P4.17 DETERMINATION OF LIQUID WATER PATH AND EFFECTIVE RADIUS FOR WATER CLOUDS USING MICROWAVE AND VISIBLE MEASUREMENTS

Guosheng Liu* and Hongfei Shao
Florida State University, Tallahassee, Florida
Mark Tschudi and Julie Haggerty
NCAR, Boulder, Colorado

1. INTRODUCTION

The radiative properties of water clouds are closely related to two cloud microphysical parameters: liquid water path (LWP) and effective radius (r_e). For the same LWP, smaller water droplets will have larger optical depth in the shortwave and reflect more solar radiation. The aerosol's indirect radiative effect is the increase of cloud reflection by providing more cloud condensation nuclei. In relation to INDOEX (Indian Ocean Experiment) project, the ultimate goal of this study is to assess the aerosol's effect on cloud microphysics and radiative properties. As a first step, we are developing retrieval algorithms for LWP and r_e using data collected by AIMR (Airborne Imaging Microwave Radiometer) and MCR (Multi-Channel Radiometer). The AIMR is a cross-scanning, dual-frequency (37 and 90 GHz), dual polarization microwave radiometer. The MCR is a cross-scanning 7-channel radiometer with wavelengths ranging from 0.64 μm to 10.8 μm although only the 0.64 μm channel was fully functional during the entire INDOEX experiment. Only the 0.64 μm channel is used in our retrieval algorithm at this moment. During the INDOEX intensive observation period (January through March of 1999), AIMR and MCR were deployed on NCAR C-130 aircraft. Data were collected during 18 flights over Indian Ocean covering an area approximately from 10° S to 10° N and 65 to 75°E.

2. RETRIEVAL METHOD

The retrieval algorithm starts with determining LWP from AIMR microwave data first. Cloud height, cloud temperature and sea surface temperature are derived from other remote and in situ measurements onboard the aircraft. Detailed description of the LWP algorithm can be found in Liu et al. (2001). Fig. 1 shows the frequency distribution of retrieved "liquid water path" for clear-sky regions, which provides the indication of the algorithm's systematic and random errors. It is seen that the frequencies peaks near zero, indicating no systematic error, and the standard deviation of the retrieved LWPs is 18 g m^{-2}, which is the indication of random error.

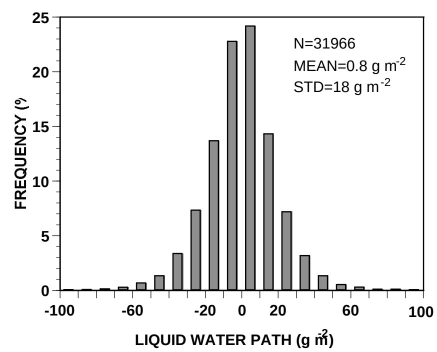

Fig. 1 Frequency distribution of retrieved LWP for clear-sky regions. The mean and standard deviation are indications of systematic and random errors.

The retrieval of effective radius is based on a lookup table generated by a radiative transfer model (Ricchiazzi et al. 1998) for various solar and instrument viewing angles. The inputs of the lookup table are LWP (retrieved from AIMR) and 0.64 μm reflection function (calculated from MCR). Fig. 2 is the frequency distribution of the difference between model calculated and actually

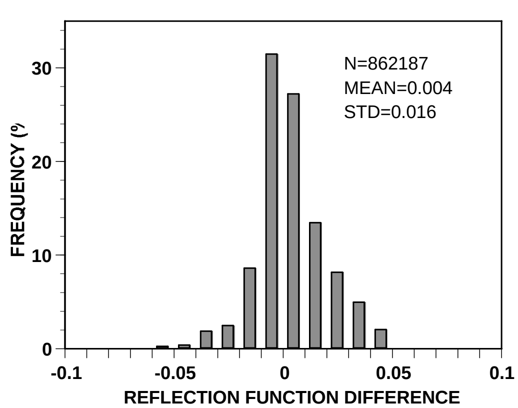

Fig.2 Frequency distribution of the difference between calculated and observed reflection function (0.64 μm) for clear-sky pixels. The mean and standard deviation are indications of systematic and random errors.

* Corresponding author address: Guosheng Liu, Florida State Univ., Dept. of Meteorology, Tallahassee, FL 32306-4520; e-mail: liug@met.fsu.edu

observed reflection function at 0.64 μm for clear-sky conditions. It is seen that the systematic error is near 0 and the random error is also small, ~0.016.

Fig. 3 is an example for explaining the lookup table method based measurements from 0653Z to 0658Z on Feb. 27, 1999. The curves are isolines for r_e calculated by radiative transfer model runs. From the observed values of LWP and reflection function, effective radius can be determined by interpolation. The small dots are actual observations at pixel scale and the large dots are averaged r_e at every 10 g m^{-2} LWP bin. On average, r_e increases with LWP from ~4 μm at LWP being a few g m^{-2} to ~12 μm when LWP is ~150 g m^{-2}. Scatters of the data at pixel level could be partially caused by the inhomogeneity of the cloud field.

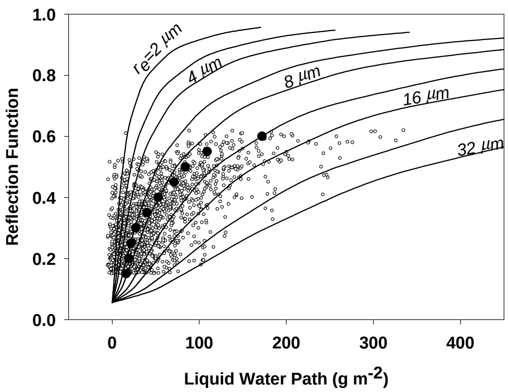

Fig. 3 Schematic diagram for retrieving effective radius from liquid water path and reflection function at 0.64 μm.

3. RESULTS

Figure 4 shows the retrieved LWP, observed radiance (I) at 0.64 μm, and retrieved r_e for a 5-minute flight on Feb. 27, 1999, based on the retrieval algorithms described above. The clouds are scattered cumulus with a depth of about 600 m within the boundary layer. Retrieved LWPs ranges from 0 to more than 300 g m^{-2}, while retrieved r_e is from 0 to ~20 μm. Bright clouds (high I values) generally correspond to greater LWP and larger r_e values. This example suggests that the retrievals are reasonable at least qualitatively although further validations using more quantitative methods are needed.

Using the LWP and r_e retrieved from all data collected during INDOEX, we are studying the relationship between LWP and r_e, and how this relationship is related to the aerosol concentration. Because deep cumulus clouds usually are associated with larger LWP and r_e, r_e generally

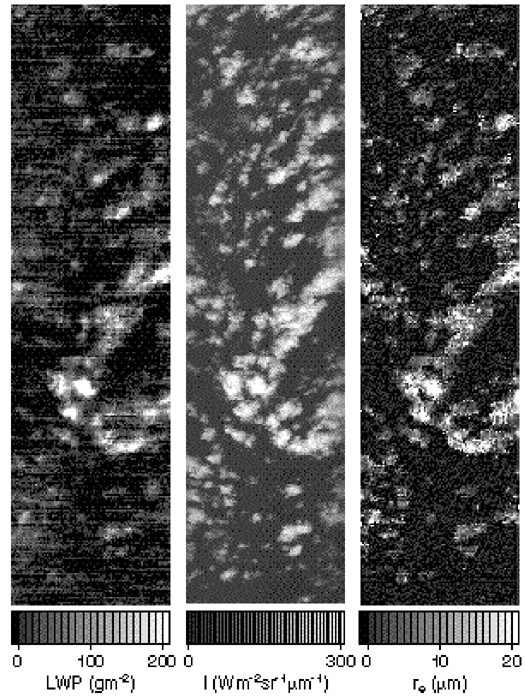

Fig.4 Retrieved LWP (left), observed reflected radiance at 0.64 μm (middle) and retrieved effective radius (right) for a 5-minute flight on Feb. 27, 1999. The area is roughly 12 km by 45 km.

increases with LWP. However, the rate of the increase (or the slope) is expected to be related to the number concentration of the water droplets, which, in turn, is a function of cloud condensation nuclei. By examining the slope, the aerosol's indirect effect on solar radiation may be assessed. Results based on this approach will be report at the conference.

Parallel to the data analysis using aircraft data, we are also conducting similar studies using simultaneously observed visible and microwave data from TRMM satellite. While aircraft observations provide detailed data at a fine resolution, satellite data cover a much broader area and much longer time period.

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References

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Ricchiazzi, P., S. Yang, C. Gautier, and D. Sowle, 1998: SBDART: A research and teaching software tool for plane-parallel radiative transfer in the Earth's atmosphere. Bull. Amer. Met. Soc., 79, 2101-2114.