SOLAR ILLUMINATION CONDITIONS AT 4 VESTA: PREDICTIONS USING THE DIGITAL ELEVATION MODEL DERIVED FROM HST IMAGES. T. J. Stubbs[1,2,3] and Y. Wang[1,2,3], [1]Goddard Earth Science and Technology Center, University of Maryland, Baltimore County, Baltimore, MD, USA, [2]NASA Goddard Space Flight Center, Greenbelt, MD, USA, [3]NASA Lunar Science Institute, Ames Research Center, Moffett Field, CA, USA. Corresponding email address: Timothy.J.Stubbs[at]NASA.gov.

Introduction: As with other airless bodies in the Solar System, the surface of 4 Vesta is directly exposed to the full solar spectrum. The degree of solar illumination plays a major role in processes at the surface, including heating (surface temperature), space weathering, surface charging, surface chemistry, and exospheric production via photon-stimulated desorption. The characterization of these processes is important for interepreting various surface properties. It is likely that solar illumination also controls the transport and deposition of volatiles at Vesta, as has been proposed at the Moon and Mercury [e.g., 1]. If there are permanently shadowed regions (PSRs) on Vesta – or at least regions that, on average, receive very little solar illumination – then they could act as cold traps for volatiles.

Characterizing the solar illumination conditions is particularly timely since the Dawn mission is due to arrive at Vesta in July 2011 [2]. The Dawn mission is equipped with a framing camera (FC), a visible-IR mapping spectrometer (VIR/MS), as well as a gamma ray and neutron spectrometer (GRaND). Along with radio science data, this will eventually allow the Dawn science team to better characterize the shape and orbit of Vesta. In the meantime, it is important to have solar illumination predictions in order to guide Dawn's observation strategy and inform the initial interpretation of surface science observations from all of the instruments. In particular, it is possible that cold traps predicted by our modeling could correlate with hydrogen-rich deposits identified in the GRaND data [3, 4].

The Shape and Orbit of 4 Vesta: Based on HST images, Vesta is a triaxial ellipsoid with radii of 289, 280 and 229 ± 5 km (mean radius of 258 ± 12 km) [5]. It has a prograde rotation with a relatively rapid spin period for an asteroid of 5.342 hours, and a large axial tilt of 29 ± 10°. Vesta is close to being an oblate spheroid, but for the enormous impact crater centered near its south pole with a diameter of 460 km.

Vesta's current orbit has an aphelion at 2.572 AU and perihelion at 2.151 AU, which places it in the Inner Main Asteroid Belt on the sunward side of the Kirkwood Gap (3:1 resonance at 2.50 AU due to gravitational perturbation from Jupiter). Its orbit is nearly circular with an eccentricity of only 0.089 and semi-major axis of 2.361 AU. Vesta's orbital period is 1325.15 days (3.63 years), which gives an average orbital speed of 19.34 km/s. The orbital inclination is 7.135° to the ecliptic plane (5.56° to the invariable plane), the longitude of the ascending node is 103.91° and the argument of perihelion is 149.83°. Based on current estimates, Vesta's orbital plane is believed to have a precession period of 81,730 years [6].

For the shape of Vesta we use the 5 × 5° DEM based on HST images [5], which is publicly available from the Planetary Data System (PDS). To our knowledge, this is the best DEM of Vesta currently available. The orbital information for Vesta is obtained from the Dawn SPICE kernel, which currently limits us to the current epoch (1900 to present).

Shadowing Model: In order to perform these solar illumination calculations for Vesta we have adapted the ray tracing code that we developed for use with DEMs produced from data obtained by the Lunar Orbiter Laser Altimeter (LOLA) aboard the Lunar Reconnaissance Orbiter (LRO) [7, 8]. This model has been verified by comparisons with results from Mazarico code using the "horizon method", and comparisons with the LRO Wide Angle Camera (WAC) [9]. Since we are only interested in solar illumination/shadowing at the surface in this study, we have adopted some aspects of the horizon method in order to increase computational efficiency. However, unlike the Mazarico code, our model is global and not limited to the polar regions.

In order to try and better capture some of the topographical subtleties that can be important for detrmining the degree of solar illumination/shadowing at the surface, we linearly interpolated the 5 × 5° DEM to a resolution of 1 × 1°. We believe that interpolating the DEM is a more satisfactory method for producing smoother and more realistic results, than simply just interpolating the predictions from the original 5 × 5° DEM. By using linear interpolation (as opposed to a spline interpolation, for example), we have ensured that we are not "inventing" any new data points, but simply making the most of those available.

In our calculations we consider one vestal year due to the limitation imposed by the SPICE kernels mentioned above. We have found that we get reliable and accurate illumination results if we perfom the calculations 36 times per rotation period at 180 locations along Vesta's orbital path (separated equally in time rather than space, since we are concerned with time-averaged illumination). In testing, we found that the results converged at this resolution to within < ≈0.1%. In each illumination calculation, we determine: (1) the fraction of the solar disk visible at the surface, which accounts for topography along the horizon, (2) the solar incidence angle that includes the effect of local slope, and (3) the solar illumination flux normalized to the unobstructed Sun directly overhead – this basically combines the previous two parameters. We do not consider scattered sunlight from other surface elements, just direct solar illumination.

Illumination/Shadow Results: Figure 1 shows the average solar illumination flux results, which indicate that the most illuminated regions occur around the equator with vaues of up to ≈0.3. Note that each surface element experiences night about half the time, so the average has to be <0.5, and for a simple cosine dependence for the dayside illumination on a spherical object we get a maximum possible average peak value of 0.318 (1/π). As expected, the flux drops off toward the poles, and the effects of the near-oblate spheroidal shape start to become apparent.

Perhaps the most interesting result is that there do not appear to be any permanently shadowed regions on Vesta. This is not too surprising, since Vesta has a very large axial tilt (~29°) that acts to expose the poles to the Sun during local summer. For comparison, the Moon and Mercury have axial tilts of ≈1.5° and ≈2.1°, respectively, which are far more condusive to producing PSRs. The least illuminated regions (< ≈12%) occur only at high southern latitudes, which is clearly due to the shadowing associated with the enormous impact crater at the south pole.

Conclusions: Based on the coarse 5 × 5° DEM (interpolated here to a resolution of 1 × 1°) produced from HST images [5], there do not appear to be any permanently shadowed regions on Vesta. However, it should be appreciated that this DEM was too coarse to resolve any impacts, apart from the enormous one at the south pole. At Vesta's equator, 5° corresponds to ≈22.5 km, so an impact crater there would have to be ~100 km in diameter to even be partially resolved. Therefore, PSRs could be present in impact craters that are substantial in size, yet too small to be resolved with this DEM. A prime location for such a crater would be within the enormous south pole crater.

Although of secondary importance, these results also indicate the absence of permanently illuminated regions (PIRs) on Vesta. However, the central peak region in the giant south pole crater does not appear to be particularly well resolved with this DEM, so this could yet prove to be a PIR.

The predictions presented here will help guide observations by the Dawn mission, as well as support initial interpretation of its science measurements (particularly those from the GRaND instrument).

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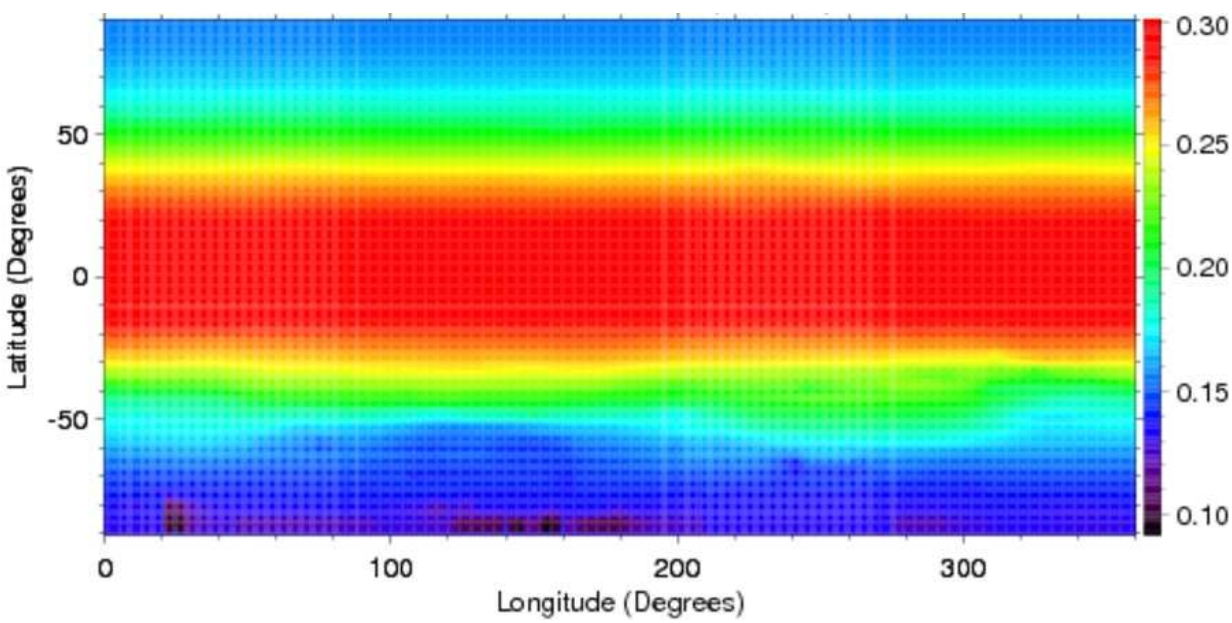

Figure 1: The average solar illumination at the surface of Vesta. The units are normalized to the full Sun directly overhead.