HIGH SPECTRAL RESOLUTION LIDAR VALIDATION OF MODIS DERIVED CLOUD PHASE AND ALTITUDE

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Introduction

To retrieve cloud optical thickness and particle size from satellite measurements, one must first have some idea of the cloud phase, that is, whether the cloud is composed of ice or water or some combination of both. Furthermore, little work has previously been performed to infer cloud phase in operational satellite data products. This is changing with the advent of data from the MODIS (Moderate resolution Imaging Spectro radiometer) on the NASA Terra platform. An operational MODIS cloud product concerns the inference of cloud thermodynamic phase. The phase retrieval (ice, water, mixed, or uncertain) is based on analysis of measurements at 8.5 and 11 microns, and thus is applicable for both daytime and nighttime data. The problem addressed here is upon the comparison of the satellite cloud phase product with independent determinations of cloud phase measured with the University of Wisconsin High Spectral Resolution Lidar (HSRL).

HSRL Background

The HSRL provides vertical profiles of backscatter cross-section, extinction cross-section, and depolarization. The HSRL divides the return signal into separate molecular and particulate scattering profiles. The Rayleigh scattering by molecules is used as a calibration target that provides robust recovery of cross section measurements. Residual depolarizations in the receiver are very small and a small receiver field of view (110 micro-radians) minimizes depolarization caused by multiple scattering. Thus, the HSRL depolarization signal allows easy distinction between scattering from spherical water droplets that induce little depolarization and ice crystals, which are non-spherical, and thus highly depolarizing. Clouds with depolarization greater then 25% consist of ice while depolarization less then 15% are generally water clouds or aerosols.

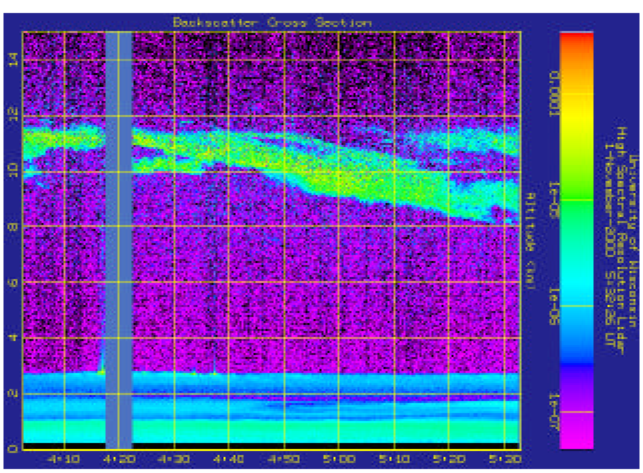

Figure 1. Plot of the aerosol backscatter cross-section. The X and Y-axis represent Time and Altitude. The shading corresponds with backscatter cross-section.

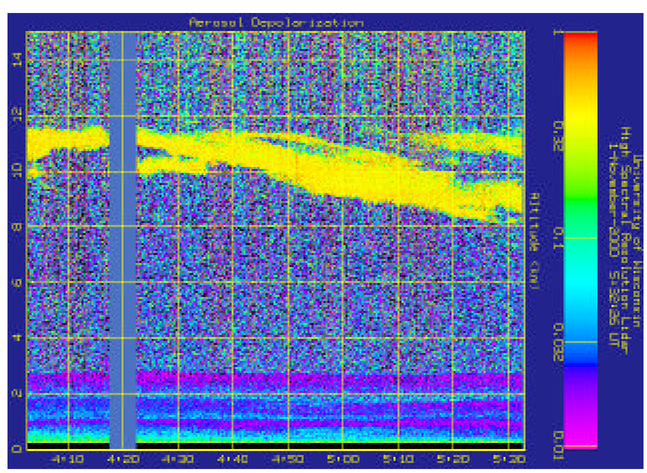

Figure 2. Plot of aerosol depolarization from the same data as Figure 1. Notice the highly depolarizing ice cloud (light shaded) and the thin water cloud below (dark shading).

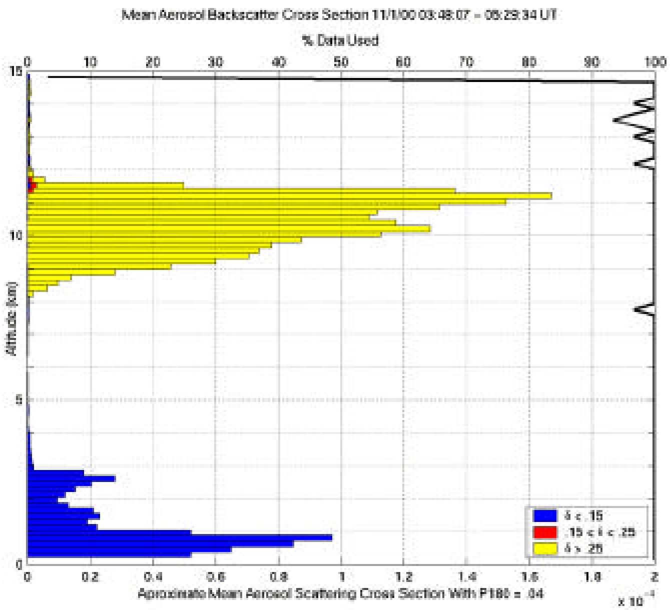

Figure 3. The aerosol scattering cross-section and depolarization for the entire data set generated from 3 minute averaged data with 165-meter vertical resolution. Depolarization values are divided into 3 ranges consisting of d < 0.15 (black), 0.15 <d < 0.25(gray), and d > 0.25 (light shading). Depolarization less then 0.15 are generally water droplets or aerosol. Depolarization greater then 0.25 are ice clouds. The black line represents the percent of the 3 minute averaged profiles used in the figure.

Results

This paper uses HSRL measured cloud phase and cloud altitudes acquired over Madison, Wisconsin to validate simultaneous, co-located MODIS retrievals. Data is taken starting 1-2 hours before the TERA overpass and continues 1-2 hours after the over-flight. Figures 1-3 are examples of HSRL-derived data products used for MODIS comparisons. Figure 1 and 2 show a vertical cross section of the backscatter cross-section and depolarization for February 20th, 2001. Notice that figure 2 consists of ice clouds from 8–12 km with depolarization's greater then 25% and an aerosol layer from the surface to 3 km with low depolarizations.

Figure 3 is the estimated scattering cross-section and depolarization averaged across the entire data-taking period of the 20th of February 2001. The length of each bar represents the mean of the scattering cross-sections measured during the data collection period that has a molecular scattering error <2%. The black line shows the percent of the data used at each altitude. The scattering cross section is computed using the measured particulate backscatter cross section, ß' and an estimated backscatter phase function of $P(180)/4\pi=0.04$. The value of 0.04 is derived from a 1-year climatology of HSRL lidar data. The approximate scattering cross section is then equal to: ß'/0.04. Each bar is divided into colored segments based on depolarization. The length of the segment is determined by the fraction of the measurements weighted by the scattering cross-section. The plot was developed to be representative of MODIS satellite that has 1 km resolution compared to the 1-meter resolution of the HSRL. Averaging the HSRL data decreases the spatial resolution that better correlates with 1 km MODIS data. Figure 3 clearly shows an ice cloud at 8-12 km and a layer with low depolarizations from the surface to 3 km.

The HSRL measurements will be compared with simultaneous Modis cloud phase results in the presentation.