Geophysical Research Abstracts
Vol. 19, EGU2017-8790, 2017
EGU General Assembly 2017

The influence of basal drag on ice flow across Antarctica and Greenland

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Ice sheet stability is largely controlled by the sub-glacial ice-bed boundary, but this is currently one of Earth's least understood landscapes. Basal drag is the spatially emergent force that resists ice flow at this boundary. It is affected by roughness of the bed topography and interactions between subglacial hydrology and basal sediments. The behaviour of ice sheets depends on spatial patterns in basal drag, and consequently computer simulations of their dynamics are highly sensitive to how basal drag is prescribed or derived. This is a significant problem, since the derivation of basal drag is computationally expensive, often geographically limited, and poorly constrained by observations. Here, we present a novel, computationally-light method to determine the relative contribution of basal drag to ice sheet dynamics from surface velocity and elevation data without prior knowledge of ice thickness or bed conditions. We apply it across both the Antarctic and Greenland ice sheets to reveal insights into basal drag at high resolution and over unprecedented spatial extents. We identify where ice sheet beds are conducive to ice flow but also locations which accommodate disproportionately high basal resistance thereby controlling non-local / regional ice dynamics. Results are substantiated by independent investigations in regions where evidence is available, and illuminate previously unidentified basal conditions where it is not. We anticipate that our method will provide improved observation-based estimates of basal friction coefficients that will enhance convergence speed and accuracy of 3D ice flow models and it will be a valuable tool for helping focus and plan future geophysical measurement campaigns within vast remaining regions of ice sheets with poorly constrained basal boundary conditions.