The Impact of Clouds and Precipitation over the Maritime Continent on the Propagation of the MJO into the Western Pacific

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Introduction

The processes that determine the interaction between the islands of the maritime continent (MC) and the eastward propagation of the Madden-Julian Oscillation (MJO) are poorly understood, leading to the so-called "prediction barrier" in forecasting MJO propagation. We are undertaking a series of observational and modeling analyses to understand why some MJO episodes successfully cross the MC while others do not.

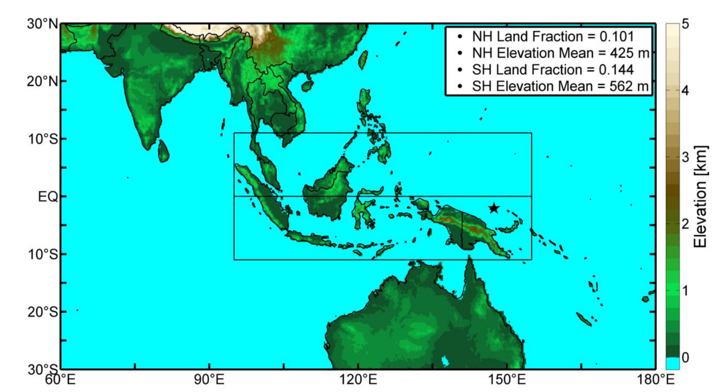

Fig. 1. Elevation of the islands that make up the MC. Black lines denote the northern hemisphere (NH) and southern hemisphere (SH) domains that we take averages over. The location of the ARM Manus site [146.43°E, 2.06°S] is given by the solid black star.

Science Questions

- Through what processes does the MJO modify the diurnal cycle of surface heating, cloudiness, and precipitation over the MC?
- How do these processes feedback onto the strength of the MJO?

Datasets

- Cloud and radiation observations from the DOE ARM Manus site
- Precipitation retrievals from the TRMM 3B42 dataset
- Strength of the MJO is inferred by the amplitude of the Wheeler-Hendon Real-time Multivariate MJO index [RMM]

Mean Precipitation as the MJO Crosses the MC

- The MJO approaches the MC in Phases 2-3, is over the MC in Phases 4-5, and exits the MC in Phases 6-7.
- The MJO precipitation anomaly is larger over water, likely because MJO cloudiness acts to suppress convection over land (Fig. 7).

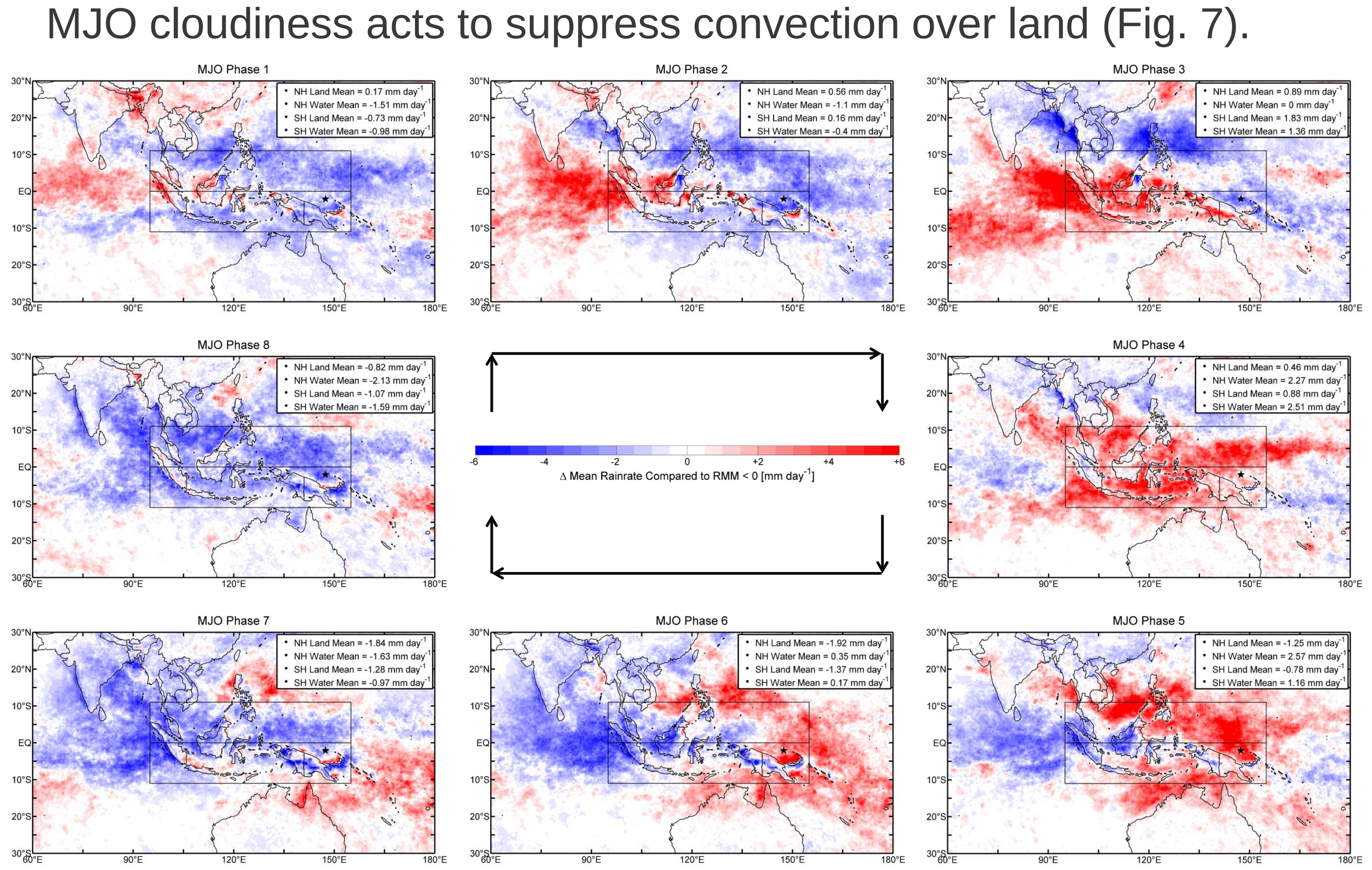

Fig. 2. Precipitation anomalies over the MC by MJO Phase. Anomalies are computed with respect to all time periods when the RMM amplitude was less than 1.

Investigating MJO Weakening Across the MC

To investigate the processes that may lead to MJO weakening across the MC, we started by compositing environmental variables for cases in which the RMM amplitude either increases (i.e., the MJO strengthens) or decreases (i.e., the MJO weakens) between Phases 3 and 5. For example, the difference in mean SST is shown in Fig. 3.

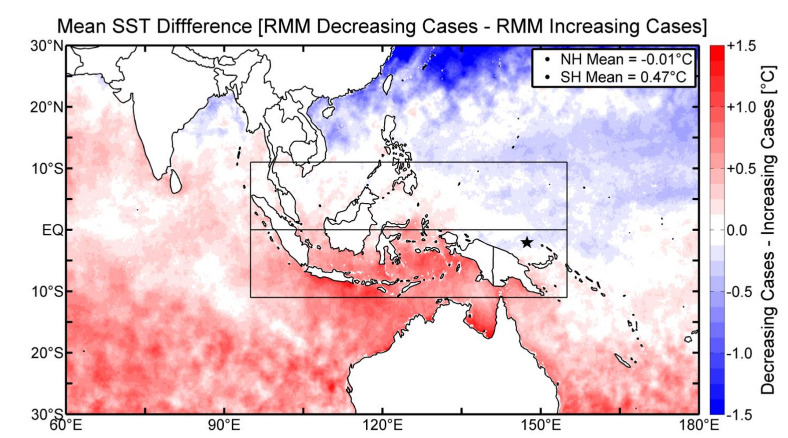

Fig. 3. The difference in the mean SST during MJO Phase 3 for cases in which the RMM amplitude decreases and cases in which the RMM amplitude increases from Phase 3 to Phase 5.

- The north-south dipole in the SST anomaly is suggestive of a seasonal component in the ability of the MJO to cross the MC.
- The east-west gradient in SST may reflect the influence of El Niño.

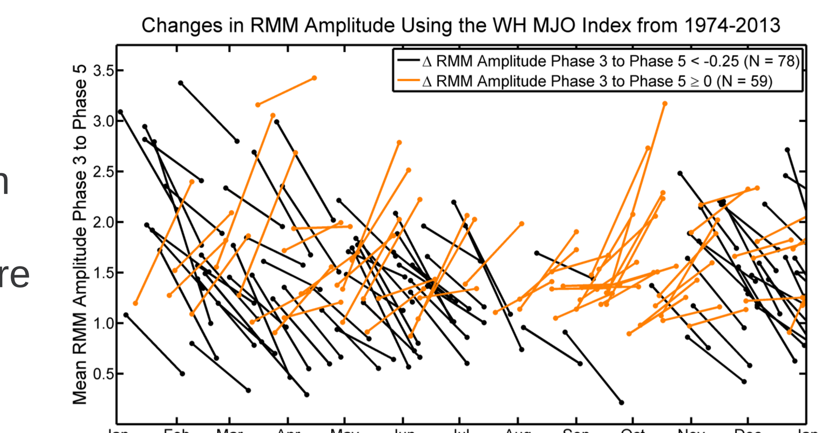

Fig. 4. Change in the amplitude of the RMM index from Phase 3 to Phase 5 conditioned on the day of the year when the MJO approaches the MC. Cases where the RMM amplitude decreases are shown in black and cases where it increases are shown in orange.

- MJO episodes are more likely to cross the MC in NH summer/fall.

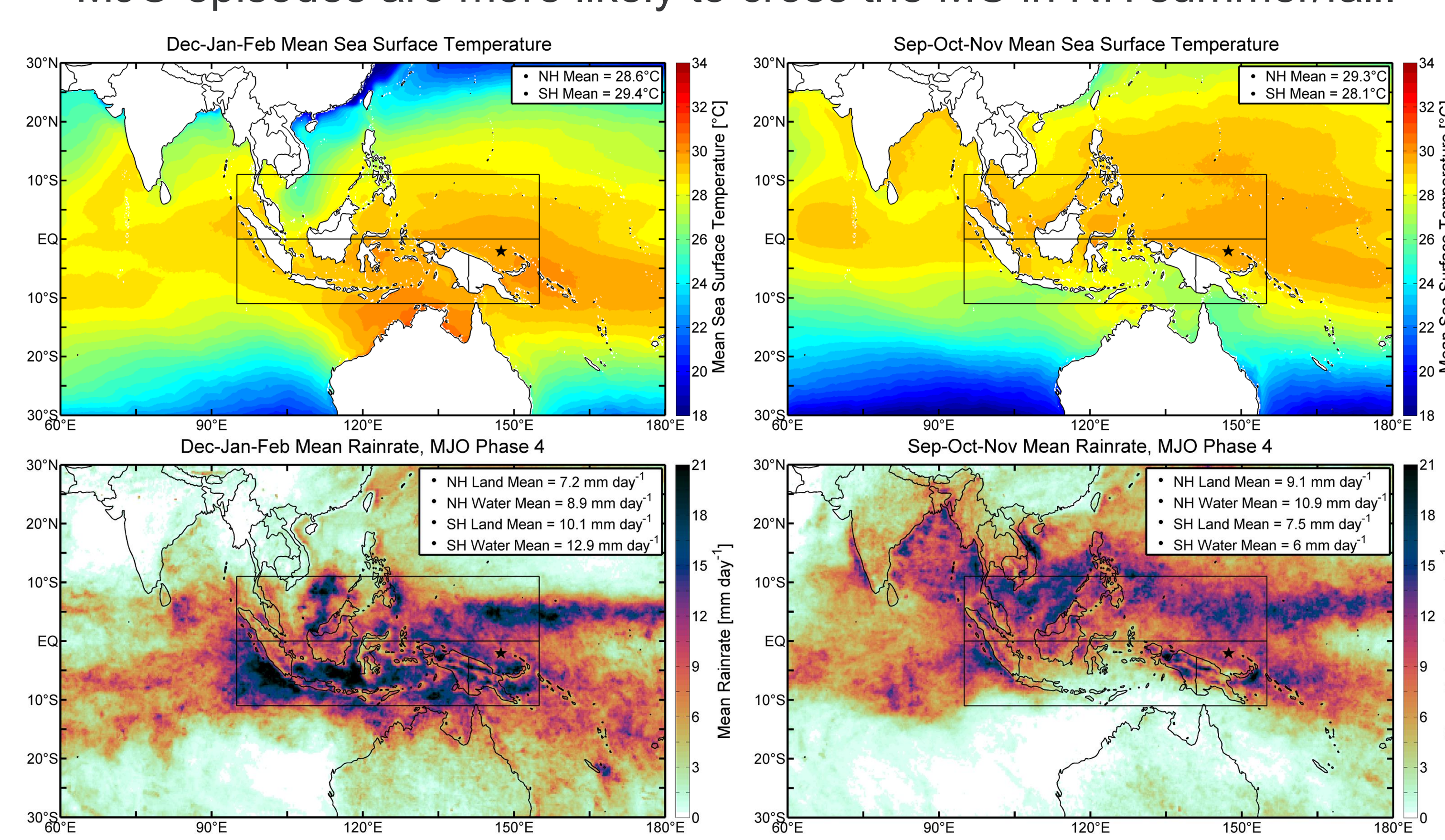

Fig. 5. The seasonal mean sea-surface temperature (top row) and MJO Phase 4 rainrate (bottom row) for Dec-Jan-Feb (left column) and Sep-Oct-Nov (right column).

- The MJO is likely to weaken over the MC if the precipitation maxima is in the SH and may strengthen if the maxima is in the NH.
- We hypothesize that this is related to the fact that there is more and higher land in the SH compared to the NH.

Conclusions

1) The MJO is likely to weaken when its precipitation maxima crosses the MC in the SH where there is more land compared the NH.
2) Cloudiness associated with the MJO acts to suppress precipitation over land by reducing the amount of downwelling solar radiation that reaches the surface and subsequently the surface heating.
3) The suppression over land is smaller when the MJO precipitation maxima crosses the MC in the NH vs. when it crosses in the SH. This may provide insight as to why the MJO signal often weakens during Dec-Jan-Feb and may strengthen during Sep-Oct-Nov.

In a related work, we use a CRM to explore the relationships between the MJO, the diurnal cycle, and rainfall over land (see Hagos poster).

Cloud Radiative Effects by MJO Phase

- The ARM data from Manus (2.06°S) shows that MJO cloudiness has a larger impact on the solar radiation reaching the surface in Dec-Jan-Feb compared to Sep-Oct-Nov.

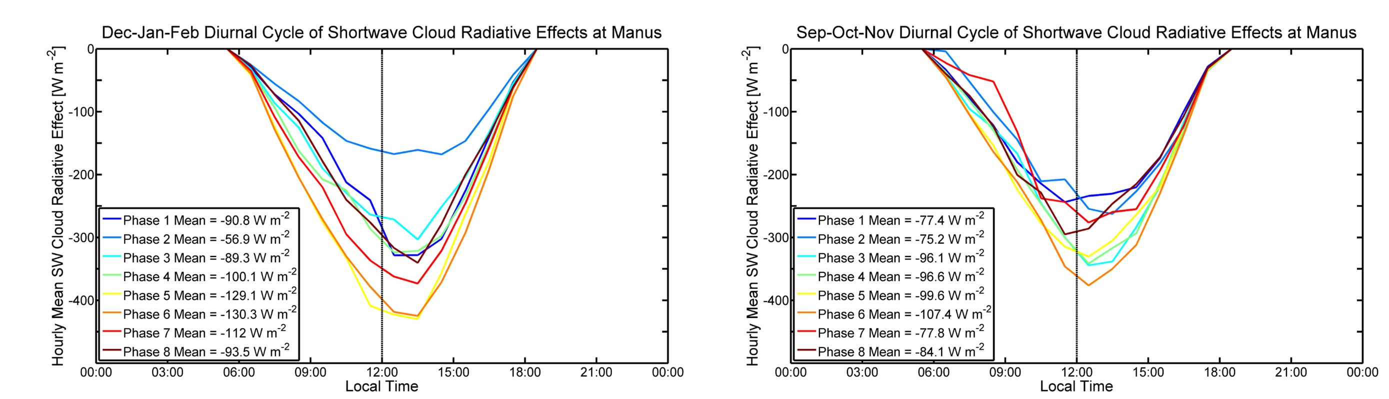

Fig. 6. The diurnal cycle of shortwave (SW) cloud radiative effects (cloudy SW flux – clear sky SW flux) by MJO Phase for Dec-Jan-Feb (left) and Sep-Oct-Nov (right).

- The stronger SW cloud radiative effect acts to reduce surface heating and subsequently the net precipitation over land.

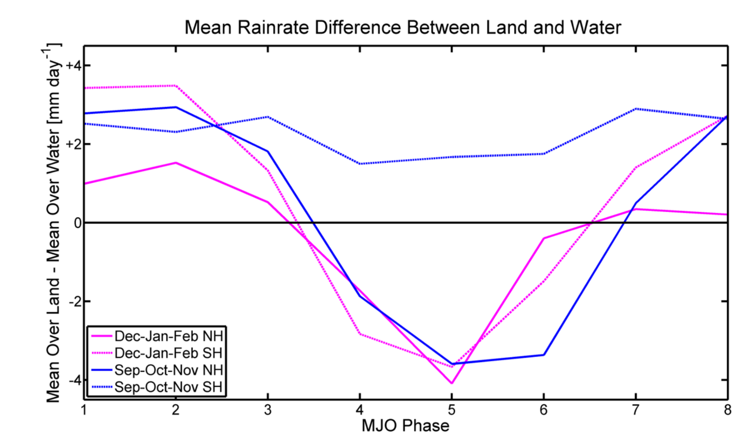

Fig. 7. The difference in mean rainrate between land and water during Dec-Jan-Feb (purple lines) and Sep-Oct-Nov (blue lines) for the NH (solid lines) and the SH (dashed lines).

- The suppression of precipitation over the islands of the MC is larger when the precipitation maxima is in the SH (Dec-Jan-Feb) compared to when the MJO crosses the MC largely in the NH (Sep-Oct-Nov).

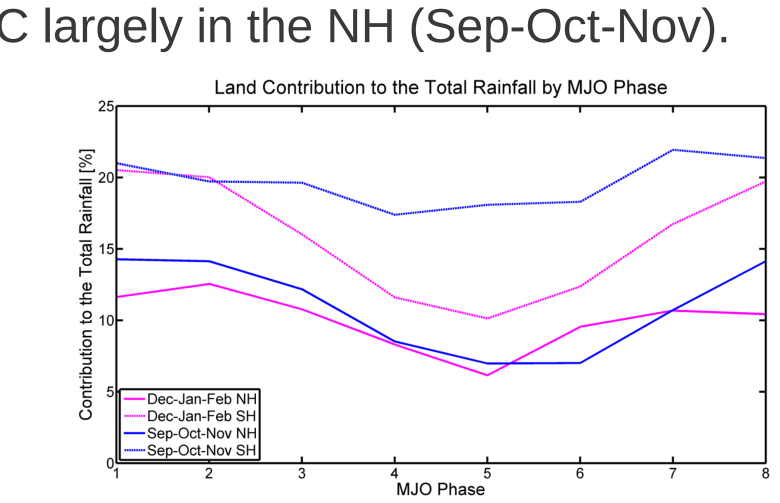

Fig. 8. The land contribution to the total rainfall during Dec-Jan-Feb (purple lines) and Sep-Oct-Nov (blue lines) for the NH (solid lines) and the SH (dashed lines).