

## Cloud thermodynamic phase detection with polarimetrically sensitive passive sky radiometers

The primary goal of this project has been to investigate if ground-based visible and near-infrared passive radiometers that have polarization sensitivity can determine the thermodynamic phase of overlying clouds, i.e. if they are comprised of liquid droplets or ice particles. While this knowledge is important by itself for our understanding of the global climate, it can also help improve cloud property retrieval algorithms that use total (unpolarized) radiance to determine Cloud Optical Depth (COD). This is a potentially unexploited capability of some instruments in the NASA Aerosol Robotic Network (AERONET), which, if practical, could expand the products of that global instrument network at minimal additional cost.

We performed simulations that found, for zenith observations, cloud thermodynamic phase is often expressed in the sign of the Q component of the Stokes polarization vector. We chose our reference frame as the plane containing solar and observation vectors, so the sign of Q indicates the polarization direction, parallel (negative) or perpendicular (positive) to that plane. Since the quantity of polarization is inversely proportional to COD, optically thin clouds are most likely to create a signal greater than instrument noise. Besides COD and instrument accuracy, other important factors for the determination of cloud thermodynamic phase are the solar and observation geometry (scattering angles between 40 and 60 degrees are best), and the properties of ice particles (pristine particles may have halos or other features that make them difficult to distinguish from water droplets at specific scattering angles, while extreme ice crystal aspect ratios polarize more than compact particles).

We tested the conclusions of our simulations using data from polarimetrically sensitive versions of the Cimel 318 sun photometer/radiometer that comprise AERONET. Most algorithms that exploit Cimel polarized observations use the Degree of Linear Polarization (DoLP), not the individual Stokes vector elements (such as Q). For this reason, we had no information about the accuracy of Cimel observed Q and the potential for cloud phase determination. Indeed, comparisons to ceilometer observations with a single polarized spectral channel version of the Cimel at a site in the Netherlands showed little correlation. Comparisons to Lidar observations with a more recently developed, multi-wavelength polarized Cimel in Maryland, USA, show more promise. This divergence between simulations and observations has prompted us to begin the development of a small test instrument called the Sky Polarization Radiometric Instrument for Test and Evaluation (SPRITE). This instrument is specifically devoted to the accurate observation of Q, and the testing of calibration and uncertainty assessment techniques, with the ultimate goal of understanding the practical feasibility of these measurements.