Modeling and Estimation of Sediment Density from Hyperspectral BRDF

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Abstract:

The angular dependence of sand and sediment reflectance, as characterized by the bi-directional reflectance distribution function (BRDF), provides a mechanism for observing and modeling the effects of density in reflectance data. Density effects in granular materials have been described in radiative transfer models and are known, for example, to influence the size of the opposition effect (Hapke, 1993; 2012). In some instances, such as in the description of the coherent backscatter opposition effect, explicit models for wavelength dependence have also been derived (Akkermans et al, 1986; Hapke, 2012).

In the models developed by Hapke (Hapke 1993; 2012), density appears indirectly through a "porosity factor," that varies as a nonlinear function of the actual porosity and also depends on other factors such as the grain size distribution and typical shape of the grains. The porosity factor appears in both single scattering and multiple scattering terms in the derived solutions, and the nonlinear dependencies and interactions of sands and other sediments with other physical variables in the landscape, such as moisture and surface roughness, further complicate the analysis.

In past work (Bachmann, Gray, Abelev, Philpot, et al, SPIE 2012), we have shown that density effects expressed in hyperspectral BRDF data are consistent in laboratory goniometer data, field goniometer measurements with the NRL Goniometer for Portable Hyperspectral Earth Reflectance (GOPHER), and airborne hyperspectral imagery. However,

in coastal sands the relative change in reflectance as sand density varies depends on its composite nature, which especially influences the multiple-scattering pathways (Bachmann, Philpot, Abelev, Korwan, submitted to Rem. Sens. Envir.). As a result, in this past study, we observed that the specific types of constituents, which depend on coastal type, influence whether reflectance actually increases or decreases with increasing density.

This paper examines field hyperspectral goniometer data and its potential utility for retrieving sand and sediment density from airborne hyperspectral imagery. Analysis and comparisons include laboratory studies, as well as field observations of hyperspectral BRDF with GOPHER and coordinated airborne hyperspectral data collected at the Virginia Coast Reserve (VCR) Long Term Ecological Research (LTER) site (Virginia Coast Reserve LTER, available online), and in Queensland, Australia, form the basis of the study. During coordinated field studies, in order to relate BRDF data to the retrieval of geophysical variables such as relative density, coincident geotechnical data recorded at each BRDF sample location included important physical variables that impact BRDF, such as density, grain size distribution, and moisture content, among others. Our laboratory studies (Bachmann, Gray, Abelev, Philpot, et al, SPIE 2012; Bachmann, Philpot, Abelev, Korwan, submitted to Rem. Sens. Envir.) have been based on samples derived from the VCR LTER and several earlier experiments (Bachmann, Nichols, Montes, Fusina, et al, 2010). These studies provide complementary data in which single variables, such as density, can be isolated and varied independently of other physical variables that effect BRDF. Control of single variables in the laboratory aids in the interpretation of data measured in the field.

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