

DEVELOPMENT OF A REGIONALLY SPECIFIC LIBRARY FOR THE SANTA MONICA MOUNTAINS USING HIGH RESOLUTION AVIRIS DATA

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1 Introduction

The ability to map vegetation to the species level is of wide interest in ecology. For example, plant physiological responses vary at the species level, offering the potential of improving our ability to extrapolate branch and whole tree measures of plant photosynthesis, respiration and transpiration to landscape scales. Species-level maps of vegetation have additional applications in resource inventories, biodiversity mapping and fire-hazard assessment as additional examples. One of the primary motivating factors for this research has been improved species-level maps of chaparral in the Santa Monica Mountains. Improved maps are valuable due to differences in fuel characteristics (ignition potential, leaf surface to volume ratios) and biomass accumulation between chaparral dominants such as chamise (*Adenostoma fasciculatum*) and *Ceanothus* species (*C. megacarpus*, *C. spinosus*) (Philpot, 1977; Regelbrugge and Conard, 1996).

An imaging spectrometer, such as the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) has the potential of mapping vegetation to the species level due to the large number of wavelengths it samples and the manner in which unique chemical and architectural properties control associated reflected radiance. In this paper, we utilize high-resolution AVIRIS to augment a regionally specific, spectral library for the Santa Monica Mountains for use in Multiple Endmember Spectral Mixture Analysis. These spectra were acquired to enhance existing field-based libraries and to address limitations in the library, including low diversity in viewing geometry and species and scale differences between AVIRIS and field spectra. These factors, we suggest, significantly lower classification accuracy in 20 meter AVIRIS data. We analyzed high-resolution AVIRIS acquired along flight lines designed to cross calibration sites, span a range in species and to complement existing low-resolution data. High and low resolution AVIRIS reflectance data were unmixed using the improved library. Results were assessed using existing ground truth and compared to past results based on unimproved spectral libraries

2 Background

Remotely sensed systems do not map species, which are ultimately defined by fine scale taxonomic and genetic attributes. Rather, reflected radiance varies as a function of canopy structure (e.g. leaf orientation and density, branch density, crown cover and geometry) and canopy chemistry (canopy moisture, chlorophyll concentration in leaves). When canopy structural properties and chemistry are uniquely associated with a specific type of plant in a region, it is possible to map vegetation to the species level. For example, although incredible species diversity occurs in the tropics, even broad-band systems such as Landsat Thematic Mapper can map plant species if they have unique enough structure and chemistry. A good example is provided by *Cecropia sciadophylla* and *Vismia japurensis*, both of which have been mapped using Landsat TM by a number of authors because they form relatively extensive, uniform stands of regenerating vegetation in disturbed landscapes in central Amazonia (Lukas et al., 1993; Adams et al., 1995; Foody et al., 1996 ; Roberts et al. 1998a). In many ecosystems, high plant diversity, a patchy distribution and non-unique structure and chemistry preclude the ability to map plant species.

Roberts et al., (1997a; 1998b) introduced the idea of a regionally specific spectral library. They recognized that the ability to separate plant species using remote sensing will vary from one region to the next and will decrease as the geographic area covered increases. Provided a region can be defined, within which suites of spectrally distinct species coexist, it should be possible to map them as distinct within the region given an adequate spectral library. One approach, which takes advantage of a spectrally diverse reference library is Multiple Endmember Spectral Mixture Analysis (MESMA; Roberts et al., 1996, 1998b), in which the number and types of endmembers are allowed to vary on a per pixel basis. MESMA has been

used to map snow covered area and grain size (Painter et al., 1997;1998), chaparral dominants (Roberts et al., 1996;1998b; Gardner, 1997), conifer species (Roberts et al., 1999) and soil types (Okin et al., 1998).

In earlier work, a regionally specific spectral library was developed for the Santa Monica Mountains and applied to map chaparral species using MESMA (Roberts et al., 1996, 1997,1998b; Gardner, 1997). MESMA was applied to fall data sets acquired over the entire range from 1994 to 1997 (Roberts et al., 1998c). Initial accuracy assessment demonstrated high accuracy for many species, but also identified some serious limitations in the maps (Gardner, 1997). Subsequent field work identified additional shortcomings. Likely causes for decreased accuracy included 1) a lack of species diversity in field spectra; 2) scale problems, in which field spectra measured over a 10-100 cm IFOV were not representative at the 20 meter scale of AVIRIS and 3) variability in AVIRIS view zenith, which ranged between 17 degrees in the backscatter view direction to 17 degrees in the forward view. These problems resulted in significant errors in map accuracy and artifacts in the region where the two flight lines were merged due to changes in viewing geometry. In this paper we use low altitude, high resolution AVIRIS data to augment a field-based spectral library to assess the potential of high resolution AVIRIS for development of regionally specific libraries and improved vegetation mapping.

3 Methods

3.1 Data

Between 1995 and 1997 over 6,000 spectra have been collected in the Santa Monica Mountains. These spectra were initially acquired in June and October 1995 using an Analytical Spectral Devices full range instrument and a lift supplied by the Los Angeles County Fire Department (Ustin et al., 1998). The library was subsequently expanded to include a greater diversity of plant species using a 3 meter ladder and leg extenders to acquire canopy level spectra on sloping terrain (Gardner, 1997; Roberts et al., 1997). Additional field acquisitions have occurred as late as October, 1998 to acquire spectra of specific dominants. An earlier version of this library was used by Roberts et al., (1997) and Gardner (1997) to map species in AVIRIS data acquired in October 19, 1994.

In addition to field spectra, we had access to over 300 field polygons that list species present and percent cover. The polygons were originally mapped and incorporated into a GIS to assess map accuracy. In this study, they were used to help identify reflectance targets for specific plant species.

Low altitude, high resolution AVIRIS data were collected along east-west flight lines on October 5, 1998, in order to improve the regionally specific spectral library for the Santa Monica Mountains. Flight lines were designed to cross field calibration sites and cover a range in species diversity. In order to assess the performance of the new spectral library and its potential applicability to coarser resolution data, analysis with the new library was extended to AVIRIS acquired on October 23, 1996. In order to compare the old and new libraries, the old library was applied to both data sets.

3.2 AVIRIS Processing

Reflectance was retrieved and liquid water mapped from AVIRIS high resolution data using techniques developed by Green et al. (1993). Three flights of high resolution data were processed to reflectance. These flight lines were concentrated on the southern half of the range, centered approximately over Point Dume. A total of 23 scenes were processed. Once processed to reflectance, field polygons acquired for accuracy assessment were used to help identify pure stands of over 20 species in the high resolution data. Solar and viewing geometry were used to categorize spectra based on position within a swath as being either in the forward, nadir or backscattering view orientations. An effort was made to locate representatives of each type of geometry for each species. Limitations in the number and accuracy of field polygons still restricted our ability to identify a large number of plant species, including most riparian species, oak species and many types of soft chaparral such as deer weed (*Lotus scoparius*). Nevertheless, several hundred species-level spectra were obtained over a range of lighting and viewing geometries.

Reflectance spectra were extracted for these stands and merged with a revised field-based and laboratory-based spectral library developed for Fall images. The combined library was then used to apply a series of ~250 two-endmember models using multiple endmember spectral mixture analysis (MESMA). To test the portability of these spectra to low resolution data, the library was also applied to a 20 m data set acquired over the area on October 23, 1996, just after the Calabasas fire. To determine the extent to which the new library improved upon the older library, the older field-based library was also applied to unmix the newer high resolution data.

4 Results

Initial results were very promising. High quality reflectance spectra were obtained for all 23 scenes, representing over 7 million spectra. To illustrate the high quality of retrieved reflectance, example spectra for several vegetation types are shown in Figure 1. Initial results showed that the new library outperformed the older library at all spatial scales. At fine resolution, we were able to distinguish two species of *Ceanothus*, a majority of the dominants and riparian areas (Figure 2). At coarser resolution, we were not able to map riparian areas, but were able to map large areas that previously had gone unmapped or were misclassified (Figure 3). The most significant factor limiting our ability to utilize the high resolution data was our own limited knowledge of the field site, in which many pure stands that could be located in the image and used in the library could not be identified from our field data. We are currently using the high resolution data to guide further acquisition of field polygons and significantly increase the number of species represented in the library. We are also extending our analysis to include other geographic regions and have recently applied a slightly modified spectral library to the front range of the Santa Ynez Mountains, north of the city of Santa Barbara to map species with some success. The Santa Barbara flight lines are particularly interesting because they include large, uniform stands of several species that do not occur in large patches in the Santa Monica mountains (but are present), including purple sage (*Salvia leucophylla*), California sage scrub (*Artemisia californica*), coyote bush (*Baccharis pilularis*) and introduced *Eucalyptus* species.

5 Summary

Here we describe initial results combining high resolution AVIRIS reflectance spectra with field and lab based spectra to augment a regionally specific library for the Santa Monica Mountains. We found that high resolution AVIRIS spectra effectively complement field and laboratory spectra, greatly expanding the diversity of species sampled and increasing variability in view geometry at a potentially more appropriate spatial scale. The combined Hires/Field library outperformed the older spectral library at both coarse and fine spatial scales. Significant findings included improved species separation (ie *Ceanothus spinosus* vs *C. megacarpus*) as well as improved mapping of riparian areas, oak woodland and senesced grass in fine resolution data. In addition, we found that some classes did not map well at coarser, 20 meter resolution, including riparian areas, *Ceanothus spinosus* and many roads. Poor mapping of these land-cover types is likely due to the small spatial extent of these cover types (ie most riparian areas form thin strips less than 20 meters wide) or sub-20 meter spatial variability. The older spectral library described in Roberts et al. (1997) and Gardner (1997), performed well at coarse resolutions but required optimal ordering of two and three endmember models to match the performance of the new library that required no model ordering.

Hi-resolution AVIRIS reflectance, when combined with field and laboratory spectra, offers the potential of developing regionally specific libraries over a wide range of ecosystems. Fine- and coarse-resolution AVIRIS have been acquired over semi-arid and arid shrublands, grasslands, a diversity of forest types, wetlands and urban areas. Each of these AVIRIS acquisitions presents a unique opportunity to expand our knowledge of the reflectance of different types of land cover and better inform mapping efforts. In this paper we investigate the potential of developing such a library from high-resolution AVIRIS for the Santa Monica Mountains. Improved species level maps derived for our study site support the concept of a regionally specific spectral library and the use of high resolution AVIRIS for developing such libraries. The potential of high resolution AVIRIS applied to other ecosystems for similar library development is good.

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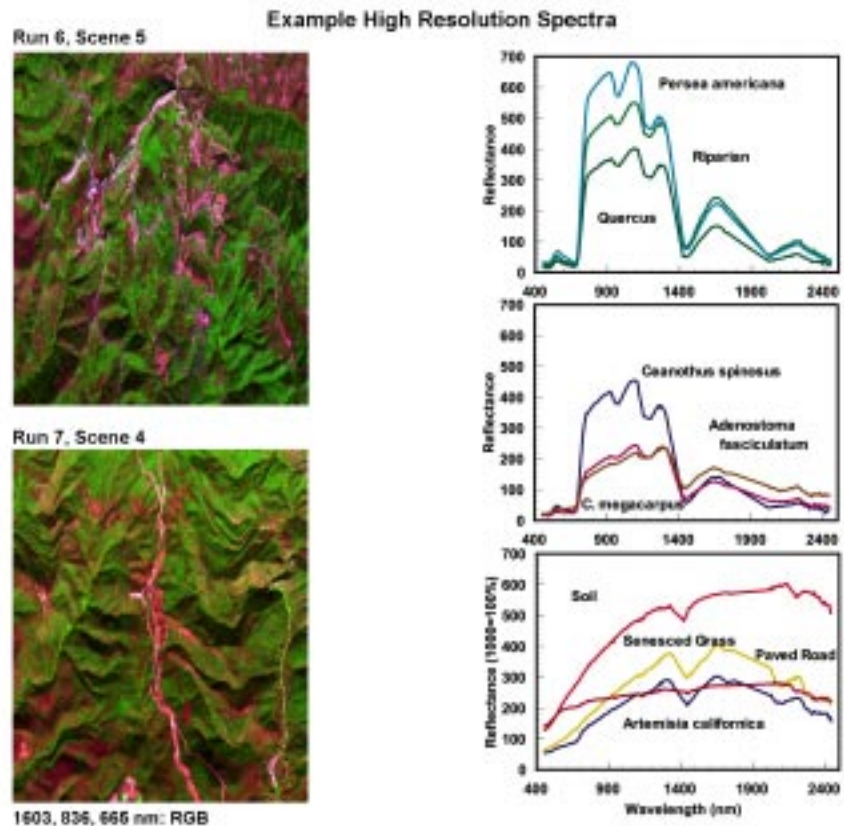


Figure 1) Example spectra from high resolution AVIRIS data

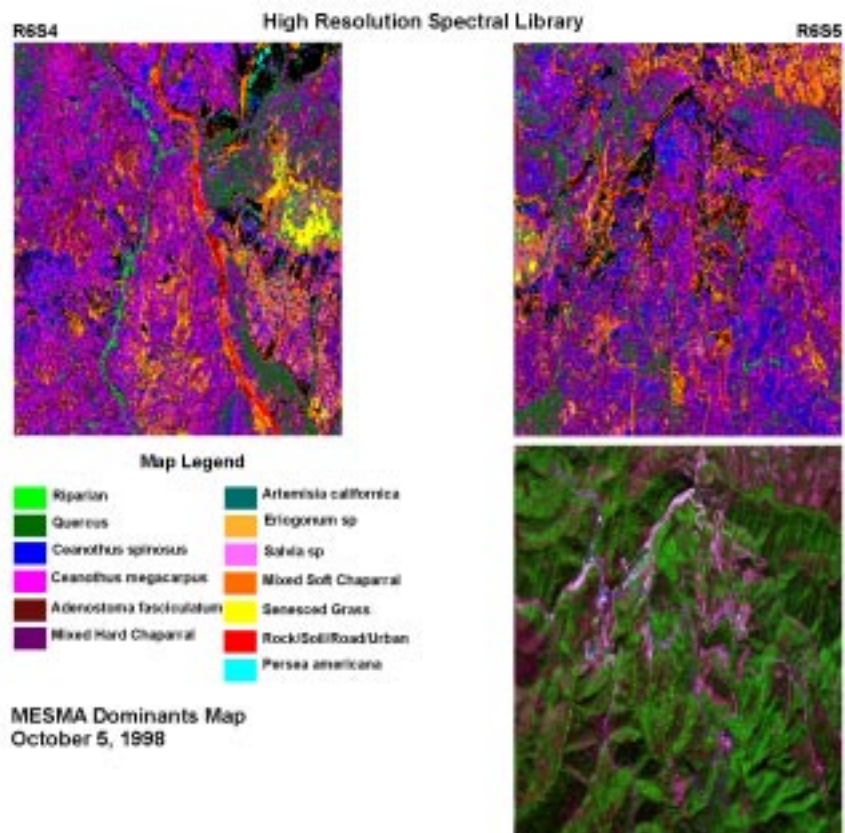


Figure 2) MESMA maps generated using the combined hi-res/field-based library

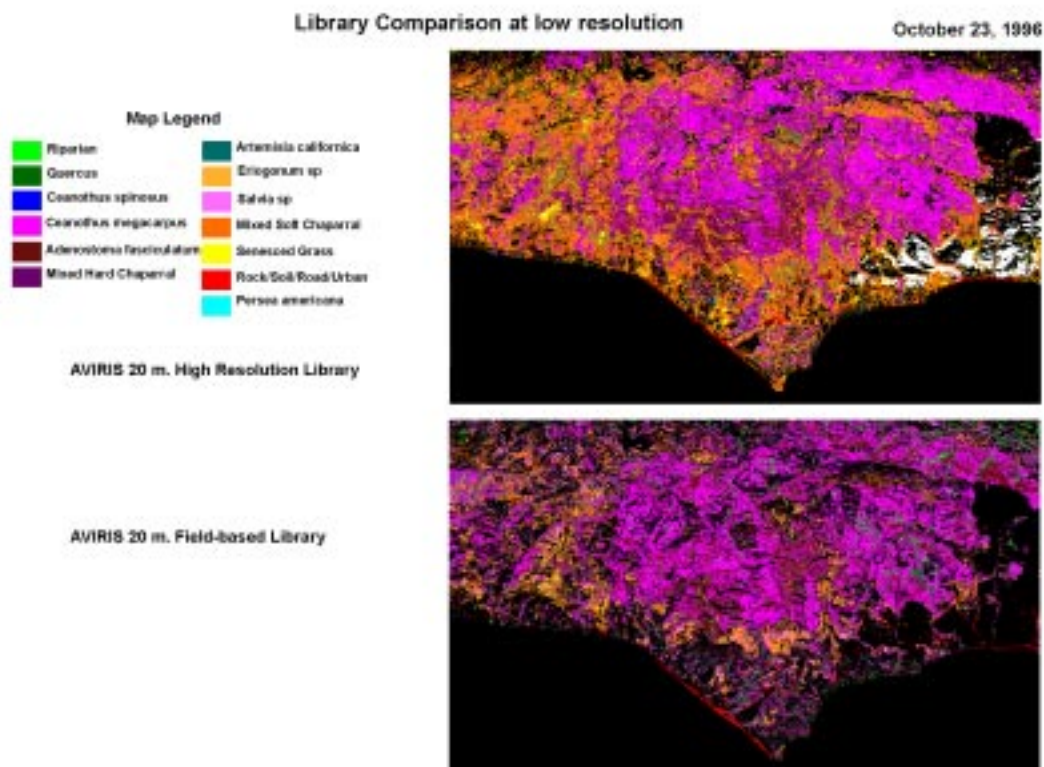


Figure 3) Comparison of new and old spectral libraries applied to coarse resolution AVIRIS

