Paper ID: 66541
oral
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 1 (2A)

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SPATIAL-SPECTRAL PROBABILISTIC MODEL FOR INFERRING THE MINERALOGY OF LUNAR AND MARTIAN SURFACES

Abstract

A priority for the Artemis mission is the in-situ utilization of lunar resources, which may be aided by the determination of mineral compositions across the surface using remote sensing analysis. Although a similar priority exists for Mars, the two are rarely considered simultaneously. Furthermore, remote sensing applications for planetary bodies often do not quantify the uncertainty in their mineralogy estimates or utilize spatial information. We address these gaps by proposing a new spatial-spectral probabilistic model to estimate the mineralogy of lunar and Martian surfaces, using hyperspectral data.

Some previous studies have attempted to infer Martian mineralogy using probabilistic methods, and performed hyperspectral image analysis on both the Moon and Mars simultaneously [1,2,3]. We combine these ideas, and advance further upon them by incorporating spatial locality, which exploits the assumption that adjacent regions are likely to have similar composition. We employ the predominant method in spectral unmixing, the Hapke model, to estimate the proportion of each endmember per pixel and corresponding grain sizes. We will evaluate our model under three different circumstances: (1) inferring mineral assemblage for each pixel independently; (2) using superpixel segmentation; and (3) using Markov random fields. These three methods allow comparison between a pixel-independent model (1), grouping spatially contiguous pixels using clustering (2), and quantifying the uncertainty in the mineral assemblage due to spectral and spatial information simultaneously (3).

To ensure our model is accurate, we test it on synthetic data generated from well-known spectral libraries (i.e. RELAB Brown/NASAKeck and U.S. Geological Survey spectral libraries) [4]. When applying our model to planetary data we use hyperspectral images from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) and the Moon Mineralogy Mapper (M^3) [5,6]. We evaluate our method on volcanic regions of interest, Nili Patera on Mars and Aristarchus on the Moon. Their geologic similarities enable us to use the same spectral library [7,8]. We may verify our solution using previous research findings and the spectral data from surface samples collected on each: Apollo and Luna samples from the Moon and Curiosity Rover samples from Mars [9,10,11,12]. Overall, we aim to develop a novel method for estimating the mineralogy of volcanic regions on the Moon and Mars, which may inform us of their geological evolution and volatile inventories.

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