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Mixing of surface materials investigated by spectral mixture analysis with the Moon Mineralogy Mapper

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Mapping of surface units on the Moon, as well as identification and quantification of mineralogical components is the main task of the imaging spectrometer Moon Mineralogy Mapper (M^3) [1] onboard Chandrayaan-1. In spectral analysis, mixing of surface materials need to be considered because they may have implications for the interpretation of the lithology. Materials that are juxtaposed within the field of view result on linear combinations of reflectance spectra [2]. Lateral contamination by remote components [e.g. 3,4], minerals in a rock [5,6], coatings [e.g. 7-9] and adjacency effects due to scattered light [10], are non-linear processes. In the present study, we perform linear Spectral Mixture Analysis (SMA) [11] using the Multiple-Endmember Linear Spectral-Unmixing Model (MELSUM, [12,13]) that allows limiting the number of components used in a model and guarantees positive mixing coefficients, and the sum of the mixing coefficients constrained to one. We use MELSUM both for spectral endmembers selection and to produce corresponding image fractions. This method is convenient for an initial assessment of large data sets [13] prior to using more quantitative methods for compositional analysis [5,6].

We have used a mosaic of all M^3 images that cover $\sim$80% of the surface and 10-20 nm spectral sampling. In order to avoid the effects of thermal emission, the analysis is performed in the range 0.4-2.18 μm (65 channels). A sphere-based Lommel-Seeliger photometric correction has been performed to standardize the effects of the geometry of illumination at large scale [14].

From a global scale, resulting spectral endmembers describe the most abundant components at the surface of the Moon: Anorthosite, high-calcium pyroxene (HCP), low calcium pyroxene (LCP) and olivine. Plagioclase-rich soils (anorthosite) are detected in the highlands, especially in the south hemisphere, with few spots in fresh impact craters (e.g. Copernicus). HCP and olivine are highly correlated with the mare basalts. However, spots are found also in fresh impact craters (e.g. Aristillus for HCP, Tycho, for LCP, Aristarchus for olivine) where exposed materials are likely crustal. Olivine fraction is weak but it defines a homogenous unit in Oceanus Procellarum and Mare Imbrium, around Aristarchus. Low fractions of mature soils indicate the locations of fresh impact craters. Overall, these spatial distributions are similar to the mineralogical maps obtained by [15] using a radiative transfer model on Clementine data, although image fractions are simply indicators of relative detections of minerals.

Further development will be focused on more detailed descriptions of the lithology, mixing processes, and quantitative estimate of the surface maturity of the various lunar soils. In theory, image fractions represent areal mixtures of materials. A step forward will be the use of a radiative transfer model to calculate more accurate abundances of minerals from the spectral endmembers, and then to derive mineral maps from the image fractions.

References: [1] Pieters et al., 2009, LPICo # 6002. [2] Singer and McCord, 1979, 10th LPSC 1835-1848. [3] Shoemaker 1962, Phys Astron Moon 283-380. [4] Pieters et al., 1985, JGR, 90. [5] Hapke 1981, JGR 86. [6] Shkuratov et al., Icarus 137. [7] Adams 1973, Science 171. [8] Cassidy and Hapke, 1975, Icarus 25. [9] Lucey et al. 2000, JGR 105. [10] Sanders et al., 2001, RSE, 78. [11] Adams et al., 1986, JGR, 91. [12] Combe et al., 2008, PSS 56. [13] Combe et al., 2008, 39th LPSC 2247. [14] Hapke and Van Horn, 1963, JGR 68. [15] Lucey 2004, GRL 31.