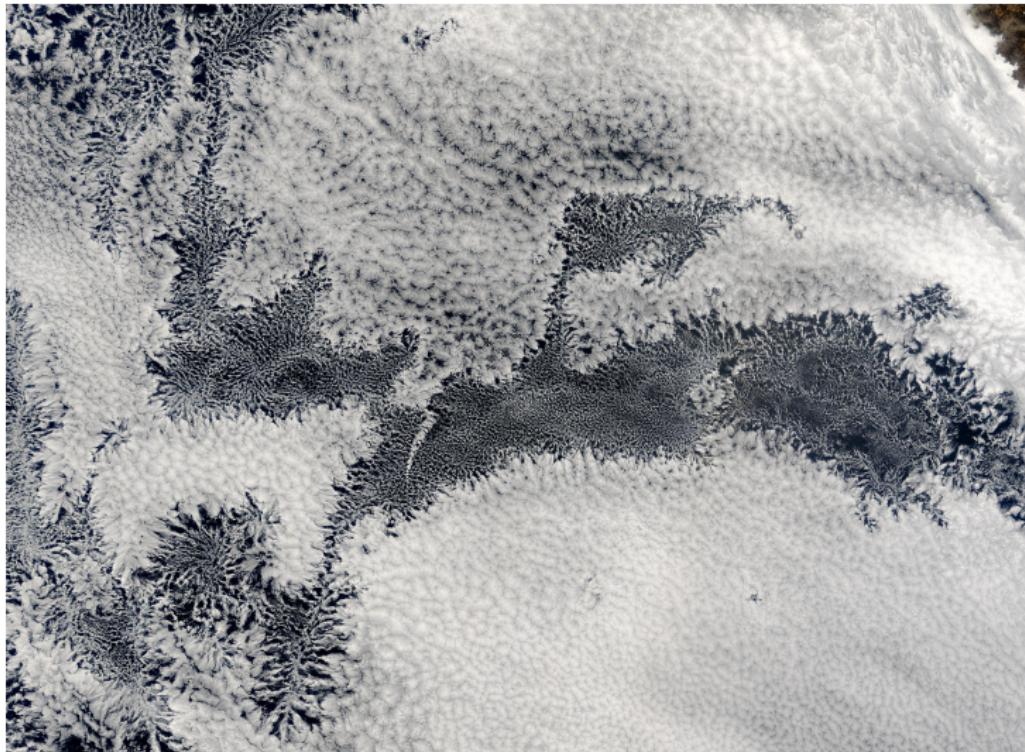


Aerosol Removal and Cloud Collapse Accelerated by Supersaturation Fluctuations with a Positive Feedback in Turbulent Cloud: a Cloud-Chamber Study

Kamal Kant Chandrakar
Dr. Will Cantrell, Dr. Raymond A. Shaw
and II-Chamber Group

Michigan Technological University

Acknowledgment : NSF, NASA Earth and Space Science Fellowship



Source: NASA Visible Earth-MODIS image

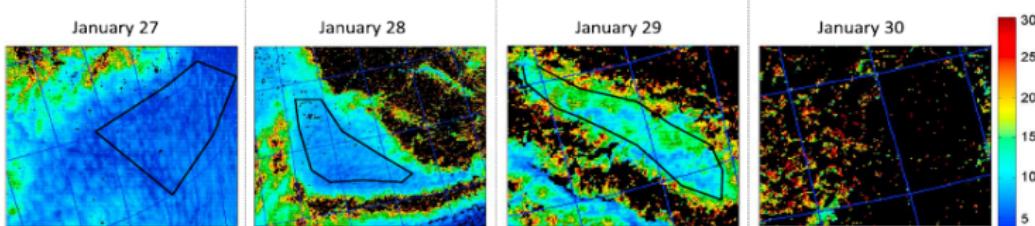
January 27

January 28

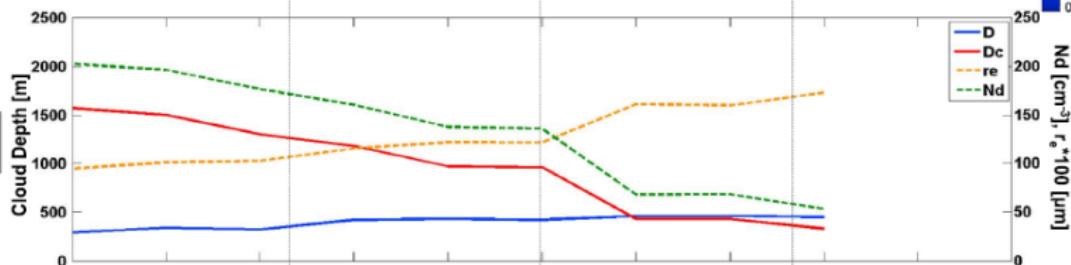
January 29

January 30

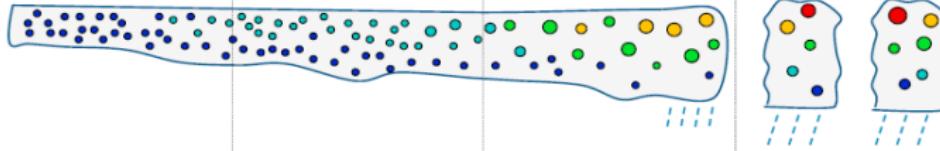
a



b

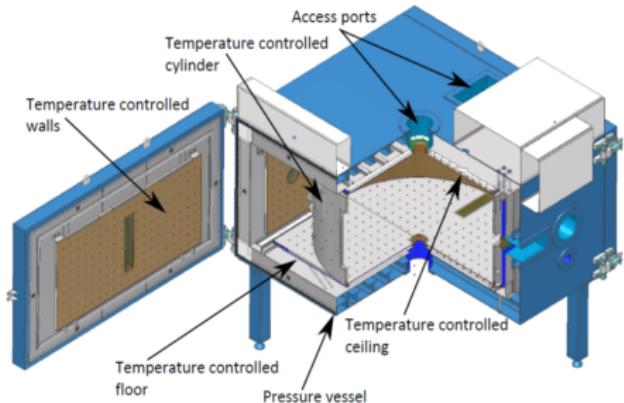
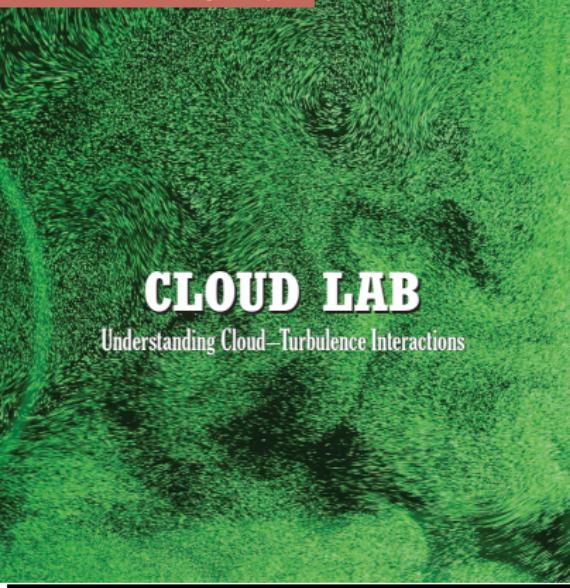


c



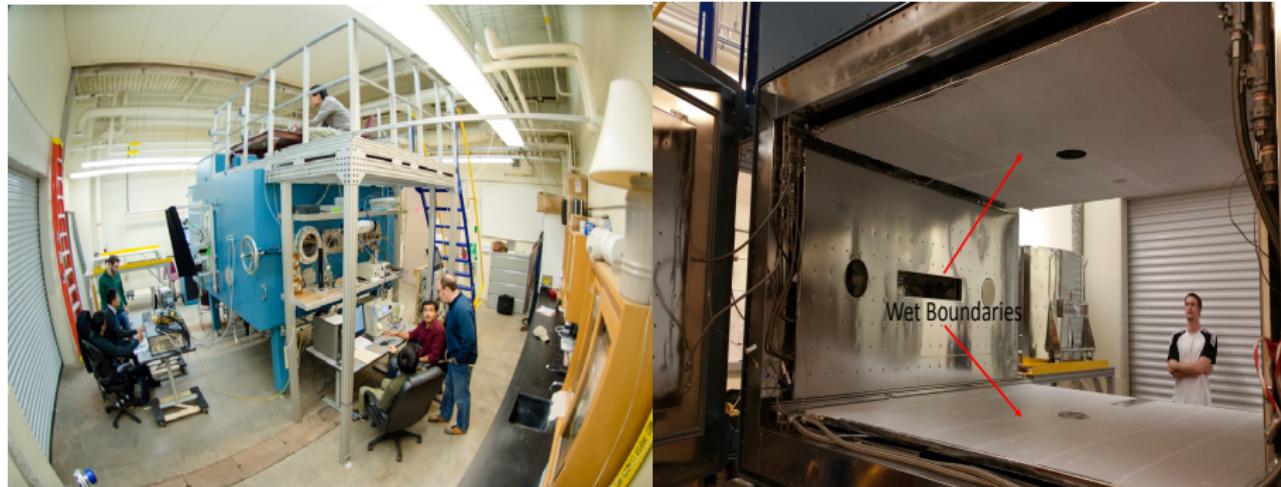
Goren and Rosenfeld JGR 2015

The Π - Chamber

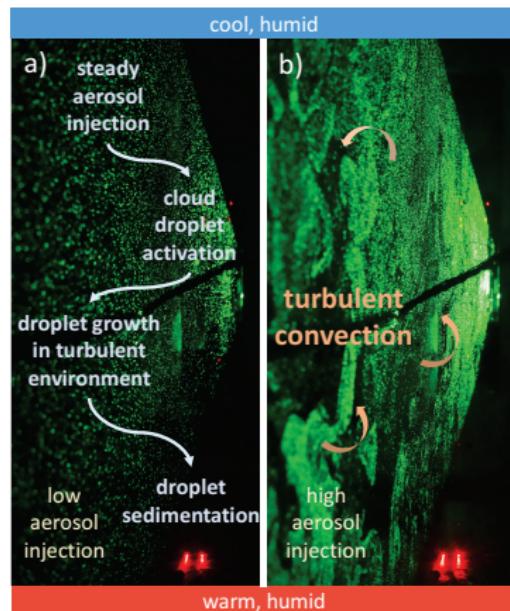
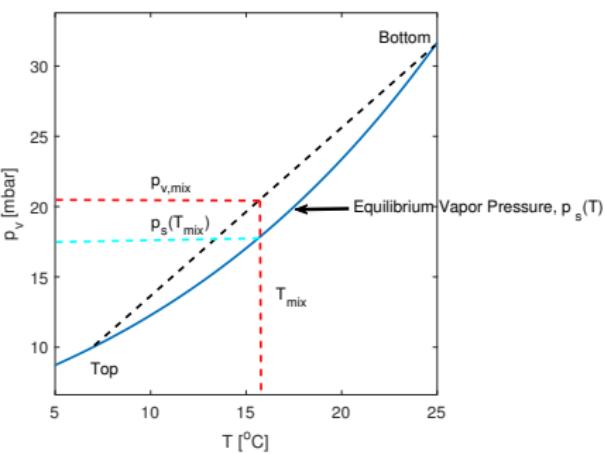


Chang et al. BAMS 2016

The Π - Chamber



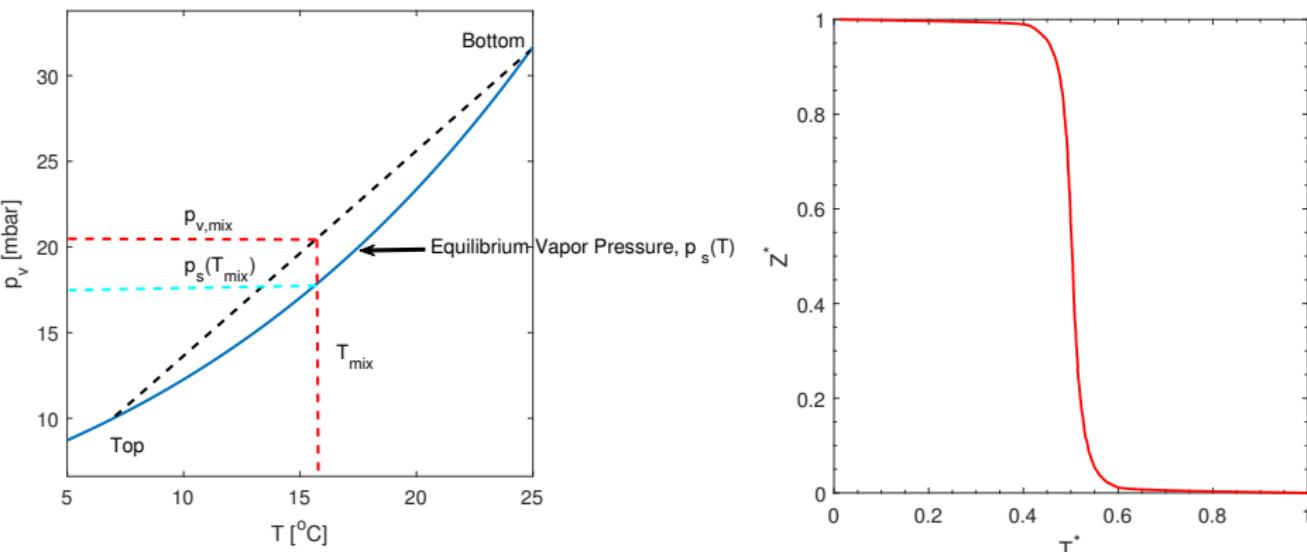
Turbulent Mixing Cloud Formation in the Π-Chamber



Chandrakar et al. PNAS 2016

Supersaturation in the chamber: Idealized vs Reality

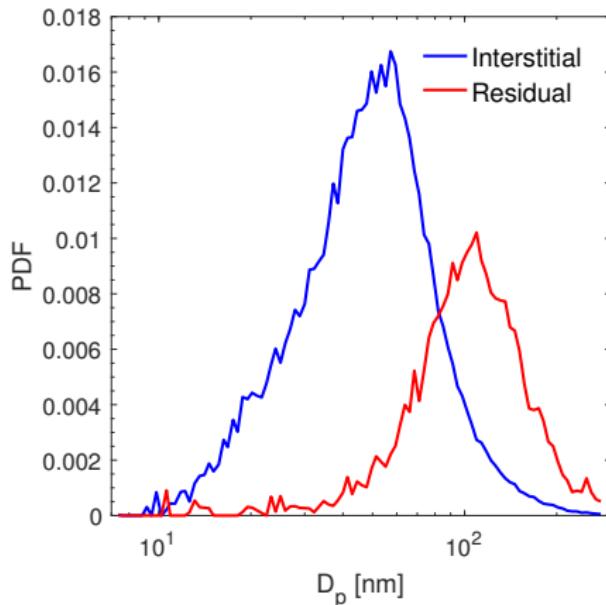
Water vapor flux to the side wall is significant: nearly 1/3 reduction in supersaturation with a saturated side wall at mean temperature



Supersaturation in the Chamber: Idealized vs Reality

Residual:

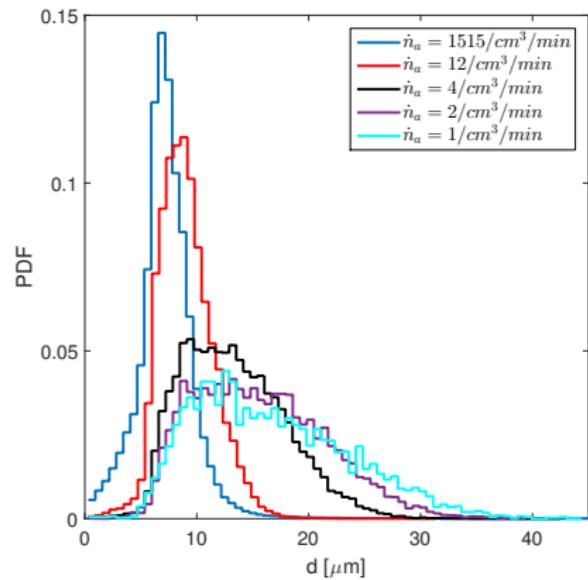
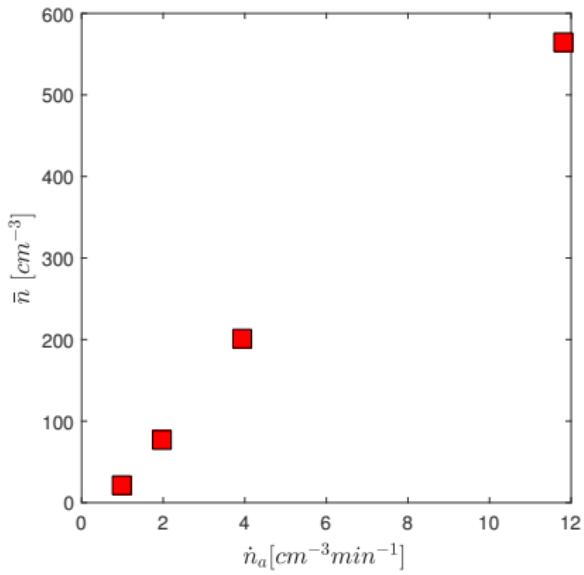
$D_{mode} \approx 110 \text{ nm} \rightarrow$
 $s_c = 0.1\%$



Note: The apparent difference in area under the PDFs is a result of linear size binning displayed in a semilog plot.

Chandrakar et al. GRL 2017

Droplet Size Distribution at Steady-State



Chandrakar et al. PNAS 2016

Stochastic Condensation Growth

$$ds(t) = \left[\underbrace{\frac{s_o - s}{\tau_t} - \frac{s}{\tau_c}}_{\text{mixing to } s_o \quad \text{droplet growth}} \right] dt + \underbrace{\left(\frac{2\sigma_{s_0}^2 dt}{\tau_t} \right)^{1/2} \eta(t)}_{\text{fluctuation}}$$

Condensation Growth:

$$\frac{dr^2}{dt} = 2\xi s, \quad \frac{d\sigma_{r^2}^2}{dt} = 4\xi \overline{s' r'^2}$$

Chandrakar et al. PNAS 2016, JAS 2018

Turbulent Induced Broadening

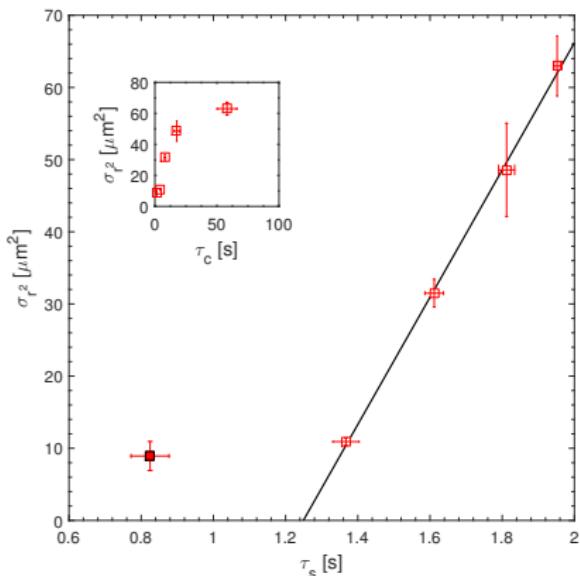
$$\bar{s} = \frac{s_0 \tau_s}{\tau_t}; \quad \sigma_s^2 = \frac{\sigma_{s_0}^2 \tau_s}{\tau_t}$$

$$\sigma_r^2 \propto \overline{s' r^{2'}} \rightarrow \frac{\sigma_{s_0} \tau_s}{\tau_t} t^{1/2}$$

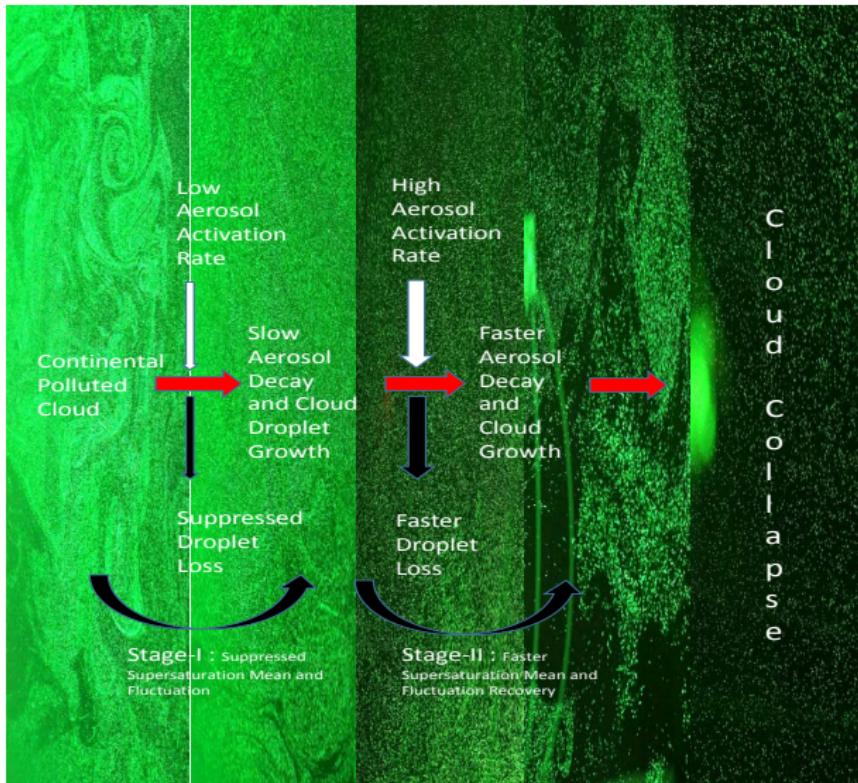
$$\tau_s : \frac{1}{\tau_s} = \frac{1}{\tau_t} + \frac{1}{\tau_c}$$

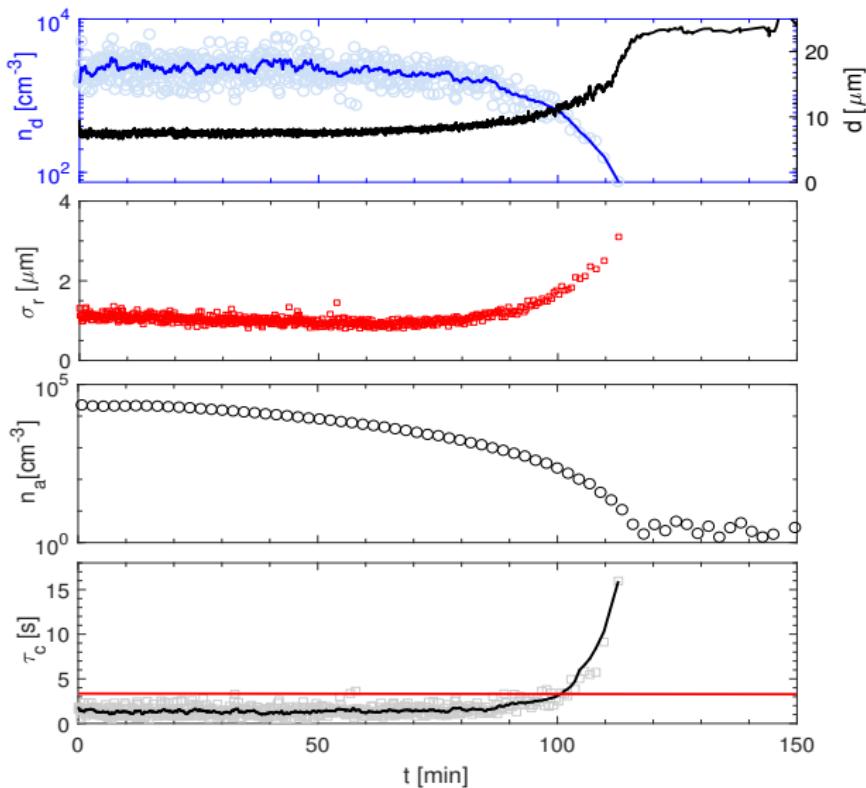
τ_t : Turbulence correlation time
 (fixed)

τ_c : Phase relaxation time, $\propto \frac{1}{n \bar{r}}$
 (controlled by aerosol injection)

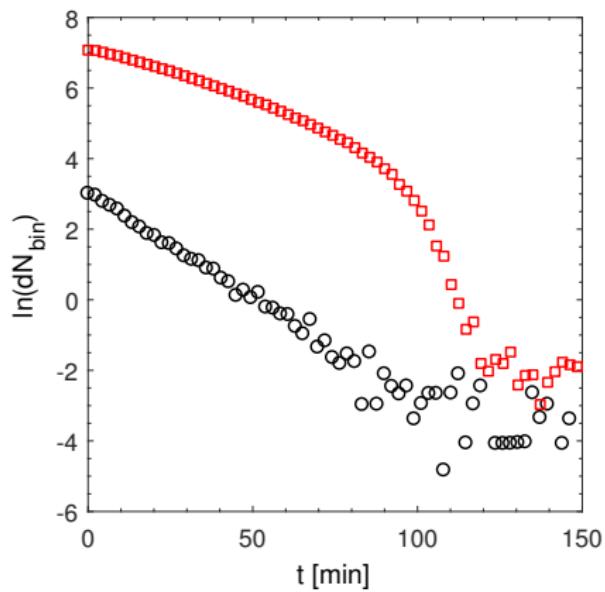
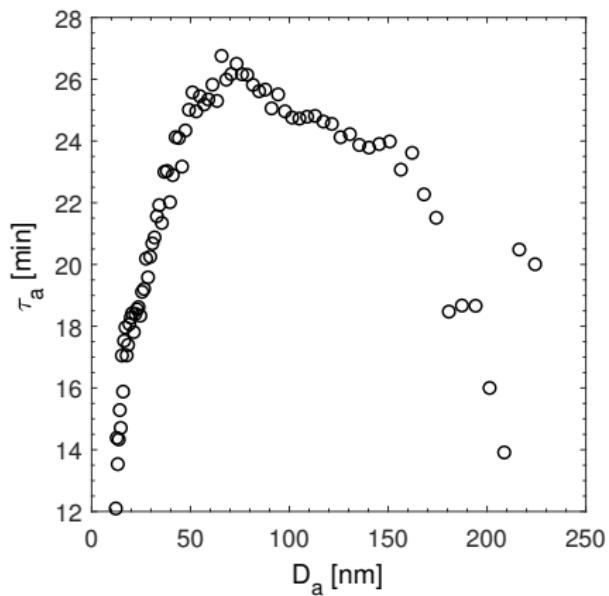


Chandrakar et al. PNAS 2016

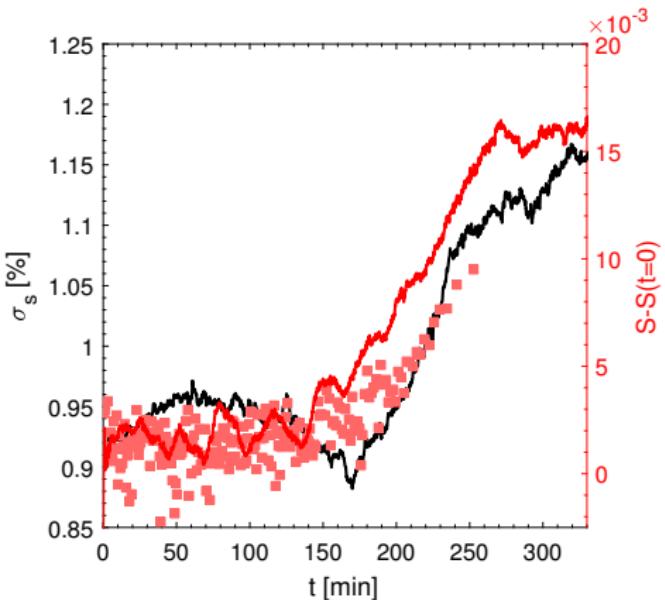
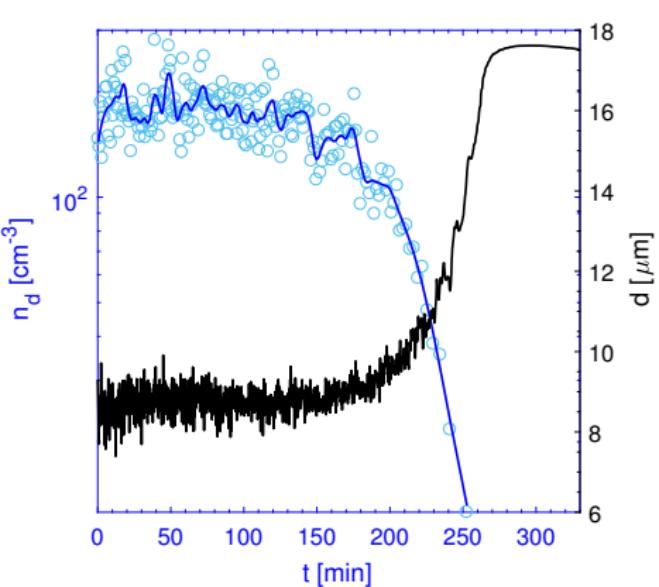




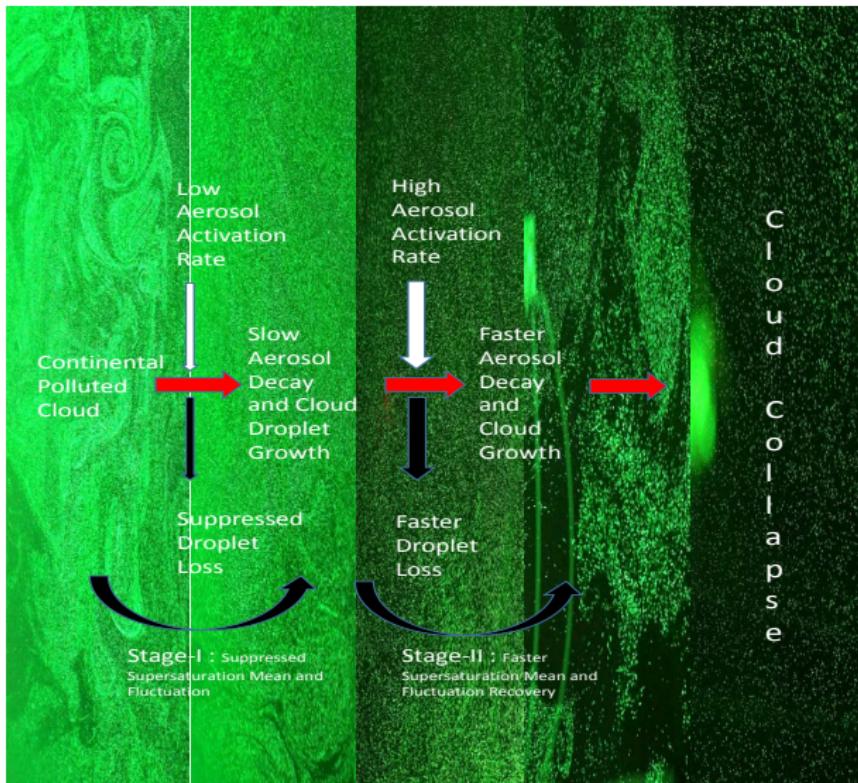
Chandrakar et al. GRL 2017



Chandrakar et al. GRL 2017



Chandrakar et al. GRL 2017



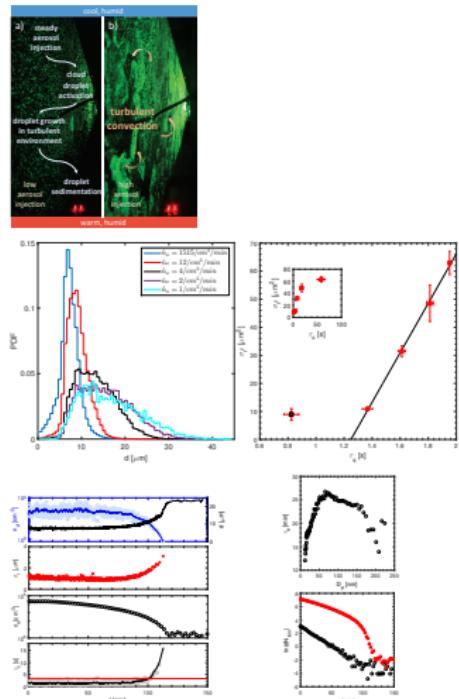
Summary

- Cloud form via isobaric mixing in a turbulent moist Rayleigh-Bénard convection.

- Stochastic theory and experiments suggest:

$$\sigma_s^2 = \frac{\sigma_{s_0}^2 \tau_s}{\tau_t} \text{ and } \sigma_r^2 \propto \overline{s' r^{2'}} \rightarrow \frac{\sigma_{s_0} \tau_s}{\tau_t} t^{1/2}.$$

- Cloud cleansing enhanced through supersaturation fluctuations: a positive feedback.



Thank You