Radar "Ice Cores" of the Outlier Polar Ice Deposits on Mars: Records of the Past and Recent Climate

Background: 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 comprised of kilometers-thick deposits of water ice. In addition, surveys by Conway et al. (2012) and Sori et al. (2019) have identified craters in the surrounding terrains which contain "outlying" deposits of ice (Figure 1), which may or may not have formed at the same time as the deposition of the polar caps. These, as well as other efforts to identify and characterize ice, have used radargrams from the SHARAD (SHAllow RADar) sounding radar onboard NASA's Mars Reconnaissance Orbiter (MRO) to analyze the subsurface in these icy areas, as radar images can essentially act as large-scale ice cores. 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 (Campbell et al., 2013; Castaldo et al., 2017; Grima et al., 2012).

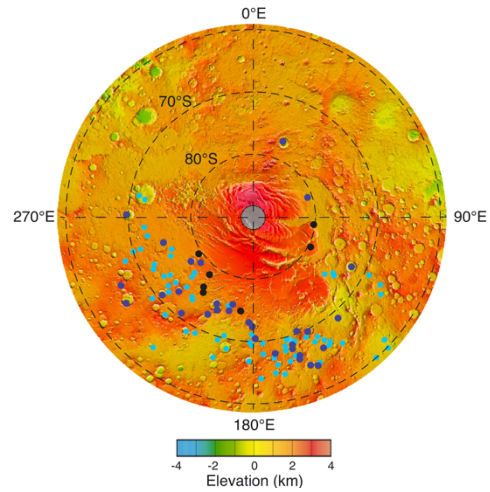

Figure 1. From Sori et al. (2019) Locations of icy crater deposits near the southern polar cap. All three colors of points indicate outlying crater deposits that will be considered in this work.

Research Objectives and Motivation: I propose to leverage this technique to analyze the physical properties of northern and southern outlying polar ice deposits. From my analyses, I will be able to draw conclusions about the purity, composition, and surface roughness of these ice deposits. Comparing similarities and differences between the ice deposits in the two hemispheres, as well as how the outlier deposits compare to their corresponding nearby polar ice caps, will allow me to assess how localized or global the climate processes were which led to the formation of polar ice deposits. In addition, I will analyze the subsurface radar echoes of the southern icy outliers and search for the existence of any buried CO_2 deposits that may have been sequestered from the atmosphere in past climate events (Figure 2).

The main objective of this project is to identify differences in physical properties between southern and northern icy outlier deposits. Conway et al. (2012) found evidence that supports similarities in composition between the NPLD and outlying ice deposits located in northern craters. While the NPLD has been found to be made up of pure water ice (Grima et al., 2009), large deposits of CO_2 ice have been found sequestered in the SPLD (Phillips et al., 2011). Given the similarity in composition between the NPLD and northern outlying ice deposits, it stands to reason that such a similarity may exist between the SPLD and corresponding southern outlying ice deposits. This motivates my search for sequestered deposits of CO_2 ice within the southern outlying ice deposits. If such CO_2 deposits are found, it would highlight a major difference between the northern and southern outlier ice deposits, and would also place new constraints on the thickness of the atmosphere in Mars' past. CO_2 sequestered in the ice would have once been in the atmosphere, which would have a significant impact on the Martian atmosphere and climate system. For example, the amount of CO_2 that has been found in the SPLD alone is enough to have doubled the atmospheric pressure on Mars pre-sequestration (Phillips et al., 2011). Even if sequestered CO_2 deposits are not found in these southern outliers, other differences in composition, purity, and/or surface roughness could provide exciting insights on the icy processes at work in each hemisphere.

Methods: To determine if a difference in physical properties of ice in the northern and southern outlying crater deposits exits, I will examine the ice at two different spatial and temporal scales. First, I will use the reflectivity of the primary surface echo to infer the roughness and dielectric constant of the younger surface ice. Similar techniques have been used to make global maps of SHARAD parameters (Campbell et al., 2013; Castaldo et al., 2017; Grima et al., 2012), but have not been used to study these outlying icy crater deposits. This will allow me to compare the present-day conditions of ice in the northern and southern hemispheres of Mars. I will also leverage the subsurface capabilities of SHARAD to analyze older layers of ice below the surface in these outliers, with the additional goal of determining the existence of sequestered CO_2 similar to that which Phillips et al. (2011) found within the SPLD. By analyzing the properties of both subsurface and surface reflectors, I will be able to make comparisons of physical properties of northern and southern icy outliers as well as the climate conditions that could have formed them.

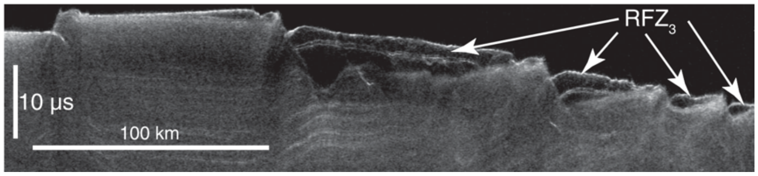

Figure 2. Example SHARAD radargram from Phillips et al. (2011). Reflection-free subsurface zones ("RFZ") were found to be pure CO2 deposits.

Intellectual Merit: Such a study of the outlying ice deposits has not yet been done. The Martian ice acts as a record of the climate in which it formed, so understanding the ice in both hemispheres is necessary in order to be able to answer the questions of what conditions were present in Mars' past. I expect that this study will provide new insights on the similarities and differences in composition, purity, and surface conditions of ice in the northern and southern hemispheres. Analyzing these properties can tell us how the ice was deposited; for example, very pure ice would be indicative of a deposition via snowfall, while low ice contents generally imply formation due to condensation of atmospheric water vapor within pore spaces of the regolith. Finding layers of ice with different properties would also provide strong evidence for changes in the climate, which could be linked to orbital/rotational variations analogous to Milankovitch cycles on Earth. This work may also confirm the presence or absence of sequestered CO_2 deposits in the southern outlying ice deposits, which if found would place new constraints on the thickness of Mars' atmosphere pre-sequestration of the CO_2.

Purdue University is an ideal institution at which to carry out this research. Here, I am advised by Prof. Ali Bramson, who has extensive experience working with SHARAD observations of Martian ice (e.g., Bramson et al., 2015) and is a Co-I on the NASA-funded Subsurface Water Ice Mapping (SWIM) project, which uses multiple types of observations (including radar) to map subsurface ice through the mid-latitudes of Mars. I will also be working with Prof. Mike Sori (also at Purdue University), using his database of southern outlying ice deposits (Sori et al., 2019) as the set of southern deposits I will be characterizing.

Broader Impacts: Indiana is home to the newest of our national parks: Indiana Dunes National Park (INDU). Using my experience as an Astronomy Ranger at Bryce Canyon National Park, I will work with the chief rangers of interpretation and education and INDU, Bruce Rowe and Kim Swift, to develop a night sky educational program that connects what we see in the sky to geology here on Earth. Though INDU is near the light pollution of Chicago, major planetary bodies are still visible. This night sky program will be held outdoors on the park's West Beach weekly during the main summer season (April–November) and focus on water and sand dunes throughout the solar system that are also present in the park. This park is uniquely located near major metropolitan areas, and as such these programs will serve communities that are traditionally underserved by science outreach. More details on this planned project can be found in my Personal Statement.

References:

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