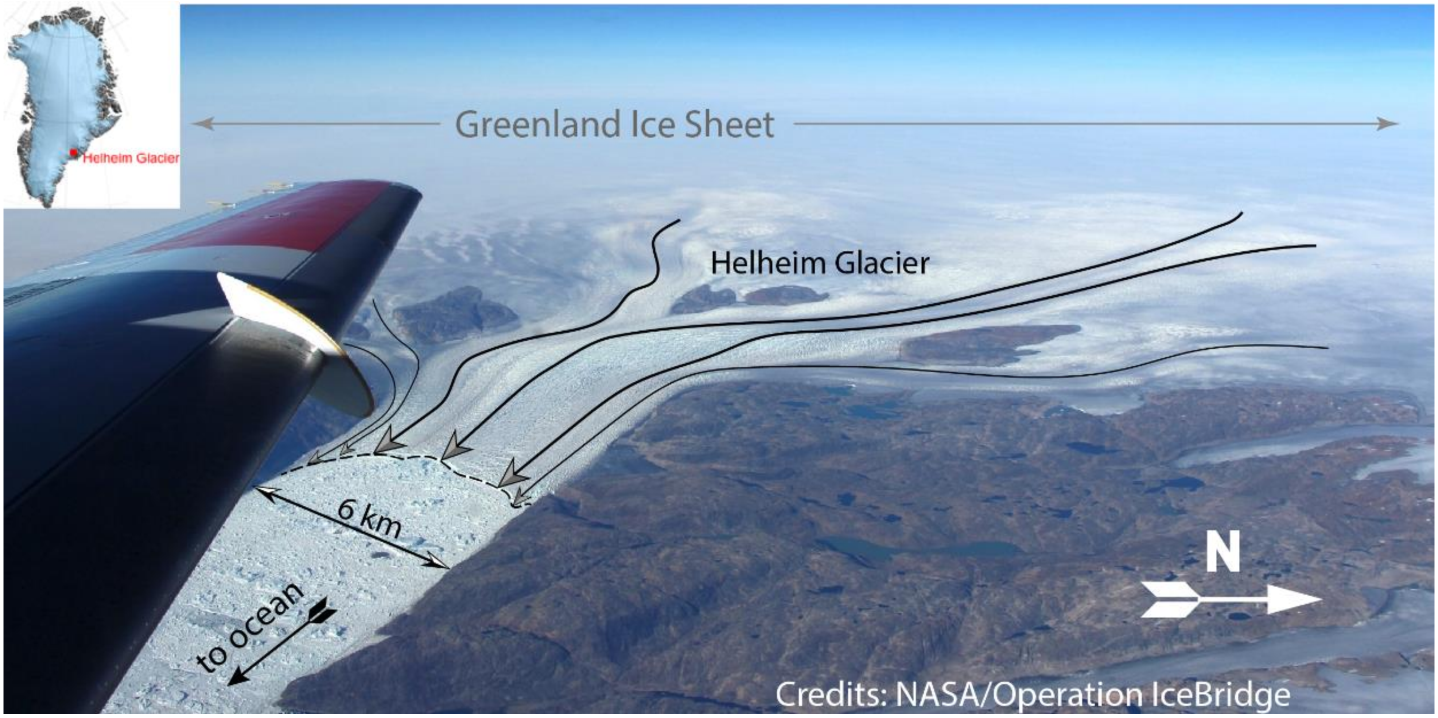
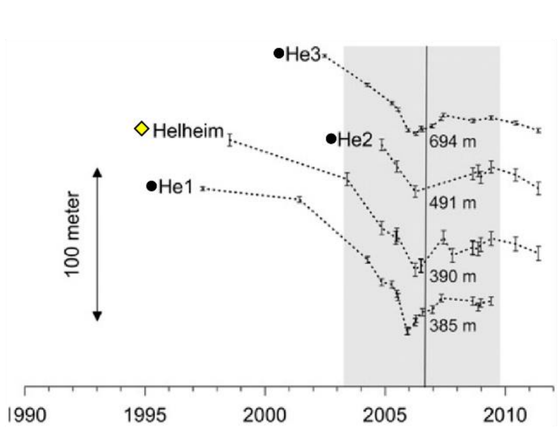
Insights from a detailed surface-elevation reconstruction of Helheim Glacier, southeast Greenland, 1981-2016

Carolyn Roberts, Beata Csatho, and Toni Schenk
Department of Geology, University at Buffalo, Buffalo, NY



Abstract: In response to changing oceanic and atmospheric conditions, the Greenland Ice Sheet (GrIS) has been losing mass at an increasing rate this century, compared to mass loss rates from the 20th century. In recent years, mass loss in southeast Greenland has contributed to more than half of the total mass loss for the entire ice sheet. A significant contributor to southeast GrIS mass loss is Helheim Glacier, a large marine-terminating outlet glacier with a drainage area >50,000 km^2 and ice speeds >7 km/yr. The altimetry record shows that Helheim Glacier has experienced a complex elevation history (Fig. 1). While the initial thinning phase suggests a dynamic response to changes from calving front retreat, the cause of the abrupt termination of thinning in 2005, and subsequent thickening and oscillatory behavior is not known. To better understand this behavior, and the physical processes responsible, highly accurate elevation records are required at glacier-scale (>10 km^2). Here we reconstruct the 1981 - 2016 elevation history of Helheim Glacier by employing a novel change detection method that improves the vertical accuracy of Digital Elevation Models using laser altimetry time series. Our elevation record shows the surface of the glacier is responding to the disturbance from sustained calving front retreat during 1998 - 2005 via dynamic thinning diffusing upglacier from the calving front (i.e., thinning decreases in magnitude with increasing distance from where the glacier meets the ocean), and that this diffusion process is controlling the glacier's overall behavior. We also identify a series of perturbations unrelated to changes occurring at the calving front. The perturbations materialized in 2005, 2007, 2011, 2013, 2015 and 2016, expressed as elevation changes >20 m over small areas (<5 km^2) coincident with significant bedrock gradients (slopes >10 degrees). This process occurs in topographically confined regions of both fast-flowing tributaries and the main trunk, and appears to be controlling the recent oscillatory behavior. We find that the oscillatory elevation behavior is due to changes taking place in the subglacial environment (i.e., at the ice-bedrock interface), either due to changes in basal lubrication, or the filling & draining of subglacial lakes. This is the first study to capture surface changes from subglacial water routing at a fast-flowing Greenland outlet glacier.



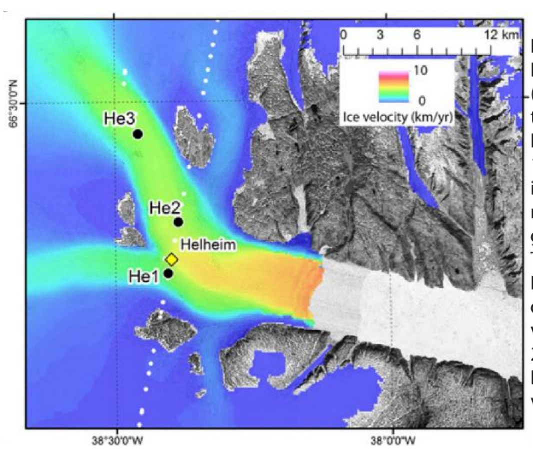


Fig. 1. Elevation change time series at Helheim from combined altimetry record (Fig. S2 in Csatho et al., 2014, Laser altimetry reveals complex pattern of Greenland Ice Sheet dynamics: PNAS, v. 111, p. 18478–18483), showing thinning-thickening-thinning behavior with abrupt termination of initial thinning. Numbers show glacier surface elevations on 8/31/2006. The gray box marks the duration of the ICESat mission. Time series locations are displayed on a Landsat basemap with ice velocity data from Rignot and Mouginot, 2012, Ice flow in Greenland for the International Polar Year 2008–2009: GRL, v. 39, p. L11501.