Entrainment in Cumulus Ensembles: Cumulus Parameterization versus Giga-LES

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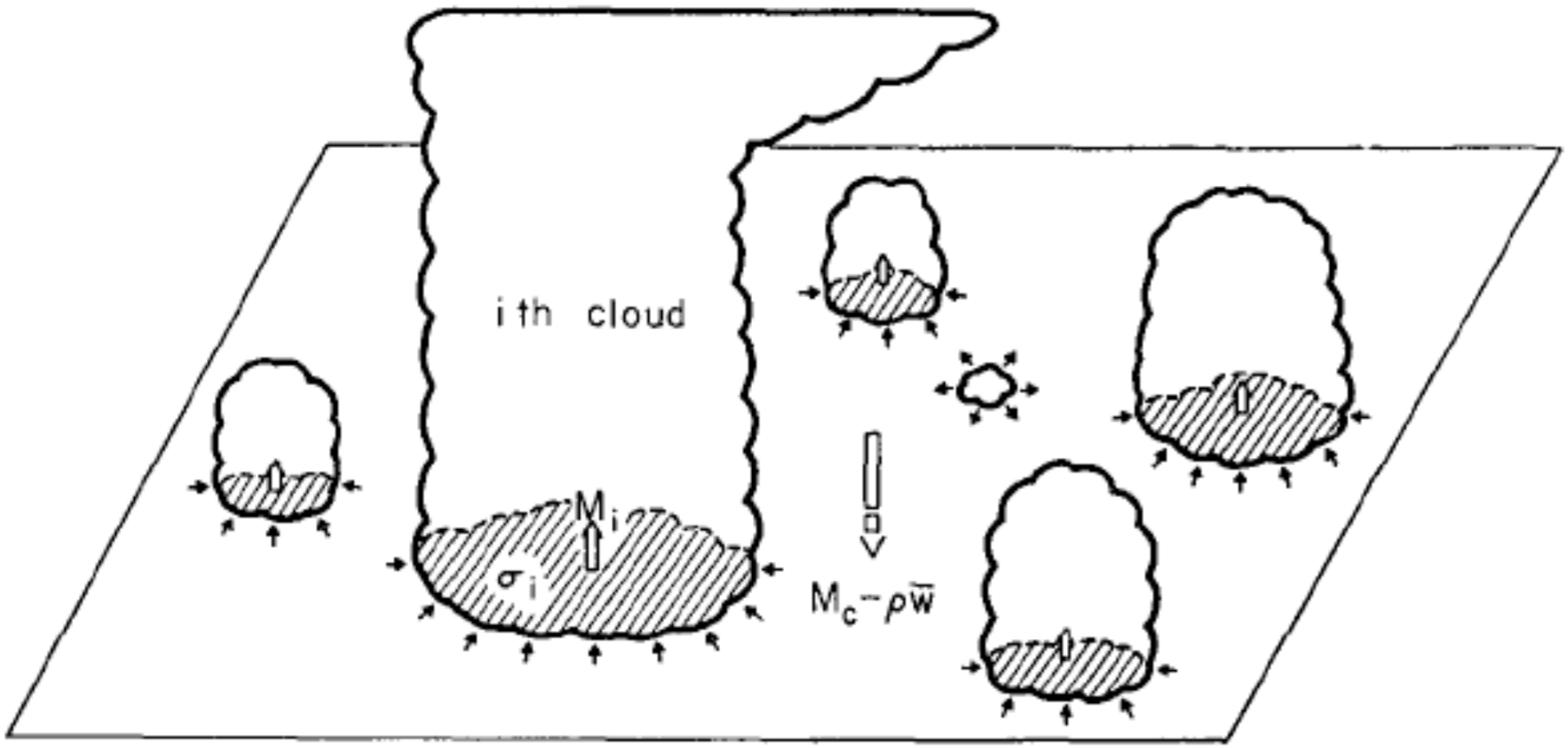
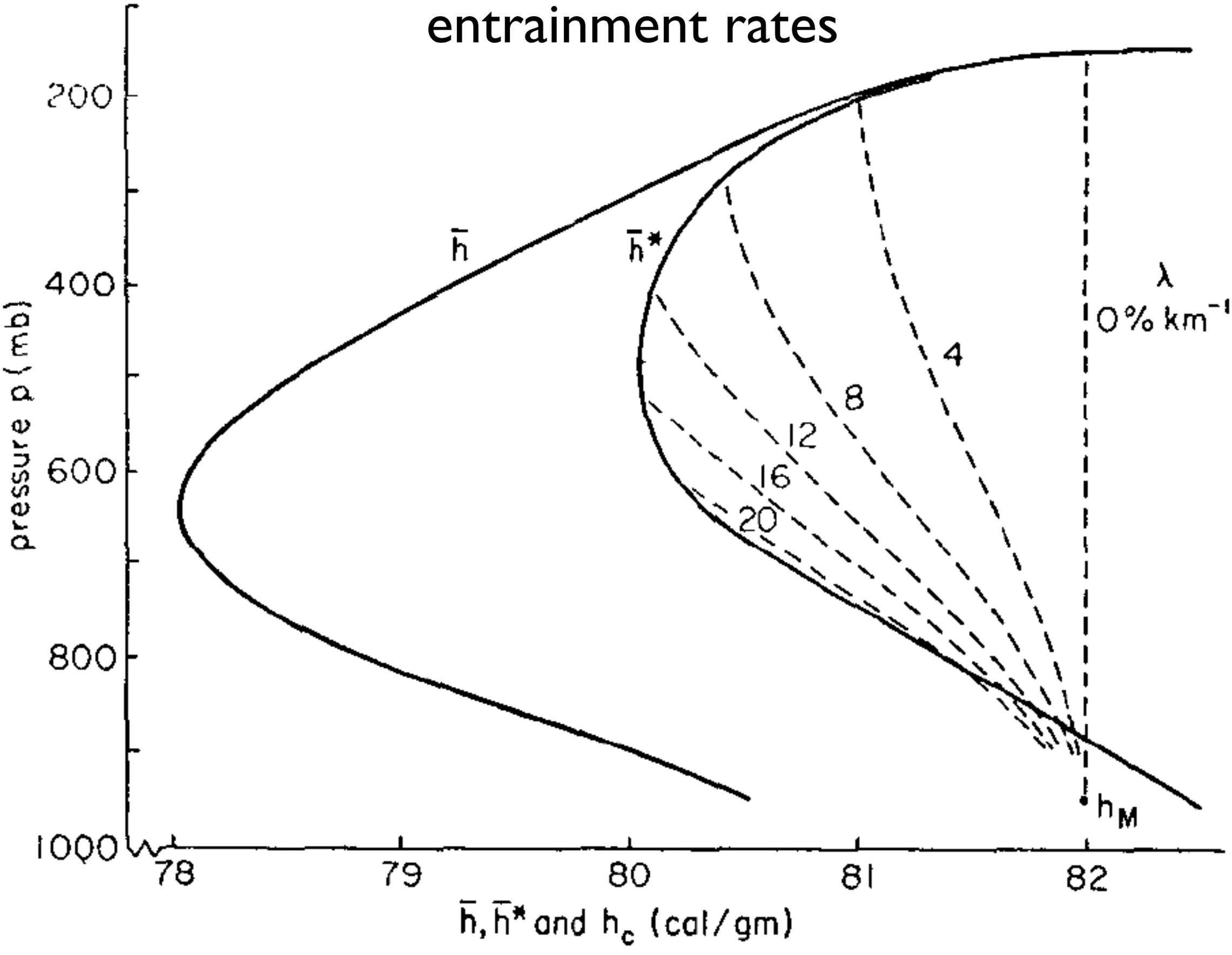


FIG. 1. A unit horizontal area at some level between cloud base and the highest cloud top. The taller clouds are shown penetrating this level and entraining environmental air. A cloud which has lost buoyancy is shown detraining cloud air into the environment.

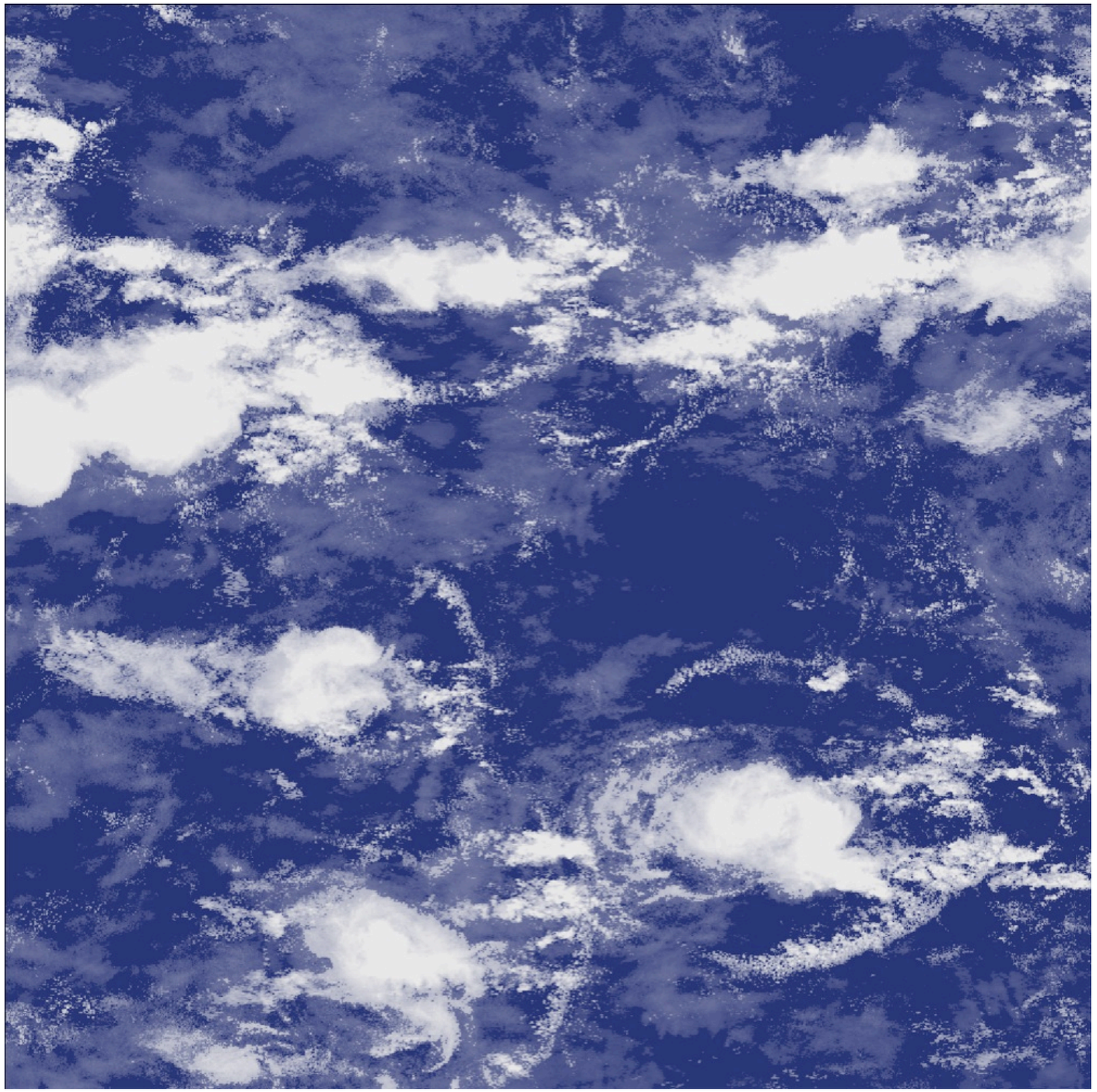
Moist static energy profiles for different fractional entrainment rates



A large-domain LES of deep convection

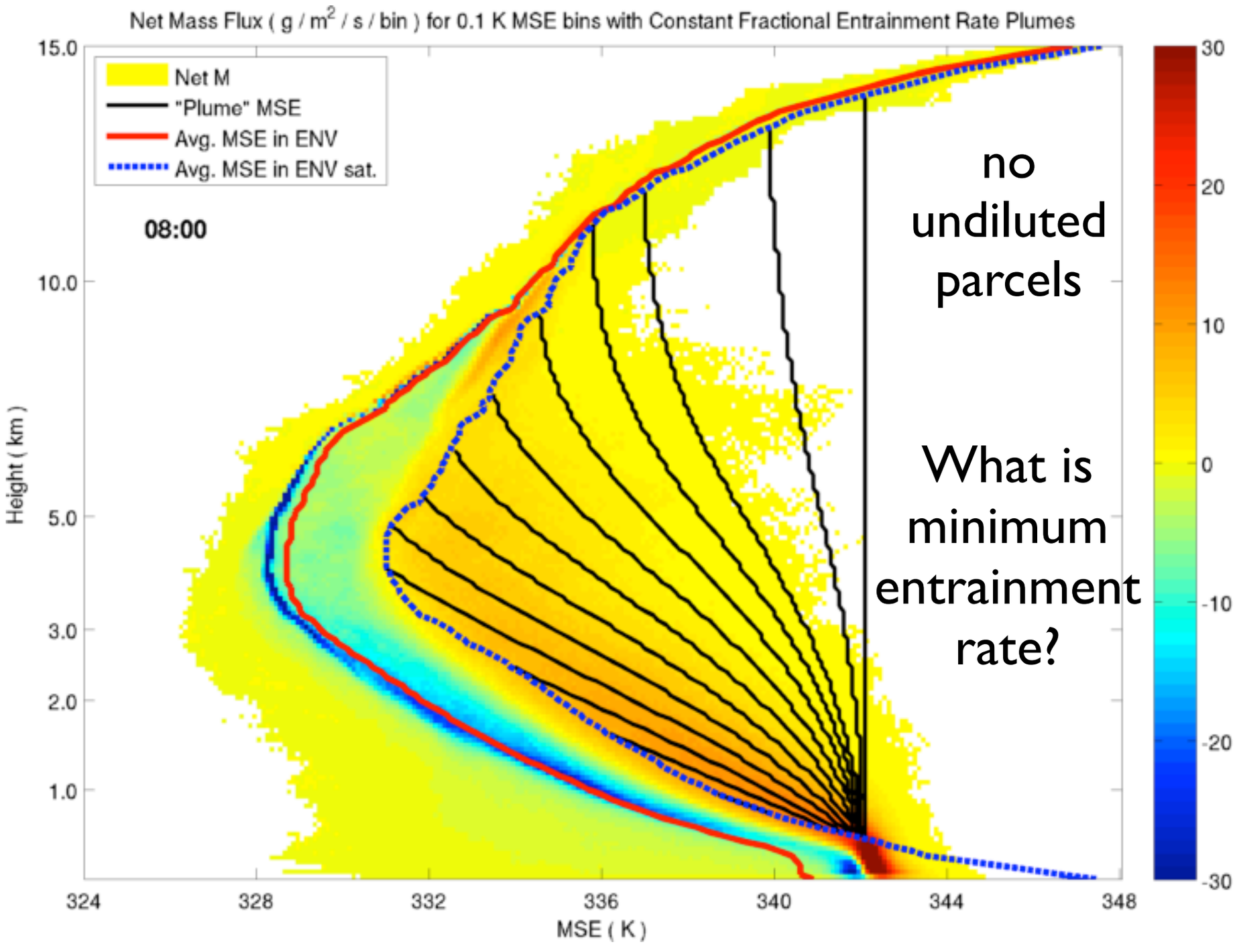
- Idealized GATE (tropical ocean) simulation with shear.
- Used a CSRM (SAM) with 2048 x 2048 x 256 (10^9) grid points and 100-m grid size for a 24-h LES.

LES “visible image” 180 km x 180 km



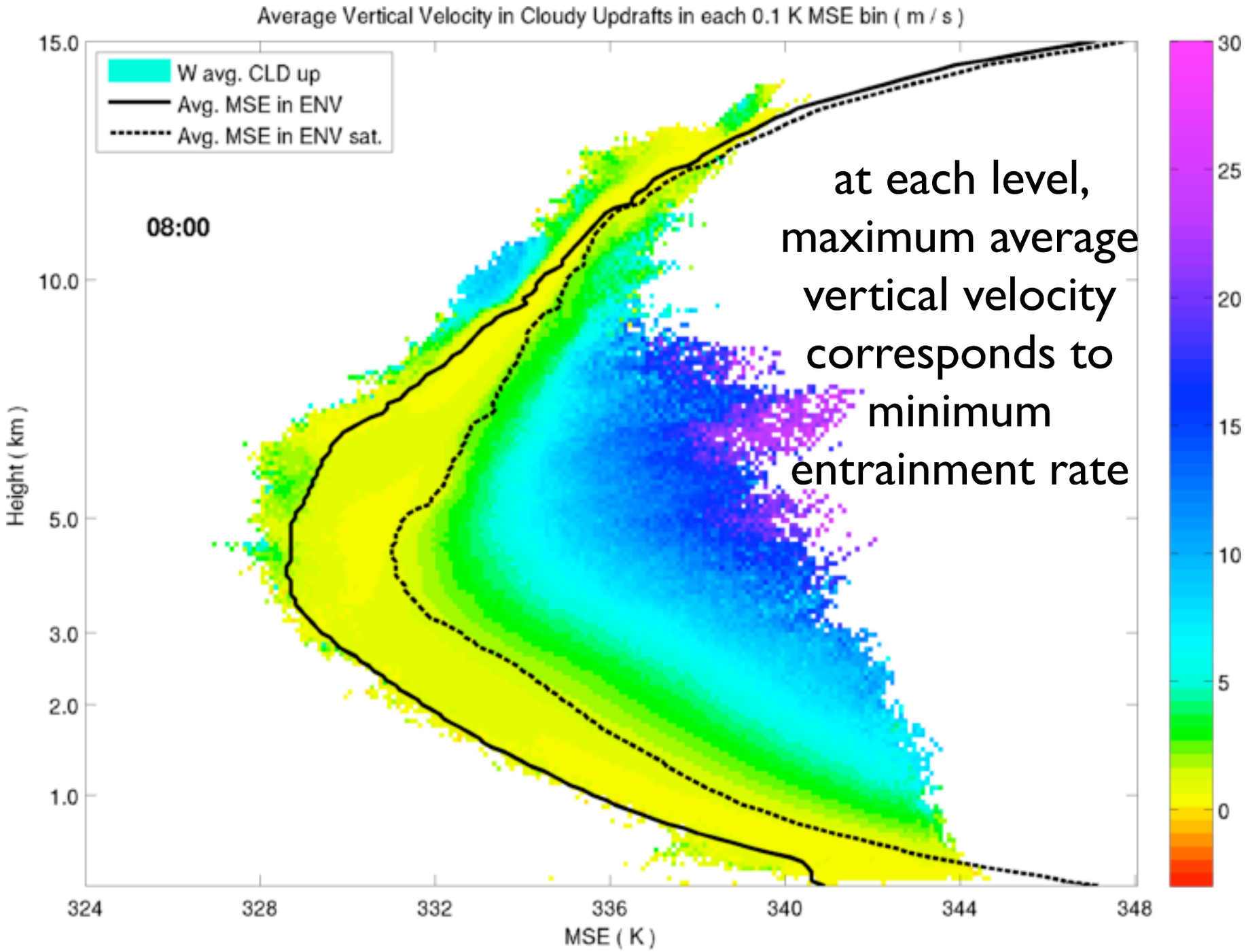
Updraft Properties

Mass Flux Spectrum vs z

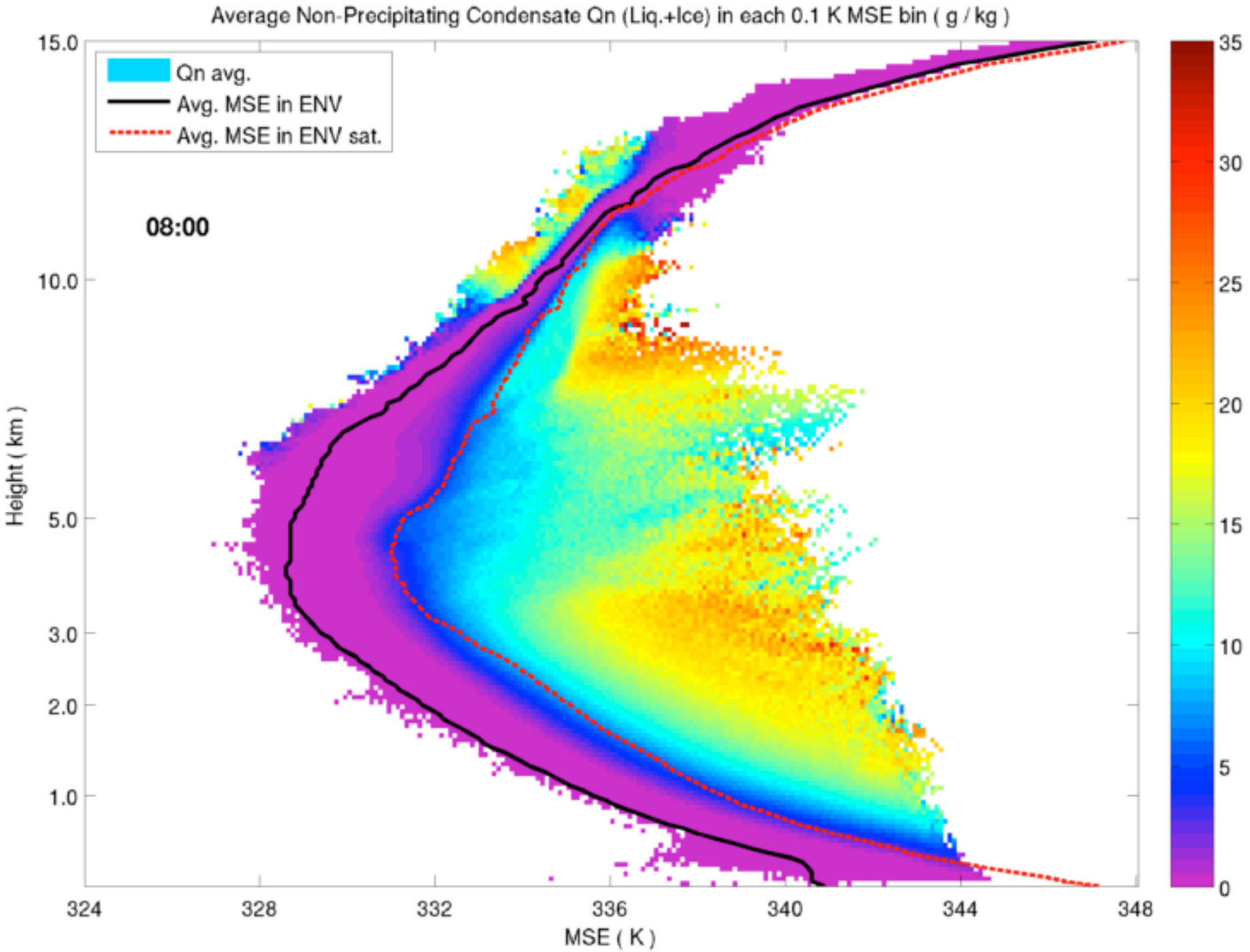


with MSE profiles for several fractional entrainment rates

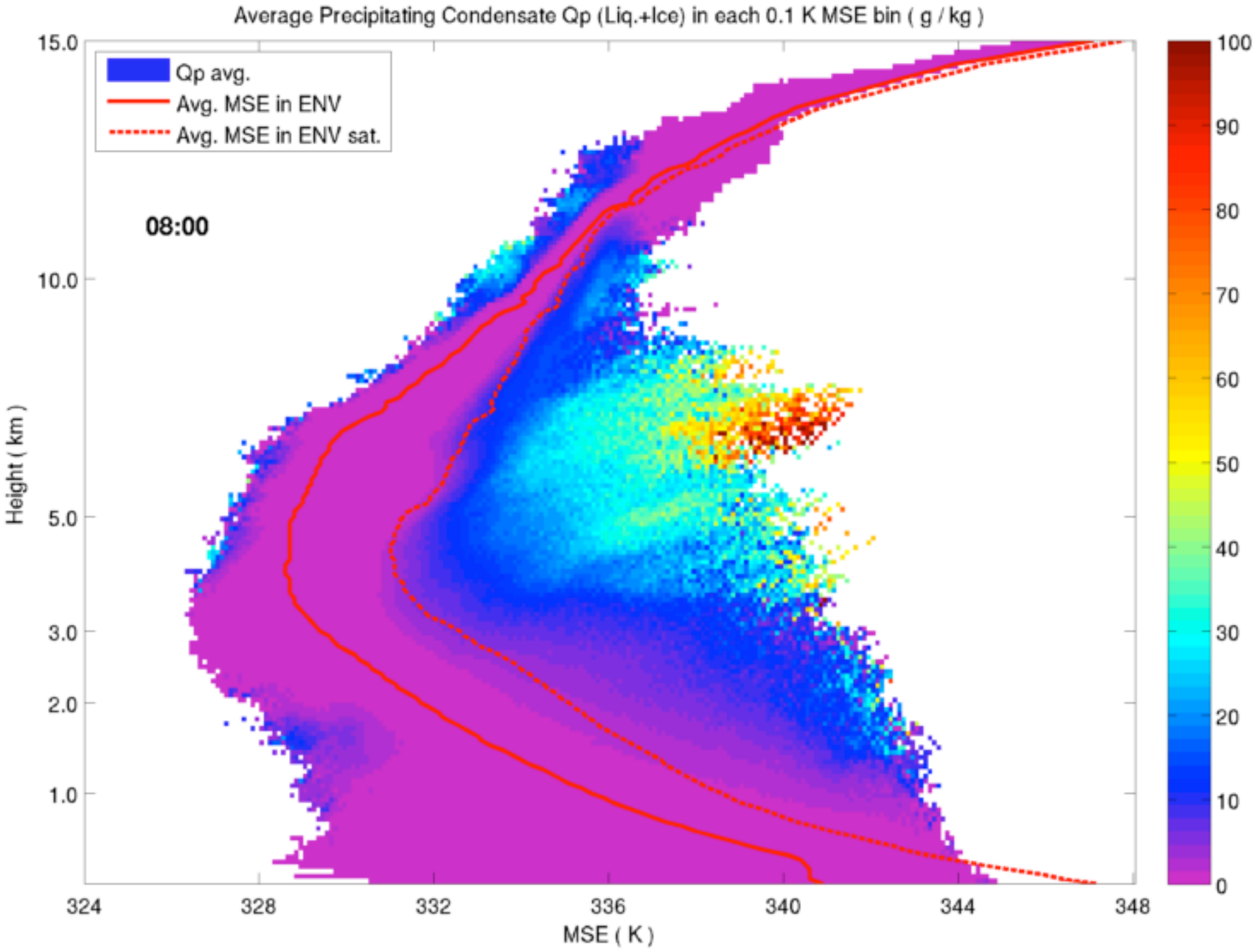
Average Vertical Velocity in Cloudy Updrafts vs z and MSE



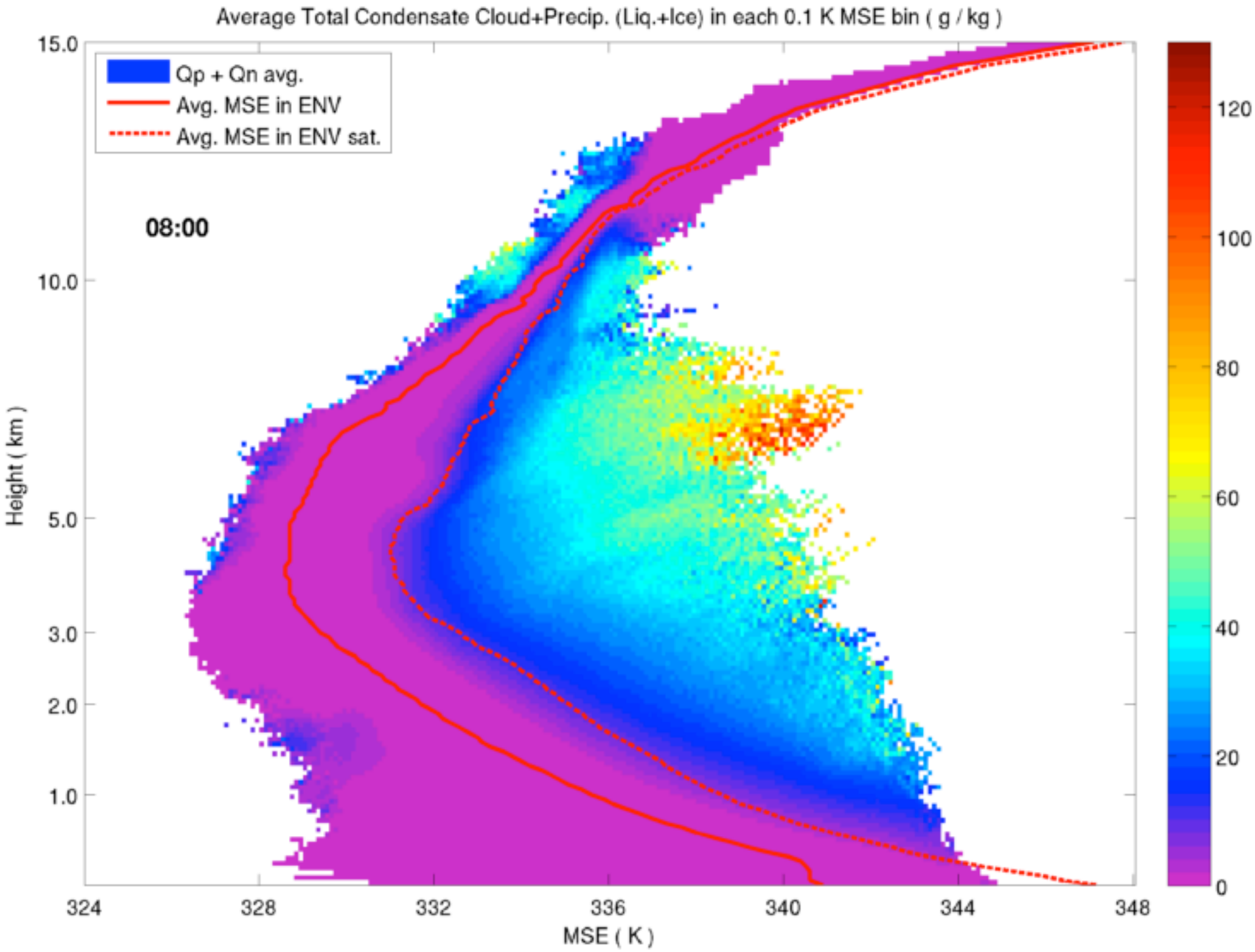
Average Cloud Condensate vs z and MSE



Average Precipitating Condensate vs z and MSE



Average Total Condensate vs z and MSE

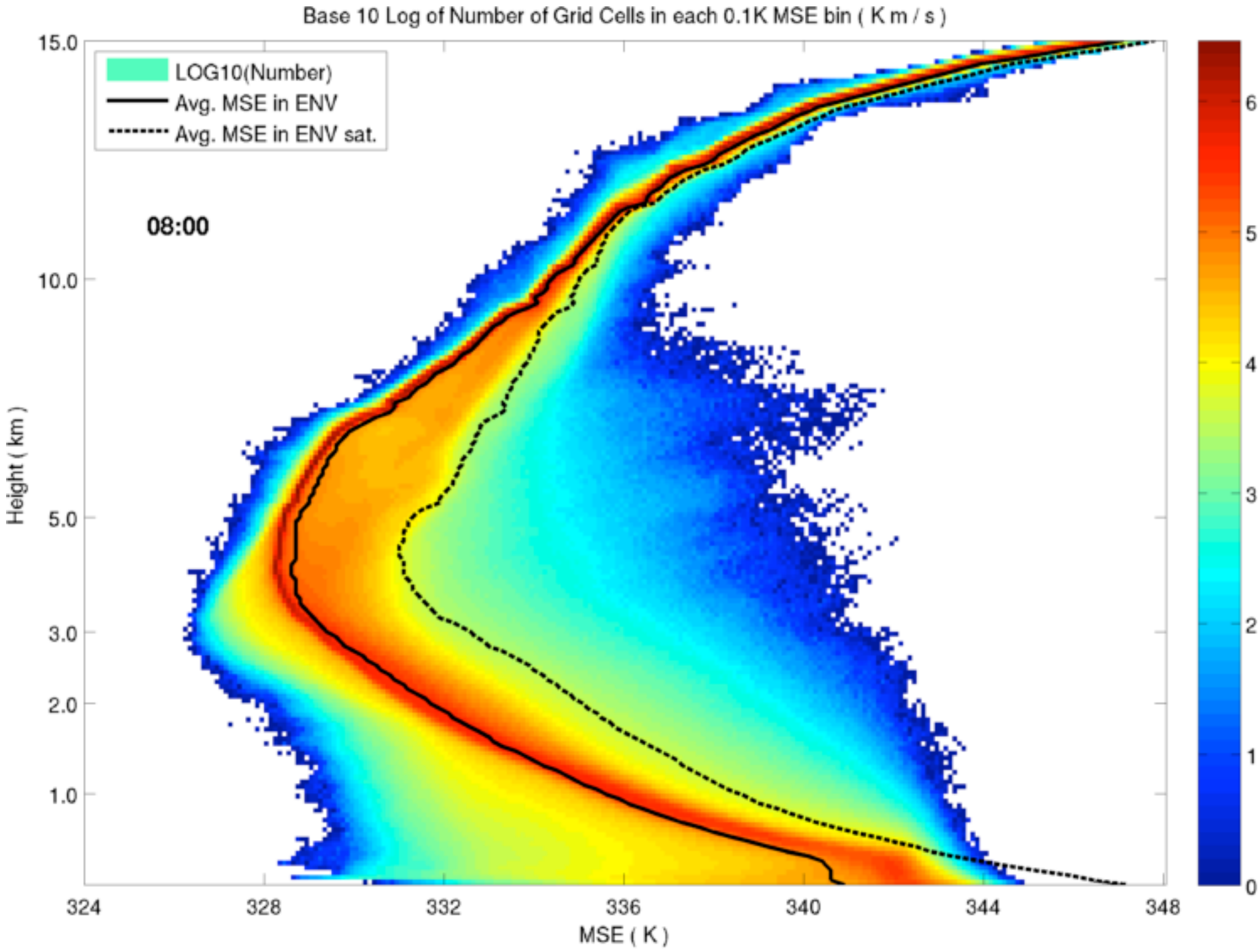


Vertical velocity depends on entrainment and drag (loading).

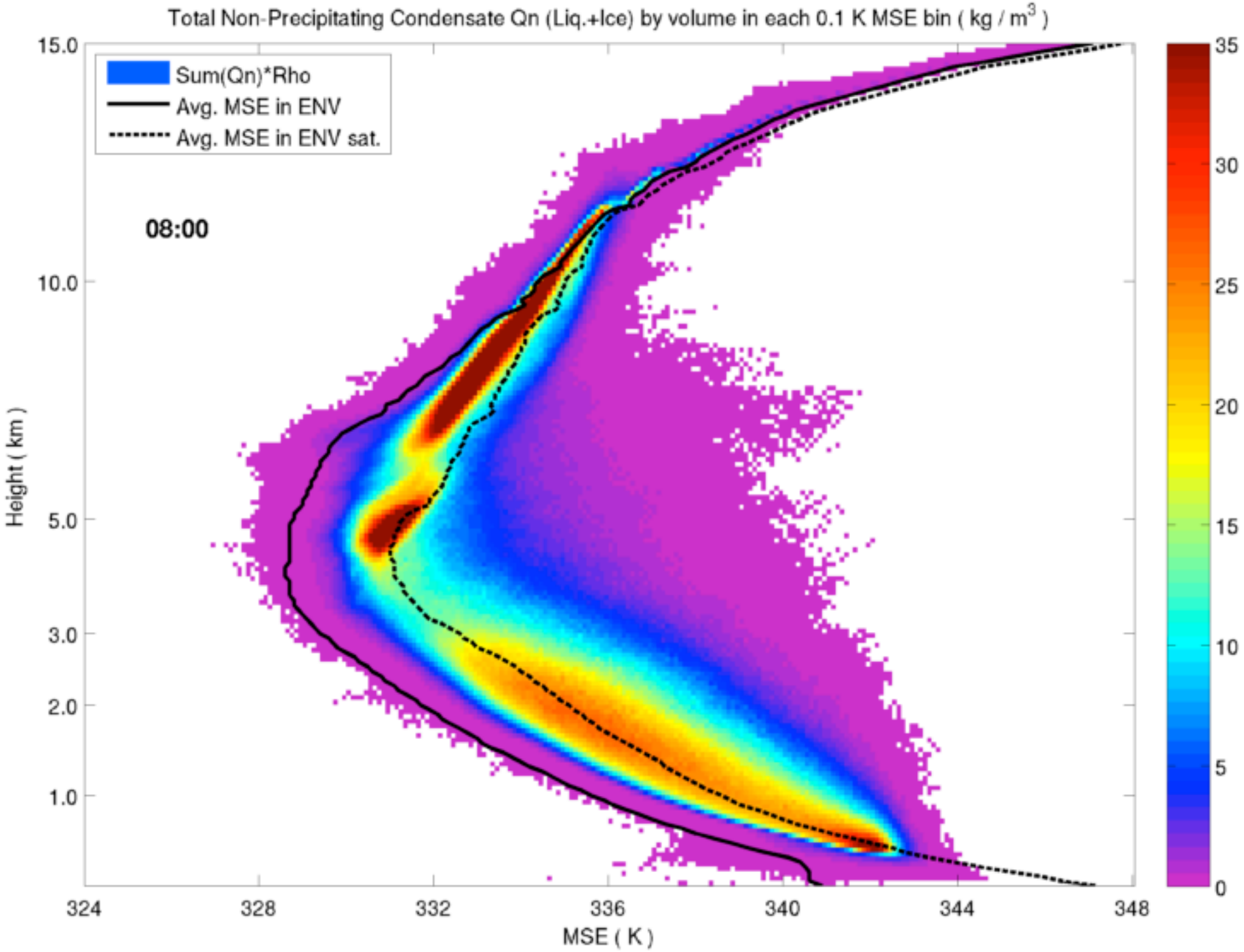
Can we use Doppler radar retrievals of vertical velocity and condensate to back out (minimum) entrainment rate?

Environment Properties

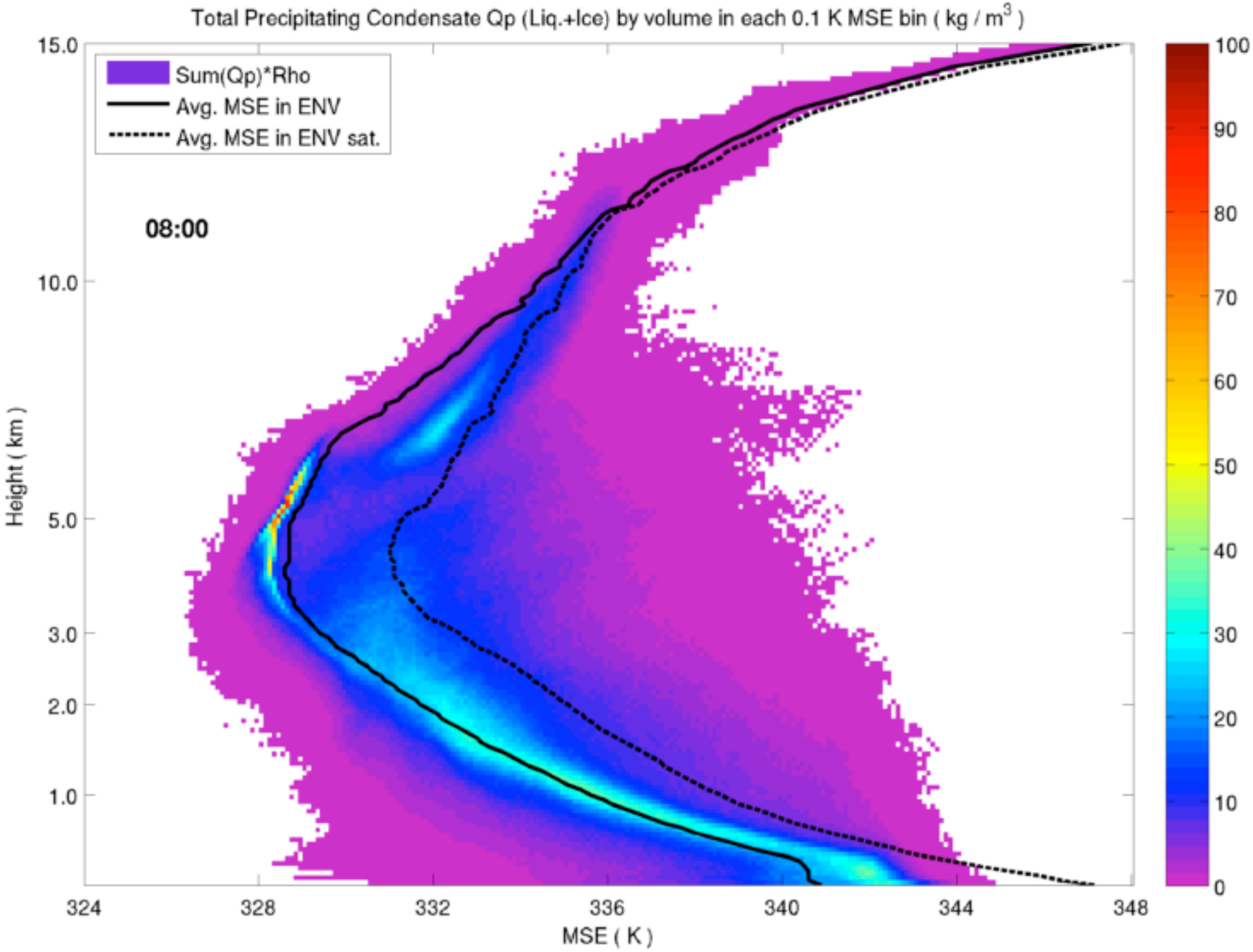
MSE Histogram vs z



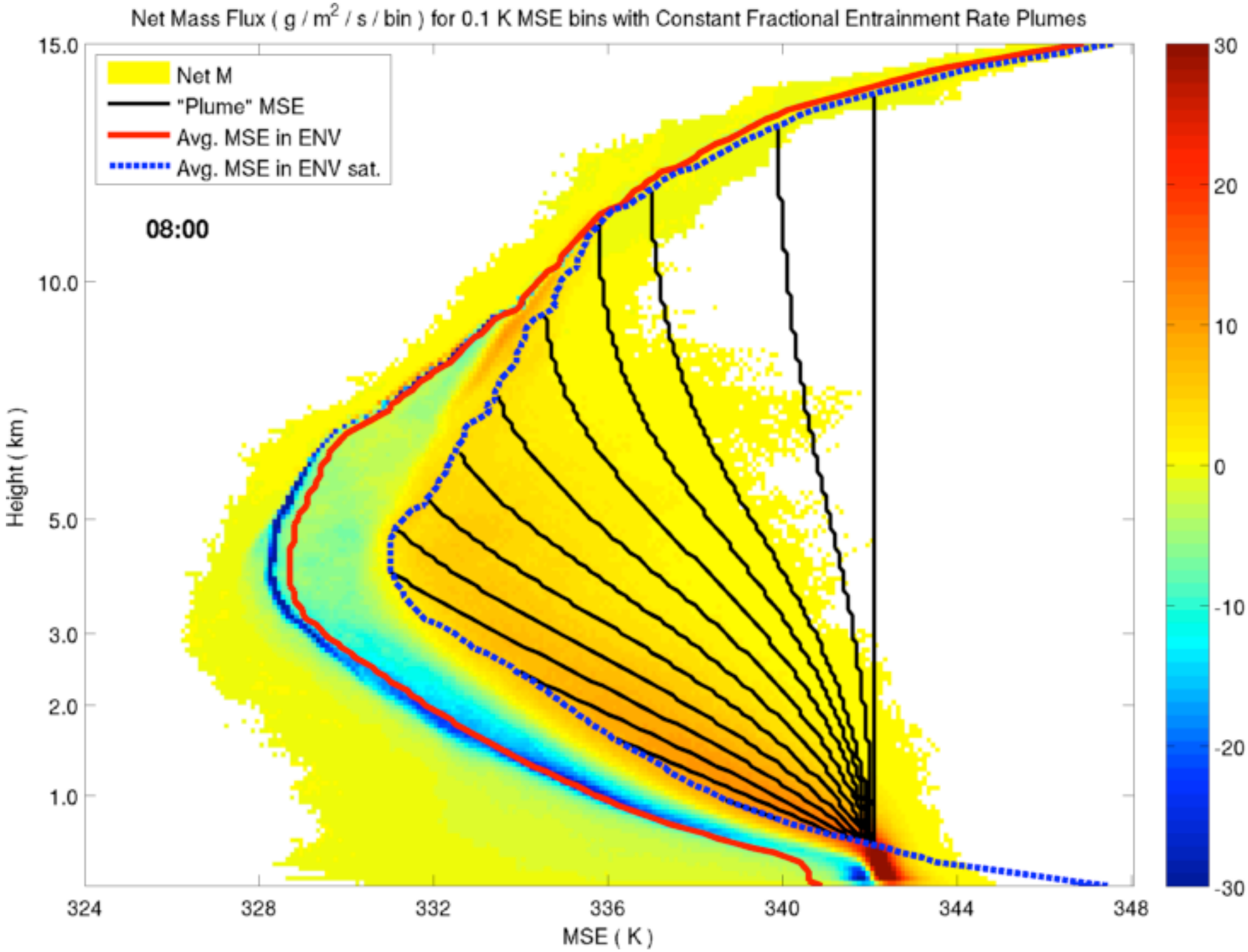
Cloud Condensate Spectrum vs z



Precipitating Condensate Spectrum vs z

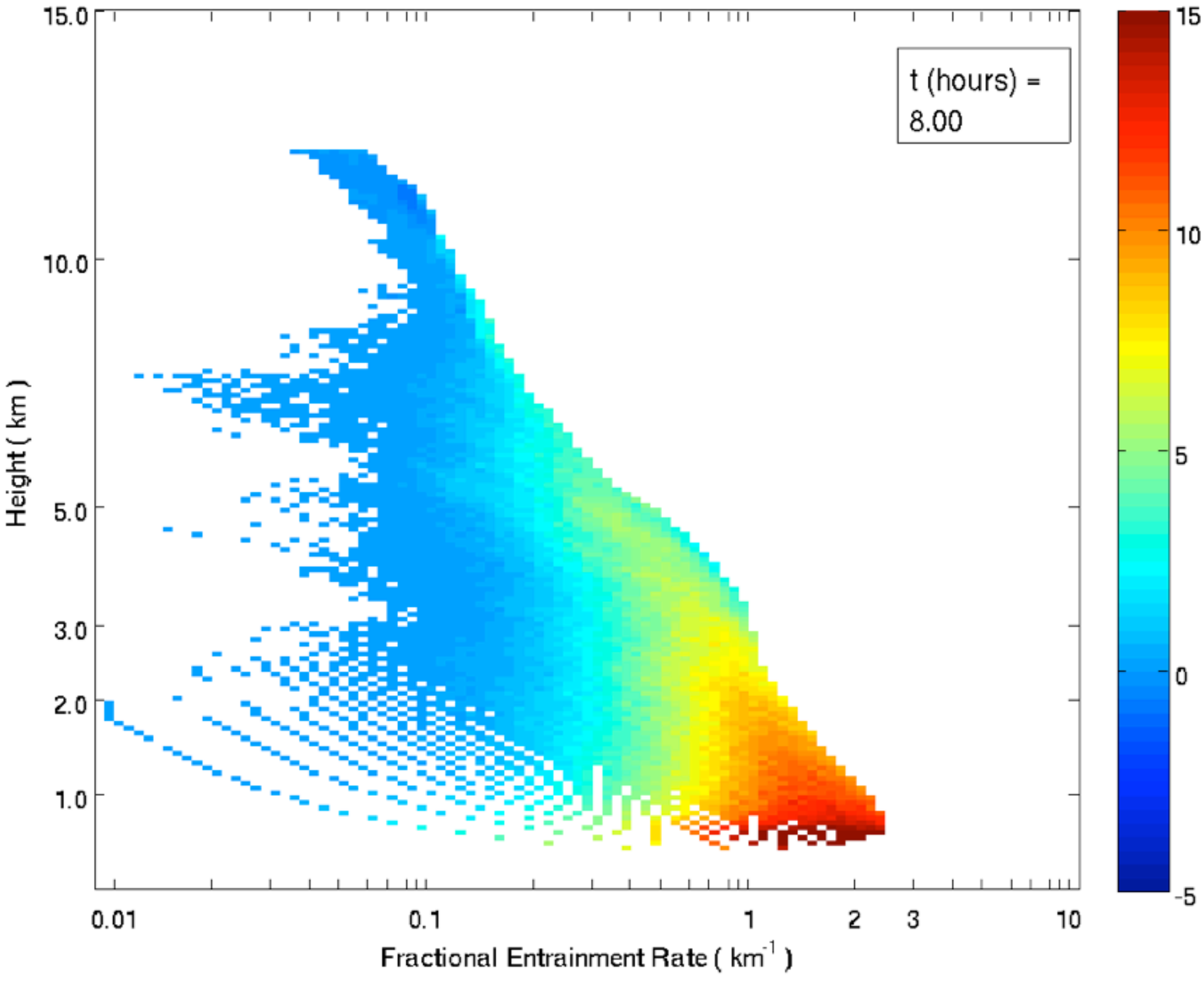


Mass Flux Spectrum vs Moist Static Energy



with MSE profiles for several fractional entrainment rates

Mass Flux Spectrum vs Fractional Entrainment Rate



Summary

- The Giga-LES contains a spectrum of updrafts with different entrainment rates.

- Each updraft type has characteristic properties: updraft speed, cloud condenate, precipitating condensate, etc.

- Perhaps Doppler radar can be used to infer (minimum) entrainment rates.