RADAR SUBSURFACE SOUNDING OVER THE PUTATIVE FROZEN SEA IN CERBERUS PALUS, MARS. R. Orosei[1], M. Cartacci[2], A. Cicchetti[2], C. Federico[3], E. Flamini[4], A. Frigeri[3], J. W. Holt[5], L. Marinangeli[6], R. Noschese[2], E. Pettinelli[7], R. J. Phillips[8], G. Picardi[2], J. J. Plaut[9], A. Safaeinili[9], R. Seu[2], [1]Istituto di Astrofisica Spaziale e Fisica Cosmica, Istituto Nazionale di Astrofisica, 00133 Rome, Italy (roberto.orosei@iasf-roma.inaf.it), [2]Dipartimento INFOCOM, Università di Roma "La Sapienza", 00184 Rome, Italy, [3]Dipartimento di Scienze della Terra, Università di Perugia, 06123 Perugia, Italy, [4]Agenzia Spaziale Italiana, 00198 Rome, Italy, [5]Institute for Geophysics, University of Texas at Austin, Austin, TX 78758, [6]International Research School of Planetary Sciences, Università degli Studi "Gabriele d'Annunzio", 65127 Pescara, Italy, [7]Dipartimento di Fisica "E. Amaldi", Università Roma Tre, 00146 Rome, Italy, [8]Southwest Research Institute, Boulder, CO 80301, [9]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

Introduction: Here we present observations acquired by the orbiting radar sounders MARSIS and SHARAD over Eastern Elysium Planitia, Mars. This area encompasses Cerberus Palus, located between 144.5°E and 152.5°E, and between 1°N and 8.9°N, where the Mars Express High Resolution Stereo Camera acquired images of surfaces with platy textures that were interpreted as evidence for a frozen sea close to Mars' equator [1]. Other studies of the Martian topography and images have focused on these platy textures that are at scales as large as hundreds of meters to kilometers, interpreting them as being resultant of lava-flows, mud-flows, or ice-flows [2], with both lava and water erupting from Cerberus Fossae and reaching Cerberus Palus through Athabasca Valles. The surface of the area is extremely young, perhaps less than 10 Ma old. The area is not uniform in age, however, as multiple events are testified by overlapping flows and variation in crater density. According to [3], the stratigraphy of the area should consist of several layers of lava flows, many of which could be just a few tens of meters thick.

MARSIS [4] and SHARAD [5] are synthetic-aperture, orbital sounding radars, carried respectively by ESA'a Mars Express and NASA's Mars Reconnaissance Orbiter. They work by transmitting a low-frequency radar pulse that is capable of penetrating below the surface, and is reflected by any dielectric discontinuity present in the subsurface. Whereas MARSIS is optimized for deep penetration, having detected echoes down to a depth of 3.7 km over the South Polar Layered Deposits [6], SHARAD is capable of a tenfold-finer vertical resolution, namely 15 m or less, depending on the dielectric constant of the material being sounded. MARSIS is capable of transmitting at four different bands between 1.3 MHz and 5.5 MHz, with a 1 MHz bandwidth. SHARAD operates at a central frequency of 20 MHz transmitting a 10 MHz bandwidth.

MARSIS and SHARAD Data: In spite of the extensive coverage, no subsurface interfaces could be clearly seen by MARSIS, although there is a very weak, shallow, discontinuous subsurface echo in the area around 152°E, 6°N. Although somewhat puzzling, this is perhaps due to the relatively fine subsurface layering hypothesized for this area [3], which would be below the vertical resolution of MARSIS.

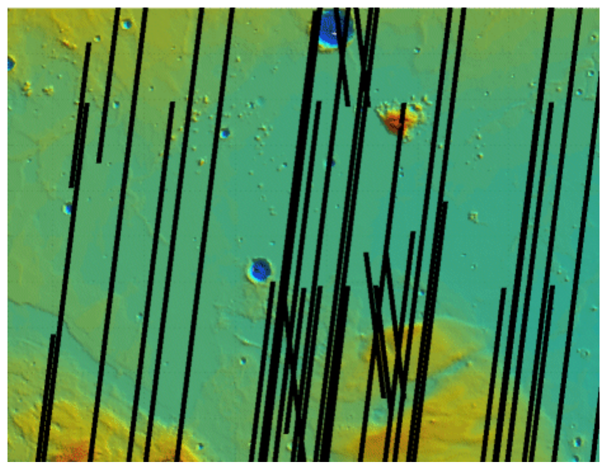

Fig. 1: *Topographic map of the area comprised between 135°E and 165°E, and between 0° and 15°N. SHARAD ground tracks are shown as thick black lines. Cerberus Palus corresponds to the flat, low lying central part of the map.*

Approximately 60 observations have been successfully acquired by SHARAD so far, but the coverage is still far from being complete, as shown in Fig. 1. Very often, one or more subsurface reflections can be seen, sometimes continuing for more than 100 km. However, whereas the surface reflection remains constant in strength, the subsurface echo fluctuates, sometimes becoming lost in noise. This could be an effect of inhomogeneities of the material, or it could be resulting from a rough subsurface interface. The time delay of subsurface reflections corresponds to depths ranging from ~50 m to ~150 m, depending also on the unknown dielectric permittivity of the surface material. SHARAD subsurface echoes from part of the easternmost portion of Cerberus Palus are stronger than those detected over other areas

Modeling surface and subsurface reflections: We have mapped surface and subsurface reflection strengths, as well as time delay between surface and subsurface echoes, over the putative frozen sea, and we have applied a simplified model of radar signal propagation to estimate the dielectric properties of the surface material. The propagation model is taken from [7], and requires the assumptions that surface and subsurface echoes are specular reflections from plane parallel layers, and that dielectric properties are uniform within the layers. Topographic roughness computed in [8] from MOLA data is very low in this area, so that the surface can indeed be assumed to be mirror-like.

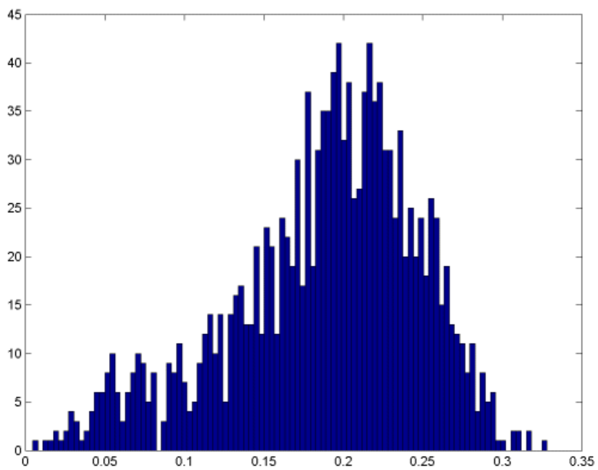

Fig. 2: *Histogram of estimated values of the loss tangent over Cerberus Palus. It can be seen that most values are > 0.1, and thus incompatible with a surface made of either pure or dirty ice. Low values are affected by an error which is equal or greater than their magnitude, and thus cannot be used to infer the nature of the surface material.*

Values for the real dielectric permittivity ε of ices and rocks are comprised between 3 and 9, while values for the loss tangent $\tan\delta$ (the ratio between the imaginary and real part of the complex dielectric constant, a measure of signal attenuation within the medium) span across order of magnitudes, depending on the material: as a rule of thumb, they are $\sim 10^{-4}$ for pure water ice at low temperature, $\sim 10^{-3}$ for dirty ice or very porous rocks, and 10^{-2} to 10^{-1} for dense rocks.

Unfortunately, a value for $\tan\delta$ can be computed only if the real dielectric permittivity ε of both surface and subsurface can be estimated, which is not possible from SHARAD data alone. Because of the limited range of variation for these parameters, however, we estimate that the error affecting $\tan\delta$ due to lack of knowledge of the values of ε is at most ±0.05. Such error is well above the values of $\tan\delta$ for ice, but high values of $\tan\delta$ can be safely interpreted as due to the presence of rock instead of ice as surface material. Results are shown in Fig. 2 and Fig. 3.

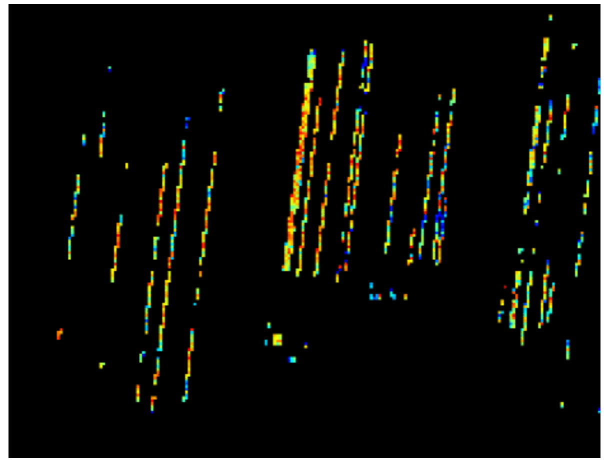

Fig. 3: *Color-coded map of loss tangent values over Cerberus Palus. Areas of low loss (in blue) are sparse and limited in size. The largest of these areas is centered around 152°E, 5°N.*

Summary: The area of Cerberus Palus has been explored, but not fully covered, by both MARSIS and SHARAD. MARSIS has not clearly detected any subsurface interface, perhaps because of the relatively fine subsurface layering hypothesized for this area. SHARAD sees subsurface reflections over most of the area, with varying depths and strengths. Low-loss surface material in Cerberus Palus is found only in small patches over the putative frozen sea. The largest of these areas is centered around 152°E, 5°N. No conclusions can be drawn on the nature of this low-loss surface material due to the relatively large error on the estimate. However, high losses are seen throughout the vast majority of the area: the hypothesis of a frozen sea several tens of meters thick covering the entire area is uncompatible with these results.

References: [1] Murray J. B. et al. (2005) *Nature*, *434*, 352-356. [2] Williams R. M. E. and Malin M. C. (2004) *JGR*, *109*, CiteID E06001. [3] Hartmann W. K. and Berman D.C. (2000) *JGR*, *105*, 15011-15025. [4] Seu R. et al. (2007) *Science*, *317*, 1715-1718. [5] Picardi G. et al. (2005) *Science*, *310*, 1925-1928. [6] Plaut J. J. et al. (2007) *Science*, *316*, 92-95. [7] Porcello L. J. et al. (1974) *Proc. IEEE*, *62*, 769-783. [8] Kreslavsky M. A. and Head J. W. (2000) *JGR*, *105*, 26695-26712.