Impact of a cold pool parameterization on the diurnal cycle and intraseasonal variability in the GEOS AGCM

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A11O-2503

Introduction

Cold pools and sub-grid organization offer a potential solution to the "entrainment dilemma," an apparent tradeoff between realistic convective variability and biases in the mean state.
Here we implement a cold pool (CP) parameterization based on Del Genio, *et al.* (2015) in the NASA GEOS AGCM run with Grell-Freitas convection. We examine two potential CP effects on deep convection: (1) Entrainment is made a decreasing function of cold pool area, and (2) source parcel moist static energy is drawn from the non-cold pool environment.

Cold pool parameterization

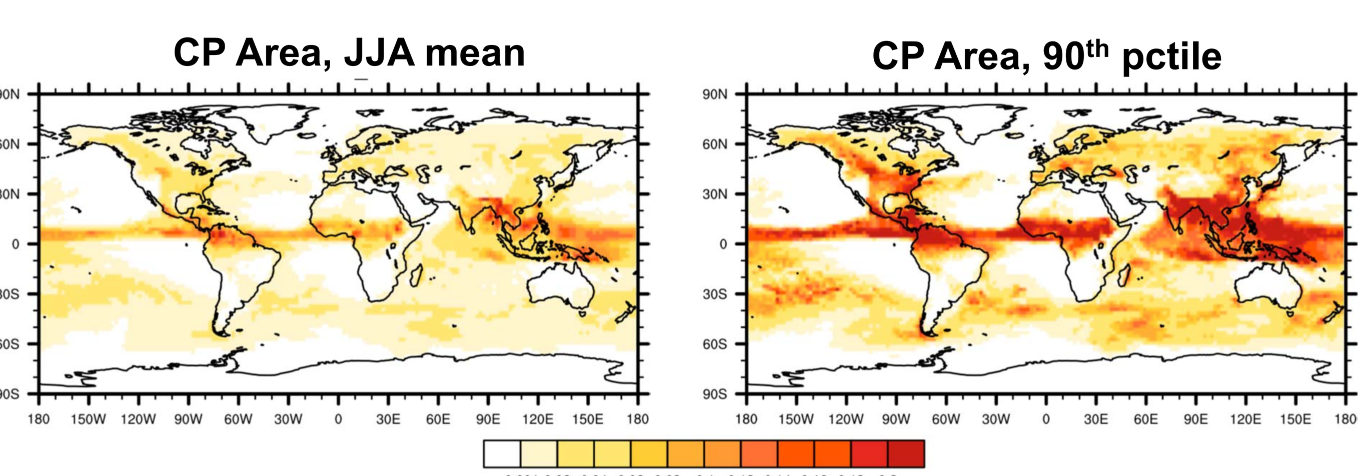
Downdrafts are generated by congestus and deep plumes from the Grell-Freitas convection scheme. New cold pools are initiated when downdraft θ_v is at least 0.5 K colder than the environment. Cold pool area fraction, a_{cp}, θ_{cp} and q_{cp} evolve prognostically based on additional downdraft input and a decay timescale of 4 hours.

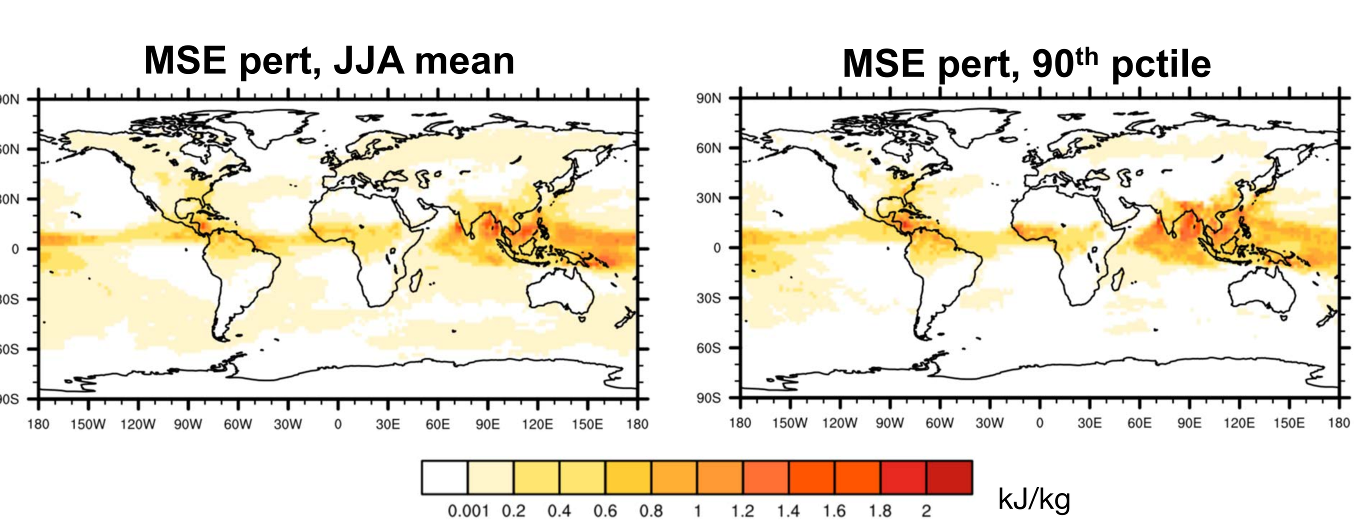
$$\frac{\partial a_{cp}}{\partial t} = \frac{m_d g}{\Delta p} - \frac{a_{cp}}{\tau} \qquad \tau = 4\ \mathrm{hr}$$

Environmental properties are diagnosed,

$$\theta_{env} = \frac{\overline{\theta} - a_{cp}\theta_{cp}}{1 - a_{cp}} \qquad \theta' = \theta_{env} - \overline{\theta}$$

where θ' is the convective source air perturbation (similarly for q'). In "ENT" experiments, deep convective entrainment is scaled based on cold pool area.





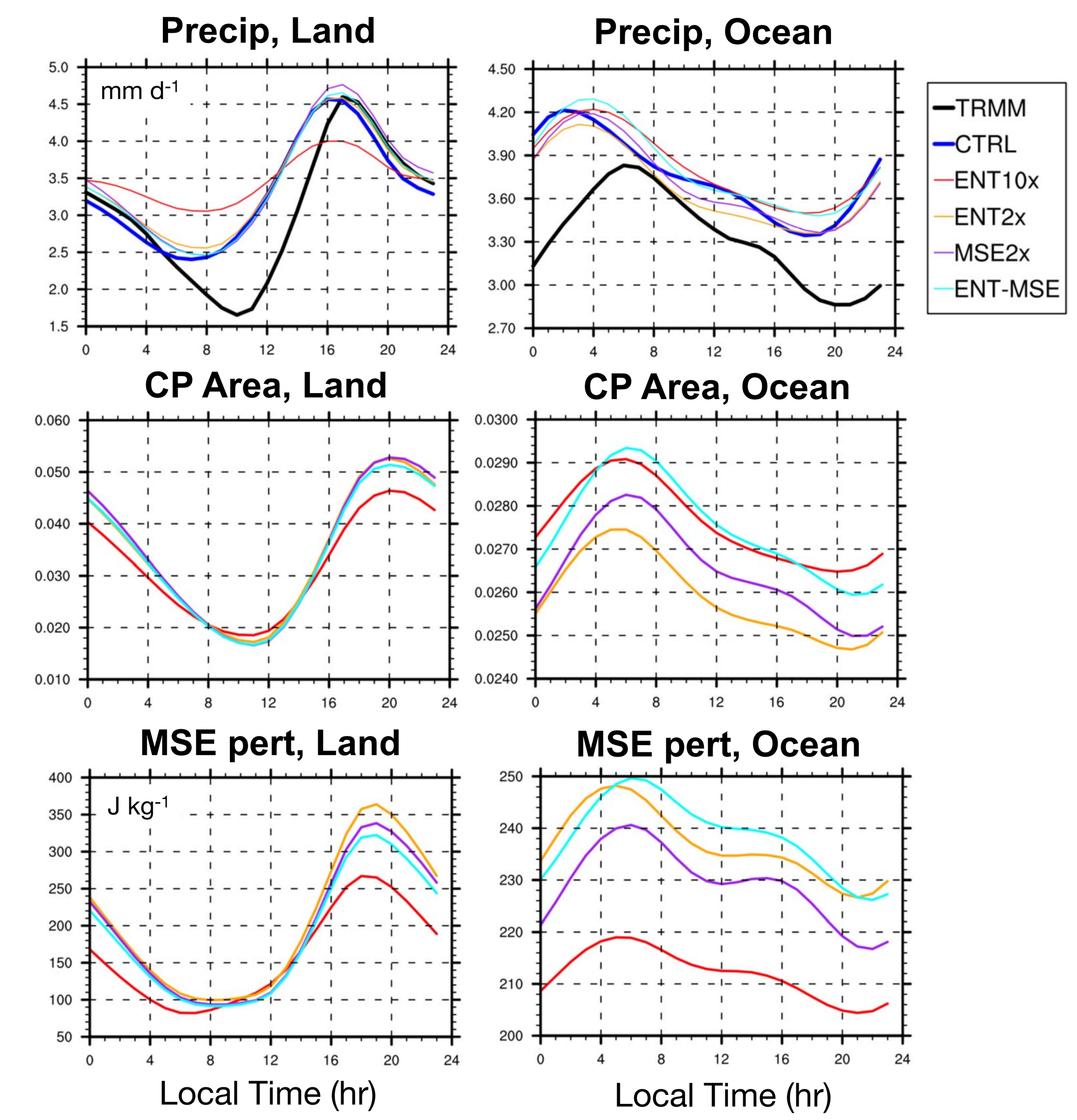
Diurnal cycle

Diurnal cycle averaged 30S-30N over land and ocean.

A high entrainment factor reduces diurnal cycle magnitude.

Both approaches delay (~1 hour) the peak precipitation.

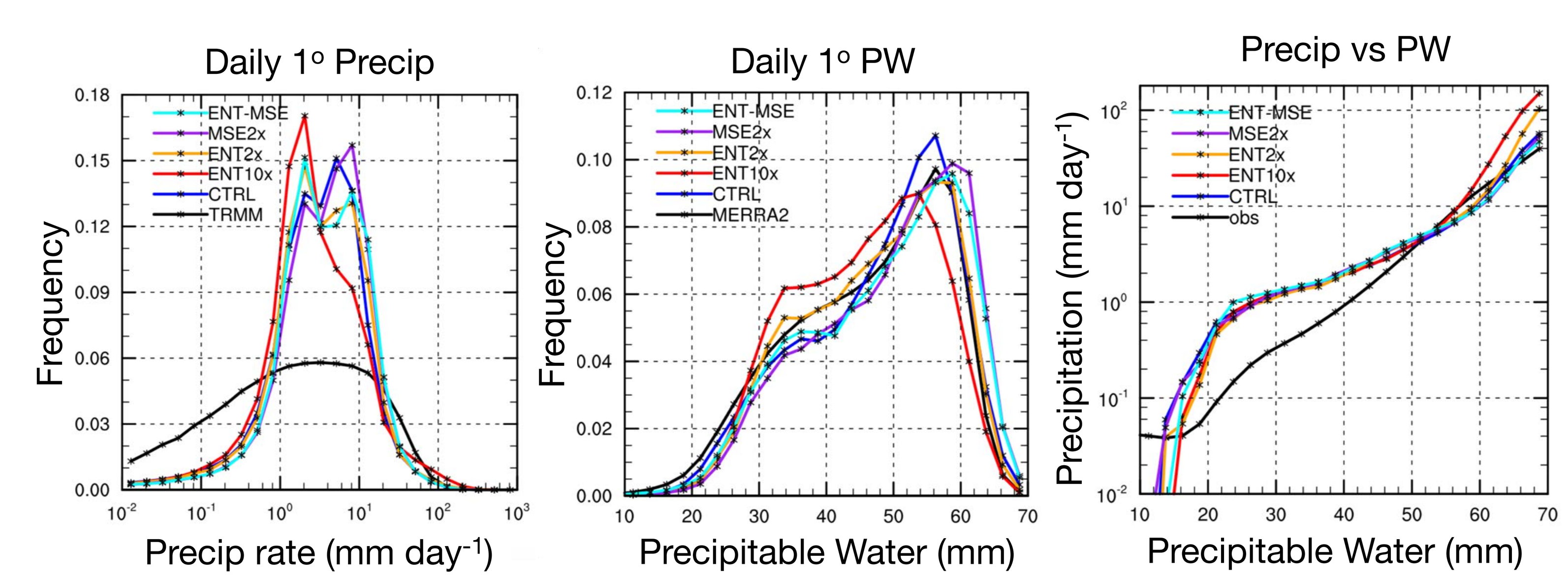
Cold pool area and source air MSE perturbation peak in early evening, following maximum precipitation.

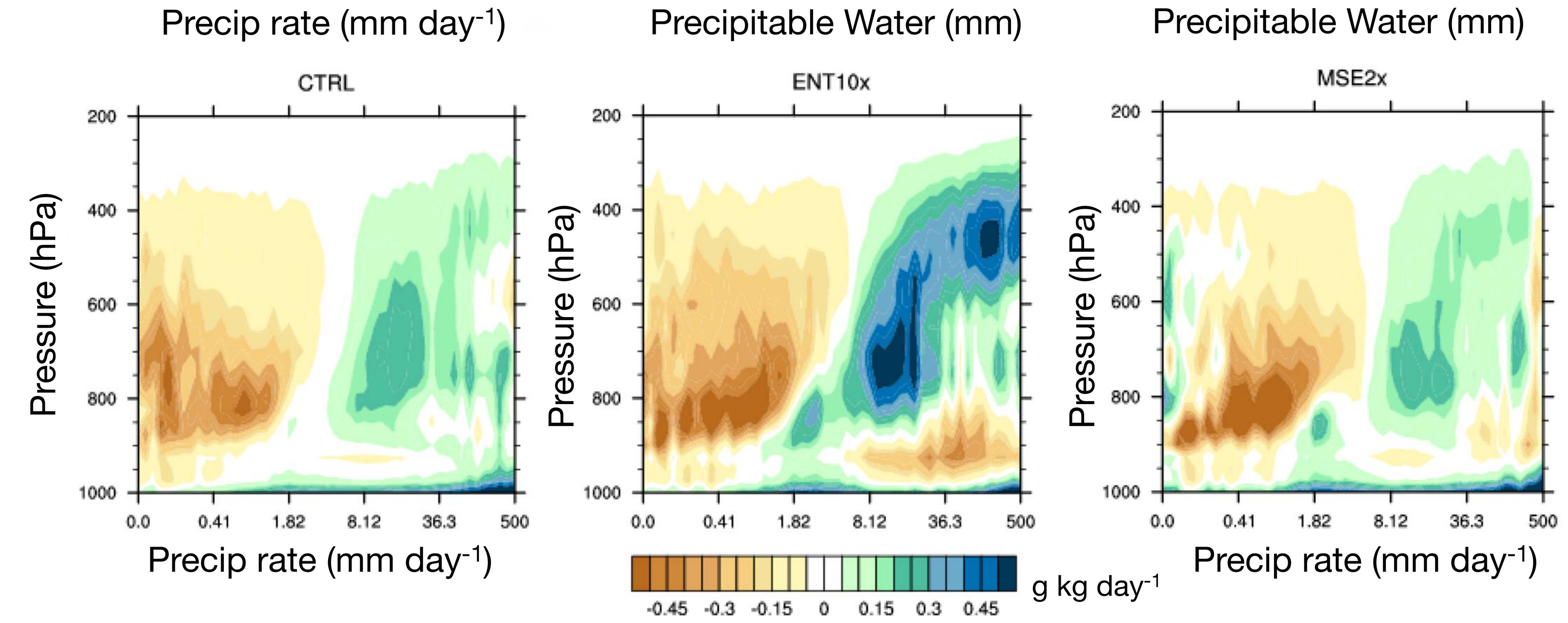


CTRL	GEOS AGCM with prescribed SST, no cold pools
ENT10x	Deep convection entrainment factor 10x, decreasing to 1x at CP area 0.15, no MSE perturbation
ENT2x	Convective entrainment factor 2x, decreasing to 0.2x at CP area 0.15, no MSE perturbation
MSE2x	Entrainment factor 1, with MSE perturbation doubled
ENT-MSE	Entrainment factor 2x decreasing to 0.2x at CP area 0.15, MSE perturbation 2x

Process metrics

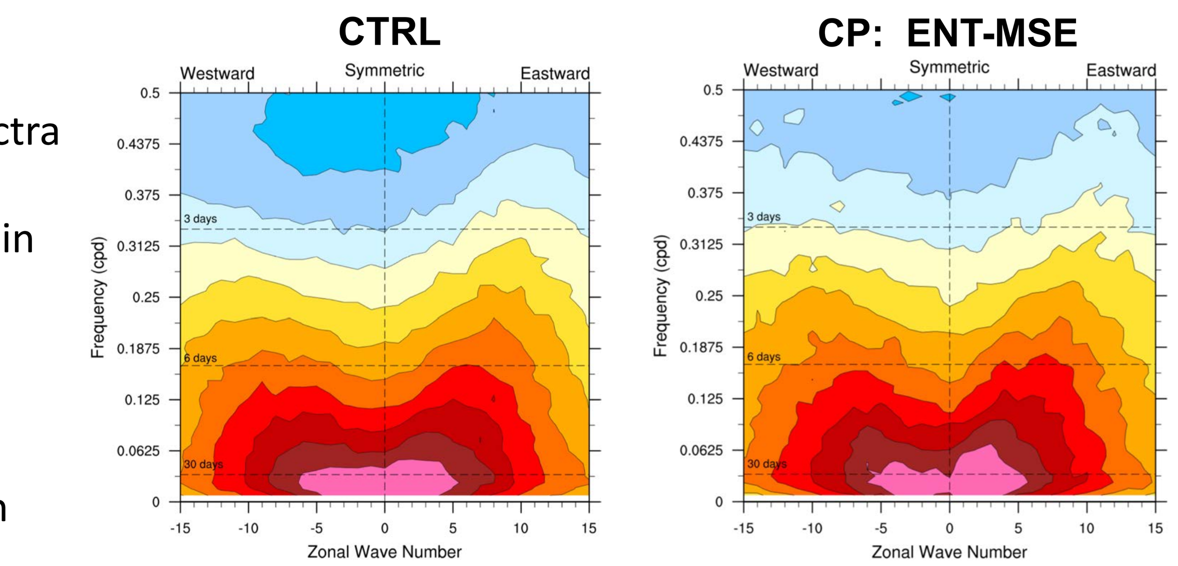
(top) PDFs of precip, precipitable water, and their relationship.
(bot) Profiles of humidity tendency binned by precip rate, for three cases.



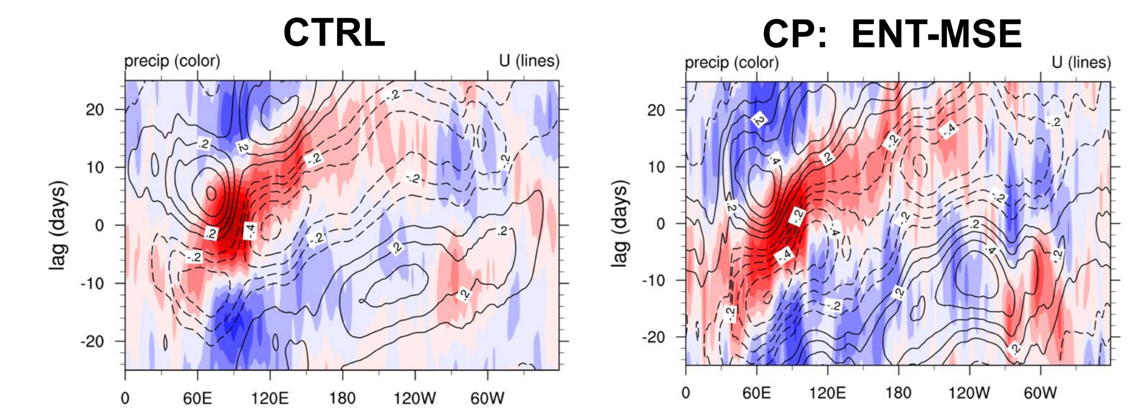


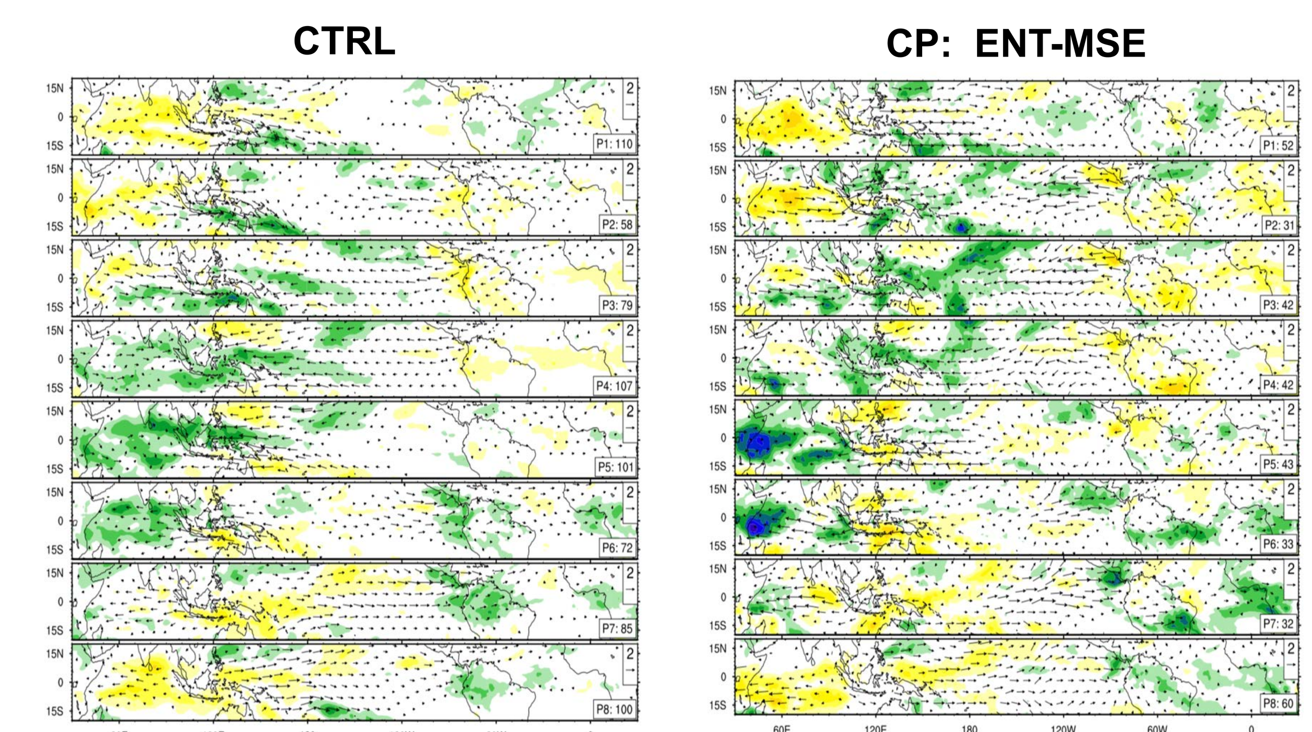
Intraseasonal variability

Wavenumber-frequency spectra of OLR show a small increase in eastward variance.



Lag-correlation diagrams of precip (shading) and U850 (contours) show possible extension of eastward propagation.





Summary

- Source parcel MSE perturbation and variable entrainment linked to cold pool area both produce a modest (~1 hr) delay in diurnal peak precipitation.
- Combined effects have a weak impact on MJO statistics.
- Variable entrainment shifts PW distribution to drier values, weaker precipitation, and strengthens relationship between precipitation rate and moisture tendency.
- MSE' shifts distributions to wetter PW, stronger precip.

References

- Freitas, S. R., et al., 2018: Assessing the Grell-Freitas Convection Parameterization in the NASA GEOS Modeling System. *J. Adv. Model. Earth Syst.*, 10(6): 1266–1289.
- Mapes, B. and R. Neale, 2011: Parameterizing Convective Organization to Escape the Entrainment Dilemma, *J. Adv. Model. Earth Syst.*, 3.
- Del Genio, A., et al, 2015: Constraints on Cumulus Parameterization from Simulations of Observed MJO Events. *J. Climate*, 28, 6419-6442.

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