CLIMATE CENTRAL

Lost Winter

Analysis: Climate change adding more winter days above freezing — affecting snowfall, winter sports, ecosystems, and more

December 2024

KEY FACTS

- **Across the Northern Hemisphere, climate change — due primarily to burning oil, coal, and methane gas — is causing a significant increase in winter days with minimum temperatures above freezing, otherwise called lost winter days.**
- **Analysis of daily minimum temperatures during winter (December, January, February) in 123 countries shows that more than one-third (44) experienced at least one additional week's worth of days above freezing annually during the past decade (2014-2023) due to human-caused warming.**
- **On average, climate change added more winter days above freezing in European countries compared to nations in other regions.**
- **Around 44% of cities analyzed (393 of 901) experienced at least one additional week's worth of days above freezing annually due to climate change. Cities throughout Asia and Europe were among those that saw the most additional days above freezing due to global warming.**
- **In the United States, 28 states and around 63% (39 out of 62) of cities analyzed experienced at least a week's worth of lost winter days each year due to climate change.**
- **Losing winter's chill affects snowfall, winter sports, water supplies, spring allergies, crops, and more.**

➤ **Download data** for 123 countries and territories and 901 cities

INTRODUCTION

The coldest time of the year sustains snow and ice for winter recreation and other activities, and it replenishes the snowpack that supplies freshwater. Winter chill also plays a critical role in plant, animal, and insect life cycles, influencing ecosystems throughout the rest of the year.

Climate change is decreasing the frequency of the cold temperatures that define the winter season. This warming trend, which is driven by human-caused climate change, not only disrupts the season itself, but also erodes the benefits it provides year round.

Climate Central assessed how warming temperatures, attributed to climate change, affected the number of days above freezing (0°C) during winter (December, January, February) in 123 countries across the Northern Hemisphere over this past decade (2014-2023).

The analysis uses observed temperature data as well as estimates of counterfactual temperatures (or temperatures that would have occurred in a world without human-induced climate change) derived from the Climate Shift Index (CSI) system.

Findings show the locations across the globe where cold winter days are disappearing in a warming world, compared to a world without climate change.

RESULTS

1. Nations across the Northern Hemisphere experienced significantly more above-freezing winter days during the past decade compared to a world without climate change.

Between 2014-2023, more than one-third of the countries analyzed (44 of 123) experienced, on average, at least a week's worth of lost winter days — days between December-February where minimum temperatures exceeded 0°C — annually due to climate change (see Figure 1 and Table 1).

In other words, human-caused warming added a week's worth of winter days above freezing in these locations, compared to a world without climate change.

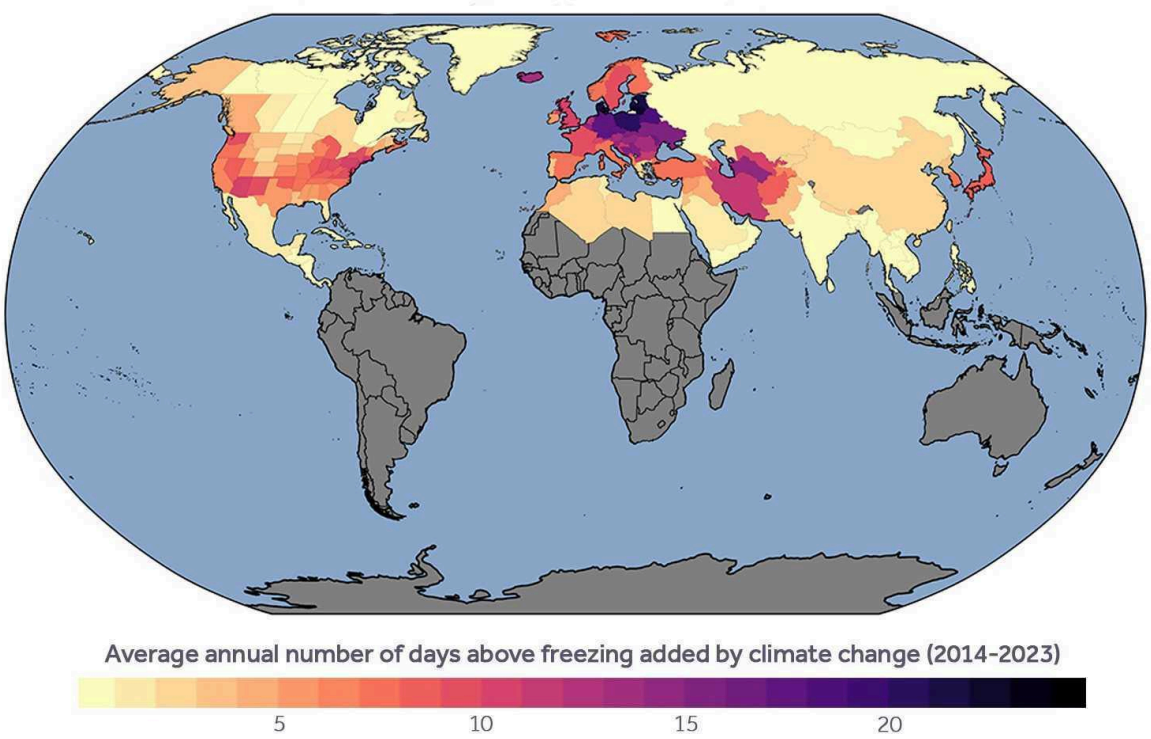

Figure 1. Annual lost winter days — or winter days with minimum temperatures above 0°C — added by climate change, averaged over a ten-year period (2014-2023).

2. On average, climate change added more winter days above freezing in European countries compared to other nations.

- Twenty-five countries experienced between a week's worth and two weeks' worth of lost winter days annually as a result of climate change. These include **France**, **Italy**, **Japan**, **the Netherlands**, **Norway**, **Spain**, and **the United Kingdom**. In other words, human-caused warming added between a week's worth and two weeks' worth of winter days above freezing in these locations, compared to a world without climate change.

- Nineteen countries — primarily in Europe — saw an average of at least two additional weeks' worth of lost winter days annually due to human-caused climate change over the past decade, compared to a world without climate change. This includes **Germany**, **Poland**, **the Czech Republic**, and **Belgium**.

- **Denmark, Estonia, Latvia,** and **Lithuania** each experienced an average of at least three additional weeks' worth of lost winter days due to climate change.

- This is in the context of Europe being the fastest-warming continent, warming twice as fast as the global average since the 1980s.

Country	Winter days above 0°C annually	Winter days above 0°C added by climate change annually
Lithuania	32	23
Latvia	31	22
Estonia	30	22
Denmark	71	21
Poland	40	20
Belarus	24	19
Germany	54	18
Czech Republic	36	18
Republic of Moldova	33	16
Ukraine	30	16
Luxembourg	56	16
Slovakia	31	15
Serbia	43	15
Bosnia and Herzegovina	44	15
Belgium	68	15
Hungary	45	15
Turkmenistan	49	15
Slovenia	40	15
Romania	35	14
Iceland	21	13
Austria	23	13
Netherlands	75	12
Croatia	60	12
Islamic Republic of Iran	58	12
North Macedonia	41	12
Bulgaria	46	12
United Kingdom	79	11
Azerbaijan	44	11
Switzerland	23	10
Uzbekistan	25	10
France	67	10
Sweden	17	10
Liechtenstein	15	10
Montenegro	44	9
Japan	52	8
Afghanistan	35	8
Turkey	46	8
Spain	74	8
Republic of Korea	34	8
Andorra	13	7
Finland	9	7
Italy	69	7
Norway	12	7
Georgia	27	7

Table 1. Countries with at least seven additional winter days with minimum temperatures above 0°C each year due to human-caused climate change. Results represent averages over the past decade (2014-2023).

3. Cities across Asia and Europe experienced the most lost winter days due to a warming climate.

- On average over the past decade (2014-2023), around 44% of cities analyzed (393 of 901) experienced at least seven lost winter days per year due to human-caused climate change. In other words, human-caused warming added at least 10 winter days above freezing in these locations, compared to a world without climate change.

- Thirty-five cities across **Asia** and **Europe** saw the greatest number of lost winter days — at least three weeks' worth of above-freezing winter days were added, on average, because of global warming (see Table 2).

- Six cities experienced at least a month's worth of lost winter days each year: **Fuji, Japan; Khujand, Tajikistan; Turin and Verona, Italy; Bergen, Norway; and Riga, Latvia.**

- In the **United States**, 28 states and around 63% (39 out of 62) of cities analyzed experienced at least a week's worth of lost winter days each year due to climate change (see Table 3).

City/Prefecture	Country	Winter days above 0°C annually	Winter days above 0°C added by climate change annually
Fuji	Japan	64	35
Khujand	Tajikistan	58	30
Turin	Italy	64	30
Bergen	Norway	65	29
Verona	Italy	74	29
Riga	Latvia	40	28
Qom	Iran	74	26
Brescia	Italy	78	26
Copenhagen	Denmark	61	25
Stavanger	Norway	72	25
Fukayacho	Japan	62	25
Kristiansand	Norway	48	25
Trondheim	Norway	30	25
As Sulaymaniyah	Iraq	62	24
Munich	Germany	45	24
Nagaoka	Japan	58	23
Hiroshima	Japan	61	23
Szczecin	Poland	54	23
Ashikaga	Japan	55	23
Vienna	Austria	49	22
Ashgabat	Turkmenistan	65	22

Kermanshah	Iran	38	22
Milan	Italy	70	22
Hanzhong	China	54	22
Karaj	Iran	32	21
Lichuan	China	64	21
Sandnes	Norway	73	21
Gdansk	Poland	45	21
Lublin	Poland	38	21
Ankang	China	56	21
Helsinki	Finland	25	21
Kyiv	Ukraine	28	21
Shiyan	China	54	21
Poznan	Poland	46	21
Kyoto	Japan	60	21

Table 2. Cities with the most winter days with minimum temperatures above 0°C added each year due to human-caused climate change. Results represent averages over the past decade (2014-2023).

State	Winter days above 0°C annually	Winter days above 0°C added by climate change annually
District of Columbia	48	12
Connecticut	34	11
New Jersey	45	11
Rhode Island	42	11
Massachusetts	34	11
Arizona	58	11
Maryland	51	10
Delaware	57	10
Pennsylvania	29	10
Virginia	52	10
Ohio	34	10
Washington	39	10

Table 3. U.S. states with the most winter days with minimum temperatures above 0°C added each year due to human-caused climate change. Results represent averages over the past decade (2014-2023).

EFFECTS OF LOST WINTERS

Among other things, warming winters and less-frequent freezes can have significant impacts on:

- **Snowfall and ice**. Warming winters can affect the timing, location, and amount of snowfall, with a range of impacts for people, ecosystems, and water supplies. Climate models suggest that Northern Hemisphere snow cover will decrease at a rate of -8% per 1°C of global surface air warming. Snow forms when the temperature is at or below freezing (0°C) — therefore, more days above freezing as a result of climate change could mean less accumulating snow. Our warming atmosphere holds about 7% more moisture per 1°C of temperature rise (or 4% more moisture per 1°F of temperature rise); and as winters warm, more of that extra moisture could fall as rain instead of snow. Freezing temperatures are necessary for ice to form and not melt, so fewer days below freezing affects lake ice coverage and duration (including Great Lakes ice in the U.S. and Canada).

- **Winter sports and recreation.** Freezing or below-freezing temperatures are essential to almost all winter sport and recreation activities, which contribute to many economies and cultures around the world. The global winter sports industry was valued at approximately USD 12.5 billion in 2023. The winter recreation industry faces a "bleak future" because of rising temperatures and reduced snow and ice accumulation, according to a joint statement from the International Ski and Snowboard Federation and the World Meteorological Organization. February temperatures in the 19 cities to host the Winter Olympics since 1950 have warmed by 2.7°C (4.8°F) on average since 1950. By the 2080s, under a high-emissions scenario, nearly all previous Winter Olympics host cities would be unable to provide reliably safe and fair conditions for outdoor snow sports.

- **Water supplies.** Warming winters can reduce mountain snowpack — a critical source of spring meltwater that refills reservoirs and enables crop irrigation in some regions of the world, worsening an already growing global water crisis.

- **Disease-carrying pests.** Cold winters keep the populations of disease-carrying pests like mosquitoes and ticks in check. But warmer, shorter winters can worsen pest-related health risks.

- **Growing seasons and allergies.** Warmer, shorter winters mean earlier spring thaw and later fall freeze — giving plants more time to grow and release allergy-inducing pollen earlier in the spring and later into the fall.

- **Fruit and nut crops.** Warmer, shorter winters can disrupt the chill that fruit and nut crops depend on. In other ways, shifting growing seasons can expose crops to damaging frost during the early stages of growth.

Methods

Calculating days with temperatures above freezing (0°C)

We analyzed observed global temperatures 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 temperatures 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 uses the latest peer-reviewed attribution science to quantify 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 change of 0°C 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 data for the months corresponding to the Northern Hemisphere's winter season: December, January, and February. We then counted the number of days in each year when the daily minimum temperature exceeded 0°C over the ERA5 and counterfactual temperatures from 2014-2023 and calculated the difference to assess how climate change has impacted freezing winter temperatures. We refer to the additional days with minimum temperatures above freezing due to climate change as "lost winter days."

We spatially averaged the counts within each of the 123 countries and territories in the Northern Hemisphere to report country-level averages. For some larger countries, such as Canada and the United States, we also averaged over states/provinces to provide more detailed data. We repeated the analysis for cities with populations greater than 750,000 (inclusive of the broader metropolitan population, based on data from World Cities Database) to achieve city-specific counts of lost winter days attributable to climate change. Some locations with smaller populations were included to support an expanded results set.

Numbers in this report are typically rounded to the nearest significant figure. During the analysis, numerical values for observed and counterfactual data were calculated to high precision, but for reporting and presentation purposes, the number of decimal places was reduced. As a result, rounding may lead to small discrepancies when performing arithmetic operations on the presented values. These discrepancies are an artifact of rounding and do not affect or reflect the underlying precision of the analysis.

Appendix

Additional analysis of the following locations is available separately: Canada; Denmark; France; Germany; Italy; Japan; Norway; Poland; Spain; the United Kingdom; and the United States (Michigan and Wisconsin). Find files and data here: https://www.climatecentral.org/report/lost-winter-days-2024

REPORT CONTRIBUTIONS

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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.

Major funding provided by the Bezos Earth Fund.