The Effect of Natural and Anthropogenic Forcing on ENSO Amplitude in the CESM Large Ensemble

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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. Emile-Geay et al. (2007) suggested the role of ENSO in the effect of solar and orbital forcing on the Earth's climate, and Liu and Alexander (2007) determined that ozone changes dampen CO_2-forced reduction of ENSO amplitude. The conflicting relationship of ozone and CO_2 has also been shown for ENSO diversity, as Stevenson et al. (2019) showed that the effects of ozone and greenhouse gasses on the development of Eastern and Central Pacific ENSO events tend to cancel out. 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.

2 Research Goals

- Determine the effect of a range of climate factors on Ninõ amplitude.
- Examine mechanisms responsible for observed effect(s)

- The following factors will be considered:
  - Greenhouse gas emissions
  - Aerosol emissions
  - Biomass burning
  - Land use/cover
  - Ozone

3 Research Methods

3.1 Procedures

1. Data source: Community Earth System Model (CESM LME) output, publicly available but compiled by mentor
   - Full-forcing and single-forcing ensembles using recorded radiative forcing from 1920-2005, and RCP 8.5 projections from 2005-2100
   - 2000-year control run with pre-industrial forcing
2. The Python programming language with the Scipy package will be used to perform all calculations.
3. Running centered 20-year Niño 3.4 variance will be calculated for each ensemble member and the PI control.

3.2 Data Analysis

1. Mean and standard error will be calculated for each ensemble.
2. Probability Distribution Function (PDF) will be estimated for the control run.
3. Niño 3.4 index for single-forcing ensembles will be subtracted from full-forcing ensemble to isolate changes associated with individual factors.
4. Mean and standard error for full-forcing and single-forcing cases will be compared to that of the control.
5. The bootstrap method will be used to compare the single and full-forcing distributions.
6. Control Niño 3.4 variance PDF's will be calculated for high and low AMO and AMOC index using CVDP (Climate Variability Diagnostics Package) provided by mentor.
7. Correlation between Niño variance and equatorial Pacific ocean tempecature will be calculated for the full-forcing ensemble.
8. A mixed-layer heat budget analysis may be calculated to examine changes to ocean structure.

3.3 Risk and Safety

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

3.4 Role of Mentor and Student

Student	Shared	Mentor
Perform all calculations Produce plots and documentation	Discuss and interpret results and data	Review results and methods Suggest changes and future calculations Provide/compile datasets

References

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