The Impact of Anthropogenic Forcing on ENSO Amplitude

Ben Goldman

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Climate Change: Global Warming vs. Climate Variability

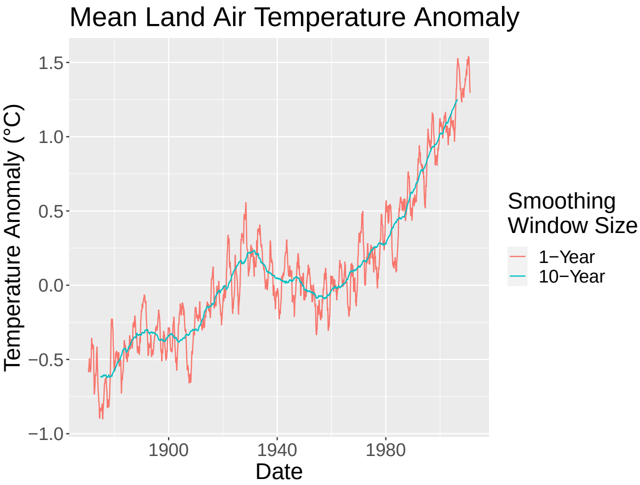


Figure 1: Global mean land air temperature in GISSTEMP 4 dataset. (Team et al., 2019) and (Lenssen et al., 2019)

Greenhouse Gasses and Friends

- Forcing: any external factor that affects climate.

  GHG Greenhouse gasses

  AER Aerosols (natural: volcanic ash, artificial: smoke)

  BMB Biomass burning

  LULC Land use/cover (deforestation, desertification)

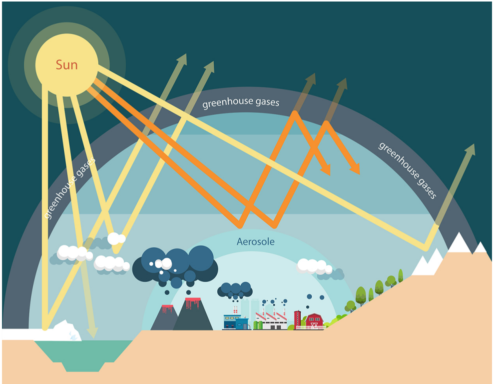


Figure 2: Factors that contribute to the greenhouse effect. `https://www.coolaustralia.org/the-greenhouse-effect-secondary`

El Niño, La Niña, and ENSO

- ENSO = El Niño/Southern Oscillation
- El Niño is the warm phase, and La Niña is the cool phase.
- Warming and cooling of the Pacific Ocean.
- Affects human societies through temperature and rainfall. (Ropelewski and Halpert, 1987)

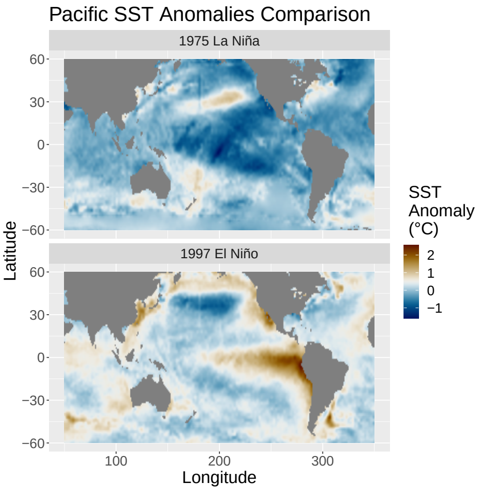


Figure 3: Comparison of SST anomaly between 1975 La Niña event and 1997 El Niño event in HadISST 1 dataset. (Rayner et al., 2003)

Review of Literature

- ENSO's properties observed vary across different decades. (Lübbecke and McPhaden, 2014).
- 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).

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

Questions

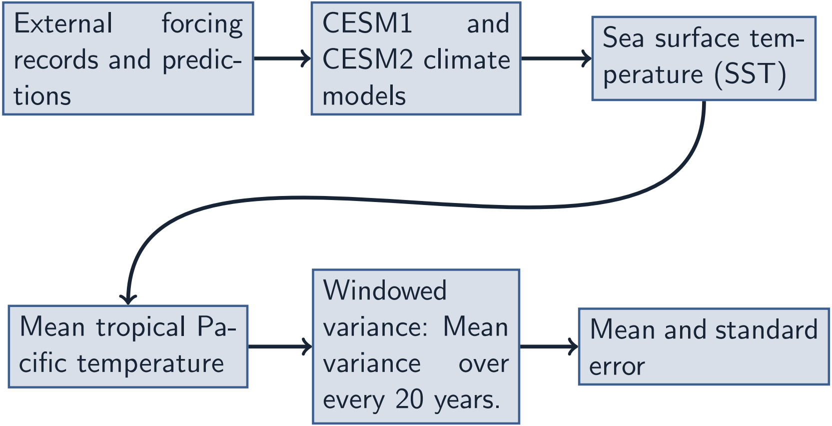
1. Do the CESM1 and CESM2 predict increased or decreased ENSO intensity in the future?
2. Is the predicted increase (or decrease) due to human activities?

Methods and Results

Data: Community Earth System Model

- Community Earth System Model (CESM) Versions 1 and 2 (Kay et al., 2015) (Danabasoglu et al., 2020).
- Predicts climate over 21st century with global warming.
- Ensemble: collection of multiple simulations.
- Single forcing ensembles that represent influence of single factor.

Measuring ENSO Intensity



ENSO is Becoming Stronger

- Increase in ENSO intensity in both ensembles. (Exceeds 2 standard errors)
- Increase slows down in CESM1 and decreases in CESM2 after around 2050.

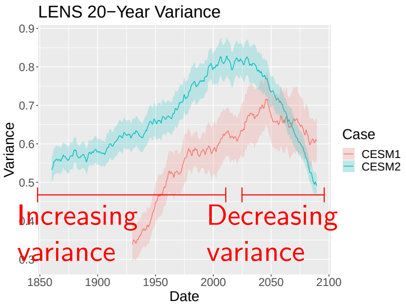


Figure 4: ENSO intensity ensemble mean and standard error for CESM1 and CESM2

Influence of Aerosols and Greenhouse Gasses

- Influence of each factor on ENSO amplitude.
- Increased variance due to greenhouse gas emissions.
- Somewhat increased variance from aerosol emissions, but not linear.

Takeaway: Human activities are triggering predicted strengthening of ENSO.

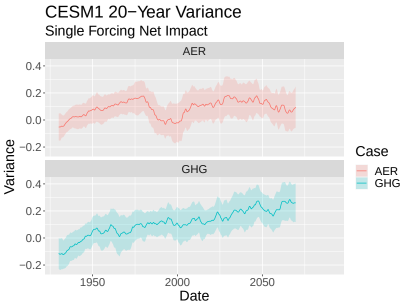


Figure 5: Influence of GHG, AER, and BMB forcing on ENSO amplitude in CESM1

Wavelet Analysis

- Separate ENSO record into changes in period over time.
- In CESM1, increase in ENSO intensity is mainly strengthening of longer-period cycle.
- In CESM2, longer-period ENSO weakens after 2025.
- Indicates that longer frequency bands are more susceptible to climate change.

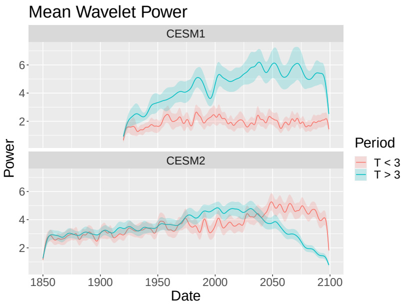


Figure 6: Wavelet power spectrum for the Niño 3.4 index in the fully-forced CESM1 and CESM2 ensembles

Discussion

- Rising greenhouse gas levels strengthen ENSO cycle.
- Aerosol influence is nonlinear because aerosol levels are not purely increasing.
- Stronger ENSO may lead to greater temperature variability and extreme weather.
- External forcing affects lower frequency ENSO more.

Limitations and Applications

Limitations:

- Niño 3.4 index shown to be inaccurate for some models (Cai et al., 2018).
- CESM may contain biases.
- Models are only an approximation of the Earth's actual climate.

Application: to improve our ability to predict ENSO and help people prepare for increased likelihood of extreme weather.

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Role of Mentor and Student

Student:

- Analyze raw data on computer
- Produce graphics for analysis and publication
- Write documentation
- Identify key features of results

Mentor:

- Review student writing
- Interpret results in the context of climatology
- Conduct parallel analysis
- Provide raw data from facility

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