Figure 3a caption: Series of 2-way radar attenuation maps showing the effects of no regolith, an exponential regolith distribution and the “best-case” regolith distribution on attenuation. The ice shell depth map used is map a in Hemingway & Mittal et. al. 2019. Shows attenuation variation between low loss (pure ice) attenuation model, and high loss (pure ice & chloride) attenuation model. Calculations are in units of relative penetration depth.

Figure 3b caption: Series of 2-way radar attenuation maps showing the effects of no regolith, an exponential regolith distribution and the “best-case” regolith distribution on attenuation. The ice shell depth map used is map d in Hemingway & Mittal et. al. 2019. Shows attenuation variation between low loss (pure ice) attenuation model, and high loss (pure ice & chloride) attenuation model. Calculations are in units of relative penetration depth.

Figures 3a and 3b show the spatial distribution of attenuation calculations across two surface-wide ice shell depth maps. We take both ice shell depth maps a and b from Hemingway & Mittal et al. 2019. These maps are generated from gravitational data (CASSINI?), shape model (CASSINI?), and a range of simulated density variations between the sub-surface ocean and ice shell.

The First column of graphs in each paneled figure shows first the ice shell depth map (top left), then the exponential regolith distribution (middle left), and then the “best-case” regolith distribution (bottom left). The exponential regolith distribution varies latitudinally, starting at the north pole with 20 meters of regolith to 700 meters at the south pole. The “best-case” distribution also only varies latitudinally. Regolith build-up begins at the equator with .2 meters of regolith and exponentially increases in deposition until 5 degrees of latitude before the south pole up to 250 meters of regolith.

Properties of these regolith distributions originate from Martin et al. 2023. They identify regolith distribution increasing toward the South pole due to cryovolcanic activity centered around the tiger-stripe region. The maximum reported regolith depth is 700 meters. We hypothesize from their analysis (or is it in their paper) that the cryovolcanic activity creates a boundary of 5 degrees latitude where the regolith begins deposition. Two hundred fifty meters of maximum regolith depth was attributed to the “best case” as a middle-ground between the exponential and no-regolith distribution cases.

Figures 3a and 3b show similar effects of regolith distributions in their respective low and high-loss scenarios. Both depth maps with no regolith using the low loss attenuation model show radar penetration of 100% across the entire surface. With low loss and the exponential regolith distribution, map A penetrates the ice-ocean interface across 28.9% of the surface, while map B shows complete radar penetration across 21.5 % of the surface. We see 100% radar penetration across the entire surface in map A for the low-loss attenuation model and best-case regolith distribution. In comparison, in map B, only 91% of the surface is penetrated.

These differences and further differences between maps in the high-loss scenarios are attributed to the smaller range in ice shell depths in map B compared to map A. This difference is easily noticeable in the south pole, where the mean depth to the ice-ocean interface for map A between 90 °S and 60 °S is ~4.5 km, and for map B is ~17 km.

In the high loss, no regolith case for map A, 8% of the surface is penetrated by radar to the ice-ocean interface, and 0% of the surface in map B is penetrated completely. A small amount of radar that reaches the sub-ice ocean is located near the south pole where the ice shell is thinnest. The high loss, exponential regolith distribution case for map A has 2% surface penetration to the ocean, whereas map B has 0% radar penetration reaching the ice-ocean interface. The high-loss, best-case regolith distribution scenarios are very similar to the high-loss exponential regolith distribution scenarios. In map A, 3% of the surface is penetrated to the ice-ocean interface, while for map B, 0% is penetrated to the ice-ocean interface.

It should be noted that in most cases (all cases besides the high-loss exponential regolith distribution cases), a majority of the surface is penetrated to greater than 80% of the relative ice shell depth.