International update

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A selective presentation

• Main focus on European work towards oldest ice
• I have included information kindly supplied by China, Japan and Australia
• And some other European work that might be of interest
• I have repeated some information I gave last year just for those who weren’t here
Priority projects

• IPICS 2k - 2000 year array of ice core records
• IPICS Terminations and seesaws
• IPICS Last Interglacial
• IPICS Oldest Ice - goal is 1.5 Ma ice core record
• Technology - new drilling and exploration tools

Other activities/white papers

• IPICS Ice Dynamics (in preparation, e.g. EGRIP)
• Non-polar cores – support action on protecting endangered ice archives

http://pastglobalchanges.org/ini/end-aff/ipics/intro
Oldest ice and Europe

• Ambitious “grand challenge” project to drill ice core extending 1.5 million years
• Need to find and test the most probable locations
• The 10 EPICA nations agreed to join a “Beyond EPICA” project (Estonia and Austria might join later) and seek national and EU funding
• EU awarded ~€3M for a “Coordination and Support Action” for 3 years from October 2016
• Involves site selection work around Dome C and Dome F regions
Beyond EPICA – Oldest Ice
Phases

• pre-site survey: determination of optimal drill site 2016-2019
• Phase 1: Ice-core drilling 2020-2024
• Phase 2: Scientific exploitation 2025-2028

Pre-site survey: which conditions?

• undisturbed ice (layering, requires melting)
• sufficient age (little melting)
• sufficient layer thickness for analyses
Beyond EPICA – Oldest Ice

- Coordinator: AWI (Olaf Eisen, Germany), 14 partners in 10 nations
- 8 workpackages
  1. Logistics
  2. Geophysics
  3. Rapid access drilling
  4. Site selection (go/no-go), science plan, focus on deepest 100 m
  5. Drilling plan (decide drill, fluid, etc)
  6. Finance plan (commitment of in-kind and money)
  7. International and interdisciplinary collaboration
  8. Management of this project
Location

• A location near Concordia will be much easier (logistics) and cheaper for us, so is our first priority
• Survey work in DML/DF as backup
• We assume that other nations will survey and target other “blobs”
Summary of approach at each site

• ice thickness (radar) => bedrock
• internal layering (radar) => integrity
• vertical strain rate (pRES, sfc. strain)
• geothermal heat flux (DTS, pRES, flow model)

• age: transfer from ice cores, extend with flow model

• final verification:
  rapid access drilling with RADIX, SUBGLACIOR
DML/Dome F: Jan17 (Nov16 - Feb17)

ca. 20,000 km of airborne radar
Concordia region plan

• 2015/16 UTIG/AAD airborne survey
  – Define target area (most likely on Blob A - Little Dome C)
• 2016/17 Mini-traverse to Little Dome C
  – pRES
  – Ground-based radar (Delores)
  – Strain net
  – UK RAID and Subglacier tests
• Ice flow modelling and narrow target area
• 2017/18 (but see later) Subglacier drilling to ensure there is old ice
Age predictions at Little Dome C (Parrenin, 2015):

- If Geothermal flux is equal or lower that at Dome C (66.8 mW m\(^{-2}\)): 1.5 million years old
- If Geothermal flux is only 5 mW m\(^{-2}\) higher (71.8 mW m\(^{-2}\)): 0.5 million years old
3D effects could be important:
- Horizontal grid $<< H$
- Radar layers help to understand pRES data
  - GPS strain-rates useful to process pRES englacial strain-rates.
  - Density is useful: pRES combines compression and compaction.
UK Rapid Access Isotope Drilling and pRES for basal temperature and LGM depth
Delores radar (shortened cables)

Transmitter

Receiver
Radar survey 16/17
Delores, drill site ~9000
UK RAID drill
Video

• (Not included in presentation file)
Vertical strain rate measured after one year interval (Red = Jan 2014, Blue = Jan 2015).

Linear strain to 2300 m, with strain rate of $0.0169 \pm 0.0005 \times 10^{-3} \text{ yr}^{-1}$.
ERC ICE&LASERS - ANR SUBGLACIOR

http://www.iceandlasers-subglacior.org
General probe design
How successful?

• All planned radar run, very tight grid around “Little Dome C” and “Patch North”
• pRES, strain net deployed
• UK RAID works but was very slow, reached 105 m, so no accurate basal temperature
  – Should be deployed properly next season
• Many aspects of SUBGLACIOR were successfully tested, but issues with the borehole casing, thermal finger and other parts means they only drilled 1 m of ice
  – Will require further test next season
Concordia region (revised schedule)

• 2017/18
  – pRES repeat
  – Strain net repeat
  – New ground based radar? (NPI)
  – RAID drilling (UK): isotopes and temperature profiles
  – RADIX drilling (CH): isotopes and deepest ice
  – Subglacior further test season (FR)
  – Basal ice dating by cosmogenics

• 2018/19 Needed now for Subglacior drilling at single site
International collaboration

• Specific WP for collaboration internationally (IPICS) and with other disciplines (paleocean, modelling)
• Liaison and Advisory Group
  – Ed Brook
  – Tas van Ommen
  – Kumiko Goto-Azuma
  – Marie France Loutre (PAGES, models)
  – Ed Waddington
  – Ros Rickaby (Oxford, paleoceanography)
• Many workshops including in particular
  – “Oldest ice” international workshop, summer 2018
  – Conference or workshop: “From 40k to 100k: Understanding the mid-Pleistocene Revolution”, ~October 2018 (perhaps later)
Aim

- Have in place all preconditions for starting a drilling
- Although national contributions will be essential, we don’t envisage running a drilling phase unless we also have EU funding for that, so we hope to provoke a call to start work in 2020
How we envisage international collaboration in Oldest Ice

• Sharing of geophysical data and of best practice for site selection, dating and drilling

• Share most appropriate equipment (eg rapid access) at different sites

• Collaborative analysis where a consortium lacks expertise or manpower

• Best use of available logistics to be discussed within existing COMNAP and barter systems

• Eventual replication and comparison papers
Known oldest ice plans of other nations

- China reached 798 m at Dome A in 2016-17 (146 m drilled in season)
- Russia has aspirations to look for old ice on Ridge B (250 km upstream of Vostok) – no funding yet
- Australia has received a major funding boost to develop an overland traverse and plans to drill a second core somewhere near Dome C
- Japan – see later
Kunlun Station, drill site

- S 80°25′01″ E 77°06′58″
- Elevation: 4090m
- Ice thickness: 3200 m

T at -10m snow: -58.4°C, lowest T-surface: -82.5°C
Pressure: 558~584 hPa
Distance to Zhongshan Sta.: 1258km
Deep ice core drill

China: PRIC

Japan: NIPR and Geo Techs Co.

Drill system

Drill
ID: 95mm
Length: 12.2m
Core barrel: 380cm

Reaming Drill

Communication

Winch
Up to date, 7 summer seasons’ work completed

- **2009/2010**: 0m, site construction
  (start to build the 4000m deep ice core drill supported by NIPR)
- **2010/2011**: 0m, site construction
- **2011/2012**: -120m, casing pipe 100m
- **2012/2013**: -130m, set up deep ice core drill
  **No field work in 2013/2014**
- **2014/2015**: -303m
- **2015/2016**: -654m, site construction completed
- **2016/2017**: -801m
## 2016-2017 Season

### Continue ice core drill

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td><strong>The total drilling days</strong></td>
<td><strong>20 days</strong> (7 days for repairing and maintenance)</td>
</tr>
<tr>
<td><strong>The Drilling runs</strong></td>
<td>87 runs (17 runs for ice chips fishing, 3 runs for falling bolts fishing)</td>
</tr>
<tr>
<td><strong>The total drilling penetration</strong></td>
<td>146.21 meters</td>
</tr>
<tr>
<td><strong>The total length of ice cores</strong></td>
<td>145.86 meters</td>
</tr>
<tr>
<td><strong>The depth of borehole</strong></td>
<td>800.93 meters</td>
</tr>
<tr>
<td><strong>Drilling fluid injection volume</strong></td>
<td>3600 L</td>
</tr>
<tr>
<td><strong>Ice chips produced</strong></td>
<td>≈ 12 oil drums</td>
</tr>
<tr>
<td><strong>Average penetration /run</strong></td>
<td>≈ 2.43 meters</td>
</tr>
<tr>
<td><strong>Average core length /run</strong></td>
<td>≈ 2.18 meters</td>
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</tbody>
</table>
Future Seasons

Additional 4 seasons to reach the bottom (largely depend on drilling time at Dome A, typically 15-20 days per season during past years):

- 2017/2018 (50 days)
- 2018/2019 (50 days)
- 2019/2020 (50 days)
- 2020/2021 (50 days)
- ?? ?? ??
Australian Antarctic Ice Core Plans

Australia recently announced its overall *Antarctic Strategy and 20 Year Action Plan*. This plan includes an initiative to take a leading role in the recovery of an ice core that extends well beyond a million years.

This will be a collaborative undertaking and will begin early in the coming decade. Australia is exploring partnerships and participating in site selection activities in the Dome C region as part of the International Partnerships in Ice Core Sciences.

Dome C bed elevation data from joint US-Australian-French survey as part of the ICECAP Project. (*Young et al., The Cryosphere Disc. 2016*)
The Australian Antarctic Science Strategic Plan 2011-12 to 2020-21 has, within its Antarctic Palaeoclimate stream, a strong emphasis on work in East Antarctica toward the IPICS2k/PAGES2k network.

Recent work to develop the East Antarctic network centred on the Aurora Basin North ice core, recovered in 2013-14 season.

Plans exist to extend the spatial coverage, likely with an intermediate depth core in the Mt Brown (Wilhelm II Land) region (Vance et al., 2016). This is under assessment as a proposal for 2017/18 or 2018/19 seasons.

Also under assessment is a joint US-Australian proposal* for drilling at Law Dome (2017/18, 2018/19) to recover samples for reconstructing C-14 of carbon monoxide, as a proxy for atmospheric hydroxyl variability. (*Petrenko, Etheridge)

Announcement on the outcomes of these proposals are expected soon.

In other work, the Australian Program continues to update the high resolution record from Law Dome; most recently with a 30 metre firn core in Feb. 2017.
Japan - NIPR
Survey areas (~1200 km in total length on high-bed elevation areas) in 2017-18 season (JARE59)

Bed elevation around DF. Red contours indicate estimated boundary between wet bed and dry bed

JARE54 survey
### International collaboration for radar surveys

|-------------|-------------|-------------|-------------|-------------|-------------|

Japan-Norway-US-Germany meeting (Sep. 2016@NIPR)

**AWI airborne radar**

Data sharing, discussion

**JARE ground radar (3 areas)**

Select 1-2 areas

**Japan-Norway-US collaborative ground survey (1-2 areas, detailed) with CReSIS radar**

Analyses, site selection

Transportation, construction

Pilot hole, casing

Red letters indicate JARE field activities.
# The third Dome Fuji deep coring

<table>
<thead>
<tr>
<th>Field activities</th>
<th>Preparation in Japan</th>
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<tbody>
<tr>
<td>DF2 core transp., Radar, Shallow coring</td>
<td>Radar, Shallow drill</td>
</tr>
<tr>
<td>Radar surveys</td>
<td>Deep drill</td>
</tr>
<tr>
<td>Transp. (fuel, goods)</td>
<td>Deep drill, Winch, Field devices</td>
</tr>
<tr>
<td>Constructions, Pilot hole, casing</td>
<td>Equipments for analyses and pilot hole</td>
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<table>
<thead>
<tr>
<th>Phase IX</th>
<th>Phase X</th>
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<tbody>
<tr>
<td>JARE58 2016</td>
<td>JARE64 2022</td>
</tr>
<tr>
<td>JARE59 2017</td>
<td>JARE65 2023</td>
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<tr>
<td>JARE60 2018</td>
<td>JARE66 2024</td>
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<tr>
<td>JARE61 2019</td>
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<tr>
<td>JARE62 2020</td>
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<tr>
<td>JARE63 2021</td>
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<table>
<thead>
<tr>
<th>Number of scientists</th>
<th>0</th>
<th>6</th>
<th>4-5</th>
<th>0</th>
<th>9</th>
<th>10</th>
<th>10</th>
<th>10</th>
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<tbody>
<tr>
<td>+4-6 (international)</td>
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### Phase IX

- **Number of scientists**: 0, 6, 4-5 +4-6 (international), 0, 9, 10, 10, 10
- **Field activities**: DF2 core transp., Radar, Shallow coring, Radar surveys, Transp. (fuel, goods), Constructions, Pilot hole, casing, Deep drilling, Deep drilling, Deep drilling, logging

### Phase X

- **Number of scientists**: 10, 10, 10, 10
- **Field activities**: Deep drilling, Deep drilling, Deep drilling, Deep drilling, logging

*Note: The table above represents the activities and number of scientists for each phase of the Dome Fuji deep coring project.*
New UK core: WACSWAIN 2018-19

Skytrain Ice Rise, 616 m core (18/19), plus rapid access isotopes at Sherman Island (19/20)
To assess LIG state of Ronne Ice Shelf and WAIS
Greenland - EGRIP

- 2016 reached 117.5 m
- Plan for 2017 – 1200 m
- For ice dynamics
- (Analysis ongoing for 584 m Renland)
“Ice memory”


- International project to take ice from endangered glaciers to Antarctica to store it

- Led by Jerome Chappellaz

- Initial cores planned at Col du Dome (Alps) and Illimani (Bolivia)
Col du Dome, France (4300 m)

- 3 cores (128 m) drilled August 2016
- 1 to be analysed in Grenoble, other two to Concordia (2020?)
Illimani, Bolivia (6300 m)

- Container on way to Bolivia Feb 2017
- Again 3 cores are planned
Workshop

• March 8-10, 2017 Paris
• Led by France and Italy, but expecting attendance from Switzerland, USA, Brazil, Russia, China, Germany
• Should also serve as a workshop to share best practice for non-polar ice cores