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PRELIMINARY ANALYSIS OF AIS SPECTRAL DATA ACQUIRED FROM SEMI-ARID SHRUB COMMUNITIES IN THE OWENS VALLEY, CALIFORNIA

SUSAN L. USTIN, Department of Botany, University of California, Berkeley, CA 94720, USA; BARRETT N. ROCK, Jet Propulsion Laboratory, Pasadena, CA 91109, USA

ABSTRACT

Spectral characteristics of semi-arid plant communities were examined using 128 channel AIS data acquired on October 30, 1984. Both field and AIS spectra of vegetation were relatively featureless and differed from substrate spectra primarily in albedo. Unvegetated sand dunes were examined to assess spectral variation resulting from topographic irregularity. Although shrub cover as low as 10% could be detected on relatively flat surfaces, such differences were obscured in more heterogeneous terrain. Sagebrush-covered fans which had been scarred by fire were studied to determine the effect of changes in plant density on reflectance. Despite noise in the atmospherically corrected spectra, these provide better resolution of differences in plant density than spectra which are solar-corrected only. A high negative correlation was found between reflectance and plant cover in areas which had uniform substrates and vegetation types. A lower correlation was found where vegetation and substrates were more diverse. Thus shadows caused by substrate roughness or plant canopies also appear to have an important effect on brightness, making predictions from spectral characteristics difficult. Spectra obtained during periods of active plant growth may be more useful in vegetation studies.

INTRODUCTION

High spectral resolution imaging spectrometers such as AIS have potential for identification of minerals and plants based on the unique absorption features of their spectra. For ecologists, this may lead to new ways of studying and monitoring ecosystem processes, detecting environmental stresses, and measuring plant productivity. These instruments are also of considerable interest to exploration geologists working in arid and semi-arid regions, since in such areas the interpretative problems arising from mixed spectral reflectances should be minimal, due to the relatively low vegetation cover.

The primary objectives of our study are to evaluate the importance of vegetation in mixed pixel AIS data from representative semi-arid shrub communities, to assess dynamic changes in spectral features of vegetation over the year, and to develop methods by which the spectra of vegetation and substrate may be separated.

Owens Valley, CA was chosen as a test site because it has a diverse combination of plant communities and substrate types. A creosote bush community, typical of the warmer Mojave desert, extends into the southern end of Owens Valley on alluvial fan skirts from the Sierra Nevada to the west and the Inyo Mountains to the east. Vegetation on fans farther north is more typical of the Great Basin sagebrush community. Saltbush communities are found on the valley floor and on other alkaline soils. Major geologic units in the surrounding areas are Mesozoic granitic intrusives, Tertiary volcanics (primarily basalts), and Paleozoic sediments. Differences in plant density and species diversity exist within the various substrate types, offering the opportunity to examine the impact of vegetation on spectral characteristics.

AIS DATA AND CALIBRATION PROCEDURES

At present, we have had three flights over our study sites, on July 10 and October 30, 1984 and April 2, 1985. All flights obtained 128 channel AIS data, most of them in the "rock" grating position mode, 1.21-2.40 μm (Vane et al., 1983). For comparison, on some flights data from one line were recorded in the "tree" mode, ca. 0.85-2.10 μm. Thematic Mapper Simulator (NS001) imagery, Nikon black and white photographs, Zeiss color infrared images, and ground track videotapes were collected simultaneously.

Data reported here are entirely from the October overflight. The data acquired in July are of questionable value due to a high concentration of smoke from a large brush fire in Sequoia National Park to the west of Owens Valley. However, preliminary examination of these data supports the observations and conclusions of this report.

The October 30, 1984 flight occurred at 1145-1245 hours PST, on a cloud-free day. Mean flight altitude was 5.25 km above the terrain, with an instantaneous field of view of about 10 m. Data were analysed on a VAX/IDIMS system using the SPAM (Spectral Analysis Manager) package developed by the Jet Propulsion Laboratory. Prior to data analysis, a solar irradiance correction was applied to compensate for brightness variation with wavelength in the solar spectrum. We compared results of this correction with those of two additional methods for removing atmospheric absorptance effects: a "flat field" method ratioing pixel reflectances by the mean reflectance obtained from a 32 by 50 pixel area judged to be spectrally and spatially homogeneous, and a theoretically based correction algorithm (J. Solomon, personal communication) which ratios each pixel reflectance by the mean reflectance along the flight line for each channel.

RESULTS AND DISCUSSION

Coinciding with the October overflight, we performed an experiment with a Collins Visible Infrared Intelligent Spectrometer (VIRIS) to examine the effect of spectral mixing at different distances above the plant and soil surfaces. When the spectrometer was close to the canopy, the spectral pattern was distinctively plant-shaped; however, this pattern was progressively damped out as distance increased (Ustin et al., 1985). This response appears to be due to shadows within the canopy branches and the increasing contribution of sand to the spectra. From this we conclude that the influence of vegetation in October AIS data would be most evident in albedo effects.

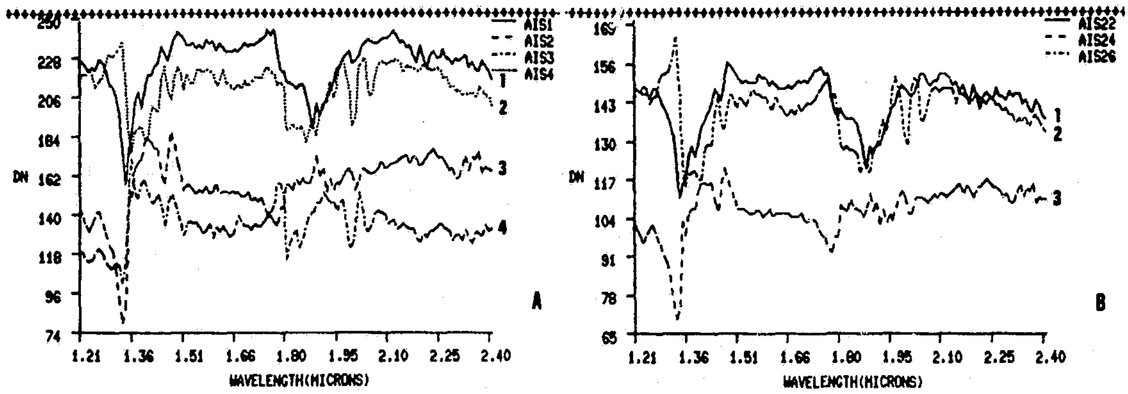

Fig. 1. AIS sand spectra with (a) flat field correction and (b) theoretically based atmospheric correction. Curve 1 is sunlit dune, 2 shaded aspect, 3 a flat surface.

Data from an unvegetated sand dune region show that topographic differences, such as changes in slope and aspect, confound interpretations of even atmospherically corrected spectra. Figure 1 shows data from the same 3-by-3 pixel areas using the flat field correction (1a) and the atmospheric correction (1b). Curve 1 is from the sunlit side of a dune, curve 2 from the shaded side, and curve 3 from a flat surface normal to the AIS (curve 4 in 1a, from the shaded side of another dune, is not shown on 1b). From these and other curves, it appears that both correction methods yield comparable results, although the digital number (dn) values depend on the method of correction. The curves are featureless and essentially flat or slightly increasing across the spectrum, as expected for quartz sands. At another area which was studied in detail, we could distinguish a saltbush vegetation cover of only 10% (based on ground transects) from a non-vegetated uniform sandy surface of similar slope, because of brightness differences. However, these differences were within the dn range seen in Figure 1 on the two aspects of the same sand dune. During spring, greater divergence in spectral response curves between vegetation and substrate may provide a less ambiguous basis for their distinction.

Spectral data in Figure 1 and in Figures 2 and 3, from the Symmes Creek and Division Creek sites on fans on the west side of the valley, all show considerable noise, making identification of absorption features difficult or impossible. We found that omitting the water absorptance bands and replotting portions of the spectra (e.g., 2.10-2.40 μm) reduced the apparent noise in the atmospherically corrected spectra. Still less noise is evident in data to which only the solar correction was applied (Figure 2a), but the differences between spectra from different areas within sites are less than in spectra corrected for both solar and atmospheric effects (Figure 2).

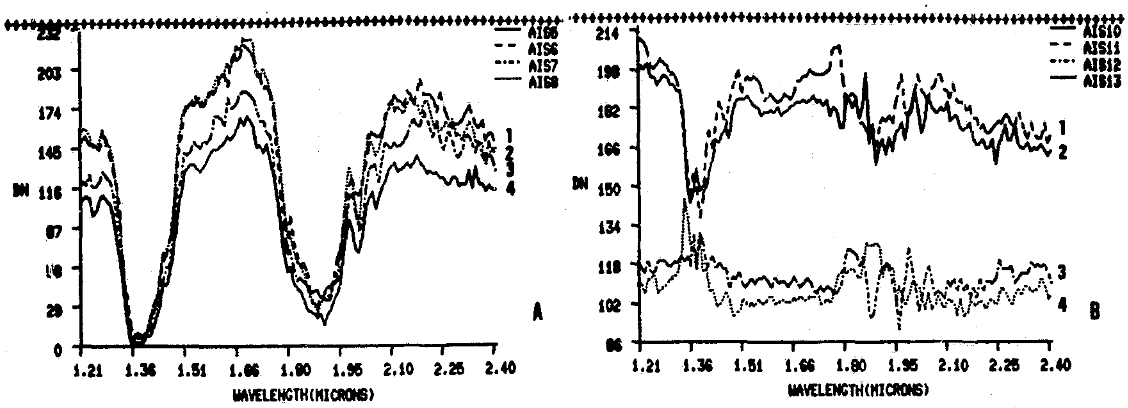

Fig. 2. AIS spectra (a) without atmospheric correction and (b) with atmospheric correction. Spectra 1 and 2 are from an area which had been burned, spectra 3 and 4 the non-burned vegetation.

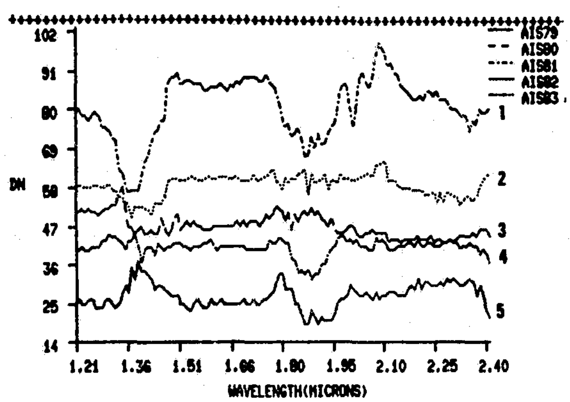

Fig. 3. AIS spectra from surfaces which differ in plant cover and substrate. Spectrum 1 is from burned alluvium, 2 burned basalt, 3 non-burned alluvium, 4 non-burned basalt, and 5 non-vegetated basalt.

Despite the greater noise in data with the atmospheric correction, they show clear differences related to vegetation cover. At Symmes Creek (Figure 2), alluvial substrates are essentially homogeneous and spectral differences relate to an abrupt change in vegetation density due to a brush fire which removed the plant cover in 1977. The upper two curves in 2a and 2b are from the burned area, which has a total plant cover of 23% including litter. The lower two curves are from the surrounding undisturbed sagebrush community, which has 46% cover. Reflectance differences between these two areas, assuming the curves are flat and using the dn value at 1.21 µm from randomly chosen 3-by-3 pixels (n=18 and 15 on and off the burn, respectively), are statistically significant (ANOVA, $p<.0001$).

We also measured plant density on and off burns at two other sites near Symmes Creek. Burns at these sites were much older (pre-1947) and had greater plant densities, but adjacent unburned areas did not vary significantly in cover. Twelve to 15 spectral curves were obtained from randomly chosen 3-by-3 pixels within each of these areas. As described above, curves from each area were averaged and compared with plant cover, which ranges from 23 to 48 %. A linear regression of mean dn from all three sites with mean total plant cover produced a negative correlation coefficient of 95 % (n=6). Thus, shrub cover has a consistent effect in lowering substrate albedo, and the amount of change is related to plant density.

At Division Creek, a similar sagebrush community occurs on both a granitic alluvial substrate and a basalt flow. In 1982, a fire removed the vegetation across both substrates. Curves in Figure 3 are representative of 12-16 reflectance spectra from each of these surfaces. The upper curve (1) is from the burned alluvial surface, which has a 9 % plant cover, nearly all of which consists of herbaceous dicot litter at this season. The next curve (2) is from the burned basalt, which has a surprisingly high reflectance. It has a high cover, 52 %, almost all of which is grass litter. Curves 3 and 4 are from the non-burned areas on the alluvial and basalt substrates, which support a similar shrub community with covers of 64 % and 45 %. The lowest curve (5) is from a non-vegetated basalt outcrop. Although there is a good correlation of dn with cover (71 %), it is lower than that from the other burns. This probably reflects the greater substrate roughness on the basalt flow and differences in physiognomy (shrub vs. herbaceous). Thus, although the amount of plant cover is clearly the major determinant of reflectance, shadows caused by plant canopies and substrate roughness may also be an important source of albedo variation. The presence of vegetation reduces the differences in reflectance between the two substrates, thus masking any geologic absorption features. Although this feature is somewhat difficult to detect in curve (1), other curves from the burned alluvial surface clearly show a hydroxyl absorbance of presumed substrate origin, at 2.19 μm, and which was confirmed by field VIRIS spectra. This feature is absent in all AIS data from surfaces with greater plant cover.

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