

**COMBINING SATELLITE AND CLOUD PROFILING RADAR CLOUD
CLIMOTOLOGIES OVER THE OKLAHOMA ARM CART SITE**

J. Adam Kankiewicz*, Donald L. Reinke, Thomas H. Vonder Haar

Cooperative Institute for Research in the Atmosphere/Center for Geosciences
Colorado State University
Fort Collins, CO 80523-1375

*Corresponding Author: J. Adam Kankiewicz, E-mail: kankie@cira.colostate.edu, FAX:
970-491-8241, Phone: 970-491-8233

OBJECTIVE:

While extensive studies on the horizontal distribution of clouds have been performed (e.g., Rossow and Walker 1993), reliable vertical distributions of cloud layers are few (e.g. Baum et al. 1995). Space-based measurements of multiple cloud layers are problematic in that lower cloud layers tend to be obscured by upper clouds. The advantage of satellite cloud detection is the horizontal distribution of cloud cover. However we are limited to producing "inferred" vertical cloud layering information from the space-based vantage point.

Several attempts have been made to produce a vertical distribution of cloud. Wang and Rossow (1995) used rawinsonde observations (RAOBS) to identify vertical cloud structures over tropical ocean sites. Forsythe, et al. (2000) presented a technique for inferring cloud layers from satellite using a classification technique. However, all of the current satellite-based techniques are hindered by the inability to see "obscured" cloud decks from beneath or above. The intent of this study is to address the current capability for building a layered cloud product from satellite, and to examine the feasibility of combining satellite and cloud profiling radar data to produce an improved "complex layered cloud" product.

An ideal location to compare satellite and ground-based cloud measurements is over the U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) Southern Great Plains (SGP) site situated over north central Oklahoma (Stokes and Schwartz 1994). High frequency RAOBS and a continuously observing cloud radar combine to make an ideal ground-based cloud-observing platform.

The ARM CART Millimeter-Wave Cloud Radar (MMCR) is a zenith-pointing radar that operates at a frequency of 35 GHz and takes vertical profiles of the atmosphere every 10 seconds. The main purpose of this radar is to determine cloud boundaries (e.g., cloud bottoms and tops). The radar possesses a Doppler capability that allows the measurement of cloud constituent vertical velocities (more information on the MMCR can be found in Moran et al. 1995).

Satellite data from the new Climatological and Historical ANalysis of Clouds for Environmental Simulations (CHANCES-97) database (Vonder Haar et al., 1995) are studied over the ARM CART region. CHANCES-97 is a high-resolution, global, 5-km, 1-hr, 1-yr database under production by STC-METSAT that will cover the period from July 1997-July 1998 when finished. The easy accessibility, high spatial and temporal resolution of the CHANCES-97 data set makes it an ideal candidate for cloud studies.

Two months of co-located CHANCES-97 satellite and high-resolution MMCR data are compared over the Oklahoma ARM CART region to gain further insight into the vertical

distribution of clouds. IR-based cloud top estimates from satellite and RAOBS are also compared to the cloud top heights observed by the MMCR in an attempt to better understand cloud top radiances recorded from spaced-based observing platforms.

RESEARCH ACCOMPLISHED:

MMCR data were averaged over a 30 minute period (centered on the hour) to allow for the advection of clouds through the ARM CART region. These MMCR data were then objectively analyzed to determine cloud tops and bases (when possible) following a method similar to that used by Clothiaux et al. (submitted). A “cloud mask” was then produced for the Jan-Feb 1998 period with single and multiple cloud layers noted.

To help reduce possible errors in the satellite data (i.e. navigation, displacement, etc.) that might be incurred if one views the satellite data grid cell directly over the MMCR, a 3x3 grid of data (15 km wide) is used. Though one does tend to smooth out data sampled by this method, it does allow more robust cloud statistics. Within this larger grid box, the CHANCES-97 data set include an observed 48.6% cloud cover amount while the MMCR noted a 63.3% cloud cover amount over this same time frame. It appears that two factors contribute to this disparity. First, the vast majority of the missed cloud cases in the CHANCES-97 data set were do to low nighttime stratus cases not being flagged as cloudy by the single channel IR cloud detection algorithm employed by in the CHANCES-97 processing. Secondly, the radar appears to detect thin, high level ice clouds that are not sufficiently thick to register as a cloud top in the satellite infrared data. In addition, the radar cloud top algorithm could be slightly overestimating low stratus cloud. To minimize discrepancies between these two data sets, when doing a direct comparison, we isolated the cases to situations where we had homogeneous, "optically thick", clouds where agreement is much better.

In terms of multiple cloud layer conditions, the MMCR noted that 19.5% of the time there were multiple layered clouds present. Due to attenuation of the radar signal, cloud base information was not possible to retrieve during heavy precipitation cases. Low cloud conditions (with cloud tops less than 2.5 km) were observed 29% of the time, while only 15.6% of the time were the low cloud conditions noted as the only cloud layers present.

The two-month period at the beginning of 1998 saw multiple synoptic scale disturbances moving through the north-central Oklahoma region. Between these larger disturbances, stable atmospheric conditions prevailed (with both clear and stratus cloud conditions observed). A thirteen-day (extending from 3 Jan through 14 Jan 1998) sample of the MMCR cloud mask (lower plot region) along with the satellite observed temperatures (upper plot region) are shown in Fig. 1. One observes a reasonable correlation between colder (warmer) satellite-observed temperatures and higher (lower) MMCR observed clouds. Also shown in Fig. 1 is a graphic example of multiple cloud layers that were not observable from satellite (e.g., day 8). Though not discussed here, IR-based cloud top retrievals will be presented at the conference. The distinctions between “physical” cloud top (as observed from the cloud radar) and “thermal” cloud top (as observed by satellite)

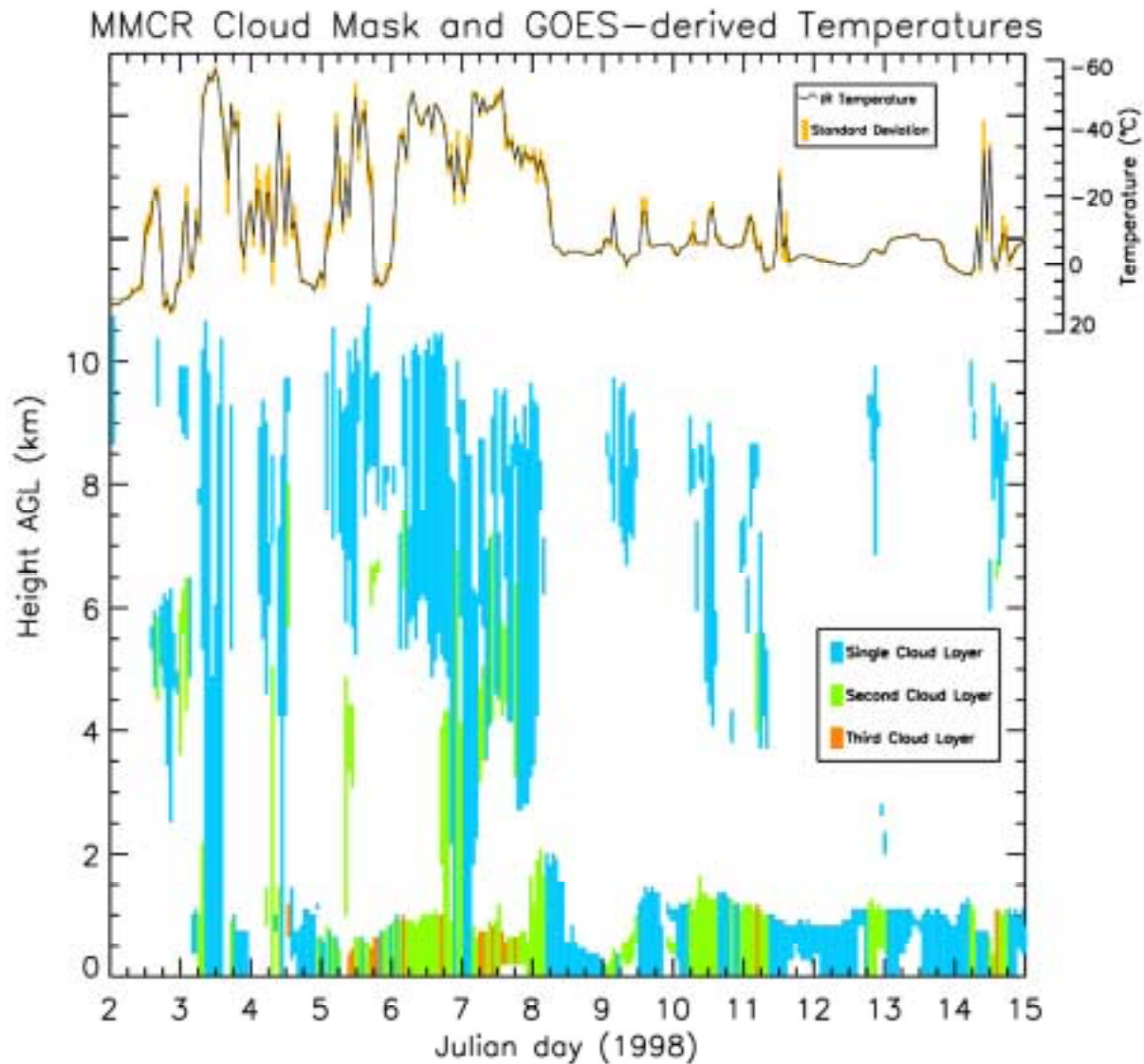


Fig. 1. MMCR-derived cloud mask (lower portion of plot) for the period from 3 Jan 1998 through 14 Jan 1998. Clouds that were observed to be the only layer within the vertical column are shaded blue, while clouds noted to be the second and third layers within the column are shaded green and red, respectively. GOES-derived temperatures (with standard deviation shaded) are plotted above the MMCR cloud mask.

CONCLUSIONS AND RECOMMENDATIONS:

Based on initial combinations of ARM CART MMCR with geostationary satellite data, we believe that one can produce an improved analysis of the vertical and horizontal distribution of clouds. While the potential military and civilian forecasting applications of very high-resolution satellite cloud climatologies (e.g., CHANCES) are exciting, more

research has to be performed on the issue of vertical cloud climatologies. The planned CloudSat mission (which will orbit an active cloud radar) will provide a much needed look at the global distribution of layered clouds.

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