Spatiotemporal Heat Index Assessment in the Monterrey Metropolitan Area during Heat Wave occurrence

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Abstract

The rise in global temperatures has become a concern as every year reaches new record high temperatures and heat wave occurrences are more common. Alongside with this, worldwide population has also increased, resulting in highly urbanized areas where mitigation and adaptation to extreme heat has only just started to be considered in order to improve citizens' quality of life and health. The Monterrey Metropolitan Area is characterized by semi-arid climate conditions which pose significant environmental challenges related to environmental resilience and recently, extreme heat conditions. In this research, the heat wave occurrences of 2023 and 2024 in Monterrey were evaluated using the Heat Index (HI) metric, information from the Air Quality and Climate Monitoring Network of Nuevo León and satellite temperature imagery from the Mexican National Meteorological Service in order to determine the most vulnerable areas and the health threats that high temperatures may cause. The resulting HI calculated using the ArcGIS Pro Heat Index function alongside the Inverse Distance Weighted spatial interpolation method indicate that Heat Index values depend on relative humidity percentages beside temperature, as higher humidity levels are linked to an increase in HI. The Monterrey Metropolitan Area can experience HI of more than 30°C, making the risk of heat stress most likely to occur. It is recommended to the population to be extremely cautious if exposed to the heat for long periods and to avoid outdoor activities if possible if the Heat Index exceeds the 41°C.

1. Introduction

Between 1970 and 2020 global temperatures rose by 0.28°C (Silberstein, M.; 2024) and over the same period, the worldwide population has more than doubled with 56% residing in urban areas. According to the UN (2024), it is expected that these numbers reach 68% by 2050.

This increase in temperature has been mainly linked to anthropogenic greenhouse gas emissions, which must be reduced worldwide in order to stop global warming (von Rosing 2025). Without sufficient policies to mitigate climate change and the continuous growth of urban areas, current projections suggest an overall increase in global mean temperature by 2100 of 3.7 °C to 4.8°C relative to pre-industrial levels (Pelizzon, 2025).

Highly urbanized areas contribute significantly to climate change on both local and global scale (Koch, 2021). Residents living in densely populated cities are more vulnerable to the consequences brought by increasing temperatures in comparison with people settled in the city outskirts or rural areas, as urbanization exacerbates the urban heat island (UHI) effect, causing higher summer temperatures and seriously damaging the physical and mental health of residents (Ebi et al., 2021).

Urban expansion has resulted in higher temperatures within urban cores compared to surrounding areas, subjecting residents to hotter temperatures and more intense heat waves compared to rural areas (Yadav et al., 2023). As urban areas grow and the impacts of climate change worsen, UHIs are a challenge for city planners and public health officials (Tian, 2023). The rising occurrence of heat waves, ongoing high temperatures, and the restricted ability of urban settings to release heat highlight the urgent necessity for efficient strategies to mitigate UHI effects (Ali-Toudert et al., 2006).

Studies show that across the world, hot days are getting hotter and more common. This gives an indication that necessary steps and strategies will be required to control and reduce the effect of heat waves (HW) (Yadav et al., 2023). In order to further evaluate the behavior of heat waves and its impact on the health of individuals, the use of remote sensing is key, as it offers spatial and temporal coverage of the study areas and allows the identification of hot spots, supporting urban planning and public health interventions (Shi et al., 2021; Diem et al., 2023).

As stated by Hu et al., (2023), Liu et al., (2023) and García et al., (2022), urbanized areas often experience higher heat wave risk and more severe UHI effects, which are further exacerbated during extreme heat events. Instruments such as the Heat Index metric can be used for temperature analysis in cities to estimate the risk of heat stress that the population faces, especially during heat waves or abnormally hot days and to determine the most susceptible zones.

The Monterrey Metropolitan Area (MMA) has expanded rapidly in both size and population. According to the National Population Council (CONAPO for its acronym in Spanish) (2020) it houses 5.3 million inhabitants in a 7440 km^2 area, with only 1119 km^2 being occupied with urban centres and around 98.6% of the population living in them. Along with the increase in temperatures and the worsening local climate conditions, the MMA has faced HWs more frequently.

This study aims to assess the Heat Index in the MMA and validate the results with satellite temperature imagery provided by the Mexican National Meteorological Service (SMN for its acronym in Spanish) during the 2023 and 2024 heat waves, as these years marked record high temperatures in the Metropolitan Area.

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2. Study Area

The Monterrey Metropolitan Area is located in northeastern Mexico and is conformed by 16 municipalities: Apodaca, Cadereyta Jiménez, El Carmen, Ciénega de Flores, García, San Pedro Garza García, General Escobedo, General Zuazua, Guadalupe, Juárez, Monterrey, Pesquería, Salinas Victoria, San Nicolás de los Garza, Santa Catarina and Santiago. It's the second largest urban area in Mexico behind Mexico City and is considered a dynamic metropolis being the sixth fastest growing urban area in Mexico, with a growth rate of 2.5% as of 2022 (CONAPO, 2020).

The MMA is characterized by semi-arid conditions and a strong partial variability in precipitation (González-Hernández. 2019), which poses significant environmental challenges related to environmental resilience and recently, extreme heat conditions. These settings make Monterrey one of the hottest cities in Mexico, with temperatures 5°C warmer in its built-up urban core (Vivideconomics, 2022). As stated by Mexico's National Meteorological Service, the MMA has a record high of 48°C and, in recent decades, daily average temperatures have exceeded 28°C for around ten days a year.

This current extreme heat state is associated with a significant rise in mortality, with an 18.7% increase in all-ages deaths on the hottest days compared to average temperatures (O'Neill, M. et al., 2005). With temperatures reaching over 40°C, the MMA faced 102 deaths in 2023 due to extreme heat (DGE, 2023; CENAPRECE, 2024).

2.1 Climate Monitoring System

In order to monitor the environmental conditions, Mexico has developed institutions responsible for ensuring climate monitoring in its major cities (Mayora, F. 2020). For the Monterrey Metropolitan Area, the Integrated Environmental Monitoring System (SIMA for its acronym in Spanish) provides essential data for assessing air pollution and temperature since 1992 and currently consists of 15 automatic monitoring stations across the MMA (Table 1, Figure 1).

ID	SIMA Station	Location	Municipality
SE	Southeast	Tecnológico de Nuevo León	Guadalupe
NE	Northeast	Los Naranjos Park	San Nicolás de los Garza
CE	Centre	Obispado neighborhood	Monterrey
NO	Northwest	San Bernabé Militarized Highschool	Monterrey
SO	Southwest	El Jarocho Park	Santa Catarina
NTE	North	Los Olivos Section II Park	General Escobedo
NO2	Northwest 2	García City Hall	García
NE2	Northeast 2	Centro Neighborhood	Apodaca
SE2	Southeast 2	DIF Juárez Centro Neighborhood	Juárez
SO2	Southwest 2	CDI Gymnasium, Sauces Neighborhood	San Pedro Garza García
SUR	South	TEC Garza Lagüera Highschool	Monterrey
NTE2	North 2	CEDEEM UANL Graduate Unit	San Nicolás de los Garza
SE3	Southeast 3	Jerónimo Treviño 1st Sector Neighborhood	Cadereyta
NE3	Northeast 3	Roberto Rocca Tech School	Pesquería
NO3	Northwest 3	Misión de San Juan Neighborhood	García

Table 1. Climate Monitoring System Stations

However, not all of them began operating in the same year; 5 began operations in 1992 (Obispado, San Bernabé, Tecnológico de Nuevo León, Los Naranjos Park and El Jarocho Park stations), two in 2009 (Los Olivos Section II Park and García City Hall stations), two more in 2012 (Apodaca Centro Neighborhood and DIF Juárez Centro Neighborhood stations), one in 2014 (CDI Gymnasium, Sauces Neighborhood station), three more in 2017 (TEC Garza Lagüera Highschool, Jerónimo Treviño 1st Sector Neighborhood and CEDEEM UANL stations) and one in 2020 (Roberto Rocca Tech School station).

In general, all stations are monitored automatically and have the capacity to measure suspended particles, both PM10 and PM2.5 (Lucia, F.-M. A., & Ulises R.-S. H., 2023).

Figure 1. SIMA's Climate Monitoring Stations across the MMA

3. Materials and Methods

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3.1 SIMA Data

The temperature and relative humidity information collected from the SIMA monitoring stations for the study years was used to determine the weeks with higher temperatures and, crossing the data with local news temperature reports, it was found that the 25th week of 2023 (mid June) and the 21st week of 2024 (third week of May) registered higher mean temperatures with 33.6°C and 32.3°C respectively (Figure 2).

Before calculating the HI, the temperature and relative humidity data from the monitoring stations was interpolated using the Inverse Distance Weighted (IDW) method, as it estimates unknown values as weighted averages of known data points, with weights inversely related to distance (Lu, G., & Wong, D., 2008). This was performed in order to cover the whole MMA and not only the climate monitoring stations.

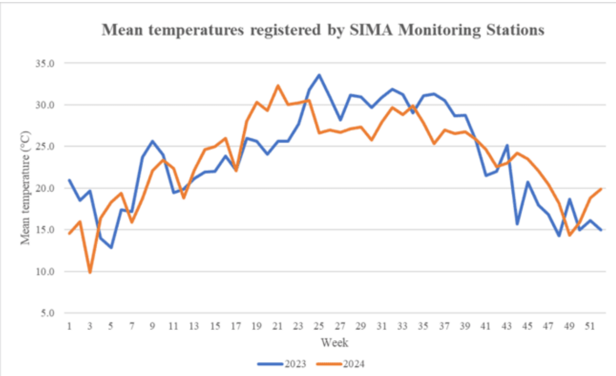


Figure 2. Mean temperatures registered by SIMA Monitoring Stations

3.1.1 Inverse Distance Weighted method

The Inverse Distance Weighted (IDW) method is a spatial interpolation technique that estimates values at unsampled locations based on the values and distances of nearby sampled points. It is a straightforward and non-computationally intensive method regarded as one of the standard spatial interpolation procedures in geographic information science (Lu, G., & Wong, D., 2008). Karakaya et al., (2016) mention that the IDW algorithm is a moving average interpolator that is usually applied to highly variable data such as soil chemistry results, consumer behavior observations and environmental monitoring data.

The generic equation for inverse distance weighted interpolation is:

$$Z_{x,y} = \frac{\sum_{i=1}^{n} Z_i W_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

where: $Z_{x,y}$ = point to be estimated
Z_i = control value for the i^{th} sample point
W_i = weight assigned to sampling point

The spatial distribution and clustering of sample points alongside the radius within which neighbours are selected can affect the interpolation of measurements and influences both accuracy and computational efficiency, as IDW performs better with regularly distributed sample points (Benmoshe, N., 2025; Maleika, W., 2020). The spatial interpolation was conducted using the Inverse Distance Weighted (IDW) interpolation available in the ArcGIS Pro Spatial Analyst toolbar.

3.2. Heat Index

The current climate change is responsible for the growth in the number of extreme climatic events like heat waves (Yadav et al., 2023) and, to estimate the effect on the human body, a number of different indices have been developed based on weather variables including air temperature, humidity, solar radiation and wind.

The Heat Index (HI) was developed by the U.S. National Weather Service (NWS) to issue heat watches, warnings, and advisories and depends only on air temperature and relative humidity. It has found wide applicability for estimating human heat stress and has proven useful in research aimed at estimating future changes associated with global climate change (Lanzante, J. 2024).

The NWS has linked different Heat Index values to environmental health threats (Anderson et al., 2013) (Figure 3). HI values between 27°C - 32°C and 32°C - 41°C indicate caution and extreme caution respectively while the 41°C to 54°C range signals danger. Heat Index readings below 26°C are considered safe with no adverse effects related to heat exposure (Romps, D. M. & Lu, Y. C., 2022).

	Relative Humidity (%)								
Temperature (°C)	10%	20%	30%	40%	50%	60%	70%	80%	90%
26	25	25	26	26	27	27	27	28	28
27	26	26	26	27	27	28	29	30	31
28	27	27	27	28	28	29	31	32	34
29	27	27	28	20	30	31	33	35	37
30	28	28	29	30	31	33	35	38	41
31	29	29	30	31	33	35	38	41	45
32	30	30	31	32	34	37	40	44	49
33	31	31	32	34	36	40	43	48	54
34	31	32	33	35	38	42	47	52	>52
35	32	33	35	37	41	45	50	>52	>52
36	33	34	36	39	43	49	>52	>52	>52
37	34	35	38	41	46	51	>52	>52	>52
38	35	37	39	43	49	>52	>52	>52	>52
39	36	38	41	46	52	>52	>52	>52	>52
40	37	39	43	48	>52	>52	>52	>52	>52
41	38	41	45	51	>52	>52	>52	>52	>52
42	39	42	47	52	>52	>52	>52	>52	>52
43	40	44	49	>52	>52	>52	>52	>52	>52
44		46	52	>52	>52	>52	>52	>52	>52
45	42	47	>52	>52	>52	>52	>52	>52	>52
46	43	49	>52	>52	>52	>52	>52	>52	>52
47	44	51	>52	>52	>52	>52	>52	>52	>52
48	45	52	>52	>52	>52	>52	>52	>52	>52
49	47	>52	>52	>52	>52	>52	>52	>52	>52
50	48	>52	>52	>52	>52	>52	>52	>52	>52

Safe	< 26
Caution	27 - 32
Extreme Caution	32 -41
Danger	41 - 54
Extreme Danger	>52

Figure 3. Heat Index health threat values (NWS, n.d)

For this study, the Heat Index was calculated using the Heat Index function located in the ArcGIS Pro Raster Analysis Functions, which uses the following equation to calculate the apparent temperature based on ambient temperature and relative humidity:

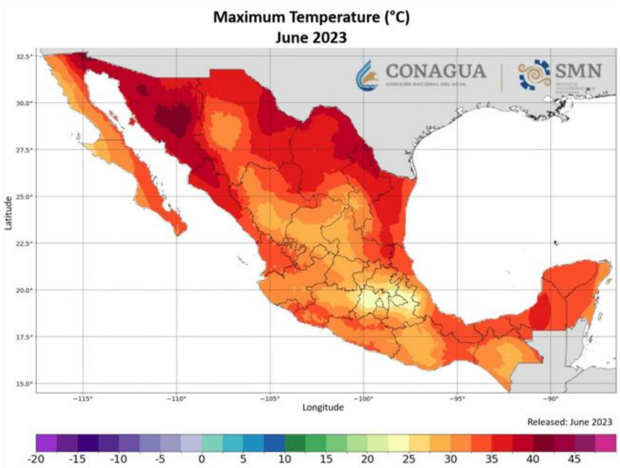
$$Heat\ Index = (-42.379 + (2.04901523 * T) + (10.14333127 * R) - (0.22475541 * TR) - (0.22475541 * TR) - (6.83783e^{-3} * TT) - (5.481717e^{-2} * RR) + (1.22874e^{-4} * TTR) + (8.5282e^{-4} * TTR) - (1.99e^{-6} * TTRR)) \quad (2)$$

where: T = air temperature
R = relative humidity

3.2. SMN satellite imagery

The Mexican National Meteorological Service provides climatology information for the national territory, including temperature databases, which consist of monthly reports with monthly maximum temperature anomaly, outlook and monthly maximum mean temperatures.

For the maximum mean temperatures, in June 2023, the SMN reported values between 41.46°C and 21.93°C, with the Monterrey Metropolitan Area having temperatures around 35 degrees. In the case of May 2024, the maximum temperatures in the country rose up to 38.98°C with reported minimums of 22.94°C. The MMA presented similar maximum mean temperatures for both study years as the recorded temperatures during 2024 were around 36°C (Figure 4 and Figure 5).



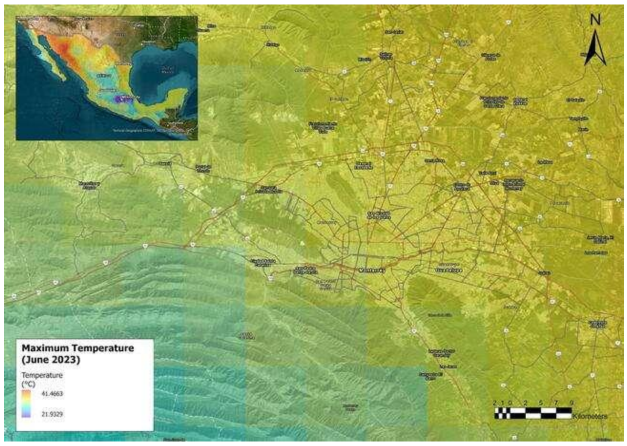


Figure 4. SNM maximum temperature for 2023 (Mexico and Monterrey Metropolitan Area)

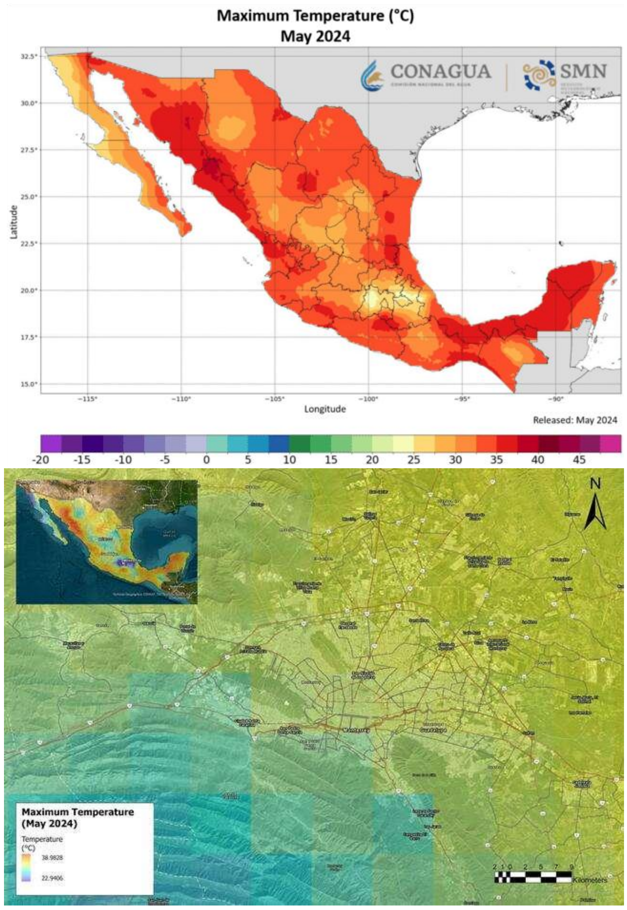


Figure 5. SMN maximum temperature for 2024 (Mexico and Monterrey Metropolitan Area)

4. Results

4.1. IDW

The data from SIMA registered hourly temperature and humidity values in all monitoring stations, which were later converted into weekly mean values (Table 2) to perform the IDW analysis in the Metropolitan Area.

Station ID	2023		2024	
	Relative Humidity (%)	Temperature (°C)	Relative Humidity (%)	Temperature (°C)
SE	47.32	33.70	51.83	32.56
NE	48.30	33.46	51.99	31.03
CE	37.54	32.24	47.17	31.87
NO	32.21	34.19	41.99	32.34
SO	35.48	33.54	46.95	31.87
NTE	41.83	34.13	18.72	32.75
NO2	37.08	33.47	47.64	31.88
NE2	41.46	34.11	47.97	32.38
SE2	48.45	33.28	52.42	32.96
SO2	34.99	33.62	46.70	32.06
SUR	37.85	33.78	47.26	32.73
NTE2	39.50	34.19	48.12	32.74
SE3	48.42	32.82	51.60	32.42
NE3	46.13	33.02	54.38	31.98
NO3	N/A	33.54	45.58	32.47

Table 2. Relative humidity and mean temperatures for week 25th (2023) and week 21st (2024)

During the 25th week of 2023, the MMA registered mean temperatures between 32.81°C and 34.18°C, with the Northeast 3 (NE3), Southeast 3 (SE3) and Centre (CE) stations registering the lowest values and the northern monitoring stations (NE, NE2,NO) recording temperatures over 33 degrees. Overall, the western municipalities of Cadereyta and Juárez recorded the lowest temperatures, with an average of 32°C, while the centre and eastern regions registered values up to 34 degrees, with the municipalities of Apodaca and San Nicolás being the highest.

2024 had similar results during the 21st week, with temperatures ranging between a minimum of 31°C and 33.96°C recorded in the northeast (NE) and southeast 2 (SE2) SIMA stations respectively. The municipalities of Juárez, Cadereyta and the limits between Monterrey and the west part of San Nicolás were the most affected by the heat, as they registered over 32.5°C. On the other hand, eastern San Nicolás presented temperatures nearing 31 degrees.

In general, during both the 2023 and 2024 heat waves most of the municipalities recorded temperature values over 30 degrees but the susceptible areas differed, as the north and northwest MMA were the most afflicted in 2023 and in the 2024 heat wave the southwest zone presented higher temperatures.

For the relative humidity analysis, 2023 presented lower values compared to 2024, with minimum humidity of 30% and a maximum percentage of 48. The zones that presented lower temperatures had relative humidity levels over 40% as recorded in the northeast and southeast SIMA stations (NE, SE2 and SE3), while the municipalities characterized for higher temperatures during the study period had relative humidity levels between 32 and 40 percent. This was confirmed with the humidity lectures obtained in the northwest and southwest monitoring stations (NO, SO, and SO2).

In the 2024 analysis, the humidity levels were in a range between 18% and 54%., with both maximum temperatures and relative humidity data found in the municipalities of Juárez and Cadereyta with over 50% humidity levels as stated by the NE3, SE2 and SE3 data. The west part of the Monterrey Metropolitan Area presented relative humidity levels between 18% and 40%, with the lowest being registered in the northern outskirts of the city in the north and northwest (NTE and NO) meteorological stations.

The humidity levels for 2024 varied largely compared with the values obtained during the 2023 heat wave, but in both cases, the maximum humidity percentage exceeded the 45 percent (Figure 6).

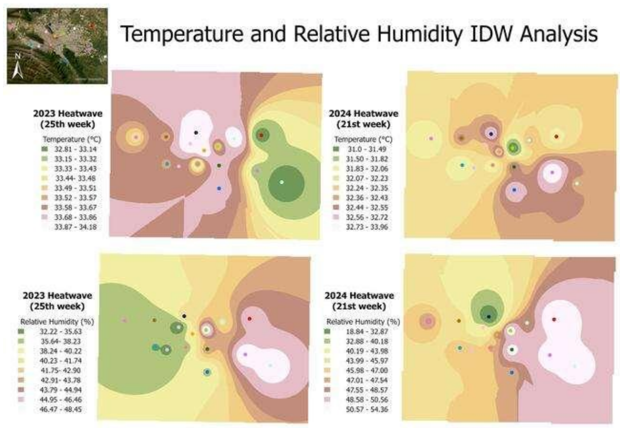


Figure 6. Temperature and Relative Humidity IDW Analysis

4.2. Heat Index

The Heat Index for the study years was calculated from the IDW analysis for both temperature and relative humidity. Although both had similar results with HI values over 35°C, the outcome differed between SIMA Stations.

For 2023 the Northeast (NE), North (NTE) and Southeast 2 (SE2) stations were the most affected, as they registered a maximum HI of 36.71°C, while the western side of the MMA and part of the central area had Heat Index values of 33.63°C, as registered in the Southwest (SO), Southwest 2 (SO2), Centre (CE) and Northwest (NO) Stations, being the lowest registered in the analysis. Overall, during the 25th week of 2023, the eastern part of the Monterrey Metropolitan Area presented a higher HI compared to the west and south sides (Figure 7).

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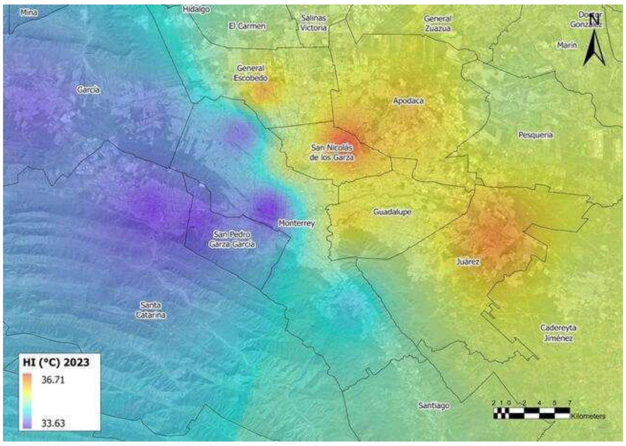

Figure 7. Heat Index Analysis for 2023

In the case of the 2024 inspection, the eastern side of the MMA presented higher HI values, as the Southeast (SE), Southeast 2 (SE2) and Northeast 3 (NE3) stations had a heat index of 37.92°C while the western side reported HI temperatures between 31 and 33°C. Despite the fact that in 2023 the North station (NTE) was one of the most afflicted, during the 21st week of 2024 registered the lowest temperatures with a HI of 30.61°C (Figure 8).

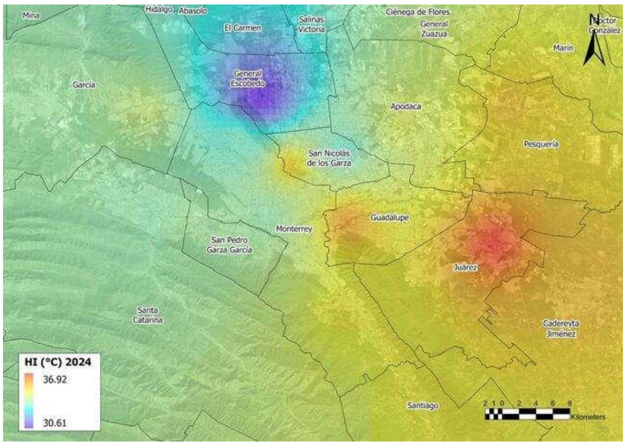

Figure 8. Heat Index Analysis for 2024

For the most part, during both study years the MMA's eastern side was prone to a higher HI, with values over 35°C. The municipalities of Juárez and San Nicolás de los Garza were the most affected by the rise in temperatures.

In order to assess the risk of heat stress, the Heat Index metric provides a general warning according to the HI values presented, as well as a health impact description in the case of prolonged exposure to heat (Table 3).

Warning	Heat Index	Health Impact
Safe	< 26 °C	No adverse effects expected due to heat
Caution	27 - 32 °C	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	32 - 41 °C	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Danger	41 - 52 °C	Sunstroke, heat cramps or heat exhaustion likely possible with prolonged exposure and/or physical activity
Extreme Danger	52 °C or higher	Heat stroke or sunstroke highly likely

Table 3. Danger levels associated with the Heat Index (NWS, n.d.)

In the case of the 2023 heat wave, the residents of the north and southeast regions of the Monterrey Metropolitan Area (San Nicolás, Apodaca and Juárez municipalities) had to be extremely cautious of the climate conditions due to Heat Index values greater than 36 degrees. They were more susceptible to suffer a sunstroke, muscle cramps and/or heat exhaustion if exposed to high temperatures for a long period. Although the western municipalities (García, Santa Catarina, and San Pedro) and part of the Monterrey municipality presented the lowest HI with mean values of 33°C, the inhabitants of these zones also had to take precautions as the warning for them also indicated extreme caution.

During the 2024 heat wave, the highest HI reported was of almost 37 degrees in the Juárez municipality and partially in the Monterrey and Pesquería municipalities, meaning their residents had to take extreme caution as they were exposed to sunstroke, muscle cramps, and/or heat exhaustion with prolonged exposure to the heat. Contrarily, the San Nicolás municipality and the surroundings of the NTE climate monitoring station (Escobedo municipality) experienced a Heat Index between 31 and 30.61°C, meaning this zones were under caution as the inhabitants were vulnerable to fatigue if exposed to heat for a long period of time or by prolonged physical activity outdoors.

In general, the Monterrey Metropolitan Area can face Heat Index conditions over 30°C during heat waves. This makes the MMA population prone to fatigue, sunstroke, muscle cramps and heat exhaustion if exposed to the heat or by doing outdoor activities during a long period, so it is imperative that citizens -especially people with pre-existing health conditions- take measures to protect themselves from high temperatures to minimize the impact on their health.

High humidity levels can increase the HI, which makes it feel hotter and can lead to exhaustion or sunstroke. This is because high humidity makes it harder for sweat to evaporate and cool the body (Yadav et al., 2023). The 2024 heat wave presented a higher relative humidity compared to 2023 and a wider value range as well, which made it difficult to find thermal comfort. During 2023, the HI conditions were not as strenuous but the MMA population was still at risk if exposed for long periods to the heat.

5. Conclusions

The interpolated data of temperature and relative humidity from the SIMA stations was used to calculate the HI for the entire Metropolitan Area instead of just using the results from each monitoring station. When comparing the SMN temperature images and the results obtained in the Heat Index analysis for both study years, it is confirmed that the areas with higher mean temperatures coincide with the HI obtained, as they reported high temperatures as well. Moreover, for both study years the eastern side of Monterrey, emphasizing the Juárez and San Nicolás de los Garza municipalities, were the most affected with HI values over 35°C.

While the temperature images were only used as an indicator to evaluate which areas of the Monterrey Metropolitan Area are the most affected by the heat waves, they report monthly maximum temperatures while the HI images generated with the information from the SIMA meteorological stations use weekly mean data. It is possible that the accuracy may contrast as the SMN period is different from the study period.

Although both study years had similar results with HI values of more than 30°C, elements such as climate conditions, environmental factors and anthropogenic activities may have influenced the spatiotemporal variability. The MMA faces dire conditions in the summer days, especially during heat waves, as the population's health can be compromised and a method to reduce temperatures on a local scale has not been implemented yet. With Heat Index values over 30°C as it is the case for the study years, citizens may experience fatigue, muscle cramps and heat exhaustion that can lead to sunstroke if exposed for long periods to the heat. This can be fatal for people with pre-existing health conditions and vulnerable groups such as children and the elderly, so it is vital to take preventive actions to minimize the health impact and reduce temperatures.

Numerous researches have acknowledged the critical role of spatial planning and urban governance in adaptation to and mitigation of extreme heat (Kotharkar, R., & Ghosh, A., 2021). According to Yadav et al., (2023) urbanization plays a critical role in shaping temperature-health outcomes. Factors such as urban design, land cover and accessibility to green spaces can significantly influence vulnerability to extreme heat events. It is imperative to develop strategies that integrate urban planning and the rehabilitation of existing blue and green infrastructure for a more heat resilient Metropolitan Area. The obtained results indicate that during a heat wave occurrence, the Monterrey Metropolitan Area can experience HI values of more than 30 degrees, making the risk of heat stress for the citizens most likely to occur. Heat Index results of this magnitude means that the population have to be extremely cautious if exposed to the heat for long periods of time and that they may be in danger if the HI exceeds the 41°C. It is recommended to avoid outdoor activities if possible.

The purpose of this research was to assess the MMA's Heat Index during heat waves occurrences to determine its spatiotemporal variability. It is recommended to cross-examine the obtained HI with satellite thermal images of the study period instead of monthly temperature images for more precise results. Also, as the IDW metric performs better with regularly distributed sample points (Maleika, W., 2020), it is suggested to execute both temperature and humidity analysis with sampling points distributed also at the outskirts of the MMA for a more accurate Heat Index result.

Additionally, it is important to note that because the Heat Index depends not only on temperature but it also considers the relative humidity percentage, the affected areas varied between 2023 and 2024 as both presented different humidity levels across the Monterrey Metropolitan Area. It is suggested to replicate the methodology during more heat wave occurrences and over a longer study period in order to pinpoint which areas are the most vulnerable during heat waves and to determine both the risk assessment and vulnerability patterns in Monterrey.

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