# Monthly Covariability of Amazonian Convective Cloud Properties and Radiative Diurnal Cycle

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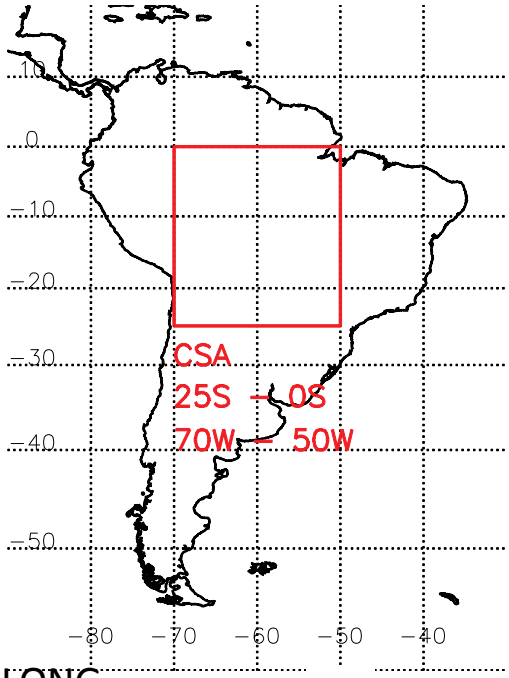
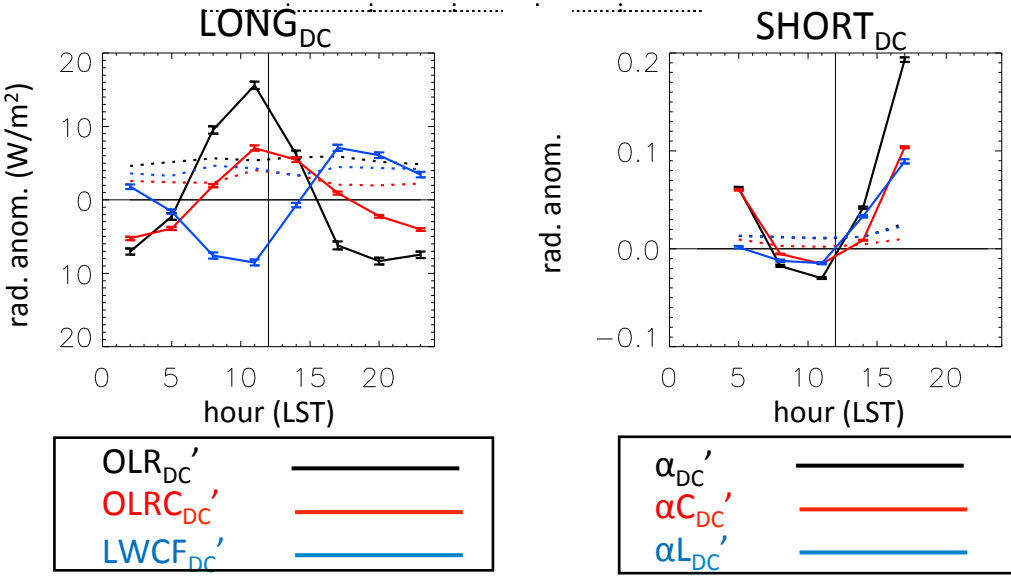
# Introduction

- Variability in the diurnal cycle of the TOA radiative flux contributes to the long term mean imbalance
- However, recent research indicates that in convectively active regions, there is enough variability on monthly time scales to contribute to the total interannual variability of TOA flux balance by up to 7 W m-2 (80%) [Taylor 2014]
- In order to simulate TOA flux realistically, we must understand the causes for monthly variability in the TOA flux diurnal cycle
- Diurnal cycle in cloud properties strongly influence diurnal cycle in TOA flux

# Amazonian radiative diurnal cycle



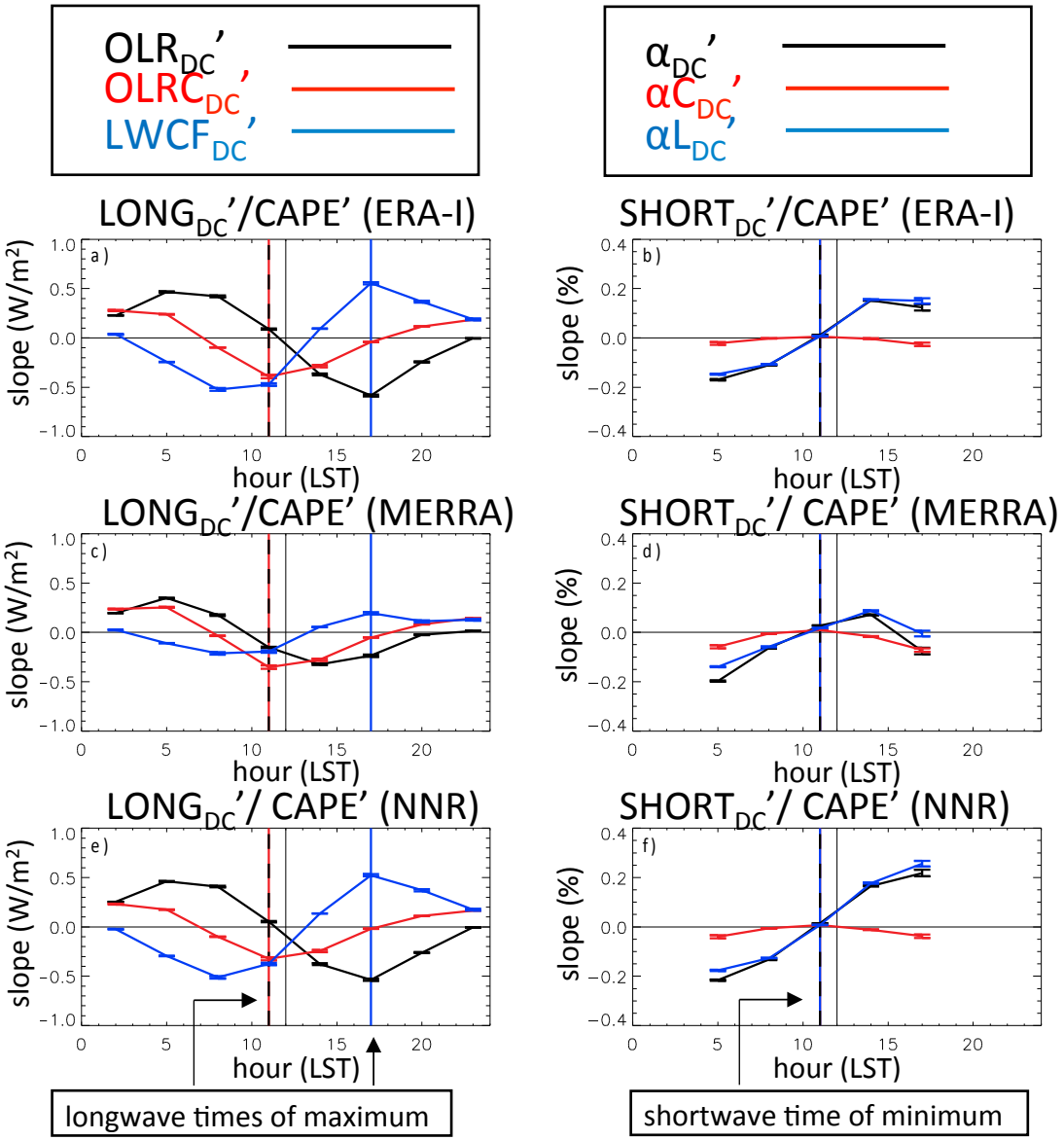




- CERES observations show that both clear sky and cloud diurnal cycles influence the OLR diurnal cycle
- Clear sky follows diurnal cycle of surface heating
- Cloud effect follows the convective diurnal cycle, and shifts the OLR diurnal cycle earlier in the day
- Albedo diurnal cycle is mainly controlled by diurnal cycle in solar incidence angle
- Clouds decrease (increase) morning (afternoon) albedo

# Diurnal cycle sensitivity to reanalysis atmospheric state

- Previous efforts use multiple atmospheric state variables to characterize monthly variability in the convective environment
- Common examples: 500 hPa vertical velocity, CAPE, upper tropospheric humidity, lower tropospheric stability, etc.

# Diurnal cycle sensitivity to reanalysis atmospheric state [from Dodson and Taylor 2016]

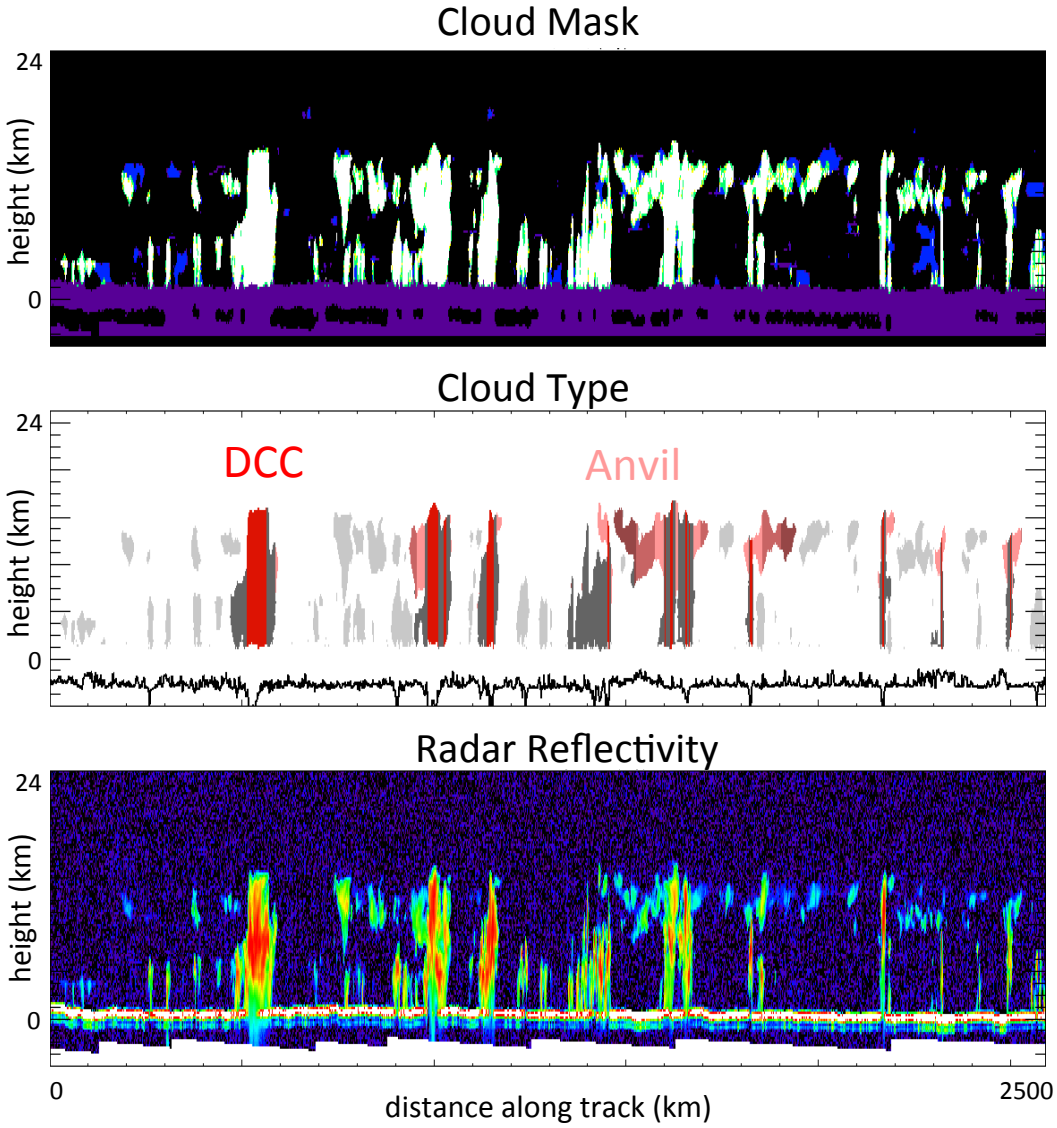



- The monthly anomalies in diurnal cycle of TOA flux variables (3 hr resolution) are regressed against anomalies of atmospheric state variables
- Increased CAPE shifts the time of maximum OLR earlier in the day, and increases afternoon albedo while lowering morning albedo
- For OLR, both the cloud radiative effect and the clear sky effect control the diurnal cycle sensitivity, but the cloud effect is probably the larger effect
- For albedo, the cloud effect is by far the primary driver of the albedo diurnal cycle sensitivity
- Reanalysis results for ERA-Interim, MERRA, and NCEP/NCAR Reanalysis disagree on the magnitude of the longwave sensitivities, and the shape of the albedo curves in the late afternoon

# Alternatives to conventional atmospheric state variables

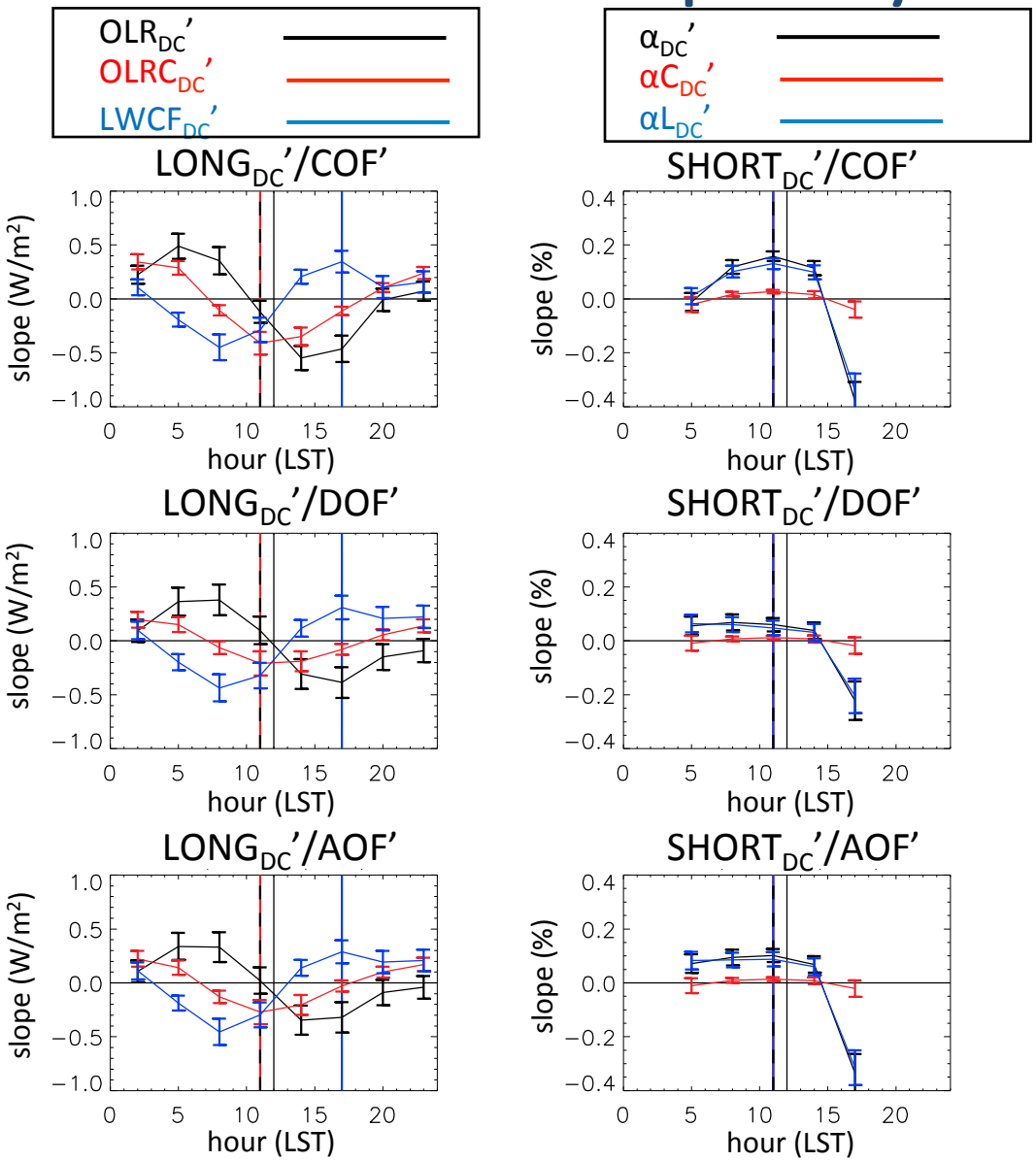
- Satellite observations of clouds can be used as an alternative to reanalysis information of the convective environment
- CloudSat offers observations about several different aspects of convection that may be useful for characterizing monthly convective activity

# CloudSat Data – Identifying convection



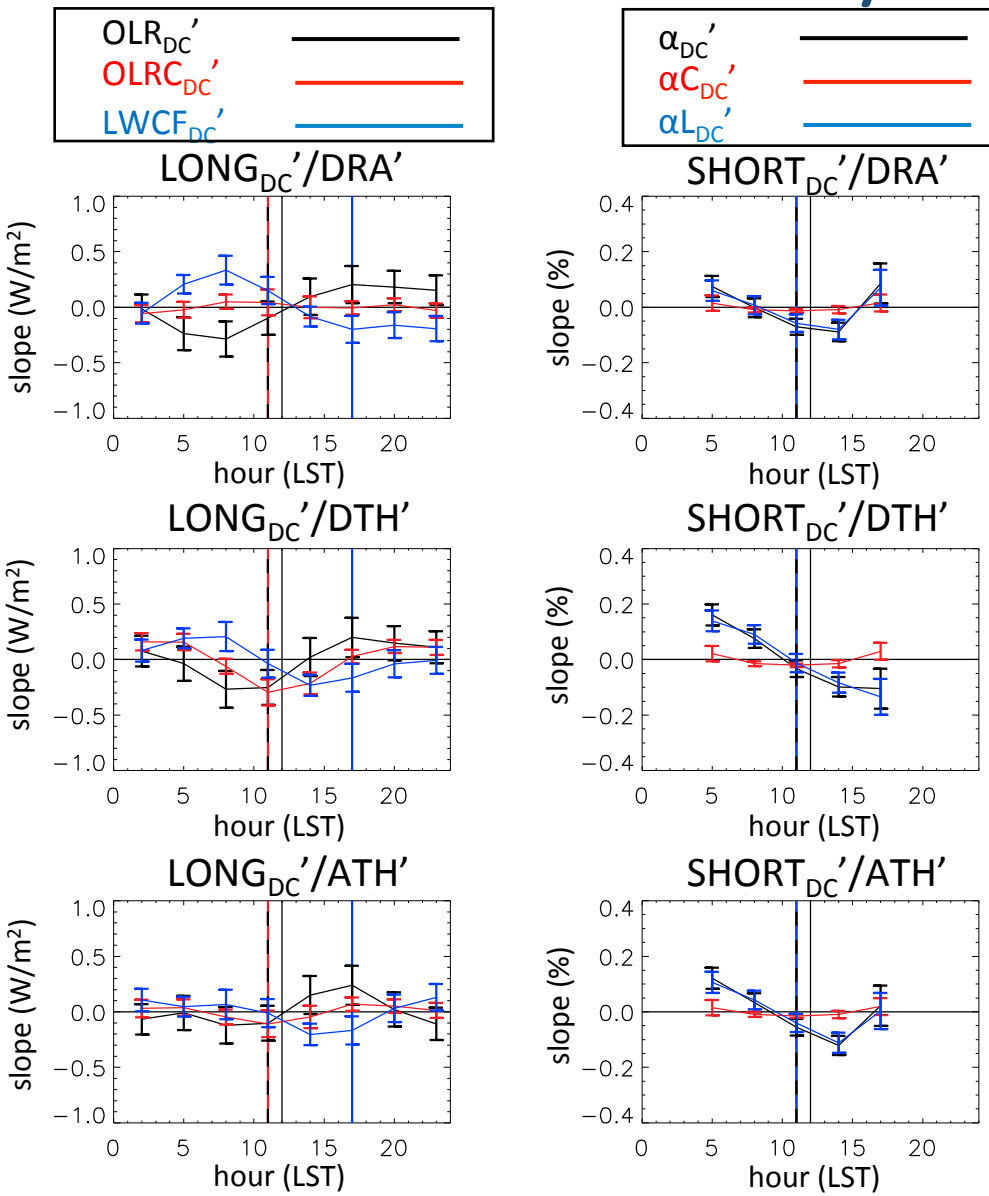

- CloudSat can be used to identify deep convective cores (DCCs) and associated anvil clouds
- DCCs are identified by height and reflectivity criteria, on a single vertical profile basis
- Anvils are identified as middle- to high clouds that are contiguously attached with a DCC

# Diurnal cycle sensitivity to CloudSat convective frequency



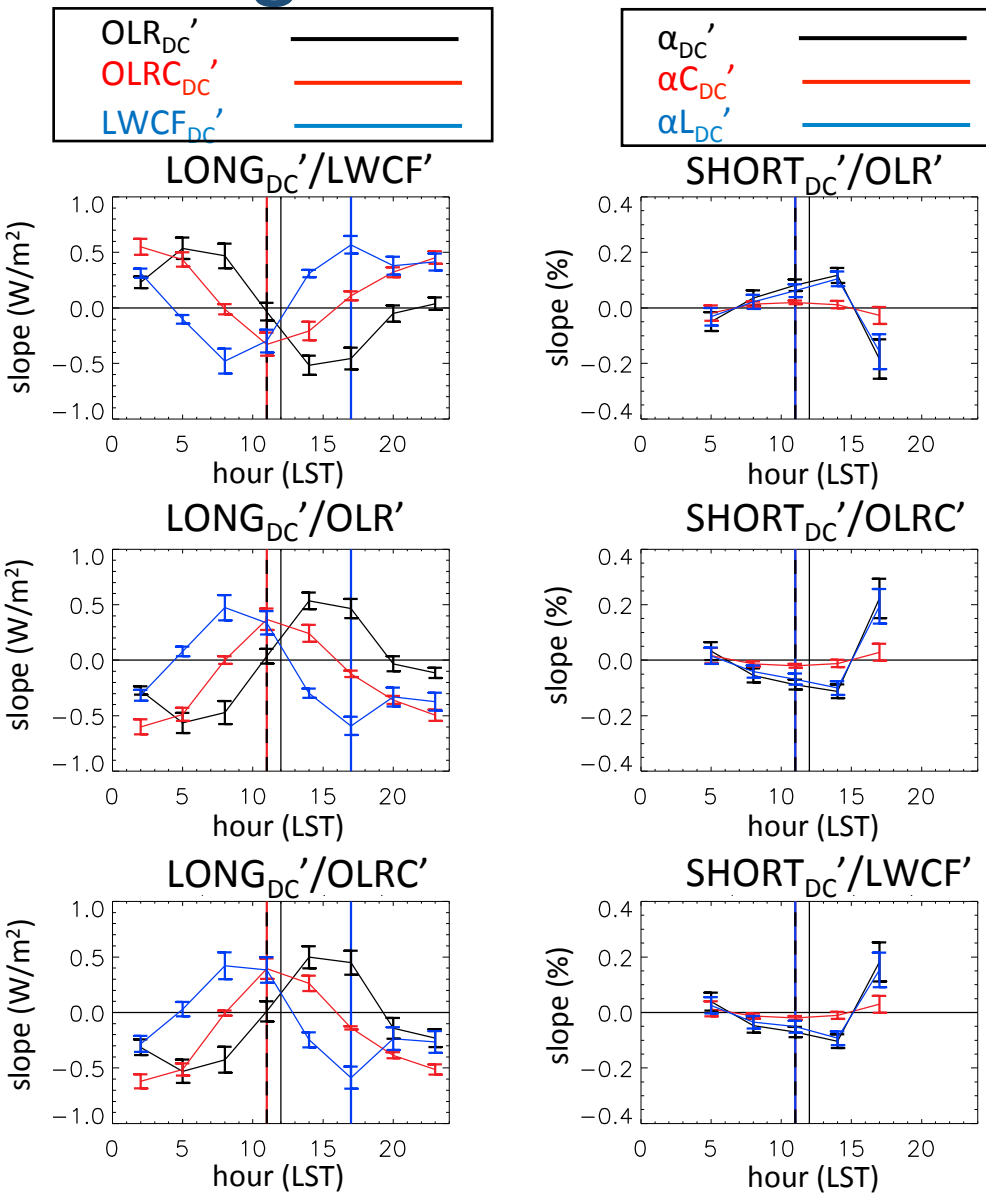

- The most simple is cloud occurrence frequency, for all clouds (COF), DCCs (DOF), and anvils (AOF)
- The longwave sensitivity to COF' monthly variability closely resembles the sensitivity to CAPE' in both timing and amplitude
- The results for COF', DOF', and AOF' closely resemble each other
- The shortwave results differ from the CAPE' results

# Diurnal cycle sensitivity to CloudSat convective intensity and top height




- The DCC upper cloud reflectivity anomaly (DRA) is a proxy for the updraft intensity
- The longwave and shortwave sensitivities to DRA' are the opposite of the sensitivity to cloud frequency
- The cloud top heights for DCCs (DTH) and anvils (ATH) are often used as proxies for convective intensity
- The DTH' and ATH'-based results also have the opposite sign to cloud frequency, as well as smaller magnitude for longwave
- Different metrics for convective intensity give different answers

# Diurnal cycle sensitivity to CERES longwave TOA flux

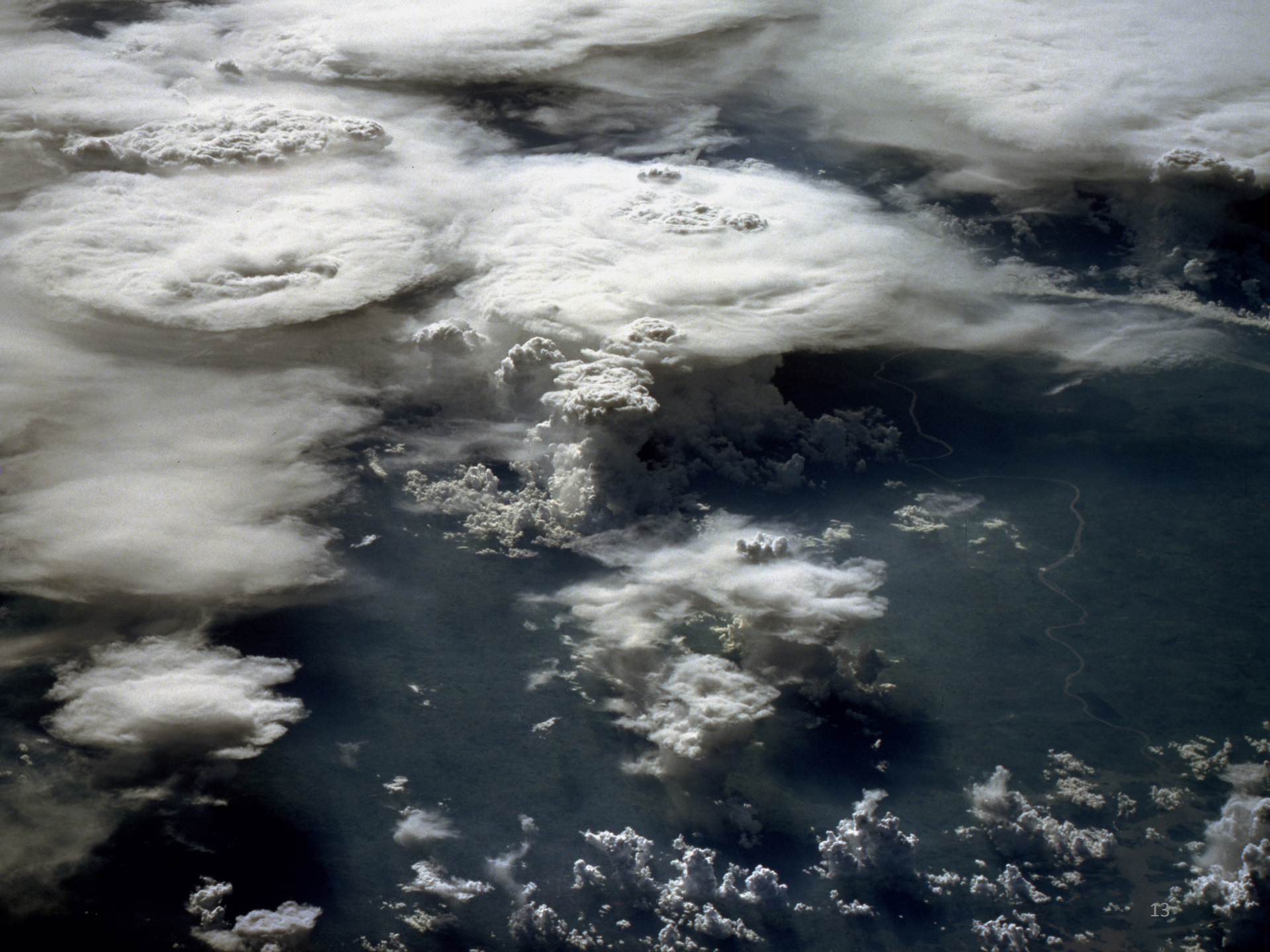



- We can use CERES observations to support or refute the CloudSat results
- OLR and LWCF are commonly used as proxies for convective intensity
- The LWCF' sensitivity results are very similar to the COF' sensitivity results
- Both OLR' and OLRC' results are similar to LWCF' results after accounting for negative sign
- The CERES results support the conclusion that convective frequency most strongly controls diurnal cycle variability, and other convective variables have minor secondary roles

# Conclusions

- The CloudSat sensitivity results depend strongly on which index of convective activity is used
- CERES results support the conclusion that convective frequency is the primary influence on the radiative diurnal cycle variability, and other convective variables are of secondary importance

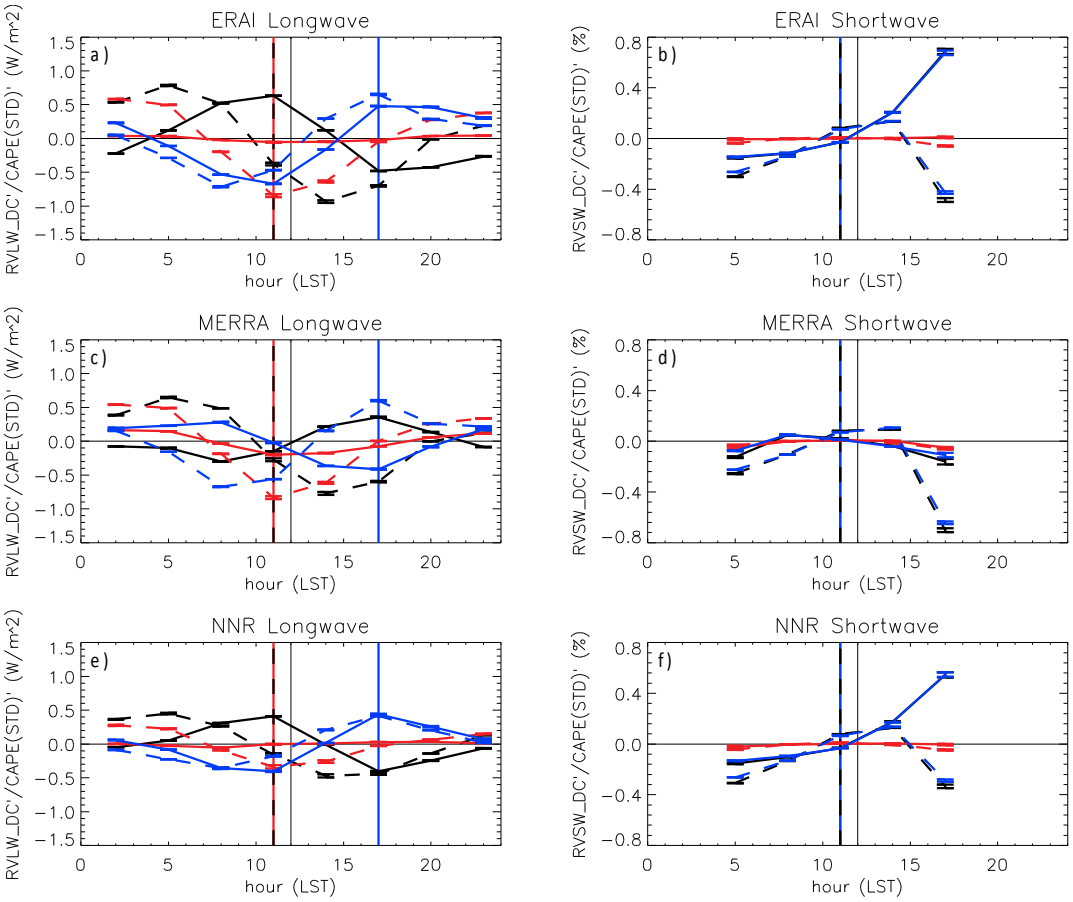
# fin



# [EXTRA] Data Sources

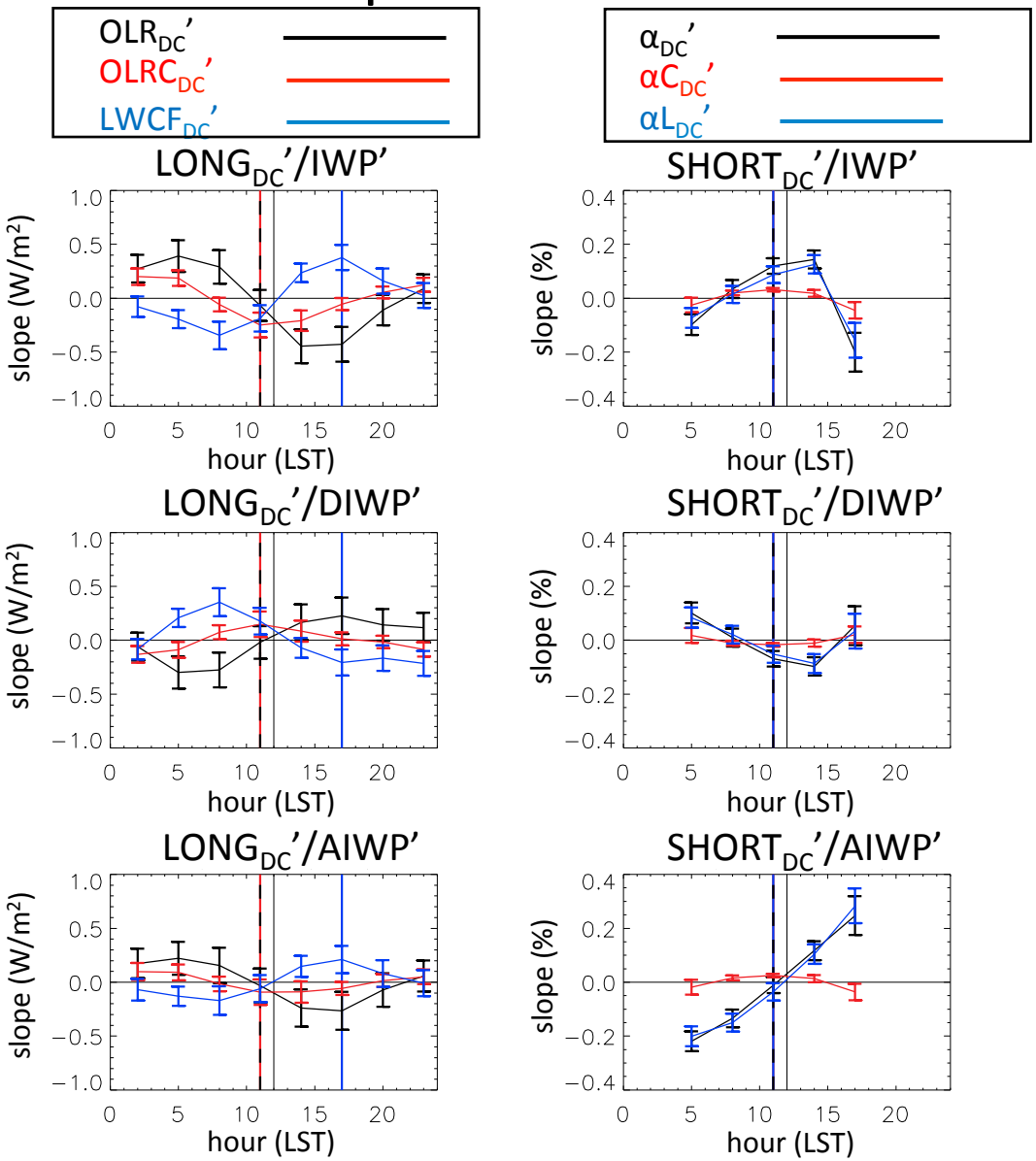
- CERES
  - observes diurnal cycle of TOA flux
  - diurnal cycle enhanced by geostationary observations
- Reanalysis
  - three used for comparison
    - ERA-Interim
    - MERRA
    - NCEP/NCAR Reanalysis (NNR)
  - used to estimate monthly variability of CAPE, upper tropospheric humidity, lower tropospheric stability, etc.
- CloudSat
- used to observe convective anvils, upper convective cores

# [EXTRA] Diurnal cycle sensitivity to reanalysis atmospheric state




- Disagreements between reanalyses become larger when the data are subset into wet vs. dry seasons
- For wet season only, MERRA disagrees with ERA-I and NNR on both timing and amplitude of longwave and shortwave diurnal cycle sensitivities to CAPE'
- ERA-I and NNR disagree on amplitude of longwave sensitivity
- Other disagreements arise from using other ASVs not shown
  - MERRA is not the sole problem
- These disagreements suggest an alternative data source representing the atmospheric state is necessary to improve robustness of conclusions

# Diurnal cycle sensitivity to CloudSat atmospheric state




- Ice water path (IWP) is another proxy for convective intensity, frequently used in evaluating climate models
- The disagreement in IWP results highlight the disagreement
- The sensitivity to IWP' results have the same sign and similar magnitude to COF'
- However, the sensitivity to DIWP' results have the opposite sign to and smaller magnitude than the DOF' results
- The longwave sensitivity to AIWP' are the same sign as, but smaller magnitude than, the AOF' results
- The results for ice water content are similar to IWP