Mercury Space Weathering Maps Description

1. Data Overview

The Mercury space weathering maps represent the abundance in weight percent (wt%) of four different particle types, nanophase native iron (shortened to "iron" or "Fe") and amorphous carbon (shortened to "carbon" or "C") and microphase native iron and amorphous carbon. Nanophase and microphase particles are roughly defined as particles with diameters of 10–100 nm and >100 nm, respectively. The submicroscopic particle maps represent the sum of the nanophase and microphase abundances for each respective phase (i.e., native iron and amorphous carbon). The maps cover the entire surface of Mercury (-180–180°E longitude and -90–90°N latitude) at 2 pixels per degree (0.5 degrees per pixel or 21290.4 m/pixel). The space weathering maps were derived using the radiative transfer model with the Visible Infrared Spectrograph (VIRS) data from the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) mission. The space weathering maps include interpolations over missing pixels, especially over the poles. The six maps are in equirectangular projection with a longitude of central meridian at 0°.

2. Map Derivation

The derivation of the space weathering maps with the radiative transfer model is thoroughly described in Trang et al. (2017). Our space weathering maps are based upon the models of Hapke (2001) and Lucey and Riner (2011), where we use the radiative transfer technique to model the MESSENGER VIRS. In Trang et al. (2017), we used the VIRS Derived Data Product (DDR) to November 14, 2014; however, these archived maps include all available VIRS DDR including the flybys and orbital observations of Mercury, which are all PDS data (http://pds-geosciences.wustl.edu/messenger/mess-e_v_h-mascs-3-virs-cdr-caldata-v1/messmas_2001/). The modeling only includes wavelengths between 0.3–0.85 µm. We excluded longer wavelengths because the data were noisy due to elevated temperatures (Izenberg et al., 2014).

The radiative transfer technique is a model that can reproduce a visible to near-infrared spectrum using physical principles. Our radiative transfer model is based upon the work of Hapke (1981; 1993), where the model was modified to describe nanophase (Hapke, 2001) and microphase particles (Lucey and Riner, 2011). To use this model, we needed to make assumptions about the regolith on Mercury, such as the regolith consists of transparent silicates where the density of each particle is 3.0 g/cm^3. The average grain size of these silicates is 20 µm (Warell et al., 2010). We assumed that the optical properties of this silicate regolith include a real index of refraction of 1.4 and a reflectance of 80% at all visible wavelengths. Lastly, we assumed that these silicate particles contain varying amounts of nanophase and microphase native iron and amorphous carbon where the microphase particles are ~1 µm in size and the nanophase particles are smaller than the wavelength of visible light. We used the Cahill et al. (2012) and the Rouleau and Martin (1991) optical constants to describe the optical properties of native iron and amorphous carbon, respectively. Next we used the model of Hapke

(2001) and Lucey and Riner (2011) to model the absorption coefficient of nanophase and microphase iron and carbon, respectively. We then combined these absorption coefficients to calculate the single scattering albedo, which we then converted into a model reflectance spectrum using a viewing geometry of 45° for both incidence and emission angle and 90° for the phase angle.

Next, we used the radiative transfer model to make thousands of model reflectance spectra with each model spectrum representing a different abundance of nanophase and microphase iron and carbon. We compared each model spectrum to each observed VIRS spectrum and computed a root-mean-square (RMS). For a given observed spectrum, the model spectrum with the smallest RMS is considered the best fitting spectrum. Because we know the nanophase and microphase iron and carbon abundances for each model spectrum, we are also able to obtain the nanophase and microphase iron and carbon abundances associated with each observed spectrum. To improve modeling efficiency, for each VIRS spectrum, we only make comparisons to model spectra that have a 750-nm reflectance within 0.5% of the 750-nm reflectance of the VIRS spectrum.

The results (nanophase and microphase particle abundances) were binned at 2 pixels per degree. We organized the results into their respective bins based upon the location of their spectral footprint. Therefore footprints that overlapped onto other areas were not included in those bin calculations as the center of the footprint is not within those other bins. Next, we determined the median value of each bin so therefore the values in the maps are median abundance values. The submicroscopic particle abundance maps are from the addition of median nanophase and microphase abundance values for each respective phase (i.e., iron and carbon) at a pixel location. Finally we interpolated the maps using the Generic Mapping Tool (GMT) with the surface function (adjustable tension continuous curvature splines) using a tension factor of 0.1. The interpolation of several areas, particularly the poles, resulted in negative values (<0 wt%). These values are unrealistic and these pixels should be ignored.

Included with these maps are a count map and error maps (one for each particle type). The count map represents the number of records for each pixel that was included in the median calculation. The nanophase and microphase native iron and amorphous carbon error maps show the L1 scale of the median—or 1.4826 times the median absolute difference. However, we did not report an error for pixels with a single data point. We propagated the errors from the nanophase and microphase native iron and amorphous carbon to determine the errors of the submicroscopic native iron and amorphous carbon.

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