Investigaciones Geográficas • Instituto de Geografía • UNAM
eISSN: 2448-7279 • DOI: https://doi.org/10.14350/rig.60845 • RESEARCH PAPERS
Issue 114 • August • 2024 • e60845
www.investigacionesgeograficas.unam.mx

Contributions of Ernesto Jáuregui to atmospheric sciences in Mexico with emphasis on urban climatology

Contribuciones de Ernesto Jáuregui a las ciencias atmosféricas en México con énfasis en la climatología urbana

Adalberto Tejeda-Martínez,* Irving Rafael Méndez-Pérez** and Elda Luyando López***

Received: 23/01/2024. Accepted: 19/02/2024. Published: 13/06/2024.

Abstract. The main scientific contributions of Ernesto Jáuregui (1923-2014) to Mexico's atmospheric sciences are reviewed in four lines of research: synoptic and mesoscale climatology, climatology of atmospheric pollution, urban climatology, and human bioclimatology. His contributions were more remarkable in the last two lines, with publications ranging from 1970 to the beginning of the 21st century. His work was mainly based on measured meteorological or climatic data, i.e., without resorting to simulation models, and he did not venture into the phenomenon of the urban surface or subsurface heat island. His research in urban climatology focused on Mexico City, although it included some other cities, such as Toluca, Mexicali, or Guadalajara, and paved the way for the rise of urban climatology in the first two decades of this century, which includes cities distributed throughout the national territory.

Keywords: synoptic climatology, urban climate, air pollution diffusion, Mexico.

Resumen. Se reseñan las principales contribuciones científicas de Ernesto Jáuregui (1923-2014) a las ciencias atmosféricas de México en cuatro líneas de investigación: climatología sinóptica y de mesoescala, climatología de la contaminación atmosférica, climatología urbana y bioclimatología humana. En las dos últimas líneas sus aportaciones fueron mayores, con publicaciones que van de 1970 a inicios del siglo XXI. Su trabajo partió, principalmente, de datos meteorológicos o climáticos medidos, es decir, sin recurrir a modelos de simulación, y no incursionó en el fenómeno de la isla urbana de calor superficial o subsuperficial. Sus investigaciones en climatología urbana se centraron en la Ciudad de México, aunque abarcó algunas otras ciudades, como Toluca, Mexicali o Guadalajara, y abrió el camino al auge de la climatología urbana en las dos primeras décadas de este siglo, que incluye ciudades distribuidas a lo largo del territorio nacional.

Palabras clave: climatología sinóptica, clima urbano, dispersión de contaminantes, México.

* Grupo de Climatología Aplicada de la Universidad Veracruzana. Circuito Gonzalo Aguirre Beltrán s/n, Zona Universitaria, Xalapa, Veracruz, 91090, México. ORCID: https://orcid.org/0000-0002-2513-3454. Email: atejeda.martinez@gmail.com; atejeda@uv.mx. Autor de correspondencia.
** Centro de Ciencias de la Tierra de la Universidad Veracruzana. Circuito Gonzalo Aguirre Beltrán s/n, Edificio B Facultad de Instrumentación Electrónica, Zona Universitaria, Xalapa Veracruz, 91090, México. https://orcid.org/0000-0002-3263-0125. Email: irmendez@uv.mx
*** Instituto de Ciencias de la Atmósfera y Cambio Climático, UNAM. Circuito de la Investigación Científica s/n, Ciudad Universitaria, CDMX, 04510, México. https://orcid.org/0000-0002-9985-1993. Email: ellu@atmosfera.unam.mx

INTRODUCTION

Ernesto Jáuregui Ostos was born on 4 August 1923 in Pueblo Viejo, Veracruz, Mexico. His career as a researcher – first at UNAM's Institute of Geography, and later at the Center for Atmospheric Sciences, also of UNAM, both of similar duration – started in the late 1950s and ended half a century later. He died on 18 September 2014 in Mexico City.

As Serrano-Juárez (2023) points out, Jáuregui was a spearhead of climatology, particularly for the Institute of Geography of UNAM.

His work can be grouped into four research lines: synoptic and mesoscale climatology, atmospheric pollution climatology, urban climatology, and human bioclimatology; he mainly contributed to the latter two, which he addressed since the decade of 1970. This document outlines the four research lines, with an emphasis on urban climatology and bioclimatology. A wide selection of his works will be cited under the criterion that they are accessible and that Jáuregui is one of the main authors; the results or methods used will be described only in some cases, since this work aims to outline the evolution of the four lines of research without going into details. Works by other authors will also be mentioned to show how Jáuregui's work served as a starting point for urban climatology in Mexico and to point out the current paths of this area. For example, in quantitative terms, the publications on the urban heat island (UHI) have evolved as follows: between 1950 and 1980, there were only ten texts in or about Mexico, while there were forty in the past two decades of the 20th century, and their number has increased to nearly a hundred in this century, a boom that emerged from the work of Jáuregui.

SYNOPTIC AND MESOSCALE CLIMATOLOGY STUDIES

This line of research, as the others that are summarized below, shows the return of Jáuregui to topics he addressed at the beginning of his professional career as a researcher, almost cyclically. The types of weather and their variations in Mexico were addressed in two major works at that time (Jáuregui, 1971a, 1975a), when the implementation of numerical models for meteorological forecasting was still remote, so the classifications of types of weather and their evolution were promising tools.

Another topic, the climatology of tropical phenomena, started with his classic work about the easterly waves that affect Mexico (Jáuregui, 1967), followed by articles on tropical cyclones in the north and northwest of the country (Jáuregui, 1983a, 1989a, 1995a) and on the Gulf of Mexico (Jáuregui and Zitácuaro, 1995), concluding with a practical article on the trends of tropical storms and the climatology of hurricanes that landed in Mexican coasts in the second half of the twentieth century, along with the empirical probability of impacting the Mexican coasts, depending on their location in the Atlantic or Pacific oceans (Jáuregui, 2003).

On the other hand, regional climatology studies include Puebla-Tlaxcala (Jáuregui, 1968), the Colorado River Valley (Jáuregui, 1969a), the state of Querétaro (Soto and Jáuregui, 1970), the Gulf of Mexico (Jáuregui and Soto, 1975; see Figure 1), the states of Sonora and Baja California (Jáuregui and Cruz-Navarro, 1981), the state of Mexico (Jáuregui and Vidal-Bello, 1981). 1981) and, without considering urban effects, the climates of Cuernavaca (Jáuregui, 1961) and Mexico City (Jáuregui, 1965, 1971b y 1975b).

A study into extreme temperatures and aridity (Soto and Jáuregui, 1965) opens the series of works on both topics. It continued with secular variations in general circulation and their relationship to drought events in northern Mexico (Klaus and Jáuregui, 1975), and rainfall fluctuations in Mexico (Jáuregui, 1979a), or these and their relationship to drought events (Jáuregui and Klaus, 1976). These publications form a set consistent with the work of Jáuregui (1959, 1979a) addressing the behavior of precipitation on Mexico's territory and started with a study of the period 1900-1958 in Tacubaya, while the work of 1979 focused on the fluctuations of rainfall in several cities of Mexico throughout the previous hundred years. The series ended with publications on observational climate change detection and variability in Mexico (Jáuregui, 1992, 1997a, and 1997b).

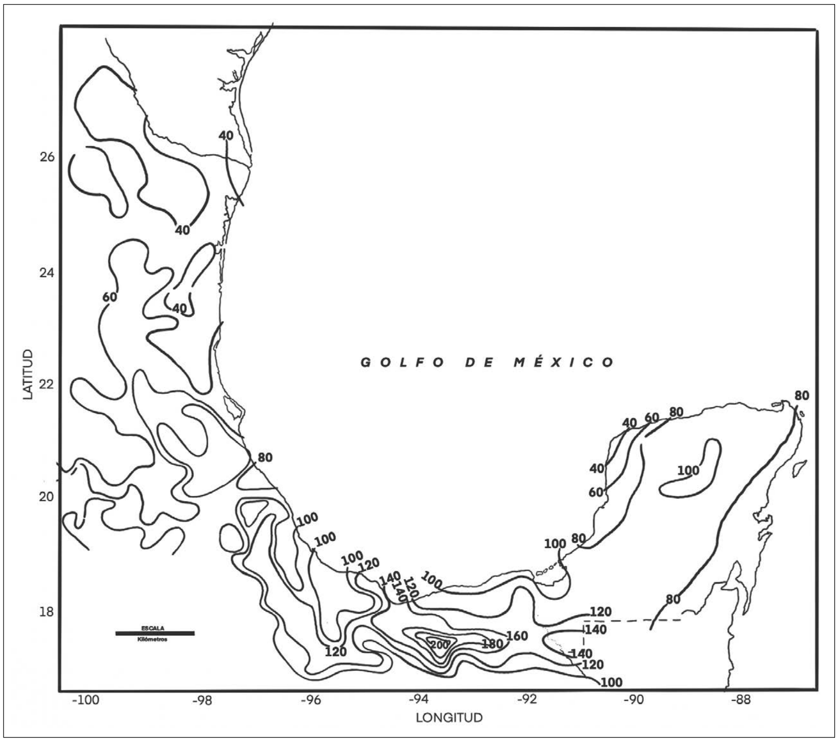

Figure 1. Annual mean number of days with measurable precipitation on the Gulf of Mexico slope, adapted from Figure 5 of Jáuregui and Soto (1975).

THE RELATIONSHIP BETWEEN CLIMATOLOGY AND AIR POLLUTION

Jáuregui's (1958) work on the turbidity of the atmosphere in Mexico City opens the author's scope to the climatology of air pollution and urban (bio) climatology.

He started by showing that air turbidity in Mexico City was mainly due to dust storms caused by turbulence associated with clouds (local convection) or by winds in the absence of clouds (incursions of dry polar air). He also noticed a reduction in visibility that could not be attributed to dust storms (Jáuregui, 1958), which ultimately turned out to be caused by other air pollutants. In addition, he noted a low correlation between precipitation in a given year and dust storms the following year (Jáuregui, 1960). In the same study, he detected a marked reduction in visibility northeast of Tacubaya around 3:00 p.m. during 15 years.

He elaborated on the meteorological aspects of pollution in Mexico City (Jáuregui, 1969b) and the temporal variations in visibility (Jáuregui 1983b, 1983c), which he quantified three decades later as attenuations to solar radiation due to pollution (Jáuregui and Luyando, 1999). In another work, he attempts to explain the meteorological aspects of air pollution in Mexico City by associating them with the spatial and temporal distribution of sulfur dioxide (Klaus and Jáuregui, 1979) and its transport (Jáuregui *et al.*, 1981), the distribution of carbon monoxide (Jáuregui, 1984; see Figure 2), lead (Jáuregui, 1989b; Rosas *et al.*, 1995) and air pollution associated with urban climatology in Mexico City (Klaus *et al.,* 1988).

Subsequently, he returned to dust storms (Jáuregui, 1989c), which, as of his work, had decreased in frequency, but air pollution in Mexico City had increased (Jáuregui, 1988). As in the latter publication, other studies described meteorological conditions, particularly surface wind patterns, that promote or inhibit atmospheric diffusion (Jáuregui, 1983d; Jáuregui and Luyando, 1992). The publications mentioned above focused on Mexico City but also addressed the climatology of pollutant dispersion in other parts of the country, such as the

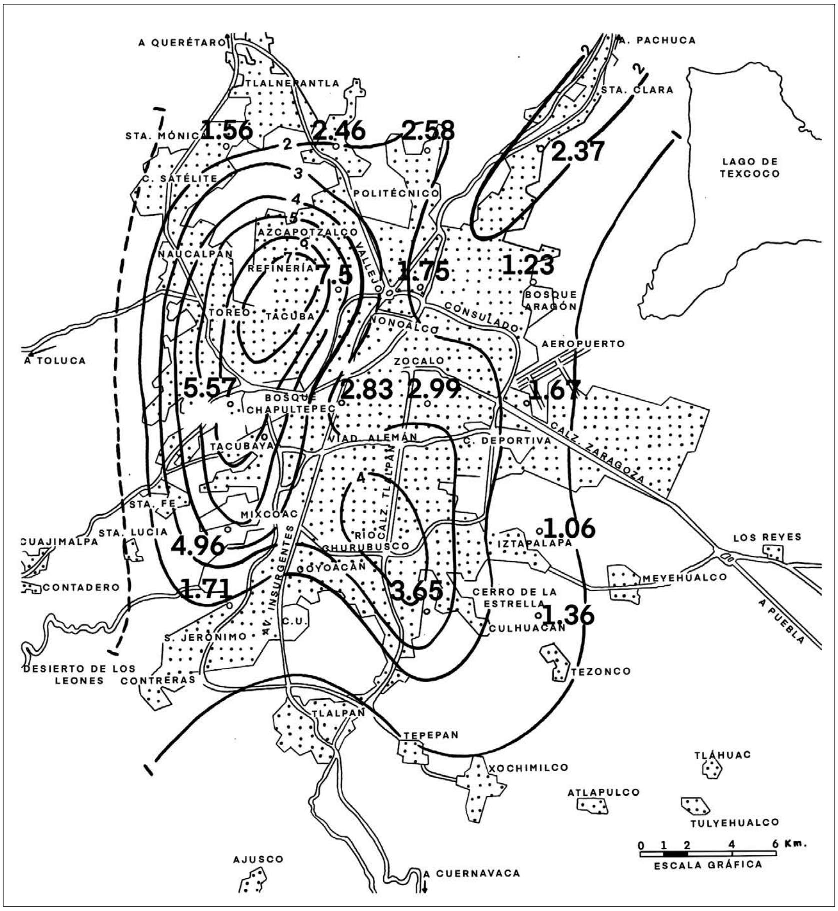

Figure 2. Annual arithmetic mean of carbon monoxide concentrations at 10 a.m. in 1976 in Mexico City (then Mexico, D.F.), adapted from Figure 3 in Jáuregui (1984).

surroundings of Laguna Verde, Veracruz (Jáuregui *et al.*, 1980), and Tijuana (Jáuregui, 1981).

URBAN CLIMATOLOGY

In the classification proposed in the book by Oke *et al.* (2017, Chapter 7), Jáuregui only dealt with the urban heat islands (UHI) of the atmosphere, either within the urban canopy or in the boundary layer but did not venture into the study of surface or subsurface UHIs. It was based on observational data, either from fixed weather stations or from tours in instrumented vehicles, but without using climate or meteorological models.

Recent research on UHI in Mexico began in the 1970s, although there are two isolated antecedents, both at the end of the 18th and 19th centuries. Between 1790 and 1791, Antonio Pineda, a Guatemalan naturalist, found that the temperature ranged between 18 °C and 21.5 °C in downtown Celaya, Guanajuato, while it ranged between 17 °C and 18 °C on the outskirts of this city (González-Claverán, 1988). Between 1895 and 1896, Manuel Moreno y Anda detected a difference of 1.4 °C in Mexico City between the city center (urban) and a then-rural zone, the Tacubaya Observatory, a finding that was noted in a memoir with a delayed publication date (Moreno and Anda, 1895).

Seven decades later, Riquelme (1968), using thermo-hygrometric instruments installed at four points in Mexico City, measured an urban thermal excess of 2 °C relative to the rural environment. He attributed this to the buildings and factories in the city center, in contrast to the areas covered by vegetation on the outskirts.

Almost simultaneously, Jáuregui (1971b) carried out car tours to measure the temperature at 80 points throughout Mexico City. He found a thermal excess of 4 °C to 5 °C between the "area with the highest density of buildings" and the rural environment.

These two works precede a cascade of studies that emerged in the mid-1980s, perhaps not overly abundant, but which produced about 130 publications on thermal alterations due to urbanization in Mexico over the past fifty years, with an average of two and a half works per year. This trend was likely driven by three scientific meetings held in the country: the Technical Conference on Urban Climatology and its Applications, with Particular Emphasis on Tropical Zones, held in Mexico City from 26 November to 30, 1984 (WMO, 1986); the III Congress of the Mexican Organization of Meteorologists from 14 November to 18, 1988, also in Mexico City (OMMAC, 1988), which for the first time was open to topics not strictly meteorological, such as urban climatology, attended by several research institutions, not only operational; and the First International Symposium on Air Pollution and Urban Climate, from 19 to 22 November 1990 in Guadalajara, convened by the World Meteorological Organization and OMMAC (WMO and OMMAC, 1990).

Studies on urban climatology can be divided into three periods characterized by the number of publications and their content.

1950-1980, Entrepreneurship Period

Modern urban climatology in Mexico is based on the work of Riquelme (1968) and Jáuregui (1971b). The latter begins with the history, background, literature review, and physical bases of UHI. It is the start of what its author was to investigate over the next three decades, not only in terms of the UHI, but also on various aspects of urban climatology, such as the bioclimatic characteristics of the city and even inside inhabited premises.

In the work of Jáuregui (1971b), data were recorded during car tours in Mexico City on a route that included 80 points along 80 km between 1968 and 1969, with thermometers with an accuracy of 0.1 °C. In the dry season, from November to April, more pronounced average temperature differences of 4 °C to 5 °C were observed between the city center and the rural outskirts. This work was also based on data from more than 70 fixed weather stations. Regarding minimum temperatures, the recorded differences were 8 °C to 10 °C in the dry season and 4 °C to 6 °C in the rainy season. As for maximum temperatures, the differences ranged from 4 °C (22 °C in the periphery versus 26 °C in the center) to 8 °C (22 °C vs. 30 °C). As expected, relative humidity was inversely related to temperature but followed the same spatial patterns.

These results correspond to the urban canopy for all cases of the routes traveled in an instrumented vehicle. However, some of the fixed weather stations were located on rooftops, that is, on the borderline between the canopy and the boundary layer.

In two articles (1973a, 1973b), Jáuregui revisited the previous results. As these are international publications, he started with the historical and urban context of Mexico City and its atmospheric circulation systems. Regarding the mean annual temperature, he reported 17 °C at the center versus 15 °C at the periphery in the period 1937–1966. However, the most important contribution is probably the inverse logarithmic relationship between UHI intensity and wind velocity; according to this relationship, the UHI almost disappears when the wind velocity exceeds 5 m/s.

In a review of research in urban climatology in the Federal Republic of Germany for comparative purposes (Jáuregui, 1974a, see Figure 3), he addressed again the UHI of Mexico City, where the maximum temperatures in March 1969 showed a difference of 8 °C between the city center (30 °C) and the rural outskirts (22 °C); in the minimum temperatures, he detected a difference of 10 °C (14 °C versus 4 °C) in February of the same year.

In a subsequent study, Jáuregui (1975c) lowered the spatial scale and addressed the microclimate of the Chapultepec forest that covers approximately 800 ha in western Mexico City. On 3 December 1970 at 6 a.m., he recorded 2 °C inside the forest and 8 °C in the surrounding built-up areas 2 km

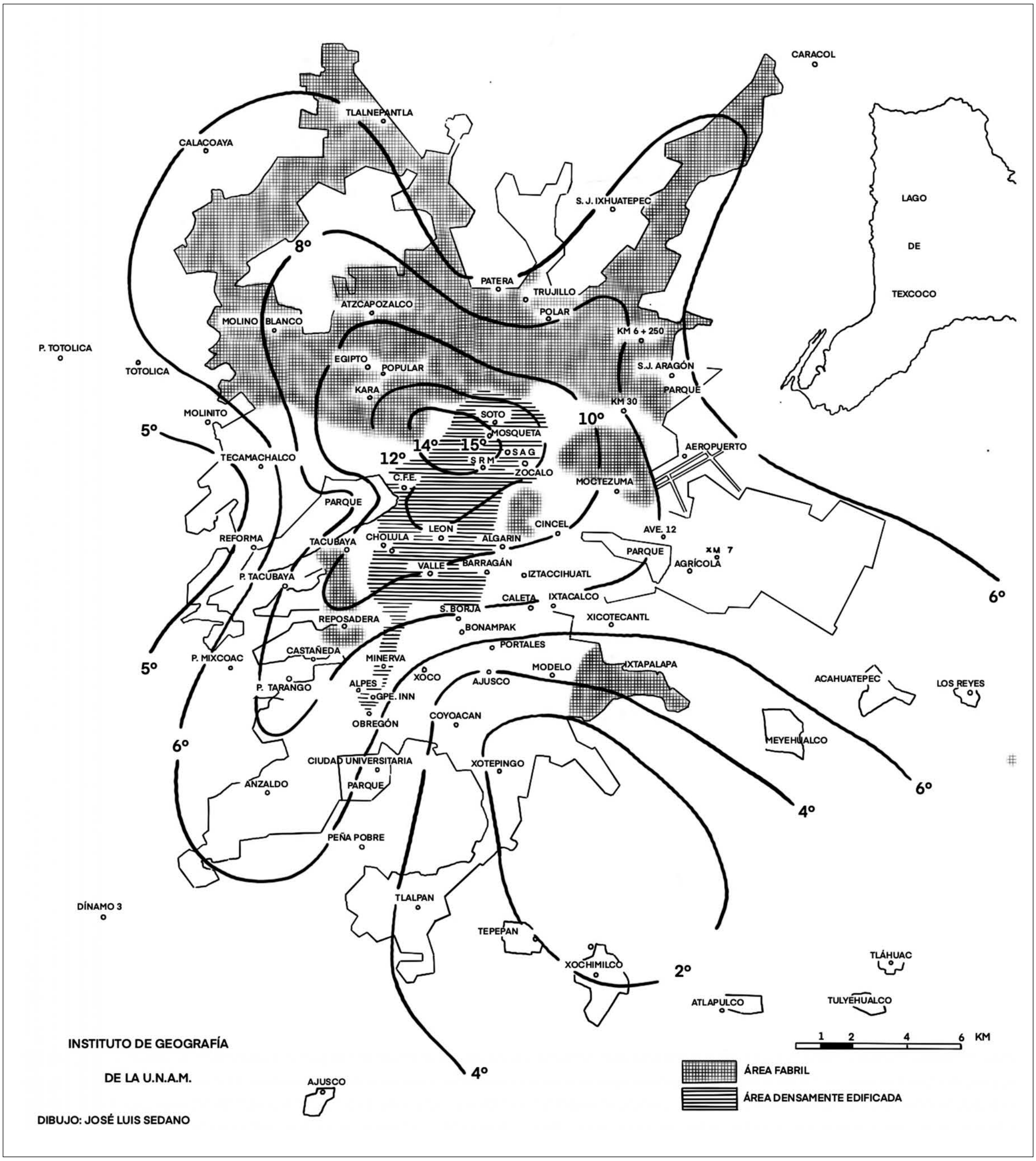

Figure 3. Distribution of the minimum temperatures in Mexico City on 23 February 1969, adapted from Figure 3 in Jáuregui (1974a).

to 3 km away from the center of the undergrowth, while relative humidity ranged from 75 % to 45 %. At night, the forest-city temperature contrast is 9 °C versus 13 °C (Figure 4).

While Jáuregui started his series of works on urban climatology in Mexico City, Gäb (1970a, 1970b) carried out vehicle tours and used data from fixed weather stations to develop the first description of the atmospheric UHI in Puebla. He found that the historic city center tended to be warmer than the surrounding areas, except for the wooded areas, which were between 2 °C and 4 °C cooler than the surrounding areas, as were higher areas with denser vegetation, such as the Loreto and Guadalupe hills.

Fifty kilometers from Mexico City but 420 meters higher (2660 m a.s.l. vs. 2240 m a.s.l.), the city of Toluca has a colder climate. Jáuregui (1979b) detected differences of 5 °C between the city and the countryside in tours on 2 February 1977 between 10:25 a.m. and 12:45 p.m. local time, based on 47 observation points. On 3 February, between 4 p.m. and 6 p.m., he identified two heat islands, with temperatures of 3 °C or 2 °C in the city versus -2 °C in the countryside. The work included other routes, but the ones mentioned above are the best examples. It also compared the weather observatory in the city center with two peripheral stations, finding that the urban/rural contrast for minimum temperatures ranged from 6 °C in February to 1 °C in July.

Jáuregui (1974b) associated the phenomenon known as the *rain island*, i.e., rainfall increases in cities, with convective currents due to the heating of urban areas by solar radiation and its resulting turbulence, and, to a lesser extent, with the abundance of condensation nuclei generated by the city.

The development of bioclimatic studies in Mexican cities started during this period. Jáuregui and Soto (1967) found that wet-bulb temperature was a relevant variable to establish an index of discomfort, and that optimal comfort conditions occurred in the northwest and center of the great Mexican plateau; afterwards, they produced a cartography of bioclimates for the whole country (Soto and Jáuregui, 1968). For bioclimatic purposes, Jáuregui (1971c) analyzed the temperature variation simultaneously in two clinics in Mexico City.

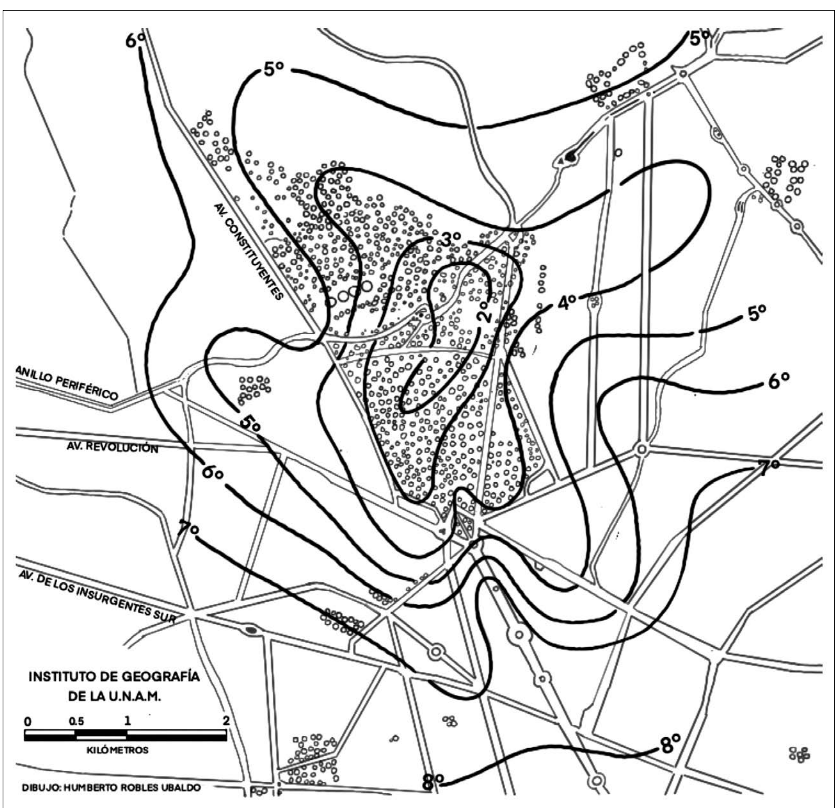

Figure 4. Distribution of temperature (°C) in the Chapultepec Forest on 3 December 1970 (route on a vehicle from 5:28 a.m. to 6:48 a.m.), with clear skies and no wind, adapted from Figure 5 in Jáuregui (1975c).

1981-2000, Interest in Other Mexican Cities

During the last two decades of the 20th century, there was growing interest in the effects of urbanization on air temperature and, occasionally, surface temperature. There are approximately ten publications on the subject for Mexican cities between 1950 and 1980, followed by a 4-fold increase in the next two decades (1981–2000), a figure that doubled for 2001–2022. Furthermore, the significant increase in the number of urban areas in this period stimulated several studies related to urban microclimate and, of course, the possible temporal trends of its variables.

In the two decades of this period, Mexico City continued to be studied as a whole or by zones. The work of Jáuregui (1986) is probably the most important to date on the subject. It confirms, with more recent data from fixed stations, the presence of one or two islands, with differences of more than 5 °C relative to the main island for the hours of minimum temperatures, and shows how the accumulated nighttime cooling in January 1976 was 16 °C in a rural environment (Mexico City airport) versus 14 °C in the urban environment (Tacubaya Observatory); however, in July of the same year, it was higher in urban (10 °C) than rural areas (8 °C). Jáuregui (1993a) took up the measurements of Moreno and Anda (1895) to document the UHI in Mexico City at the end of the nineteenth century and revisited the subject (Jáuregui, 1993b). He analyzed the effects of urbanization on the thermal trends spanning nine decades, from 1900 to 1990 (Jáuregui, 1995b) and their relationship with the soil/atmosphere energy balance, a topic he would address again two years later (Jáuregui, 1997c). The book by Jáuregui (2000) provides an overview of Mexico City's urban climate, not just the temperature.

During this period, studies on other cities and works by other authors started appearing; some remained at the level of undergraduate and postgraduate degree theses and will not be mentioned here due to lack of space or because most of them are difficult to access.

Jáuregui (1986, 1987), using time series of minimum and maximum temperatures, performed a comparative analysis of the evolution of the atmospheric UHIs of Mexico City, Guadalajara, Monterrey, and Veracruz for the early 1980s and found positive differences at night and almost zero or even negative differences during the day. Barradas (1987) published evidence of the "thermal island" in Xalapa, the capital city of the state of Veracruz in the east of the country, located in the middle of mountains with steep geography. Lemus and Gay (1988) addressed variations due to local effects of temperature and precipitation in the city of Aguascalientes, located in the center of the country, from 1921 to 1985. Tejeda and Acevedo (1990) revisited the atmospheric UHI in Xalapa using data from rooftop thermometers. They documented the island at the border between the urban canopy and the boundary layer, detecting that the thermal gradient due to altitude differences does not neutralize the effect of the UHI in the city's shopping center, which is at mid-altitude in the urban area. Using time series analysis, Ojeda *et al.* (1993) investigated the effects of global climate change, the Southern Oscillation, and urbanization in the cities of Veracruz and Xalapa and the semi-rural town of Las Vigas, all in the center of the state of Veracruz.

Vidal and Jáuregui (1991) addressed the evolution of atmospheric UHI from 1977 to 1990 in Toluca. Jáuregui *et al.* (1992) focused on Guadalajara again with time series for 1931–1970 and associated thermal trends with population growth. Davydova-Belitskaya *et al.* (1999) also studied thermal trends for the 20th century in Guadalajara, associating them with large-scale and local-scale phenomena. Villahermosa, in the state of Tabasco, is possibly the first city located in the humid tropics of Mexico for which an atmospheric UHI is documented with data collected during car tours (Cervantes *et al.*, 2000).

At the micro-scale, results start emerging. Pozos and Barradas (1988) focused their study on temperatures in the southern part of Mexico City. Jáuregui (1990, 1991a) revisited the effect of the Chapultepec forest and its lake on the freshness of the environment and the possible generation of convective precipitation. He also explored the effect of revegetation and generation of a water body in the former Lake Texcoco on the climate of eastern

Mexico City (Jáuregui, 1990, 1991a). Barradas (1991) conducted microclimatology in small parks in the city and found that the phenomenon already reported by Jáuregui (1990, 1991b) in Chapultepec also occurs on a smaller scale.

As already mentioned, one of the aspects poorly explored by Jáuregui was climate modeling, except in the article by Jáuregui *et al.* (2000), which explores the response of the climate of the Valley of Mexico to changes in land use. However, one work that precedes it is that of Luna-González (1997) using a non-hydrostatic meteorological model.

This period witnessed a proliferation of studies on bioclimate and its relation to accelerated urbanization in some cities of Mexico (Jáuregui, 1990) or in tropical cities, not only in Mexico (Jáuregui, 1991, 1997d), sometimes carrying out combined evaluations of bioclimatic conditions and air pollution, as in Mexico City (Jáuregui, 1995c), or providing an overview of bioclimatology in developing countries (Jáuregui, 1995c). 1993c), as well as approaches to the human bioclimatology of Mexico City (Jáuregui *et al.*, 1997).

The studies by Jáuregui and Klaus (1982) and Klaus *et al.* (1983) are pioneer approaches to the spatial and temporal effects of urbanization on rainfall. Almost a decade later, the topic reappeared in the work of Jáuregui and Romales (1996). Klaus *et al.* (1999) reported the influence of the UHI on the regularity of atmospheric circulation structures in the Mexico City basin, while Jáuregui and Luyando (1998) found a direct relationship between UHI intensity and the potential evaporation measured with a type-A evaporimeter for the same city. On the other hand, Martínez-Arroyo and Jáuregui (2000) investigated the environmental effects of urban lakes in Mexico City, particularly regarding temperature.

An aspect worth noting is that only in this period did publications start appearing on the behavior of humidity in the urban atmosphere, its relationship with air temperature, or the effect of the green areas of Mexico City (Barradas, 1991). Jáuregui and Tejeda (1997) analyzed the contrast between relative humidity and urban-rural vapor pressure in Mexico City. They concluded that the relative humidity patterns respond to the temperature patterns (although with inverse gradients); however, they did not reach definitive conclusions regarding vapor pressure because the differences between the two environments resulted from the uncertainty of the instruments.

Changes in the soil/atmosphere energy balance largely explain the presence of UHIs (Oke *et al.,* 2017, Chapter 6); hence the importance of measuring these changes. However, the appropriate tools for applying the *eddy covariance* technique became commercially accessible until the last third of the twentieth century. The first simultaneous measurements of net radiation, heat stored at the surface, and turbulent fluxes of sensible and latent heat in Mexico City date back to the mid-1980s but were reported several years later by Oke *et al.* (1992). A second measurement campaign was conducted in this city in the mid-1990s and was reported by Oke *et al.* (1999). For a suburban area of Mexico City, Barradas *et al.* (1999) reported the behavior of the energy balance. In all these publications, there is a clear decrease in latent heat flow in urban areas or suburbs compared to the rural landscapes of Mexico City.

2001-2022, the Incentive for Other Researchers

During the first decade of this century, Jáuregui continued publishing works mainly, but not only, on the climatology or bioclimatology of Mexico City. He addressed the impact of changes in land use on the climate of the region around Mexico City (Jáuregui, 2004). He analyzed the potential impact of urbanization in the nine Mexican cities with more than one million inhabitants and found significant warming trends ranging from 0.02 °C to 0.74 °C in the second half of the twentieth century (Jáuregui, 2005). Applying the climate change scenarios of the Intergovernmental Panel on Climate Change (IPCC) for an eventual doubling of atmospheric CO2, Jáuregui and Tejeda (2001) produced human bioclimate scenarios for Mexico City under the hypothesis of constant relative humidity and using a simple bioclimatic index based on a linear function of temperature and relative humidity. Jáuregui (2009) discussed heat waves in Mexico City and their trend from the late 19th to

the late 20th century, using the author's definition of maximum temperatures of 30 °C or higher for three consecutive days (Figure 5).
The topics addressed by Jáuregui in previous decades were revisited, such as the distribution of pollutants in Mexico City, particularly ozone (Klaus *et al.*, 2001), the surface/atmosphere energy balance (Tejeda and Jáuregui, 2005), or the climate within urban parks (Jáuregui and Heres, 2008). The latter work was based on simulations of human bioclimate with energy balance indices in a protected natural reserve area in the foothills northwest of Mexico City.

At the beginning of the second decade of this century, Jáuregui gradually started withdrawing from research work. However, the number of recent publications by various authors related to various urban centers is largely a continuation of the work on urban climatology that our author started more than half a century ago.

After the initial (1950–1980) and the apprenticeship (1981–2000) stages, the present century is a consolidation stage. Table 1 lists most publications on the effects of urban zones on the thermal climate by cities, approaches, and applications. For this period, undergraduate and postgraduate theses were not excluded from this review since, as they are recent, most of them are accessible via the Internet.

Mexico City stands out as the city with the most publications, followed by Guadalajara and Puebla, but Monterrey, the second most populous city in the country, is almost absent. Most studies on UHIs refer to the atmosphere, but studies addressing surface temperatures are not scarce, and most of them used satellite technology. Table 1 shows that only five studies are based on computational models; the work by Grajeda *et al.* (2018) is relevant because they performed a three-dimensional thermal simulation on an avenue in the center of the city of Veracruz. Another noteworthy aspect is that no drones were used to detect surface UHIs; these studies have been carried out using satellite images, as mentioned above.

On the other hand, in 12 of the 19 cities, research has been carried out to reduce the UHI through vegetated areas (refer to the *Land use or UHI mitigation* column in Table 1), which is beneficial from an environmental point of view, especially in cities located in warm or arid areas such as Ciudad Juárez, Colima, Hermosillo, Mexicali, Poza Rica, Tampico, Torreón, or Tuxtla Gutiérrez. However, several studies were based on the unproven assumption that the UHI is a hazard

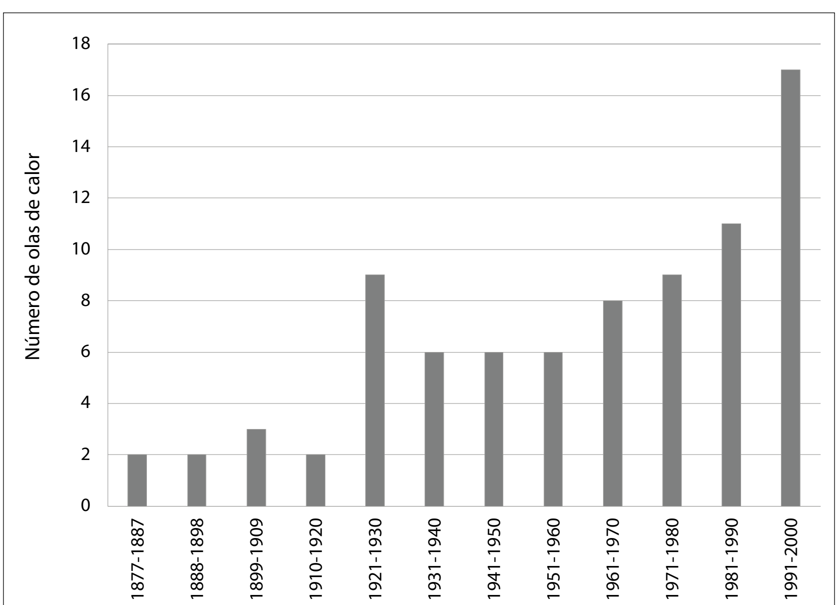

Figure 5. Frequency of heat waves (temperatures of 30 °C or higher for three consecutive days, 1877–2000), adapted from Figure 2 by Jáuregui (2009)..

to society; however, in terms of health and climatic comfort, it could represent an advantage on cold nights in temperate places such as Puebla, Querétaro, Xalapa, or Toluca (Tejeda *et al.*, 2022). This is not the case for Mexico City and its metropolitan area, for which the risk associated with the UHI has been evaluated – not assumed – by Vargas and Magaña (2020).

It should also be noted that of the 19 cities listed in Table 1, only twelve are state capitals. Regarding the *UHI-society relationship* column, most works discuss the effects of the UHI on social aspects, such as health or comfort; however, the other point of view, i.e., the effects of socioeconomic conditions on the UHI, is missing, reported by Serricolea *et al*. (2022) for the surface UHI in Santiago, Chile.

CONCLUDING REMARKS

Ernesto Jáuregui's contributions to the knowledge of the atmosphere in Mexico started in the late 1950s and spanned half a century. They can be grouped into four lines of research: synoptic and mesoscale meteorology, air pollution climatology, urban climatology, and human bioclimatology. The latter two produced the most abundant studies and have had the greatest impact. To note, these four lines were developed by Jáuregui almost simultaneously or alternating his research activities between them. For example, in synoptic and mesoscale meteorology or climatology, studies on tropical storms started in the late 1960s and continued until the early twenty-first century with six publications. The same is observed regarding climate variability, a topic for which he produced five articles between the end of the decade of 1950 and the end of the twentieth century; a similar trend is observed for the climatology of atmospheric dispersion, although the production was more abundant (at least 17 articles). From 1970 to 2010, these publications appear as seasonings to the vast production – more than 50 articles – on urban climatology and human bioclimatology, which in many ways fostered the boom of urban climatology that Mexico is experiencing, as illustrated by the publications on UHIs referred to in Appendix 1.

REFERENCES

Araiza-Olivares, G. A. (2022). La isla de calor en la Ciudad de México: Un análisis decadal (1950-2010). *Revista Geográfica de América Central, 69*(2), 415-436. https://doi.org/10.15359/rgac.69-2.15

Baca-Cruz, A. G. (2014). *Identificación y comportamiento de la isla de calor en la zona conurbada de Veracruz-Boca del Río en el año 2011.* Tesis de Licenciatura en Ciencias Atmosféricas, Universidad Veracruzana.

Balderas-Romero, G. (2018). Efectos climáticos de la urbanización en la zona metropolitana de Puebla. En N. Santillán y R. García-Cueto (Eds.), *Ambiente urbano 2050* (pp. 69-95). Universidad Autónoma de Baja California. http://urban.diau.buap.mx/publicaciones/efectos-climaticos-de-la-urbanizacion-de-la-zmp.pdf

Ballinas, M. y Barradas, V. L. (2016), The Urban Tree as a Tool to Mitigate the Urban Heat Island in Mexico City: A Simple Phenomenological Model. *Journal of Environmental Quality,* (45), 157-166. https://doi.org/10.2134/jeq2015.01.0056

Barradas, V. L. (1987). Evidencia del efecto de "Isla térmica" en Jalapa, Veracruz, México. *Revista Geofísica*, (26), 125-135. https://www.researchgate.net/profile/Victor-Barradas/publication/263272978_Evidencia_del_efecto_de_Isla_Termica_en_Jalapa_Veracruz_Mexico/links/53df97c50cf27a7b83068cd4/Evidencia-del-efecto-de-Isla-Termica-en-Jalapa-Veracruz-Mexico.pdf

Barradas, V. L. (1991) Air temperature and humidity and human comfort index of some city parks of Mexico City. *International Journal of Biometeorology,* (35), 24-28. https://doi.org/10.1007/BF01040959

Barradas, V. L., Tejeda, A. y Jáuregui, E. (1999). Energy balance measurements in a suburban vegetated area in Mexico City. *Atmospheric Environment,* (33), 4109-4113. https://doi.org/10.1016/S1352-2310(99)00152-1

Barrera-Alarcón, I. G., Caudillo-Cos, C. A., Medina-Fernández, S. L., Ávila-Jiménez, F. G. y Montejano-Escamilla, J. A. (2022). La isla de calor urbano superficial y su manifestación en la estructura urbana de la Ciudad de México. *Revista de Ciencias Tecnológicas, 5*(3), 312-330.

Biles, J. J. y Lemberg, D. S. (2020). A Multi-scale Analysis of Urban Warming in Residential Areas of a Latin American City: The Case of Mérida, Mexico. *Journal of Planning Education and Research, 43*(4), 1-16. https://doi.org/10.1177/0739456X20923002

Canul, R. A., Barrera, F. J. y Aldana, G. P. (2020). Heat islands in the city of San Francisco de Campeche: detection and solution. *ECORFAN, 6*(10), 16-20. http://dx.doi.org/10.35429/EJROP.2020.6.10.16.20

Casillas-Higuera, A., García-Cueto, R., Leyva-Camacho, O. y González-Navarro, F. F. (2014). Detección de la isla urbana de calor mediante modelado dinámico en Mexicali, B.C. México. *Información Tecnológica*, *25*(1), 139-150. http://dx.doi.org/10.4067/S0718-07642014000100015

Cervantes, J., Barradas, V., Tejeda, A., Angulo, Q., Triana, C. y Gutiérrez, G. (2000). Aspectos del clima urbano de Villahermosa, Tabasco, México. *Universidad y Ciencia, 16*(31), 10-18.

Cervantes, J., Barradas, V., Tejeda A. y Pereyra, D. (2001). Clima urbano, bioclima humano, hidrología y evaluación de riesgos por hidrometeoros en Xalapa, Ver., Anexo 4. En C. Capitanachi (Coord.), E. Utrera y C. B. Smith, *Unidades ambientales: bases metodológicas para la comprensión integrada del espacio urbano* (pp. 1-54). Universidad Veracruzana, Instituto de Ecología, A.C.

Colunga, M., Cambrón, V., Suzán, H., Guevara, A. y Luna, H. (2015). The role of urban vegetation in temperature and heat island effects in Queretaro city, Mexico. *Atmósfera, 28*(3), 205-218. https://doi.org/10.20937/ATM.2015.28.03.05

Contreras-Cardosa A., Plata-Mendoza J. A., Velásquez-Angulo G. y Quevedo-Urías, H. (2008). Determinación de la isla de calor urbano en Ciudad Juárez mediante programa de cómputo. *CULCyT*, *26*(5).

Cui, Y. y De Foy, B. (2012). Seasonal variations of the urban heat island at the surface and the near-surface and reductions due to urban vegetation in Mexico City. *Journal of Applied Meteorology and Climatology,* 5*1*(5), 855-868. https://doi.org/10.1175/JAMC-D-11-0104.1

Davydova-Belitskaya, V., Skiba, Y. N., Bulgakov, S. N. y Martínez, A. A. (1999). Modelación matemática de los niveles de contaminación en la ciudad de Guadalajara, Jalisco, México. Parte 1. Microclima y monitoreo de la contaminación. *Revista Internacional de Contaminación Ambiental, 15*(2), 103-111. https://www.redalyc.org/articulo.oa?id=37015206

Davydova, V. y Alamilla, D. (2019). Variación de la temperatura relacionada con el intenso desarrollo de la zona conurbada de Guadalajara, México (1996-2018) En *N. Zapata. Biotecnología y Ciencias Agrícolas. ECORFAN-México.*

Estrada, F., Martínez-Arroyo, A., Fernández-Eguiarte, A., Luyando, E. y Gay, C. (2009). Defining climate zones in Mexico City using multivariate analysis. *Atmósfera, 22*(2), 175-193. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8625

Evans, J. M. y De Schiller, S. (2005). La isla de calor en ciudades con clima cálido-húmedo. El caso de Tampico, México. *Avances en Energías Renovables y Medio Ambiente*, (9), 37-42. http://sedici.unlp.edu.ar/handle/10915/83074

Flores-De la O, J. L., Villanueva-Solis, J. y Quiroa-Herrera, J. A. (2018). Evaluación de los efectos microclimáticos que tiene la vegetación de la isla de calor urbana: Parque en la ciudad de Torreón. México. *Revista de Ciencias Ambientales, 52*(2), 123-140. https://doi.org/10.15359/rca.52-2.7

Fuentes-Pérez C. A. (2014). Islas de calor urbano en Tampico, México. Impacto del microclima a la calidad del hábitat. *Revista Electrónica Nova Scientia, 7*(13), 495-515. https://www.researchgate.net/publication/276075465_Islas_de_calor_urbano_en_Tampico_Mexico_Impacto_del_microclima_a_la_calidad_del_habitat

Gäb, G. M. (1970a). *Untersuchungen zum Stadtklima von Puebla (Mexiko).* Rheinische Friedrich-Wilhelms-Universität.

Gäb, G. M. (1970b). Investigaciones del clima de la ciudad de Puebla. *Revista Comunicaciones de la Fundación Alemana, 2*, 25-43.

Galindo, I. (2009). *A satellite time slots climatology of the urban heat island of Guadalajara Megacity in Mexico from NOAA ¡/AVHRR THERMAL Infrared Monitoring (TIR).* European Geosciences Union General Assembly, 11. EGU2009-12795.

Galindo, I. (2010). Identificación y estudios de las islas urbanas de calor de las ciudades de Guadalajara y Colima, propuestas de estrategias de mitigación. Primer Encuentro Académico CONAVI-CONACYT.

Galindo-Estrada, I. (2014). Las islas urbanas de calor: un problema creciente. En *Diálogos entre ciudad, medio ambiente y patrimonio, de R. Valladares-Anguiano* (pp. 151-155). Universidad de Colima.

García-Cueto, O. R., López-Velázquez, J.E., Bojórquez-Morales, G., Santillán-Soto, N. y Flores-Jiménez, D. E. (2021). Trends in temperature extremes in selected growing cities of Mexico under a non-stationary climate. *Atmósfera, 34*(3), 233-254. https://doi.org/10.20937/ATM.52784

García-Cueto, O. R., Jáuregui, E., Toudert, D. y Tejeda, A. (2007). Detection of the urban heat island in Mexicali B. C. and its Relationship with land use. *Atmósfera, 20*(2), 111-131. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8578/8048

García-Cueto, O. R., Tejeda, A. y Bojórquez, G. (2009). Urbanization effects upon the air temperature in Mexicali, B.C. *Atmósfera*, *22*(44), 349-365. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-62362009000400002

Godínez-Tovar, A. G. y López-Gutiérrez, M. (2018). *Dinámica de la Isla de Calor Urbana y su efecto en la distribución espacio-temporal de la lluvia en las ciudades* *de Querétaro y San Juan del Río*. Tesis de licenciatura, Facultad de Geografía. Universidad Autónoma del Estado de México.

Gómez-Martínez, F., De Burs, K. M., Koch, J. y Widener, J. (2021). Multi-temporal land surface temperature and vegetation greenness in urban green spaces of Puebla, Mexico. *Land, 10*(2), 155. https://doi.org/10.3390/land10020155

González-Claverán, V. (1988). *La expedición científica de Malaspina en Nueva España, 1789-1794.* El Colegio de México. https://repositorio.colmex.mx/concern/books/gt54kn83t?locale=es

González-Rocha, S. N. (2013). *Áreas verdes, estrategia para disminuir la isla de calor y contaminantes atmosféricos.* Tesis doctoral, Instituto de Ciencias Avanzadas. Universidad Popular Autónoma de Veracruz.

Grajeda, R. M., Alonso, E. M. y Esparza, C. J. (2018). Vehicular anthropogenic heat in the physical parameters of an urban canyon for warm humid climate. En En E. Ng, S. Fong, C. Ren (Eds.), *34th International Conference on Passive and Low Energy Architecture* (pp. 225-230). The Chinese University of Hong Kong.

Haro-Carbajal, E. T. (2013). *La vegetación urbana, una estrategia de mitigación de la isla urbana de calor en Colima.* Tesis de doctorado en Arquitectura. Universidad de Colima.

Hernández, A. (2010). *Detección satelital de la isla de calor de la ciudad de Guadalajara.* Tesis para optar al grado de Ingeniero Topógrafo Geomático, Facultad de Ingeniería Civil, Universidad de Colima.

Jáuregui, E. (1958). El aumento de la turbiedad del aire en la Ciudad de México. *Ingeniería Hidráulida en México, 12*(3), 9-18.

Jáuregui, E. (1959). Notas sobre la precipitación en Tacubaya para el periodo 1900-1958. *Ingeniería Hidráulica en México,* (13), 29-39.

Jáuregui, E. (1960). Las tolvaneras de la ciudad de México. *Ingeniería Hidráulica en México, 14*(4), 60-66.

Jáuregui, E. (1961). El clima de la ciudad de Cuernavaca. *Ingeniería Hidráulica en México, 15*(3), 1-16.

Jáuregui, E. (1965). Mesoclima y bioclima del Valle de México. *Publicaciones del Instituto de Geografía-UNAM, 1*, 99-123.

Jáuregui, E. (1967). Las ondas del este y los ciclones tropicales en México. *Ingeniería Hidráulica en México, 21*(3), 197-208.

Jáuregui, E. (1968). *Mesoclima de la región Puebla-Tlaxcala*. Instituto de Geografía-UNAM, Dirección General de Publicaciones-UNAM.

Jáuregui, E. (1969a). El clima del Valle del Río Colorado. *Boletín del Instituto de Geografía-UNAM,* (1), 31-64. https://doi.org/10.14350/rig.59180

Jáuregui, E. (1969b). Aspectos meteorológicos de la contaminación del aire de la ciudad de México. *Ingeniería Hidráulica en México, 23*(1), 17-28.

Jáuregui, E. (1971a). Variaciones de largo periodo de los tipos de tiempo de superficie en México. *Boletín del Instituto de Geografía-UNAM, 4*, 7-22. https://doi.org/10.14350/rig.58858

Jáuregui, E. (1971b). *Mesomicroclima de la Ciudad de México*. Instituto de Geografía, UNAM. Dirección General de Publicaciones-UNAM.

Jáuregui, E. (1971c). Evaluación del bioclima en dos clínicas de la ciudad de México. *Boletín del Instituto de Geografía-UNAM, 4*, 23-36. https://doi.org/10.14350/rig.58859

Jáuregui, E. (1973a). The urban climate of Mexico City. *Erdkunde, 27*(4), 298-307. https://www.erdkunde.uni-bonn.de/archive/(1973)/the-urban-climate-of-mexico-city/at_download/attachment

Jáuregui, E. (1973b). *Untersuchungen zum Stadtklima von Mexiko-Stadt.* Inaugural Dissertation, Universidad de Bonn, Alemania.

Jáuregui, E. (1974a). Las investigaciones sobre el clima urbano y contaminación del aire en la República Federal de Alemania. *Boletín del Instituto de Geografía-UNAM,* (5), 71-89. https://doi.org/10.14350/rig.58878

Jáuregui, E. (1974b). 'La isla de lluvia' de la Ciudad de México. *Recursos Hidráulicos, 3*(2), 138-151.

Jáuregui, E. (1975a). Los sistemas de tiempo en el Golfo de México y su vecindad. *Boletín del Instituto de Geografía-UNAM,* (6), 7-36. https://doi.org/10.14350/rig.58888

Jáuregui, E. (1975b). Las zonas climáticas de la Ciudad de México. *Boletín del Instituto de Geografía-UNAM,* (6), 47-58. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0188-46111975000100003

Jáuregui, E. (1975c). Microclima del Bosque de Chapultepec. *Boletín del Instituto de Geografía-UNAM,* (6), 63-72. https://doi.org/10.14350/rig.58892

Jáuregui, E. (1979a). Algunos aspectos de las fluctuaciones pluviométricas en México en los últimos cien años. *Boletín del Instituto de Geografía-UNAM*, (9), 39-64. https://doi.org/10.14350/rig.58914

Jáuregui, E. (1979b). La isla de calor en Toluca, Méx. *Boletín del Instituto de Geografía–UNAM,* (10), 27-37. https://doi.org/10.14350/rig.58913

Jáuregui, E. (1981). Climatología de difusión de la ciudad de Tijuana, B. C. *Boletín del Instituto de Geografía-UNAM,* (11), 55-91. https://doi.org/10.14350/rig.58936

Jáuregui, E. (1983a). Die Gefährdung der nordwestküste Mexikos durch die tropischen Zyklonen des nordostpazifiks. *Studia Geographica,* (16), 123-135.

Jáuregui, E. (1983b). Variaciones de largo periodo de la visibilidad en la Ciudad de México. *Geofísica Internacional, 22*(3), 251-275. https://doi.org/10.22201/igeof.00167169p.1983.22.3.868

Jáuregui, E. (1983c). Visibility trends in Mexico City. *Erkunde, 37*(4) 296-300. https://www.jstor.org/stable/25644697

Jáuregui, E. (1983d). Una primera estimación de las condiciones de difusión atmosférica en la República Mexicana. *Boletín del Instituto de Geografía-UNAM,* (13), 9-51. https://doi.org/10.14350/rig.58953

Jáuregui, E. (1984). La distribución espacial y temporal del monóxido de carbono en la Ciudad de México, y su relación con algunos factores meteorológicos. *Boletín del Instituto de Geografía-UNAM,* (14), 93-126. https://doi.org/10.14350/rig.59470

Jáuregui, E. (1986). The urban climate of Mexico City. *Urban climatology and its applications with special regard to tropical areas.* T. R. Oke (Ed.), *World Climate Programme*, *WMO* 652 (pp. 63-86). https://library.wmo.int/?lvl=notice_display&id=7604

Jáuregui, E. (1987). Urban heat island development in medium and large urban areas in Mexico. *Erkunde*, (41), 48-51. http://www.jstor.org/stable/25645088

Jáuregui, E. (1988). Local wind and air pollution interaction in the Mexico Basin. *Atmósfera, 1*(3), 131-140. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/25944

Jáuregui, E. (1989ª, sept-dic.). Los ciclones del norte de México y sus efectos sobre la precipitación. *Ingeniería Hidráulica en México,* 43-50. http://www.revistatyca.org.mx/ojs/index.php/tyca/article/view/609

Jáuregui, E. (1989b). Variaciones espaciales y temporales del plomo atmosférico en la Ciudad de México. *Geografía y Desarrollo, 2*(4), 15-21.

Jáuregui, E. (1989c). The dust storms of Mexico City. *International Journal of Climatology,* (9), 169–180. https://doi.org/10.1002/joc.3370090205

Jáuregui, E. (1990). Distribución de la temperatura efectiva en México. *Memorias de la II Reunión Nacional de Energía y Confort* (pp. 136-139). Universidad Autónoma de Baja California, Instituto de Ingeniería.

Jáuregui, E. (1990-1991a). Effects of revegetation and new artificial water bodies on the climate of northeast Mexico City. *Energy and Buildings,* (15-16), 447-455. https://doi.org/10.1016/0378-7788(90)90020-J

Jáuregui, E. (1990/91b). Influence of a large urban park on temperature and convective precipitation in a tropical city. *Energy and Buildings,* (15-16), 457-463. https://doi.org/10.1016/0378-7788(90)90021-A

Jáuregui, E. (1991). The human climate of tropical cities: an overview. *International Journal of Biometeorology,* (35), 151-160. https://doi.org/10.1007/BF01049061

Jáuregui, E. (1992). Aspects of monitoring local/regional climate change in a tropical region. *Atmósfera, 5*(2), 69-78. http://www.ejournal.unam.mx/atm/Vol05-2/ATM05202.pdf

Jáuregui, E. (1993a). La isla de calor urbano de la Ciudad de México a fines del siglo XIX, *Boletín del Instituto de Geografía-UNAM,* (26), 31-39. https://doi.org/10.14350/rig.59016

Jáuregui, E. (1993b). Mexico City's urban heat island revisited. *Erdkunde, 47*, 185-195. https://doi.org/10.3112/erdkunde.1993.03.03

Jáuregui, E. (1993c). Urban bioclimatology in developing countries. *Experientia, 49*(2), 964-968. https://doi.org/10.1007/BF02125643

Jáuregui, E. (1995a). Rainfall fluctuations and tropical storm activity in Mexico. *Erdkunde, 49*, 39-48. https://www.erdkunde.uni-bonn.de/archive/(1995)/rainfall-fluctuations-and-tropical-storm-activity-in-mexico/at_download/attachment

Jáuregui, E. (1995b). Algunas alteraciones de largo período del clima de la Ciudad de México debidas a la urbanización. Revisión y perspectivas. *Boletín del Instituto de Geografía-UNAM,* (31), 9-44. https://doi.org/10.14350/rig.59035

Jáuregui, E. (1995c). Clima urbano y contaminación atmosférica en la Ciudad de México. Análisis actual y aspectos futuros. En *Umwelt und Gesellschaft in Lateinamerika: Wissenschaftliche Jahrestagung der Arbeitsgemeinschat Deutsche Latinoamerikaforshung (ADLAF) 1994,* (pp. 156-167). Marburger Geographische Schriften 129.

Jáuregui, E. (1997a). Climate changes in Mexico during the historical and instrumented periods. *Quaternary International,* (43), 7-17. https://doi.org/10.1016/S1040-6182(97)00015-3

Jáuregui, E. (1997b). Climate variability and climate change in Mexico: A review. *Geofísica Internacional, 36*(3), 201-205. https://doi.org/10.22201/igeof.00167169p.(1997).36.3.658

Jáuregui, E. (1997c). The last Ms for 40th anniversary issue. Aspects of urban human biometeorology. *International Journal of Biometeorology,* (40), 58-61. https://doi.org/10.1007/BF02439413

Jáuregui, E. (1997d). Heat island development in Mexico City. *Atmospheric Environment, 31*(22), 3821-3831. https://doi.org/10.1016/S1352-2310(97)00136-2

Jáuregui, E. (2000). *El clima de la Ciudad de México*. http://www.publicaciones.igg.unam.mx/index.php/ig/catalog/book/51

Jáuregui, E. (2003). Climatology of landfalling hurricanes and tropical storms in Mexico. *Atmósfera, 16*(4), 193-204. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-62362003000400001

Jáuregui, E. (2004). Impact of land-use changes on the climate of the Mexico City Region. Investigaciones

Geográficas. *Boletín del Instituto de Geografía, UNAM,* (55), 46-60.

Jáuregui, E. (2005). Possible impact of urbanization on the thermal climate of some large cities in México. *Atmósfera, 18*(4), 249-252. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8550

Jáuregui, E. (2009). The heat spells of México City. *Investigaciones Geográficas,* (70), 71-76. https://doi.org/10.14350/rig.18078

Jáuregui, E. Cervantes, J., Tejeda, A. (1997). Bioclimatic conditions in Mexico City: an assessment. *International Journal of Biometerology,* (40), 166-177. https://doi.org/10.1007/s004840050038

Jáuregui, E. y Cruz-Navarro, F. (1981). Algunos aspectos del clima de Sonora y Baja California. Equipatas y surgencias de humedad. *Boletín del Instituto de Geografía,* (10), 143-180. https://doi.org/10.14350/rig.58927

Jáuregui, E., Godínez L. y Cruz, F. (1992), Aspects of heat-island development in Guadalajara, Mexico. *Atmospheric Environment, 26B*(3), 391-396. https://doi.org/10.1016/0957-1272(92)90014-J

Jáuregui, E. y Heres, M. E. (2008). El clima/bioclima de un parque periurbano de la Ciudad de México. *Investigaciones Geográficas,* (67), 101-112. https://www.researchgate.net/publication/38104500_El_clima-bioclima_de_un_parque_periurbano_de_la_Ciudad_de_Mexico

Jáuregui, E., Jazcilevich, A., Fuentes, V. y Luna, E. (2000). Simulated urban climate response to historical land use modification in the basin of Mexico. *Climatic Change,* (44), 515-536. https://doi.org/10.1023/A:1005588919627

Jáuregui, E. y Klaus, D. (1976). Some aspects of climate fluctuations in Mexico in relation to drought. *Geofísica Internacional*, *16*(1), 45-61. https://doi.org/10.22201/igeof.00167169p.1976.16.1.926

Jáuregui, E. y Klaus, D. (1982). Stadtklimatische Effekte der Raum-Zeitlichen Niederschlangsverteilung Aufgezeigt am Beispiel von Mexiko-Stadt. *Erkunde*, (6), 278-286. https://www.erdkunde.uni-bonn.de/archive/1982/stadtklimatische-effekte-der-raum-zeitlichen-niederschlagsverteilung-aufgezeigt-am-beispiel-von-mexiko-stadt

Jáuregui, E., Klaus, D. y W. Lauer. (1981). Una Primera estimación del transporte de SO_2 sobre la Ciudad de México. *Geofísica Internacional, 20*(1), 55-79. https://doi.org/10.22201/igeof.00167169p.1981.20.1.2169

Jáuregui, E. y Luyando, E. (1992). Patrones de flujo del aire superficial y su relación con el transporte de contaminantes en el Valle de México. *Boletín del Instituto de Geografía-UNAM*, (24), 51-78. https://doi.org/10.14350/rig.59008

Jáuregui, E. y Luyando, E. (1998). Long-term association between pan evaporation y the urban heat island in Mexico City. *Atmósfera, 11*(1), 45-60. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8425

Jáuregui, E. y Luyando, E. (1999). Global radiation attenuation by air pollution and its effects on the thermal climate in Mexico City. *International Journal of Climatology,* (19), 683-694. https://doi.org/10.1002/(SICI)1097-0088((1999)05)19:6<683::AID-JOC389>3.0.CO;2-8

Jáuregui, E. y Romales, E. (1996). Urban effects on convective precipitation in Mexico City. *Atmospheric Environment*, *30*(20), 3383-3389. https://doi.org/10.1016/1352-2310(96)00041-6

Jáuregui, E. y Soto, C. (1967). Wet-bulb temperature and discomfort index areal distribution in Mexico. *International Journal of Biometeorology, 11*(1), 21-28. https://doi.org/10.1007/BF01424271

Jáuregui, E. y Soto, C. (1975). La vertiente del Golfo de México: Algunos aspectos fisiográficos y climáticos. *Boletín del Instituto de Geografía-UNAM,* (6) 37-45. https://doi.org/10.14350/rig.58889

Jáuregui, E. y Tejeda, A. (1997). Urban–rural humidity contrasts in Mexico City, International Journal of Climatology, *17*(2), 187-196. https://doi.org/10.1002/(SICI)1097-0088(199702)17:2<187:AID-JOC114>3.0.CO;2-P

Jáuregui, E. y Tejeda, A. (2001). A scenario of bioclimatic conditions in Mexico City for CO2 doubling. *Atmósfera, 14*(3), 125-138. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8481

Jáuregui, E. y Vidal-Bello, J. (1981). Aspectos de la climatología del estado de México, *Boletín del Instituto de Geografía–UNAM,* (11), 21-54. https://doi.org/10.14350/rig.58935

Jáuregui, E., Valdovinos, M. A. y Rodríguez, J. M. (1980). Atmospheric diffusion characteristics at a coastal site in the tropics. *Geofísica Internacional, 19*(3), 259–268. http://revistagi.geofisica.unam.mx/index.php/RGI/article/download/1322/1496/1490

Jáuregui, E. y Zitácuaro, I. (1995). El impacto de los ciclones tropicales del Golfo de México en el estado de Veracruz. *La Ciencia y el Hombre, 7*(21), 75-120. https://cdigital.uv.mx/handle/123456789/5331

Klaus, D. y Jáuregui, E. (1975). Variaciones seculares de la circulación general y su relación con la sequía del norte de México. *Recursos Hidráulicos, 4*(4), 580-594. http://geoprodig.cnrs.fr/items/show/118802

Klaus, D. y Jáuregui, E. (1979). Análisis espectral del bióxido de azufre en la Ciudad de México y su relación con algunos parámetros meteorológicos. *Geofísica Internacional, 18*(3), 263-308. https://doi.org/10.22201/igeof.00167169p.1979.18.3.940

Klaus, D., Jáuregui E., y Lauer, W. (1983). Stadbedingte Niederschlagseffekte im Grossraum von Mexiko City. *Arch. Met. Geoph. Biocl. Ser. B*, *33*(3), 275-288.

Klaus, D., Jáuregui, E., Poth, A., Stein G., y Voss, M. (1999). Regular circulation structures in the tropical basin of Mexico City as a consequence of the urban heat island effect. *Erkunde, 53*(3), 231-243. http://www.jstor.org/stable/25647174

Klaus, D., Lauer, W. y Jáuregui, E. (1988). Schadstoffbelastung und Stadtklima in Mexiko-Stadt. Mitteilungen Deutsche Meteorologische Gesellschaft, (vol. 4, pp. 23-28). Akademie der Wissenschaften und der Literatur in Mainz. https://katalog.slub-dresden.de/id/0-129510106

Klaus, D., Poth, A., Voss, M. y Jáuregui, E. (2001). Ozone distributions in Mexico City using principal component analysis and its relation to meteorological parameters, *Atmósfera, 14*(4). 171-188. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8484

Lemus-Flores, S. (2016). *Isla de calor en la Ciudad de Puebla.* Tesis de Licenciatura en Geografía, UNAM. https://ru.dgb.unam.mx/handle/20.500.14330/TES01000751268

Lemus, L. y Gay, C. (1988). Temperature, precipitation variations and local effects Aguascalientes 1921-1985. *Atmósfera, 1*(1), 39-44. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8267

Lino, J. J. (2019). *Detección y caracterización espacial de la isla urbana de calor en la zona periferia de la ciudad de Xalapa en el municipio de Emiliano Zapata, Veracruz.* Tesis de Licenciatura en Geografía, Universidad Veracruzana.

López-García, A. R. (2018). Modelación espacial del riesgo por calor extremo en el Área Metropolitana de Guadalajara, México. *Revista Iberoamericana de Ciencias, 5*(5), 52-63. http://www.reibci.org/publicados/2018/oct/3100104.pdf

López-González, F. M., Navarro-Navarro, L. A., Díaz-Cervantes, R. E. y Navarro-Estupiñán, J. (2021). Vegetation cover and urban heat islands/oases distribution in Hermosillo City, Sonora. *International Journal of Borders, Territories and Regions, 33*(6). https://doi.org/10.33679/rfn.v1i1.2088

Luna-González, E. (1997). *Simulación del clima termal y la calidad del aire del Valle de México, usando un modelo meteorológico no hidrostático*. Tesis de maestría. Facultad de Ingeniería. UNAM.

Luyando-López, E., Tejeda, A. y Jitrik, O. (2018). Ponderación de la isla de calor en la zona metropolitana de la Ciudad de México por extensión y población, y su comparación con el calentamiento esperado para mediados del siglo XXI. En Santillán, N. y R. García-Cueto. *Ambiente urbano 2050* (pp. 49-68). Universidad Autónoma de Baja California.

Martínez-Arroyo, A. y Jáuregui, E. (2000). On the environmental role of urban lakes in Mexico City. *Urban Ecosystems,* (4), 145-166. https://doi.org/10.1023/A:1011355110475

Medina-Acosta, I. L., Villanueva-Solís, J. y Quiroa-Herrera, J. A. (2019). Cambio climático urbano y su impacto en la vivienda de Torreón. *Revista de divulgación científica, CienciaCierta*, (57), 37-41. http://www.cienciacierta.uadec.mx/2019/01/10/cambio-climatico-urbano-y-su-impacto-en-la-vivienda-de-torreon/

Méndez-Astudillo J., Caetano E. y Pereyra-Castro, K. (2022). Synergy between the Urban Heat Island and the Urban Pollution Island in Mexico City during the Dry Season. *Aerosol and Air Quality Research, 22*(8), 1-16. https://doi.org/10.4209/aaqr.210278

Méndez-Romero, E. A. (2016). *Alteraciones térmicas derivadas de la urbanización en la ciudad de Xalapa, Veracruz. Análisis espacial y temporal: 1982-2015.* Tesis de Maestría, El Colegio de Veracruz.

Mercado-Maldonado, L. (2022). Mitigación y adaptación al efecto de isla de calor urbana de clima cálido seco. El caso de Hermosillo, Sonora. *Vivienda y Comunidades Sustentables, 6*(11), 85-110. https://doi.org/10.32870/rvcs.v0i11.187

Mercado, L. y Marincic, I. (2017). Morfología de isla de calor urbana en Hermosillo, Sonora y su aporte hacia una ciudad sustentable. *Revista de Ciencias Biológicas y de la Salud, 19*(E3), 27-33. https://www.redalyc.org/articulo.oa?id=672971095010

Morales-Méndez C. C., Madrigal-Uribe- D. y González-Becerril, L. A. (2007). Isla de calor en Toluca, México. *Ciencia ergo-sum, 14*(3), 307-316. https://cienciaergosum.uaemex.mx/article/view/7150

Moreno y Anda, M. (1895). Comparación de los climas de México y Tacubaya. *Memorias de la Sociedad Científica "Antonio Alzate"* (tomo 10, 1895-1896) (pp. 397-407). https://memoricamexico.gob.mx/es/memorica/temas?ctId=7&cId=ODA2YjRhYmQtNzhlMi00YmU5LTgyNzAtYzM0NzRmNmFhZTVk&cd=false

Navarro-Tec, S., Orozco-del Castillo, M. G., Valdiviezo-Navarro, J. C., Ordaz-Bencomo, D. R., Moreno-Sabido, M. R. y Bermejo-Sabbagh, C. (2018). Análisis del crecimiento urbano y su relación con el incremento de temperaturas en la ciudad de Mérida utilizando imágenes satelitales. *Research in Computing Sciences, 147*(7), 258-294. http://dx.doi.org/10.13053/rcs-147-7-22

Noh-Abarca, K. M., Fernández, C., Sánchez, A. y Teutli, M. (2019). Evaluation of urban heat island for Puebla

City, Mexico. *Sustainable Development and Planning, 217*, 867-879. 10.2495/SDP180731

Ojeda, M. M., Tejeda, A., Mahe, M. y Sánchez, S. (1993). Análisis preliminar de las tendencias climáticas en tres localidades del estado de Veracruz, y sus posibles causas, Investigaciones Geográficas, *Boletín del Instituto de Geografía de la UNAM,* (2), 49-68. https://doi.org/10.14350/rig.59020

Oke, T. R., Mills G., Christen A. y Voogt, J. A. (2017). *Urban climates*. Cambridge University Press. https://doi.org/10.1017/9781139016476

Oke, T. R., Spronken-Smith, R. A., Jáuregui, E. y Grimmond, C. S. (1999). The energy balance of central Mexico City during the dry season. *Atmospheric Environment,* (33), 3919-3930. https://doi.org/10.1016/S1352-2310(99)00134-X

Oke, T. R., Zeuner, G. y Jáuregui, E. (1992). The surface energy balance in Mexico City. *Atmospheric Environment*, *26B*(4), 433-444. https://doi.org/10.1016/0957-1272(92)90050-3

OMMAC. (1988). *Memorias del III Congreso Nacional y III Congreso Iberoamericano de Meteorología. México, D.F., 14 al 18 de noviembre*. Organización Mexicana de Meteorólogos, A.C.

OMM y OMMAC. (1990). *Memorias del Primer Simposio Internacional sobre Contaminación del Aire y Clima Urbano*. Guadalajara, Jalisco, 19 al 22 de noviembre. Organización Meteorológica Mundial y Organización Mexicana de Meteorólogos, A.C.

Palafox, E. B., López, J. O., Hernández, J. L. y Hernández, H. (2021). Impact of urban land-cover changes on the spatial-temporal land surface temperature in a tropical City of Mexico. *International Journal of Geo-Information, 10*(2), 76. https://doi.org/10.3390/ijgi10020076

Pozos, B. y Barradas, V. L. (1988). Evolución de la temperatura de la región sur de la Ciudad de México debido a la urbanización. *Memorias del III Congreso Interamericano de Meteorología y III Congreso Mexicano de Meteorología* (pp. 157-159).

Riquelme, D. (1968). Microclimas del área metropolitana de la Ciudad de México. *Anuario de Geografía,* (8), 103-105.

Rivera-Rivera, A. L. (2012). *Urban Heat Islands in Monterrey, Mexico, using remote sensing imagery and geographic information systems analysis*. Tesis de maestría, División de Ingeniería y Arquitectura. Instituto Tecnológico y de Estudios Superiores de Monterrey. https://repositorio.tec.mx/handle/11285/571584

Rivera, E., Antonio, X., Origel, G., Sarricolea, P. y Adame, S. (2017). Spatiotemporal analysis of the atmospheric and surface urban heat islands of the Metropolitan Area of Toluca, Mexico. *Environmental Earth Sciences,* (76), 225. http://hdl.handle.net/20.500.11799/68533

Romero-Dávila, S., Méndez, C. C. M., y Némiga, X. A. (2011). Identificación de las islas de calor de verano e invierno en la ciudad de Toluca, México. *Revista de climatología,* (11), 1-10. https://climatol.eu/reclim/reclim11a.pdf

Rosas-Lusett, M. A. (2019). Islas de calor en la zona conurbada del Río Pánuco. *Architecture, City and Environment*, *13*(39), 63-74. http://dx.doi.org/10.5821/ace.13.39.5359

Rosas-Lusett, M. A., Bartorila, M. A. y Ocón, S. (2016). Laguna del Carpintero, regulador climático en el área urbana de Tampico, Tamaulipas, México. *Legado de Arquitectura y Diseño,* (20), 113-124. https://legadodearquitecturaydiseno.uaemex.mx/article/view/4765

Rosas, I., Belmont R. y Jáuregui, E. (1995). Seasonal variation of atmospheric lead levels in three sites in Mexico City. *Atmósfera, 8*(4), 157-168. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8393

Salas-Esparza, M. G y Herrera-Sosa, L. C. (2017). La vegetación como sistema de control para las islas de calor urbano en Ciudad Juárez, Chihuhua. *Revista Hábitat Sustentable,* (7), 14-23. https://doi.org/10.22320/07190700.2017.07.01.02

Sánchez-Hernández, A., Cruz, M. A. y Teutli, M. (2019). Valoración ambiental del centro histórico de Atlixco, Puebla. R*egiones y Desarrollo Sustentable, 19*(37), 151-168. http://coltlax.edu.mx/openj/index.php/ReyDS/article/view/91

Serrano-Juárez, J. D. (2023). Ernesto Jáuregui Ostos (1923-2014), punta de lanza de la climatología en el Instituto de Geografía de la UNAM. *Investigaciones Geográficas,* (112). e60828. DOI: https://doi.org/10.14350/rig.60828.

Serricolea, P., Smith, P., Romero-Aravena, H., Serrano-Notivoli, R., Fuentealba, M. y Meseguer-Ruiz, O. (2022). Socioeconomic inequalities and the surface heat island distribution in Santiago, Chile. *Science of the Total Environment, 1*(822), 155152. 10.1016/j.scitotenv.2022.155152

Soto, C. y Jáuregui, E. (1965). *Isotermas extremas e índice de aridez en la República Mexicana*. Instituto de Geografía-UNAM. Dirección General de Publicaciones-UNAM.

Soto, C. y Jáuregui, E. (1968). *Cartografía de elementos bioclimáticos en la República Mexicana.* Instituto de Geografía-UNAM, Dirección General de Publicaciones-UNAM.

Soto, C. y Jáuregui, E. (1970). Frecuencia y distribución de algunos elementos del clima del estado de Querétaro. *Boletín del Instituto de Geografía-UNAM,* (3), 103-139. https://doi.org/10.14350/rig.58851

Tejeda, A. y Acevedo, F. (1990). Alteraciones climáticas por la urbanización en Xalapa, Ver. *La Ciencia y el Hombre,* (6), 37-48. https://cdigital.uv.mx/handle/123456789/5077

Tejeda, A. y Jáuregui, E. (2005). Surface energy balance measurements in the Mexico https://www.revistascca.unam.mx/atm/index.php/atm/indexCity region: a review. *Atmósfera, 18*(2), 1-23. https://www.revistascca.unam.mx/atm/index.php/atm/article/view/8535

Tejeda, A., Méndez-Pérez, I. R. y Cruz-Pastrana, D. A. (2021). Domestic Electricity Consumption in Mexican Metropolitan Areas under Climate Change Scenarios. *Atmósfera, 35*(3), 449-465. https://doi.org/10.20937/ATM.52902

Tereshchenko, I. E. y Filonov, A. E. (2001). Air temperature fluctuations in Guadalajara, Mexico, from 1926 to 1994 in relation to urban growth. *International Journal of Climatology,* (21), 483-494. https://doi.org/10.1002/joc.602

Torres-Quintana J. L. (2020). *Estrategias de mitigación de Islas de calor urbano en Toluca*. Tesis doctoral, Universidad Autónoma de México.

Tzoni-Barranco, M. C. (2015). *Áreas verdes urbanas: una alternativa para mitigar la isla de calor en la ciudad de Puebla*. Tesis de Maestría en Urbanismo, UNAM.

Vargas, N. y Magaña, V. (2020). Climatic risk in the Mexico City metropolitan area due to urbanization. *Urban Climate,* (33). https://doi.org/10.1016/j.uclim.2020.100644

Vidal, J. y Jáuregui, E. (1991). Evolución de la isla de calor en Toluca, Méx. *Memoria del III Encuentro de Geografía de América Latina. INEGI-UAEM*. Observatorio Geográfico América Latina.

Villanueva-Solís, J., Quiroa-Herrera, J. A. y González-Calderón, A. J. (2022). Vulnerabilidad climática urbana: isla de calor y marginación. El caso de Torreón, Coahuila. *Hatso Hnini Revista de Investigación de Paisaje y Espacio Construido, 1*(2). https://revistahatsohnini.com.mx/index.php/inicio/article/view/20

Villanueva-Solís, J., Ranfla-González, A. y Quintanilla-Montoya, A. L. (2013). Isla de calor urbana: modelación dinámica y evaluación de medidas de mitigación en ciudades de clima árido extremo. *Información Tecnológica, 24*(1), 15-24. http://dx.doi.org/10.4067/S0718-07642013000100003

WMO. (1986). *Urban Climatology and its applications with special regard to tropical areas. Proceedings of the technical conference organized by the World Meteorological Organization and co-sponsored by the World Health Organization*. (pp. 26-30). WMO 652.

Zavaleta-Palacios, M., Díaz-Nigenda, E., Vázquez-Morales, W., Morales-Iglesias, H. y Lima, G. N. (2020). Urbanización y su relación con la isla de calor en Tuxtla Gutiérrez, Chiapas. *Ecosistemas y Recursos Agropecuarios, 7*(2), e2485. https://doi.org/10.19136/era.a7n2.2485

Appendix 1. Publications addressing the UHI in México during 2001–2022 by city and approach or application.

City*	Approach or application						
	Atmospheric UHI	Surface UHI	Detection and climatic trends	Land use or UHI mitigation	UHI-society relationship	Urban planning	Technology (remote sensing or computer modeling)
Atlixco	Sánchez-Hernández *et al.* (2019)		Sánchez-Hernández *et al.* (2019)				
CDMX	Jáuregui y Heres (2008) Estrada *et al.* (2009) Cui y De Foy (2012) Ballinas y Barradas (2016) Luyando-López *et al.* (2018) Vargas y Magaña (2020) Méndez-Astudillo *et al.* (2022) Araiza-Olivares (2022)	Cui y De Foy (2012) Barrera-Alarcón *et al.* (2022)	Estrada *et al.* (2009) Araiza-Olivares (2022)	Jáuregui y Heres (2008) Cui y De Foy (2012) Ballinas y Barradas (2016)	Vargas y Magaña (2020) Méndez-Astudillo *et al.* (2022)	Cui y De Foy (2012) Luyando-López *et al.* (2018) Barrera-Alarcón *et al.* (2022)	Ballinas y Barradas (2016)
Ciudad Juárez	Contreras-Cardosa *et al.* (2008) Salas-Esparza y Herrera-Sosa (2017)		Contreras-Cardosa *et al.* (2008)	Salas-Esparza y Herrera-Sosa (2017)		Salas-Esparza y Herrera-Sosa (2017)	
Colima		Galindo (2010), Haro-Carbajal (2013)	Galindo (2010) Haro-Carbajal (2013)	Haro-Carbajal (2013)			Galindo (2010) Haro-Carbajal (2013)

Appendix 1. Continue...

City*	Approach or application						
	Atmospheric UHI	Surface UHI	Detection and climatic trends	Land use or UHI mitigation	UHI-society relationship	Urban planning	Technology (remote sensing or computer modeling)
Guadalajara	Tereshchenko y Filonov (2001) López-García (2018) Davydova y Alamilla (2019)	Galindo (2009) Galindo (2010) Hernández (2010) Galindo-Estrada (2014)	Tereshchenko y Filonov (2001) Galindo (2010) Hernández (2010) Galindo-Estrada (2014) Davydova y Alamilla (2019)		Davydova y Alamilla (2019)	López-García (2018)	Galindo (2009) Galindo (2010) Hernández (2010) Galindo-Estrada (2014) López-García (2018)
Hermosillo	Mercado y Marincic (2017) Mercado-Maldonado (2022)	López-González *et al*. (2021)		Mercado y Marincic (2017) López-González *et al*. (2021)	Mercado y Marincic (2017)	Mercado-Maldonado (2022)	López-González *et al*. (2021)
Mérida	Biles y Lemberg (2020)	Navarro-Tec *et al*. (2018) Palafox-Juárez *et al*. (2021)	Navarro-Tec *et al*. (2018) Biles y Lemberg (2020)			Palafox-Juárez *et al*. (2021)	Navarro-Tec *et al*. (2018)
Mexicali	García-Cueto *et al*. (2007) García-Cueto *et al*. (2009) Casillas *et al*. (2014)	Villanueva-Solís *et al*. (2013)	García-Cueto *et al*. (2007) Casillas *et al*. (2014)	García-Cueto *et al*. (2009) Villanueva-Solís *et al*. (2013)		García-Cueto *et al*. (2007)	García-Cueto *et al*. (2009) Villanueva-Solís *et al*. (2013)
Monterrey		Rivera-Rivera (2012)				Rivera-Rivera (2012)	

Appendix 1. Continue.

City*	Approach or application						
	Atmospheric UHI	Surface UHI	Detection and climatic trends	Land use or UHI mitigation	UHI-society relationship	Urban planning	Technology (remote sensing or computer modeling)
Poza Rica	González-Rocha (2013)			González-Rocha (2013)			
Puebla	Tzoni-Barranco (2015) Lemus-Flores (2016) Balderas-Romero (2018) Noh-Abarca *et al.* (2019) Gómez-Martínez *et al.* (2021)	Balderas-Romero (2018)	Balderas-Romero (2018)	Balderas-Romero (2018) Noh-Abarca *et al.* (2019) Gómez-Martínez et al. (2021)	Tzoni-Barranco (2015) Lemus-Flores (2016) Gómez-Martínez *et al.* (2021)	Noh-Abarca *et al.* (2019)	
Querétaro	Colunga *et al.* (2015) Godínez-Tovar y López-Gutiérrez (2018)			Colunga *et al.* (2015) Godínez-Tovar y López-Gutiérrez (2018)		Colunga *et al.* (2015) Godínez-Tovar y López-Gutiérrez (2018)	
San Francisco, Campeche	Canul-Turriza *et al.* (2020)		Canul-Turriza *et al.* (2020)	Canul-Turriza *et al.* (2020)			

Appendix 1. Continue..

City*	Approach or application						
	Atmospheric UHI	Surface UHI	Detection and climatic trends	Land use or UHI mitigation	UHI-society relationship	Urban planning	Technology (remote sensing or computer modeling)
Tampico o conurbación alrededor del río Pánuco	Evans y De Schiller (2005) Fuentes-Pérez (2014) Rosas-Lusett *et al.* (2016) Rosas-Lusett (2019)		Evans y De Schiller (2005) Fuentes-Pérez (2014) Rosas-Lusett (2019)	Rosas-Lusett *et al.* (2016) Rosas-Lusett (2019)	Fuentes-Pérez (2014)	Evans y De Schiller (2005)	
Toluca	Morales-Méndez *et al.* (2007) Romero-Dávila *et al.* (2011) Rivera *et al.* (2017) Torres-Quintana (2020)		Morales-Méndez *et al.* (2007) Romero-Dávila *et al.* (2011) Rivera *et al.* (2017)	Torres-Quintana (2020)			Rivera *et al.* (2017)
Torreón	Flores *et al.* (2018) Medina-Acosta *et al.* (2019) Villanueva-Solís *et al.* (2022)			Flores *et al.* (2018) Medina-Acosta *et al.* (2019)		Medina-Acosta *et al.* (2019) Villanueva-Solís *et al.* (2022)	
Tuxtla Gutiérrez	Zavaleta-Palacios *et al.* (2020)		Zavaleta-Palacios *et al.* (2020)			Zavaleta-Palacios *et al.* (2020)	

Appendix 1. Continue..

City*	Approach or application						
	Atmospheric UHI	Surface UHI	Detection and climatic trends	Land use or UHI mitigation	UHI-society relationship	Urban planning	Technology (remote sensing or computer modeling)
Xalapa	Cervantes *et al.* (2001) Méndez-Romero (2016) Lino (2019)		Méndez-Romero (2016) Lino (2019)		Cervantes *et al.* (2001)	Cervantes *et al.* (2001)	
Veracruz	Baca-Cruz (2014)						Grajeda *et al.* (2018)
Otras varias	García-Cueto *et al.* (2021)		García-Cueto *et al.* (2021)	Tejeda *et al.* (2022)	Tejeda *et al.* (2022)	García-Cueto *et al.* (2021)	

In this table, the term "city" is used generically to refer to cities, urban areas, metropolitan zones, and similar terms.