Longwave spectrum simulation with a-train cloud fields

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1. Introduction

CALIPSO and CloudSat provide most accurate cloud vertical profiles today. CALIPSO and CloudSat combined profiles include boundary layer clouds and thin cirrus which often missed by imagers.Using these cloud fields and MODTRAN, we performed series of TOA nadir-view spectral radiance sensitivity studies to cloud properties to understand what atmospheric property changes can be inferred from nadir-view spectral radiance changes.

2. Purpose of the work

To answer the following questions:

1) Does TOA longwave spectral radiance provide enough constrain to uniquely determine atmospheric and cloud properties?

2) If so, what accuracy is needed to detect atmospheric and cloud properties at a climate data record level.

3. CALIPSO-CloudSat derived cloud fields.

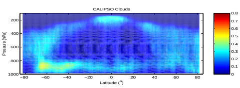

Figure 1: Cloud occurrence probability in 200 m thickness layer and 1 degree latitude zone derived from CALIPSO and CloudSat cloud mask. One month of data were used. In our simulation performed in this study, CALIPSO-CloudSat derived clouds are collocated with CERES footprints. In addition, MODIS derived cloud properties, and atmospheric temperature and water vapor profiles from GEOS-4 analysis were used for computing TOA nadir-view spectral radiances by MODTRAN5.

4. Simulations.

We used data from one CALIPSO-Cloudsat orbit, which contains about 1000 CERES footprints. We selected two regions. Each regions contains about 80 footprints.

1) Compute the mean spectrum for each region. (Resulting two mean spectra are called true spectrum for period 1 and period 2 in Figure 2).

2)Using singular value decomposition and only using the first component, we alter 80 spectra by keeping only the first component (perturbed spectra).

3) Using 1000 spectra as a look-up table, we look for the best matched spectrum to each 80 perturbed spectrum. To pick the best match, we simply use RMS differences from all 2500 wave numbers (all match) and from 750 cm^-1 to 990 cm^-1, 1400 cm^-1 to 1800 cm^-1, and 2180 cm^-1 to 2500 cm^-1 (partial match).

4) We then compare the resulting mean spectrum (retrieved spectrum) with original mean spectrum (true spectrum) and cloud fraction profile associated with them.

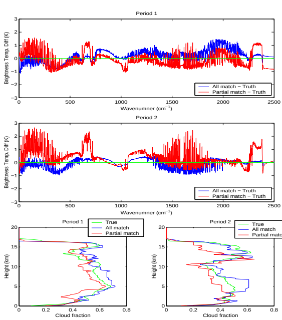

Figure 2: Top and Middle plots) Brightness temperature difference between retrieved and true spectra (retrieve - true). Blue line indicates the difference computed with retrieved spectrum using all spectral regions. Red line indicates the difference computed with retrieved spectrum using part of spectral regions indicated above. Using all spectral regions improves the agreement.Bottom plots) Vertical cloud fraction profiles correspond the mean spectra used for top and middle plots.

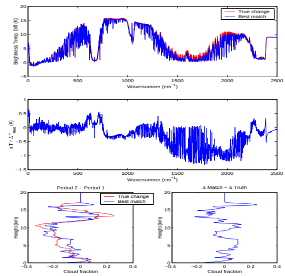

Figure3:(Top) Brightness temperature difference between two periods shown in Figure 2. The differences computed with true and retrieved spectra are plotted by, respectively, red and blue lines. (Middle) The difference between red and blue lines shown in the top plot. Bottom left) Cloud fraction profile difference from two periods. Bottom right) Difference of the cloud fraction profile shown in the bottom left plot.

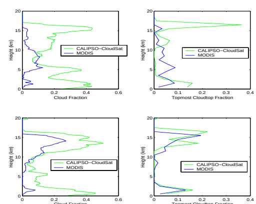

Figure 4: Top and Bottom left) Cloud fraction vertical profile derived from CALIPSO-CloudSat (green) and MODIS (blue). An empirical relation between the optical thickness and cloud base was used to estimate cloud base for MODIS derived cloud top. Top and Bottom right) Vertical profile of cloud fraction computed with topmost cloud top only.

Comparison between Figure 2 and Figure 4 indicates that the vertical cloud fraction profile (not only topmost cloud top profile) might need to be relatively accurate in order to match TOA brightness temperature within 1 K. Cases with more than 1 K brightness temperature are shown in Figure 5 below.

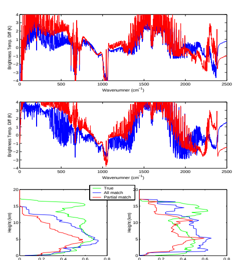

Figure 5:Same as Figure 2 but for difference cases.

5. Nonlinearity.

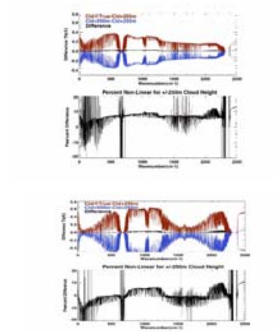

Figure 6:Brightness temperature difference spectra computed with increasing the cloud top height by 250 m and 500 m for ice clouds (top) and water clouds (bottom). Cloud fields from 1000 CERES footprints used in Figure 2 are used.

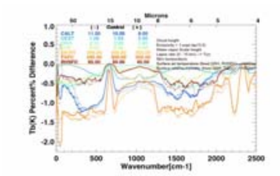

Figure 7: Brightness temperature sensitivity to atmospheric and cloud properties. The sensitivity test was done by one cloud layer.

Comparison of Figures 6 and 7 might indicate that if many spectra are averaged, all spectral regions respond linearly to cloud height change.

8. Summary and recommendations

1) To achieve the brightness temperature to within 1 K, vertical profiles of clouds need to be accurate. This requires more than topmost cloud top vertical profiles.

2) It might be very difficult to infer atmospheric and cloud property differences from the TOA brightness temperature difference.

3) Understanding atmospheric and cloud property changes associated with observed CLARREO nadir view radiance change might be understood by comparing modeled radiances with retrieved cloud and atmospheric properties and observed CLARREO radiances.