The Madden Julian Oscillation in CESM2: *Sensitivity to Indo-Pacific Surface Conditions*

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Overview

The Madden Julian Oscillation (MJO) is frequently deficient in climate models. Its absence can cause into question the fidelity of simulated tropical climates and the reliability of future changes in sub-seasonal variability that have an established dependence on the MJO. These includes tropical cyclones, monsoons and ENSO. The commonly proposed remedies for the poor performance are improved atmospheric physics or increased resolution.

However, there are potentially other sources for the bias given the experience with the MJO in the recent release of the NCAR Community Earth Sytem Model (CESM2). The questions raised are:

- **What is the barrier impact of the Maritime Continent (MC)?**
- **How important are surface flues over the MC?**
- **Is the MJO sensitive to SST distributions in the Indo-Pacific region?**

Maritime Continent Experiments

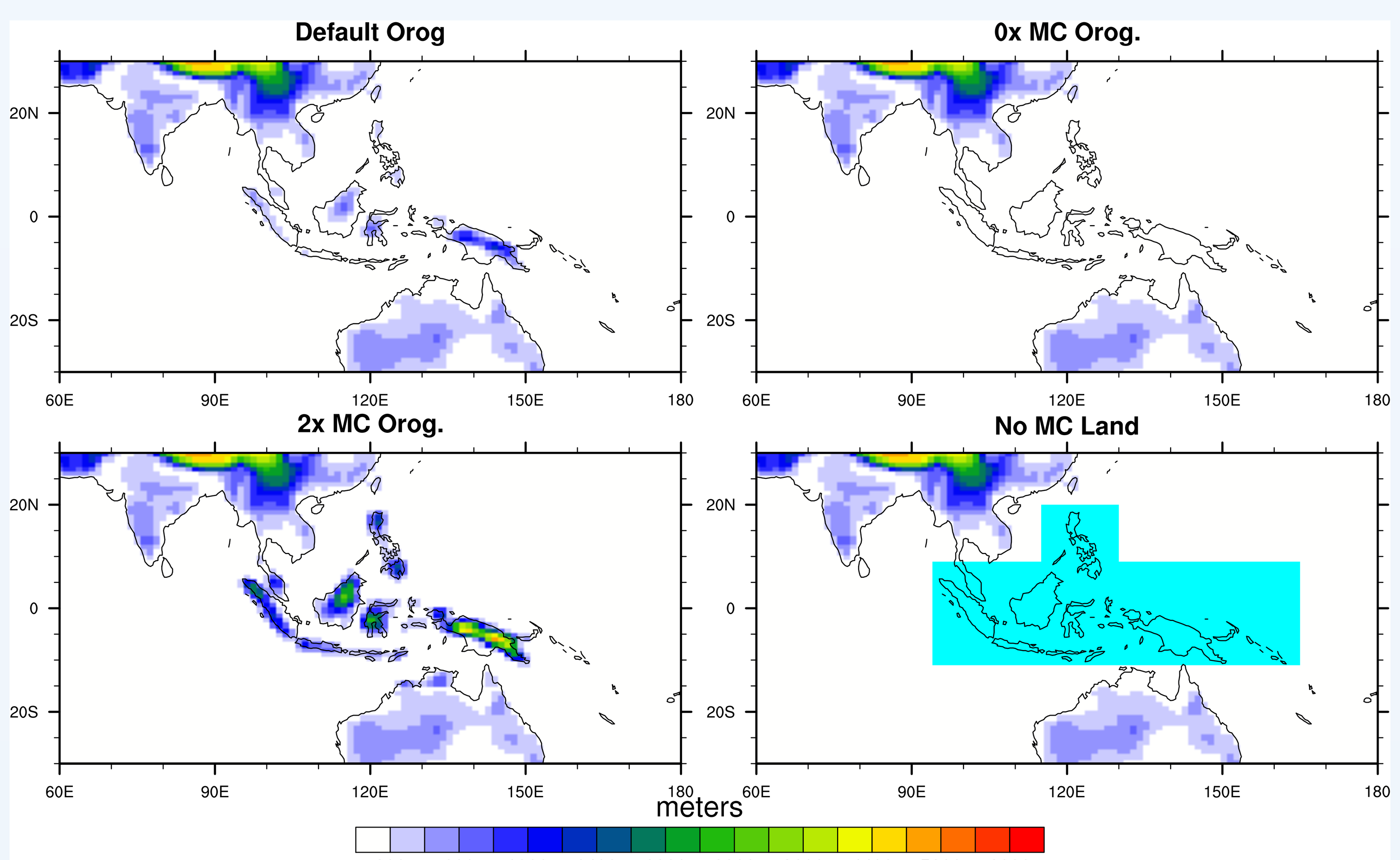
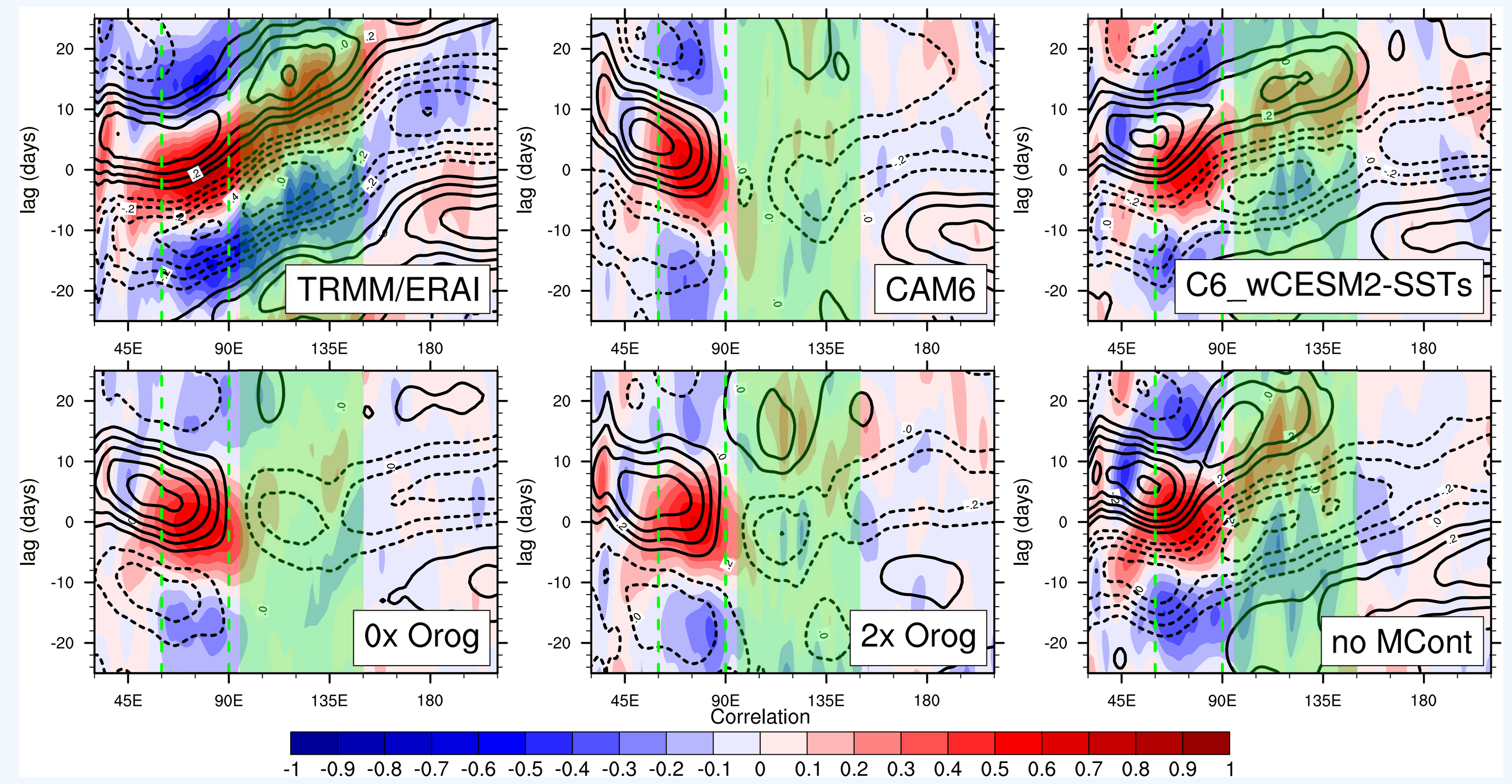


Figure 1: Maritime continent AMIP sensitivity experiments modifying the surface boundary forcing datasets.

Experiments

- AMIP sensitivity experiments from 1979-2005
- CAM6 configuration (1 degree/30 vertical levels)
- Modification of regional surface datasets
- Barrier impact on the MJO (e.g., Zhang and Ling 2017)
  - *0x MC Orography*
  - *2x MC Orography*
- Surface flux impact on MJO (e.g., Neale et al. 2008)
  - *Remove MC Islands -> interpolated SSTs*
- Investigate role of prescribed SSTs on MJO
  - Transplant CESM2 interactive SSTs into CAM6 AMIP

The Role of the Surface Forcing



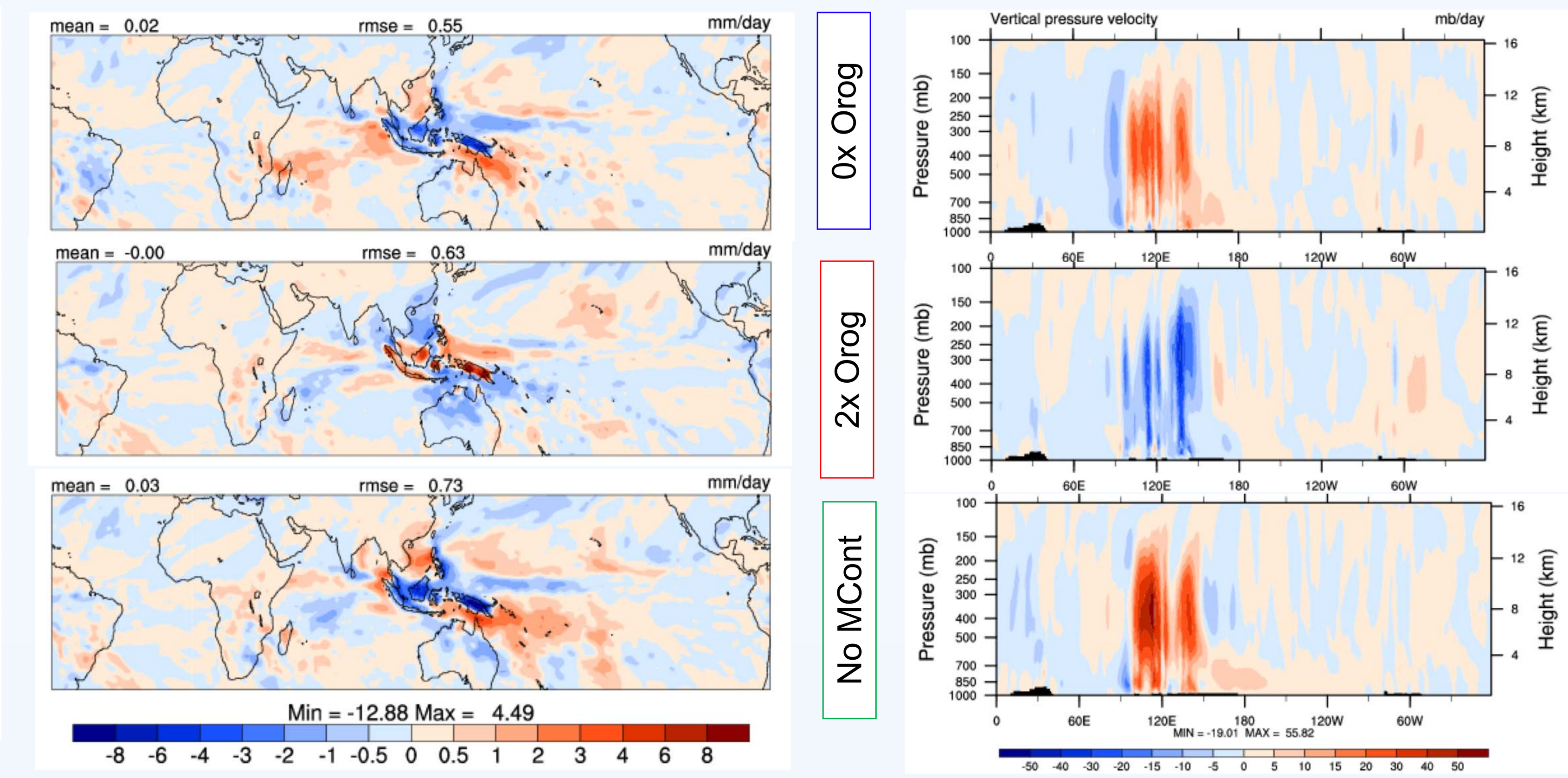


Figure 2: (Top Left) 15S-15N lag correlation of 20-100 day filtered precipitation in the Indian Ocean (green lines) with precipitation (colors)and 850-mb zonal wind (contours) at all other longitude. Broad MC region shown in shaded green.

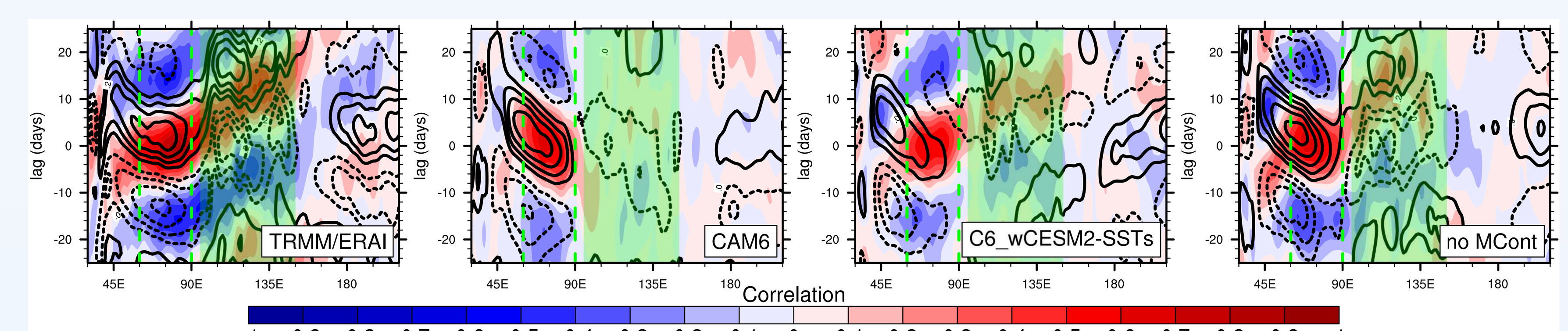
Figure 3: (Top) Perturbations of precipitation (mm/day) and vertical omega velocity (mb/day) for the three MC experiments.

Figure 4: (Bottom) As Figure 2, but correlating against surface latent heat fluxes (lines) for a sub-set of cases (contours).

Influence of MC Islands

- Decreasing/increasing orography weakens/strengthens precipitation and Walker circulation (WC)
- MJO does not improve; no barrier effect?
- Removing land mask of MC 'looks' like 0x mean climate
- **BUT** MJO is significantly improved; surface flux impact?
- Latent heat flux coupling traverses the MC

- Prescribing CESM2 coupled SSTS improves MJO
- Mean state feedbacks?



What is special about CESM2?

Interactive Ocean and Physics

- CESM2 has continuous propagation of MJO across the MC
- Low-level flow in quadrature with precipitation
- Warm surface temperature anomalies lead precipitation anomalies
- Are temperature anomalies necessary to maintain MJO across MC?

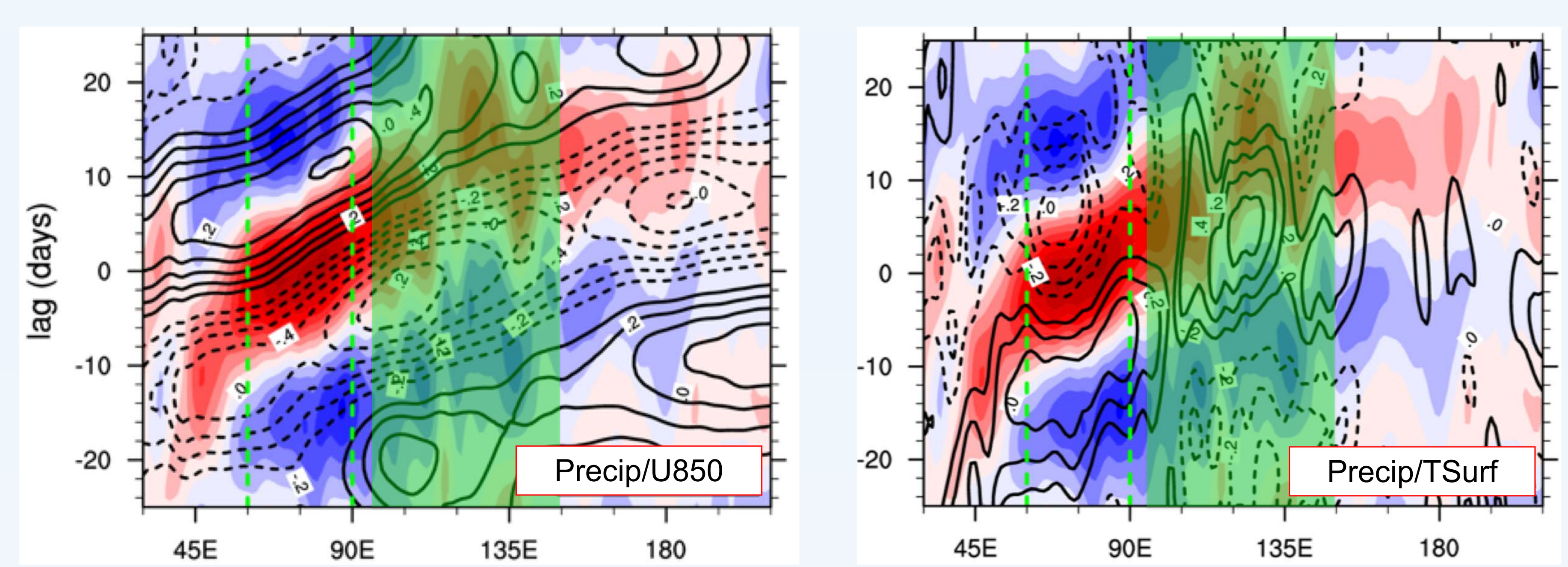


Figure 5: CESM2 lag correlation of 20-100 day filtered precipitation in the Indian Ocean with precipitation at other longitudes (colors) and with [LEFT] 850-mb zonal wind (lines) and [RIGHT] surface temperature(lines)at all other longitudes

Summary

CAM6 and CESM2 MJO

- Significant improvements in CESM2
- Coherent propagation over the MC
- Improvements not seen in CAM6 AMIP
- MC orography is not a barrier to propagation

- Removing MC islands has similar mean climate impacts to reducing orography
- **BUT** MJO propagation is much improved -> CESM2
- Similarly using CESM2 SSTs as AMIP-type boundary conditions improves propagation
- Each sees more coherent coupling to surface LH fluxes
- Surface temperature anomalies not necessary for driving the MJO

References

Neale, R., & Slingo, J. (2003). The Maritime Continent and Its Role in the Global Climate: A GCM Study. Journal of Climate, 16(5), 834–848.

Zhang, C., & Ling, J. (2017). Barrier Effect of the Indo-Pacific Maritime Continent on the MJO: Perspectives from Tracking MJO Precipitation. Journal of Climate, 30(9), 3439–3459