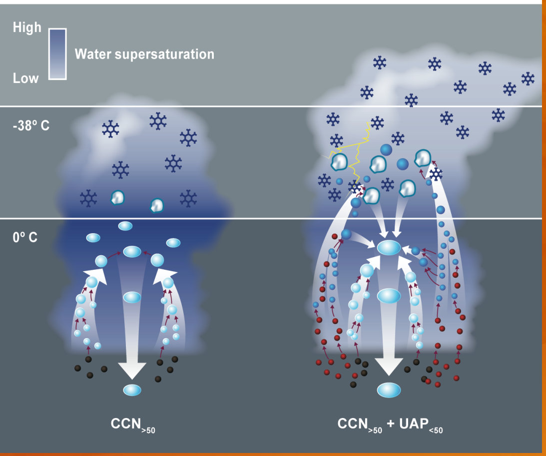

Fan et al. (2018), Science, 359.

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GOAMAZON 2014–2015

Substantial Convection and Precipitation Enhancements by Ultrafine Aerosol Particles

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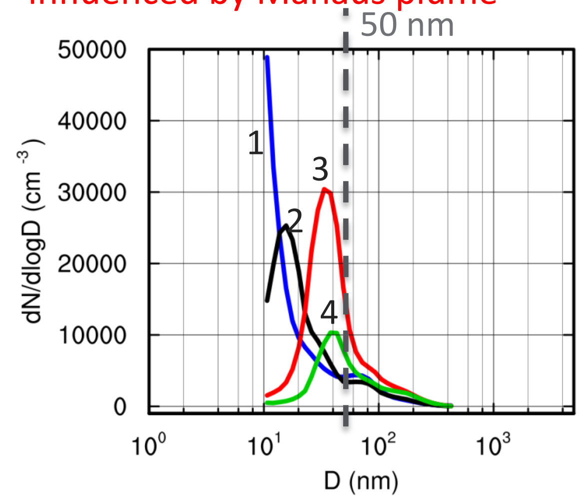
Also see poster #50

Background

- Aerosol-deep convective cloud (DCC) interaction is most complicated and least understood.
- A major bottleneck is to disentangle aerosol impacts from the impact of meteorological variables.
- Aerosol impact on convective intensity was not able to verified directly by observations due to lack of observation of updraft speed.
- Traditionally CCN-size particles are larger than 60 nm, while ultrafine aerosol particles (UAP) were thought to be too small to affect cloud formation.
- UAP are abundant in the areas with industry and human activities

G-1 aircraft measurements of aerosol size distribution at different locations (1,2,3,and 4) influenced by Manaus plume



Previous concept on invigoration

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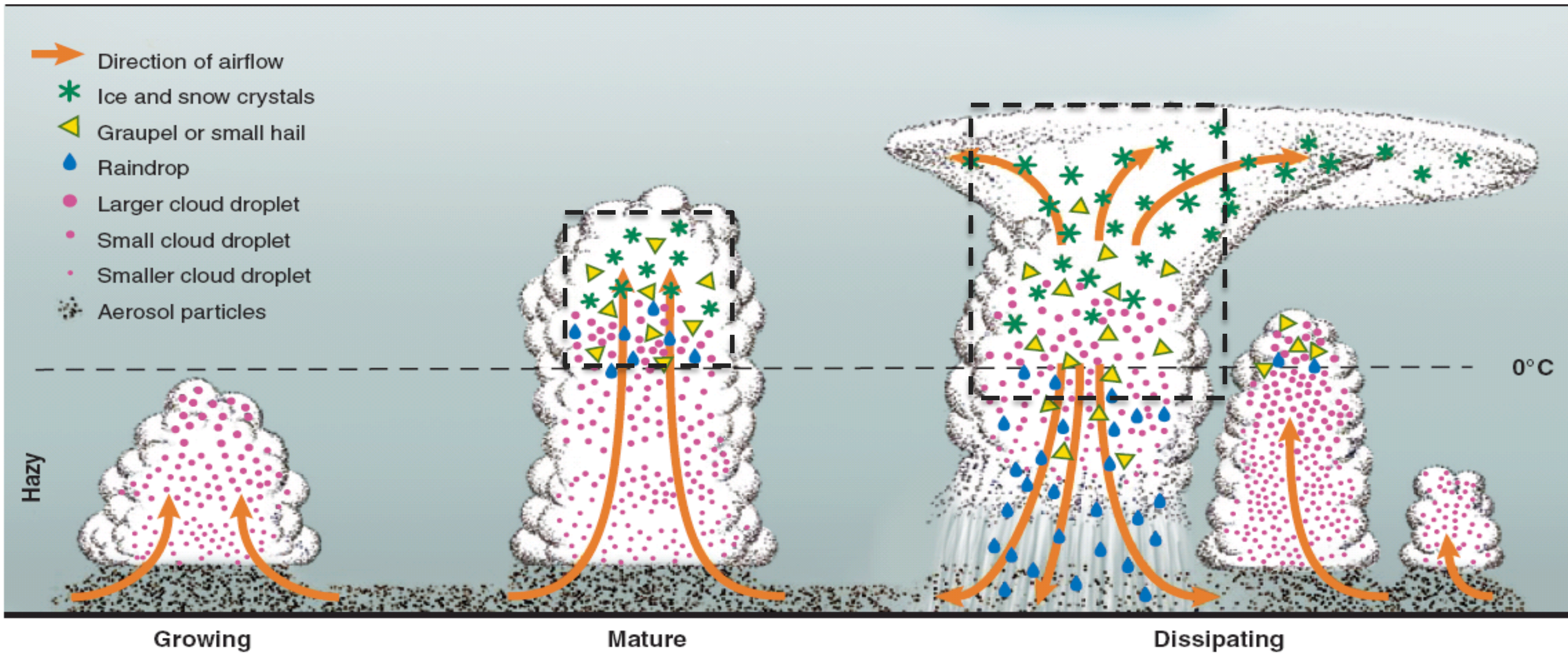
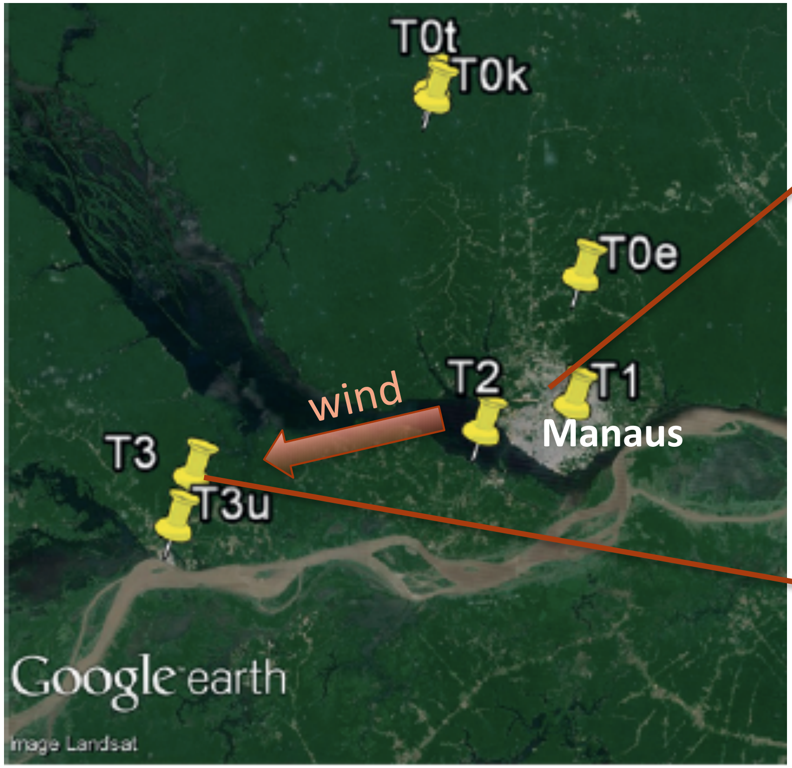
- **“Cold-phase invigoration”:** *Rosenfeld et al., Science, 2008*



Unique observations

- Unique experimental setting and observational data from GoAmazon allowed us at the first time to **pinpoint aerosol impacts** apart from changes of meteorological fields



Observed enhancement of convective Intensity and Precipitation by Aerosols

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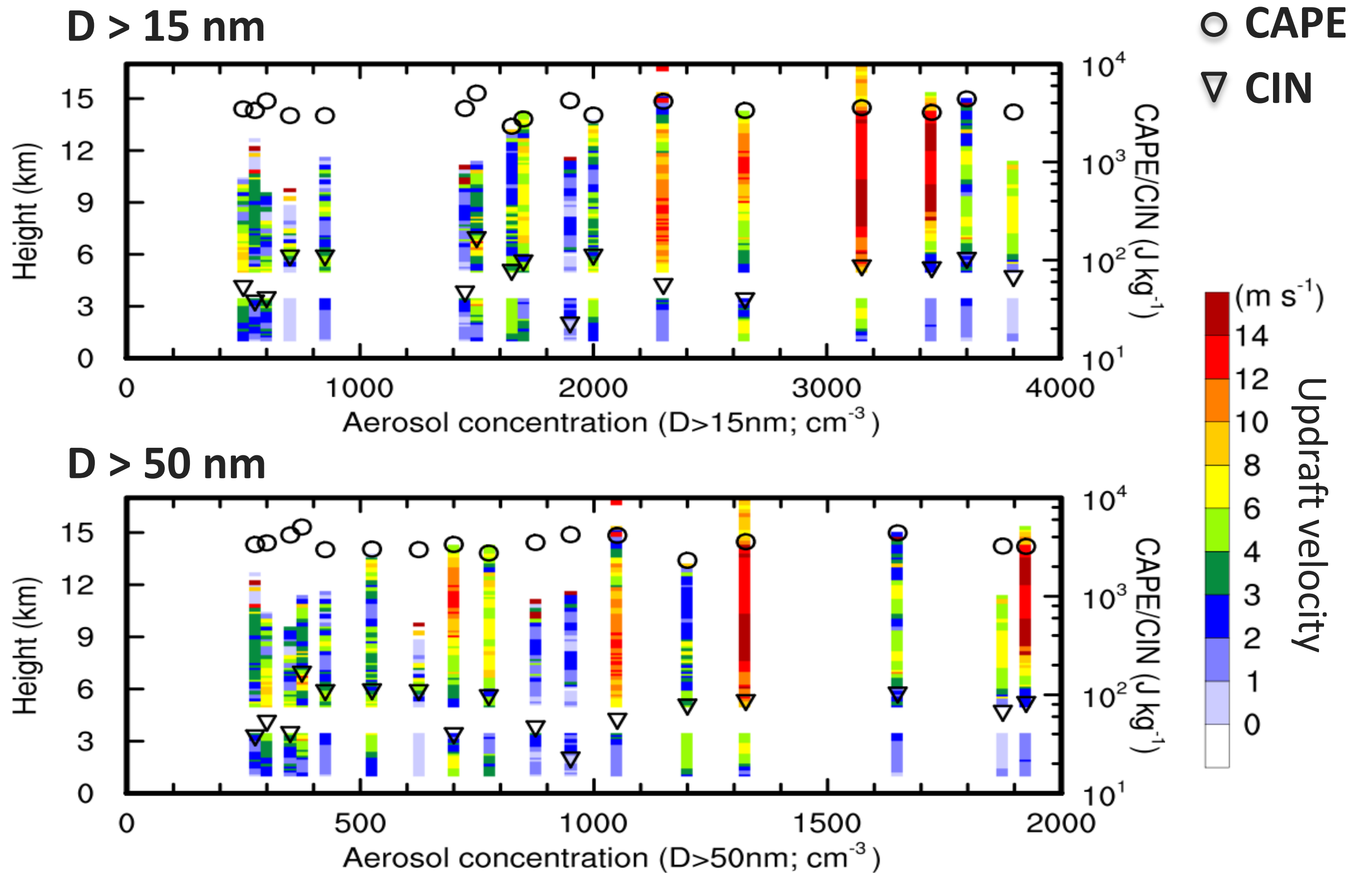
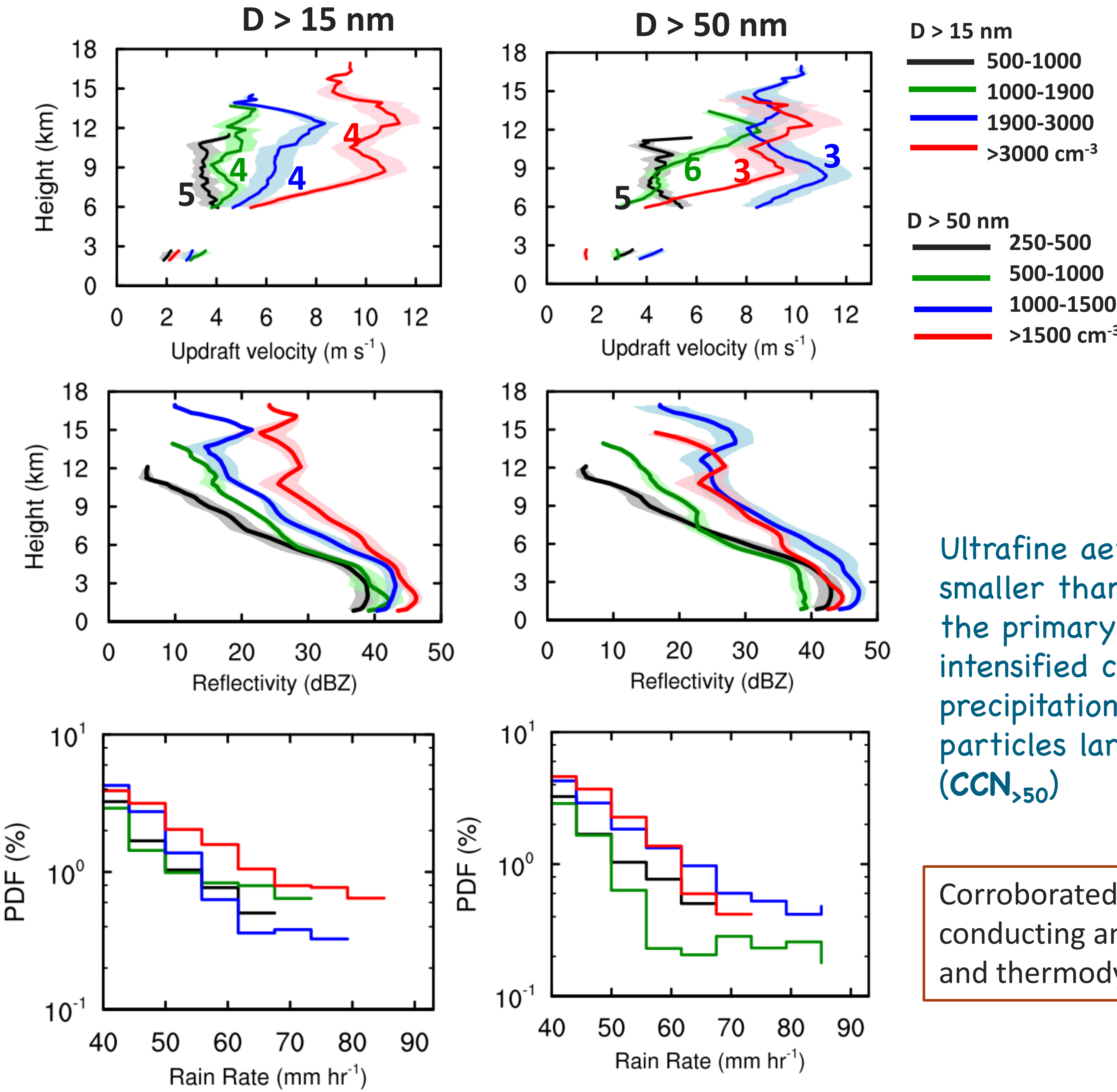
Carefully selected the locally-occurring storm cases from the 2014 wet season over March-May: 17 DCCs with valid aerosol measurements



- Updraft velocity increases with an increase of aerosols counting *D* > 15 nm.
- However, the relationship with aerosols does not hold well when excluding aerosols smaller than 50 nm.



Ultrafine aerosol particles smaller than 50 nm (**UAP$_{<50}$**) are the primary drivers for intensified convection and precipitation, not the aerosol particles larger than 50 nm (**CCN$_{>50}$**)

Corroborated the aerosol effect by conducting analysis of dynamics and thermodynamic controls.

Similarly large enhancement from model simulations

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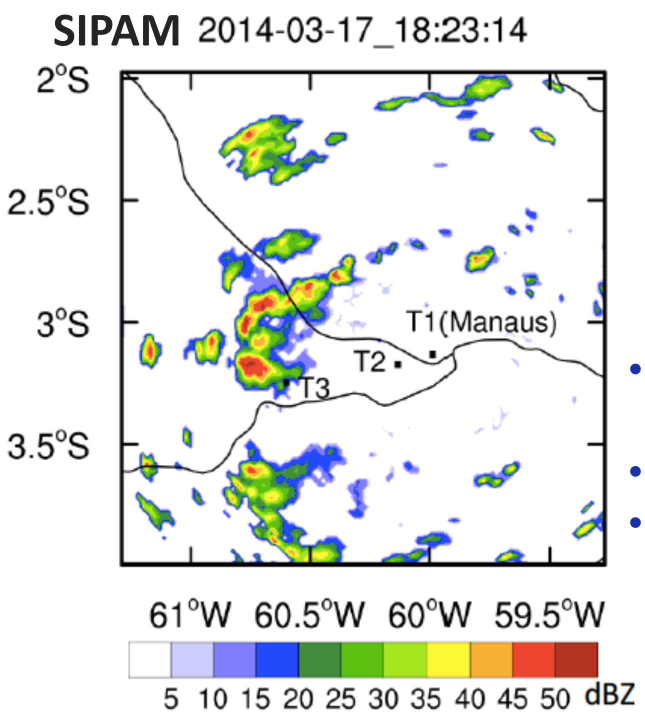
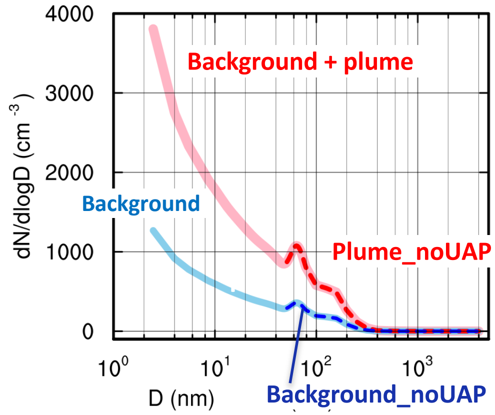
- To reveal the mechanisms responsible for the observed intensification of updrafts by $UAP_{<50}$, we conducted WRF with **spectral-bin microphysics (WRF-SBM)** for a typical wet season convective event on **17 March 2014** (0.5 km resolution)



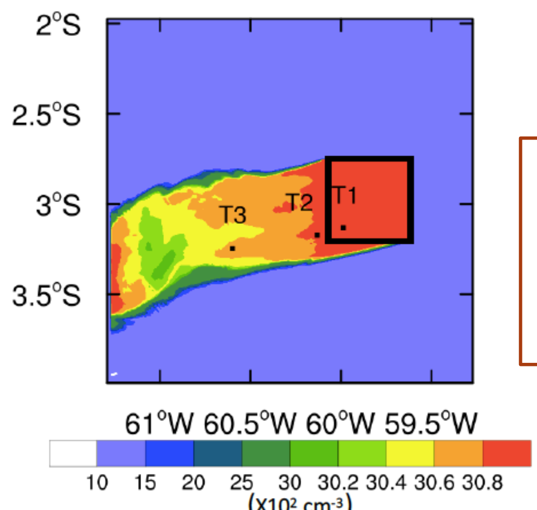
Background: Manaus background (820 cm^{-3} UAP +130 cm^{-3} CCN)

Background + plume: Manaus background with Manaus plume (2460 cm^{-3} UAP +390 cm^{-3} CCN for Manaus)

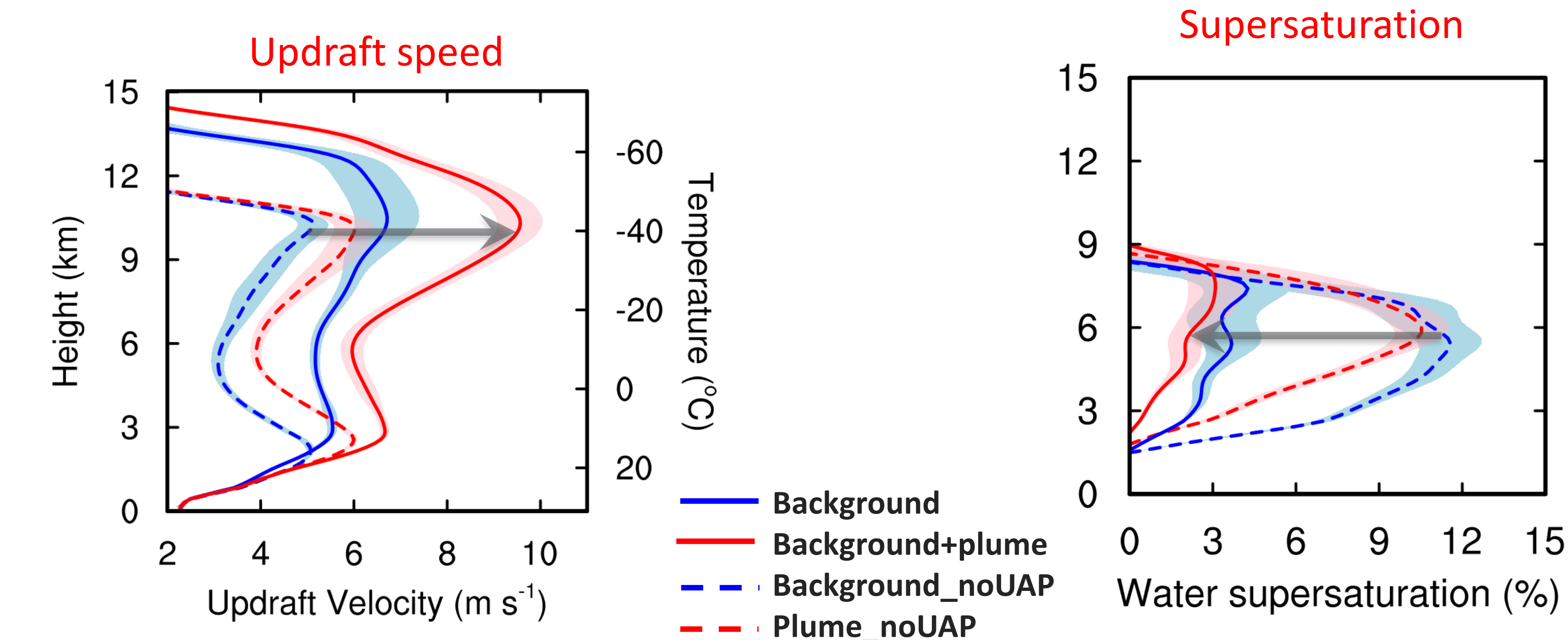
Background_noUAP and **Plume_noUAP** are the corresponding cases by removing UAP

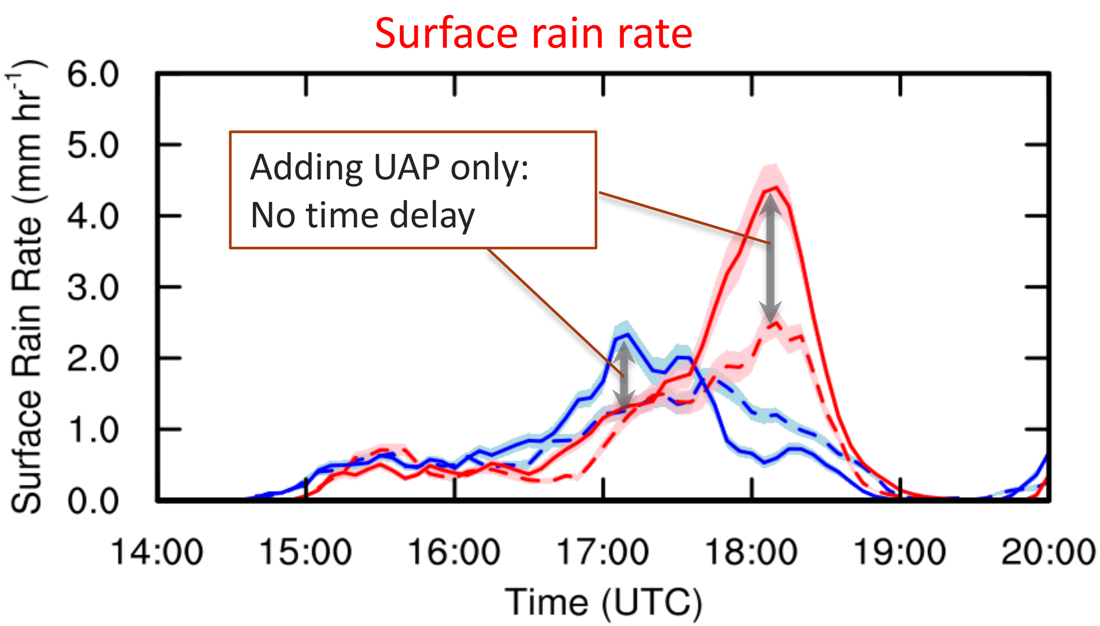


- Weak wind shear
- High CAPE
- Winds were northeasterly at the 850 hPa level



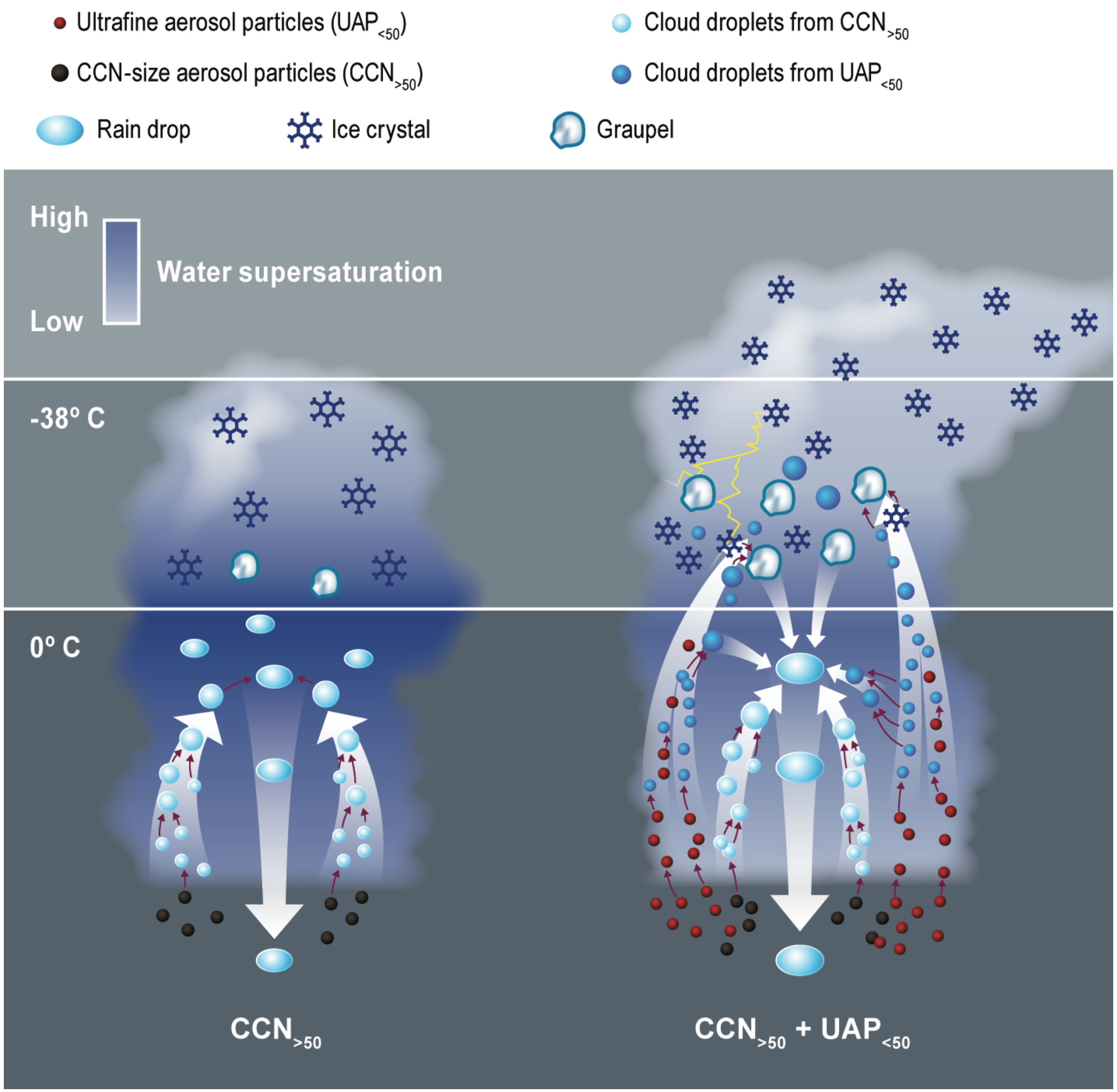
The simulated baseline case (P3_PG) was extensively evaluated





- The observed **large enhancements** in convective intensity and precipitation by $UAP_{<50}$ from Manaus pollution plume are reproduced.
- It is through a new mechanism we called "**warm-phase invigoration**"

Features of “warm-phase invigoration”



- **Does not delay rain** (in contrast to the effect of $CCN_{>50}$) because $UAP_{<50}$ can only be activated well above cloud base when rain has already formed and supersaturation has been enhanced.
- The effect is **much more powerful** compared to ”cold-phase invigoration” because the enhanced heat is larger and is at the bottom part of storm clouds.

Significance

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- This finding implies that from **pre-industrial times to the present day**, aerosols from human activity may have **significantly influenced storms in warm and humid places**, such as in southeast China, India, South and East US.
- The study open **a new door to understanding cloud physics through ultrafine aerosols**, conventionally thought to be too small to from droplets.
- The work would push the **atmospheric observation field to make progress** in measuring ultrafine particles, vertical motion and supersaturation in storms, all of which are very challenging.
- Also would stimulate **more field campaigns over the warm and humid regions** to tackle this problem more robustly and systematically.