The MJO in YOTC TRMM Data and the GISS GCM

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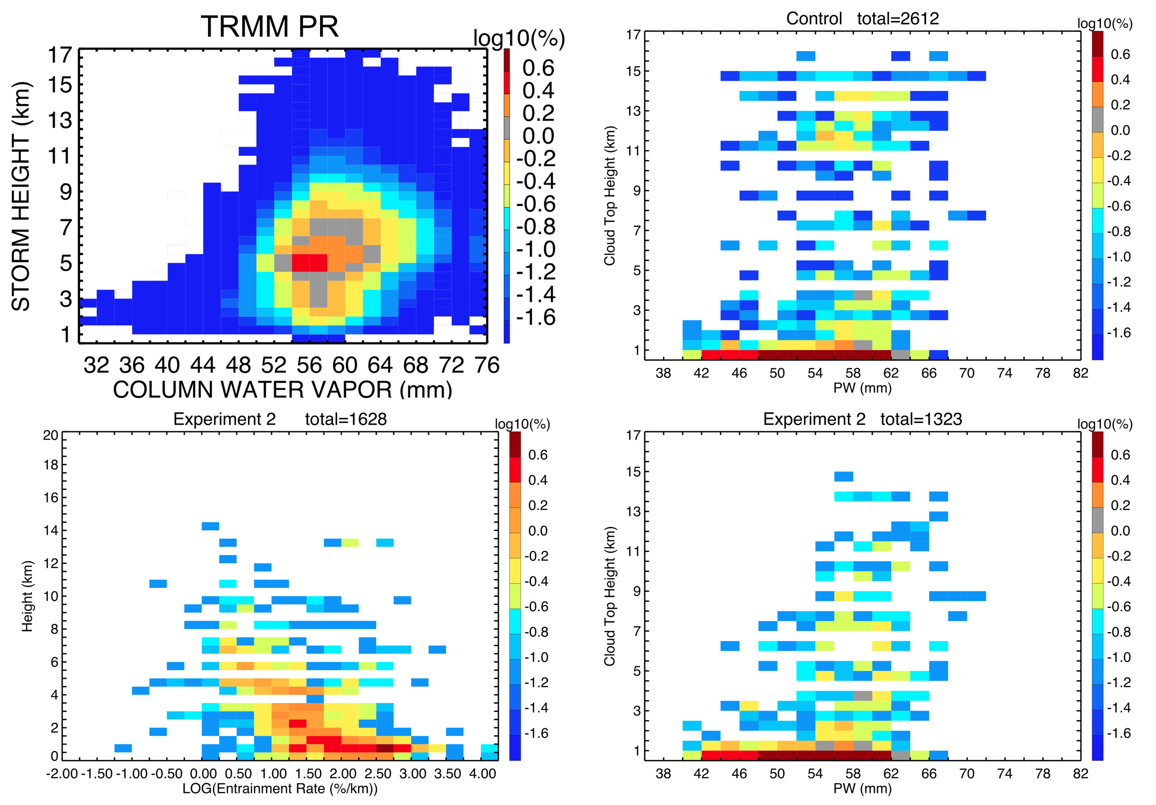
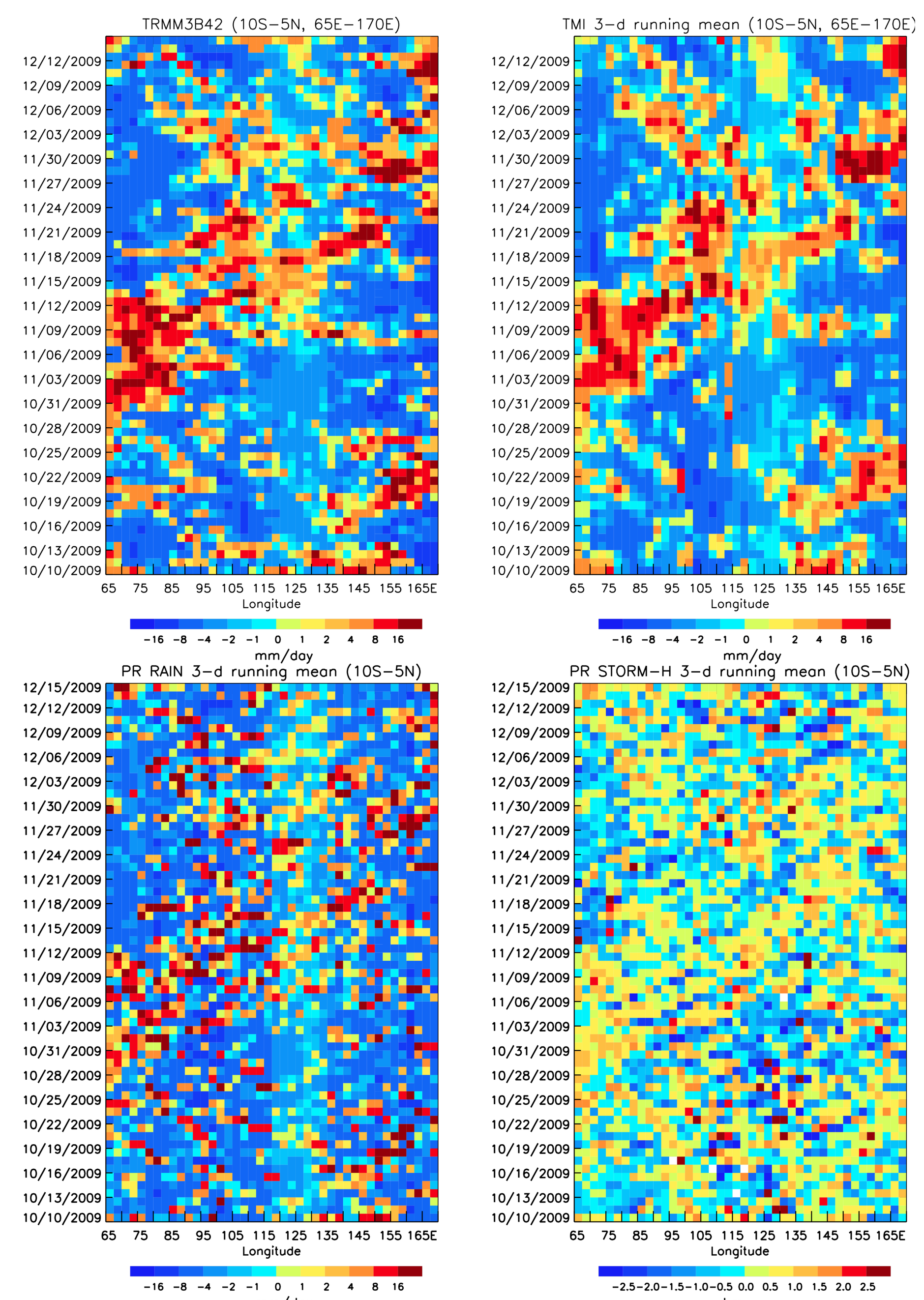
Introduction

The Madden-Julian Oscillation (MJO) is considered to be a stringent test of GCM cumulus parameterizations. Some progress has been made in recent years in producing MJO-like variability in free-running models, but these can only be evaluated in a climatological sense. As part of the activities associated with the Year of Tropical Convection (YOTC), a Diabatic Processes and Vertical Structure of the MJO model intercomparison is being conducted. The project includes 20-day hindcasts of two MJO events in 2009, using successive daily initializations of the models with an ECMWF analysis product. This allows climate GCMs to be compared directly to TRMM data on weather time scales.



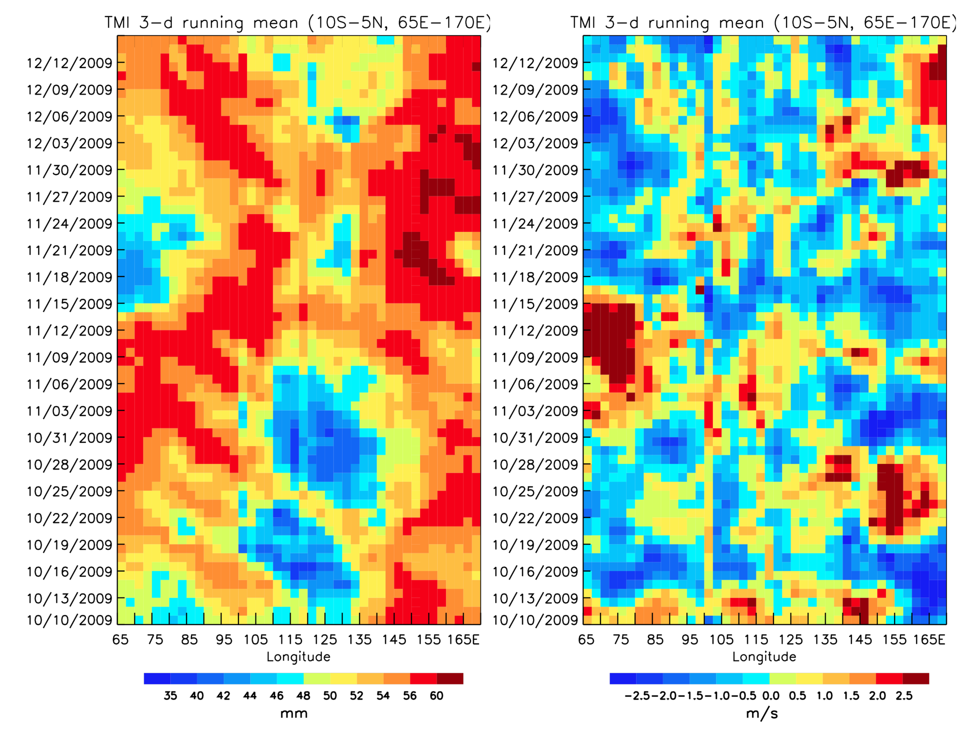
A key feature of cumulus parameterizations that produce MJO-like variability is significant sensitivity of convection to tropospheric humidity. TRMM PR storm height data over the tropical oceans show that the onset of deep convection does not occur until TMI column water vapor reaches ~44 mm (upper left). The GISS CMIP5 GCM, which does not simulate an MJO, shows little sensitivity of convection depth to water vapor during DYNAMO (upper right), while a newer model version with strong entrainment (lower left) shows sensitivity similar to that observed (lower right). The latter model is being used for the YOTC intercomparison.

YOTC MJO Event E in TRMM Rain Products



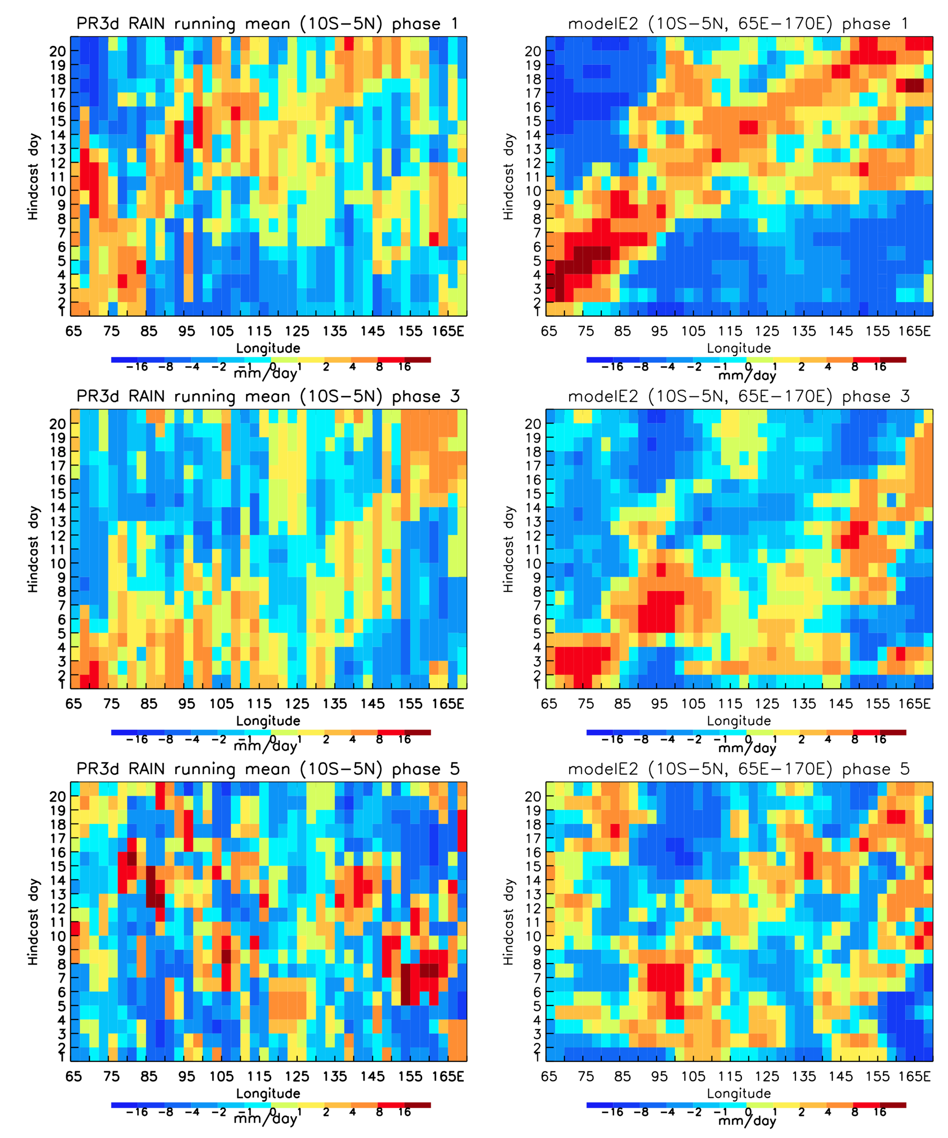
Shown above are Hovmöller diagrams of various TRMM rain products for YOTC MJO Event E. Daily mean TRMM 3B42 rain rate anomalies slowly propagate eastward from the Indian Ocean in early November. Indian Ocean convection is stationary for about a week before the onset of propagation. 3-day running mean TMI rain rate anomalies show an almost identical structure. Analogous PR rain rate anomalies are noisier due to the less complete spatial coverage, but the propagating signal is still visible. PR storm heights are ~2-4 km higher during the active phase of the MJO than during the suppressed phase throughout the event.

TMI CWV and Surface Wind Speed



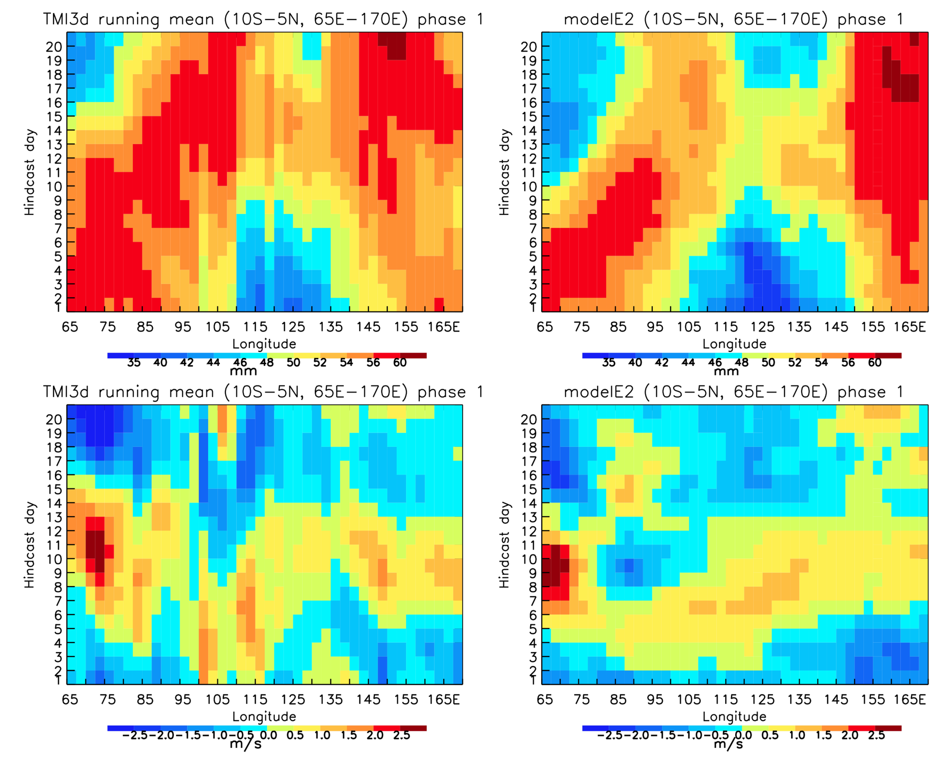
Consistent with ideas about the MJO being a "moisture mode" in which fluctuations in humidity are integral to the dynamics, TMI column water vapor is consistently high in the locations of the MJO disturbed phase and much drier elsewhere. Westward propagating disturbances are also obvious in the humidity field, but their signal in the precipitation field is much weaker, suggesting a fundamentally different coupling between convection, moisture and the dynamics for these waves. The onset of propagation appears to coincide with strong Indian Ocean positive wind speed anomalies near and just west of the disturbed area in the second week of November, but this is not a consistent feature of the MJO as it propagates eastward onto the Maritime Continent.

Rain Anomalies in TRMM PR and GCM for Hindcasts Starting in Different MJO Phases



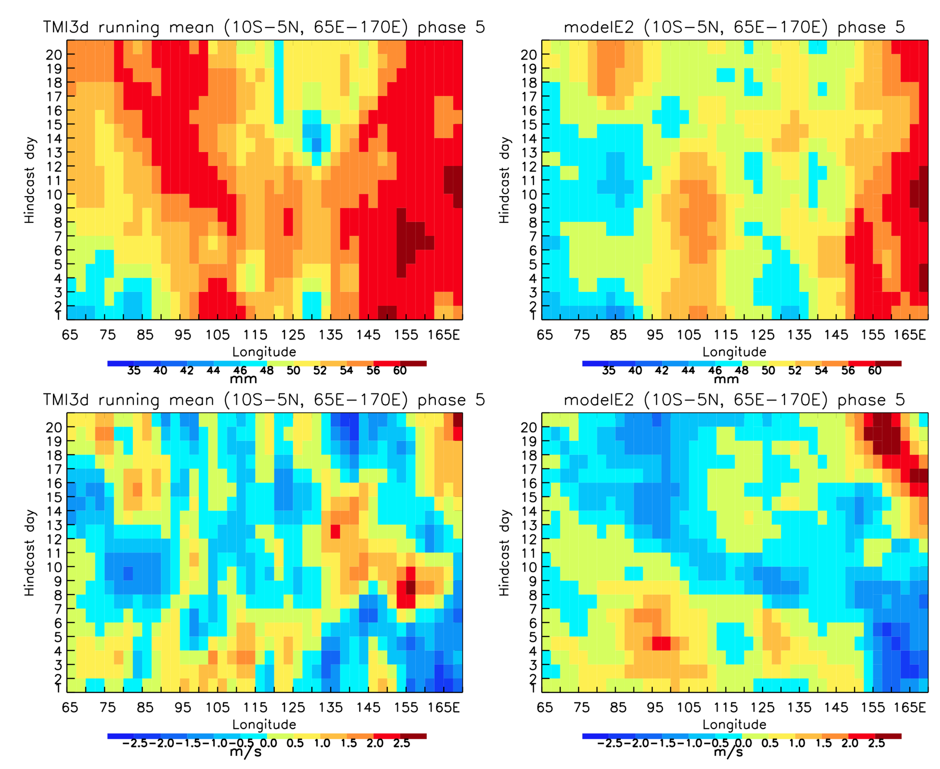
The GISS GCM was run through a series of 20-day hindcasts initialized daily with the ECMWF YOTC analysis. To evaluate how well the GCM simulates MJO Event E, we create composite 20-day Hovmöller diagrams of TRMM PR rain rates for all segments that begin in a given Wheeler-Hendon MJO phase (left panels above) and analogous composites of the GCM hindcasts (right panels above). For phase 1 initialization (Oct. 29 – Nov. 3), when the MJO is being initiated in the western Indian Ocean, the GCM produces a relatively realistic disturbance that propagates eastward at ~6 m/s, similar to that observed. The biggest discrepancy between the model and data is that the observed MJO does not begin for about a week after convection anomalies appear, while the GCM MJO begins immediately. For phase 3 initialization (Nov. 7-15), after MJO propagation has begun, the GCM correctly predicts the weakening of the disturbance on day 10 as it reaches the Maritime Continent, which appears to be associated with the prior generation of a new disturbance over the Maritime Continent which has reached the West Pacific by day 10. For phase 5 initialization (Nov. 21-23), the GCM prediction is mostly inaccurate. It does predict the emergence of the original disturbance over the West Pacific, although several days earlier than observed. But it also produces a coherent second propagating disturbance beginning on day 7 that is only weakly evident in the data.

Phase 1 CWV and Wind Speed from TMI and GCM



Analogous phase 1 composites of column water vapor (upper panels) suggest that the biggest difference between the GCM and observations early in the hindcast is the stronger dry anomaly over the Maritime Continent and West Pacific in the model. Kim et al. (2013) show that propagating vs. non-propagating MJOs are often distinguished by the degree of upstream dryness; this might explain the too-early onset of propagation in the model. Note that the West Pacific is moist throughout the period in both data and model, even though strong rain anomalies do not break out until the second half of the hindcast period, suggesting that details of the vertical structure may matter as well. The GCM reproduces the strong observed winds at onset, but a few days earlier than observed.

Phase 5 CWV and Wind Speed from TMI and GCM



The generally poor performance of the GCM when initialized in phase 5 is reflected in its widespread dry bias in the Indian Ocean and Maritime Continent. Even in the data, the MJO signal is not clearly evident, either in column water vapor or wind speed. The GCM has essentially no predictability in this situation, which is symptomatic of the difficulty that many models have in propagating the MJO into the West Pacific.

Conclusions

✧Improvements to the CMIP5 GISS Model E2 GCM, most notably the strengthening of convective entrainment, now allow the model to produce MJO-like variability when run as a free-standing climate model.

✧YOTC MJO event E is clearly visible in TRMM rain products. TRMM 3B42 and TMI agree on all the major MJO rain anomaly features, and TRMM PR also detects the MJO signal despite its sparse sampling.

✧TRMM PR storm heights are ~2-4 km higher in the active MJO phase than in the suppressed phase, with little variation over the MJO lifecycle.

✧The MJO is visible in TMI column water vapor and surface wind speed fields but is no more evident than in westward propagating disturbances, attesting to the unique convection-humidity-dynamics coupling of the MJO.

✧GCM 20-day hindcasts have excellent predictability when initialized during the Indian Ocean propagating phase and good predictability when initialized at MJO onset, except that propagation begins too soon. When initialized during the Maritime Continent disturbed phase, the GCM has virtually no predictability.