Polarized radiance distribution measurements of skylight for passive remote sensing of aerosol optical properties

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The intensity and polarization of skylight, measured at the surface, can be used as a passive remote sensing tool to provide information on the optical properties of aerosols in the atmosphere. Wang and Gordon[1] have discussed techniques to use measurements of the intensity of skylight to obtain much of the aerosol phase function. Zhang and Gordon (this meeting) show that elements of the aerosol polarized scattering matrix (Mueller matrix) can be obtained if the Stokes vector of the downwelling skylight is known.[2]

We have developed instrumentation which can measure the first three elements of the Stokes vector (the intensity and two linear polarization components) for the downwelling skylight. This system is based on the RADS-II Electro-Optic "Fisheye" Camera Radiance Distribution System[3] and uses a "Fisheye" camera lens, a filter changer, and a cooled CCD image sensor to measure a hemisphere of the spectral radiance distribution. With the spectral filter changer, measurement at several spectral bands can be performed in a short time (minutes). By placing dichroic sheet type polarizers in one of the filter wheels, RADS-II becomes an analyzer-type polarimeter (RADS-IIP).[4] With proper calibration, RADS-IIP enables spectral measurement of the sky light polarized radiance distribution. The data process involves taking three data images with the polarizers in different orientations, i.e., the preferred transmission axes oriented in different directions, and these images combined to acquire three of the light field Stokes parameters.

Calibration of the system requires determination of the normal radiometric parameters for a fisheye system (lens rolloff, system linearity, absolute response, spectral bandpass, etc.)[5] and the system Mueller matrix for each polarizer orientation and each viewing angle. Laboratory tests of the Mueller matrix calibration have shown that the accuracy of our calibration is better than 2% at all viewing angles (an example is shown in Figure 1). We

have also done field tests which compare the fisheye systems radiometric accuracy with a simple pointing radiometer (an example is shown in Figure 2). Our polarization accuracy is estimated to be 2%, while our radiance accuracy is estimated to be 5 -10%.
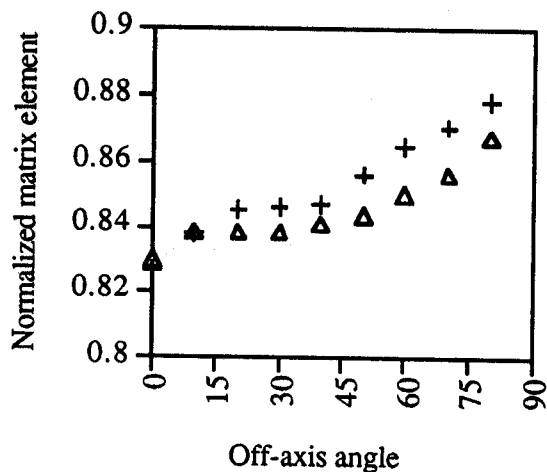
Figure 1) Mueller matrix, M12 with the polarizer in position 3. "+" is direct measurement, while triangles are values resulting from the calibration procedure.
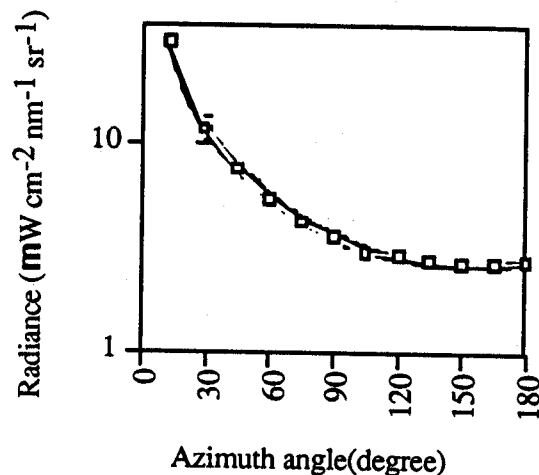
Figure 2) Comparison of RADS-IIP radiance (line) with radiance measurements by a simple pointing radiometer (squares). Measurements taken in alumcantor, at 560 nm.

With this system one obtains images of the individual Stokes vectors. In these images, features such as the Arago neutral point (a minimum degree of polarization in the principal plane) and the general shape of the degree of polarization and plane of polarization are evident. Also, because of the whole hemisphere of data is available, effects such from factors such as surface albedo variations, which might not be evident in point measurements of the skylight, become apparent. An example of the type of data and the effect of surface variations is shown in Figure 3, a data set obtained on Virginia Key (Miami) where the surface varies between bright island sand, trees, and open water.
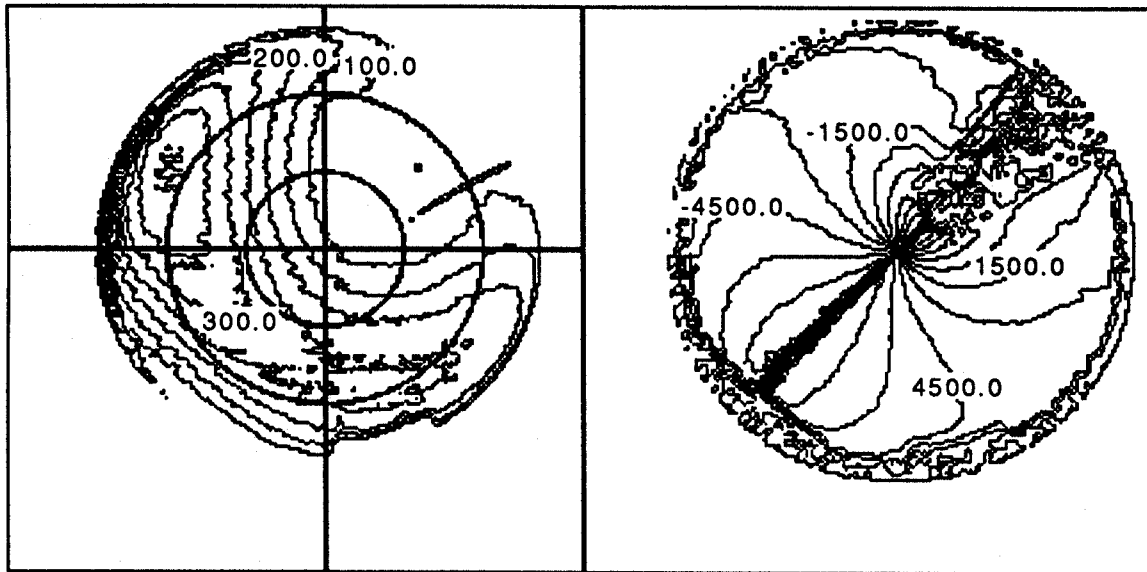
Figure 3a) Degree of linear polarization. Units are % x10. Sun is in upper right quadrant, maximum polarization is shifted towards upper portion due to surface albedo variations. Wavelength is 440 nm.

Figure 3b) Corresponding plane of polarization, units are 100x angle (degrees). 90 degrees implies polarization plane is horizontal. Shows high degree of anti-symmetry around principal plane, more than the degree of polarization, thus less sensitivity to surface albedo. Wavelength is 440 nm.

References

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5) Voss, K. J. and G. Zibordi, "Radiometric and geometric calibration of visible spectral electro-optic 'fish-eye' camera radiance distribution system", J. Atmo. Ocean. Tech., 6, 652-662 (1989).