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Decadal variability of the extratopical response to the MJO: AMV and PDO modulation in the UKESM climate model

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The extratropical response to the Madden-Julian Oscillation (MJO) is modulated by two prominent modes of low-frequency sea surface temperature (SST) variability: the Atlantic Multidecadal Variability (AMV) and the Pacific Decadal Oscillation (PDO). Utilizing the UK Earth System Model (UKESM) 1100 year pre-industrial control simulation from CMIP6, this study offers a unique opportunity to explore decadal variability with an extensive dataset, surpassing the limitations of previous studies which focussed on reanalysis products.

The results underscore a statistically significant influence of both AMV and PDO on the extratropical response across all MJO phases. Non-linear interactions between the MJO teleconnection and SST forcing are observed prominently in the modification of the response to MJO phase 6 (enhanced convection over the western Pacific), with AMV+ and PDO+ background states amplifying distinct teleconnection patterns, notably the negative North Atlantic Oscillation (NAO-) and the deepened Aleutian Low responses, respectively. These changes are greater in magnitude than would be expected from the linear superposition of the individual atmospheric responses to the SST mode and the MJO. The amplification of the MJO phase 6 teleconnection to the North Atlantic aligns with prior research based on ERA5 reanalysis data.

While modulation of the response to MJO phase 3 (enhanced convection over the eastern Indian Ocean) is evident, it is less pronounced compared to phase 6, and the mechanisms via which it acts are less clear. Intriguingly, alterations in the teleconnection, such as a weaker Aleutian Low during PDO+, contradict the anticipated modulation. Since MJO phase 3 and PDO+ tend to weaken and strengthen the Aleutian Low, respectively, it would be reasonable to expect that these effects would cancel. Instead, the weakening of the Low after MJO phase 3 is increased during PDO+.

A possible mechanism for the modulation of the teleconnections is a linear superposition of Rossby wave modes excited by the MJO, contingent upon the SST state. In the case of MJO phase 6, this corresponds to an amplification of the existing modes, and hence of the expected response. For MJO phase 3, however, there is an indication that other Rossby wave modes may also be excited in certain SST states, leading to interference which is out of phase with the primary response.

Acknowledging the limitations of observational and reanalysis datasets, this study underscores the pivotal role of climate models in the effective study of decadal and multi-decadal variability. Importantly, the study has significant implications for extratropical forecasting over the coming decades. The modulation of the MJO teleconnection by AMV and PDO suggests modifications in predictability, crucial for refining forecasting techniques. Furthermore, these results provide a contextual foundation for studies examining MJO teleconnections in future climates, enabling a more accurate dissection of responses influenced by internal and anthropogenically forced variability.