Glaciation and Geosphere Evolution - Greenland Analogue Project

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nwmo

NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

- Greenland Analogue Project
- Subproject A
- Subproject B
- Subproject C

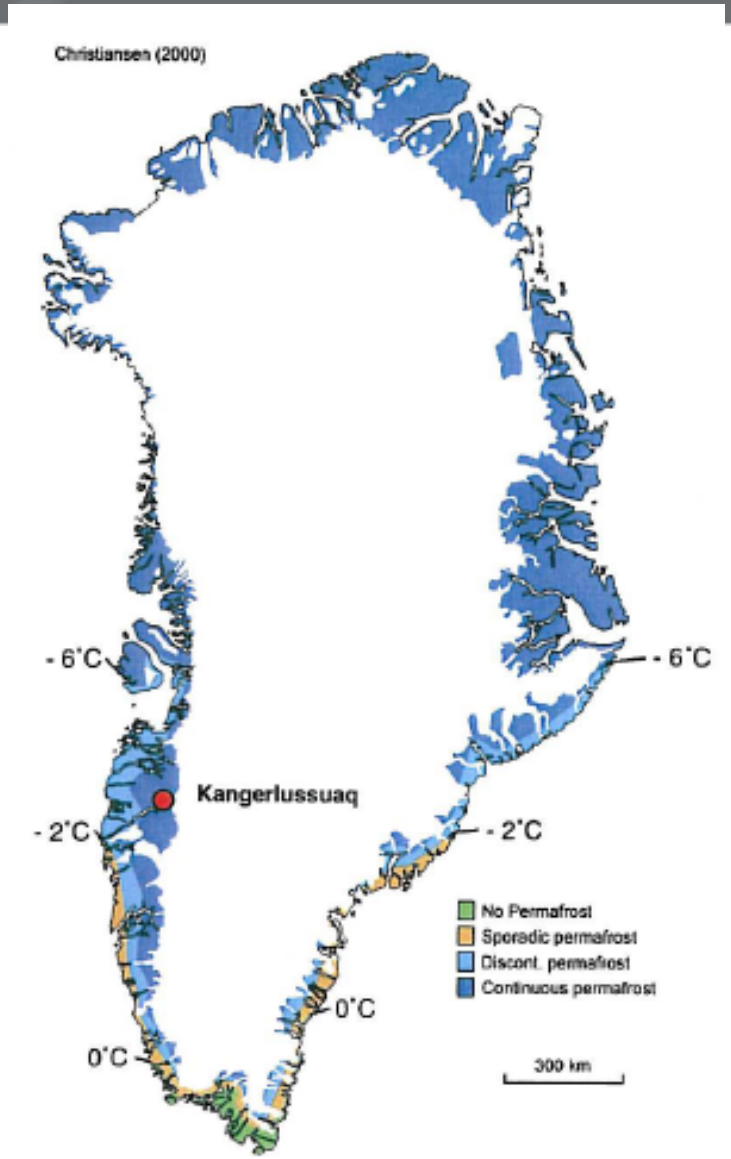
2009-2012

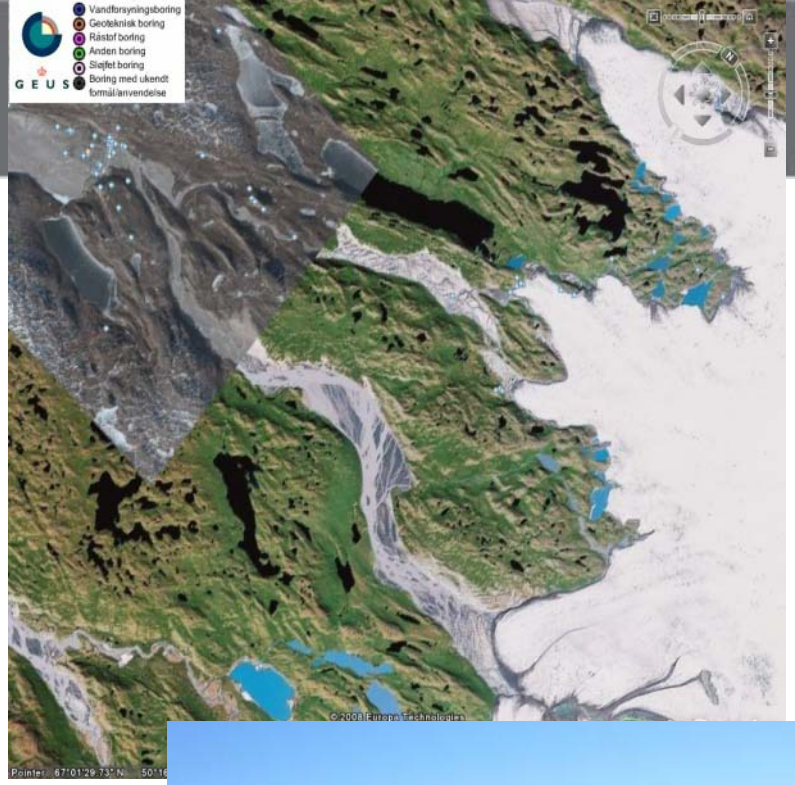
GAP overall aim is to improve current understanding of how an ice sheet affects groundwater flow and water chemistry at repository depth

Main Questions

- Where are sources of subglacial waters?
- To what depth does glacial meltwater penetrate into the bedrock?
- What is the chemical composition if such water reaches repository depth (~500 m)?
- What pressure gradients may occur at the bed of the ice sheet, driving ground water flow?
- Can taliks in front of the ice sheet act as concentrated discharge points for deep groundwater? Impact of permafrost on the flow system?

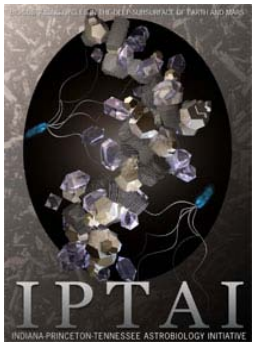
Research area





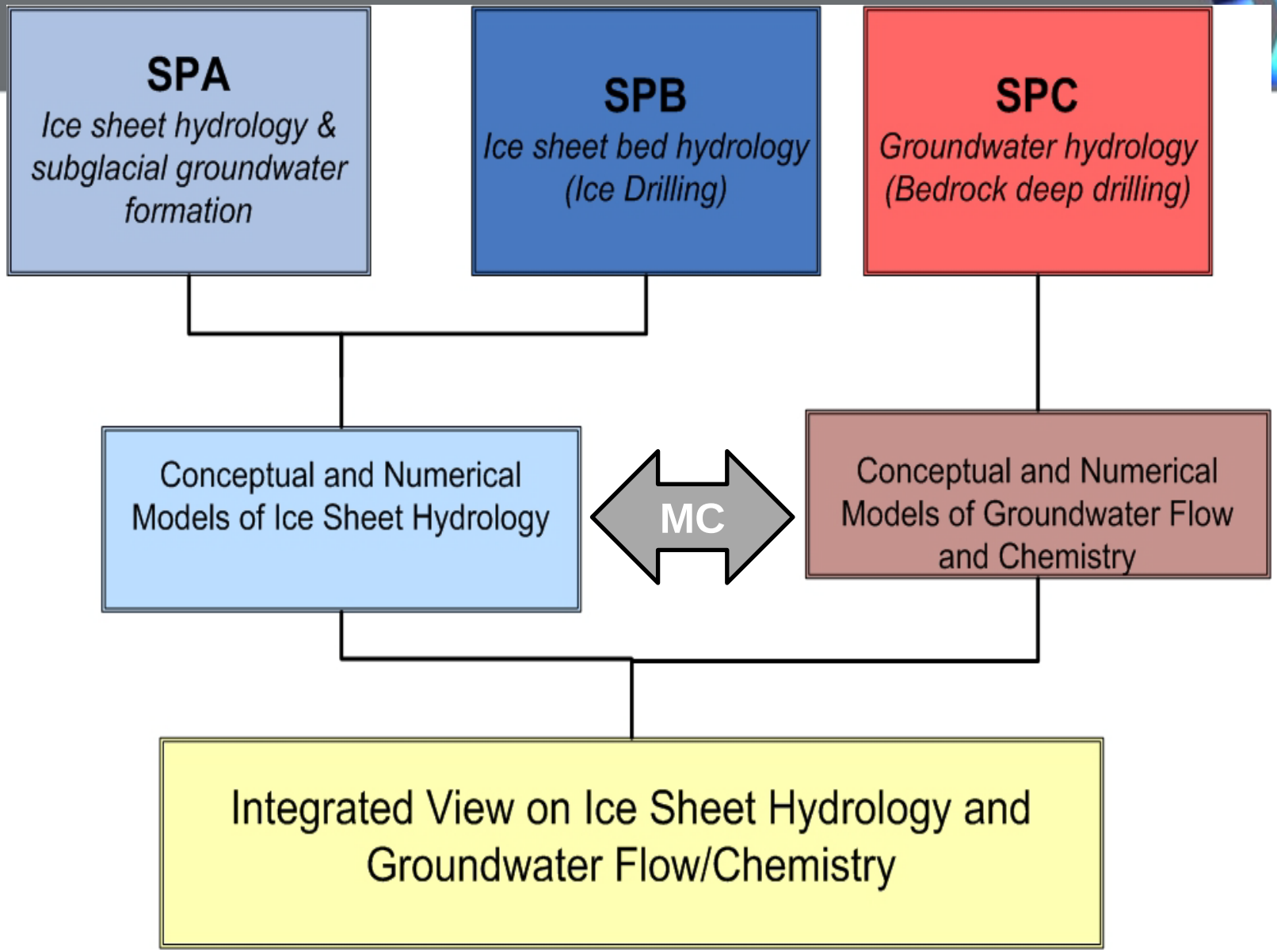
GAP participants

UPPSALA UNIVERSITET



Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada


SPA
Ice sheet hydrology & subglacial groundwater formation
SPB
Ice sheet bed hydrology (Ice Drilling)
SPC
Groundwater hydrology (Bedrock deep drilling)
Conceptual and Numerical Models of Ice Sheet Hydrology
MC
Conceptual and Numerical Models of Groundwater Flow and Chemistry
Integrated View on Ice Sheet Hydrology and Groundwater Flow/Chemistry

Subproject A

- **Overall objectives**
- **Summary of work to-date**
- **Upcoming plans**

Subproject A

- Ground based and airborne radar campaigns (ice thickness, subglacial thermo-hydrological conditions, DEM)

- AWS and GPS stations

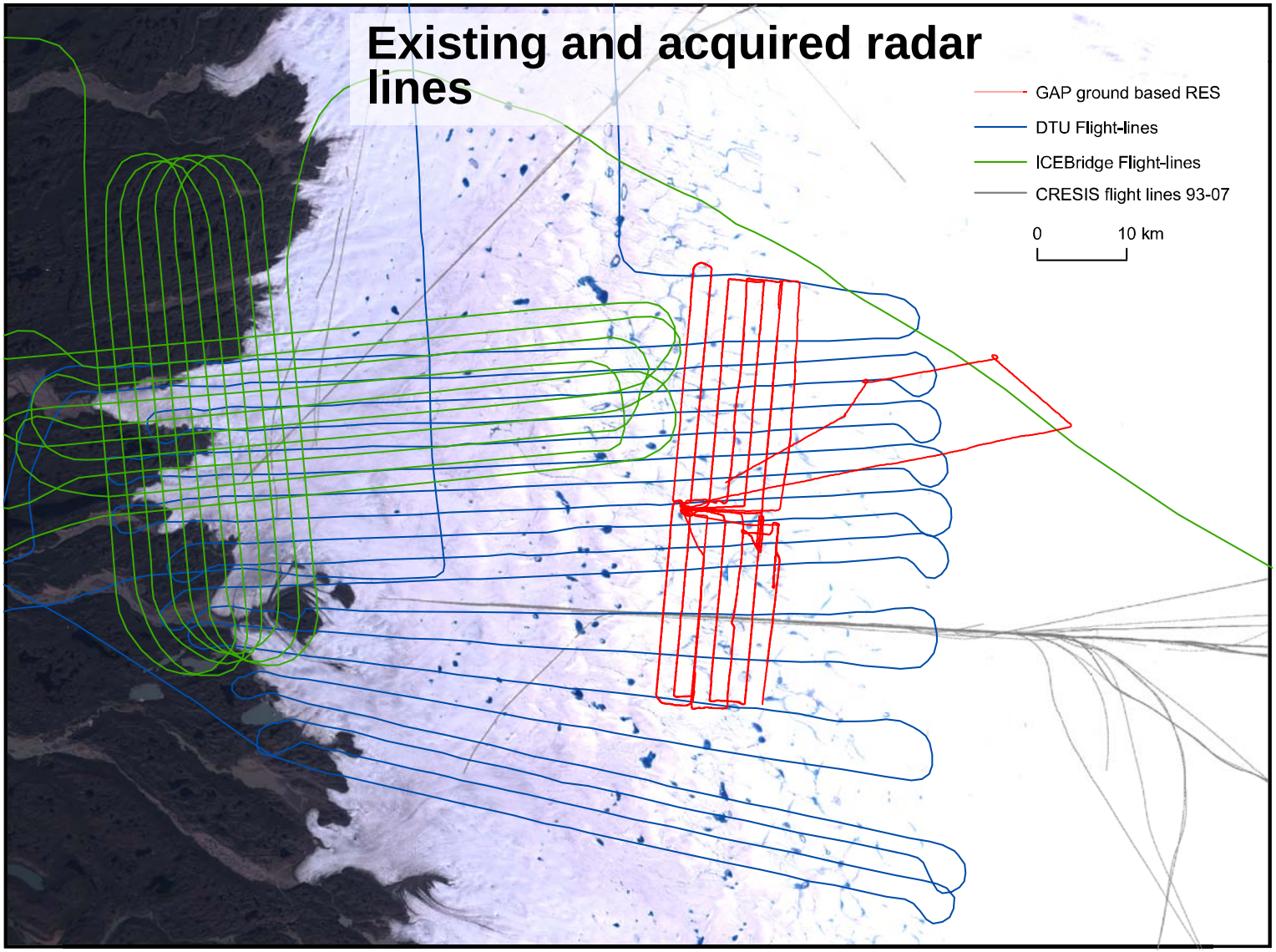
- Fixed continuous impulse radar (daily/seasonal changes in reflectivity → information about water at bed)

- Detailed radar surveys at moulins (englacial drainage)

Subproject A:Tracer investigations

- First successful use of electronic systems as tracers (2-8 km)
- Dye Tracing (<8 km)
- Sulphur Hexafluoride (2-35 km)

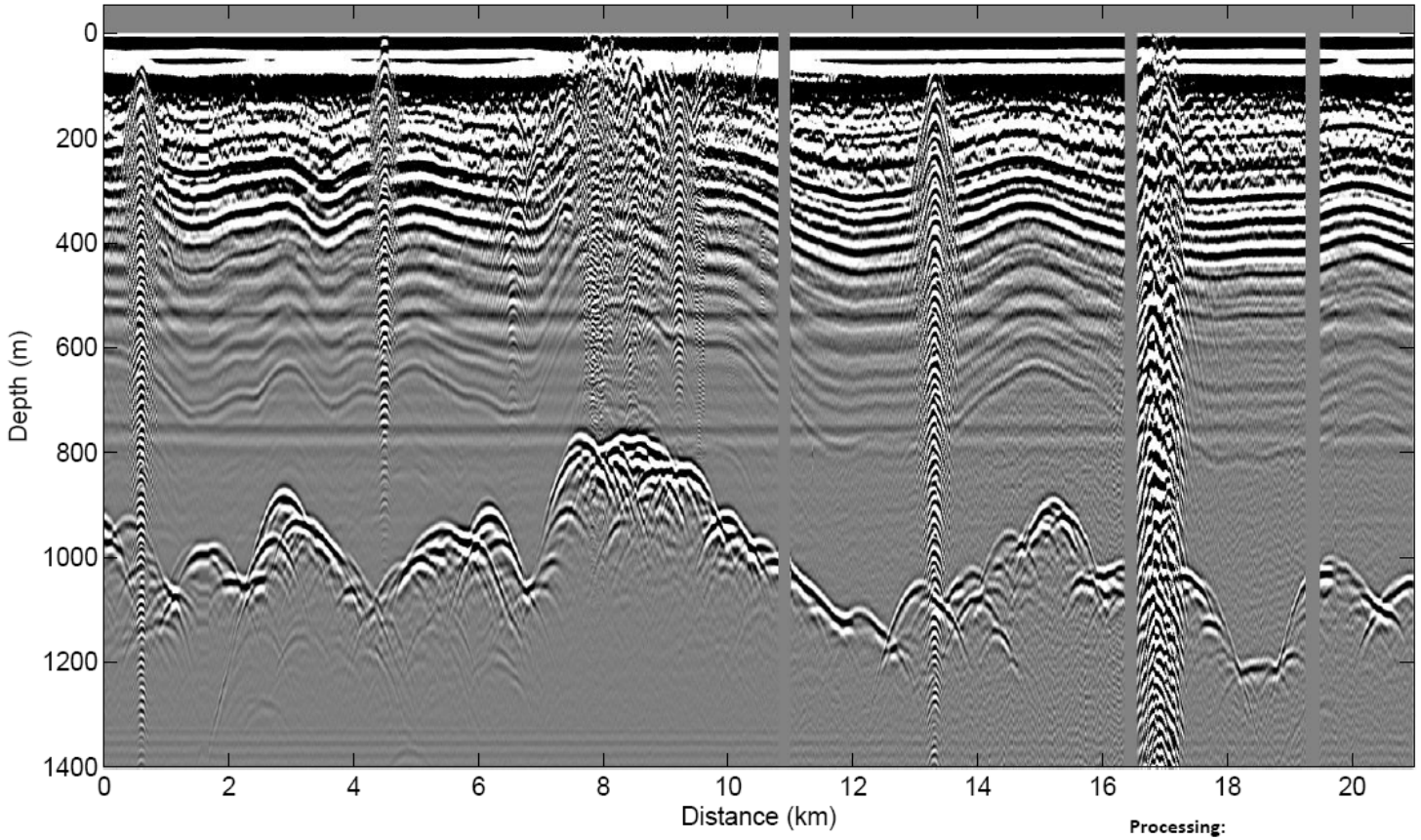
Subproject A: Radar lines



Subproject A - RES profile

Example of RES profile

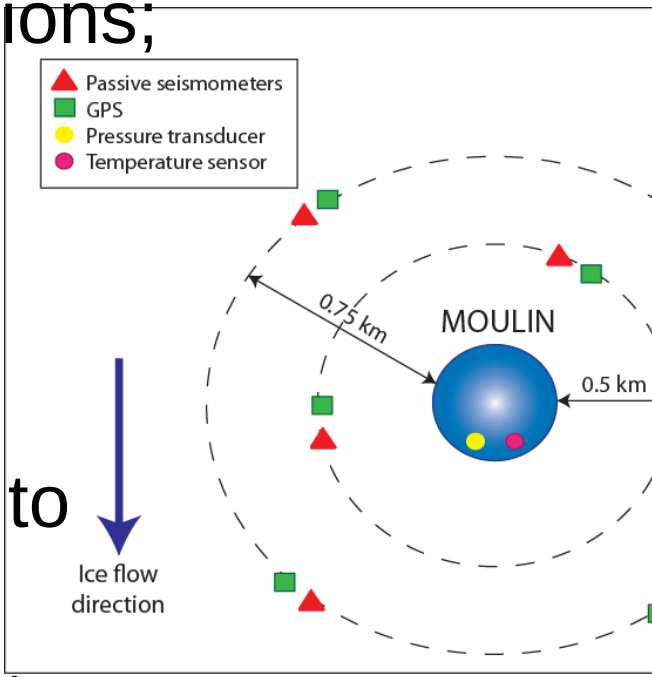
(RS22–RS21)



Processing:
Dewow, Lowpass filtered,
normal move-out corrected.
Using 168 m/µs in depth conversion

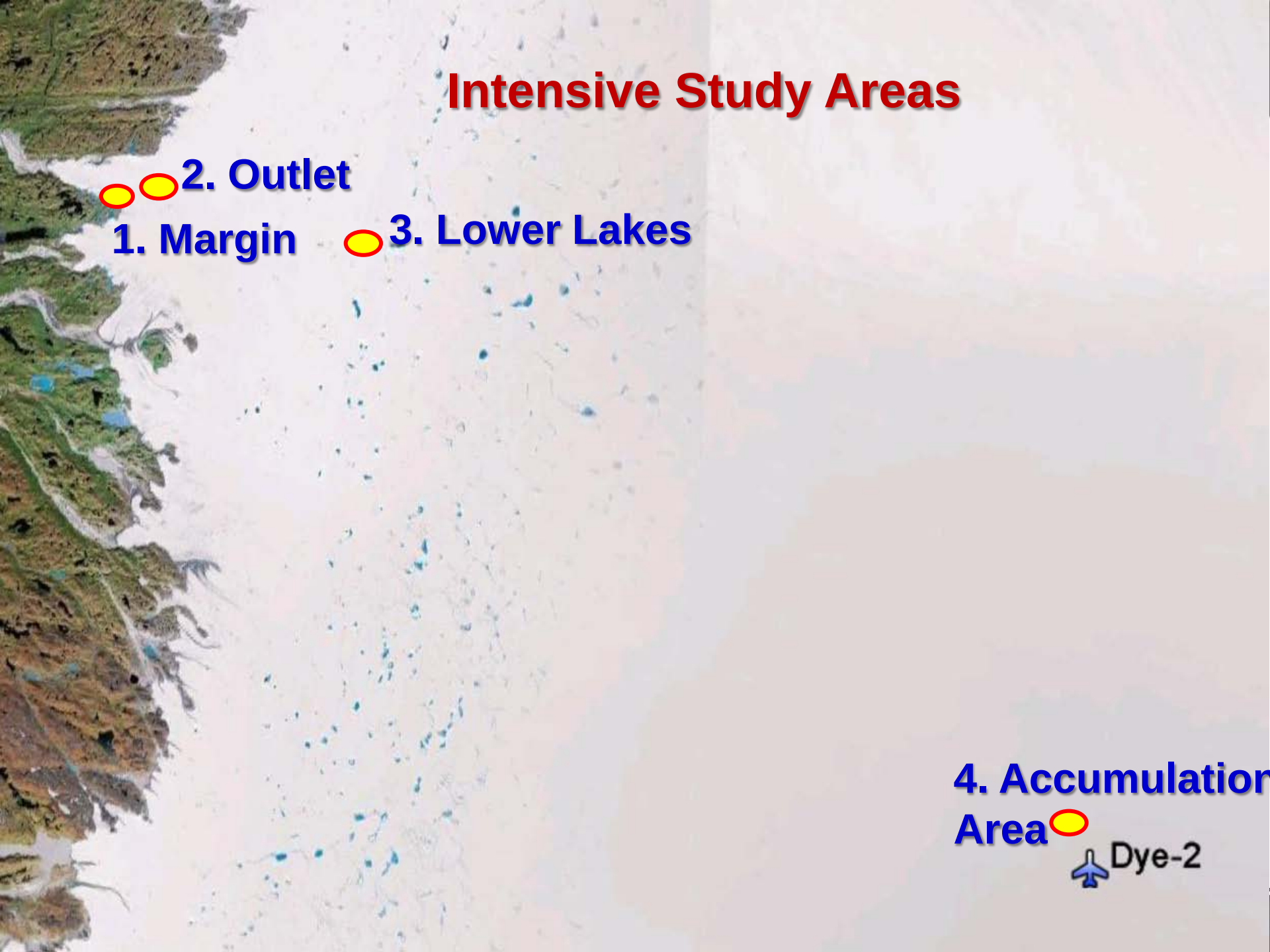
Subproject A: ongoing and future work

- Surface water drainage investigations; how do moulins re-activate?
- Passive seismometers to identify fracturing events: englacial and subglacial
- kGPS to link dynamical response to hydrology
- Pressure transducer and temperature sensor to examine moulin freezing rate
- Continued ground and air based radar
- Development of hydrofracture model



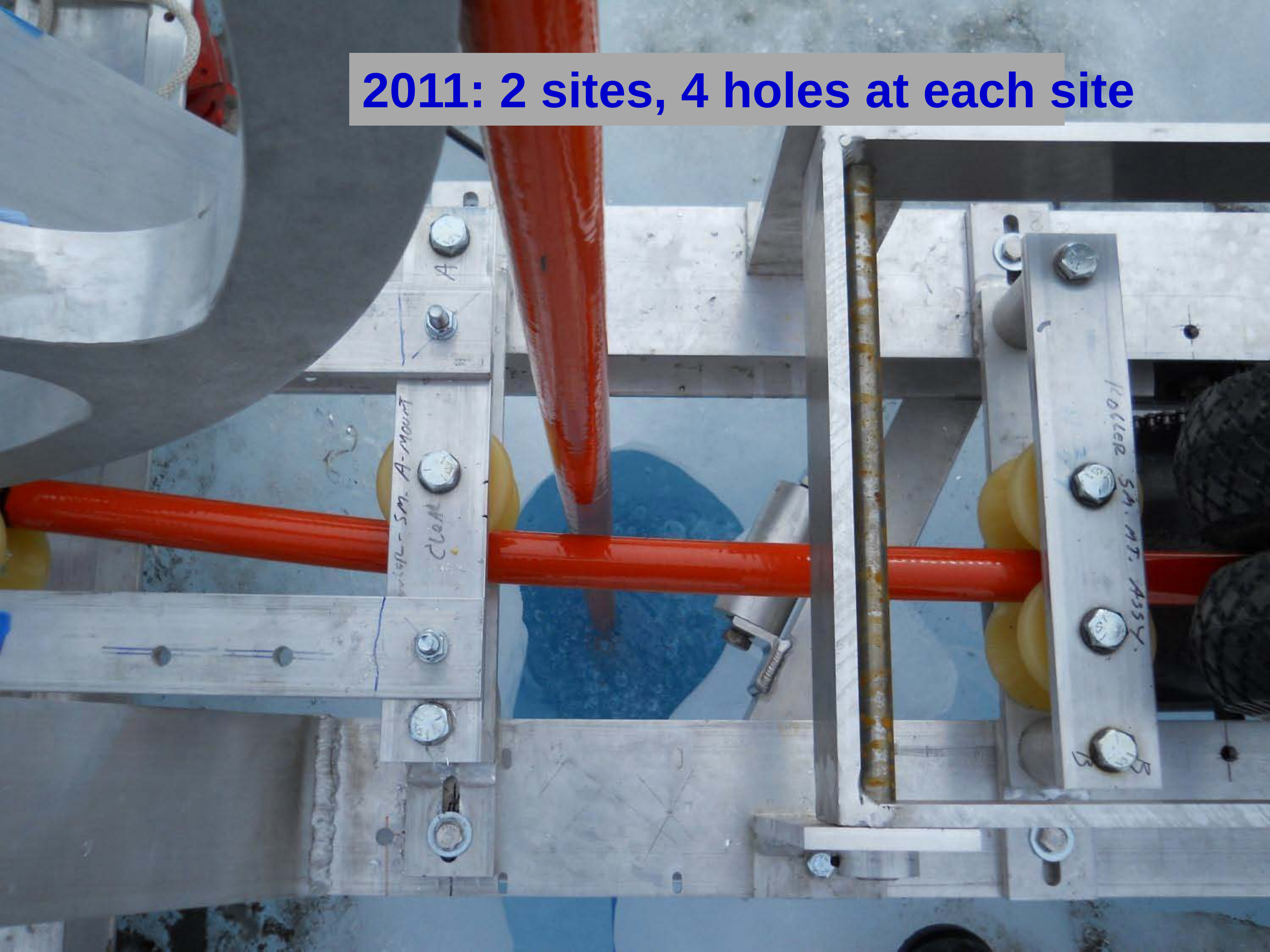
Subproject B

- Overall objectives
- Summary of work to-date
- Upcoming plans


Intensive Study Areas
2. Outlet
1. Margin
3. Lower Lakes
4. Accumulation Area
Dye-2


Site 1

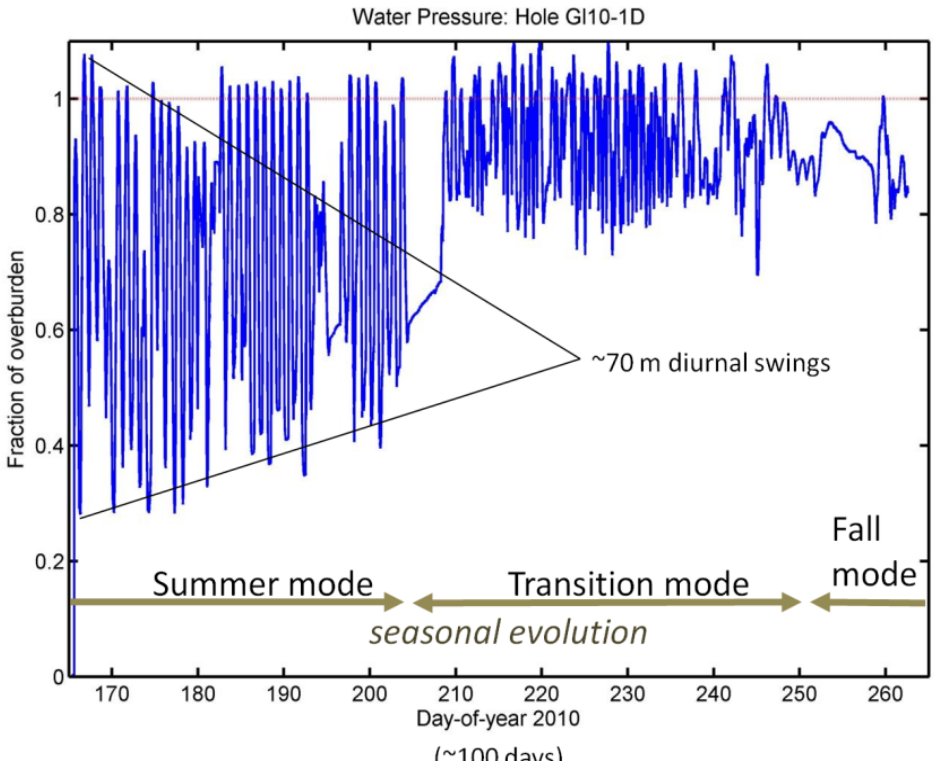
2011: 2 sites, 4 holes at each site



Debris laden ice near the bed

Preliminary Subproject B Findings

- The bed below Sites 1 and 2 consists of a thin veneer of sediment on top of bedrock.
- Ice 5 – 10 m laden with sediment, fine sand to boulders.
- Slug tests suggest high transmissivity at the bed.
- Basal water pressures exceed ice overburden at times, but also fall to less than 25% for short periods.
- Subglacial system exhibits diurnal water pressure variations and signs of complex connection pathways and very short residence times.
- Pattern of pressure variations change between summer and fall.



GAP Plans for 2011 and 2012– Subproject B

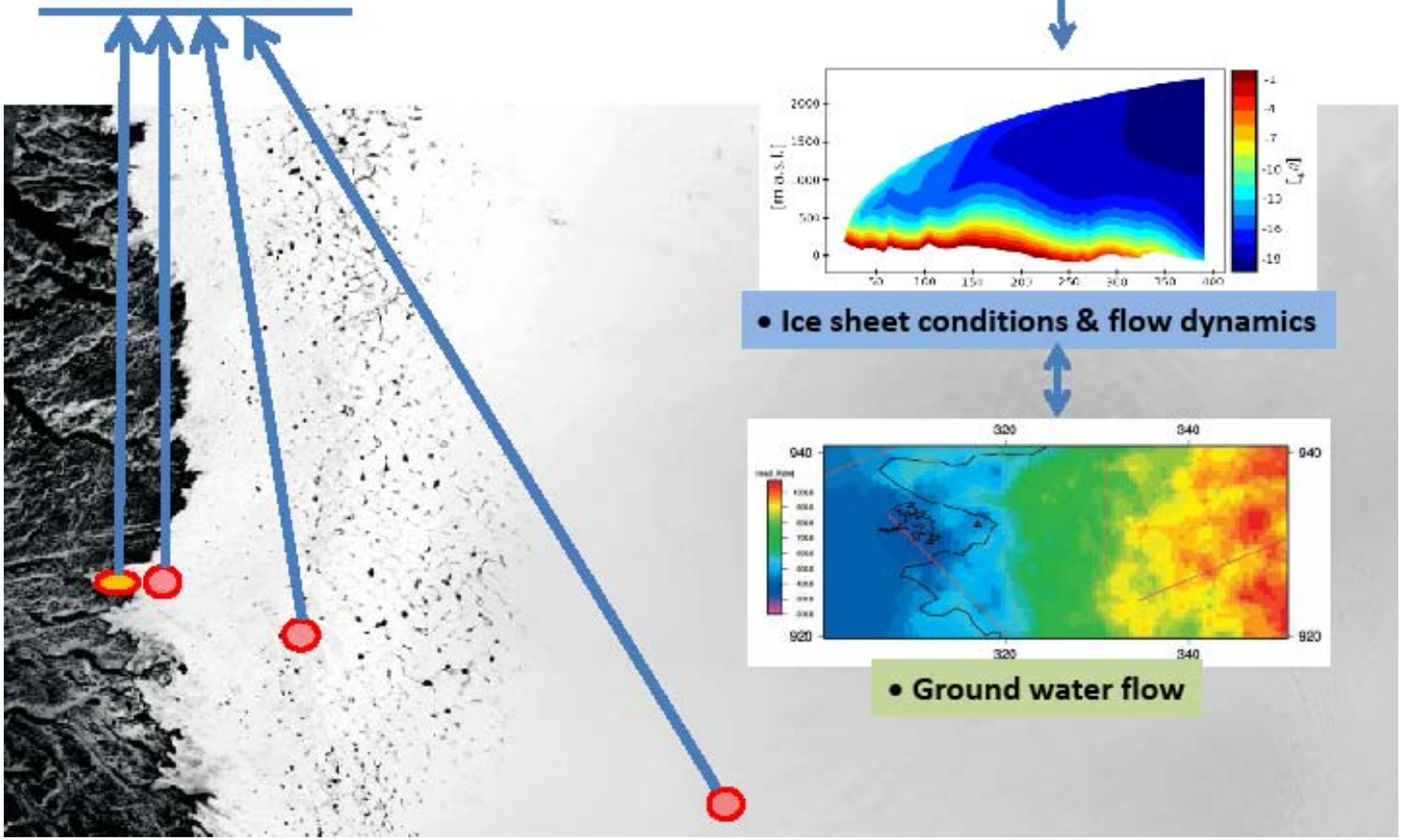
Borehole data:
ice temp,
ice deformation,
bed conditions

+

Other surface
velocity &
climate data

→

Adjoint model
data assimilation



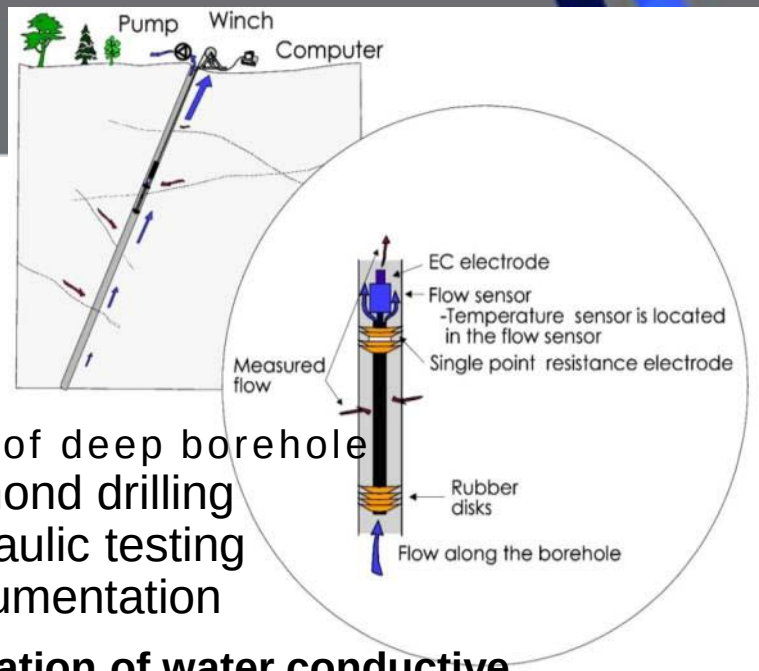
• Ice sheet conditions & flow dynamics

• Ground water flow

Subproject C

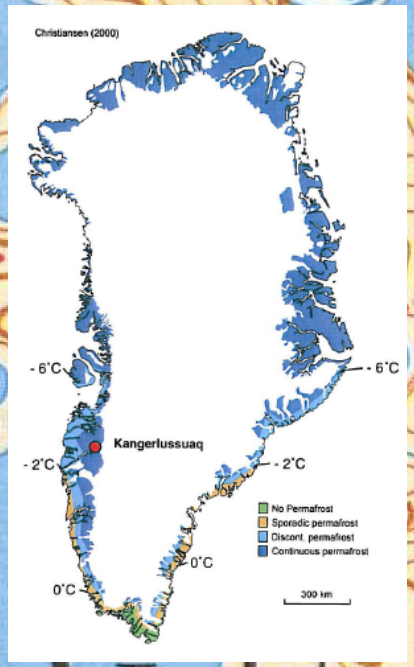
- Overall objectives
- Summary of work to-date
- Upcoming plans

Subproject C activities



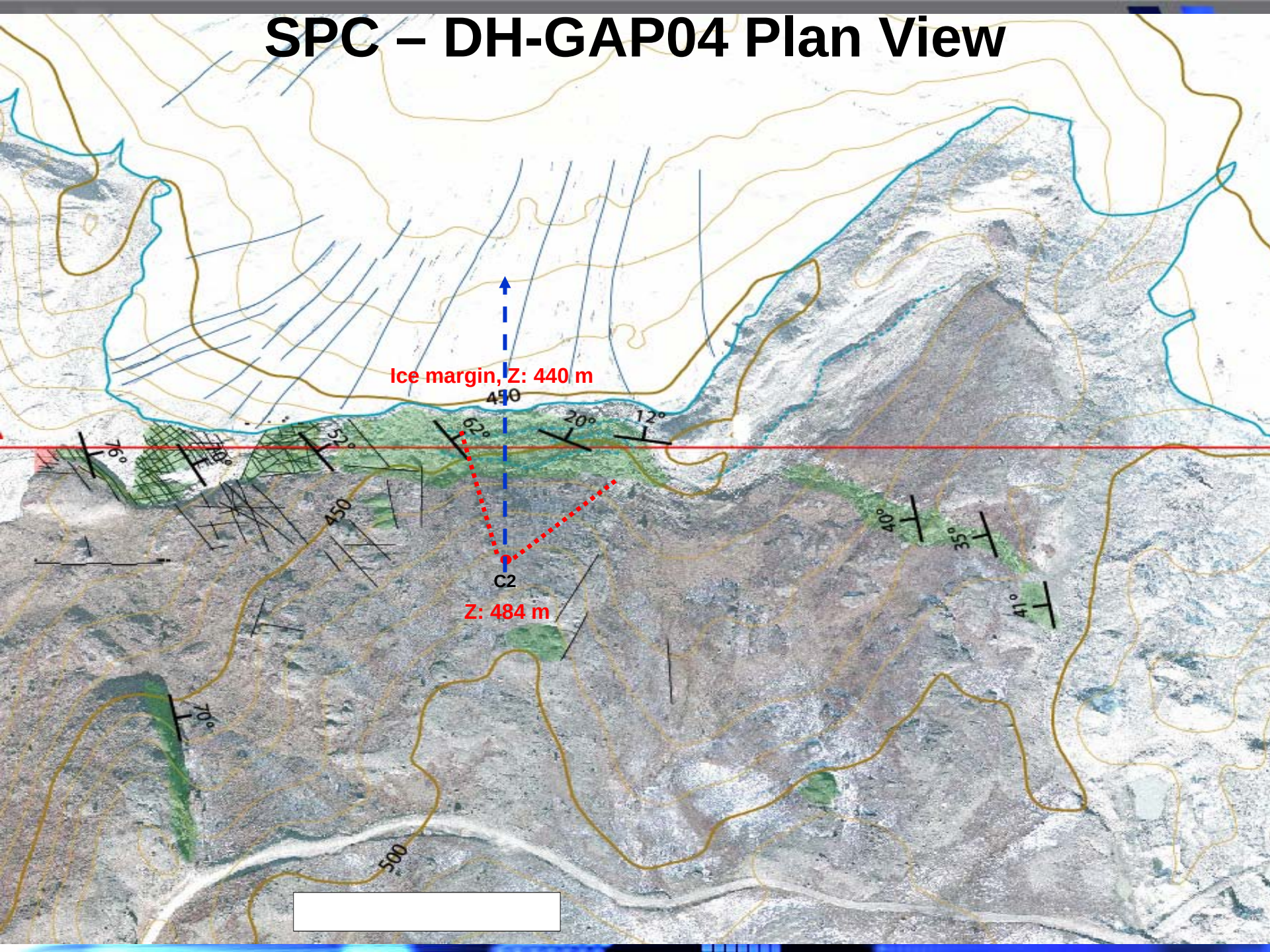
- Hydrogeochemical sampling
  - DH-GAP1 (’talik borehole’)
  - Pingo Spring & other surface waters
- Investigations at the Talik Lake
  - Depth & temperature profiling
  - Geothermal modeling
  - SKB biosphere project
- Water-rock interaction studies
  - Fracture calcites
  - Crush & leach
  - Parallel redox front project
- Aquatroll monitoring in DHGAP-01

- Drilling of deep borehole
  - Diamond drilling
  - Hydraulic testing
  - Instrumentation
- **Identification of water conductive sections**
  - Support location of the sampling sections
  - Support hydrogeological characterization of the bedrock
- **Time constraints due to permafrost**
- **Posiva Flowlog (PFL)**
  - Transmissivity of open fractures
  - Hydraulic head (over pressure/under pressure)
  - Single point resistance (rock)
  - Temperature & EC/measuring section (water)

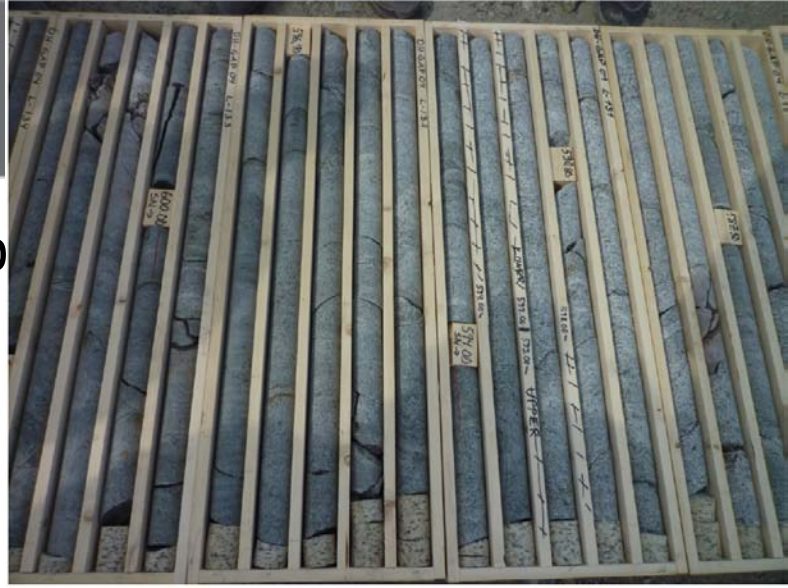

Christiansen (2000)
- 6°C
- 6°C
Kangerlussuaq
- 2°C
- 2°C
0°C
No Permafrost
Sporadic permafrost
Discont. permafrost
Continuous permafrost
300 km

N
(Isrands søen)
.493
DH-GAP03
575
501
507
491
476
506
DH-GAP01
.440
(Israndsdalen)
0 250 500 1 000 1 500 2 000

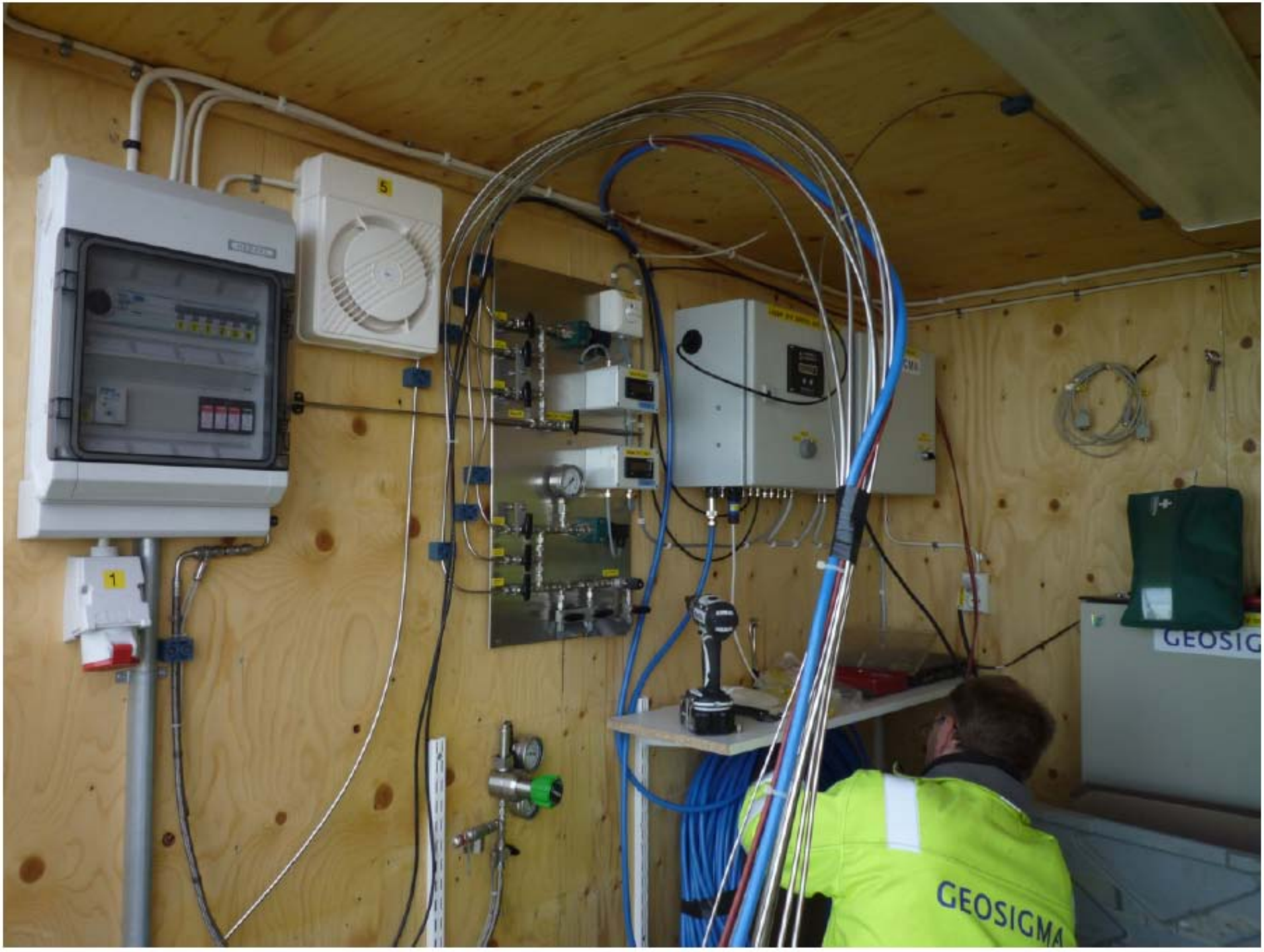
SPC – DH-GAP04 Plan View



Deep borehole drilling



- 687 m length borehole, 70 degree dip
- Permafrost extends to ~ 400 m depth
- Mafic and felsic gneiss (detailed core-logging to be done in Olkiluoto, Finland)
- 10 m fixed section packered off at 599 m (drillhole length)
- Temperature, EC and pressure monitored in fixed section, EC and pressure in upper and lower sections.
- DTS cable provides a continuous temperature profile down to 600 m.
- All three sections can be sampled with nitrogen purging.
- Fall 2011 field campaign to collect samples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GEOSIGMA

Questions?

Photo from henrypatton.org