Enigmatic groundwater in Greenland's permafrost

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Mikkel Toft Hornum, PhD candidate, UCPH and UNIS

Main supervisor: Ylva Sjöberg
Co-supervisors: Aart Kroon and Andy Hodson

CatchNet

Catchment Transport and Cryo Hydrology Network

CENPERM

Center for Permafrost

UNIS

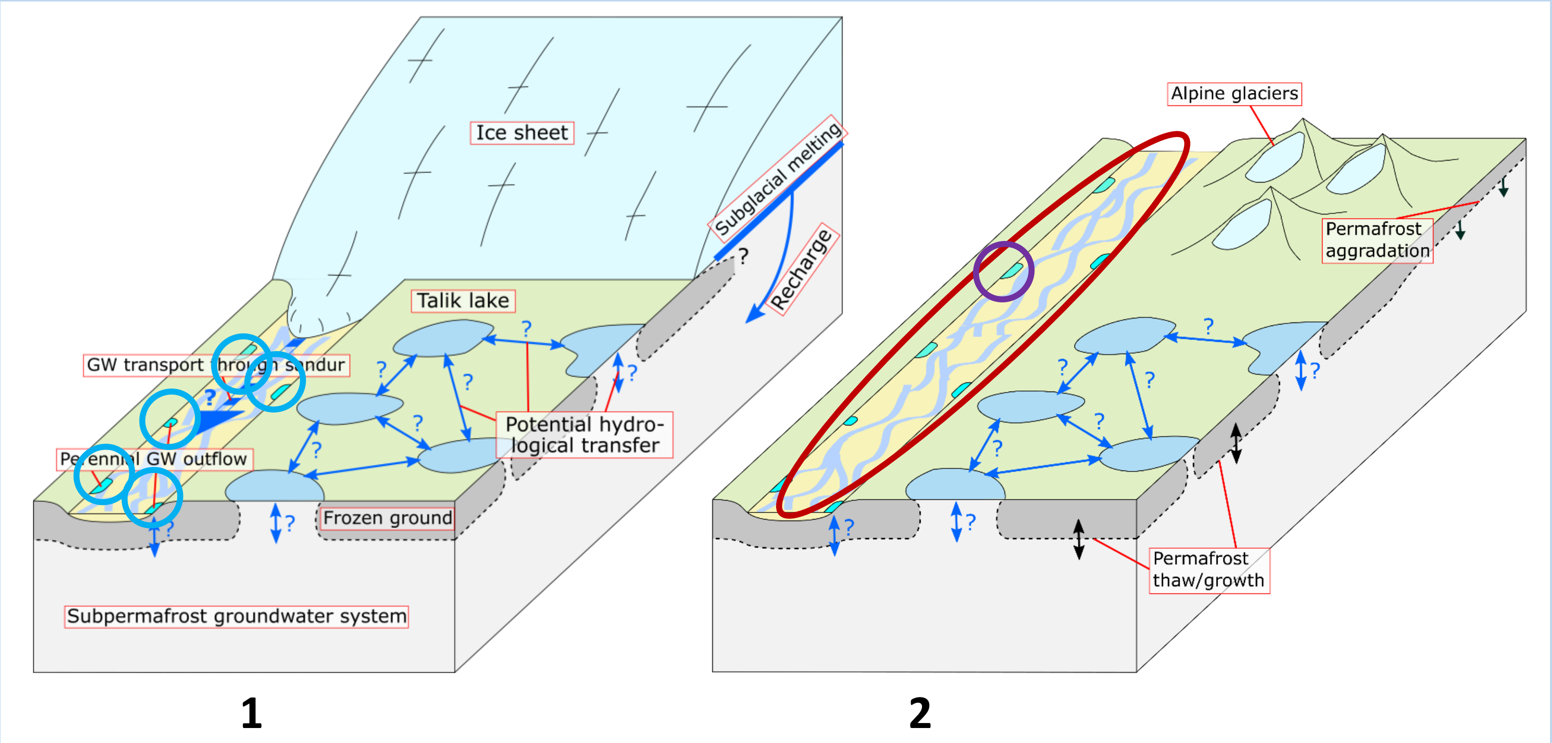
The University Centre in Svalbard

Outline

- The PhD project on one slide!
  - Title: 'Numerical modelling of periglacial hydrology'
  - Graphical summary
  - Papers
- Enigmatic groundwater in Greenland's permafrost
  - Discovery of abundance of presumed groundwater springs on satellite imagery
  - Field campaign
  - Results
    - Major ion chemistry
    - Stable water isotopes
    - Dissolved methane concentration
  - Conclusions

Graphical summary of my PhD project

Hydrological connections between the surface and deep groundwater system in the periglacial landscape



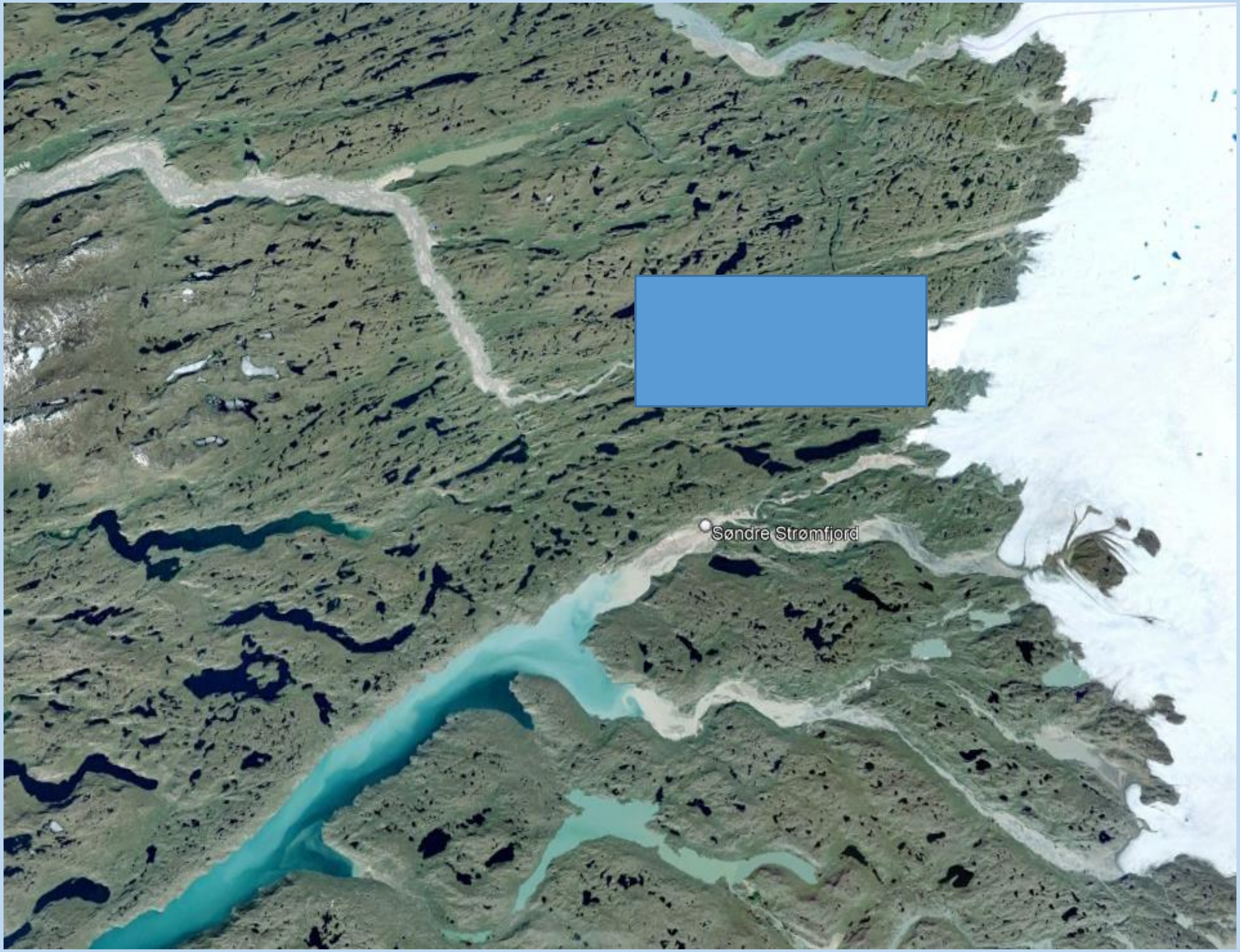
Papers 1 and 3: Basal permafrost aggradation as a spring-driving mechanism

Paper 2: Groundwater flow along geological boundary revealed by ERT

This study (paper 4): Groundwater springs in Isortoq Valley

- Hornum, M. T., Hodson, A., Jessen, S., Bense, V., & Senger , K. (2020), 'Numerical modelling of permafrost spring discharge and open system pingo formation induced by basal permafrost aggradation, *The Cryosphere*
- Hornum, M.T., Bense, V., van der Ploeg, M., Kroon, A., Verbakel, L., Sjöberg, Y., 'Arctic spring systems driven by permafrost aggradation', In prep. for *GRL*
- Hornum, M. T., Betlem, P., & Hodson, A. (2021), 'Groundwater Flow Through Continuous Permafrost Along Geological Boundary Revealed by Electrical Resistivity Tomography', *Geophysical Research Letters*

Field area – Kangerlussuaq



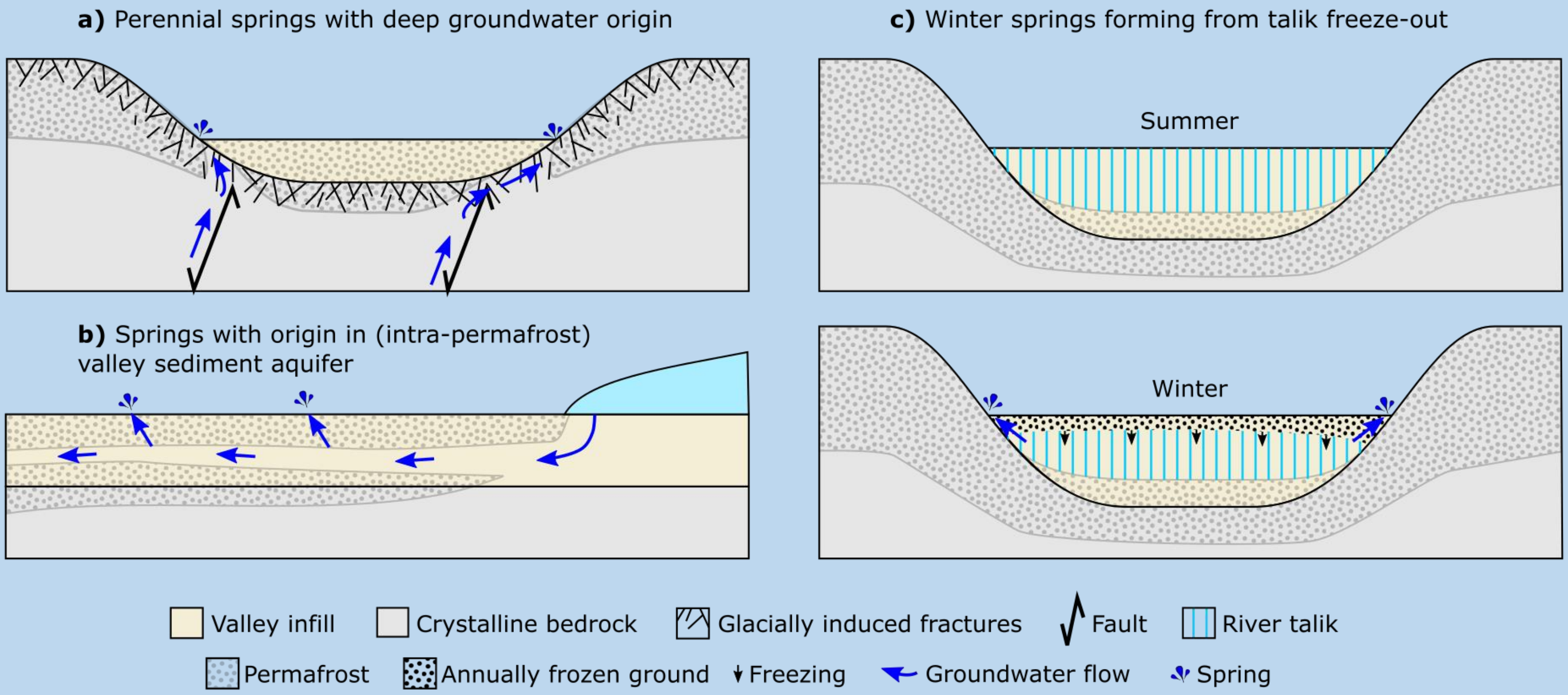
Discovery of (presumed) groundwater springs in Isortoq Valley

- Where does the water come from?
- Is spring discharge bringing greenhouse gases?

Icings in the Kangerlussuaq area observed on satellite imagery 2018-2020

Forty individual icings observed in Isortoq Valley

Working hypotheses




Field work 1-6 April 2022
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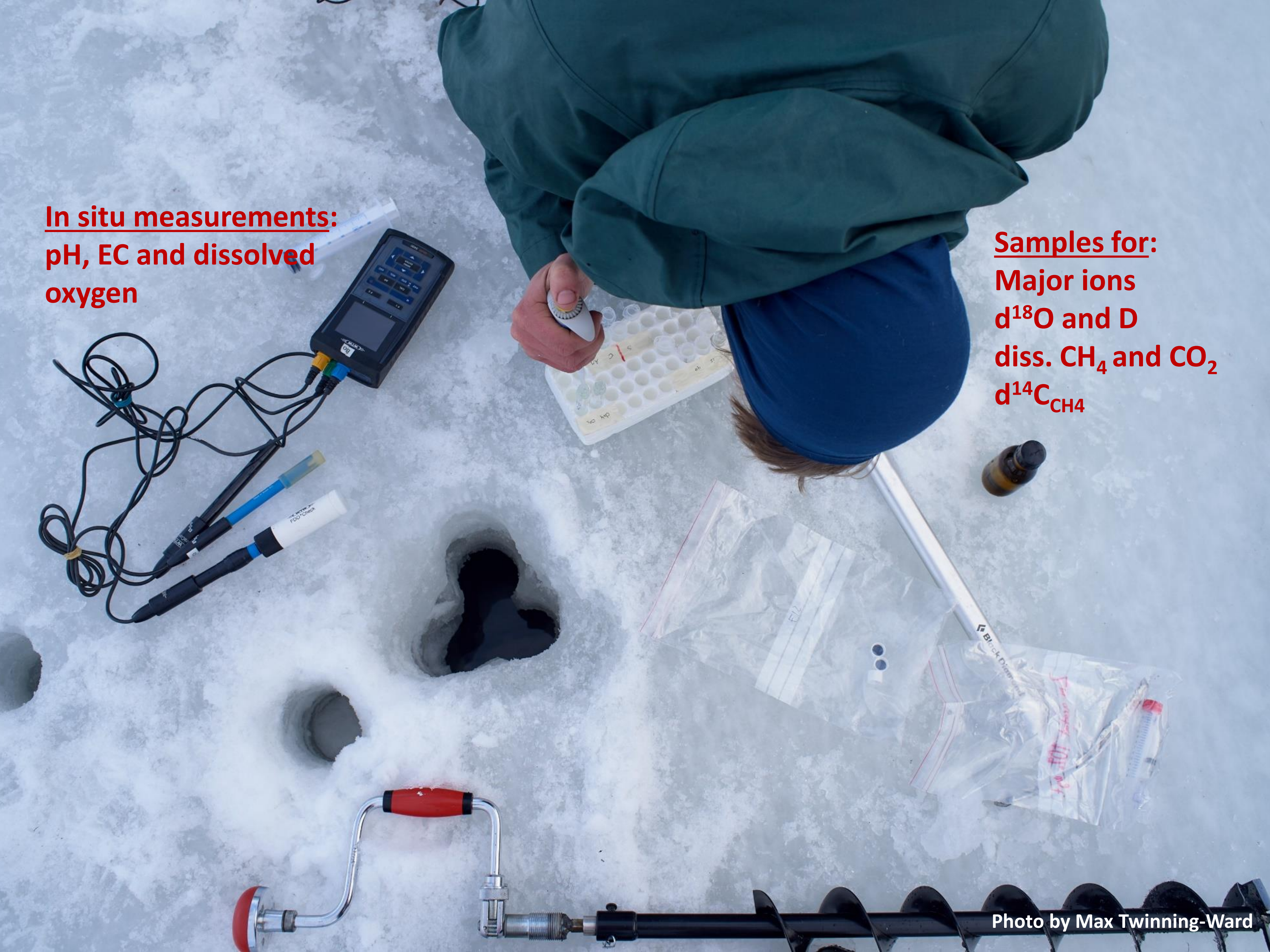
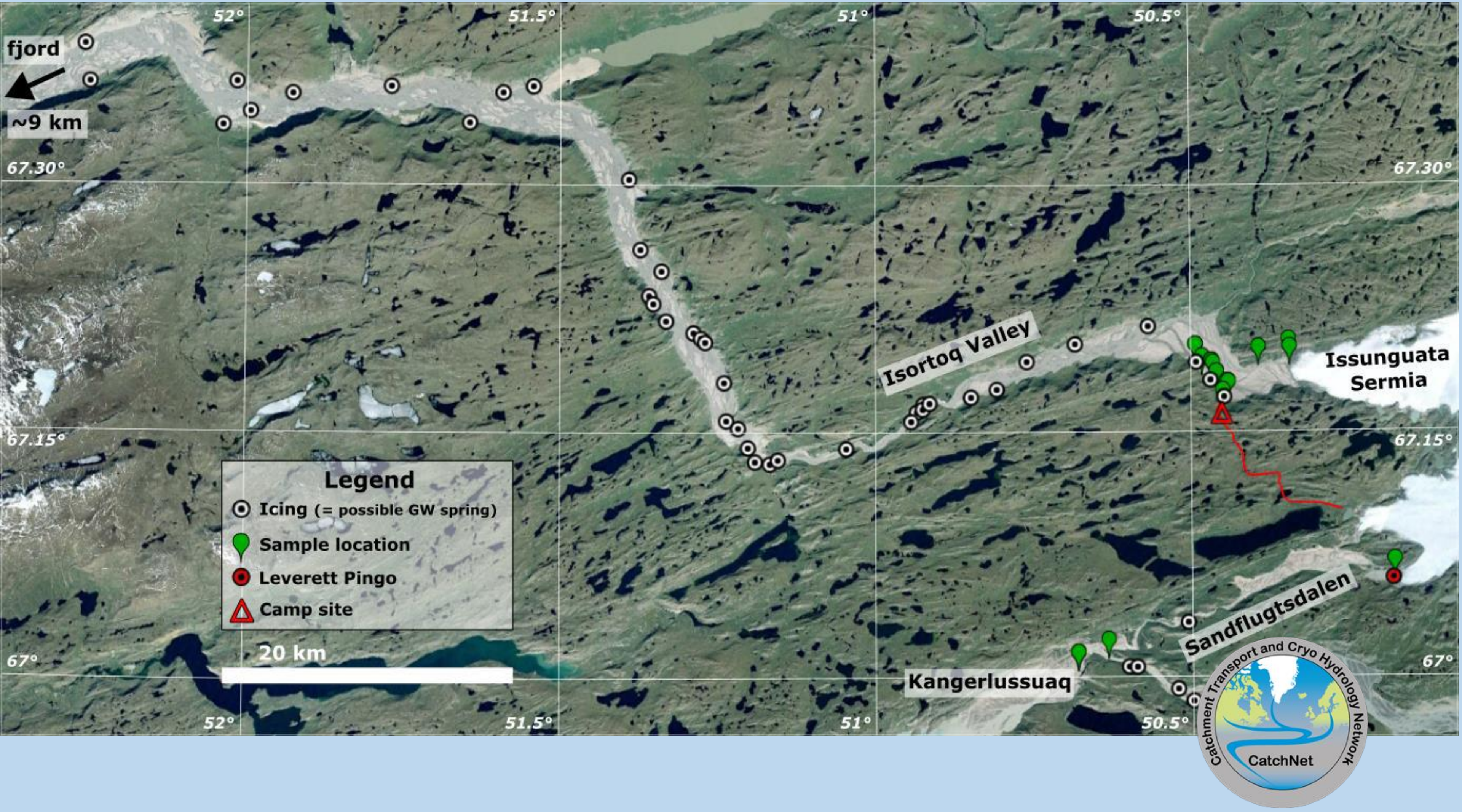
First view of Isortoq Valley

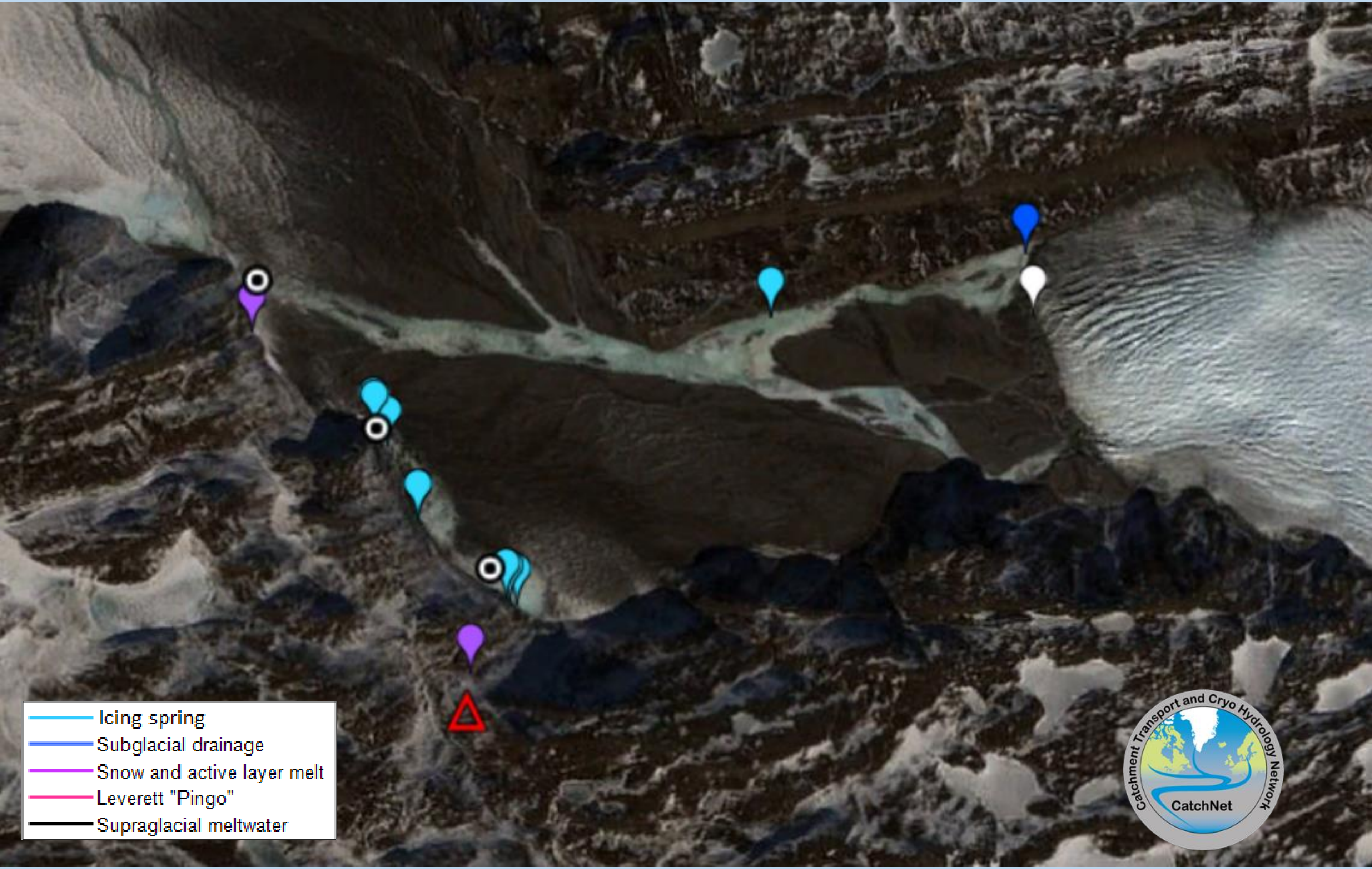
Video by Max Twinning-Ward


In situ measurements:
pH, EC and dissolved
oxygen
Samples for:
Major ions
d^{18}O and D
diss. CH_4 and CO_2
d$^{14}C_{CH4}$
Photo by Max Twinning-Ward

Sample locations

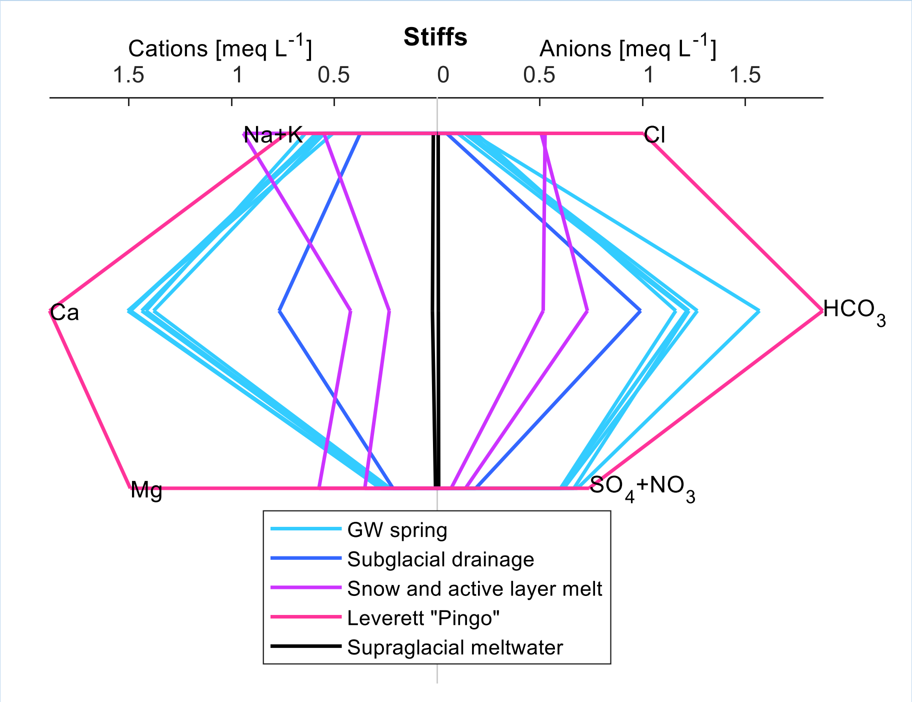


Sample locations



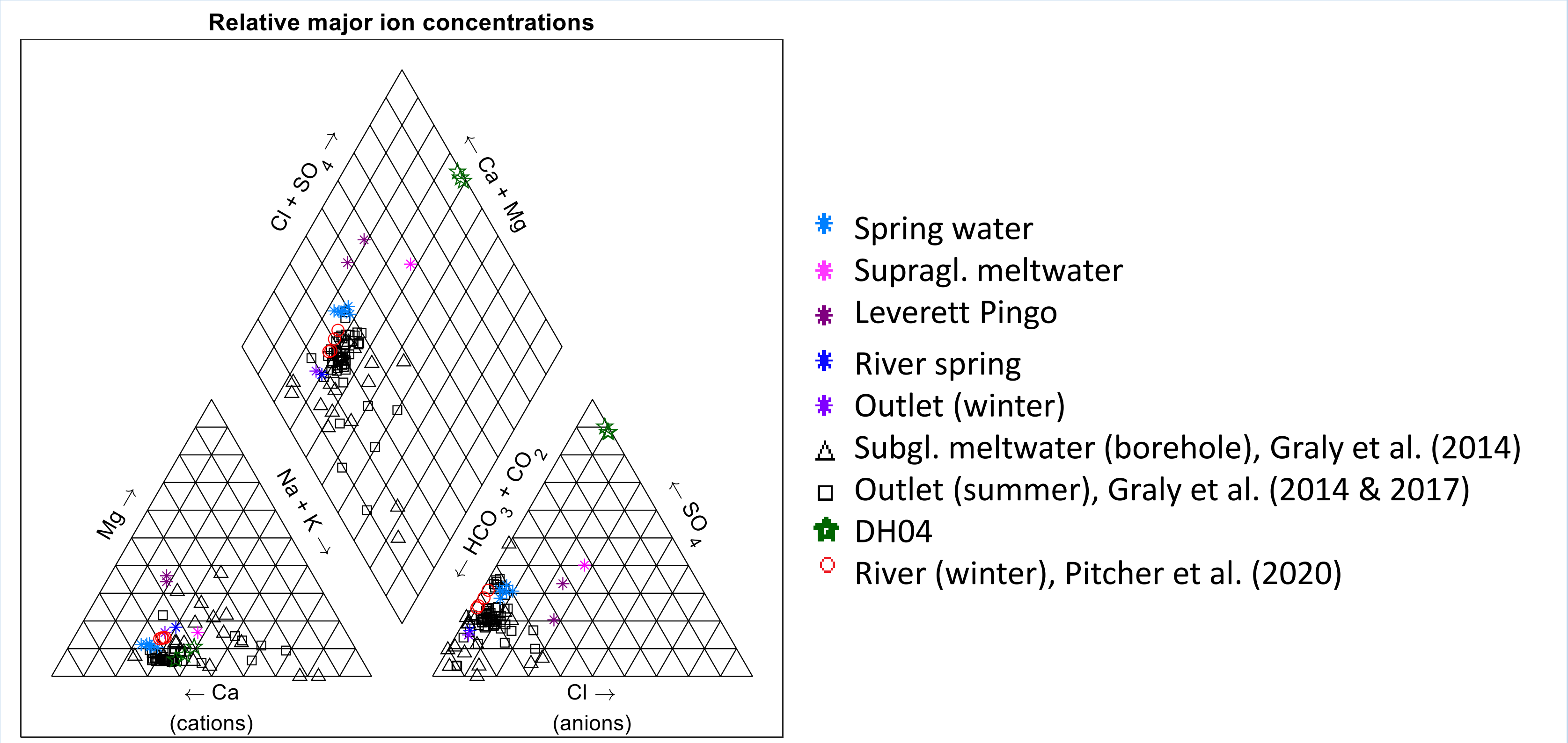
Satellite photo taken 4 April 2022. Planet.com

Major ion concentration



First glance: Groundwater springs differ from other samples

Major ion concentration



Pitcher, L. H., Smith, L. C., Gleason, C. J., Miège, C., Ryan, J. C., Hagedorn, B., et al. (2020). Direct observation of winter meltwater drainage from the Greenland Ice Sheet. *Geophysical Research Letters*, e2019GL086521. https://doi.org/10.1029/2019gl086521

Graly, J. A., Humphrey, N. F., Landowski, C. M., & Harper, J. T. (2014). Chemical weathering under the Greenland ice sheet. *Geology*, *42*(6), 551–554. https://doi.org/10.1130/G35370.1

Graly, J., Harrington, J., & Humphrey, N. (2017). Combined diurnal variations of discharge and hydrochemistry of the Isunnguata Sermia outlet, Greenland Ice Sheet. *The Cryosphere*, *11*, 1131–1140. https://doi.org/10.5194/tc-11-1131-2017

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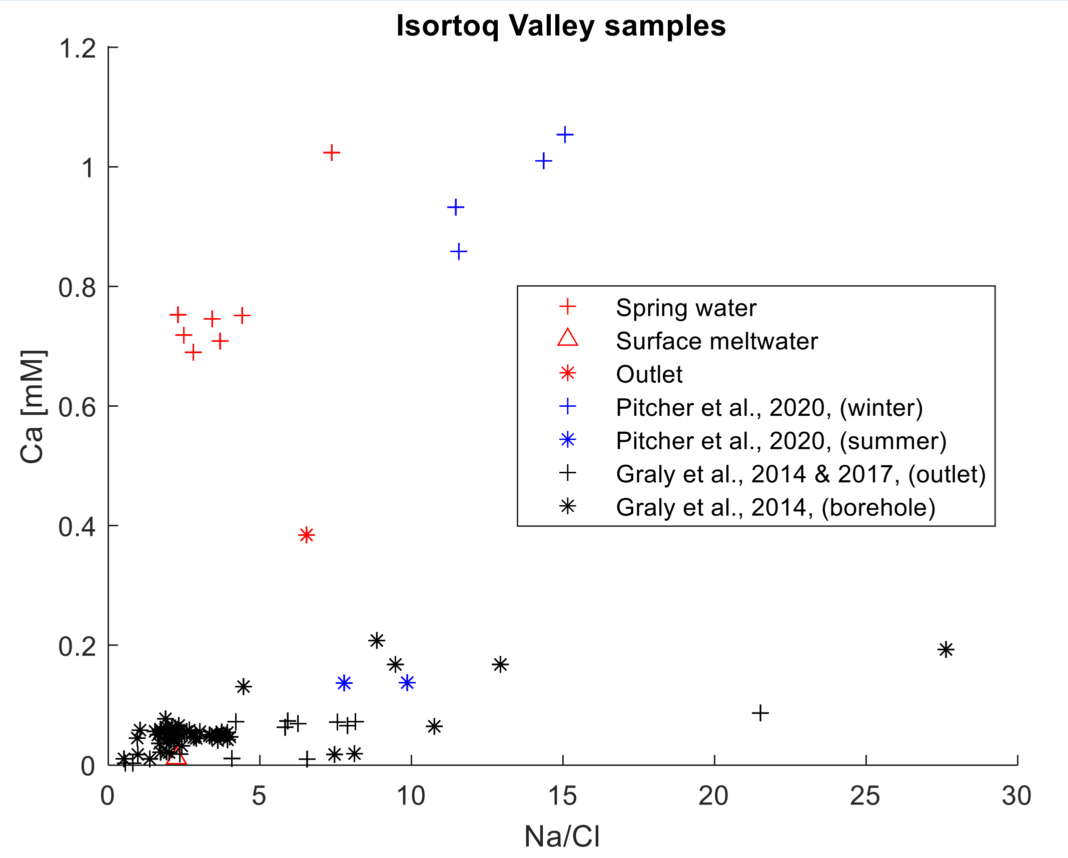
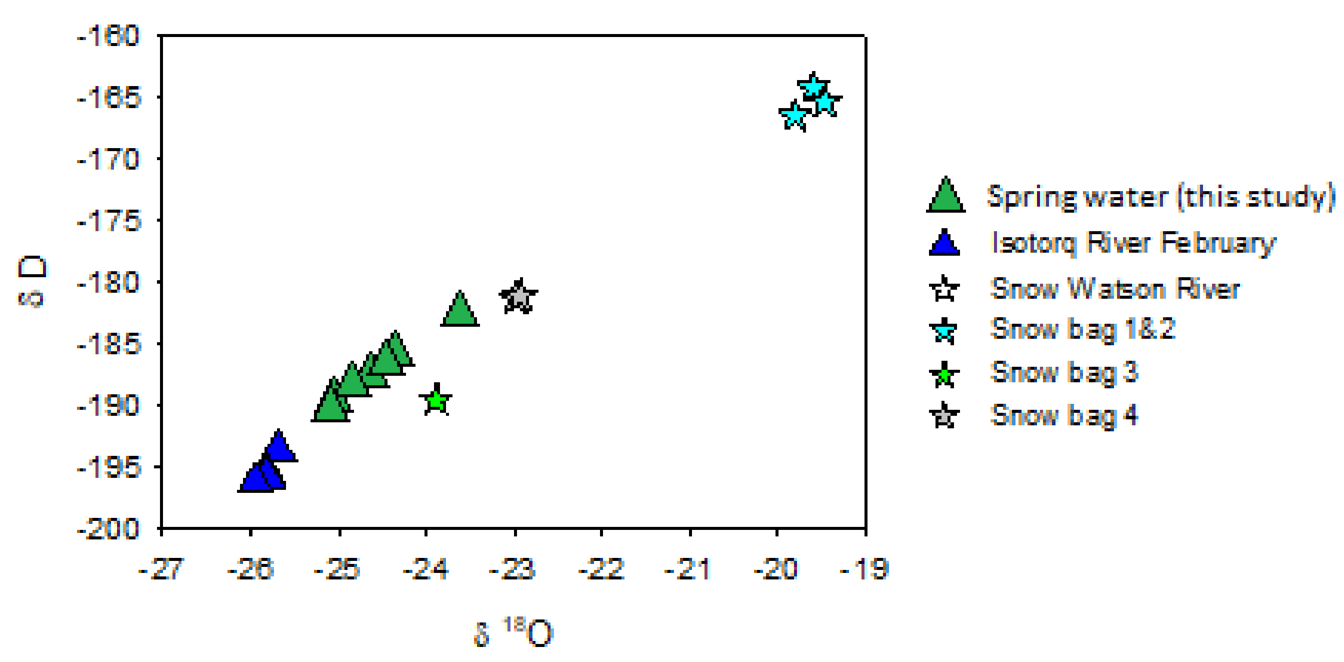
Major ion concentration

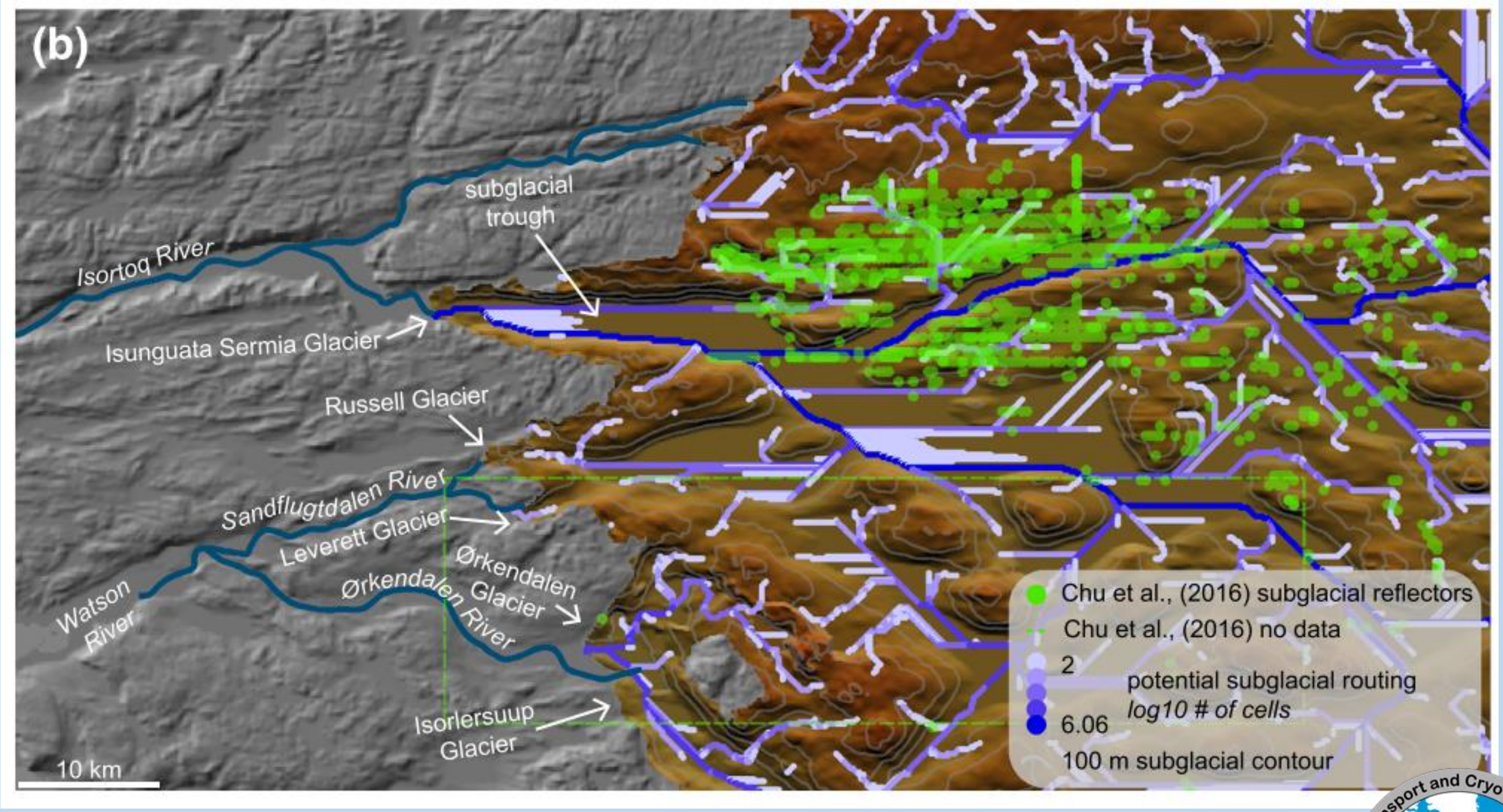


Stable water isotopes



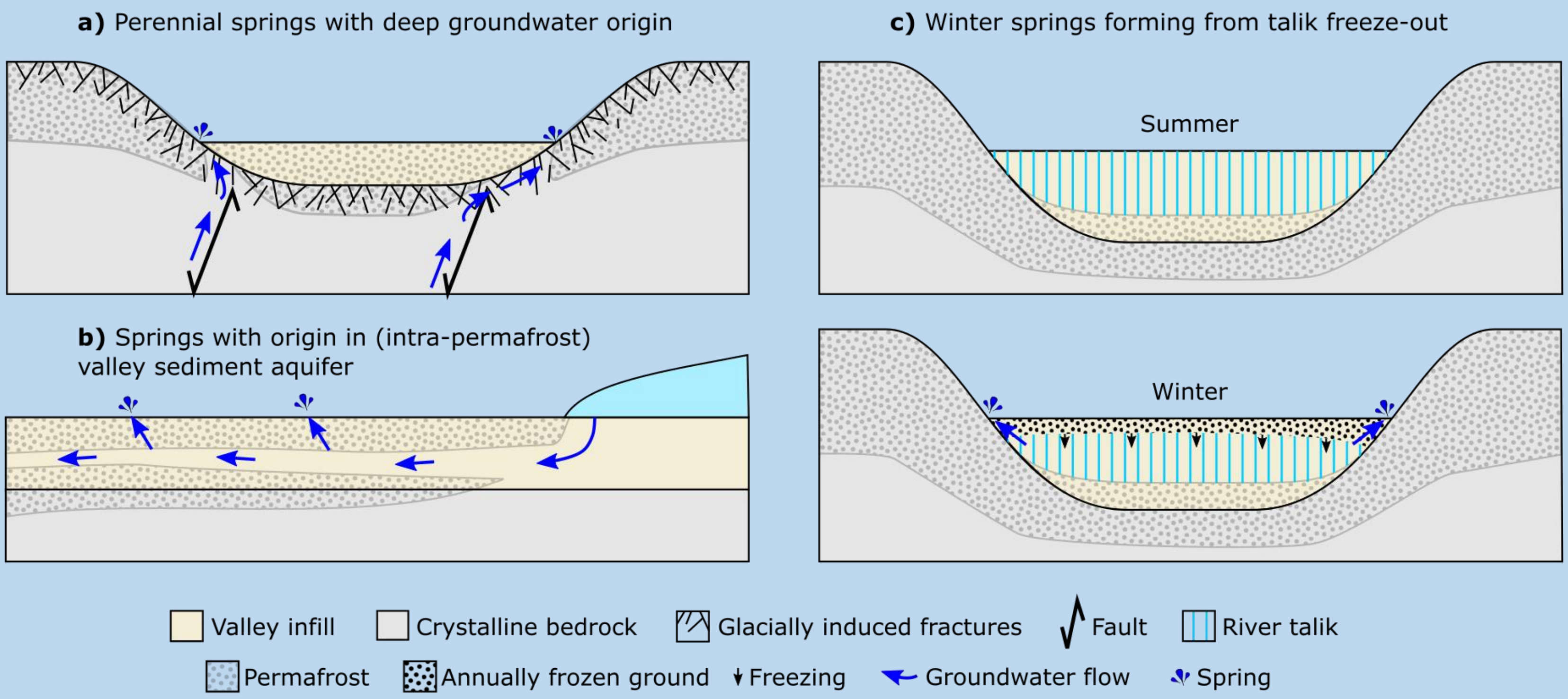
Modified from Pitcher et al. (2020)

Potential spring water source



Pitcher et al. (2020)

Working hypotheses



Discharge and dissolved methane concentration

- Mean discharge: 6 L/s
- Mean CH_4 conc.: 55 mg/L
- CH_4 flux: 31 ton/yr
- Simple upscaling (disregarding ebullition)
  - 40 presumed groundwater springs
  - Assumptions
    - Other springs have similar discharge and CH_4 conc.
  - CH4 flux to the surface via groundwater springs in Isortoq Valley: **413 ton/yr**
- Corresponding to CH_4 emission from ~100 km^2 vegetation in the field area

	Q (L/s)	*C_{CH4} (mg/L)*
Spring 1	5	>35
Spring 2	10	>48
Spring 3	3	>80
Mean	**6**	**55**

[1]Geng, M. S., Christensen, J. H., & Christensen, T. R. (2019). Potential future methane emission hot spots in Greenland. *Environmental Research Letters*, *14*, 12. https://doi.org/10.1088/1748-9326/aaf34b

Conclusions

- Previously unknown groundwater springs discovered
  - Three to four confirmed occurrences, but there are likely ~50 springs
- Spring water stable isotope and major ion chemistry is distinct from river water, subglacial melt water and snow samples
- Deep subglacial water storage might be sourcing the springs
- The spring water is bringing considerable amounts of methane, which potentially contributes significantly to the regional budget

Photo by Max Twinning-Ward