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Riftquakes: Recording and Modeling Seismic Signals of Rifting at Pine Island Glacier

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Nearly 50% of Antarctic ice discharge into the ocean occurs via iceberg calving (Depoorter et al 2013). Large tabular icebergs calve from ice shelves along large fractures called rifts, but the physics of rifting are poorly understood. How fast does rift propagation occur? Does the timing of rift fracture coincide with episodes of unusual ice motion? We investigate these questions using data from seismometers and GPS sensors deployed on Pine Island Glacier ice shelf (PIG) from January 2012 to December 2013 surrounding the calving of iceberg B31, which exceeded 700 km² in size and calved in November 2013 along a large rift. Using TerraSAR-X imagery, we identify a large 7km-long rift that must have occurred between May 8 and May 11, 2012. We identify a large-amplitude seismic signal on May 9, 2012, which we attribute to the rifting event. The signal is broadband, containing energy at frequencies higher than 1 Hz and lower than 0.01 Hz, and exhibits pronounced dispersion characterized by high frequencies arriving before low frequencies. We use features of the May 9 “riftquake” to detect thousands of similar events, which we classify using K-shape clustering. We hypothesize that the observed signals are flexural gravity waves generated by a bending moment applied to the ice shelf during fracture. To test this hypothesis, we model the ice shelf as a dynamic beam supported by an inviscid, incompressible ocean. We find that the model reproduces observed riftquake waveforms when forced with a bending moment. We then use a Markov Chain Monte Carlo inversion to model representative events from each cluster of observed events. The inversion reveals that source durations on the order of seconds have the highest likelihood of explaining observed riftquake waveforms, suggesting that rifting occurs on elastic timescales. Finally, we locate the riftquakes and find that a swarm of events originating at the rift tip occurs just after the start of a period of acceleration at PIG, suggesting that the stress concentrations driving rift opening are influenced by changes in ice dynamics.