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Natural Variations and Forced Changes in Historical and Future Precipitation and Drought

How precipitation and drought respond to greenhouse gas (GHG)-induced global warming is of great concern to the society. Quantifying this response using observations is, however, difficult because of large unforced natural variations in precipitation and drought. Although many studies have analyzed historical precipitation and drought data over global land, the unforced variability and forced changes have not been well separated in these analyses. As a result, differences resulting from sampling (of the natural variability) are often incorrectly considered as evidence of model deficiencies. Improved understanding of the natural variations and the GHG-forced response in precipitation and drought records and model simulations is critical for model evaluation and decadal climate prediction. This proposal addresses following questions: 1) how much of the observed change in precipitation and drought is due to unforced natural variation and how much is due to response to historical external forcing over various land areas? 2) What are the characteristics of the forced changes and unforced variations and the associated atmospheric circulations? and 3) can we improve projections of near-future changes in regional precipitation and drought by combining decadal natural variations with model-simulated response to future GHG forcing?

We will use the CMIP5 large multi-model ensemble of the 20th and 21st century climate simulations to estimate the forced response of land precipitation and drought to GHG and other known forcing from 1900-present and for near-future decades using advanced statistical analyses. Since this represents our best estimate of the externally forced response, we will remove this estimated forced signal from the observed precipitation and drought index fields, with the remaining part in the observational data considered as the unforced natural variations. We will then compare the unforced natural variations with the forced changes over global land to address the first question. To address the second question, we will perform advanced statistical analyses to characterize the temporal and spatial features in the forced changes and unforced variations, investigate their relationship to remote ocean and land surface (e.g., snow cover) conditions and the associated atmospheric processes using observations, reanalysis data and model simulations. This analysis will focus on how decadal variations in tropical and mid-latitude sea surface temperatures (SSTs) and snow cover over Eurasia and North America may influence atmospheric circulation and lead to dry and wet periods over the U.S., Australia, Africa, the Mediterranean region, South and East Asia, and other areas. Finally, we will explore the possibility to use the unforced decadal variations to improve model-simulated land precipitation and drought changes in the next few decades to address the third question.

Intellectual Merit: The results from this project will significantly improve our understanding of natural variability in land precipitation and drought, especially the decadal variations associated with ocean and land surface conditions and their associated atmospheric processes. This improved knowledge will greatly facilitate proper comparisons of observed and model-simulated response of precipitation and drought to human-induced global warming and reduce the chances to confuse natural variations with externally forced changes in comparisons of observed and model-simulated changes. The results will also help interpret recent extreme climate events, such as the recent droughts and heat waves in the Southwest U.S., by providing a better context of natural variations. The results also have the potential to improve our projections of near-future precipitation and drought over many land areas, as natural variations will continue to be important compared with GHG-induced changes in the coming decades.

Broader Impacts: Results from this project will have direct implications for farmers, water resources managers, and other policymakers and stakeholders in the U.S. and many other countries. The project will support two graduate students for their PhD research, with at least one of them to be a minority student. The project will also allow the PI to continue to educate the media (reporters), policymakers, and the general public (farmers, K-12 teachers and students, and ordinary citizens) on how drought may change under global warming. It will also help the PI develop an undergraduate course on "Water and Climate Change" and other climate courses at SUNY, Albany.