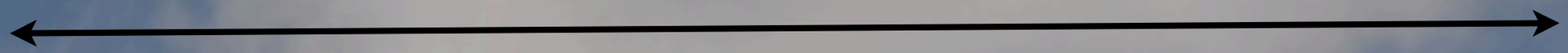
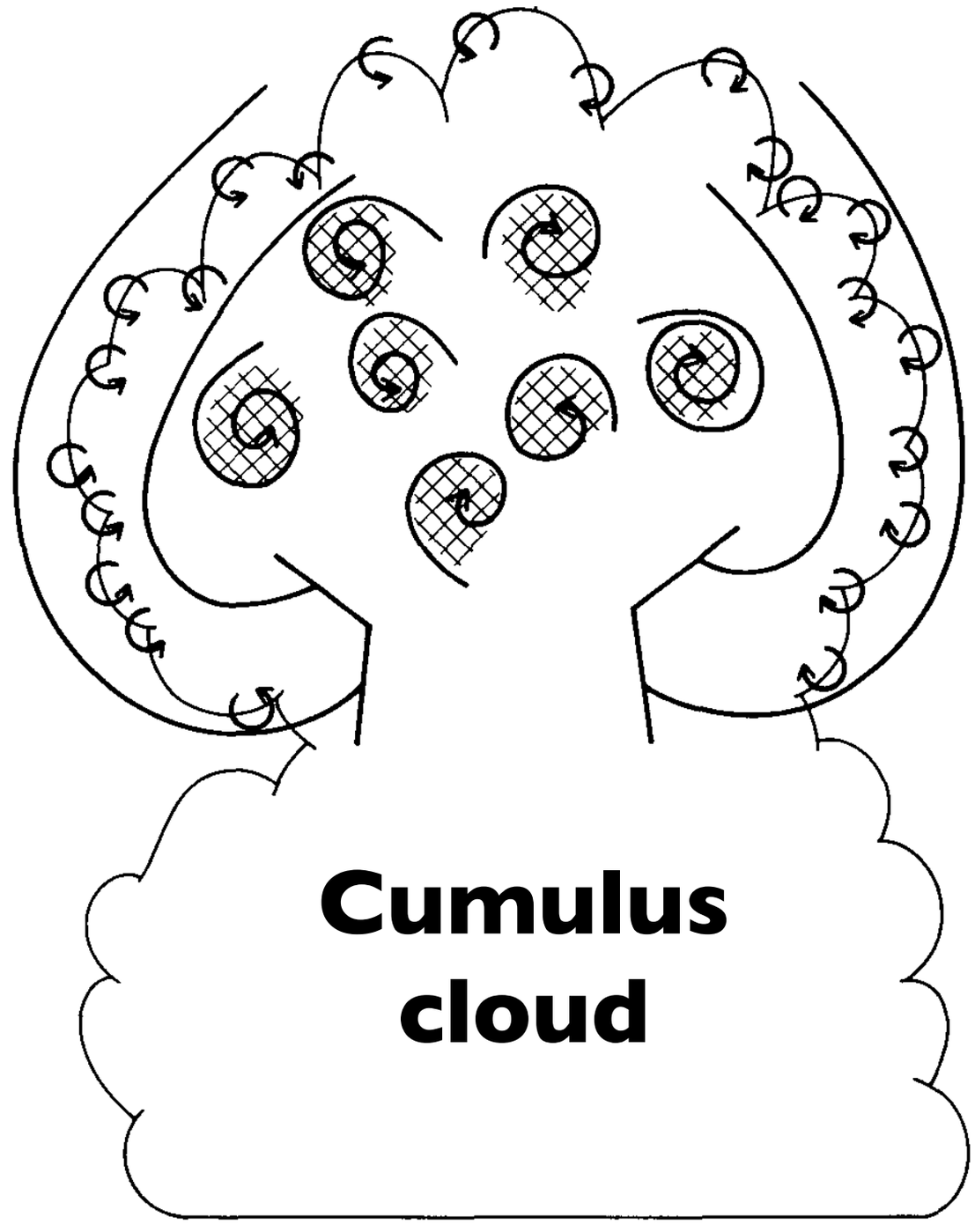


Turbulent Mixing

Kelvin-Helmholtz Instability: Re=900 and 1400

Kelvin-Helmholtz Instability: Re=900 and 1400

Entrainment and Mixing

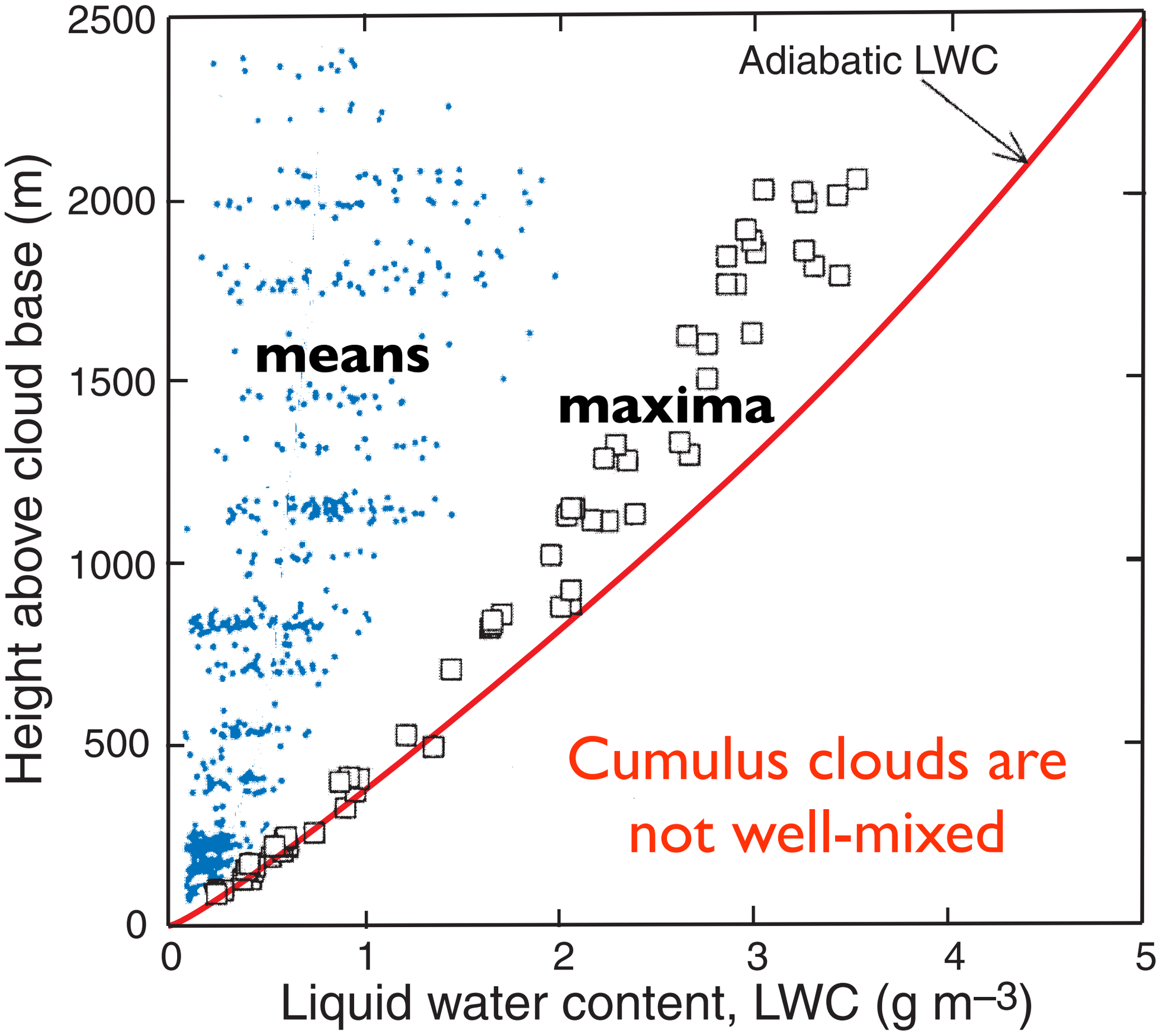


Mixing Time Scale

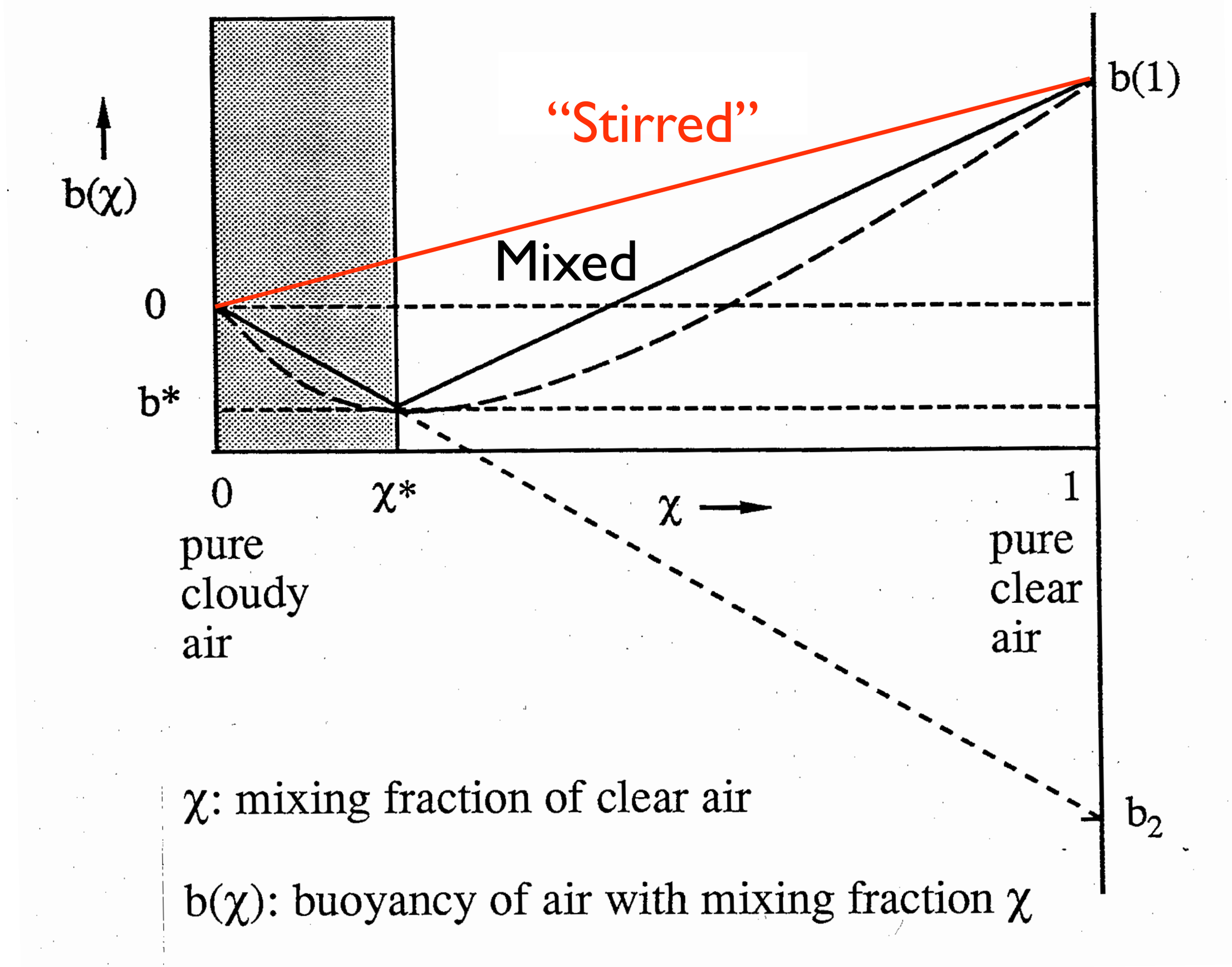
$$\tau = \left(\frac{d^2}{\epsilon}\right)^{1/3},$$

d is entrained blob size, ϵ is dissipation rate of turbulence kinetic energy.

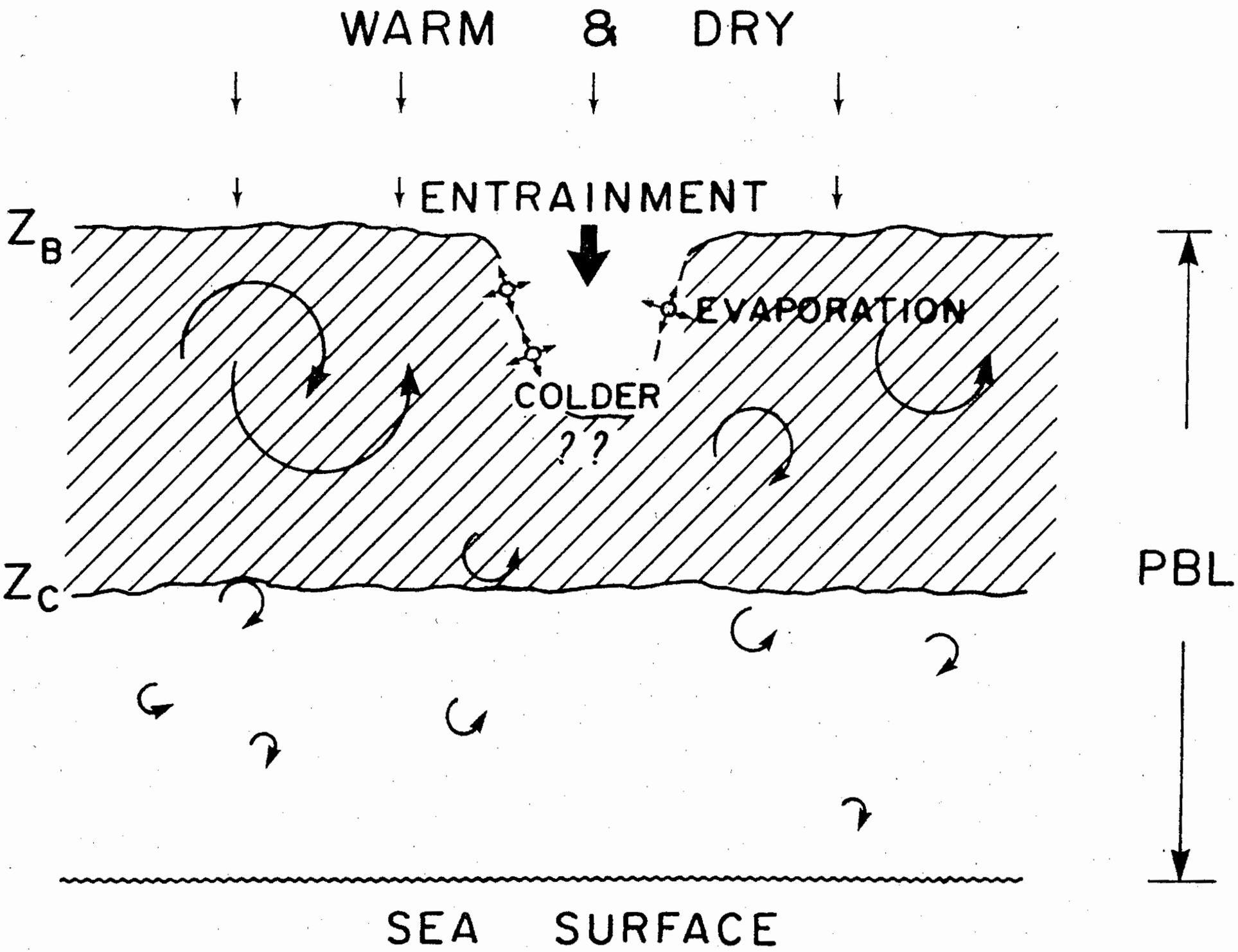
For a **cumulus cloud,** $U \sim 2$ m/s, $L \sim 1000$ m, so $\epsilon \sim U^3/L = 10^{-2}$ m^2/s^3. For $d = 100$ m, $\tau \sim 100$ s.


Adiabatic LWC
means
maxima
Cumulus clouds are
not well-mixed
Height above cloud base (m)
Liquid water content, LWC (g m–3)
2500
2000
1500
1000
500
0
0
1
2
3
4
5

Buoyancy vs Mixture Fraction

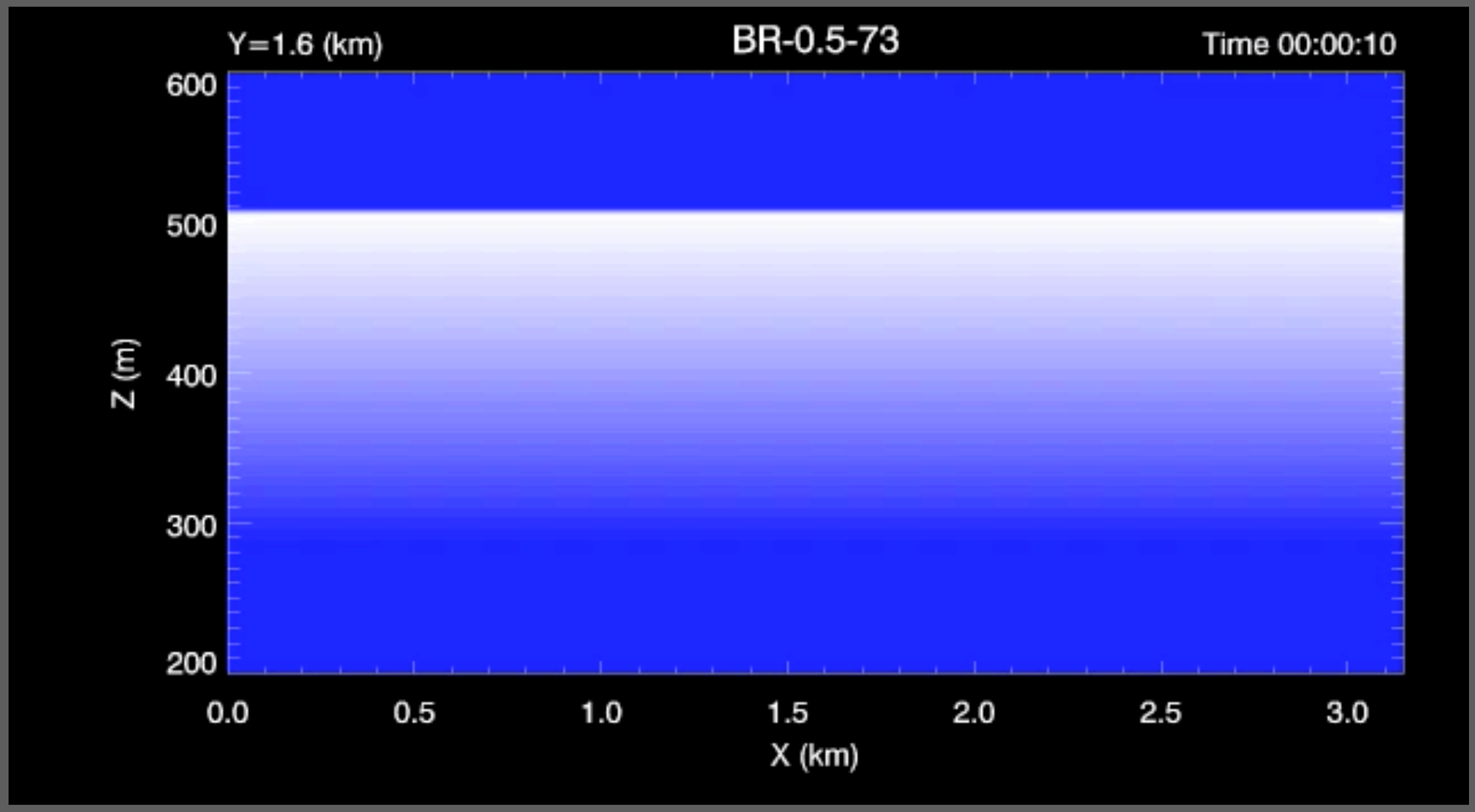


Cloud-top Entrainment Instability (CEI)



LES with a 5-m isotropic grid
(Yamaguchi and Randall 2008)

Yamaguchi, T., and D. A. Randall, 2008: Large-eddy simulation of evaporatively driven entrainment in cloud-topped mixed layers. J. Atmos. Sci., 65, 1481–1504.



- Newly entrained thermals tend to follow the dry paths of earlier thermals.
- The dry paths become wider.

LES with a 5-m isotropic grid
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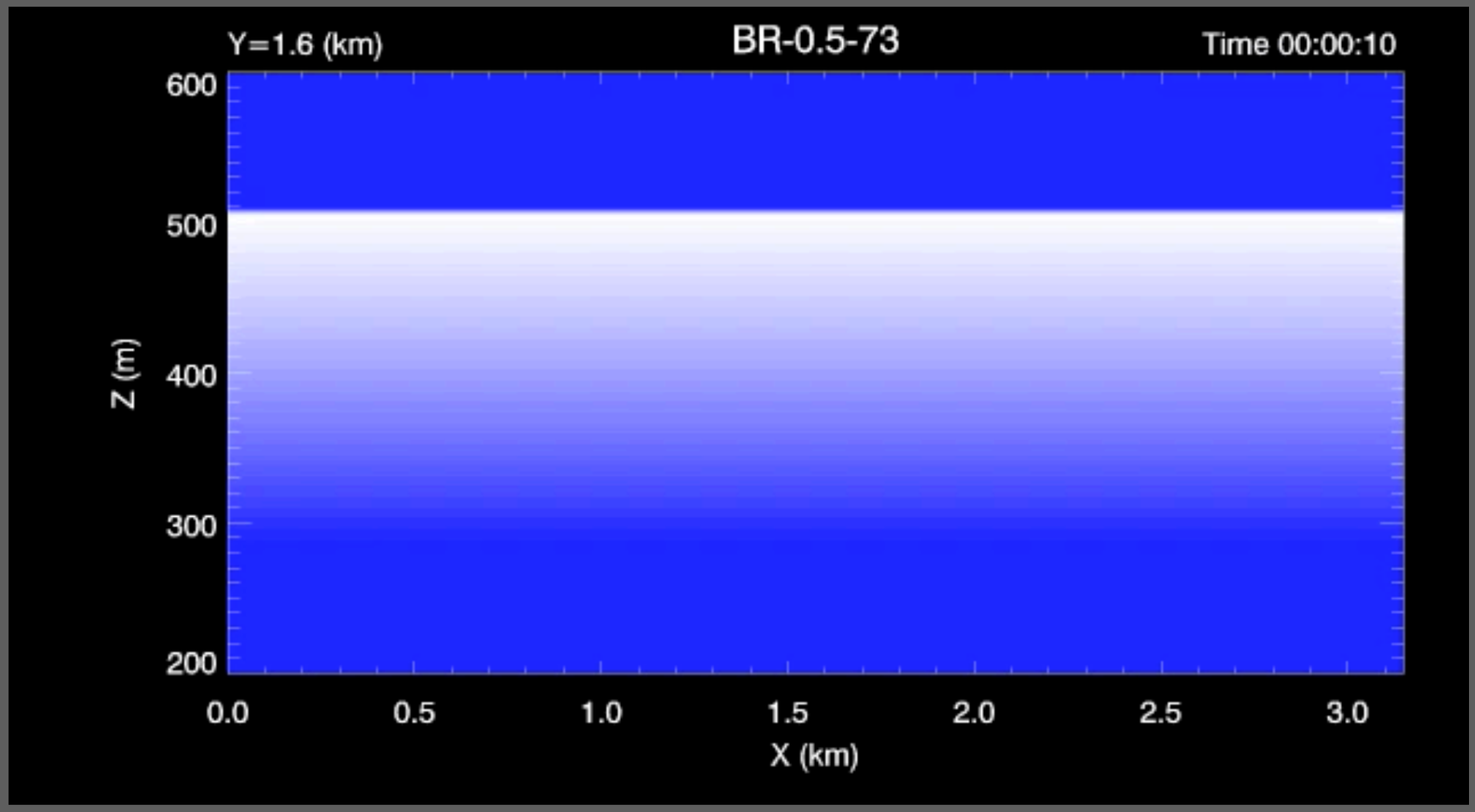

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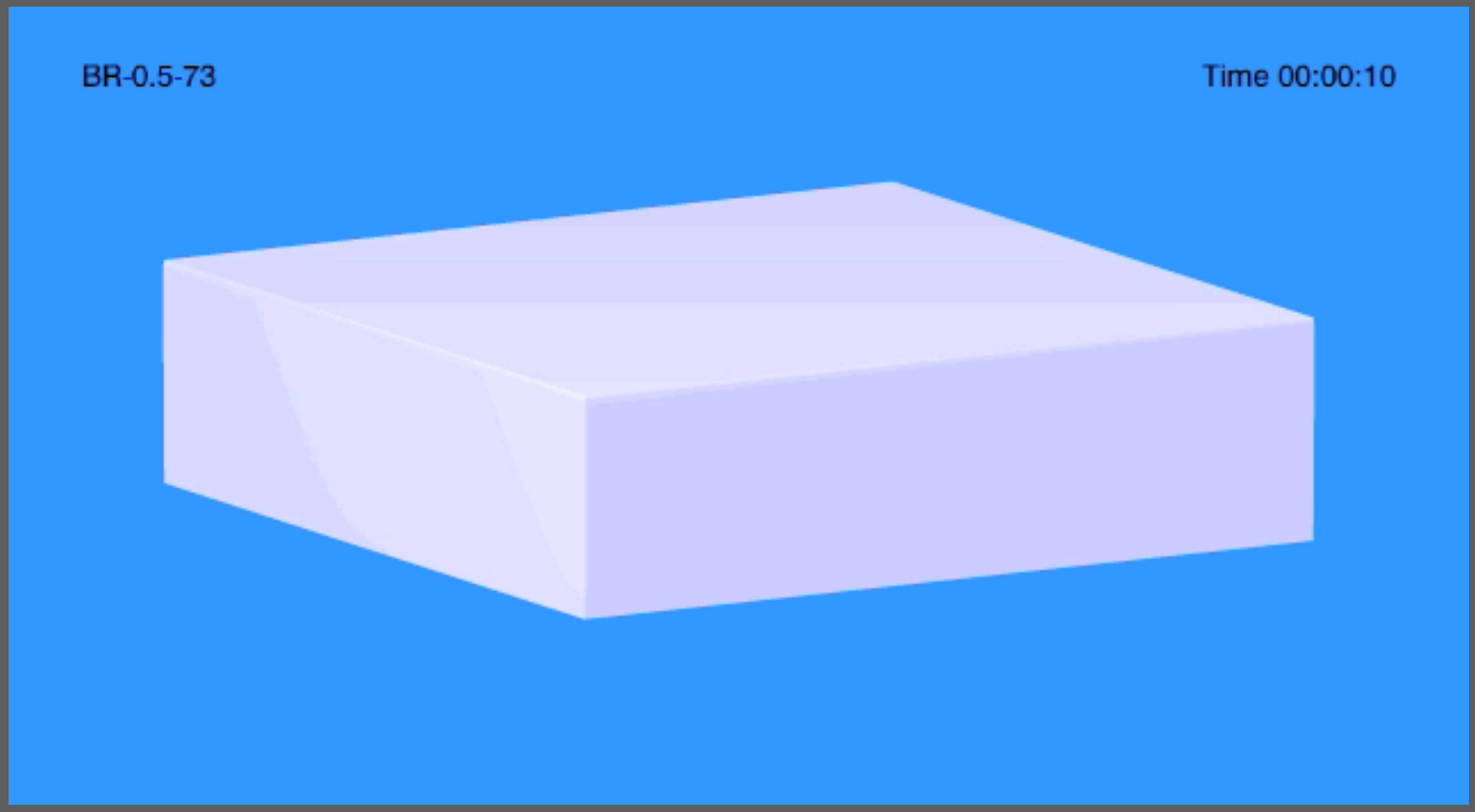

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