Mechanics Underlying Rapid Ice Sheet Motions

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ABSTRACT

Two mechanics questions are discussed which arise in evaluating possible scenarios of accelerated deglaciation in Greenland and Antarctica. The studies are in collaboration with Thibaut Perol (Harvard), John D. Platt (Harvard), and Victor C. Tsai (Caltech).

A first question is, how fast can a glacier imbibe a meltwater lake, and what are the aftereffects? It focuses on Greenland where, as spring commences, a broad swath of more marginal, and more southerly, glacier surface is awash with rapidly flowing meltwater. Where there are depressions in the ice surface, that forms large surficial lakes. One such lake, instrumented, was found to drain catastrophically into the ice sheet on a one-hour time scale, at a volumetric flow rate faster than the average flow over Niagara Falls. We suggest that the time scale can be understood as being due to hydraulic fracture along the bed, at the ice/rock interface, by turbulently flowing water. The step-like shear stress redistribution along the bed causes a transient surge of the neighboring ice sheet.

A second question is, why do Ice Streams exist on the Western Antarctic Ice Sheet? They are streams of 40-80 km horizontal width, flowing rapidly towards the Ross Sea at 100s of m/yr. They are bordered by slow moving ice, frozen to the bed, but no structure in the bed (which was seafloor during the last glacial minimum) can be cited to set their margins. Because fluid pore pressure in the bed below the streams is nearly sufficient for flotation of the ice, there is little basal resistance. That allows fast flow but causes lateral shear stress, and hence shear heating, within the creeping sheet to increase rapidly with stream width. We examine and find evidence supportive of the hypothesis that the width is set by the onset of internal melting within the sheet. That rains liquid to the bed below, and may create a channelized marginal drainage, which partly alleviates the high pore pressure nearby and may effectively lock the ice outboard of the channel to the bed.