

## **QBO Modulation of the Interannual Variability of the Madden-Julian Oscillation**

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Madden-Julian oscillation (MJO), the dominant mode of intraseasonal variability in the tropical troposphere, has a significant impact on global weather and climate. Here we present that the year-to-year variation of the MJO activity shows significant changes with the quasi-biennial oscillation (QBO) in the tropical stratosphere. Specifically, the boreal winter MJO amplitude, evaluated by various metrics, is typically stronger than normal during the QBO easterly phase at 50 hPa and weaker than normal during the QBO westerly phase at 50 hPa. This relationship, which is possibly mediated by the QBO-related static stability change and/or radiative feedback in the tropical upper troposphere, is robust whether or not the activeness of the MJO or QBO is considered. In consistent with this finding, subseasonal-to-seasonal (S2S) prediction models systematically show a higher MJO prediction skill during the QBO easterly phase at 50 hPa. This result suggests that interannual variability of the MJO and the related tropical-extratropical teleconnections can be better understood and predicted by taking not only the tropospheric circulation but also the stratospheric mean state into account. The possible mechanisms of QBO-MJO coupling and its seasonality are discussed. The QBO-MJO coupling in 2016 winter when QBO was disrupted for the first time in the observational record, is also briefly discussed.