HAPKE-BASED LINEAR SPECTRAL UNMIXING OF CRISM SINGLE SCATTERING ALBEDO DATA.
N. A. Scudder1, T. D. Glotch1, Y. Liu1, and T. Condus1, 1Department of Geosciences, Stony Brook University, 255 Earth and Space Sciences Building, Stony Brook, NY 11794-2100, noel.scudder@stonybrook.edu

Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) is a hyperspectral imager that maps the Martian surface at ~20 m/pixel from 362 to 3920 nm at 6.55 nm/channel. This data provides high-resolution compositional and geological information on surface features [1]. A range of compositional data products based on spectral band analysis and indexing is already well-established [2], but mineral abundances can be difficult to determine from these data. High spatial and spectral resolution make it possible to perform quantitative spectral unmixing to determine the abundance and spatial distribution of surface minerals.

Reflectance spectra are highly non-linear in the visible-near infrared (VNIR) wavelength range. For this reason, most linear unmixing studies have focused on the mid-infrared wavelength region. However, single scattering albedo (SSA) spectra add linearly in the VNIR range [3] and can be derived either from optical constants \( n \) and \( k \) or reflectance, making single scattering albedo a valid unmixing parameter. Here we introduce a linear unmixing model for single scattering albedo spectra derived from CRISM data.

Methods: The model calls upon the linear deconvolution algorithm SMA [4] in the Davinci data analysis software maintained by Arizona State University (davinci.asu.edu). CRISM single scattering albedo spectra were derived by using the method of [5], assuming surface scattering can be modeled by the Hapke bidirectional scattering function [6]. We created a VNIR spectral end-member library by acquiring reflectance spectra of pure mineral samples of multiple grain sizes and deriving average optical constants via an iterative model approach based on the Shkuratov approximation of radiative transfer [7]. The optical constant library is composed of 25 end-members spanning pyroxene, olivine, plagioclase, carbonates, sulfates phyllosilicates, and oxides. Additionally, synthetic positive and negative slope end-members were added to account for any differences in spectral slope between the CRISM and laboratory spectra. For our analysis, we utilized 224 channels ranging between 1.03 and 2.50 \( \mu \)m.

To convert mineral optical constants to single scattering albedos to be used in our model, we assign several possible grain sizes to each mineral and create an SSA end-member library consisting of multiple SSA’s for each mineral. To prevent oversolving, the number of end-members must not exceed the number of channels, and as a rule of thumb should be less than half that, so here only a few grain size guesses per mineral can be tested at a time. For our approach, we input a list of grain sizes to be used for all minerals and the model runs over all unique combinations of five of these, allowing mineral-specific inclusions or exclusions, to single out the combination with the lowest RMS error and best visual fit. Once synthetic slope abundances are normalized out, the result is a model spectrum and a list of grain size-specific mineral abundances.

Results: Laboratory testing is a vital and ongoing process to determine the accuracy and inclinations of the model. We have so far performed testing on a variety of single, two, and three-mineral mixtures of pyroxene, plagioclase, and olivine initially prepared by [8]. Reflectances of these mixtures were converted directly to SSA using an approximation for bidirectional reflectance [9]. Pure pyroxenes were modeled at 80-95% pyroxene, with a grain size prediction biased 5-35% lower than known. Olivine forsterite was modeled at 75-85% forsterite with a similar grain size bias. Labradorite plagioclase was the most difficult for the model, at 50-60% labradorite, a relatively high RMS error, and a grain size bias of 15-30% higher. These biases carry over into the 2 and 3 mineral mixtures, indicating a systematic difference in the derivation techniques of the end-members and mixture spectra.

Figure 1. A 3-component mixture and its well-fit modeled spectrum of olivine, enstatite, and augite, with a mass abundance ratio of 6:2:1. The number after the mineral name corresponds to the grain size.
For these mixtures, the model predicts olivine and pyroxene to within 20% of actual mass abundance, but labradorite is always underrepresented and distorts the abundances of other minerals. Laboratory testing of phyllosilicates, oxides, carbonates, and sulfates is planned for the immediate future.

We applied the model to a portion of CRISM image FRT0000A253_07_IF163L_TRR3 (Fig. 2) as well as several single spectra (e.g. Fig. 3) from south of Cross Crater (202.7E, -31.8N). When modeling the many spectra in an image, it is not reasonable to use a brute-force approach with many grain size combinations, so we instead chose limited sets of likely grain sizes. In the resulting maps, plagioclase (45%), pyroxene (30%), and olivine (10%) dominate on average, but in certain places phyllosilicate abundance reaches up to 20%.

The mineral maps generated from this model agree well spatially with CRISM-derived index maps, but the model fails to accurately recognize minerals below a detection limit of approximately 5% abundance.

Discussion/Future Work: Mineral end-members that have relatively flat, featureless single scattering albedos in the 1.0-2.5 micron range (e.g. halite) make unmixing difficult, as the model may use them in high abundance as an unphysical baseline boost to its derived spectrum. This puts an inherent limit on the minerals this model can accurately unmix, and we will need to fully account for this effect with anorthite and certain carbonates in our library. The end-member library itself is a constraint on the utility of this model, since only those minerals can be found by the model, so updating the library with the best spectra and most useful mineral choices is a continuous process.

Thus far we have made very simple approximations for potentially important factors in our model such as shadowing, porosity effects, and phase function. Further work will address these parameters more thoroughly. In the immediate future, a less approximate conversion from reflectance to single scattering albedo will also be implemented, as this has a significant impact on the final unmixing model. Testing of the model on known mineral mixtures is also of great importance and will continue in order to better analyze and correct image unmixing results.

We plan to apply this model to other areas of interest on the Martian surface such as jarosite or carbonate-rich sites, and hope to use THEMIS thermal inertia data to more intelligently constrain surface grain size estimates. At present, this model can determine abundances of certain minerals with reasonable accuracy and produces mineralogy maps that are in agreement with previously derived data products.