Improving Madden-Julian Oscillation Simulation: Atmosphere-Ocean Coupling and Land/Orographic Effect

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Accurate forecast of the intraseasonal perturbation such as the Madden-Julian Oscillation (MJO) in the tropics is one of the keys to improve the subseasonal forecast in the both tropics and extratropics. However, realistic simulation of MJO is still a challenge for many general circulation models. In this study, we identify two key ingredients that are needed to be accurately presented in the models: atmosphere-ocean coupling and land/orographic effect of the Maritime Continent (MC).

We demonstrate the significant improvement of MJO simulation by coupling an ocean mixed-layer model (SIT) to ECHAM5, CAM5, and HiRAM. The result suggests that the improvement provided by coupling is model independent in view of different parameterization schemes in three models. An extremely high vertical resolution (e.g., 1-m in the top 10 meters) in the ocean model is the key factor leading to the improvement by accurately resolving the diurnal cycle of oceanic warm layer. The modeled ocean in this setup therefore better synchronizes with the atmosphere by correctly respond to atmospheric forcing through surface energy exchange and properly simulate the intraseasonal atmosphere-ocean coupling.

Three long-term simulations considering realistic MC, mountain-removed MC, and island-removed MC were conducted using T213 ECHAM5-SIT. Our results reveal that the orography and land-sea contrast in the MC exert significant influences on the MJO by modulating its eastward propagation (both route and speed), strength, and structure. Near-surface moisture convergence to the east of the deep convections, which is considered the key ingredient leading to the eastward propagation of MJO, is significantly stronger when both orography and islands were considered. Current understanding, both theoretical and empirical, is developed mostly in the aqua-planet framework. Both orographic and land-sea effects in the MC need to be fully understood and simulated to advance the understanding and forecast of the MJO.