# INVESTIGATION OF RADAR SUBSURFACE SOUNDING THROUGH SEASONAL CYCLES COLLECTED BY MARS SHALLOW RADAR (SHARAD) IN THE SOUTH POLAR AREA

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## ABSTRACT

Radar subsurface sounding has been applied to many different geological problems on Earth, including quantifying thickness of ice sheets, depth of bedrock and water table, and fracture imaging. Advancements in radar subsurface sounding technology have made exploration of other planets, such as Mars, possible. Usage of this method to understand planetary geology has thus increased dramatically within the past three decades, as it provides non-intrusive and rapid imaging that has aided in interpreting the natural history and current condition of Mars [1].

Mars Shallow Radar (SHARAD), which complements Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) on Mars Express, is a nadir-looking synthetic-aperture radar that currently collects both surface and subsurface data on Mars. SHARAD is provided by the Agenzia Spaziale Italiana as a facility instrument mounted on the Mars Reconnaissance Orbiter (MRO) [2]. SHARAD is designed to resolve smaller objects or finer layers than MARSIS, achieving sub-kilometer depth resolution due to its higher center frequency and bandwidth, which are 20 MHz and 10 MHz, respectively (Table 1) [2]. SHARAD's signal, as a tradeoff, is rarely able to record a basal reflection, unlike MARSIS. Therefore, SHARAD's primary objective is to map dielectric interfaces between layers down to a few hundred meters in selected areas, such as the polar layered deposits and stratigraphy within sedimentary rocks [3].

This investigation focuses on the change of SHARAD's signal characteristic over seasonal cycles in the south polar layered deposits, especially the solid $CO_2$ frost on the surface. Unlike the solid

**Table 1.** SHARAD and MARSIS Instrument Parameters [2].

| | SHARAD | MARSIS |
|---|---|---|
| **Frequency Band** | 15-25 MHz | 1.3 to 2.3, 2.5 to 3.5, 3.5 to 4.5, 4.5 to 5.5 MHz |
| **Vertical Resolution, theoretical, Reciprocal Bandwidth, $\varepsilon_r = 4$** | 7.5 m | 75 m |
| **Transmitter Power** | 10 W | 10 W |
| **Pulse Length** | 85 μs | 250 or 30 μs |
| **PRF** | 700 or 350 Hz | 127 Hz |
| **Antenna** | 10 m tip-to-tip dipole | 40 m tip-to-tip dipole |
| **Postprocessor SNR (Worst to Best)** | 50 to 58[a] dB | 30 to 50[b] dB |
| **Horizontal Resolution (Along Track X Cross Track)** | 0.3 to 1 km by 3 to 6 km | 5 to 10 km by 10 to 30 km |

(a) Estimate (b) Actual

$CO_2$ frost in the north polar region, which disappears completely during summer time in response to solar radiation, the south polar solid $CO_2$ frost retains a thin layer on the surface mixed with dust and water ice [4, 5]. The $CO_2$ frost becomes thicker during winter from condensation and precipitation, and becomes thinner due to sublimation during summer [5]. This phenomenon allows for the investigation of change in SHARAD's signal characteristic, such as its amplitude and phase, due to the seasonal cycles and the thickness of the $CO_2$ frost in the south polar region.

For this investigation, 39 datasets, collected over a two and a half year period (January 15th 2007 to July 10th 2009), were selected to analyze possible SHARAD signal changes that occurred during seasonal cycles. These datasets are, for the most part, evenly distributed throughout that time span, which provides a constant temporal interval. All the orbital tracks are shown as black lines in Figure 1, and the area of interest is within the blue box. This area shows strong radar signal returns and provides high quality data, as seen in Orbit #10654 and #13771 (Figure 2A and 2B, respectively). These datasets are located on a relatively flat surface, and exhibit minimal surface clutters, such as craters or rough topography, in that region. Reflections and orientation of internal layers in the subsurface are clearly defined due to the sufficient dielectric contrast between layers, which may indicate the variation of dust and sand content [5]. Erosion features on the surface that are present as layers in the shallow portion of the subsurface pinch out to the surface.

Choosing a field site which exhibits high quality and reliable data is essential to this investigation. By identifying layers and investigating signal characteristics in each orbit track, more insight can be gained into how the change of the $CO_2$ frost's thickness through seasonal cycles affects SHARAD's signal. A 3-D subsurface map can be constructed using seismic interpretation software , Kingdom Suite [6], for a better understanding of the Martian subsurface geometry and past depositional environments. More importantly, this investigation will extend the knowledge and evaluate the utility of the radar sounding method for future explorations of Mars. The extended abstract will further discuss data processing and creation of the 3-D subsurface map.

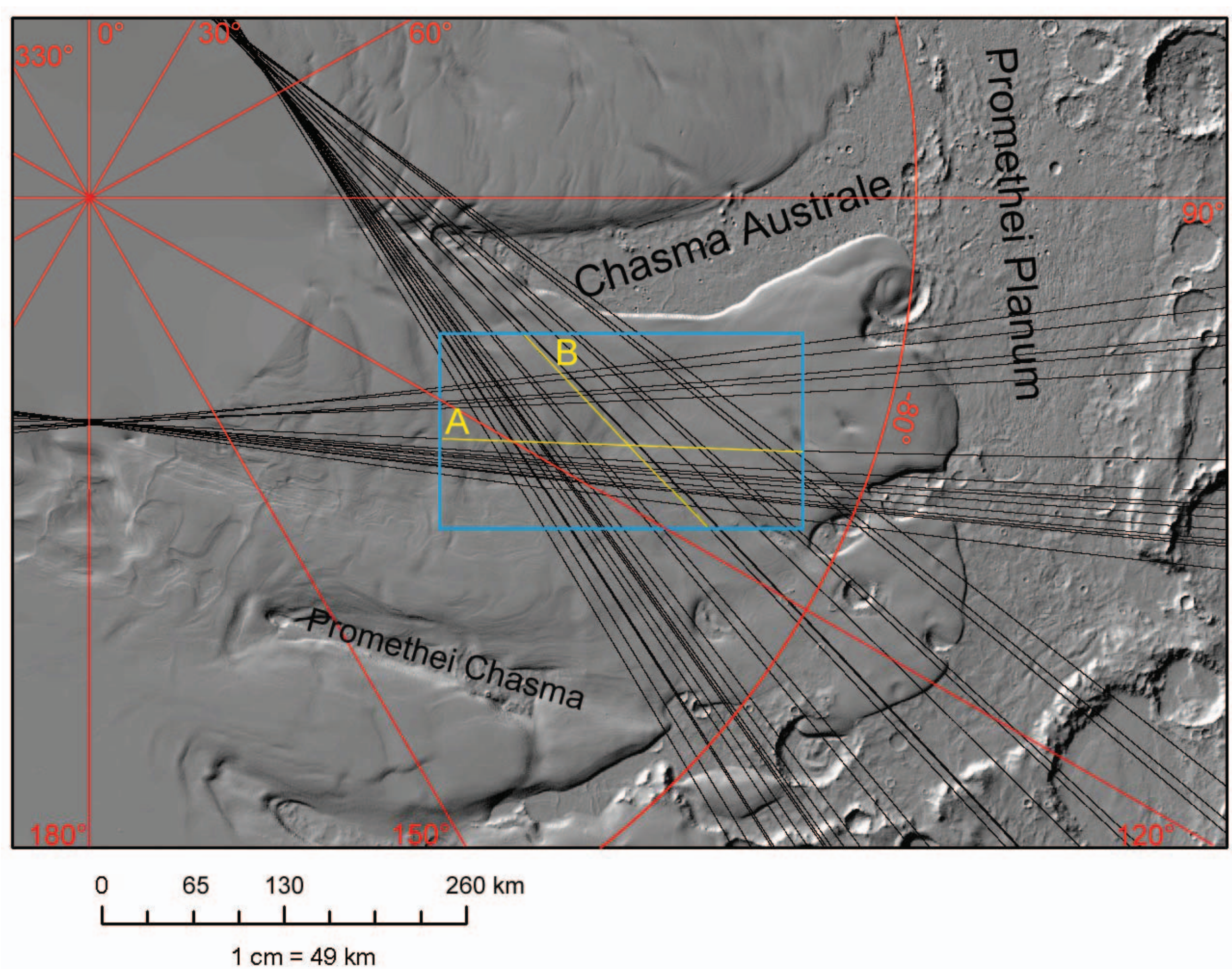


**Figure 1.** Field area (blue box) between Chasma Australe and Promethei Chasma in the south polar region where all of the orbit tracks (black lines) intersect each other. Echograms from transects A and B are presented in Figure 2.

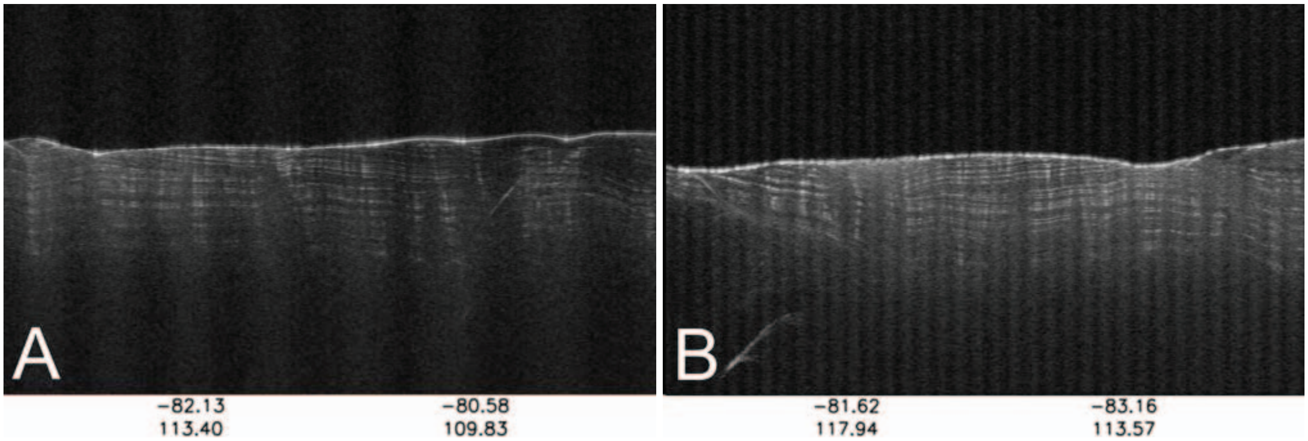


**Figure 2.** (A) Orbit #10654 acquired on Nov 8th, 2008, and (B) Orbit #13771 acquired on Jul 4th, 2009. Both are unfocused raw data. The strong reflection is from the surface and the internal layers are well defined. Both transects are identified in the area of focus shown in Figure 1 for reference.

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