P3.37

A Validation Study of the GOES Sounder Cloud Top Pressure Product

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1. INTRODUCTION

One of the derived operational products from the Geostationary Operational Environmental Satellite (GOES-8) Sounder is the Cloud Top Pressure measurement. This product is available for the GOES-8 domain in real-time at hourly time resolution. The sounder outputs the average cloud top pressure reading from a 3X3 (nine pixels approximately 35x45 km) Field of View (FOV), and the single FOV, as well as the maximum and minimum values from the 3X3 FOV. The data used for validation purposes comes from the March 2000 Intensive Operational Period (IOP) from the Department of Energy's (DOE) Atmospheric Radiation Measurement (ARM) program Cloud and Radiation Testbed (CART) site near Lamont, OK. This includes cloud top height derived from a ground-based combination Micropulse Lidar/Millimeter Cloud Radar (MPL/MMCR), which uses an algorithm developed by Eugene Clothaiux (Clothiaux et al. 2000). MPL/MMCR output is every ten seconds during the IOP. GOES cloud top data range from 7 March 2000 to 31 March 2000, giving 600 possible observation times. Data were filtered to give only observation times that contain one cloud layer to provide an accurate comparison between the ground-based and space-based observation locations.

2. Method

In order to prepare the two data sets for an objective comparison, the GOES cloud top pressure observations were converted into altitude in meters. This was achieved by using radiosonde data from the CART site. A pressure-height profile was constructed from the closest radiosonde to the time of observation. Radiosondes were launched every six hours during the IOP from the CART site. Once this conversion was done, the two data sets could be compared using a time series plot (Fig. 1).

Since the MPL/MMCR is subject to attenuation effects and local cloud top height deviations at the single observation point over the CART site, the data needed to be desensitized. This was achieved by using a range binning process which entailed placing every MPL/MMCR observation surrounding the GOES sounder observation time (five minutes before and after the GOES observation time was used) into a range bins of 250m. Each range bin must have a given amount of observations in it to be considered valid (a threshold of observation). Those range bins that do not meet the threshold value are discarded, while the temporal average cloud top height is used from the valid range bins. Noticeable improvement in the results was seen after this range binning tool place. This is demonstrated in scatter plots within figures 2 and 3. Notice the considerable improvement in agreement when the binning methodology is used.

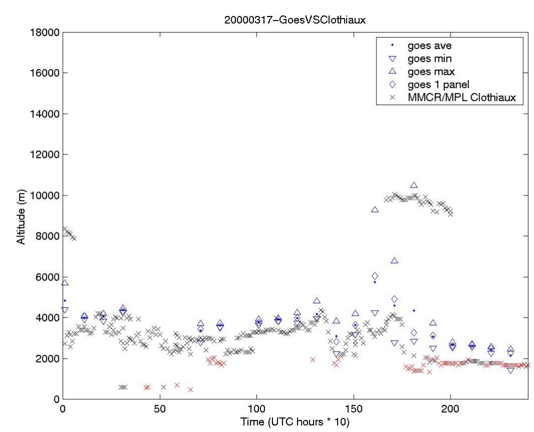

Figure 1: An example of GOES and MPL/MMCR cloud top height time series. This is for 17 Mar 2000.

To further filter the data for a direct comparison, measures were taken to eliminate observation times where multiple cloud layers were present. Although the GOES sounder product cannot explicitly detect multiple cloud layers, use of the 3X3 FOV maximum and minimum cloud top height values can give a reasonable estimate of the existence of multiple cloud layers. The

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determination of multiple cloud layers was done by specifying a maximum variance in the 3X3 FOV maximum and minimum cloud top height. Any observation time that had a variance greater than 2000 meters would be deemed to be a multiple cloud layer situation. Through the use of two different methods of filtering, the ground-based data was desensitized and multiple cloud layers were eliminated, allowing for an objective comparison between the two independent observations.

3. Results

The first direct comparison made between the GOES and MPL/MMPL was detection of clouds. This is a yes/no comparison, either the instrument is reporting a cloud top height or it is not. For this comparison, the temporal threshold for the MPL/MMCR data set was set to a very low value 16% of observations needed for a valid cloud. The value was set so low in order to minimize attenuation effects of the instruments. The GOES sounder and MPL/MMCR agree on the existence or lack there of a cloud 75% of the time (345/460). It should be noted that for 140 of 600 possible observation times, the sounder was in eclipse mode.

To further compare the two measurements, scatter plots with both GOES sounder and MPL/MMCR cloud top height values were produced. To demonstrate the importance of data filtering, the progression of filtering techniques is shown with their respective scatter plots.

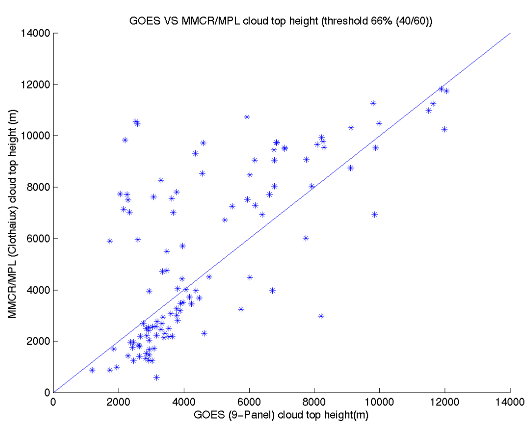

Figure 2: A scatter plot comparing GOES and MPL/MMCR cloud top height with no data filtering. Little correlation is seen.

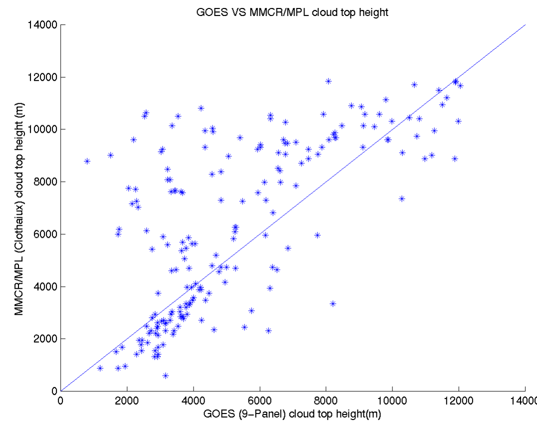

Figure 3: Scatter plot using binning process for MPL/MMCR.

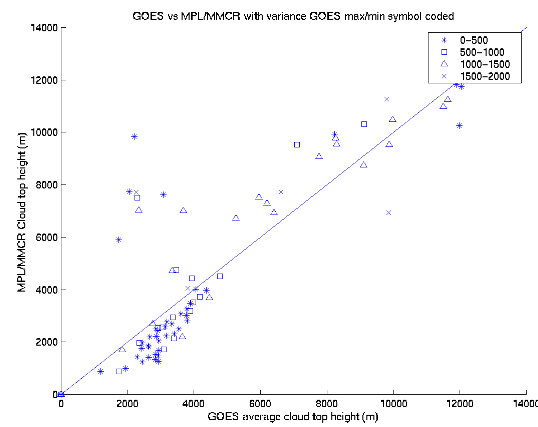

Figure 4: Scatter plot using binning process for MPL/MMCR and filtering out multiple cloud layers. Amount of variance between sounder 3X3 FOV maximum and minimum cloud top height is symbol coded.

At this point after using the two different filtering techniques, significant correlation was seen in the scatter plot. But there still were eight outliers (seen in a cluster in Figure 4 in the upper-left corner) where the GOES sounder were placing the cloud top height around 2000 meters, and the MPL/MMCR cloud top height around 6000 meters-10000 meters. This group of outliers can be seen in Figure 4. Such large variance between the two sources is alarming, so each individual outlier was examined to determine why the discrepancy exists. Six of the eight outliers could be explained by examining the data close up. This was done by going back to the time series plots as seen in Figure 1.

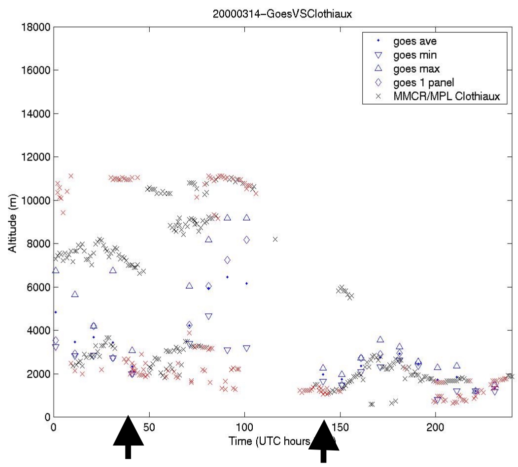

Figure 5: Two instances of outliers that can be explained by examining the time series. Attenuation effects and multiple cloud layers led to the outliers.

After six of the eight outliers were accounted for, they were discarded from the scatter plot. Eliminating these outliers led to an increase in correlation as seen in Figure 6. Of the two remaining outliers that could not be accounted for by manual inspection, both were found to be high cirrus cloud tops.

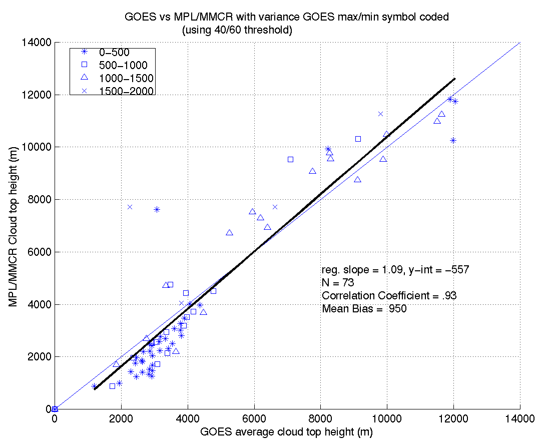

Figure 6: A correlation coefficient of .93 and a mean bias of 950m is seen after application of filtering techniques and removal of outliers.

4. Conclusions

In order to ensure a direct comparison between GOES sounder cloud top height and ground-based MPL/MMCR cloud top height, measures were taken filter out instances of multiple cloud layers. Once this was achieved, high correlation was seen between the two sets of observations. With a mean bias of 950m between the two data sets, the GOES sounder cloud top pressure product can be seen as an accurate instrument. Both of the instances where the GOES sounder had significant error (> 2500m), cirrus clouds were present. The error in the GOES sounder measurement can be attributed to the low optical depth and emmitance of the clouds. This exposes the limits of the current GOES sounder instrument, and demonstrates the need for development of a higher resolution sounder instrumentation.

2. ACKNOWLEDGEMENTS

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