UNDERSTANDING PHOBOS SHALLOW SUBSURFACE GEOPHYSICAL PROPERTIES FROM MARSIS RADAR OBSERVATIONS.
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Introduction: Phobos hyperspectral observations suggested a close analogy to D-type asteroids with a composition similar to carbonaceous and ordinary chondritic material [1]. Moreover, Phobos low density has also been an indicator of high porosity and potential subsurface enrichment in volatiles mainly suggested to be water ice [2]. Such compositional and geophysical settings are favorable factors for low-frequency radar wave penetration [3]. Most recent spectral observations by the Mars Express visible and infrared mineralogical mapping spectrometer (OMEGA) during flyby's suggested that the surface regolith layer lacks the presence of hydrated minerals, [4] but potential presence of subsurface ice below the regolith is possible but yet to be explored [18][19]. In this effort we use the MARSIS low frequency sounding radar data acquired over the Mars Express flyby's from 2004 to 2014 to constrain the ambiguity on potential subsurface ice occurrence and to constrain the shallow subsurface density (first 200 meters).

Methodology: Our approach is based on a radiometric analysis of the MARSIS surface echoes for Phobos acquired during different flybys using two methods to assess the surface dielectric properties and compare the deduced values to ones from laboratory dielectric characterizations of chondritic samples under relevant porosity and ice enrichment conditions. We first use the time-decay method [5] to assess the average radar loss function in dB/m for each MARSIS frame, and then we use the normalized surface SNR variation for each frame to estimate the real part of the dielectric constant as derived from the surface attenuation in the radar propagation equation. Results are then being compared to the attenuation function SELENE radar data that provide an adequate analogue for the MARSIS Phobos flyby data, as both bodies are airless and hence do not have a plasma environment that can compromise the radiometric analysis. For the comparative radiometric analysis we selected orbits crossing smooth and flat terrains with below the MARSIS and SELENE Raleigh radars surface roughness criteria. Figure 1, shows the MARSIS orbits projection for Phobos considered in our analysis. Figure 2, shows the SELENE comparative orbits acquired over the Idelson Crater on the Moon that is substantially flat in its central area and is used herein as a validation of both the time decay method and the estimation of the dielectric constant from the normalized radar surface SNR.

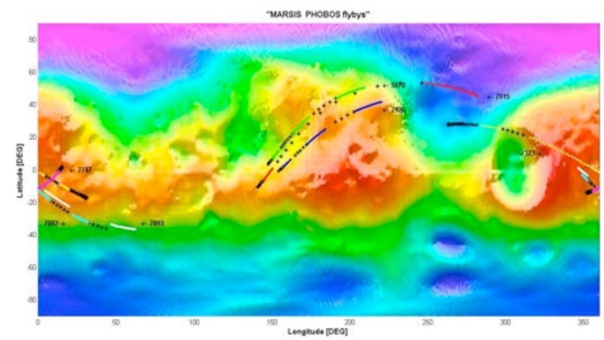

Fig.1. MARSIS orbit projection on Phobos topographic map. Orbits of particular interest are over low topographic areas.

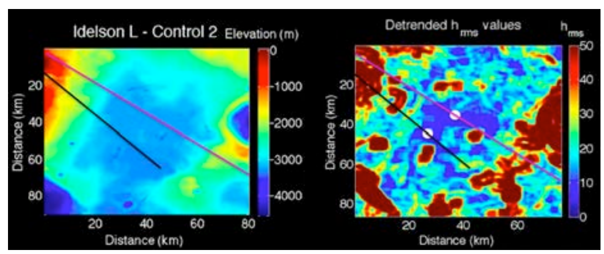

Fig.2. SELENE Radar orbit projection on Idelson crater topographic model on the Moon (Left part) and the calculated Hrms at 5 MHz (right part).

Preliminary results: the losses estimated form dielectric characterization of Phobos chondritic analog samples with no-ice inclusion [2] and from low frequency attenuation empiric scattering models [6] suggest an average two-way losses of respectively 0.077 dB/m and 0.024 dB/m at the MARSIS 3 MHz band; a total theoretical two-way losses of ~0.11 dB/m. Considering the observed total normalized surface SNR on the MARSIS frames for Phobos which ranged between 14 and 22 dB we estimate the theoretical penetration depth to range from ~127 to ~200m. Such exploration depth is sufficient to penetrate beneath the regolith layer and attempt to explore the validity of the subsurface ice enrichment hypothesis using the radar signal time-decay method in the MARSIS data. As the technique does not require the occurrence of discrete subsurface reflection, it is the most adapted signal analysis method to perform a radiometric study of the Phobos MARSIS radar data as no obvious subsurface signal has been unambiguously identified in the current frames for Phobos. Our preliminary observation of the total losses observed on Phobos smoothest surface orbit number 7915, is 0.057 dB/m that is ~50% below the theoretical estimate that assumes no ice inclusion. When compared to the total losses observed in SELENE radar sounding data that is measured to be 0.076 dB/m over our control site in Idelson's crater fill (which is also hypothesized to be ice-free), the losses observed on Phobos are substantially below the theoretical and lunar ones.

In the conference we will present the measured losses over all MARSIS reported flyby's for Phobos and derive the implication of such observations in constraining subsurface density and potential ice inclusion. We will also present a first order topographic analysis of selected section of the MARSIS orbit projection on Phobos where we carried our radiometric analysis. If the current observations are not biased by anomalic surface roughness they could be used to verify the Phobos potential subsurface Ice-enrichment hypothesis as will be discussed at the time of the conference.

References. [1] Lewis, J. S. (2004). Physics and Chemistry of the Solar System. *Elsevier Academic Press*. p. 425. [2] Busch, M. W.; *et al.* (2007), *Icarus* 186 (2): 581–584. [3] Heggy et al., (2012), *Icarus*, 221, 925–939. [4] Rivkin, A. S.; et al. (2002), *Icarus* 156 (1): 64. [5] Boisson et al., (2011), *JGR-Planets*, 114, E08003-11. [6] Heggy et al., (2006), *JGR-Planets*, 111, E06S04-08

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