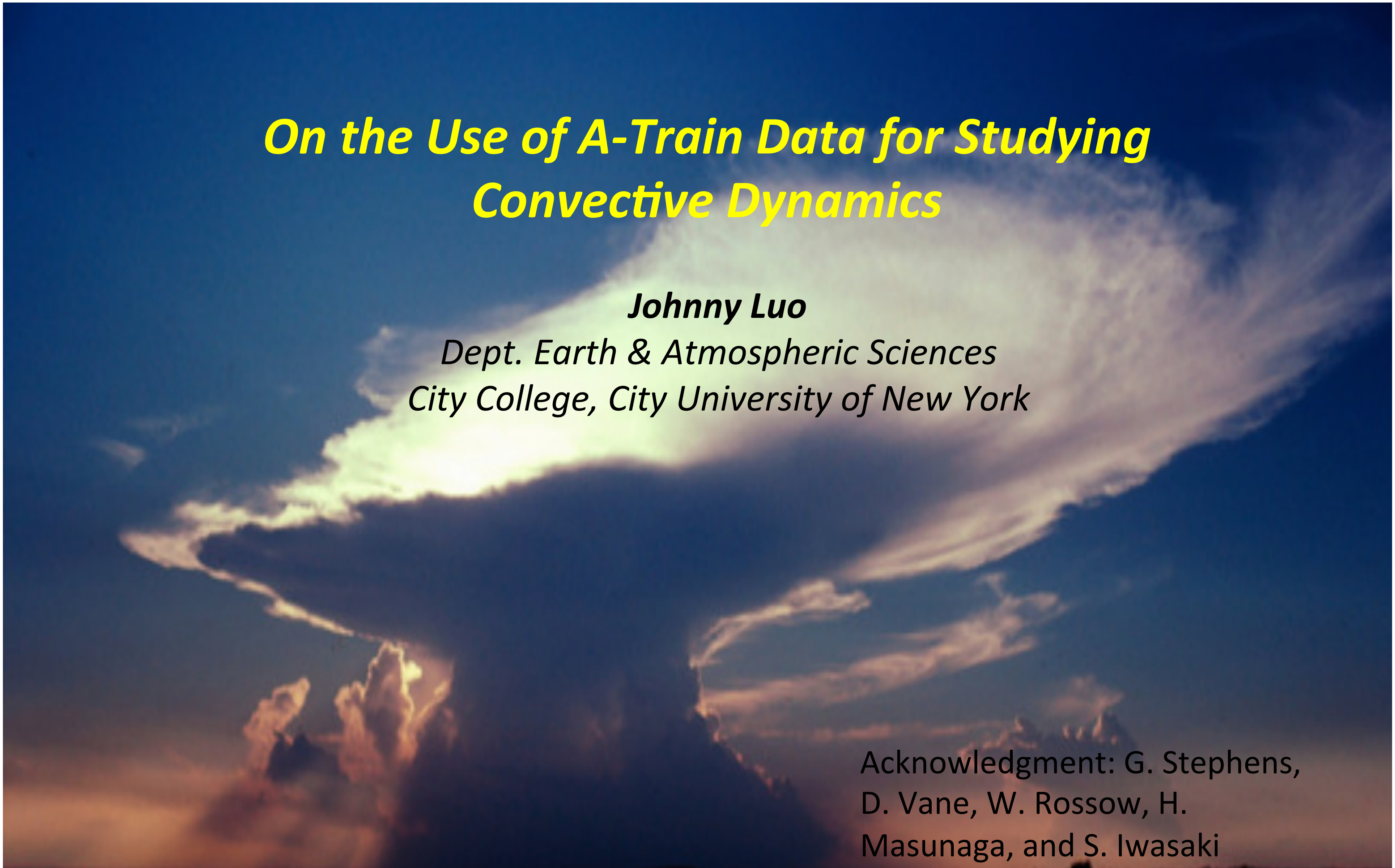

On the Use of A-Train Data for Studying Convective Dynamics

Johnny Luo
Dept. Earth & Atmospheric Sciences
City College, City University of New York

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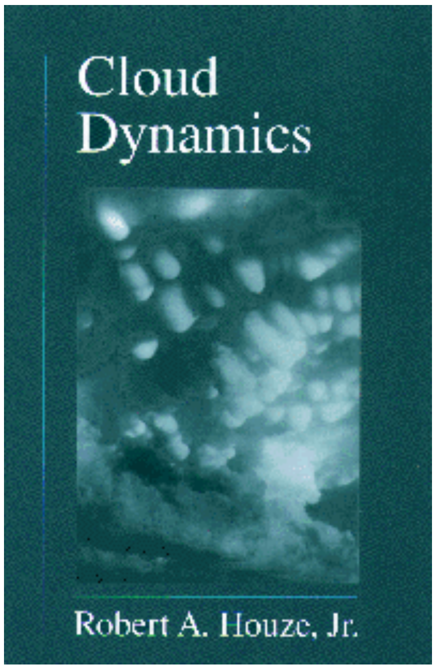
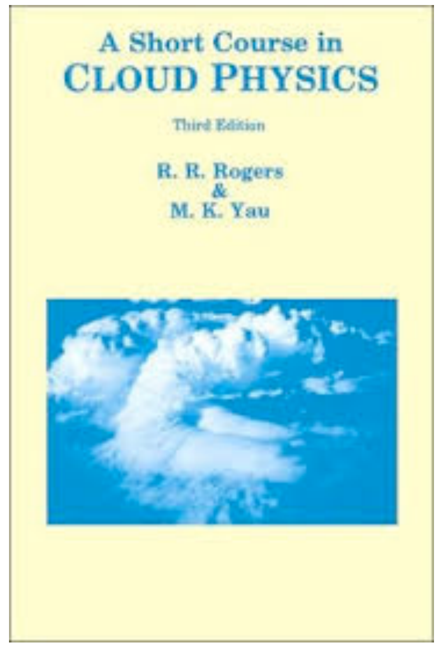
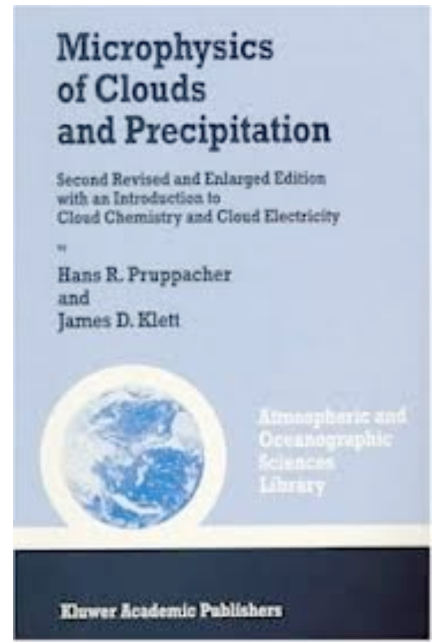
CALIPSO-CloudSat 10-Year Progress Assessment and Path Forward Workshop
Paris, France, June 8-10 2016

What is cloud dynamics?







"…the *macrophysical* features of cloud formation and growth"

Cloud Physics usually refers to cloud microphysics

Outlines

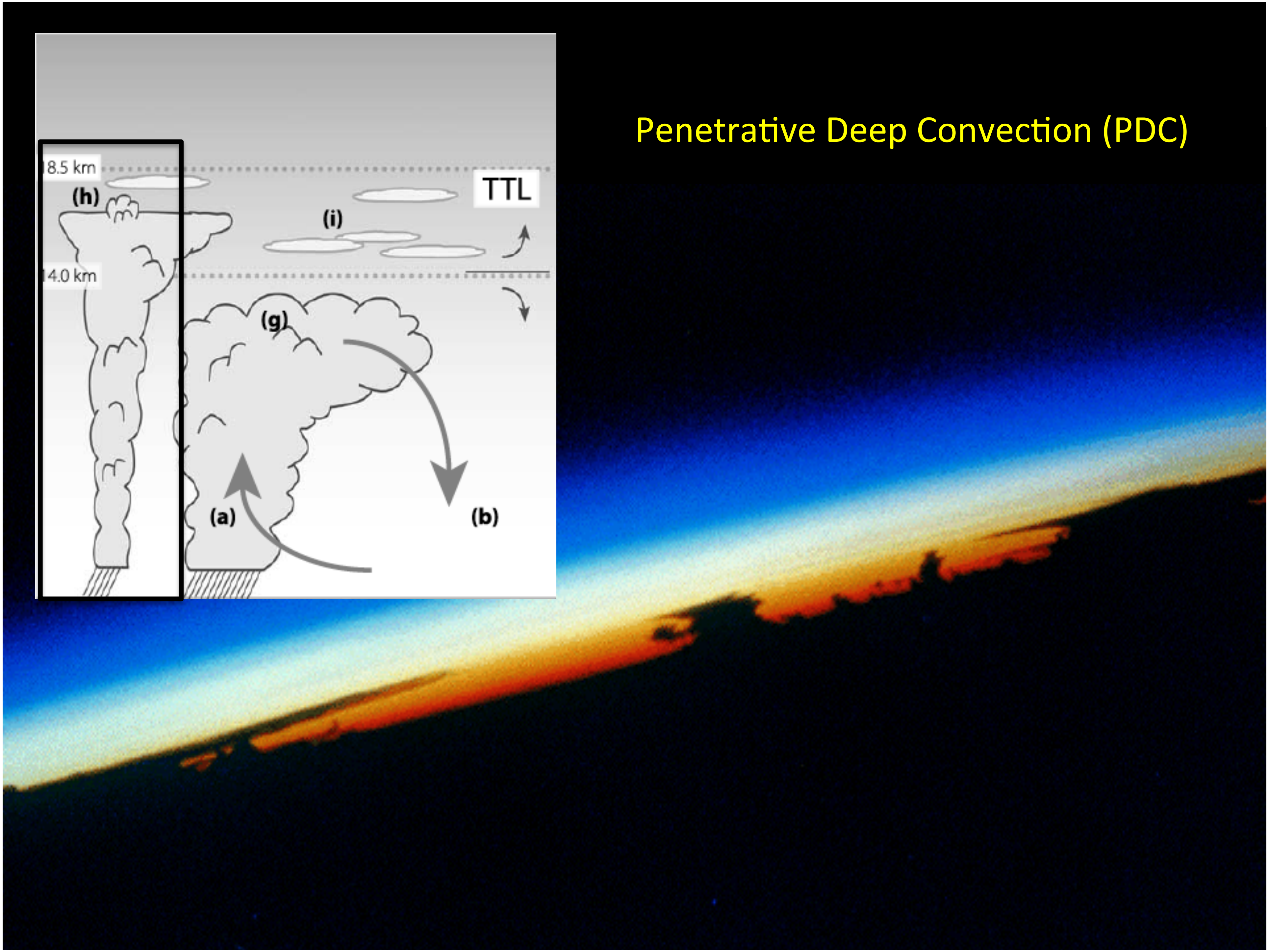
1. Motivation

2. Example 1: Penetrative deep convection & burps into the lower stratosphere

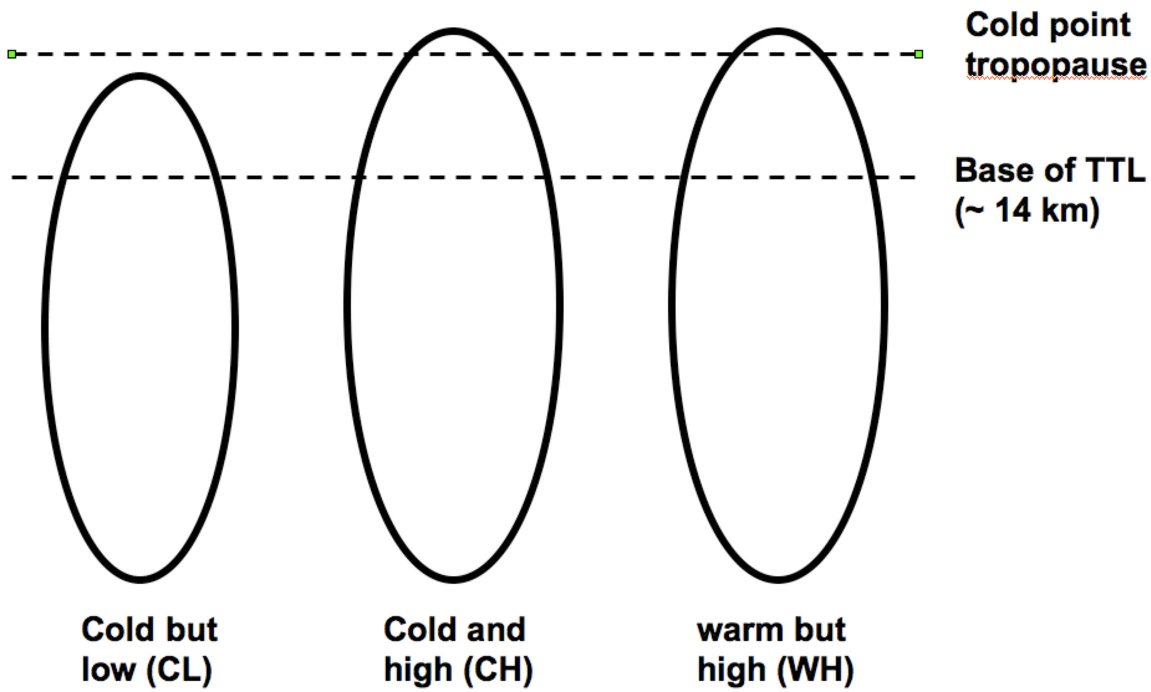
3. Example 2: Convective vertical velocity & mass flux

4. Summary

Penetrative Deep Convection (PDC)



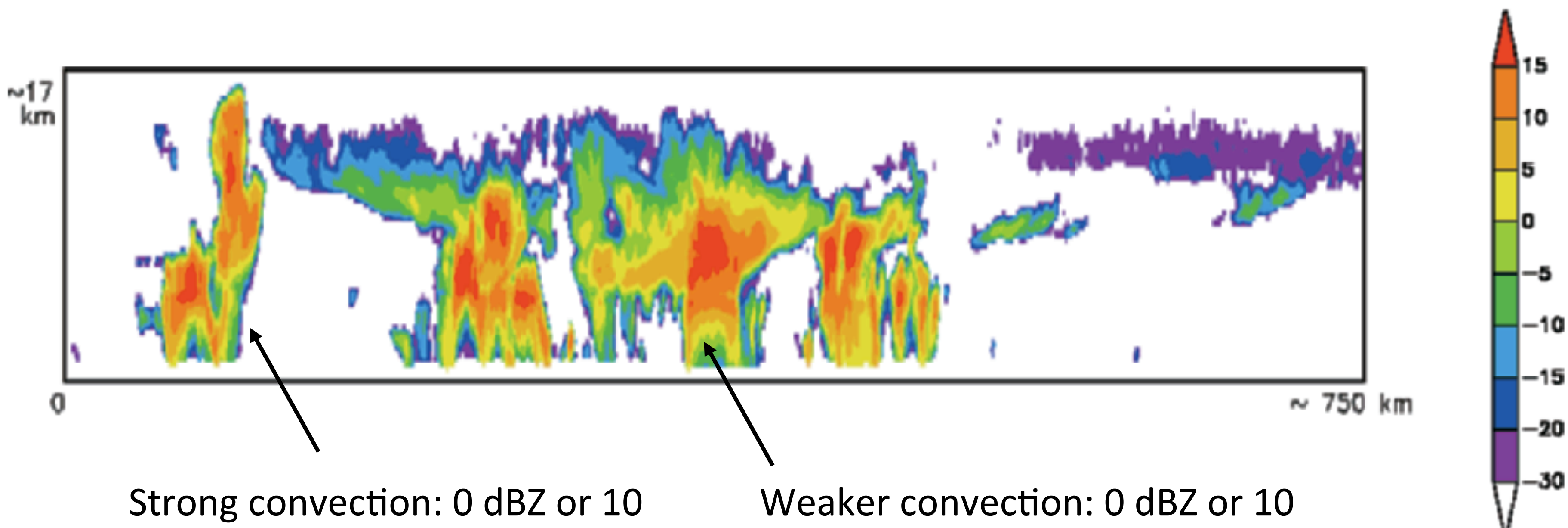
In searching for very cold/tall deep convection, we found the following three types, in relation to the *cold point tropopause*



Warm(cold) means warmer (colder) than the cold point T
High (low) means higher (lower) than the cold point H

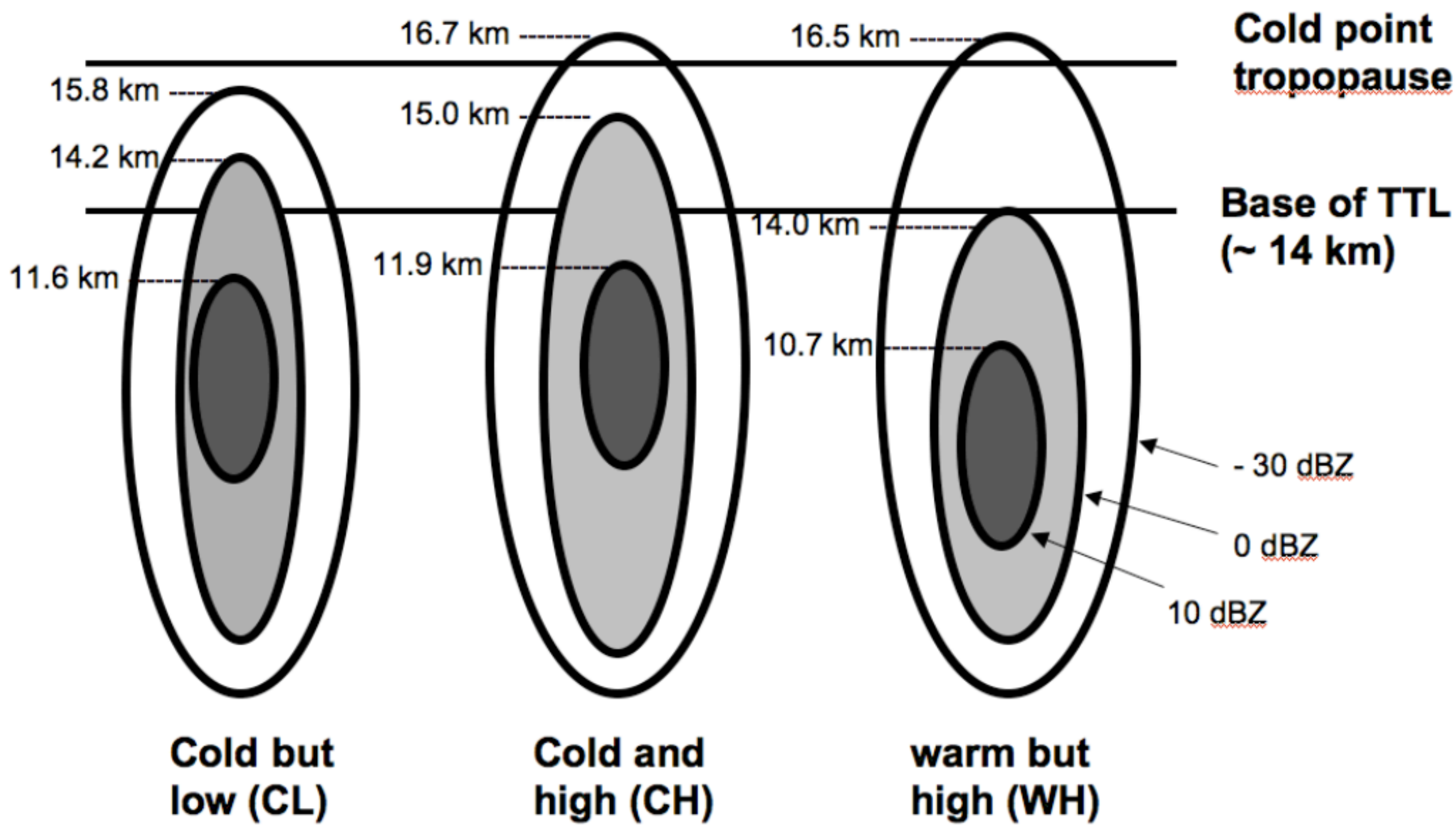
Luo et al. (2008)

An important indicator of convective strength: ***radar echo top height***



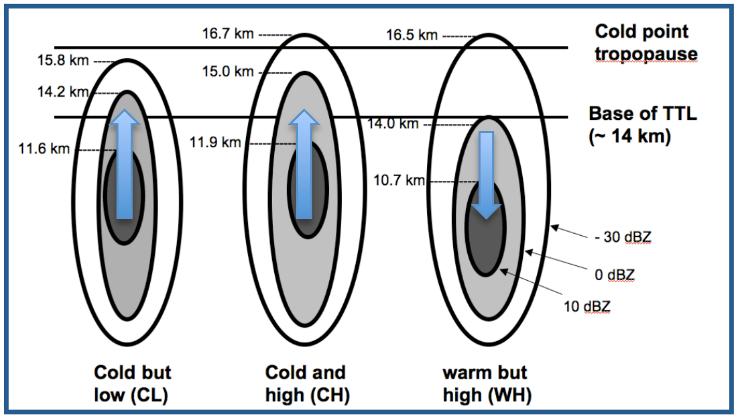
Strong convection: 0 dBZ or 10 dBZ close to cloud top (17 km)

Weaker convection: 0 dBZ or 10 dBZ much lower than the cloud top



larger radar echoes mean larger particles and/or greater cloud water content.

What can we infer from the three types of penetrating convection?

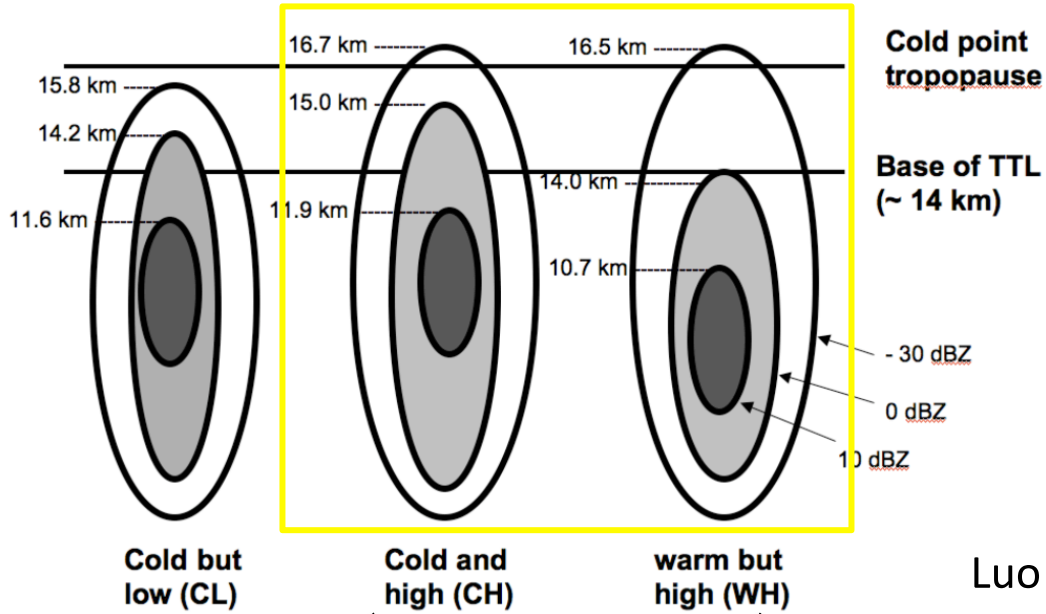


We hypothesize that:

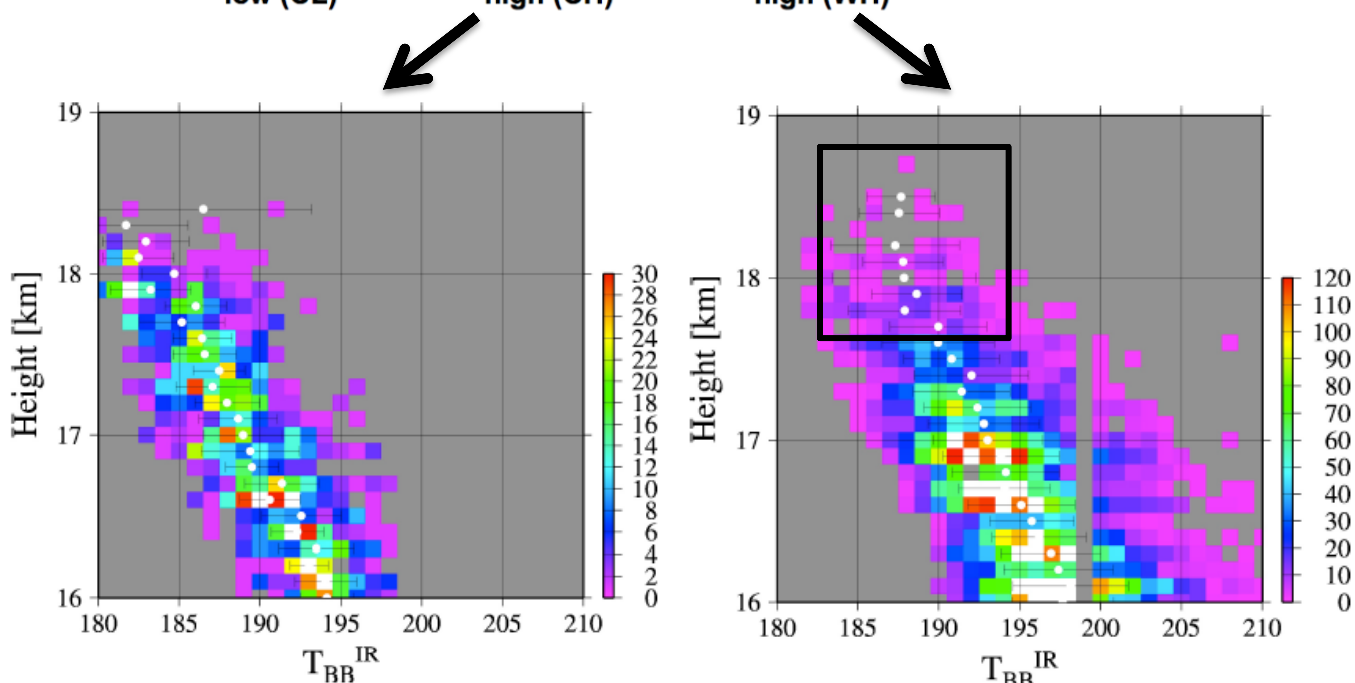
1) CL is *newly developed*, "undiluted" convection most likely in the early stage of the penetrative convective lifecycle.

2) CH is associated with the *mature stage* of the penetrative convection.

3) WH is associated with the *dissipating stage* with large particles already falling back to lower levels.



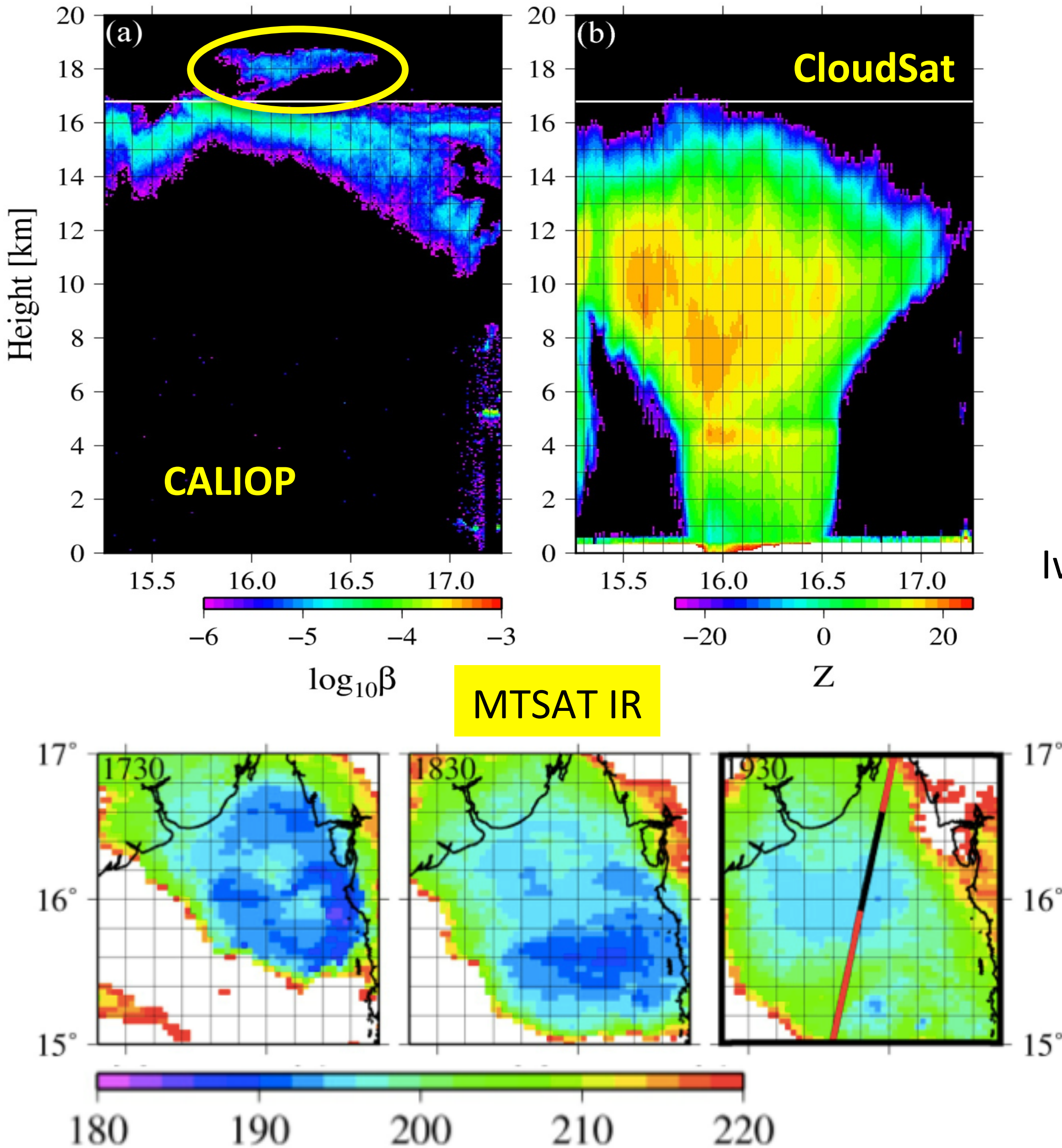
Luo et al. (2008)



Iwasaki et al. (2012)

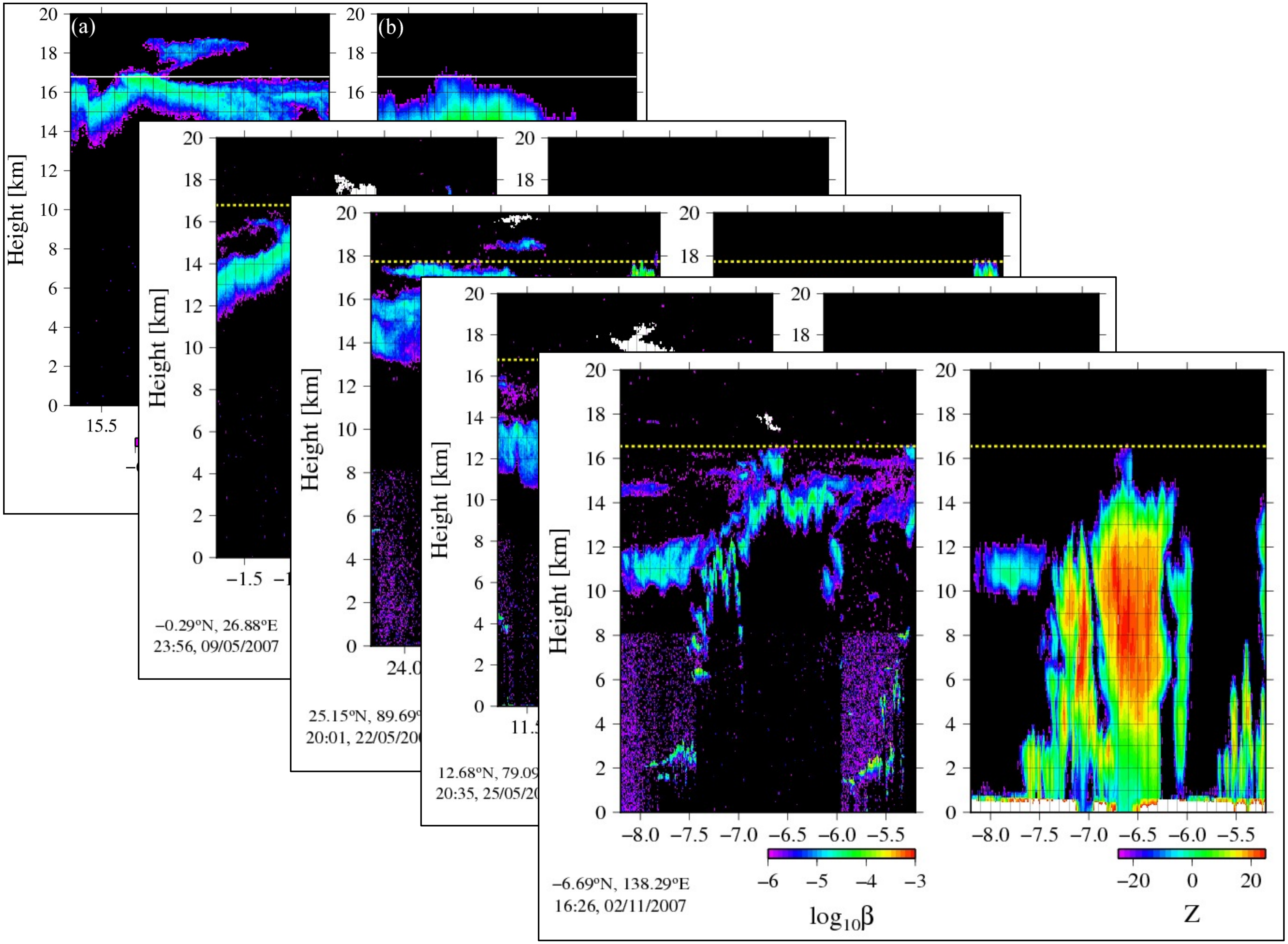

CALIPSO
CloudSat

Stratospheric Cirrus Associated with Overshoots

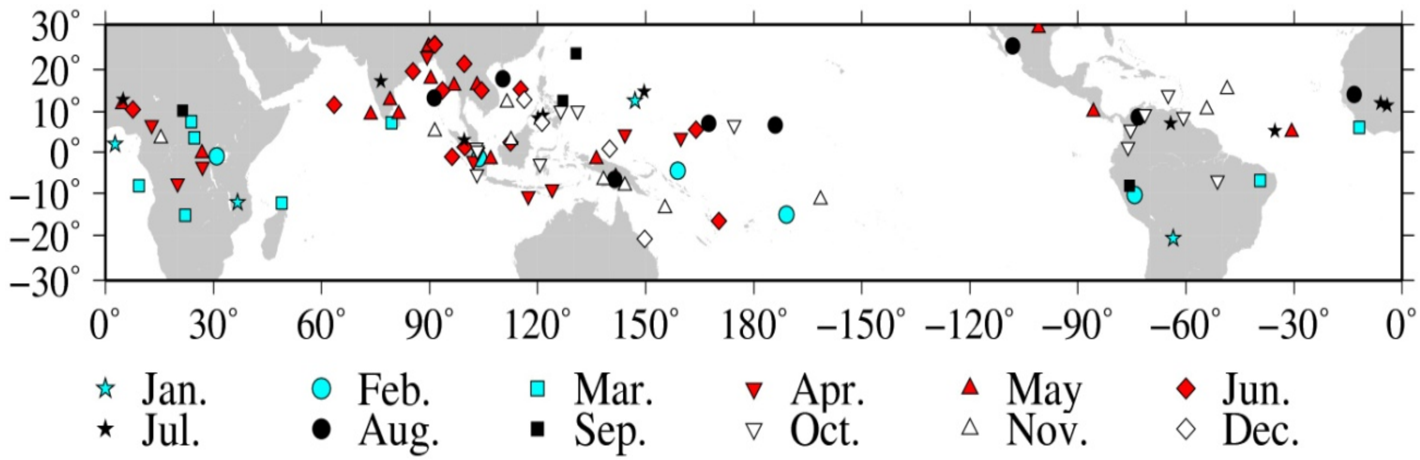


Penetrative deep convection can burp bubbles into the lower stratosphere

Iwasaki, Luo, et al. (2015)



Iwasaki, Luo, et al. (2015)



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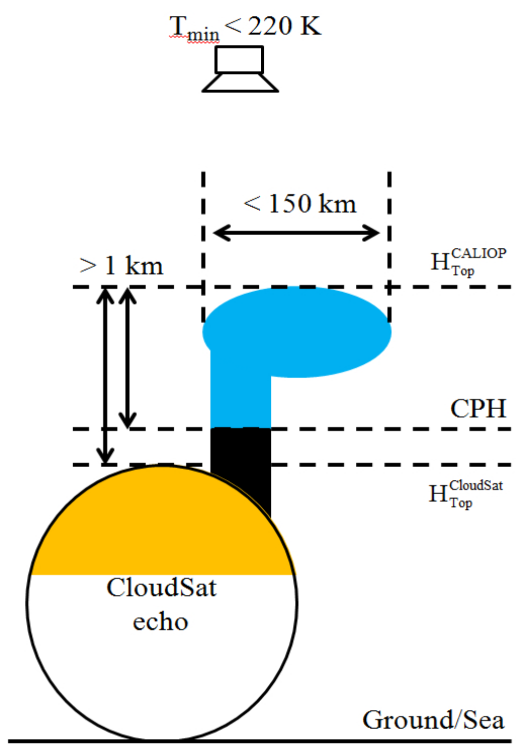

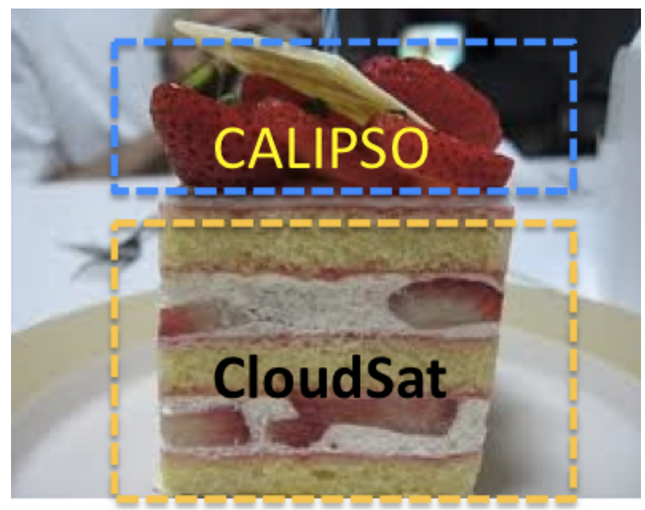

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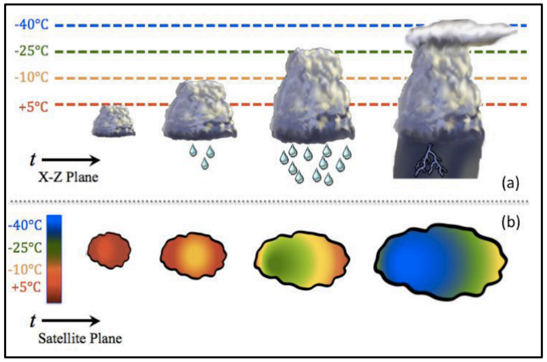
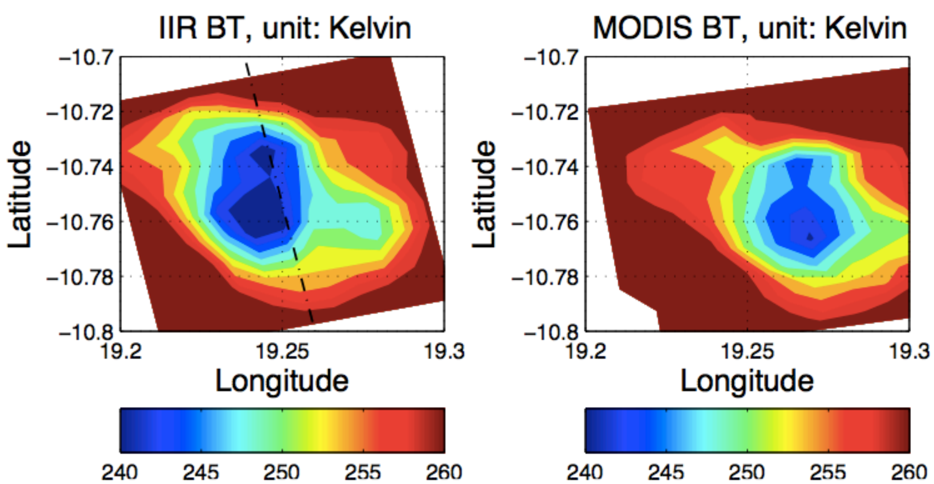
A-Train data provide important info for inferring convective dynamics near cloud top



Cloud-top w

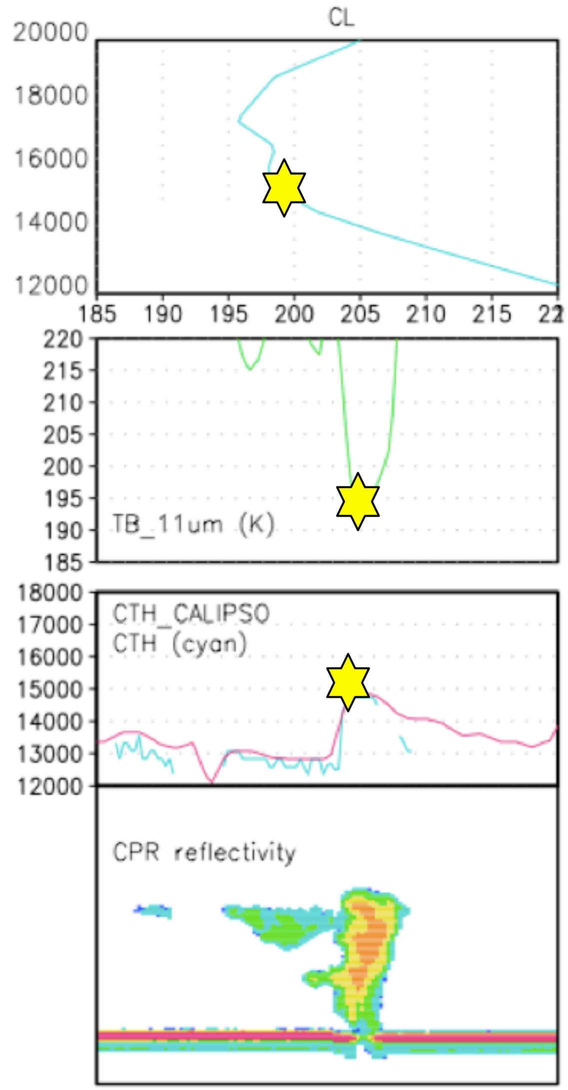
$$w = \left(\frac{\partial T}{\partial z}\right)^{-1} \boxed{\frac{dT_{BB}}{dt}}$$

← ~ 2 min →



Luo et al. (2014)

A-Train data provide important info for inferring convective dynamics near cloud top



Cloud-top buoyancy

$$B = g\frac{T_{parcel} - T_{env}}{T_{env}}$$

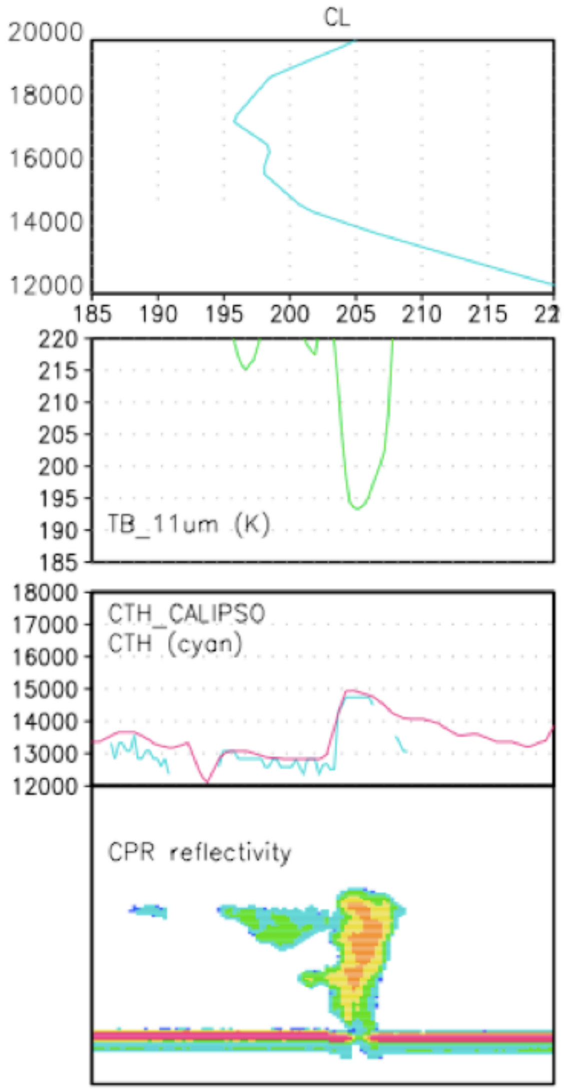
T_{parcel} = 193 K;

T_{env} = 198 K (b/c CTH = 15km)

Negatively buoyant!

Luo et al. (2010); Wang et al. (2014)

A-Train data provide important info for inferring convective dynamics near cloud top



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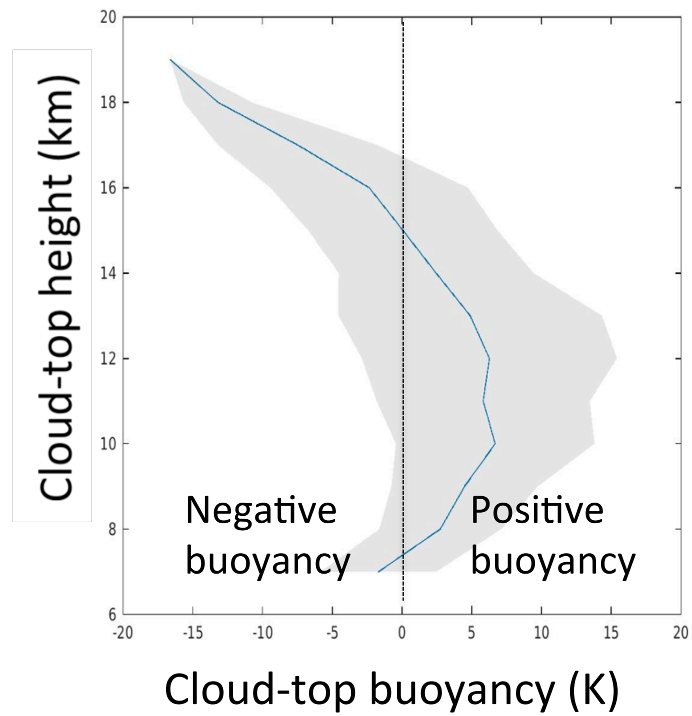


Luo et al. (2010); Wang et al. (2014)

A single-column plume model

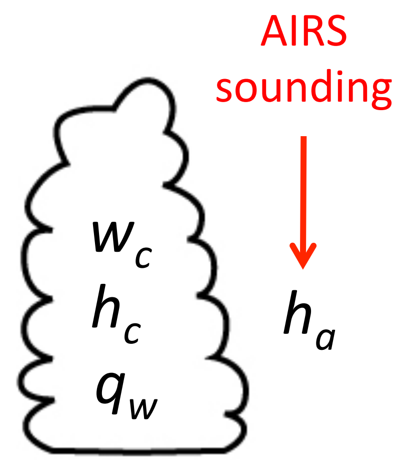
- Basic equations

Basic equations

$$\frac{1}{2}\frac{\partial w_c^2}{\partial z} = a_B B - \epsilon w_c^2 - c_D w_c^2,$$

$$\frac{\partial (h_c - L_i q_i)}{\partial z} = -\epsilon (h_c - L_i q_i - h_a),$$

$$\frac{\partial q_w}{\partial z} = -\epsilon q_w + \frac{1}{w_c}(\dot{q}_{\mathrm{cond}} - \dot{q}_{\mathrm{auto}}),$$

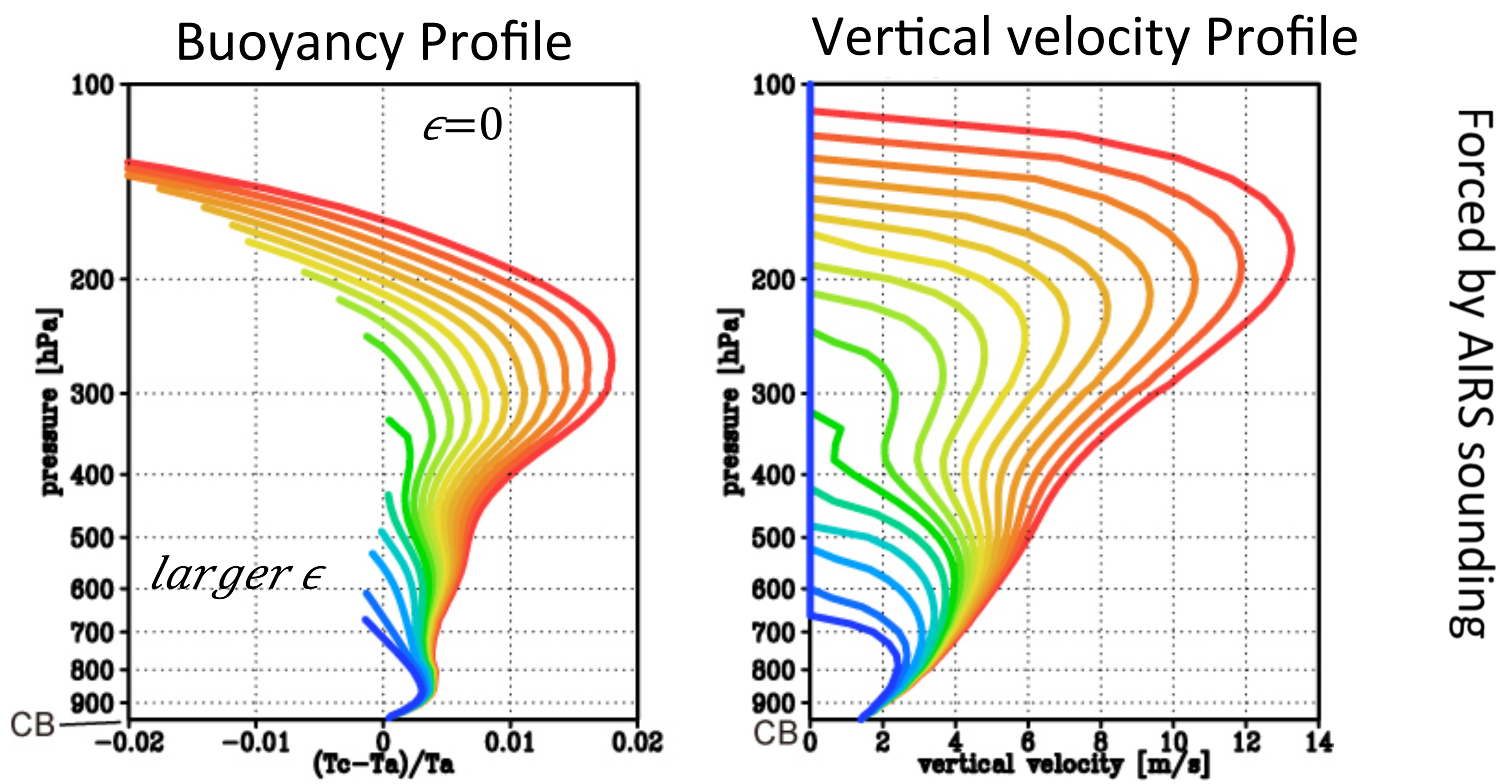


As far as w_c is concerned, the most important parameter is the entrainment rate (ε).

Masunaga and Luo (2016)

Simulated buoyancy (ΔT/T) and w_c *profiles* under different ε

ε: 0 – 0.4/km (red to blue)

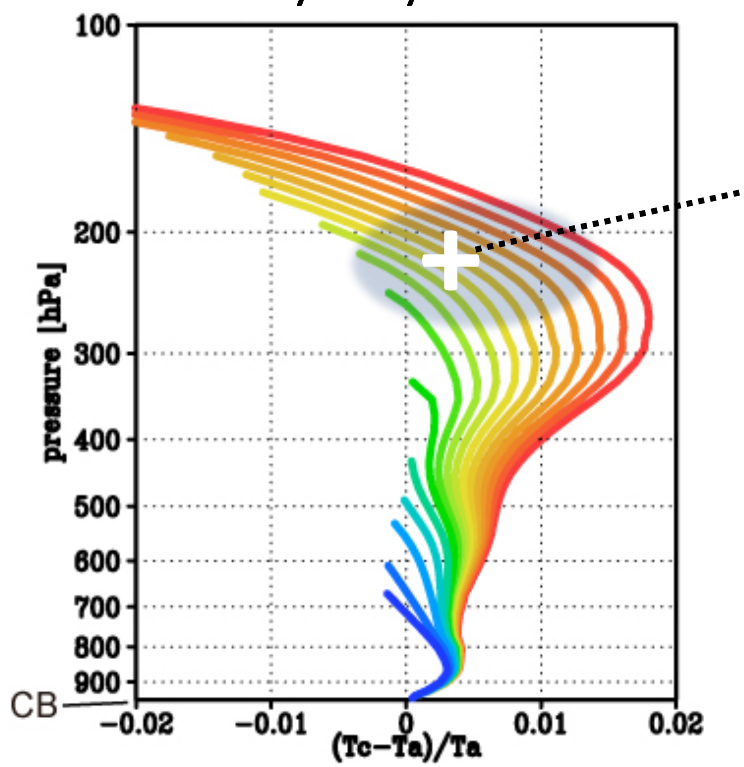


Masunaga and Luo (2016)

Observations (cloud-top buoyancy and w_c) are used to constrain different possibilities

$$\hat{w}_c(z) \equiv \sum_i p(\epsilon_{\mathrm{tur},i}|z_T, \Delta T_T) w_{c,i}(z) = \sum_i p(\epsilon_{\mathrm{tur},i}) p(z_T, \Delta T_T|\epsilon_{\mathrm{tur},i}) w_{c,i}(z),$$

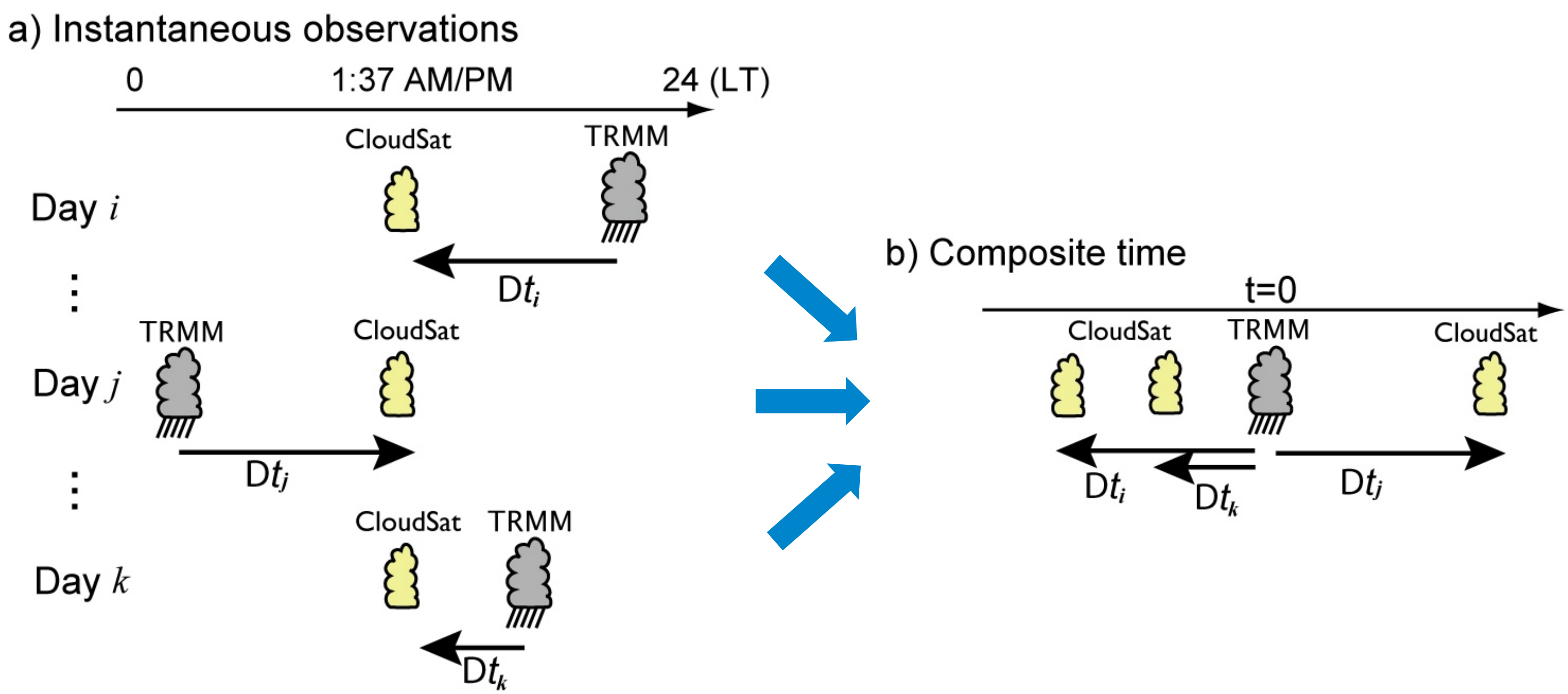
Buoyancy Profile



Hundreds of thousands of observed data points are used to weigh these different profiles.

Masunaga and Luo (2016)

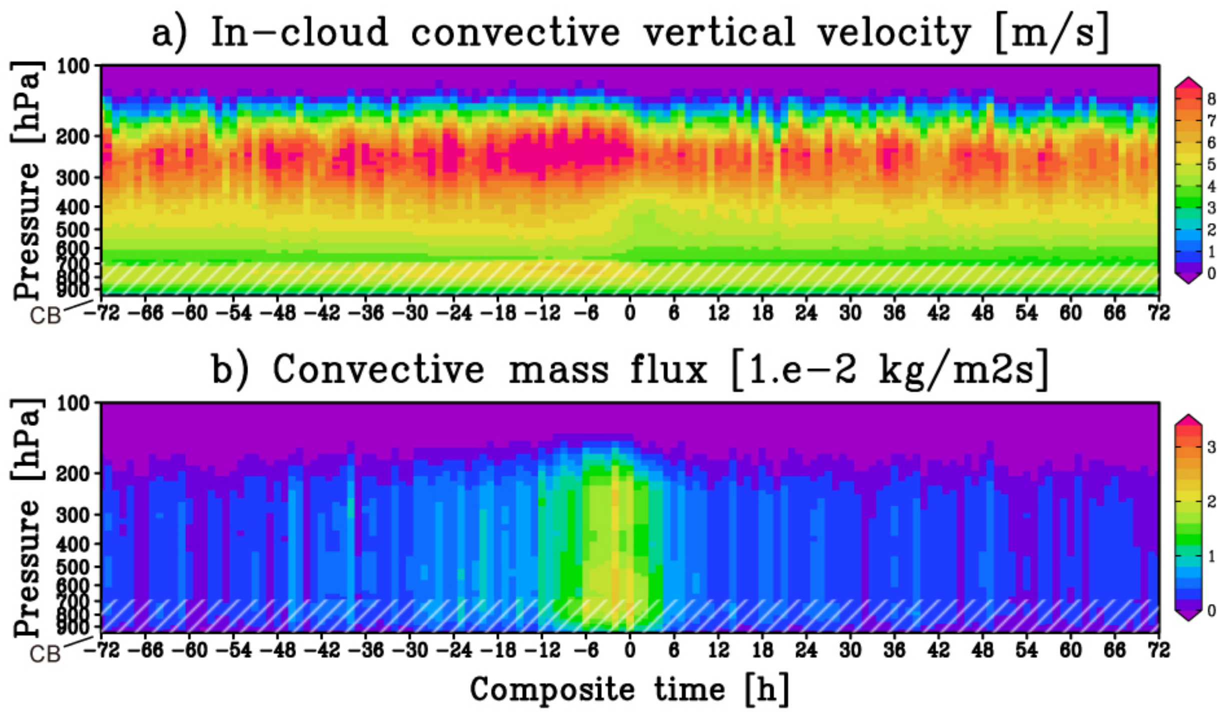
Composite Observations w.r.t. Convective Life Stages



Masunaga (2012);
Masunaga and Luo (2016)

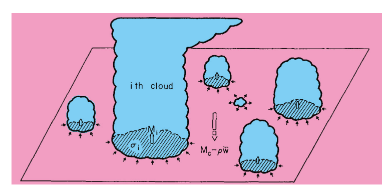
W_c relatively invariant over time

M_c follows convective life cycle, controlled by convective coverage



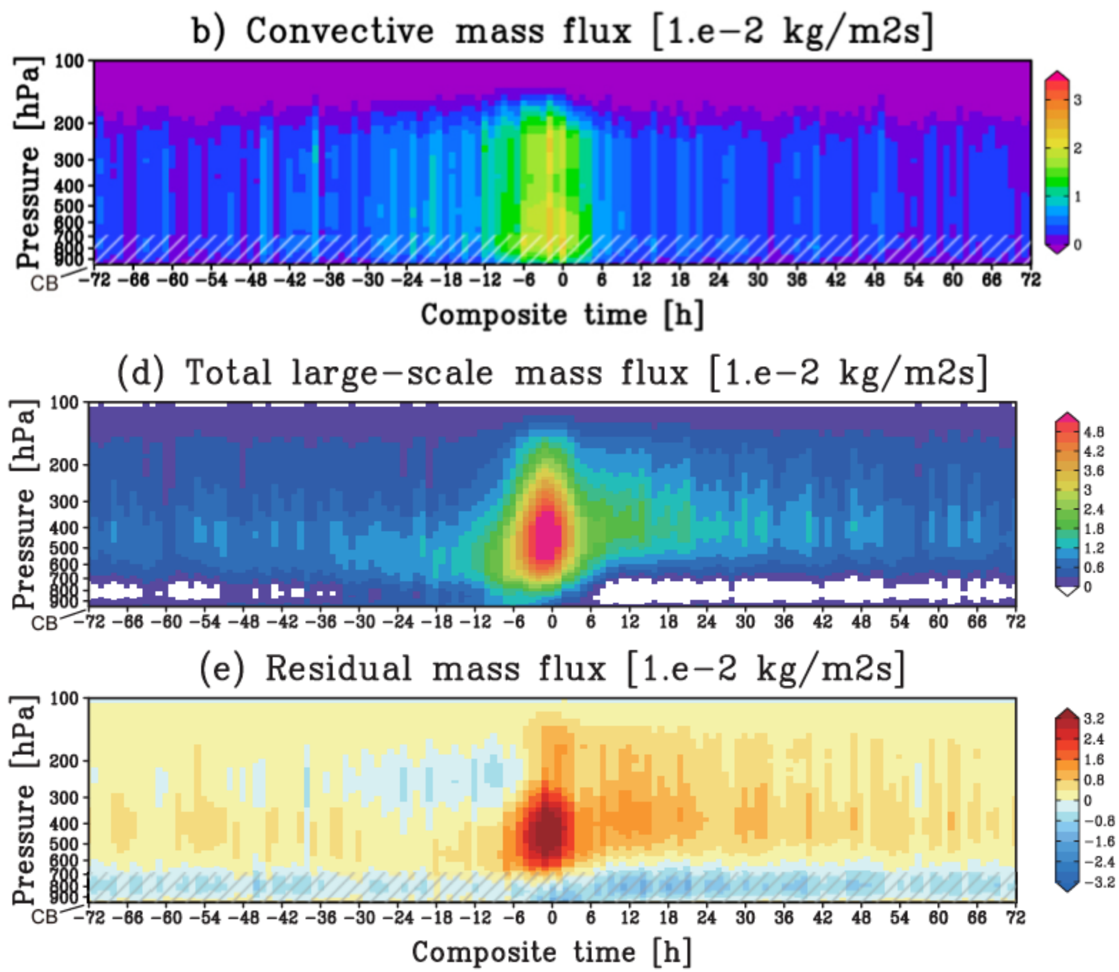
Masunaga and Luo (2016)

$$M_c = \sigma W_c$$



$$\overline{M} = M_c + M_R + M_*$$

, where $\overline{M_R}\frac{\partial \overline{s_a}}{\partial p} = \frac{\overline{Q_R}}{g}$



M_c

$\overline{M}$

M_*

Masunaga and Luo (2016)

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1. Motivation
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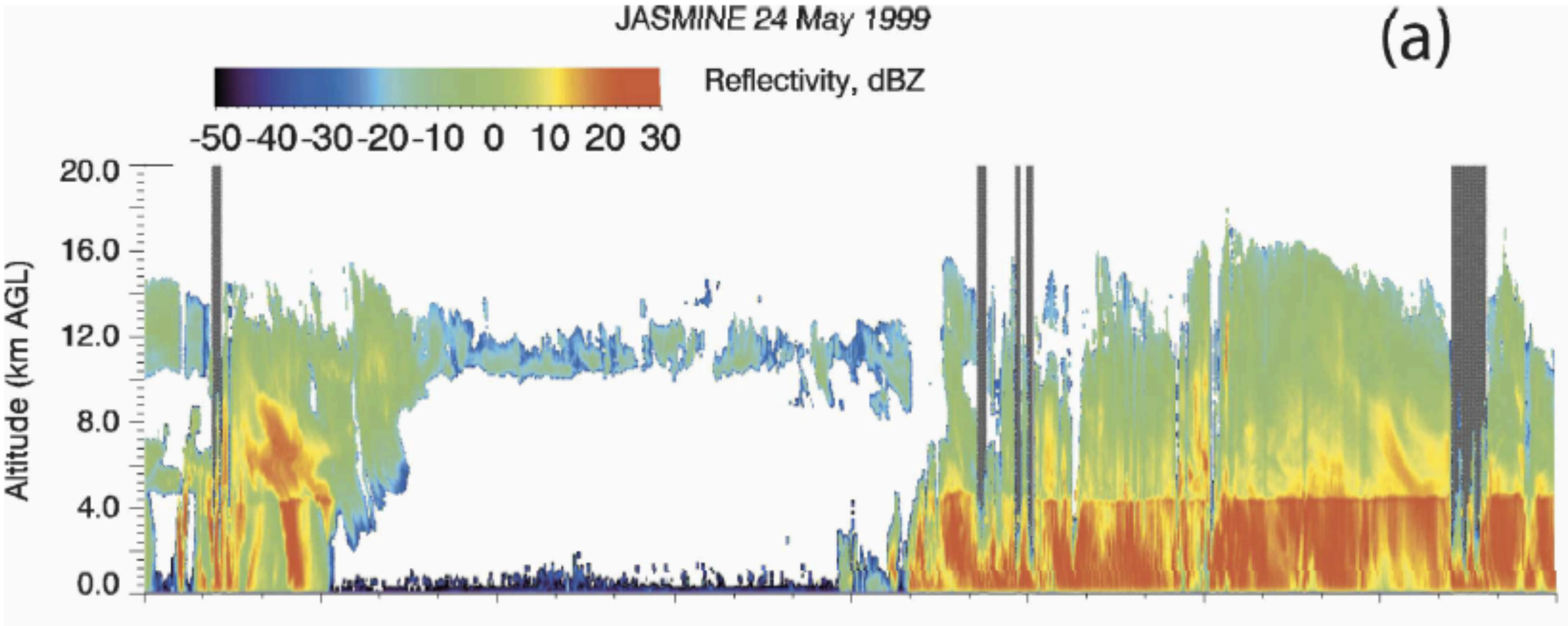
Summary

- CloudSat/CALIPSO add new insights into pentrative deep convection processes
    - CloudSat + MODIS reveal convective life stage
    - CALIPSO picks up irreversible stratosphere-troposphere exchange

- A-Train data (CloudSat, IIR, MODIS, AIRS), aided by a plume model, piece together the convective mass flux jigsaw puzzle
    - A-Train enables new observations that have bearings on convective dynamics (e.g., buoyancy, vertical velocity)
    - A plume model can assimilate such info and generate convective mass flux estimates

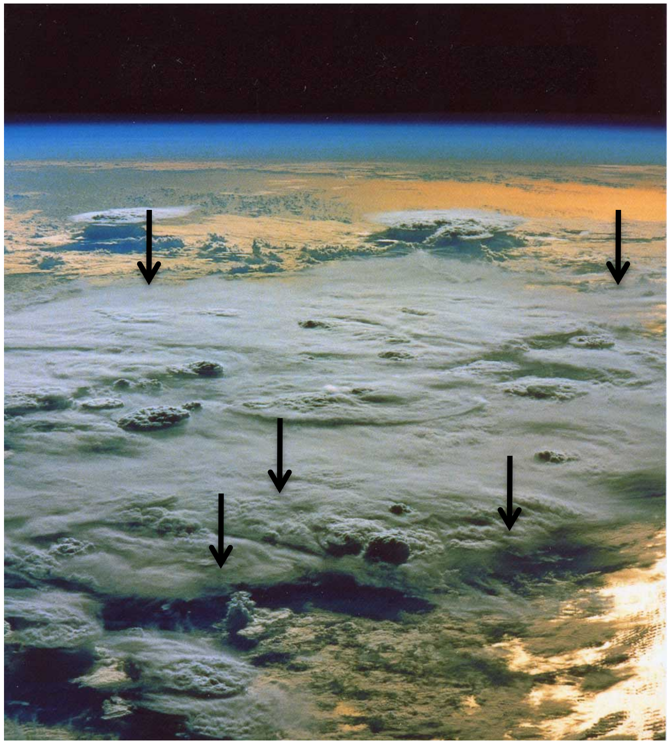
Ground-based Ka band radar (34 GHz). Gray shading marks up attenuation



Stephens and Wood (2007)

<u>A prejudice against CloudSat-CALIPSO (10 yrs ago)</u>: W-band radar and lidar are for fluzzy clouds and aerosol; they are not serious players in studying convection.

The top-down views of CloudSat/CALIPSO nicely get around the difficulty



Congratulations,
CALIPSO and CloudSat!