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MJO-TC Teleconnections and Their Influence on North American Precipitation: Implications for Subseasonal Prediction

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Abstract This study investigates the impact of the Madden-Julian Oscillation (MJO) on North American summer precipitation, focusing on tropical cyclones (TCs). Using observations and state-of-the-art subseasonal-to-seasonal (S2S) models, the influence of the MJO on total precipitation (P) and TC-related precipitation (TCP) is analyzed across MJO phases. Results indicate that TCs significantly contribute to the MJO's modulation of precipitation, particularly in regions like the Gulf Coast, Florida, and western Mexico. The anomalous probability of extreme precipitation events associated with the MJO is strongly linked to the MJO-TCP connection, highlighting the importance of capturing these interactions for reliable S2S forecasts of precipitation. We also show that S2S models underestimate TCP's role in total P anomalies and extreme precipitation probabilities related to the MJO. This underscores the need for improved modeling of the MJO-TC relationship to increase subseasonal forecast skill of total and extreme precipitation in North America.

Plain Language Summary The Madden-Julian Oscillation (MJO) influences global precipitation, including rainfall in North America, by modulating tropical cyclone (TC) activity. TCs significantly contribute to both average rainfall and extreme precipitation events, making the MJO-TC connection critical for subseasonal forecast models. This study demonstrates that current models underestimate the role of TCs in both mean precipitation anomalies and the probability of extreme precipitation events during different phases of the MJO. Our results show that TCs amplify the MJO's impact on rainfall in key regions, including the Gulf Coast, Florida, and western Mexico, highlighting the importance of accurately capturing this relationship. The weaker MJO-TC relationship in models may result from biases in how TCs and the MJO are represented, including their frequency, intensity, convection, and interactions. Addressing these biases is essential for improving predictions of total and extreme rainfall on subseasonal timescales.

Key Points:

- The Madden-Julian Oscillation and tropical cyclones jointly modulate summer mean and extreme precipitation in North America
- Subseasonal models capture some MJO-TC interactions but underestimate tropical cyclones' contribution to MJO-driven precipitation
- Improving MJO and TC representation, and their joint influence, is key to extending subseasonal forecast skill in North America

Supporting Information:

Supporting Information may be found in the online version of this article.

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1. Introduction

The Madden-Julian Oscillation (MJO) is considered the leading source of global subseasonal variability and predictability (Jiang, Adames, et al., 2020; Neena et al., 2014; Stan et al., 2022; Woolnough, 2019). The MJO exerts its influence on surface weather in the tropics as well as in the higher latitudes through its eastward-propagating convective envelope that modulates tropical precipitation variability (DeMott et al., 2015; Jiang, Adames, et al., 2020), which influences the extratropics through teleconnections (Henderson et al., 2017; Seo & Son, 2012). During boreal summer, the MJO affects total and extreme precipitation in North America and ocean basins, including the eastern Pacific, the Gulf of Mexico, and the Caribbean (Barlow & Salstein, 2006; Jones & Carvalho, 2012; Schreck III, 2021; Zhou et al., 2012). One important pathway through which the MJO influences these areas is the modulation of tropical cyclone (TC) activity, including TC genesis and track density (Camargo et al., 2009, 2019; Maloney & Hartmann, 2000; Manganello & Kinter, 2021).

The significant impact of the MJO on the surface weather in many part of the globe has motivated research into both dynamical and statistical predictions of the MJO and its teleconnections, especially in the subseasonal-to-seasonal (S2S) range (2–6 weeks) (Henderson & Maloney, 2013; Stan et al., 2022; Vitart, 2017; Zheng et al., 2019). Some features of the MJO have been shown to be predictable beyond 25-day lead times in many operational and experimental machine-learning models (Vitart, 2017; Y. Lim et al., 2018; Shin et al., 2024).