Short statement for Arctic Observing Summit 2020

Seismological monitoring in the Arctic for fostering multidisciplinary studies of the solid Earth and the cryosphere

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Introduction

Due to the effect of climate change in the cryosphere and the increasing interest of industry and policymakers in potential exploitation of geo-resources in the Arctic, there is a clear need for a better understanding of the natural processes on the Earth's surface and in the Earth’s crust in polar regions. Seismology is an important contributor to monitoring efforts in the Arctic, both for studying geotectonic processes and inferring sub-surface structures using earthquake observations, as well as for the study of glaciers, ice sheets, and permafrost using the new field of cryoseismology. In order to improve these capabilities, it is essential to extend the seismic monitoring infrastructure in the Arctic and to develop new methodologies to exploit the full potential of the already available seismic data for cryosphere and solid Earth research.

Importance for solid Earth research

A large component of climate research has focused on historical climate scenarios, using them as models for today’s observed climate change. Past climates cannot be understood without knowing past geology and the geographic distribution of land and sea, which has a large influence on water circulation and thereby heat transport in the oceans. Furthermore, knowing the history of the Earth’s crustal structure can help constraining sea level variations due to post-glacial uplift (*Dangendorf et al., 2017*). The geotectonic situation in the Arctic is unique with a concentration of slow to ultra-slow spreading mid-ocean ridges. Large interest exists for interdisciplinary studies to investigate the diversity of phenomena related to the formation of new oceanic lithosphere and the structure and history of continental margins, in particular at the ultra-slow spreading Gakkel Ridge in the largely inaccessible Arctic Ocean. There is also the need to investigate the earthquake hazard and risk of method release in the region because of potential impacts for the exploitation of newly discovered off-shore hydrocarbon reservoirs in the Arctic. The key for all mentioned issues is a better knowledge of today's tectonics, crust and uppermost mantle structures, and plate dynamics in and around the Arctic, which can only be investigated by geology and geophysics, and seismology in particular.

Importance for cryospheric research

The new research field of environmental seismology studies structures and their temporal variations in the shallow sub-surface that are caused by non-tectonic sources, such as cryospheric processes or atmospheric forcing *(Larose et al., 2015)*. In particular, seismic signals originating from glaciers and ice sheets have been recently extensively studied, making cryoseismology a rapidly developing frontier research topic in Earth Sciences (*Podolskiy and Walter, 2016; Aster and Winberry, 2018)*. It constitutes a powerful method for better understanding glacial dynamic processes and inferring englacial and subglacial conditions in previously inaccessible areas, complementing traditional glaciological observations from field or remote sensing due to its independence from visibility conditions, spatial extent beyond single observation points, and unique high temporal resolution also during polar nights. Furthermore, using continuous seismic records of permanent stations allows for systematic analysis of long-term trends and changes in seasonal patterns of cryo-seismicity or sub-surface structures (e.g., permafrost) over a time period of several years or decades. The potential of seismology has been shown for example through the study of deep icequakes to uncover stick-slip motion and basal friction laws (see e.g., *Aster and Winberry, 2018; Pirli et al., 2018*), through the quantification of calving to better understand mass loss of glaciers (*Köhler et al., 2016, Sergeant et al., 2019*), through recent experimental studies to improve permafrost active layer monitoring (*James et al 2019*), and by revealing the solid Earth response to large scale ice melting (*Mordret et al., 2016*).

Recommendations

Due to the geographic distribution of sea and land, as well as the harsh climate, the seismic network covering the Arctic is sparse, limiting seismic monitoring to larger magnitude events only. Currently, permanent seismic networks with varying spatial coverage are being operated in Alaska, Canada, Greenland (GLISN, *Dahl-Jensen et al., 2010*), Norway, Russia and on Svalbard. Western Svalbard has a comparably dense permanent network for Arctic standards with an average interstation distance of about 100 km and long continuous records (some for several decades), which makes it in particular suitable for studying changes in glacier activity (*Gajek et al., 2017; Asming and Fedorov, 2015*).

The network of permanent seismic stations in the Arctic should therefore, where possible, be extended to improve detectability and location accuracy of tectonic events and (low-magnitude) cryo-seismicity. Specific topics of interest could be pursued by targeted, temporary deployments on-shore/off-shore. Furthermore, existing seismic data should be used to extend regional cryoseismological monitoring to so far unstudied regions and unconsidered time periods. For a better calibration of seismic measurements, multi-disciplinary, integrated field campaigns should be carried out combining passive and active seismic methods with direct observations of cryosphere processes such as calving and permafrost thaw depths. All these goals can only be accomplished by intensifying international cooperation.

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