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Characterization of air quality degradation episodes of PM_{10} in the Metropolitan Area of São Paulo and their relationship with meteorological conditions

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Abstract: Air pollution is one of the main environmental problems in large urban centers, affecting people's health and impacting quality of life. The Metropolitan Area of São Paulo (MASP) presents frequent exceedances of air quality standards of inhalable particulate matter (PM_{10}), a consequence of pollutant emissions modulated by meteorological conditions. This study aims to identify and characterize persistent exceedance events (PEE) of PM_{10} at MASP between 2005 and 2017, relating them to meteorological conditions. The criteria used to select the events were: i) events that occurred at least in 50% of the air quality monitoring stations chosen for this study and, ii) among the events that met the first criterion, those with a duration equal to or greater than 5 days, which correspond to the 80% percentile of the event duration distribuition.71 persistent episodes of exceedance were selected. The results show that the exceedance of PM_{10} lasted up to 14 consecutive days and were predominant in the austral winter, accompanied by an increase in maximum temperature (T), a decrease in wind speed (WS) and relative humidity (RH), and wind direction predominantly from the northwest during the peak concentration of the pollutant. On average, a concentration increase of 60% was observed at the peak of PEE.

Keywords: Air quality, inhalable particulate matter, Metropolitan Area of São Paulo.

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1. Introduction

One of the main environmental problems in large urban centers is the deterioration of air quality [1] , related to industrialization and urbanization. The Metropolitan Area of São Paulo (MASP), composed of 39 cities, with a population of approximately 21 million people and concentrating 48% of the vehicle fleet of the State of São Paulo, is an example of a region that experience this environmental problem in a daily basis [2].

Episodes of exceedance in air quality standards may be caused by the intensification of emission sources and the occurrence of weather conditions unfavorable to the dispersion of air pollutants. Thus, the weather conditions affect air quality, influencing both the accumulation and dispersion of pollutants, because they are responsible for transport, to provide conditions for chemical reaction of pollutants, deposition, and dispersion of them. Some seasons are more susceptible to the accumulation of concentrations of certain pollutants. At MASP, high concentrations of particulate matter (PM) are more frequent in the austral winter, a season characterized by thermal inversions, atmospheric stability, and weather conditions unfavorable to pollution dispersion [3]. This season at MASP is also characterized by the influence of a semi-stationary system of high surface pressure, the South Atlantic Subtropical High (SASH), that collaborates for the occurrence of periods of drought [4]. Thus, this study aims to identify and characterize persistent exceedance episodes (PEE) due to inhalable particulate matter (PM_{10}) at MASP between 2005 and 2017, relating them to synoptic situations.

2. Data and Method

For the present study, hourly data of concentration of the atmospheric pollutants CO, PM_{10}, $PM_{2.5}$ (fine mode particle matter), NO_2, O_3, and SO_2, monitored by *Companhia Ambiental do Estado de São Paulo* (CETESB) between 2005 and 2017 were used. 10 CETESB automatic monitoring stations were selected at MASP, depending on their location and data availability: Diadema, Ibirapuera, Mauá, Osasco, Parque Dom Pedro II, Pinheiros, Santana, Santo Amaro, São Caetano do Sul e Taboão da Serra. Data from the following surface weather variables were used: daily maximum temperature (T), relative humidity (RH), pressure (P), wind speed (WS), wind direction (WD), and solar radiation (SR), from IAG/USP meteorological station.

The hourly pollutant concentration database was reduced to a daily database, by calculating the maximum moving average value for each day. The period used to calculate the moving average varies from one pollutant to another, according to procedures established by the WHO (World Health Organization) (Table 1). The time series of meteorological variables were also reduced, calculating daily averages and maximum of T, P, WS.

Table 1: Primary air quality standards established by WHO for various pollutants.

	Averaging Period	WHO
PM_{10}	24h	50 µg/m^3
O_3	8h	100 µg/m^3
CO	8h	-
SO_2	24h	20 µg/m^3
NO_2	1h	200 µg/m^3

The following criteria have been used to define and identify PEE: i) events that occurred at least in 50% of the air quality monitoring stations chosen for this study (being 10 stations in total) and, ii) ii) among the events that met the first criterion, those with a duration equal to or greater than 5 days, which correspond to the 80% percentile of the event duration distribuition. 71 PEE were selected.

3. Results

Considering the daily database between 2005 and 2017, using the WHO air quality standard and the previously mentioned criteria for the identification of PEE, 71 events were identified. It was observed that the maximum concentration of PM_{10} during the episodes occurred in the final days of such persistent events, suggesting a progressive increase of pollution. Thus, such days of maximum concentration were defined in this study as peak days.

To determine the average behavior of pollutants and surface weather variables during the temporal evolution of persistent episodes, days before the beginning of the events, peak days (days of maximum concentration of PM_{10}) and days after the end of the events were considered. Figure 1 shows the average behavior of pollutants associated with persistent events. For peak days there is an increase in the concentrations of all pollutants, but with variable intensity. In the previous days,

PM_{10} already shows some concentration records above the standard recommended by WHO (50 µg.m^{-3}). On peak days this situation worsens, so that its median increases by 60%, and is above the WHO standard.

$PM_{2.5}$ showed a behavior similar to PM_{10}. In the previous days, concentrations above the WHO standard were already observed, worsening the situation on peak days, with an increase of $PM_{2.5}$ median by approximately 66%, above the WHO standard. The concentrations of the pollutants SO_2, NO_2, and CO increased during the selected events but remained within the WHO standard in most cases. Among these pollutants, it can be observed that SO_2 was the least altered, since its median concentration increased by only 30% during the events. For the O_3 concentrations there was an increase of its median on peak days, but in the three periods analyzed most of its observations remained below the WHO standard.

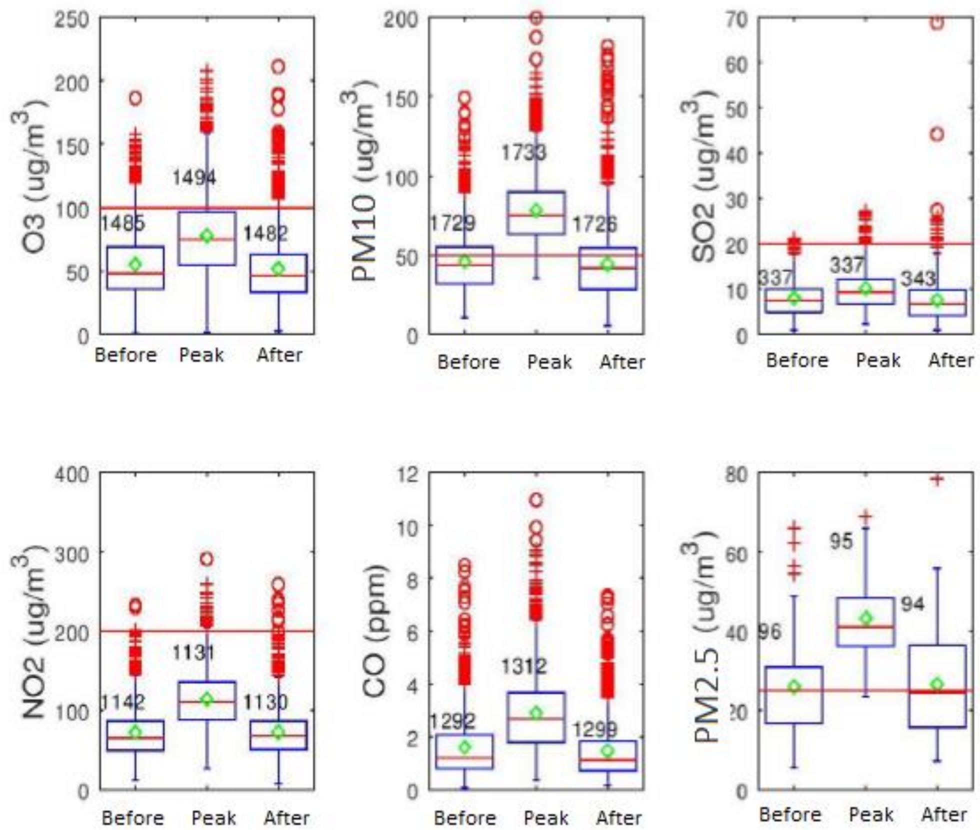

Figure 1: Boxplot with the behavior of pollutants before, at the peak, and after the 71 persistent events of exceedance due to the PM_{10} at MASP. The median concentrations are represented in red; the 25th and 75th percentiles are represented by the blue boxes; the 1st and 99th percentiles are represented by the blue vertical lines; the horizontal red line represents the WHO concentration pattern (except for CO); ("+, o") represent the outliers, the concentration averages are represented by the green circles. The values shown in each box represent the numbers of observations used. Data source: selected CETESB stations.

Figure 2 shows the average behavior of the following surface weather variables: T, SR, RH, WS, P. With the beginning of the events, there was an increase in the surface T, which reached its median of 28°C during the peak. The same behavior occurred for SR, but with less intensity. However, it is observed that for RH, WS, P there was a decreasing behavior on peak days. For peak days a predominance of northwest surface winds was observed.

For the days after the events, T and SR decreased, whild RH increased, with its median reaching 83%. The same occurred for WS, with a increase in its median of 0.4 m/s.

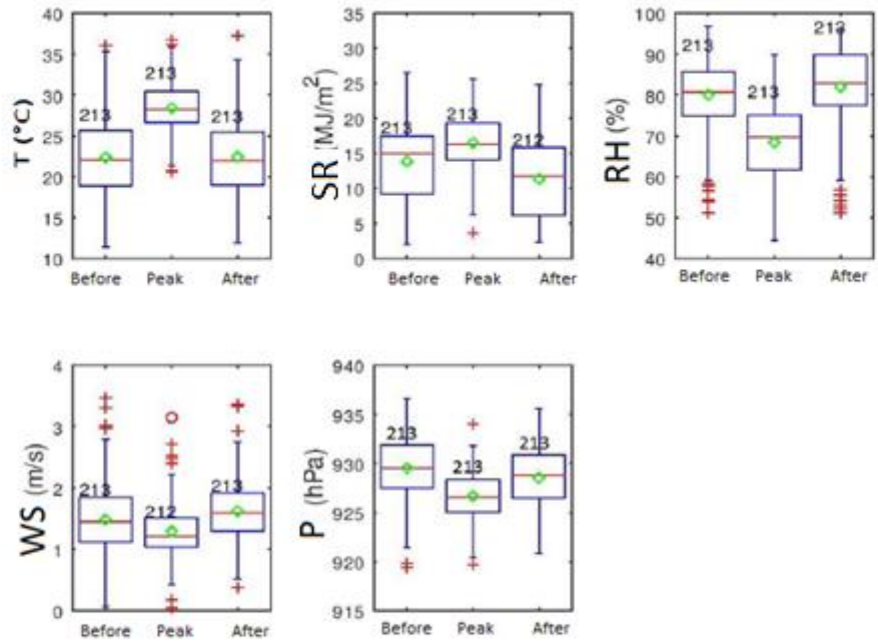

Figure 2: Similar to Figure 1, but for surface weather variables: Maximum temperature(T), relative humidity (RH), pressure(P), wind speed (WS), and solar radiation (SR). The numbers shown in each box represent the number of valid points used. Data source: IAG weather station.

4. Discussion

It was observed that the beginning of PEE coincides with changes in surface weather variables that suggest unfavorable conditions for dispersion, possibly explained by favorable weather conditions for its accumulation, associated with atmospheric stability conditions. This weather scenario contributed to the gradual increase in concentrations of PM_{10} and thus contributing to the beginnings of persistent events. With the gradual increase of PM_{10} concentrations, it was observed that its maximum concentration occurred in the final days of the persistent events, defined in this study as peak days. On these peak days, behaviors such as increased T, decreased RH, and WS and winds with the predominantly northwest direction were observed, thus indicating a prefrontal scenario for such peak days. Winds from the northwest may also suggest transporting PM_{10} from the interior of São Paulo State. During the peak, there was also an increase in concentrations of pollutants such as $PM_{2.5}$, O_3, CO, NO_2, CO compared to the days before the start of the persistent events. Thus, it was observed that the meteorological scenario influences and shapes the air quality, which can influence both the accumulation and the emission of pollutants in the atmosphere.

5. Conclusions

This study analyzed the average behavior of surface meteorological variables and pollutant concentrations in the evolution of 71 persistent events of PM_{10} exceedance between the years 2005 and 2017 in the MASP. Thus, the definition and identification of PEE by analyzing data from 13 years of surface weather variables, bring greater consistency in the observed behavior and can relate such events to synoptic situations and weather patterns, reducing the influence of local conditions and effects. It was observed that on days of maximum concentration of PM_{10} during the temporal evolution of persistent events, a prefrontal scenario occurred with changes in meteorological variables, such as an increase in maximum temperature, a decrease in wind speed, and relative humidity and predominant northwest wind direction. This scenario also contributes to the increase of concentrations of other pollutants in greater or lesser intensity, such as $PM_{2,5}$, CO, O_3, NO_2, and SO_2.

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References

1. Cohen 1, A,J.; Brauer 2, M.; Burnett 3, R.; Anderson 4, H. R.; Frostad 5, J.; Estep 6, J.; Balakrishnan 7, K.; Brunekreef 8, B.; Dandona 9, B.; Dandona 10, R.; Feigin 11, V.; Freedman 12, G.; Hubbell 13, B.; Jobling14, A.; Kan 15, H.; Knibbs 16, L.; Liu 17, Y.; Martin 18, R.; Morawska 19, L.; Pope 20, C. A.; Shin 21, H.; Straif 22, K.; Shaddick 23, G.; Thomas 24, M.; Dingenen 25, R.; Donkelaar 26, A. van.; Vos 27, T.; Murray 28, C.J.L.; Forouzanfar† 29, M. H. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. The Lancet **2017**, V.389, pp.1907-1918. DOI: https://doi.org/10.1016/S0140-6736(17)30505-6.
2. Companhia Ambiental do Estado de São Paulo, CETESB, 2019. Relatório de Qualidade do ar. Available online:https://cetesb.sp.gov.br/ar/wp-content/uploads/sites/28/2020/07/Relat%C3%B3rio-de-Qualidade-do-Ar-2019.pdf (accessed: 9 September 2020) In Portuguese.
3. Santos 1, T.C.; Reboita 2, M. S.; Carvalho 3, V. S. B. Investigation of the relationship between atmospheric variables and the concentration of MP_{10} and O_3 in the state of São Paulo. Revista Brasileira de Meteorologia **2018.** V.33, pp. 631-645. DOI:https://doi.org/10.1590/0102-7786334006.
4. Coelho 1, C. A. S.; de Oliveira 2, C.P.; Ambrizzi 3, T.; Reboita 4, M. S.; Carpenedo 5, C. B.; Campos 6, J. L. P. S.; Tomaziello 7, A. C. N.; Pampuch 8, L. A.; Custódio 9, M. S.; Dutra 10, L. M. M.; Da Rocha 10, R. P.; Rehbein 11, A. The 2014 southeast Brazil austral summer drought : regional scale mechanisms and teleconnections. Climatic Dynamics **2016.** V. 46, pp. 3737-3752. DOI: https://doi.org/10.1007/s00382-015-2800-1.