Glacier melt

- Understanding the response of glaciers and ice-sheets to climate is important globally for making accurate projections of sea level change

- Observed changes in glaciers and ice sheets can be the product of changes to the surface mass balance (accumulation and ablation)

- Several ways to measure mass balance, including satellite gravimetry, laser or radar altimetry from aircraft or satellite and **direct ground-based measurements at a network of stakes**

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Stake networks

- Understanding the response of glaciers and ice-sheets to climate is important globally for making accurate projections of sea level change

- Stakes drilled into the snow or ice surface, and stake heights are measured twice per year in order to record the annual net gains (snowfall in winter) and net losses (melt and sublimation in summer) at each location in the network

- With a reliable interpolation/extrapolation procedure, glacier-wide mass gains (accumulation) and losses (ablation) can be summed to determine the "net mass balance", which gives an indication of glacier health

- Direct measurements of glacier mass-balance are labour-intensive, so the question of *optimal network design* naturally arises

Data

- The SFU Glaciology Group in the Department of Earth Sciences has collected glacier mass balance data in the Yukon Territory of Canada since 2006. We currently have fairly complete melt season data sets for one glacier over five summers (2007, 2008, 2009, 2011, 2012) and will likely be able to add 2014 to this soon

- These data comprise measurements (with numerous sources of error) of cumulative summer ablation at 6 - 17 locations for each of the years listed above

- Estimates of the glacier-wide mass balance can also be obtained by a physically based mass-balance model with unknown inputs that are constrained by each other

Research questions

- **Example research questions:**
  1. How many stakes are required to obtain an estimate of glacier-wide mass balance within a prescribed precision, assuming the spatial distribution of mass balance is not known a priori (otherwise the answer is 1)?
  2. Within a given stake network, how many and which stakes could be omitted while maintaining a given precision in the estimate of glacier-wide mass balance?
  3. What is the optimal design of a stake network (spatial layout) comprised of a fixed number of stakes?
  4. How does the optimal network design vary with geographic and environmental conditions (e.g. glacier geometry, hypsometry, elevation range, orientation, accumulation regime and other variables influencing the surface energy balance)? This is the most interesting question for the end-user?
  5. How to combine physical and computer model data to make better predictions and estimate unknown inputs