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Improved grounding line constraints and evidence of retreat of Totten Glacier, East Antarctica

Feras Habbal (1), Jamin Greenbaum (1), Cyril Grima (1), Duncan Young (1), Jason Roberts (2,3), Tas van Ommen (2,3), and Donald Blankenship (1)

(1) University of Texas Institute for Geophysics, University of Texas at Austin, Austin, United States , (2) Australian Antarctic Division, Kingston, Australia, (3) Antarctic Climate & Ecosystems Cooperative Research Centre, University of Tasmania, Hobart, Australia

Accurately mapping grounding line positions is critical for characterizing the stability of coastal marine basins, the retreat of which will raise global sea level. Commonly used satellite-based grounding line detection methods, such as differential radar interferometry methods (InSAR), rely on tidal deflection of ice shelves to identify the transition from grounded to floating ice. For regions where these data sets exist, satellite methods provide high spatial resolution. However, for grounding zones comprised of thick ice overlying narrow channels, the stiffness of the ice limits the tidal flexure below the threshold of detectability for satellite-based methods. In contrast, constraining the extent of floating ice using hydrostatic calculations, derived from measurements of ice thickness and ice surface elevation, circumvents the reliance on tidal deflection to identify the floating to grounded ice transition. The largest source of uncertainty in identifying flotation from hydrostatic calculations is associated with a firn correction, which represents the variation in density with depth associated with the compaction of snow at the surface into ice at depth. Firn densification is strongly dependent on local climate forcing, and is predominantly a function of the local temperature, accumulation rate, and wind speed. Here we present a new approach for identifying flotation with hydrostatic calculations based on firn corrections (i.e. depth-density profiles) synthesized from airborne radar-derived surface density measurements and local ice core data. This approach yields spatially varying firn corrections collocated with airborne observations of ice geometry. We validate these hydrostatic calculations with additional, established radar techniques used to directly detect subglacial water. We apply this approach to constrain the grounding line position around Totten Glacier, the major outlet of the vast Aurora Subglacial Basin and the most rapidly thinning glacier in East Antarctica, and show that a large area of the grounding line has retreated by an amount consistent with observed thinning rates.

We also show that regions of Totten Glacier's grounding line have not been accurately mapped due both to the lack of satellite coverage and, alarmingly, because thick ice along the coast lies above relatively narrow channels. We show that the stiffness of the ice overlying these channels results in tidal deflections that are below the limit of detectability of InSAR grounding line mapping. To demonstrate this, we apply a numerical flexure model that uses symmetric boundary conditions, in contrast to the traditional analytic formulation of tidal flexure that imposes a freely floating boundary condition. Our model results are similar to the traditional ice tongue model for ice shelves longer than 10 km, but deviates significantly for ice overlying narrower channels that, due to the ice stiffness, do not achieve sufficient tidal deflection to be detected by InSAR.