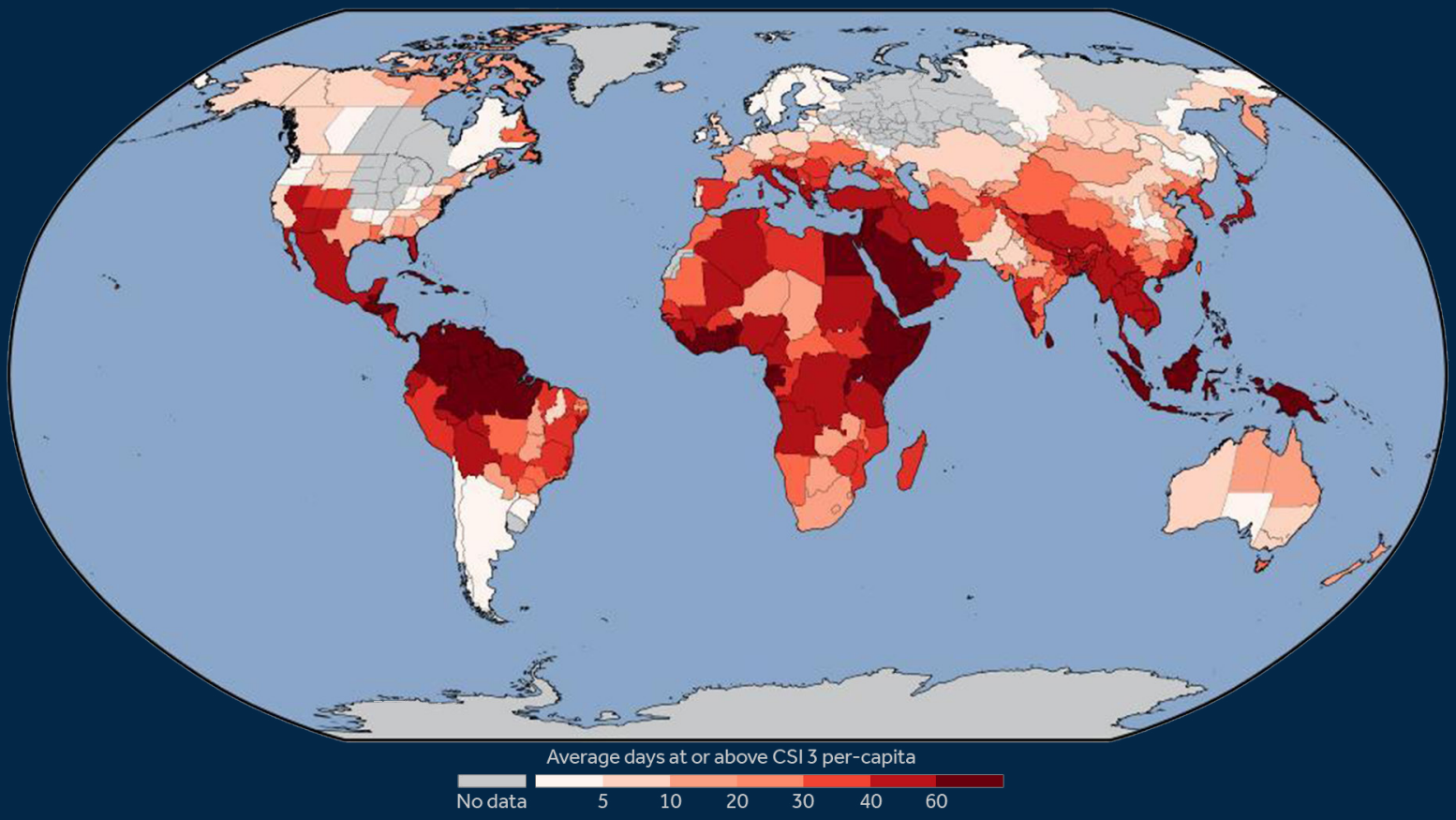
People Exposed to Climate Change: June-August 2024

A Climate Central seasonal analysis of how climate change boosted temperatures worldwide between June-August 2024



September 18, 2024

CLIMATE CENTRAL

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Key Facts

June through August 2024 was Earth's hottest season on record. During this period, the effects of human-induced climate change, mainly from burning fossil fuels, were evident in all regions of the world in the form of extreme heat, as well as heavy rainfall, deadly floods and storms, and raging wildfires. This analysis uses Climate Central's Climate Shift Index (CSI) to determine the influence of climate change on temperatures around the globe between June-August 2024.

This report finds that human-caused climate change increased heat-related health risks for billions, and made heat extreme events longer and more likely around the globe. Key findings include:

- **One in four people on the planet** had no break from climate change-driven heat. On every day in June, July, and August, they experienced unusually warm temperatures made at least three times more likely by climate change.
- Global exposure peaked on August 13, 2024, when **4.1 billion people — half (50%) of all people worldwide** — experienced unusual temperatures made at least three times more likely by climate change.
- The average person on the planet experienced **17 extra days of risky heat because of climate change**. Risky heat days are days with temperatures hotter than 90% of the temperatures recorded in a local area from 1991-2020. Heat-related health risks rise when temperatures climb above this local threshold.
- Over **2 billion people (25% of the global population) experienced 30 or more days of risky heat** that were made at least three times more likely by climate change. This included nearly the entire population of the Caribbean and at least three in every four people in: Western Asia, Micronesia, Northern Africa, and Southern Europe.
- **72 countries, home to more than 2.3 billion people, experienced their hottest June-August period** since at least 1970. The average person in these countries experienced a *very strong* influence of climate change on 34 of the 92 total days from June-August.
- **180 cities in the Northern Hemisphere (experiencing summer in June-August) had at least one dangerous extreme heat wave** (at least five consecutive days with temperatures hotter than 99% of temperatures recorded in that city from 1991-2020). Across these 180 cities, extreme heat waves of this intensity and duration are, on average, **21 times more likely today** because of human-caused climate change.

Data

➤ **Download data** for June 1, 2024 to August 31, 2024: Climate Shift Index (CSI) levels for 22 major regions; 218 countries, territories, or dependencies; 254 states, territories, or provinces of the largest countries; and 940 cities around the world.

INTRODUCTION

Humans have raised the temperature of the planet mainly by burning coal, oil, and natural gas. Human-caused emissions of the three most important heat-trapping greenhouse gasses have continued to climb to ever-higher levels, along with global temperatures.

Global average temperatures in 2023 — Earth's hottest year on record — were 1.5°C warmer[1] than early industrial (1850-1900) levels. 2024 is likely to exceed 2023 as the planet's hottest year on record.

Extreme heat is a growing health risk in our warming climate. In 2023, a record 2,325 people died from heat in the U.S. alone. Extreme heat is among the deadliest weather-related hazards globally, but under-reporting in many regions limits understanding of the full scale of heat-related health impacts.

June through August 2024 was Earth's hottest season on record — during which the planet had its single hottest day on record (July 22, 2024). Earth's 13-month record-breaking heat streak began in June 2023 and ended in July 2024[2], which was just 0.04°C cooler than the hottest month on record (July 2023).

The effects of human-induced climate change were evident in all regions of the world during this period, particularly in the form of extreme heat. See ***Heat and Beyond*** box below.

This report documents how human-caused climate change influenced this unprecedented three-month period of heat for people around the world. We use two primary tools for this analysis:

1. **Temperature anomalies:** this shows how much warmer or cooler conditions were relative to the 1991-2020 average. Note that this baseline already includes about 0.9°C of warming above pre-industrial levels. Temperature anomalies highlight conditions that people would recognize as unusual.

2. **Climate Shift Index (CSI):** this metric, developed by Climate Central, quantifies the influence of climate change on daily temperatures. Positive CSI levels 1 to 5 indicate temperatures that are increasingly likely in today's climate. A CSI level of 2 (3, etc.) means the temperature is at least two times (three times, etc.) more likely in today's climate than in a world without human-caused climate change. See ***The Climate Shift Index (CSI)*** box below for details.

[1] This single-year temperature anomaly pushes the planet closer toward the multi-decade average warming limit of 1.5°C that nearly all countries have committed to in the Paris Agreement. Heat-trapping pollution is a leading cause of long-term warming trends.
[2] According to ERA5 data from Copernicus Climate Change Service/ECMWF. Refer here for a detailed description of the differences between different global temperature datasets.

This analysis is focused on the average personal experience of unusually warm conditions that were *very strongly* influenced by climate change from June 2024 through August 2024. To do this, we compute the average per capita exposure to CSI level 3 or higher for people in 22 major global regions and 218 countries, territories, or dependencies. We also compute city-wide CSI signals for 940 cities.

RESULTS

1. At least one in four people felt a very strong climate change influence each day

On every single day from June 1, 2024 to August 31, 2024, at least **one in every four people on the planet** (i.e., at least 2 billion people) experienced temperatures made at least three times more likely by climate change (CSI level 3 or higher; Figure 1). In other words, one in four people had no break from climate change-driven heat during June, July, and August.

At least **one in every three people on the planet** (i.e., at least 2.7 billion people) experienced this level of climate change-driven heat on 69 June-August days (75% of the season).

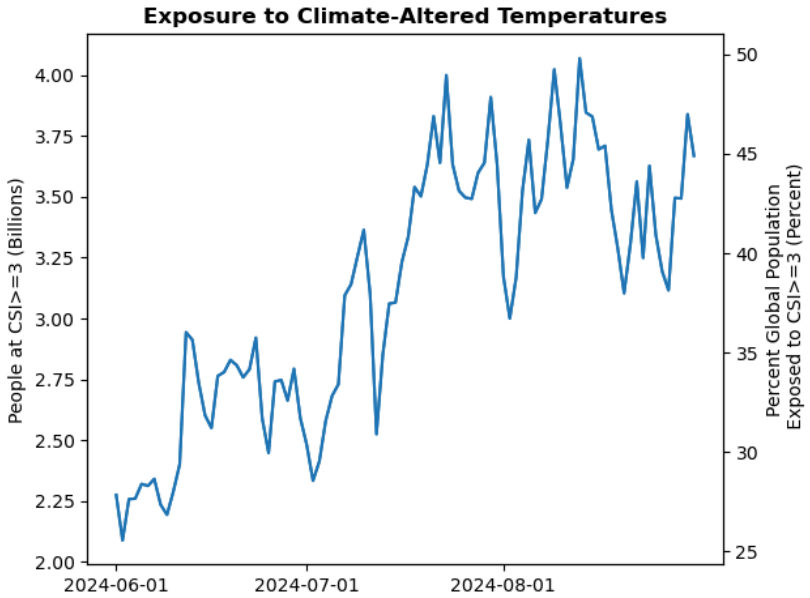

Figure 1. Daily global population exposed to Climate Shift Index (CSI) level 3 or higher. Analysis based on ECMWF ERA5 data. Produced September 6, 2024.

Global exposure peaked on August 13, 2024, when 4.1 billion people — **half (50%) of all people worldwide** — experienced unusual heat at CSI level 3 or higher.

On July 22, 2024, Earth's single hottest day on record, 3.6 billion people (45% of the global population) experienced unusual heat at CSI level 3 or higher.

2. Risky heat boosted by climate change

The average person on the planet experienced 34 days of risky heat during the last three months. Risky heat days are hotter than 90% of temperatures observed in a local area over the 1991-2020 period, also referred to as temperatures above the 90th percentile (see ***Risky Heat Days*** box below).

We used the CSI system to calculate the number of risky heat days that would have occurred without human-caused climate change (i.e., in a counterfactual scenario). Specifically, we counted the number of days above the 90th percentile temperature from June 1, 2024 to August 31, 2024, and then subtracted the number of times the counterfactual temperatures exceeded this level.

This shows that **human-induced climate change added 17 risky heat days** to the average person's experience over these three months (Figure 2). Without climate change, per-capita average exposure to risky heat would have been 17 days (50%) lower during the last three months.

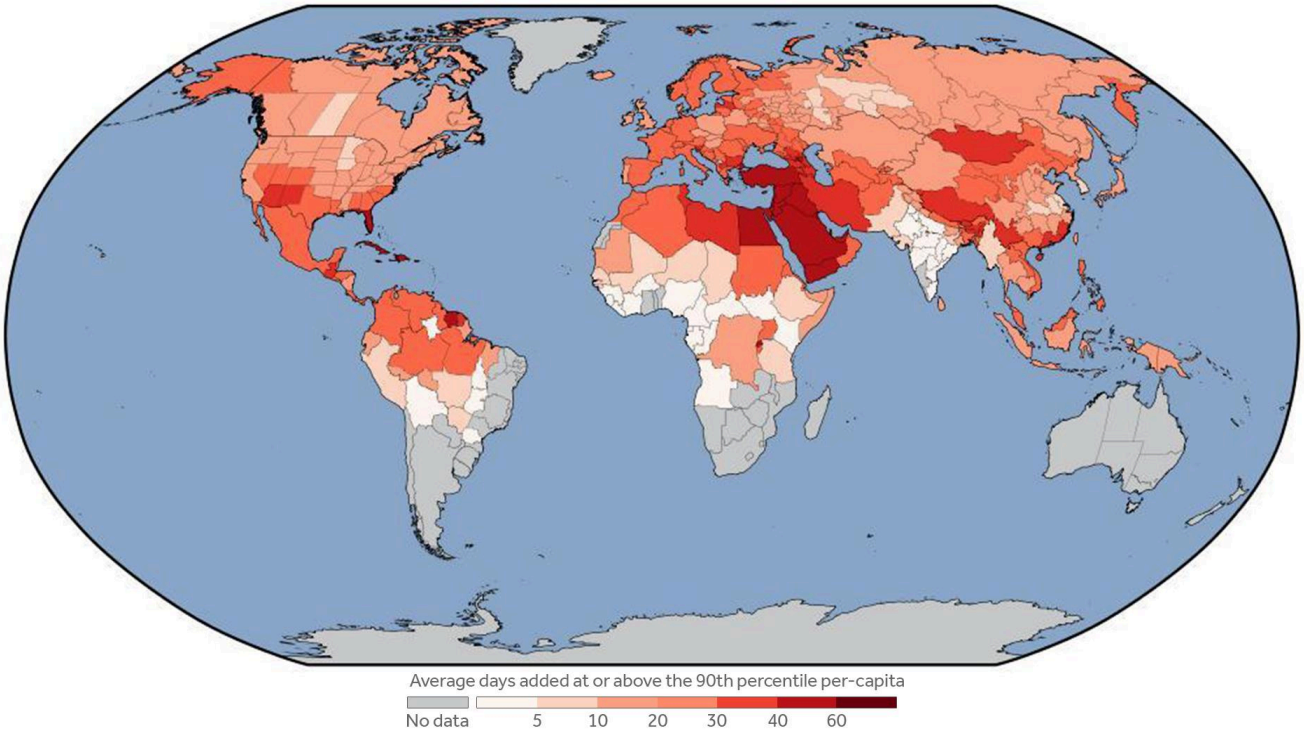

Figure 2. Additional June-August 2024 days with temperatures above the 90th percentile, added by the burning of fossil fuels. Presented as per-capita averages for countries and states. Analysis based on ECMWF ERA5 data and the Climate Shift Index (CSI) system. Produced September 6, 2024.

Risky Heat Days

Risky heat days are hotter than 90% of temperatures observed in a local area over the 1991-2020 period. Heat-related health risks rise when temperatures climb above this local threshold. This is a conservative approximation of the local minimum mortality temperature (MMT), an indicator of the local links between temperature and mortality.

A location's MMT is the daily average temperature at which the risk of heat-related death is lowest. The relative risks of heat-related illness and mortality increase steeply as temperatures climb above the local MMT because people are not used to these temperatures.

MMTs vary across climatic zones because health-related heat thresholds depend on the local climate and related long-term adaptation among local populations. MMTs are generally higher in the temperature distribution in temperate (80th percentile) and continental climates (75th percentile) and lower in arid (68th percentile) and tropical (59th percentile) climates. See ***Methods*** below for details.

Over **2 billion people (25% of the global population) experienced 30 or more days of risky heat** that were made at least 3 times more likely by climate change (Table 1). This included 99.7% of the entire population of the Caribbean and at least about three in every four people in: Micronesia (92%), Western Asia (90%), Northern Africa (76%), and Southern Europe (73%).

Explore the full dataset for details on specific countries with risky heat days added by climate change.

	Population exposed	Percent of global population
1+ day	6,123,780,000	77%
7+ days	4,540,065,000	57%
30+ days	2,044,592,000	26%
61+ days	332,589,000	4%

Table 1. Global population exposed to various durations of risky heat days (above 90th percentile) with a CSI level 3 or higher from June 2024 to August 2024. Analysis based on ECMWF ERA5 data.

3. Regions with unusual heat boosted by climate change

Over the last three months, there were several major regions with unusually warm conditions (Figure 3). Some 211 (97%) of the 218 countries, territories, or dependencies analyzed experienced a warmer-than-normal June-August 2024. In many of these countries, these unusually warm temperatures were significantly influenced by climate change (see Section 5).

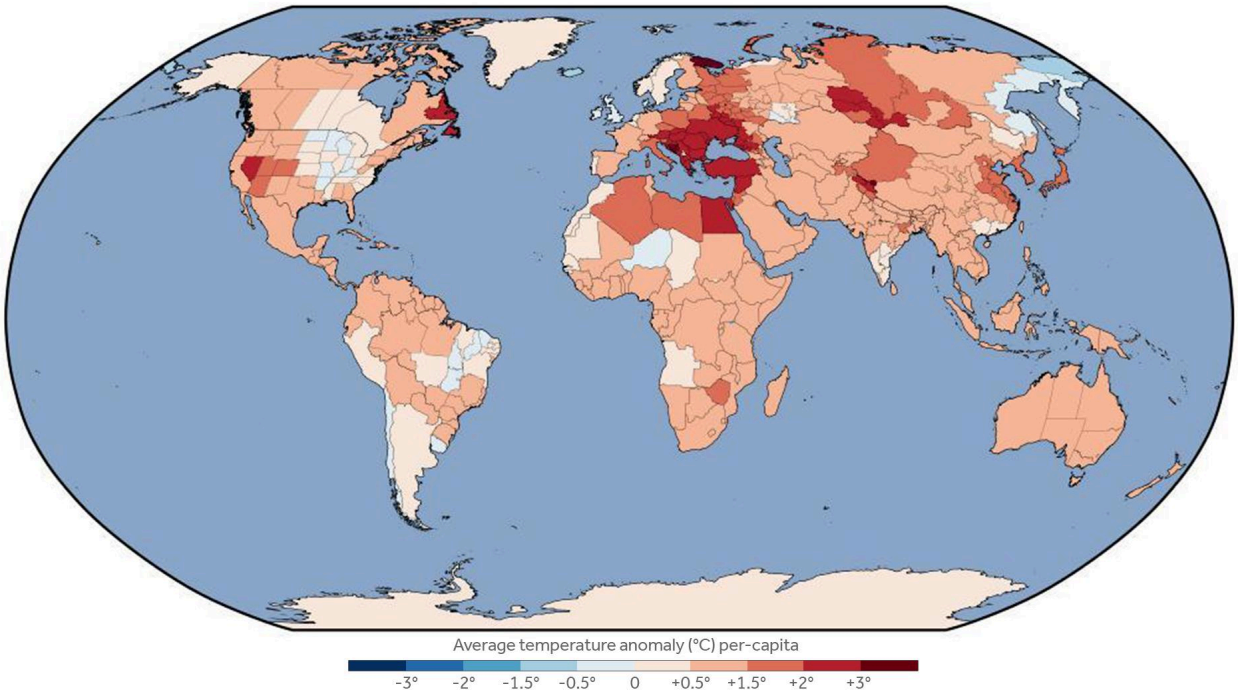

Figure 3. Global temperature anomalies (departures from normal) for June 2024 to August 2024 relative to the 1991-2020 standard normal period. Presented as per-capita averages for countries and states. Analysis based on ECMWF ERA5 data. Produced September 6, 2024.

Among the 22 regions analyzed, the highest regional average temperature anomalies were in each of the regions listed in Table 2. For example, on average, someone living in Eastern Europe experienced temperatures 1.9°C above normal, and 14 days with temperatures *very strongly* influenced by climate change (CSI level 3 or higher).

Region	Per-capita mean temperature anomaly (°C)	Per-capita days at CSI 3 or higher
Eastern Europe	1.9°	14
Western Asia	1.6°	58
Southern Europe	1.5°	39
Northern Africa	1.4°	53
Eastern Asia	1.3°	23

Table 2. Major global regions with highest per-capita mean temperature anomalies from June 2024 to August 2024, along with regionally averaged per-capita days at CSI 3 or higher. Analysis based on ECMWF ERA5 data.

The CSI reveals the influence of climate change on unusual heat in each region (Figure 4). Note that locations with relatively large temperature anomalies do not necessarily experience the strongest CSI

signals. This is because CSI levels depend on how the daily temperature compares to: 1) the strength of the local warming trend, 2) the spread, or variance, of possible local temperatures, and 3) the amount of warming predicted by climate models.

Places with strong warming trends and low temperature variance (e.g., tropical regions and many places near the ocean) can have high CSI levels even for modest temperature anomalies. Conversely, places and seasons with high temperature variance (e.g., much of the United States during the spring and fall) require larger temperature anomalies to produce detectable positive or negative CSI levels.

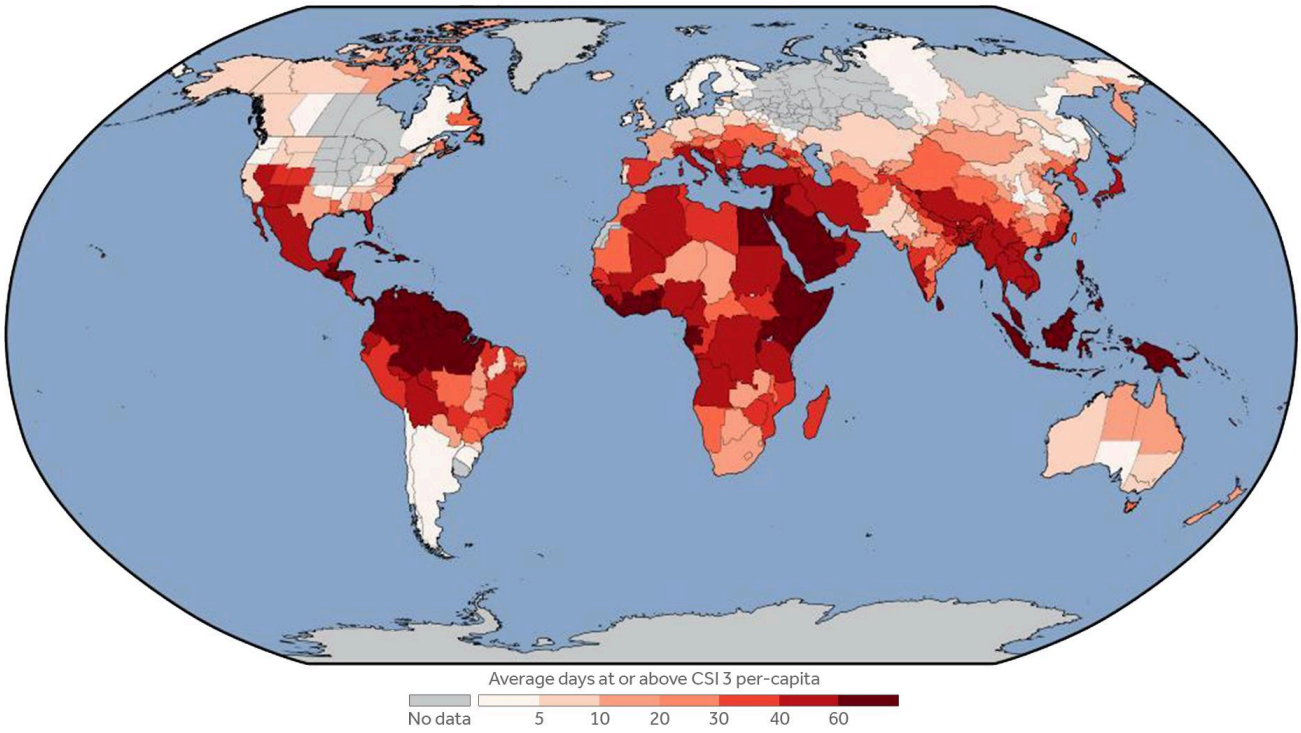

Figure 4. Number of June-August 2024 days at Climate Shift Index (CSI) level 3 or higher. Presented as per-capita averages for countries and states. Analysis based on ECMWF ERA5 data. Produced September 6, 2024.

Of the 22 regions analyzed, people living in the regions listed in Table 3 had the highest exposure to climate change-driven heat (unusual heat made at least three times more likely by climate change) during all of June, July, and August.

Region	Per-capita days at CSI 3 or higher (percent of season)	Per-capita mean temperature anomaly (°C)
Micronesia	86 (93%)	0.7
Caribbean	81 (88%)	1.0
Melanesia	70 (76%)	0.9
Central America	62 (67%)	0.8
Western Asia	58 (63%)	1.6

Table 3. Major global regions with the most per-capita days at CSI 3 or higher from June 2024 to August 2024, along with per-capita mean temperature anomalies. Analysis based on ECMWF ERA5 data.

The CSI focuses on temperature, but climate change also drives other weather extremes and impacts. During June 2024 to August 2024, World Weather Attribution identified 62 significant extreme events around the world based on factors such as number of people (or percent of the population) impacted, fatalities, state of emergency declarations, records set, and more. These 62 events included heat waves, floods, fires, droughts, hurricanes, and storms. Many of these occurred in areas with a *very strong* influence of climate change on temperatures as measured by the CSI.

4. Countries with record heat boosted by climate change

In 2024, **72 countries, territories, or dependencies, home to more than 2.3 billion people, experienced their hottest June-August period since ERA5 records began in 1970.**

Climate change played a major role in this record heat. The average person in these 72 countries, territories, or dependencies experienced a *very strong* influence of climate change (CSI level 3 or higher) on 34 days, or 37% of the June-August season.

These were: Albania, Anguilla, Antigua and Barbuda, Aruba, Bahrain, Barbados, Bosnia and Herzegovina, British Virgin Islands, Bulgaria, Cameroon, Central African Republic, China, Comoros, Commonwealth of the Northern Mariana Islands, Croatia, Curaçao, Cyprus, Democratic People's Republic of Korea, Dominica, Egypt, Federated States of Micronesia, French Guiana, Gabon, Greece, Grenada, Guadeloupe, Guam, Hungary, Islamic Republic of Iran, Israel, Japan, Jordan, Kiribati, Kuwait, Lebanon, Libya, Malawi, Maldives, Marshall Islands, Martinique, Montenegro, Montserrat, Mozambique, Nauru, Nepal, North Macedonia, Occupied Palestinian territory, Oman, Palau, Philippines, Puerto Rico, Qatar, Republic of Korea, Republic of Moldova, Romania, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Saudi Arabia, Serbia, Seychelles, Singapore, Sint Maarten, Slovakia, Solomon Islands, Somalia, Suriname, Syrian Arab Republic, Trinidad and Tobago, Turkey, U.S. Virgin Islands, and Zimbabwe.

5. Countries with longest and most intense fingerprints of climate change

In 80 countries, the average person experienced a *very strong* influence of climate change (CSI level 3 or higher) on **at least two out of every three days** (at least 61 of the 92 total days) during the last three months (Table 4). More than half of these 80 countries were primarily located in: the Caribbean; Eastern Africa; and Western Asia.

Continent	Countries with per-capita CSI 3 or higher for at least two-thirds of the season	Country with most per-capita days at CSI 3 or higher	Country with most people exposed to CSI 5 for 60+ days	Continent-wide population exposed to CSI 5 for 60+ days
Africa	19 out of 54	Rwanda (90 days)	Nigeria (120 million)	481 million (32%)
Asia	16 out of 50	Maldives (82 days)	Indonesia (128 million)	333 million (7%)
Europe	0 out of 43	Malta (52 days)	Greece (198 million)	240,000 (0.03%)
North America	29 out of 36	Aruba and Curaçao (92 days)	Mexico (44.2 million)	112 million (19%)
Oceania	11 out of 22	Guam (88 days)	Papua New Guinea (9.2 million)	11 million (21%)
South America	5 out of 13	Suriname and French Guiana (90 days)	Bolivarian Republic of Venezuela (26 million)	74 million (17%)

Table 4. Summary of countries with highest CSI duration and intensity from June 2024 to August 2024. All CSI values refer to average temperature. Analysis based on ECMWF ERA5 data.

For a deeper look into the countries and cities with significant fingerprints of climate change, see Appendix, or explore the full dataset.

Heat and Beyond: a global look at extreme weather impacts over the past 3 months

Over the last three months, the effects of human-induced climate change from the burning of fossil fuels have been evident in all regions of the world, as deadly heat waves, record-breaking rainfall events, storms, hurricanes, and severe drought have brought damage and destruction to millions of people.

Extreme temperatures driven by climate change broke records everywhere. Mexico recorded its hottest June day ever, Barcelona saw its hottest day ever in July, and Australia reached 41.6°C in August despite it being winter. South Korea broke its record of consecutive tropical nights, with temperatures above 25°C for 26 days in a row, while Spain experienced its hottest night ever: 39°C in Almeria.

In some countries, temperatures were so high that they melted pavements. In others, the heat prevented emergency helicopters from flying and getting people to hospitals. And throughout the world, extreme temperatures forced the closure of schools and workplaces.

Hundreds of people died and thousands had to be treated for heat stress during the annual Hajj pilgrimage to Mecca, as temperatures exceeded 50°C in Saudi Arabia. In Abu Dhabi and Oman, temperatures above 40°C felt as hot as 60°C when factoring in humidity. Life-threatening heat was also recorded in Pakistan, Japan, India, where cases of heat stroke and heat-related deaths put both hospitals and morgues under pressure.

Fossil fuel-driven extreme temperatures created favorable conditions for wildfires. Dozens of European cities were on the highest level of wildfire risk alert. Croatia and North Macedonia had to battle with over 160 wildfires that erupted within 24 hours. Parts of Cyprus, Turkey, Albania, Spain and Portugal had to be evacuated as flames destroyed and damaged towns and cities, injured and killed people, and destroyed entire livelihoods. Brazil's forests burned at an alarming rate, with climate change making the wildfire in Pantanal more intense, according to an attribution study from World Weather Attribution. This prompted the Environment Minister to announce a "war" against fire, as the country experienced summer temperatures during its winter months. Bolivia saw a record number of fire points, where an estimated 2 million hectares of wildfire burned.

In Turkey, at least 12 were killed by the fire that broke out amidst climate change-driven heat conditions. Firefighters battled several wildfires in Greece in June, July and August. In the U.S., wildfires ranged from California to Texas, speeding through vegetation that was dried out by drought conditions. In Canada, Jasper Fire destroyed about a third of the township, and caused about $600 million in insured losses.

Several regions also suffered from unprecedented rainfall and widespread flooding. Ethiopia saw its worst flood in modern history, killing 257 people. In Nigeria, Lagos battled with deadly floods that killed 170 people. Other African countries that experienced deadly floods that displaced thousands of people include Algeria, Ivory Coast, and Yemen.

Over 5 million people were affected by flash floods caused by heavy rains in Bangladesh. In India, Delhi recorded its heaviest June rainfall in 88 years, Mumbai received a staggering 300mm of rain in only 6 hours, and Kerala saw deadly floods that killed 365 and wrecked whole villages. Scientists found that human-induced climate change intensified the deadly rainfall.

Heavy rain killed 209 people in Pakistan, 40 people in Afghanistan, and 30 people in China, where flooding caused what was described as a "wartime" situation. South Korea saw a once-in-200-years heavy rainfall, Canada experienced a once-in-100-year storm, and the U.S. faced a once-in-a-millenium rainfall. Streets were submerged, people got trapped in cars, subways became rivers, and thousands of structures were destroyed.

Human-induced heat worsened drought conditions all over the world, including in Russia, China, Italy and Ghana, leading to crop failures, prompting governments to declare emergency measures, and resulting in export bans. In Italy alone, drought-related damages are estimated to be around $3 billion this year.

Ocean temperatures have reached their highest temperatures in at least 400 years, being a major concern regarding this hurricane season. These high temperatures have already created conditions that made hurricanes and storms more powerful and intense. Hurricane Beryl, Hurricane Debby, and Hurricane Ernesto were all linked to climate change. They resulted in power outages and death in the U.S. and the Caribbean.

6. Cities with dangerous extreme heat waves boosted by climate change

Some **180 cities** in the Northern Hemisphere (experiencing summer in June-August) had **at least one dangerous extreme heat wave** during the last three months (Figure 5). In this analysis, we defined a dangerous extreme heat wave as at least five consecutive days that were hotter than 99% of temperatures in that city from 1991-2020. For the following discussion, cities were limited to those in the Northern Hemisphere, experiencing summer during June-August.

To estimate the influence of climate change on each of these dangerous extreme heat waves, we calculated the multi-day CSI of each event using the Climate Shift Index system (see ***Methods*** for an explanation of the calculation). The multi-day CSI indicates the increase in likelihood of an event occurring as a result of climate change.

Extreme heat waves of the intensity and duration experienced in these 180 cities from June-August 2024 are, on average, **21 times more likely in today's climate** than they would otherwise be in a world without human-caused climate change.

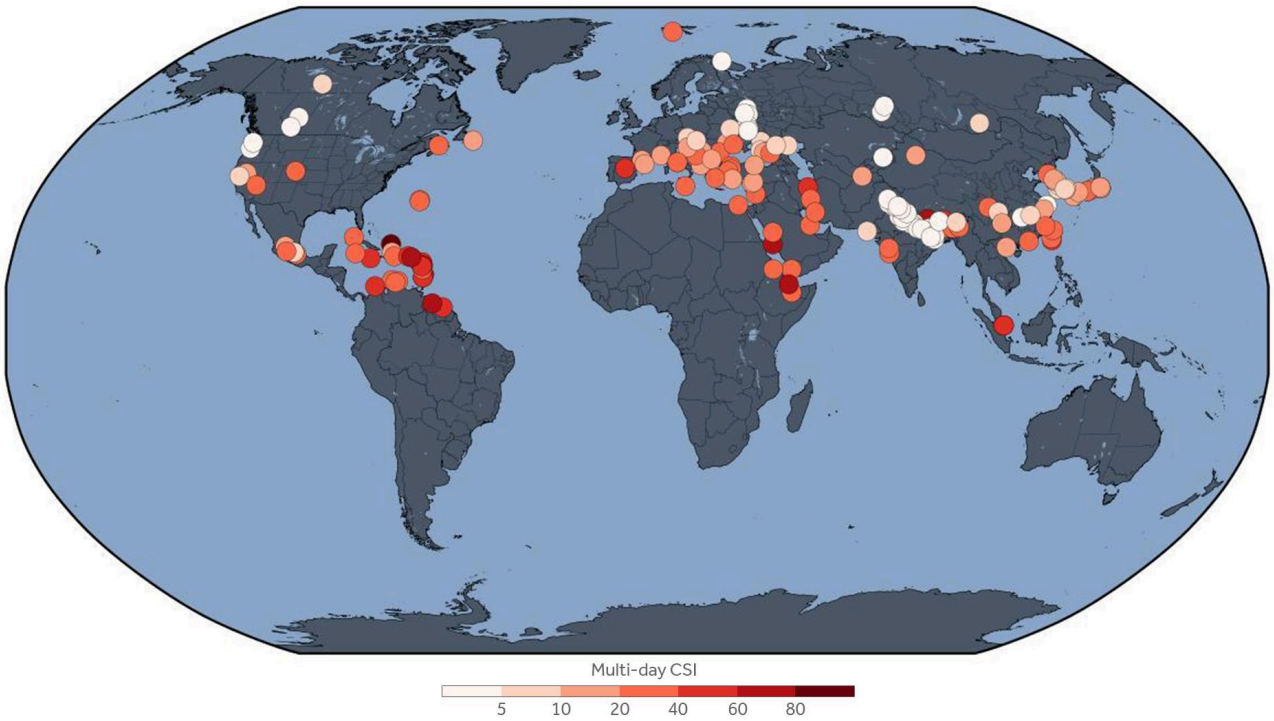

Figure 5. Northern Hemisphere cities with extreme heat waves (at least five consecutive days with temperatures above the 99th percentile) during June-August 2024. Colors indicate the multi-day CSI of each city's longest extreme heat wave. The multi-day CSI indicates the increase in likelihood of such an event occurring as a result of climate change. Analysis based on ECMWF ERA5 data and the CSI system. Produced September 6, 2024.

Longest extreme heat waves		
City	**Number of days**	**Multi-day CSI** *(times more likely in today's climate)*
Longyearbye, Svalbard	25	39
Monaco	24	18
Athens, Greece	18	21
Esfahan, Iran	16	33
Hangzhou, China	15	12
Alexandria, Egypt	14	35
Kawasaki, Japan	14	17
Yokohama, Japan	14	17
Vatican City	13	32

Most anomalous extreme heat waves		
City	**Temperature anomaly (°C)**	**Multi-day CSI** *(times more likely in today's climate)*
Portland, Oregon, U.S.	8.2°	4
Chongqing, China	7.9°	10
Sacramento, California, U.S.	7.4°	7
Chisinau, Moldova	7.4°	17
Murmansk, Russia	7.4°	2
Belgrade, Serbia	7.4°	17
Odessa, Ukraine	7.2°	22
Kyiv, Ukraine	7.1°	9
Chengdu, China	7.1°	22

Extreme heat waves with the highest multi-day CSI (increase in likelihood of occurring in today's climate)	
City	**Multi-day CSI** *(times more likely in today's climate)*
Grand Turk, Turks and Caicos Islands	89
Castries, Saint Lucia	74
Djibouti, Djibouti	71
Jeddah, Saudi Arabia	66
Pointe-a-Pitre, Guadeloupe	65
Kathmandu, Nepal	63
Georgetown, Guyana	63
Charlotte Amalie, U.S. Virgin Islands	61
Calliaqua, Saint Vincent and the Grenadines	60

Table 5. Cities with dangerous extreme heat waves from June through August 2024 that were longest (left), most anomalous (middle), and had the highest multi-day CSI, or increase in likelihood of occurring in today's climate as a result of climate change (right). Data limited to Northern Hemisphere cities. Analysis based on ECMWF ERA5 data.

Region	City with longest heat wave	Duration of longest heat wave (days)	Multi-day CSI of longest heat wave (times more likely)	Mean temperature (°C) during longest heat wave	Start/end dates of longest heat wave
Caribbean	Grand Turk, Turks and Caicos Islands	8	89	28°	Aug 16 - 23
Central America	Morelia, Mexico	9	28	25°	Jun 2 -10
Central Asia	Dushanbe, Tajikistan	12	12	27°	Jul 25 - Aug 5
Eastern Africa	Djibouti, Djibouti	11	71	37°	Jul 7 - 17
Eastern Asia	Kobe, Japan	13	36	32°	Jul 27 - Aug 8
Eastern Europe	Bucharest, Romania	13	25	30°	Jul 10 - 22
Northern Africa	Alexandria, Egypt	14	35	28°	Jul 20 - Aug 2
Northern America	Saint George, Bermuda	7	32	28°	Aug 8 - 14
Northern Europe	Longyearbye, Svalbard	25	39	10°	Jul 21 - Aug 14
South America	Georgetown, Guyana	7	63	29°	Aug 20 - 26
Southeastern Asia	Bagam, Indonesia	9	40	29°	Jul 23 - Jul 31
Southern Asia	Kathmandu, Nepal	9	63	25°	Jul 26 - Aug 3
Southern Europe	Madrid, Spain	7	52	31°	Jul 24 - 30
Western Asia	Jeddah, Saudi Arabia	8	66	35°	Jul 10 - 17
Western Europe	Monaco	24	18	26°	Jul 26 - Aug 18

Table 6. Cities in each region (Northern Hemisphere only) with the longest extreme heat wave (June-August 2024), along with a summary of that event's multi-day CSI, duration, mean temperature, and dates. Analysis based on ECMWF ERA5 data.

The Climate Shift Index (CSI)

Humans have caused global average temperatures to increase by 1.2°C (2.1°F) since 1850. But people do not experience global average temperatures. Instead, we mainly experience climate change through shifts in the daily temperatures and weather patterns where we live.

Climate Central's Climate Shift Index (CSI) system quantifies the local influence of climate change on daily temperatures around the world.

The CSI quantifies how much human-caused climate change has shifted the odds of daily temperatures that people experience locally. The CSI is grounded in peer-reviewed attribution science and was launched by Climate Central in 2022. The data are accessible via our free map tool.

The CSI scale is centered on zero. A CSI level of zero means that there is no detectable influence of human-caused climate change. In other words, that day's temperature is equally likely in both the modern climate and one without global warming.

Positive CSI levels 1 to 5 indicate conditions that are increasingly likely in today's climate. A CSI level of 1 means that climate change is detectable (technically, the temperature is at least 1.5x more likely). CSI levels 2 and higher correspond with the multipliers (2 = at least 2x more likely, 3 = at least 3x more likely, etc.). The CSI scale is currently capped at level 5 which means that a CSI of 5 includes higher values and thus should be read as *at least 5*. CSI level 5 events would be very difficult to encounter in a world without climate change—not impossible, but extremely unlikely.

The CSI can also be applied to temperatures that are unusually cool. For instance, a CSI level -2 means that the temperature in question is two times less likely (equivalently 1/2 as likely) due to human-caused climate change.

Climate Central's Climate Shift Index map tool shows which parts of the world are experiencing high CSI levels, every day. Explore the global CSI map for today, tomorrow, and any day this past year.

METHODS

Calculating the Climate Shift Index

All Climate Shift Index (CSI) levels reported in this brief are based on daily average temperatures and ECMWF ERA5 data from June 1-August 31, 2024. See the frequently asked questions for details on computing the Climate Shift Index, including a summary of the multi-model approach described in Gilford et al. (2022).

Daily global population exposure

For each day, we identified the grid cells with CSI values of 3 or higher. We then used the proportion of population based on the Gridded Population of the World v4 estimate for 2020 living in each cell, summed over the globe where CSI values were 3 or higher, and then multiplied by the estimated global

population of 8.17 billion to get an up-to-date estimate of the global population distribution and population exposure to CSI 3.

For country-level population analyses, we similarly scaled the population within the country in the Gridded Population of the World v4 2020 estimate by the country-level estimates in Britannica's list of the populations of the world's countries, dependencies, and territories. This scaling was only applied on country-level analyses (not for state/province, region, or continent estimates).

Regional/country analysis

The country-level analysis includes 218 countries, dependencies, and territories. It excludes entities that are smaller than 0.25°, the size of a grid cell.

For this analysis, we calculated the temperature anomaly, number of days at or above various CSI thresholds, and population exposure to various CSI levels (all based on average temperature) over the June 1, 2024 to August 31, 2024 period. For each region/country, we then selected the data within its geographical boundary and found the population-weighted temperature anomaly, the population-weighted number of days at various CSI thresholds, and total population exposed to CSI level 5 for one and 60 days. Reported temperature anomalies are relative to each country's or region's 1991-2020 normal daily June-August temperatures.

Analysis of risky heat days considered days that were hotter than 90% of temperatures observed in a local area over the 1991-2020 period. The 90th temperature percentile is a conservative approximation of the local minimum mortality temperature (MMT), an indicator of the local links between temperature and mortality. Tobías et al. (2021) estimated local MMT in 683 global locations using local temperature and mortality data, and calculated the MMT percentile (MMTP) for each location, defined as "the percentile of the temperature distribution corresponding to the MMT." The MMTP varied globally. Across countries, MMTPs ranged from the 5th to 99th percentile. Across climatic zones, MMTPs generally decreased from temperate climates (80th percentile) to continental (75th), arid (68th), tropical (59th), and alpine (41th) climates. This is broadly consistent with an earlier study (Gasparrini et al. (2015) that found that the MMT percentile ranged from approximately the 60th percentile in the tropics to the 80th-90th percentile in temperate regions.

To find the days added by climate change above various thresholds, we developed the counterfactual temperature. The counterfactual temperature is an estimate of the temperature a location would have experienced in a world without climate change. We used the probabilistic underpinning of our CSI model by finding the probability of meeting or exceeding an observed temperature in today's climate, and finding the temperature with the same probability in a world without climate change. This is the counterfactual temperature. Then, for each day, for each location, we checked if the counterfactual temperature was below the threshold, and if the observed temperature was above the threshold. If both of these conditions were met, we qualified that day as a day above that threshold added by climate change.

Calculating the multi-day CSI for extreme risky heat waves
The multi-day CSI is a measure of the increase in likelihood of a series of daily temperatures occurring due to climate change. The multi-day CSI is a single value used to analyze the impact of climate change on a series of hot days, rather than individual days.

The multi-day CSI is calculated using the continuous likelihood ratios that underlie the discrete daily CSI numbers. For each heat wave, we take the log of the likelihood ratio for each day and then average. We then multiply by the variance in day-to-day temperatures based on the past 30 years and divide by the variance in the multi-day average temperature. Finally, we undo the log transformation. We can show mathematically that this is the likelihood ratio for the multi-day average temperature. For a 10-day heat wave, this tells us how much climate change has boosted the likelihood of encountering the temperature averaged over those 10 days.

State/province analysis
The state-level analysis includes 254 states and territories in Australia, India, Russia, China, Canada, Brazil, and the United States. It excludes entities that are smaller than 0.25°, the size of a grid cell.

For this analysis, we calculated the temperature anomaly, number of days at or above various CSI thresholds, and population exposure to CSI level 5 (all based on average temperature) over the June 1-August 31, 2024 period. For each state/province, we then selected the data within its geographical boundary and found the population-weighted temperature anomaly, the population-weighted number of days at various CSI thresholds, and total population exposed to CSI levels of 5 for one and 60 days. Reported temperature anomalies are relative to each state/province's 1991-2020 normal daily June-August temperatures.

City analysis
We analyzed 940 cities from around the world. These are various U.S. cities, and cities with populations exceeding one million people. For each city, we found the CSI and temperature anomaly time series from the nearest 0.25° grid cell. We then computed the mean temperature anomalies over the months of June 2024, July 2024, and August 2024, and the number of days at CSI levels 2, 3, 4, and 5 (all based on average temperature). Reported temperature anomalies are relative to each city's 1991-2020 normal daily June -August temperatures. We also found the 99th percentile daily temperature for every city over the past 30 years, calculating the number of days that every city experienced above that threshold, as well as the number of streaks of days exceeding five and seven days in length. The entire list of cities and their statistics is available for download.

The cities identified in the text above were selected based on the intensity of the particular statistic as well as their population.

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APPENDIX

Below, we take a deeper look into the countries and cities with significant fingerprints of climate change.

Africa

The African continent was significantly affected by climate change-driven temperatures in June, July and August, with millions of people exposed to dangerous temperature levels. Across the continent, **over 481 million people** were exposed to at least 60 days of temperatures at CSI levels 5 or higher. This means that climate change made temperatures on those days at least five times more likely.

Most affected regions: Northern, Eastern, Western and Middle Africa saw a high number of days with temperatures above normal, with the average person experiencing between **49 and 58 days** with temperatures made at least three times more likely because of climate change. In Southern Africa, people endured 18 such days.

Countries with significant increases: **Egypt**, **Libya**, **Rwanda**, and **Tunisia** all saw over 30 added **risky heat days** (days with temperatures hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature). **Rwanda** had the highest number of per-capita days with CSI 3 or higher, reaching 90 days with temperatures made at least three times more likely because of climate change. Meanwhile, **Nigeria** led in terms of the number of people affected, with **120 million people** exposed to temperatures at least five times more likely because of climate change, with CSI 5 conditions for over 60 days.

Cities experiencing the most heat: **Lagos** (Nigeria), **Kampala** (Uganda), **Lome** (Togo), **Alexandria** (Egypt), and **Addis Ababa** (Ethiopia), **Libreville** (Gabon) among others, all saw at least 80 days with temperatures at CSI 3 or higher. This means that temperatures were at least three times more likely because of climate change.

Notable country-specific events:

- **Egypt**: Cairo and Giza recorded 18 days with temperatures above dangerous extreme heat levels (99th percentile, or hotter than 99% of observed days over the 1991-2020 period), with Alexandria experiencing 37 such days. The temperature anomaly was 2.43°C in Cairo and Giza, and 1.79°C in Alexandria.
- **Kenya**: Mombasa and Nairobi faced 83 and 59 days, respectively, at CSI 5 or higher. This means that climate change made temperatures at least five times more likely on those days.
- **Nigeria**: Lagos, Port Harcourt, Sagamu, and Aba experienced at least 83 days with temperatures at CSI 5 or higher, while Ibadan, Awka, Onitsha, Nneyi-Umuleri, and Benin City experienced at least 69 days at CSI 5 or higher. This means that climate change made temperatures at least five times more likely on those days.

Some countries experienced their hottest June-August season since 1970, including **Egypt**, **Libya**, **Somalia**, **Mozambique**, and **Central African Republic**, among several others across Sub-Saharan Africa, reflecting the severity of the climate crisis.

Asia

Asia experienced unprecedented levels of extreme heat in June, July and August, with significant increases in temperature and days of risky heat driven by climate change. During these three months, **333 million people** were exposed to at least 60 days with temperatures made at least five times more likely because of climate change, or at a CSI level 5 or higher. Western Asia, Southeastern Asia, and Eastern Asia all recorded their hottest seasons since 1970.

Most affected regions: The average person in Western Asia and Southeastern Asia experienced 58 days at CSI 3 or higher, the highest in the continent. Southern Asia experienced 30 days, Eastern Asia 23 days, and Central Asia 19 days at CSI 3. About a third of people in Western Asia (31%) were exposed to **risky heat** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature) *very strongly* influenced by climate change (with a CSI level of 3) for **at least 61 days**.

Population exposed to risky temperatures: More than 1.3 billion people in Eastern Asia were exposed to **dangerous extreme heat levels** (hotter than 99% of temperatures observed) for at least seven days, with nearly 10 million exposed to at least 30 days added by climate change. South-eastern Asia had another 104 million people exposed to similar dangerous extreme heat for at least seven days added by climate change; Southern Asia had 248 million, Western Asia had over 190 million, and Central Asia had 37 million people affected.

Countries with significant increases: Countries that experienced over 30 additional **risky heat days** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature). These include **Saudi Arabia**, **Kuwait**, **Lebanon**, **Qatar**, **Turkey**, **Iran**, **Iraq**, the **United Arab Emirates**, among others. **Maldives** had the most per-capita days at CSI 3 or higher, with 82 days of temperatures made at least three times more likely because of climate change. **Indonesia** saw the largest number of people affected by climate change-driven temperatures, with 128 million people exposed to CSI 5 for 60 or more days, meaning that temperatures were at least five times more likely because of climate change on those days.

Cities experiencing the most heat: Several major cities faced several days with extreme temperatures significantly influenced by climate change:

- **Indonesia**: Makassar (88 days), Sumedang (83 days), and Palembang (81 days) saw the highest number of days with CSI 5 or higher. This means that in those days, temperatures were at least five times more likely because of climate change. Jakarta, Medan, and other Indonesian cities experienced at least 50 days similarly with CSI 5 or higher.

- **Saudi Arabia**: Jeddah endured 35 days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed), with Mecca and Riyadh seeing 23 and 10 days, respectively.
- **Japan**: Tokyo had 27 days with CSI levels at 5 or higher. This means that climate change made temperatures on those days at least five times more likely. Yokohama saw 41 such days and Osaka saw 50 such days. Temperature anomalies ranged from 1.4°C to 2.6°C above normal. All these cities saw at least 3 weeks worth of days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed).
- **South Korea**: Seoul saw 22 days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed), similar to Suwon (21 days), Icheon (25 days) and Tongjin (21 days).
- **China**: Hangzhou (26 days), Urumqi (22 days), and Shanghai (20 days) saw a high number of days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed), with several other cities recording over two weeks worth of extreme temperatures, including Wuhan, Guiyang, and Chengdu.

Prolonged streaks of extreme heat: Cities like **Esfahan** (Iran), **Hangzhou** (China), **Kawasaki** and **Yokohama** (Japan) experienced the longest streaks of extreme temperatures in Asia, with at least two weeks when climate change made temperatures at least five times more likely. During the period, average temperatures reached above 30°C.

Several countries, including **Saudi Arabia**, **Kuwait**, **Lebanon**, the **Philippines**, and **Japan**, experienced their hottest June-August season since 1970. In **Japan**, 6.63 million people were exposed to dangerous extreme heat levels (hotter than 99% of temperatures observed) for 30 added days due to climate change, while **Turkey** saw 1.17 million people impacted under similar conditions.

Europe

Europe similarly faced increasing days of extreme heat in June, July and August, with Southern Europe being the most affected region. It experienced the highest number of extreme heat days influenced by climate change when compared to other parts of the continent. Across Europe, **240,000 people** were exposed to at least 60 days with temperatures made at least five times more likely because of climate change (CSI 5).

Most affected regions: the average person in Southern Europe experienced 39 days with temperatures made at least three times more likely because of climate change (CSI 3), with 26 of those days were of temperatures made at least five times more likely (CSI 5). Eastern Europe saw 14 days with temperatures three times more likely because of climate change, followed by Western Europe with 10 days.

Population exposed to risky temperatures: **127 million people in Southern Europe** were exposed to dangerous extreme heat levels (hotter than 99% of temperatures observed) for at least seven days, with 14 million exposed to at least 30 days added by climate change. Eastern Europe had 188 million people

exposed to similar dangerous extreme heat levels for seven days added by climate change, followed by western Europe, with 22.9 million people affected.

Countries with significant increases: **Bulgaria**, **San Marino**, **Slovenia, North Macedonia** and **Latvia** saw 30 additional **risky heat days** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature). **North Macedonia** had the most per-capita days with temperatures made at least three times more likely because of climate change (at CSI 3 or higher), with an average of 52 days. **Greece** had the largest population exposed to CSI 5, or five times more likely because of climate change, for 60 or more days, with 198,000 people affected. 518,000 people were exposed to dangerous extreme heat levels (hotter than 99% of temperatures observed) for an additional 30 days due to climate change.

Cities experiencing the most heat: The cities that experienced most days with temperatures *very strongly* influenced by climate change (at CSI 3 or higher) are **Longyearbyen** (Norway), **Cherkessk** (Russia), **Vatican City** (Vatican), and **Rome** (Italy), all experiencing at least two-thirds of the season with temperatures made at least three times more likely because of climate change. Other cities also experienced prolonged periods of heat significantly influenced by climate change:

- **Rome** and **Milan** (Italy) both endured at least a month of CSI 5, meaning that climate change made temperatures at least five times more likely. **Rome** saw 39 days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed).
- **Athens** (Greece) faced 30 days at CSI 5 or higher. It saw 32 days with temperatures above the dangerous extreme heat level (hotter than 99% of temperatures observed).
- In Eastern Europe, cities like **Bucharest**, **Belgrade**, and **Sarajevo** recorded some of the highest temperature anomalies in Europe, exceeding 2.9°C above normal for the period.
- In Spain, **Barcelona**, **Madrid**, and **Valencia** faced almost a third of the season with temperatures at CSI 5. This means that in June, July and August, at least a third of the days registered temperatures made at least five times more likely because of climate change.

Bulgaria, **Montenegro**, **Moldova**, **North Macedonia**, **Greece**, and others experienced their hottest June-August season since 1970.

Northern America

Across the Northern American region, **112.3 million people** were exposed to 60 days or more with temperatures made at least five times more likely because of climate change (CSI 5 or higher). The **Caribbean region** was the most affected in these three months, with the average person there exposed to extended periods of heat *very strongly* influenced by climate change.

Most affected regions: the average person in the **Caribbean** experienced 81 days with temperatures made at least three more likely because of climate change (CSI 3), the highest number of days in the region. On average, Central Americans experienced 62 days with temperatures *very strongly* influenced by climate change (CSI 3), followed by North Americans, experiencing 12 days.

Population exposed to risky temperatures: when looking at the population exposed to risky temperatures (hotter than 90% of temperatures observed in a local area) for at least 61 days, **Caribbeans** were the most impacted (40.7 million people), followed by **North Americans** (14.3 million people) and **Central Americans** (7.3 million people). **All of the Caribbean population** faced 30 days or more of risky temperatures made at least three times more likely because of climate change (CSI 3); 80% were exposed to these conditions for at least 61 days.

Countries with significant increases: Several Caribbean countries saw over 59 additional **risky heat days** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature). These include **Aruba**, **Curaçao**, **Dominica**, **Saint Lucia**, **Barbados**, **Jamaica**, and **Haiti**. **Aruba** had the highest per-capita days at CSI 3 or higher, with 92 days with temperatures made at least three times more likely because of climate change. **Mexico** had the largest number of people exposed to CSI 5 for 60 or more days, affecting 44.2 million people.

Cities experiencing the most heat: Numerous cities across North America experienced prolonged periods of extreme heat:

- In the Caribbean, **Willemstad** (Curaçao), **Oranjestad** (Aruba), and **Kralendijk** (Bonaire) saw every day of the season with temperatures made at least three times more likely because of climate change, with most of those days at up to five times more likely (CSI 5 or higher).
- **San Juan** (Puerto Rico) and **Kingston** (Jamaica) each experienced 90 days or more of temperatures made at least three times more likely because of climate change (CSI 3).
- In Mexico, **Morelia**, **Puebla**, and **Mexico City** recorded at least 73 days at CSI 3 or higher.
- In the United States, **Miami**, **Tampa**, and **Las Vegas** all saw at least 49 days with temperatures made at least three times more likely because of climate change (CSI 3 or higher)

The **Caribbean** and **Central America** experienced the hottest June-August season since 1970, with widespread impacts across the region.

Oceania

Oceania has faced a significant rise in days with temperatures significantly influenced by climate change, particularly in **Micronesia** and **Melanesia**, with both regions experiencing some of the highest Climate Shift Index (CSI) levels. Across the continent, **over 11 million people** were exposed to 60 days or more with temperatures made at least five times more likely because of climate change (at CSI level 5 or higher).

Most affected regions: the average person in Micronesia experienced 86 days with temperatures made at least three times more likely because of climate change (CSI 3 or higher). Melanesia followed with 70 days.

Population exposed to risky temperatures: 267,000 people in Micronesia and 87,000 people in Melanesia were exposed to **dangerous** extreme **heat** (hotter than 99% of temperatures observed in a local area) for at least seven days added by climate change.

Countries with significant increases: Several countries in Oceania experienced over 30 additional days of **risky heat** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature), including **Guam**, **Nauru**, **Kiribati**, **Marshall Islands**, and the **Commonwealth of the Northern Mariana Islands**. **Guam** recorded the highest per-capita days at CSI 3 or higher, with an average of 88 days with temperatures made at least three times more likely because of climate change. **Papua New Guinea** had the largest population exposed to temperatures made at least five times more likely because of climate change (CSI 5) for 60 or more days, affecting 9.2 million people.

Cities experiencing the most heat: Several cities across Micronesia, Melanesia and Polynesia experienced over 70 days with temperatures made at least three times more likely because of climate change (CSI 3), including **Meneng Terrace** and **Yaren** (Nauru), **Hagåtña** and **Maina** (Guam), **Palikir** and **Weno** (Micronesia), **Capitol Hill** (Northern Mariana Islands), **Ngerulmud** and **Koror** (Palau), and **Apia** (Samoa). In Australia, **Hobart** and **Darwin** saw the highest number of days with temperatures made three times more likely because of climate change, with 22 and 17 days, respectively.

Many Pacific nations, including **Guam**, **Nauru**, **Kiribati**, and the **Marshall Islands**, recorded the hottest June-August season since 1970, underscoring the precedence of temperatures in these regions.

South America

In South America, the average person experienced **36 days** of temperatures made at least three times more likely because of climate change in June, July and August. **73.9 million people** were exposed to 60 days at CSI level 5 or higher, meaning that temperatures were at least five times more likely because of climate change on those days.

Population exposed to risky temperatures: Climate change significantly increased exposure to dangerous extreme heat levels (hotter than 99% of temperatures observed in a local area), with 25.3 million people affected for at least seven days and over 683 thousand for 30 days.

Most affected regions: **Suriname** and **French Guiana** saw over 30 additional days of **risky heat** (hotter than 90% of temperatures observed in a local area over the 1991-2020 period, which is a conservative approximation of the local minimum mortality temperature), with the population of both countries also experiencing 90 days with temperatures made at least three times more likely because of climate change (at CSI 3 or higher). **Bolivia** and **Venezuela** had the largest populations exposed to temperatures made at least five times more likely because of climate change for 60 or more days during this season.

Cities experiencing the most heat: Several cities faced at least 70 days with temperatures *very strongly* influenced by climate change (CSI 3 or higher), including **Georgetown** (Guyana), **Paramaribo** (Suriname), **Caracas**, **Valencia**, and **Barquisimeto** (Venezuela), as well as **Belem**, **Macapá**, and **São Luís**, (Brazil), **Quito** (Ecuador) and **Bogota** (Colombia). **Caracas** and **Paramaribo** recorded the highest mean temperature anomalies for South America, at around 1.3°C.

Both **Suriname** and **French Guiana** experienced their hottest June-August season since 1970, alongside other regions of South America seeing significant temperature anomalies.