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Glacier dynamic ice loss quantified through seismic eyes (CalvingSEIS) - Report

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Abstract
Glacial contribution to eustatic sea level rise is currently dominated by loss of the smaller glaciers and ice caps, about 40% of which are tidewater glaciers that lose mass through calving ice bergs. The most recent predictions of glacier contribution to sea level rise over the next century are strongly dependent upon models that are able to project individual glacier mass changes globally and through time. A relatively new promising technique for monitoring glacier calving is through the use of passive seismology. CalvingSEIS aims to produce high temporal resolution, continuous calving records for the glaciers in Kongsfjord, Svalbard, and in particular for the Kronebreen glacier laboratory through innovative, multi-disciplinary monitoring techniques combining fields of seismology and bioacoustics to detect and locate individual calving events autonomously and further to develop methods for the quantification of calving ice volumes directly from the seismic and acoustic signals.

Coordinates: 78°53'N/12°30'E
Keywords: icequakes, glacier monitoring, cryo-seismology

1. Introduction

About 40% of global glaciers and ice caps (excluding Greenland and Antarctica) loose mass through iceberg calving, while current models (e.g. in the IPCC) are currently not equipped to realistically predict dynamic ice loss, mainly because long-term continuous calving records are inexistent. Combined seismic/acoustic strategies are the only technique able to capture rapid calving events, continuously, and back through time over decades. CalvingSEIS focuses on the glaciers in Kongsfjord, Svalbard, because the research village of Ny Ålesund houses a passive seismic instrument since 1994 and is only 15 km from one of the fastest flowing and most heavily studied glaciers in Svalbard, Kronebreen. Through innovative, multi-disciplinary monitoring techniques combining fields of seismology and bioacoustics, individual calving events will be detected and located autonomously.

CalvingSEIS will generate a catalogue of calving events using state-of-the-art terrestrial remote sensing techniques to measure calving ice volumes, velocities, and ice-ocean interactions. This forms the basis for scaling the seismic calving record to mass loss and will invoke process-based understanding at the transition zone between glacier and ocean. Underwater bio-acoustic sensors will collect not only glacier sounds, but record the entire fjord soundscape instigating studies between biotic, abiotic and anthropogenic components; e.g. marine animal interaction with glacier sounds from calving and melting. The dynamic ice loss time series can reveal fine scale processes and key climatic-dynamic feedbacks between glacier calving, climate history, topographic setting, terminus evolution and fjord conditions and form an unprecedented dataset for developing, calibrating and validating glacier dynamic models.

The vision of CalvingSEIS is to produce unprecedented high temporal resolution calving fluxes, autonomously and continuously, to gain deeper insight into rapid calving processes and feedbacks related to glaciological, meteorological and oceanographic parameters that have so far gone undetected due to inexistent data. The produced calving histories will then form an integral base to equip glacier models with realistic calving parameterizations important for accurate future

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predictions. Our specific objective is to estimate dynamic ice loss at Kronebreen (and other glaciers in Kongsfjord) from existing and newly acquired, local and regional seismic data. There are no other techniques available that are able to continuously detect calving events through seasons and years and thus development of such methods and applications will provide knowledge enhancement locally in terms of detailed processes understanding of the climatic-dynamic feedbacks that dictate a tidewater glacier's health.

2. Data Acquisition

2.1 Experiment design and schedule

The experiment contains two phases, a seasonal phase 1 and a dedicated experimental phase 2.

During phase 1, two seismic arrays were installed during April to August/ September 2016 in the vicinity of the research base Ny-Ålesund to assess the potential of a local seismic array to reliably monitor and estimate mass loss on nearby calving glaciers, and in addition to locate a local seismic tremor signal which is observed at KBS in all available records. In previous work we could show that calving can be qualitatively monitored even on regional scale by seismic arrays but calibration to mass balancing requires more complete / local observations. Three instruments were deployed around the permanent GEOFON/GSN station KBS while eight instruments were deployed west of Ny-Ålesund to form a 8-point array. One site (HDF1) was installed far upstream on the glacier as a proto-installation to inquire about glacial seismic signals far away from the highly active calving front.

Phase 2 of the experiment was a two-week campaign in August 2016 particularly focused on glacier calving at the front of Kronebreen, a fast tidewater glacier on Svalbard. Simultaneous measurements of seismic, underwater acoustic, ground-based radar and LIDAR were taken in close proximity to the front to acquire a high-resolution dataset of iceberg volumes together with the associated seismic signals. This dataset is a core component during the research within the CALVINGSEIS project.

2.2 *Geometry/Location*

Figure 1: *Study area around Kongsfjord, northwestern Spitsbergen. Location of sensor arrays and individual site HDF1 are shown by red dots.*

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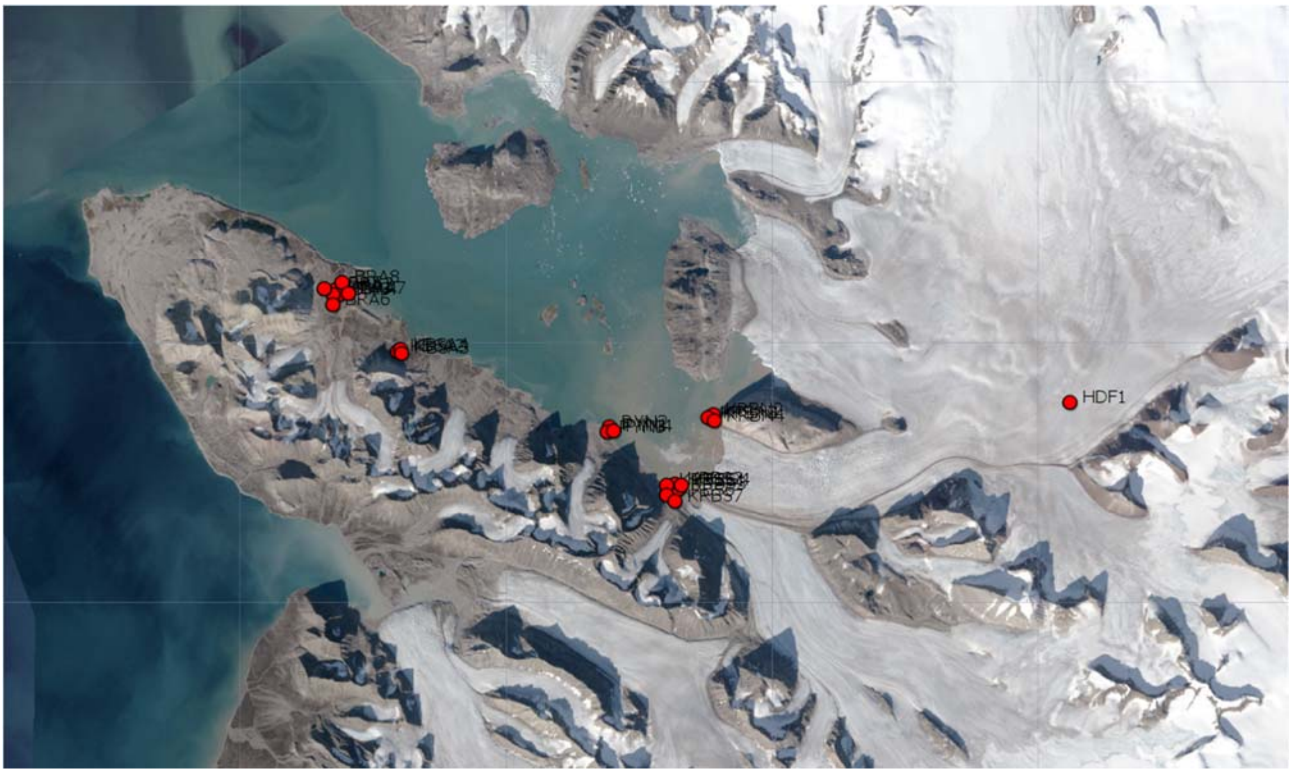

Figure 2: *close-up on sites near glacier front of Kronebreen*

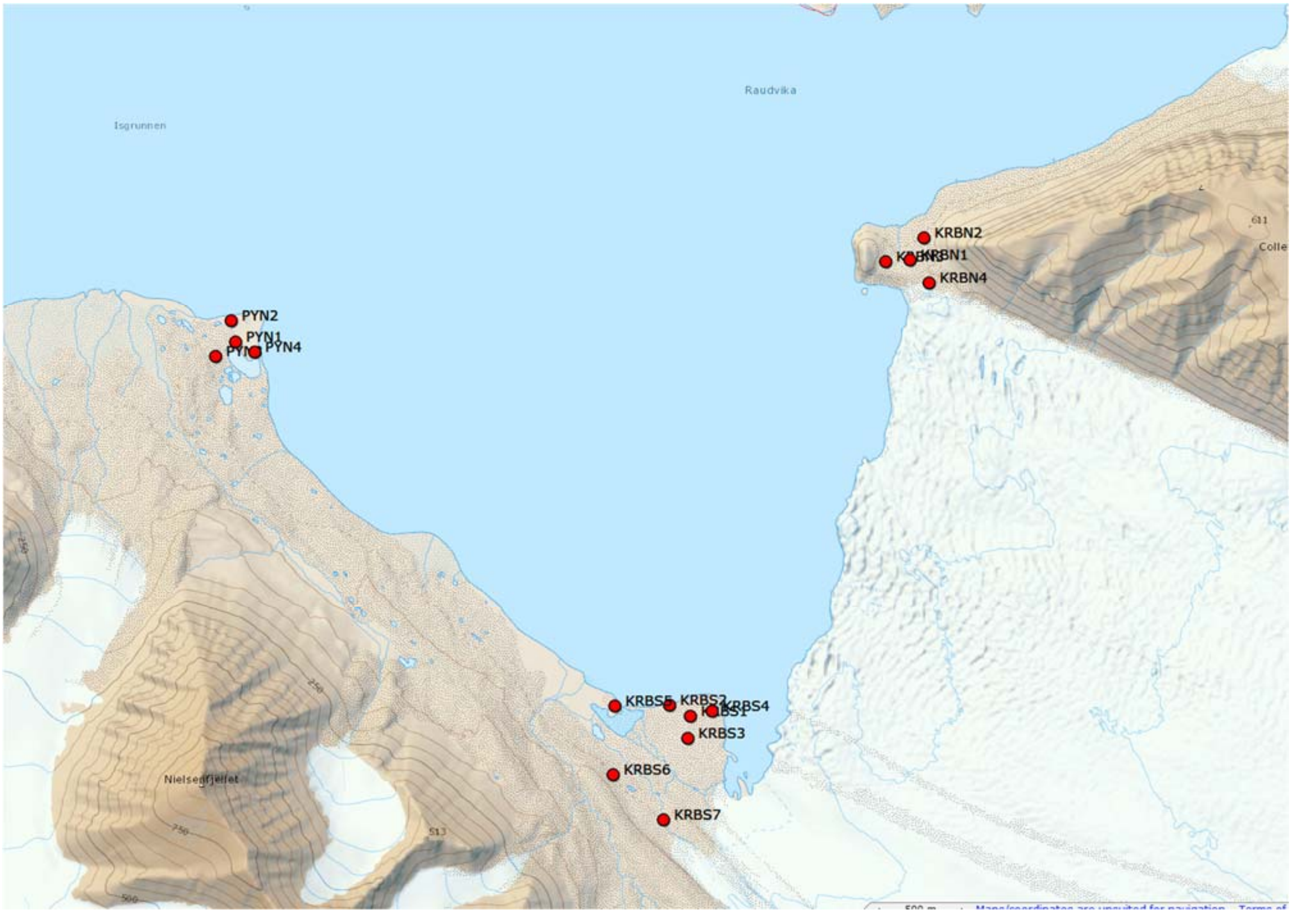

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Figure 3: *close-up on sites in the vicinity of Ny-Alesund*

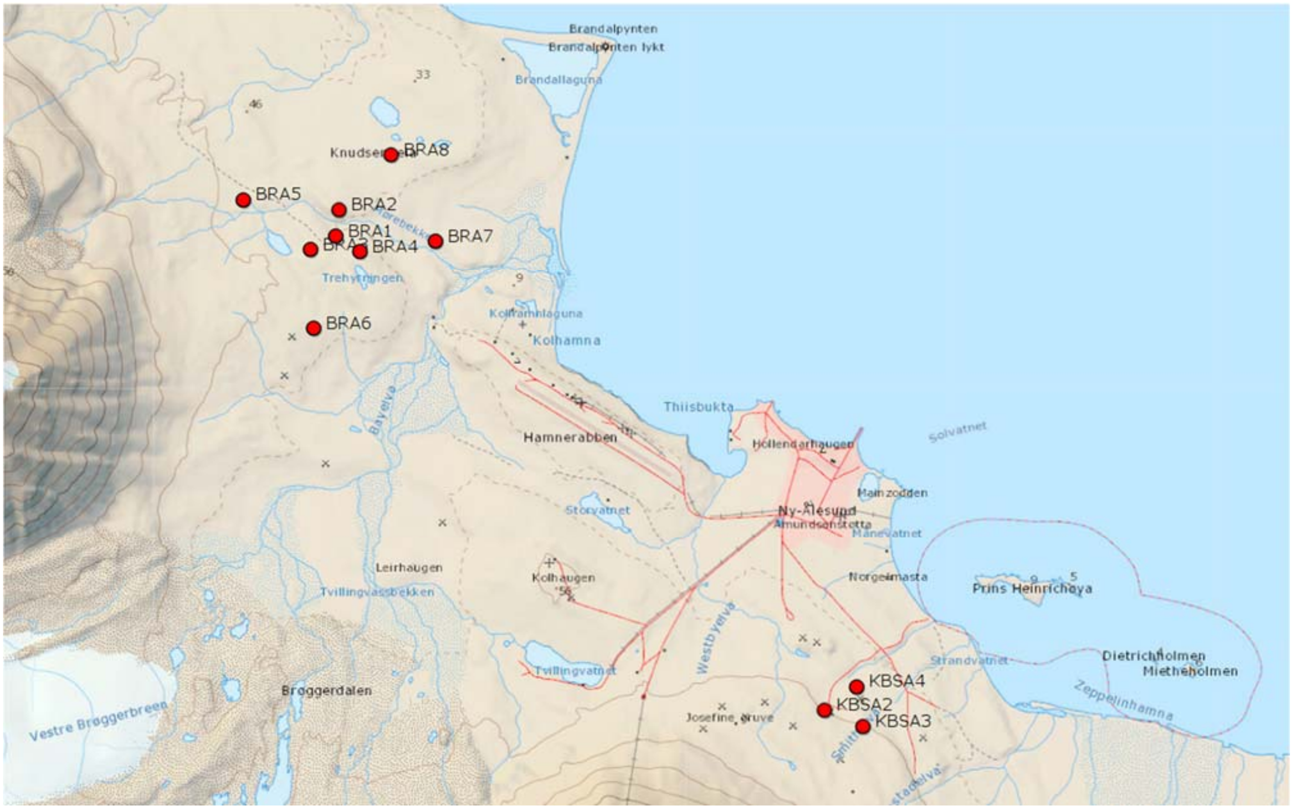

Table 1: *Station locations, associated recording units and operation time. All recorders are Cube3D units.*

sitename	*latitude (°)*	*longitude (°)*	*altitude (m)*	*recorder*	*operation period (yyyymmdd)*
KBSA2	*78.9151*	*11.9329*	*43.3*	*884*	*20160419 - 20160823*
KBSA4	*78.9163*	*11.9402*	*22.4*	*885*	*20160419 - 20160823*
KBSA3	*78.9145*	*11.9421*	*39.6*	*886*	*20160419 - 20160823*
BRA1	*78.9360*	*11.8107*	*35.6*	*609*	*20160410 - 20160904*
BRA2	*78.9373*	*11.8112*	*39.3*	*635*	*20160410 - 20160904*
BRA3	*78.9353*	*11.8050*	*34.4*	*851*	*20160410 - 20160904*
BRA4	*78.9354*	*11.8167*	*42.3*	*853*	*20160410 - 20160904*
BRA5	*78.9375*	*11.7884*	*46.9*	*852*	*20160412 - 20160904*
BRA6	*78.9317*	*11.8070*	*36.7*	*850*	*20160412 - 20160904*
BRA7	*78.9360*	*11.8347*	*11.8*	*883*	*20160412 - 20160904*
BRA8	*78.9399*	*11.8229*	*23.4*	*849*	*20160412 - 20160904*
HDF1	*78.9064*	*13.2126*	*517.1*	*889*	*20160415 - 20160827*
KRBN1	*78.8962*	*12.5344*	*20.6*	*724*	*20160824 - 20160902*
KRBN2	*78.8975*	*12.5379*	*17.4*	*725*	*20160824 - 20160902*
KRBN3	*78.8961*	*12.5274*	*31.8*	*719*	*20160824 - 20160902*
KRBN4	*78.8950*	*12.5399*	*43.1*	*720*	*20160824 - 20160902*
KRBS1	*78.8702*	*12.4779*	*12.1*	*714*	*20160824 - 20160903*

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sitename	***latitude (°)***	***longitude (°)***	***altitude (m)***	***recorder***	***operation period (yyyymmdd)***
KRBS2	*78.8708*	*12.4717*	*9.9*	*715*	*20160824 - 20160903*
KRBS3	*78.8690*	*12.4772*	*9.0*	*717*	*20160824 - 20160903*
KRBS4	*78.8705*	*12.4838*	*11.9*	*722*	*20160824 - 20160903*
KRBS5	*78.8706*	*12.4563*	*11.8*	*718*	*20160827 - 20160903*
KRBS6	*78.8668*	*12.4567*	*17.2*	*716*	*20160827 - 20160903*
KRBS7	*78.8644*	*12.4715*	*27.1*	*723*	*20160827 - 20160903*
PYN1	*78.8900*	*12.3443*	*8.0*	*721*	*20160827 - 20160903*
PYN2	*78.8912*	*12.3429*	*11.4*	*886*	*20160827 - 20160903*
PYN3	*78.8891*	*12.3388*	*18.0*	*885*	*20160827 - 20160903*
PYN4	*78.8895*	*12.3499*	*4.0*	*884*	*20160827 - 20160903*

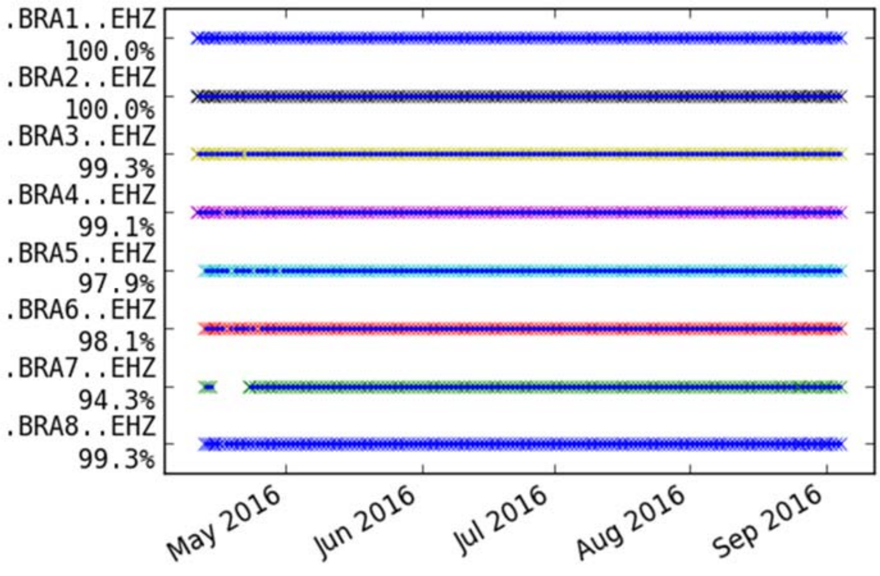
2.3 Instrumentation
All deployed sites consisted of a 4.5 Hz geophone and Cube3 recording units from the GIPP Pool Potsdam.

2.4 Acquisition parameters
All data were recorded at 100 sps sampling rate, with an amplifier gain of 16 (low power AD converter), and at cycled GPS mode with 30 minutes interval and 5 minutes on time.

3. Data Processing
Raw data were converted to MSEED using the GIPPtools software package (https://www.gfz-potsdam.de/en/section/geophysical-deep-sounding/infrastructure/geophysical-instrument-pool-potsdam-gipp/software/gipptools/).

4. Data Description
Continuous waveform data were recorded at 100 sps on three components (ZNE). The data completeness is shown for the Z-component in Figure 3:

Figure 3: *Displays of data completeness, sorted by array. Only vertical component is shown, components EHN and EHE have identical availability.*



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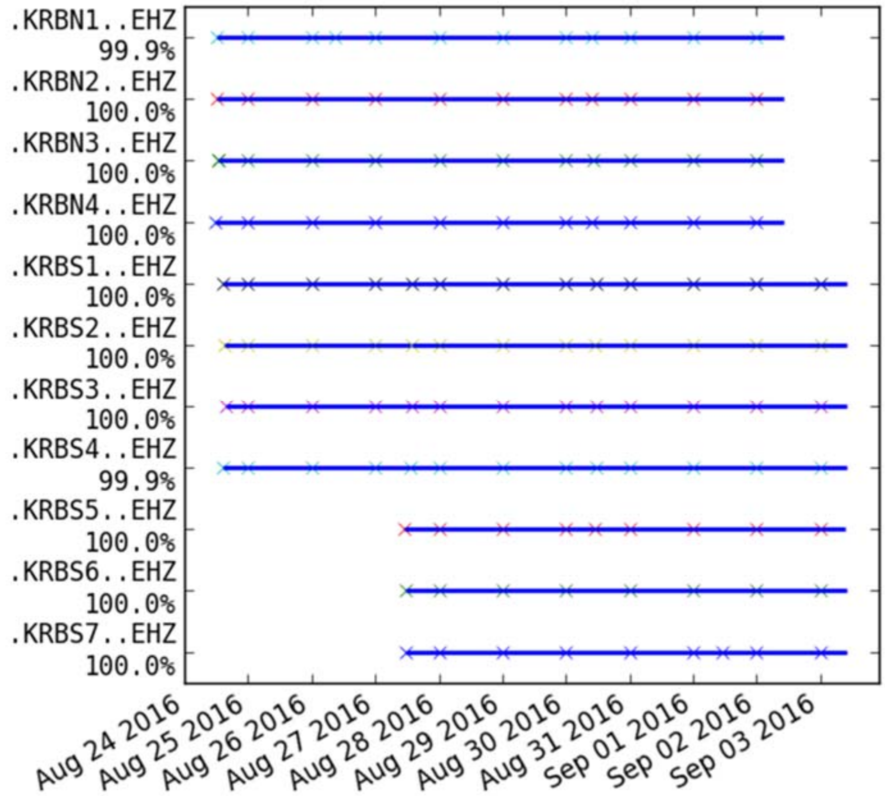

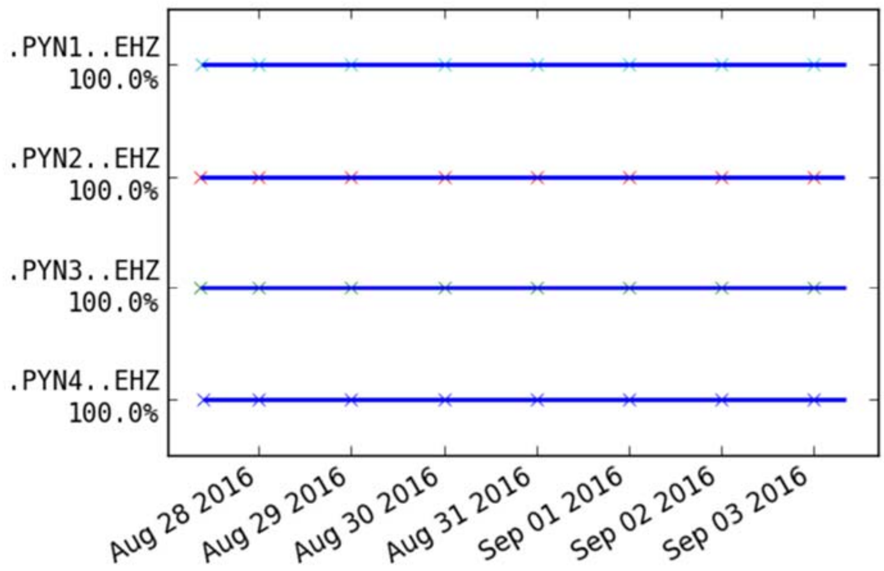

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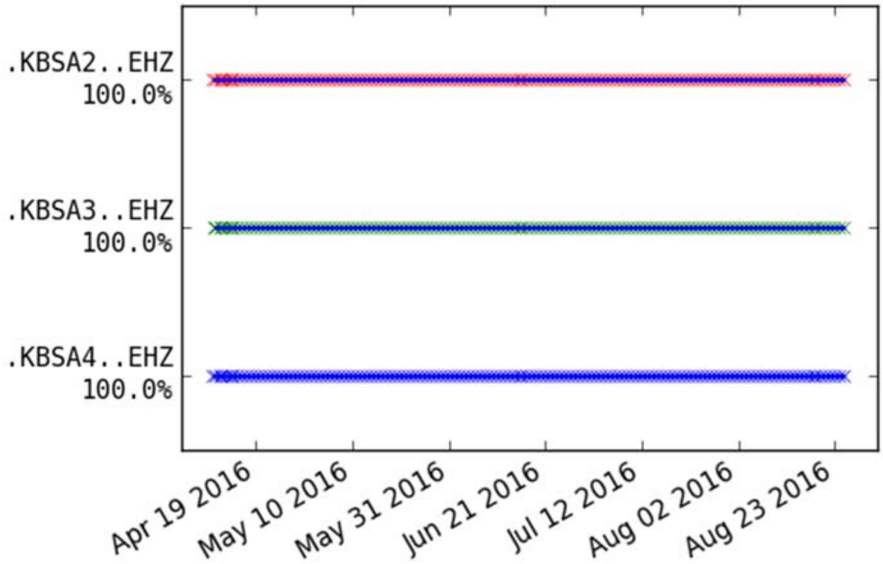

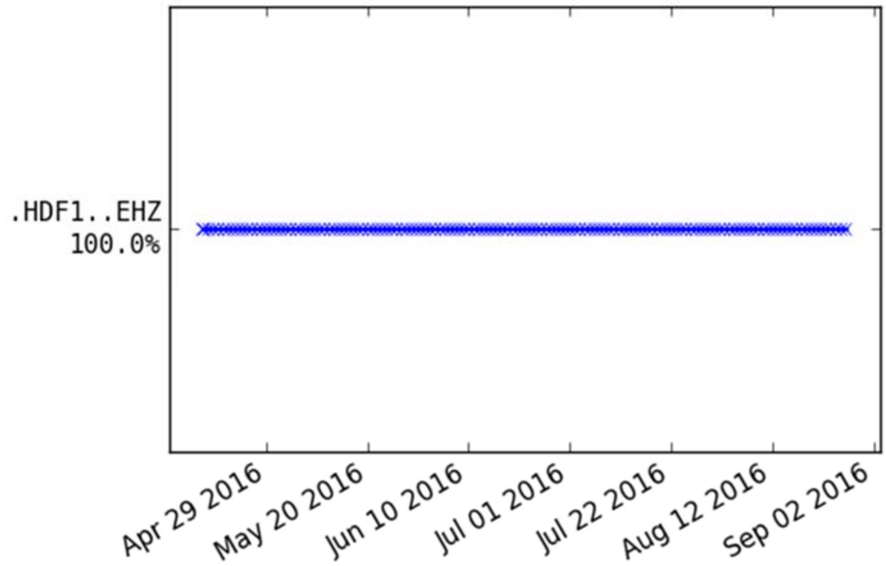

4.1 File format (s)
Data are contained in raw recorder format (directory RAW) and a consistently converted MSEED format structure (directory MSEED). MSEED files are sorted by site and contain daily miniseed files with three channels, EHZ, EHN, EHE.

4.2 Data content and structure:
The RAW data directory is sorted by recording device, the MSEED directory by station.

5. Data Quality/Accuracy
For instrument deployment in phase one, small holes were drilled into the frozen ground to accommodate the geophone pins. Instruments were covered first with sand and then buried under a rock pile. Noise levels in almost all records increased during the melt season since ground coupling of the instruments degraded and tilting occurred. The coupling and leveling of the BRA array stations was restored on August 25th.

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6. Data Availability/Access

Data are archived at the *GIPP Experiment and Data Archive* where they will be made freely available for further use after Oct 1st, 2020 (end of embargo period) under a “Creative Commons 4.0 International License” (CC BY 4.0). When using the data, please cite the data publication and report (see below).

Recommended citation for data described in this report:

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References

Köhler A., Weidle C. (2018). Potentials and pitfalls of permafrost active layer monitoring using the HVSR method: A case study in Svalbard, Earth Surface Dynamics, 7(1), 1–16. https://doi.org/10.5194/esurf-7-1-2019

Köhler, A. Nuth, C., Maupin, V., Van Pelt, W., Characterization of seasonal cryo-seismicity from a single seismic on-ice station at Holtedalfonna, Svalbard. Submitted to Annals of Glaciology – Progress in Cryoseismology

Köhler A., Nuth C., Kohler J., Berthier E., Weidle C., Schweitzer J. (2016). A 15 year record of frontal glacier ablation rates estimated from seismic data, Geophysical Research Letters, https://doi.org/10.1002/2016GL070589