IN-FLIGHT RADIOMETRIC CALIBRATION OF AVIRIS IN 1994

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1. INTRODUCTION

The AVIRIS sensor must be calibrated at the time it measures spectra from the ER-2 airborne platform in order to achieve research and application objectives that are both quantitative and physically based. AVIRIS is radiometrically calibrated in the laboratory prior to each flight season (Chrien, 1990). However, the operational environment inside the Q-bay of the ER-2 at 20 km altitude differs from that in the AVIRIS laboratory with respect to temperature, pressure, vibration and high-frequency electromagnetic fields. Experiments at surface calibration targets are used in each flight season to confirm the accuracy of AVIRIS in-flight radiometric calibrations (Conel et al., 1988; Green et al., 1988, 1990, 1992, 1993). For these experiments, the MODTRAN radiative transfer code (Berk et al., 1989) is constrained by using in situ measurements to independently predict the upwelling spectral radiance arriving at AVIRIS for a specific calibration target. AVIRIS calibration is validated in flight by comparing the MODTRAN-predicted radiance to the laboratory-calibrated radiance measured by the AVIRIS sensor for the same time over the calibration target. In this paper, we present radiometric calibration results for the AVIRIS in-flight calibration experiment held at the beginning of the 1994 flight season.

2. IN-FLIGHT CALIBRATION EXPERIMENT

On April 5, 1994 an in-flight calibration experiment was held at Lunar Lake, Nevada located 130 km east of Tonopah at 38.38 degrees north latitude and 115.98 degrees west longitude. Lunar Lake is a small dry lake approximately 3 km in diameter at 1600 m elevation. This dry lake was selected because it is one of the highest dry lakes in North America. The high elevation assures an atmosphere that is straightforward to model, with less water vapor and aerosols than lower sites.

On a portion of the dry lake surface, a calibration target was designated for comparison of the MODTRAN-predicted radiance to the AVIRIS-measured radiance. This target was 40 by 200 m in dimension, with the long axes parallel and in the center of the AVIRIS flight line. In the half hour preceding and following the AVIRIS data acquisition, the surface spectral reflectance was measured using a field spectrometer that covers the AVIRIS spectral range. A total of 40 measurements were acquired; these were evenly spaced over the target and averaged to determine the calibration target spectral reflectance (Figure 1).

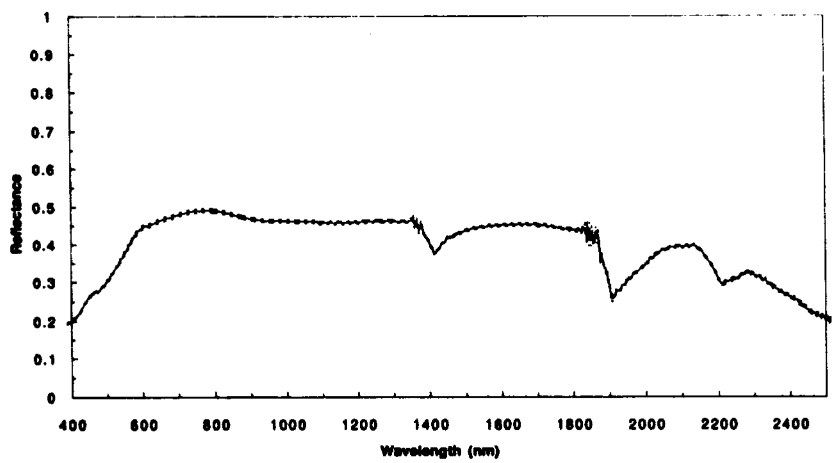

Figure 1. Average calibration target spectral reflectance ± 1 standard deviation.

At the calibration target solar radiometer, measurements were acquired from sunrise through local solar noon with a solar radiometer that measures 10 discrete spectral channels in the range from 370 to 1050 nm. These data were reduced with the Langley technique to generate atmospheric optical depths for the calibration target. The optical depths were used to select the midlatitude summer atmospheric model and adjust the visibility to 250 km in MODTRAN. With these constraints the MODTRAN atmospheric model optical depths agreed closely with the measured optical depths (Figure 2). Data from the radiometer channel centered at 940 NM were analyzed to derive the total column water vapor (Reagan et al., 1987, Bruegge et al., 1990). A value of 4.9 ± 0.2 precipitable mm was determined and used to constrain the water vapor profile in MODTRAN. MODTRAN was run with the spectral surface reflectance, optical depth and water vapor determined to predict the upwelling spectral radiance at the time of the AVIRIS over flight of the target at 18:10 UTC (Figure 3). An updated exo-atmospheric solar irradiance spectrum (Green and Gao, 1993) was used in MODTRAN. The MODTRAN-predicted radiance and AVIRIS spectral resolution were convolved and compared to the AVIRIS laboratory calibrated radiance for the calibration target (Figure 4). An absolute average agreement across the spectral range was 95.3 percent, excluding the regions of near-zero radiance at 1400 and 1900 nm.

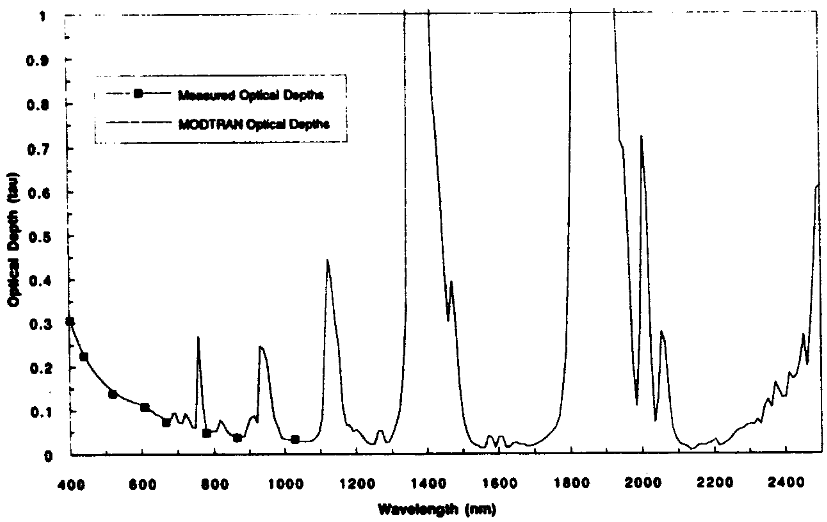

Fig. 2. Measured discrete optical depths with the MODTRAN spectral optical depths for the calibration experiment atmosphere.

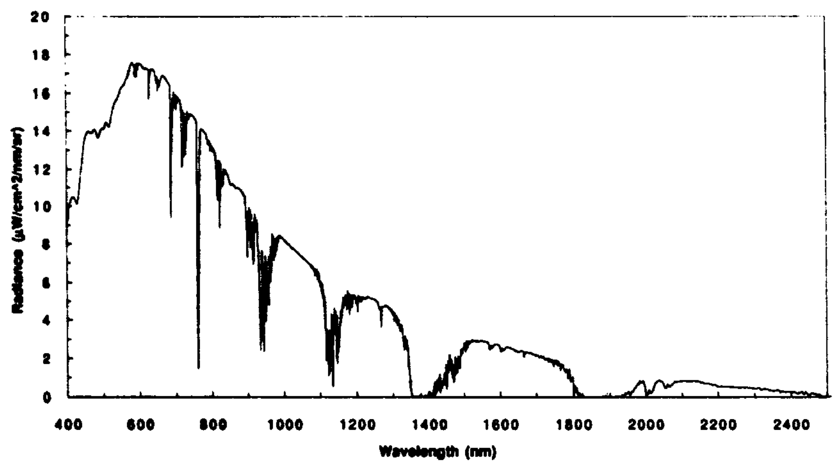

Fig. 3. MODTRAN-predicted radiance for the calibration target at the time of AVIRIS over flight.

AVIRIS in-flight radiometric precision (signal-to-noise ratio) was also determined with data from this calibration experiment. Noise was estimated as the standard deviation of the dark spectra measured at the end of each image line. An uncalibrated AVIRIS signal was taken from the Lunar Lake calibration target. This signal was scaled to the AVIRIS reference radiance (Green et al., 1988) and divided by the noise to give the AVIRIS in-flight signal-to-noise ratio for 1994, compared to that of 1993 (Figure 5). In 1994, the signal-to-noise ratio in the 400- to 600-nm spectral region is shown to be significantly improved due to the installation of a new focal plane in the first spectrometer. AVIRIS continues to show exceptionally high in-flight signal-to-noise performance across the spectral range. This performance is expected to further improve with installation of new focal planes for the 1995 flight season.

3. RADIOMETRIC CALIBRATION ERROR DISCUSSION

The residual 4.7-percent disagreement in radiometric calibration shown between the AVIRIS laboratory-calibrated radiance and MODTRAN-predicted radiance for the calibration target is attributed to several sources: 1) AVIRIS laboratory standard and calibration procedure errors, 2) errors in the in situ measurements and data reduction and, 3) imprecision in the MODTRAN model and calculation of upwelling spectral radiance.

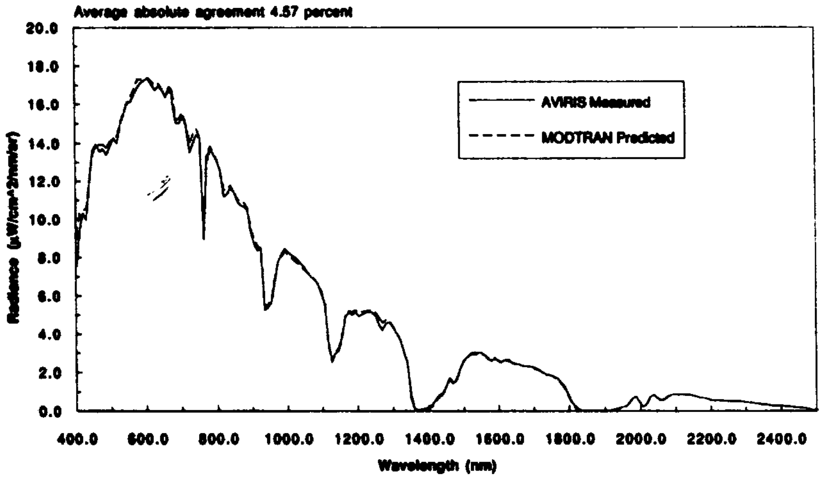

Fig. 4. Comparison of the MODTRAN-predicted radiance and AVIRIS laboratory-calibrated radiance for the Lunar Lake calibration target at 18:10 UTC on April 5, 1994.

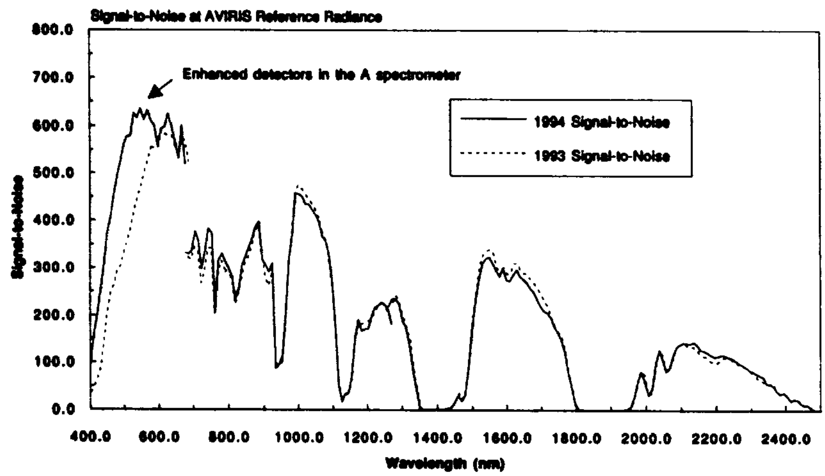

Fig. 5. AVIRIS in-flight 1994signal-to-noise ratio compared to 1993 AVIRIS reference radiance.

4. CONCLUSION

The in-flight calibration experiment at Lunar Lake, Nevada on April 5, 1994 shows 95.3-percent agreement at the calibration target between the MODTRAN-predicted radiance and AVIRIS laboratory-calibrated radiance. The 1994 in-flight signal-to-noise ratio is shown to equal the 1993 performance over most of the spectral range, and to have improved between 400 and 600 nm. The AVIRIS sensor continues to demonstrate high in-flight radiometric calibration accuracy and precision across the spectral range. This level of radiometric performance is required to achieve the physically based objectives of research and application with AVIRIS-measured spectra. Work continues on improving the radiometric calibration accuracy and precision of AVIRIS.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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