

Vertical Updraft Accelerations and Convective Life Cycle Transitions

A wide-angle photograph of a coastal scene under a dramatic sky. The upper half of the image is filled with large, billowing cumulus clouds against a deep blue sky. A bright, partially obscured sun is visible through the clouds on the right side. Below the horizon, a sandy beach or dune area is visible, with some low-lying vegetation and a small red sign on a post in the foreground. The ocean waves are visible in the distance.

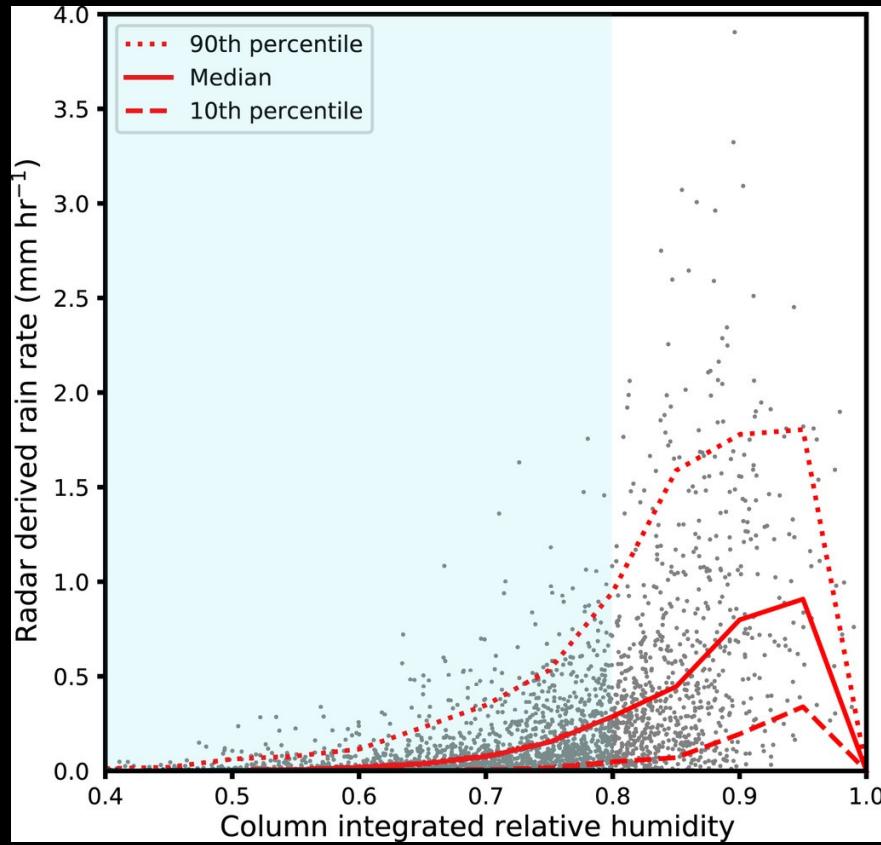
Scott Powell (scott.powell@nps.edu)
Naval Postgraduate School, Monterey, CA

34th Conference on Hurricanes and Tropical Meteorology

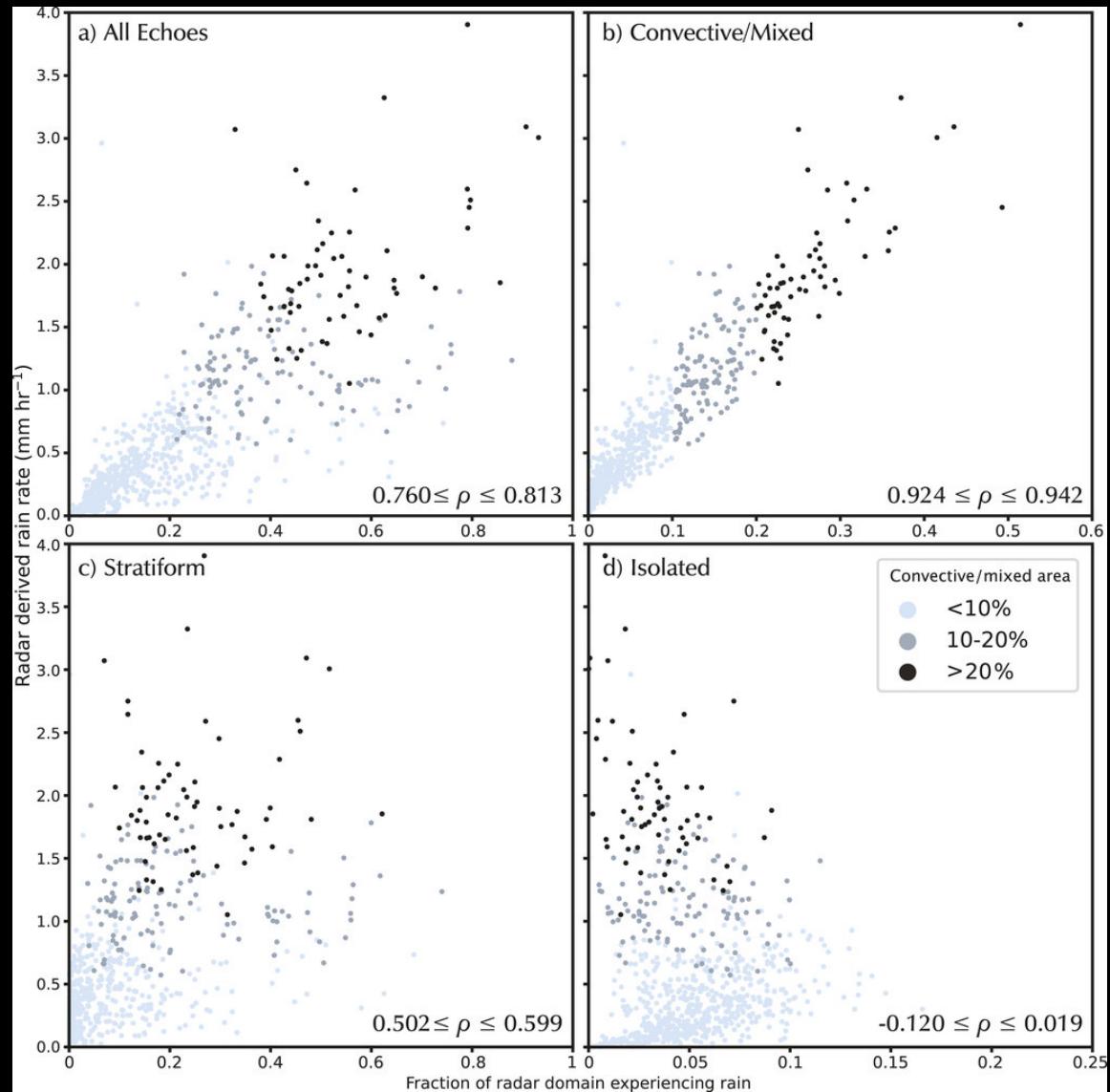
This work will be sponsored primarily by the Office of Naval Research under Award N0001421WX01472.

Photo: Shallow postfrontal convection at Pacific Grove, CA, on 25 January 2021, during a test rawinsonde launch for the planned California Investigation of Convection over Ocean (CALICO), planned for early 2022.

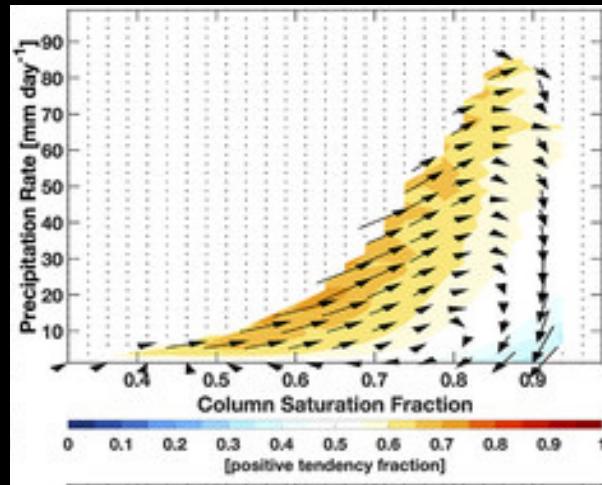
Rain rate vs. Column relative humidity



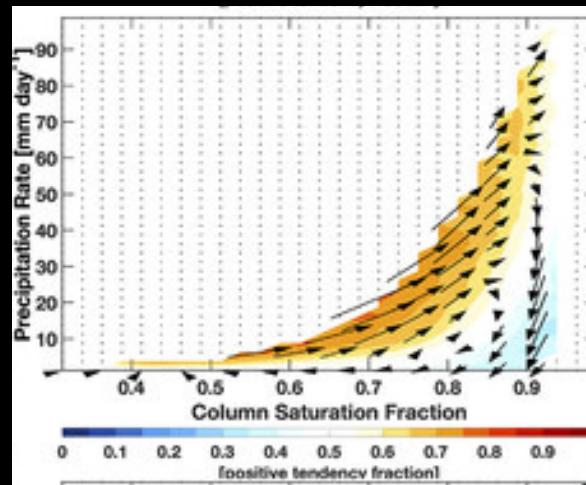
Rain rate vs. Fractional coverage by radar echo type



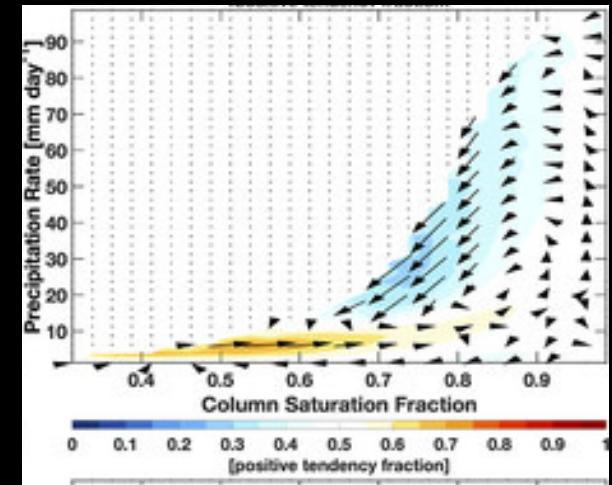
Observations + reanalysis



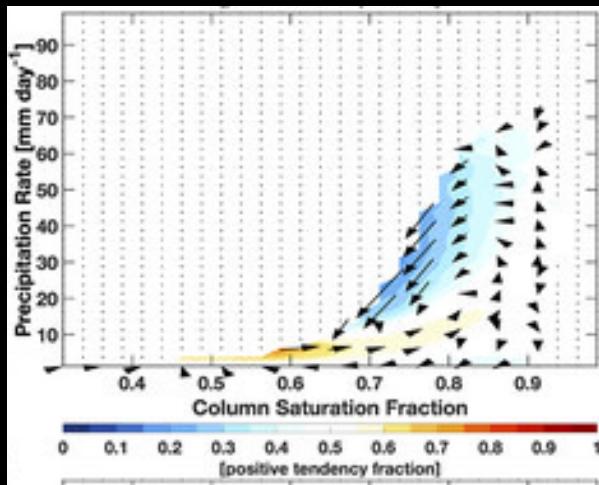
SPCESM



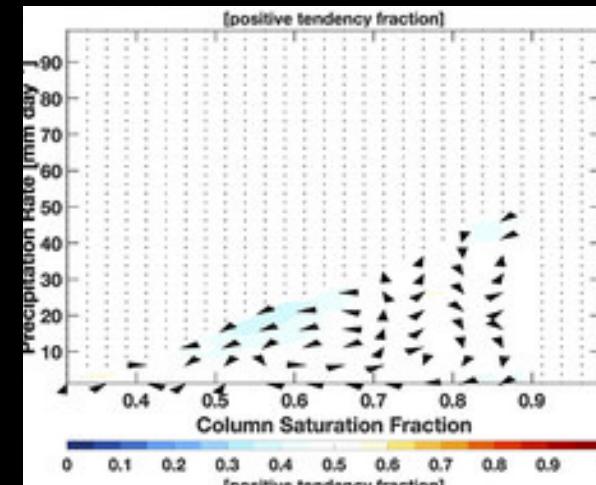
CESM2



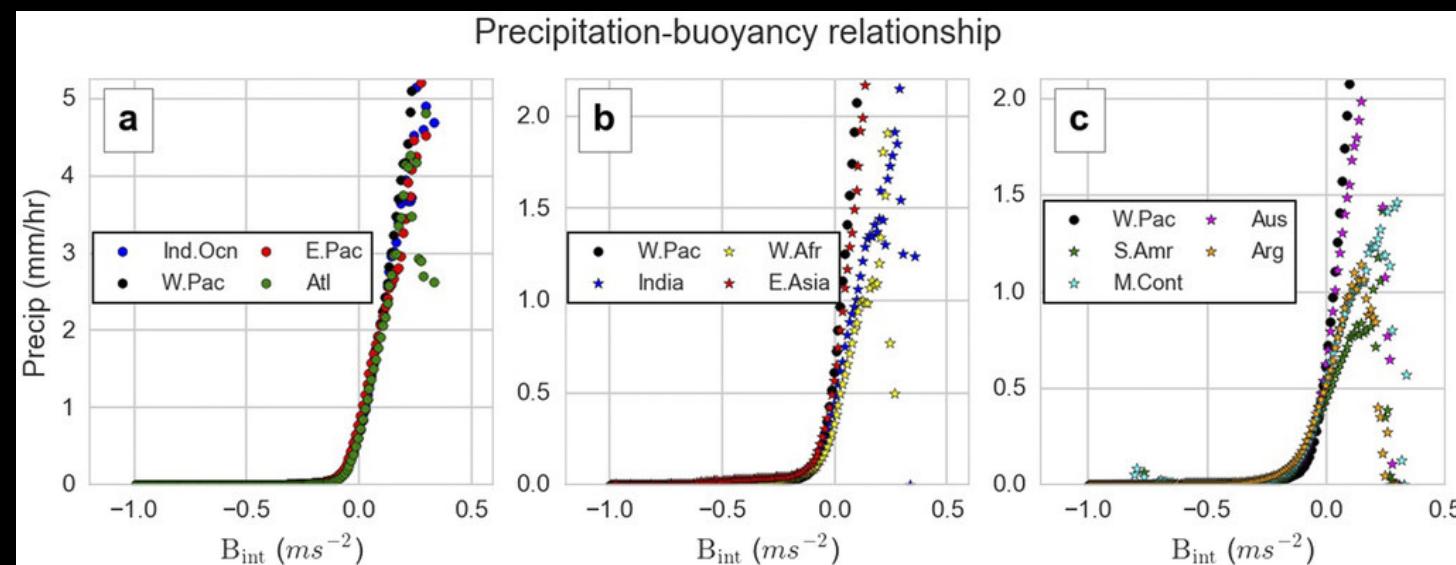
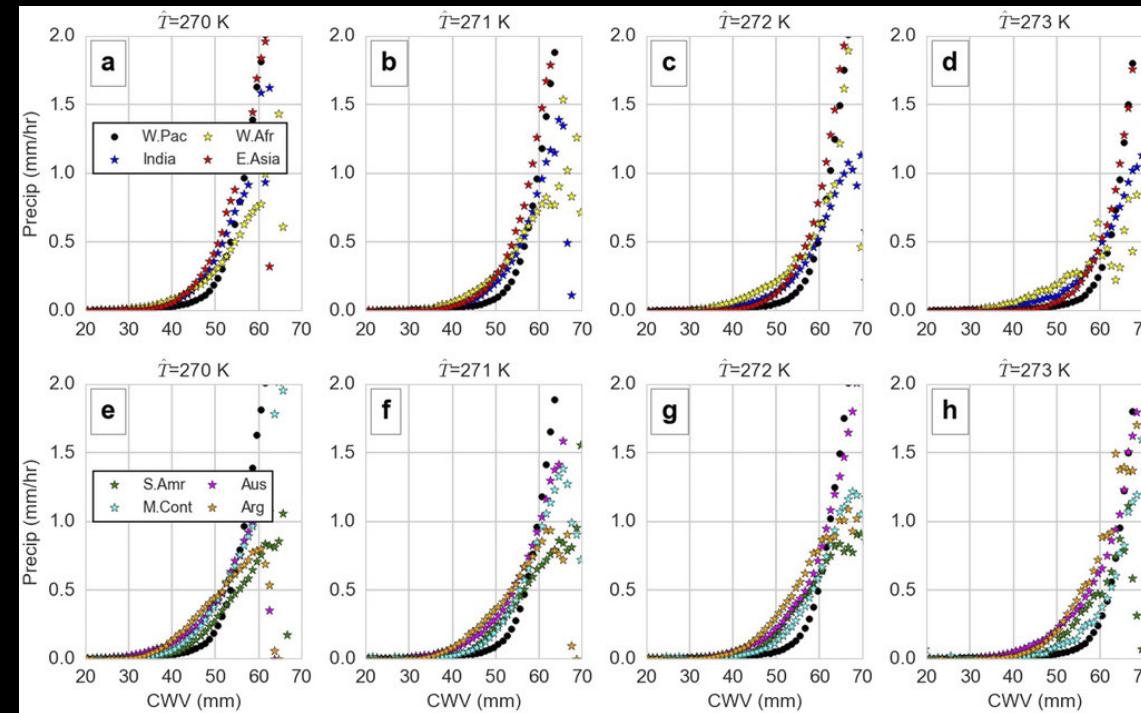
CCSM4



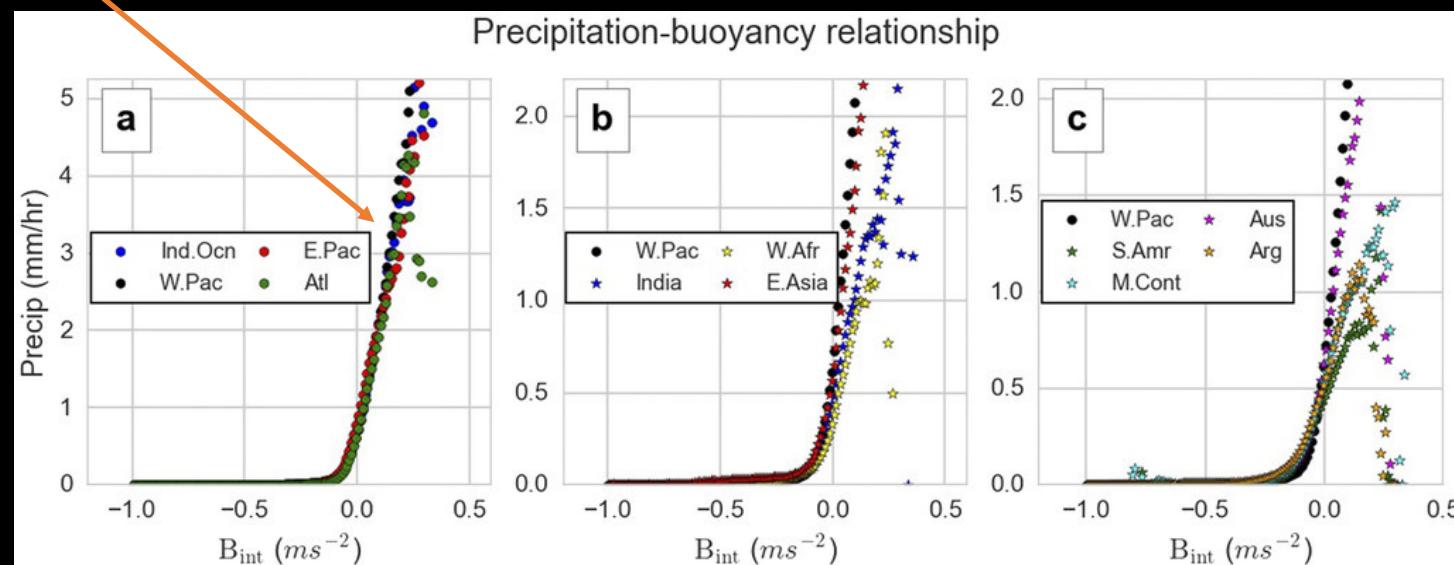
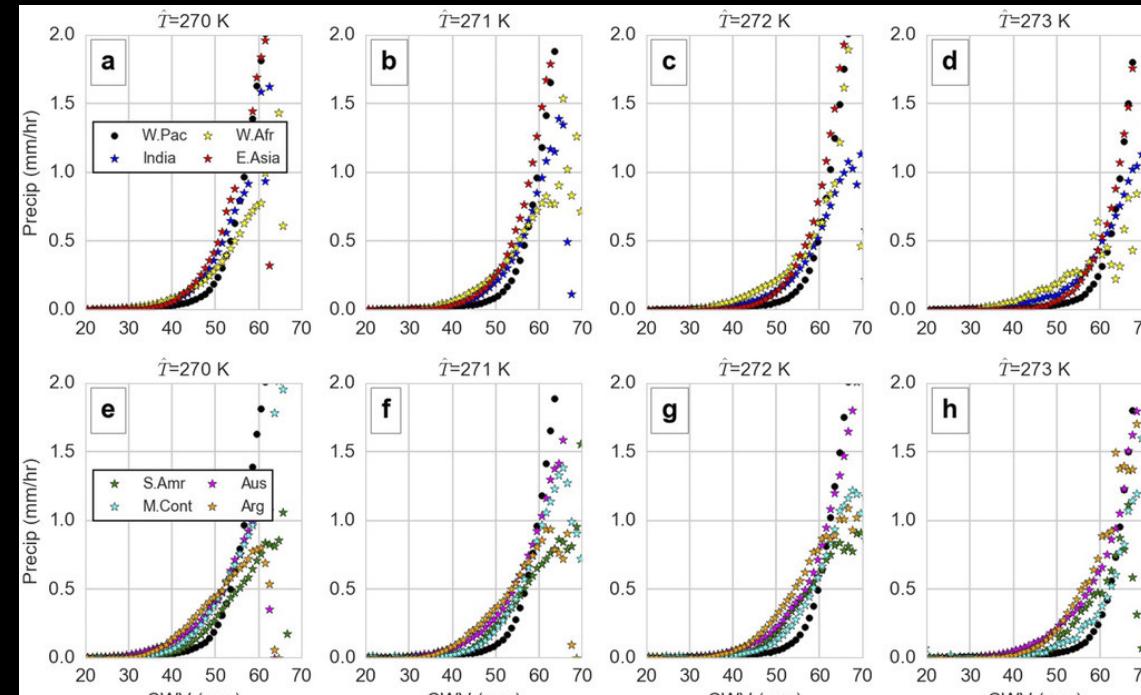
CAM3



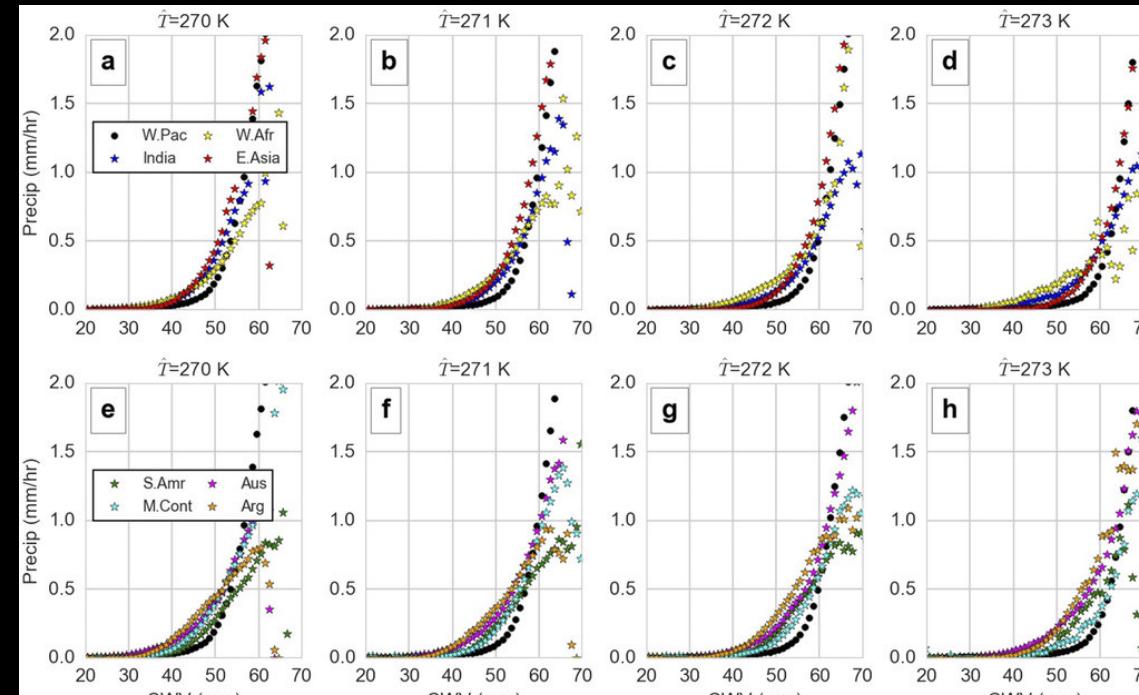
Many global models parameterize physics in ways that do not properly capture convective life cycle.



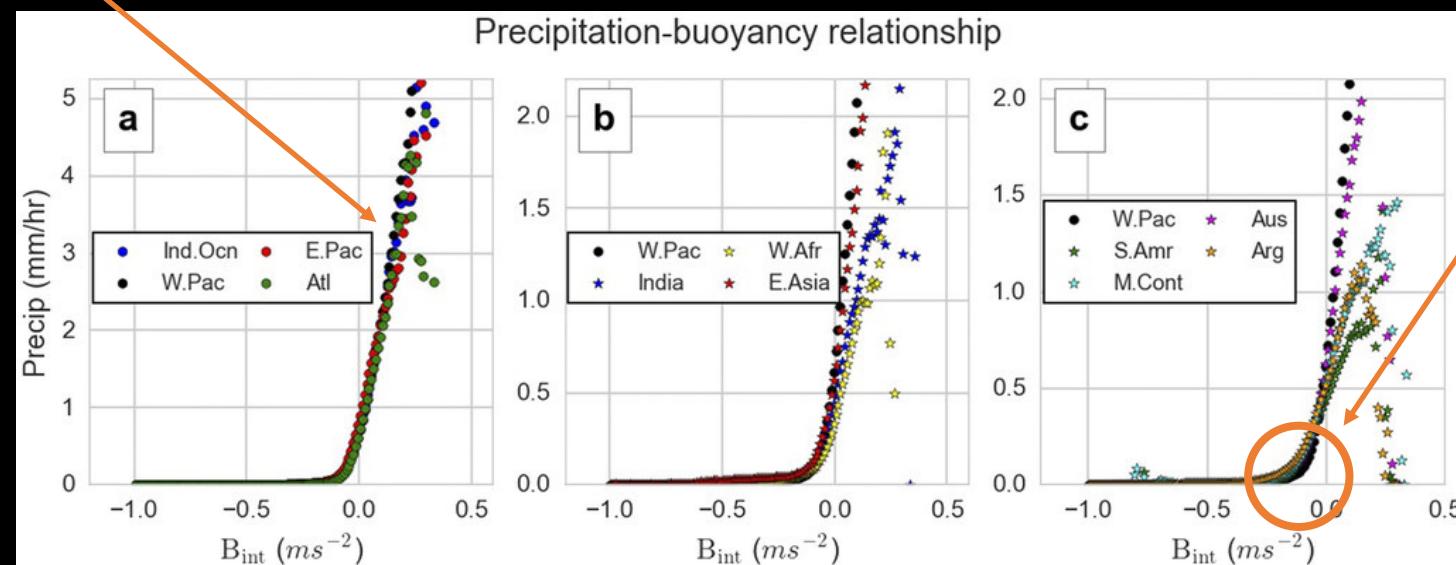
Well-defined
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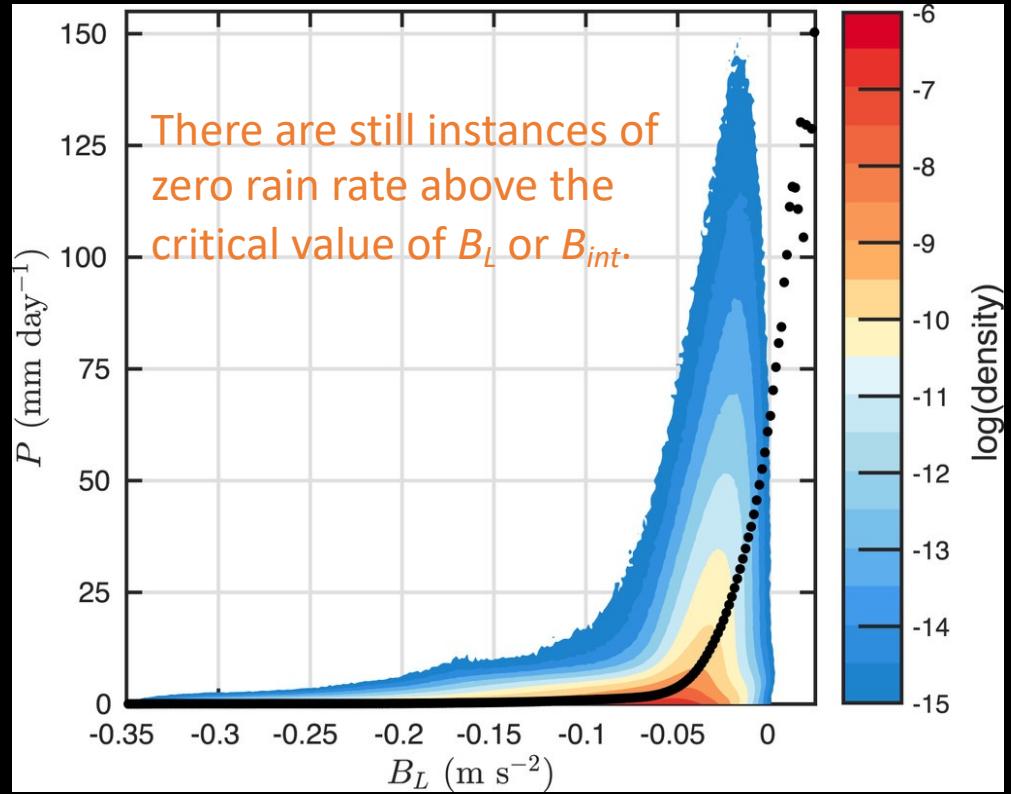
Well-defined relationship when combining temperature and humidity into a single term (B_{int}), but...



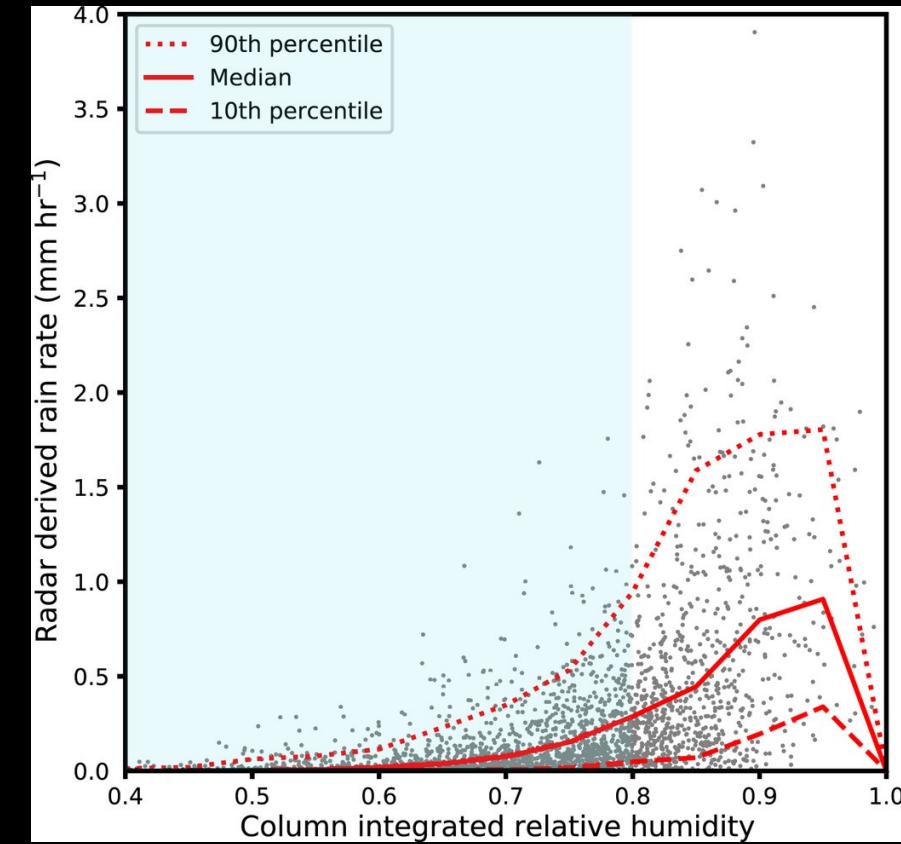
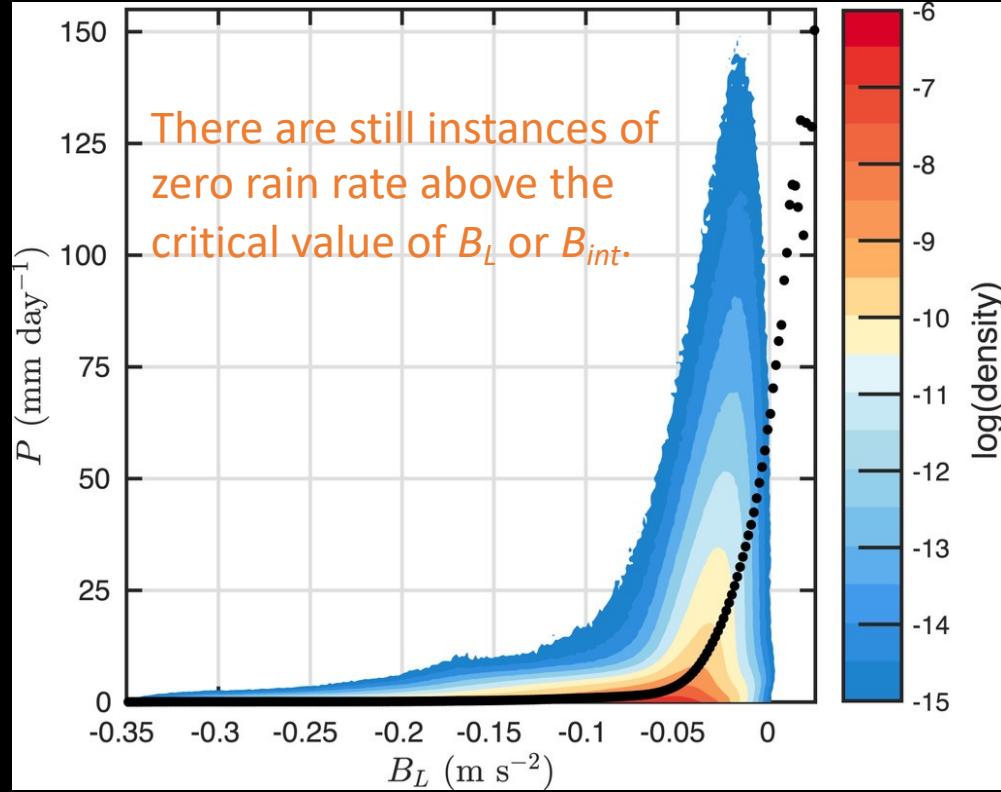
B_c is the critical value above which rain rate rapidly increases.



Adames et al. (2021)

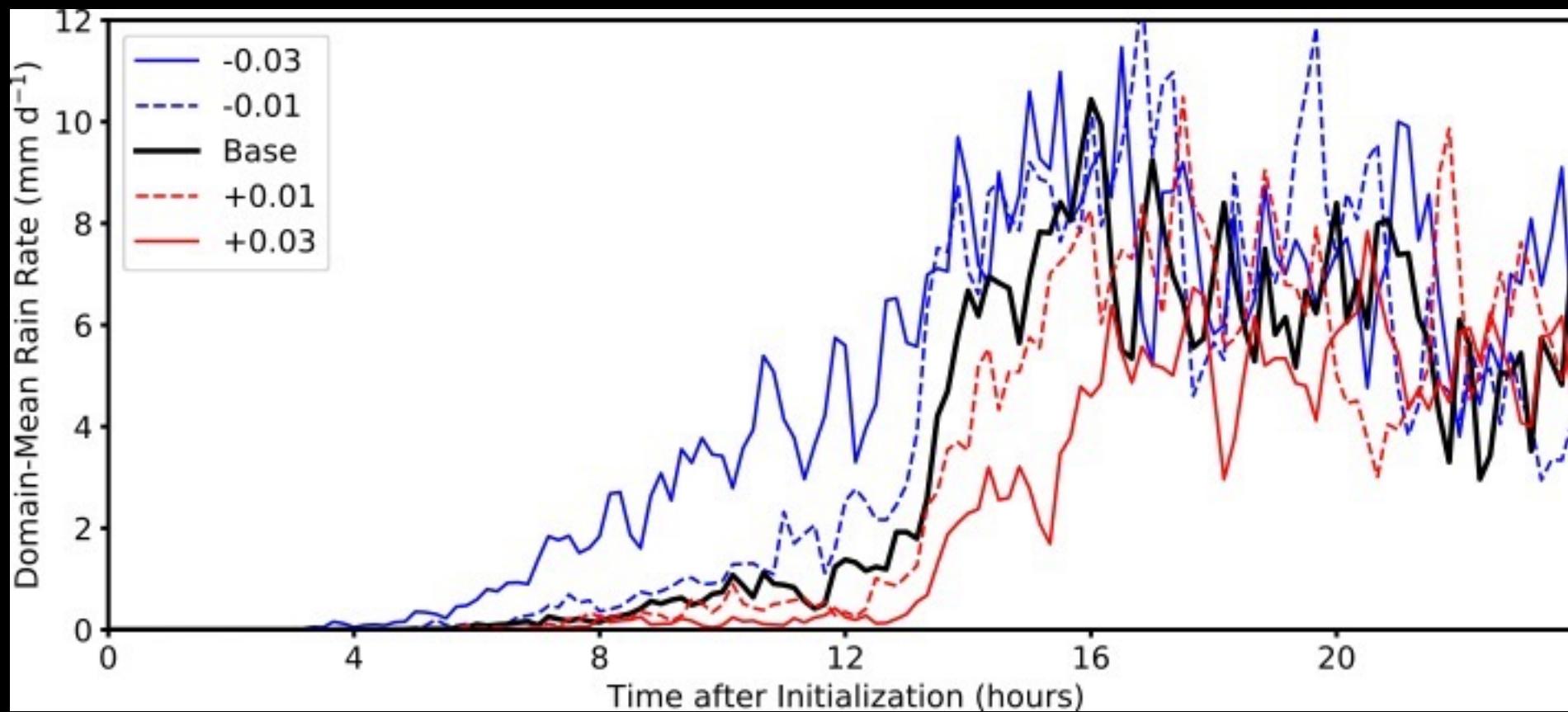


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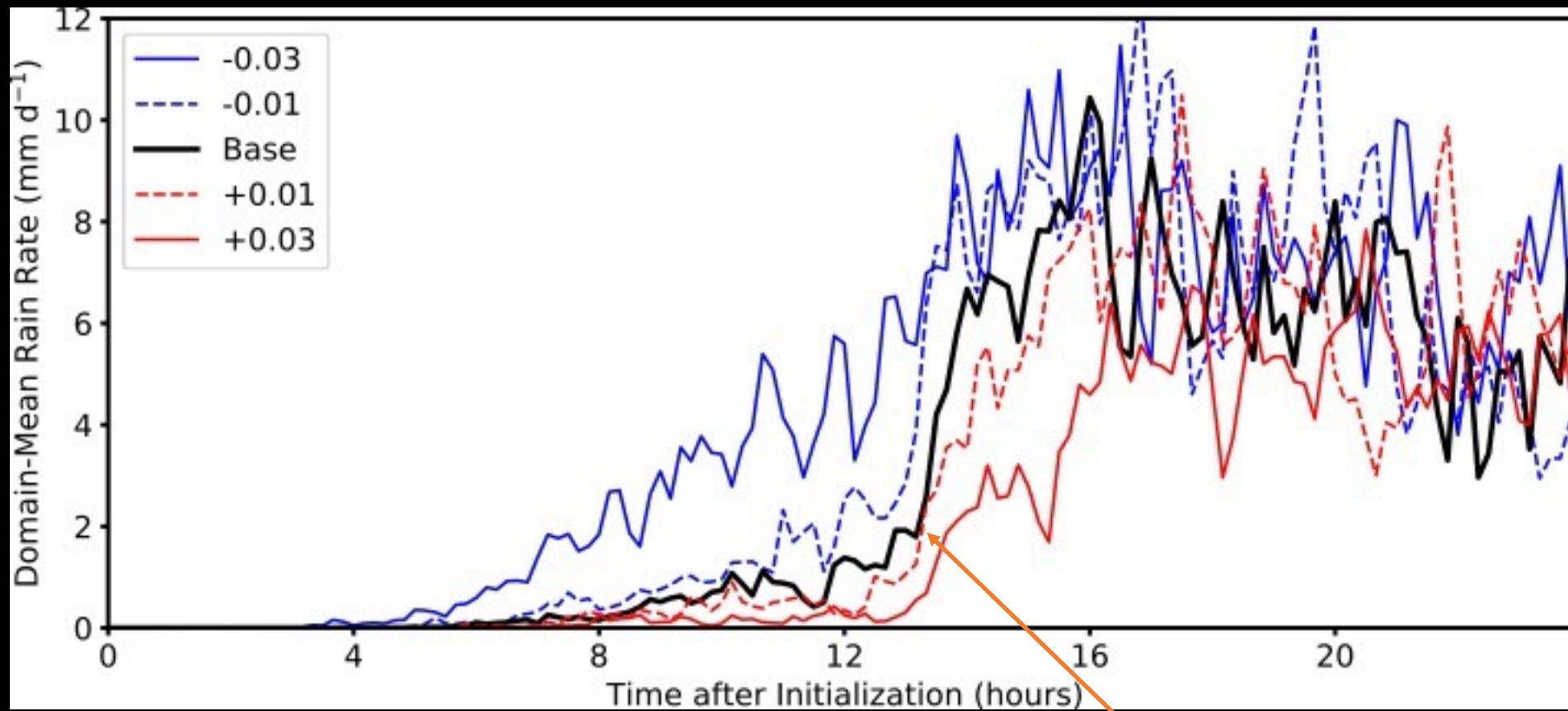


Idealized Simulations of Convection

Rain Rate (each color/dashed/solid line represents simulation with different initial conditions)

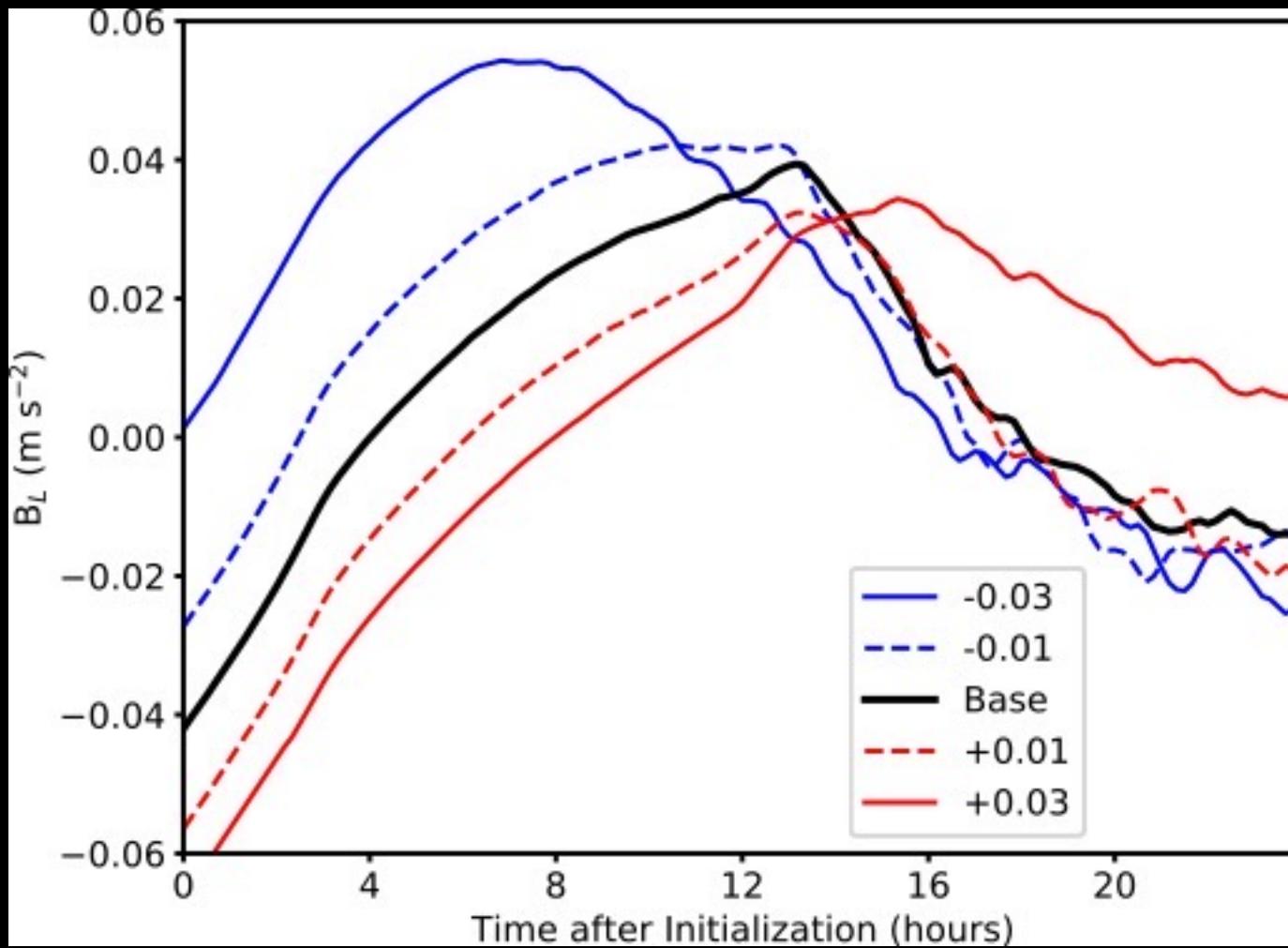


Rain Rate (each color/dashed/solid line represents simulation with different initial conditions)



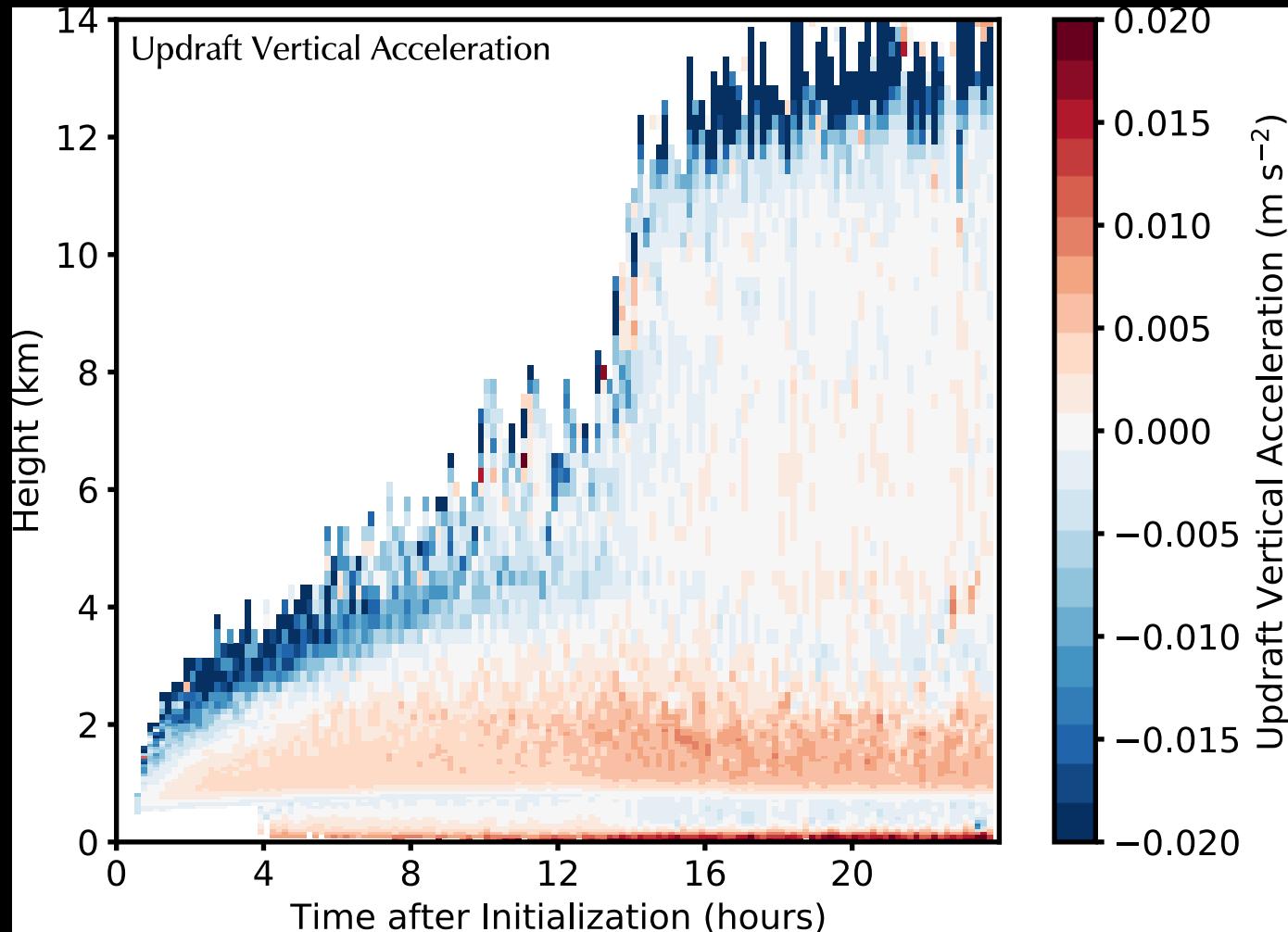
Rapid transitions to
deep convection occur
after several hours.

B_L (averaged using T and q at non-cloudy data points)

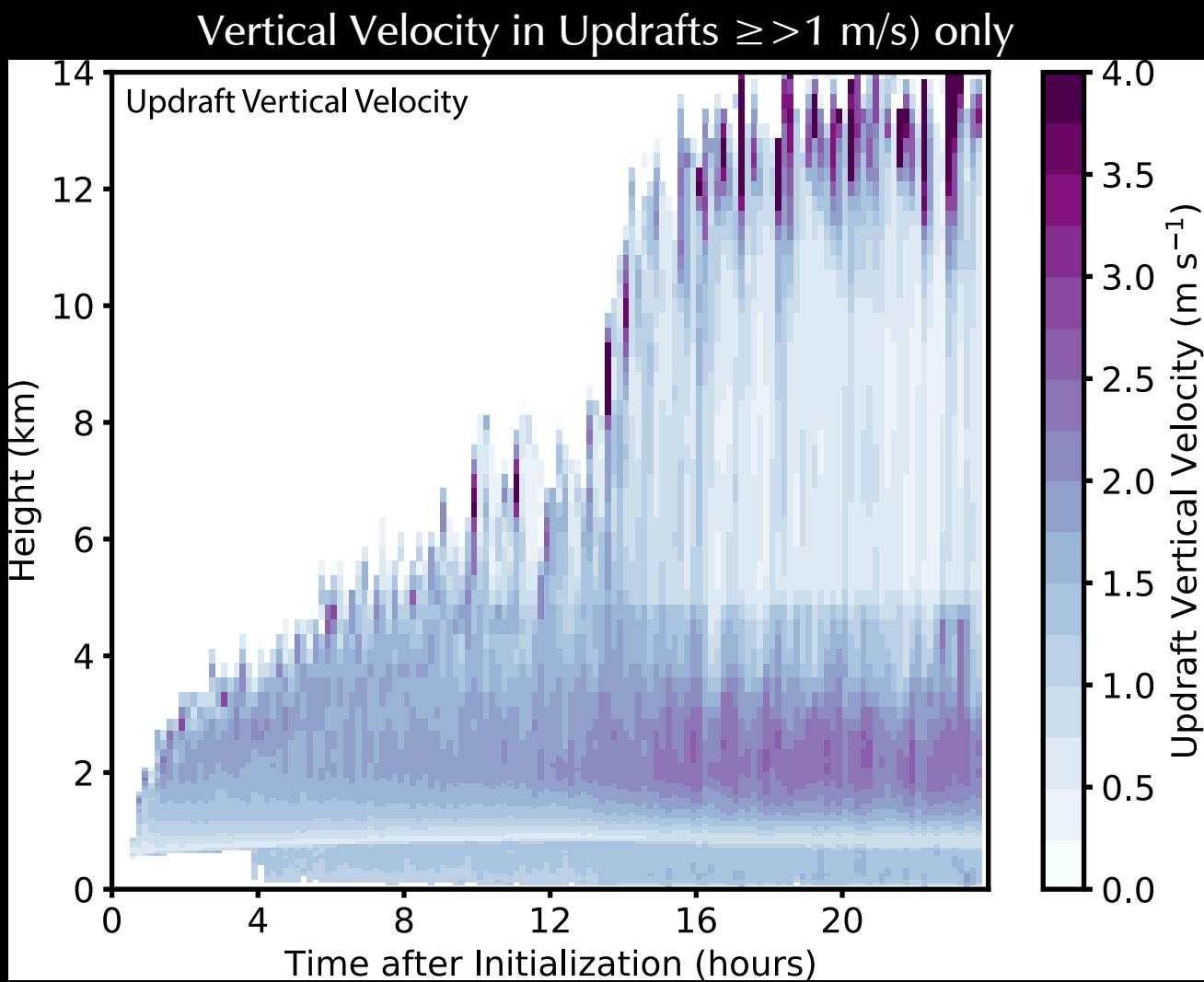


$$\frac{Dw}{Dt} = B - \frac{1}{\rho_0} \frac{\partial p'}{\partial z}$$

Vertical Acceleration in Updrafts (≥ 1 m/s) only

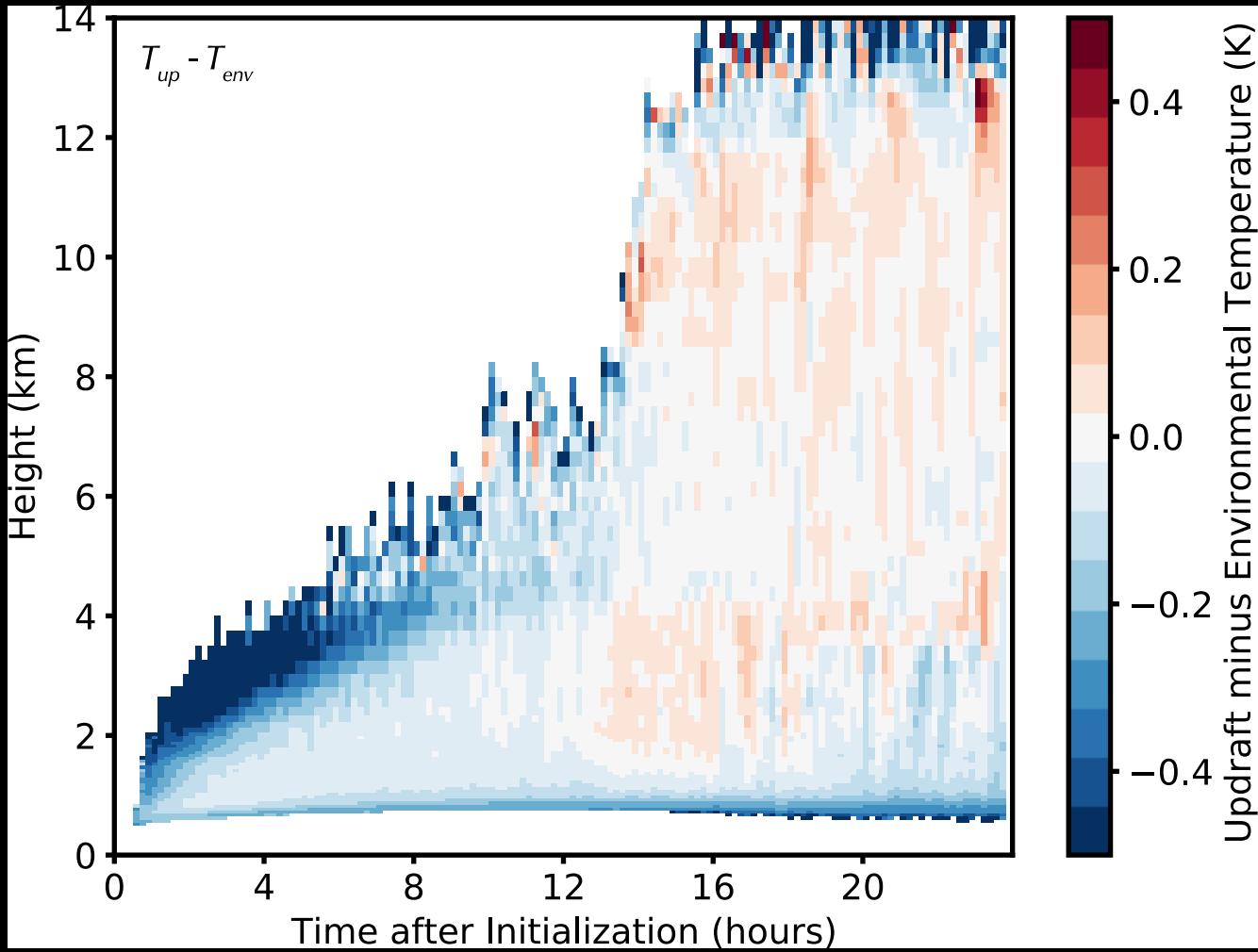


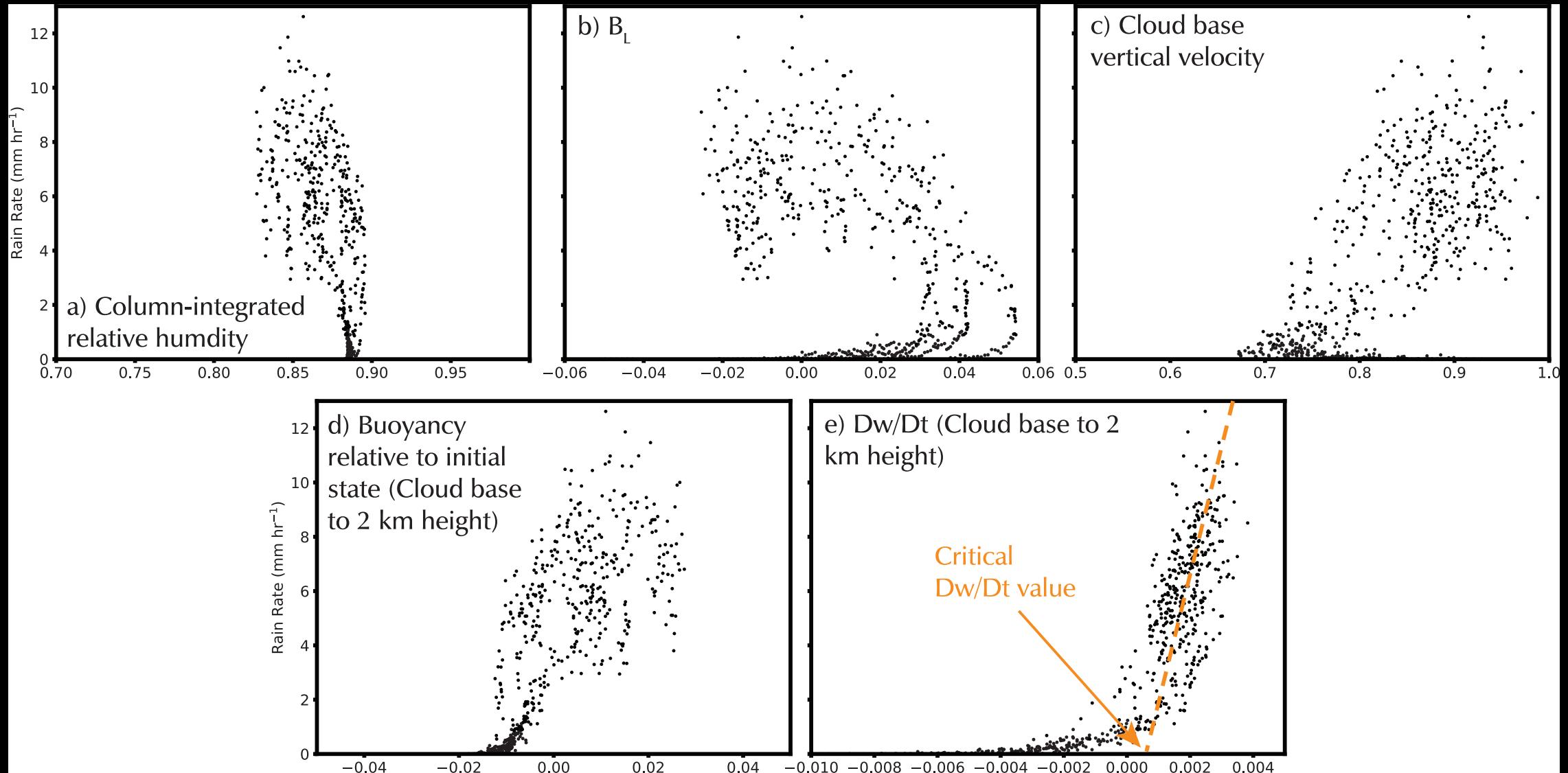
$$\frac{Dw}{Dt} = B - \frac{1}{\rho_0} \frac{\partial p'}{\partial z}$$



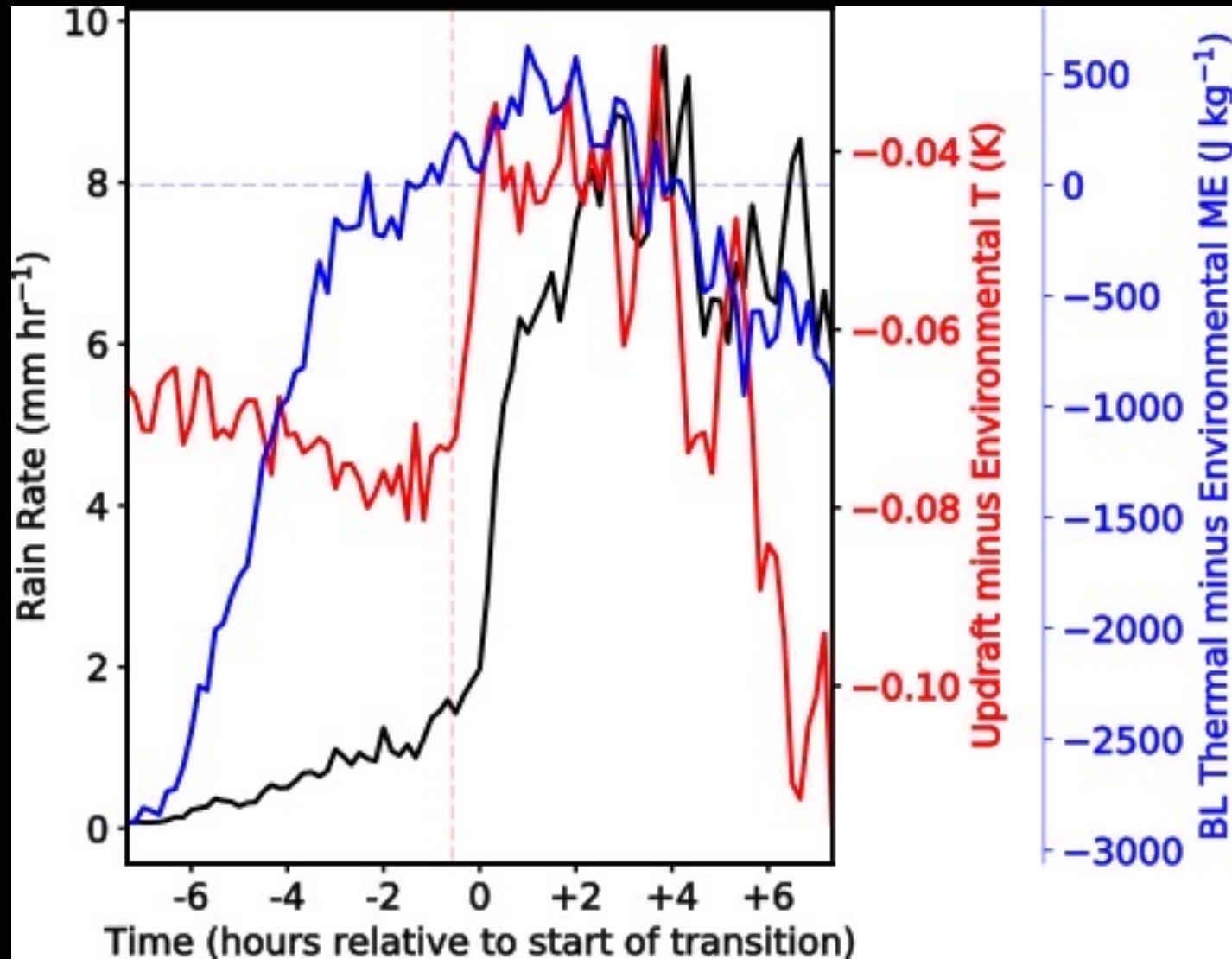
$$\frac{Dw}{Dt} = B - \frac{1}{\rho_0} \frac{\partial p'}{\partial z}$$

Mean Updraft Temperature minus Mean Environmental Temperature



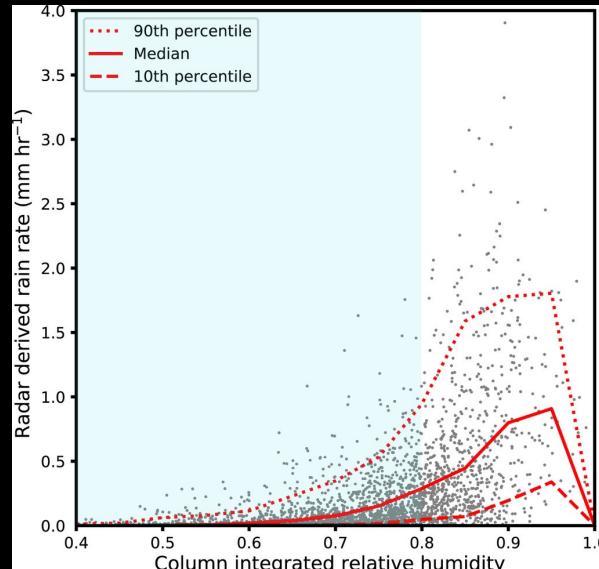


Moist enthalpy
 $\mathcal{H} = c_p T + L_v q$



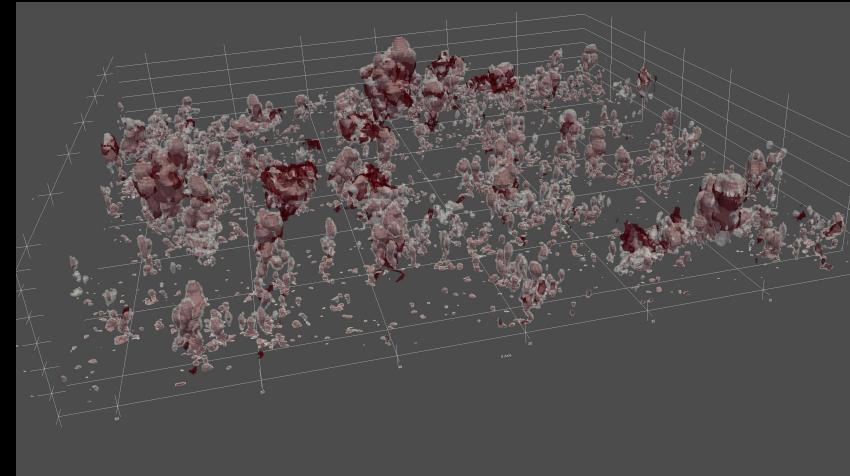
"Summary Slide" (Conclusions)

1. Non-negligible scatter in rain rate exists as a function of humidity or variables that incorporate both temperature and humidity structure of lower-troposphere. Cumulus parameterizations struggle to realistically depict convective life cycle.



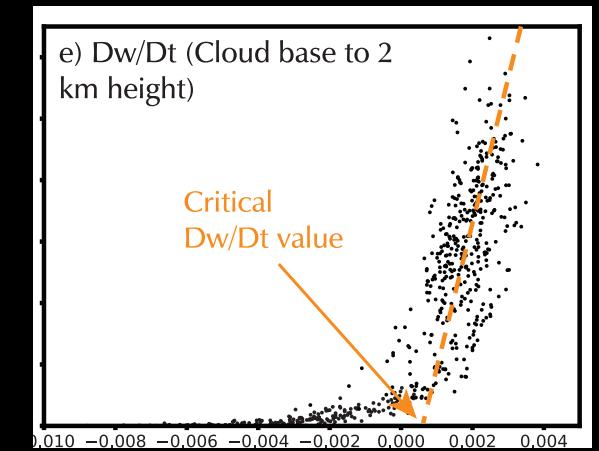
10 May 2021

Questions?
scott.powell@nps.edu

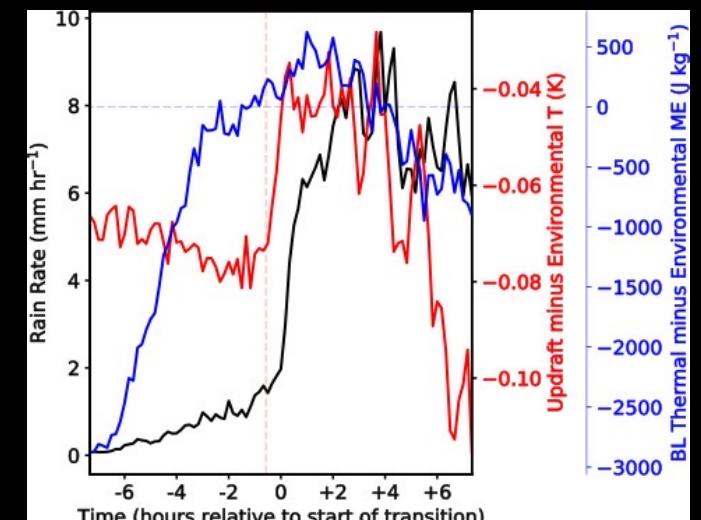


2. Model simulations were executed to simulate shallow-to-deep convective transitions using observed profiles of temperature and humidity as initial conditions.

3. Dw/Dt in updrafts appears predict rain rate effectively (but how do we observe Dw/Dt?).



4. Rapid transitions of convection from shallow to deep were preceded by rapid increases in updraft temperature and moist enthalpy in boundary layer thermals feeding those clouds.



S.W. Powell: Convective Lifecycle Transitions