A COMPARISON OF TOPOGRAPHIC ROUGHNESS OF THE MOON, MARS AND MERCURY. Yuzhen Cai and Wenzhe Fa, Institute of Remote Sensing and Geographical Information System, Peking University, Beijing 100871, China (yzcai@pku.edu.cn).

Introduction: The surface of a terrestrial planet is mainly shaped by both endogenic (e.g., volcanism, tectonism) and exogenetic (e.g., impact cratering) geologic processes [1, 2]. Volcanism produces various features like lava flows, domes, cones and sinuous rilles. Impact cratering, on the other hand, can form rugged features like steep crater wall and ejecta. Over geologic timescale, these processes form the present surface topography of a terrestrial planet. Topographic roughness quantitatively measures how topography changes at a given spatial scale, and is related to the evolution of a planet's surface [3].

Previously, surface roughness of the Moon, Mars and Mercury has been studied, showing a distinctive dichotomy between cratered terrains and volcanic related smooth plains for the three bodies [4, 5, 6]. However, different roughness parameters were used in different studies, making comparison among the three bodies difficult. In this study, we mapped surface roughness of the Moon, Mars and Mercury at similar scales using the latest topography data, and investigated the effect of the volcanism and impact cratering on surface roughness.

Data and Methods: In our study, we used the latest high-resolution elevation data acquired by orbital laser altimeters. Considering the spatial resolution and accuracy, we chose LRO Lunar Orbiter Laser Altimeter (LOLA) data for the Moon (57 m spacing, a precision of ~0.1 m) [7], MGS Mars Observer Laser Altimeter (MOLA) for Mars (~300 m resolution) [8], and MESSENGER Mercury Laser Altimeter (MLA) data for Mercury (~390 m, <0.15 m range error) [9].

In roughness mapping, we chose bidirectional slope, root-mean-square (RMS) height, the Hurst exponent, and median differential slope (MDS) as roughness parameters. In our analysis, we mainly compare the smooth plain regions that include maria on the Moon, lowlands on Mars, and smooth plains (SP) on Mercury, and cratered terrains that include highlands on the Moon and Mars, and heavily cratered terrain (HCT) on Mercury. We mainly focus on the effects of volcanism and impact cratering on surface roughness, because at large scale these two processes are the most dominant.

Bidirectional Slope, RMS Height, and the Hurst Exponent: Bidirectional slopes were calculated at 17 m, 61–327 m, 300–800 m baselines for the Moon, Mars, and Mercury, respectively. The window size for RMS height calculation is 0.25°× 0.25° (1024 points) for the Moon and Mars, 1°×1° (1000 points) for Mercury. In Hurst exponent calculation, we chose a 1° latitudinal topographic profile.

Table 1 shows the statistic values of the three parameters for the three bodies. As in previous studies [4, 5, 6], there is a distinctive dichotomy in these parameters. Median bidirectional slopes for cratered terrains are ~3 times as those of smooth plains. Among the three bodies, Mars has the smallest bidirectional slope and RMS height. Bidirectional slope of the Moon is larger than that of the Mercury, and RMS height of Mercury is much larger. The Hurst exponent for the Moon's highlands is ~0.1 larger than that for the HCT on Mercury and highlands on Mars. The Hurst exponents of the lunar maria and martian lowlands are the same, and are ~0.13 larger than that of the smooth plains on Mercury.

Median Differential Slope: We calculated the differential slope at baselines from 0.1 to 100 km, and then chose three baselines to generate a composite RGB map: ~50 km (red), ~5 km (green; scale at which contrast between smooth plains and cratered terrain is the largest), and ~0.3 km (blue; the smallest baseline of the three bodies).

In Fig. 1a, lunar maria appear deep blue in general and the majority of lunar highlands shows yellow or green, indicating that maria are much rougher at hectometer scale, whereas lunar highlands are rougher at kilometer scale. For Mars, volcanic units (e.g., Amazonis planitia and Elysium planitia) and the lowlands show deep blue to blue-green tone, indicating that these regions are rougher at hectometer baselines. In the south plateau, regions north of 50°S appear blue-green tone, and those south of 50°S appear yellow or green (Fig. 1b). On Mercury, the northern smooth plains display similar color like the lunar maria, and the heavily cratered terrain and intercrater plains show the green or yellow tone (Fig. 1c). These results indicated that smooth plains are roughest at 0.39 km and heavily cratered terrain is roughest at 4.68 km.

Figs. 1d and 1e show the MDS of the cratered terrains and smooth plains for the three bodies. The lunar highlands are smoother than mercurian HCT at baselines <~1 km and turn rougher than HCT at baselines >~1 km. At all baselines studied, lunar highlands and Mercury HCT are always rougher than Mars highlands. The behaviors of the smooth plains are relatively simple: Mercury smooth plains show the largest MDS, and Mars lowlands have the lowest MDS at the all baselines studied.

Previous studies on crater density of terrestrial planets show that at diameters >8 km, lunar highlands have the largest R values, and mercurian SP have the smallest R values, and martian highlands have R values between them (Fig. 1 of [10]). Among smooth plains, R values of mercurian SP are the largest, and those of lunar maria are the smallest. From these results, we found that scale dependent behaviors of the MDS is generally consistent with those of crater density. These show that crater density is the dominant factor that affects the topographic roughness of the Moon and Mercury. However, the martian surface has the larger R values but smaller MDS, possibly implying that other processes (e.g., eolian, fluvial processes) influence surface roughness as well.

Conclusions: Using high-resolution topography data, we mapped and compared bidirectional slope, RMS height, the Hurst Exponent, and differential slope for cratered terrains and smooth plains on the Moon, Mars and Mercury. The results show that these three bodies have a distinctive dichotomy in these parameters. For cratered terrains, the lunar highlands are smoother than mercurian HCT at baselines <~1 km and become rougher at larger baselines, and Mars highlands are the smoothest. For smooth plain regions, mercurian SP are the roughest, and lunar maria are rougher than the lowlands on Mars. Based on the previous crater density results, we found that for the Moon and Mercury, crater density is the probably the main factor affecting surface roughness.

References: [1] Kreslavsky M. A. et al. (2013) *Icarus, 226*, 52–66. [2] Pommerol A. et al. (2012) *PSS*, *73*, 287–293. [3] Shepard M. K. et al. (2001) *JGR, 106*, 32777–32795. [4] Rosenburg M. A. et al. (2011) *JGR, 116*, E02001. [5] Kreslavsky M. A. and J. W. Head (2000) *JGR, 105*, 26695–26711. [6] Fa W. et al. (2016) *GRL*, *43*, 3078–3087. [7] Smith D. E. et al. (2010) *SSR, 150*, 209–241. [8] Smith D. E. et al. (2001) *JGR, 106*, 23689–23722. [9] Sun X. and G. A. Neumann (2015) *IEEE TGRS, 53*, 2860–2874. [10] Strom R. G. et al. (2005) *Science*, *309*, 1847–1849.

Table 1. Topographic roughness statistics for geologic units on the Moon, Mars and Mercury [a].

Planets	Geologic units	Bidirectional slope (deg.)	RMS height (m)	Hurst exponent
The Moon	Maria	$2.8^{+3.4}_{-2.3}$	$18.0^{+33.5}_{-10.5}$	$0.79^{+0.84}_{-0.75}$
	Highlands	$8.1^{+10.7}_{-6.2}$	$181.8^{+301.2}_{-102.2}$	$0.91^{+0.93}_{-0.88}$
Mars	Lowlands	$0.4^{+0.7}_{-0.2}$	$12.2^{+18.2}_{-8.5}$	$0.79^{+0.84}_{-0.71}$
	Highlands	$1.2^{+2.6}_{-0.6}$	$63.6^{+135.2}_{-32.9}$	$0.82^{+0.87}_{-0.75}$
Mercury	SP	$2.0^{+3.8}_{-1.2}$	$129.9^{+205}_{-87.9}$	$0.66^{+0.77}_{-0.55}$
	HCT	$4.7^{+8.0}_{-2.6}$	$323.1^{+495.5}_{-216.2}$	$0.81^{+0.86}_{-0.76}$

[a]Median values are given with 25% (after -) and 75% (after +) percentile points.

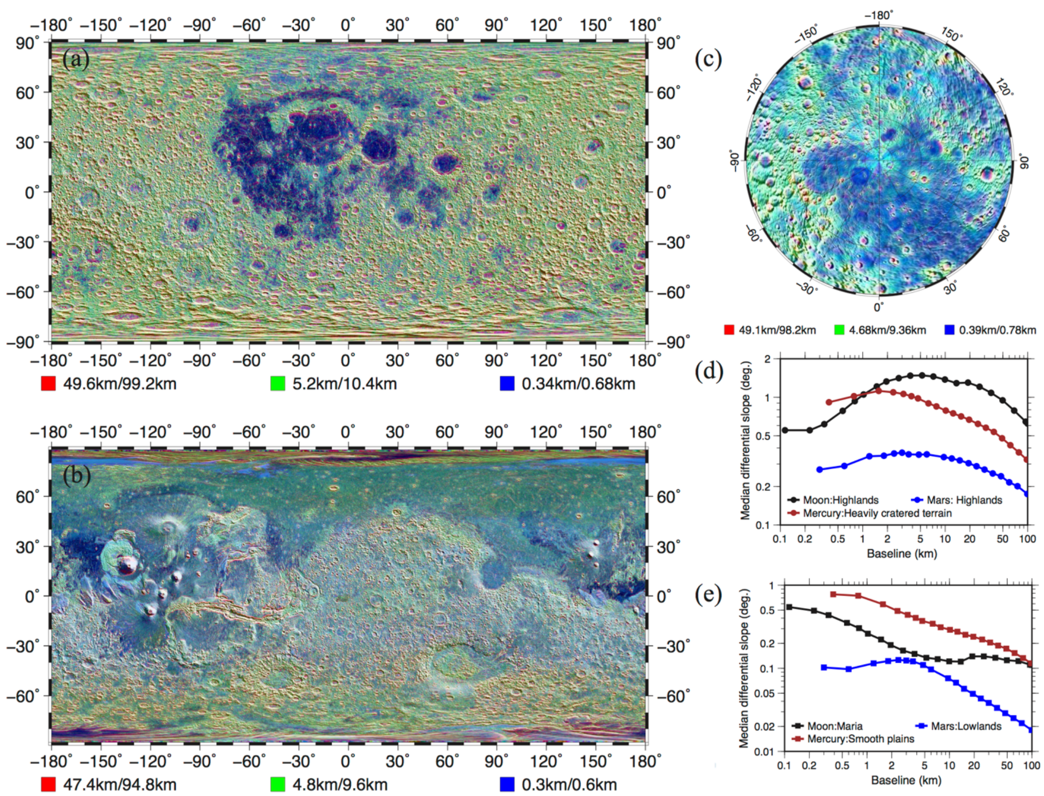

Figure 1. Composite color map of the differential slope for (a) the Moon, (b) Mars, and (c) Mercury with latitude >45°N, and median differential slope for (d) cratered terrains and (e) smooth plains as a function of baseline.