Variability in Air Quality Exceedances and Large – Scale Meteorology Regimes

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INTRODUCTION

- Air pollution in Southeastern Texas region is an issue due to $PM_{2.5}$ and O_3 exceedances..
- Industrial activities, heavy traffic, and meteorological conditions contribute to air quality.
- Study of broad weather trends and air quality exceedances in Southeastern Texas over a decade.
- Summer seasons impact Gulf Coast Urban regions due to higher temperatures, stagnant air, increased energy consumption, and wind patterns.

PURPOSE

- To determine if there is a strong relationship between $PM_{2.5}$ and O_3.
- If this relationship depends on weather conditions.

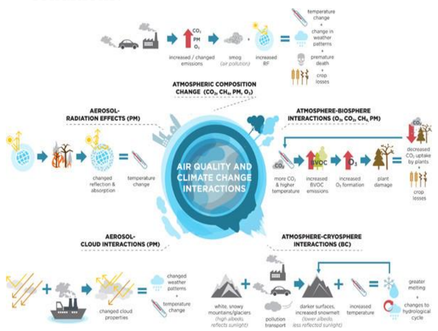


Figure 1. An overview of the main categories of air quality and climate change interactions including a depiction of an example interaction for each category.(von Schneidemesser et al. 2015)

METHODS

Utilizing large scale weather regimes determined from self-organizing maps (SOMs) and data obtained using Texas Commission on Environmental Quality (TCEQ) instruments for the Houston Metropolitan region from June 2010-September 2019. Pandas and Matplotlib libraries were used to process, analyze and visualize meteorological data, resulting in scatter plots and histograms.

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RESULTS & DISCUSSION

Table 1. Description of weather classifications (Wang et al. 2022).

Weather Regime	Description
Pre-Trough **0, 1, 2, 3**	A low-pressure system moves into the area, leading to southerly winds and increased moisture from the Gulf, which can lead to thunderstorm formation.
Post-Trough **7, 13, 14, 15**	A low-pressure system moves out of Southeast Texas, leading to dry northwesterly winds originating over inland regions. As the low-pressure system moves away, a high-pressure system may begin to influence the region, potentially bringing some moisture from the ocean.
Anticyclonic **4, 8, 12, 13**	Characterized by high-pressure systems, weak winds aloft with daily afternoon sea breezes below, and sunny conditions.
Transitional **5, 6, 9, 10**	These patterns occur during changes between the other regimes and include weak disturbances.

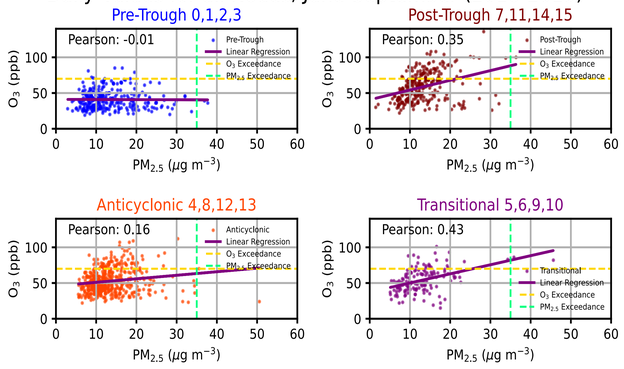


Figure 2: Scatter plots showing varying O_3-$PM_{2.5}$ correlations under different synoptic conditions.

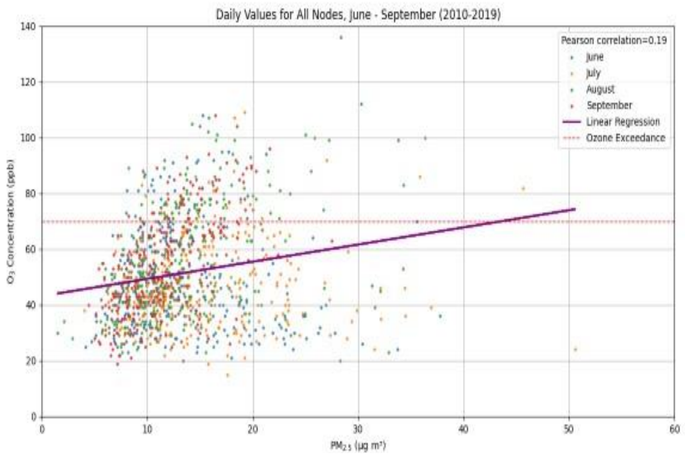


Figure 3: Scatter plot of daily maximum O_3 vs $PM_{2.5}$ shows weak positive correlation (Pearson = 0.19). Stronger correlations and exceedances occur in August-September, highlighting need for late summer air quality monitoring.

Ozone (O_3) Distribution for Weather Regimes June-September (2010-2019)

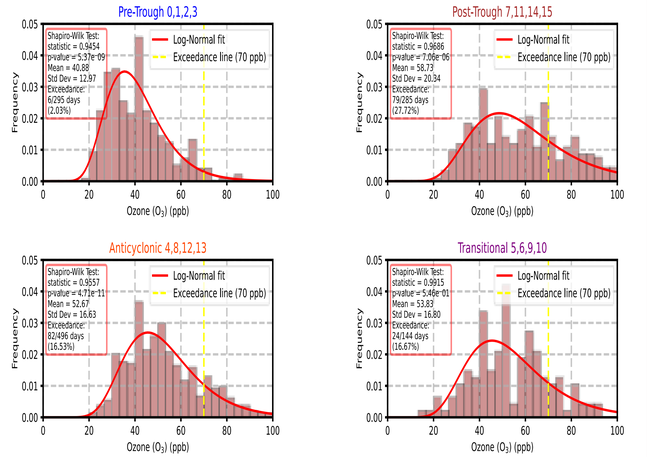


Figure 4: Ozone (O_3) concentrations across the four weather regimes from 2010 to 2019. Among these regimes, the post-trough regime exhibited the highest number of days where ozone concentrations exceeded the threshold value. Shapiro-Wilk tests confirm non-normality (log normal).

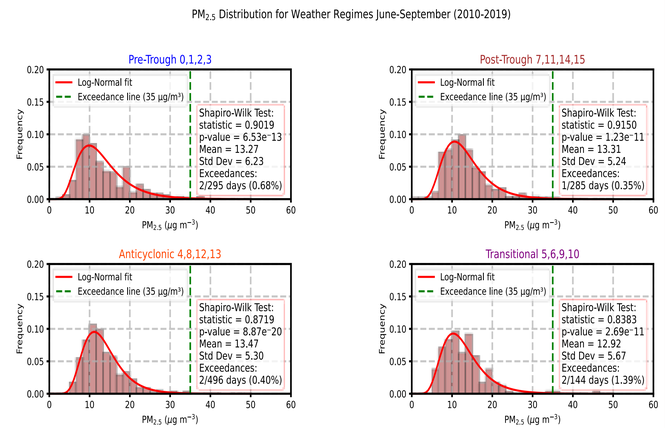


Figure 5: $PM_{2.5}$ concentration distributions across four weather regimes (2010-2019), showing similar right-skewed patterns with minor variations. Shapiro-Wilk tests confirm non-normality.

"Long-term exposure to $PM_{2.5}$ contributed to more than 4 million deaths in 2019."

"The number of deaths attributable to ambient $PM_{2.5}$ increased by about 23% globally over the past decade."

(Health Effects Institute 2024)

CONCLUSION

- Weather patterns and background contributions influence pollutant relationships, highlighting the need for targeted air quality management.
- A slight positive correlation (Pearson = 0.19) exists between daily maximum O_3 and $PM_{2.5}$, with stronger correlations and recurrent exceedances in August and September.
- $PM_{2.5}$ concentrations under different weather regimes (2010-2019) show consistent right-skewed distributions, with mean concentrations around 13 μg/m³ and Shapiro-Wilk test results (p-values $< 1.23 \times 10^{-11}$) confirm significant departures from normality for all distributions.

FUTURE WORK

- Aims to identify geographical differences in these correlations, highlighting areas more exposed to poor air quality.
- Potentially illuminates significant correlations between air quality exceedances and socioeconomic factors.
- Examine the relationship between air quality exceedances and their impacts on underrepresented communities.

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- Table 1 contains text adapted from a ChatGPT-generated summary of synoptic regime descriptions from Wang et al. 2022.

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