Altitudes for Marine Stratocumulus Derived from the CALIPSO Lidar and MODIS Data

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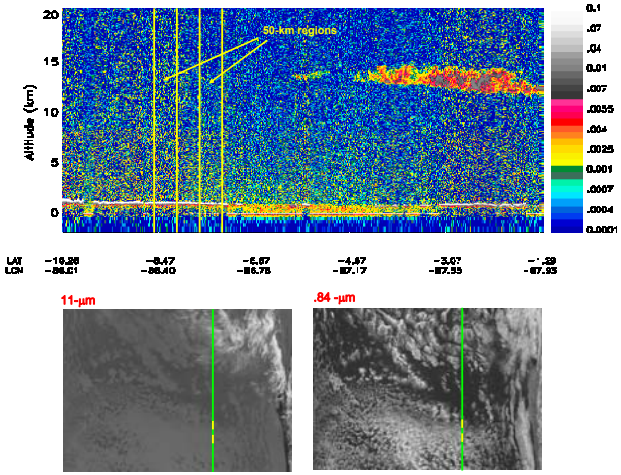


1. Example of 1000-km CALIPSO scene and corresponding MODIS images

Goal: Assess MODIS MOD06 and partly cloudy pixel retrievals of cloud temperatures through comparison with CALIPSO derived heights for marine stratocumulus.

2. Partly Cloudy Pixel Retrieval Method

Retrieval scheme follows Arking and Childs (1985)

- For single-layered cloud systems, identify overcast pixels and determine altitude of cloud layer.
- For each pixel, radiances are given by

$$I = (1 - A_C) I_S + A_C I_C(z_C, \tau, R_e)$$

A_C = Fractional cloud cover within a pixel

I_S = Average cloud-free radiance within a pixel

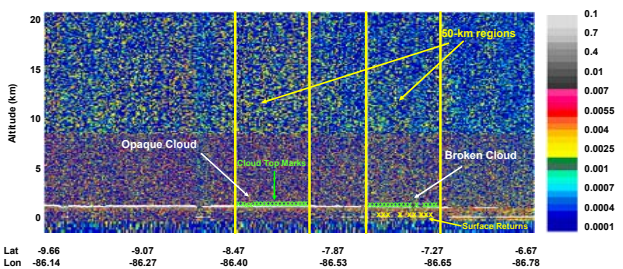
$I_C(z_C, \tau, R_e)$ = Average overcast radiance within a pixel

z_C = Average cloud altitude obtained from nearby overcast pixels

- For each pixel, adjust A_C, τ, R_e so that calculated radiances at 0.64, 1.6, 2.1, 3.7, and 11 μm match those observed.

3. Cloud Top Detection Method

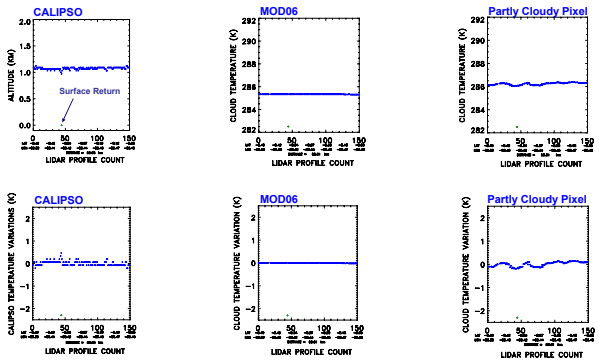
The attenuated backscatter coefficient must be greater than a threshold level of .05 km^{-1} sr in three adjacent levels for a minimum thickness of 90 meters and two adjacent profiles for a minimum width of 600 meters.



4. Analysis Strategy

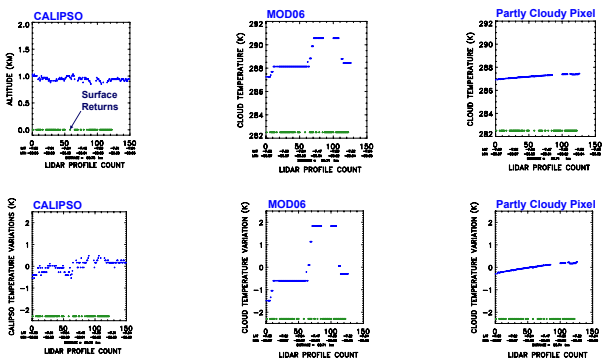
- 50-km scale chosen to ensure large numbers of regions overcast by opaque clouds and containing single-layered systems of broken clouds while avoiding systems of multiple cloud layers.
- MOD06: MODIS Atmosphere operational retrieval.
- Partly cloudy pixel: retrieval that accounts for partially covered 1-km pixels.
- CALIPSO cloud temperatures derived from coincident temperature profile.

Overcast 50-km Scene



All three approaches yield temperature variations no greater than 0.7 K.

Broken Cloud 50-km Scene



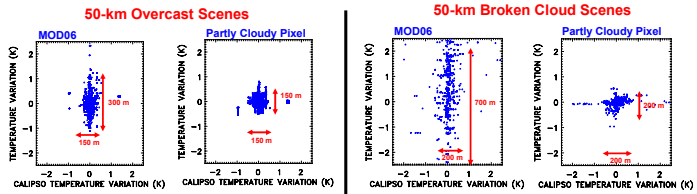
Findings:

- CALIPSO and partly cloudy pixel retrievals limit temperature variations to no more than 1.3 K.
- MOD06 suggests temperature variations of as much as 3.5 K.
- CALIPSO's lowering of altitudes when clouds are broken may be symptomatic of simple cloud detection.
- Large variations in MOD06 cloud temperatures are symptomatic of partially covered 1-km pixels.

5. Composites

- Composites for 41 50-km overcast scenes and 43 50-km broken scenes.

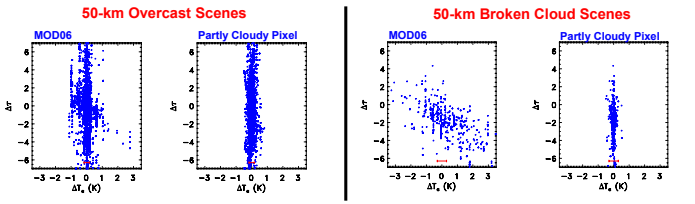
CALIPSO and MODIS Cloud Temperature Variations



All systems agree (within 300 m) on cloud temperature variations when overcast marine stratus is opaque. (Lapse rate assumed to be −7 K/km).

MOD06 temperatures suggest altitudes vary by as much as 700 m when marine stratus is broken.

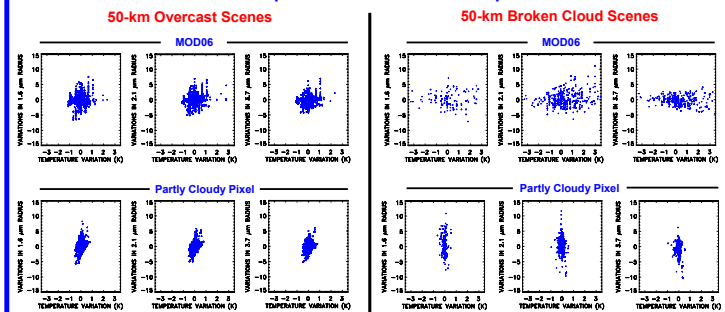
MODIS Cloud Optical Depth and Cloud Temperature Variations



Variations of optical depth with temperature agree for overcast opaque clouds.

MOD06 optical depths related to cloud temperatures as expected for partly cloudy pixels that are assumed to be overcast.

MODIS Cloud Droplet Radius and Cloud Temperature Variations



All approaches agree on droplet radius variations when overcast marine stratus is opaque.

MOD06 suggests that droplet radii derived using 2.1-μm reflectances increase as temperature increases when marine stratus is broken.

6. Future Work

- Correlate CALIPSO derived cloud temperatures with MODIS temperatures.
- Increase sample of 50-km scenes.

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