EPSC Abstracts
Vol. 13, EPSC-DPS2019-865-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Reassessing Europa's Surface Roughness

Gregor Steinbrügge (1), J.R.C. Voigt (2), D.M. Schroeder (3), A. Stark (4), M.S. Haynes (5), K.M. Scanlan (1), C.W. Hamilton (2), D.A. Young (1), H. Hussmann (4), C. Grima (1), D.D. Blankenship (1)
(1) Institute for Geophysics, University of Texas at Austin, Austin TX, USA (2) Lunar and Planetary Laboratory, University of Arizona, Tucson AZ, USA (3) Department of Geophysics, Stanford University, Stanford, CA, USA (4) Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany (5) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Abstract

We re-evaluated the surface roughness of Europa at scales between 30 m and 5 km using stereo-pair images collected by the Solid State Imager (SSI) aboard the Galileo mission with a resolution between 9 m and 255 m per pixel. These images have been adjusted relative to each other to obtain consistent mosaics used for geomorphological mapping. Overall we have a set of nine regions covered by stereo images. The roughness is derived for different geologic terrains which have been distinguished by geomorphological mapping and analyzed separately. For each facies studied, we report the structure function, the breakpoints, and the respective power laws parameterized in terms of Hurst exponents. We also discuss the implications for laser and radar performance as well as for a potential lander.

1. Introduction

Little quantitative information is currently available about the surface roughness of Europa but it is an important mean to quantitatively investigate the morphology of surfaces and to understand surface processes. It is thereby a constraint on models studying the surface evolution since different geological processes usually express themselves by different roughness values on various scales. Surface roughness is also a performance driver for various remote sensing instruments on upcoming Jupiter Icy Moons Explorer (JUICE) [4] and the Clipper mission [5], e.g, the radar sounders Radar for Icy Moon Exploration (RIME) [1] and the Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON) [2] or the Ganymede Laser Altimeter (GALA) [3]. Further, the potential of finding a suitable landing site for a future lander [6] is dependent on the low scale roughness. However, in the outer Solar System, topographic information is sparse.

For Europa, only a small number of digital terrain models (DTMs) were created using photoclinometry and, in a few cases, using stereo images [7]. While the surface roughness has been analyzed previously [8], these studies do not differentiate by surface type classification within a single DTM.

2. Methods

We performed geomorphological mapping using mosaics of Galileo stereo images collected by the Solid State Imager (SSI). The resolution of the stereo images is between 9 m and 255 m and they cover nine study areas distributed within seven distinct regions across the surface of Europa. Within these areas we mapped a total of twelve geological units. In order to evaluate the surface roughness, we first remove the slope from the DTM. We then calculate the root-mean-square height deviation within every unit and study area as a function of distance between pixels. On a fractal surface the so obtained structure function follows a linear trend when plotted in a double logarithmic plot. In case of a linear behavior we can perform a fit and hence determine the Hurst exponent of the terrain type. The surface roughness can then be expressed by the roughness at unity scale y_0 and the Hurst exponent

$$y(x) = y_0 \, (x/x_0)^{H}.$$

However, there are usually breakpoints within the structure function where the roughness transitions from one exponent to another one, representing a change in the underlying power law. The location of the breakpoints is assumed to be related to different processes which form or modify the surface and are therefore of special interest within this work.

3. Results

We show that it is very characteristic for Europa's surface to have break points located at the wavelength of few hundreds of meters. We associate this baseline to be characteristic for ridges. Below this break point Europa's surface tends to be very rough with Hurst exponents in the order of 0.8. However, above the breakpoint the Hurst exponent tends to drop rather quickly to values between 0.2 and 0.4 in absence of prominent long scale topography on the moon. We also extrapolated the roughness to the 1 m scale to give some estimate of the small scale roughness. Assuming that no further breakpoints below the image resolution are present we find values between one and two meters on the 1 m scale for chaos terrain and average values around 0.6 meters for ridged terrain illustrating a complex surface.

4. Conclusion and Implications

Since surface roughness can be a significant performance driver for remote sensing instruments we also investigated the implication for the upcoming JUICE and Europa Clipper missions. We find that on the baseline of laser altimeter footprints the expected roughness values are generally comparable or above rough terrestrial planets, which in the case of the GALA, is compensated by the high albedo of the moon. For radar, we conclude, that valid returns are expected for almost all terrain types and roughness ranges at the REASON HF frequency (9 MHz) and for the smoother parts on the VHF frequency (60 MHz), benefiting from the lower Hurst exponents at the Fresnel zone scale. For a possible lander, Europa poses a significant challenge as a lander design must be more robust with respect to rough surfaces as compared to current Mars landers.

Acknowledgements

We thank Bernd Giese for supporting this work by providing the digital terrain models. A. Stark was supported by a research grant from Helmholtz Association and German Aerospace Center (DLR) (PD-308). This work was supported by the REASON investigation within the Europa Clipper project. A portion of this work was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA.

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