Response to Reviewer 1

Title: Climate Modes evaluation datasets from CMIP6 pre-industrial control simulations and observations

Authors: Mohapatra et al.

This paper analyzes eight commonly examined climate modes derived from CMIP6 pre-industrial control simulations. The study aims to provide a foundation for evaluating climate mode interactions, model performance, attribution studies, and internal variability diagnostics. The topic is valuable, and the constructed dataset could be useful to the climate community. However, several clarifications and revisions are needed before the manuscript can be considered for publication. My detailed comments follow.

Reply: We thank the reviewer for appreciating the work and providing valuable suggestions and useful comments, which helped us to improve the manuscript. Below we have provided a reply to each comment in detail, with replies in blue color.

Line 58: please add citations distinguishing CP and EP ENSO types.

Reply: Qi et al. 2021, Singh et al. 2011, Xu et al. 2017 and all been added.

References:

- Qianqian Qi, Wansuo Duan, Hui Xu, (2021) The most sensitive initial error modes modulating intensities of CP- and EP- El Niño events, Dynamics of Atmospheres and Oceans, Volume 96,101257,ISSN 0377-0265, https://doi.org/10.1016/j.dynatmoce.2021.101257.
- Singh, A., T. Delcroix, and S. Cravatte (2011), Contrasting the flavors of El Niño-Southern Oscillation using sea surface salinity observations, J. Geophys. Res., 116, C06016, doi:10.1029/2010JC006862.
- Xu, K., Tam, C.-Y., Zhu, C., and Liu, B. (2017) CMIP5 projections of two types of El Niño and their related tropical precipitation in the twenty-first century, J. Clim., 30, 1–10, 725 https://doi.org/10.1175/JCLI-D-16-0413.s1.

Line 98: ENSO teleconnection biases remain in CMIP6. Please see Fang et al. (2024)

Reference: Fang, Y., Screen, J. A., Hu, X., Lin, S., Williams, N. C., & Yang, S. (2024). CMIP6 Models Underestimate ENSO Teleconnections in the Southern Hemisphere. *Geophysical Research Letters*, *51*(18), e2024GL110738. https://doi.org/https://doi.org/10.1029/2024GL110738

Reply: Thank you for your valuable suggestion. We agree that ENSO teleconnection biases remain an issue in CMIP6 simulations. We have added the citation to Fang et al. (2024) and revised the text accordingly.

Revised Text: "Based on historical simulations, CMIP6 exhibits clear advances, for instance, improved representation of several ENSO characteristics, more realistic IOD spatial patterns, and better reproduction of AMO variability, yet persistent issues remain, such as biases in IOD amplitude and weak coupling between near-surface and subsurface processes and teleconnection processes particularly in Southern Hemisphere for ENSO (Planton et al., 2021; McKenna et al. 2020; Fang et al. 2024)"

Line 143: the manuscript compares only with ERSSTv5. Why not validate using multiple observational SST datasets? Please justify or add datasets to quantify observational uncertainty.

Reply: To assess observational uncertainty, we additionally computed the EP-El Niño index using the HadISST dataset. The results from HadISST and ERSSTv5 show very consistent spatial patterns, with a correlation of 0.98 between the two datasets (Fig. R1). Given this strong agreement, we retained ERSSTv5 in the manuscript for clarity and consistency and have added justification and clarification in the revised text.

Since the main purpose of this data description paper is to present the derived datasets from piControl simulations, the inclusion of observational datasets is to demonstrate the realism of the spatial patterns of the climate modes, rather than to achieve exact amplitude agreement.

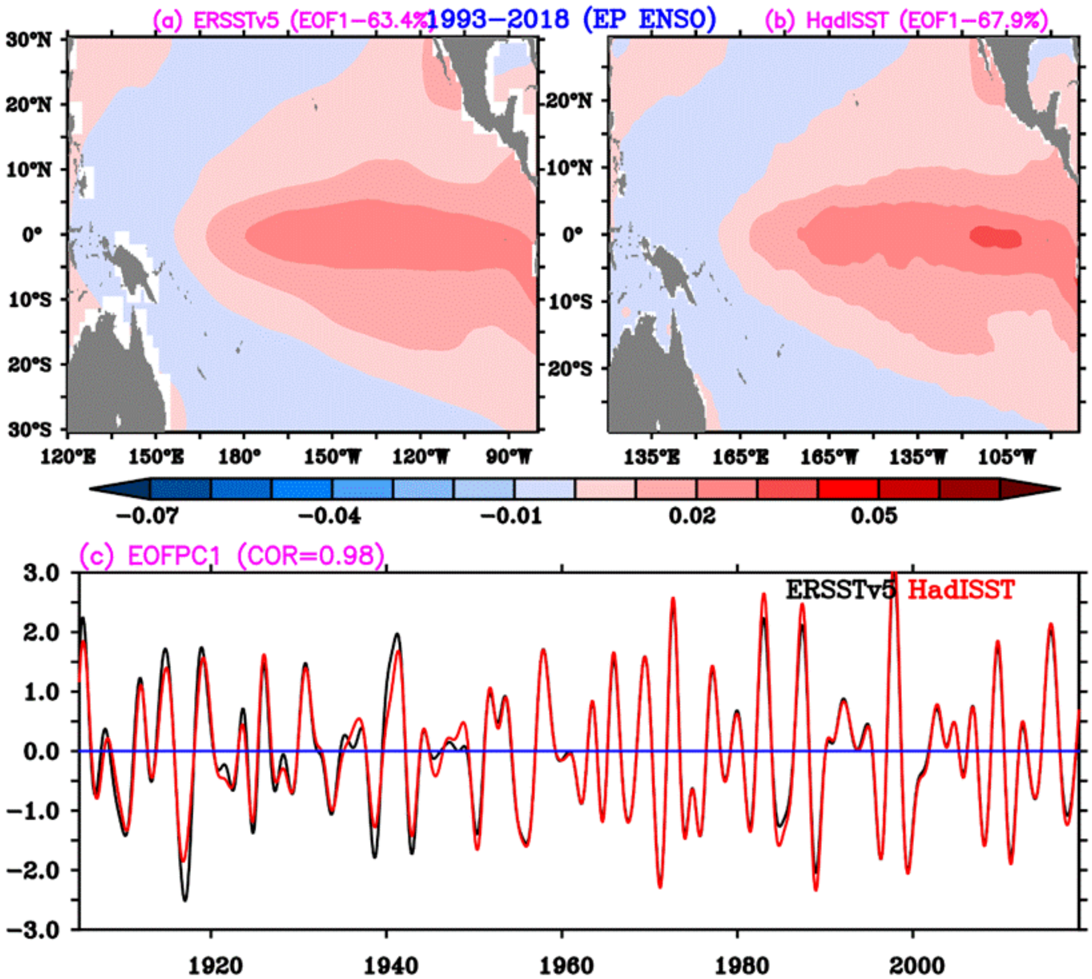

Figure R1. Spatial pattern of EP-El Nino (Leading mode of variability in sea surface temperature) from (a) ERSSTv5 and (b) HadISST. (c) Time series of EP-El Niño index (PC1) from ERSSTv5 (black) and HadISST (red).

Line 170: clarify whether 1°×1° interpolation is optimal. Are results sensitive to interpolation resolution? A brief justification or sensitivity comment would strengthen confidence.

Reply: Thank you for this helpful comment. We interpolated all datasets to a common 1° × 1° grid to ensure consistency across models and observations while retaining the large-scale spatial variability relevant to this study. This resolution represents a practical balance between preserving spatial details and minimizing interpolation-induced noise, and it is commonly adopted in multi-model comparison studies. To assess robustness, we performed the EOF analysis (For EP-El Niño) using a coarser resolution (e.g., 2°×2°), and the main spatial and temporal patterns remain largely unchanged. This suggests that our results are not sensitive to the choice of interpolation resolution. A clarification has now been added in the revised manuscript.

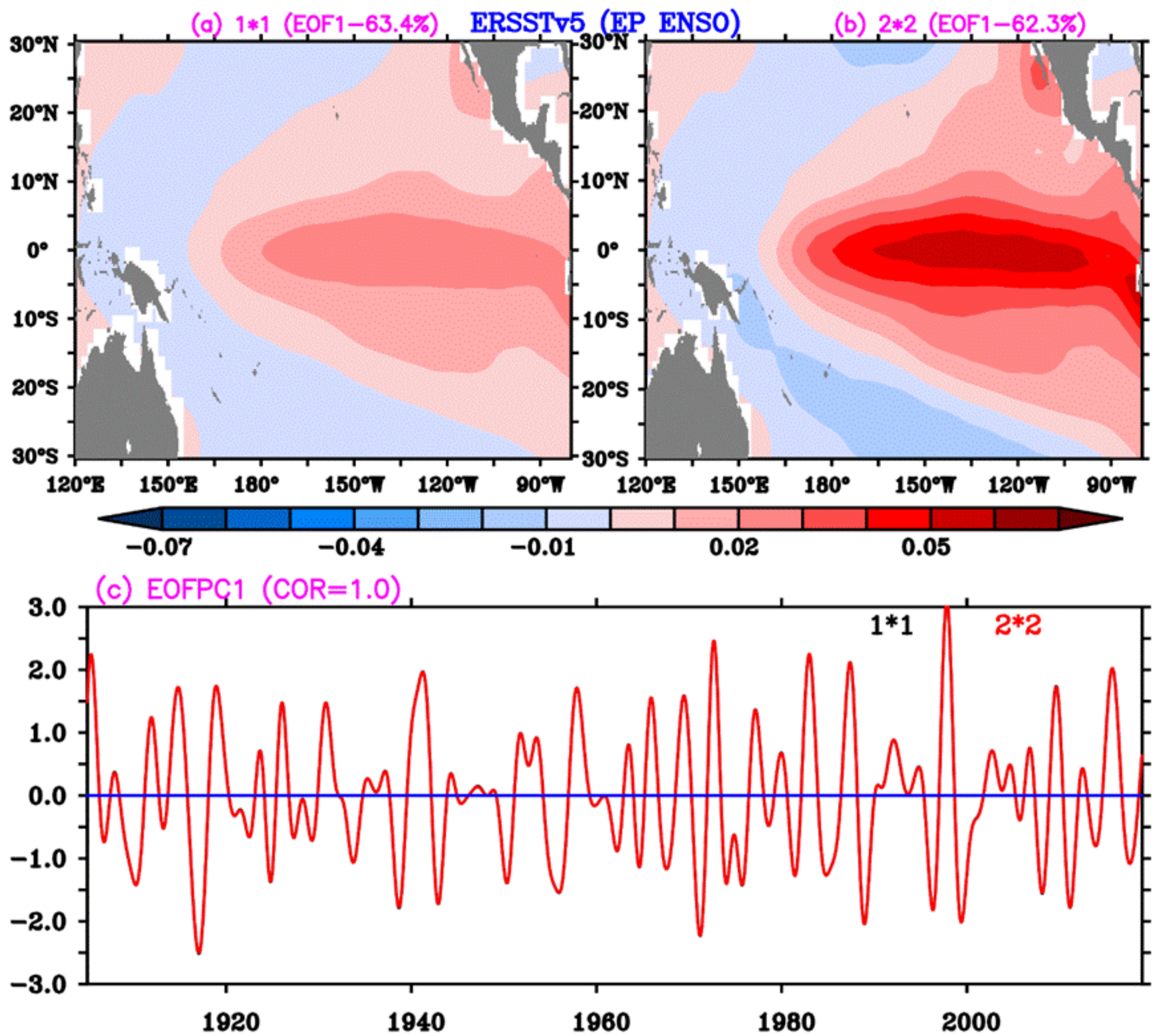

Figure R2. Spatial pattern of EP-El Niño (Leading mode of variability in sea surface temperature) from ERSSTv5 based on different horizontal resolutions of (a) 1°×1° and (b) 2°×2°. (c) Time series of EP-El Niño index (PC1) based on 1°×1° and 2°×2°.

Line 203: “10-year”

Reply: Modified.

Table captions should appear at the top of tables according to journal guidelines.

Reply: Modified.

Line 335 / Fig. 4f: IPO period varies across models. Please explain possible causes.

Reply: Thank you for the comment. The variation in IPO periodicity across models likely arises from differences in mean state biases, ocean–atmosphere coupling strength, and the representation of Pacific thermocline structure and ocean adjustment timescales. In addition, longer piControl simulations allow better sampling of low frequency internal variability, leading to broader spectral power and longer periodicities.

However, as ESSD guidelines primarily emphasize dataset description rather than detailed scientific interpretation, we have included only a brief clarification in the revised manuscript.

Line 410: explain the mechanism responsible for cooling over the North Atlantic. Possible related factors include AMOC weakening, aerosol forcing representation, internal variability, or model drift.

Reply: The North Atlantic cold bias, an issue that persisted from CMIP5 into CMIP6, arises from a combination of factors: misplacement and weakening of the Gulf Stream due to insufficient ocean resolution and excessive mixing, weak AMOC transport, surface heat flux errors, and freshwater-induced stratification. These combined processes reduce the northward and vertical ocean heat transport, inducing the cold bias in the north Atlantic. (Huo et al. 2024, Moreno et al. 2022, Weijer et al. 2020)

As per the ESSD guidelines, we have included only brief clarification in the revised manuscript.

Reference:

- Huo, W., A. Drews, T. Martin, and S. Wahl. 2024. "Impacts of North Atlantic Model Biases on Natural Decadal Climate Variability." Journal of Geophysical Research: Atmospheres 129, no. 4: e2023JD039778. https://doi.org/10.1029/2023JD039778.
- Moreno-Chamarro E, Caron LP, Loosveldt Tomas S, Vegas-Regidor J, Gutjahr O, Moine MP, Putrasahan D, Roberts CD, Roberts MJ, Senan R, Terray L, Tourigny E, Vidale PL (2022) Impact of increased resolution on long-standing biases in HighResMIP-PRIMAVERA climate models Geosci. Model Dev 15:269–289. https://doi.org/10.5194/gmd-15-269-2022
- Weijer, W., Cheng, W., Garuba, O. A., Hu, A., & Nadiga, B. T. (2020). CMIP6 models predict significant 589 21st century decline of the Atlantic Meridional Overturning Circulation. Geophysical Research 590 Letters, 47(12), e2019GL086075.

Line 473: "50 years."

Reply: Modified.