Vertical variation of turbulent entrainment mixing processes in marine stratocumulus clouds over ENA using digital holography

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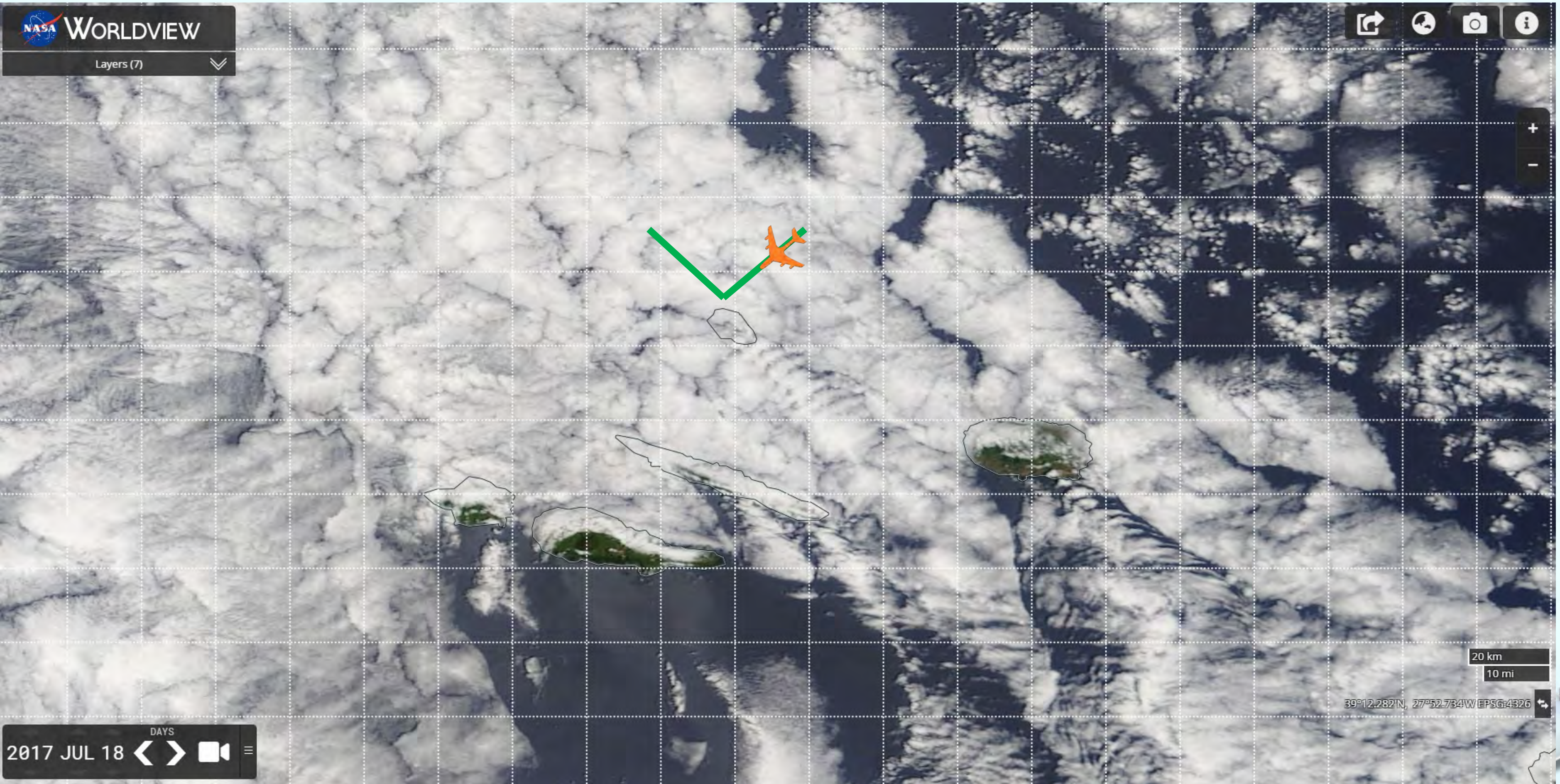

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HOLODEC (Holographic Detector for Clouds)

A joint development between Michigan Technological University, Mainz University, and NCAR

Conventional

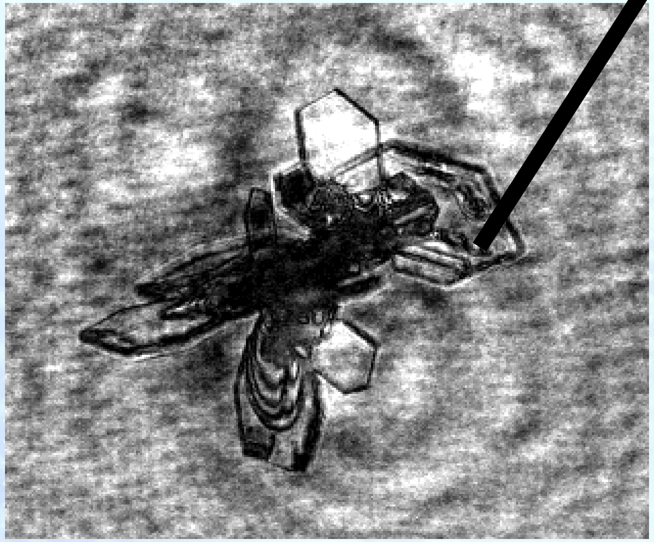
1 particle in beam at a time

Holodec

13 cc ~10^3 droplets

30-60 m

From: eol.ucar.edu



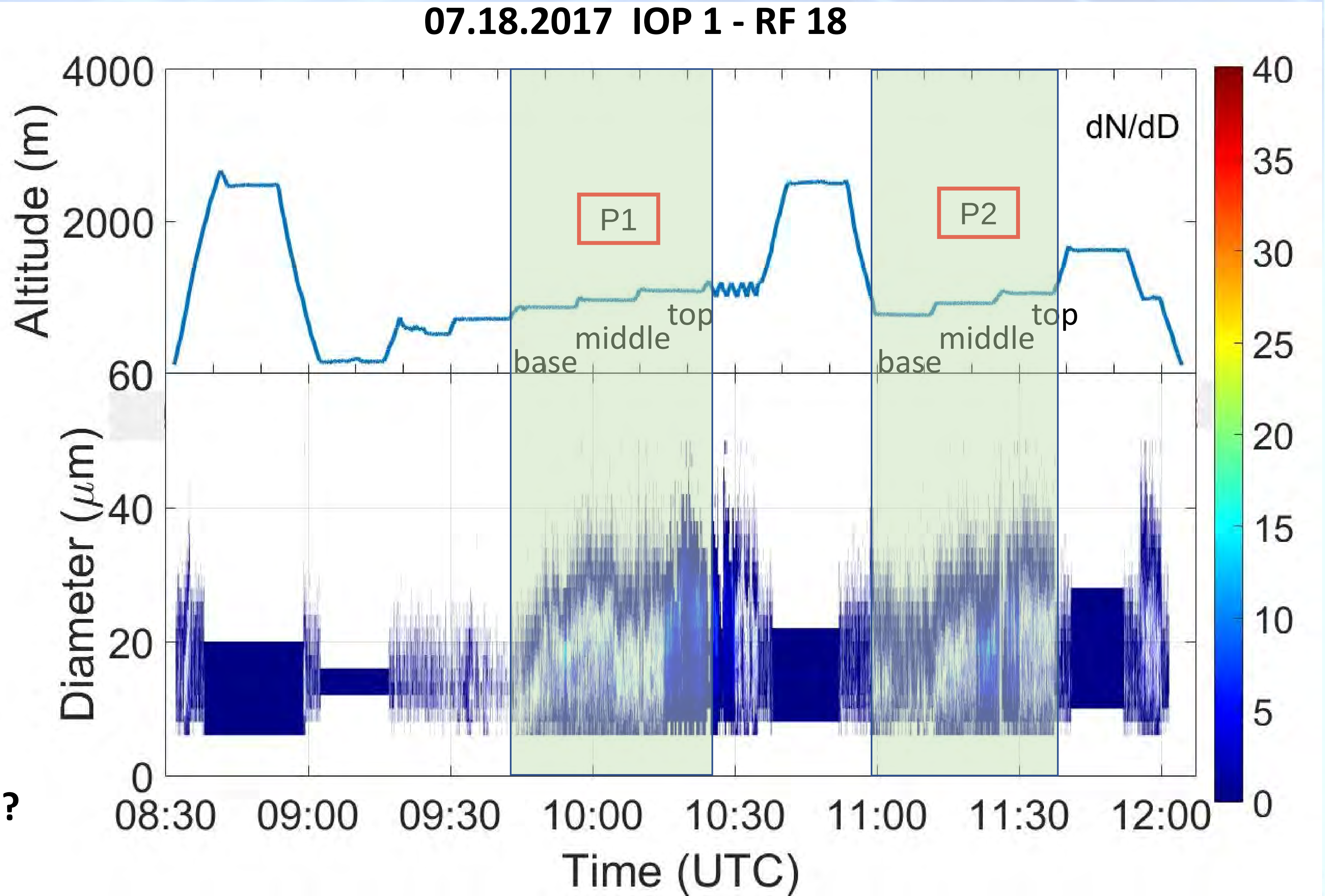
- Instantaneous cm scale cloud properties
- No spatial/temporal averaging
- Current focus on warm clouds IOP1

Raymond Shaw, MTU

Objectives:

1. How does entrainment mixing behavior vary with altitude in a stratocumulus layer?

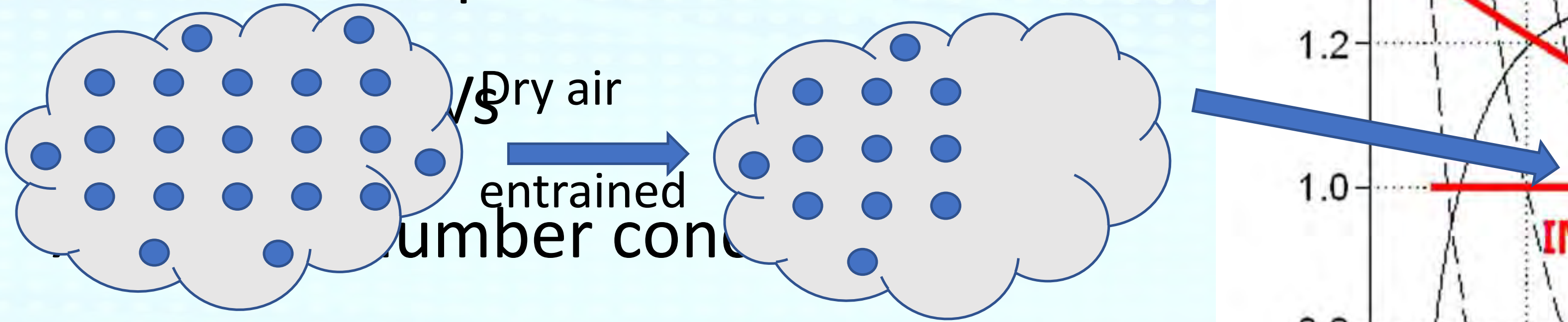
2. Can we explain this behavior using turbulence measurements?



Mixing diagrams attempt to display the mixing regimes

Extreme In-homogenous mixing

Y - Mean droplet volume



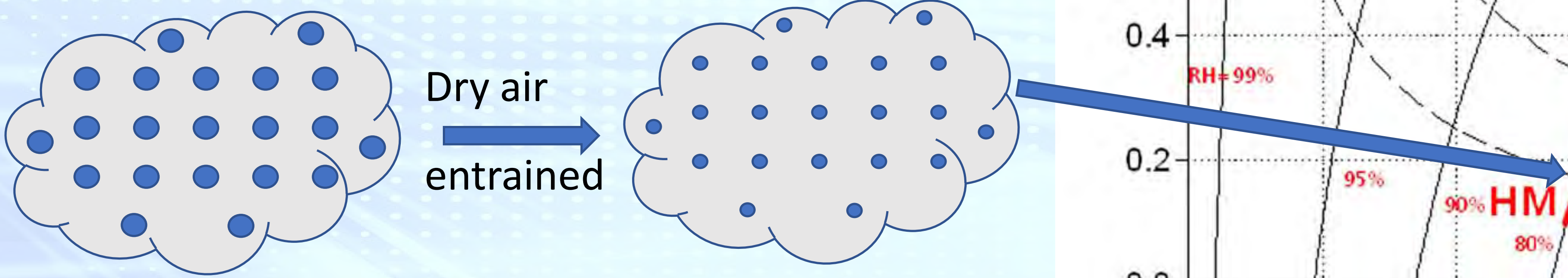
vs

…umber conc…

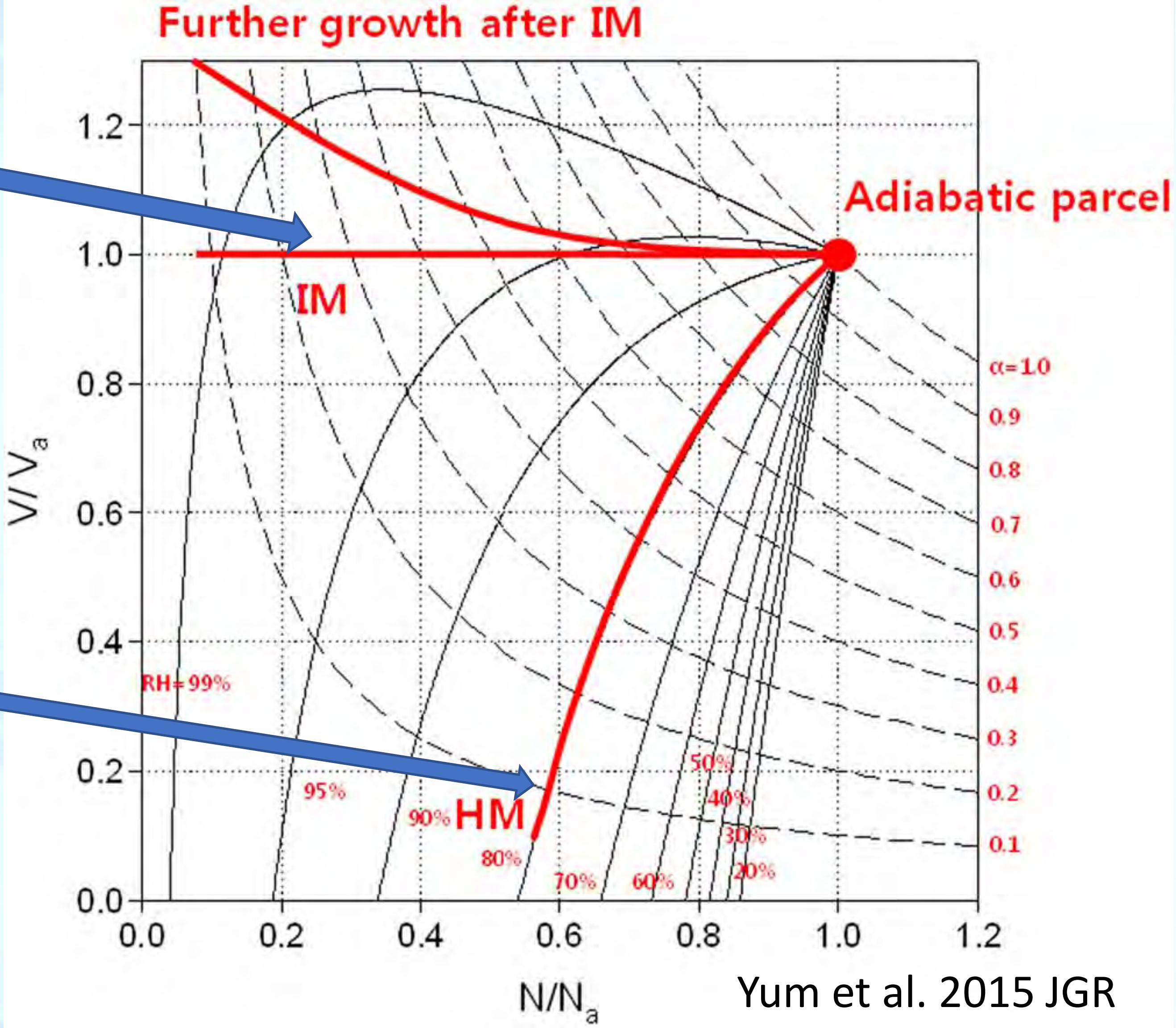
V = constant, $N < N_a$

a - Normalized by the adiabatic value

Homogenous mixing



$V < V_a$, N = constant



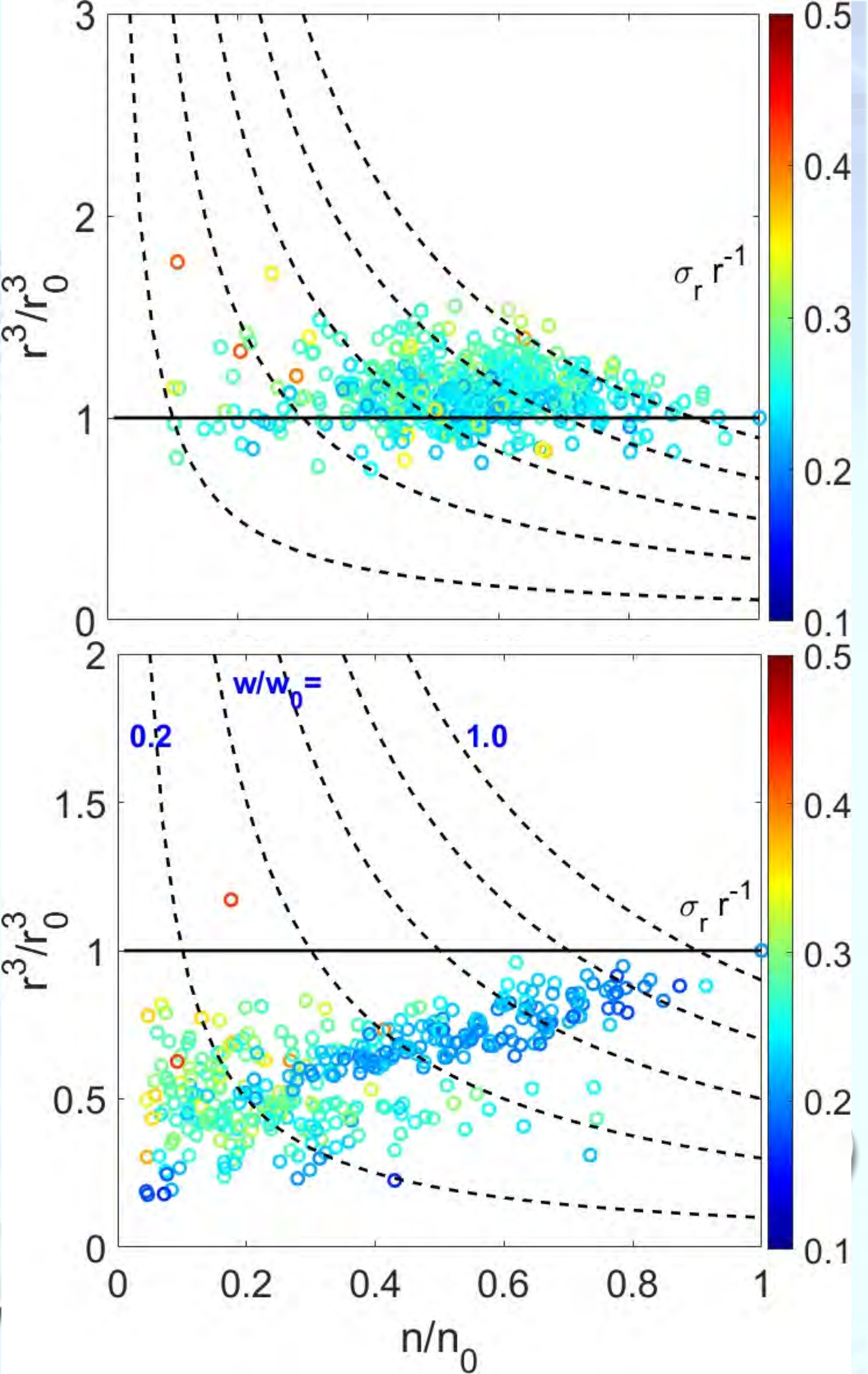
Yum et al. 2015 JGR

Mixing Diagram observations

- Each data point is a hologram and colored by the relative dispersion of the hologram.
- Cloud top shows primarily inhomogeneous type mixing (IM)
- Cloud base shows primarily homogeneous type mixing (HM)
- Confirms that mixing proceeds from IM near cloud top to HM near cloud base (Yum et al. 2015 JGR)

Cloud top

Cloud base



Damkohler No.

$$Da = \frac{\tau_t}{\tau_r}$$

τ_t – Turbulence mixing time scale
τ_r – Microphysical time scale

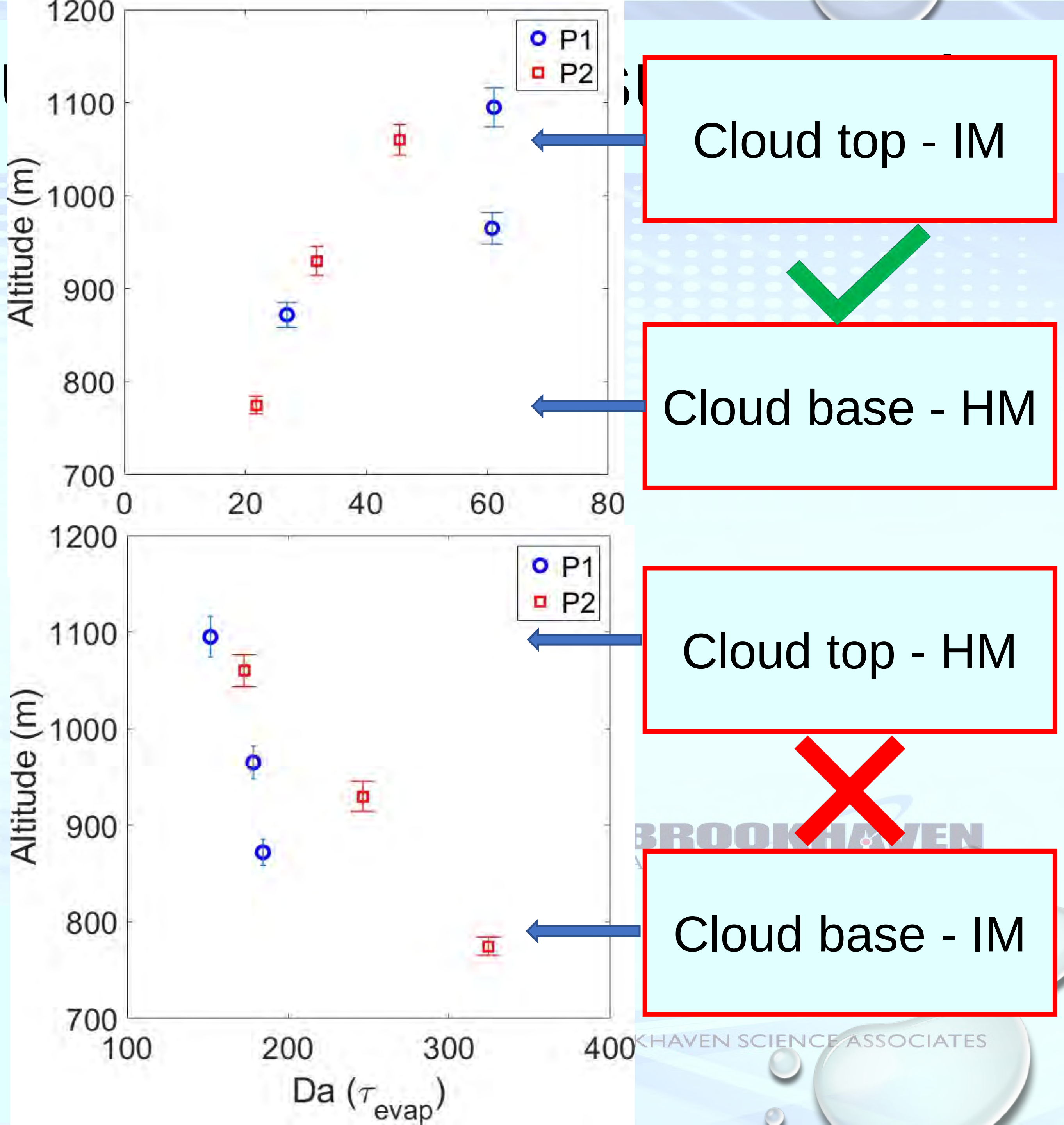
Large Da – Fast microphysics - IM
Small Da – Slow microphysics - HM

$$\tau_t = \frac{u'^2}{\varepsilon} \qquad \tau_{phase} = \frac{1}{4\pi D n r}$$

ε - dissipation rate
u' – velocity fluctuation
D – diffusivity

$$\tau_{evap} = -\frac{r_a^2}{2AS_0}$$

A – growth parameter,
S_0 – supersaturation deficit



Which microphysical time scale to use?

$$\tau_{phase} = \frac{1}{4\pi D n r}$$

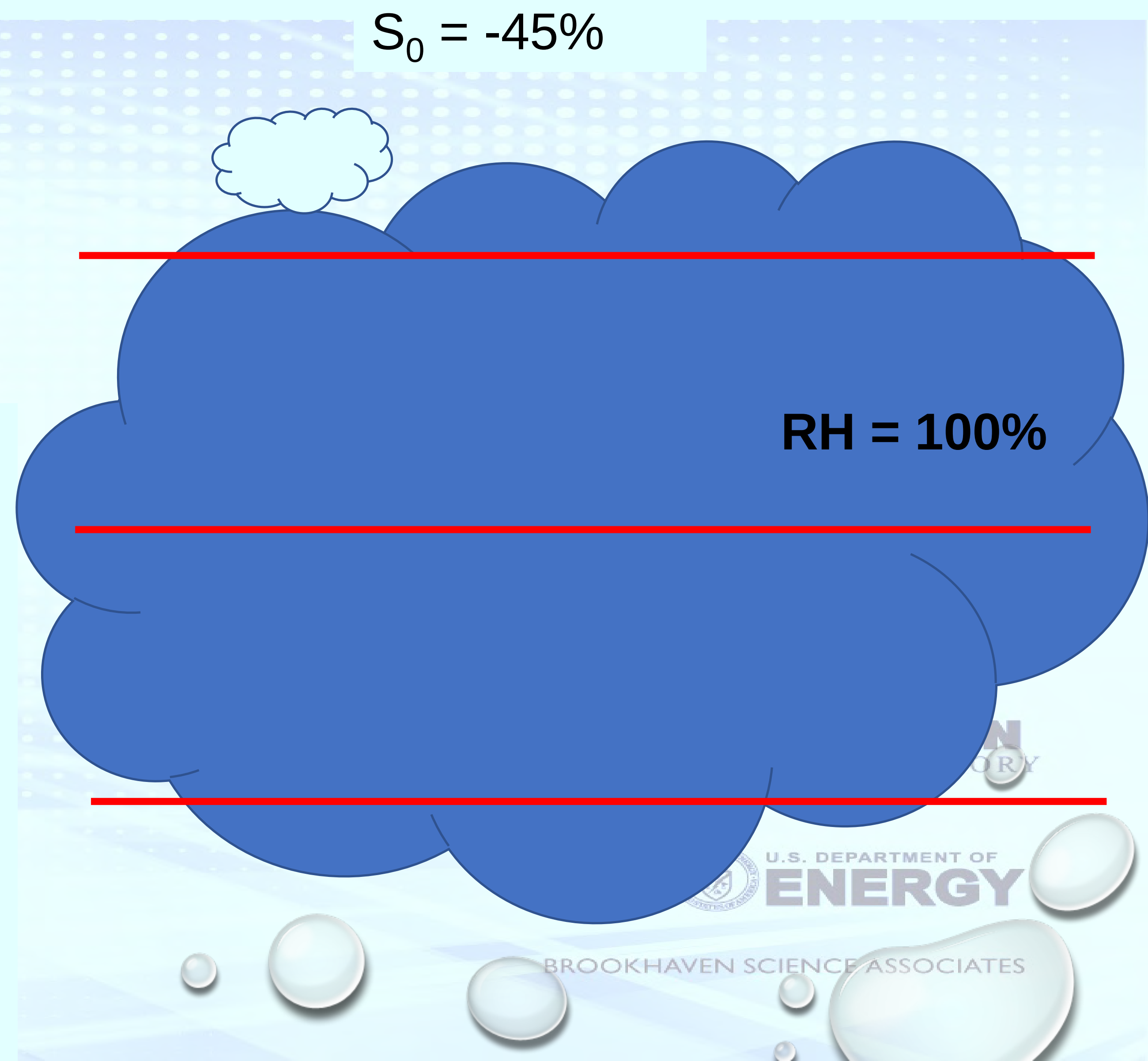
Considers ensemble of droplets, n is important

$$\tau_{evap} = -\frac{r_a^2}{2AS_0}$$

Considers each droplet individually
S_0 – Above cloud saturation deficit (-45%)
S_0 is important

For Cloud top, mid and base,
T_{evap} assumes S_0 = constant?

As parcel descends, mixing and droplet evaporation will bring it closer to saturation



Considering variation of S_0 with height

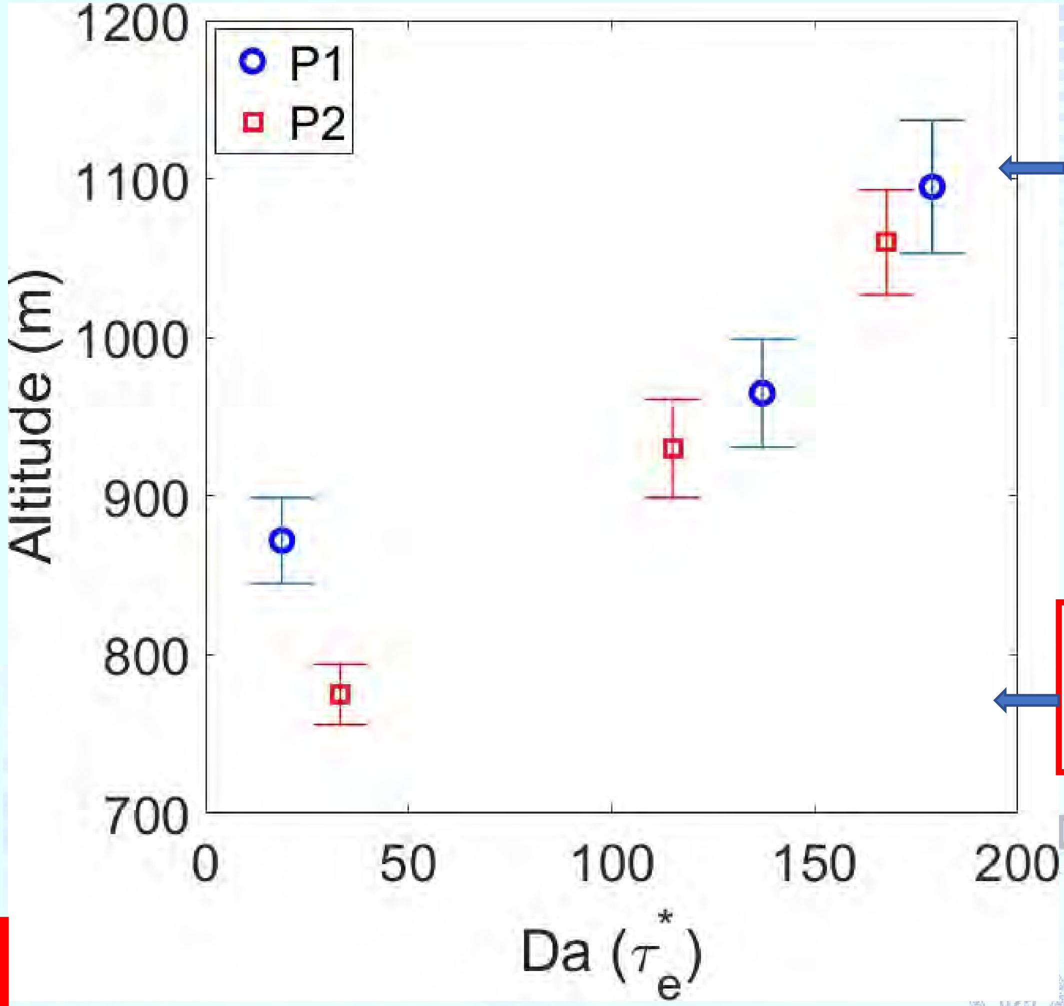
$$\tau^*_{evap} = -\frac{r_a^2}{2AS_0(z)}$$

S_0 (z) – Saturation deficit as a function of cloud height

$S_0(1.0)$ = 1.0 * S_0 at cloud top
$S_0(0.5)$ = 0.5 * S_0 at cloud middle
$S_0(0.0)$ = 0.0 * S_0 at cloud base

T_{evap} now agrees with mixing diagram observations and T_{phase}

Variation of S_0 with height needs to be considered



Cloud top IM

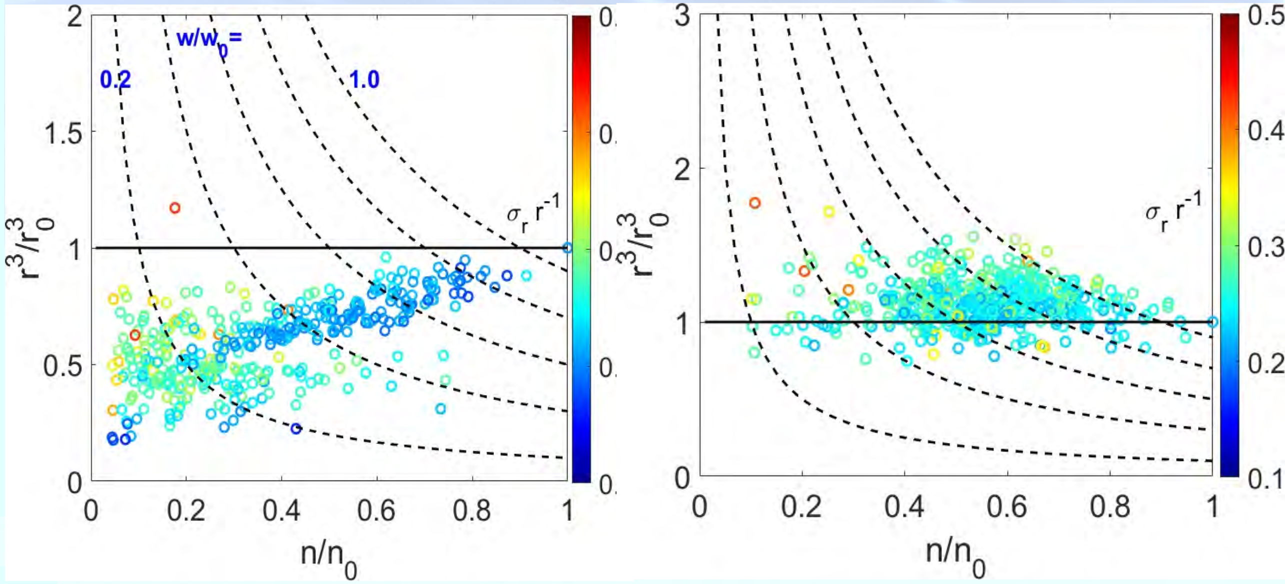
Cloud base HM

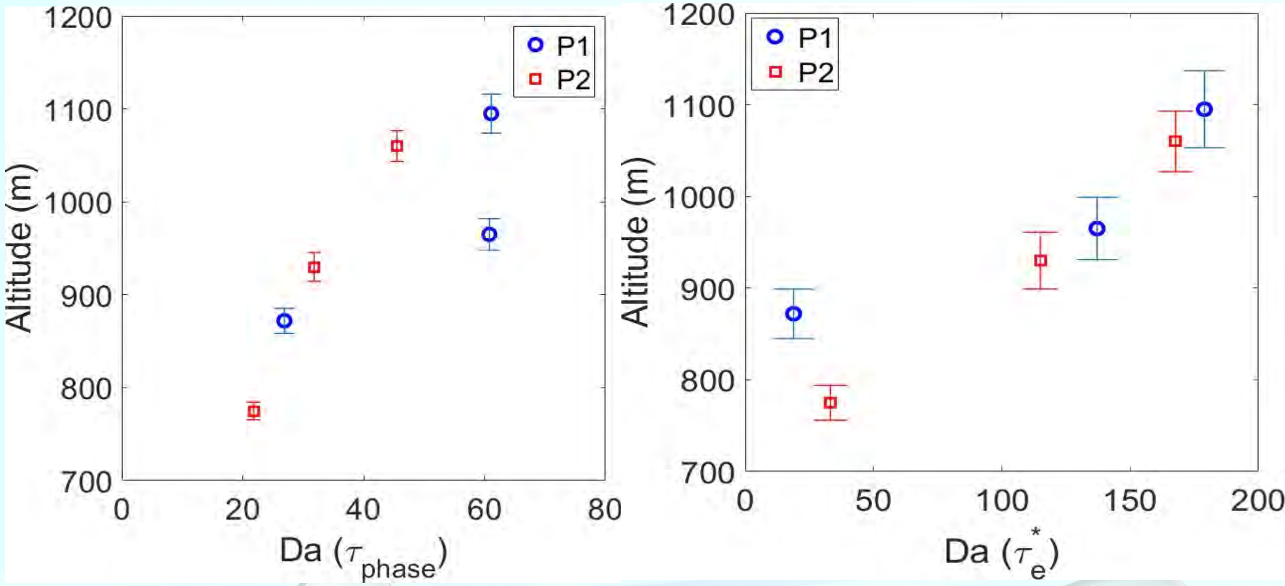
Conclusions

1. Mixing: inhomogeneous near cloud top, homogeneous near base.

2. Damkohler number measurements can explain this behavior.

3. T_{evap} needs to consider variability of S_0 with height within stratocumulus cloud layer.





Future work/collaborations

1. Effect of aerosols on mixing and drizzle formation.

   - Size and concentration

2. Flight legs parallel and perpendicular to mean wind direction show considerable difference.