Rain and Babies

Kate Thayer-Calder

CMMAP Graduate Student Colloquium 2011

My Research Is...

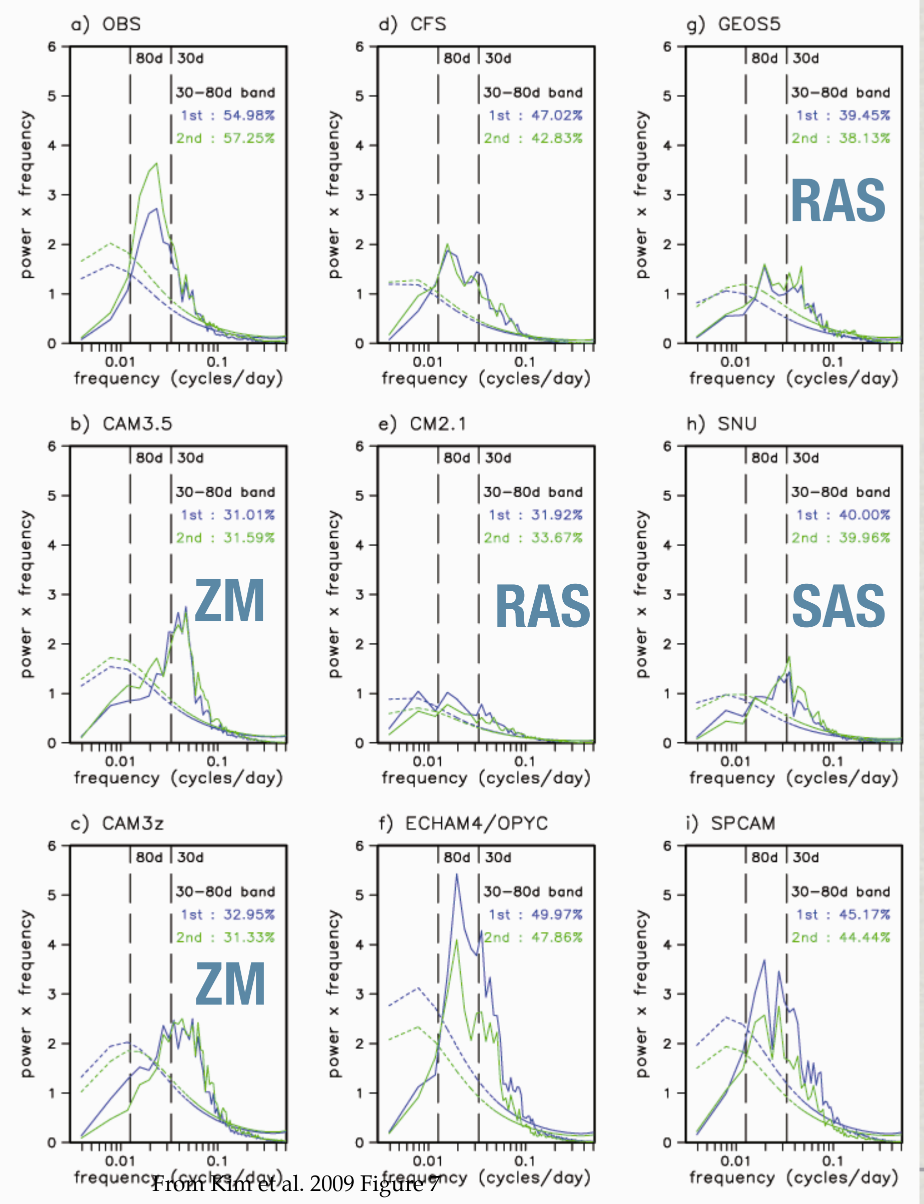
I'm working on improving a convection parameterization to better simulate the Madden-Julian Oscillation (MJO) and tropical deep convection variability in Global Climate Models (GCMs).

TRANSLATION

I want to put better clouds in my computer program.

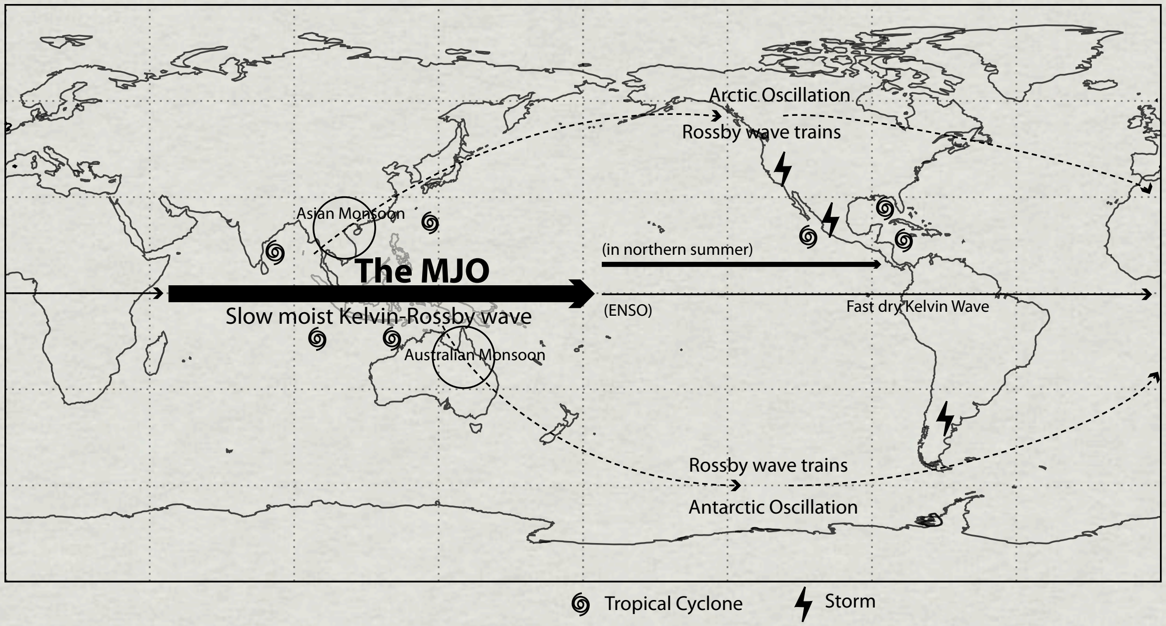
Problems with Clouds

- GCMs have had problems simulating tropical precipitation (especially the MJO) for decades.
- Associated problems include poor precipitation variability, tropical waves that travel too quickly, and double ITCZs.



From Kim et al. 2009 Figure 7

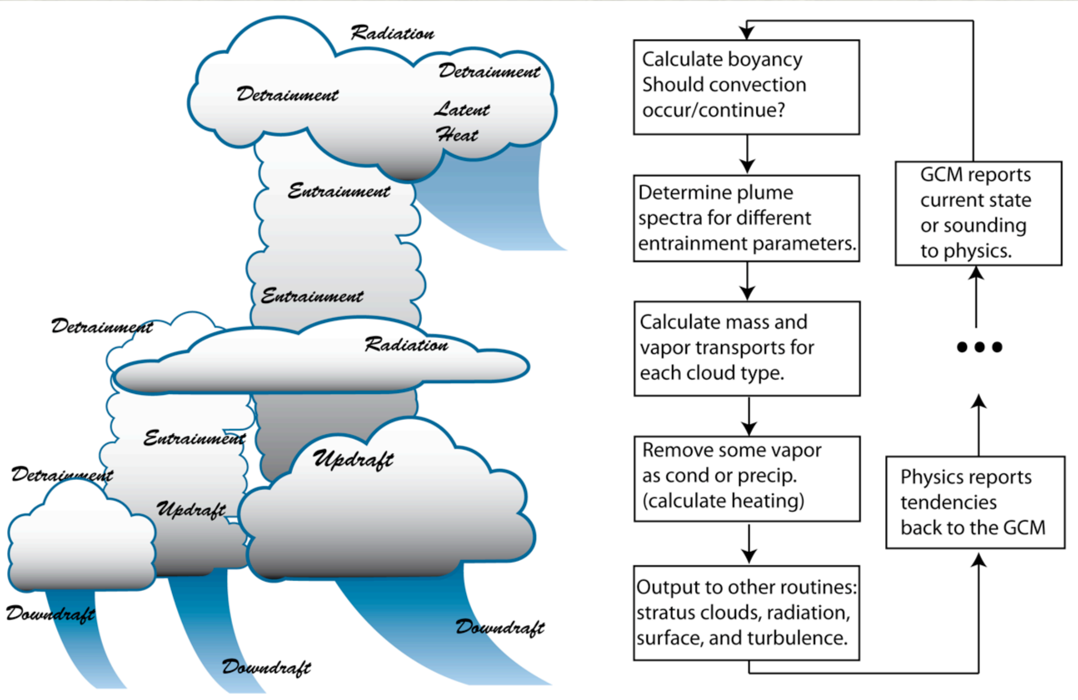
What the Heck is the MJO?



- Equatorial, eastward propagating giant mass of storms in the Indian Ocean and Western Pacific.
- Global-scale disturbance
- Typically appears every 30-70 days and travels at 4-6 m s^{-1}
- **And we don't really know why...**

Why do clouds in Models Suck?

Parameterizations

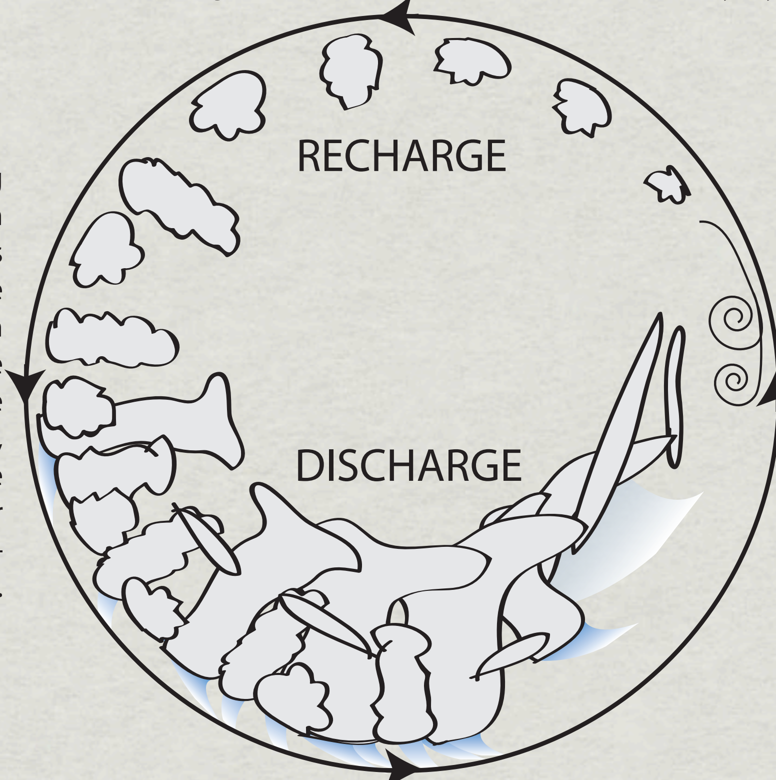


- GCMs can only resolve structures much larger than their grid size (O~1000km). Clouds and convection operate on much smaller scales.
- The smaller scale processes are represented by simple statistical models in each GCM grid cell and column.

What do Clouds have to do with the MJO?

Convection is suppressed by the large-scale subsiding air on either side of the MJO deep convection. Shallow or trade-wind cumuli dominate, and begin to moisten and thicken the boundary layer.

Penetrating convection moistens through the whole column and erodes the stability of the troposphere, priming the region for deeper convection.

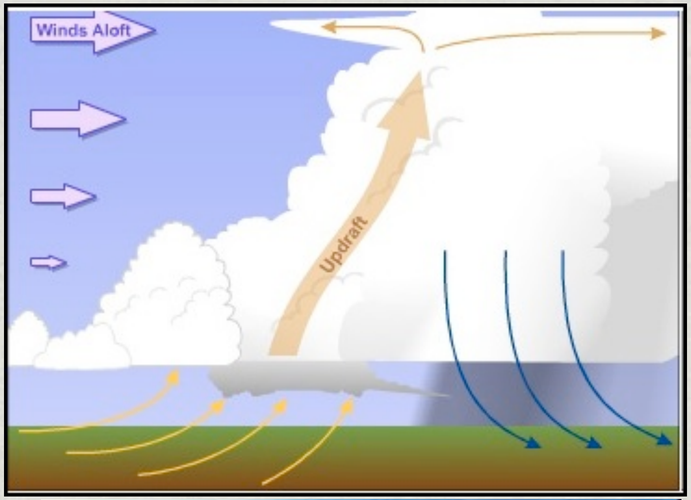


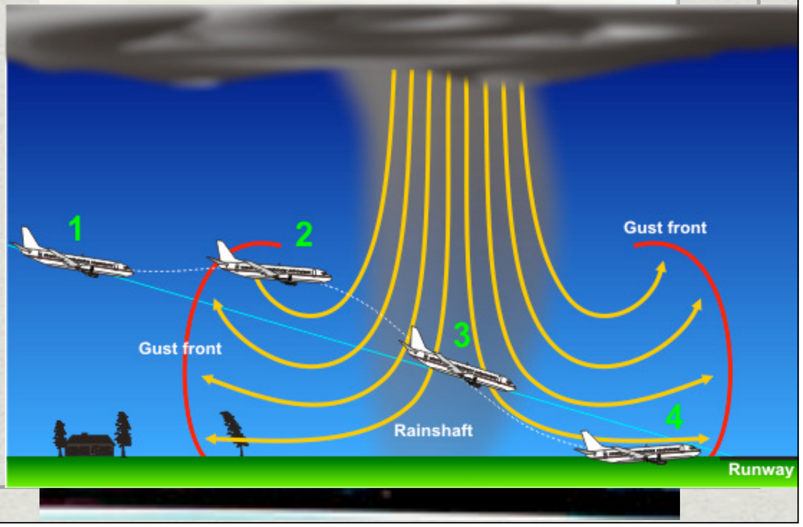
Heating from convection traveling along the equator forms surrounding Rossby wave circulations, and advects in dry, cooler air from the subtropics.

Deep convection occuring in a very moist environment should have an increased precipitation efficiency and decreased effectiveness of convective downdrafts.

Downdrafts

- Precipitation evaporating into cool, dry, mid-tropospheric air causes it to loose buoyancy and sink.
- Important process
  - Distribute moisture through the column as rain falls and evaporates
  - Cool and re-stabilize the boundary layer, reducing cape and suppressing convection locally (cold pools)
  - Increase turbulent mixing through the column, especially in the boundary layer
  - Gusty surface winds can increase surface fluxes and lift boundary layer air to form new convection





How are Downdrafts Represented in GCMs?

- Current representations of Downdrafts in global models:

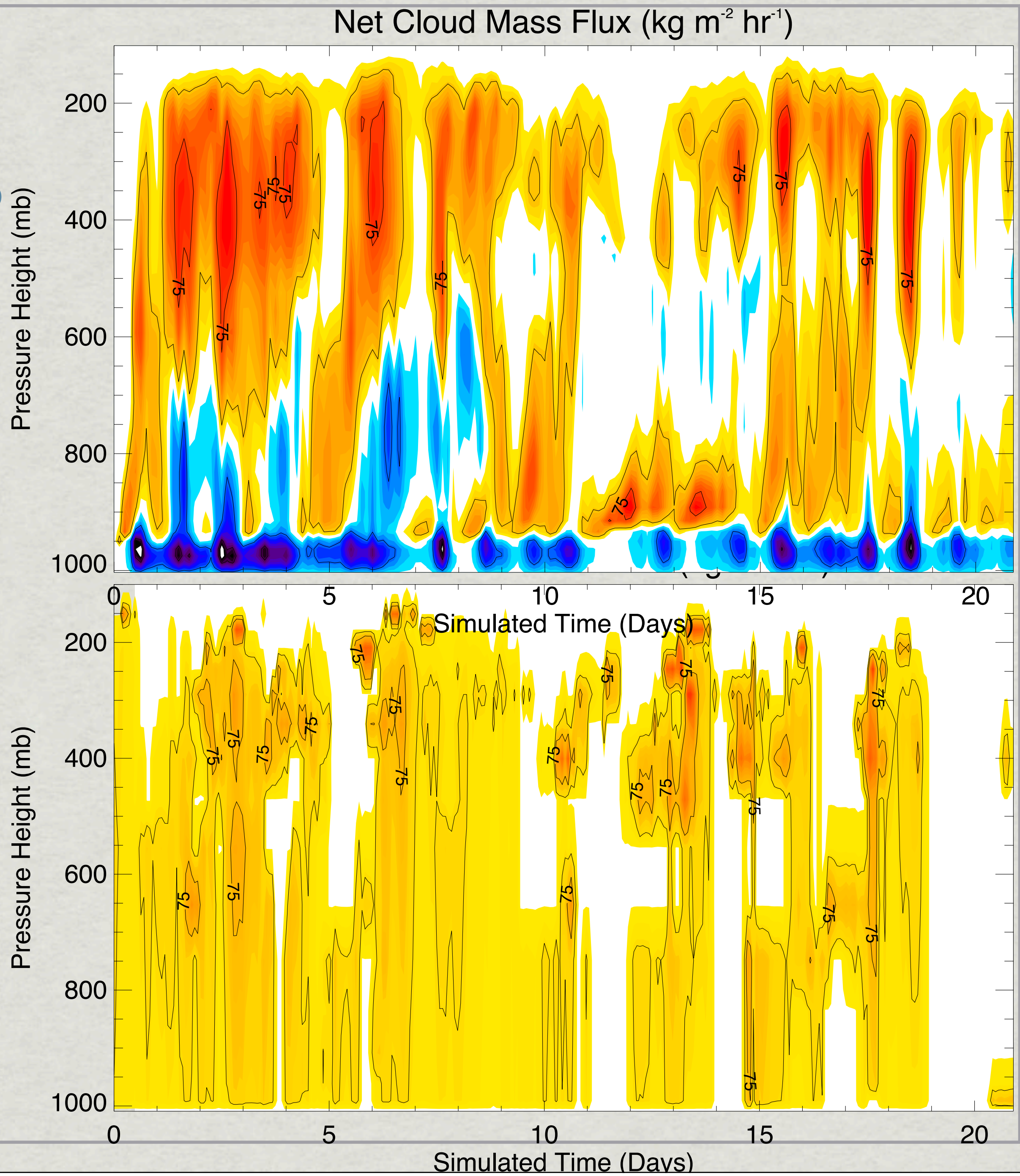
1. None

2. A fixed percentage of rain is evaporated, and the moistening and cooling tendencies are added on to the convective tendencies

3. Integrated into the parameterization, but held separate from the surface (MMF, Emanuel)

Updrafts & Downdrafts

- Updrafts move most of their mass starting at cloud base and peaking in the upper levels
- Downdrafts evaporate rain and inject low MSE air into the boundary layer



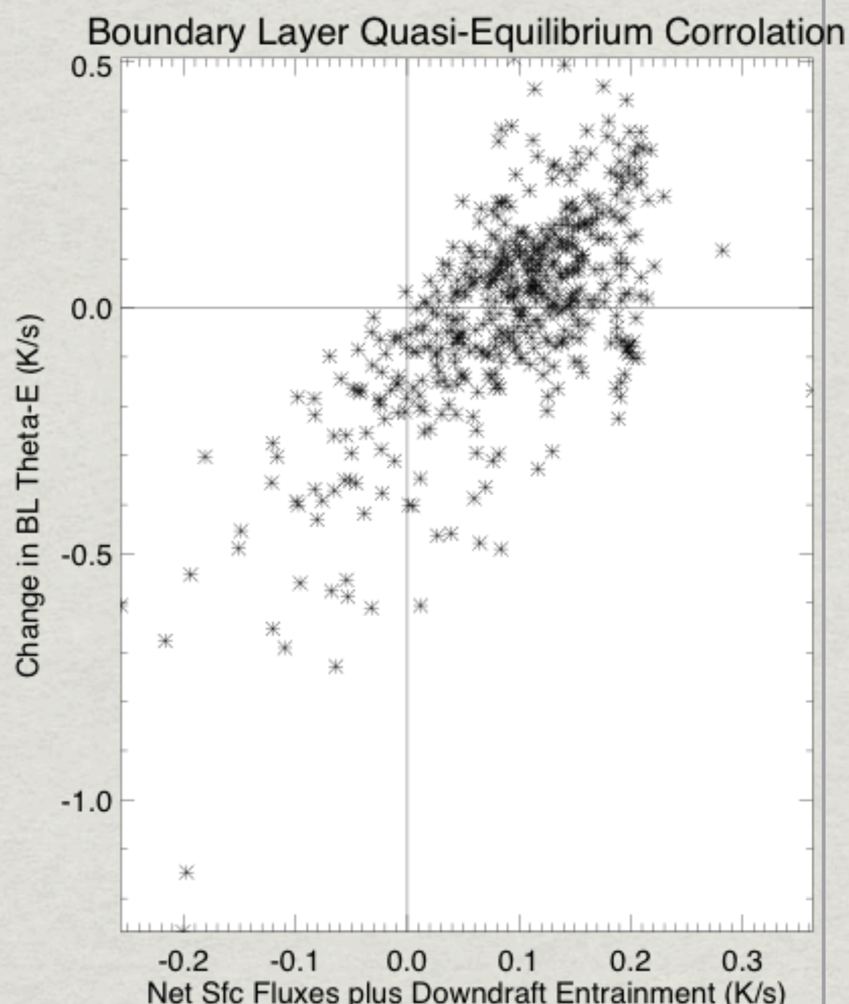
How do Downdrafts make better clouds?

- Important process
  - Distribute moisture through the column as rain falls and evaporates
  - Cool and re-stabilize the boundary layer, reducing cape and suppressing convection locally (cold pools)
  - Increase turbulent mixing through the column, especially in the boundary layer
  - Gusty surface winds can increase surface fluxes and lift boundary layer air to form new convection

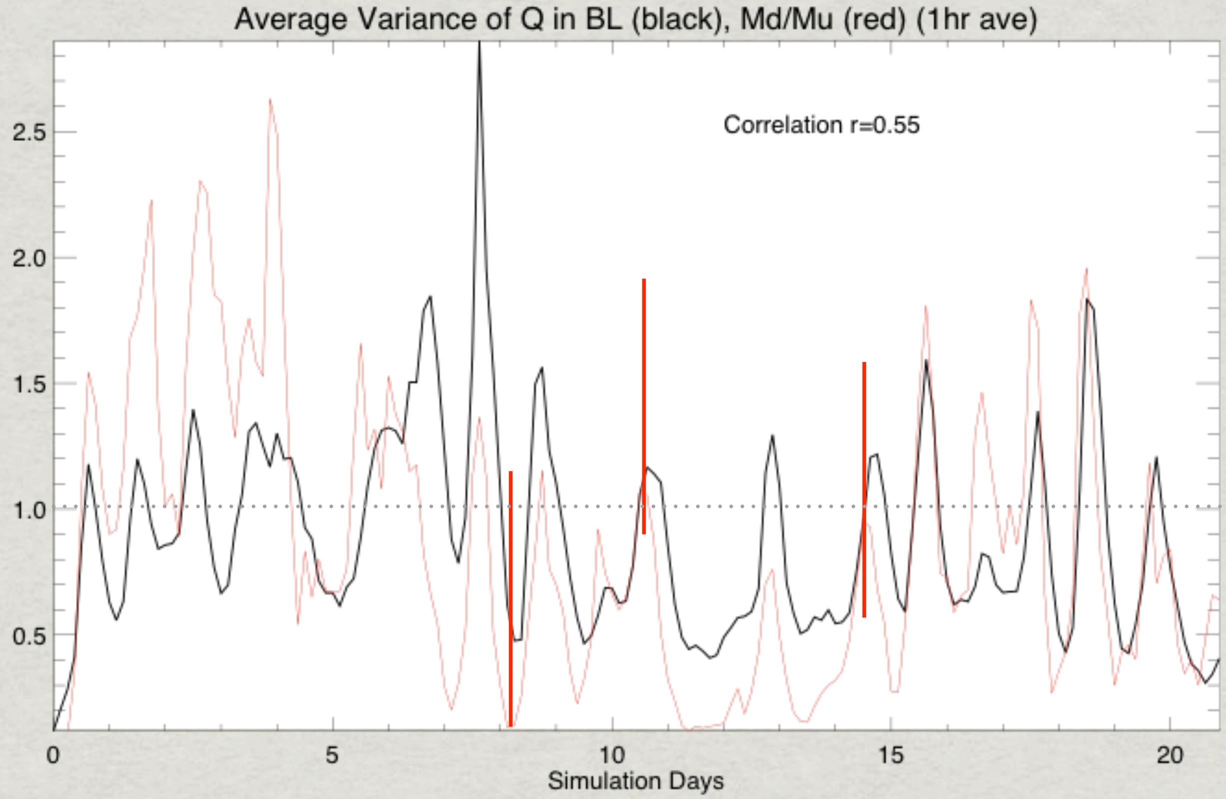
Boundary Layer Quasi-Equilibrium

$$\frac{d\theta}{dt} \cong Q_{Rb} + \frac{F_S}{b} - \frac{m_d \delta\theta_e}{b}$$

- Warming surface fluxes are mostly balanced by downdraft injection of cool mid-trop air
- Without downdrafts, the boundary layer is always warm. When it reaches a critical temperature, convection starts.
- So, without downdrafts to balance, week (but penetrating) convection is constantly occurring.

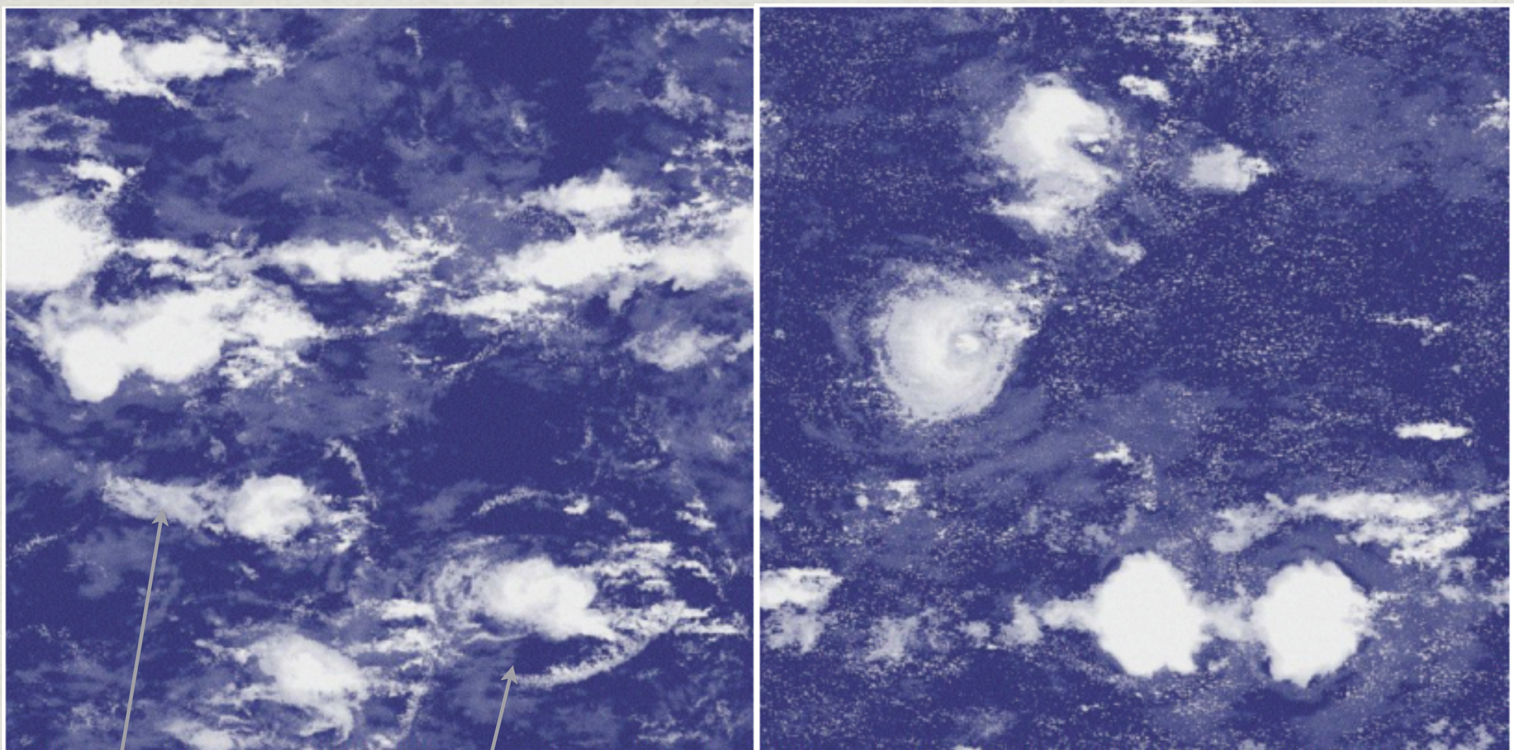


Boundary Layer Variability

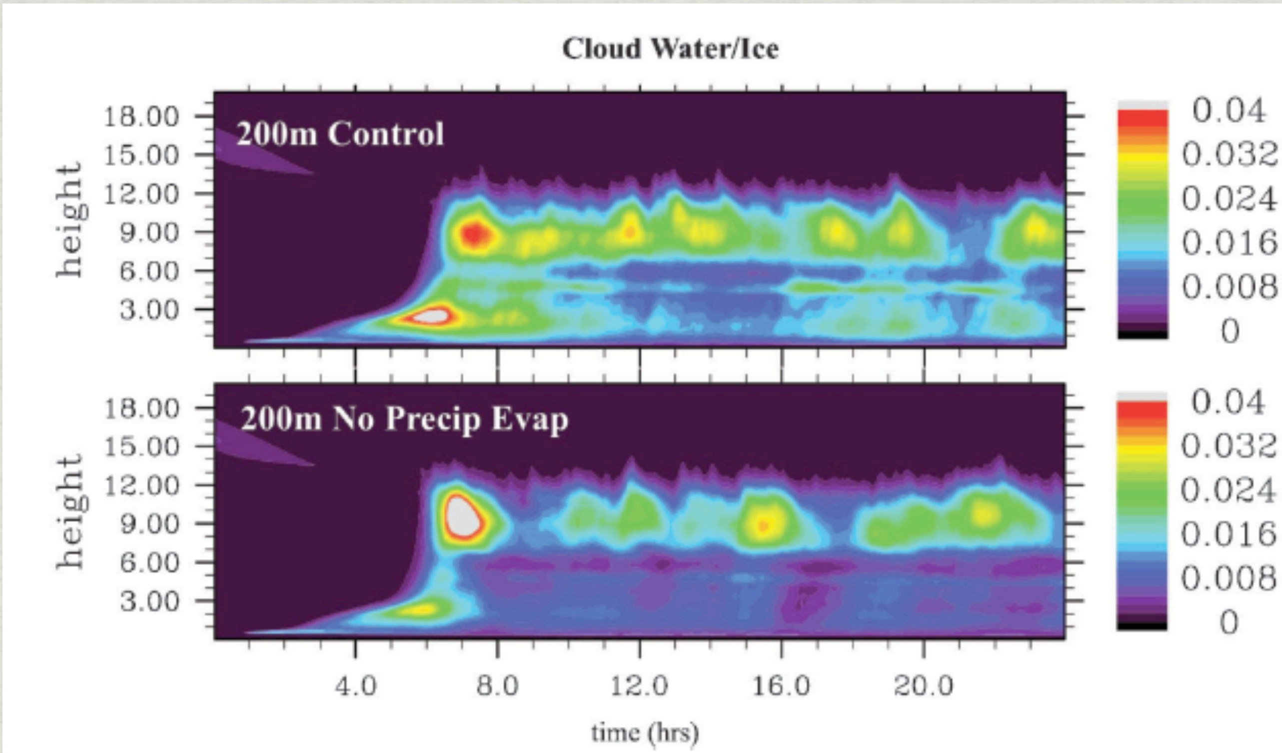


- Most models only predict the averages, but clouds are formed in the extremes
  - the most warm, most moist air becomes a cloud.
  - the driest, coolest air is the clearest.

Has anybody else noticed this?



Has anybody else noticed this?



- Without downdrafts, the boundary layer heats up quickly, spawning deep convection, but no mid- or lower-level convection.

Next Steps

- Derive the downdraft formulation
- Implement in Pan-Randall parameterization (maybe)
- LEARN (rinse, repeat)

Why is this important?

- Helps answer questions.
- Helps with weather prediction.
- Helps with long-term climate modeling.