EPSC Abstracts
Vol. 9, EPSC2014-605-1, 2014
European Planetary Science Congress 2014

Anisotropy of topography

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Abstract

Over the last decade, the topography of many solar system bodies has been determined by laser altimetry. Many statistical analyses have been done on Mars [1], the Moon [2] or Mercury [3]. The roughness at kilometer-scale has been compared to geomorphological maps of Mars [4]. Also a comparative study of roughness between Mars, the Moon and Mercury has been made[5]. All of these studies used 1-D along-track profiles and implicitly assumed that the topography is statisticallyisotropic. Here we make a first attempt at an anisotropic analysis.

1. Data

We used the MOLA instrument database to study Mars [6]. The absolute vertical accuracy is ~10 m but depends on the accuracy of the reconstruction of the spacecraft orbit. The surface spot size is 130 m. Although ideally, anisotropy should be studied in two spatial dimensions, here the along-track shot spacing is 330 m whereas the across-track shot spacing depends on the mapping orbit and varies with latitude since the orbit is quasi-polar. We therefore started with more regular along-track 1-D analyses

The MOLA Martian topography database is available in the PDS archive. This database has been filtered to remove noise and atmospheric clouds reflectors. We used the MOLAUtils tools developed to extract all the points in a given surface [7].

The second steps consist on re-assembling the measurement points in order to build 1-D profiles from different orbital traces. Each new profile is defined by a central position (latitude and longitude), and by azimuthal angle, clockwise from North.

As mentioned, the MOLA dataset is quite regularly spaced along-track (quasi North-South direction), but very irregularly spaced across track (in East-West direction). In order to create a regularly sampled profile, we average all measured points within boxes 10 km wide. The total length of each profile is 3000 km, thus made of 300 boxes. This degradation of the spatial resolution is necessary to produce regularly sampled profiles.

2. Method

Many studies of the topography have been conducted using simple statistics [8], fractal analysis [9,1], and median differential slopes [4,5].

We used here spectral analysis in order to estimate the scale symmetry. To describe the scaling, we determined the power spectra (second order moments), from each profile. In order to reduce the noise sensitivity, we applied a Hanning apodization window to the data. If the process is scaling over a significant range of scale, we expect to obtain power spectra. By plotting each spectrum on a log log graph, we can estimate the slope $-\beta$ that characterizes the scaling of the variance (2^{nd} moment). For each profile, we computed β and deduced the scaling exponent H using $H=2\beta+1$. H can be interpreted as a degree of smoothness, where higher H implies smoother fields. If the field is quasi Gaussian, then H quantifies the rate at which the mean fluctuations increase with scale and the fractal dimension of contours of constant altitude is 2-H. In the more general multifractal case, there is an "intermittency correction" to H (for the earth ≈ 0.06) and each contour has a different fractal dimension.

3. Results

Figure 1 presents our analysis on a fraction of the Martian surface from latitude 10°S to 50°N, from longitude 30°E to 210°W. The maps represent the H exponent as a function of the position for all profiles with an azimuth of 90° (East-West profile).

One can clearly see that H is not homogeneous in space, showing that the roughness is depending on the geological context, as previously shown [4].

Figure 2 is presents the histograms of H as a function of azimuth. The distribution of H seems to be independent of the direction. Nevertheless, at azimuth 90° and -60°, the bell shaped distribution seems to be asymmetric, with a significant less frequent values at 0.6.

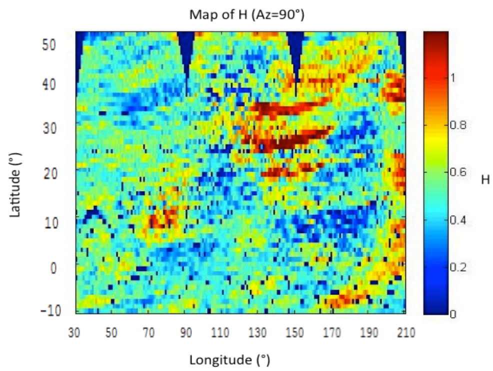

Figure 1: Map of H exponent at azimuth=0°. The spatial resolution is 1° in latitude and longitude.

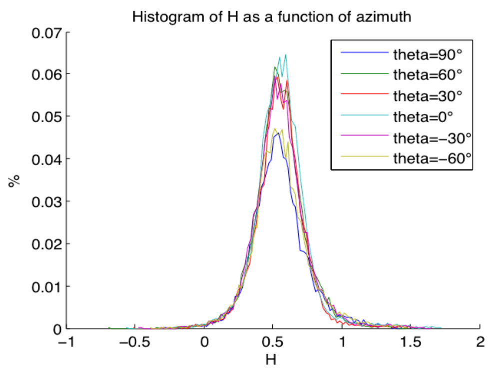

Figure 2: Histogram of the H exponent as a function of azimuth, using ~10000 profiles. The mean value is around 0.7.

4. Discussion and conclusion

We described a method to produce 1-D profiles for a known position and azimuth angle using the MOLA points at a resolution from 3000 to 10 km. Using the fractal formalism, we estimated the H exponent to describe the scale symmetry on several positions and azimuths. Our results show that H varies in space quite a lot. Although some statistical variability is expected, the observed variability is large and is likely indicative of topography with strong multifractal variability, a possibility we investigate elsewhere. Although the histograms of H depend only weakly on azimuth,a small asymmetryseems to be present for azimuth 90° and -60°.(figure 2)..

References

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