

# The Impact of Anthropogenic Forcing on ENSO Amplitude

Ben Goldman

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# Climate Change: Global Warming vs. Climate Variability

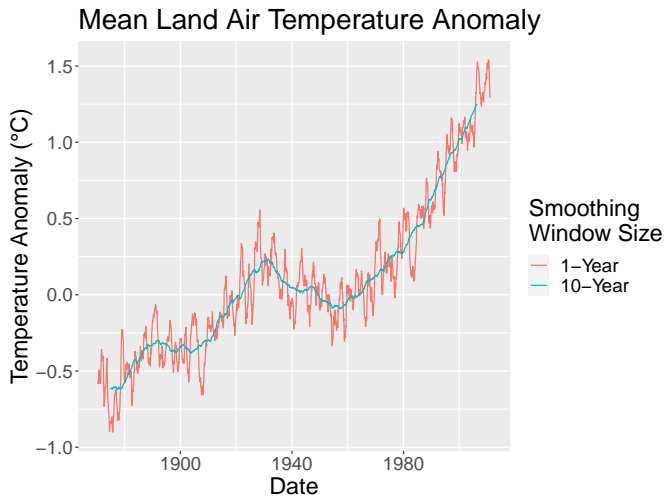


Figure 1: Global mean land air temperature in GISSTEMP 4 dataset. (Team et al., 2019) and (Lenssen et al., 2019)

# 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)

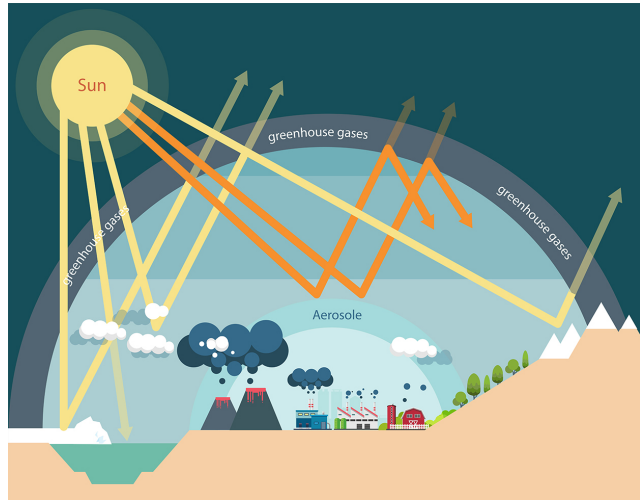
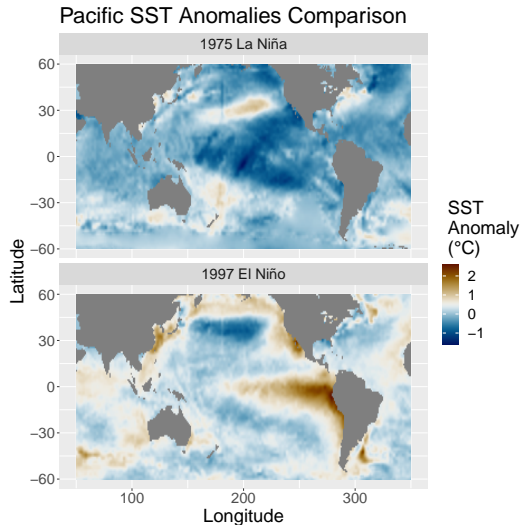


Figure 2: Factors that contribute to the greenhouse effect. <https://www.coolaustralia.org/the-greenhouse-effect-secondary>

# 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)



- ENSO's properties observed vary across different decades. (Lübbecke and McPhaden, 2014).
- Weakened ENSO during the Ice Age due to reduced CO<sub>2</sub> levels (Zhu et al., 2017).
- Models show possible increasing ENSO activity in the future (Zheng et al., 2017) and (Maher et al., 2018).

## 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

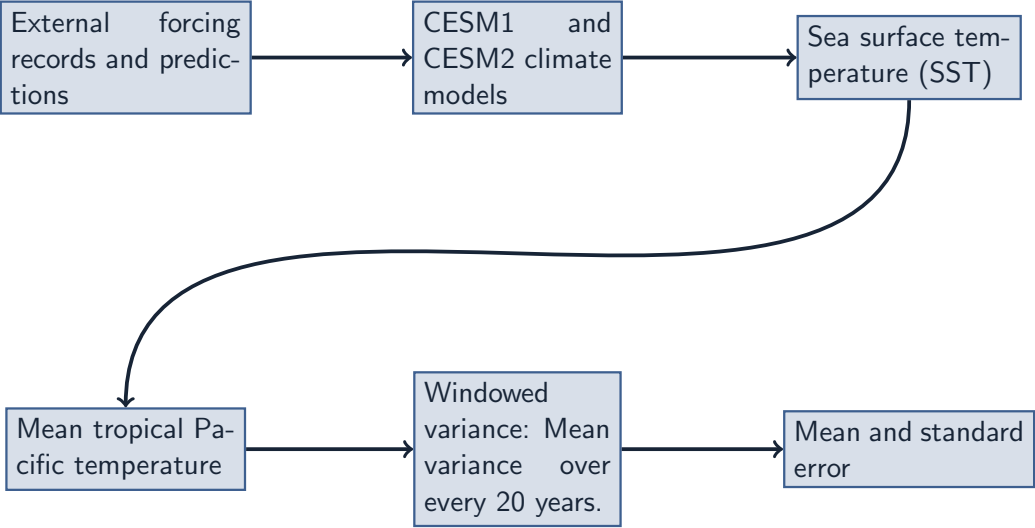
1. Do the CESM1 and CESM2 predict increased or decreased ENSO intensity in the future?
2. Is the predicted increase (or decrease) due to human activities?

# Methods and Results

- 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.

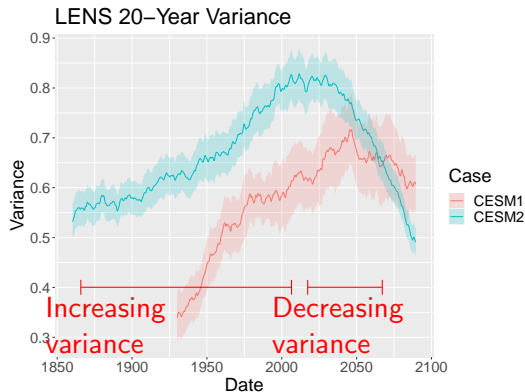
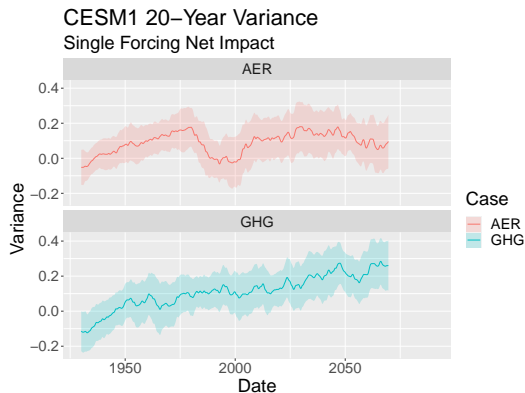


Figure 4: ENSO intensity ensemble mean and standard error for CESM1 and CESM2

# Influence of Aerosols and Greenhouse Gases

- 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

- 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.

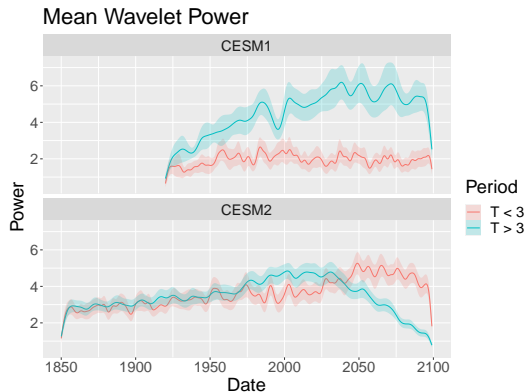


Figure 6: Wavelet power spectrum for the Niño 3.4 index in the fully-forced CESM1 and CESM2 ensembles

## 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

- 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:

- 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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