Environmental controls on the lifecycle of tropical mesoscale convective systems

Kathleen A. Schiro[1], Piyush Garg[1], Everest Litchford[1,2], and James Russell[3]

[1]University of Virginia

[2]Cornell University

[3]University of Utah

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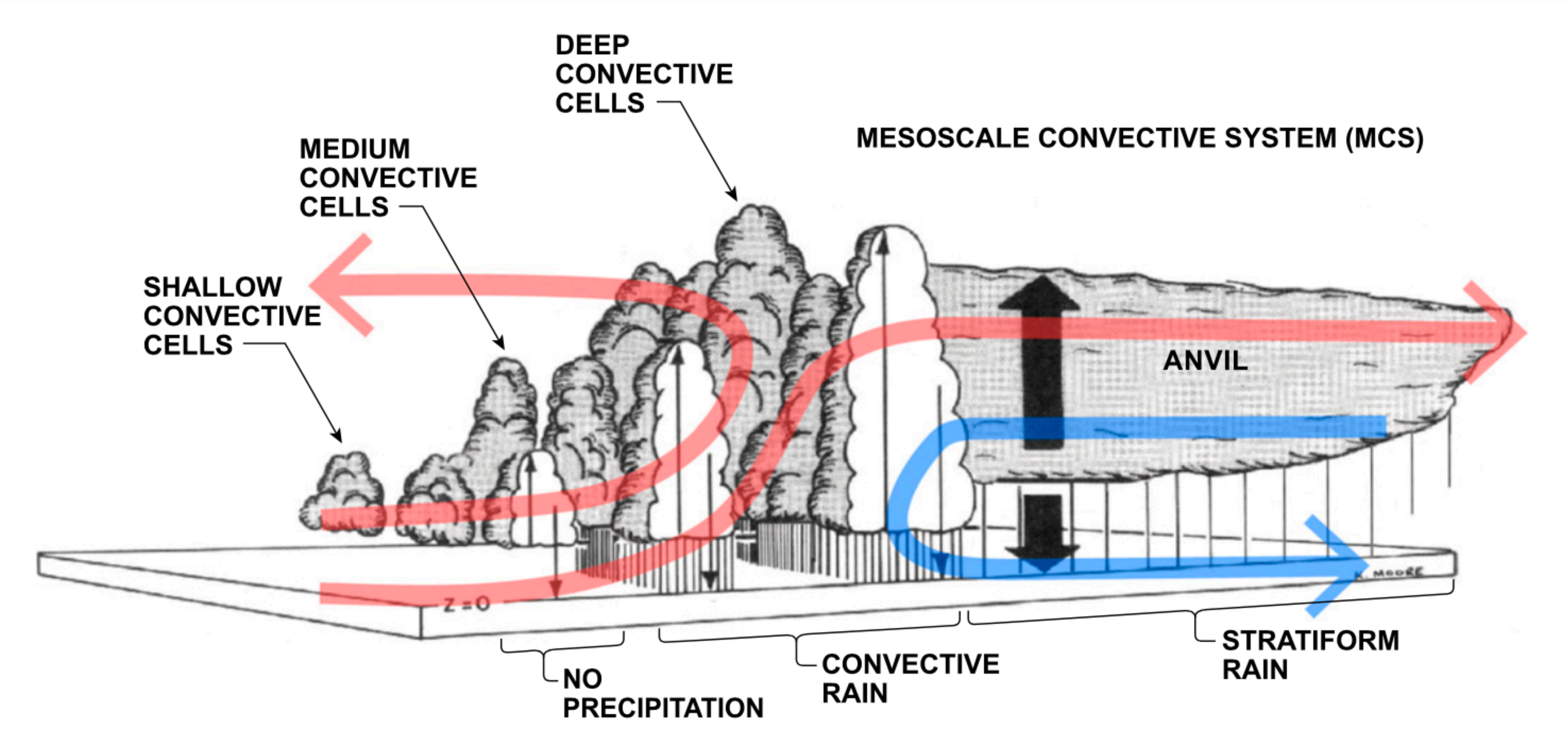
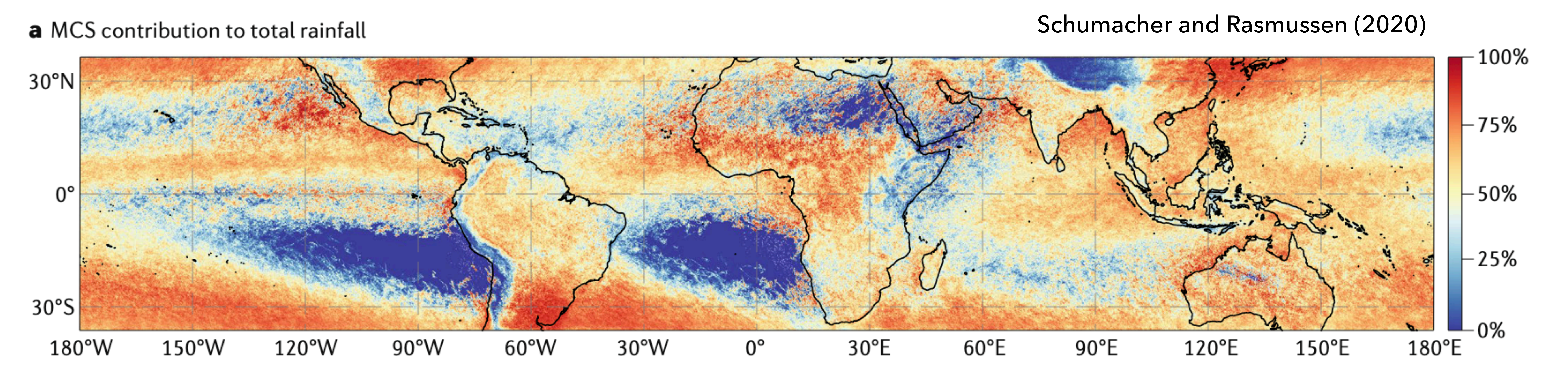
What do we know about tropical MCSs?



Houze (2018)

What do we know about tropical MCSs?

A significant fraction of precipitation in the tropics is contributed by MCSs, with some notable regional dependences.



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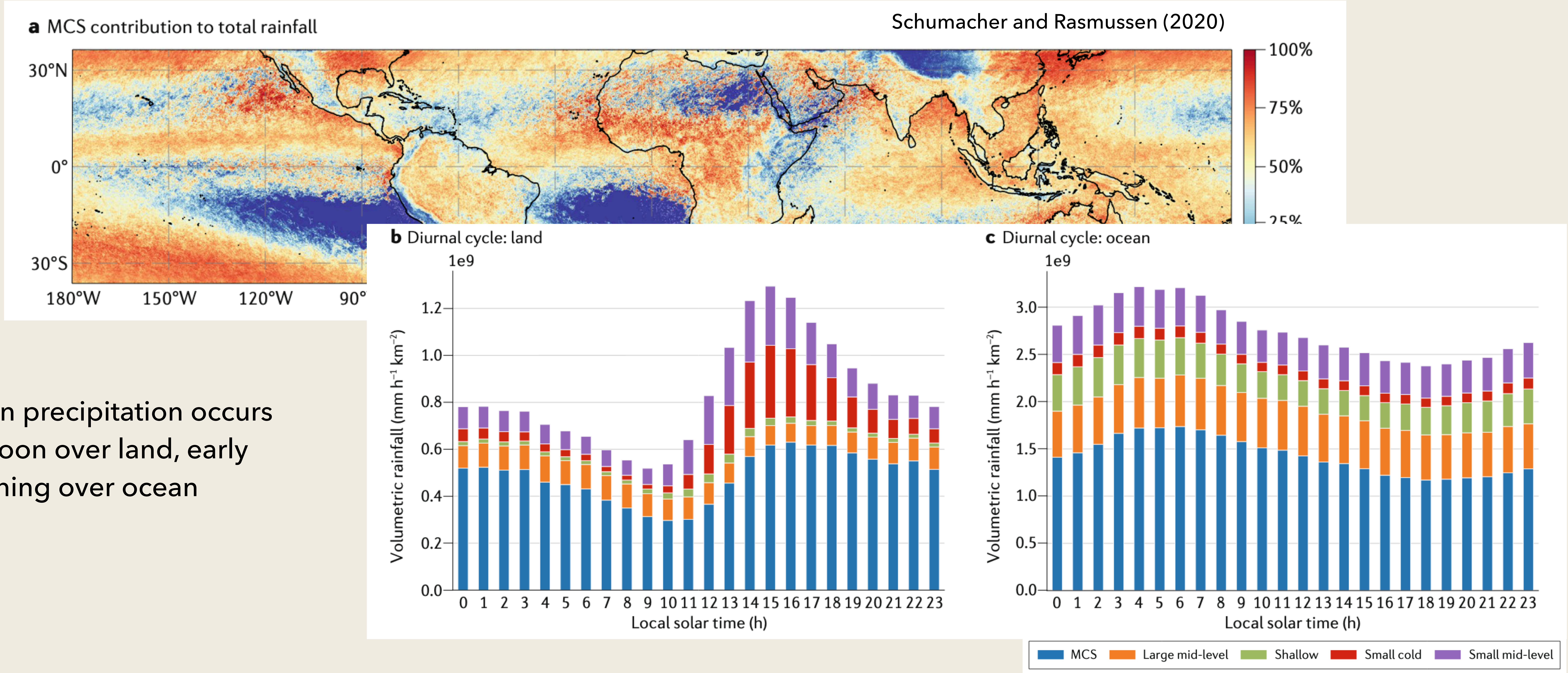
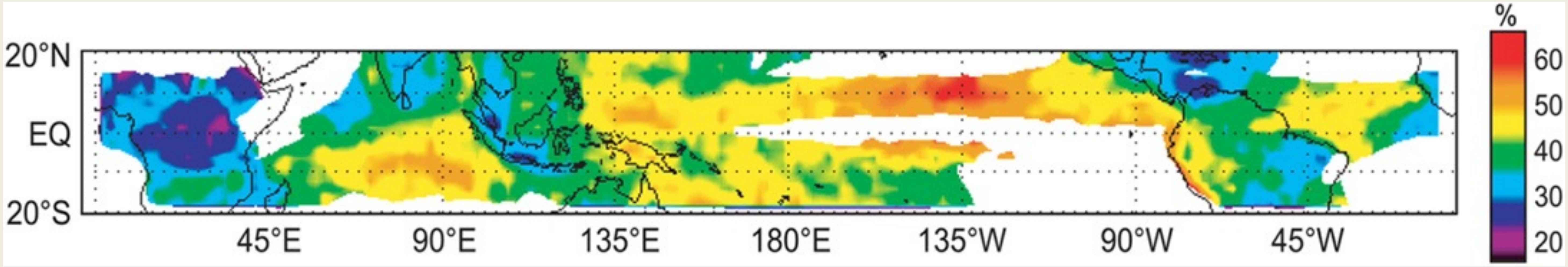


The peak in precipitation occurs in afternoon over land, early morning over ocean

What do we know about tropical MCSs?

Greater stratiform rain areas over ocean than over land.



Stratiform Area Fraction (Schumacher and Houze 2003)

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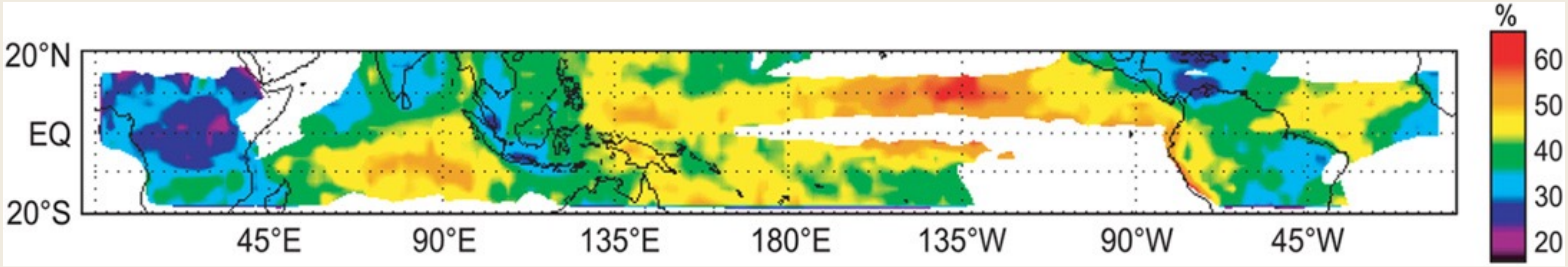
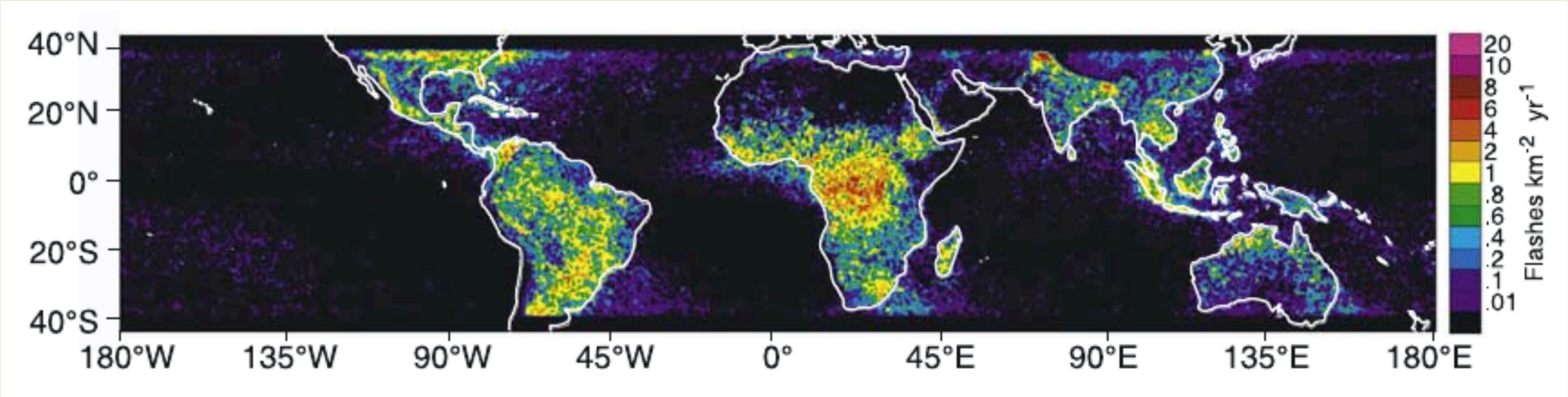


Stratiform Area Fraction (Schumacher and Houze 2003)

Higher flash rates over land than ocean (indicative of more intense updrafts).



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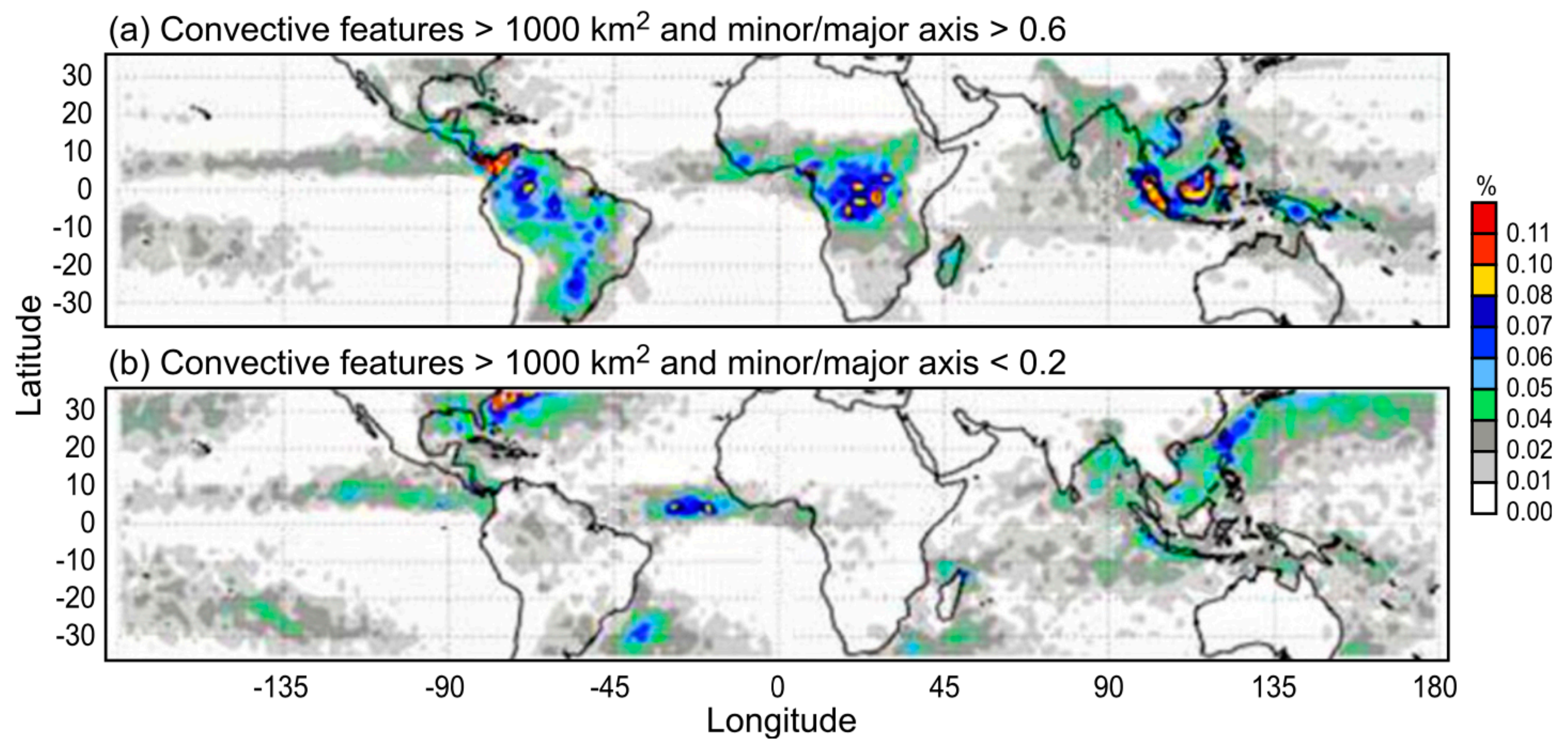
More circular MCSs over land than ocean.



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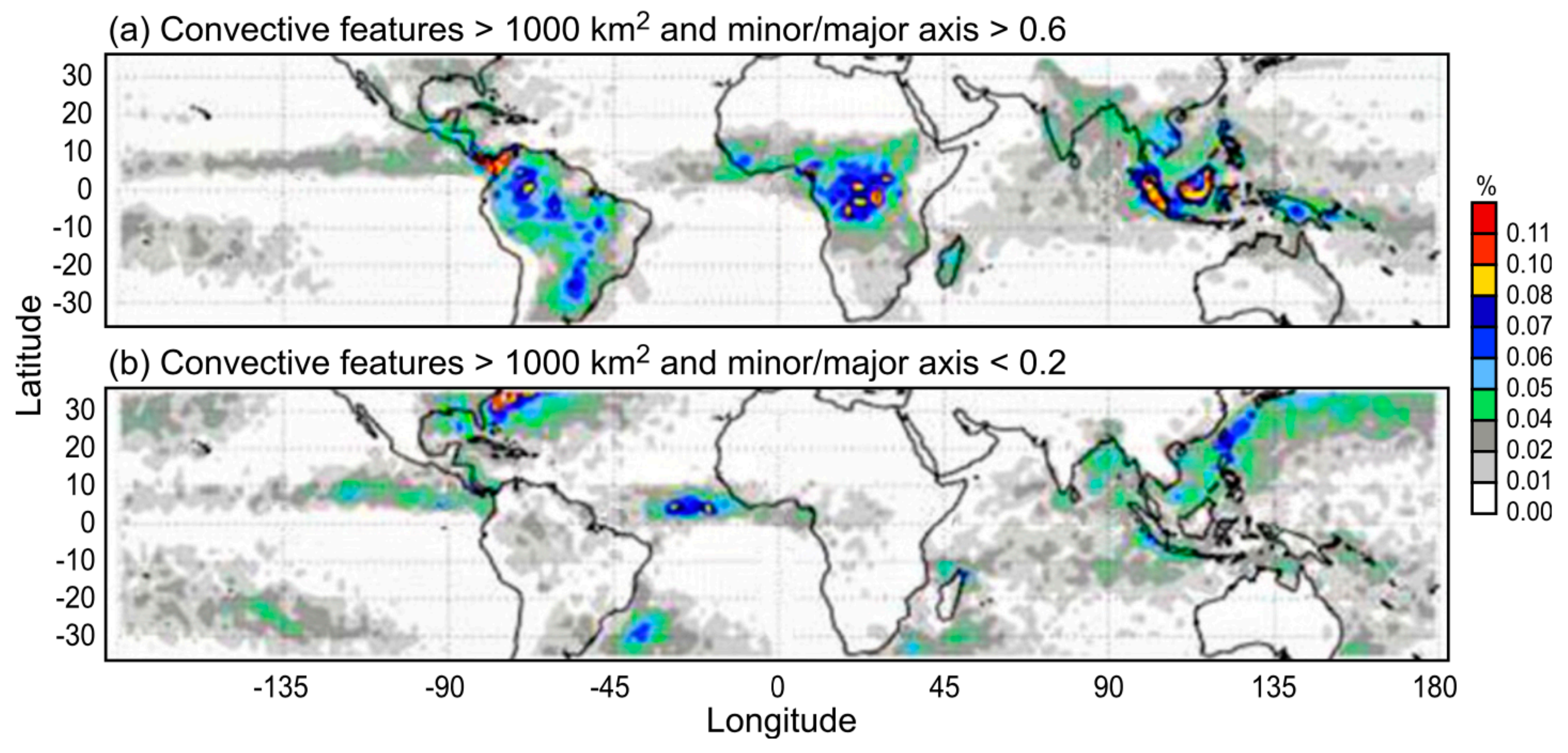

How are we going to parameterize MCSs in GCMs if there are large differences in MCS characteristics between continental and oceanic regions?

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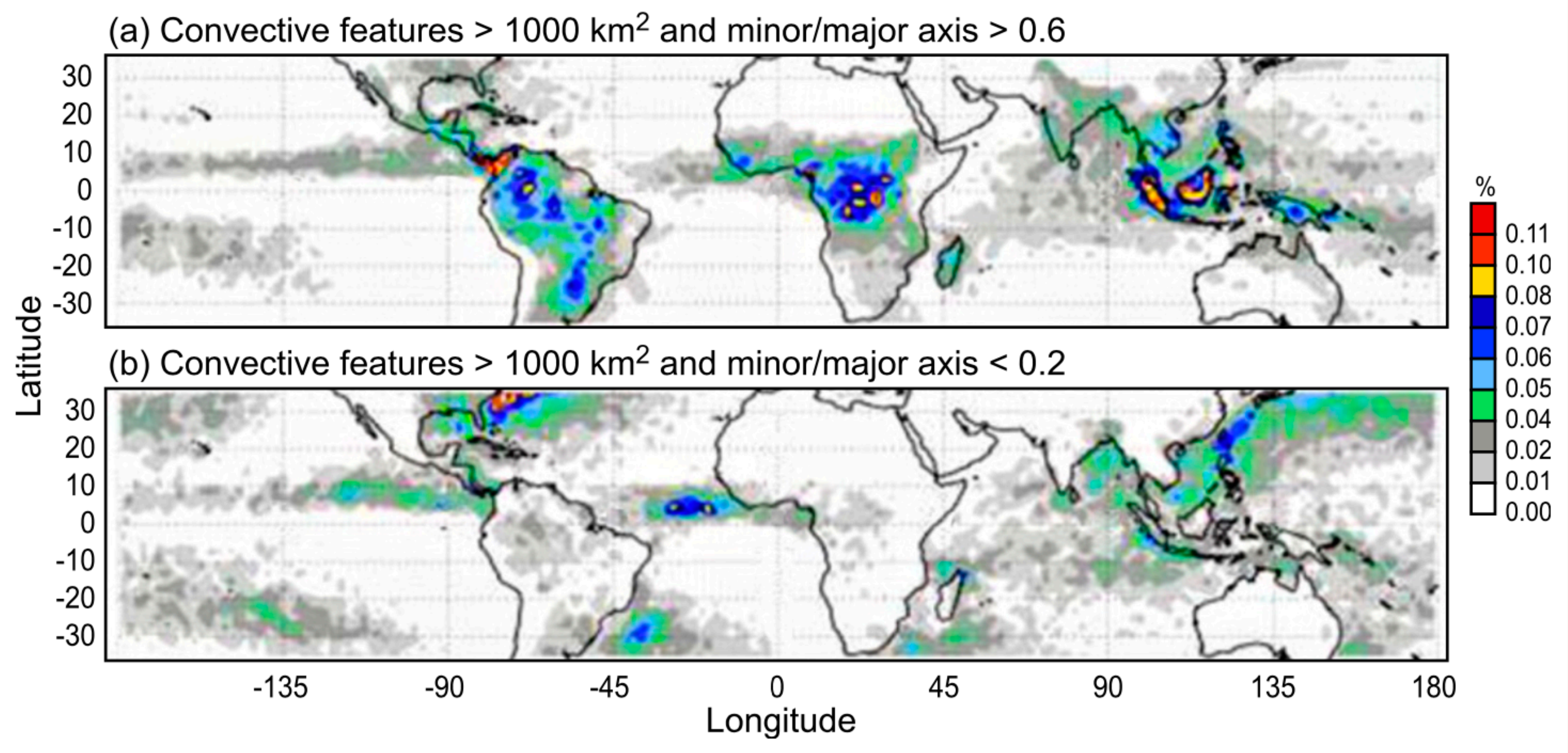
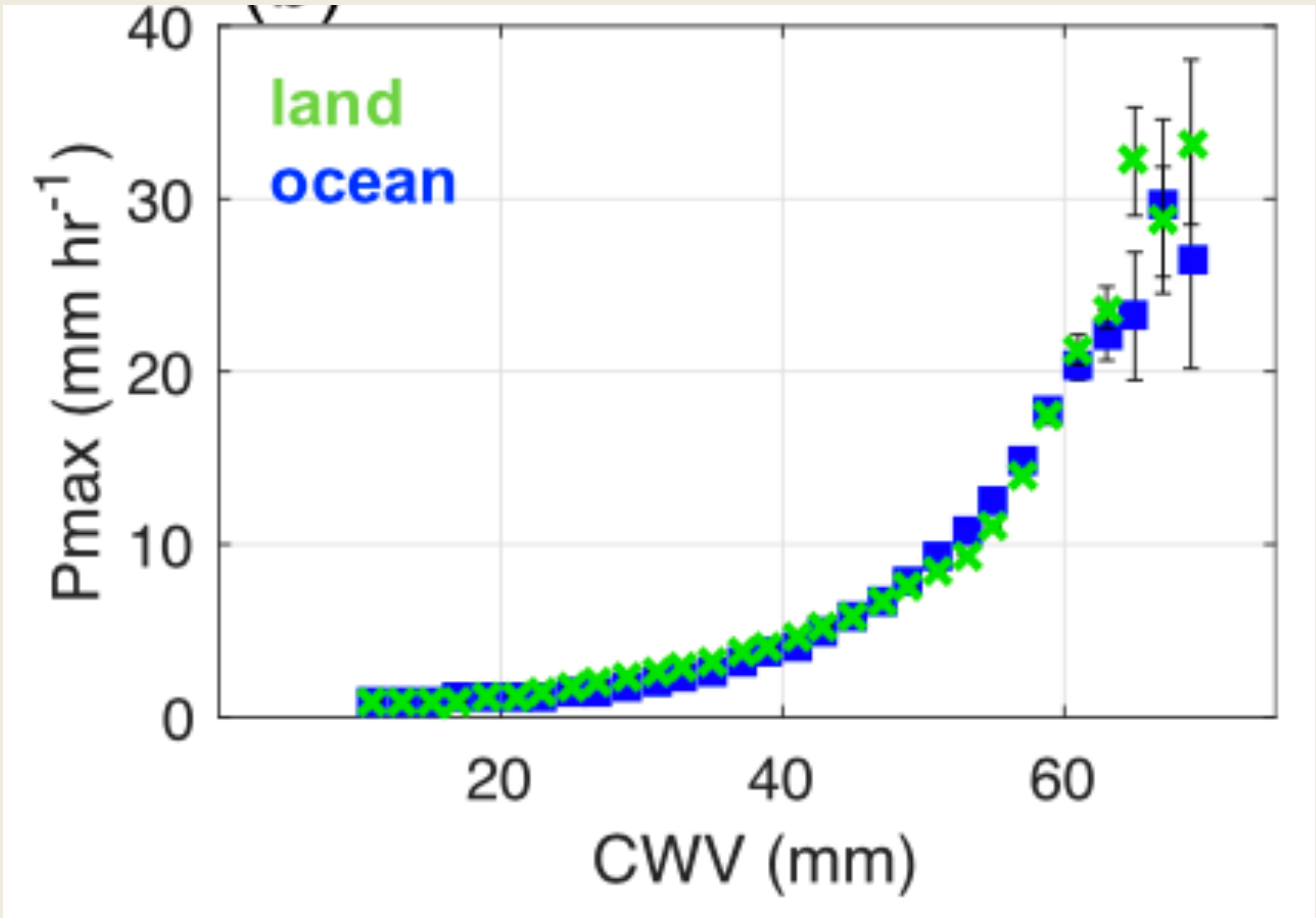


How are we going to parameterize MCSs in GCMs if there are large differences in MCS characteristics between continental and oceanic regions?

Is there anything similar about the way they interact with their thermodynamic environments?

For the same amount of moisture, continental and oceanic MCS rain rates are similar.

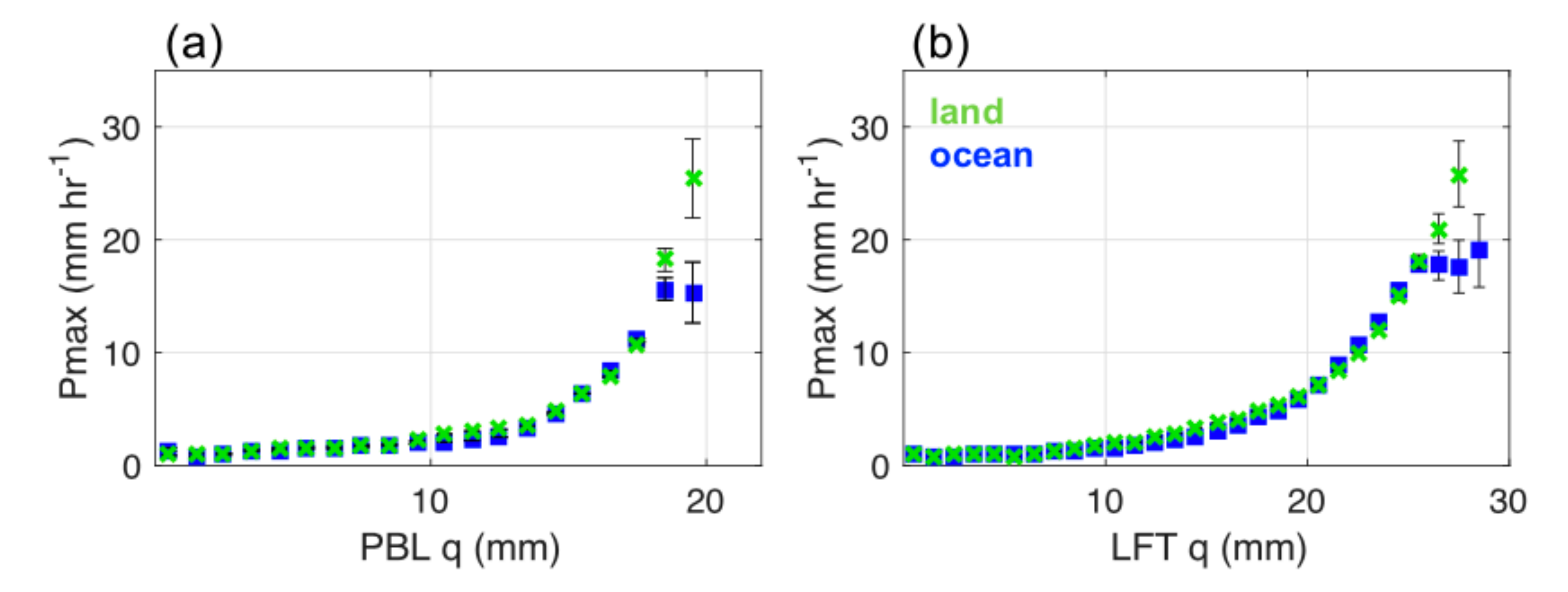


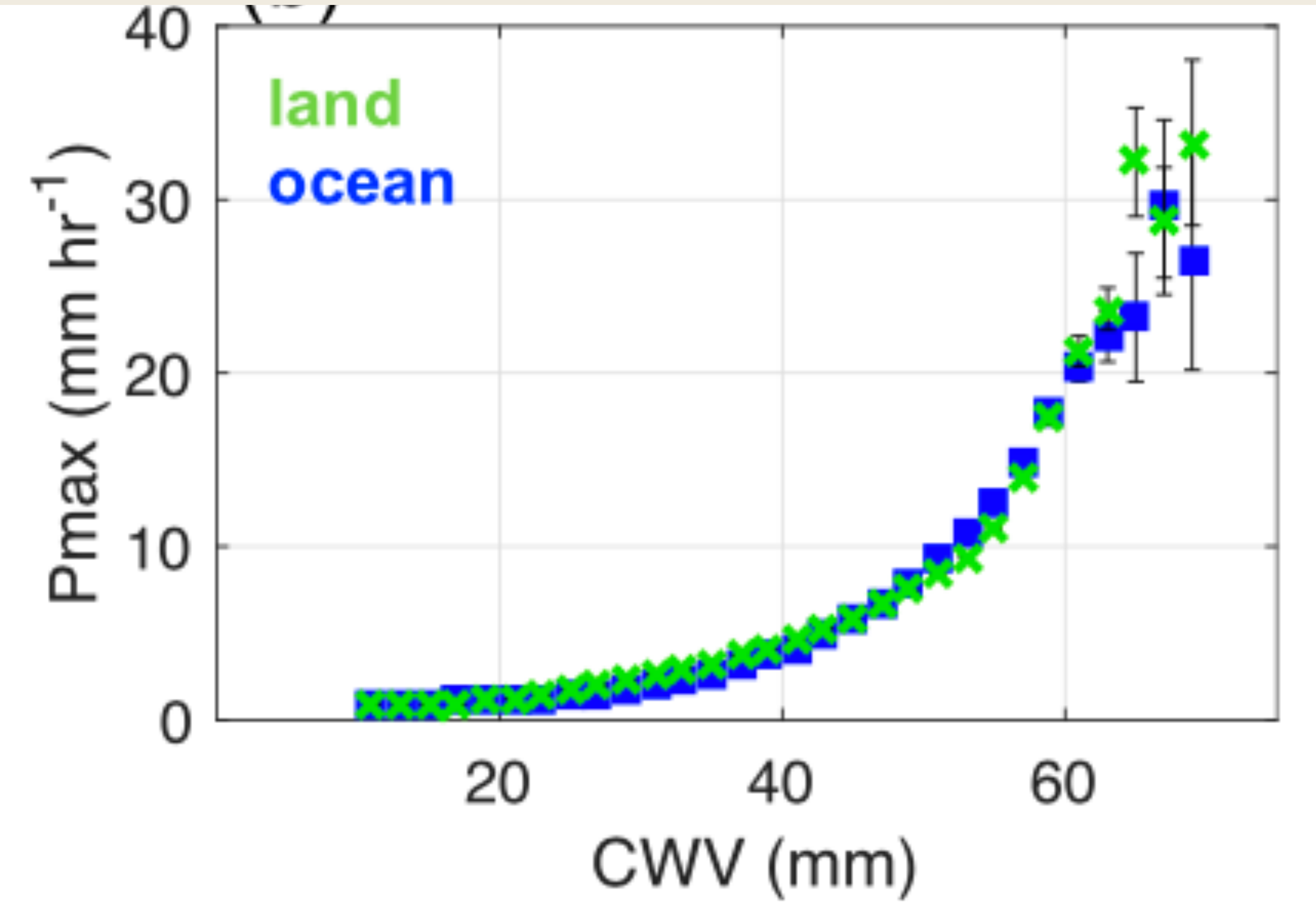
Data: ISCCP Convective Tracking and MSWEP Precipitation (1983-2008)

Schiro et al. (2020)

For the same amount of moisture, continental and oceanic MCS rain rates are similar.

Strong dependence of precipitation intensity on boundary layer and lower free tropospheric moisture.





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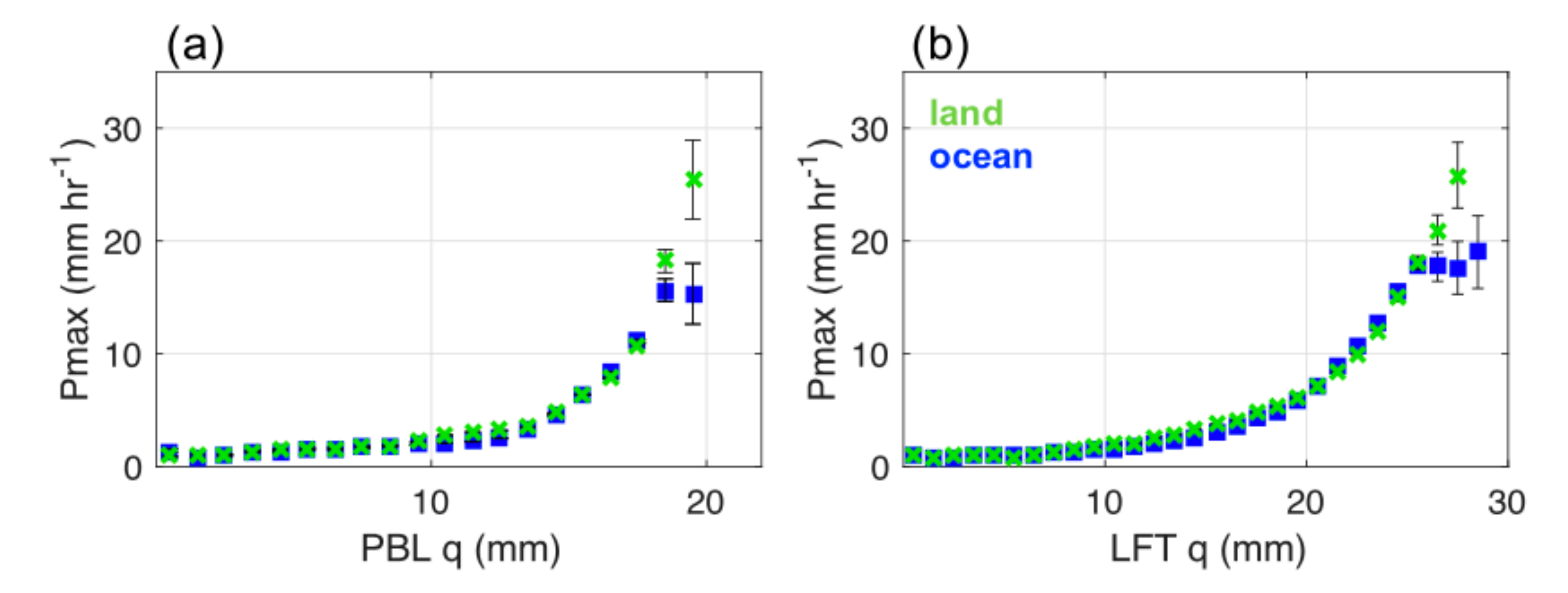

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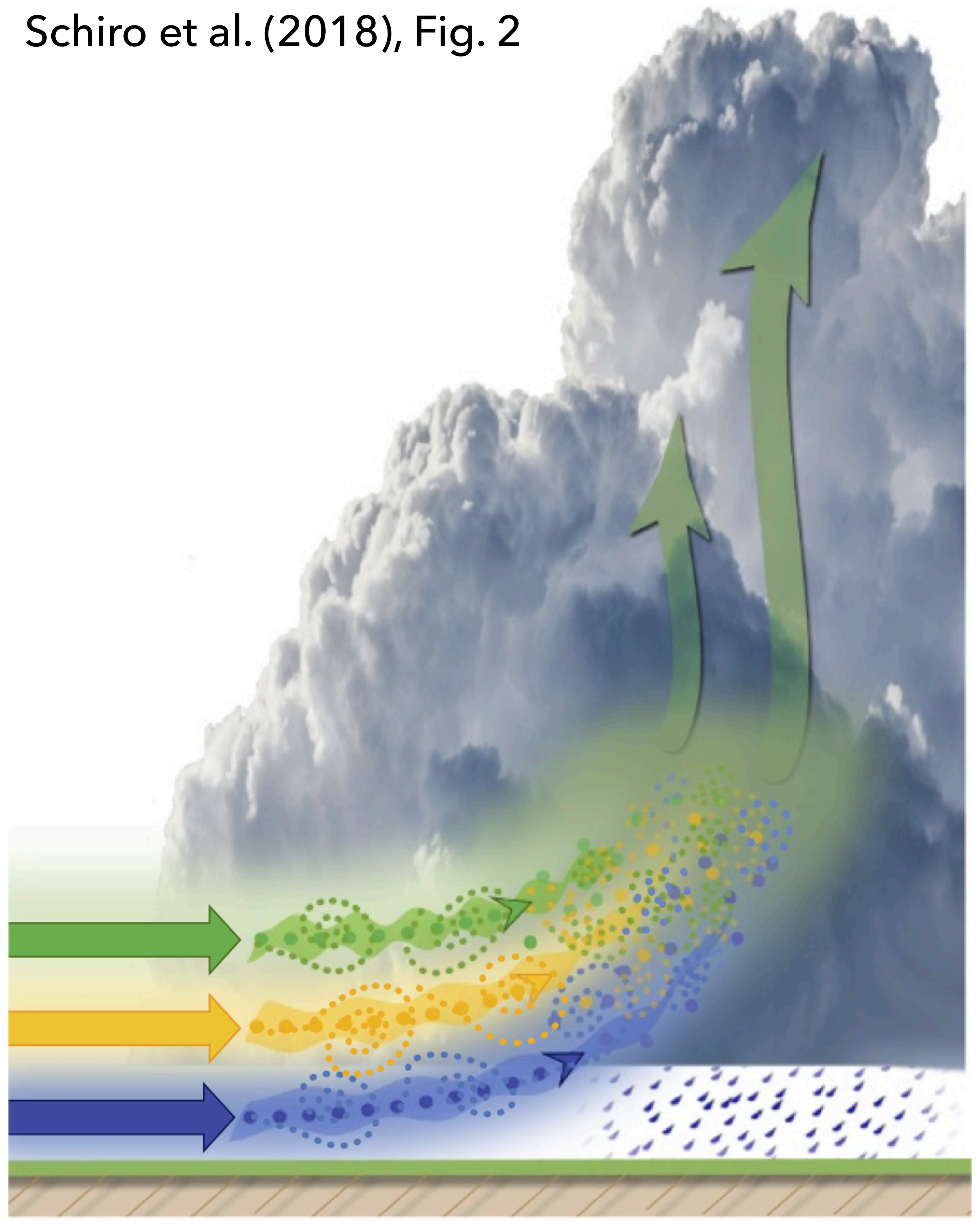
Schiro et al. (2018), Fig. 2



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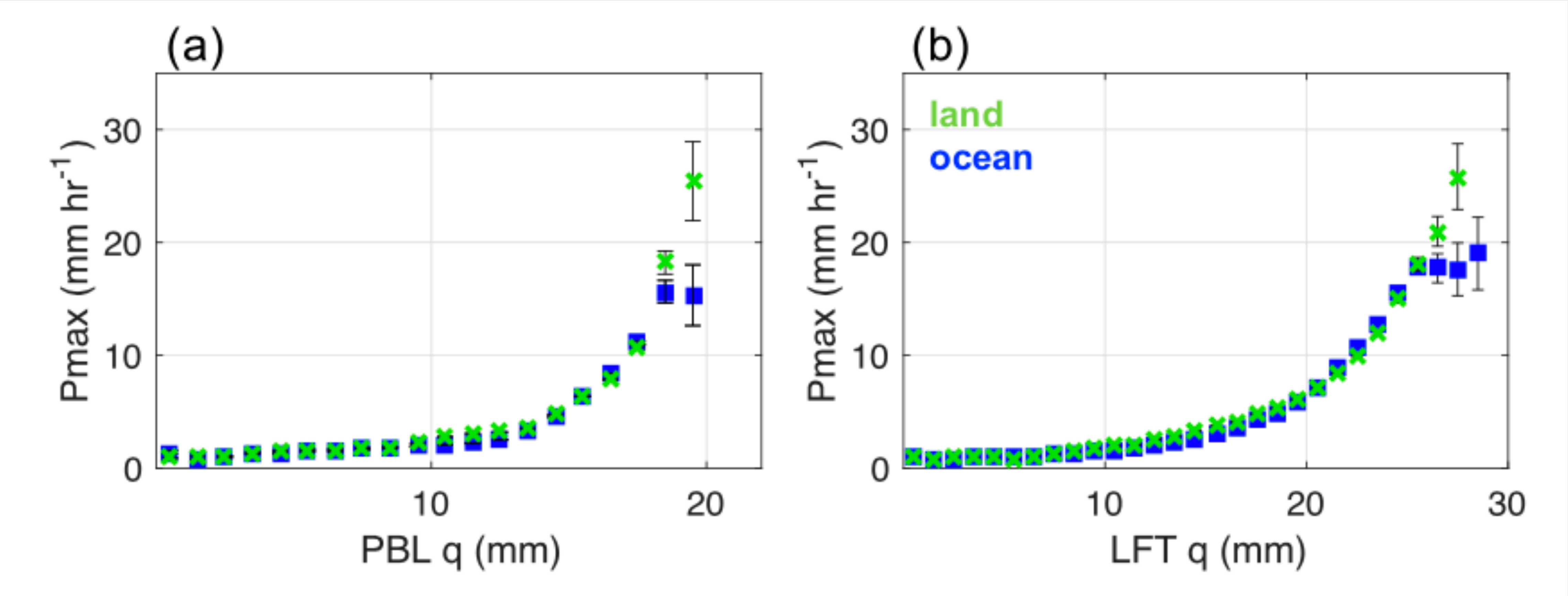

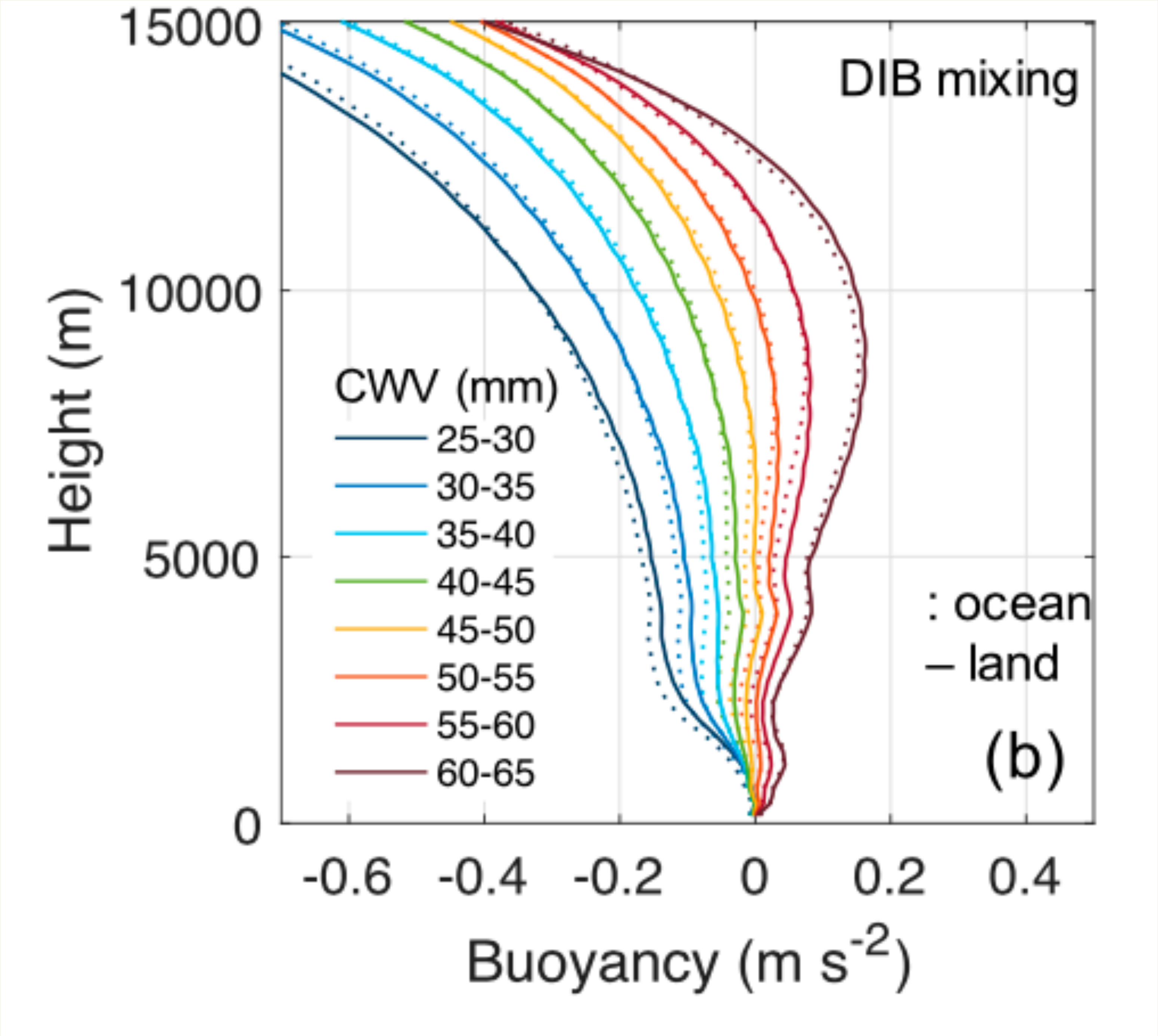

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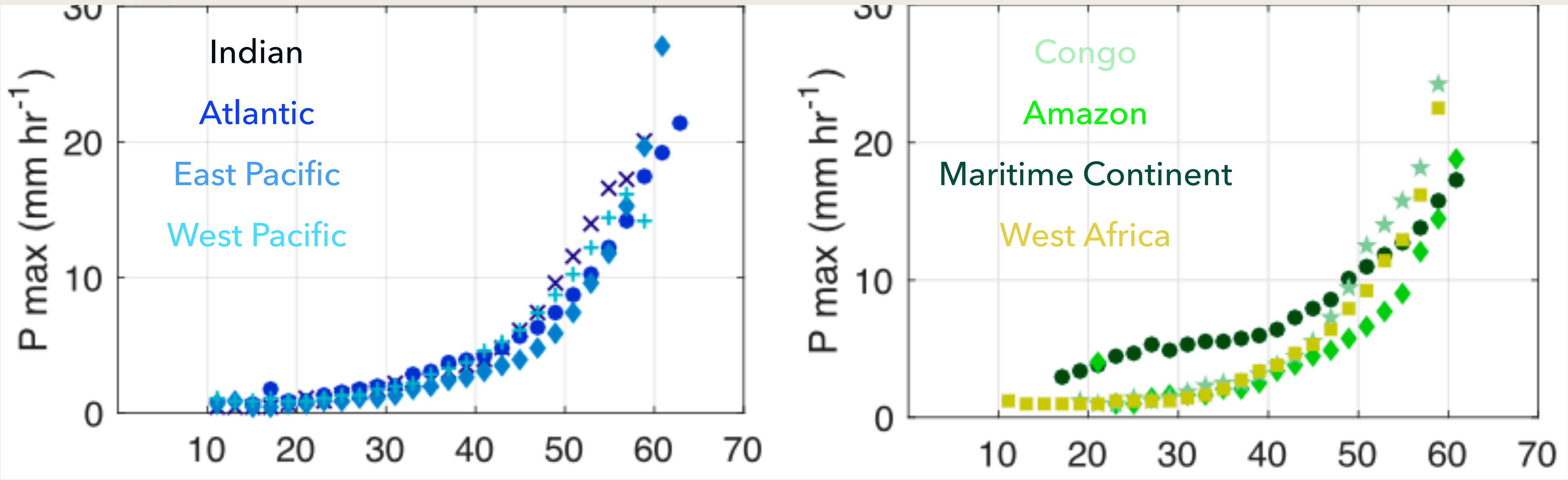
Subtle regional differences in moisture-precipitation relationship, which likely relates to differences in buoyancy.



Column Water Vapor (mm)

Data: ISCCP Convective Tracking and MSWEP Precipitation (1983-2008)

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GOAL: Refining a buoyancy framework for prediction of MCS precipitation intensity

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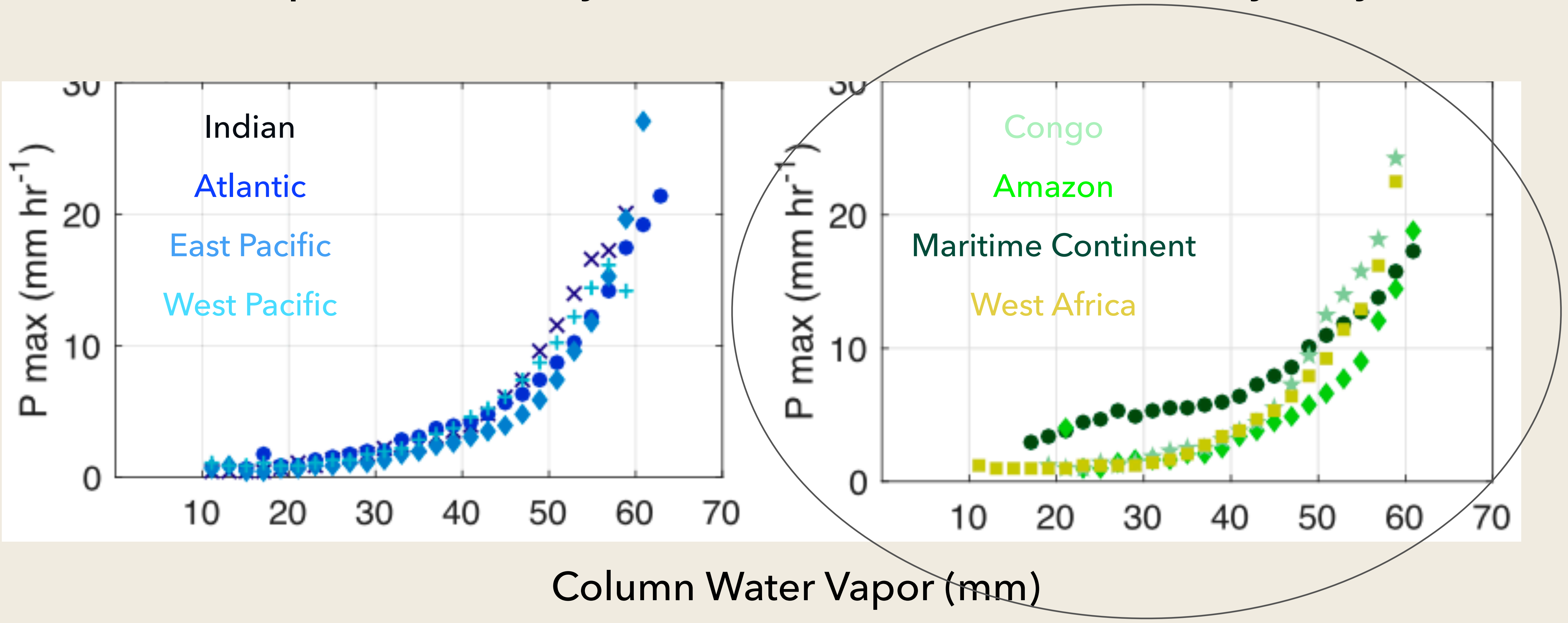

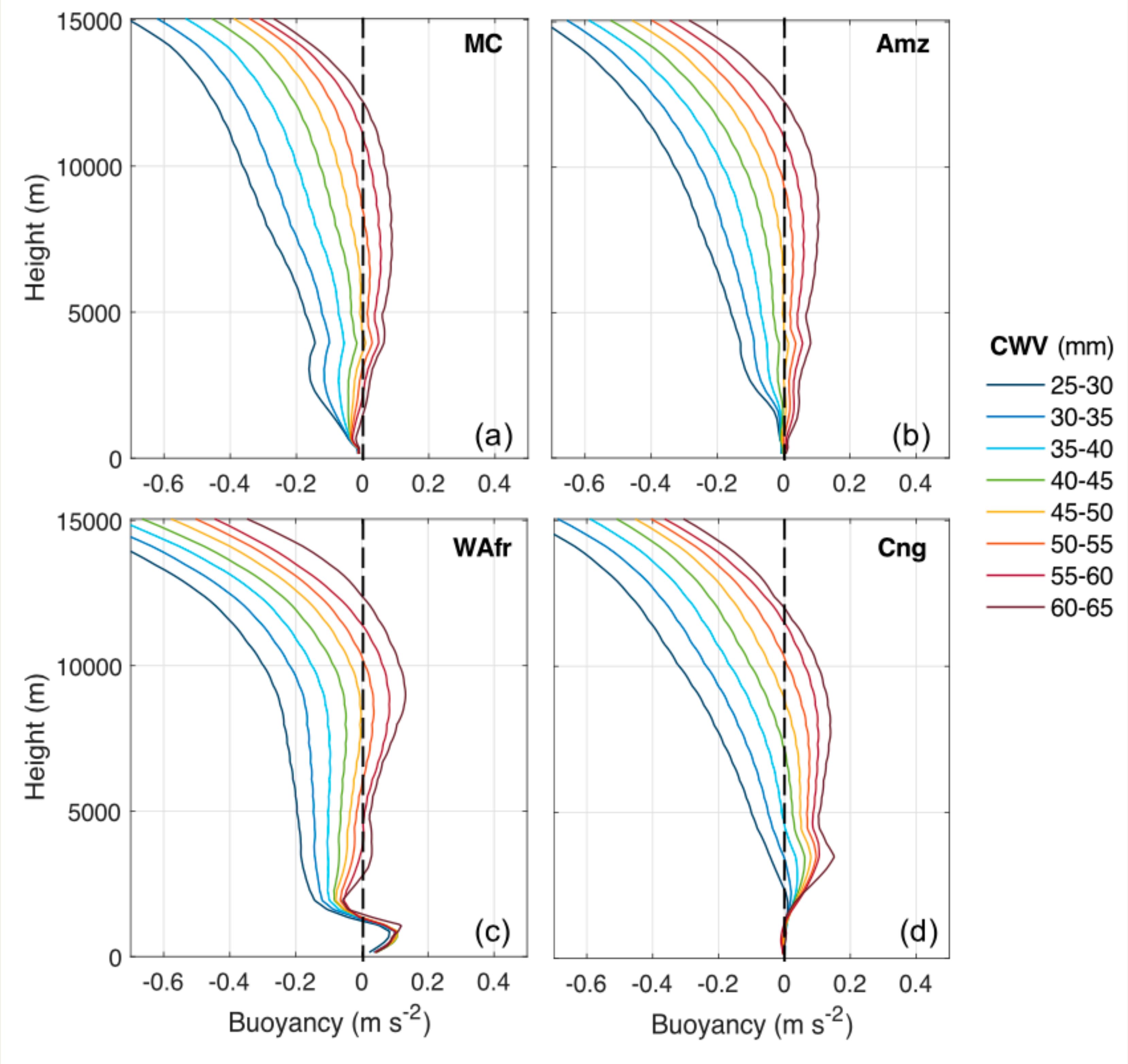

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Summertime convection, Charlottesville, VA, USA

Windsond (Sparv Embedded)

GRAW Sonde

Undergraduate Students: Rebecca Hall (UVA), Everest Litchford (Cornell U)

Preliminary Results Mini Field Campaign

Summer 2021 | Charlottesville, VA

Summary - Part 1

MCS precipitation intensity largely determined by total column moisture in all regions - continental and oceanic - despite many known land-ocean differences in MCS characteristics.

Buoyancy-based framework relating variability in the thermodynamic environment to precipitation variability seems promising, even for organized convection

*How applicable would such a framework be in regions like the southeast US?

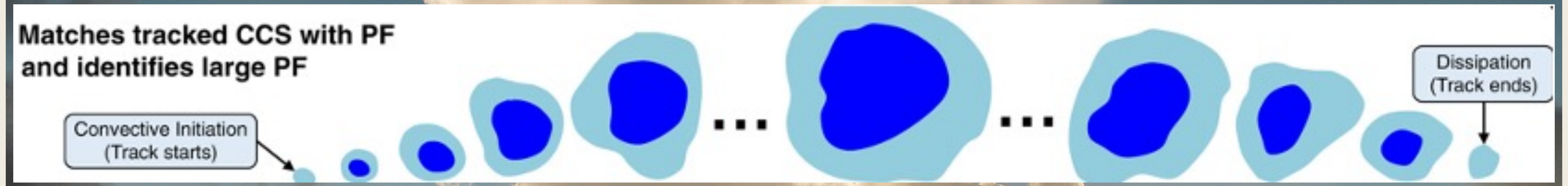

What about the convective lifecycle? How long an MCS lasts, how quickly it moves, how organized it becomes, all determine how much precipitation falls and its effect on the environment.
Growth
Credit: Matthew Rader


Source: NOAA
Maturity


Decay
Source: EUMETSAT

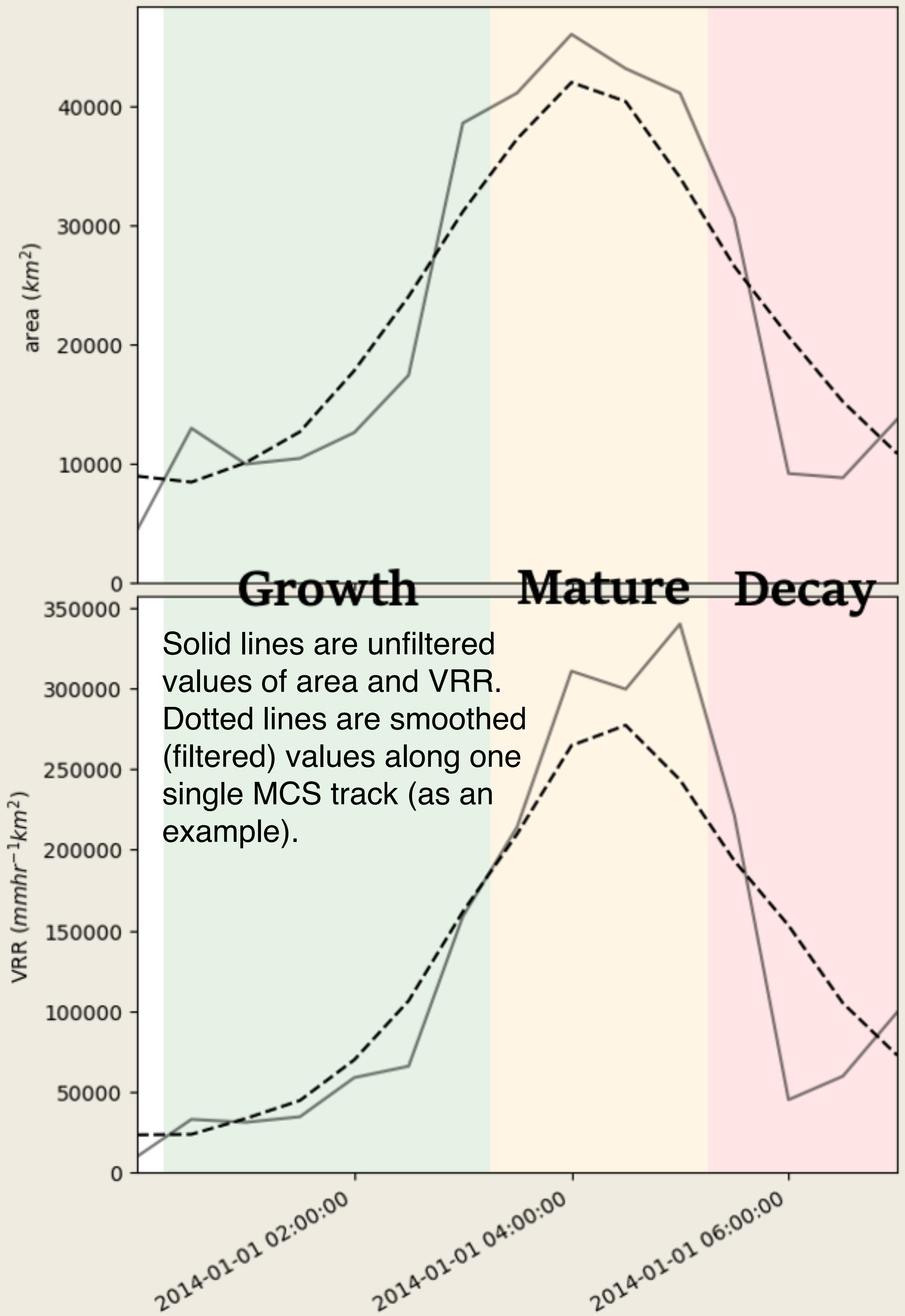
Certain characteristics of the deep convective lifecycle has been difficult to study in the tropics, in comparison to midlatitudes, due to a lack of radar data. **We have been observationally limited in studying the thermodynamic controls on the convective lifecycle everywhere.** Yet, with recently developed mesoscale tracking databases, new novel compositing are possible.

Feng et al. (2021)



Using TIMPS MCS tracking data to study convective lifecycle

- Tracked IMERG Mesoscale Precipitating Systems (TIMPS) Version 1.1
- Global tropics (30S-30N) and for 2015-2019
- Growth, mature and decay phase definitions are based on the thresholds of volumetric rain rate (VRR) and precipitation area
  - A change of more than at least 50% in both variables is used to define the gradient



The role of cold pools in the convective lifecycle

- Squall-line strength and longevity was most sensitive to the strength of the component of low-level (0–3 km AGL) ambient vertical wind shear perpendicular to squall-line orientation (Weisman et al. 1988; Rotunno, Weisman and Klemp 1988; Weisman and Rotunno 2004)
- Optimal state based on the relative strength of the circulation associated with the storm-generated cold pool and the circulation associated with the ambient shear

Weisman and Rotunno (2004)

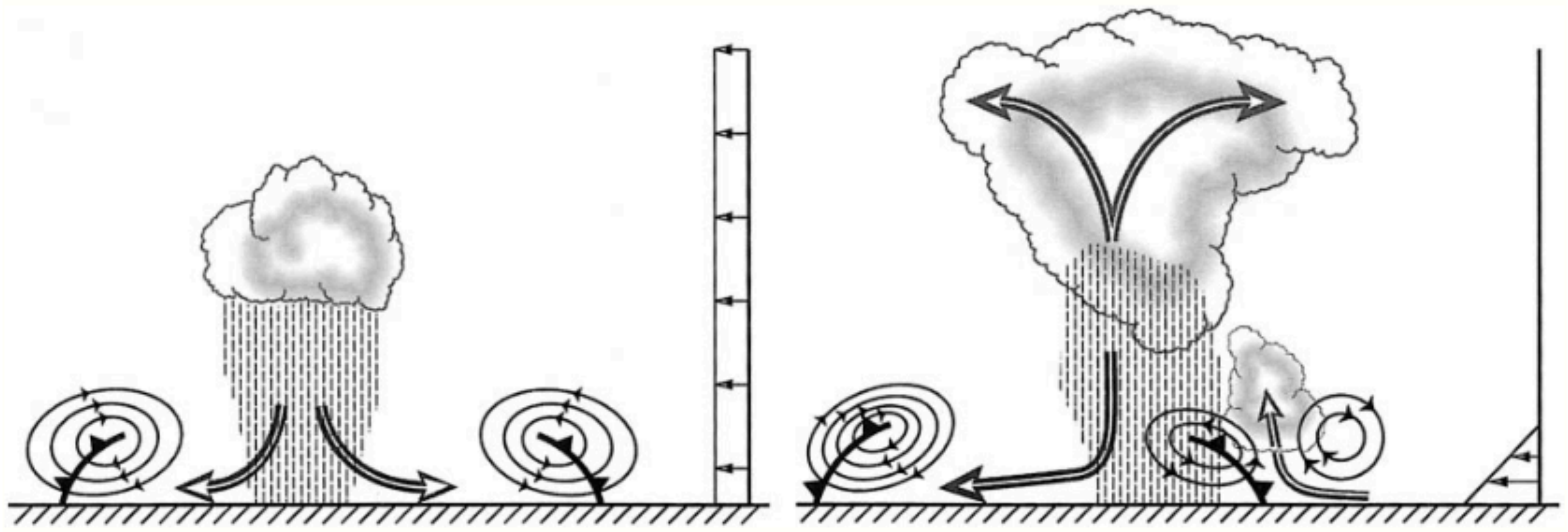
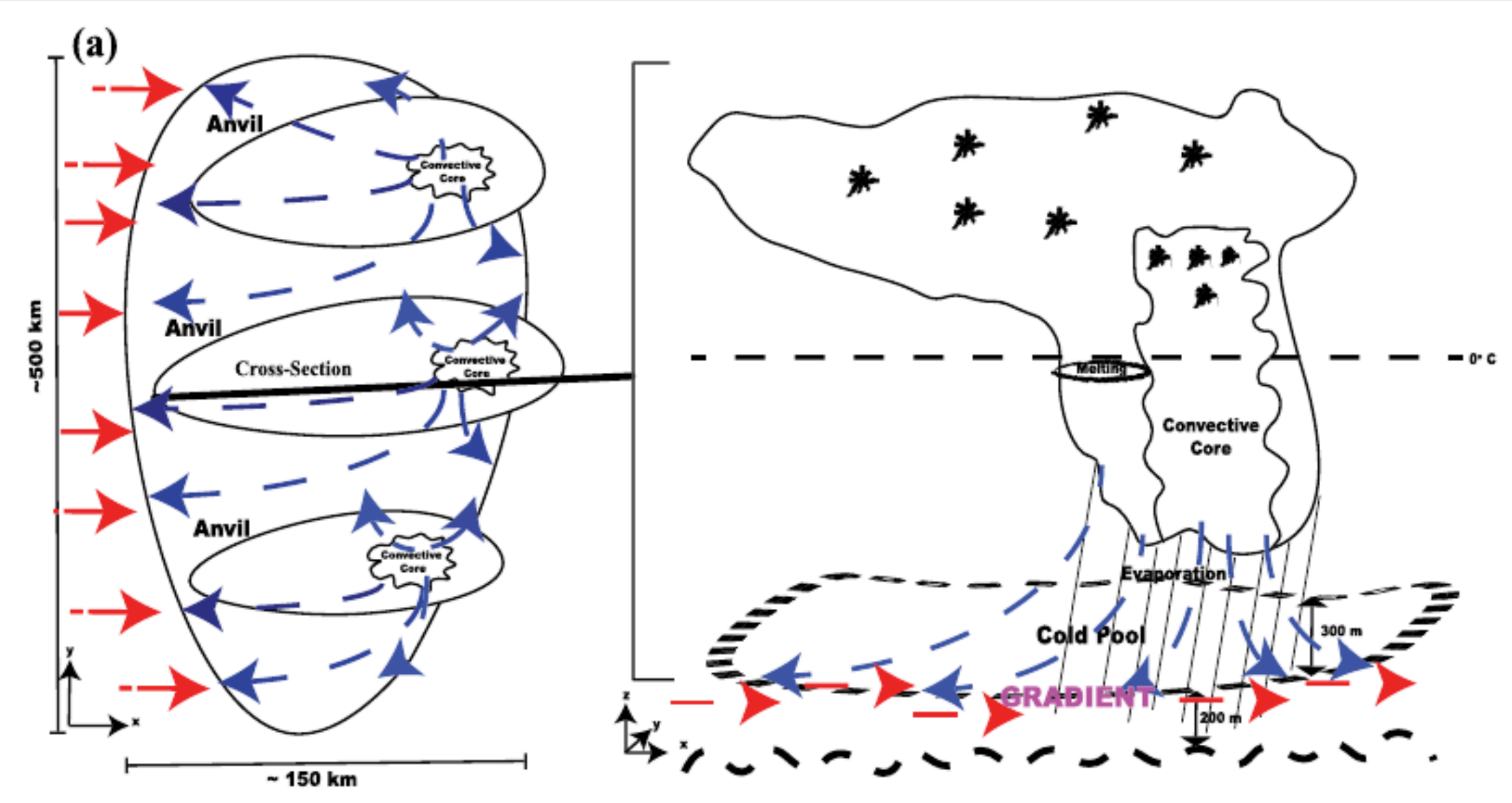
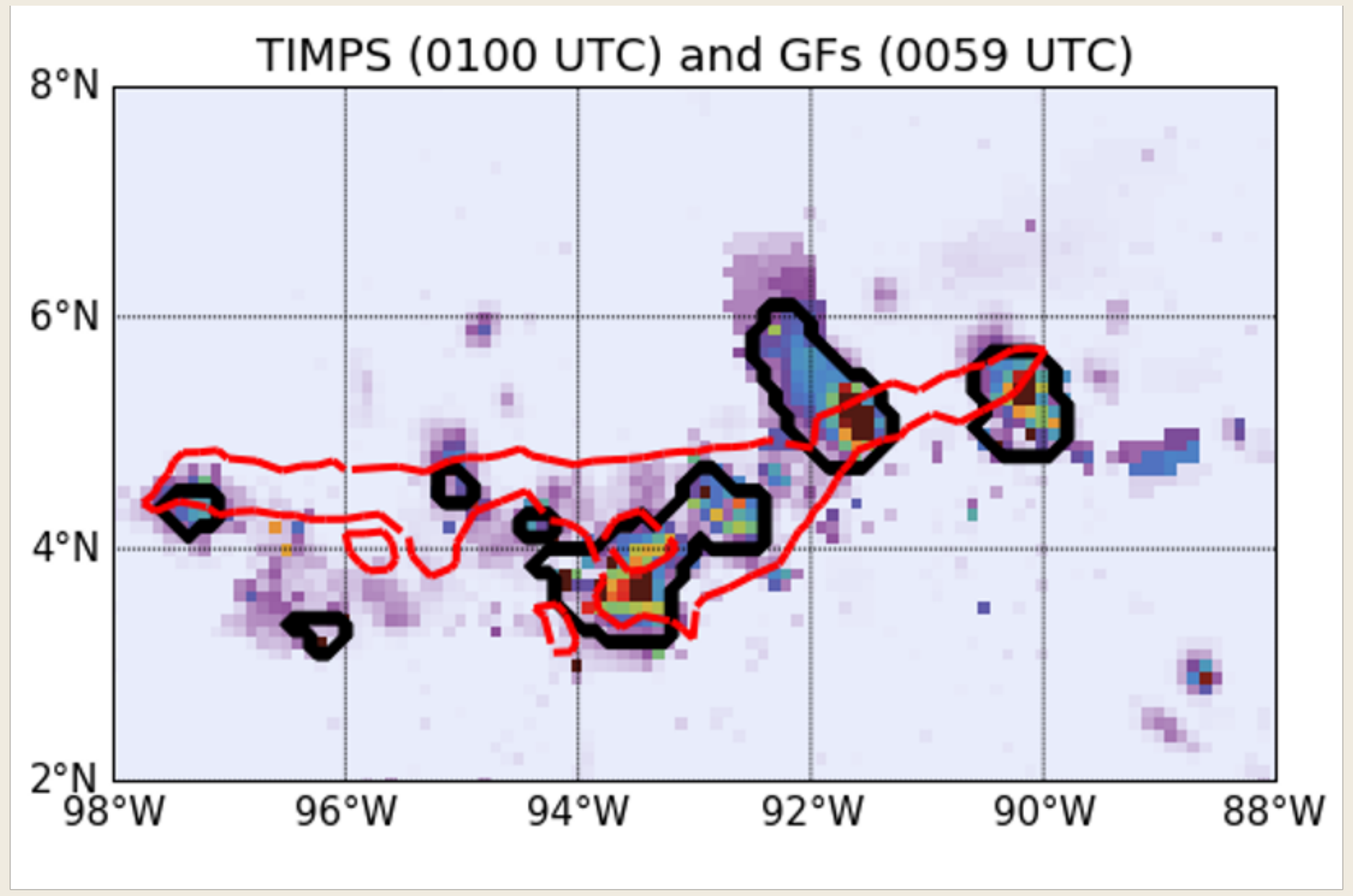


FIG. 1. (left) Cold pool spreads away from a decaying convective cell in an environment with no vertical wind shear. (right) Low-level vertical wind shear balances cold-pool circulation on the downshear side, enhancing the ability to regenerate convective cells through deeper lifting.

Collocating MCSs and Cold Pools



Garg et al. (2020) approach to identifying and characterizing tropical oceanic mesoscale cold pools using space borne scatterometer winds from RapidScat

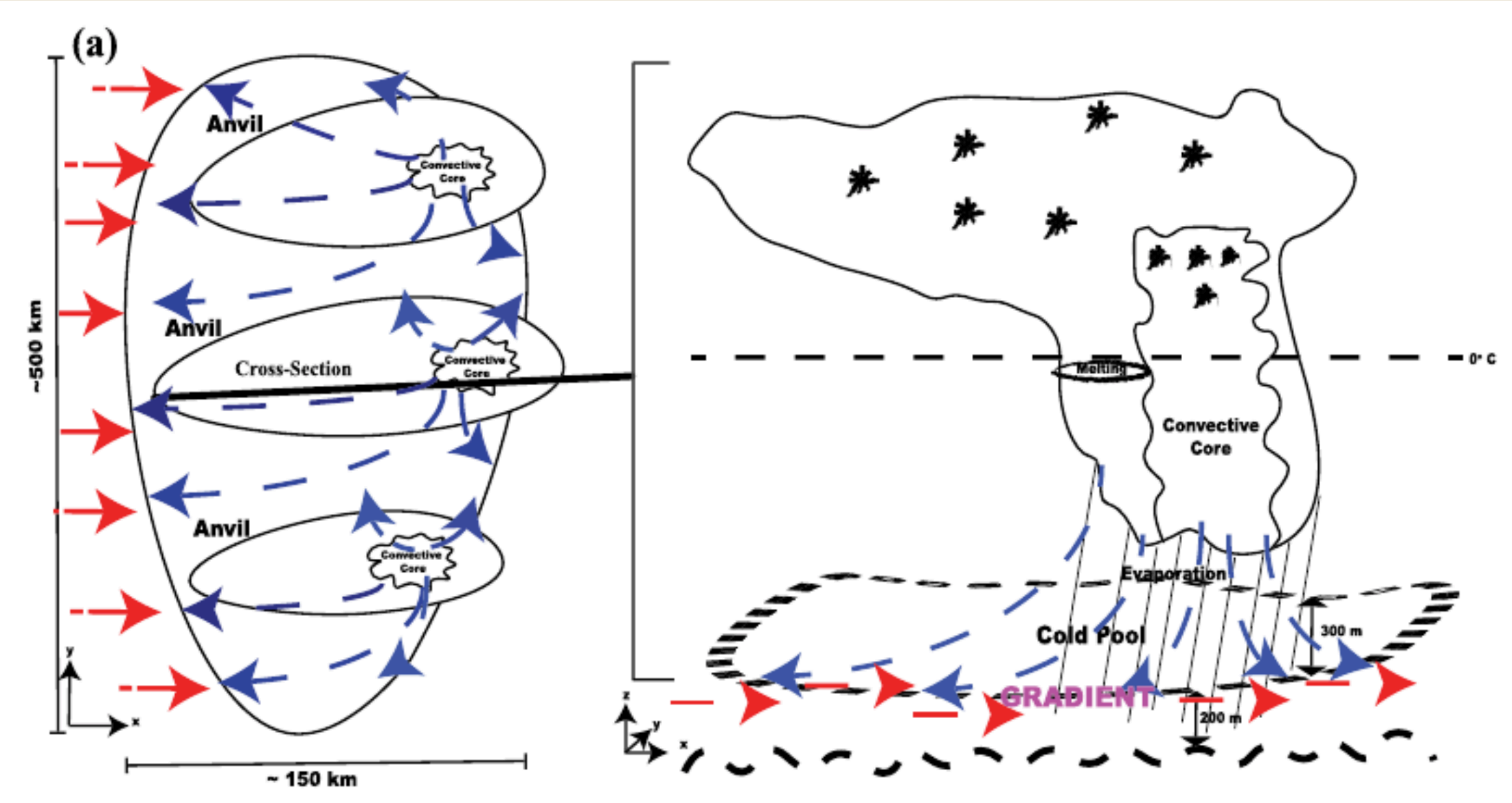


An example collocation of a cold pool (red outline) and an MCS in the TIMPS tracking database.

Collocating MCSs and Cold Pools

and thermodynamic data

ERA5 reanalysis, AIRS L2 retrievals, AIRS/Aqua single footprint retrievals



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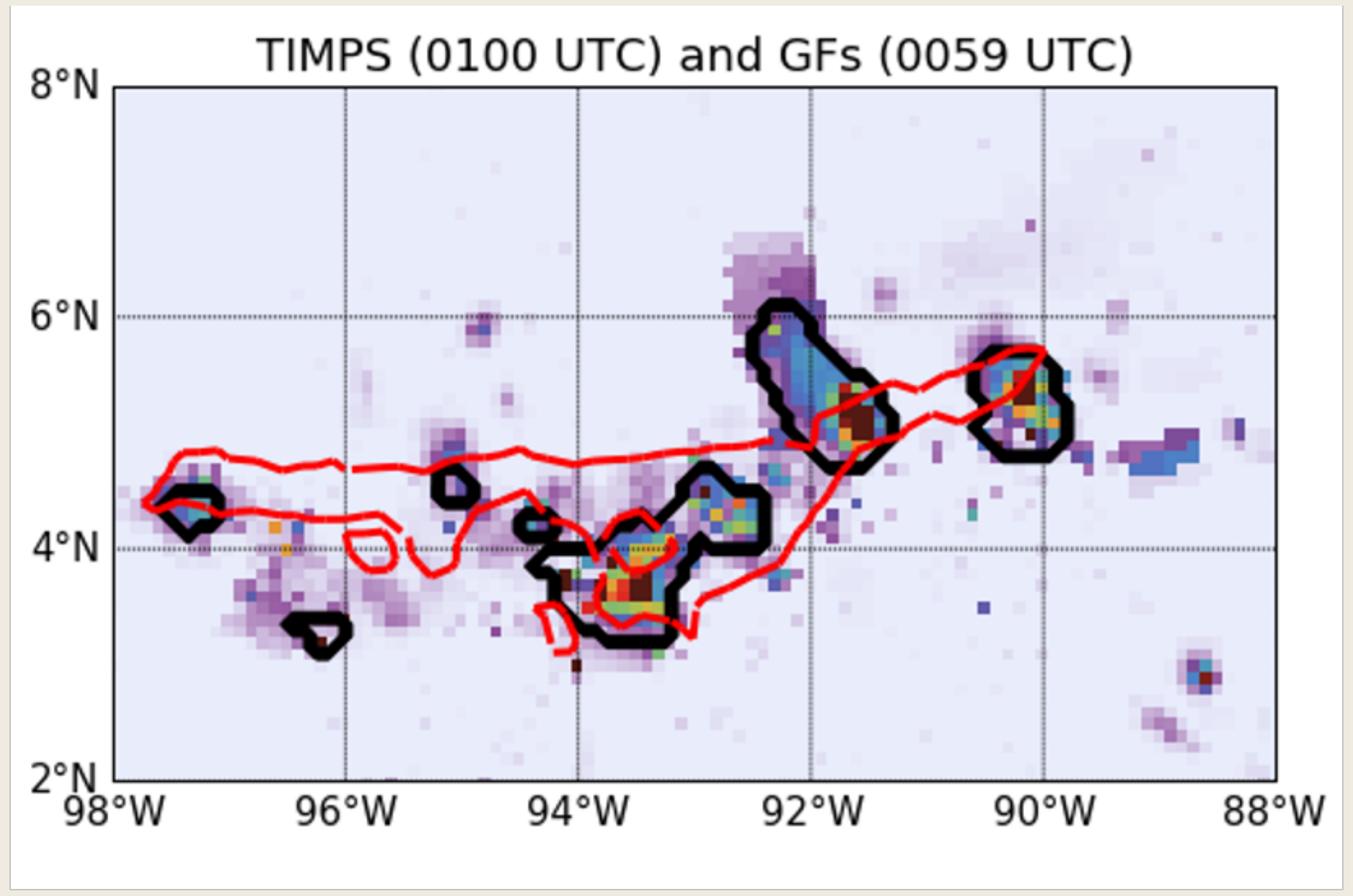

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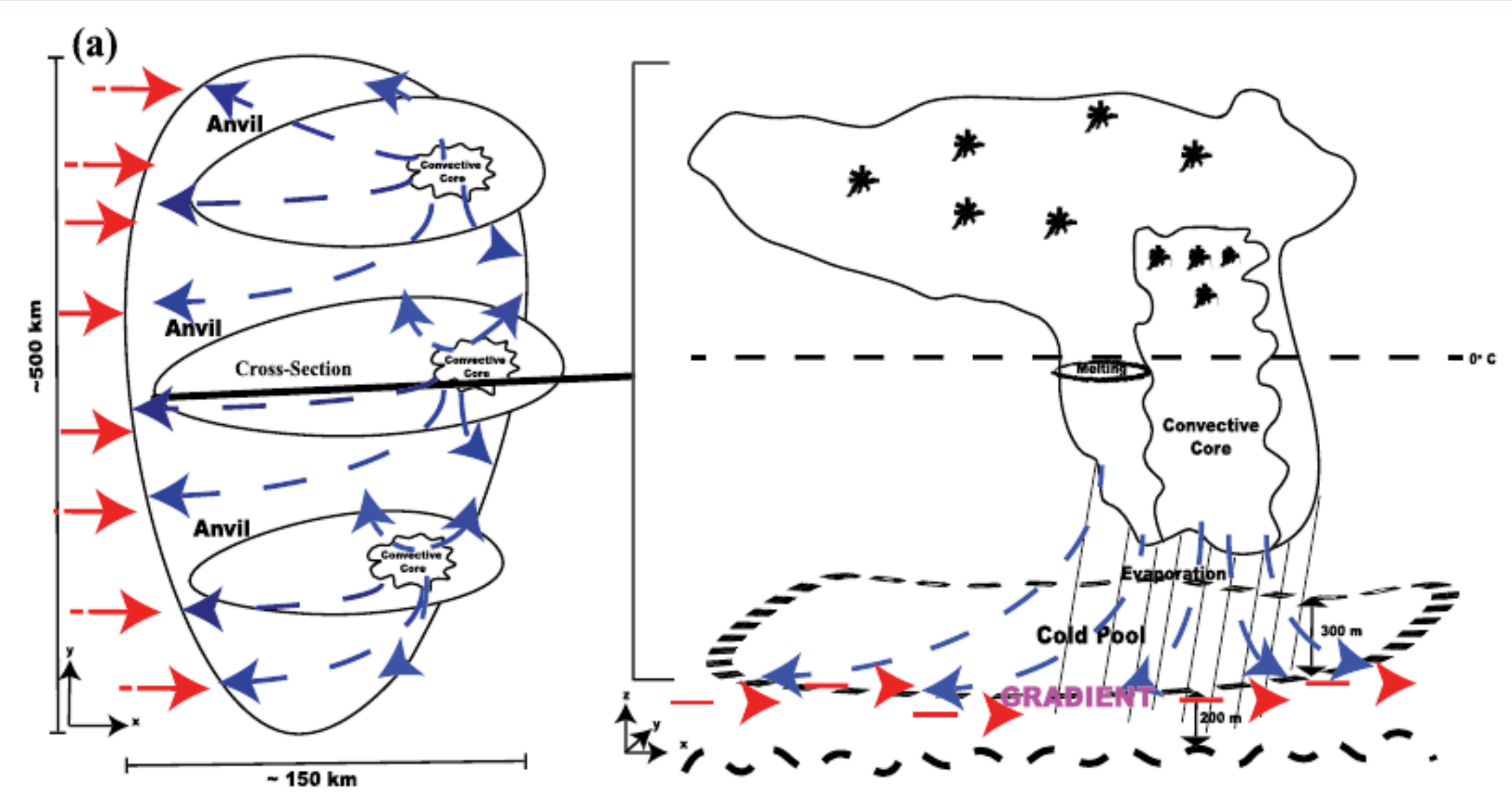

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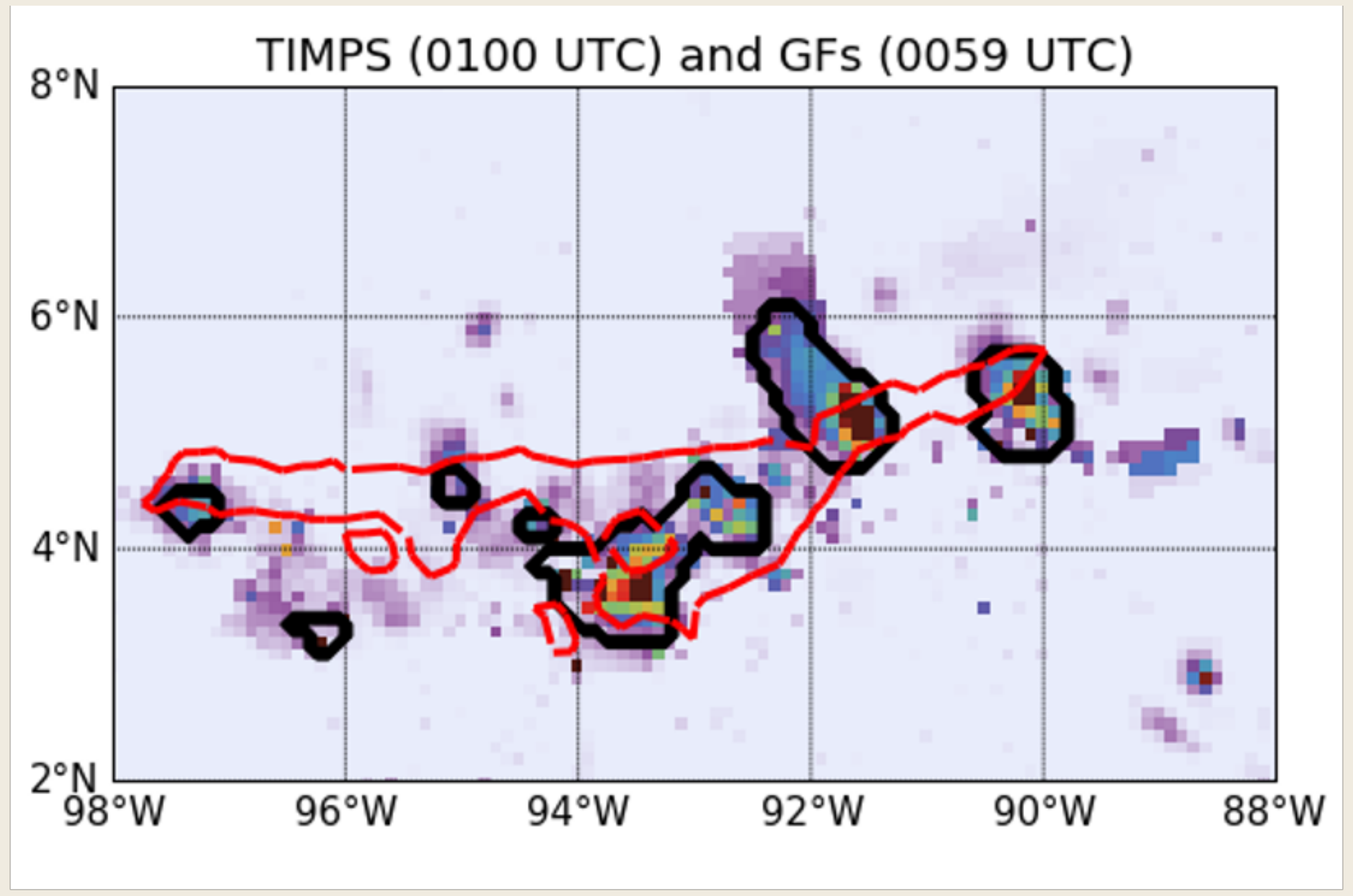

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Can cold pool characteristics be used to predict MCS characteristics and lifetime?

MCS area largest during its mature phase. Cold pool area largest during MCS growth.

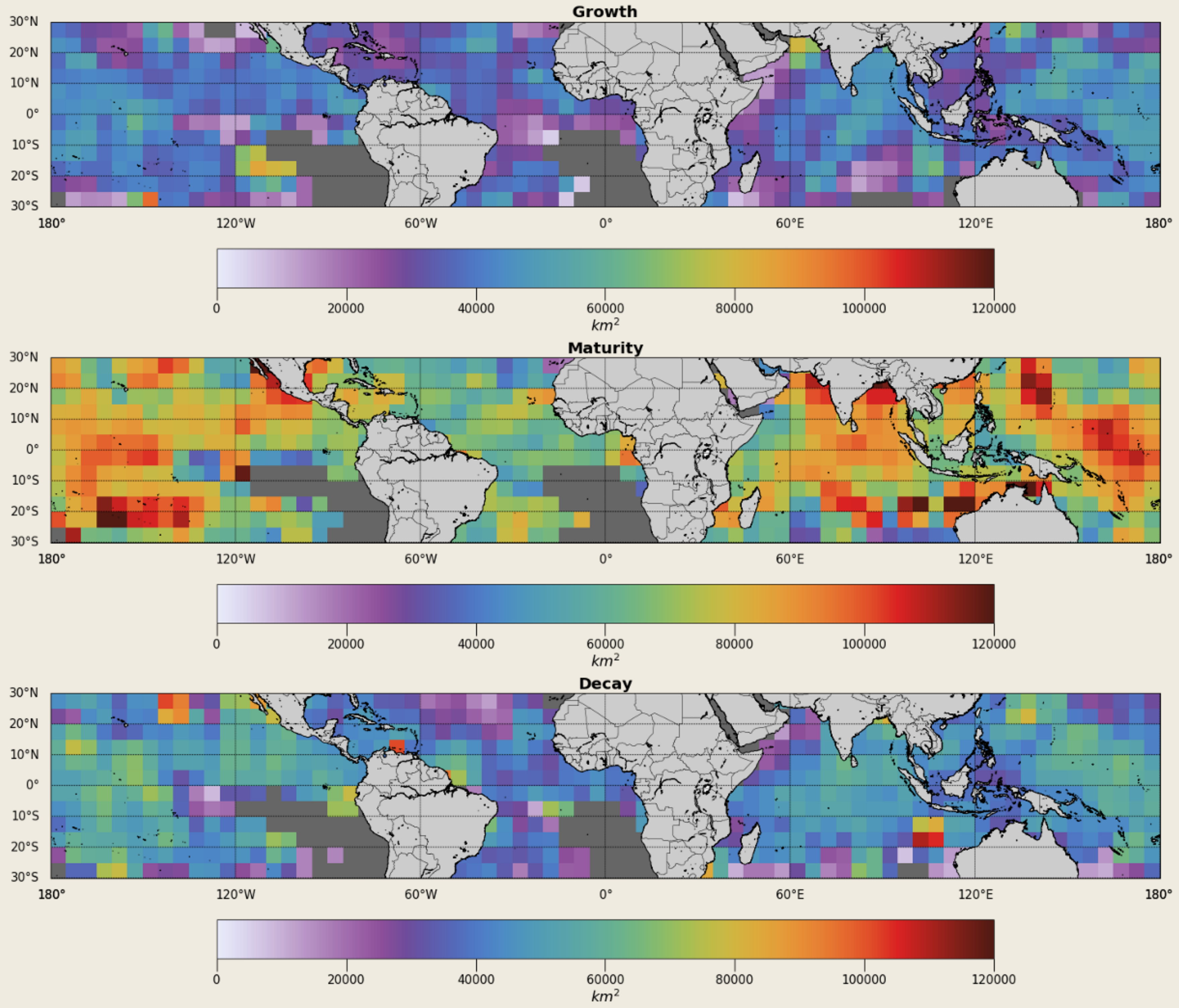
MCS Phase

Growth

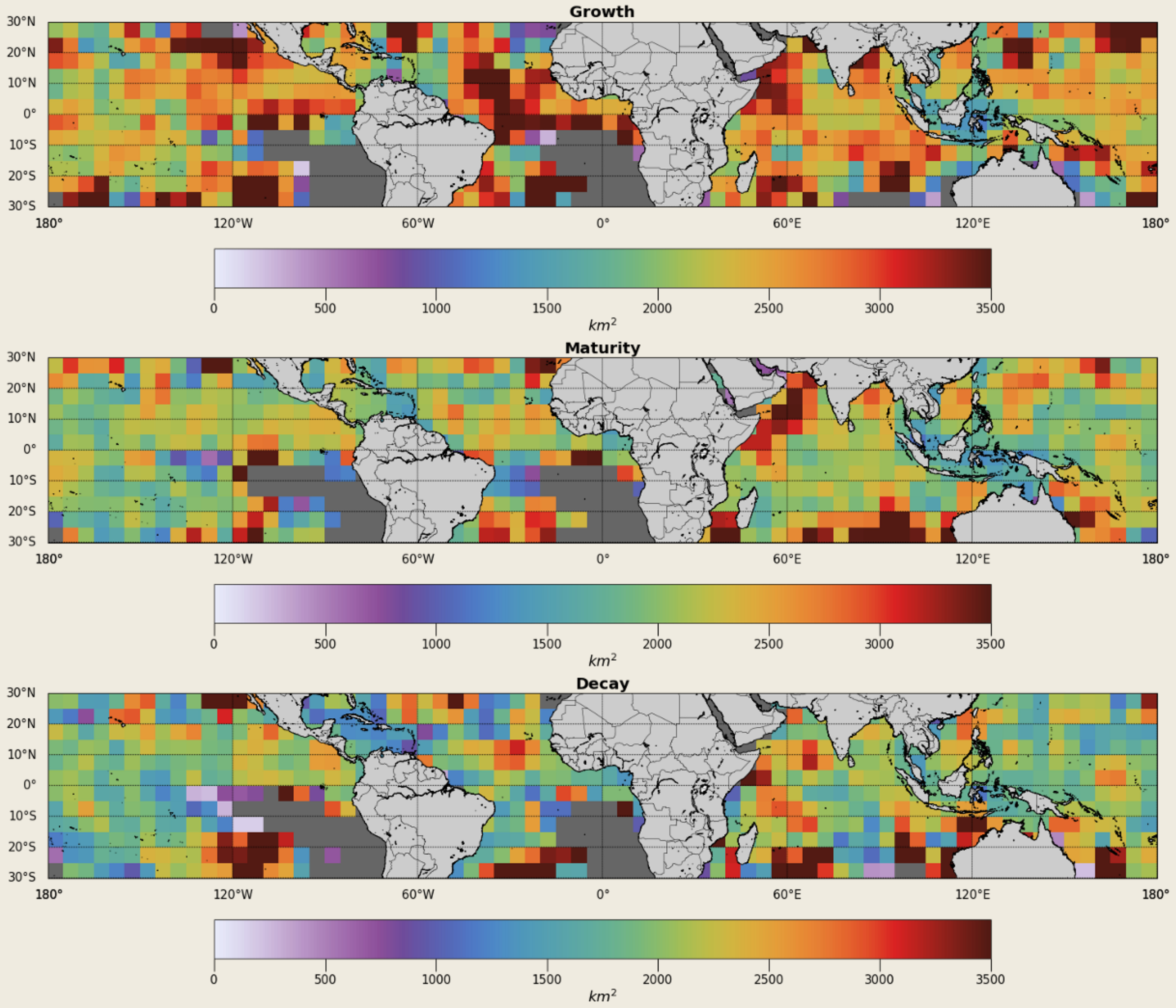
Mature

Decay

MCS AREA



Cold Pool Size

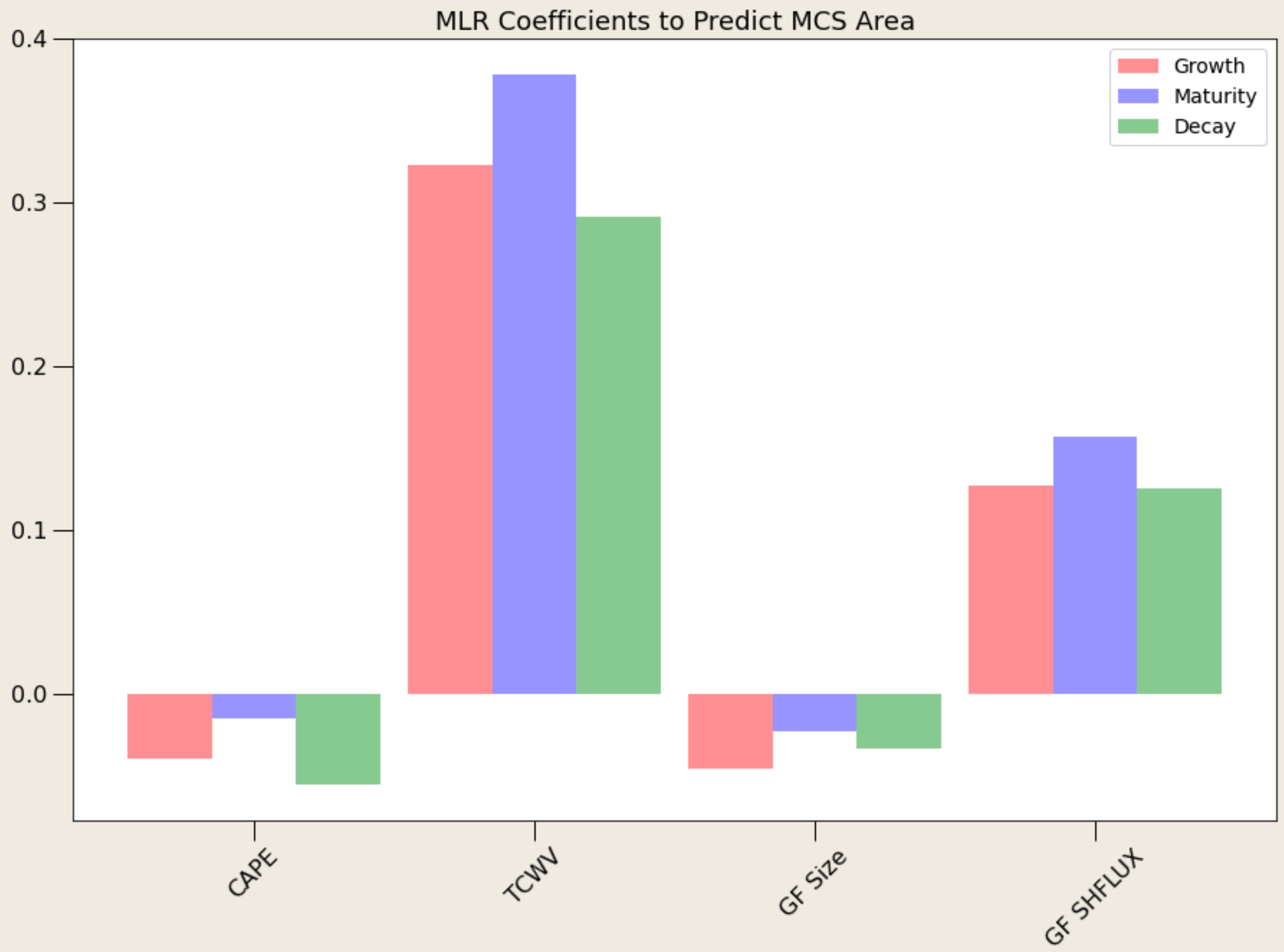


Analysis: Piyush Garg (UVA)

Evaluating Predictors of MCS size

Preliminary Analysis

- Total column water vapor (TCWV) appears to be the best predictor of MCS area in growth, mature, and decay lifecycle phases.
- Cold pool nearest-neighbor sensible heat flux (ERA-5 Reanalysis thermodynamics, RapidSCAT winds) the second best predictor of MCS area
- Predictive capability doesn't change much among phases for each of the variables
- Environmental CAPE not a good predictor of MCS area
- Cold pool size also not a good predictor



*Analysis done only for MCS property vs. GF property detected within the same phase. Future work will evaluate how GF properties in growth phase relates to MCS properties in later stages

Analysis: Piyush Garg (UVA)

Summary - Part 2

Combining MCS tracking databases with the first-ever global cold pool dataset (Garg et al. 2020) permits statistical evaluation of the role of cold pools in the convective lifecycle over tropical oceans.

Ongoing work is examining how cold pool properties modify MCS precipitation intensity, areal extent, and clustering behaviors