Substantial Convection and Precipitation Enhancements by Ultrafine Aerosol Particles

JIWEN FAN
Pacific Northwest National Laboratory
Richland, WA

Acknowledgement:

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
Previous concept on invigoration

“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.

- Map showing locations T0t, T0k, T0e, T2, T1, T3, T3u, and Manaus with arrow indicating wind direction.
Observed enhancement of convective intensity and precipitation by aerosols

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

Corroborated the aerosol effect by conducting analysis of dynamics and thermodynamic controls.
Similarly large enhancement from model simulations

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

The simulated baseline case (P3_PG) was extensively evaluated.
The observed large enhancements in convective intensity and precipitation by UAP\textsubscript{<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 $\text{CCN}_{>50}$) because $\text{UAP}_{<50}$ 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

- 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 form 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.