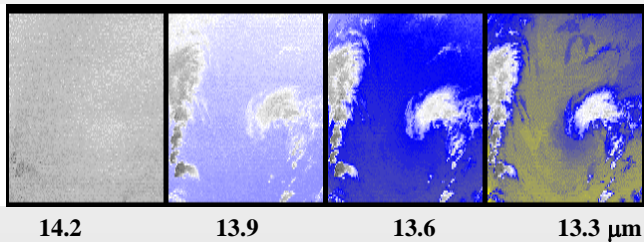


## Cloud Top Properties Algorithm Overview

Cloud-top properties (temperature, pressure, and effective emissivity) are derived using the IR window and longwave CO<sub>2</sub> absorption bands (both day and night) at 5-km spatial resolution. CO<sub>2</sub> slicing infers cloud-top pressure and effective emissivity (cloud fraction times cloud emissivity at 11 μm) using differing partial absorption of several MODIS CO<sub>2</sub> bands near 15 μm, with each band being sensitive to a different level in the atmosphere. Pressure is derived from ratios of differences in radiances between cloudy and clear-sky regions at two spectrally close channels. Adjustments are made for radiance biases so that clear (calculated) and cloudy (observed) radiances are both referenced to the NCEP/EMC Global Forecast System forward calculated radiances. The cloud pressure determined from the most opaque channel pair (with the weighting functions highest in the atmosphere) is selected; this optimizes the sensitivity to high thin cirrus. Thereupon, the effective cloud amount is determined using the cloud pressure and the observed cloud signal in the infrared window channel at 11 μm. For low clouds (> 700 hPa), the CO<sub>2</sub> channel SNR decreases, so the IR window 11 μm brightness temperature is assumed to be the opaque cloud-top temperature and a cloud-top pressure is assigned using the NCEP/EMC GFS temperature profile.

## CO<sub>2</sub> channels see different levels in the atmosphere

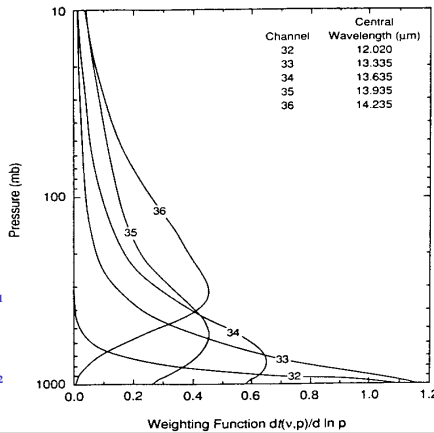


Different ratios reveal cloud properties at different levels

hi - 14.2/13.9  
mid - 13.9/13.6  
low - 13.6/13.3

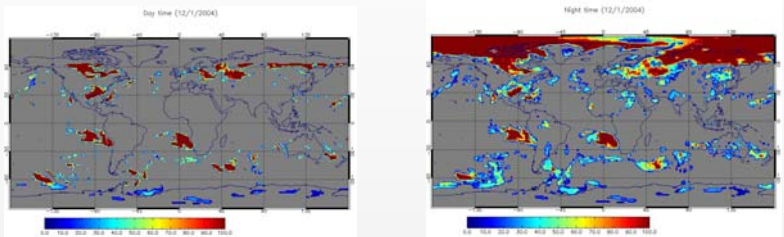
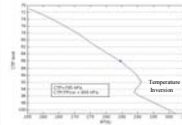
$$\frac{(I_{\lambda_1} - I_{\lambda_1}^{clr})}{(I_{\lambda_2} - I_{\lambda_2}^{clr})} = \frac{\eta \epsilon_{\lambda_1} \int \tau_{\lambda_1} dB_{\lambda_1}}{\eta \epsilon_{\lambda_2} \int \tau_{\lambda_2} dB_{\lambda_2}}$$

Meas      Calc

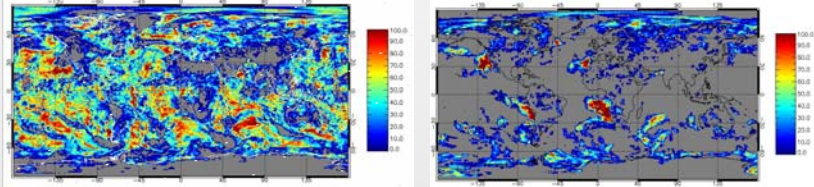


## Low Level Cloud Property Estimation in the presence of Temperature Inversions

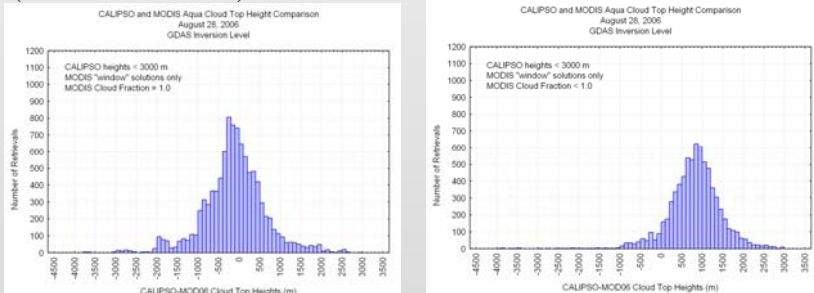
Temperature inversions pose a challenge for cloud property estimation of for low level clouds. CO<sub>2</sub> slicing looks for a solution between the tropopause and the top of the inversion layer. Low level clouds often occur just below the inversion layer. The left figure shows a typical temperature inversion profile found in the GDAS. The frequency of low level temperature inversion at night (figure at right below) is much larger than the frequency at day time (figure at left below). More are found over oceans than land.



Collection 5 frequency of cloud top pressures lower than or equal to 800 hPa (left) and frequency difference between C5 and inversion correction algorithm (right). All clouds with pressure altitudes ≥ 600 hPa were placed at the level of inversion when original height was higher (lower pressure).



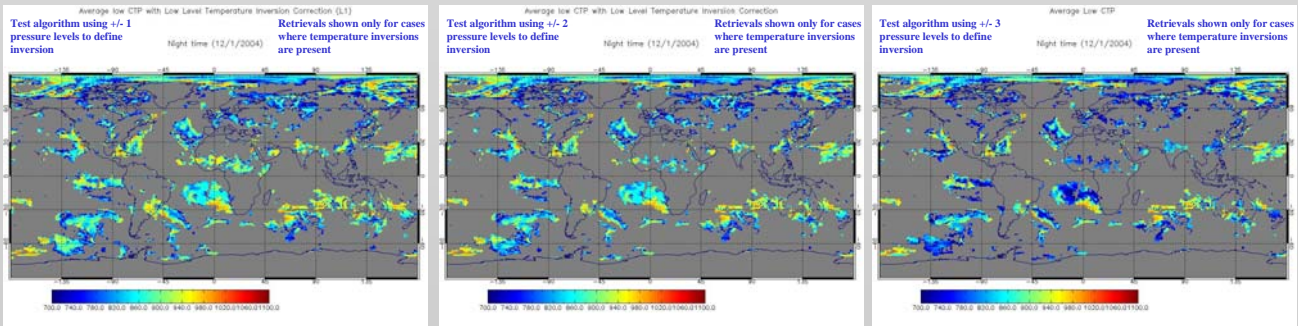
## CALIPSO comparison with adjusted MODIS Aqua Cloud Top Heights (CALIPSO – MODIS)



MODIS CTPs after inversion correction compare well with CALIPSO heights for opaque clouds below 3000 m, but are too low by 1000 m for partly cloudy observations. Further work is needed to mitigate this problem.

## Defining low level temperature inversions

Cloud top properties retrieval is sensitive to the temperature inversion layer thickness. Identification of the presence of an inversion changes if it is consistent +/- 1, +/-2, and +/-3 pressure levels; more low level temperature inversions are found with thinner layers.



Low cloud top pressure with temperature inversion using +/- 1 pressure level

Low cloud top pressure with temperature inversion using +/- 2 pressure level

Low cloud top pressure with temperature inversion using +/- 3 pressure level

## Conclusions

- \* CO<sub>2</sub> slicing places low clouds too high in the atmosphere in the presence of low level inversions.
- \* Temperature inversions occur more often over ocean than over land.
- \* Identification of inversion presence depends on the thickness criteria.
- \* Clouds with pressure altitudes ≥ 600 hPa were placed at the level of inversion when original height was higher.
- \* Results compare well with CALIPSO for low opaque clouds; more work is needed for partly cloudy observations in the presence of inversions.