# Determination of Foliar Chemistry from Airborne Imaging Spectrometer Data for Canopy Stress Assessment

**C. Banninger**

Institute for Image Processing and Computer Graphics
Joanneum Research, Graz, Austria

Abstract

Spectral absorption bands in the shortwave infrared spectral region (1100-2500 nm) related to foliar biochemical constituents can provide information on the state of health and vitality of plant communities. Canopy lignin and nitrogen content of Norway spruce needles show a weak to fair correlation to changes in the depth of their corresponding absorption features in Airborne Imaging Spectrometer (AIS-2) data acquired from a metal-stressed Norway spruce forest. The presence of a multiplicity of absorption bands related to a variety of foliar biochemical substances and scene, sensor, and atmospheric noise contamination of the AIS-2 canopy spectra hinder the extraction of pertinent biochemical information useful for forest damage assessment.

## 1. INTRODUCTION

The measurement of plant absorption features related to essential biochemical constituents can be used to determine their abundance in a plant's foliage and thereby provide information on the state of health and vitality of a plant canopy. Absorption bands associated with foliar cellulose, lignin, starch, and protein occur within the shortwave infrared region between 1100 - 2500 nm and can be resolved by high spectral resolution sensor systems, such as the NASA-JPL Airborne Imaging Spectrometer (AIS-2) described in Table 1. Previous studies have identified specific absorption features corresponding to lignin and protein whose depth or magnitude have been related to the concentration of these substances in tree foliage. However, the close proximity and overlapping nature of the various biochemical absorption features result in a mixing of the information content contained within them and a consequent diffusing of the relationship between specific biochemical substances and their corresponding absorption bands. Unmixing models are currently being explored as a means to separate the different biochemical components comprising an absorption feature, but the complexity of a plant's biochemical make up and its resultant spectral absorptance characteristics may preclude more than generalised and simplified models being developed in the near future. Until more refined models are available, an approach that combines the information content of all contributing foliar biochemical substances in an absorption band is being examined for use as an indicator of plant health and vitality, as, in general, changes in the concentration of these substances due to stress conditions occur sympathetically.

## 2. DATA COLLECTION, PROCESSING, AND ANALYSIS

Canopy lignin and nitrogen (a major component of protein) contents of a metal-stressed Norway spruce forest situated in southeastern Austria were derived from needles collected from trees at 50-m grid intervals over the test site. These point source data were then transformed to respective isopleth maps covering the entire study area. AIS-2 data of the forest canopy acquired in July 1986 were log residually transformed (Green and Craig, 1985) to remove scene, solar irradiance, and atmospheric effects before the extraction of canopy spectra from 20 x 20 m ground sample areas situated along several transects that crossed the test site. A continuum removal procedure (Clark and Roush, 1984) was applied to the log residual data to help clarify and enhance the definition of the absorption features related to lignin and protein. The depth of these features at 1185, 1450, 1685, 1920, 2140 and 2270 nm for lignin and 1155, 1510, 1725, 2060, 2180, and 2300 nm for protein were correlated with point-weighted averages of canopy lignin and nitrogen concentrations derived from their respective isopleth maps for corresponding spectra sampling areas. For absorption features representing the influence of adjacent and overlapping lignin and protein absorptance bands at 1155 and

TABLE 1
AIS-2 SENSOR SYSTEM

| | |
|---|---|
| Number of Bands: | 128 (contiguous) |
| Spectral Sampling Interval: | 10.5 nm |
| Nominal Spectral Resolution: | 21 nm |
| Spectral Range: | 809–2523 nm |
| Tree Mode Range: | 809–2143 nm |
| Rock Mode Range: | 1184–2523 nm |
| Detector Array Size: | 64 × 64 elements |
| Flying Height: | 5000 m (a.g.l.) |
| Nominal Pixel Size: | 10 m (nadir) |
| Nominal Swath Width: | 640 m |
| Radiometric Range: | 12 bits (summation to 16 bits) |

TABLE 2
CORRELATION BETWEEN COMBINED NEEDLE LIGNIN AND PROTEIN (NITROGEN) CONTENT AND AIS-2 ABSORPTION BANDS

| n = 34 | 1155/1185 nm | 1450/1510 nm | 1685/1725 nm | 2140/2180 nm | 2270/2300 nm |
|---|---|---|---|---|---|
| Lignin-Nitrogen Needle Content | 0.54 (***) | 0.37 (**) | 0.35 (**) | 0.31 (*) | 0.42 (***) |

Level of Significance: * $0.90 < p \leq 0.95$
** $0.95 < p \leq 0.98$
*** $p > 0.98$

1185 nm, 1450 and 1510 nm, 1685 and 1725 nm, 2140 and 2180 nm, and 2270 and 2300 nm, the combined canopy concentrations of these two constituents were used in the regression analysis.

## 3. RESULTS AND CONCLUSIONS

Compared to the result of a previous study (Banninger, 1989), in which canopy lignin and protein concentrations were correlated individually with their respective AIS-2 absorption bands, the use of combined lignin and protein canopy concentrations resulted in an improvement in the relationships derived between the depth of the absorption features and the canopy content of the responsible biochemical constituents. The correlation values derived for these relationships are given in Table 2.

These improvements, though significant, still fail to explain more than approximately 30 per cent of the variance in the depth of the absorption features vis-a-vis canopy lignin and protein content. The presence of scene, solar irradiance, and atmospheric effects not removed in the log residual

process contribute a noise component to the AIS-2 data that can mask and distort the biochemical information content of the absorption features. Most biochemical features in the spectra are also complex in nature and subtle in appearance and are composed of numerous overlapping absorption bands related to several biochemical compounds in addition to lignin and protein (such as cellulose, starch, and sugar), which serve to diffuse the influence of any individual biochemical compound on the configuration of the cumulative absorption features comprising the various individual absorption bands.

## ACKNOWLEDGMENTS

I thank Dr. John Aber of Complex Systems Research Center in Durham, New Hampshire, for undertaking the lignin and nitrogen analysis of the spruce needle samples.

## REFERENCES

Banninger, C, 1989, "Mapping Stress-Related Biochemical Changes in Coniferous Forests with Airborne Imaging Spectrometer (AIS-2) Data", *Proc. 9th EARSeL Symposium,* Espoo, Finland, pp. 512-518.

Clark, R.N. and Roush, T.L., 1984, "Reflectance Spectroscopy: Quantitative Analysis Techniques for Remote Sensing Applications", *J. Geophys. Res.,* Vol. 89, No. B7, pp. 6329-6340.

Green, A.A. and Craig, M.D., 1985, "Analysis of Aircraft Spectrometer Data with Logarithmic Residuals", *Proc. 1st Airborne Imaging Spectrometer Workshop*, NASA Jet Propulsion Laboratory, Pasadena, California, pp. 111-119.