Evaluating Downdraft Parameterizations with High Resolution CRM Data

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Convective Downdrafts

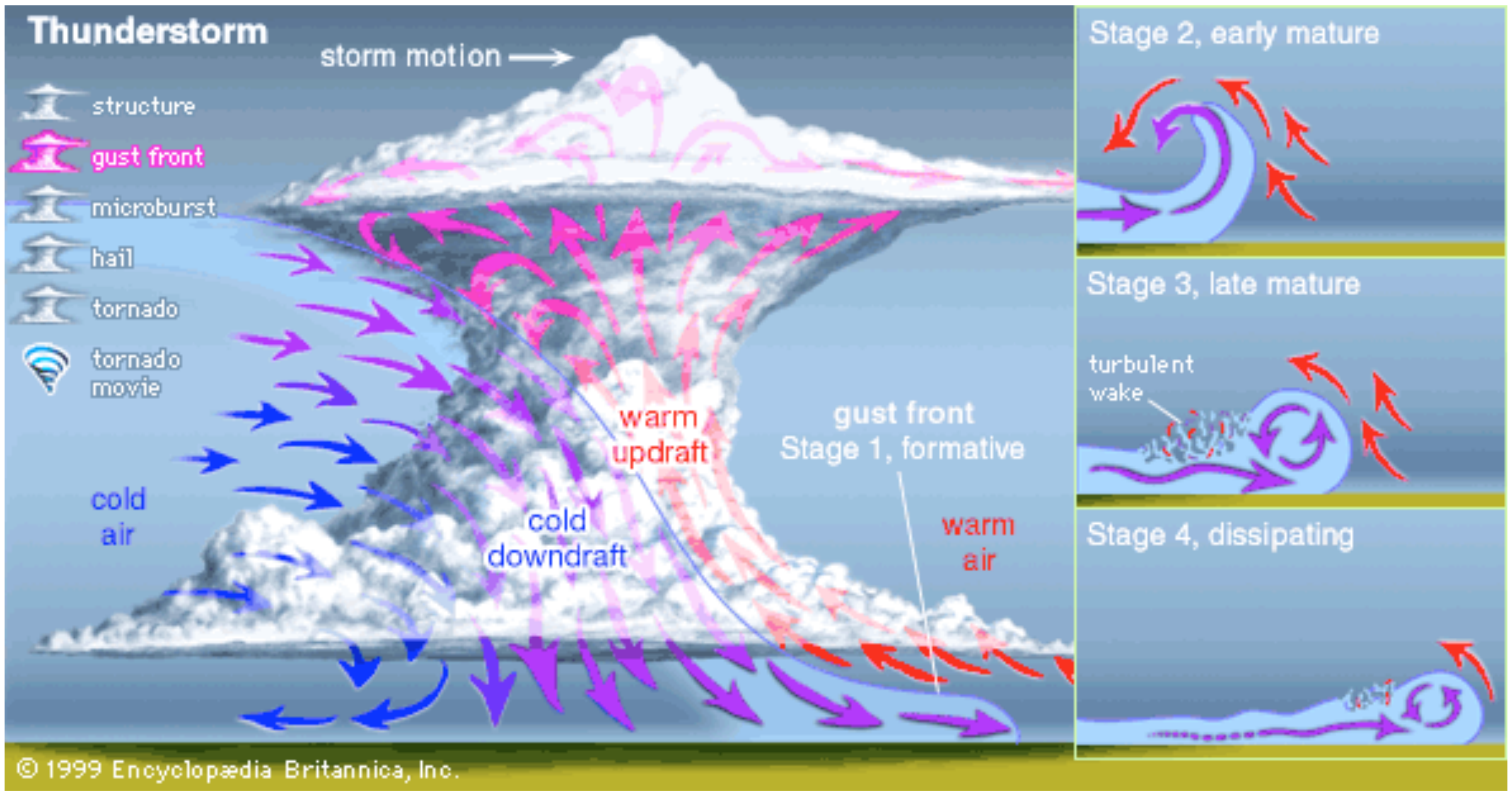


Diagram: http://www.britannica.com/thunderstorms_tornadoes/

- Cloudy air that flows downward after loading by precipitation or cooling by evaporation.
- Cooled air in the boundary layer creates cold pools and gust fronts.

Photo: http://wxbrad.com/downbursts-or-straight-line-winds-vs-tornadoes/

Photo: http://www.indianasnewscenter.com/news/local/Wind-Turbines-Damaged-in-Ohio-148816585.html

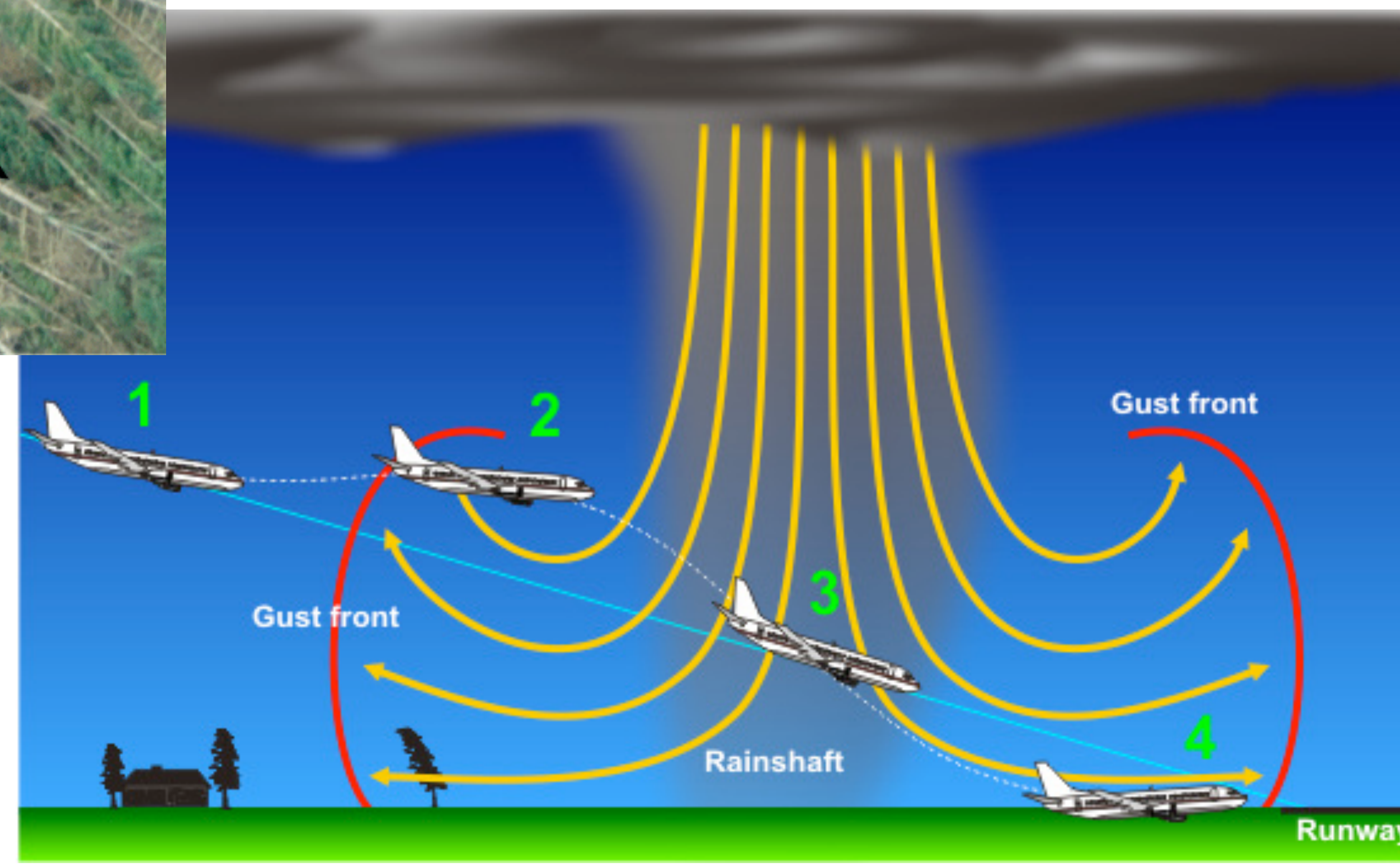


Diagram: http://www.srh.noaa.gov/jetstream/tstorms/wind.htm

Downbursts and Microbursts

(why you should care)

Gust Fronts (why you should care)

For the climate...

- Important source of cool air and moisture at low levels.
- Regulating influence on deep convection through reduction of CAPE.
- Organization of convection at gust front.
- Increased surface fluxes from cool, gusty winds
- Transport of “clean” mid-trophospheric air into the boundary layer.

Problems in GCMs Related to Downdrafts

- Deep convection occurs too frequently
- Dry biases in the mid troposphere
- Deep convection is decoupled from the boundary layer
- Poor representation of tropical variability
- Issues with the ITCZ, monsoons, the diurnal cycle, MCSs, and others

Moisture Anomalies

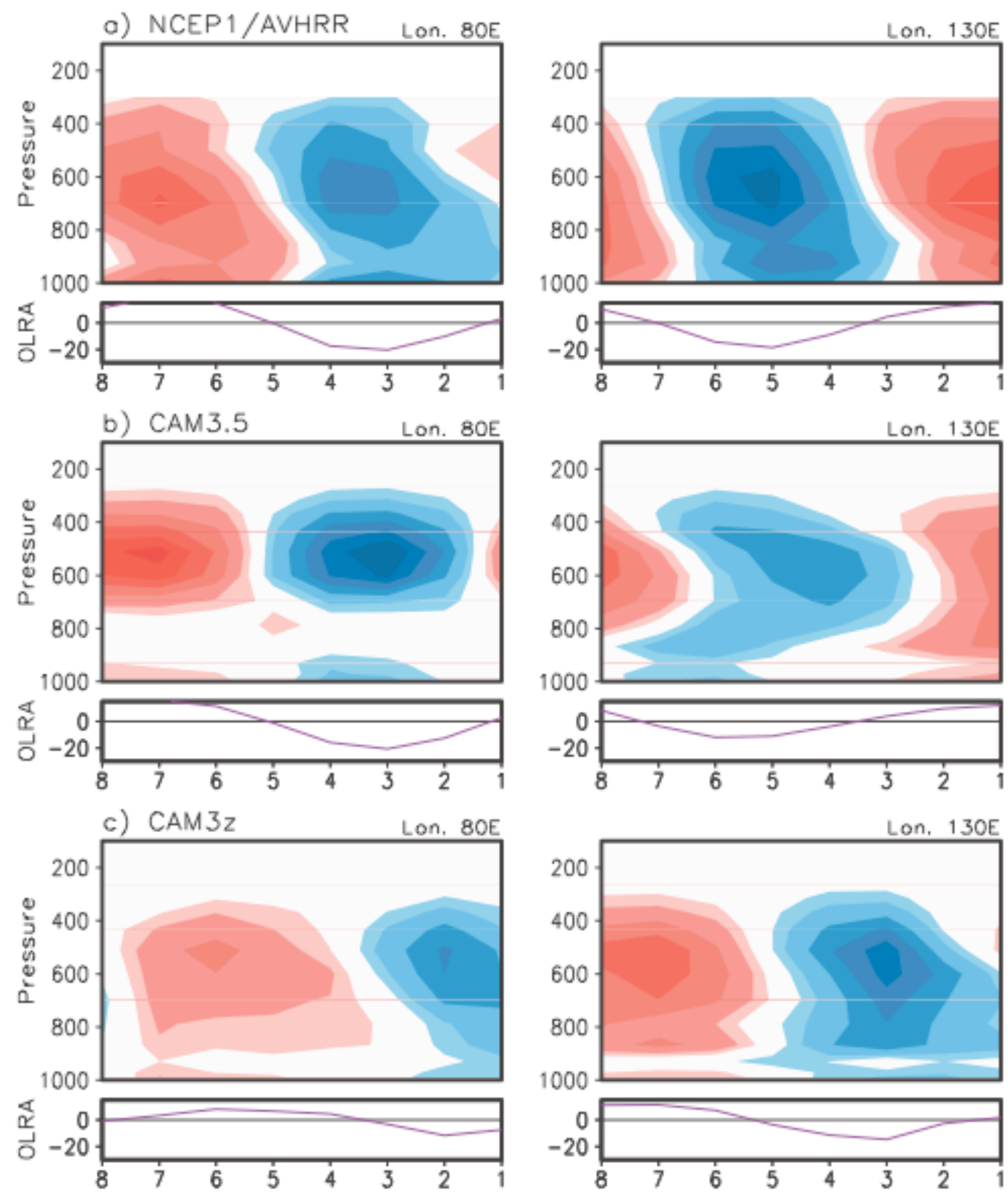


Figure: Kim et al. (2009)

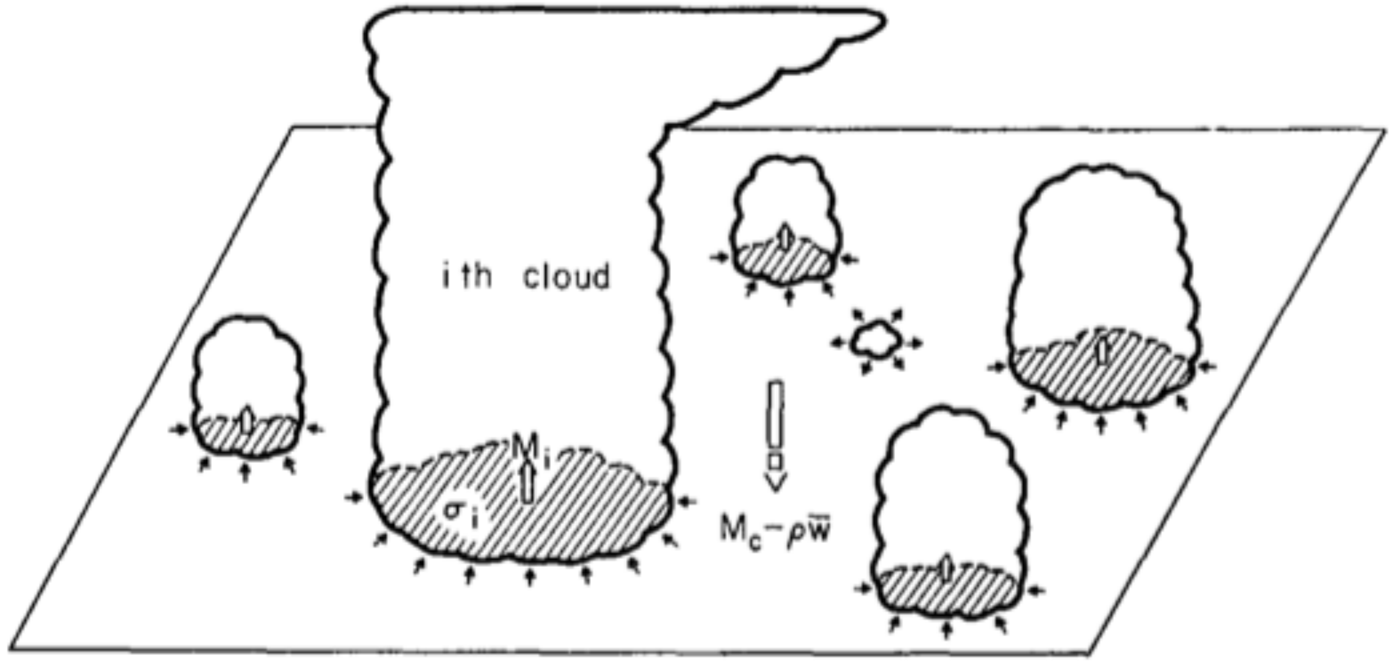


Diagram: Arakawa and Schubert (1974)

- **Arakawa and Schubert (1974)** : plume-based with no mention of downdrafts.
- **Moorthi and Suarez (1992)** : Relaxed AS, commonly used today, no downdrafts.
- **Pan and Randall (1998)** : No explicit downdrafts (CKE could be arguable)
- **Park and Bretherton (2009)** : The CAM5 “shallow” scheme, no downdrafts.

How are downdrafts represented in GCMs?

Missing in some

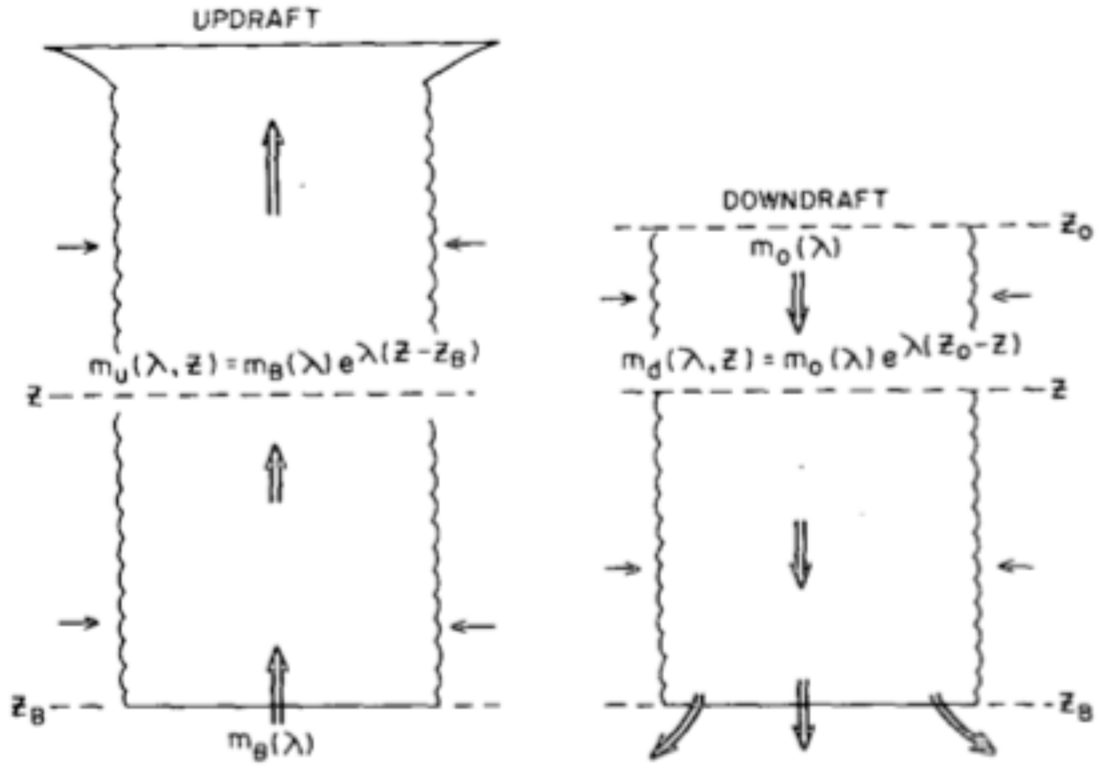


Diagram: Johnson (1976)

- **Johnson (1976)** : no mixing up/downdrafts, Md is a fixed fraction of Mu, Zd is a set fraction of updraft height
- **Zhang and McFarlane (1995)** : no mixing, Md is a fixed fraction of Mu, Zd is at min h*, evaporation limited to 20% of rain, all downdraft detrainment below cloud base
- **Emanuel (1991)** : Only environmental air entrained, fixed amount of precip available to evaporate

How are downdrafts represented in GCMs?

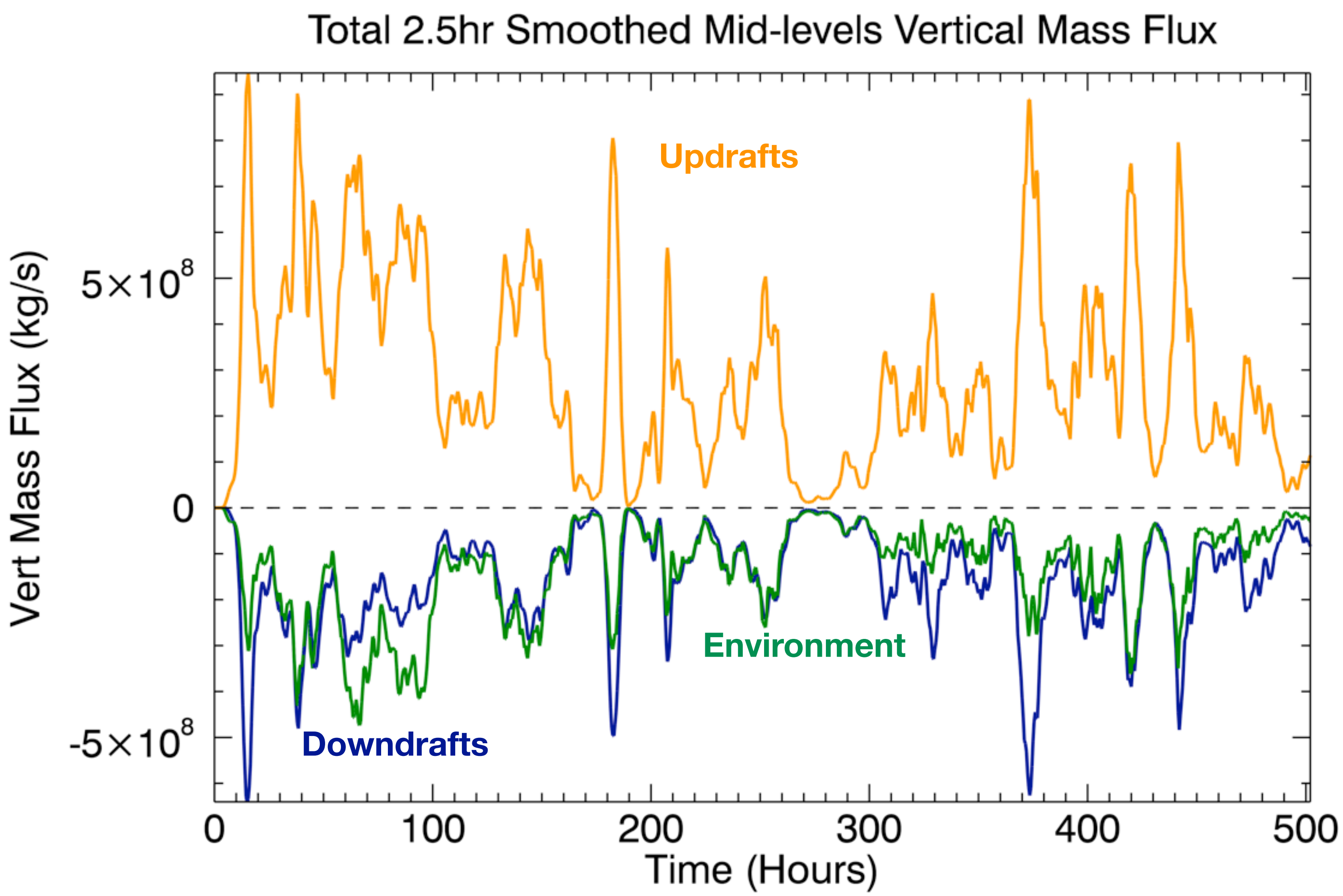
Radical simplifications.

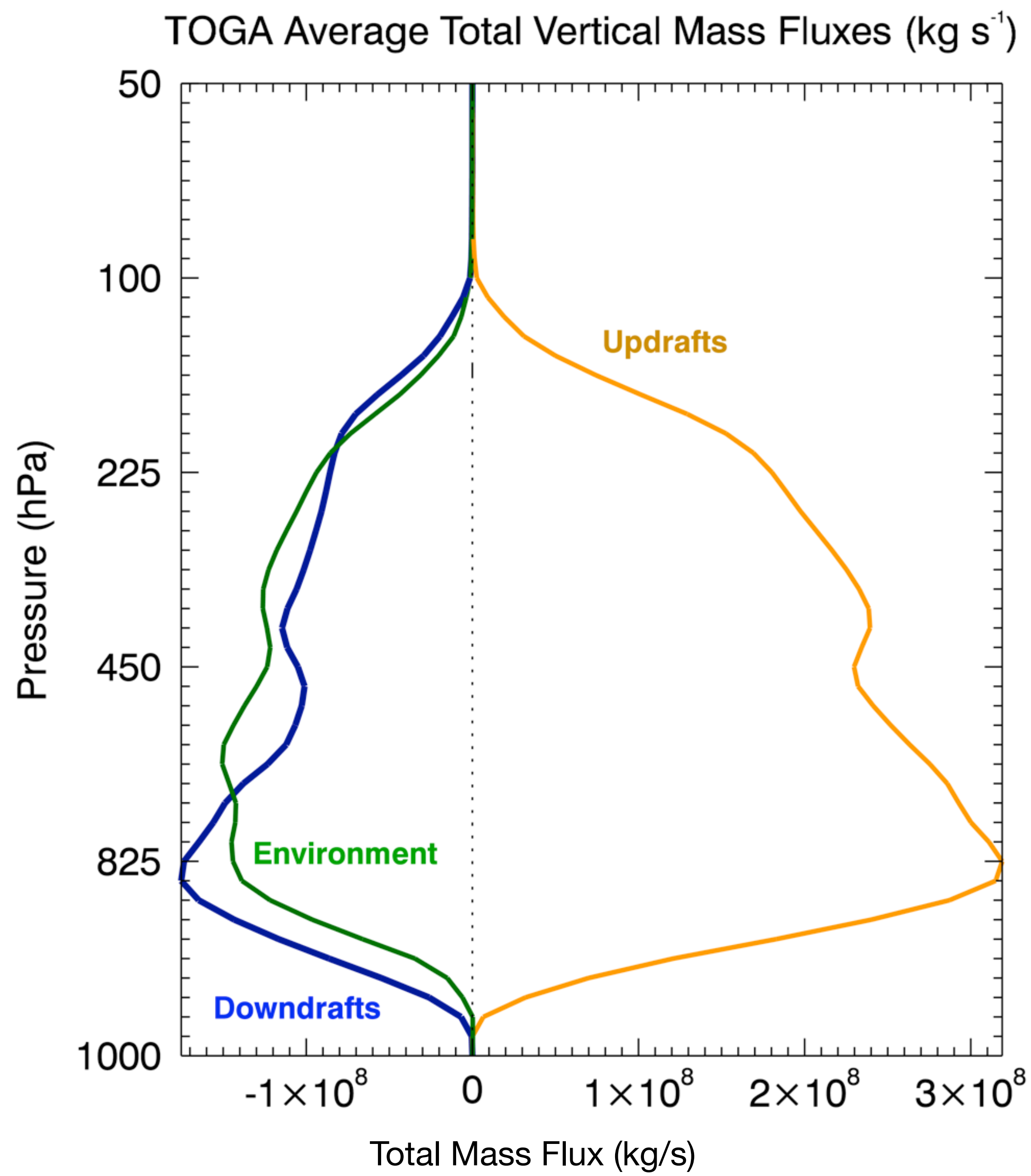

Photo: me

How realistic are all of those assumptions?

Testing Method

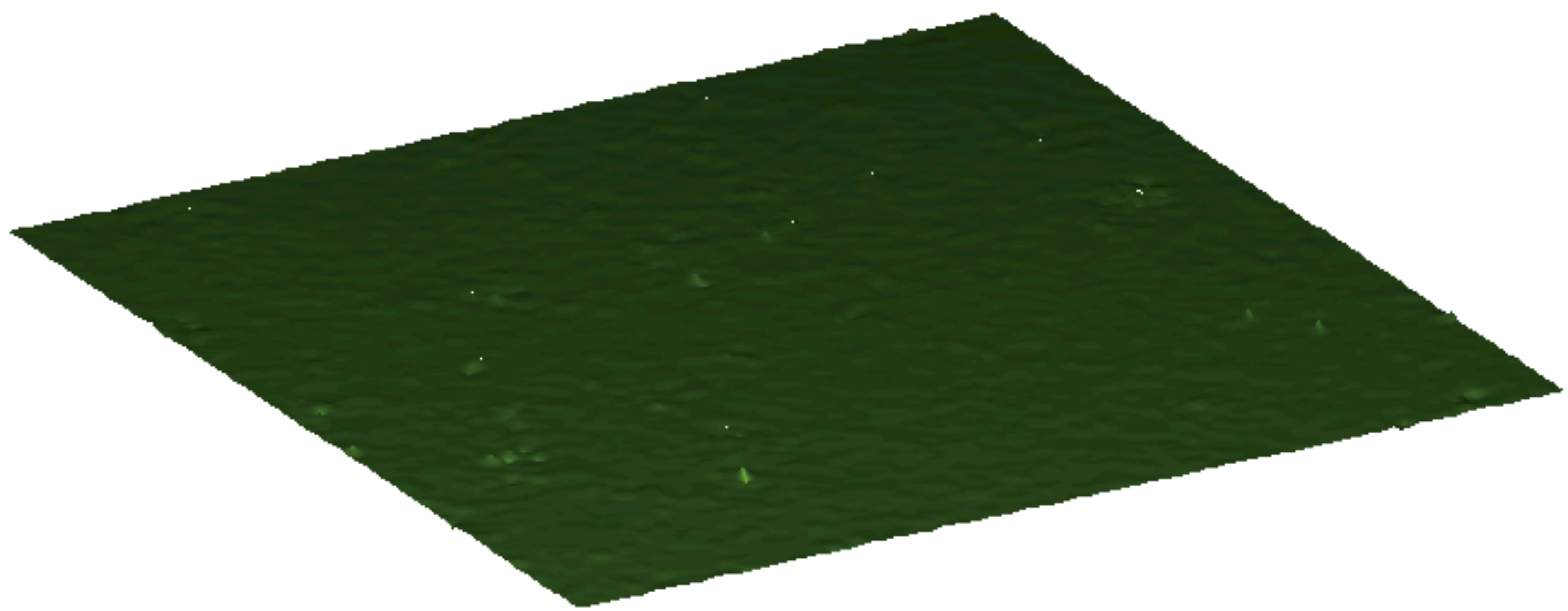
- Method: Use high resolution Cloud Resolving Model (CRM) runs to examine the effects of downdrafts.
- Model: **System for Atmospheric Modeling (SAM)** v6.8.2
  - Anelastic equations
  - Prognostic liquid water/ice static energy, total non-precipitating water, and total precipitating water
  - Single moment microphysics, CAM radiation, and parameterized sub-grid-scale turbulence
- *TOGA COARE* Simulation
  - 128x128 km^2 domain with 1km horizontal resolution
  - 64 vertical levels up to 5hPa (About 100m resolution near the surface)
  - 10 second timestep, ocean surface





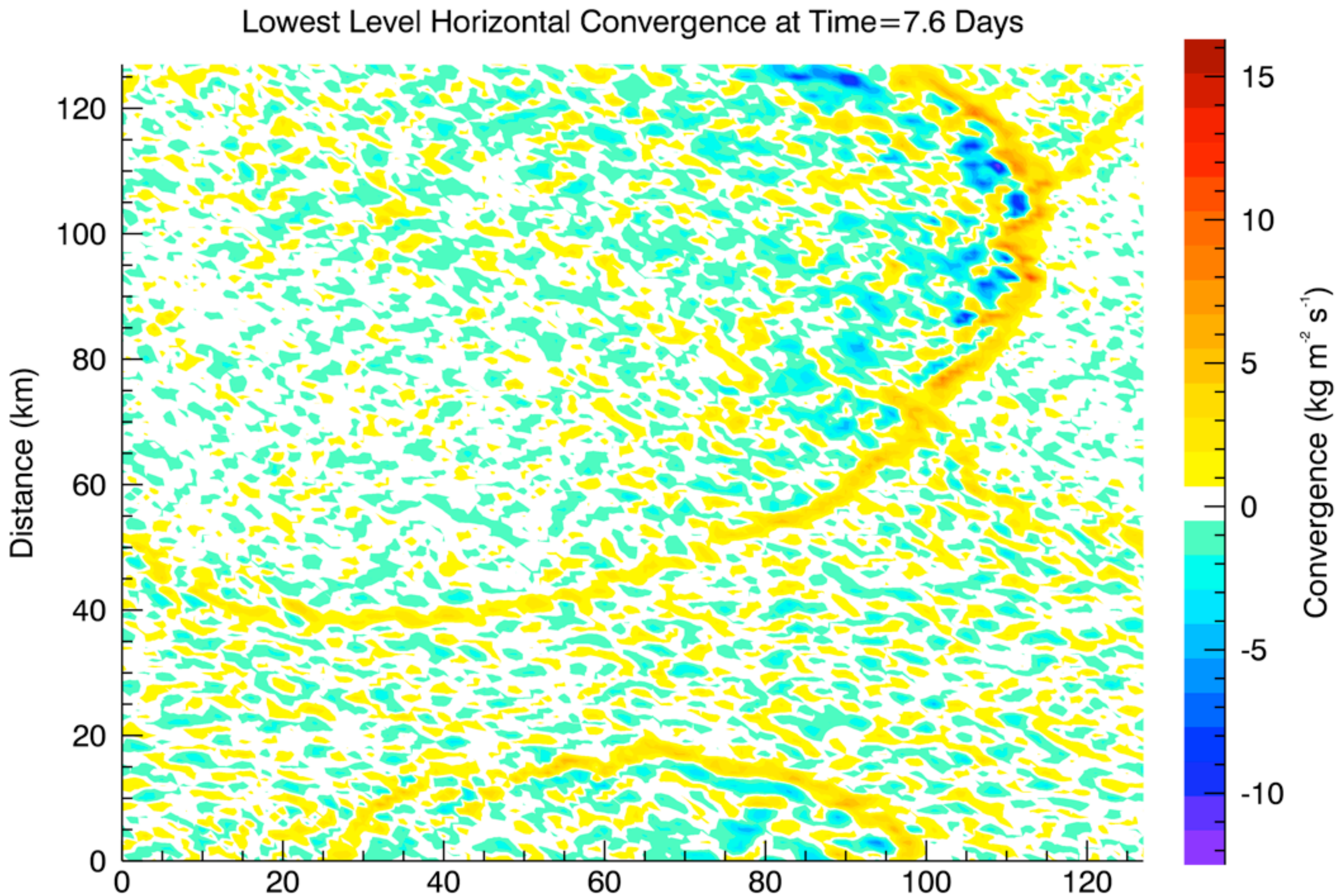
Assumption: Downdrafts don't matter

Downdrafts move as much or more mass vertically through the column as the dry environment does.



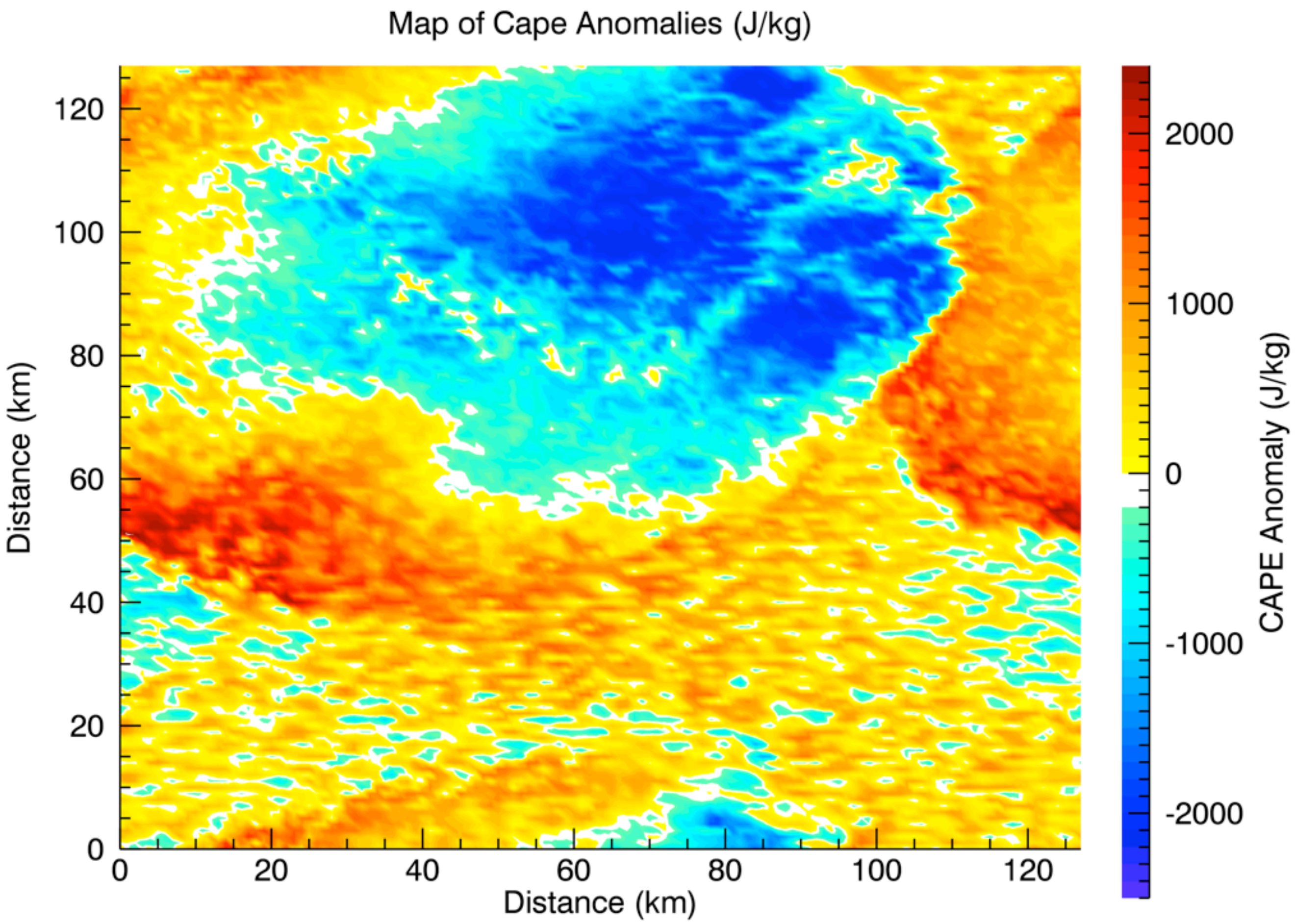
Assumption:
Downdrafts only cool

299K layer - 12.5 days of TOGA

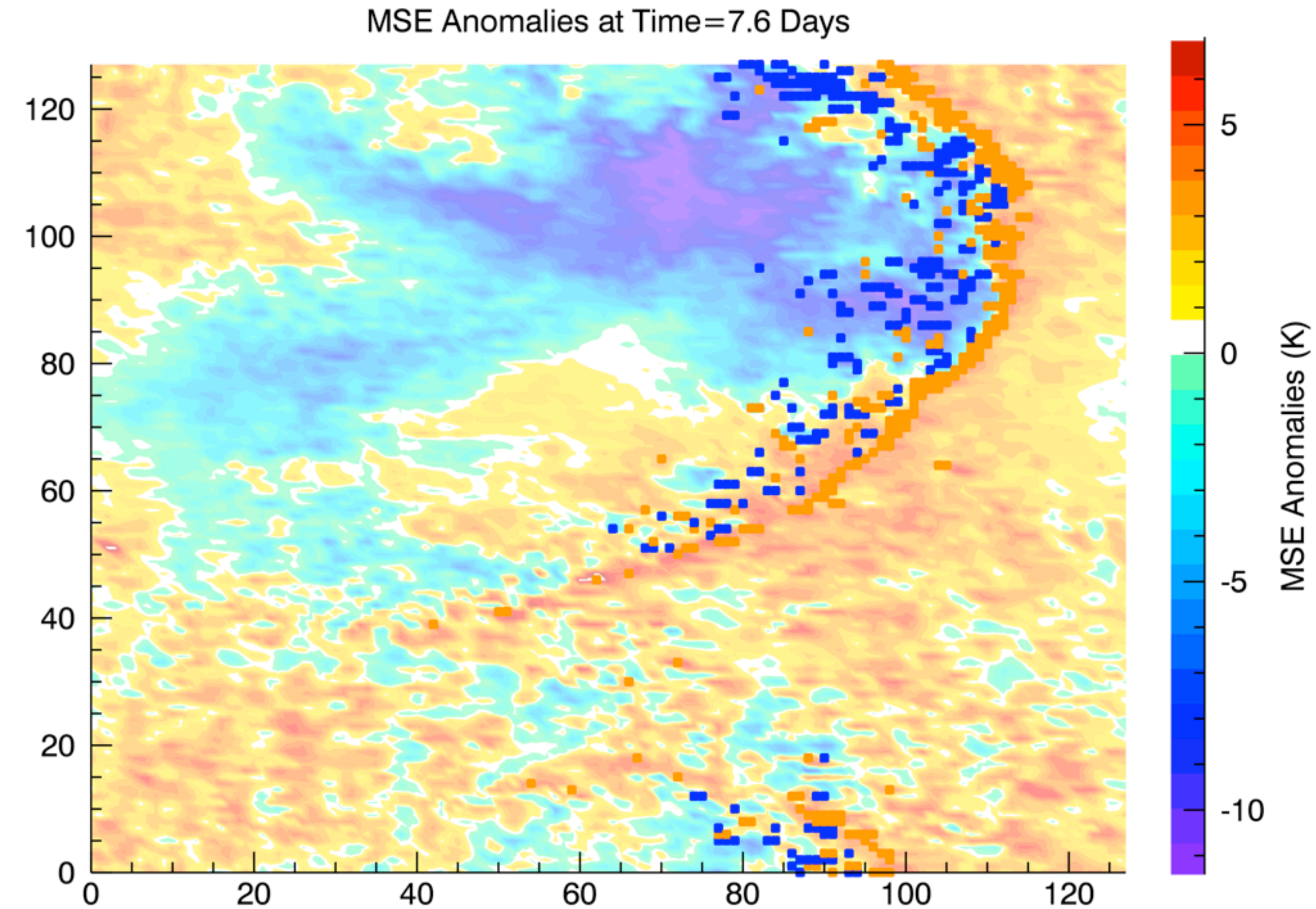


Assumption: Downdrafts only cool

Variability created by coldpools increases the organization and propagation of convection through boundary layer convergence.



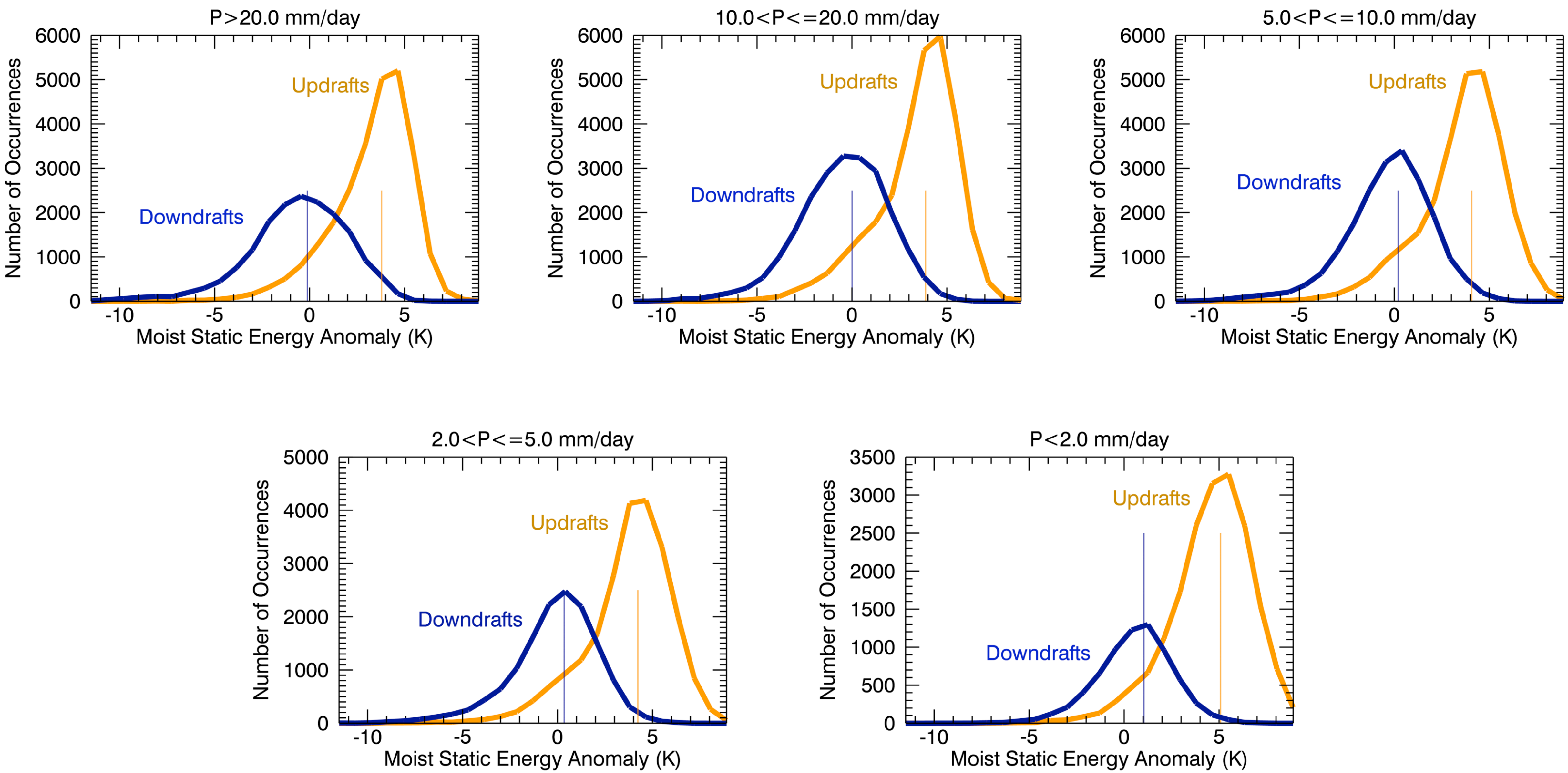
CAPE



MSE

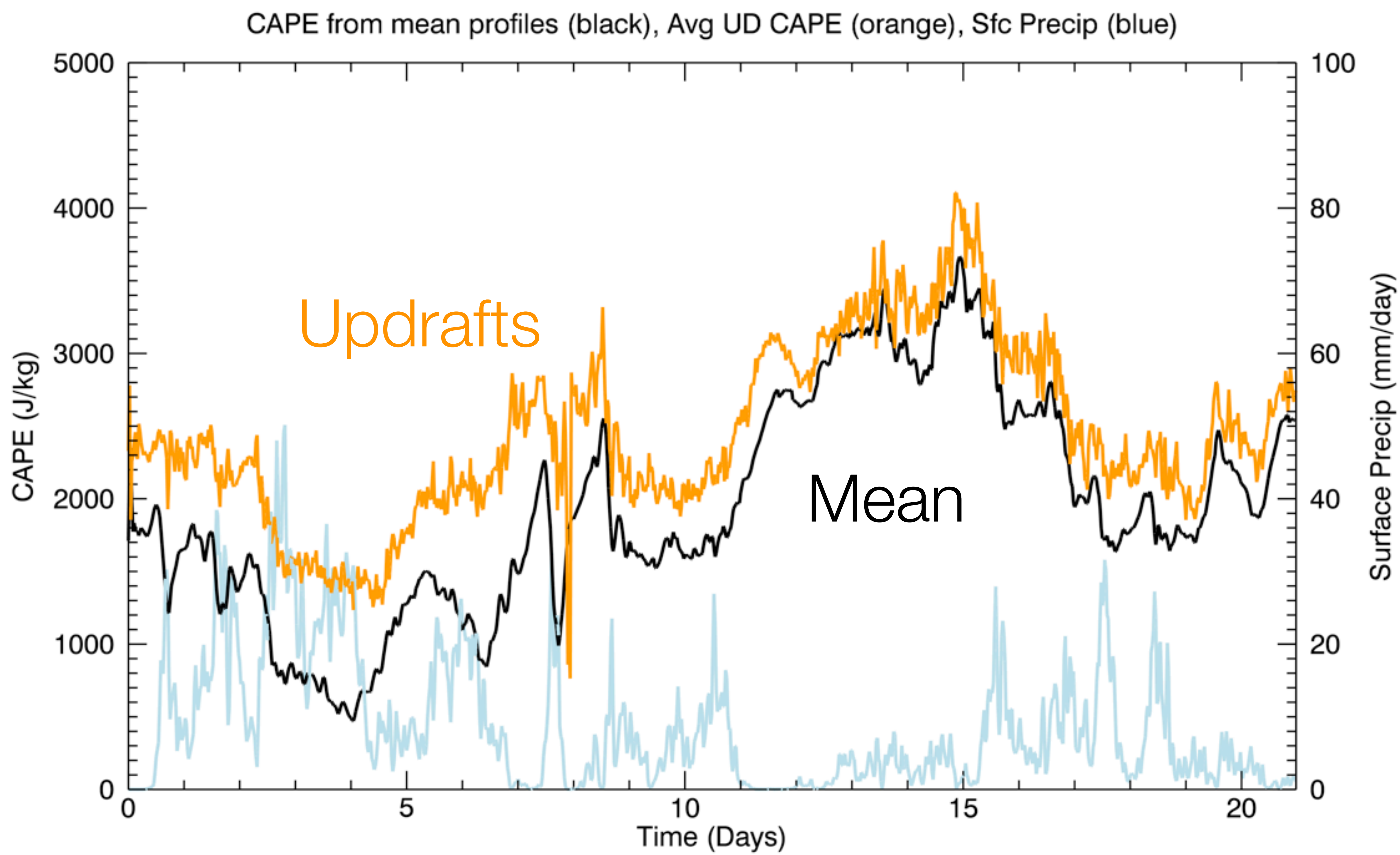
Assumption: Downdrafts only cool

CAPE variability created by coldpools can impart more buoyant properties to lifted parcels than the mean.



Assumption: Updrafts have mean BL Properties

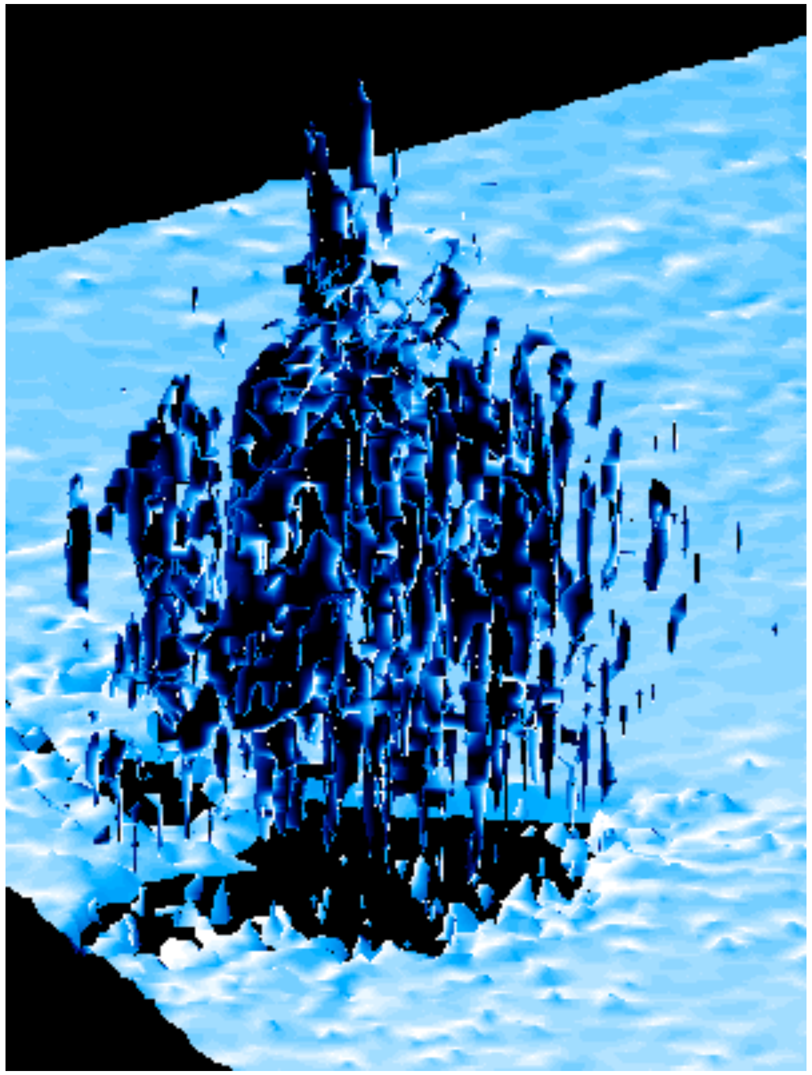
Updrafts are anomalously warm, and downdrafts are too. Negative buoyancy comes from condensate loading.



Assumption: Updrafts have mean BL Properties

Cells marked as updrafts have a much higher CAPE than a parcel lifted with mean properties would.

How Realistic Are These Assumptions?



- Downdrafts are an important part of the vertical mass budget and should be included if only for this.
- Boundary layer variability created by downdraft coldpools enhances horizontal mass convergence and can force environmental lifting.
- Coldpools influence the initial thermodynamic properties of cloud parcels, and updrafts are more buoyant than assumed.

Improving the coupling between convection and the BL

- Improving the ability to forecast extreme weather is important, but...
- Climate models need work before they can reliably forecast tropical precipitation variability.
- TO DO:
  - Ensure all climate models represent some form of downdraft mass flux
  - Add a coldpool parameterization that represents parcel warming, surface flux changes, and mesoscale organization