Covariability in the monthly mean convective and radiative diurnal cycles in the Amazon

Jason B. Dodson and Patrick C. Taylor

NASA Langley Research Center

jason.b.dodson@nasa.gov

1. Research Focus

Monthly variability in regional radiative diurnal cycles can influence the long term mean radiative balance by up to 7 W m^{-2}. In convectively active regions, such as the Amazon, the convective diurnal cycle is a major contributor to the radiative cycle.

- •Radiative diurnal cycle variability is significantly related to anomalies in multiple atmospheric state variables (ASVs).
- •The frequency and properties of both deep convective cores (DCCs) and anvils (DCAs) are also significantly influenced by anomalies in ASVs.
- •Therefore, deep convection is a likely major link between ASV anomalies and radiative diurnal cycle anomalies.

We use recent satellite observations to investigate the details of this possible link. Information from both DCCs and DCAs are necessary. DCAs have larger radiative effects than DCCs because of their larger areal coverage, and linger long enough after convective termination for stratiform processes to alter cloud properties. However, DCCs are the primary source of hydrometeors, and so also have a significant influence on DCA properties.

Primary questions:

1) What are the significant day/night differences in the observed convective cloud properties, and what is the monthly variability in differences?
2) What is the sensitivity of the observed day/night differences to monthly ASV variability?

2. Data/Methodology

We use conditional sampling of cloud properties observed by CloudSat based on time of day and three ASVs:

- •Free Tropospheric Stability (FTS, defined as 250 hPa equiv. pot. temp. minus 850 hPa)
- •Lower Tropospheric Stability (LTS, defined as 700 hPa pot. temp. minus 850 hPa)
- •250 hPa relative humidity (RH250)

ASVs are provided by an average of the NCEP/NCAR Reanalysis, the ERA Interim, and MERRA

Data are averaged monthly over 25°S to 0°S, 50°W to 70°W, with seasonal cycle removed (denoted as (Var'), from June 2006 to March 2011.

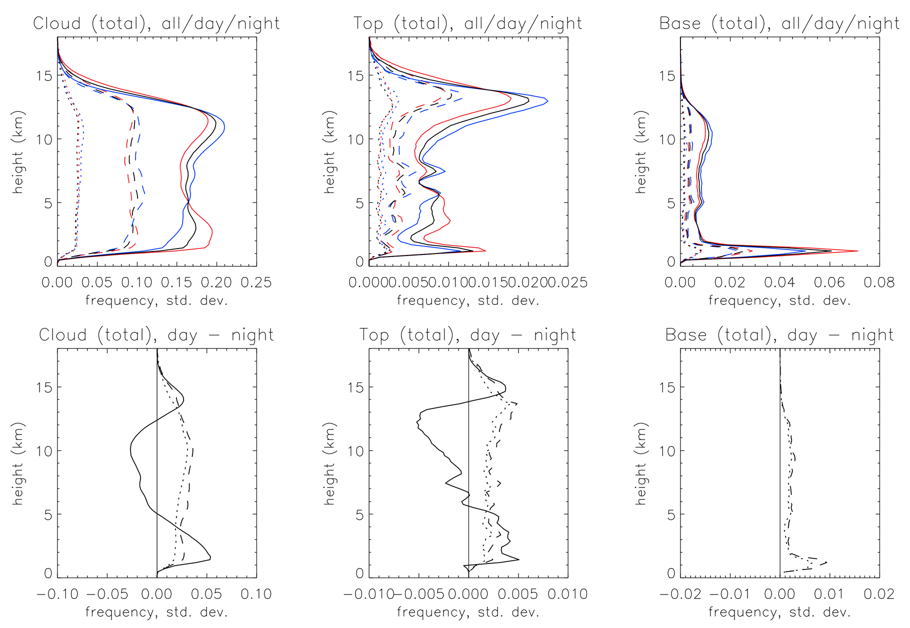
Two types of clouds are examined:

- •DCCs: > 10 km tall, has a max. refl. of 0 dBZ, and a >-5 dBZ reflectivity in the middle troposphere
- •DCA: cloud base > 5 km altitude, contiguously attached to a DCC as observed by CloudSat

5. Conclusions

1) Daytime clouds are more frequent in the upper and lower troposphere than nighttime clouds. While the total cloud variability is mostly explained by seasonal variability, the variability in day/night contrast is related mostly to other factors. [describe DCC varb.]
2) There is an inverse relationship between the frequency and updraft intensity of DCCs. The day/night contrast in COF sensitivity to ASVs is mostly small, except for CU cong. to RH250. DCAs show a different reflectivity sensitivity to ASVs during night than day, indicating different physical processes affecting DCA microphysical structure

3. Cloud Occurrence Frequency

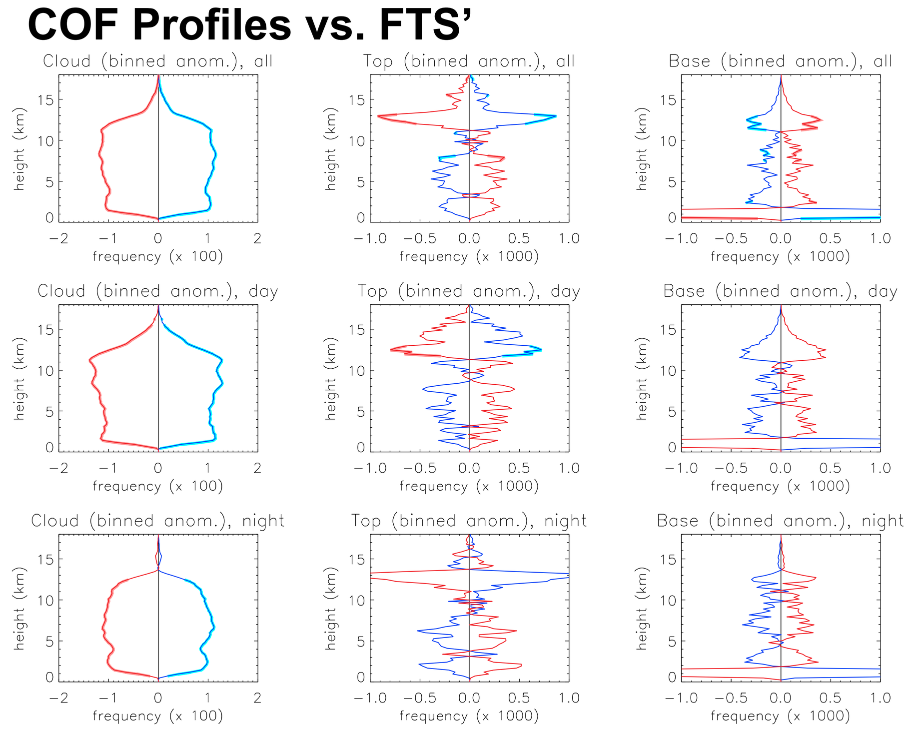


(Top) Vertical profiles of cloud occurrence frequency (COF) (a), cloud top frequency (b), and cloud base frequency (c). Black lines are for day/night, and red (blue) is for day-only (night-only). Solid line is the mean, dashed line is the total variance, and the dotted line is the deseasonalized variance.

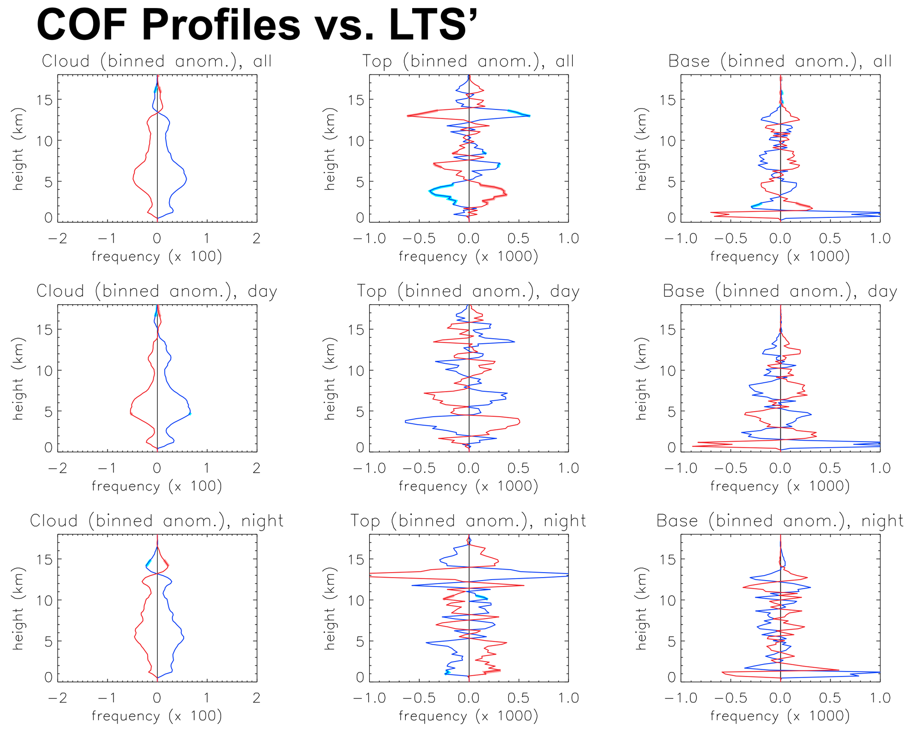
(Bottom) Same as top, but for day minus night.

- •CloudSat shows a tri-modal convective cloud structure (shallow CU, CU congestus, and DCC/DCA), with additional cirrus and a mid-level cloud layer (5-7 km)
- •Low level and near-tropopause clouds are more frequent in day; mid- and upper troposphere clouds are more frequent at night
- •Seasonal variability accounts for ~75% of the total COF variability
- •Seasonal variability accounts for only ~25% of the variability in day/night contrast

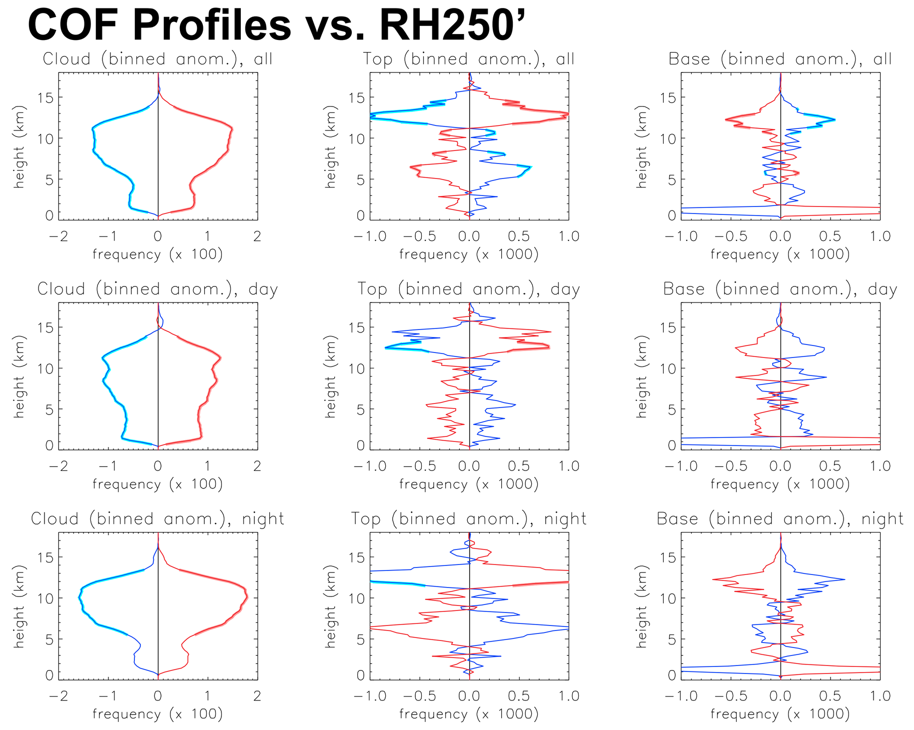
COF Profiles vs. FTS'



COF Profiles vs. LTS'



COF Profiles vs. RH250'



The vertical profiles of COF (left), cloud top frequency (middle) and cloud base frequency (right), sorted by positive (red) and negative (blue) ASV monthly anomaly. Top is day/night, middle (bottom) is day-only (night-only). FTS results are shown in (a), LTS in (b), and RH250 in (c). Highlighted altitudes have statistically significant difference of means at 90%.

- •With negative FTS', COF increases at all altitudes, with shallow CU and CU cong. suppressed in favor of DCCs and high clouds
  - downward shift in cloud base freq. with negative FTS' indicates increased dominance of convective clouds in the atmospheric column
  - no significant day/night difference in FTS' sensitivity
- •When LTS decreases, COF increases at all altitudes except the in tropopause layer, and DCCs and CU cong. are preferred over shallow CU
  - this effect is smaller than those of FTS' and RH250'
- •When RH250 increases, clouds at all altitudes become more frequent, with DCCs and high clouds preferred over shallower clouds
  - nighttime anvil and CU cong. cloudtops show higher sensitivity to RH250' than daytime
  - this may show a negative response of penetrating DCCs to RH250

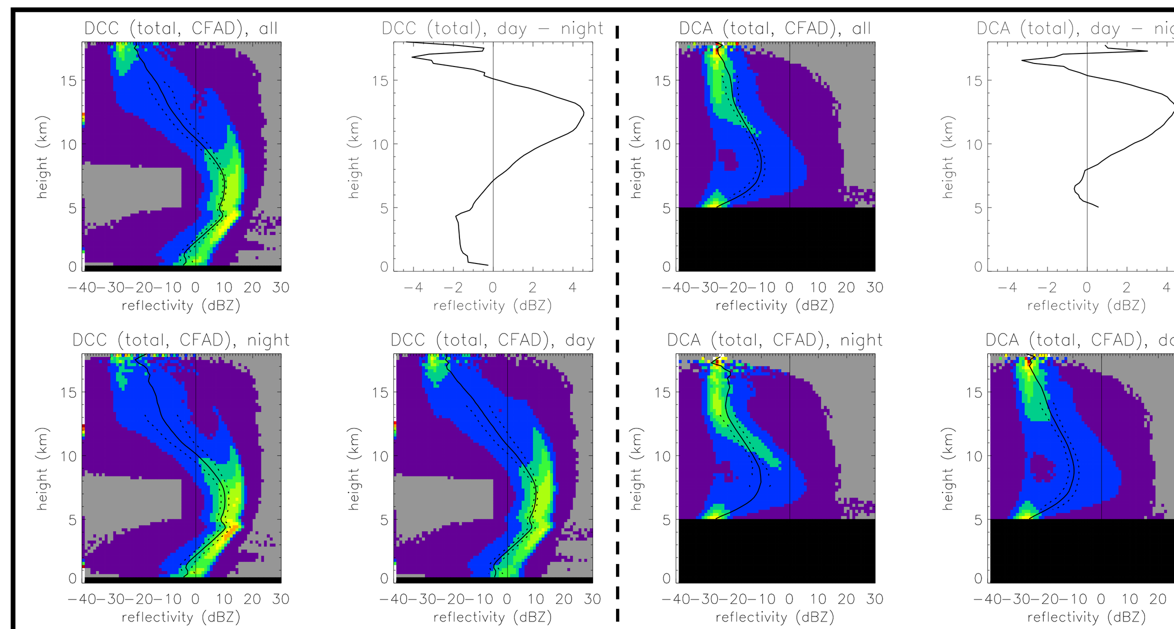
Selected References

Stephens, G. L., D. G. Vane, R. J. Boain, G. G. Mace, K. Sassen, Z. Wang, A. J. Illingworth, E. J. O'Connor, W. B. Rossow, S. L. Durden, S. D. Miller, R. T. Austin, A. Benedetti, C. Mitrescu, and the CloudSat Science Team (2002), THE CLOUDSAT MISSION AND THE A-TRAIN, Bull. Amer. Meteor. Soc., 83, 1771-1790.

Taylor, P. C. [2014], Variability of Regional TOA Flux Diurnal Cycle Composites at the Monthly Time Scale, J. Atmos. Sci., 71, 3484-3498.

Yang, G.-Y. and J. Slingo [2001], The Diurnal Cycle in the Tropics, Mon. Wea. Rev., 129, 784-801.

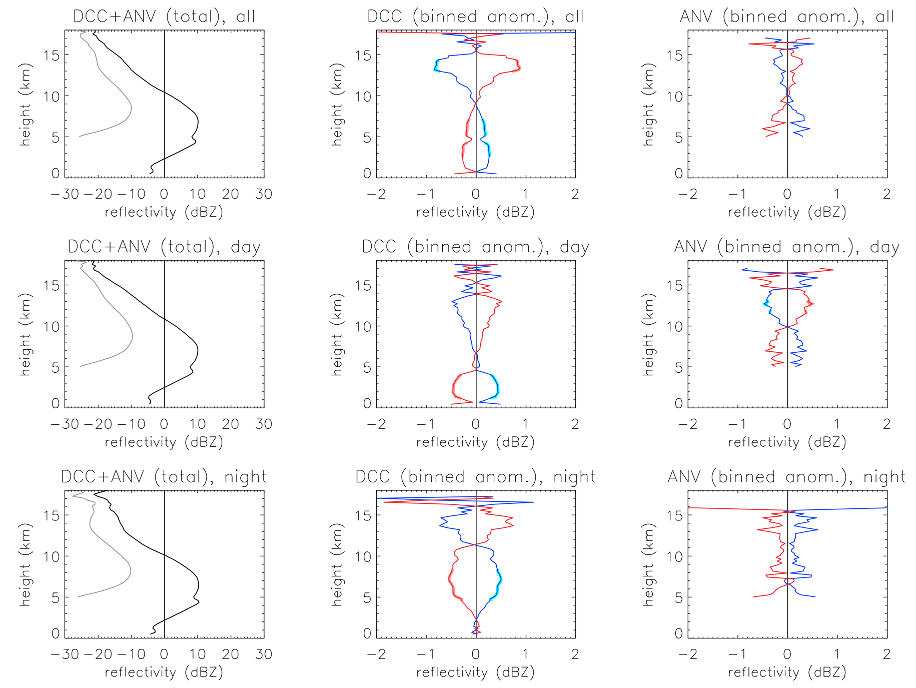
4. Radar Reflectivity



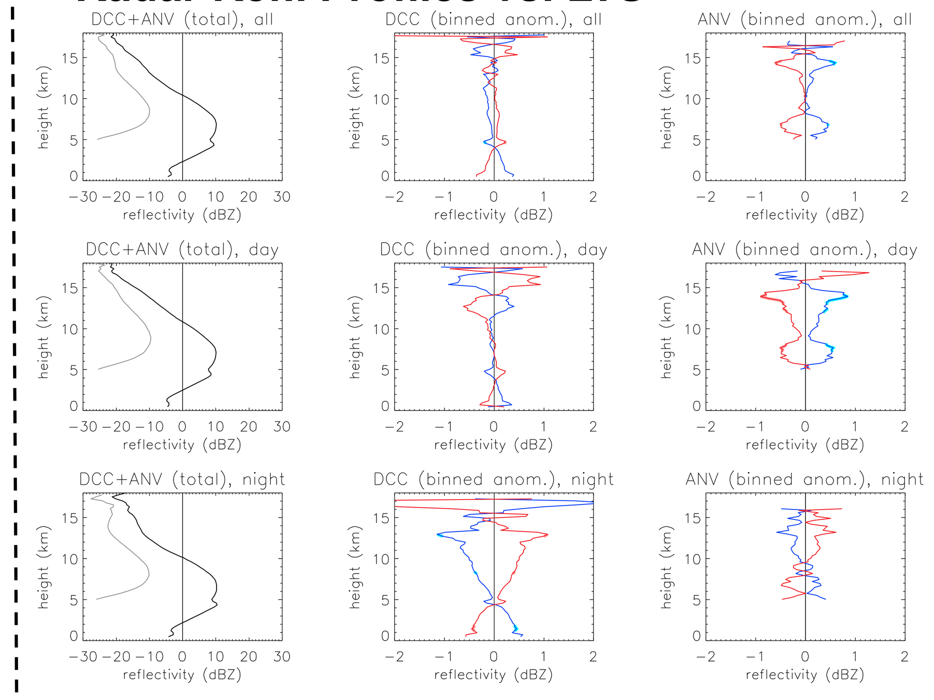
The Contoured Frequency by Altitude Diagrams (CFADs) for (a) DCCs and (b) DCAs. Top left is day/night, and lower left (lower right) is night-only (day-only). The black curves near the center of the data are the average reflectivity profiles. Upper left shows the day mean profile minus night.

- •DCC refl. shows a distinctive double arc shape (caused by graupel/hail and snow in the upper cloud), a dark band near the freezing level, and attenuation by rain below the freezing level
- •Upper tropospheric reflectivity is higher during day (indicates stronger updrafts lofting large hydrometeors, while nighttime reflectivity is higher in the lower troposphere (perhaps lighter rainfall) and near the tropopause.
- •DCA CFADs show similar properties with DCCs above the freezing level, except with a single arc shape – the hail/graupel remains in the DCC, while the snow is detrained.

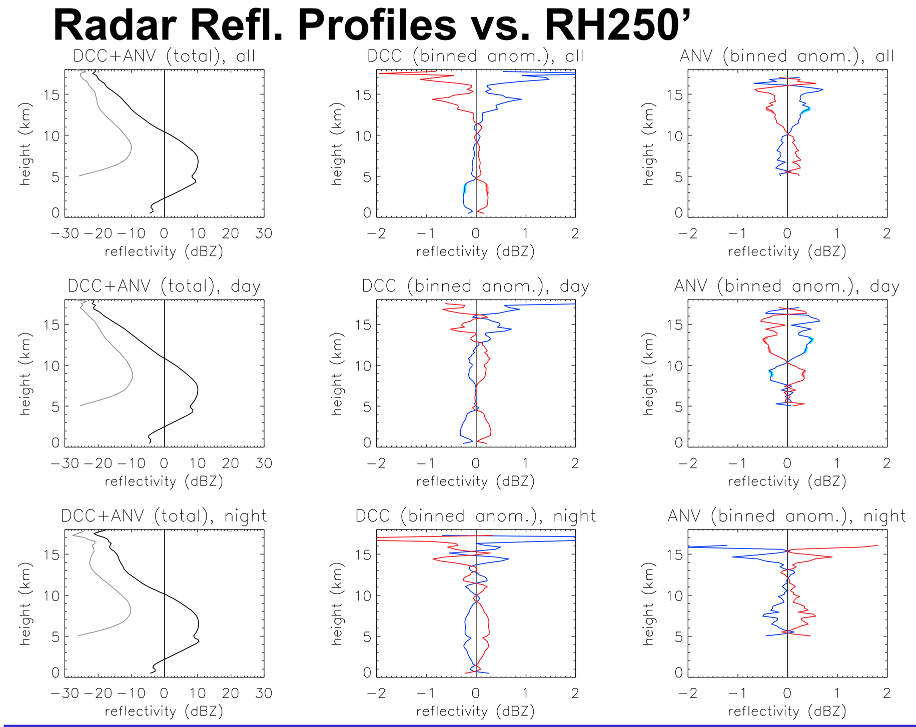
Radar Refl. Profiles vs. FTS'



Radar Refl. Profiles vs. LTS'



Radar Refl. Profiles vs. RH250'



The average vertical profile of radar reflectivity for DCCs and DCAs (left), the DCC profiles sorted by positive (red) and negative (blue) ASV anomaly (middle), and the sorted DCA profiles (right). Top is day/night, middle (bottom) is day-only (night-only). (a) shows the results sorted by FTS', (b) by LTS', and (c) by RH250'. The highlighted altitudes show statistically significant difference of means.

- •The reversed refl. sensitivity between the upper and lower DCC may be indicative of variability in attenuation (heavier rain means lower refl.), or it may indicate a reversed sensitivity of the velocity profile
- •Positive FTS' associates with larger upper tropospheric DCC reflectivity values, indicating stronger updrafts
  - this sensitivity profile also occurs in the anvil top during day, but night anvils have lowered refl. at all altitudes
- •Positive LTS' results in increased upper tropospheric DCC refl. only at night
- •Positive RH250' results in a minor decrease in upper tropospheric DCC reflectivity
  - DCAs have a similar (though opposite sign) sensitivity to RH250' as FTS'
- •There appears to be an inverse relationship between DCC frequency and intensity in the sorted data for all ASVs
  - may be a function of mass continuity

This work has been supported by [funding info get]