AERI Cloud Optical Depth Retrieval From MPL-Measured Cloud Boundaries

D. H. DeSlover
University of Wisconsin-Madison
Cooperative Institute for Meteorological Satellite Studies
Madison, Wisconsin

W. L. Smith
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Introduction

The ability to derive cloud microphysical properties from Atmospheric Emitted Radiance Interferometer (AERI) data has improved with the recent addition of cloud boundaries that are determined from the Cloud and Radiation Testbed (CART) Micropulse Lidar (MPL) measurements. A series of 18 microwindows were chosen to measure cloud emission within the infrared atmospheric window (8 micron to 12 micron) from the AERI data. These spectral regions represent the least contaminated portion of the atmospheric window, while providing ice absorption spectral characteristics that vary from weak to strong absorption across the atmospheric window. The resultant spectral optical depth signature is indicative of particle size, where smaller particles yield a greater variance in optical depth in regions of weak ice absorption. A similar approach can be applied to liquid water clouds. A Matlab-based graphical user interface (GUI) has been developed to easily visualize the temporal and spectral results. Retrieval of cloud optical depth from AERI measurements has progressed to the point where it is near automation, and is a project that has high priority.

Approach

The retrieval requires a vertical temperature profile (from radiosonde data) and Line-By-Line Radiative Transfer Model (LBLRTM) clear-sky atmospheric transmission profile (calculations from radiosonde data) to invert the cloud optical depth from the MPL-measured cloud boundaries (DeSlover et al. 1999). CART radiosonde data provide atmospheric state measurements, which are input to LBLRTM to calculate the clear-sky contribution in the atmospheric column. The remaining radiance represents the cloud contribution, located at a level and temperature determined by MPL and radiosonde measurements, respectively. Thus, the cloud optical depth is known, assuming uniform extinction between the cloud boundaries. The AERI and MPL acquire data over a 24-hour period; therefore, radiosonde measurements and subsequent LBLRTM calculations must be interpolated to the AERI data acquisition frequency (roughly 10 minutes). Each vertical profile (temperature and transmissivity) is interpolated to 50-m vertical resolution. Each profile is then interpolated in time to match the AERI measurement.

Figure 1 illustrates the result of this procedure for data acquired over the Southern Great Plains (SGP) CART central facility on February 20, 1998. The upper plot shows MPL-derived cloud boundaries (cross, cloud top; circle, cloud base) as a function of time. The lower plot provides the resultant emissivity for each of the 18 spectral microwindows, which are color-coded in the legend (wavenumber, cm^{-1}). The figure was captured from a Matlab GUI developed for rapid data visualization, integrating both MPL and AERI measurements and results. The interactive GUI allows the user to switch between cloud boundaries and AERI-measured radiance (or brightness temperature) for each of the spectral microwindows as a function of time (upper panel); and cloud emissivity or optical depth for each spectral microwindow as a function of time (bottom panel). The color-coded radio buttons provide the user with the ability to display selected time series of spectral data. Finally, the dashed line in both panels represents the record number selected at the bottom of the display interface; where depressing the "Spectral" button would switch to the "Spectral Screen" (Figure 2).

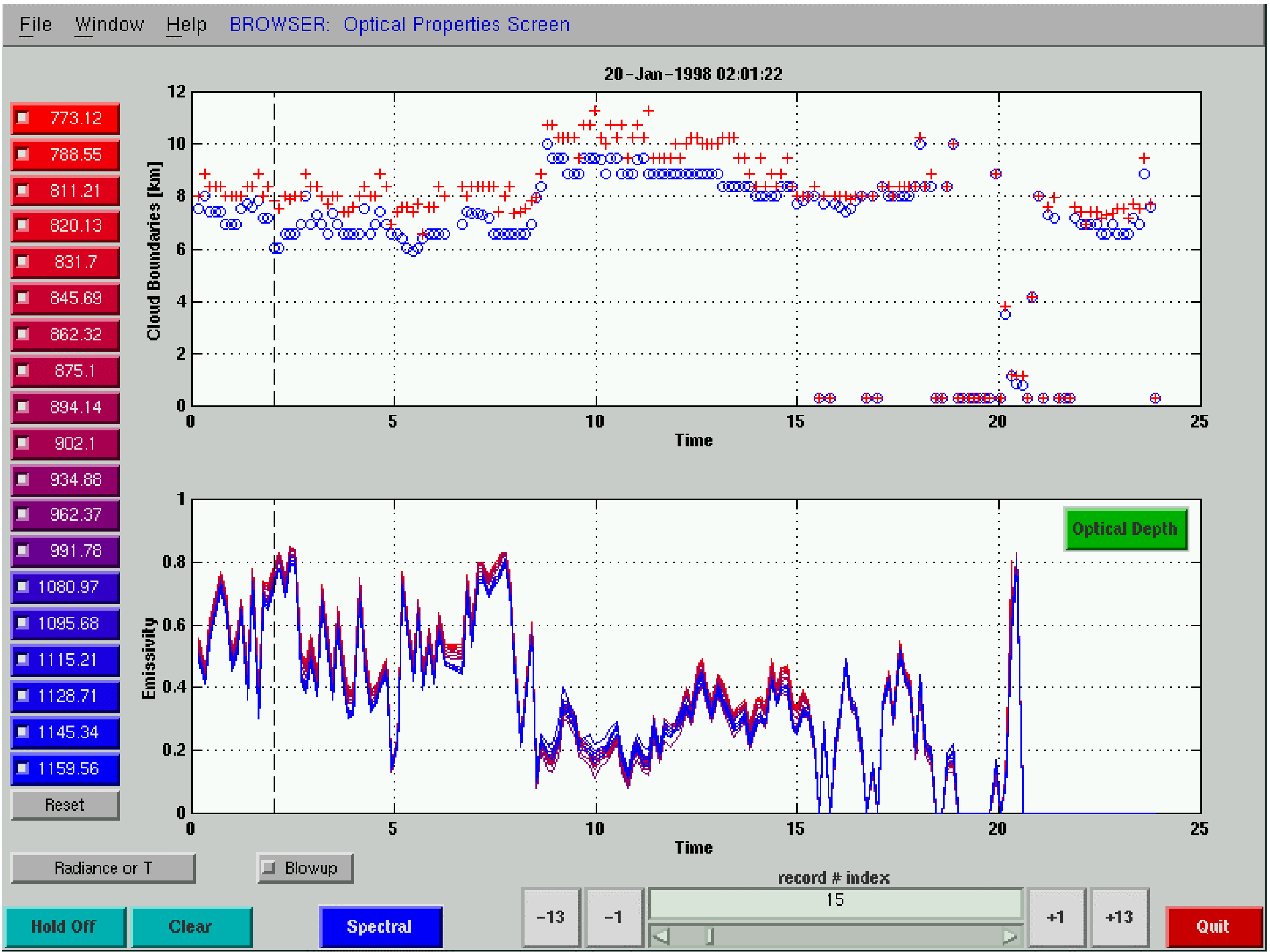

Figure 1. Matlab GUI utility for time series visualization of AERI-measured cloud emissivity (or optical depth, bottom panel) and MPL-measured cloud boundaries (top panel) for data acquired at the SGP CART central facility on January 20, 1998. Data located at the dashed line are shown in Figure 2, as a function of wavenumber.

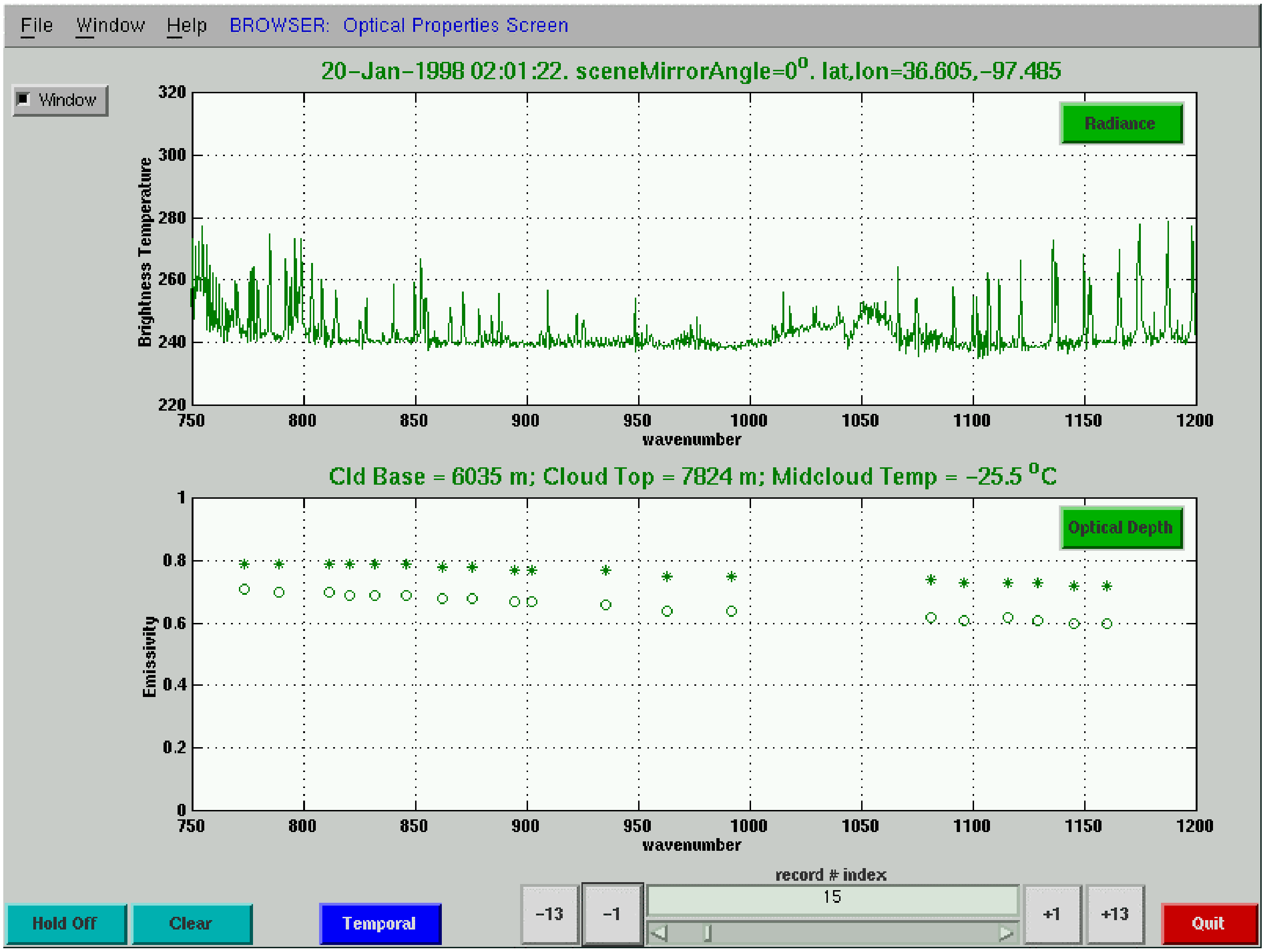

Figure 2. Spectral representation of data shown by dashed line in Figure 1. Upper panel illustrates AERI-measured downwelling atmospheric radiance. Lower panel shows cloud emissivity derived for both geometrically thick and infinitesimally thin cloud layers (asterisks and circles, respectively).

Figure 2 shows the spectral version of the data given by the dashed line in Figure 1, near 0200 Universal Time Coordinates (UTC). AERI-measured radiance is shown in the upper panel, while the cloud emissivity is given in the lower panel. Emissivity data are given for two assumptions: a uniform extinction cross section through a cloud of geometric thickness defined by the MPL (where the cloud base and top altitudes are indicated above the lower panel) with effective temperature defined near cloud center (denoted with asterisks); and infinitesimally thin cloud with a temperature defined by cloud base (circles). There is a difference on the order of 10% when comparing the two methods; where the first method is a better representation of the true cloud emission. The latter method assumes all the cloud emission is from the cloud base, which is warmer than the effective temperature of the cloud and therefore has a lower emissivity based on this assumption. The spectral variation in emissivity is due to particle size, which occurs because absorption due to ice is not constant across the atmospheric window. Rather, it varies from strong absorption (smaller wavenumbers) to weak absorption (larger wavenumbers), such that the emission cross section is dependent on the effective cross-sectional area of the ice particle. This interactive GUI also allows the user to switch between cloud emissivity and optical depth, change the data record, and overlay consecutive records to observe spectral changes in the data over time.

Summary

The goal is to completely automate this procedure and add cloud optical depth measurements to the Atmospheric Radiation Measurement (ARM) data stream as a value-added product. This will benefit the single-column modeling community by providing measured cloud data for improvement in net-flux calculations. A cloud climatology could also be determined by summarizing these data for various cloud parameters (altitude, effective temperature, and emissivity) for various atmospheric conditions (e.g., diurnal, seasonal). Finally, a discrete ordinance theory (DISORT) model will be used to generate an estimate of particle size. This procedure has been successful in determining effective radii for similar data acquired from aircraft (Chung et al. 1999).

References

Chung, S., S. Ackerman, P. F. van Delst, and W. P. Menzel, 1999: Model calculations and interferometer measurements of ice cloud characteristics. *J. Geophys. Rev.* Submitted.

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