UNIVERSITY OF CAMBRIDGE

International Partnerships in Ice Core Sciences
IPICS

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

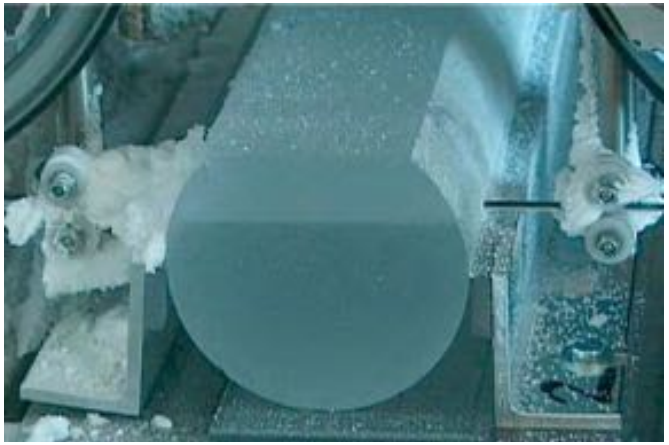
Other activities/white papers

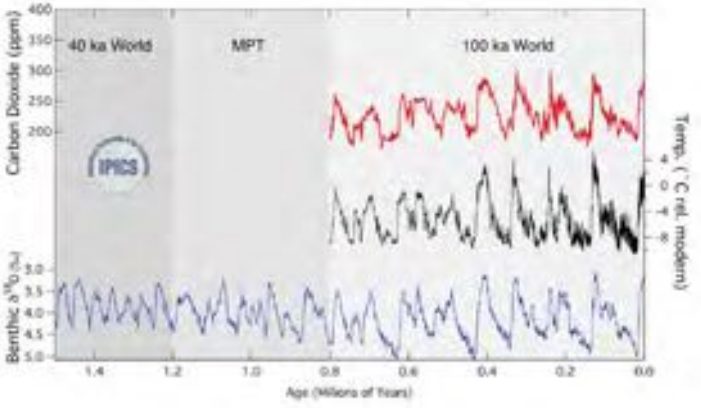
- IPICS Ice Dynamics (in preparation, e.g. EGRIP)
- Non-polar cores – support action on protecting endangered ice archives

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

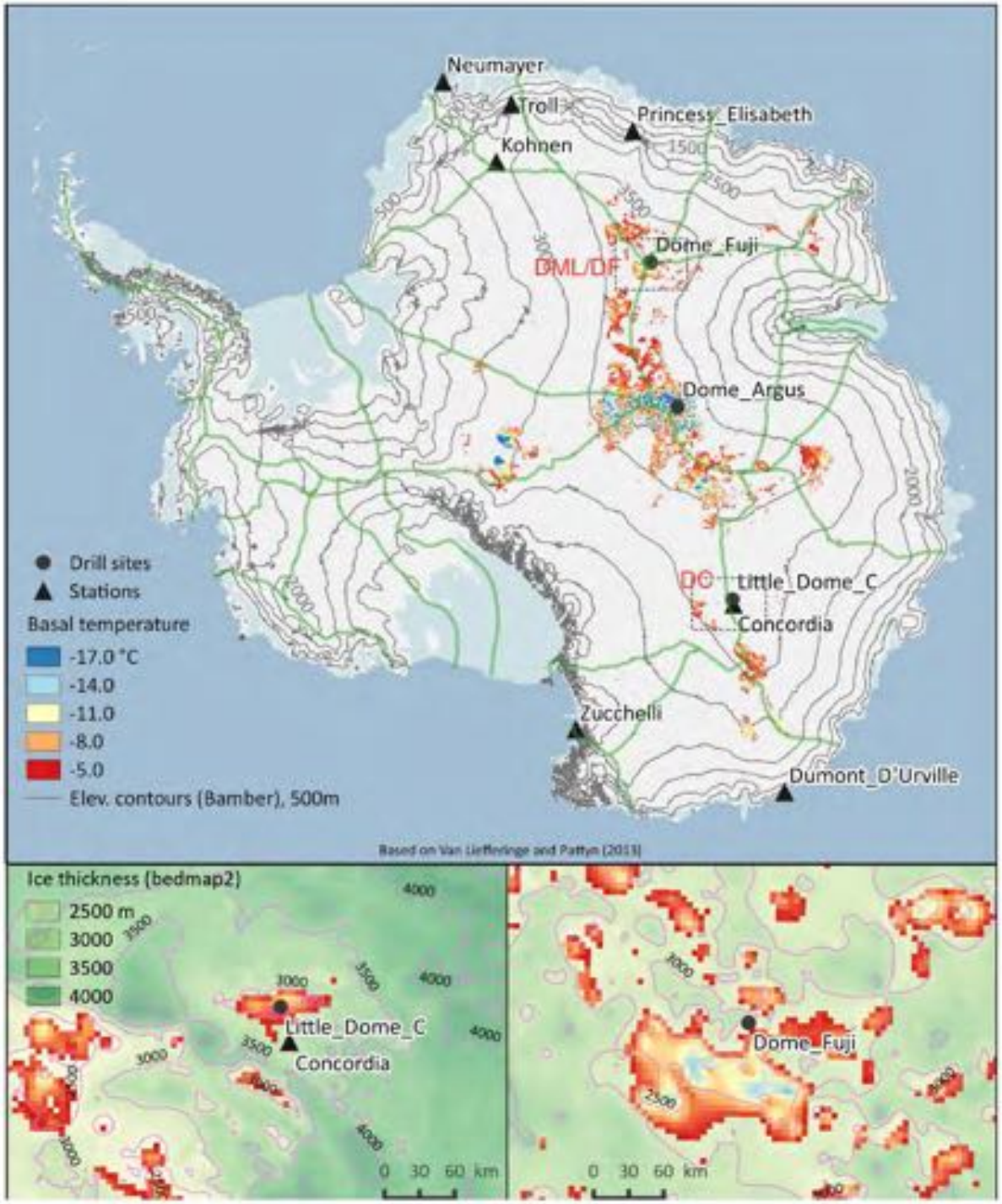
Pre-site survey: which conditions?

- 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

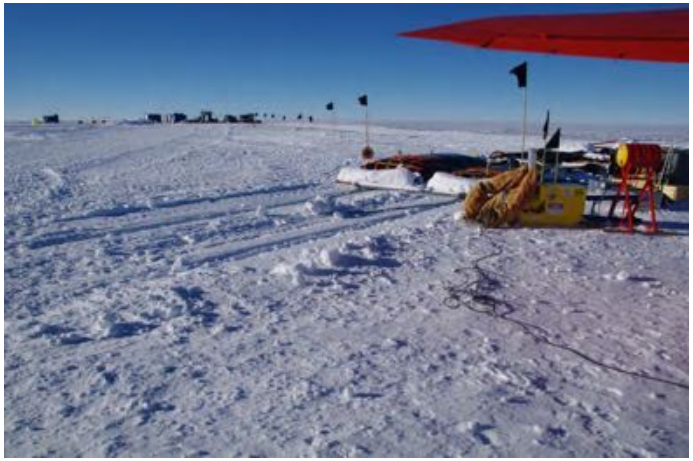
- ice thickness (radar) => bedrock
- internal layering (radar) => integrity
- vertical strain rate (pRES, sfc. strain)
- geothermal heat flux (DTS, pRES, flow model)

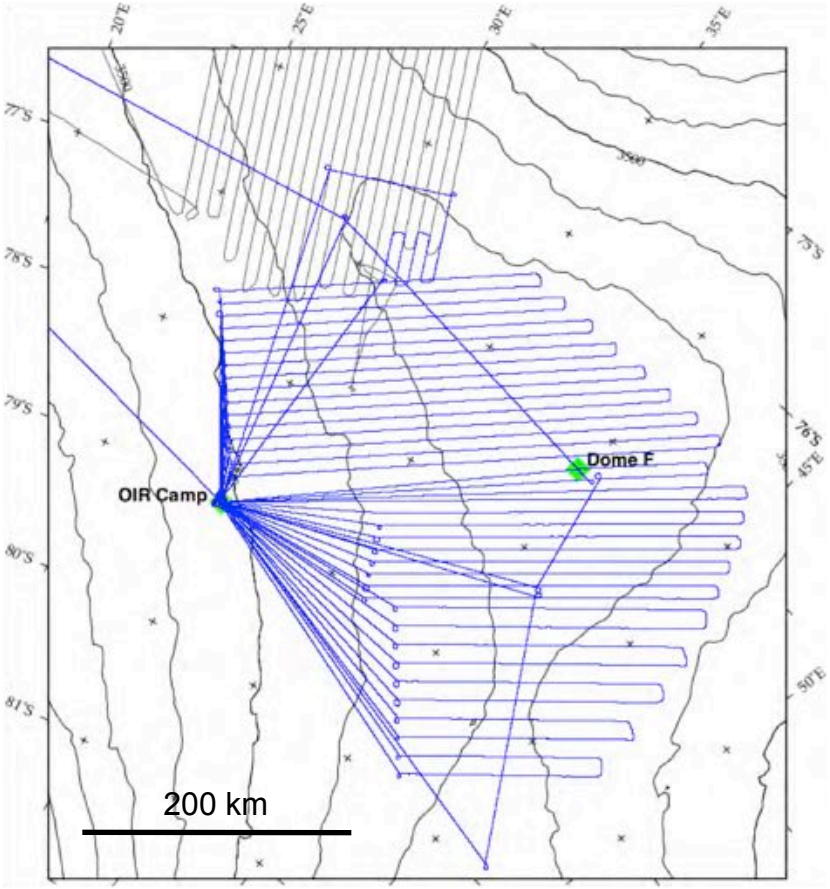
- age: transfer from ice cores, extend with flow model

- final verification:
  rapid access drilling with RADIX, SUBGLACIOR

DML/Dome F: Jan17 (Nov16 - Feb17)

ca. 20,000 km
of airborne radar

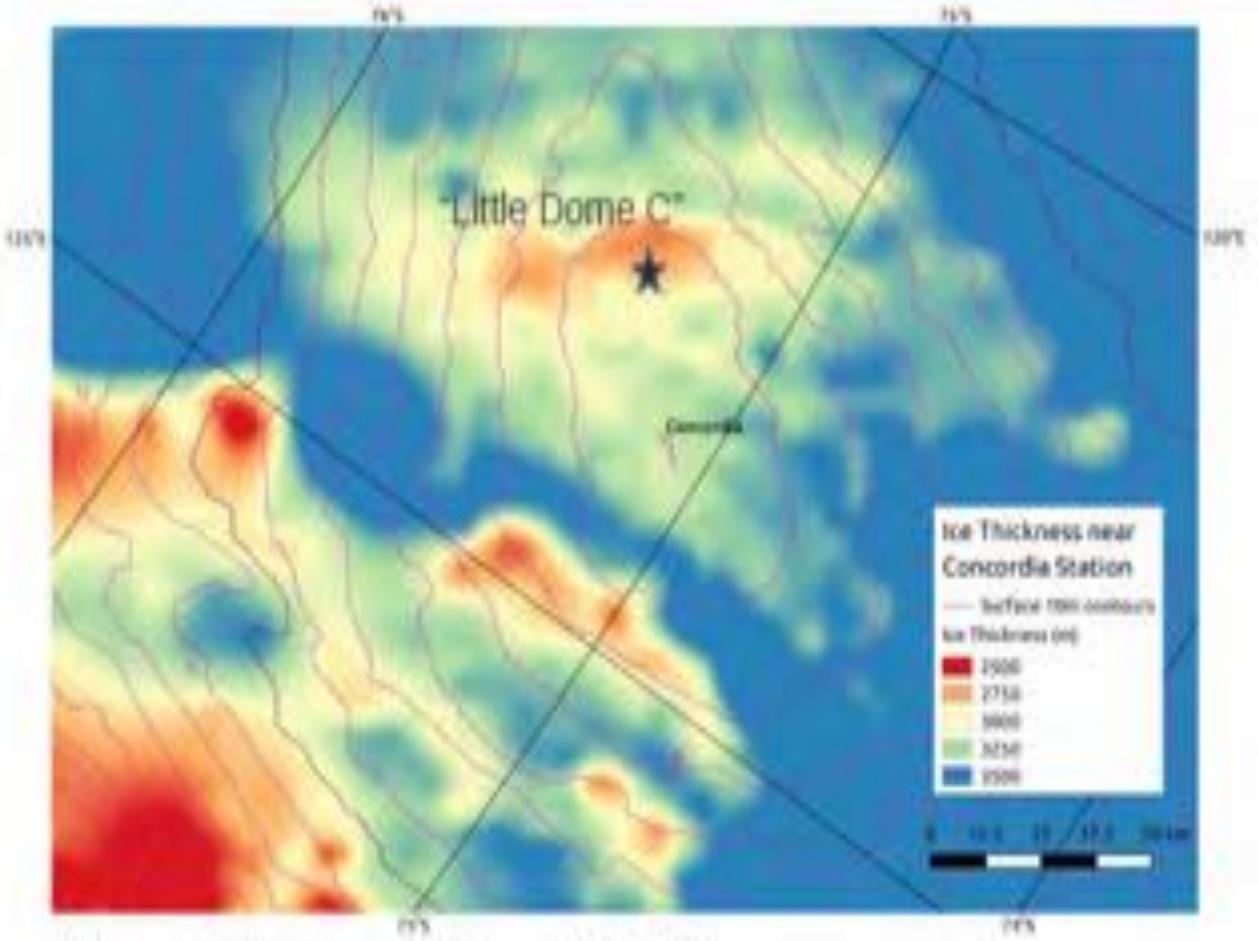




Concordia region plan

- 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 Subglacior tests
- Ice flow modelling and narrow target area
- 2017/18 (but see later) Subglacior drilling to ensure there is old ice

Why?

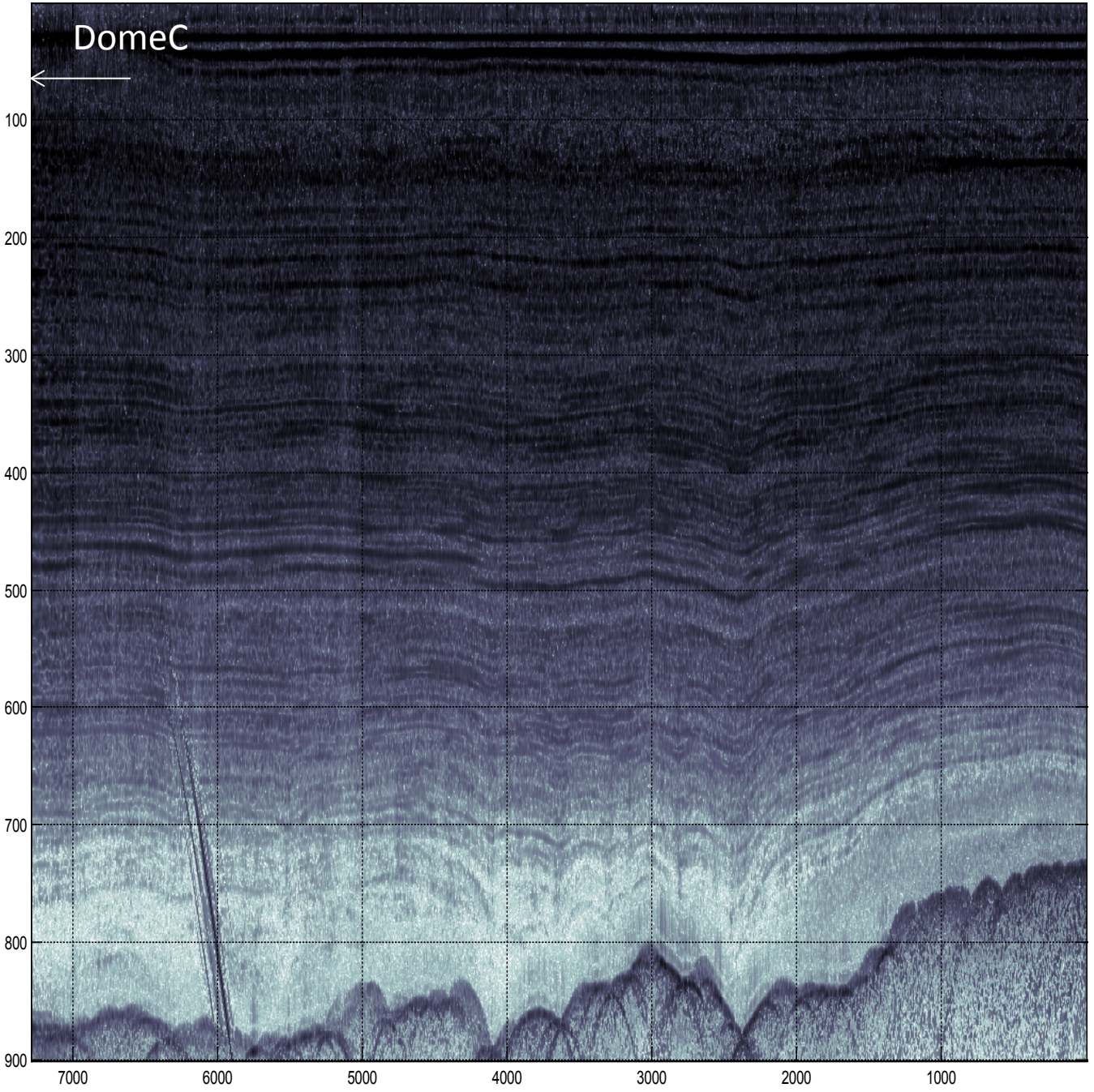


Age predictions at Little Dome C (Parrenin, 2015):

- 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**

BAS W36 SEQ517-554



Radar survey – DELORES ground based

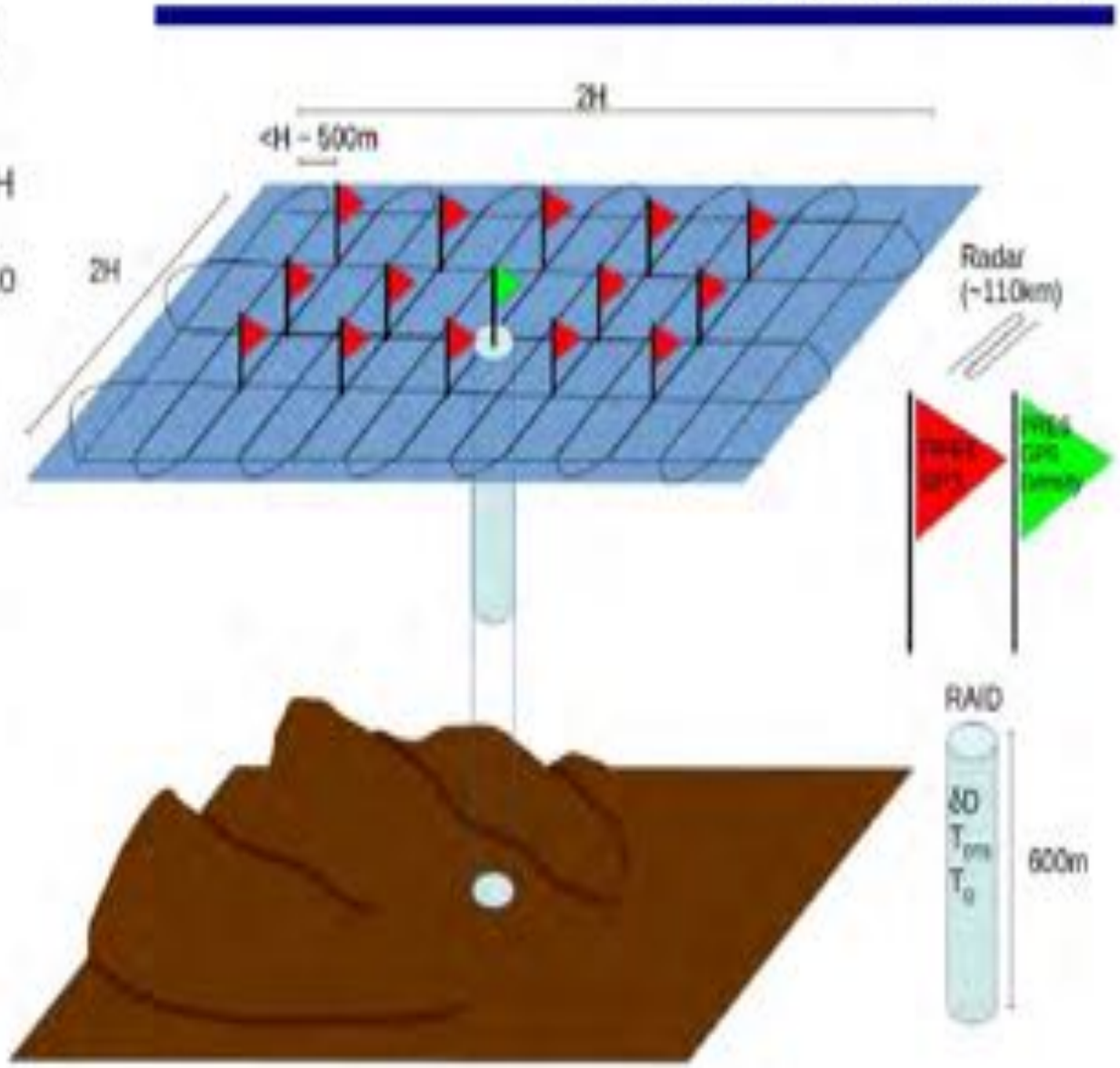
3D effects could be important

-Horizontal grid << H

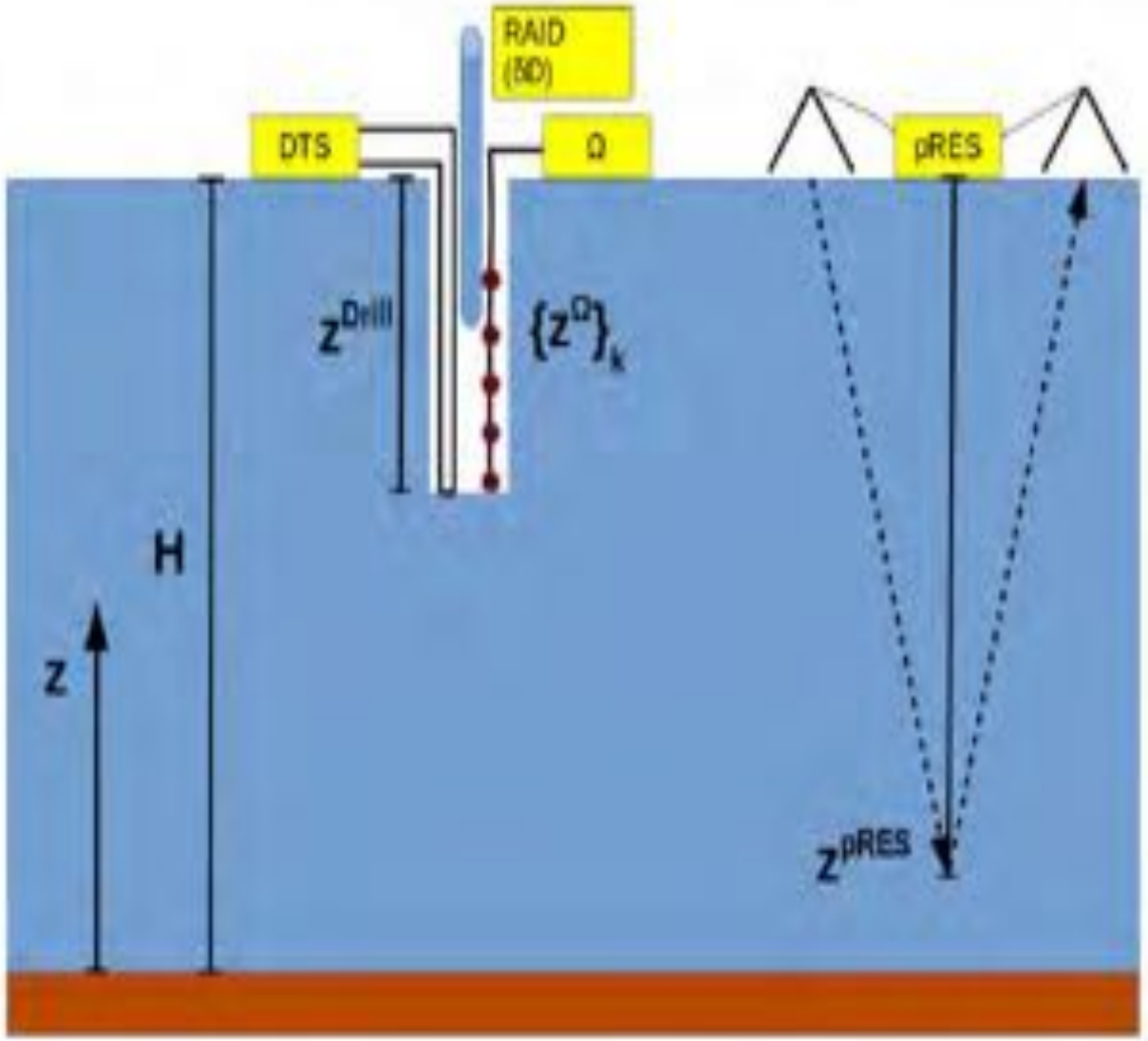
-Radar layers help to understand pRES data

- GPS strain-rates useful to process pRES englacial strain-rates.

-Density is useful: pRES combines compression and compaction.

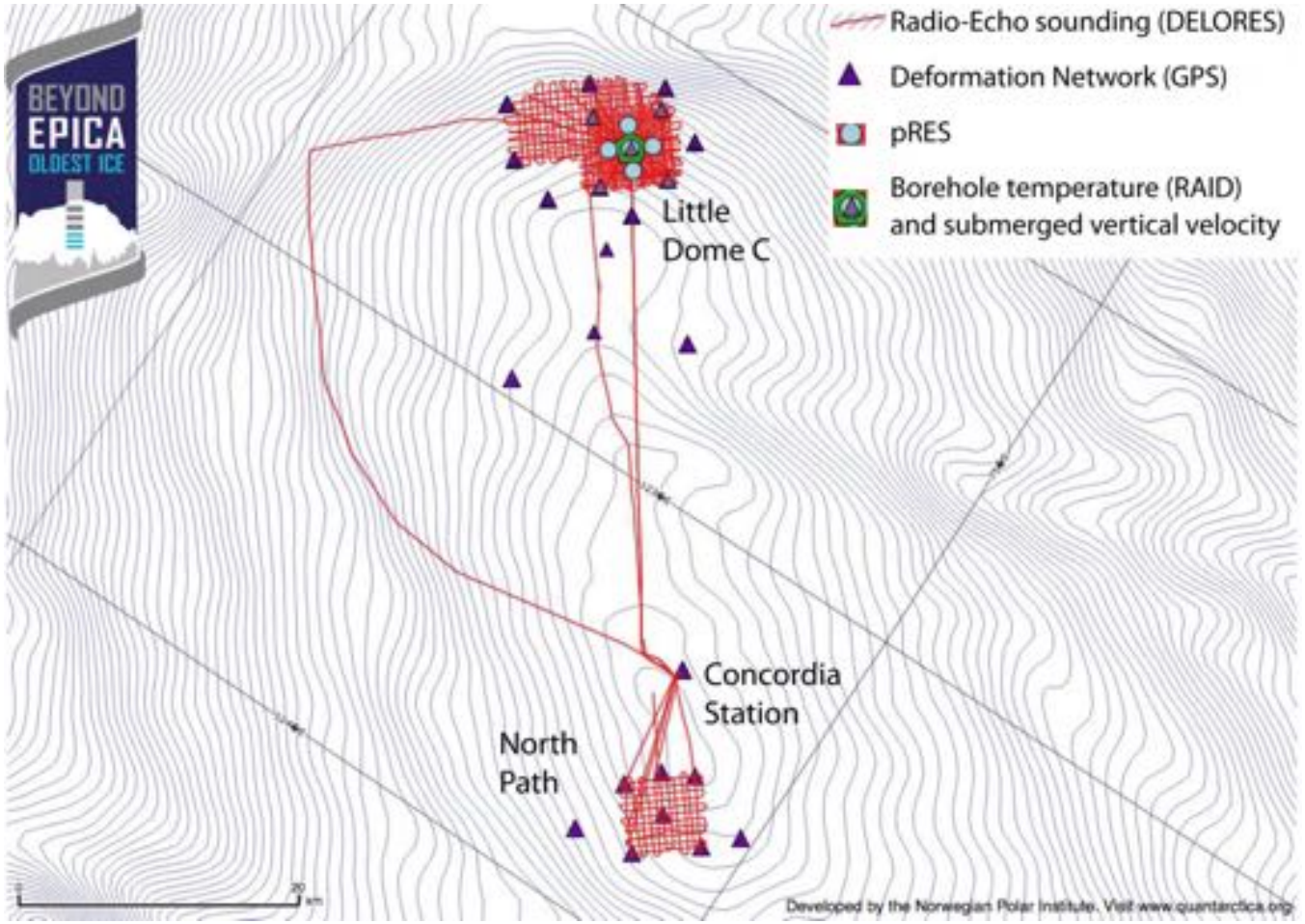


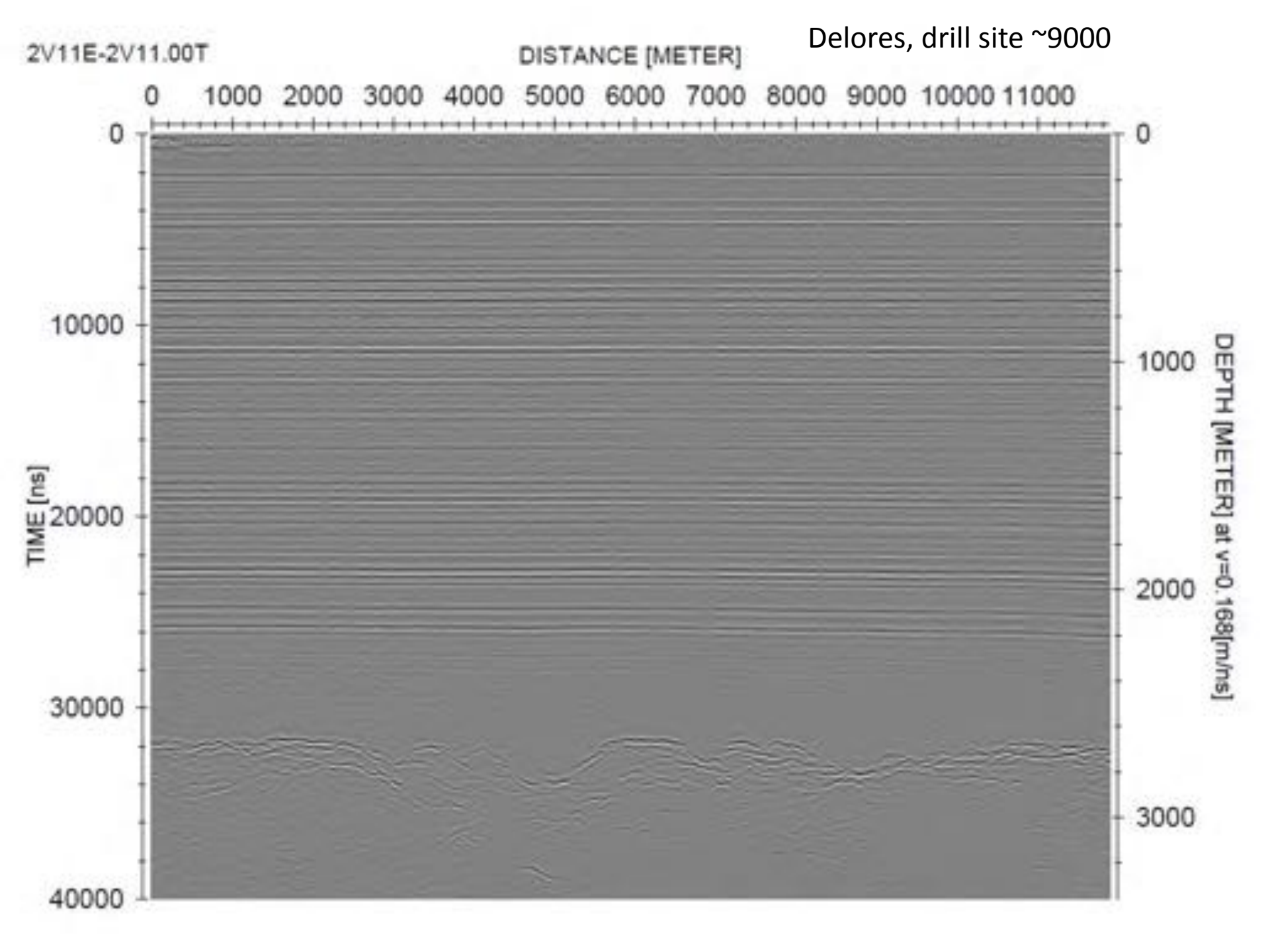
UK Rapid Access Isotope Drilling and pRES for basal temperature and LGM depth



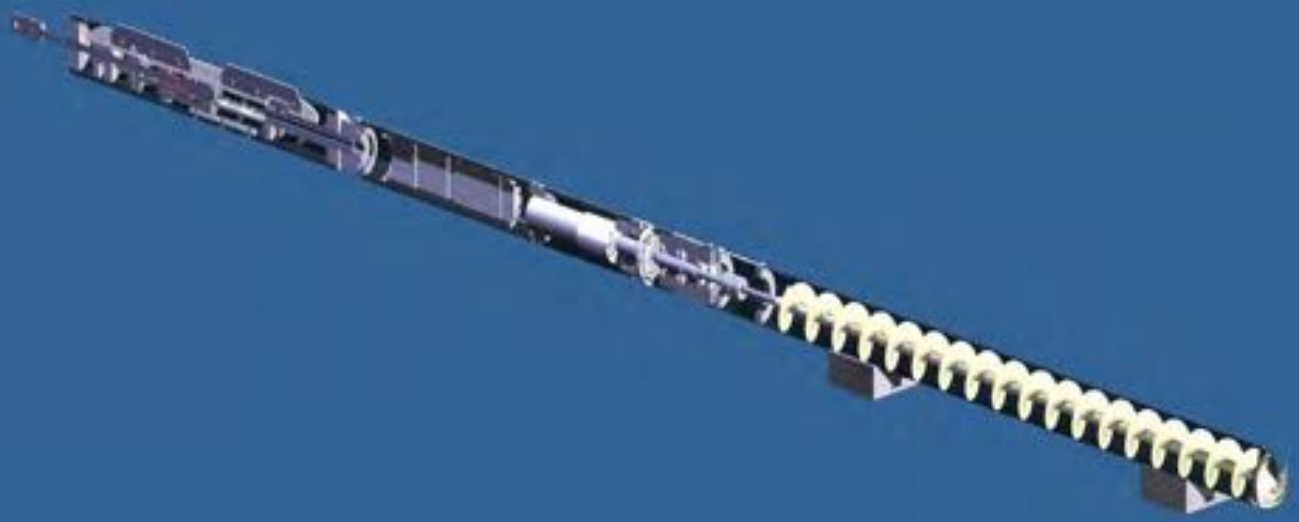

Delores radar (shortened cables)
Receiver
Transmitter

Radar survey 16/17




Delores, drill site ~9000
2V11E-2V11.00T
DISTANCE [METER]
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000
TIME [ns]
0 10000 20000 30000 40000
DEPTH [METER] at v=0.168[m/ns]
0 1000 2000 3000

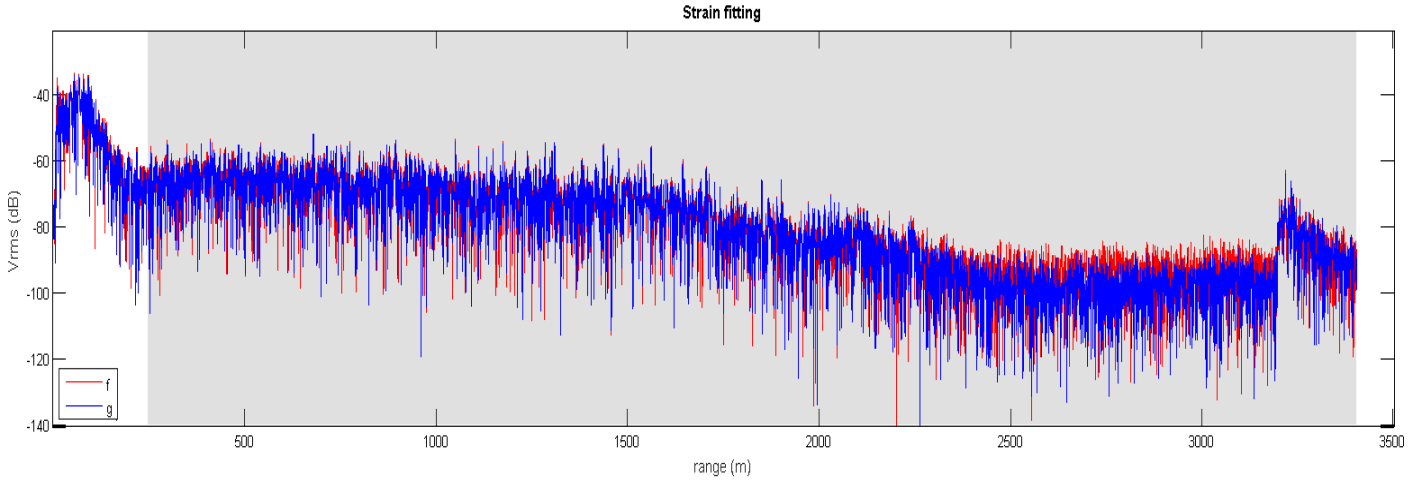
UK RAID drill



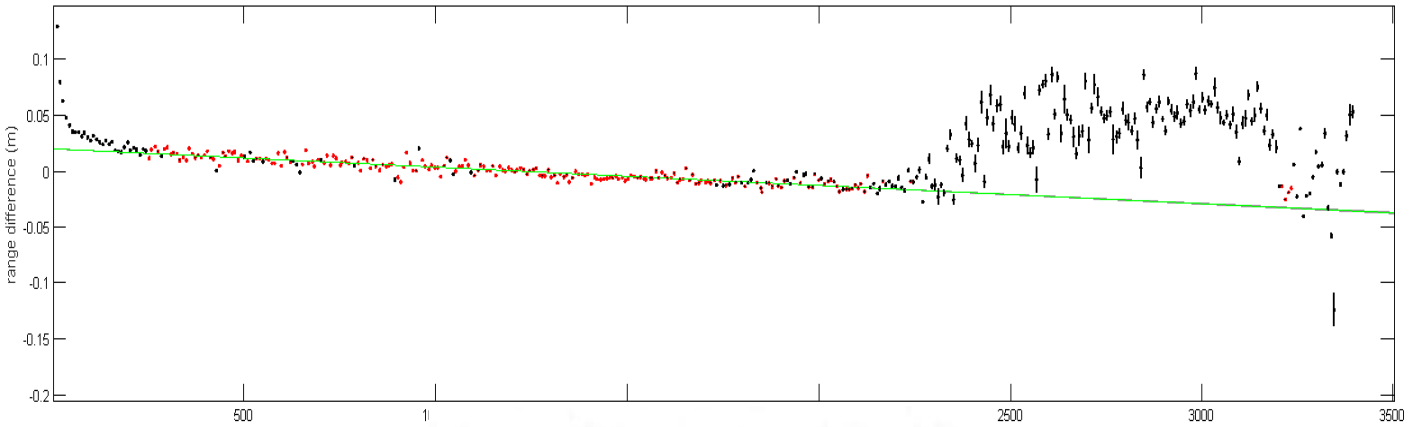
Video

- (Not included in presentation file)

Vertical strain rate measured after one year interval (Red = Jan 2014, Blue = Jan 201

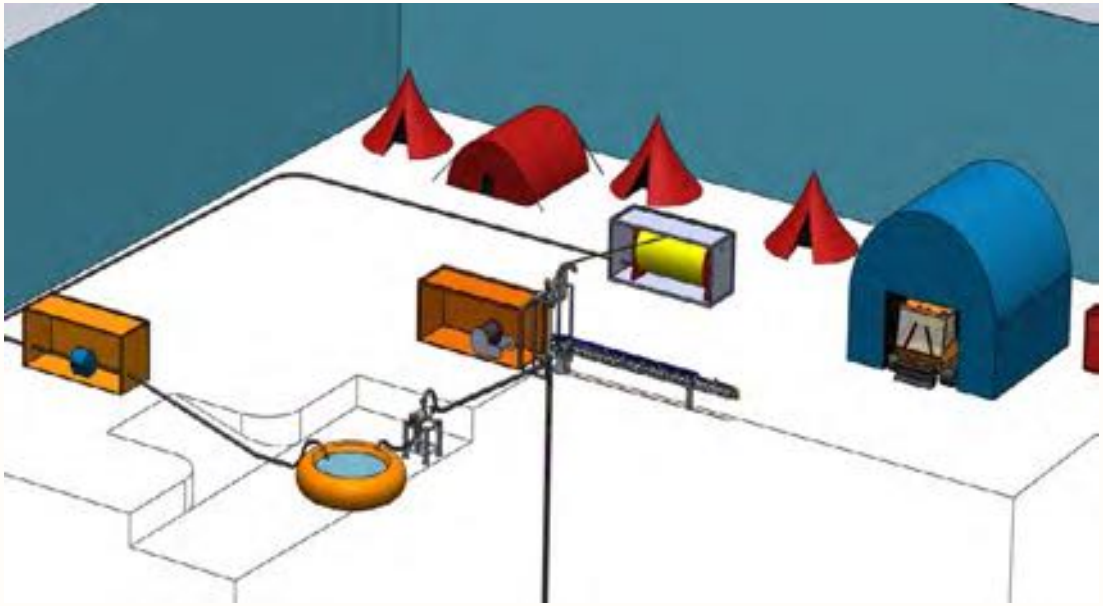


linear strain to 2300 m, with strain rate of 0.0169 +/- 0.0005 x10^{-3} yr^{-1}



$$u_{\bar{z}}(\bar{z}) = -\left[m + \left(a - \frac{\partial H}{\partial t} - m\right)\omega(\zeta)\right]$$

ERC ICE&LASERS – ANR SUBGLACIOR



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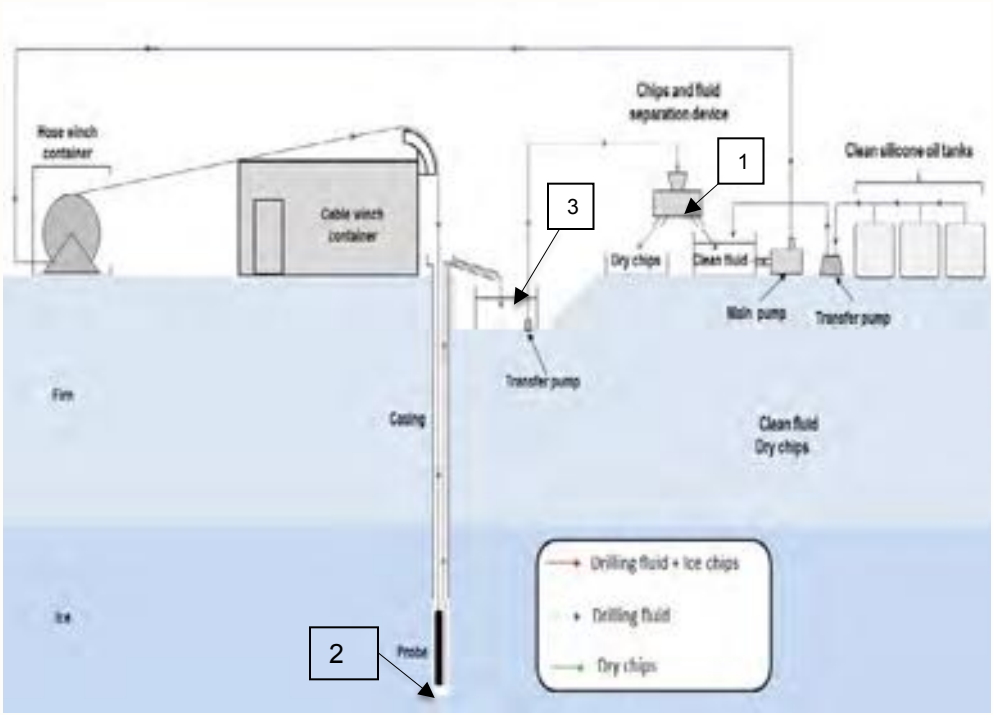
General probe design



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ERC ICE&LASERS – ANR SUBGLACIOR

No Article	Nom	Qté
1	Collecteur	1
2	Anti couple suspension	1
3	Tube extérieur	1
4	Convertisseur D-C DC	1
5	Electronique + Batteries	1
6	Electronique SPECTRO	1
7	Partie optique SPECTRO	1
8	Ligne suspension	1
9	Assemblage tête	1
10	Eléments chauffants	1

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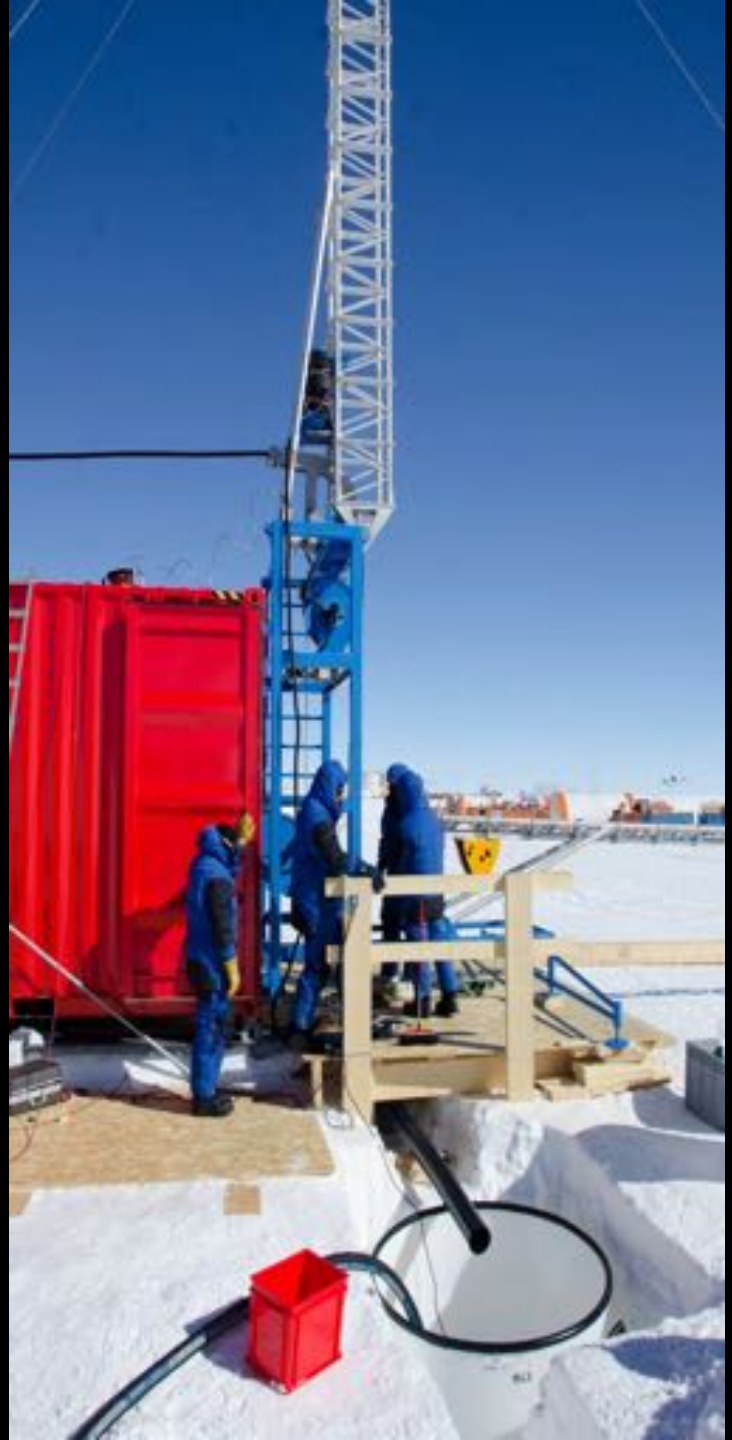
http://www.iceandlasers-subglacior.org



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 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

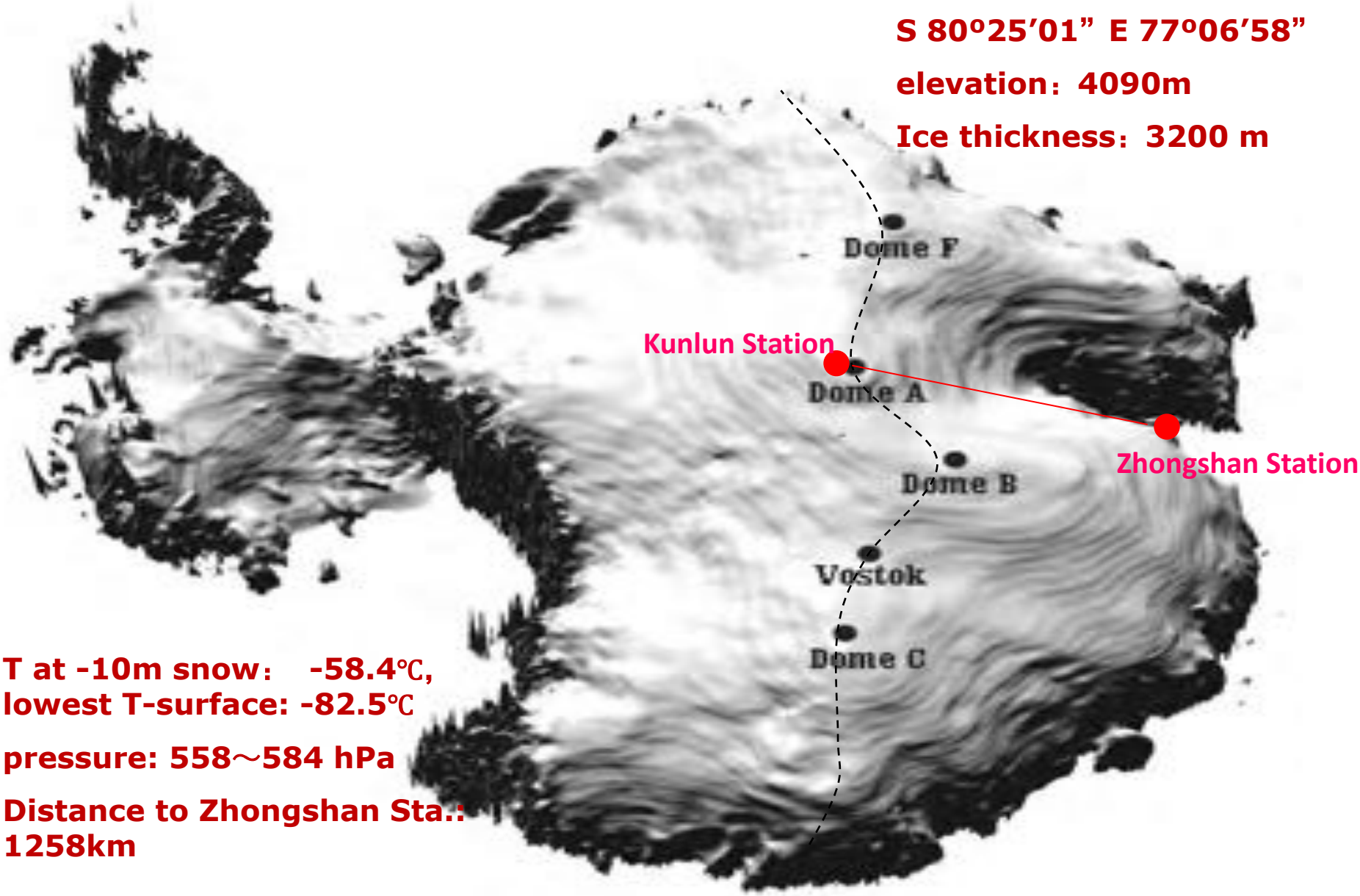
How we envisage international collaboration in Oldest Ice

- 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℃,
lowest T-surface: -82.5℃

pressure: 558～584 hPa

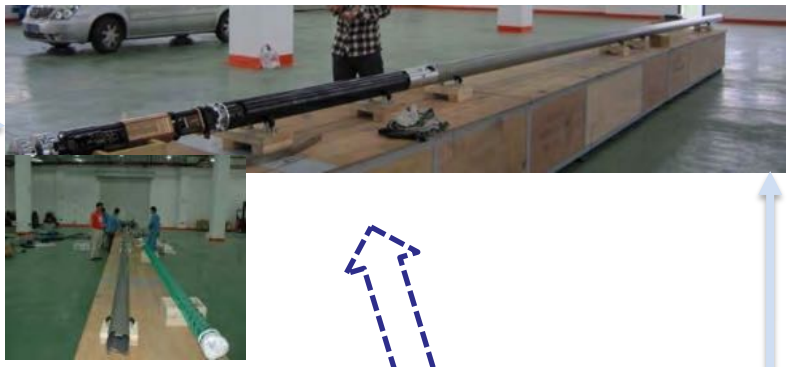
Distance to Zhongshan Sta.: 1258km

Deep ice core drill

China:
PRIC

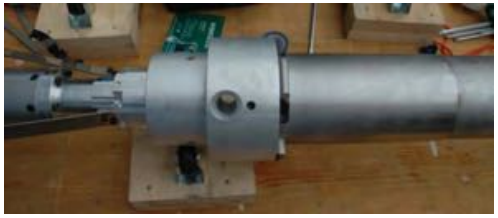
Japan:
NIPR
and Geo
Techs Co.

Drill



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

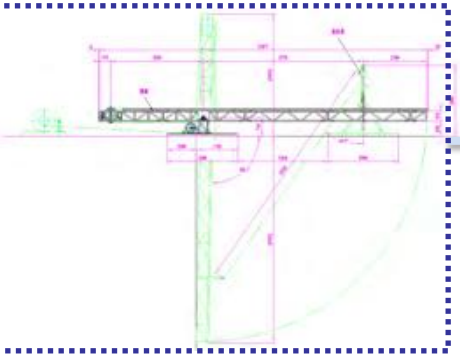
Reaming Drill



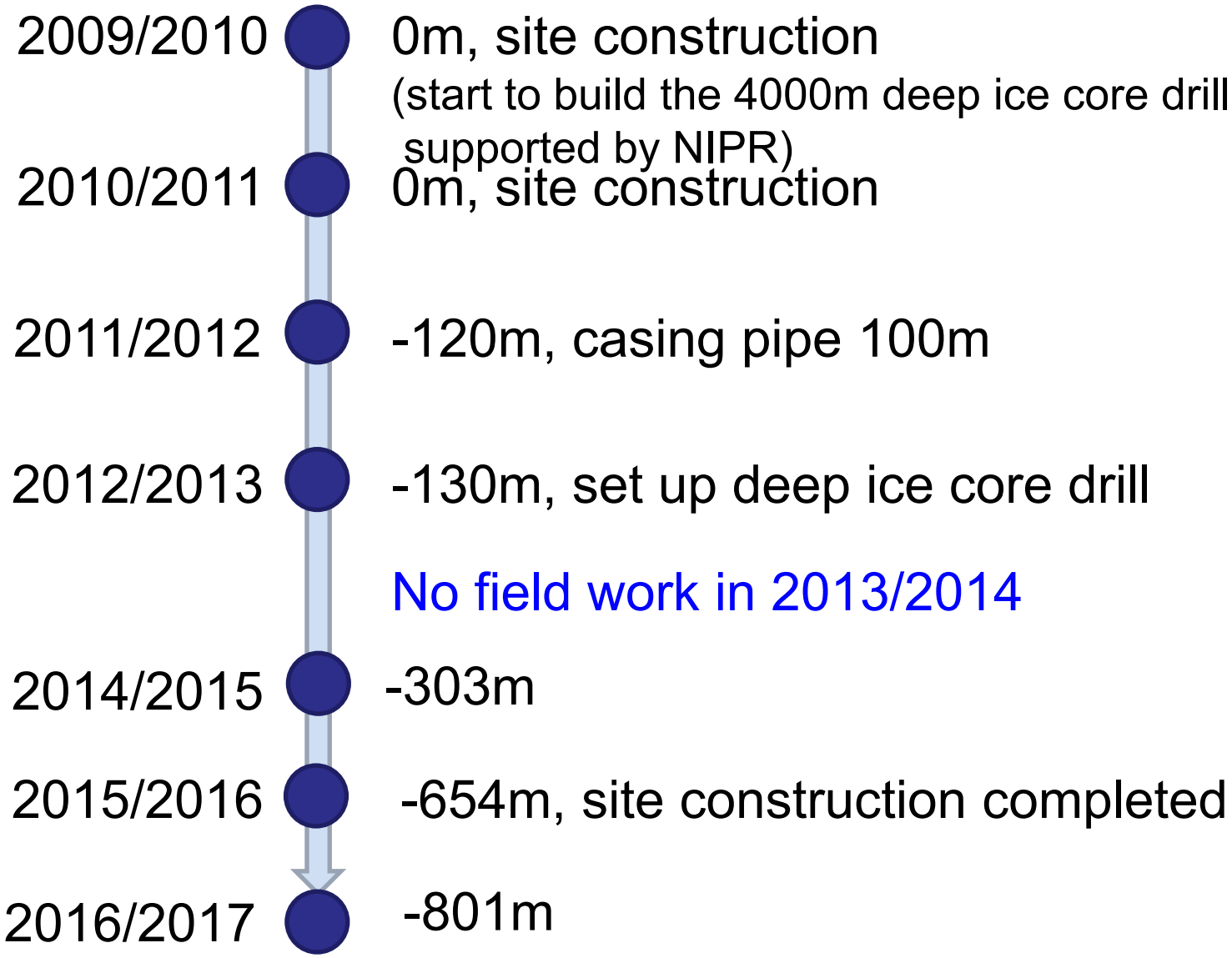
Drill system

Communication

Winch



Up to date, 7 summer seasons' work completed



2016-2017 Season Continue ice core drill

The total drilling days	**20 days (7 days for repairing and maintenance)**
The Drilling runs	87 runs (17 runs for ice chips fishing 3 runs for falling bolts fishing)
The total drilling penetration	146.21 meters
The total length of ice cores	145.86 meters
The depth of borehole	800.93meters
Drilling fluid injection volume	3600 L
Ice chips produced	≈ 12 oil drums
Average penetration /run	≈ 2.43 meters
Average core length /run	≈ 2.18 meters

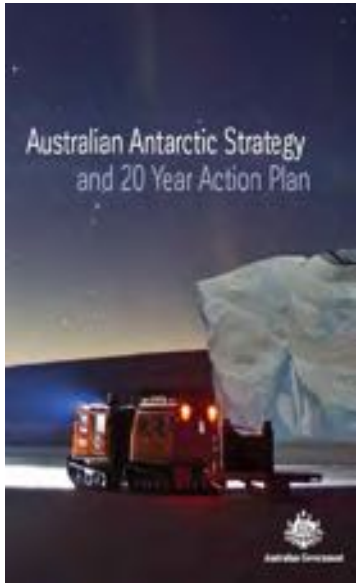
Future Seasons

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

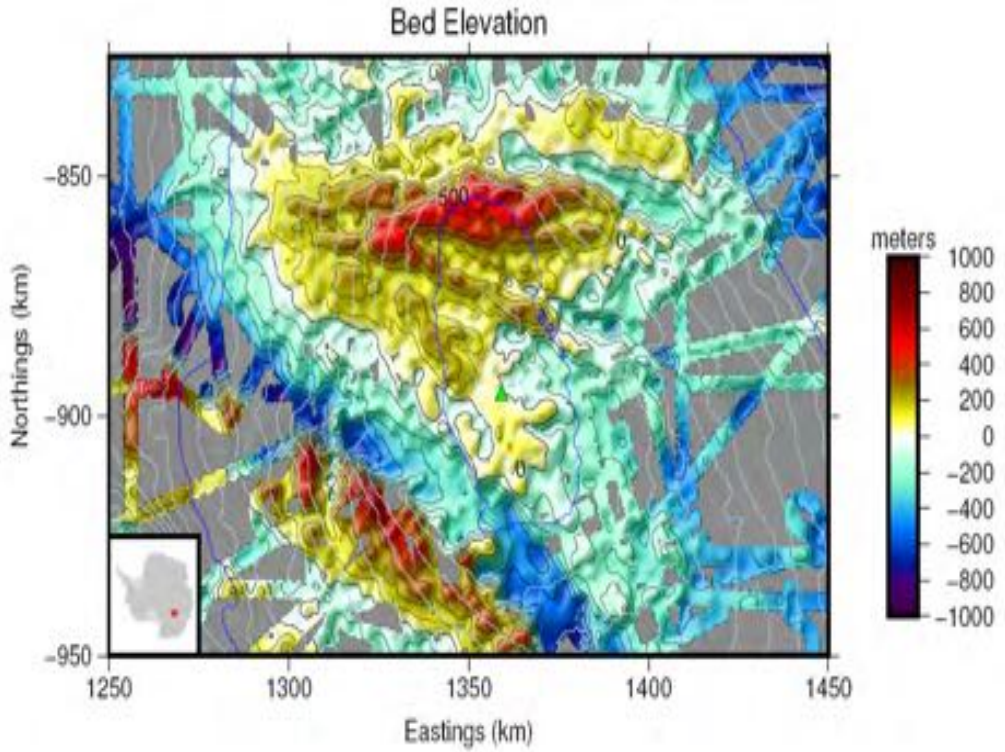
2017/2018 (50 days)
2018/2019 (50 days)
2019/2020 (50 days)
2020/2021 (50 days)
? ? ?

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)*

Australian Antarctic Ice Core Plans

The *Australian Antarctic Science Strategic Plan 2011-12 to 2020-21* has, within its *Antarctic Palaeclimate* stream, a strong emphasis on work in East Antarctica toward the IPICS2k/PAGES2k network.

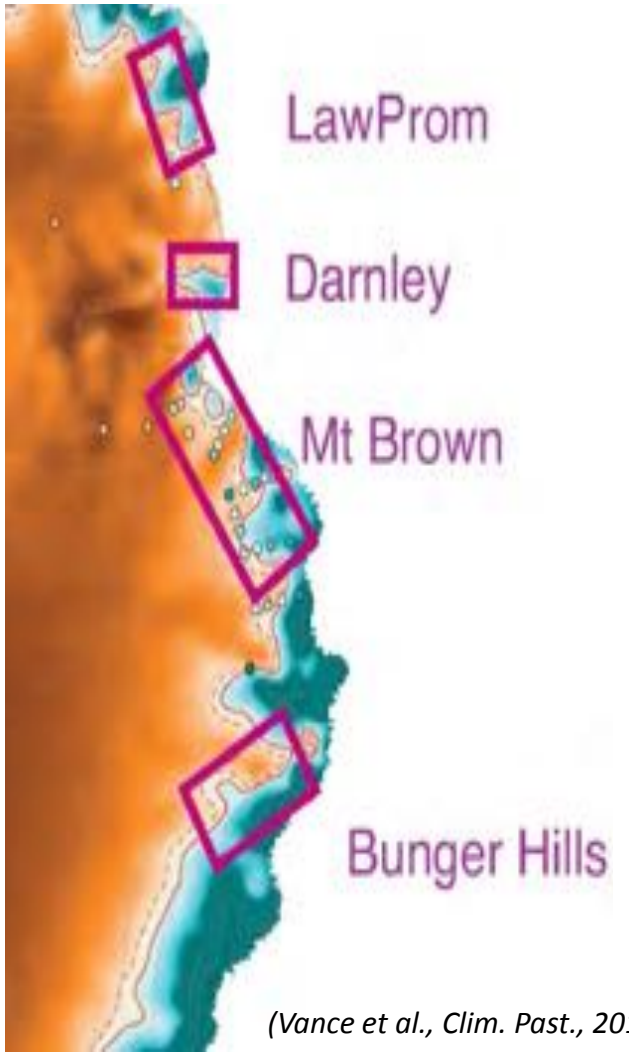
Recent work to develop the East Antarctic network centred on the Aurora Basin North ice core, recovered in 2013-14 season.

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.

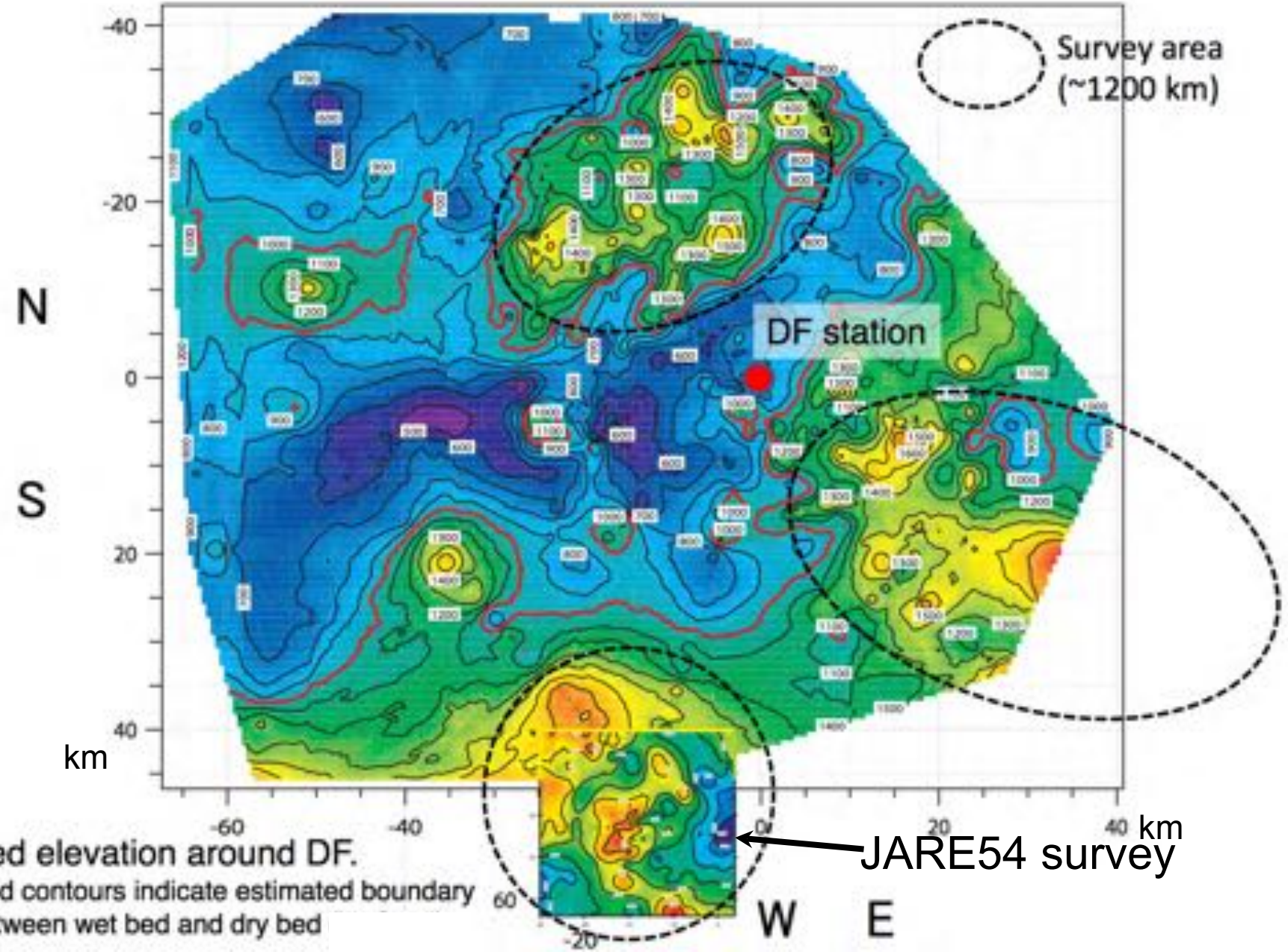
In other work, the Australian Program continues to update the high resolution record from Law Dome; most recently with a 30 metre firn core in Feb. 2017.



(Vance et al., Clim. Past., 201

Japan - NIPR

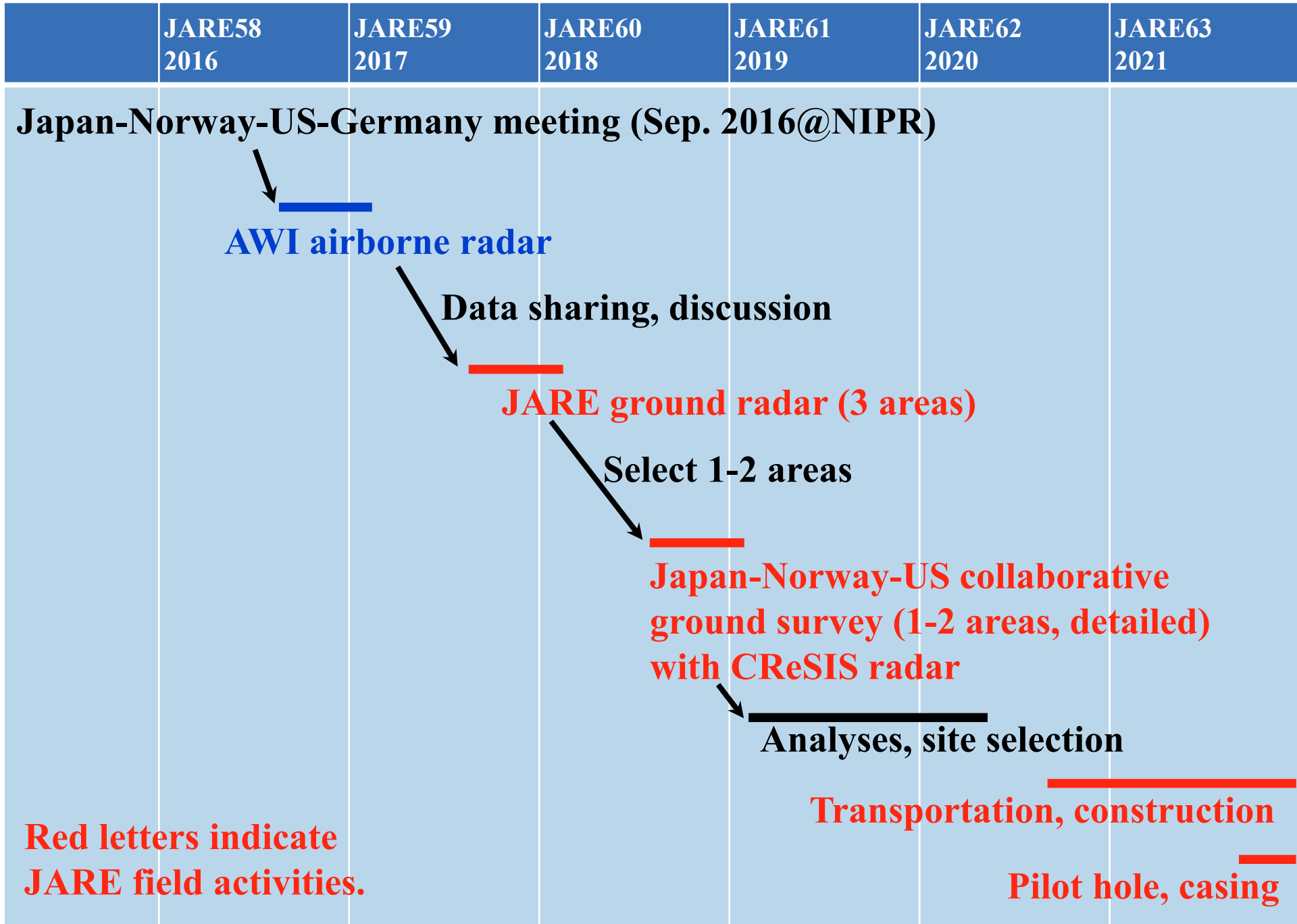
Survey areas (~1200 km in total length on high-bed elevation areas) in 2017-18 season (JARE59)



Bed elevation around DF.

Red contours indicate estimated boundary between wet bed and dry bed

International collaboration for radar surveys



The third Dome Fuji deep coring

Phase IX → **Phase X**

	JARE58 2016	JARE59 2017	JARE60 2018	JARE61 2019	JARE62 2020	JARE63 2021	JARE64 2022	JARE65 2023	JARE66 2024
Number of scientists	0	6	4-5 +4-6 (international)	0	9	10	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
Preparation in Japan	Radar, Shallow drill	Deep drill	Deep drill, Radar	Deep drill	Deep drill, Winch, Field devices	Equipments for analyses and pilot hole			

New UK core: WACSWAIN 2018-19

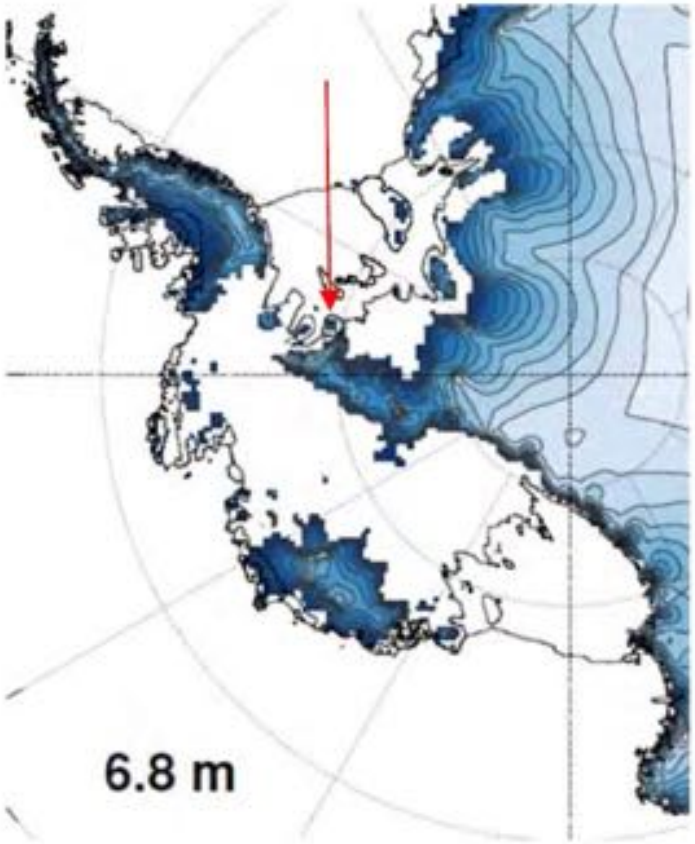


Figure 5. *Ice sheet model simulation for air temperature +4˚ and SST +2˚ C uniformly around Antarctica, after 2000 years (N. Golledge, pers. comm.). Red arrow shows Skytrain Ice Rise.*

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

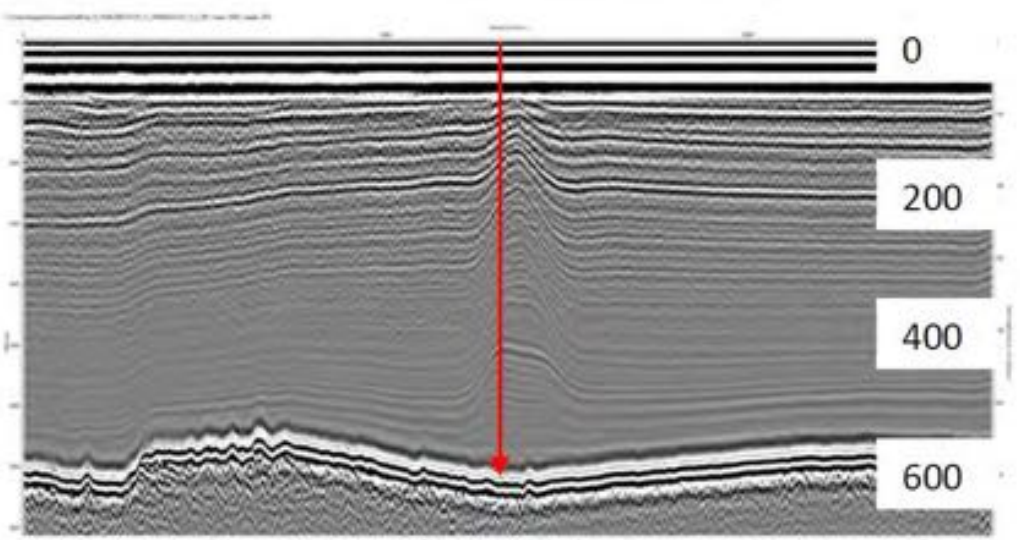


Figure 6. *Delores radar profile ~25 km long across the summit of Skytrain Ice Rise, Raymond bump in the middle, depths (m) on right. Proposed drill location marked with red arrow.*

Greenland - EGRIP

- 2016 reached 117.5 m
- Plan for 2017 – 1200 m
- For ice dynamics
- (Analsysis ongoing for 584 m Renland)

“Ice memory”

- http://fondation.univ-grenoble-alpes.fr/menu-principal/nos-projets/preservation-des-patrimoines/ice-memory-in-english-/
- 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