Climatic forcing of terrestrial methane escape through permafrost in Svalbard

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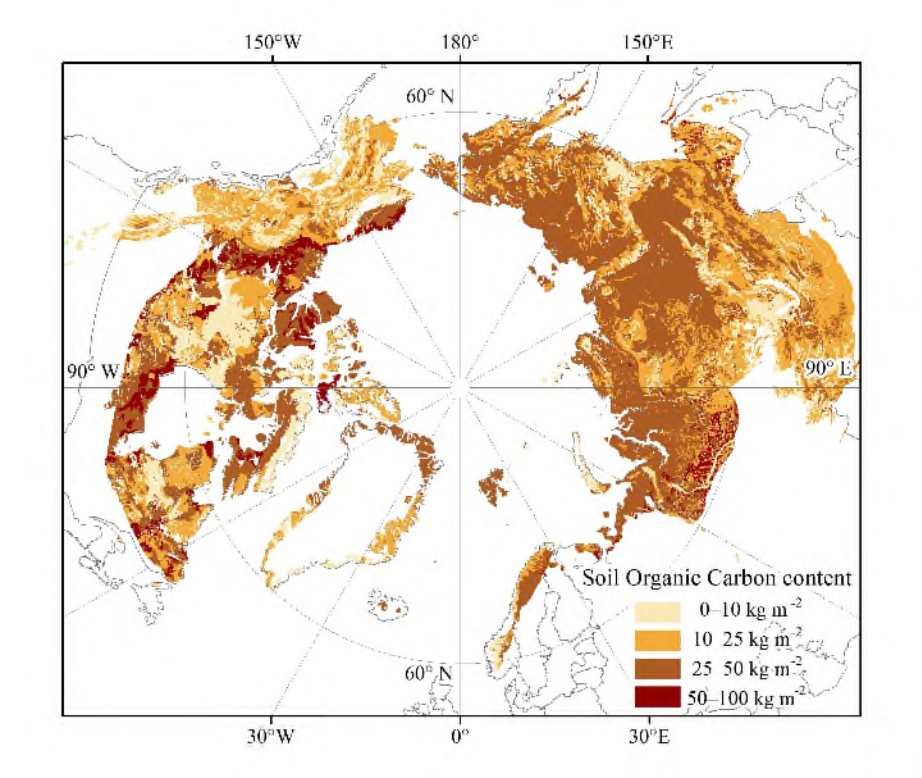
Introduction for NFR: 2019

Ten years ago:

- Soil carbon stocks in Arctic permafrost known to be vast and vulnerable: perhaps 1700 Pg (Tarnocai et al, 2009)

Today's view:

- 1,030 ±150 Pg (0-3 m): one third of Earth's soil carbon in 15% of its global soil area (Schuur et al, 2015: right)
- Distribution of deeper "soil" carbon better understood, but uncertainty persists



Bolin Centre for Climate Research, 2017

Landscape change in Svalbard

- 11 k.a.: ice sheets in retreat, high sea level
- Sediment in-filling of fjords and sea floor uplift
- Today: sediments freeze - continuous permafrost and lots of methane trapped beneath

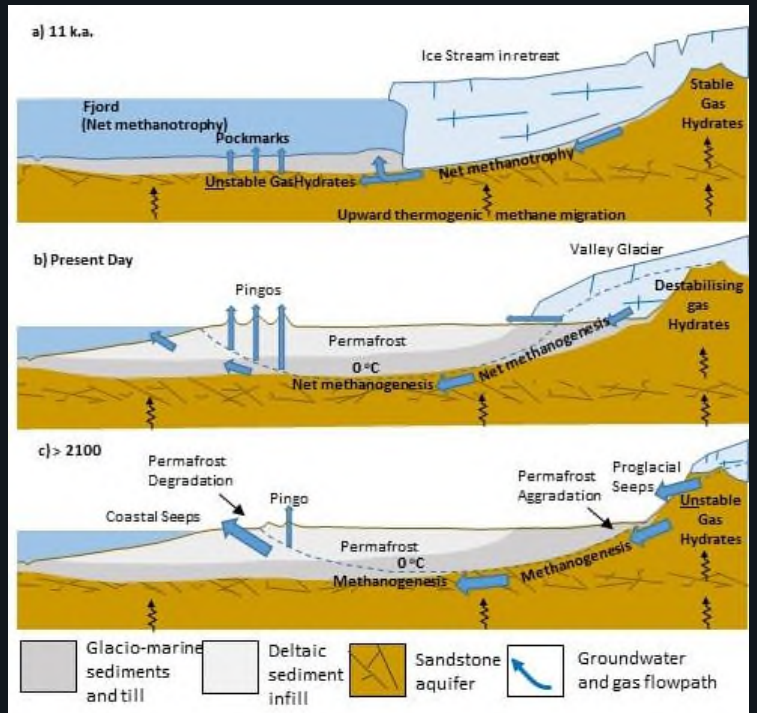
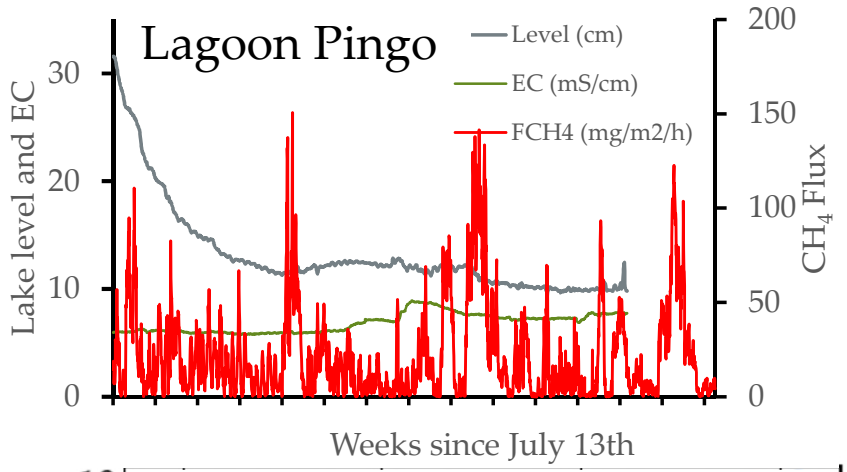
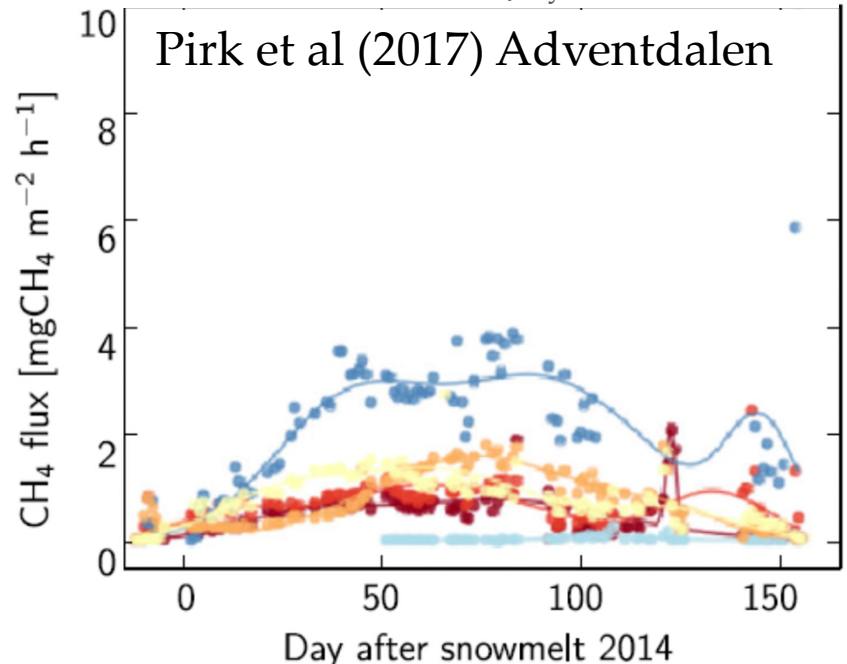


Figure 1. Conceptual model of dominant methane sources (hydrates, deep thermogenic methane reserves and zones of net methanogenesis), sub-surface sinks (zones of net methanotrophy) and migration pathways during landscape development in a Svalbard fjord valley (after Hodson, et al, In Review).

Methane emission from uplifted pockmarks:

- Ongoing sea level change means some pockmarks are above current sea level
- We discovered they are still active hotspots of methane emission:
- Annual fluxes:
  Pingo: ~ 100 gC m^{-2} a^{-1}
  Chambers: 1 – 2 gC m^{-2} a^{-1}
  (Pirk et al, 2017, median values)





LowPerm

Methane emission from pingos:

- Partially frozen groundwater springs form small hills
- Many have springs bringing high methane concentrations from beneath permafrost
- Many pingos might in fact be former pockmarks

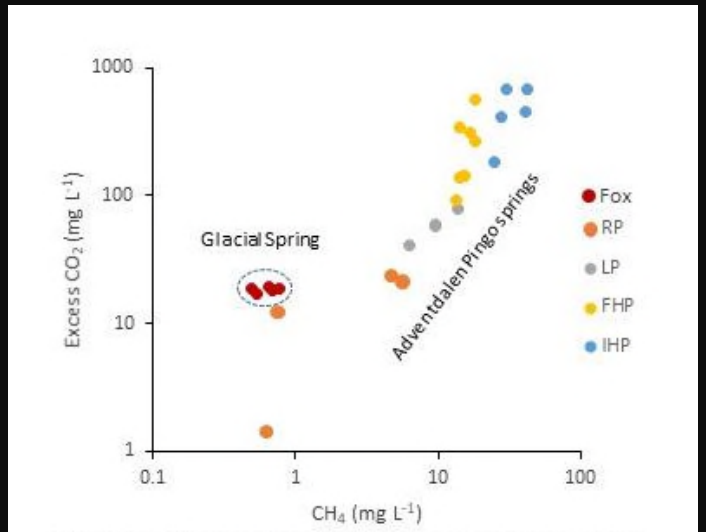
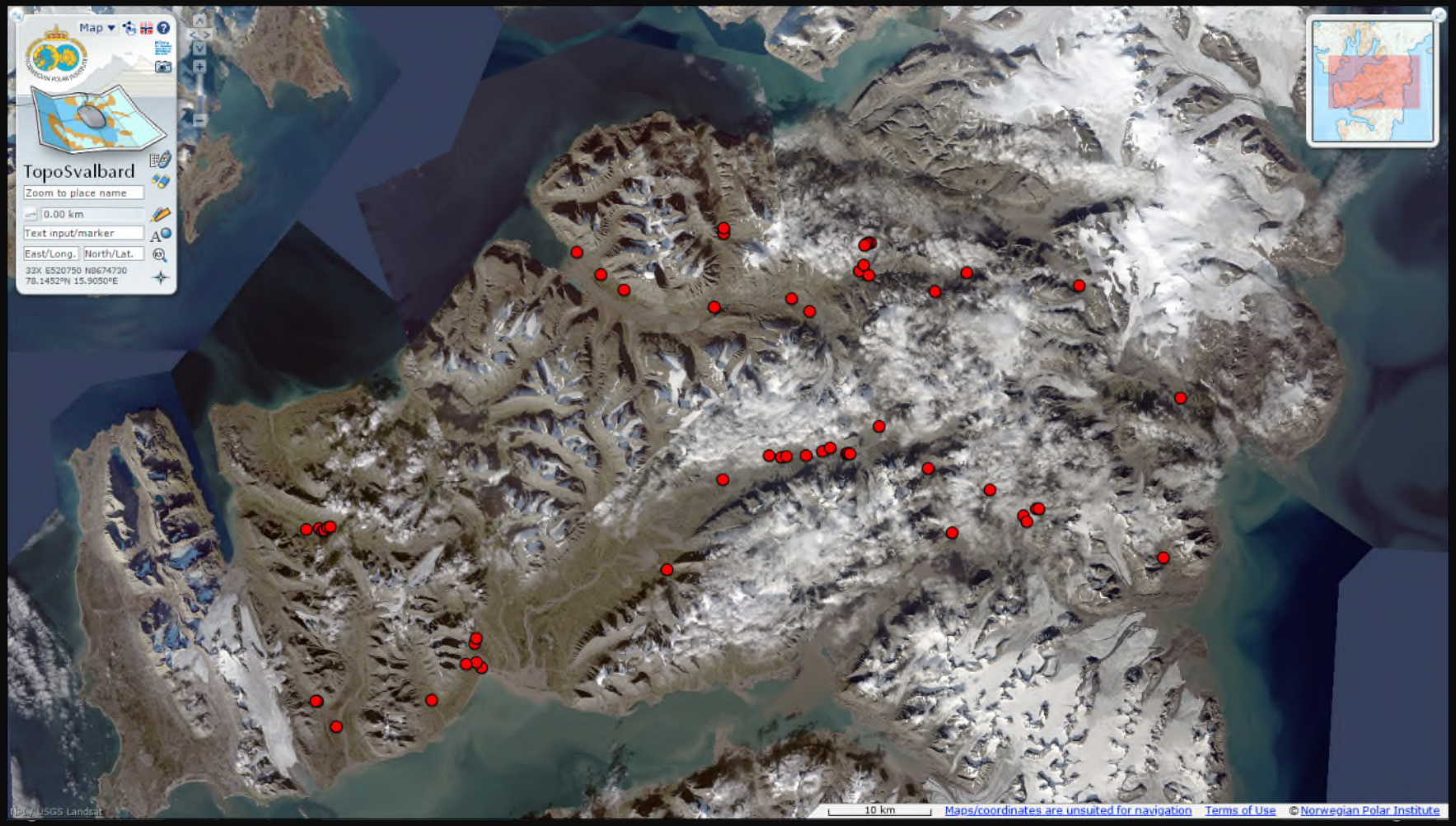


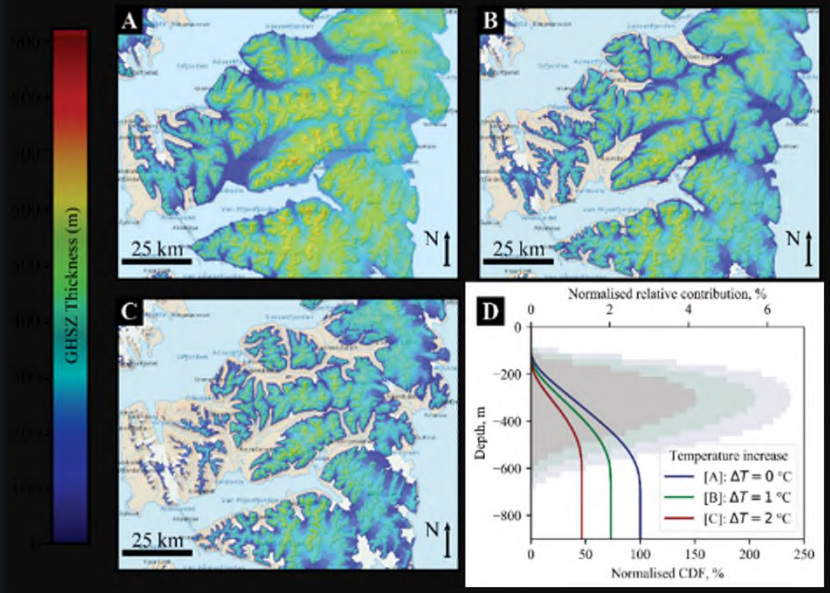
Figure 2. Methane and dissolved CO_2 levels in four pingo springs during winter 2016 and one glacial spring during 2018. Their locations are shown in Figure 3. The highest CH_4 concentrations are marginally in excess of the solubility limit for methane in water at 0°C, suggesting proximity to a degrading methane clathrate.

Pingo Distribution in Central Spitsbergen

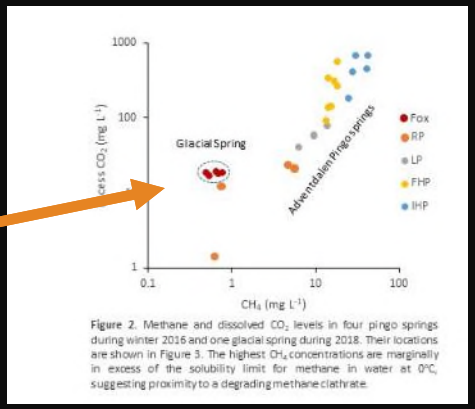


Methane emission from glaciers:

- Today, methane hydrates remain stable in mountains
- Glacier retreat means stability of these hydrates is at risk



- We have also discovered methane in ground water springs that flow beneath the retreating glaciers



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Adventdalen pingos and landscape

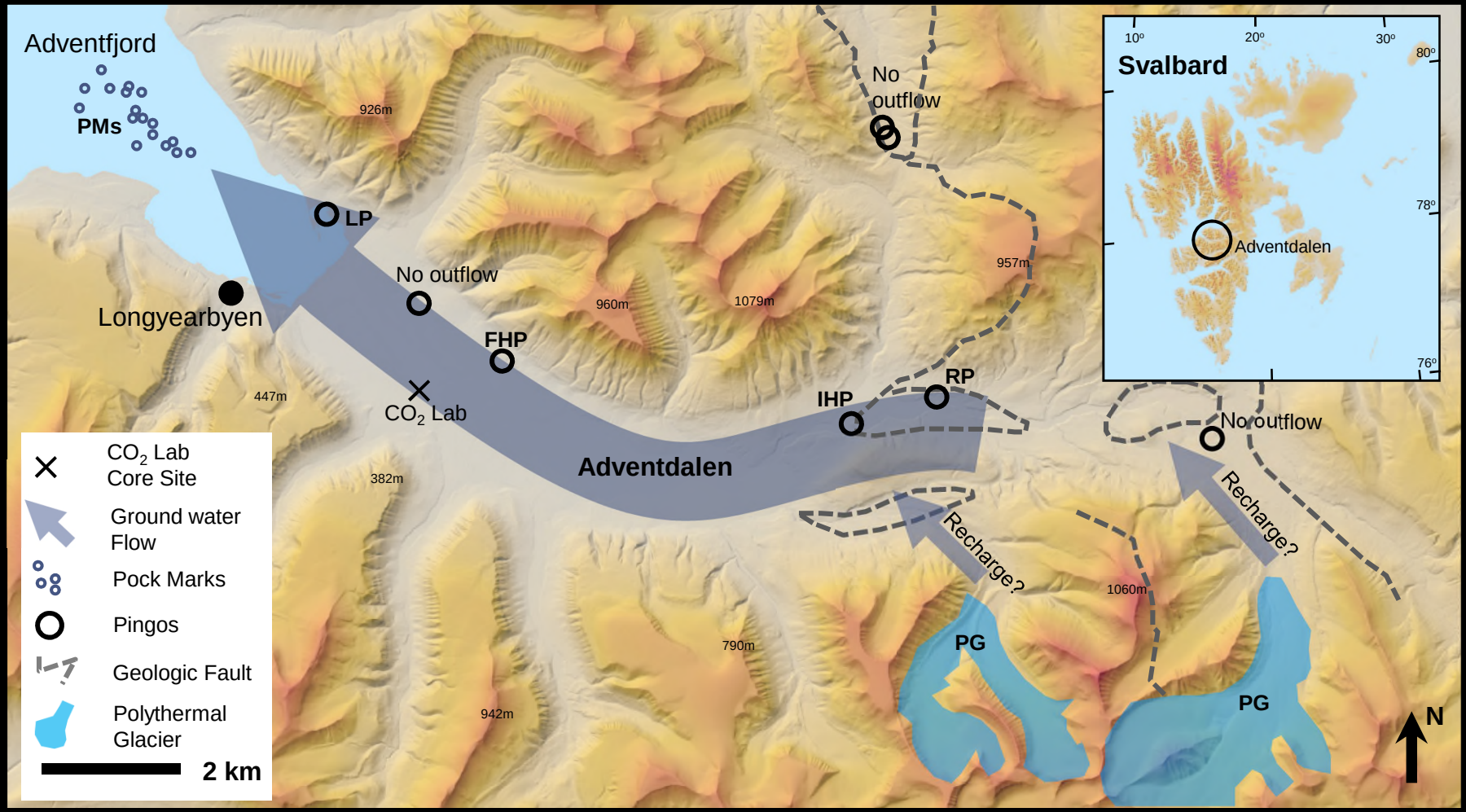

Figure 1. Adventdalen and its open system pingos. Active springs exist at Lagoon Pingo, Førstehytte Pingo, Innerhytte Pingo and River Bed Pingo (LP, FHP, IHP and RP respectively). Map develop online at www.svalbardkartet.npolar.no

About the project

- Adventdalen's pingos, permafrost and glaciers are a perfect laboratory for studying the origin, movement and fate of permafrost trapped beneath permafrost
- The primary goal for CLIMAGAS will therefore be to develop a predictive understanding of climate-sensitive methane release to the atmosphere through permafrost in Svalbard.

Obj. 1: Characterise the active terrestrial methane seeps in Central Svalbard, quantify the flux of gas typically released through them and assess their representativeness for other glaciated Arctic environments,

Obj. 2: Understand the origin and fate of the methane through geochemical and microbiological investigations at known methane seepage sites,

Obj. 3. Develop a predictive framework for the future using an integrated modelling approach that links climate forcing, changes in sub-permafrost groundwater recharge/discharge dynamics and biogeochemical processes.

Approach

1. Mine the rich data resources to develop a solid platform for predictive modelling and system conceptualisation
2. Measure the outflow characteristics to enable inverse deduction and therefore better understand the system
3. Establish sources and sinks of methane discharging from ground surface
4. Use 2) to calibrate model for predictive purposes over next 100 years

- Linked to 1): Senger, Christiansen (UNIS)
- Linked to 2): Hodson (UNIS); Yde and Gillespie (HVL); Jessen (U.Cop); Turchyn (U. Cambs.)
- Linked to 3) Øvreås (UiB); Tveit (UiT); Redeker (U. York)
- Linked to 4) Bense (U. Wag.); Frampton (U. Stock) and Hodson (UNIS)

UNIS

Thank you