Linking cloud microphysics with macrophysics in climate models through entrainment-mixing processes

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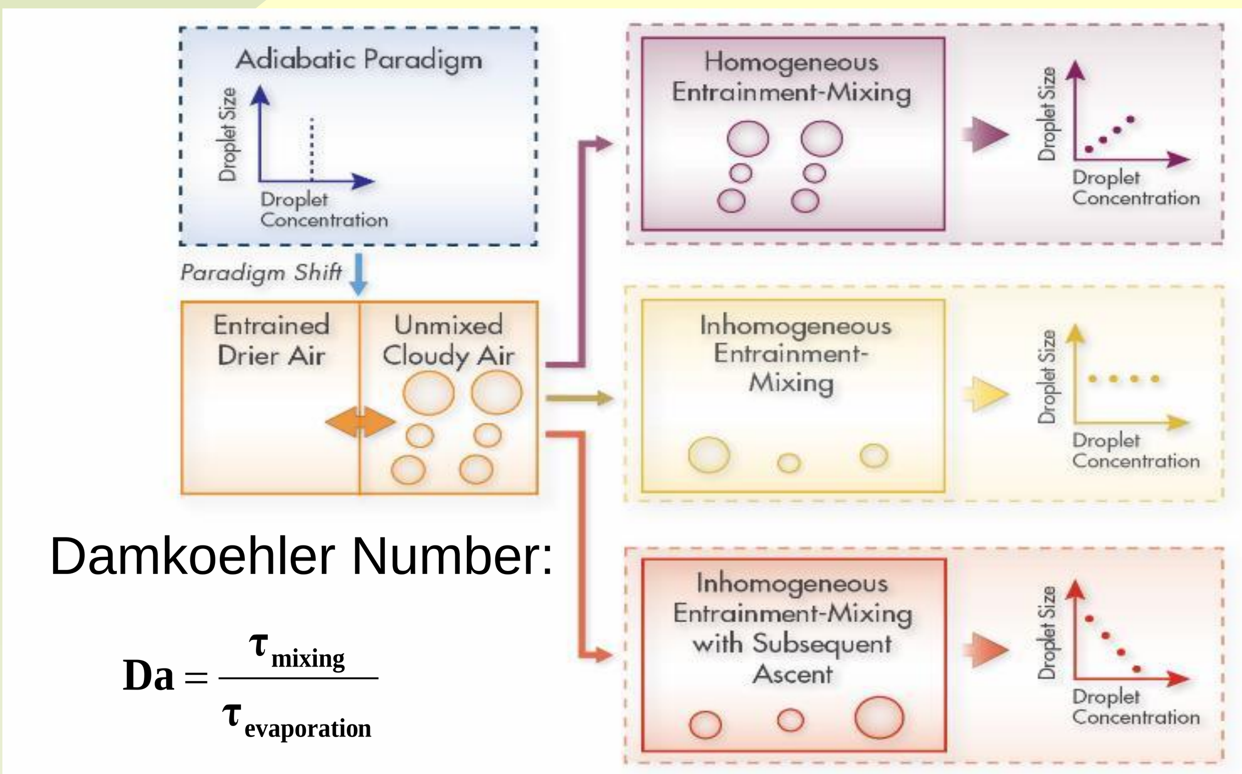
1 Motivation: Three Crucial Topics



- Cloud Microphysics
- Subgrid (co-) variability
- Cloud fraction and RH
- Links to a variety of turbulent entrainment-mixing processes and how?

Fig. 1. Illustration of different microphysical relationships caused by a variety of turbulent entrainment-mixing processes in clouds.

2 Unifying Microphysical/Dynamic Measures

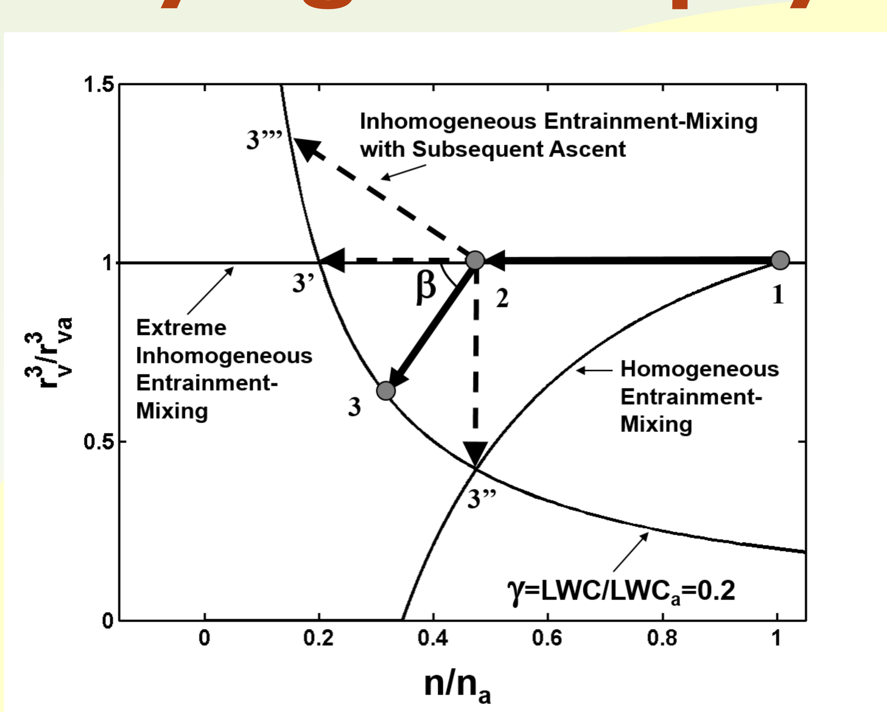


Fig. 2a. Illustration of unifying microphysical measure via mixing diagram of normalized cubic volume-mean radius vs. normalized droplet concentration. : homogeneous mixing degree

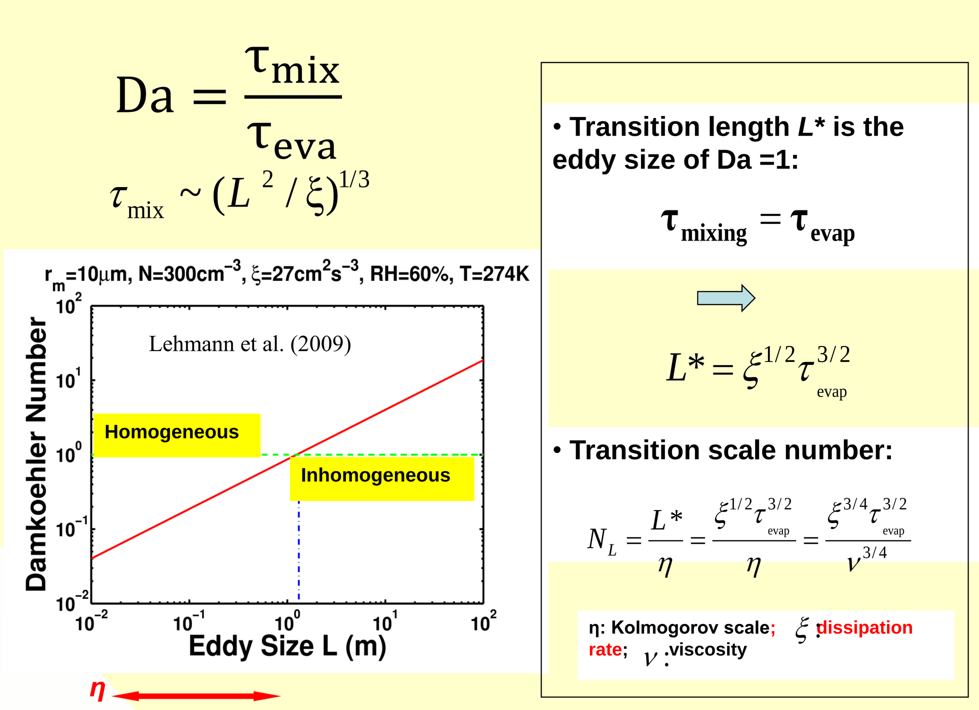
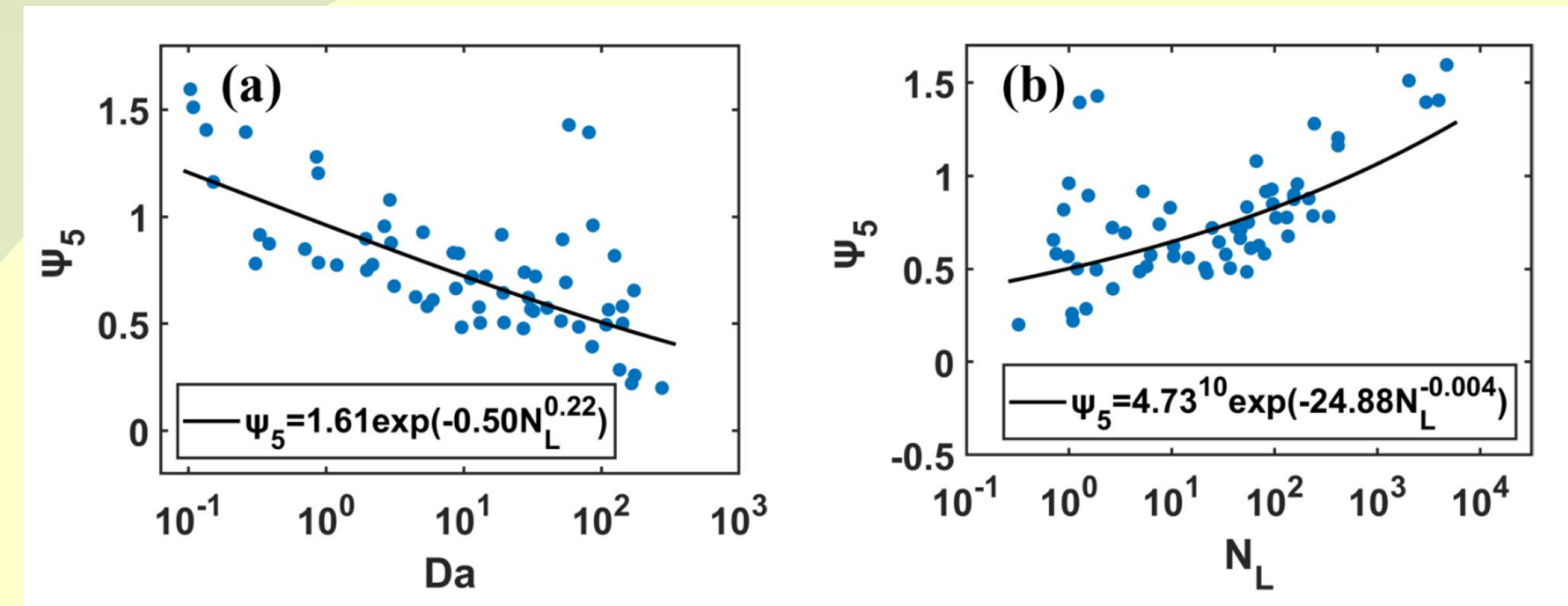


Fig. 2b. Two dynamical measures used in the parameterization of turbulent entrainment-mixing processes that expresses the microphysical measure as a function of a dynamical measure D_a, or N_L

A larger N_L or smaller Da indicates a higher homogeneous mixing degree ϕ >> a unifying parameterization?

3 Entrainment-Mixing and Variability



$$\psi_5 = \mathrm{dis}(r_{vc}^3)/\mathrm{dis}(\mathrm{LWC}_c)$$

Fig. 3. Relationship of the homogeneous mixing degree based on the ratio of relative variability of mean-volume radius (rv) and liquid water content (LWC)to Da (a) and N_L (b). The data are from POST (Gao et al. 2021). See Zhang et al. (2021) for effects of (co-variability) of droplet concentration and liquid water content on autoconversion.

4 Entrainment-Mixing and Cloud Fraction

(4a): Representation of entrained RH

$$RH_d = c\frac{RH - CF}{1 - CF} + (1 - c)\left(1 - \frac{1 - RH}{(1 - CF)^2}\right)$$

RH = grid mean RH; CF = cloud fraction; c = empirical parameter of 0 to 1 that likely relates further to subgrid variability?

(4b): Representation of dissipation rate

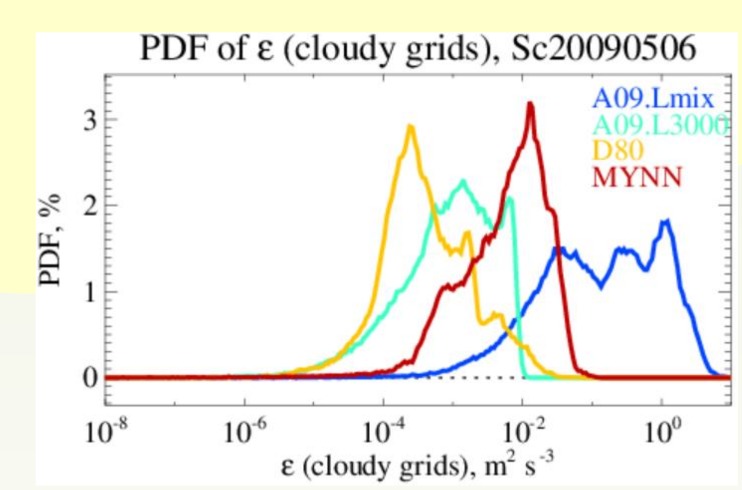


Fig. 4. Different parameterizations of dissipation rate in WRF-Solar.

Δ = WRF_Ent - WRF_No ent

- **Total irradiance (-30 ~ 20 W/m^2)**
- **Direct irradiance (-25~25 W/m^2)**
- **Diffuse irradiance (-15 ~ 15 W/m^2)**
- **Cloud-radiative relationships**
- **Distinct for diffuse irradiance**

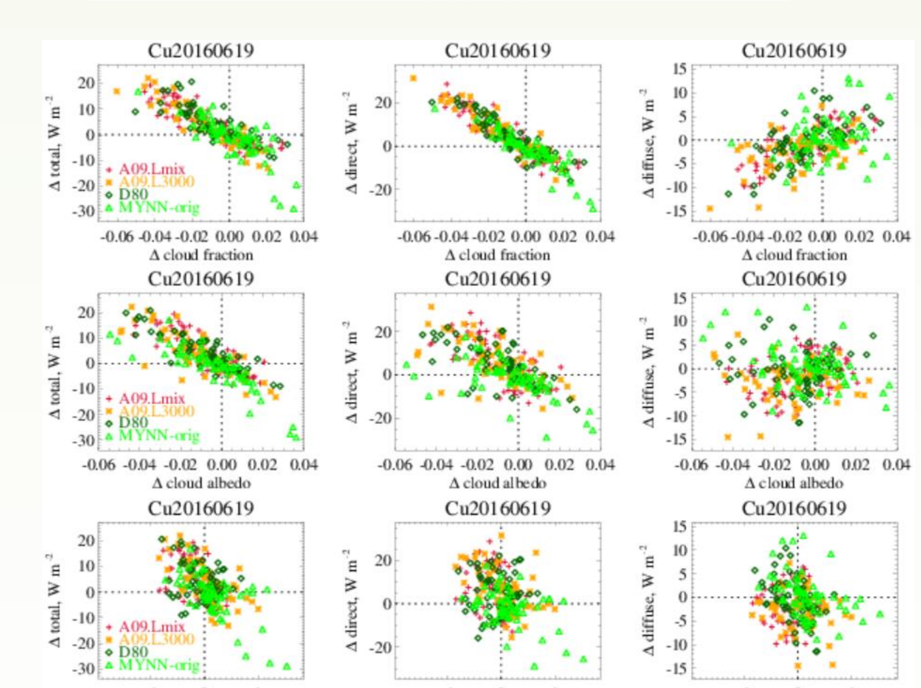


Fig. 5. Influences on cloud and radiative properties of different parameterizations of dissipation rate.

Ongoing research: How to tie together dissipation rate pathway and cloud fraction pathway in models??

References

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