Monitoring the Madden-Julian Oscillation with upper-level geopotential height gradient $\nabla_x z'$

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Given the dominant convection and circulation features of the Madden-Julian oscillation (MJO), its observation relies mostly on the measurements of convection, such as outgoing longwave radiation (OLR), and circulation-based measurements, such as zonal wind and velocity potential. For example, the Real-time Multivariate MJO (RMM) index, the most commonly used MJO index, is constructed from the combined empirical orthogonal function (CEOF) of OLR, 200-hPa and 850-hPa zonal winds. However, using OLR as a measurement of convection may have numerous shortages, such as the unavailability of data access before the satellite era and the calculation error of modeling output OLR.
This research explores an alternative MJO diagnostic parameter option, the 150-hPa zonal anomalous height gradient ($\nabla_x z'$), which may overcome the limitations of OLR. Statistical analyses of MJO events during extended winter (NDJFM) from 1979 to 2013 suggest that the 150-hPa $\nabla_x z'$ is highly correlated with OLR and shows a strong signal of MJO in the wavenumber-frequency spectrum. The 150-hPa $\nabla_x z'$ is also shown to be able to extract MJO signals from the version 2 of NCEP Climate Forecast System (CFSv2) output while OLR fails in a case study during the Dynamics of the Madden-Julian Oscillation (DYNAMO) field campaign in 2011. It is believed that 150-hPa $\nabla_x z'$ is a good alternative option of OLR for studying MJOs before the satellite era and in model evaluations.

Keywords: Madden-Julian Oscillation, diagnostic parameter, geopotential height, zonal anomalous height gradient, MJO index