1.10 Validation of CERES/VIRS Cloud Property Retrievals Using Ground-based Measurements Obtained at the DOE ARM Sites

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1. Introduction

Cloud properties are being derived from the Tropical Rainfall Measurement Mission (TRMM) Visible Infrared Scanner (VIRS) as part of the Clouds and the Earth's Radiant Energy System (CERES) project. The VIRS began operation during December 1997. For reliable application of satellite datasets in cloud process and single column models, it is important to have a reasonable estimate of the errors in the derived cloud properties. When properly used, ground-based measurements and retrievals can provide a ground truth dataset for estimating errors in the satellite products. The goal of this study is to validate the CERES/VIRS daytime cloud retrieval algorithms using the ground-based measurements and retrievals. This paper reports a comparison of preliminary cloud property retrievals from CERES/VIRS and surface data taken during the first half of 1998.

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2. Data and Methods

Data taken by the Atmospheric Radiation Measurement (ARM) Program are being used to help validate the CERES/VIRS cloud retrievals. Two ARM site datasets taken over the Southern Great Plains (SGP) (36.61N, 262.51E) and Tropical Western Pacific (TWP) (0.52S, 166.92E and 2.06S, 147.42E) are used for this study. The CERES cloud products include the cloud base/top heights, temperature, liquid water path (LWP), ice water path (IWP), effective radius/diameter, and optical depth. The main algorithm used during the daytime is the VIST (Visible Infrared Solar-Infrared Technique) described by Minnis et al. (1995). The methodology, data, and a summary of the results are given by Minnis et al. (1999).

The satellite-derived cloud parameters are compared to coincident measurements and retrievals using ground-based lidars, radars, soundings, and microwave radiometers in concert with a 2-stream radiative transfer code (Dong et al., 1997). In the comparison of the satellite and ground-based data, the CERES cloud products are averaged in space to 30 km x 30 km resolution, while the surface data are averaged over the hour centered on the TRMM overpass.

3. **Results and discussion**

Only 17 single boundary layer stratus clouds have been found during the first half year of 1998 where CERES/VIRS passed over ARM SGP site as shown in figure 1. There are several reasons for such few samples. The CERES/VIRS flight trajectory over ARM SGP site occurs at night more than half time of the time during this period. Few stratus clouds occur during the summer season and upper level clouds often occur above the stratus.

Figure 2 shows the comparison of cloud heights and temperature between CERES/VIRS and surface. The cloud base and top heights are measured by ground-based lidar and radar, respectively, and cloud base and top temperatures are found from a local radiosonde sounding using the observed heights. The effective cloud temperature is derived from the VIRS 10.8-µm (infrared) channel and the effective cloud height is derived from the temperature from a numerical weather analysis product from the NASA Data

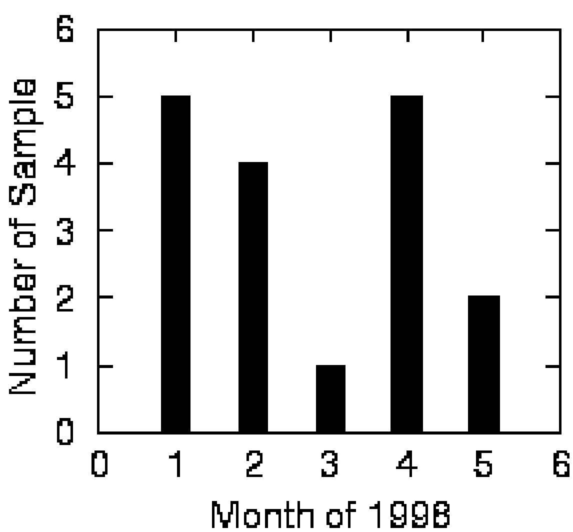

Figure 1. VIRS/CERES pass over ARM SGP Site (36.61, 262.51)

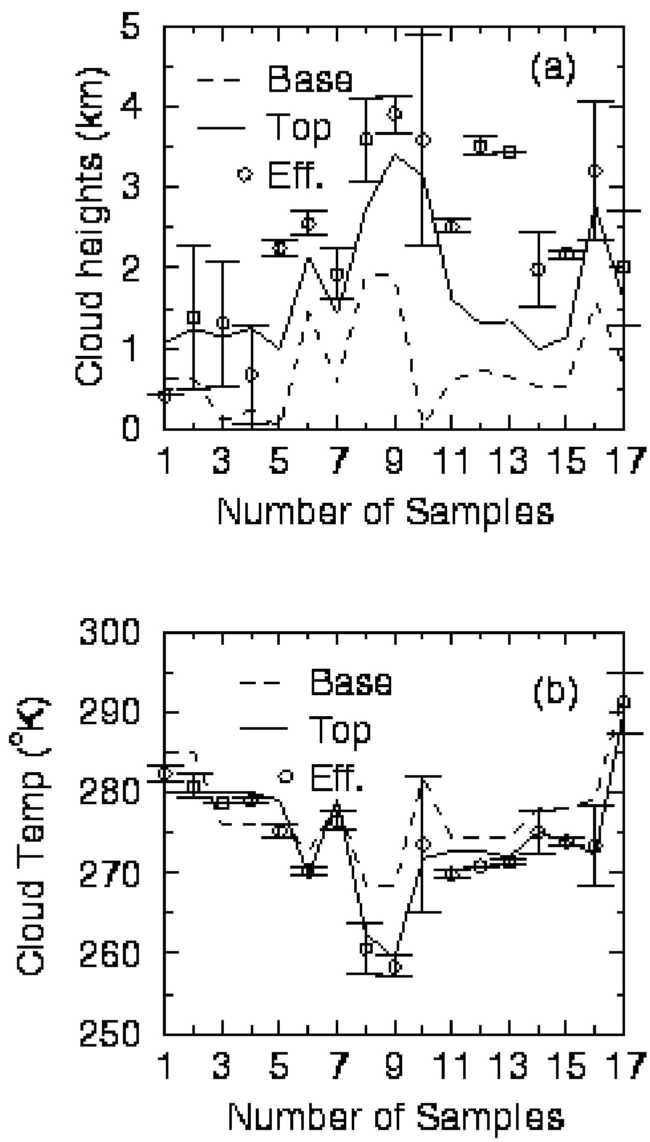

Figure 2. The cloud base/top height and temperature are measured from ground-based lidar/radar and radiosonde sounding. The effective height and temperature are inferred from VIRS IR channel.

Assimilation Office (DAO). Since this is a comparison between spatial (VIRS) and temporal average (surface), any VIRS derived effective cloud temperature and height (mean plus standard deviation) within the surface measured cloud base/top height and temperature should be treated as good agreement. Based on this rule, most of

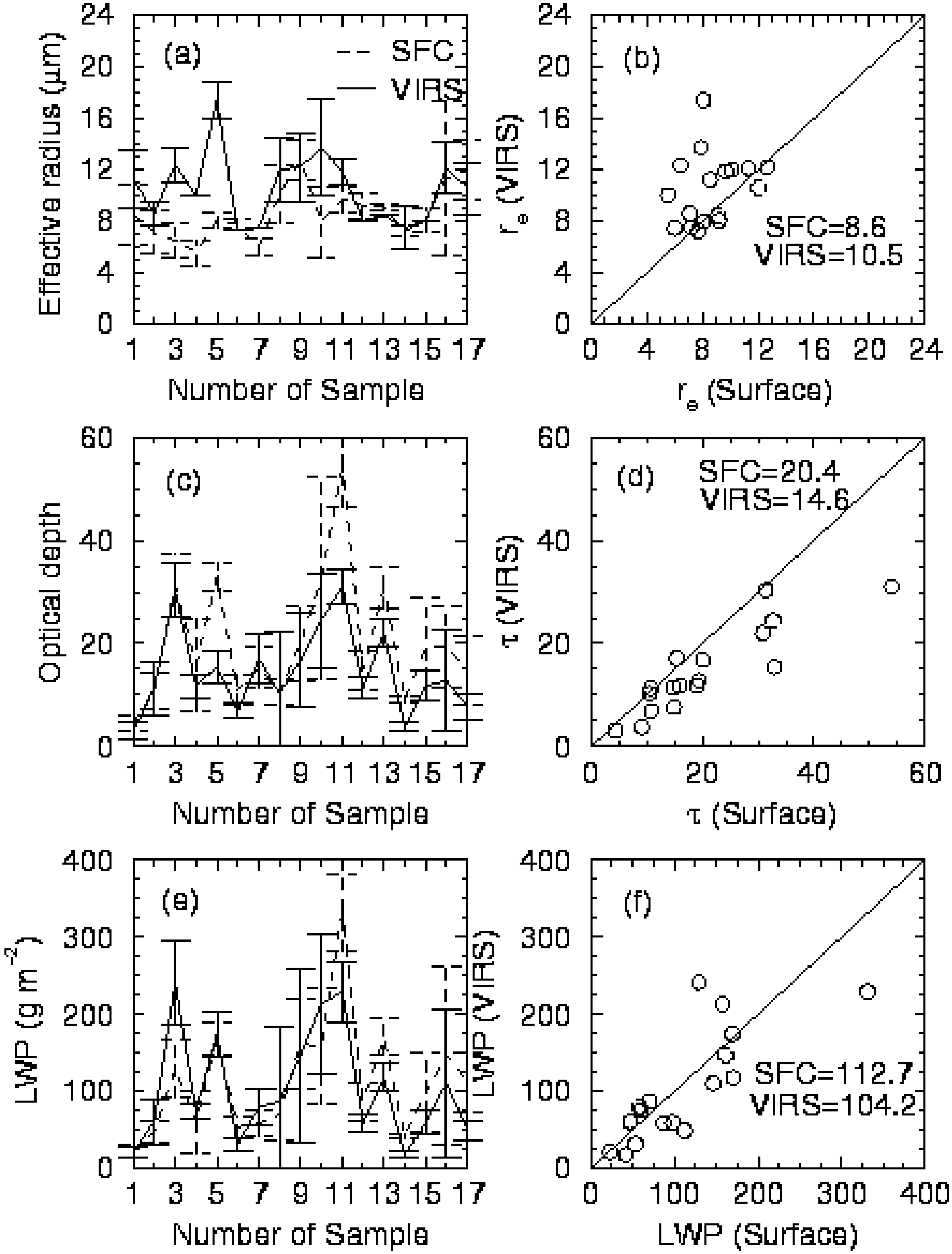

Figure 3. Comparison of VIRS/CERES (solid line) with surface retrievals (dashed line) at ARM SGP site from January to May of 1998.

VIRS derived effective temperatures match well with surface measurements except samples 11, 12, and 13. Conversely, the satellite-derived effective cloud heights rarely agree with the surface data. This result suggests that the algorithm for inferring cloud effective height from the temperature or the sounding database needs to be improved. Because stratus often form under a low-level inversion, it is possible that the vertical resolution of the DAO product misses many of these inversions.

A similar approach can be used for examining figure 3 where good agreement is assumed if there is any overlap between VIRS and surface retrievals (mean plus standard deviation). Again, based on this rule, most of VIRS-retrieved cloud droplet effective radius and optical depth agree well with surface retrievals as shown in figure 3a and 3c. The big deviation in sample 5 is due to the cirrus cloud contamination. From the scatterplots in figure 3b and 3d, the average VIRS-retrieved effective radius is about 22% higher than the surface mean value, while the VIRS-retrieved optical depth is about 28% lower than surface data. It is difficult to say which one is right at this time from this preliminary result and big difference in spatial and temporal average. Nevertheless, there is excellent agreement in LWP as shown in figures 3e and 3f indicating that the differences compensate each other. The radar-based method constrains the retrieval with the microwave radiometer-based value of LWP. Thus, the LWP is the most independent of the surface variables.

Some of the microphysics differences may be due to the different view angles to cloud between satellite and surface. For example, the satellite derived cloud droplet effective radius represents the top of cloud which is higher than surface retrieved layer-mean value. In general, the maximum droplet size occurs at cloud top in stratus clouds. The satellite-derived effective radius could be reduced to account for the vertical distribution of droplet size as suggested by Nakajima and King (1990). Such a change, however, would diminish the agreement in LWP. Drizzle within stratus may also affect the retrievals differently for the two approaches. Additional study is needed to quantify the effects of vertical distribution and drizzle.

4. **Concluding remarks and further research**

The initial comparisons shown here indicate that CERES satellite retrievals are producing accurate results for stratus cloud microphysics, especially for the liquid water path. The conversion of cloud temperature to altitude, however, requires some adjustment.
Evaluation of the radar retrievals with in situ measurements will help explain the observed differences.

These results represent only one cloud type at one location. Additional comparisons are need for cirrus clouds at the ARM SGP site and both stratus and cirrus clouds at ARM TWP site. Furthermore, techniques for deriving and evaluating cloud microphysics in overlapped and mixed phase clouds.

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