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Understanding the Barrier Effects of the Maritime Continent on MJO Prediction

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The Madden-Julian Oscillation (MJO) is one of the leading sources of tropical and extra-tropical predictability on subseasonal-to-seasonal timescales, but numerical models often suffer from systematic errors in capturing the MJO dynamics. Large-scale convection associated with the MJO is initiated over the Indian Ocean and propagates eastward across the Maritime Continent (MC) and into the western Pacific. As an MJO event enters the MC, it often weakens or completely dissipates due to complex interactions between the large-scale MJO and the MC landmass and its topography. This MC barrier effect is responsible for the dissipation of 40-50% of observed MJO events, though the exact nature of the barrier effect is unclear. Common mechanisms include the physical barrier of the islands of the MC, and the dynamical barrier of strong diurnally driven circulations that exist around those islands. The MC barrier effect is often exaggerated in when it comes to MJO prediction.

In this study, we examine convection-permitting, atmosphere-ocean coupled model simulations of an MJO event to determine how the MJO responds to physical and dynamical changes implemented over the MC region. In addition to the control simulation with real topography, we introduce two idealized simulations – (1) where we flatten the topography of the MC to sea level, but leave the land-sea distribution as is, and (2) where we entirely remove the MC islands and replace them with a 50-m deep ocean. How the MJO responds to the implemented changes can help us determine whether some physical processes that occur over the MC are more detrimental to MJO propagation than others. The differences between the control simulation and the first scenario can tell us about the physical barrier effect of the MC on MJO propagation. The complete removal of land in the second scenario also removes the diurnal changes associated with air-sea boundaries (e.g., land-sea breezes and convergence zones between islands), exploring whether the barrier effect of the MC on the MJO is more dynamically driven.

Results show that flattening the MC terrain only has a small impact on large-scale MJO characteristics. However, as expected, removing the land, and diurnal cycle associated with it, drastically smooths the MJO's propagation and the produced MJO shows no sign of dissipation over the MC region. We examine the model simulations to gain insight on what physical processes are behind the changes among model simulations and to expose some modeling difficulties that could contribute to numerical models' exaggerating the effects of the MC barrier effect.