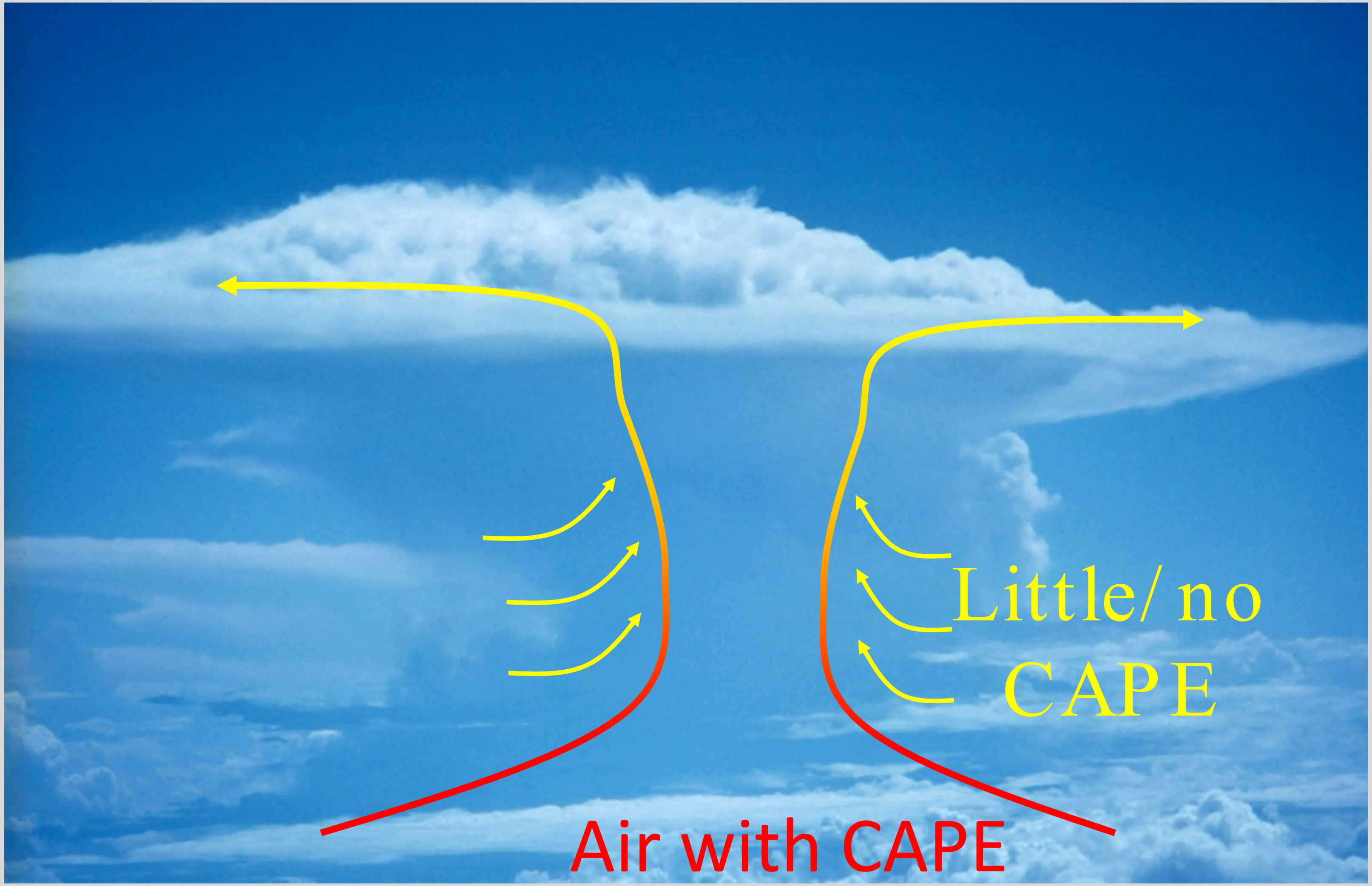
Toward a unified perspective on what controls entrainment in deep convection

John M. Peters
Assistant Professor
Department of Meteorology and Atmospheric Science
Penn State University

ASR
Atmospheric System Research

Entrainment: the engulfment of environmental air by a cloud



Reduces cloud buoyancy via dilution

Entrainment: the engulfment of environmental air by a cloud

Large entrainment

Small entrainment

1 km^{-1} (Shallow Cu)

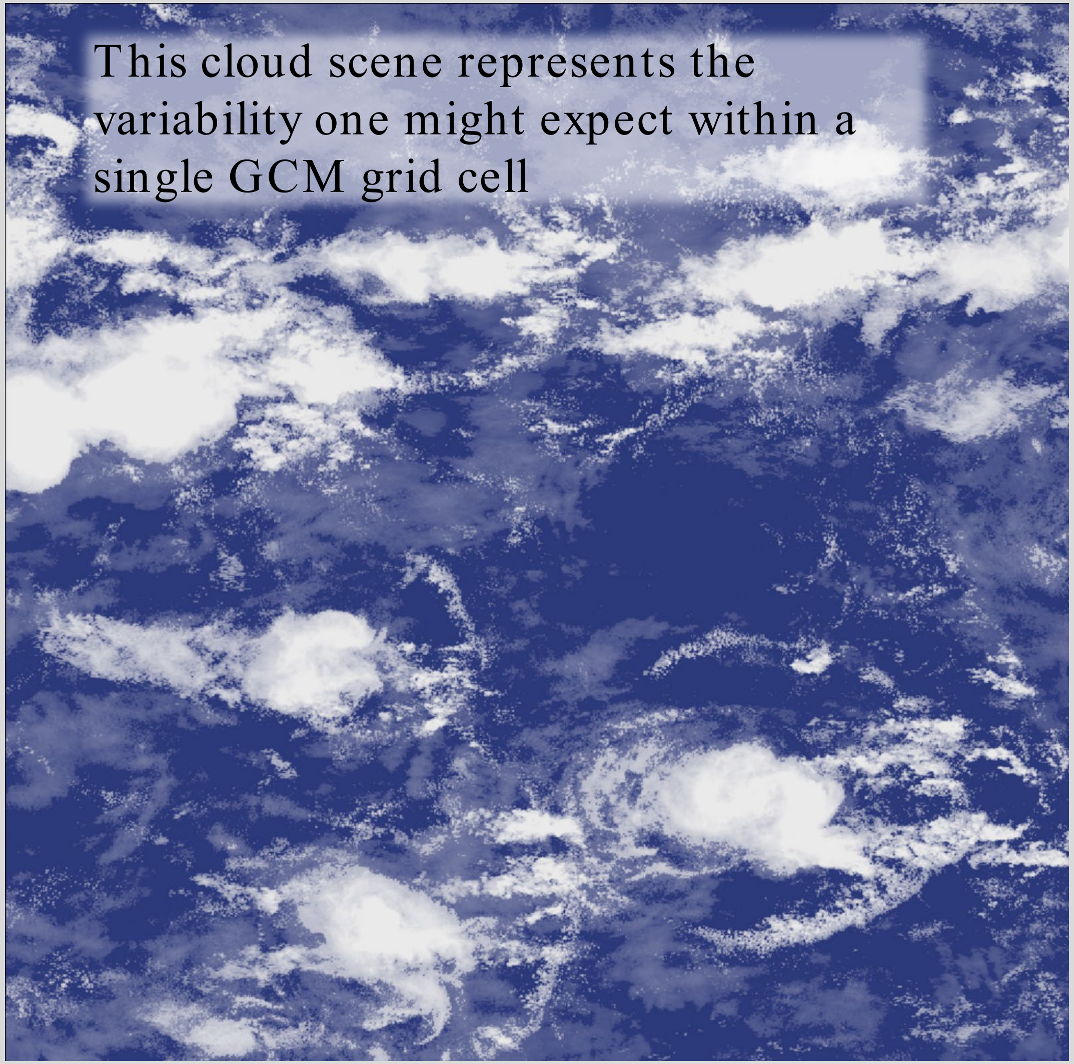
.5 km^{-1} (Congestus)

.1 km^{-1} (Most tropical deep convection, disorganized midlatitude deep convection)

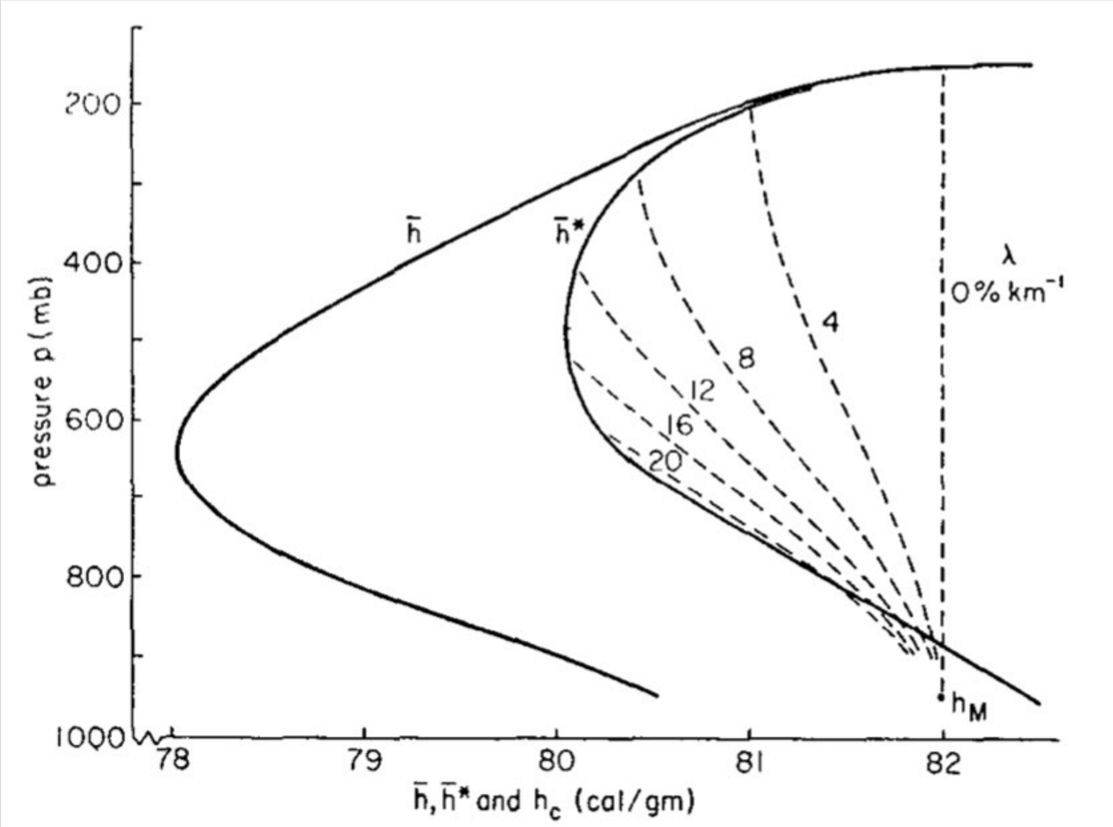
.05 km^{-1} (MCSs)

.01 km^{-1} (Supercells, TCs?)

Entrainment is a central element to cumulus parameterizations

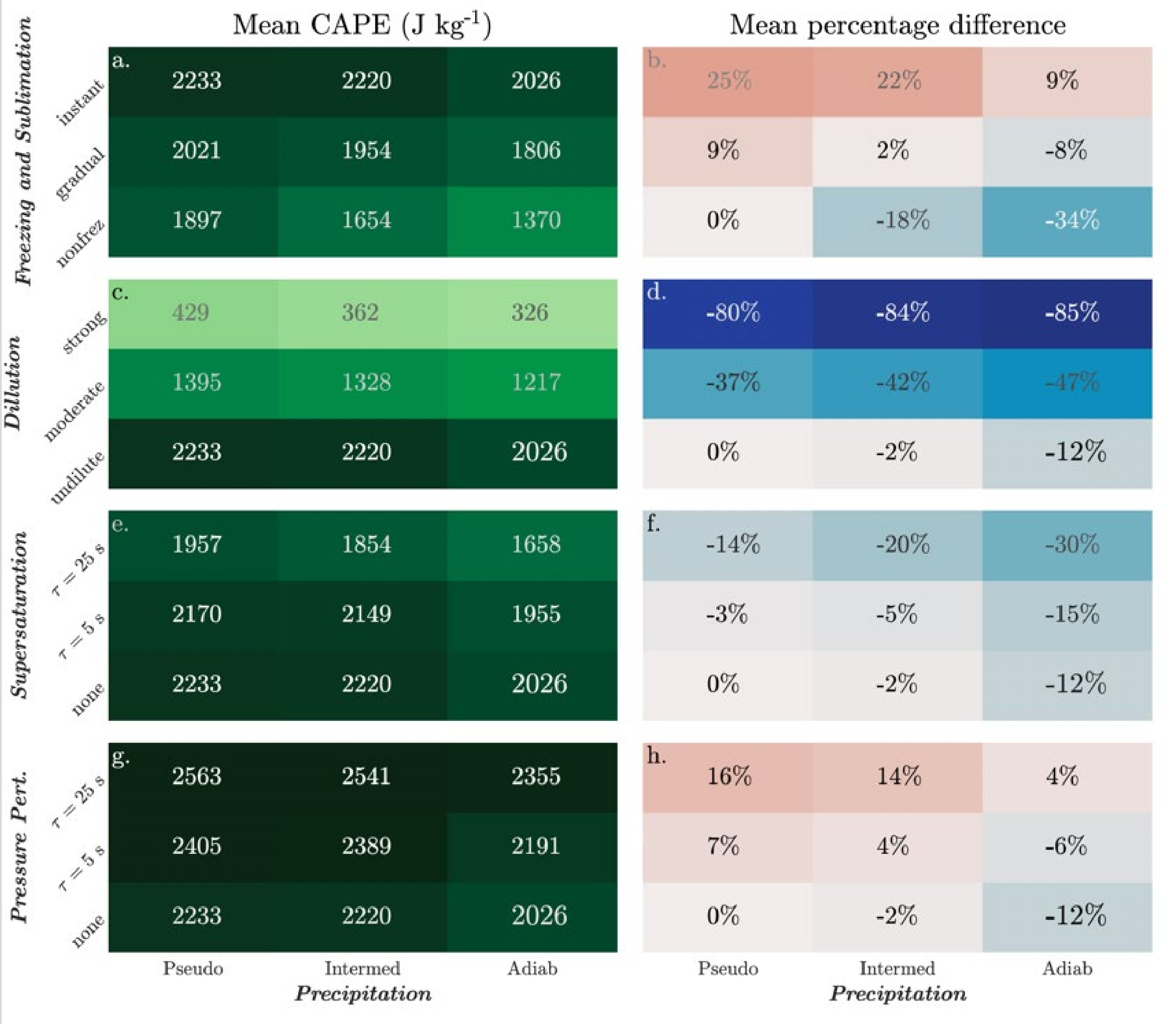


From Khairoutdinov et al. (2009)



From Arakawa and Schubert (1974)

Understanding entrainment is also important to forecasting convection



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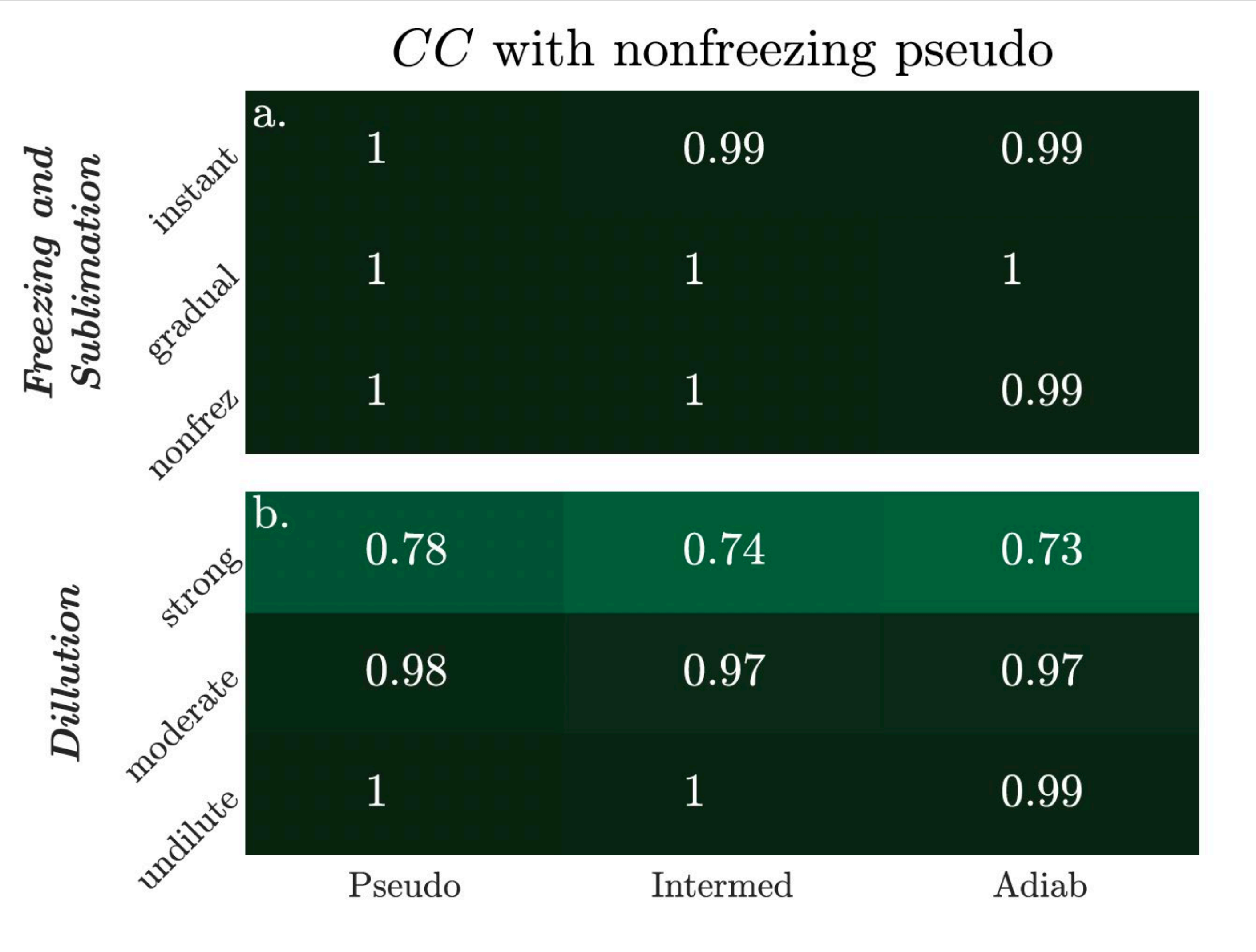
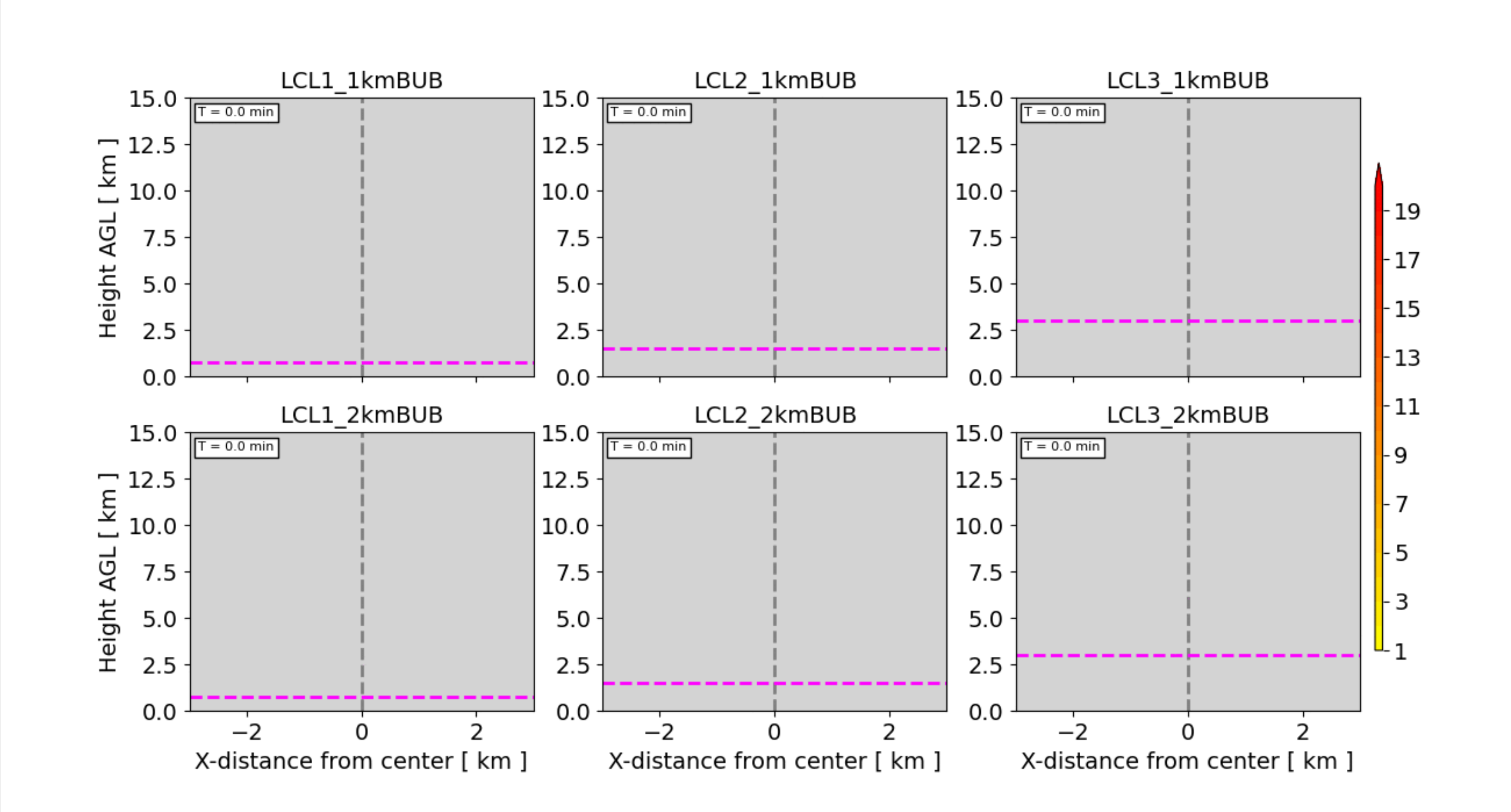


Deeper PBL, higher LCL, equates to wider updrafts and weaker fractional entrainment



Simulations from Mulholland, Peters, and Morrison (2021)

Hypothesized factors that regulate entrainment

Weak shear

Strong Shear

LCL height?

Cold pools?

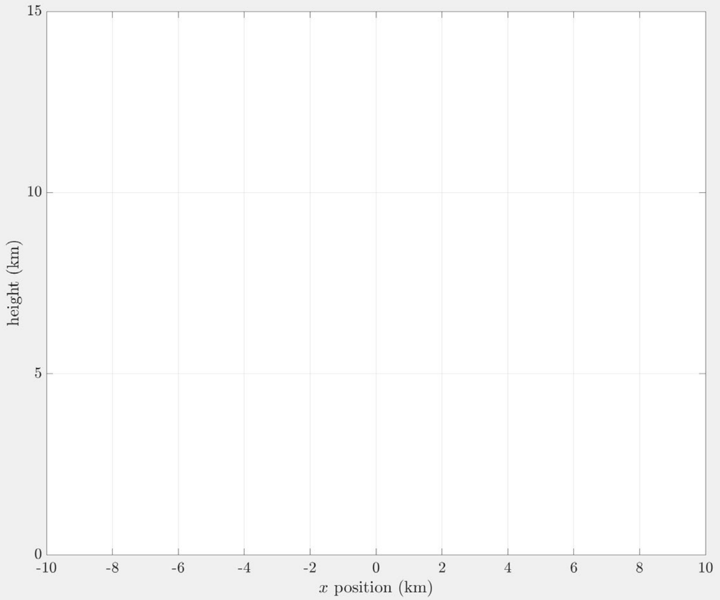
Airmass boundaries?

Cloud organization?

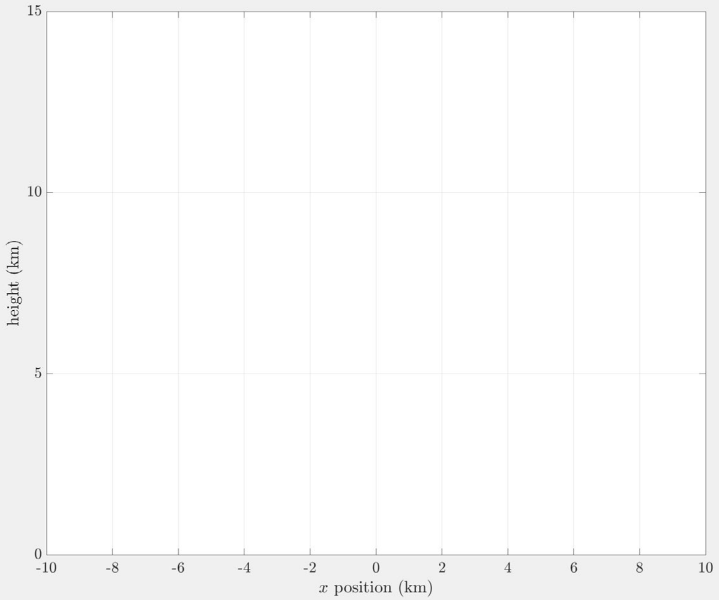
The shear magnitude itself

Shear – may increase entrainment in initial developing updrafts

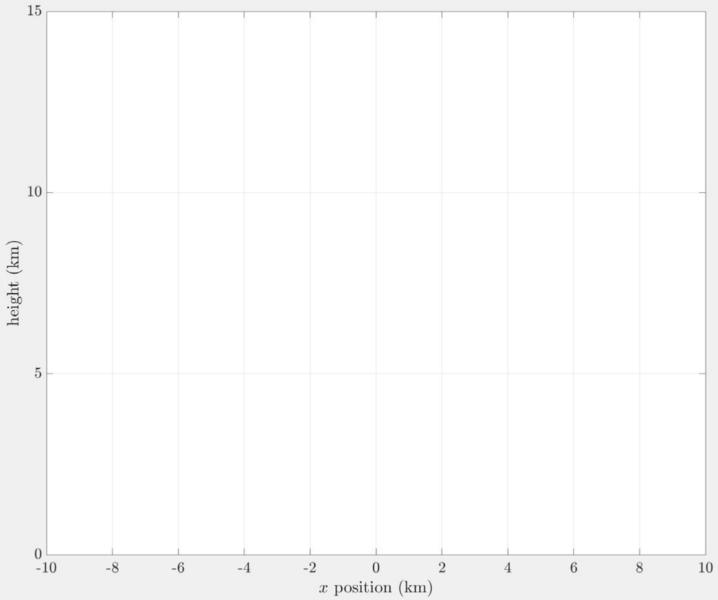
No Shear



Moderate Shear



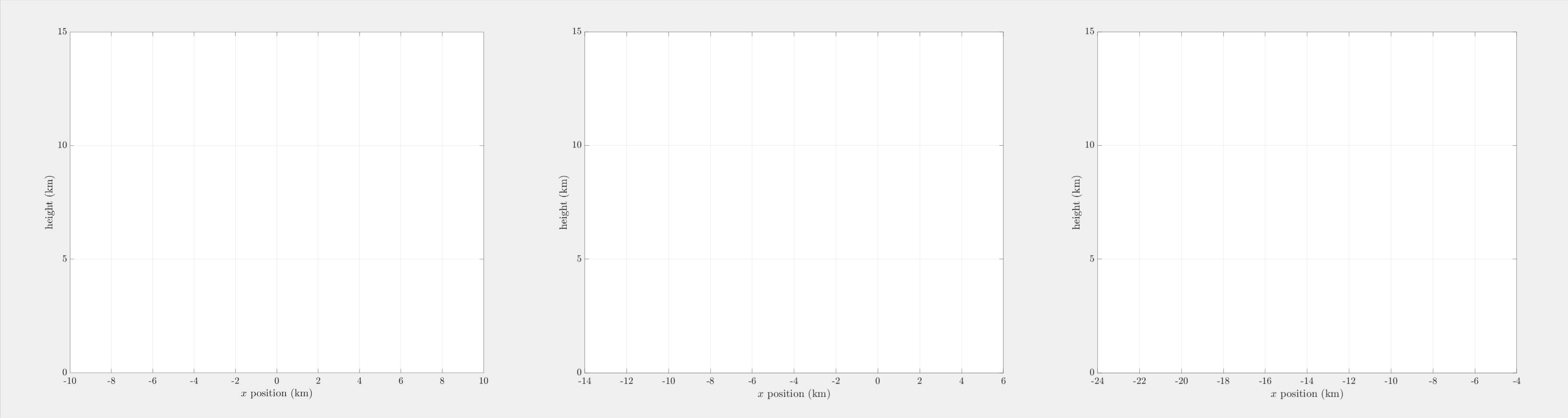
Strong Shear



Simulations from Peters et al. (2022)

But ultimately reduces it once updrafts have matured

No Shear Moderate Shear Strong Shear

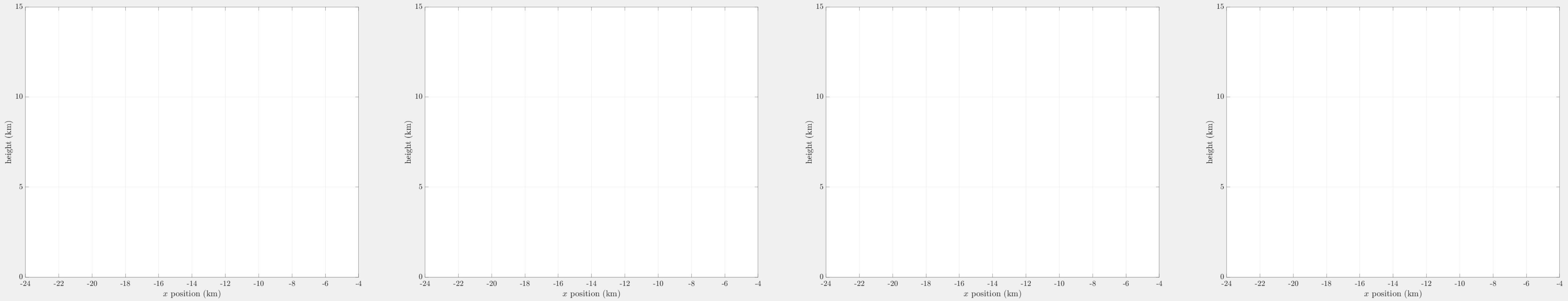


Simulations from Peters et al. (2022)

Only small changes to environment translate to big changes in entrainment effects

Initial forcing radii

1800 m ***1900 m*** ***2000 m*** ***2100 m***



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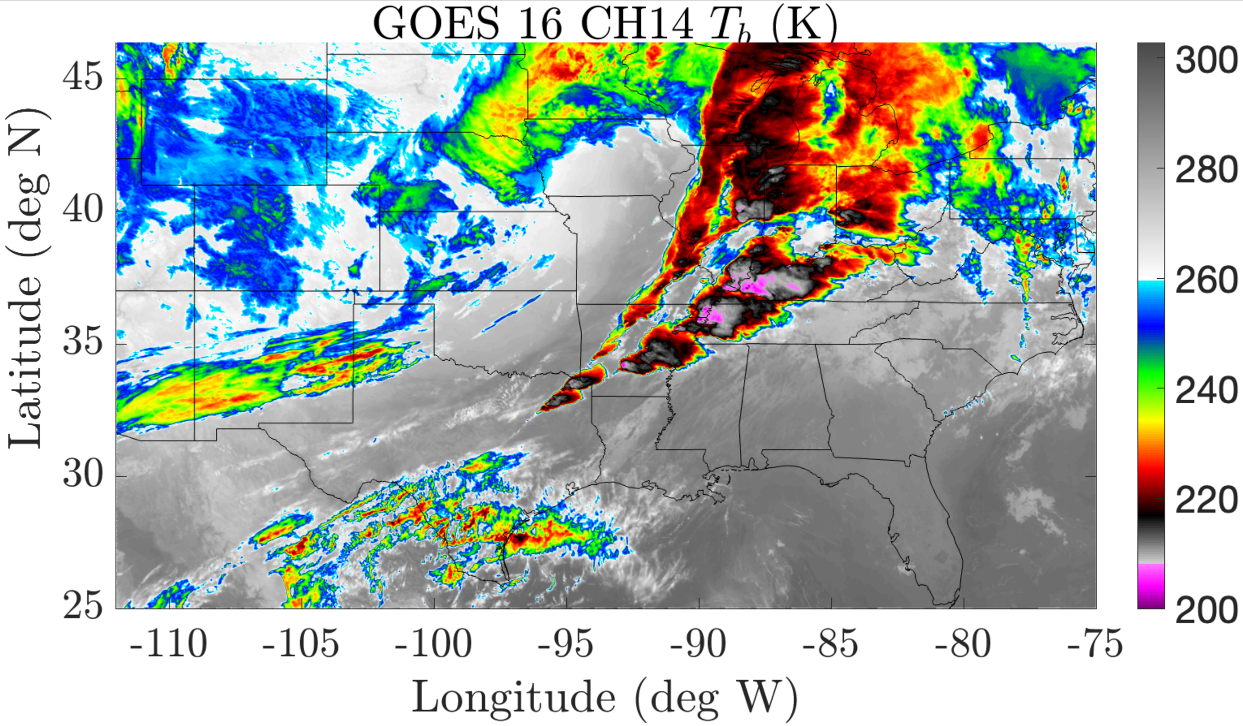
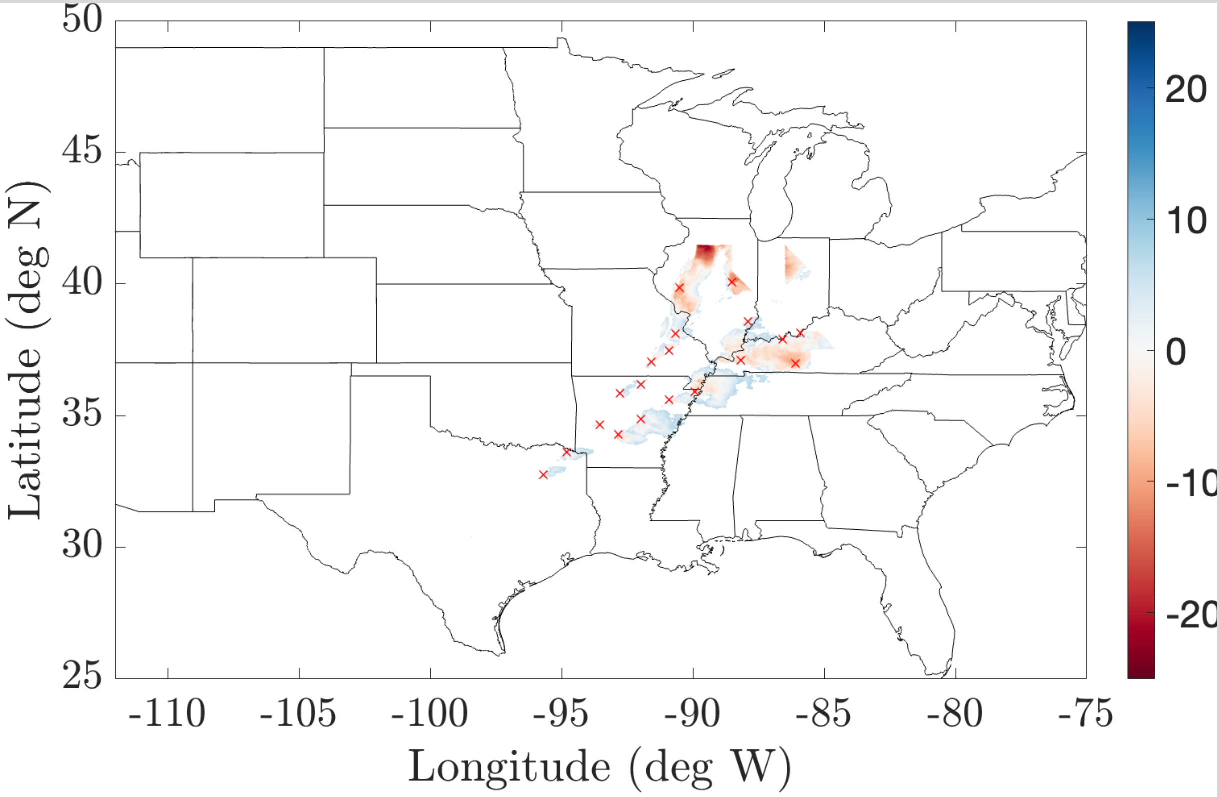
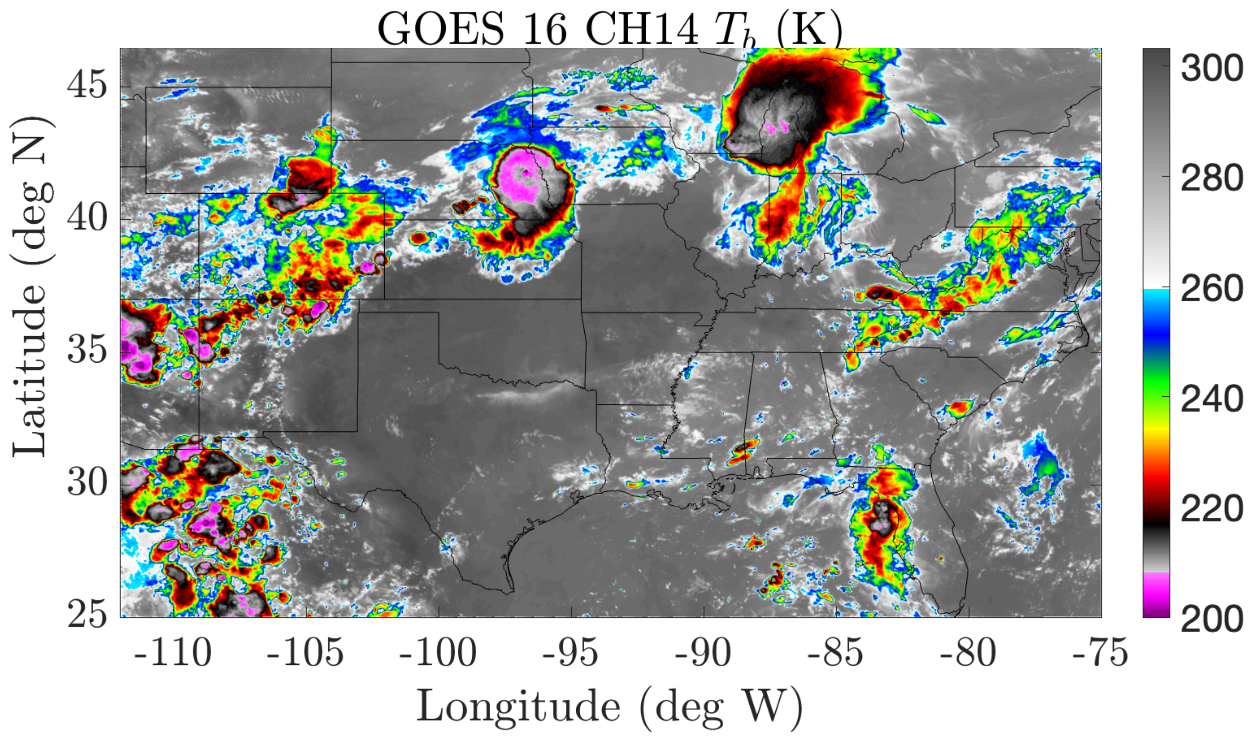
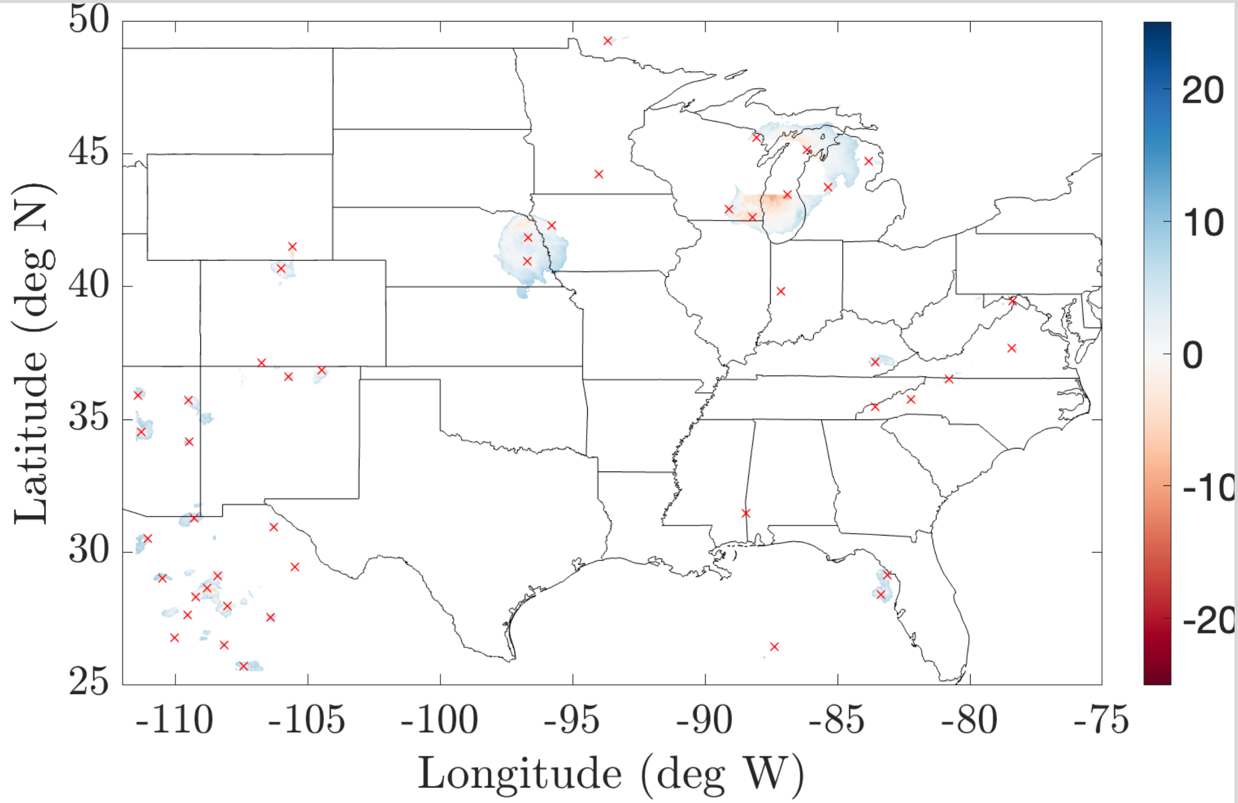




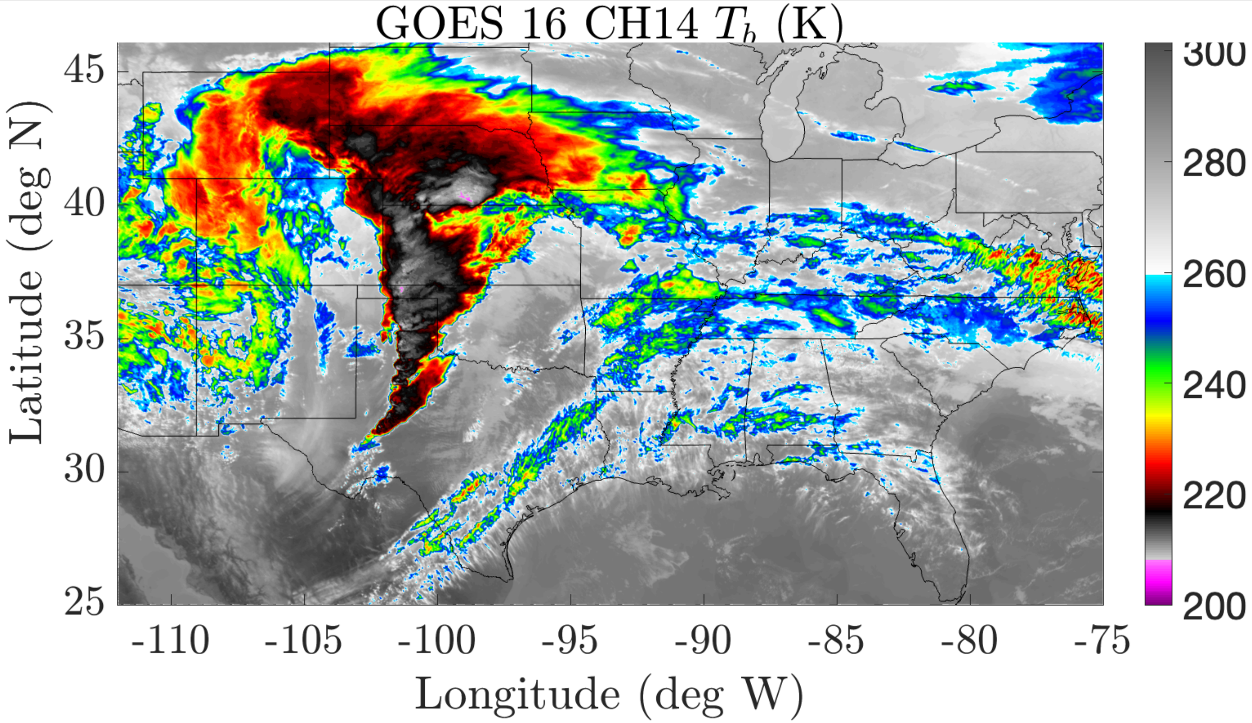
Percentage temp difference of anvil from undiluted EL

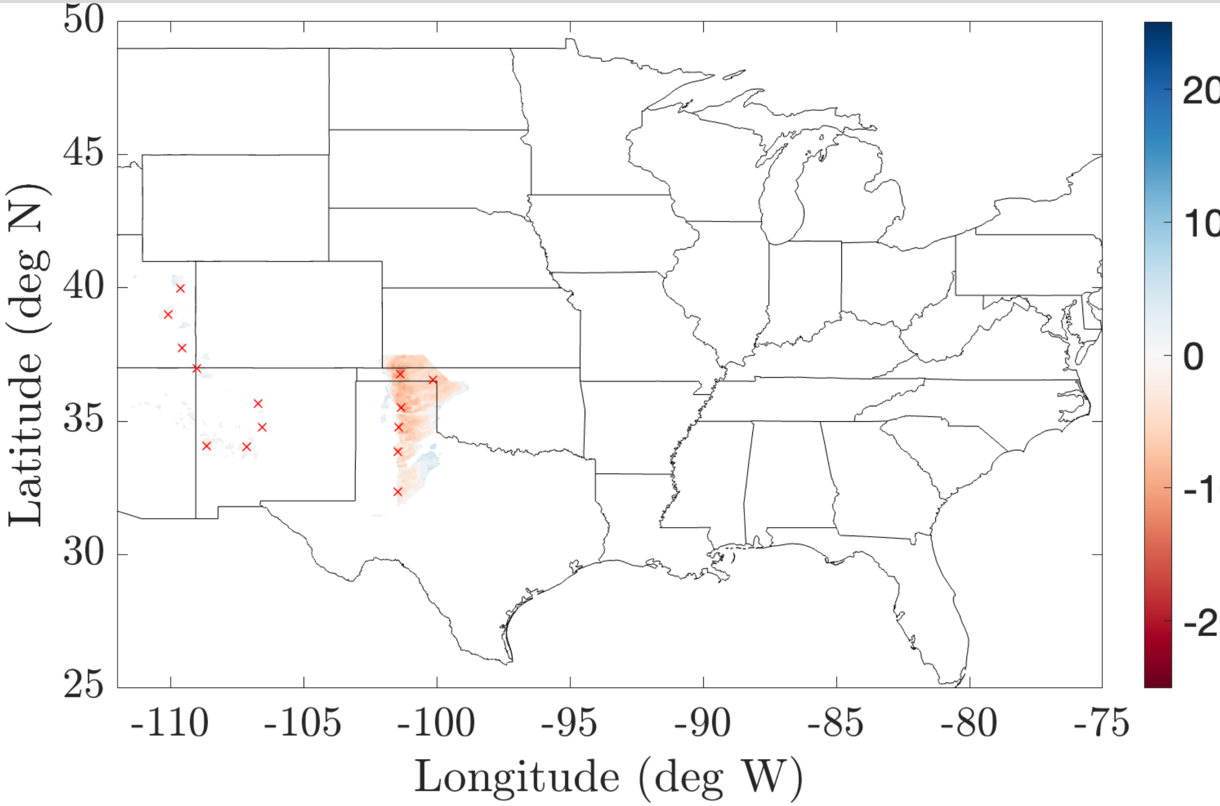


GOES 16 CH14 T_b (K)
Latitude (deg N)
45
40
35
30
25
-110
-105
-100
-95
-90
-85
-80
-75
Longitude (deg W)
300
280
260
240
220
200



Latitude (deg N)
50
45
40
35
30
25
-110
-105
-100
-95
-90
-85
-80
-75
Longitude (deg W)
20
10
0





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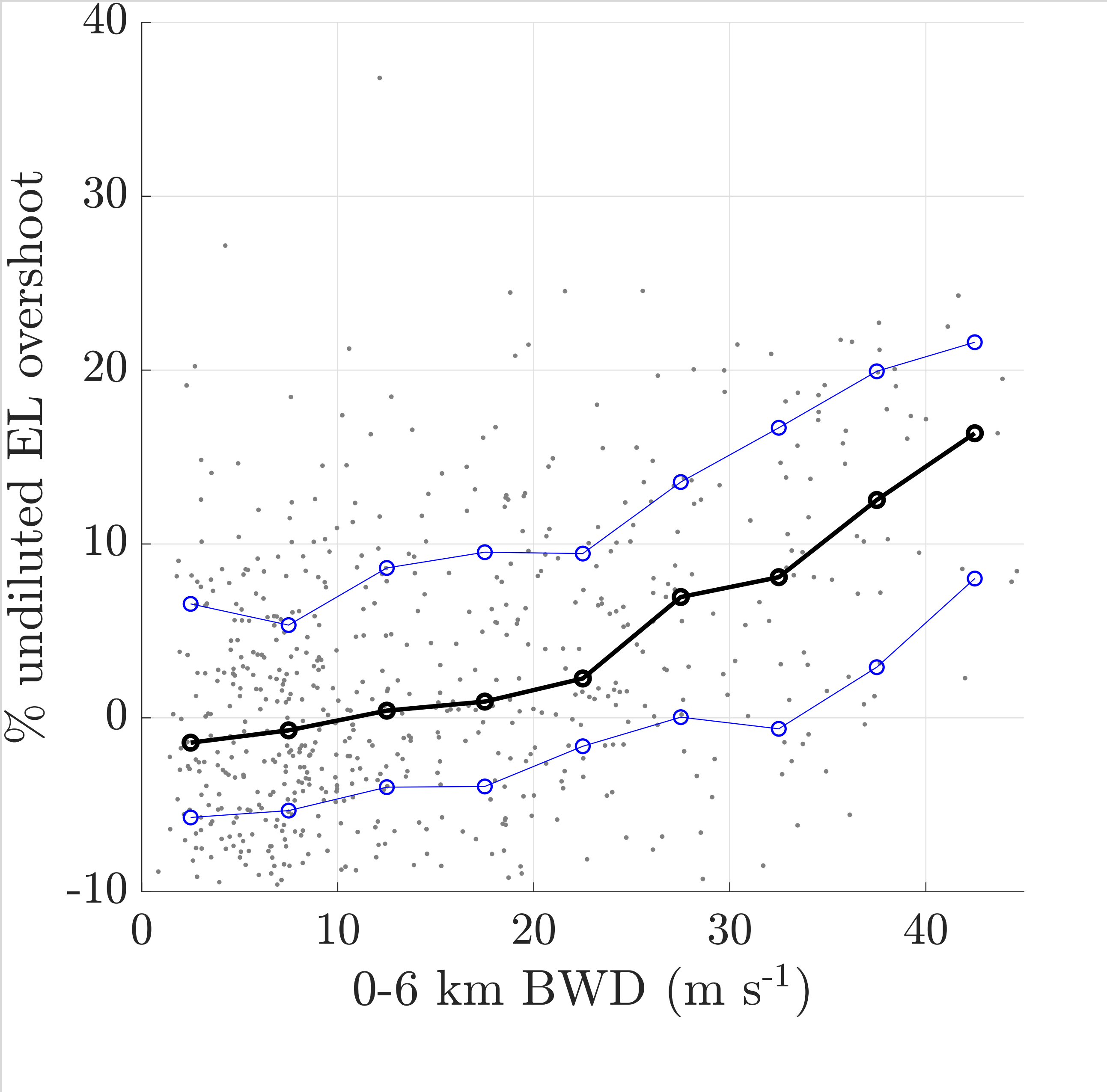

% undiluted EL overshoot
0-6 km BWD (m s-1)
40
30
20
10
0
-10
0
10
20
30
40