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Searching for glacier-induced seismic events using a combined approach of STA/LTA triggering and unsupervised pattern recognition

Andreas Köhler (1), Anne Chapuis (2), Christopher Nuth (1), and Christian Weidle (1)

(1) University of Oslo, Department of Geosciences, Oslo, Norway (andreas.kohler@geo.uio.no), (2) Norwegian University of Life Sciences UMB

In seismology, mainly supervised classification methods are used for signal detection. These approaches rely on manually prepared training data sets or examples of known event types. Unsupervised pattern recognition techniques generate an initial understanding of the unknown data properties without utilizing existing class or event labels. Here, we present a processing scheme which combines classical event detection using a sensitive STA/LTA trigger and unsupervised clustering of all detected signals based on amplitude statistics, frequency spectrum, and temporal characteristics. The Self-Organizing Map (SOM) algorithm, a sort of unsupervised neural network, is employed. SOMs generate an intuitive, two-dimensional visualization of a data set of arbitrary dimension. This representation allows us to evaluate and validate automatically generated clusterings which is a very crucial step in finding a meaningful cluster solution.

The method is applied to single-channel geophone data recorded over several months in 2009 and 2010 close to Kronebreen, a calving glacier on Svalbard. Our approach is suitable and reasonable within this context, since no detailed information about the character of potentially observable glacier seismic signals was available a priori. We aim to identify and investigate signals which could be related to glacial activity. Direct (visual) observations of the glacier front are available for one week which allow us to compare seismic event clusters with ground-true data.

A large number of signals is detected by the STA/LTA trigger. Given the final event clustering, we are able to distinguish between false alarms, instrumental noise/artifacts, and signals which are interpreted as seismic events. Due to the lack of man-made noise in the remote study area, most events are likely related to glacial activity, in addition to a few local earthquakes. We are able to successfully correlate about 10% of the directly observed calving events close to the geophone (<1 km) with our detections. Events observed at larger distances cannot be matched with detections, most likely due to the high noise level in the data. Considering the signal clusters which are identified as glacier events using the matching direct observations, the temporal distribution of events is analyzed within the entire recording period.