1. Data Overview

The lunar space weathering maps comprises of three different maps: the nanophase, microphase and, submicroscopic iron abundance maps. The nanophase iron abundance map characterizes the abundance of iron particles <33 nm located in glassy rims and agglutinates. The microphase iron abundance map characterizes the abundance of iron particles >33 nm situated in agglutinates. The submicroscopic iron abundance map is the sum of the nanophase and microphase iron abundance maps. These maps show these abundances in weight percent (wt%). The spatial range of these maps is from 60°S–60°N and 180°W to 180°E with a spatial resolution of 30 pixels per degree (~1 km/pixel). The nanophase and microphase iron abundances generally range between 0–2 wt% and the submicroscopic iron abundance ranges between 0–4 wt%. Areas containing no data have negative values (i.e., $-3.4 \cdot 10^{38}$). The data experienced a readjustment in the data points as it was converted to an equirectangular projection with a longitude of central meridian at 0° using the Integrated Software for Imagers and Spectrometers (ISIS). The original data derives from the Kaguya Multiband Imager (MI) data with MAP-level calibrations (i.e., radiometric, photometric, geometric, and topographic corrections), which can be obtained from the Kaguya website (https://darts.isas.jaxa.jp/planet/pdap/selene/). This data set is a global data set covering most of the lunar surface. We then applied the Hapke radiative transfer model to estimate the nanophase and microphase iron abundance across the lunar surface.

2. Map Derivation

Trang and Lucey (2019) contains a detailed description of the modeling of these space weather maps. To summarize, we derived the space weathering maps by using the radiative transfer model for submicroscopic particles (Hapke, 2001; Lucey and Riner, 2011). We calibrated this model to Apollo samples with known nanophase and microphase iron abundances, which we also estimated the error for each particle type (up to 0.1 and 0.4 wt% for nanophase and microphase iron particles, respectively). The purpose of this calibration is to estimate the visible to near-infraed reflectances of the lunar soils without any nanophase and microphase iron—when it was fresh and before it was exposed to space weathering—with respect to its FeO content (i.e., soils with greater FeO content exhibit lower overall visible to near-infrared reflectances). This reflectance is called the host reflectance. Although the overall host reflectance is dependent on the mineralogy, Lucey (2014) showed that these differences are minor and this simplification is sufficient for this space weathering model.

After the calibration, we applied the radiative transfer model to the Kaguya MI data. In summary, this model works by, first, estimating the host reflectance for a given pixel. Because the host reflectance is dependent on FeO, we use the lunar, Kaguya MI-based FeO map, as derived from Lemelin et al. (2015) to determine the appropriate host reflectance. In this model, we also account for ilmenite in this model by using the lunar, Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC)-based TiO_2 map. From here, we add nanophase and microphase iron particles into the model, which will change the overall visible to near-infraed, until the model spectrum matches the Kaguya MI spectrum for the same given pixel.

The radiative transfer model is dependent on a number of assumptions. In this work, we assumed that the regolith consisted of 15 μm silicate grains—called host particles—and ilmenite. The host particles are the carriers of the nanophase and microphase iron particles with a model reflectance spectrum (i.e., host reflectance). This host spectrum is dependent on the FeO of the soil (where the values are known from the FeO map by Lemelin et al. (2015)), which was derived by Trang and Lucey (2019). To produce the model reflectances (reflectance based on a regolith contain the host regolith with nanophase and microphase particles), we calculate the absorption coefficients of the host, the nanophase, and microphase iron particles (at various nanophase and microphase iron abundances), which we combine to find its single scattering albedo. We performed a mixing model with the single scatter albedo of the host (with the submicroscopic particles) and ilmenite. The proportion of ilmenite is based upon the TiO_2 map from Sato et al. (2017), where Trang and Lucey (2019) derived a conversion between the two variables. Because we cannot model the effects of submicroscopic particles on ilmenite, we assumed that the nanophase and microphase iron particles that would be within ilmenite is actually in the host particle. Consequently, this would increase the nanophase and microphase iron abundances in high Ti areas, The reported values, however, are based upon the nanophase and microphase iron abundances distributed equally among both host and ilmenite particles. The single scattering albedo is then converted to reflectance. Next, we searched for a model reflectance spectra that best fit the MI reflectance spectra from 415–1550 nm by adjusting the nanophase and microphase iron abundances. After finding the best fitting model reflectance spectrum and because we know the nanophase and microphase iron abundances used to find the best fitting model spectrum, we mapped these abundances onto a simple cylindrical map using the Generic Mapping Tool (GMT). The submicroscopic iron abundance map was subsequently made by summing the nanophase and microphase iron abundances.

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