ILLUMINATION CONDITIONS ON PHOBOS: IMPLICATIONS FOR SURFACE PROCESSES, VOLATILES AND EXPLORATION. T. J. Stubbs[1,2], Y. Wang[3,2], and D. A. Glenar[3,2], [1]NASA Goddard Space Flight Center, [2]SSERVI/DREAM2, [3]University of Maryland, Baltimore County. (Timothy.J.Stubbs@NASA.gov)

Introduction. Illumination conditions at airless bodies, such as Phobos, control the temperature of the surface and subsurface [1], volatile sequestration and transport [2, 3, 4, 5], as well as surface charging by the photoemission of electrons [6]. They can also serve as a proxy for solar wind exposure, especially on the farside of Phobos, which is an important space weathering process [7]. Previous studies have considered illumination conditions on Phobos in order to determine diurnal temperature behavior [8, 9], constrain surface conditions for robotic landers [10], estimate the loss and evolution of water [11, 12], and find preferred landing sites for human exploration [13]. In this study we simulate present-day illumination conditions at Phobos and assess whether locations exist where volatiles, in particular water ice, could be sequestered in the near subsurface on billion year timescales [2, 3], or accumulated by the "thermal ice pump" effect [14].

Earlier investigations of Phobos temperature and volatile sequestration have assumed a sphere or triaxial ellipsoid shape for Phobos [11, 8]. In this study we use a more realistic digital terrain model (DTM) for the shape of Phobos [15] in order to capture the shadowing effects from its global-scale irregular shape and smaller structures, such as craters, which can have a significant influence on both global and local illumination conditions [3].

Orbital Characteristics. Like Mars, Phobos is in a much more elliptical around the Sun than the Earth. The Mars-Phobos system has a semi-major axis of 1.524 AU and is ≈21% farther from the Sun at aphelia than perihelia. Therefore, each of the "seasons" on both Mars and Phobos has different durations. The solar constant at Mars semi-major axis is about 586 Wm^{-2}.

Phobos itself is in a near-circular equatorial orbit about Mars (inclination ≈1°) with an obliquity of ≈25°; so has similar seasons to Mars. It is in synchronous rotation (tidally-locked) with an orbital period of about 7h 39m. Phobos has a semi-major axis of only 2.76 Mars radii, so it passes into eclipse (i.e., through the shadow of Mars). On average, Phobos spends 5.6% of its time in full eclipse, which mostly occurs around the equinoxes.

Digital Terrain Model. For the shape of Phobos, we use the Willner et al. [15] global DTM with ≈100m/pixel (≈0.5 deg) resolution, which was derived from Mars Express/High Resolution Stereo Camera and Viking Orbiter images using stereo-photogrammetric methods. Earlier studies investigating volatiles, at best, approximated the shape by a triaxial ellipsoid with dimensions of about 27 × 22 × 18 km [10, 11, 12].

Methods. We adopt a similar approach in this illumination study to that previously performed for Asteroid 4 Vesta [3]. The elevation of the local horizon for each point on Phobos is determined, which allows the rapid calculation of: (i) the visible fraction of the solar disk, (ii) solar incidence angle, and (iii) solar flux [3, 16]. Since we are considering average present-day conditions, we run our illumination simulations for a complete Martian year between two recent perihelia on 24 January 2013 and 12 December 2014. Calculations are performed every 10 minutes (about every 0.5 h in local time), such that predictions converge to << 0.1%. Full and partial Mars eclipses are accounted for using an algorithm, which assumes Mars is a circular occulting disk. The inclusion of Mars eclipse effects is important for accurately simulating condtions on the Mars-facing nearside of Phobos.

Results. Preliminary predictions for the average incident solar flux are shown in Figure 1, which reveals many interesting features, such as high fluxes around crater rims (e.g., Stickney), doubly-shadowed craters (e.g., Limtoc) and strong asymmetries between poleward- and equatorward-facing crater walls (e.g., Drunlo). Perhaps most significantly, there are regions (most likely small craters) that receive very low average solar flux (<40 Wm^{-2}). These will likely be, on average, the coldest places on Phobos. Previous thermal modeling predictions have indicated that water ice could survive in the top few meters of the asteroidal regolith over billions of years, if the average surface temperature is below about 145 K [2]. Preliminary results indicate that some regions on Phobos satisfy this criterion under present-day conditions.

In addition, the thermal ice pump mechanism [14], in which water molecules are pumped down into the regolith during the day-night temperature cycle, could also be acting on Phobos. Again, preliminary results suggest that some locations, especially near the South Pole, could sequester water ice from this mechanism.

Implications. Should water ice, or other volatiles, be present at relatively shallow depths at certain locations on Phobos, then this could serve as a witness plate to the history of the Mars-Phobos system, as well as provide resources to future explorers.

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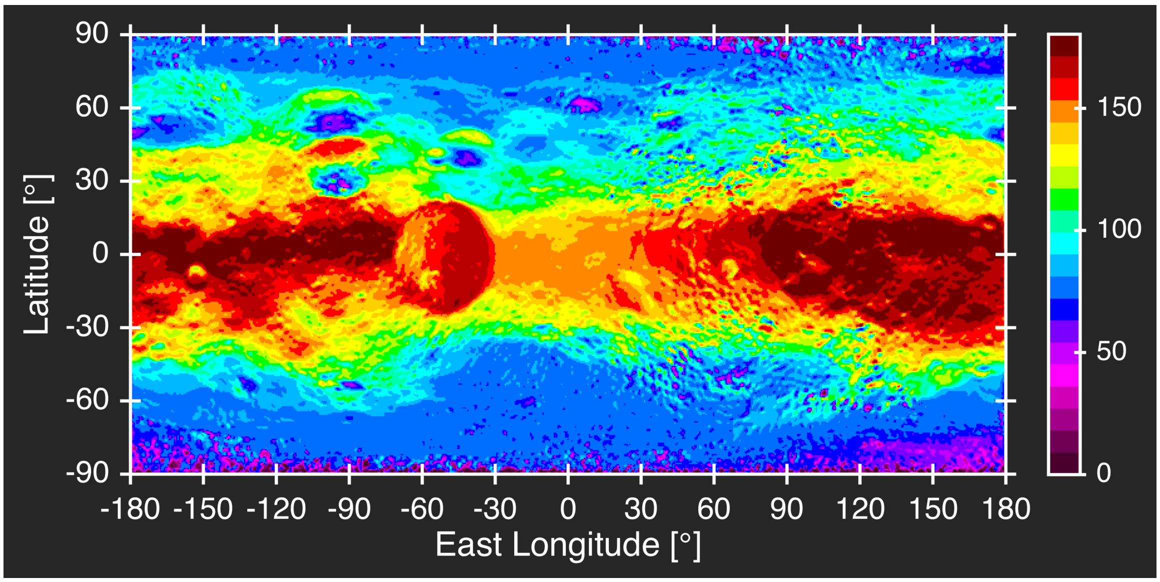

Figure 1. Average incident solar flux at the surface of Phobos under present-day conditions. These preliminary results are based on illumination calcuations performed every 10-minutes for a complete Mars year. Mars eclipse effects have been taken into account.