Controls on the vertical profile of moistening as a function of precipitation rate

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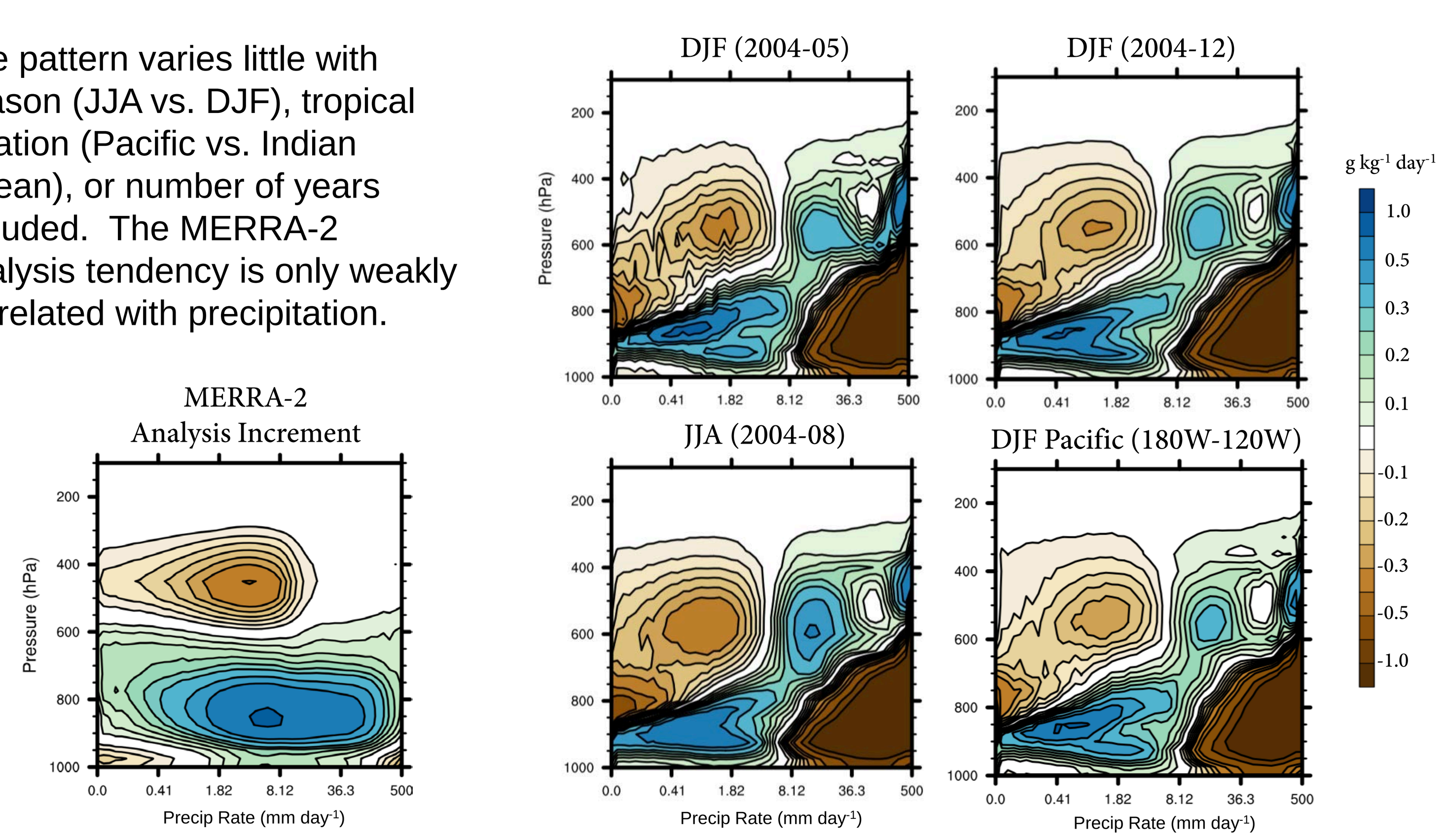
Introduction

The relationship between moisture tendency and precipitation rate has been identified as a process diagnostic relevant for simulation of the MJO. AGCMs with moistening that progressively deepens with precipitation rate demonstrate greater MJO skill (*Klingaman et al., 2015*). However, the processes that give rise to this net moistening pattern are poorly understood. Here we use the NASA Global Earth Observing System (GEOS) AGCM to examine the moisture budget in precipitation-space and understand its sensitivity to changes in model parameters. Comparison is made with the MERRA-2 and ERA-5 reanalyses to place model results in context.

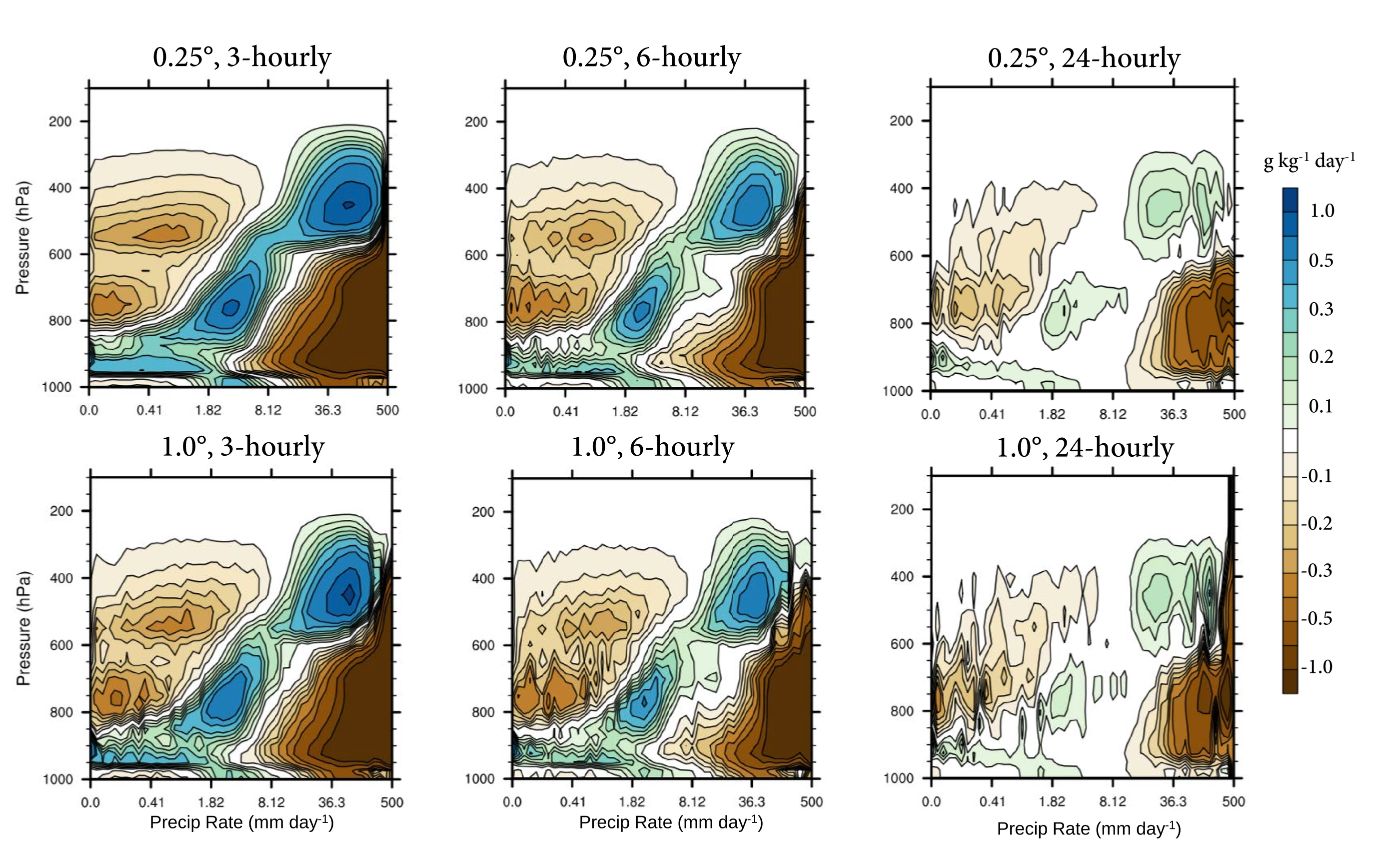
Moistening profiles from reanalysis

Moistening patterns using 3-hourly ~0.5 degree MERRA-2 reanalysis, over Indian Ocean (10S-10N, 60E-160E) for DJF, except as otherwise noted.

The pattern varies little with season (JJA vs. DJF), tropical location (Pacific vs. Indian Ocean), or number of years included. The MERRA-2 analysis tendency is only weakly correlated with precipitation.

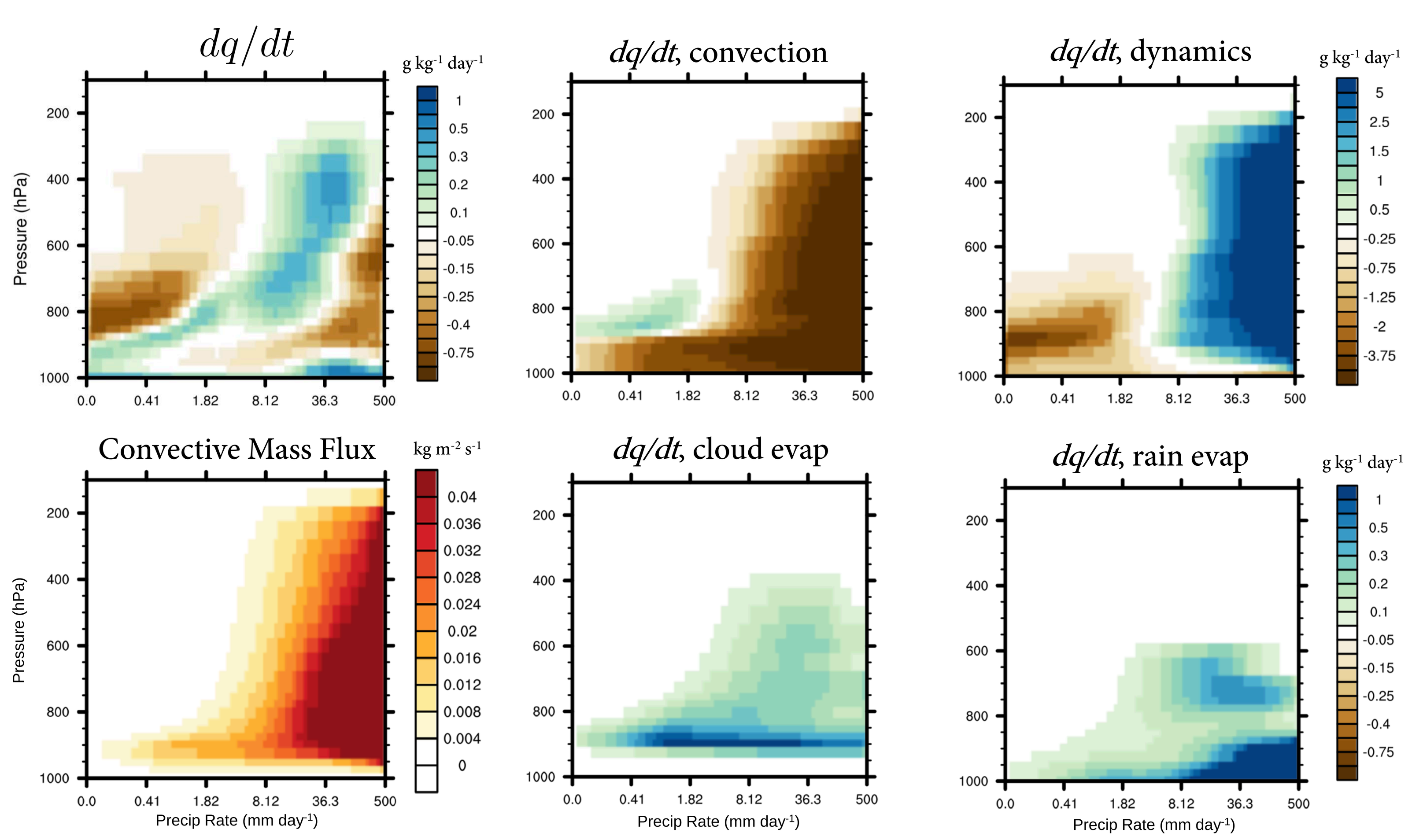


Moistening patterns using ERA-5 reanalysis. Pattern is insensitive to horizontal resolution (0.25° vs 1.0°) but degrades when using daily vs. 3-hourly input.



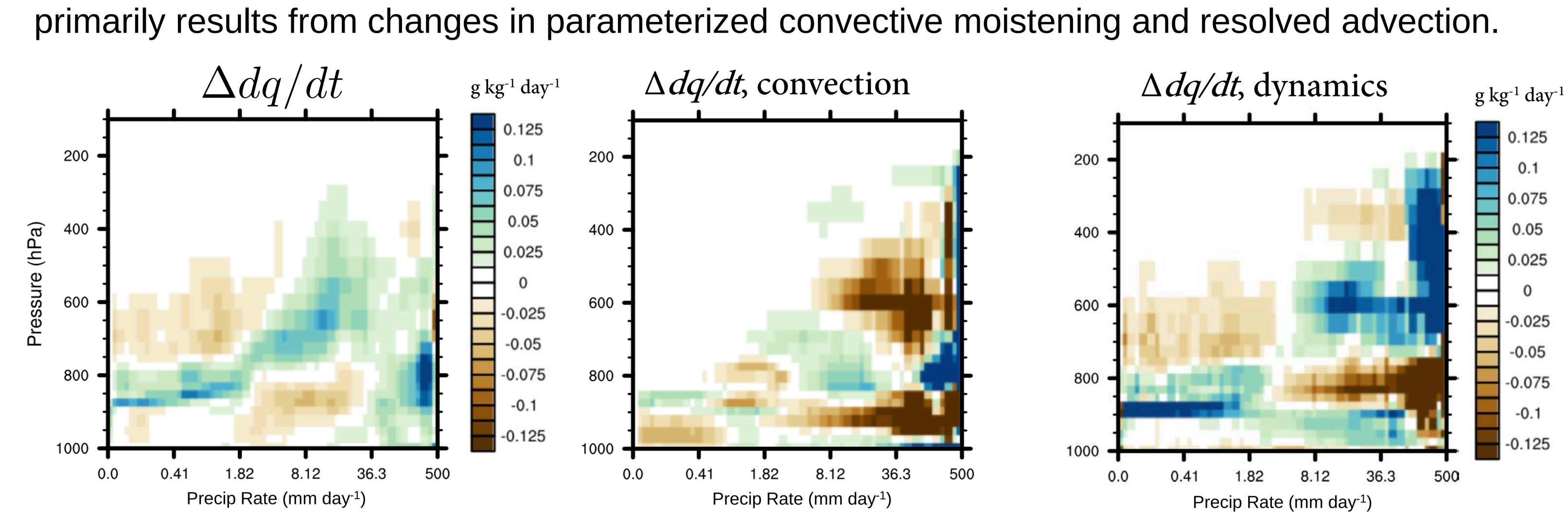
Moisture budget for the control case

We conduct two free-running 1.0° (c90) AGCM simulations over 2004-2008, one with default settings (CTRL) and one with doubled entrainment rate for deep convection (EXP). Humidity tendencies for CTRL shown below, using 3-hourly output over Indian Ocean for DJF.

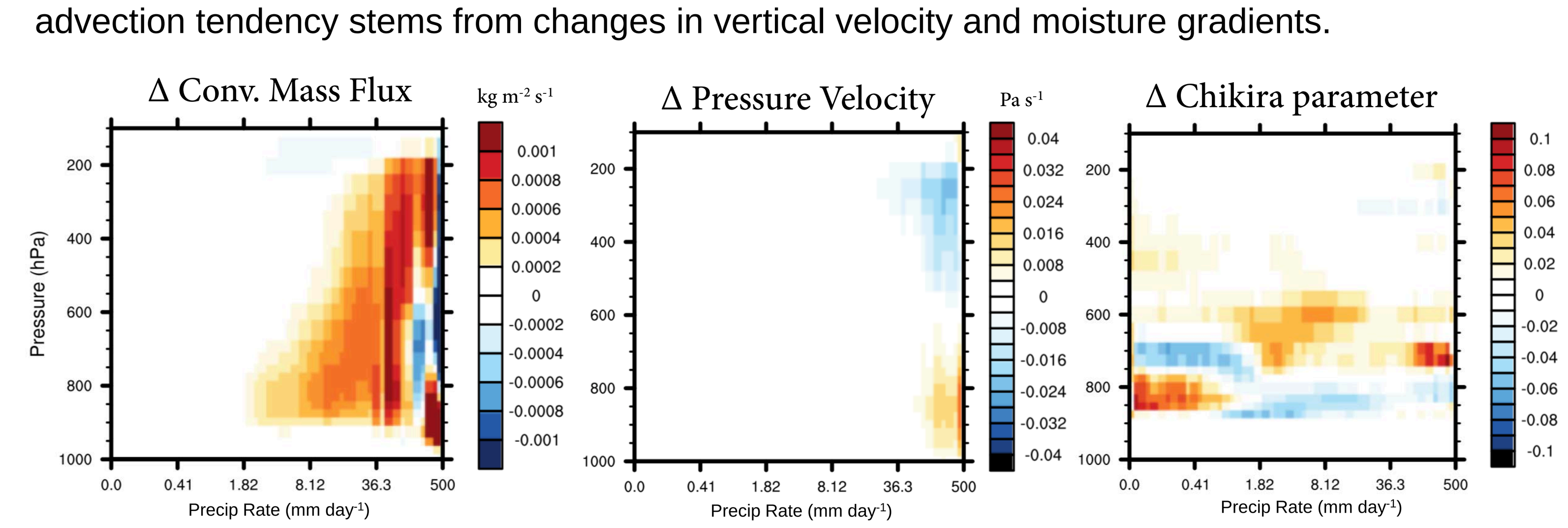


Effect of convective entrainment on moisture tendency

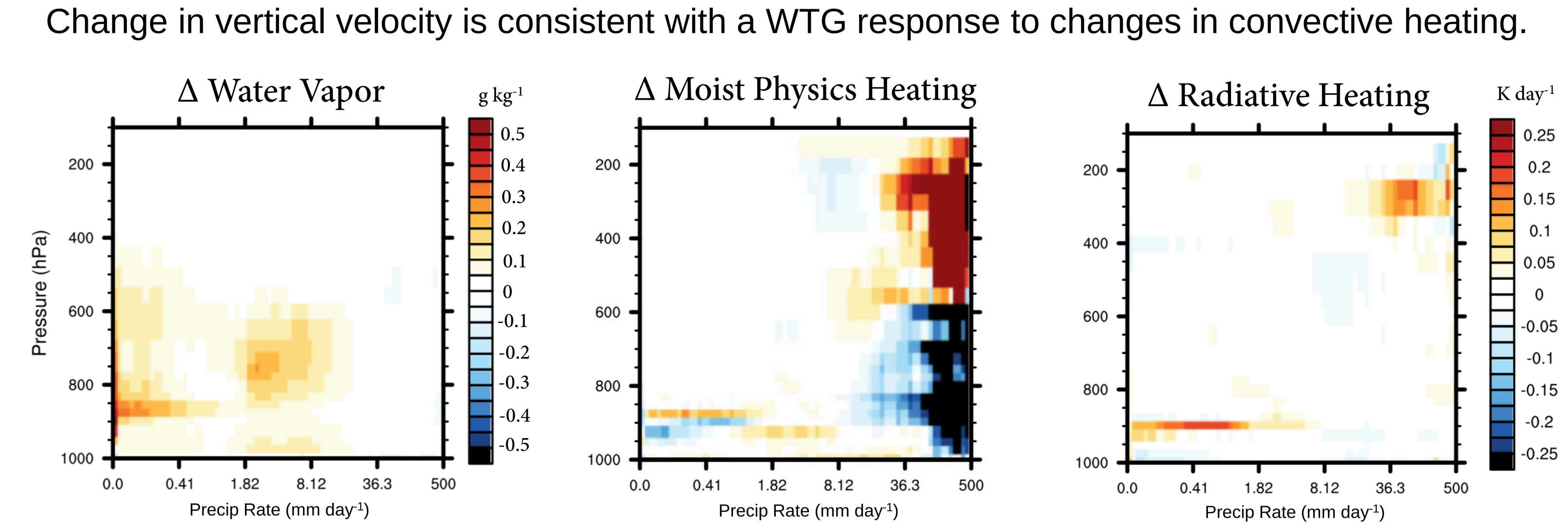
The difference (EXP-CTRL) in moistening from doubled convective entrainment is shown below. **The main effect is to strengthen the pattern of progressively deeper moistening.** This primarily results from changes in parameterized convective moistening and resolved advection.



Convective mass flux (below) increases for moderate-to-heavy precip rates. The resolved advection tendency stems from changes in vertical velocity and moisture gradients.

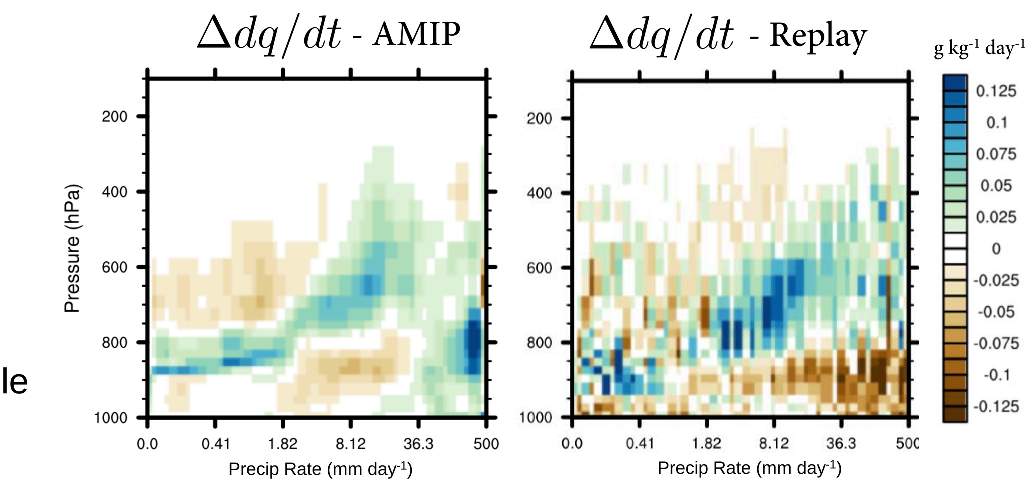


Change in vertical velocity is consistent with a WTG response to changes in convective heating.



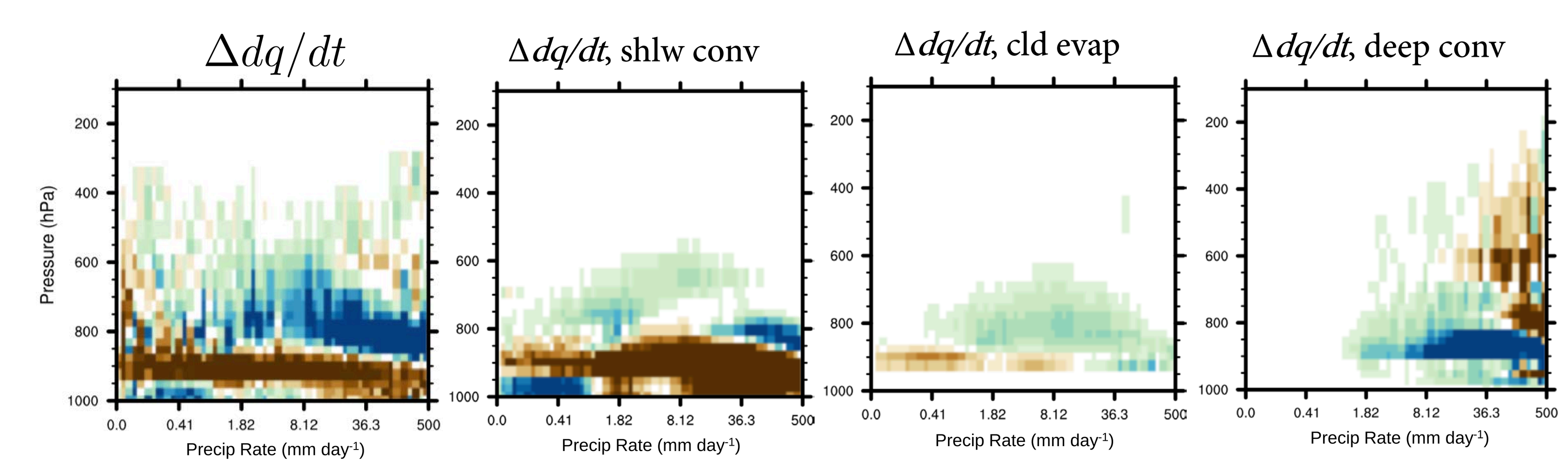
Using a "replay" with constrained T, Q, U, V

Internal variability in AMIP simulations requires long integrations to extract a stable tendency difference. Comparable differences are seen in "replay" mode, with GEOS constrained by the MERRA-2 analysis, with a single month of run time.



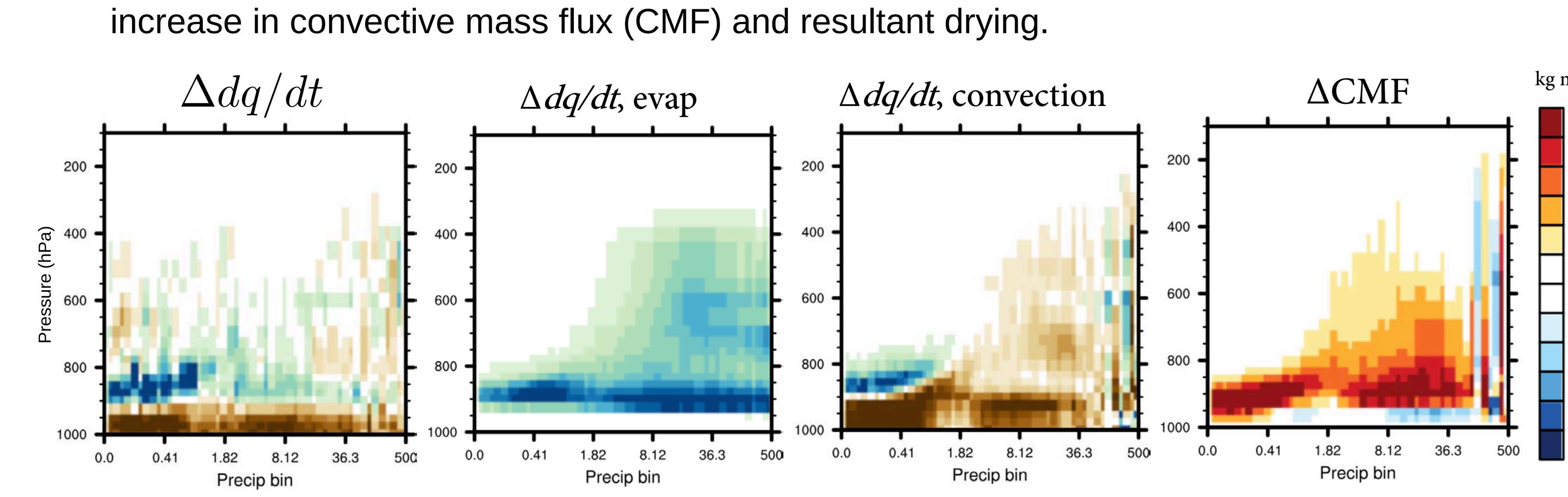
Replay with reduced shallow convective entrainment

Reducing mixing rate ~15% in Park & Bretherton shallow convection alters moistening patterns from shallow and deep convection and convective cloud evaporation.



Replay with increased convective cloud evaporation

Increasing convective cloud evaporation rate by 25%. Pattern is modified indirectly from increase in convective mass flux (CMF) and resultant drying.



Summary

- Moistening structure is sensitive to temporal, but not spatial, resolution of input data. It is insensitive to season and tropical longitude band, but varies between reanalyses.
- Increasing entrainment in parameterized convection – known to increase MJO variability in many models – enhances the pattern of progressive moistening in both free-running and "replay" experiments.
- This raises questions about the mechanism by which convective entrainment influences model MJO skill.
- The impacts of parameter changes on moistening structure can be difficult to predict, with large indirect effects filtered through secondary terms.

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