

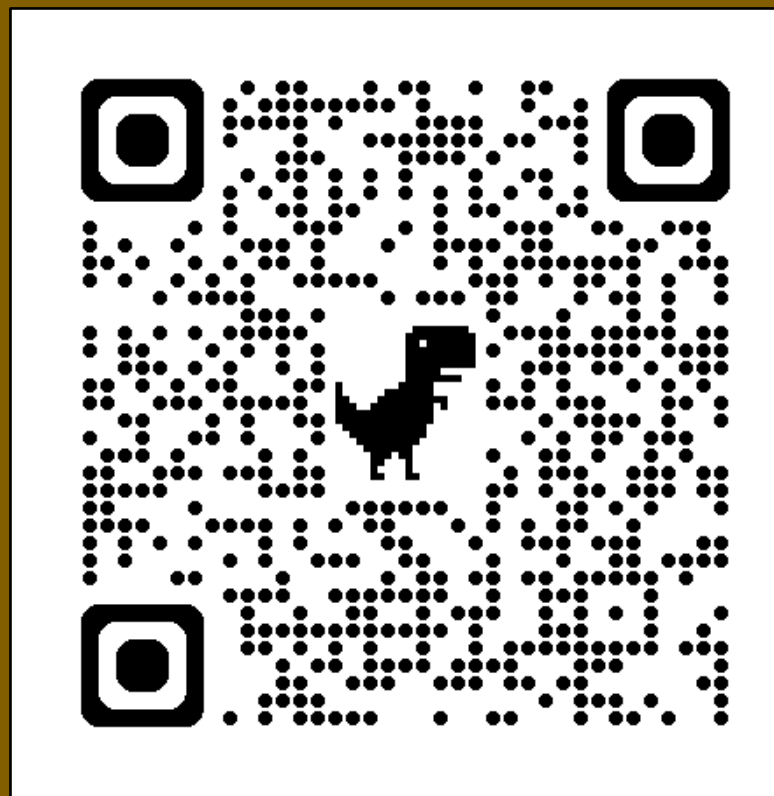


The Evolution of Ozone's Weekday-Weekend Effect Across Colorado's Front Range

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Ozone Fundamentals

Ground-Level Ozone:

- Ground-level Ozone (O_3) is a secondary air pollutant with negative impacts on public health and the environment such as lung and cardiovascular conditions, decreased lifespan, material degradation, and reduced agricultural yields
- The United States Environmental Protection Agency (EPA) has set National Ambient Air Quality Standards (NAAQS) for O_3 at 70 ppbv
- Precursor compounds such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react with one another in the presence of sunlight to create O_3

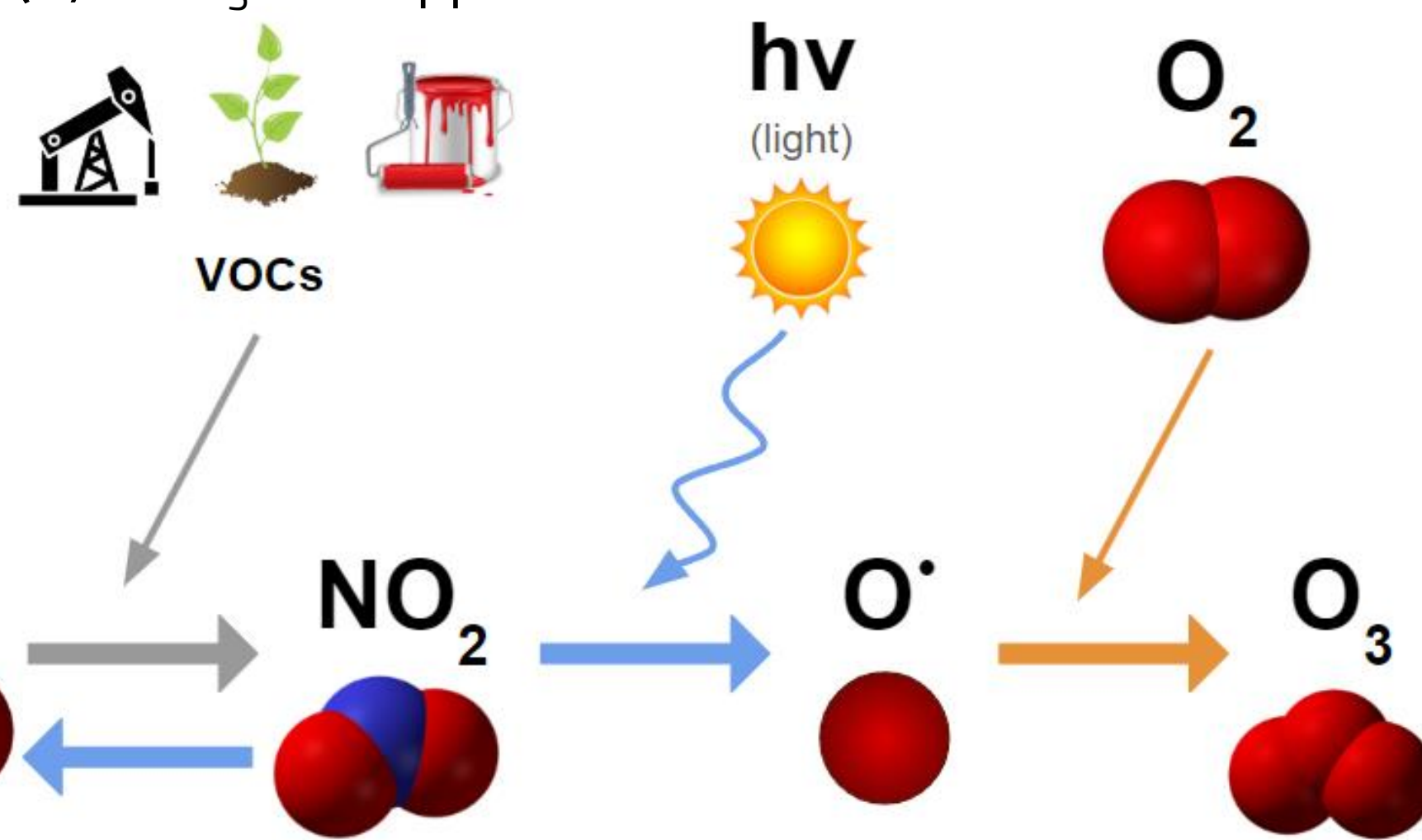


Figure 1: Reactions between precursor compounds and light transfer O atoms to form O_3 .

- NO_x concentrations and O_3 production do not follow a linear relationship
- Precursor compounds stem from human activities that follow daily and weekly patterns; this causes O_3 to display similar trends

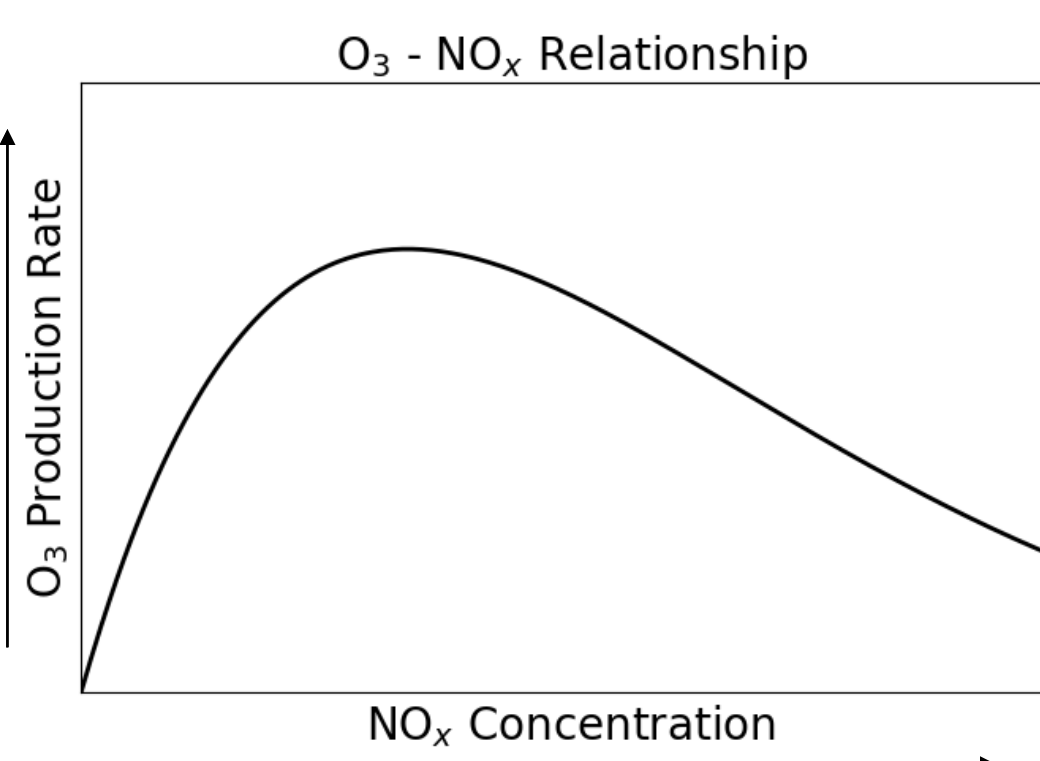
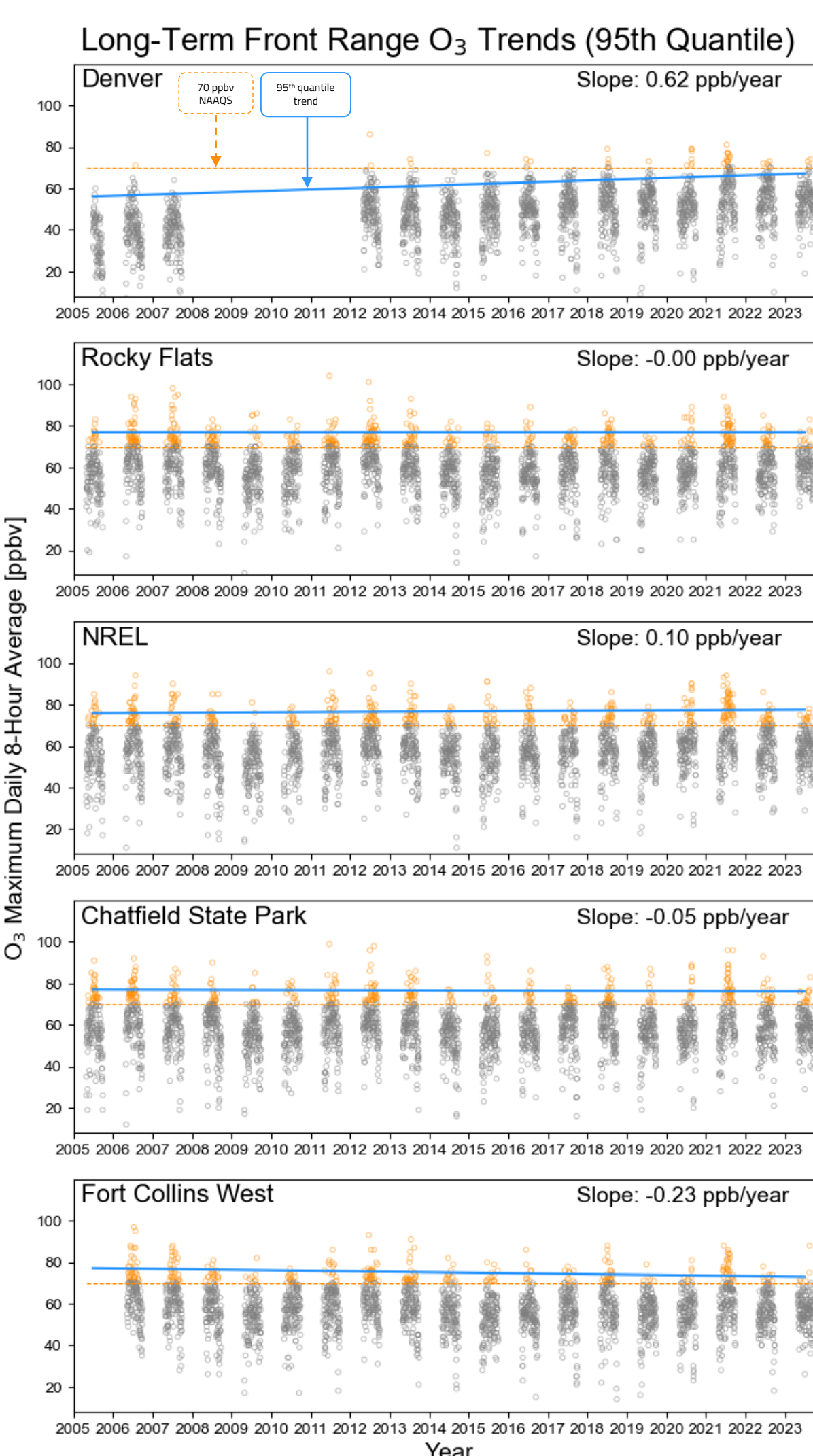


Figure 2: Example response of O_3 production rate to changing NO_x concentrations

Ozone in Colorado's Front Range

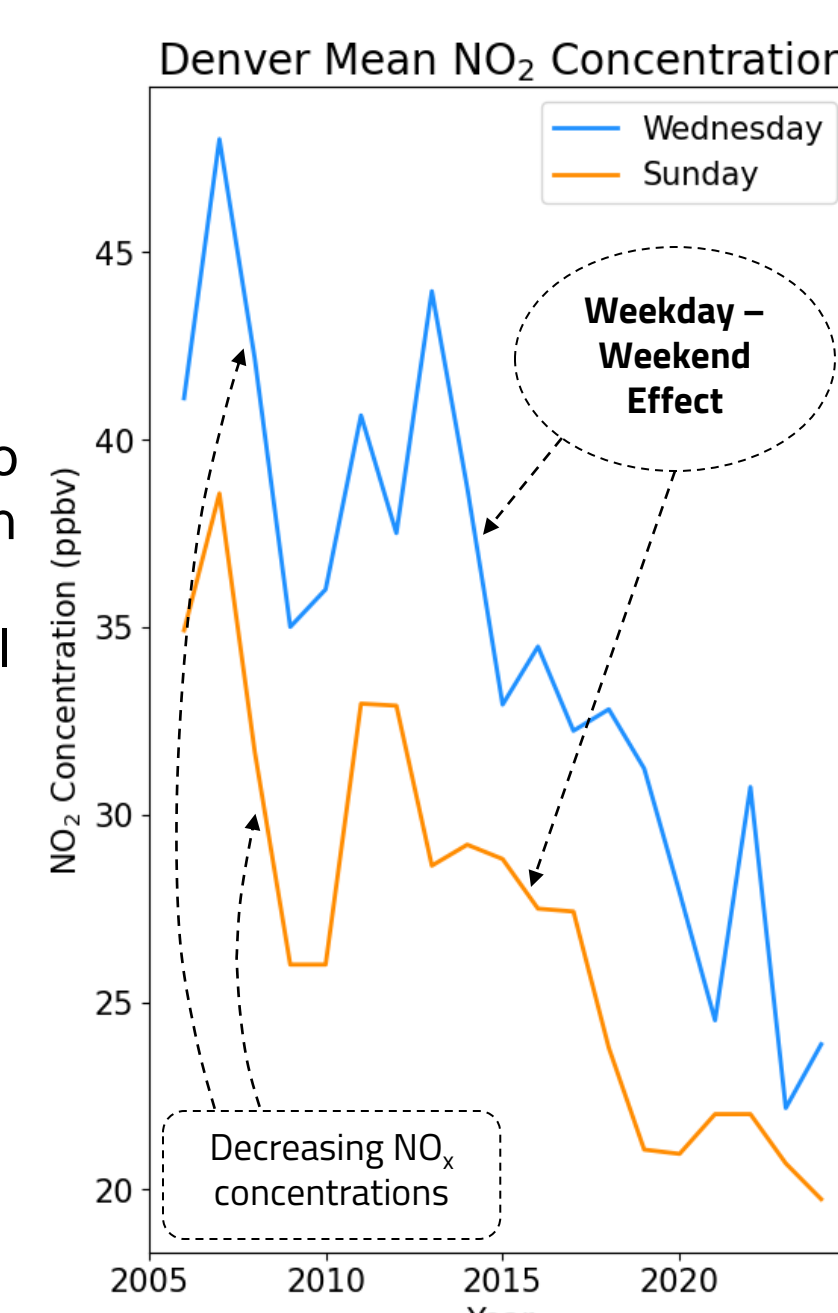


History of Ozone in Colorado

- Colorado's Front Range has consistently exceeded the O_3 NAAQS and is designated as an O_3 nonattainment area
- Local and state regulations have been established to reduce the emission of O_3 precursors
- A decreasing trend in NO_x has been observed, but not O_3

Figure 3 (left): Front Range O_3 trends at selected sites from 2005 – 2023. A 95th quantile regression was utilized to assess the trend in exceedance days. There is no notable widespread change in O_3 concentrations over time, and exceedance days are still consistent.

Figure 4 (right): Denver NO_2 concentrations from 2005 – 2023. NO_2 is decreasing overall, and NO_2 concentrations are higher during the week than the weekend (**Weekday-Weekend Effect**).



Ozone Weekday-Weekend Effect Over Time

Methodology:

- Colorado Department of Public Health and Environment (CDPHE) monitors O_3 at multiple sites in Colorado's Front Range
- O_3 data from a series of long-term sites with frequent and significant exceedance days were selected for analysis

Data Analysis:

- Daily data was restricted to the summertime (May – September) timeframe
- Considering the established weekday-weekend NO_x pattern, a weekday-weekend analysis for O_3 was conducted to investigate O_3 's sensitivity to changing NO_x

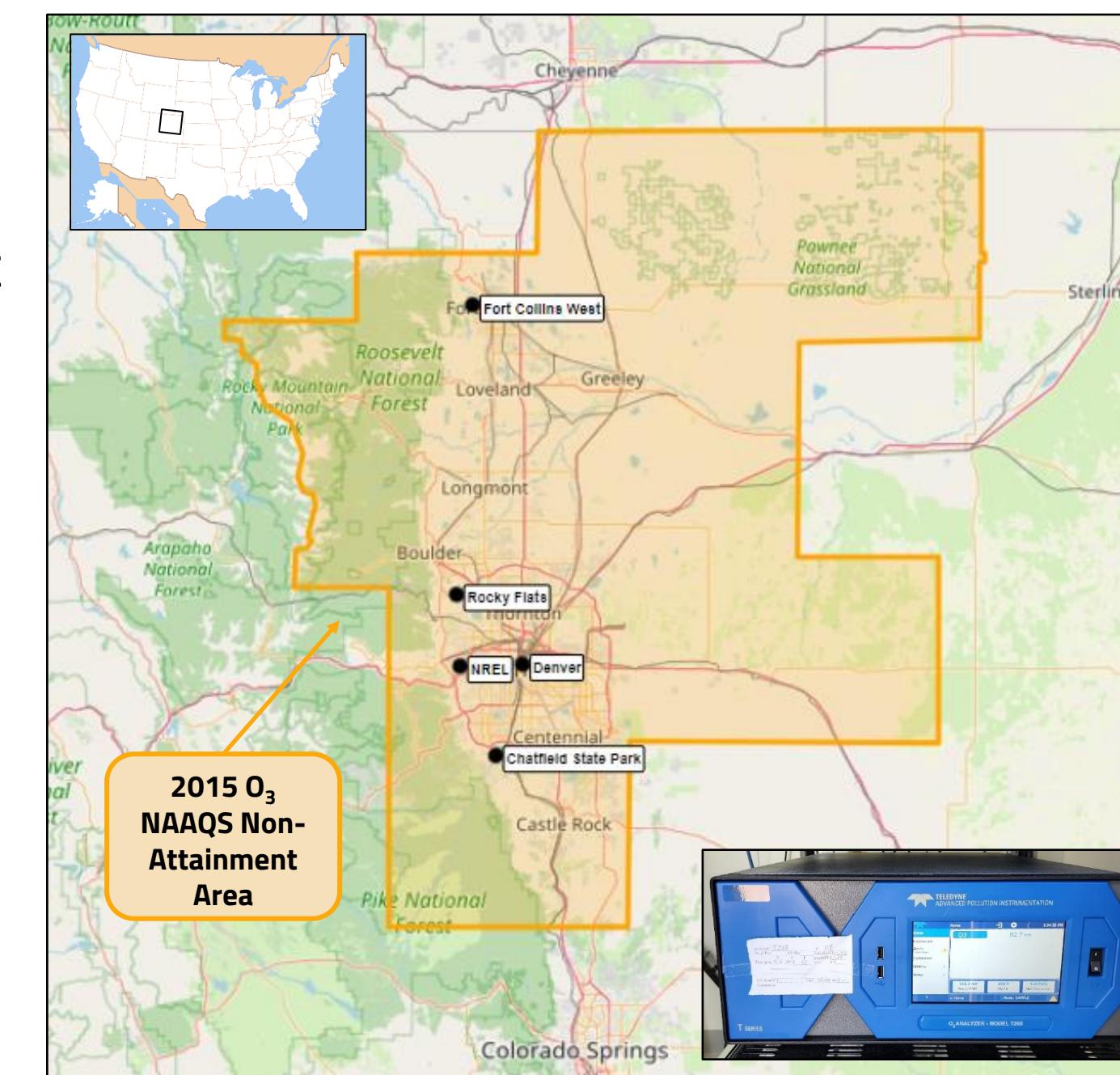


Figure 5: Colorado's nonattainment area and detector locations for this analysis; Instrumentation (Teledyne T265 O_3 Analyzer) at the Fort Collins West location.

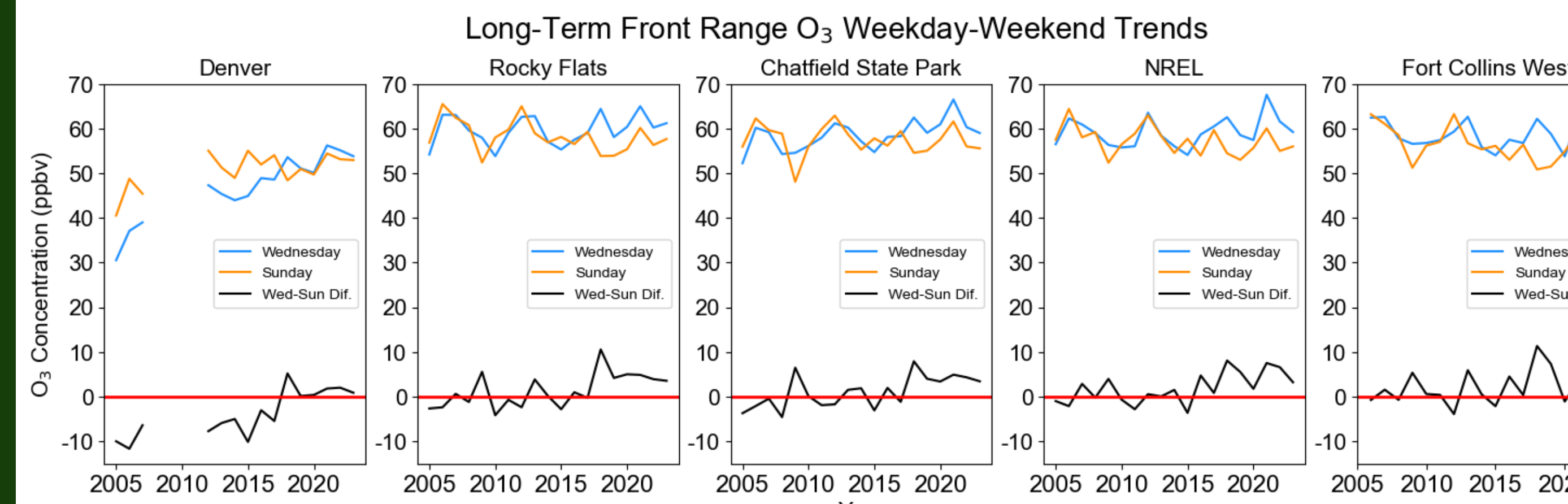


Figure 6: Yearly average Wednesday and Sunday O_3 concentrations for each site from 2005-2023, with their differences (calculated as Wednesday averages – Sunday averages). No decreasing trend in O_3 is observed, and around 2017 the difference begins to trend positively.

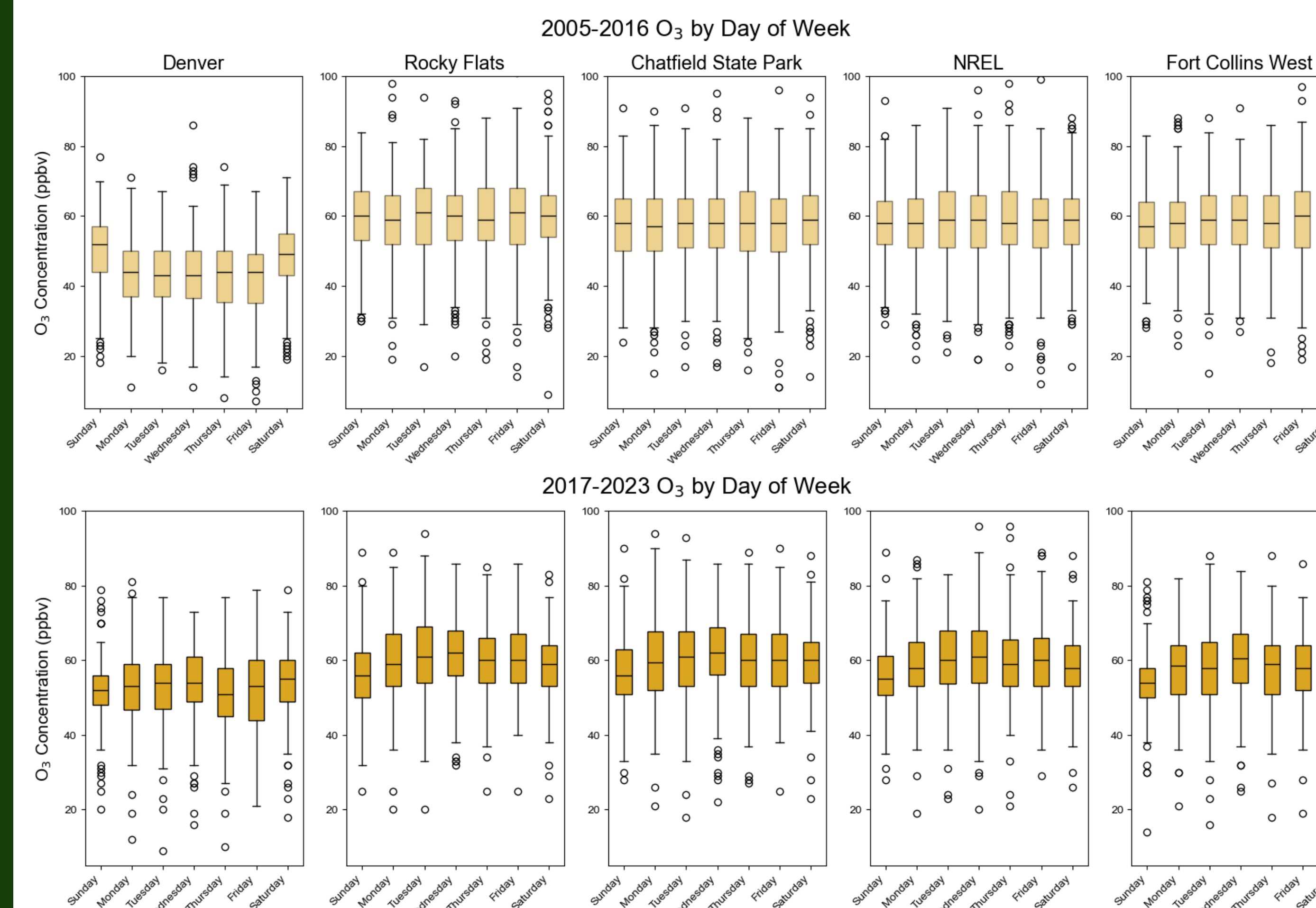


Figure 7: Boxplots detailing O_3 concentration by day of week for each site for 2005-2016 and 2017-2023 periods. Over time, greater O_3 concentrations have begun to develop on weekdays compared to weekends.

Conclusions

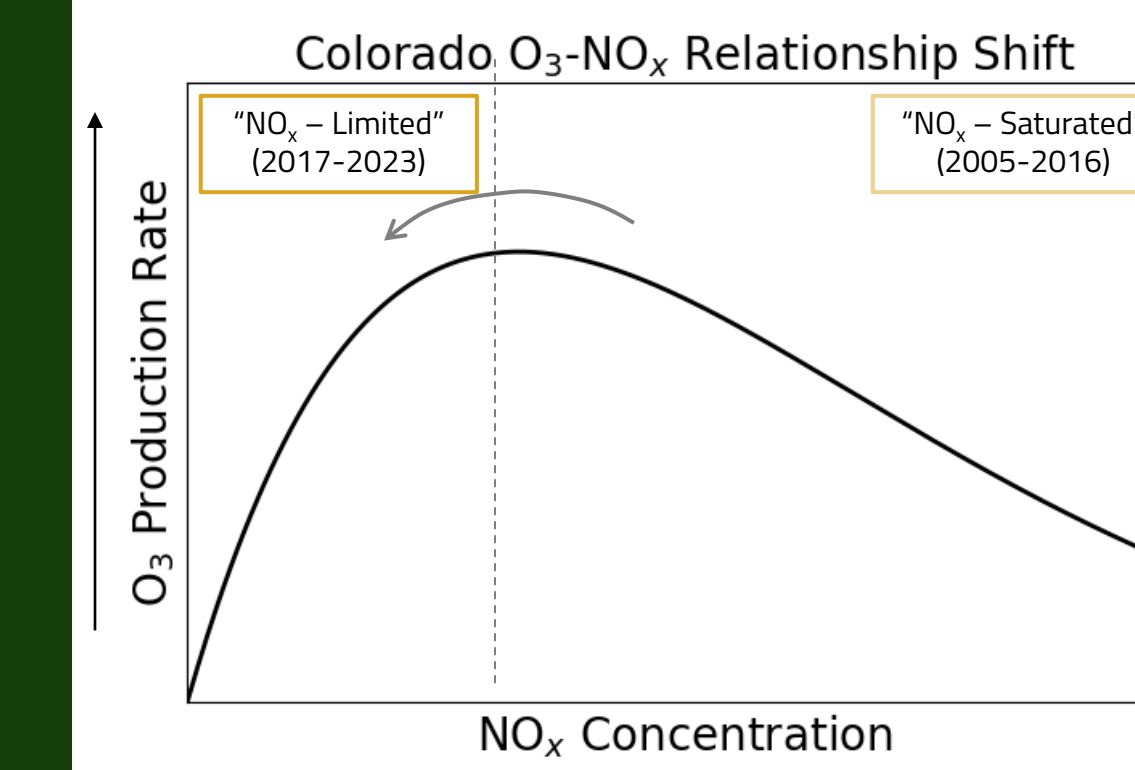


Figure 8: O_3 production rate has shifted from increasing with decreasing NO_x concentrations during 2005-2016, to decreasing with decreasing NO_x concentrations during 2017-2023.

Conclusions:

- O_3 formation is becoming more sensitive to NO_x as overall NO_x concentrations are decreasing
- This indicates a shift from a NO_x -saturated to a NO_x -limited environment
- This information can help inform new regulations and technology; continued NO_x emission reductions will result in less O_3 production

Further Work

VOCs:

- The method utilized for this analysis assumes that VOC concentrations do not follow a weekday-weekend pattern, however VOC's contribution to O_3 production must also be evaluated
- Initial findings indicate that VOC concentrations and their summed OH reactivities follow a similar weekday-weekend effect as NO_x
- A larger suite of tracer compounds and more locations should be analyzed

Additional Factors:

- Severe wildfire years (e.g. 2021) display particularly high O_3 values, which may be further explored
- The impact of transport patterns on Front Range O_3 should also be investigated

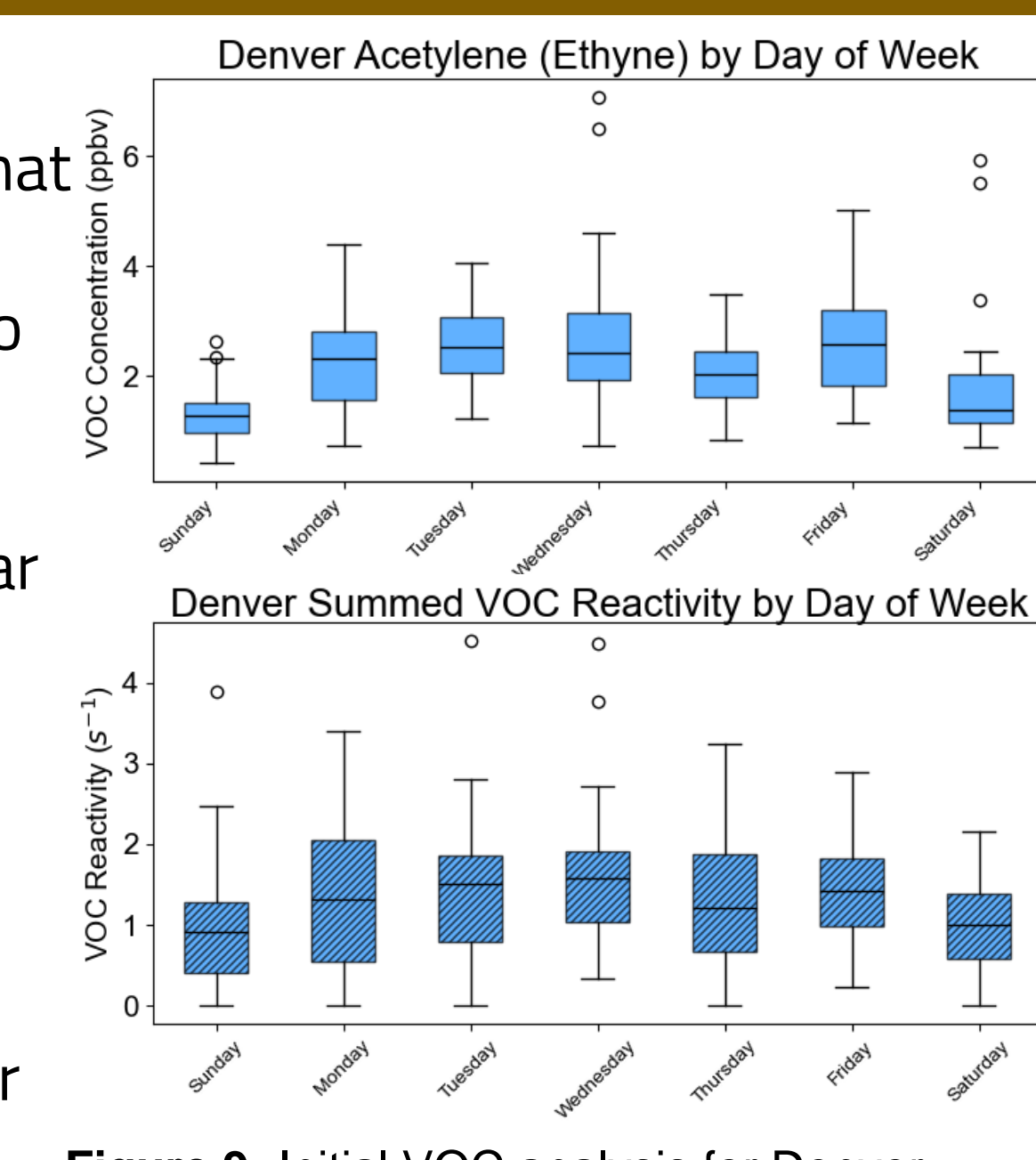


Figure 9: Initial VOC analysis for Denver. The urban tracer compound acetylene exhibits a weekday-weekend effect, and so does the summed OH reactivity of 50 compounds.

Acknowledgements

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