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MJO initiation and propagation simulated with a global kilometer-scale climate simulation: Implication for the cross-scale interaction

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The Madden–Julian oscillation (MJO) is the most predominant tropical intraseasonal variability and is a source of modulating global weather patterns. An accurate simulation of the MJO still remains a challenge for general circulation models (GCMs), and in fact, climate simulations with GCMs often struggle with the mean state-variability tradeoff. For this issue, a global storm-resolving climate simulation, which a recent increase in computing power makes possible, is expected to be a useful way because of its merit of direct coupling between moist processes and dynamics.

The present study examines the MJO representation in an AMIP-type ~10-year simulation with the Nonhydrostatic Icosahedral Atmospheric Model (NICAM) at 3.5-km horizontal resolution, in comparison with that in one of conventional GCMs (MIROC6). This NICAM simulation successfully reproduces the realistic initiation frequency, propagation, and hierarchical structure of MJO convection, as well as realistic mean states (e.g., mean tropical precipitation), whereas MIROC6 overly underestimates the number of robust MJO events, and the activity of westward-propagating synoptic-scale waves embedded within MJO convective envelopes. As specific processes, the enhanced mixed Rossby-gravity wave-like systems seem to be a precursor and building blocks of the MJO simulated with NICAM at least over the Indian Ocean, consistent with several observational studies. In addition, NICAM-MJO propagation into the western Pacific is helped by high-frequency intermittent advective moistening that can be triggered by the upper-tropospheric PV intrusion from the extratropics. This feature is also found in some of observed MJO events.

Our results suggest that good MJO simulations can attribute to representing the feedback from a complex of synoptic-scale waves onto MJO convective envelopes appropriately, and that the extratropics sometimes plays an active role in MJO dynamics. A success in simulating and scrutinizing these cross-scale interactions about the MJO is one of clear merits of kilometer-scale climate simulations without the assumption of a priori scale separation and quasi-equilibrium characteristics.