SHARAD Data Mapping for Surface Composition Detection

Luigi Castaldo[1], Daniel Mège[1], Roberto Orosei[2], Giovanni Alberti[3] , Joanna Gurgurewicz[1, 4]

[1]Institute of Geological Sciences, Polish Academy of Sciences, Wrocław, Poland, [2]Istituto di Radioastronomia, Istituto Nazionale di Astrofisica, Bologna, Italy, [3]CO.RI.S.T.A., Napoli, Italy, [4]Space Research Centre, Polish Academy of Sciences, Warsaw, Poland

MPSE 2014 - Mars Connecting Planetary Scientists in Europe - June 3–5, 2014

Abstract

Synthetic Aperture Sounding is an important advance over conventional sounding, and it can be used to directly resolve the stratigraphy of the subsurface and to determine the composition of the first meters of the surface. The Radar Shallow Subsurface Radar (SHARAD) was designed to study the structure and composition of the Martian surface and subsurface [1]. The study of the reflectivity of the surface echo is a means to obtain information on the composition and geometry of the ground. A mathematical method of calibration has been developed, adopting a model of surface scattering in place of "ground truth", to estimate the variation of geophysical parameters from geometry variations, slopes, material composition and ice presence.

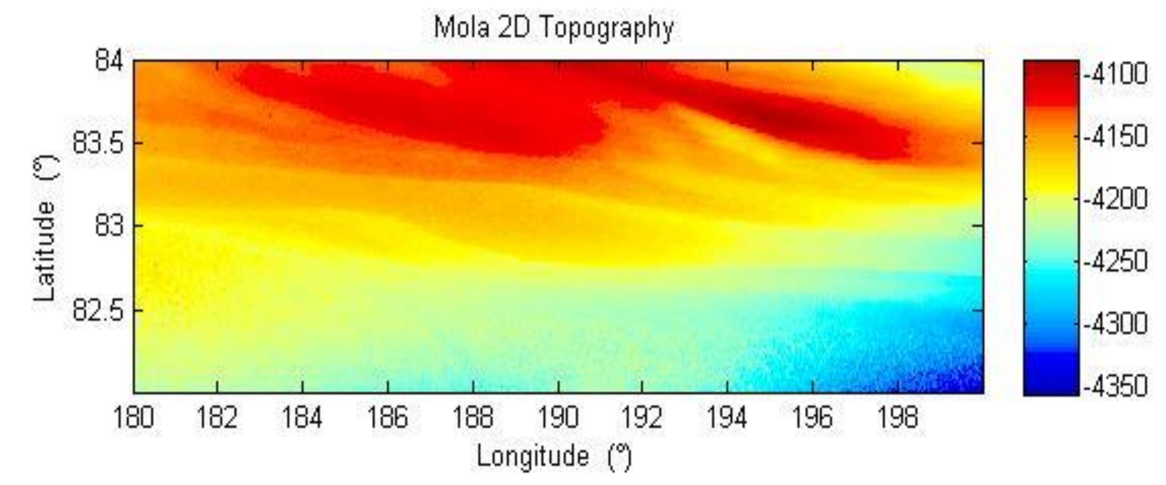
Goal

The goal is to model the relationship between surface permittivity constant and radar power measurements. Obtaining calibrated radar data can be used to extract geologic information on the first meters of the Martian surface. To this aim, Sharad Level 1b products have been used, as processed by the ground segment of the SHOC Radar Center in Rome and available on PDS node.

Model

The effects of scattering due to surface roughness and slope has been taken into account. A fractal geometry model has been adopted as it is scale invariant, and has high fidelity in surface backscattering estimate. The data adopted for the fractal backscattering estimate are the Precision Experiment Data Records of MOLA [2]. The fractal geometry has been used to match a mathematical abstraction of fractal physics and electromagnetic field. Under those assumptions a model has been developed to use fractal geometry parameters from MOLA altimetry data [3]. The model is based on the following main assumptions: (1) scattering takes place at the interface between two media, i.e. space and the Martian surface; (2) the first medium is supposed to have the permittivity of open space, the second medium is supposed to be homogeneous and non-dispersive. A chosen calibration area is located inside the North Polar Cap, between 82° N and 84° N, and between 180° E and 200° E. The area consists primarily of water ice with a few percent of dust [4] and this will be the input area of the model.

North Polar Cap



The standard radar equation is used for the calibration

$$P_r = P_t G \sigma_0 \frac{A_{eff}\, a_z}{H^4 (4\pi)^2}$$

where

$$A_{eff} = \lambda \frac{\sqrt{\left(\frac{c_0 H}{B_w}\right)}}{\sin(\theta_{3dB})}$$

effective area at 3dB

$$a_z = 2\, PRF\, N_{pre} \frac{H}{V_t} \tan\left(\frac{\theta_{3dB}}{2}\right)$$

broadening factor

G= antenna gain H= antenna gain σ_0= RCS (Radar Cross Section) for linear polarization P_r= Power backscattered P_t= Power trasmitted

Surface Relative Permittivity is evaluable from the inversion of Fresnel Equation

$$R^2 = K_{ice} \frac{Echo H^4}{G^2 \sigma_{0norm} A_{eff}\, a_z}$$

where

$$K_{ice} = \frac{G_{ice} \sigma_0 A_{eff} A_z}{P_r H^4}$$

calibration constant

$$\epsilon = \left(\frac{1+\sqrt{R^2}}{1-\sqrt{R^2}}\right)^2$$

Fresnel equation

R= Fresnell coefficient G= antenna gain σ_0= RCS for linear polarization H= Height of the satellite $Echo$= Filtered backscattered power A_{eff}= effective area at 3db a_z= broadering factor trasmitted

Sharad penetration for the first layer of surface

$$px = \frac{c_0}{2 f_c \sqrt{\varepsilon}}$$

where

$$f_c = \frac{80}{3} Mhz$$

under sampled frequency

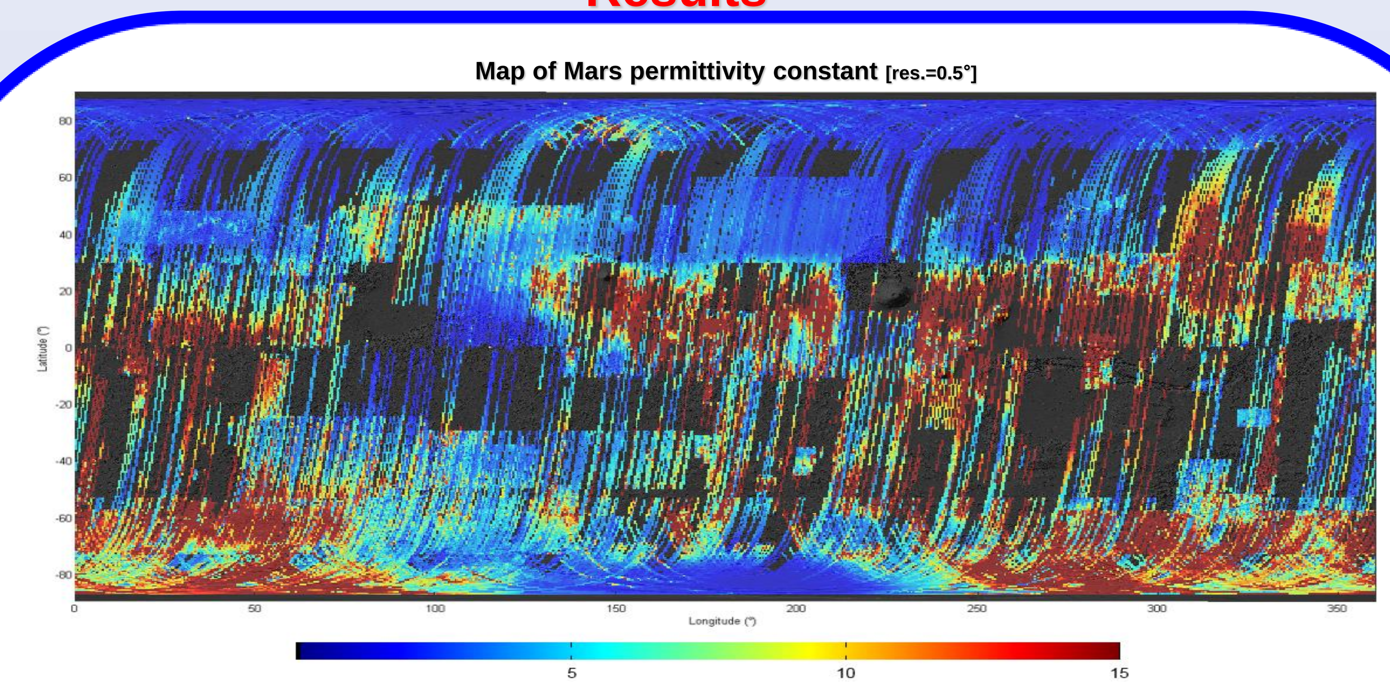
$$v_s = \frac{1}{\sqrt{\mu_0 \varepsilon_0 \varepsilon_r}}$$

propagation speed in non empty space

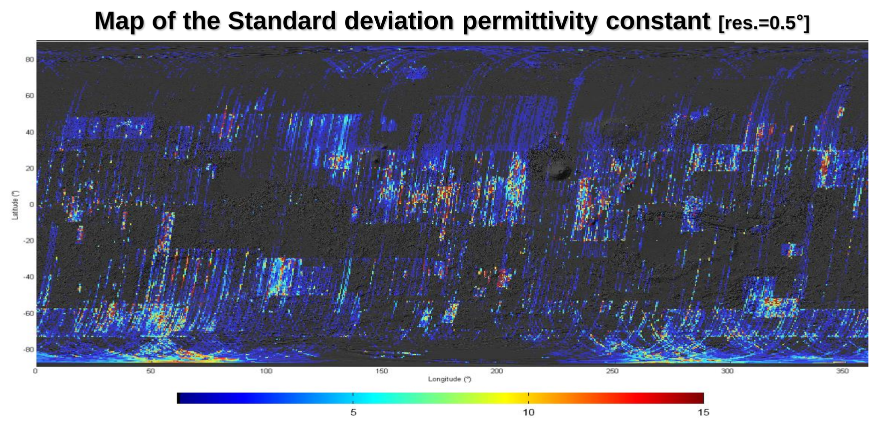
px = pixel spacing c_0=speed of light f_c=sampling frequency

Results

Map of Mars permittivity constant [res.=0.5°]

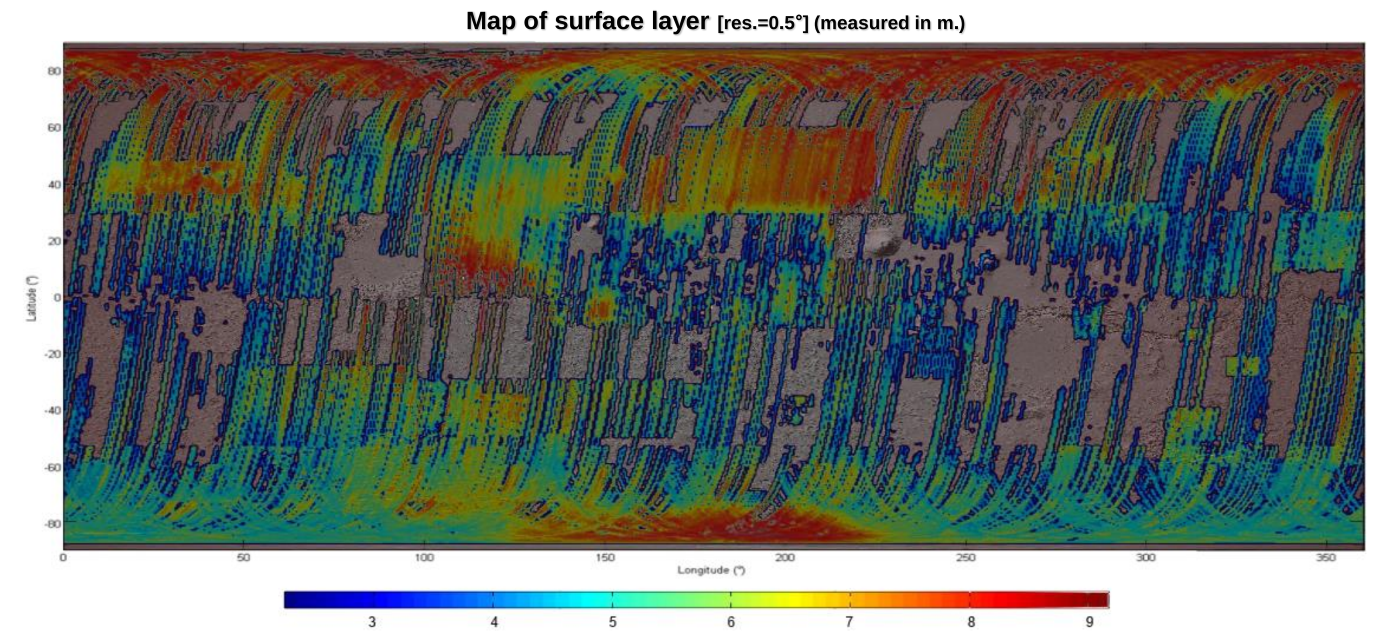


Map of the Standard deviation permittivity constant [res.=0.5°]

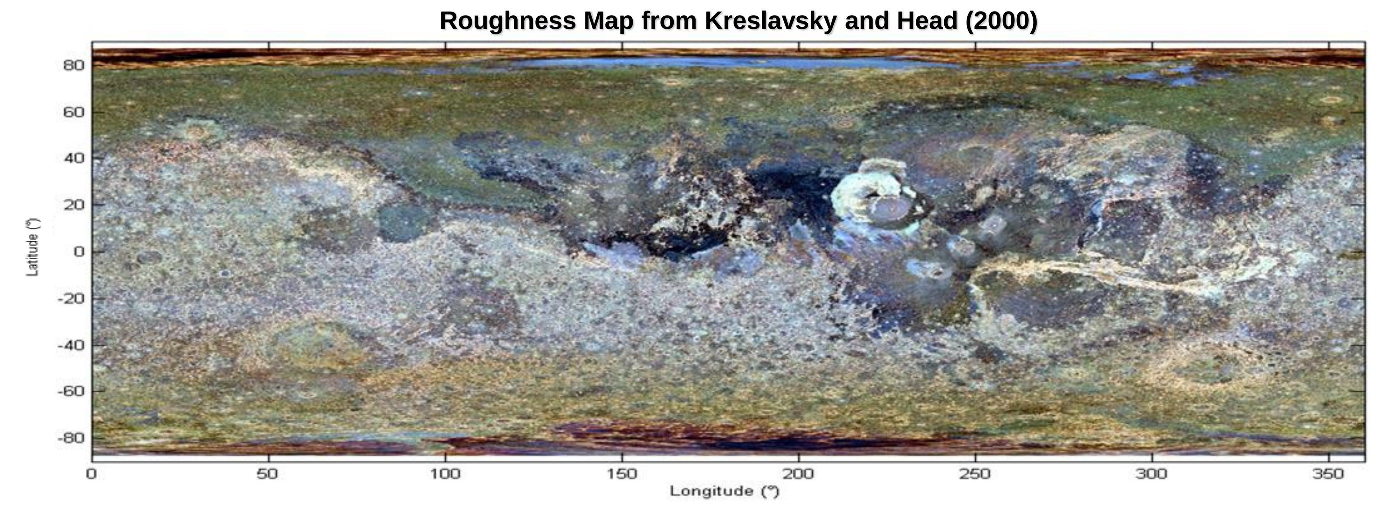


The generally low values of the standard deviation testifies to the accuracy of the model.

Map of surface layer [res.=0.5°] (measured in m.)



Roughness Map from Kreslavsky and Head (2000)



Brightness is proportional to roughness. Roughness has been removed prior to retrieving the permittivity constant.

Discussion

Signal calibration made possible the realization of mapping the real part of the permittivity constant for the Martian surface. Such maps provide a look into the nature and statistical distribution of the materials constituting the Martian surface. Permittivity constant maps have been used to help identify the areas where shallow ice, or regolith can be found. The results of the model shows that a good roughness correction has been applied to the signal. Because Sharad has a better vertical resolution than MARSIS, it reveals more information on the first subsurface layers. This method has the potential of revealing local permittivity deviations from large-scale structures. Future studies will be designed to validate the method and will focus on areas of particular geological interest.

References

[1] Seu, R. J. Phillips, D. Biccari, R. Orosei, A. Masdea, G. Picardi, A. Safaeinili, B. A. Campbell, J. J. Plaut, L. Marinangeli, S. E. Smrekar, D. C. Nunes, (2007) SHARAD sounding radar on the Mars Reconnaissance Orbiter, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, E05S05, doi:10.1029/2006JE002745.[2] Kreslavsky, M.A., Head, J.W. (1999), Kilometer scale slopes on Mars and their correlation with geologic units: initial results from Mars Orbiter Laser Altimeter (MOLA) data. J. Geophys. Res. 104, pp. 21911–21924. [3] Seu, R. et al., (2007) SHARAD sounding radar on the Mars Reconnaissance Orbiter, . Geophys. Res., VOL. 112, E05S05, doi:10.1029/2006JE002745. [4] Castaldo L., et al., (2013) Scientific Calibration of SHARAD Data over Martian Surface, Signal Processing Symposium, Jachranka Village, Poland, 978-1-4673-6319-8/13/S31.00 c IEEE /ISBN COPYRIGHT REG. NO. ISBN 978-1-4673. [5] Mätzler C., (1998), Microwave properties of ice and snow, in Schmitt, B., et al. (eds.) "Solar System Ices", Astrophys. and Space Sci. Library, Vol. 227, Kluwer Academic Publishers, Dordrecht, pp. 241-257.