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Calving dynamics at Helheim Glacier from a high-resolution observational network.

Nick Selmes (1), Robin Aspey (2), Tim Baugé (3), Suzanne Bevan (1), Stuart Edwards (4), Alistair Everett (1), Timothy James (1), Pavel Loskot (5), Adrian Luckman (1), Ian Martin (4), Tavi Murray (1), Tim O'Farrell (2), and Ian Rutt (1)

(1) Swansea University, Geography Department, Swansea, United Kingdom , (2) Department of Electronic and Electrical Engineering, University of Sheffield, United Kingdom, (3) Research and Technology, Thales UK, United Kingdom, (4) School of Civil Engineering and Geosciences, Newcastle University, United Kingdom, (5) College of Engineering, Swansea University, United Kingdom

Calving glaciers play a crucial role in the mass balance of the Greenland Ice Sheet; acceleration of these glaciers results in increased mass loss from the ice sheet interior and a corresponding rise in sea level. Understanding the controls on calving is crucial for predicting the dynamic response of tidewater glaciers to environmental change, but understanding of calving is hindered by the difficulty of obtaining appropriate field measurements, and by the complexity of the system being observed. We designed and deployed a wireless network of GPS nodes which transmit to off-glacier base stations every few seconds, allowing observations right up to node loss through calving. We ran a network of 20 sensors over the period July - September 2013 on the highly crevassed surface of Helheim Glacier, one of the largest and fastest flowing of the Greenland outlets. Topographic change, additional velocities, and calving flux were provided by two sets of stereo time-lapse cameras, TanDEM-X satellite imagery, repeat airborne lidar, and airborne and spaceborne optical remotely-sensed imagery.

At the start of our field season we observed the expression on the fjord surface of a point-source sub-glacial meltwater plume. We monitored the evolution of the plume and its effect on the exposed calving face and ice mélange from time-lapse cameras, optical remotely-sensed imagery and lidar data. We compare these observations to our record of frontal positions to study the plume's role in controlling the spatial extent of iceberg calving.

Our 53 day study period contained several large calving events which resulted in frontal retreat of $\sim$1.5 km. We present the glacier's dynamic and topographic response to these calving events through this very large and rich dataset. Typically the glacier ice flows down slope and speeds up as ice progresses towards the calving front, with notable acceleration after each calving event. Intriguingly we see periods where sensors behave in unexpected ways including periods of uplift lasting several days, and deceleration of the ice after calving events. We explain these events in the context of a calving model where icebergs are initiated at basal crevasses and rotate backwards due to buoyant forces.