Tidal Modulation of Ice Flow on Helheim Glacier, East Greenland

A report for the Dan and Betty Churchill Exploration Fund

Leigh A. Stearns, PhD candidate, University of Maine Climate Change Institute

Background

Mass from the interior of the Greenland Ice Sheet is transported to the ocean by numerous large, fast-flowing outlet glaciers. Changes in the flow configuration of these outlet glaciers modulate ice sheet mass balance and sea level. Recent estimates show that Greenland's contribution to sea level more than doubled in the past decade, increasing from 0.23 ± 0.08 mm/yr in 1996, to 0.57 ± 0.10 mm/yr in 2005, and that the majority of this mass loss is due to changes in the dynamics of a few large outlet glaciers [Rignot and Kanagaratnam, 2006; Stearns and Hamilton, 2007]. One of these glaciers is Helheim Glacier (Figure 1), a tidewater glacier in southeast Greenland.

Ocean tides are known to affect the flow of glaciers terminating at tidewater [e.g. Lingle et al., 1981, Meier and Post, 1987; O'Neel et al., 2003] and may provide an important control on calving and subglacial melting by repeatedly circulating water beneath floating tongues [Motyka et al., 2003]. Boundary conditions at the frontal margins of tidewater glaciers provide important constraints on the balance of forces affecting ice flow and iceberg calving. For many large outlet glaciers in Greenland, the boundary condition at the calving front (floating vs grounded ice) is not well known, owing to limited knowledge of ice thickness and fjord bathymetry. Additional measurements are necessary to improve ice sheet models and sea level rise predictions.

The interaction of tidal forces and ice flow varies depending on grounding conditions. In a recent paper [Hamilton et al., 2007], we show that Kangerdlugssuaq Glacier, another large tidewater glacier in East Greenland, was close to flotation in summer 2005 on the basis of large uplift rates observed in a short GPS time series collected near the front of the glacier. Our analysis for Kangerdlugssuaq Glacier was based on modeled ocean tides, owing to a lack of field measurements in the fjord. As an added component of our involvement in the multi-national Helheim Glacier project, we set out to collect overlapping high data-rate time series of GPS ice flow and tidal measurements during the summer of 2007. These deployments will allow us to examine the effect of ocean tides on ice flow and, by inference, to test the response of the glacier to other perturbations (e.g., changes in force balance).

Preliminary Results

We made three separate trips to Helheim Glacier between late June and late August, 2007. The first trip was devoted to deployment of a network of 12 GPS receivers on the glacier surface, installation of GPS reference sites on rock, and the installation of a tide gauge in a small protected bay close to the terminus of the glacier (Figure 1). The second trip took place in late-July and was devoted to servicing the GPS and tidal instruments; several GPS units deployed near the glacier terminus on the first trip were relocated to sites farther upglacier. All equipment was recovered from the glacier and the fjord during the third trip in late-August.

We measured tidal height using an inexpensive pressure transducer and data logger. A *Global Water WL15-U* instrument was installed in about 2 m of water in a small ice-free bay. The transducer was weighted to keep it in contact with the fjord bottom, while a sealed cable transmitted data to a logger that was secured by a large rock on the shoreline above the high-water mark. Data were recorded at rate of 1 sample/minute. The instrument lasted for ~5 weeks before losing battery power. Initial data processing shows the record is continuous and of good quality (Figure 2). The GPS data analysis is proceeding at a slower pace, but initial quality checks show the data to be continuous at most stations for the period from early-July through late-August.

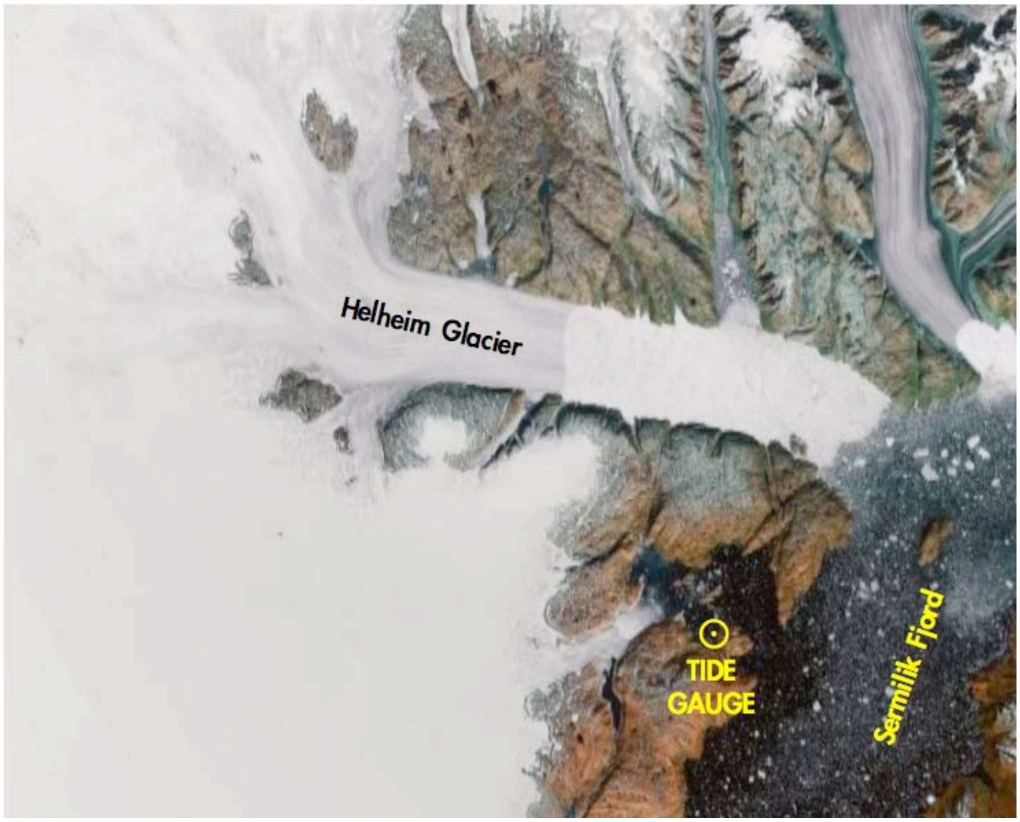

Figure 1. Field area in southeast Greenland. The tide gauge was deployed in a small protected bay connected to Sermilik Fjord, approximately 60 km from the open ocean. Ice conditions are too hazardous in the fjord close to the glacier terminus.

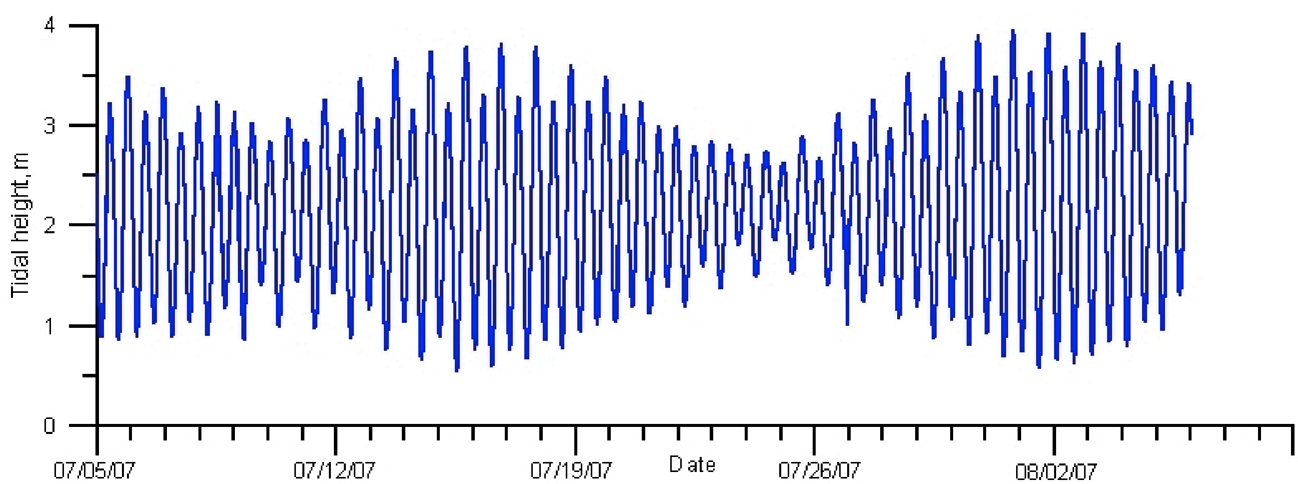

Figure 2. Record of tidal height variations in Sermilik Fjord, East Greenland, for early-July though mid-August, 2007. Note the clear diurnal, semi-diurnal, neap and spring tides.

References

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