Arctic Permafrost: The importance of snow

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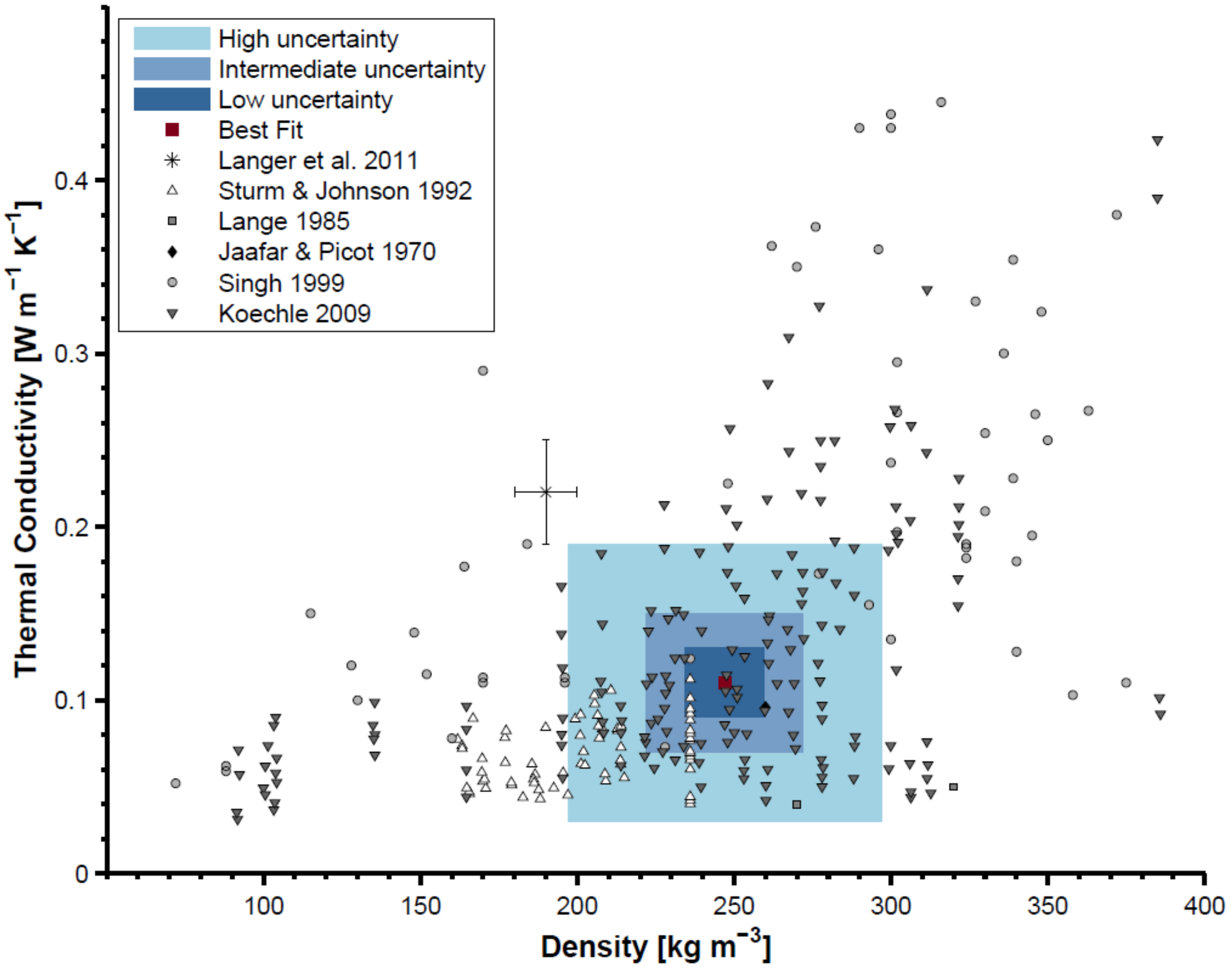
EARSel2023 Workshop
Bern, February 2023

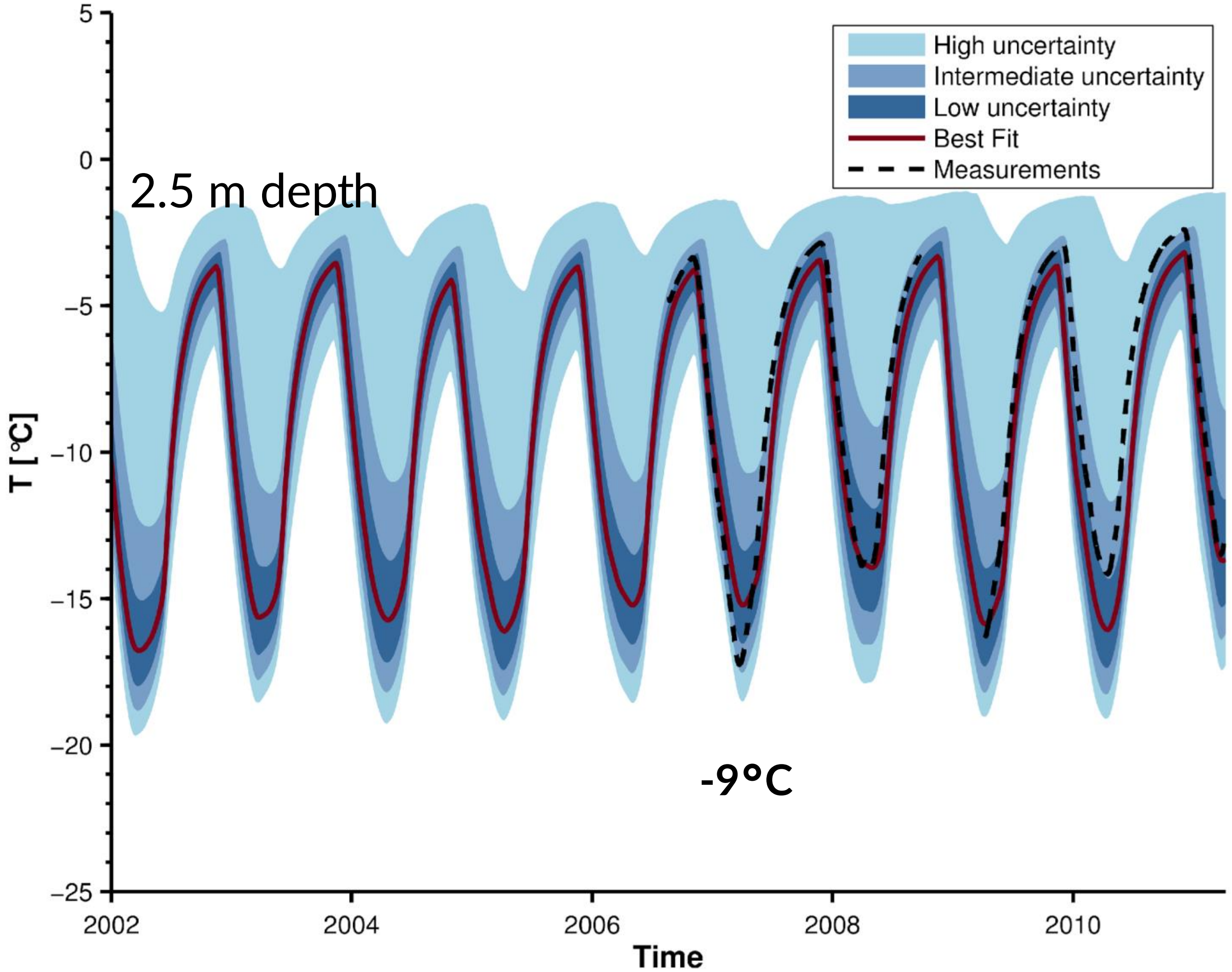
Snow properties: observations



Snow thermal conductivity

- spreads over a wide range (in space, but also within one season)
- incomplete (lacks data for some regions and times)
- no real “best fit”

Permafrost temperature: modeling



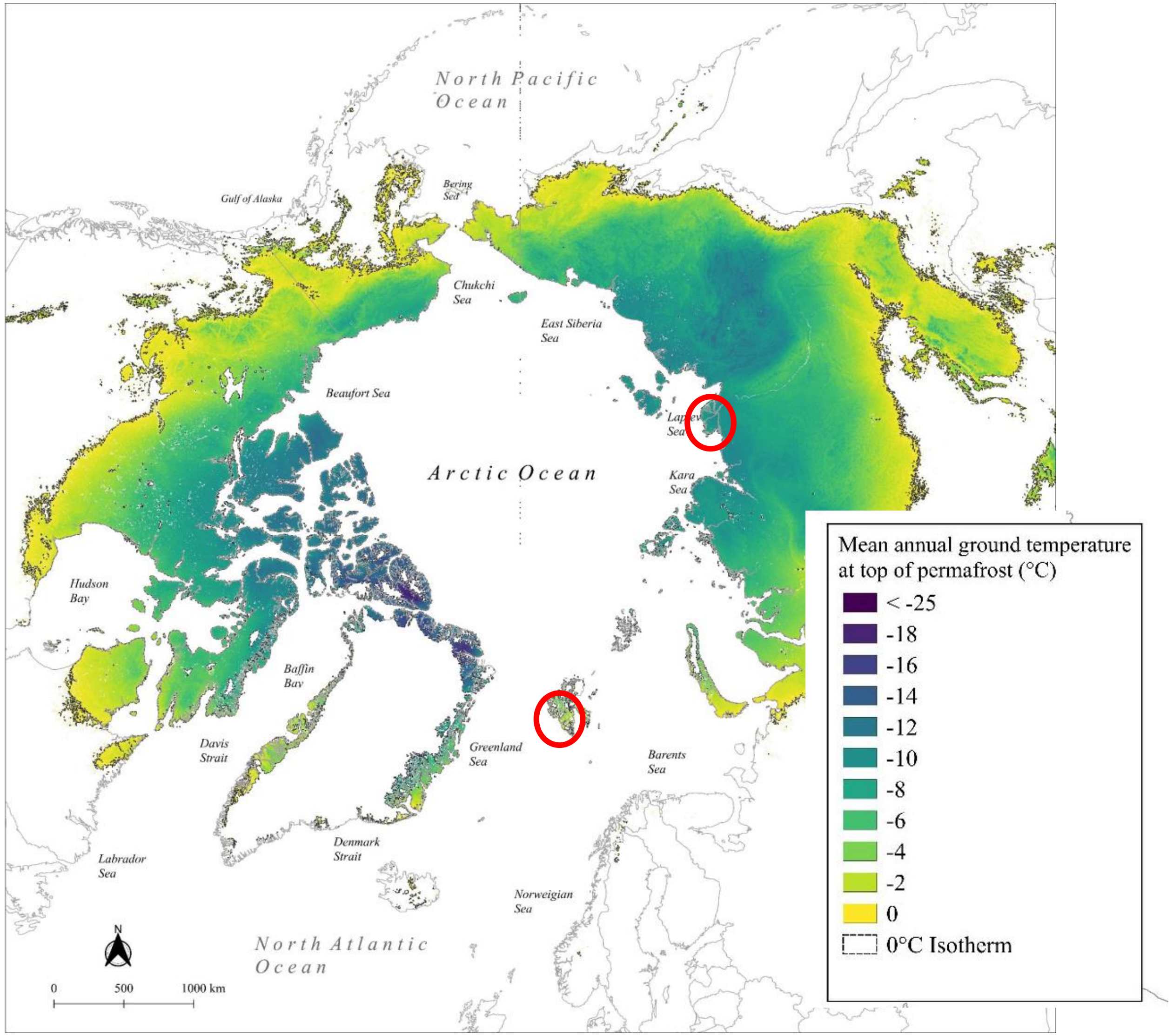
1D soil heat transfer model input:

- land surface temperature (MODIS)
- SWE (GlobSnow)
- observed snow (bulk) properties

→ largest uncertainties due to thermal properties of the snow cover

Langer, Westermann, Heikenfeld, Dorn, Boike (2013). Satellite-based modeling of permafrost temperatures in a tundra lowland landscape. Remote Sensing of Environment 135, 12-24.

Arctic permafrost distribution



- defined by temperature
- subsurface phenomenon
- northern exposed landmass ~ 15%

○ Long Term Permafrost Observatories
Warm maritime - Svalbard
Cold continental - Siberia

Boike et al. (2023). Arctic Permafrost. Soil Encyclopedia, based on Obu et al. (2021)

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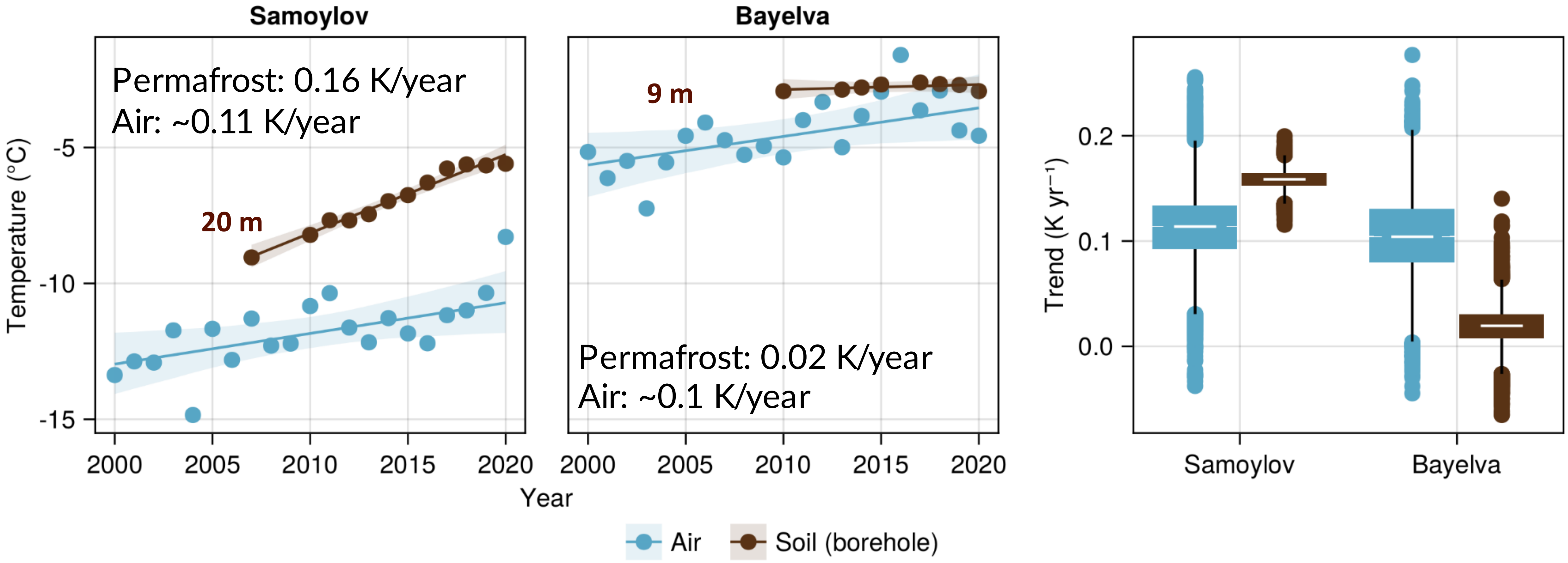
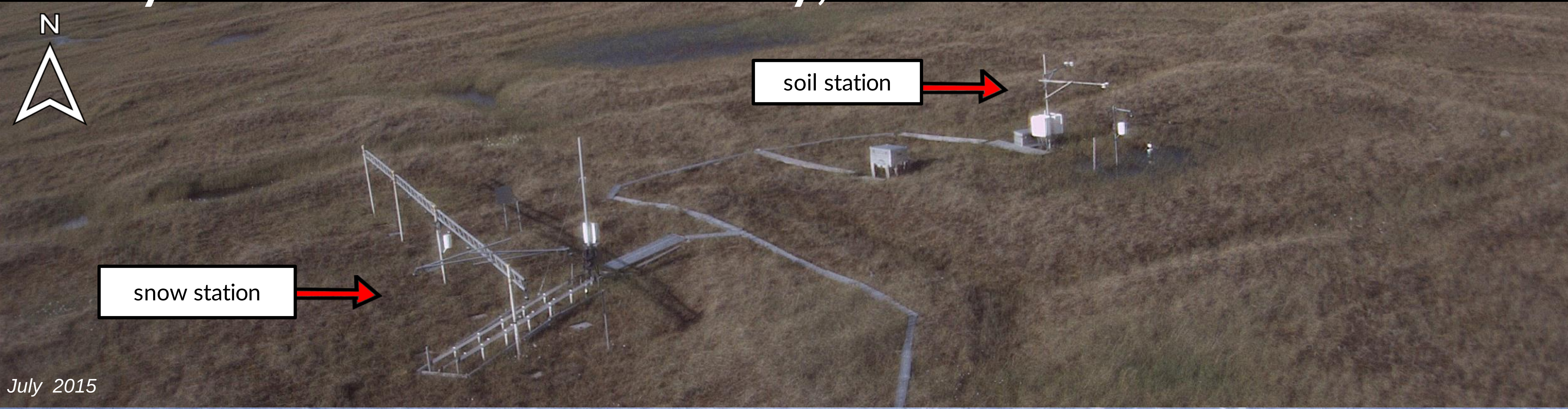
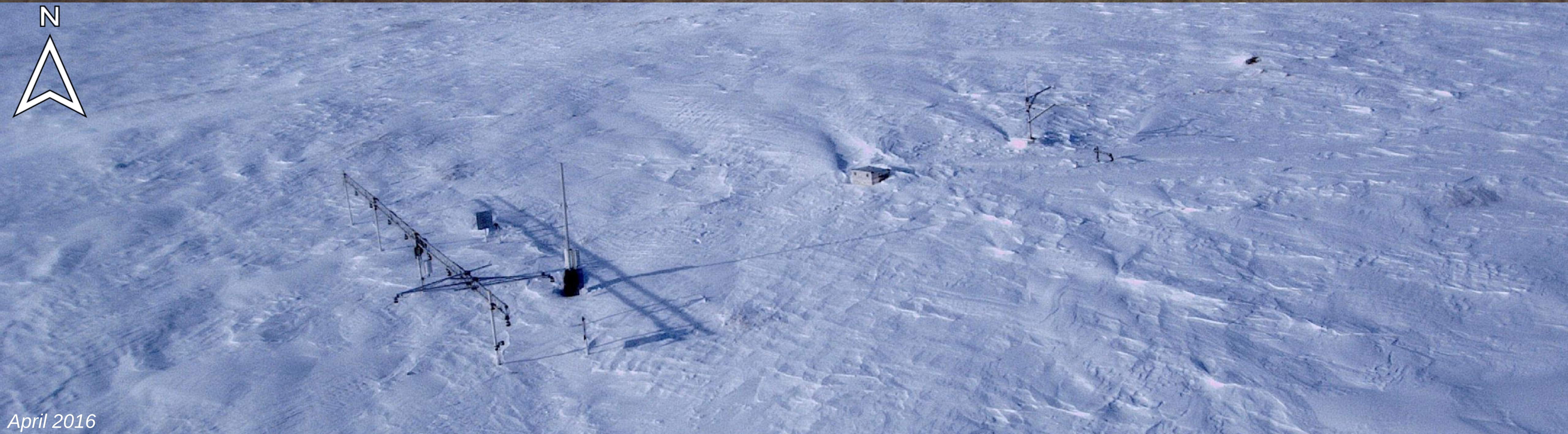
Long term permafrost observatory data



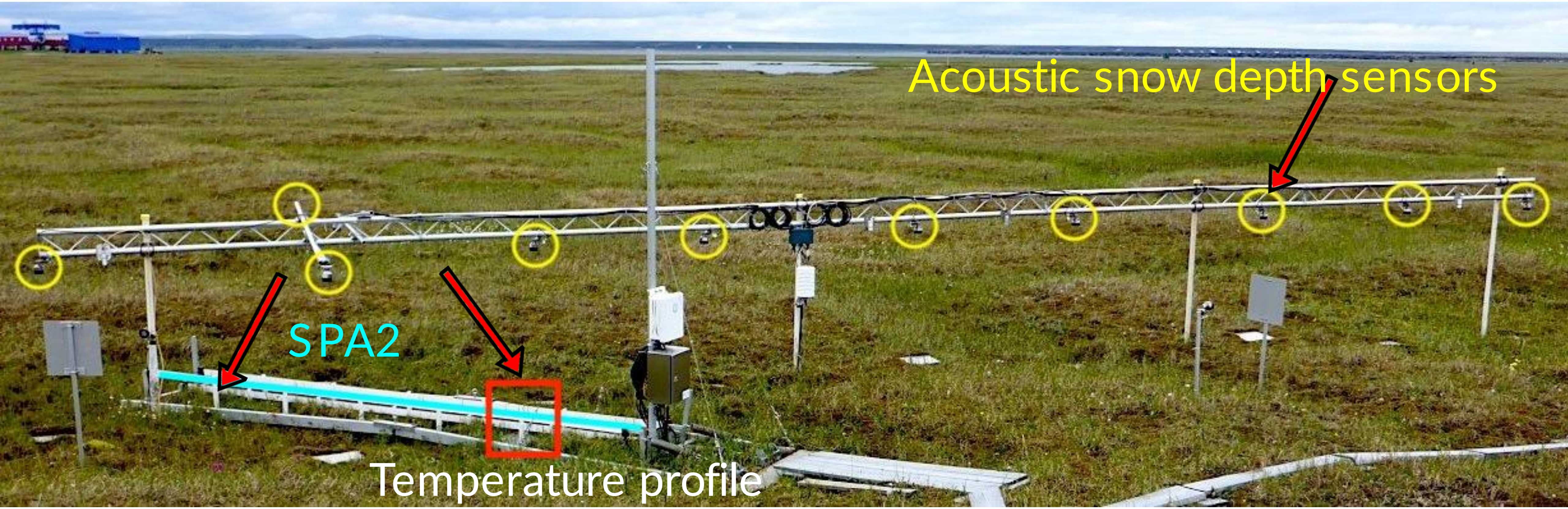
Groenke, Langer, Nitzbon, Westermann, Gallego, Boike (2022). Investigating the thermal state of permafrost with Bayesian inverse modeling of heat transfer, The Cryosphere, in review. https://doi.org/10.5194/egusphere-2022-630.

Samoylov Permafrost Observatory, Siberia



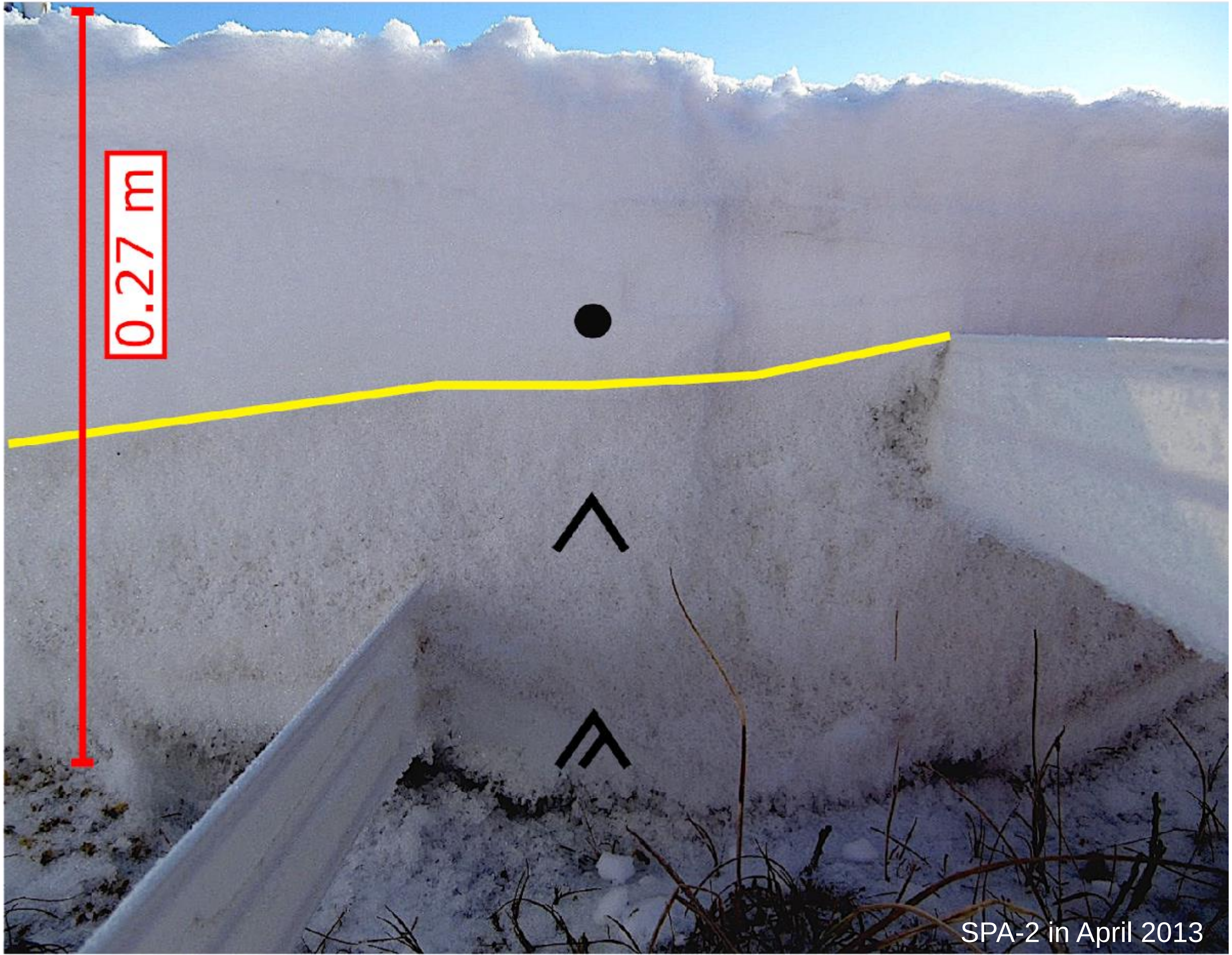


Samoylov (Siberia) automated snow observation



Snow station with SnowPackAnalyzer (SPA-2) unit in July 2016

- 10 snow depth sensors (yellow)
- snow density along 3 horizontal straps (turquoise)
- snow temperature in 8 depths (red)



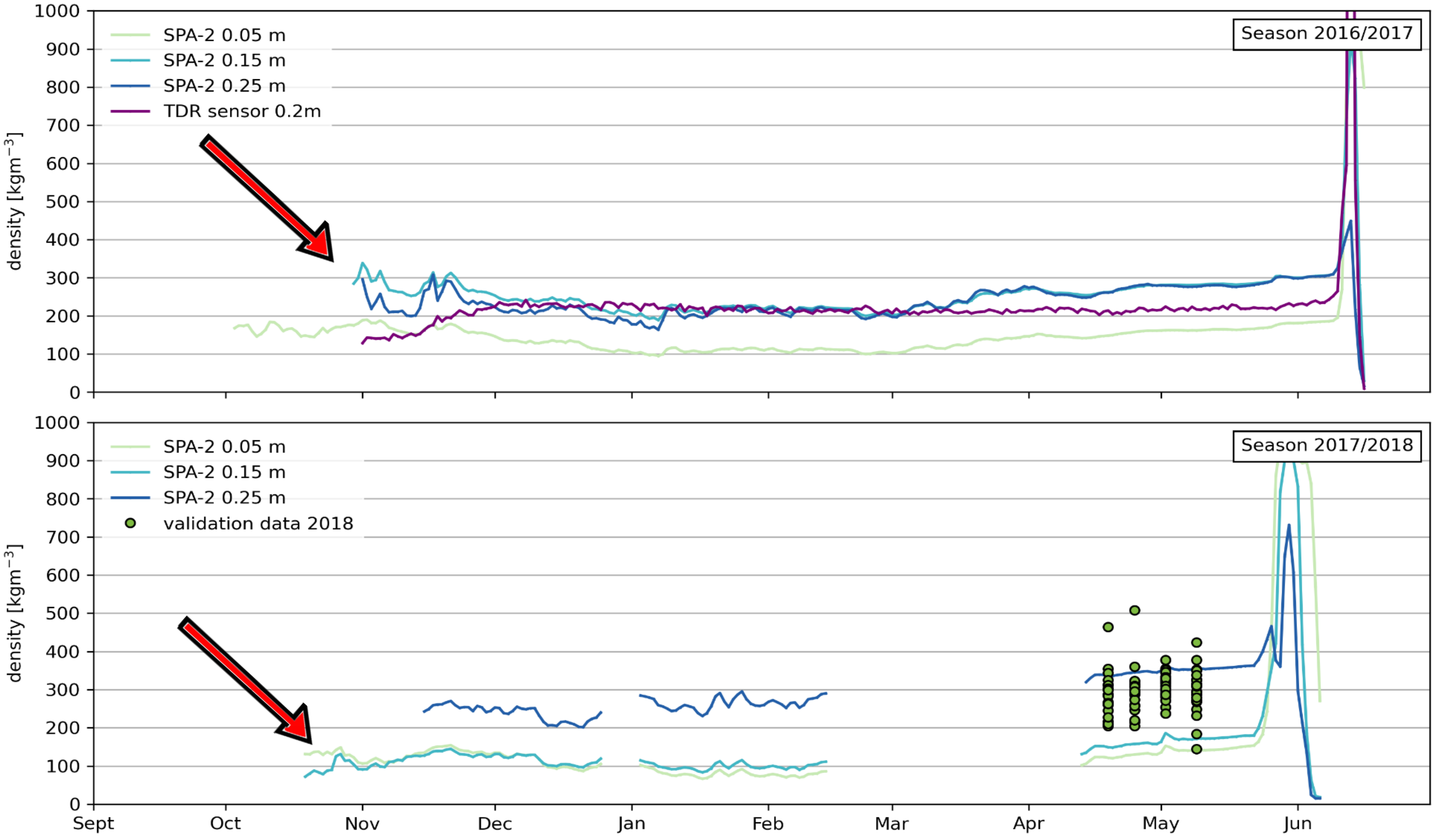
● Rounded grains

∧ Depth hoar (hollow cups)

Depth hoar (chains)

Symbols after Fierz et al. (2009)

Snow physical properties



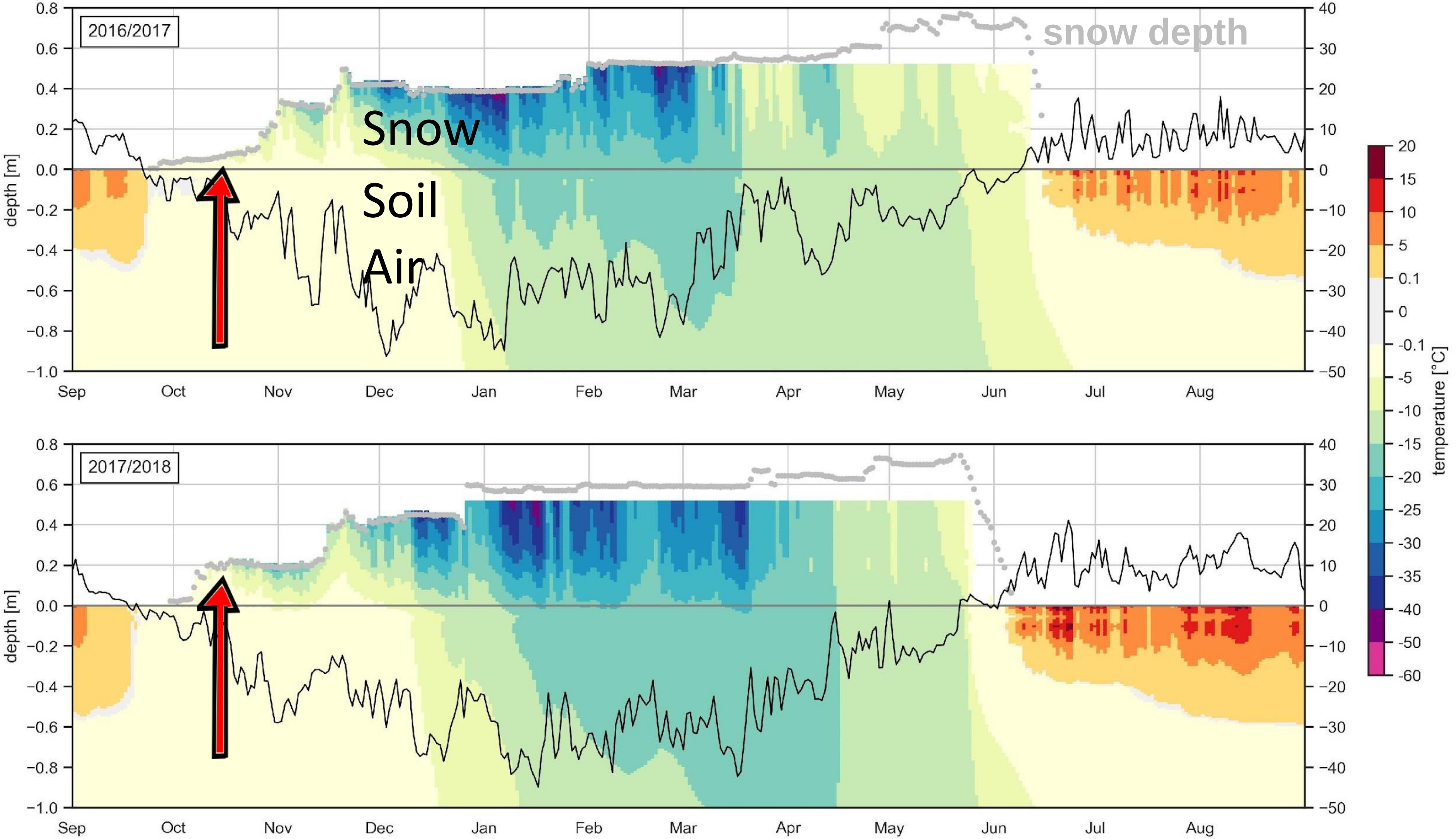
Similarities (of the two winters)

- low density snow at base of snow from early winter on
- densification of all snow towards snow melt period (start in March)

Differences

- low density snow in second year almost twice as thick

Snow-permafrost thermal dynamic



- snow cover build up very different between the two years
- during cold winter period, snow max thickness similar
- but effect of snow on soil temperatures different

Martin, J. (2022). Influence of the inter-annual variability of snow physical properties on the ground thermal regime – through observations and modelling (Samoylov Island, Siberia). Master's thesis.

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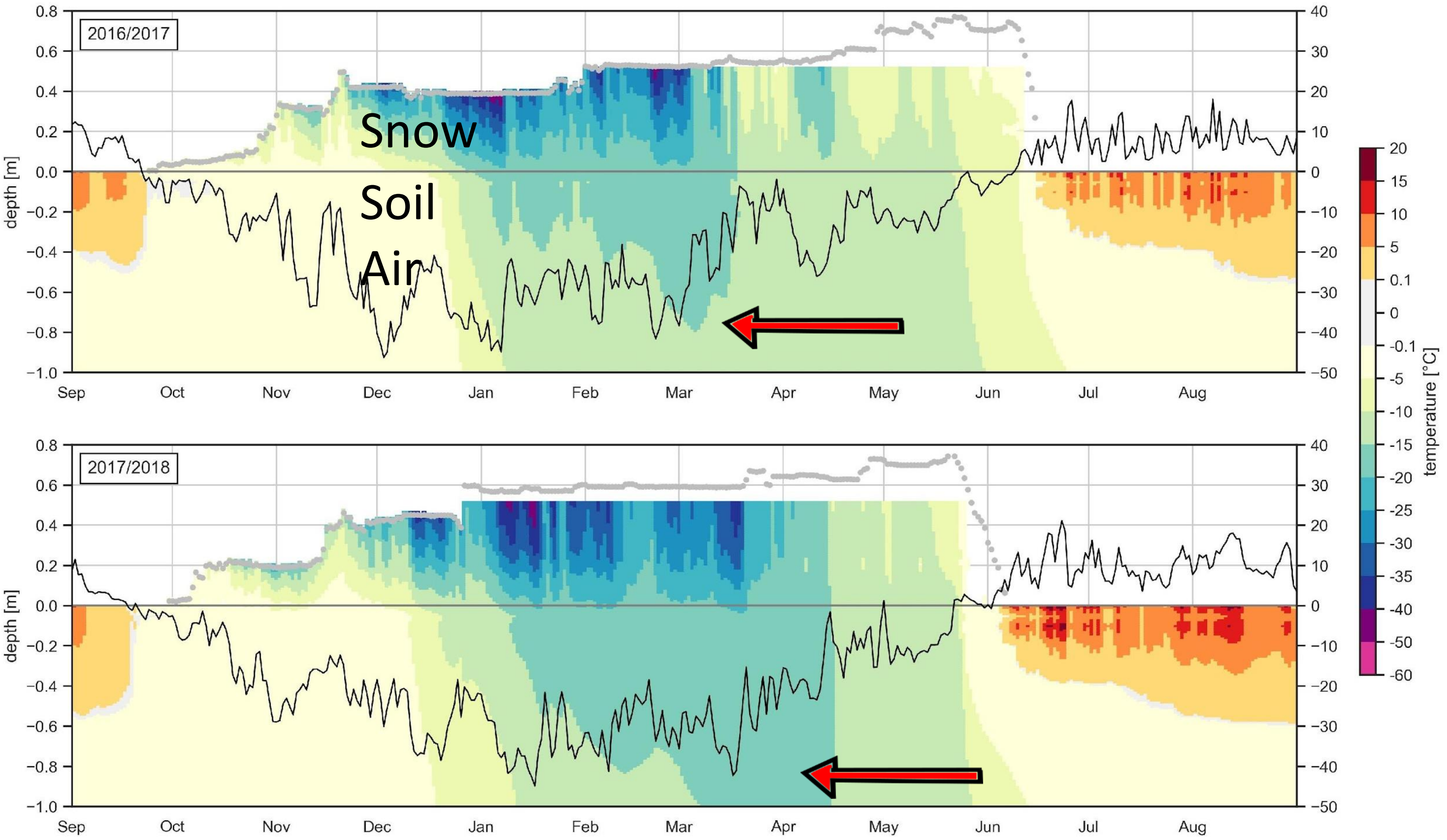
Snow-permafrost thermal dynamic

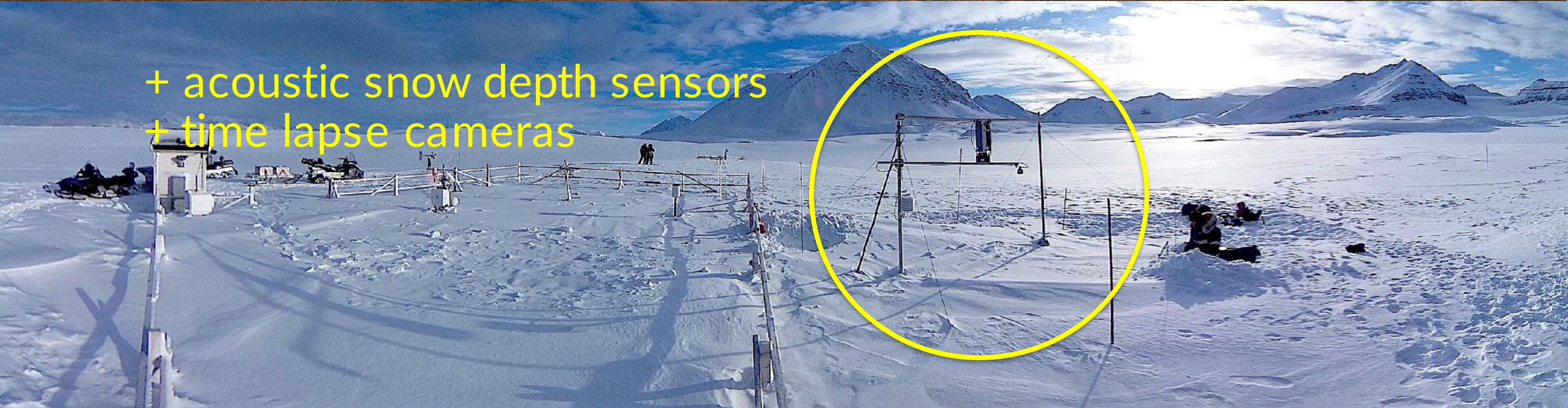


- thicker depth hoar layer should provide more insulation

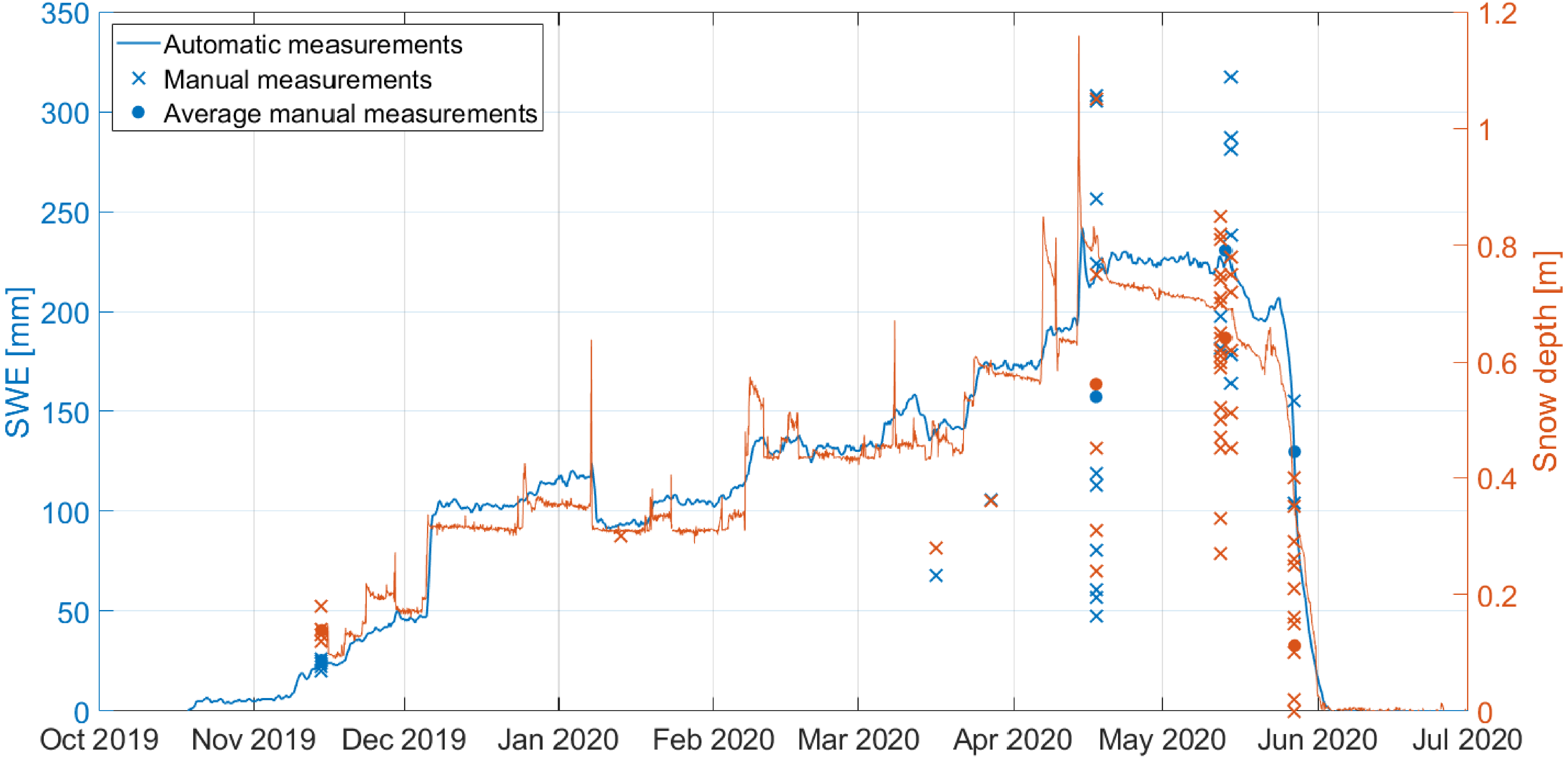
→ further analysis required!

Martin, J. (2022). Influence of the inter-annual variability of snow physical properties on the ground thermal regime – through observations and modelling (Samoylov Island, Siberia).

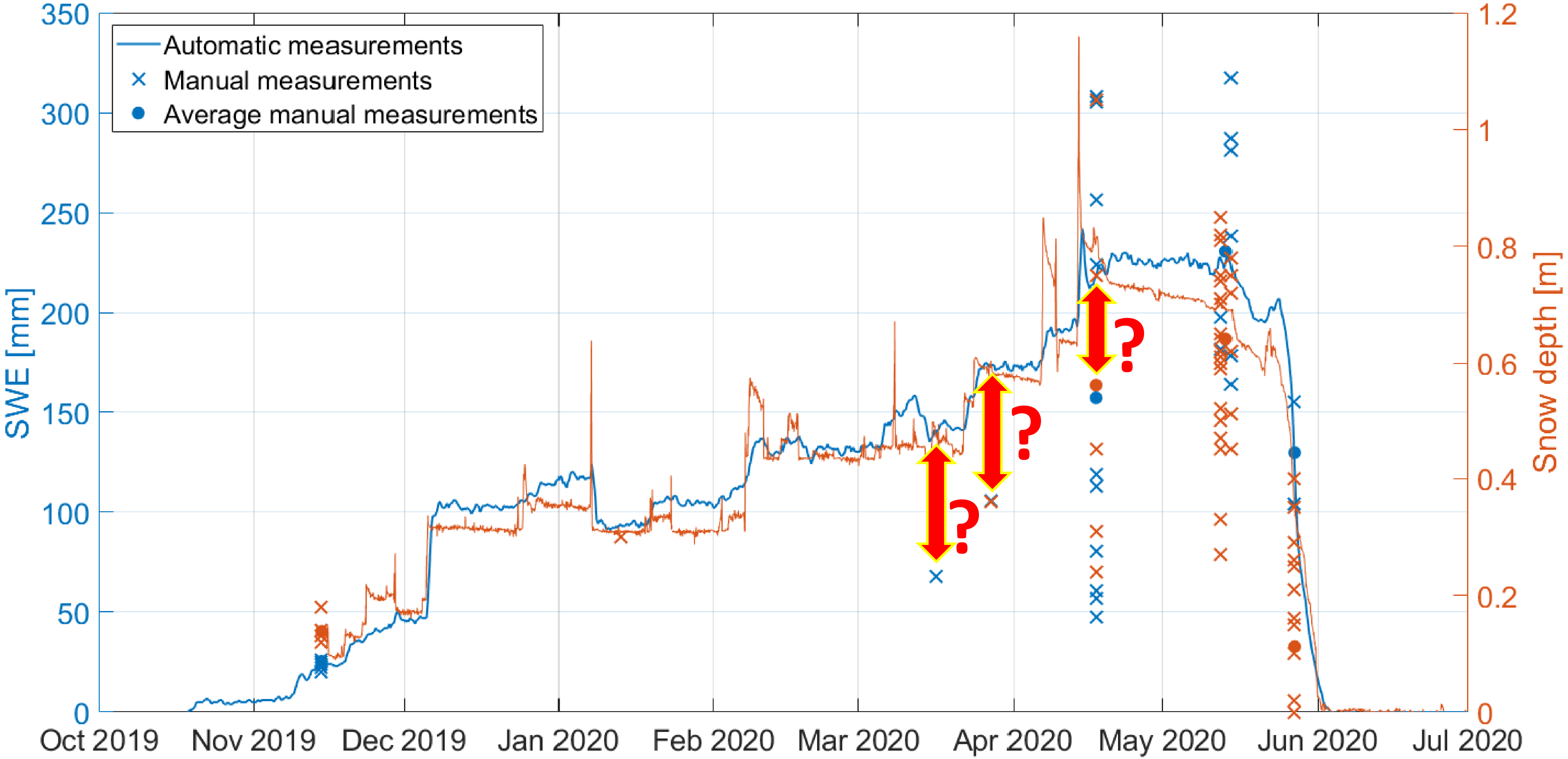
Bayelva Permafrost observatory, Svalbard



Comparison data 2019/2020



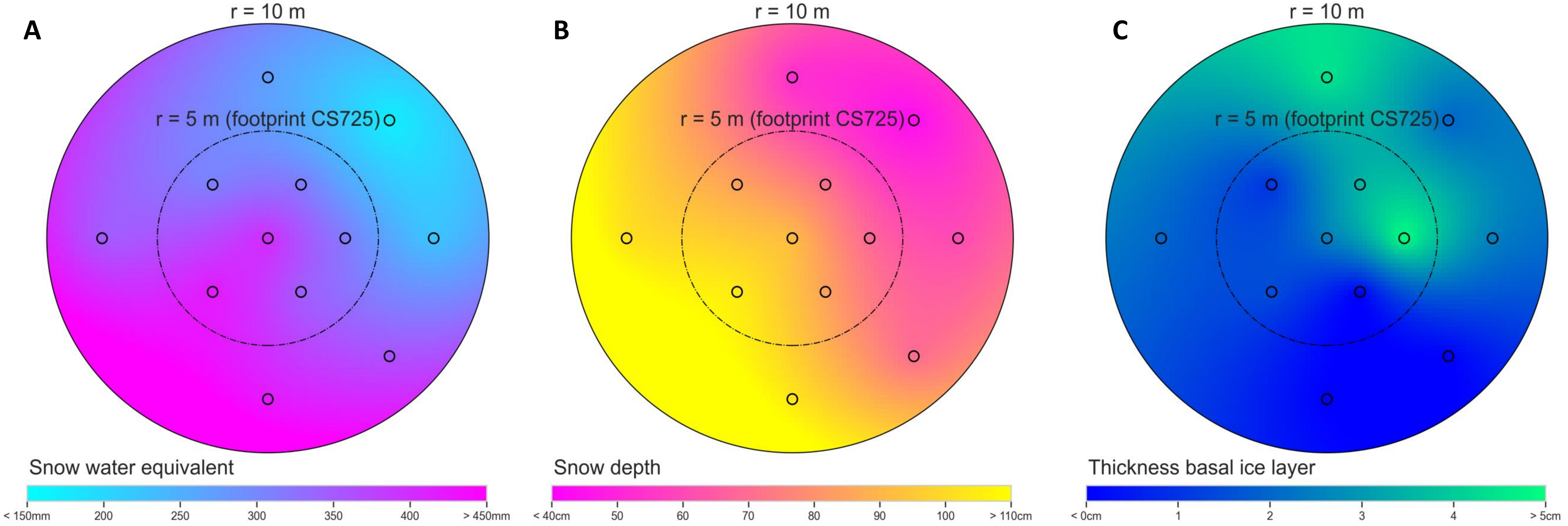
Comparison data 2019/2020



Sampling
March 2021

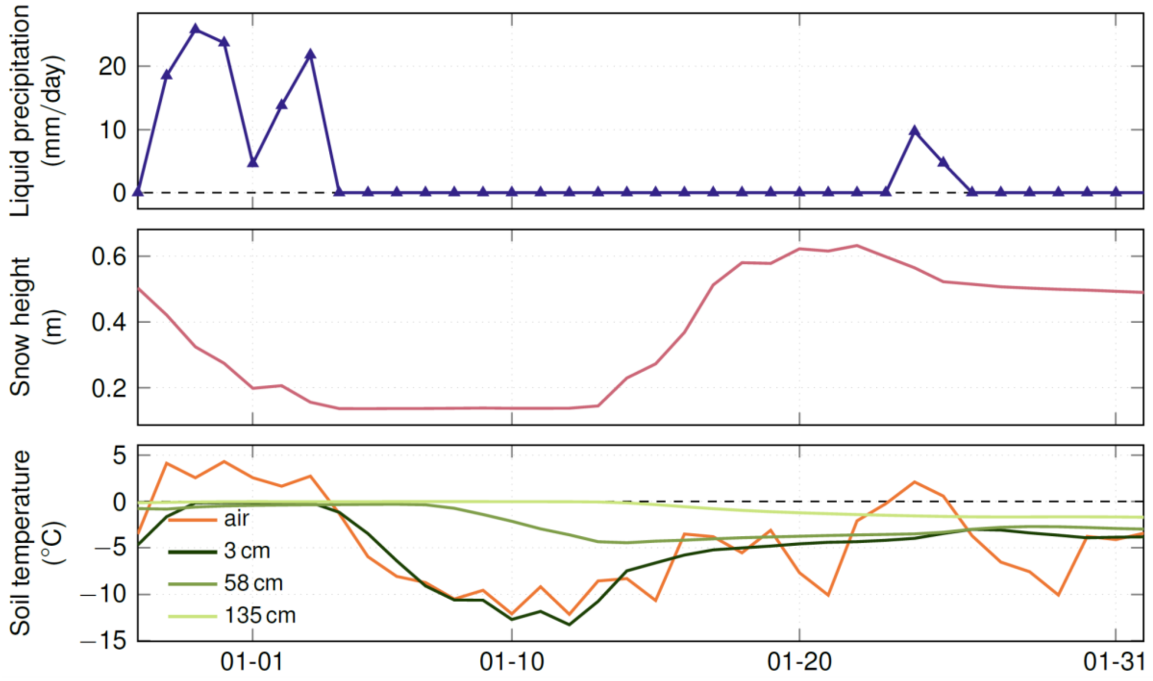
Picture by Esther Horvath

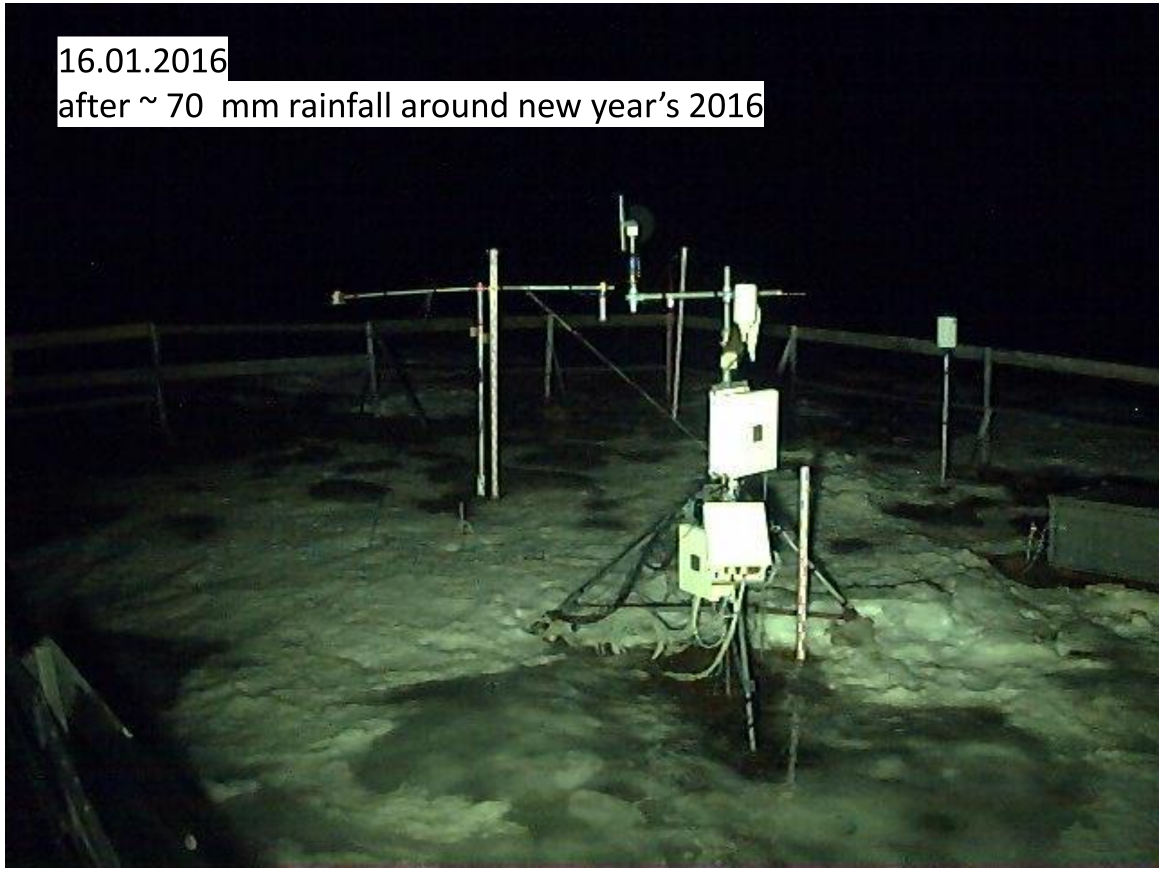
Spatial variability observed with manual sampling (2020/2021)



Spatial variability of (A) SWE [mm], (B) snow depth [cm] and (C) the thickness of the basal ice layer [cm] in the 12 snow pits. The small circle marks the sensor footprint.

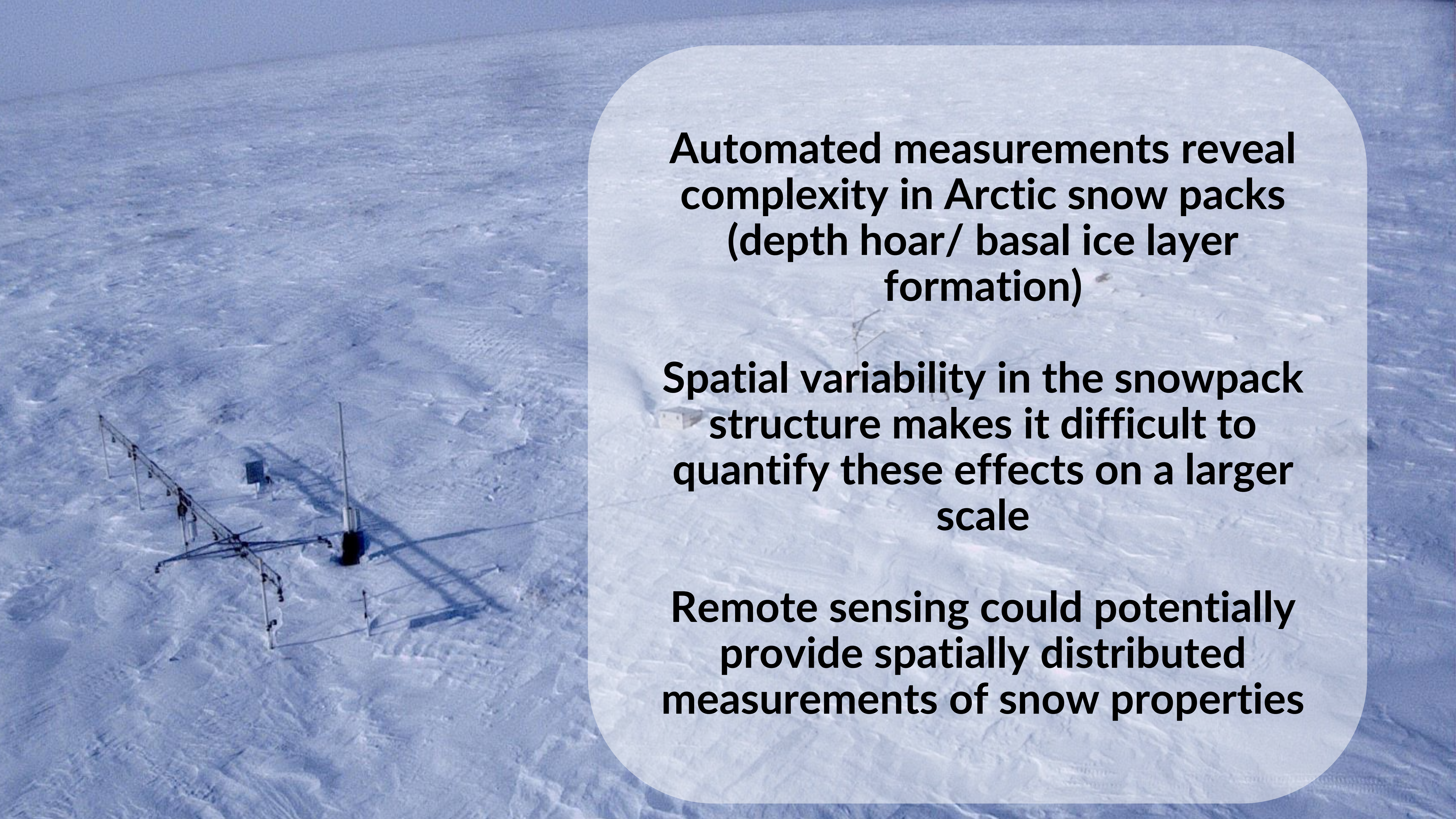
Snow-permafrost thermal dynamic





Winter 2015-2016

- rainfall destroyed the snow cover
- initial warming of soil due to infiltration of water; subsequent ice layer formation
  → cooling of soil
- basal ice cover persisted until spring 2016



Automated measurements reveal complexity in Arctic snow packs (depth hoar/ basal ice layer formation)

Spatial variability in the snowpack structure makes it difficult to quantify these effects on a larger scale

Remote sensing could potentially provide spatially distributed measurements of snow properties

Thank you!

Questions: Julia.boike@awi.de

Picture by Esther Horvath