Understanding the effects of aerosols on deep convective clouds

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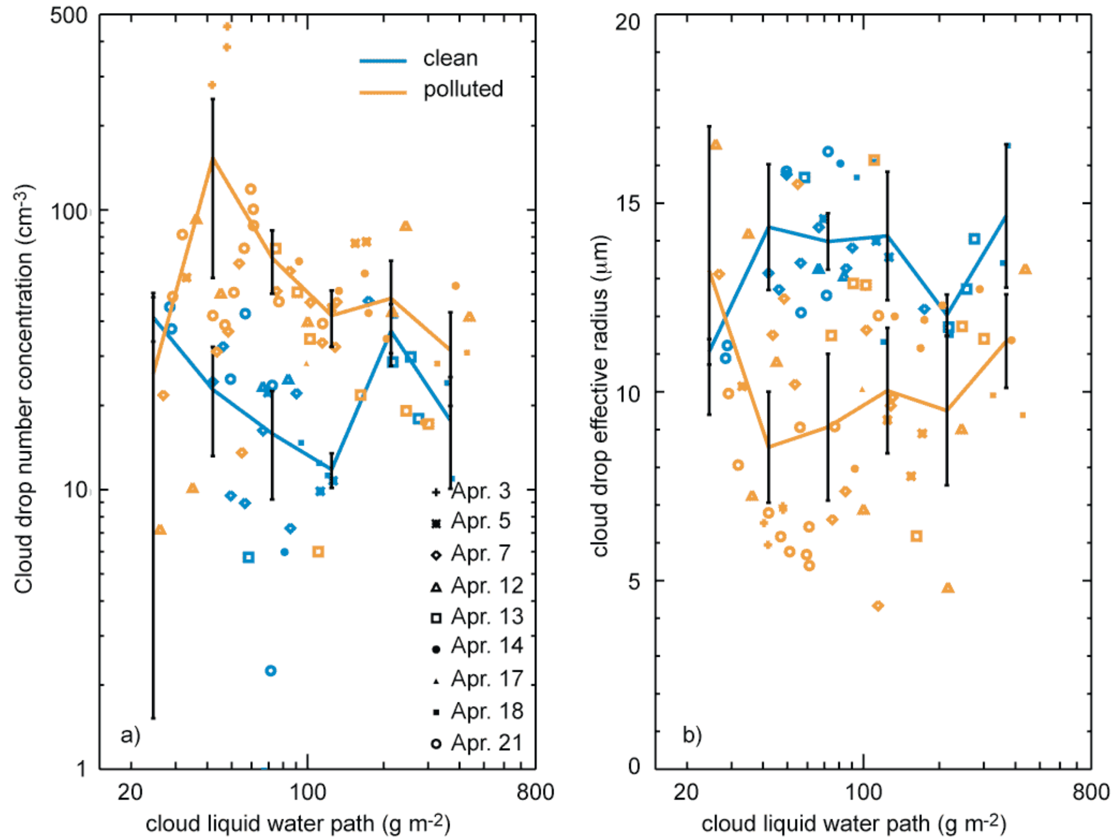
Indirect effect of aerosols: shallow clouds

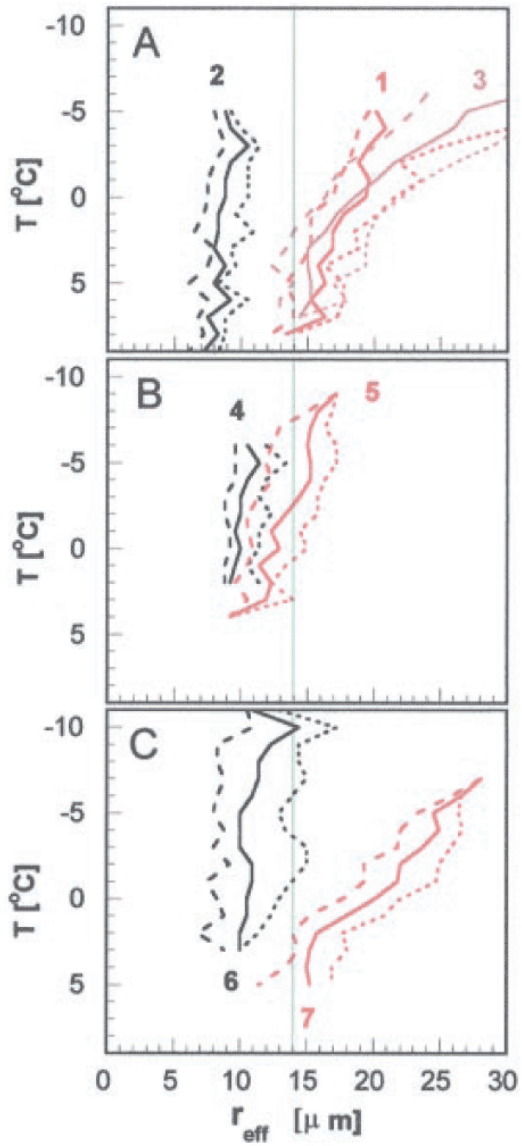


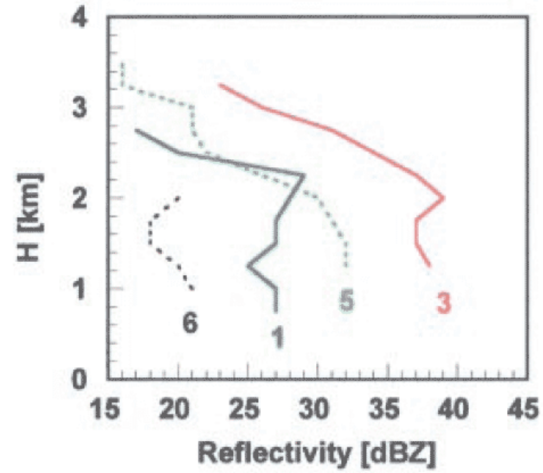
Combined aircraft and satellite observations from the Northeast Pacific (off N. California).

Clean/polluted from aircraft measurements of particle (>0.1µm) concentration below cloud (polluted > 50 cm^{-1}).
LWP from AMSR-E retrieval (Wentz and Meissner retrieval).

Wilcox, Roberts and Ramanathan (2006)

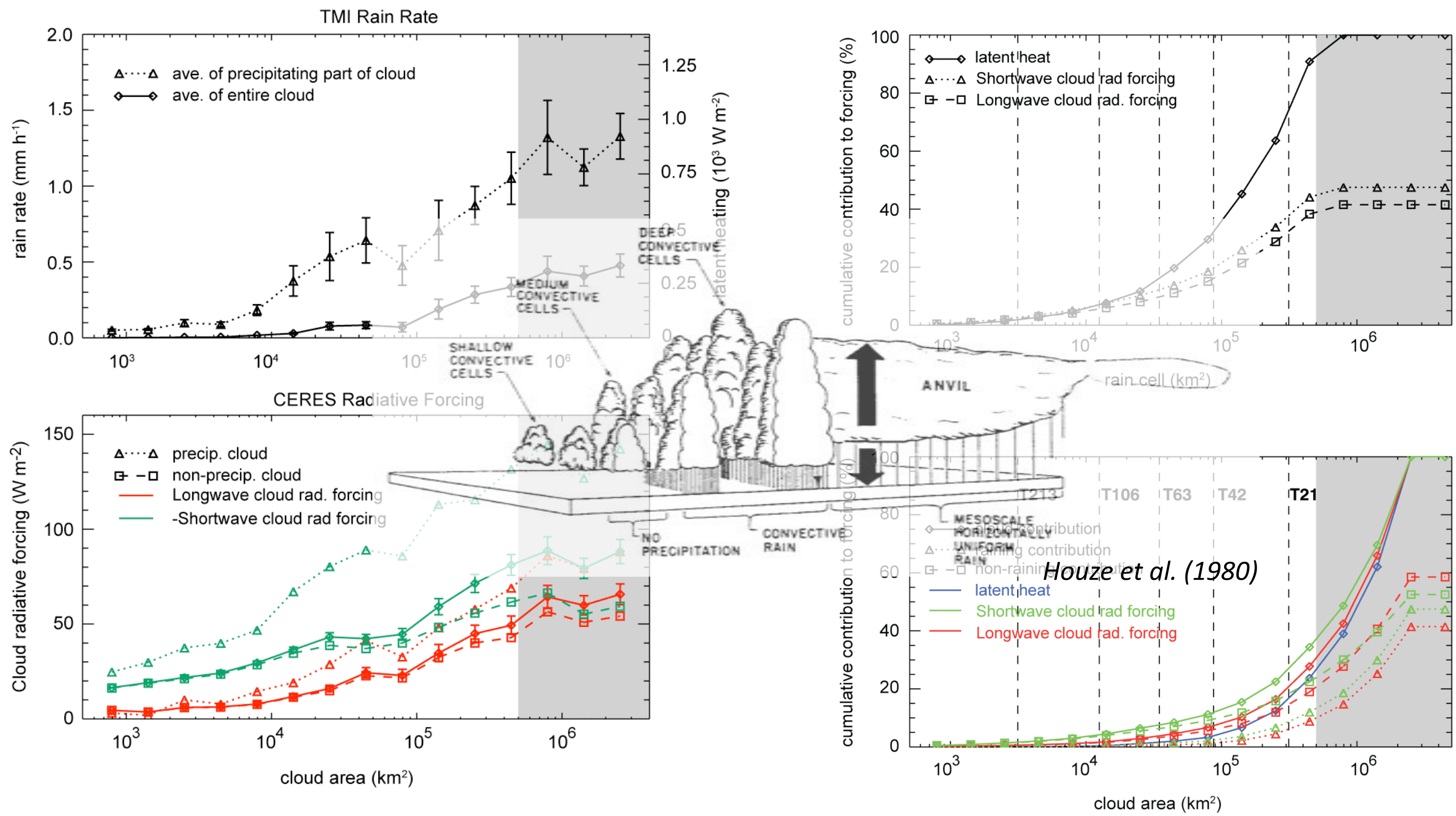
Indirect effect of aerosols: convective clouds





Rosenfeld (2000)

The importance of organized convection



TRMM observations from the Indian Ocean winter monsoon ITCZ.

Wilcox and Ramanathan (2001)

The importance of organized convection

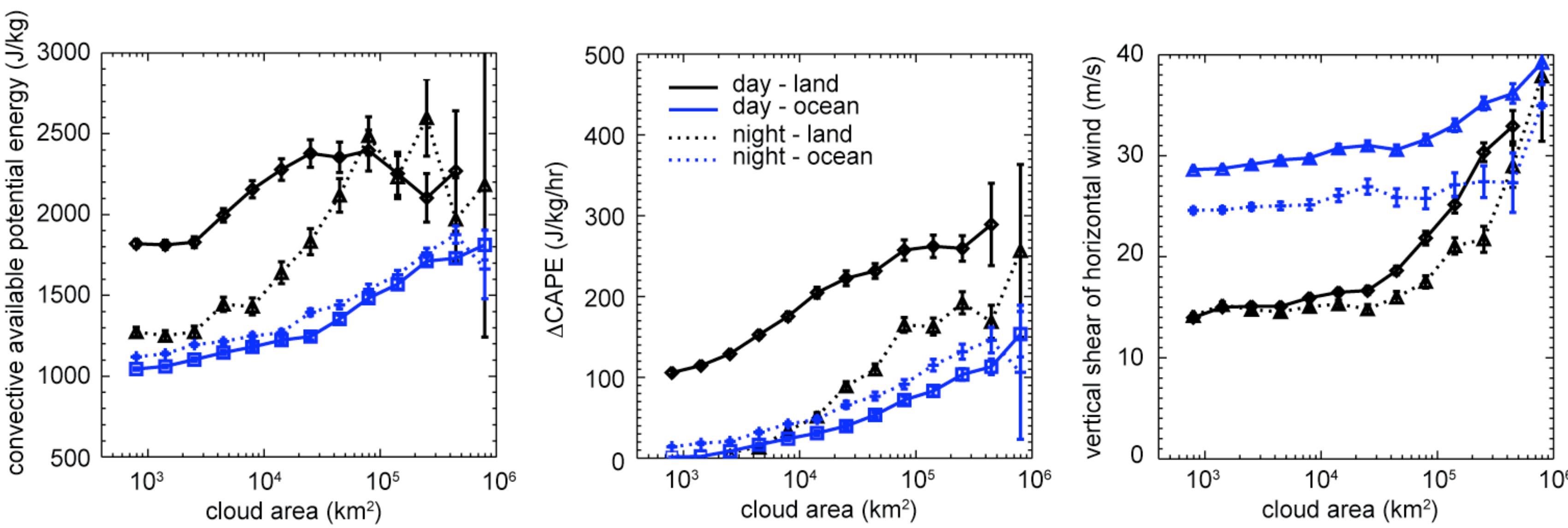
In the tropics, cloud cover, net latent heating of the atmosphere, and net cloud radiative forcing in the atmosphere and at the surface are dominated by condensate produced in organized convective systems.

Organized convective systems rely on the interactions among:

•"Large-scale" environment (CAPE and shear)

•convective scale updrafts/downdrafts

•Mesoscale updrafts/downdrafts



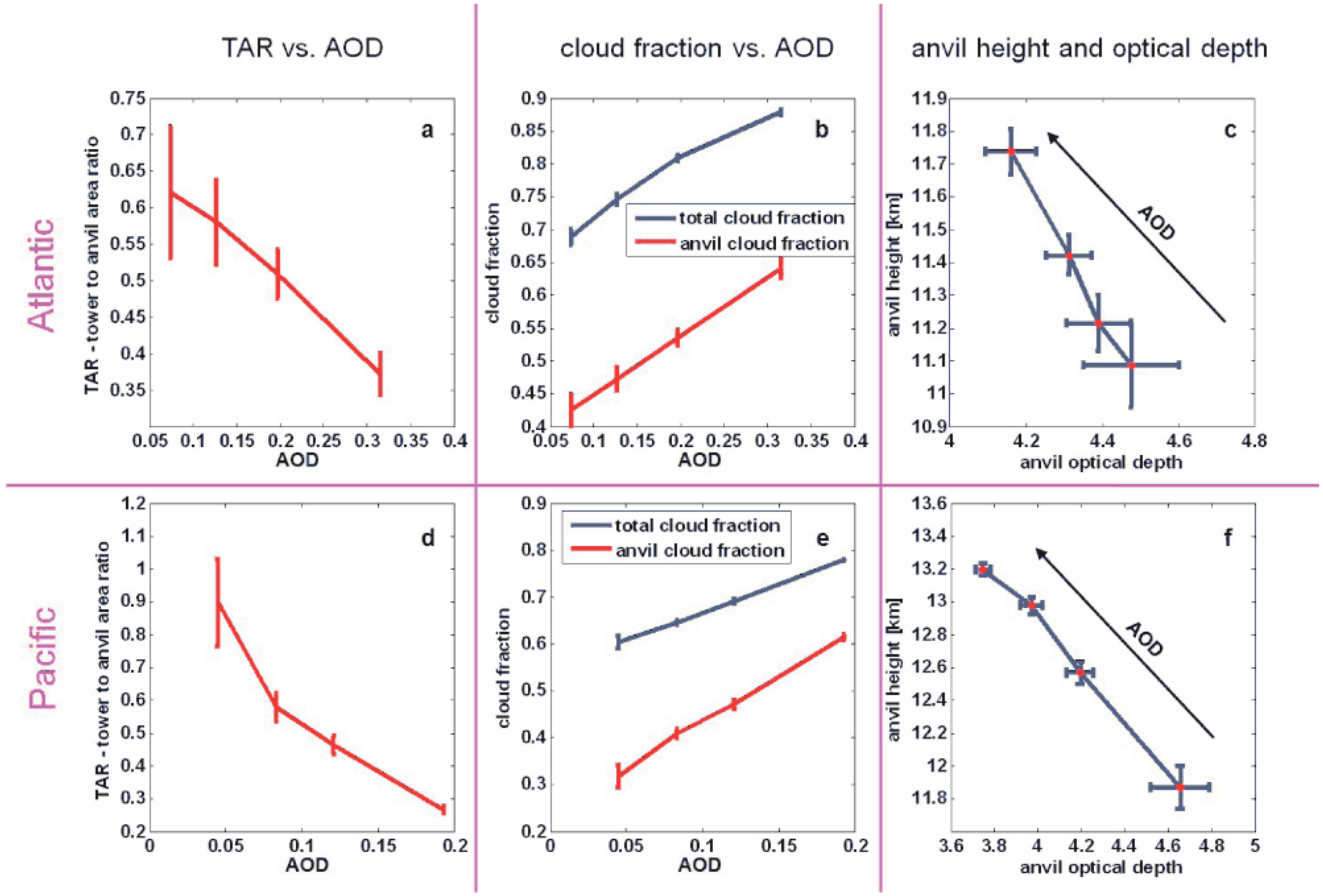
Observations from MODIS and a 1-deg. experimental model analysis (i.e. a satellite data assimilation product) over India and Northern Indian Ocean during summer monsoon.

Research question:

What effect does a substantial perturbation to the convective cloud microphysics have on the mesoscale organization of the system?

CRM modeling community has paid substantial attention to the question of how much total precipitation is produced from convective cloud systems under different aerosol load.

Key question for climate is more likely to be: what is the impact of aerosol perturbations on cloud cover and net cloud radiative forcing.



Koren et al. propose that:

- •reduced cloud drop size invigorates convection
- •higher cloud tops experience higher winds
- •higher winds spread anvil clouds further

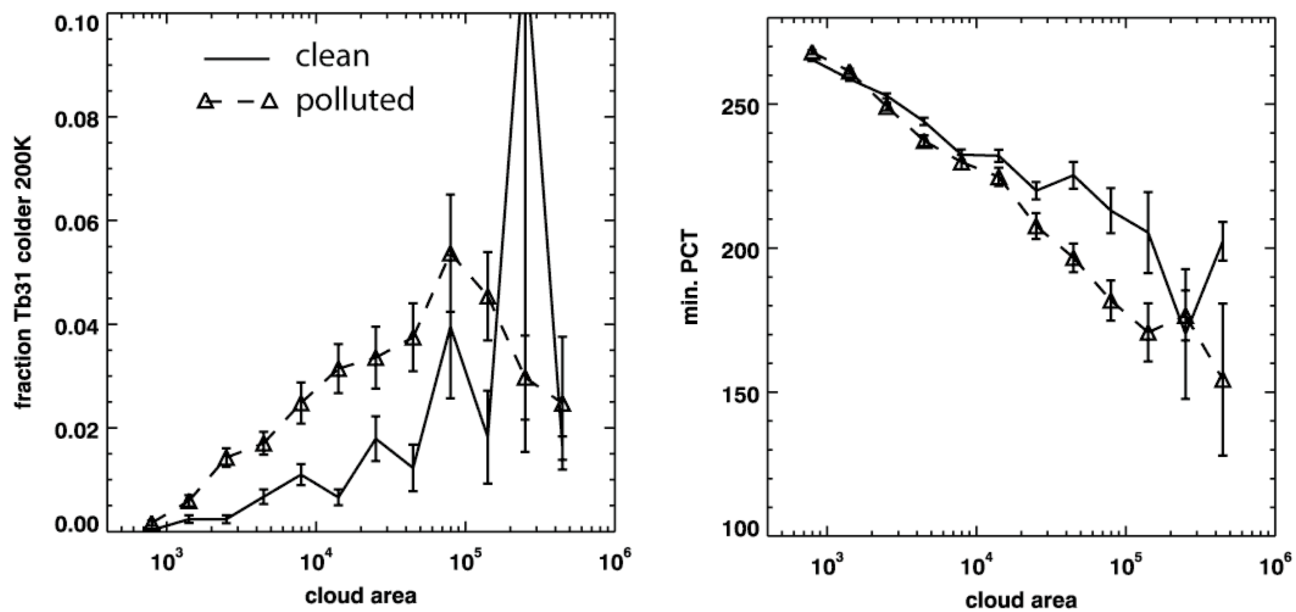
Koren et al. (2010)

However, organized convective systems have extensive mesoscale circulations.

Consider that:

- More than 40% of anvil condensate may be produced by the mesoscale anvil circulation (Gamache and Houze, 1983)
- The tower to anvil ratio is itself strongly controlled by the environmental shear and humidity

Daytime Aqua, JJA 2004-2007; South Asia (land only)



PCT = microwave 89GHz Tb

More coverage of cold cloud tops and more ice in polluted cloud to generate the same size cloud,
i.e. the tower to anvil ratio appears to be higher for polluted clouds over India.

Additional research questions:

- What controls the ratio of deep convective cores to total cloud system horizontal scale?
- How can microphysical modification of the deep convective cores influence total cloud system scale?
- How does this response depend on the dynamic and thermodynamic environment within which the cloud system resides?

Are beginning research program designed to address these questions using:

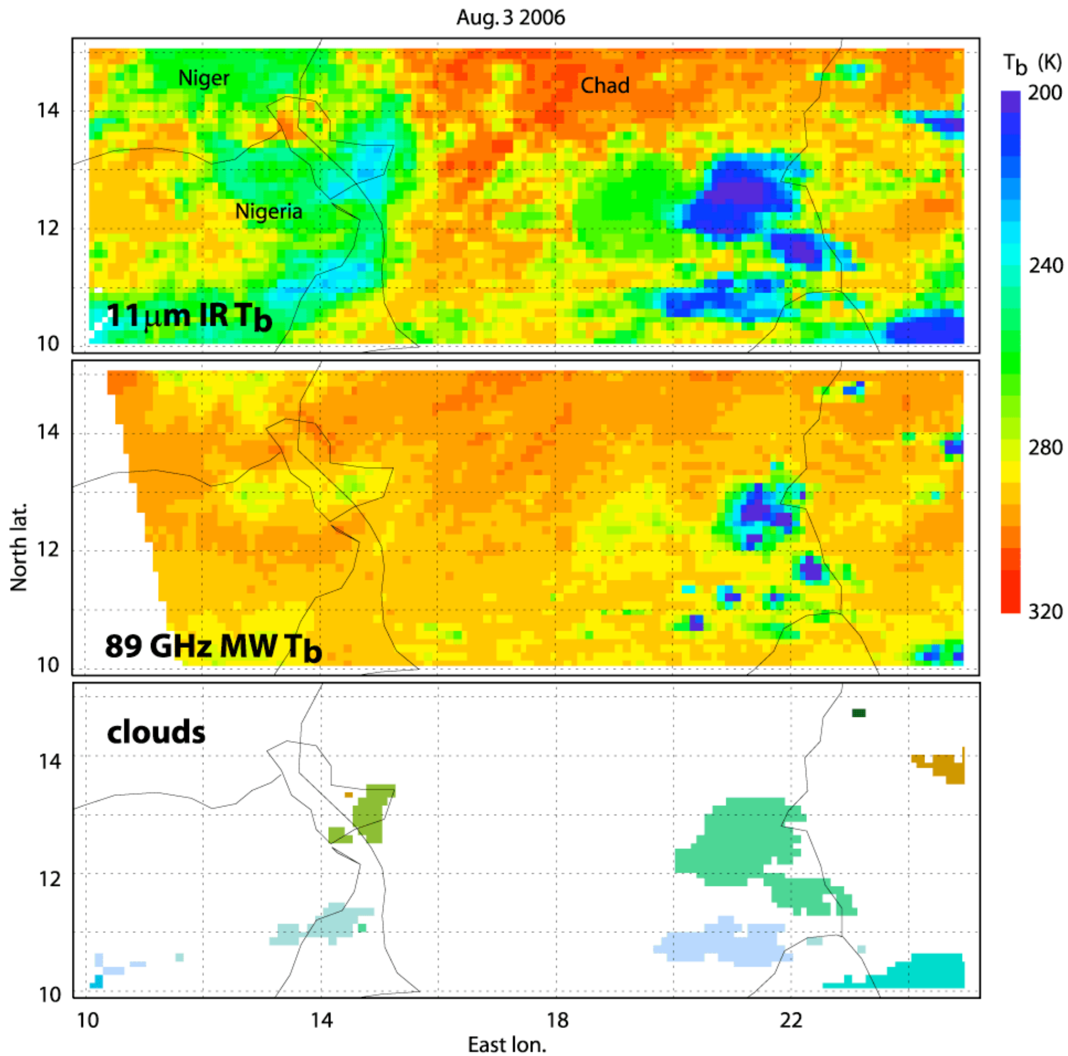
- MODIS and AMSR-E observations of brightness temperature,
- MODIS retrievals of cloud-top properties,
- MODIS retrievals of aerosol optical depth,
- MERRA reanalysis temperature/humidity/winds, and
- CERES cloud radiative forcing
- Cloud resolving model simulations

Cloud resolving model simulations are critical for isolating individual factors determining cloud structure.

Results will be determined from large ensembles of observed and simulated clouds.

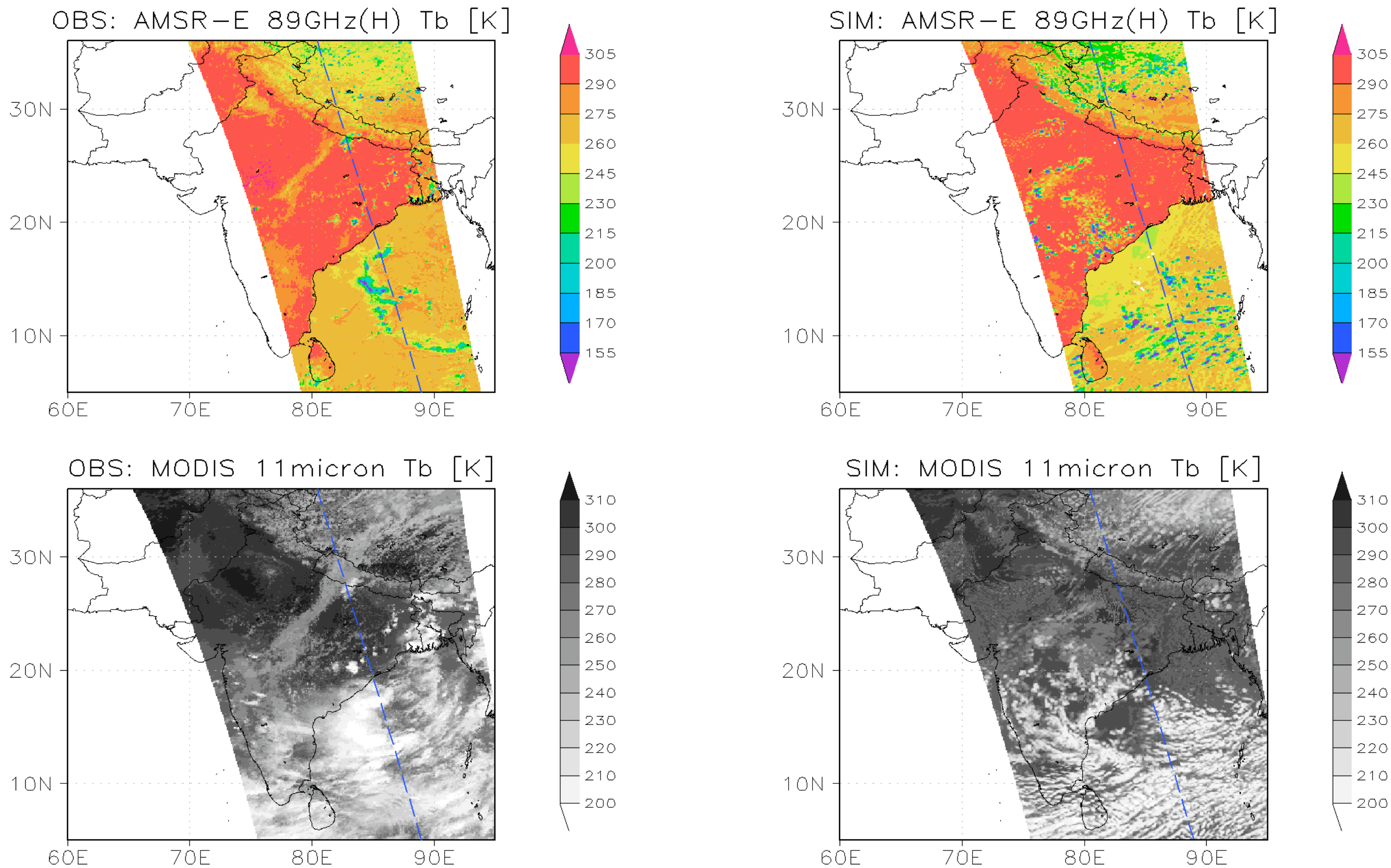
The SDSU satellite simulator will generate brightness temperature fields from the model output to be analyzed using the same approach as applied to the satellite data.

Cloud detection



From many satellite overpasses an ensemble of millions of deep convective clouds can be constructed.

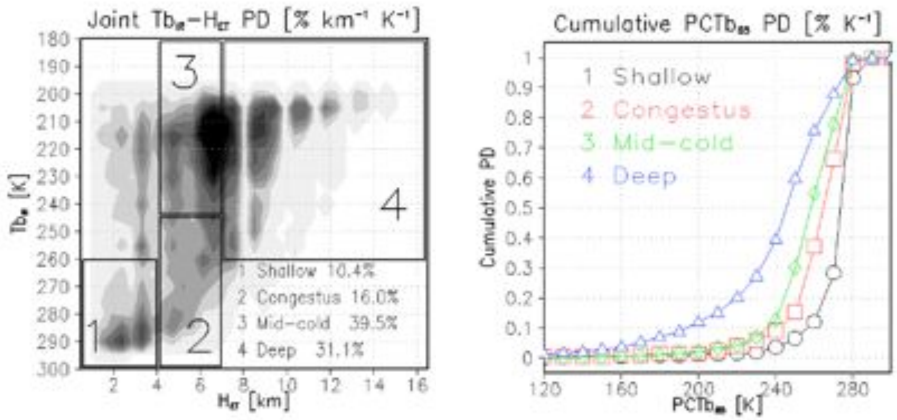
Simulated brightness temperatures with GCE model



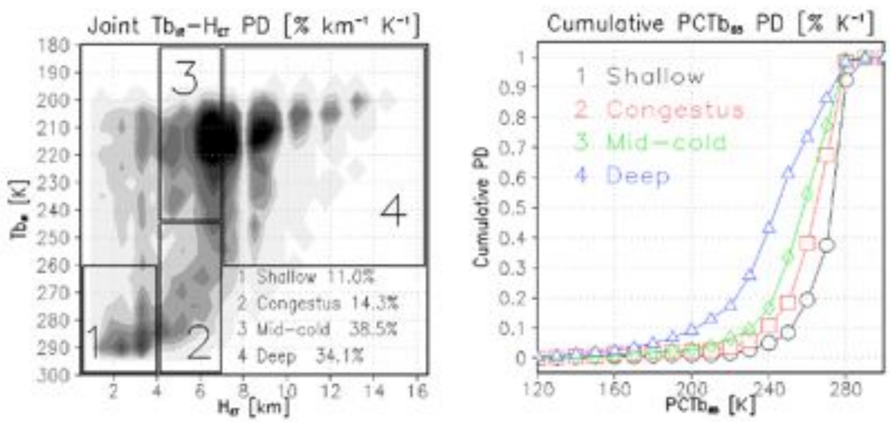
Goddard Cumulus Ensemble model with the Colorado State RAMS 2-moment microphysical scheme as passed through the Goddard Satellite Data Simulation Unit.

Simulated brightness temperatures with GCE model

High CCN (1000 cm^{-3})



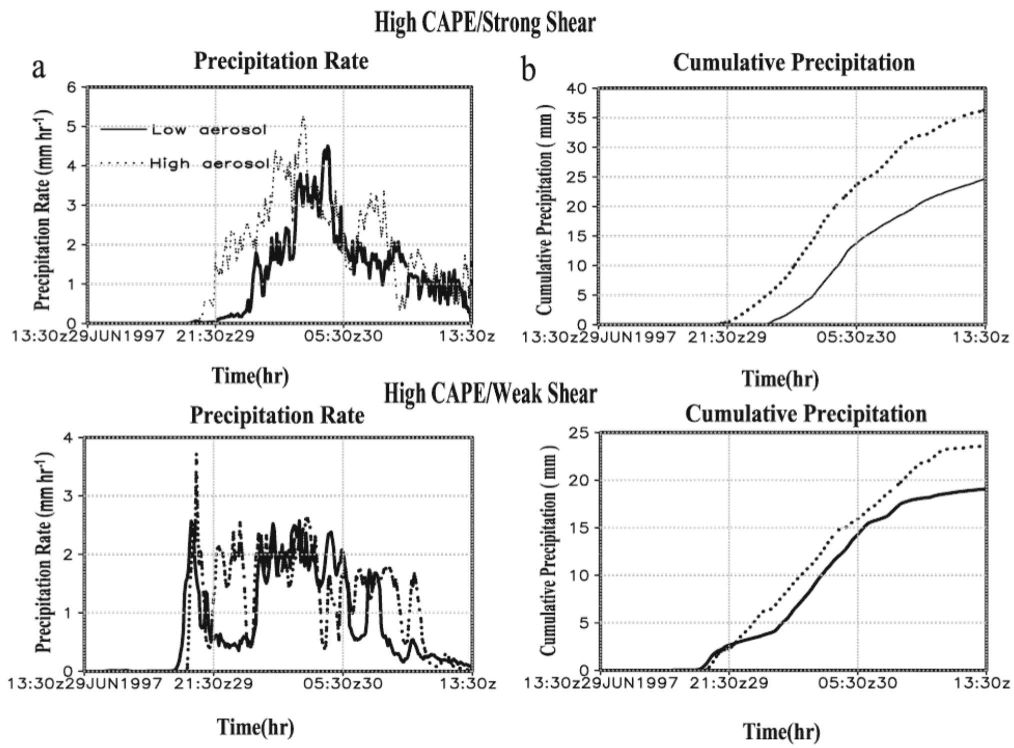
Low CCN (50 cm^{-3})



In this simulation increasing the CCN leads to a higher proportion of lower clouds, but the high clouds have lower microwave brightness temperature, indicating a higher concentration of large ice particles.

Strategy

Following the lead of Lee et al (2008):



- Observe cloud system scale and structure for range of CAPE and vertical wind shear environments.
- Simulate clouds for different CCN amounts and a range of environments spanning the observations.
- Investigate the dependence of cloud system structure and scale on aerosol amount for different environments.