Numerical simulation of heavily drizzling cloud regimes in VOCALS

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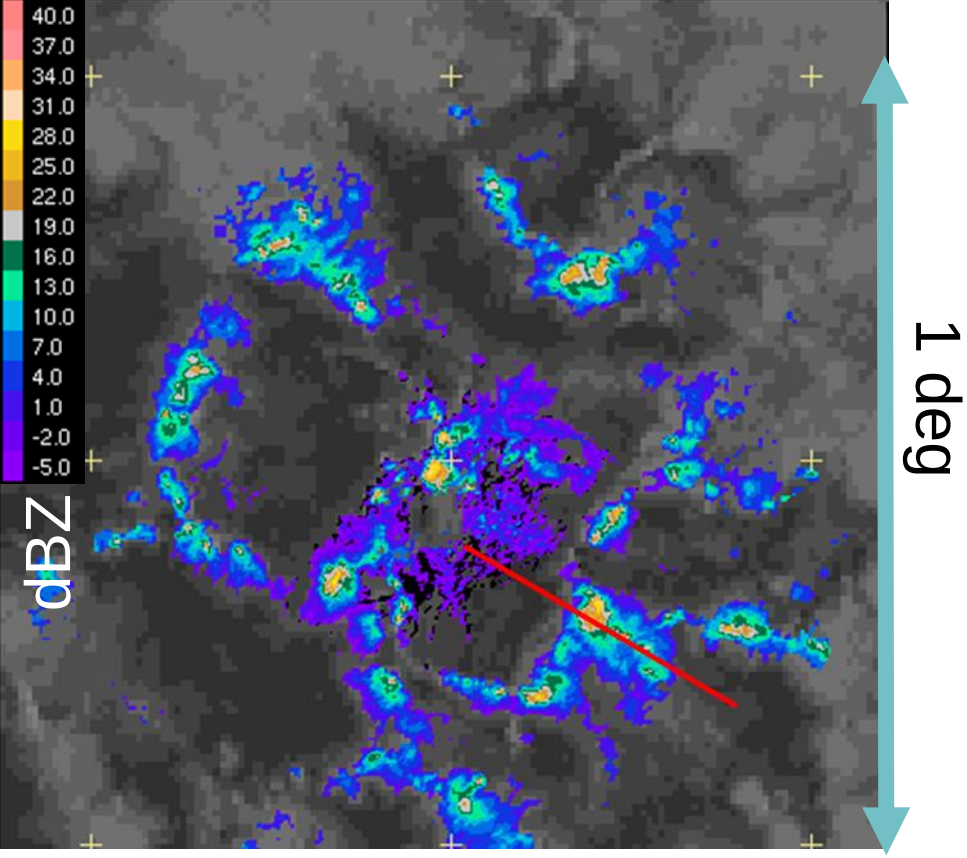
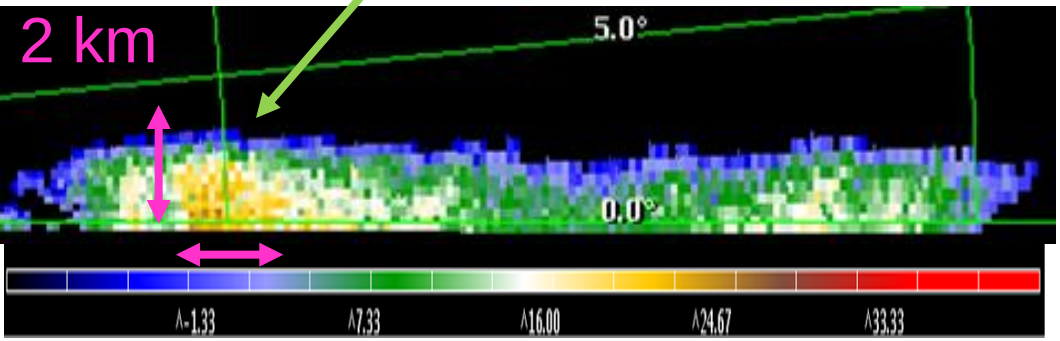
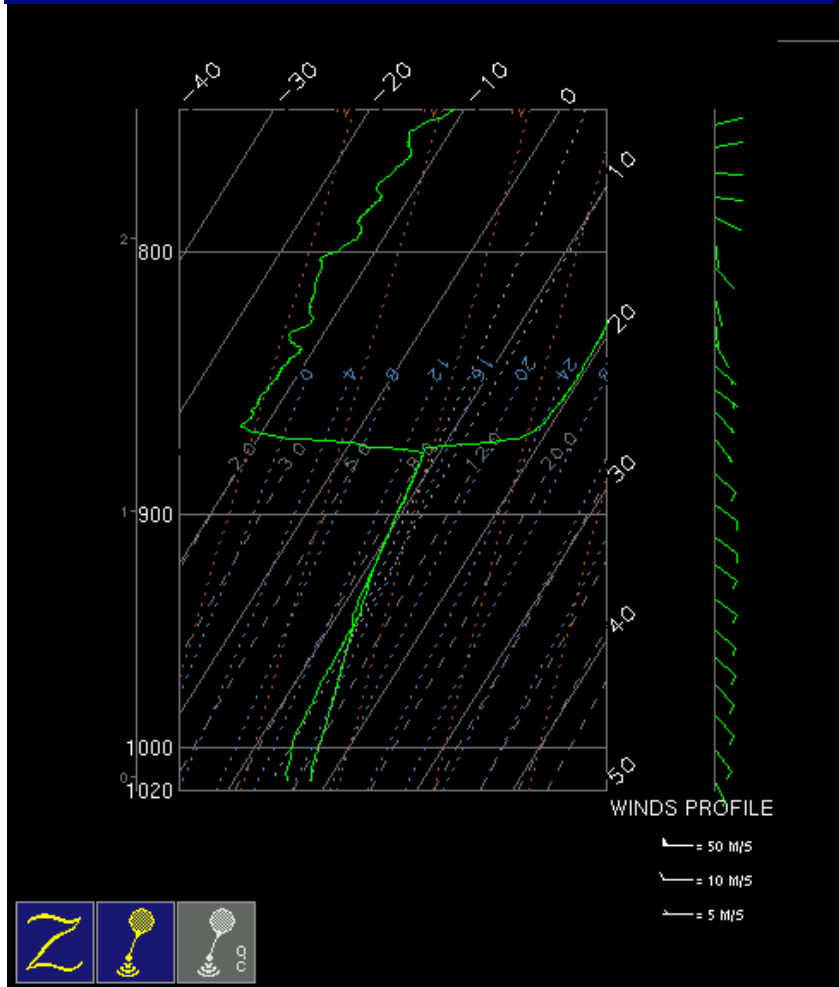
Typical open cells with intermediate drizzle



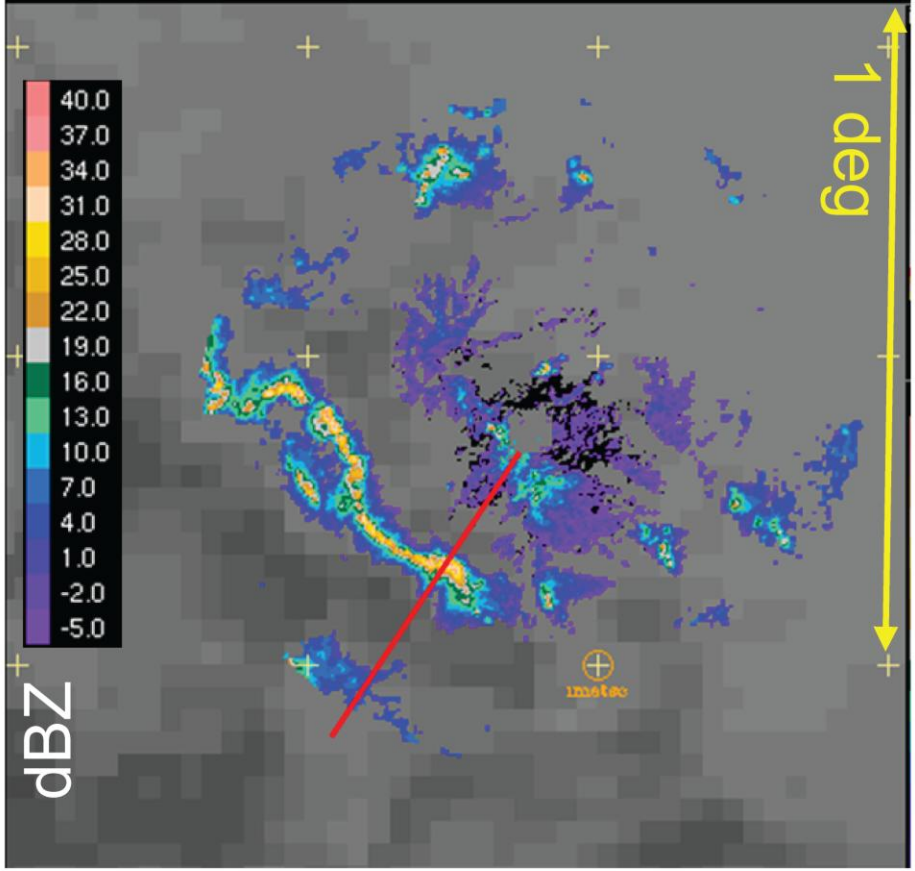
Max 27 dBZ

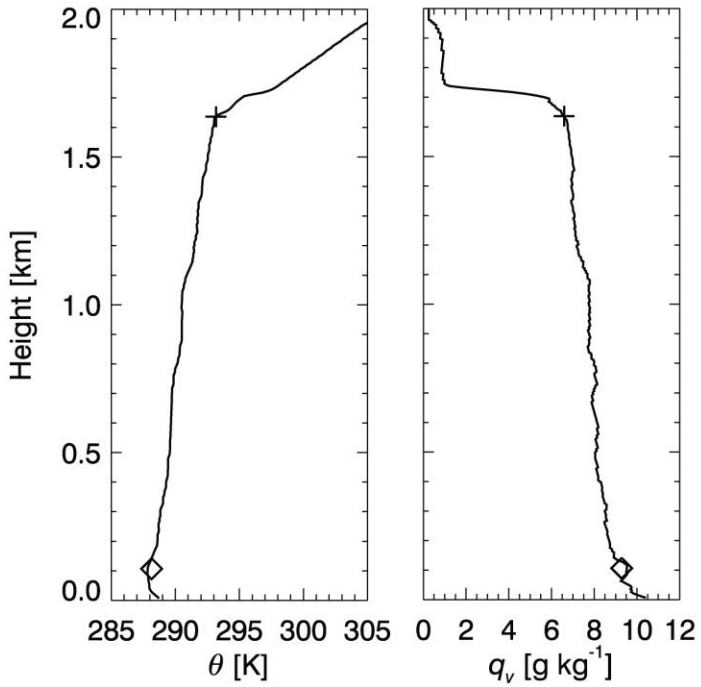


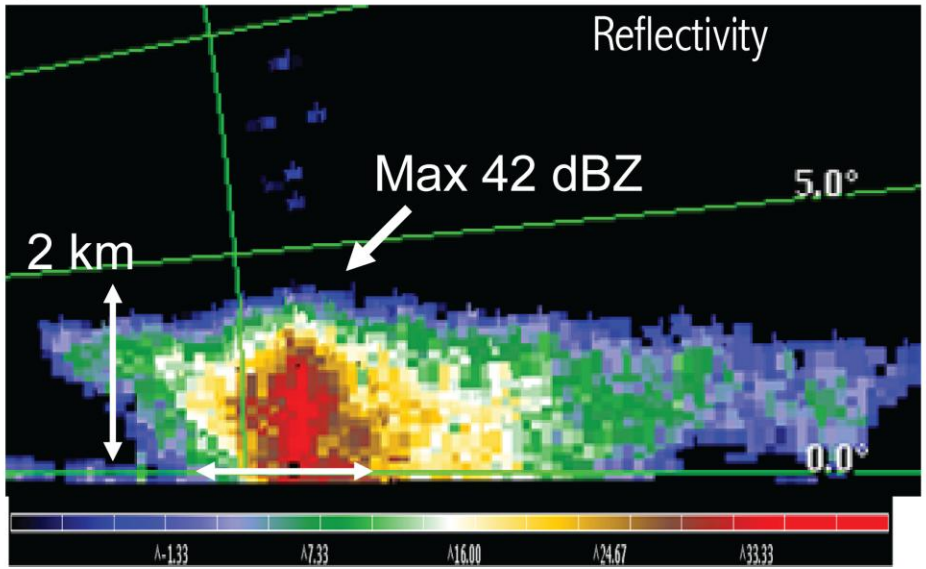
23 Oct 2008, 12 UTC

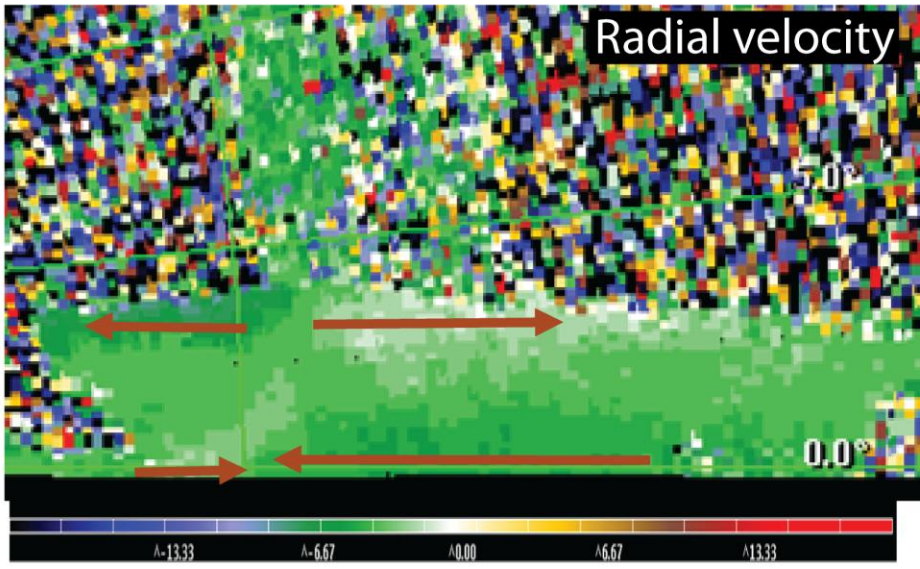


Strong drizzle

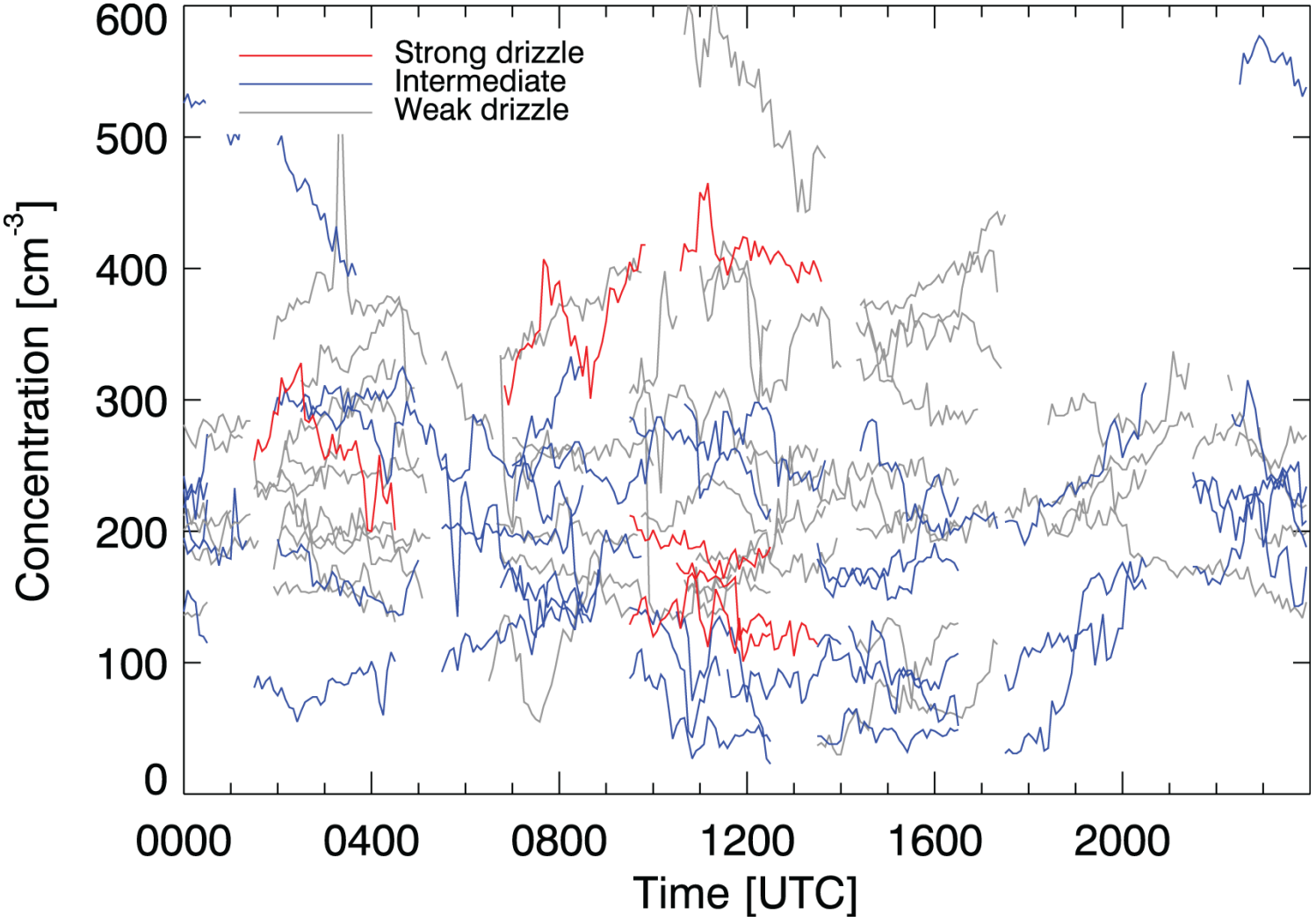








Ship-based CCN concentration, stratified by drizzle category

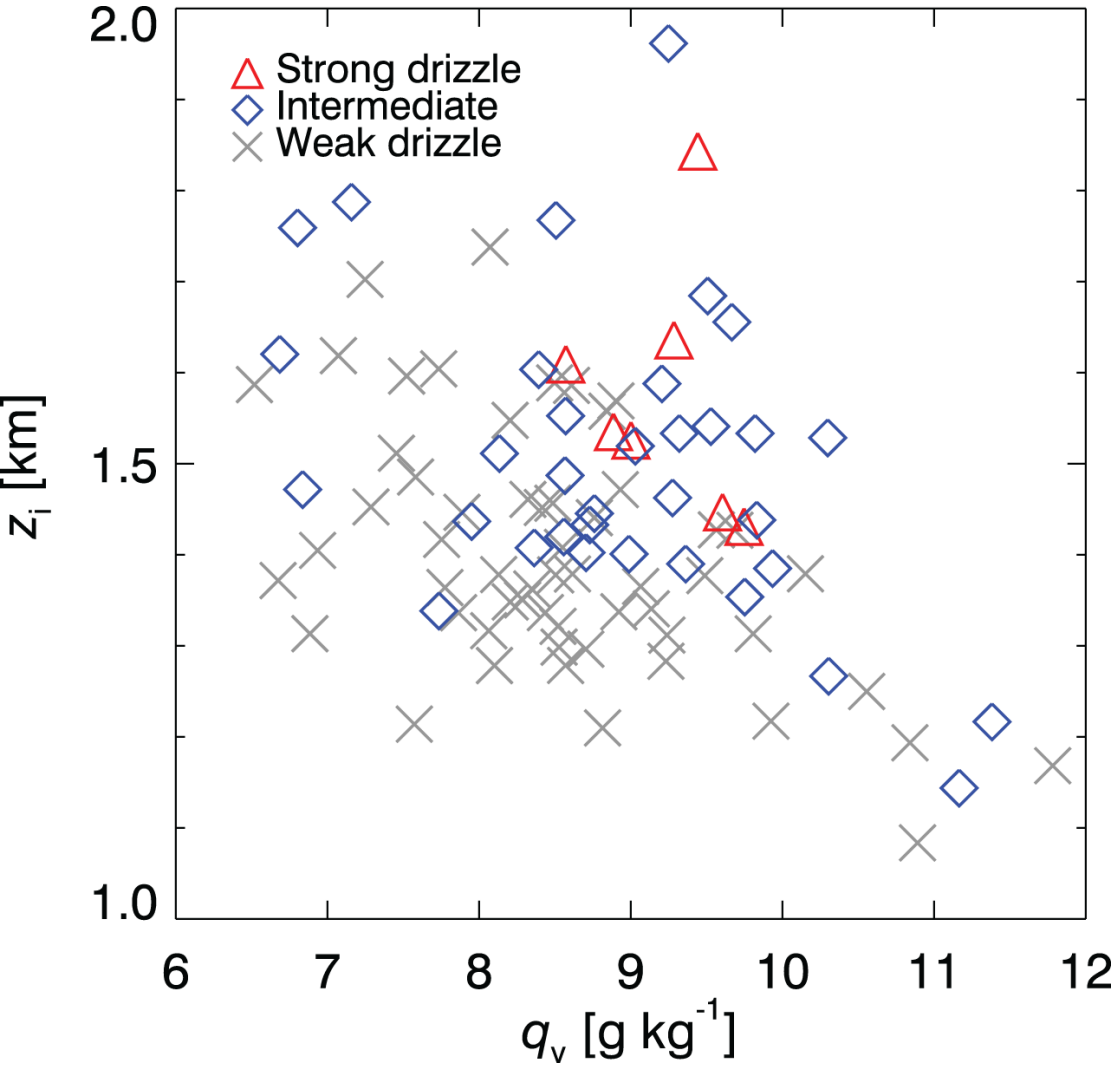


- *S* = 0.6%
- Each trace is ±1.5 h from sounding time

CCN data from Dave Covert

Analysis of R/V RHB soundings

Mean moisture over the 10-200 m layer (q_v)
versus inversion height (z_i) for different drizzle conditions



- Boundary layers were both moist and deep (1.4 to 2 km in height) for stronger drizzle events

- Typical, weaker drizzle events that tended to be either drier or shallower.

Near–LES approach

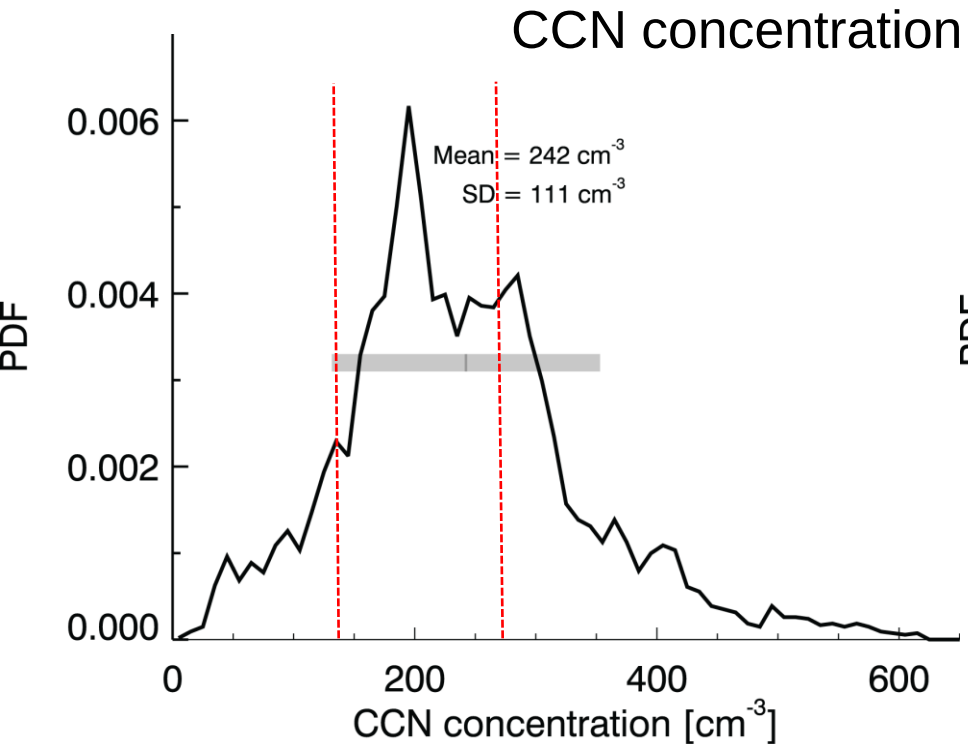
System for Atmospheric Modeling (SAMEX) — Explicit Microphysics; Khairoutdinov and Randall (2003); microphysics based on Kogan (1991)

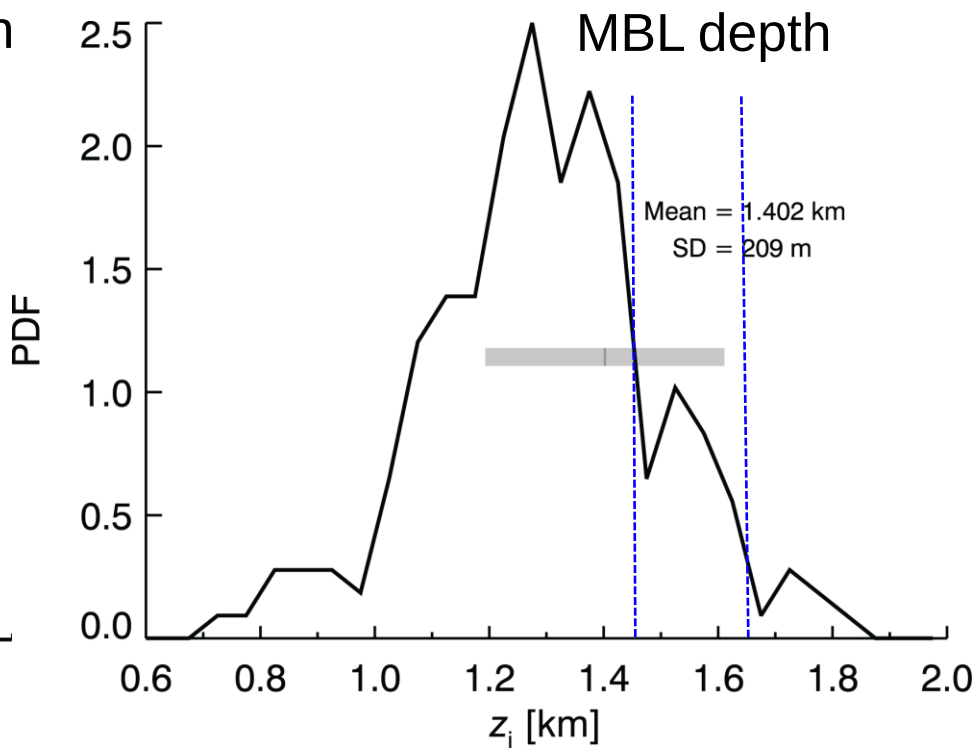
- 26 Oct 2008
- LW radiation only — 105 W m^{-2} jump at cloud top
- Interactive surface fluxes (H ≈ 5 W m^{-2}; LE ≈ 55 W m^{-2})
- Size-resolved ("bin" or "explicit") microphysics
- 34 droplet bins; 19 CCN bins
- Initial CCN ~135/cc, shape based on RICO distribution
- **Reflectivity calculated directly from DSD**

Domain: 57.6 x 57.6 km^2

- *dx*=*dy*=150 m
- *dz* stretched: 25 m at *z* = 0; 40 m at *z* = 800 m; 25 m at *z* = 1800 m
- Grid: 384x384x96, run for 12 h

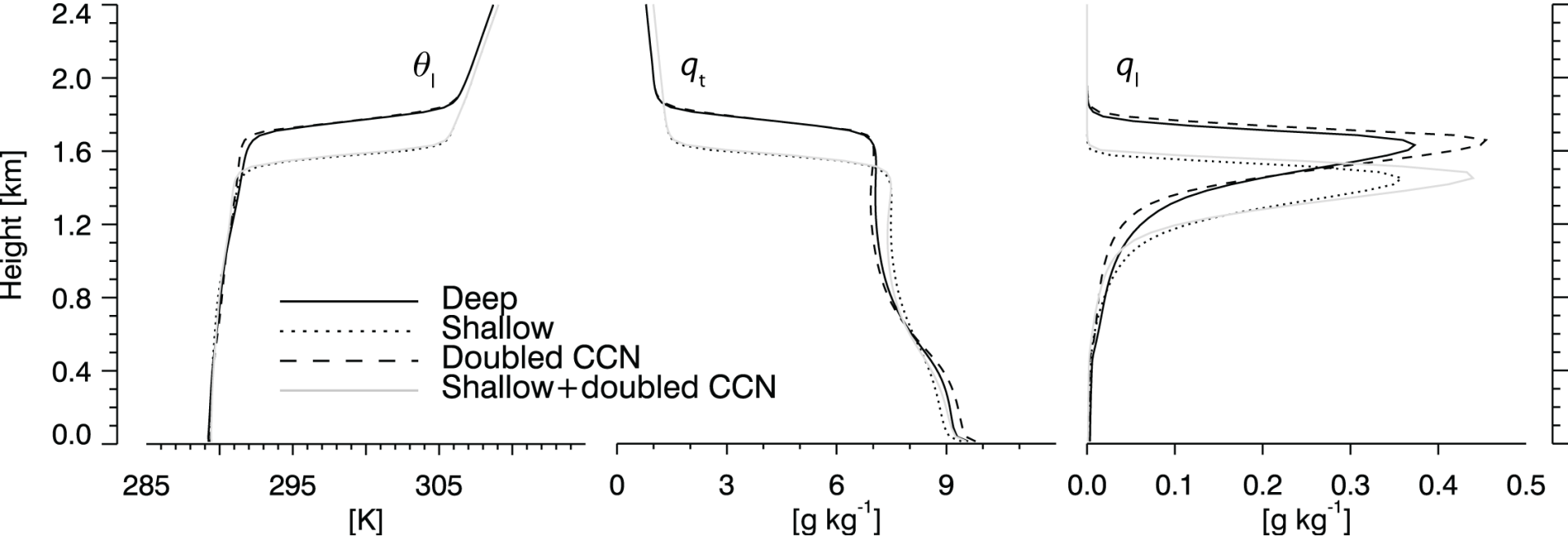
Factor separation technique





Simulation	MBL depth [m]	CCN concentration [cm^{-3}]
Deep (control simulation)	1650	135
Shallow	1450	135
Doubled CCN	1650	270
Shallow + Doubled CCN	1450	270

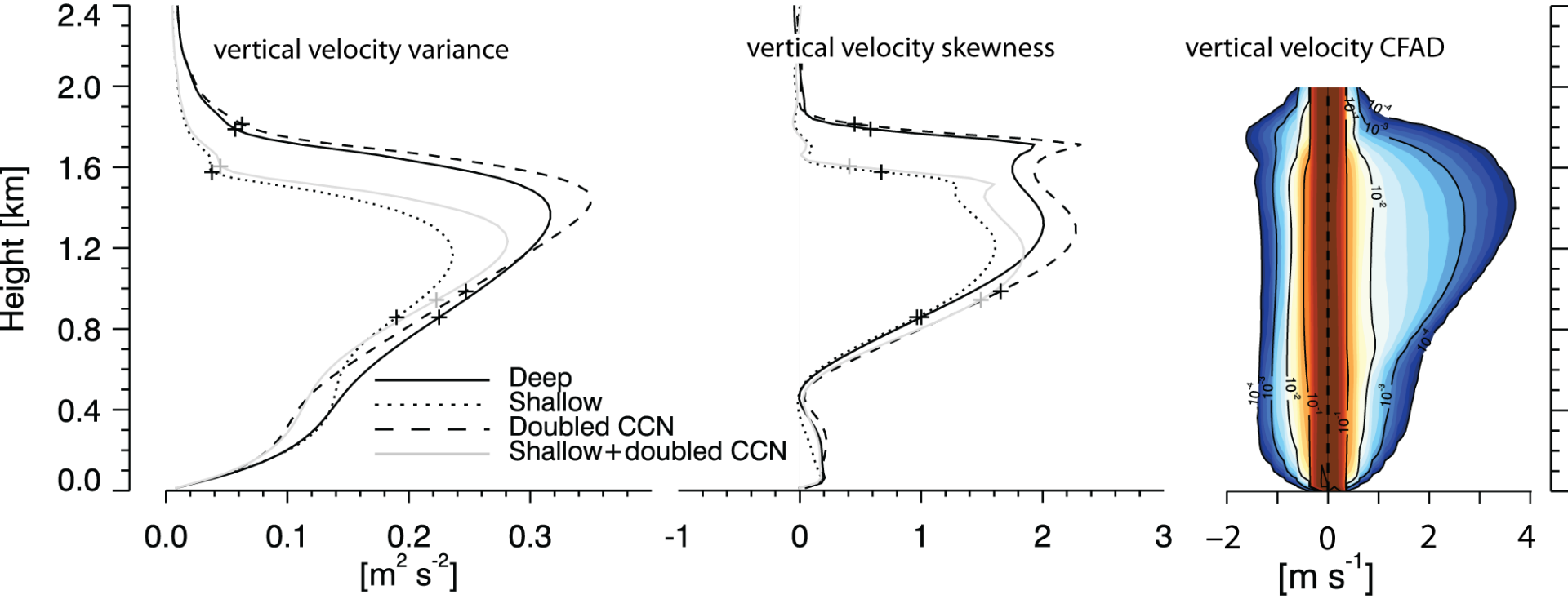
Near–LES results (1)



Average quantities from 8–12 h

Simulation	R [mm d^{-1}]	w_e [cm s^{-1}]
Deep (control simulation)	0.98	0.76
Shallow	0.44	0.58
Doubled CCN	0.57	0.85
Shallow + Doubled CCN	0.28	0.72

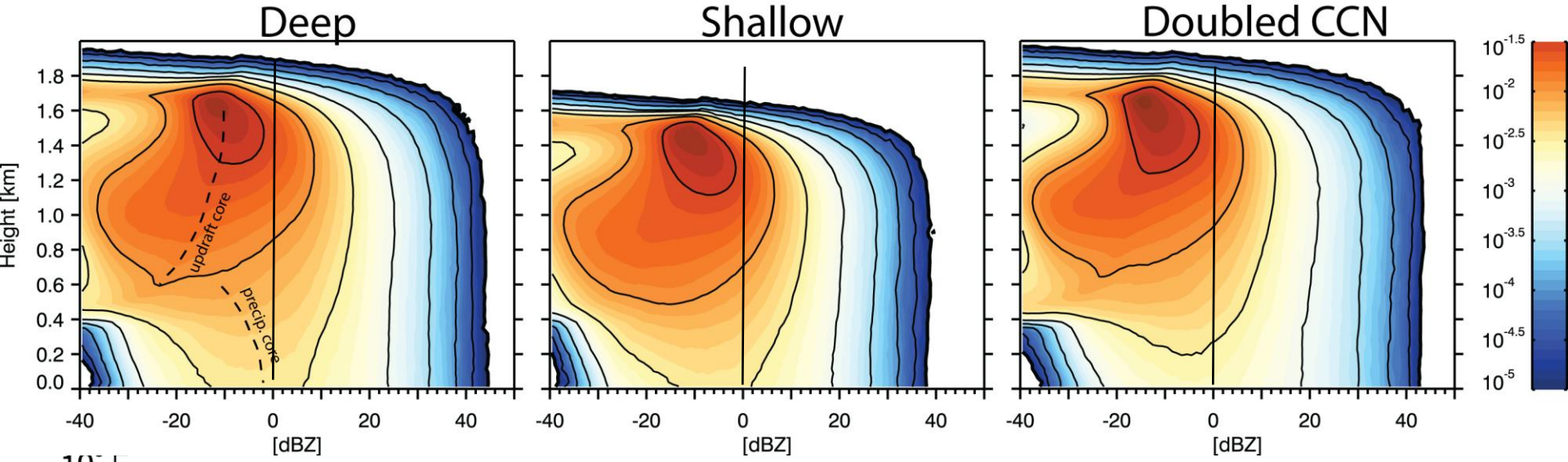
Near–LES results (2)

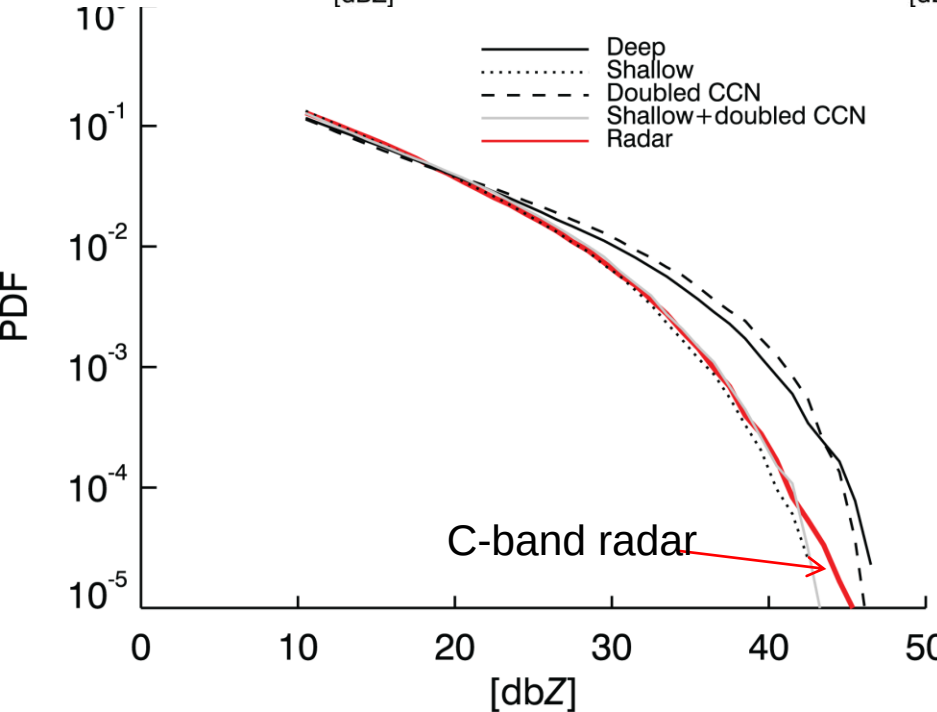


Average quantities from 8–12 h

Near–LES results (3)

CFADs of simulation reflectivity

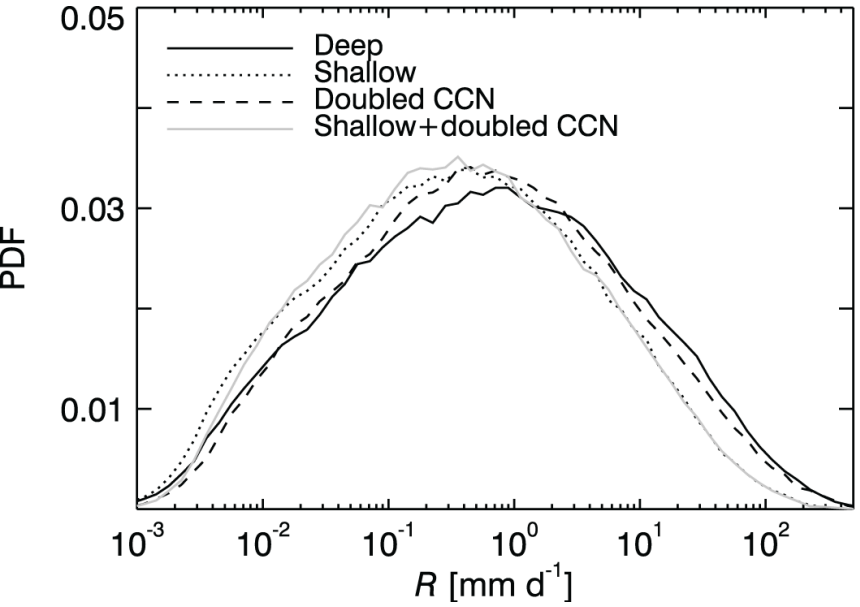




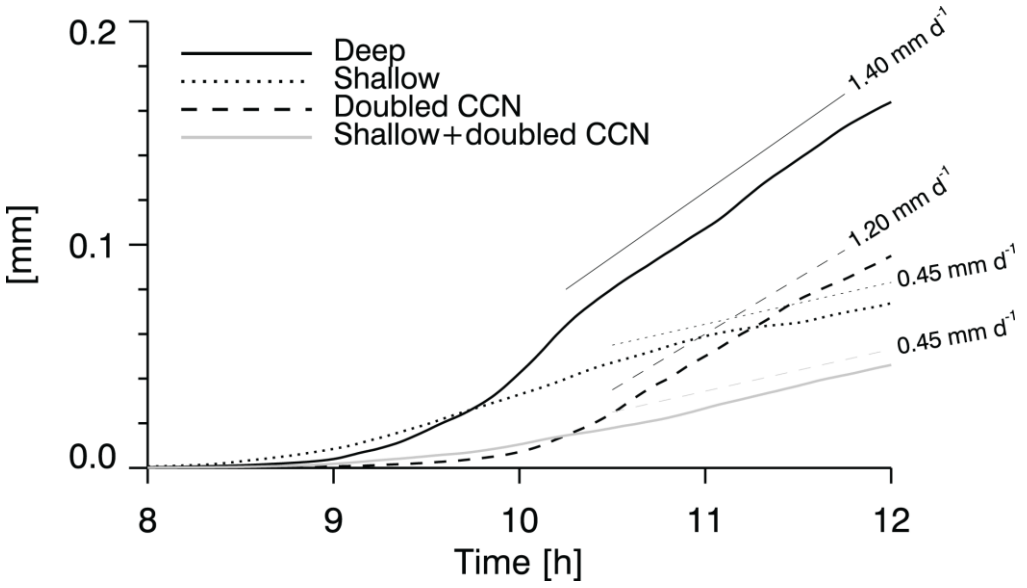
- PDFs of reflectivity > 10 dB*Z* over entire domain
- Radar may be overshooting high reflectivity regions away from the ship
- Point reflectivity calculation (model) vs. volume sampling (observations)

Near–LES results (4)

PDFs of surface precipitation rate



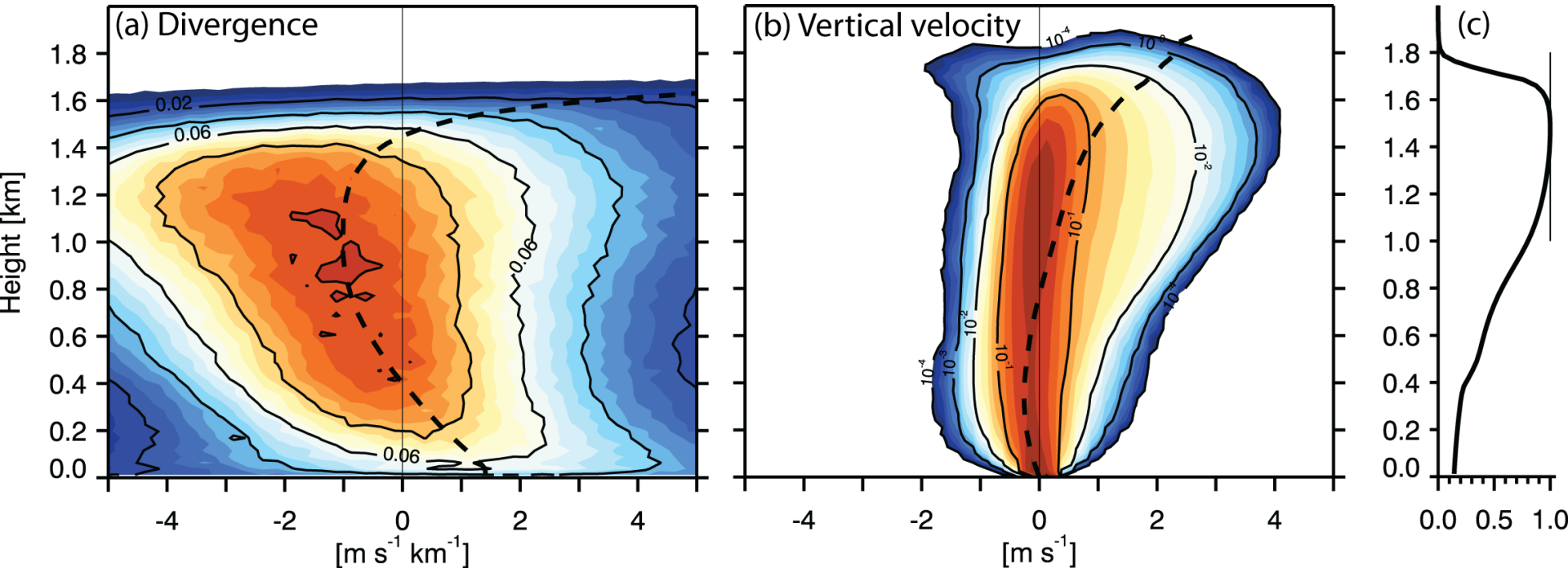
Accumulated surface precipitation from 8–12
Line slopes are precipitation rate.

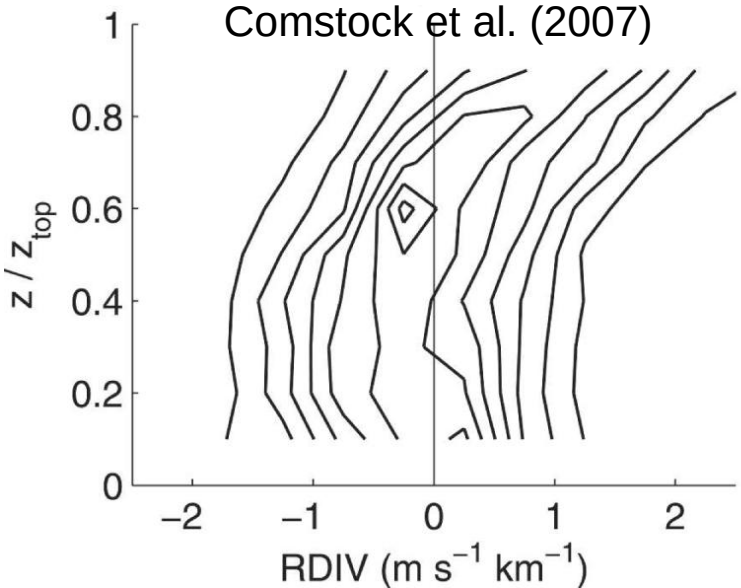


Primary (i.e., over a short enough timescale that feedbacks are minimal) responses to BL depth and CCN concentration:

- The two deep simulations have similar precipitation rates.
- The two shallow simulations have similar precipitation rates.
- *The effect of increased CCN is to delay the onset of precipitation.*

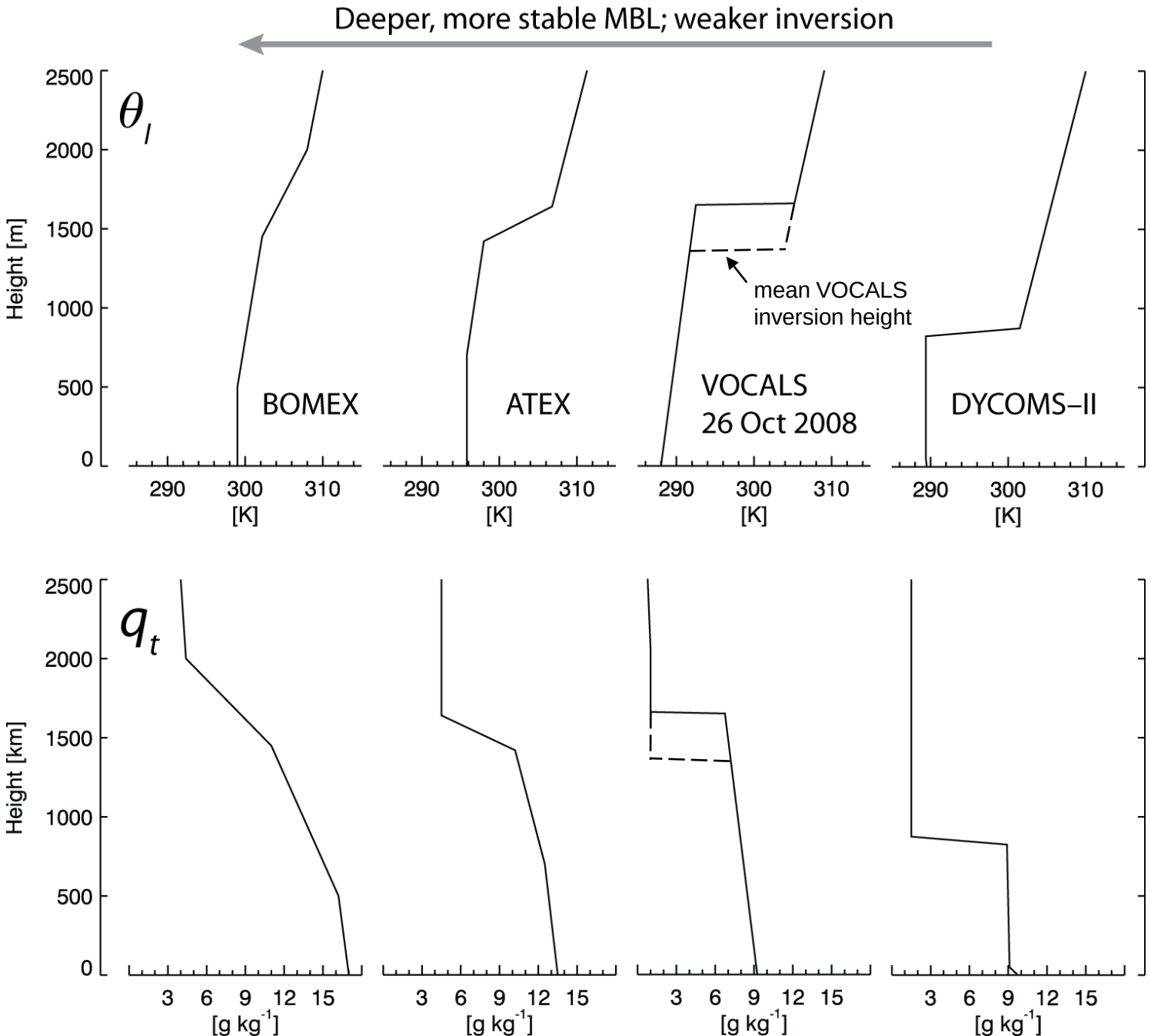
Divergence and vertical velocity CFADs in cells





- Conditionally sampled at points ≥10 dB
- Midlevel convergence
- Divergence below and above

Context with other MBL regimes



Conclusions

- Larger drizzle rates are generally associated with deep, moist boundary layers and both low and high CCN concentrations.
- Simulated precipitation is more sensitive to changes in boundary layer depth than to commensurate changes in CCN concentration.
- These are the first-order, primary feedbacks of boundary layer depth and CCN on precipitation. The longer integrations are more difficult to interpret (complicated dynamical feedbacks; coalescence processing; “buffering”).