Ph.D. Defense Announcement
Shim Yook
Friday, May 19 at 1:00 pm MT

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Ph.D. Defense

May 19, 2023
1:00 pm MT

Defense
ATS Large Classroom (101 ATS) or Teams

Post Defense Meeting
ATS Community Space Conference Room (116 ATS)

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The Role of Earth System Interactions in Large-Scale Atmospheric Circulation and Climate

The complex interactions among different components of the Earth system play a key role in governing the climate variability through various physical processes. For example, an interaction between the fluctuations in one component of the Earth system and associated variations in another component of the Earth system can either amplify or dampen the climate variability depending on the nature of their two-way feedback mechanisms. Thus, understanding the role of various physical interactions among components of the Earth system is critical to understand the changes in climate as well as to reduce the uncertainty in future climate projections. This dissertation focuses on discovering the key processes and interactions among different components of the Earth system on the climate variability using observations and model hierarchies.

In Part 1, the interactions between the atmospheric circulation and western North Pacific SST anomalies are explored in two sets of simulations: a simulation run on a coupled atmosphere-ocean general circulation model (GCM), and 2) a simulation forced with prescribed, time-evolving SST anomalies over the western North Pacific. The results support the interpretation of the observed lead/lag relationships between western North Pacific SST anomalies and the atmospheric circulation and provide numerical evidence that SST variability over the western North Pacific has a demonstrable effect on the large-scale atmospheric circulation throughout the North Pacific sector.

In Part 2, the role of moist lapse rate in altering the temperature variability under climate change is explored. To reduce the complexity of the problem, the changes in the temperature variance under global warming are first analyzed in the simplest version of model hierarchy: a single column Rapid Radiative Transfer Model with a simplified convective adjustment. Similar analyses have been repeated with varying model hierarchies with additional complexities: a global general circulation model in global RCE setting with fixed SST, and fully coupled Earth system models. The results highlight the role of moist lapse rate as a potential constraint for climate variability in the tropical atmosphere simulated by different model hierarchies.

In Part 3, the effects of coupled chemistry-climate interactions on the amplitude and structure of stratospheric temperature variability are quantified in two numerical simulations: A “free running” simulation that includes fully coupled chemistry-climate interactions; and a “specified chemistry” version of the model forced with prescribed chemical composition. The results indicate that the inclusion of coupled chemistry-climate interactions increases the internal variability of temperature by a factor of ~two in the lower tropical stratosphere through dynamically driven ozone-temperature feedbacks. The results highlight the fundamental role of two-way feedbacks between the atmospheric circulation and chemistry in driving climate variability in the lower stratosphere.

In Part 4, the effects of coupled chemistry-climate interactions on the large-scale atmospheric circulation are further explored based on two observational case studies of the Antarctic ozone holes of 2020 and 2021. The 2020 and 2021 were marked by two of the largest Antarctic ozone holes on record. It has been demonstrated that the ozone holes of 2020 and 2021 were associated with large changes in the atmospheric circulation consistent with the climate impacts of Antarctic ozone depletion. The ozone holes were also unusual for their associations with aerosol burdens due to two extraordinary events: the Australian wildfires of early 2020 and the eruption of La Soufriere in 2021. The results provide suggestive evidence that injections of both wildfire smoke and volcanic emissions into the stratosphere can lead to hemispheric-scale changes in surface climate.

This dissertation provides a detailed look at the complex aspects of the coupled interactions among different components of the Earth system and their roles on climate variability and large-scale dynamics. To clarify the role of the different physical processes contributing to the climate responses, this study performed a comprehensive analysis based on observations as well as a series of numerical experiments run on different configurations of climate model hierarchies. The findings herein improve our understanding of different Earth system interactions and their influences on global climate and large-scale atmospheric dynamics.