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Frequency analysis of extreme air temperature events in an urban center in the Brazilian savanna

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ABSTRACT
The increase in the planet's average air temperature in recent years has influenced the pattern of natural climatic phenomenons, with levels outside the normal range, the occurrence of prolonged dry periods, torrential rains and heat waves. Due to the climate crisis, extreme events have become increasingly frequent and more intense. With that in view, the aim of this article was to analyze the frequency of occurrence of extreme air temperature events between 2003 and 2023 in Cuiabá-MT-Brazil, as well as to understand the relationship between these extreme heat wave events and the occurrence and intensity of ENOS events. To this purpose, extreme events were analyzed using daily maximum air temperature data for the period from January 1, 2003 to October 31, 2023 obtained from the automated station of the National Meteorological Institute (INMET) located in Cuiabá - MT (CÓDA907), and ONI (Oceanic Niño Index) data. The results showed a significant increase of 86% in the occurrence of extreme events in 2020, compared to 2007, the year with the lowest number of occurrences. Therefore, it is extremely important that issues such as climate emergency, climate change and climate resilience are discussed as a means of public policy, preventing these increases from becoming even worse in frequency and/or intensity.

kEYWORDS: Extreme Events. ENOS. Climate Emergency. .

1 INTRODUCTION

Dealing with climate change and global warming, and with their consequences such as: cold and heat waves, floods, torrential rains, has become one of the main challenges of the century. According to the Climate and Health Observatory (2022), extreme weather and climate events are generally classified as being of hydrological, geological or geophysical origin, meteorological and climatological, with the latter classification encompassing droughts and dry spells, wildfires and forest fires, hailstorms, frosts and cold and heat waves.

Furthermore, according to Araújo (2012), several scientists attribute the frequency of these events to the global warming process itself, which ends up boosting the phases of ENOS - El Niño Southern Oscillation - events. ENOS events are characterized by thermal variations or anomalies on the surface of the Equatorial Pacific Ocean (CPTEC/INPE, 2023; SUN et al., 2023).

According to the United Nations (2020), extreme climate events have increased significantly in their frequency, intensity and severity, thus requiring measures to contain urban warming (WANG et al., 2022). Adapta Clima (2023), a platform of the Ministry of the Environment and Climate Change, points out that most Brazilian cities have socio-environmental problems related to their pattern of development and transformations of space, such as: high population density, scarcity of green areas and soil sealing, which end up influencing the increase in heat waves.

Cuiabá-MT-Brazil, the subject of this research, like many Brazilian cities, is experiencing the dilemma and consequences of its rapid urban expansion, attributed to the strong influence of real state speculation, making its urban area environmentally unfavorable, suppressing its green areas, which today no longer reflect the title it once had of "Green City". Naturally, given its location: the Cuiabá depression, Cuiabá already had a harsh climate with high temperatures and low relative humidity, and was commonly considered the hottest city.

Therefore, this article aims to analyze the frequency of occurrence of extreme air temperature events between 2003 and 2023 in Cuiabá-MT-Brazil, in addition to understanding the relationship between these extreme climate events together with the occurrence and intensity of ENOS events.

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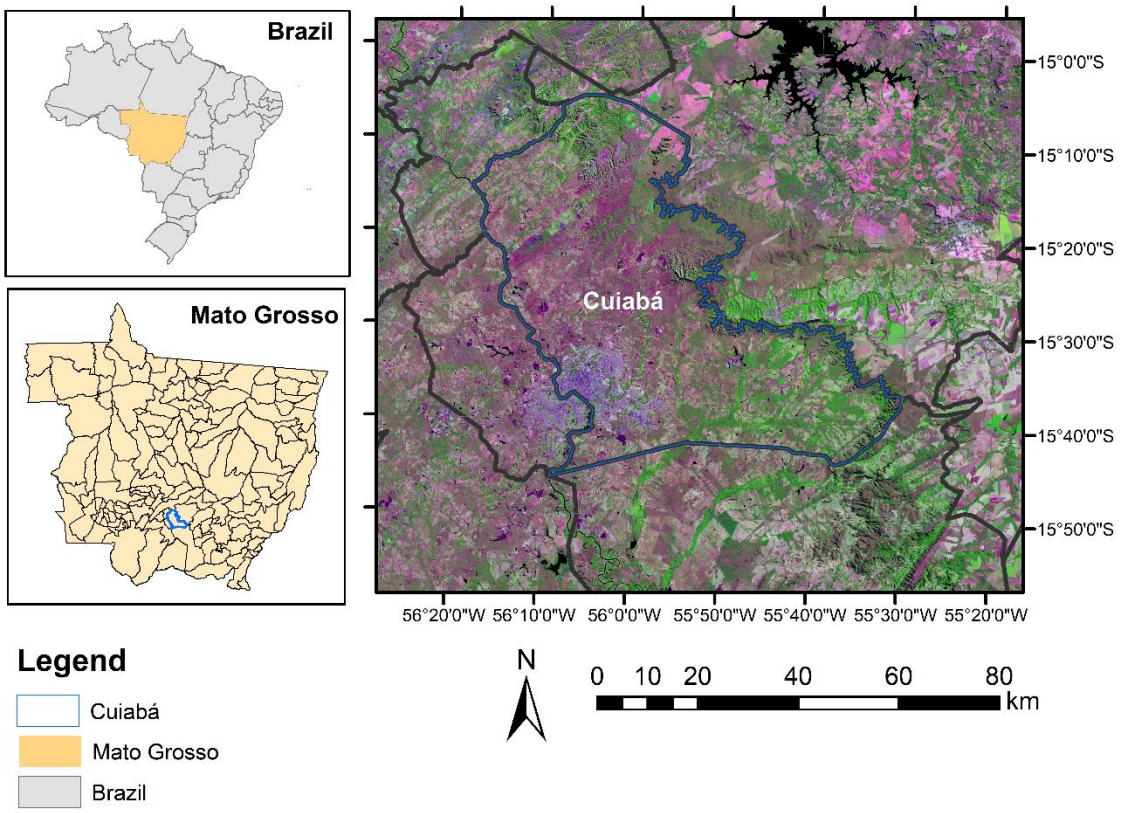
2 STUDY AREA

Cuiabá, the capital of the state of Mato Grosso, is located in the southern region of the state, with a total area of 4,327.45 km² and an altitude of 165 m, in a region known as the "Cuiabá depression" (SOUZA, 2019) (figure 1).

Figure 1 - Map of Brazil, showing Mato Grosso, Cuiabá



With a population of 650,912 inhabitants and a housing density of 150.4 inhabitants/km2 (IBGE, 2022), Cuiabá is divided into four administrative regions (West, North, East and South), with its urban area occupying approximately less than 10% of its total area (ROCHA et al., 2017). Despite being located in a depression, it is also formed by some alluvial plains of the Cuiabá, Pari, Coxipó and Aricá-Açu rivers, among others (DANTAS et al., 2005). Its hydrography is also made up of several streams such as Moinho, Barbado, Prainha and Salgadeira. The predominant biome is the Cerrado with denser forests near the watercourses (CALLEJAS, 2012).

Considering its climate classification, Cuiabá has a semi-humid tropical climate, type Aw, where 'A' means that the average monthly temperatures throughout the year are above 18 °C and that in at least one of the months of the year there is a total average rainfall of less than 60 mm, while the 'w' subtype determines the occurrence of rainfall in summer (KÖPPEN-GEIGER, 1928), indicating two well-defined periods, the hot-dry period (HD) between May and

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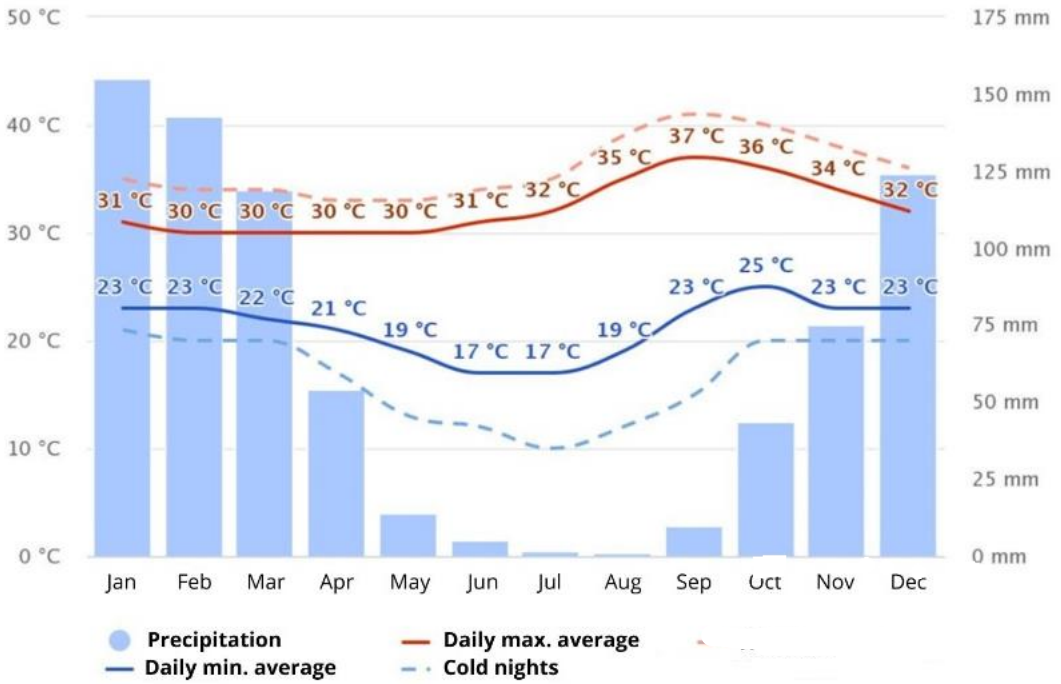
September and the hot-humid period (HH) between October and April (MAITELLI, 1994) (figure 2).

Figure 2 - Average daily minimum and maximum air temperatures and average monthly rainfall from 1993 to 2023



Source: Meteoblue, adapted by the authors, 2023.

There is a high concentration of rainfall during the period between October and April, while in the other months (May-September) rainfall does not exceed 25mm, and this is the same period in which the highest minimum and maximum temperatures occur.

The accumulated annual rainfall is usually around 1500mm/year (SOUZA, 2019; SAMPAIO, 2006), with January being the month with the highest rainfall. In the months with the lowest rainfall, the relative humidity reaches approximately 55%, sometimes as low as 15% in extreme cases, and in summer it reaches 80%. With regard to temperatures, from October to March the monthly average is 27 °C, while in the coldest months, June and July, it is 22 °C, but temperatures often exceed 40 °C.

3 METHODOLOGY

The purpose behind this research is the relationship between extreme air temperature events and ENOS events, as well as the relationship between urbanization itself and the advent and increase in the frequency and intensity of heat waves. To study extreme events, meteorological data was obtained from the National Meteorological Institute (INMET) weather station (Code A901 - 15°33'S/56°03'O) located at the 13th Motorized Infantry Brigade in the urban area of Cuiabá-MT.

The maximum daily air temperature data was analyzed over the 20-year period from January 1, 2003 to October 31, 2023, totaling 7609 days of observation. However, the data had some gaps, which were not taken into account in the analysis (table 1).

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Table 1 - Days with gaps during the period January 2003 to October 2023

Number of days with gaps in the 20-year interval (2003-2023)	
Hot dry period (HD)	Hot humid period (HH)
424 days	446 days

Disregarding the gaps, the analysis of extreme events begins by understanding the maximum air temperature that would be the limit for classifying it as an extreme event, so the 90th percentile was used (PETSCH, AMARAL, SANCHES, 2023). A value of 37.4°C was found, so data higher than 37.4°C was considered an extreme event in this study.

With the ENOS events (El Niño and La Niña), these were obtained and analyzed using the ONI (Oceanic Niño Index) which considers values of 0.50 or higher to be El Niño, and La Niña when values are equal to or less than -0.50 (LINDSEY, 2009). It should be noted that this study used the average annual ONI values obtained from the National Weather Service's Climate Prediction Center (CPC) platform.

4 RESULTS AND DISCUSSIONS

Figure 3 shows a strong influence of El Niño, with an average annual ONI value of strong intensity (1.5), the highest value obtained for the period between 2003 and 2023. It should be noted that these values are the average for the year. La Niña was observed in 2022, but with moderate intensity (0.50).

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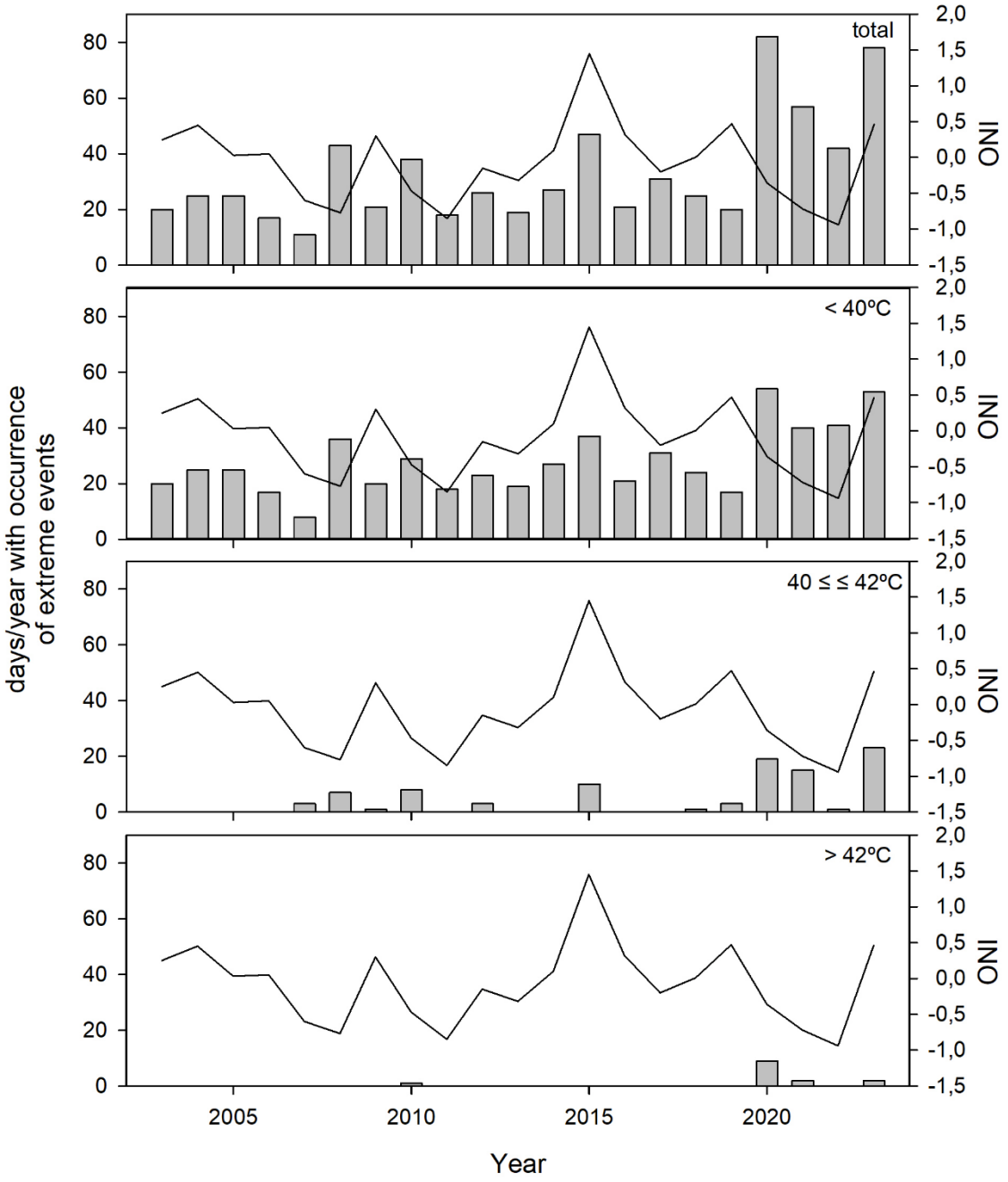
Figure 3 - Days/year with extreme events and their intensities. The black line demarcates the average annual ONI values.



With regard to the values of extreme events, it can be seen that they are mostly between 37.4°C and 40°C, but it is possible to observe a warming, with events above 42°C being recorded in the last three years. Since 2020, the intensity and frequency of extreme events in Cuiabá-MT have doubled compared to their previous levels.

This significant increase in 2020, around 76% compared to the previous year, is related to the increase in fires in the Pantanal biome, near Cuiabá. According to Instituto Centro de Vida (2020), between January and August 2020, Cuiabá already recorded a 7% increase in hotspots compared to 2019.

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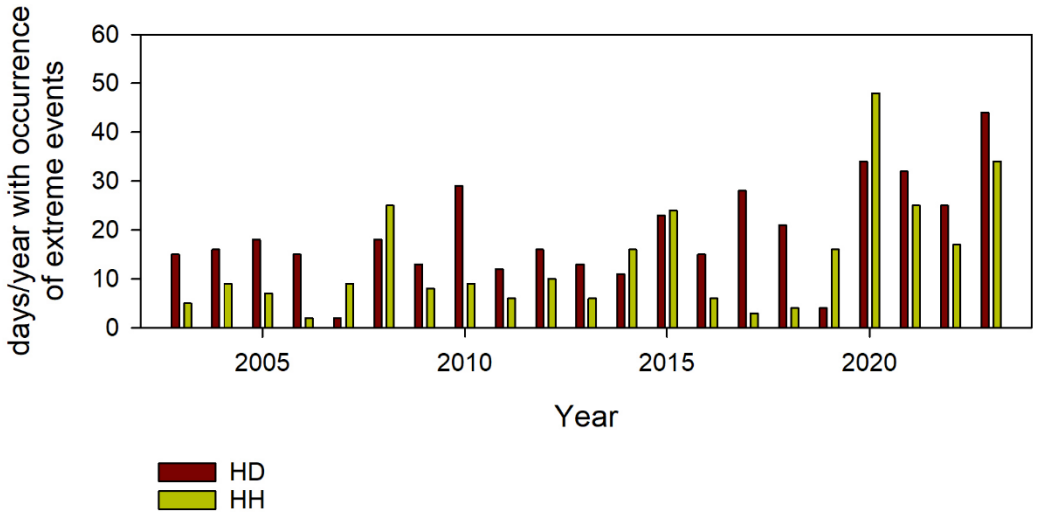
As can be noted, during the years 2021 and 2022, the number of occurrences of extreme events was high, reaching 57 and 42 occurrences respectively. However, it should be noted that 2023 has already seen 78 occurrences, and in this study we only analyzed up to October 31 (Julian day 304), which means that 25% of the days have seen extreme events.

Despite the ONI values being presented as an annual average, noting from the National Weather Service's Climate Prediction Center (CPC) platform (CPTEC, 2023), since the months of June-July-August, Cuiabá has been under the effects of El Niño, with values around 0.92. Cuiabá also has low rainfall, which also favors an increase in the rates of fires and retained heat (INPE, INMET, ANA AND CENAD, 2023). According to Guimarães and Reis (2012) Cuiabá, under the effect of El Niño, has a thermal anomaly of approximately 0.6°C.

Considering the year of lowest occurrence of extreme events, 2007 with only 11 occurrences, it should be noted that that year was under the influence of La Niña, in which the waters of the Equatorial Pacific Ocean are colder and consequently there are drops in temperatures (INMET, 2023).

Considerando os períodos climáticos QS e QU, observa-se que há uma variação irregular entre as ocorrências por período e ano.

Figure 4 - Days/year with extreme events in the hot-dry (HD) and hot-humid (HH) periods.



Considering the total quantities of the 20 years analyzed, it can be seen that the HD period has 30% more occurrences than the HH period, with the months of August and September having the highest number of occurrences, which are the months with the highest records of low humidity and fires in the region.

In 2016 and 2017, the HD period represented around 80% of extreme event occurrences, while in 2019 and 2020 there was a reversal, with the HH period representing the majority of extreme event occurrences. Although the behavior is variable in relation to the years and periods, it is clear to see that Cuiabá-MT is experiencing a significant increase in the intensity and frequency of extreme events.

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5 CONCLUSION

Given its location and climate classification, Cuiabá-MT already has a rigorous climate compared to other locations, but this research showed a significant increase in the intensity and frequency of extreme events, demonstrating that since 2019/2020 there has been an increase of approximately 60% compared to previous years. The analysis of the HD and HH periods showed that the HD period has a more frequent occurrence of extreme events, because of the Pantanal fires (proximity to the study site) and the low relative humidity at the period.

It is concluded that the methodology used in this research demonstrates a relationship between ENOS events and the frequency and intensity of extreme events in Cuiabá, but not enough to justify the increase in frequency and especially intensity. Therefore, it is reinforced that the process of urbanization and the suppression of vegetation that Cuiabá has been going through over the years (2003-2023) must be relevant factors for this increase. It is extremely important that issues such as climate emergency, climate change and climate resilience are discussed as a means of public policy, to prevent these increases from becoming even more serious in terms of frequency and/or intensity.

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