APPLICATION OF LOWTRAN 7 AS AN ATMOSPHERIC CORRECTION TO AIRBORNE VISIBLE/INFRARED IMAGING SPECTROMETER (AVIRIS) DATA

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ABSTRACT

Previous atmospheric correction models applied to imaging spectroscopy data have included such methods as residual or scene average, internal average relative (IAR) reflectance, flat-field correction, single spectrum, and empirical line algorithm or regression method. Basic assumptions of these methods are *a priori* knowledge of the site, the existence of a spectrally neutral area with no vegetation or sparse vegetation cover, wavelength-independent average scene reflectance, or the existence of field measurements taken at the time of image acquisition. Compensation for atmosphere using LOWTRAN 7 has the potential to overcome most of the limitations imposed by the previous methods and is a versatile simulation model that has been parameterized for a variety of conditions. The application methodology is described for a 1987 AVIRIS scene of Fish Slough, a desert wetland near Bishop, California.

DESCRIPTION OF PREVIOUS ATMOSPHERIC CORRECTION MODELS

Atmospheric correction models for imaging spectroscopy have included residual or scene average method, IAR reflectance, flat-field correction, single spectrum method, and empirical line or regression method. All remove the majority of atmospheric effects: minimizing atmospheric water vapor absorption features and compensating for the solar spectral irradiance curve.

The residual (log residual, if logarithmic variables are used) or scene average method expresses scaled reflectances in terms of image-derived quantities such that the observed radiance is equal to the product of the surface reflectance and the ratio of the scene-averaged observed radiance to the scene-averaged surface reflectance. The method assumes that the path radiance is equal to zero which may not be valid in the shorter wavelengths below 1200 nm (Conel *et al*, 1987) and may present problems with vegetated scenes where the wavelengths of interest range from the visible to the infrared. If the scene average is dominated by a particular material in the image, the resulting residual atmospheric correction will affect the scene in a multiplicative fashion.

IAR reflectance is determined by dividing each spectrum by the overall average spectrum for the whole image. Caution must be used when applying this technique as spurious features can be introduced into the converted spectra if the average spectrum contains strong absorption features related to the surface composition. Noise problems may be accentuated due to moderate vegetation cover (Kruse, 1988).

Flat-field correction relies on the existence of a neutral, homogeneous area with no absorbing minerals or vegetation, thereby assuming *a priori* knowledge of the site. The correction is applied by dividing the brightness value of each pixel in each band by the average value of the flat field in that band. The flat-field correction only removes multiplicative effects and will remove scene noise, if there is multiplicative scene noise in all channels. If noise is restricted to the flat field, noise will then be introduced into the scene. Artifacts introduced by this method include a shift in wavelength for some features (Carrere and Abrams, 1988; Rock *et al*, 1988) and changing the intensity and/or distorting other spectral bands of interest (Clark and King, 1988).

The single spectrum method requires *a priori* knowledge to select a single spectrally well-characterized ground target, situated at about the average scene elevation. The ground target spectrum is divided by the radiometrically-corrected, but otherwise uncalibrated, image digital numbers for the same area. The resulting quotients for each wavelength channel provide a set of scalars for calibrating the image. Problems include the characterization of the field calibration target, definition of the test areas for verifying the calibration results, and determination of the proper shape of the scattering curve to subtract from the image data (Crowley *et al*, 1988).

Empirical line algorithm or regression method requires two targets of contrasting and equivalent spectral resolution for which both surface reflectance and airborne spectrometer response are known. Regression plots of the reflectance versus scanner response can be used to recover ground reflectance. A source of concern is how well the field-measured reflectances represent the standard targets (Conel *et al*, 1988).

LOWTRAN OPTIONS

LOWTRAN was developed by the Air Force Geophysics Laboratory to predict transmission losses and sky backgrounds that affect the performance of electro-optical surveillance, guidance and weapons systems. LOWTRAN has been used to simulate the 1900 nm waterband (Conel *et al*, 1986) and to verify AVIRIS channels.

LOWTRAN 7 has undergone significant improvements over previous versions with modification in the code to perform multiple scattering calculations in the visible and infrared portions of the spectrum while incorporating the effects of clouds and other atmospheric aerosols (Isaacs and Vogelmann, 1988). Different profiles—tropical, midlatitude summer, midlatitude winter, subarctic summer, subarctic winter, and U.S. standard—can be combined with any of several aerosol models: urban, rural, desert (new option in LOWTRAN 7), maritime, tropospheric, or user-designated (radiosonde data).

The input parameters for the Fish Slough scene were a midlatitude summer profile with desert aerosols along with the following information in Table 1 (*Local Climatological Data, Monthly Summary, Bishop, California, July 1987*).

Table 1. Additional Input Parameters

El (km)	Air Temp (°C)	RH (%)	Wind Speed (m/sec)	Visibility (km)
1.329	35	9	8	48

LOWTRAN ATMOSPHERIC CORRECTION MODEL

Two basic assumptions of the LOWTRAN model are also explicit in the other atmospheric corrections previously discussed: a horizontally homogeneous atmosphere and a small elevation variation within the scene. However, the image may be subsectioned and the LOWTRAN atmospheric model may be reiteratively run with different input values for elevation to compensate for changes in elevation.

AVIRIS observed radiance can be expressed as

$$L_o = L_{ps} + L_g = L_{ps} + L_O t_1 \rho t_2 \tag{1}$$

or, rearranging

$$\rho = \frac{L_o - L_{ps}}{L_O t_1 t_2} \tag{2}$$

where L_o = observed radiance

L_{ps} = observed radiance due to path scattering

L_g = obs. radiance due to ground-reflected radiation

$L_\odot$ = solar radiance

t_1, t_2 = transmittance along downward, upward paths

ρ = ground reflectance

By assuming a spectrally constant reflectance (0.1, in this case), LOWTRAN can be used to model L_{ps} and L_g for the assumed reflectance. Substituting back into Eq. 2, we get

$$\rho = \frac{L_o - L_{ps}}{\left[\frac{L_g}{0.1}\right]} = \frac{0.1}{L_g}\left[L_o - L_{ps}\right] \tag{3}$$

where L_g is now the ground reflected radiance, assuming 0.1 reflectance. Ground reflectance (ρ) values can then be computed on a channel-by-channel basis using Eq. 3.

CONCLUSIONS

Application of LOWTRAN 7 as an atmospheric correction to AVIRIS data has the potential to overcome most of the limitations imposed by previous methods. It eliminates the need for *a priori* knowledge of the scene to identify spectrally neutral areas with no absorption features in their spectra and eliminates the need for target ground measurements taken at the time of the image acquisition. In addition, LOWTRAN 7 can compensate for multiple scattering, is parameterized for a variety of atmospheric profiles, and has the option of specifying a user-designated input model (*e.g.*, substituting radiosonde data for ground climatological data). The atmospheric correction is useful for both vegetated and geologic scenes.

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