Environmental factors regulating deep convective updraft width across a spectrum of convective modes

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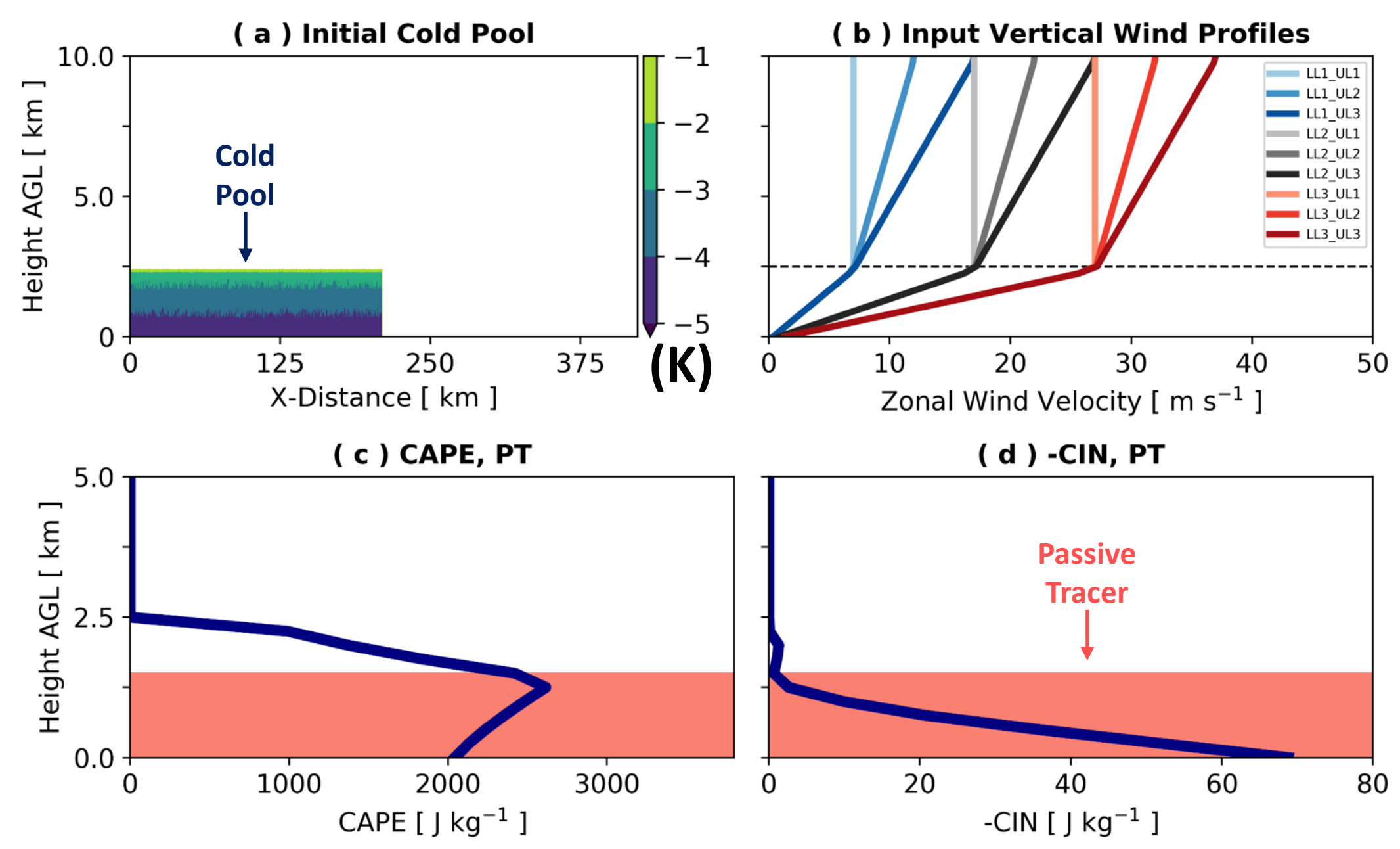
Part 1: Low- and upper-level shear variation effects on squall lines

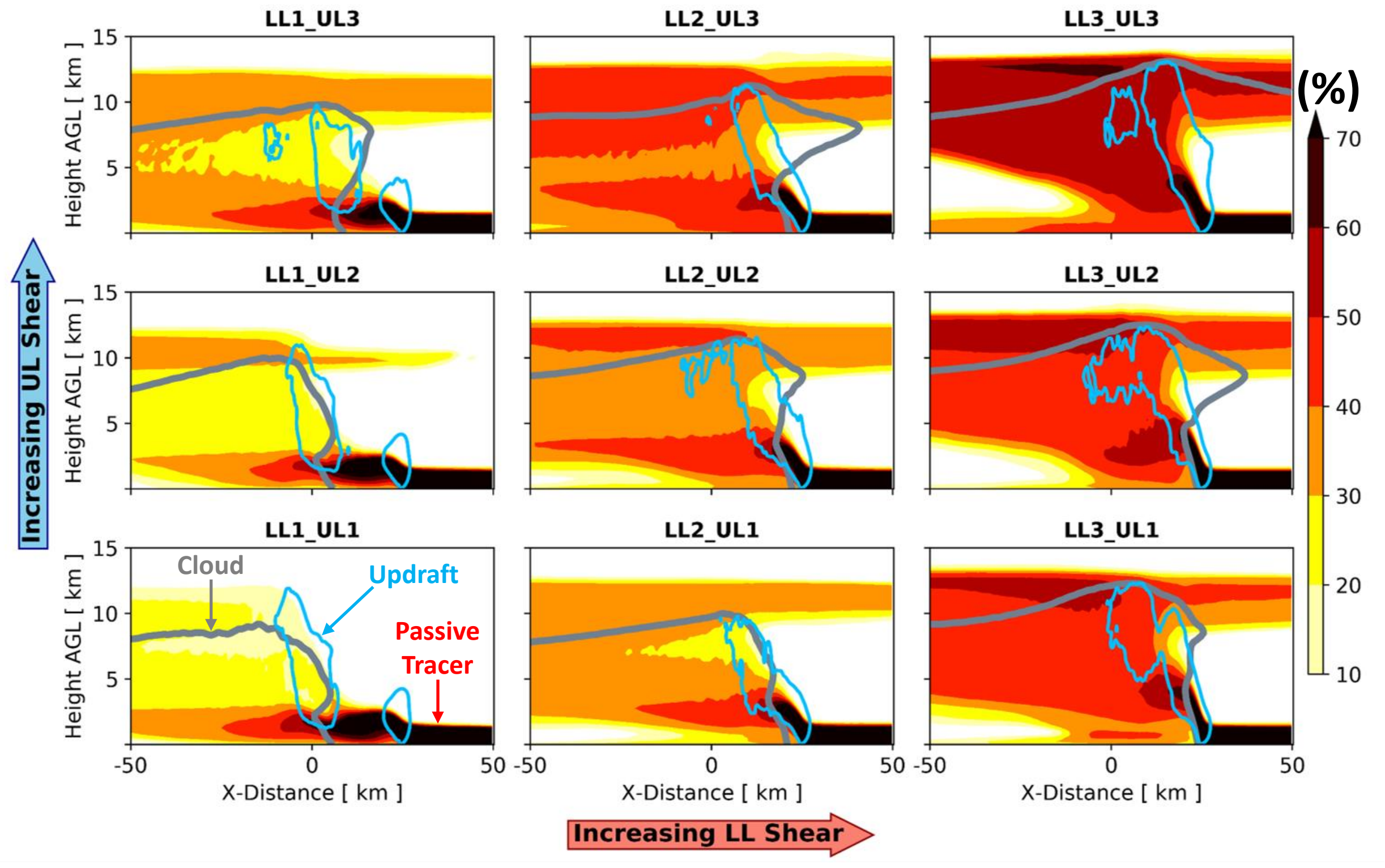
Methods

Input Parameters for CM1



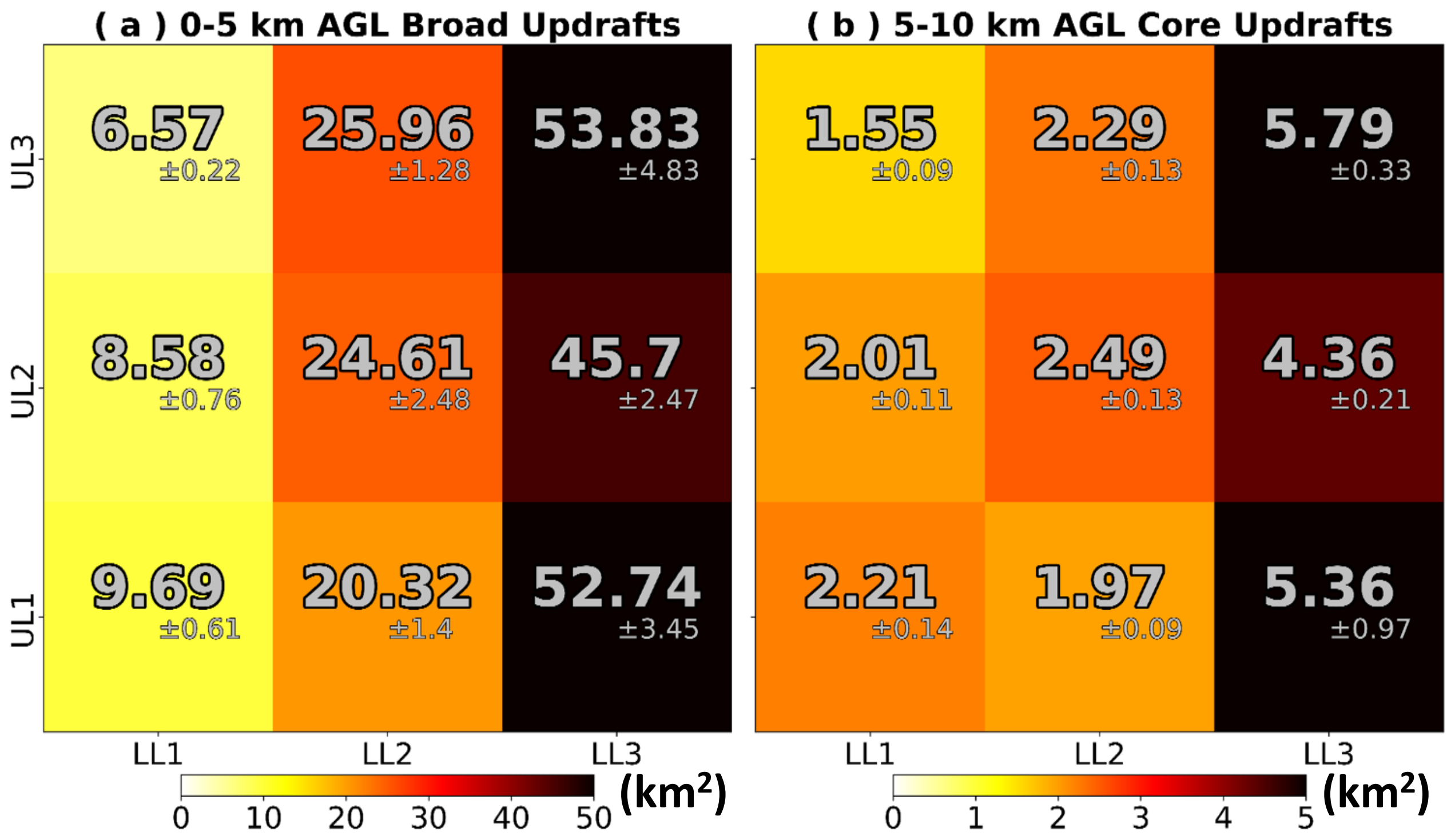
- Cloud Model 1 (CM1; Bryan and Fritsch 2002; MWR) simulations of sheared quasi-2D squall lines
- **(a)** – cross section of 2.5 km deep cold pool used to initiate quasi-2D squall lines
- **(b)** – three different low-level (0-2.5 km) and upper-level (2.5-10.0 km) shear magnitudes
- **(c)** – vertical profile of CAPE (blue line) and passive tracer layer (shading) for measuring entrainment-driven dilution
- **(d)** – vertical profile of -CIN (blue line) and passive tracer layer (shading)

Passive Tracer Concentration, Updraft, Cloud



- (a) – larger low-level "broad" ($w \geq 5$ m s^{-1}) and upper-level "core" ($w \geq 20$ m s^{-1}) updraft areas in stronger low-level shear simulations
- (b) – little sensitivity of updraft area to upper-level shear variations

Updraft Area



(a) 0-5 km AGL Broad Updrafts (km²)

	LL1	LL2	LL3
UL3	6.57 ±0.22	25.96 ±1.28	53.83 ±4.83
UL2	8.58 ±0.76	24.61 ±2.48	45.7 ±2.47
UL1	9.69 ±0.61	20.32 ±1.4	52.74 ±3.45

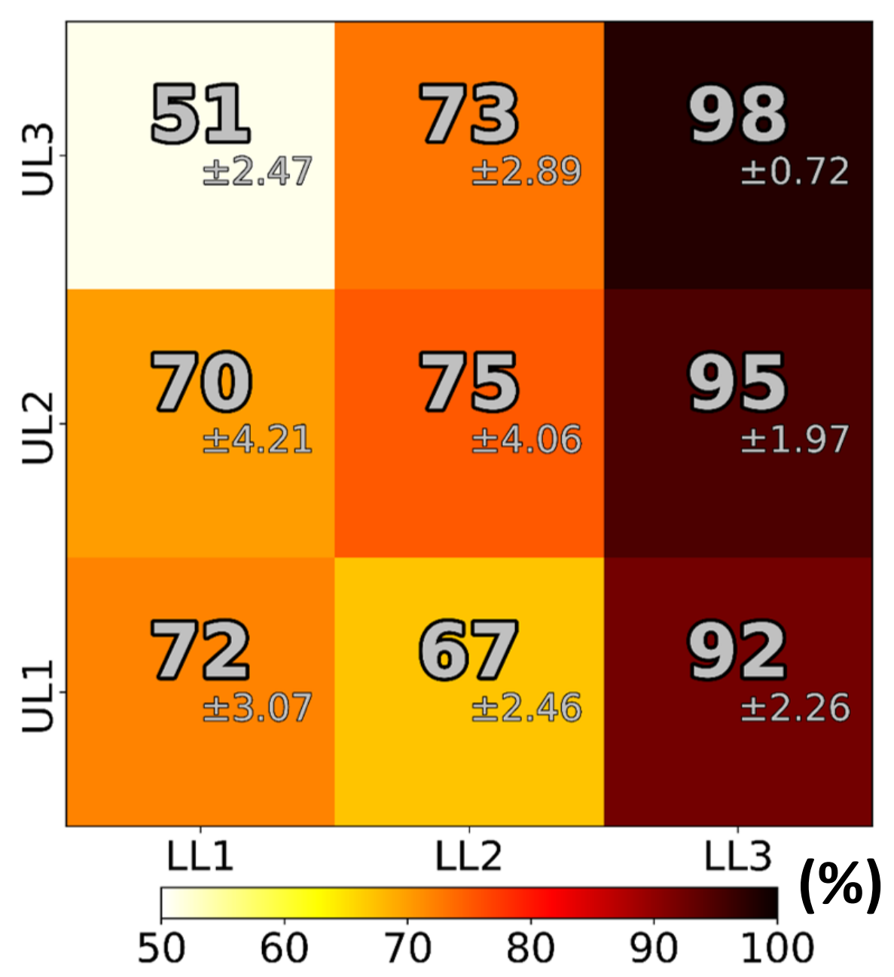
(b) 5-10 km AGL Core Updrafts (km²)

	LL1	LL2	LL3
UL3	1.55 ±0.09	2.29 ±0.13	5.79 ±0.33
UL2	2.01 ±0.11	2.49 ±0.13	4.36 ±0.21
UL1	2.21 ±0.14	1.97 ±0.09	5.36 ±0.97

Results

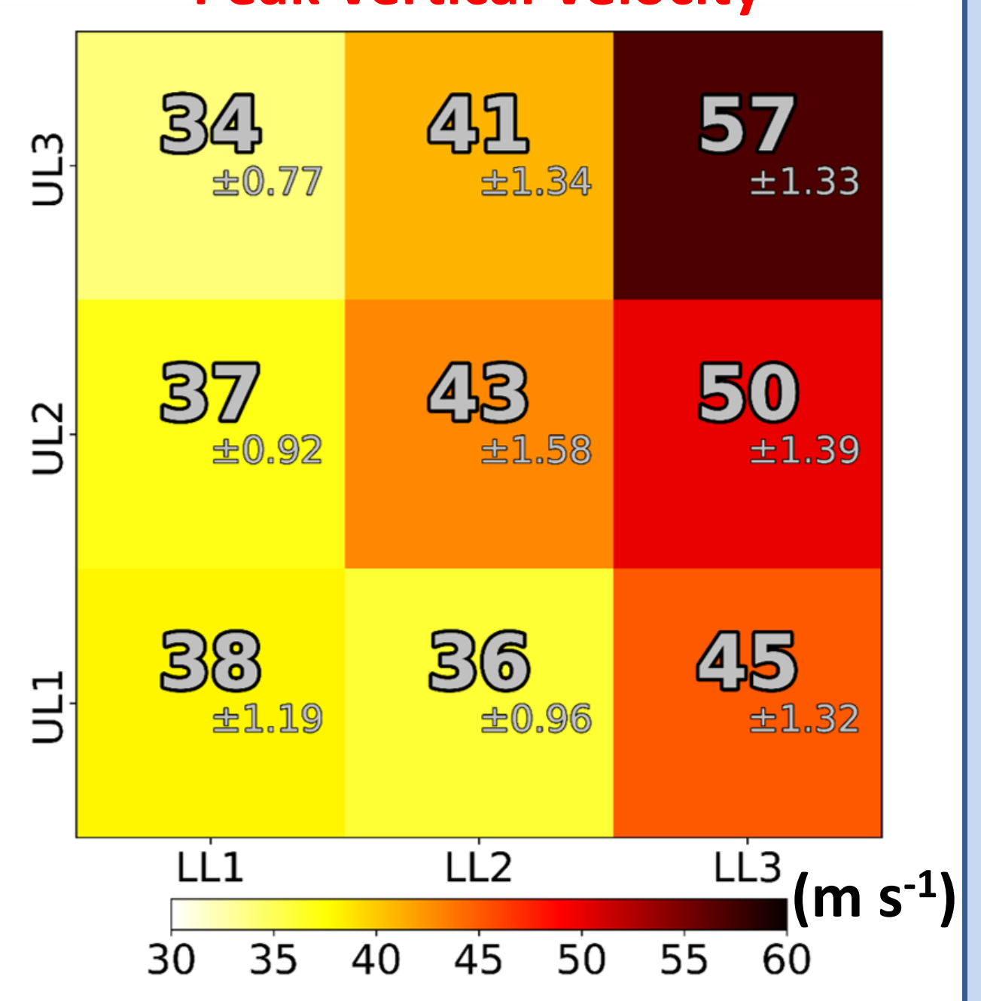
- Taller, more vertically aligned updrafts in stronger low-level shear simulations
- Reduced entrainment-driven dilution for updrafts in stronger low-level shear simulations
- Stronger peak updrafts in stronger low-level shear simulations

Passive Tracer Concentration



(%)	LL1	LL2	LL3
UL3	51 ±2.47	73 ±2.89	98 ±0.72
UL2	70 ±4.21	75 ±4.06	95 ±1.97
UL1	72 ±3.07	67 ±2.46	92 ±2.26

Peak Vertical Velocity



(m s⁻¹)	LL1	LL2	LL3
UL3	34 ±0.77	41 ±1.34	57 ±1.33
UL2	37 ±0.92	43 ±1.58	50 ±1.39
UL1	38 ±1.19	36 ±0.96	45 ±1.32

Conclusions

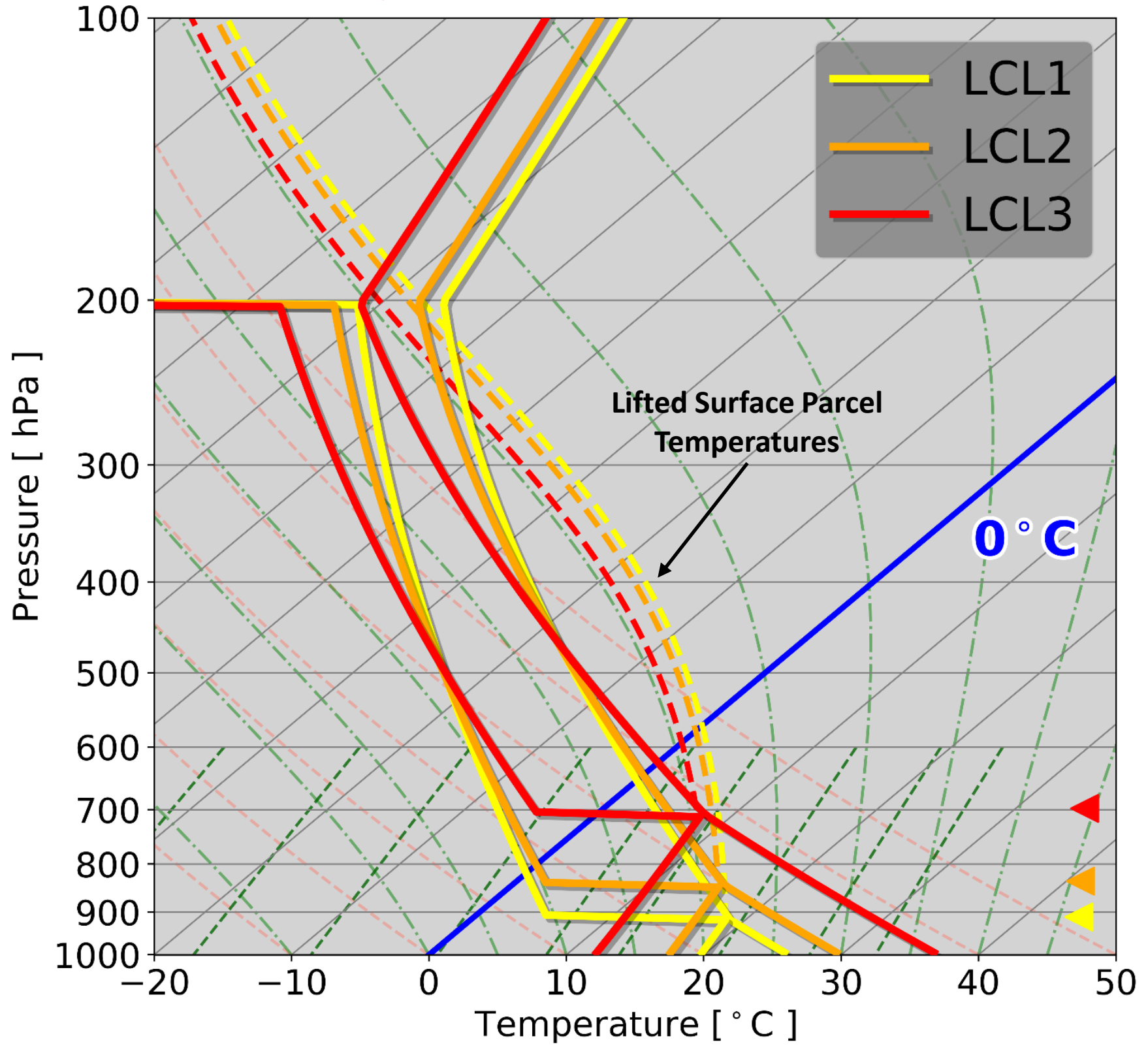
- Squall line updraft properties are more sensitive to variations in low-level shear as opposed to variations in upper-level shear
- Simulations with stronger low-level shear exhibited updrafts that were ***wider, less dilute, stronger, and taller***
- Results build upon Alfaro and Khairoutdinov (2015; JAS) and Alfaro (2017; JAS)

Mulholland, J. P., J. M. Peters, and H. Morrison, 2021: How does vertical wind shear influence entrainment in squall lines? *J. Atmos. Sci.*, **78**, 1931–1946, https://doi.org/10.1175/JAS-D-20-0299.1

Part 2: LCL height variation effects on unsheared deep convection

Methods

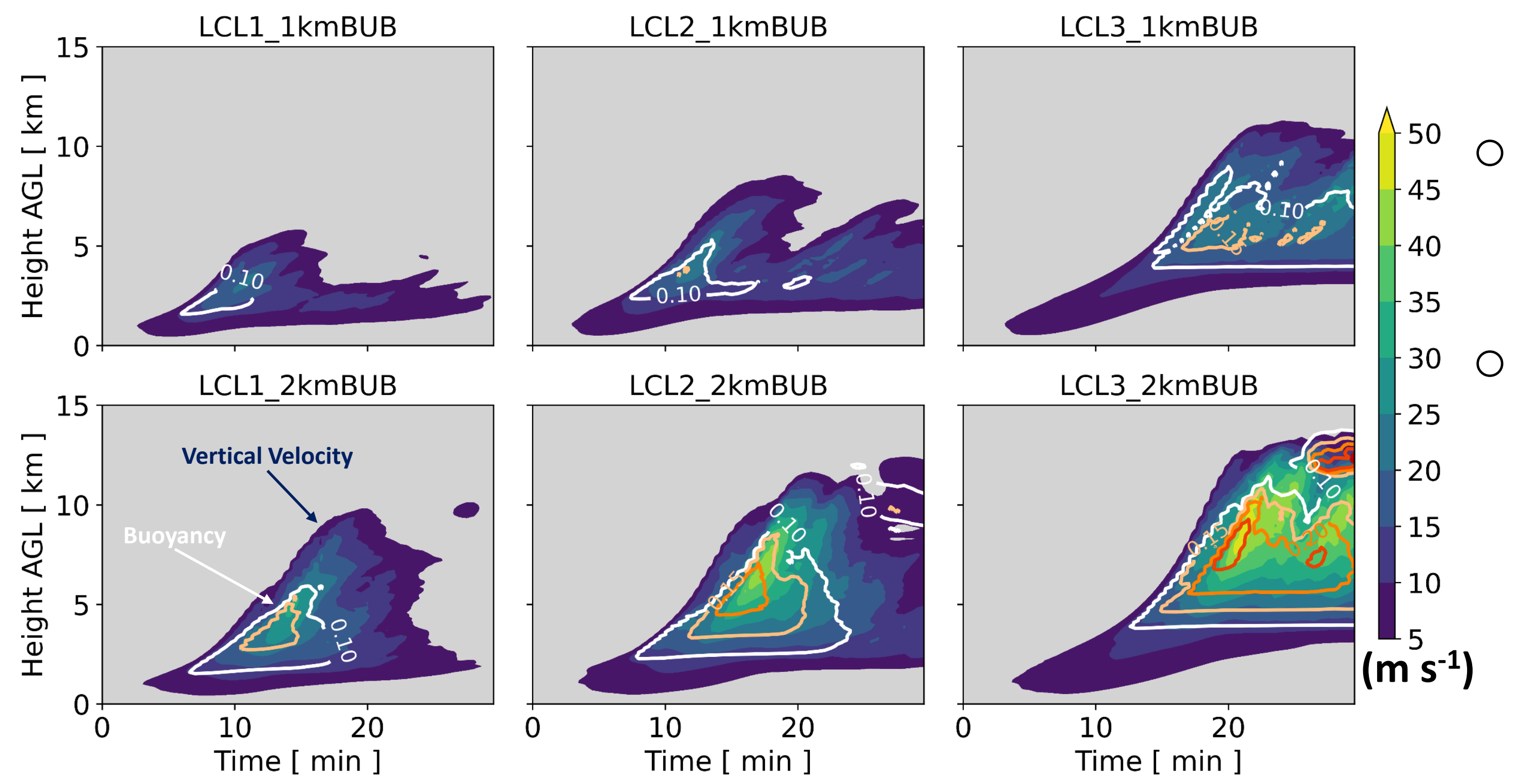
Input Parameters for CM1



- Cloud Model 1 (CM1; Bryan and Fritsch 2002; MWR) simulations of unsheared deep convection
- Three different LCL heights:
  - LCL1 = 0.5 km
  - LCL2 = 1.5 km
  - LCL3 = 3.0 km
- Slight decrease in convective available potential energy (CAPE) as the LCL height was raised

Results

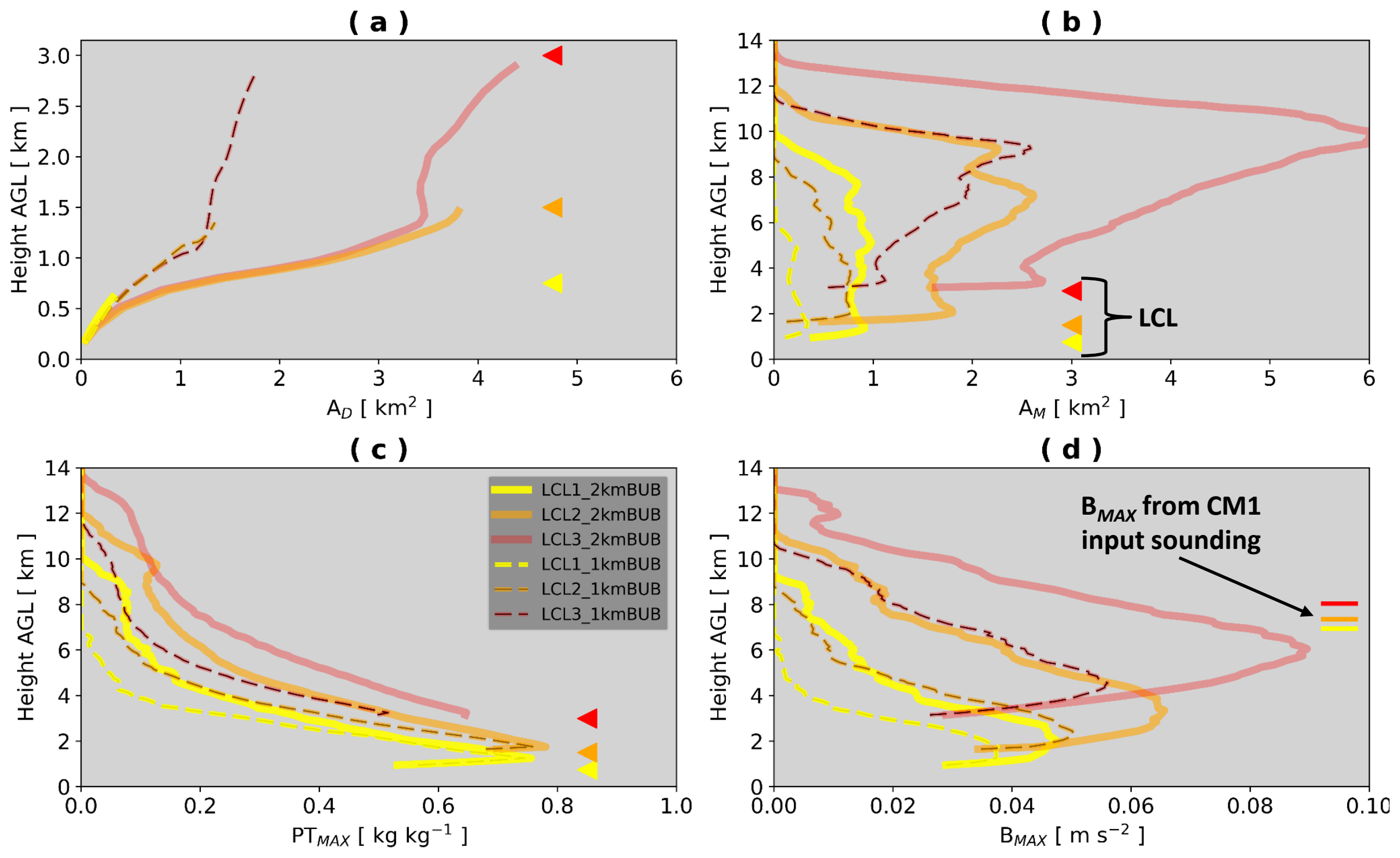
Vertical Velocity, Buoyancy



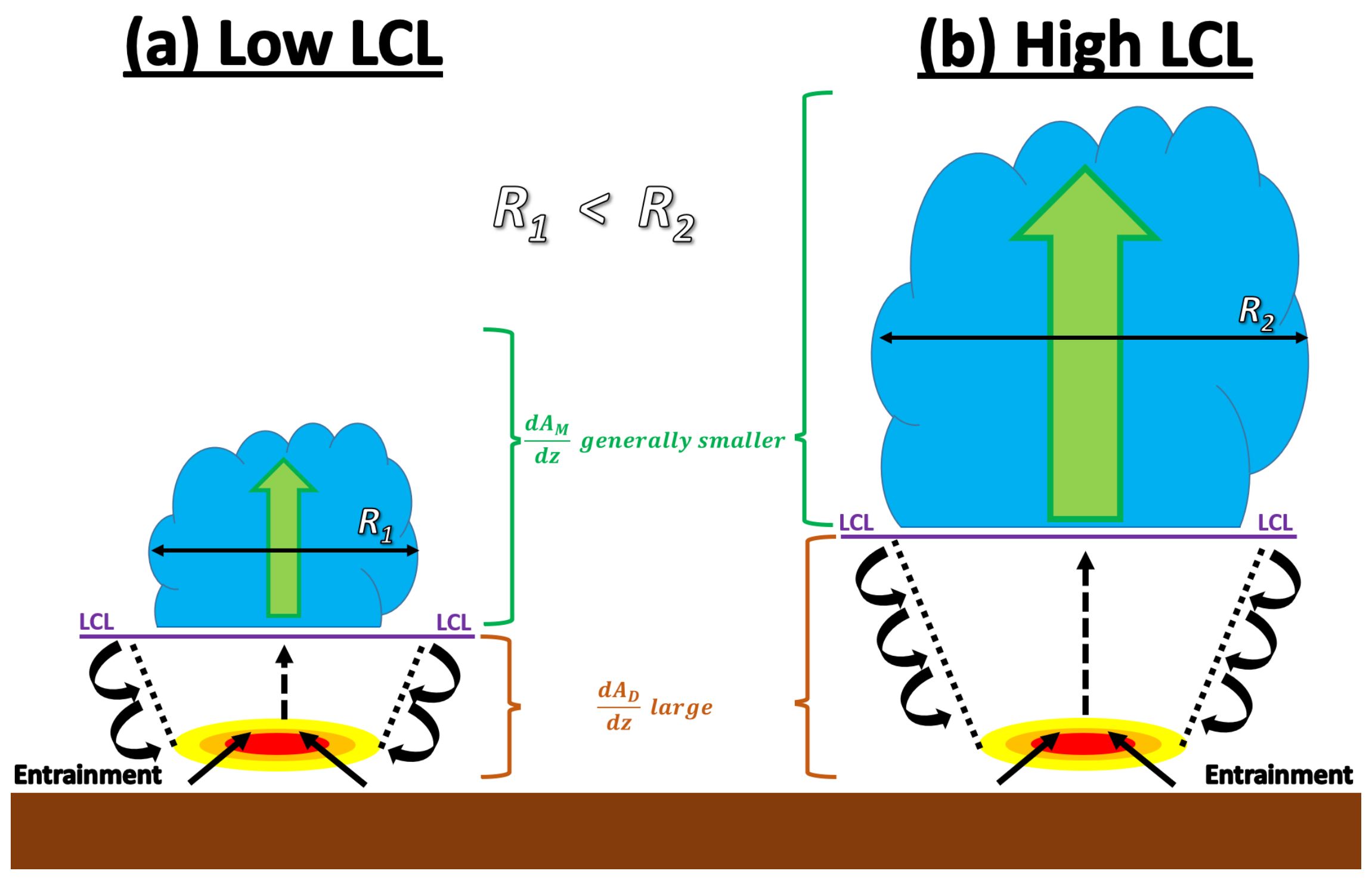
- Convection takes longer to develop in higher LCL simulations
- Longer-lasting, deeper, stronger, and more buoyant deep convection in the higher LCL simulations

Thermal Tracking Attributes

- (a) – larger dry updraft area (A_D) at LCL for higher LCL simulations
- (b) – larger moist updraft area (A_M) above LCL for higher LCL simulations
- (c) – less entrainment-driven dilution (i.e., larger PT_{MAX}) in higher LCL simulations
- (d) – larger buoyancy (B_{MAX}) in higher LCL simulations



Conclusions



- Rising and expanding dry thermals/updrafts below LCL have a greater vertical distance to traverse before reaching saturation and forming clouds in higher LCL environments (Williams and Stanfill 2002; PHY)
- This process "sets the stage" for wider moist updrafts above the LCL
- Resulting clouds in higher LCL environments are ***wider, less dilute, stronger, and deeper***

Mulholland, J. P., J. M. Peters, and H. Morrison, 2021: How does LCL height influence deep convective updraft width? *Geophys. Res. Lett.*, **48**, 1–8, https://doi.org/10.1029/2021GL093316

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NSF AGS-1928666, NSF AGS-1841674, DOE-ASR DE-SC0020104, and DOE DE-SC0000246356