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Viscoelastic Earth Response to a Changing Ice Cap: Mass Balance, Surface Elevation, and Basal Characteristics in Langjökull, Iceland

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With an area of 925 square kilometers and a volume of 195 cubic kilometers , Langjökull is the second-largest ice cap in Iceland. Over the last 20 years, the ice cap has been the subject of various investigations concerning its surface elevation: in 1995, a 100m resolution digital elevation model (DEM) was compiled from skidoo lines of GPS point measurements, in 2007, a 25m resolution DEM was compiled for the entire glacier from LiDAR and SPOT measurements, and LiDAR measurements taken in 2013 led to a third complete DEM for the entire ice cap. Complementing these surface elevation measurements are surface mass balance measurements dating back to 1996 . These two datasets have been cross-referenced, and imply spatial variation in elevation change and surface mass balance, influenced by ice dynamics. Investigation is ongoing.

The current state of scholarship surrounding Langjökull, however, fails to include a potentially integral component of our understanding of the spatially variable and overall changes in the ice cap. Iceland is unique in its proximity to an active tectonic ridge, and as such the earth underneath Iceland's ice caps is younger and more easily deformed than that of most ice systems. Multiple investigations of earth rheology in Iceland estimate the thickness of the lithosphere, as well as the viscosity of the upper mantle, using variations of techniques that compare measured GIA under a changing ice sheet (usually Vatnajökull) with earth model predictions, calibrating parameters for mantle viscosity and lithosphere thickness (e.g. Jacoby et al., Pure and Applied Geophysics; Sjöberg et al., 2004, Geophysical Journal International; Pagli et al., Journal of Geophysical Research). Generally, these studies determine lithospheric thickness to be 10-40km, and mantle viscosity between 1e18 and 2e19 pa-s. Barnhoorn et al, (2011, Journal of Geodynamics) estimates elastic thickness to be 27-40 km, and mantle viscosity to be between 2e18 and 2e19 pa-s.

These figures imply a Maxwell time on the order of about 3 years. That is, elastic and viscous responses to changes in load on the surface of Iceland are equal in magnitude after roughly that amount of time. As such, simple elastic models for earth rebound underneath the changing ice sheet over the last 20 years are insufficient to understand the full nature of changes in the earth's underlying structure. In order to rigorously track change in Langjökull, we apply a self-gravitating viscoelastic earth model to our current understanding of changes in surface mass balance and surface elevation. Quantifying the relative contributions of the short time-scale viscoelastic changes of the Earth's surface and surface mass balance to surface elevation changes will clarify the dynamics of the ice sheet, including previous hypotheses concerning the surging Hagafellsjökull Eystri in 1998-1999, and the Hagafellsjökull Vestari surge of 1979-1980. The ultimate goal is to inform our understanding of the dynamics of the Langjökull ice cap with the help of surface elevation measurements, surface mass balance figures, and a newly integrated tool, rigorous solid earth models underneath the ice.