MASS WASTING FEATURES AND PERIODIC DYNAMICS CHANGES ON PHOBOS. H. Kikuchi[1], N. Hirata[2], H. Miyamoto[3], R. Hemmi[3], K. Wada[4], [1]JAXA, Sagamihara, Japan. [2]Univ of Aizu, Aizu, Japan. [3]Univ of Tokyo, Tokyo, Japan. [4]Chiba Tech, Narashino, Japan. (kikuchi.hiroshi@jaxa.jp)

Introduction: The dynamics of the surface of Phobos are changing on a long-term and periodic basis. Phobos' orbit is damped by tidal forces on Mars, and thus the dynamics of Phobos surface is different than it once was. Also, Phobos is still the closest satellite to the planet, and even its slight orbital eccentricity is affected by tidal forces. In both cases, the surface gravity field changes significantly in the Mars side and anti-Mars side regions [1].

Geologically young and distinctive features were identified on the surface. Inside craters and depressions, landslide landforms or albedo streamers are observed. These have been admitted in large numbers on the Mars and anti-Mars sides, and are interpreted to be landforms driven from changing tidal forces by long-term orbital changes [2]. Blue units are also observed on the Mars side of Phobos. The blue units were initially defined by the Phobos 2 spacecraft as regions with average visible/near-infrared (NIR) color ratios of 1–1.4 [3], or defined by Mars Express data as the regions in range V/NIR > 1.1 [4]. These regions are interpreted to expose fresh material in the interior as the surface material is moved, owing to the most cyclically variable Phobos surface dynamics in the current orbit [5]. Because the overall Phobos surface is supposed to be covered by a uniform regolith of ejecta deposits, such regions covered with fresh material are likely to be dominated by the initial Phobos material. Such area could be targets for future exploration such as MMX mission.

Phobos is the most long-term databased small body, with updated imaging data and shape models. Thus, we identify mass wasting features and investigate the relationships between the regions and dynamics considering the effect of the eccentricity, using the latest image data and shape model.

Method: For searching mass wasting features, we use high-resolution images acquired by HRSC onboad Mars Express, HiRISE onboad Mars Reconnaissance Orbiter, and Viking orbiter images.

For calculating a dynamical slope (i.e., slope angles on Phobos influenced by several factors including tidal of Mars, centrifugal, and gravitational forces of Phobos), we assume a homogeneous mass distribution for Phobos, and descrive the gravitational accelaration by

$$\begin{cases} x'' = \dfrac{1}{1 + e\cos\nu}(U_x + 3x) \\ y'' = \dfrac{1}{1 + e\cos\nu}U_y \\ z'' = \dfrac{1}{1 + e\cos\nu}U_z - z \end{cases}$$

where ν is the true anomaly, e is the eccentricity, and U is the potential due to the Phobos mass [5]. We use the recent shape model [6]. The true anomaly (ν) is varied every 10° and the dynamic slope at each point calculated as the angle between the normal vector of each plate in the shape model and the direction of the acceleration.

Results: Mass wasting features are newly observed inner walls of craters, depressions, and grooves with steep slopes greater than 30° where they had not been previously reported (Fig. 1). We observe these features on the Mars side and the anti-Mars side but also on the leading side and trailing side regions. The maximum change in the dynamic slope is 1.4 degrees when ν was varied (Fig. 2).

Discusions: Combining our survey with previously observed areas of mass wasting features, these are observed throughout the entire area of the steep dynamic slope of the Phobos surface. This suggest that changes in tidal forces dose not necessarily drive these topographic features.

The inner wall of the Todd crater and the eastern side of the outer Stickney crater are the areas of greatest change in periodic dynamic slope. On the other hand,

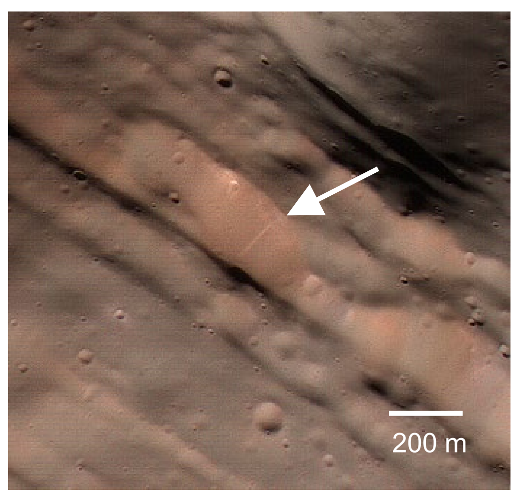

Figure 1. An albedo stream inside of a groove. Part of HiRISE images PSP_007769_9015.

the color map shows relatively red units in this region [3,4]. Therefore, our results do not indicate that the periodic surface dynamics changes throughout the Phobos surface are causing the red material in the surface layer to migrate and expose the blue units.

If the material on the Phobos surface moves by periodic dynamics changes, the candidate regions with large periodic variations were East of Stickney crater, Todd crater, D'Arrest crater, Limtoc crater, and deep grooves (Fig. 2). Around these geological features, there may be information about the material inside Phobos.

Conclusion: Scrutinizing high-resolution images, we identify mass wasting features in regions that have not been previously reported. Regions with these characteristics are observed throughout Phobos. Our results show these regions with high (>30°) dynamic slopes and dose not correlate well with the magnitude of the periodic changes. The areas with significant periodic changes in dynamics, such as East of Stickney crater, Todd crater, D'Arrest crater, Limtoc crater, and deep grooves, may still be undergoing some change and should be an area of focus for future exploration such as MMX mission.

References: [1] Shi X. et al. (2016) *Geophys. Res. Lett., 43*, 12,371-12,379. [2] Scheeres D. J. et al. (2019) *Adv. Space Res. 63*, 476-495. [3] Murchie S. L. et al. (1991) *Jour. Geophys. Res. 96,* 5925-5945. [4] Kikuchi H. (2021) Icarus, 354, 113997. [5] Ballouz R. L. et al. (2019) *Nature Geo, 12,* 229-234. [6] Ernst et al. submitted to *Earth Planets and Space.*

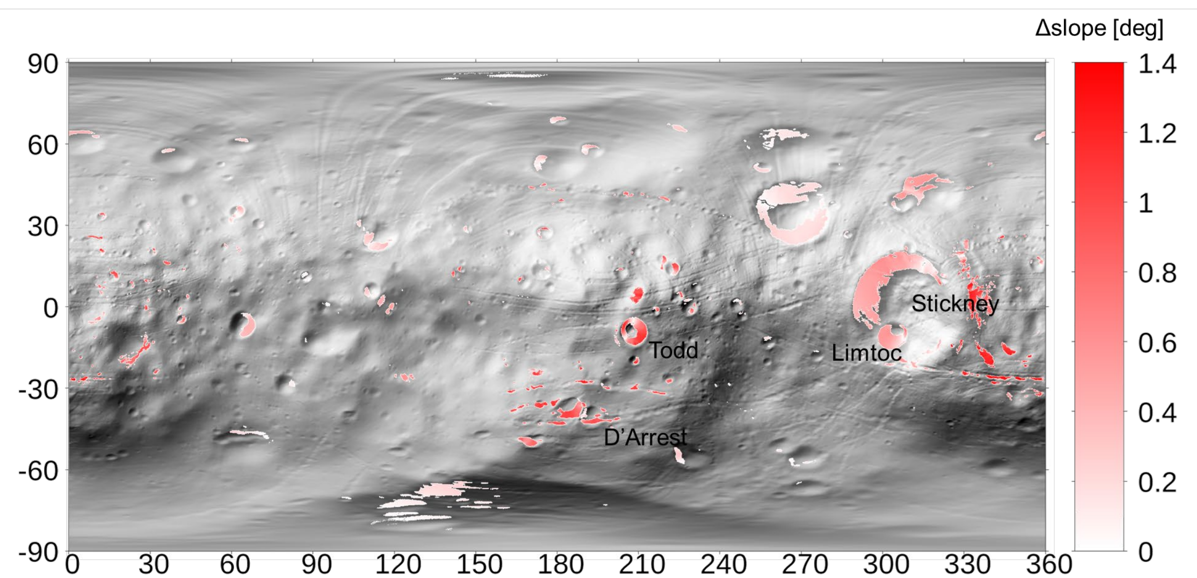

Figure 2. Map showing dynamic slope changes in areas with slopes greater than 30° combined with the shaded relief map. By changing the true anomaly, the dynamic slope of the Phobos surface changes. The intensity of the red color indicates a greater change in dynamic slope.