Future Changes of the Madden-Julian Oscillation in CESM2

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Introduction

The Madden-Julian Oscillation (MJO) is a slow, eastward moving mass of clouds in the tropics. The MJO has a time period of ~30-60 days and moves at ~5 m/s with enhanced or suppressed convective activity present in areas along the MJO pathway. The MJO has influences on global climate and weather extremes by generating upper-level circulations that propagate into the extratropics. Monsoons, frequency of extreme precipitation and temperature events, and other modes of climate variability (e.g. NAO, ENSO) are found to be modulated by the MJO (e.g. Neale et al. 2008; Zhou et al. 2012). During active MJO periods, extreme events on a global scale are ~40% higher (Jones et al. 2004). Given its dominance in the intraseasonal timescale and its global impacts, the MJO is regarded as an important source for the subseasonal prediction. Thus, understanding how the MJO will be changing in the future is the motivation behind this project which has important implications in better understanding changes in the MJO-related phenomena.

The focus of this research will be to study how the amplitude, propagation, and zonal extent of the MJO will change in the future as these are the possible future changes in the MJO documented in the previous studies (e.g., Maloney et al. 2019).

Methods

Data of daily zonal wind at 850hPa (U850) and precipitation from CESM2 ensemble members r4i1p1f1 and r11i1p1f1 were obtained. The historical runs are used from 1979 to 2014. SSP585, the future run, is used from 2065 to 2100 to represent the future projections in the MJO. The runs have the same time period length for a more consistent comparison, and February 29th was removed to ensure a 365-day calendar. The anomalies were calculated by first calculating the annual climatology and then removing the first three harmonics. The data were also filtered to extract 25-90 day intra-seasonal signals via a bandpass filtering function. Then the winter season from October to March was extracted, when the MJO is most active.

Results

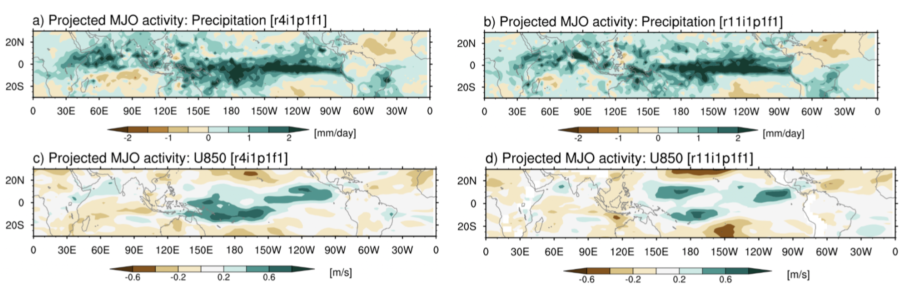

Figure 1| Projected MJO precipitation and zonal wind activity (variance of anomalies). a,b,c,d, Future - historical difference map between SSP585 and historical data for (a)-(b) precipitation and (c)-(d) U850.

Fig. 1 shows the future-historical difference of the variance in precipitation and U850. Both ensembles show similar results where greater precipitation, or greater MJO convection, is projected in the central to eastern pacific (Fig. 1a and b). Fig. 1c and d convey changes in the zonal wind activity. Slight differences in future projections are found in the two ensembles; ensemble r4i1p1f1 shows higher values of change in the pacific ocean roughly below the equator in the western pacific whereas ensemble r11i1p1f1 shows more dispersed values in the Pacific ocean with peak values mostly above the equator. In general, the results suggest a stronger MJO in the future especially over the Pacific Ocean.

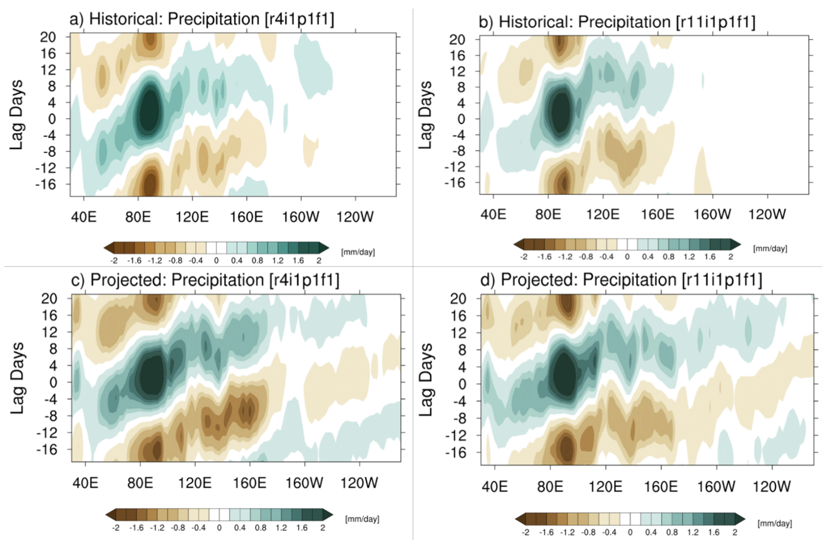

Figure 2 | Changes in MJO Propagation. a,b,c,d, Historical lead-lag maps based on convectional activity in the Indian Ocean for ensemble member (a) r4i1p1f1 and (b) r11i1p1f1. (c) and (d) Same as (a) and (b) but for projected lead-lag maps.

In Fig. 2, the enhanced convectional activity over the Indian Ocean (IO, 85-95E, 10S-10N) was used to calculate the lead-lag composite. The timeseries of filtered precipitation anomalies averaged over the IO was derived to represent IO convection. The timseries allowed us to determine the type of convectional activity (i.e. enhanced or suppressed) based on the positive or negative values. Then, the lead-lag composite from day -20 to 20 was obtained based on IO convection at day 0 which indicates the MJO propagation. When comparing the respective historical (Fig. 2a and b) and projected (Fig. 2c and d) ensemble members, the figures indicate more eastward MJO activity. This can be used to infer more eastward MJO propagation and more eastward extent in the future.

Conclusion

The results in this study confirm the findings in previous studies that MJO amplitude may increase, the propagation may be more eastward, and the zonal extent may increase. Above changes in the MJO may lead to changes in its related weather phenomena. For example, precipitation induced by the MJO over the West Coast of North America is found to extend more eastward in a warming climate (Zhou et al. 2021). How future MJO changes lead to changes in its related teleconnections and weather phenomena and the underlying mechanisms need further analysis in our future study.

Bibliography

Jones, C., Waliser, D.E., Lau, K.M. and Stern, W., 2004. Global occurrences of extreme precipitation and the Madden–Julian oscillation: Observations and predictability. *Journal of Climate*, *17*(23), pp.4575-4589.

Maloney, E.D., Adames, Á.F. and Bui, H.X., 2019. Madden–Julian oscillation changes under anthropogenic warming. *Nature Climate Change*, *9*(1), pp.26-33.

Neale, R.B., Richter, J.H. and Jochum, M., 2008. The impact of convection on ENSO: From a delayed oscillator to a series of events. *Journal of climate*, *21*(22), pp.5904-5924.

Zhou, S., L'Heureux, M., Weaver, S. and Kumar, A., 2012. A composite study of the MJO influence on the surface air temperature and precipitation over the continental United States. *Climate dynamics*, *38*(7), pp.1459-1471.

Zhou, W., Yang, D., Xie, S.P. and Ma, J., 2020. Amplified Madden–Julian oscillation impacts in the Pacific–North America region. *Nature Climate Change*, *10*(7), pp.654-660.