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Inflight Calibration of AVIRIS in 1992 and 1993

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Abstract

In order to pursue the quantitative research objective of AVIRIS, the spectral, radiometric characteristic of the sensor must be known at the time of flight data acquisition. AVIRIS is rigorously calibrated in the laboratory. In addition, three times each year these characteristics of AVIRIS are validated through an inflight calibration experiment. Absolute radiometric calibration and signal-to-noise results are present for the inflight calibration experiment orchestrated in 1992 and 1993.

1.0 Introduction

AVIRIS was developed to pursue quantitative research of the Earth's terrestrial surface and atmosphere from calibrated geometrically coherent spectroradiometric measurements. In contrast to a broadband sensor, an imaging spectrometer resolves the molecular absorption and particle scattering signatures of surface and atmospheric constituents. From imaging spectrometer measurements, constituents are unambiguously identified and the abundance is determined. As an example of AVIRIS data, the combined spectral and spatial characteristics of AVIRIS are shown in Slide 10 with an image acquired over Moffett Field including the southern part of the San Francisco Bay, California.

To achieve the quantitative research objectives of the AVIRIS sensor, the calibration of AVIRIS must be valid while AVIRIS is acquiring data from the NASA ER-2 aircraft. The operational environment inside the Q-bay of the ER-2 at 20 km altitude differs from that in the AVIRIS laboratory in temperature, pressure, vibration and high frequency electromagnetic fields. AVIRIS is calibrated in the laboratory prior to each flight season (Chrien, 1990). To validate, characterize and monitor the calibration and performance of AVIRIS in the flight environment, inflight reflectance-based calibration experiments using ground targets are routinely carried out at the beginning, middle and end of each flight season (Conel et al., 1988; Green et al., 1988; Green et al., 1990; Green et al., 1992). The AVIRIS results for inflight calibration experiments in 1992 and 1993 are presented in this paper.

2.0 AVIRIS Inflight Calibration Experiment

At the beginning of the 1992 and 1993 operational periods, inflight calibration experiments were held at Rogers Dry Lake, California. At the time of the AVIRIS overflight the surface reflectance and atmosphere properties were measured with field instruments for a calibration target on the homogeneous dry lake bed. The surface reflectance of this target was characterized with 20 measurements of a specific 200 m by 40 m area on the lake bed. The resulting standard deviation of the mean of these measurements for the calibration target is less than 0.5 percent reflectance across this spectral interval. The reflectance of the calibration target measured in 1992 is given in Figure 1.

To characterize the atmosphere, solar irradiance measurements were acquired with a stable solar radiometer (Bruegge et al., 1990) from sunrise through local solar noon in ten discrete spectral channels in the range from 370 to 1050 nm. Data from nine of these channels were used to estimate the atmospheric optical depth by the Langley technique at the time of the AVIRIS overflight. Data from the channel centered at 940 nm of this radiometer were used to estimate the total column water vapor during the AVIRIS data acquisition (Reagan et al., 1987; Bruegge et al., 1990).

The surface reflectance, optical depth and water vapor determination were used to constrain the MODTRAN radiative transfer code (Berk et al., 1989). The MODTRAN code predicted radiance spectrum at the AVIRIS aperture is compared with AVIRIS sensor reported radiance. This sensor reported radiance is traced to the laboratory irradiance lamp and onboard calibrator (Green, 1993).

MODTRAN has been modified to allow: 1) inclusion of the measured surface reflectance, 2) constraint of the MODTRAN atmospheric models with the measured optical depths, and 3) direct constraint of MODTRAN with the measured water vapor amount. In addition, an updated high spectral resolution solar irradiance spectrum (Green and Gao, 1993) has been incorporated in the modified MODTRAN code.

3.0 Radiometric Calibration

The MODTRAN predicted radiance and AVIRIS measured radiance spectra for the experiment held on the 30th of May 1992 is given in Figure 2. The mean absolute agreement excluding the regions of strong atmospheric absorption is 6.9 percent. Results for the experiment held on the 18th of May 1993 are given in Figure 3. An agreement of 5.2 percent was achieved.

This disagreement at the 5 to 7 percent level between the predicted and measured radiance may be attributable to at least three sources of error. First, systematic error in the field measurements and their reduction may be present. Second, the MODTRAN calculation of upwelling radiance may contain some error. Third, some change in performance of AVIRIS is likely from the laboratory to flight environment, and finally, the laboratory irradiance and model solar irradiance standard may disagree at some level.

4.0 Spectral Calibration

Through analysis of the atmospheric absorption bands measured in the AVIRIS spectrum, the inflight spectral calibration of AVIRIS may be determined (Green et al., 1988; Green et al., 1990). This analysis has been carried out for the calibration experiments on 30th of May and 9th of October 1992. For the 30th of May, the four AVIRIS spectrometers showed a better than 1 nm agreement between the laboratory spectral calibration and the inflight determination. On the 9th of October however, a –2.4 nm shift in the B spectrometer spectral calibration was measured. This shift is likely related to the fiber to spectrometer connection. In 1993 an improved connector was installed for all AVIRIS spectrometers. It is recommended that the spectral calibration of the B spectrometer be shifted –2.4 nm if required for the proposed data analysis. It is worth noting that AVIRIS was originally designed to a spectral accuracy of 5 nm.

For the 18 May 1993 inflight calibration experiment the spectral calibration in all four spectrometers was determined to agree with the laboratory measurements at better than 0.5 nm.

5.0 AVIRIS Data Precision

For these experiments in 1992 and 1993 the inflight precision was determined based on variation in the signal from a homogeneous portion of Rogers Dry Lake. This precision is presented as signal-to-noise in Figure 4. These signal-to-noise plots have been scaled to the AVIRIS reference radiance (Green et al., 1988) to allow direct comparison. In Figure 5 the precision is presented for 1992 and 1993 as noise equivalent delta radiance. In each of these years AVIRIS vastly exceeded the original signal-to-noise requirement for the sensor.

6.0 Conclusion

In 1992 and 1993 the calibration of AVIRIS was validated for the sensor inflight through a series of field experiments. Based on these experiments, the absolute radiometric calibration of AVIRIS is shown to be approaching 5 percent. In 1992 a spectral shift of -2.4 nm has been identified and is easily corrected by shifting the B spectrometer spectral calibration. In 1993 the inflight spectral calibration is found to correspond to the laboratory determination. Plans are under development to push the radiometric calibration of AVIRIS to 2 percent and spectral calibration to 0.1 nm. The current and planned quality of radiometric and spectral calibration is required for the quantitative algorithms being proposed and tested with AVIRIS data.

7.0 ACKNOWLEDGMENTS

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8.0 REFERENCES

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9.0 FIGURES

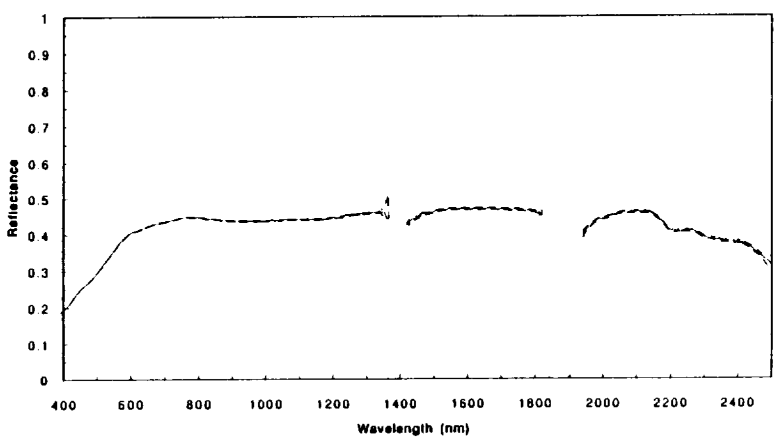

Figure 1. Field measured reflectance and uncertainty for the calibration target on Rogers Dry Lake, California on May 30 1992.

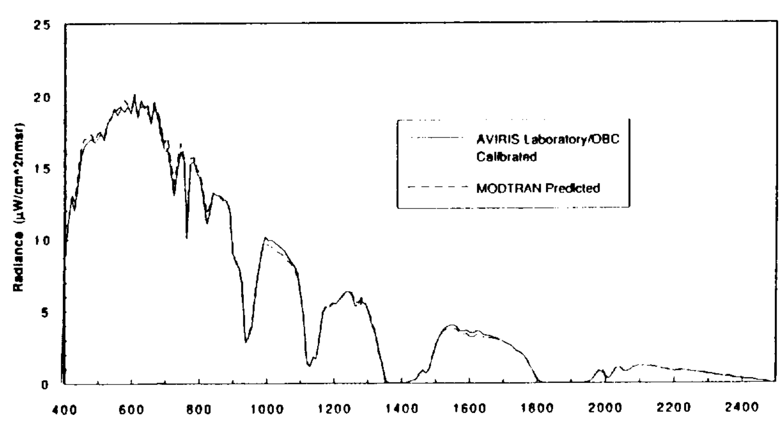

Figure 2. Comparison of the MODTRAN-predicted and AVIRIS-measured radiance for the inflight calibration experiment held on the 30th of May 1992.

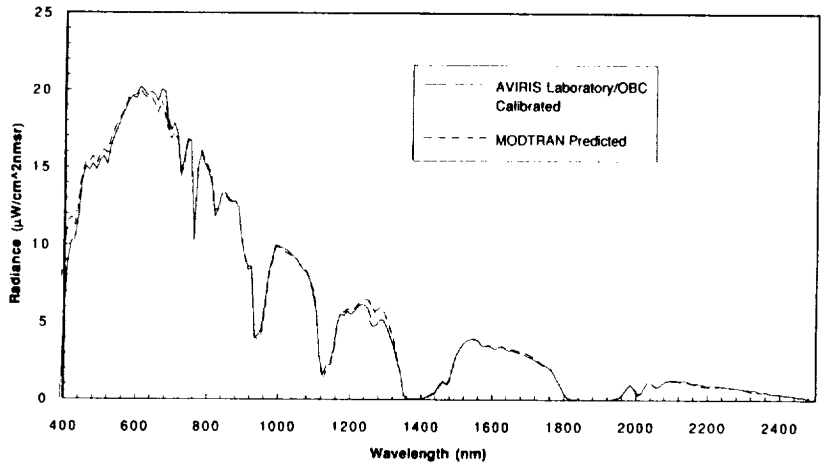

Figure 3. AVIRIS-measured and MODTRAN-predicted radiance for the Rogers Dry Lake inflight calibration experiment of the 18th of May 1993.

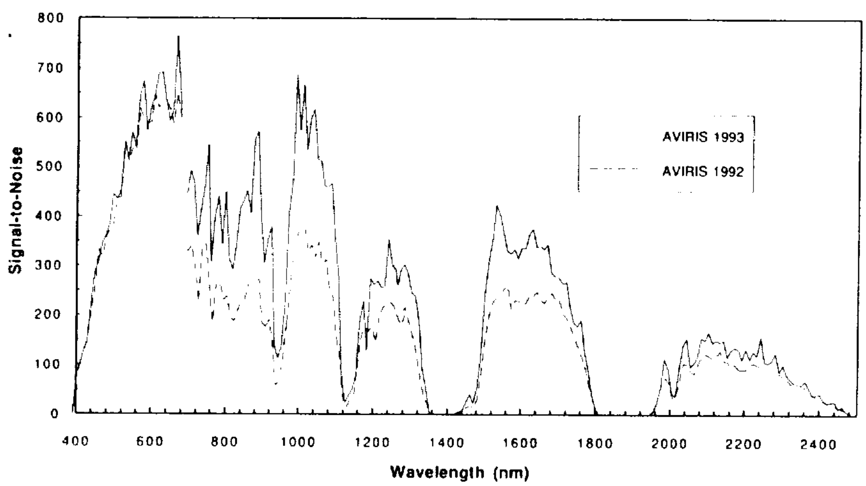

Figure 4. Inflight signal-to-noise for 1992 and 1993.

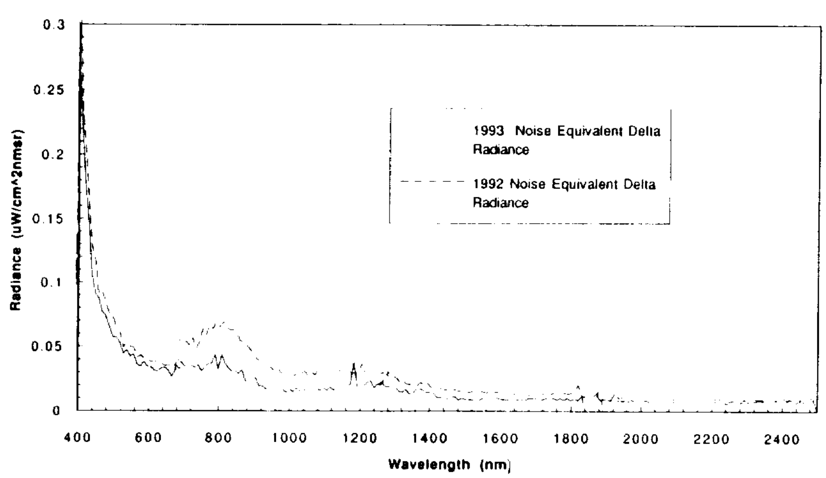

Figure 5. 1992 and 1993 inflight noise equivalent delta radiance.

10.0 SLIDE

Slide 10. AVIRIS color image cube of Moffett Field, California. The top panel is a color composite of three of the 224 AVIRIS spectral channels. The side panels portray the 224 spectral measurements acquired for each spatial sample.