

The Impact of Anthropogenic Forcing on ENSO Amplitude

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Climate Change

- The earth is getting warmer. (Pachauri et al., 2014)
- Climate varies on different scales.
- Long-term trends and short-term noise.
- **Forcing**: any external factor that affects climate.
 - Greenhouse gasses
 - Aerosols (natural: volcanic ash, artificial: smoke)
 - Biomass burning
 - Land use/cover (deforestation, desertification)

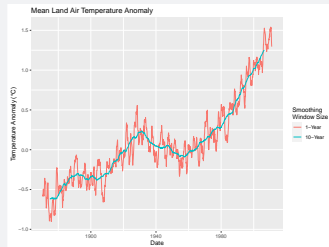
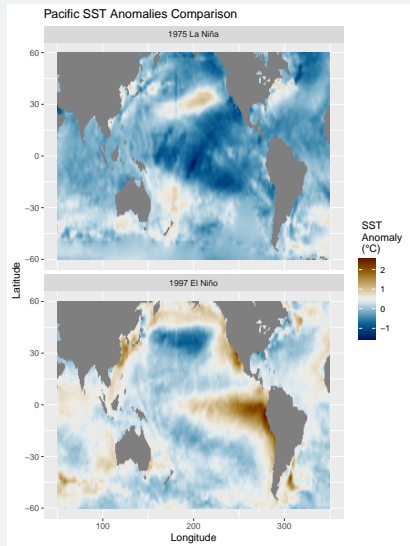


Figure 1: Global mean land air temperature in GISSTEMP 4 dataset. (Team et al., 2019) and (Lenssen et al., 2019)

El Niño (ENSO)

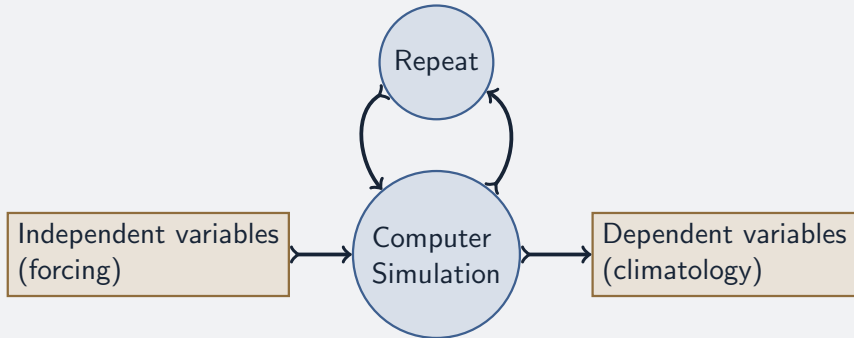
- Warming and cooling of the Pacific Ocean.
- Affects human societies through temperature and rainfall. (Ropelewski and Halpert, 1987)
- May be affected by climate change.

Figure 2: Comparison of SST anomaly between 1975 La Niña event and 1997 El Niño event in HadISST 1 dataset. (Rayner et al., 2003)



Climate Simulation

- Run climate simulation with predicted forcing levels as input.
- **Ensemble**: set of repeated simulations.



- ENSO changes over time (Lübbecke and McPhaden, 2014).
- ENSO responds to external forcing.
 - Correlation between ENSO strength and sunspot activity (Emile-Geay et al., 2007).
 - Weakened ENSO during the Ice Age due to reduced CO₂ levels (Zhu et al., 2017).
- Models show possible increasing ENSO activity in the future (Zheng et al., 2017) and (Maher et al., 2018).
- Factors other than CO₂ can affect ENSO.
 - Ozone emission may reduce ENSO activity (Nowack et al., 2017)
 - Aerosol emission may reduce ENSO activity (Stevenson et al., 2017)

Gap:

- Little research using a large ensemble to examine the effect of individual factors on ENSO.
- Considerable disagreement between studies on whether ENSO will strengthen or weaken due to global warming

Role of Mentor and Student

Mentor:

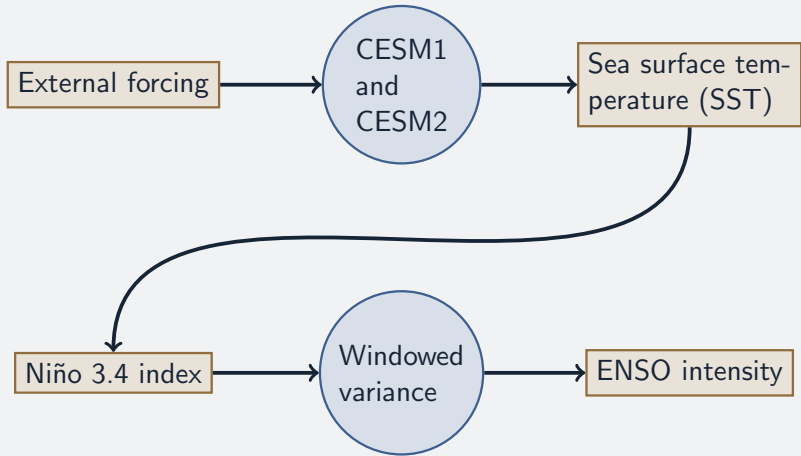
- Suggest future methods
- Conduct parallel analysis to complement student work
- Provide raw precollected data
- Interpret data produced by student
- Review student writing

Student:

- Analyze data on computer
- Produce graphics for analysis and publication
- Write documentation
- Suggest interpretations of data

- CESM1 (Kay et al., 2015)
- CESM2 (Danabasoglu et al., 2020)
- Observed forcing levels from 1850-2005
- Predicted forcing levels from 2005-2100
- Ensembles have 40 and 50 simulations respectively
- Control simulation with pre-1850 forcing levels

Measuring ENSO Intensity



Signal and Noise

- Butterfly effect
- Use ensemble mean to remove noise.
- The larger the ensemble, the less noise there is.

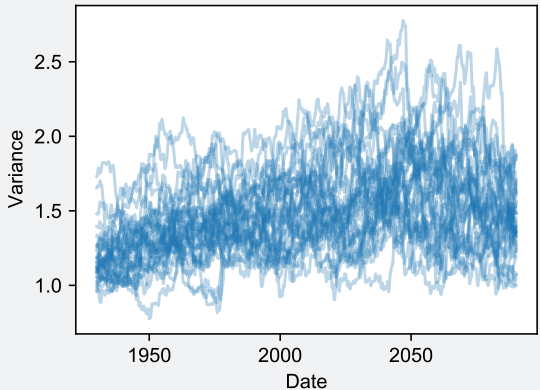


Figure 3: ENSO intensity for each run of the CESM1 Large Ensemble

ENSO is Becoming Stronger

- Increase in ENSO intensity in both ensembles.
- Increase slows down in CESM1 and decreases in CESM2 after around 2050.
 - May be caused by aerosol emissions.

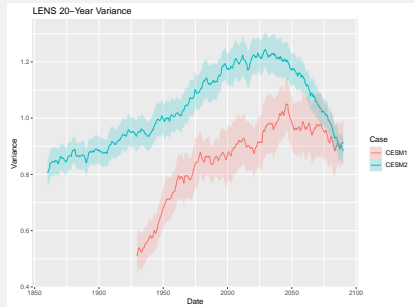


Figure 4: ENSO intensity ensemble mean and standard error for CESM1 and CESM2

Single Forcing Ensembles

Influence of Aerosols and Greenhouse Gasses

Correlation With Ocean Temperature

Stratification

Wavelet Analysis

Power Spectrum

Conclusions

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