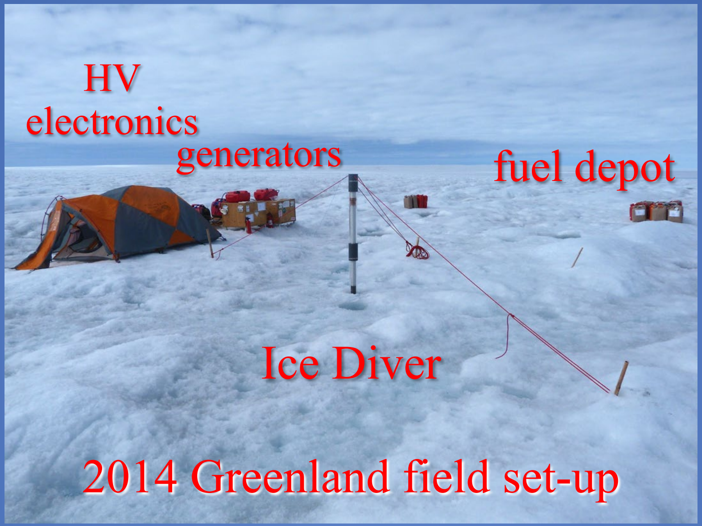
The Ice Diver Dust Logger



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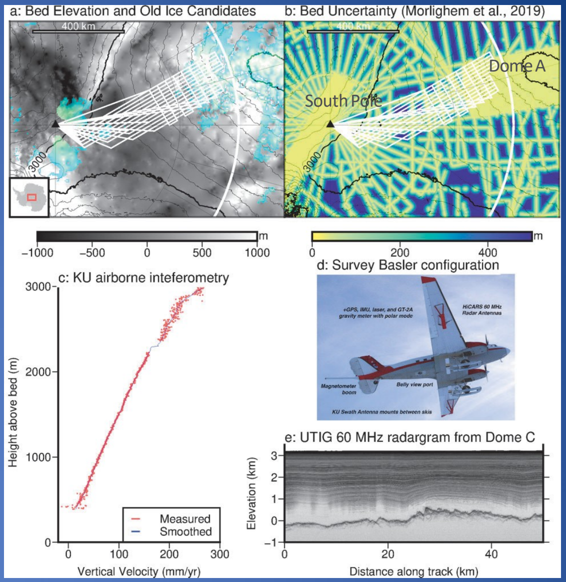
Supported by NSF and NASA

COLDEX (proposed 21-26)
and the search for Myr ice

- Exploration for Old Ice Sites in the Antarctic Interior
  - Airborne and ground based geophysics
  - RAID boreholes
  - Thermal probe/dust logger
- Glaciological Modelling



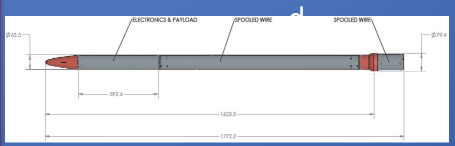
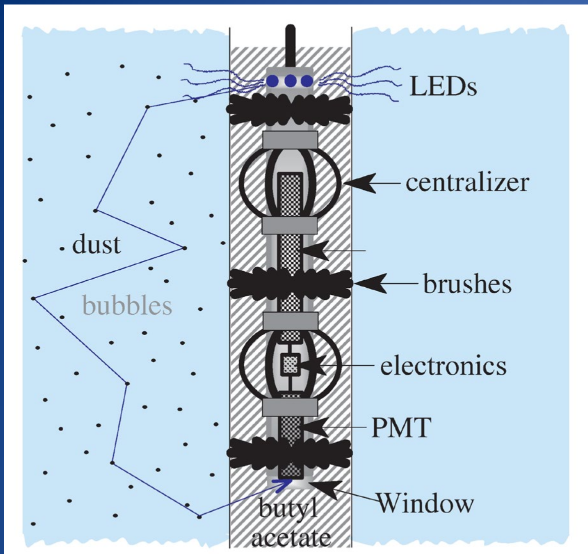
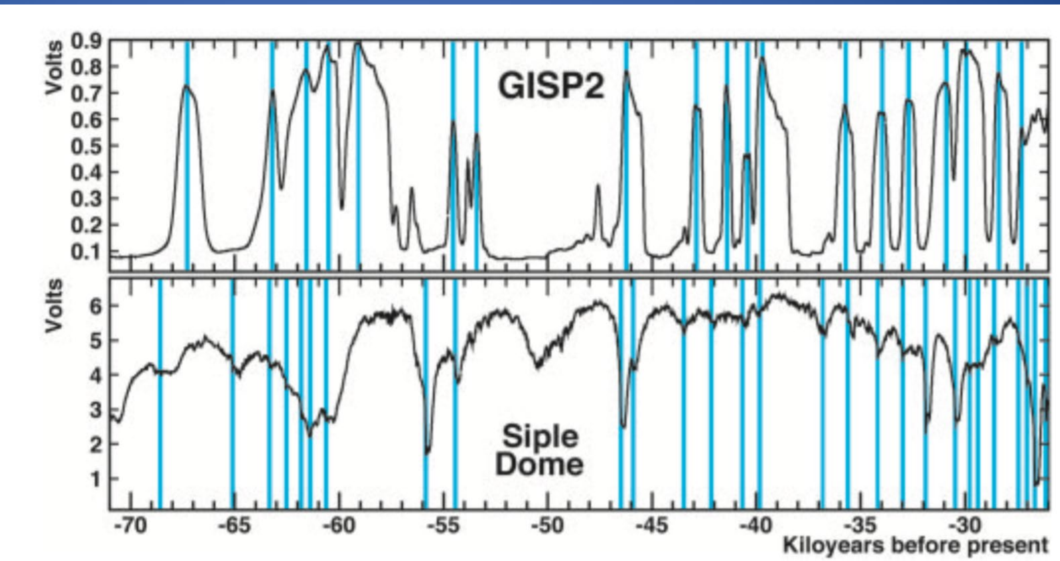


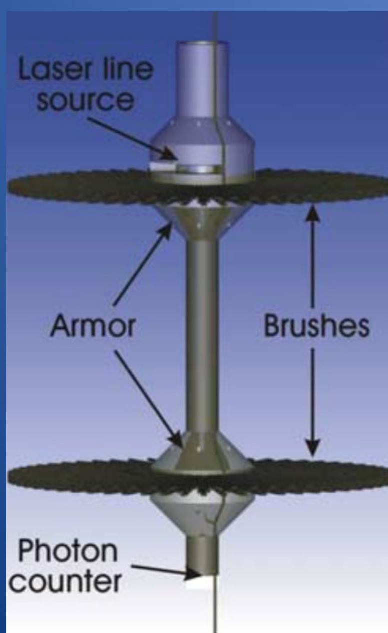
Figure 5. a. Ice Diver with mountaineering tent for high-voltage power supplies. A pressure vessel housing (black) is just aft of the copper melt head. A steel section between the electronics and the heated rear flange contains the spool of high-voltage wire. b. Complete field set-up (in the first field test), except for the science tent. c. All gear for ice penetration to 800 m used half the available volume of the Bell 212 helicopter. d. Schematic of probe used in Greenland (distances in mm).

Optical DustLogging in Boreholes

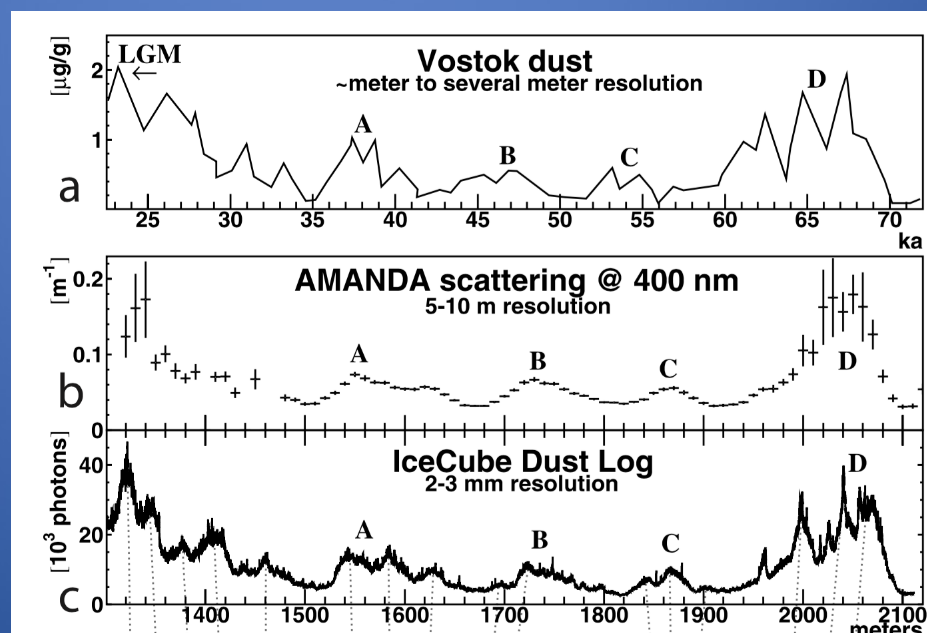




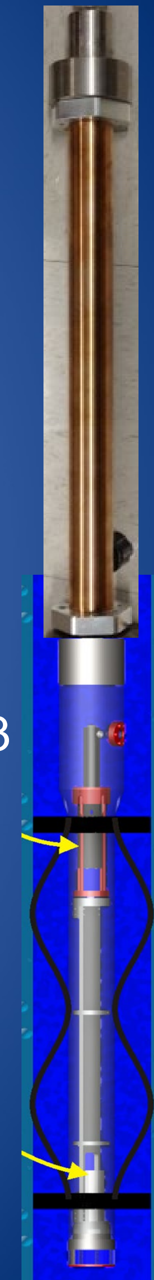
2001



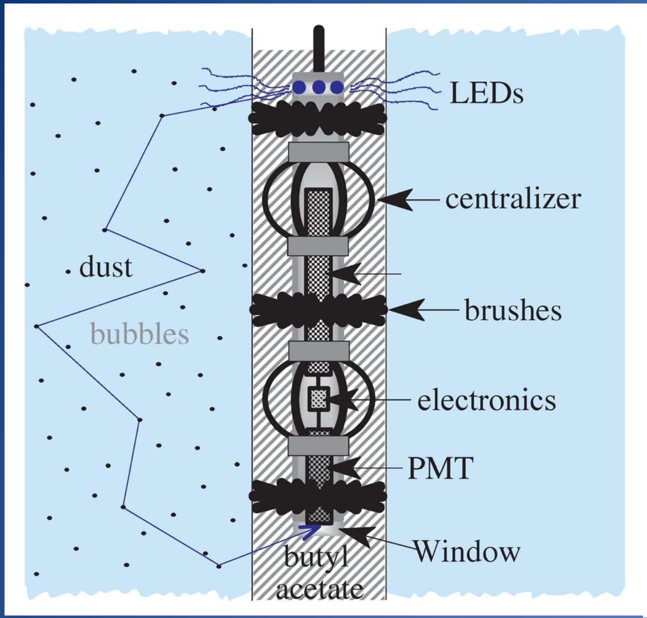
2005

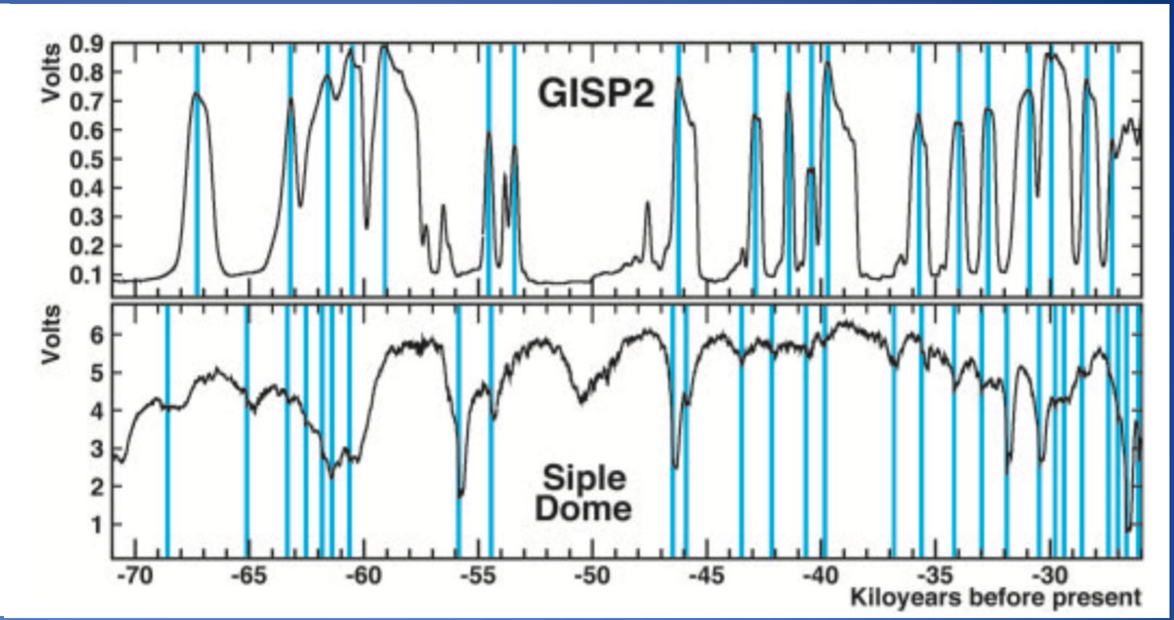


2013



Early days



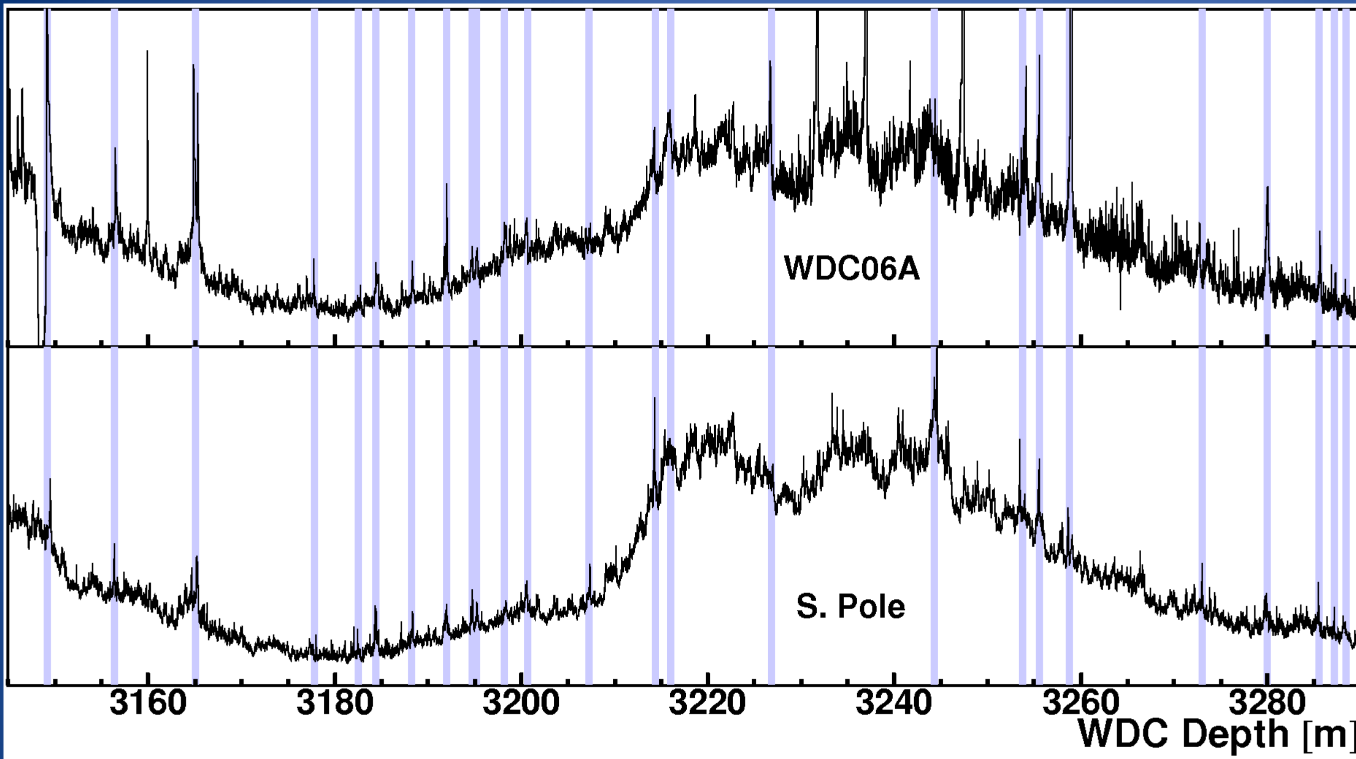


Buford Price
STC
1999

2001-2004
SDM
GISP2
GRIP
NGRIP

drill fluid >2 years

Clean borehole data

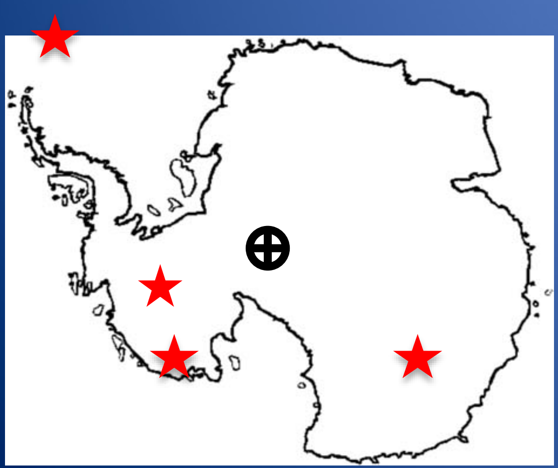


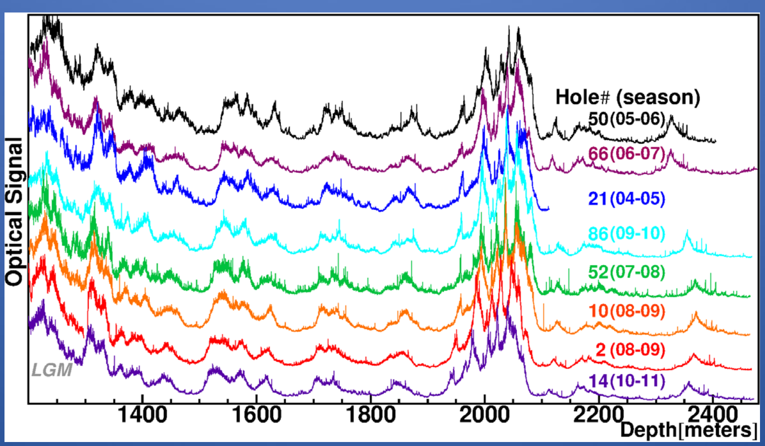
WAIS Divide

drill fluid ~1 year

IceCube

fresh water

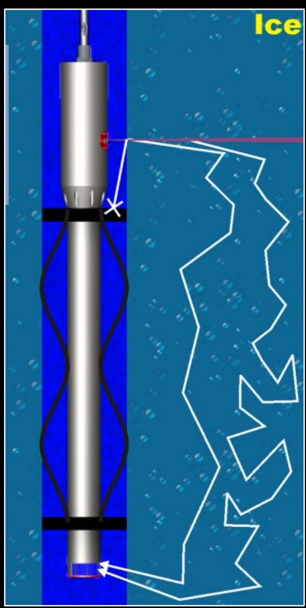




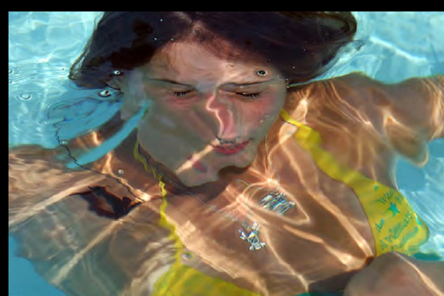
Detailed age *vs* depth without a core

Borehole quality is critically important

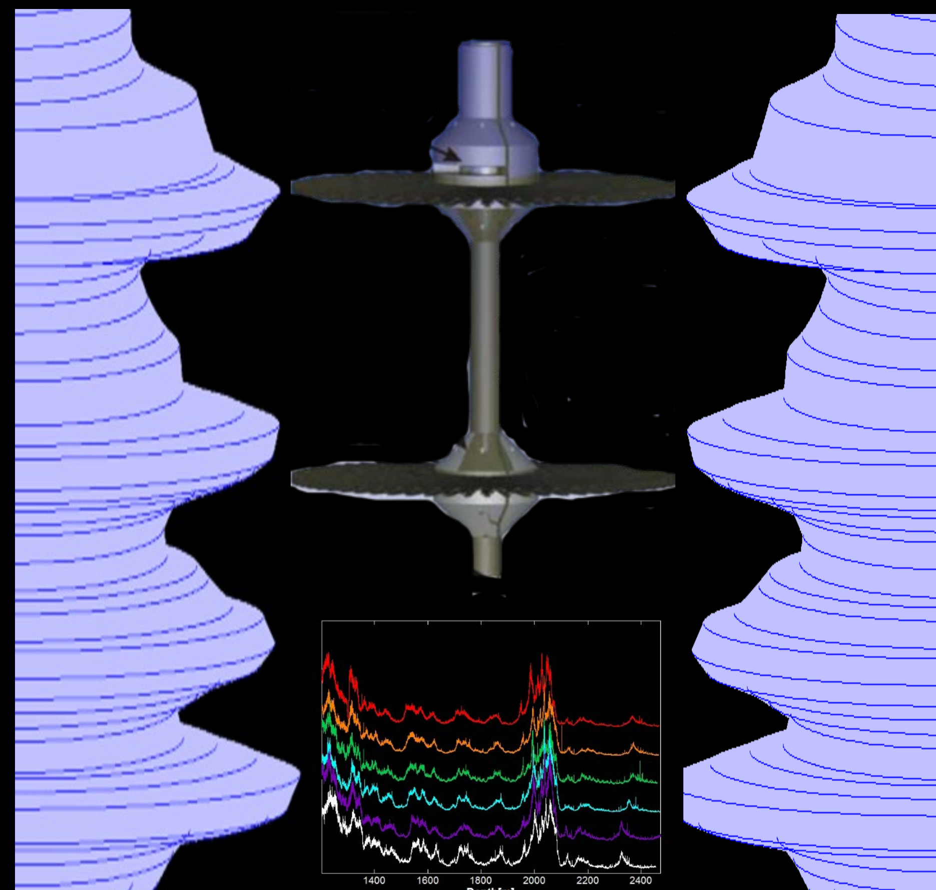
Mechanically drilled



Clean fluid?
Cleans walls?
Ice chips?
Fluorescence
Refraction



Hot-water / Melter



Dust Diving for Old Ice

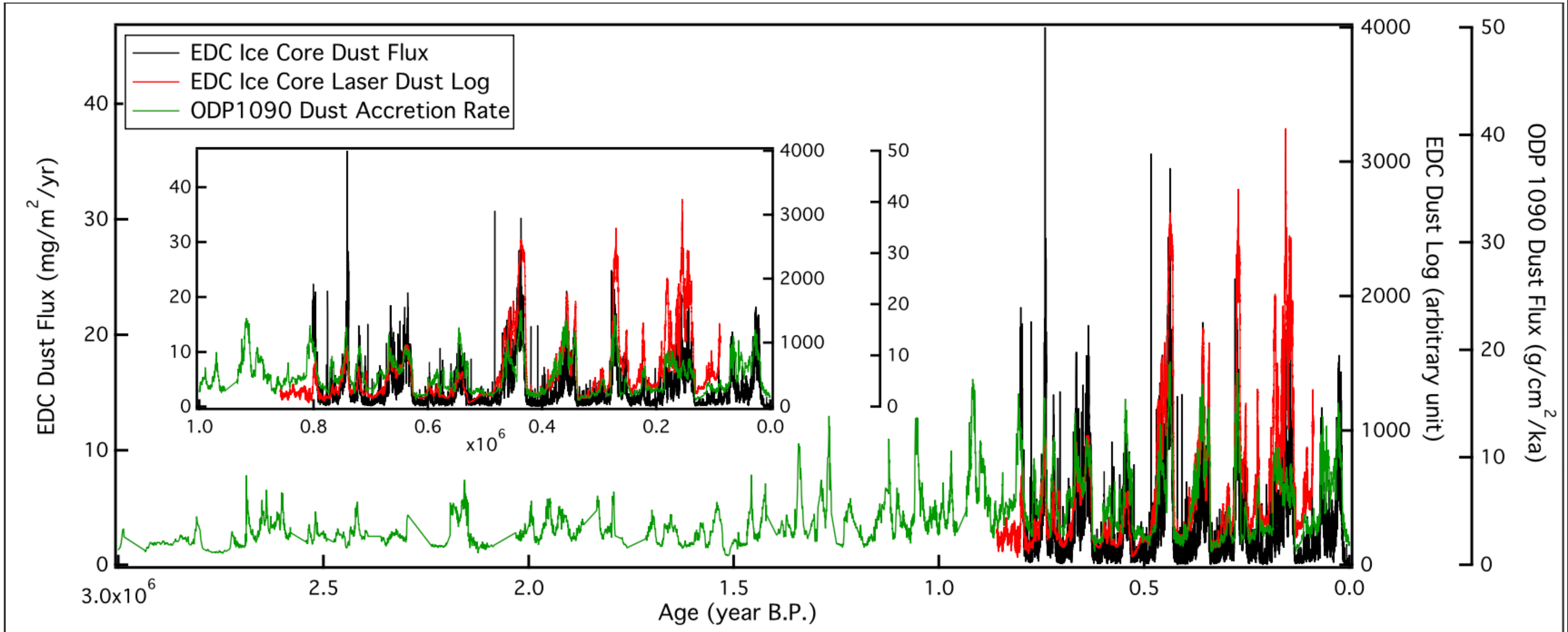


Figure 4. Comparison of laser light scattering borehole log in the EDC ice core borehole (red) (Ice Cube Collaboration, 2013) with records of dust measured in the ice core (black) (Lambert et al., 2008) and a dust record from the ODP 1090 sediment core (green) (Martinez-Garcia et al., 2011). Glacial dust peaks are similar in all three, indicating that dust logger data older than 800 ka B.P. could be used to map marine sediment ages to the ice core record.

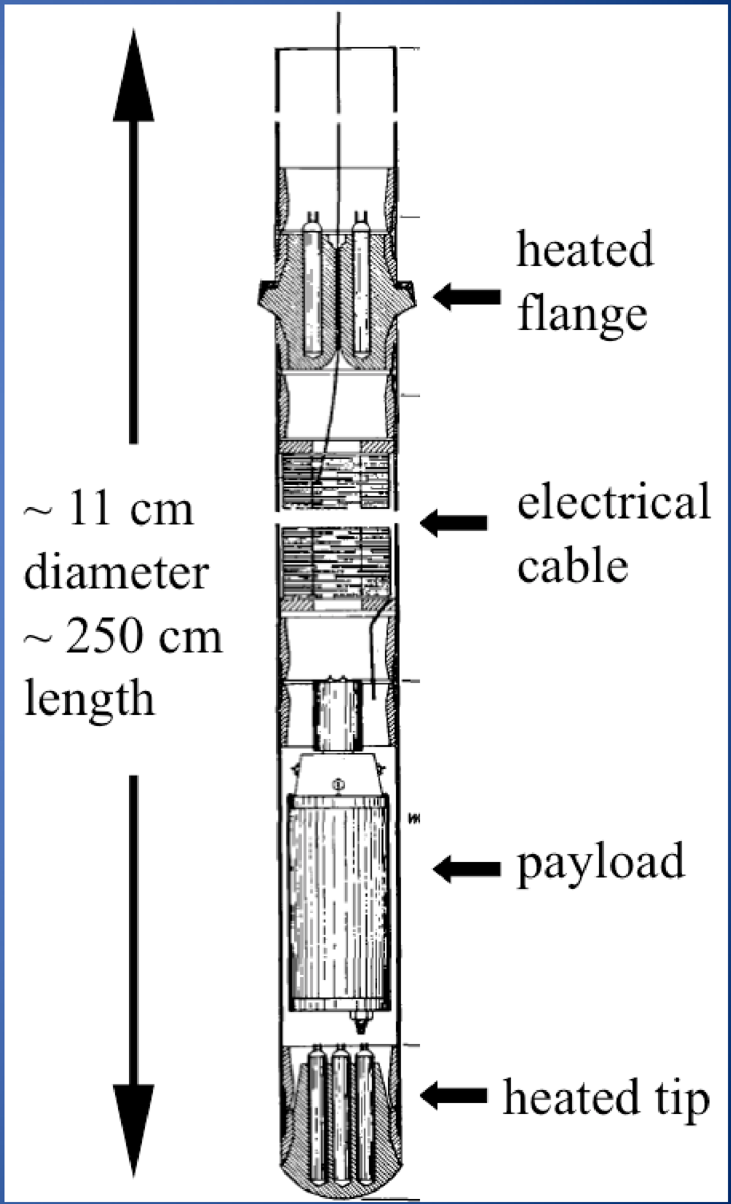
Ice-Melt Probes

History: 1960s-early 1970s [Philberth, 1976; Aamot, 1970], reached 100s m to 1 km depth in Greenland

Operation: (1) electrical power from surface -> heat at points of melting, (2) cable spools from vehicle, (3) autonomous pendulum (or electrical) steering, (4) hole refreezes behind

Pros: logistically light with only slow increase with increasing depth, autonomy, clean

Cons: slower (1-10 m/hr, i.e., 1000 m/4 days), no core or open hole (one-way trip), obstruction by dirt, unreliability



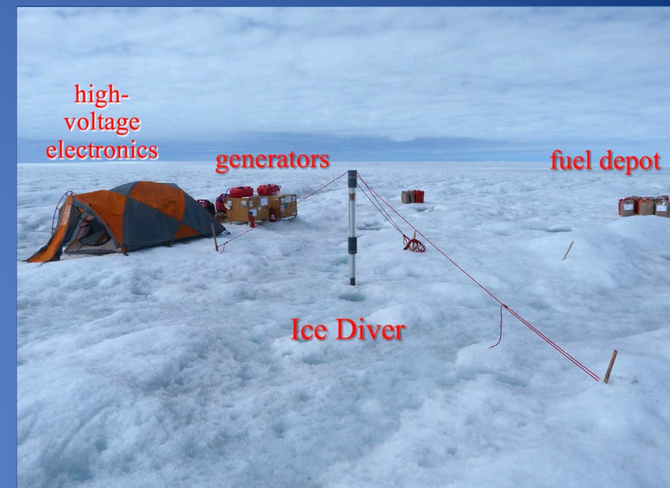
University of Washington Ice Diver Melt Probe

Developed under NSF (MRI and OPP) sponsorship

Philberth-type probe made reliable with modern design

2013 field test -- all equipment plus half anticipated fuel for 700 m depth – 650 kg

< 1 full Bell 212 helicopter load



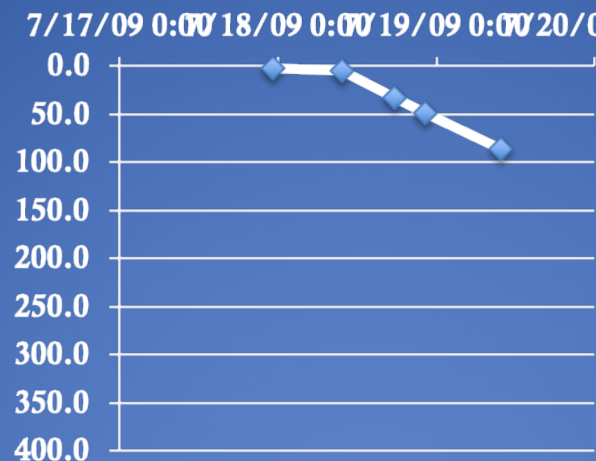
2014 Greenland field test set-up

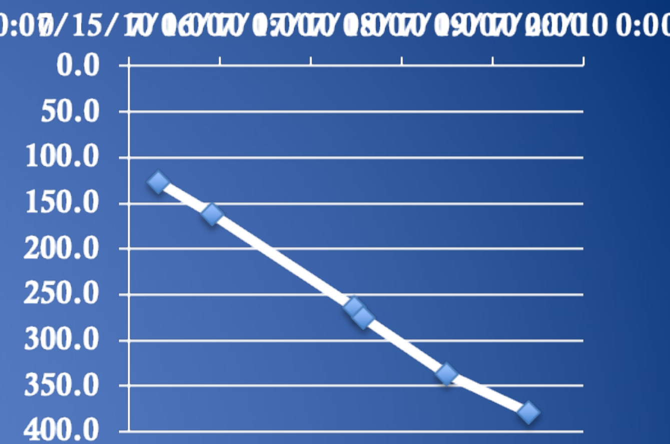
Probe descent to 400 m, descent rates 2.5 to 6.6 meters per hour

2014 Field Test Experience

4.5 kW/2000 V probe 14-15 July 2014

- tilt ≅ varied within 1 degree
- near-autonomous operation
- 6.6 m/hr descent speed (modeled)
- electrical fault in heater after 7 hrs

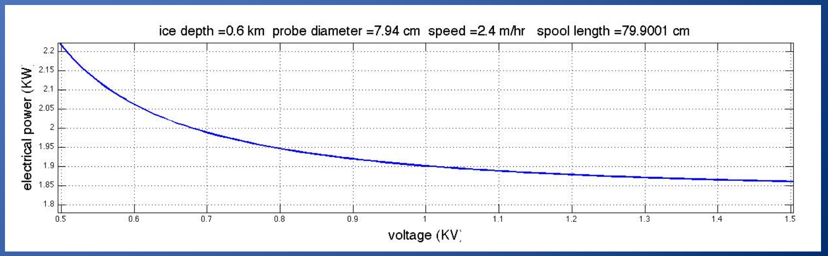




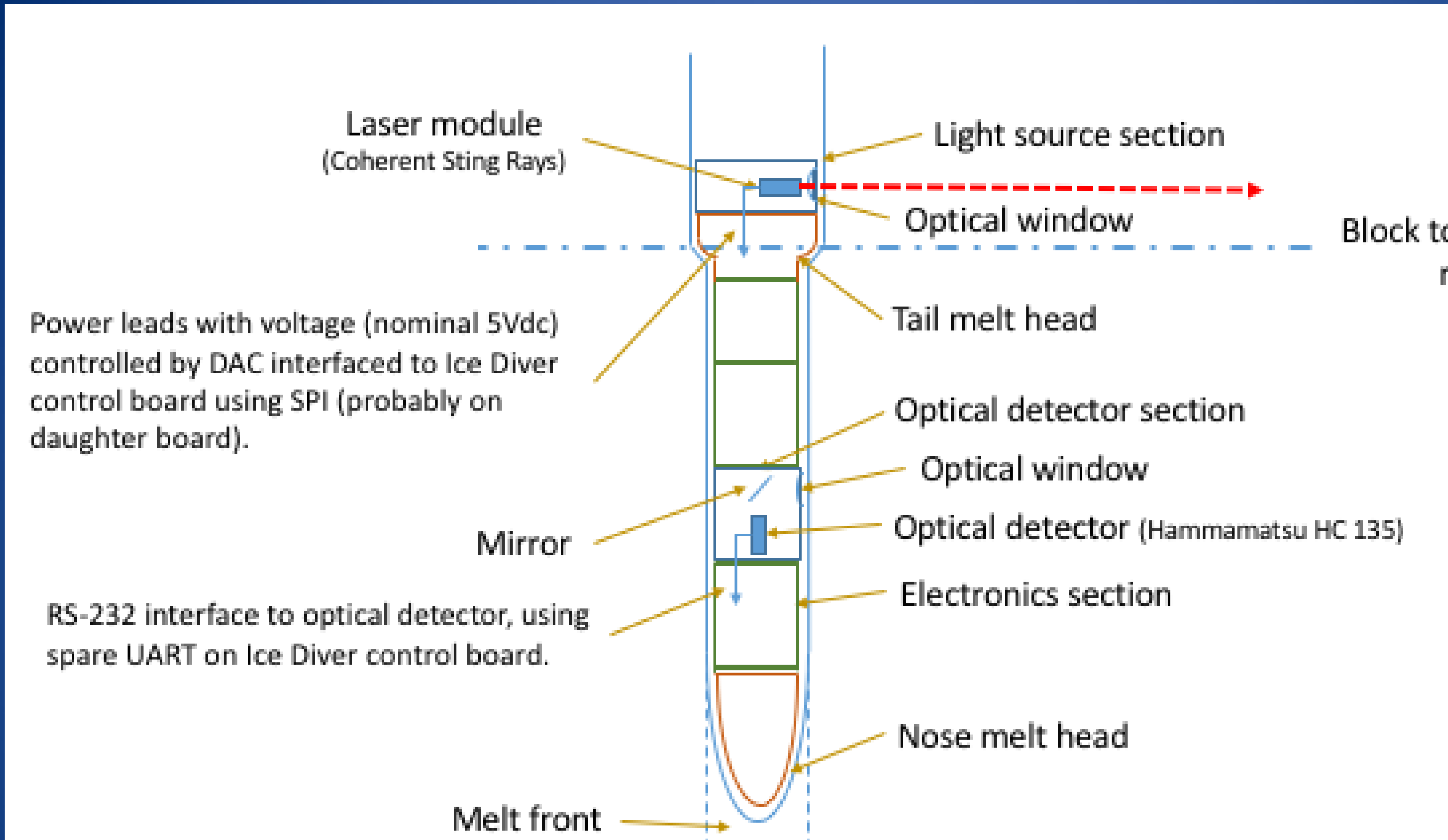
2.15 kW/1050 V probe 19-20 July 2013 & 16-20 July 2014

- Restart after 1 year hiatus
- Final depth 400 ± 50 m, consistent with TDR (436 m)

2014 descent speed 2.6 m/hr, consistent with modeling



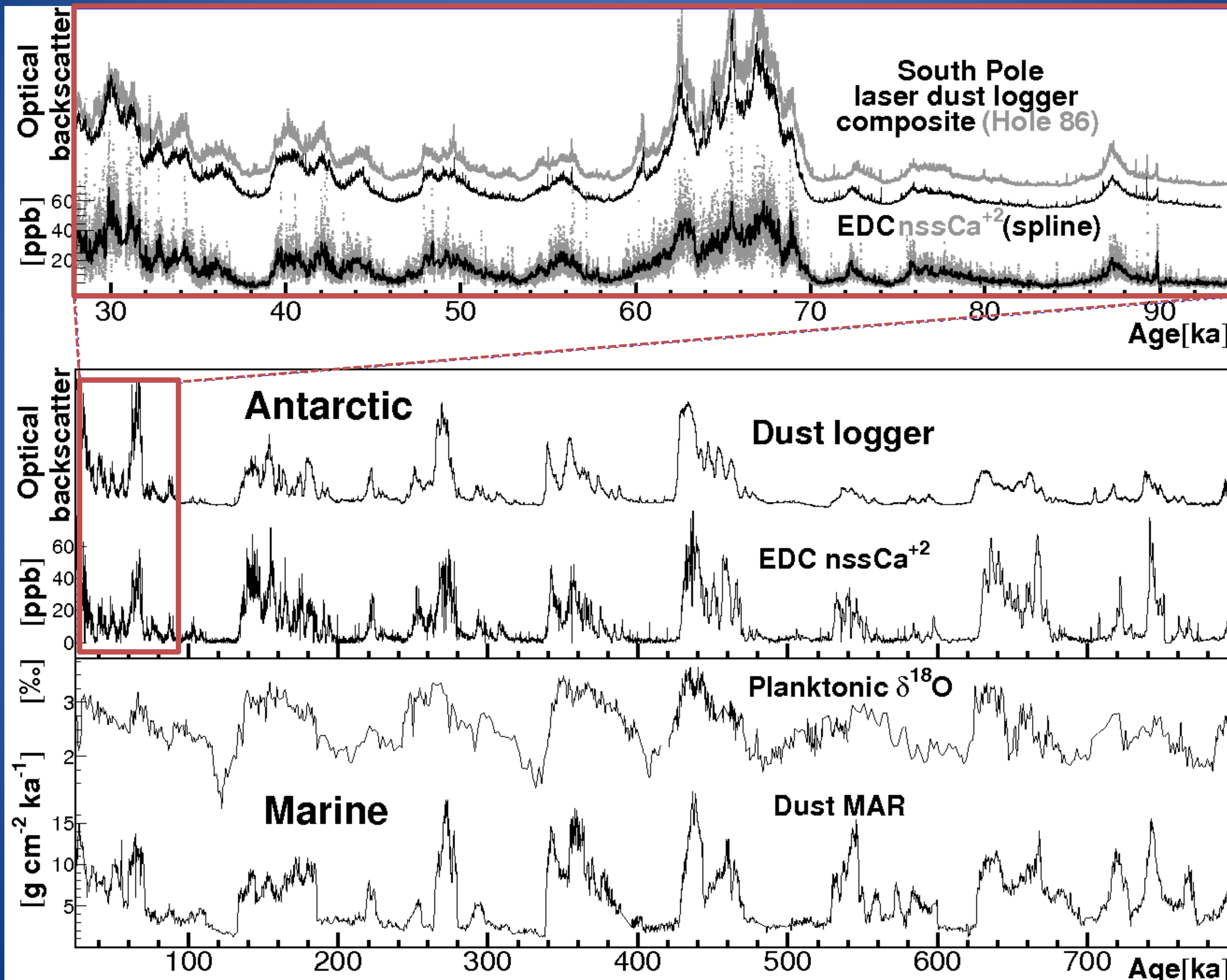
UW Ice Diver for Optical Dust-Logger Deployment



Integration with Ice Diver allows dust-log acquisition at lower costs, thus in more locations

- Pendulum-steering flange neatly blocks direct light path
- Low data rate consistent with telemetry up power wires
- Challenges: 2.5 km depth (vs. 1 km design), East Antarctic temps (-57C vs -15C)
- Solutions: lengthen wire spools (and probe), add heaters along length of probe, revise electronics to control profiler and telemeter data

Dust Diving for oldest ice



Thank you!