MAY 2023

Wildfire Weather:

Analyzing the 50-year shift across America

CLIMATE CENTRAL

Climate change is worsening wildfires across the United States and putting more people at risk. Warming from heat-trapping pollution is affecting weather conditions in ways that increase the risks of wildfire. Long-term warming trends are drying out forests, grasslands, and other landscapes—helping fires spread and hindering opportunities to fight and prevent them.

To explore growing wildfire risks across the U.S., Climate Central analyzed historical trends in fire weather—the combination of high heat, low humidity, and strong winds.

This analysis includes data from 476 weather stations to assess trends in 245 climate divisions spanning the contiguous U.S. during a 50-year period (1973-2022). Results show that wildfire seasons are lengthening and intensifying, particularly during spring and summer in the West. Parts of Southern California and the Southwest are seeing around two additional months of fire weather compared to the early 1970s.

Annual fire weather days are also increasing in many parts of the East, although by fewer days on average than in the West. But even these smaller increases can be impactful in the densely populated East, where more people and property could be exposed. Seasonal trends are emerging in the East, with many areas experiencing more fire weather days during spring.

Significant differences in climate, topography, land use, and population distribution mean that wildfire risks are regionally distinct. But fire weather isn't limited to the western U.S. As this analysis demonstrates, all U.S. regions experience conditions that increase the likelihood of more extreme fires.

As fire weather occurs more frequently, communities across the country must adapt to living with more frequent fire weather and the associated risks.

Download local data

Wildfire Risks in a Warming World

Humans caused nearly 90% of wildfires between 2018 and 2022. But people aren't only responsible for igniting wildfires—human activity influences the weather and environmental conditions that increase the likelihood that wildfires will start and spread. At least two-thirds of the rapid increase in fire weather in the western U.S. in recent decades can be attributed to human-caused climate change. The latest Intergovernmental Panel on Climate Change reports project more frequent fire weather conditions with increased warming.

Once a fire is lit, three main factors influence its behavior: weather, fuels, and topography. Changes to weather can affect fire behavior and increase fire risks, regardless of the nature of the fuels present or the natural contours of the land.

FIRE WEATHER FUNDAMENTALS

Fire weather generally refers to meteorological conditions that promote the spread of wildfires, although definitions can vary. Variables such as temperature, relative humidity, wind, precipitation, and other atmospheric conditions all affect fire behavior.

Climate Central's analysis focuses on three meteorological conditions fundamental to fire weather: relative humidity, temperature, and wind. These conditions prime a landscape for wildfire when they converge in particular ways. To be considered a fire weather day under this analysis, these conditions must co-occur at or above certain levels.

- **Relative humidity** is a measure of how close air is to saturation, expressed as a percentage. When relative humidity levels are very low, the air feels dry and it draws moisture from the land, leaving the vegetation parched and prone to burn. As temperature increases, relative humidity decreases. Relative humidity is lowest during the afternoon when air temperatures are highest. NOAA's Storm Prediction Center (SPC) defines regional relative humidity thresholds for fire weather based on local climate.

- **Hotter temperatures** affect humidity and dryness and they also have a direct influence on fire behavior, heating the fuels and making them more likely to ignite. Cooler nighttime temperatures have historically meant lower risks of wildfires growing and spreading overnight. But as climate change brings warmer nighttime temperatures, fire weather conditions can extend into more hours of the day.

- **Wind** supplies oxygen to a fire, causing it to burn more rapidly. Wind also increases evaporation and helps to dry out the land, which provides more fuel for the fire. Changes in wind speed or direction can cause a fire to shift, and can increase the rate of spread and intensity of the fire. Wind also carries embers, which help a fire spread.

Box 1. How scientists measure dry conditions for risk of fire

Similar to relative humidity, **vapor pressure deficit (VPD)** is another way to monitor surface dryness, or aridity. The more water vapor in the air, the greater the pressure (i.e., vapor pressure) it exerts at the surface. The greater the difference between the vapor pressure and the vapor pressure at saturation, the greater the evaporation potential from the ground. As VPD increases (meaning the air is further away from saturation), plants must draw more moisture from their roots, which can lead to plants drying out or dying. Relative humidity and VPD have been linked to burned forest areas in the western U.S.

OTHER ENVIRONMENTAL FACTORS THAT INFLUENCE WILDFIRE

Fire weather is an important precondition for wildfire—it affects fire ignition, behavior, and eventually suppression. But other environmental factors can also raise the risk and danger of wildfire.

- **Fuels** are any combustible material that can feed a fire, including grass, trees, leaves, and other vegetation. Increased rainfall during winter or spring can lead to more vegetation growth, which can then dry out during the heat of summer and increase the risk of wildfire. The spread of invasive grasses and other plants is creating more combustible and fire-prone environments in many places. Climate change is impacting the amount of fuel in the landscapes. In the mountain West, rising temperatures contribute to tree mortality caused by beetles, leading to a buildup of dead trees that could lead to larger and worse wildfires. More intense storms, driven by climate change, blow down trees and create dead wood that becomes fuel for future fires.

- **Droughts** contribute to the drying of fuels and increase in fire activity. Climate change is a major contributor to the severe and persistent droughts in southwestern North America in recent decades. In an arid climate like the West, there is limited ground moisture to evaporate into the atmosphere. As a result, warming temperatures are drying out the air (sometimes called "hot droughts"). This low relative humidity accelerates evaporation from vegetation already in place, like leaves, brush, or dead trees, increasing the risk of intense fires.

- **Dry lightning**, or cloud-to-ground lightning that occurs without any accompanying rainfall nearby, is the lightning type most likely to cause wildland fires, particularly in the West.

- **Topography** can cause dramatic shifts in fire behavior. Slope steepness and direction, elevation, barriers, and land configuration all play a role.

Fire Weather Trends Across the U.S.

To investigate trends in fire weather, a key factor of wildfire risk, Climate Central analyzed data from 476 weather stations to assess trends in 245 climate divisions spanning the 48 contiguous U.S. states during the past 50 years (1973-2022). The results of this analysis are described primarily in terms of broad geographic regions (i.e., West and East)— however these two groups are comprised of multiple climate regions and climate divisions (see Table 1).

The contiguous U.S. is 2.5°F warmer today than it was in 1970. Warming that influences fire weather has been observed across the country. But key regional climate differences spanning from the West to the East broadly translate into distinct fire weather trends.

The East generally experiences more humid heat due to a combination of warm ocean currents and moisture blown in from the Gulf of Mexico. The West typically experiences dry heat (as in low humidity, which is more favorable for fire weather) because cool coastal currents do not contribute as much moisture to the air.

Although the critical thresholds for fire weather vary across the country, this analysis shows decreasing relative humidity has been a major factor in boosting annual fire

weather days for many locations across the U.S. (see Figure 1). This is consistent with research that shows drier conditions are expanding across North America.

The seasonality of fire weather trends also differs across the U.S. The West has seen the greatest jump in fire weather days in the summer (particularly in the Southwest), while areas in the East are experiencing a greater uptick in fire weather during the spring.

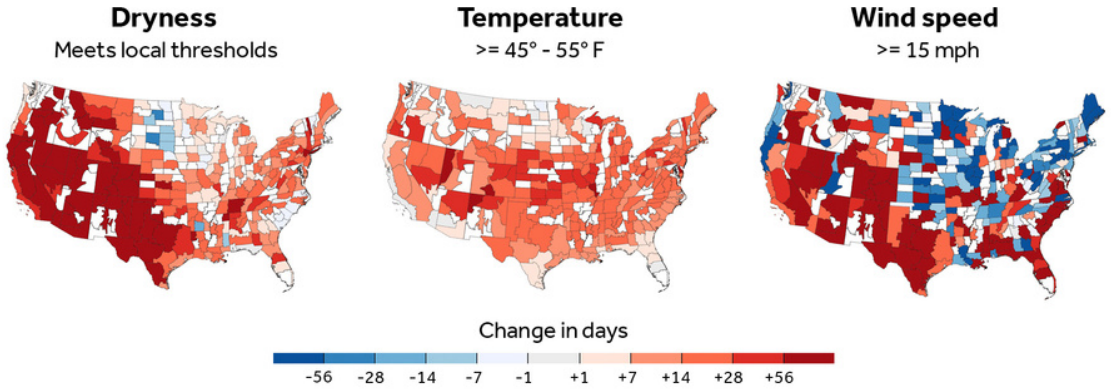

FIGURE 1: Average annual change in the number of days in which the analytical threshold was met or exceeded for each of the three meteorological conditions fundamental to fire weather (relative humidity, temperature, and wind speed) from 1973 to 2022. Source: NOAA/NCEI's Local Climatological Data and Climate Central analysis

FIRE WEATHER TRENDS IN THE WEST

Western states experience the most extreme fire weather conditions. The Southwest experiences nearly two more months of fire weather days each year, on average.

Long-term warming trends lead to accelerated evaporation from soils and plants, creating drier conditions. This drying has been driving increases in the frequency of fire weather days, affecting states from the Pacific Coast to the western Great Plains and from the Canadian to the Mexican borders.

This analysis shows a strong increase since the 1970s in the average number of annual fire weather days experienced in the West. These results are consistent with findings from previously published research.

Southern California, Texas, and New Mexico have experienced some of the greatest increases in fire weather days each year, with some areas now seeing around two more months of fire weather compared to a half century ago.

Some places, including parts of Texas, California, Oregon, and Washington, are experiencing fire weather more than twice as often now than in the early 1970s.

Increases in fire weather days were higher in the western interior regions compared to western coastal regions. Living along the coast typically means higher humidity levels, so it's unusual for these areas to reach the low relative humidity threshold used in the analysis. Although these

coastal areas experience relatively few fire weather days per year, the analysis shows an increase in the frequency of these conditions over time (see Figure 1).

By contrast, some parts of Idaho, North Dakota, and South Dakota have experienced a decline in the frequency of fire weather days. The Dakotas are part of a region where springs have been cooling slightly, while much of the rest of the country (and world) has been warming. This temperature trend in the Dakotas is unlikely to continue, and it might be influenced by natural variation and the cooling effects of agricultural development and crop irrigation.

Group	NCEI Climate Region	Aggregated NCEI Climate Divisions (#)	Average annual fire weather days	Average change in annual fire weather days	Households in the wildland urban interface (WUI)
West	Western South	23	24	13	3,993,322
	Northern Rockies & Plains	29	26	5	797,184
	Southwest	19	55	37	3,742,001
	West	10	43	23	5,673,582
	Northwest	14	13	9	1,940,298
East	Southeast	35	12	2	10,620,125
	Eastern South	20	6	2	2,163,899
	Ohio Valley	36	4	2	4,215,197
	Upper Midwest	27	4	1	2,165,125
	Northeast	32	11	1	8,816,086

TABLE 1: Climate Divisions within Climate Regions (both as defined by NOAA's National Centers for Environmental Information), as they are broadly grouped in the analysis (West or East). Note: the NCEI South region was split into the western South (Texas, Oklahoma, and Kansas) and eastern South (Arkansas, Louisiana, and Mississippi) and grouped as indicated in Table 1.

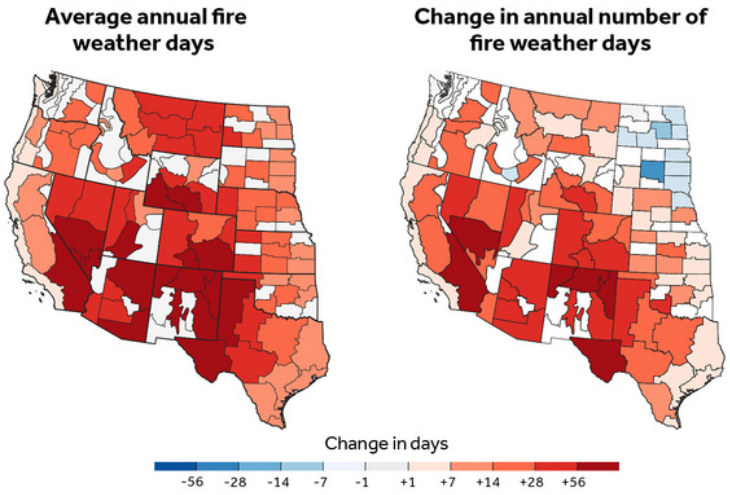

FIGURE 2: Average annual fire weather days (left) and change in annual number of fire weather days (right) from 1973–2022 in the West. Source: NOAA/NCEI's Local Climatological Data and Climate Central analysis

NCEI Climate Division	State	Average annual fire weather days	Average change in annual fire weather days
Southeast Desert Basins	CA	83	63
Northwestern Plateau	NM	70	59
Northern Mountains	NM	76	59
Northeastern Plains	NM	73	59
Trans Pecos	TX	66	58
South Central	NV	94	57
Southeast	AZ	69	55
South Central	AZ	43	45
Arkansas Drainage	CO	61	45
Northeast	AZ	68	44

TABLE 2: Top 10 locations with greatest change in fire weather days during the analysis period (1973-2022) (West)

FIRE WEATHER TRENDS IN THE EAST

A band stretching from coastal Maine through the Northeast and Piedmont Valley and into northern Florida experiences the highest average number of annual fire weather days in the East (in many places, it's more than a week). Parts of the Southeast experience several weeks of fire weather on average each year. Northern Florida experiences around a month. This at-risk band roughly aligns with the most populated corridors along the East Coast—demonstrating how increasing fire weather days could put more people at risk in the region.

The analysis shows relatively modest changes to the average number of fire weather days in the East since the 1970s, and findings vary spatially. Generally, the humid heat more commonly seen in the East (compared to dry heat) makes it less likely for these areas to reach the regionally-specific thresholds used in the analysis.

Parts of the Southeast and Northeast have experienced some of the greatest increases in annual fire weather days across the East. The Northern Piedmont in North Carolina is now seeing nearly two weeks more of fire weather compared to a half century ago. New York's coastal area and northern New Jersey—which already experience some of the most frequent fire weather—saw increases of around 10 days since 1973. Areas deeper in the South haven't escaped change; parts of Louisiana and Alabama now experience more than one extra week of fire weather.

However, most eastern areas included in this analysis saw, at most, a few more days of fire weather since 1973—and around 20% of eastern climate divisions saw either no change or a decrease.

Most of New England has seen a decrease in annual fire weather days, driven largely by fewer days where the wind speed exceeded the threshold. Wind is driven, in part, by air temperature differences between land and water. Slowing wind speeds could be partially attributed to a decrease in the temperature gradient between land and sea along the Gulf of Maine, as sea surface temperatures have warmed drastically due to climate change.

While the changes in fire weather days overall are smaller in the East than in the West, seasonal trends are emerging. Across much of the region, the greatest increase in fire weather days is happening in the spring months. This change aligns with spring warming trends experienced in many eastern states. While most of the East experiences humid summers, this analysis shows increased dryness during summers in the Northeast—however, a decrease in the number of days where the wind threshold was met dampened fire weather trends in this region.

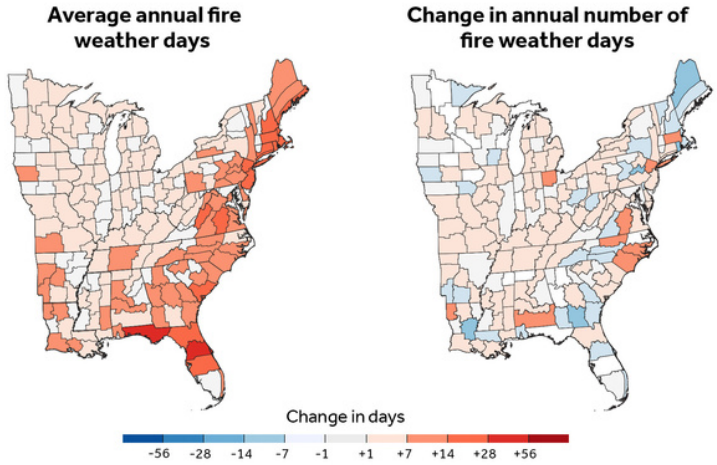

FIGURE 3: Average annual fire weather days (left) and change in annual number of fire weather days (right) from 1973–2022 in the East. Source: NOAA/NCEI's Local Climatological Data and Climate Central analysis

NCEI Climate Division	State	Average annual fire weather days	Average change in annual fire weather days
Northern Piedmont	NC	12	13
Northern	NJ	26	10
Coastal	NY	24	10
Northwest	LA	12	10
Central Coastal Plain	NC	7	10
Coastal Plain	AL	6	9
Eastern Piedmont	VA	15	8
Central	MA	14	8
Southern Coastal Plain	NC	9	8
Northwest	OH	6	7

TABLE 3: Top 10 locations with greatest change in fire weather days during the analysis period (1973-2022) (East)

Why Fire Weather Matters

As fire weather becomes more prevalent, there are more days when extreme conditions can blow up small blazes into big ones, or fuel the continued growth of large wildfires. This strains firefighting agencies and creates greater risks to public health, property, and local and regional economies from flames and smoke.

Many communities in the U.S. accustomed to living with wildfire risks are now dealing with more frequent fire weather. But for some parts of the country, the increase in fire weather days brings novel risks for which they may be unprepared. In addition to increasing the risk of fire, these extreme conditions are causing problems even when wildfires don't ignite.

MORE PEOPLE AND PROPERTY AT RISK

Urbanization and development of forests, forest edges, and other areas where fires are prone to burn—known as the wildland urban interface (WUI)—put more residents in harm's way and forces firefighting agencies to allocate greater resources toward protecting homes.

Between 1990-2020, land that falls within delineated WUI zones has expanded from about 7% of the total area in the continental U.S. to around 9%.

California contains the most households in the WUI (5.1 million) of the 48 contiguous states. But most of the WUI is concentrated in the East—nearly 80% of WUI lands as well as more than 60% of WUI households is in eastern states. The Southeast alone has around 10.6 million housesholds in the WUI.

Three of the top states with the greatest number of households in the WUI also saw an increase in fire weather days during the period of Climate Central's analysis: California, Texas, and North Carolina.

The increase of human activity in forested or dry areas causes more wildfire ignitions, including at times of year when lightning is uncommon and fires would naturally be rare. And the percentage of human-caused wildfires (compared to those caused by lightning) has grown during the past two decades—an especially hazardous trend as conditions conducive to extreme fires occur more frequently.

Wildfires are costly. The 2022 western wildfire season caused about $3.2 billion (adjusted) in damages. The National Interagency Fire Center estimates that fire suppression efforts cost federal agencies around $4.4 billion in 2021.

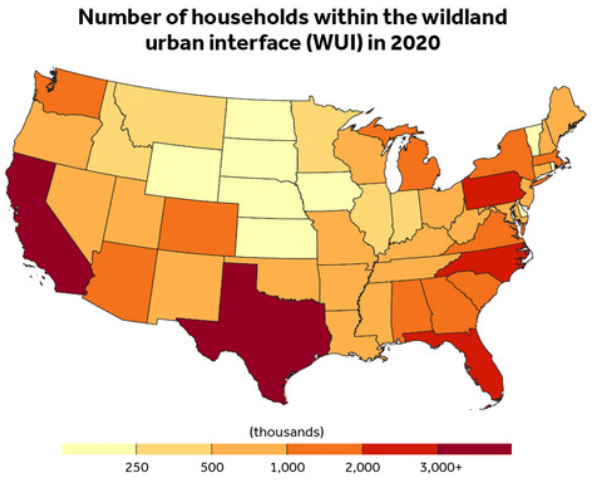

FIGURE 4. Number of households within the wildland urban interface (WUI) in 2020, by state. Source: US Forest Service, University of Wisconsin-Madison's SILVIS Lab

RESOURCE ALLOCATION DURING WILDFIRES

Fire weather conditions restrict the ability of firefighters to manage and put out wildfires. With climate change, nights have warmed significantly, even more so than days. This has decreased the overnight relative humidity that once helped firefighters gain control over wildfires.

As firefighting agencies try to respond to larger and more numerous fires, their resources are stretched thin, forcing difficult decisions about responding to some fires while allowing others to burn unchecked.

DANGEROUS SMOKE

Smoke is a dangerous pollutant that can contribute to a variety of health problems, including exacerbated asthma symptoms and increased susceptibility to some viruses (such as influenza or COVID-19). Smoke exposure poses especially high risks to those with other health problems, particularly among seniors and others with weakened lung health. The impacts from smoke aren't isolated to areas near a wildfire. Large fires in the West can affect air quality from coast to coast.

PRESCRIBED BURNING LIMITATIONS

The same weather variables that influence fire weather (including relative humidity, temperature, and wind speed) are factors in determining the safe application of prescribed fire—an important fuel-reducing forest management activity. These controlled fires, although used throughout the country, are more widely applied in the East—not only to reduce fire fuels (such as leaf litter, downed trees, and grasses), but also to remove invasive species, improve wildlife habitat, and support fire-dependent ecosystems.

More fire weather days means fewer windows in which prescribed burning can be conducted. Without controlled burns, more fuel can build up on the landscape, increasing wildfire risks. And with fewer opportunities for prescribed fire activity, more land managers will apply prescribed fire simultaneously, which can compound risks from their smoke.

PLANNED POWER OUTAGES

Fire weather days are a new challenge for utilities striving to keep up with record power demand during heat waves. In response to high-risk fire weather conditions, and in the hopes of avoiding ignitions from downed power lines and other equipment, power companies in the West in recent years started to shut off electricity to millions of people during public safety power shutoffs (PSPSs). These PSPSs create health risks to those who depend on power for refrigeration of medications and to stay cool during heat waves. Wildfire-related PSPSs in California in 2019 had an estimated economic impact of around $10 billion.

ADAPTING TO MORE FREQUENT FIRE WEATHER

There are solutions to mitigating risk in the face of longer and more extreme wildfire seasons, and communities can take steps to adapt. These include increased use of land management techniques that eliminate excessive fuels—including prescribed burns, thinning of small trees, and creating defensible space around homes and other structures—and allowing small fires to burn themselves out when it's safe to do so.

Adaptation to more fire weather in a warming world is critical. Reducing carbon pollution to net zero by 2050 by aggressively switching away from fossil fuels would help limit global warming and stabilize the climate conditions that worsen fire weather conditions and wildfire risks.

RESOURCES

- Find daily fire reports at the National Interagency Fire Center.
- National fire and smoke maps are available at AirNow.
- Regional fire maps are available through: the CAL FIRE Report and the California Smoke Information Map; the Southern Group of States Foresters Wildfire Risk Assessment Portal; and the Northeast-Midwest Wildfire Risk Assessment Portal.
- The weekly U.S. Drought Monitor map shows parts of the U.S. that are in varying levels of drought.
- The National Wildfire Coordinating Group has a glossary of wildfire terms.
- The National Fire Protection Agency provides resources about wildfire preparedness.
- Check out the Society for Professional Journalists' toolbox on covering fires.

METHODOLOGY

This analysis defines a "fire weather day" as one where the following three conditions co-occur in at least two hourly measurements:

- Relative humidity within 5% of regional thresholds defined by NOAA's Storm Prediction Center (based on predominant fuel type and local climate)
- Temperature of at least 45-55°F, depending on the season (winter: 45°F; summer: 55°F; spring and fall: 50°F)
- Sustained wind speeds of 15 mph or greater (10 mph or greater for Florida locations)

Hourly observations for 476 stations across the contiguous United States were obtained from 1973-2022 using NOAA/NCEI's Local Climatological Data. Stations needed to pass several data completeness checks in order to be included in this analysis. Using the thresholds detailed above, Climate Central calculated the number of annual and seasonal fire weather days at each station over the past 50 years. Thresholds were not available for Alaska, Hawaii, or Puerto Rico, and therefore these locations were not included in this analysis. Results were mapped to each station's climate division. For climate divisions with multiple stations, data were averaged across all stations. Additionally, we calculated the average annual and seasonal fire weather days and used linear regression to calculate the total change. Data were rounded to the nearest whole day. Some climate divisions only had one weather station inside its boundary. While confidence in our results increases with additional stations, our results are consistent with recent findings (for example, here and here).

Results at the climate division level are summarized in this report by NCEI Climate Region and broadly grouped into West and East as in Table 1. Note: throughout this report, the NCEI South region was split into the western South (Texas, Oklahoma, and Kansas) and eastern South (Arkansas, Louisiana, and Mississippi) and grouped as indicated in Table 1.

While definitions of fire weather vary, our analysis used thresholds based on those used by NOAA's Storm Prediction Center for an elevated fire weather forecast, which is the lowest risk category they use. Our criteria was chosen in order to identify not only the days we could expect a fire to break out, but days where the combined meteorological conditions pose a threat to people and infrastructure (i.e., days which could trigger a public safety power shutoff in the West). Our analysis is based on criteria that uses relative humidity to represent the amount of moisture in the air. It is common for analyses to use vapor pressure deficit (VPD) as another method for measuring atmospheric moisture.

Since this analysis does not account for all the important factors that affect fire behavior (i.e., fuels or topography), it paints only a partial picture of the risks associated with increasing fire weather.

The total number of households (housing units) by state in the wildland urban interface (WUI) was obtained from the University of Wisconsin-Madison's SILVIS Lab.

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.