Research Plan for the Impact of Anthropogenic Forcing on ENSO Amplitude

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May 11, 2021

1 Rationale

El Niño/Southern Oscillation (ENSO) is a cyclical change in the temperature of the equatorial Pacific Ocean. It is accompanied by disturbances to the Walker Circulation and reduced upwelling in the eastern Pacific (Bjerknes, 1969). ENSO has extreme effects on global climate, affecting the intensity of rainfall in the Americas, the location of Rossby Waves, the paths of storms, and much more (Liu and Alexander, 2007). Because of these critical effects, determining how climate change will affect ENSO is crucial.

Scientists have begun to research the effects of natural and anthropogenic forcing on ENSO. For example, Zhu et al. (2017) showed that during the Last Glacial Maximum, lower CO_2 levels reduced ENSO variability. Levine et al. (2017) suggested that the Atlantic Multidecadal Oscillation (AMO) may also play a role in determining ENSO amplitude and demonstrated the difficulty in predicting long-term changes to ENSO. Researchers have also shown the effect of natural forcing on ENSO variability. Zheng et al. (2018) showed that ENSO variability is highly dependent on internal variability, and therefore a model with a large ensemble is necessary to measure a robust signal. Despite the copious noise in the simulated ENSO amplitude record, progress has been made in determining the sign of changes to ENSO amplitude over the 21st century. Recent studies (Maher et al., 2018), (Cai et al., 2018) suggest that ENSO is likely to intensify, using records of increased ENSO amplitude in large model ensembles as evidence.

These past studies provide a background of predicted increased ENSO amplitude. With this background as a starting point, this study aims to assess probable causes for this predicted increasing amplitude. Using 2 recent derivatives of the National Center for Atmospheric Research's (NCAR)

Community Earth System Model version 1 (CESM1), the CESM1 Large Ensemble and the CESM1 Single Forcing Ensembles. Using these tools, significant increases to ENSO amplitude over the 21st century were attributed to the combined influence of greenhouse gases and aerosol emissions on ocean stratification and mixed layer heat transfer. However, some questions remain, and new data sources beckon. Firstly, past results conducted indicate a predicted decrease in ENSO amplitude after approximately 2060, which the researchers aim to investigate. Additionally, the sign of changes to ENSO amplitude under greenhouse forcing agree with those under aerosol forcing, where other studies indicated that they should be the opposite due to the differing nature of greenhouse and aerosol emissions (Deser et al., 2020). Moreover, it is still unclear specifically how greenhouse and aerosol emissions affect mixed layer heat transfer. Finally, Large Ensemble and Single Forcing runs are nearly complete for NCAR's next generation of the CESM, CESM2. Past methods will be repeated on this dataset and results will be compared to those from the CESM1, with the hope that the CESM2 results will provide insight into those descrepancies that appear in the CESM1 output. Additionally, deeper analysis of the role of air currents and ocean structure will be conducted for each ensemble to further clarify the processes that mediate the aformentioned forced effect on ENSO amplitude.

2 Research Goals

- Estimate future changes to ENSO amplitude in the NCAR's Community Earth System Model Version 2 (CESM2)
- Compare these changes to those previously found in the CESM1.
- Examine contributions of greenhouse gasses, aerosols, and natural forcing in both models.
- Explore physical mechanism that mediates emissions' effect on ENSO amplitude.

3 Methods

3.1 Materials and Data

- NCAR's CESM1 and CESM2 will be used.
  - Fully forced historical and projected simulations.

- Single forcing simulations that are forced by all but one factor.

- The Python and R programming language will be used with third party packages as needed.

3.2 Procedures

Methods are subject to change in response to results

- Prodedures from previous version of this study will be repeated using the Python and R languages.
- ENSO amplitude will be measured in each simulation by calculating the 20-year running variance of the Niño 3.4 index.
- A bootstrap process will be used to isolate the influence of single forcings, comparing their contributions in the context of global warming.
- Correlation coefficient between Niño 3.4 variance and sea temperature will be calculated for each simulation.
- A mixed-layer heat budget analysis will be used to further clarify the role of heat transfer in determining changes to ENSO under global warming.

3.3 Risk and Safety

No risk/safety issues relevant as all methods are digital.

4 Role of Mentor and Student

Student	Shared	Mentor
Perform all calculations	Discuss and interperet results	Review results and methods
Produce plots and documents		Provide large datasets

References

Bjerknes, J. (1969). Atmospheric teleconnections from the equatorial pacific. *Mon. Wea. Rev*, 97(3):163–172.

Cai, W., Wang, G., Dewitte, B., Wu, L., Santoso, A., Takahashi, K., Yang, Y., Carréric, A., and McPhaden, M. J. (2018). Increased variability of eastern pacific el niño under greenhouse warming. *Nature*, 564(7735):201–206.

Deser, C., Phillips, A. S., Simpson, I. R., Rosenbloom, N., Coleman, D., Lehner, F., Pendergrass, A. G., DiNezio, P., and Stevenson, S. (2020). Isolating the evolving contributions of anthropogenic aerosols and greenhouse gases: a new cesm1 large ensemble community resource. *Journal of Climate*, 33(18):7835–7858.

Levine, A. F., McPhaden, M. J., and Frierson, D. M. (2017). The impact of the amo on multidecadal enso variability. *Geophysical Research Letters*, 44(8):3877–3886.

Liu, Z. and Alexander, M. (2007). Atmospheric bridge, oceanic tunnel, and global climatic teleconnections. *Reviews of Geophysics*, 45(2).

Maher, N., Matei, D., Milinski, S., and Marotzke, J. (2018). Enso change in climate projections: Forced response or internal variability? *Geophysical Research Letters*, 45(20):11–390.

Zheng, X.-T., Hui, C., and Yeh, S.-W. (2018). Response of enso amplitude to global warming in cesm large ensemble: uncertainty due to internal variability. *Climate Dynamics*, 50(11-12):4019–4035.

Zhu, J., Liu, Z., Brady, E., Otto-Bliesner, B., Zhang, J., Noone, D., Tomas, R., Nusbaumer, J., Wong, T., Jahn, A., et al. (2017). Reduced enso variability at the lgm revealed by an isotope-enabled earth system model. *Geophysical Research Letters*, 44(13):6984–6992.