

# **Calibration to Surface Reflectance of Terrestrial Imaging Spectrometry Data: Comparison of Methods**

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Many algorithms for spectral analysis of imaging spectroscopy data of the Earth's surface require that the data be calibrated to surface reflectance. Calibration requires removing instrumental response, solar irradiance, atmospheric transmittance, and atmospheric scattering from the radiance detected at the sensor. Depending on the amount of support data, this can be a formidable task. This paper examines four methods of calibration: 1) a radiative transfer model from the University of Colorado (ATREM: Gao and Goetz, 1990; Gao *et al.*, 1992), 2) a MODTRAN-based method developed at the Jet Propulsion Lab by Green *et al.*, (1991), 3) a ground calibration using known sites as standards, and 4) a combined approach using radiative transfer methods and ground calibration. Data from the Airborne Visual and Infra-Red Imaging Spectrometer (AVIRIS) instrument were evaluated from data sets obtained over multiple years and multiple sites.

Models that rely on solar irradiance alone contain serious errors. Experience with solar irradiance problems has led to a modification of the ATREM algorithm in 1993 to empirically correct for such problems. To date, the published solar irradiance spectra have disagreements of greater than  $\pm 7\%$  at AVIRIS 1992 resolution and sampling. Unfortunately, these disagreements create spectral features of similar magnitude in calibrated spectra. Further, it is not clear which, if any, of the published solar irradiance measurements is correct. It is even possible that some of the spectral features in the solar spectrum are variable.

In general, the radiative transfer models produce good corrections of atmospheric transmission as a function of elevation throughout the scene. However, because of small errors in wavelength precision and resolution, a perfect correction will be difficult to achieve, even if the radiative transfer code predicted atmospheric transmission perfectly. Unknowns in the solar irradiance spectra add to the difficulty in achieving accurate calibration, as do errors in the instrument radiance calibration. The channel to channel variations in the radiative transfer methods limit effective signal to noise to about 30 to 60 for the current ATREM and 50 to 110 for Green's method (using 1993 data), depending on the wavelength region. Analysis of 1994 AVIRIS data, collected over Mountain Pass, California and calibrated using Green's method, show the effective signal to noise to be significantly higher. The advantage of the radiative transfer model is that it can be relatively quick computationally, and takes the least effort of the methods compared in this paper. We have also encountered conditions where the simplistic scattering treatment in the radiative transfer models was not sufficient to correct for the scattering observed in AVIRIS data.

The ground calibration method uses targets at the surface with known reflectance as standards and provides locally the best calibration to ground reflectance. Its inability to properly correct for topographic variations in atmospheric path results in elevation dependent residual atmospheric absorptions. It also requires high quality spectra (field or laboratory) of the ground sites, and 1 to 2 person-months of effort per calibration.

The hybrid method of radiative transfer model plus ground calibration produces the best overall result, providing good correction as a function of elevation, while removing artifacts from errors in the radiative models and solar spectrum. It requires the most effort.

### References

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