Observation of COVID-19's Impact on $PM_{2.5}$ Concentration as a Result of Independence Day Fireworks

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Introduction

The Environmental Protection Agency (EPA) describes $PM_{2.5}$ as "fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller" (Particulate, 2020). Between 2010-2017, over 25% of studied $PM_{2.5}$ measurement sites from state agencies and PurpleAir exceeded 35 $\mu g/m^3$ of $PM_{2.5}$ by 9 p.m. local time on July 4 (Samson & Masters, 2018). 35 $\mu g/m^3$ is important as it is the EPA's air quality standard (NAAQS, 2016). Despite this dramatic increase in $PM_{2.5}$ concentration being common across numerous U.S. measurement sites on Independence Day, COVID-19 could impact this trend in 2020 as a result of municipal firework displays being cancelled or from a potential uptick in the number of residential firework displays.

Hypothesis

In 2020, fireworks will again cause spikes in $PM_{2.5}$ concentration during the evening of July 4, albeit not to the same magnitude as in 2010-2019 as COVID-19 will have caused the majority of large municipal firework shows to cancel. The magnitude of the decrease in a $PM_{2.5}$ spike may vary from site-to-site due to meteorological factors, primarily wind speed and direction.

Methodology

Ten measurement sites with large average increases in $PM_{2.5}$ ($\Delta PM_{2.5}$) on July 4/5 were selected from the EPA **(Fig. 1**), and a list of 72 annual firework displays near those ten sites were compiled **(Fig. 2)**. Meteorological data was then gathered from NOAA's Local Climatology Data and compared to $\Delta PM_{2.5}$. Wind direction was used to determine how direct wind motion was transporting $PM_{2.5}$ from municipal displays to measurement sites (θ). $PM_{2.5}$ data from 2010-2019 was collected through pre-generated EPA files. However, data for 2020 was manually recorded in real-time through AirNow, a partner of the EPA, due to time constraints.

County	Ave. $\Delta PM_{2.5}$ ($\mu g/m^3$)
Weber, UT	491
Jefferson, KY	227
Snohomish, WA	200
Sarpy, NE	191
Marion, IN	185
Polk, IA	180
Clark, NV	161
Vigo, IN	147
Jefferson, MO	146
Fresno, CA	132

Fig. 1 The ten PM2.5 sensor locations being studied and their respective $\Delta PM_{2.5}$ between 2010-2019.

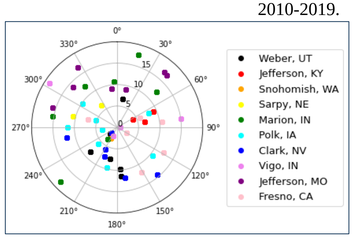

Fig. 2 The relative position of firework displays (within 20 miles of a measurement site) based on distance in miles and bearing in degrees. The origin acts as the location of the ten measurement sites.

Results

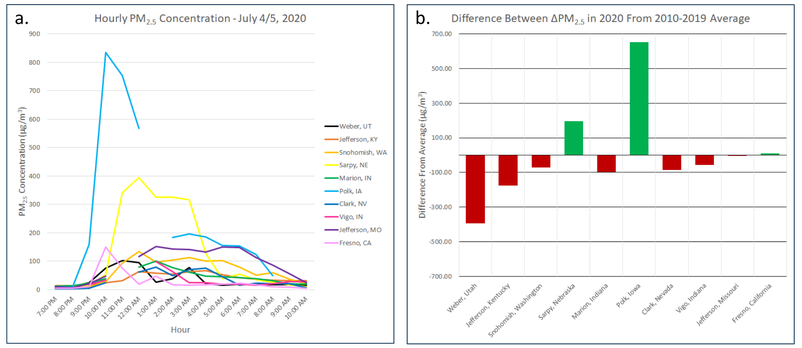

Fig. 3 (a) $PM_{2.5}$ concentration between 7:00 PM on July 4 and noon on July 5 local time during 2020. **(b)** Difference between $\Delta PM_{2.5}$ in 2020 from the average $\Delta PM_{2.5}$ from 2010-2019.

In 2020, $PM_{2.5}$ concentrations again spiked during the evening of July 4 **(Fig. 3a)**, but $\Delta PM_{2.5}$ values differed from average. Most of the ten measurement sites experienced decreased $\Delta PM_{2.5}$ values from the average. However, Polk, IA and Sarpy, NE saw large increases instead **(Fig. 3b)**. Initially, expected causes for this variability were atmospheric conditions. θ was initially believed to be the greatest factor causing $\Delta PM_{2.5}$ variability, however it, along with temperature and precipitation, exhibited no correlation with $\Delta PM_{2.5}$. Wind speed could correlate with $\Delta PM_{2.5}$, but the only evidence supporting this is that none of the sites had average wind speeds above 5.5 knots during July 4 evenings. Temperature inversions are another potential cause of $\Delta PM_{2.5}$ variability (Pailthorp, 2020). However, locations with small $\Delta PM_{2.5}$ also tended to exhibit strong temperature inversions **(Fig. 4)**. These findings may point to $PM_{2.5}$ spikes being more greatly affected by collective smaller residential firework displays as opposed to large-scale municipal displays.

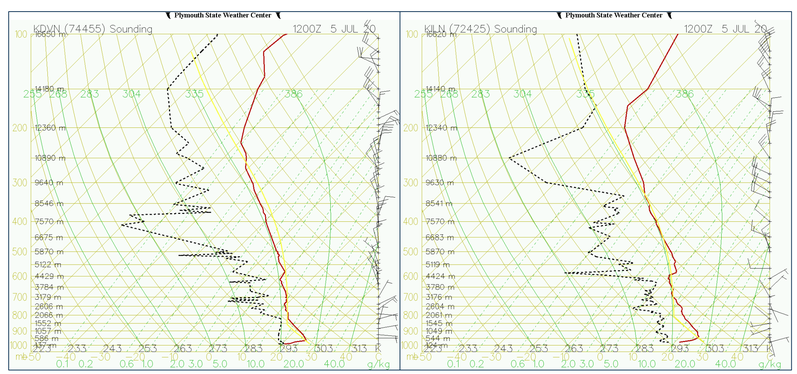

Fig. 4 July 4, 2020 radiosonde observations (RAOB) from near Polk, IA (left) and near Jefferson, KY (right) (Plymouth, n.d.). Polk, IA and Jefferson, KY had $\Delta PM_{2.5}$ of 833 and 53 $\mu g/m^3$ respectively.

Conclusions

- $PM_{2.5}$ concentration dramatically increased in numerous U.S. locations during the evening of July 4 in 2020, consistent with 2010-2019.
- Polk, IA and Sarpy, NE experienced dramatic increases in $\Delta PM_{2.5}$ in 2020 compared to the 2010-2019 average. All eight other measurement sites saw similar or dramatically decreasing values in $\Delta PM_{2.5}$.
- COVID-19 could have potentially caused decreased $\Delta PM_{2.5}$ values, primarily supported through the large decreases in $\Delta PM_{2.5}$ in Weber, UT and Jefferson, KY. However, this is not conclusive for the following reasons:
  - θ, wind speed, precipitation, temperature, and temperature inversions did not appear to explain variability in $\Delta PM_{2.5}$, yet other atmospheric conditions not observed in this study may still effect $\Delta PM_{2.5}$.
  - Variability in $\Delta PM_{2.5}$ appears to be more an effect of collective residential firework displays and less of a result of larger scale municipal firework displays.

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Acknowledgements

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