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)

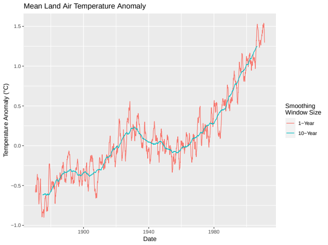


Figure 1: Global mean land air temperature in GISSTEMP 4 dataset. (Team et al., 2019) and (Lenssen et al., 2019)

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.

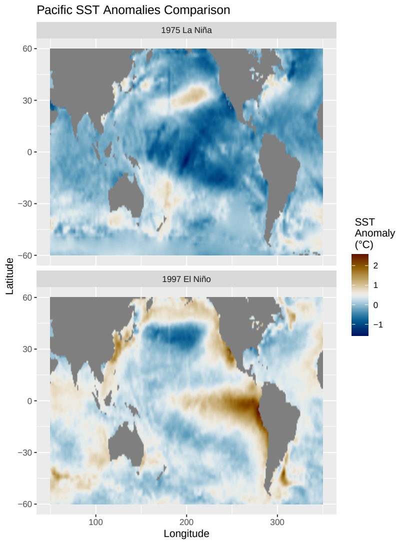
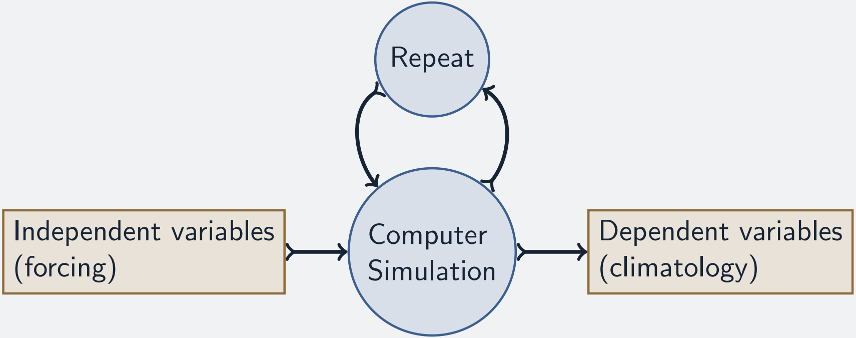


Figure 2: Comparison of SST anomaly between 1975 La Niña event and 1997 El Niño event in HadISST 1 dataset. (Rayner et al., 2003)

Climate Simulation

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



ENSO and Climate Change

- 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 CO_2 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 CO_2 can affect ENSO.
    - Ozone emission may reduce ENSO activity (Nowack et al., 2017)
    - Aerosol emission may reduce ENSO activity (Stevenson et al., 2017)

Gap and Questions

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

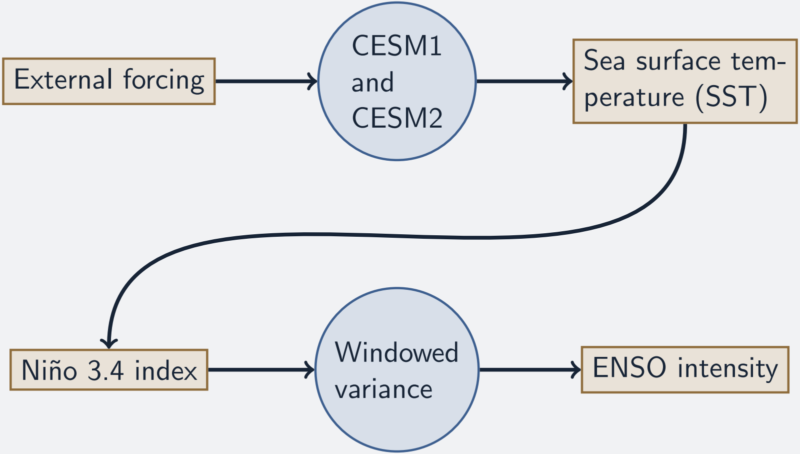
Student:

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

Model Setup

- 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.

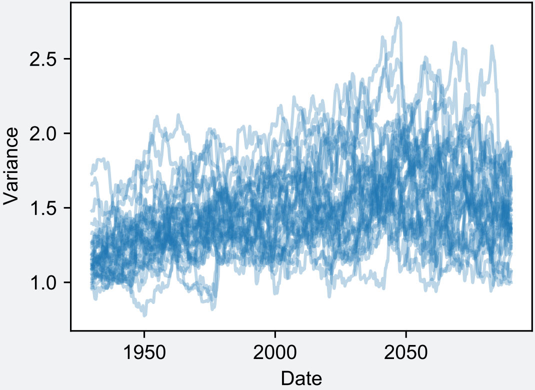


Figure 3: ENSO intensity for each run of the CESM1 Large Ensemble

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.

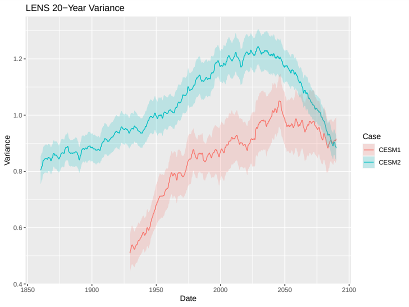


Figure 4: ENSO intensity ensemble mean and standard error for CESM1 and CESM2

Single Forcing Ensembles

Influence of Aerosols and Greenhouse Gasses

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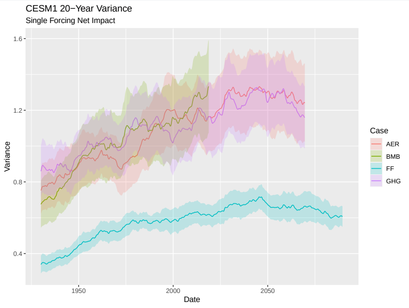

Figure 5: Influence of GHG, AER, and BMB forcing on ENSO amplitude in CESM1

Correlation With Ocean Temperature

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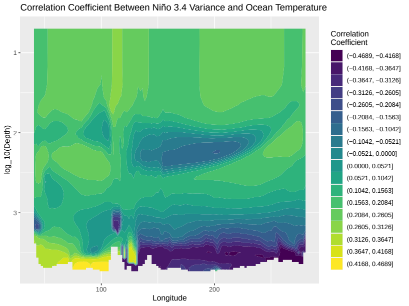

Figure 6: Correlation coefficient between ENSO amplitude and ocean temperature in the fully-forced CESM1 ensemble

Wavelet Analysis

Power Spectrum

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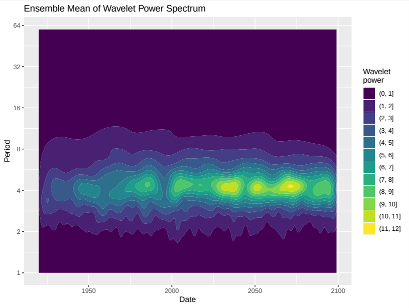

Figure 7: Wavelet power spectrum for the Niño 3.4 index in the fully-forced CESM1 ensemble

Conclusions

- There is likely to be an increase in ENSO strength over the next 100 years. Agrees with citet:cai2018increased.
- Increase is likely caused by the combined influence of greenhouse gasses and aerosols.
- Global warming increases ENSO intensity by warming upper layers of the Pacific faster than central layers.

Discussion

Application	Improve prediction ability to help people prepare for increased likelihood of extreme weather.
Limitation	Niño 3.4 index may not be fully accurate for various models (Cai et al., 2018).
Next steps	- Examine other variables to further analyze mediator process. - Continue wavelet analysis methods to focus on individual frequency bands.

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