EGU25-12146, updated on 21 Apr 2026
https://doi.org/10.5194/egusphere-egu25-12146
EGU General Assembly 2025

Mechanisms of Surface Ozone's Chemical Response to High Temperatures: Differences Between Urban and Rural Areas

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As climate change leads to more frequent and intense high-temperature events, elevated O_3 episodes during periods of extreme heat have raised widespread concerns. This research investigates how O_3's chemical response to elevated temperatures varies between urban and rural areas, particularly focusing on different emission conditions defined by ozone precursor regimes.

Simulations are carried out using the UKCA Box Model under idealised meteorological conditions. It runs chemistry-only zero-dimensional experiments in a single grid cell with chemistry relevant to the troposphere and the stratosphere. Using the UKCA Box Model, we simulated conditions typical of summer 2022 at three global hotspots (Yangtze River Delta, England and California), analysing scenarios where O_3 precursors are either limited by VOCs in urban environments or by NO_x in rural settings. The simulations were conducted across a temperature range of 20°C to 40°C while controlling for relevant factors such as photolysis, humidity, emissions, and initial concentrations. To determine the O_3 precursors regimes, photochemical indicators such as NO_y, H_2O_2/HNO_3, $H_2O_2/(O_3+NO_2)$ and $HCHO/NO_2$ were employed.

The results suggest a significant diversity of O_3's chemical response to temperature in urban and rural areas. In urban areas characterised by VOC-limited conditions, O_3 levels exhibited a nearly linear increase with rising temperatures. In contrast, rural areas, where O_3 is typically NO_x-limited, displayed a more complex relationship where negative correlations were found. Additionally, humidity emerged as a critical factor influencing these chemical dynamics. The mechanism by which O_3 responds chemically to temperature changes will be examined by analysing O_3 production and destruction budgets.

Our findings highlight that the O_3 precursor regimes are crucial in evaluating the impact of temperature responses on ozone from a chemical perspective. This research contributes valuable insights into the mechanisms driving O_3 responses to temperature changes during extreme heat events. It underscores the importance of considering urban and rural differences in ozone studies and can inform future emission control strategies aimed at mitigating ozone pollution under varying temperature conditions.

Keywords: Surface ozone; Temperature response; UKCA Box model; O_3 precursor regimes; Urban and rural