MEASURING NEAR INFRARED SPECTRAL REFLECTANCE CHANGES FROM WATER STRESSED CONIFER STANDS WITH AIS-2

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ABSTRACT

AIS-2 data was acquired over two paired conifer stands in West Germany for the purpose of detecting differences in spectral reflectance between stressed and natural canopies. Water stress was induced in a stand of Norway spruce near Munich and white pine near Frankfurt by severing the sapwood near the ground. Water stress during the AIS flights was evaluated through shoot water potential and relative water content, measurements. Preliminary analysis with raw AIS-2 data using SPAM indicates that there were small, inconsistent differences in absolute spectral reflectance in the near infrared .97-1.3um between the stressed and natural canopies.

INTRODUCTION

Recent theory and laboratory results have suggested that an increase in near infrared leaf reflectance occurs as leaf water content decreases with increasing plant water stress (Ripple 1986). Additionally, some theories have related leaf water stress to canopy air pollution damage (Rock et al. 1986). This study was designed to test the ability of the AIS-2 to discriminate an induced water stress in two pairs of conifer stands as part of a larger project in West Germany studying remote sensing of air pollution damage to the Black Forest. The paired plot study design was produced by inducing stress on half of the study plot leaving the remaining half as control. This experimental design allowed a rigorous comparison of reflectance differences with variables such as tree species and age, canopy illumination, sun-angle, sensor angle and atmospheric effects all equal, hence eliminating them from the comparative analysis.

BACKGROUND WATER RELATIONS

Ecologically significant measures of the water status of vegetation are leaf water potential and relative water content (RWC). Leaf water potential is a measure of the energy status of water in plant tissue and RWC is a measure of water content in the leaf tissues relative to that occuring at saturation water content. Water stress in plants is measured as a decrease in leaf water potential from 0 bars and as a decrease in RWC from 100%. Leaf water potential is easily measured on a conifer shoot with a pressure chamber apparatus in the field (e.g. Ritchie and Hinckley, 1975), expressed as a pressure (-bars). RWC is calculated as (fresh wt-dry wt)/(saturation wt-dry wt) and expressed as a percentage.

METHODS & STUDY SITES

Water stress can be rapidly induced, in one hour to one day depending on tree size, by severing the stem sapwood through which water flows from the roots to the canopy. Complete severing of the sapwood causes a rapid increase in the level of leaf water stress which is then maintained until the death of the tree 30 or more days later (Brix and Mitchell, 1985; Running, 1980).

The study was located at two sites in West Germany with the aid of our German colleagues who located and made available the forest stands, arranged for the cutting of the trees and assisted in the collection of field data. A 50x50m plot of trees was stressed by either girdling of the sapwood or complete severing of the trunk.

One stand was of Norway spruce located near Munich and the other was a plantation of white pine in the Frankfurt Forest. The Norway spruce were approximately 30m in height and about 60cm in diameter, with a closed canopy and 5-10 cm ring of sapwood. Girdling was done with chainsaws on 2 July with the AIS flight occurring 13 days later on 15 July.

The Frankfurt Forest site was prepared with a much greater physical effort. The white pine stand was a high density plantation approximately 7m in height, and 15-20cm in diameter, most of which was sapwood. For this reason the trees were completely severed by cutting the trunk about 1m above ground and strapping trunks upright with steel banding to the stumps. Severing of the 2400 trees was begun 2 July and was completed 7 July. AIS flights were 15 and 21 days after severing of the Frankfurt plot.

Shoot water potentials were collected during or the day after AIS-2 overflights to measure the difference in stress between cut trees and adjacent uncut trees (Table 1). Shoot water potentials were related to relative water content so that an estimate of RWC near the time of AIS flight could be made (Fig. 1).

Table 1. Water stress measurments taken at the time of AIS flights. Shoot water potentials are averages of 5-7 measurements, and RWC the average from 5 samples.

	Days after cutting	Shoot water potential (bars)	RWC (%)
Munich			
Girdled trees	13	-21.0	86
Control trees	13	-9.1	91
Frankfurt			
Severed trees	16	-19.5	79
Control trees	16	-13.3	89

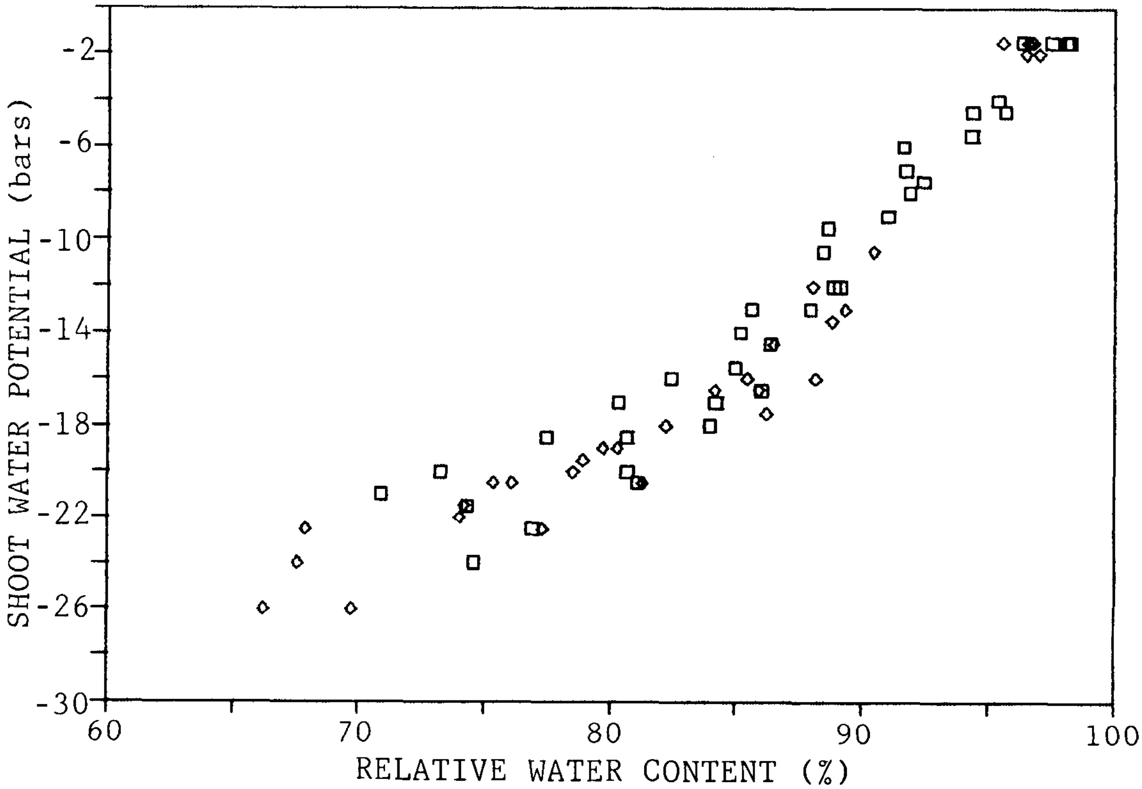


Fig. 1. Relationship between shoot water potential and RWC for **severed (□) and control (◇) white pines on the Frankfurt** site. Measurements from 5 samples of each treatment collected the day after AIS-2 flight.

AIS DATA ANALYSIS

AIS data was collected in "tree mode" 0.8-2.2um with an approximate ground pixel size of 6.5m. In "tree mode" the usable range of AIS data ends at approximately 1.6um due to second order light contamination. Analyisis of AIS data was begun using the Spectral Analysis Manager (SPAM) at JPL. Quality of AIS data was very good and the raw data, without normalizations or atmospheric corrections, was used.

SPAM was used to plot average spectral curves for stressed and control trees, constructed from 5 to 7 pixels selected from a plot.

RESULTS AND DISCUSSION

Spectral plots of the white pine at Frankfurt taken 21 days after severing show a slightly higher reflectance from the control trees compared to the severed trees in the 0.97-1.3um region, contradicting expected patterns (Fig. 2). When a log residual normalization to remove common atmospheric effects was done, spectral separation was improved across the spectrum. Spectral plots of the Norway spruce, Munich site, were obtained from two AIS flights at approximately 1030hr and 1330hr 13 days after girdling of the trees. For the 1030hr flight (Fig. 3) the girdled trees had greater reflectance than the

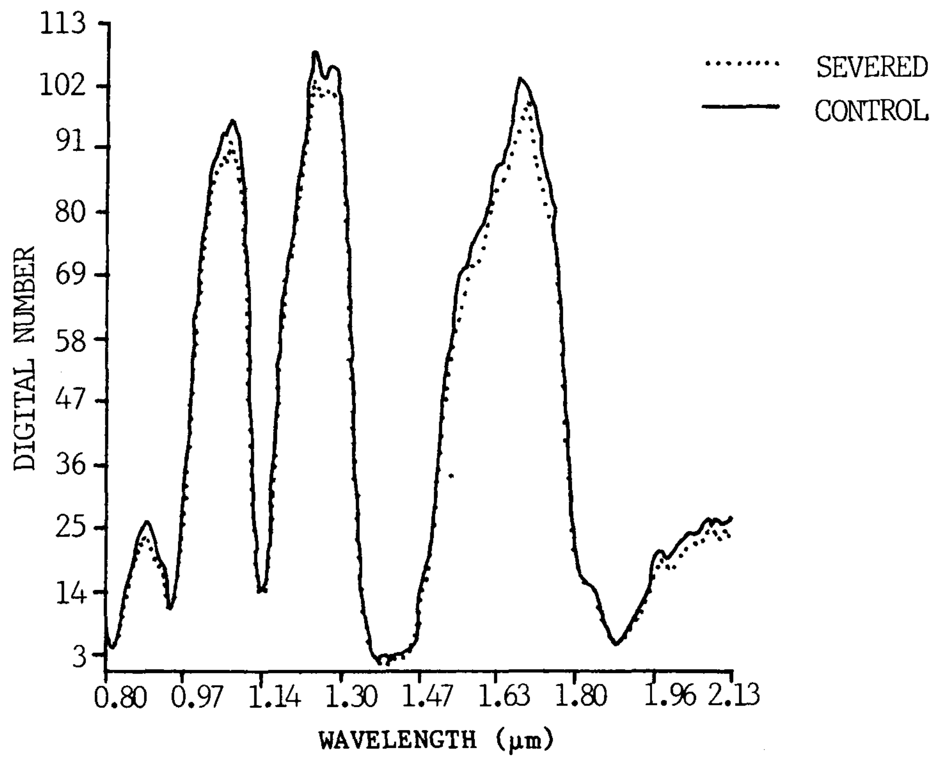
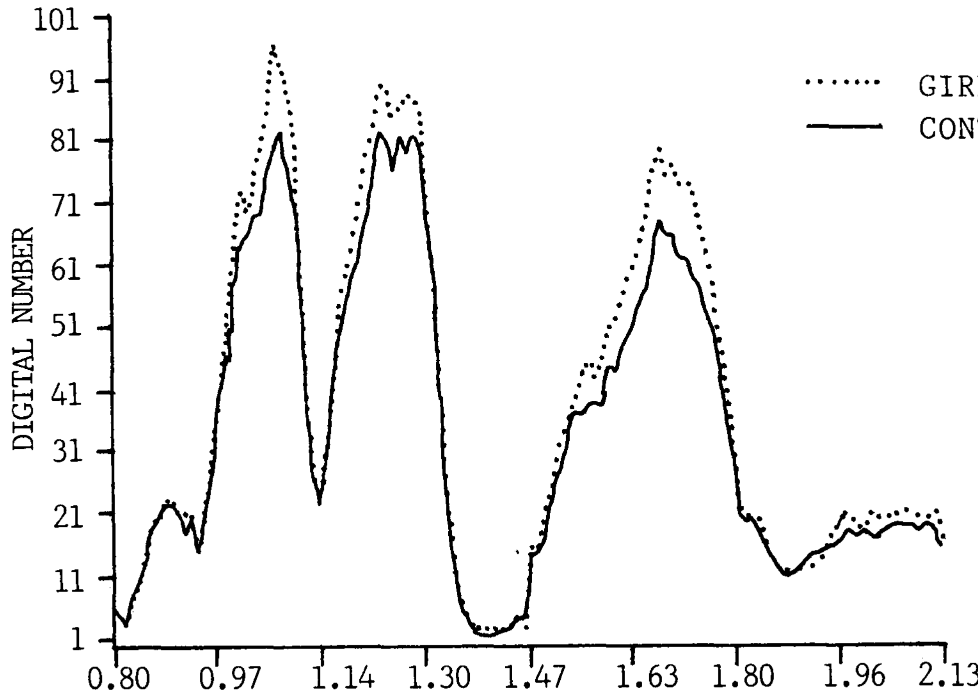


Fig. 2. Spectral reflectance of severed and control white pines at the Frankfurt site from AIS flight 21 days after severing. Estimated difference of 6 bars in shoot water potential and 10% absolute difference in RWC between severed and control trees.

control trees at the peaks of reflectance in the infrared. The difference in shoot water potential at that time was 12 bars, and 5% in RWC. However, for the 1330hr overflight reflectance from the girdled canopies was lower than that from the control, a reversal of reflectance differences seen for the 1030hr flight. The difference in shoot water potential at this time was 7 bars, and 4% in RWC.

SUMMARY

Anaylsis of raw AIS-2 data to date has found small differences in the amplitude of reflectance in the near infrared region, .97-1.3um, between stressed and control canopies. For white pine, reflectance from the stressed canopy was slightly lower than the control canopy. For Norway spruce, control canopy reflectance was greater than the stressed canopy in the morning, but this relationship was reversed in the early afternoon. At this time our results do not consistently support the current hypothesis that near infrared reflectance increases with leaf water stress. We will next analyze the NS001 TM simulator data and the TIMS data to attempt to find consistency in the spectral response of these canopies to the induced water stress.



WAVELENGTH (µm)

Fig. 3. Spectral reflectance of girdled and control Norway spruce at the Munich site from morning AIS flight 13 days after girdling. A difference of 12 bars in shoot water potential between girdled and control trees was measured in the field at time of overflight.

ACKNOWLEDGMENTS

We thank Barry Rock for his support and assistance in this research. Funding for this research was provided for by the NASA Graduate Student Researchers Program and NASA Grant #NAGW 829. Special thanks to our German colleagues; Georg Kritikos, Barbara Koch, Manfred Schramm and Martin Lamberty for their efforts in making available the study sites and assistance in the field.

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