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Progress in American monsoon research: Factors relating Gulf of California sea surface temperatures to rainfall based on MM5 and WRF model simulations and satellite observations

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Satellite observations have suggested that sea surface temperatures (SST) in the northern Gulf of California (GC) may play a critical role in the timing and amount of summer rainfall over the U.S. southwest. In particular, the onset of relatively heavy rainfall occurs after these SSTs exceeded 29°C. Here we explore this idea in a modeling context using both the NCAR/Penn State Mesoscale Model version 5 (MM5) and the Weather Research Forecasting (WRF) model to simulate the onset of the North American monsoon (NAM) in Arizona (AZ) for 1999. This study explores the impact of GC SSTs on factors affecting deep convective precipitation: the regional atmospheric circulation, water vapor mixing ratio, convective available potential energy (CAPE) and convective inhibition (CIN). The impact of GC SSTs on rainfall is also addressed. After analyzing the predicted evolution of the above properties, and their dependence on GC SSTs in numerous MM5 simulations conforming to conditions at the beginning of the 1999 monsoon onset period for AZ, a new understanding emerges as to how the lower atmosphere over the GC may interact with SSTs to release moisture for monsoon rainfall. When the GC SST is 29°C or less, an inversion is present over the GC due to warmer air aloft. When GC SSTs reach 30°C or higher, moist marine boundary layer (MBL) air may become buoyant relative to the drier overlying air. This buoyancy can erode the marine inversion and allow MBL air to mix with the free troposphere. This enhances the moisture content of low-level southerly winds during favorable synoptic conditions, enhancing the moisture flux into AZ. The predicted dependence of the AZ regional rainfall rate on the northern GC SST is remarkably similar to the observed dependence, featuring an abrupt increase in rainfall rate when the SST exceeds 29°C. Both modeling and observations indicate the existence of a threshold SST in the northern GC responsible for an abrupt increase in rainfall over AZ. A comparison with the WRF simulations is currently underway, and results will be presented at the meeting. MM5 results underscore the need for a boundary layer parameterization having high vertical resolution with an accurate treatment of physical processes in order to capture the sensitivity of AZ rainfall to GC SSTs.