Repeating Icequakes at the Grounding Line of Rutford Ice Stream, West Antarctica

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Abstract

Basal microseisms in Antarctica, or icequakes, are valuable data sources that we can use to determine features and processes at the bed to improve our understanding of ice flow dynamics in the region. In the 2018/19 austral summer, we collaborated with the British Antarctic Survey (BAS) to deploy several seismic arrays of short period instruments over ˜2 months in Rutford Ice Stream in West Antarctica to monitor natural source seismicity. During this recording period, we detected several swarms of repeating icequakes (˜40 s interevent time) at our grounding line array that originate from a common basal source, which we hypothesize to be stick-slip motion over sticky spots/asperities. Smaller scale repeating icequakes, both in terms of amplitude and interevent times, also exist among the original larger repeating icequakes and are also hypothesized to originate from multiple smaller sticky spots that had less consistent loading and slipping. We built an auto-picker to detect these repeating icequakes over our recording period and located them using the automatic earthquake location Python package QuakeMigrate, and here we present our results as well as what they tell us about the basal topography. Further investigation of the interevent offsets between repeating signals of varying amplitudes and their frequency characteristics via FFT will provide more insights into the basal features, which we will corroborate with GPR basal topography data. Relations of the repeating icequakes to aseismic slip and tides will also be investigated. The findings at our grounding line array, where the repeating icequakes were first detected, can later support similar searches at the inland arrays. Antarctic ice streams remain a major source of uncertainty in projections of sea level rise, and our work seeks to constrain this uncertainty by improving our understanding of ice stream dynamics through basal conditions.

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Research Site - Rutford Ice Stream

- Numerical models are used to quantify Antarctica's future contribution to sea-level rise, but remain poorly modeled due to inadequate bed information
- Icequakes are a rapid, high-volume method to gain information about glacier beds

Fig. 1. Location of the Rutford Ice Stream (RIS) on a map of Antarctica. The RIS is situated on the West Antarctic Ice Sheet (WAIS) and drains into the Ronne Ice Shelf. As part of the BEAMISH project to perform a detailed survey of the Rutford bed, we collaborated with the British Antarctic Survey (BAS) to install several seismic arrays at inland RIS and one close to the RIS grounding line. We are currently focusing on the grounding line array, which consists of 29 stations that are each equipped with a 3-component geophone sampling at 1000 Hz.

Repeating Signals & Clustering

- Repeating signals can give information about sticky spots - localized regions of high basal drag surrounded by a weaker bed
- Basal shear stress (resistance) of ice streams are disproportionately supported on sticky spots
- Repeating events picked using a self-developed amplitude-based picker, located using the QuakeMigrate software and clustered with DBSCAN
- Resolve sticky spot characteristics (dimensions, #) and cluster interactions within the unexplored Rutford grounding line array

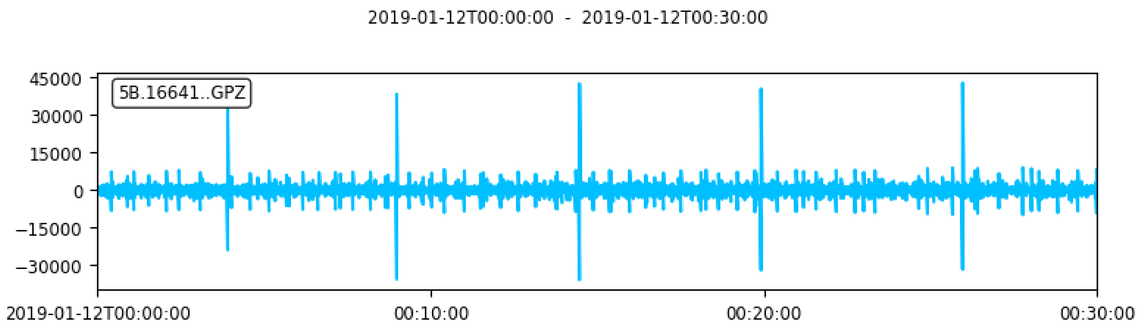
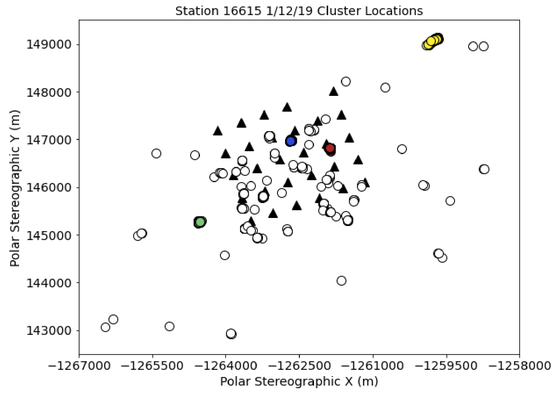


Fig. 2. Vertical component trace of Station 16641, part of the grounding line array

Cluster Analysis (Ongoing)



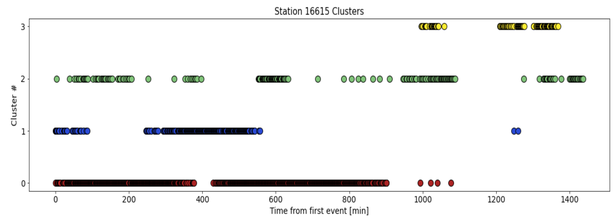


Fig. 4. One-day timeline of Station 16615 clusters

Fig. 3. Horizontal locations of Station 16615 clusters located using DBSCAN, a machine learning method for grouping events based on proximity (~100 m) and density (minimum number of events that are all chained together by the proximity distance). Successfully grouped clusters are shown in color while events that remain white were either too far away from other events or were not able to form a dense enough cluster.

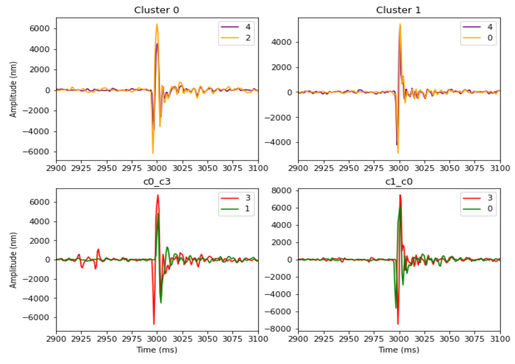


Fig. 5. Overlain Station 16615 traces for intra-cluster (top row) and inter-cluster (bottom row)

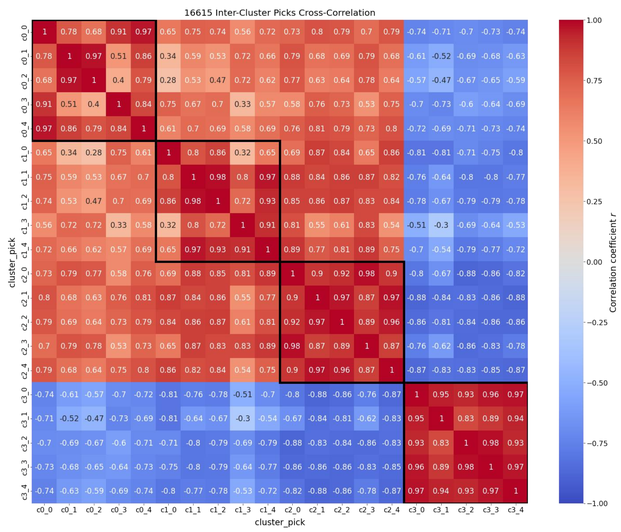


Fig. 6. Cross-correlation heatmap of Station 16615 intra- & inter-cluster picks computed around a small wave-arrival window

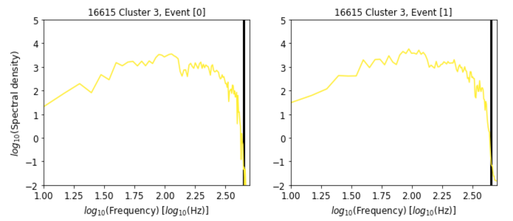


Fig. 7. Log-log plots of Station 16615 events

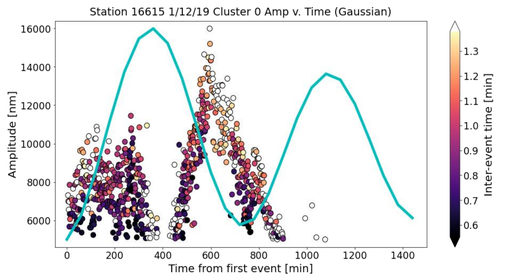


Fig. 8. Amplitude vs. time plot for cluster 0 in Station 16615 compared with tidal data

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References

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