Turbulence in Cumulus Clouds

Literature Seminar, MIM, speaker: Josef Schröttle, April 2012

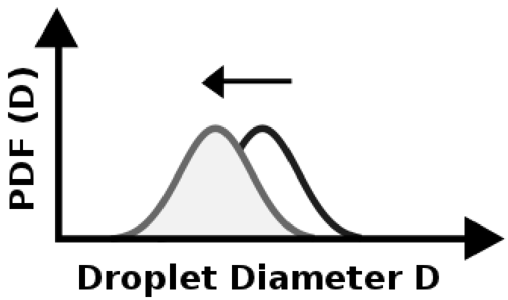
Lehmann, K., Siebert, H., and Shaw, R. A., 2009: **Homogeneous and Inhomogeneous Mixing in Cumulus Clouds**: Dependence on Local Turbulence Structure, *JAS*

Gerber, H., G. Frick, J. Jensen, and J. Hudson, 2008: **Entrainment, mixing, and microphysics** in trade-wind cumulus. *J. Meteorol. Soc. Japan*

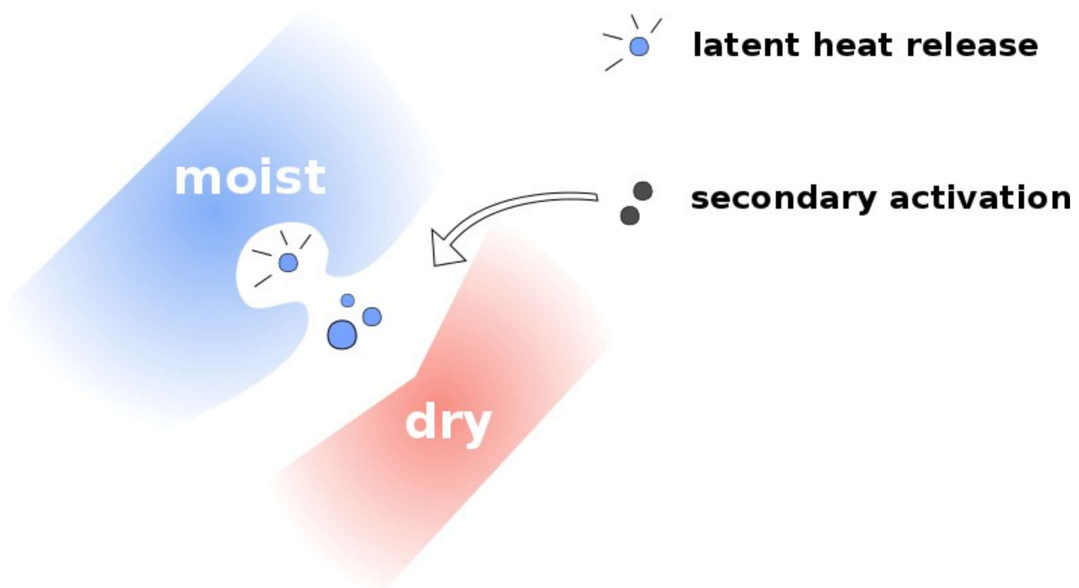
Homogeneous versus Inhomogeneous

Definition

Homogeneous - Inhomogeneous Mixing

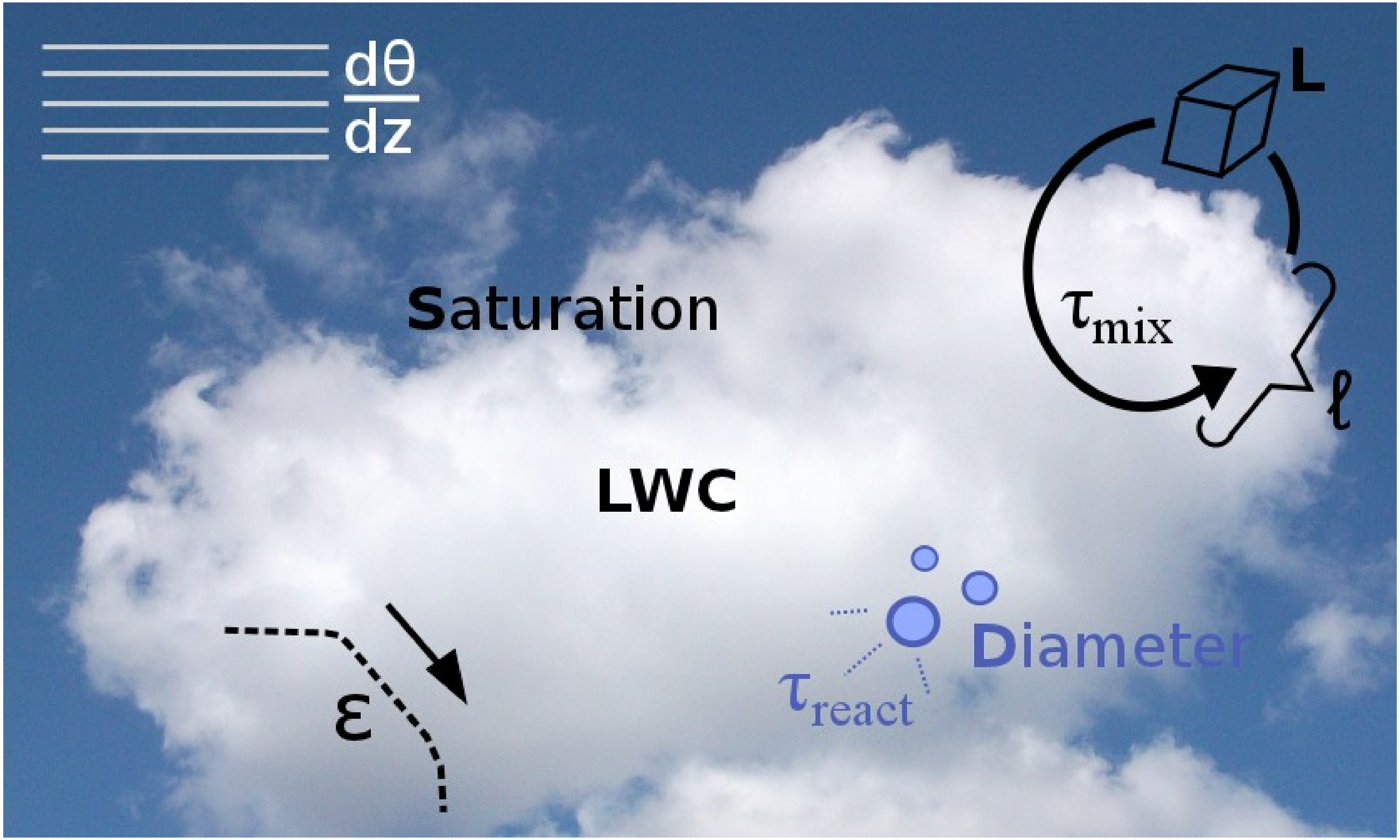


Mixing occurs **rapidly**, temperature and humidity field are homogeneous. All droplets experience similar conditions.



Slowly, on the edge between moist and dry air, inhomogeneous mixing takes place. Some droplets evaporate quicker than others depending on their environment.

Concept



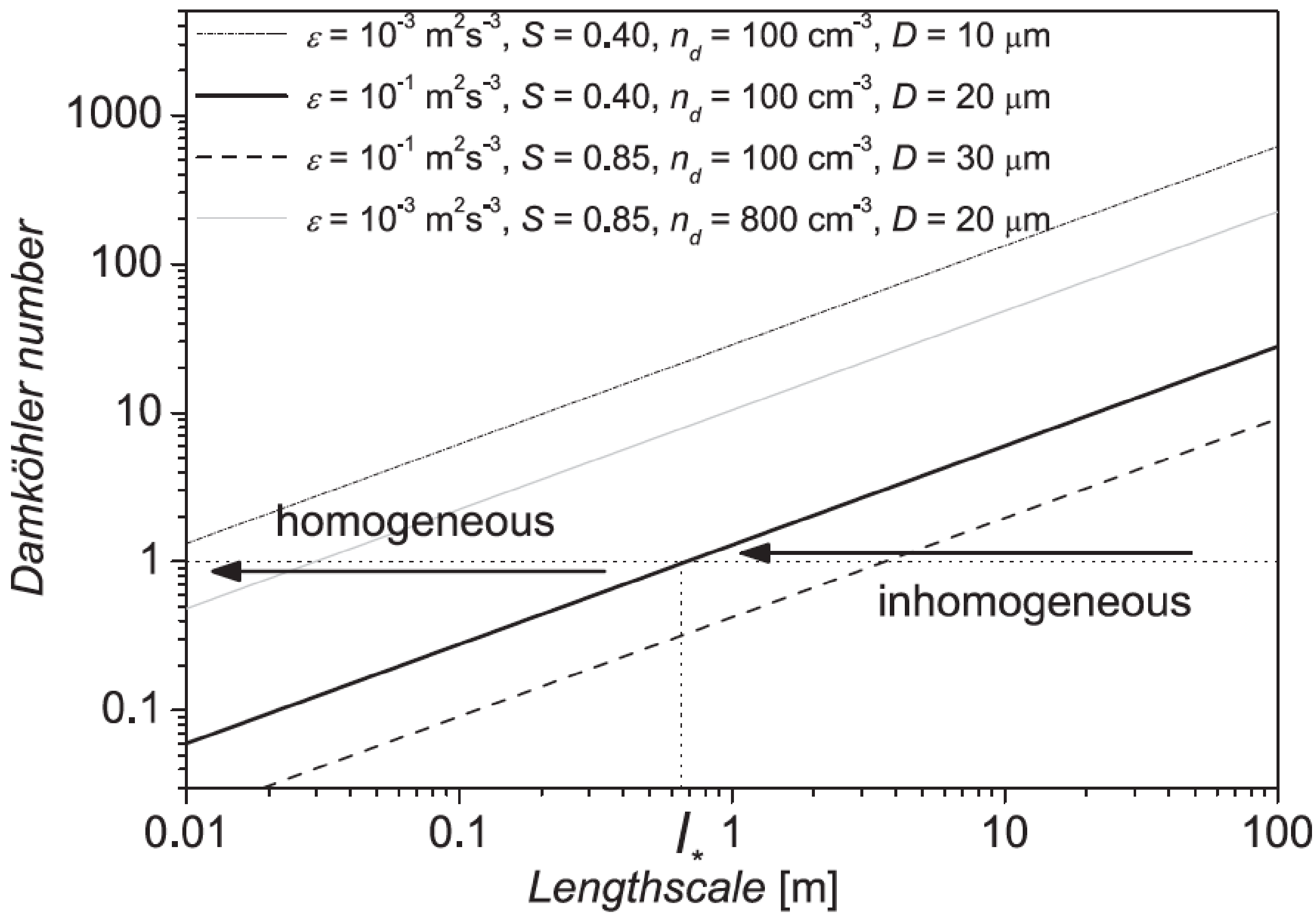
Relationships

$$Da = \frac{\tau_{mix}}{\tau_{react}}$$

$$\tau_{mix} = \left(\frac{l_e^2}{\epsilon} \right)^{1/3}$$

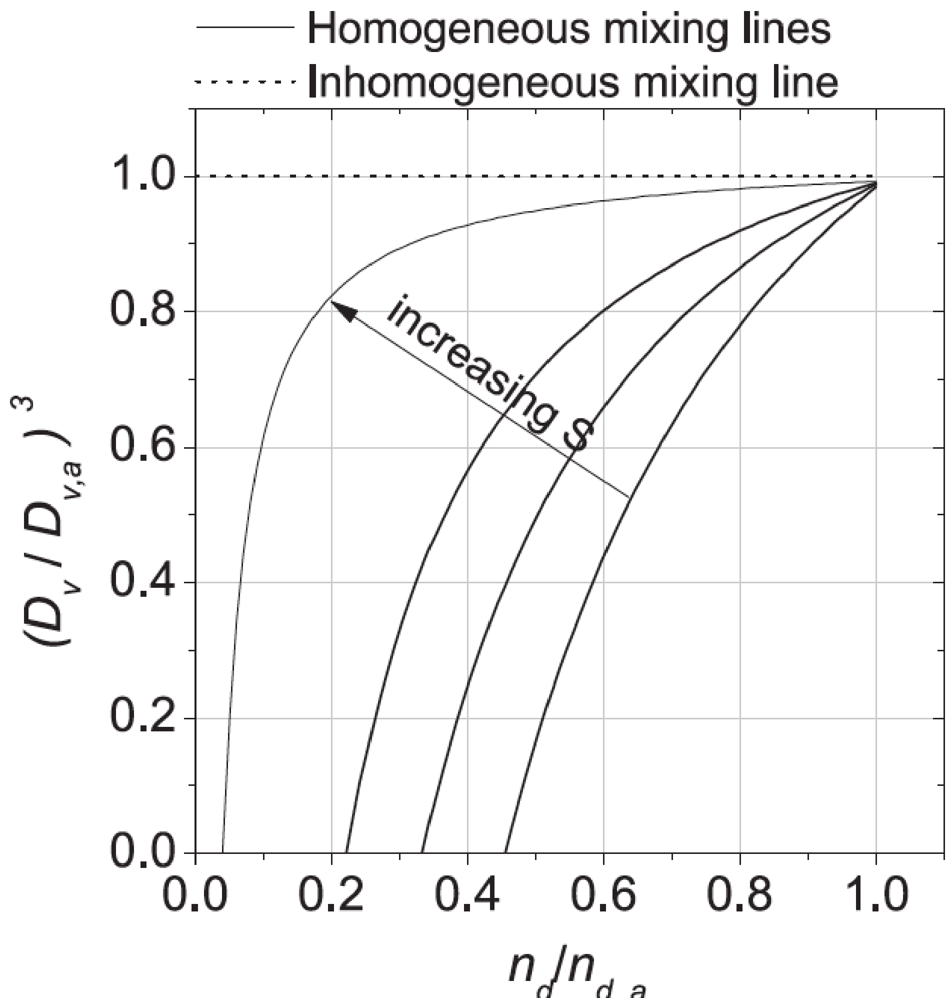
$$\tau_{react} = \frac{D^2 \left(F_k + F_d \right)}{8 \left(S - 1 \right)}$$

Transitional length scale l_* (Lehmann et al. 2009)



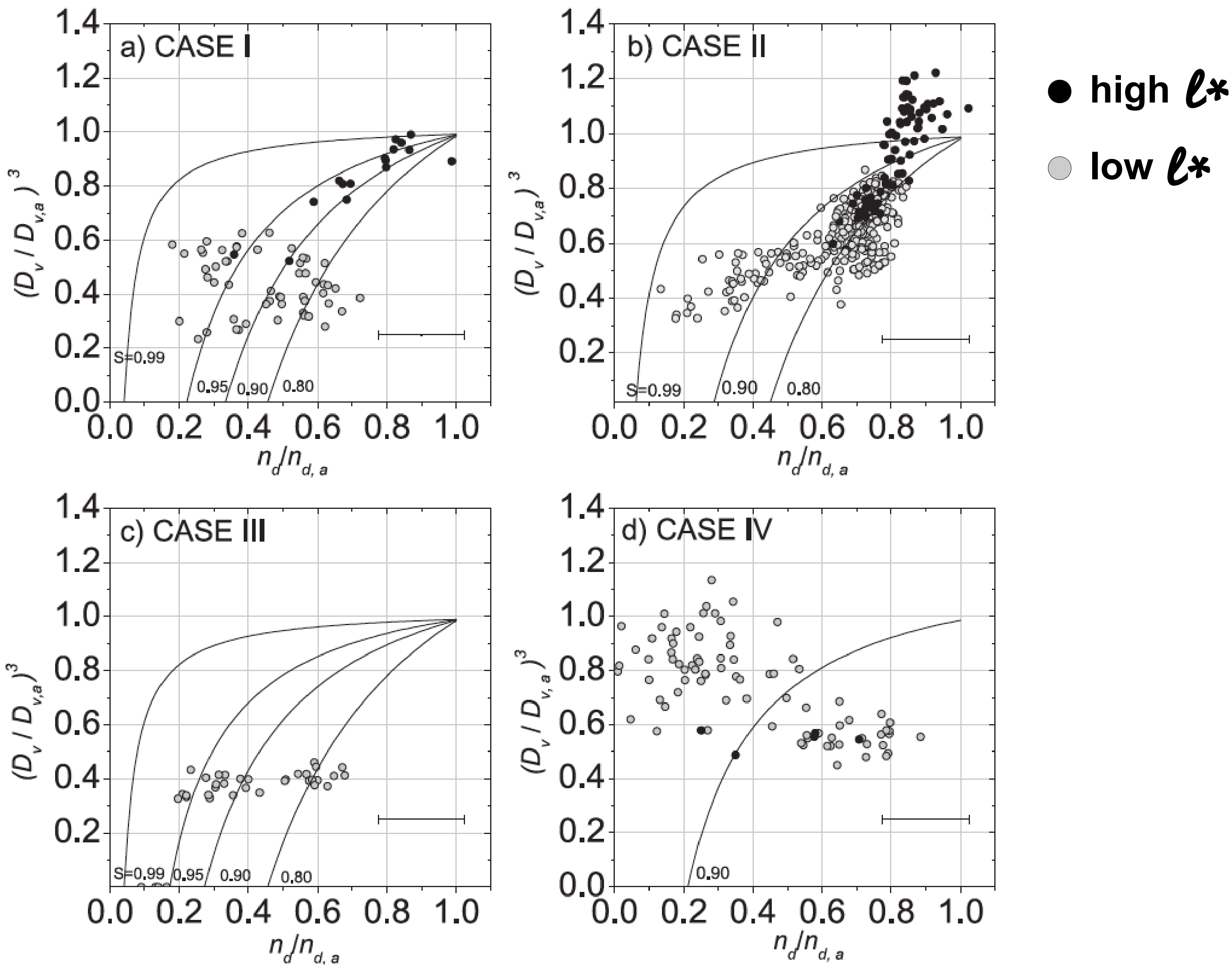
$$l_* = \epsilon^{1/2} \tau_{react}^{3/2}$$

Liquid Water Content (LWC)

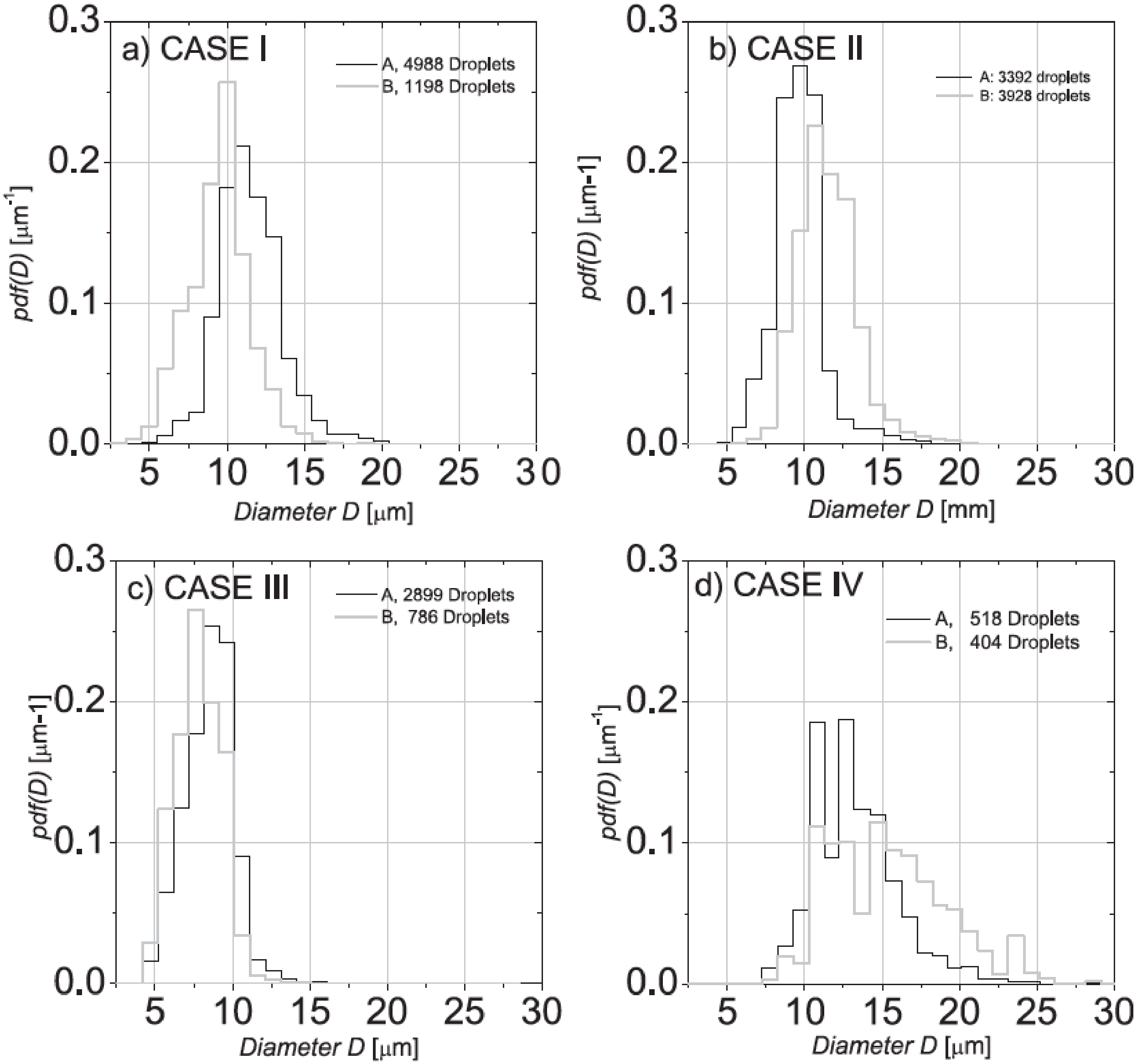


$$LWC(p, T) \sim z \qquad LWC \approx \frac{1}{6}\pi\rho_w N D_v^3$$

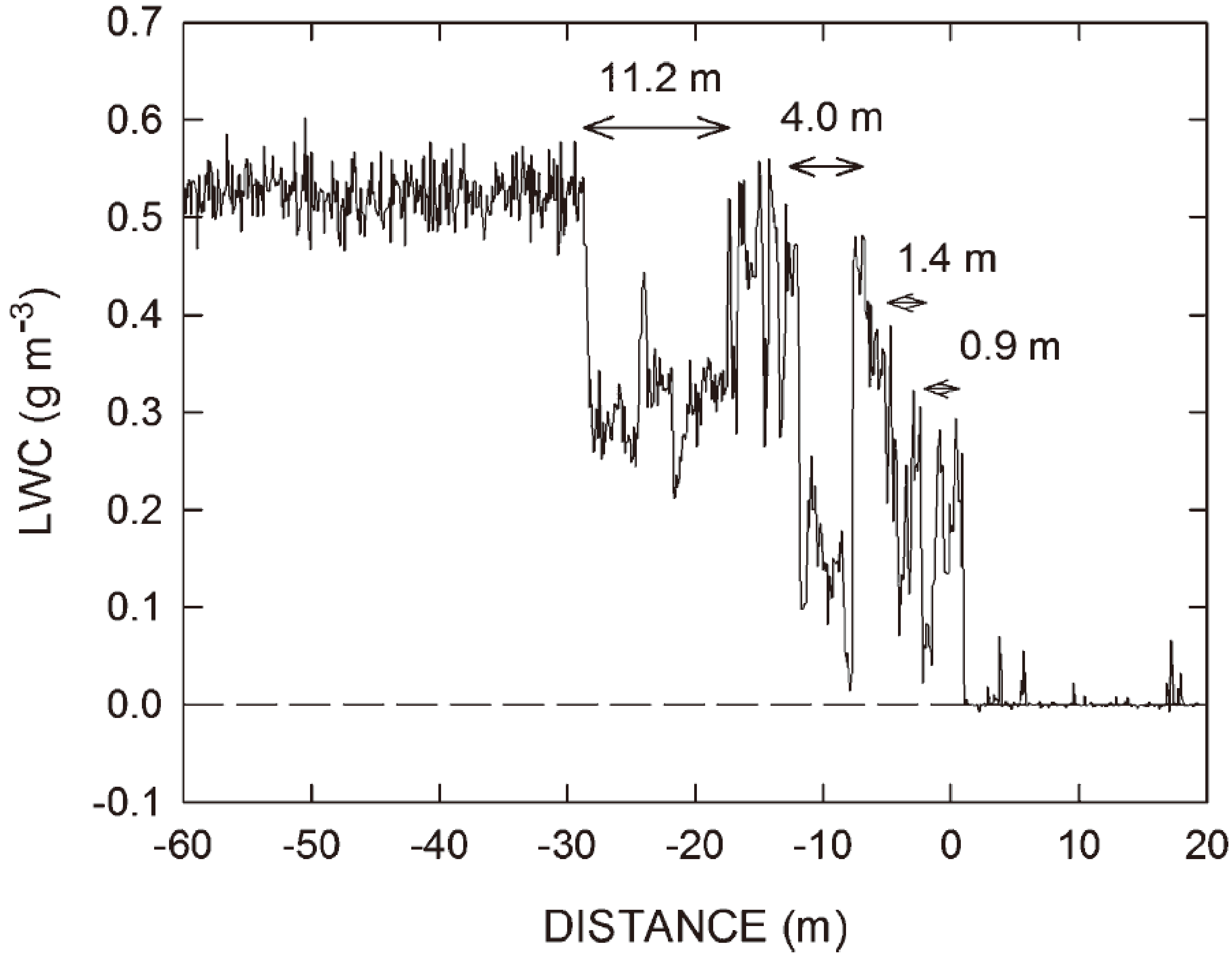
Measurements



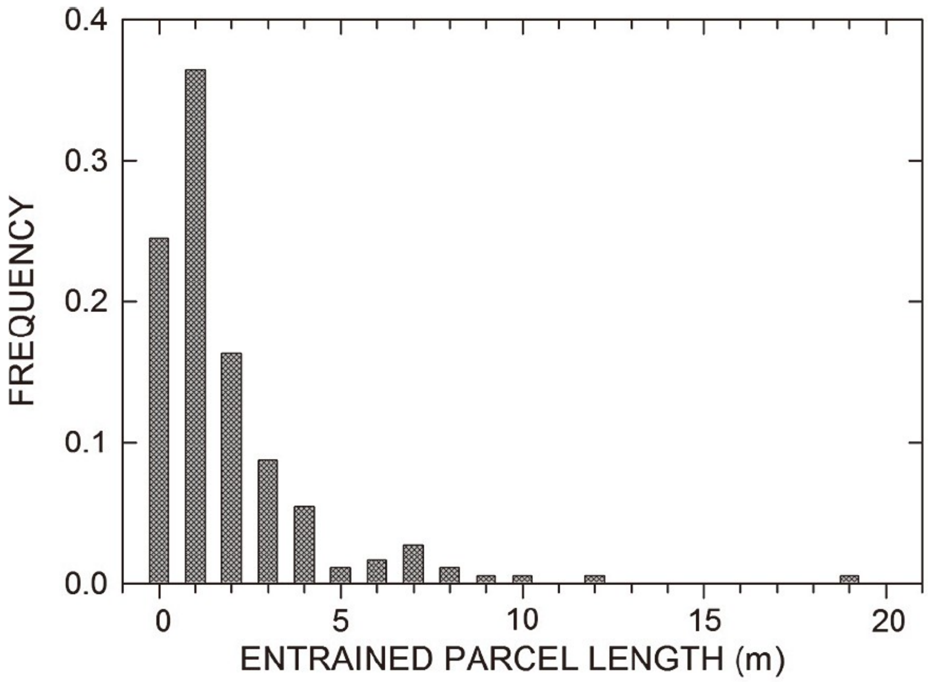
Droplet Spectra

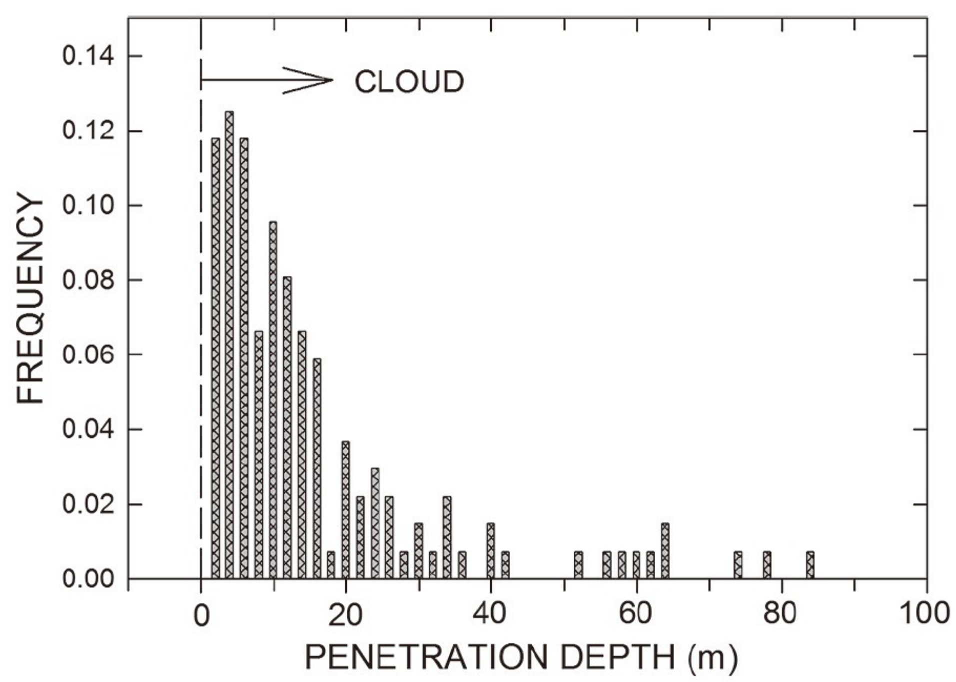


Entrainment and LWC (Gerber et al. 2008)



Entrainment length scales (Gerber et al. 2008)





Discussion

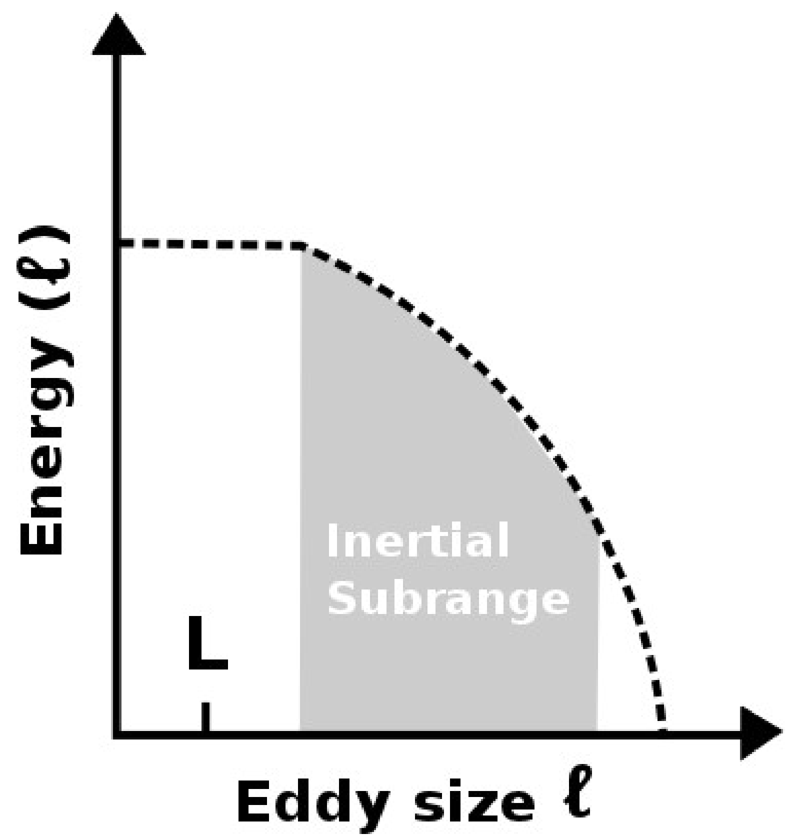
<u>**Range** of eddy sizes ℓ_e</u>

• 100 m **cutoff** in situ aircraft measurements, LES ≥ 50 m

• ℓ_* and $\mathcal{D}a$ characterize **homogeneous** or **inhomo-geneous** entrainment

• Inhomogeneous, if ℓ_* within **inertial subrange**

• **Coalescence** and varying saturation **S** influence τ_{react}, **stochastic** model developed



Conclusions

Entrainment changes characteristic parameters: **ε, $\ell*$, S and τ_{react}**

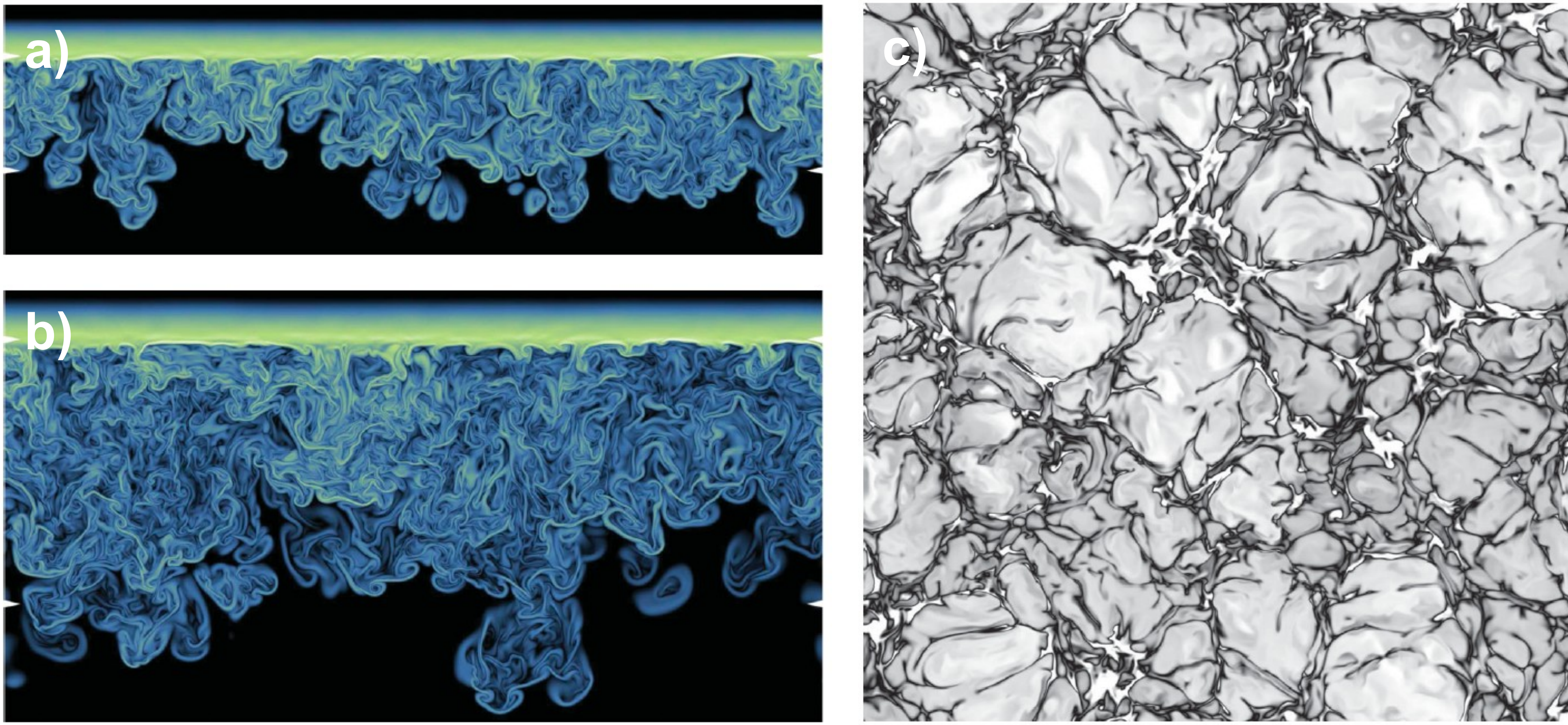
- **ε** decreases due to **decrease in buoyancy**, **higher up** in the cloud, possibly **increases initially** at cloud edges.

- This decrease in **ε** leads to a decrease in **$\ell*$** and possibly leads to rather **heterogenous** mixing.

- **Saturation** ratio **S** in the environment of the cloud increases, locally.

- Thereby, **N** decreases, droplets evaporate quicker and τ_{react} decreases. This favors **homogeneous** mixing, as $\mathcal{D}a$ increases.

Outlook: Radiative Cooling at Cloud Top



Mellado J. P., 2010: **The evaporatively driven cloud-top mixing layer.** *JFM*

a) Buoyancy field from the side after ≈ 8 s
b) after ≈ 15 s
c) from below after ≈ 15 s