EGU2020-11632
https://doi.org/10.5194/egusphere-egu2020-11632
EGU General Assembly 2020

Forced monsoon rainfall changes and the moist static energy budget: the Sahel and elsewhere

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The Sahel is the semi-arid, transitional region separating the Sahara Desert from humid equatorial Africa, i.e. the poleward-most region to which appreciable rains from the West African monsoon extend during northern summer. The severe drought it experienced in the 1970s and 1980s was one of the 20th century's most striking (and devastating) hydroclimatic events worldwide. In climate model simulations of future global warming, Sahelian rainfall does anything from intense drying to even greater wettening depending on which climate model is used. In this talk, I present recent research on rainfall in the Sahel using the moist static energy (MSE) budget -- what are the physical factors that drive its variations, and how do we expect them to change as the planet warms --- and the extent to which inferences from the Sahel can or cannot extend to other regions and other external forcings.

Using climate model simulations both of Earth's present-day conditions and of future global warming, I show that the drying influence of the Sahara Desert is a dominant factor in present-day and that this influence is strengthened with warming due to an increasing difference in moisture between the desert and the Sahel. This enhancement of an existing moisture (and energy) gradient is a robust response of the atmosphere to mean ocean surface warming and has a firm theoretical basis. By comparing climate model simulations of the present-day Sahel climate to real-world observations, I argue that this Sahara-driven drying mechanism is overly strong in those models that dry the Sahel most in future simulations. This response to mean warming of global sea surface temperatures (SSTs) is readily explained using the MSE budget, whereas the Sahel rainfall response to changes in the spatial pattern of SSTs (such as during the 1970s-80s drought) are more easily interpreted via the popular energetic framework for Intertropical Convergence Zone (ITCZ) shifts. I discuss the interplay between these and other theoretical frameworks for forced monsoon rainfall changes in the Sahel and other monsoon regions and offer ideas for refining and extending those theories.