Ph.D. Defense Announcement
Marc Alessi
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Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
Riehl Conference Room (211 ACRC)

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CLIMATE MODEL ERROR IN THE EVOLUTION OF SEA SURFACE TEMPERATURE PATTERNS AFFECTS RADIATION AND PRECIPITATION PROJECTIONS

Atmosphere-ocean general circulation models (AOGCMs) are the primary tool climate scientists use in predicting the effects of climate change. While they have skill in reproducing global-mean temperature over the historical period, they struggle to replicate recently observed sea surface temperature (SST) trend patterns. In this dissertation, we quantify the impact of potential future model error in SST pattern trends on projections of global-mean temperature and Southwest U.S. (SWUS) precipitation. We primarily use a Green's function (GF) approach to identify which SST regions are most relevant for changes in these variables. Our findings demonstrate significant sensitivity of both global-mean temperature and SWUS precipitation to the pattern of sea surface warming, meaning that a continuation of AOGCM error in SST trend patterns adds uncertainty to climate projections which are currently not accounted for.

In Chapter 1, we quantify the relevance of future model error in SST to global-mean temperature projections through convolving a GF with physically plausible SST pattern scenarios that differ from the ones AOGCMs produce by themselves. We find that future model error in the pattern of SST has a significant impact on projections, such as increasing total model uncertainty by 40% in a high-emissions scenario by 2085. A reversal of the current cooling trend in the East Pacific over the next few decades could lead to a period of global-mean warming with a 60% higher rate than currently projected. These SST pattern scenarios work through a destabilization of the shortwave cloud feedback to affect temperature projections.

In Chapter 2, we focus on near-term projections of precipitation in the SWUS. The observed decrease in SWUS precipitation since the 1980s and heightened drought conditions since the 2000s have been linked to a cooling sea surface temperature (SST) trend in the Equatorial Pacific. Notably, climate models fail to reproduce this observed SST trend, and they may continue doing so in the future. In this chapter, we assess the sensitivity of SWUS precipitation projections to future SST trends using a GF approach. Our findings reveal that a slight redistribution of SST leads to a wetting or drying of the SWUS.

A reversal of the observed cooling trend in the Central and East Pacific over the next few decades would lead to a period of wetting in the SWUS.

In Chapter 3, we analyze SWUS precipitation sensitivity to SST patterns on long timescales (7+ years) according to a GF approach and a convolutional neural network (CNN) approach. The GF and CNN identify different SST regions as having greater influence on SWUS precipitation: the GF highlights the Central Pacific known from theory to be relevant, while the CNN highlights the South-Central Pacific. To determine if the South-Central Pacific has a physically meaningful and so far overlooked influence on SWUS precipitation, rather than just a statistical relationship, we force an atmosphere-only climate model with an SST anomaly inspired by an Explainable Artificial Intelligence (XAI) method. We find that SSTs in the South-Central Pacific influence SWUS precipitation through an atmospheric bridge dynamical pathway, justifying the CNN's sensitivity physically.

The fact that we cannot fully trust the evolution of SST patterns in AOGCMs has many implications for the field of climate science and for how the world responds to global warming. It is critical for climate change adaptation and mitigation assessments to consider this previously unaccounted for uncertainty in climate projections. Climate scientists can do this by developing SST pattern storylines based on observations and our understanding of the ocean-atmosphere system. If we fail to communicate known uncertainties for both global-mean and regional projections, the world could lose faith in the climate science community, resulting in less of a global response to climate change.