Analysis of Particulate Matter Fraction in an Urban Area, Brazil

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INTRODUCTION

Air pollution can be considered one of the main environmental threats to human health, and the risks associated with particulate matter (PM_{10} and $PM_{2.5}$) are of particular relevance[1]. Utilizing sustainable fuel alternatives is crucial for reducing atmospheric emissions, especially in major cities where vehicular traffic is the primary source of pollution. Even cities that have good urban planning, like Curitiba in the state of Paraná (Brazil), air pollution can still be a challenge. The present study focuses on analyzing the patterns of $PM_{2.5}$ and PM_{10} in Curitiba's central area.

METHODOLOGY

The sampling campaign took place in the central area of Curitiba, a medium-sized[2] Brazilian city with a population of just over 1.5 million inhabitants[3]. The station, managed by the Water and Land Institute, is located in Ouvidor Pardinho Square, an areas with moderate traffic primarily consisting of cars. The surrounding environment features low-rise buildings and a few trees (Figure 1).

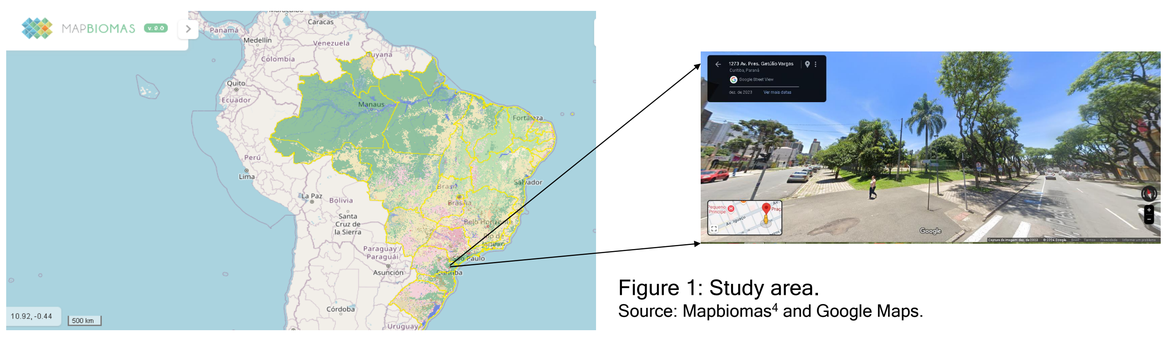


Figure 1: Study area.
Source: Mapbiomas[4] and Google Maps.

We analyzed hourly data for $PM_{2.5}$ and PM_{10} from 2023 using the Openair package in R[5].

RESULTS

Particulate matter concentrations remained low throughout the sampling period, except during the dry season from May to August (Figure 2). The average concentrations recorded were $PM_{2.5}$: 9.7 ± 8.6 µg m^{-3} and PM_{10}: 20.5 ± 17.1 µg m^{-3}. According to the new WHO[6] guidelines, there were 39 days when $PM_{2.5}$ levels exceeded the recommended limits, and 22 days for PM_{10}.

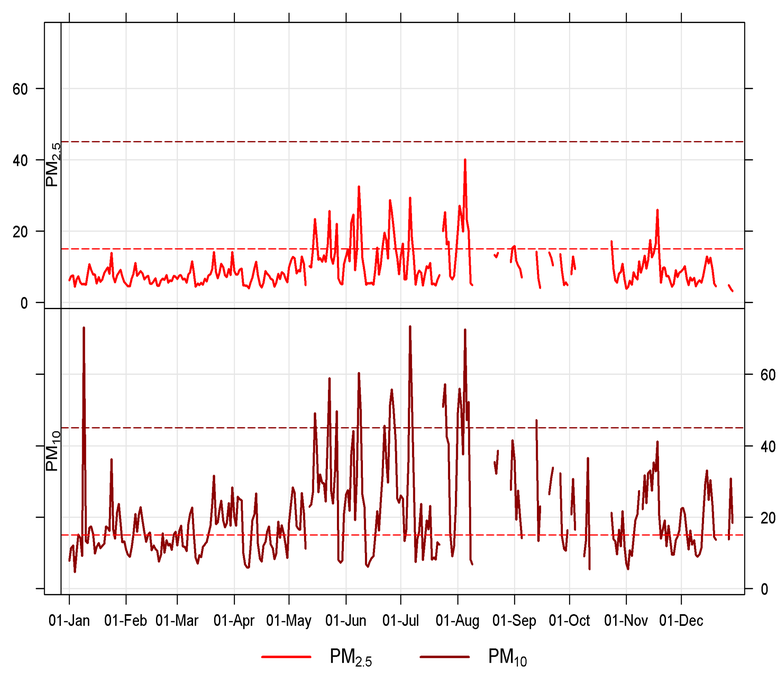


Figure 2: Daily data for $PM_{2.5}$ and PM_{10}. The dashed lines represent the limits established by the WHO, with red indicating 15 µg m^{-3} and dark red indicating 45 µg m^{-3}.

The PM was primarily associated with emissions from local sources, as concentrations tended to increase during periods of higher vehicle circulation (Figure 3a). On weekends, we noted similar concentrations for $PM_{2.5}$ (Figure 3b), while PM_{10} concentrations were lower (Figure 3c).

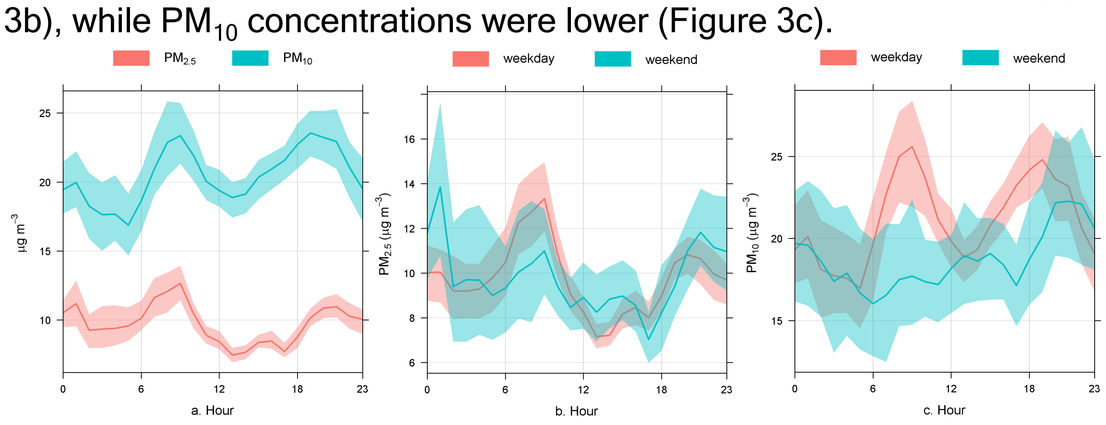
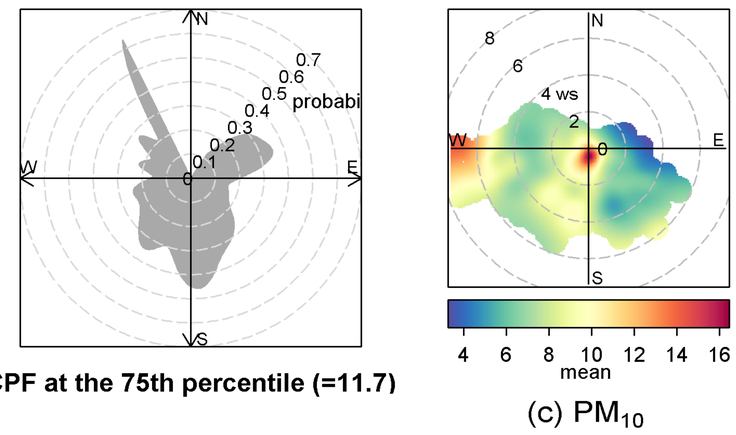


Figure 3: a) Diurnal cycle of $PM_{2.5}$ and PM_{10} for the entire period; b) Diurnal cycle for $PM_{2.5}$ during weekday and weekend; c) Diurnal cycle for PM_{10} during weekday and weekend.

Figures 4a and 4c show the probability of concentrations above 75th percentile arriving in the region from the south. Figures 4b and 4d indicate that the contribution in both fractions ($PM_{2.5}$ and PM_{10}) were primarily local, with wind speeds less than 2 m s^{-1}. However, there were also contributions from long-range transport (above 6 m s^{-1}) coming from the south/southwest (20 µg m^{-3}) and from west (30 µg m^{-3}).

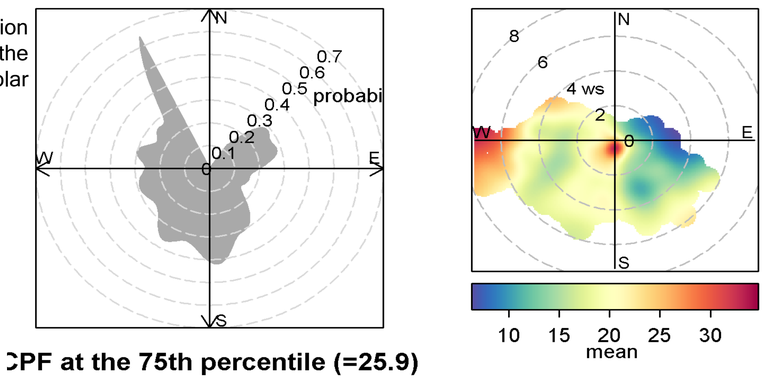
(a) $PM_{2.5}$ (b) $PM_{2.5}$



CPF at the 75th percentile (=11.7)

Figure 4: a) Conditional probability function (CPF) plot of $PM_{2.5}$ concentrations above the 75th percentile (11.7 µg m^{-3}); b) Bivariate polar plot of $PM_{2.5}$.

(c) PM_{10} (d) PM_{10}



CPF at the 75th percentile (=25.9)

Figure 4: c) Conditional probability function (CPF) plot of PM_{10} concentrations above the 75th percentile (25.9 µg m^{-3}); d) Bivariate polar plot of PM_{10}.

Figure 5 illustrates the monthly variation of pollutant concentrations across different wind directions. Notably, higher levels were observed during south winds from May to August for both fractions. Additionally, in August, elevated concentrations were detected across all directions.

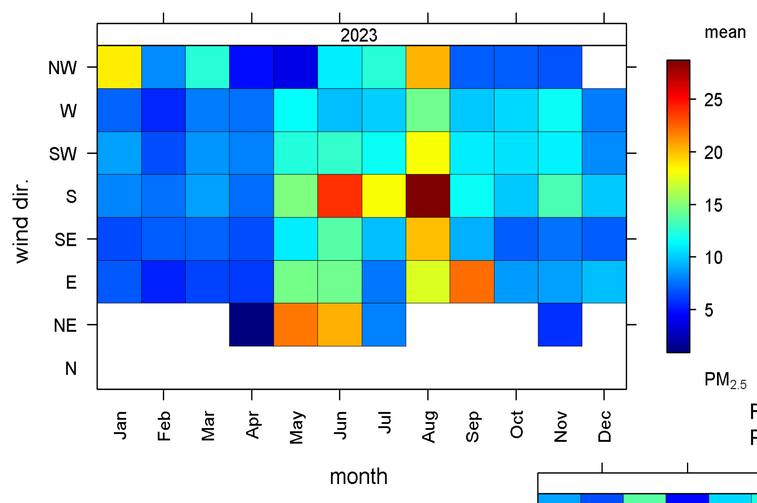
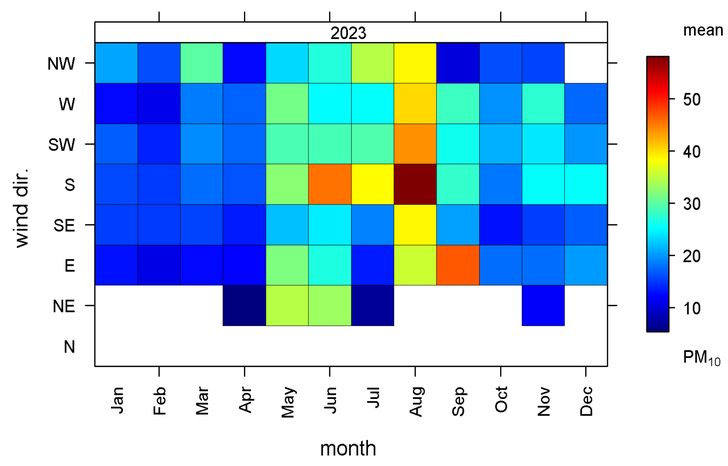


Figure 5: Trendlevel output for $PM_{2.5}$ and PM_{10} with wind directions.



CONSIDERATIONS

Medium-sized cities often face with air pollution problems linked to vehicle fleets, even when urban growth is carefully planned, as seen in Curitiba. In Brazil, pollution levels typically peak during the winter months, coinciding with the dry season. Additionally, long-range transport can exacerbate these pollution events, as smoke from forest fires in the north and central-west regions of the country is transported to the south/southeast, impacting air quality negatively.

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Acknowledgements