Marine Boundary Layer Cloud-top-height from MODIS, CALIPSO and COSMIC Over Subtropical Eastern Oceans

Feiqin Xie

Department of Physical & Environmental Sciences
Texas A&M University – Corpus Christi

Coauthors: L. Adhikari (TAMUCC), D. L. Wu (GSFC), R. Wood (UW)

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Liquid water cloud fraction – Aqua

Six selected regions with prevailing boundary layer clouds.

[King et al., 2013]
Marine Atmospheric Boundary Layer Clouds

Cloud photos courtesy of Dr. B. Stevens
Different Cloudy Boundary Layer Structure

I. Stable boundary layer, possibly with non-turbulent cloud
(no cumulus, no decoupled Sc, stable surface layer)

II. Stratocumulus over a stable surface layer
(no cumulus, decoupled Sc, stable surface layer)

III. Single mixed layer, possibly cloud-topped
(no cumulus, no decoupled Sc, unstable surface layer)

IV. Decoupled stratocumulus net over cumulus
(no cumulus, decoupled Sc, unstable surface layer)

V. Decoupled stratocumulus over cumulus
(cumulus, decoupled Sc, unstable surface layer)

Lock et al., 2000, MWR
MBL Height Measurement

• **Vertical profiling**
  – Balloon sounding – profiling \( T/q \)
  – GPS radio occultation (refractivity, bending angle)

• **MBL-top tracer tracking**
  – CALIPSO lidar, clouds and aerosol backscattering
  – MODIS, cloud-top-temperature, cloud fraction
  – Limitation: only works when tracers are available

\[
\Gamma_T = 6.9 \text{ (K/km)} \quad \delta_T = 2.35 \text{ (K)}
\]

\[
C_T H = (S_T - C_T T) - \delta_T \Gamma_T
\]
Stratocumulus-topped MBL

The inversion-base height is consistent with Cloud-top-height.
Lower boundary layer height $\rightarrow$ lower clouds.
GPS Radio Occultation

Neutral atmosphere
(Below ~70 km)

\[ N = 77.6 \frac{P}{T} + 3.73 \times 10^5 \frac{P}{T^2} - 40.3 \times 10^6 \frac{n_e}{f^2} \]

Figure Courtesy of UCAR COSMIC
$T_{\text{dry}} = a_1 * P / N$

Height (km)

Bend

CALIPSO

2008-07-27
MODIS Cloud Measurement

Cloud-top-temperature (K)

Cloud Fraction (%)

$$CTH = \frac{(SST - CTT) - \delta T}{\Gamma_T}$$
MODIS Cloud-top-height
MODIS-CTH - Lapse rate

CTH\textsubscript{MODIS}
- Lapse Rate (LR)
- Cloud Fraction (CF)

CTH\textsubscript{CALIPSO}

GPS (20.34°S, 74.28°W)

LR = 6.9
LR = 7.5
LR = 8.0
MODIS Cloud-top-height

MODIS Lapse Rate CTH & Cloud Fraction

CTH Difference: $\text{CTH}_{\text{LapseRate}} - \text{CTH}_{\text{MODIS-V6}}$
Cloud-Top-Height vs. MBL Height

2007-2010

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Conclusions and Future Works

- MODIS cloud-top-temperature (CTT) along with SST can be used to derive the cloud-top-height (CTH) based on the lapse rate method.
- CALIPSO Cloud-top-height climatology compares well with COSMIC GPS RO with best agreement over stratocumulus region (<200 m) near the coast of subtropical eastern Pacific ocean.
- Significant discrepancy is found over tropical and trade wind region, where broken clouds and weaker boundary layer inversion and moisture gradient complicate the detection of CTH from CALIPSO lidar and GPS RO measurements, respectively.
- The lapse rate method is sensitive to the lapse rate and the cloud fraction. More robust retrieval algorithm need to be developed to offer best quality CTH retrieval.
- CALIPSO and GPS RO offer independent CTH measurements and will be used to verify and improve the MODIS CTH retrieval, which will be used to derive cloud top entrainment rate given the cloud top wind and large-scale subsidence rate estimation.
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