Helmholtz Centre Potsdam
GFZ German Research Centre
for Geosciences

Andreas Köhler, Christian Weidle, Christopher Nuth

Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Report

Scientific Technical Report STR17/09 - Data
GIPP Experiment and Data Archive

www.gfz-potsdam.de

Recommended citation:

Köhler, A., Weidle, C., Nuth, C. (2018): Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Report, (Scientific Technical Report STR - Data; 17/09) (GIPP Experiment and Data Archive), Potsdam: GFZ German Research Centre for Geosciences.
DOI: http://doi.org/10.2312/GFZ.b103-17094

Supplementary datasets:

Andreas Köhler; Christian Weidle; Christopher Nuth (2017): Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Datasets. GFZ Data Services.
DOI: http://doi.org/10.5880/GIPP.201303.1

Imprint

HELMHOLTZ CENTRE POTSDAM
GFZ GERMAN RESEARCH CENTRE
FOR GEOSCIENCES

Telegrafenberg
D-14473 Potsdam

Published in Potsdam, Germany
January 2018

ISSN 2190-7110

DOI: http://doi.org/10.2312/GFZ.b103-17094
URN: urn:nbn:de:kobv:b103-17094

This work is published in the GFZ series
Scientific Technical Report (STR)
and electronically available at GFZ website
www.gfz-potsdam.de

Andreas Köhler, Christian Weidle, Christopher Nuth

Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Report

Scientific Technical Report STR17/09 – Data
GIPP Experiment and Data Archive

Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Report

Andreas Köhler[1], **Christian Weidle**[2,*] & **Christopher Nuth**[1]
[1] *Institutt for geofag, Universitetet i Oslo, PB 1047, 0316 Oslo, Norway*
[2] *Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Otto-Hahn-Platz 1, 24118 Kiel*
[*] *corresponding author*

Abstract

The consequences of climate change are highly important in the polar regions as ice-sheets and glaciers respond strongly to change in average temperature. The analysis of seismic signals (icequakes) emitted by glaciers (i.e., cryo-seismology) is thus gaining importance as a tool for monitoring glacier activity. To understand the scaling relation between regional glacier-related seismicity and actual small-scale local glacier dynamics and to calibrate the identified classes of icequakes to locally observed waveforms, a temporary passive seismic monitoring experiment was conducted in the vicinity of the calving front of Kronebreen, one of the fastest tidewater glaciers on Svalbard (Fig. 1). By combining the local observations with recordings of the nearby GEOFON station GE.KBS, the local experiment provides an ideal link between local observations at the glacier to regional scale monitoring of NW Spitsbergen. During the 4-month operation period from May to September 2013, eight broadband seismometers and three 4-point short-period arrays were operating around the glacier front of Kronebreen.

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

1. Introduction

The primary objective of this project was to improve the understanding of the relation between dynamic glacial processes and observations of glacier-related seismic signals on Svalbard. This was planned to be accomplished through the detection, localization, classification, and analysis of the spatial-temporal distribution of icequakes recorded over the past 15 years at existing, permanent seismic stations on Svalbard. To classify and characterize different types of icequakes, we combined independent glacier observations of surging and calving with seismic data of a temporary local seismic monitoring experiment. The overall goal of this project was to evaluate the potential of future continuous seismic glacier monitoring on Svalbard.

Our previous work has shown that regionally observed glacier seismicity is dominated by a class of events that can be clearly related to individual tidewater glaciers on Spitsbergen. The temporal distribution shows a clear seasonality with a strong increase in late spring, reaching its maximum during the end of the summer melt season when sea surface water temperature is highest. Seismic signals show a clear peak in the amplitude spectrum between frequencies of 1 and 5 Hz, making them easier to distinguish from tectonic earthquakes.

The Kongsfjord region in northwest Spitsbergen is one major source for this type of glacier seismicity. We have relocated events in that region in 2013 using the data of the field experiment. Locations at the termini of glaciers and correlation with direct, visual calving observations at Kronebreen, show that these events are dominantly caused by iceberg calving (Köhler et al., 2015, 2016).

Our results clearly prove the feasibility of seismic glacier monitoring on Svalbard. We have not only successfully characterized the types and spatio-temporal distribution of glacier seismicity, but also showed how seismic observations can be used to monitor and improve the understanding of glacier dynamic processes. Important future applications will be

DOI: 10.2312/GFZ.b103-17094

continuous, high-temporal resolution monitoring and quantification of ice loss through calving and the fast detection of beginning or ongoing glacier surges on Svalbard.

2. Data Acquisition

2.1 Experiment design and schedule

The primary objective of the temporary deployment was to accurately locate seismic signals emitted by the surrounding glaciers, in particular the fast moving Kronebreen, and relate these events to certain types of glacial processes. Therefore, the deployment focused around the glacier front of Kronebreen with its highly active calving front.

Three 4-point mini-arrays were equipped with short-period instrumentation to cover the high-frequency part of the calving signals which are dominant between 1 and 5 Hz.

To eventually locate other, longer period types of signals from the glacier – for instance resonance vibrations or sliding of the glacier on its bed – a larger network was installed in the vicinity and upstream of the glacier with broadband seismometers.

2.2 *Geometry/Location*

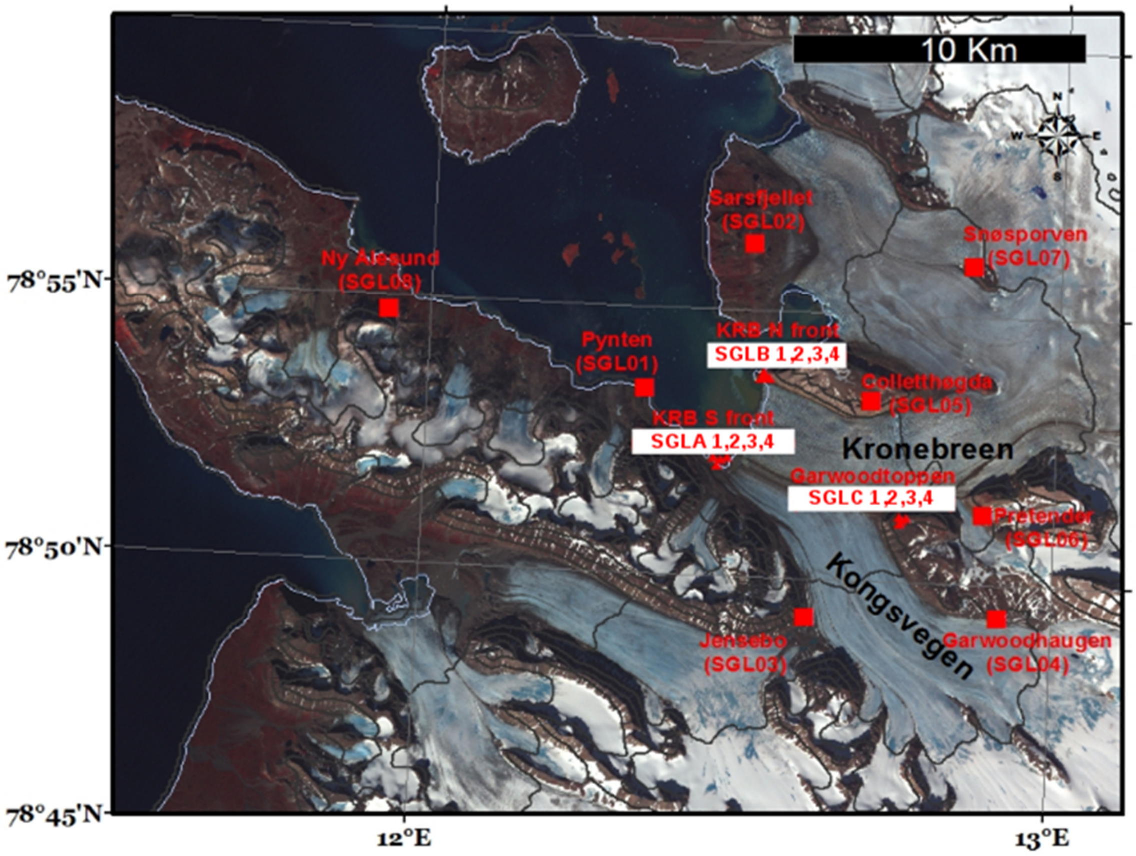

Figure 1: *Study area in northwestern Spitsbergen. Station network is shown by red squares (broadband instruments) and triangles (short-period mini-arrays)*

Site name	Longitude	Latitude	Elevation	Sensor no. / Digitizer	Recorder no.
SGL01	12.3465°	78.8912°	9.1 m	T3A99 / D639	DCM753
SGL02	12.5110°	78.9377°	308.8 m	T3B02 / D636	DCM843
SGL03	12.6137°	78.8214°	278.5 m	Trillium 14	EDL3089
SGL04	12.9179°	78.8230°	366.7 m	T3A11 / D598	DCM836
SGL05	12.7069°	78.8897°	467.2 m	T3A96 / D638	DCM852
SGL06	12.8894°	78.8551°	363.6 m	T3A70 / D600	DCM854
SGL07	12.8620°	78.9329°	330.6 m	T3A95 / D602	DCM847
SGL08	11.9347°	78.9122°	67.2 m	Trillium 13	EDL3090
SGLA1	12.4633°	78.8678°	8.9 m	185	715
SGLA2	12.4682°	78.8698°	12.7 m	183a	615
SGLA3	12.4799°	78.8705°	11.6 m	181a	716
SGLA4	12.4571°	78.8705°	12.2 m	177	723
SGLB1	12.5271°	78.8955°	35.6 m	179	722
SGLB2	12.5432°	78.8958°	53.6 m	178	720
SGLB3	12.5344°	78.8964°	18.1 m	174	721
SGLB4	12.5322°	78.8978°	15.8 m	182a	609
SGLC1	12.7568°	78.8518°	565.8 m	184a	719
SGLC2	12.7562°	78.8540°	609.3 m	175	717
SGLC3	12.7665°	78.8535°	624.6 m	180	718
SGLC4	12.7599°	78.8530°	602.8 m	176	724

Table 1: *Station locations and associated recording units. Recorders DCMxxx are Güralp recorders, EDLxxxx EarthData recorders and three-digit numbers are Cube3D recorders.*

2.3 Instrumentation

The network contained a broadband and a short-period array component. Broadband seismometers were provided by Kiel University (Güralp CMG-3T & DM24 @ SGL01, 02, 04, 05, 06, 07) and the GIPP Pool of the GFZ German Research Centre for Geosciences in Potsdam (Trillium 120 & EDL @ SGL03, 08). A total of 12 4.5Hz geophones and Cube recording units were installed in three 4-point arrays, two on both sides of the glacier tongue (SGLA1-4, SGLB1-4) and one further upstream on a Nunatak (exposed mountain within a glacier; SGLC1-4).

2.4 Acquisition parameters

Station spacing between the broadband instruments is 3-6 km. Distance between the three arrays is about 3.5 km (SGLA – SGLB) and 5 km (SGLA/B – SGLC), and each of the 4-point arrays had an aperture of ~500 m. All data were recorded at 100 Hz sampling rate.

3. Data Processing

Raw data were converted to MSEED (FDSN, 2012) using the *GIPPtools*[1] software package (for Cube and EDL recordings) and Güralp proprietary conversion tools (gcf2msd) for the Güralp data.

---

[1] www.gfz-potsdam.de/gipp → Software → GIPPtools

4. Data Description

Continuous waveform data was recorded at 100 sps on three components (ZNE) from April 30th to September 15th, 2013. The data completeness is shown for the Z-component in Figures 2 and 3 for the broadband and short-period units, respectively:

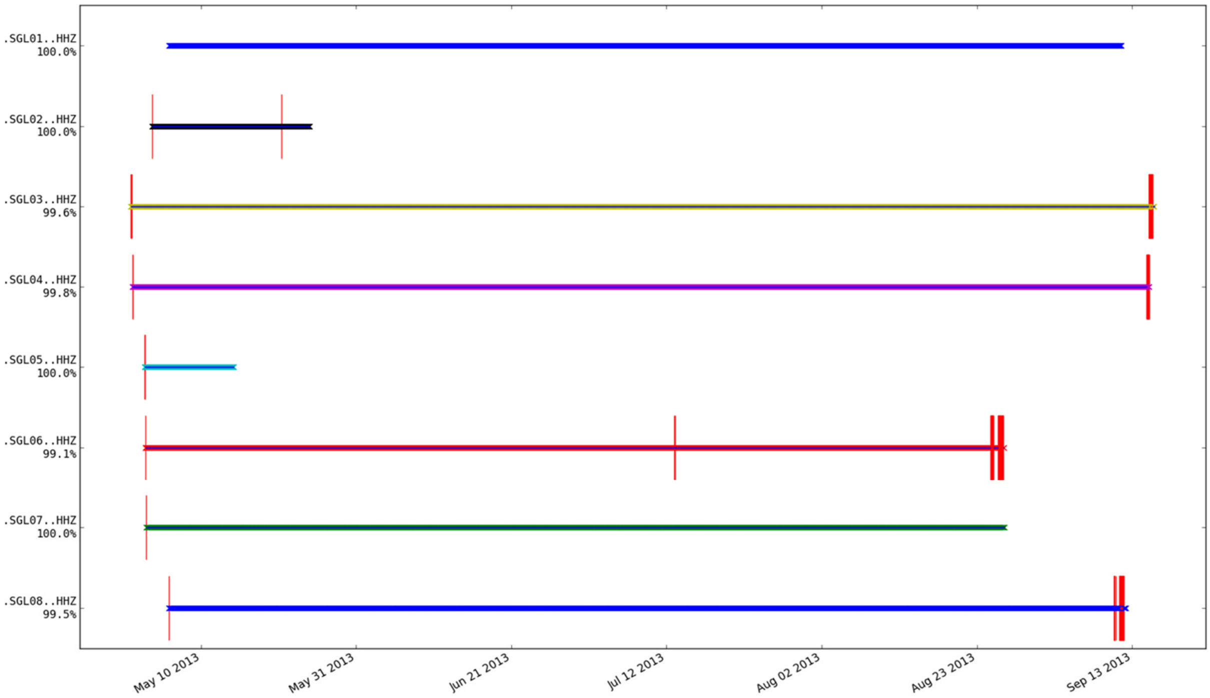

Figure 2: *Data availablity of broadband data from the SEISMOGLAC experiment.*

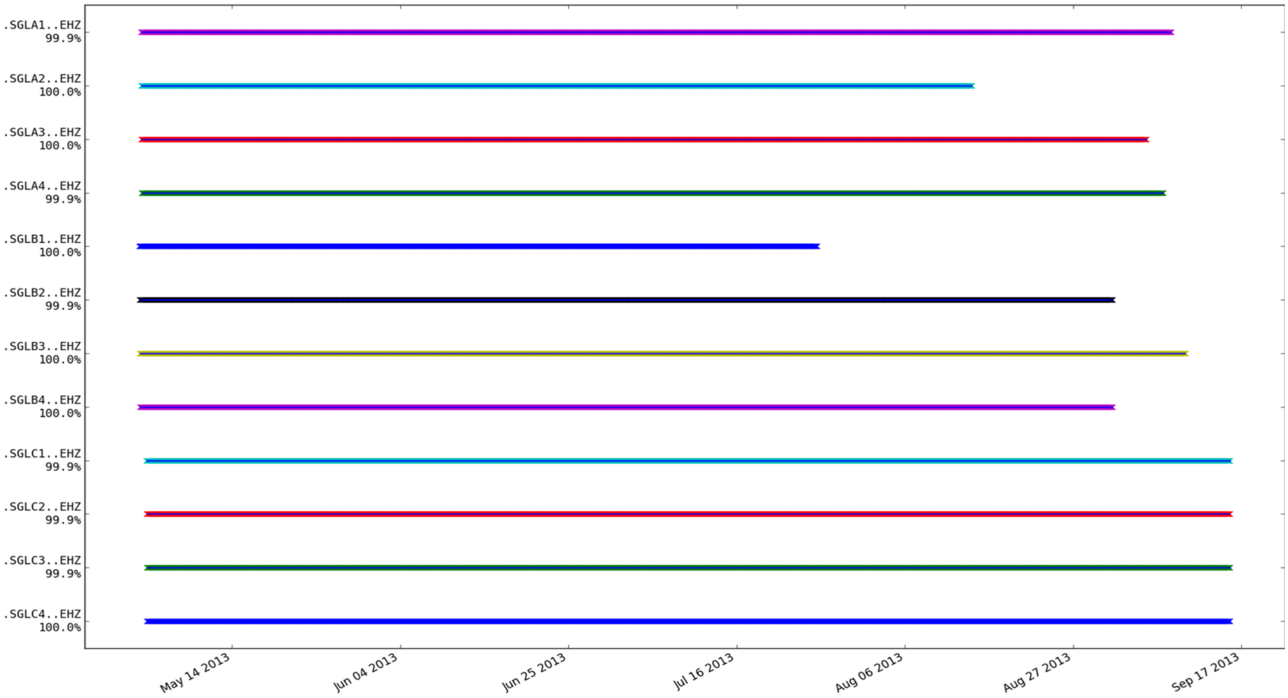

Figure 3: *Data availablity of short-period data from the SEISMOGLAC experiment.*

DOI: 10.2312/GFZ.b103-17094

4.1 File format (s)

Data are contained in raw recorder format (directory RAW) and a consistently converted to MSEED format structure (directory MSEED).

4.2 Data content and structure:

The RAW data directory is sorted by each recording device. The MSEED directory contains a per Julian day data structure with data from each station in a subdirectory.

5. Data Quality/Accuracy

station	May	June	July	August	September	Usable?
SGL01	Very high noise level/broken sensor	Very high noise level/broken sensor	Very high noise level/broken sensor	Very high noise level/broken sensor	Very high noise level/broken sensor	0 days?
SGL02	ok	-	-	-	-	21 days
SGL03	ok, gap:1.6. 11:46-17:48	Vertical ok – no horizontal components from 2.6.-22.6.	ok	ok	ok	4.5 months
SGL04	ok – spikes	ok – spikes	ok – spikes	ok – spikes	ok – spikes	4.5 months
SGL05	ok – time shift 12.3s!	-	-	-	-	12 days
SGL06	ok	ok	Very high noise level/tilted sensor	Very high noise level/tilted sensor	-	2 months
SGL07	ok	ok	ok	ok	-	4 months
SGL08	ok until 21.5. 18:28, gap until 31.5. 05:13	ok until 18.6. 17:23, gap/bad data until 22.6. 02:09, ok after	High noise level – but still events	High noise level – but still events	High noise level – but still events	<4 months
SGLA1	ok	ok	ok	ok	ok	4 months +
SGLA2	ok	ok	ok	ok – 14.8.	-	3.5 months
SGLA3	ok	ok	ok	ok	ok	4 months +
SGLA4	ok	ok	ok	ok	ok	4 months +
SGLB1	ok	ok	ok until bear/fox attack	-	-	3 months
SGLB2	ok	ok	ok	ok	-	4 months
SGLB3	ok	ok	ok	ok	ok	4 months +
SGLB4	ok	ok	ok	ok		4 months
SGLC1	ok	ok	ok	ok	ok	4.5 months
SGLC2	ok	ok	ok	ok – 3.8. ~9:00 – beginning losing coupling, still events	lost coupling, no events	3-4.5 months
SGLC3	ok	ok	ok until ~19.7., beginning losing coupling, still events	lost coupling, no events	lost coupling, no events	2.5-4.5 months
SGLC4	ok	ok	ok	ok	ok	4.5 months

Table 2: *Data completeness and quality indications.*

6. Data Availability/Access

Data is archived at the *GIPP Experiment and Data Archive* where it will be freely available for further use under a “Creative Commons Attribution-ShareAlike 4.0 International License” (CC BY-SA 4.0).

When using the data, please cite the SEISMOGLAC dataset (see below) as well as Köhler et al. (2015), and acknowledge the use of GIPP instruments. You can additionally cite this Scientific Technical Report STR, especially if referring to specific details explained therein.

Recommended citation for data described in this publication:

Köhler, A., Weidle, C., & Nuth, C. (2017) Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) – Dataset. GFZ Data Services.
DOI: http://doi.org/10.5880/GIPP.201303.1

Recommended citation for this report:

Köhler, A., Weidle, C., Nuth, C. (2018): Seismic Monitoring of Glacier Activity on Svalbard (SEISMOGLAC) - Report, (Scientific Technical Report STR - Data; 17/09) (GIPP Experiment and Data Archive), Potsdam: GFZ German Research Centre for Geosciences.
DOI: http://doi.org/10.2312/GFZ.b103-17094

Acknowledgments

This study was funded by the Research Council of Norway (project SEISMOGLAC, 213359/F20). Instrumentation of the local seismic field measurement at Kronebreen was provided by the Geophysical Instrument Pool of the GFZ German Research Centre for Geosciences in Potsdam and Kiel University. Special thanks go to Thomas Schellenberger (University of Oslo) and Jack Kohler (Norwegian Polar Institute) for support during station deployment in 2013. We appreciate financial support from the Industrial Liaison fund, University of Oslo.

References

FDSN (2012): *SEED Reference Manual* – Standard for the Exchange of Earthquake Data. SEED Format Version 2.4, Publisher: IRIS.

Köhler, A.; Nuth, C.; Schweitzer, J.; Weidle, C. & Gibbons, S. (2015) Dynamic glacier activity revealed through passive regional seismic monitoring on Spitsbergen, Svalbard. Polar Research, 34, 26178; http://doi.org/10.1093/gji/ggv297

Köhler, A.; Nuth, C.; Kohler, J.; Berthier, E.; Weidle, C. & Schweitzer, J. (2016) A fifteen-year record of frontal glacier ablation rates estimated from seismic data. Geophysical Research Letters, Wiley-Blackwell, 43, 12155-15164; http://doi.org/10.1002/2016gl070589

Nuth, C.; Köhler, A.; Weidle, C. (2014) Seismic Sounds of Calving: a calving event and its corresponding seismic signal caught on video: https://www.youtube.com/watch?v=bZn2qyVjCoIURL

ISSN 2190-7110