. Draft chapters from authors due to the publisher no later than 1 January 2020. Final manuscripts due no later than 1 June 2020

Budget

Changes to planned use of funds for 2019 and 2020

Year (YYYY)	Purpose/Activity	Amount (in USD)	Contact Name	Contact Email
Total				

We don't have any changes to the planned use of funds for 2019 and 2020. We plan to use the 2019 for:

1) travel and accommodation for students and one early career teacher for participating to the PAIS-IODP school (June10-14, 2019)
2) travel and accommodation for early career scientists and students to attend the ISAES in Korea July, 2019)
3) to support the senior and early careers scientists to attend the AGU fall meeting 2019.

We plan to use the 2020 budget for:

1) supporting travel and accommodation costs for students, early and senior career scientists to attend the SCAR-OSC 2020
2) Attend the IODP-ECORD 2020 summer schools
3) Support request for organizing workshops-meeting from the PAIS community

Membership

Role	First Name	Last Name	Affiliation	Country	Email	Date Started	Date Term is to End
Co-chief officer	Tim	Naish	Antarctic Research Centre Victoria University of Wellington	NZ	Timothy.Naish@vuw.ac.nz	January 1st 2016	December 31st 2020
Co-chief officer	Laura	De Santis	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale OGS	Italy	ldesantis@inogs.it	January 1st 2016	December 31st 2020

Other members

First Name	Last Name	Affiliation	County	Email
Carlota	Escutia (ex-officio)	IACT-Univ Granada	Spain	cescutia@ugr.es
Robert	DeConto (ex-officio)	Univ. of Massachusetts	USA	deconto@geo.umass.edu
Claus-Dieter	Hillenbrand	British Antarctic Survey	UK	hilc@bas.ac.uk
Louise	Sime	British Antarctic Survey	UK	lsim@bas.ac.uk
Karsten	Gohl	Alfred Wegener Institut	Germany	karsten.gohl@awi.de
Ross D.	Powell	Northern Illinois University	USA	r.powell@mchsi.com
Michael	Bentley	Durham University	UK	m.j.bentley@durham.ac.uk
Barbara	Stenni	Cà Foscari University of Venice	Italy	barbara.stenni@unive.it
Julia	Welner	U. of Houston	USA	jswellne@Central.UH.EDU
Rob	McKay	Victoria University of Wellington	New Zealand	Robert.McKay@vuw.ac.nz
Richard	Levy	GNS Science	New Zealand	rlevy@gns.cri.nz
Paolo	Stocchi	NIOZ	Netherlands	Paolo.Stocchi@nioz.nl
Florence	Colleoni	OGS	Italy	fcolleoni@inogs.it
Jae Il	Lee	KOPRI	South Korea	jae leeji@kopri.re.kr
Yusuke	Sugamuna	NIRP	Japan	suganuma.yusuke@nipr.ac.jp
Sun	Bo	Polar Research Institute of China	China	sunbo@pric.gov.cn

Marcelo	Reguero	Instituto Antartico Argentina	Argentina	regui@fcnym.unlp.edu.ar
Marcelo	Leppe	INACH	Chile	mleppe@inach.cl
Peter	Bijl	U. Utecht	Netherlands	P.K.Bijl@uu.nl
J. Abel	Flores	U. Salamanca	Spain	flores@usal.es
Anton	van Putte	Royal Belgium Institute for Natural Sciences	Belgium	antonarctica@gmail.com
Leanne	Armand	Macquarie University	Australia	leanne.armand@mq.edu.au
Mathieu*	Casado	Post-doc at LSCE and LIPhy	France	mathieu.casado@lsce.ipsl.fr
Pamela*	Santibañez	Instituto Antártico Chileno | INACH	Chile	psantibanez@inach.cl
Gerhard	Kuhn	AWI, Germany	Germany	Gerhard.Kuhn@awi.de
Trevor	Williams	TAMU-IODP	USA	williams@iodp.tamu.edu
Denise	Kulhanek	TAMU-IODP	USA	kulhanek@iodp.tamu.edu

*Please identify Early Career Scientists with * in first column*

SCAR Fellowship Reviewers

First Name	Last Name	E-mail	Principal Expertise
Laura	De Santis	ldesantis@inogs.it	Seismic stratigraphy
Florence	Colleoni	fcolleoni@inogs.it	Ice sheet modelling / Paleoclimate modelling

Significant Deviations from the Implementation Plan

N/A

Additional information (optional)

Outreach, communication and capacity-building activities

Video "Antarctic Scientific Deep Sea Drilling: a long history. Produced and made by Kim Kimberly. https://www.youtube.com/watch?v=GN9faSiGUZQ

Outreach and educational material from the IODP exp. 379 https://iodp.tamu.edu/outreach/expeditions/amundsen_sea_ice_sheet_history.html and IODP Exp 382 https://iodp.tamu.edu/outreach/expeditions/iceberg_alley_paleoceanography.html

"Antarctic Scientific Deep Sea Drilling: a long history" by Kim Kimberly.
https://www.youtube.com/watch?v=GN9faSiGUZQ

Outreach event *"Then and now"* with public speeches (by Jim Kennett, Peter Barrett, Fred davey, Rob McKay, Laura De Santis, presented by Tim Naish and Denise Kulhanek) live-recorded in Lyttleton (NZ) on March 8th and available from the PAIS web site http://www.scar-pais.org/index.php/insights/video

Blogs, videos and educational resources made during the IODP:
exp 374 https://joidesresolution.org/expedition/374/
exp 379 https://joidesresolution.org/expedition/379/
exp 382 https://joidesresolution.org/expedition/382/

Various media outreach during and after IODP Expedition 379 and 382 in various countries (TV, radio, print & online media)

Participation to the IODP-ECORD School of Rock (Pavia, Italy) 24-27 July 2018

EGU symposium talk (webcasted and still available online): https://meetingorganizer.copernicus.org/EGU2019/orals/30246
Cryosphere as the thermometer of Cenozoic Earth system evolution
Florence Colleoni, Laura De Santis, and Andrea Bergamasco

Interview with Science journalist on exp. 389 (also in the interview Karsten Gohl, Julia Wellner and Rob DeConto) https://www.sciencemag.org/news/2019/04/newly-drilled-sediment-cores-could-reveal-how-fast-antarctic-ice-sheet-will-melt

PAGES brief article on paleo sea level and ice sheet modeling (lead author Bas deBoer): DeBoer B., Colleoni F., De Conto R., Golledge N. "Paleo ice sheet modeling to constrain past sea level", in press (to be published in the next PAGES issue May 19th).

Organization of the PAIS-IODP school, College Station June 10-15 2019.
Dowdeswell, Julian & Hambrey, Michael, 2018. The Continent of Antarctica. Published by Pakadakis, Newbury, UK. It is a highly illustrated book intended for a lay-readership, and featured as a "Book of the Week" in Nature soon after it came out last autumn (our hemisphere!), as well as on the SCAR website.
PAIS representatives belonging to the Association of Polar Early Career Scientists (APECS) took part in a group review of the upcoming report on the ocean and cryosphere from the Intergovernmental Panel on Climate Change (IPCC). A review of the IPCC SROCC project has been by Mathieu Casado published in
nature: https://www.nature.com/articles/d41586-018-05956-7

One of the PAIS co-chiefs has co-led the editing of a white paper titled "The coupled polar climate system: global context, predictability and regional impacts" Lise Lotte Sørensen and Laura De Santis (Lead Contributors), Jon Ove Hagen, Lene Kielsen Holm, Philippe Huybrechts, Anais Orsi, Julienne Stroeve, Gonçalo Vieira, Michiel van den Broeke, Carlo Barbante and Marie-Noëlle Houssais. Published by the EU-PolarNet project in 2019. https://www.eu-polarnet.eu/news-and-events/conferences-and-workshops/white-paper-workshop/

- Imperial College Festival 2018 (http://www.imperial.ac.uk/news/185986/imperial-festival-transforms-under-12s-into-mini/)

- Pint of Science London Talks 2018: Understanding Antarctica (talks by Martin Siegert and Tina van de Flierdt)
- Pint of Science London Talks 2019: 'The Frozen Continent' (https://pintofscience.co.uk/event/the-frozen-continent; talks by Martin Siegert and David Wilson) and 'Polar Thinking' (https://pintofscience.co.uk/event/big-climate-question---small-village-answers; by Tamsin Edwards)
- Pint of Science Trieste talks 2019: "Iceberg in vista: come cambia il livello del mare" talk by Florence Colleoni.

Tim Naish appointed Leader of WCRP/CliC "Melting Ice Sheets and Global Consequences" Grand Challenge. Attended the WCRP 40th Joint Scientific Committee meeting and science plan implementation workshop at WMO in Geneva in May, 2019. WRCP co-ordinates scientific initiatives such as CMIP6 and ISMIP6 for IPCC Assessment Reports. We are trying to align the new SCAR AISSL SRP with the CliC and Melting Ice Grand Challenge.

Richard Levy, Tim Naish and Nick Golledge have $7M NZ Sea-level Rise Programme. While this programme will improve predictions of sea-level rise for NZ they are working with international collaborators Paolo Stocchi, Natalya Gomez, Regina Hock, Ben Marzeion, Rob DeConto, include latest Antarctic ice sheet projections into Bob Kopps probabilistic projection framework for global and regional sea-level change. This type of approach will be used in the AISSL programme so the global consequences and impacts of Antarctic-driven sea-level rise can be assessed.

Notable Papers

1. Wilson, D., Bertram, R.,Needham, E., van de Flierdt, T.,Welsh, K.,McKay, R., Mazumder, A.,Riesselman, C.,Jimenez-Espejo, F., Escutia, C. 2018. Ice loss from the East Antarctic Ice Sheet during late Pleistocene interglacials. ***Nature 561*****,** 383-386.

   This work provides evidence from marine sedimentological and geochemical records for ice margin retreat or thinning in the vicinity of the Wilkes Subglacial Basin of East Antarctica during warm late Pleistocene interglacial intervals. This has important implications for the sensitivity of the marine margins of the East Antarctic Ice Sheet as the climate continues to warm. It is yet another high profile outcome from the IODP Leg 318 drilling expedition off Wilkes Land coast, that was supported and co-ordinated by PAIS.

2. Golledge, N., Keller, E., Gomez, N., Naughten, K., Bernales, J., Truse, L. Edwards, T., 2019. Global environmental consequences of twenty-first-century ice-sheet melt. ***Nature*** **566**, 65-71.

   This paper shows using simulations of the Greenland and Antarctic ice sheets constrained by satellite-based measurements of recent changes in ice mass, that increasing meltwater from Greenland will lead to substantial slowing of the Atlantic overturning circulation, and that meltwater from Antarctica will trap warm water below the sea surface, creating a positive feedback that increases Antarctic ice loss. In the simulations, future ice-sheet melt enhances global temperature variability and contributes up to 25 centimetres to sea level by 2100. However, uncertainties in the way in which future changes in ice dynamics are modelled remain, underlining the need for continued observations and comprehensive multi-model assessments. Co-produced by PAIS and ISMASS.

3. Shakun, J.D., Corbett, L.B., Bierman, P.R., Underwood, K., Rizzo, D., Zimmerman, S.R., Caffee, M., Naish, T., Golledge, N., Hay, C., 2018. Minimal East Antarctic Ice Sheet retreat onto land during the past 8 million. ***Nature 558**, 284-287.*

   This paper is based on the ANDRILL 1B and shows that land-based sectors of the EAIS that drain into the Ross Sea have been stable throughout the past eight million years. These findings indicate that atmospheric warming during the past eight million years was insufficient to cause widespread or long-lasting meltback of the EAIS margin onto land. The paper shows that variations in Antarctic ice volume in response to the range of global temperatures experienced over this period—up to 2–3 degrees Celsius above preindustrial temperatures, corresponding to future scenarios involving carbon dioxide concentrations of between 400 and 500 parts per million—were instead driven mostly by the retreat of marine ice margins, in agreement with the latest models.

4. Rintoul, S.R., Chown, S.L., DeConto, R., England, M., Fricker, H., Masson-Delmotte, V**.,** Naish, T., Siegert, M., Xavier, J. C. accepted. Choosing the future of Antarctica. ***Nature 558**, 233-240.*

   The Tinker Muse Fellows present two narratives on the future of Antarctica and the Southern Ocean, from the perspective of an observer looking back from 2070. In the first scenario, greenhouse gas emissions remained unchecked, the climate continued to warm, and the policy response was ineffective; this had large ramifications in Antarctica and the Southern Ocean, with worldwide impacts. In the second scenario, ambitious action was taken to limit greenhouse gas emissions and to establish policies that reduced anthropogenic pressure on the environment, slowing the rate of change in Antarctica. Choices made in the next decade will determine what trajectory is realized. Co-produced by all SCAR SRPs.

5. Kingslake, J., Scherer, R., Albrecht, T., Coenen, J., Powell, R., Reese, R., Stansell, N., Tulaczyk, S., Wearing, M & Whitehouse, P., 2018. Extensive retreat and re-advance of the West Antarctic Ice Sheet during the Holocene. ***Nature 558***, https://doi.org/10.1038/s41586-018-0208-x.

   This paper shows, that during the last 10,000 years the grounding line of the West Antarctic Ice Sheet (which marks the point at which it is no longer in contact with the ground and becomes a floating ice shelf) retreated several hundred kilometres inland of today's grounding line, before isostatic rebound caused it to re-advance to its present position. The research is based on drilling sediment cores at the grounding of the Whillans Ice Stream and integration with ice sheet and glacio-isostatic adjustment modelling, which shows a negative feedback due to bedrock rebound as ice retreats that might halt retreat and even stimulate readvance. This work was presented at the PAIS Conference in 2017, Trieste, Italy.

6. Brook, E., Buizert., C. 2018. Antarctic and global climate history viewed from ice cores. ***Nature 558***. doi.org/10.1038/s41586-018-0172-5.

   This paper was commissioned by Nature for an Insight volume to celebrate the SCAR 60th anniversary. It summarises the state of play of Antarctic ice core research, showing that a growing network of ice cores reveals the past 800,000 years of Antarctic climate and atmospheric composition show tight links among greenhouse gases, aerosols and global climate on many timescales, demonstrate connections between Antarctica and distant locations, and reveal the extraordinary differences between the composition of our present atmosphere and its natural range of variability as revealed in the ice core record. Further coring in extremely challenging locations is now being planned, with the

goal of finding older ice and resolving the mechanisms underlying the shift of glacial cycles from 40,000-year to 100,000-year cycles about a million years ago, one of the great mysteries of climate science.

7. Levy, R.H., Meyers, S.R., Naish, T.R., Golledge, N.R., McKay, R.M., Crampton, J.S., DeConto, R.M., De Santis, L., Florindo, F., Gasson, E.G.W., Harwood, D.M., Luyendyk, B.P., Powell, R.D., Clowes, C., Kulhanek, D.K. 2019. Antarctic ice-sheet sensitivity to obliquity forcing enhanced through ocean connections ***Nature Geoscience*** 10.1038/s41561-018-0284-4.

This paper examines the strong emergence of an strong obliquity (axial tilt) control on Antarctic ice-sheet evolution during the Miocene by correlating the Antarctic margin geological records from 34 to 5 million years ago with a measure of obliquity sensitivity that compares the variance in deep sea sediment core oxygen-isotope data at obliquity timescales with variance of the calculated obliquity forcing. The analysis reveals distinct phases of ice-sheet evolution and suggests the sensitivity to obliquity forcing increases when ice-sheet margins extend into marine environments. This reconstruction of the Antarctic ice-sheet history suggests that if sea-ice cover decreases in the coming decades, ocean-driven melting at the ice-sheet margin will be amplified. This paper is an outcome of the PAIS Conference in Trieste, Italy in 2017.

8. Colleoni, C., De Santis, L., Siddoway, C., Bergamasco, A., Golledge, N., Lohmann, G., Passchier, S., Siegert, M, 2018, Spatio-temporal variability of processes across Antarctic ice-bed–ocean interfaces. ***Nature Communications***, DOI: 10.1038/s41467-018-04583-0.

This review article was commissioned by Nature at the 2107 PAIS Conference, Trieste, Italy. It summarises advances in how understanding how the Antarctic ice sheet will respond to global warming relies on knowledge of how it has behaved in the past. It discusses challenges and opportunities for future research that will be the focus of the new SCAR AISSL Programme. The use of numerical models, the only means to quantitatively predict the future, is hindered by limitations to topographic data both now and in the past, and in knowledge of how subsurface oceanic, glaciological and hydrological processes interact. Incorporating the variety and interplay of such processes, operating at multiple spatio-temporal scales, is critical to modeling the Antarctic's system evolution and requires direct observations in challenging locations. As these processes do not observe disciplinary boundaries neither should our future research.

9. Sangiorgi, F., Bijl, P., Passchier, S., Salzmann, U., Schouten, S., McKay, R., Cody, R., Pross, J., van de Flierdt , T., Bohaty, S., Levy, R., Williams, T., Escutia, C., Brinkhuis, H., 2018, ***Nature Communications***, DOI: 10.1038/s41467-017-02609-7

This research documents paleoceanographic conditions and the (in)stability of the Wilkes Land subglacial basin (East Antarctica) during the mid-Miocene (~17–13.4 million years ago) by studying sediment cores from offshore Adélie Coast. Inland retreat of the ice sheet, temperate vegetation, and warm oligotrophic waters characterise the mid-Miocene Climatic Optimum (MCO; 17–14.8 Ma). After the MCO, expansion of a marine-based ice sheet occurs, but remains sensitive to melting upon episodic warm water incursions. The results suggest that the mid-Miocene latitudinal temperature gradient across the Southern Ocean never resembled that of the present day, and that a strong coupling of oceanic climate and Antarctic continental conditions existed and that the East Antarctic subglacial basins were highly sensitive to ocean warming. This was another outcome of the IODP Leg 318 Expedition co-ordinated by PAIS (PRAMSO).

10. Dziadek, R., Gohl, K., Kaul, N., and the Science Team of Expedition PS 104, 2019 Elevated geothermal surface heat flow in the Amundsen Sea Embayment, West ***Antarctica, Earth and Planetary Science Letters 506***, doi.org/10.1016/j.epsl.2018.11.003.

    This study provides ground-truth for regional indirect geothermal heat flux (GHF) estimates in the Amundsen Sea Embayment, which is part of the West Antarctic Rift System, by presenting in situ temperature measurements in continental shelf sediments. The results are critical for correct parameterizations in ice sheet and solid Earth deformation modelling associated with ice sheet dynamics.

11. Escutia, C., DeConto, R., Dunbar, R., De Santis, L., Shevenell, A., Naish, T., 2019, Keeping an Eye on Antarctic Ice Sheet Stability, ***Oceanography 32***, https://doi.org/10.5670/oceanog.2019.117

    This review paper was invited as part of a special issue on the achievements and future of the Integrated Ocean Discovery Program. It summarises 40 years of ocean drilling on the continental margin of Antarctica. Many of these drilling projects (IODP, ANDRILL, CRP, SHALLDRILL) were co-ordinated within the SCAR PAIS community and its predecessors (ACE, ANTOSTRAT), and have revolutionized our understanding of Antarctic ice sheet evolution and behaviour, especially during warmer-than-present climates of the past that have provided significant insights into future change and have been used to develop and improve numerical ice sheets models.

Direct support from outside organizations received for your activities

USD ~$60M from IODP to support 2 Antarctic drilling expeditions.

The ANDRILL project provides support ($25,000) for the participation of early career scientists and senior to the PAIS/PRAMSO workshop during the ISAES in rep. S. Korea

The IODP US Science Support Program provides $20,000 for organizing the PAIS-IODP school.

Major collaborations your group has with other SCAR groups and with organizations/groups beyond SCAR

Within SCAR

PAIS is very much linked to some activities carried out by SERCE, AntClim21 and AntEco. An AntClim21 paper led by Thomas Bracegirdle and co-authored by F. Colleoni (as PAIS representative) has just been published: “Back to the Future: Using Long-Term Observational and Paleo-Proxy Reconstructions to Improve Model Projections of Antarctic Climate” Geosciences 2019, 9, 255

Outside SCAR

The International Ocean Discovery Program IODP http://www.iodp.org/ is the main outside organization providing enormous support for the PAIS drilling expeditions in Antarctica, both in terms of offshore (ca. 50x2 million US$ in 2019 expeditions) and shore-based science and communication-outreach programs and for pre-cruise work and meetings. A recent paper highlighting progress made in synergy in the past 45 years between the SCAR geoscience

paleoclimate projects and IODP has been published in the special issue on Scientific Ocean Drilling: looking to the future. “Keeping an Eye on Antarctic Ice Sheet Stability” Carlota Escutia, Robert M. DeConto, Robert Dunbar, Laura De Santis, Amelia Shevenell, and Timothy Naish. 2019. Oceanography , vol. 32, n. 1. https://doi.org/10.5670/ oceanog.2019.117.

The ANDRILL project has also strong land direct linkages and provides budget support for future drilling initiative planning within the PAIS community

The International Collaboration for Exploration of the Cryosphere through Aerogeophysical Profiling (ICECAP) international consortium includes scientists from the United States, United Kingdom, France, China and Australia, to investigate how and why the ice sheet and ice shelves of East Antarctica are evolving. The project is strongly linked to PAIS as it produces images of the bedrock below the ice sheet and of the internal layers in the ice sheet at a resolution of only a couple of metres.

New phases of the different modeling intercomparision exercise for paleoclimate have been launched:
PMIP4: main coupled climate climate simulations focused on mid-Holocene, the LGM, the LIG, but with transient simulations (i.e. evolving forcing).
PLIOMIP2: focused on several timeslices of the mid-Pliocene Warm period (mPWP) with highly similar orbital configuration than present-day instead of simulating averaged conditions of the whole mPWP as for phase 1. Mainly coupled climate simulations.
MIOMIP: just launched. This initiative focuses on the Miocene period and aims at simulating at least one time slice of the mid Miocene Climatic Optimum, and one timeslice within the Late Miocene (8-5Ma) which is the interval for which most proxy data are available already. For the moment the first phase will gather what have been done in terms of proxies and climate simulation. A second phase should be based on common design of simulations. PAIS members also proposed an ice sheet modeling comparison project during this 2nd phase, focused on Antarctic ice sheet.

PAIS members are also contributing to WCRP-ISMIP6 which will provide Antarctic and Greenland contributions to future sea-level rise of the IPCC AR6 Assessment report as will as projections through the joined SCAR-IACS-WCRP ISMASS Group. PAIS and ANTCLIM21 and future SRPs are building stronger linkages with WCRP/CLiC.

Updates for your group’s SCAR web page

We update (almost) regularly our web page http://www.scar-pais.org/ and we keep updated also the SCAR official PAIS web site.

Other information for publicity purposes - None