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Glacial Acceleration - Remote-Sensing Observations, Geomathematical Classification and Relevance for Sea-level Change Assessment

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Glacial acceleration is a central process in climatic and cryospheric change, yet at the same time our communal lack of appropriately understanding glacial acceleration processes makes these one of the largest sources of uncertainty in assessment of sea-level rise, as established in the Fifth Assessment Report of the Intergovernmental Panel for Climate Change. Three types of glacial acceleration have been identified: Continuously fast-moving ice streams, surge-type glaciers and tidewater glaciers. Surge-type glaciers, characterized by their quasi-periodic cycle between long quiescent phases of normal flow and short surge phases of accelerated flow and rapid advancement, have seen the least amount of research and are still incompletely understood. Tidewater glaciers also have a quasi-cyclic behaviour but on a long time scale of typically 1000 years that relates poorly to observations. Current ice sheet models used to predict glacial contribution to sea-level rise treat all fast-flowing ice identically, therefore limiting certainty of estimations.

In this paper, the problem of observing and classifying glacial acceleration is approached by means remote-sensing and spatial mathematical analysis. The Bering-Bagley Glacier System, Alaska, is analysed as the prototype of a surge glacier and compared to Jakobshavn Isbrae, a fast-moving outlet glacier of the Greenland Ice Sheet, and Pine Island Glacier in the Amundsen Sea sector of West Antarctica. All glaciers have seen recent accelerations but are dynamically different. The analysis is based on ICESat Geoscience Laser Altimeter System (GLAS) data (2003-2009), CryoSat-2 Synthetic Aperture Interferometric Radar Altimeter (SIRAL) data (2010-present), data collected during four flight campaigns in Alaska (2011-2013) and data from ICESat-2 simulator instruments MABEL and SIMPL (2014, 2015), complemented by airborne and satellite imagery. Our approach uses a spatial statistical concept of generalized spatial surface roughness and characteristic parameters, which are mathematically related to physical concepts including crevassing, deformation and aerodynamic roughness length. A connectionist classification system aids in discrimination of deformation types. Roughness and elevation changes in several glacier systems are analysed to investigate links between glacial acceleration and its causes. Results are relevant for assessment of the sea-level rise through mass loss from the terrestrial cryosphere and for understanding relationships between observations and physical processes.

Figure 1: Bering Glacier during surge (2011)

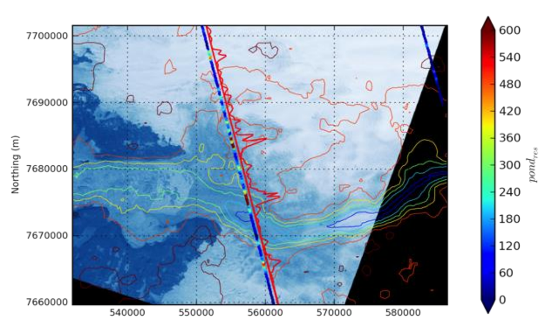

Figure 2: Jakobshavn Isbrae (GLAS track and roughness, bed topography crevassing from ASTER imagery) [1]

Reference: [1] Herzfeld et al, 2014, Journal of Glaciology, v. 60 (223), pp. 834-848, doi:10.3189/2014JoG13J129