AVIRIS DATA QUALITY FOR CONIFEROUS CANOPY CHEMISTRY

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ABSTRACT

An assessment of AVIRIS data quality for studying coniferous canopy chemistry was made. Seven flightlines of AVIRIS data were acquired over a transect of coniferous forest sites in central Oregon. Both geometric and radiometric properties of the data were examined including: pixel size, swath width, spectral position and signal-to-noise ratio. A flat-field correction was applied to AVIRIS data from a coniferous forest site. Future work with this data set will exclude data from spectrometers C and D due to low signal-to-noise ratios. Data from spectrometers A and B will be used to examine the relationship between the canopy chemical composition of the forest sites and AVIRIS spectral response.

INTRODUCTION

The objective of this study is to determine whether or not AVIRIS data can be used to study coniferous canopy chemistry. This involves two steps: (1) an evaluation of AVIRIS data quality and (2) if in step one the data proves good enough, an examination of the relationship between canopy chemical composition and AVIRIS spectral response. The first step is the subject of this paper.

DATA COLLECTION

Seven flightlines of AVIRIS data were collected on August 1, 1988 over forest test sites in central Oregon. Together these zones form an east-west transect which exhibits a gradient of climate and fertility encompassing the western coast range, the interior coast range, the low elevation west cascades, the mid-elevation west cascades, the high cascade summit, the east slope cascades, and the interior high desert. AVIRIS data were acquired over 13 of the total 14 sites distributed troughout the transect where ground data had been collected in previous studies. The site missed was in the western coast range. Average spectra from three-by-three pixel windows over three forest sites are shown in Figure 1.

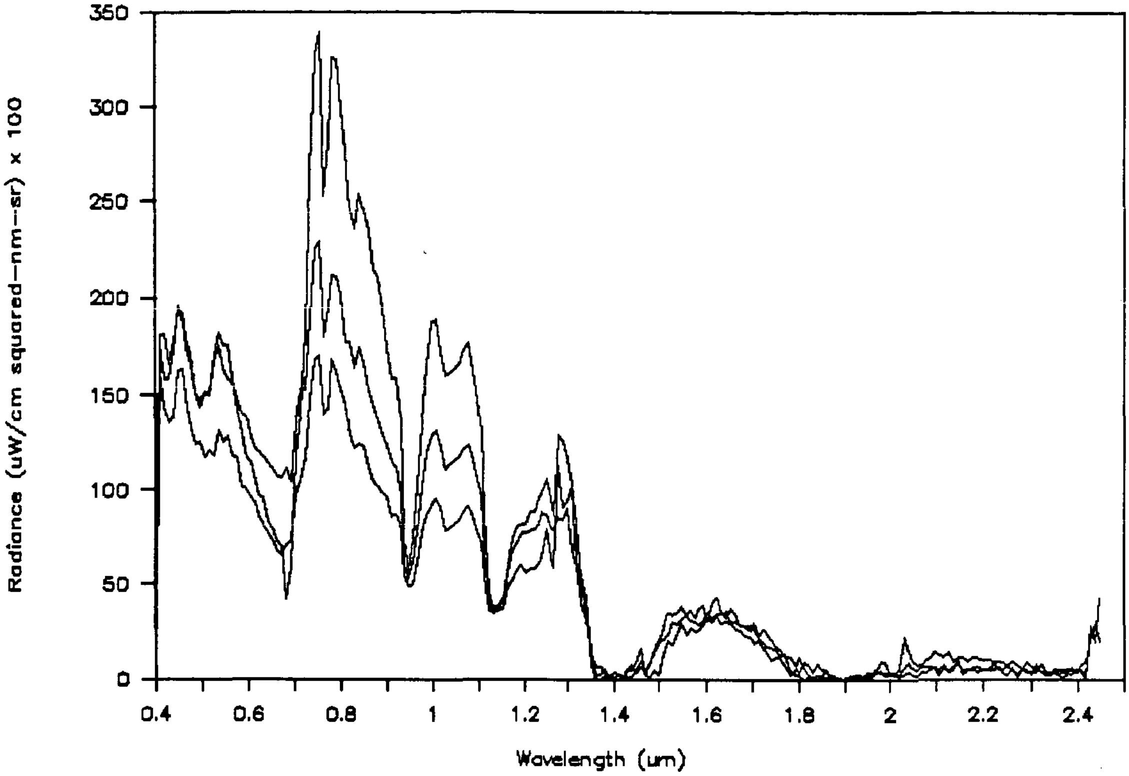

Fig. 1. Nine pixel mean AVIRIS spectra from three forest sites: Casacde Head (top), Metolius (middle), and Santiam Pass (bottom).

METHODS AND RESULTS

Both geometric and radiometric properties of the radiometrically corrected AVIRIS data received from JPL were examined. Pixel size in the along-track and across-track directions were measured on three flightlines. United States Geological Survey orthophoto quadrangles were used as the basis for comparison. Swath width was calculated as the average across-track pixel size multiplied by the number of pixels per line (614). These measurements and calculations for each flightline are shown in Table 1.

Table 1. Mean pixel size and swath width of AVIRIS data

Site Name	Across-Track Mean Pixel Size	Along-Track Mean Pixel Size	Swath Width
Cascade Head	18.3 m	18.9 m	11,236 m
Trout Creek	17.6 m	17.5 m	10,806 m
Metolius	17.8 m	16.7 m	10,929 m

The average across-track pixel size ranged from 17.6 to 18.3 m while in the along track direction it ranged from 16.7 to 19.1. The swath width ranged from 10,806 to 11,236 m. This variation is most likely due to differences in topographic relief between these flightlines.

An atmospheric model, LOWTRAN 6 (Kniezys et al., 1983), was used to evaluate AVIRIS spectral position. Known atmospheric absorption features were compared to those from a flat-field AVIRIS spectrum. This comparison is shown in Figure 2. where a fifty pixel average spectrum from a beach and LOWTRAN 6 output from the mid-lattitude summer model of solar spectral irradiance reflected by a hypothetical fifty percent reflector are plotted.

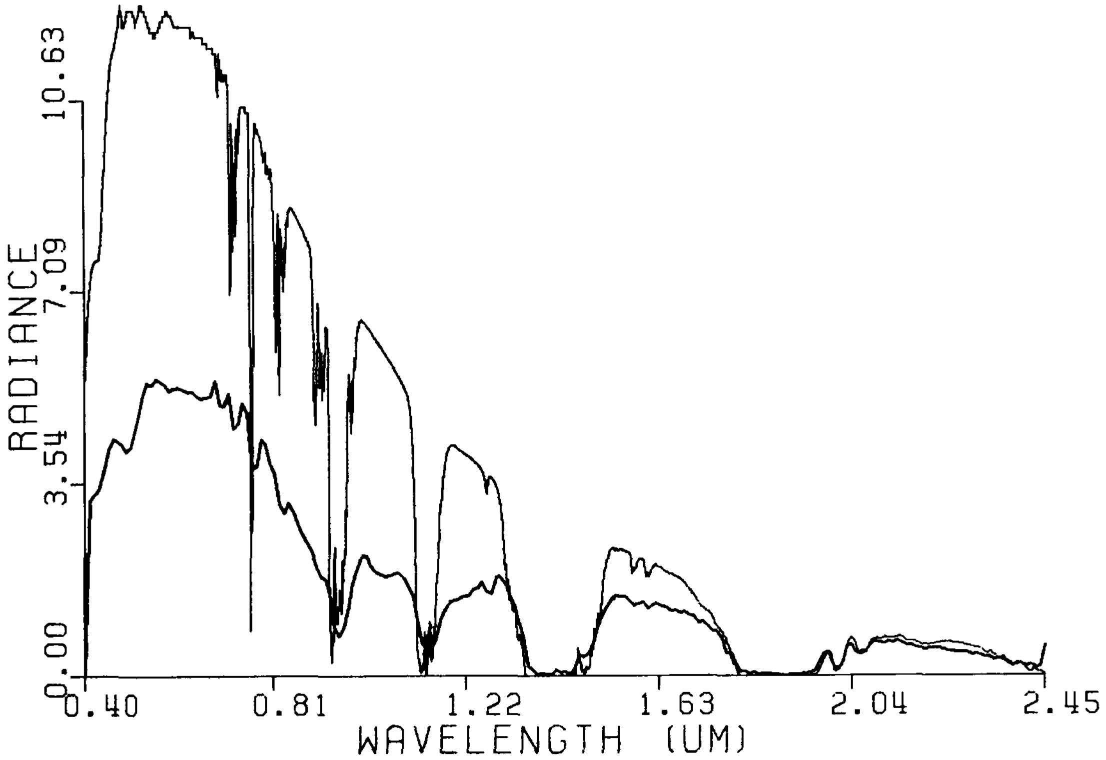

Fig. 2. Solar spectral radiance (uW/cm squared-nm-sr) from LOWTRAN (top) and an AVIRIS flat-field (bottom) showing the relative positions of atmospheric water and carbon dioxide absorption features.

As can be seen in Figure 2. the atmospheric water absorbtion features at 0.942, 1.135, 1.389 and 1.876 micrometers (Coulson, 1975) as well as atmospheric carbon dioxide features at 1.4, 1.6 and 2.0 micrometers (Liou, 1980) are properly located within the appropriate 10 nanometer AVIRIS spectral band.

Visual inspection of the data revealed a noise pattern, present in all channels and especially noticable in homogeneous areas, that made the image look like corrugated cardboard. This periodic noise was evident in the Fourier domain as noise spikes, but was not filtered out prior to the following analysis of the signal-to-noise ratio. Sudden shifts in scene brightness were also evident in several flightlines, but did not occur between imaging of the forest study site and the beach site used in this analysis.

The ratio of mean radiance to standard deviation of the radiance over a homogeneous surface was used to estimate the ratio of signal-to-noise for each AVIRIS spectral band. Assuming the beach was a relatively homomgeneous surface an estimate of the signal-to-noise ratio for each AVIRIS spectral band was obtained by computing the mean radiance of the fifty beach pixels and dividing it by the standard deviation of those fifty pixels. This is a "best case" estimate of the signal-to-noise ratio for this flightline since beach sand is a highly reflective target as compared to the rest of the scene, but it does provide an upper bound.

To obtain a signal-to-noise estimate for forested sites of interest in this study a similar method was employed. Nine adjacent pixels were extracted over the forest test site from the same flightline as the beach and for each channel the mean was divided by the standard deviation. In this case the assumption of homogeneity is not as good as for the beach and will lower the estimate of signal-to-noise. To minimize this effect a dense stand with a high leaf area index was chosen to provide as homogeneous a target as possible. This estimate served as a lower bound on the signal-to-noise ratio for forest targets on this flightline. Estimates of signal-to-noise ratios for both targets in all bands are shown in Figure 3.

The signal-to-noise ratio is lower in nearly all channels for data taken over the forest test site than for data from the beach (as would be expected from their different albedos). Excluding the atmospheric water absorption bands centered at 1.38 and 1.87 micrometers, the greatest difference between the two estimates is in spectrometers C and D. In spectrometer C between 1.55 and 1.68 micrometers the mean signal-to-noise ratio as calculated from the beach AVIRIS data is 20.8 while the mean signal-to-noise ratio for the forest data is 7.7. In spectrometer D between 2.08 and 2.26 micrometers the estimates for the signal-to-noise ratio are 14.6 and 2.3 for the beach data and the forest data, respectively.

A flat-field approach (Roberts et al., 1986) was used to correct for atmospheric effects in data from the forest site. The spectrum from the beach was divided into the forest spectrum to produce the spectrum shown in Figure 4. This spectrum looks like a typical vegetation spectrum with some exceptions: the flat region centered at approximately 1.2 micrometers, the noisy portion between approximately 2.0 -2.4 micrometers, and the decending values between 0.4

- 0.55 micrometers.

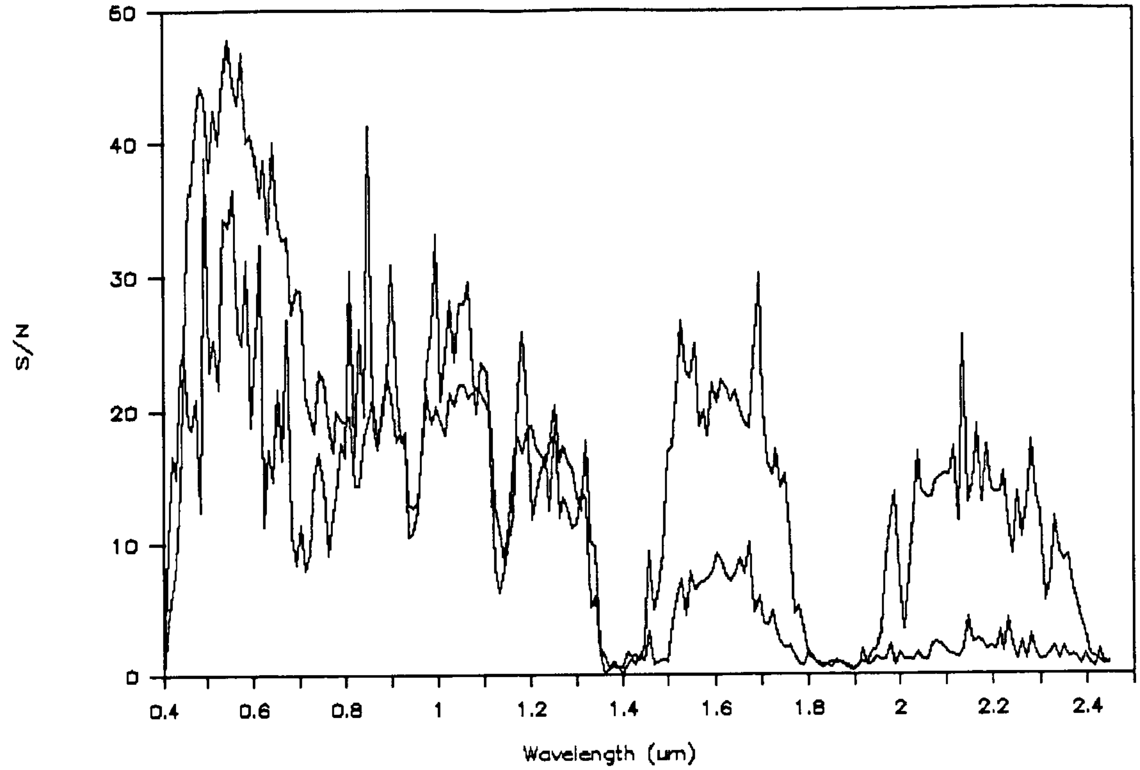

Fig. 3 AVIRIS signal-to-noise (S/N) estimates for a flat-field (top) and forest site (bottom)

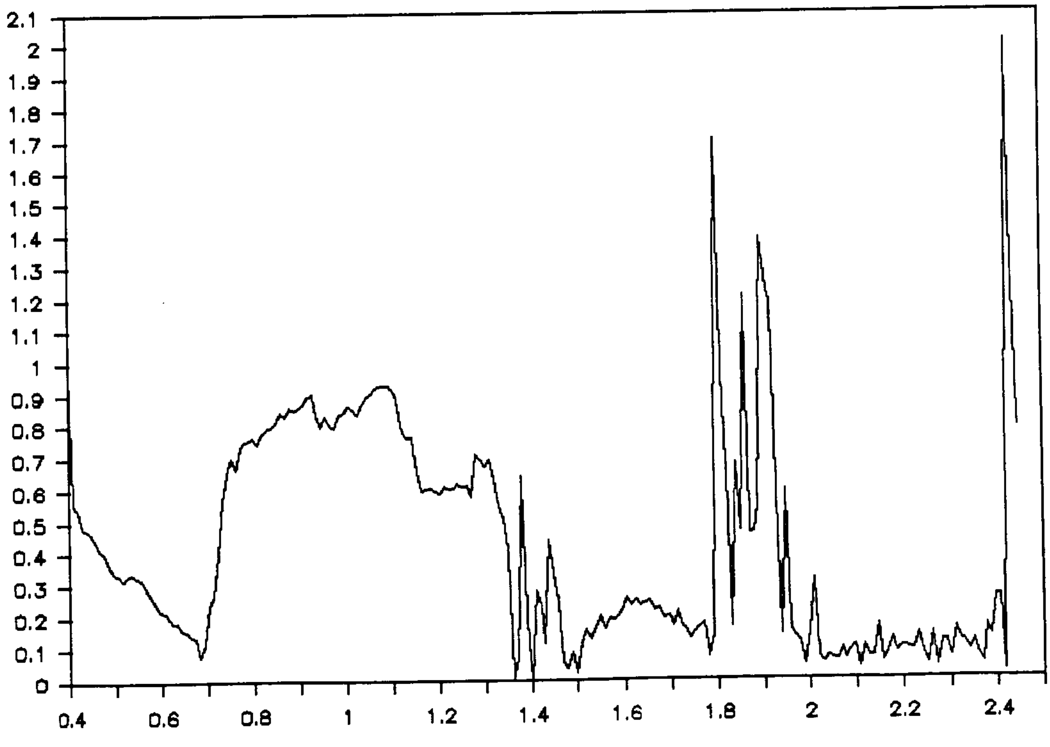

Fig. 4. Ratio of an AVIRIS forest spectrum to a flat-field spectrum

DISCUSSION AND CONCLUSIONS

Site coverage of 13 out of 14 sites, spatial resolution of better than 20 m, and spectral position of within one AVIRIS bandwidth are all expcted to be sufficient for this study of coniferous canopy chemistry. Excluding the atmospheric water absorption bands the signal-to-noise ratio in spectrometer A and B as bounded by even the low estimate in Figure 3. is above ten for nearly all bands and should be adequate for this work. AIS data of similar spectral resolution for this same forest site exhibited signal-to-noise ratios greater than ten in all channels and correlated well to canopy chemistry in a previous study (Swanberg and Peterson, 1987).

The mean signal-to-noise ratio in spectrometers C and D, however, fall somewhere in the range 7.7 - 20.8, and 2.3 - 14.6, respectively. If one believed that the true signal-to-noise ratio for the forest site were actually closer to the upper bound the data could be considered useable; however, it is probably closer to the lower bound. The lower bound, calculated from data of the forest site, is an underestimate, but all efforts were made to use as homogeneous a forest target as possible and any lack of homogenity probably accounts for only a small percentage of the noise in this estimate.

Although the results of flat-field correction were encouraging they exhibit a number of problems. The flat region at 1.2 micrometers can be explained by the discrepancy in that spectral region between the beach spectrum and the LOWTRAN model output. The noisy region between 2.0 - 2.4 micrometers can be attributed to the AVIRIS signal-to-noise ratio in spectrometer D. The decending values between 0.4 - 0.55 micrometers can not easily be explained. This technique and additional methods of atmospheric corection will need to be examined before data from several flightlines can be compared.

FUTURE WORK

Since the signal-to-noise ratios in spectrometers C and D are unacceptabely low, future work with these data will be restricted to data from spectrometers A and B. Fourier filters will be constructed for each flightline to reduce periodic noise and methods to normalize data from different flightlines with respect to the dark current offsets will be investigated. Atmospheric corrections will be invesigated to corect for differences in elevation as well as possible differences in atmospheric composition between sites. Finally, the relationship between canopy chemical composition, as characterized in previous studies, and AVIRIS spectral response at each site will be examined.

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