Vertical structure and physical processes of the Madden-Julian oscillation

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Diabatic processes in the MJO

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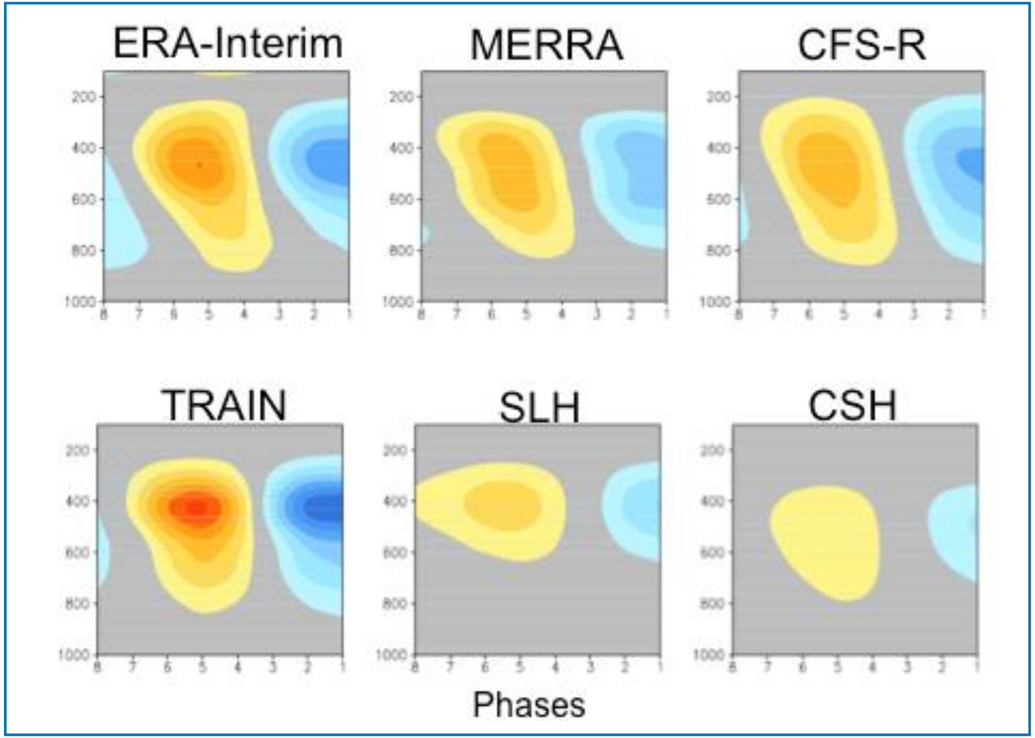

MJO composite heating anomalies from re-analysis products (top row) and satellite retrievals (bottom row), Jiang et al (2009, 2011).

- Interaction between diabatic processes and large-scale circulation thought to be crucial for the MJO and its representation in models.
- What component is most important? Role of heating vs. role of moistening.
- Uncertainty in shape, tilt and magnitude of heating profiles from observations/reanalysis.

Experiment Design

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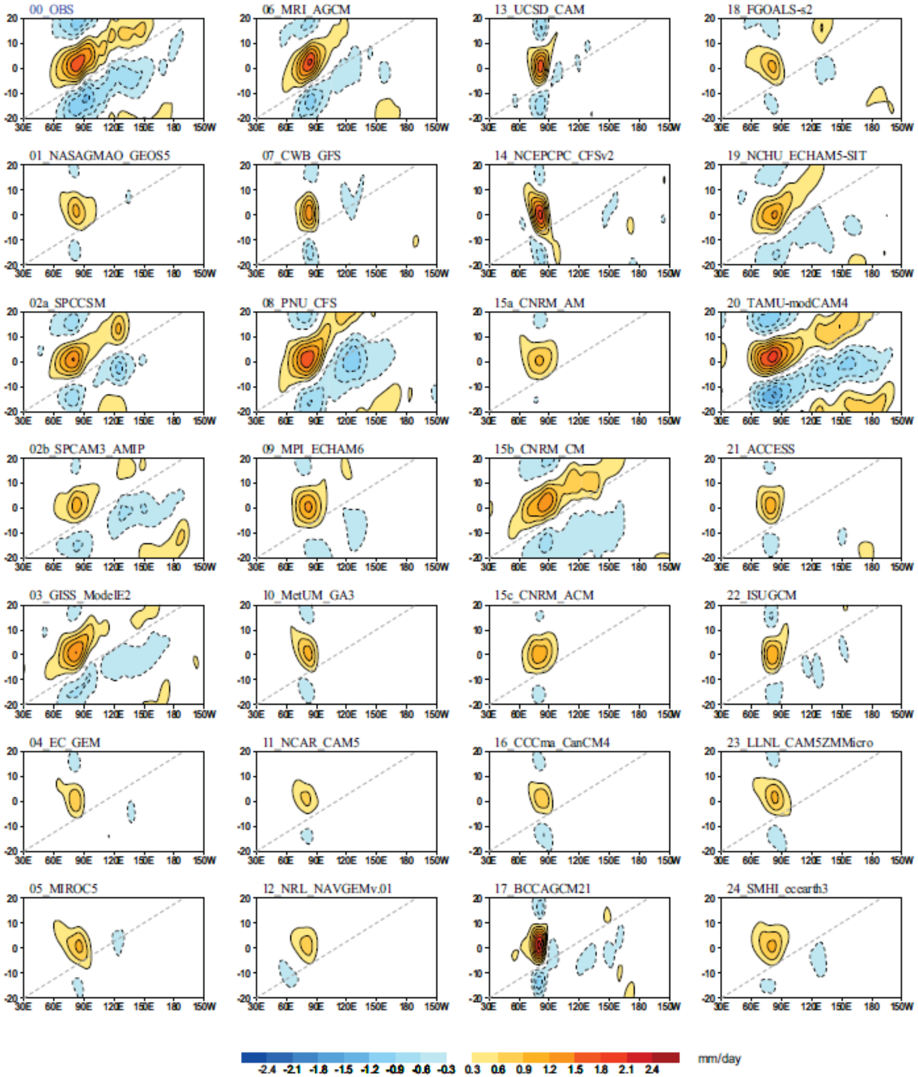
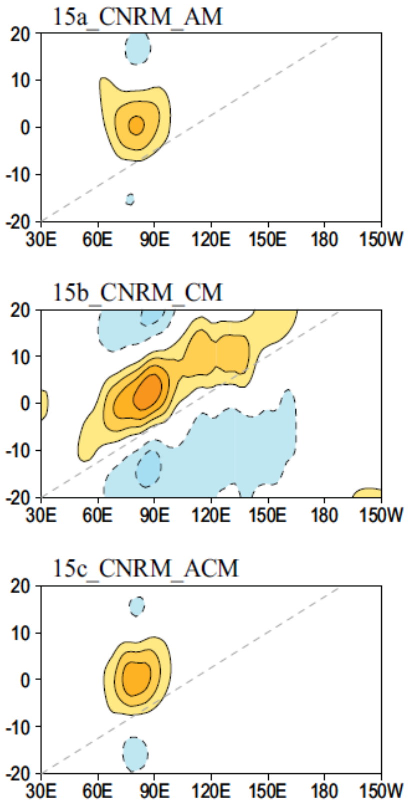
Experiment 1 20-year integrations	Overall MJO activity Global teleconnections Mean state errors	UCLA/JPL X. Jiang D. Waliser
Experiment 2 2-day hindcasts	Timestep-level analysis Physical tendencies Initial drift	Met Office P. Xavier J. Petch
Experiment 3 20-day hindcasts	Predictability Drift towards attractor Link experiments 1 & 2	NCAS / Reading N. Klingaman S. Woolnough

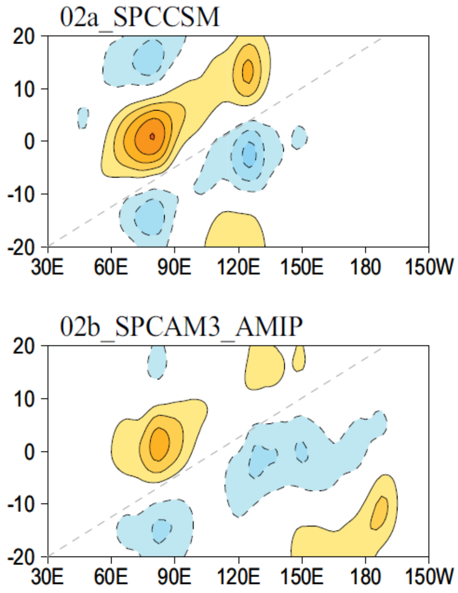
All data are now available! https://earthsystemcog.org/projects/gass-yotc-mip/
Endorsed by GASS, MJO Task Force and YoTC

Propagation in the Indian Ocean





Role of air-sea coupling



Jiang et al. (2015), *JGR*

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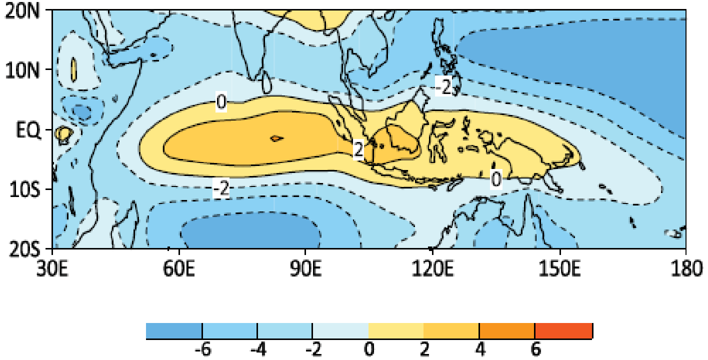
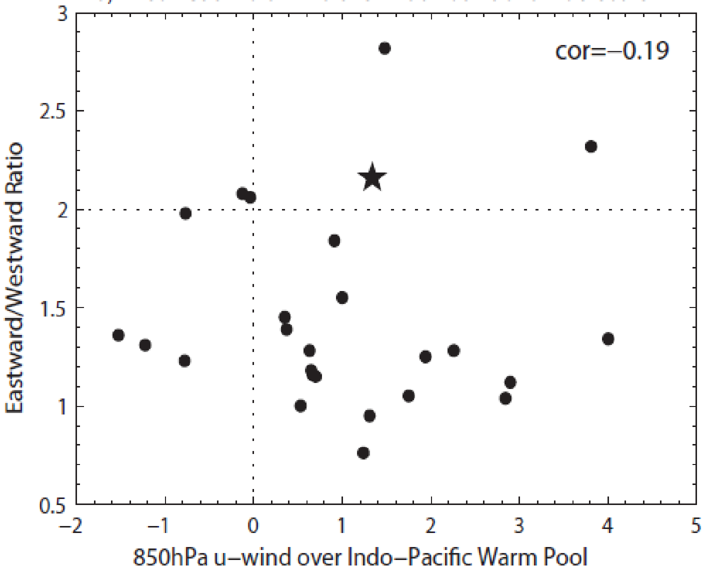
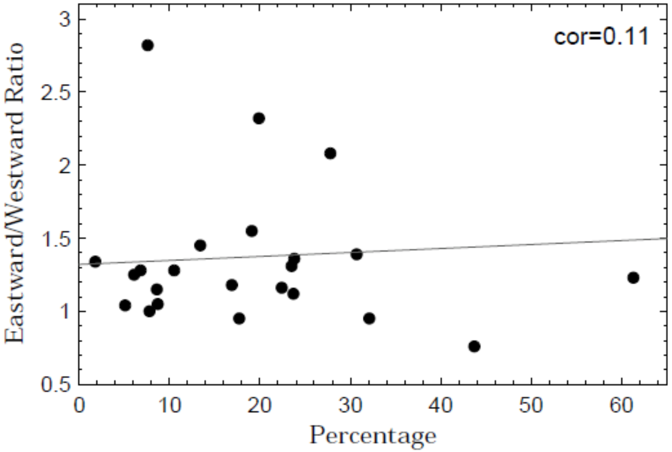
a) Winter mean 850hPa u-wind



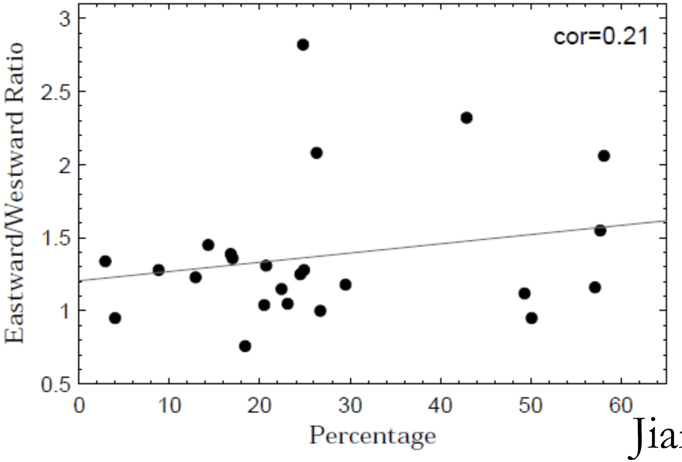
b) Mean 850hPa u-wind over Indo-Pacific and MJO Score



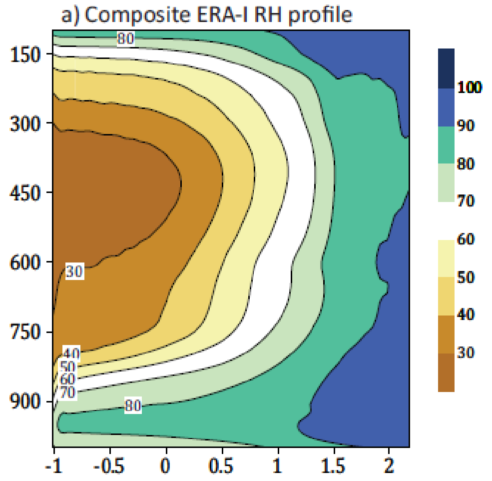
a) Grid−scale Partition to Total Mean Rainfall

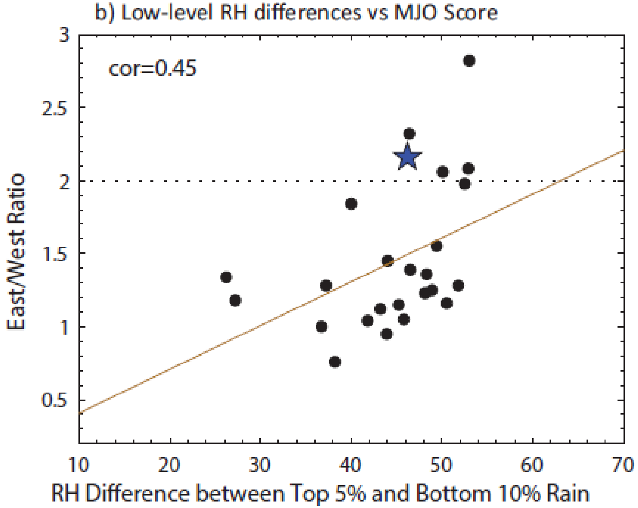


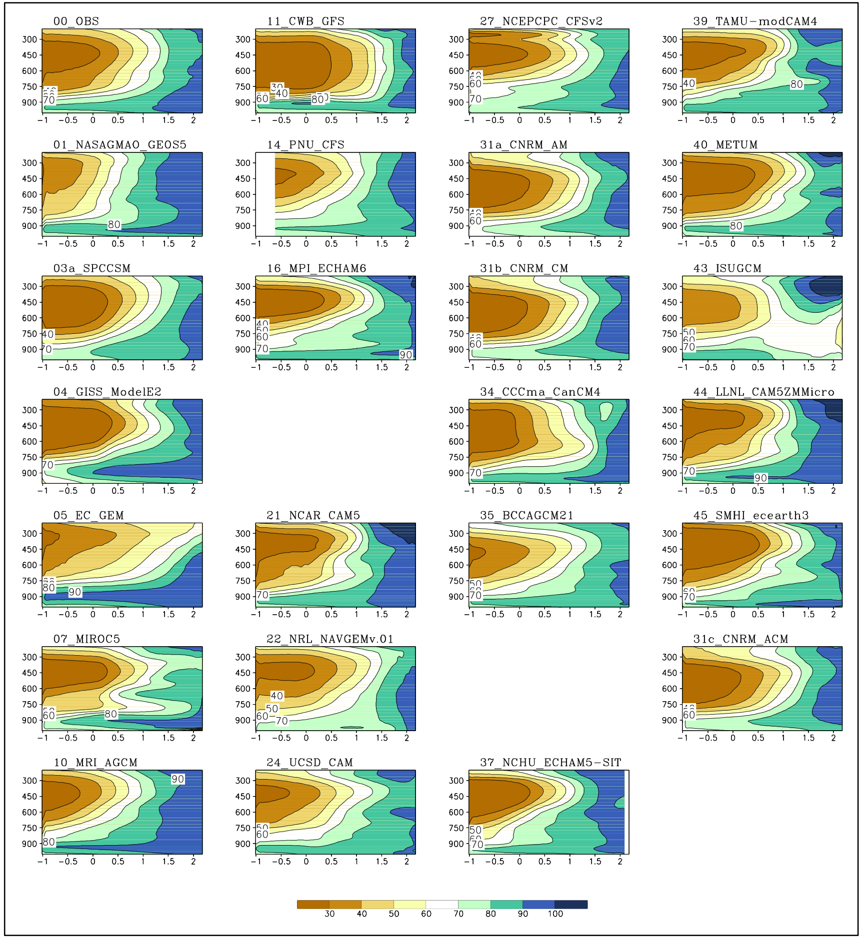
b) Grid−scale Parition to STD of Total Rainfall ISV



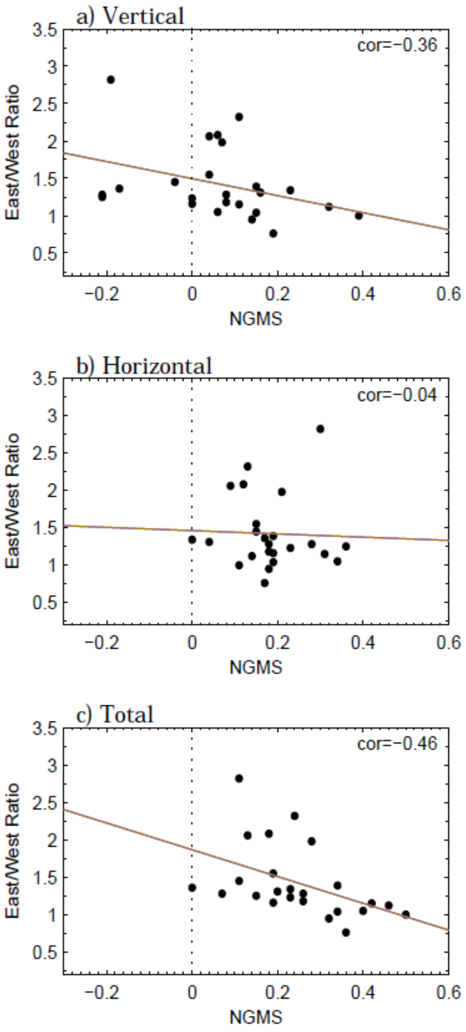
Jiang et al. (2015), *JGR*







Jiang et al. (2015), *JGR*



Normalised Gross Moist Stability

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- Essentially the ratio of (a) to (b), where
  - (a) = Change of moist entropy within the column
  - (b) = Convective intensity within the column
- Efficiency with which convection removes moisture from the column, relative to import from large-scale convergent circulation.
- Positive NGMS (stratiform heating): convection removes moist static energy from column very efficiently → damps instabilities.
- Negative NGMS (shallow/congestus heating): convection is inefficient in removing moist static energy → promotes instabilities.

Jiang et al. (2015), *JGR*

Vertical structure of the MJO

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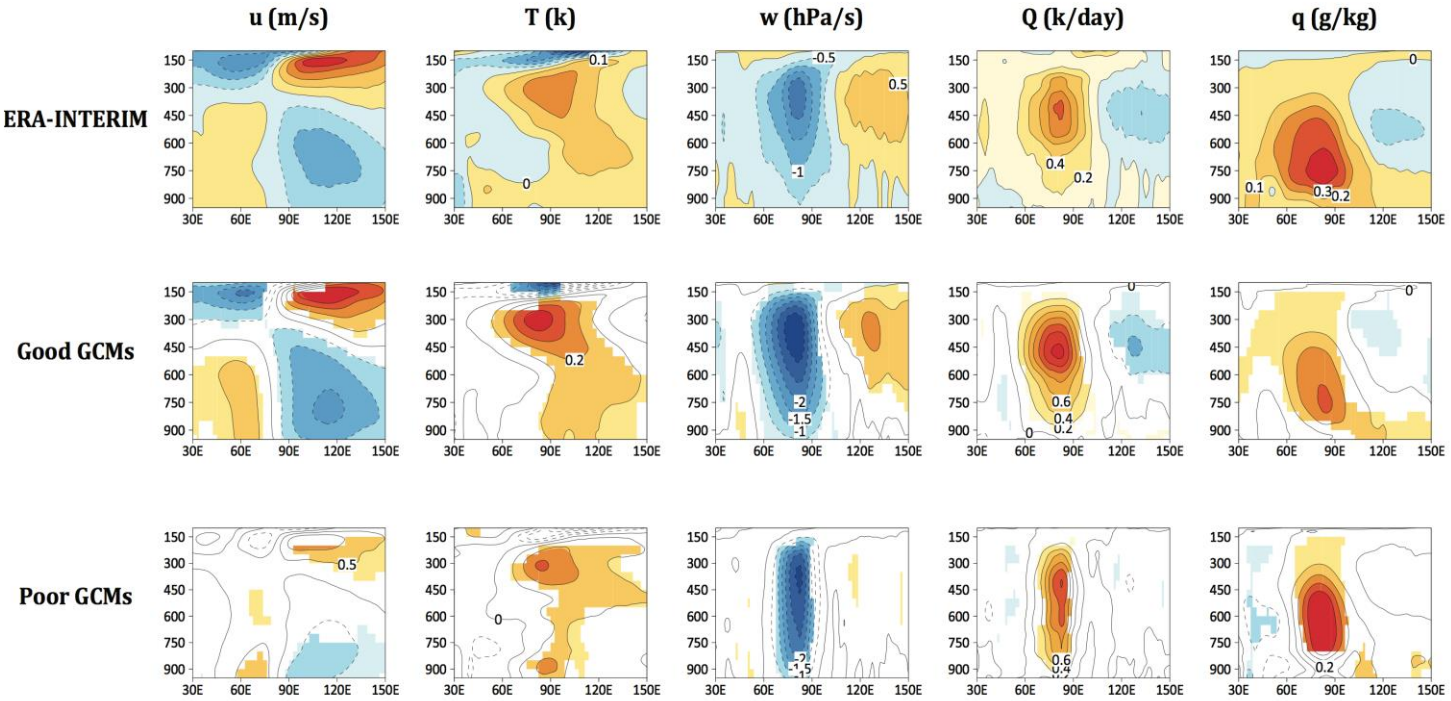


Regressions on intra-seasonally filtered rainfall at 75-85E and 5S-5N.

Models with high MJO fidelity (by propagation) show tilted heating, as well as stronger easterly anomalies and warm temperatures to the east of MJO convection.

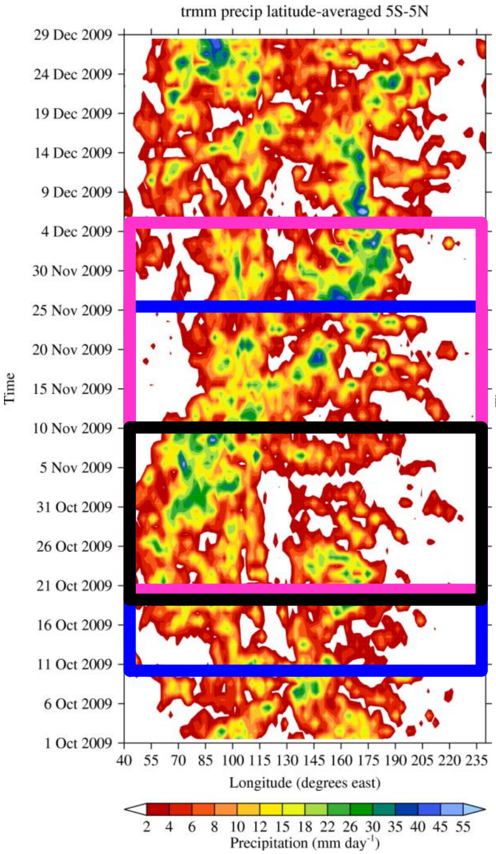
Jiang et al. (2015), *JGR*

Hindcast experiments

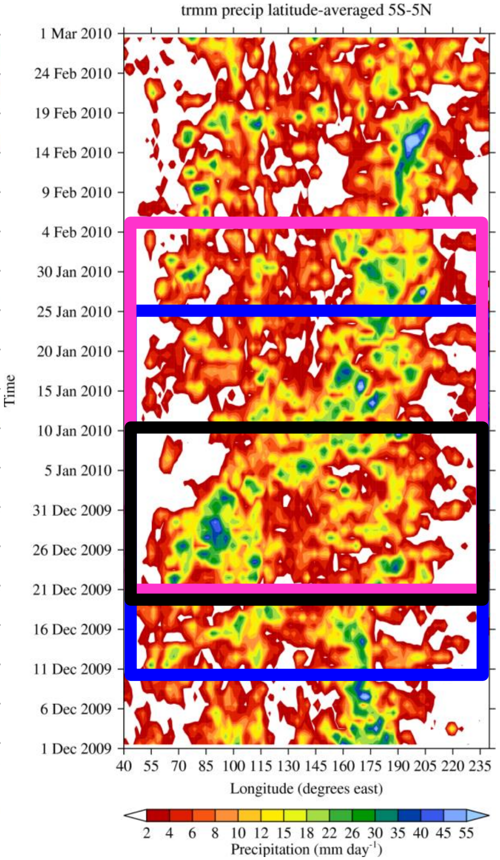
- 20-day hindcasts
  - initialized every day in the **blue** rectangles (47 days per case) to capture MJO genesis and lysis at 10 days' lead time (**pink** rectangles)
  - 3-hr output: prognostic and surface fields globally; sub-grid tendencies (T, q, u, v) 50S-50N

- 2-day hindcasts
  - initialized every day in the **black** rectangle (22 days/case)
  - timestep output over Warm Pool (10S-10N, 60E-180)

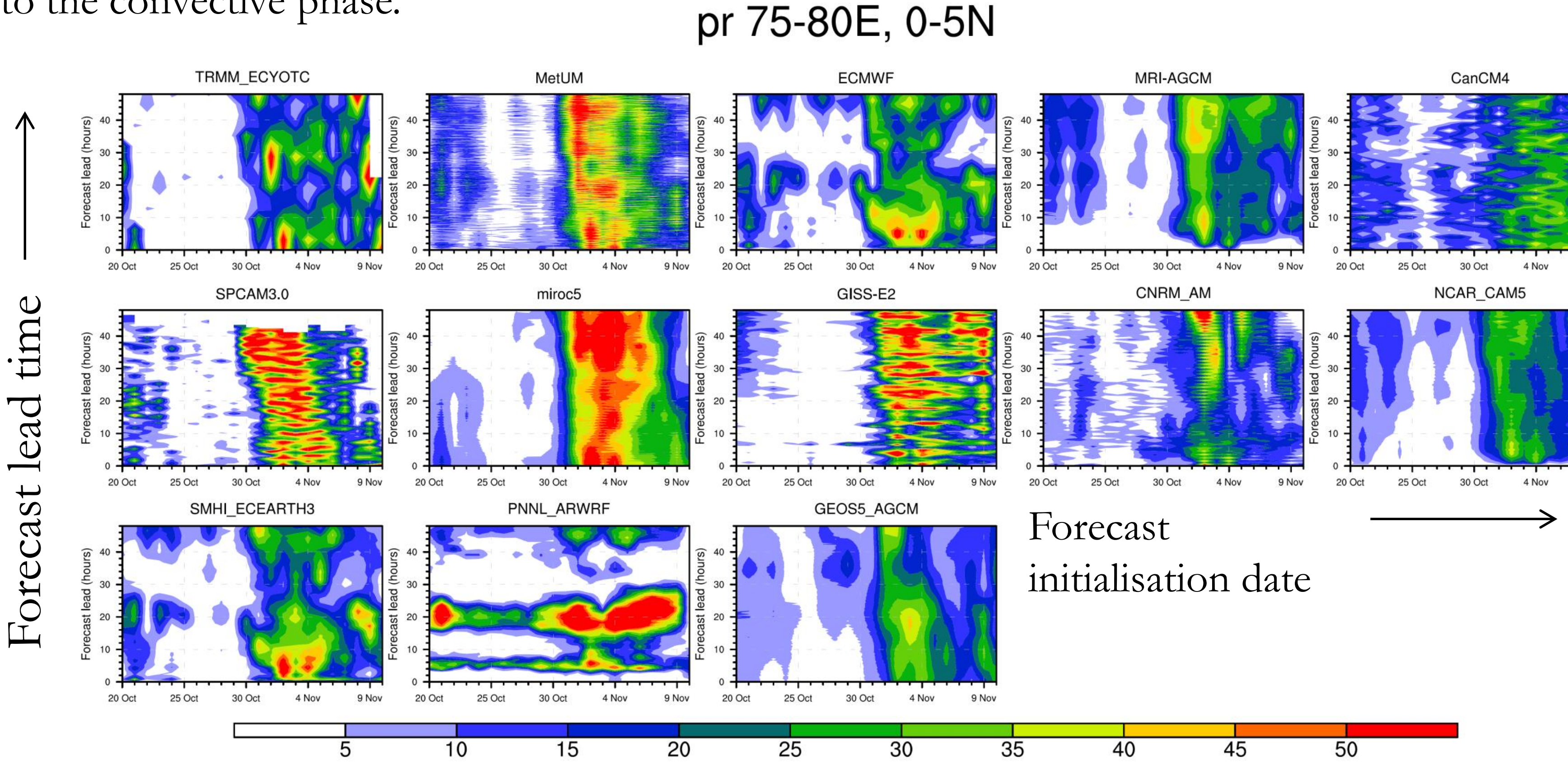
YoTC Case E



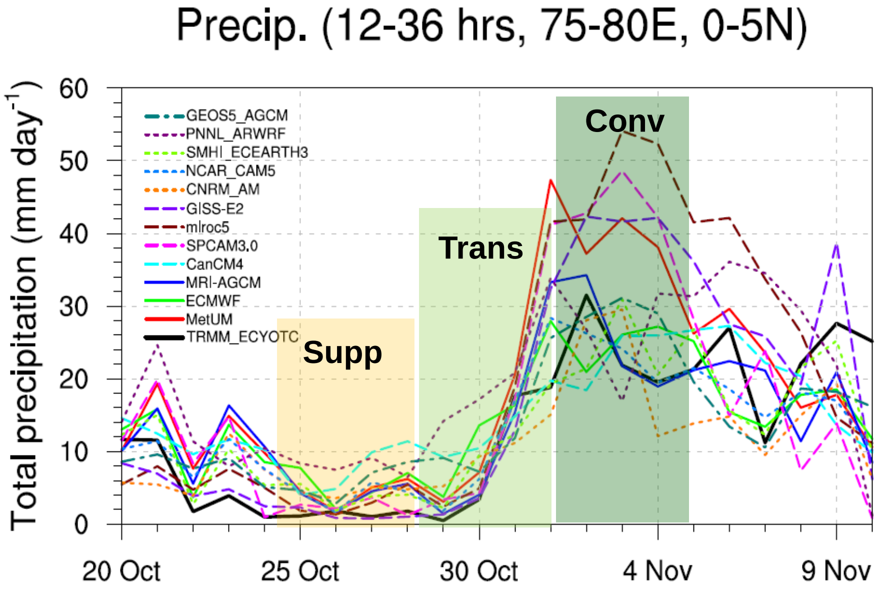
YoTC Case F

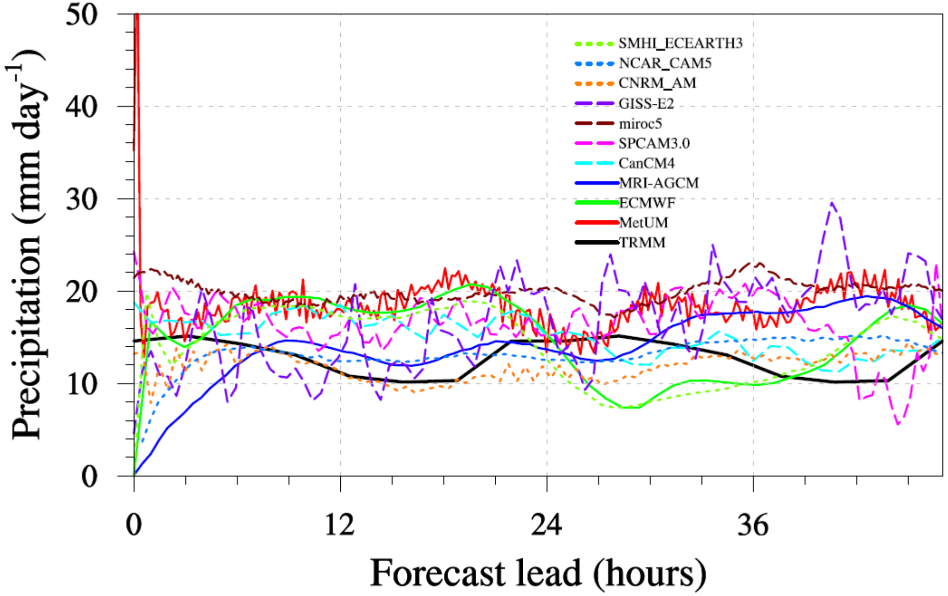


Most models are unable to forecast the transition from the suppressed to the convective phase.



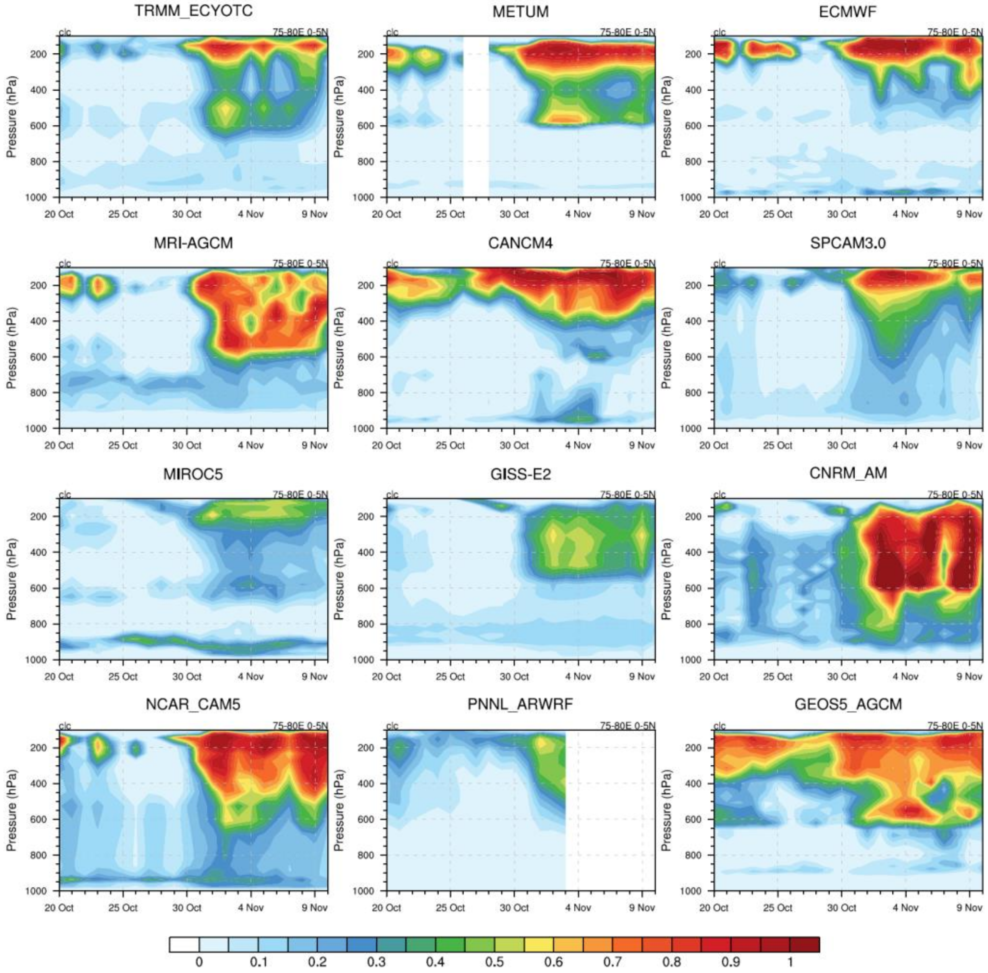
Xavier et al. (2015), *JGR*





Xavier et al. (2015), *JGR*

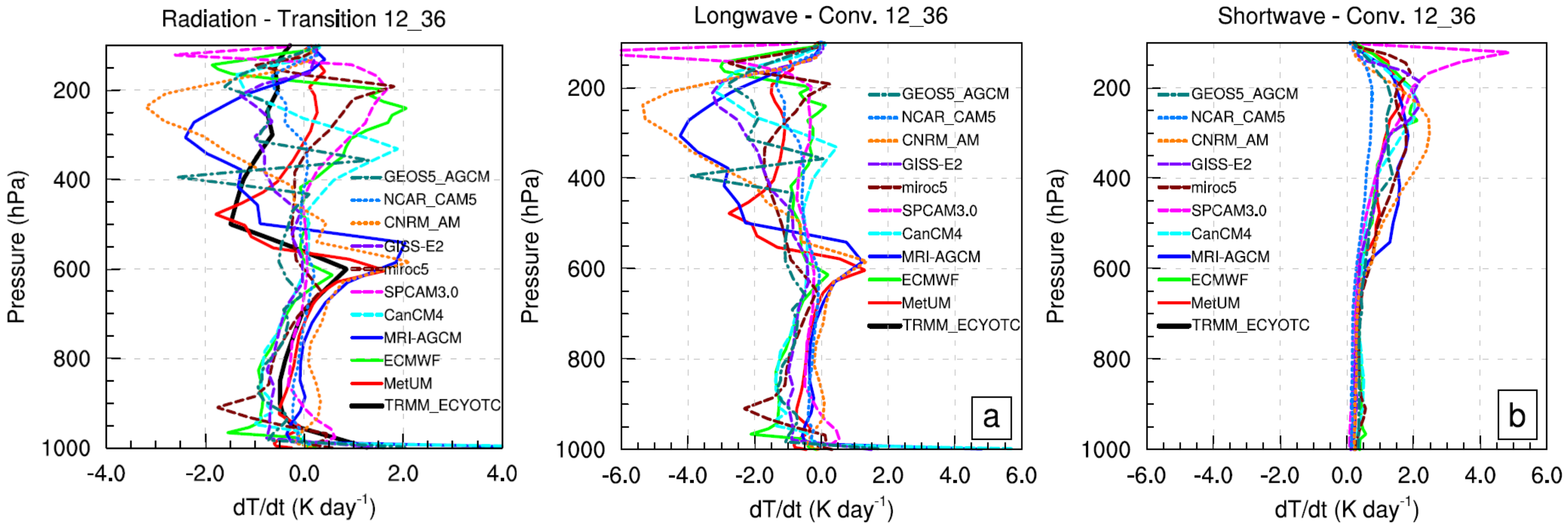
Total cloud fraction in 75-80E, 0-5N



- There are disparities among models in the vertical profiles of cloud cover in all phases.
- There is also variability in the differences between the suppressed and convective phases (e.g., CNRM shows large differences between these phases, while GEOS5 shows almost no difference).

Xavier et al. (2015), *JGR*

Radiative-heating rates during the convective phase



Xavier et al. (2015), *JGR*

Differences in temperature and specific humidity

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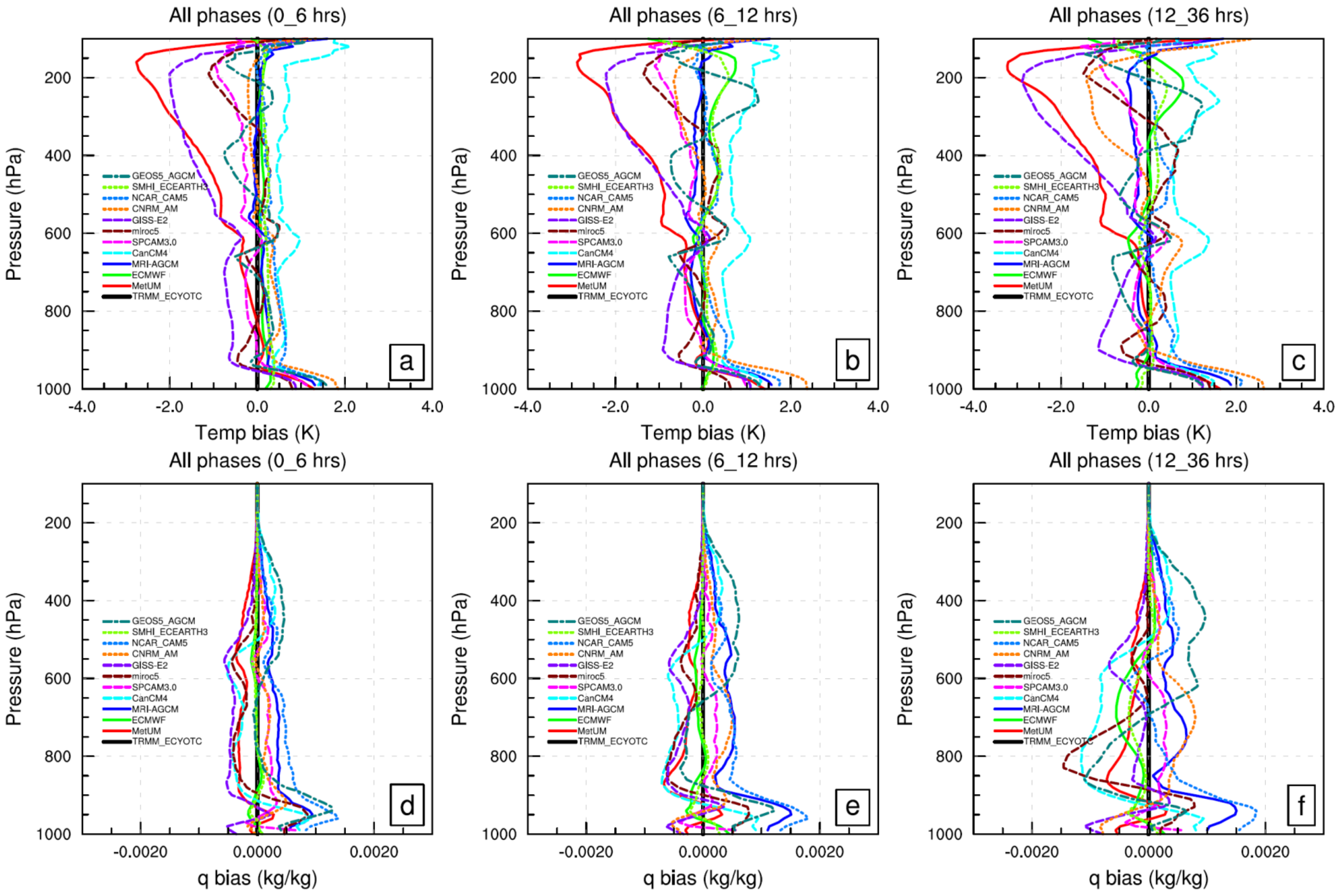

Differences computed against high-resolution YoTC analyses (from ECMWF)

Some upper-level temperature features linked to differences in radiative-heating profiles and in vertical profiles of cloud cover.

Xavier et al. (2015), *JGR*

20-day hindcast performance

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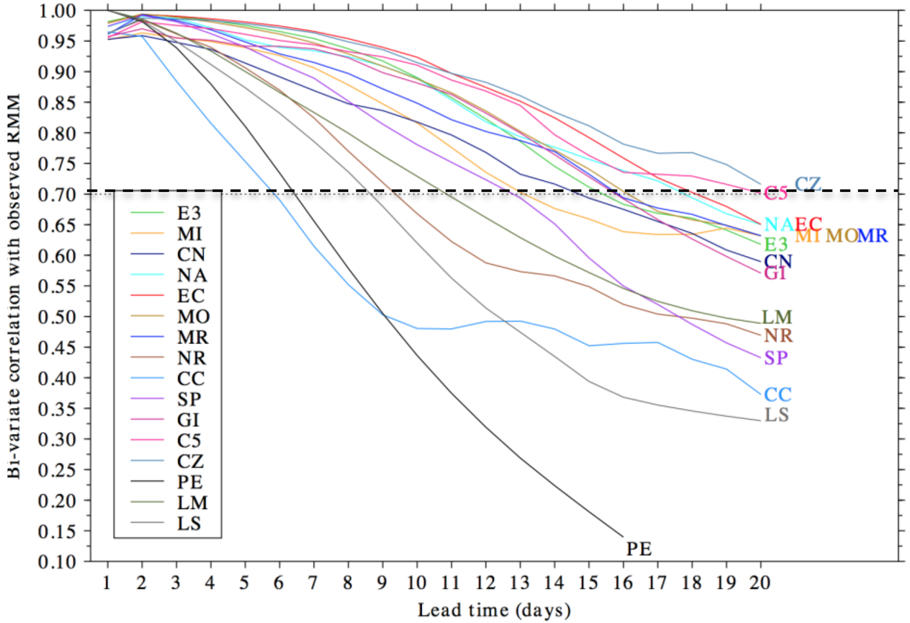
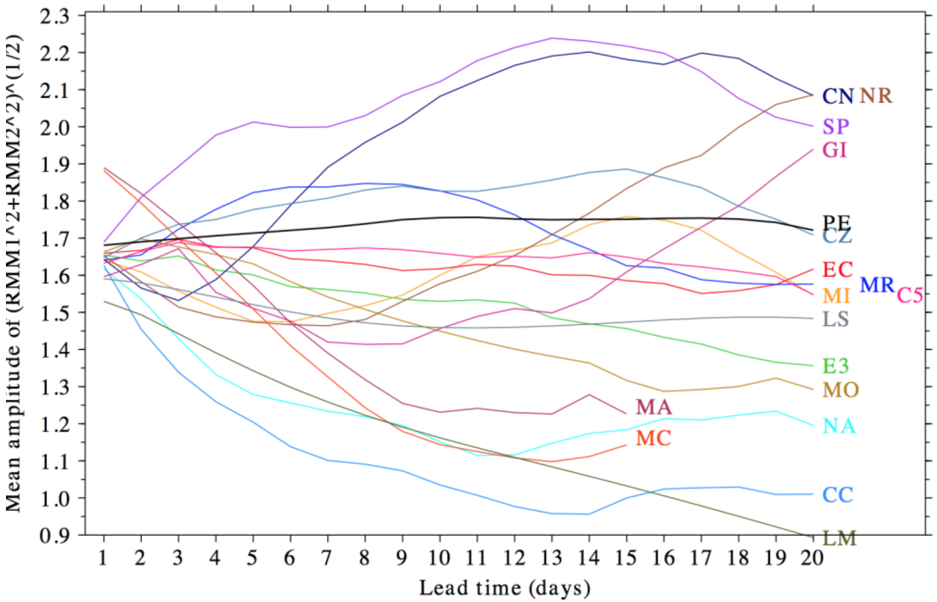
RMM bi-variate correlation



RMM amplitude



Models that maintain the observed RMM amplitude tend to have high bi-variate correlations, but not vice versa.

Klingaman et al. (2015a), *JGR*

Hindcast vs. climate performance

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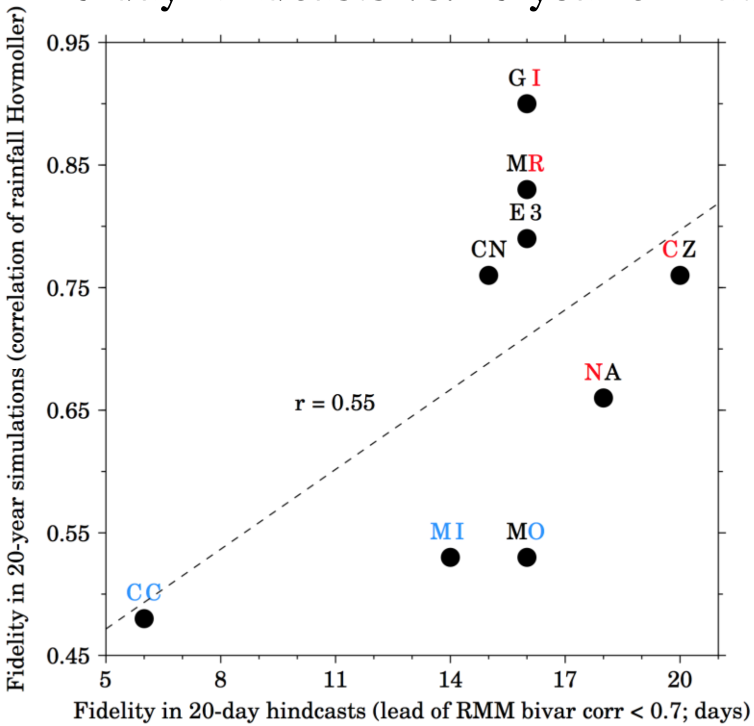
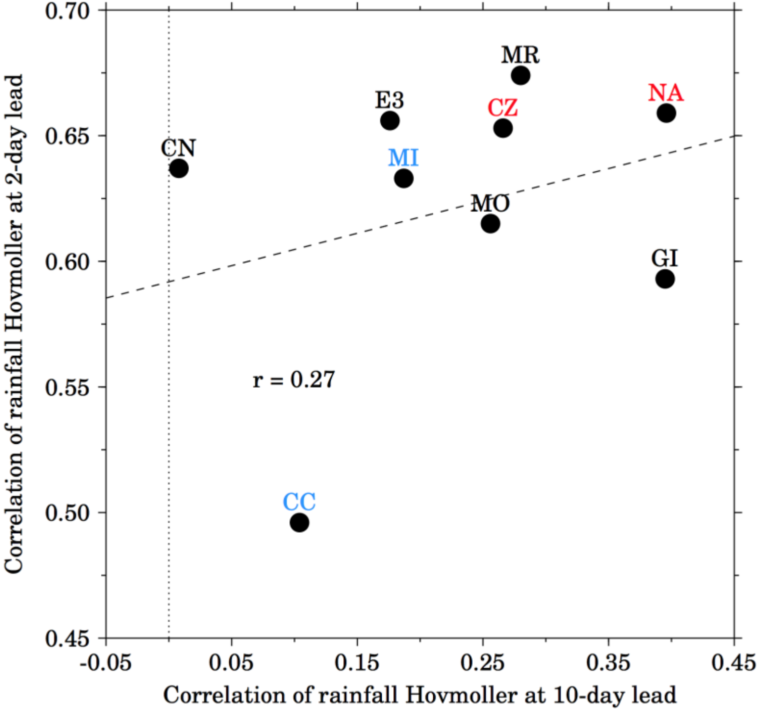
20-day hindcasts vs. 20-year climate



20-day hindcasts vs. 2-day hindcasts



Klingaman et al. (2015b), *JGR*

Diabatic heating profiles

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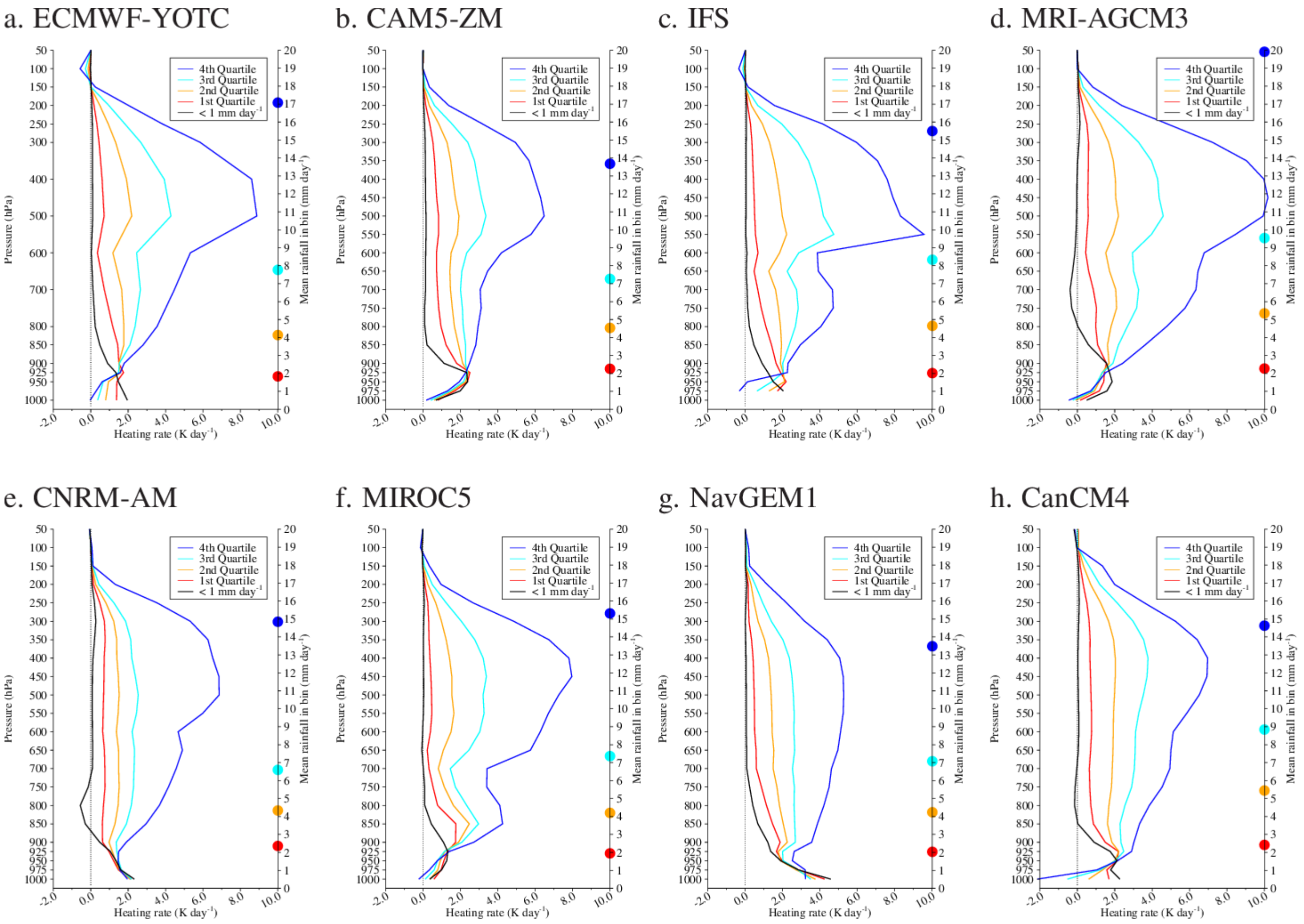


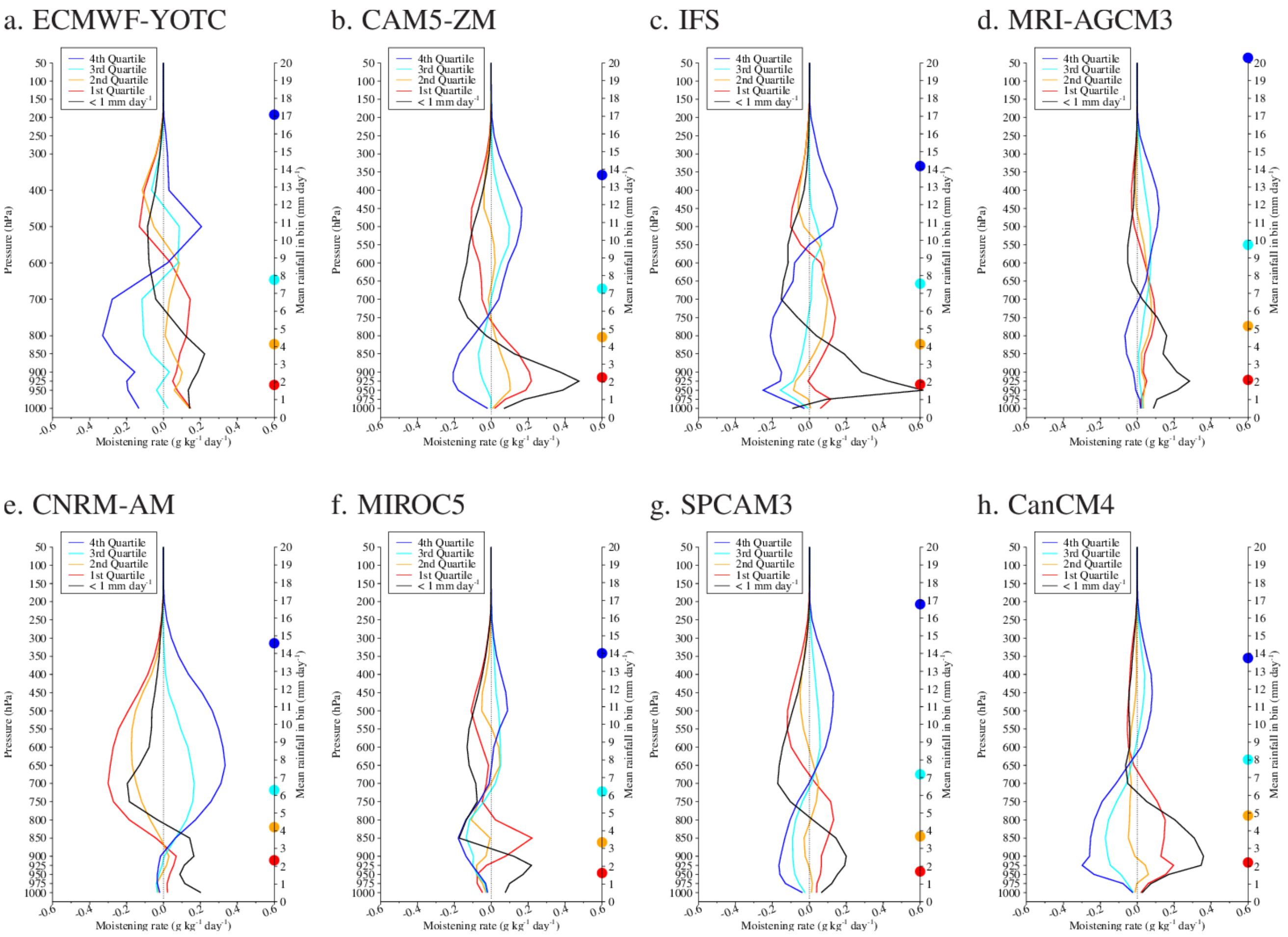
Panels are ordered by model performance.

Composite heating profiles for rain-rate quartiles from **dry** to **wet**. **Black** line for rates < 1 mm/day.

No relationship between shape of the heating profile and model performance.

Klingaman et al. (2015a), *JGR*

Net moistening profiles



Composite net moistening (dq/dt) profiles for rain-rate quartiles from **dry** to **wet**. **Black** line for rates < 1 mm/day.

Models with better performance have low and/or mid-tropospheric moistening in driest two precipitation quartiles.

Klingaman et al. (2015a), *JGR*

Net moistening profiles

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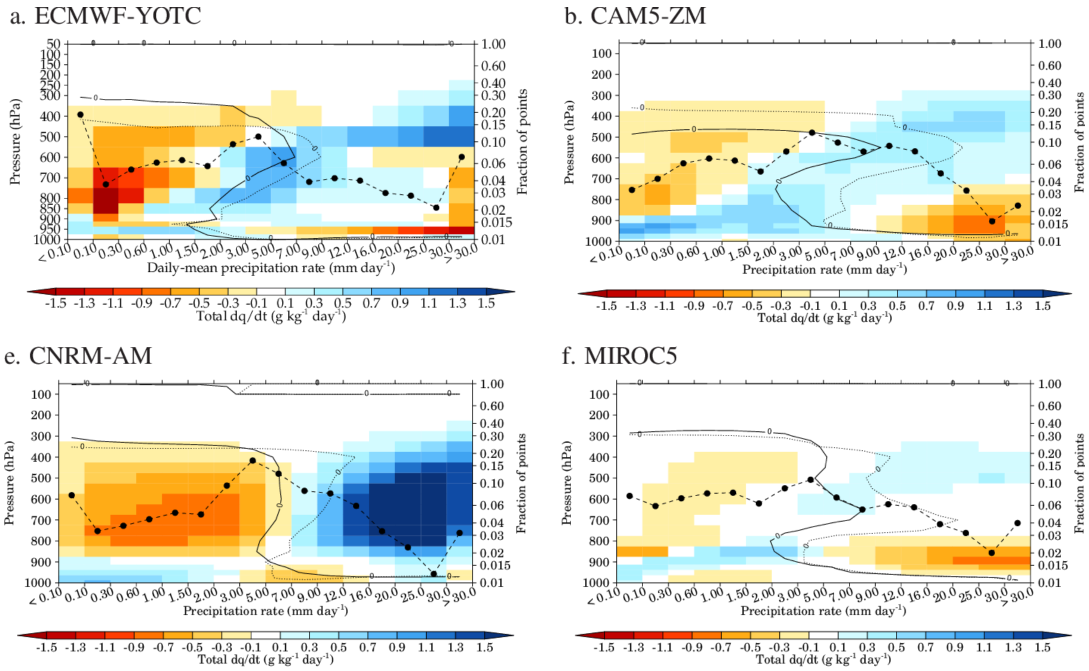

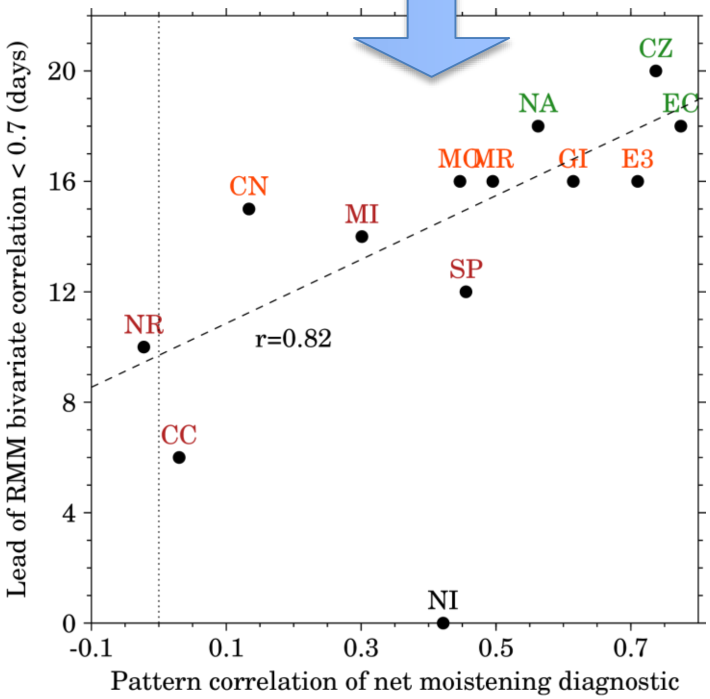

Higher-performing models (like CAM5-ZM) show a clear transition from low-level moistening for light rainrates to upper-level moistening for heavy rainrates

Klingaman et al. (2015a), *JGR*

Net moistening metric

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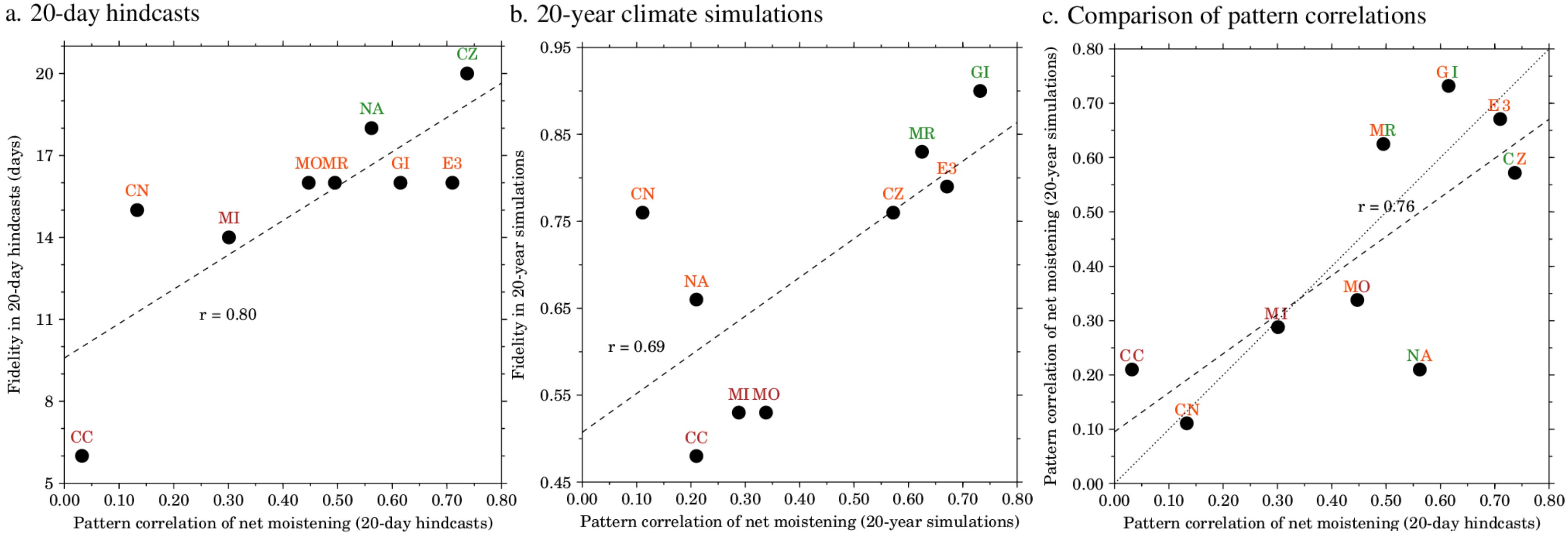

The net moistening metric also distinguishes between higher- and lower-fidelity models in the 20-year climate simulations. The metric accounts for variations in performance between the two experiments.

Klingaman et al. (2015b), *JGR*

RH-precipitation metric

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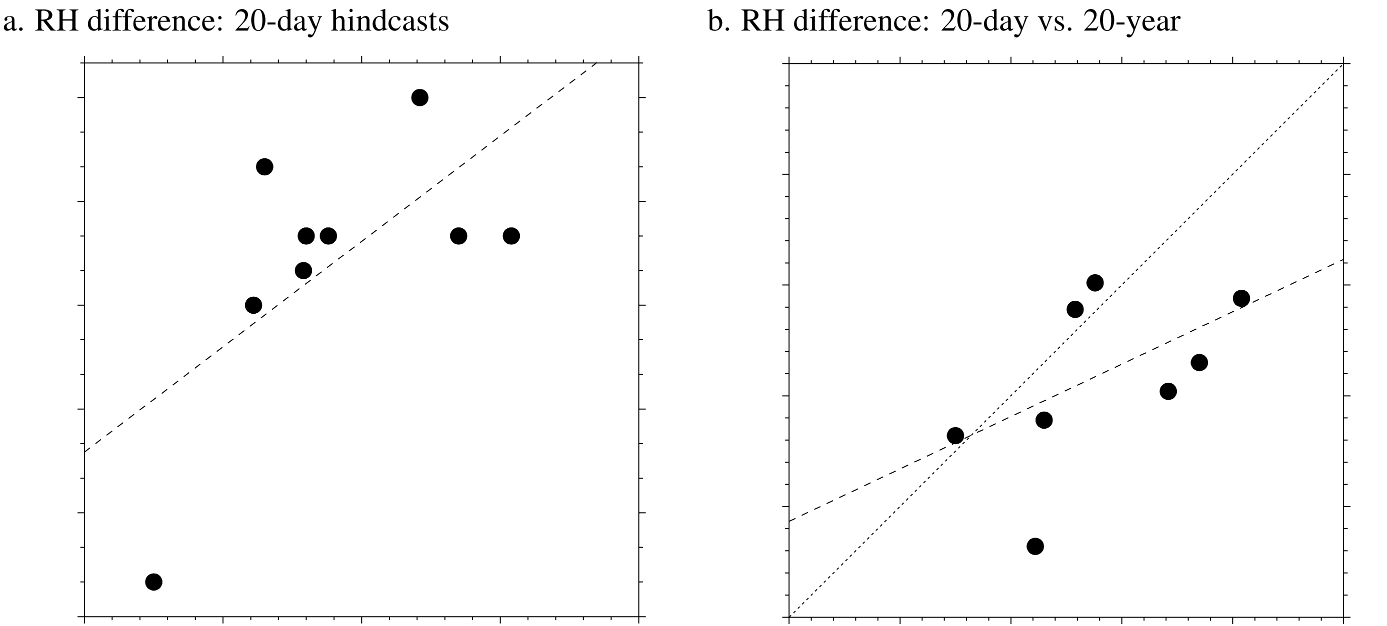

850-500 hPa mean RH

Difference between heaviest 5% and lightest 10% of daily rain rates at each gridpoint, averaged over the Warm Pool

High values indicate ability to suppress rainfall in dry environments.

Lower correlations between this metric and fidelity in 20-day hindcasts than with fidelity in climate simulations.

Klingaman et al. (2015b), *JGR*

Summary and conclusions

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- The "Vertical structure and physical processes of the MJO" project provides a rich dataset, including sub-grid tendencies, for analysis of many phenomena beyond the MJO. Data are available! https://earthsystemcog.org/projects/gass-yotc-mip/

- We found a modest relationship between MJO fidelity and net moistening, with the highest-fidelity models showing low- and mid-level moistening at light to moderate rain rates, from both sub-gridscale physics and resolved dynamics.

- We found no relationships between MJO fidelity and the shape of the diabatic-heating profile or its evolution with increasing precipitation rate.

- Models that performed well in hindcast mode (for these two cases) did not necessarily perform well in climate mode, and vice versa. The net-moistening metric accounts for these variations in performance.