All-Sky Optical Polarization Imaging in Variably Cloudy Skies

Joseph A. Shaw*, Nathan J. Pust, and Andrew Dahlberg
Electrical and Computer Engineering Department, Montana State University,
Bozeman, MT, 59717, http://www.coe.montana.edu/ee/jshaw

Scattering of light in the atmosphere gives rise to a spatially and temporally variable pattern of polarization for visible and near-infrared skylight. To first order, Rayleigh scattering theory predicts that the pattern contains a band of strong polarization oriented 90° from the Sun (Fig. 1). However, scattering by aerosols and cloud particles reduces the overall degree of polarization and partially or completely obscures the pattern. Therefore, a more accurate prediction of skylight polarization involves, in addition to the usual wavelength and angles, the aerosol size distribution and optical depth, cloud phase (liquid or ice), cloud particle size distribution and optical depth, and surface reflectance.

We have developed an imaging polarimeter that records an all-sky Stokes vector image in ≤ 0.4 s from four images at different polarization settings (N. J. Pust and J. A. Shaw, Appl. Opt. 45(22), 5470-5478, 2006). The Stokes image acquisition time is sufficiently fast to avoid polarization errors from cloud motion during the four-image acquisition time. The imager's polarization sensitivity is controlled electronically using liquid crystal variable retarders, and images are obtained in five 10-nm bands from 450 to 700 nm. The imager will be described and example data shown and explained for ground-based measurements in clear, hazy, and variably cloudy conditions. The measurements show that surface reflectance is a dominant variable in determining degree of polarization, and clouds generally decrease the polarization and alter its spectral slope, but only rarely do clouds alter the angle of polarization. An additional important result obtained recently is that fluctuations in the skylight degree of polarization show evidence of enhanced aerosols several hours before visible clouds form in an apparently clear sky (the so-called "twilight zone" between and around clouds).

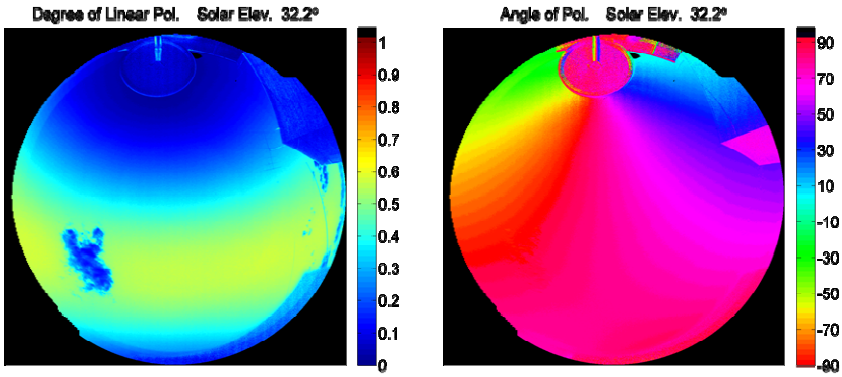

Fig. 1. Degree of linear polarization (left) and angle of polarization (right) of the full sky at 450 nm with a small cloud positioned within the band of maximum polarization.