ILLUMINATION CONDITIONS IN PHOBOS' POLAR AREAS. R. Ziese[1], K. Willner[2], J. Oberst[1,2], [1] Technische Universität Berlin, Berlin, Germany (ziese@tu-berlin.de), [2] German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany (konrad.willner@dlr.de).

Introduction: In recent years the Martian moon Phobos was identified as a target by several planetary mission proposals, e.g. US led Phobos And Deimos & Mars Environment (PADME) [1], Mars-Moons Exploration, Reconnaissance and Landed Investigation (MERLIN) [2], PANDORA missions [3], ESA's + Roscosmos' Phobos Sample Return mission (formerly Phootprint, see [4]), DePhine [5] and JAXA's Mars Moon eXplorer (MMX) mission, due to launch in 2024 [6]. Illumination conditions are critical for remote sensing missions, whereas solar power availability and thermal conditions are critical aspects for planning of landed missions [7,8] and need in-depth investigations.

Resulting from its changing solar distance, proximity to Mars and irregular shape, solar illumination on Phobos follows complex temporal and spatial patterns.

Phobos moves near the equatorial plane of Mars, with its rotational axis perpendicular to its orbit plane, resulting in seasons, involving strong variations of the solar irradiation, just like on Mars.

Owing to the eccentricity of the Martian orbit and solar distance varying by 17%, winter seasons on Phobos' Southern hemisphere are particularly long and cold.

In addition to direct solar irradiation, solar light scattered or reflected by Mars, as well as occultations by Mars need to be considered. Moreover, in particular at the poles, reflection and scattering of light at the irregular surface of Phobos itself might cause relevant contributions to the incoming flux.

For further thermal modeling of Phobos' surface it is necessary to also take into account thermal emissions from the Martian surface and different parts of Phobos' surface.

This study focuses on the polar areas (approximately +/-65° latitude, respectively), which are subject to unique illumination conditions and are of interest to future landed missions. While we aim at modeling the thermal conditions in Phobos' polar regions, we only discuss the incoming solar flux and illumination in this paper.

Previous Work: Since detailed shape models were not yet available, previous investigators used simple ellipsoid models to estimate Phobos' surface temperatures [9] and heat transfer to subsurface layers [10] for different latitudes, longitudes and seasons, based on solar radiation, effects of reflected sunlight and thermal radiation from Mars, resulting in an increased average temperature on the Mars-facing-side of Phobos in its synchronous rotation [9]. Also, the effects of eclipses were considered.

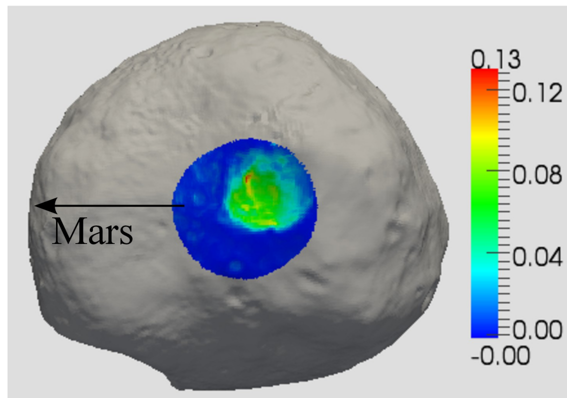

Fig. 1: Total view factors for the South pole

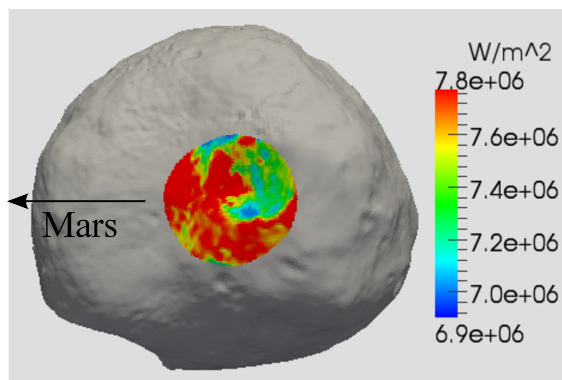

Fig. 2: Solar irradiation in W/m² for a complete rotation starting at epoch 2016-11-28T12:00:00 including indirect contributions of near-by other facets.

In contrast, [11] and [12] studied the direct incident solar flux for Phobos using a recent shape model [13]. Global charts of incident solar flux for certain fixed dates in different seasons [11] as well as average incident solar flux for a complete Martian year [12] were derived.

Methods & Results: We applied methods, as described by [14] and [15] to determine the irradiation function for one Martian year, including seasonal variations in solar distance and the effect of occultations, as well as resulting illumination on Phobos using a detailed shape [13] and a recently developed rotational model [16].

To include single-scattering by Phobos' surface onto other parts of Phobos the view factors F_{ij} (giving the fraction of flux radiated by facet j that reaches facet i) for these areas are computed. The total view factors $F_i = \sum_j F_{ij}$ for the South Pole are exemplarily shown in Fig. 1. A facet having a total view factor of 0 does not receive any irradiation from other facets while for a facet having a total view factor of 1 the field of view is completely filled by other facets of the surface.

The values of the total view factors for the South Pole lie in between 0.0 and 0.13 leading to contributions to the irradiation that are small when compared to direct insolation but relevant for facets that are not directly illuminated - in particular with regard to thermal emissions by other facets.

An illumination map for the South Pole at the beginning of the Southern summer season including direct and indirect contributions to the insolation for a complete Phobos rotation of 7.65 hours starting at the epoch 2016-11-28T12:00:00 (UTC) is shown in Fig. 2.

To assess the correctness of the simulations and the quality of the shape model we generated synthetic images, based on the shape model and illumination geometry at a given time. In particular, we assumed camera parameters of the SRC (HRSC Super Resolution Channel, aboard Mars Express) and illumination geometries of selected Mars Express Phobos flybys. The synthetic images were then compared with the actual SRC images. Fig. 3 shows a comparison of a simulation for epoch 2006-05-06T23:15:24 (UTC), during Northern spring season, with the corresponding SRC image.

Conclusion and Future Work: Our illumination studies show intricate light patterns at Phobos' pole regions. Using similar methods as [9] we will also consider Mars shine and thermal emissions by other parts of Phobos' surface within our continuing studies. A complex thermal environment on Phobos is expected to be characterized by very local temperature patterns depending on self-heating, and self-shadowing as well as on contributions by Mars shine.

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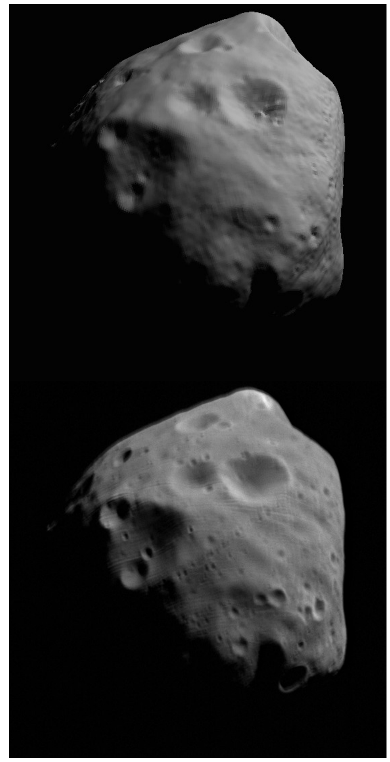

Fig. 3: Comparison of illumination conditions for epoch 2006-05-06T23:15:24 (Northern hemisphere during Northern spring season). Top: Simulated illumination, bottom: SRC image H2979_0007.

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