IPICS Oldest ice workshop, Monday June 18th, 2018, Davos

This one-day meeting of about 50 international experts aimed to build on the work done in the workshop that followed the 2016 IPICS OSC in Hobart. It also serves as a meeting to internationalise the European beyond EPICA-Oldest Ice project. Specifically the aims are:
1. Ensuring knowledge and coordination between the different national/regional oldest ice projects, within a shared IPICS framework
2. Developments in ideas and best practice for survey to identify old ice, dating old ice, approaches to analysis and to disturbed or diffused ice, etc
(this meeting will not be concerned to any significant degree with logistic coordination, as this requires a different set of people at another venue)

Setting the scene. Chaired by IPICS chairs
08.30 Introduction and welcome. (**IPICS co-chairs (Hubertus Fischer and Tas van Ommen**)
08.35 Climate of the last 1.5 Ma and the mid-Pleistocene Transition – a quick overview (**Eric Wolff**)
08.50 Conditions for finding oldest ice (update) (**Hubertus Fischer**)
Sharing plans Chair: Ed Brook
09.00 European plans for oldest ice, including geophysics at Little Dome C (**Carlo Barbante, Robert Mulvaney,** with input from Catherine Ritz and others)
09.30 Australian plans for oldest ice in the Little Dome C area (**Tas van Ommen**)
09.45 Japanese plans/ideas for oldest ice at Dome F (**Shuji Fujita**)
10.00 Chinese progress at Dome A, blue ice activities at Grove Mountains (**Li Yuansheng**)
10.15 Russian plans/ideas for oldest ice at Ridge B (**Vladimir Lipenkov**)
10.30 Coffee
10.50 Korean plans for oldest ice in the Dome C area (**Soon do Hur**)
11.05 US plans/ideas for oldest ice core (concentrating on RAID at the moment) (**Mary Albert**)
11.20 Blue ice studies at Allan Hills (**John Higgins**, to include Ar dating)
11.40 Discussion about these plans and international cooperation
Rapid access drills, progress and potential
12.00 5 minute talks on different systems (**Joel Savarino** (France), **Thomas Stocker** (on behalf of Jakob Schwander (Switzerland), **Robert Mulvaney** (UK), **Jeff Severinghaus** (US))
12.40 Lunch
Geophysics Chair: Dorthe Dahl-Jensen
13.40 10 minute talks on new radar data and ideas to help identify areas with old ice (**Duncan Young, Prasad Gogineni, Olaf Eisen**) followed by discussion
Dating and disturbance Chair: Tas van Ommen
14.40 Dating old ice (**Amaelle Landais** and **Raimund Muscheler**)
15.00 Progress and potential for 81Kr dating of ice (**Wei Jiang**, USTC Hefei)
15.10 How to date old ice (discussion)
15.30 Tea
15.50 Problems of flow disturbance, diffusion and resolution (**Dorthe Dahl-Jensen, Bernhard Bereiter**)
End by 16.30

Very brief notes on issues that were raised, not including routine information already in IPICS SSC minutes

After a welcome from the IPICS chairs, Eric Wolff presented motivation for drilling a core that crosses well into the MPT, explaining how the ice core data would differentiate between many of the hypotheses about what occurred across the MPT. He described understanding the MPT as one of the top challenges in Quaternary science, but said that the project would also contribute new context and process understanding to C cycle and ice sheet work for IPCC. He emphasised that we need to get to 1.2 Ma to be sure of passing the MPT and to 1.5 Ma to have multiple 40 ka cycles. Discussing the inclusion of blue ice studies in the meeting he said that a continuous, dated and monotonic (i.e. in stratigraphic order) record is desirable (but he would take something less). Mentioning that we will hear about many possible projects today, he said that replication at different sites is essential before we have faith that we have achieved a viable record. Hubertus Fischer discussed the criteria for finding an old ice site. The criteria have not changed significantly since the Fischer (2013) paper but we now have much better data to assess whether those conditions are met.

Carlo Barbante discussed European plans, which seem to be the most advanced. Site selection work under an EU Coordination and Support Action has investigated sites near Concordia station, and in the Dome F region. Robert Mulvaney showed new geophysical data that define the local candidates in the Little Dome C (LDC) region. The likely preferred site is about 40 km SW of Concordia. It is well above an apparent subglacial water table, and modelling suggests 1.5 Ma ice 150 m above the bed. Carlo explained that the EU had issued a call for proposals for drilling: the beyond EPICA – Oldest Ice Core project had passed the first step and the proposal for funding was being written with a September deadline, with a probable decision in December 2018. If it is successful then the addition of national in kind and cash funding would allow drilling to start with the casing in 2020-21, reaching the modeled old ice not earlier than 2022/23 and the bed including replicate drilling in 2023/24, followed by replicate coring and borehole logging. The LDC camp would be light (about 12 people) mainly supported from Concordia Station.

Australian plans (Tas van Ommen) are also based near Concordia, and they have achieved funding. The plan is to establish an overland traverse and an inland camp in 2020-21, with drilling planned for 2021-22 until 2024-25 (reaching the bed). The camp would be summer-only, 12-16 pax, with a Basler-capable skiway making it nominally independent of Concordia. Australia would be seeking international collaborations to fully exploit their core.

Japan (Shuji Fujita, SF) has established a "3rd deep ice coring promotion committee" chaired by Kenji Kawamura, with SF as deputy. Their favoured area is NDF, an area about 60 km from Dome F with ice about 2200 m thick. The current plan is for a pilot hole in 2021-22, and drilling finishing in 2024-25. The Japanese also indicated that they are open to collaboration with other nations and are working on site selection activities with the CRESIS group and Norwegian Polar Institute.

China (Li Yuansheng) is still drilling at Kunlun station where the 10 m temperature is -58.4°C. and the thickness 3200 m. The drilling reached 801 m in 2016/17, and 750 m is now at PRIC. The problem has been that they have only had about 2 weeks per season to drill, making progress very slow. They hope to extend this to 50 days in 2019/20, and then reach the bottom in the following year. The latest modelling suggests the ice will be <1Ma old. China is also investigating a promising blue ice area at Grove Mountains and have built a new large diameter blue ice drill.

Volodya Lipenkov described the Russian Vostok Oldest Ice Challenge (VOICE). Particular scientific progress has been made with the proposed dating method involving the growth of air hydrates which suggests the presence of 1.4 Ma ice in the evidently mixed ice at 3530 m at Vostok. Russia is interested in a location on Ridge B, ~260 km upstream of Vostok, with the idea that if there is disturbed old ice at Vostok there might be undisturbed old ice upstream. A drilling project is not yet funded but a reconnaissance traverse study to Ridge B is planned. A new deviation drilling of the 5G hole through disturbed ice is desired.

Korea (Soon do Hur) explained that they plan to develop a traverse capability and find a drill site between 2017 and 2020, and develop hot water and ice core drills in the following years. They have identified a candidate site about 200 km east of Concordia. They aim to traverse in this direction in 2019-20, and their timetable would have them setting up a drill camp in 2023-24 and drilling in the following 3 years.

Mary Albert explained that the US not yet prioritised oldest ice, with Hercules Dome as their next major core (last interglacial target, starting 2020-21). However, oldest ice drilling is bookmarked in the US long-range science plan after Hercules Dome. The RAID drill would however allow them to search for suitable sites and would have a test season in 2018-19, with bedrock collection as a first aim in later seasons, followed by oldest ice site selection work. The US has a number of blue ice projects planned or underway at Taylor Glacier and Taylor and Allan Hills, the latter a site where ice older than 800 ka has been identified.

Finally in this section, John Higgins described the blue ice studies at Allan Hills. Two holes drilled to 150 and 200 m have yielded ice of >2 Ma, although the ice is not monotonic or well-ordered. Dating has been by measuring ^{40}Ar, whose concentration increases with time in the atmosphere, and which gives (assuming no in situ production), dates to +/- 100 ka. Unfortunately ^{13}C measurements in the very oldest ice show evidence of respiration, so that CO_2 levels in that ice are not meaningful. John showed cross-plots of CO_2 and CH_4 vs δD indicating that the relationship between climate parameters before the MPT was not greatly different from that we see in well-ordered ice cores. δD for the pre-MPT ice did not hit glacial maxima levels and CO_2 was tentatively in the range 220-280 ppm, again suggesting that deep glacial values are missing. They are looking at ideas for new dating methods such as $^{87}Sr/^{86}Sr$ in sea salt.

The next session discussed briefly the rapid access tools that might be available to help us identify and confirm old ice sites. The French Subglacior may be the most sophisticated concept, with spectrometers for water isotopes and methane inside the drill. Joel Savarino explained that Subglacior encountered some problems, related to casing materials in the bottom of the hole stopping the melt head portion of the drill. If next tests are successful, it might be tried at LDC in 2019-20 but would not now contribute to European site selection. Thomas Stocker described RADIX (led by Jakob Schwander). This Swiss drill is much simpler, aiming to drill a 2 cm diameter hole to 3000 m, and to collect water isotope samples and carry out a dust log in the hole. It will be tested at EGRIP in summer 2018 and if successful will be used at LDC in 2018-19. The BAS Rapid Access Isotope Drill (Robert Mulvaney) drilled to 461 m last season, almost its design plan, before getting stuck (the stuck portion was abandoned but this was not a major loss). It produces only chips for isotopes and chemistry in a 78 mm hole down to 600 m, and is not aiming at the bed, but rather at (a) deploying temperature sensors and (b) checking the depth of the LGM. Finally Jeff Severinghaus further described the US RAID drill, which should be considered a rock drill with ice capabilities.

In the geophysics session, both data and instruments were discussed, including radar surveys in the Concordia and Dome F region. Layers are not seen in the deepest ice and it is not yet clear whether this is because the signals don't exist (due to diffusion or mixing/folding) or whether a better radar would resolve them. Prasad Gogineni showed designs for a new radar that will be tested at EGRIP in July this year and then would be available for the Antarctic sites in 2018-19. This much more powerful radar should decipher much weaker layers if they are present.

Amaelle Landais and Raimund Muscheler started the discussion about dating, which will be crucial for all our efforts. Radiometric methods are promising but ^{81}Kr still needs too much ice at 1.5 Ma (though sample sizes are decreasing), and some sites seem to have added crustal ^{40}Ar making this method also unreliable at those sites. This stresses the need for 1.5Myr old ice to be found well above bedrock. Cosmogenic isotopes also suffer some issues: ^{10}Be at Dome C showed spikes that are not yet understood and need to be filtered, while ^{36}Cl suffers postdepositional losses. There is however hope that it might work in glacial ice where dust levels are higher. The use of O_2/N_2 could be vital provided diffusion has not damaged the orbital signal. Air content and $\delta^{18}O_{air}$ might also be used as orbital tuning measures. Finally matching records with marine sediments (with dust particularly promising) would be valuable as long as records are in stratigraphic order. If records are well-ordered then all these methods together should work well; if not then the radiometric methods assume much greater importance.

Wei Jiang presented data about improvements in methodology and application for ^{81}Kr at Hefei (USTC). This has a half life of 230 ka and 1 kg of ice contains about 1000 ^{81}Kr atoms, so that counting statistics become important after many half lives. They have successfully obtained dates of 1 Ma at Vostok with 5 kg ice and 20% uncertainty. In discussion we considered whether this method could be made viable with reasonable sample volumes at 1.5 Ma (a further two half lives beyond 1 Ma).

Finally Dorthe Dahl-Jensen considered how flow disturbance is seen in many sites, and how it could be detected. Bernhard Bereiter considered how diffusion might affect what we could hope to resolve, given that the 1.5 Ma ice might be at 10 ka/m. With the current range of diffusion coefficients, the precessional CO_2 variability should be largely preserved, but cycles of O_2/N_2 might not be. However, the diffusion coefficients are poorly known and must be improved.

Known attendees (additional observers were present):

Name	Affiliation	Country
Mary Albert	Dartmouth	USA
Ayako Abe-Ouchi	Tokyo	Japan
Nerilie Abram	ANU	Australia
Carlo Barbante	Venice	Italy
Bernhard Bereiter	Bern	Switzerland
Nancy Bertler	VUW	NZ
Bo Sun	PRIC	China
Ed Brook	OSU	USA
Jerome Chappellaz	IGE/IPEV	France
Dorthe Dahl-Jensen	Copenhagen	Denmark
Olaf Eisen	AWI	Germany
Jenna Epifanio	OregonSU	USA
Gwen Fenton	AAD	Australia
Hubertus Fischer	Bern	Switzerland
Massimo Frezzotti	PNRA	Italy
Shuji Fujita	NIPR	Japan
Prasad Gogineni	Alabama	USA
John Goodge	Minnesota	USA
Kumiko Goto-Azuma	NIPR	Japan
Magareta Hansson	Stockholm	Sweden
John Higgins	Princeton	USA
Hou Shugui	Nanjing	China
Soon Do Hur	KOPRI	Korea
Elisabeth Isaksson	NPI	Norway
Jay Johnson	Wisconsin	USA
Yeadong Kim	KOPRI	Korea
Amaelle Landais	LSCE	France
Khanghyun Lee	KOPRI	Korea
Li Yuansheng	PRIC	China
Volodia Lipenkov	AARI	Russia
Heinz Miller	AWI	Germany
Robert Mulvaney	BAS	UK
Raimund Muscheler	Lund	Sweden
Ikumi Oyabu	NIPR	Japan
Fred Parrenin	IGE	France
Frank Pattyn	ULB	Belgium
Catherine Ritz	LGGE	France

Joel Savarino	IGE	France
Jochen Schmitt	Bern	Switzerland
Jeff Severinghaus	Scripps	USA
Sarah Shackleton	Scripps	USA
Andrea Spolaor	Venice	Italy
Hans-Christian Steen-Larsen	Bergen	Norway
Barbara Stenni	Venice	Italy
Thomas Stocker	Bern	Switzerland
Thorsteinn Thorsteinsson	Icelandic Met Office	Iceland
Michiel van den Broeke	Utrecht	Netherlands
Tas van Ommen	AAD	Australia
Wei Jiang	Hefei	China
Jim White	INSTAAR	USA
Frank Wilhelms	AWI	Germany
Eric Wolff	BAS	UK
Duncan Young	UTIG	USA