# Convective Mass Fluxes and Tracer Transport

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I. Most cumulus parameterizations currently used for tracer transport idealize convective systems as a deep convective cell or an ensemble of such cells, despite observational evidence that such systems also include uppper-tropospheric mesoscale circulations (*e.g.,* Leary and Houze, 1980, *JAS*).

II. Donner (1993, *JAS;* 2001, *JClim*) developed a cumulus parameterization which includes upper-tropospheric mesoscale circulations. This presentation will consider two experiments with this parameterization in GFDL SKYHI GCM:

Cell Meso: Parameterization with convective cells and mesoscale circulations.

Cell: Parameterization with convective cells only.

III. Middle and upper-tropospheric mass fluxes are substantially greater in Cell. If Cell is a proxy for most mass-flux cumulus parameterizations, these results suggest a strategy for reducing excessive tracer transport by cumulus convection (Allen, 1997, *JGR*).

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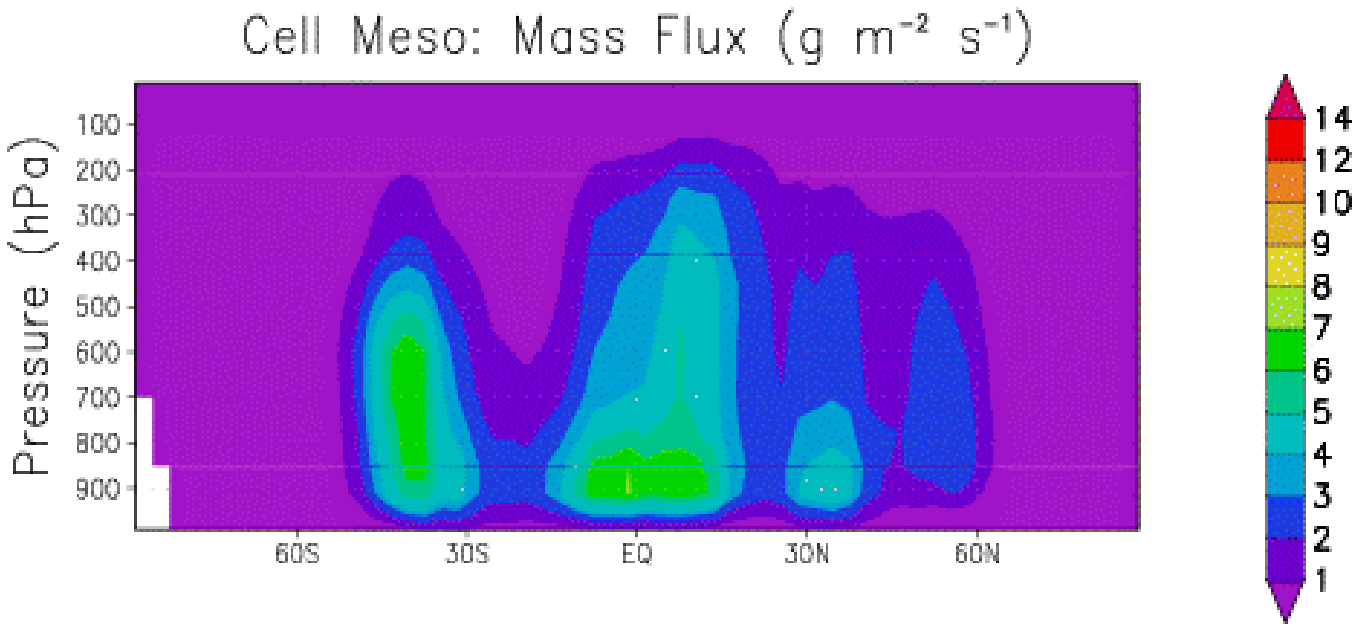
Cell Meso: Mass Flux (g m⁻² s⁻¹)
Pressure (hPa)
100
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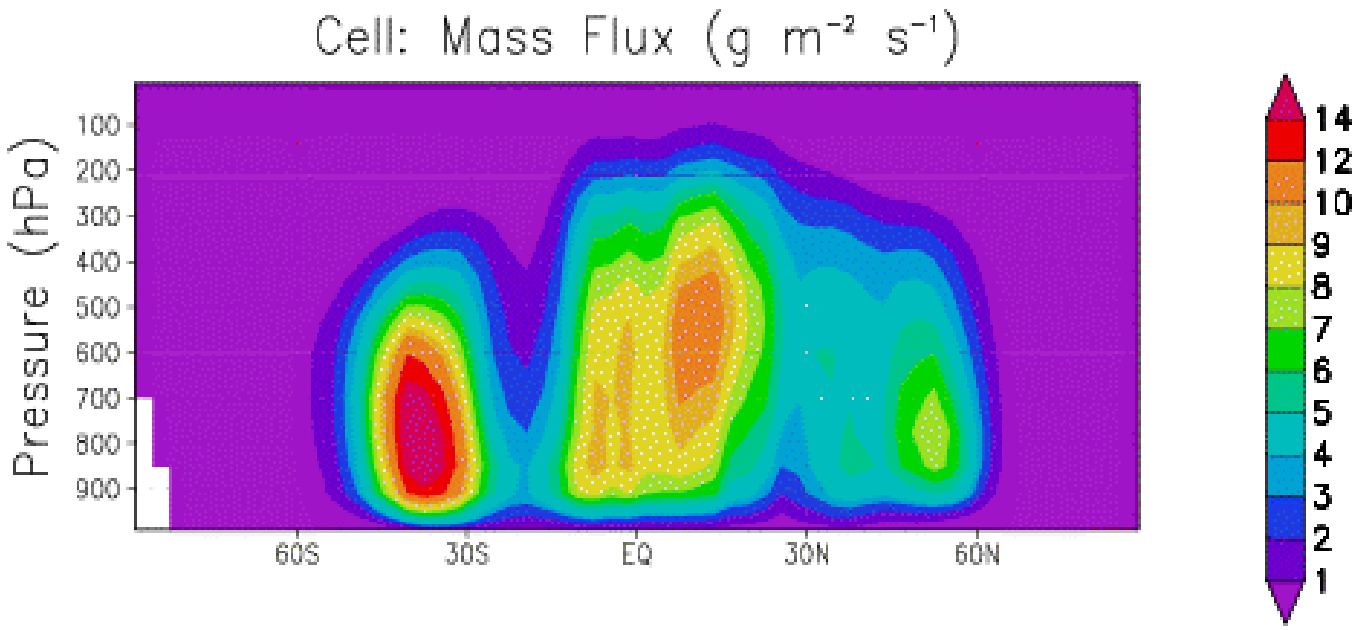
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# Effects of Cumulus Convection on Large-Scale Flow

Cumulus Parameterization Heat Source:

$$Q_\theta = \frac{\pi}{c_p}\sum_{i=1}^{6} L_i\overline{\gamma_i^*} - \frac{\partial}{\partial p}\overline{\omega'\Theta'}$$

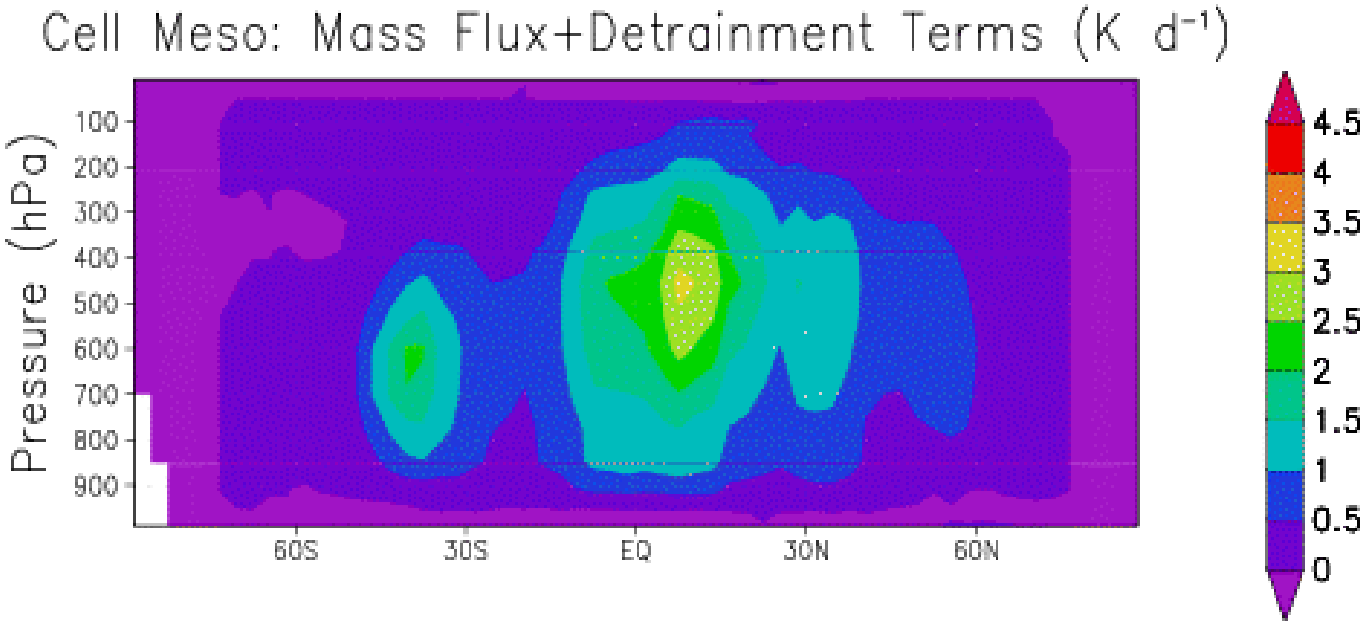
Cumulus parameterization heat source is sum of phase changes in convective system and convergence of heat fluxes associated with convective system, including compensating subsidence.

The heat source can also be expressed as

$$Q_\theta = \frac{M_C}{\rho}\frac{\partial}{\partial z}\bar{\theta} + \frac{1}{\rho}\sum_{dc} D_i(\Theta^*_{D_i} - \bar{\Theta}) + \frac{\pi}{c_p}(L_2\overline{\gamma_2^*} + L_4\overline{\gamma_4^*})$$

Physically, the RHS is the sum of mass flux, detrainment, and evaporation terms.

NOTATION: $\gamma_i$ condensation, evaporation, deposition, sublimation, freezing, and melting for $i = 1, \ldots, 6$; $M_C$ cumulus mass flux; $D_i$ detrainment from $i$th detraining cloud (dc); $\pi$ is ratio of potential temperature $\theta$ to temperature. Asterisk denotes convective-system process. $L_2 < 0, L_4 < 0$


Cell Meso: Mass Flux+Detrainment Terms (K d⁻¹)
Pressure (hPa)
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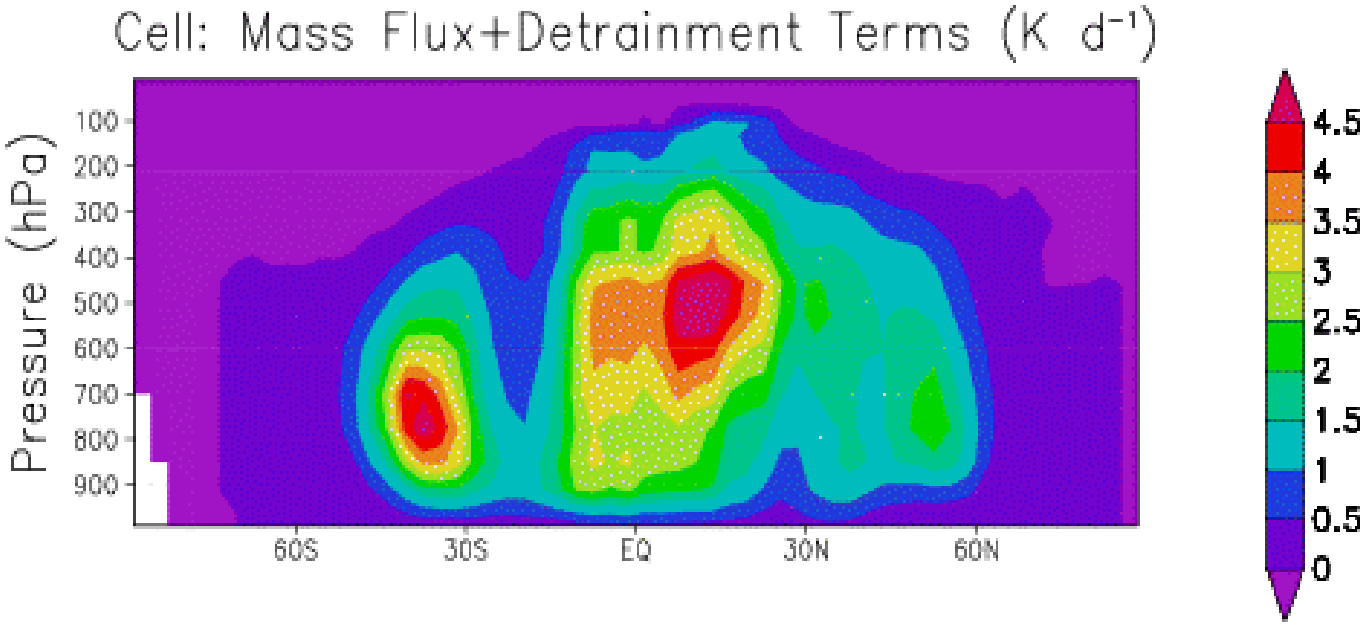
Cell: Mass Flux+Detrainment Terms (K d⁻¹)
Pressure (hPa)
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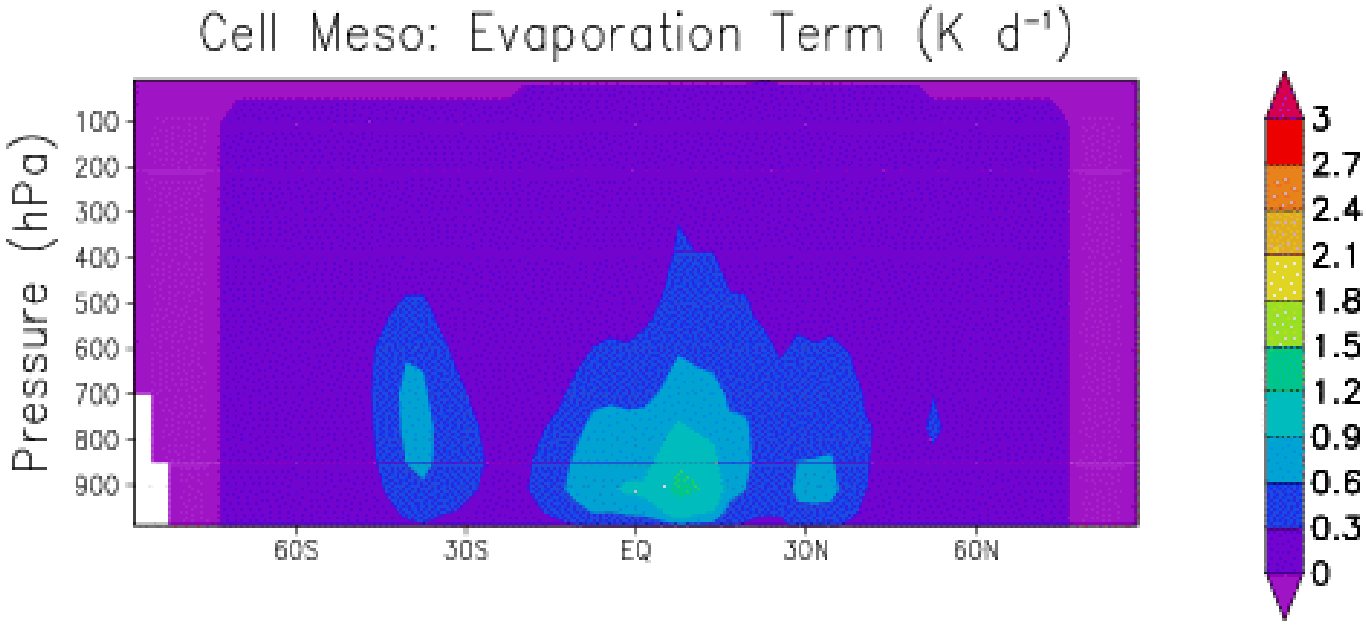
Cell Meso: Evaporation Term (K d⁻¹)
Pressure (hPa)
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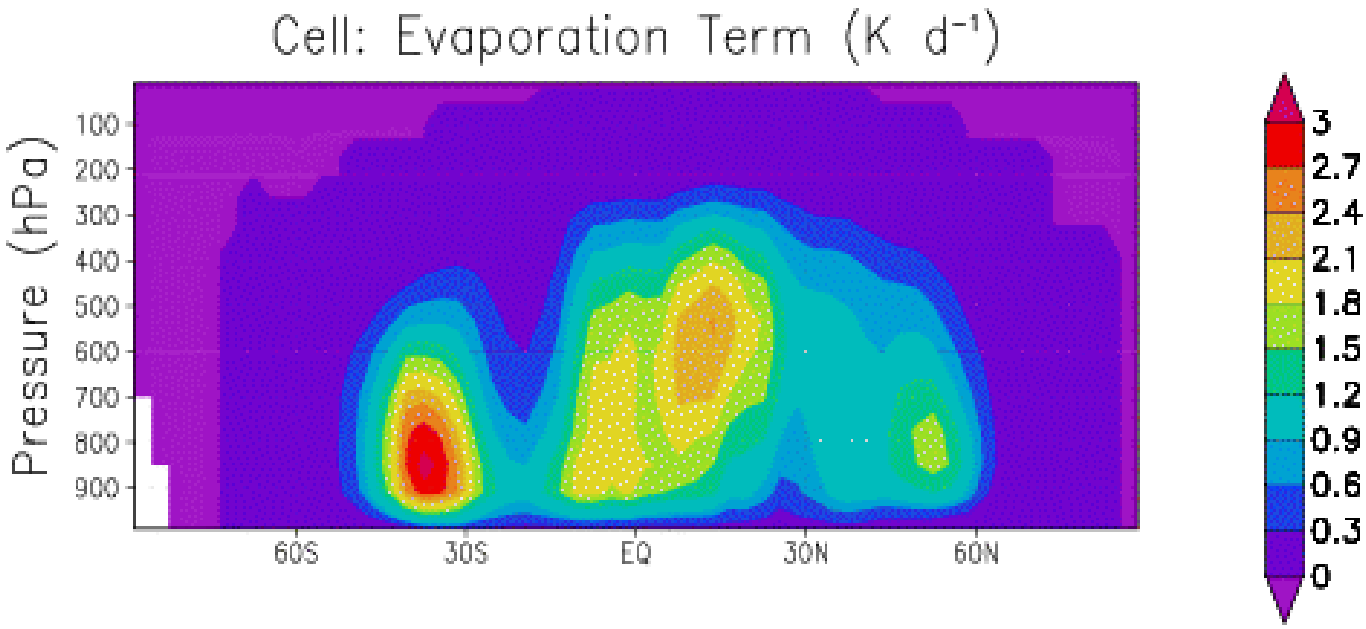
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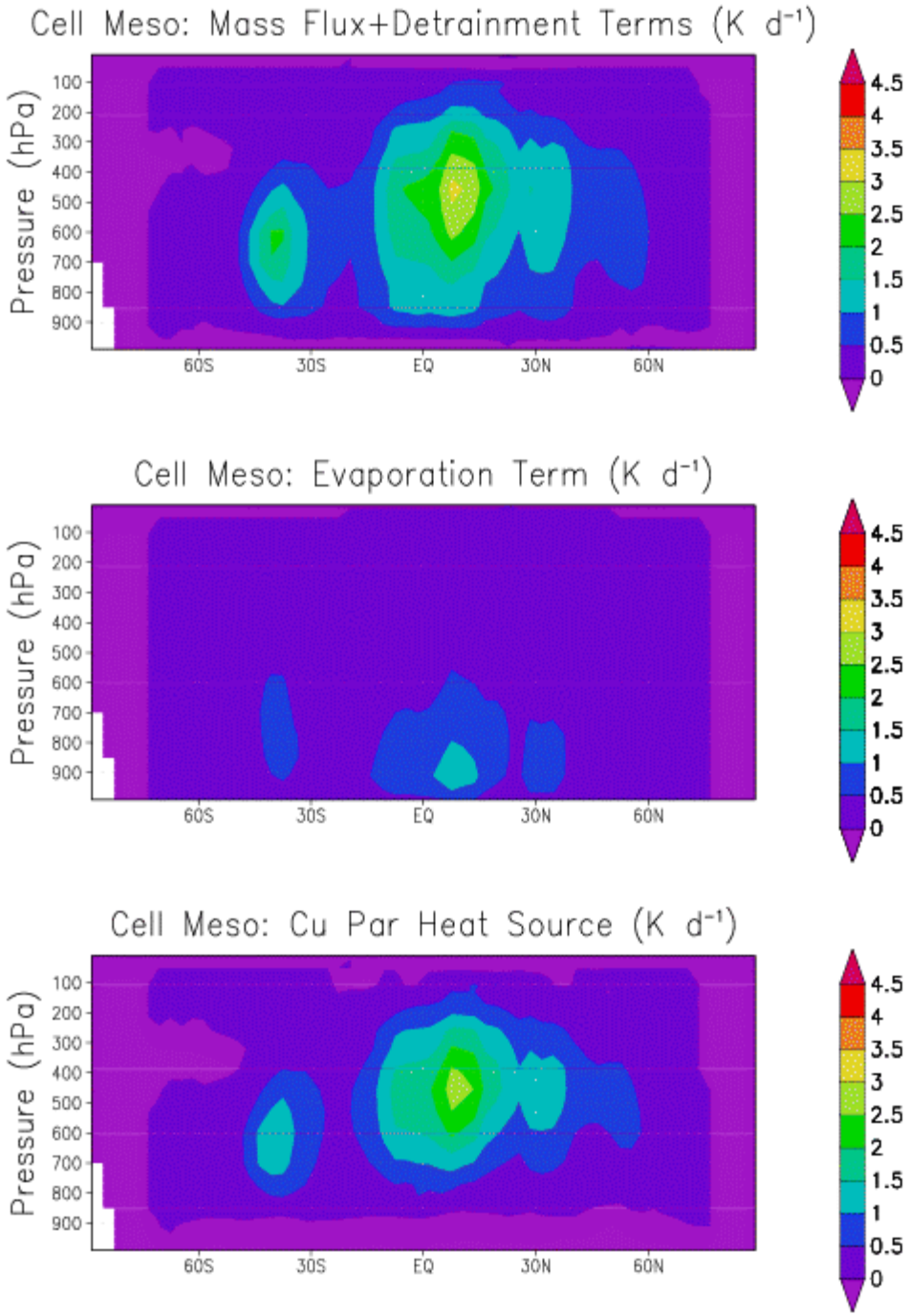
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Cell Meso: Cu Par Heat Source (K d⁻¹)
Pressure (hPa)
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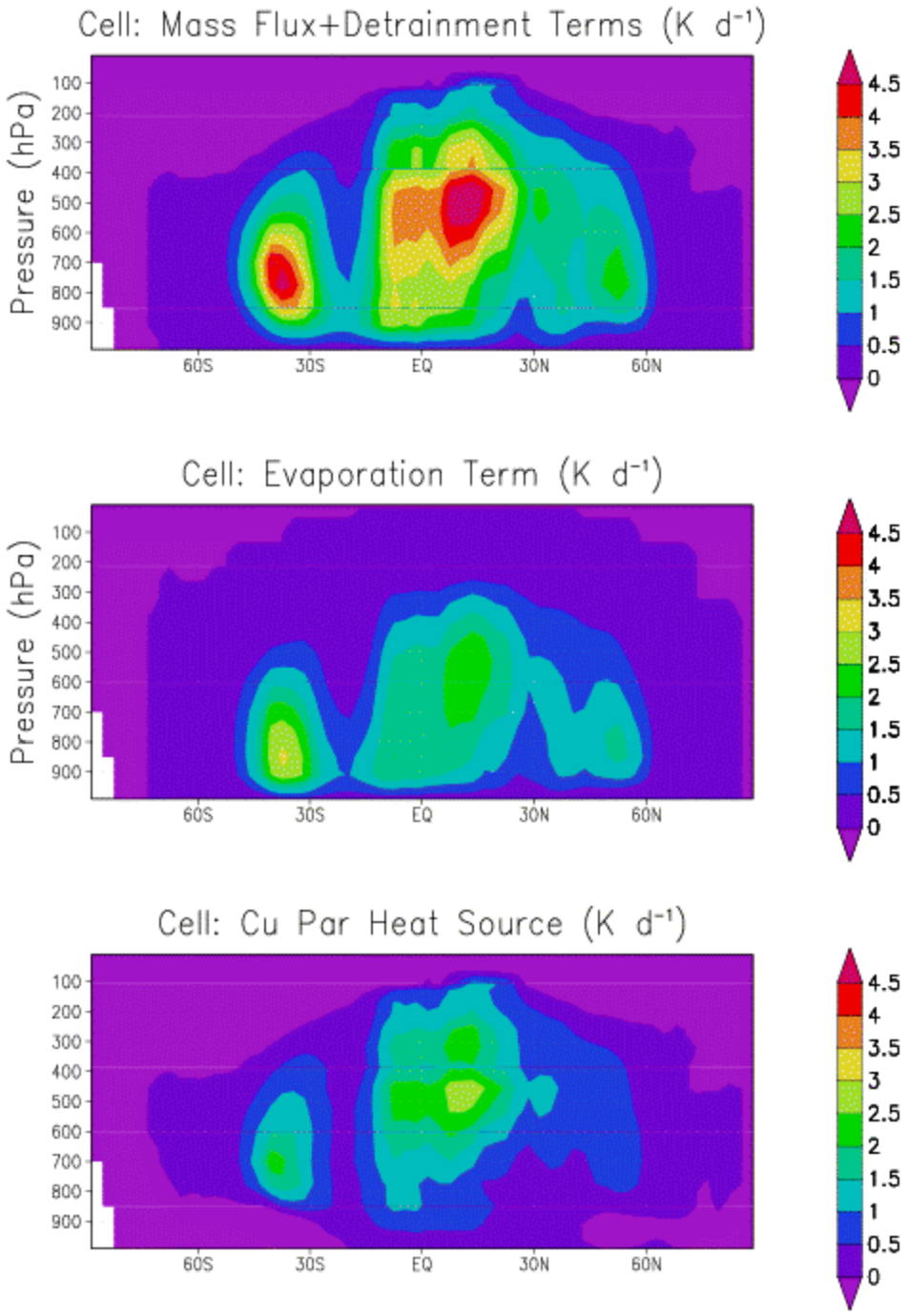
Cell: Mass Flux+Detrainment Terms (K d⁻¹)
Pressure (hPa)
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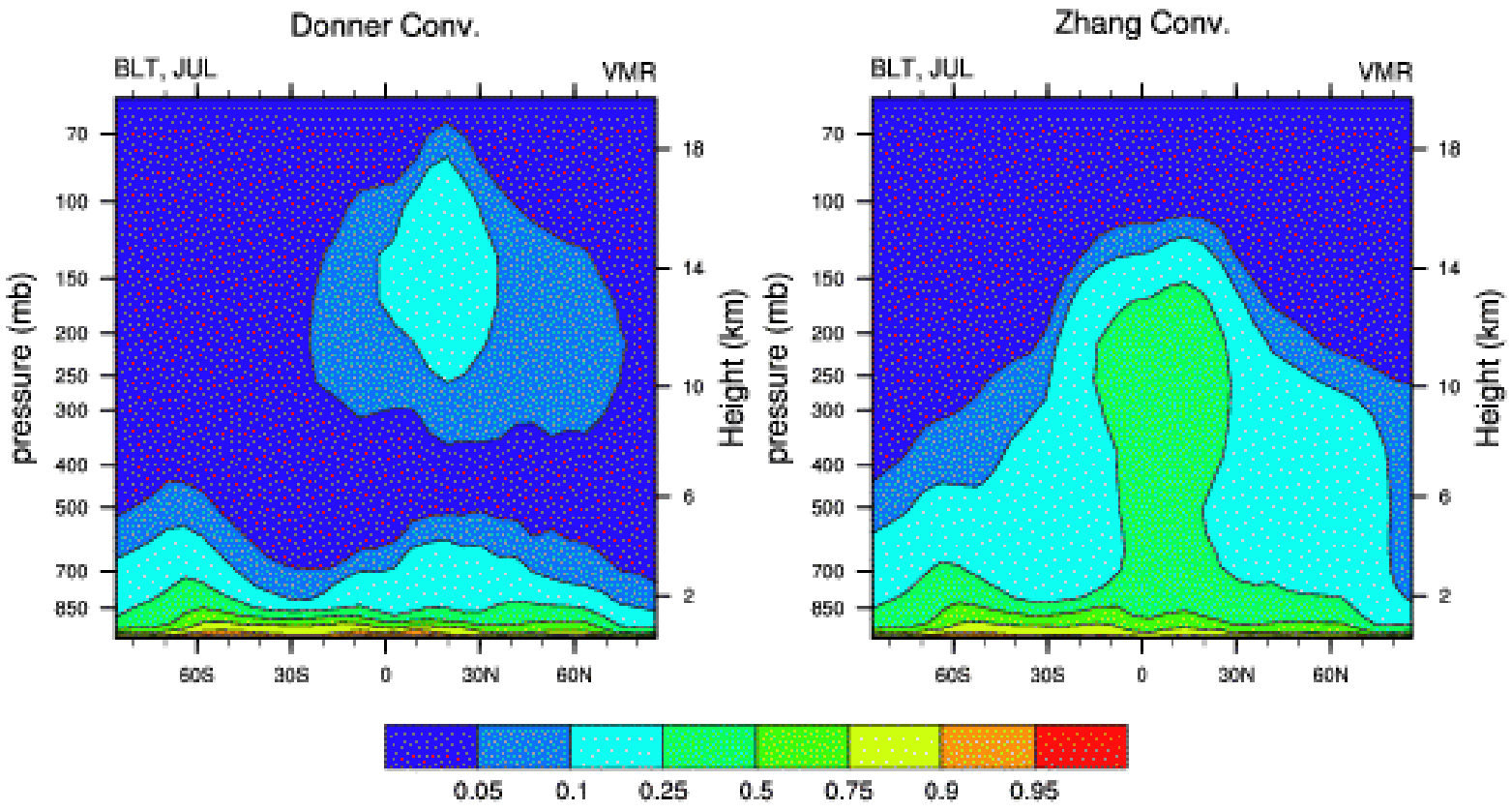
# MATCH, BL Tracer, JUL

(Donner vs. Zhang)



# Conclusions

I. Net mass fluxes in convective systems with upper-tropospheric mesoscale components are generally less than systems without such components.

II. Cumulus Heating=Subsidence+Detrainment+Evaporation

III. Evaporation (cooling) works against subsidence (heating) if it is concentrated in the middle and upper troposphere, requiring greater subsidence (mass fluxes). Middle- and upper-troposphere cooling is destabilizing, which convection works to balance. When mesoscale circulations are present, evaporation is less in the middle and upper troposphere and concentrated instead in mesoscale downdrafts in the lower troposphere, where it is stabilizing and reduces the need for convective stabilization. This is the physical reason for reduced mass fluxes when mesoscale circulations are present, even though the net heating from convective systems is much less sensitive to the presence of such circulations.

IV. In MATCH, a synthetic tracer is distributed quite differently when the Donner parameterization with mesoscale circulations is used, as opposed to when the Zhang parameterization, which does not include mesoscale circulations, is used. Changes are consistent with lower mass fluxes in Donner parameterization.

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