Investigation of the Relationship between Homogeneous Mixing Fraction and Transition Scale Number with the Explicit Mixing Parcel Model

Chunsong Lu[1], Yangang Liu[1], Shengjie Niu[2], Steven Krueger[3], Timothy Wagner[4]

1. Brookhaven National Laboratory (BNL), New York
2. Nanjing University of Information Science and Technology (NUIST), Jiangsu, China
3. University of Utah, Salt Lake City, Utah
4. Creighton University, Omaha, Nebraska

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Motivation

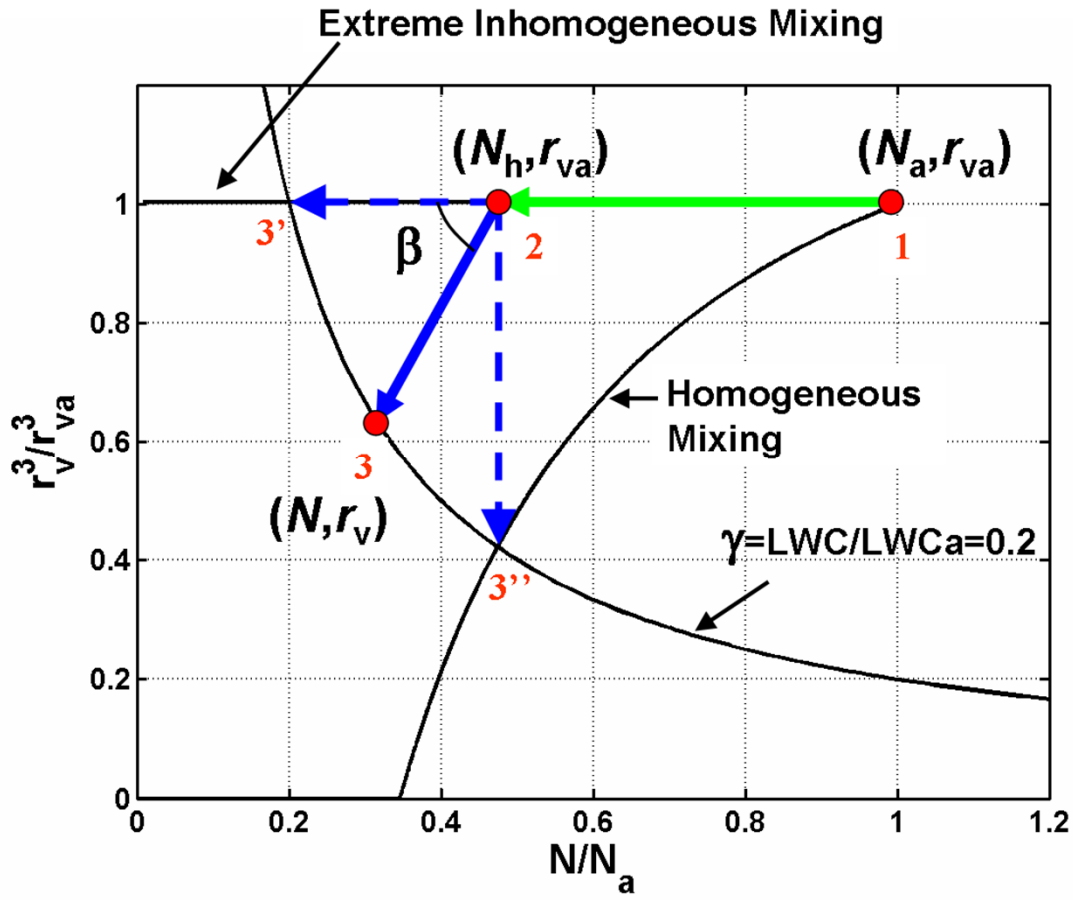
- Entrainment-mixing processes affect
  (1) warm-rain initiation
  (2) aerosol indirect effect
  (3) cloud-climate feedback
  (4) radar retrieval of liquid water content

- The effects of entrainment-mixing processes are influenced by different entrainment-mixing mechanisms (homogeneous or inhomogeneous).

- How to parameterize these different mechanisms?

Three homogeneous mixing fractions **VS** Two transition scale numbers

Three Homogeneous Mixing Fractions --- Ψ_1

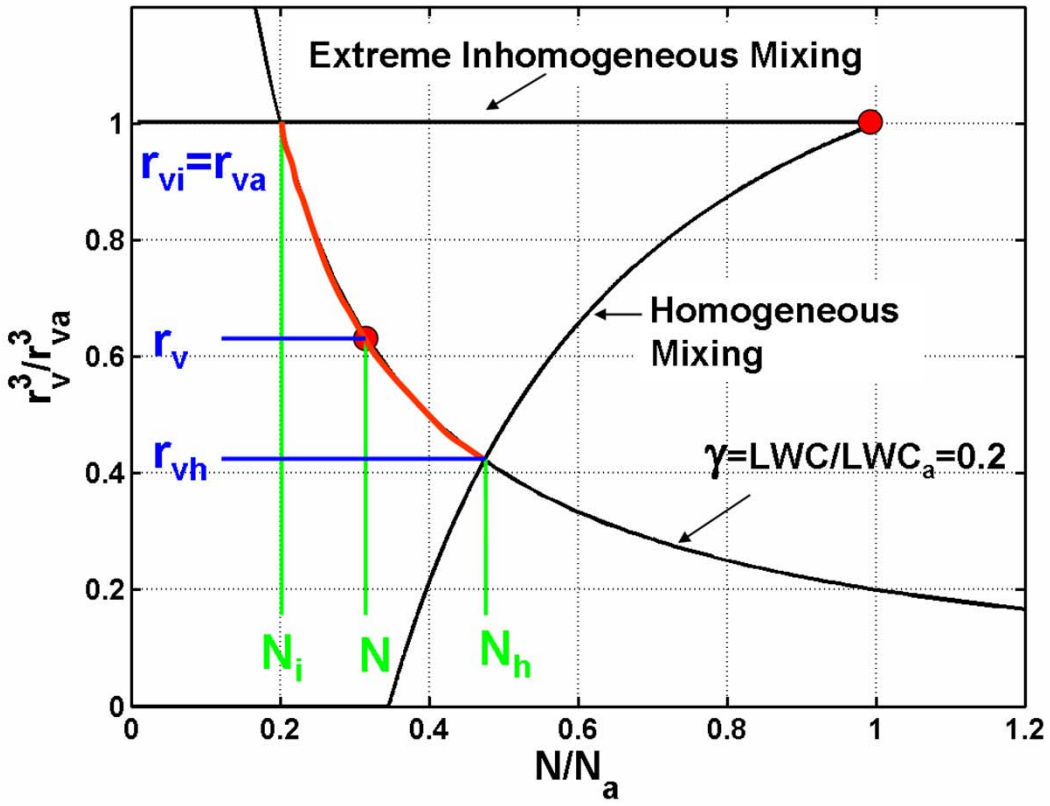


$$\psi_1 = \frac{\beta}{\pi / 2}$$

Homogeneous: Ψ_1=1; extreme inhomogeneous: Ψ_1 =0

Three Homogeneous Mixing Fractions --- ψ_2

$$\psi_2 = \frac{1}{2}\left(\frac{N - N_i}{N_h - N_i} + \frac{r_v^3 - r_{va}^3}{r_{vh}^3 - r_{va}^3}\right)$$



Three Homogeneous Mixing Fractions --- Ψ_3

$$\psi_3 = \frac{\ln N - \ln N_i}{\ln N_h - \ln N_i} = \frac{\ln r_v^3 - \ln r_{vi}^3}{\ln r_{vh}^3 - \ln r_{vi}^3}$$

This definition, Ψ_3, turns out to be related to α:

$$\psi_3 = 1 - \alpha$$

where α was defined by Morrison and Grabowski (2008):

$$N = N_0 \left(\frac{q}{q_0}\right)^{\alpha}$$

N, q: number concentration and liquid water mixing ratio after entrainment and mixing, respectively.

N_0, q_0: number concentration and liquid water mixing ratio after entrainment but before mixing, respectively.

Two Transition Scale Numbers (1)

A larger scale number (N_L) means a higher probability of homogeneous mixing (Lu et al., 2011).

$$N_L = \frac{\varepsilon^{1/2}\tau_{react}^{3/2}}{\eta}$$

ε: Dissipation rate
η: Kolmogorov scale

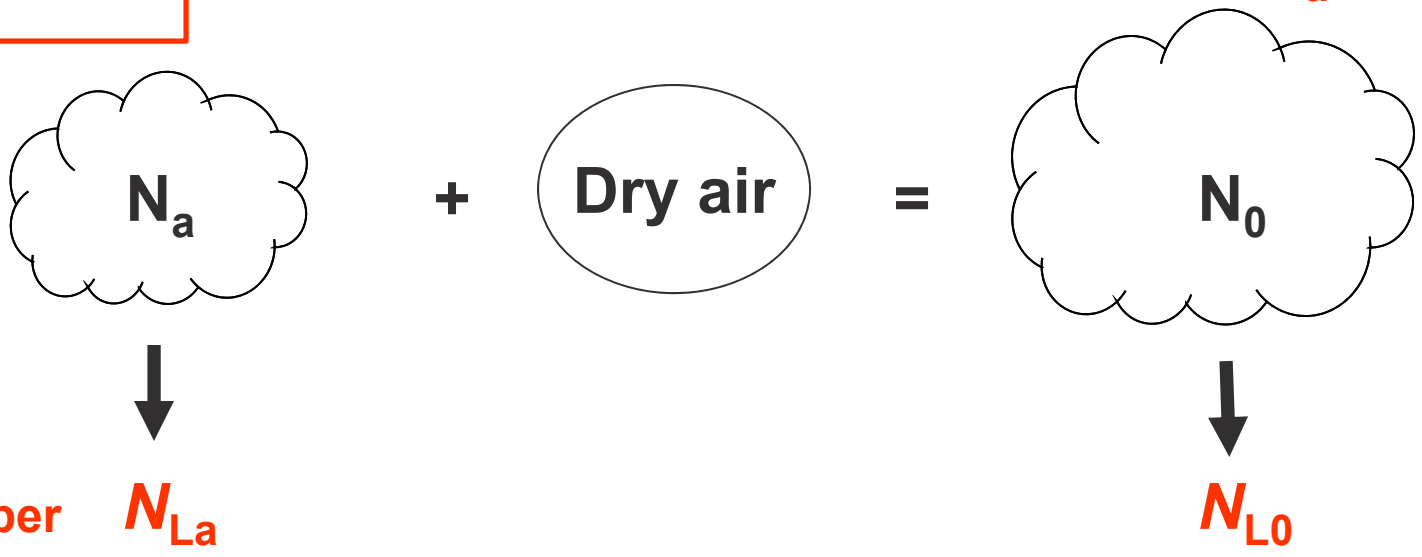
τ_{react} is defined as either the time when droplets completely evaporate or the time at which relative humidity reaches 99.5% (Lehmann et al., 2009).

Two Transition Scale Numbers (2)

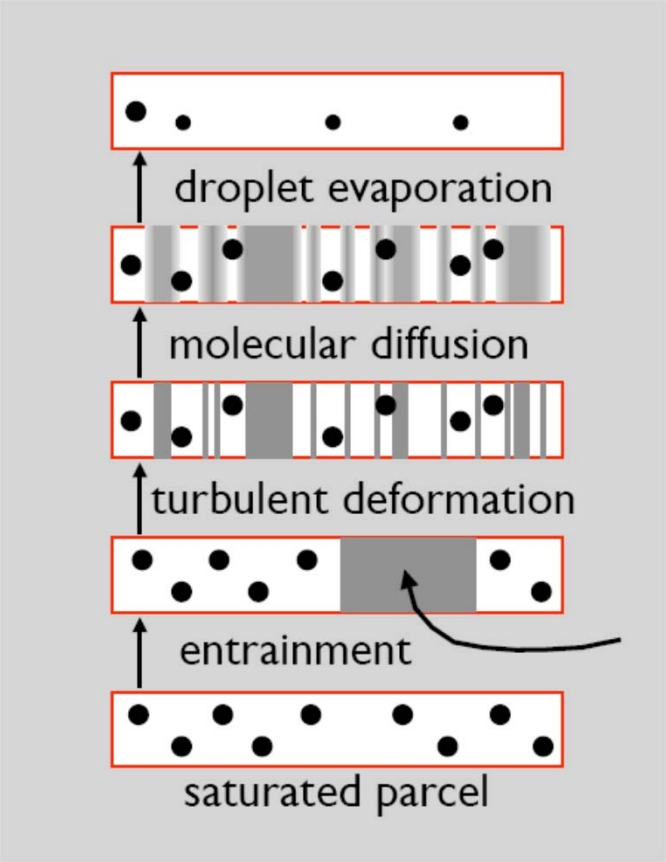
τ_{react} is the time when $r < 0$ or $s > -0.005$.

$$\begin{cases} \dfrac{dr}{dt} = A\dfrac{s}{r} \\ \dfrac{ds}{dt} = -Brs \end{cases}$$

r: droplet radius;
s: supersaturation;
A: a function of pressure and temperature;
B: a function of pressure, temperature and droplet number concentration (N_a or N_0).



Explicit Mixing Parcel Model (EMPM)



Krueger (2008)

Domain size:

20 m × 0.001 m × 0.001 m ;

Adiabatic Number Concentration:

102.7, 205.4, 308.1, 410.8, 513.5 cm^{-3};

Relative humidity:

11%, 22%, 44%, 66%, 88%;

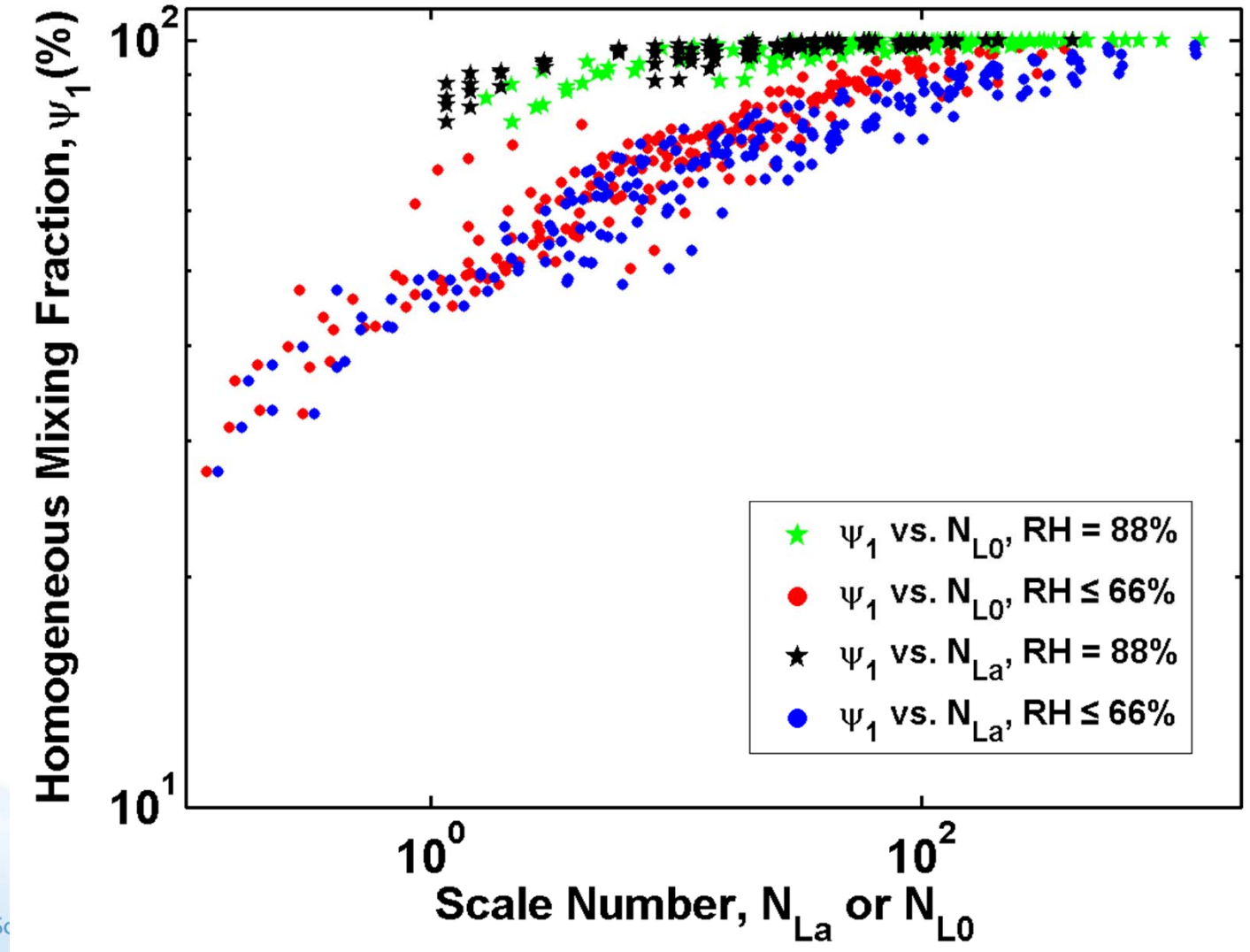
Dissipation rate:

1e-5, 5e-4, 1e-3, 5e-3, 1e-2, 5e-2 m^2s^{-3};

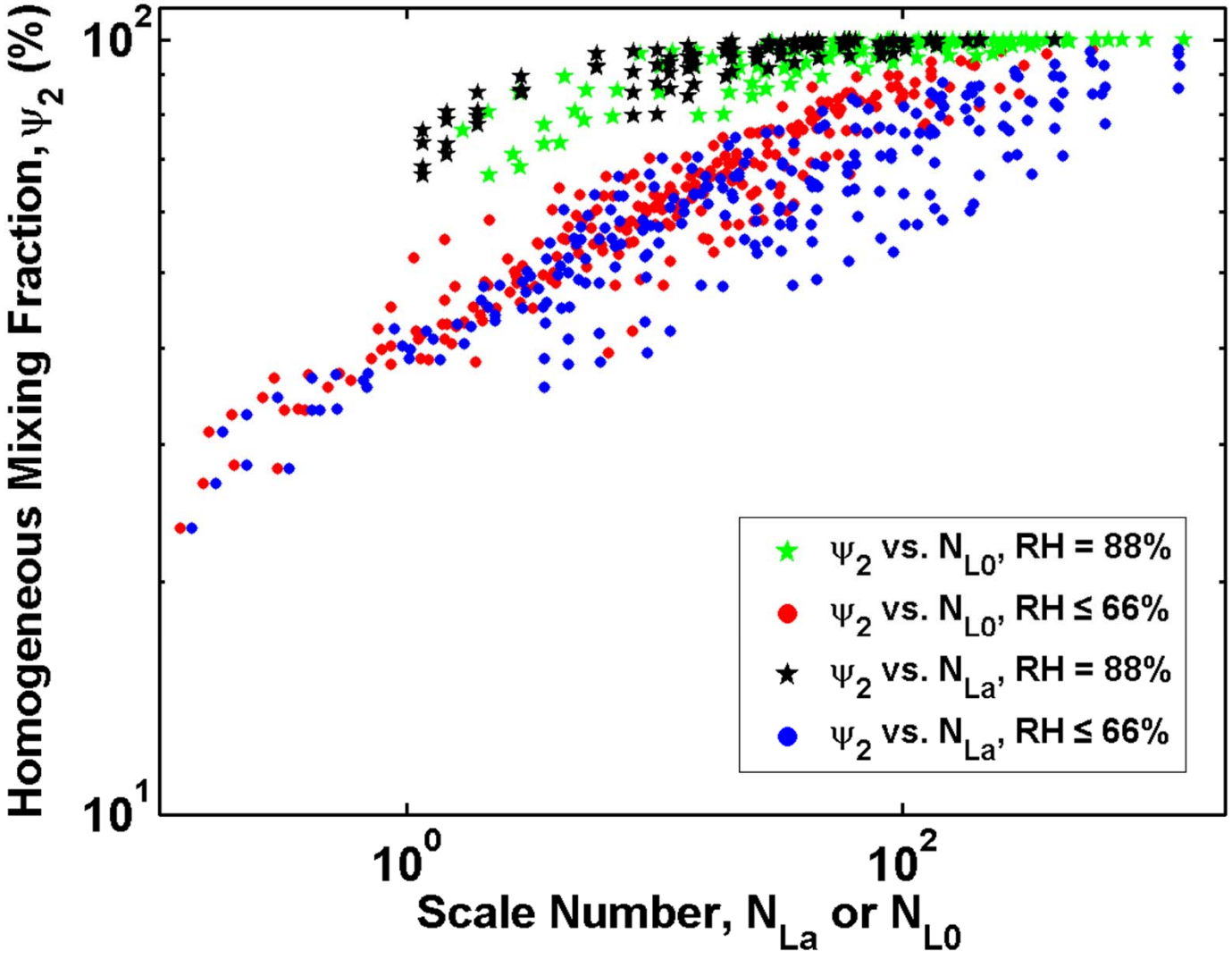
Dry air ratio:

0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9.

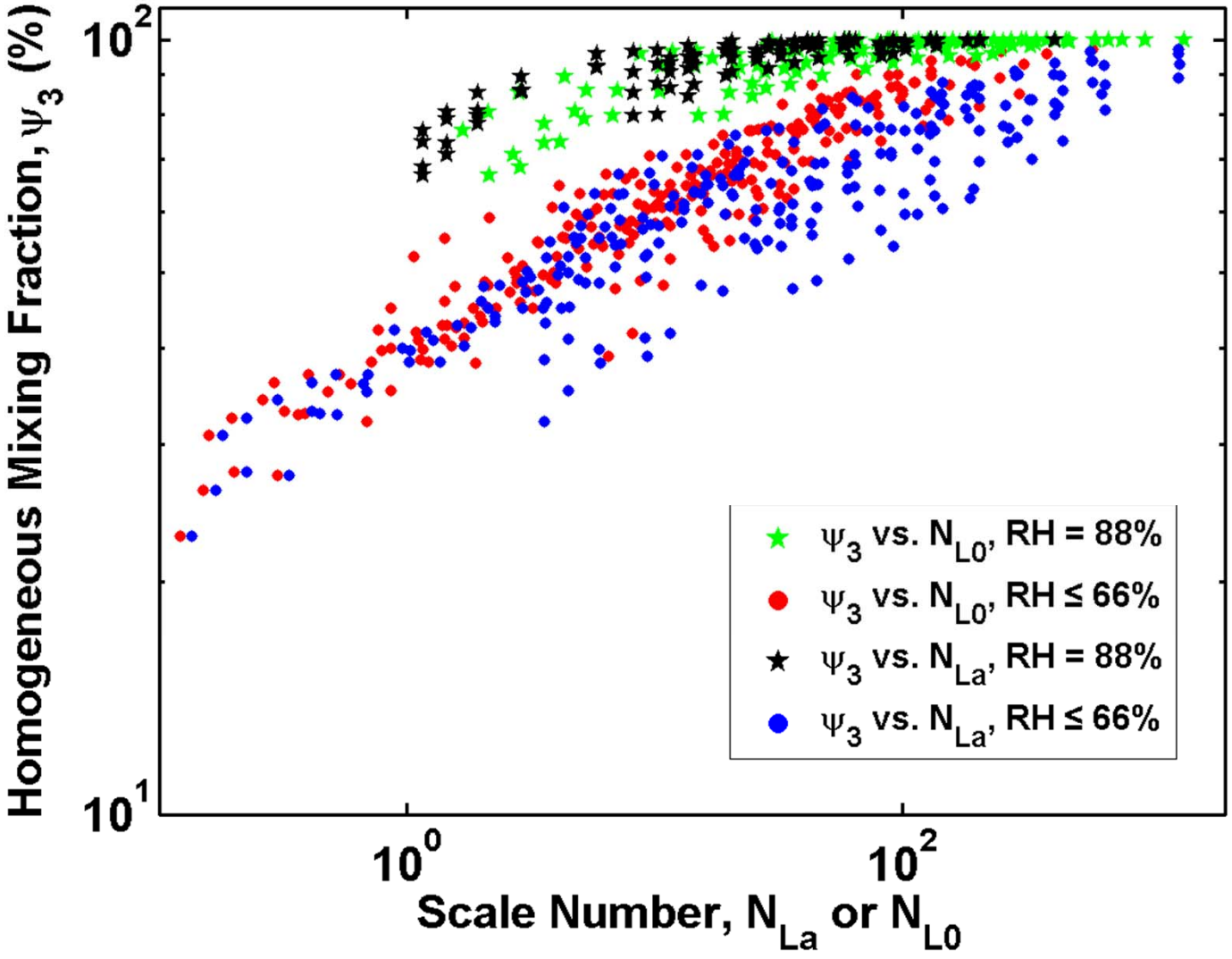
Ψ_1 vs. N_{La} and N_{L0}



Ψ_2 vs. N_{La} and N_{L0}



Ψ_3 vs. N_{La} and N_{L0}



Summary

- Three homogeneous mixing fractions and two transition scale numbers are found positively related with the EMPM model results;
- It is suggested to use the transition scale number considering dry air ratio;
- This scale number could relate microphysical effect of entrainment mixing to estimation of entrainment rate with a new approach (Lu et al., 2012).

A New Approach for Estimating Entrainment Rate in Cumulus Clouds

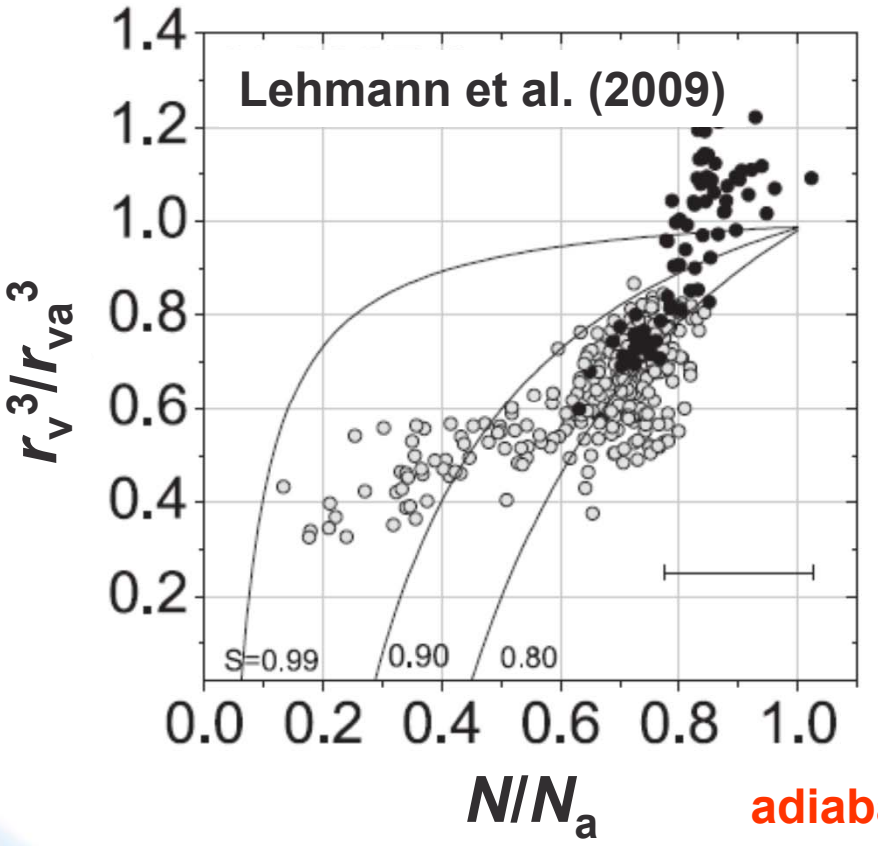
Breakout Session----Entrainment

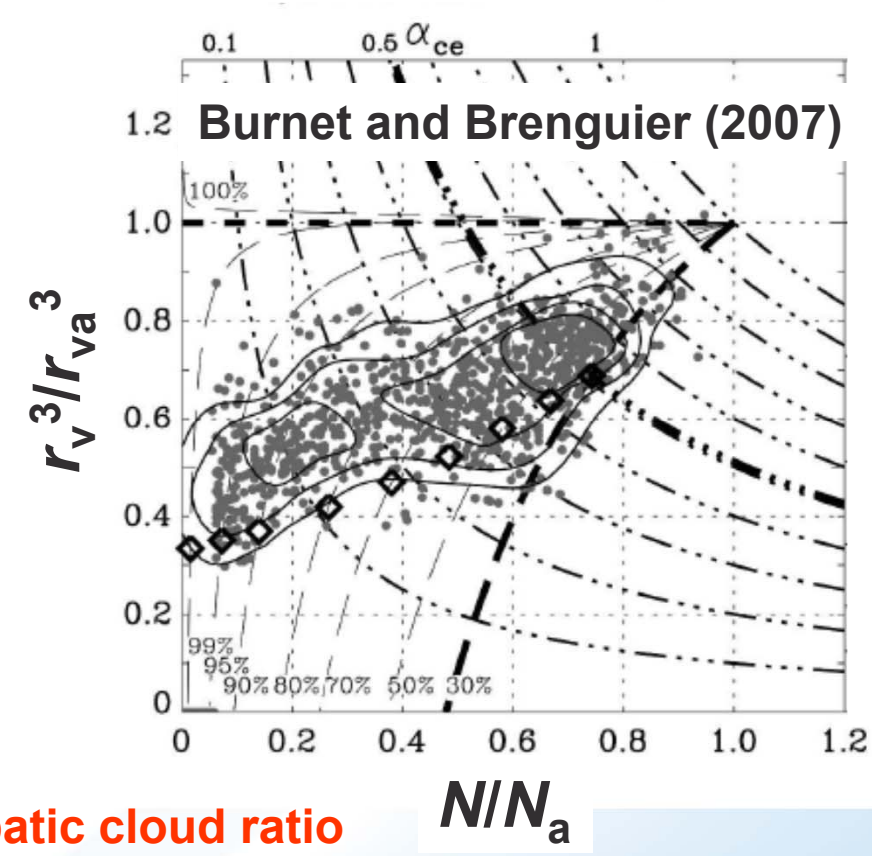
Breakout Room 2 – Regency F

7:30 p.m.–9:00 p.m.

Backup

The Reason Why N_{L0} Is Better (1)

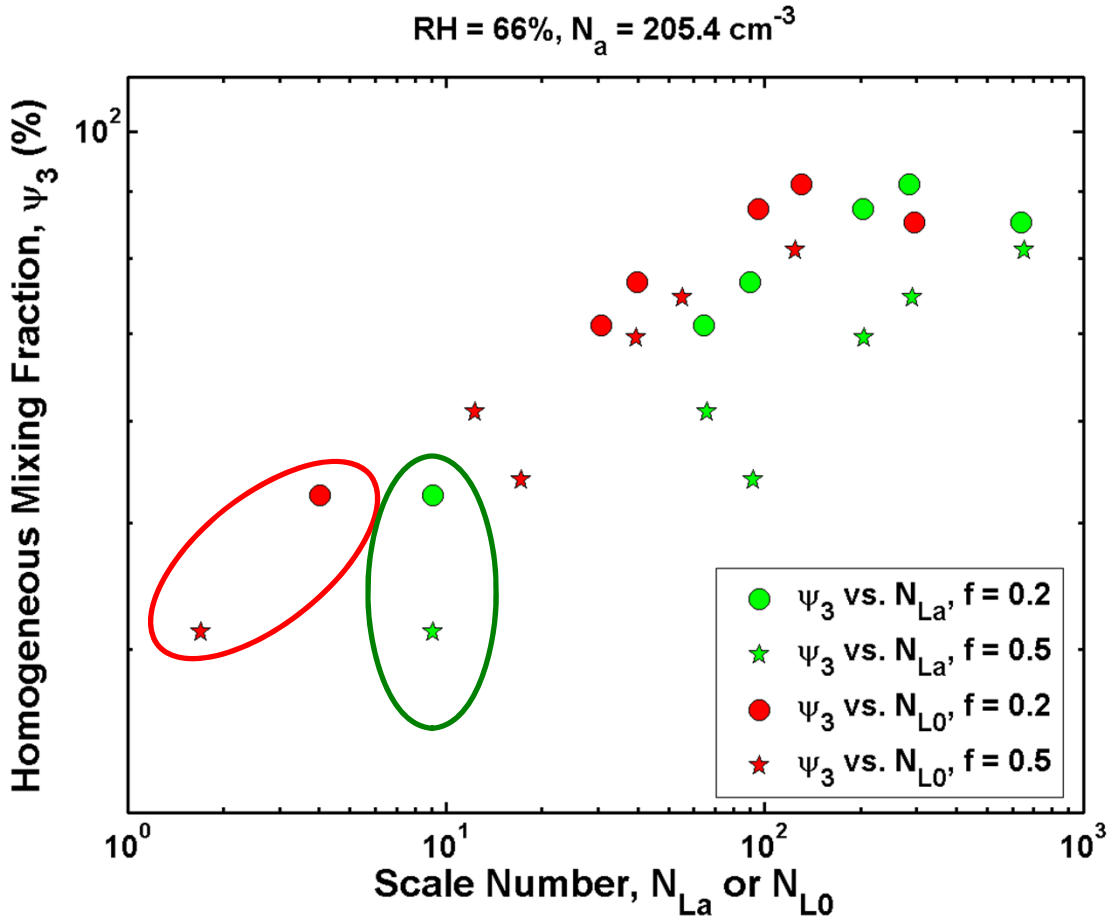




adiabatic cloud ratio

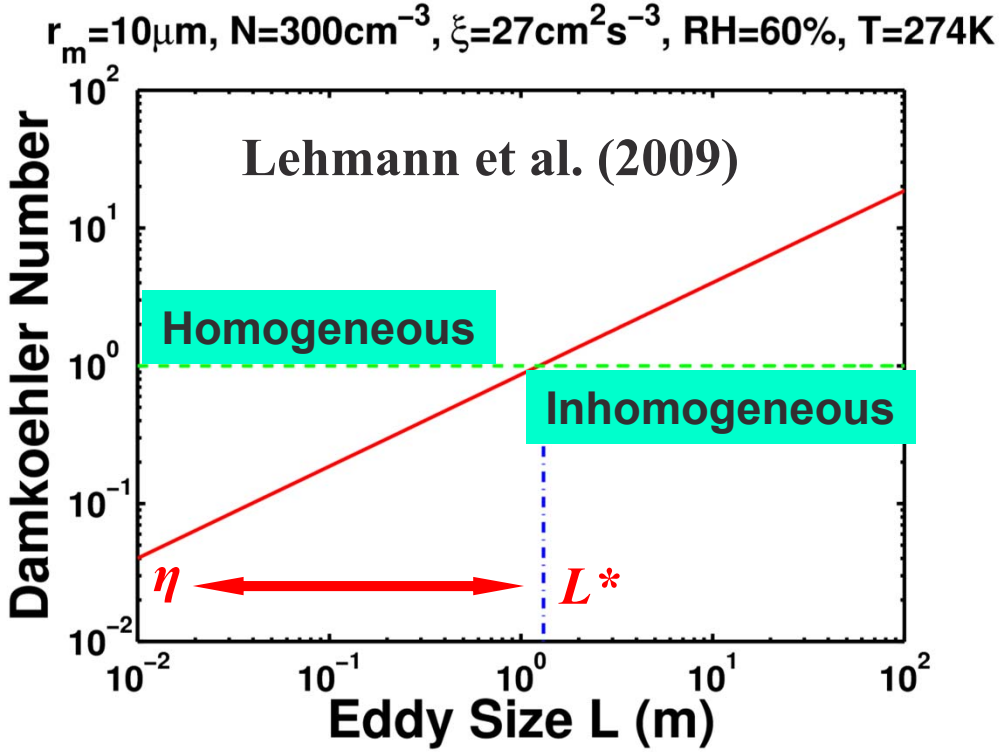
Mixing changes from homogeneous to inhomogeneous mixing when dry air ratio increases.

The Reason Why N_{L0} Is Better (2)



N_{L0} considers the effect of dry air ratio, but N_{La} does not.

Definition of Transition Scale Number (N_L)



A larger value of N_L indicates a higher probability of homogeneous mixing.

Lehmann et al. (2009) defined transition length (L^*) by setting Da =1.

$$Da = \tau_{mix} / \tau_{react} = 1$$

$$\tau_{mix} \sim (L^2 / \xi)^{1/3}$$

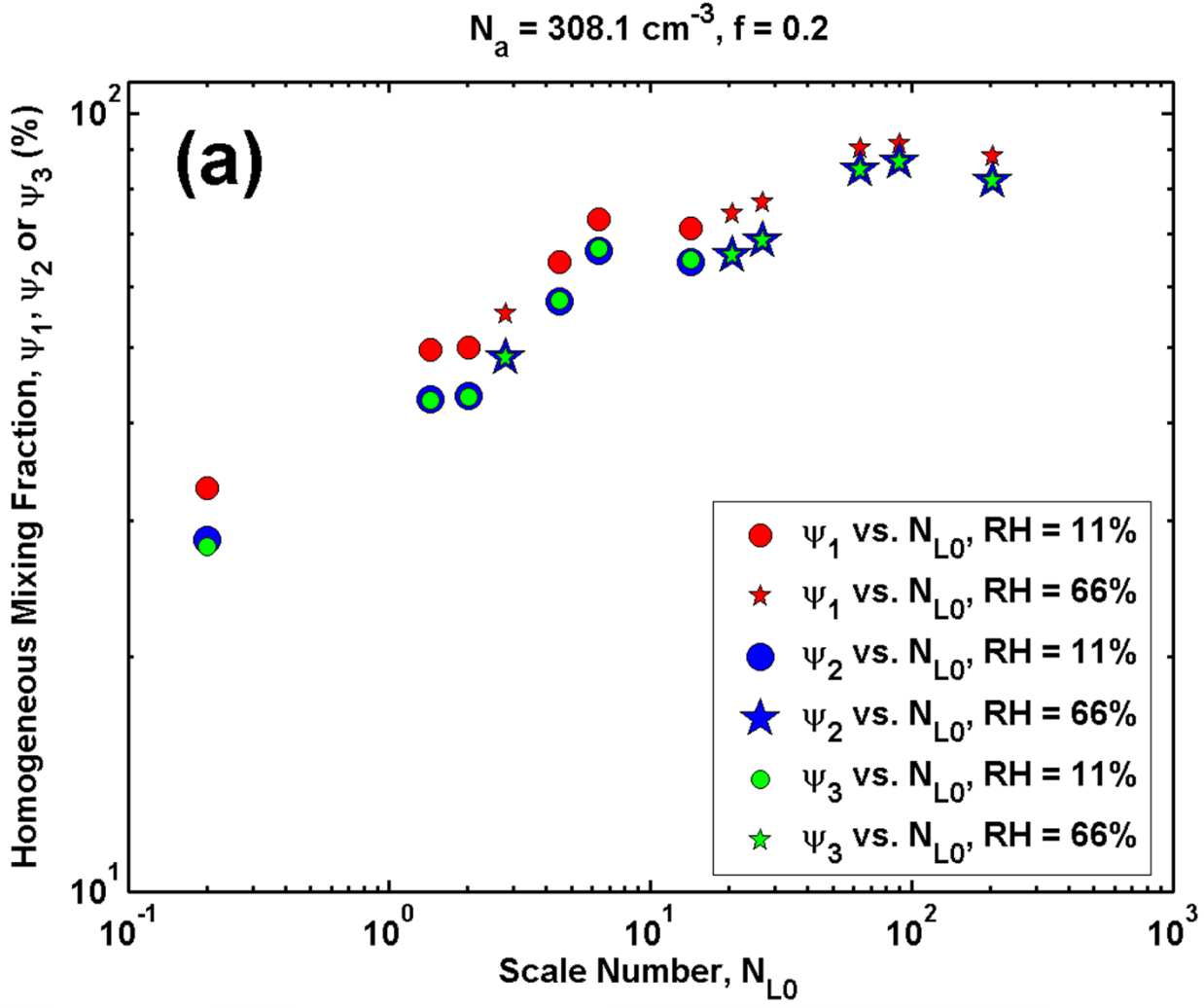
$$\rightarrow L^* = \xi^{1/2} \tau_{react}^{3/2}$$

We define transition scale number (N_L) as (Lu et al., 2011):

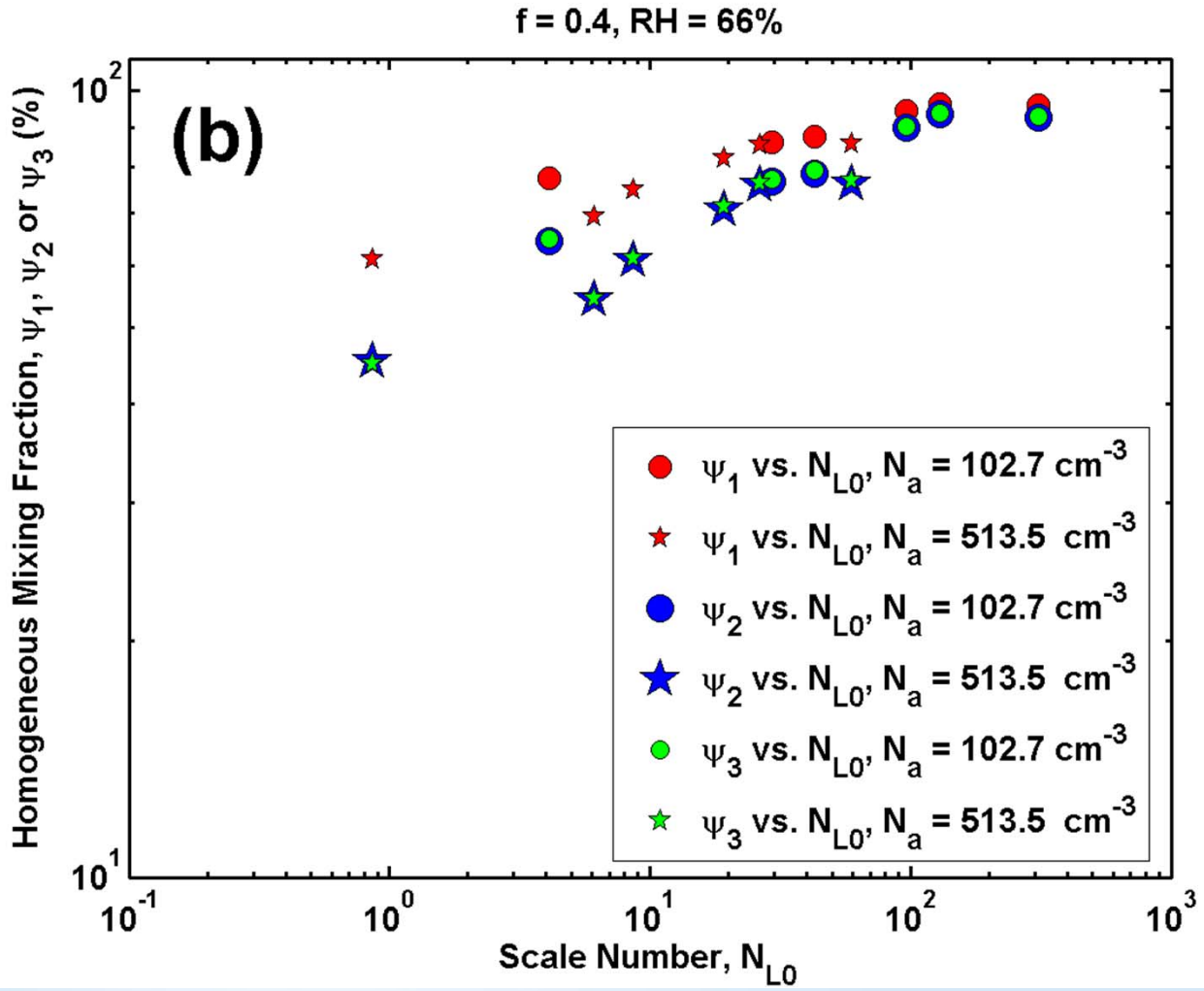
$$N_L = \frac{L^*}{\eta} = \frac{\xi^{1/2} \tau_{react}^{3/2}}{\eta}$$

η: Kolmogorov scale

Sensitivity Test on Relative Humidity (RH)



Sensitivity Test on Adiabatic Number Concentration (N_a)



Sensitivity Test on Dry Air Ratio (f)