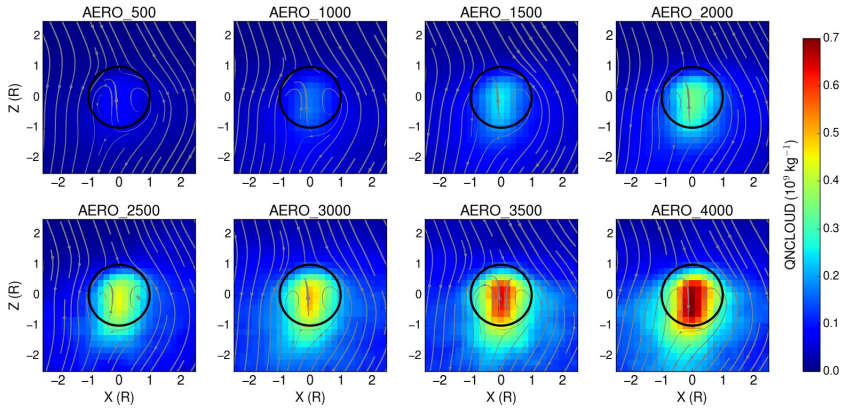
Dynamics and Microphysics of Cumulus Thermals within Simulations of Aerosol-Deep Convection Interactions:

Thermal bubble statistics of dynamics and microphysics from LES



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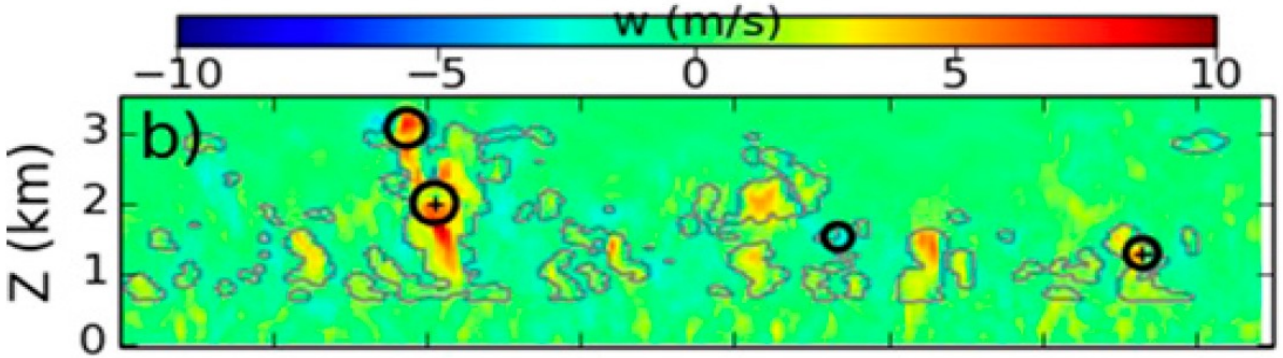
Hernandez-Deckers, D., Matsui, T., and Fridlind, A. M.: Updraft dynamics and microphysics: on the added value of the cumulus thermal reference frame in simulations of aerosol–deep convection interactions, Atmos. Chem. Phys., 22, 711–724, https://doi.org/10.5194/acp-22-711-2022, 2022.

Objective

- **Long-term goal**: Build strong foundation for new thermal-based parameterizations of moist convection to better represent aerosol-cloud interactions beyond traditional "steady-state dry entraining plume" at various grid scales (a few km ~ a few deg).
- **Objective**: Investigate the properties of simulated "cumulus thermals" from cloud-process simulations with different background aerosols.

Cumulus Thermals: Rising buoyant bubbles with spherical vortex-like circulations



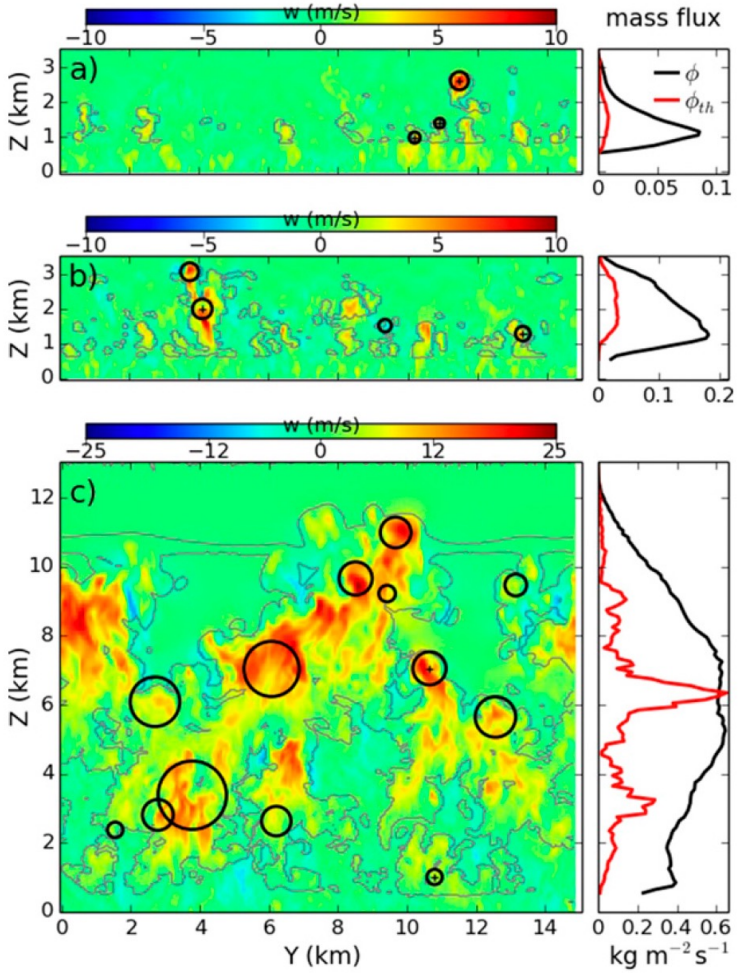
(Hernandez-Deckers and Sherwood 2016 JAS)

Thermal Tracking Algorithm

Thermal Tracking Method (Hernandez-Deckers and Sherwood 2016 JAS). Used 1min NUWRF output for 3hr period.

1. Identify thermal centers from the local maxima of vertical velocity (w_{max}).
2. Track successive w_{max} points based on velocity components (U,V,W).
3. Determine thermal boundaries (size), assuming spherical shape.
4. Compute and record thermal properties of microphysics (Q, N) and thermodynamics (R, B, D, LTL).

(from Hernandez-Deckers and Sherwood 2016 JAS).



Thermals account for 15-20% of total mass flux.

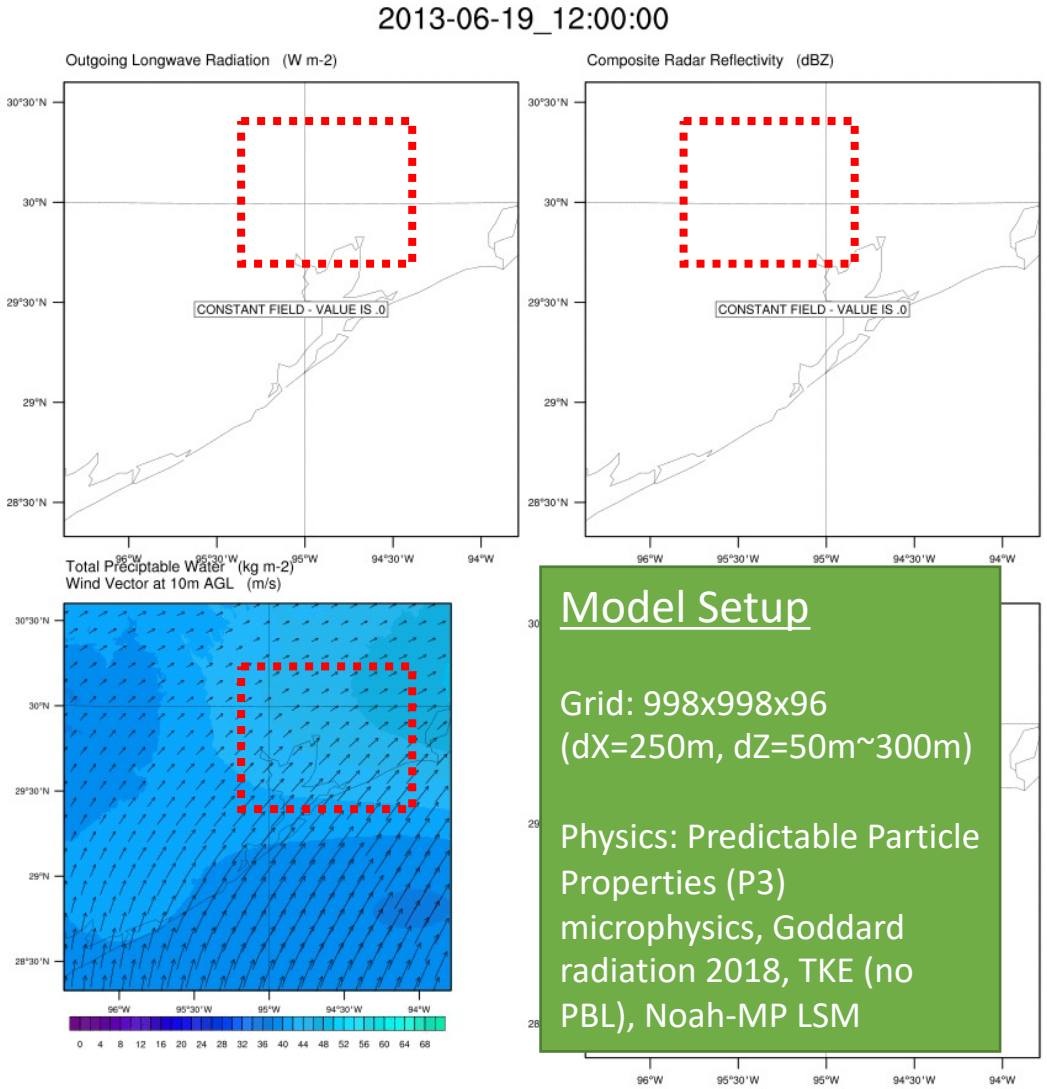
NUWRF “very” Large Eddy Simulations over Houston, TX

Event

- 19-20, June 2013
- Houston, Texas
- See breeze-driven scattered deep convection

Aerosols Sensitivities

- Boundary layer CCN conc from clean to polluted: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000 cm^{-3}.
- CCN size distributions: Log-normal distribution (Dm=100nm, sigma=1.8, kappa=0.2

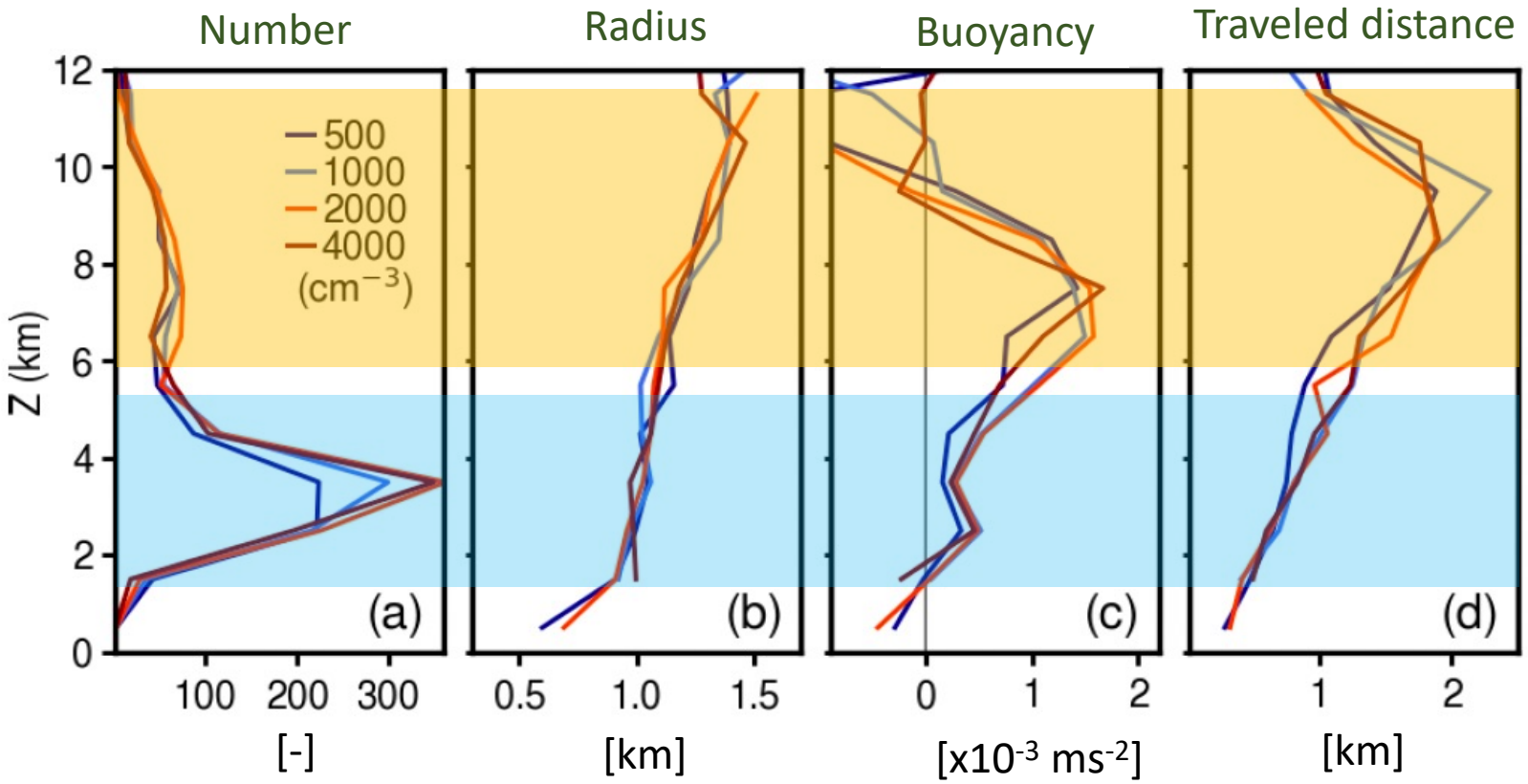


Model Setup

Grid: 998x998x96 (dX=250m, dZ=50m~300m)

Physics: Predictable Particle Properties (P3) microphysics, Goddard radiation 2018, TKE (no PBL), Noah-MP LSM

Vertical Properties of Thermals

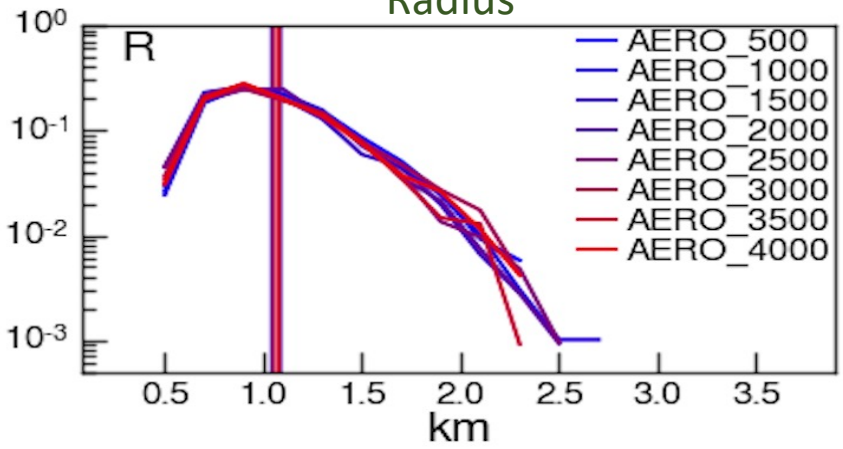


Larger long-lived fewer thermals

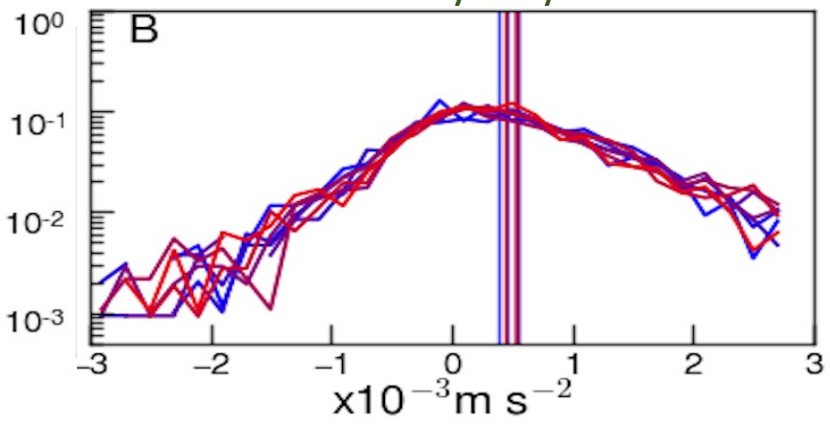
Smaller short-lived numerous thermals

Thermal Distributions

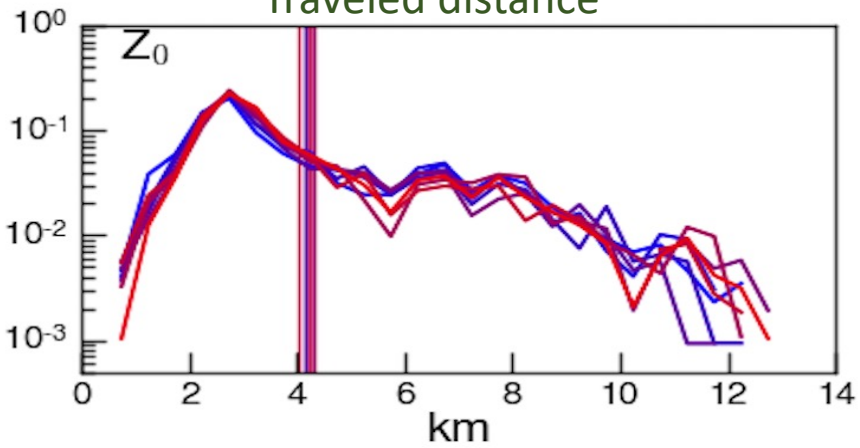
Radius



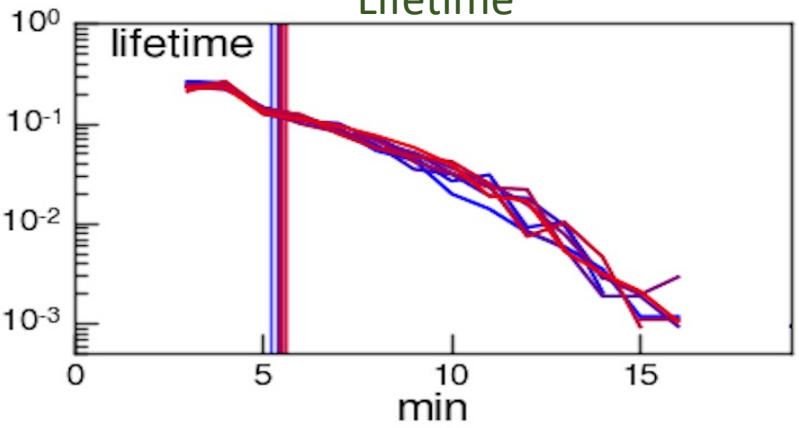
Buoyancy



Traveled distance

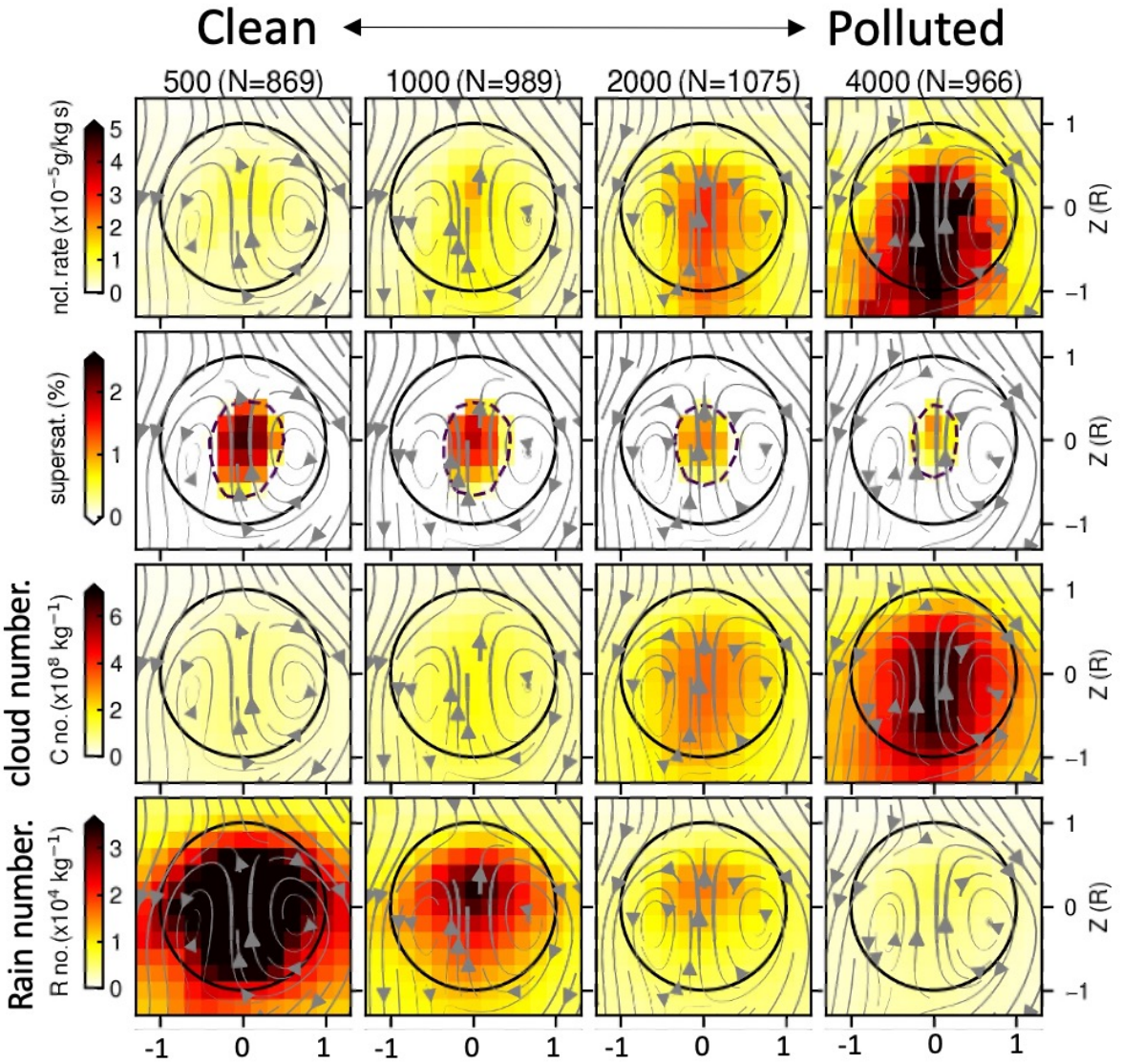


Lifetime



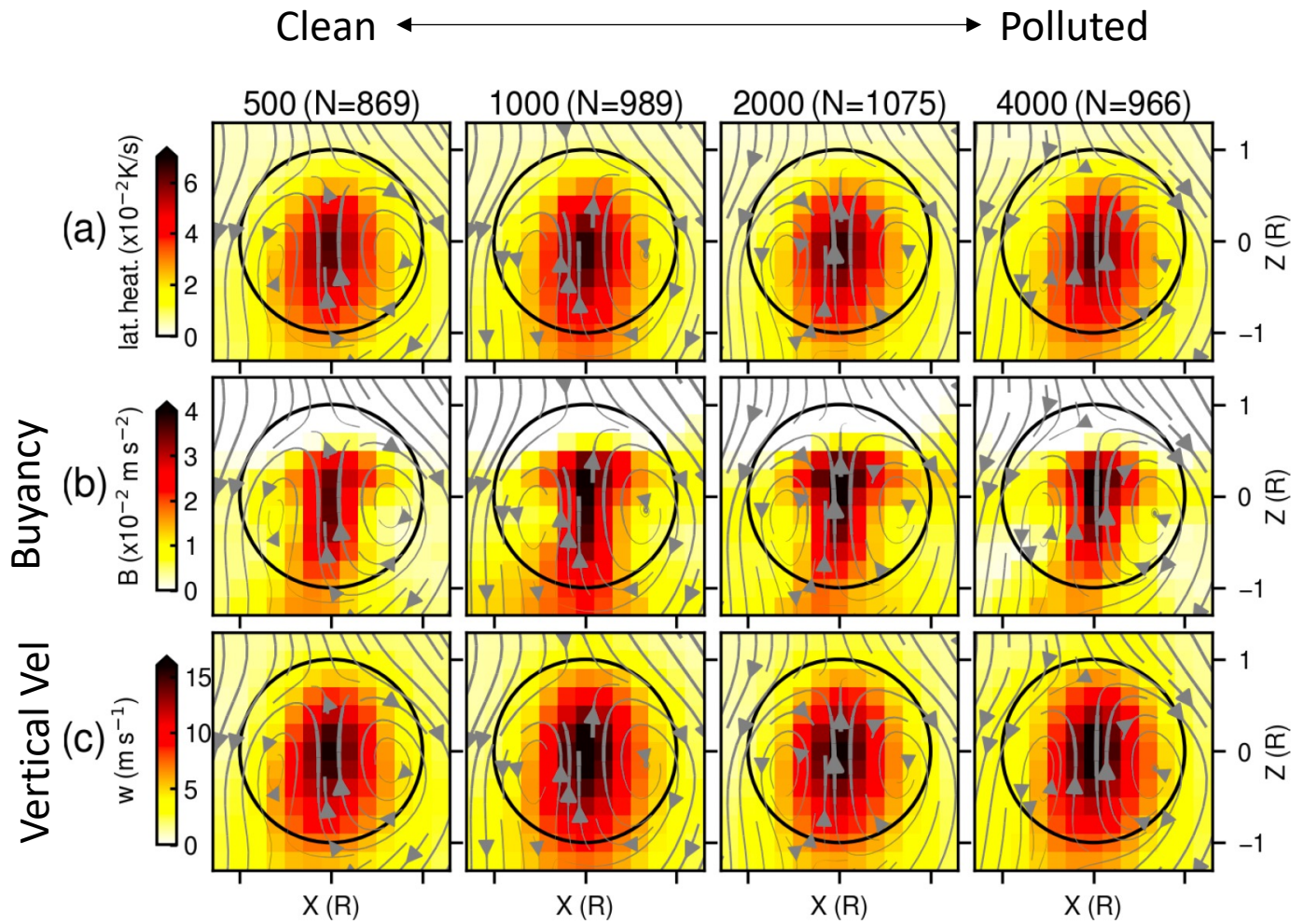
Not systematically altered by CCNs.

Normalized cross sections of thermals -Microphysics-



Tightly linked to background CCN conc.

Normalized cross sections of thermals -Thermodynamics-



Not tightly linked to background CCN conc.

Cloudy Updraft Grids Vs Tracked Thermals

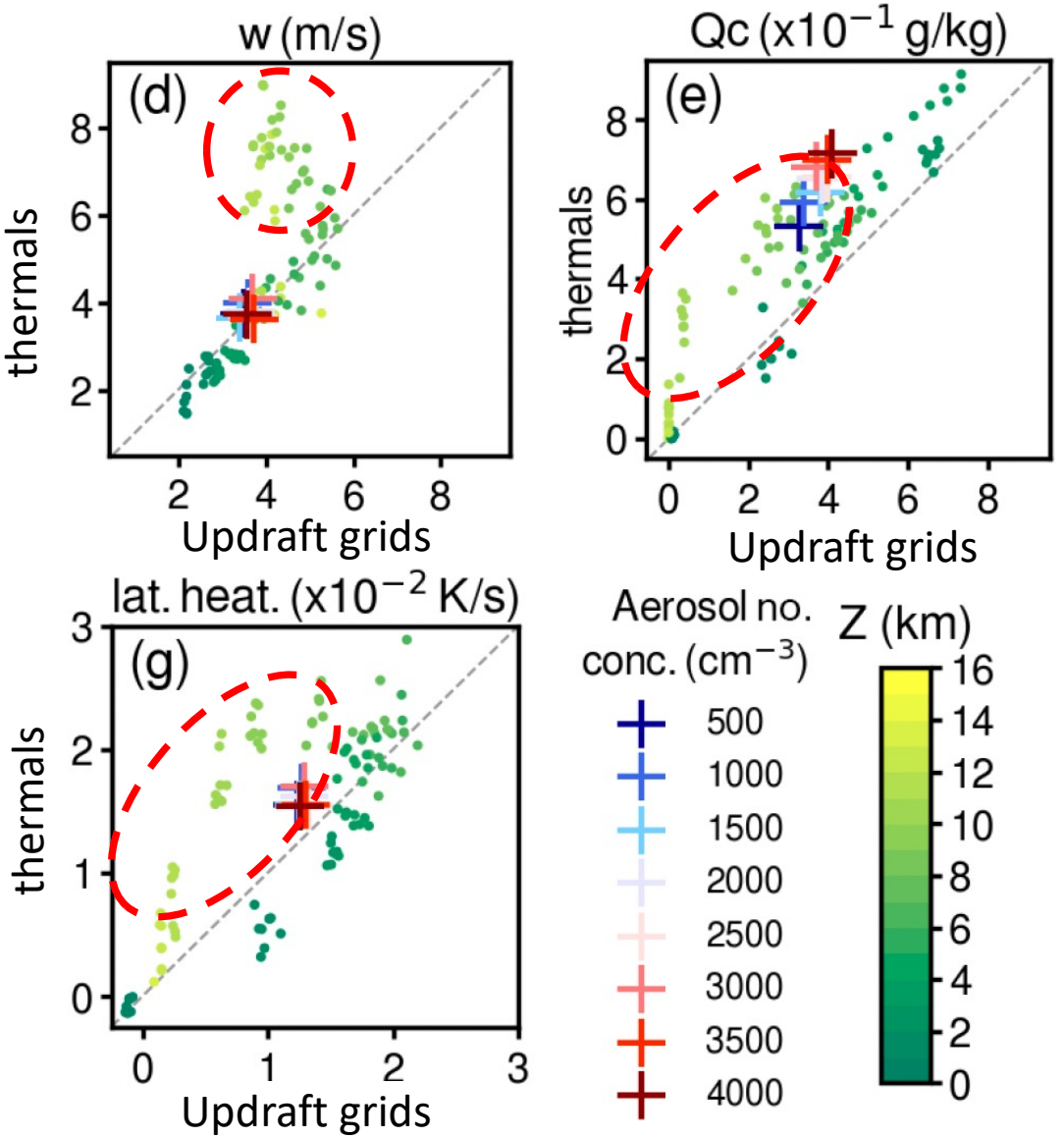
Traditional approach

Cloudy Updraft Grids (w>1m/s & Q_{tot}>0.01g/kg)

New approach

Tracked Thermals: Thermal features are search from same cloudy updraft grids (w>1m/s & Q_{tot}>0.01g/kg)

In upper portions (>10km), thermals tend to have **larger** vertical velocity (W), more condensates (Qc), and stronger latent heating than cloudy updraft grids.

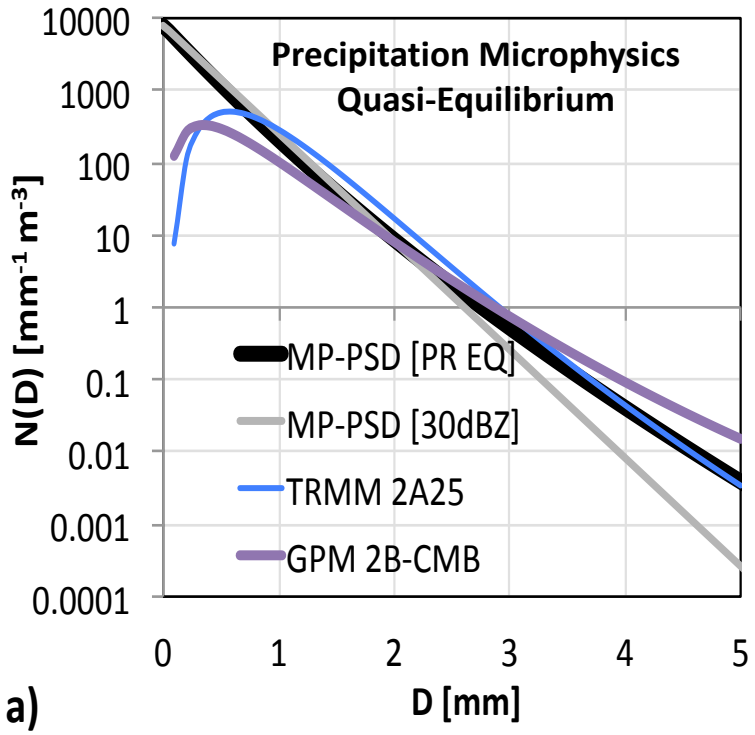


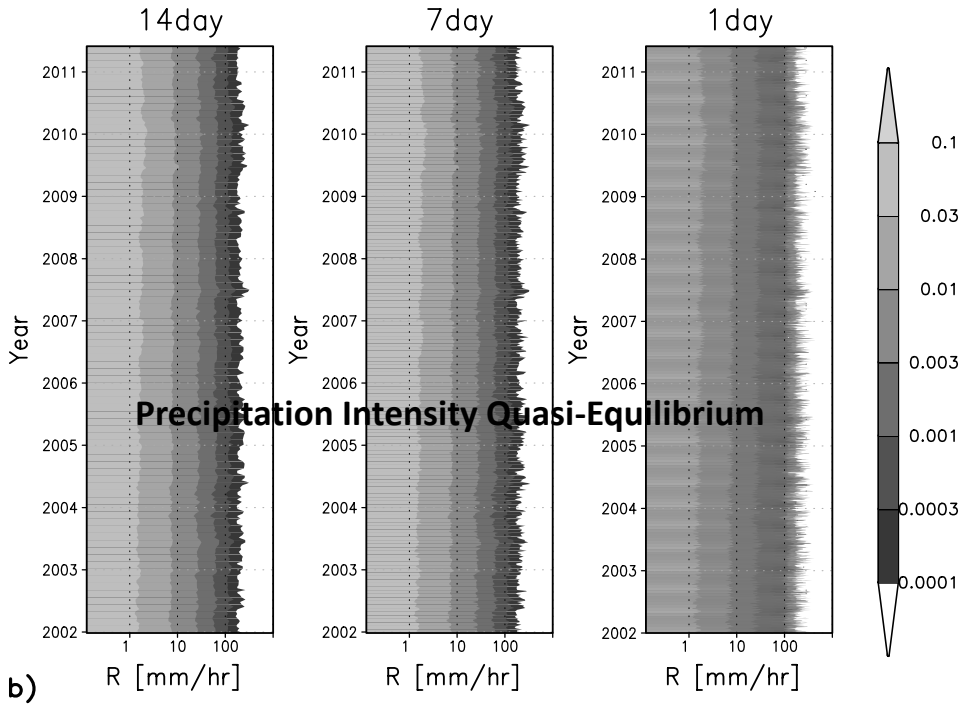
Remarks

- Thermal microphysics are strongly affected by background CCNs, but radius, buoyancy, and lifetime are not related to background CCNs.
- In comparison with traditional grid analysis, the novel thermal tracking analysis provides tighter coupling of updraft properties between thermodynamics and microphysics at upper level.
- Future research is required to capture more detailed ice microphysics properties of cumulus thermals and transient nature of thermal train.

Can EarthCare satellite support?

Tropical Convection and Microphysics Quasi-Equilibrium





When TRMM observation are integrated over the entire tropics, precipitation particle size distributions (microphysics) and precipitation intensity (convection) spectrum become equilibrium states on the month-to-daily time scale, regardless of variability of tropical meteorology. So as latent heating and vertical velocity?

Matsui, T., W.-K. Tao, S. J. Munchack, G. Huffman, and M. Grecu (2015), Satellite View of Quasi-Equilibrium States in Tropical Convection and Precipitation Microphysics, *Geophysical Research Letters*, 42, doi:10.1002/2015GL063261