Comparison of Cloud Vertical Structure from Passive Satellite Measurements and ARM Radar-Lidar Measurements

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http://www-angler.larc.nasa.gov/satimage/products.html

Motivation: Need 3-D monitoring of clouds & radiation fields

- Cloud vertical structure well-defined only over ARM surface sites with radar/lidar
  - provides X-Z + time monitoring of cloud & radiation processes
- Cloud horizontal structure determinable from passive satellite data, limited vertical information available
  - provides X-Y-1/2Z + time monitoring
- Global vertical structure statistics can be computed from CloudSat/CALIPSO data
  - use to enhance passive satellite retrievals
    - => provides 3-D + time cloud structure over ARM domains

Objective: Validate 3-D monitoring of cloud structure

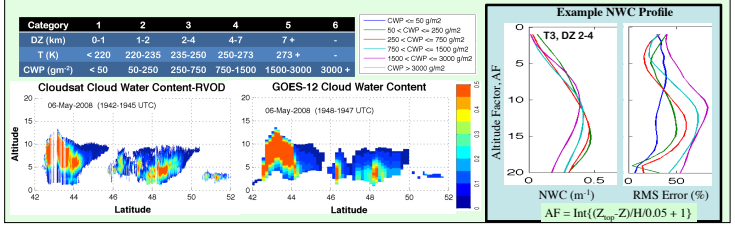
- Compare cloud base & top heights from GOES with SGP radar/lidar (ARSCL): **thick ice only**
- Compare IWC profiles from GOES/CloudSat with IWC profiles based on SGP radar retrievals

Data & Methods

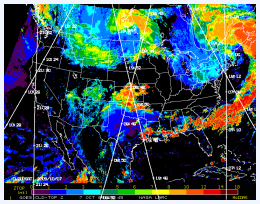
- Cloud properties from GOES-11/12 over SGP using VISST/SIST *(Minnis et al. 2011)*
  - Cloud effective height, Z_{eff}, corresponds to radiating temperature of cloud, T_{eff}
  - Cloud physical top, Z_{top}, ~1.1 optical depth above Z_{eff}: 1- 2 km higher for thick ice clouds
    - computed using formula based on *Minnis et al. (2008)*
  - Cloud thickness estimated as, $H = f(T_{eff}, Re, \ln\tau, WP)$, based on CloudSat/CALIPSO/MODIS data
  - Cloud ice/water path $WP = f(Re, \tau)$
  - Cloud ice/water content $WC(Z) = WP * NWC[T_{eff}, H, WP, (Z_{top}-Z) / H]$
- Cloud top & base heights from ARSCL data *(Clothiaux et al., 2000)*
- Cloud IWC & LWC from SGP MMCR *(Deng & Mace, 2006; Dong & Mace, 2003)*

Normalized Water Content (NWC) Profiles from CloudSat Cloud Water Content- RVOD Product

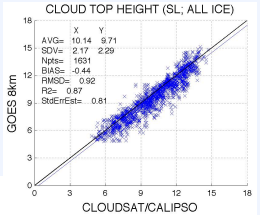
Category	1	2	3	4	5	6
DZ (km)	0-1	1-2	2-4	4-7	7 +	-
T (K)	< 220	220-235	235-250	250-273	273 +	-
CWP (gm^{-2})	< 50	50-250	250-750	750-1500	1500-3000	3000 +



GOES Thick Ice Cloud Top Heights: CALIPSO validation



- Before comparing with ARSCL Z_{top}, GOES Z_{top} must be confirmed using top-down lidar data. Matches performed for May – June 2009 over CONUS domain shown with Z_{top} with overlaid CALIPSO orbit paths. Only single-layer (SL) ice clouds having $\tau > 8$ are used in the comparisons.



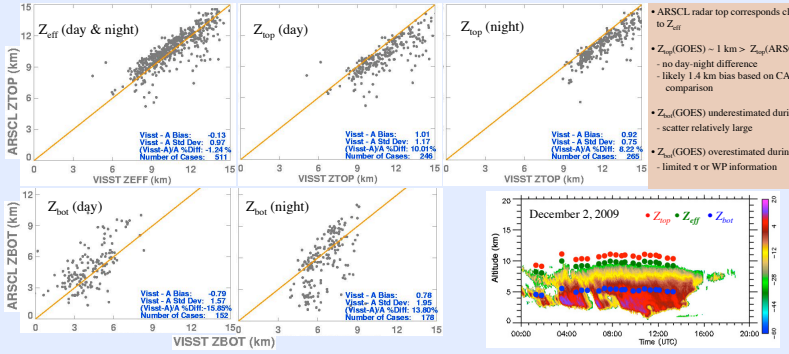
Summary of Biases for T_{eff} Ranges

Te Bin	2011 Bias (km)
ALL	-0.44
Te < 220k	0.26
220 ≤ Te < 235	-0.34
235 ≤ Te < 250	-0.79
250 ≤ Te < 273	-0.63

- Empirical correction for GOES-derived cloud-top height based on MODIS-CALIPSO pairs not sufficient, still too low by 400 m
  - Simple VZA correction may need improvement
- Comparisons with ARSCL can be interpreted properly

Cloud top & Base Heights: ARSCL vs GOES

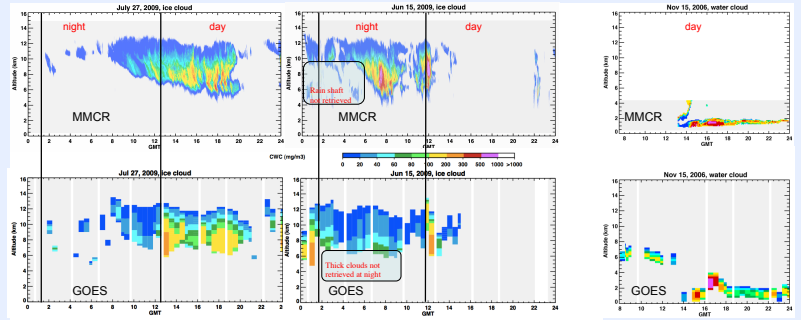
- Match VISST/SIST averages for 20-km radius circle centered at SCF; only ice clouds, All days in 2009 used
  - day: $\tau > 10$, $T_{eff} < 245$ K; night: $\tau > 6$, $T_{eff} < 233$ K
- ARSCL: No $Z_{bot} < 1$ km because CloudSat cannot provide information below 1 km; half-hourly average



- ARSCL radar top corresponds closely to Z_{eff}
- Z_{top}(GOES) ~ 1 km > Z_{top}(ARSCL)
  - no day-night difference
  - likely 1.4 km bias based on CALIPSO comparison
- Z_{bot}(GOES) underestimated during day
  - scatter relatively large
- Z_{bot}(GOES) overestimated during night
  - limited τ or WP information

Cloud Water Content Profiles: MMCR vs GOES

Examples show lower resolution GOES CWC profiles compared to MMCR for 3 cases of variable cloud depths



- GOES profiles capture general behavior of CWC as seen from the surface, but smearing of peaks
- Magnitudes generally consistent, except at night when τ is limited to less than 20, thin cloud profiles ok
- Some height/thickness issues that must be taken into account before quantitative assessment be made
  - e.g., water cloud example: thickness too large spreading LWC too thin & Z_{top} at 17 UTC too large

Summary

- ARSCL thick, ice cloud-top heights too low (1 - 2 km); radar cannot see small xtals at top or thru thick clouds
  - VAP can be developed using matched GOES and radar data to adjust thick high cloud tops
- GOES thick, ice cloud base heights high (low) during day (night) by 0.8 km; improved method needed
- Initial profile comparisons are encouraging, variety of issues still need to be addressed
  - how to make quantitative assessments when heights and thickness errors are separate problems?
  - matching of pixels with radar beam: parallax, size of box, time vs. space, etc.
  - improved resolution possible? Multi-layer clouds? (see Chang poster), how to treat cloud base with precip?

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