EPSC Abstracts
Vol. 15, EPSC2021-465, 2021, updated on 28 May 2022
https://doi.org/10.5194/epsc2021-465
Europlanet Science Congress 2021

The first tens of meters of the Martian midlatitude subsurface: How to analyze SHARAD signal?

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Abstract

Radar data interpretation for subsurface analysis is based upon the comparison with simulations, to discriminate a subsurface echo from a surface reflector. Our goal is to detect subsurface ice at Mars's midlatitudes — that have been shown to be present in the first tens of meters below the surface [1]—, using data from the SHAllow RADar (SHARAD) onboard Mars Reconnaissance Orbiter (MRO).

We are specifically interested in looking into the southern midlatitudes of Mars, a highly craterized area with a variety of structures on the surface. This is why we have to be extra careful in the radar data analysis with the simulations, and we are faced with issues that are not necessarily present for the study of the poles.

We will present a method that allows us to complete the simulations and helps us to resolve further ambiguities.

Sounding the close subsurface of Mars's midlatitudes

The MARSIS and SHARAD Nadir-looking radars have been sounding the surface of Mars since respectively 2005 and 2006, at different frequencies — between 1.8 and 5 MHz for MARSIS, and 20 MHz for SHARAD [2]—. Their data have allowed us to better understand the composition and structure of the Martian subsurface.

On fathom radar profiles, echo coming from the subsurface from nadir could arrive with the same delay that surface echoes arriving from a slant direction. This ambiguity is classically resolved by simulation of the measurement from Digital Terrain Models (DTMs) as developed for MARSIS [3,4]: given a surface model and an orbitography, we can simulate the surface-related component of the signal. By comparing the radar data to the simulation, we can therefore — in theory — fully identify the subsurface reflectors.

The question is especially complex when the objective is to detect ice at Martian midlatitudes at depths lower than a few tens of meters. Furthermore, given that the radar signal mostly comes from the nadir and a limited area around, we will have a high sensibility for the variations in local slopes in the surface models used for the simulations.

In order to accurately simulate the surface component of the signal, the surface model resolution must be in the order of the wavelength or lower (15m for the case of SHARAD). This is why we will need higher resolution DTMs than the one mainly used for MARSIS simulations (MOLA). DTMs can be generated from different data types, but to have high resolution models, the privileged method is stereo photogrammetry [5]. As an example, with the CTX camera onboard MRO, we can reach a typical resolution of 12 meters, compared to the 463 meters of MOLA.

The area that we are focusing on is located in Terra Cimmeria, around (172°E ; 39°S), and shows a number of canal-like structures, along with numerous craters. Those structures are located a few degrees off-nadir, therefore very close to the main surface echo, complicating the analysis with the simulations. In fact, a slight variation of the model from the actual topography can change the result of the simulation, and the process of stereo photogrammetry introducing noise, we will necessarily be faced with some differences between simulations and radar data. Another issue is that on this specific area, only MOLA and HRSC DTMs are available, with a maximum resolution of 200m per pixel, far from the 15m of the wavelength.

With the aforementioned issues, we are left with ambiguities that we cannot resolve as is, so we must find a way to get around it. We will therefore present a method that allows to complete the simulation by resolving the remaining ambiguities. This method applied to the area discussed above allowed us to study in details the echoes analyzed by [6] and to revisit the results.

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