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Projected changes in high ozone pollution events over the Eastern United States over the 21st century

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Over the past few decades, thresholds for the United States (US) National Ambient Air Quality Standard (NAAQS) for ozone (O_3), established to protect public health and welfare, have been lowered repeatedly. We recently applied methods from extreme value theory (EVT) to maximum daily 8-hour average ozone (MDA8 O_3) observed by the Clean Air Status and Trends Network (CASTNet) to quantify the significant decline in both frequency and magnitude of high O_3 pollution events over the Eastern US from 1988 to 2009. These improvements to Eastern US air quality have been reported in prior studies and result from changes in air quality regulations and subsequent control measures (e.g., the "NO_x SIP Call") as demonstrated by our analysis of 1-year and 5-year return levels. Here we extend this analysis to future projections of high O_3 pollution events spanning the course of the 21st century. To this aim, we analyze simulations from the GFDL CM3 chemistry-climate model under selected Representative Concentration Pathway (RCP) scenarios: RCP4.5 and RCP8.5 (representing a moderate and strong climate warming with a global mean temperature change by 2100 compared to present day of +2.3K and +4.5K, respectively). Under both scenarios, NO_x emissions decrease by $\sim$80% over North America by 2100 under the assumption of aggressive ozone pollution controls. A third scenario, termed RCP4.5_WMGG, in which well-mixed greenhouse gases follow the RCP4.5 scenario but O_3 and aerosol precursor emissions are held at 2005 levels, enables us to isolate the role of climate change from that of emission reductions. As we find a positive bias in GFDL CM3 MDA8 O_3 compared to the Eastern US CASTNet O_3 measurements during summer (a common feature in the current generation of models), we develop a correction method based on quantile-mapping. This bias correction effectively removes the model bias while preserving the temporal changes in MDA8 O_3 as simulated under different RCPs over the course of the 21st century. We show that the model adequately represents the observed surface ozone response to NO_x emission controls over the Eastern United States. Specifically, we analyze (i) regional differences in the frequency and return level of high O_3 pollution events during the course of the 21st century as well as (ii) differences among the RCPs by the middle and end of the 21st century. The number of high O_3 pollution events declines strongly in both the RCP4.5 and RCP8.5 scenarios, illustrating the effectiveness of air quality control measures. This change is reflected in the probabilistic return value: 1-year return levels for O_3 decline in both scenarios strongly over the first half of the 21st century, although stronger and faster in RCP4.5 than RCP8.5. Under the RCP4.5 scenario, CM3 predicts almost no exceedances of the NAAQS for ozone by the middle of the 21st century. In contrast, the RCP4.5_WMGG scenario (i.e. no emission controls) shows by 2100 similar or slightly higher (up to 3 ppb) 1-year return levels for O_3 compared to present day values.