

UN-MIXING OF REFLECTANCE SPECTRA: NATURAL SURFACES SCENARIOS.

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1. INTRODUCTION

Natural geological surfaces have various mineralogical compositions and physical properties. Reflectance spectra, obtained from heterogeneous surface are complex nonlinear functions of particle size, abundance, material opacity and type of surfaces (e.g. dust, sand, bedrock, where particles are mixed at different scales) [1]. The choice of mixture end-members is scale dependent. When observed at microscopic scale, a rock sample is composed of an intimate, non-linear, mixture of minerals which constitute the end-members [2]. At the field scale we are dealing with macroscopic mixtures. These mixtures are generally assumed to be dominated by linear behavior; the probability of a photon being spread among the contributors to the mixture only depends on the areal contribution of each constituent [3]. Not many empirical studies of mixtures in natural surface scenarios were produced.

We try here to check empirically how linear mixtures of natural surfaces, what is the contribution of intimate mixtures to the reflectance spectra for different natural situations? Is it possible to identify properly all the constituents linearly un-mixing field spectra?

2. THEORETICAL BACKGROUND

Empirical models use simulated mixtures with known proportions of components for un-mixing. Mixtures are usually fabricated from powdered samples, with controlled proportions and known grain size [4,2]. Physical models such as Hapke's [5] and Shkuratov's [6] can estimate grain size distribution of a mixture from spectra using optical constants of its components, but this a priori knowledge is required or vice versa, composition can be estimated but grain size has to be known. In nature, mineral composition of rocks is extremely variable as well as grain size. Since not all mineral optical constants are known, existing models cannot be applied for every case. Models show successful predictions for a limited number of simulated mixtures allowing retrieving their components, their abundances and grain sizes. It is therefore important to use natural scenarios and try to understand mixture behavior (areal linear vs intimate non linear) based on field observations.

3. METHODOLOGY

Several sites were chosen to represent surface variations. Our study area is located at Makhtesh Ramon, Central Negev, in southern Israel. This site presents exposed areas often devoid of vegetation and offering a great variety of combinations of mineralogical constituents: clays mainly composed of kaolinite or montmorillonite, some sandstones, basalts and carbonate rocks. Some rocks are also coated by desert varnish, mainly composed of iron oxides, or fine particles that will also disturb their spectral signature. Spectra were collected in the field with an ASD FieldSpec FR2 spectral device, which has 2251 narrow bands in VIS-NIR-SWIR (0.4-2.5 μm), and a bandwidth of 0.01 μm . Measurements were performed around midday for optimal sun illumination and minimum shadow. ASD optical fiber was placed at nadir (perpendicular to the surface), at a height of approximately 1 meter above the surface. The fiber FOV is 25° so the observed surface is a circle of about 0.44 m in diameter. Each time a picture was taken with a digital camera placed near the ASD optical fiber to obtain a picture of the surface illustrating the spatial organization of end-members corresponding to the measurement.

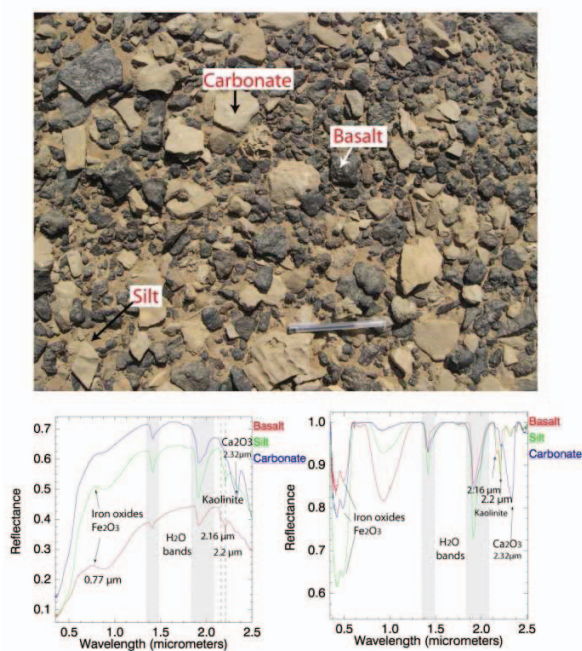


Fig. 1- natural surface scenario and end-member's reflectance spectra, normal (left) and continuum removed (right) spectra [8].

End-member samples were collected from the measured areas. Afterwards each sample was measured in the laboratory, under artificial illumination, with an ASD touch probe. Digital images were classified using Support Vector Machine Classification algorithm in the ENVI software package (ITT Visual Information Solutions), in order to assess the approximate proportions of each end-member in the field of view.

Field spectra were linearly unmixed using conventional linear un-mixing algorithm [7] and resulting proportions were compared to percent coverage calculated from digital images.

4. RESULTS

Reflectance spectra from four scenarios were observed. Composing end-members for these cases are: basalts, carbonates and fine particles (silt) with varying abundances (figure 1). Proportions of each constituent were derived by image classification (figure 2). Knowing end-member abundances linear mixtures were calculated from end-member spectra. Results show higher reflectance than expected for calculated spectra comparing to

measured for all cases. This may be caused either by non-linear contribution of end-members or by shadow effects. Absorptions in the VIS (0.4-0.7 μ m) are deeper for calculated spectra, absorptions in the NIR (1-1.3 μ m) are deeper for measured spectra and absorptions in the SWIR are about the same, though not equal. These differences can point to non-linearity in the mixture.

Results of conventional linear un-mixing algorithm applied on observed spectra are presented in table 1. Derived fractions are different compared to those derived from image classification. Linear un-mixing algorithm poorly identified the silt fraction in two cases, and the basalt fraction was overestimated in most of the cases. Some level of un-certainty can be attributed to spectral variation of each end-member due to physical properties of the sample: grain size, roughness, coating, composition.

Figure 2 – Classification result of SVM algorithm for end-member abundances estimation.

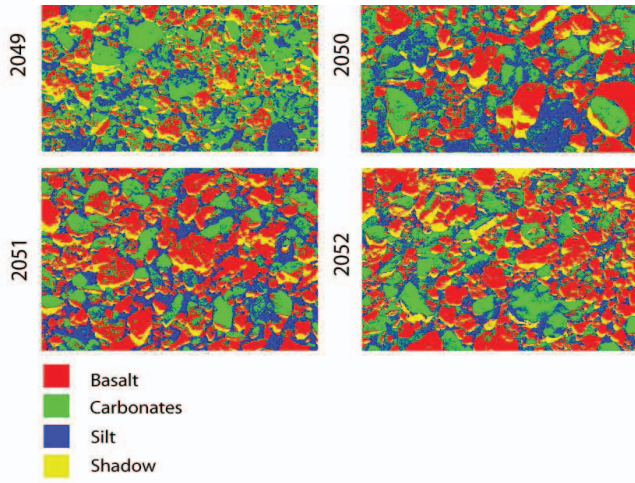
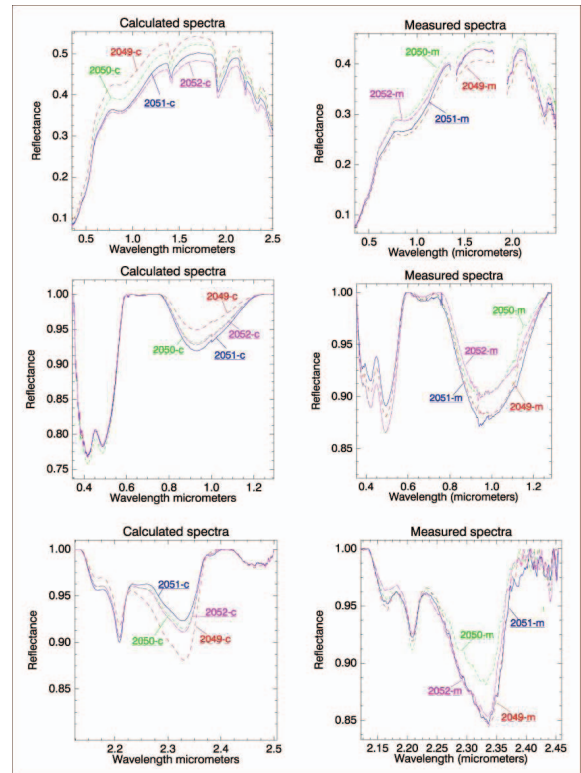


Figure 3 – Calculated and measured spectra of mixtures.



No		Basalt	Silt	Carbonates	Shadow
2049	Proportions %	24	22	42	11
	Linear unmixing %	82	0	18	-
2050	Proportions %	32	24	35	9
	Linear unmixing %	51	27	22	-
2051	Proportions %	42	24	25	9
	Linear unmixing %	39	28	33	-
2052	Proportions %	39	19	27	15
	Linear unmixing %	73	2	25	-

Table 1- end member’s proportions calculated and estimated from linear un-mixings.

Shadow effect was also not taken into account as an end-member for linear mixture estimation, as adding some uncertainty to the calculations. These deviations should be taken into account.

5. CONCLUSIONS

As it was observed from preliminary results of selected natural cases macro-scale mixtures might present some non-linear behavior. Both calculated linear mixtures, and linear un-mixing showed different results for predicted fraction abundances. End-member spectra can vary as the result of sample variations: presence of coatings in different amounts, difference in roughness, different composition, etc. Shadow effect can add some level of non-linearity that should also be evaluated. More cases will be observed in further research, end-member components and grain size variations will be estimated for better understanding of macro-mixtures behavior.

6. REFERENCES

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