Improved intraseasonal variability in the NASA GEOS AGCM with 2-moment microphysics and a shallow cumulus parameterization

Nathan Arnold[1], Donifan Barahona[1], and Deepthi Achuthavarier[1,2]

1. NASA GMAO, Goddard Space Flight Center
2. USRA / GESTAR

GMAO Global Modeling & Assimilation Office

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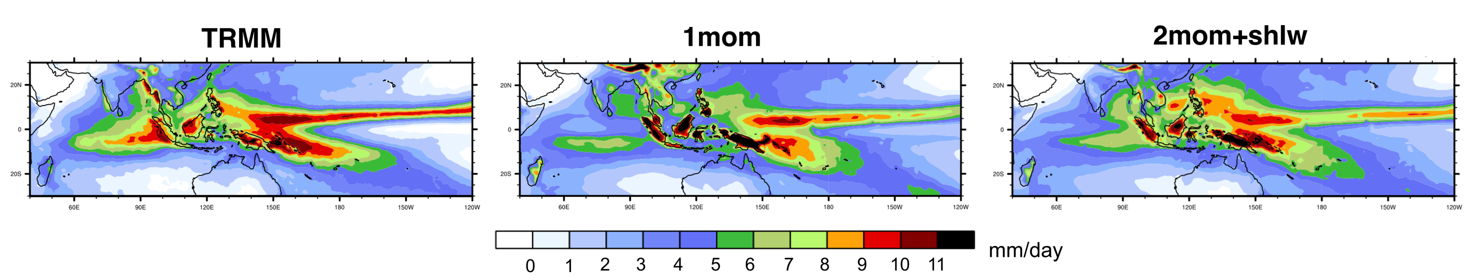
Summary

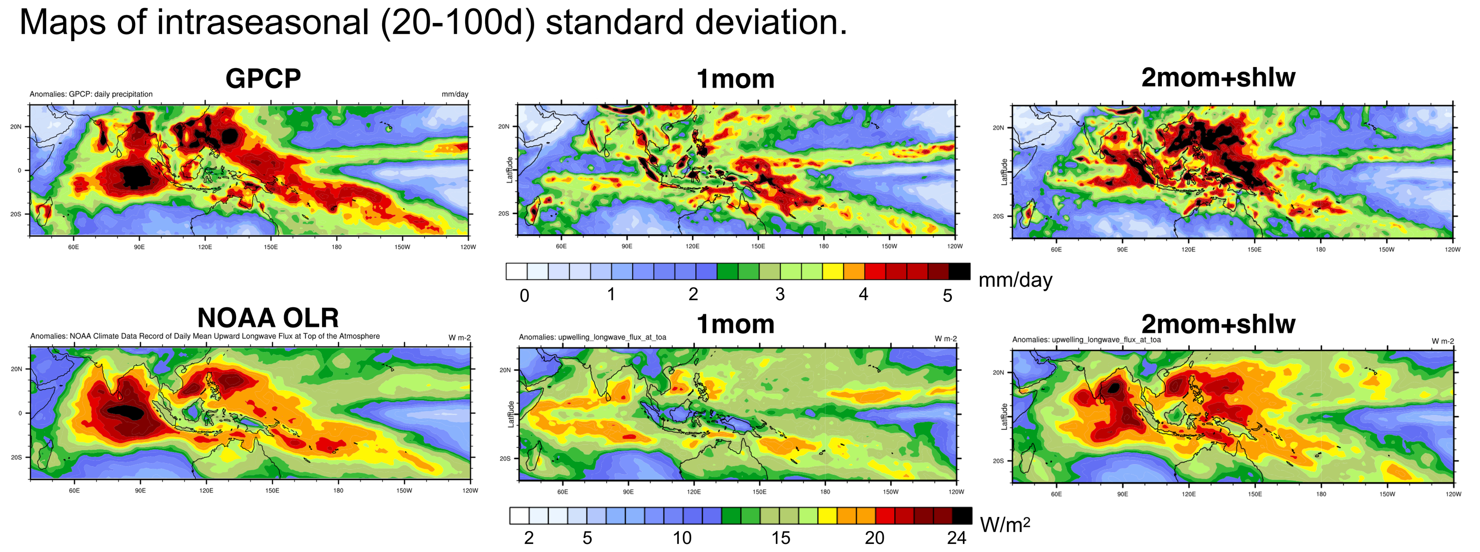
Weather and climate models have long struggled to realistically simulate the Madden-Julian Oscillation (MJO). Here we present a significant improvement in MJO simulation in NASA's GEOS atmospheric model with the implementation of 2-moment microphysics and the UW shallow cumulus parameterization. Comparing ten-year runs (2007-2016) with the old (**1mom**) and updated (**2mom+shlw**) model physics, the updated model has increased intra-seasonal variance with increased coherence. Surface fluxes and OLR are found to vary more realistically with precipitation, and a moisture budget suggests that changes in rain re-evaporation and the cloud longwave feedback help support heavy precipitation. Preliminary results also show improved MJO hindcast skill.

Mean Precipitation

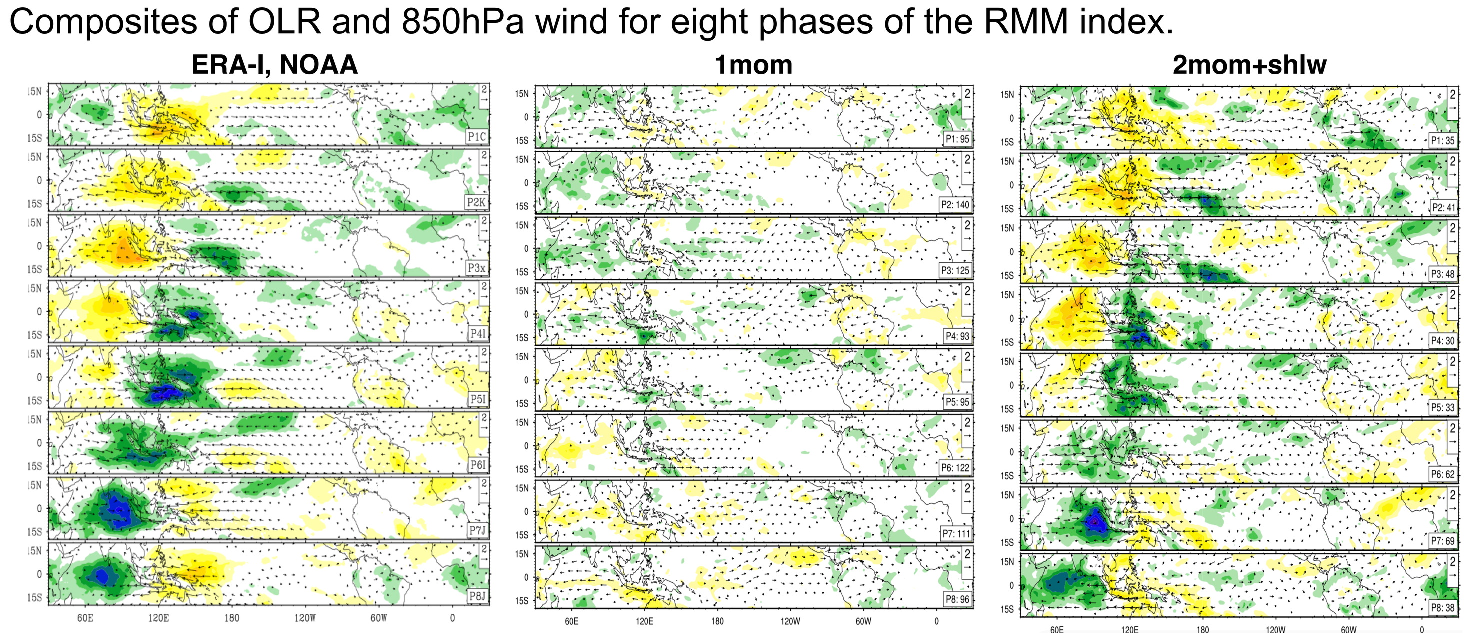


Stronger intraseasonal variability

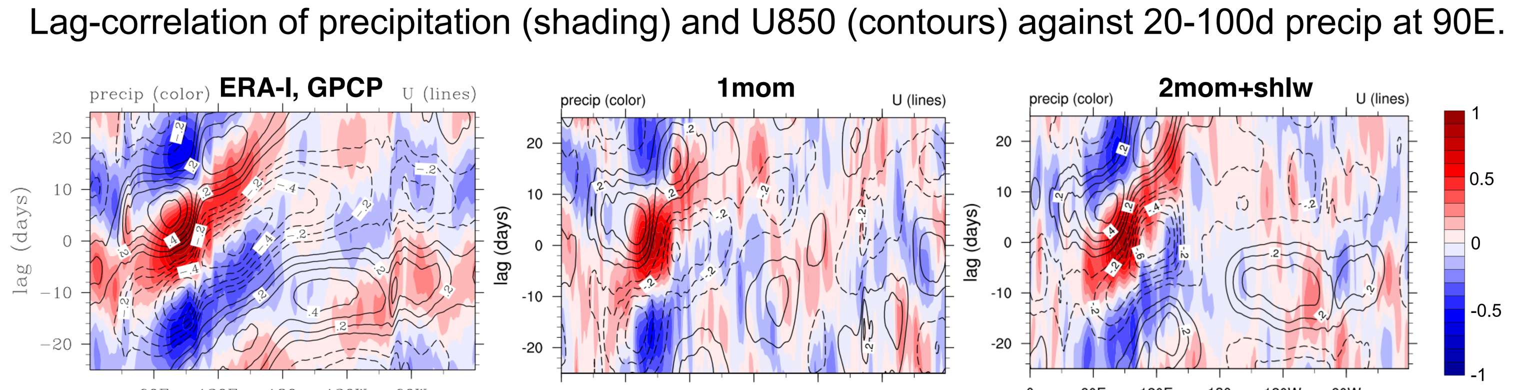
Maps of intraseasonal (20-100d) standard deviation.



Composites of OLR and 850hPa wind for eight phases of the RMM index.



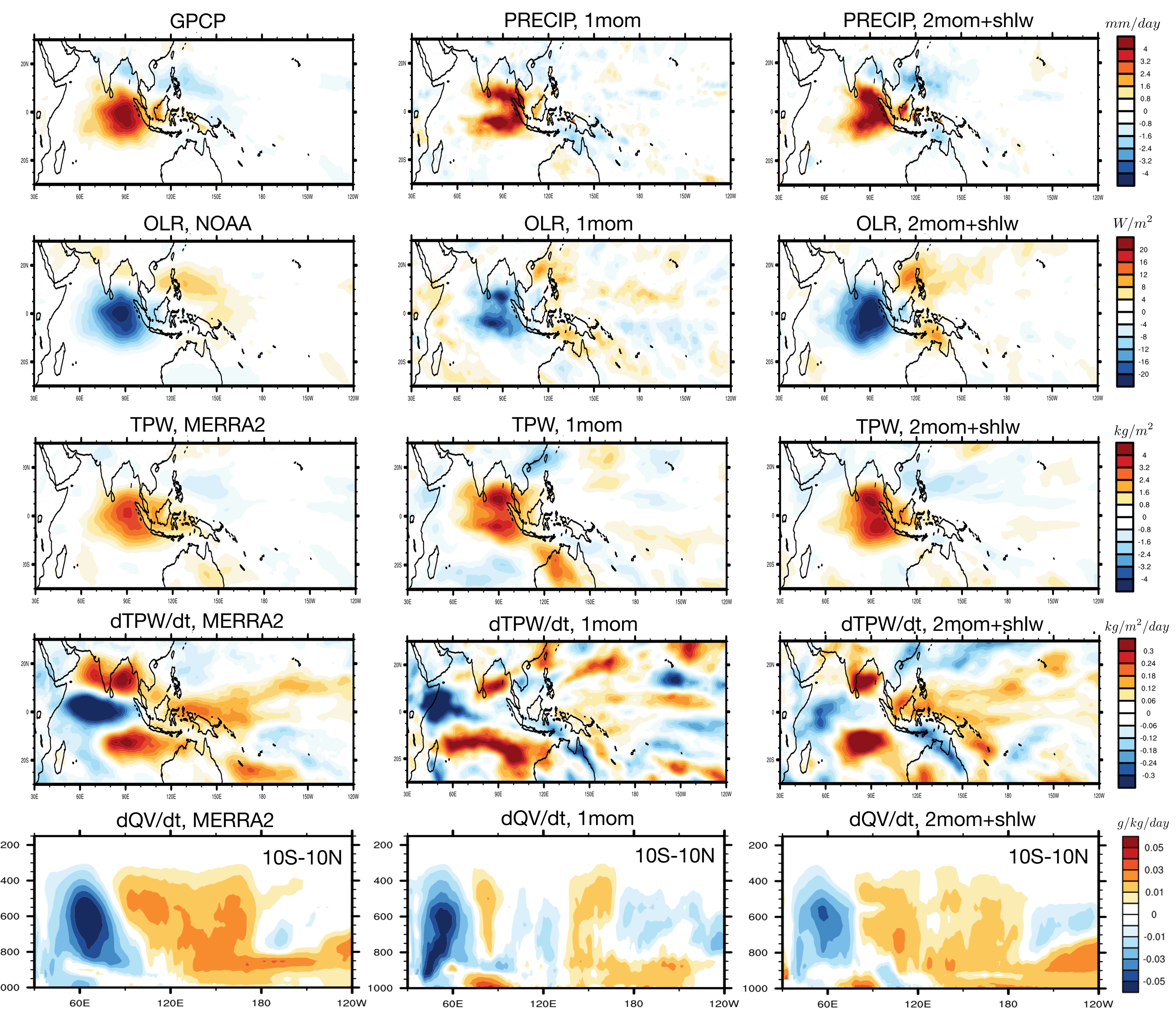
Lag-correlation of precipitation (shading) and U850 (contours) against 20-100d precip at 90E.



E-mail: nathan.arnold@nasa.gov | *Web:* gmao.gsfc.nasa.gov

Enhanced eastward moistening tendency

Anomaly fields regressed against 20-100 day precip averaged 80-100E, 10S-10N.



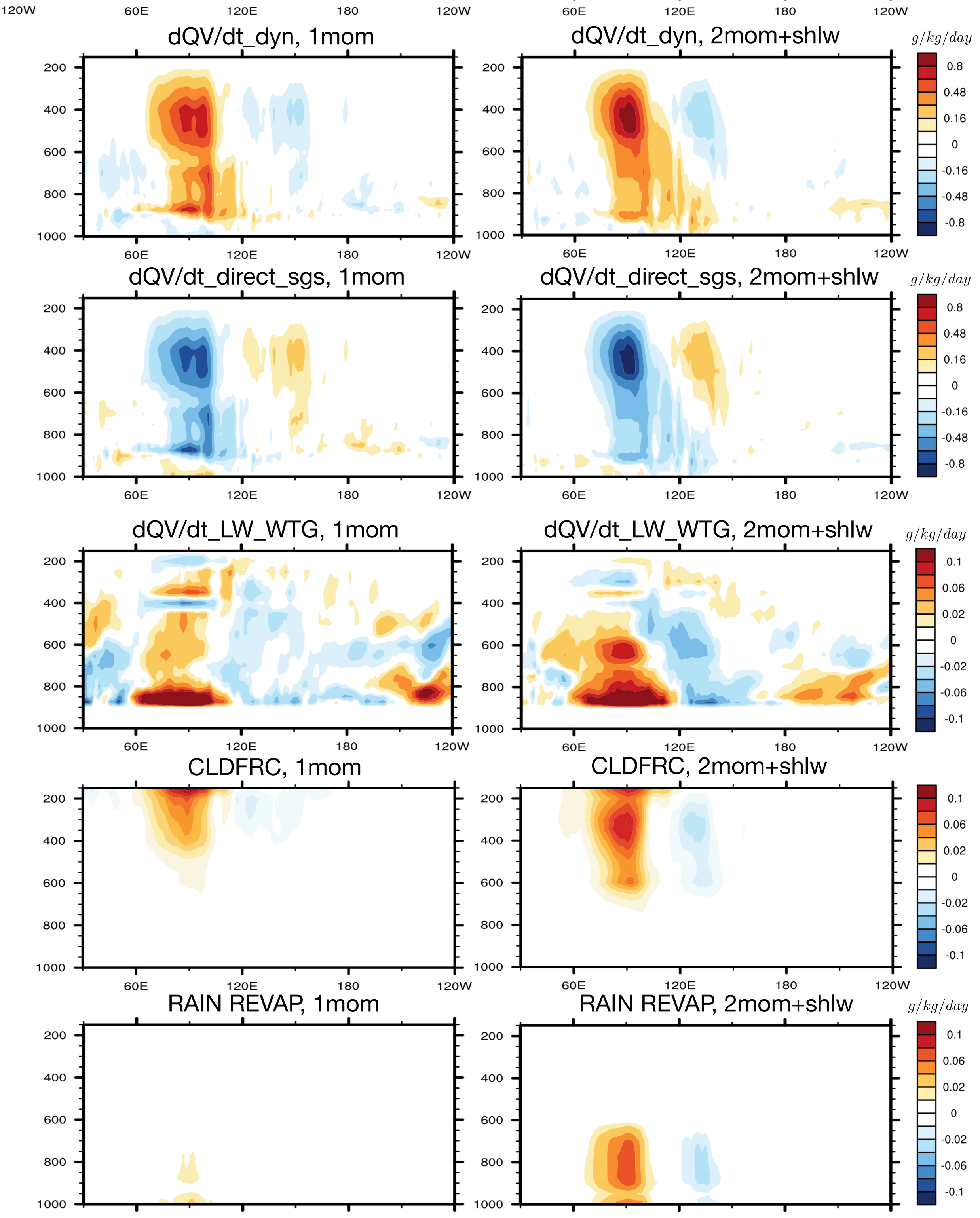
Significant increase in eastward moistening tendency.

Enhanced low level ascent east of the precipitation maximum.

Increased moistening associated with WTG response to anomalous longwave heating.

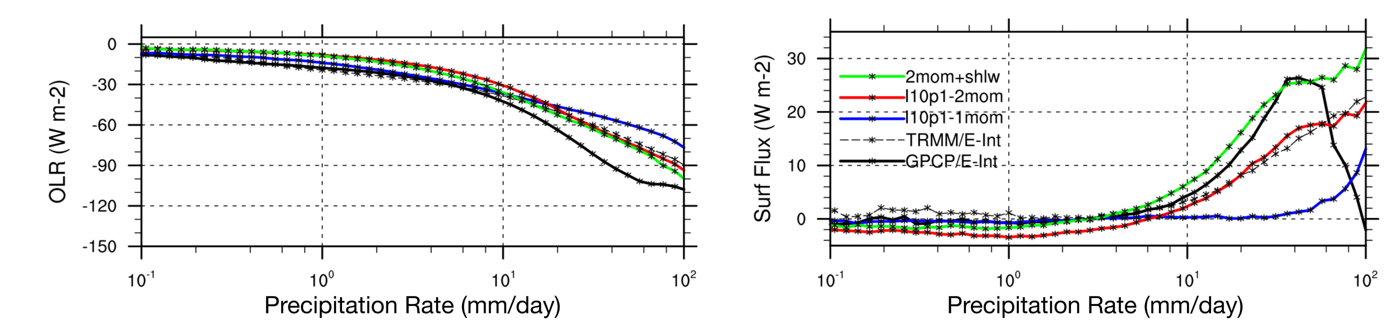
Longwave heating changes result from increased cloud fraction and ice content.

Enhanced re-evaporation of precipitation also contributes to moisture maintenance.



Stronger radiative and surface flux feedbacks

Anomalous OLR (left) and surface enthalpy flux (right) binned by precipitation rate (60-180E, 15S-15N). In updated model, heavy precipitation rates are associated with larger longwave and surface flux anomalies, in better agreement with observations.

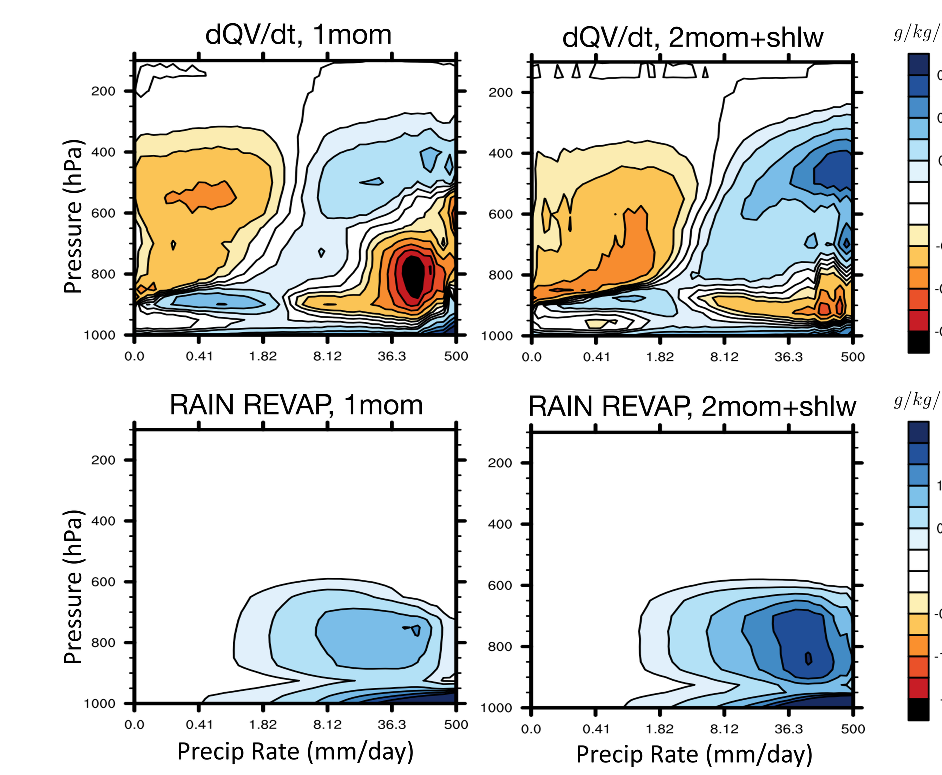


Reduced column drying with heavy precipitation

Humidity tendency profiles binned by precipitation rate (60-180E, 15S-15N).

1mom marked by excessive drying at high precip rates, weak moistening with moderate precip. **2mom+shlw** allows more continuous shallow-deep convection transition, better supports deep convection.

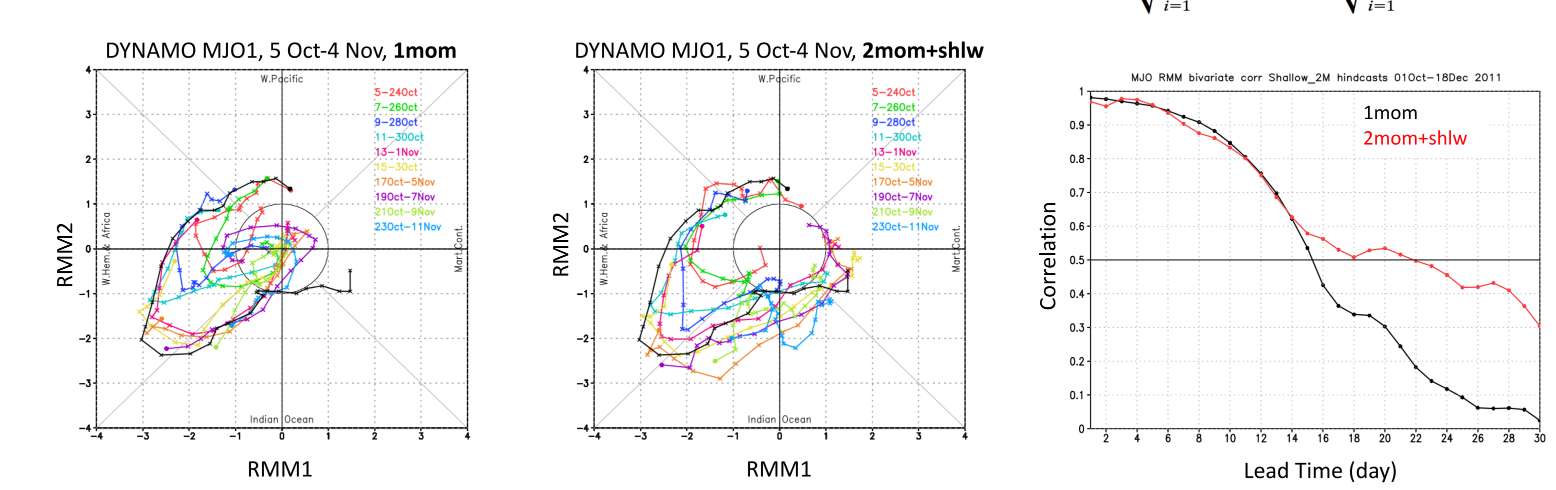
Enhanced re-evaporation of precipitation contributes to the tendency changes.



Impact on MJO Hindcasts for the DYNAMO period

Bivariate RMM correlation vs. hindcast lead time (right), and RMM phase diagrams (left). **2mom+shlw** maintains larger MJO amplitudes and extended period of skill.

$$\mathrm{COR}(\tau) = \frac{\sum_{t=1}^{N} [a_1(t)b_1(t) + a_2(t)b_2(t)]}{\sqrt{\sum_{t=1}^{N} [a_1^2(t) + a_2^2(t)]}\sqrt{\sum_{t=1}^{N} [b_1^2(t) + b_2^2(t)]}}$$



Conclusions

- The addition of 2-moment microphysics and a shallow cumulus parameterization leads to much stronger MJO activity in the GEOS model.
- The proximate cause is greater moistening coincident with and east of intra-seasonal precip over the Indian Ocean.
- Coincident moistening seems due to enhanced re-evaporation of precipitation, and shallow WTG ascent associated with an improved longwave feedback.
- Mechanisms of eastward moistening are less clear, but due in part to enhanced shallow ascent.

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