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Aerosol Impacts on Convection and Precipitation - from Amazon to Houston

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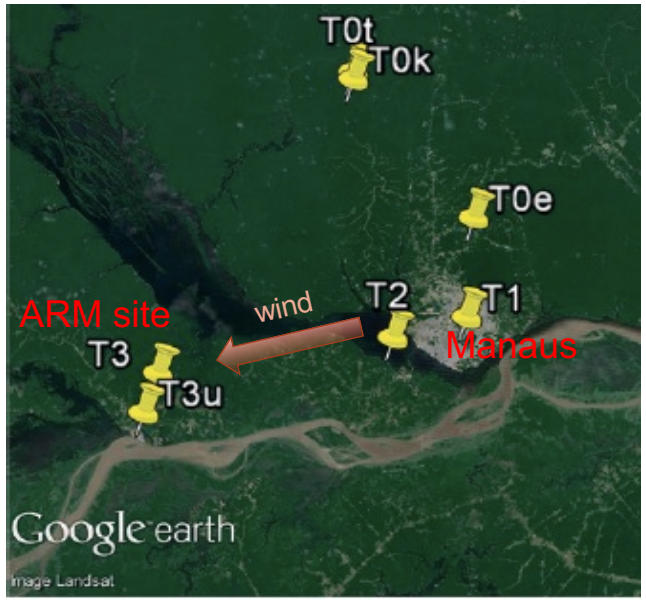
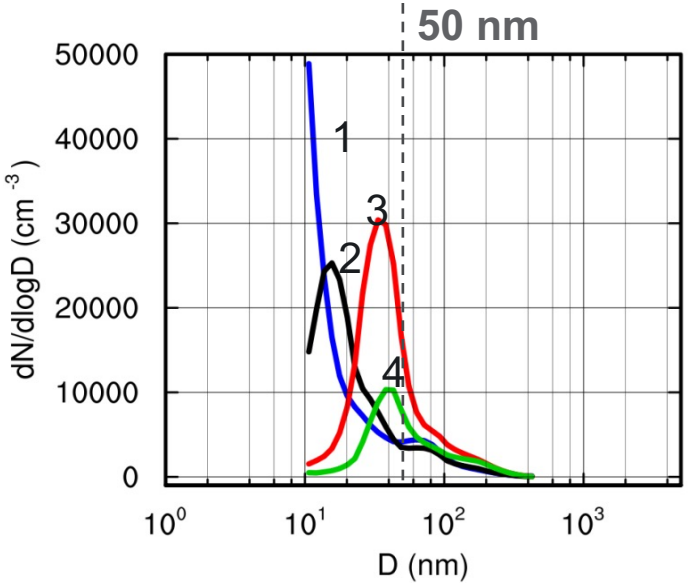
Ultrafine aerosol particles invigorate convection and precipitation in Amazon

❑ Uniqueness of Amazon environment and GoAmazon

- **Warm and humid** condition; similar day-to-day weather in wet season.
- GoAmazon was designed to **disentangle aerosol impacts** from the impact of meteorological variables. Downwind site
- **Unique observational data**: convective intensity and aerosol size distribution from 10 nm
- **Ultrafine aerosol particles** (<50 nm; UAP) are high but large aerosol particles (>50 nm) that can be activated at cloud bases are low.



❑ Carefully selected 17 locally-occurring deep convective cases from the 2014 wet season with valid aerosol and convective core measurements



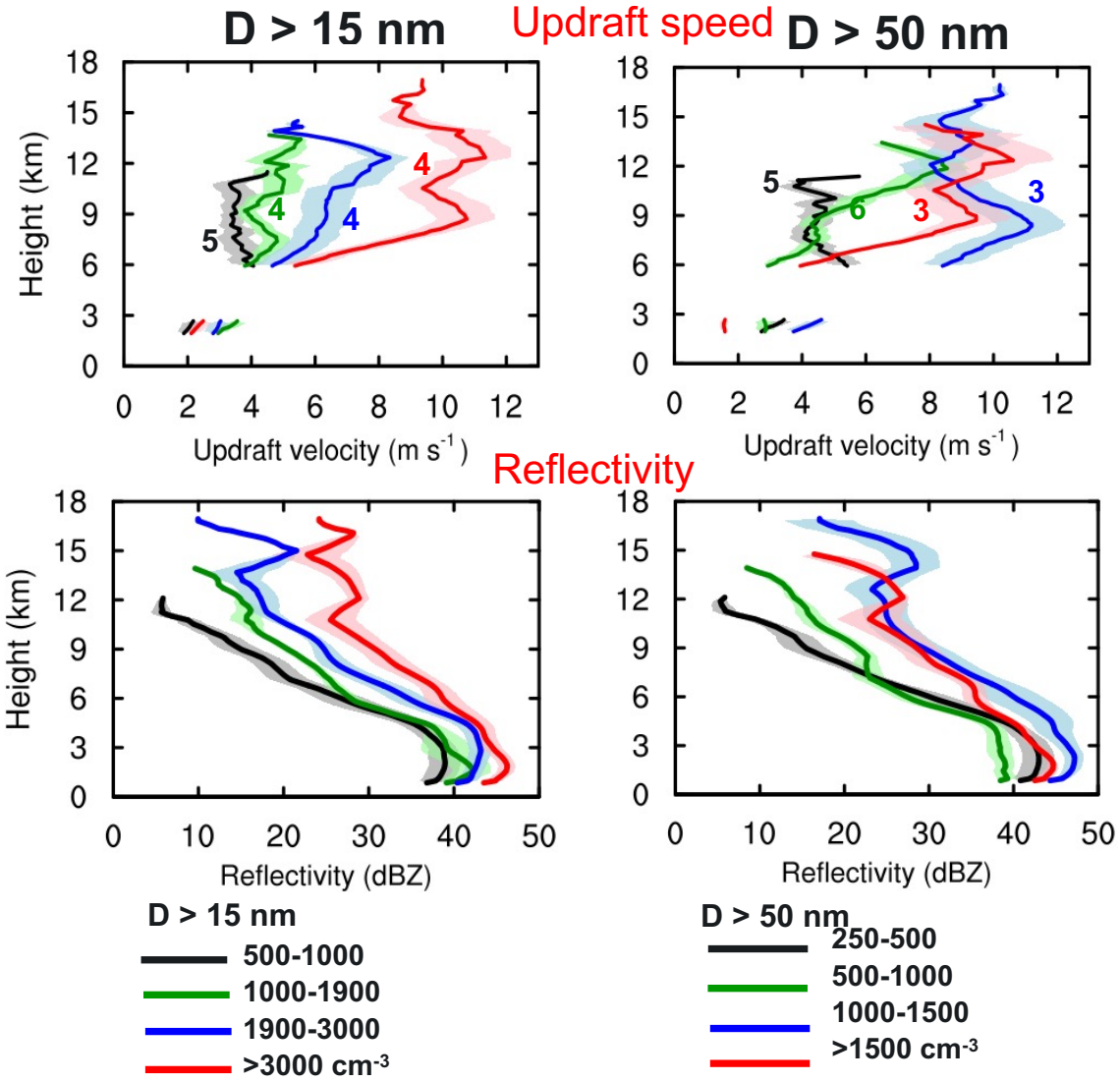
G-1 aircraft obs. of aerosol SD at different locations (1,2,3, and 4) influenced by Manaus plume

Fan et al., Science, 2018

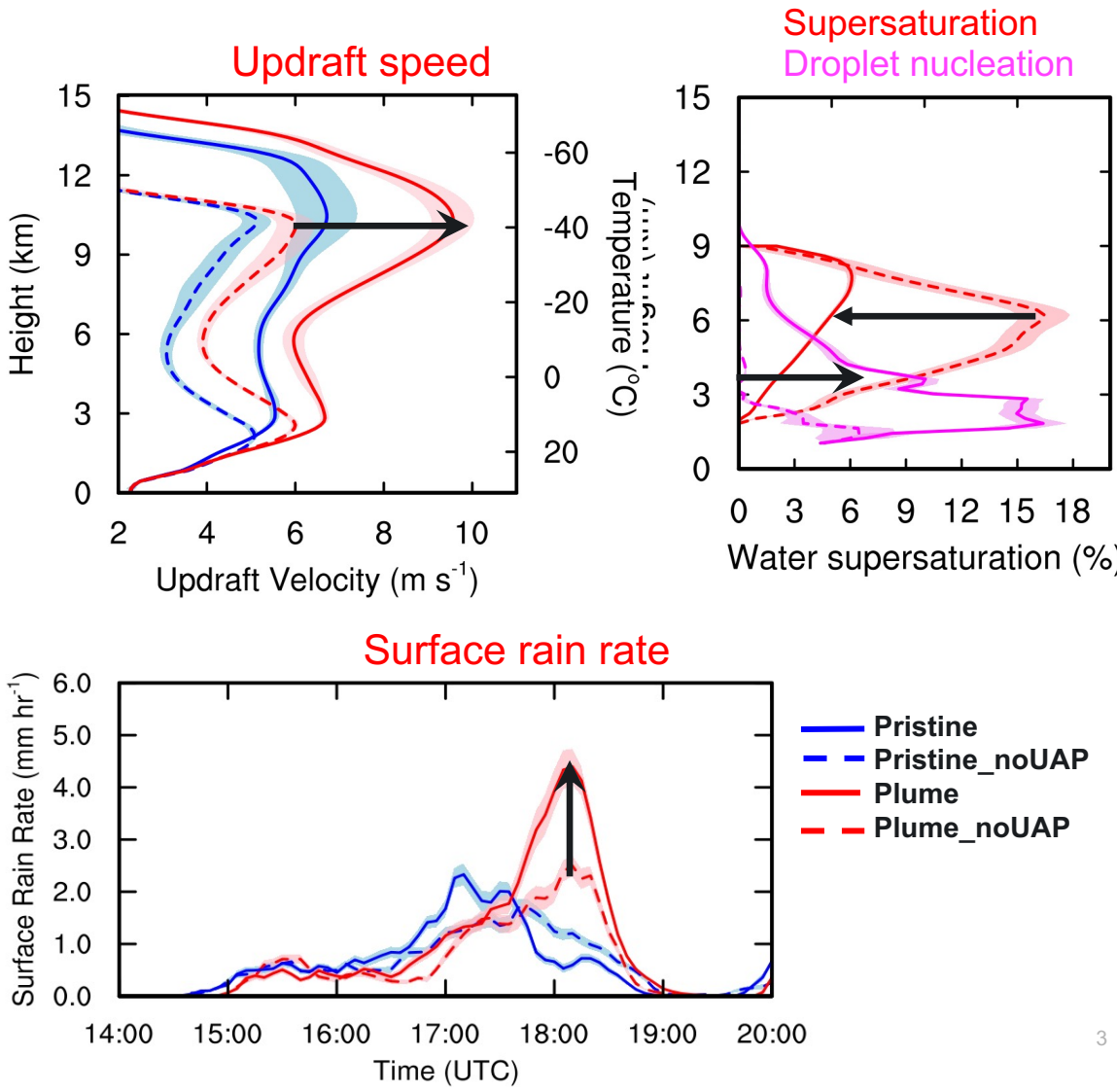
Observed and modeled large invigoration effect by UAP

WRF-SBM at 0.5 km

❑ Observed large effects



❑ Modeled effects similar to observed



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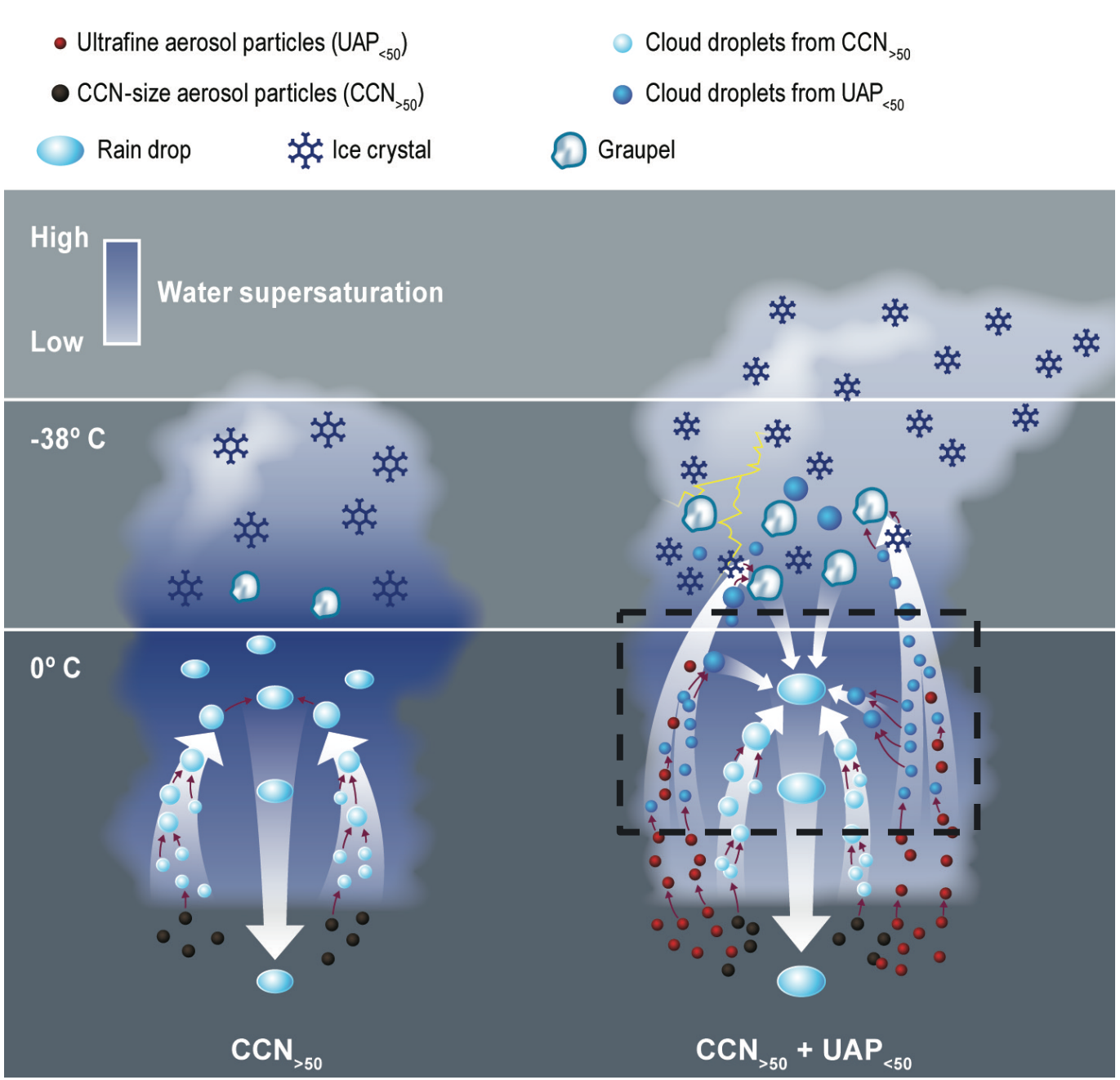
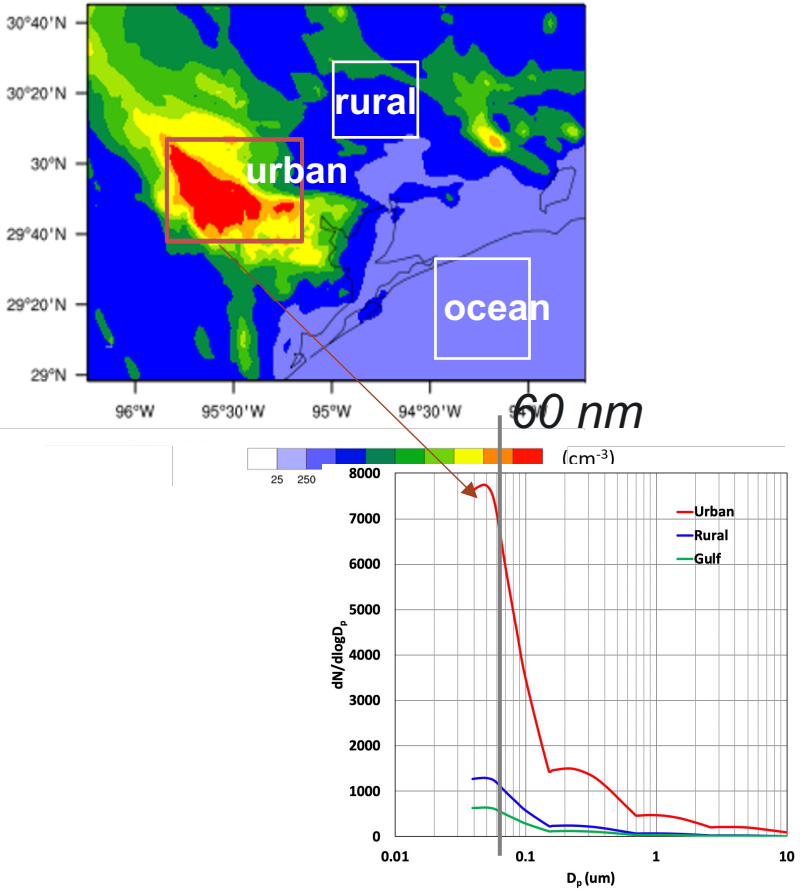
"Water-phase invigoration"

- Does not delay rain or suppress warm rain (in contrast to the effect of $CCN_{>50}$)
- The effect is much more powerful compared to "cold-phase invigoration" because (a) the enhanced heat is much larger and (b) the heating is at the low and middle levels.
- Manifested by UAP in the clean environment

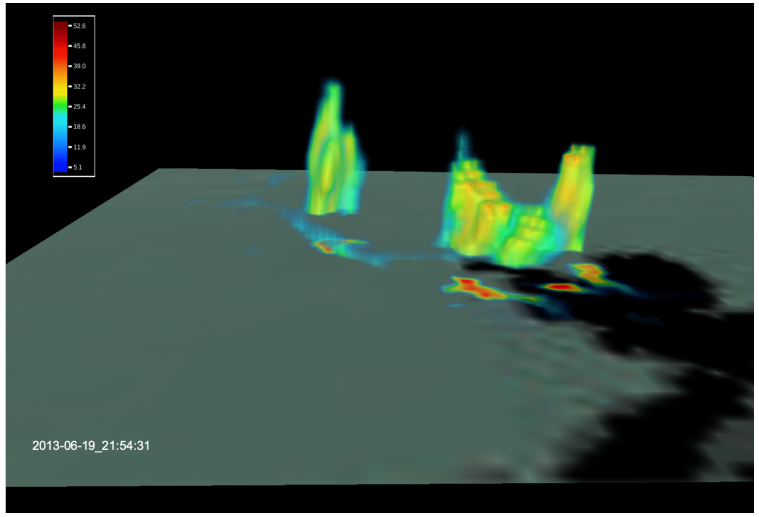


Similar mechanism found in Houston but the effect has a smaller magnitude

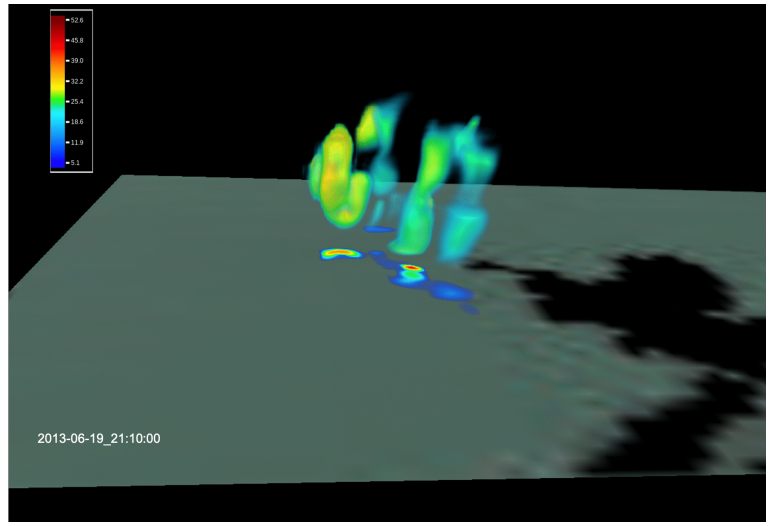
- A sea-breeze induced thunderstorm June 19-20, 2013 (the ACPC model intercomparison case).
- Simulated with WRF-Chem-SBM; 0.5 km grid spacing



Observation

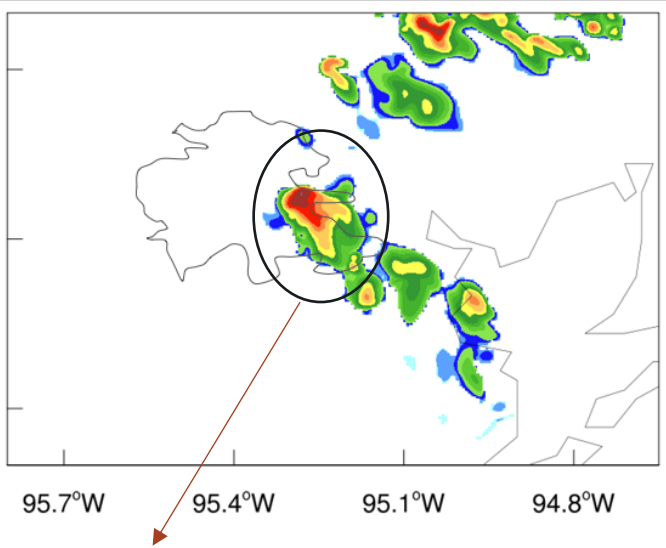


Simulated



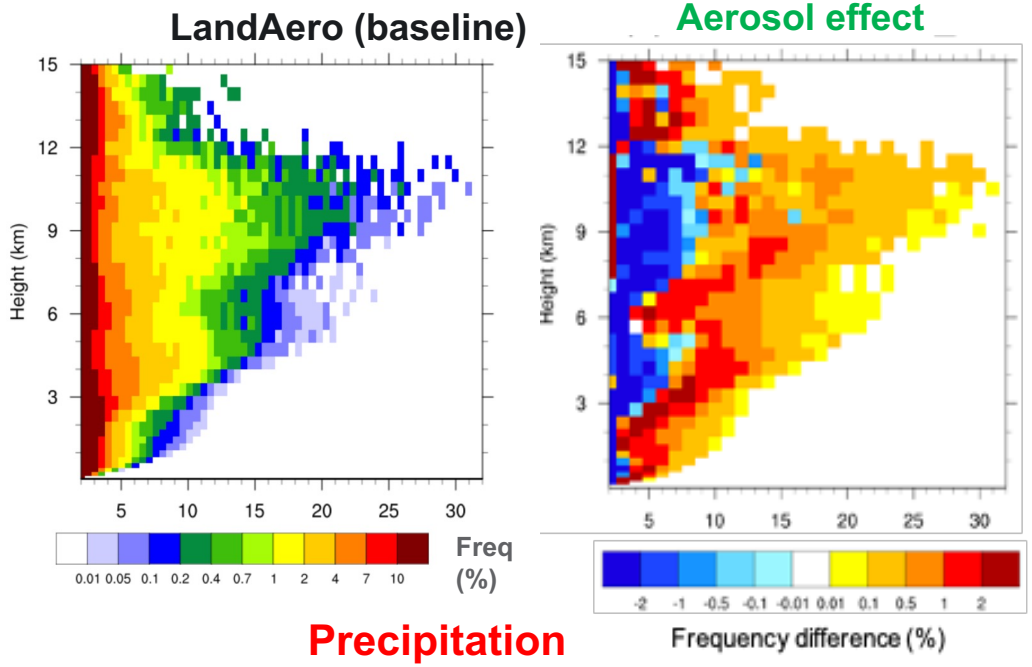
Fan et al., ACP, 2020

Anthropogenic aerosols enhance convective intensity and precipitation

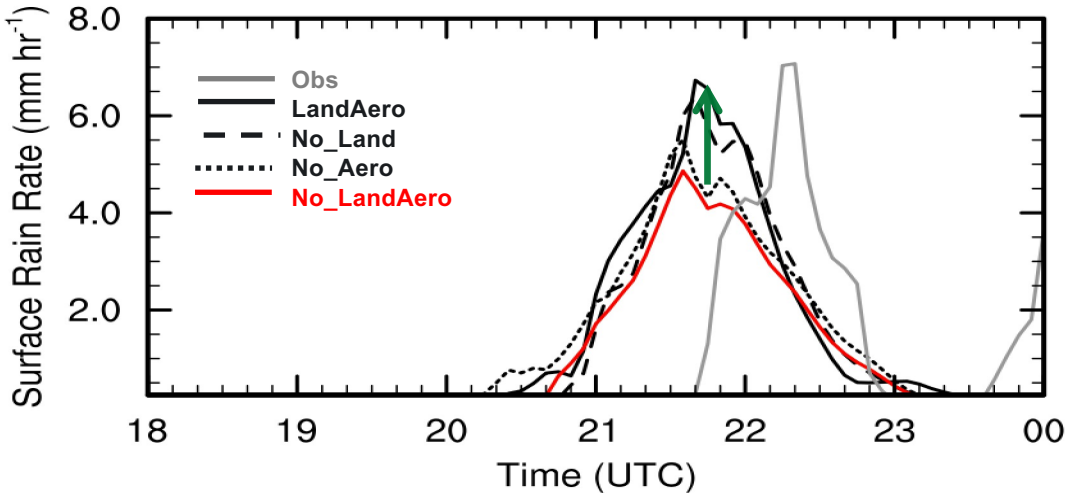


Strong convection occurred at the **urban-rural boundaries**!

Updraft speed



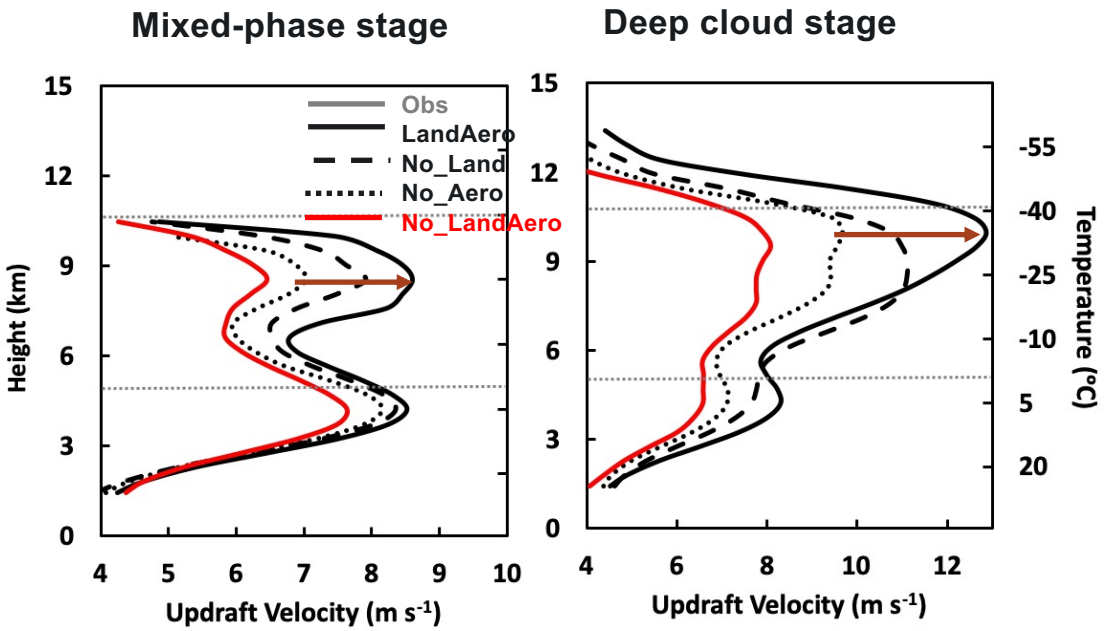
Precipitation



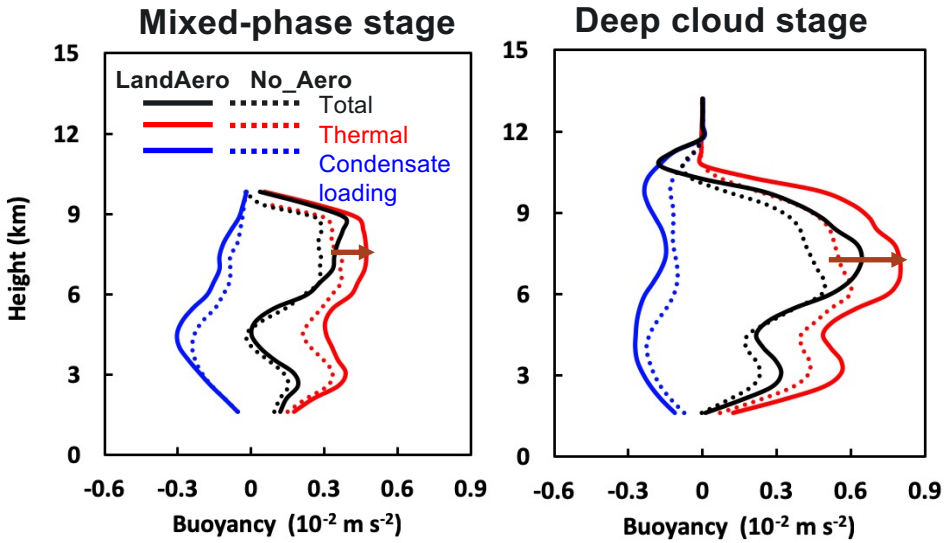
Aerosol effect:
The gap between the solid black and dotted lines

Aerosol effect accelerates development from the mixed-phase to deep cloud

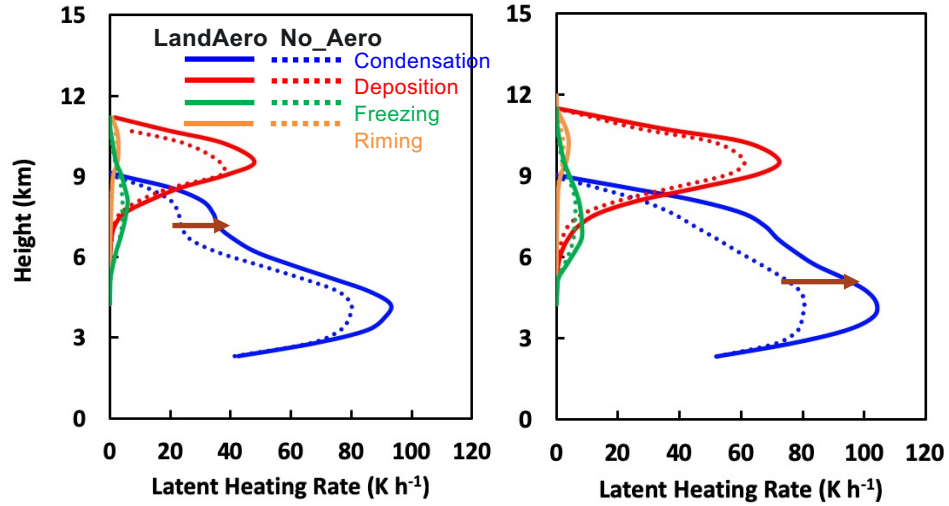
Updraft velocity (mean of top 25th percentiles)



Buoyancy + Condensate loading



Latent heating

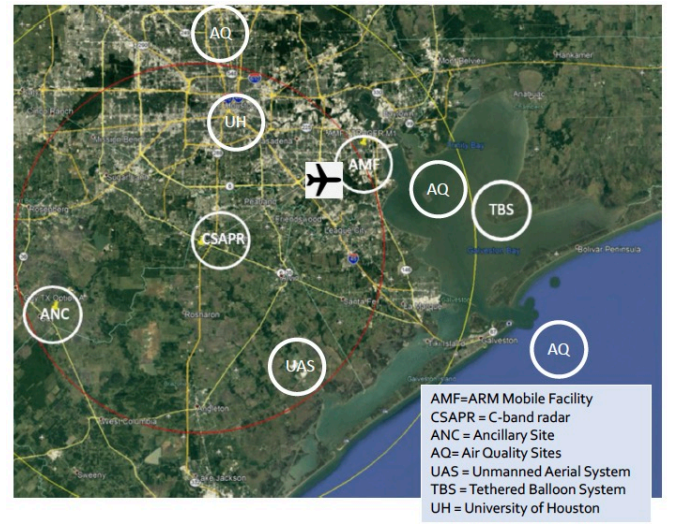


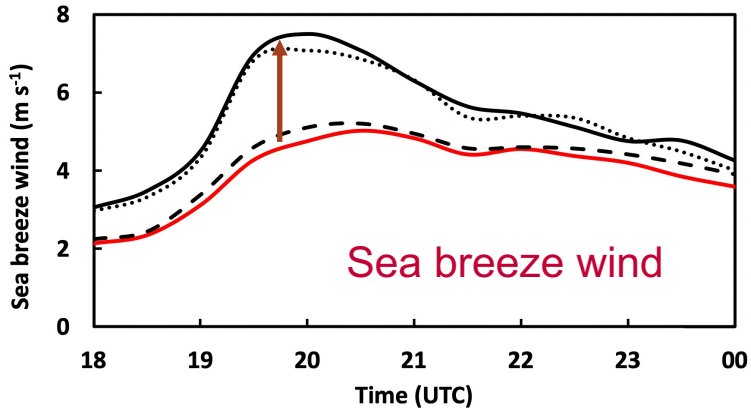
- At mixed-phase stage, aerosols begin to play an important role, mainly through enhanced condensation heating at 6-9 km
- This accelerates the development into deep convection.
- At deep cloud stage, water-phase invigoration is more significant because more ultrafine particles are activated

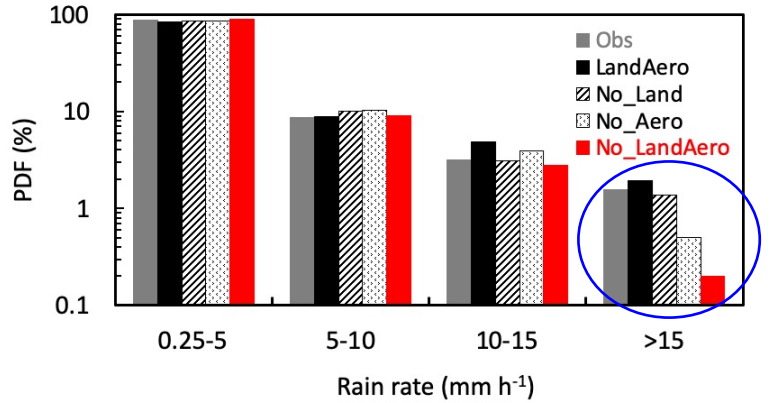
Challenges in Houston - TRACER

Oct. 2021 - Sep. 2022 with IOP Jun.-Sep. 2022

- **Exciting data: high frequency measurements in cloud microphysics, thermodynamics, and aerosols for tracked convective cells during cell lifecycles.**
- **Mingle with the urbanization effect since the sites are in the metropolitan area**
  - Enhanced sea breeze by urban heating (enhance convection at the shallow cloud stage and initiate the mixed-phase cloud earlier)
  - Aerosol effect and urbanization effect work together: non-linear amplification effect on heavy precipitation rates and strong updrafts
- **Aerosol properties over Houston could be very complicated; strong aerosol-radiation interaction could suppress convection in Houston** (*Fan et al., JGR, 2008*)
- **Might be difficult to find a number of cases with similar meteorology but contrasting aerosols.**







Fan et al., ACP, 2020