Downdrafts, Low Level Cooling, and Relative Humidity

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CMMAP Team Meeting
Physical Processes Breakout
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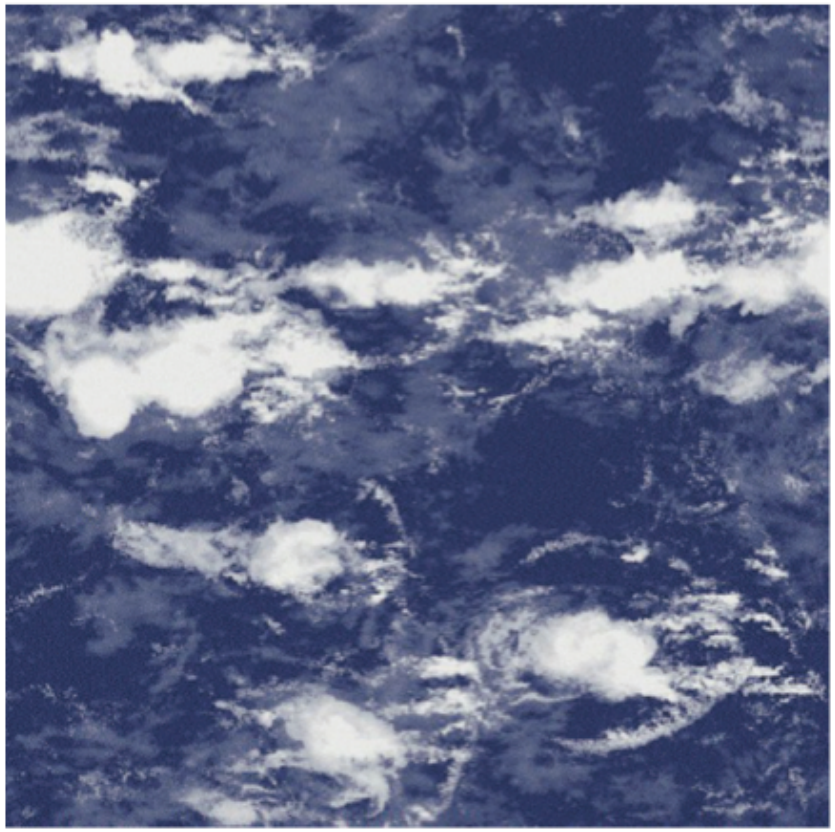
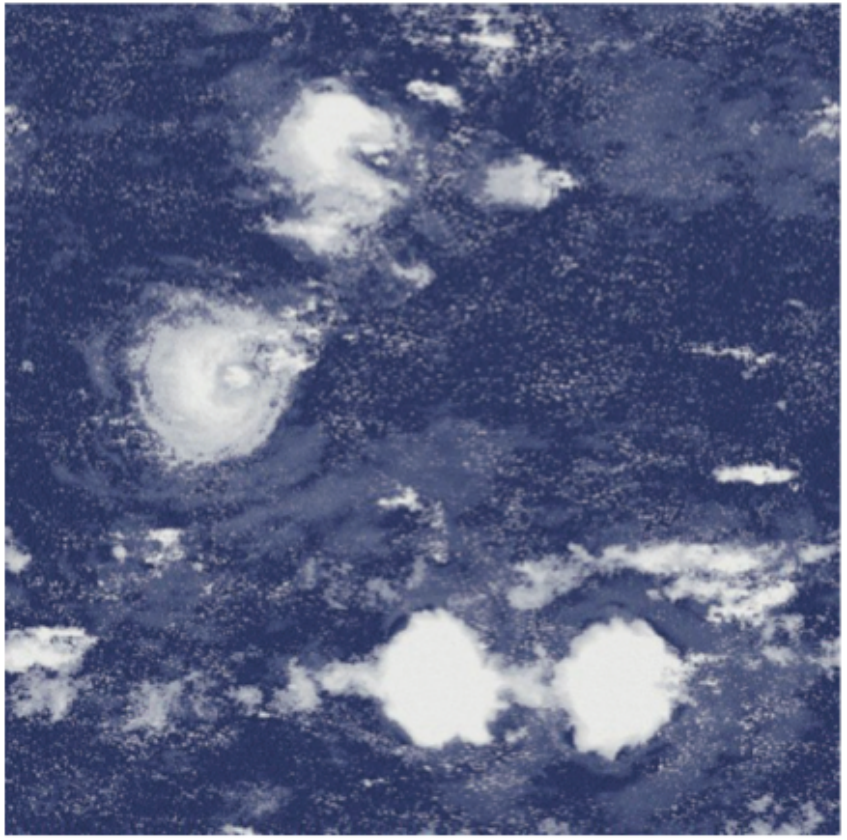
Improvement of Downdrafts in Convective Parameterizations:
Examining Assumptions with High Resolution CRM Data
Katherine Thayer-Calder and David Randall

Figures: Khairoutdinov et al. (2010)



Control

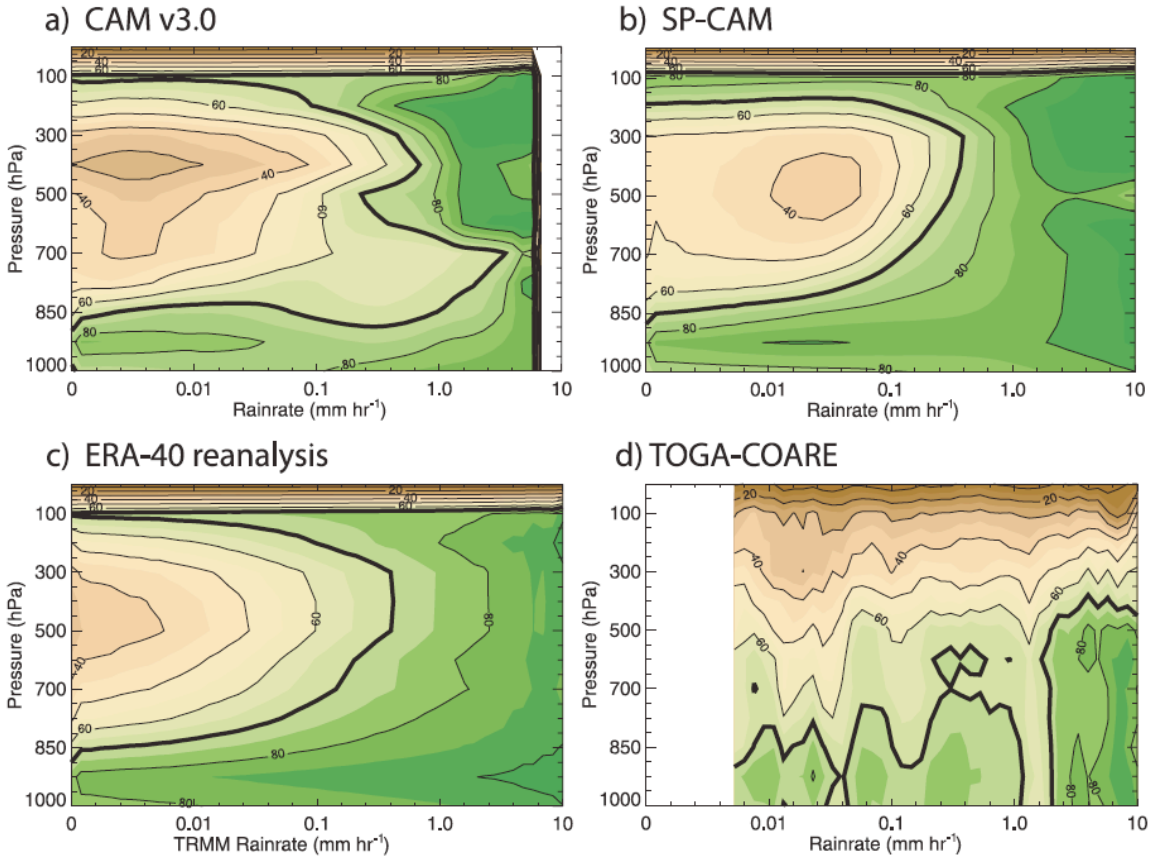


No Precip Evaporation

Super LES Cloud Fields

Tropical Convection

- It rains too often
- It rains too lightly
- Deep convection does not "feel" the humidity of the mid troposphere



Three Ways to Decrease the Frequency and Power of Deep Convection

1. Relative Humidity Cut-Off Criteria (Tokioka et al, 1988)
   - Do not allow deep convection to occur until shallow and stratiform convection (and SGS fluxes) have sufficiently moistened the boundary layer or column.

2. Increased Updraft Entrainment
   - Increased entrainment will decrease the buoyancy of updraft parcels when they encounter dry air and deep convection will not occur until the column is sufficiently moistened

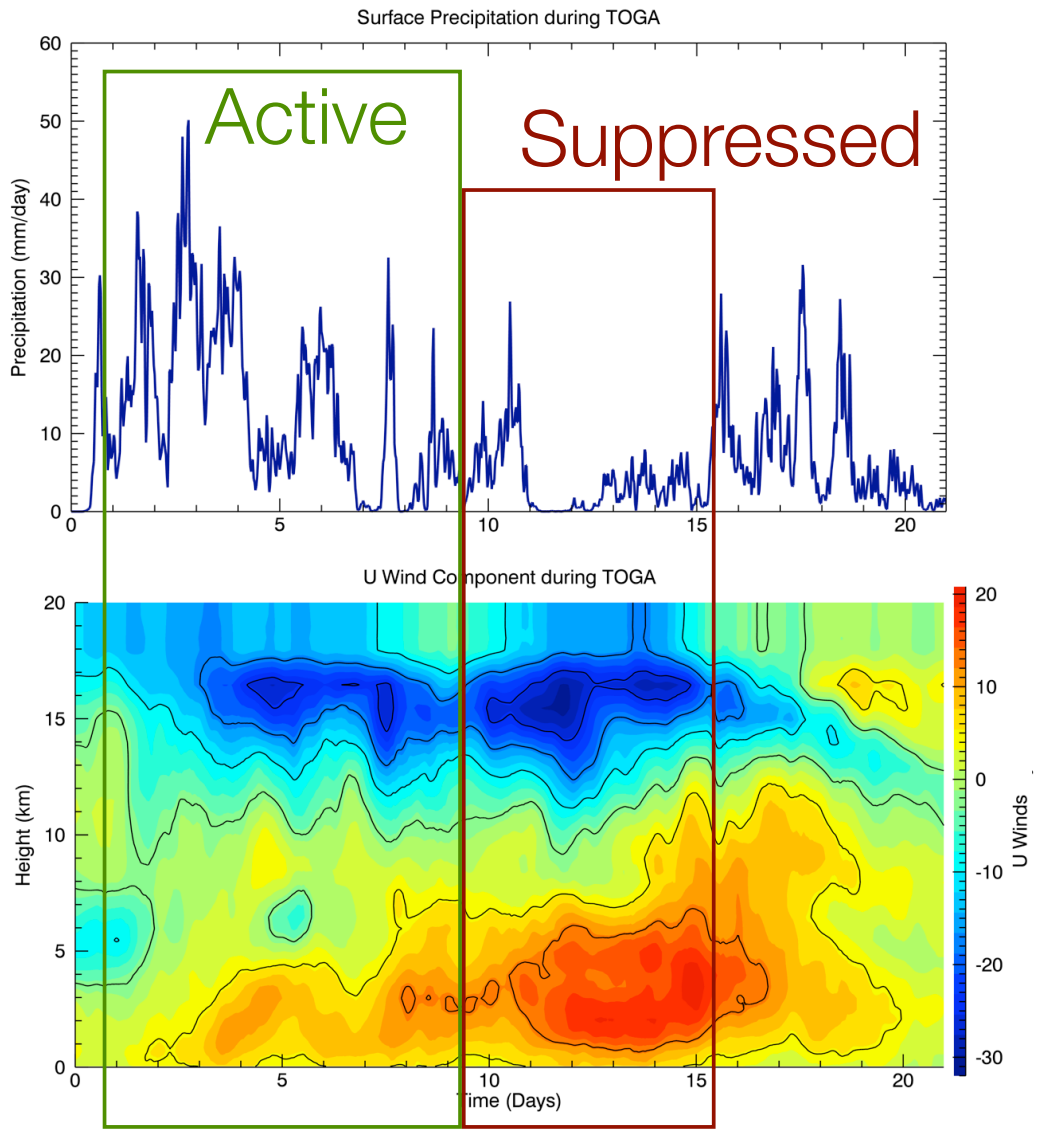
3. Better Downdrafts
   - As precipitation falls through dry air in the mid-troposphere, it evaporates more, increasing boundary layer cooling by downdrafts (and increasing the mid-troposphere moisture). Future convective energy is reduced.

SAM

- Method: Use high resolution Cloud Resolving Model (CRM) runs to examine the effects of downdrafts.

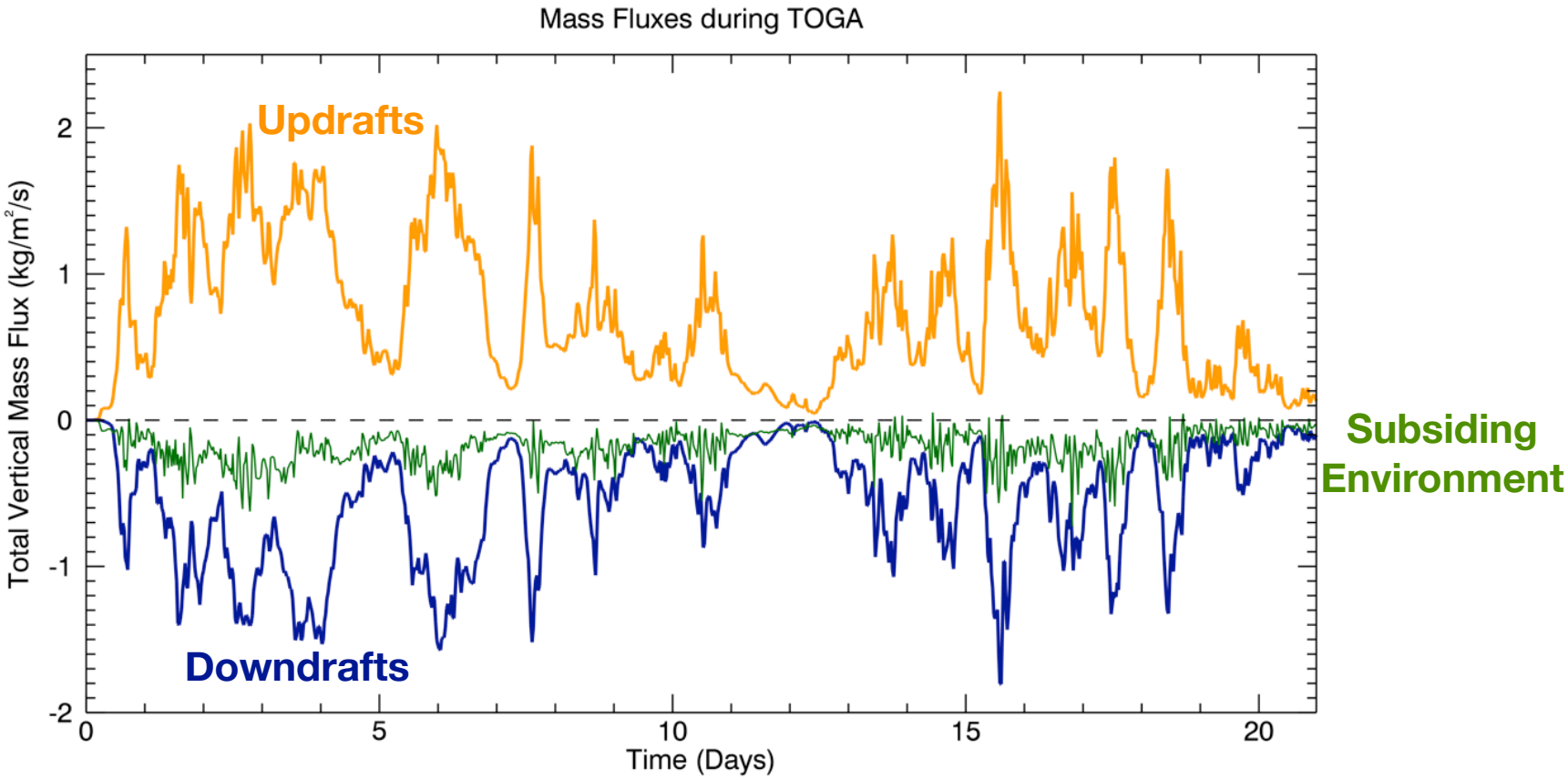
- System for Atmospheric Modeling (SAM) version 6.8.2
  - Anelastic equations
  - Prognostic liquid water/ice static energy, total non-precipitating water, and total precipitating water.
  - Single moment microphysics and sub-grid-scale turbulence/dissipation parameterized, CAM radiation

- Toga-Coare Run (TOGA)
  - 128x128 km^2 domain with 1 km horizontal resolution
  - 64 vertical levels up to 5 hPa (BL is about 100m per level)
  - 10 second timestep - 21 Day Simulation
  - Large-Scale forcing from TOGA-COARE IOP



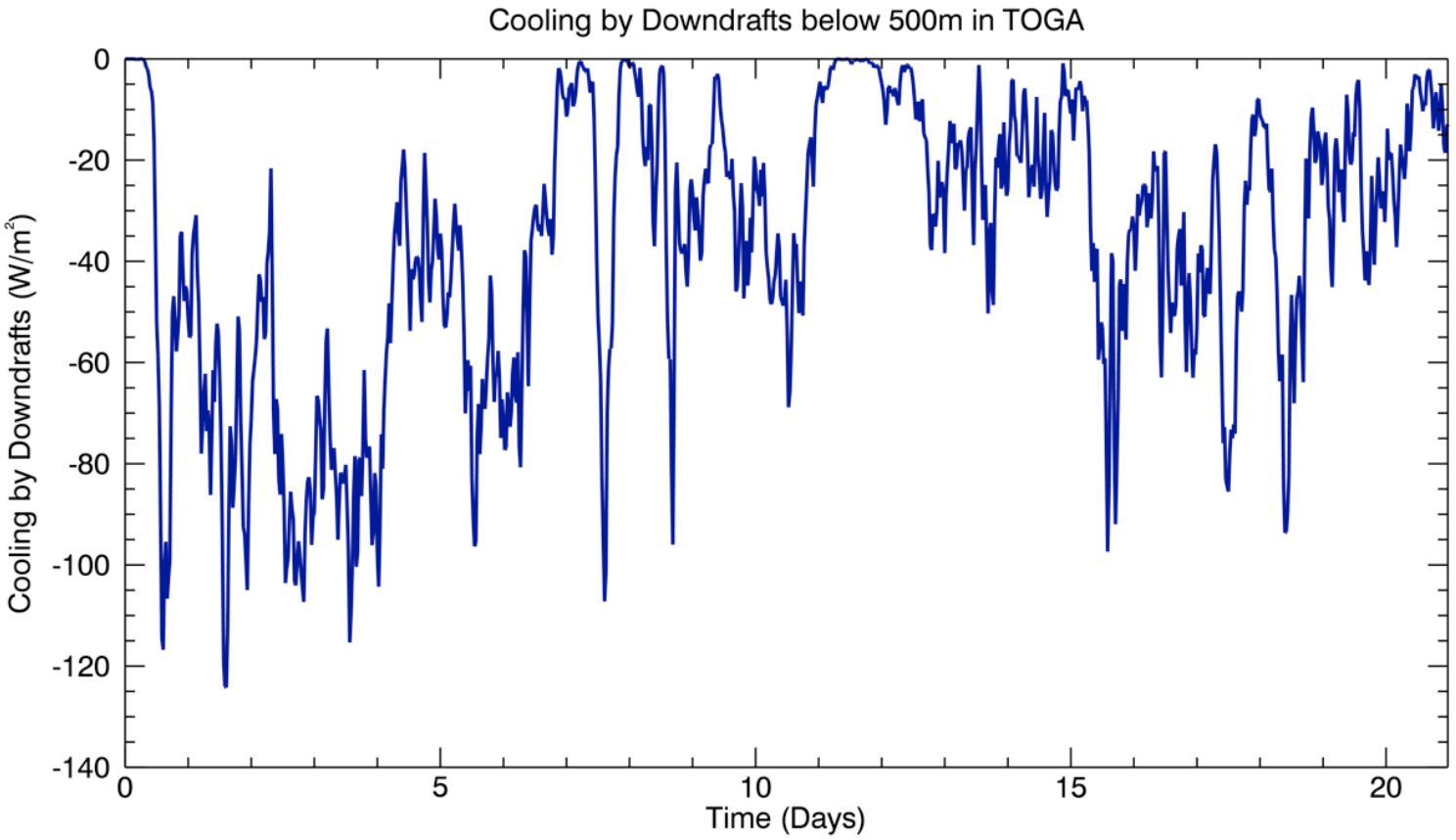
A Quick Look At The TOGA Run

Passage of an MJO Event



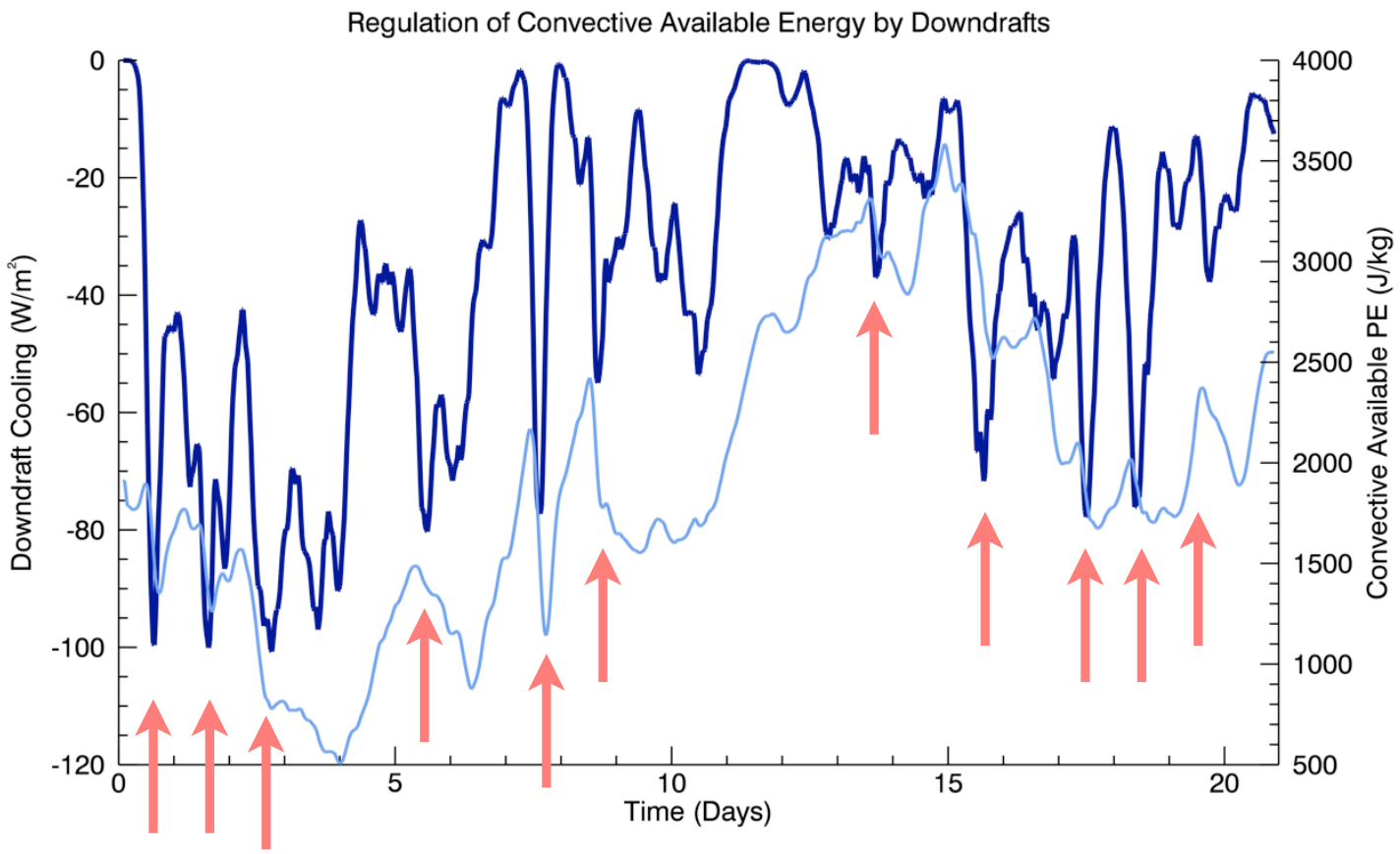
Do Downdrafts Even Matter in the Tropics?

Yes, I think so.



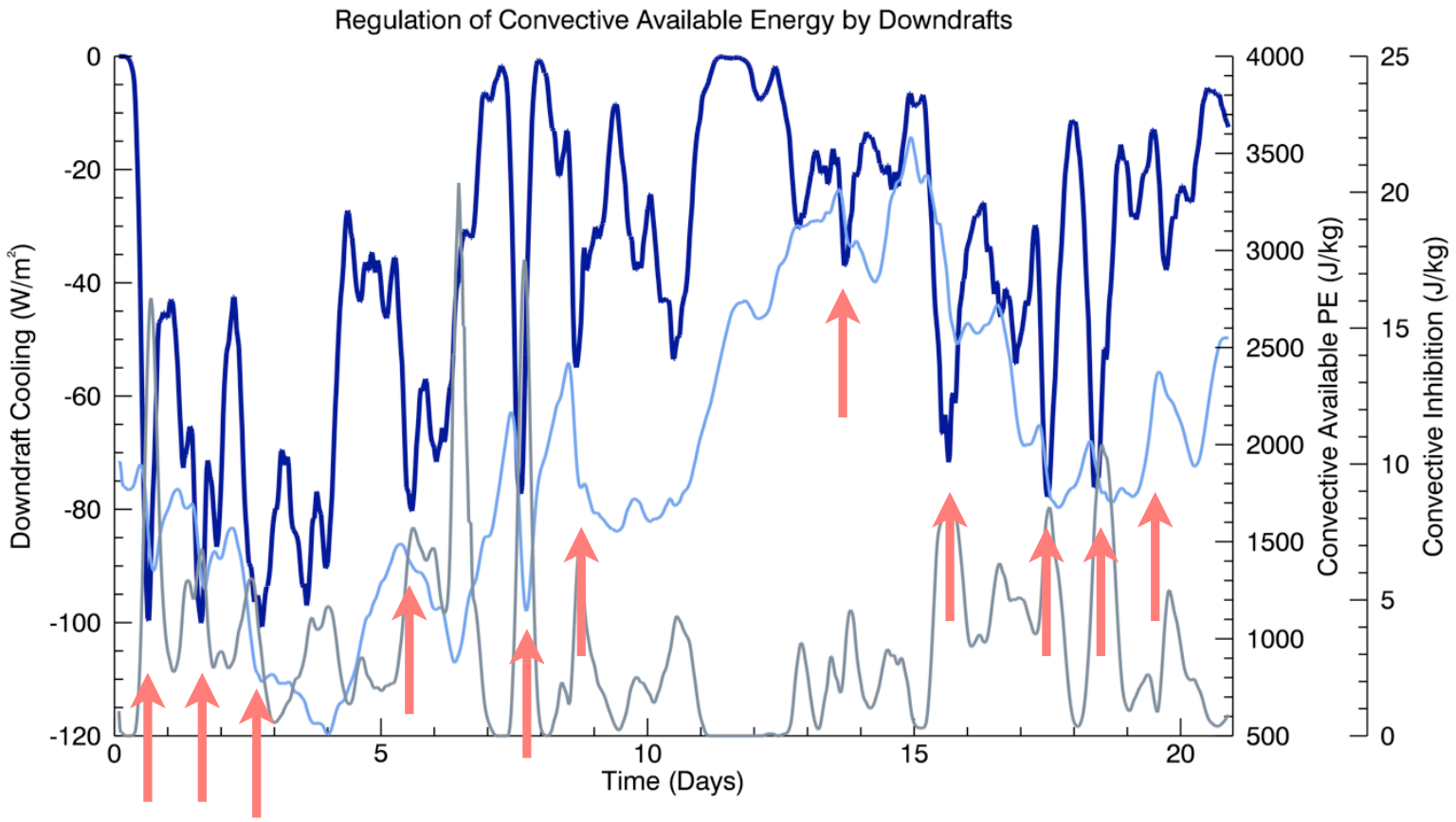
Boundary Layer Cooling by Downdrafts

$$\sum_{0}^{i=6} C_p M_d^i (T_d^i - T_A^{i-1})$$



Regulation of Convection by Downdrafts

4.5 Hour Running Mean



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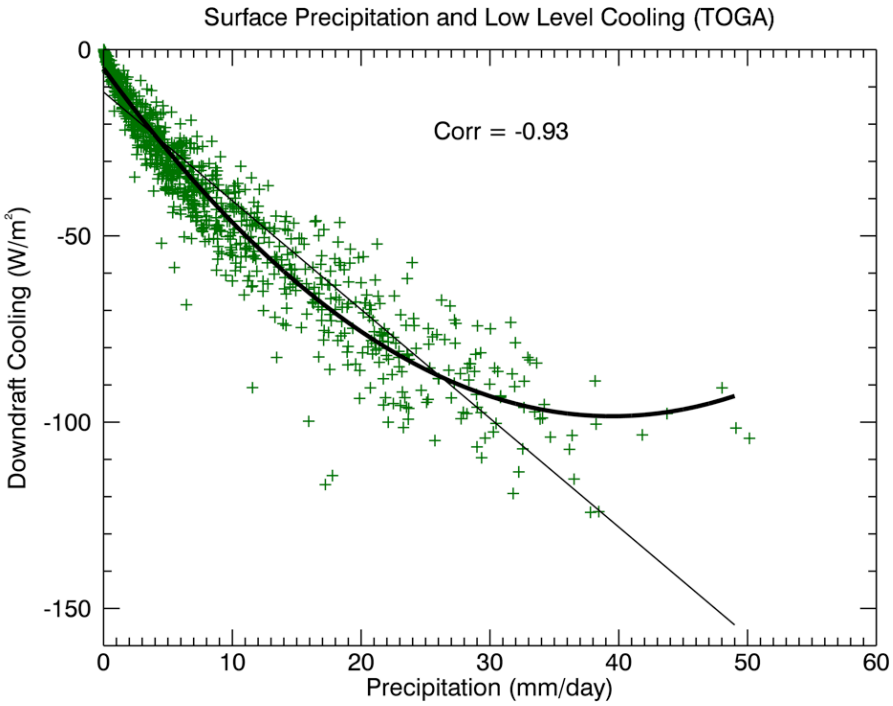
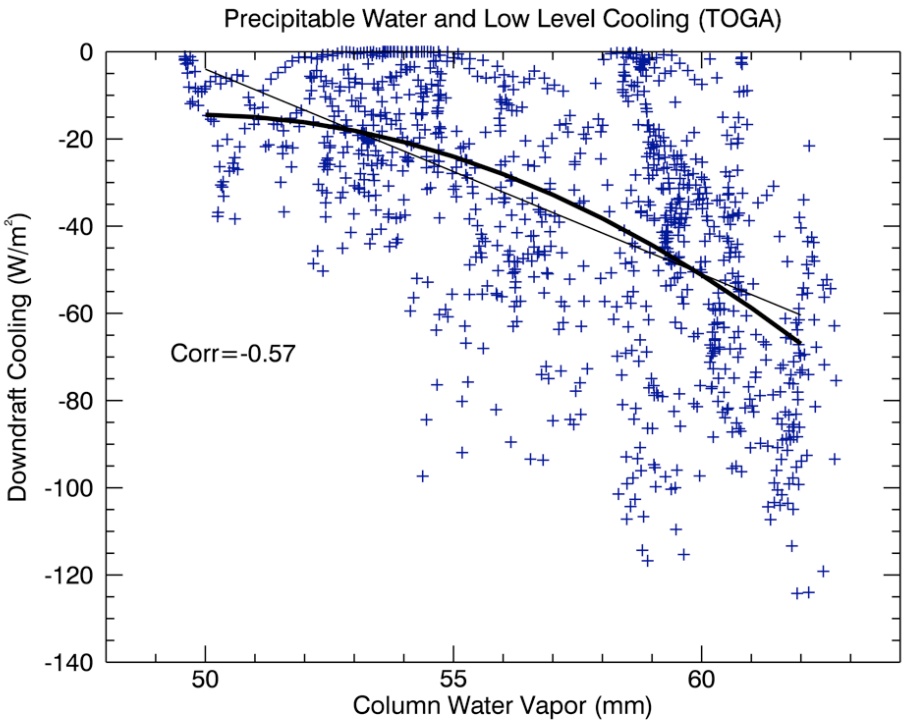
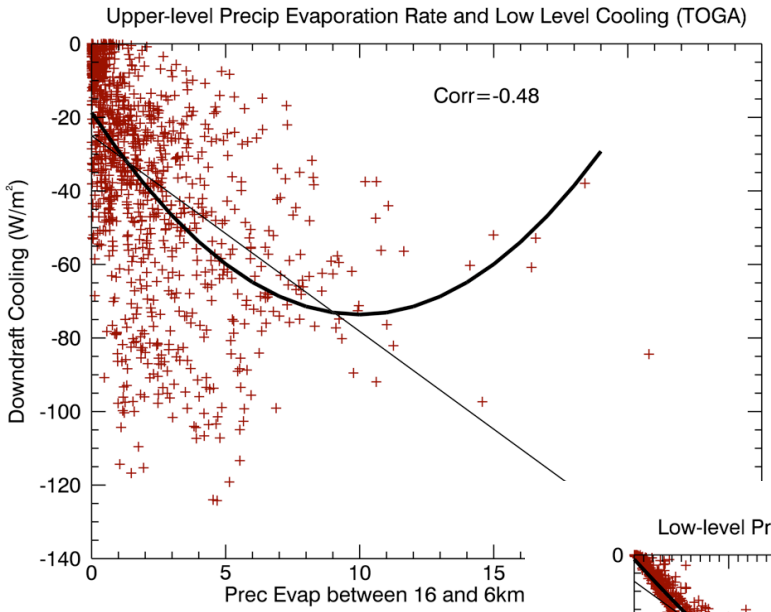
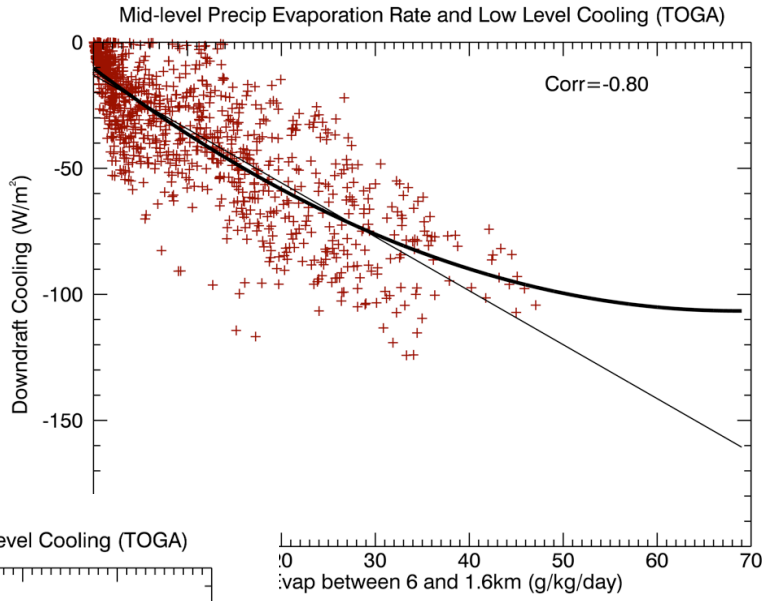


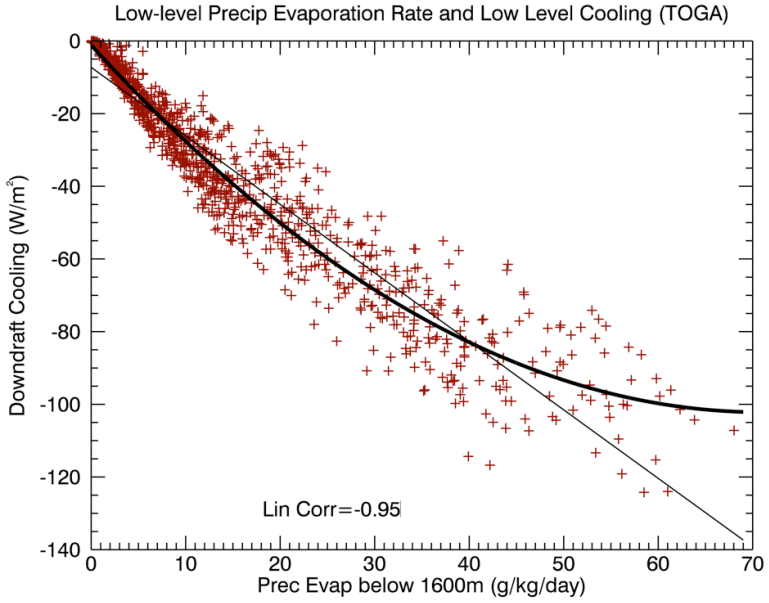


What is correlated with the amount of Downdraft Cooling?

Precip hitting the ground? Yes
Vapor in the column? No

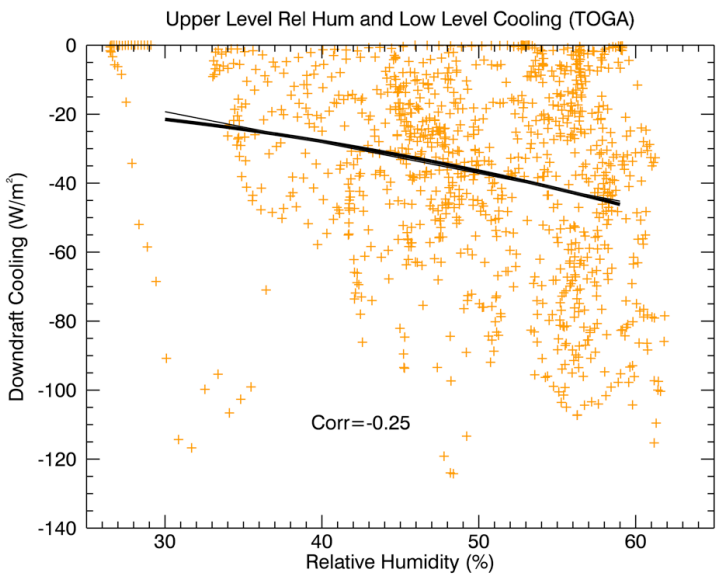


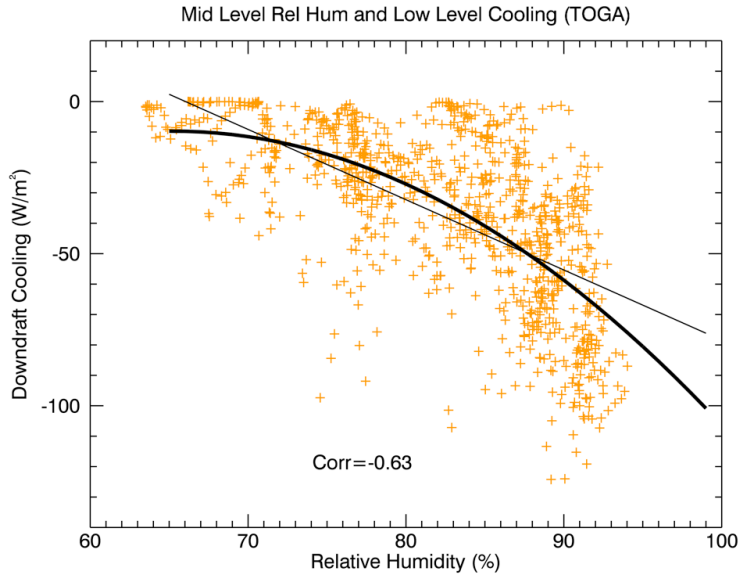


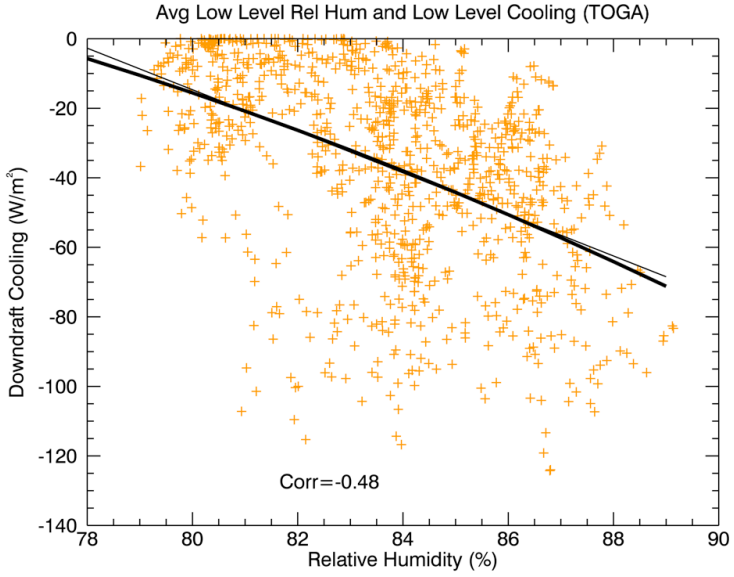


What is correlated with the amount of Downdraft Cooling?

Evaporation of Precip? Yes

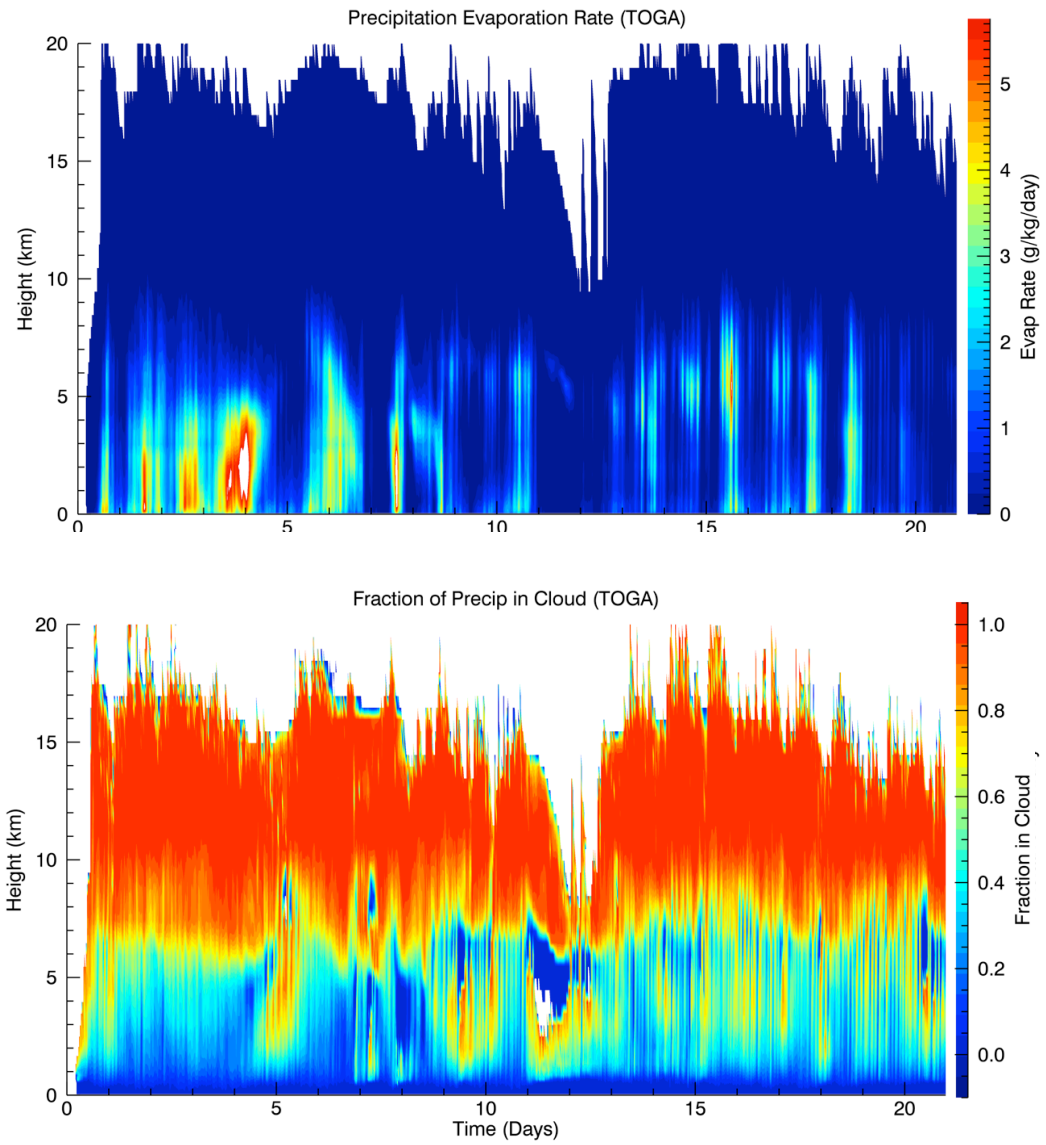






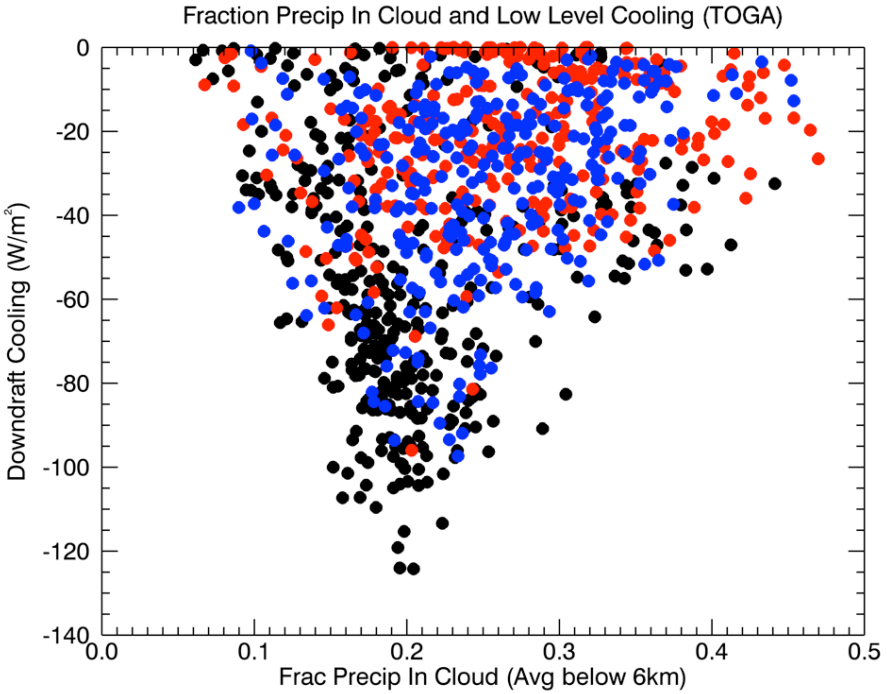
What is correlated with the amount of Downdraft Cooling?

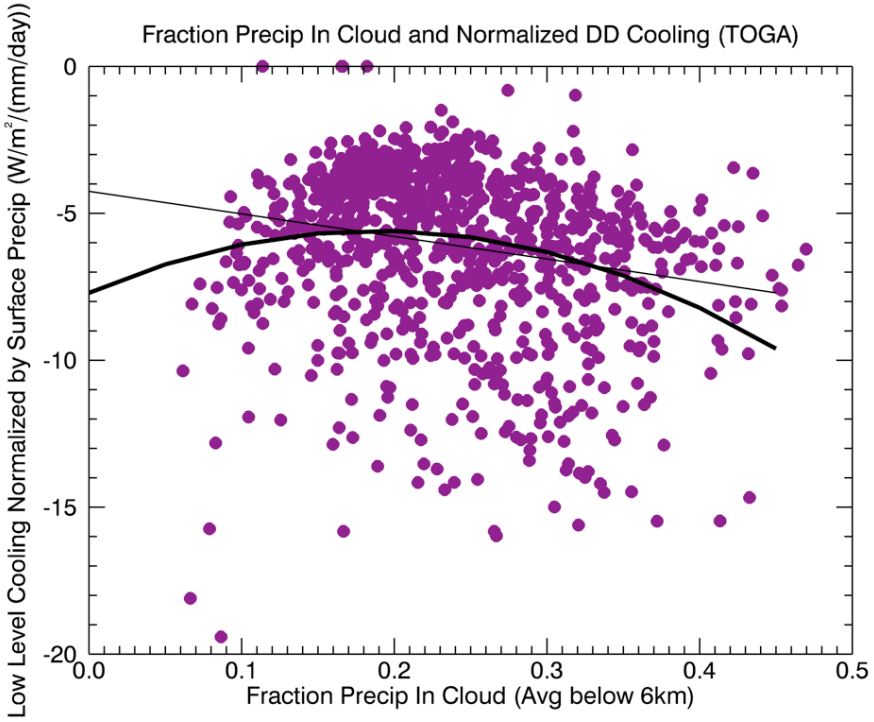
Relative Humidity? Not in the way I was expecting.



Why doesn't RH directly affect evaporation?

More Rain = More Evaporation
Stratiform vs Convective





Cloud and Precipitation Geometry?

Clearly, this is a complex relationship

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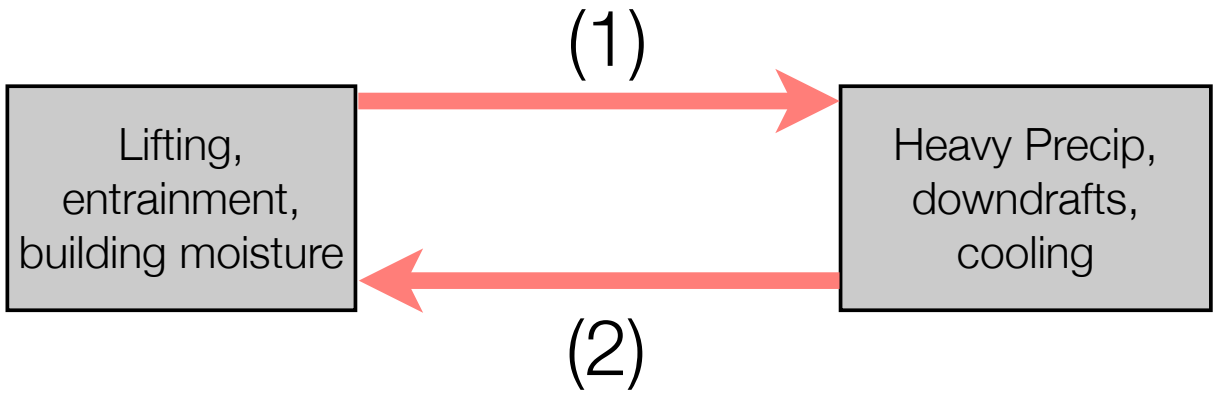

- Downdrafts could be more re-active than interactive.
- A two step process would result in a lagging relationship between downdrafts and mid-tropospheric relative humidity

Downdrafts, Low Level Cooling, and Relative Humidity

- Downdrafts are an important part of the vertical mass budget and should be included if only for this.
- Downdrafts produce significant cooling in the boundary layer during convective events.
- Boundary layer cooling by downdrafts is well correlated to the amount of precipitation at the surface and the amount of evaporation below 1600m.
- It is not well correlated to relative humidity or moisture deficits in the column.
- The amount of precipitation in and outside of clouds (convective vs stratiform) look promising, but the numbers aren't there.
- Probably, entrainment keeps convection light until the column is moistened. ***Then*** heavy precipitation drags down cooler air, reducing CAPE and shutting off deep convection.