EGU General Assembly 2020

EGU2020-8136, updated on 25 Oct 2021
https://doi.org/10.5194/egusphere-egu2020-8136
EGU General Assembly 2020

Geophysical imaging of permafrost in the SW Svalbard – the result of two high arctic expeditions to Spitsbergen

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The Arctic regions are the place of the fastest observed climate change. One of the indicators of such evolution are changes occurring in the glaciers and the subsurface in the permafrost. The active layer of the permafrost as the shallowest one is well measured by multiple geophysical techniques and in-situ measurements.

Two high arctic expeditions have been organized to use seismic methods to recognize the shape of the permafrost in two seasons: with the unfrozen ground (October 2017) and frozen ground (April 2018). Two seismic profiles have been designed to visualize the shape of permafrost between the sea coast and the slope of the mountain, and at the front of a retreating glacier. For measurements, a stand-alone seismic stations has been used with accelerated weight drop with in-house modifications and timing system. Seismic profiles were acquired in a time-lapse manner and were supported with GPR and ERT measurements, and continuous temperature monitoring in shallow boreholes.

Joint interpretation of seismic and auxiliary data using Multichannel analysis of surface waves, First arrival travel-time tomography and Reflection imaging show clear seasonal changes affecting the active layer where P-wave velocities are changing from 3500 to 5200 m/s. This confirms the laboratory measurements showing doubling the seismic velocity of water-filled high-porosity rocks when frozen. The same laboratory study shows significant (>10%) increase of velocity in frozen low porosity rocks, that should be easily visible in seismic.

In the reflection seismic processing, the most critical part was a detailed front mute to eliminate refracted arrivals spoiling wide-angle near-surface reflections. Those long offset refractions were however used to estimate near-surface velocities further used in reflection processing. In the reflection seismic image, a horizontal reflection was traced at the depth of 120 m at the sea coast deepening to the depth of 300 m near the mountain.

Additionally, an optimal set of seismic parameters has been established, clearly showing a significantly higher signal to noise ratio in case of frozen ground conditions even with the snow cover. Moreover, logistics in the frozen conditions are much easier and a lack of surface waves recorded in the snow buried geophones makes the seismic processing simpler.

Acknowledgements

This research was funded by the National Science Centre, Poland (NCN) Grant UMO-2015/21/B/ST10/02509.