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THE CHARACTERIZATION OF SURFACE VARIEGATION EFFECTS ON REMOTE SENSING

William A. Pearce
EG&G Washington Analytical Services Center, Inc.
5000 Philadelphia Way
Lanham, Maryland 20706

Improvements in remote sensing capabilities hinge very directly upon attaining an understanding of the physical processes contributing to the measurements. In order to devise new measurement strategies and to learn better techniques for processing remotely gathered data, we need to understand and to characterize the complex radiative interactions of the atmosphere-surface system. In particular, it is important to understand the role of atmospheric structure, ground reflectance inhomogeneity and ground bidirectional reflectance type. Our goals, then, are to model, analyze, and parameterize the observable effects of three dimensional atmospheric structure and composition and two dimensional variations in ground albedo and bidirectional reflectance.

To achieve these goals, we employ a Monte Carlo radiative transfer code to model and analyze the effects of many of the complications which are present in nature. We can, for example, treat finite clouds as well as vertical atmospheric structure. We can model the effects of two dimensional structure in ground albedo and directional reflectance. We can examine alternate data acquisition strategies perhaps involving variations in detector viewing direction, solar illumination direction, or polarization sensitivity. Most importantly, for the purposes of analysis and characterization, we can divide the detected radiance into components. The radiance transmitted directly through the atmosphere from the ground to the detector is the component which carries the most significant information about the character of the surface. The radiance arising solely from atmospheric scattering is a term which, in effect, should be subtracted from the data as it has no bearing on the surface character. Lastly, there is a ground diffuse component comprised of radiation which, having scattered from the ground, is atmospherically scattered prior to detection. This last term is responsible for non-local adjacency effects. Its influence on the data usually may be described by an atmospheric spread function.

Specifically, the objectives of the present study are to investigate the sensitivity of the radiance components and the atmospheric spread function to: variations in the vertical aerosol profile; variations in the aerosol size distribution (and, hence, its scattering distribution); variations in the detector look direction and solar illumination direction; variations in ground reflectance type and bidirectional reflectivity; the presence of clouds in the vicinity of the point of view.

RESULTS

As the modal radius of the atmospheric aerosol size distribution increases, the associated scattering phase function is enhanced both in the forward and backward directions. For remote sensing, it is the changes in the forward scattering peak which are more important. Our simulations show significant sensitivity in the inner regions of the spread function (within 250 meters of the point of view). Figure 1 illustrates this, showing the atmospheric modulation transfer function, or MTF (the Fourier transform of the atmospheric line spread function) for three log-normal size distributions with modal radii of 0.13, 0.26, and 1.04 micrometers (bottom curve, middle curve, and top curve, respectively).

For Lambertian ground reflectance, there is relatively little sensitivity to detector nadir angle for nadir angles less than about 40 degrees. For larger nadir angles, however, the atmospheric line spread function becomes asymmetric and depends upon the illumination angle. Figure 2 shows the atmospheric line spread function for a detector nadir angle of 50 degrees (detector pointing roughly into the sun), while the dashed curve is for 180 degree receiver azimuth. The solar zenith angle for both cases is 47 degrees. The line spread function here is computed from the gradient of the intensity in a scan across a fixed albedo boundary. The asymmetry is due primarily to the forward-backward asymmetry of the aerosol scattering phase function.

Variations in the form of the vertical aerosol density profile tend to scale the range of the atmospheric spread function. This scaling appears to be roughly linear in the average aerosol altitude.

Clouds in the vicinity of the point of view can influence the detected radiance. In particular, the shadow of a cloud produces much the same intensity gradient when scanning across its edge as is obtained for a high contrast ground albedo boundary. Figure 3 shows a detailed comparison of the radiance components for two cases. The solid lines show (from top to bottom on the right side of the figure) total radiance, ground direct radiance and atmospheric radiance as detected from nadir while scanning across a Lambertian albedo boundary (albedos 0.4 and 0.07). The symbols correspond to a similar scan across a cloud shadow boundary (the ground albedo is 0.4, the solar zenith angle is 47 degrees, and the altitude of the cloud top is 7 km.). The pluses indicate total radiance; the solid squares show the ground direct radiance; the open squares show the ground diffuse component; and the crosses mark the atmospheric radiance. Here, the atmospheric component varies because the cloud shades the scattering atmosphere as well as the ground. The ground direct radiance varies less abruptly on the dark side of the shadow due to cloud transparency and translucence. The overall effect for the two cases is remarkably similar even though the components contributing to the total behave rather differently. Note that the range of the effect of the shadow on the detected intensity is significantly large.

SIGNIFICANCE AND FUTURE WORK

Our simulations have shown that the form of the aerosol scattering phase function is an important determinant of the atmospheric spread function. For nadir observation, the central peak of the spread function is primarily affected. For observations well away from nadir, the spread function can become asymmetric even though ground reflectance is Lambertian. The shape of the spread function is not very sensitive to the vertical profile of the aerosol. We have found that the shadows of high, dense clouds produce changes in the total detected radiance quite similar in range and magnitude with those associated with a high contrast ground albedo boundary. The radiance components, however, are not so similar.

The next major variable to be studied is the sensitivity of observed radiances to variations in ground bidirectional reflectance and to two-dimentional patterns of varying reflectance type. We wish especially to understand to what extent variations in bidirectional reflectance can be used to improve classification and identification of surface areas. We wish to study the utility of polarization sensitive detectors. We will extend our study of the effects of clouds, looking both at high thin clouds and at the detailed effects associated with low thick clouds.

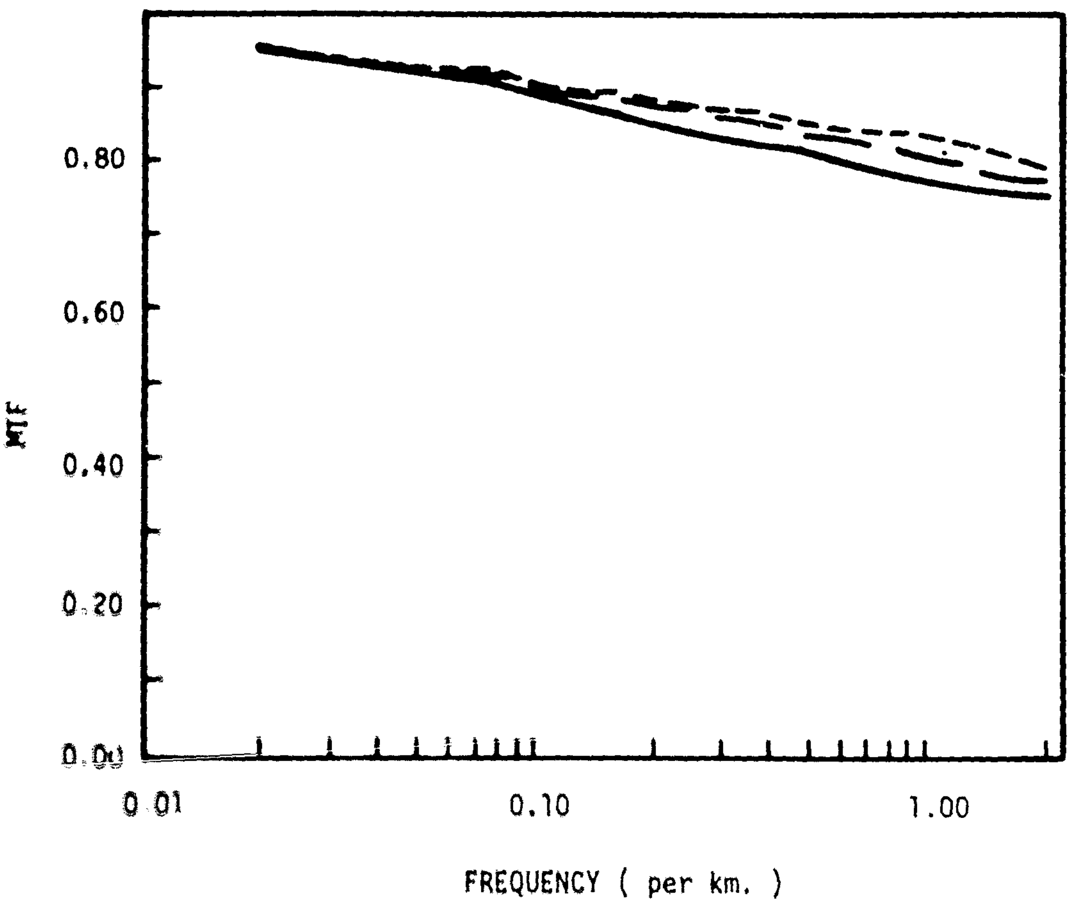


FIGURE 1.

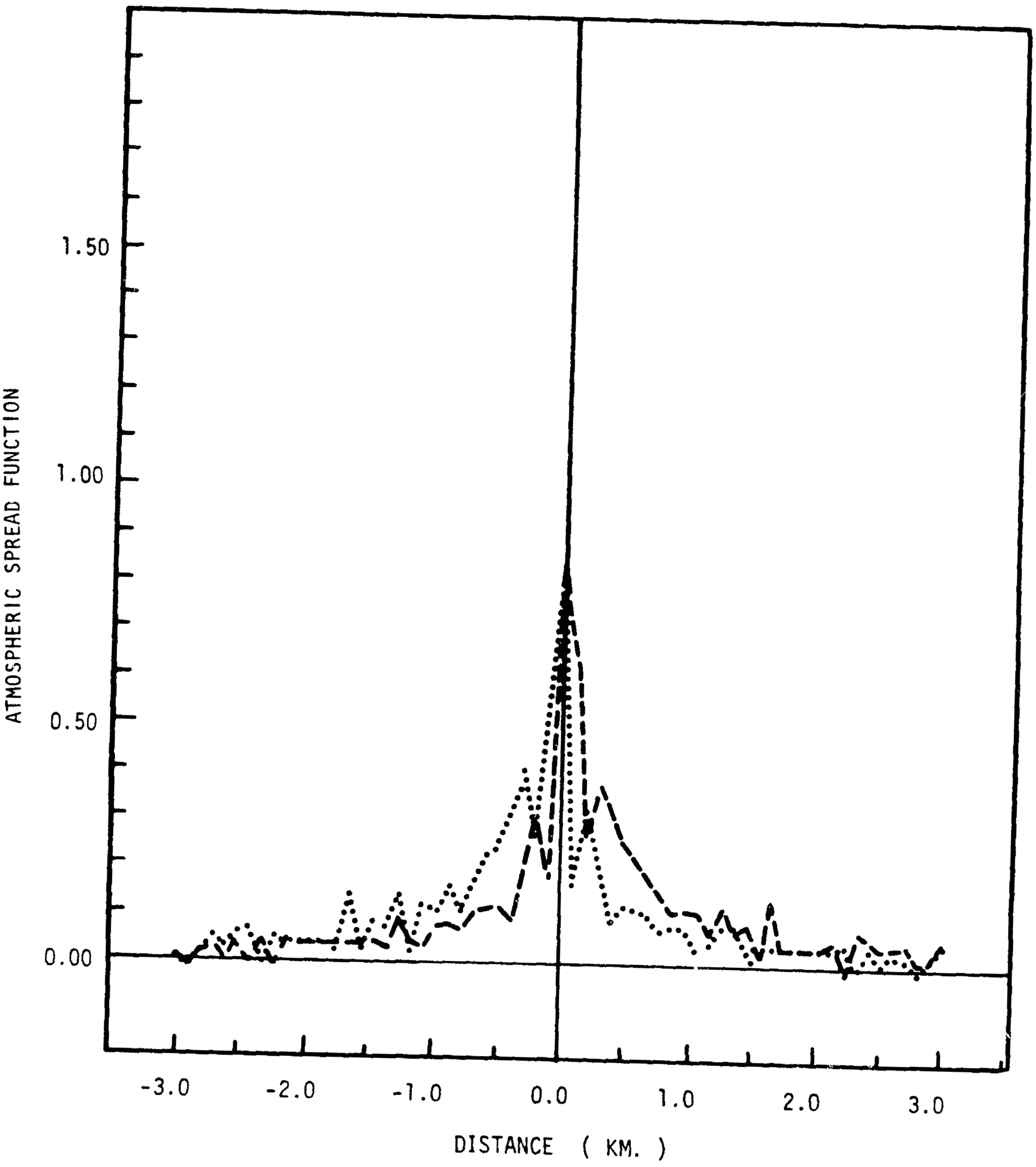
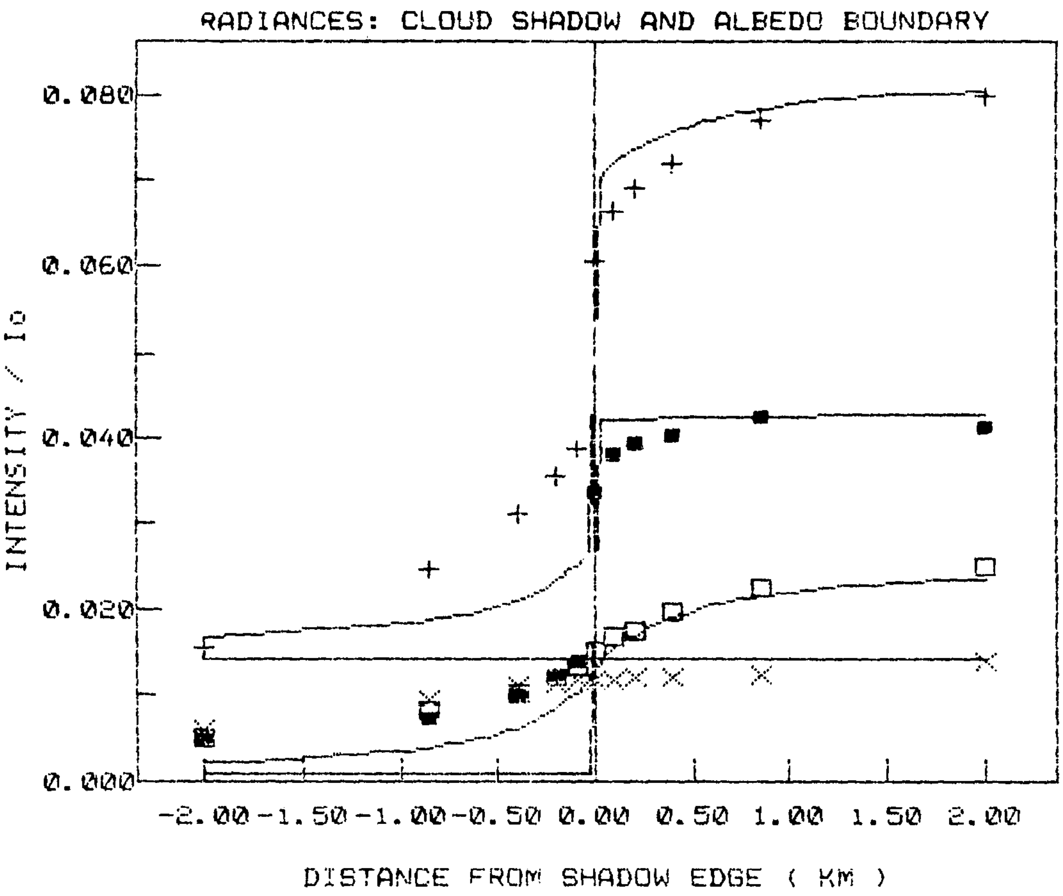

ATMOSPHERIC SPREAD FUNCTION
1.50
1.00
0.50
0.00
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
DISTANCE (KM.)

FIGURE 2.



C1 CLOUD

FIGURE 3.