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Spreading fast motion and the pace of ice sheet change

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Louis Agassiz brought recognition that ice sheets were once much more extensive. Very recent work reveals that retreat from the last glacial maximum caused large rises (order 10 m) in sea level at rates (several cm/a) that would be catastrophic in the modern world. In light of warming in IPCC scenarios, an urgent question is how much and how fast could the remaining ice in Antarctica and Greenland shrink. Ice sheet flow models incorporating realistic ice deformation inform us with high confidence that large multi-meter sea level rise (mainly from melt in Greenland) can be expected within about 1000 years without a major shift in the trajectory of human activity. Processes not included in these models (primarily fast basal motion stimulated by basal water) could yield faster shrinkage. How much faster remains uncertain.

The attack from warming will be focused around the low-elevation and floating edges of the ice sheets. Already a number of outlet glaciers in Greenland and Antarctica have recently accelerated apparently because of thinning or disintegration of floating termini probably induced by warm ocean water. Seasonal speedups from summer melt penetrating to the bed are being recognized in Greenland. A central question is whether these effects near the edges can be sustained and spread into the deep interior. Is spreading rate limited to multi-century to millennial scale diffusion associated with ice deformation or can a continuing up-flow propagation of a front of fast basal motion quickly access the interior to greatly speed the response.

We look for some broad perspective by drawing on a range of observations primarily from surging glaciers (in which fast motion originates locally and spreads out) and the Siple Coast ice streams of West Antarctica (where information about millennial to shorter-term evolution is relatively abundant) and by exploring some simple conceptual models based on continuity (diffusion and displacement of topography) and force balance (horizontal stress propagation). This conceptual approach will not reduce the uncertainty, but may illuminate some interesting next steps.