Sleepless Nights

Faster nighttime warming due to climate change is impacting sleep quality across the globe

INTRODUCTION

Global mean temperatures have risen by more than 1.3°C since 1850, and set a new record in 2023. The primary cause of this warming is rising levels of carbon dioxide in the atmosphere from burning coal, oil, and natural gas.

Nighttime temperatures have increased even more rapidly than daytime temperatures as the world heats up.

Hot nights make it harder for people to recover from the heat of the day, with wide-reaching and severe consequences. There is growing evidence that as nighttime temperatures rise, human sleep is being eroded around the world. A lack of quality sleep can have a range of associated impacts, including increasing the risk of many physical and mental health problems, impairing cognitive functioning, negatively affecting children's brain development, learning and school performance, and making workplace accidents more likely. Hot nights are also associated with increased mortality risks, with a study showing that the relative mortality risk on days with hot nights can be 50% higher than on days with non-hot nights. These climate-change-driven increases in nighttime temperatures have unequal impacts on sleep and health both within and between countries due to many factors including age, gender and access to air conditioning.

The purpose of this analysis is to analyze nighttime temperatures in the context of a warming global climate, with a focus on summer (December-February in the Southern Hemisphere, June-August in the Northern Hemisphere). To do this, we calculated the number of days where the nighttime temperature — the minimum temperature — exceeded 18°, 20°C, and 25°C. We also used the Climate Shift Index daily attribution system to quantify how climate change has influenced the number of uncomfortably hot nights. The Climate Shift Index system uses observed patterns of warming and 24 global climate models to estimate the nighttime temperature that would have occurred in a counterfactual climate without human-caused

climate change. The difference between the observed number and the counterfactual number gives the number of uncomfortable nights added by climate change. For this analysis, we focus on the average over the last 10 years — 2014-2023.

While our analysis is global, we conducted more detailed analysis in the United States, India, and the United Kingdom. In the U.S. and India, annual number of days above each threshold were calculated in cities with a population over 100,000. In the U.K., the city population threshold was reduced to 20,000. Additionally, the mean count was calculated for each subdivision and then county within the U.K. for each year.

The threshold 20°C was chosen due to the potential health and sleep impacts of nighttime temperatures exceeding this threshold. The Expert Team on Climate Change Detection and Indices (ETCCDI) defined Tropical Nights as when the daily minimum temperature exceeds 20°C and this threshold has been used by various meteorological agencies in Europe (including Spain, France, Switzerland, Germany, Ireland, U.K.). Additionally, the European Environment Agency's "Tropical Nights index" is defined as the annual number of days with a minimum night temperature of at least 20°C, causing physiological discomfort and impacting human health by preventing body temperature from cooling off during the night. In the U.S., the Centers for Disease Control and Prevention recommends keeping the room temperature between 18.3°C to 20°C (65 to 68°F) at night and the National Sleep Foundation suggests between 15.6°C to 19.4°C (60 to 67°F) is optimal.

Additional analysis was done at the 25°C threshold to account for countries with higher night-time temperatures (for example, tropical nights are defined as above 25°C in Japan) and due to the fact that other studies show that sleep quality deteriorates above this threshold. A recent study provides "the first planetary-scale evidence that warmer-than-average temperatures erode human sleep", and shows that nighttime minimum temperatures greater than 25°C increase the probability of getting less than seven hours of sleep by 3.5 percentage points compared with the estimated optimum minimum nighttime temperature. The World Health Organization also recommends the room temperature should be kept at 24°C during the night.

Studies specific to the U.K. indicate that a lower threshold may be relevant for countries that have a slightly cooler climate. Egton Medical Information Systems Group (EMIS) in the U.K. have suggested that the most comfortable bedroom temperature ranges between 15°C and 20°C, with temperatures above this associated with restlessness. The Sleep Charity in the U.K. defines a smaller range of comfortable temperatures for sleep between 16°C and 18°C. Thus, the analysis was repeated in the U.K. using 18°C.

RESULTS

1. Frequency of uncomfortable nighttime temperatures is increasing

1.1 Global

Every region considered had net warming during their respective summer season (Figure 1) that was influenced by climate change. On average (2018-2023), between 5 and 25 days above 20°C were added by climate change across the eastern U.S., southern Australia, the southern portion of South America, and western and eastern Asia. In other regions of the world such as southern Africa along with the northernmost portion of the continent, Spain, and northern Mexico, between 25 and 40 days were added. Meanwhile, larger changes of 40 days or more were observed in the southwestern US and Brazil. Over this time period, the average person on Earth experienced 4.8 additional days above 20°C as a result of higher nighttime temperatures induced by climate change.

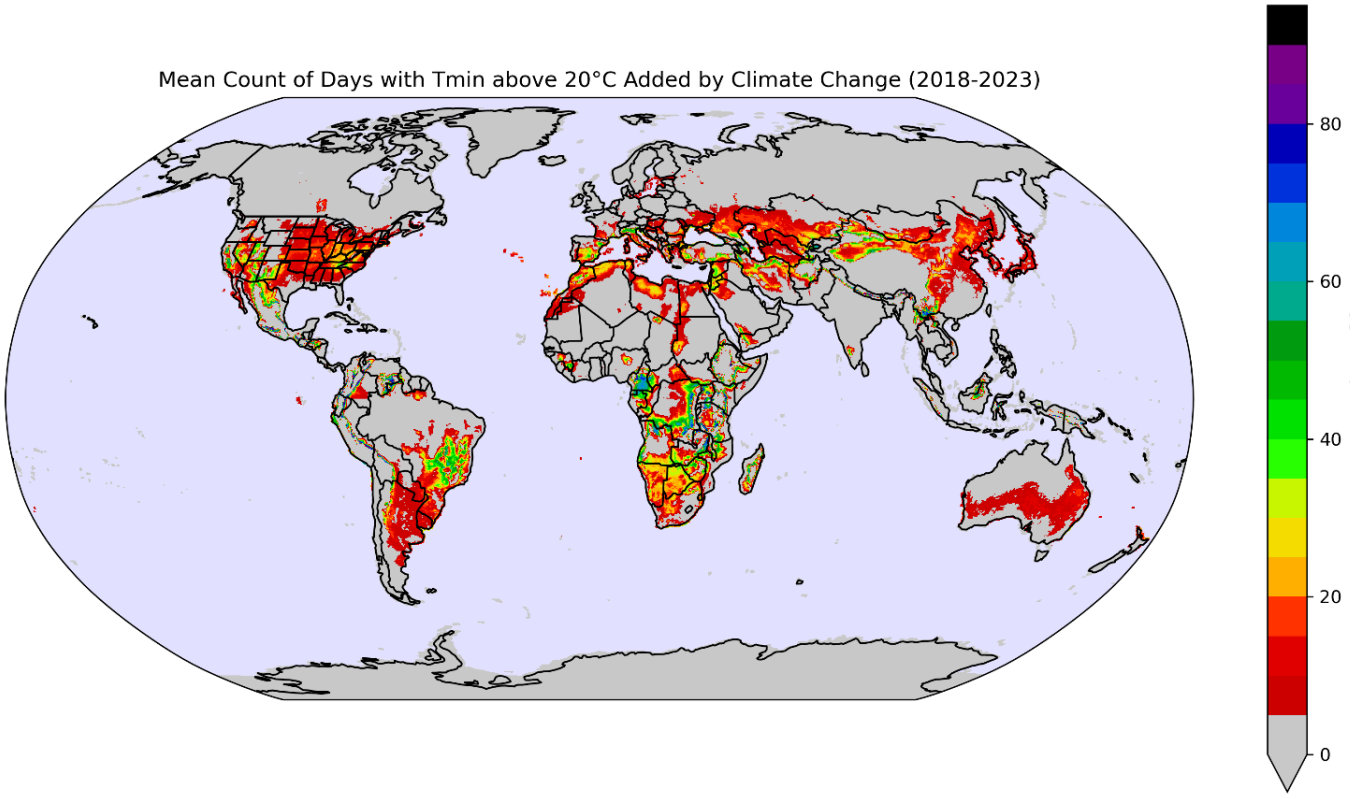

Figure 1. Average number of days with minimum nighttime temperatures above 20°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2018-2023.

Widespread changes were also observed in the number of days where the minimum temperature exceeded 25°C. In several northern African countries, Saudi Arabia, southeast Asia, and the southern and southeast US, climate change added 40 or more days of uncomfortable nighttime temperatures. Up to 20 days additional were observed in the eastern US, most of Australia, northwestern Africa, and other regions across the globe. The average person from 2018-2023 experienced an additional 11.5 days per year above 25°C.

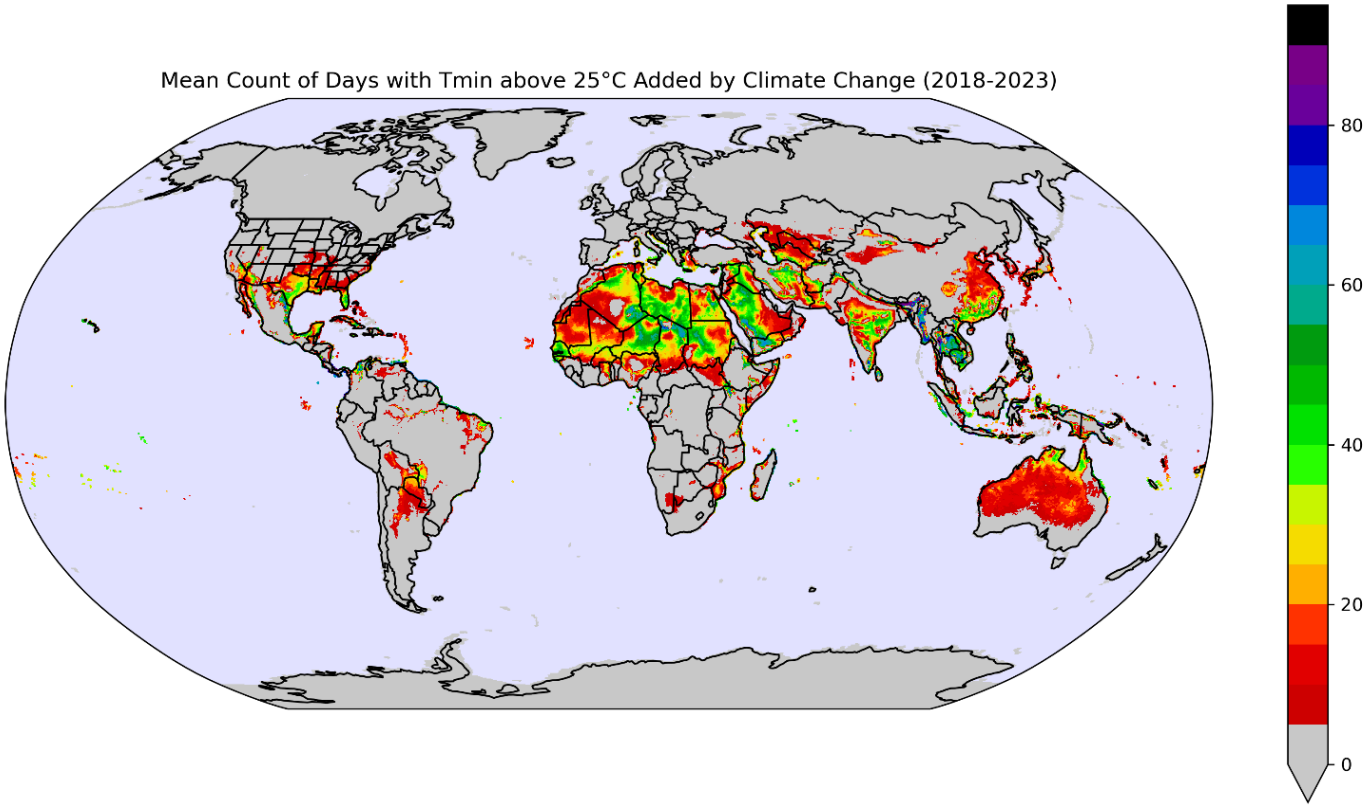

Figure 2. Average number of days with minimum nighttime temperatures above 25°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2018-2023.

1.2. United States

Most cities in the U.S. saw an average of at least 5 days where the minimum temperature exceeded 20°C (Figure 1). Nine of the top ten cities with the greatest number of days added by climate change where minimum temperatures exceed 20°C are in central and northern California. Merced, Clovis, Fresno, Visalia. Bakersfield, Redding, Chico, Turlock, and Yuba City all experienced an average of between 45 and 58 days above this threshold added by climate change. St. George, Utah holds the 10th spot, with an average of 41 days influenced by climate change. Climate change is making nights warmer even in cooler states. For example, every city evaluated in Wisconsin and Michigan had more than 10 days, with maximum exposure in Appleton, WI (16 days) and Muskegon, MI (23 days).

Many cities across the U.S. also saw a similar trend in the number of days added by climate change where the temperature exceeded 25°C (Figure 2). The top 24 cities in the U.S. with the highest number of days added by climate change were in Florida, Texas, Louisiana, Nevada, and Arizona, with between 40 and 53 additional days on average. Notable cities include Port St. Lucie, FL (53 days), Scottsdale, AZ (52 days), Laredo, TX (49 days), and North Las Vegas, NV (48 days). Other cities in the same five states, along with cities such as Mobile, Alabama, Gulfport, Mississippi, Honolulu, Hawaii, Charleston, South Carolina, Indio, California, and Virginia Beach, Virginia experienced an additional 20 to 40 days with this threshold due to climate change. Climate change added between 10 and 20 days to the number of nights where temperatures exceeded 25°C across many other cities in the U.S.

1.3. India

In both observations and in the counterfactual climate, the nighttime summer temperatures across India often exceed 20°C over the entire summer period (Figure 1). The cities that had the largest number of days where the minimum temperature exceeded 20°C are Gangtok, Darjeeling, Shimla, and Mysore, with an average of 54, 31, 30, and 26 days added by climate change, respectively. Between 15 and 22 days were added in Tumkur, Hassan, Bangalore, and Pathankot, while 2 to 7 added days were observed in Sopur, Srinagar, Mandya, DehraDun, Shimoga, Jammu, and Hindupur. The other cities analyzed did not observe any additional days above the threshold due to climate change, indicating that everyday in the summer season is above 20°C in the counterfactual and observed scenarios.

Meanwhile, climate change has had a greater influence on nighttime temperatures above 25°C. The cities most impacted are Jalpaiguri, Guwahatii, Silchar, Dibrugarh, Siliguri located in the states West Bengal and Assam, where between 80 and 86 days above the threshold were added by climate change, on average. Approximately 50 to 80 days were added above the threshold by climate change in cities across Kerala, Karnataka, Chandrapur, Maharashtra, Tamil Nadu, Punjab, Jammu and Kashmir, and Andhra Pradesh, including major cities like Mumbai which experienced an additional 65 days. Many cities across India saw between 15 and 50 additional days where the minimum temperatures exceeded 25°C, includingJaipur, with an additional 19 days due to climate change. In other cities such as Lucknow, Kolkata, and Ahmedabad, the minimum summer temperature is almost above 25°C in the counterfactual and observed scenarios.

1.4. United Kingdom

The country that experienced the greatest number of additional days above 18°C in the U.K. was England. Two days above this threshold were added by climate change per year, on average. Over the same period, Wales experienced an average increase of 0.5 days, while the changes in Scotland and Northern Ireland were negligible.

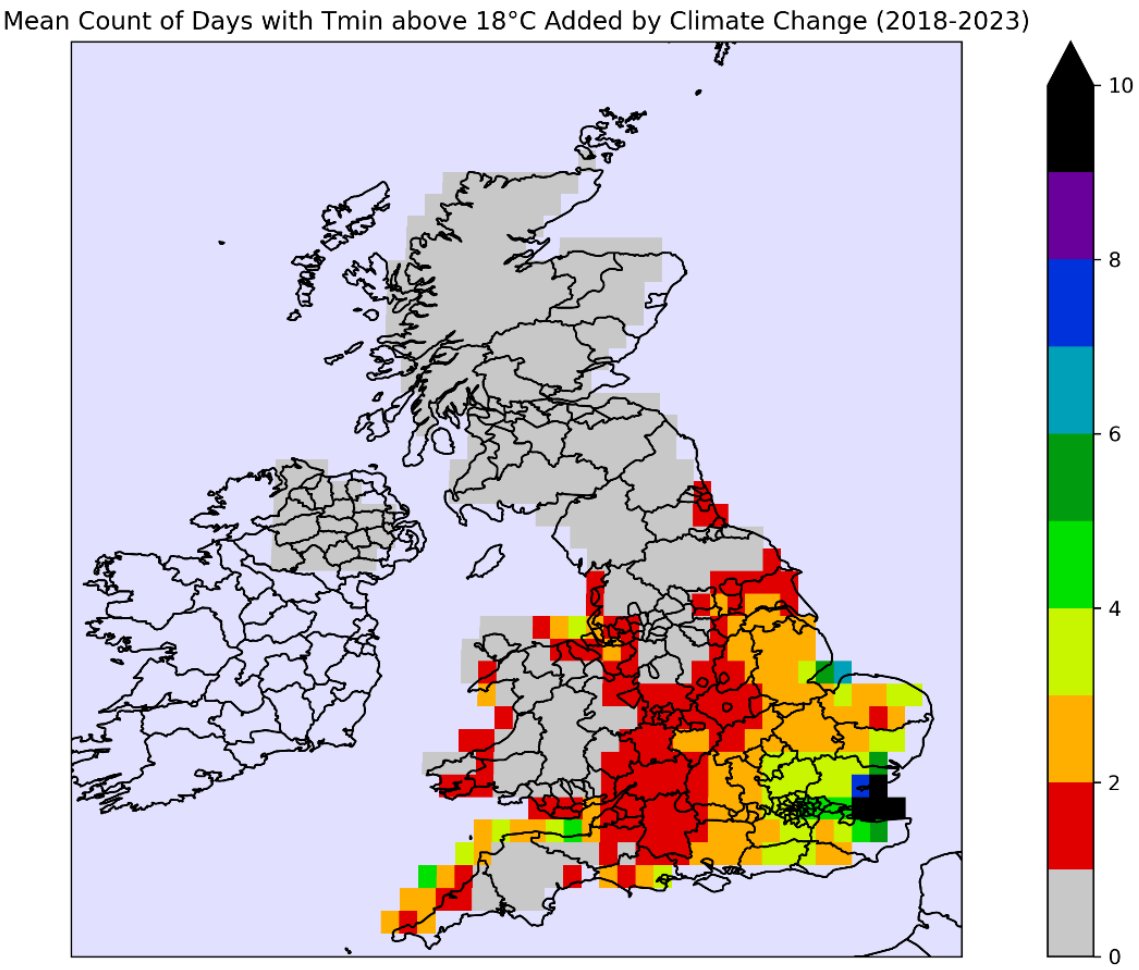

Figure 3. Average number of days with minimum nighttime temperatures above 18°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2018-2023.

On the subdivision level, London, East of England, and South East observed the largest increase in nighttime temperatures over 18°C due to climate change (Figure 3). The former experienced an additional 4 on average and the latter two experienced an additional 3. One to two days above this threshold were added in East Midlands, South West, Yorkshire and The Humber, and West Midlands, while North West and North East experienced the smallest number of days influenced by climate change at less than one.

Climate change added between 10 and 16 more days where the minimum temperature during the summer exceeded 18°C in 18 cities across the U.K. The top five cities include Clacton-on-Sea, Margate, Littlehampton, Brighton, and Hove, where approximately 16, 15, 13 days were added per year to the former three cities, and 12 days were added to the latter two. Of the 314 cities analyzed, 33 cities observed an average of 5 additional days above 18°C per year.

Nighttime temperatures in the U.K. rarely exceed the 20°C threshold. From 2018-2023 in English subdivisions and in U.K. countries, less than one day is added by climate change. The largest number of days added by climate change in a single year occurred in 2022 in East of England and East Midlands, where an additional 1.5 days above 20°C were added..

Changes were slightly more notable on a city level across the U.K. The city that saw the largest change from 2018-2023 was Clacton-on-Sea, with approximately 4 additional days per year with nighttime temperatures above 20°C. Margate, Minister, Leigh-on-Sea, and Southend observed an additional 2 days above this threshold on average, while most other cities saw 1 day or less. Meanwhile, no cities observed a minimum temperature above 25°C in the observed or counterfactual scenarios.

METHODS

Calculating Days Above Uncomfortable Temperature Thresholds

An analysis of observed temperature patterns in the U.S., India, and the U.K. was done using ERA5 reanalysis temperature data. The data is available at a resolution of 0.25° (31 km). Additionally, the analysis utilized counterfactual temperatures, or the temperature that would have occurred in a world without human-induced climate change. This is estimated using Climate Central's Climate Shift Index (CSI) system. The system is grounded in the latest peer-reviewed attribution science, quantifying the influence of climate change on daily temperatures around the world.

We typically express this influence as a change in the likelihood of the observed temperature due to climate change. However, it is also possible to use the CSI system to estimate the temperature without climate change. To do this, we find the probability of exceeding the observed temperature in the modern climate. We then find the temperature with the same probability in a climate with no global warming (global mean temperature of 0° relative to the preindustrial period). We estimate these counterfactual temperatures using each of the observation and model-based methods in the CSI system and then average.

For the global analysis, we extracted the data corresponding to each hemisphere's summer season: June, July, August for the Northern Hemisphere, and December, January, February for the Southern Hemisphere. We then counted the number of days in each month where the minimum temperature exceeded 20°C and 25°C over the ERA5 and counterfactual temperatures from 2014-2023. We then summed the annual count for each year in both scenarios and found the difference to assess how climate change has impacted nighttime temperatures.

We spatially averaged the counts within each county boundary for England, Scotland, Wales, and Northern Ireland, and again in the nine English Subdivisions to assess changes between the

number of days above each threshold added by climate change. This analysis was repeated again for cities in the U.S. and India with a population greater than 100,000, and for cities with a population above 20,000 in the U.K. to achieve city-specific attributability counts.

About Climate Central

Climate Central is an independent group of scientists and communicators who research and report the facts about our changing climate and how it affects people's lives. They collaborate widely with TV meteorologists, journalists, and other respected voices to reach audiences across diverse geographies and beliefs. Their work addresses climate science, sea level rise, extreme weather, energy, and related topics. Climate Central is a policy-neutral 501(c)(3) nonprofit.