Shallow Ice Radar Expression of TAM glaciers within Ross Ice Shelf, and a New Method to Distinguish Mechanisms of Ice Sheet Thinning

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Using IcePod airborne instrumentation, the ROSETTA-Ice Project has so far collected 55 east-west profiles and 12 north-south tie lines of shallow and deep ice penetrating radar over Ross Ice Shelf (RIS). Distinct reflections in the shallow ice radar (SIR) clearly define areas of ice in the profiles that originated from each of the Transantarctic Mountains glaciers, identifiable in sequential profiles spaced 10 to 50 km apart. SIR also images the base of the ice sheet, when thickness is <450m. The new data verify that RIS thickness decreases between the grounding line and the calving front, and they reveal that the glacier-ice thicknesses for Beardmore, Nimrod, Byrd, and Mullock Glaciers also decrease. A majority of change in thickness of the ice sheet is attributable to strain (e.g. Thompson et al., 1984), and a lesser amount arises from basal processes at the ocean-ice interface. We devised a new means to assess the latter, using glacier-ice delimited in SIR profiles as a marker for thickness change. Other inputs are ice sheet velocity from Rignot (2017), time elapsed along flow lines from Moholdt (unpub), and vertical strain from RIGGS (Thompson et al. 1985). The objective is to identify areas of basal melting or freeze-on that may aid in the refinement of models of ocean circulation and ice shelf stability.

We first mapped the margins and top of within-shelf glacier ice using reflections in the SIR. These provide markers for accurate measurement of depth-to-reflector and glacier-ice thickness. For Beardmore and Nimrod Glaciers, a comparison of profiles between L530 and L870 encompasses the along-flow change over a 350 km distance. (Line numbers reflect position within ROSETTA-Ice survey, with lower numbers toward South.) The thickness from the surface to the reflector provides a measure of 'upper' ice thickness, T_a (formed by accumulation, firn compaction and strain). T_a increases from 127 to 155 m (38 m change, or +30% of the original thickness). Beardmore glacier-ice thickness, T_g, decreases from 232 to 140m, a change of 92 m (-40%). T_a for Nimrod Glacier increases from 100m to 140 m, then the reflector again rises to 100m depth. Nimrod glacier-ice thins from 215 to 167 m. Our calculations show that the amount of thinning unrelated to strain is -0.4 m/yr to -0.1 m/yr (-4 m to -1 m decadal change) for these two glaciers, a potential indication of basal melting.

Changes in Byrd and Mullock Glaciers were measured from profile L720 to L870, a distance of 150 km. Byrd glacier-ice thins by 210 m over this distance, while Mullock Glacier thins from 270 to 0 m, and disappears. SIR profiles reveal a dramatic thinning and rise of the RIS base beneath Mullock Glacier and the west margin of Byrd Glacier, while the depth-to-reflector remains unchanged. Mullock Glacier ice disappears entirely, and the thickness is halved for the west side of Byrd Glacier. The drastic decrease in thickness of shelf ice that coincides with the disappearance of the glacier-ice reflector suggests high rates of basal melting.

The mapped reflectors offer a new means to investigate the basal processes affecting shelf thickness. The change in thickness that is not attributable to strain may be a result of processes at the base of the ice shelf (melting, freeze-on) that can be mapped and made available for use in circulation models. The method may be readily applied to evaluation of other ice shelves for which shallow ice radar data exist.