Wyoming and Climate Change

CO_2 Should Be Celebrated, Not Captured

CO2COALITION

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EXECUTIVE SUMMARY

This report examines the actual and projected effects of the climate on the State of Wyoming in response to proposals to reduce emissions of carbon dioxide (CO_2) through the use of "carbon capture" in order to avert purportedly catastrophic atmospheric warming.

This research concludes that Wyoming – like the planet – is benefiting from warming that began more than 300 years ago. Efforts to reduce CO_2 emissions are unnecessary and exorbitantly expensive and would make no measurable difference in temperature.

Carbon Dioxide

Claims that carbon dioxide is a pollutant posing an "existential threat" are contradicted by scientific data. Today's levels of CO_2, while representing a recent increase, are significantly lower than they have been during nearly all of Earth's history.

Pre-Industrial Revolution CO_2 levels were approximately 280 parts per million (ppm) and began accelerating in the mid-20th century during the post-World War II economic boom. Current levels are about 420 ppm, a 50% increase during the last 200 years. Though elevated compared to the recent past, modern concentrations of CO_2 are one-sixth of the average over the last 600 million years. Viewed in this geologic context, we are at near-historically low levels of CO_2.

Temperature

Data for Wyoming contradict the 4th National Climate Assessment (NCA4) assertion that "the frequency and intensity of extreme high temperature events are virtually certain to increase."

Our data analysis shows that high daily temperatures peaked during the Dust Bowl years of the 1930s and have been in a 90-year decline. This is confirmed by reviewing the percentage of days that were reported to be hotter than 100°F (37.8°C) by Wyoming temperature stations. There is no discernible increase, and the largest numbers occurred in the first half of the 20th century when CO_2 levels were 70% of recent measurements.

There has been, however, a beneficial increase in the minimum nighttime temperatures, which has led to a lengthening of the Wyoming growing season. Since the late 1800s, these nighttime temperatures have increased about 2°F (1.1°C).

In summary, the slight increase of about 1.2°F (0.7°C) in the average temperature in the last 120 years is being driven by reductions in extreme cold rather than increases in extreme heat.

Precipitation

Although drought is projected by the most recent National Climate Assessment (NCA4) to worsen because of climate change, the historical data refute this claim. The most notable characteristic of

Wyoming precipitation is that the amount varies greatly year-to-year but exhibits no overall trend of increase or decrease. Precipitation in Wyoming appears to be controlled primarily by short-term weather-driven events and not by any CO_2-linked climate change.

Similarly, NCA4 predicts declining snowpack, but real-world observations show that only two of eight ski resorts in the state experienced a declining trend in snowfall over the last decade, while five showed increasing snowfalls.

Severe Weather

NCA4 claims an increasing incidence of severe weather is a product of climate change, but scientific data indicate no such trend. According to the World Health Organization's Centre for Research on the Epidemiology of Disasters, deaths from natural disasters have plunged more than 90% from a yearly average of 54,000 in the 1920s to 4,500 in the last decade. The incidence of tornadoes, which are Wyoming's primary dangerous weather hazard, varies year-to-year but shows no discernible trend of increase.

Agriculture

Contrary to claims of agricultural declines, global food production is greatly outpacing population growth. This boost in agriculture is attributable to modest warming, increasing carbon dioxide (CO_2 fertilization effect) and the use of fossil fuel-derived nitrogen fertilizers. Because of a naturally warmer climate and the CO_2 produced by the use of fossil fuels, the world currently sustains tenfold the number of people (8.04 billion) than at the beginning of the Industrial Revolution (791 million).

Furthermore, modestly rising temperatures are benefiting Wyoming agriculture by extending growing seasons. On a broader scale, the length of growing seasons in the contiguous United States has increased by more than two weeks since the beginning of the 20th century.

Greening

The most significant positive consequence of rising concentrations of atmospheric carbon dioxide is that of greatly increased plant growth. Global leaf area increased by a stunning 5.4 million km^2 from 2000 to 2017. This area is equivalent to the area of the Amazon rainforest. Notably, the Northern Great Plains is one of seven areas globally experiencing the greatest increase in plant growth.

Emission Reduction Costs and Effects

A review of recent CO_2 emission data from the U.S. Energy Information Administration (EIA 2016) reveals that Wyoming emissions were 1.2% of the U.S. total. Assuming elimination of Wyoming's CO_2 emissions in 2010, the amount of warming averted would be only 0.0009°F (0.0005°C) by 2050 and 0.0012°F (0.0022°C) by 2100. This temperature difference is far less than humans experience every few seconds in a "constant" environment – far below our ability to even measure and scarcely different from zero.

Models for Future Climate Predictions

Plans to spend enormous sums of money in a rush to “net zero” are based on mathematically complicated computer models that predict a significant rise in future temperatures. However, the models regularly fail to replicate real-world observations and have been found to overestimate warming effects by two to five times.

This scientific analysis shows that Wyoming’s ecosystems are thriving and prospering. Furthermore, the state’s deposits of fossil fuels represent not only a valuable energy source but a reserve of carbon whose release into the atmosphere as carbon dioxide promises to benefit plant and animal life for centuries.

BACKGROUND

The CO_2 Coalition was established in 2015 as a non-partisan educational foundation operating under Section 501(c)(3) of the IRS code for the purpose of educating thought leaders, policy makers, and the public about the important contribution made by carbon dioxide (CO_2) to our lives and economy. The CO_2 Coalition seeks to engage in an informed and dispassionate discussion of climate change, humans' role in the climate system, the limitations of climate models, and the consequences of mandated reductions in CO_2 emissions.

This report is the fourth in a series of state and regional studies by the CO_2 Coalition on the effects of the changing climate on various parts of the United States of America. Previous regional and state reports include:

- Pennsylvania's Regional Greenhouse Gas Initiative Relies on Faulty Data: Why RGGI is a "Solution in Search of a Problem" (July 2021).
- Virginia and Climate Change: Separating Fact from Fiction (June 2022).
- The American Midwest and Climate Change: Life in America's Breadbasket is Good and Getting Better (June 2023).

The current report is based principally on the work of the following:

- Dr. Frits Byron Soepyan – CO_2 Coalition Research and Science Associate, Ph.D. Chemical Engineering
- Gregory Wrightstone – CO_2 Coalition Executive Director, MS Geology
- Dr. William Happer – CO_2 Coalition Chair, Ph.D. Physics

These and other contributors to this evaluation represent the fields of climatology, meteorology, physics, geology, agronomy, engineering and more.

INTRODUCTION

Wyoming has vast resources of coal, oil and natural gas. With 40% of the nation's coal resources, the state has been the United States' top producer since 1986, primarily from the Powder River Basin located in the northeastern part of the state. It is also a national leader in the production of oil and natural gas, ranking in the top 10 in production of both products. According to the U.S. Energy Information Administration (EIA 2023), the Cowboy State produces almost 12 times more energy than it consumes, making it the second largest net energy supplier among the states after Texas.

Even though the Wyoming economy is heavily dependent on the mining and extraction of fossil fuels, its governor, Mark Gordon, has adopted a strong "decarbonization" policy. At a speech to the Harvard Kennedy School's Institute of Politics in late 2023 (Frumkin and Healey 2023), he stated:

> *It is clear that we have a warming climate. It is clear that carbon dioxide is a major contributor to that challenge. There is an urgency to addressing this issue.*

The Governor accepts that there will be CO_2-driven climate change disasters. To reduce the state's production of carbon dioxide, he advocates that Wyoming become "carbon negative" using carbon capture technology to remove more CO_2 from the atmosphere than is emitted by the people and industries of the state.

Opposition to the governor's carbon capture plan was swift, with the Wyoming GOP passing a no confidence vote:

> *Governor Gordon's current path accepting climate change, and his goals of decarbonizing the West, is counterproductive to the best interests of Wyoming.*

That was followed by a letter from 30 legislators and the Secretary of State demanding that the Governor convene a debate that would include experts provided by the CO_2 Coalition to determine the cause and effect of climate change and the merits of his "carbon negative" policy. After first accepting the debate challenge, he later reneged. In the letter demanding a debate, Sen. Cheri Steinmetz stated:

> *We believe that all Wyomingites will most benefit from a real, in-depth discussion of these issues. It is time for a fair debate at a neutral location, with a neutral moderator of your choosing.*

The CO_2 Coalition believes that public policy on such matters should be driven by scientific review and analysis, not political agendas. To provide that scientific analysis, this report will review data that we would have provided to the governor had a debate occurred. We encourage those in positions to make policy decisions to dispassionately review the data included here to determine the answers to the following questions:

- Is Wyoming experiencing a climate crisis?
- Are extreme weather events like droughts, floods, crop failure and heat waves increasing in Wyoming?
- How much warming would be averted if Wyoming emitted no carbon dioxide?
- Are increasing levels of carbon dioxide beneficial or harmful?

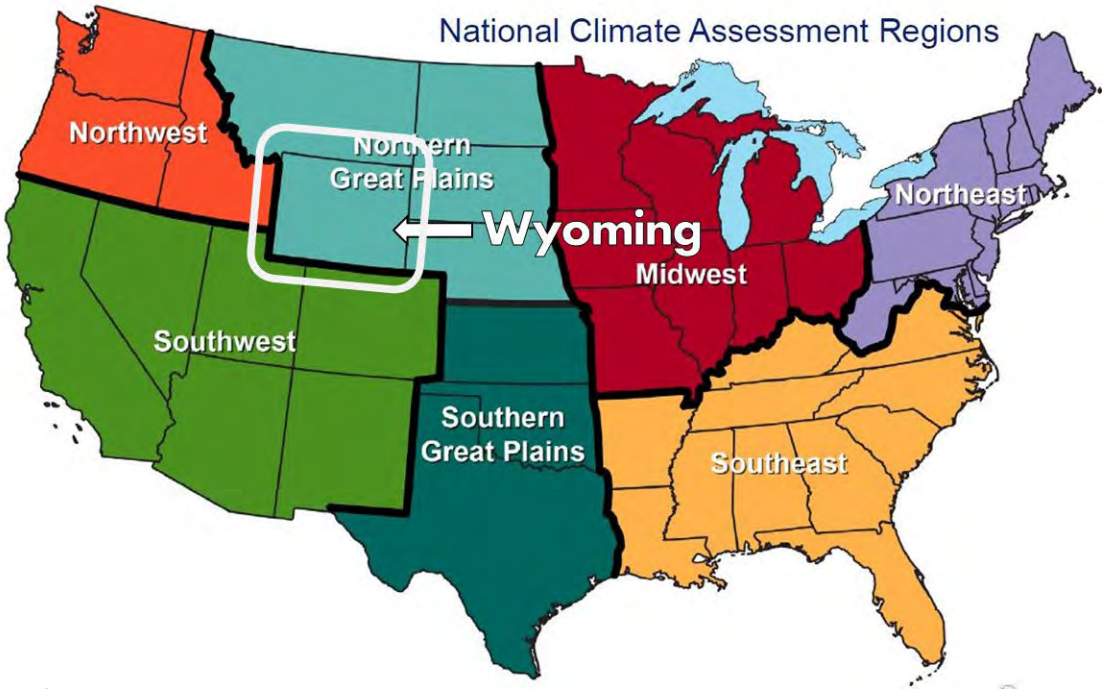
The answers to these questions and much more will be addressed here using peer-reviewed papers and data from governmental and statutory agencies. The information included will provide Governor Gordon and the Wyoming legislature facts to support their decision-making about energy and climate policy.

SCIENTIFIC DISCUSSION

CLIMATE CRISIS CLAIMS

Promotion of the need to reach "negative net carbon" through CO_2 capture is predicated on claims of ongoing and future devastating calamities resulting from CO_2-enhanced warming. In the most recent National Climate Assessment (NCA4), Wyoming was included as part of the Northern Great Plains regional assessment (Figure 1).

Figure 1: Assessment regions of the Fourth National Climate Assessment (NCA4)



Source: Fourth National Climate Assessment (NCA4)

The report contained quite a long list of looming climate-related disasters that are predicted to befall Wyoming and the other states of the Northern Great Plains due to climate change. These include:

- Increasing number of very hot days and heat waves
- Increasing drought
- Increasing flooding
- Decreasing stream flow
- Increasing stream and river temperatures
- Negative impacts on agricultural production
- Decreasing snowfall and snowpack

Within this report, we will examine these and other assertions of climate-related catastrophe to assess the validity of the claims.

CARBON DIOXIDE THROUGH TIME

Increasing carbon dioxide is claimed to be the primary driver of allegedly dangerous modern atmospheric warming. To put modern atmospheric concentrations into proper perspective, it is helpful to review how CO_2 levels have changed through time.

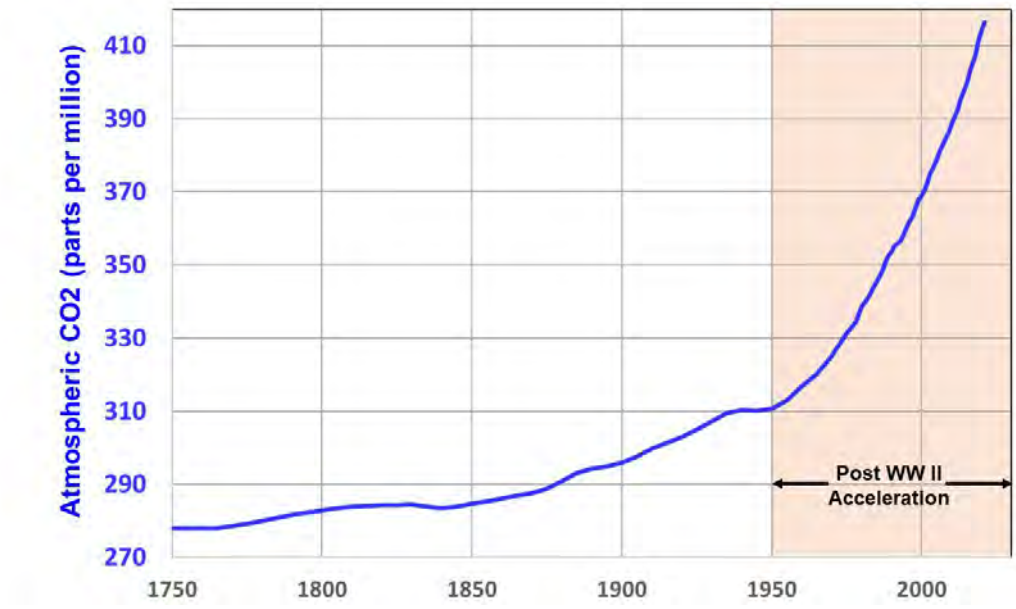
The current level of CO_2 in the atmosphere as measured at the Mauna Loa Observatory is 422 parts per million (ppm) by volume (as of December 2023). This is an increase of 142 ppm from the pre-industrial concentration of about 280 ppm in the mid-1800s. This approximately 50% increase appears significant when viewed through the narrow time frame of a few decades or centuries. However, appearances are deceiving.

Time scale is important. Put in a long geologic perspective, today's levels of CO_2, while representing a recent increase, are significantly lower than they have been during nearly all of Earth's history. We shall see that today's historically low CO_2 concentration is preventing trees and plants from reaching their full growth potential via photosynthesis.

Pre-Industrial Revolution CO_2 levels were approximately 280 ppm and began accelerating in the mid-20th century during the post-World War II economic boom (Figure 2). Current levels are about 420 ppm, or a 50% increase during the last 200 years. This increase is attributable to human emissions of CO_2 primarily from the use of fossil fuels and, to a lesser extent, the manufacture of cement.

Bear in mind that, if CO_2 were driving warming, it should be apparent in the period of the last 70-plus years when levels were increasing at a significant rate.

Figure 2: Carbon dioxide concentration (1750 to 2022)

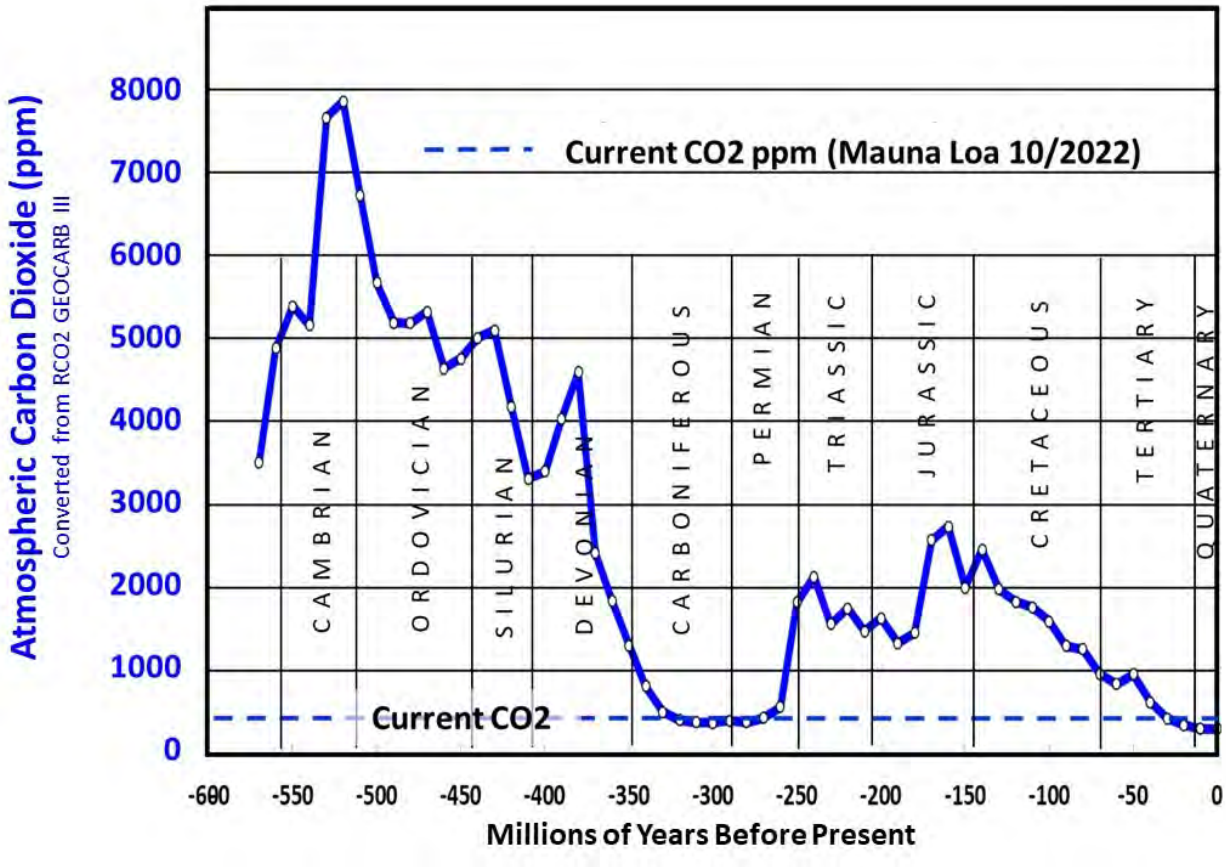


Source: European Environment Agency (2019)

While the increase in the recent past appears to be significant, it is necessary to place this increase in the longer geological context. In this longer view (Figure 3), we find that our current modern levels of slightly more than 400 ppm are one-sixth of the average concentration over the last 600 million years and only 5% of peak levels of 8,000 ppm. Therefore, we are actually at near-historically low levels.

In a later section of this paper, you will find that increasing atmospheric CO_2 is leading to great increases in global vegetation and crop productivity. This is because ancestors of the vegetation that populates our planet today thrived when CO_2 levels were more than 2,500 ppm. The very low concentrations today do not provide enough CO_2 to maximize plant growth potential.

Figure 3: 600 million years of carbon dioxide concentration



Source: Berner and Kothavala (2001)

TEMPERATURE

The primary alleged negative consequence of increasing atmospheric CO_2 is that its greenhouse effect is raising temperatures to unusual and unprecedented levels. According to the National Climate Assessment Special Science Report (NCA4):

> *Heatwaves have become more frequent in the United States since the 1960s.*

To assess the validity of the claims of increasing heat waves and unusual warming, we have accessed Wyoming-specific data from the National Oceanic and Atmospheric Administration's U.S. Historical Climatology Network (USHCN).

The USHCN is a group of 1,218 stations selected from the larger U.S. Cooperative Observer Program to provide a spatially representative estimate of contiguous U.S. temperatures from 1895 to the present (Fiebrich 2009). The Wyoming data include 29 stations scattered across the state, which are listed in Appendix A.

Temperature Adjustments and Fabrication of Data

The data used from USHCN is the highest quality direct thermometer records available for Wyoming. Even so, there are several problems intrinsic to the data that serve to accentuate modern warming and cool the older data.

- Urban heat island effect that raises recent temperatures
- Adjustments to measured historical temperatures
- Fabricated data for stations that no longer exist or are no longer reporting

To learn more about how the data have been manipulated, please see Appendix B on temperature adjustments and fabrication of data.

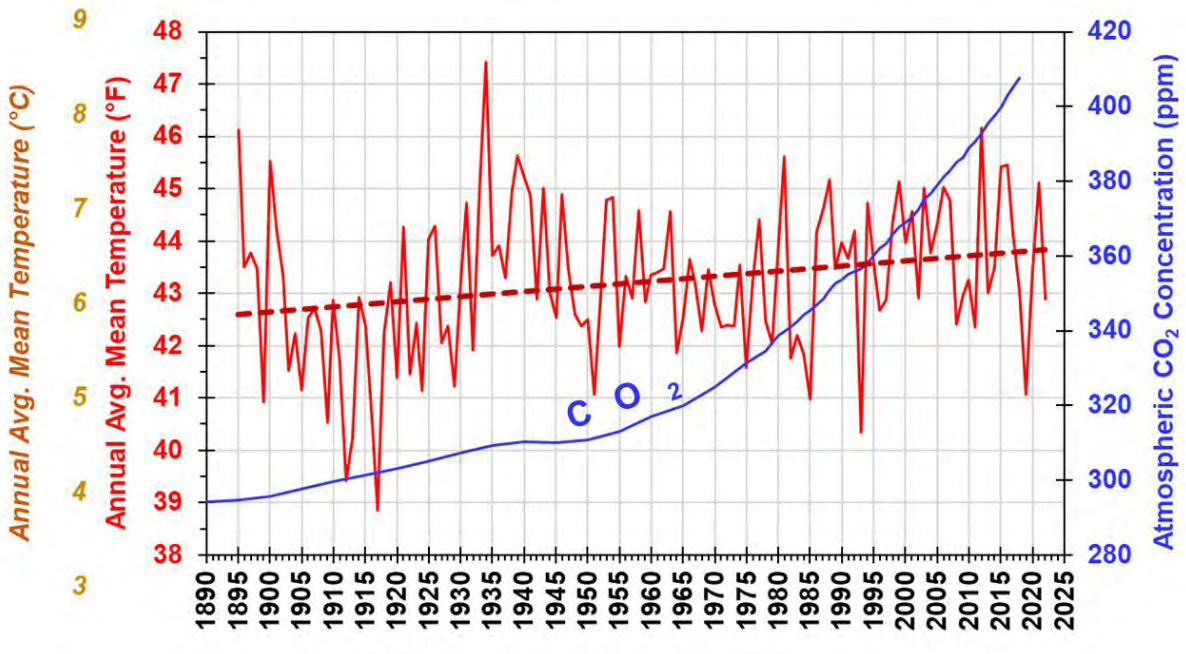
Average Wyoming Temperature

The annual average mean temperature for Wyoming (Figure 4) plots the sum of all reported values for Wyoming during a 12-month period, divided by the number of values. Also included in the chart are atmospheric CO_2 concentrations (in blue). This chart reveals that there has been a general temperature increase of about 1.2°F (0.7°C) since 1895, but this warming occurred in fits and starts with trends of warming and cooling, and zero correlation to the gradual increase in CO_2.

Note that the recent average temperatures have been less than what Wyoming experienced during the early 1930s. Of particular note are the four temperature trends below:

- 1895 to 1910 – Steep decline in temperature with slight increase in CO_2.
- 1910 to 1934 – More than 5°F of warming occurred during this period, when CO_2 levels increased only slightly. This was the highest rate of warming observed in the entire record.
- 1934 to 1979 – Nearly 5°F of cooling occurred just as CO_2 levels were significantly increasing.
- 1979 to 2022 – Modest warming during a period of significantly increasing CO_2.

Figure 4: Wyoming average temperature vs. atmospheric carbon dioxide



Temperature source: NOAA National Centers for Environmental Information (2023c)

CO_2 source: European Environment Agency (2019)

High Temperatures in Wyoming

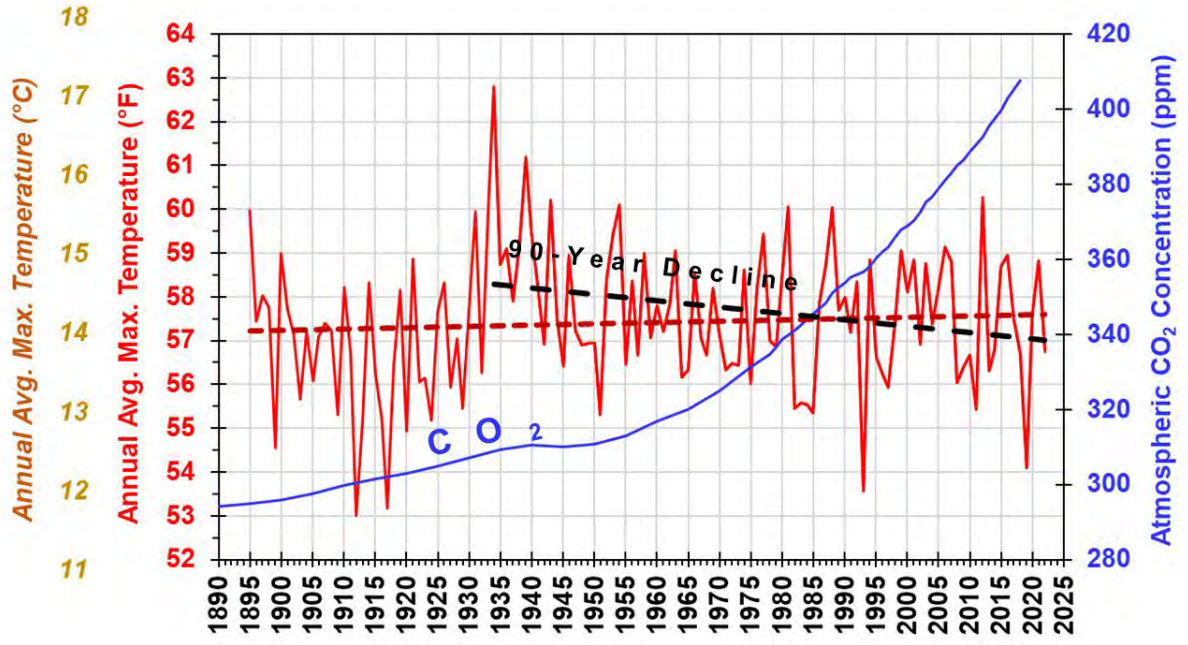
One of the greatest dangers being forecasted by those promoting a climate crisis is that of heat waves and extreme heat events. Below, in Figures 5 and 6, we examine high temperature records and find that extreme heat has been in decline in Wyoming over the last 90 years.

Contrary to the 4th National Climate Assessment (NCA4) assertion that "the frequency and intensity of extreme high temperature events are virtually certain to increase," the Wyoming data do not support this assertion.

The chart for the annual average maximum temperature (Figure 5) shows that high temperatures peaked during the Dust Bowl years of the 1930s and have been in a 90-year decline. This is confirmed by reviewing the percentage of days that Wyoming stations reported temperatures above 100°F (37.8°C) (Figure 6). Figure 6 shows no discernible increase in the annual number of hot days, with the largest number of hot days observed in the first half of the 20th century, when CO_2 levels were 70% of recent measurements.

Note: The highest temperature for Wyoming of 116°F (46.7°C) was recorded on July 12, 1900, at Bitter Creek in Sweetwater County. (Day 2022)

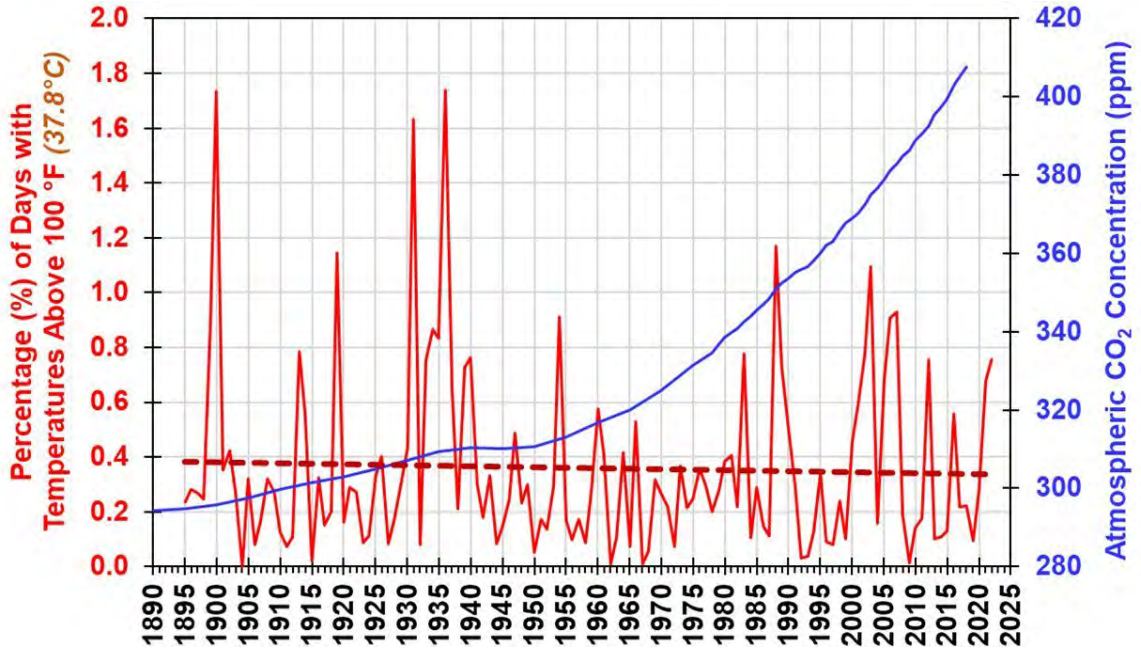
Figure 5: Wyoming annual average maximum temperature vs. atmospheric carbon dioxide



Temperature source: NOAA National Centers for Environmental Information (2023c)

CO_2 source: European Environment Agency (2019)

Figure 6: Percentage of very hot days in Wyoming



Temperature source: NOAA National Centers for Environmental Information (2023c)

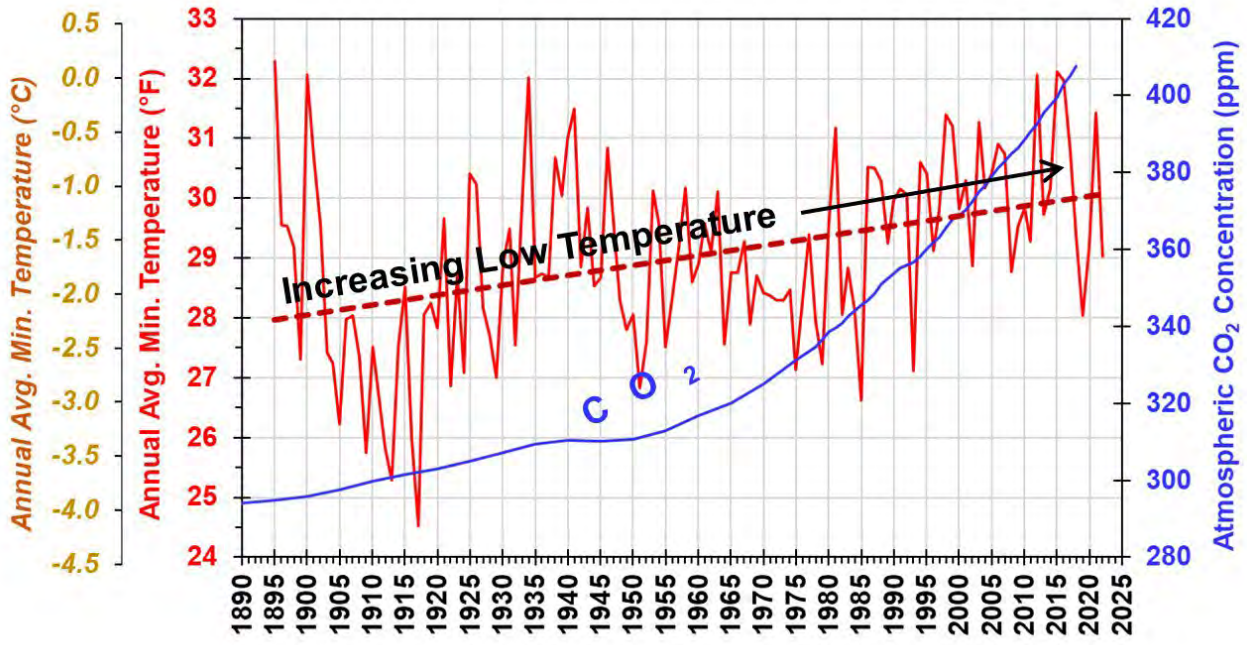
CO_2 source: European Environment Agency (2019)

Low Temperatures in Wyoming

We have just verified that heat waves and very high temperatures have NOT been increasing in the Cowboy State despite increasing atmospheric carbon dioxide. Decreasing nighttime low temperatures would be very detrimental to agricultural production. Thankfully, these low temperatures have been rising, leading to an increase in the length of the growing season.

As any resident of Wyoming can attest, winter can be brutally cold in this region. The good news is that the lowest temperatures have been warming slightly. Figure 7 shows that the minimum temperatures in Wyoming have increased about 2°F (1.1°C) since the late 1800s. This has led to a decrease in the number of very cold days (Figure 8). In a later section on agriculture, the benefits of lengthening growing seasons on Wyoming agriculture will be discussed.

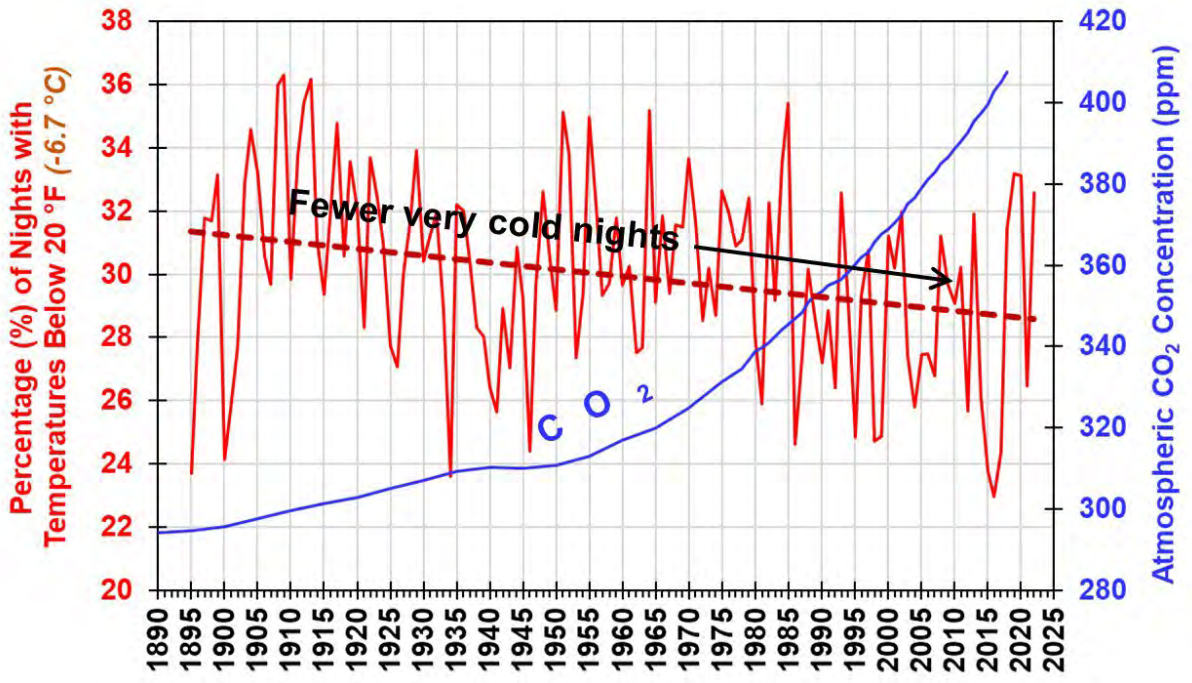
Figure 7: Low temperatures in Wyoming are not as cold



Temperature source: NOAA National Centers for Environmental Information (2023c)

CO_2 source: European Environment Agency (2019)

Figure 8: Fewer very cold nights in Wyoming lead to longer growing seasons



Temperature source: NOAA National Centers for Environmental Information (2023c)

CO_2 source: European Environment Agency (2019)

In summary, the slight increase of about 1.2°F (0.7°C) in the average temperature in the last 120 years is being driven by reductions in extreme cold weather rather than increases in extreme heat.

PRECIPITATION – FLOODS, DROUGHTS AND SNOWPACK

In the Fourth National Climate Assessment (NCA4), its Key Message #1 for the Northern Great Plains regional assessment focused on predicted negative impacts of changing patterns of precipitation due to CO_2-driven warming:

> *Annual trends toward earlier spring melt and reduced snowpack are already affecting water resources in the western United States …*

Claims of increasing flooding and drought are standard fare for nearly all government-funded studies. Drought and flooding are particularly important for Wyoming due to the large negative impacts that these severe weather events have on the agricultural productivity of the area.

Drought is the single greatest threat to agriculture around the world. According to the United Nations Food and Agriculture Organization (UNFAO 2023), drought "has been established as the single greatest culprit of agricultural production loss." They estimate that drought costs the agricultural sector $37 billion in losses annually. While drought can make life difficult for the general population, it is agriculture that bears 82% of all drought impacts. However, as will be discussed in a later section of

this report, increasing concentrations of CO_2 help plants to become more resistant to drought and to produce more food, which is good news for farmers.

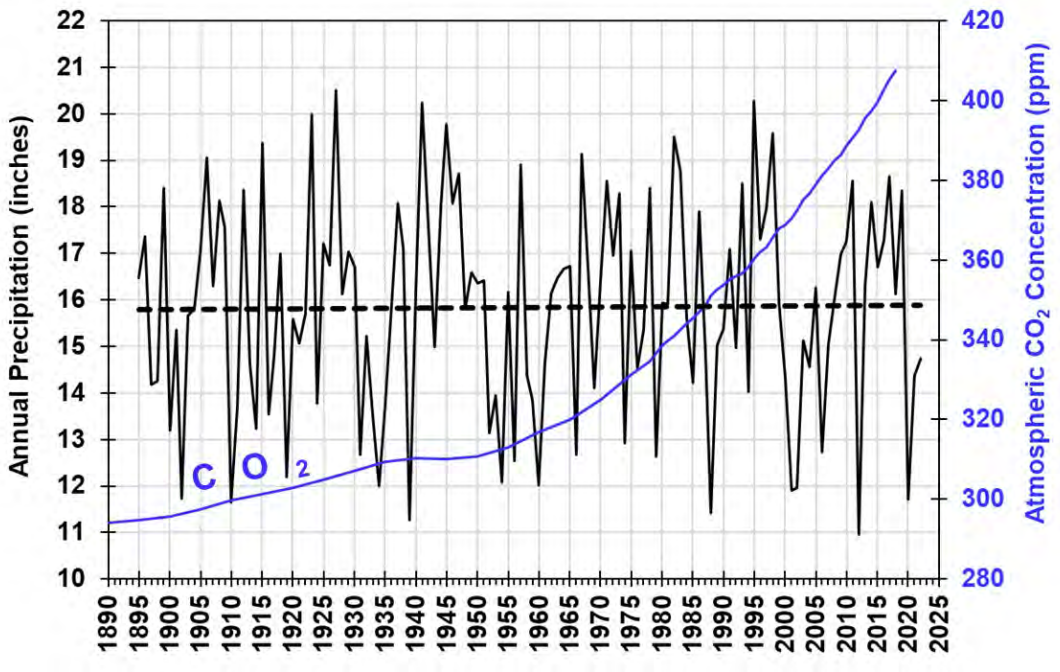
With that in mind, we will now "follow the science" to assess the data concerning drought, which is primarily driven by changes in precipitation and soil moisture. Drought is worsened by high temperatures and heat waves, but as noted in the previous section, high temperatures are not increasing. Therefore, heat-driven drought has not been a significant factor in recent decades.

Annual precipitation in Wyoming since 1895 is shown in Figure 9. The most notable characteristic of Wyoming precipitation is that the amount varies greatly year-to-year but has no overall trend of increase or decrease. Precipitation in Wyoming appears to be controlled primarily by short-term weather-driven events and not by any CO_2-linked climate change.

The lack of increasing drought is confirmed by the Wyoming Palmer Drought Severity Index (Figure 10, NOAA National Integrated Drought Information System 2023). Positive values of the PDSI imply wet conditions, while negative values of the PDSI signify dry conditions. PDSI values greater than 4 indicate "very wet conditions," and PDSI values less than -4 suggest "extreme drought." Based on Figure 10, wet and dry periods in Wyoming fluctuate greatly over the years with no discernible trend of increase or decrease.

Since drought is the primary scourge of crop growth throughout the world, the confirmation of no increase in drought is good news for the future of agriculture in Wyoming. Flooding events during the spring planting season and the fall harvest can have significant negative effects on production, but these pale in comparison to drought.

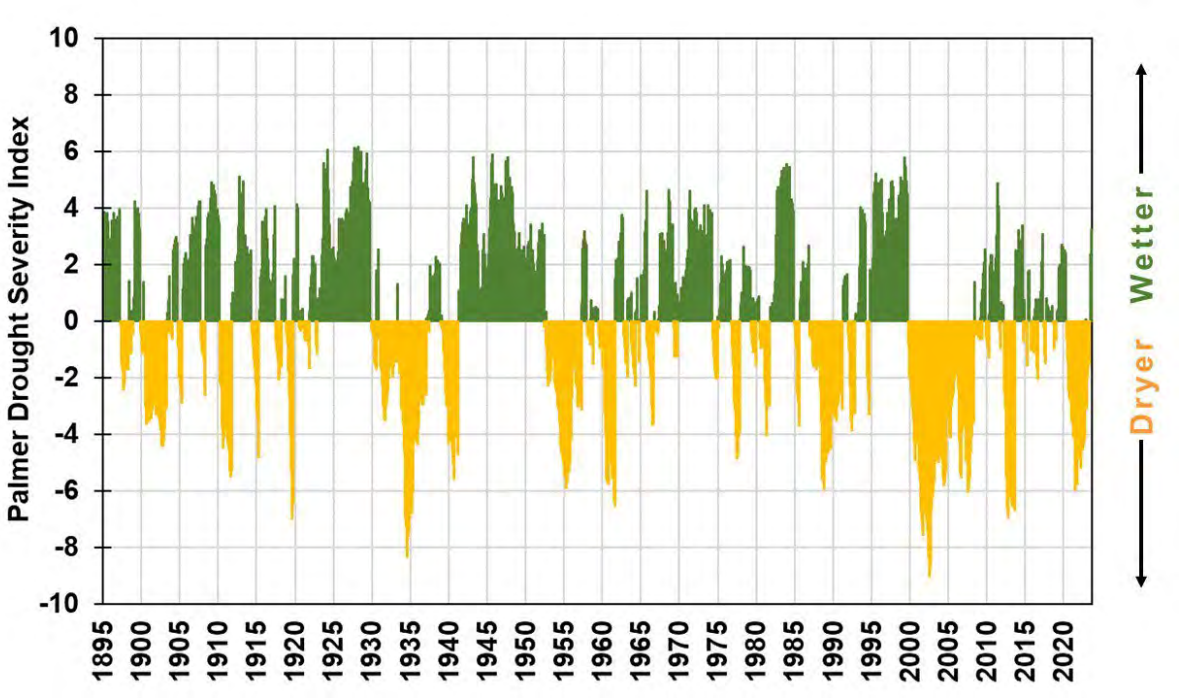
Figure 9: Wyoming annual precipitation (inches), 1895–2023



Precipitation source: NOAA National Centers for Environmental Information (2023a)

CO_2 source: European Environment Agency (2019)

Figure 10: Wyoming Palmer Drought Severity Index (PDSI)



PDSI source: NOAA National Centers for Environmental Information (2023a)

CO_2 source: European Environment Agency (2019)

The 4th National Climate Assessment (NCA4) predicts "large declines in snowpack in the western United States." Similar predictions are a common source of media attention. For example, the New York Times (Spiers 2024) published an opinion piece January 2, 2024, titled "The End of Snow." In the article, the author expressed an often-cited narrative of declining and disappearing snow due to CO_2-driven global warming.

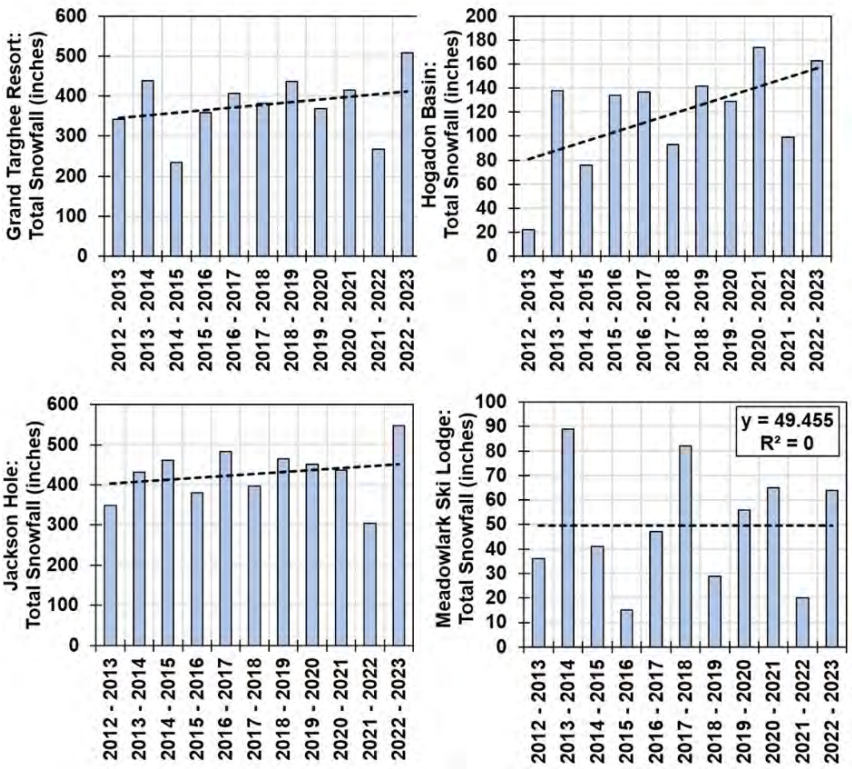
> *I'm not sure our grandkids will even know what snow is.*

In the Northern Great Plains, snowpack water storage is an important component for recharging reservoirs and groundwater. Additionally, tourism revenue attributable to ski resorts provides 4% of Wyoming's gross domestic product and contributed $2 billion to Wyoming's economy in 2022 (Heinz 2023).

To assess historical snowfall data, records from ski resorts in Wyoming were compiled (Mountain News LLC 2023). Figures 11 and 12 show the annual snowfall in inches at eight major ski resorts in Wyoming. As with the precipitation data, the amount of snow varies considerably year-to-year, but only two of the eight resorts experienced a declining trend in snowfall over the last decade, while six showed increasing or stable amounts.

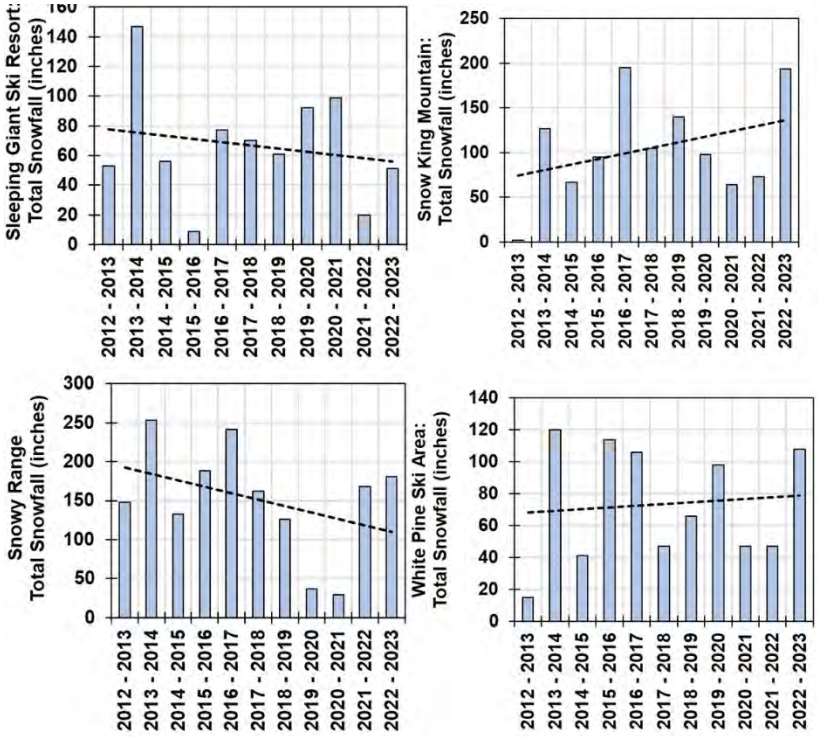
This information should provide great comfort to winter enthusiasts who can expect great skiing well into the future despite the predicted continued increases of atmospheric carbon dioxide.

Figure 11: Annual snowfall at various ski resorts in Wyoming



Source: Mountain News LLC (2023)

Figure 12: Annual snowfall at various ski resorts in Wyoming



Source: Mountain News LLC (2023)

SEVERE WEATHER

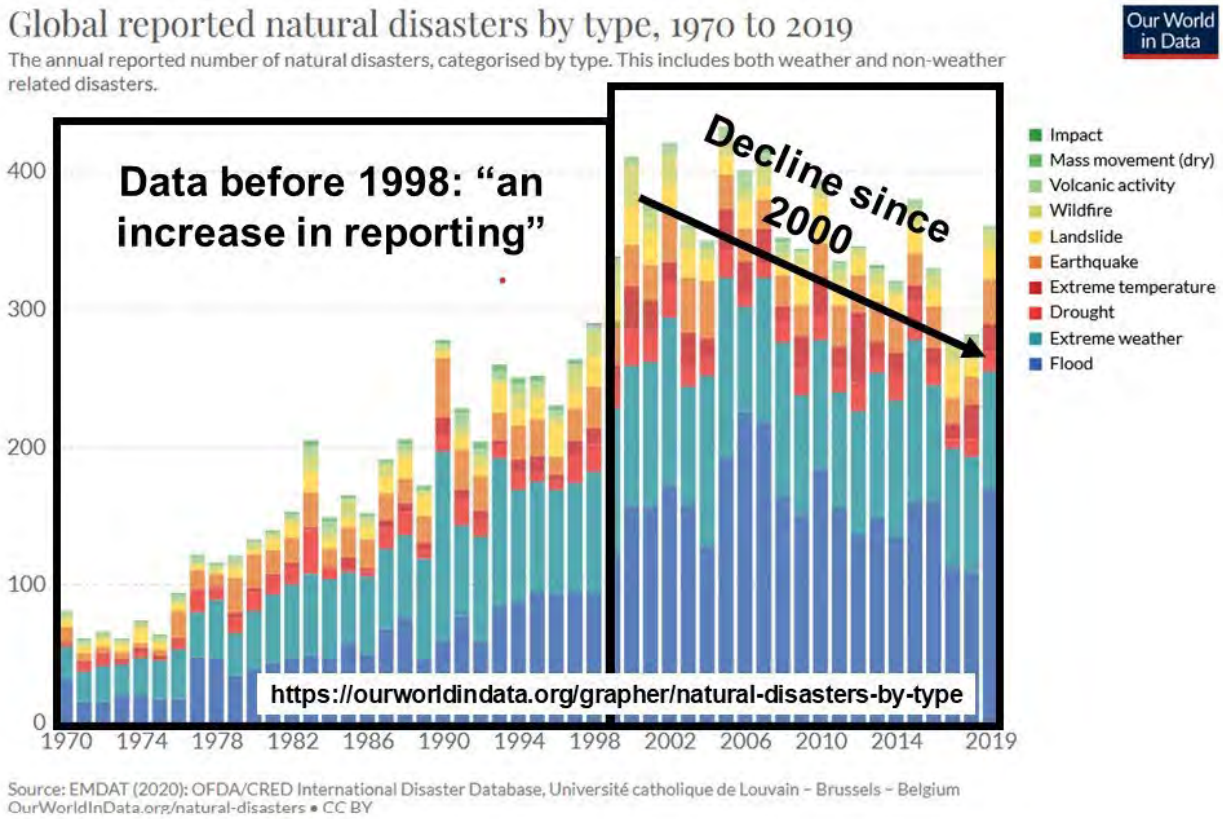
Claim: Severe weather is increasing

> *More frequent and intense extreme weather and climate-related events, as well as changes in average climate conditions, are expected to continue to damage infrastructure, ecosystems, and social systems that provide essential benefits to communities.*
>
> – 4th National Climate Assessment (NCA4) 2018

Fortunately for the citizens of Wyoming and globally, severe weather and natural disasters have been declining. According to data gathered by the World Meteorological Organization, natural disasters have declined approximately 10% since 2000.

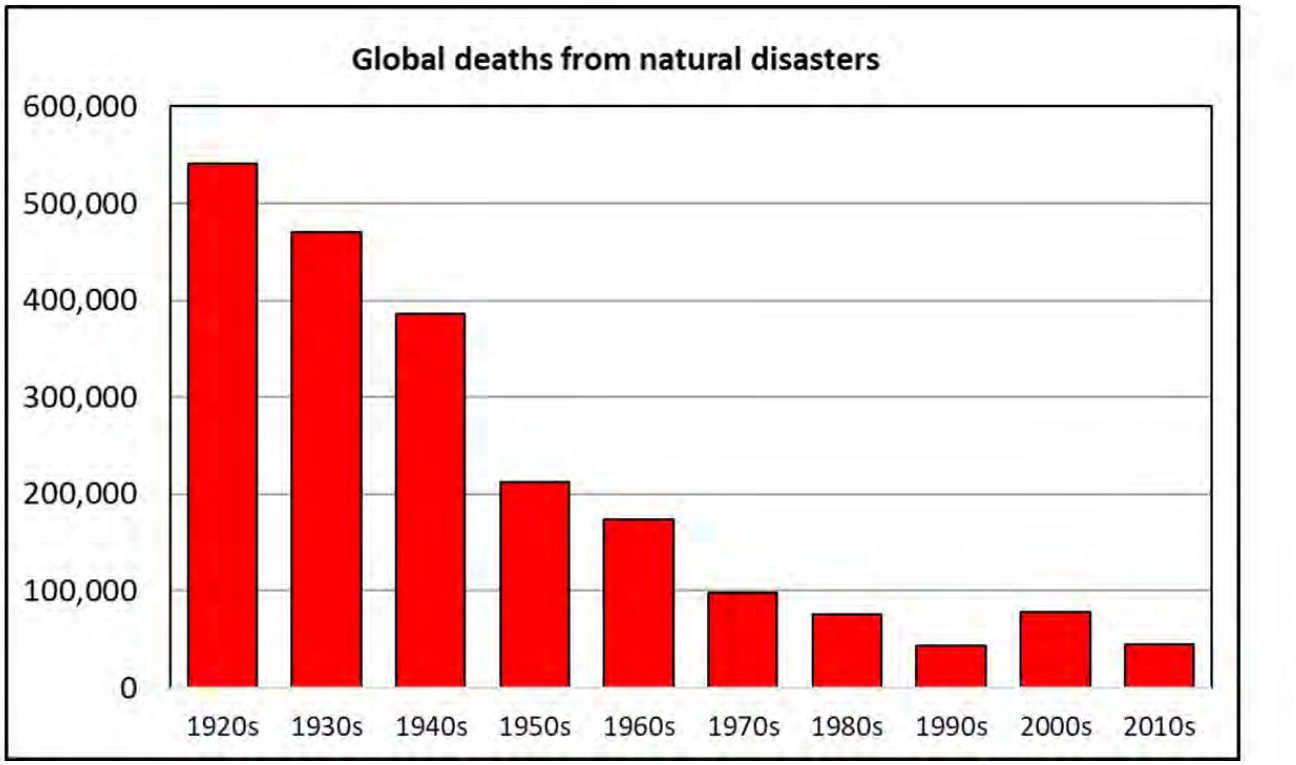
Note: The increase in the period of 1970 to 2000 was attributed to increasing numbers of reporting stations being added, not an actual increase in disasters.

Figure 13: Number of reported global natural disasters



Source: World Meteorological Organization (2021)

Figure 14: Global deaths from natural disasters (average per decade)



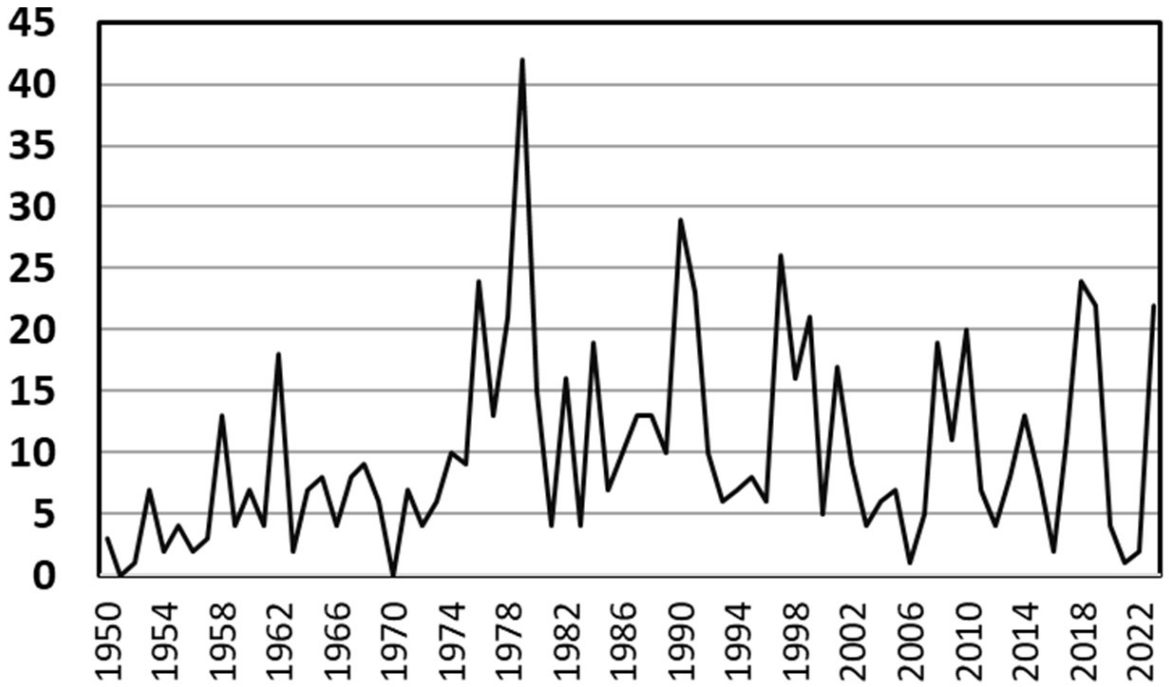
Source: EM-DAT (2022)

Contrary to a common misperception, severe weather events, including tornadoes, are not caused by warming temperatures, but rather, by an increase in the differential between warm and cold air masses. However, the decreased temperature gradient from north to south, predicted from greenhouse gas-induced warming, would decrease the intensity of the forces driving extreme weather.

In Wyoming, the primary severe weather events are tornadoes. Even so, there are relatively few of these catastrophic events. According to the Wyoming State Climate Office (2024), this is due in part to the state's very low population density and geographical location. The Rocky Mountains serve to block the clash between the warm, moist Gulf Coast air and the cooler air flow from the west that is the cause of nearly all tornadoes in the Great Plains.

Figure 15 shows the number of tornadoes documented in Wyoming since 1950. Like the count of global natural disasters in Figure 13, the increase from 1950 to the late 1970s is attributed to better reporting rather than an actual increase in the number of tornadoes.

Figure 15: Number of Wyoming tornadoes reported annually



Source : NOAA National Centers for Environmental Information (2023b)

AGRICULTURE

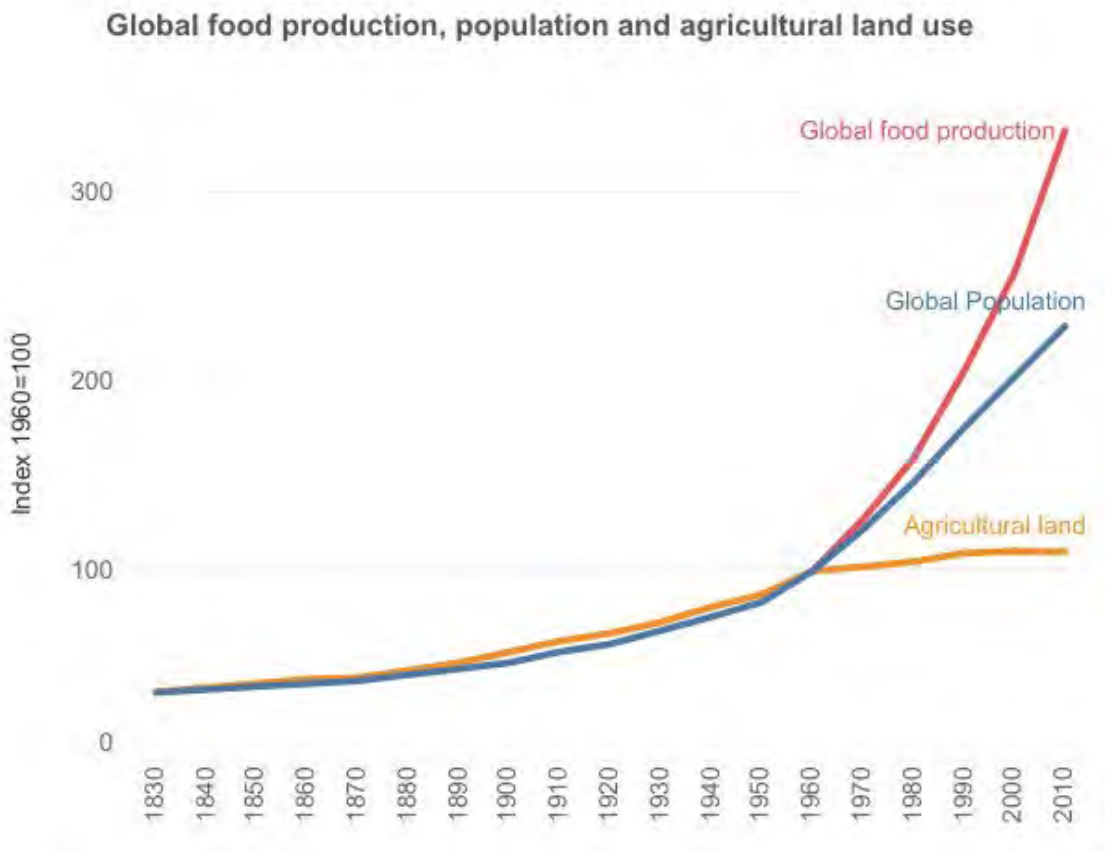
> *The rising level of atmospheric CO_2 could be the one global natural resource that is progressively increasing food production and total biological output, in a world of otherwise diminishing natural resources of land, water, energy, minerals, and fertilizer. It is a means of inadvertently increasing the productivity of farming systems and other photosynthetically active ecosystems. The effects know no boundaries, and both developing and developed countries are, and will be, sharing equally…* ***the rising level of atmospheric CO_2 is a universally free premium, gaining in magnitude with time, on which we all can reckon for the foreseeable future.*** – Wittwer (1995)

Contrary to claims of agricultural declines, global agricultural production has been breaking records year after year. Food production is greatly outpacing population growth (Figure 16). This boost in production is attributable to modest warming, increasing carbon dioxide (CO_2 fertilization effect) and the use of fossil fuel-derived nitrogen fertilizer (Wrightstone 2023). Because of a naturally warmer climate and the CO_2 produced by the burning of fossil fuels, the world today sustains tenfold the number of people (8.04 billion) than at the beginning of the Industrial Revolution (791 million).

In addition to boosting plant growth and crop harvests, increasing CO_2 also reduces the amount of water that plants lose during transpiration. Transpiration is the loss of water vapor through stomata, i.e., small holes in the leaves. Plants have stomata that allow them to "inhale" CO_2 from ambient air. Using energy from sunlight, plants decompose water molecules (H_2O), and combine the hydrogen atoms with the CO_2 molecules from the air to produce sugar. Waste oxygen molecules (O_2) exit

through the stomata. Unfortunately, water molecules can also escape from the stomata. This process dries out the plant. When plants sense that there is more CO_2 in the air, they grow leaves with fewer stomata, and they partially close existing stomata. In other words, fewer leaf holes are needed for CO_2-enriched air. As a result, less water vapor escapes from the leaf, and this increases the resistance of plants to drought.

Figure 16: Global food production index, population and land use for agriculture



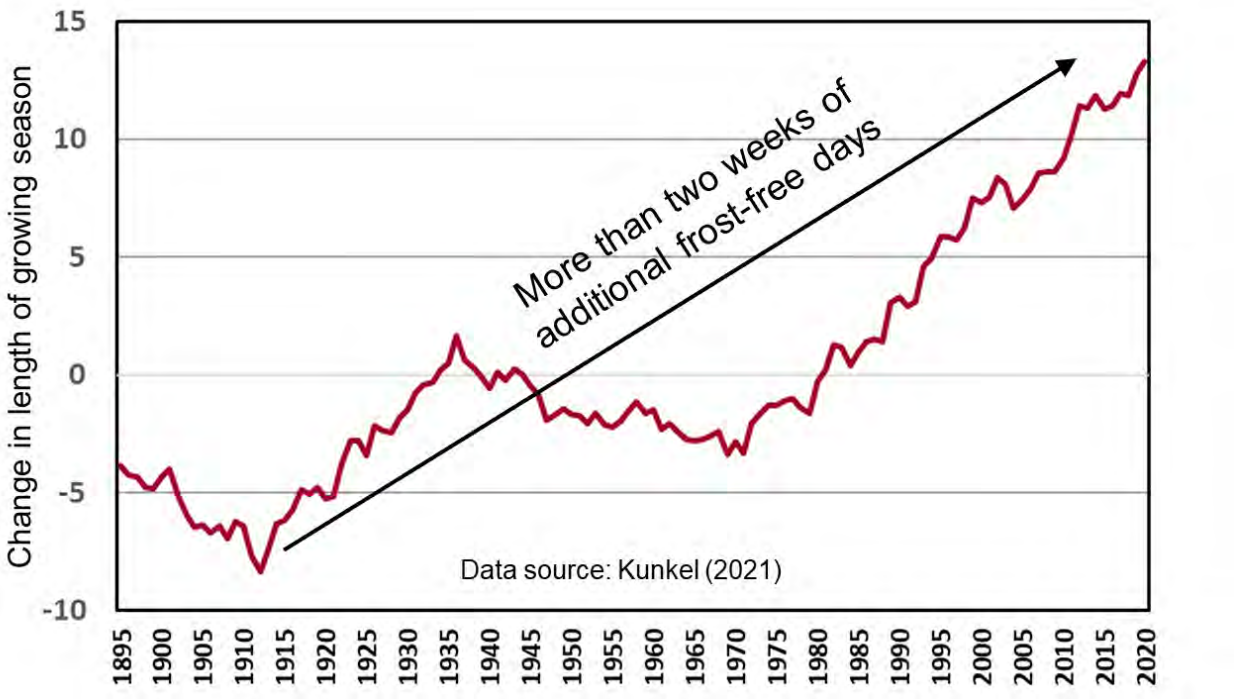
Source: OECD (2023)

In Wyoming, the growing season is short and summer temperatures can be cool. When selecting crops, farmers need to choose crops that can quickly mature and thrive in cool weather.

Modestly rising temperatures are benefiting the Wyoming agricultural sector by extending growing seasons. The length of growing seasons in the contiguous United States has increased by more than two weeks since the beginning of the 20th century (Kunkel 2021, Figure 17).

Killing frosts end earlier in the spring and arrive later in the fall, providing farmers the opportunity for more plantings. Rising temperatures have greatly reduced the risk of killing frosts in late spring, which are the weather-related events most feared by orchard growers.

Figure 17: Growing season is lengthening in the contiguous United States



Data source: Kunkel (2021)

It has been well documented that more CO_2 directly benefits plant growth. The first to link high CO_2 concentrations to faster plant growth was Swiss botanist Jean Senebier in 1796. Since then, many thousands of peer-reviewed studies have confirmed his conclusion. Research has also shown that increased CO_2 helps plants resist drought, extreme heat, pollution and other environmental stresses. In fact, CO_2 has long been used to boost greenhouse yields. Optimal greenhouse concentrations have been reported to be between 800 and 1,200 ppm, more than twice our current atmospheric levels (Wang et al. 2022).

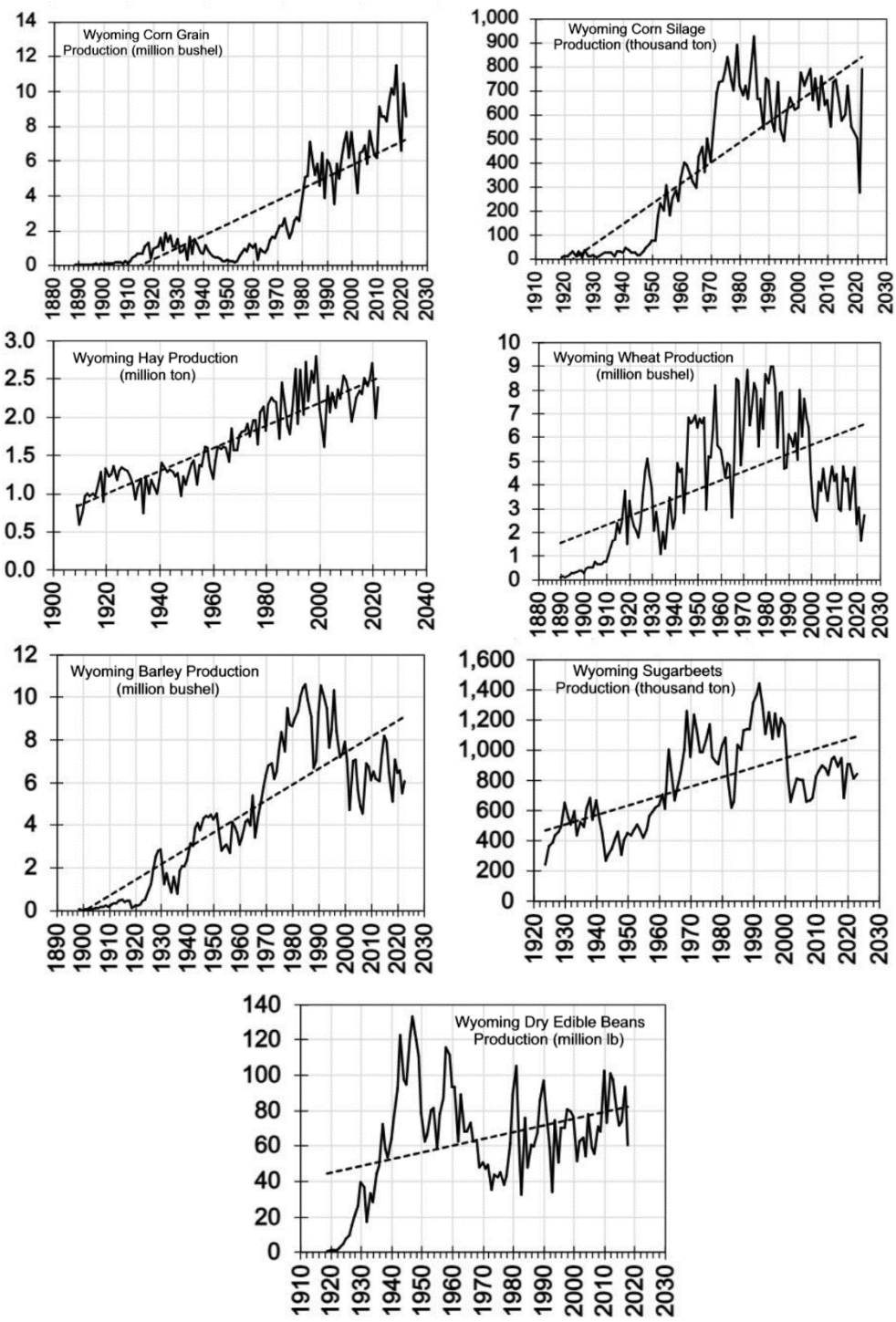
A valuable recent study, *Environmental Drivers of Agricultural Productivity Growth: CO_2 Fertilization of US Field Crops* (Taylor and Schlenker 2023) has quantified how much of the increase in crop growth is attributable to CO_2-driven enhancement. The subject of the study, the United States, is the biggest producer of corn and several other crops, accounting for 33% of global corn production and 7% of global wheat production.

The researchers found a large CO_2 fertilization effect: A "1 part per million increase in atmospheric CO_2 equates to a 0.4%, 0.6% and 1% yield increase for corn, soybeans and winter wheat," respectively. Based on these metrics, our 140-ppm increase in CO_2 since the beginning of the Industrial Revolution has led to 56%, 84% and 140% increases in corn, soybeans and wheat, respectively.

Similarly, Wyoming crops are thriving (Figure 18). The USDA National Agricultural Statistics Service (2022) listed barley, corn, dry beans, hay and haylage, wheat, and sugar beets among the major crop products of Wyoming. Recent declines in wheat are likely due to a reduction in the number of acres devoted to the crop, rather than any climate change-related decline.

If more CO_2 and warmer weather were going to cause a decline in food production, should there not have been some recognizable negative effects by now, after 150 years? Contrary to predictions, all signs point to robust food production globally and in Wyoming, which will continue to increase far into the foreseeable future.

Figure 18: Crop production in Wyoming



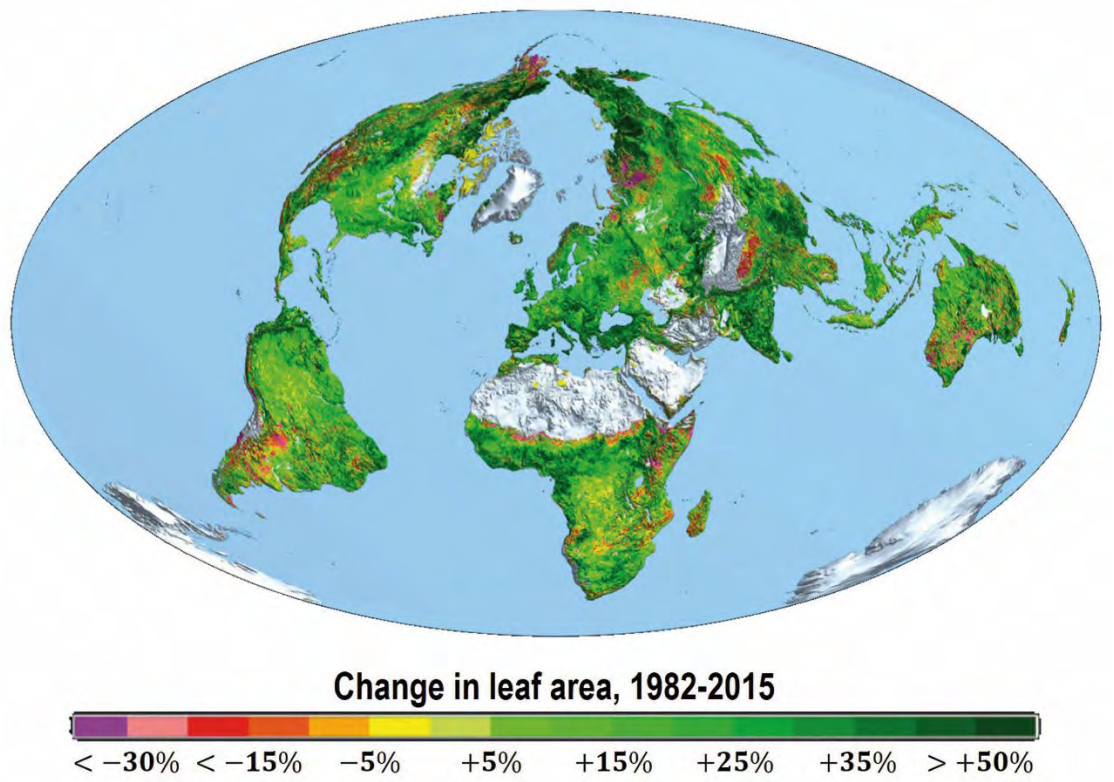
Source: USDA National Agricultural Statistics Service (2023)

BENEFITS OF INCREASING CO_2

The most significant positive consequence of a rising concentration of atmospheric carbon dioxide is that of greatly increased plant growth. Nearly all plants on Earth flourished during periods of much higher CO_2, and their growth has been stunted over the last several million years by near-historically low levels of the gas. Although CO_2 has increased in concentration by 50% over levels prior to the Industrial Revolution, it remains at suboptimal levels for plant growth.

Significant increases in global vegetation have been occurring since at least 1981, when the first satellites enabled large-scale observations (Figure 19). According to Zhu (2016), up to 50% of the Earth's vegetated area is experiencing a persistent and widespread increase in vegetation (greening) while less than 4% is experiencing a decrease (browning). This study documents that the CO_2 fertilization effect is responsible for the bulk of the greening (70%), with additional contributions coming from nitrogen deposition (9%) and warming (4%). Greening from CO_2 fertilization is responsible for most of the greening in the tropics, while the primary driver in the high latitudes and high altitudes was climate change (warming).

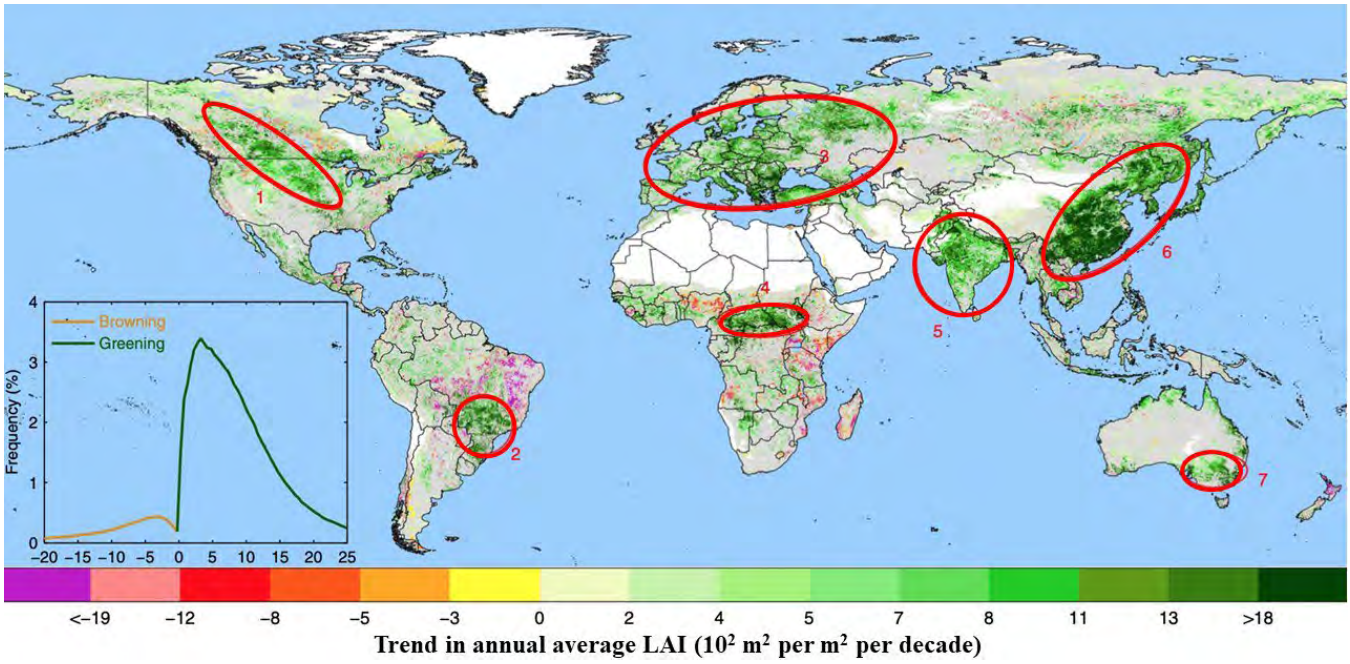
Figure 19: A greening planet



(Modified from Zhu 2016, permission R Myneni)

According to Chen (2019), global leaf area increased by a stunning 5.4 million km^2 (2.1 million square miles) from 2000 to 2017. This area is equivalent to the area of the Amazon rainforest (Piao et al. 2020). Please note that the Northern Great Plains is one of seven global areas that are experiencing the greatest increases in plant growth.

Figure 20: Trend in annual average leaf area



Source: Chen (2019)

The colder areas of the planet have benefited the most from gradual warming since the end of the Little Ice Age in the mid-1800s, with vegetation and tree lines extending into higher latitudes and altitudes. Dr. Tim Ball (1986), for example, documented that the Canadian tree line has marched northward 100 kilometers (62 miles) during the period from 1772 to 1972.

EMISSION REDUCTIONS: COSTS AND EFFECTS ON TEMPERATURE

The U.S. Environmental Protection Agency's model to assess the climate implications of policies is the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC). This model assumes a varying equilibrium climate sensitivity from 1.5 to 4.5°C (the amount of warming from a doubling of atmospheric CO_2).

A review of recent CO_2 emission data from the U.S. Energy Information Administration (EIA 2016) reveals that Wyoming emissions were 1.2% of the total United States emissions of 5,161 million metric tons per year. Looking only at Wyoming's emissions, the MAGICC simulation (using 2.0°C sensitivity) estimates that Wyoming would avert only 0.0009°F (0.0005°C) of warming by 2050 and 0.004°F (0.002°C) by 2100 (Figure 21) if the state had achieved a complete elimination of CO_2 emissions by 2010.

This projected reduction in future warming is far less than the difference in temperature that humans experience every few seconds in a "constant" environment and far below our ability to even measure – scarcely different from zero. According to MAGICC, any attempt by Wyoming to reduce the planet's atmospheric temperature by diminishing CO_2 emissions would be climatically meaningless.

Figure 21: Amount of warming averted by elimination of CO_2 emissions

Model for the Assessment of Greenhouse-gas Induced Climate Change						
How much temperature rise will be averted by 100% reduction in Wyoming's CO_2 emissions?						
Jurisdiction	**CO2 emissions by state (2016)***	**% of US emissions**	**Temperature rise averted by decreasing CO2 by 100% (Climate sensitivity of 2.0°C)**			
			by 2050 (°C)	**by 2050 (°F)**	**by 2100 (°C)**	**by 2100 (°F)**
United States	5,161.00	100.0%	**0.041**	**0.0738**	**0.1040**	**0.1872**
Wyoming	60.7	1.2%	**0.0005**	**0.0009**	**0.0012**	**0.0022**

*Carbon dioxide emission data from U.S. Energy Information Administration

(MAGICC – Model for the Assessment of Greenhouse Gas–Induced Climate Change)

The near-zero effect of Wyoming's proposed emission reductions needs to be assessed in the context of the rapid expansion of global emissions from developing nations, in particular India, China, Russia and Brazil.

Regarding the cost of CO_2 capture, Farouq Ali and Soliman (2023) presented a range of about $50 to $100 per metric ton of CO_2 captured for the case of power generation. In 2016, the amounts of CO_2 emitted in Wyoming were estimated to be 60.7 million metric tons (EIA 2016).

Using the above range of $50 to $100 per metric ton of CO_2, the cost of CO_2 capture in Wyoming to achieve net zero emissions would be $3.0 billion to $6.1 billion. Spending such large amounts of taxpayer dollars to prevent a temperature rise on the order of thousandths of a degree Fahrenheit or less, will likely not stand up to economic scrutiny.

MODELING FUTURE CLIMATE

Plans to spend enormous sums of money in a rush to "net zero" are based on mathematically complicated computer models that predict a significant rise in future temperatures. If we are to base policy decisions on predictive models, we should find out if the models are capable of forecasting accurately. The science tells us that they are not.

A short explanation of how climate models work is in order. The models are based on assessments of climate sensitivity, which is the estimated temperature response to a doubling of atmospheric CO_2 concentrations. In other words, if our current 420 ppm level of CO_2 doubled to 840 ppm, what increase in temperature could we expect? On top of this greenhouse gas-induced warming, the models also estimate positive "feedbacks" such as an increase in water vapor to magnify the warming effect.

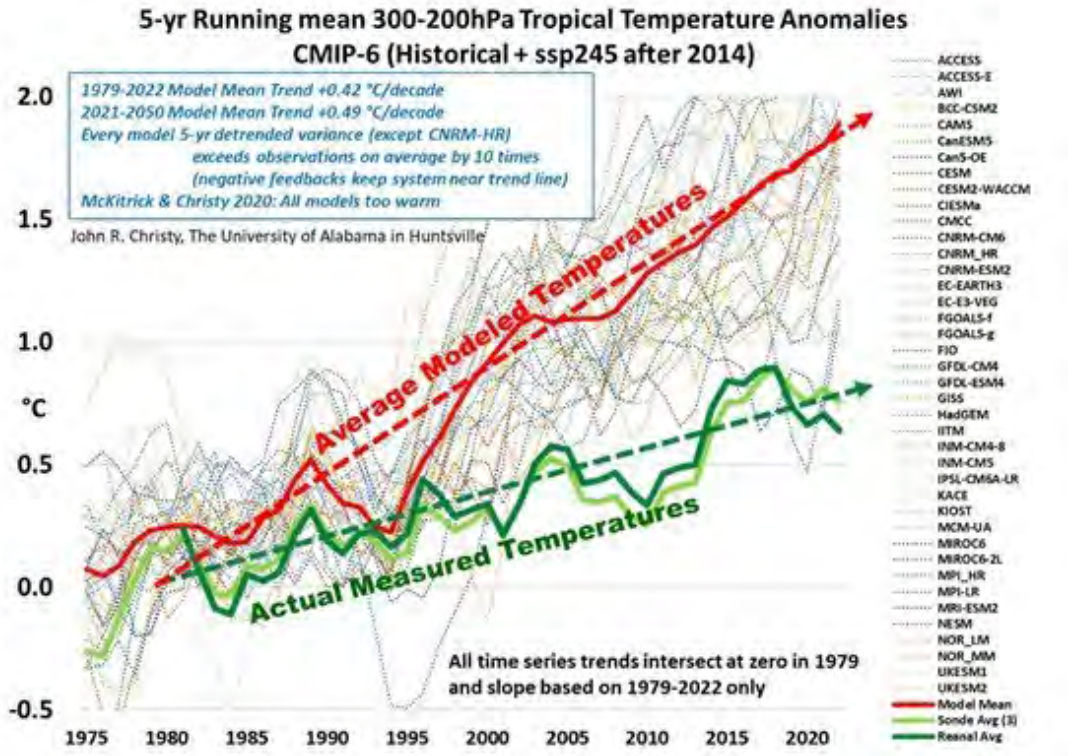
The most recent version of the 100-plus climate models (CMIP6 2022) projects that a doubling of CO_2 would cause a warming of 1.8–5.6°C (3.2–10.1°F). Contrast that to the climate sensitivities calculated by respected physicists Happer, Lindzen and van Wijngaarden in recent CO_2 Coalition publications. In

these publications, they estimate that climate sensitivity is less than 1.5°C, and most likely below 1.0°C:

- 2n-Stream Radiative Transfer – van Wijngaarden and Happer (2022b)
- Infrared Forcing by Greenhouse Gases – van Wijngaarden and Happer (2022a)
- On Climate Sensitivity – Lindzen (2020)

A detailed examination by John Christy, a distinguished climatologist at the University of Alabama at Huntsville and Alabama State Climatologist, provides a stark assessment of the validity (or non-validity) of the models that are used to justify the efforts to attain net zero emissions (Figure 22). The chart below documents that the average of the modeled temperatures predicts a warming rate of 0.42°C per decade, whereas the measured temperature increase was 0.17°C per decade. This inconsistency means that the models are overpredicting temperature increase by at least 2.5 times (McKitrick and Christy 2018). If natural temperature drivers have been responsible for 50% of the measured warming, then the overprediction would rise to five times too high.

Figure 22: Average of the modeled tropical temperature anomalies vs. real-world temperatures



(Modified from Christy 2023)

Governments are enacting polices that rely on complex computer programs, using an array of complicated equations "tweaked" by the scientists who built them to arrive at a temperature forecasted some 100 years into the future. We cannot confidently forecast temperatures a mere 10 days into the future. Yet we are asked to base climate policies and risk trillions of dollars on models that have failed the test of prediction versus observation again and again.

CONCLUSION

The recent proposal by Wyoming Governor Mark Gordon to use "carbon capture" to achieve what he terms "negative net zero" (Gordon 2021) is based on a flawed theory that increasing CO_2 in the atmosphere is leading to harmful effects on Wyoming's environment and its people. Within this report, we have documented that modest warming and increasing carbon dioxide are clearly beneficial for the Cowboy State's ecosystems and citizenry.

The data tell us the following:

- Current levels of carbon dioxide are at near historically low concentrations.
- Adjustments to historic temperature records have artificially amplified modern warming.
- Wyoming temperatures have increased a modest 1.2°F (0.7°C) since 1895.
- Heat waves peaked in the 1930s and have been in slight decline since that period.
- Nighttime low temperatures have increased, lengthening growing seasons.
- Precipitation data, while varying greatly from year-to-year, show no increasing or decreasing trend.
- Droughts are not increasing in Wyoming.
- Severe weather and natural disasters are declining.
- Agricultural production, globally and in Wyoming, is thriving due to modest warming and more CO_2.
- Vegetation in Wyoming and around the world is increasing.
- Greenhouse-induced warming that would be averted (< 0.003°F) by eliminating Wyoming's CO_2 emissions would be too small to measure and achieved, if at all, at enormous cost.
- Models used to project future temperatures significantly overpredict the amount of warming in coming decades.

APPENDIX A

USHCN Wyoming Stations

The table below provides information regarding the USHCN stations in Wyoming (NOAA National Centers for Environmental Information 2023c), where the temperature data are gathered. The following information are provided in the table:

- Column 1: The index for the station.
- Column 2: The ID number of the station.
- Column 3: The latitude where the station is located.
- Column 4: The longitude where the station is located.
- Column 5: The elevation of the station, in meter.
- Column 6: The state where the station is located.
- Column 7: The name of the station.

	Wyoming USHCN Stations					
1	480140	43.7728	-111.0339	1962	WY	ALTA 1 NNW
2	480540	44.3789	-108.0314	1169.5	WY	BASIN
3	480552	42.6339	-106.3775	1831.8	WY	BATES CREEK #2
4	481675	41.15	-104.8167	1868.4	WY	CHEYENNE WSFO AP
5	481730	41.7592	-104.8219	1616.7	WY	CHUGWATER
6	481840	44.5219	-109.0633	1549	WY	CODY
7	481905	44.8711	-104.1533	1060.7	WY	COLONY
8	482595	43.2281	-108.9489	1699.3	WY	DIVERSION DAM
9	482715	43.5397	-109.6553	2119.9	WY	DUBOIS
10	483100	41.265	-110.9508	2080.3	WY	EVANSTON 1 E
11	484065	41.5314	-109.4767	1852.3	WY	GREEN RIVER
12	485345	44.5619	-110.3986	2398.8	WY	LAKE YELLOWSTONE
13	485415	41.3125	-105.6744	2214.7	WY	LARAMIE RGNL AP
14	485830	42.7506	-104.4811	1551.4	WY	LUSK 2 SW
15	486195	43.4131	-106.2772	1481.3	WY	MIDWEST
16	486440	43.8567	-110.5889	2072	WY	MORAN 5 WNW
17	486660	43.8581	-104.2136	1315.2	WY	NEWCASTLE
18	487115	43.2458	-108.6942	1658.1	WY	PAVILLION
19	487240	41.1722	-104.1583	1578.9	WY	PINE BLUFFS 5W
20	487260	42.8797	-109.8642	2193	WY	PINEDALE
21	487388	44.7764	-108.7592	1332	WY	POWELL FLD STN
22	487760	43.0308	-108.3742	1510.3	WY	RIVERTON
23	487845	41.5942	-109.0653	2055	WY	ROCK SPRINGS AP
24	487990	41.4528	-106.8053	2069.6	WY	SARATOGA
25	488160	44.8406	-106.8383	1143	WY	SHERIDAN FLD STN
26	488995	42.0803	-104.2236	1249.1	WY	TORRINGTON EXP FARM
27	489615	42.1106	-104.9492	1413.7	WY	WHEATLAND 4 N
28	489770	44.0108	-107.9686	1237.5	WY	WORLAND
29	489905	44.9767	-110.6964	1898.9	WY	YELLOWSTONE PK MAMMOTH

APPENDIX B

Temperature Adjustments and Fabrication of Data

The temperature data included in this report are from the National Oceanic and Atmospheric Administration's (NOAA) U.S. Historical Climatology Network. There are three issues intrinsic to the data that have served to artificially exaggerate warming for over 100-plus years.

- Urban heat island effect that raises temperatures
- Adjustments to measured historic temperatures
- Fabricated data for stations that no longer exist or are no longer reporting

Urban heat island – Changes in infrastructure led to many monitoring stations being closer to newly constructed buildings and nearer to other heat sinks such as asphalt, concrete and brick structures. In addition, many facilities that were once pristine rural sites ideally situated decades ago have been encroached upon by suburban expansion and heat-trapping infrastructure.

NOAA claims that their "homogenization" techniques compensate for these warming influences. However, examination of the sites tells a different story.

Watts (2022) physically examined monitoring stations and found that approximately 96% of U.S. temperature monitors used to assess climate change fail to meet NOAA's published standards for "acceptable" and uncorrupted placement of stations. According to Watts:

> *Data from the stations that have not been corrupted by faulty placement show a rate of warming in the United States reduced by almost half compared to all stations.*

Adjustments to data – NOAA often adjusts the data from actual measured temperatures to a temperature that their scientists believe it should be. One of the adjustments that has been made is "time of day" bias, which refers to data collected in the afternoon (too hot) or early in the morning (too cold). These are legitimate reasons to remove or alter data from the series.

There was a bigger skew to afternoon highs in the early data (pre-2002), which led to adjustments that "cooled" the older data. The more recent data alterations (post-2002) warmed the data. This type of alteration represents about 25% of the adjustments.

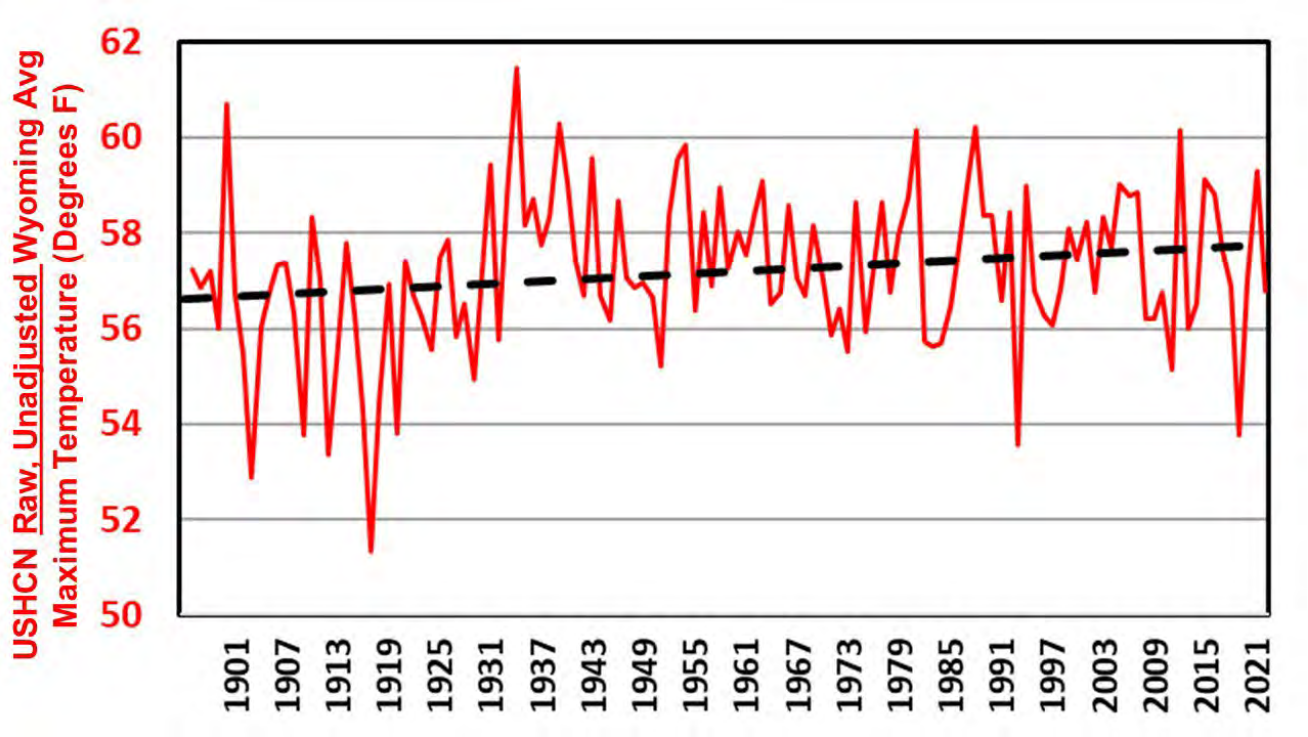
Fabrication of data - The majority of remaining alterations are calculations based on assumptions that are used in lieu of missing thermometer readings. For example, in the United States, USHCN-adjusted temperatures are calculated for all 1,218 stations every month regardless of whether the station actually reported data. Station reporting has declined sharply over the last 30 years.

About 50% of the adjusted data in 2021 came from modeled temperatures, rather than a thermometer (Heller 2022). In other words, temperature data from a station that no longer exists or is no longer

reporting data are created based on what the modelers think that the temperature *should be* rather than *what the temperature is*.

All these adjustments tend to increase the recent temperatures and cool past data. And *that is how NOAA is able to turn a very slight rise of 0.5°F (0.1°C) in average maximum temperature (Figure A-1) in Wyoming into an exaggerated warming of nearly 2.0°F (1.1°C) (Figure A-2).*

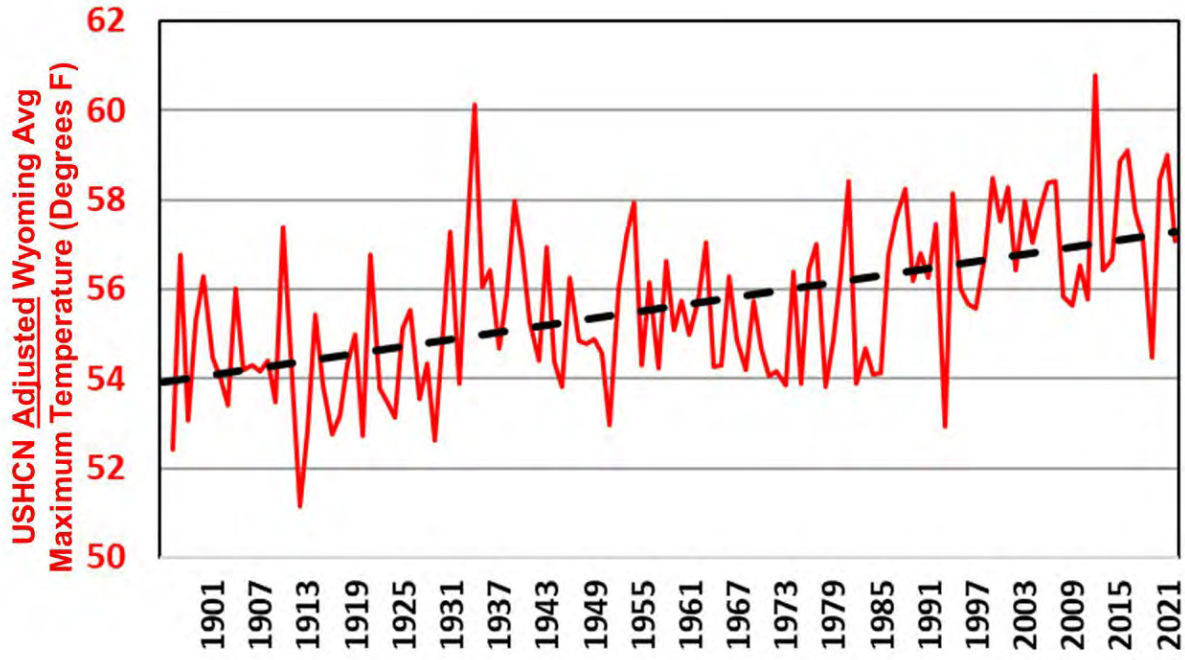
Figure A-1: Raw, unadjusted Wyoming USHCN data



Source: NOAA National Centers for Environmental Information (2023c)

All this creates artificially elevated warming where little warming existed before modifications were made to the raw data.

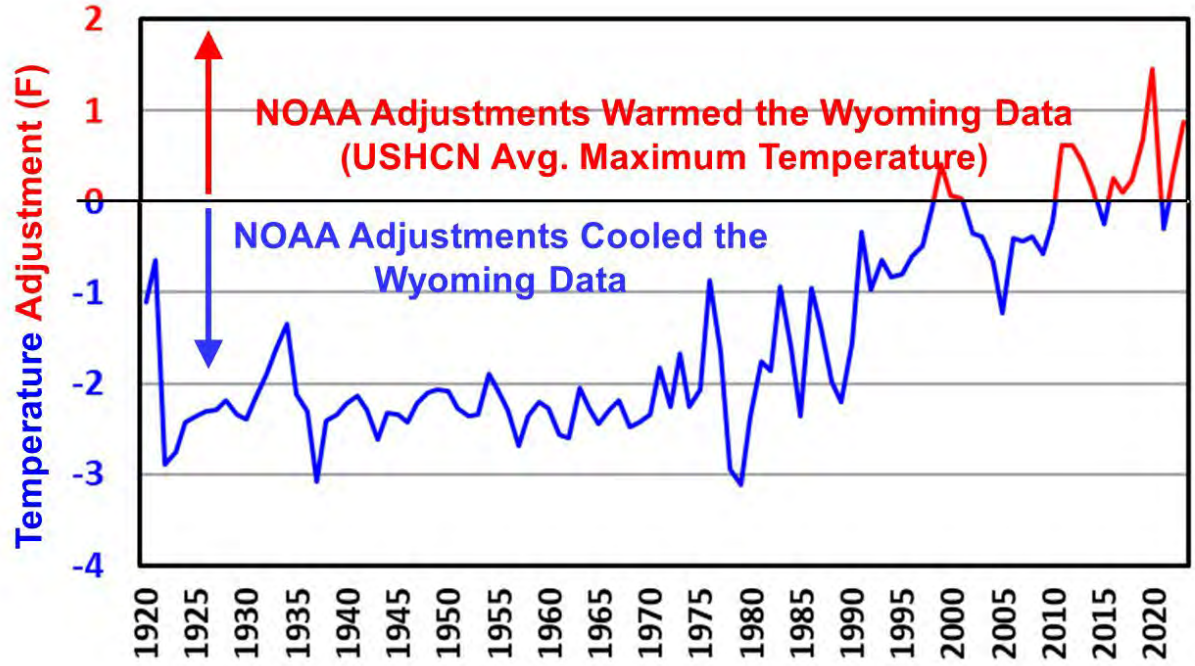
Figure A-2: Adjusted Wyoming USHCN annual average maximum temperature data



Source: NOAA National Centers for Environmental Information (2023c)

Comparing the raw Wyoming temperature data to the final adjusted NOAA data (Figure A-3), we find consistent and significant reductions in the older temperatures and increases in modern temperatures.

Figure A-3: Adjustments cool the older temperatures and warm the recent



Source: NOAA National Centers for Environmental Information (2023c)

ACKNOWLEDGEMENTS

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Frits Byron Soepyan – CO_2 Coalition Research and Science Associate, Ph.D. Chemical Engineering

Frits Byron Soepyan graduated with Bachelor of Science degrees in Chemical Engineering and Mathematics and a Ph.D. in Chemical Engineering from The University of Tulsa.

As a Ph.D. student at The University of Tulsa, Dr. Soepyan collaborated with Chevron, and provided Chevron with a solution for sand transport in pipelines through the development of the computer program TUSTORM (Tulsa University Sand Transport – Optimization and Ranking Methodology), which has been used by Chevron in major capital projects.

Afterwards, as a Postdoctoral Research Associate at the National Energy Technology Laboratory (NETL), using an in-house software, FOQUS (Framework for Optimization, Quantification of Uncertainty, and Surrogates), Dr. Soepyan conducted research in the energy sector, which involved CO_2 capture. Then, as a Process Systems Engineer at AristoSys, LLC, Dr. Soepyan contributed to projects that include emission reduction, decarbonization, hydrogen production, and proposal reviews.

After learning about the benefits of CO_2 and the danger of "net zero," Dr. Soepyan joined the CO_2 Coalition, where he became a Research and Science Associate shortly after joining.

Gregory Wrightstone, CO_2 Coalition Executive Director

As a geologist with degrees in geology from Waynesburg University (BS) and West Virginia University (MS), Wrightstone was deeply involved in the early research and exploration for the vast shale gas reserves in the eastern United States.

He was the co-author of the first peer-reviewed comprehensive paper on the Marcellus Shale Mega Giant Gas Field, the largest natural gas accumulation in the world. He also authored studies on a previously undocumented Super-Giant field, the Burket Shale.

Wrightstone was accepted as an Expert Reviewer for the Intergovernmental Panel on Climate Change (AR6) and is the author of the bestselling climate change-related *Inconvenient Facts* and the newly released *A Very Convenient Warming*.

Dr. William Happer – CO_2 Coalition Chair, Ph.D. Physics

Dr. Happer began his professional career in the Physics Department of Columbia University in 1964, where he served as Director of the Columbia Radiation Laboratory from 1976 to 1979. He joined the Physics Department of Princeton University in 1980.

He invented the sodium guidestar that is used in astronomical adaptive optics systems to correct the degrading effects of atmospheric turbulence on imaging resolution. He has published over 200 peer-reviewed scientific papers; he is a Fellow of the American Physical Society, the American Association for the Advancement of Science and a member of the American Academy of Arts and Sciences, the National Academy of Sciences and the American Philosophical Society.

He served as Director of Energy Research in the U.S. Department of Energy from 1991 to 1993. Dr. Happer was a co-founder in 1994 of Magnetic Imaging Technologies Incorporated (MITI), a small company specializing in the use of laser-polarized noble gases for magnetic resonance imaging. He served as Chairman of the Steering Committee of JASON from 1987 to 1990. From 2018 to 2019 he served as Deputy Assistant to the President and Senior Director for Emerging Technologies at The National Security Council in the White House.

At present he is Chair of the Board of Directors of the CO_2 Coalition, a nonprofit 501(c)(3) organization established in 2015 to educate thought leaders, policymakers and the public about the vital contribution made by carbon dioxide to our lives and our economy.

ABOUT THE CO_2 COALITION

The CO_2 Coalition was established in 2015 as a non-partisan educational foundation operating under Section 501(c)(3) of the IRS code for the purpose of educating thought leaders, policy makers and the public about the important contribution made by carbon dioxide to our lives and the economy. The Coalition seeks to engage in an informed and dispassionate discussion of climate change, humans' role in the climate system, the limitations of climate models and the consequences of mandated reductions in CO_2 emissions.

In carrying out our mission, we seek to strengthen the understanding of the role of science and the scientific process in addressing complex public policy issues like climate change. Science produces empirical, measurable, objective facts and provides a means for testing hypotheses that can be replicated and potentially disproven. Approaches to policy that do not adhere to the scientific process risk grave damage to the economy and to science. The Coalition is comprised of more than 150 of the top experts in the world who are skeptical of a theoretical link between increasing CO_2 and a pending climate crisis while embracing the positive aspects of modest warming and increasing CO_2. They include physicists, chemists, engineers, geologists, economists and more. More than 70% of the members hold doctorates or commensurate degrees and include two members of the National Academy of Sciences.

REFERENCES

Ball TF (1986) Historical Evidence and Climatic Implications of a Shift in the Boreal Forest Tundra Transition in Central Canada. Climatic Change 8, 121–134, DOI: https://doi.org/10.1007/BF00139750

Berner RA, Kothavala Z (2001) GEOCARB III: A revised model of atmospheric CO_2 over Phanerozoic time, IGBP PAGES and World Data Center for Paleoclimatology, Data Contribution Series # 2002-051. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA

Chen C, et al. (2019) China and India lead in greening of the world through land-use management, Journal of Nature Sustainability, doi.org/10.1038/s41893-019-0220-7

Christy J (2023) The University of Alabama in Huntsville

CMIP6 (2022) WCRP Coupled Model Intercomparison Project (Phase 6) – World Climate Research Programme, https://esgf-node.llnl.gov/projects/cmip6/

Day D (2022) Southeast Wyo Temperatures Explode, Set Records; Torrington At 107, Cheyenne Hits 99. Cowboy State Daily, https://cowboystatedaily.com/2022/07/18/wyo-weatherman-don-day-denies-residents-are-melting-says-next-two-weeks-will-be-hot/

European Environment Agency (2019) Trends in atmospheric concentrations of CO_2 (ppm), CH4 (ppb) and N2O (ppb), between 1800 and 2017, European Environment Agency

EIA (2016) EIA's Energy Outlook 2016, https://www.eia.gov/pressroom/presentations-/sieminski_11022016.pdf

EIA (2023) Wyoming State Profile and Energy Economics, U.S. Energy Information Administration, https://www.eia.gov/state/analysis.php?sid=WY

EM-DAT (2022) EM-DAT Center of research on the Epidemiology of Disasters (CRED), https://www.emdat.be/

Farouq Ali SM, Soliman MY (2023) Limitations and Fallacies of Carbon Capture and Storage (CCS) and Impact on Oil and Gas Production. Presented at: SPE Annual Technical Conference and Exhibition, San Antonio, TX, USA, October 2023, DOI: https://doi.org/10.2118/214950-MS

Fiebrich C (2009) Automation: A Step toward Improving the Quality of Daily Temperature Data Produced by Climate Observing Networks, Journal of Atmospheric and Oceanic Technology, https://doi.org/10.1175/2009JTECHA1241.1

Frumkin N, Healey SM (2023) 'Small But Mighty': Wyoming Governor Mark Gordon Talks Energy, Economic Goals at Harvard IOP Forum. The Harvard Crimson, Inc., https://www.thecrimson.com/article/2023/10/24/mark-gordon-iop-forum/

Gordon M (2021) Statement of Governor Mark Gordon of Wyoming Before the Senate Energy and Natural Resources Committee, https://www.energy.senate.gov/services/files/BAEB9A1D-6D39-48E4-8099-2310FCDE2301

Heinz M (2023) Wyoming's Outdoor Recreation Can Become An Economic Powerhouse, Cowboy State Daily, https://cowboystatedaily.com/2023/12/02/wyomings-outdoor-recreation-can-become-an-economic-powerhouse/

Heller T (2022) A Mountain Of Lies, Real Climate Science, https://realclimatescience.com/2022/02/a-mountain-of-lies/#gsc.tab=0

Kunkel KE (2021) Update to data originally published in: Kunkel KE, Easterling DR, Hubbard K, Redmond K (2004) Temporal variations in frost-free season in the United States: 1895–2000. Geophys. Res. Lett. 31:L03201

Lindzen RS (2020) On Climate Sensitivity, CO_2 Coalition, https://co2coalition.org/wp-content/uploads/2021/08/On-Climate-Sensitivity.pdf

MAGICC – Model for the Assessment of Greenhouse Gas–Induced Climate Change, https://www.cato.org/carbon-tax-temperature-savings-calculator

McKitrick R, Christy J (2018) A Test of the Tropical 200- to 300-hPa Warming Rate in Climate Models; Updated 2023 by Christy, https://doi.org/10.1029/2018EA000401

Mountain News LLC (2023) Wyoming Snow Report, OnTheSnow, https://www.onthesnow.com/wyoming/skireport

NCA4 (2018) National Climate Assessment Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II

NOAA National Centers for Environmental Information (2023a) Climate at a Glance: Statewide Time Series, https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series

NOAA National Centers for Environmental Information (2023b) Storm Events Database, https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=56%2CWYOMING#

NOAA National Centers for Environmental Information (2023c) U.S. Historical Climatology Network (USHCN), https://www.ncei.noaa.gov/products/land-based-station/us-historical-climatology-network

NOAA National Integrated Drought Information System (2023) U.S. Gridded Palmer Drought Severity Index (PDSI) from gridMET, Drought.gov, https://www.drought.gov/data-maps-tools/us-gridded-palmer-drought-severity-index-pdsi-gridmet

OECD (2023) How we feed the world today, Organization for Economic Co-operation and Development,

https://www.oecd.org/agriculture/understanding-the-global-food-system/how-we-feed-the-world-today/

Piao S, Wang X, Park T, Chen C, Lian X, He Y, Bjerke JW, Chen A, Ciais P, Tømmervik H, Nemani RR, Myneni RB (2020) Characteristics, Drivers and Feedbacks of Global Greening. Nature Reviews Earth & Environment 1, 14–27, DOI: https://doi.org/10.1038/s43017-019-0001-x

Spiers E (2024) The End of Snow, New York Times, https://www.nytimes.com/2024/01/02/-opinion/climate-angst.html

Taylor C, Schlenker W (2023) Environmental drivers of agricultural productivity growth: CO_2 fertilization of US field crops; Working Paper 29320, National Bureau of Economic Research

UNFAO (2023) United Nations Food and Agriculture Organization, Agriculture on the proving grounds – Damage and loss, https://www.fao.org/resources/digital-reports/disasters-in-agriculture/en/

USDA National Agricultural Statistics Service (2022) Wyoming Agriculture, https://www.nass.usda.gov/Statistics_by_State/Wyoming/Publications/Brochures/Wyoming%20AG%20Profile%20Brochure.pdf

USDA National Agricultural Statistics Service (2023) Quick Stats, https://quickstats.nass.usda.gov/

United States Environmental Protection Agency (2023) Greenhouse Gas Inventory Data Explorer, https://cfpub.epa.gov/ghgdata/inventoryexplorer/#electricpowerindustry/entiresector/allgas/category/all

van Wijngaarden W, Happer W (2022a) Infrared Forcing by Greenhouse Gases, CO_2 Coalition Climate Issues in Depth, https://co2coalition.org/wp-content/uploads/2022/03/Infrared-Forcing-by-Greenhouse-Gases-2019-Revised-3-7-2022.pdf

van Wijngaarden W, Happer W (2022b) Radiative Transfer Paper for Five Greenhouse Gases Explained, https://co2coalition.org/publications/van-wijngaarden-and-happer-radiative-transfer-paper-for-five-greenhouse-gases-explained/

Wang T, Du H, Zhao Z, Zhang J, Zhou C (2022) Impact of Meteorological Conditions and Human Activities on Air Quality During the COVID-19 Lockdown in Northeast China. Frontiers in Environmental Science 10, 877268, DOI: https://doi.org/10.3389/fenvs.2022.877268

Watts A, Burnett HS, Taylor J, Lakely J (2022) MEDIA ADVISORY: 96% of U.S. Climate Data Are Corrupted. The Heartland Institute, https://heartland.org/opinion/media-advisory-96-of-us-climate-data-is-corrupted/

World Meteorological Organization (2021) The Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019), WMO-No 1267, ISBN: 978-92-63-11267-5

Wyoming State Climate Office (2024) Wyoming Climate Atlas, Severe Weather,

http://www.wrds.uwyo.edu/sco/climateatlas/severe_weather.html

Wittwer SH (1995) Food, Climate and Carbon Dioxide: The Global Environment and World Food Production. CRC Press, Boca Raton

Wrightstone G (2023) A Very Convenient Warming – How modest warming and more CO_2 are benefiting humanity, Silver Crown Productions LLC

Zhu Z, Piao S, Myneni R, Huang M, Zeng Z, Canadell JG, Ciais P, Sitch S, Friedlingstein P, Arneth A, Cao C, Cheng L, Kato E, Koven C, Li Y, Lian X, Liu Y, Liu R, Mao J, Pan Y, Peng S, Peñuelas J, Poulter B, Pugh TAM, Stocker BD, Viovy N, Wang X, Wang Y, Xiao Z, Yang H, Zaehle S, Zeng N (2016) Greening of the Earth and Its Drivers. Nature Climate Change 6, 791–795, DOI: https://doi.org/10.1038/nclimate3004