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Compound events increase the ground-level tropospheric ozone concentrations worldwide.

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Compound extreme weather events (CE), characterized by the concurrent influence of multiple weather and climate drivers, have the potential to exacerbate the concentration of air pollution on the atmosphere. Attributing specific extreme weather events directly to climate change is challenging; however, it is widely acknowledged that climate change will intensify different extreme events by changing their frequency, intensity, spatial extent, duration, and timing. Several types of weather extremes, such as stagnation conditions and heatwaves (HW), can lead to hazardous air quality situations by allowing some pollutants, such as ozone (O3), to accumulate and persist in the near-surface environment. O3 is in general more pronounced in the summer due to the photochemical nature of the source. Given its highly heterogeneous distribution across both space and time, combined with a relatively short life-time, it becomes imperative to gain insights into the patterns governing the global spatial data distribution related to this complex phenomenon. This study aims to evaluate the amplifying effects of CE (concurrence of stagnation and heatwaves) on O_3 peak levels globally during the summer season.

The study utilizes the simulations of historical 1980-2009) and future (2050-2079) climate under the Shared Socio-economic Pathways (SSP) SSP2-4.5 and SSP5-8.5. Using a model from the Coupled Model Intercomparison Project Phase 6 (CMIP6), the investigation explores the global temporo-spatial trends and disparities in compound-event occurrences across countries.

We find that O_3 concentrations during the summer are higher in the center of North America and the center of the Asian continent compare with the other parts in the world (surpassing the 85 pbb during summer). A significant disparity in ozone concentrations was observed between the SSP2-4.5 and SSP5-8.5 scenarios. The SSP5-8.5 scenario demonstrates notably higher concentrations of peak O_3 compared to the historical period, with increase of up to 20 ppb in certain regions, such as the Asian continent. Furthermore, it is noteworthy that O_3 concentrations are expected to decrease in the future in the central part of North America in both scenarios up to 15 ppb during the summer season.

Focusing on CE throughout the summer season and under all scenarios studied, elevated O_3 concentrations are observed worldwide during CE compared to non-event conditions, particularly during heatwaves, with an increase of 40, 35 and 40 ppb during summer in the historical, SSP2-4.5 and SSP5-8.5 scenarios in comparison with non-event conditions. These heatwave events generally dominate the formation of O_3 peak concentrations during CE.

Comparatively, during stagnation events, the highest peak O_3 concentrations undergo a substantial increase in the mid-to-late century scenario, notably in the Asian continent, with a projected increase of nearly 12% in O_3 for the SSP2-4.5 scenario and a 25% increase for the SSP5-8.5 scenario. Conversely, during combined heatwave and stagnation events in the SSP2-4.5 scenario, a decrease in average concentrations is expected in the future across all continents.

These results underscore the imperative need to further mitigate air pollutant emissions during weather extremes to minimize the adverse impacts of these events on air quality and human health.