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Editorial: Dynamics and impacts of tropical climate variability: Understanding trends and future projections

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Editorial on the Research Topic
Dynamics and impacts of tropical climate variability: Understanding trends and future projections

Tropical climate variability such as the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) exert significant socio-economic and environmental impact on a global scale. El Niño, ENSO positive phase, is characterized by surface warming in the central-eastern equatorial Pacific Ocean, weakened trade winds, suppressed upwelling, and atmospheric convection displacements. Consequently, shifts in climate occur, in which anomalous drying typically prevails over Indo-Pacific-rim countries (e.g., India, Indonesia, Australia) and increased rainfall occurs over eastern Pacific-rim countries (e.g., southwest US, Peru). IOD positive phase, with anomalous cooling in the eastern and warming in the western tropical Indian Ocean, leads to drying over Indonesia and parts of Australia, while east Africa and India generally experiencing wetter-than-normal conditions. Opposite impacts are generally seen in their negative phases. ENSO and IOD also modulate intraseasonal variability like the Madden Julian Oscillation and extreme weather phenomena like tropical cyclones.

Given the significant impacts, one critical question is how tropical climate variability responds to greenhouse forcing, encapsulating various aspects, e.g., variability magnitude, frequency, dynamics, detectability, teleconnections, impacts, and predictability. The latest generation of models and paleo reconstructions have indicated a likelihood of changing ENSO and IOD in a warming climate (Abram et al., 2020; Cai et al., 2021a,b; Karamperidou et al., 2021; Lopez et al., 2022). However, uncertainties remain given persisting challenges in paleo reconstructions (Emile-Geay et al., 2021) and modeling (e.g., McKenna et al., 2020). Research efforts have accelerated in the last two decades to address these issues, leveraging on advances in observations, models, theories, paleo reconstructions, data science, computing power, as well as coordinated multi-institutional efforts such as the Coupled Model Intercomparison Project (CMIP).

Increasing capacity to perform long-integration and large-ensemble climate simulations, for instance, has allowed a better understanding of ENSO future projection uncertainties (e.g., Maher et al., 2018). It allowed an identification of a link between future and past ENSO variability through non-linear processes in that when past ENSO variability is high, future ENSO variability tends to be low, and vice versa (Cai et al., 2020). Such a link is reaffirmed by Hyun et al. in terms of internal climate variability based on global surface temperature, using two large-ensemble climate models. They additionally infer that past/present internal variability in the extratropics also influences future ENSO amplitude. The study calls for an improved representation of global internal climate variability to reduce ENSO projection uncertainty. ENSO projection uncertainty is further highlighted by Rashid in a single model with large ensemble members, detecting a modest but statistically significant increase in future ENSO amplitude, found to be most prominently linked to changes in zonal winds and zonal sea surface temperature (SST) gradient.

A closely related issue which has been gaining attention is the time by which greenhouse-forced signal emerges beyond the range of internal variability, often referred to as "time of emergence" (ToE). Recent studies based on CMIP models focusing on the tropical Pacific Ocean have underscored the likelihood for ENSO-related SST ToE toward the end of 21st century, with ENSO-related rainfall emerging earlier by around 2040 (Cai et al., 2021b; Ying et al., 2022). Assessment of ToE should be extended for teleconnection over continents globally due to the more direct societal impact, especially given the projected increase in ENSO teleconnection over several land regions (McGregor et al., 2022). Here Johnson et al. examine ensemble simulations with a high-resolution climate model, finding that robust changes in temperature, precipitation, and 500-hPa geopotential height at the peak of ENSO events emerge by mid-21st century over tropical South America and Southeast Asia. Their results suggest that the increased risk of greenhouse-forced ENSO-related extremes, such as drought, floods, heatwaves, and cold extremes, could be detectable in the coming decades. Determining ToE is influenced by how the signal is identified; e.g., separating ENSO into Eastern Pacific and Central Pacific types can lead to better signal detectability, thus an earlier ToE (Geng et al., 2022).

Forced changes in tropical climate variability are linked to changes in the mean-state; e.g., projected increase in ENSO variability is tied to a weakened Walker Circulation and associated changes in the equatorial Pacific Ocean (e.g., Cai et al., 2021b). Investigating how the latest generation climate models represent the mean climate and produce projected changes is an important step toward projection uncertainty reduction. Here, Stellema et al. examined the representation and projected changes of the Pacific Equatorial Undercurrent (EUC) and its sources in CMIP5, CMIP6 models, and an eddy-permitting ocean model. They found that while these ocean circulations can be largely reproduced by the models, there remain notable biases (e.g., in terms of seasonality) with limited improvements from CMIP5 to CMIP6. The EUC is projected to strengthen in the Western Pacific, with CMIP6 models and the high-resolution ocean model showing the least and most significant change, respectively.

A realistic simulation of equatorial ocean dynamics is required to capture tropical variability-induced changes in remote regions through ocean teleconnection. In examining the relationship between ENSO and South Pacific Meridional Mode (SPMM) in observations and multiple models, Dewitte et al. found that many CMIP5 and CMIP6 models do not properly capture strong SPMM events that follow strong El Niño events. The associated ENSO-related equatorial waves that lead to coastal warming off Central Chile that characterizes the SPMM are not well-simulated by the models. On the other hand, in investigating the predictability of SST variability in the eastern region of the IOD utilizing a convolutional neural network (CNN), a machine learning subclass, on a collection of CMIP5/6 models, Feng et al. suggest that CMIP models can capture the dynamics of Indian Ocean variability and its teleconnection with Pacific climate variability. They found that employing the CNN method allows the eastern IOD SST variability to be forecast up to 6 months in advance, about double the persistence.

Continued research is needed to reduce projection uncertainty in tropical climate variability, encompassing mechanisms, teleconnections, impacts, and predictability; particularly because of the complex dynamics which involve interactions between oceans and atmosphere, between variability and mean state, across basins, and across time scales.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abram, N. J., Hargreaves, J. A., Wright, N. M., Thirumalai, K., Ummenhofer, C. C., and England, M. H. (2020). Palaeoclimate perspectives on the Indian Ocean Dipole. *Quat. Sci. Rev.* 237, 106302. doi: 10.1016/j.quascirev.2020.106302

Cai, W., Ng, B., Geng, T., Wu, L., Santoso, A., and McPhaden, M. J. (2020). Butterfly effect and a self-modulating El Niño response to global warming. *Nature* 585, 68–73. doi: 10.1038/s41586-020-2641-x

Cai, W., Santoso, A., Collins, M., Dewitte, B., Karamperidou, C., Kug, J.-H., et al. (2021b). Changing El Niño Southern Oscillation in a warming climate. *Nat. Rev. Earth Environ.* 2, 628–644. doi: 10.1038/s43017-021-00199-z

Cai, W., Yang, K., Wu, L., Huang, G., Santoso, A., Ng, B., et al. (2021a). Opposite response of strong and moderate positive Indian Ocean Dipole to global warming. *Nat. Clim. Change* 11, 27–32. doi: 10.1038/s41558-020-00943-1

Emile-Geay, J., Cobb, K. M., Cole, J. E., Elliot, M., and Zhu, F. (2021). "Past ENSO variability: Reconstructions, models, and implications," in *El Niño Southern Oscillation in a Changing Climate*, eds M. J. McPhaden, A. Santoso, and W. Cai (Washington, DC: American Geophysical Union), 87–118. doi: 10.1002/9781119548164.ch5

Geng, T., Cai, W., Wu, L., Santoso, A., Wang, G., Jing, Z., et al. (2022). Emergence of changing Central-Pacific and Eastern-Pacific El Niño-Southern Oscillation in a warming climate. *Nat. Commun.* 13, 6616. doi: 10.1038/s41467-022-33930-5

Karamperidou, C., Stuecker, M., Timmermann, A., Yun, K.-S., Lee, S.-S., Jin, F.-F., et al. (2021). "ENSO in a changing climate: challenges, Paleo-perspectives, and outlook," in *El Niño Southern Oscillation in a Changing Climate*, eds M. J. McPhaden, A. Santoso, and W. Cai (Washington, DC: American Geophysical Union), 471–484. doi: 10.1002/9781119548164.ch21

Lopez, H., Lee, S.-K., Kim, D., Wittenberg, A. T., and Yeh, S.-W. (2022). Projections of faster onset and slower decay of El Niño in the 21st century. *Nat. Commun.* 13, 1915. doi: 10.1038/s41467-022-29519-7

Maher, N., Matei, D., Milinski, S., and Marotzke, J. (2018). ENSO change in climate projections: forced response or internal variability? *Geophys. Res. Lett.* 45, 11390–11398. doi: 10.1029/2018GL079764

McGregor, S., Cassou, C., Kosaka, Y., and Phillips, A. S. (2022). Projected ENSO teleconnection changes in CMIP6. *Geophys. Res. Lett.* 49, e2021GL097511. doi: 10.1029/2021GL097511

McKenna, S., Santoso, A., Gupta, A. S., Taschetto, A. S., and Cai, W. (2020). Indian Ocean Dipole in CMIP5 and CMIP6: characteristics, biases, and links to ENSO. *Sci. Rep.* 10, 11500. doi: 10.1038/s41598-020-68268-9

Ying, J., Collins, M., Cai, W., Timmermann, A., Huang, P., Chen, D., et al. (2022). Emergence of climate change in the tropical Pacific. *Nat. Clim. Chang.* 12, 356–364. doi: 10.1038/s41558-022-01301-z