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RESEARCH ARTICLE

Correlation between Rising Temperature and Increasing Wildfires in the Western Continental United States

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ABSTRACT: This research aims to find a direct correlation between the rising temperature and increasing wildfires within the United States (US), especially the western continental states where most of the total US wildfires have happened. In addition, this research studies the available historical statewide temperature data to find evidence of climate changes in the US. The findings in this study suggest future investigation on the impact of temperature and climate zone shifts on wildfires.

KEYWORDS: Earth and Environmental Sciences; Climate Science; Global Warming; Climate Zone; Temperature; Wildfires; Correlation.

Introduction

Wildfires and climate changes have made headlines over recent years. Rising temperature is usually described as a significant indicator of global warming. The prevailing view of the cause is greenhouse gases,[1] which primarily consist of carbon dioxide from burning fossil fuels. Burning thousands of acres of forest also contributes to greenhouse gas emission,[2] and thereafter, exacerbates global warming. The rising temperature consequently contributes to droughts and even more wildfires.

This article highlights the impact of global warming and reminds people to make a more significant effort to limit wildfires to preserve forests. This is one of the key preventive actions to limit global warming under 2.7 degrees Fahrenheit (1.5 degrees Celsius) by 2100 – a key threshold to prevent more droughts, storms, and fires.[3]

Data and Methods

DATA:

All data used in this study were obtained from public sources established by U.S. government agencies, as described below.

Fire The historical wildland fire data used in this research is primarily from Monitoring Trends in Burn Severity[4] (MTBS) by the U.S. Geological Survey Center for Earth Resources Observation and Science (EROS) and the USDA Forest Service Geospatial Technology and Applications Center (GTAC). MTBS includes all wildland fires of 1000 acres or greater in the western United States and 500 acres or greater in the eastern United States from 1984 to 2021.

Temperature Historical average temperature data used in this research is from National Oceanic and Atmospheric Administration[5] (NOAA). The 48 contiguous states have annual average temperature data available from 1895 to 2021, and the Alaskan temperature record started in 1925. Data from 1984 to 2021 are used for correlation analysis with wildland fires. The temperature data from 1895 to 2021 are used to study climate zones and climate zone shifts for the 48 contiguous states.

Region An initial analysis of the wildfire data indicates that during the 20 years from 2002-2021, more than 100 million acres or about 70% of the total US wildfires happened in the western continental states in the US, namely Alaska, California, Idaho, Oregon, Nevada, Montana, Washington, Utah, Wyoming, and Colorado. Therefore, this research focused on those states.

Methods

This research leverages several statistical approaches, including trend analysis, correlation analysis, and linear regression. Starting with a general trend analysis of the wildfires and the temperature changes, then focusing on the correlations between these two data sets to derive a linear regression model. The research benefits from the rich historical data that is publicly available. The work is mainly done in Excel using Data Analysis.

Results and Discussion

General Trend:

The statewide temperature correlation analysis provides a simplified and reasonable view of climate zones by grouping the most correlated states. Figure 1 is color-coded, showing the climate zones as of 1989 using the temperature data from 1895 to 1989 and the climate zones of 2021 using the temperature data from 1990 to 2021. This result is consistent with the USDA Hardiness Zone.[6,7] By referencing the USDA hardiness zone map, this research picks five anchor states by considering pairwise state temperature correlation analysis, census regions, and hardness zones, including Alabama (AL), California (CA), South Dakota (SD), New York (NY), and New Mexico (NM). For example, SD correlates with its eight neighbor states with a correlation of over 80% (with the states outside the region with less than 60% correlation), and it is relatively the geographical center of the same hardness zone. If the correlation between a state's annual temperature time series and an anchor state is above 0.7, the state is in the same climate zone as the anchor state. A clear climate zone shift is observed. For example, Col-

DOI: 10.36838/v5i2.22

orado (CO) and Georgia (GA) shifted to the warm moist-arid climate zone in 2021 from warm arid and warm moist, respectively. The climate zone shift is strong evidence of climate change, which leads to more wildfires.

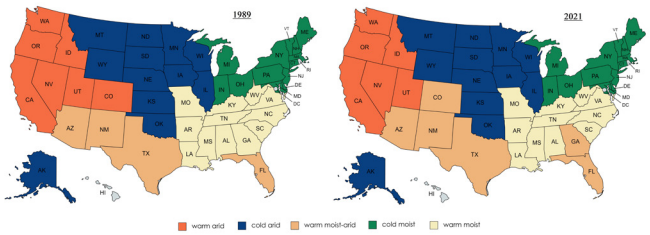

Figure 1: Climate Zone Shift from1989 to 2021

Figure 2 shows the state-level wildfire data of the United States, excluding Hawaii, during the last 20 years. According to Christopher Potter of NASA's Earth Sciences Division[8], the forests in warm arid (orange) and arctic (cold arid – blue) climate zones are more vulnerable to rising temperatures and, therefore, more likely to have significant wildfire occurrence. One surprising fact is that Alaska has the most wildfire in the United States, which means Alaska has become a major carbon dioxide source and accelerated climate change. In 2015 alone, Alaska burned 5.1 million acres of forests.[9]

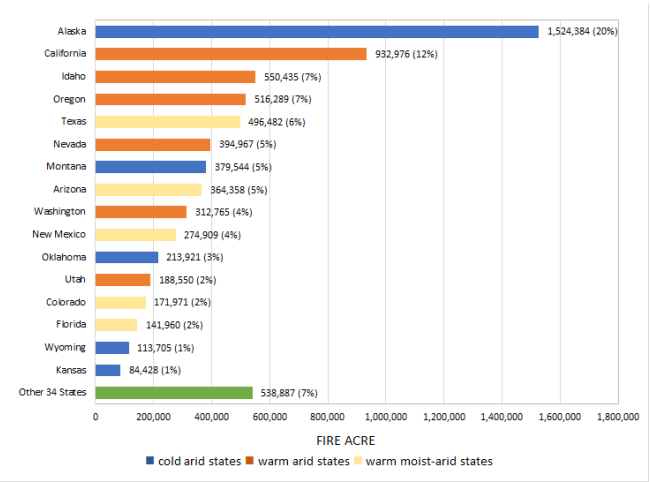

Figure 2: Annual Average Wildfire Acres by State in the US in Recent 20 Years (2002-2021)

Figure 3 shows the historical temperature from 1895 to 2021 of four representative states: Montana (north), New York (east), Florida (south), and California (west). Overall, 1990 was the warmest year in records dating back to 1895. The elevated temperature remained and trended upward starting in 2015. The solid red line in each graph is the average temperature from 1895 to 2021. The black dotted line in each graph is the average temperature from 1895 to 1989 and from 1990 to 2021. The average temperature of all four representative states exhibited a step function with a jump of over 1.5 Fahrenheit starting in 1990.

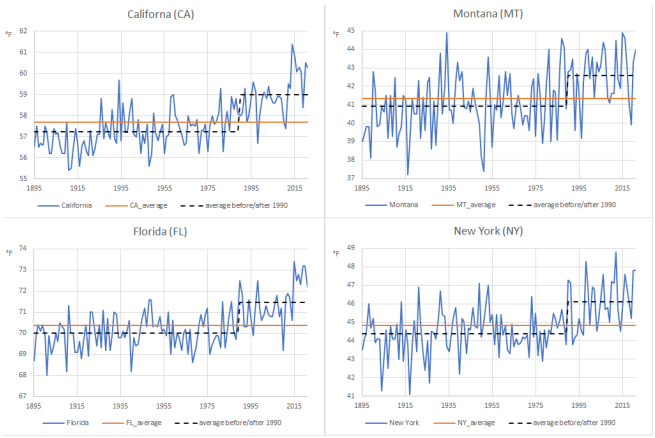

Figure 3: Temperatures in the Selected States consistently show that the global warming trend started in 1990

Over the 30-year period from 1989 to 2021, the national annual average temperature and total wildfire acres have followed the upward trends, as shown in Figure 4. On a five-year rolling average basis, the national average temperature increased by 1.5°F from 52.5°F to 54.0°F. It demonstrates a long-term impact. Meanwhile, the total wildfires increased 160% from 3.6 million acres in 1989 to 9.3 million in 2021. There may be several factors why rising temperature leads to more wildfires. One reason could be that higher temperatures will lead to dryer soil by evaporating more moisture from the ground at a higher rate. Therefore trees are dryer and become more flammable. Another possible reason is that warmer conditions can trigger outbreaks of insects that kill trees and make them more susceptible to fire. The temperature peak seems to lead to the wildfire increases. The rolling average data indicates that temperature rise leads to wildfire rise. It can be clearly observed that both the temperature and wildfires started increasing in 2000 and have stayed at a high level since 2005. This paper further studies the stable elevated 17 years of the temperature and its impact on the number of wildfires.

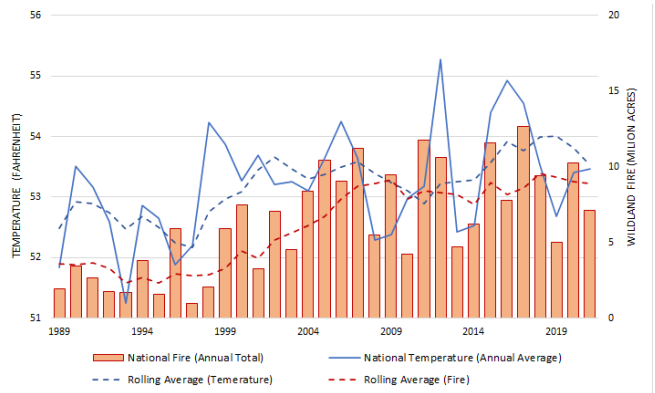

Figure 4: National Annual Average Temperature, Total Wildfire, and their Five-Year Rolling Averages

Correlation and a Linear Model:

Because a close relationship between the temperature moves and wildfire changes was observed, a simple linear regression model is built to capture the correlation between the yearly changes in temperature and the number of wildfires in the western states. As shown in Figure 5, over the most recent se-

venteen years, from 2005 to 2021, the year-over-year changes of wildfires in these states are significantly positively correlated with the year-over-year changes in annual average temperature (R2=0.36, p-value = 0.01). For every degree Fahrenheit increase in the yearly average temperature, there was a two-million-acre increase in the number of wildfires in these states. The most recent seventeen years' data were used to ensure statistical significance as the temperature has escalated since 1990, as presented in Figure 3.

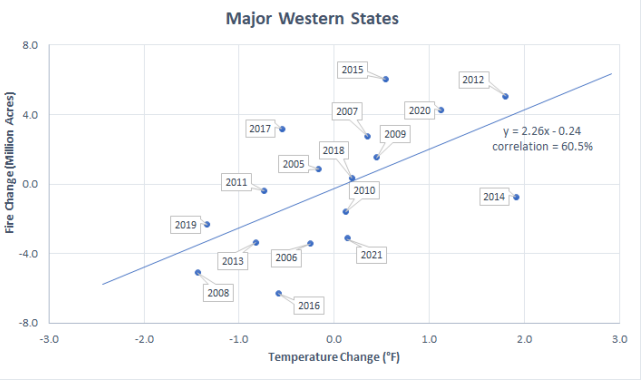

Figure 5: Relationship between Year-over-Year Wildland Fire Changes and Temperature Changes

Conclusion and Future Work

Since 1990, the temperature has stayed elevated, and there have been more wildfires. This study finds a climate zone shifted from 30 years ago by analyzing historical state-level temperature data. The analysis of temperature and wildfire data in recent years showed that increasing wildfires are related to global warming, such as rising temperatures and climate zone shifts. The data analysis also suggested that when temperature increases to and maintains a certain level, i.e., a breaking point, for a prolonged period, local climate changes may happen, leading to climate zone shifts and more wildfires. A linear regression model showed that for every degree Fahrenheit increase in the annual average temperature, the wildfires increase by about 2 million acres in the western states.

It is well known that fossil fuel contributes to global warming; however, less attention is being paid to the impact of wildfires. Because forests take decades to grow back or never grow back, the effect is significant. We should also use human interventions to remove deadwood or overgrown forests to avoid as many wildfires as possible.

Other climate factors certainly contribute to wildfires as well, such as precipitation, wind, etc.; however, due to data availability, they were not included in this study and will be considered in future work.

The temperature data is available on both national and global. The global trend is consistent with our study in the US.[5] This research could be further expanded to population growth, industry behavior, etc.

Acknowledgments

I want to express my gratitude to Jericho High School and the school teachers for providing me with opportunities to attend AP Statistics and Scientific Research classes to prepare me to collect data and perform basic data analysis. In addition, without my parent's help and encouragement, this idea would not have been possible. Their love and support are important factors for me to complete this research.

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Authors

William Zhu is a junior attending Jericho High School in New York. He is a passionate baseball player. Due to the amount of time he spent outside during high pollen seasons, he started having seasonal allergies, which led to him paying attention to environmental and climate changes, such as the research done in this paper. He runs a blog: *https://www.hippog.org/* trying to promote environmental awareness and to find a direction for himself to have positive impacts.

DOI: 10.36838/v5i2.22