Deep convective cloud system size and structure: thermodynamic forcing and modification by aerosols

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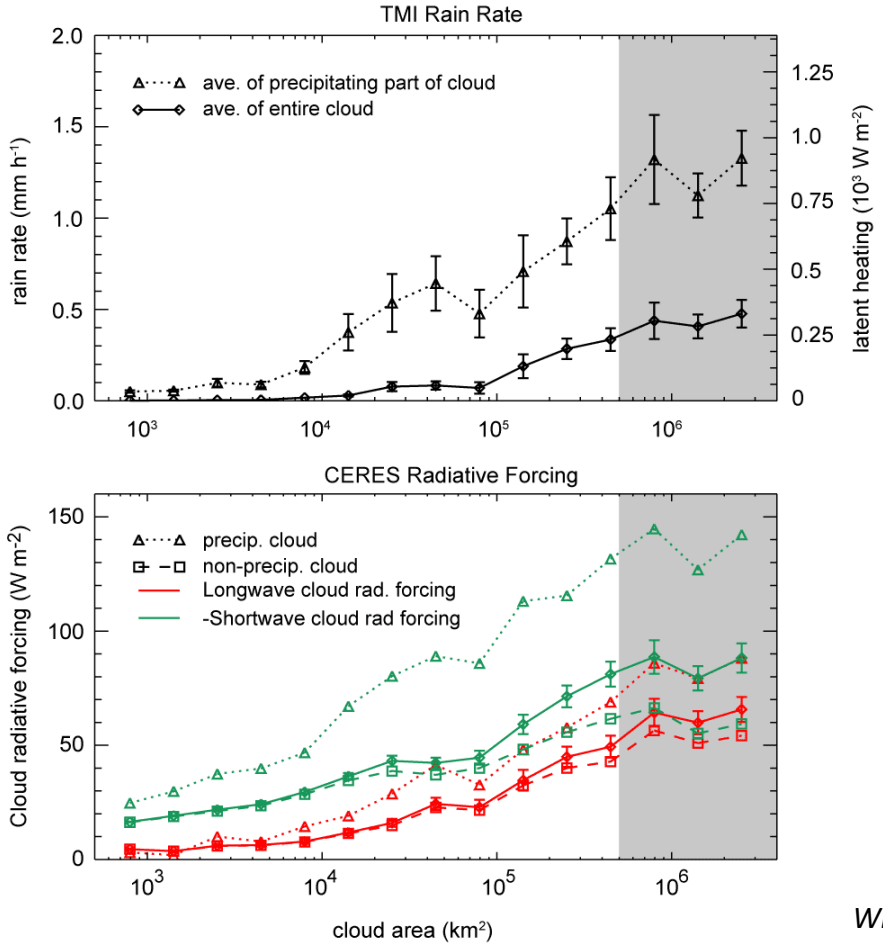
Why care about aerosols and cloud scales?

- Much recent work has documented the microphysical modification of deep convective clouds:
  - Smaller drops
  - Modification of vertical distribution of mixed phase cloud
  - Changes in convective heating profile
  - Invigoration

- Aerosols hypothesized to increase anvil cloud coverage:
  - Significant potential radiative impact

- **What influences the size convective cloud systems?**

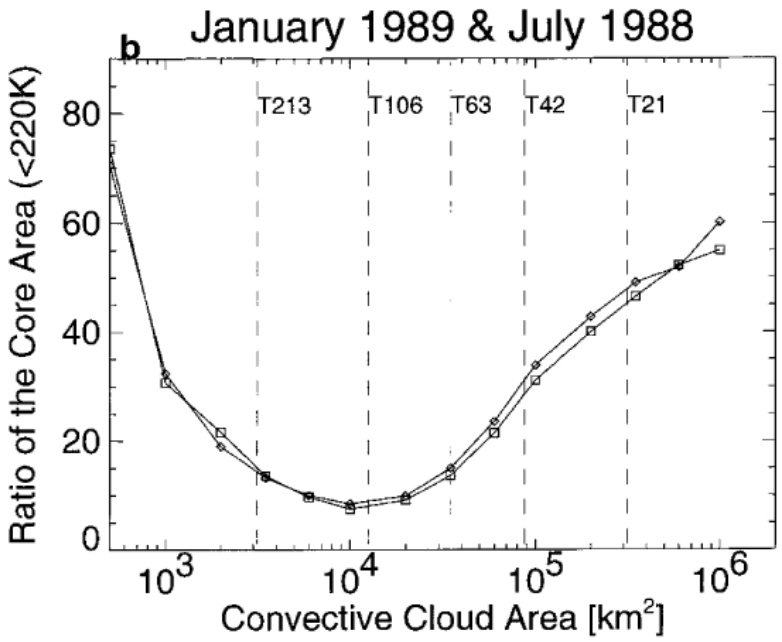
Scale-dependent cloud properties



Wilcox and Ramanathan (2001)

TRMM observations from the Indian Ocean winter monsoon ITCZ.

Scale-dependent cloud properties



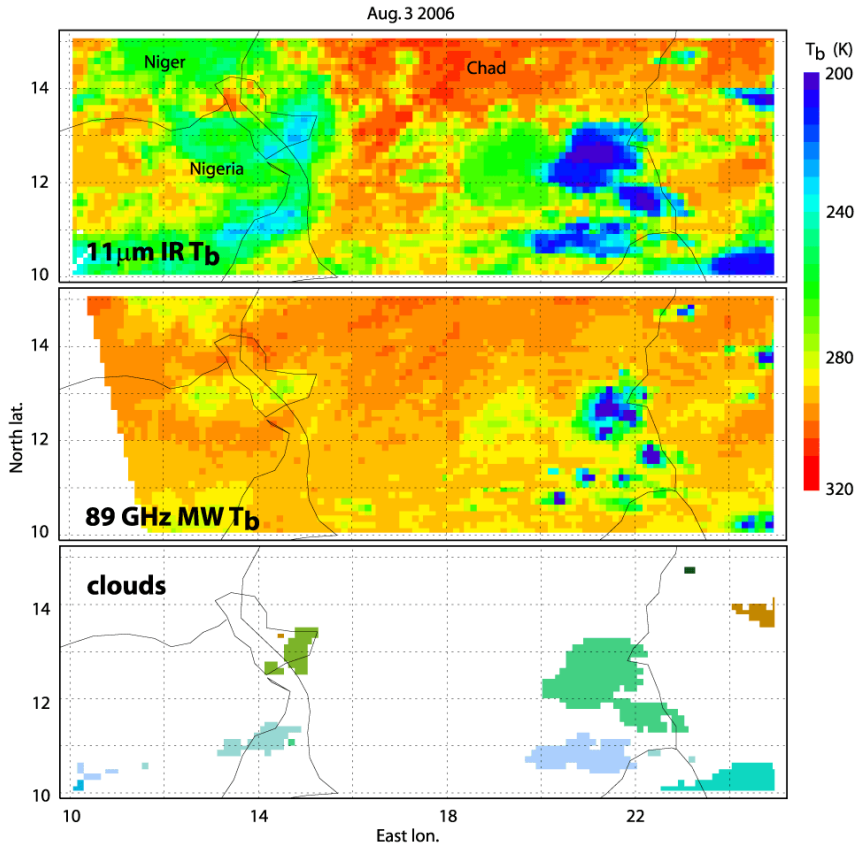
Roca and Ramanathan (2000)

INSAT observations from the Indian Ocean winter monsoon ITCZ.

Cloud detection

MODIS

AMSR-E



- Detect and spread algorithm (Boer and Ramanathan 1997) – Detect core of deep convection and spread out to attach anvil cloud based on MODIS IR brightness temperatures (Roca and Ramanathan 2000).
- Evaluate scales of clouds
- Evaluate scale dependence of IR and MW brightness temperature distributions within cloud boundaries.
- Evaluate effects of thermodynamic environment on scales and scale-dependent properties.

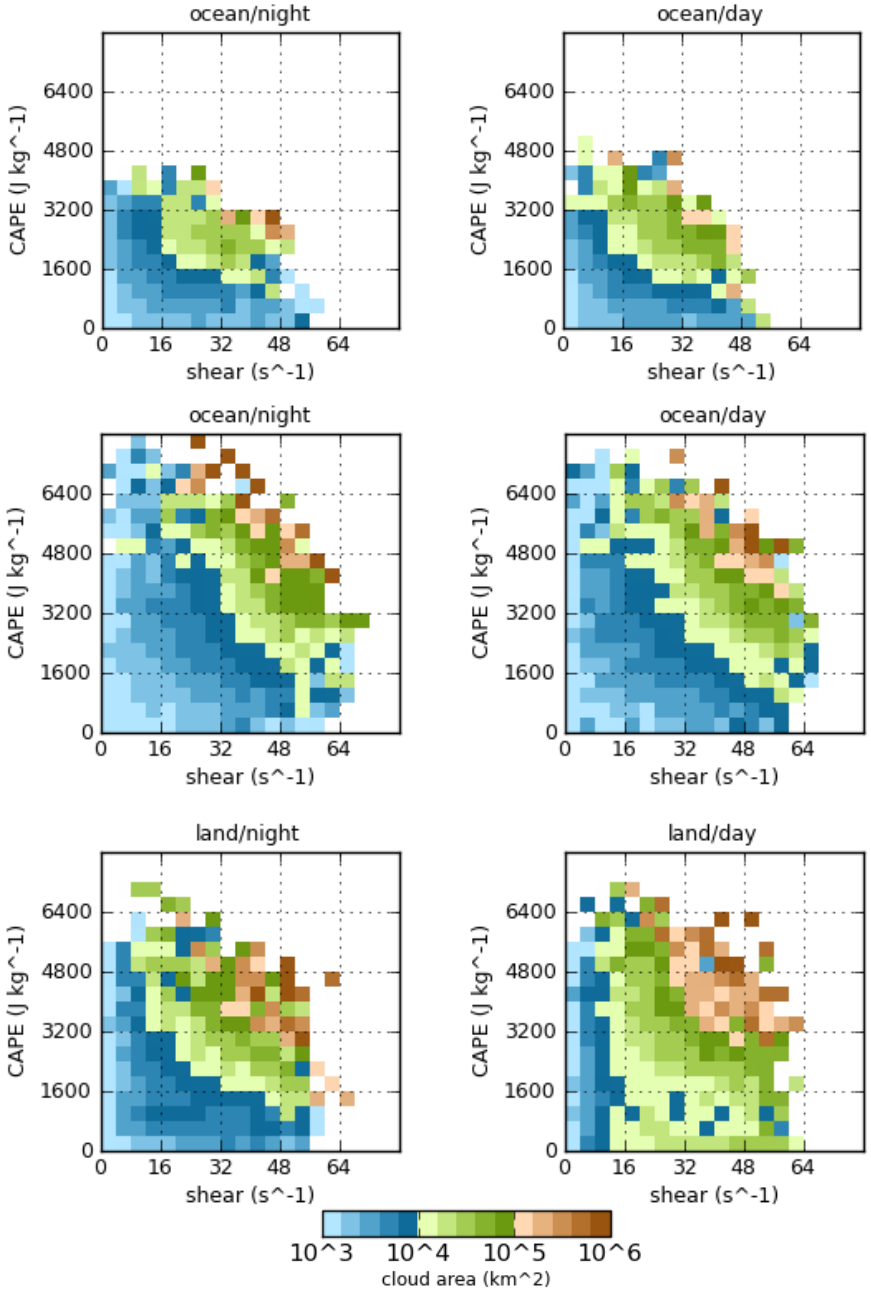
Relationship between cloud size and CAPE/shear

winter ocean

ocean

summer

land

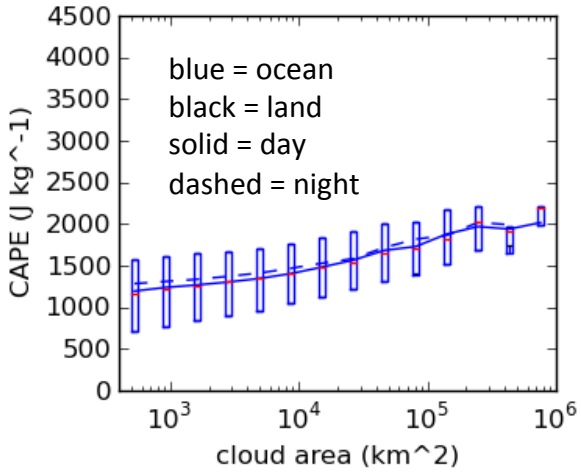


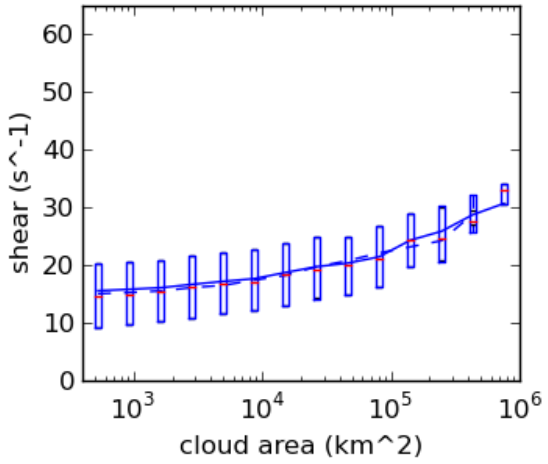
all results for Indian Ocean and S. Asia

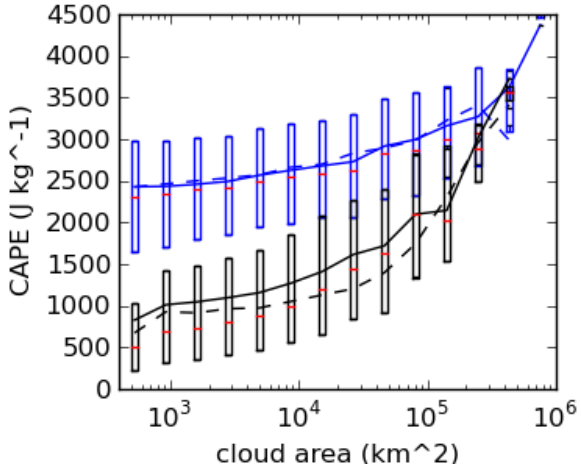
Relationship between cloud size and CAPE/shear

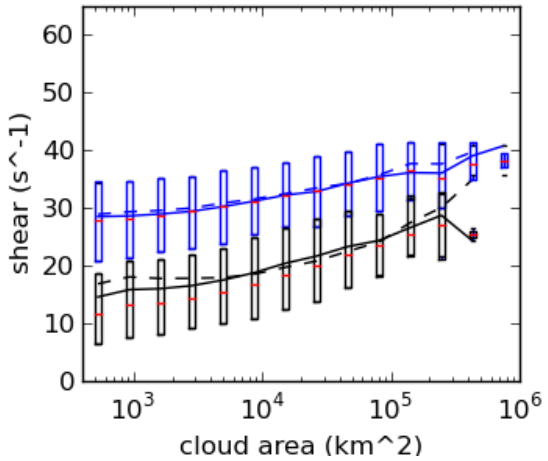
winter

summer





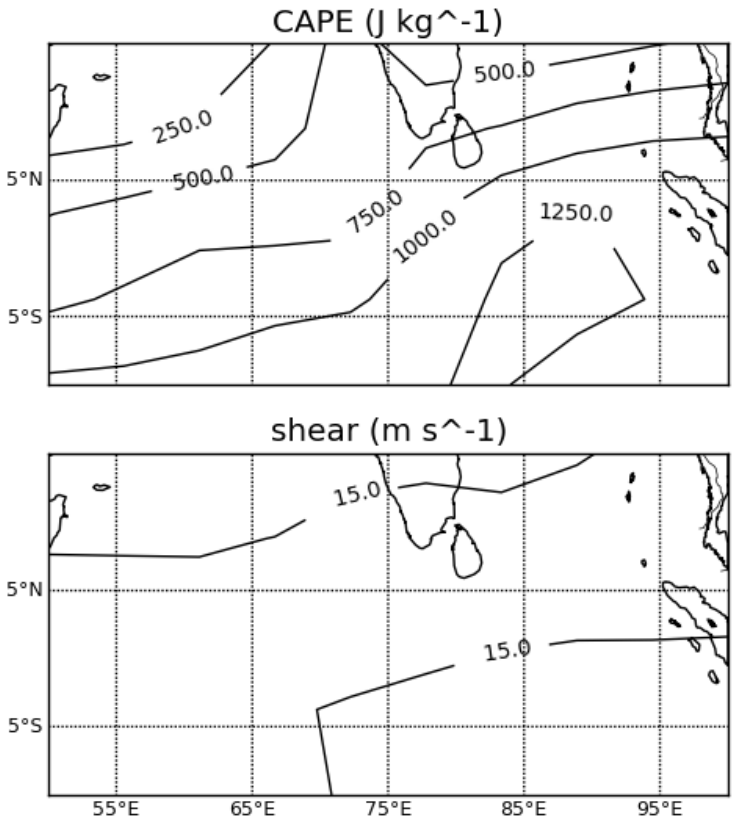




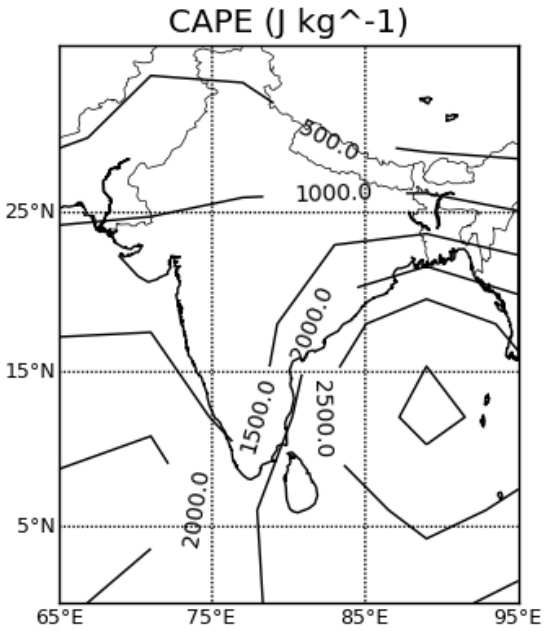
Which raises at least two interesting questions:

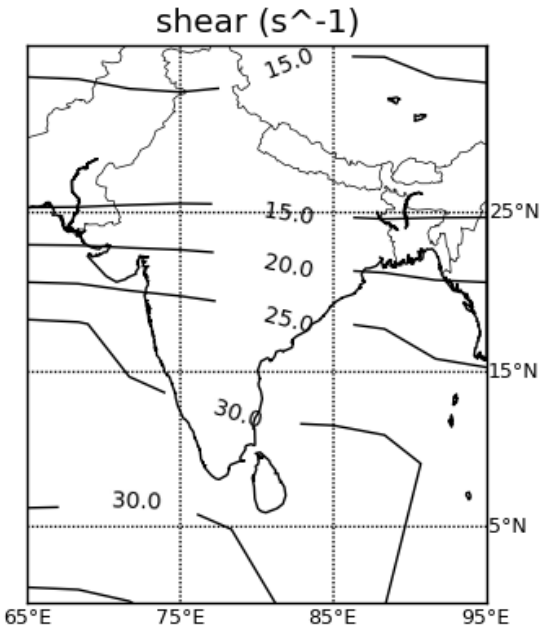
Why are the CAPE and shear values so different?

winter



summer



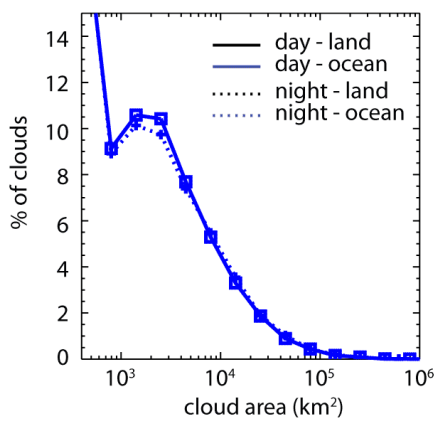


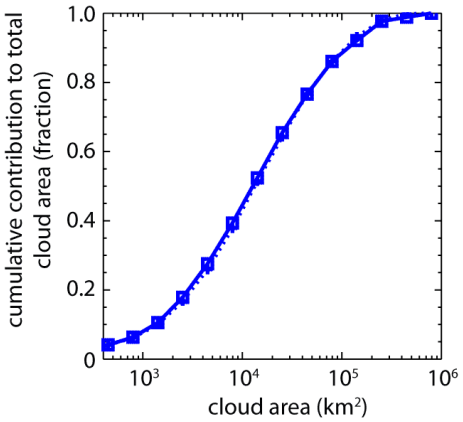
- CAPE and shear strongly influence evolution and structure of convective clouds, as shown by the cloud models.
- We use MERRA at 2/3 x 1/2 deg. resolution for each cloud to develop empirical description of this relationship.
- CAPE calculated according to Emanuel (1994).

Why aren't the size distributions more different?

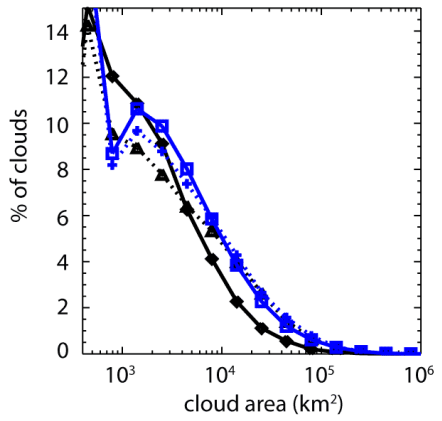
size distribution | cumulative size distribution

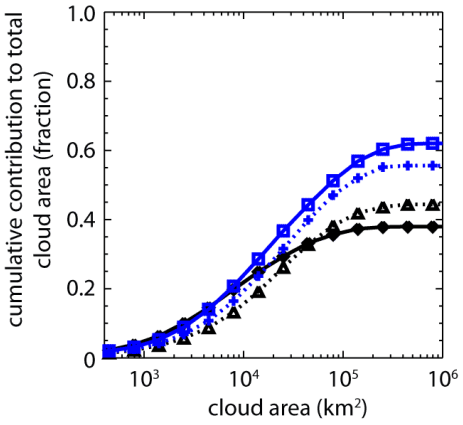
winter





summer

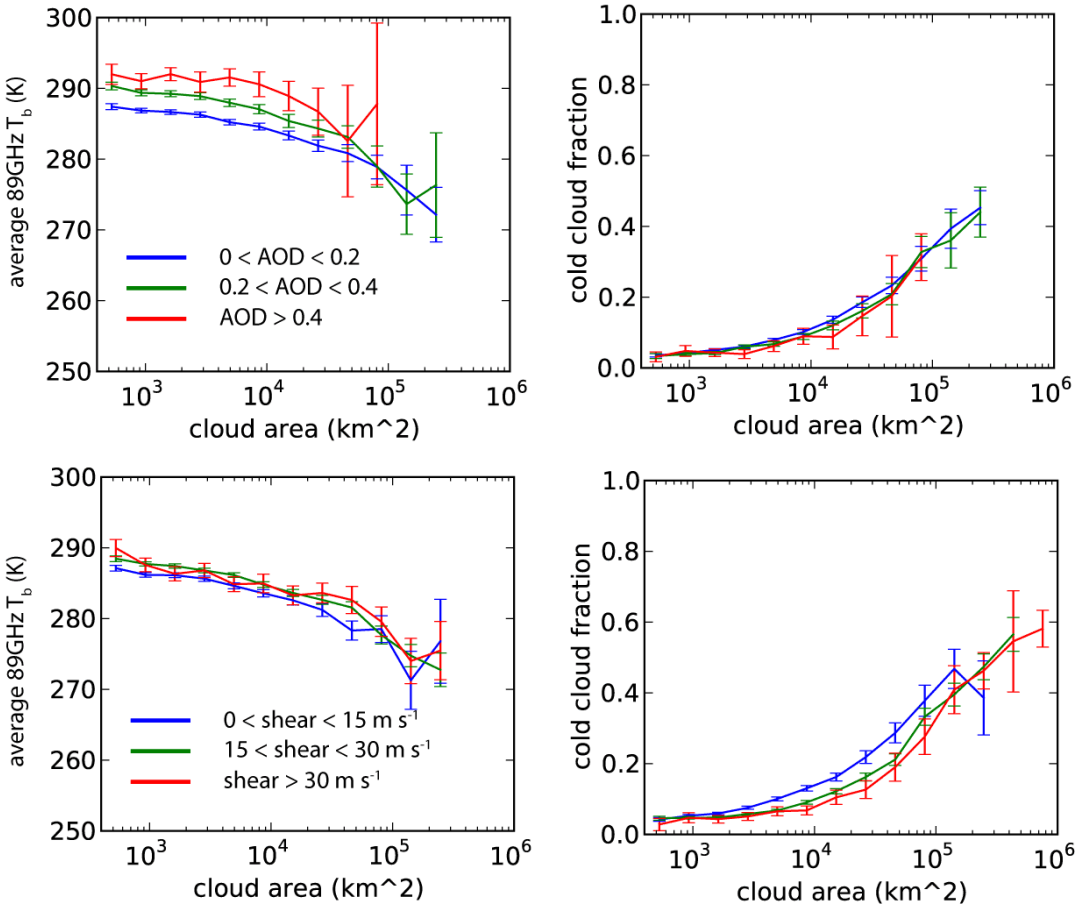




- Cloud cover dominated by clouds in the 10^4 to 10^5 km^2 size range.
- Summer continental systems and winter oceanic systems are more efficient at creating cloud cover for a given level of instability and shear compared to summer oceanic systems.

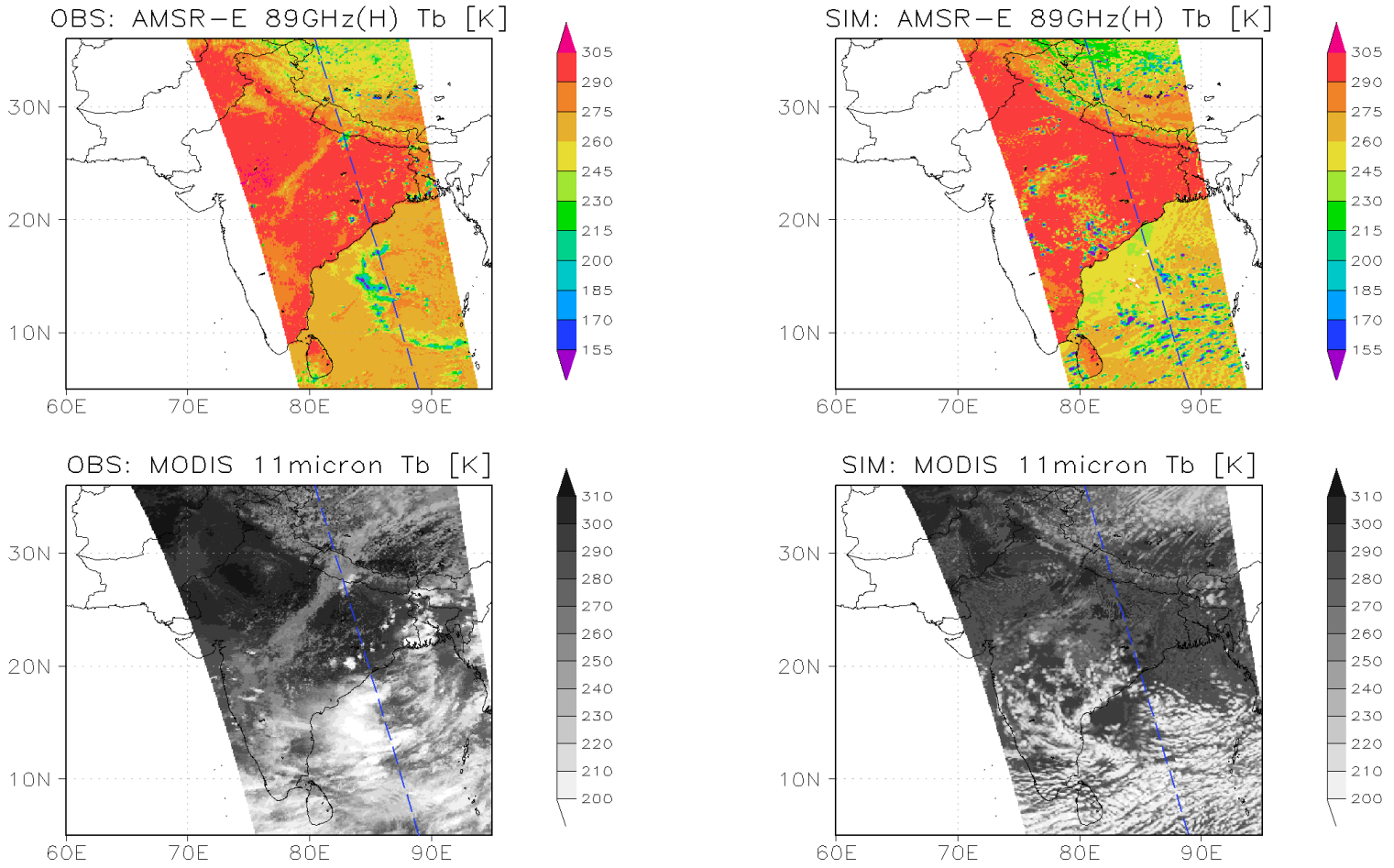
Sensitivity of cloud structure to aerosols and environment

wintertime oceanic clouds



- Cold cloud fraction is fraction of cloud area colder than 220 K.
- Sensitivity of cold cloud fraction to shear is stronger than sensitivity to AOD in spite of clear signal of microphysical differences in polluted cloud.

Simulated brightness temperatures with GCE model



Goddard Cumulus Ensemble model simulations as passed through the Goddard Satellite Data Simulation Unit.

Summary

- Properties of convective clouds depend systematically on the size of the cloud.
- This provides a convenient means of assessing the relationships between cloud structure, the thermodynamic properties of the environment, and the cloud scales.
- Cloud size increases systematically with CAPE and shear of the environment around the core of the cloud – with significant variability and strong regional differences.
- The variability acts to mitigate large regional differences in CAPE and shear; i.e. cloud systems of comparable scale are achieved for lower values of CAPE and shear across the cloud size spectrum in regions with lower mean values of CAPE and shear.
- While IR/MW brightness temperatures indicate the microphysical modification of clouds, the cold cloud fraction is far more sensitive to changes in shear than variations in AOD.
- A large database of clouds co-located with MERRA provides a means of controlling for the environmental variability in aerosol-cloud studies.
- Such a study is analogous to controlled experiments with a cloud model where CCN and CAPE/shear are varied systematically.