2009 IPICS Workshop on Science and Technology for the Next Generation of International Ice Coring, Corvallis, OR July 6-7, 2009

Workshop Report (Draft)

Compiled by IPICS co-chairs Edward Brook, Oregon State University, and Eric Wolff, British Antarctic Survey.

Contents:

1. Meeting overview and acknowledgements.

Under the auspices of IPICS (International Partnerships in Ice Core Sciences) the international community of scientists involved in ice coring is developing and starting to implement ambitious plans for a range of collaborative efforts that will use ice cores to further understand important aspects of climate and environmental change on time scales of years to millions of years. IPICS originated from discussions held at the National Science Foundation as part of a meeting entitled "The Future of U.S. Ice Core Science" in 2002 (ICWG, 2003), which pointed to international collaboration as a key element of future work, and identified the nucleus of the current IPICS scientific agenda. As a planning body IPICS has formed a steering committee and since had several international meetings focused on defining four scientific focus areas that require international collaboration in science and logistics for success. These meetings have been partially supported by funds from both NSF and European collaborators, with the two most recent meetings held in Europe in 2005 and 2008.

IPICS has identified the following four large-scale scientific projects:

Project 1. Drilling and analyzing a 1.5 million year ice core record, almost doubling the length of the longest existing record.

Project 2. Developing a detailed quantitative, four-dimensional understanding of climate and environmental change in both Polar Regions over the last 40,000 years, by drilling and analyzing a network of ice cores covering that time period.

Project 3. Developing a detailed quantitative, four-dimensional understanding of climate and environmental change globally over the last 2,000 years using a network of cores covering that time period.

Project 4. Recovering an ice core record of the last interglacial period in Greenland.

A fifth element of IPICS concerns the development of the next generation of drilling technology required for implementing these projects, including developing new, environmentally friendly drilling fluids that work in a variety of field environments, and development of easily deployable drilling tools.

The 2009 Workshop brought together the members of the IPICS steering committee, other interested ice core researchers, scientists from related fields (glaciology, paleoclimatology, climatology), selected graduate students and early career scientists, and key members of polar research organizations in IPICS countries. It was held immediately before the PAGES Open Science meeting in July 2009 in Corvallis, OR. In contrast to previous IPICS meetings, which concentrated on defining scientific problems, this workshop focused on the current state of scientific knowledge with respect to IPICS goals (essentially a scientific progress report), and on defining specific actions (for example further survey work, construction of equipment, submissions of specific research proposals) needed to advance each of the projects further, time lines for those actions, and specific responsible parties.

2. Agenda

2009 IPICS Workshop on Science and Technology for the Next Generation of International Ice Coring, Corvallis, OR July 6-7, 2009

CH2M Hill Alumni Center Room 115

FINAL AGENDA

Day 1 July 6		
Coffee	8:30-9:00	
Plenary	9:00-9:30	Introduction to the workshop and review of IPICS status (Ed Brook)
Plenary	9:30-11:00	Science Session 1: Climate and environmental history of the last 2 millennia from ice cores. (Chair: Eric Steig)
	9:30-9:40	*Introduction (Eric Steig)*
	9:40:10:05	*Ruminations on the 2K ice core array from Antarctic climate studies (D. Bromwich and J. Nicolas)*
	10:05-10:30	*Reconstruction of paleoclimate from Andean ice cores (Mathias Viulle)*
	10:30-10:55	Holocene stable isotope records in Greenland *(Bo Vinther)*
	10:55-11:00	*Wrap up (Eric Steig)*
Break	11:00-11:30	
Plenary	11:30-1:00	Science Session 2: What do we know, and what do we want to know, about the last interglacial period from ice cores? (Chair: Ed Brook)
	11:30-11:45	*Introduction to the ice core record of the last interglacial and NEEM update (Jim White)*
	11:45-12:05	*Terrestrial Perspectives (Chronis Tzedakis)*
	12:05-12:25	*Marine Perspectives (Jerry McManus)*
	12:25-12:45	*Climate Model Perspectives (Bette-Otto Bliesner)*
	12:45-1:00	*Discussion*
Lunch	1:00-2:00	
Breakout Groups	2:00-4:00	Separate planning sessions for 2 ka and NEEM/Last Interglacial projects. (Chairs: 2ka: Eric Steig; Interglacials: Jerome Chappellaz)
Break	4:00-4:30	
Plenary	4:30-5:30	Group discussion of results of planning sessions. (Chair: Eric Wolff)
Steering Committee	5:30-6:30	IPICS Steering Committee Business Meeting (Ed Brook and Eric Wolff)
Conference Dinner	6:30-9:00	Dinner at Gathering Together Farm

Day 2 July 7		
Coffee	8:30-9:00	
Plenary	9:00-10:30	Science Session 3: 1.5 Million Years of Polar Ice Sheet History (Chair: Eric Wolff)
	9:00-9:05	*Oldest Ice Science Plan (Eric Wolff)*
	9:05-9:20	*New data from AGAP for finding oldest ice (Richard Hindmarsh)*
	9:20-9:35	*New data from ICECAP for finding oldest ice (Duncan Young)*
	9:35-9:45	*Latest geophysical data from Dome A, and implications for an oldest ice site (Hou Shugui)*
	9:45-10:00	*Accumulation rates across the Antarctic plateau (Massimo Frezzotti)*
	10:00-10:15	*Where current ice sheet models with existing data say the oldest ice is (Richard Hindmarsh)*
	10:15-10:30	*Discussion*
Break	10:30-11:00	
Plenary	11:00-12:30	Science Session 4: Climate Dynamics of the last 40,000 Years from Ice Cores (Chair: Rob Mulvaney)
	11:00-11:15	*Introduction and review of 40 ka ice core records (Rob Mulvaney)*
	11:15-11:30	*40 ka greenhouse gas records (Hubertus Fischer)*
	11:30-11:45	*Speleothem records of the last 40 ka (Dominik Fleitman)*
	11:45-12:00	*Oceanography/modelers perspective on the patterns of orbital and millennial-scale variability over Antarctica (Axel Timermman)*
	12:00-12:15	*Modes of climate variability during MIS3 (Nick Pisias)*
	12:15-12:30	*Discussion*
Lunch	12:30-1:30	
Breakout	1:30-3:30	Separate planning sessions for 1.5 Ma and 40 ka projects. (Chairs: Oldest Ice: Jeff Severinghaus; 40ka: Rob Mulvaney)
Break	3:30-4:00	
Plenary	4:00-5:00	Group Discussion of results of planning sessions. (Chair: Ed Brook)
Plenary	5:00-5:30	Wrap up and next steps. (Chairs: Ed Brook and Eric Wolff)

PAGES OPEN SCIENCE MEETING RECEPTION AT 6:30 PM ON JULY 7 IN CH2M HILL ALUMNI CENTER (THIS BUILDING)

3.Summaries of Breakout Planning Sessions (Draft)

Oldest Ice Project

The plenary session for oldest ice consisted of an introduction by Eric Wolff, three talks about new data to constrain the site for oldest ice (AGAP, presented on behalf of AGAP by Richard Hindmarsh; ICECAP presented by Duncan Young; Chinese data around Dome A, prepared by Hou Shugui), a talk about how accumulation rates vary across the East Antarctic plateau (Massimo Frezzotti), and a talk about how ice sheet models can constrain the site for oldest ice (Richard Hindmarsh). The breakout group in the afternoon, chaired by Jeff Severinghaus, covered many similar topics but also considered technological and financial/political aspects.

We first confirmed the scientific reasoning behind drilling a 1.5 Ma ice core. Although Baerbel Hönisch's recently-published B isotope data across the mid-Pleistocene Transition (MPT) provide a first estimate that CO_2 drawdown was most likely not the cause of the MPT, more precise and well-resolved ice core data are certainly still needed. Furthermore, ice core data would deal with many other possibilities about the cause of change from 40ka to 100 ka cycles, as laid out in the science plan. The non-ice-core people present expressed their excitement at the prospect of a 1.5 Ma record: it would, as with the existing 800 ka record, provide a solid template that would encourage and focus work in other archives, while also providing solid data to drive models with. The issue is to find somewhere where we have enough confidence in finding old ice to prepare a case to funding agencies.

The new radar data from the multinational projects AGAP and ICECAP will provide a huge new resource in regions that have until now been poorly covered. AGAP collected 120,000 km of flight lines both north and south of Dome A. Preliminary data show the bed even in the deepest areas, a rugged ("Alpine") topography of the Gamburtsev mountains near dome A, and good radar layers that will require very intensive work to pick and study. Heinz Miller reported that the German DoCo project had flown linking lines between most of the existing ice core sites and Dome A, with the Dome A-Dome F link scheduled to be filled in in 2009/10. (Relatively young) layers have been followed from Vostok to Dome A. ICECAP flew 30,000 km of lines over the Aurora SubGlacial Basin and other regions in 2009/10 and has another season that will encompass Dome C and its region next year. The efficiency of flying the Basler with its long range (as used by ICECAP and AWI) for such deep field work was emphasized. ICECAP has already shown traceable radar layers at 400 ka (based on ice core data). China has local radar data around the new Kunlun station at Dome A. Hou's presentation emphasized a range of estimates of accumulation rate at Dome A, ranging from 2.4 cm/yr based on volcanic markers (similar to Dome C and Dome F) to a much lower estimate based on firn modeling. This needs to be clarified with more data.

The need to have low but positive accumulation rates at the chosen sites was clear from the presentation by Massimo Frezzotti. He pointed out the different influences on accumulation rate, and especially the influence of wind erosion (creating for example the megadunes region). He felt that, for accumulation and ice flow reasons, we should restrict the search to a relatively narrow band around the ice divides.

Richard Hindmarsh presented a series of modeling sensitivity studies: these showed the difficulty of finding the right site. The places with thickest ice are unlikely to yield old ice because of basal melting. In principle oldest ice will be at slightly thinner sites without melting. However where there is not melting we will have to decide to what height above the bed we expect to trust the ice against flow disturbance. The most

important data to improve estimates of where the oldest ice is would be geothermal heat flux.

In the discussion, we concluded that a continuous record was really what was required. A composite record, such as might be obtained from splicing sections in a blue ice region, might be an eventual fallback. However, the difficulties of placing the floating chronologies, and of persuading people of the verity of the record, argued strongly against treating this as anything other than a last resort.

We agreed that the IPICS goals require both gas (CO_2) records and water isotopes; this also argues against megadunes regions or anywhere where a hiatus is expected. We discussed various methods of dating the oldest ice core (other than wiggle matching to marine records): O_2/N_2, $^{40/36}Ar$, $^{10}Be/^{36}Cl$,... We discussed some of the problems of working in ice that might have been warm for many hundreds of thousands of years: the possible diffusion of gases and isotopes over a scale of meters should be calculated in order to assess what time/depth gradient is acceptable.

The most important data need of the ice modeling effort seems to be geothermal heat flux: one way to achieve this would be to use rapid access methods to emplace thermistor strings to measure temperature profiles. Need to check what depth is needed to get an acceptable estimate (initial thought was 500 m, though 1000 m would be even better). Although hot water drilling would be one option, pneumatic drilling (air-driven ram drill) could be faster and more cost-efficient.

We agreed that the candidate sites would most likely be within 50 km of the ice divide (preferably on the lower accumulation south side), with a flat bed. We should focus AGAP/ICECAP data processing to these areas. The linking lines to Dome F are the top priority for new survey, and there are still regions in the DF direction that need survey.

It is still not clear if frozen or melted bed is better; disturbance more likely in frozen bed, loss of old ice more likely if melted. Best might be a very low melt rate?

We agreed that, before committing to what would be a very expensive project, it was highly desirable to use a rapid-access holemaker to assess whether we really have ice of the expected age. However it is necessary to scope what is required (what measurements would be essential to establish the age?), and assess whether such a system would be cheap enough and quick enough to justify the inevitable logistic and development costs (say <20% of cost of whole ice core, <<1 season).

Finally, we confirmed what the science plan says: that at least two (and we think three) holes will be needed, to ensure success, and to give the certainty that replication provides. We should try to promote the project to the funding agencies as part of a master plan involving all three holes, on the scale of astronomy, particle physics, and ocean drilling programmes.

It was also agreed that a reasonably long Eos-type article about the criteria for oldest ice site selection should be prepared, and also to encourage Richard and colleagues to publish their insights into likely sites based on ice sheet modeling.

<u>Last Interglacial</u>

Main "last interglacial" questions related with 21st century concerns (based on the Past4Future European project structure) :

- What is the risk of abrupt changes in interglacials? (tipping points, including e.g Arctic sea ice)
- Can we understand the greenhouse gas records of the interglacial periods? (permafrost, hydrates, carbon sink, hydrological cycle in the tropics, timing between CO2

and sea level during inception)
- What is the risk of rapid collapse of ice sheets? What climate is associated with such ice sheet features? Where does the water come from? (GIS, WAIS)
- Were there significant changes in ocean circulation during previous interglacial periods? (NADW shutdown)
What ice cores do we have? Where do we need new ones? :
- Greenland : NGRIP, hopefully NEEM, a bit of Dye 3, Camp Century and Redland
- Antarctica : EDC, EDML, Dome Fuji, Vostok, Taylor Dome, Talos Dome, Mount Moulton, Berkner (end of MIS5e), WAIS ? (Little chance)
- Any other site providing high resolution? It needs large thickness, large accumulation, small melting at the base (NGRIP-type in Antarctica?)
- Consider revisiting former boreholes by replicating ice coring at the right depth
- Future fast access drill for « mapping » the last interglacial GIS and WAIS
Some conclusions :
- NEEM will be wonderful ("and will need a replicate core", quoting Jim!) but some questions require other information : Bipolar relationship, GHG budget (notably CO2), behavior of the WAIS, GIS size during the Eem.
- Some technological consequences : Replicate drilling, redrill MIS5e sections of existing holes, "Island" site in the WAIS to document MIS5e, site with possibly annual resolution over MIS5e in EAIS
- Document GIS over MIS5e with fast drilling
- Need for additional radar info over WAIS
- Need of more interaction between ice core and modeling (if WAIS removed, what effect on tracers over EAIS?)
- We go for a redrafting of the last interglacial white paper (including a general intro. On comparing previous interglacial's, to be done in the course of September (last interglacial small working group).

IPICS 40K

The plenary session focused on a synthesis of existing records, and perspectives from the climate modeling, terrestrial, and ocean data communities. Rob Mulvaney and Hubertus Fischer summarized climate records and greenhouse gas evolution as they are understood now. Mulvaney emphasized the difference between east Antarctic and west Antarctic climate evolution, and the potential for coastal sites to reveal changes in ice sheet elevation. Fischer emphasized the need for high resolution greenhouse gas and isotope data to really understand the biogeochemistry of the deglaciation. Dominik Fleitmann discussed the relationship between speleothem records globally and the ice core record and the potential to tie the absolute dating of speleothems (U-Th dating) to the ice core record. Axel Timmerman discussed models of the southern ocean climate system and the potential for multiple ice core records to reveal climate mechnisms. Nick Pisias discussed statistical analysis of stage 3 climate records and climate modes revealed by that analysis.

Discussions in the breakout centered on the characteristics of existing records, and potential new sites. A synthesis paper was planned, and the urgent need for synthesis was discussed. Rob Mulvaney and Ed Brook chosen as initial leaders, but generating funding for a graduate student or post doc to take on synthesis should be a high priority. New records from Talos Dome and Berkner Island will need to be incorporated, as well as the NEEM record. New sites under discussion include

Roosevelt Island, South Pole, Hercules Dome, Renland, and possibly revisiting Taylor Dome.

IPICS 2K

Progress continues to be made in implementing the IPICS 2K science plan, with a strong focus on Antarctica, where multiple new cores are in progress or currently being planned. These include

- Roosevelt Island (New Zealand, Denmark, U.S.
- Amundsen coast (S. Korea)
- Detroit Plateau on the Antarctic Peninsula (Brazil, U.S.)
- North Victoria Land north of the deep core site at Talos Dome
- Intermediate depth cores south of Vostok (France)
- Aurora Basin (Denmark, U.S., Australia)
- Norwegian/US traverse records
- Coastal Dronning Maude Land (Germany, Switzerland)
- Beardmore Glacier (NZ)

There was wide agreement that it would be valuable to have new cores obtained in the Arctic, to update existing records that largely end in the 1980s. There was wide agreement at the meeting that the IPICS 2K group should synthesize all existing records, with the goal of a publication summarizing ice core evidence for the "State of knowledge of Antarctic climate of last ~1000 to 2000 years." Individual groups were encouraged to finalize their best, well-dated continuous records to 500 or more years and to make these available to the community, preferably through one of the international data centers (e.g. NSIDC). Researchers are also encouraged to submit information to SCAR at www.icereader.org. IceReader provides a central reference to available data (but does not currently archive data other than ITASE). We agreed on a deadline of December 10th, 2010 for the updated synthesis paper. In January 2010, we will review who is taking the lead on such a paper.

4. Minutes of IPICS Business Meeting

21 people were present (see appendix), representing 16 of the 22 IPICS nations. Apologies had been received from a number of the missing nations; alternates attended for some nations. Eric Wolff (EW) chaired the meeting on behalf of the co-chairs (Ed Brook (EB) and EW).

1. The minutes of the 2008 meeting in Vienna were formally confirmed, and no matters arising (except those covered elsewhere in the agenda) were raised.

2. EW reported that during the year the SC had welcomed Austria as a new member of IPICS, with Elisabeth Schlosser as the SC national member.

3. EW reported that the co-chairs have been in further discussion with the International Association of Cryospheric Sciences (IACS, part of IUGG), a move already agreed by the SC in Vienna. As a result we have sent a letter of intent to IACS expressing our wish to form an IACS/IPICS standing group within IACS. This will be discussed by IACS at their meeting in Montreal later this month. If agreed it will have the effect of leaving IPICS associated with, but not belonging to, a geographic (SCAR), temporal (PAGES) and material (IACS) parent. There is unlikely to be any large financial benefit from the new association, but gives us further profile and the possibility to arrange meetings with

theirs.

4. The co-chairs wanted to remind members of the committees set up for each priority project (a) that they are members and (b) that they are responsible for pushing the implementation and synthesis aspects forwards. ACTION: EW to e-mail all members of project SCs to confirm their membership.

5. The workshop had discussed the idea of turning the IPICS-NEEM white paper into a last interglacial project. The meeting agreed unanimously that this should be done, and the relevant committee is tasked to complete this.

ACTION: last interglacial project team.

6. Future IPICS meetings and workshops: First we discussed what meetings are required. The first need is for each of the priority projects to be able to hold small workshops to push their projects forward. This is the responsibility of each project to organise; they should notify the Co-Chairs (who will notify the SC) beforehand, and communicate the results of each workshop to the Co- Chairs. IPICS unfortunately only has very limited funds, but these can be used to get a meeting started (but only hundreds of dollars per meeting are available from this source, and meetings will generally have to be self funded by attendees, or through grants obtained for each meeting). It was not clear that we need to organise a free-standing IPICS SC business meeting. Instead the meeting agreed that it would be desirable for IPICS to act as organisers of an ice core symposium, possibly with the International Glaciological Society, with a preferred date of spring 2012. Clearly, a business meeting could be held in conjunction with that, but business in between would be done by e-mail. It was agreed to invite SC members to offer to host such a meeting. We already have one nice offer from Hou Shugui to host a future meeting in Nanjing, although we will need to discuss with him whether this would be a project meeting or the postulated ice core symposium, and compare his offer with any others we receive. ACTIONS: EW to ask IGS if it would co-sponsor an ice core symposium with IPICS; EW/EB to invite offers for a symposium in 2012; project chairs to organise appropriate workshops, and communicate plans and outcomes to the Co-Chairs.

7. Actions required by constitution: We need each nation to re-confirm their national SC representative. We also agreed that we must ask each nation to tell us what mechanism it has for choosing that person, to ensure that we have a person with the appropriate authority. We agreed to leave the additional members (co-opted for each project) as they are. We agreed to start the procedure for electing co-chairs for 4 years from April 2010. Jeff Severinghaus agreed to run the procedure, and he will call for any additional nominations (the existing co-chairs agreed to stand again). ACTION: EW/EB to ask each national representative to tell us how they are selected and to confirm they will continue; Jeff Severinghaus to call for nominations for co-chairs.

8. Any other business: Nancy Bertler felt IPICS should try to make a more direct relationship with IPCC. ACTION: Hubertus Fischer agreed to ask Thomas Stocker what would be appropriate.

Appendix: attendance at the business meeting
Tas van Ommen (Australia)
Jefferson Simoes (Brazil)
Bo Vinther (Denmark) (representing Dorthe Dahl-Jensen)
Rein Vaikmäe (Estonia)
Jérôme Chappellaz (France)
Amaelle Landais (France) (representing Valerie Masson-Delmotte)
Heinz Miller (Germany)
Thamban Meloth (India) (representing Rasik Ravindra)
Massimo Frezzotti Italy)
Hideaki Motoyama (Japan)
Soon Do Hur (Korea) (representing Sungmin Hong)
Nancy Bertler (New Zealand)
Vladimir Lipenkov (Russia)
Margareta Hansson (Sweden)
Hubertus Fischer (Switzerland)
Rob Mulvaney (UK)
Eric Wolff (UK) (Co-Chair)
Ed Brook (USA) (Co-Chair)
Jeff Severinghaus (USA)
Eric Steig (USA)
Jim White (USA)

5. Workshop Attendees

2009 IPICS Workshop on Science and Technology for the Next Generation of International Ice Coring, Corvallis, OR July 6-7, 2009

Attendance List

Name		Email	Affiliation
Jinho	Ahn	jinhoahn@gmail.com	Oregon State University, USA
Mary	Albert	mary.r.albert@dartmouth.edu	Dartmouth College, USA
Carlo	Barbante	barbante@unive.it	University of Venice, Italy
Thomas	Bauska	bauskat@geo.oregonstate.edu	Oregon State University, USA
Charles R.	Bentley	bentley@geology.wisc.edu	University of Wisconsin – Madison, USA
Nancy	Bertler	Nancy.Bertler@vuw.ac.nz	Joint Antarctic Research Institute, Victoria Univ., NZ
David	Bromwich	bromwich.1@osu.edu	Byrd Polar Research Center, Ohio State U., USA
Edward	Brook	brooke@geo.oregonstate.edu	Oregon State University, USA
Jérôme	Chappellaz	jerome@lgge.obs.ujf-grenoble.fr	CNRS / LGGE, France
Peter	Clark	clarkp@onid.orst.edu	Oregon State University, USA
Alexey	Ekaykin	ekaykin@aari.nw.ru	Arctic and Antarctic Research Institute, Russia
Hubertus	Fischer	hubertus.fischer@climate.unibe.ch	University of Bern, Switzerland
Dominik	Fleitmann	fleitmann@geo.unibe.ch	University of Bern, Switzerland
Massimo	Frezzotti	massimo.frezzotti@enea.it	ENEA, Italy
Margareta	Hansson	margareta.hansson@natgeo.su.se	Stockholm University, Sweden
Richard	Hindmarsh	rcah@bas.ac.uk	British Antarctic Survey, UK
Bäerbel	Höenisch	hoenisch@ldeo.columbia.edu	Lamont-Doherty Earth Observatory, USA
Soon Do	Hur	sdhur@kopri.re.kr	Korea Polar Research Insitute, Korea
Elisabeth	Isaksson	elisabeth.isaksson@npolar.no	Norwegian Polar Institute
Kenji	Kawamura	kawamura@nipr.ac.jp	National Institute of Polar Research, Japan
Karl	Kreutz	karl.kreutz@maine.edu	University of Maine, USA
Amaelle	Landais	amaelle.landais@lsce.ipsl.fr	IPSL/LSCE/CNRS/CEA/UVSQ, France
Vladimir	Lipenkov	lipenkov@aari.nw.ru	Arctic and Antarctic Research Institute, Russia
Jerry	McManus	jmcmanus@ldeo.columbia.edu	Lamont-Doherty Earth Observatory, USA
Thamban	Meloth	meloth@ncaor.org	National Centre for Antarctic & Ocean Research, India
Heinrich	Miller	Heinrich.Miller@awi.de	Alfred Wegener Institute, Germany
Logan	Mitchell	mitchelo@geo.oregonstate.edu	Oregon State University, USA
Hideaki	Motoyama	motoyama@nipr.ac.jp	National Institute of Polar Research, Japan
Robert	Mulvaney	rmu@bas.ac.uk	British Antarctic Survey, UK
Bette	Otto-Bliesner	ottobli@ucar.edu	National Center for Atmospheric

			Research, USA
Nick	Pisias	pisias@coas.oregonstate.edu	Oregon State University, USA
Julia	Rosen	rosenj@geo.oregonstate.edu	Oregon State University, USA
David	Schneider	daveschneider99@gmail.com	National Center for Atmospheric Research, USA
Jeffrey	Severinghaus	jseveringhaus@ucsd.edu	Scripps Institution of Oceanography, USA
Mark	Siddall	mark.siddall@bristol.ac.uk	Department of Earth Sciences, University of Bristol, UK
Jefferson	Simoes	jefferson.simoes@ufrgs.br	Universidade Federal do Rio Grande do Sul,Brazil
Joseph	Souney	joseph.souney@unh.edu	U.S. Ice Drilling Program Office, UNH, USA
Eric	Steig	steig@ess.washington.edu	University of Washington, USA
Axel	Timmermann	axel@hawaii.edu	IPRC, University of Hawaii, USA
Mark	Twickler	Mark.twickler@unh.edu	U.S. Ice Drilling Program Office, UNH, USA
Chronis	Tzedakis	p.c.tzedakis@leeds.ac.uk	University of Leeds, UK
Rein	Vaikmäe	rein.vaikmae@ttu.ee	Tallinn University of Technology, Estonia
Paul	Vallelonga	vallelonga@unive.it	IDPA-CNR, Italy
Tas	van Ommen	tas.van.ommen@aad.gov.au	AAD and ACE CRC, Australia
Bo	Vinther	bo@gfy.ku.dk	Centre for Ice and Climate, University of Denmark
Mathias	Vuille	mathias@atmos.albany.edu	SUNY Albany, USA
James	White	james.white@colorado.edu	University of Colorado, Boulder, USA
Eric	Wolff	ewwo@bas.ac.uk	British Antarctic Survey, UK
Duncan	Young	duncan@ig.utexas.edu	University of Texas Institute for Geophysics, USA