Preliminary seismological interpretation of landslide and seiche event in NW Greenland, 17/6/2017

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Context and seismic monitoring

On Saturday evening on the 17th of June, 2017, a large landslide occurred in NW Greenland, around 20km from the small fishing village of Nuugaatsiaq, population 100, which lies on an island in Karrat Fjord. The slide slipped into the fjord, inducing a large seiche. Shortly afterwards, waves inundated much of the village, producing widespread destruction - 11 houses were swept out to sea, and 4 people are missing, presumed dead. Though the damage was greatest at Nuugaatsiaq, the villages of Illorsuit and Niaqornat were also strongly affected. In total, approximately 200 people have been evacuated from the 3 villages, and the public in the wider area is very much on edge, not least because there appear to be additional unstable areas adjacent to the causative slide.

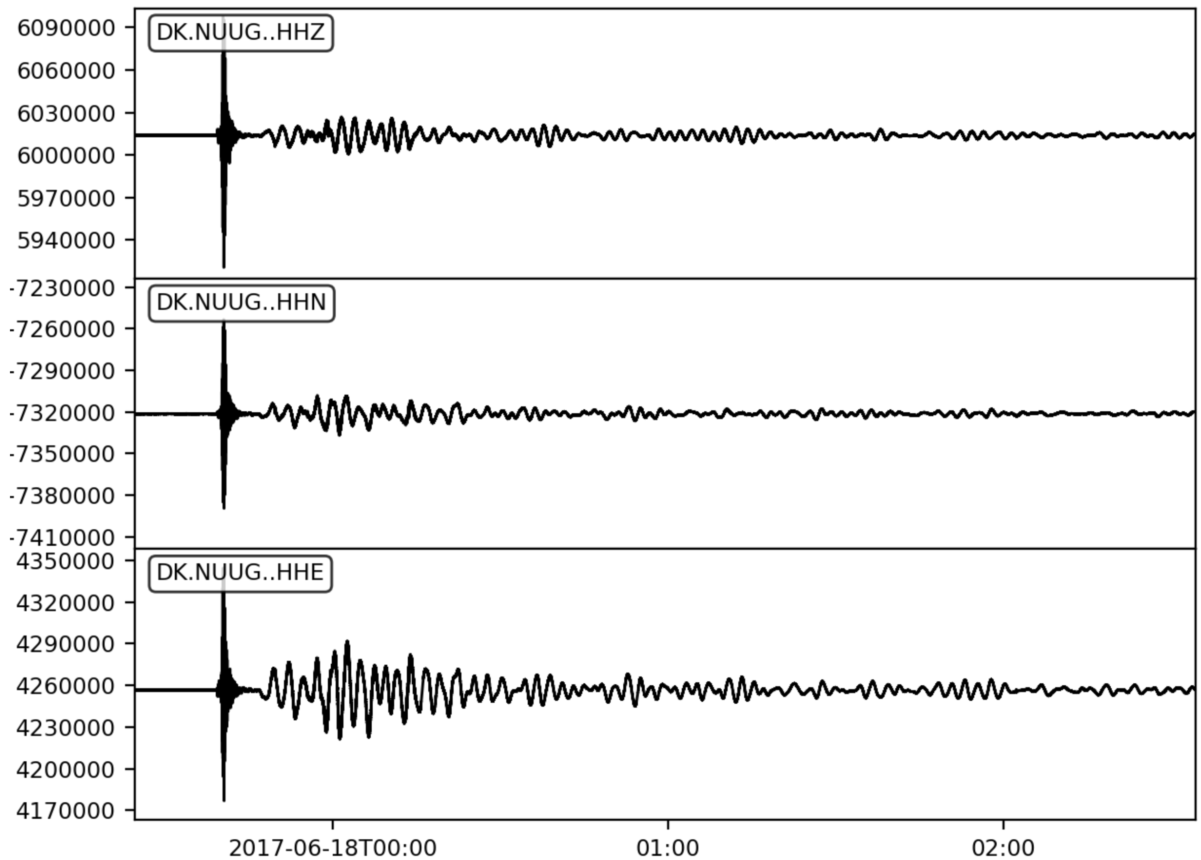
The slide was so large that it generated seismic energy visible across the globe, and very first analysis suggested the event was caused by an earthquake with a magnitude of Ml4.1. Subsequent careful examination of the available seismic waveforms indicates no significant triggering tectonic event directly preceded the slide. The landslide lit up all stations from GLISN (http://glisn.info), a modern 30-station-strong broadband seismic network covering Greenland and built over the last decade through an international effort led by GEUS and IRIS. A GLISN broadband seismic station, NUUG, installed by ETH Zurich, has been operational in the town since 2010. The STS2 is located in a small purpose-built hut at 36m elevation on the outskirts of the village, and so was not damaged by the inundation. The station recorded the seismic energy generated by the slide and responded to the ground tilt induced by the fluctuating water levels from the resultant seiche; its waveforms were transmitting to global data centers in real-time until about 10 minutes after the large waves began arriving, when power and communications were lost at the village. The complete dataset of the event was retrieved when power was temporarily reconnected the following Tuesday.

Photo of the village highlighting the location of the NUUG seismic station, July 2010 (photo: John Clinton)

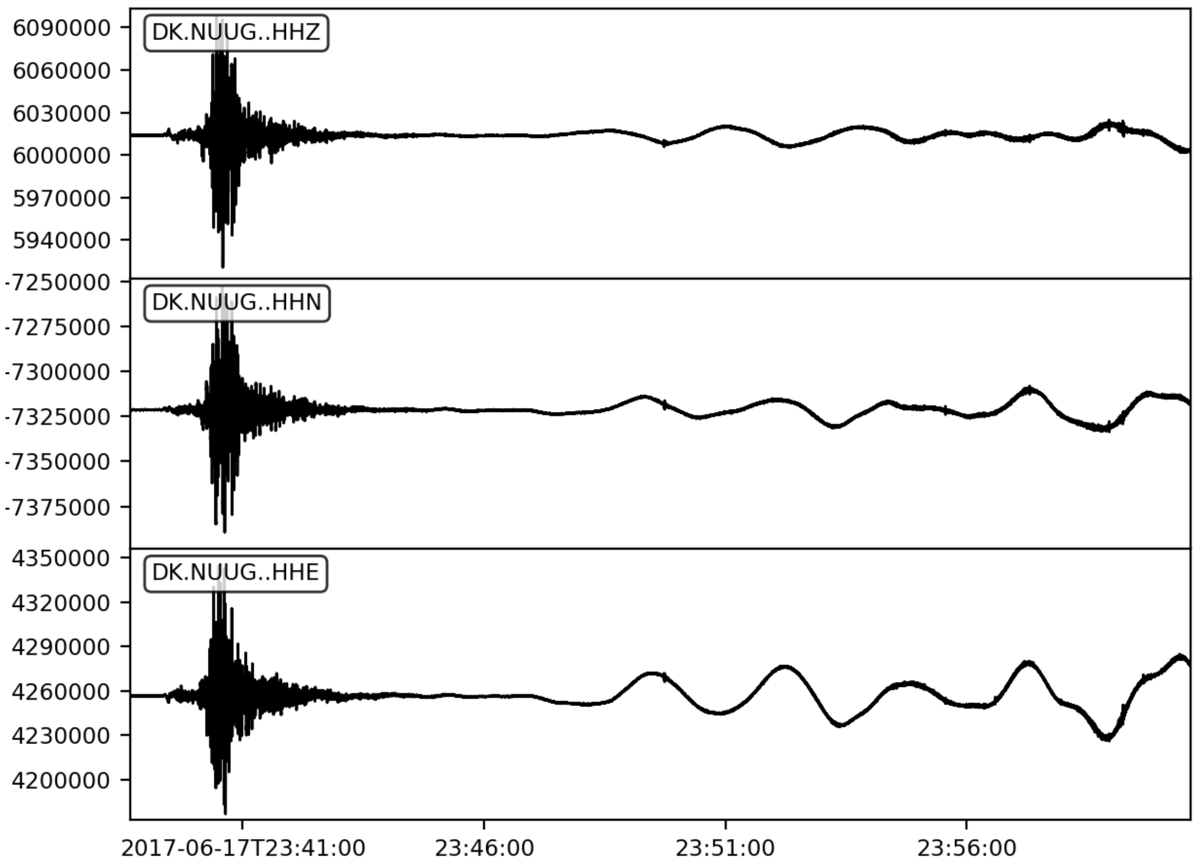
Photo of NUUG seismic station from off-shore, July 2010 (photo: John Clinton)

Observations from NUUG

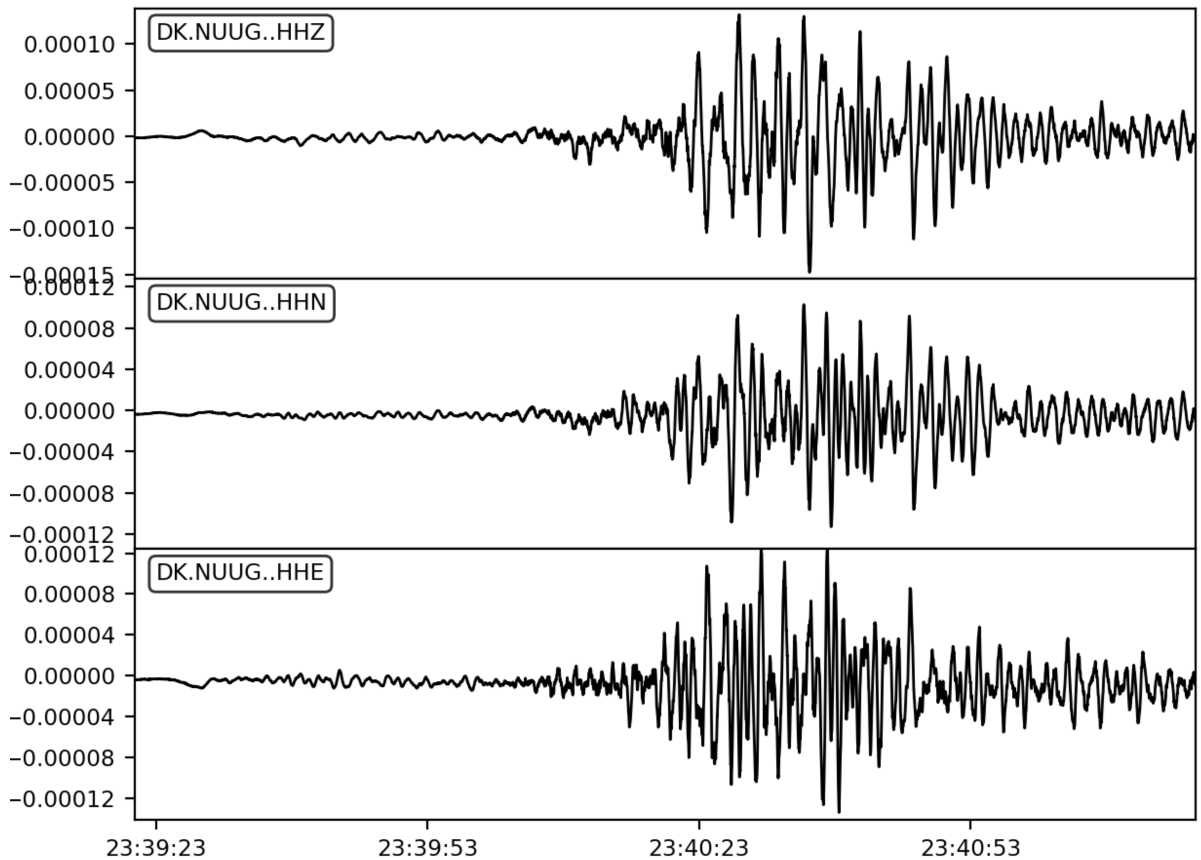
The timeseries from NUUG clearly records both the slide and the resulting inundation events. Seismic waves from the landslide reached the town at 23:39 UTC and had a duration of about 5 minutes. This long duration and the relatively monochromatic, long-period signal that slowly increases in amplitude are indicative of complex landslide signals. Long-period, large-amplitude water waves pounded the shoreline of the village for hours after the landslide. These signals emerge in the seismograms around 7 minutes after the start of slide, and include over 20 cycles of waves, with a period of 3 minutes, lasting over 3 hours. This signal is the broadband seismic sensor responding to ground tilt induced by the changing sea level.



Raw time-series recorded at NUUG (y-axis in counts), duration 3 hours. Very long period seiche event follows minutes after the higher frequency slide event, high amplitude waves continue for about 45 minutes, though the waves continue to resonate in the fjord for many hours. Note massive offset in counts for the station - the sensor cannot be remotely re-centered, it is planned to replace the sensor in July.



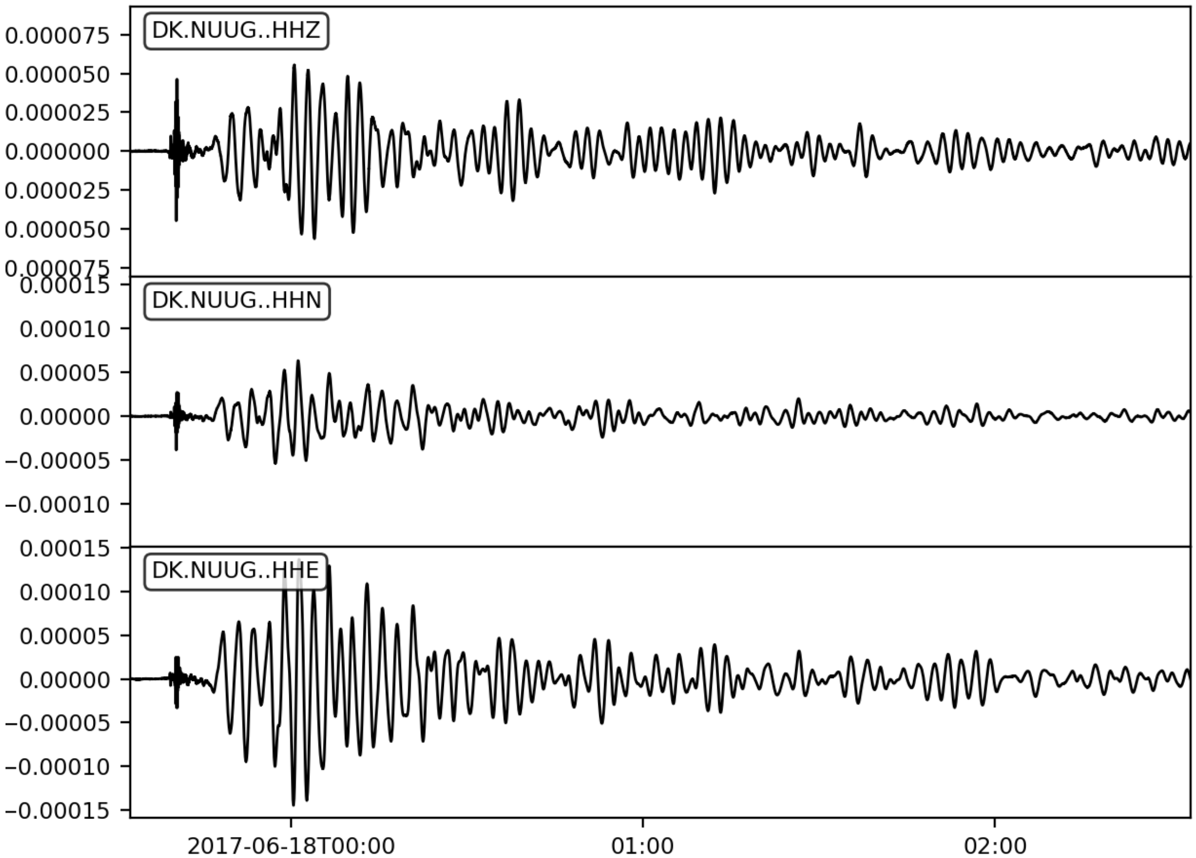
Raw time-series recorded at NUUG (y-axis in counts), duration 20 minutes. Duration of slide event is about 5 minutes.



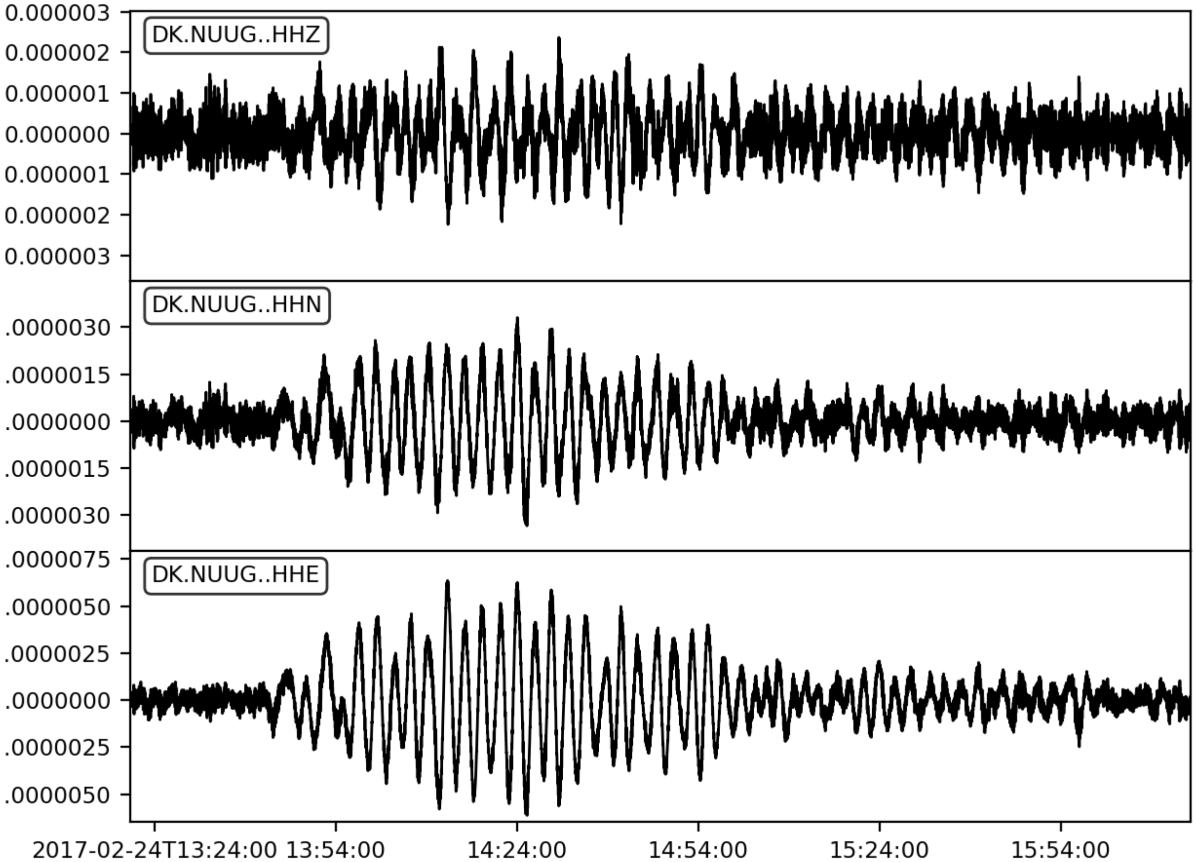
Velocity time-series from NUUG, (y-axis in m/s). Focusing on first few minutes of the slide signal. Note very long period onset followed by high frequency, high amplitude energy about 1 minute later.

Comparisons with glacial calving events

This station has in the past recorded similar seiche signals from glacier calving events from nearby Rink Glacier (doi:10.3189/2013JoG12J118). Such calving events are detected as glacial earthquakes (doi:10.1126/science.1088057), and a large example occurred earlier this year. The following figures compare seiche signals induced from the slide and a glacial earthquake. They are remarkably similar in frequency and duration, even though the amplitude is about a factor of 30 larger for the destructive signal following the landslide.



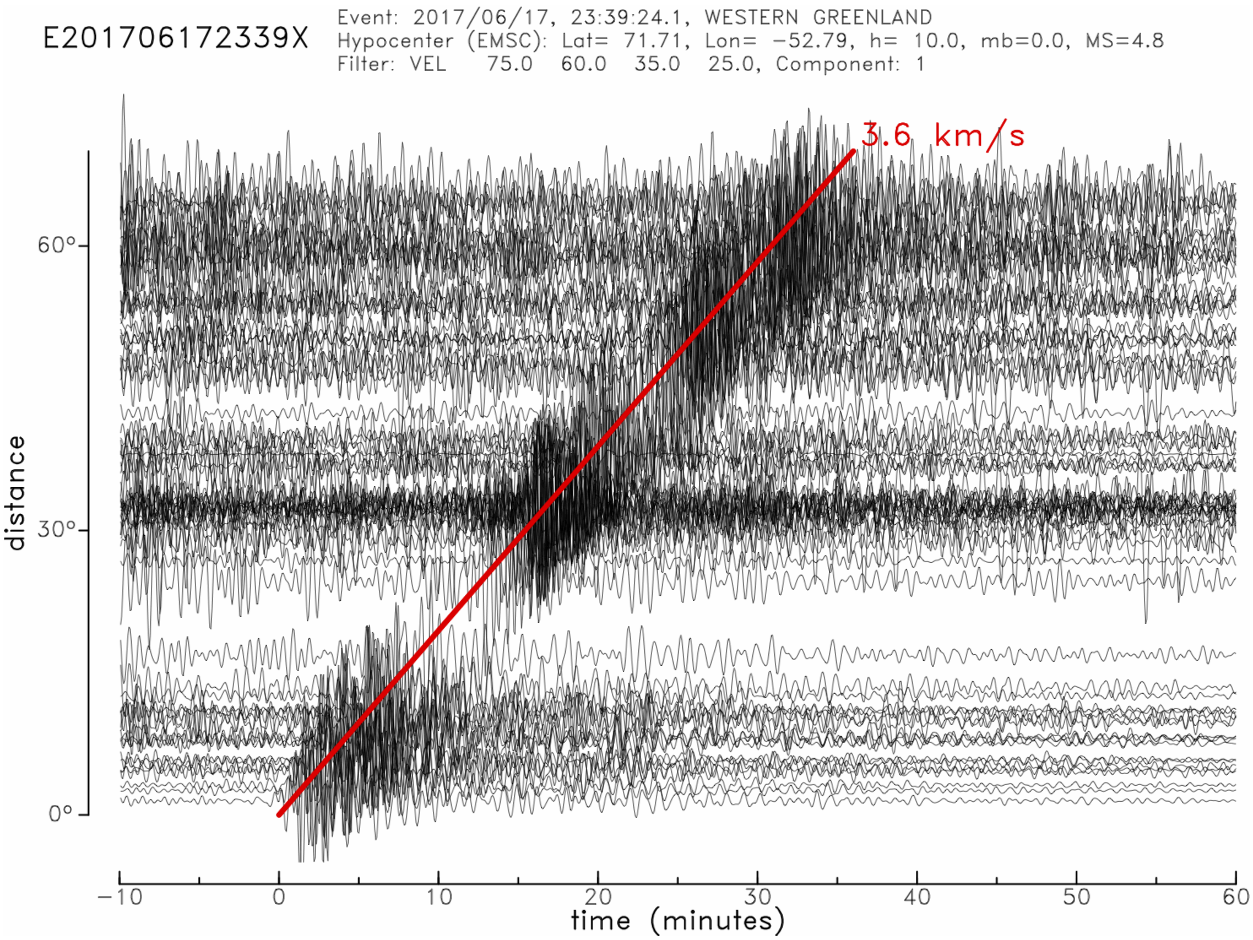
Seiche signal from the landslide, displacement time-series (y-axis in m). Approx 3 hour window.



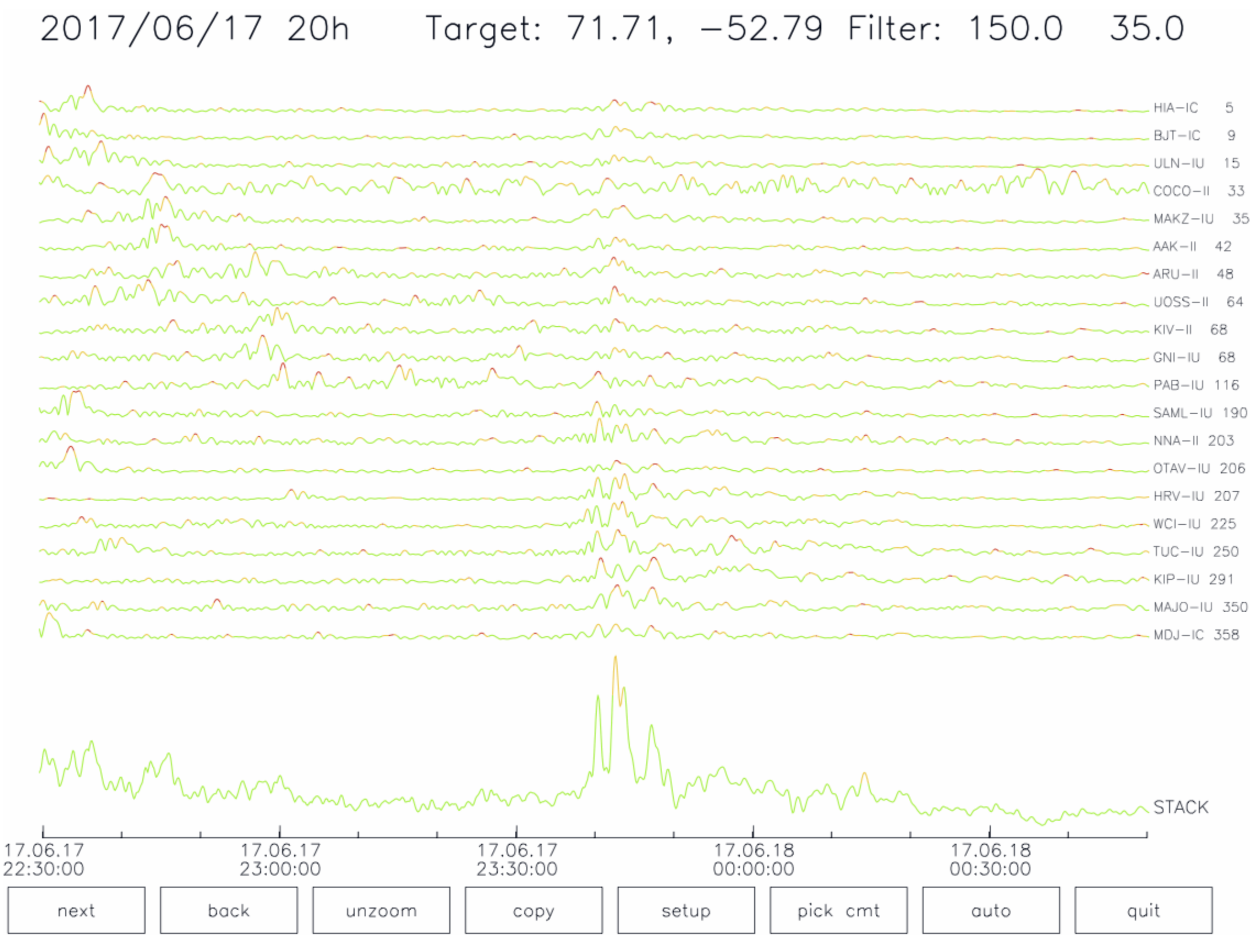
Seiche signal for a large, teleseismically observed Glacial Calving event at Rink Glacier occurring earlier this year (y-axis in m). Approx 3 hour window.

Observations from regional and global seismic stations

The long-period signals observed across the GLISN network, and around the globe, are consistent with generation by a landslide source, and show larger amplitudes and greater complexity than the glacial-earthquake signals regularly observed as a result of large glacier-calving events at nearby Rink Glacier. The long-period signal suggests failure occurred in two or more stages.



Record section showing vertical-component seismograms (filtered to velocity, 25-75 sec period) from stations of the GLISN and GSN seismic networks.



Landslide signal (envelope function) as recorded globally at stations of the Global Seismographic Network (GSN). Seismograms are sorted by azimuth (top to bottom, azimuth given at right of each trace), and have been migrated to the source location; effects of dispersion and attenuation have been removed from each trace. The signal is far more complex than that typical for a moderate-to-large-sized tectonic earthquake or glacial earthquake.