Geophysical Research Abstracts,
Vol. 10, EGU2008-A-11155, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-11155
EGU General Assembly 2008


# GeoPebble: A wireless seismic and GPS sensor for monitoring of fast-flowing glaciers

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Recent discoveries of high-frequency fluctuations in the flow speed of Antarctic and Greenland glaciers and ice streams suggests the need for new instrumentation to fully measure this intriguing behavior. Some of the fast-flowing glaciers ($>$ 1 m/day) in Greenland and Antarctica change flow speed on diurnal, seasonal, and annual time scales. These flow speed variations are associated with seismic emissions at both long period (30–100s) and short period ($\sim$ 1 s). Measuring the flow speed variability with satellite remote sensing is difficult because of the long repeat times of those sensors. Measuring the spatial pattern of this signal is difficult with ground based high-precision (geodetic-quality) GPS because of the high cost of those instruments. The seismic sensors available to date are also expensive and must be retrieved at the end of the experiment.

We have developed an inexpensive combined single-frequency GPS and short-period seismic sensor ("geopebble") that is wirelessly connected to a base station. Because flow speeds are high and the variations in flow are also high for the large outlet glaciers in Greenland and the ice streams of Antarctica, we can use single-frequency GPS receivers to measure position and calculate velocity. These receivers have accuracies of the order 0.1m, which is adequate for our application. They are also relatively inexpensive, and low power. The seismic sensor is a three-component geophone, which is also relatively inexpensive, but still adequate to measure microseismicity associated with surges and slips of glaciers (they will not detect the low-frequency events that are recorded at great distances from the glacier, however.) The geopebble has a wifi radio to transmit the digitized seismic signal and the GPS phase measurements to the base station. Thus the sensor can be deployed on, e.g., heavily-crevassed outlet glaciers in

Greenland with the expectation that some might not be recovered. However, the data will always be available.

These instruments are also valuable for reflection seismic surveys where they will allow us to do away with the multiconductor cables that typically stretch between geophones and connect to the central digitizer.