MARS AS AN ANALOG TO ANTICIPATE RADAR SURFACE REFLECTIVITY AT EUROPA.

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Introduction. The Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) is an active dual-frequency (9 / 60 MHz, i.e. 33 / 5 m) instrument led by the University of Texas Institute for Geophysics (UTIG) to investigate Jupiter's moon Europa from the upcoming NASA's Europa Clipper [1]. REASON will investigate subsurface waters and ice shell structure (Sounding), surface elevation (Altimetry), tides (Ranging), surface physical properties (Reflectometry), and the ionospheric environment (Plasma). The success of these measurements is partly dependent on the wavelength-scale roughness that defines the transmission and reflection losses at the surface. However, such roughness has never been directly measured at Europa, and down-extrapolation from coarser topography can be signficantly biased [2]. The goal of this study is to evaluate the trends of this bias for Martian terrains at different radar frequencies, so that surface losses at Europa simulated from down-extrapolated roughness can be better appreciated within the framework of well-observed and heterogeneous bare planetary terrains, while still considering the differences of the geophysical settings. We derive surface reflectivity from analytic backscattering models [2] applied to roughnesses down-scaled from the Mars Orbiter Laser Altimeter (MOLA) [3]. The modeled reflectivity is then compared to actual surface echo measurements from the Shallow Radar (SHARAD) [4].

Modeled Reflectivity. Backscattering models derive the effective reflectivity of a surface from its roughness and dielectric permittivity. The roughness of planetary terrains has a fractal behaviour, i.e. it varies with the length over which it is measured. Current fractal backscattering models define the relevant scale of measurement to be the wavelength of the radar frequency [5]. Here, we use roughness down-extrapolated to radar wavelength by [3] from the MOLA dataset initially measured at 463-m horizontal scale. Then, we derive the corresponding surface reflectivity for MARSIS, SHARAD, REASON, and the upcoming Radar for Icy Moon Exploration (RIME). Fig. 1 provide results assuming the whole surface is made of compact and clean water ice ($\varepsilon = 3.15$). Fig. 2 compares the distribution of the reflectivity for the four frequencies considered. The distributions are dominantly bi-modal, extending over 30-40 dB each. The weaker and stronger peaks are signatures of the rough cratered plateaus and the smooth northern plains, respectively. The difference between the two modes is less pronounced at 4 MHz (12 dB) than at other higher frequencies (19 dB). Globally, REASON at 9 MHz is about 15 dB stronger than REASON at 60 MHz with little dependency to the type of terrains.

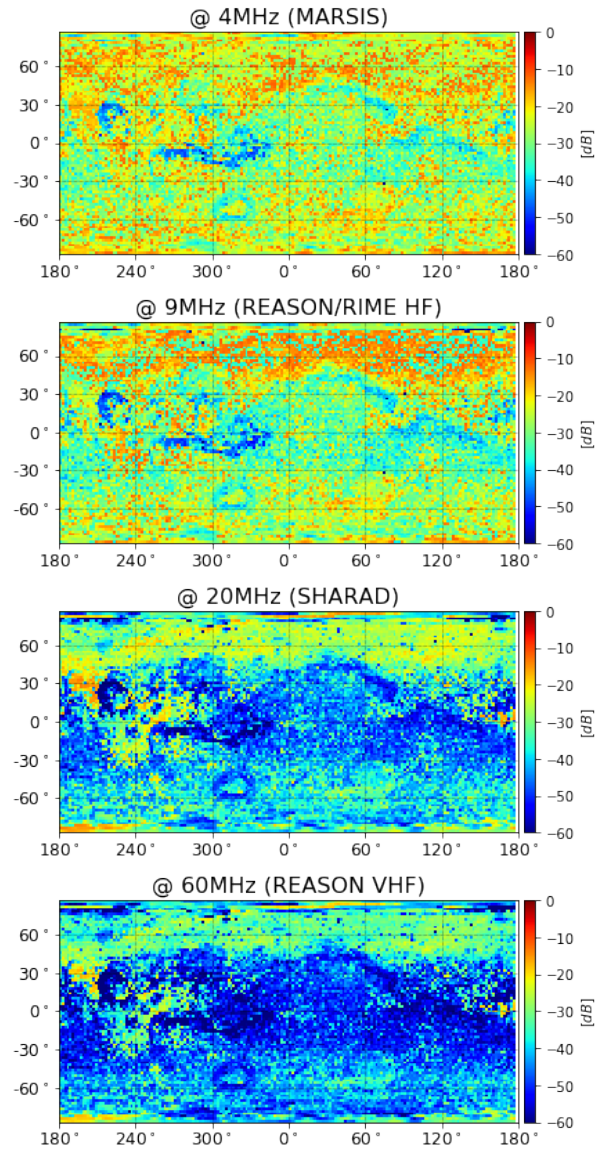

Figure 1: Modeled Martian surface reflectivity from extrapolated roughness at four frequencies with respect to a mirror-like perfect reflector (i.e., a reflectivity of unity, or 0 dB). The surface is assumed to made of water ice planet-wide ($\varepsilon = 3.15$).

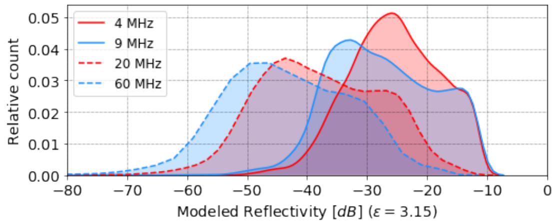

Figure 2: Distribution of Martian surface reflectivity from the four radar frequencies on Fig. 2.

Observed Reflectivity. The modeled reflectivity at 20 MHz is compared to the one observed by SHARAD [4] over a region covering both rough and smooth terrains in Southern Elysium Planitia (Fig. 3). The data set is calibrated so that the reflectivity of the South Polar Layered Deposits equals the one of smooth pure ice ($\varepsilon = 3.15$) [4]. Noteworthy, the observed reflectivity is affected by additional unknown variations of the surface dielectric permittivity throughout the region of interest, by opposition to the modeled reflectivity. Nonetheless, the observed data is dispersed over a smaller fraction than the modeled data, and about 30 dB stronger (Fig. 3. Bottom). The peak for the smooth terrains has more relative counts than for rough terrains. To have a better insight on this latter behaviour, we further broke down the reflectivity in terms of coherent and incoherent contribution following the Radar Statistical Reconnaissance (RSR) methodology [6]. The backscattering model does not predict any strong coherent contribution, while coherent energy is dominant in the observed data over the smooth terrains.

Discussion. The reflectivity sets in this study are provided in terms of signal losses relative to a mirror-like reflector with a reflectivity of unity (0 dB), related to the geophysical losses induced by surface backscattering, independent of instrumental or geometric losses. By definition, it is the inverse of the "radar potential" concept used to assess REASON's performance [7]. The 15 dB systematic difference between the modeled 9 MHz and 60 MHz frequencies at Mars, regardless of the terrain type, gives a trend for the relative signal return expectations at Europa with REASON. Absolute reflectivity does not appear to be predicted well. The tens of dB offset between the modeled and observed data is too large to be uniquely due to unknown dielectric permittivity (which is not taken into account in this study). A better explanation comes from the dominant coherent contribution detected in the observed SHARAD reflectivity only. The presence of coherent energy is indicative of a relatively smooth surface at wavelength scale. Its systematic absence in the modeled data set suggest that the extrapolation of the roughness down to smaller scales does overestimate the true roughness in a significant manner.

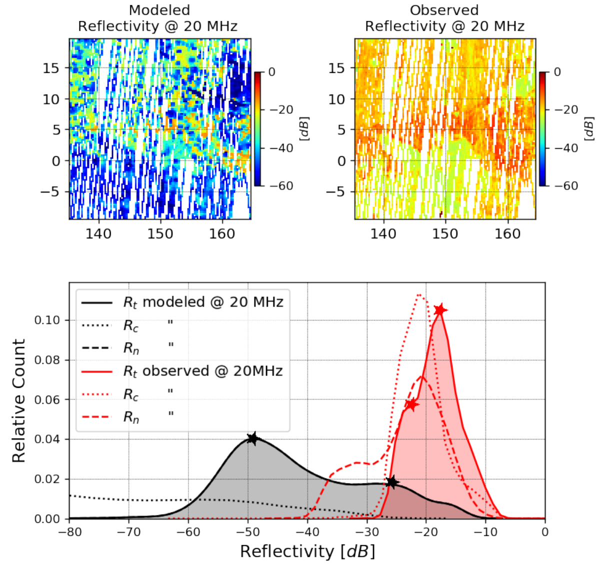

Figure 3: Modeled (Top Left) and Observed (Top right) reflectivity at 20 MHz in a zone south of Elysium. (Bottom) Distributions of the total reflectivity (R_t) as well as coherent (R_c) and incoherent (R_n) contributions. The R_t and R_n curves overlap in the modeled case. Stars highlight the two main modes of each R_t curve.

We will investigate if this trends are systematic over a wider variety of Martian terrains with both SHARAD and MARSIS data to determine what this observation means for the Europan case.

References: **[1]** C. Grima, Blankenship, and Schroeder. "Radar signal propagation through the ionosphere of Europa". In: *PSS* 117 (2015), pp. 421–428. **[2]** B. A. Campbell, R. R. Ghent, and M. K. Shepard. "Limits on inference of Mars small-scale topography from MOLA data". In: *GRL* 30 (2003), p. 1116. **[3]** C. Gerekos et al. "Martian roughness analogues of Europan terrains and implications on radar backscatter". In: (in prep.). **[4]** C. Grima et al. "Quantitative analysis of Mars surface radar reflectivity at 20 MHz". In: *Icarus* 220 (2012), p. 84. **[5]** B. A. Campbell and M. K. Shepard. "Coherent and incoherent components in near-nadir radar scattering: Applications to radar sounding of Mars". In: *JGR* 108 (2003), p. 5132. **[6]** C. Grima et al. "Planetary landing-zone reconnaissance using ice-penetrating radar data: Concept validation in Antarctica". In: *PSS* 103 (2014), pp. 191–204. **[7]** Young D. A. et al. "REASON For Europa: Data products and algorithms". In: *AGU Fall Meeting 2018, Washington, DC* P51G-2955 (2018).