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Variability in Eastern North American surface ozone under climate warming scenarios: Key role for jet position

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Climate warming is generally expected to degrade air quality in many polluted regions. Model estimates of the magnitude, and in some cases the sign, of the surface ozone response to projected warming, however, disagree regionally. These discrepancies underscore a need for improved process-level understanding of the factors controlling the regional ozone response to warming. Furthermore, developing accurate approaches to estimate regional surface ozone changes directly from projected changes in regional climate requires this process understanding.

Over Eastern North America, synoptic variability is known to be a key driver of summertime ozone pollution episodes. We investigate the hypothesis that this variability depends on the position of the jet within this region by analyzing June-August (JJA) daily surface ozone in a suite of CMIP5 and related sensitivity simulations from 1860 to 2100 in the GFDL CM3 chemistry-climate model. Specifically, we use the CM3 CMIP5 Historical (1860-2005; 5-member) and RCP4.5 (2006-2100; 3-member) ensemble simulations. An additional scenario with evolving well-mixed greenhouse gases following the RCP4.5 scenario but emissions of aerosol and ozone precursors held constant at 2005 levels, denoted RCP4.5*, enables us to isolate the impact of climate warming alone from the impact of large decreases in ozone precursor emissions occurring under RCP4.5.

We demonstrate that the daily variability of JJA surface ozone is a strong function of the position of the jet-stream over Eastern North America in all three scenarios. The jet stream moves poleward with climate change under the RCP4.5 and RCP4.5* scenarios, and we show that ozone variability follows the position of the jet. The consistent response in both the RCP4.5 and RCP4.5* simulations demonstrates that the large decreases in ozone precursor emissions under RCP4.5 (North American nitrogen oxides (NO_x) decrease by about a factor of 5 over the 21st century) are not driving the northward shift of ozone variability. While the relationship with jet latitude remains, the decrease in ozone precursor emissions under RCP4.5 leads to a reduction in variability over the entire region.

We further show that the strength of the correlation between ozone and temperature is a strong function of the jet position. The quantitative relationship (slope between ozone and temperature), however, depends strongly on NO_x emissions, consistent with recent observation-based work. These findings demonstrate that historical relationships between surface ozone and meteorological quantities such as temperature are unlikely to apply in the future.

Although this study focuses solely on Eastern North America, the relationships found here are likely also present in other mid-latitude regions influenced by the mid-latitude jet. The strong dependence of surface ozone variability on jet latitude, a quantity easily computed from climate models, implies that understanding future changes in jet location can be used to derive changes in summertime surface ozone variability and the ozone-temperature correlation. Our results further imply that inter-model discrepancies in jet location likely contribute to the wide range of current estimates for changes in surface ozone in northern mid-latitude regions.