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The gap between ice-penetrating radar observations and the boundary conditions used in ice-sheet models

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Modern, ice-sheet-wide ice-penetrating-radar surveys are now underway (e.g., IceBridge, ICECAP), but beyond ice thickness, how can ice-sheet models make use of these new data? Ice-sheet models employ data-constrained gridded models of bed properties relevant to ice dynamics, but heretofore such grids have included only elevation (i.e. ice thickness), geothermal flux, and the location of subglacial lakes. Here we evaluate the gap between radar observations and the boundary conditions presently used in ice-sheet models. Radar can detect large bodies of subglacial water, but distinguishing between thawed and frozen beds from bed echoes alone remains challenging, partly because of the strong temperature dependence of englacial radar attenuation. However, frozen and thawed beds have been successfully delineated from radar data in Greenland using additional information from internal layer morphology. Changes in the surface and ice-flow character observed from satellite imagery can also delineate regions of possible basal sliding, further narrowing the frozen/thawed transition. Internal layer morphology could also be used as a target for ice-sheet models seeking to accurately represent the ice-flow history of modern ice sheets. In addition, recent studies have shown that bed roughness in Antarctica is anisotropic, spatially varying, and related to large-scale ice dynamics. Bed roughness can be measured from the detrended bed topography and can be simply related to basal drag; it typically follows a power-law relationship at horizontal scales between $\sim$10 to 500 m, so it may not be necessary to finely sample bed roughness in order to usefully relate it to basal drag. Finally, distinguishing between bedrock and deformable subglacial till is also possible, when radar data is used in combination with other geophysical data (seismics, gravity). We suggest that efforts involving the synthesis of radar data (both internal and bed echoes), together with satellite remote-sensing data, simple ice-flow models and other geophysical data, provide the clearest path forward for producing additional boundary conditions of value to ice-sheet models. Initial candidates for such boundary conditions include the delineation of the frozen/thawed bed transition, gridded layer morphology, and bed roughness.