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P. 3

OREGON TRANSECT: COMPARISON OF LEAF-LEVEL REFLECTANCE WITH CANOPY-LEVEL AND MODELLED REFLECTANCE

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1. INTRODUCTION

The Oregon Transect Ecosystem Research (OTTER) project involves the collection of a variety of remotely-sensed and in-situ measurements for characterization of forest biophysical and biochemical parameters. The project includes nine study plots located along an environmental gradient in west-central Oregon, extending from the Pacific coast inland approximately 300km. These plots represent a broad range in ecosystem structure and function. Within the OTTER project, the sensitivity of the AVIRIS signal to absorption by foliar biochemicals is being examined (*Johnson and Peterson, 1991*). AVIRIS data were acquired over all plots in conjunction with four OTTER Multi-sensor Aircraft Campaigns spanning the growing season. Foliage samples were gathered during each campaign for biochemical determination (at Ames Research Center), to estimate stand-level constituency at each plot.

Directional-hemispheric leaf reflectance throughout the 400-2400nm region was measured in the laboratory as an aid to interpreting concurrent AVIRIS data. Obtaining leaf spectra in this manner reduces or eliminates the confounding influences of atmosphere, canopy architecture, and reflectance by woody components, understory, and exposed soils which are present in airborne observations. These laboratory spectra were compared to simulated spectra derived by inverting the PROSPECT leaf-level radiative-transfer model (*Jacquemoud and Baret, 1990*), and to canopy reflectance derived from AVIRIS data by use of the LOWTRAN-7 (*Kneizys et al., 1989*) atmospheric radiative-transfer model.

2. LEAF REFLECTANCE MEASUREMENT

Five foliage samples were collected by shotgun or pruning pole from mid-to-upper canopy at each of four OTTER plots in early June, 1991. Red alder (*Alnus rubra*), a broadleaf, was collected at one plot; the other plots contained western hemlock (*Tsuga heterophylla*), a conifer. Each sample was divided into two sub-samples, one for biochemical analysis and another for spectral analysis.

The biochemistry sub-samples were maintained in a frozen state until analysis. These samples were assayed by wet chemical techniques for total nitrogen, total phosphorus, total chlorophyll, amino acids, sugar and starch. Specific leaf area (cm^2 leaf area/g dry wt) was also measured.

Each spectral sub-sample was immediately inserted into an airtight transparent plastic bag along with a moist paper towel. These bags were grouped and placed inside a black bag to shield from light exposure, and refrigerated for a period of 10-14 days.

Reflectance measurement (bandwidth 6 nm, sampling interval 2 nm) was performed on a Perkin-Elmer 330 spectrophotometer (Norwalk CT), resident at Ames Research Center. For each conifer sample, several needles attached to twig were placed in the instrument sample holder, and scanned. For the broadleaf samples, one entire leaf without woody material was scanned. Calibration standards were used to convert raw channel response into absolute reflectance and to verify accuracy of spectral response to within $\pm 2\text{nm}$.

3. LEAF REFLECTANCE VS. SIMULATED REFLECTANCE

The PROSPECT model simulates leaf reflectance (and transmittance) in the 400-2400nm region as a function of chlorophyll concentration ($\mu\text{g}/\text{cm}^2$) and water content (equivalent water thickness). The model was inverted to estimate chlorophyll concentration by fitting to the diffuse leaf reflectance component of each measured spectrum. Predictions from inversions with low root mean square error between the simulated and measured spectra were significantly (.01 level) correlated with assay values ($r=0.93$, $n=6$, $se=4.2 \mu\text{g}/\text{cm}^2$). Measured reflectance was consistently lower than modelled reflectance in the 1500-1800nm region, possibly as a result of biochemical absorption, with the largest residuals occurring between 1690 and 1710nm.

4. LEAF REFLECTANCE VS. CANOPY REFLECTANCE

The LOWTRAN-7 code was used to convert AVIRIS at-sensor radiance acquired 22-May-91 into canopy reflectance. Total atmospheric optical depth at each plot at or near the time of AVIRIS overflight was measured by sun-photometer. These

optical depths were used to estimate horizontal visibility by fitting to LOWTRAN-calculated total transmittance throughout the 400-1000nm range (Green, 1990). Using this visibility, the Continuum Interpolated Band Ratio technique (Carrere et al., 1990) was then applied to the 940nm absorption feature to estimate water vapor abundance. Subsequently, canopy reflectance (ρ) was retrieved from at-sensor radiance (after Green, 1990) by:

$$\rho = (L_r/L_{r\alpha})\alpha \quad (1)$$

where L_r is the net canopy-reflected radiance in the AVIRIS signal, and $L_{r\alpha}$ is the modelled radiance reflected from a surface with albedo α for the given solar zenith and surface elevation.

These spectra were compared with the mean leaf spectra at each site. The canopy spectra are similar in shape to the measured leaf spectra for both broadleaf and conifer. The degree of similarity increases with greater leaf-area-index (LAI), as background exerts less influence on the signal. Conifer leaf reflectance exceeds canopy reflectance by a factor of two along the NIR plateau, and by a factor of three in the shortwave IR. Less disparity is observed in the alder, where leaf reflectance exceeds canopy reflectance by a factor of less than two along the NIR plateau, and by a factor of two in the shortwave IR. AVIRIS reflectance spectra from canopies with high LAI will be used to test an adaptation of the PROSPECT model to canopy level simulation.

5. REFERENCES

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