Review of the
International Partnerships in Ice Core Sciences

Background

International Partnerships in Ice Core Sciences (IPICS) consists of ice core scientists, engineers, and drillers from the leading laboratories and national operators carrying out ice core science, acting to further the aims as described in the mission statement. The mission is to define and develop priorities, enable coordination between different ice core laboratories, act as a voice for the ice core community, and train the next generation of ice core scientists. It now consists of representatives from 24 nations, and we believe all nations with an active ice core programme are members.

IPICS has been active since 2002. Although it has no formal parentage, it is affiliated in different forms to PAGES (Past Global Changes), SCAR (as an Expert Group under the Physical Sciences Working Group), and IUGG-IACS, thus providing a link to its major international partners in terms of discipline (palaeoscience), geography (SCAR) and medium (ice, IACS). It has also received support for meetings from the US National Science Foundation and the European Polar Board, as well as national agencies. The current co-chairs are Eric Wolff (UK) and Ed Brook (USA). These positions will be up for election in 2017.

More information can be found on their webpage: http://www.pages-igbp.org/ini/end-aff/ipics/intro

In an effort to help IPICS shape their direction and to review its progress, SCAR facilitated a review of IPICS. This review was mainly for SCAR to help best support IPICS in their efforts and activities. IPICS has been kind enough to provide a short overview of their past achievements and a brief look at what they plan for the next few years. This document can be downloaded here: https://www.dropbox.com/s/n1t5jly6wqlqpgs/2016_IPICS_Achievements.pdf?dl=0

Summary of Reviews

All six external reviews were very positive toward IPICS efforts. IPICS is an effective and productive activity coordinating international ice coring. The structure of the group seems to be working well and the Open Science Conference and support of early career researchers are particularly important to the community.

SCAR benefits from sponsoring this group as it helps to coordinate ice core activities in the Antarctic, and beyond. SCAR could work more closely with IPICS on outreach and communication efforts, which are important to both groups.

It is recommended that SCAR continues to support the important efforts of IPICS.

Report provided to External Reviewers on Acheivements of IPICS

Expert Group: IPICS (International Partnerships in Ice Core Sciences)

Review document, May 2016

1. Introduction

International Partnerships in Ice Core Sciences (IPICS) consists of ice core scientists, engineers, and drillers from the leading laboratories and national operators carrying out ice core science, acting to further the aims as described in the mission statement. The mission is to define and develop priorities, enable coordination between different ice core laboratories, act as a voice for the ice core community, and train the next generation of ice core scientists. It now consists of representatives from 24 nations, and we believe all nations with an active ice core programme are members.

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Further details about IPICS can be found on our website, held under the PAGES website at pastglobalchanges.org (Note that, at the time of writing, access to the website is patchy as the PAGES domain has suffered heavy external attack. It is hoped this will be solved very soon.)

2. Achievements

The most notable achievement of IPICS has been to maintain a spirit of international collaboration and co-operation, and a coherency of voice in promoting ice core science. This has been achieved simply by sharing information and through our two open science conferences. However the activity generated by IPICS is probably best illustrated by discussing in turn the priority projects, then the activities of ICYS (Ice Core Young Scientists) and finally the Open Science Conferences. We will concentrate on activity undertaken since IPICS became a SCAR EG in 2008.

Before starting that, it should be obvious that not all IPICS activity is relevant to SCAR, as ice cores are also obtained in Greenland, and at non-polar locations. However an analysis we undertook after the SCAR Horizon Scanning exercise suggested that ice cores could contribute information to 27 of the 80 identified priorities – as well as the more obvious issues related to climate, ice sheet, and the atmosphere and the ocean surrounding Antarctica, ice cores can provide information about for example the impact of human activity, the frequency of solar events, and the changing environment to which ecosystems must adapt.

3. Priority projects

IPICS set itself a goal to define a series of priority projects, around which international efforts could coalesce, but keeping them to a small number (maximum 5). The current white papers are for Oldest ice, Last Interglacial, IPICS-40k, and IPICS-2k. There is also a white paper about technical challenges such as drilling technology.

a. Oldest ice

Ice cores have so far reached back 800,000 years. In doing that (through the European EPICA Dome C core, now replicated back to 720 ka by the Japanese Dome Fuji core), they have added unprecedented information about climate forcing and the resultant climate response, opening this entire period up to serious quantitative analysis and modelling. The entire period is characterised by glacial cycles recurring on an ~800 ka period. However it is well-known from marine records that, prior to 800 ka, climate had a periodicity of 40 ka. There are a number of ideas about why this shift (the so-called "Mid-Pleistocene Transition") occurred, and an ice core reaching back into them would directly confront many of the ideas, including ones involving changing greenhouse gas concentrations. This white paper therefore proposes to find a place (in Antarctica, the only contender) to obtain ice up to 1.5 million years old, and to drill and analyse such a core.

The whole ice core community has been excited by this challenge, which has also attracted strong interest in neighbouring communities. In specific actions, IPICS has held two "Oldest Ice" workshops, attached to its open science meetings in 2012 and 2016. The first of these workshops led to a major international paper (Fischer et al, 2013) defining the conditions needed to obtain such a core. A series of airborne geophysical campaigns have provided data relevant to finding old ice, and ice modelling work has also been directed at the problem. Both the data and modelling work have been widely shared within the overall umbrella of IPICS oldest ice. Several nations or groups have expressed aspirations or started action to obtain a potential oldest ice core, and in each case they have cited the international context of IPICS, and the need for replicated records and international endorsement. Additionally, several new types of rapid access drill have been developed (and are now being tested) specifically with the goal of reaching and testing for old ice.

The oldest ice project remains a powerful aspiration which now has momentum in several nations (for example there was recently a funding call for exploratory work to find oldest ice from the European Union). It is likely that drilling will take place in the early part of the next decade, assuming suitable sites are indeed found. IPICS member organisations will lead each possible project, and IPICS as a whole can take credit for defining the project and providing it with momentum and visibility that have led to the current progress. This is a project that is entirely Antarctic based, and which SCAR may want to take a particular interest in.

Example publications specifically related to this white paper:

Fischer, H., et al. (2013), Where to find 1.5 million yr old ice for the IPICS "Oldest Ice" ice core, *Climate of the Past*, *9*, 2489-2505, doi:10.5194/cpd-9-2771-2013.

Van Liefferinge, B., and F. Pattyn (2013), Using ice-flow models to evaluate potential sites of million year-old ice in Antarctica, *Climate of the Past*, *9*(5), 2335-2345, doi:10.5194/cp-9-2335-2013.

Alemany, O., et al. (2014), The SUBGLACIOR drilling probe: concept and design, *Ann. Glaciol.*, *55*(68), 233-242, doi:10.3189/2014AoG68A026.

b. Last Interglacial

This priority began as a white paper entitled "The last interglacial and beyond: A northwest Greenland deep ice core drilling project". Its aim was to obtain a record through the last interglacial from Greenland. The best attempt at this was completed with the drilling and publication of the NEEM ice core (NEEM Community Members, 2013), and so it was agreed to replace that white paper

with a more general one entitled “History and Dynamics of the Last Interglacial Period from Ice Cores”. This was done in early 2015.

The last interglacial is of huge interest particularly because of the lessons it can teach us about sea level under a climate warmer than today. During the last interglacial (130-115 ka ago), both polar regions were at some stage warmer than today, and sea level was apparently 6-9 m higher than it is today. This calls for ice loss from both Greenland and Antarctica. Determining where the ice came from, and under what conditions, is a very important challenge to the ice core, and the wider glaciology, community. The NEEM record, along with earlier Greenland ice cores, constrains the sea level rise from Greenland, while posing a challenge as to why so much Greenland ice survived apparently large temperature change. Additionally it places a burden on us to find several metres of sea level rise from Antarctica, with West Antarctica normally emphasised. The white paper therefore call for acquisition and interpretation of new, high-resolution records of last interglacial forcing and climate response in both Greenland and Antarctica, with a particular emphasis on locations that might give decisive evidence about the state of the West Antarctic Ice Sheet.

A number of last interglacial records have been obtained from Antarctica in recent years, including Dome C, Dome Fuji, EDML, Talos Dome and Mount Moulton. Numerous parameters are now measured on such cores including novel isotopic measurements (Schneider et al., 2013). New records are in the pipeline, and projects aimed firmly at the WAIS question have recently been proposed (Steig et al., 2015). Advances in determining the relative timing in each hemisphere have allowed much improved modelling targets for understanding the evolution of climate during the last interglacial. Overall, IPICS science has significantly defined the conundrums of the last interglacial, but further work is needed to solve them.

Example publications specifically related to this white paper:

Capron, E., A. Govin, E. J. Stone, V. Masson-Delmotte, S. Mulitza, B. Otto-Bliesner, L. C. Sime, C. Waelbroeck, and E. W. Wolff (2014), Temporal and spatial structure of multi-millennial temperature changes at high latitudes during the Last Interglacial, *Quat. Sci. Rev.*, *103*, 116-133.

Masson-Delmotte, V., et al. (2011), A comparison of the present and last interglacial periods in six Antarctic ice cores, *Clim. Past*, *7*(2), 397-423.

NEEM Community Members (2013), Eemian interglacial reconstructed from a Greenland folded ice core *Nature*, *493*, 489-494, doi:10.1038/nature11789.

Schneider, R., J. Schmitt, P. Kohler, F. Joos, and H. Fischer (2013), A reconstruction of atmospheric carbon dioxide and its stable carbon isotopic composition from the penultimate glacial maximum to the last glacial inception, *Climate of the Past*, *9*(6), 2507-2523, doi:10.5194/cp-9-2507-2013.

Steig, E. J., K. Huybers, H. A. Singh, N. J. Steiger, Q. H. Ding, D. M. W. Frierson, T. Popp, and J. W. C. White (2015), Influence of West Antarctic Ice Sheet collapse on Antarctic surface climate, *Geophys. Res. Lett.*, *42*(12), 4862-4868, doi:10.1002/2015gl063861.

c. IPICS-40k

The last 40,000 years includes the transition from the last glacial maximum into the Holocene warm period, and a sequence of abrupt swings in climate most clearly seen in Greenland ice cores, and known as Dansgaard-Oeschger (DO) events. It has long been clear that DO events and the glacial

termination have a global character, with a different style of millennial change in Antarctica. The challenge in the white paper "The IPICS 40,000 year network: a bipolar record of climate forcing and response" is to document, for Greenland and different regions of Antarctica the timing and nature of these events.

In recent years, several new records have emerged and a number of papers have integrated them together, using new techniques to tie timescales together between north and south, and to tie greenhouse gas timescales to the climate records in the ice phase. Arguably the most impressive advance has come with the production of new high resolution records, of a resolution comparable to that of Greenland cores, from the US WAIS Divide project. This project has shown conclusively how tightly coupled northern and southern climate are, and defined the lags between them, which greatly constrains possible mechanisms (WAIS Divide Project members, 2015). In other work, the evolution of carbon dioxide across the last glacial termination has been defined at very high resolution, confirming the existence of a series of rapid jumps of around 10 ppm in 200 years (Marcott et al., 2014). New records have further refined our knowledge of Holocene climate evolution, with a particular advance coming from a new record from the tip of the Antarctic Peninsula (Mulvaney et al., 2012).

Projects from the IPICS community have slowly added very detailed spatial and temporal detail to our knowledge of climate change in the last 40 ka, and provided strong evidence for modellers to use to work on ideas about changes in overturning circulation of the ocean, and the interactions between such changes and longer-term forcing. However to obtain further evidence it will be necessary to look at more than one termination, and at millennial changes under a range of boundary conditions. At the IPICS SC meeting in 2016, it was therefore agreed to end the 40k project and widen it into a more general project about glacial terminations and abrupt climate change. This becomes possible as more ice cores from Antarctica reach beyond the last glacial cycle. A new white paper will replace the 40k one later this year.

Example publications specifically related to this white paper:

Marcott, S. A., et al. (2014), Centennial-scale changes in the global carbon cycle during the last deglaciation, *Nature*, *514*(7524), 616-619, doi:10.1038/nature13799.

Mulvaney, R., N. J. Abram, R. C. A. Hindmarsh, C. Arrowsmith, L. Fleet, J. Triest, L. C. Sime, O. Alemany, and S. Foord (2012), Recent Antarctic Peninsula warming relative to Holocene climate and ice-shelf history, *Nature*, *489*(7414), 141-144, doi:http://www.nature.com/nature/journal/v489/n7414/abs/nature11391.html#supplementary-information.

Pedro, J. B., S. O. Rasmussen, and T. D. van Ommen (2012), Tightened constraints on the time-lag between Antarctic temperature and CO2 during the last deglaciation, *Climate of the Past*, *8*(4), 1213-1221, doi:10.5194/cp-8-1213-2012.

Wais Divide Project Members (2015), Precise interpolar phasing of abrupt climate change during the last ice age, *Nature*, *520*(7549), 661-665, doi:10.1038/nature14401

http://www.nature.com/nature/journal/v520/n7549/abs/nature14401.html#supplementary-information.

d. IPICS – 2k

Understanding present and future climate change requires a knowledge of natural climate variability. The period of the last 1-2 millennia provides sufficient time to see a range of cyclic internal behaviours and sporadic forcing such as volcanic eruptions, and is also a time over which high resolution climate modelling is feasible. The white paper "The IPICS 2k Array: a network of ice core climate and climate forcing records for the last two millennia" sets the challenge to produce a spatial array of records, preferably with annual resolution, extending back towards or beyond 2000 years ago.

In practice there is a nice range of annually resolved records from Greenland, and a few records extending some centuries from non-polar ice, but the main effort has gone into assembling suitable records from Antarctica. This is challenging because vast swathes of central East Antarctica have low snowfall and lack the resolution to use techniques commonly used on high resolution records. The effort has been devolved to the PAGES sub-project Antarctica-2k, led by IPICS SC member van Ommen and then Stenni. Antarctic records have been included in the major synthesis of the last 200 years (PAGES 2k consortium, 2013), and a major effort is underway, with a special issue in the pipeline, to improve the Antarctic contribution to this project. A major breakthrough is the improved ability to tie records together from north and south, and with volcanic eruption signals (Sigl et al., 2015). This arises in turn from the existence of annually counted timescales from both hemispheres, and new markers of unusual events that allow certainty in tying cores together. While the 2k effort remains focussed on climate variables, in particular temperature, accumulation rate and sea ice extent, the data have also been used to better understand how aspects of anthropogenic pollution have emerged in recent decades and centuries.

Example publications specifically related to this white paper:

Pages 2k Consortium (2013), Continental-scale temperature variability during the past two millennia, *Nature Geoscience*, *6*(5), 339-346, doi:10.1038/ngeo1797.

Sigl, M., et al. (2015), Timing and climate forcing of volcanic eruptions for the past 2,500 years, *Nature*, *523*(7562), 543-+, doi:10.1038/nature14565.

e. Drilling

The white paper "Ice core drilling technical challenges" set out a series of advances in technology that could be required by the ice core community. Advances have been made through individual initiatives, and close communication, including in particular a major ice core drilling workshop held under IPICS auspices in Wisconsin in 2013. There have been impressive achievements in for example drilling in warm ice, replicate and deviation drilling, and in the potential for rapid access drilling that includes downhole analysis.
For further details, please see the special issue of Annals of Glaciology on this topic at http://www.ingentaconnect.com/content/igsoc/agl/2014/00000055/00000068

f. New white papers and initiatives

In addition to the revision of the 40k white paper, it was agreed at the SC meeting in 2016 that a new white paper on ice cores to advance understanding of ice dynamics should be produced. This will address the ways that ice cores can help us to understand changes in fabric and other properties

and their role in ice dynamics. The new EGRIP project in East Greenland is the first contributor to this project, but there is also potential for Antarctic projects investigating for example ice flow over ice rises, and the nature of unexpected deep ice features observed in radar records. It is expected that this white paper will enhance collaborations between ice core and ice dynamics and modelling experts.

It is also intended to promote more work on non-polar glaciers, probably as an initiative within IPICS 2k. IPICS has also endorsed and encouraged a new project "Saving Ice in Danger" to drill cores from endangered glaciers and store them in guaranteed cold conditions in Antarctica.

4. Ice Core Young Scientists (ICYS)

At the SC in 2012 it was agreed that IPICS should encourage early career scientists to form their own grouping. This has been done and ICYS now arranges social and training events at major conferences. There is some overlap with APECS and we encourage the ICYS SC to work with APECS. At the recent open science conference a 1-day workshop, consisting mainly of topics intended to enhance early careers, was held. IPICS is adopting a hands-off approach to ICYS, offering to help where required, but letting ICYCS organise its own agenda without interference.

5. Open Science Conference

The first IPICS Open Science Conference (OSC) was held at Giens, France in 2012, organised by a committee led by Jérôme Chappellaz. Over 200 attendees enjoyed an excellent week of talks, posters and discussions.

The second IPICS Open Science Conference was held in Hobart, March 7-11, 2016; the venue was chosen after an open competition. It was organised by a team led by Tas van Ommen. Over 200 people attended a very successful week of talks and poster sessions. The IPICS Steering committee, now with representatives from 24 nations (Iceland and Chile recently joined), met in Hobart and discussed the status and updates of priority projects. ICYS held a one-day workshop in Hobart with over 80 attendees that discussed career development and science communication. SCAR was one of a number of sponsors that supported early career travel to each of the OSCs. A special joint issue of the journals *Climate of the Past* and *The Cryosphere* is being produced as a product of the meeting – we anticipate around 20 papers.

About half the OSC attendees completed a survey after the meeting, and were overwhelmingly positive about it; 90% of those who responded to a question asking them to compare the OSC to other conferences they had attended in the last 3 years stated that the OSC was "better" or "much better"!

The third OSC will be held in 2020, with a venue to be decided by open competition during 2017.

6. Future plans

In the sphere of agenda setting, IPICS will undertake the production of the new white papers on "Glacial terminations and abrupt climate change" and "Ice cores for ice dynamics". IPICS40k will be closed as a result.

IPICS will continue to exchange information and encourage collaborative work on its priority projects. In practice this is done mainly through the work of IPICS scientists within projects funded nationally or multi-nationally, or within initiatives such as PAGES Antarctic2K. We will take particular care to promote the oldest ice project, which requires considerable effort also from geophysics, glaciology and logistic partners. We anticipate that liaison meetings will be held under the auspices of projects such as the "European Beyond EPICA – Oldest Ice" project, but will intervene if this is not the case. We will also propose and promote relevant scientific sessions for our priority projects at meetings such as EGU, AGU and the PAGES OSM.

We will continue to encourage and offer support to ICYS, who generally arrange events at each major meeting (EGU, AGU).

Finally we will put in place plans for the 2020 IPICS Open Science Conference. In relation to SCAR this is the major event for which we request funds, and we will therefore anticipate making funding requests for it for the years 2019 and 2020.

7. Summary

IPICS can now claim to represent ice core scientists and engineers around the world. It has been successful in setting agendas and in providing a voice and presence for ice core science. As well as major advances by individual ice core scientists, IPICS initiatives and workshops have provided momentum to particular topics and provided focus for individual groups to contribute more than the sum of their parts. ICYS is providing a network for early career scientist while the OSCs have been very popular cement for the community. We hope this will commend IPICS to SCAR for its continuance as an EG.

Eric Wolff and Ed Brook, co-chairs, May 2016.

Reviewer 1

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

IPICS is a very dynamic working group, which has provided a number of strategic scientific goals for the ice core community to work within. This has created a true sense of community and international cooperation, has helped individual researchers to demonstrate the importance of research proposals aligned with the IPICS goals, and raised the profile of ice core science. The IPICS framework began with four scientific priorities and has involved two successful open science meetings that are designed to become a 4-yearly event for the community. An early career network has also more recently been established.

A review of the scientific priorities of IPICS earlier this year has identified some of the scientific goals have now been achieved, while it identified new challenges for the community that will become new priorities. IPICS states that it's "mission is to define and develop
priorities, enable coordination between different ice core laboratories, act as a voice for the ice core community, and train the next generation of ice core scientists". In my opinion IPICS is clearly meeting its objectives.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

The future plans of IPICS are:
To continue to support international cooperation in the goal of retrieving oldest ice.
To continue to support the generation of a 2k array of ice core records, including supporting the PAGES Antarctica2k working group.
To transform the last interglacial priority into a broader priority to study past interglacials
To cease the 40k priority, and replace this with a priority to use ice cores to study physical processes within ice sheets.
To develop a new priority around engineering solutions/innovations for ice core drilling and borehole analysis.
There are plans to possibly include a non-polar priority within IPICS in the future.
To hold a 3rd IPICS Open Science meeting in 2020. Funds will be applied for in 2019 and 2020 to support this.
To continue to provide guidance and support where required for the ICYS early career network.

The IPICS plans are extremely well aligned with the current status of ice core science, and have been well planned by the steering committee that includes members from each nation with an ice core research program.

I have nothing to add apart from my support for the direction of IPICS outlined by the steering committee.

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

The benefit to SCAR in sponsoring IPICS is that the ice core community is well established under the IPICS framework, and the IPICS science priorities guide research towards coordinated goals. This gives ice core research greater significance and helps to foster funding opportunities at a national level.

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

IPICS offers to SCAR a coordinated approach to ice core science. This is not just in Antarctica, but also includes Greenland and non-polar ice cores beyond the SCAR remit. IPICS is a well-run working group that has the support of the international ice core research community.

In terms of what extra IPICS could contribute, I have nothing to add. The steering committee model appears to be very effective and the evolution of IPICS to adapt to changing science priorities is already well planned. The forum has also expanded to include ECR and engineering/technical communities associated with ice core research.

Please provide any additional comments you would like to be considered as part of this review:

Reviewer 2

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

To date, IPICS has been very successful in reaching its objectives. IPICS has had great success in defining, and providing momentum and visibility, for important projects. IPICS-led initiatives have led to new technology development (e.g. rapid access drills), increased geophysical exploration of Antarctica (via site selection for new drill sites), major international papers, and special issues in journals. The IPICS-led initiatives have clearly added momentum to particular topics (e.g., the search for oldest ice, the last interglacial, the last 40,000 years). And the international collaboration on the IPICS-led initiatives, and routine communication via the IPICS open science conferences, has undoubtedly allowed for the individual scientific projects to contribute more than the sum of their parts. The degree of organization, participation, and enthusiasm within the IPICS community is really outstanding. IPICS has also been very successful in engaging, teaching, and energizing the next generation of ice core scientists.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

IPICS has done a highly commendable job in routinely evaluating how well it has met its objectives, and then modifying or updating those objectives as needed. The most recent examples include the decision to end the 40 ka project and widen it into a more general project about glacial terminations and abrupt climate change, the new initiative on how ice cores can help advance understanding of ice dynamics, and the recognition for the need to promote more work on non-polar glaciers. Also, IPICS continues to have a clear vision for, and is ready to continue its promotion of, the oldest ice project.

IPICS has also done a great job in the timely planning and execution of its open science conferences, and plans are already being developed for the third IPICS Open Science Conference to be held in 2020.

IPICS should continue to propose and promote relevant scientific sessions for the IPICS priority projects at meetings such as EGU, AGU, and the PAGES OSM.

IPICS should continue to encourage and offer support to ICYS (Ice Core Young Scientists).

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

IPICS represents ice core scientists and engineers from around the world. As such, IPICS offers the opportunity to be an important Expert Group to SCAR.

Also, SCAR is charged with initiating, developing, and coordinating high quality international scientific research in the Antarctic region. IPICS represents a well-organized international community with a successful history in defining and developing priorities within the ice core research community. As such, IPICS directly contributes to SCAR's objectives by initiating new scientific objectives, and promoting international cooperation and partnerships in Antarctic ice core research.

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

As stated above, SCAR is charged with initiating, developing, and coordinating high quality international scientific research in the Antarctic region. IPICS represents a well-organized international community with a successful history in defining and developing priorities within the ice core research community. As such, IPICS directly contributes to SCAR's objectives by implementing new scientific objectives, and promoting international cooperation and partnerships in Antarctic research.

IPICS can help SCAR identify the most important scientific questions that will or should be addressed by research in and from the southern Polar Regions over the next two decades.

IPICS could perhaps help SCAR engage with policy-makers and other sectors of society to help ensure that scientific knowledge is linked to policy making.

Please provide any additional comments you would like to be considered as part of this review:

Reviewer 3

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

IPICS has easily met its objectives. It has organized the ice coring community around 5 themes laid out in white papers, and has made great progress to accomplish them. For instance, the task #2 on the last interglacial has been completed, by the drilling of the NEEM ice core, involving 13 nations from all continents. Objectives have recently been updated to reflect the evolution of the community.

IPICS has also been successful in involving the world community in ice coring, and I believe that no ice-coring nation is left out of the organization. The open science meeting held in Hobart in 2015 was a great success, drawing more than 200 participants.

IPICS has also been successful in involving young scientists, and seeded the "Ice Core Young Scientist" (ICYS) group.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

The future plans of IPICS are clearly laid out in 5 white papers. They span the whole range of timescales associated with the ice core community, from the most recent timescales to the search for the oldest ice. They also include a technical white paper on drilling technology, which is a key aspect of ice core science. These white papers are important tools to gather the ice coring community around major goals, and they clearly reflect the major scientific objectives.

In recent years, there has been a large expansion of borehole logging techniques, which are changing the way ice coring is done. These developments are not included in the current white papers, and perhaps, a technical white paper on logging would be useful, to scope out the potential of this family of methods.

IPICS's main goal has been to structure the ice-coring community. It has done this extremely well. Perhaps it can now think on how to best interact with other communities (e.g. glaciology) to develop common themes, for which ice coring could provide a valuable contribution. This is included partially in the "ice core for glaciology" white paper to-be, but perhaps this type of reflection could be expanded.

Regarding education, the ICYS group provides a venue for young scientists to further their training, which is great. However, there is no framework to help new ice-coring nations to develop their skills and expertise, both technically and scientifically. In the context of the 5 white papers, perhaps a strategy on how best to support new nations could be included. NEEM for instance, was a great example of international cooperation, and training of drillers.

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

IPICS fully belongs to SCAR. Ice coring is an important component of Antarctic research, and the results from ice-coring science fall into SCAR's objectives, in particular "Antarctica and Climate". What's more, ice-coring is a very international activity, and many past and future projects involve international consortia, bringing together scientists from several continents, going further than the traditional European or North American partnerships. In that respect, SCAR benefits form encouraging truly international scientific cooperation.

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

IPICS contributes:
- outstanding science to understand past and current Antarctic climate
- scan of the horizons to identify evolving issues related to our understanding of the climate
- provides a venue to discuss science through the open science conferences
- helps develop the capacity of early career scientists thought ICYS
- fosters an atmosphere of international cooperation, encouraging emerging Antarctic program in new ice-coring nations.

IPICS could contribute a more concerted effort in outreach towards the public. Although much is done at the national level, the community could benefit from exchanging best practices in hands-on education, and involving international news channels (or common tweeter feeds) for all field expeditions and major publications for instance. Crafting a common message and image bank that each research group could pick-up would make communication easier.

Please provide any additional comments you would like to be considered as part of this review:

IPICS is a very successful organization. Despite a low budget, it has established itself as the de-facto steering committee of the ice-coring community. Its work on establishing priorities (which are well respected) is outstanding, and deserved to be supported.

Reviewer 4

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

IPICS mission consists in four **objectives** and **I** think that all of them were **fully reached.**

- Define and develop priorities. A set of priority projects were defined: Oldest ice, Last Interglacial, IPICS-40k, and IPICS-2k and drilling techniques. Each project tackles specific scientific or technical questions that are developed in corresponding white papers. This gave more visibility and helped the ice core community to build drilling projects and to optimize the interpretation of existing records.

- Enable coordination between different ice core laboratories. IPICS now consists of representatives from 24 nations. To improve collaboration and co-operation, IPICS organized two open Science conferences and various workshops, 2 Oldest Ice workshops attached to the conferences and a major ice core drilling workshop.

- Act as a voice for the ice core community. The white papers were a very efficient way to represent the ice core community, but the special issues attached to the open conferences and the drilling techniques workshop constitute another important achievement. IPICS provided the definition, the international context and the visibility for ongoing projects, especially the Oldest Ice.

Train the next generation of ice core scientists. IPICS encouraged encourage early career scientists to form their own grouping, ICYS (Ice Core Young Scientists). At the recent open science conference a 1-day workshop, consisting mainly of topics intended to enhance early careers, was held.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

Concerning the priorities, the main changes for the future are to extend the topic IPICS40k to the other glacial terminations and a new topic 'Ice cores for ice dynamics" is appears. In both cases, production of the corresponding white papers is planned. The "Ice cores for ice dynamics" priority is very appropriate in the context of the global change and ice sheet stability.

IPICS will continue to exchange information and encourage collaborative work. There is a special emphasis on the Oldest-Ice project which requires considerable effort but will also provide collaborations opportunities for instance within the "European Beyond EPICA – Oldest Ice" project.

The promotion of scientific sessions at meetings such as EGU, AGU and the PAGES OSM will give a **strong visibility to Antarctic (polar) Science** in the geophysical and paleoclimate fields.

IPICS has been very efficient and the plans for the future rely on the same approach so I have no doubt that these plans will achieve the desired goals of IPICS.

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

Ice core science is completely within the SCAR topics. For instance, IPICS could contribute information to 27 of the 80 identified SCAR priorities. Moreover, it is an excellent showcase for polar science. Finally, it has strong links with other SCAR groups and projects (ISMASS, PAIS).

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

The Oldest Ice project will have a strong development during the next years. IPICS helped a lot to define it and will be an essential tool to facilitate collaborations and enhance visibility which will be a great benefit for SCAR.

Please provide any additional comments you would like to be considered as part of this review:

I fully support the continuation of IPICS as an Expert Group.

Reviewer 5

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

IPICS has made spectacular progress on meeting its objectives. Shortly after it began, IPICS proposed four different goals, focused on obtaining records from four distinct time periods: last interglacial, last 2000 years, last 40,000 years, and "oldest ice". Setting this goals has unquestionably led to a new spirit of international collaboration, as well as new funding, and the first three goals have largely been achieved. Interglacial ice was obtained in Greenland for the first time; dozens of new records extending to 2000 years were obtained; and several new cores were obtained in Antarctica that go to 40,000 years and beyond. Really making progress on the last interglacial in Antarctica has not been achieved, but new projects are on the horizon.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

For the next phase of IPICS, the goals remain about the same as they were set out at the beginning. I believe that this is just fine, because there is more work to be done. In particular, for the 2000-year goal, the community has gone beyond collecting the records and has also combined them in an exemplary show of international cooperation; several papers containing hundreds or records are in progress and will define the state of the art for understanding recent climate and ice sheet change in Antarctica. The major goal, not yet achieved, is the "oldest ice" and the last interglacial in Antarctica. These are extremely ambitious goals, and this is a strength. I believe the international coordination necessary to achieve these goals is not yet fully formed, and may be difficult, but I see this as a problem at the funding level, not at the IPICS level. The visibility provided by IPICS is absolutely needed if the funding agencies are to be convinced to coordinate to fund such projects.

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

IPICS has produced highly visible activities and scientific successes.

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

WAIS Divide, EPICA Dome C, the ongoing 2,000 year array, all inform Antarctic science in general.

Please provide any additional comments you would like to be considered as part of this review:

The "ice core young scientists" program deserves particular recognition as one of the success stories from IPICS. It is now an essentially independent entity, and has been an extremely useful networking opportunity for young scientists that has already led to new research ideas that have been funded, both nationally and internationally.

Reviewer 6

Progress towards objectives

In reading the achievements document provided, and based on your knowledge of IPICS and SCAR, please provide a brief summary of your impression of how well IPICS has met its objectives. *Please keep in mind that IPICS is an independent organization that heavily relies on contributions from individual scientists and various sponsors who provide small amounts of funding (SCAR provides ~ $4500/year).*

The IPICS review document provides a good overview of the activities over recent years and demonstrates that IPICS is an active scientific group. Having participated in the second IPICS open science conference in Hobart I was impressed and inspired by the energy of the ice core community. Of particular note is the participation and active involvement of early career researchers.

Future Plans

Please provide a short summary of your impression of the future plans of IPICS. Please also include any thoughts you might have on what they might consider doing.

No comment.

Sponsorship Review

From your perspective, what are the benefits to SCAR in sponsoring IPICS?

IPICS provides a valuable platform for international collaboration within the ice core community and wider scientific disciplines relevant to SCAR.

What does IPICS contribute to SCAR? What could it contribute that is not currently done?

No comment.

Please provide any additional comments you would like to be considered as part of this review:

IPICS is an active scientific group which should be renewed as a SCAR expert group.