Earth System Dynamics Discussions

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Comment on esd-2022-12

Anonymous Referee #3

Referee comment on "Contrasting projections of the ENSO-driven CO_2 flux variability in the equatorial Pacific under high-warming scenario" by Pradeebane Vaittinada Ayar et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2022-12-RC3, 2022

The study by Ayar et al. aims to investigate the ENSO-induced response of air-sea CO_2 fluxes from CMIP6 ESMs. ENSO is a big driver of inter-annual variability in the carbon cycle, and studying the response of the carbon cycle to ENSO is critical for understanding how feedbacks between the physical climate system and global carbon cycle operate. The study explores the response of our current generation of ESMs under a high CO_2 future climate scenario (future period 2071-2100) in the context of their skills over a contemporary reference period (1985-2014). The authors use a wide variety of observational data and skill metrics to show distinct relationships emerging from the different ESMs. The study is timely and significant and should be considered for publication once the authors address and clarify a few issues for the benefit of the reader and the scientific community. Specifically, I would strongly advise the authors to consider and respond to Major Comment #1 given that the authors have submitted to 'Earth System Dynamics' - a journal that does emphasize on interdisciplinary Earth system science, beyond just ocean sciences.

Major Comments:

- Even though the authors are looking at the response of coupled models, the authors have ignored any changes or even providing statements about the atmospheric response (except Lines 340-344). There is no mention of changes in trade winds and/or changes in conditions of the air-sea interface due to the weakening of the easterly trade winds (during El Niño, for example). To me, this is a key ingredient that is missing from the study. This is a CMIP-based study and since the tropical ocean-atmosphere are strongly coupled with each other, the authors do need to provide qualitative statements about how atmospheric conditions across the ESMs (preserved vs. reserved) evolve that impact the oceanic ENSO response. Quantitative analyses regarding changes in atmospheric winds across the study time periods (or a figure or two) would be better, but I recognize that a quantitative evaluation of dynamical wind response is not a trivial task.
- The authors should consider evaluation of the models for specific ENSO cases - strong El Niño or strong La Niña years. Figure 5 provides a first indication that the "preserved" ESMs agree better with the observations than the reversed ESMs. But the comparison is

noisy, and it may be better to examine specific strong and very strong ENSO events between 1950 – 2014. Approximately 10 such events can be identified for both El Niño and La Niña conditions that should allow robust statements on which of the two groups of ESMs (preserved vs reserved) validate better against observations.

Minor Comments:

- Line 2 – change to 'over the tropical ocean less carbon is released during El Niño…'
- Line 56 – it is hard to interpret what the authors mean by the phrase 'an end member future projection'. While it becomes clear eventually that the authors are referring to the high-emission scenario, maybe add a sentence or two here to clarify this phrase for the benefit of the reader.
- Line 97 – please check the grammar and punctuation
- Lines 145-146 and Lines 337-339 – it is a bit strange that while the authors define a classical Niño 3.4 domain (Lines 99-100), the study area is subsequently shifted to different longitudes. This matters because not all El Niños are similar and whether we are looking at an EP or a CP El Niño should have implications for the findings of this study. Did the authors consider evaluating the model simulations based on different El Niño types?
- I would strongly encourage a modified version of Figure 11 – again, instead of looking at 1850-2100, maybe pick a period or specific strong & very strong ENSO years, for which the authors can plot a 'best estimate' of air-sea CO_2 flux from observations and/or models (for example, see Ishii et al., 2014, Biogeosciences, https://doi.org/10.5194/bg-11-709-2014). It would be interesting to see which of the ESMs actually fall in the region where surface CO_3^{2-} concentration obs. and the most optimal estimate of air-sea CO2 fluxes overlap. Can we identify a subset within the 16 CMIP6 ESMs that validate better against the observations? This study has already laid the foundation for providing this key message, thereby really helping the improvement of future ESMs and CMIP simulations.