Radiometric Correction of Remotely Sensed Data

Douglas A. Stow

Department of Geography

San Diego State University

Introduction and Background

Radiometric correction of remotely sensed data normally involves the processing of digital images to improve the fidelity of the brightness value magnitudes (as opposed to geometric correction which involves improving the fidelity of relative spatial or absolute locational aspects of image brightness values). The main purpose for applying radiometric corrections is to reduce the influence of errors or inconsistencies in image brightness values that may limit one's ability to interpret or quantitatively process and analyze digital remotely sensed images. Throughout this section, radiometric errors and inconsistencies will be referred to as "noise", which could be considered any undesirable spatial or temporal variations in image brightness not associated with variations in the imaged surface.

The sources of radiometric noise and therefore, the appropriate types of radiometric corrections, partially depend on the sensor and mode of imaging used to capture the digital image data. Five general types of imaging systems and/or modes are utilized for generating digital remotely sensed data, each having their own characteristic sources of radiometric noise: (1) scanned aerial photography, (2) optical scanners, 3) optical linear arrays, (4) optical framing arrays, (5) scanning microwave radiometers, and (6) side-looking radars. (The emphasis of this section will be on radiometric correction of the more frequently utilized optical imaging systems.) Radiometric noise generated by remote sensing instruments can take the form of random brightness deviations from electrical sources and coherent radiation interactions or more systematic variations that have spatial structure or temporal persistence.

Sensor-related effects are not the only sources of radiometric noise. Other sources are spatial and/or temporal variations in illumination quantity and quality, atmospheric optical properties, terrain, and surface properties. Again, these variable environmental factors should only be considered "noise" when they obscure or reduce image brightness signals pertaining to surface cover types and conditions.

There are five primary reasons or objectives for applying radiometric corrections to digital remotely sensed data; four of which pertain to achieving consistency in relative image brightness and one involving absolute quantification of brightness values. Relative correspondence of image brightness magnitudes may be desired for pixels: (1) within a single image (e.g., orbit segment or image frame), (2) between images (e.g. adjacent, overlapping frames), (3) between spectral band images, and (4) between image dates. The key here is that brightness value inconsistencies caused by the sensor and environmental noise factors listed above are balanced or "normalized" across and between image coverage and spectral bands. The other principal objective is the retrieval of surface energy properties such as spectral reflectance, albedo or surface temperature, which requires absolute radiometric processing.

Reflectance Factor Retrieval

A majority of remote observations of earth surface forms and processes are based on digital images captured from airborne or satellite platforms by optical imaging systems operating in the solar reflective portion of the electromagnetic spectrum. The basis for extracting information on earth surface objects, types, quantities or patterns is the variation of surface reflectance, usually in more than one spectral band. However, other factors can influence the amount of radiance captured and recorded by a remote sensing instrument besides the reflectance properties of earth surface materials. These factors include:

In addition to artifacts and uncertainties due to environmental effects on radiation transfer are the effects of the sensor and it's mode of sampling. Even when the same instrument is used, the earth-platform-sensor geometry relationship is different for each data acquisition. The resultant data are spatially autocorrelated because of optical diffraction and the scanning process. Atmospheric scattering also produces an adjacency effect that is a source of spatial autocorrelation in the image data (Singh, 1988).

The other type of requisite image transformation is radiometric pre-processing, meaning that remotely sensed digital brightness values must be calibrated and/or converted so as to improve the relative spectral and temporal fidelity of the data. The essential first step is to radiometrically calibrate digital brightness values by converting them into spectral radiances (Robinove, 1982). Such calibration is based on published calibration coefficients derived from pre-launch laboratory calibration and post-launch empirical corrections. Radiometric calibration serves to normalize spectral radiances between wavebands of the same image and between images, if the calibration coefficients are temporally stable or updated.

The most important requirement of radiometric correction is to ensure that changes in spectral radiances for corresponding pixels of a multi-temporal image sequence are proportional to actual changes in spectral reflectance of the surface (Nelson, 1985). Differences in atmospheric optical properties and solar illumination between image dates influences the need to model their transient effects. More approximate, empirically-based models may reduce these effects through scene normalization, but radiation transfer models offer a more precise, deterministic approach.

Scene normalization models are based on empirically matching multi-temporal images based on scene features, e.g., features with stable reflectances such as rock outcrops or persistent shadows, (Chavez, 1988; Laureau, 1991; Pech et al., 1986; Schott et al., 1988). A particularly promising example of this type of modeling is the "radiometric registration" approach developed by Hall et al., (1991). In an attempt to normalize atmospheric and illumination differences between seasonal Landsat TM images of chaparral and pine-oak forest in southern California, Stow et al. (1993) radiometrically "registered" an image data from a April, 1987 scene to a scene acquired in November, 1986 image using the Hall et al. (1991) method (Figure 3). TM brightness values for both dates were converted to "Brightness" (BR), "Greenness" (GR) and "Wetness" (WT) based on the "Tasseled-cap" transform (Crist and Cicone, 1984). Dark and bright control sets (pixel samples) were selected from BR-GR plots and used to develop a linear fit equation for normalizing TM spectral radiances for April,1987 relative to TM spectral radiances for November, 1986. This enabled seasonal changes in BR, GR and WT to be derived in an attempt to infer seasonal changes in fire fuels amount and condition (which is further described in a later section).

Multi-date satellite data may also be normalized through more deterministic approaches that attempt to derive reflectance factors of land surfaces (Duggin, 1980; Moran et al., 1990). Reflectance factors are approximations of surface reflectances, (and therefore, should be temporally stable), that are based on an assumption of isotropically reflecting surfaces. Such approaches are based on radiative transfer modeling of solar illumination and atmospheric effects (Spanner et al., 1990). In the typically irregular terrain of many Mediterranean-type landscapes, the differential illumination effects from variable terrain slope facets should also be modeled, based on a digital elevation model (Holben and Justice, 1979). The greatest error and uncertainty in deriving reflectance factors results from the atmospheric modeling component. Particularly problematic is the lack of concurrent data on atmospheric constituent concentrations and their horizontal and vertical distributions (Caselles and Garcia, 1989).