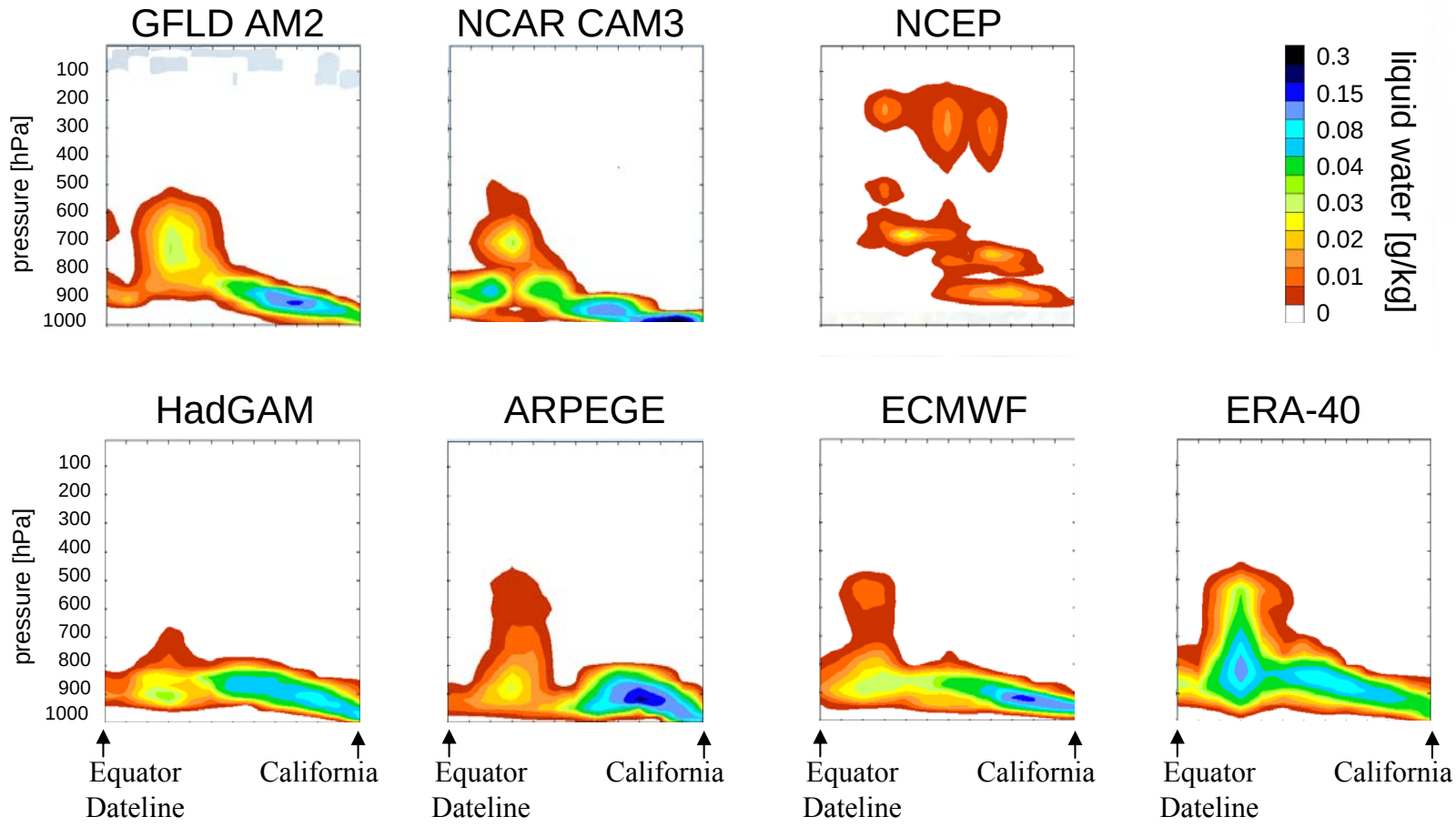
An integral approach to modeling PBL transports and clouds

Martin Köhler and Roel Neggers

- EDMF @ ECMWF now and future
  - dry PBL
  - stratocumulus
  - shallow cumulus
- stratocumulus: evaluation against observations
  - EPIC marine stratus field experiment
  - GLAS cloud and cloud top height
- ongoing work
  - down-drafts (short-hand for ***draughts***)
  - shallow cumulus (Roel)

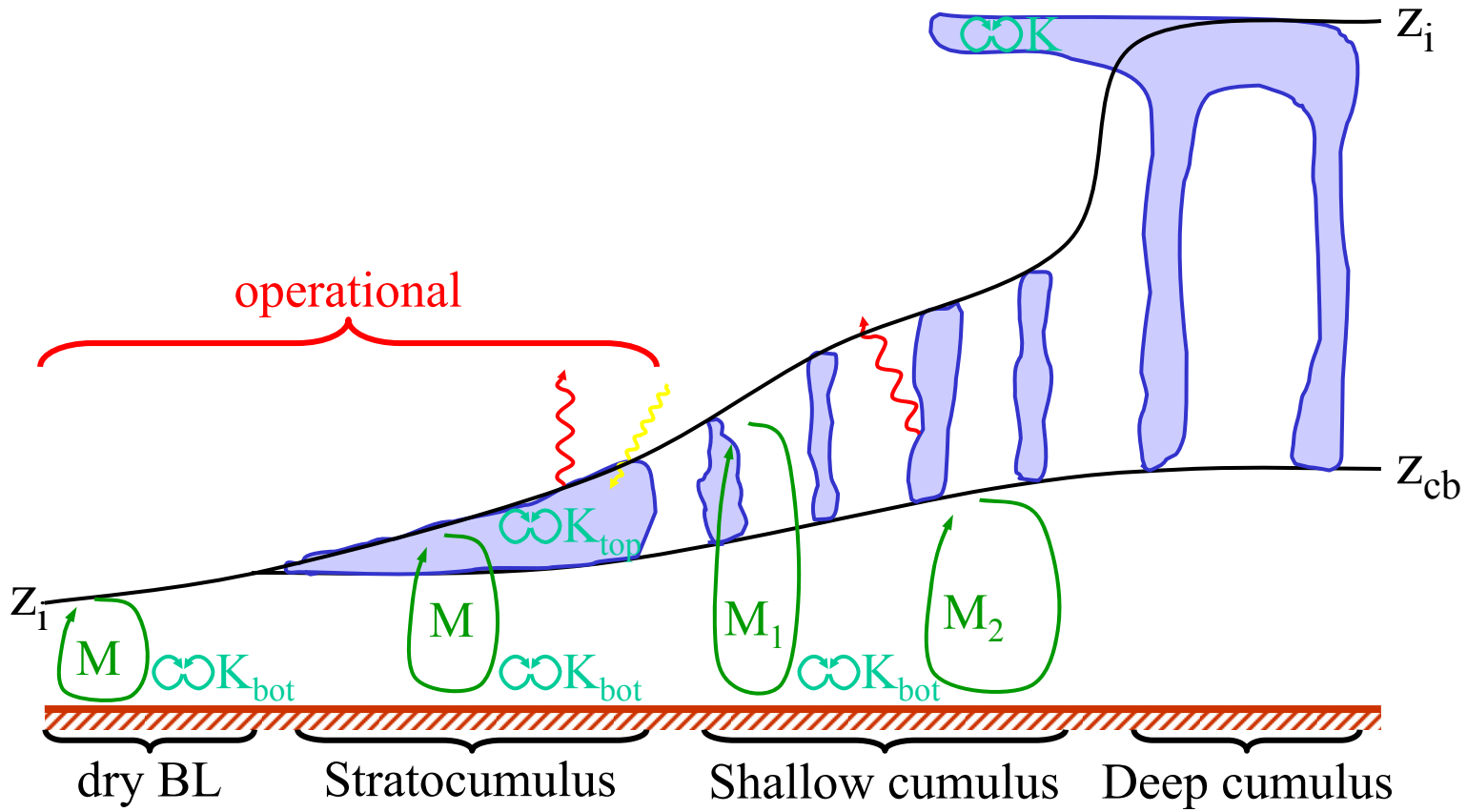
GCSS Pacific Cross-Section Intercomparison Project



Joao Teixeira

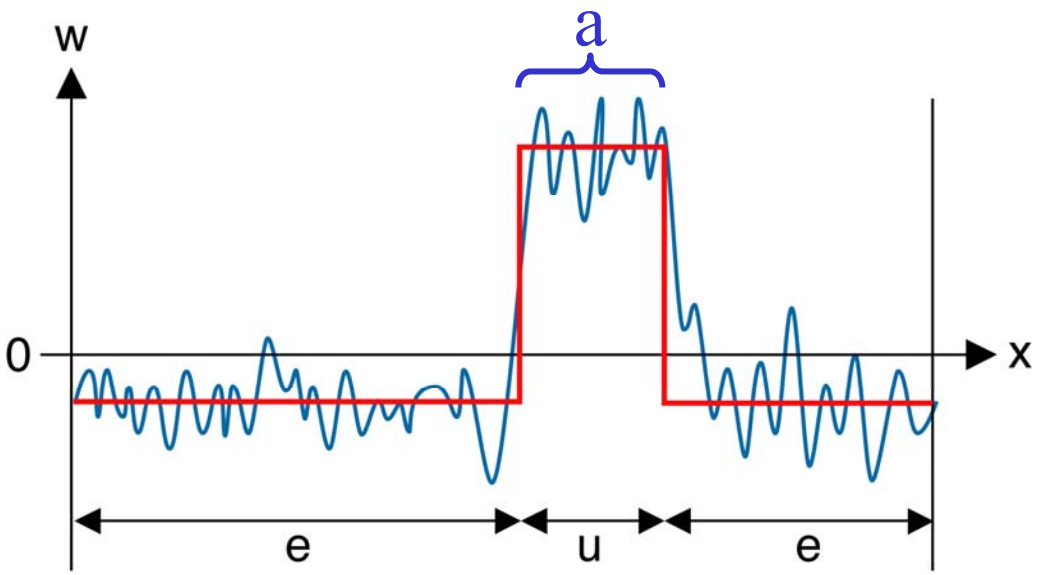
JJA1998

Integral appraoch to PBL transports: EDMF



EDMF: two box M/K decomposition

(*Siebesma and Cuijpers*, 1995)



$$\phi_u = \phi'_u + \overline{\phi}^u$$

$$\phi_e = \phi'_e + \overline{\phi}^e$$

$$\overline{\phi} = a\overline{\phi}^u + (1-a)\overline{\phi}^e$$

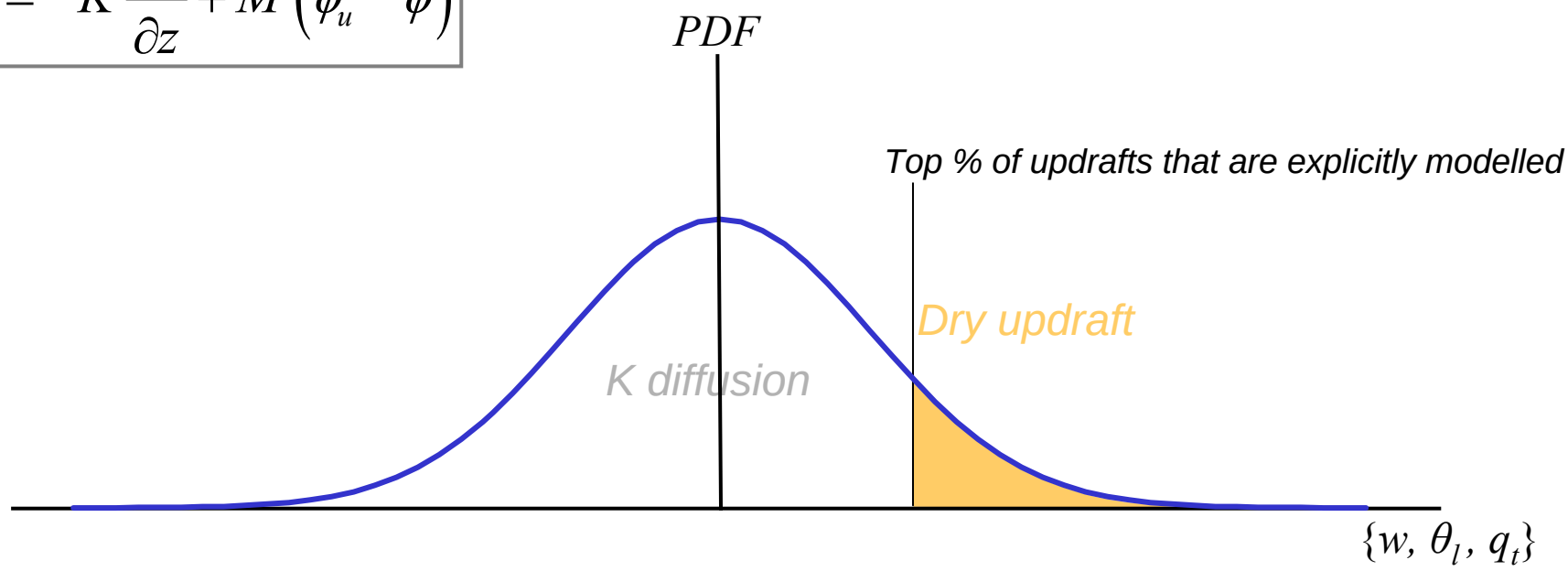
$$\overline{w'\phi'} = \underbrace{a\overline{w'\phi'}^u}_{\text{sub-core flux}} + \underbrace{(1-a)\overline{w'\phi'}^e}_{\text{env. flux}} + \underbrace{a\overline{w}_u(\overline{\phi}_u - \overline{\phi})}_{\text{M-flux}}$$

$$-K\frac{\partial\overline{\phi}}{\partial z}$$

M

A statistical mass flux framework for organized eddies

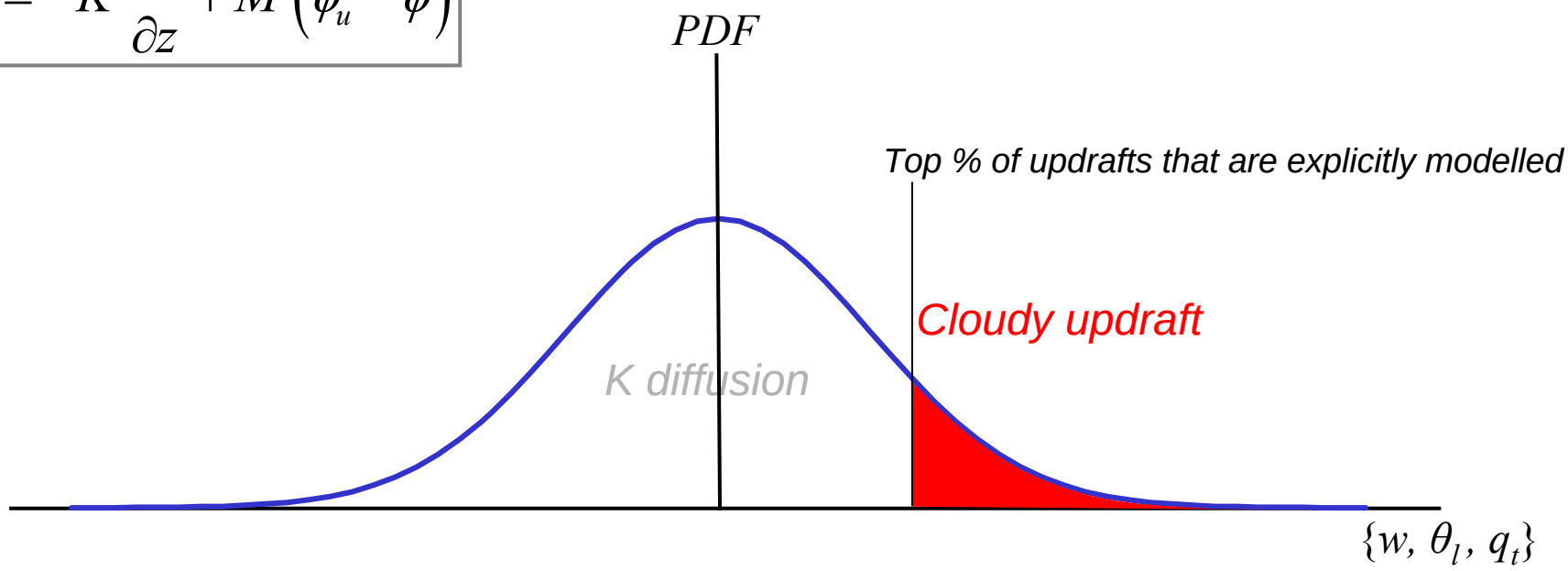
$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + M\left(\phi_u - \bar{\phi}\right)$$



dry PBL

A statistical mass flux framework for organized eddies

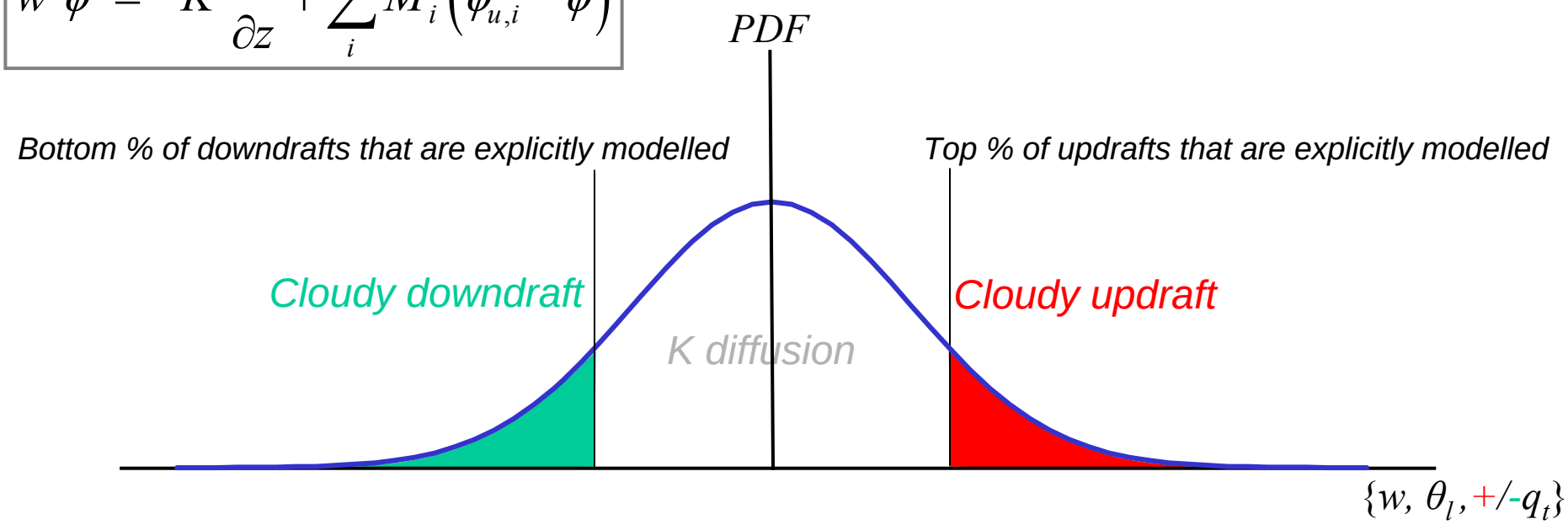
$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + M\left(\phi_u - \bar{\phi}\right)$$



Stratocumulus UP

A statistical mass flux framework for organized eddies

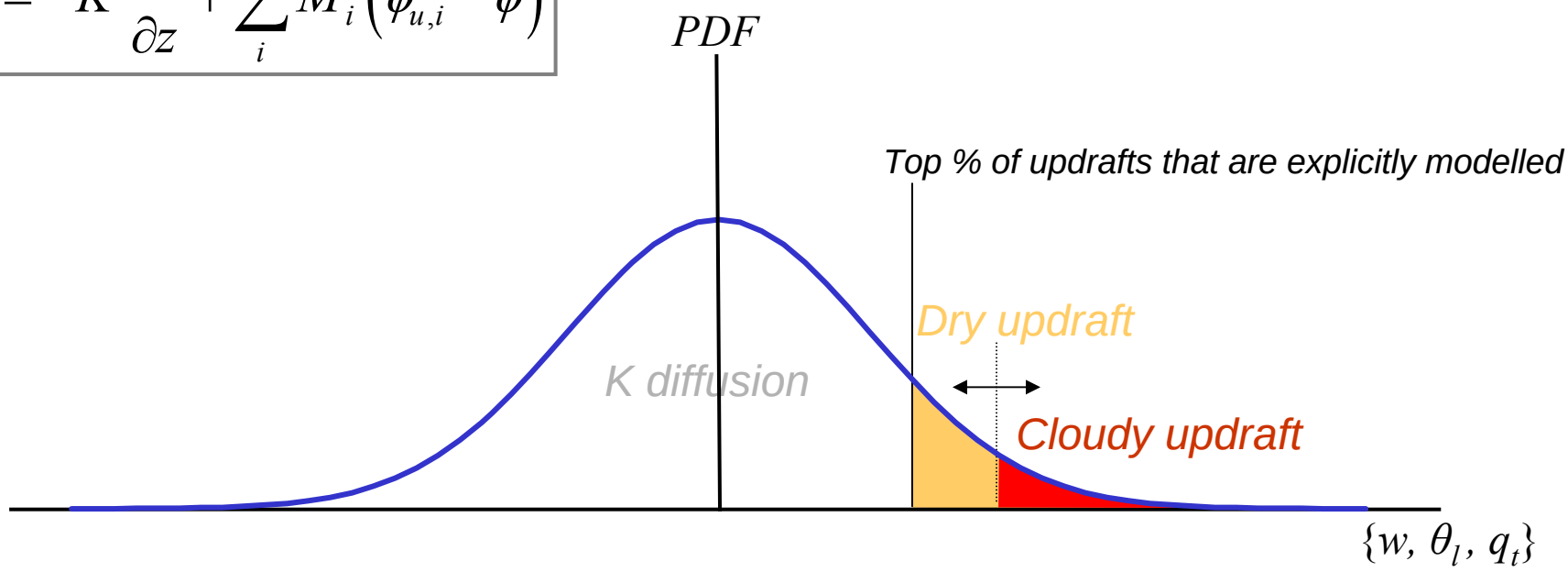
$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + \sum_i M_i\left(\phi_{u,i} - \bar{\phi}\right)$$



Stratocumulus UP / DOWN

A statistical mass flux framework for organized eddies

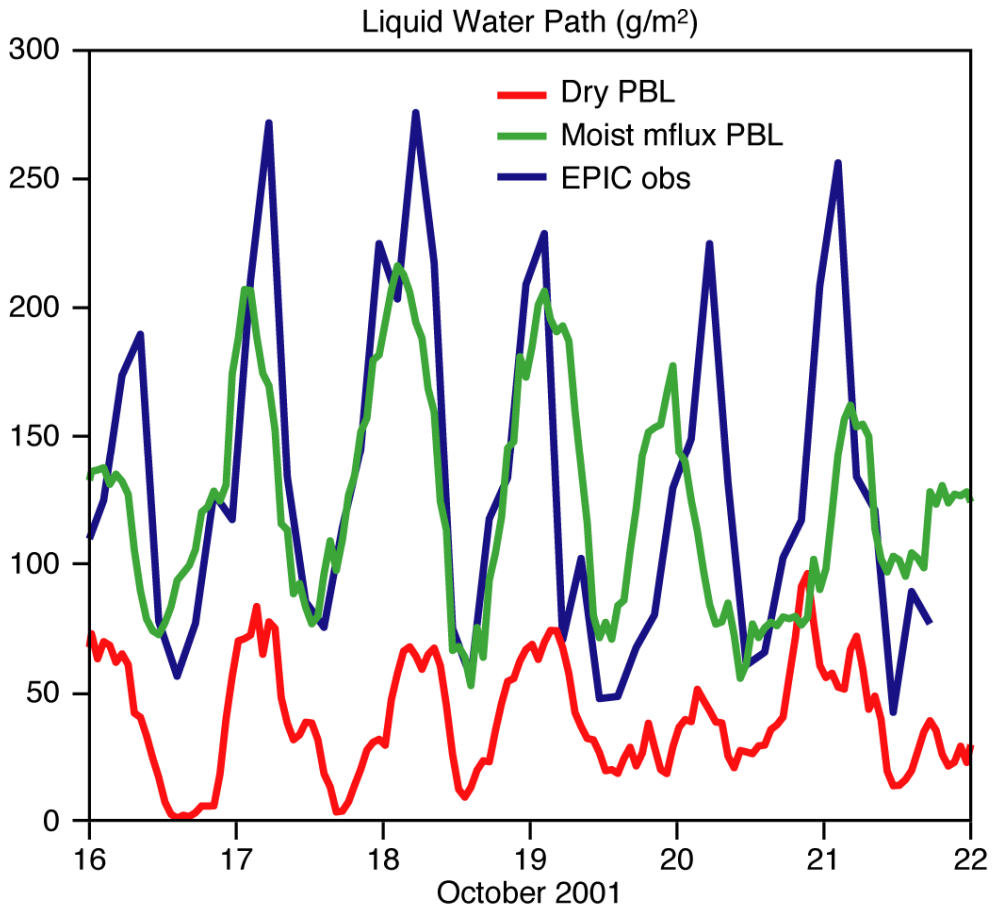
$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + \sum_i M_i\left(\phi_{u,i} - \bar{\phi}\right)$$

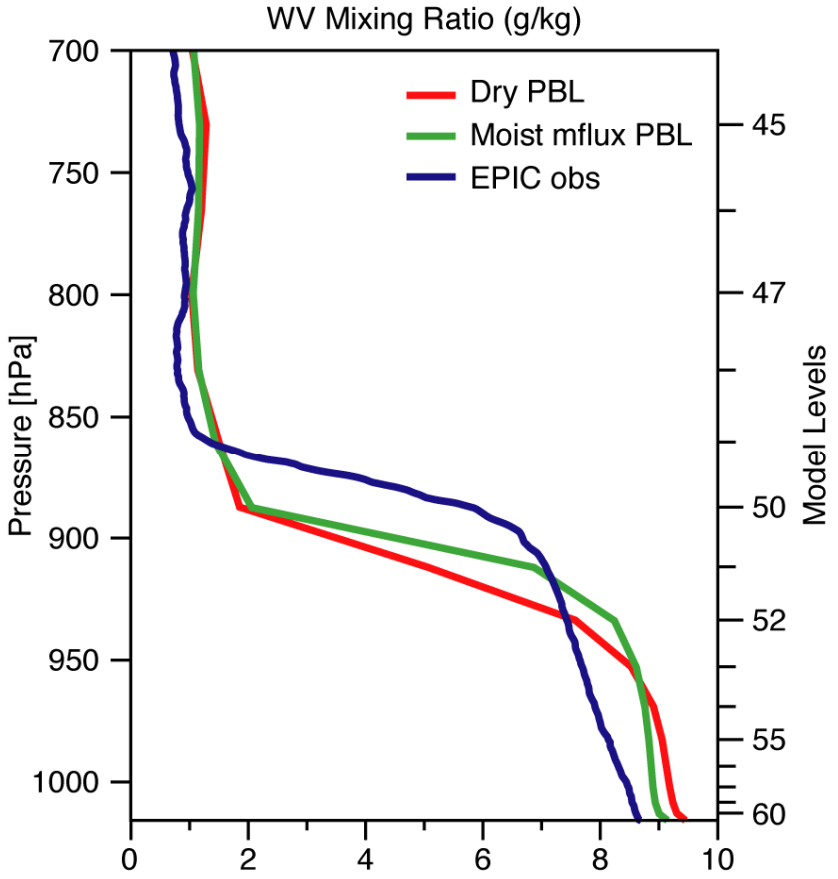


Shallow Convection

Roel Neggers

Stratocumulus UP: EPIC column from 3D forecasts

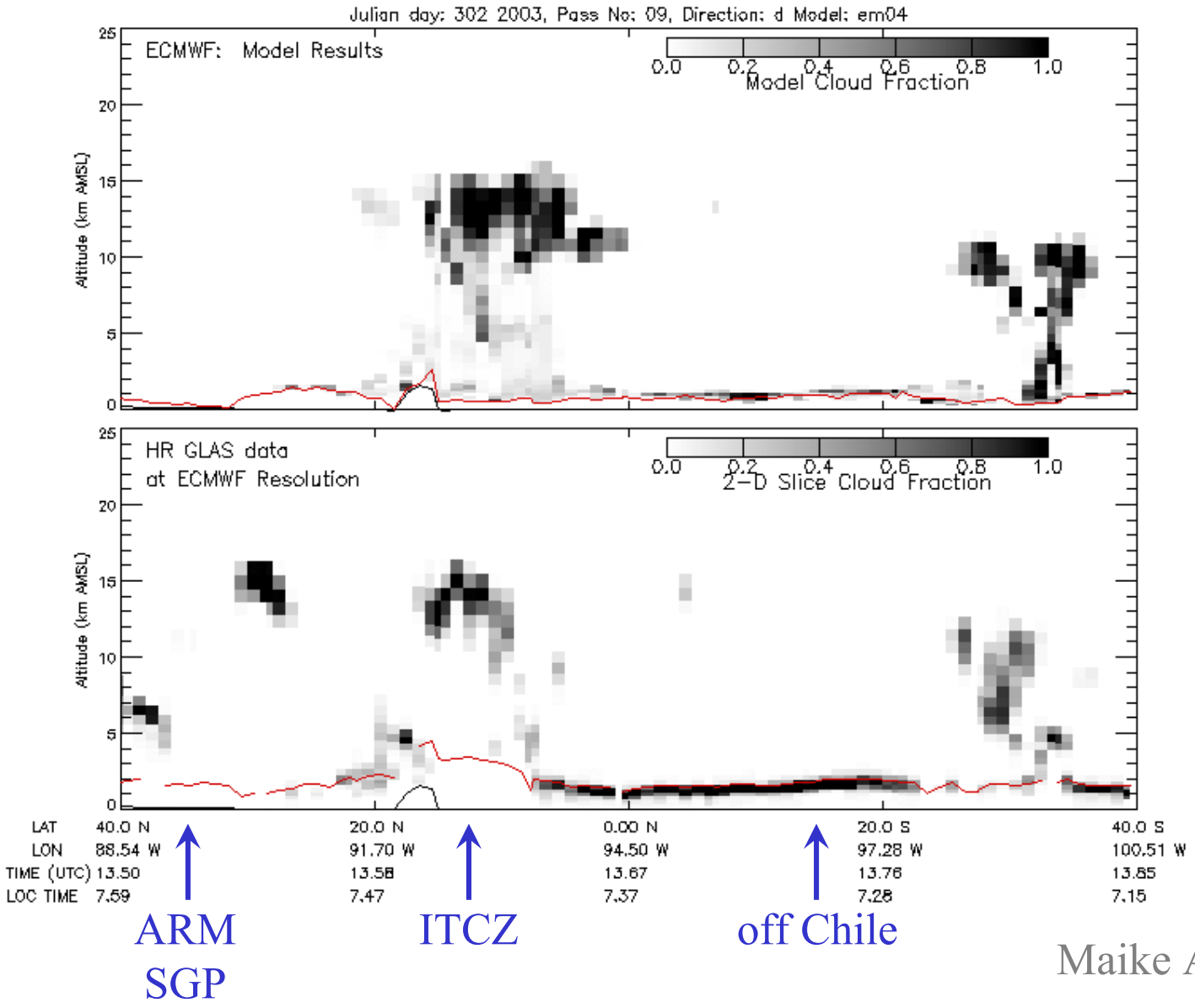




ECMWF vs GLAS cloud fraction

ECMWF

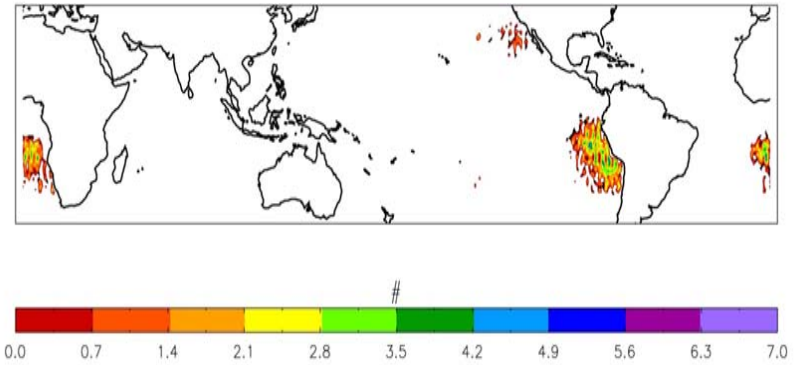
GLAS
res: 76m



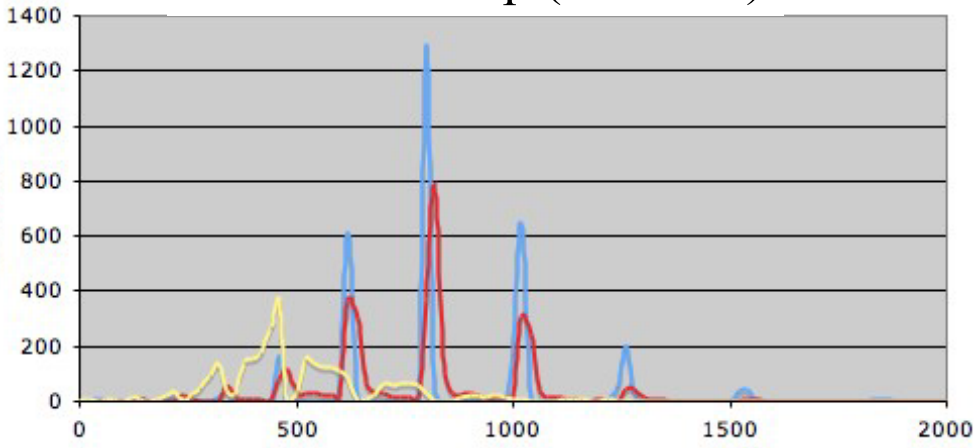
Maike Ahlgrimm

ECMWF vs GLAS cloud top height

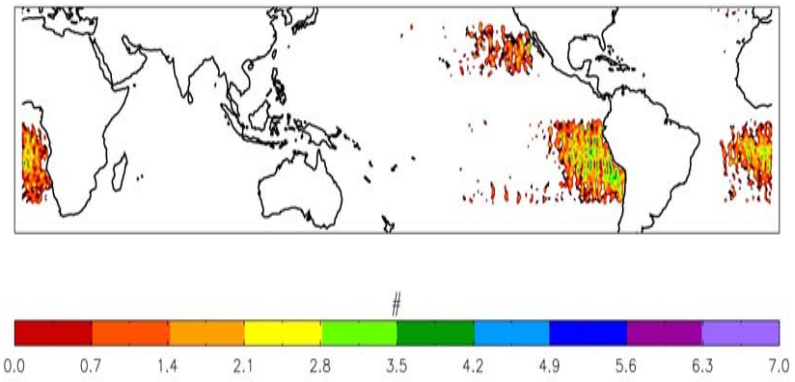
ECMWF # of samples CC>80%



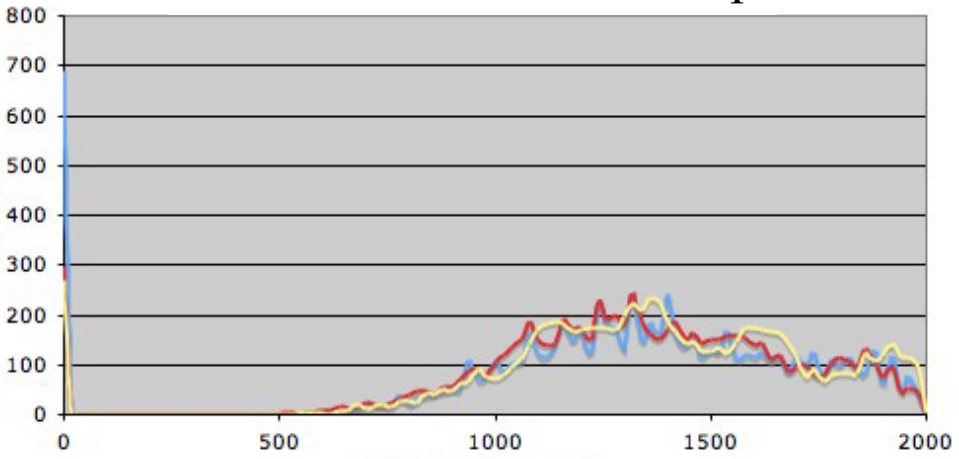
ECMWF Sc top (and base)



GLAS # of samples CC>80%



GLAS observations Sc top



cloud top < 2km

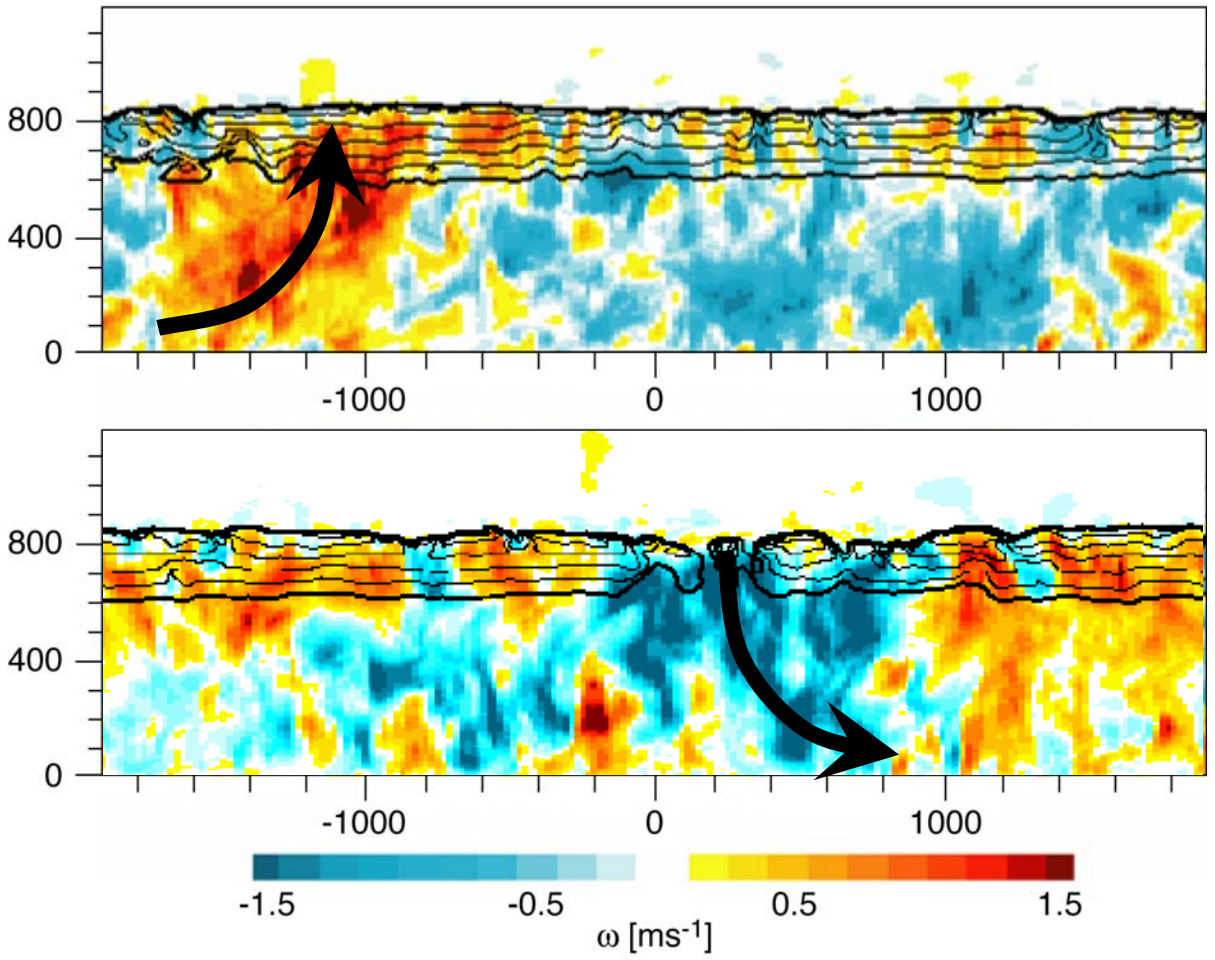
Maike Ahlgrimm

SC top too low!

stratocumulus organized eddies: DYCOMS-II LES simulation

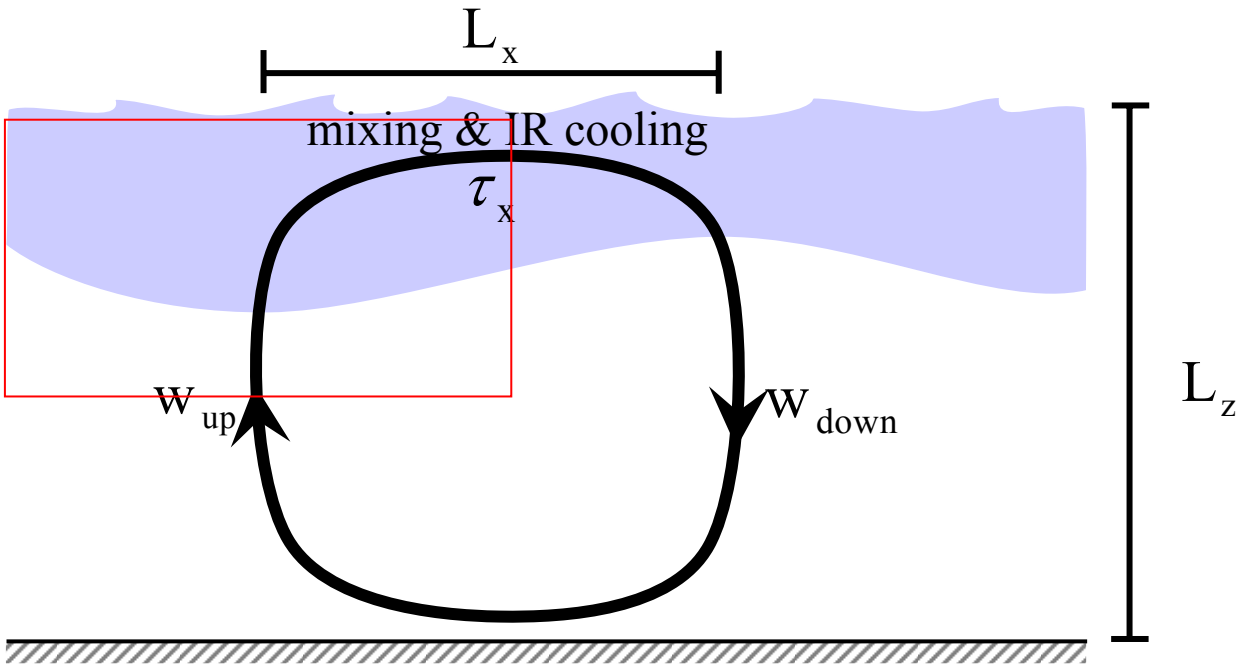
up-draft

down-draft



vertical velocity & cloud
Bjorn Stevens (*dx=35m, dz=5m*)

stratocumulus down-drafts: scaling arguments

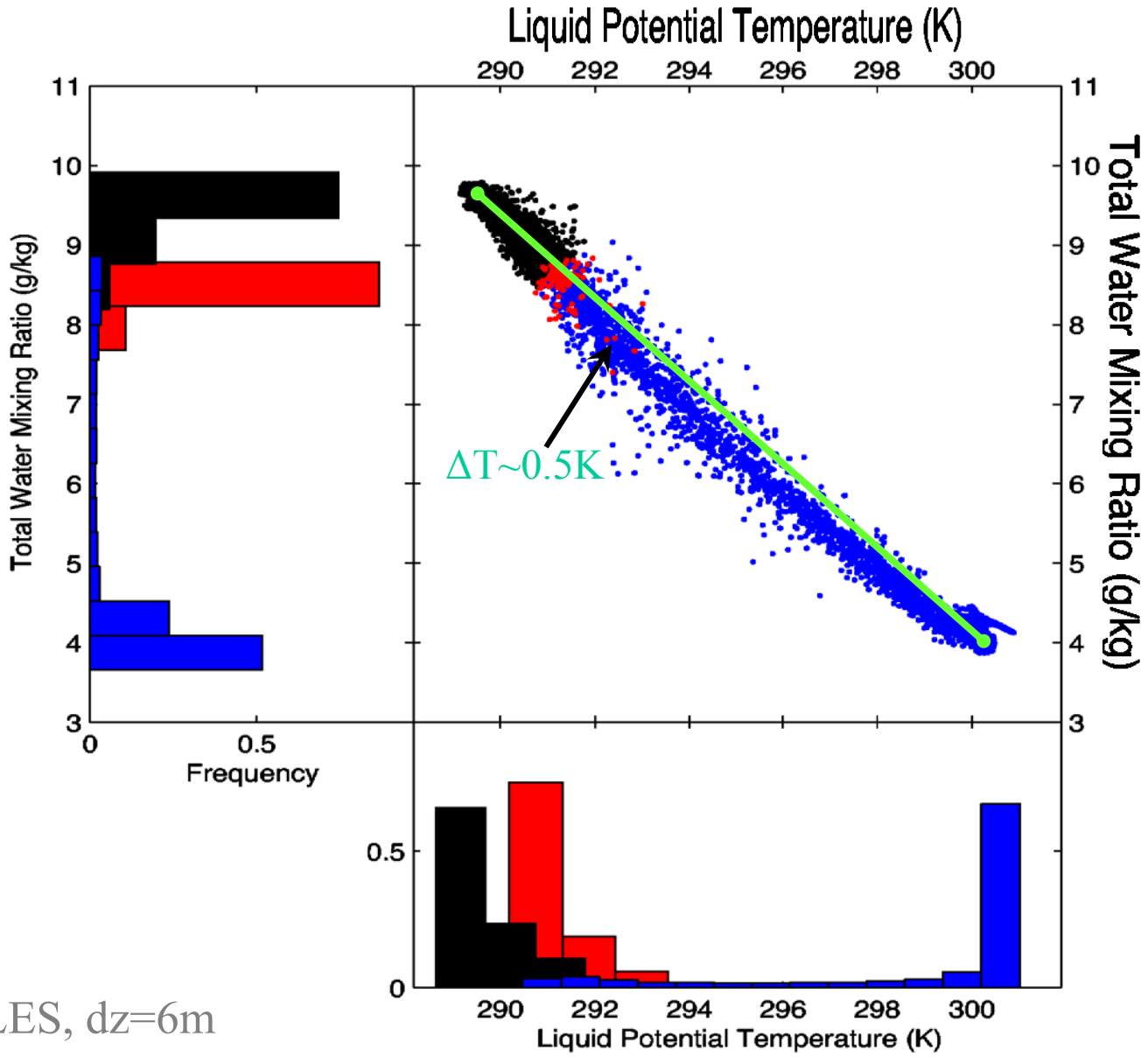


parcel time scale: $\tau_x \sim \frac{L_x}{u} \sim \frac{L_z}{w_{up}} \sim 10^3 s$

IR cooling: $\Delta T \sim \frac{R_{IR}}{\rho c_p \Delta z_{entr}} \tau_x \sim 1K$

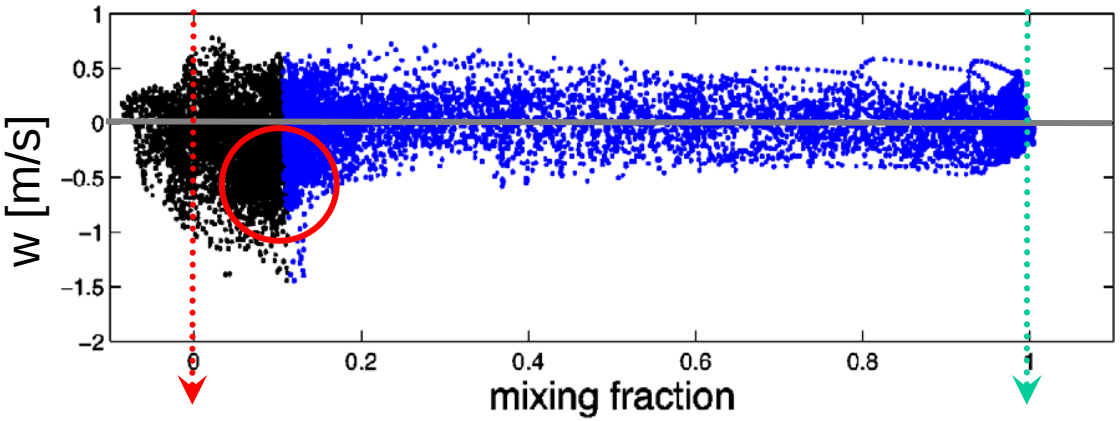
$$w^{*top} = \left(\frac{g}{\theta_v} \overline{w'\theta_v'}^{top} z_i \right)^{1/3} \sim 1 m/s$$

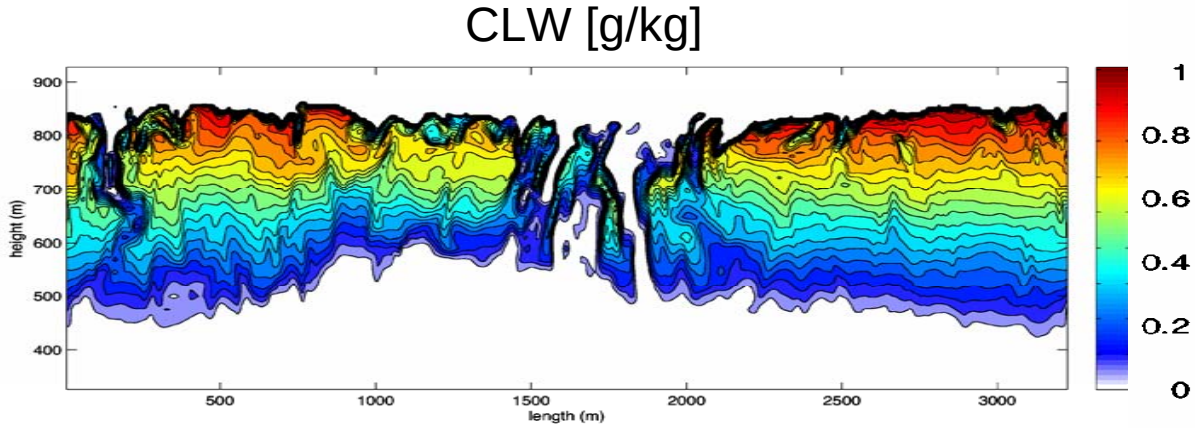
LES DYCOMS-II: mixing line scatterplot of q_t and θ_l



Steve Krueger, LES, dz=6m

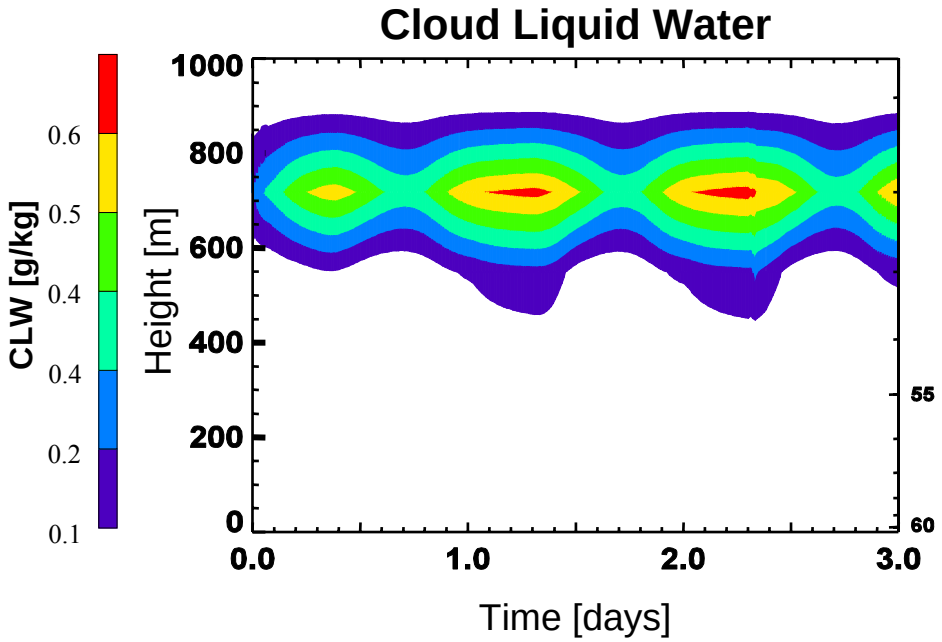
LES DYCOMS-II: entrainment properties

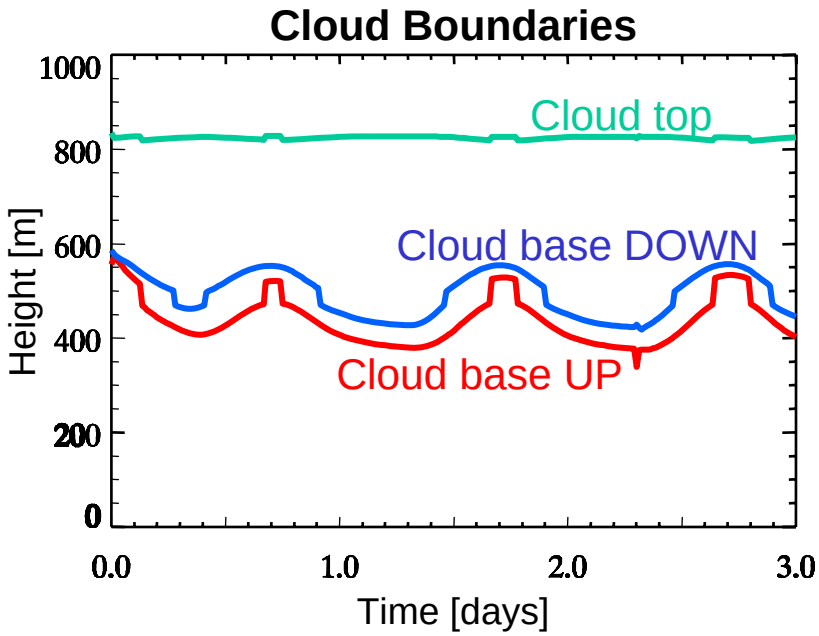




Steve Krueger, LES, dz=6m

SCM DYCOMS-II: up- and down-drafts





EDMF @ ECMWF

$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + \sum_i M_i\left(\phi_{ui} - \bar{\phi}\right)$$

- dry PBL ✓
- stratocumulus
  - updraft ✓
  - downdraft ← } Martin
- momentum ← } Martin
- plume solution ← } Martin
- shallow convection
  - dual M ← } Roel
  - dual cloud ← } Roel