mulation of boundary layer clouds wi double-moment microphysics and microphysics-oriented subgrid-scale modeling

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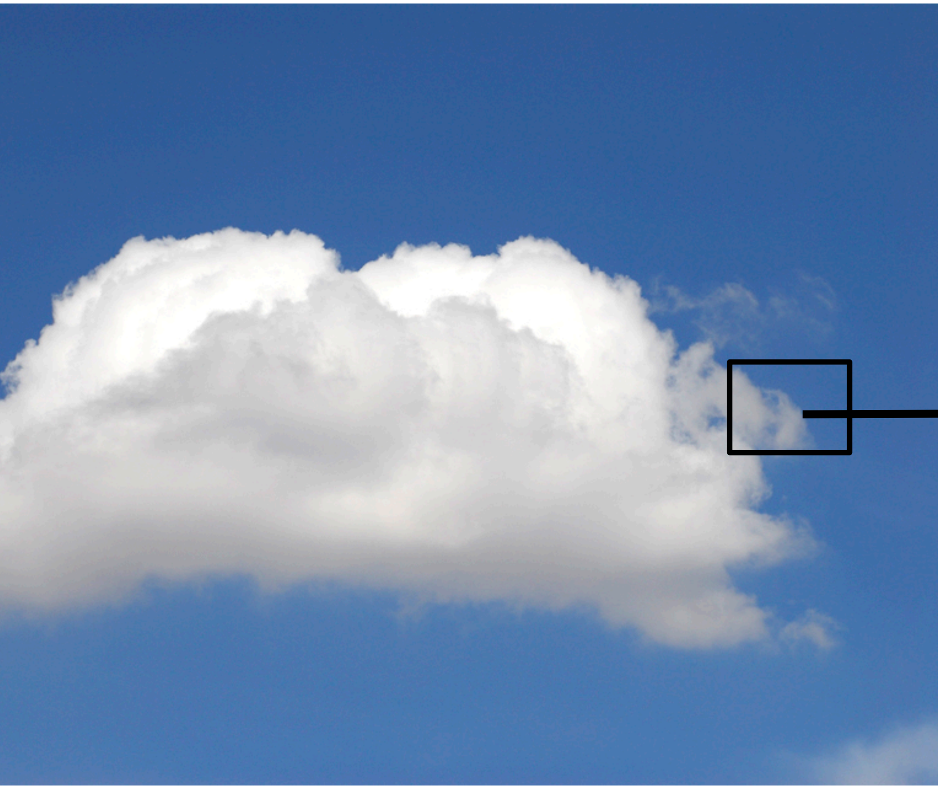

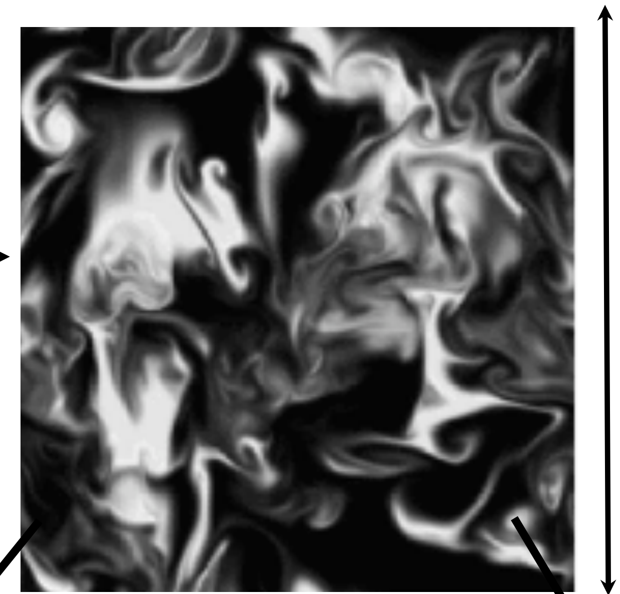

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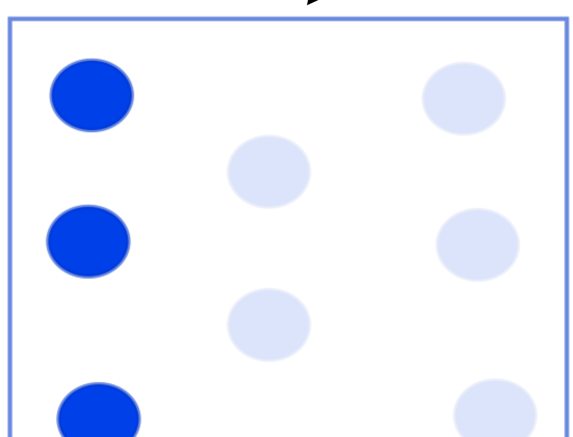
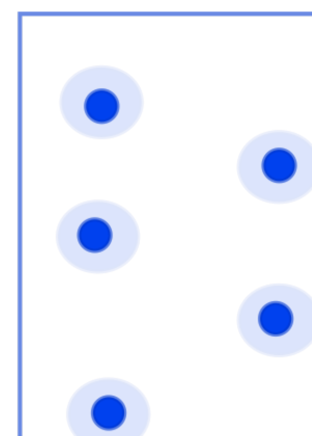
extremely
inhomogeneous
mixing

homogen
mixing

hysical
rmations due to
-scale mixing cover
range of mixing





the λ-parameterization

spatial scale of the cloudy filaments during turbulent mixing

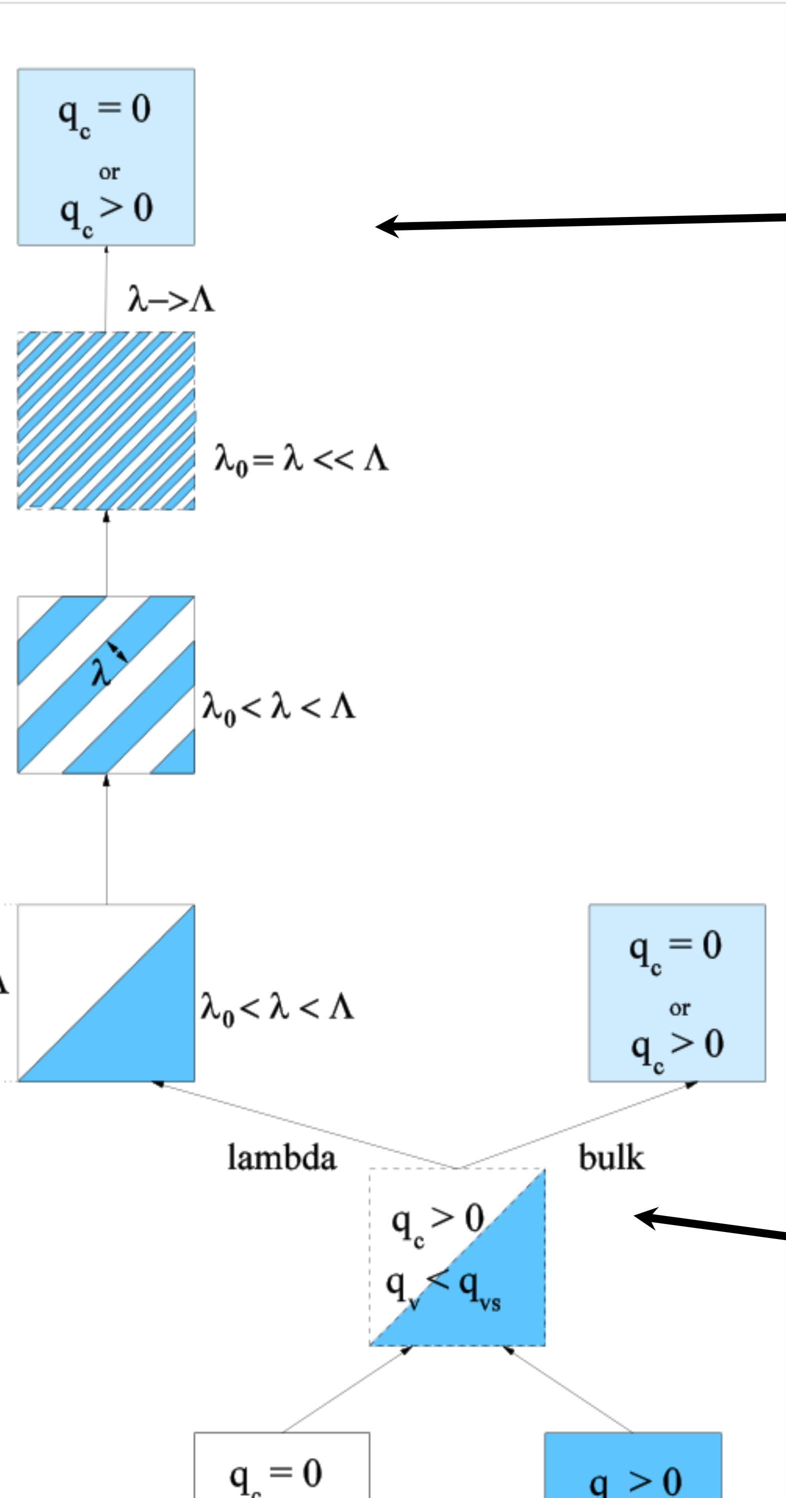
$$\frac{d\lambda}{dt} = -\gamma \epsilon^{\frac{1}{3}} \lambda^{\frac{1}{3}}$$

e model gridlength;
ne homogenization scale (~ 1 cm).

$$\lambda_0 \leq \lambda \leq \Lambda$$

e dissipation rate of TKE

in model with 1-moment microphysic



Modified model with ʎ appro
homogenization delayed unt
turbulent stirring reduces t
filament width ʎ to the valu
corresponding to the micros
homogenization scale λ_0

Bulk model:
immediate homogenizat

mixing event

- delaying evaporation due to mixing

$$q_f = q_i - C_d^*$$

$$C_d^* = \lambda_0/\lambda\ C_d$$

- cloud water mixing ratios: initial (after advect
urbulent mixing) and final (after advection, turb
g, and evaporation).

vaporation rate dictated by the mean gridbox T
d q_c (i.e., without any subgrid considerations).

- cloud filament scale and the scale of microsca

- delaying evaporation due to mixing

$$q_f = q_i - C_d^*$$

$$C_d^* = \lambda_0/\lambda \, C_d$$

NB: this logic c
used in 1-mom
microphysics as

- cloud water mixing ratios: initial (after advect
urbulent mixing) and final (after advection, turb
g, and evaporation).

vaporation rate dictated by the mean gridbox T
d q_c (i.e., without any subgrid considerations).

- cloud filament scale and the scale of microsca

- mixing scenarios

$$N_f = N_i \left(\frac{q_f}{q_i} \right)^{\alpha}$$

Morrison and Grabowsk

q_f - initial and final cloud water mixing ratios

droplet concentration after advection and turb
ing, the initial value for the microphysical adjus

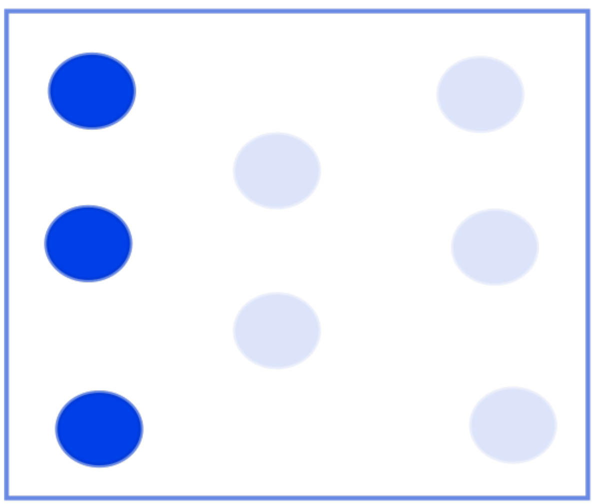
final (after advection, turbulent mixing and
rophysical adjustment) value of the droplet
centration

mixing scenarios

$$N_f = N_i \left(\frac{q_f}{q_i} \right)^{\alpha}$$

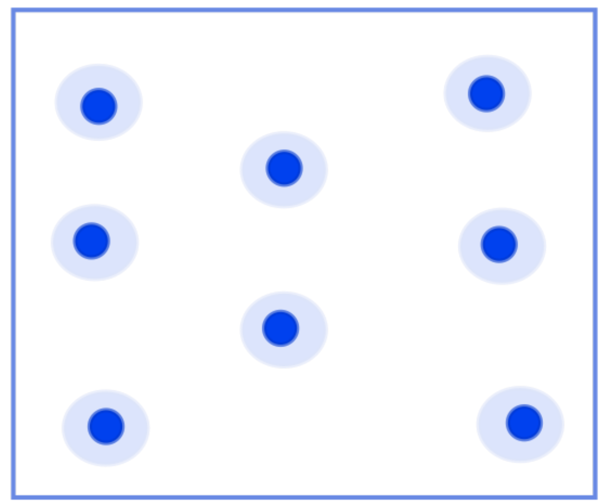
$\alpha = 1$

extremely inhomogeneous mixing



$\alpha = 0$

homogeneous mixing

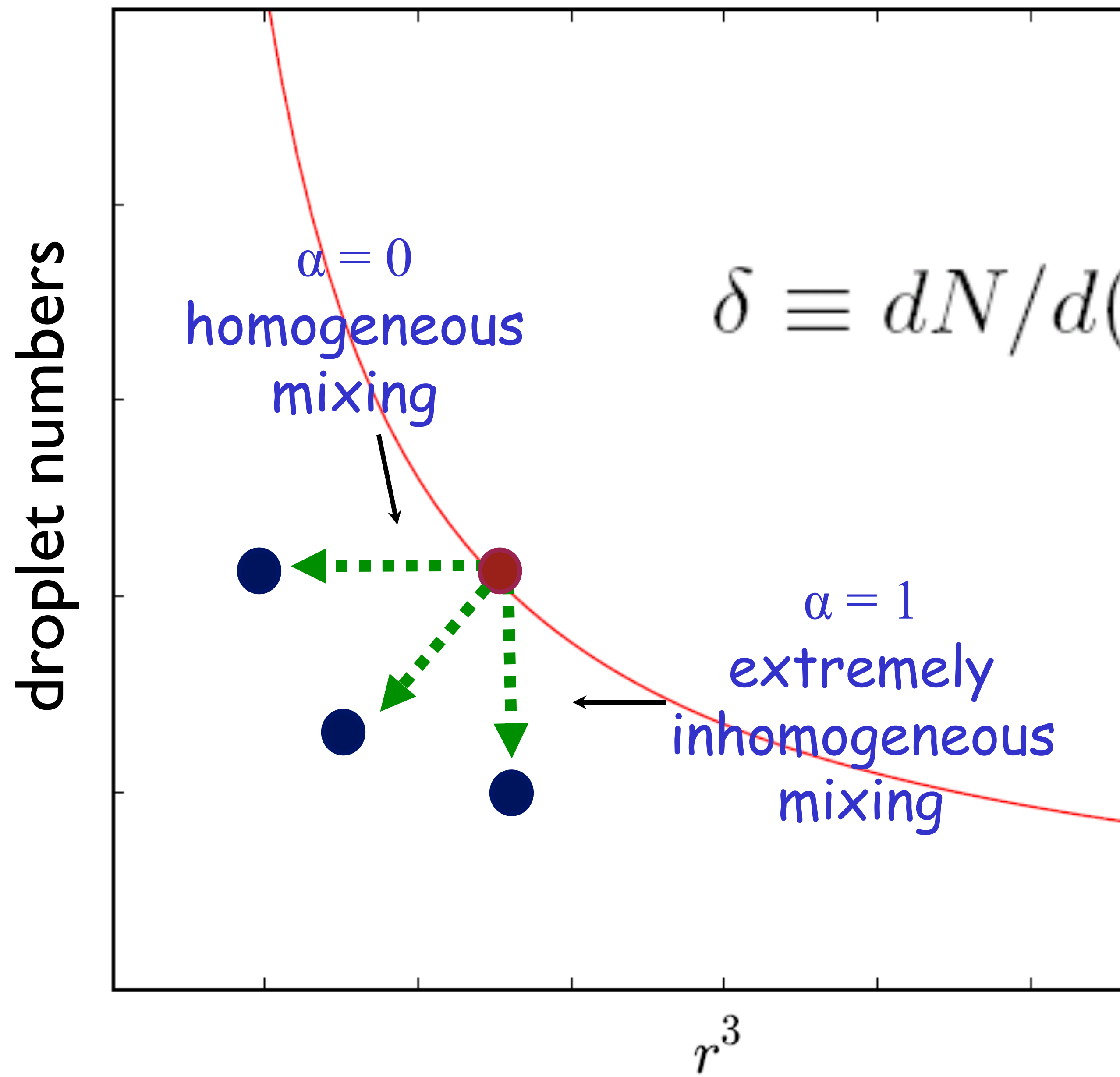


Previous studies (Slawinska et al. 2010):

Mixing scenarios and α parameter

$$N_f = N_i \left(\frac{q_f}{q_i} \right)^{\alpha}$$

$$\alpha = \frac{\delta}{1+\delta}$$



Using DNS results for
-parameterization: mixing scenario

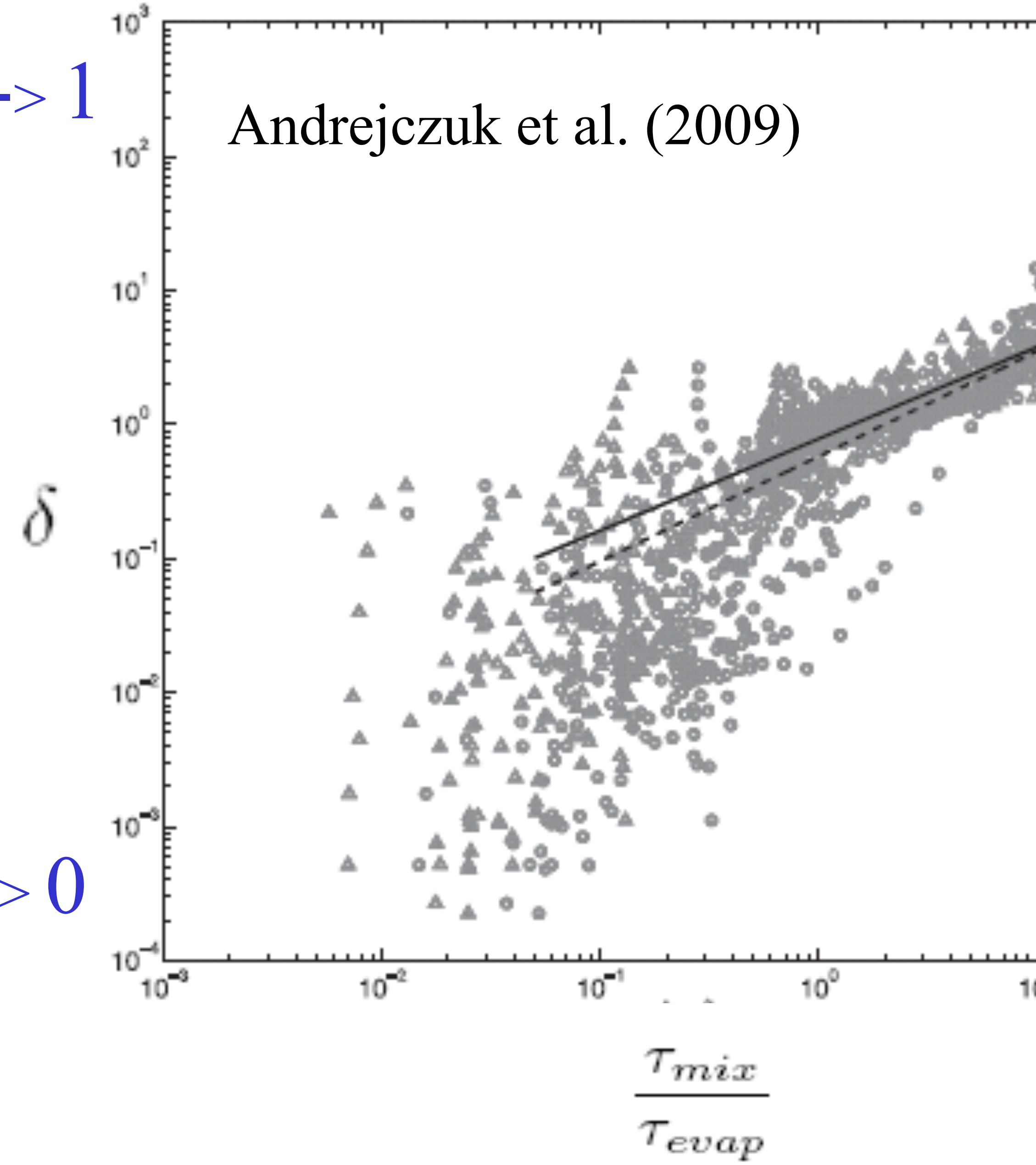
$$\frac{\lambda}{u(\lambda)} = \frac{\lambda^{\frac{2}{3}}}{TKE^{\frac{1}{2}} * \Lambda^{\frac{1}{3}}}$$

$$= \frac{r^2}{A * (1 - RH_d)}$$

$\alpha = f(\lambda, TKE, RH_d, r)$

$\alpha \to 1$

$\alpha \to 0$



e can calculate α locally as a

numerical model EULAG www.mmm.ucar.edu/eu

h the 2-moment warm-rain microphysics scheme

orrison and Grabowski 2007, 2008)

ulation setup - BOMEX (Siebesma et al. 20

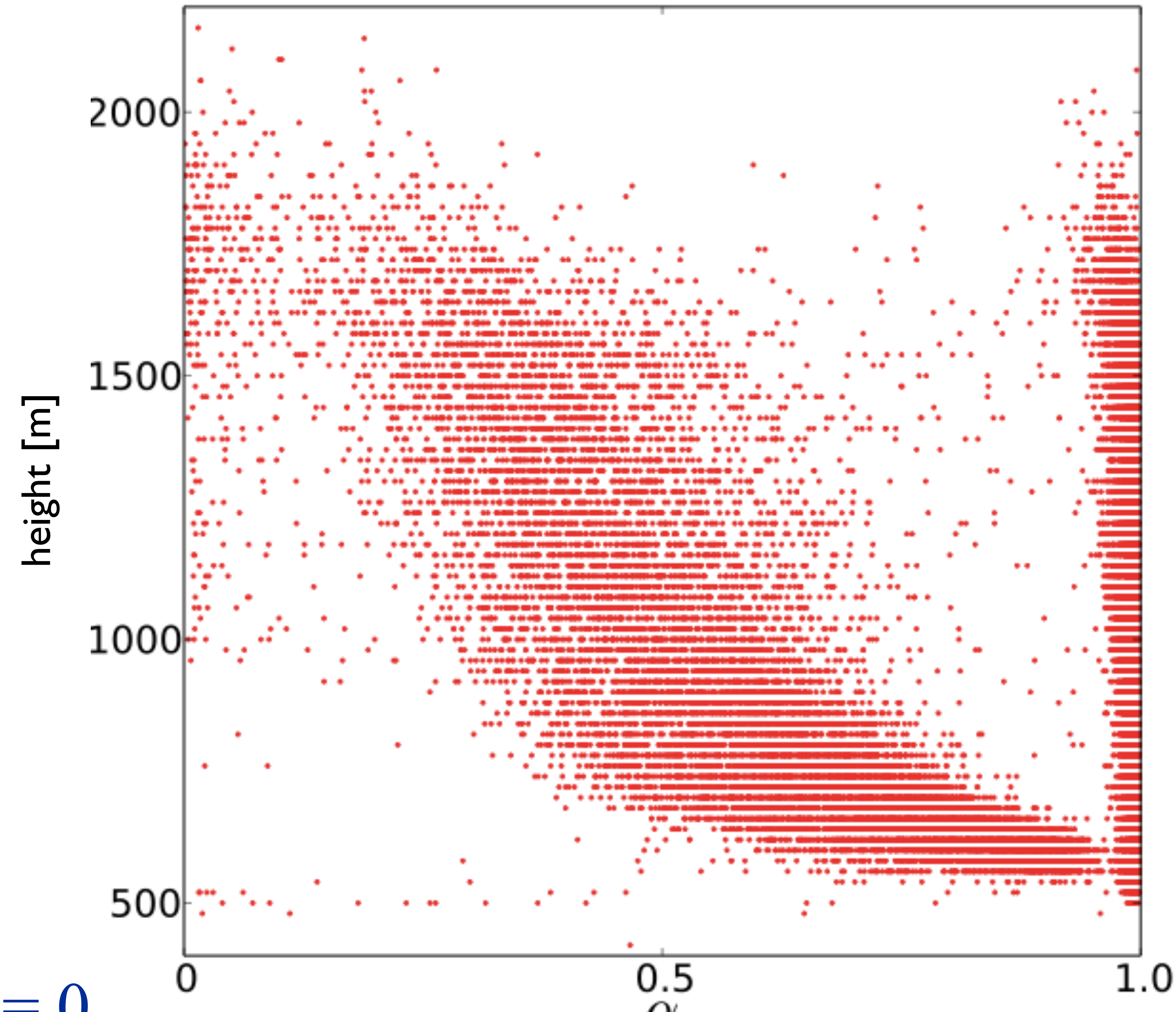
ain: 6.4km, 6.4km, 3km

size: 50m, 50m, 20m

step: 1s

al profiles from Siebesma et al. 2003

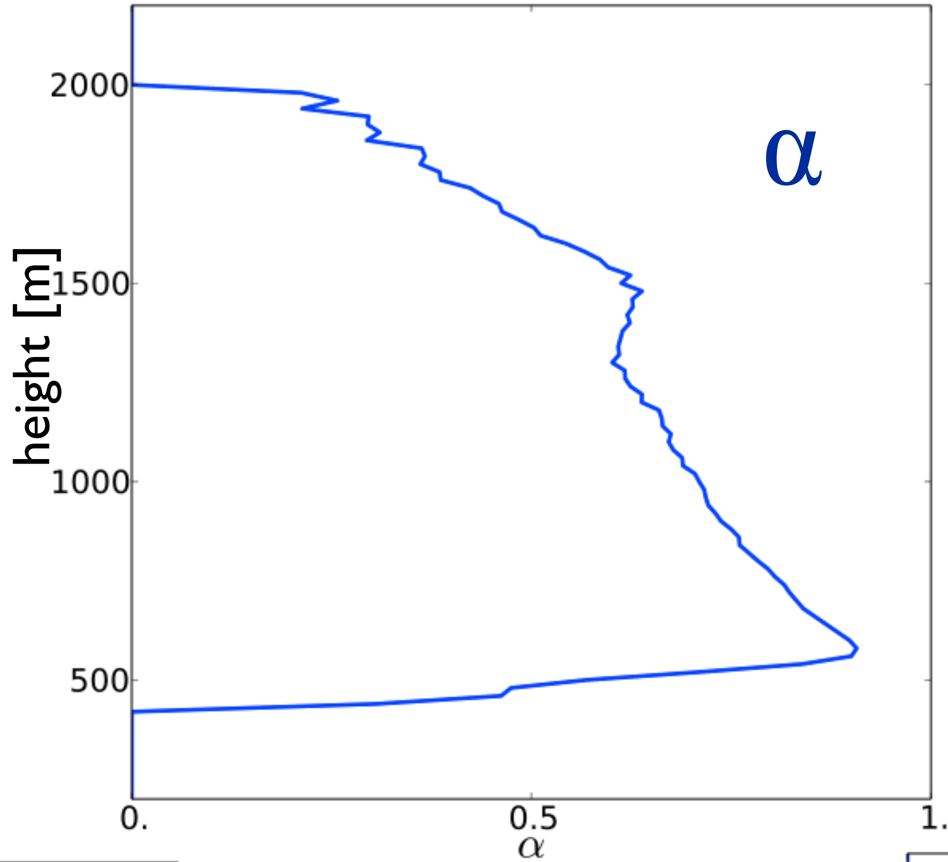
with height

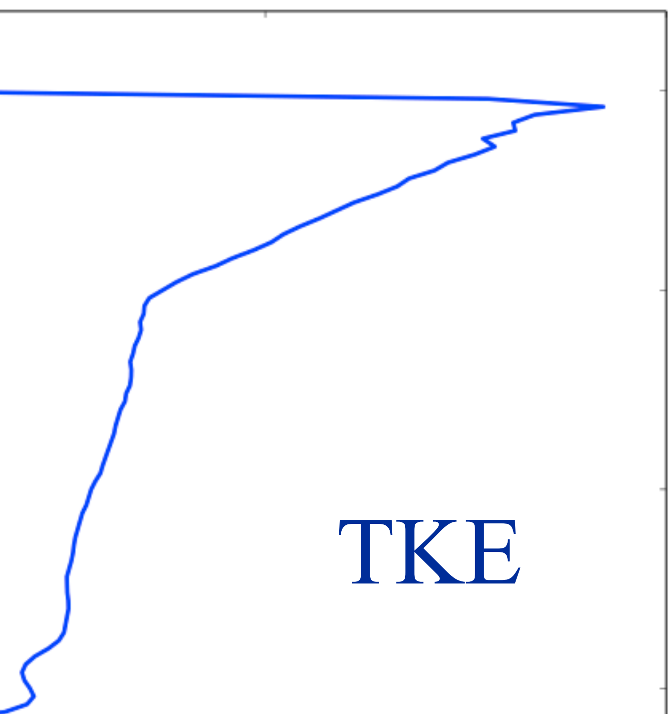


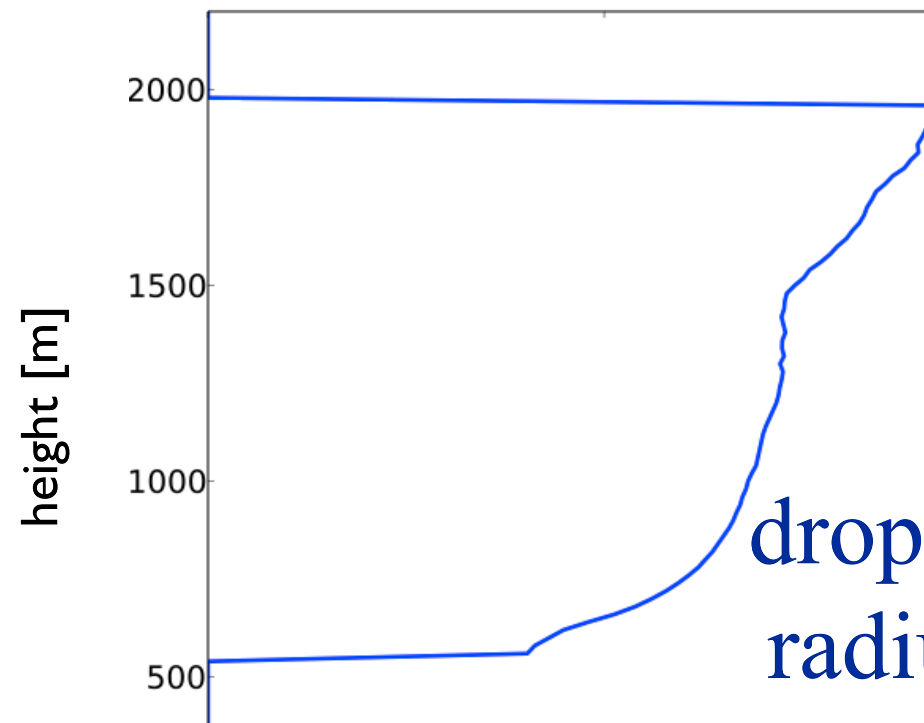
$\alpha = 0$

homogeneous

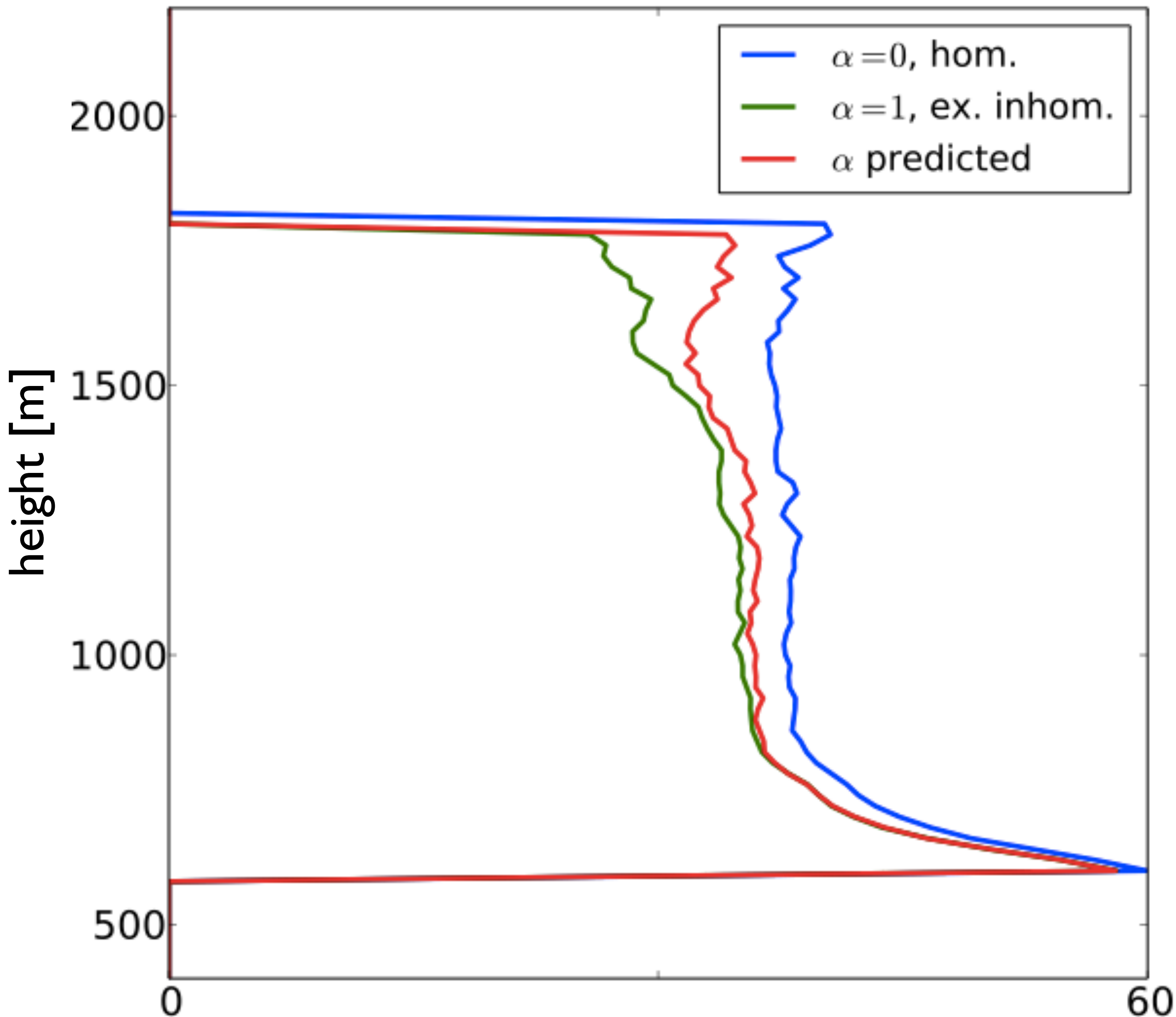
$\alpha = 1$


α
height [m]
2000
1500
1000
500
0.
0.5
1.
α


TKE


height [m]
2000
1500
1000
500

with various mixing scenarios



edicting scale of cloudy filaments λ allows
esenting in a simple way progress of the turbule
ng between cloudy air and entrained dry
onmental air.

rameter α and the mixing scenario can be predic
function of λ, TKE, RH, and droplet radius r.

BOMEX simulations, α decreases with height on
age, i.e., the mixing becomes more homogeneous
is consistent with both TKE and droplet radius
asing with height.