The effect of subsurface freezing-thawing in the SW Svalbard on the newly deglaciated areas

Majdański M., Marciniak A., Owoc B., Dobiński W., Wawrzyniak T., Osuch M., Nawrot A., and Glazer M.

Institute of Geophysics
Polish Academy of Sciences

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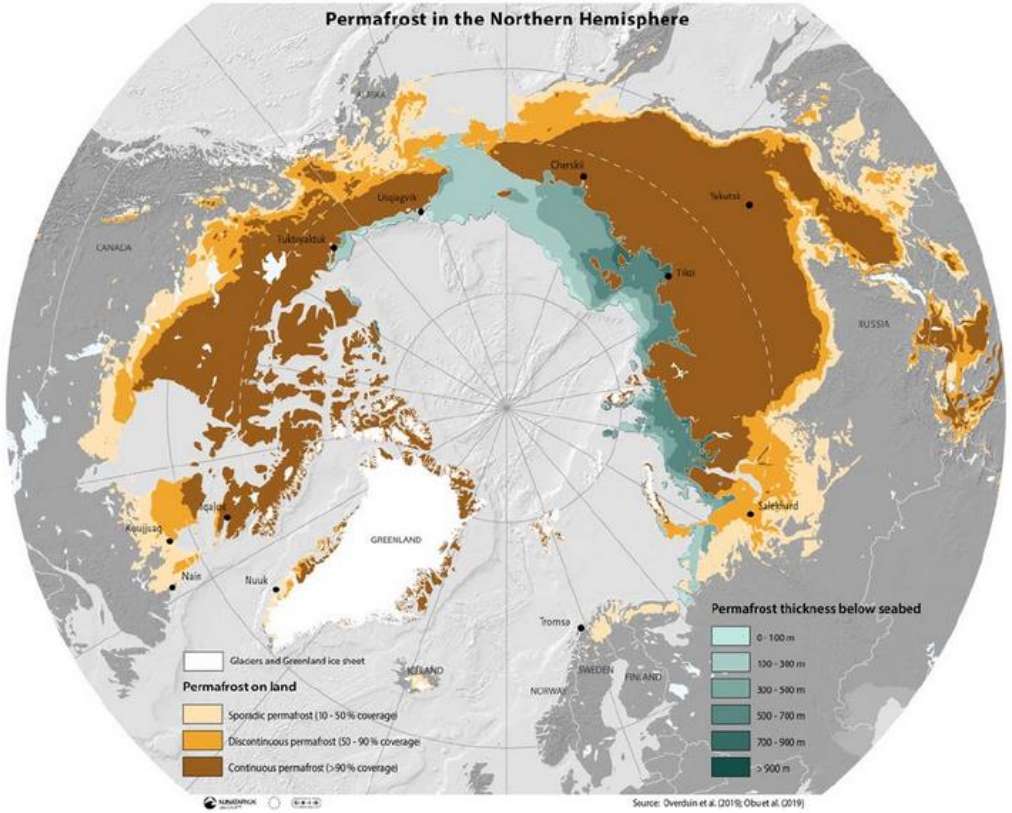
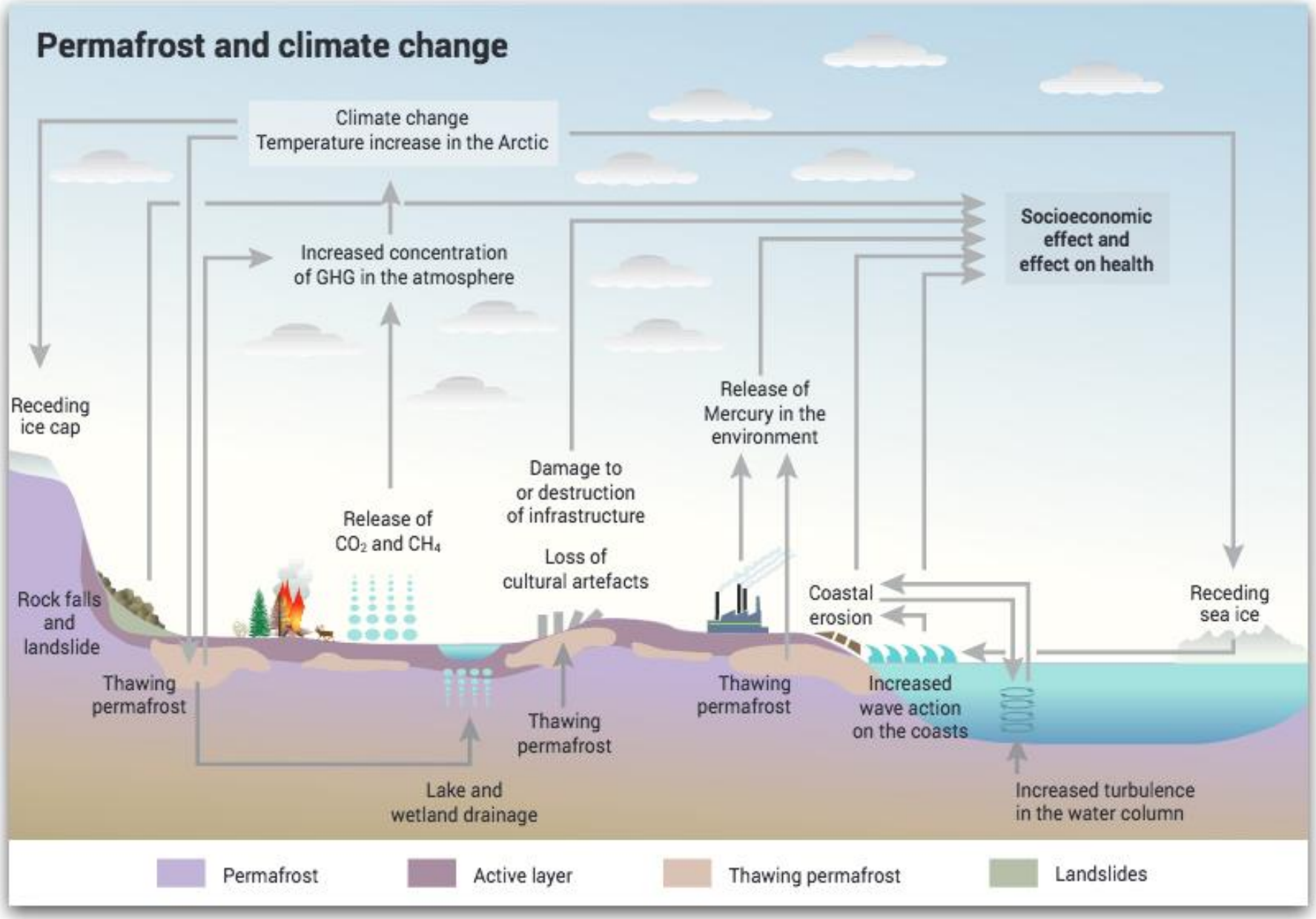
Permafrost

Permafrost is ground that continuously remains below 0°C for two or more years, located on land or under the ocean.

Almost a quarter of the Northern Hemisphere is underlain by permafrost, including 85% of Alaska, Greenland, Canada and Siberia. It can also be located on mountaintops in the Southern Hemisphere.



After Anelopolos et al., 2020, Permafrost and Periglacial Processes

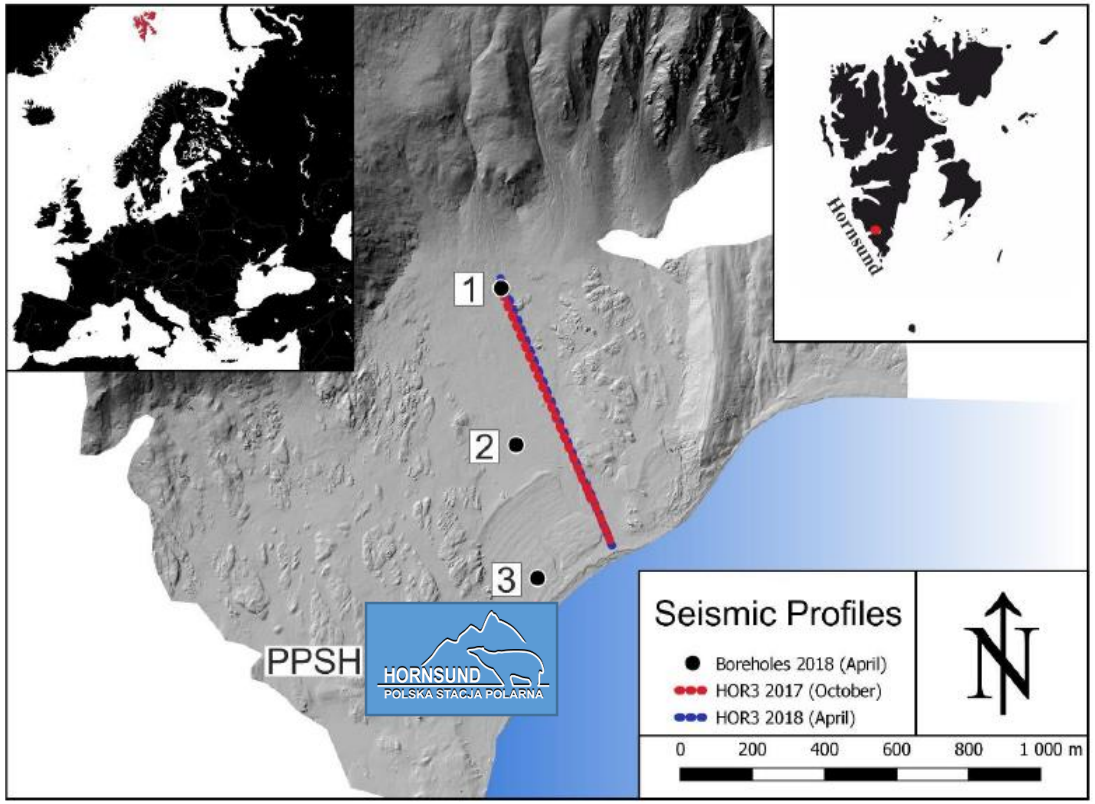


Degrading permafrost effects:

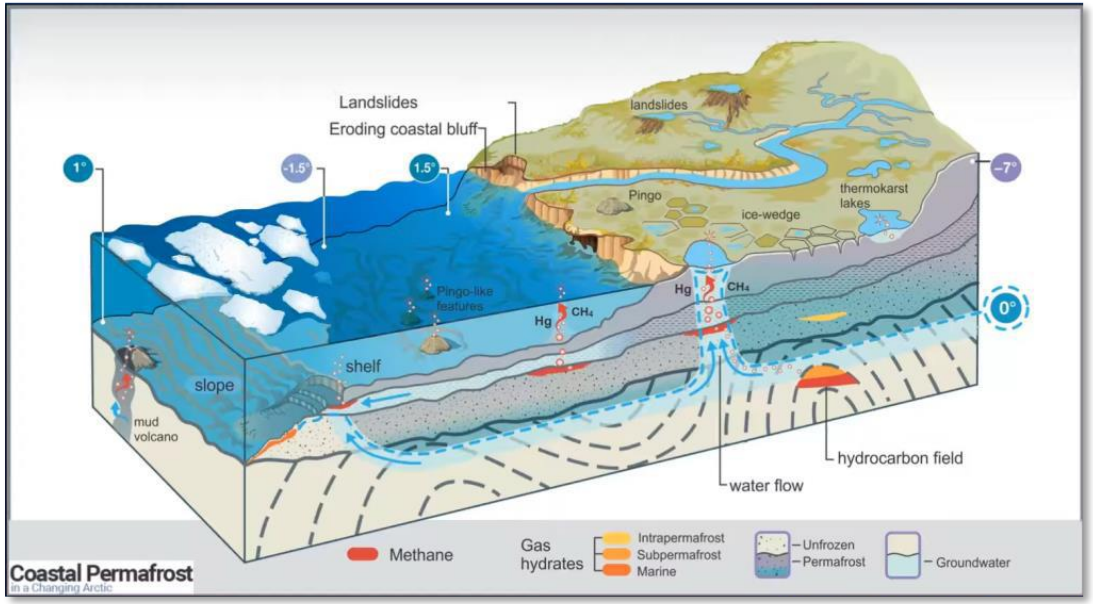
- Landslides
- Coastal erosion
- Infrastructure damage
- Hydrological system change
- CO2 & CH4 emission

www.commondreams.org

Study area



Scientific question:



http://coastalpermafrost.org

What is the shape of permafrost and its active layer between the shoreline and the Mountain slope?

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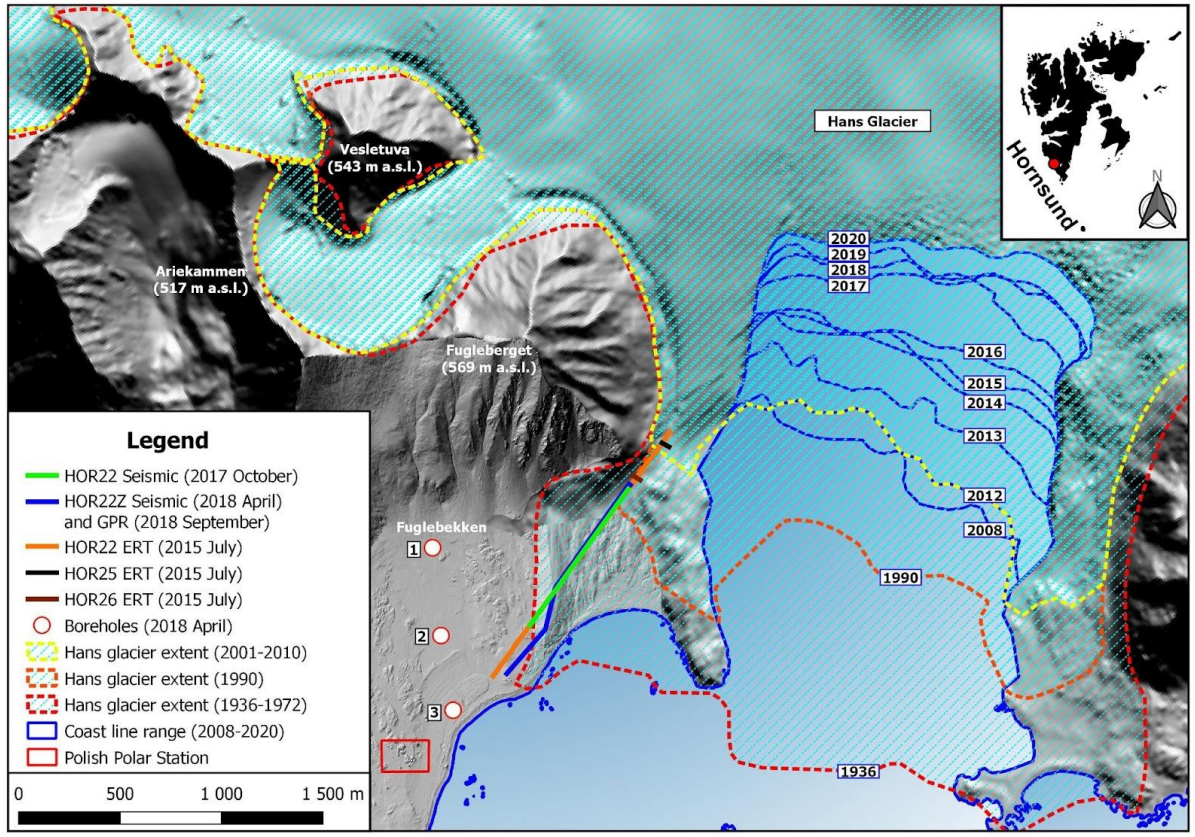
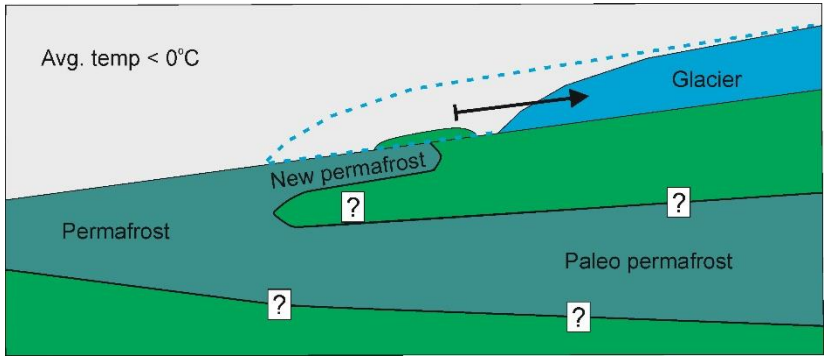
Study area & research questions



Scientific question:



What is the shape of permafrost in front of retreating glacier?

How it looks like under the end moreine?

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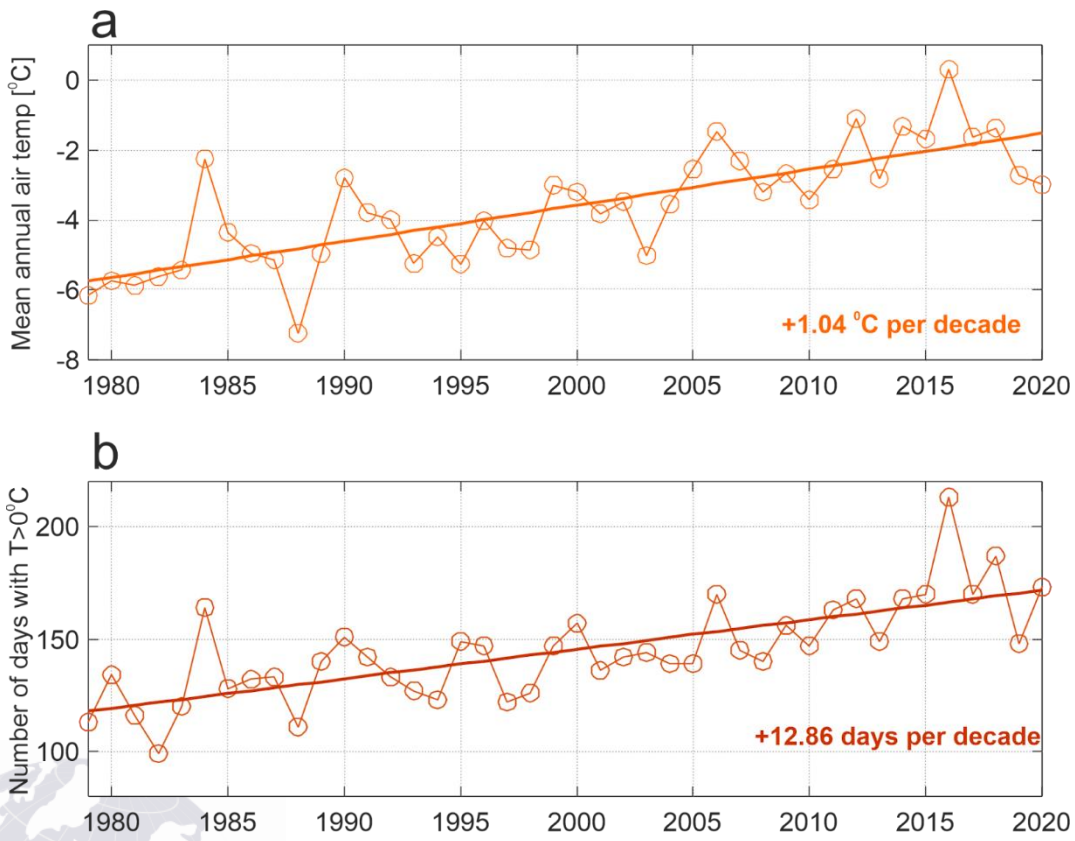
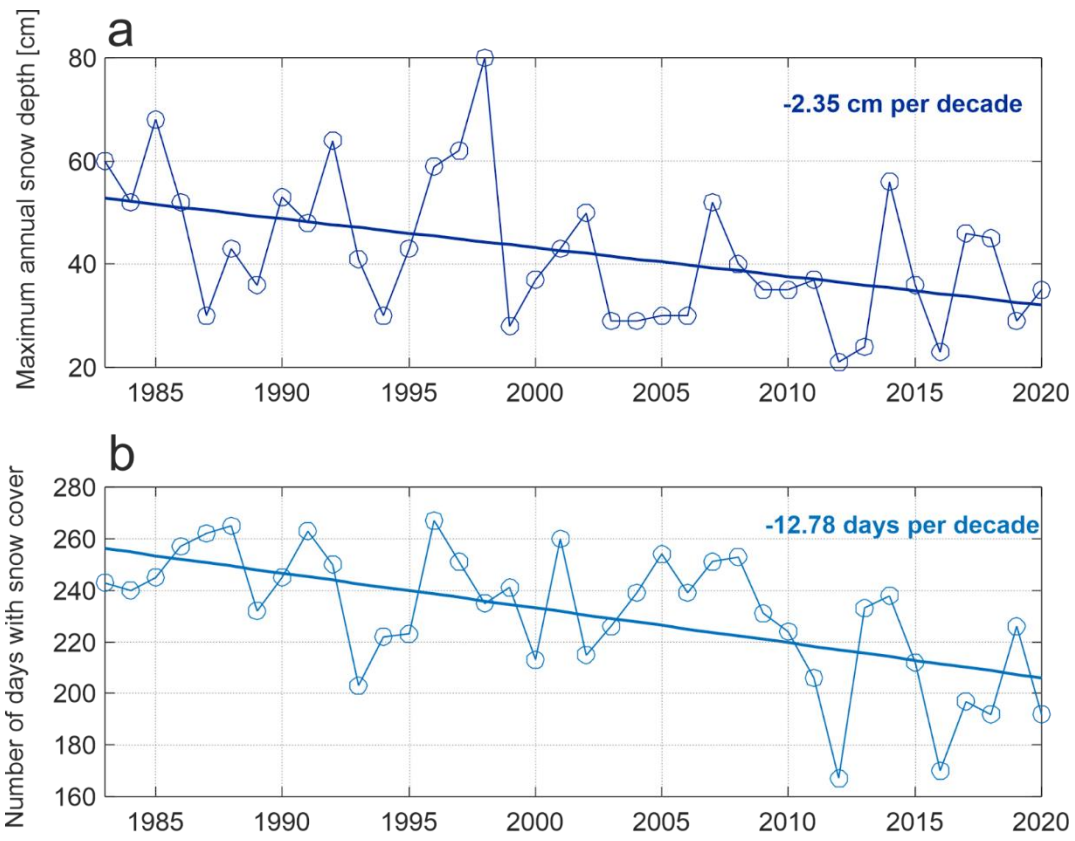
Polar amplification



Variation in (a) annual mean air temperature and (b) the number of days with positive air temperatures at Hornsund station in the years 1979–2020.



Variation in (a) maximum annual snow depth and (b) the number of days with snow cover at Hornsund station in the years 1983-2020.

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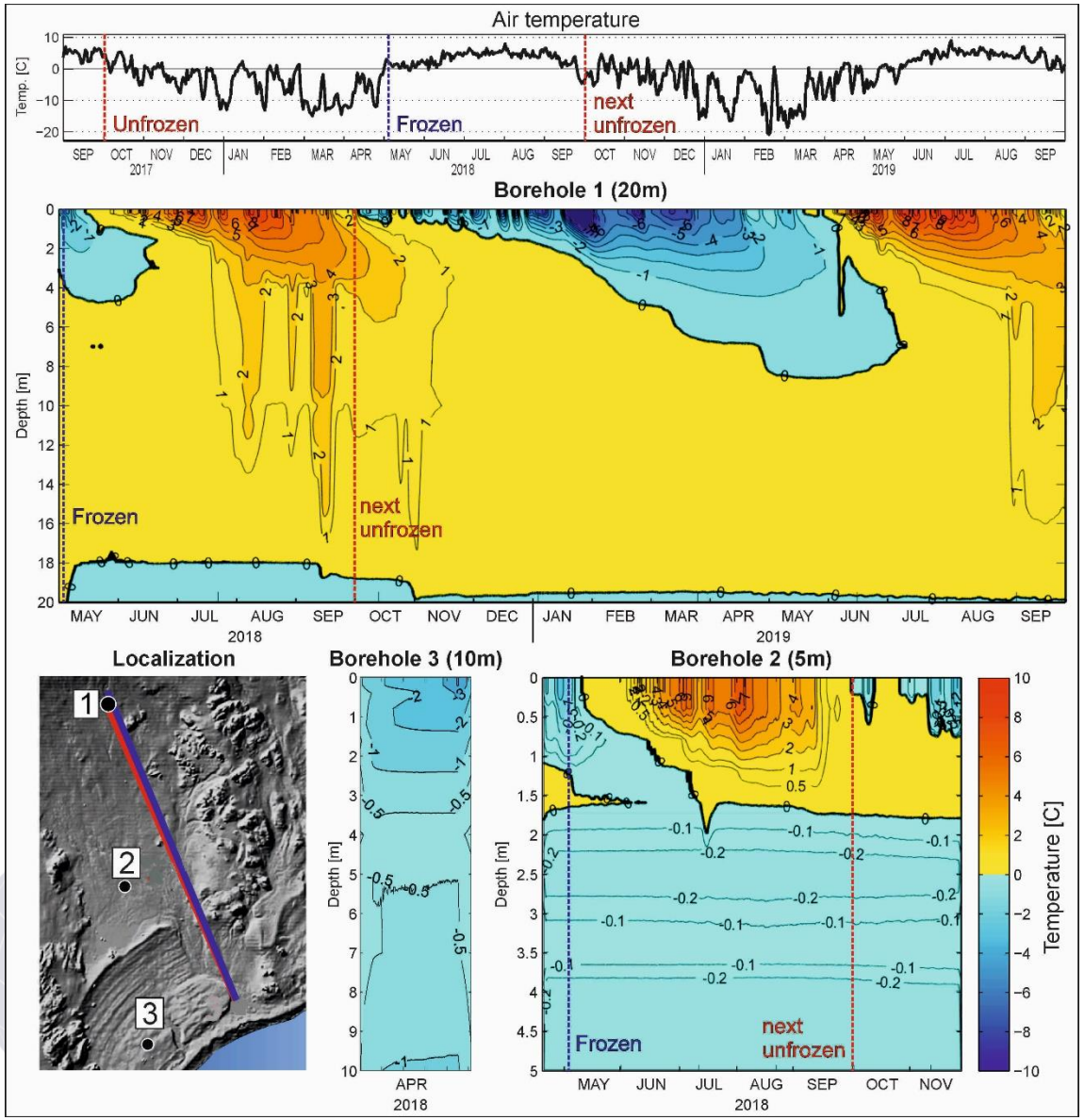
Thermal monitoring



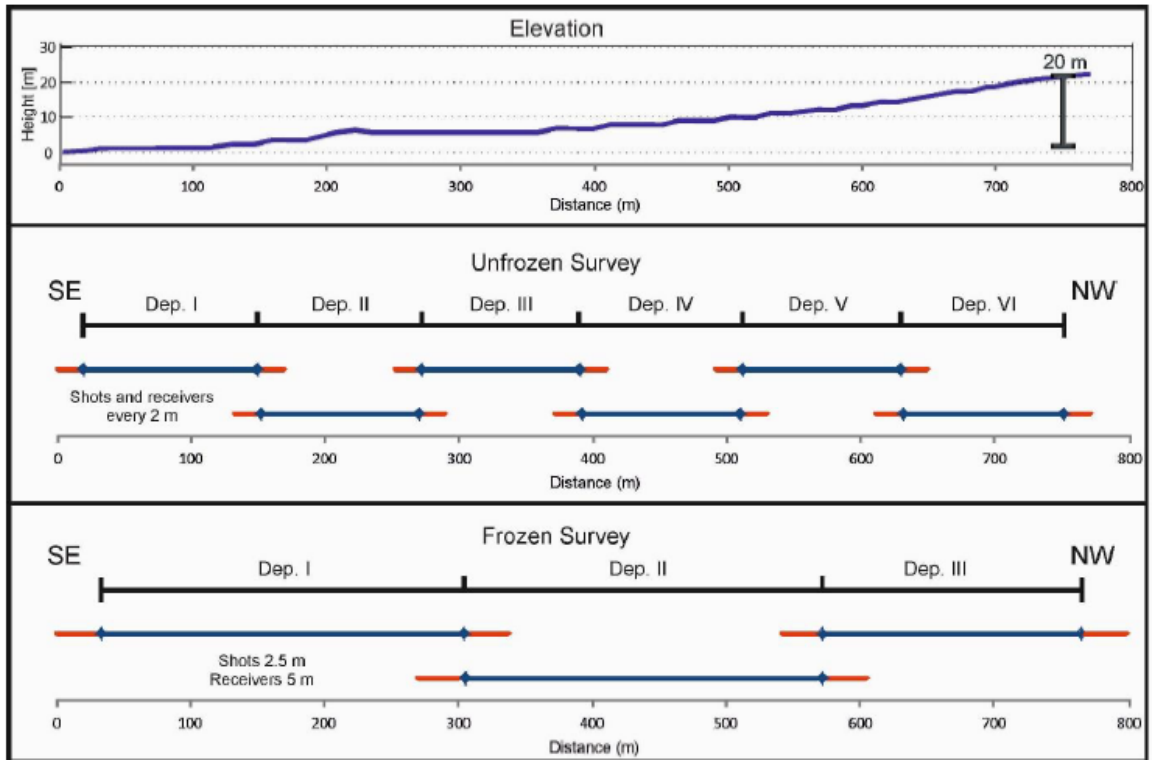
Three boreholes with continous thermal monitoring down to 5, 10 and 20 m.
Drilling need to be performer on deep snow, due to environmental restrictions

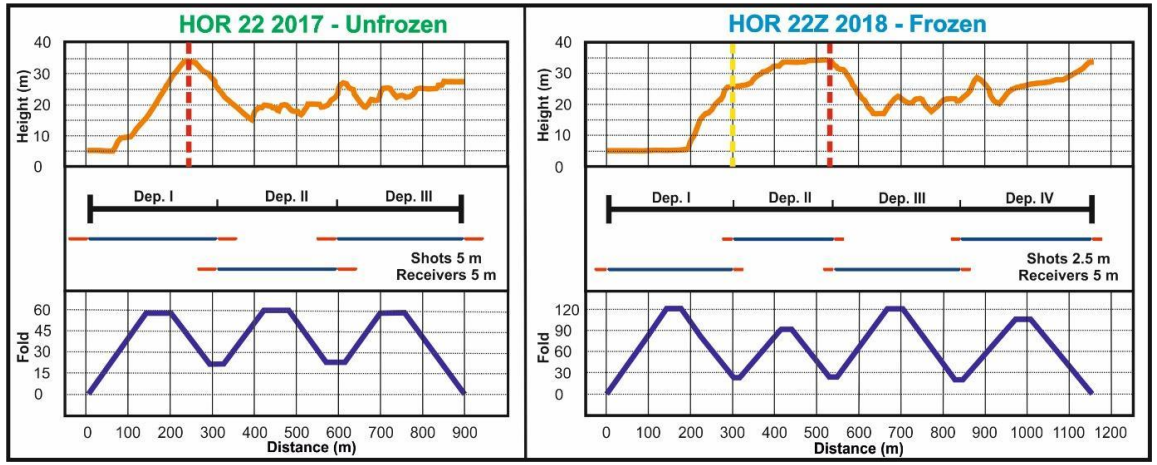
- Clear seasonal freezing/thawing pattern down to visible down to several metres
- Unusual unfrozen area at Borehole 1 – underground flow

Fieldworks – two Actic expeditions

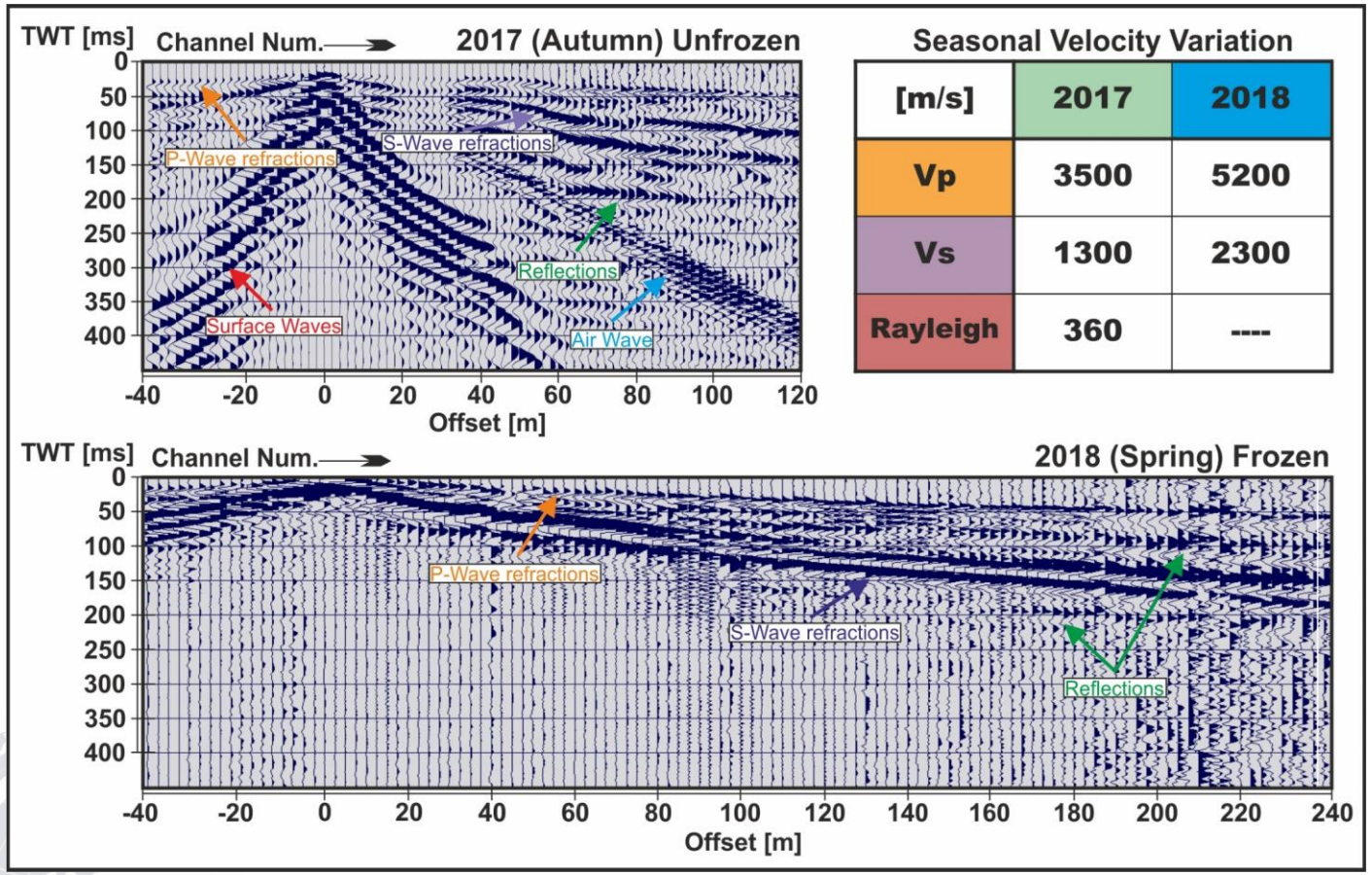
Two Arctic expeditions were organized to perform time-lapse seismic. For both seasons equipment (seismic source, deployment of stations) had to be prepared in different way. Special sledges were constructed for snow use.

Seismic acquisition geometry





Seasonal variability of seismic wavefield



Seasonal Velocity Variation

[m/s]	2017	2018
Vp	3500	5200
Vs	1300	2300
Rayleigh	360	----

Significant change in seismic velocity, for both P and S waves

Lack of Surface waves in frozen conditions

Clear wide-angle observations at long offsets

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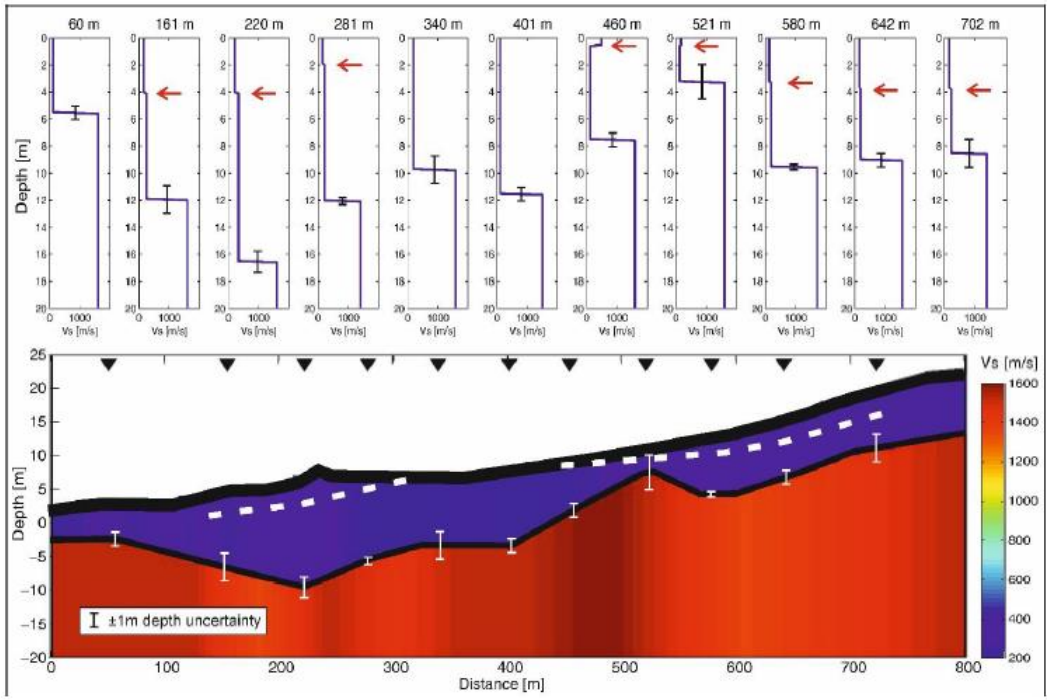
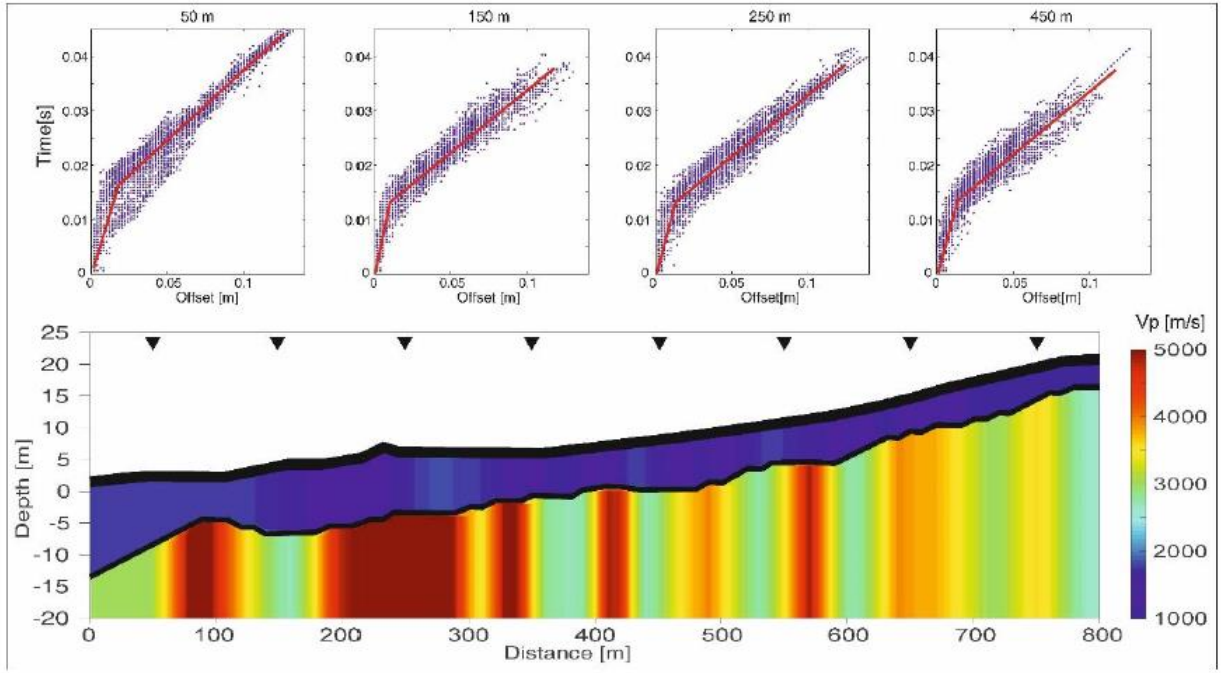
Surface waves (MASW) & refraction seismic





- Standard methods show the structure of both P and S wave velocities
- Clear boundary between sediments and compacted basements
- Uncertainties estimated with simple statistical methods

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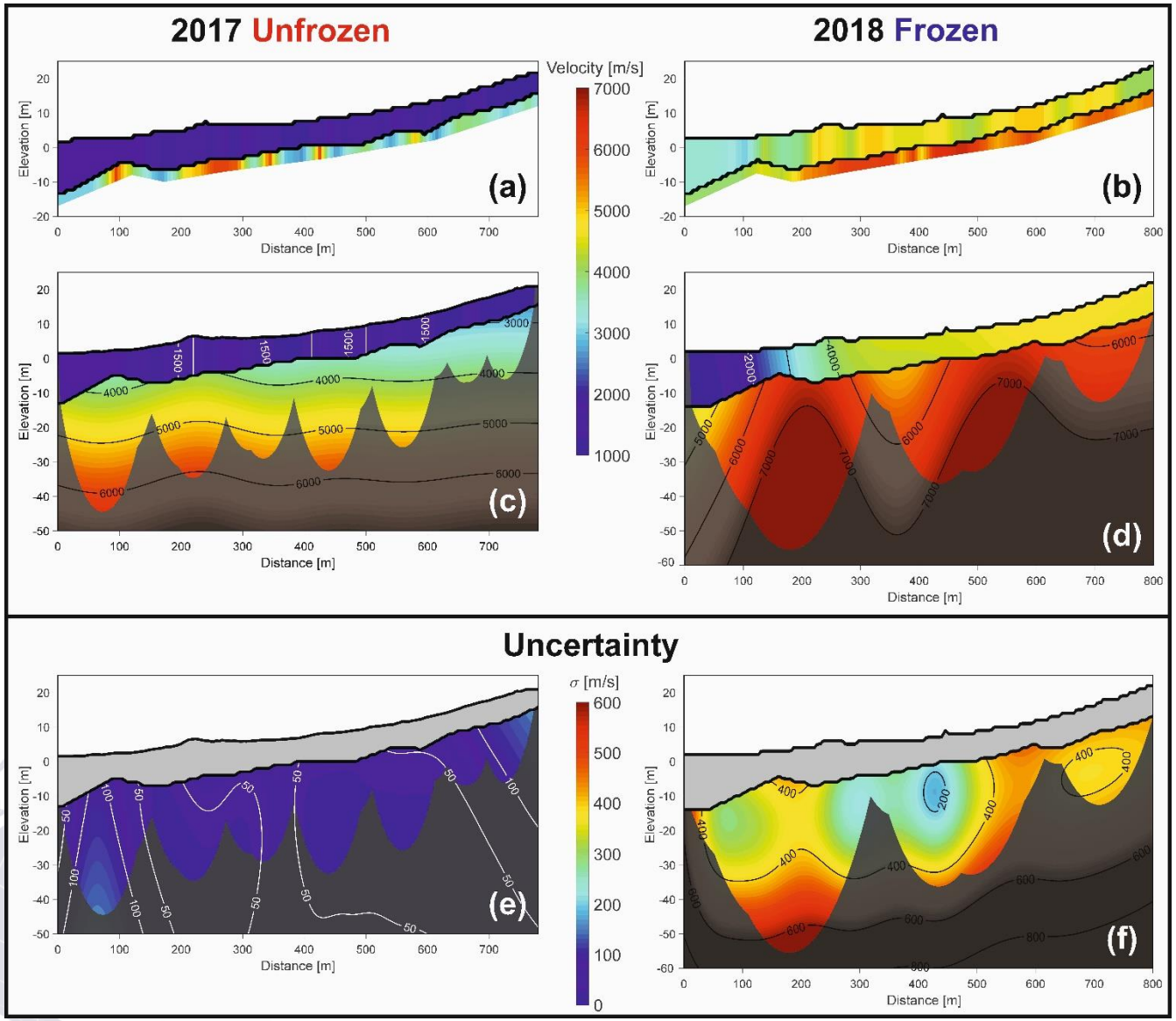
Refraction seismic & traveltime tomography

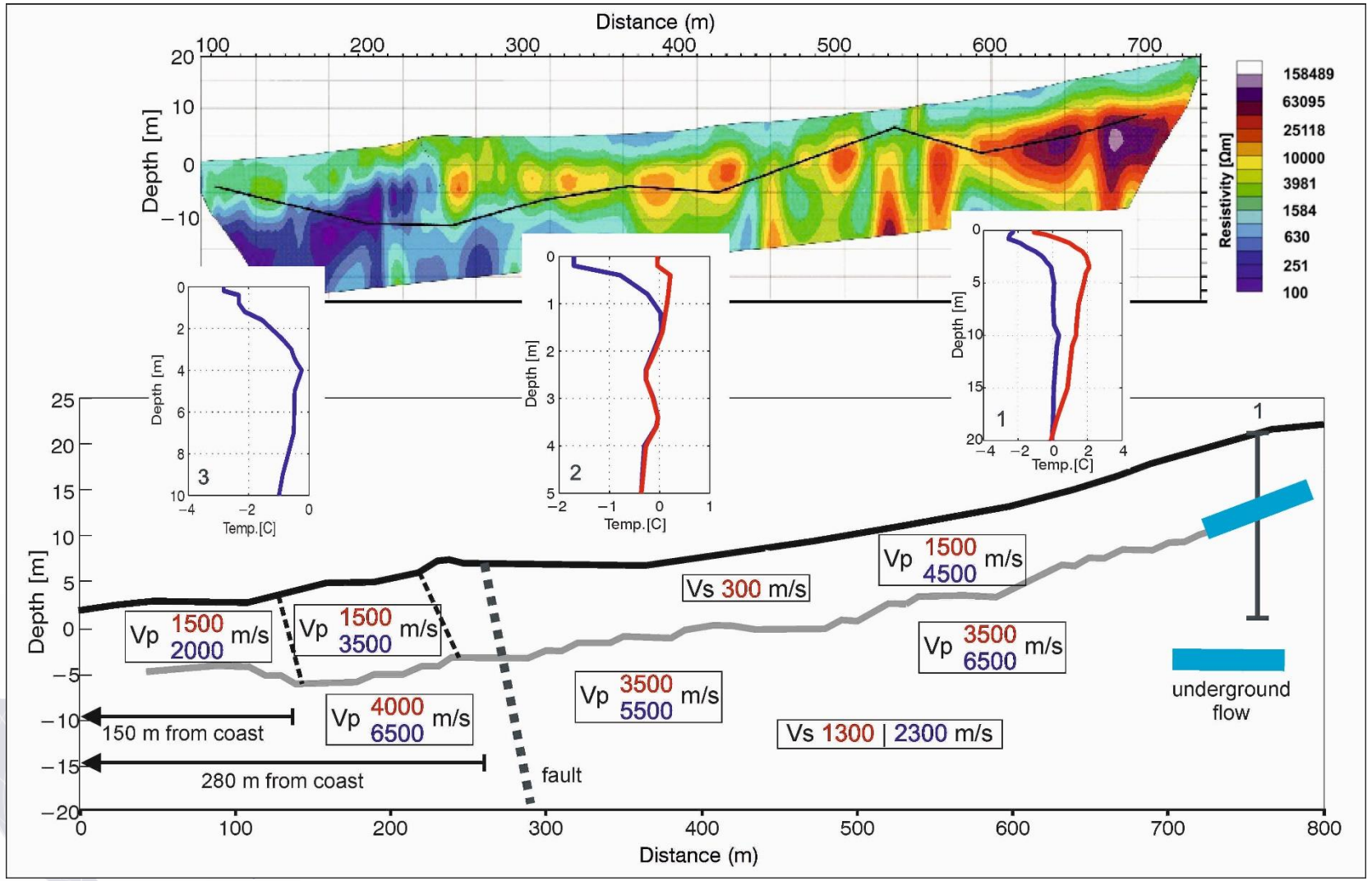


Two independent surveys (a, b) shows the same lithological boundary using short offset refractions with different geometries

Traveltime tomography, with uncertainty analysis shows significant Vp change at the depth of 30 m

After Majdański et al., Permafrost and periglatial Processes, 2022 (online first)

Time-lapse interpretation



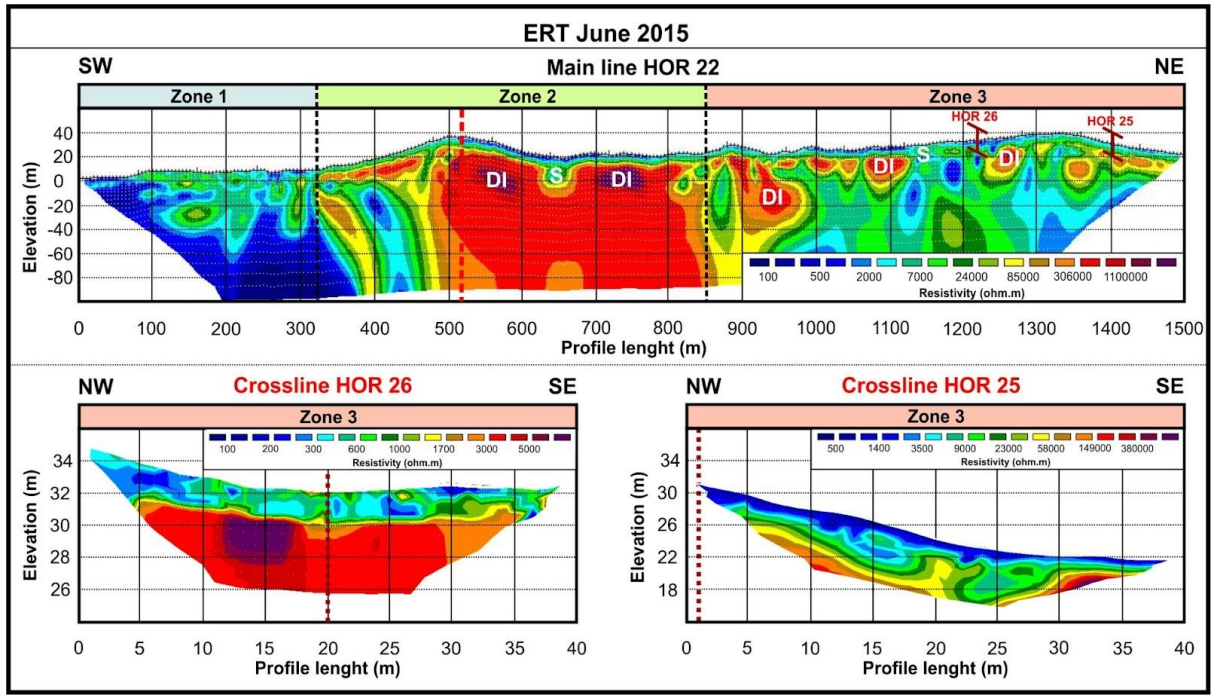
Strong seawater intrusions effect visible at 280 m from the coast

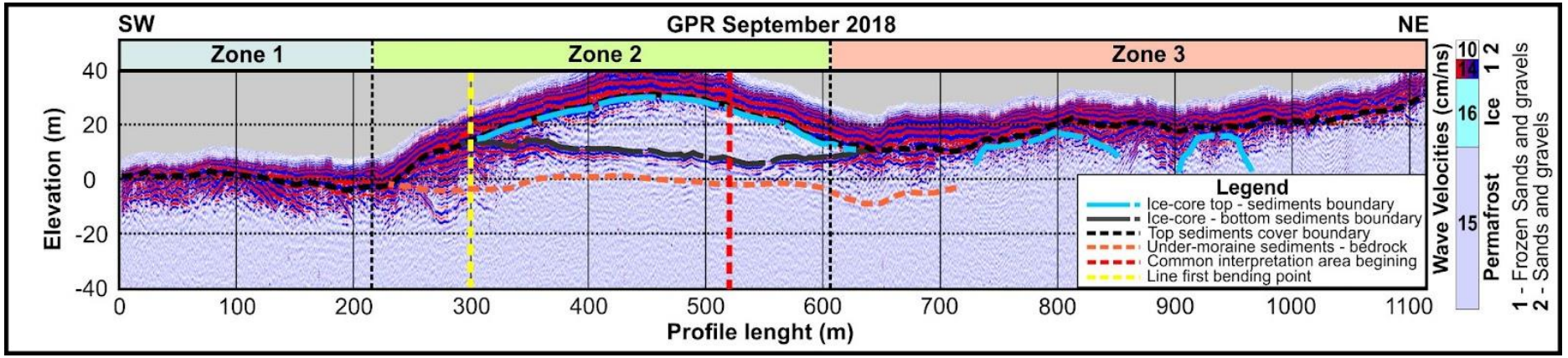
Verified seasonal changes of seismic velocities at 30 m depth

Significant hydrologial impact observed in time-lapse seismic image

ERT & GPR image of the terminal moraine

- ERT shows the ice cores in the sediments
- GPR shows ice-sediment boundary under the moraine
- Seismic shows bedrock and freezing effect in both sediment and bedrock





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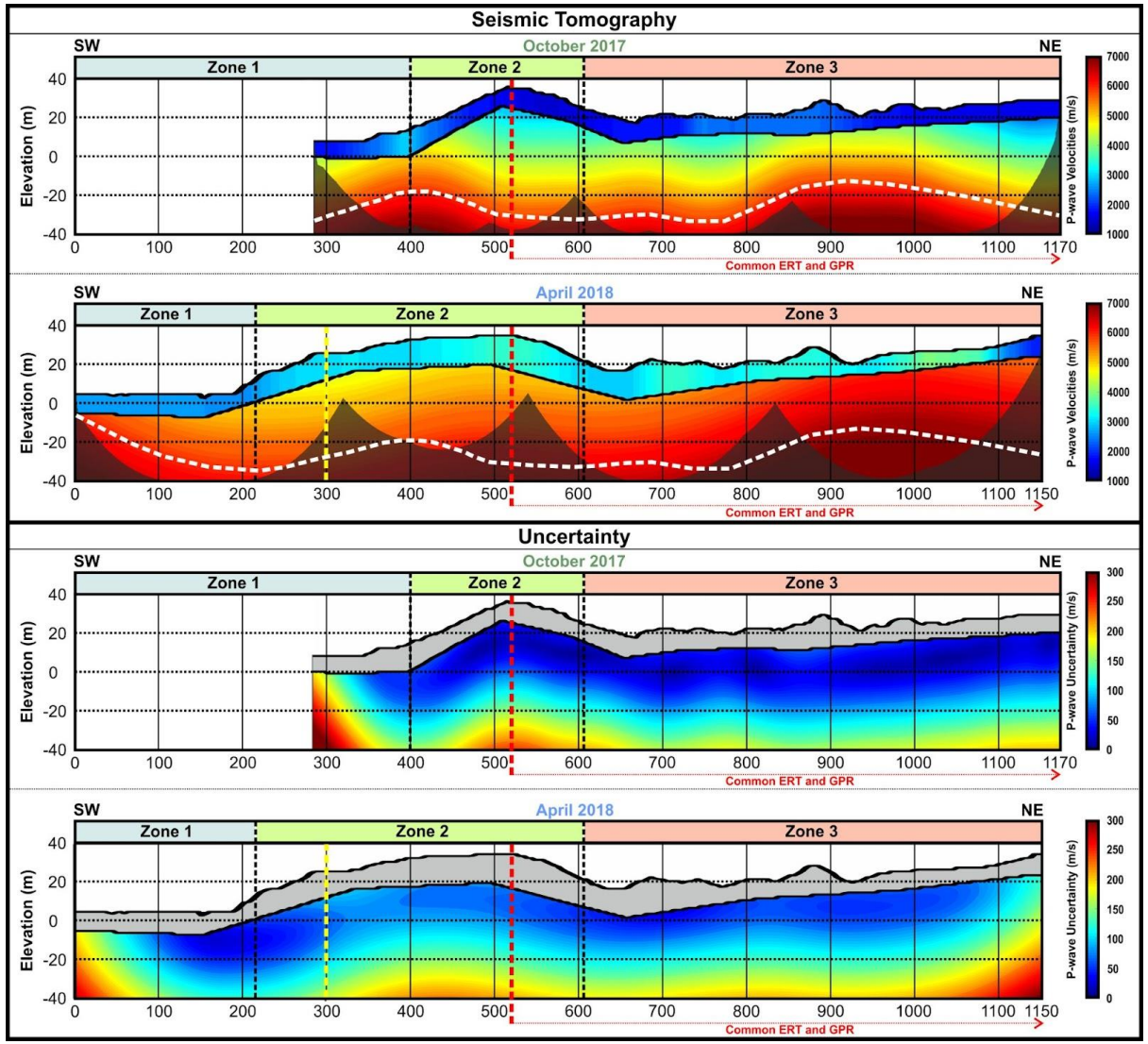
Refraction seismic & traveltime tomography

Two independent surveys (top) shows the same lithological boundary using short offset refractions with different geometries

Traveltime tomography, with uncertainty analysis shows significant Vp change at the depth of 40 m



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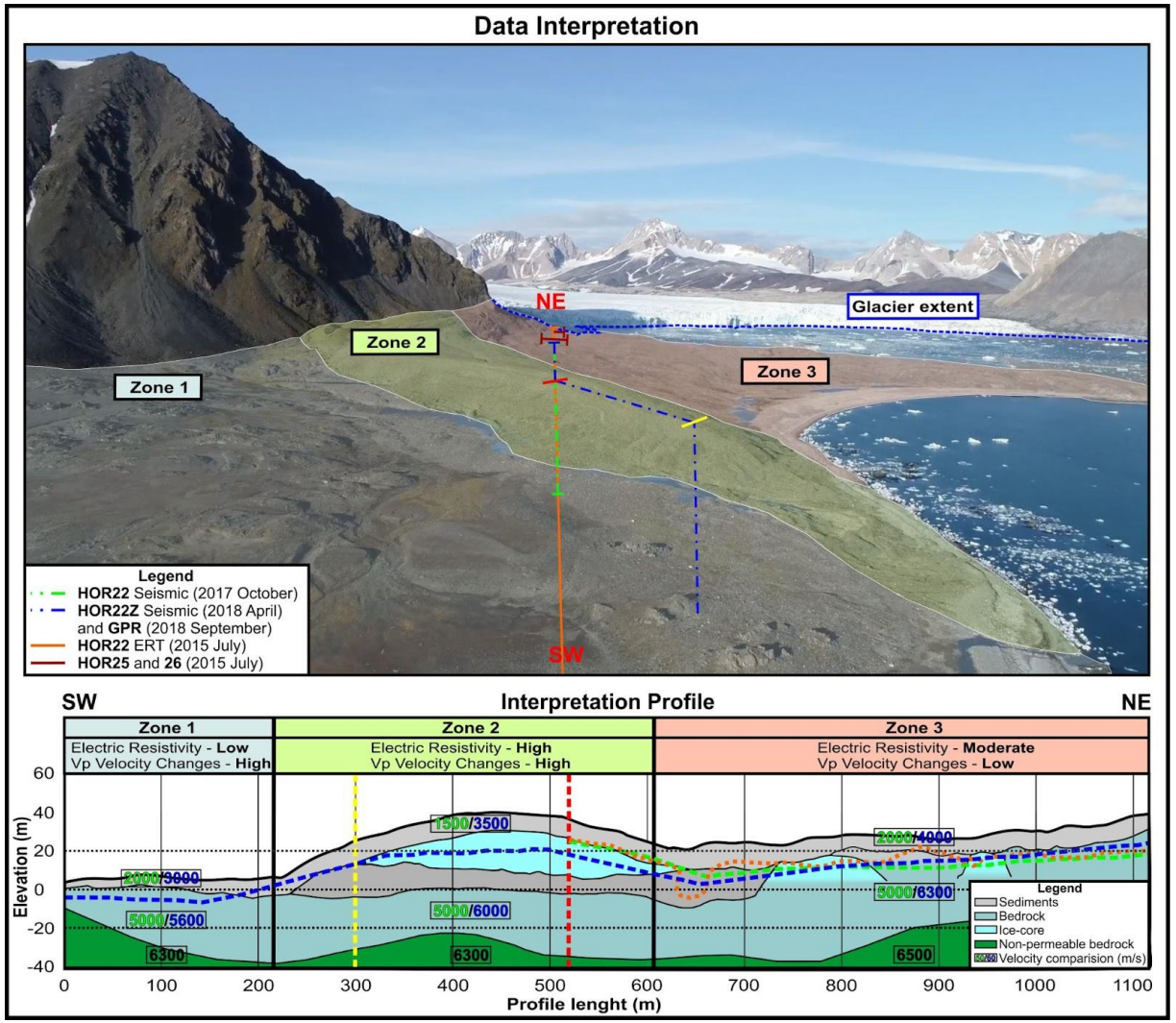
Time-lapse interpretation

Combination of various geophysical methods shows:

- clear seasonal variations in active layer
- seasonal variations under the moraine
- underground flow induced seasonal variations down to 40 m
- three distinct zones around the morain



After Marciniak et al., Polish Polar Research, 2022 (online first)

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Conclusions

- Near-surface seimic methods, developed in recent years in IG PAS can clearly image the subsurface even in difficult (Arctic) conditions

- Time-lapse seismic measurement, beside imaging the structure, can recognize underground water, freezing state, and the ice content in the medium

- Indirectly seismic can measure the temperature (at 0 or 100 C)

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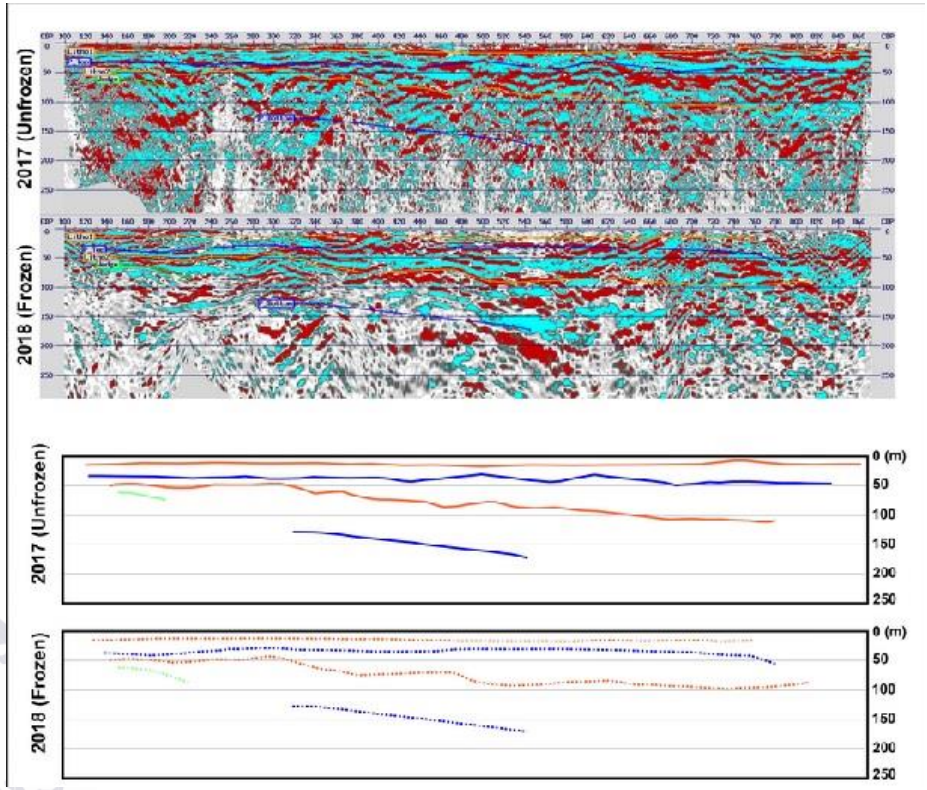
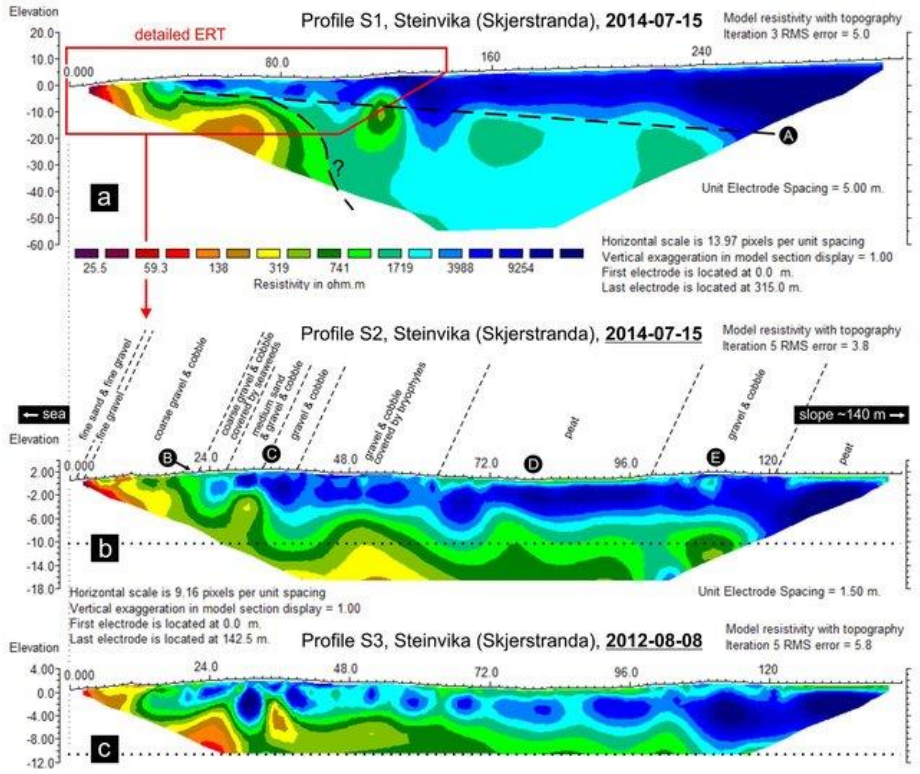
Future work …

Using reflection seismic imaging the bottom of the permafrost will be estimated. This results will be combined with marine ERT images of permafrost shape by colleagues from Wroclaw University





After Kasprzak et al. Geomorphology, 2017