Cirrus Production by Tropical Mesoscale Convective Systems

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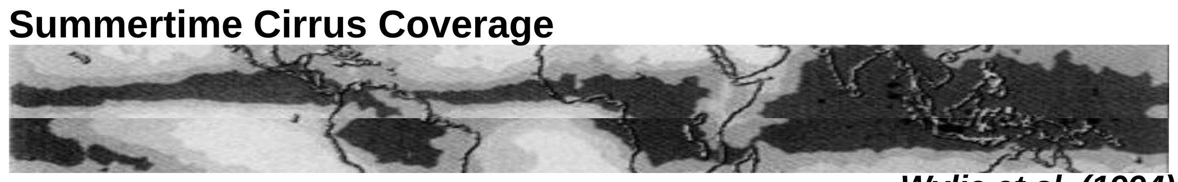
Motivation

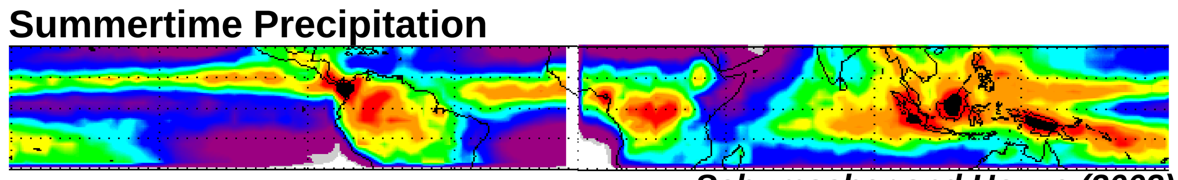
Atmospheric heating by high clouds is important for tropical circulation. Many of the high clouds in the tropics are intimately tied to the mesoscale convective systems (MCSs) producing most tropical precipitation.

Summertime Cirrus Coverage



Wylie et al. (1994)

Summertime Precipitation



Schumacher and Houze (2003)

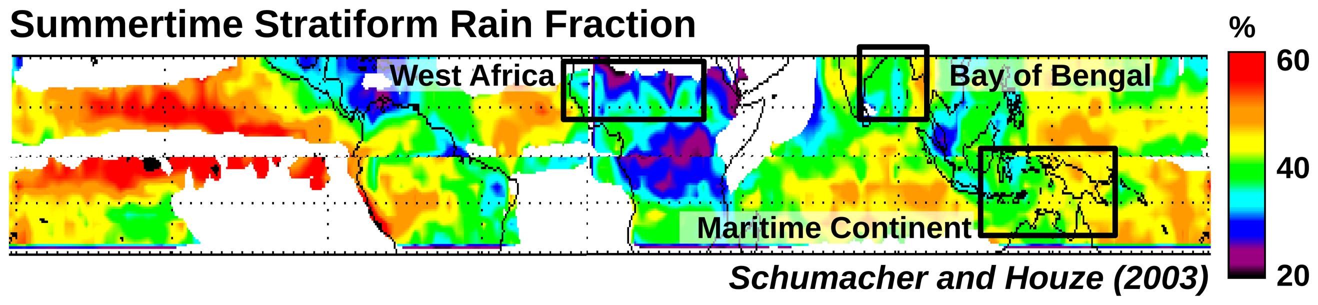
The goals of this study are to:

- Establish the characteristics of precipitation and anvil regions of tropical MCSs
- Relate ARM site ground-based observations to satellite observations of MCS anvils
- Expand the conceptual model of cloud and precipitation structure of MCSs

Regions of Interest

MCS characteristics vary from one tropical location to another. We focus on three different tropical locations, chosen because of their monsoon environments and because of the availability of time-continuous ground- or ship-based cloud radar observations.

Summertime Stratiform Rain Fraction



Schumacher and Houze (2003)

<u>West Africa</u>: continental monsoon climate, squall-line MCSs, site of the 2006 AMMA project (ground-based scanning precipitation radar and ARM WACR)

<u>Maritime Continent</u>: island monsoon climate, massive MCSs, long-term data set of scanning precipitation radar and ARM MMCR at Darwin, Australia

<u>Bay of Bengal</u>: oceanic monsoon climate, southward propagating MCSs, site of the 1999 JASMINE project (ship-borne scanning precipitation radar and a vertically pointing cloud radar)

Methodology

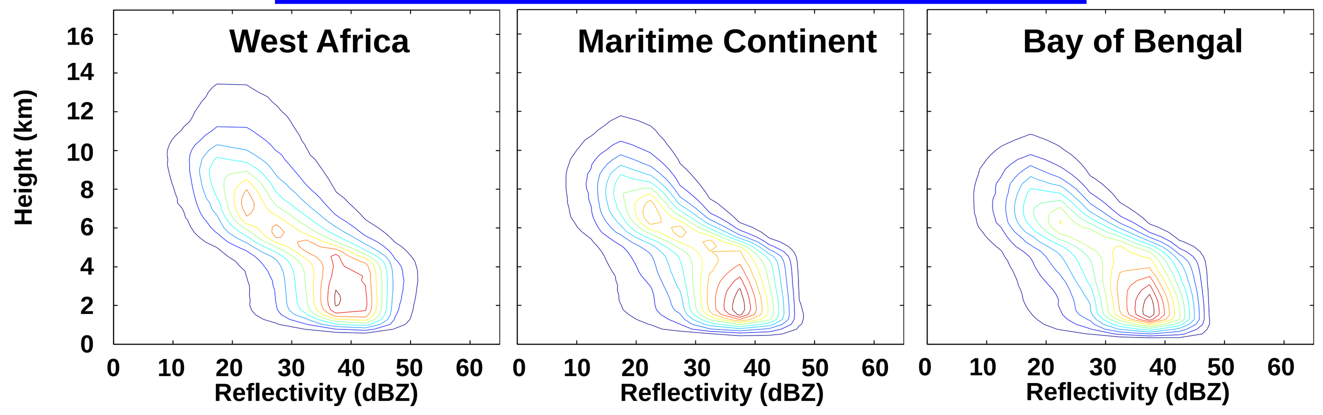
Create climatologies of TRMM Precipitation Radar (PR) and CloudSat reflectivities from each of the three regions ONLY for MCSs during the following monsoon seasons:

- W. Africa: 2006 monsoon season
- Maritime Continent: 2006-2007 monsoon season
- Bay of Bengal: 2006 monsoon season

Hourly IR geostationary satellite data insured that the data collected was from MCSs.

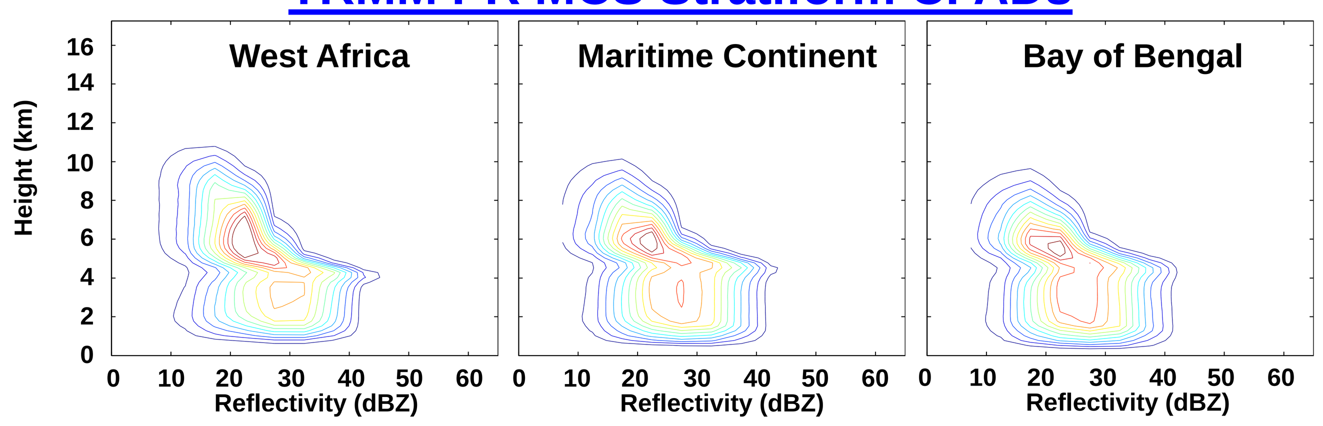
Precipitation Climatologies

TRMM PR MCS Convective CFADs



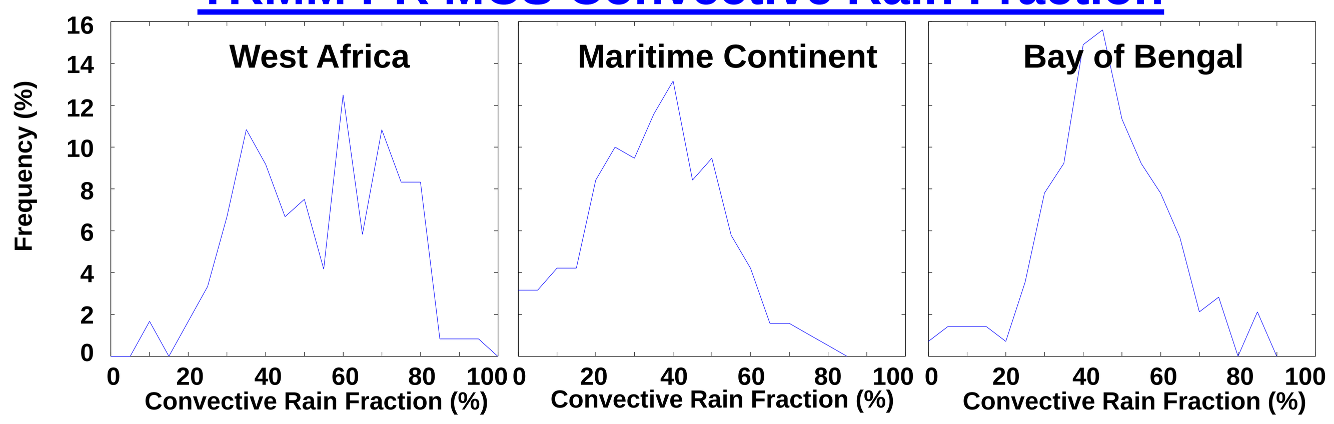
- Convective precipitation in W Africa MCSs is taller and more intense
- Convective precipitation in Maritime and Bengal MCSs is similar, with Maritime being slightly taller

TRMM PR MCS Stratiform CFADs



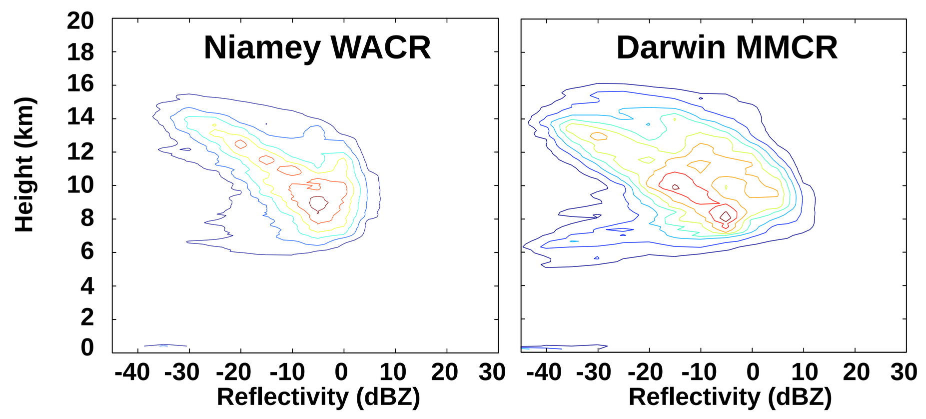
- Stratiform precipitation in W Africa MCSs taller and high reflectivities aloft, indicating large ice aloft
- Stratiform precipitation in Maritime MCSs slightly taller and with higher reflectivities aloft than Bengal

TRMM PR MCS Convective Rain Fraction



- West Africa has very high convective rain fractions in MCSs, indicating stratiform regions that are smaller and/or shorter in duration
- Maritime Continent has lowest convective rain fraction, influence of monsoonal systems with large, long lasting stratiform regions
- Bengal distribution indicates moderate convective rain fraction, and narrow distribution shows that MCSs in that region are very similar to each other

ARM Ground-based Validation



- Ground-based ARM WACR deployed at Niamey, Niger in West Africa during summer of 2006
- Ground-based ARM MMCR deployed at Darwin, Australia in the Maritime Continent (long-term dataset)
- Statistics of reflectivity CFADS for thick anvil (>6 km) from CloudSat and ARM vertically pointing cloud radars indicate that the ground-based instruments are capturing similar features
- CloudSat and TRMM only provide snap-shot views of MCSs. Ground-based instruments at Niamey and Darwin will allow for a time-continuous view of the precipitation and anvil systems, so it is important to use case-studies from these regions to analyze the evolution of the anvil production

Summary

- Anvil height and density in MCSs influenced by convective intensity and amount
- Anvil longevity possibly related to the amount of stratiform precipitation (need case studies)

<u>West Africa MCSs</u>

Deep, intense convection, small stratiform area

Anvils shallower, but high IWP

<u>Maritime Continent MCSs</u>

Moderate convection, large stratiform areas

Deep anvils

<u>Bay of Bengal MCSs</u>

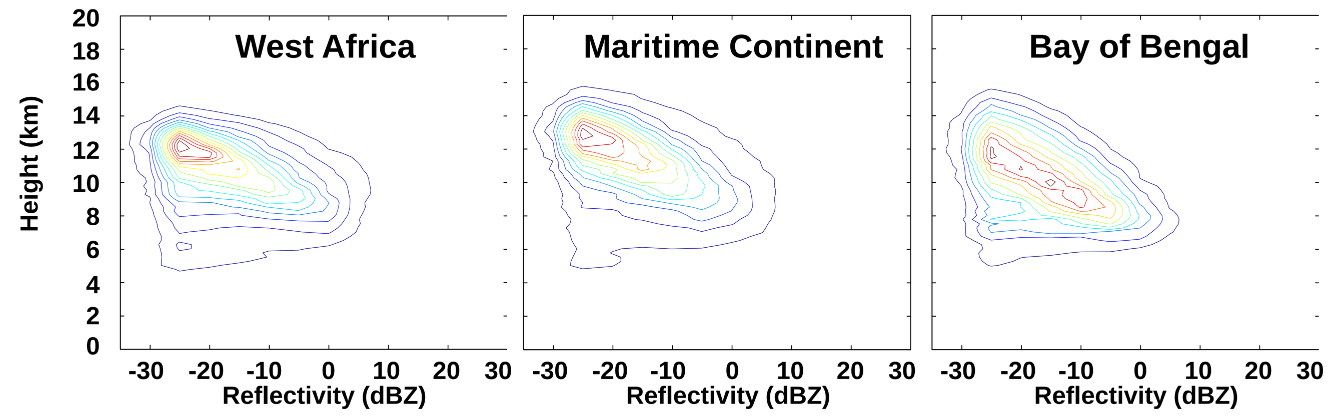
Moderate convection, moderate stratiform areas

Deep anvils

- Consistency of time-continuous ARM site radar data with CloudSat implies that ARM data will provide physical and dynamical insight into CloudSat-based climatologies

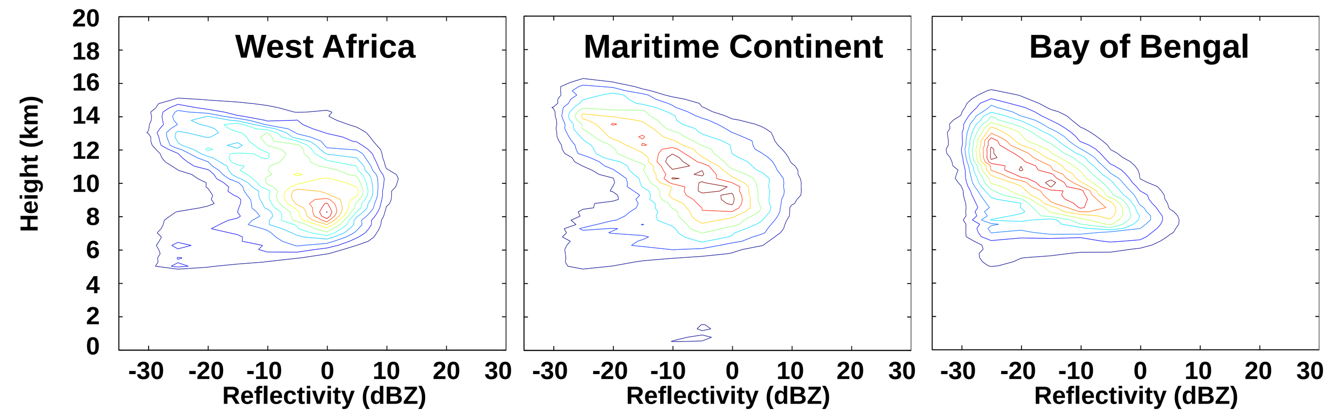
Anvil Climatologies

CloudSat MCS Anvil CFADs



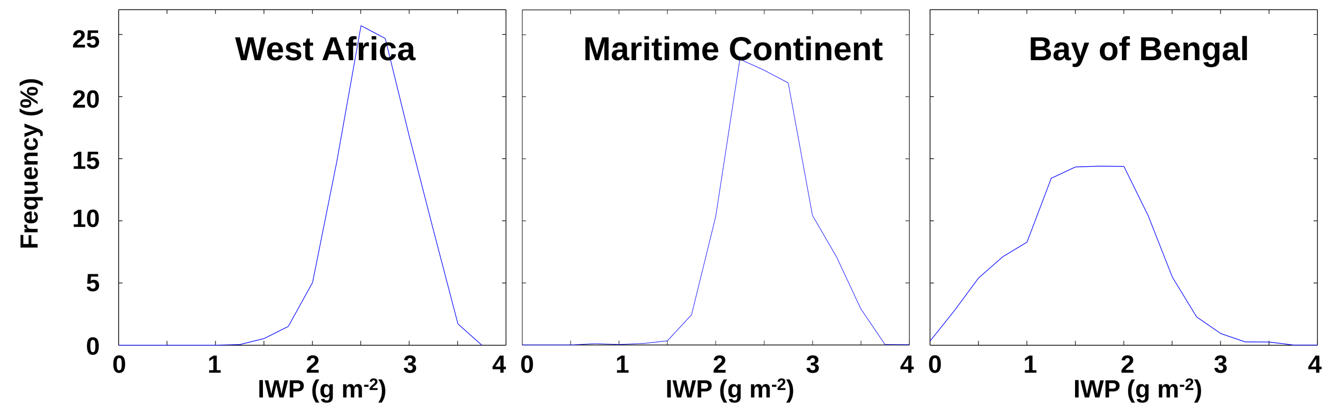
- W Africa anvil clouds have lower tops (even though convection is deeper!!)
- Maritime anvil clouds reach the highest

CloudSat MCS Thick Anvil CFADs



- Thick anvil defined as anvil greater than 6 km thick
- Thick anvil in all regions have double minima, indicating high frequency of high reflectivity near cloud bottom
- Lower maximum likely due to large aggregates?

CloudSat MCS Thick Anvil Ice Water Path



- High IWP for W Africa thick anvils, Maritime moderate IWP (mostly due to thicker anvil), Bengal low IWP
- Ice particles in intense W Africa convection likely larger, so particles are heavier and fall out rapidly producing very dense anvils (high IWP) but with lower tops