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Future meteorological drought: projections of regional climate models for Europe

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In response to the major European drought events of the last decade, projecting future drought frequency and severity in a non-stationary climate is a major concern for Europe. Prior drought studies have identified regional hotspots in the Mediterranean and Eastern European regions, but have otherwise produced conflicting results with regard to future drought severity. Some of this disagreement is likely related to the relatively coarse resolution of Global Climate Models (GCMs) and regional averaging, which tends to smooth extremes. This study makes use of the most current Regional Climate Models (RCMs) forced with CMIP5 climate projections to quantify the projected change in meteorological drought for Europe during the next century at a fine, gridded scale. Meteorological drought is quantified using the Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI), which normalize accumulated precipitation and climatic water balance anomaly, respectively, for a specific location and time of year. By comparing projections for these two indices, the importance of precipitation deficits can be contrasted with the importance of evapotranspiration increases related to temperature changes. Climate projections are based on output from CORDEX (the Coordinated Regional Climate Downscaling Experiment), which provides high resolution regional downscaled climate scenarios that have been extensively tested for numerous regions around the globe, including Europe. SPI and SPEI are then calculated on a gridded scale at a spatial resolution of either 0.44 degrees ($\sim$50 km) or 0.11 degrees ($\sim$12.5km) for the three projected emission pathways (rcp26, rcp45, rcp85). Analysis is divided into two major sections: first validating the models with respect to observed historical trends in meteorological drought from 1970-2005 and then comparing drought severity and frequency during three future time periods (2011-2040, 2041-2070, 2071-2100) to the historical control period (1971-2000). Confirming that the models successfully reproduce historical trends in European drought through validation testing is vital to establish confidence that the drought signal will be adequately predicted in future projections. Both historical validation runs and future projections are analyzed with regard to the mean (Welch two-sample t-test), overall distribution (Kolmogorov-Smirnov test), and frequency of droughts below a given percentile (Chi-square test) Historical validation also includes a non-parametric test for long-term trend. Results of these tests are presented spatially, at the highest resolution possible, highlighting regions with increasing drought risk. Use of a range of RCMs and GCM forcings provides a multi-ensemble projection, allowing for comparisons of the projected climate signal to model noise, showing where and when models agree. This study represents the highest resolution and best climate projections available applied to the hazard of extreme drought in Europe. Results will be important for policy makers and water managers as they discuss adaptation strategies for the future.