Radar attenuation and temperature near the grounding line of Whillans Ice Stream

Joseph A. MacGregor (1), Sridhar Anandakrishnan (2), and Dale P. Winebrenner (1,3)

(1) Department of Earth and Space Sciences, University of Washington, Seattle, Washington, USA
(2) Department of Geosciences, Pennsylvania State University, University Park, Pennsylvania, USA
(3) Polar Science Center, Applied Physics Lab, University of Washington, Seattle, Washington, USA

Both ice deformation and the attenuation of radar waves in ice are strongly temperature-dependent. Measurements of radar attenuation could thus constrain the temperature fields used in ice-flow models. Here we present a novel measurement of radar attenuation using a multiple echo from the ice-shelf-ocean interface detected by a 20-km long, ground-based, 2-MHz radar transect near the grounding line of Whillans Ice Stream, West Antarctica. The measured attenuation rate is calculated using the ratio of the intensities of the primary and multiply reflected echoes over the ice shelf and estimates of the air-firn and ice-ocean reflectivities. We then compare this measured value to that from a temperature-dependent attenuation model to estimate the temperature profile at this site. This model also depends on ice chemistry and density although these dependencies are weaker than the temperature dependence and have less spatial variation; here we use mean values of chemistry data from Siple Dome and nearby ITASE ice cores, and density and surface temperature data from the J-9 ice core and nearby RIGGS sites. The measured attenuation rate is close to the modeled attenuation rate when the temperature profile is linear between the surface and the ice-shelf bottom, which is consistent with the nearby and nearly linear J-9 temperature profile further out on the Ross Ice Shelf. Modeled attenuation-rate values using temperature models that include significant vertical heat advection, i.e., lower temperatures at shallower depths, are too low to match the measured attenuation rate. Attenuation measurements could therefore discriminate between possible temperature profiles when combined with an attenuation model. While here we only use the measured attenuation rate to the basal reflector, attenuation-rate measurements to several internal reflectors and the bed could further constrain the temperature profile. We have measured an in situ, depth-averaged attenuation rate that is significantly higher than those of previous studies from the grounding line of the Ross Ice Shelf; this variability emphasizes the need for reliable estimates of attenuation rates in studies of basal radar reflectivity.