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Elastic Earth response to glacial surges: Crustal deformation associated with rapid ice flow and mass redistribution at Icelandic outlet glaciers observed by InSAR

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Evolving ice caps provide varying load on the surface of the Earth, both load decrease when warmer climate reduces ice but also shift in location of large ice masses in case of surging outlet glaciers. Glaciers in Iceland are generally decreasing because of warmer climate, resulting in uplift over large areas next to the ice caps at a rate of 1-2 cm/yr. However, this general uplift may be interrupted by sudden subsidence next to ice caps. Instability in ice flow at outlet glaciers can cause sudden glacial surges, when large volumes of ice flow from accumulation areas on the ice caps towards their edges. InSAR observations have revealed subsidence associated with such glacial surges. The most pronounced of these is deformation associated with a glacial surge at the Sidujokull outlet glacier, SW Iceland. A glacial surge in 1994 was associated with transfer of 20 cubic km of ice from the accumulation area, towards the outlet areas, with a thickening of the ice front of over 50 m along a more than 20 km long circular edge of this outlet glacier. The ice advance amounted to more than 1 km over an interval of four months. Interferometric analysis of synthetic aperture radar images (InSAR) clearly reveal deformation associated with this mass redistribution. Subsidence of up to several centimeters (more than one interferometric fringe) is observed in about

20 km wide area next the ice edge. The deformation signal gradually recovers in the years after its formation, as the ice mass readjusts after the surge. The observed deformation is evaluated against an elastic deformation model. A map of inferred mass redistribution during the glacial surge is convolved with a Green's function, giving vertical displacement due to a unit point mass applied on an elastic half-space. The resulting displacement scales inversely with E, the Young's modulus of the underlying crust. Comparison of observations and model predictions suggests the effective Young's modulus is 60 GPa, significantly lower than the dynamic value of E inferred from seismic studies of the Icelandic crust.