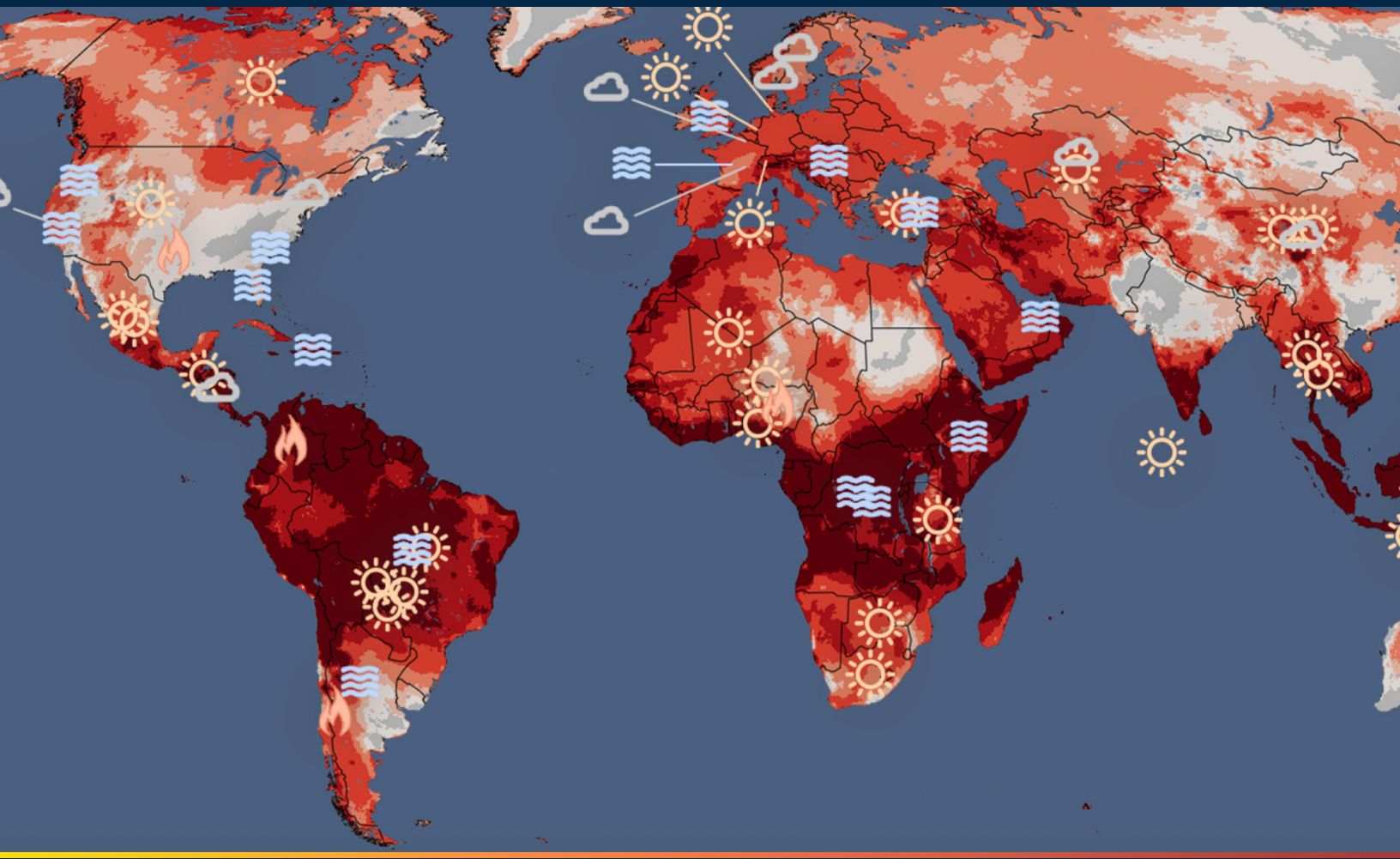
Seasonal Attribution Report

An analysis of how climate change boosted temperatures worldwide between December 2023 and February 2024



March 7, 2024

CLIMATE CENTRAL

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Key Facts

Carbon pollution drove abnormal warmth experienced by 59% of humanity between December 2023 and February 2024.

Roughly 80% of Earth's population, 6.7 billion people, were exposed to unusual warmth linked to climate change. More than half — 4.8 billion people, approximately 59% — experienced at least one day of temperatures that would be virtually impossible without the influence of carbon pollution.

For 1.7 billion people worldwide, daily temperatures during this span — meteorological winter in the northern hemisphere — reached the maximum level 5 on Climate Central's Climate Shift Index (CSI) at least 31 times. That equates to a month or more of abnormal warmth made at least five times more likely by the influence of climate change.

Data

- **Download data for December 2023-February 2024, including:**
  - **National and State data:** Includes the monthly temperature anomalies and the monthly Climate Shift Index levels for 175 countries. We also include values for states/provinces in the United States, Canada, India, and Brazil.
  - **City data:** Shows Climate Shift Index levels for 678 cities, as well as streaks of unusual temperatures.

INTRODUCTION

Primarily by burning coal, oil, and natural gas, humans have raised the temperature of the planet. Scientists report that the average temperature in 2023 was 1.5 degrees Celsius warmer than early-industrial levels (1850-1900). The purpose of this report is to document what this rise in global temperatures means 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 degree C of warming. Temperature anomalies highlight conditions that people would recognize as unusual.

2. Climate Shift Index: this is a metric developed by Climate Central that quantifies the influence of climate change on daily temperatures.

Below, we describe conditions across the planet. We also provide detailed data on 175 countries and 678 cities.

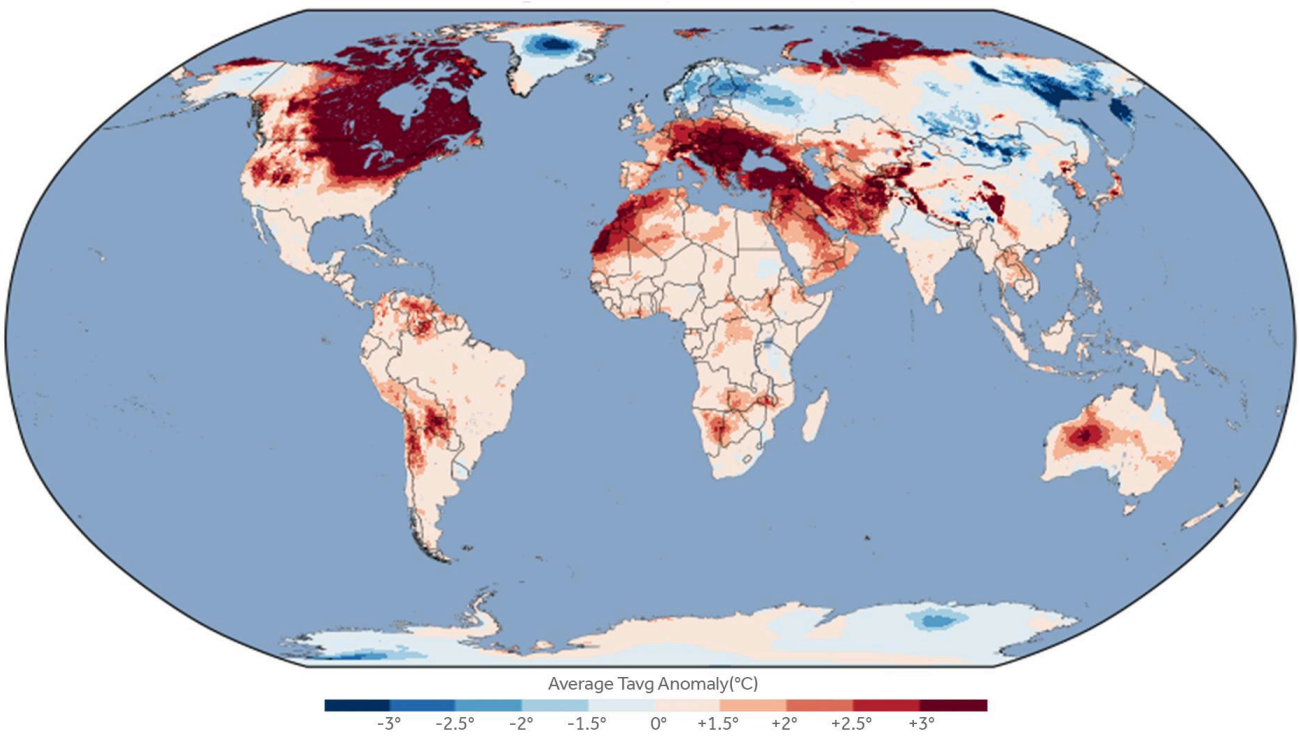

Figure 1. Global temperature anomalies for December 2023 through February 2024 relative to the 1991-2020 standard normal period. Analysis based on ECMWF ERA5 data. Produced March 6, 2024.

GLOBAL CONTEXT

Carbon dioxide levels in the atmosphere reached 422.8 ppm in January 2024. This is 3.3 ppm higher than the previous January, indicating that carbon dioxide levels are continuing to rise.

The global average temperature anomaly reported by Copernicus reached 1.66 degrees C. This is also a record for January, though it is not as dramatic as the peak value observed in September 2023.

A moderately strong El Niño is underway. El Niño tends to drive global temperatures higher, though there is typically a delay of about six months. El Niño is influencing the pattern of temperature anomalies around the world. However, it is important to remember that the 2023-24 El Niño is occurring on top of a climate that has been warmed by human activities. The daily attribution calculations in this report reference observed changes against a 30-year period. This procedure accounts for the variability from El Niño-La Niña cycles, allowing us to quantify the influence of climate change.

GLOBAL PATTERNS

Over the last three months, there were two large regions with unusually warm conditions:

- **A region covering most of Canada and the upper Midwest region of the United States.** Average December temperature anomalies exceeded 5.5 degrees C in the Canadian provinces of Saskatchewan, Manitoba, NW Territories, Alberta, and Nunavut, and the U.S. states of Minnesota, North Dakota, and Wisconsin. U.S. Midwest cities were among the most unusually warm in the world. Of the 678 global cities included in the analysis, Minneapolis had the most significant departures from their average winter temperatures.
- **A second large region extending from Germany to Pakistan.** Temperature anomalies in Germany, Hungary, Romania, Bulgaria, Turkey, Iran, and others exceeded 3 degrees C across the season.

There were also smaller but notable anomalies in:

- Western Australia
- Northwest Africa including Morocco and Western Sahara
- Bolivia and Paraguay
- Venezuela
- Western U.S.

We're able to see the climate change connection in these seven regions through the Climate Shift Index.

The Climate Shift Index shows how strongly a day's temperature is linked to climate change. This is different from the temperature anomaly. It incorporates our confidence in the amount of warming in that region based on both observed trends and 24 climate models. It also includes the expected range of day-to-day changes in temperature.

Over the last three months, we see a typical pattern in attributability to climate change as measured by the number of days at or above Climate Shift Index level 2 (at least twice as likely because of climate change). The pattern shows much higher exposure to climate-altered temperatures along the equator, with many places in northern South America, central Africa, and the Malay Archipelago having more than 60 days of Climate Shift Index level 2 or higher. While the temperature anomalies are generally lower in these regions, they also have much lower day-to-day changes in temperature than in mid or high latitudes. This makes it easier to isolate the signal of climate change from daily swings in weather.

In looking at those seven regions (as listed above), we can use the Climate Shift Index to quantify the link between these unusually warm conditions and climate change. We find that:

- Canada and the northern U.S.: All of Canada experienced more than 10 days at Climate Shift Index level 2 or higher. The U.S. states of Minnesota and Wisconsin had more than 20 days of temperatures at that level.
- Europe and western Asia: The entire region had more than 20 days at CSI 2 or higher, with some places having many more.
- Western Australia: more than 20 days at CSI 2 or higher
- Northwest Africa: more than 40 days at CSI 2 or higher
- Bolivia and Paraguay: more than 40 days at CSI 2 or higher
- Venezuela: more than 60 days at CSI 2 or higher
- Western U.S.: more than 10 days at CSI 2 or higher

The Climate Shift Index focuses on temperature, which is the most obvious connection between daily experience and global warming. However, climate change also drives other weather extremes and impacts. During December 2023-February 2024, World Weather Attribution identified 70 significant extreme events around the world. Their criteria to establish whether an event is significant include factors such as number of people (or percent of the population) impacted, fatalities, declaration of a state of emergency, records getting set, and more. The events included heat waves, floods, fire, and storms, which are mapped in the figure below. Many of these occurred in areas with climate-altered temperatures as measured by the Climate Shift Index.

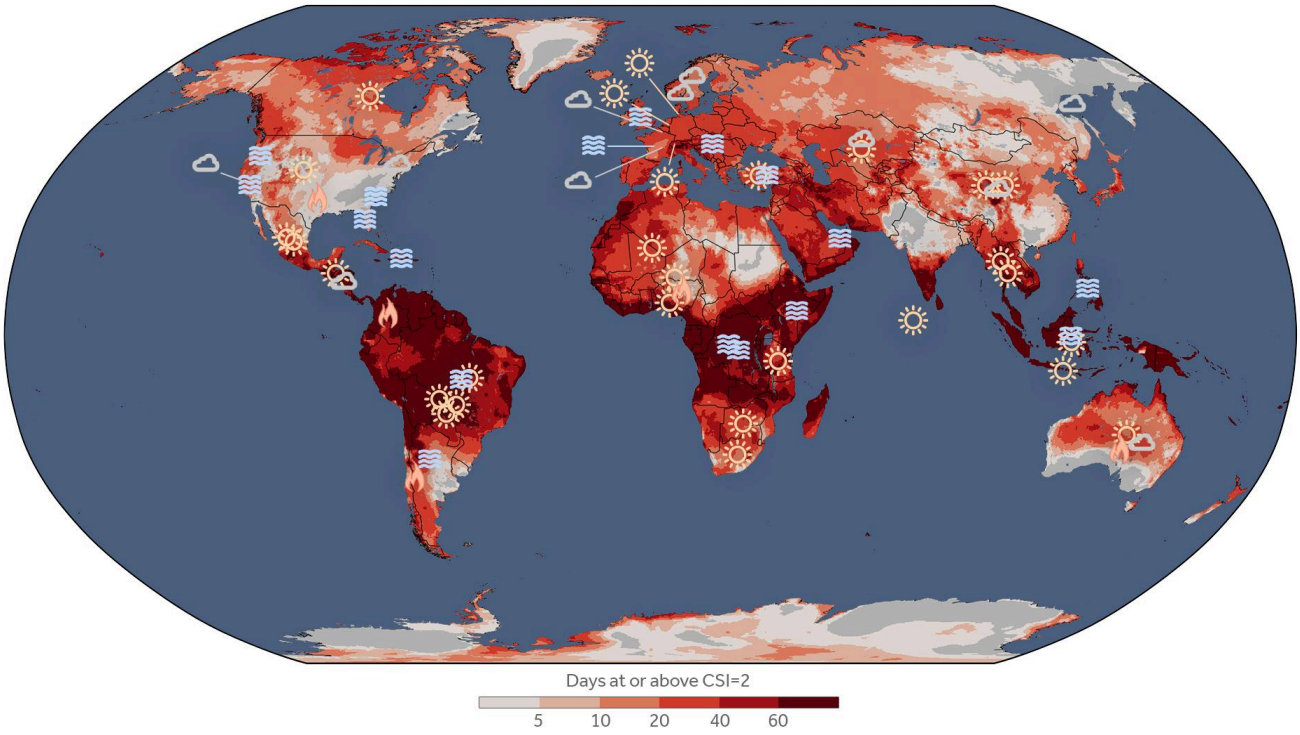

Figure 2. Number of days at Climate Shift Index (CSI) level 2 or higher. Overlaid are icons representing extreme weather events identified by World Weather Attribution that occurred over the December 2023-February 2024 period. Analysis based on ECMWF ERA5 data. Produced March 6, 2024.

Heat and Beyond: a global retrospective of extreme weather impacts in the past three months

December 2023 and January 2024 were the warmest December and January on record globally, and February is likely to follow this trend. These high temperatures were felt in all the world's regions in the form of extreme heat and intense rainfall.

In **Australia**, December marked the hottest start to summer in Sydney, when at least 19 schools were closed due to extreme fire danger from heat conditions. Maximum temperatures were well above 40°C for several days in many parts of the country, reaching 46°C and 50°C in Western Australia.

In **South America**, extreme heat contributed to wildfires in Chile and Colombia, burning at least 100,000 hectares since the beginning of 2024 and claiming 131 lives. In the Amazon basin, record temperatures paired with climate-change-driven drought affected thousands of livelihoods. Scientists predict that the human-induced extreme weather left a permanent footprint on the Amazon biodiversity and ecosystem, as local lakes reached 41°C and killed hundreds of freshwater fishes and dolphins. At the same time, torrential rains killed 33 people in Bolivia, affecting over 300 municipalities.

Over half of **Mexico** experienced moderate to exceptional drought. Mexico City is on the verge of running out of water, possibly joining other cities already in a water crisis, such as Barcelona and 200 towns in Spain, which have declared an official drought emergency after over 1,000 days of drought.

Despite it being winter, **Spain** experienced summer temperatures. The population spent January by the beach rather than in Spanish ski resorts, where the minimum night temperature did not go below 10°C - amidst concerns of extreme heat in the next few months.

In **Nigeria**, temperatures of around 40°C persisted throughout February, while Kenya's Meteorological Department warned of high temperatures across the country and urged the population to take precautions against the heat. Beyond heat-related impacts, over 300 were killed during what is considered the worst floods in decades in the **Democratic Republic of the Congo**. Deadly floods also killed an additional 65 people in the Manyara region of **Tanzania**.

Unprecedented winter heat broke nationwide records in **Japan**, sometimes by more than 6°C. Human-induced climate change also increased the frequency and severity of extreme rainfall events across Asia, resulting in fatal flooding, landslides and widespread displacement. After weeks of flooding and landslides during what is traditionally part of the dry season, 71 people died on the **Philippines** island of Mindanao, while damages to crops and infrastructure are estimated to be $40 million USD.

In the **United Kingdom**, Storm Henk was one of the several storms that left widespread flooding, leaving a negative impact on farm production.

While some regions experienced extreme heat, others felt record-breaking cold. In **China's** capital, six months after Beijing recorded its hottest-ever June, the city saw its coldest-ever December. Human-induced climate change also made extreme cold about 4°C colder in Northern Europe. **Sweden** saw its coldest January night in 25 years while freezing Arctic temperatures brought sub-zero temperatures to parts of the United States.

COUNTRY AND CITY ANALYSIS

The global analysis above focused on large-scale patterns aggregated across the season. Moving down to the national, state, and city levels, we can see new events that have impacted people around the world.

1. Climate fingerprints in the tropics

Daily temperatures in Southeast Asian, Sub-Saharan African, and Caribbean countries most clearly showed the fingerprints of climate change. In 36 countries across these regions, 579 million people experienced unusual warmth made at least five times more likely by climate change on 60 or more days between December 2023 and February 2024.

Nine countries — Brunei, Equatorial Guinea, Sao Tome and Principe, East Timor, Indonesia, Trinidad and Tobago, Malaysia, Gabon, and Rwanda— had temperatures that reached a country-wide average of 5 on the Climate Shift Index on 75 or more days. Burundi, Jamaica, Singapore, the Philippines, Mauritius, and Ethiopia. experienced at least 60 days at Climate Shift Index level 5. Temperatures in all of these countries were roughly 1 degree Celsius (2 degrees Fahrenheit) above normal for the three-month period.

Country	Continent	Days at CSI = 5 or higher	Temperature anomaly (°C)
Indonesia	Asia	85	1.1
Malaysia	Asia	84	1.0
Rwanda	Africa	79	0.8
Burundi	Africa	70	0.7
Philippines	Asia	66	1.0
Ethiopia	Africa	60	0.9
Haiti	North America	45	0.7
Malawi	Africa	43	1.4
Somalia	Africa	43	0.8
Dominican Republic	North America	42	1.1

Table 1. Countries in Southeast Asia, Sub-Saharan Africa, and the Caribbean with the highest number of days at a Climate Shift Index (CSI) of 5 or higher over the December 2023-February 2024 period. Only includes countries with populations exceeding 10 million.

2. Winter warming around the world

Notable February heatwaves in large cities were clearly influenced by climate change.

Earlier in February, **Sydney, Australia** hit 39 degrees C temperatures (102 degrees F) and reached level 5 on the Climate Shift Index scale.

In **Nairobi, Kenya**, residents endured 79 days of temperatures reaching Climate Shift Index level 5, including a late-February stretch in which temperatures reached 32 degrees C (90 degrees F).

Across **Japan**, unusually warm wintertime temperatures set more than 100 local records in February and reached level 5 on the Climate Shift Index in **Sapporo**, hitting 10 degrees C (50 degrees F) in a city where February highs are normally near freezing.

People in **Central European** countries also experienced significant climate change-influenced warming between December 2023 and February 2024. Average temperatures were roughly 3 degrees C (5 degrees F) higher than normal for the entire winter in **Switzerland, Austria, Slovenia, Slovakia, and Poland**, all of which experienced 10 or more days of warmth reaching level 5 on the Climate Shift Index.

Country	Days at CSI = 5	Temperature anomaly (°C)
Slovakia	18	3.4
Switzerland	14	2.6
Bosnia and Herzegovina	13	4.1
Lithuania	13	1.6
Moldova	13	3.6
North Macedonia	12	2.9
Slovenia	12	2.7
Austria	11	3.3
Montenegro	11	3.0
Poland	10	2.9

Table 2. European countries with the highest number of days at Climate Shift Index (CSI) level 5 or higher. These countries experienced the strongest fingerprints of climate change.

3. Winter warming in the U.S.

In the **U.S.,** winter temperature anomalies were even higher across the upper Midwest. In **Minneapolis**, where daily temperatures reached level 5 on the Climate Shift Index three times this winter, average temperatures were more than 5.5 degrees C (about 10 degrees F) above normal between December

and February. This temperature anomaly was the highest across all large global cities we analyzed, and the fourth highest in the U.S. when smaller cities are included.

City	Country	Days at CSI = 5 or higher	Temperature anomaly (°C)
Minneapolis	United States	3	5.6
Tehran	Iran	12	4.3
Belgrade	Serbia	5	4.2
Milwaukee	United States	1	4.0
Bucharest	Romania	9	4.0
Montreal	Canada	0	3.9
Yerevan	Armenia	19	3.7
Karaj	Iran	40	3.7
Detroit	United States	0	3.6
Vienna	Austria	9	3.6

Table 3. Top 10 large cities globally with the highest temperature anomalies over the December 2023-February 2024 period. Only includes cities with populations exceeding 1 million.

People in the upper Midwest and northern Great Plains regions experienced a number of days in which the influence of climate change was less pronounced than Climate Shift Index level 5, but nonetheless clear. Minneapolis residents experienced 33 days of warmth made at least twice as likely by climate change, or Climate Shift Index level 2, during the span. Residents of **Milwaukee, Detroit, and Chicago** all experienced at least 10 days of unseasonable warmth reaching Climate Shift Index level 2, contributing to average winter temperatures above 3.5 degrees C (roughly 6 degrees F) above normal in those cities.

City	State	Days at CSI = 3 or higher	Temperature anomaly (°C)
Fargo	ND	18	6.1
Duluth	MN	18	5.8
Mankato	MN	15	5.7
Minneapolis	MN	20	5.6
Wausau	WI	10	5.5

Mason City	IA	9	5.3
La Crosse	WI	8	5.1
Green Bay	WI	9	5.1
Minot	ND	2	4.8
Marquette	MI	10	4.8

Table 4. Top 10 U.S. cities tracked by Climate Central's Climate Matters program with the highest temperature anomalies over the December 2023-February 2024 period.

On the East Coast, people in **Boston, Providence, New York, and Philadelphia** all experienced at least five days of unusual warmth made at least twice as likely by climate change, which contributed to average winter temperatures roughly 2 degrees C (4-to-5 degrees F) higher than normal.

The island cities of **San Juan** (84) and **Honolulu** (50) had the most days of unusual warmth reaching level 2 on the Climate Shift Index. On the mainland, cities in the west including **San Francisco, San Jose, Juneau, Seattle,** and **Sacramento** all saw more than 20 days of warmth made at least twice as likely by climate change even though average winter temperatures there and across the West were closer to normal than in the Midwest. In **Phoenix** and **Las Vegas**, residents also experienced more than two weeks' worth of unusually warm days made at least twice as likely by climate change (Climate Shift Index level 2) although those cities' wintertime average temperatures were only slightly higher than normal.

Altogether this winter, 15 U.S. states (as well as Puerto Rico) experienced at least ten days of unusually warm weather across the state made at least twice as likely by climate change. And 71 million were exposed to at least one day of warmth reaching level 5 on the Climate Shift Index — temperatures on those days would be virtually impossible without the influence of carbon pollution.

City	State/Territory	Days at CSI = 2 or higher	Temperature anomaly (°C)
San Juan	PR	84	0.6
Honolulu	HI	50	0.2
San Francisco	CA	39	0.4
Juneau	AK	37	1.8
San Jose	CA	35	0.1
Duluth	MN	33	7.0
Minneapolis	MN	33	6.6

Fargo	ND	32	7.8
Marquette	MI	29	5.9
Wausau	WI	27	7.0

Table 5. Top 10 U.S. cities with the highest number of days at a Climate Shift Index (CSI) of 2 or higher.

The Climate Shift Index (CSI)

Humans have caused global average temperatures to increase by 1.1°C (2°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 is 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 ERA5 data from December 1, 2023 to February 29, 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).

Country Analysis
The country-level analysis includes 175 countries 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 CSI level 5 (all based on average temperature) over the December 1, 2023 to February 29, 2024 period. For each country, we then selected the data within its geographical boundary and spatially averaged the temperature anomaly, the number of days at various CSI thresholds, and population exposed to CSI levels of 5. Reported temperature anomalies are relative to each country's 1991-2020 normal December-February average temperature. We performed the same analysis on states/provinces in Canada, USA, India, and Brazil.

City Analysis
We analyzed 678 cities from around the world. These cities are cities with populations exceeding 1 million people, and various U.S. cities. 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 December 2023, January 2024, and February 2024, and the number of days at CSI levels 2, 3, 4, and 5. 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.

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. Climate Central is a policy-neutral 501(c)(3) nonprofit.