

What Controls Shallow to Deep Convective Transitions of Cloud Populations in Moist Environments?



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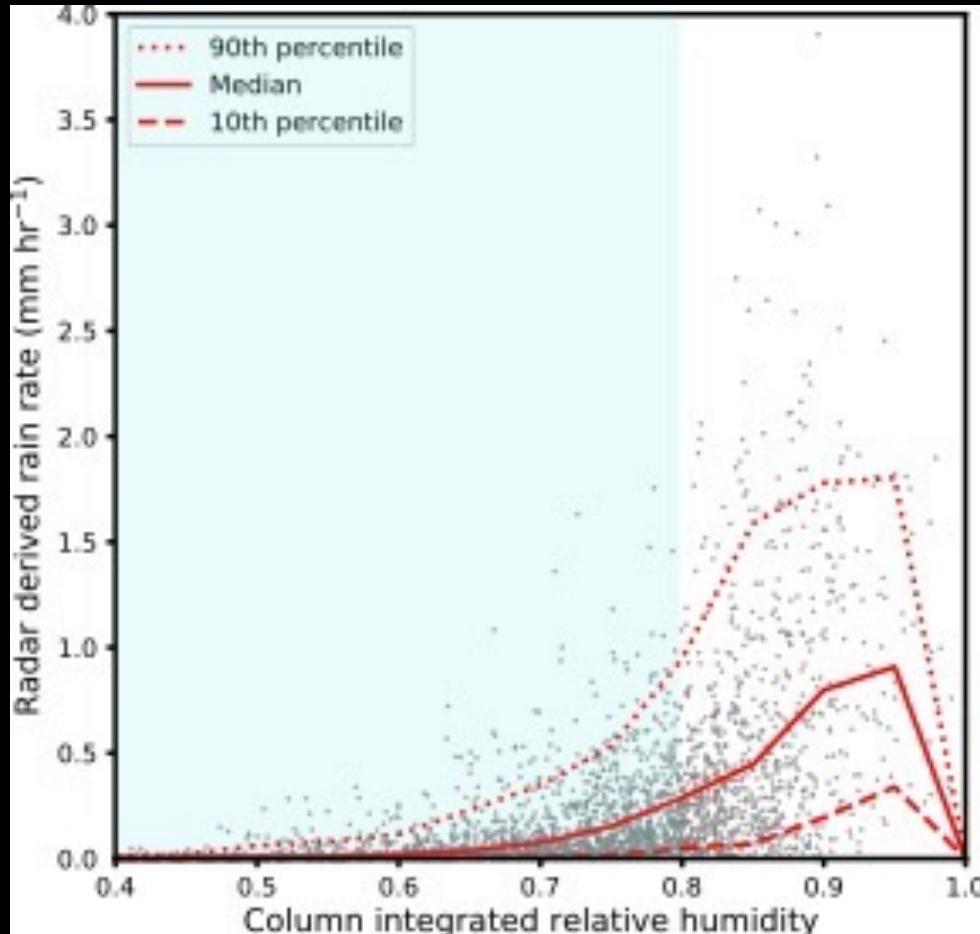
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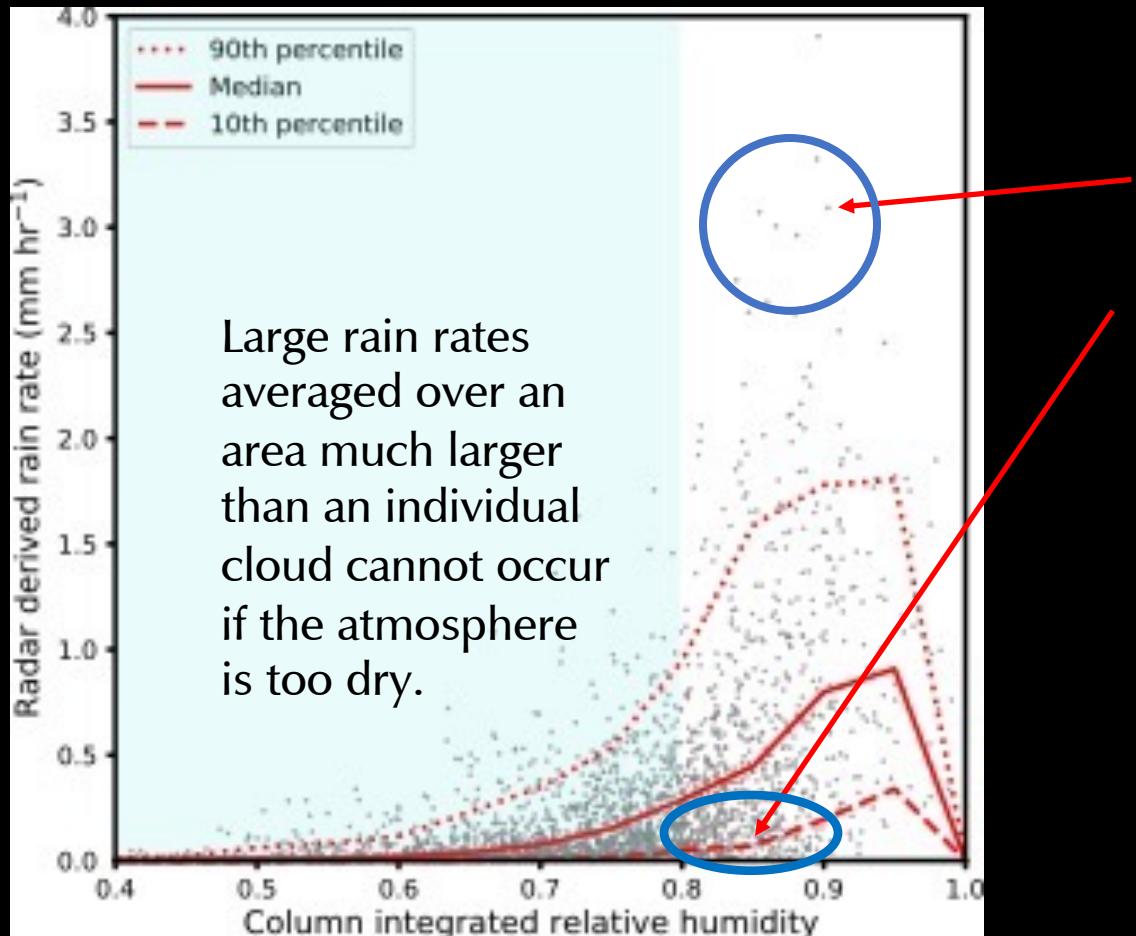
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Radar-derived rain rate vs sonde-derived CRH over tropical oceans



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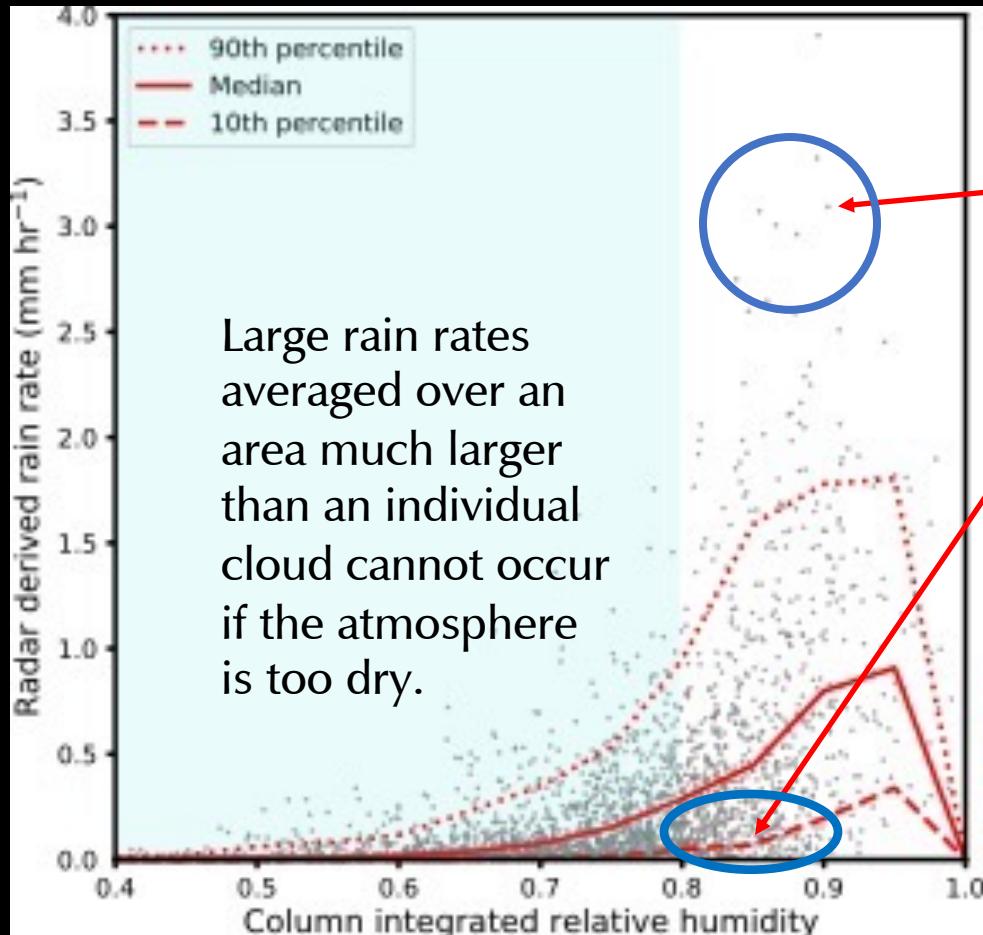
Radar-derived rain rate vs sonde-derived CRH over tropical oceans



Column-relative humidity of 80% or greater is often considered sufficiently moist for widespread deep convection to occur, but rain rates in such an environment can range from very large to near zero!

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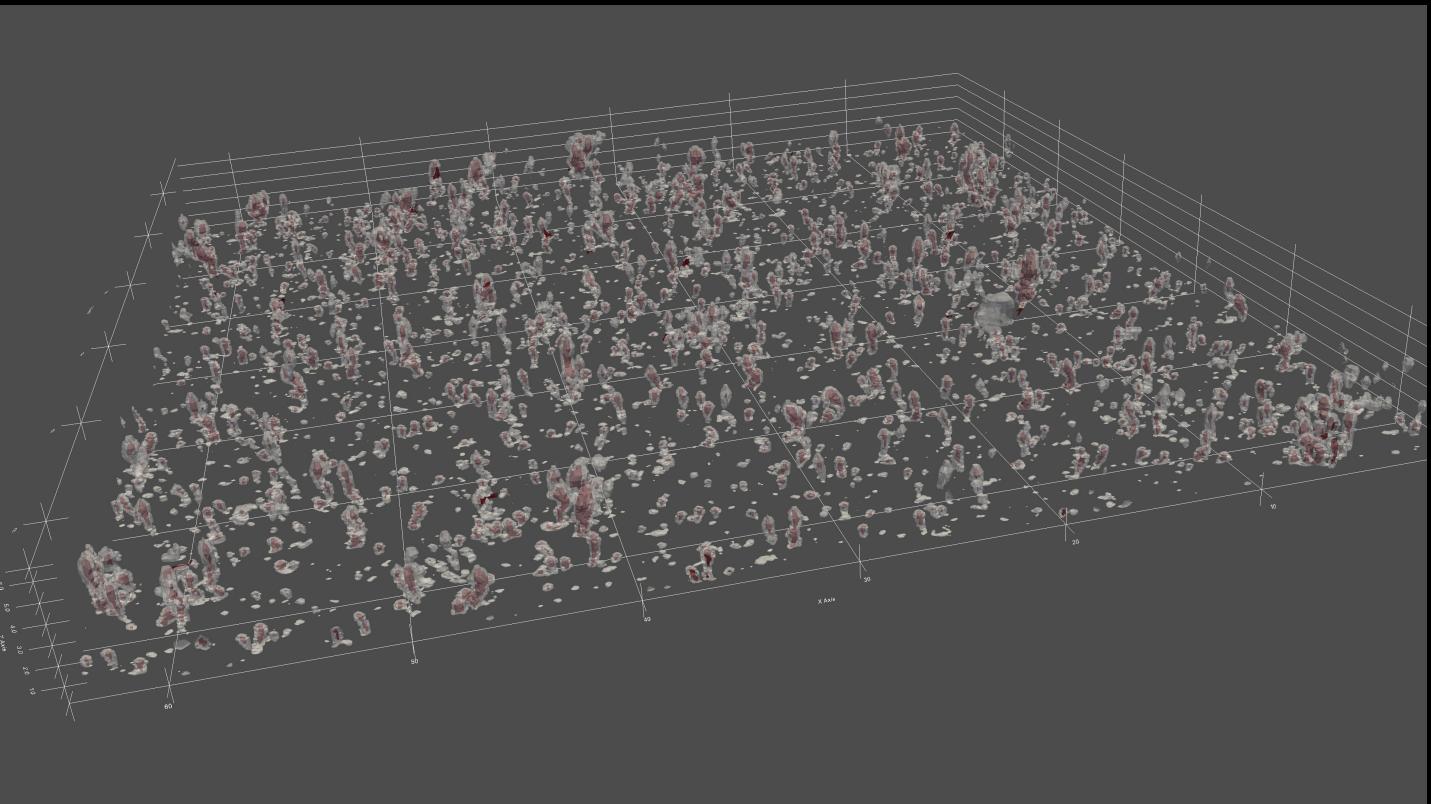


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What controls the when rain rate is zero versus large when the atmosphere is moist?

Cloud Model 1 was used to investigate the question. We will investigate the evolution of vertical acceleration in cloudy updrafts.

- Horizontal grid spacing: 100 m
- Vertical grid spacing: 50 m in BL stretched to 250 m above 3.5 km
- 64 km x 64 km x 20 km domain
- Horizontal boundaries: Periodic
- Time step: 1 second
- Microphysics: Morrison
- PBL: None
- Surface: MM5 similarity
- Radiation: NASA-Goddard
No shortwave radiation
- Turbulence: Smagorinsky
- Sea surface temperature: 302K
- Random BL theta perturbations up to 0.25 K used to promote convection



Vertical Momentum Equation

$$\frac{Dw}{Dt} = -\frac{1}{\rho} \frac{\partial \rho'}{\partial z} + B$$

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Archimedean
buoyancy



$$B \approx \frac{\theta^*}{\theta_0} + \left(\frac{R_v}{R_d} - 1 \right) q_v^* - q_{lf}$$

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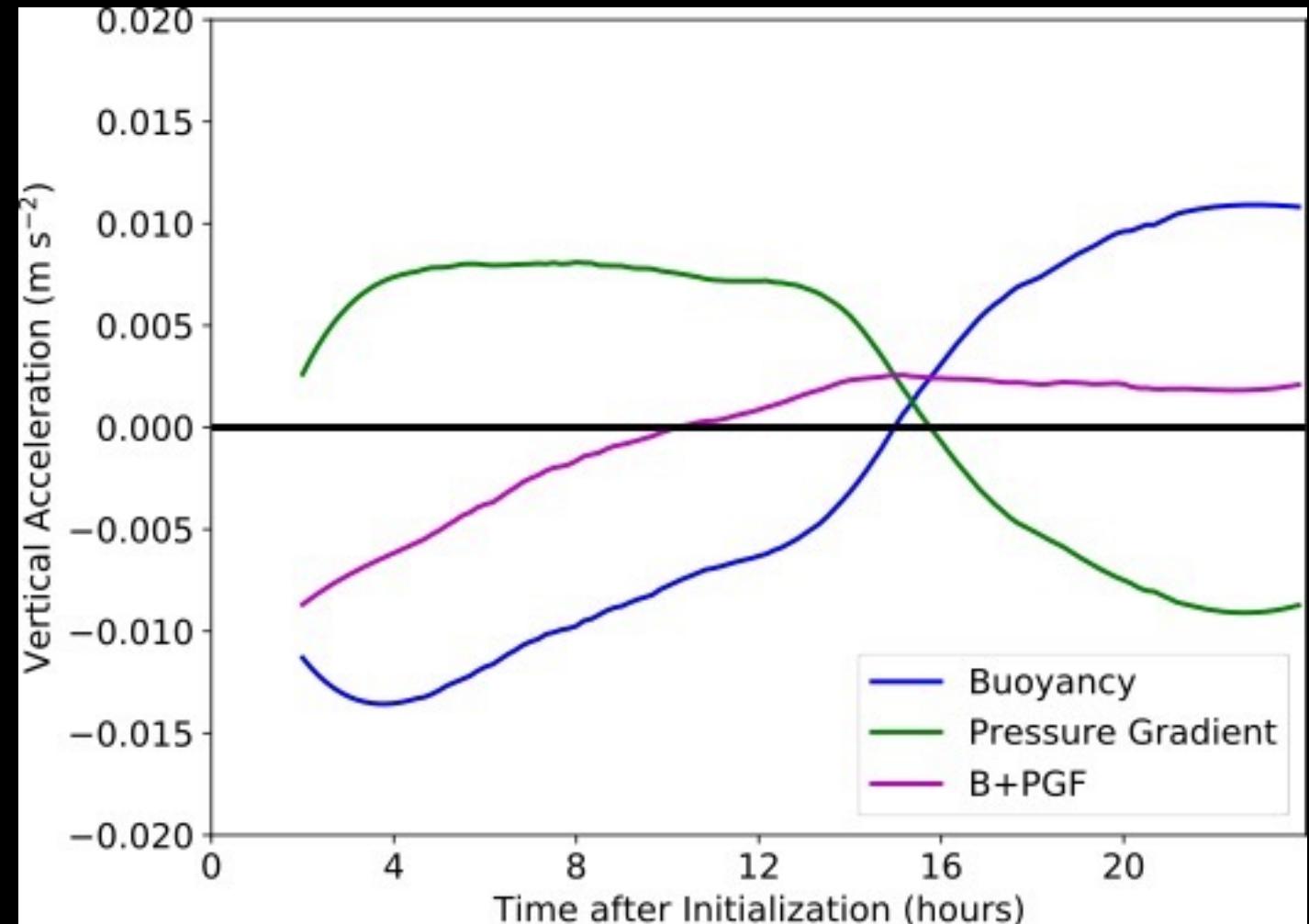
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Vertical Pressure Archimedean
Gradient buoyancy
Acceleration

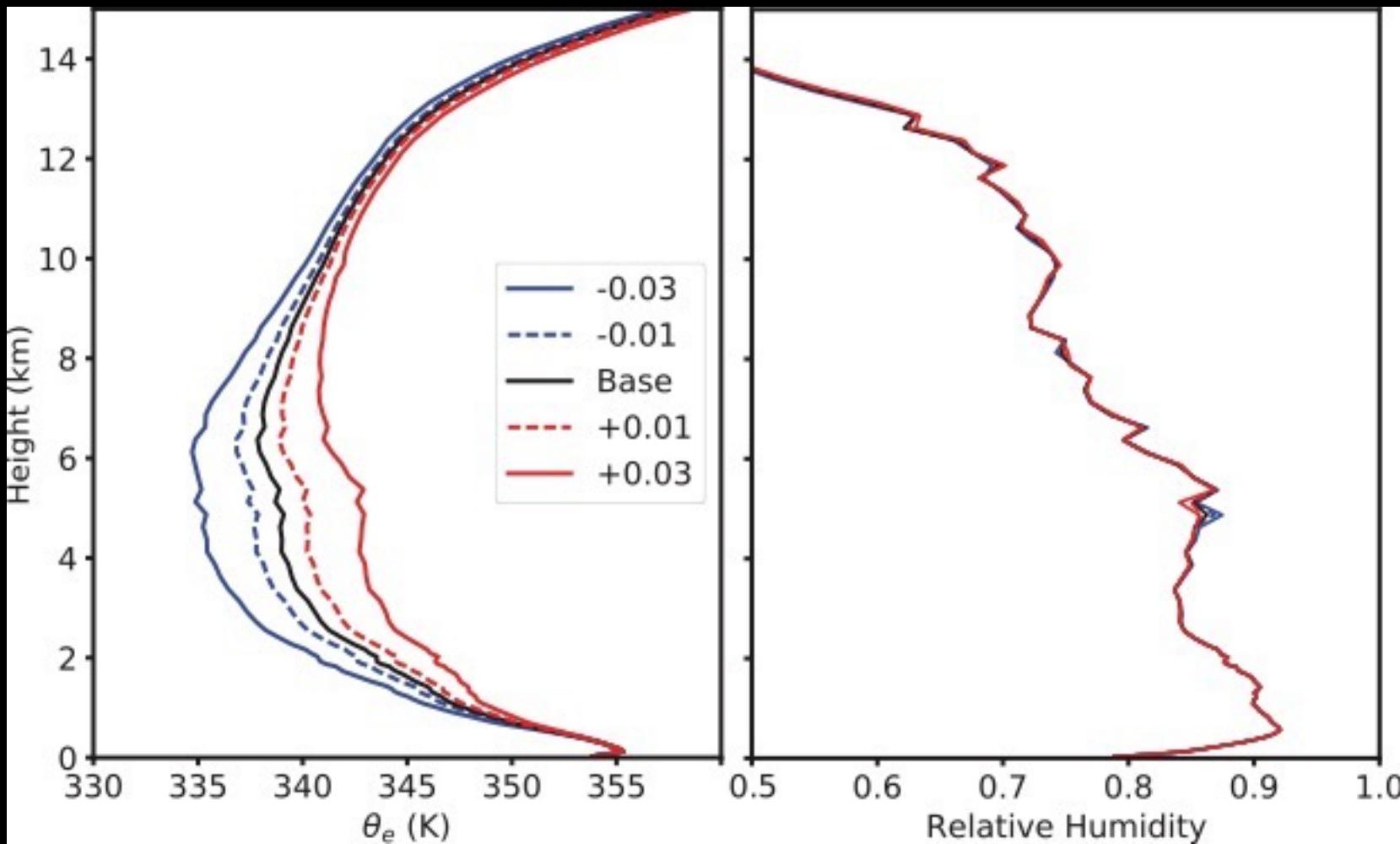
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Total vertical acceleration (i.e.,
“effective buoyancy” (Dw/Dt)

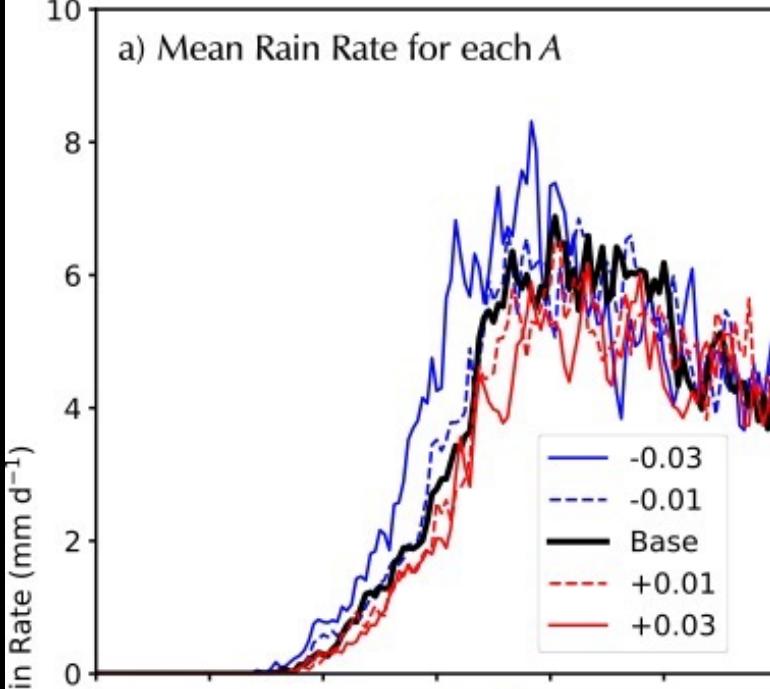


Each line represents one of 5 different initial conditions used.

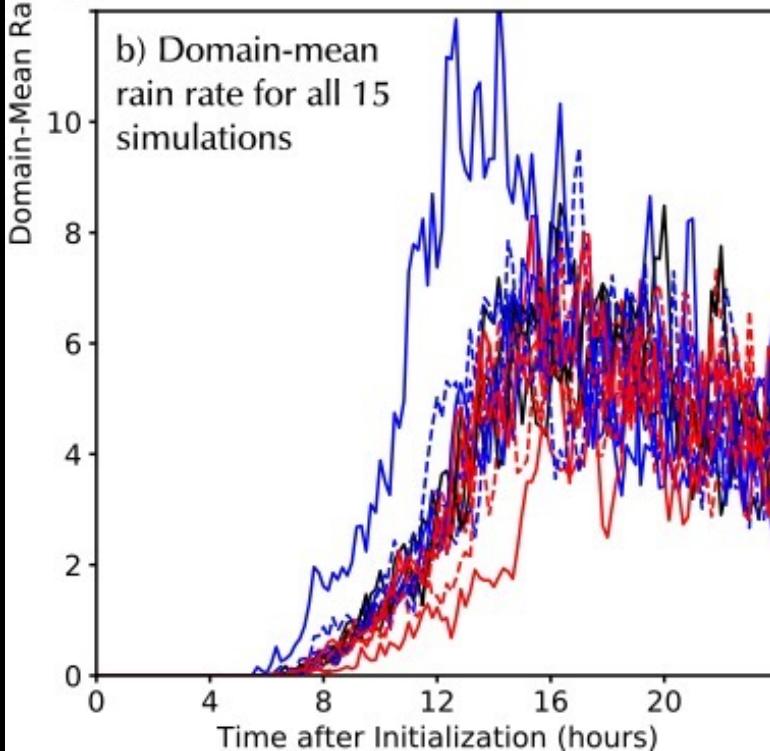


Domain-mean rain rates

“Ensemble” mean



Each simulation

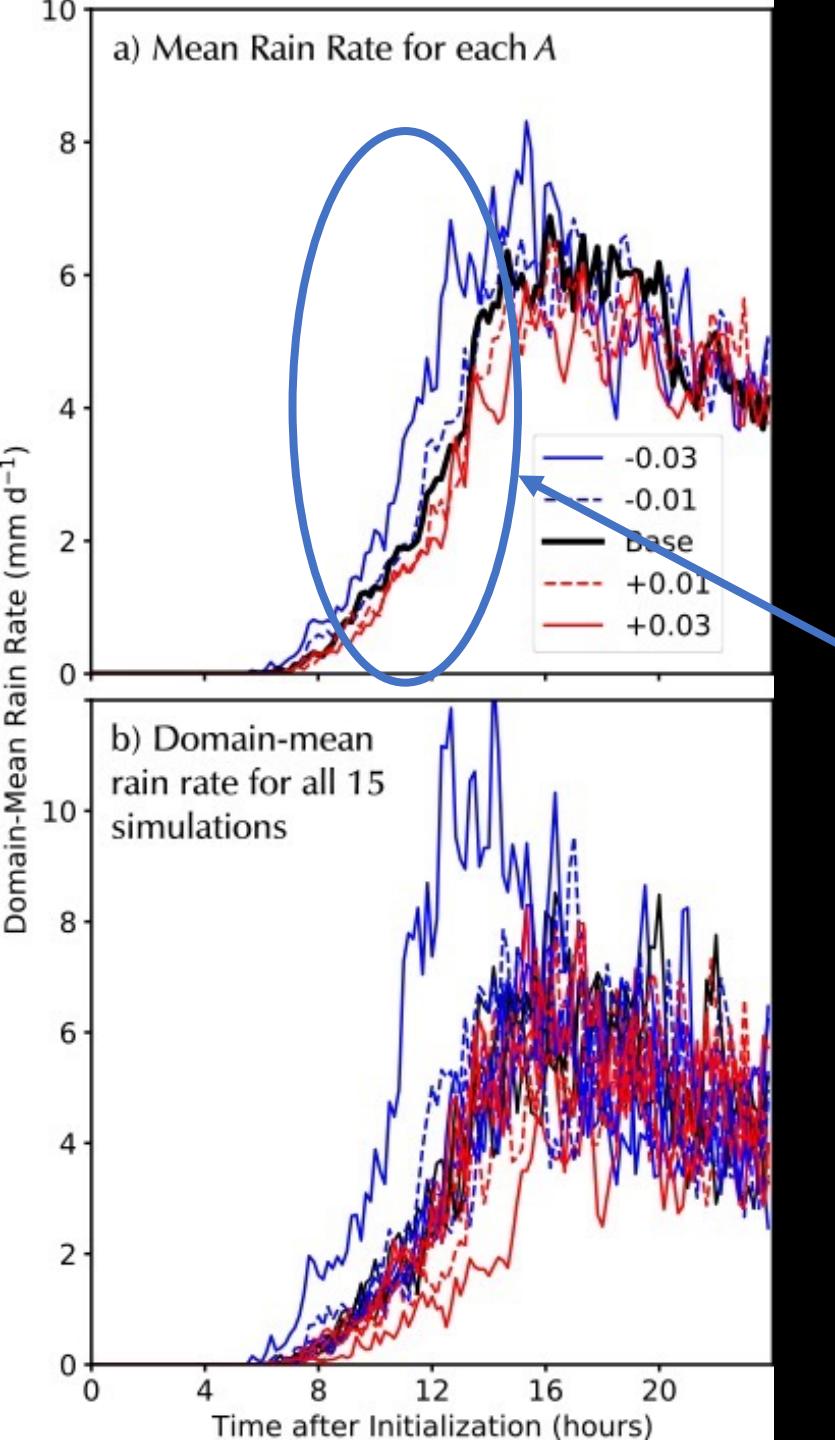


All simulations produced rain. The timing differed slightly during a few experiments depending on initial conditions.

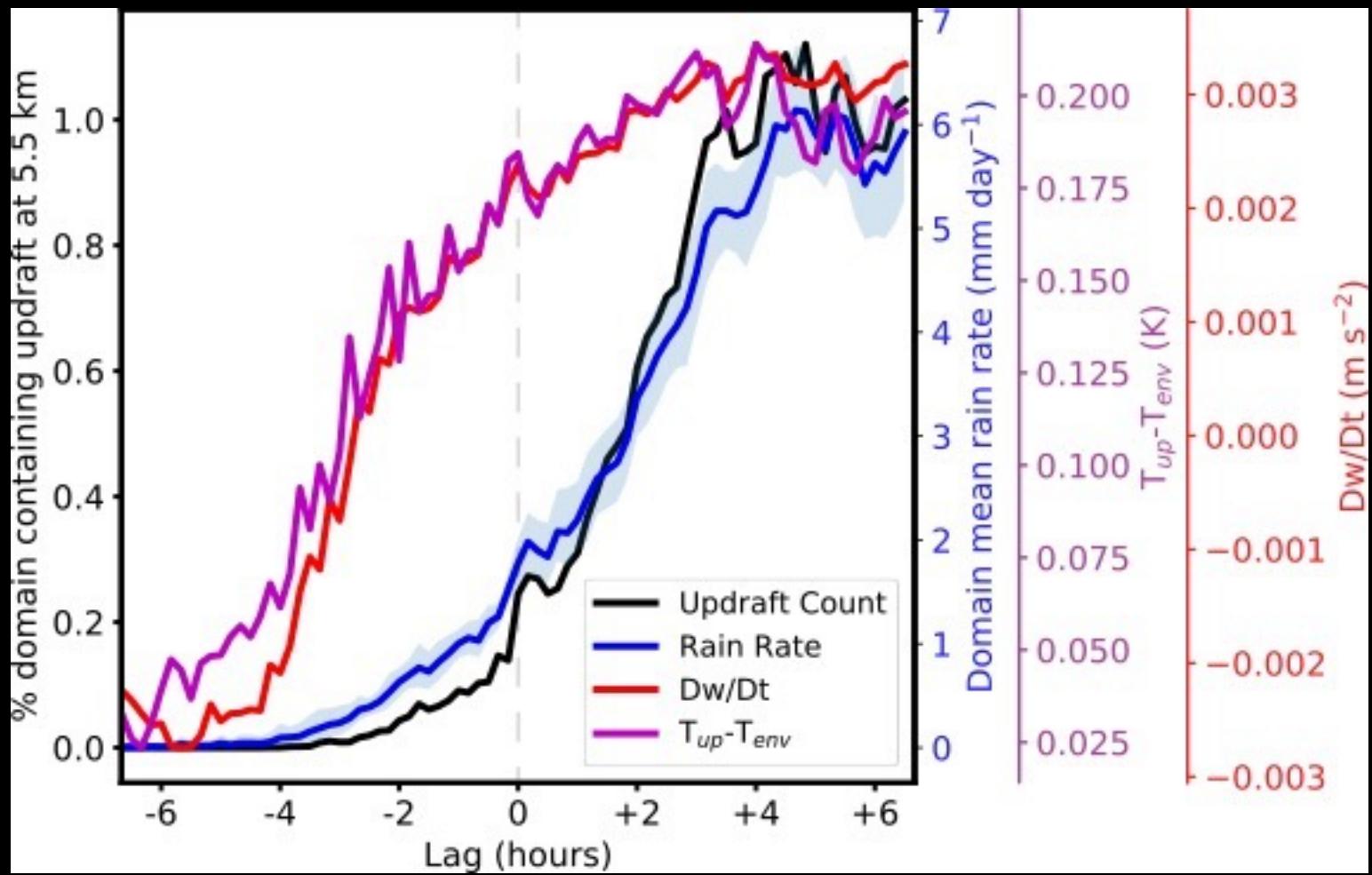
Domain-mean rain rates

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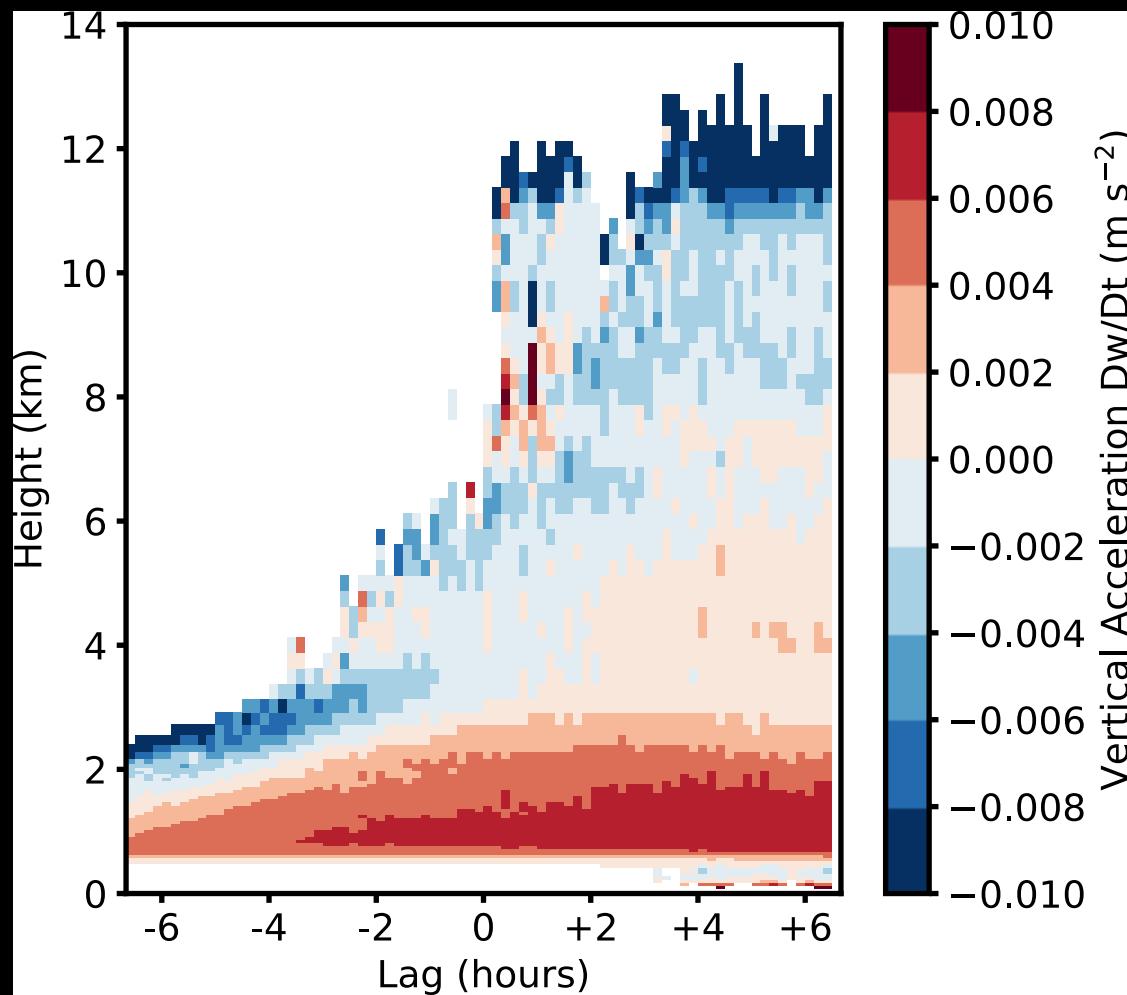
Each simulation



What happens during the period when the domain-mean rain rate rapidly increases?

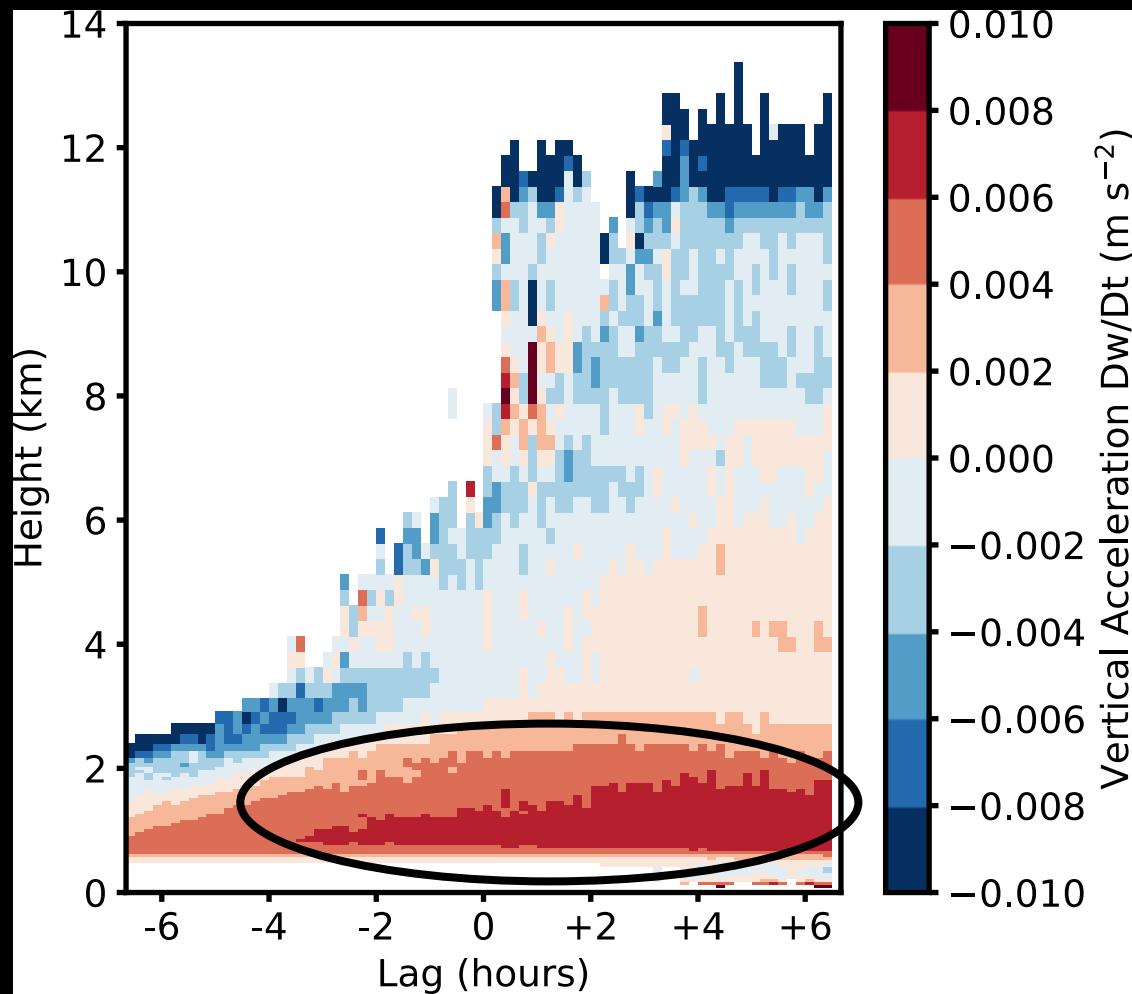


Domain-mean Dw/Dt in cloudy updrafts



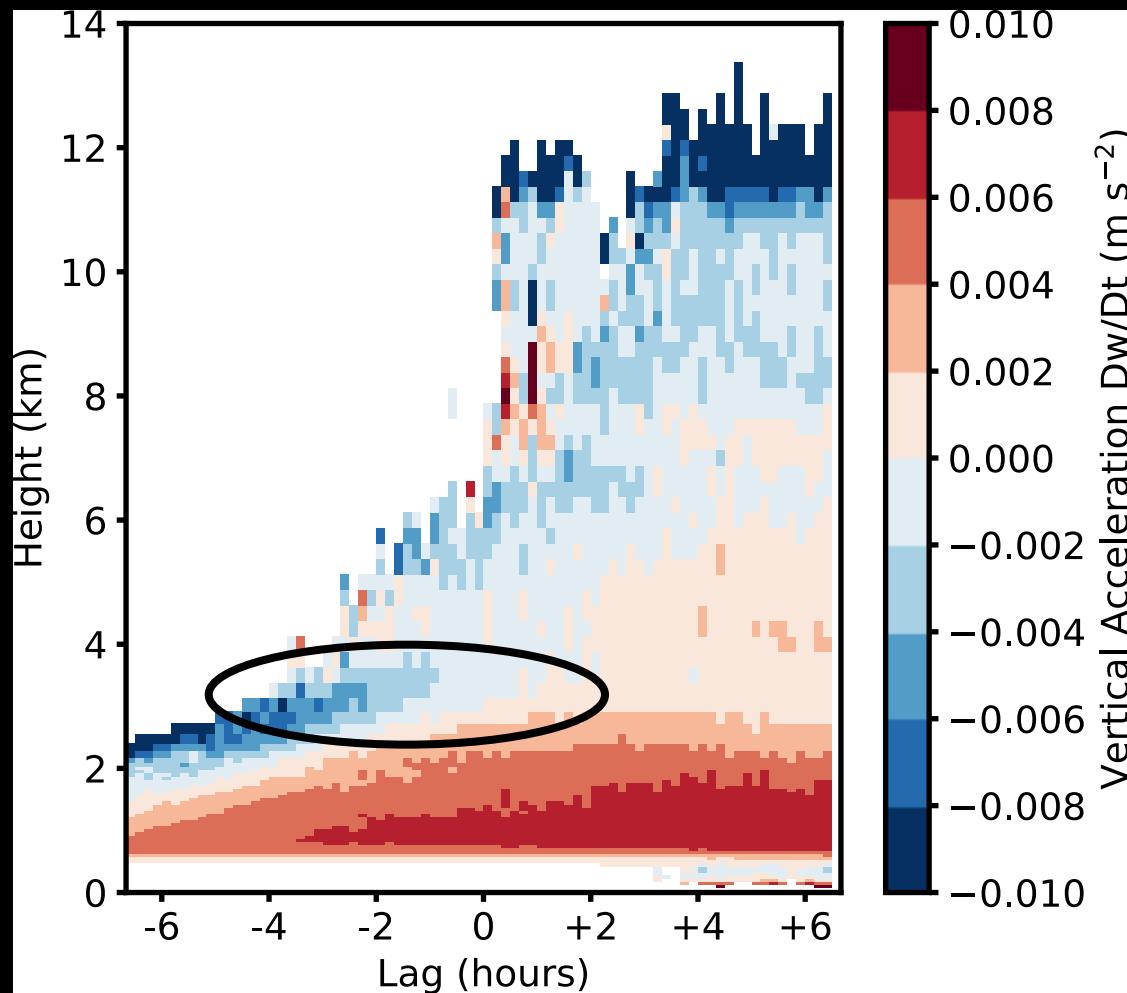
Red = Acceleration
Blue = Deceleration

Domain-mean Dw/Dt in cloudy updrafts



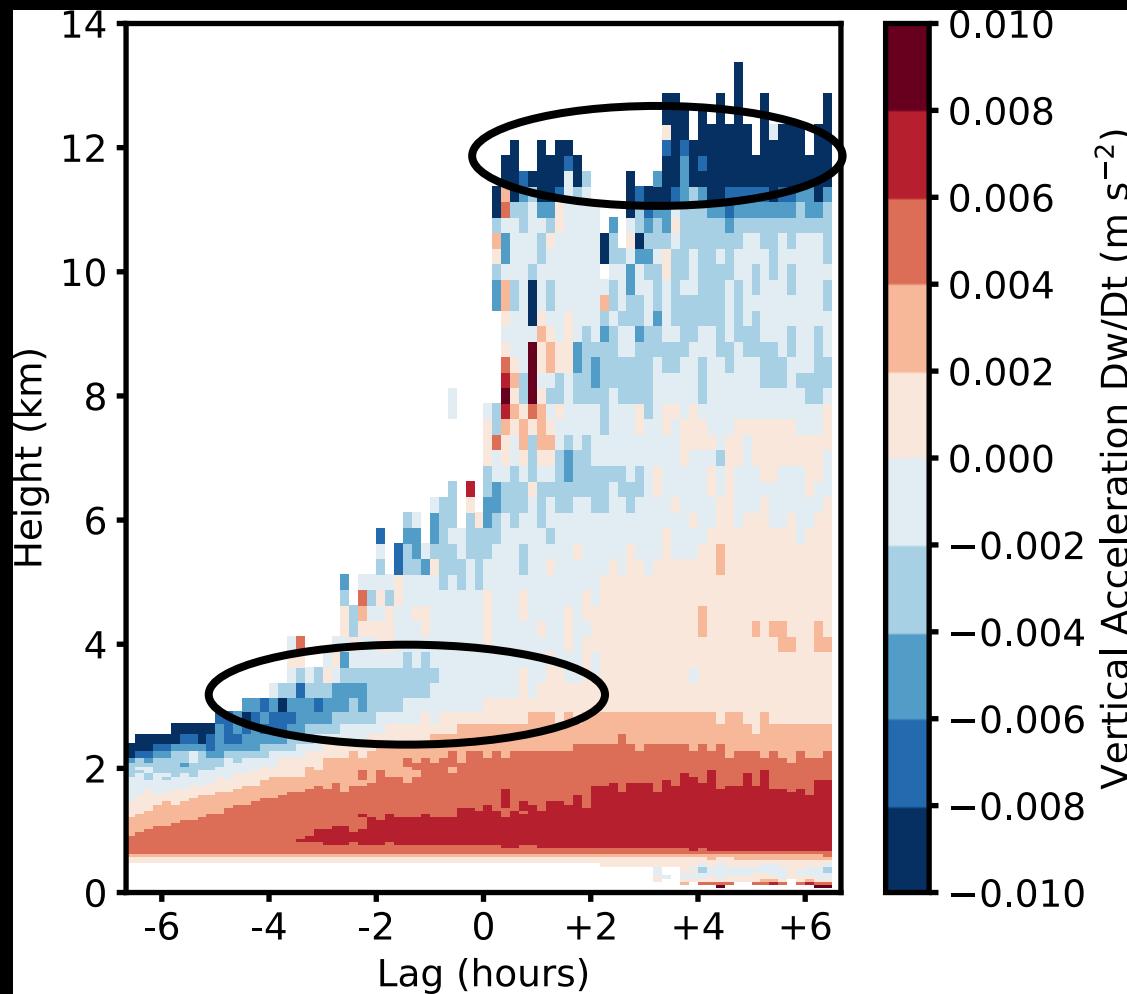
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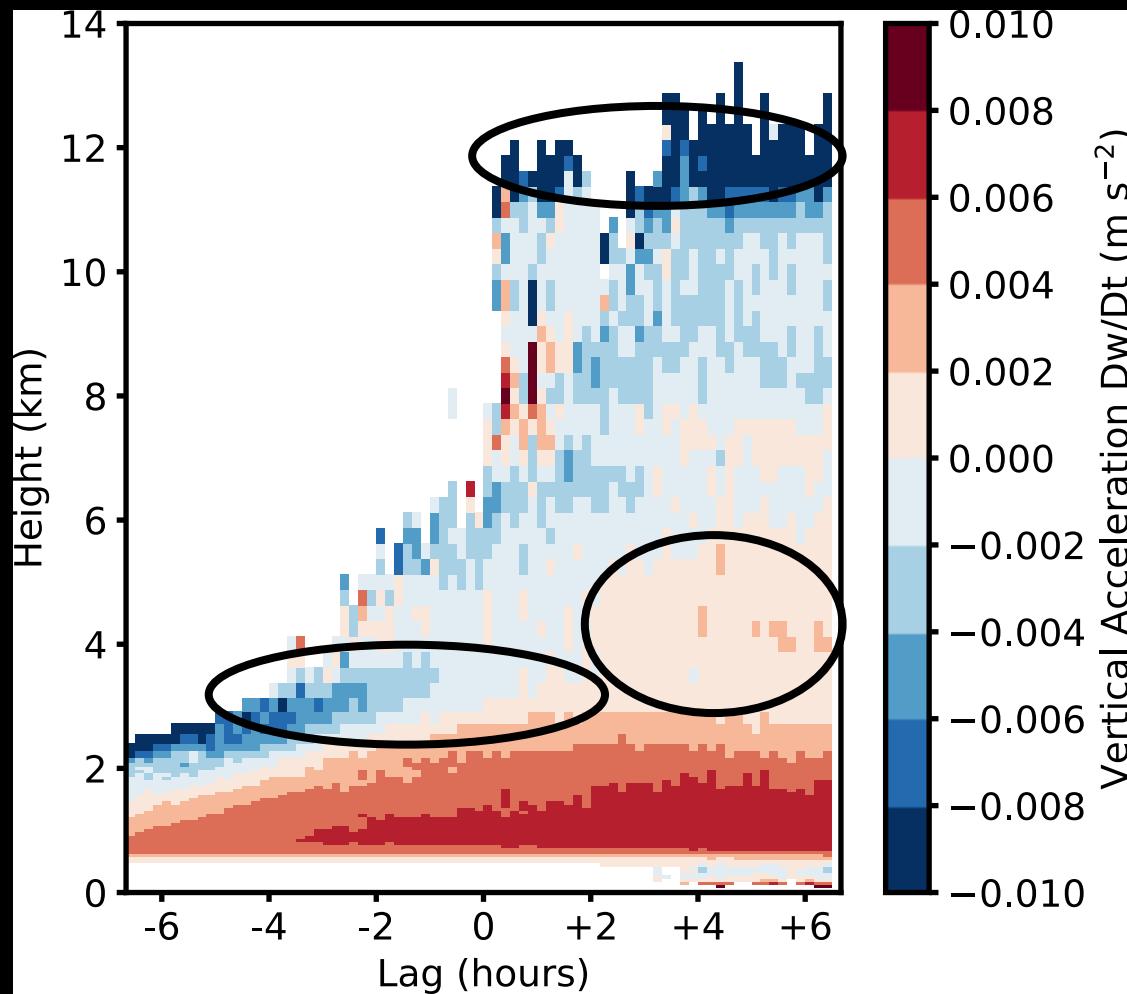
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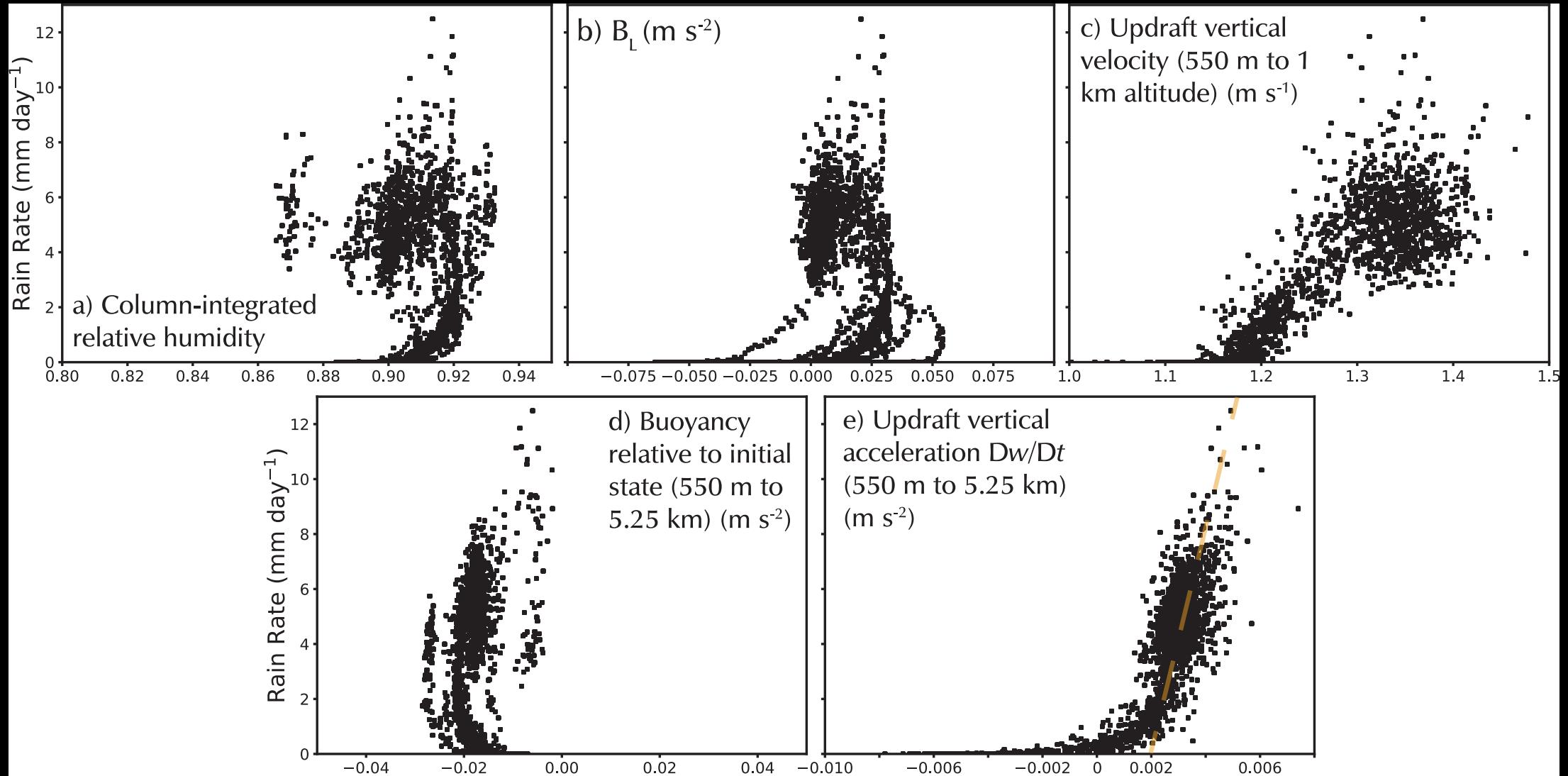
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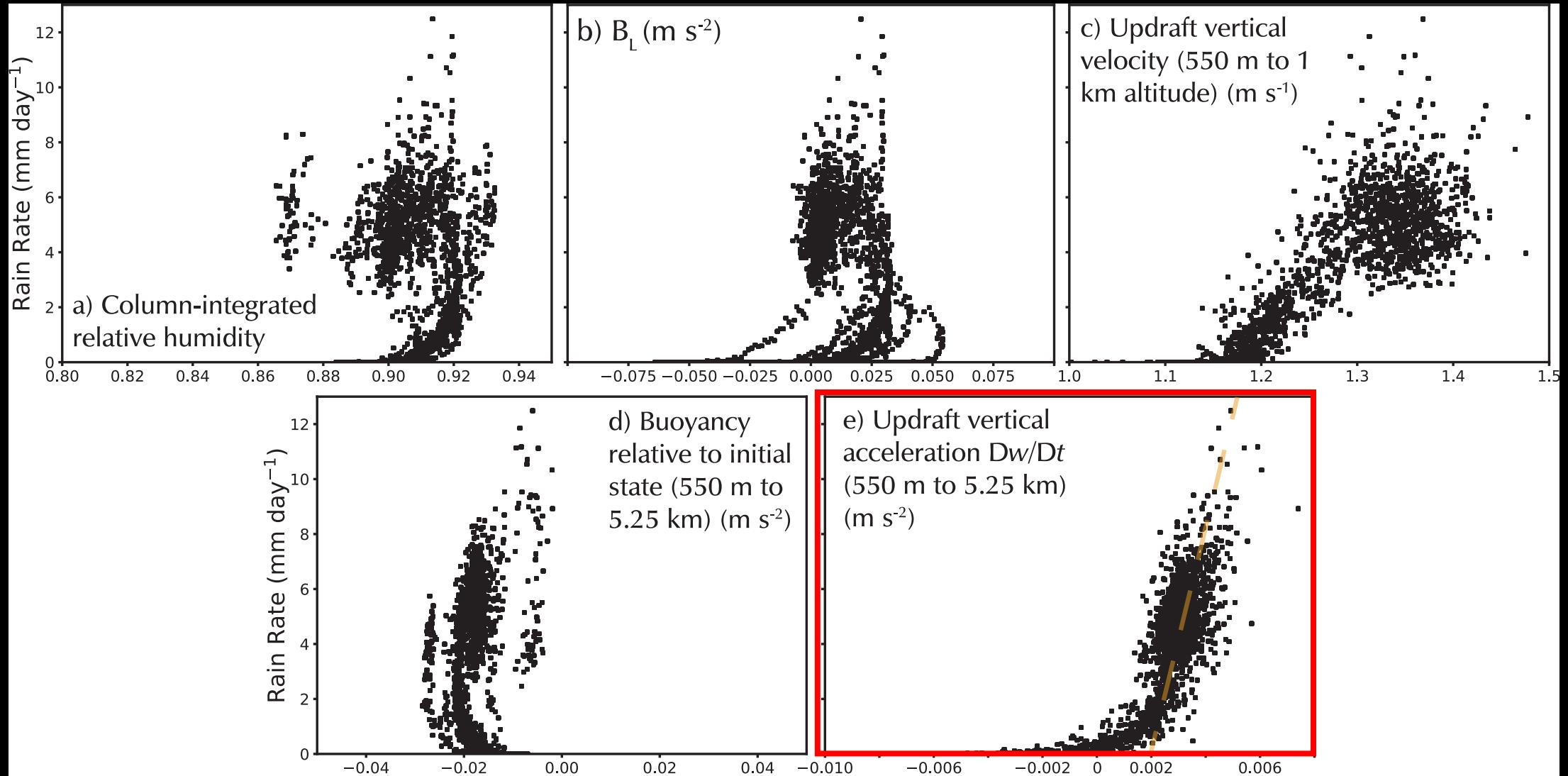


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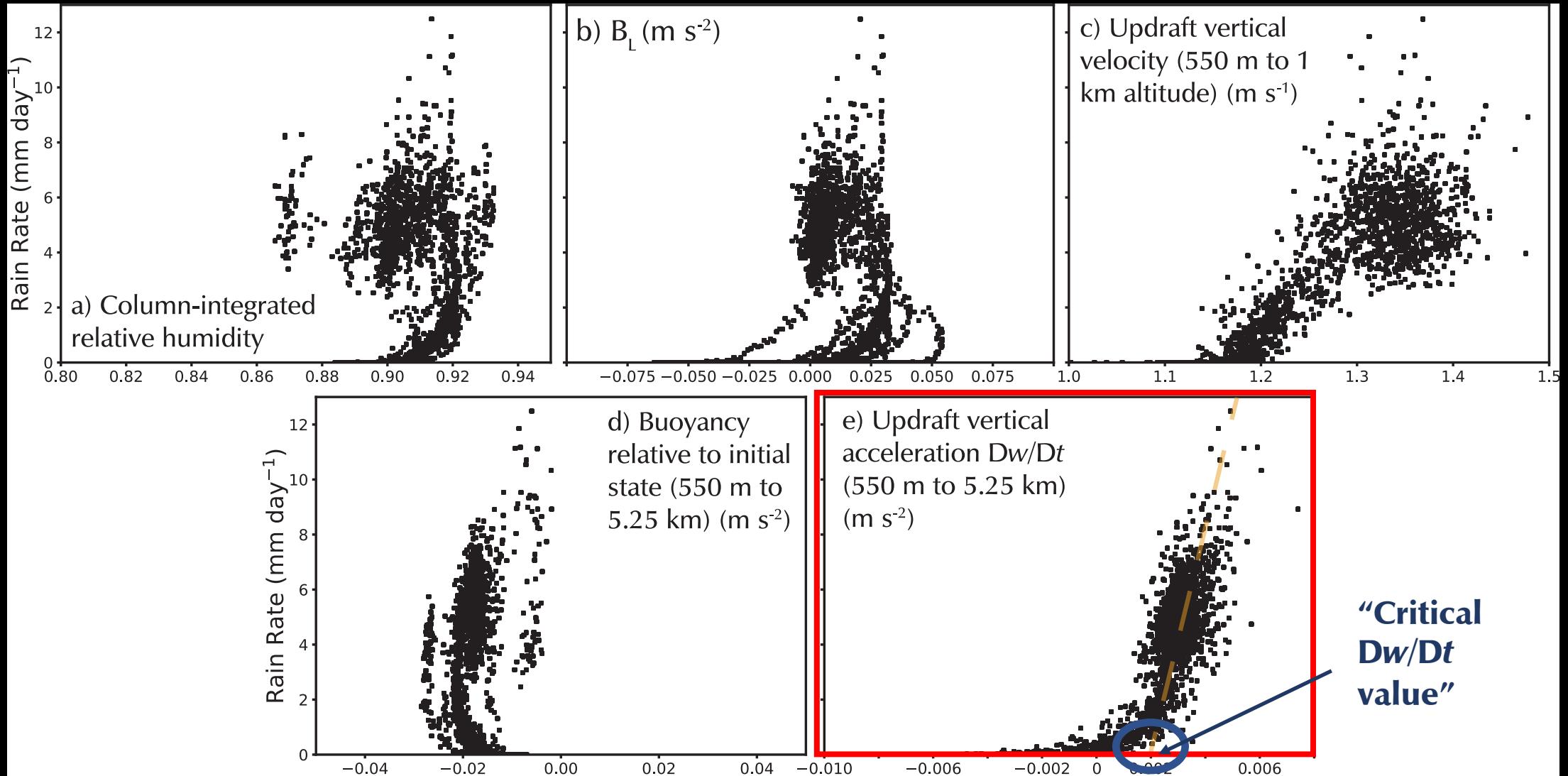
How does rain rate evolve as a function of _____?



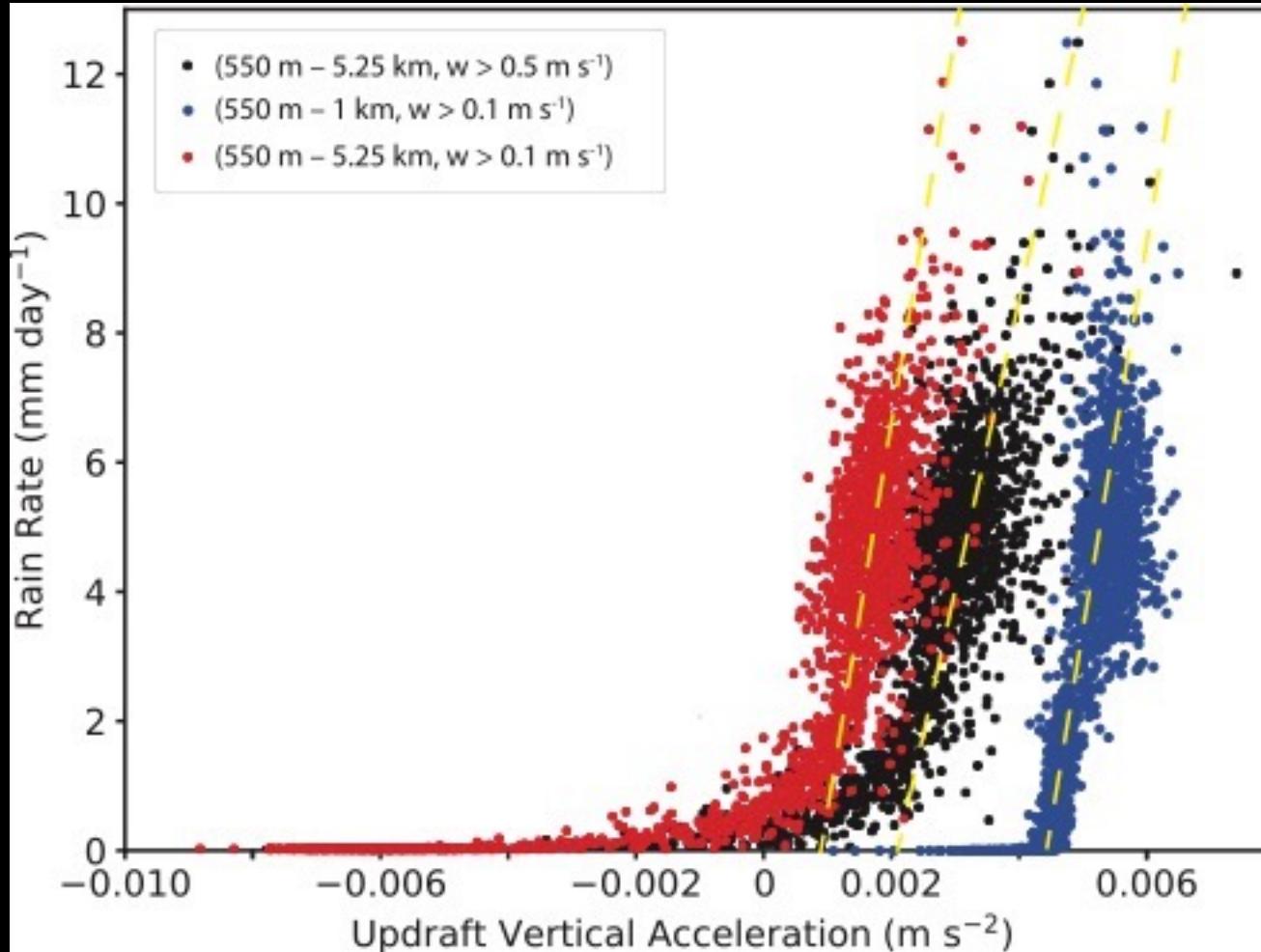
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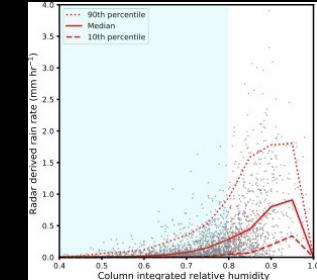
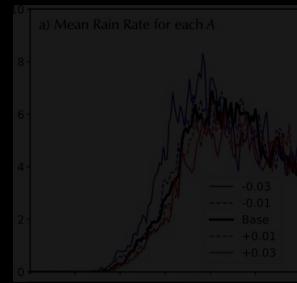


The “critical value” of Dw/Dt is sensitive to how an updraft is defined or the layer in which Dw/Dt is considered.



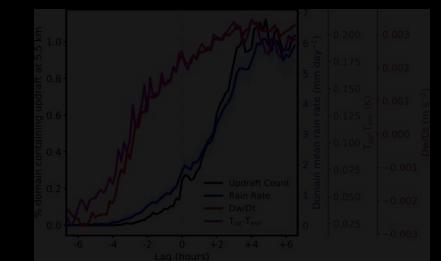
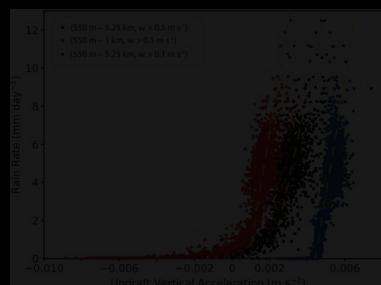
Conclusions

- Tropospheric moisture is a necessary but alone not sufficient requirement for deep convection and large precipitation rates over tropical oceans.



- Using LES in CM1, we investigate what factors control area-averaged rain rate for environments initialized with the same moisture profile and slightly different temperature profiles. All simulations produce rain at slightly different times, with more stable profiles producing rain slightly later than than more unstable profiles.

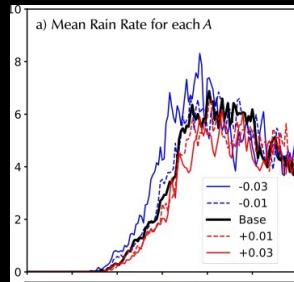
Dw/Dt, the total vertical acceleration increases in updrafts below the 0°C level in the hours prior to when simulated shallow convection commonly grows into deep convection.



Domain-mean rain rate was most sensitive to updraft Dw/Dt, such that it increased rapidly (and possibly almost linearly) after it exceeded a “critical value”.

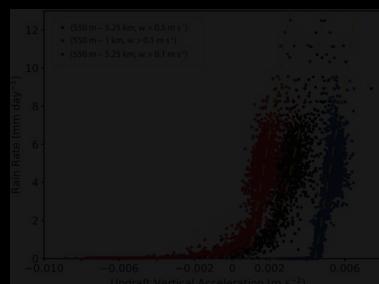
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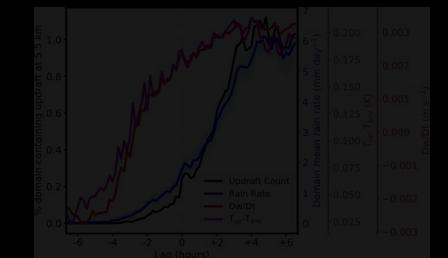
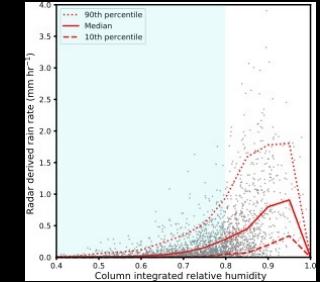


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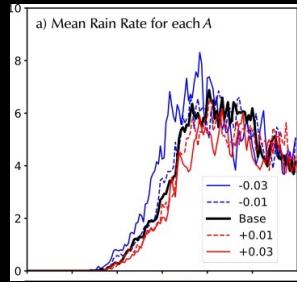


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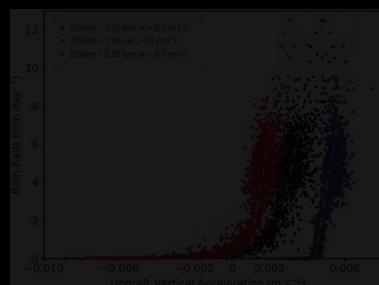
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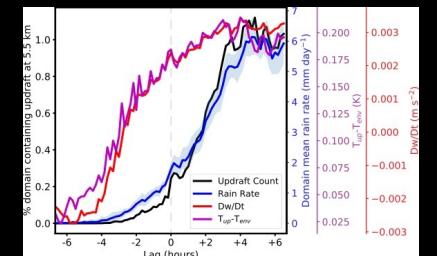
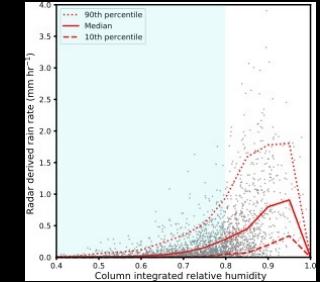


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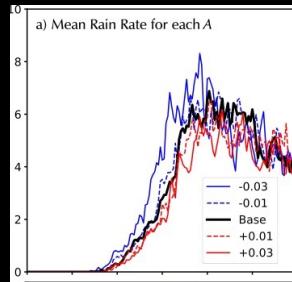


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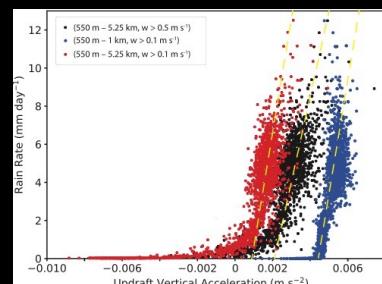
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