

SUBSURFACE RADAR OBSERVATIONS OF OUTLIER POLAR ICE DEPOSITS ON MARS. R. A. McGlasson¹, A. M. Bramson¹, G. A. Morgan², M. M. Sori¹. ¹Purdue University Department of Earth, Atmospheric, and Planetary Science, ²Planetary Science Institute (Corresponding author: rmcglass@purdue.edu).

Introduction: Martian ice likely holds the key to interpreting Mars' past climate, but much is still unknown regarding the distribution and properties of Mars' ice deposits. It is well known that Mars has extensive polar ice caps the size of Greenland. Included in these large polar caps are the north and south polar layered deposits (NPLD and SPLD, respectively), that are composed of kilometers-thick deposits of water ice.

In addition, surveys by [1] and [2] have identified craters in the surrounding terrains that contain "outlying" deposits of ice (e.g., Figures 1–3), which may or may not have formed at the same time as the deposition of the polar caps. There are many enigmatic differences between the NPLD and SPLD, for example higher dust content in the SPLD, sequestered CO₂ within the SPLD, and a younger surface age of the NPLD. The differences between the NPLD and SPLD may or may not be reflected in these outlying deposits.

Our main objective is to compare the radar surface and subsurface properties between southern and northern icy outlier deposits using radargrams from the SHARAD (Shallow Radar) sounding radar onboard NASA's Mars Reconnaissance Orbiter. These images can essentially act as large-scale ice cores. There have been some initial SHARAD observations of individual outliers [1, 2, 3], but a comprehensive radar study of the outlying ice deposits has not yet been done. Comparing the icy outliers between the two hemispheres, as well as to the nearby PLD ice, will provide new information to aid in interpreting what climate conditions were present in Mars' past and how these conditions shaped each of the polar regions.

Methods: We use radar observations from MRO's SHARAD to examine the ice in these outlying crater deposits. We leverage the subsurface capabilities of SHARAD to look for layering within the ice below the surface in these outliers. As the transmitted signal penetrates into the subsurface, echoes may be reflected by dielectric contrasts between materials. Finding layers of ice with different properties could also provide strong evidence for changes in the climate, which could be linked to orbital/rotational variations analogous to Milankovitch cycles on Earth.

To map these reflectors, we use radargrams, which map returned power at a given time delay (vertical axis) and distance along the track. Subsurface reflectors are present where the dielectric constant of the material changes, but clutter caused by reflections of off-nadir surfaces like crater walls can also cause increased power at time delays that may be similar to subsurface reflectors. Because of this clutter, we must compare the radargrams with simulated clutter models derived from Mars Orbiter Laser Altimeter (MOLA) data.

We will use these mapped reflectors to infer a dielectric constant of the material, where possible. Where the depth is known, an estimation of the dielectric constant, ϵ' , can be made based on that depth, z , and round-trip travel time of the transmitted signal, Δt , using the equation $\epsilon' = (c\Delta t/z)^2$. In some cases, the depth of the reflector may be inferred using the surface topography. Inferring a dielectric constant of the material will enable us to constrain the composition of the material in these crater deposits.

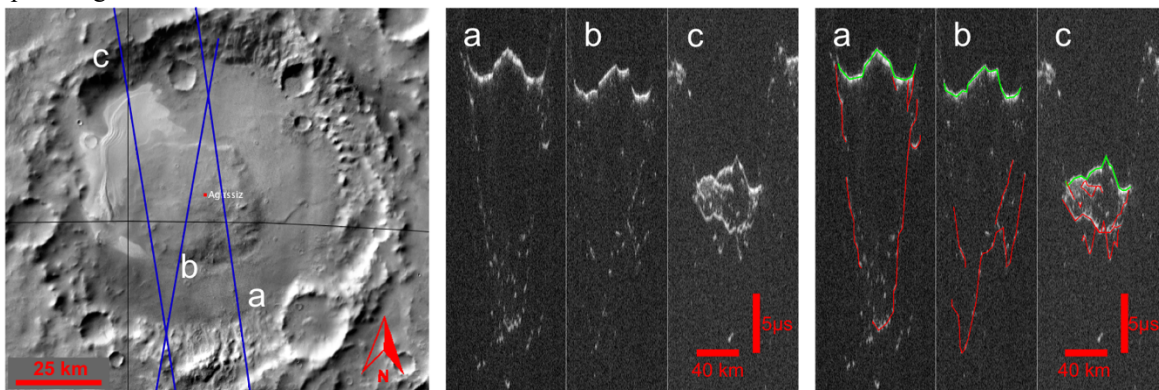


Figure 1. SHARAD radar track locations across Agassiz crater (left panel), located at -70°N , 271°E , over Thermal Emission Imaging System (THEMIS) daytime infrared 100 meter/pixel image. The center panel shows the uninterpreted radargrams across the crater, with time delay increasing from top to bottom and distance (North to South) along the horizontal axis. The right panel shows the same radargrams, but with our interpreted reflectors marked. Green indicates the surface reflector and red indicates clutter from MOLA clutter models. We found no subsurface reflectors present in these SHARAD tracks across Agassiz crater.

Preliminary Results: Here we present preliminary mapping of subsurface reflectors for three craters with icy outlier deposits: Agassiz (south, Figure 1), Burroughs (south, Figure 2), and Korolev (north, Figure 3). For each crater, we analyzed 3 SHARAD radar tracks. Agassiz crater does not appear to have any subsurface reflectors, but Korolev and Burroughs craters appear to each have 2–5 subsurface interfaces. In Burroughs crater, these reflectors seem mostly concentrated on the north side of the ice deposit. Agassiz, the most equatorial of the 3 deposits, occupies only a limited portion of the host crater, suggesting a significant amount of ice has been lost. This apparent ablation may be the reason for the lack of layering seen within the SHARAD data.

Future Work: This work will be expanded to examine the 19 northern outlier deposits identified by [1] and the 31 southern outlier deposits identified by [2].

Here, we utilized the subsurface capabilities of SHARAD to inspect the older, deeper ice. However,

additional data such as roughness and dielectric constant of the shallow (<5 m) subsurface can be extracted from these radargrams by analyzing the reflectivity of the surface echo [4–7]. We will leverage these techniques to determine the physical properties of the younger surface ice. Similar techniques have been used to make global maps of radar-derived surface properties [4–7], but have not been used to study these outlying icy crater deposits. This study will allow the additional comparison of recent conditions of ice in the northern and southern hemispheres of Mars.

References: [1] Conway, S. J., et al. (2012). *Icarus*, 220(1), 174–193. [2] Sori, M. M. et al. (2019). *JGR: Planets*, 1–21. [3] Brothers and Holt (2016). *Geophys. Res. Lett.* 42. [4] Campbell, B. A., et al. (2013). *JGR: Planets*, 118, 436–450. [5] Castaldo, L., et al. (2017). *EPSL*, 462, 55–65. [6] Grima, C., et al. (2012). *Icarus*, 220(1), 84–99. [7] Morgan, G. A., et al. (2020). *LPSC* 51, #2790.

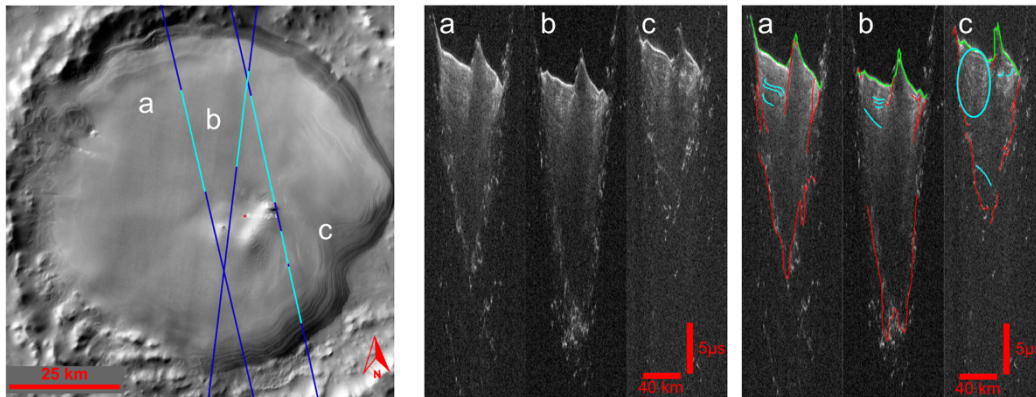


Figure 2: SHARAD radar track locations across Burroughs crater (left panel, located at -72°N , 116°E , over THEMIS daytime IR 100 meter/pixel image, with sections of light blue indicating locations of subsurface reflectors. The center panel shows the uninterpreted radargrams across the crater, with time delay increasing from top to bottom and distance (North to South) along the horizontal axis. The right panel shows the same radargrams, but with our interpreted reflectors marked. Green indicates the surface reflector, blue indicates subsurface reflectors, and red indicates clutter from MOLA simulated clutter models. The blue oval in radargram c indicates a packet of multiple less-resolved subsurface reflectors.

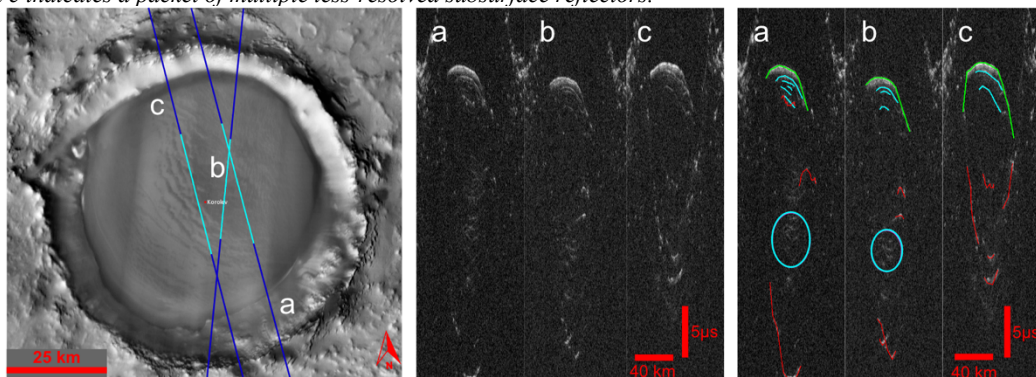


Figure 3: SHARAD radar track locations across Korolev crater (left panel, located at 73°N , 164°E , over THEMIS daytime IR 100 meter/pixel image, with sections of light blue indicating locations of subsurface reflectors. The center panel shows the uninterpreted radargrams across the crater, with time delay increasing from top to bottom and distance (North to South) along the horizontal axis. The right panel shows the same radargrams, but with our interpreted reflectors marked. Green indicates the surface reflector, blue indicates subsurface reflectors, and red indicates clutter from MOLA simulated clutter models. The blue oval in radargrams a and b indicates a packet of multiple less-resolved subsurface reflectors.