Retrieving Buoyancy Profiles and Entrainment Rate from Vertical Velocity and Reflectivity

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- Used the Giga-LES to analyze 3D updraft cores.
- Giga-LES:
  - 200 km x 200 km domain
  - Horizontal grid size = 100 m
  - Statistics of vertical velocity cores agree very well with those from LeMone and Zipser (1980).

A visualization of a Giga-LES cloud system using SHDOM, a 3D radiative transfer method.

Parcel Model for Vertical Velocity

$$\frac{1}{2}\frac{dw^2}{dz} = a(B - D) - b\lambda w^2$$

Thermodynamic Buoyancy

Hydrometeor Drag

Entrainment

From LES of deep convection: $w(z) \approx c * B(z)$.

a, b, and c are empirical constants.

Using $w(z)$ and $D(z)$ from radar, we can retrieve $B(z)$ and λ, the fractional rate of entrainment.

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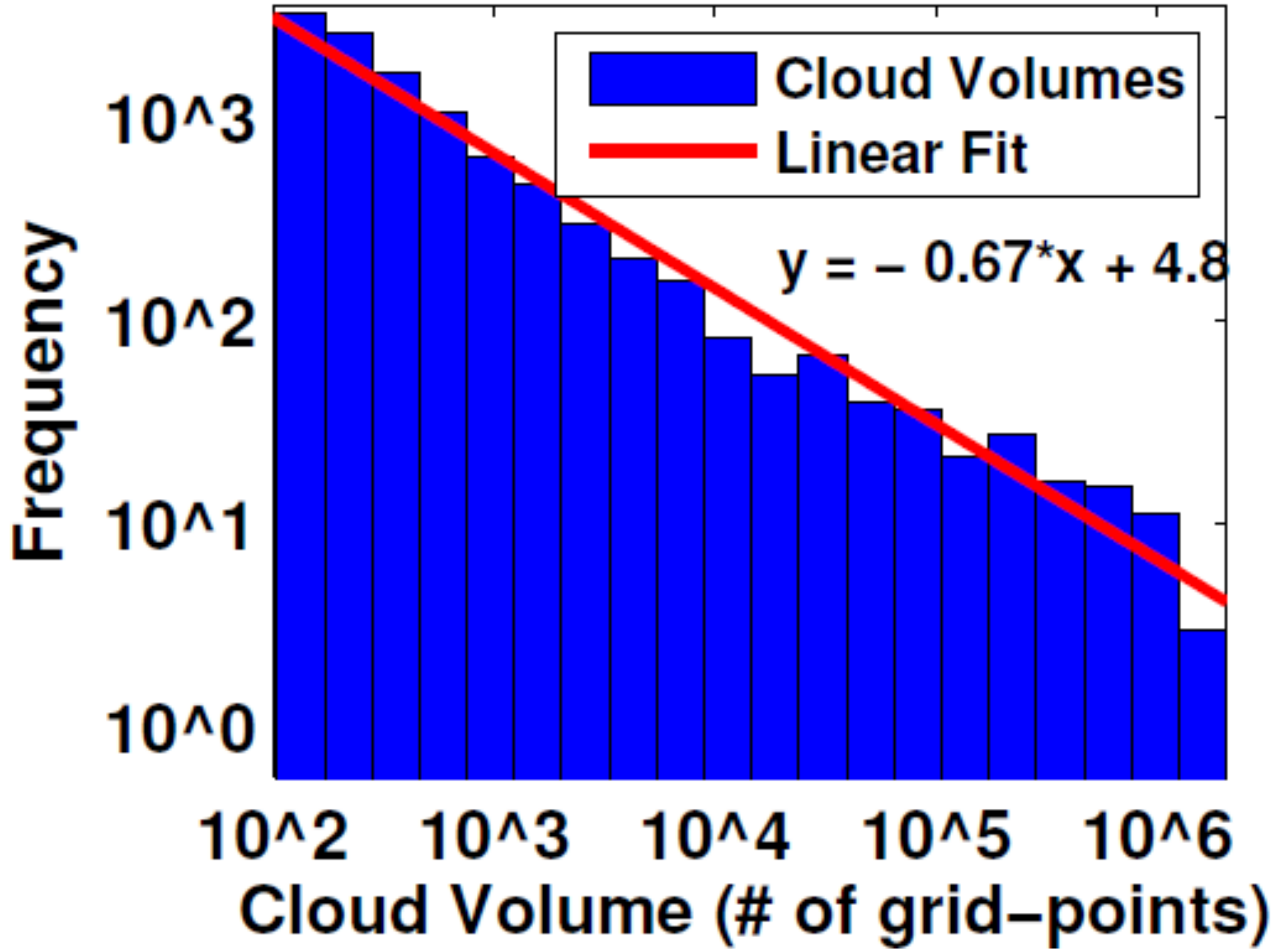
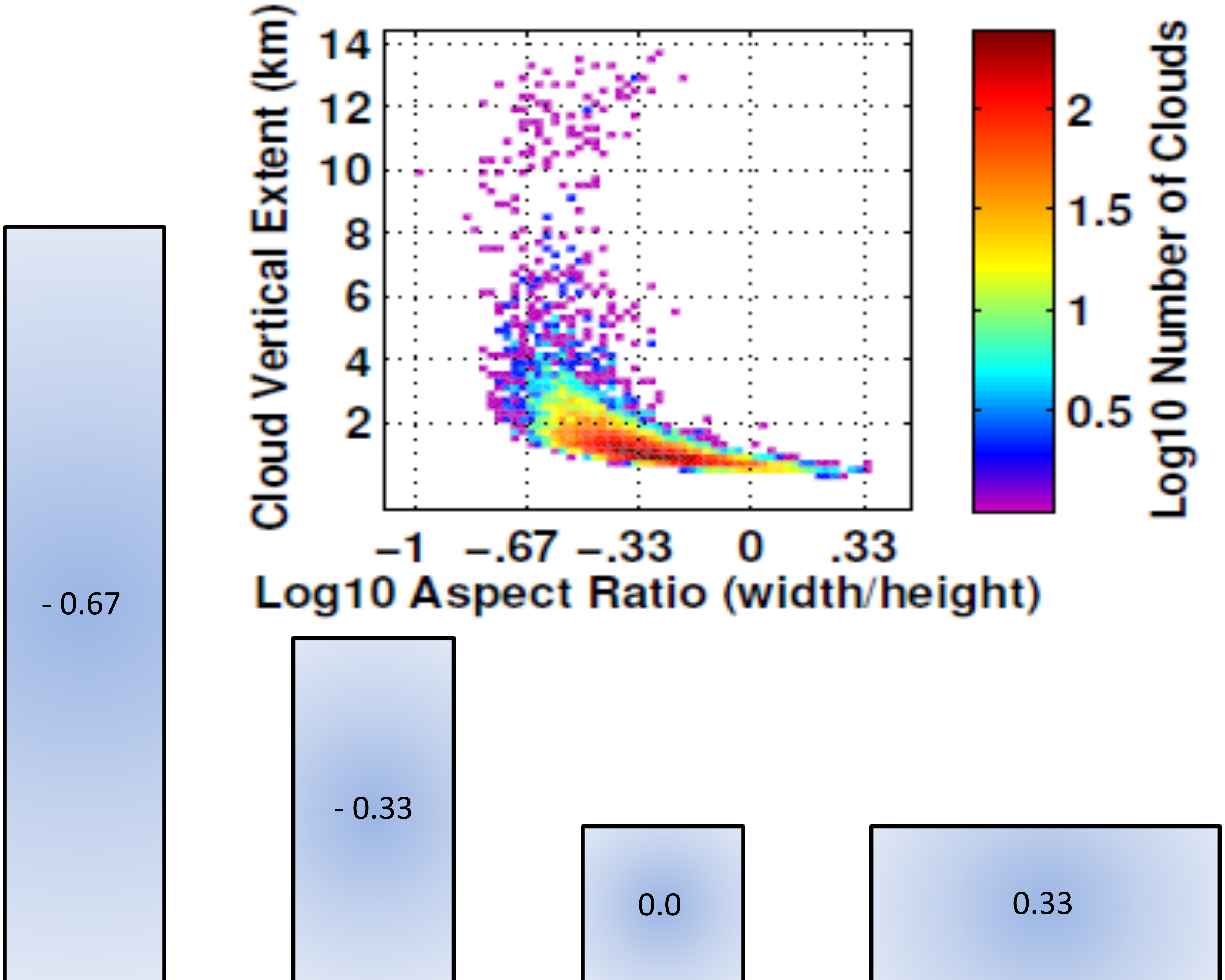
  - Vertical velocity (w) > 1 m/s and cloud water/ice mixing ratio > 0.1 g/kg
- Local core definitions, such as transect or single-level methods, provide little context in terms of updraft extent or life-cycle stage.

Distribution of 3D Cloudy Updraft Core Volumes



Largest volumes imply length dimension of O(10 km)

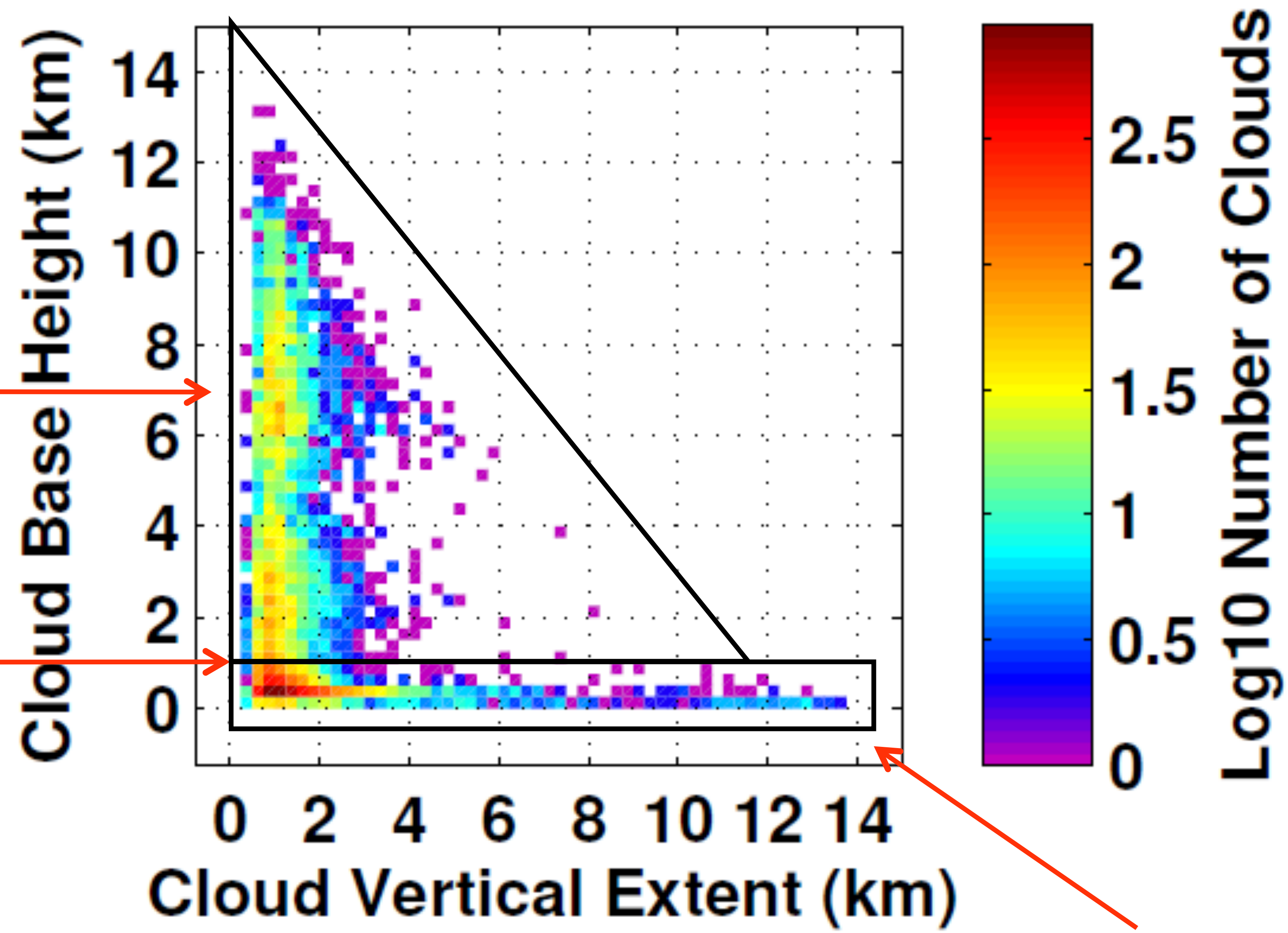
Distribution of Aspect Ratios



Partition cloudy updraft cores into two groups

Dissipating

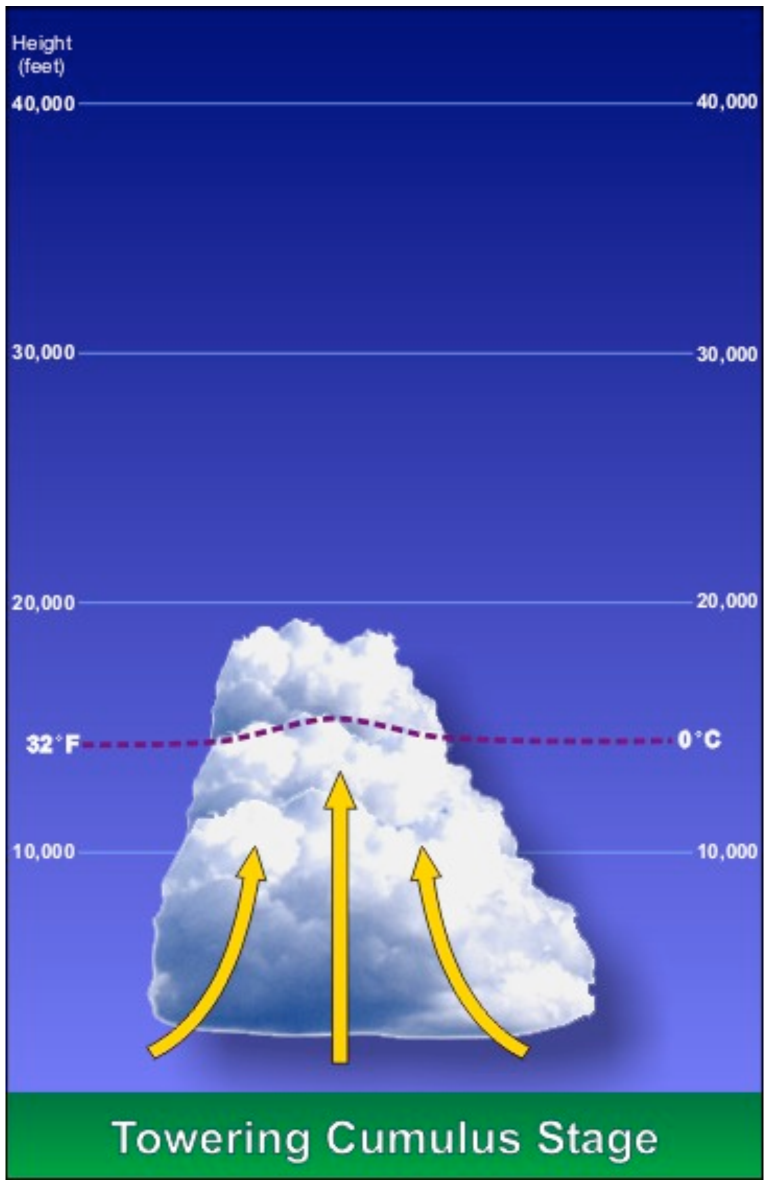
1 km cloud base height

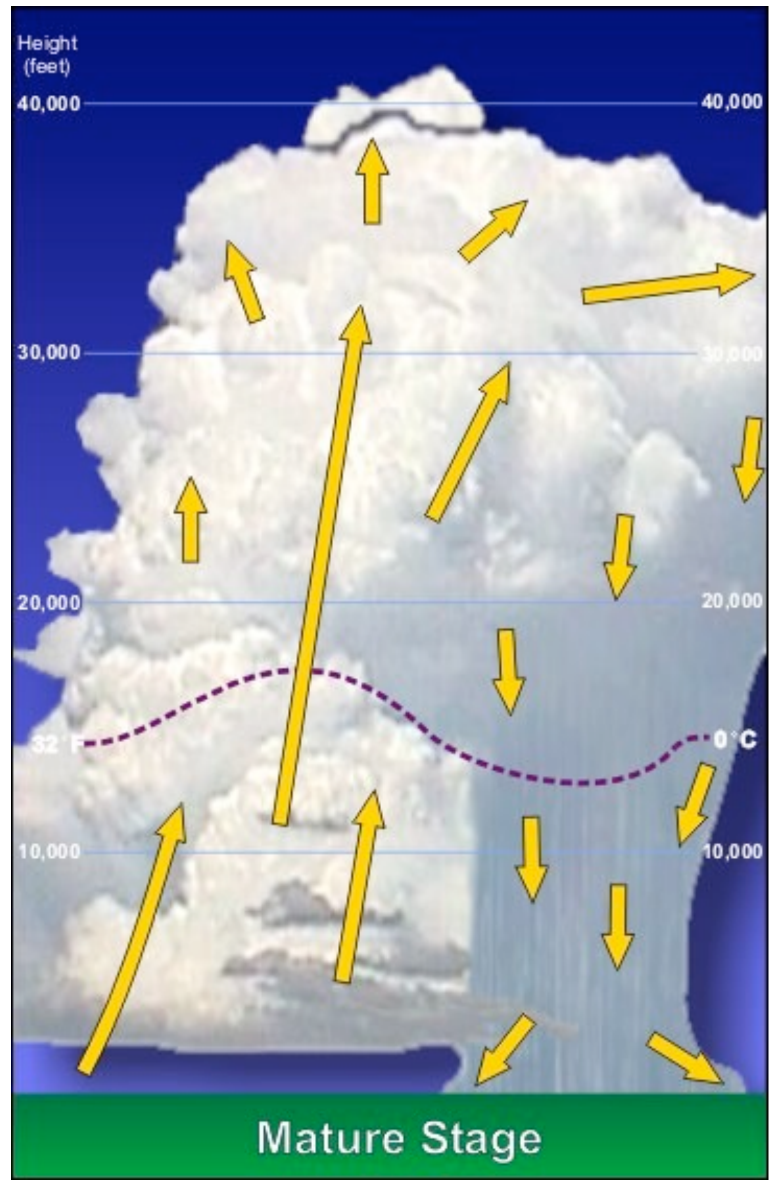


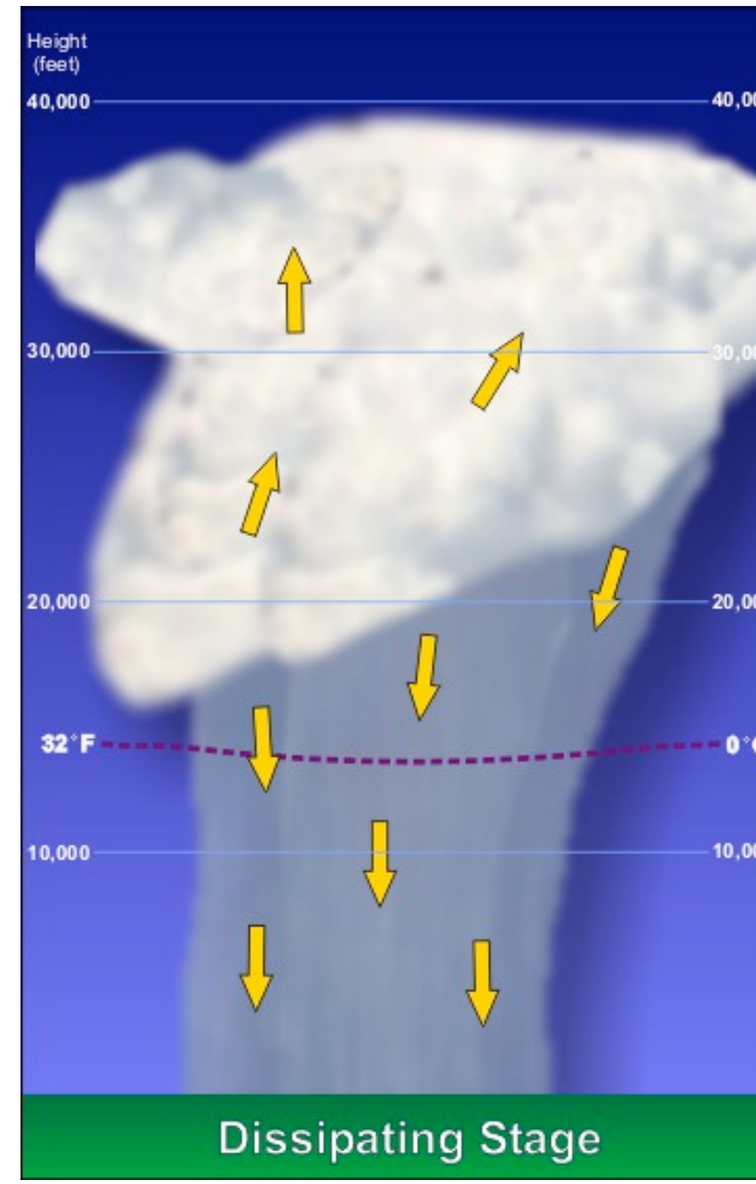
Active

Consistent with Romps (2010): active clouds are connected to lowest levels

The two groups reflect the life-cycle stages of convective cells



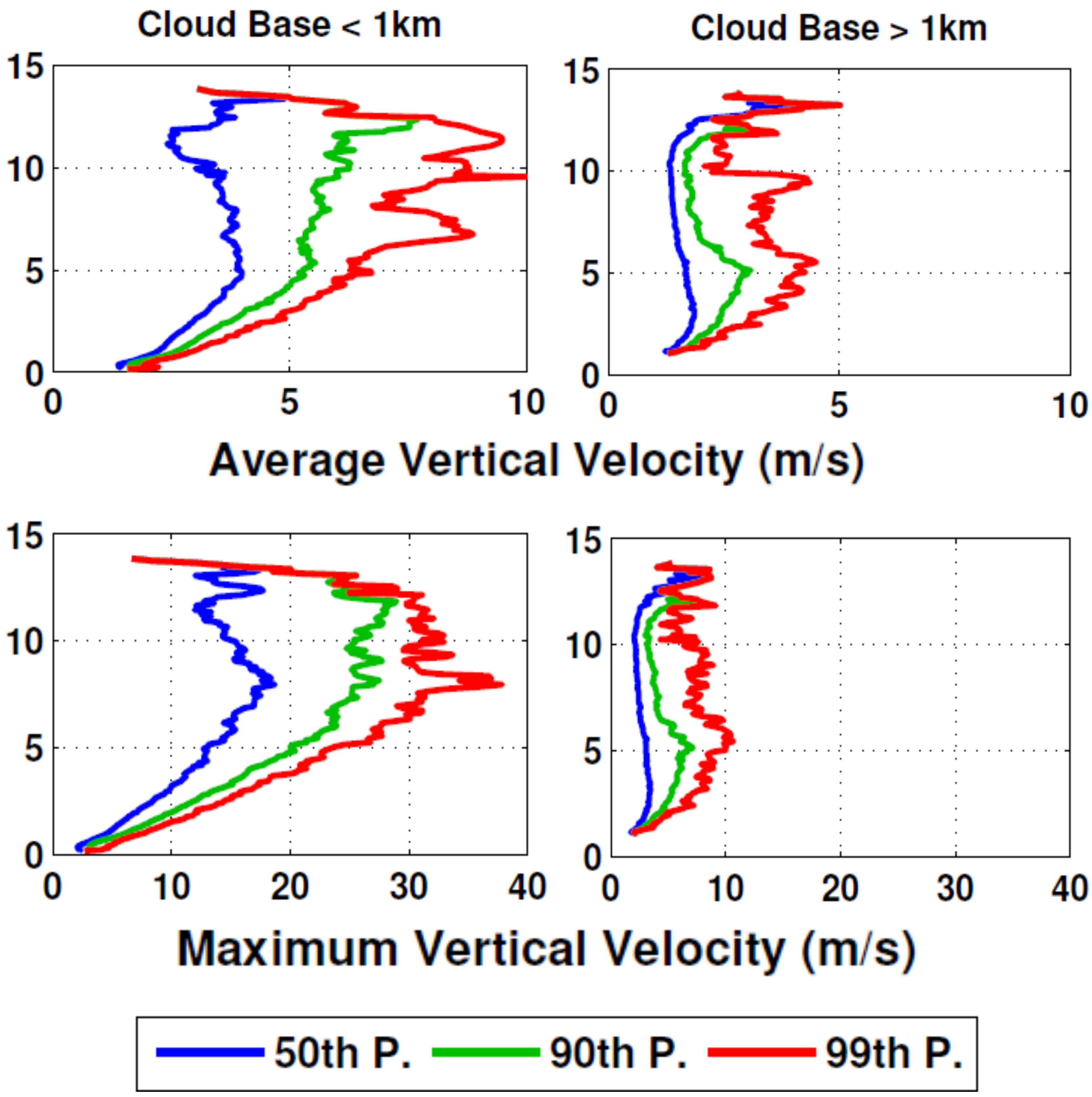




Low Cloud Bases

Higher Cloud Base

3D Cloudy Updraft Core Profiles



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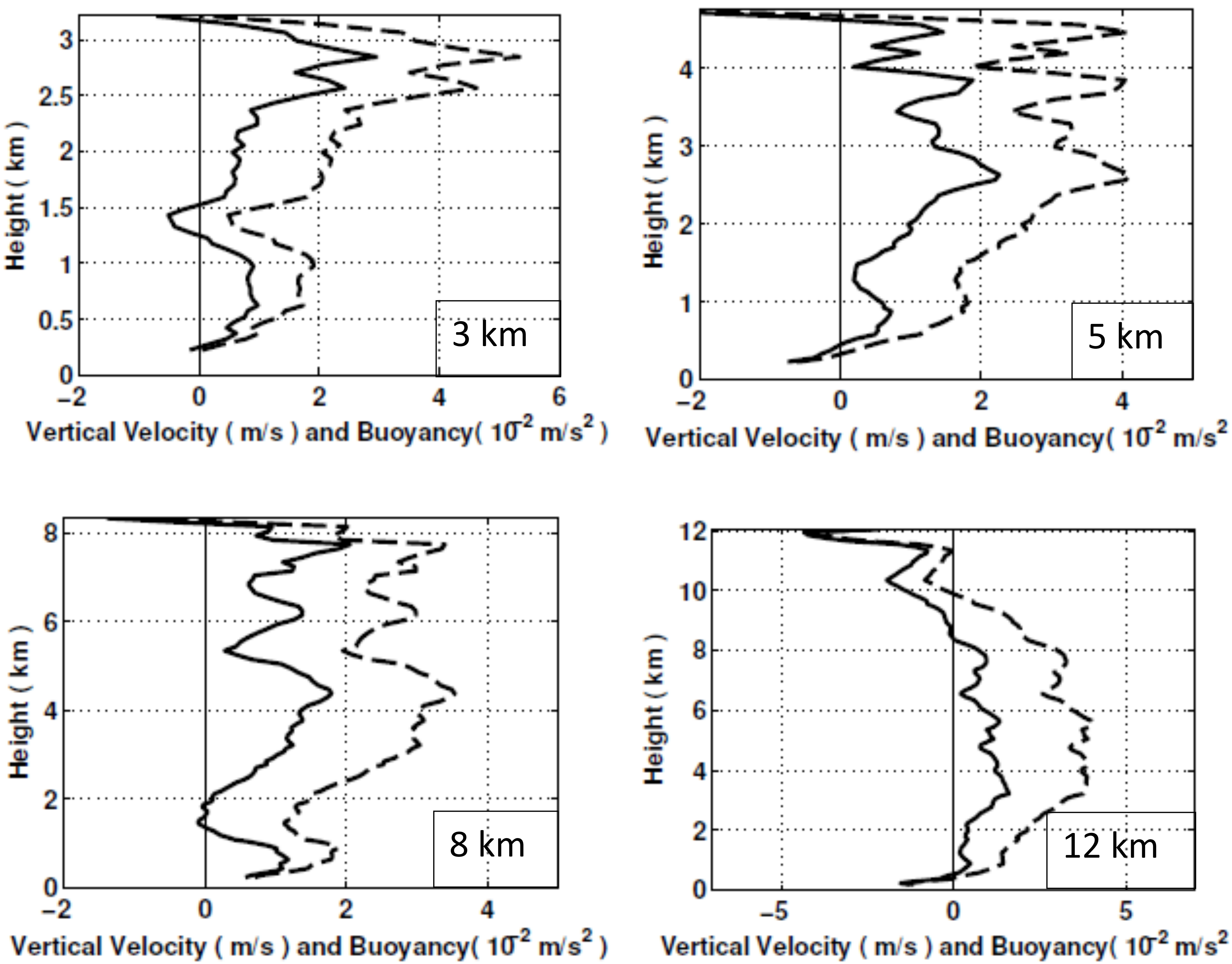
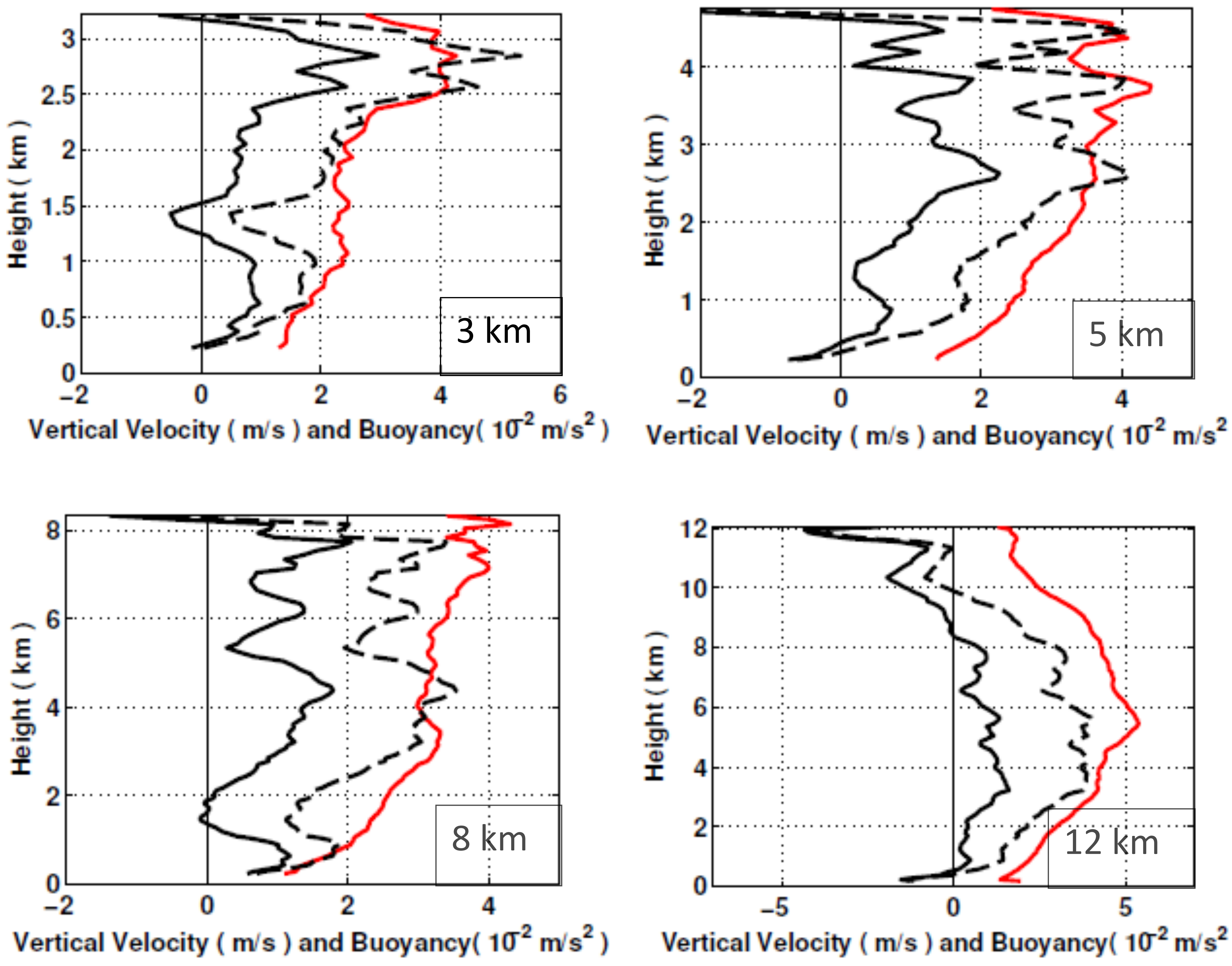
- How well can a parcel model reproduce W(z), given the total (loaded) buoyancy?
- Can the simple estimate $W = C * B_{unloaded}$ (suggested by Alison Stirling, UKMO) do as well?

Total Buoyancy, Unloaded Buoyancy



Total Buoyancy, Unloaded Buoyancy, Vertical Velocity



Parcel Model for Vertical Velocity

Use for each 3D cloudy updraft core

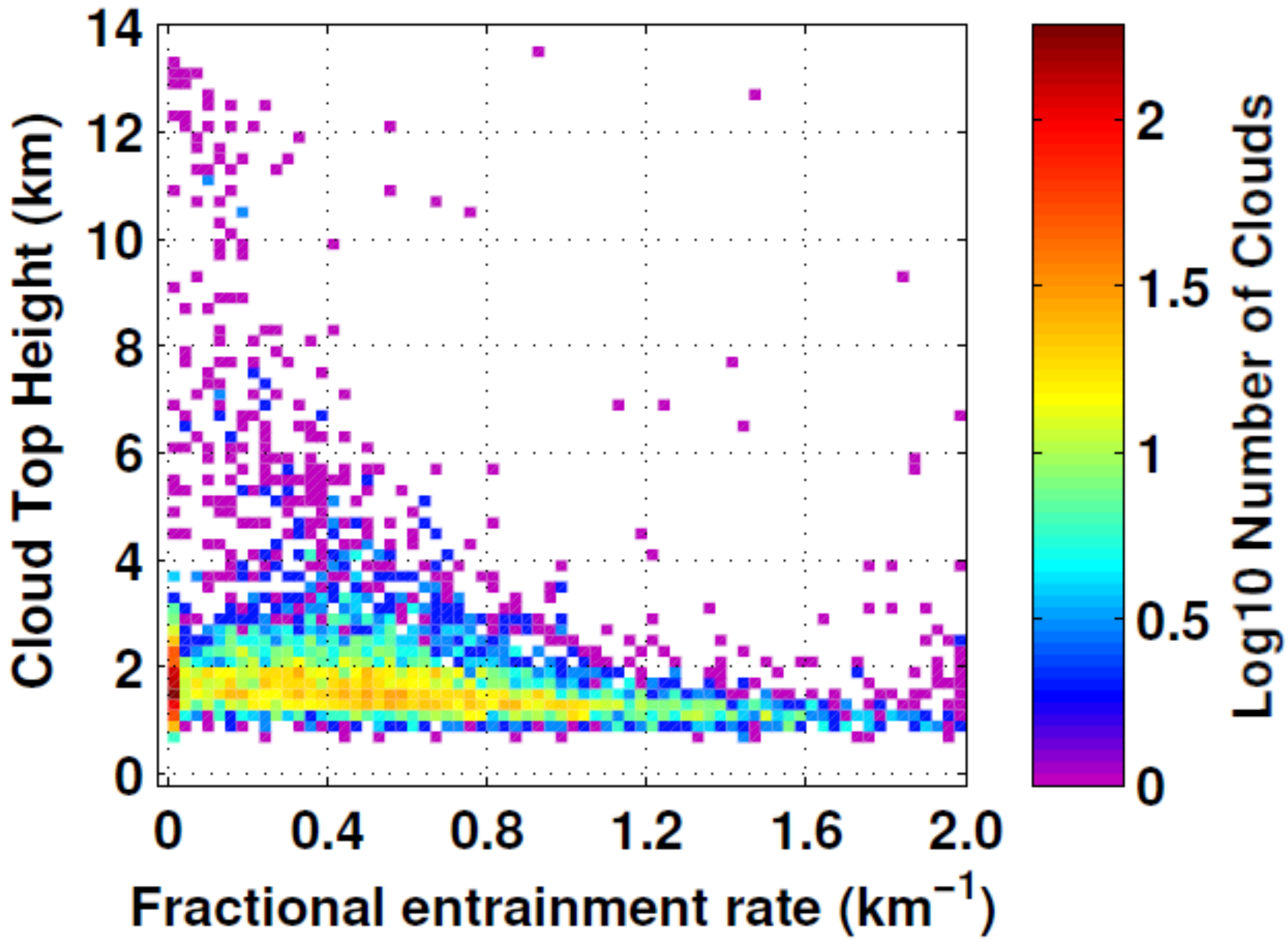
$$\frac{1}{2}\frac{dW^2}{dz} = aB - b\,\lambda\,W^2$$

Total buoyancy from cloudy updraft core

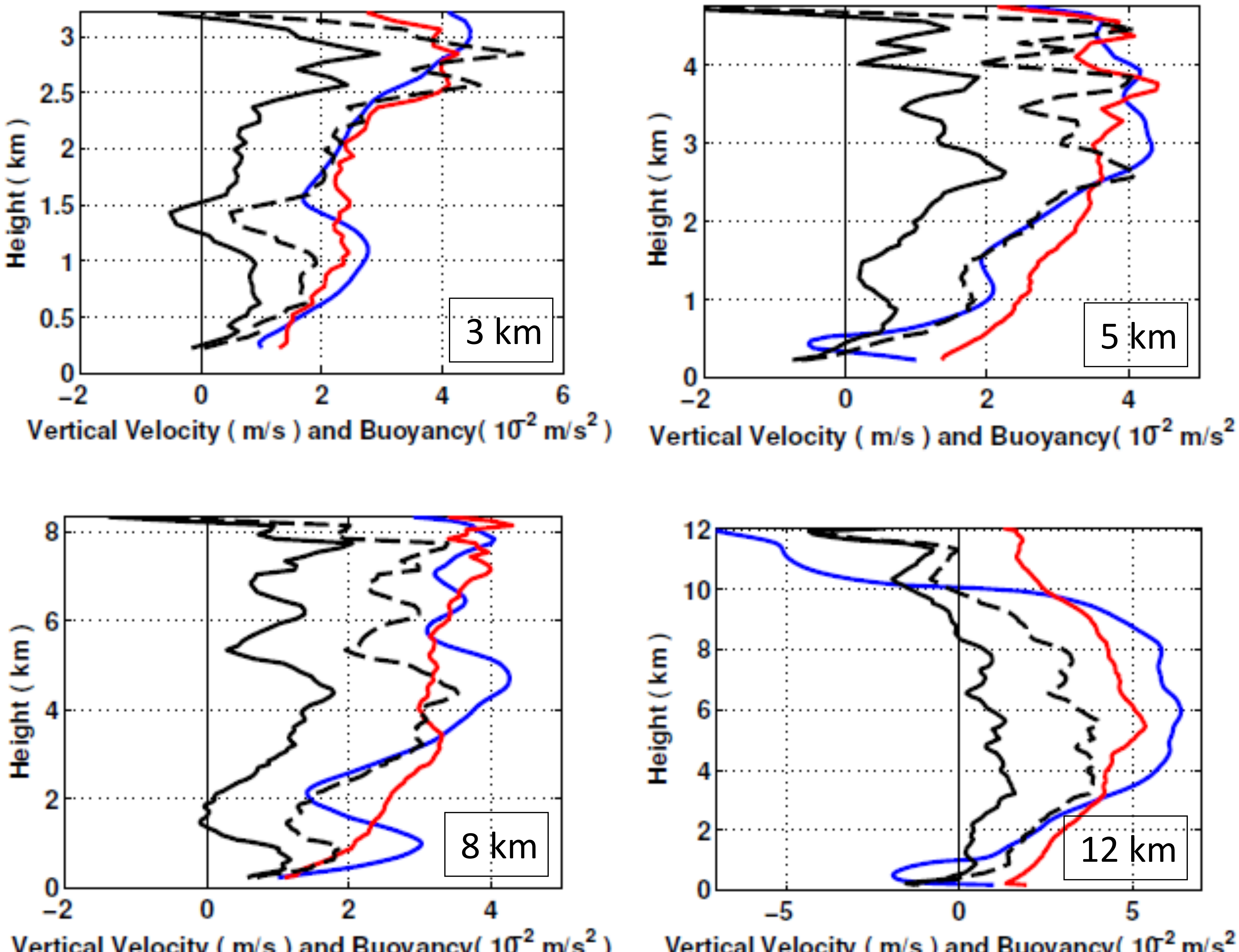
Iterate to find the fractional entrainment rate that…

…gives the best W profile (min. RMS error)

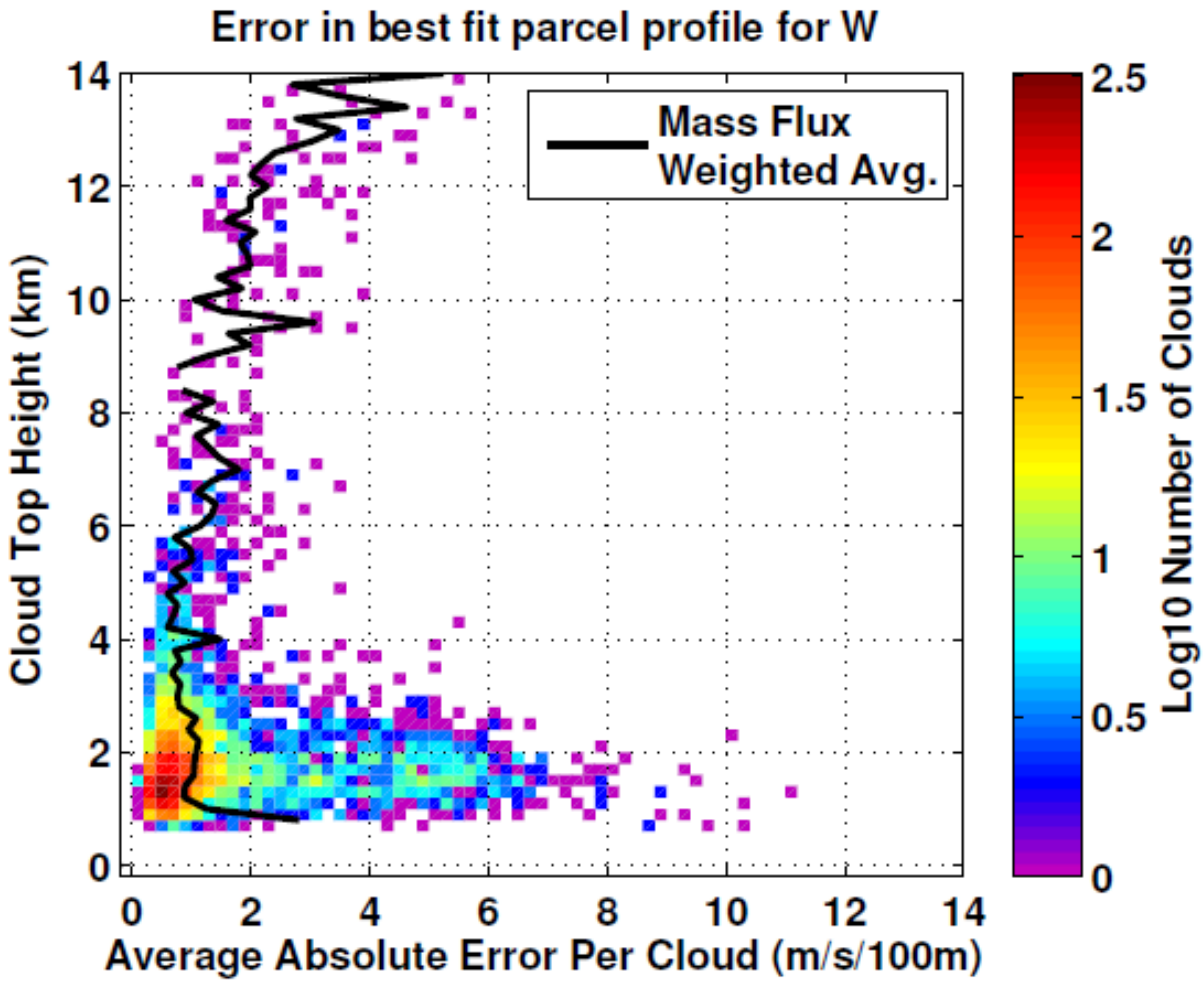
Entrainment rates from parcel model best-fit to cloudy updraft W



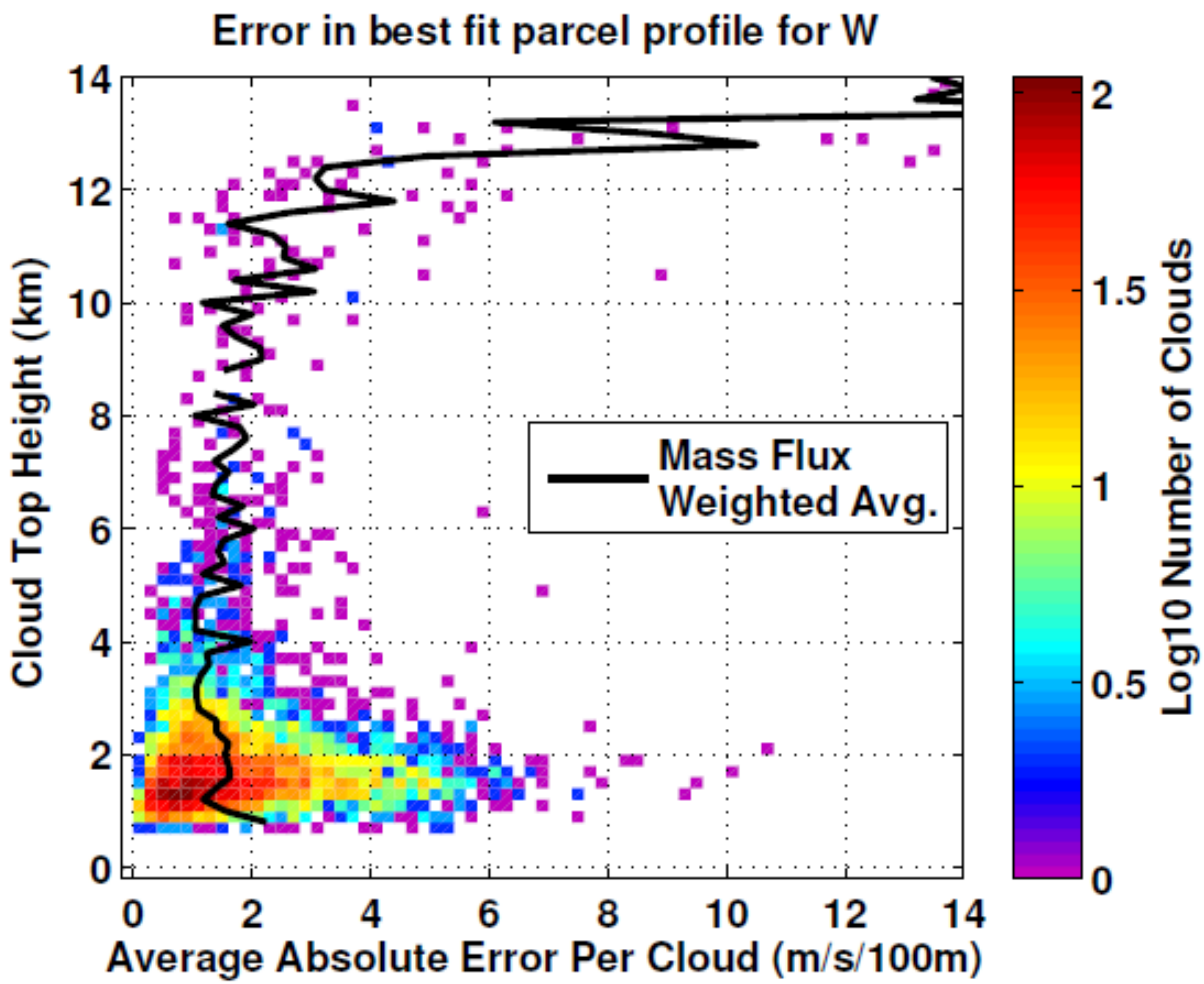
Updraft Core Vertical Velocity,
Parcel Model Vertical Velocity



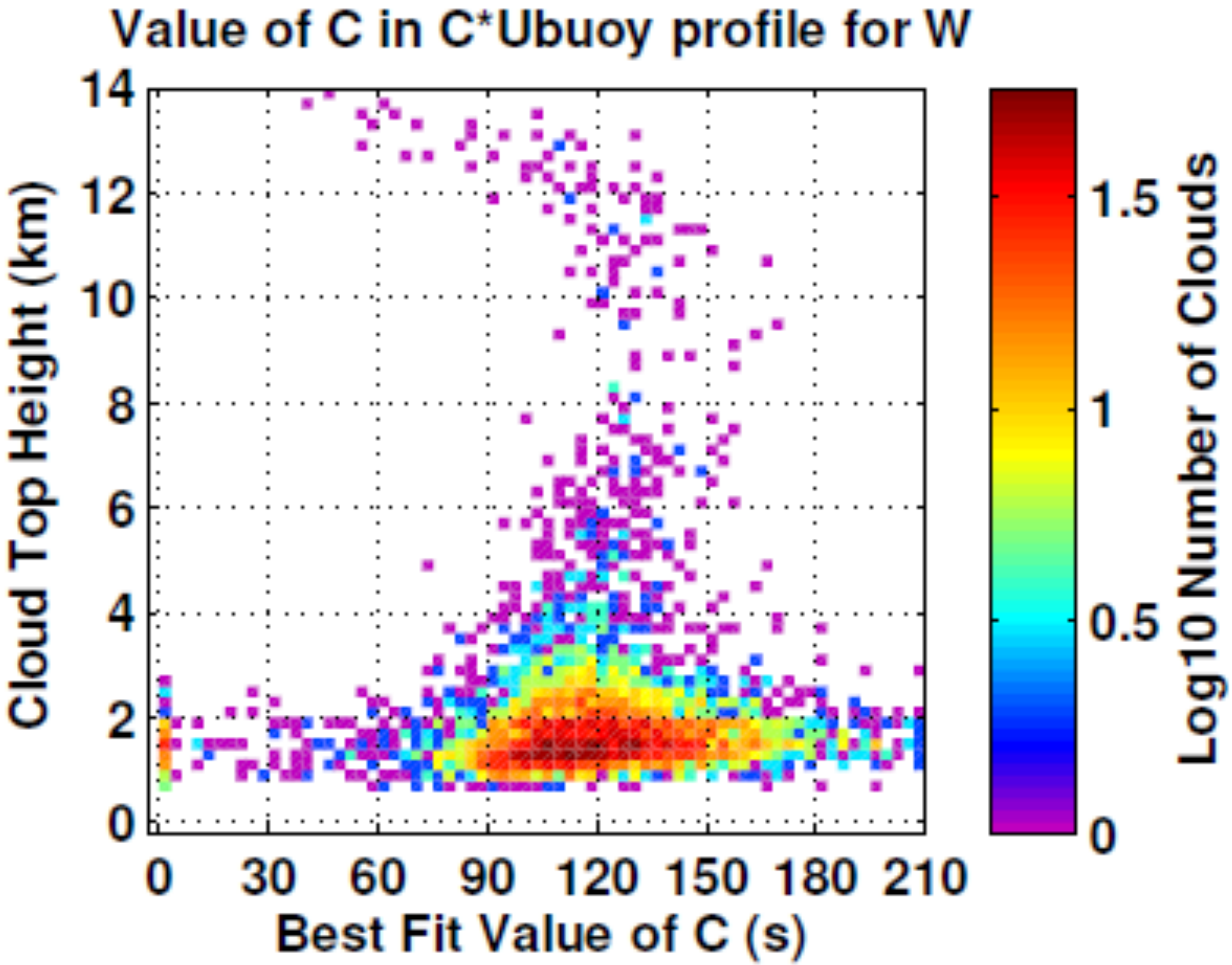
Error in parcel model W



Error for W = C * $B_{unloaded}$ (C=120 s)



For $W = C * B_{unloaded}$, what is C?



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- The MAE for Alison Stirling's estimate $W = C * B_{unloaded}$ is only slightly larger, and W requires only the "unloaded" buoyancy.
- Analyzing 3D cloudy updraft cores provides context, such as cloud base, cloud vertical extent, and cloud shape, that is not available from 1D and 2D core analyses.