A LINEAR SPECTRAL MATCHING TECHNIQUE FOR RETRIEVING EQUIVALENT WATER THICKNESS AND BIOCHEMICAL CONSTITUENTS OF GREEN VEGETATION

Bo-Cai Gao[1], and Alexander F. H. Goetz[1,2]

[1]Center for the Study of Earth from Space/CIRES, Campus Box 449
[2]Department of Geological Sciences
University of Colorado, Boulder, CO 80309-0449, U. S. A.

1. INTRODUCTION

Over the last decade, technological advances in airborne imaging spectrometers, having a spectral resolution comparable with laboratory spectrometers, have made it possible to estimate biochemical constituents of vegetation canopies. Wessman et al. (1988) have estimated lignin concentration from data acquired with NASA's Airborne Imaging Spectrometer (AIS) over Blackhawk Island in Wisconsin. In this study, a stepwise linear regression technique was used to determine the single spectral channel or channels in the AIS data that best correlated with measured lignin contents using chemical methods. The regression technique does not take advantage of the spectral shape of the lignin reflectance feature as a diagnostic tool nor the increased discrimination among other leaf components with overlapping spectral features.

A nonlinear least squares spectral matching technique (Gao and Goetz 1990) has recently been reported for deriving both the equivalent water thicknesses of surface vegetation and the amounts of water vapor in the atmosphere from contiguous spectra measured with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) (Vane, 1987). The same technique has been applied to a laboratory reflectance spectrum of fresh, green leaves (Goetz et al. 1990). The result demonstrates that the fresh leaf spectrum in the 1.0-2.5 μm region consists of spectral components of dry leaves and the spectral component of liquid water. In this paper, we describe a linear least squares spectral matching technique for retrieving equivalent water thickness and biochemical components of green vegetation.

2. METHOD

At present, the prediction of vegetation reflectances based on rigorous radiative transfer modeling and the subsequent retrieval of biochemical components of vegetation are difficult. To simplify the problem, we have assumed that the vegetation reflectance spectrum has the same shape as the transmittance spectrum (Knipling 1970). With the assumption, the reflectance spectrum, $R(\lambda)$, can be expressed as:

$$R(\lambda) = (a + b\,\lambda)\exp\left(-\sum_{i=1}^{i=n} k_i u_i\right) \tag{1}$$

where n is the total number of end members (such as liquid water, lignin, or cellulose) used in the modeling, k_i is the absorption coefficient of the i^{th} end member, u_i is the absorber amount of the i^{th} end member. The background level of the transmittance spectrum is assumed to be a linear function of wavelength and represented by the term $(a + b\,\lambda)$. This assumption is typically justified for small wavelength intervals (McMahon and Simmons 1980).

Figures 1a-1f illustrate our linear least squares fitting method for retrieving equivalent water thickness and chemical components of vegetation. Fig. 1a shows a reflectance spectrum in the 1.5-1.74 µm wavelength interval. This spectrum was obtained by removing atmospheric effects using the technique described by Gao et al. (1991) from an AVIRIS spectrum measured over an area covered by pine trees in the Oregon Transect on June 1, 1989. Fig. 1b shows the spectrum of the absorptances, the fitted straight line, and the difference spectrum.

Fig. 1c is similar to Fig. 1b but for the end member of liquid water. For clarity, both the minus log curve and the fitted straight line were shifted upward by the same amount in the plot. The water reflectance spectrum was obtained by measuring reflectances of water mixed with glass beads, which have no absorption features near 1.7 µm. Fig. 1d is also similar to Fig. 1b, but for lignin. The lignin reflectance spectrum was supplied by D. Peterson (private communication, 1990).

Fig. 1e shows an example of spectral matching using only water. The solid curve in this figure is the difference spectrum in Fig. 1b. The dashed curve is the fitted spectrum with one end member - water. In this case, the abundance vector, X, has one element. The value of x is the derived equivalent water thickness relative to the liquid water amount from the reflectance spectrum of water mixed with glass beads. The sum of the squared differences between the observed and the fitted spectra is 0.0066. Fig. 1f shows an example of spectral matching with two end members - water and lignin. In this case, the abundance vector, X, contains two elements, the equivalent thicknesses of water and lignin relative to the water spectrum and the lignin spectrum, respectively. The fit between the two curves in the 1.65-1.74 µm region in this figure is better than that in Fig. 1e. The sum of the squared differences between the two curves in Fig. 1f is 0.0036, almost half of that of Fig. 1e.

3. DISCUSSION

In the 1.3-2.5 µm region, absorption features of chemical components, such as lignin and cellulose, overlap (Curran 1989). Because of this, the derived equivalent thickness of lignin, for example, may be affected by other components using our linear spectral matching technique.

Differences do exist in shapes of absorption features of different chemical components (Elvidge 1990). For example, both lignin and cellulose have absorption features near 1.7 µm; the peak positions of the features are slightly offset. Also, the lignin absorption feature is sharper than the cellulose absorption feature. By comparing Figures 1e and 1f, one can see that if water and lignin are included in the fitting of the spectrum over pine trees, the overall fit is improved. This lends some credibility to the derived lignin amount using our technique. Furthermore, if water and cellulose are included in the fitting, the overall fit, particularly in the 1.65-1.75 µm region, is not as good as that with water and lignin.

4. ACKNOWLEDGMENTS

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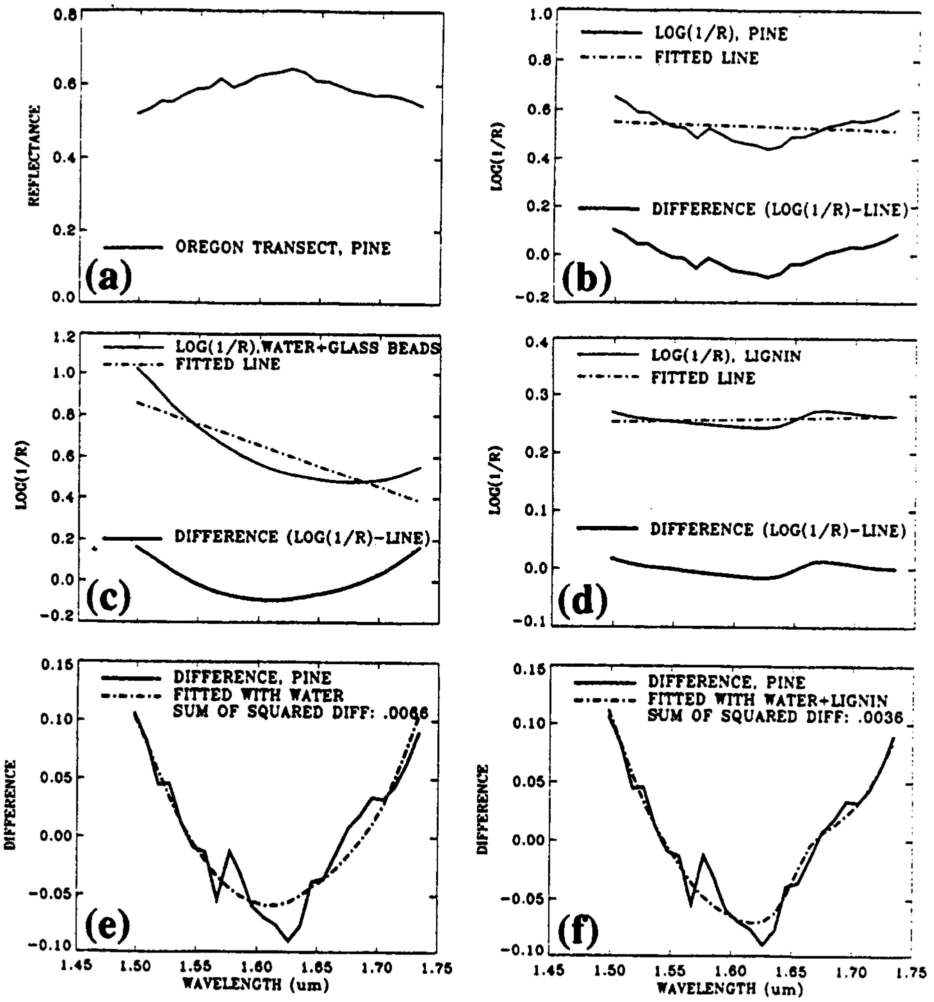

Fig. 1. Illustration of the linear least squares spectral matching technique. See text for details.

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