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Research paper

Dynamic monitoring of tropospheric ozone concentrations in northeast and Midwest Brazil: insights into seasonal variations and climatic influences

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Abstract

Rapid economic transformations, the urbanization process, and the intensification of industrialization have resulted in a notable increase in ozone (O3) emissions, particularly in the Northeast and Central-West regions of Brazil. To monitor the tropospheric ozone column (TCO) over these regions, the Aura Ozone Monitoring Instrument (OMI) was utilized for long-term, large-scale dynamic monitoring from 2008 to 2016. Seasonal variations in O3 concentration revealed that spring exhibited higher concentrations compared to winter. However, winter showed higher O3 concentrations than summer and autumn. Monthly variations displayed cyclical variability, with low values observed in April-June for Campo Grande and in October for Maceió, while high values were observed in October for Campo Grande and in May for Maceió. The spatio-temporal distribution of O3 concentration was influenced by natural and anthropogenic factors. TCO concentration showed positive correlations with temperature and wind. The monthly TCO demonstrated seasonal variation in both cities. Linear regression analysis indicated an increasing trend in TCO due to latitudinal variation between Maceió and Campo Grande during the study period.

Keywords: *OMI; TCO Concentration; Spatio-Temporal Distribution; Atmospheric Parameters; Ozone and Climate Relationship.*

1. Introduction

Satellite data is important because it enables us to monitor changes in the distribution of ozone (O3) in the atmosphere over time and space. The ozone layer is a protective gas layer in the atmosphere that absorbs the majority of the ultraviolet radiation emitted by the Sun, which is detrimental to life on Earth. Consequently, the depletion of the ozone layer can have severe implications for both human health and the environment (Souza et al., 2022).

Satellite data also plays a crucial role in our understanding of the causes and effects of atmospheric processes, such as pollution and climate change. When combined with other data sources and models, satellite data enables us to forecast future changes in the atmosphere and the ozone (O3) layer. This capability empowers policymakers to make informed decisions and implement preventive measures accordingly (Neale et al., 2021; Souza et al., 2021; Souza et al., 2020; Souza et al., 2019).

However, it is essential to acknowledge that satellite data also has limitations, including restricted spatial resolution and susceptibility to interference from clouds and adverse weather conditions. Consequently, it is crucial to complement satellite data with other measurement methods, such as terrestrial measurements and weather balloons. By integrating these diverse approaches, we can obtain a more comprehensive understanding of the atmosphere and the ozone (O3) layer (Muñoz et al., 2023).

Analyzing the relationship between tropospheric ozone column (TCO) and these atmospheric parameters is particularly significant in studying the spatial and seasonal variations of the O3 layer in Brazil, given its vast geographical extent.

Additionally, referencing previous studies conducted in West Africa is important as it provides context for the present analysis. These studies have demonstrated significant correlations between ozone column density (OCD) and atmospheric parameters, such as temperature and precipitation, in different regions and seasons (Audu, Okeke, & Ejembi, 2021).

The findings of this study hold potential value for climatologists and meteorologists, as the relationship between total ozone column (TOC) and atmospheric parameters can aid in predicting changes in the ozone (O3) layer and understanding the impacts of climate change on the atmosphere. Furthermore, the analysis of spatio-temporal variations in TOC within these regions can provide valuable insights for monitoring and safeguarding the ozone layer in these geographical areas.

Consequently, this study aims to contribute to the existing knowledge base, specifically focusing on Brazil, more specifically the regions of Mato Grosso do Sul and Alagoas. The objective of this research is to analyze the correlation between TOC and various atmospheric parameters, including temperature, precipitation, and solar irradiance, in these two distinct regions of Brazil. The analysis will be based on long-term measurements from the Aura satellite's Ozone Monitoring Instrument (OMI) sensor, spanning the period from 2008 to 2016.

2. Methods

2.1. Study area and observational data

The characteristics of the cities of Campo Grande, MS, and Maceió, AL, based on their latitude, longitude, altitude and climate: Campo Grande, MS:Latitude: Approximately 20° South, Longitude: Approximately 54° West, Altitude: Around 530 meters above sea level. Climate: Campo Grande has a humid tropical climate, with a dry winter season and a rainy summer season. Average temperatures vary between 20°C and 26°C throughout the year, with a rainy season between October and March. Maceió, AL:Latitude: Approximately 9° South, Longitude: Approximately 35° West, Altitude: Close to sea level, with some areas slightly above. Climate: Maceió has a humid tropical climate, characterized by high temperatures throughout the year and a prolonged rainy season. Average temperatures vary between 24°C and 30°C, and the rainy season occurs between May and August, with a peak of rain in June (Souza et al., 2019), Brazilian Institute of Geography and Statistics (IBGE), (Kottek et al., 2006), (Alvares et al., 2013). National Institute of Meteorology (INMET), (Lyra et al., 2014), (Souza et al., 2021).

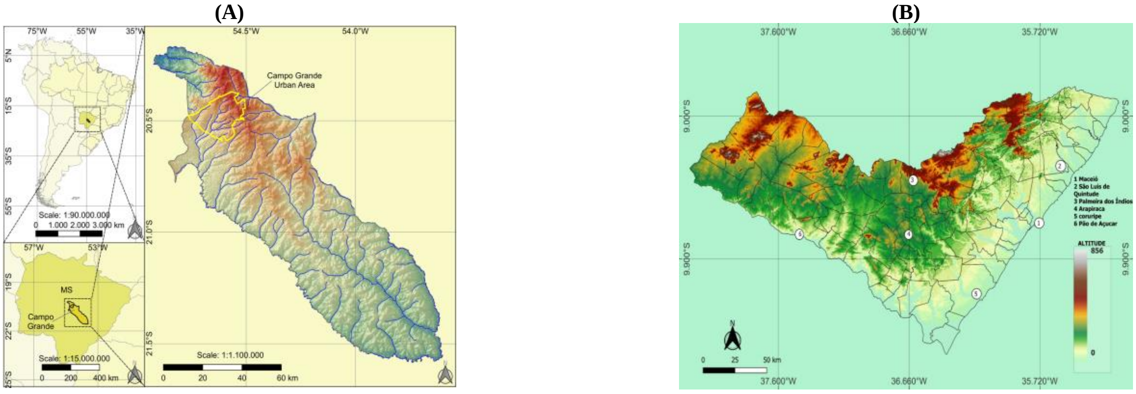
(A) (B)

Fig. 1: (A) Location of the State of Mato Grosso Do Sul and Campo Grande in Brazil, (B) Location of Automatic Meteorological Stations in the State Of Alagoas and Their Respective Altitude in Meters Above Sea Level.

2.2. Data

In this study, we performed a multivariate analysis, incorporating data on O3 concentrations and four meteorological variables: rain, evaporation, vapor pressure, air temperature, and wind speed. The dataset encompassed the period from 2008 to 2016.

2.3. Satellite data used for the study

The OMI (Ozone Monitoring Instrument) sensor on board the Aura satellite is used to measure tropospheric ozone concentration (TCO) in the atmosphere. Here are some characteristics and information about the TCO measurements performed by the OMI sensor: Working Principle: The OMI sensor measures ozone concentration in the troposphere by detecting reflected and scattered solar radiation in the Earth's atmosphere. It observes different wavelengths of sunlight to determine the amount of ozone present at various altitudes.

Spatial and Temporal Resolution: The OMI provides ozone measurements with a relatively high spatial resolution, allowing detailed observation of specific regions of the Earth. Furthermore, it has a global observation capability, allowing monitoring at different latitudes and longitudes. The frequency of measurements may vary depending on the mission configuration and monitoring objectives.

Spectral Sensitivity: The OMI is sensitive to different wavelengths of visible and ultraviolet light, which allows it to distinguish between ozone and other gases in the atmosphere. This helps with the accuracy of measurements and the identification of ozone distribution patterns at different altitudes and regions.

Data Processing: The data collected by the OMI sensor goes through an extensive calibration and validation process to ensure the accuracy and reliability of the measurements. This includes corrections to compensate for atmospheric and instrumental effects that may affect observations.

Data Products: Tropospheric ozone data collected by the OMI sensor is made available in a variety of products and formats for scientific analysis and environmental monitoring. This includes ozone distribution maps, concentration time series and other information relevant to atmospheric and climate studies.

In summary, the OMI sensor onboard the Aura satellite plays a crucial role in global tropospheric ozone monitoring, providing accurate and detailed measurements that help scientists better understand atmospheric dynamics and the impacts of human activities on air quality. (McPeters et al., 1998; Aculinin, 2006).

To investigate the impact of weather conditions on fluctuations in ozone levels, we used multiple linear regression analysis. This method is widely used to predict how ozone concentrations are affected by meteorological variables. The general equation of the adopted model was as follows:: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + \varepsilon$, where YY represents the objective variable (ozone concentration), k denotes the number of independent variables (meteorological variables), X represents the independent variables, $\beta\beta$ represents the regression coefficients (estimated using the least squares procedure), and ε denotes the error term associated with the regression analysis.

In order to assess the prediction of TCO, the Mean Standard Error (MSE) was employed after linearizing the equations. The MSE was calculated using the equation EQM (1) , where Pi represents the estimate of TCO, hi represents the actual TCO values, and n denotes the sample size. All analyses were conducted at a significance level of 5%.

$$EQM = \sqrt{\frac{1}{m}\sum_{i=1}^{n}(P_i - O_i)^2} \qquad (1)$$

$$MBE = \frac{\sum_{i=1}^{n}(P_i - O_i)}{n} \qquad (2)$$

3. Results and discussion

Table 1 displays the maximum monthly mean values of TCO, which exhibit variations of up to 259.82 DU for Campo Grande. The maximum TCO value recorded was 269 DU, while the minimum value was 251 DU. Similarly, for Maceió, the maximum monthly mean TCO value was 263.68 DU, with a maximum of 275 DU and a minimum of 251 DU. These higher values observed in November were predominantly associated with increased sunshine duration, high temperatures, and low humidity.

In the Midwest region, specifically in Campo Grande, the maximum mean monthly TCO values were observed in August, September, and October, reaching 269 DU (as indicated in Table 1).

Table 1: Descriptive Analysis of the Meteorological Variables for the Regions of Campo Grande and Maceió, Period 2008-2016

CAMPO GRANDE							
Variable	Mean	StDev	CoefVar	Minimum	Maximum	Skewness	Kurtosis
O3CG	259.82	6.8	2.62	251.33	269.62	0.23	-1.47
Tmax	29.283	1.321	4.51	26.7	30.6	-1.07	-0.07
Tmin	18.017	2.211	12.27	14.5	20.4	-0.51	-1.36
chuva	127.8	72.9	57.06	31.4	231.9	0.05	-1.43
DPre	8.42	4.5	53.49	3	15	0.22	-1.62
UR	72.76	7.23	9.94	59.6	80.8	-0.55	-0.94
HS	7.052	0.673	9.55	5.683	8.316	-0.21	0.93
RSG	1781.3	283.4	15.91	1273	2171	-0.43	-0.75
MACEIÓ							
Variable	Mean	StDev	CoefVar	Minimum	Maximum	Skewness	Kurtosis
O3MAC(DU)	263.68	7.89	2.99	250.53	274.97	-0.13	-0.84
Tmin	23.375	0.892	3.81	21.9	24.4	-0.52	-1.27
Tmax	27.367	1.344	4.91	25.4	28.8	-0.4	-1.61
Chuva	108.7	54.1	49.77	45	195	0.62	-1.18
UR	69.63	8.01	11.5	54.4	79.4	-0.57	-0.56
DCH	15.583	2.678	17.19	11	19	-0.25	-1.06
HSOL	8.233	0.565	6.86	7.5	9	0.08	-1.84
RSG	1410.1	241.6	17.13	1082.4	1760.7	-0.06	-1.12
Vel	2.342	0.409	17.48	1.66	3	-0.2	-0.38

3.1. Temporal variation of the total ozone column (TCO)

Figures 2 and 3 illustrate the average monthly and annual TCO (total column ozone) in the study locations, revealing significant seasonal variations. In all the examined areas, the maximum TCO concentrations were observed during the spring months, while the minimum concentrations occurred during the autumn months. The spatial distribution of TCO concentration gradually decreases from the Northeast to the Midwest regions of Brazil. However, due to the influence of topography and climate, regions with similar characteristics displayed comparable TCO values, resulting in lower variations (as depicted in Figure 2).

Analyzing the specific trends over time, in Maceió, the TCO concentration initially increased from 2008 to 2009, then decreased until 2010, followed by another increase until 2011. From 2011 to 2013, there was a subsequent decrease, followed by an increase in 2014. Finally, the concentration decreased again by 2016. Conversely, in Campo Grande, the TCO concentration decreased from 2008 until 2009, experienced growth until 2010, and then maintained relatively constant values. These observations reflect the varying influences of factors such as industrial pollution, energy consumption, and emissions of ozone precursors, which are influenced by temperature and radiation (as depicted in Figure 3). Although there is a slight growth in TCO concentration indicated in Figure 3, further analysis is required to draw conclusive findings.

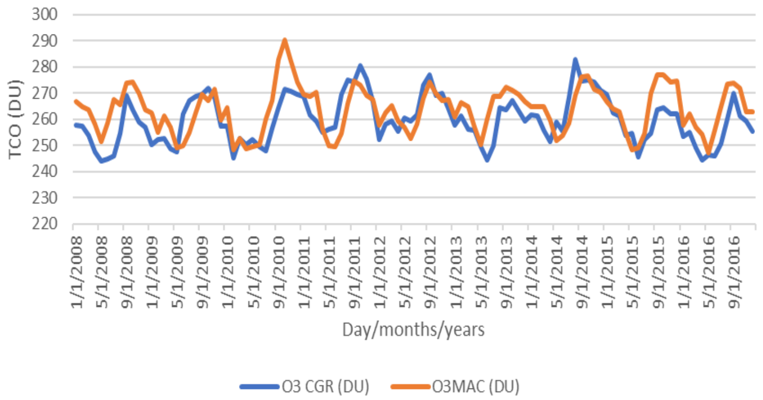

Fig. 2: Average of the Monthly Values of O3 Concentration in Maceió and Campo Grande, Period 2008 to 2016.

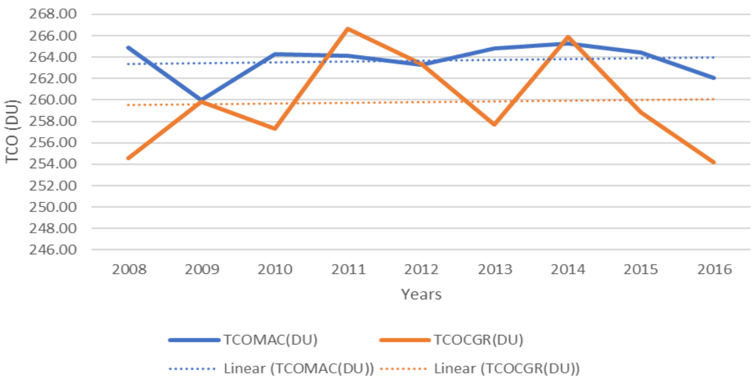

Fig. 3: Average of the Annual Values of O3 Concentration in Maceió and Campo Grande, Period 2008 to 2016.

In Figure 3, the highest average TCO values is depicted for Campo Grande in 2011, reaching 266 DU, while Maceió had its highest average TCO in 2014, reaching 265 DU. This indicates that both locations experienced periods of elevated TCO levels during those years. Figures 2 and 3 also demonstrate a gradual decrease in TCO concentration from the coastal region to the Midwest region. The lowest TCO value observed was 250.53 DU in April for Campo Grande, while the highest value of 251.3 DU occurred in April for Maceió. Table 2 provides further insights into the differences between the coastal region and the Midwest region. Precipitation and relative humidity values tend to increase as one moves from the coastal region (Maceió) to the Midwest region (Campo Grande). The average precipitation ranges from 108 mm in Maceió to 127 mm in Campo Grande. Thus, the spatial distribution of precipitation and relative humidity varied in the opposite direction to TCO.

In the coastal region, maximum temperature, insolation time, and wind speed are higher compared to the Midwest region. The wind speed ranges from 3.0 m/s to 1.66 m/s in Maceió, with an average of 2.34 m/s. In Campo Grande, the wind speed ranges from 3.36 m/s to 2.29 m/s, with an average of 2.84 m/s. Figures 4a and 4b illustrate that TCO, maximum temperature, insolation time, and wind speed exhibit a similar spatial distribution pattern, which contrasts with the distribution of precipitation and relative humidity. This pattern is influenced by elevation and latitude. Similar findings were observed in previous studies conducted in Africa and West Africa. The observed spatial distribution of TCO and atmospheric parameters shows a dependence on elevation and latitude. Temperature and TCO tend to increase along the latitude, while precipitation decreases along the latitude, aligning with previous research by Eresanya et al. (2013).
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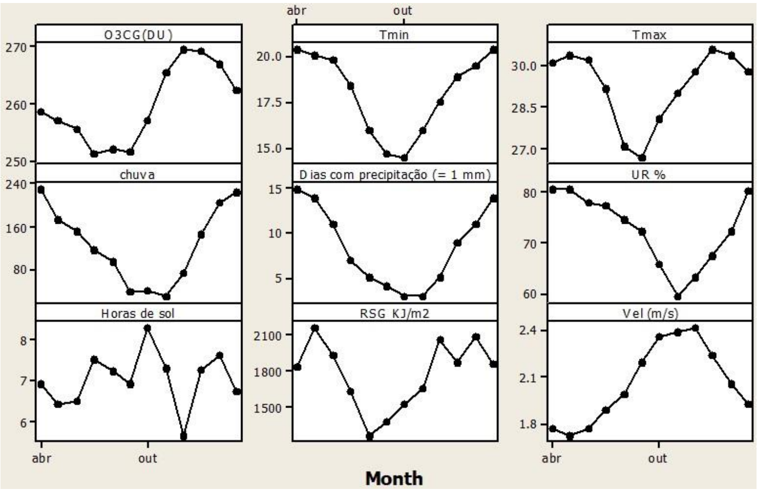

Fig. 4: (A) Variation of the Monthly Average of the Column of O_3 and of the Climatic Variables for the Period 2008-2016 for the Region of Campo Grande.

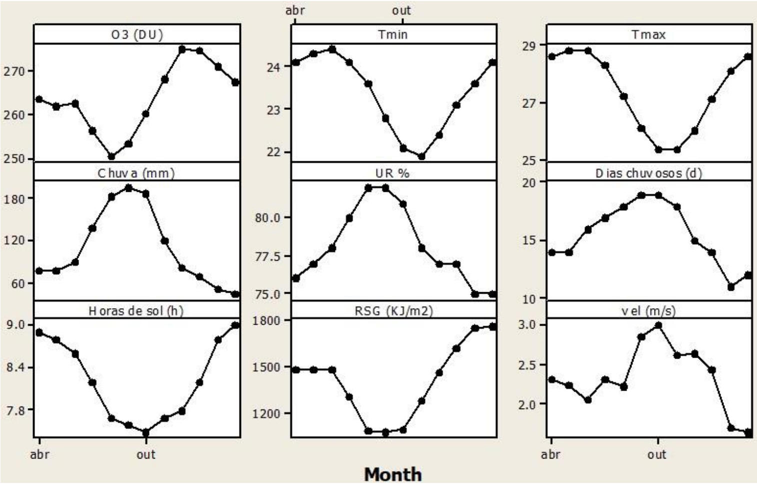

Fig. 4: (B)Variation of the Monthly Average of the O_3 Column and of the Climatic Variables for the Period 2008-2016 for the Region of Maceió.

3.2. Seasonal variations in TCO concentration

The seasonal variations of TCO concentration followed a consistent pattern in the nine-year period, with the highest concentrations occurring in spring, followed by winter, summer, and autumn. For Campo Grande, the maximum concentrations were 269 DU in spring, 269 DU in winter, 258 DU in summer, and 252 DU in autumn. In Maceió, the maximum concentrations were 263 DU in summer, 256 DU in autumn, and 274 DU in winter. These variations can be attributed to photochemical reactions driven by increased solar radiation, which lead to higher TCO concentrations.

3.3 Seasonal variations of OCD and atmospheric parameters

Figure 3 illustrates the monthly mean variations of TCO and atmospheric variables from 2008-2016 for the regions. TCO values fluctuated throughout the year, with the lowest recorded between April and July, corresponding to the dry season, and the highest between August and March, coinciding with the rainy season. These findings align with previous studies (Obiekezie, 2008; Isikwue and Okeke, 2009; Rafiq et al., 2017; Eresanya et al., 2017). Figure 4a and b provide a visual representation of the seasonal TCO patterns observed in the data.

The precipitation levels exhibit a consistent increase from October to December, reaching their maximum during the peak of the rainy season, followed by a gradual decrease until August in Campo Grande (Fig. 4b). The lowest recorded rainfall was 37 mm in Campo Grande, while the highest was observed at 231 mm. Relative humidity also displayed variation throughout the year, with high levels during the rainy season and lower levels during the dry season (Figs. 4a and 4b).

In terms of maximum temperature and insolation time, they exhibited lower values during the rainy season, when cloud activity is at its peak and less solar radiation reaches the Earth's surface. Conversely, they were higher during the dry season (Figs. 4a and 4b). Notably, Figure 4a and 4b reveal a similar pattern of variation among TCO, precipitation, and relative humidity. These variables exhibit higher values during the rainy season and lower values during the dry season. In contrast, maximum temperature and insolation time display an inverse relationship with TCO.

These observations suggest a potential connection between TCO and precipitation, as humidity is influenced by precipitation. Conversely, TCO appears to have an inverse relationship with maximum temperature and insolation time.

To confirm this, a bivariate analysis using Pearson's correlation was conducted at a significance level of 0.05. The results showed a strong positive correlation between TCO and precipitation, as well as between TCO and relative humidity (Table 2). These findings align with previous studies that have reported a positive correlation between TCO and precipitation based on seasonal variations (Sachithananthem et al., 2013).

Table 2: Correlation Coefficient (R) of TOC with Atmospheric Parameters in Selected Stations in Campo Grande and Maceió ($P<0.05$)

	Tmax	Tmin	rain	D Pre	RH %	H S	RSG	Vel	The$_3$
Campo Grande	0,603	0,257	0,169	0,095	-0,524	-0,21	0,604	0,482	1
Maceio	-0,053	-0,22	-0,775	-0,307	-0,633	0,291	0,741	-0,185	1

Meteorological factors play crucial roles in the formation, conversion, transport, and removal of O3, all of which impact TCO concentrations. Wind acts as a primary means of spreading air pollution and directly influences the speed and direction of O3 diffusion. Stable high-pressure systems are major climate phenomena that contribute to significant pollution on medium to large scales (Song et al., 2017).

In Campo Grande, the maximum temperature exhibited a positive mean correlation with TCO, whereas in another region, it displayed a weak negative correlation (Table 2). This suggests that the statistical relationship between maximum temperature and TCO is dependent on the specific study location. The duration of sunlight demonstrated both negative and positive correlations with TCO across all regions (Table 2). Additionally, Table 2 illustrates the correlation between average annual TCO concentration and temperature from 2008 to 2016. As temperature increases, the production rate of O3 accelerates due to the combined influences of heat and robust oxidation reactions (Xu et al., 2021).

The observed spatial distribution and seasonal variations of TCO and atmospheric parameters in this study can be attributed to the mechanisms involved in rainfall production and the influence of atmospheric phenomena on both O3 and atmospheric parameters. Factors such as ENSO impact the formation of O3. As a result, the spatial distribution of TCO and atmospheric parameters deviates from their seasonal variations. We found that TCO, maximum temperature, time of insolation, and wind speed exhibit similar patterns of variation, contrasting with the patterns observed for precipitation and relative humidity. However, when examined seasonally, TCO, precipitation, and relative humidity display similar patterns of variation, while maximum temperature and time of insolation show distinct patterns. This suggests that these two parameters may exhibit similar spatial patterns but differ in their seasonal variations.

The significant relationship between TCO and atmospheric parameters, whether direct or inverse, highlights the mutual influence between them. This is likely attributed to the impact of atmospheric parameters on the formation, transport, and distribution of O3, which in turn affects the climate. Studies have shown that the level of O3 undergoes periodic changes with implications for climate. Sreenivasa (2006) reported a positive association between temperature increase and ozone level. Additionally, the direction of wind plays a crucial role in determining the extent of ozone transport, as noted by Sreenivasa.

Furthermore, the observations made by Sivasakthivel and Kumar (2011) indicate that O3 primarily forms at the equator due to high insolation and is subsequently transported to higher altitudes by wind. These findings strongly suggest a relationship between O3 and atmospheric parameters. This is consistent with the findings of Allen (2004), who reported that atmospheric parameters influence the formation and transport of O3, while O3, in turn, affects atmospheric constituents.

Our study aligns with the results of previous researchers conducted at various temporal and spatial scales worldwide, contributing to the understanding of the dynamic impact of ozone on climate and vice versa. For instance, Audu et al. (2021) investigated the interaction between O3 and climate using daily TCO data and atmospheric parameters from selected stations in Nigeria, analyzing the period from 1998 to 2009 through descriptive and bivariate statistics. The results revealed spatial variations in TCO from the coastal region to the northern region, exhibiting a similar distribution pattern with maximum temperature, time of insolation, and wind speed, while differing from precipitation and relative humidity. Altitude and latitude were identified as influencing factors on the spatial distribution. The study also highlighted a significant relationship between TCO and atmospheric parameters, emphasizing the interconnectedness between ozone and climate.

After accounting for correlated data, adjusting the model to incorporate autocorrelations becomes necessary. Taking into consideration the aforementioned factors, the values of the coefficients $\beta\beta$'s can be determined. The general regression equation for the period from 2008 to 2016 is as follows for Campo Grande:

O3CG(DU) = 301 - 1.52 Tmax + 1.88 Tmin + 0.0520 rain + 0.444 DPre - 0.974 RH %
- 0.65 H S + 0.00343 RSG + 13.8 Vel

Predictor	Coef	SE Coef	T	P
Constant	508	122,3	4,15	0,025
Tmin	-23,23	13,02	-1,78	0,172
Tmax	13,44	8,077	1,66	0,195
Rain	-0,13029	0,03369	-3,87	0,031
YOUR	0,6203	0,4918	1,26	0,296
DCH	0,39	0,5243	0,74	0,511
HSOL	-16,929	7,305	-2,32	0,103
RSG	0,021792	0,00757	2,88	0,064
Vel	1,888	3,237	0,58	0,601

Predictor	Coef	IF. Coef	T	P
Constant	300. 7	51. 34th	5. 86th	0. 01st
Tmax	- 1. 515th	2. 248th	-0. 67th	0. 548th
Tmin	1. 882nd	1. 803rd	1. 04th	0. 373rd
rain	0. 05198	0. 03267	1. 59th	0. 21st
DPRe	0. 4443rd	0. 4354th	1. 02nd	0. 383rd
YOUR	-0. 9736	0. 2672nd	- 3. 64th	0. 036th
HS	-0. 648th	1. 249th	-0. 52nd	0. 64th
RSG	0. 003434	0. 004423	0. 78th	0. 494th
Vel	13. 819th	6. 016th	2. 3	0. 105th

S = 1.14532, R-Sq = 99.2%, R-Sq(adj) = 97.2%, with EQM=0.55 and MBE=0.38
For the city of Maceió:

S=1.05691; R-Sq=99.5%; R-Sq(adj)=98.2%; EQM=5.25 and MBE=0

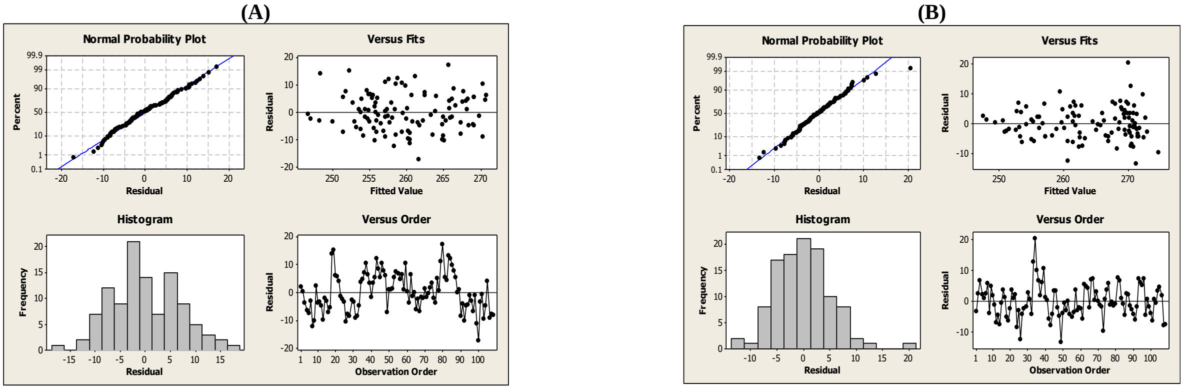
(A) (B)

Fig. 5: Residual Deviations and Observed Values Are Examined in Relation to the Adjusted Values in the TCO Adjustment Model, Along with the Histogram of the Response Variable for the Years Studied. This Analysis Is Conducted for Campo Grande (A) and Maceió (B).

Figure 5 a and b presents the graph of the residues against the normal scores, in which it is observed that the residues present a pattern very close to normality, the same conclusion can be reached in the observation of the histogram of the residue.

Root Mean Square Error (RMSE), Normalized Absolute Error (MBE) were used for verification purposes. The validation used the data using the monthly simulation dataset from January 2014 to June 2016. The performance error results also showed that the multivariate time series method performed well when compared with the time series for the two seasons. monitoring. At the Campo Grande and Maceio stations, all two performance errors for multivariate time series gave good results. The RMSE and MBE values were 0.55, 0.38 for Campo Grande and 5.25 and 0 for the city of Maceio. Although the Campo Grande station showed only two errors of better multivariate performance than Maceio, it was enough to conclude that the multivariate time series method is more appropriate to be applied.

4. Conclusions

The spatial variation of TCO, maximum temperature, time of insolation, and wind speed follows a similar pattern but differs seasonally from the variation patterns of precipitation and relative humidity. This relationship between TCO and atmospheric parameters aligns with previous research findings and provides valuable insights for climatologists studying the dynamic interplay between O3 and climate. Understanding the relationship between O3 and climate is crucial for comprehending the dynamics of Earth's atmosphere. O3, as a chemical component, plays a significant role in climate regulation by absorbing solar radiation and influencing atmospheric temperature. Moreover, as an air pollutant, O3 can impact both human health and the environment, emphasizing the importance of comprehending its relationship with other atmospheric parameters.

The observed relationship between TCO and other atmospheric parameters provides insights into the impact of O3 on climate and how various atmospheric factors influence ozone behavior. This understanding is crucial for developing effective strategies to manage ozone and mitigate its environmental impacts. The selected sites showed an increasing trend in TCO concentration, and there was a clear seasonal variation in TCO across all locations. Linear regression analysis revealed that the latitudinal variation from Maceió to Campo Grande contributed to the increasing trend of TCO during the 2008-2016 period. The spatial variability of observed TCO concentration can be attributed to the geographical characteristics of the Brazilian continent.

5. Consent to participate

All authors declare their consent to participate in the article.

6. Authors contributions

Conceptualization:AS, ESM, JFOJ, MCA, MF IP, DO, RSCN Methodology: AS, ESM, JFOJ, MCA, MF IP, DO, RSCN. Validation: AS, ESM, JFOJ, MCA, MF IP,DO, RSCN. Formal analysis writing: AS, ESM, JFOJ, MCA, MF IP,DO, RSCN. Preparation of original draft: AS, ESM ,JFOJ, MCA, MF IP, DO, RSCN. Writing - proofreading and editing: AS, ESM, JFOJ, MCA, MF IP,DO,RSCN. Visualization: AS, ESM, JFOJ, MCA, MF IP, DO, RSCN. Supervision: AS, ESM,J FOJ, MCA, MF IP, DO,TSCN. All authors read and agreed with the published version of the manuscript.

7. Funding

This research did not receive external funding.

8. Competing interests

The authors declare no conflicts of interest.

9. Availability of data and materials

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