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Background Noises versus Intraseasonal Variation Signals: Small vs. Large Convective Cloud Objects from CERES Aqua Observations

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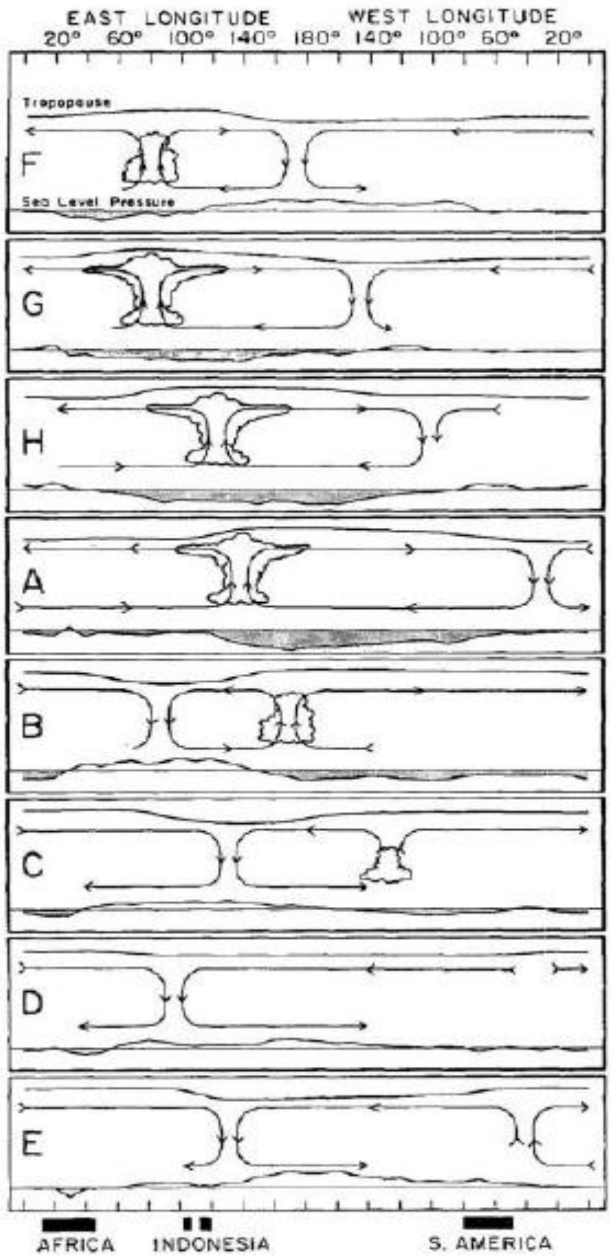
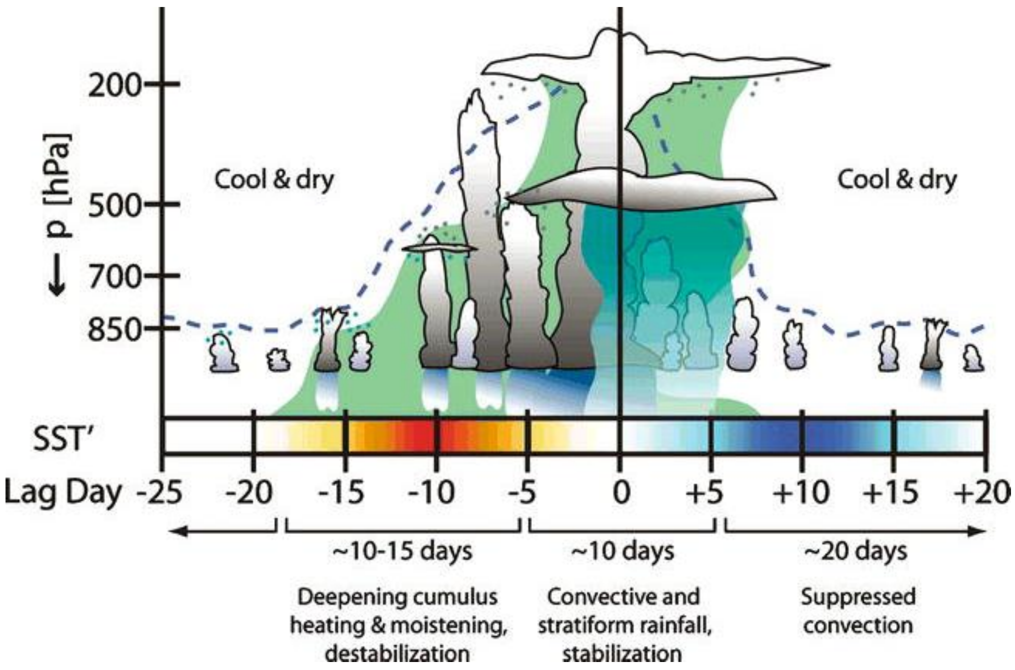
What are the relative roles of small and large convective cloud clusters during the Madden-Julian Oscillation (MJO) life cycle?

- How are the size distributions of convective cloud clusters changed during the MJO life cycle?
- How much are physical properties changed from one MJO phase to another?

Madden-Julian Oscillation (MJO) Life Cycle

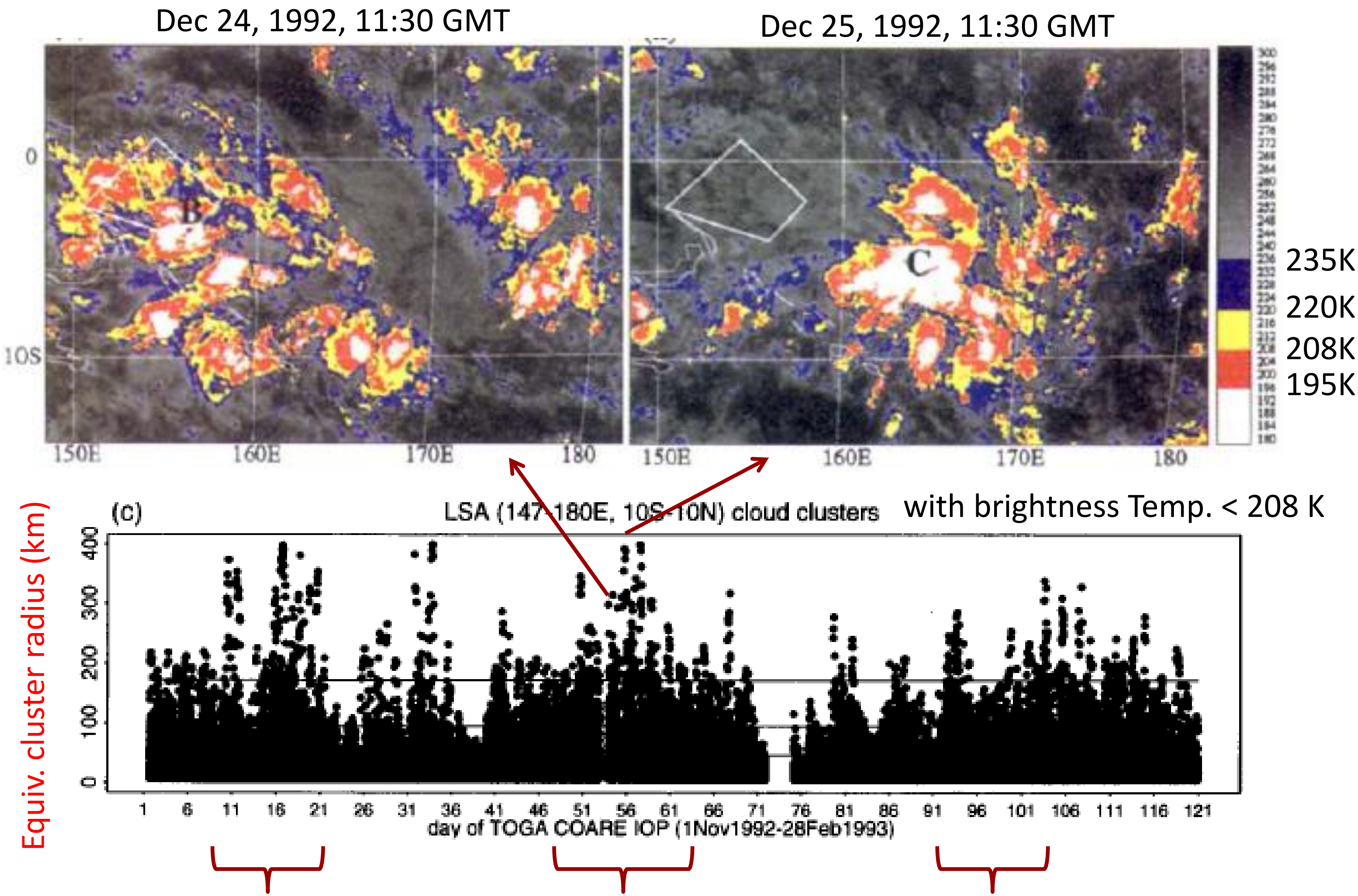




Convective cloud clusters are organized into various sizes and highly variables during the MJO life cycle.

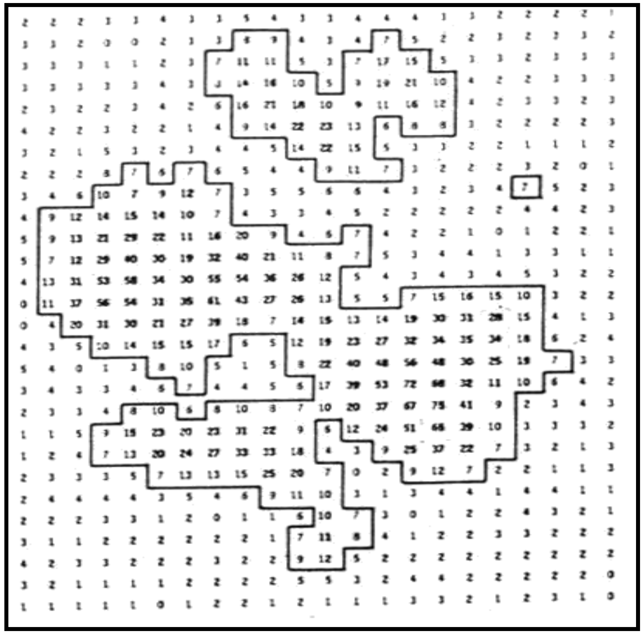
Our hypothesis is that the largest ones contribute to the intraseasonal variations while the small ones are just the background noises.

Tropical cloud cluster sizes (Chen et al. 1996)

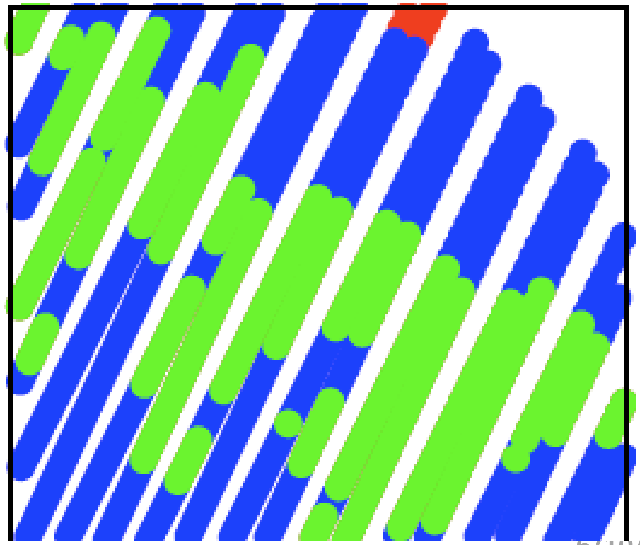


Cloud object methodology

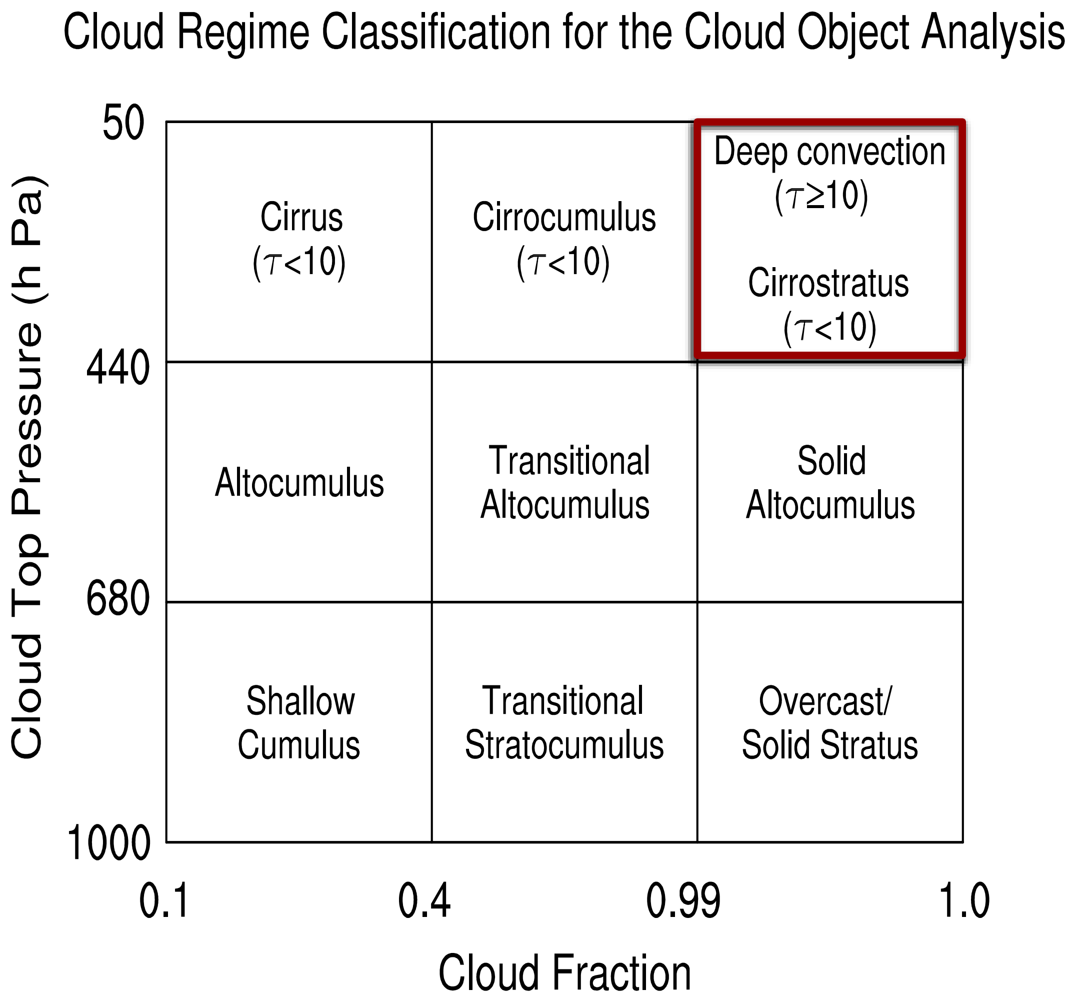
Wielick and Welch (1986)
Xu *et al.* (2005, 2007, 2008); CERES level-2 data



- A contiguous patch of cloudy regions with a single dominant cloud-system type; no mixture of different cloud-system types
- The shape and size of a cloud object is determined by
  - the satellite footprint data
  - the footprint selection criteria
- The identified cloud objects of different types can be further categorized by the large-scale atmospheric conditions based on the Madden-Julian Oscillation (MJO) index in this study



Cloud object selection criteria for different cloud regimes



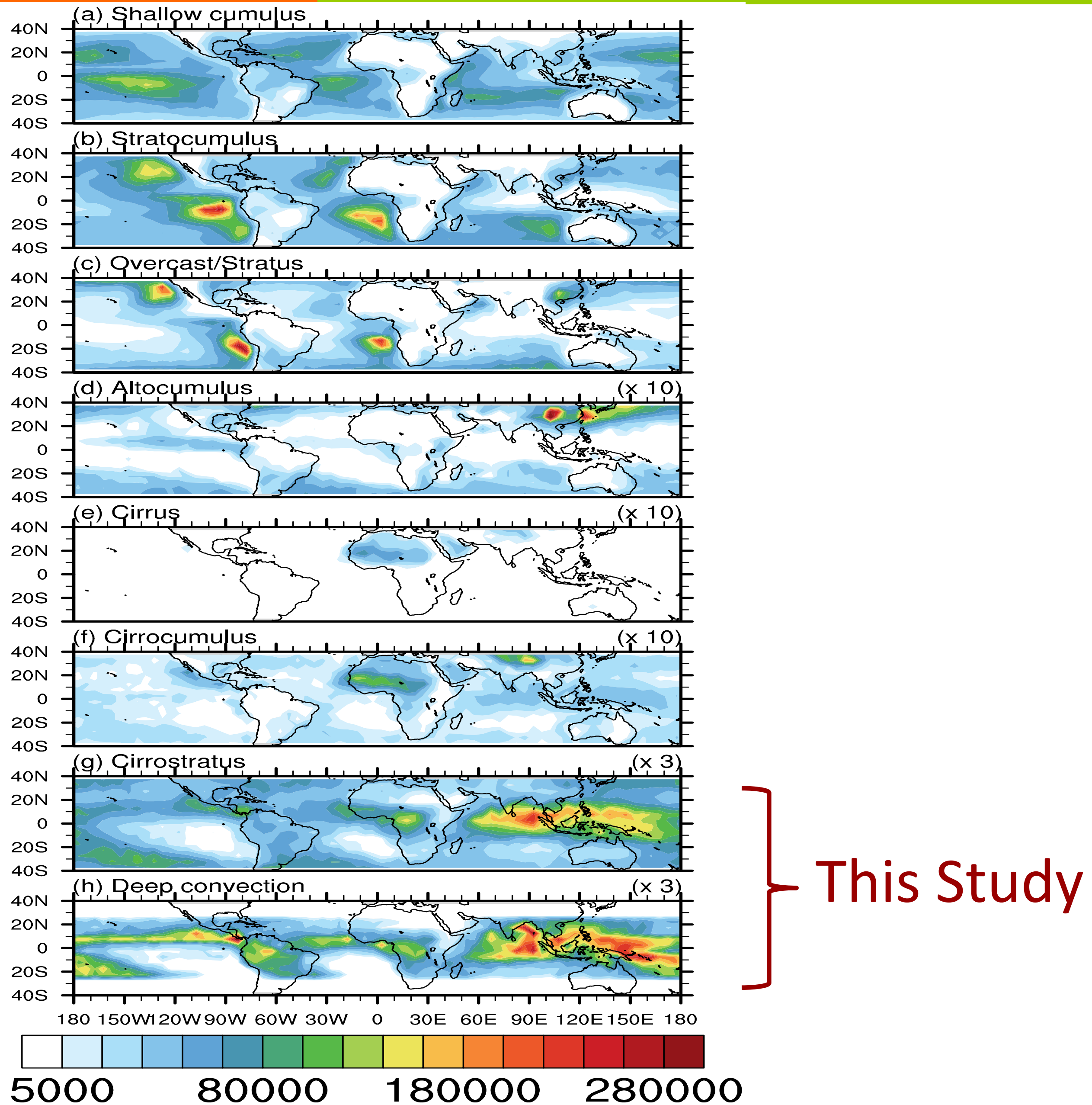
Xu, K.-M., et al. (2015): Cloud Object Analysis of CERES Aqua Observations of Tropical and Subtropical Cloud Regimes. Part I: Four-year Climatology. J. Climate (conditionally accepted)

Climatology (4 yr) of low- and upper-level cloud object areas

- ✓ Cu, Sc and Oc cloud types occur at preferred locations
- ✓ Cumulus over open ocean
- ✓ Overcast near the coasts
- ✓ Rarely over ITCZ regions or land

- ✓ Only cirrostratus (τ < 10; overcast) is abundant
- ✓ They are associated with deep convection

- ✓ Deep convection occurs over ITCZ and SPCZ; and less frequently over land



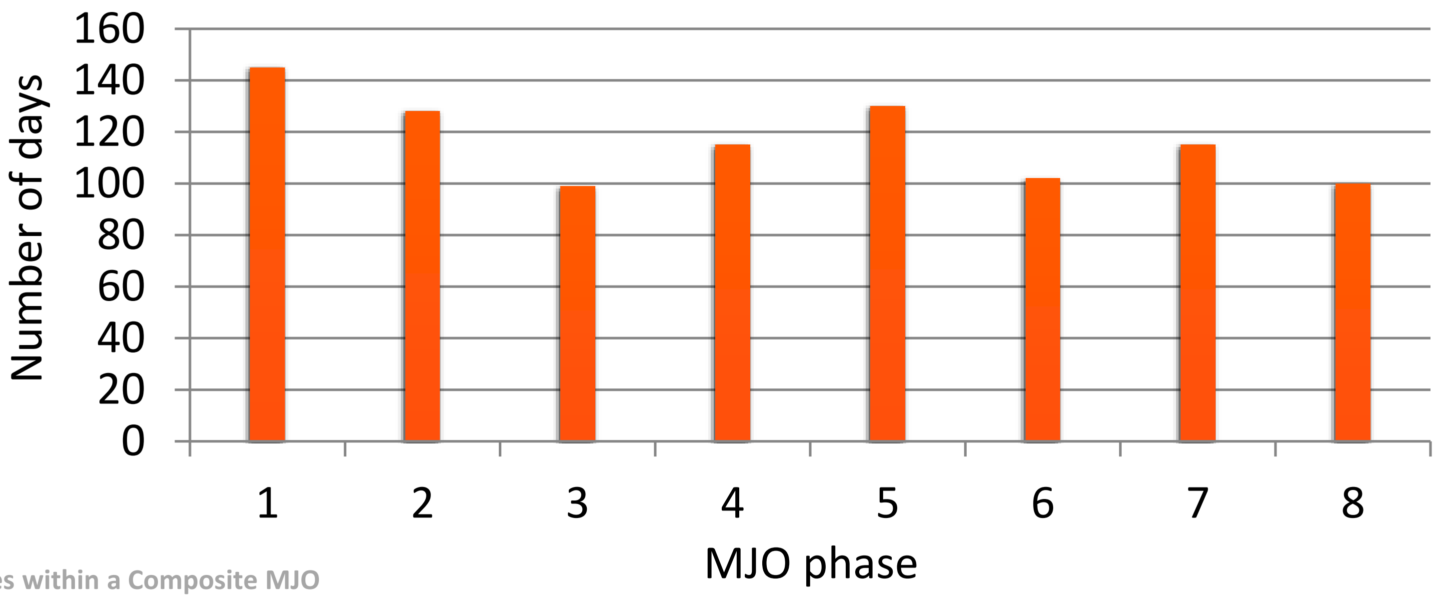
Data sets used in the analysis

✧ Clouds and the Earth's Radiant Energy System (CERES) Single Scanner Footprints (SSF)

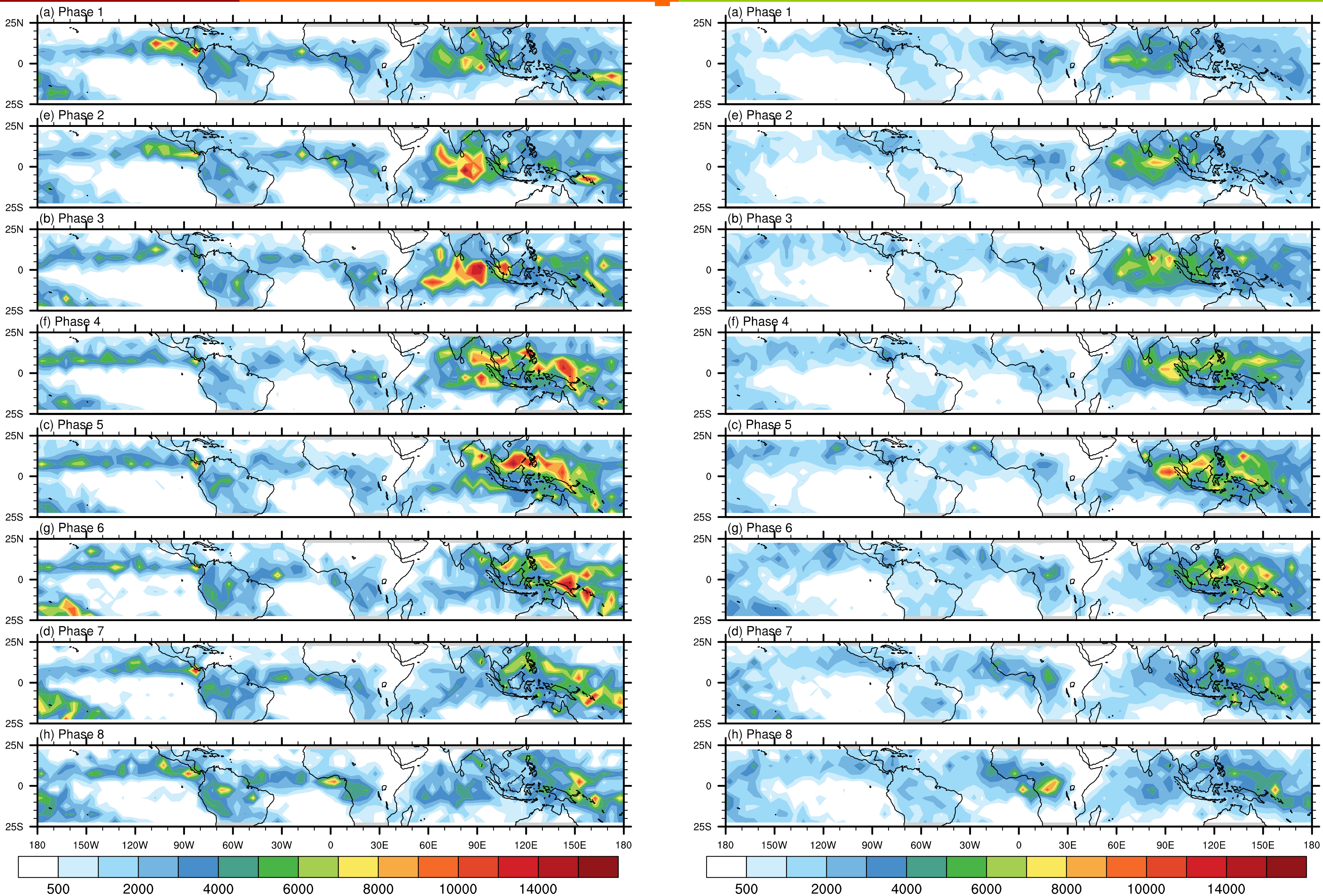
1. Four year data on Aqua: July 2006 – June 2010
2. 25°S to 25°N latitudinal band only
3. Deep convective and cirrostratus types only

✧ Real-time Multivariate MJO (RMM) index (combined EOFs of u850, u200 and OLR)

1. The days with amplitudes of $(RMM1^2+RMM2^2)^{1/2} > 1$ are used; 934 (out of 1461) days
2. All frequencies of occurrence shown later are normalized by 116.75 days

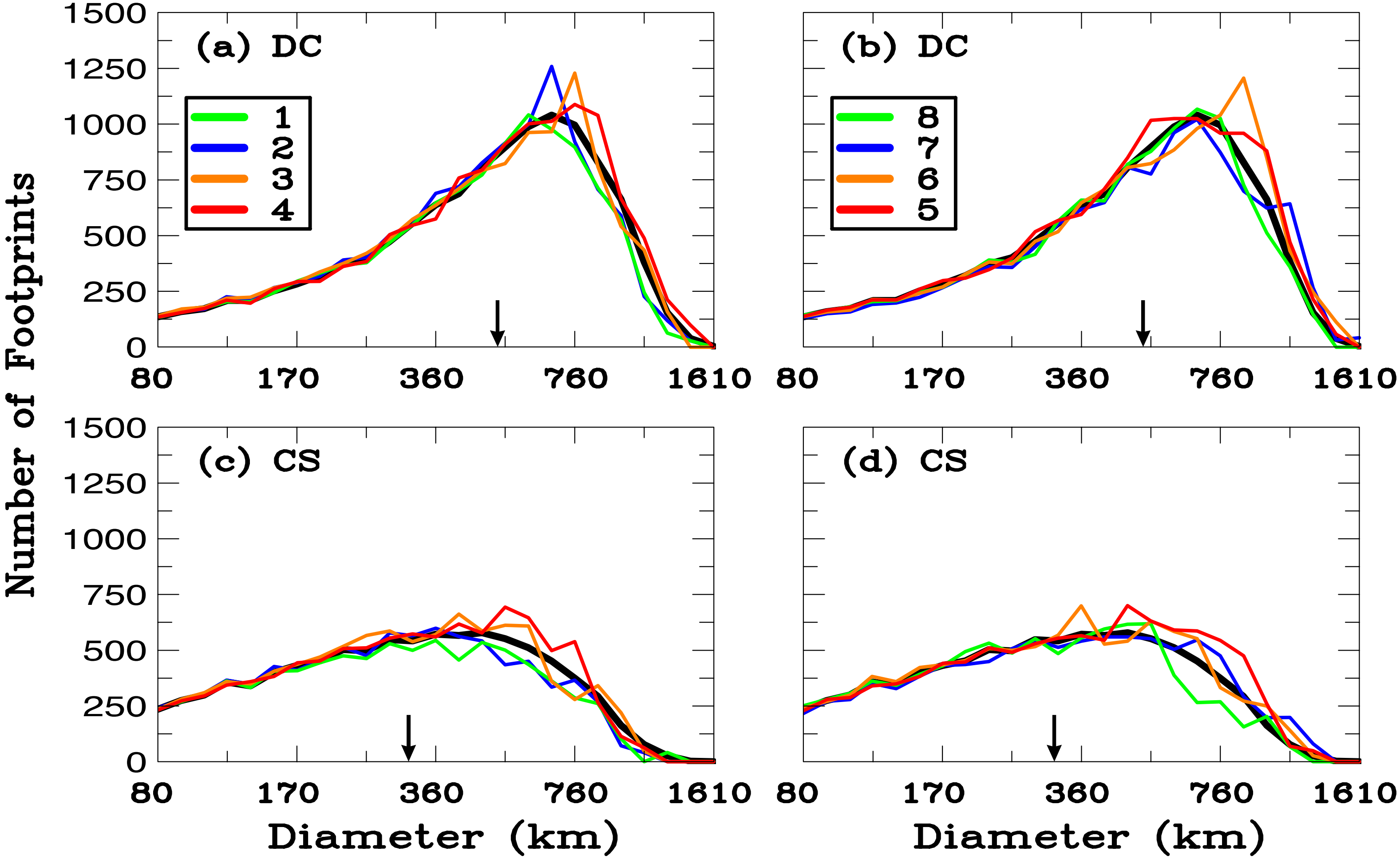


Areal coverage of DC and cirrostratus cloud objects



Color bar denotes number of footprints per 5°x5° grid mesh; ~ 0-20% areal coverage

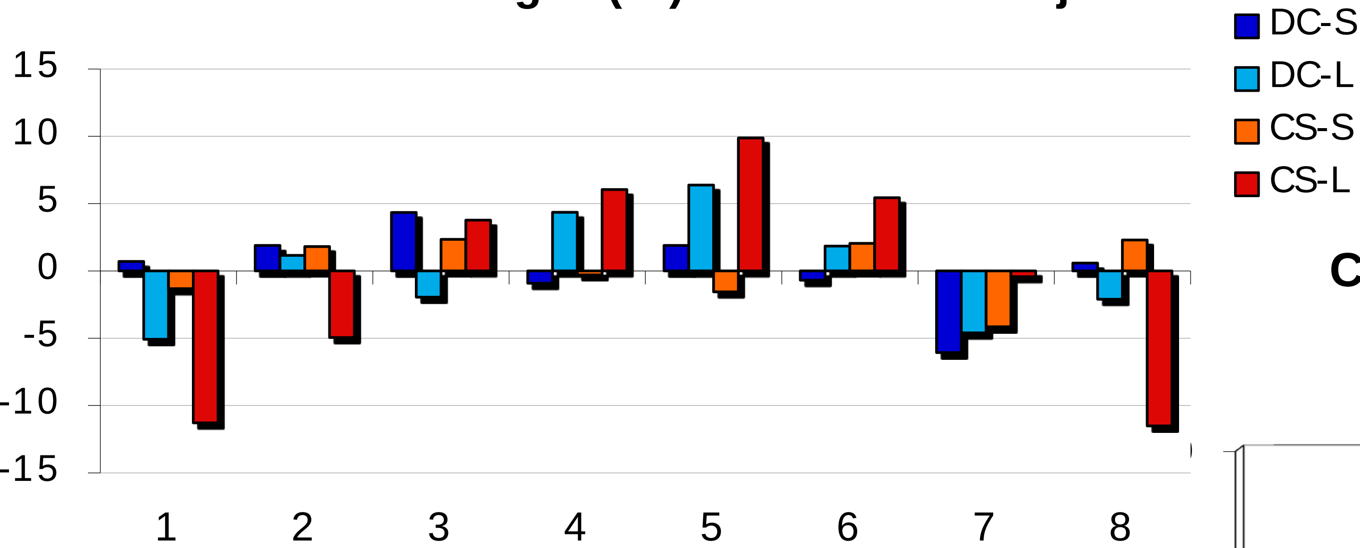
Size distributions of DC and cirrostratus cloud objects



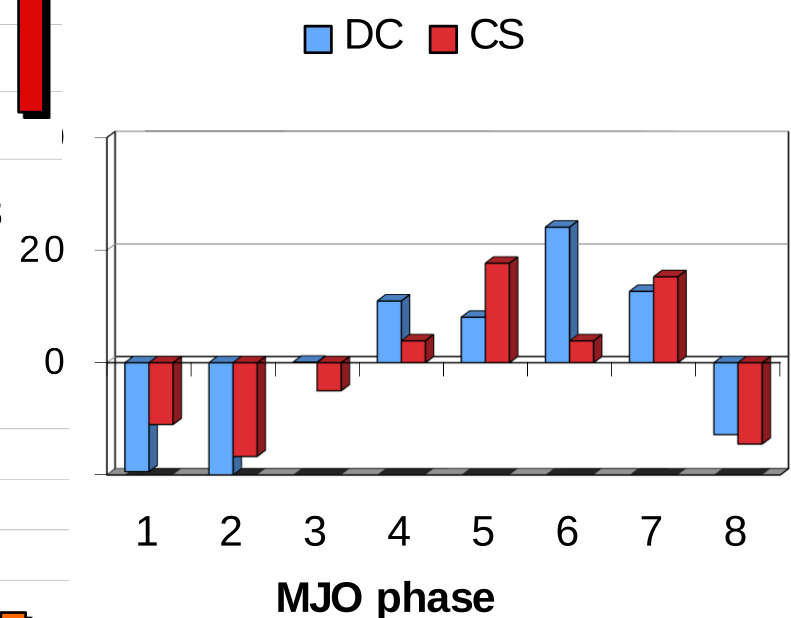
1. Very different size distributions between DC and cirrostratus cloud objects
2. The size distributions are similar for objects smaller than medium sizes for all phases
3. Phases 3-6 show more frequent appearance of the largest cloud objects

Size distribution changes for small & large cloud objects

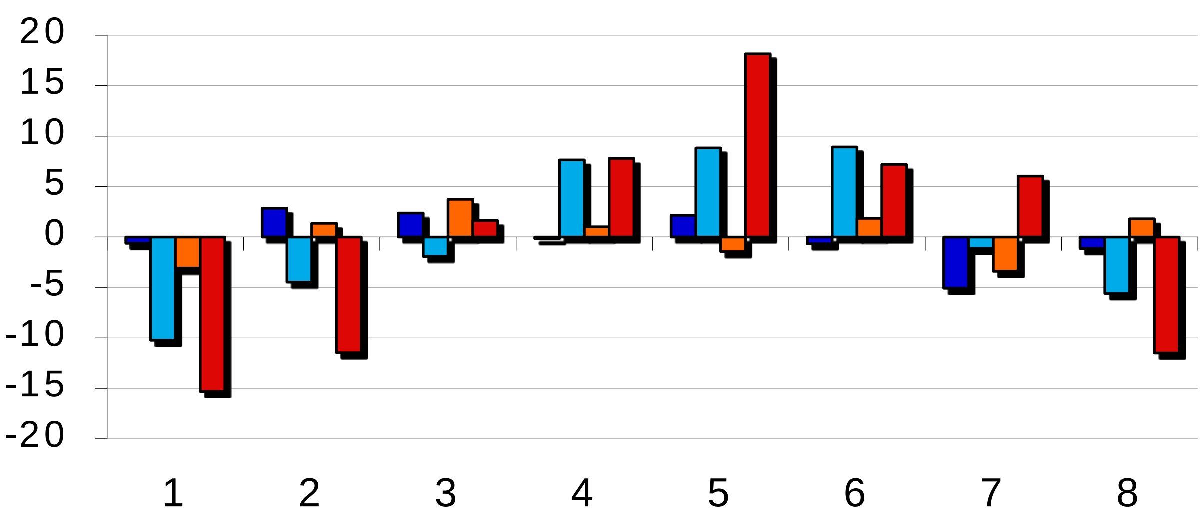
Relative changes (%) in number of objects



Change in Diameter (km)

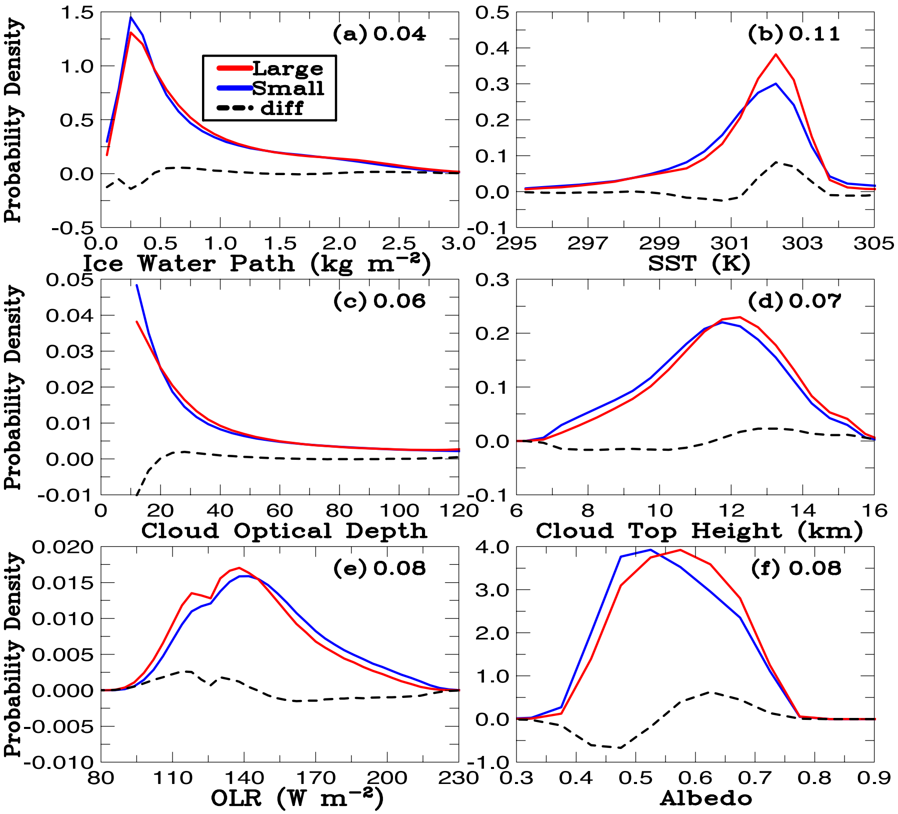


Relative changes in footprint numbers

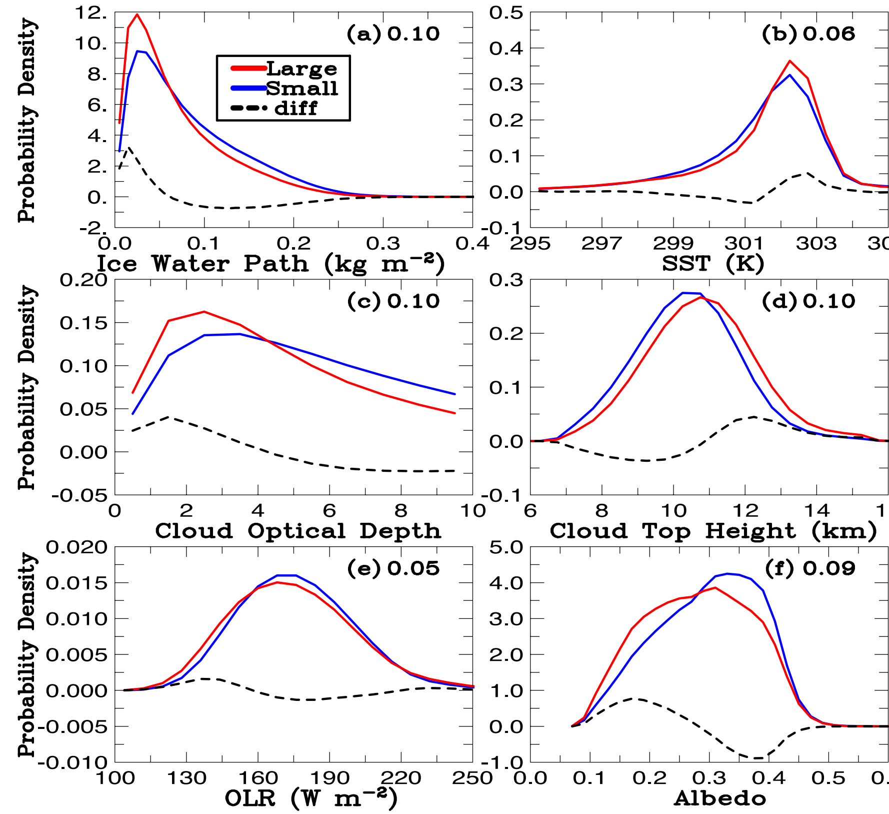


Variations of cloud and radiative properties--all MJO phases

Deep convective



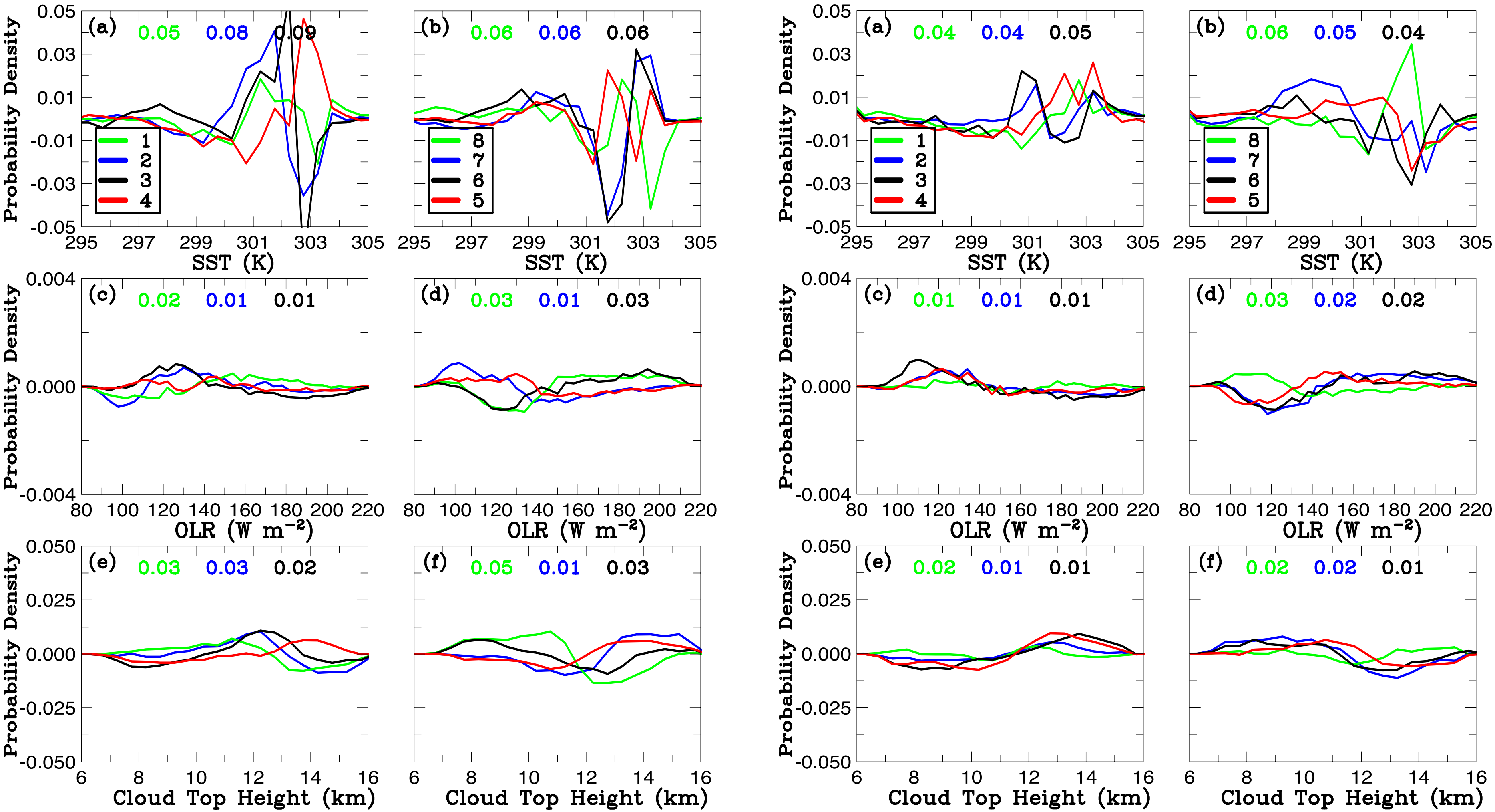
Cirrostratus



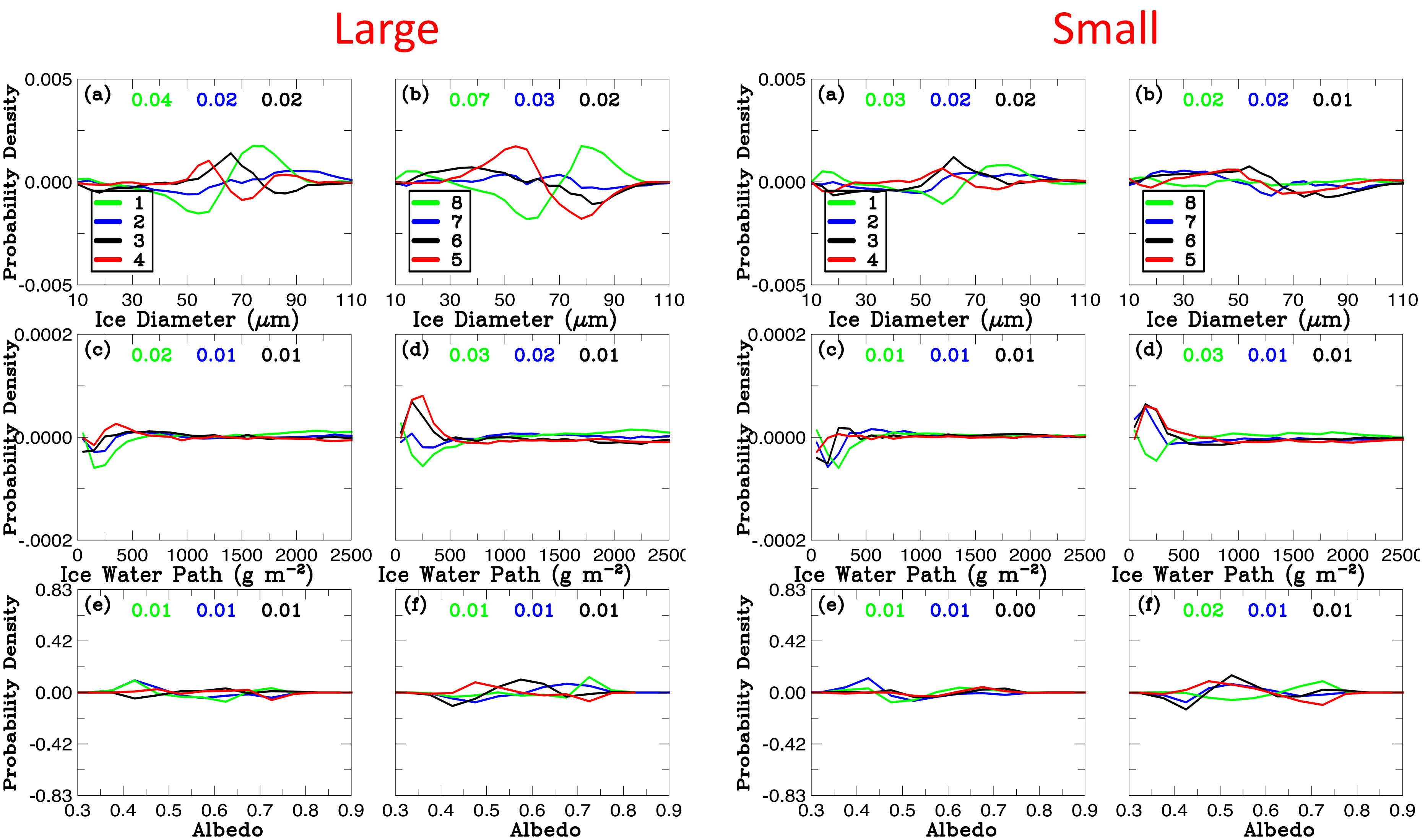
Instead of the entire PDFs for each phase, we will show the deviations of PDF from the all-phase PDFs to examine the variations with the MJO phase.

Deep convective cloud object properties, I: SST, OLR, Ht

Large | Small



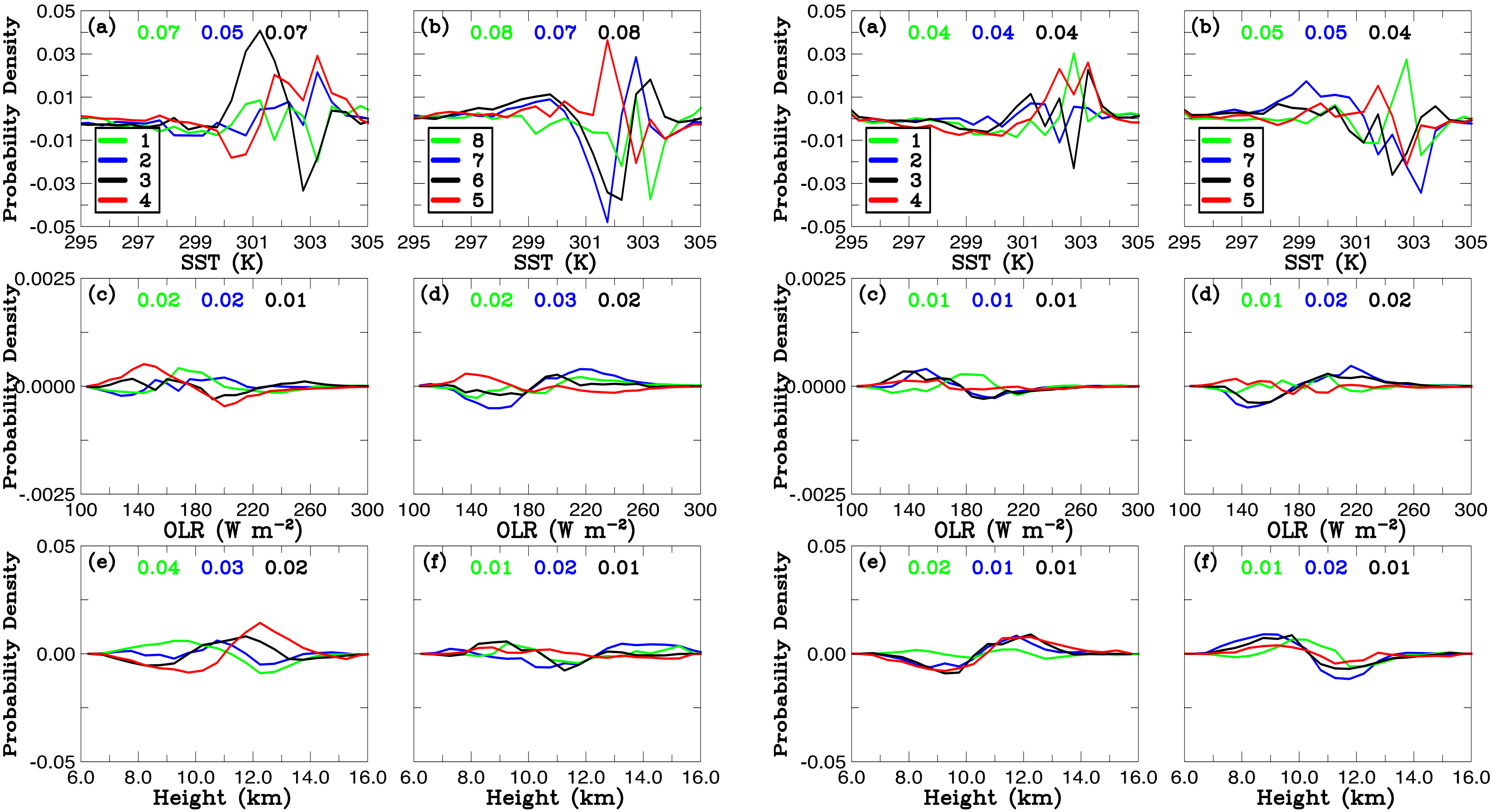
Deep convective cloud object properties, II: Optical props



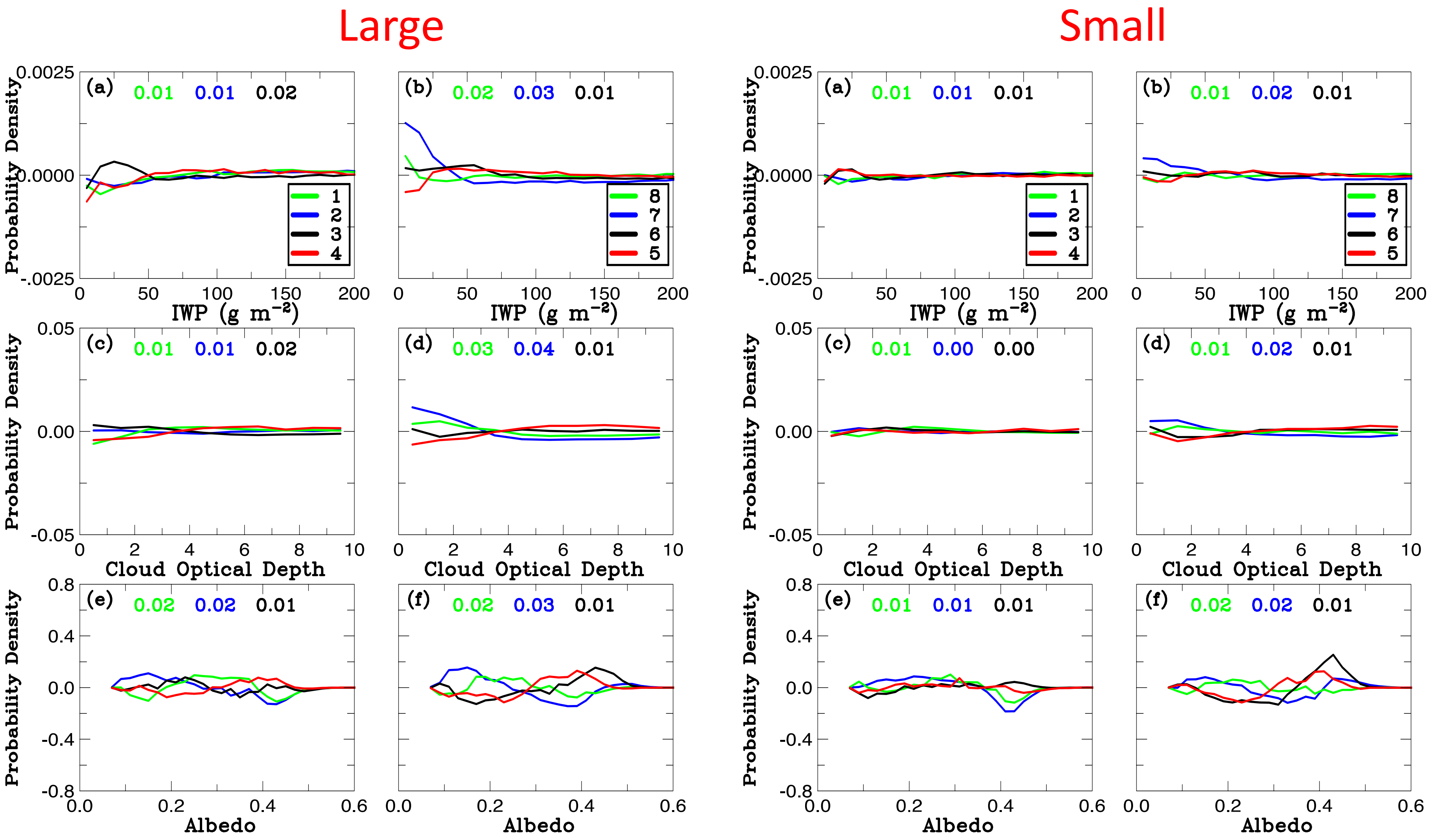
Cirrostratus cloud object properties, I: SST, OLR, Ht

Large

Small



Cirrostratus cloud object properties, II: Optical properties



Summary

Q: What are the relative roles of small and large convective cloud clusters during the Madden-Julian Oscillation (MJO) life cycle?

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➢ The contrasts between the suppressed and active phases are not as pronounced as previously thought (MJO schematics); e.g., there is abundant deep convection during the depressed phases in regions outside of the Indian-maritime Continent.

➢ There is almost no variation in the size distributions in the small ranges, but large variations in the large ranges, from one MJO phase to another.

➢ The frequency of occurrence for the large cloud objects changes with MJO phase strongly; ~20-30% range & phase lag between deep convective and cirrostratus; increased mean cloud object diameters during the mature phases.

➢ Although changes in the properties within each cloud type with the MJO phase are relatively small (i.e., compared to all-phase differences between the large and small sizes), those associated with the large-size cloud objects are marginally greater than those of the small-size cloud objects.