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Future risk of global drought from downscaled, bias corrected climate projections

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Understanding how changes in drought conditions will develop in the 21st century, including changes in severity, extent, and duration, is of great importance to many sectors such as water resources management and agricultural activity. There may also be profound implications for the occurrence of wildfires and heat waves that are associated with dry conditions. Recent severe droughts in the Western U.S., southeast Australia, Eastern Africa, Europe and northern China are testament to the impacts that large scale drought can have and are perhaps indicators of things to come. The direct use of climate model outputs for analysis of future drought however is problematic because of known model biases, particularly model simulated precipitation and temperature fields that have first order impact on droughts. Here we present a comprehensive statistical analysis of future drought conditions globally in a multi-model, multi-scenario based framework. The analysis is based on recently completed simulations using the Variable Infiltration Capacity land surface model (LSM), forced by downscaled, bias corrected climate projections using a newly developed equidistant quantile matching method. This improves upon traditional quantile matching methods by taking into account changes in the future projection climate distribution and better represents extreme years that are most associated with the development of drought. We apply this to a suite of climate models for monthly precipitation and temperature but show how this can be extended to radiation, humidity and windspeed to capture associated changes and interplay among these associated drivers, although this is limited to a small set of climate models with available data. Further enhancements include improved temporal downscaling to account for changes in, for example, storm intensities and diurnal temperature range. The bias corrected and downscaled climate forcings are used to drive the LSM to generate future projections of the terrestrial water and energy cycles. These outputs are then analyzed to understand the propagation of projected drought, including frequency and severity, and to compare these projections with analyses based on 20th C observations. Individual drought events are identified using a cluster based tracking algorithm, which follows drought development through time and space and identifies the severest events based on severity-area-duration analysis. This work improves on previous future global drought analyses based directly on climate model output, by removing the biases associated with climate model simulations, focuses on higher spatial resolution to better represent topographic and vegetation heterogeneity and uses a comprehensive land surface model as the foundation of the analyzed information.