COMPOSITIONAL VARIATIONS ON THE SURFACE OF MARS: MIXING MODEL ANALYSIS FROM A TELESCOPIC SPECTRAL IMAGE; E. Merényi, J. S. Miller and R. B. Singer, Planetary Image Research Laboratory, University of Arizona, LPL

The linear mixing model approach of Adams et al. [1] has successfully been applied to data sets of various natures, where the measured radiance could be assumed a linear combination of radiance contributions (e.g. [2] [3] [4]).

We are analyzing a visible and near-IR spectral image of Mars with linear mixing modeling on a very large spatial scale, 280 x 150 km/pixel. Since earlier applications typically dealt with 0.1-0.4 m/pixel (e.g. for Earth remote sensing and Viking Lander images) to about 1 km/pixel (Viking Orbiter pictures, for example), this requires special care in the interpretation of the mixture modeling results. Bell et al. [5] collected a very similar data set at the same time ours was recorded, which can provide a valuable comparison.

This paper reports the first step of a continuing analysis - exploration of compositional variations of the Martian surface in terms of spectral endmembers that were selected from the image itself. The second step will be to relate the image endmembers to known Earth-based reference spectra from laboratory and field measurements.

The visible and near-IR spectral region contains information about Fe$^{3+}$ and Fe$^{2+}$ mineralogy of Mars surface materials, as discussed by Singer [6] [7] and others. Relatively subtle spectral shapes and differences are of importance in terms of the mineralogies of the ferric iron bearing phases present, and therefore reflect the parent materials and modes of formation. Most of the low-albedo regions also show Fe$^{2+}$ absorptions near 0.95 microns, attributable to pyroxenes in the basaltic crustal material. Differences in pyroxene abundance and composition among low-albedo regions have been observed based in these and other data, using more conventional spectral analysis methods.

The data under investigation with mixture modeling [8] consist of a visible/NIR spectral image cube of Mars in approximate orthographic view, centered just south of Sinus Meridiani and including the NW and SE limbs. The spectral range is 0.44μm to 1.04μm in 300 channels, resampled from a set of eleven prism-dispersed 800-channel spectrograph images. The image cube scale is 6.7 pixels per arc second along the spectrograph slit (vertical), and 1 image per arc second in the scan direction (horizontal). Seeing was better than 1 arc second, with best-case resolution near 280 x 150 km at the subearth point. Data values are Mars / HD 1835, where HD 1835 is 9 Ceti, a G2V solar analog star. The values have only a multiplicative offset from Radiance Factor; the zero level is accurate. The data have been corrected for effects from the instruments and the terrestrial atmosphere. The source images for the spectral image cube were taken 07:21 - 08:08 UT September 26, 1988 at the 1.5 m telescope at the University of Arizona’s Catalina Station near Tucson, Arizona. Martian L, was 279° (southern summer), subearth latitude 21.5° S, subsolar latitude 25° S, illumination phase 4°. The .75 - .77 micron O$_2$ band was excluded from our analysis.

Following the methodology of Adams et al. [1], we can satisfactorily model the given area of Mars with 4 geologic image endmembers (Fig. 1.). (An independent PCA analysis supports that this many endmembers are justified.) These endmembers are representative spectra from Arabia, Sinus Meridiani, South Acidalia, and from a smaller area, which we call 'Meridiani Border', located just south of Sinus Meridiani. Shade was also always used as an endmember, as advocated by Adams and co-workers. The shade fraction, however, became quite featureless as we were improving on the model fit by the inclusion of additional spectral endmembers. This corresponds to the fact that at this large spatial scale the pixel-to-pixel variation of shade is smaller than in images of high spatial resolution.

'Meridiani Border' refers to two small, spatially coherent areas, to the north west and to the south (approx. [350°, 15°]) of Sinus Meridiani, which do not correspond to any major surface unit that we know of. The inclusion of a 'Meridiani Border' endmember in the mixture model was dictated by the strikingly high values mapping these regions in the rms error image when only the first 3 spectral endmembers were applied in the analysis. The selection of a 'Meridiani Border' endmember completely eliminates the error for the two small areas mentioned above, which indicates that the spectral difference between 'Meridiani Border' and the rest of the endmembers is significant. Earlier natural color and color ratio images from the Viking 2 mission may support this [9]. It appears from further analysis that this difference is in the .8 - 1. μm region. Intercomparison by ratioing 'Meridiani Border' to other endmember type
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spectra shows definite bands at \( \sim 0.81\mu m \) and \( 0.9-0.91\mu m \) (Fig. 2). Based on position, width, and shape it seems likely that these bands are due to molecular water, e.g. [10]. These bands are apparent in spectral ratios of different regions of Mars obtained simultaneously in a single spectrograph exposure (typically 0.1 second long). The optical train and Earth atmospheric effects are therefore identical, and should not introduce these observed bands. Mars atmospheric water absorptions at these wavelengths, such as measured by Rizk et al. [11], are apparently too weak to account for our observations. Checks for calibration or analysis artifacts have negative results so far. The possibility which remains is that we are detecting differences in regolith bound water in these relatively weak, high-order overtone bands. We are currently pursuing this possibility. Whether or not these bands are primarily responsible for the spectral uniqueness of 'Meridiani Border', is yet to be investigated in detail. If so, we are presented with the tantalizing suggestion of an equatorial surface region on Mars distinguished by bound water. Further analysis on the unique spectral features and possible mineralogy of Meridiani Border will be discussed.

REFERENCES:

Fig. 1. Geological image endmembers selected for this analysis.

Fig. 2. Ratio of averaged 'Meridiani Border' spectra to a spectrum from Sinus Meridiani.