# MULTI-METHOD GEOPHYSICAL CHARACTERIZATION OF THE SHAPE OF THE PERMAFROST IN THE HIGH ARCTIC (SPITSBERGEN )

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## Introduction

Global climate changes are one of the most important issues for the global natural environment. One of the most vulnerable to those changes is polar regions, where dynamic of them are significantly larger and more intense than at mid-attitudes. Results of seismic studies presented in work show seasonal changes which affecting the cryospheric components of the Hornsund area, Spitsbergen. The two data-sets, from autumn 2017, and spring 2018, were gathered during two expeditions, to directly compare the state of permafrost in different seasons. Multi-step seismic analysis, where maximum utilization of gathered data is obtained by use of multiple interpretation methods, allowed to image seasonal changes in the post-glacial geological structures and the permafrost. During the data processing steps, authors were able to estimate the main physical properties of the research area, that was necessary to further imaging of the structures with reflection seismic. The special effort was made to estimate the uncertainty of the results, making them comparable and reliable. Obtained unique geophysical information about Hornsund geocryology and its changes, may be useful also for a wide spectrum of specialists interested in the dynamics of the climate and cryospheric changes (Bælum et al. 2012, Keating et al. 2018.)

## Samples and methods

Two field expeditions conducted in 2017 and 2018, aim to perform high-resolution shallow seismic research. The seismic profiles were carefully selected, to show a variety of geological structures of the region. As a seismic source, PEG 40 automated weight-drop and 8kg sledgehammer were used. For signal acquisition, 60 1C 4.5Hz Omnirecs CUBE stations were deployed in 5m spacing. To cover the whole seismic line, walking spread acquisition scheme was applied. On every shot position, the signal excitation was repeated 4 times, to obtain optimal data quality after vertical stacking of shots. In total, nearly 2 km of seismic lines were gathered during each expedition.

## Data processing

Because of the acquisition scheme, the dataset is suitable for refraction tomography, reflection imaging methods, and MASW analysis. To obtain high-quality signals, after multiple tests, best vertical sacking method was selected. MASW processing has been performed on the dataset from 2017 (as in Tsuji et al., 2012). Both datasets were imaged to receive reflection stack using Globe Claritas software (Fig. 1). Additionally, the first breaks of refraction waves used in ray tracing tomography. That approach allowed to obtain information about the velocity field, where information from the borehole is not available. Because the work has to allow seasons comparison, information about result uncertainty is necessary. In the presented processing approach, that information is migrated between methods. Assuming, that the less accurate technique is used as the first one to gathering geophysical information, every further method result has to be more certain.

## Results

The seismic stacks revealed the complicated geocryological structure of the fore-field of the retreating Hans glacier. In both datasets from HOR22 seismic profile line, main reflective boundaries are visible. The data quality will allow measuring seasonal changes, that are already visible in the data. The MASW analysis 2D model, allowed to recognise the boundary between sediment and crystalline layer. High-velocity contrast between layers indicates the presence of the water saturated zone, which was confirmed in shallow boreholes up to 10 meters.

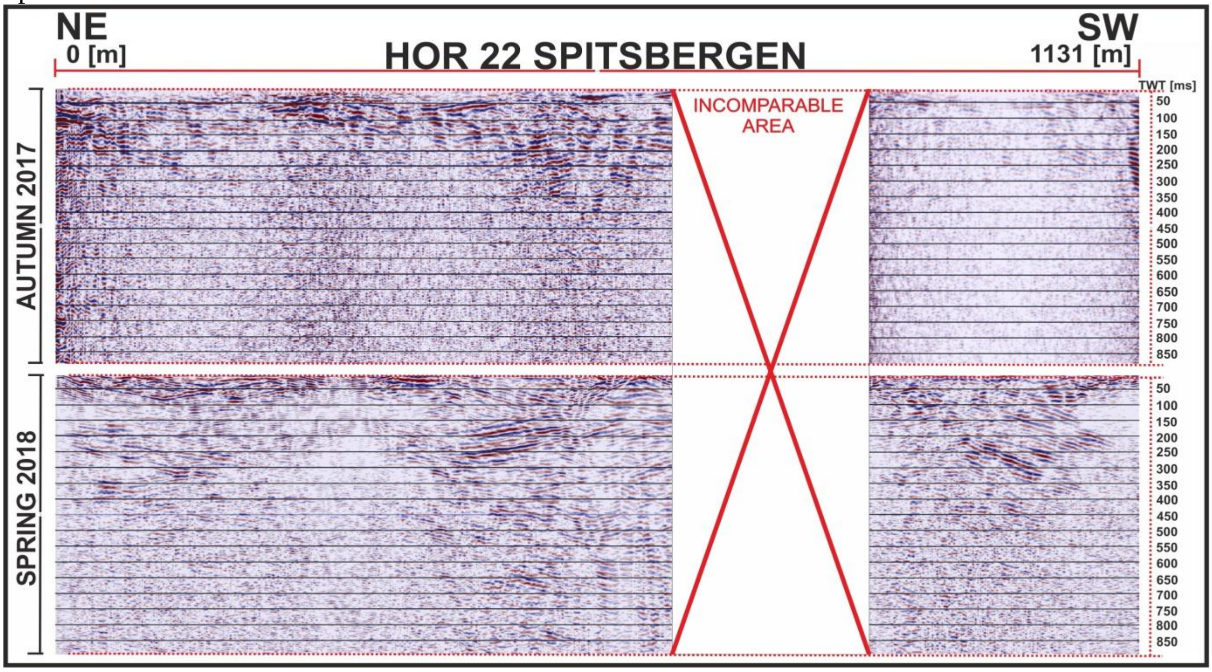


***Figure 1**. Seismic stack comparison of the datasets from HOR22 profiles, gathered during 2 seasons in a time domain. The snow coverage during Spring 2018 campaign totally muted the surface waves. As a result, the overall image quality is much better, however without the possibility to apply MASW analysis.*

## Conclusions

The analysis of high-resolution seismic profiles, performed during different seasons in Spitsbergen proved to be an efficient way to estimate the seasonal environmental changes. The first seismic results presented in the work, that are the part of the larger project revealed, that is possible to model also in wider scale seasonal changes in Hornsund geological structures with non-invasive geophysical methods. An optimal combination of seismic methods, including MASW, travel time tomography and wide-angle reflection imaging that leads to the highest quality images has been proposed. An additional, seasonal impact to the dataset provides new challenges that require the development of new processing approach, that will be useful in further permafrost studies.

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