# The Madden-Julian Oscillation under time-dependent forcing: A stochastic skeleton model approach

Noémie Ehstand[1], Reik V. Donner[2,3], Cristóbal López[1], Emilio Hernández-García[1], and Marcelo Barreiro[4]

*E.H.-G. email: emilio@ifisc.uib-csic.es*

[1]Institute for Cross-Disciplinary Physics and Complex Systems (IFISC), CSIC-University of the Balearic Islands, Palma de Mallorca, Spain

[2]Department of Water, Environment, Construction and Safety, Magdeburg–Stendal University of Applied Sciences, Magdeburg, Germany

[3]Research Department IV-Complexity Science, Potsdam Institute for Climate Impact Research (PIK) – Member of the Leibniz Association, Potsdam, Germany

[4]Departamento de Ciencias de la Atmósfera y Física de los Océanos, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay

**Abstract**

The Madden–Julian oscillation (MJO, [**?**]) is the dominant component of intra-seasonal variability in the tropics [**?**]. It is a planetary-scale wave envelope of smaller-scale convective processes, slowly propagating eastward along the equator, with a period of 40 to 50 days on average, and a propagation speed of about 5m/s. As it propagates, the MJO causes disturbances in rainfall and winds which impact weather and climate in both the tropics and the extratropics. In particular, the MJO plays a significant role in the occurrence of various weather extremes such as tropical cyclones, tornadoes, extreme rainfall events and extreme surface temperatures.

We analyze solutions of the stochastic skeleton model, a minimal nonlinear oscillator model for the MJO [**?**, **?**]. This model has been recognized for its ability to reproduce several large-scale features of the MJO. In previous studies, the model's forcing functions were predominantly chosen to be mathematically simple and time-independent. Here, we present solutions with time-dependent observation-based forcing functions. Our results show that the model, with these more realistic forcing functions, successfully replicates key characteristics of MJO events, such as their lifetime, extent, and amplitude, whose statistics agree well with observations. However, we find that the seasonality of MJO events and the spatial variations in the MJO properties are not well reproduced. Additionally, we study the model's capacity to reflect changes in MJO characteristics under the different phases of ENSO. We find that the model does not capture differences in the empirical characteristics of MJO events in response to changes in climatological background conditions corresponding to El Niño, La Niña, and Neutral ENSO.

## Acknowledgement

We acknowledge funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skolodowska-Curie Grant Agreement No 813844, from the Agencia Estatal de Investigación (MCIN/AEI/10.13039/501100011033) under the María de Maeztu project CEX2021-001164-M, and from the Agencia Estatal de Investigación and FEDER "Una manera de hacer Europa" under Project LAMARCA No. PID2021-123352OB-C32. R.V.D. acknowledges financial support by the German Federal Ministry for Education and Research (BMBF) via the JPI Climate/JPI Oceans Project ROADMAP (Grant No. 01LP2002B).

# References

[1] Madden, R. A. & Julian, P. R. *Description of Global-Scale Circulation Cells in the Tropics with a 40–50 Day Period.* Journal of the Atmospheric Sciences 29, 1109–1123, 1972.

[2] Woolnough, S. J. *The Madden-Julian Oscillation. In* Robertson, A. W. & Vitart, F. (eds), Sub-Seasonal to Seasonal Prediction, Chapter 5, pp. 93–117. Elsevier, 2019.

[3] Majda, A. J. & Stechmann, S. N. *The skeleton of tropical intraseasonal oscillations.* Proceedings of the National Academy of Sciences 106, 8417–8422, 2009.

[4] Thual, S., Majda, A. J., & Stechmann, S. N. *A Stochastic Skeleton Model for the MJO.* Journal of the Atmospheric Sciences 71, 697–715, 2014.