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Title: ESTIMATING NONLINEAR MIXING EFFECTS FOR ARID VEGETATION SCENES WITH MISR CHANNELS AND OBSERVATION DIRECTIONS

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Estimating Nonlinear Mixing Effects for Arid Vegetation Scenes with MISR Channels and Observation Directions

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Abstract - A Monte-Carlo ray-trace model has been applied to simulated sparse vegetation desert canopies in an effort to quantify the spectral mixing (both linear and nonlinear) occurring as a result of radiative interactions between vegetation and soil. This work is of interest as NASA is preparing to launch new instruments such as MISR and MODIS. MISR will observe each ground pixel from nine different directions in three visible channels and one near-infrared channel. It is desired to study angular variations in spectral mixing by quantifying the amount of nonlinear spectral mixing occurring in the MISR observing directions.

INTRODUCTION

Optical remote sensing of vegetation is an important process for a wide variety of modern applications. Vegetation covers a large fraction of the surface of the Earth and thus plays a major role in the exchange of energy and mass between the Earth's surface and the atmosphere. Satellite remote sensing is the ideal method in which to observe the condition of vegetation and to quantify changes in vegetation cover. These types of results can be difficult to generate when significant amounts of nonlinear spectral mixing is occurring. Nonlinear spectral mixing is the result of photons interacting with multiple materials in the scene before reaching the instrument. Linear mixing occurs when photons interact with single materials within a scene. Nonlinear mixing is significant in sparse vegetation scenes [1] because the often exposed soil can be a dominant factor in remote sensing measurements. Linear mixing is desirable since post-processing of data can make use of relatively simple linear techniques. No suitable analysis techniques are widely applicable when significant nonlinear mixing is present.

The near future will see a large increase in the number of space-born remote sensing instruments. The NASA EOS program will soon launch the AM-1 satellite which is a platform for both MISR [2] and MODIS, among others. These two instruments are special in that they will make observations in a range spectral channels and multiple viewing directions. It is desired to understand the degree to which the observing angle can affect the amount of nonlinear mixing occurring within sparse vegetation scenes. The results presented in this article quantify nonlinear mixing as a function of wavelength, observation zenith and azimuth angles, solar zenith angle, and plant leaf area index (LAI).

MODEL DESCRIPTION

A Monte-Carlo ray trace model appropriate for studying vegetation scenes has been developed. Vegetation scenes are defined at the leaf level using basic geometric shapes as leaf elements. Rays undergo reflection and transmission events with leaf elements and reflection events with the soil surface. The leaf and soil elements are modelled as a combination of both specular and lambertian reflectors. Many models do not account for the specular reflection component from leaves which has been shown to be important [3].

The nonlinear mixing occurring within a scene is measured by tracking the reflection and transmission histories of the individual rays as they interact with the scene elements. Each ray will interact with either a single element or multiple elements. This information is calculated for each ray and after tracing a large number of rays, the end result is the nonlinear fraction for the entire scene. The nonlinear fraction (NLF) is defined as the fraction of measured radiation which has undergone nonlinear mixing. A value of 0.0 for NLF implies that no radiation underwent nonlinear mixing (completely linear), while NLF = 1.0 implies complete nonlinear mixing. The precise value of NLF varies with scene content, vegetation/soil properties, and viewing and illumination directions.

Vegetation optical and architectural properties were obtained from measurements made at the Jornada LTER desert shrubland site in southern New Mexico [4][5]. This information was used to recreate a typical Jornada scene. The shrubs were Prosopis Glandulosa (Mesquite) which ranged in size from under a meter in diameter to over three meters. The shrub LAI was on the order of 2.0 and the mean leaf zenith angle was found to be near 45 deg with a uniform azimuthal distribution. Figure 1 shows a view of a portion of the model scene in the near-infrared. Notice that the ground surface on the sunlight side of the shrubs is brighter than the surroundings because of multiple reflections from the leaves. The large bushes in the image are approximately three meters in diameter while the smallest are half a meter in diameter. The vegetation covers 3.5% of the ground when viewed from nadir.

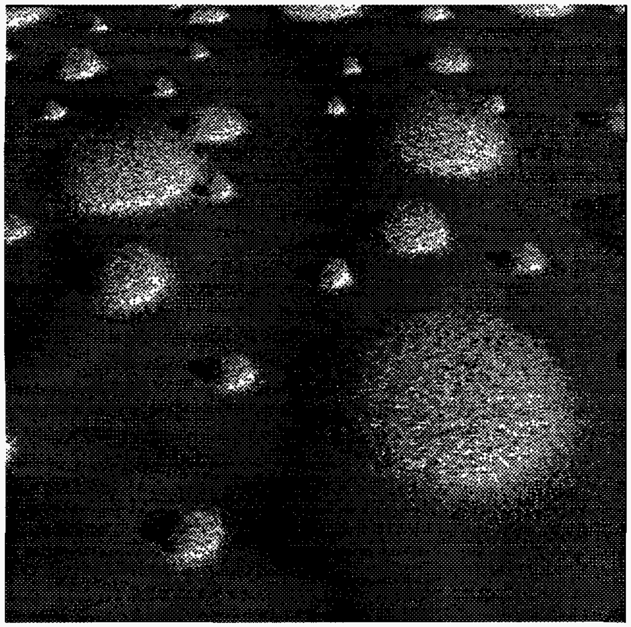

Figure 1. Vegetation scene ray traced in the near infrared.

RESULTS

This scene was studied for a range of solar zenith angles (0, 20 and 40 deg). For each of these illumination angles, the NLF was calculated for the entire hemisphere of viewing zenith and azimuth angles. These calculations were repeated for LAI = 1 and 2. This does not imply that the scene LAI was either 1 or 2, but only the plants individually. The actual scene LAI scales with the plant cover, giving 0.34 and 0.68 for the average scene LAIs. NLF results are shown in Figure 2 as polar contour plots. The radial coordinate corresponds to the viewing zenith angle while the angular coordinate corresponds to the viewing azimuth angle. The principal plane is a horizontal line bisecting the contour plots and the solar radiation is incident on the right hand portion of this line. The spacing between contours is 0.05 for LAI = 1 and 0.10 for LAI = 2.

The most obvious feature to notice in these results is the strong decrease in nonlinear mixing in the hot-spot retro-reflection direction. This occurs as a result of seeing only directly illuminated leaves and few shaded leaves. Shade is a product of both leaf transmissivity and leaf or ground reflectivity and is therefore a nonlinear mixing phenomenon.

The general effect of changes in solar zenith angle is to cause a slight increase in the NLF, especially in the hot spot region. For example, in the visible case with LAI = 1, the minimum NLF in the hotspot region ranges from 5% with θ_o = 0 deg up to 10% with θ_o = 40 deg. The limb region shows a lower sensitivity to solar angle with NLF values close to 10% at all solar angles. Similar trends are observed with LAI = 2 and in the NIR.

For LAI equal to 1 the changes in NLF between the VIS and NIR were minimal. For each of the three solar angles, the NLF directional distributions are very similar for the two spectral channels. While leaves reflect and transmit much more strongly in the NIR versus the VIS, this overall sensitivity is not unexpected since the plants are not very dense with LAI = 1. Under these conditions it is less likely for a photon to interact with multiple leaves, even in the NIR, thus resulting in the NLF insensitivity to wavelength.

The relationship between NLF and wavelength changes when the LAI is increased from 1 to 2. Figure 2 now shows that there is significantly more nonlinear mixing occurring in the NIR versus the VIS. With LAI = 2, the NLF in each contour plot in the VIS ranges from 0.06 to 0.18, while in the NIR it ranges from 0.10 to 0.20. This trend is of course due to the increased number of scattering events taking place within the shrub canopies. A similar result for nadir viewing of vegetation has been noted by others [6].

CONCLUSIONS

The fraction of nonlinear mixing has been calculated for a range of conditions of an inhomogeneous vegetation canopy. Nonlinear mixing has been shown to be invariant with wavelength for sparse canopy conditions (LAI = 1), but to be quite sensitive to wavelength with an increase in vegetation density (LAI = 2). The least amount of mixing occurs in the hotspot direction, which could possibly make this direction more desirable for making measurements when nonlinear spectral mixing is a concern.

REFERENCES

[1] Ray, T., B. Murray, "Nonlinear Spectral Mixing in Desert Vegetation," *Rem. Sens. Env.*, Vol. 55, pp. 59 - 64, 1996.

[2] Diner, D., et al, "MISR: A Multiangle Imaging Spectro-Radiometer for Geophysical and Climatological Research from EOS," *IEEE Trans. Geosci. and Rem. Sense.*, Vol. 2, pp. 200 - 214, 1989.

[3] Brakke, T., "Specular and Diffuse Components of Radiation Scattered by Leaves," *Agri. and Forest Meteo.*, Vol. 71, pp. 283 - 295, 1993.

[4] Asner, G., "Biophysical and Biochemical Sources of Variability in Canopy Reflectance," *Rem. Sens. Env.*, In Press.

[5] Asner, G., University of Colorado, Personal Communication, February, 1998.

[6] Myneni, R., et al, "Optical Remote Sensing of Vegetation: Modeling, Caveats, and Algorithms," *Rem. Sens. Env.*, Vol. 51, pp. 169 - 188, 1995.

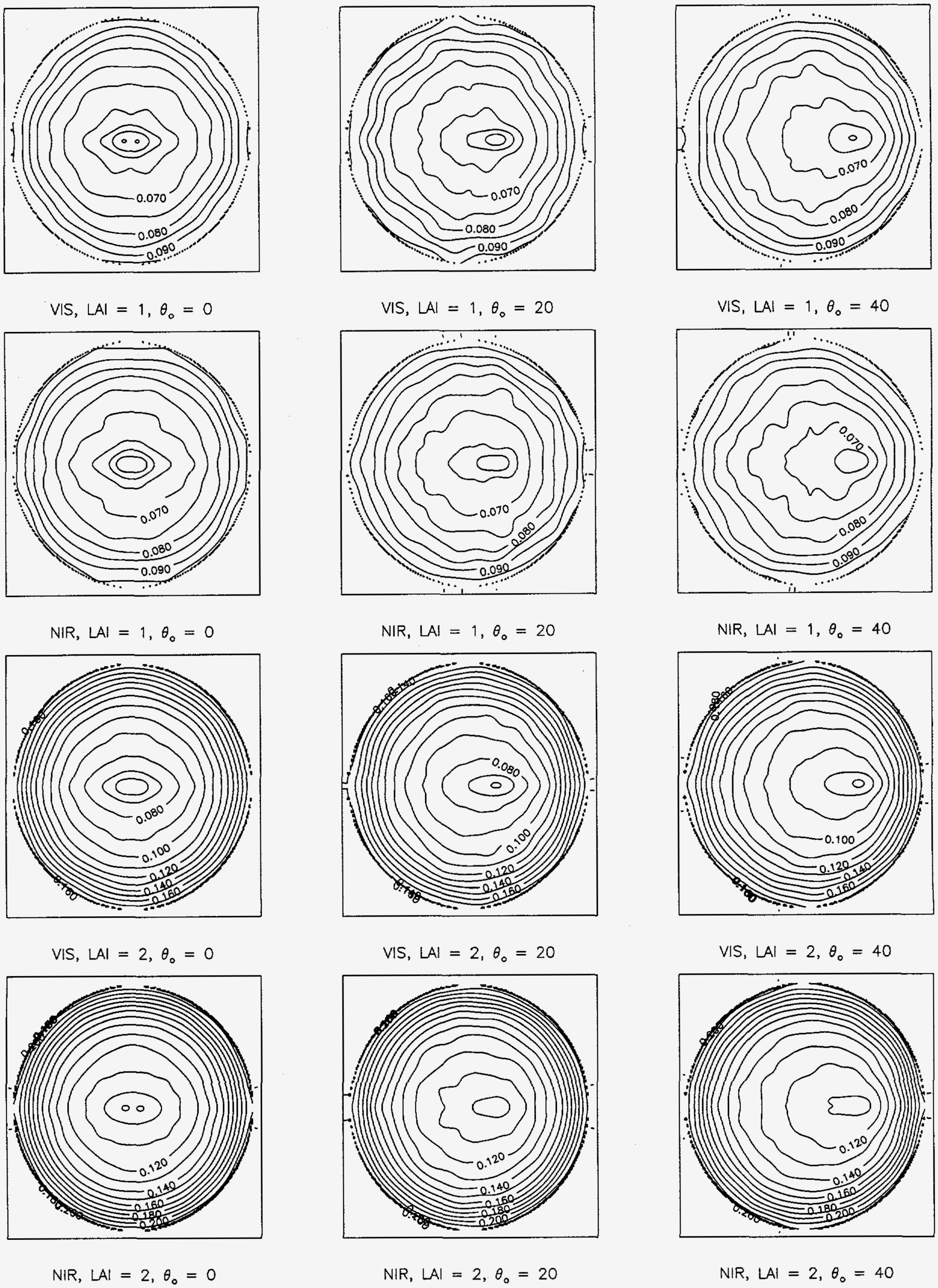

Figure 2. Directional nonlinear spectral mixing fraction as a function of wavelength, leaf area index, and solar zenith angle.