The Effect of Projected Sea Surface Temperature (SST) Pattern Changes on Tropical Precipitation using CESM 1

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Abstract

Tropical islands are highly dependent on rainfall to provide resources for drinking and agriculture. Hence, understanding changes to precipitation under a changing climate is critical for societal planning. Decadal variability in the climate system causes the strength of SST gradients to vary across the tropical Pacific that can cause precipitation patterns to transition from one decade to the next, even in the presence of longer term climate trends. To study 21st Century changes to tropical rainfall patterns in the presence of decadal variability, we use the CESM1 Large Ensemble (Kay et al. 2015) forced under RCP8.5. Each ensemble member uses different initial conditions that can be used to examine climate projections on short term (e.g. weeks, years) through long term (e.g. century) time scales. Since climate models contain climate variability such as El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), each ensemble member can have diverse projection outcomes in a given decade. While all ensemble members eventually show an El Niño-like warming pattern by 2100 relative to 1985-2005, before the mid 21st Century, preferential SST warming and precipitation intensity in the tropics in any given 20-year period can be weighted toward the west, central, or east Pacific. Further, while Niño3.4 SST generally goes up relative to 1985-2005, the tropical Pacific east-west temperature gradient change does not show as consistent an upward trend. Implications of SST and precipitation change patterns for Guam, Samoa, Hawaii, and Puerto Rico are examined. Spearman's correlation is used to examine the relationship between station island precipitation and the east-west Pacific SSTs gradient change. A strong negative correlation relative to gradient change is found for Guam, in contrast to Samoa having a high positive correlation. This study highlights the importance of decadal climate variability for understanding changes in water resources in island nations in a changing climate. This study was conducted as part of the Earth System Modeling and Education Institute summer REU program at Colorado State University.

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Introduction

Decadal variability in the climate system causes the strength of SST gradients to vary across the tropical Pacific that can cause precipitation patterns to transition from one decade to the next

In the CESM1 Large Ensemble (Kay et al. 2015), each member uses different initial conditions that can be used to examine climate projections on short term (e.g. weeks, years) through long term (e.g. century) time scales

Because climate models contain climate variability such as the Madden Julian Oscillation (MJO), El Niño Southern Oscillation (ENSO), and Pacific Decadal Oscillation (PDO), each ensemble member can have diverse projection outcomes in a given decade

Research Questions:

- How uncertain are the patterns of SST change in the future on decadal timescales?
- To what extent does the pattern of projected SST change influence precipitation change in the Tropics?
- What are the implications for precipitation on islands in the Pacific?

Methodology

Data

- NCAR CESM RCP8.5 scenario precipitation and surface temperature from 1920-2100.
  - Ensembles 6, 7, 8, 9, 10, 11, 12, & 15 (8)

Methods

- Python used to analyze and present visualization of data
- All future changes assessed relative to 1985-2005

Analysis

- Compare and contrast different ensemble members to identify those with the most prominent Eastern, Central or Western Pacific SST changes
- Identify patterns of SSTs and precipitation change in different future 20-yr periods
- Calculate trends in the 10-yr running mean of ENSO 3.4 SST and the East-West Pacific temperature gradient
- Spearman's correlation between Pacific SST gradient and station precipitation

Results

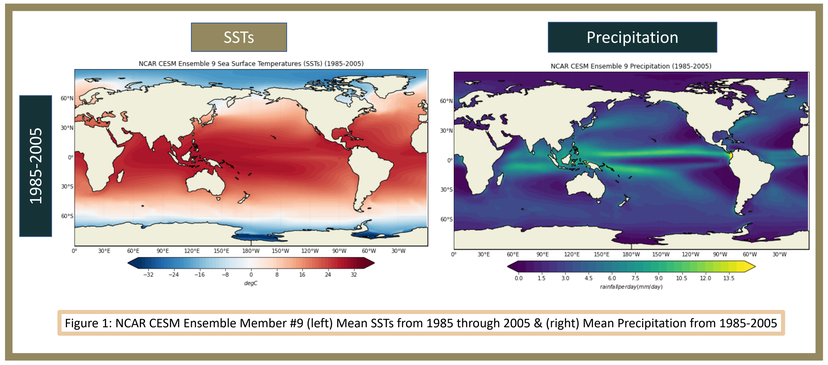

Figure 1: NCAR CESM Ensemble Member #9 (left) Mean SSTs from 1985 through 2005 & (right) Mean Precipitation from 1985-2005

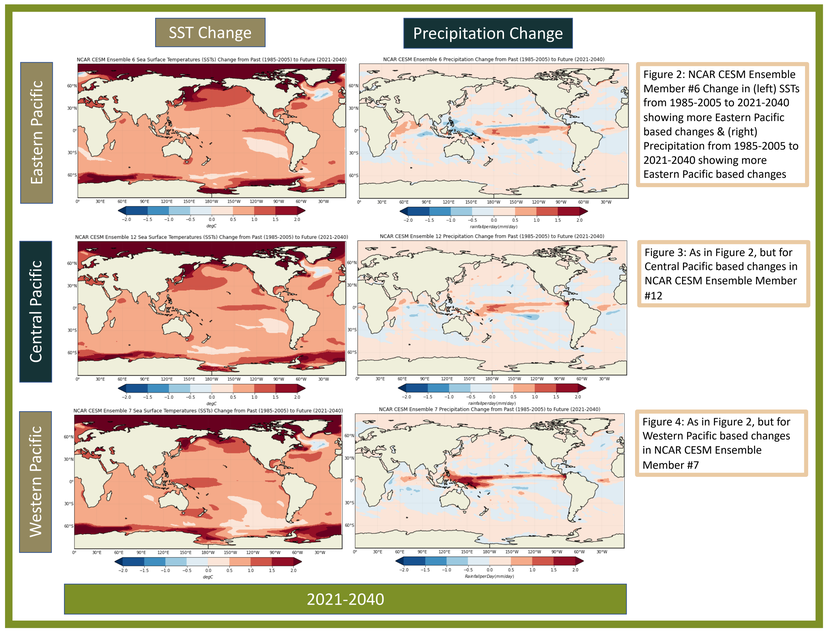

Figure 2: NCAR CESM Ensemble Member #6 Change in (left) SSTs from 1985-2005 to 2021-2040 showing more Eastern Pacific based changes & (right) Precipitation from 1985-2005 to 2021-2040 showing more Eastern Pacific based changes

Figure 3: As in Figure 2, but for Central Pacific based changes in NCAR CESM Ensemble Member #12

Figure 4: As in Figure 2, but for Western Pacific based changes in NCAR CESM Ensemble Member #7

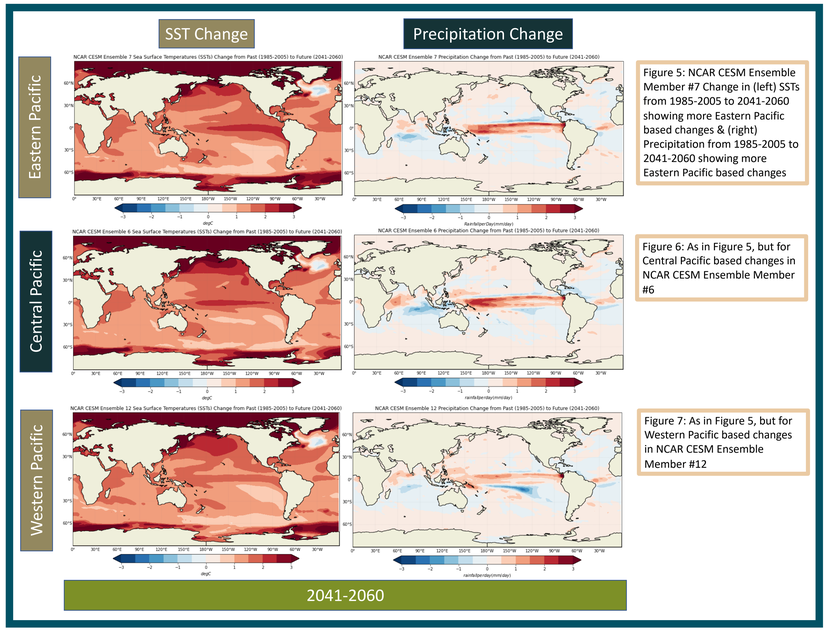

Figure 5: NCAR CESM Ensemble Member #7 Change in (left) SSTs from 1985-2005 to 2041-2060 showing more Eastern Pacific based changes & (right) Precipitation from 1985-2005 to 2041-2060 showing more Eastern Pacific based changes

Figure 6: As in Figure 5, but for Central Pacific based changes in NCAR CESM Ensemble Member #6

Figure 7: As in Figure 5, but for Western Pacific based changes in NCAR CESM Ensemble Member #12

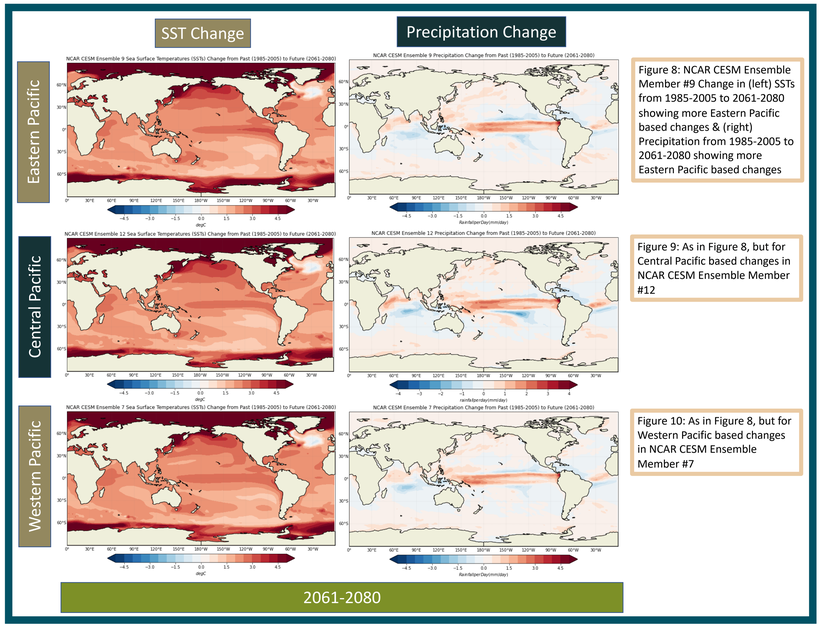

Figure 8: NCAR CESM Ensemble Member #9 Change in (left) SSTs from 1985-2005 to 2061-2080 showing more Eastern Pacific based changes & (right) Precipitation from 1985-2005 to 2061-2080 showing more Eastern Pacific based changes

Figure 9: As in Figure 8, but for Central Pacific based changes in NCAR CESM Ensemble Member #12

Figure 10: As in Figure 8, but for Western Pacific based changes in NCAR CESM Ensemble Member #7

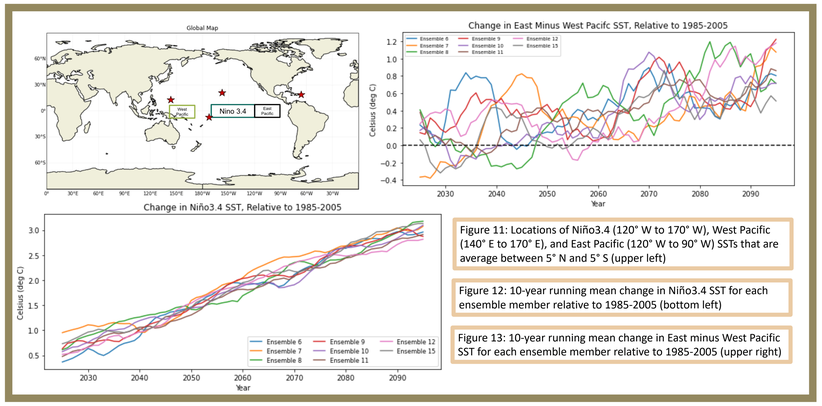

Figure 11: Locations of Niño3.4 (120° W to 170° W), West Pacific (140° E to 170° E), and East Pacific (120° W to 90° W) SSTs that are average between 5° N and 5° S (upper left)

Figure 12: 10-year running mean change in Niño3.4 SST for each ensemble member relative to 1985-2005 (bottom left)

Figure 13: 10-year running mean change in East minus West Pacific SST for each ensemble member relative to 1985-2005 (upper right)

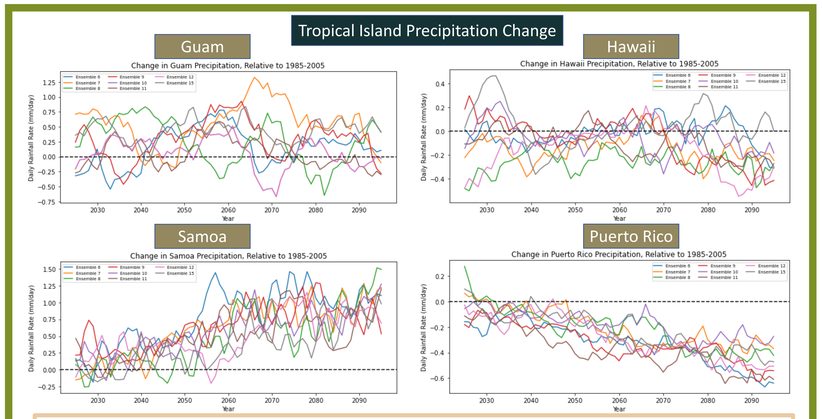

Figure 14: NCAR CESM Ensembles using a Running Mean of 10-yr for Precipitation Relative to 1985-2005 for (upper left) Guam (upper right) Hawaii, (bottom left) Samoa, & (bottom right) Puerto Rico

	E6	E7	E8	E9	E10	E11	E12	E15	Total CC	Total Std
Guam	-0.515	-0.681	-0.797	-0.539	-0.677	-0.342	-0.839	-0.360	-0.594	0.320
Hawaii	-0.059	-0.584	-0.195	-0.642	-0.640	-0.395	-0.738	-0.178	-0.428	0.320
Samoa	0.457	0.401	0.720	0.394	0.789	0.807	0.618	0.813	0.625	0.320
Puerto Rico	-0.238	-0.204	-0.694	-0.245	-0.584	-0.734	-0.395	-0.565	-0.457	0.320

	E6	E7	E8	E9	E10	E11	E12	E15	Total CC	Total Std
Guam	-0.704	-0.827	-0.816	-0.711	-0.741	-0.311	-0.909	-0.651	-0.709	0.225
Hawaii	-0.114	-0.506	-0.244	-0.443	-0.540	-0.009	-0.831	-0.371	-0.382	0.320
Samoa	0.341	0.126	0.012	-0.052	0.196	0.712	0.320	0.406	0.258	0.225
Puerto Rico	0.368	0.517	0.232	0.408	0.337	0.099	0.100	0.279	0.293	0.225

Figure 15: Spearman's correlation of local precipitation change (Figure 14) versus East-West SST gradient change (Figure 13) (left) original & (right) detrended

Key: Statistically Significant ($\alpha < 0.05$)

Conclusions

All ensemble members eventually show an El Niño-like warming pattern by 2100

In earlier decades, different ensemble members show preferential SST warming shifted either toward the west, central, or east Pacific in a given 20-year period

These SST shifts strongly influence the patterns of precipitation change during any given period

While Niño3.4 SST general go up relative to 1985-2005, the tropical Pacific East-West Temperature gradient change does not show a consistent upward trend

The precipitation change at Guam in a given 20-year period relative to 1985-2005 shows a strong negative correlation with the Pacific temperature gradient change that in some decades goes against the long term trend

Samoa has a high positive correlation with the SST gradient change, consistent with the long term trend in projected Central and Eastern Pacific warming that can also be temporarily enhanced in earlier decades

This makes it challenging to predict future changes in water resource availability for tropical islands.

Future Work

Examine Projected SST and precipitation trends using the CESM2 ensemble, which includes more ensemble members and a better representation of the MJO

Analyze the influence of wind changes on SSTs and precipitation patterns

Explore the impact of projected SSTs changes on the MJO

Observe the effect of projected SSTs and precipitation change on water resources, fire weather, and other societal impacts on Tropical Pacific islands, which are vulnerable communities

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