frontiers | Frontiers in Climate

TYPE Opinion
PUBLISHED 18 September 2024
DOI 10.3389/fclim.2024.1449710

OPEN ACCESS

EDITED BY
Bao-Jie He,
Chongqing University, China

REVIEWED BY
Romaric C. Odoulami,
University of Cape Town, South Africa

*CORRESPONDENCE
Tereza Cavazos
✉ tcavazos@cicese.mx

RECEIVED 15 June 2024
ACCEPTED 12 August 2024
PUBLISHED 18 September 2024

CITATION
Cavazos T (2024) Spring 2024: unprecedented atmospheric heatwaves in Mexico.
Front. Clim. 6:1449710.
doi: 10.3389/fclim.2024.1449710

Spring 2024: unprecedented atmospheric heatwaves in Mexico

Tereza Cavazos *

Department of Physical Oceanography, Center for Scientific Research and Higher Education of Ensenada (CICESE), Ensenada, Baja California, Mexico

KEYWORDS

heat waves, Mexico, droughts, climate change, impacts, anticyclone anomaly, subtropical highs, warm oceans

1 Introduction

In the spring of 2024, most of Mexico was under a mid-tropospheric heat dome that broke temperature records (between 30°C and 45°C) in many cities with devastating impacts on the population and ecosystems.

Between 13 April and early June 2024, most of Mexico experienced three unprecedented long-lasting heatwaves that broke temperature records (between 30°C and 45°C) in more than a dozen cities across the country, including Mexico City, which has a temperate climate. The city has the longest temperature records in Mexico, which began in 1877 in the National Astronomical Observatory of Tacubaya. According to the National Weather Service, the maximum temperature in Mexico City was broken several times during this spring, reaching a new record of 33.8°C on June 3. The three heatwaves have affected the wellbeing of the population and ecosystems and created a chain of effects that spanned from human and animal deaths to problems of urban water availability, power energy outages, discomfort, and health issues. The impacts were exacerbated by the current droughts in Mexico, drying dams, forest fires, and the seasonal drying and warming conditions typical before the summer rainy season.

Mexico City, the fifth largest city in the world with an estimated population of 22 million, was near to reaching water "day zero" as one of its main reservoir supply systems (the Cutzamala) was running dry. Lake Patzcuaro, a touristic destination in the central state of Michoacan, dried out this spring; this affected the local population as fisheries and tourism are their main economic activities. Drying and warmer-than-usual conditions also affect the export of binational waters in the US–Mexico border region. Mexico owes water to the United States from the Rio Grande/Rio Bravo, but the United States also owes water to Mexico from the Colorado River basin. According to the North American Drought Monitor, both sides of the border were under severe droughts this spring, but large areas of Mexico were under (stronger) exceptional drought since last year. Compound events of droughts with the recent heatwaves feed backed to each other, enhancing their negative impacts.

On June 5, Mexico's Health Ministry (Secretaría de Salud, 2024) reported 1937 heat-related cases and 90 deaths due to heat strokes and dehydration during the three heatwaves. Each event lasted more than a week, and their impacts have been reported in many national and international news, including the speech of the United Nations Secretary-General António Guterres in his message on World Environmental Day (June 5), who called for urgent action, as record-breaking temperatures were scorching several cities around the world. Heat stress poses a major threat to human health and increases mortality risk, particularly in urban areas

(Tuholske et al., 2021; García-Martínez and Bollasina, 2021; Vargas and Magaña, 2020) and regions under the influence of large humidity (Raymond et al., 2020; Russo et al., 2017).

As the oceans also continue to warm more than ever recorded (Cheng et al., 2024), such as the Gulf of Mexico and the North Atlantic tropical cyclone development region, near the Caribbean Sea (Figure 1A), and with the upcoming La Niña event, the country was anxiously expecting the rains based on NOAA's forecast above normal occurrence of hurricanes on the Atlantic basin, a season that began the 1st of June. Fresh air was much needed, but no tropical cyclone was formed as of June 6, and the region continued under a semi-permanent anticyclone since mid-April. Air conditioning was not enough in many cities under heat island conditions, where the type of housing and building materials are not adapted to extreme heatwaves lasting several continuous days and nights, and with problems of energy supply and water availability. However, for most of the population air conditioning is not even an option.

Relative humidity was below 40% from mid-April to May, and in large parts of Mexico, temperatures were 3°C−5°C above average (Figure 1B). The only regions that escaped from the extreme effects of these anomalous heatwaves were the Pacific coasts of Baja California and California, which were under the influence of the cold California current (Figure 1A). According to the Climate Shift Index (a climate change attribution index), the temperatures during this period in Mexico, southern Texas, southern Florida, the Caribbean Islands, Central America, and northern South America were at least 4 to 5 times more likely due to climate change. A new report of the World Weather Attribution stated that 5-day maximum temperatures during the third heatwave (end of May and beginning of June) are currently expected to occur every 15 years, while at the beginning of this century were expected every 60 years (Pinto et al., 2024). This is clearly a large-scale unprecedented event.

2 Discussion

Last year was a year of temperature breaking records around the globe. Surface air temperature warmed almost 1.5°C above the 1850 pre-industrial level (Copernicus, 2024), a threshold expected to be reached by the mid or late 2030s according to the Intergovernmental Panel on Climate Change (IPCC, 2018). In July 2023, the UN (2023) Secretary-General António Guterres said "the era of global boiling has arrived." Possibly this statement is a bit extreme, but for the level of adaptation (or maladaptation) that most populations have, it is partially true. Moreover, the unprecedented warming of the oceans produced marine heatwaves in parts of the Gulf of Mexico, the Caribbean, the Mediterranean, and the North Pacific (Copernicus, 2024). In 2024, the anomalous ocean warming has continued, except for the eastern Equatorial Pacific where the cold waters related to the La Niña event are already evident in Figure 1A, and along the California Current off the coasts of California and Baja California which are further related to a strong North Pacific subtropical anticyclone (Figure 1D). The combined effect of the cold California current and the warm air aloft, due to the North Pacific anticyclone, resulted in a thermal inversion that favors the formation of low-level marine stratus clouds and fog. These mechanisms, which are common in spring and early summer, prevented the arrival of hot weather to the coastal regions of California and Baja California in spring and early summer.

Apart from the background warming of most of the oceans and the continents, during the spring of 2024, the tropical and subtropical regions surrounding Mexico were under the remaining influence of El Niño conditions. The westerly winds of the subtropical jet stream had not migrated north in early June, as it is typical in spring. However, the jet stream was 12 m/s stronger than average in northern Mexico (Figure 1C); consequently, the wind shear was also stronger than average, a condition that during the summers of El Niño events is an important ingredient that reduces the probability of tropical cyclone and hurricane formation (Martinez-Sanchez and Cavazos, 2014). Therefore, this westerly wind anomaly needs to debilitate (with a northward or northwestward migration of the jet stream) for tropical cyclones, and easterly waves, once formed, can enter the Gulf of Mexico.

During spring, surface warming in eastern Mexico and over the Gulf of Mexico and the Caribbean produced an anomalous low pressure in the lower troposphere (below 850 hPa; Figure 1D). The North Atlantic subtropical high (NASH) was weaker than normal, further reducing the entrance of easterly winds to the Gulf of Mexico, which exacerbated the lack of fresh air into the region. Most importantly, in the mid-troposphere and upper troposphere, an anticyclone and sinking air produced adiabatic heating, clear skies, and more entrance of solar radiation, which warmed up and dried out the surface over the continent. A heat dome-like dominated central and southern Mexico from mid-April to May due to the presence of a semi-permanent anticyclone (Figures 1C, E). Heatwaves in other regions of the world have been also associated with upper level anticyclonic stationary waves and dry soils (Chen et al., 2023). Some studies have suggested that the NASH could intensify and move westward during the summer under warming scenarios due to an increased land-sea thermal contrast (Li et al., 2012; Cherchi et al., 2018); this would be the case when the continent is warmer than the ocean, but on intraseasonal timescales when the ocean is warmer or warms up at the same rate as the continent, the NASH could weaken, like this spring. The SST anomalies in the Gulf of Mexico and parts of the North Atlantic basin during the third heatwave were more than 2°C warmer than normal (Figure 1A).

Amid this extreme warming in the tropical and subtropical regions, the cold waters in the equatorial Pacific associated with La Niña condition are already evident, and the event is expected to be fully formed by the end of the summer. La Niña's atmospheric teleconnection tends to push the subtropical jet stream to the north weakening the vertical wind shear in the Gulf of Mexico; this condition commonly favors above-normal summer rains in Mexico, the Caribbean, and Central America because of regional convection and more frequent hurricanes. The summer rains were much expected in Mexico and in the whole region to alleviate the population with cool and humid air and with the precious water to fill rivers and dams and for the thirsty ecosystems. However, more extreme weather conditions may occur this summer, as intense hurricanes have been forecasted due to the anomalous warming

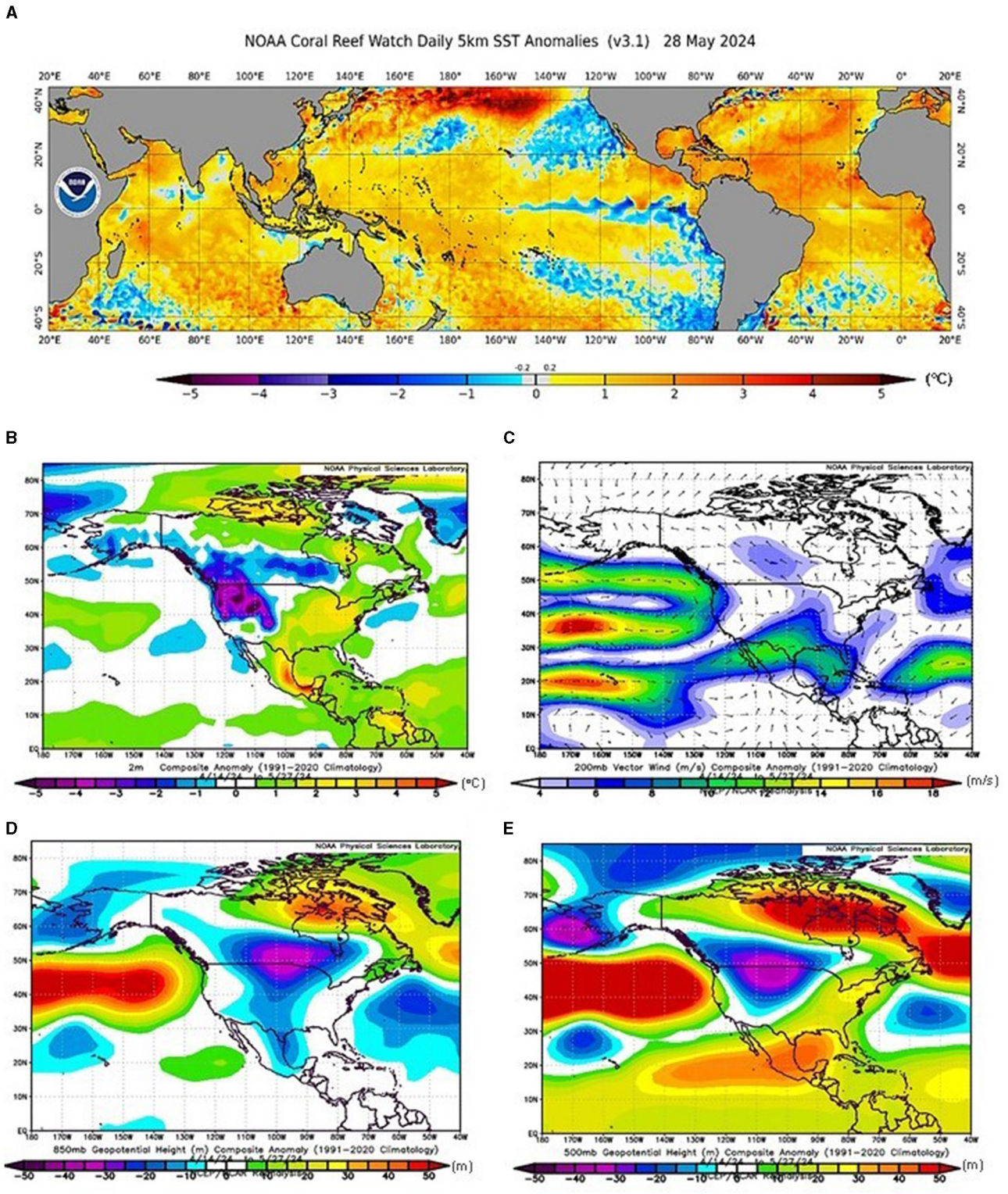

FIGURE 1
(A) Sea surface temperature anomalies (°C) for the week of 28 May 2024 during the third heat wave in Mexico. **(B–E)** Atmospheric anomalous conditions during the three heat waves in Mexico (14 April–27 May 2024). **(B)** Mean anomalies of 2 m temperature (°C); **(C)** mean anomaly of the vector wind (m/s) at the subtropical jet level (200 hPa); **(D, E)** geopotential height anomalies (m) at the 850 hPa and 500 hPa levels, respectively.

in the tropical North Atlantic basin and the arrival of the La Niña event. Indeed, the first tropical storm of the season occurred at the end of spring; tropical storm Alberto formed inside the anomalously warm waters of the Gulf of Mexico and produced large amounts of rainfall in eastern Mexico from 19 to 20 June, enough to fill out several dams in the region. Government officials from

several states agreed that ending the drought was a much larger benefit from the storm than other material damages.

3 Conclusion

This is the first time Mexico experiences and records the compounding impacts of several long-lasting extreme heatwaves and droughts in the twenty first century. This is just a taste of what can occur more often due to climate change; the future scenarios are already here. Thus, immediate action is needed to develop adaptation measures with a long-term vision; financial support should not be wasted on reactive measures in Mexico or in any other countries. However, adaptation actions to reduce climate risks need the support of transdisciplinary collaborations and different types of knowledge, local and international financial support, and political will (e.g., Cavazos et al., 2024). The role of scientist Claudia Sheinbaum, the first female Mexican President, who participated in the Intergovernmental Panel on Climate Change (IPCC) Reports, and her new Secretary of the Environment (SEMARNAT) Alicia Bárcena—former Executive Secretary of CEPAL, Economic Commission for Latin America and the Caribbean, are expected to strongly support and endorse these actions at municipal, state, and national levels for the wellbeing of the country.

Author contributions

TC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was supported by the Department of Physical Oceanography, CICESE.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Cavazos, T., Bettolli, M. L., Campbell, D., Sánchez Rodríguez, R. A., Mycoo, M., Arias, P. A., et al. (2024). Challenges for climate change adaptation in Latin America and the Caribbean region. *Front. Clim.* 6:1392033. doi: 10.3389/fclim.2024.1392033

Chen, Z., Lu, J., Chang, C. C., Lubis, S. W., and Leung, L. R. (2023). Projected increase in summer heat-dome-like stationary waves over Northwestern North America. *NPJ Clim. Atmos Sci.* 6:194. doi: 10.1038/s41612-023-00511-2

Cherchi, A., Ambrizzi, T., Behera, S., Freitas, A. C. V., Morioka, Y., and Zhou, T. (2018). The response of subtropical highs to climate change. *Curr. Clim. Change Rep.* 4, 371–382. doi: 10.1007/s40641-018-0114-1

Copernicus (2024). *Global climate highlights 2023*. Available at: https://climate.copernicus.eu/global-climate-highlights-2023 (accessed January 10, 2024).

IPCC (2018). "Summary for policymakers," in *Global Warming of 1.5°C.* eds. V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea and P. R. Shukla, et al. (Cambridge, UK and New York, NY, USA: Cambridge University Press), 3–24.

Li, W., Li, L., Ting, M., and Liu, Y. (2012). Intensification of Northern Hemisphere subtropical highs in a warming climate. *Nat. Geosci.* 5, 830–834. doi: 10.1038/ngeo1590

Martinez-Sanchez, J. N., and Cavazos, T. (2014). Eastern Tropical Pacific hurricane variability and landfalls on Mexican coasts. *Clim. Res.* 58, 221–234. doi: 10.3354/cr01192

Pinto, I., Barnes, C., Philip, S., Kew, S., Cerezo-Mota, R., Tannenbaum, A., et al. (2024). *Extreme heat killing more than 100 people in Mexico hotter and much more likely due to climate change*. Report of the World Weather Attribution.

Raymond, C., Matthews, T., and Horton, R. M. (2020). The emergence of heat and humidity too severe for human tolerance. *Sci. Adv.* 6:eaaw1838 doi: 10.1126/sciadv.aaw1838

Russo, S., Sillmann, J., and Sterl, A. (2017). Humid heat waves at different warming levels. *Sci. Rep.* 7:7477. doi: 10.1038/s41598-017-07536-7

Secretaría de Salud (2024). *Temperaturas naturales extremas (Temporada de calor 2024), Semana epidemiológica 22 (Información del 29 mayo – 5 junio 2024).* México. Available at: https://www.gob.mx/cms/uploads/attachment/file/920509/TNE_2024_SE22.pdf (accessed June 6, 2024).

UN (2023). *Hottest July ever signals 'era of global boiling has arrived' says UN chief. UN News*. Available at: https://news.un.org/en/story/2023/07/1139162 (accessed May 10, 2024).

Vargas, N., and Magaña, V. (2020). Warm spells and climate risk to human health in the Mexico City Metropolitan Area. *Weather Clim. Soc.* 12, 351–365. doi: 10.1175/WCAS-D-19-0096.1

Tuholske, C., Caylor, K., Funk, C., Verdin, A., Sweeney, S., Grace, K., et al. (2021). Global urban population exposure to extreme heat. *Proc. Natl. Acad. Sci. U.S.A.* 118:e2024792118. doi: 10.1073/pnas.2024792118

García-Martínez, I. M., and Bollasina, M. (2021). Identifying the evolving human imprint on heat wave trends over the United States and Mexico. *Environ. Res. Lett.* 16:094039. doi: 10.1088/1748-9326/ac1edb

Cheng, L., Abraham, J., Trenberth, K. E., Boyer, T., Mann, M. E., Zhu, J., et al. (2024). New Record Ocean temperatures and related climate indicators in 2023. *Adv. Atmos. Sci.* 41, 1068–1082. doi: 10.1007/s00376-024-3378-5