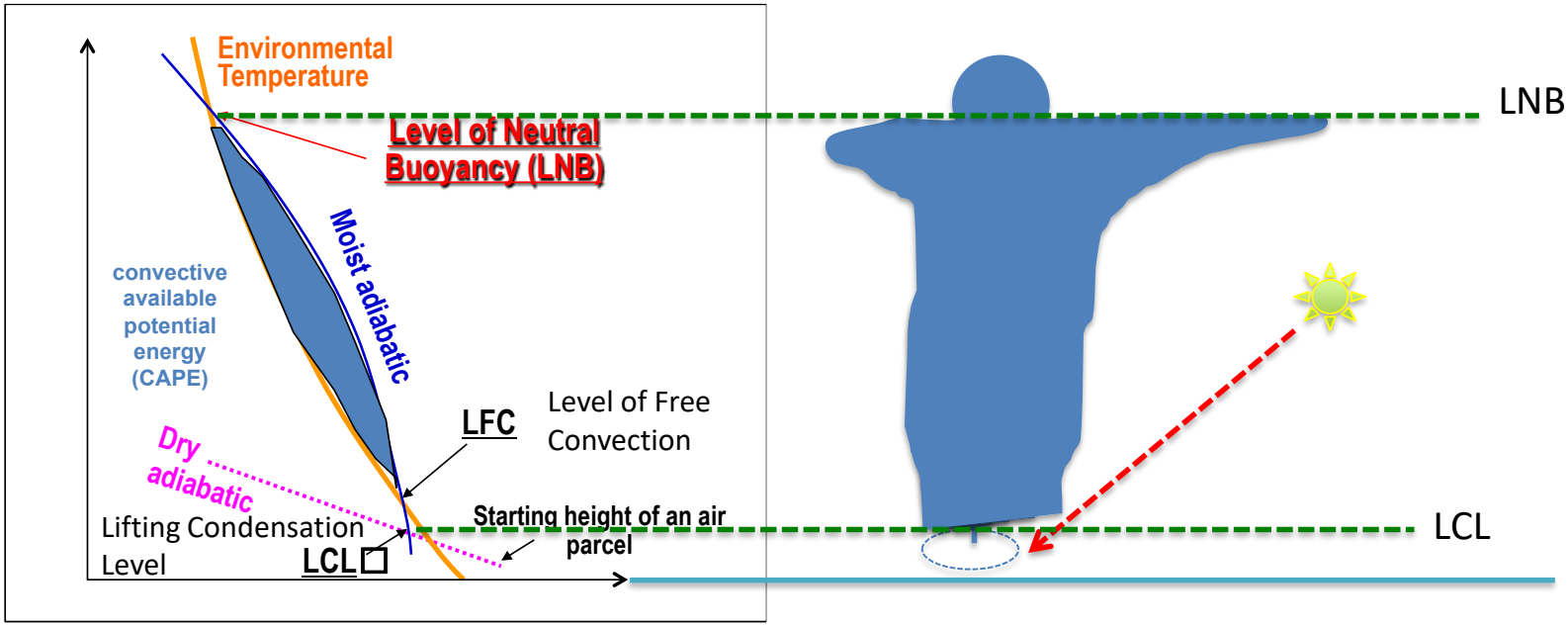
Level of Neutral Buoyancy, Deep Convective Outflow and Convective Core: New Perspectives Based on 5-Years of CloudSat Data

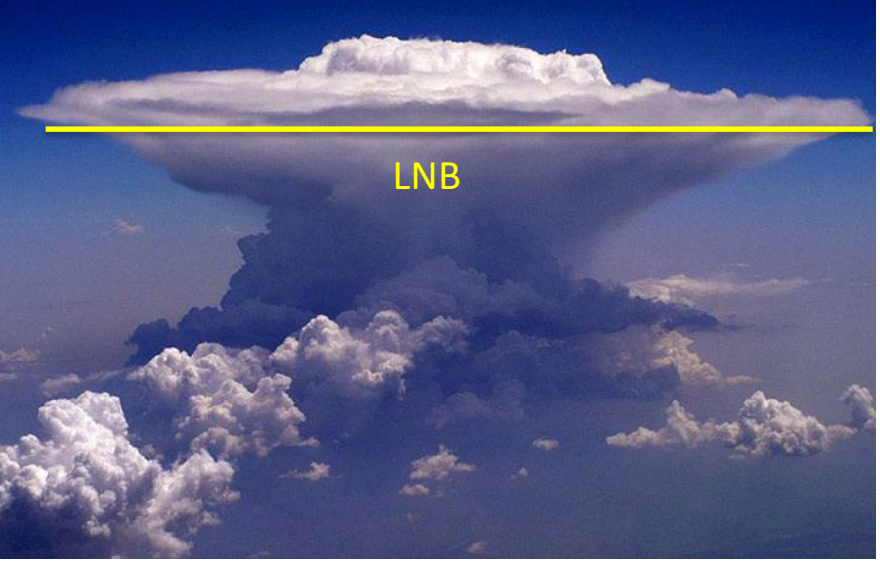
Hanii Takahashi*, Zhengzhao Johnny Luo, and Graeme L Stephens

*Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, California
*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

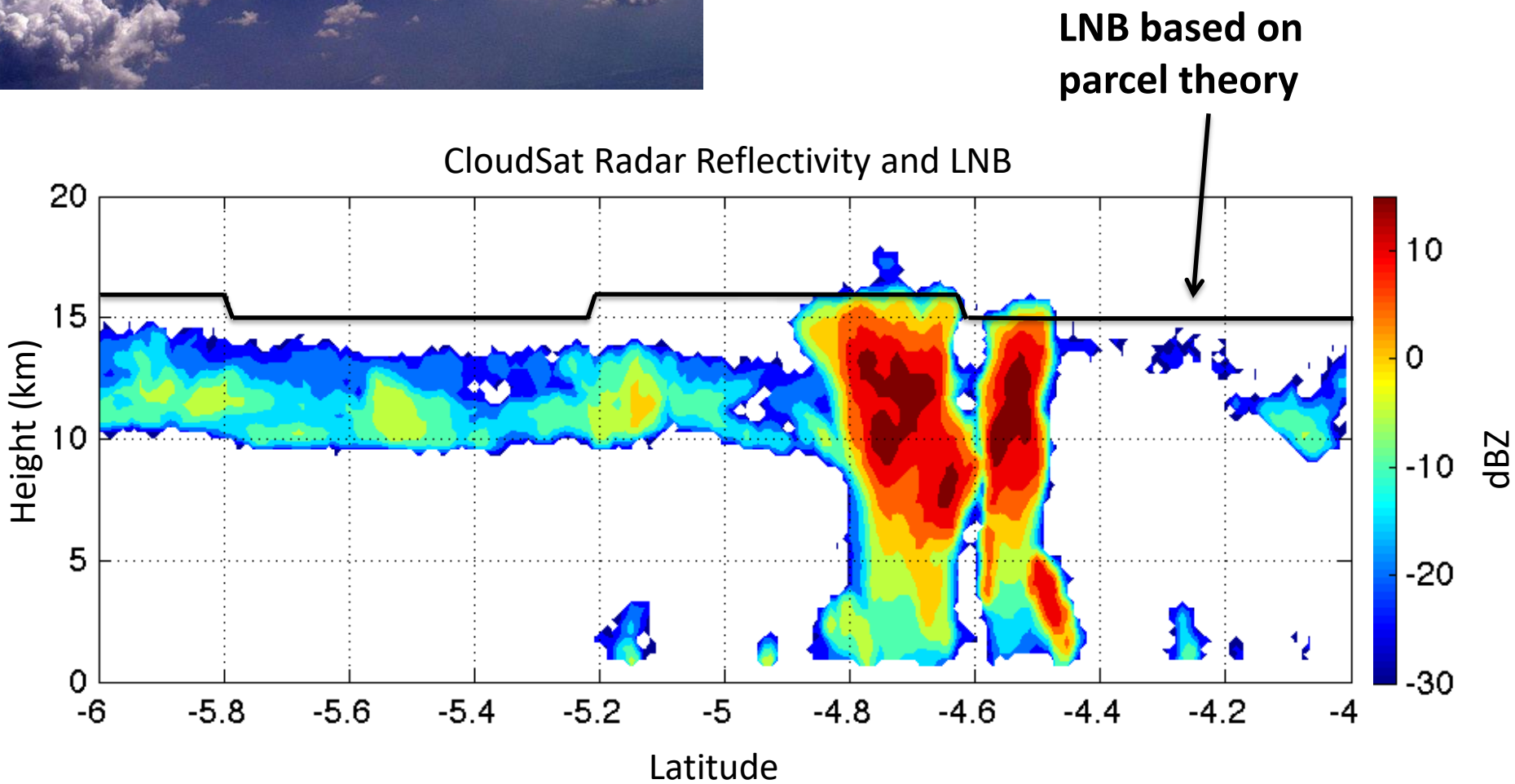
© 2017 California Institute of Technology

Parcel Theory: a simple path of a rising air parcel





The classic definition of LNB is derived from the parcel theory.



Ideal World based on Parcel Theory | **Real World**

$$/ = 0$$

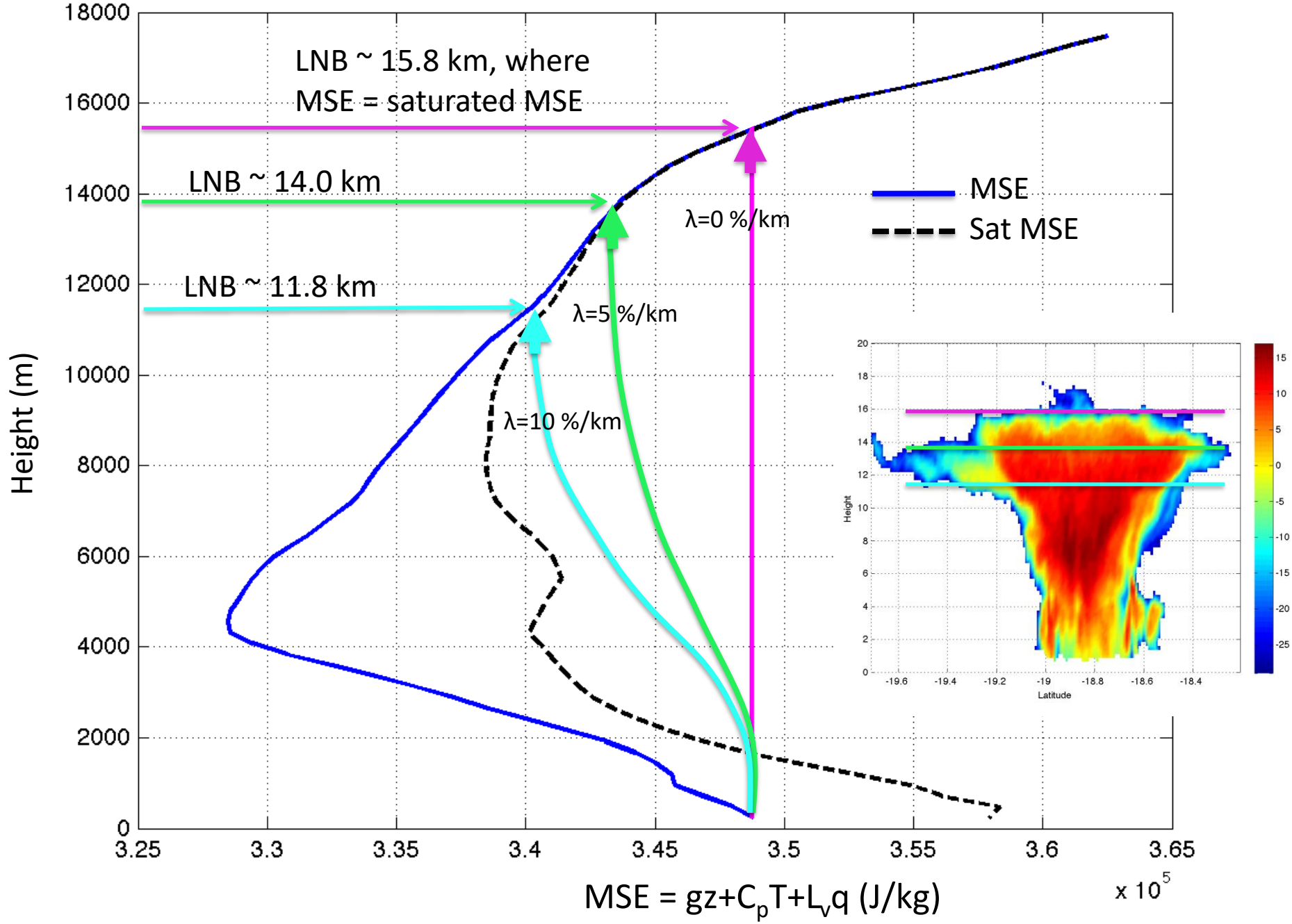
$$/ = \frac{1}{M}\frac{\P M}{\P z}$$

: the rate of change of the mass flux into the plume with height

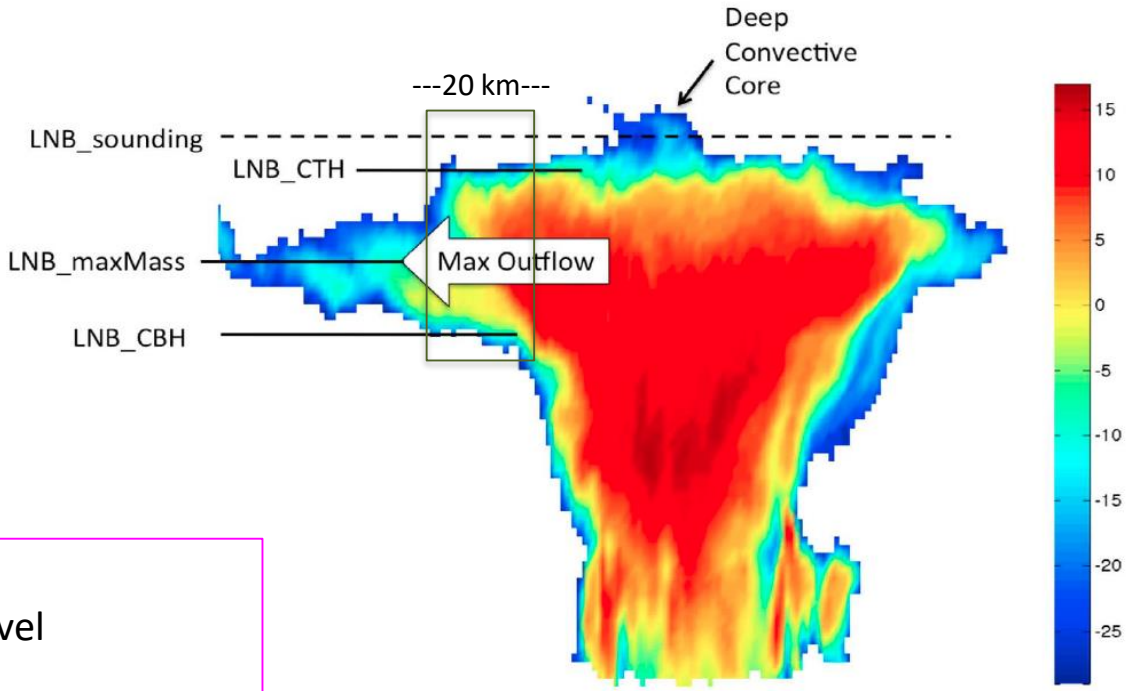
- No air mass interaction between the air parcel and its surrounding environment.
- Only accounts for the original condition of surface soundings.

- Convection interacts with the environment in complicated ways.
- Convective entrainment affects buoyancy.

Definition of LNB from Parcel Theory



Why don't we find the LNB from Cloud Object instead of using parcel theory?



LNB_observation:

- LNB_CTH: The highest detrainment level
- LNB_maxMass: The maximum mass detrainment level (maximum radar reflectivity within the anvil column).
- LNB_CBH: The lowest detrainment level

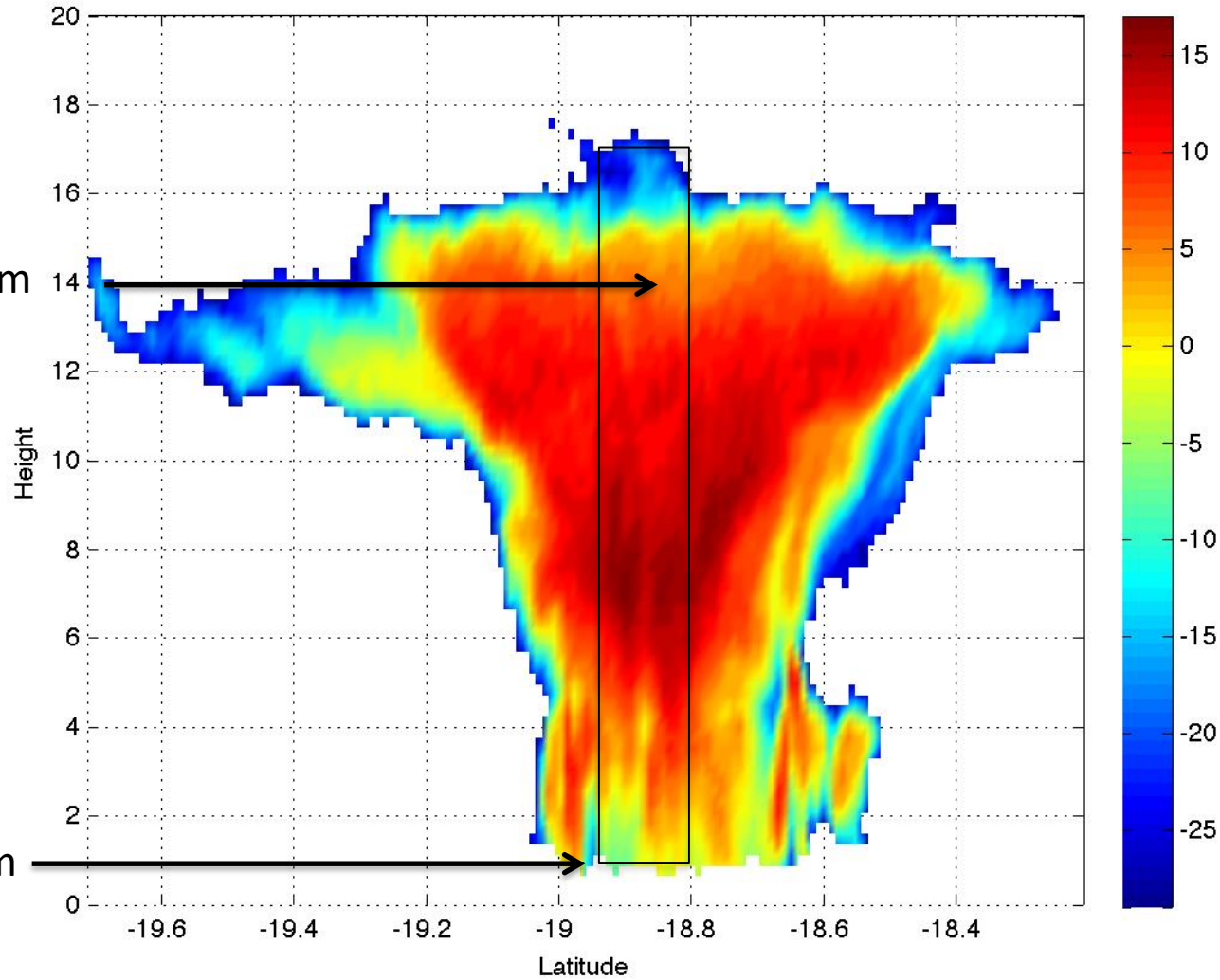
Only the first 20 km of the outflow is used to minimize ice sedimentation effect

Takahashi and Luo (2012)

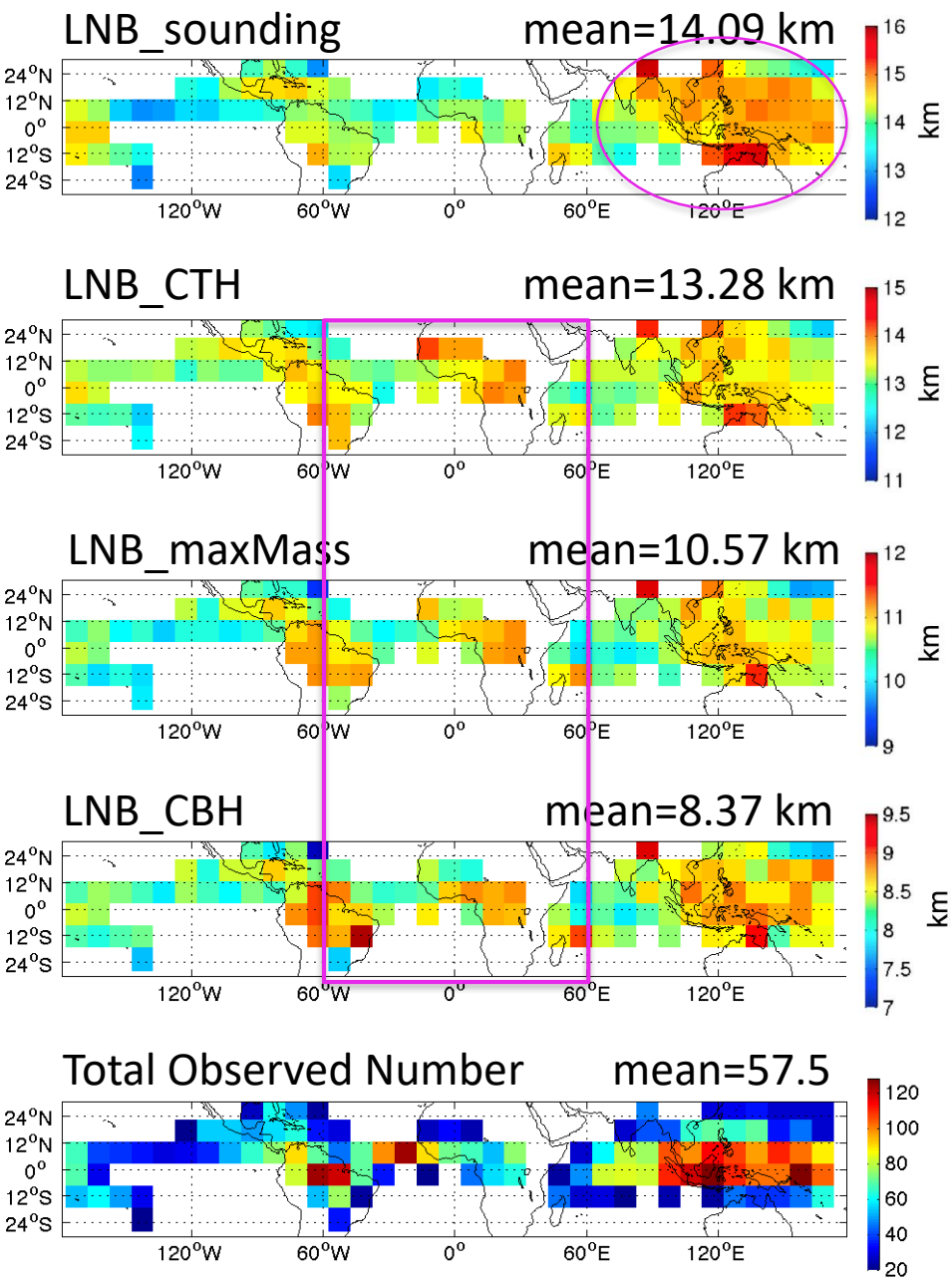
(1) Cloud mask >20
(2) Find convective core (ETH 10dBZ >10 km, CB<2km, continuous radar echo from CB to CT)
(3) Find anvils (CB ≥ 5km & anvil length ≥ 20km)

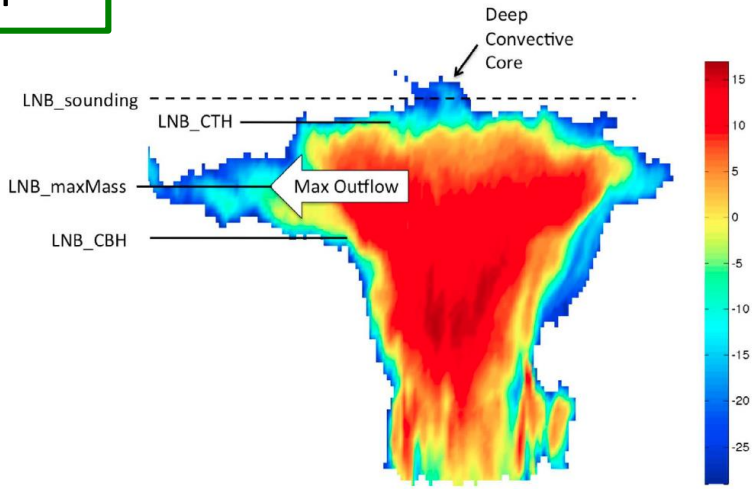
ETH 10 dBZ >10 km

CB less than 2 km



Distribution of LNB_sounding vs. LNB_observation

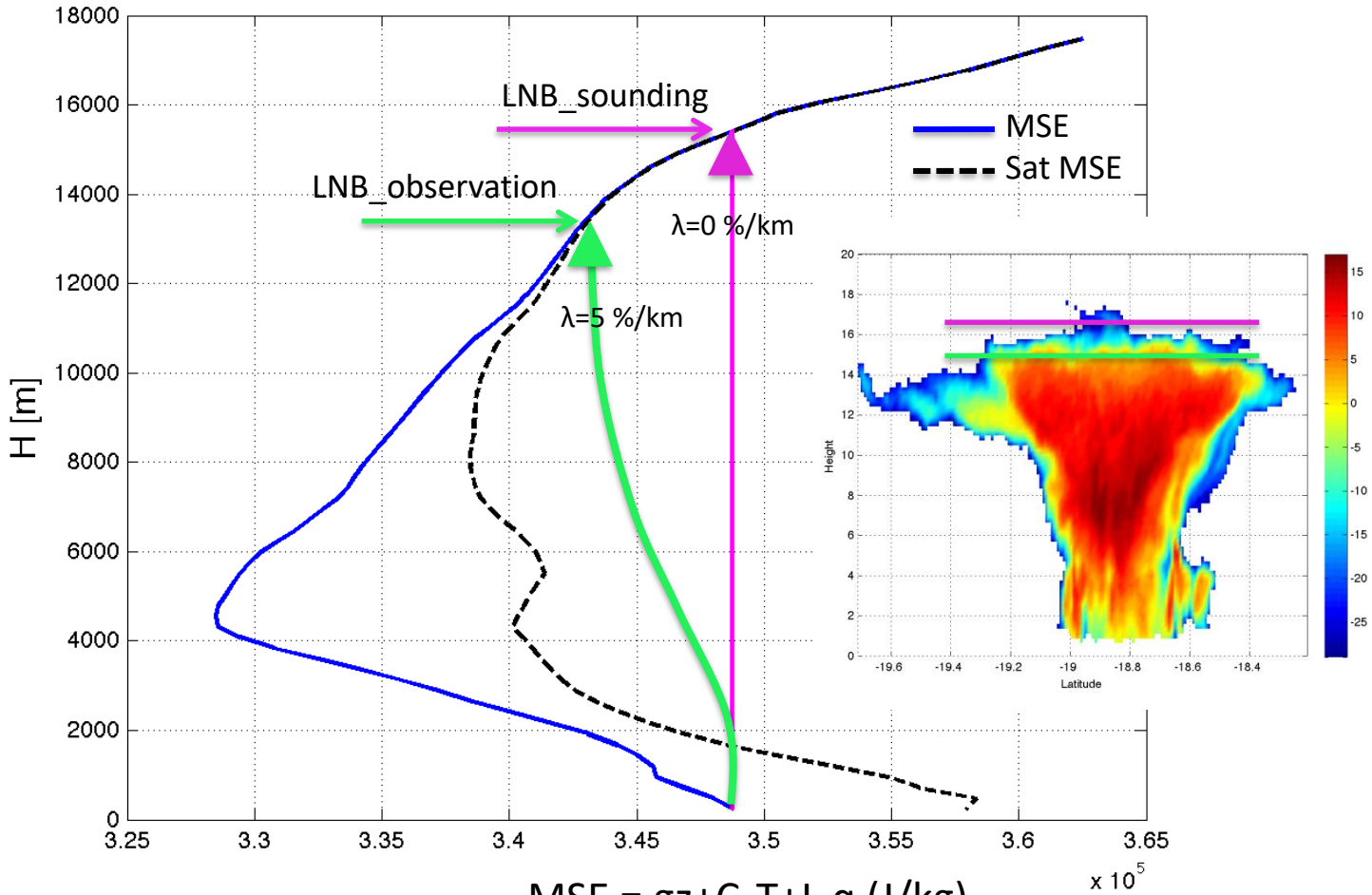




- LNB_sounding: the Warm Pool has the highest LNB.
- For LNB_observation, tropical Africa and Amazonia has the highest LNB.

The difference between LNB_sounding and LNB_observation

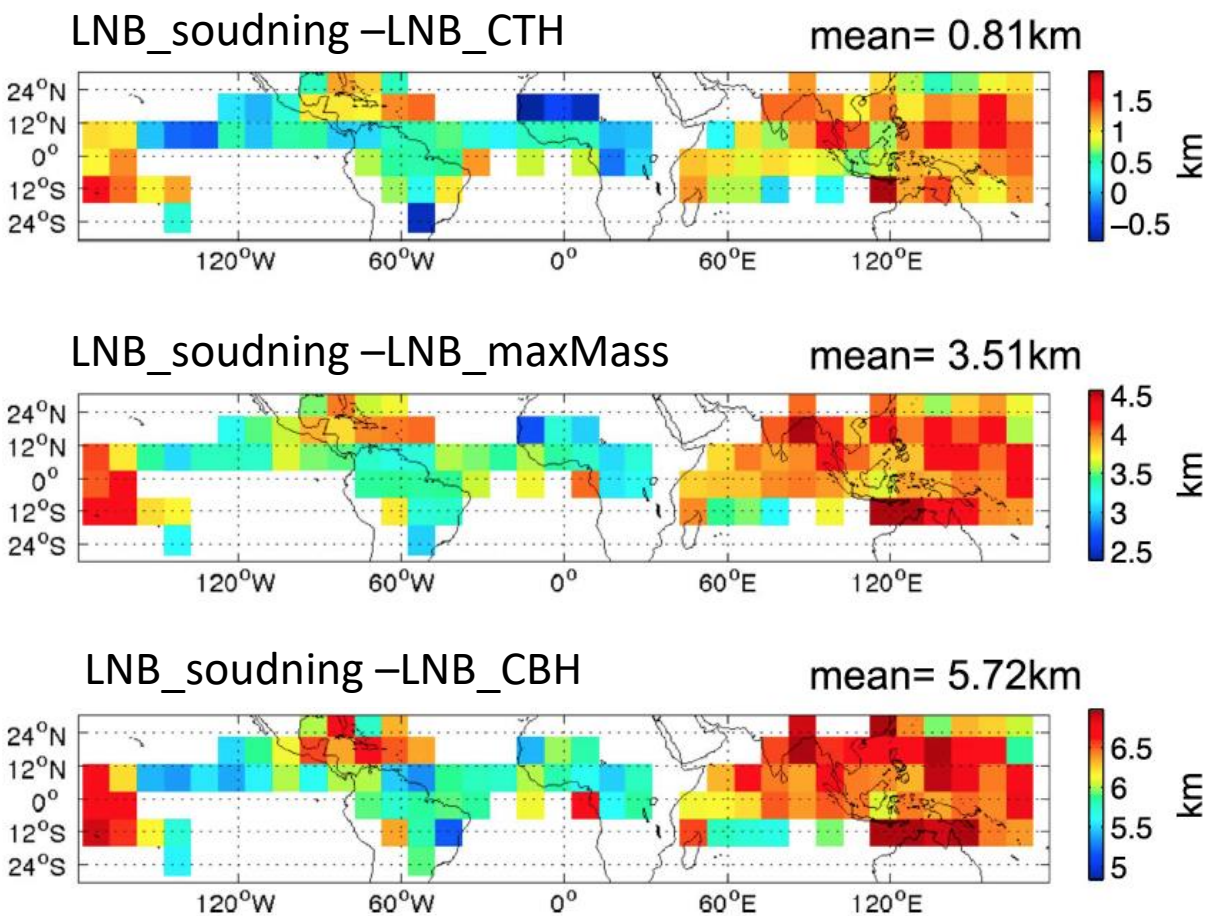
A measure of the magnitude of the entrainment effect



$MSE = gz + C_pT + L_vq$ (J/kg)

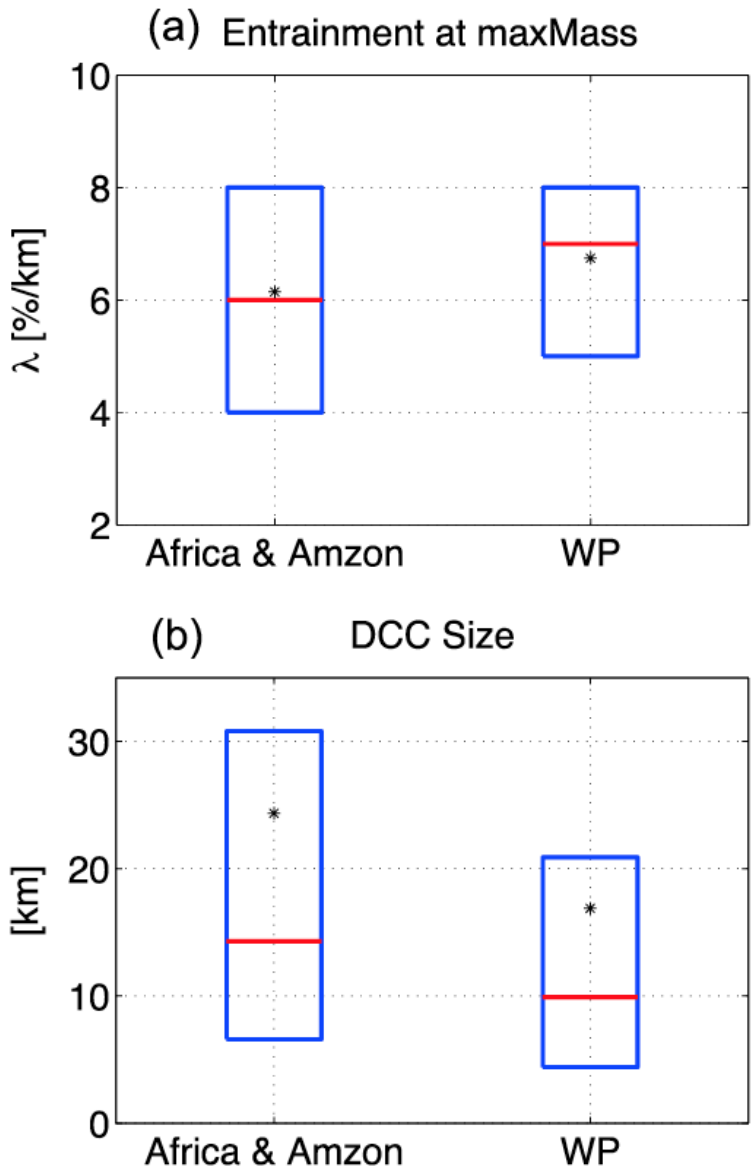
The difference between LNB_sounding and LNB_observation

A measure of the magnitude of the entrainment effect



- Deep convective clouds over the Warm Pool tend to be more diluted than those over the tropical Africa and Amazonia.

Entrainment and the Size of Convective Cores



- The convective entrainment rates are smaller for the Warm Pool than the two land regions.
- A negative correlation between DCC size and bulk entrainment rate.
- Larger convective cores are better protected from the environment and thus are less diluted by entrainment.

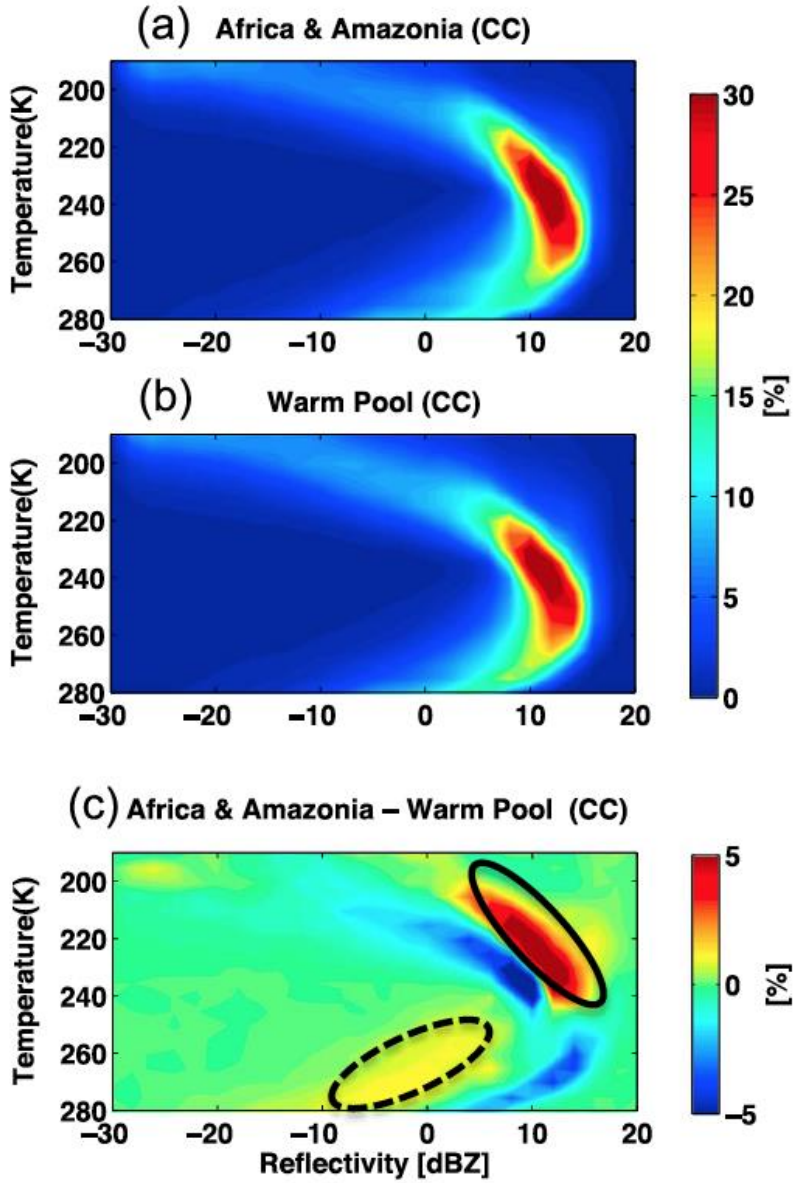
Internal vertical structure of convective cores

CFTD

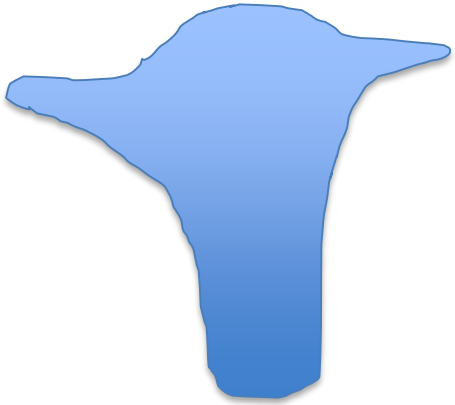
less diluted core

more diluted core

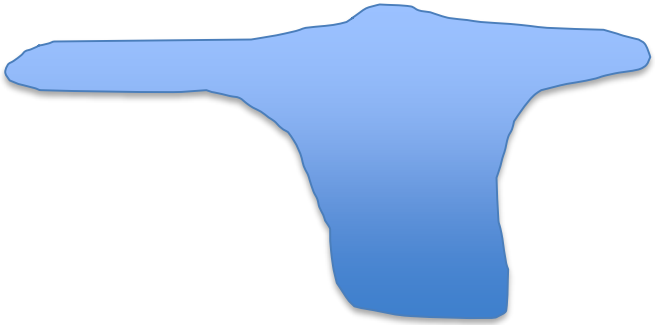
difference



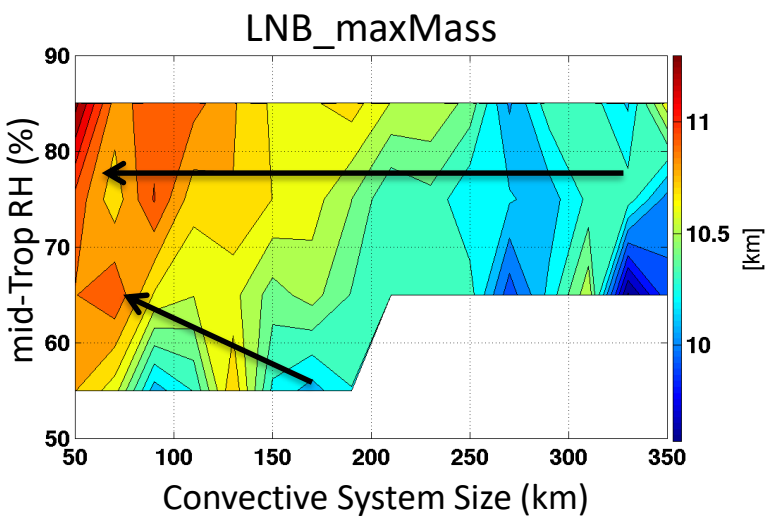
- Tropical land has more occurrences of larger radar at higher altitudes.
- Attenuation due to heavy precipitation is more severe in tropical land than the Warm Pool.

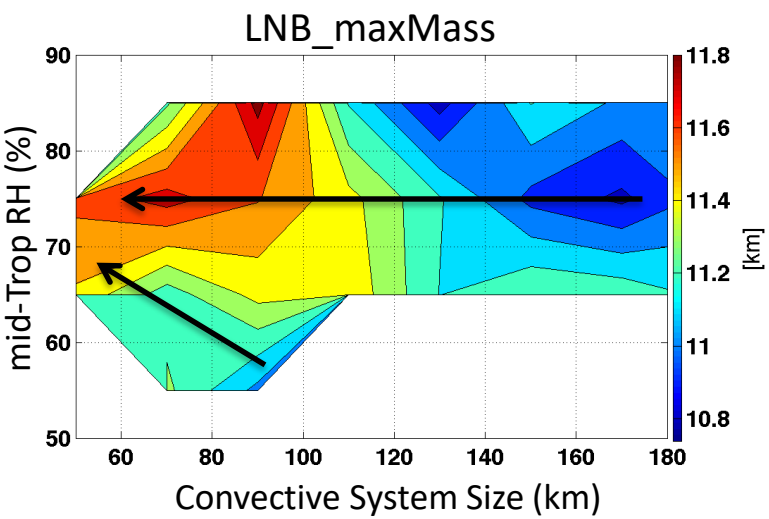


Younger Stage



Older Stage





- High_maxMass are associated with a moister Wide population that the observed size dependence has to do with convective life stage diffusions. The trend is especially pronounced for smaller systems.
- LNB_maxMass are associated with a moister Wide population that the observed size dependence has to do with convective life stage diffusions. The trend is especially pronounced for smaller systems.

Conclusions:

- The Warm Pool has the highest LNB_sounding. In terms of LNB_observation, tropical Africa has the highest value, followed by Amazonia.

- The difference between LNB_sounding and LNB_observation can be interpreted as a measure of convective dilution: the Warm Pool is more diluted than the two tropical land regions (Africa and Amazonia).

- The deep convective cores (DCCs) are smaller over the Warm Pool than the two tropical land regions. These results lend observational evidence to a long-standing assumption in convection models concerning the negative correlation between DCC size and entrainment rate.

- Comparisons in internal vertical structure of DCCs, including vertical extent of large radar echoes and near-surface attenuation by rain, suggest that the two tropical land regions contain more intense convective cores than the Warm Pool.

- Higher LNB maxMass is associated with a moister midtroposphere. LNB_maxMass is higher when convective systems are smaller.