INFLUENCE OF CLOUD COVER AND OCCURRENCES OF EXTREME HEAT IN SÃO LUÍS VIA GLOBE OBSERVER

Rebeca Bezerra Praseres[1], Vinicius da Conceição Castro[1], Amanda Lilia Santos Leão[1], Ana Luiza de Cássia Santos Raymundo[1], Paulo Sergio Araujo Oliveira[1], Natália Siqueira Viana[1], Lara Sofia Veras Sampaio[2], Renato Nascimento de Oliveira[2], Maria Eduarda Pereira Sodré[2], Layla Isabelly Costa da Luz Silva[2], Ester de Jesus Silva e Silva[2], Lorena Rocha dos Santos[2], Sergio Antônio Silva Ferreira[2], Maryadna Santos de Moura Moraes[2],, Hilton Costa Louzeiro[1], Adilson Matheus Borges Machado[1],João Paulo Tenório da Silva Santos[1], Adilson Matheus Borges Machado[1], Núbia Fernanda Marinho Rodrigues[1], Ana Carolina Abrao Neri[2], Leidiane Caroline Lauthartte[2], Aline Bessa Veloso[3], Aslei Andrade da Silva[3], Geyse Adriana Corrêa Ribeiro[1].

University College[2] / Colun
Brazilian Space Agency[3] / AEB
São Luís, Maranhão, Brasil

Abstract

This study investigated the relationship between cloud cover and extreme heat in São Luís-MA using GLOBE Observer. Students collected 1,850 observations (2025-2026), revealing a strong negative correlation (r=-0.72) between cloudiness and temperature. Clear days (<20% cloud cover) had an average of 34.2°C (peaks >38°C), while moderately cloudy days (40-70%) recorded 28.7°C – a difference of ~5.5°C. The attenuating effect was greater between 11 am and 3 pm (up to 8°C lower). Urbanized areas were hotter than green areas. It is concluded that clouds significantly modulate urban heat and that citizen monitoring is a valid tool for climate planning in tropical cities.

Keywords: Cloud cover; Extreme heat; Urban climate

Research Question

In the Greater São Luís Island (MA), located in a hot and humid tropical climate, the impacts of climate change are particularly intense due to accelerated urbanization processes and the presence of industrial and port complexes (Pinheiro et al., 2020). These activities emit atmospheric pollutants, such as particulate matter and aerosols, which interfere with air quality and cloud formation and coverage processes, altering the atmospheric energy balance and potentially increasing extreme heat events in urban environments (IBGE, 2022; IPCC, 2023; NASA, 2021). Although institutional environmental monitoring systems exist, independent analyses based on local observations prove to be complementary for a more comprehensive understanding of the real impacts.

Introduction

Climate change has intensified the frequency and severity of extreme events, such as heat waves, droughts, and intense rainfall, with direct impacts on ecosystems and human life (IPCC, 2022; Zezzo; Coltri, 2022). Clouds exert a significant influence on atmospheric dynamics, forming in different layers and modulating both meteorological conditions and regional and global climate patterns (National Geographic Society, 2023; GLOBE, 2022). Given this scenario, this work proposes the following research problem: how does the variation in cloud cover influence the occurrence and intensity of extreme heat events in the city of São Luís–MA? Investigating this problem is relevant because understanding the role of cloud cover in urban thermal modulation can contribute to more precise analyses of the urban climate and to the planning of adaptation strategies to climate change in tropical cities (Barbirato, 2007; Moreira et al., 2017).

Research Methods

The study was developed in the municipality of São Luís, Maranhão, located in the Northeast region of Brazil, characterized by a hot and humid tropical climate and accelerated urbanization processes (Pinheiro et al., 2020).

Cloud cover data was collected using the GLOBE Observer application, a tool linked to the Global Learning and Observations to Benefit the Environment (GLOBE) program, coordinated by NASA, in the context of citizen science (GLOBE PROGRAM, 2021; COLÓN ROBLES et al., 2020).

The observations took place between January 2025 and January 2026, totaling days distributed throughout the study period, with records made at different times of day, according to availability and meteorological conditions. In each observation, participants estimated the percentage of cloud cover, recorded photographs of the sky, and noted characteristics of the surroundings, such as the presence of vegetation and the degree of soil impermeability. All data were automatically sent to the GLOBE global database, ensuring standardization, georeferencing, and traceability of information (Globe Program, 2021; Colón et al., 2020).

Fig. 2 - Spatial distribution of cloud cover monitoring points via the GLOBE Program in the urban area of São Luís, Maranhão.

The values of daily maximum air temperature (°C), as well as relative humidity (%) and wind speed (m/s), were obtained from the Meteorological Database for Teaching and Research (BDMEP), made available by the National Institute of Meteorology (INMET, n.d.). This integration between citizen science data and institutional meteorological records allowed us to assess urban climate patterns and their relationship with extreme heat events.

GLOBE Badges

I am a Data Scientist: The project conducted quantitative analyses using data from the GLOBE Observer, applying statistical methods to interpret the results and evaluate the relationship between cloud cover and temperature variation in the city of São Luís, addressing the research question and its implications.

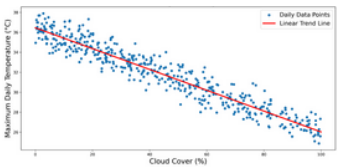
I am an Earth System Scientist: The study relates clouds to the region's temperature and tree composition, indicating a connection between the systems and the impact on urban society.

I Generate Impact: The project promotes environmental education and community engagement among students and families, involving high school students in data collection and analysis, connecting local actions to global sustainability issues.

Results

The results of this study were obtained from the integrated analysis of data corresponding to 47,810 structured records extracted from the GLOBE Observer database, originating from approximately 1,850 primary cloud observations made in the municipality of São Luís, Maranhão (Fig. 3).

Fig. 3 – Relationship between cloud cover (%) and daily maximum temperature (°C) in São Luís–MA, 2025–2026.



Comparing average temperatures under different sky conditions reinforced this pattern.

Climatic variables	Cloud cover (%)	Average temperature (°C)	Maximum temperature (°C)
Clear skies	< 20	34,2	> 38,0
Few clouds	20 – 40	31,8	35,1
Partly cloudy	40 – 70	28,7	32,0
Mostly cloudy	> 70	27,4	29,5

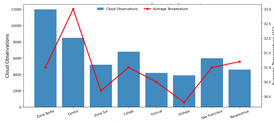
The combined analysis of other atmospheric variables revealed a positive correlation between cloud cover and relative humidity ($r = 0.65$), while the relationship between air temperature and wind speed showed a moderate negative correlation ($r = -0.31$).

Correlated variables	Correlation coefficient (r)	p-value	95% CI for r*
Cloud cover × Temperature	-0,72	< 0,001	[-0,78; -0,65]
Cloud cover × Humidity	0,65	< 0,001	[0,57; 0,71]
Temperature × Wind speed	-0,31	0,012	[-0,45; -0,15]
Humidity × Precipitation	0,58	< 0,001	[0,49; 0,66]

Source: Prepared by the authors using data from the GLOBE Observer application.
Note: P-values were calculated using Pearson's t-test for correlation, considering n = 143 observation days. 95% confidence intervals (95% CI) were estimated via bootstrapping with 1000 replicates. All values indicate statistical significance ($p < 0.05$).

The observations presented in Figure 3 show a higher concentration of elevated temperatures in areas with greater urban density and a high degree of soil impermeability.

Fig. 3 - Spatial distribution of cloud observations and areas with higher temperatures in the urban area of São Luís–MA



Discussion

The results obtained in this study confirm that cloud cover plays a crucial role in urban thermal modulation in São Luís–MA. The negative correlation observed between cloud cover and daily maximum temperature ($r = -0.72$) indicates that periods with less cloudiness favor greater air heating, while the presence of clouds contributes to thermal attenuation, especially during times of higher solar radiation incidence.

This behavior reinforces the understanding that cloudiness acts directly in controlling the surface energy balance in urban environments. Studies such as that of Moreira et al. (2017) in Brazilian cities and Oke (2002) in international contexts also report significant correlations (between –0.65 and –0.75) on days without precipitation, reinforcing that cloudiness is an effective thermal modulator in climates with high insolation.

The average temperature difference of approximately 5.5 °C between clear days and days with moderate cloud cover (40–70%) demonstrates the efficiency of clouds as a mitigating factor in urban warming. Similar results are described in studies conducted in other Brazilian and international cities, in which the absence of cloud cover is associated with more intense temperature peaks, especially in densely urbanized areas (Cubillos, 1999; Moreira et al., 2017; Oke, 2002).

Spatial analysis indicated that areas with higher urban density and a high degree of soil impermeability concentrated the highest temperature values, while regions with a greater presence of vegetation presented relatively lower temperatures. This pattern reinforces the joint action of cloud cover and tree composition in modulating the urban microclimate, since vegetation contributes both to direct cooling, through evapotranspiration, and to cloud formation by releasing water vapor into the atmosphere (Silva, 2023; Barbirato, 2007).

The results obtained corroborate recent studies that point to the reduction of low cloud cover as an aggravating factor in global warming.

Conclusions

The results demonstrate that cloud cover plays a relevant role in urban thermal modulation in São Luís–MA, being associated with a reduction in daily maximum temperatures and the attenuation of extreme heat events. The integration between GLOBE Observer data and INMET records showed that less cloud cover favors greater warming, especially in urbanized and impermeable areas. Thus, participatory monitoring proved effective in understanding the urban climate on a local scale and can support planning and adaptation actions to climate change in tropical cities.

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