



# Extreme Weather and Climate Change

by *Kenneth P. Green*

## Summary

- Assertions are made claiming that weather extremes are increasing in frequency and severity, spurred on by humanity's greenhouse gas emissions.
- Based on such assertions, governments are enacting ever more restrictive regulations on Canadian consumers of energy products, and especially Canada's energy sector. These regulations impose significant costs on the Canadian economy, and can exert downward pressure on Canadian's standard of living.
- According to the UN IPCC, evidence does suggest that some types of extreme weather have become more extreme, particularly those relating to temperature trends.
- However, many types of extreme weather show no signs of increasing and in some cases are decreasing. Drought has shown no clear increasing trend, nor has flooding. Hurricane intensity and number show no increasing trend. Globally, wildfires have shown no clear trend in increasing number or intensity, while in Canada, wildfires have actually been decreasing in number and areas consumed from the 1950s to the present.
- While media and political activists assert that the evidence for increasing harms from increasing extreme weather is iron-clad, it is anything but. In fact, it is quite limited, and of low reliability. Claims about extreme weather should not be used as the basis for committing to long-term regulatory regimes that will hurt current Canadian standards of living, and leave future generations worse off.

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## Introduction

We are often told by various media, major politicians, international celebrities, and environmental activists such as Al Gore and Greta Thunberg, that man-made climate change has already brought and will continue to bring vastly more extreme weather events. The disaster list is fairly lengthy: flooding, drought, heat waves, cold snaps, more frequent and intense forest fires, more frequent and intense rainfall/snowfall, more frequent and intense tropical storms.

Here are some quotes from notable voices on the climate change topic:

**David Suzuki:** “Earth is clearly experiencing more frequent extreme weather than in the past, and we can expect it to get worse as we burn more coal, oil and gas and pump more carbon dioxide and other greenhouse gases into the atmosphere.” (Suzuki Foundation, 2015)

**Al Gore:** “That’s why the heat records are being broken all the time now,” he said. “That’s why the storms are stronger, why the ice is melting and the sea levels rising and why the droughts and fires are hitting us so hard and so many other consequences.” (Hutzler, 2022)

**Greta Thunberg:** “‘This is the new normal’ is a phrase we often hear when the rapid changes in our daily weather patterns—wildfires, hurricanes, heatwaves, floods, storms, droughts, and so on—are being discussed. These weather events are not just increasing in frequency, they are becoming more and more extreme. The weather seems to be on steroids, and natural disasters increasingly appear less and less natural.” (Thunberg, 2022).

**António Guterres:** “Extreme weather is destroying lives and livelihoods on a daily basis—underlining the imperative need to ensure that everyone is protected by early warning services. We cannot return to the climate of the 20th century, but we must act now to limit the risks of an increasingly inhospitable climate in this and coming centuries.” (Carrington, 2024).



Canada’s government, in a new (2024) climate communications initiative “Raising the Bar” asserts that man-made climate change has escalated from being a demonstrated future threat to being so severe that we are now in a real-time *Climate Crisis*. A crisis in which we are experiencing more wildfires, floods, and droughts that “affects our economy, our infrastructure, our health, and our overall well-being.” The government’s Raising the Bar website comes with a video showing how Canadians are all-in on fighting the climate crisis. (Government of Canada, 2024).

It all sounds rather alarming. And indeed, these are somewhat extraordinary claims in many ways. They place great certainty on only lightly, fragmentarily, and inconsistently measured events and they claim great confidence in forecasts of future weather extremes. They also assert on this basis that humanity must undertake a radical energy transition that entails abandonment of fossil fuels. Not to mention, in the absence of inexpensive and equally-reliable alternatives, much of the free-market economic system, which

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has brought most of the world's population out of the abject poverty that predominated for all but the last few hundred years of human existence, would be in jeopardy.

As astrophysicist and writer Carl Sagan said, “extraordinary claims require extraordinary proof” (Sagan, 1986). And when unpacked, many of the claims regarding extreme weather, and trends in extreme weather seem to fail the test. This bulletin will review what is known about changes in extreme weather observed already (recorded in empirical data), and what is known about the ability of climate models to make projections of change in extreme weather moving forward.

It is helpful to begin with what the United Nations Intergovernmental Panel on Climate Change (IPCC) has to say in its most recent report on the physical basis of climate change.<sup>1</sup> In its Chapter on *Weather and Climate Extreme Events in a Changing Climate*, the IPCC follows six primary types of “extremes” including:

- Temperature extremes
- Heavy precipitation and pluvial<sup>2</sup> floods
- River floods
- Droughts

- Storms (including tropical cyclones) and
- Compound events (multivariate and concurrent extremes)

The IPCC assessments of changes to these extremes begin with 1950 in most cases. This is primarily due to lack of earlier data for many places in the world. But it should be noted that where long term data exist, apparent trends after 1950 sometimes disappear or change sign when an earlier start date is applied.<sup>3</sup> The IPCC holds that “It is an established fact that human-induced greenhouse gas emissions have led to an increased frequency and/or intensity of some weather and climate extremes since pre-industrial time, in particular for temperature extremes” (IPCC, 2021a).

The IPCC's confidence regarding extreme weather ranges from high confidence and strong certainty primarily concerning increasing high temperatures, to low confidence in other trends such as severe convective storms. Evidence for most changes in most extreme weather trends is only rated as likely, or of medium confidence, over limited areas.

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1 A short caveat: The UN IPCC is, first and foremost a political body, not a scientific research group. They assemble teams of scientists to generate the document mentioned above, *The Physical Science Basis*, one volume of the three-volume Sixth Assessment Report of the IPCC. This particular volume has generally been held in high regard both by those alarmed about climate change, and those who are less alarmed. I will be quoting, and inserting graphics from *The Physical Science Basis*, (2021) and its Technical Summary, and I may quote from, or use graphics from a more selective “Synthesis report released in 2023), but not “Summaries for Policymakers” or other documents that are primarily political publications, not objective reviews of climate science.

2 Pluvial floods (i.e., flash floods) are caused by heavy rainfall, and are distinct from fluvial floods, or river floods, and coastal flooding.

3 See, for example, McKittrick and Christy (2019).

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IPCC has a complex way of expressing the strength of evidence regarding any of its assertions, but essentially, they come down to the “expert judgment” of the team writing the particular section of the IPCC’s reports. It is important to note that these assertions are not purely computations of probabilities and statistics as one might use in estimating the probability of a five coming up when one rolls a die. Rather, subjective assessments by the various IPCC research teams lead to these terms of confidence and certainty. Assigning *confidence* and *likelihood* is a two-step process. First, if an author team’s expert judgment convinces them that there is sufficient data to render a determination of confidence, they may assign it a confidence expression ranging from ‘very low’ to ‘very high’. It is noted that these confidence assignments need not be symmetrical, that is,

When confidence in a finding is assessed to be low, this does not necessarily mean that confidence in its opposite is high, and vice versa. Similarly, low confidence does not imply distrust in the finding; instead, it means that the statement is the best conclusion based on currently available knowledge.

Once a confidence indicator is established, the author team then work up assessments of “likelihood.” Here is the IPCC’s definition of expressing “likelihood,” from chapter 1, Box 1.1 of the Sixth Assessment Report, AR6 2021: “If the expert judgment of the author team concludes that there is sufficient confidence and quantitative/probabilistic evidence, assessment

conclusions can be expressed with likelihood statements. Unless otherwise indicated, likelihood statements are related to findings for which the authors’ assessment of confidence is high or very high. Terms used to indicate the assessed likelihood of an outcome include: virtually certain: 99–100% probability, very likely: 90–100%, likely: 66–100%, about as likely as not: 33–66%, unlikely: 0–33%, very unlikely: 0–10%, exceptionally unlikely: 0–1%. Additional terms (extremely likely: 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate” (IPCC, 2021a: 169).

One might note that the wide ranges for these expressions, such as “medium confidence, and “about as likely as not” straddle the 50% mark quite widely. In addition, something deemed “likely” could be as low as a likelihood of 66/100. In the case of likelihood of “about as likely as not,” that classification could be assigned to something that might only have a one third chance of being representative of reality.

## Temperature Extremes

The IPCC deems it “virtually certain” on a global scale, that extremes of temperature have been observed changing since 1950. To be specific, IPCC observes there have been:

- Warmer and/or more frequent hot days and nights over most land areas;
- Warmer and/or fewer cold days and nights over most land areas;
- Warm spells/heatwaves, increases in frequency or intensity over most land areas;

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- Cold spells/cold waves decreases in frequency or intensity over most land areas.

IPCC's assessment of this highest and most measured climate variable is widely accepted to accurately reflect reality, including by the author, and need not be questioned here. Our focus is on changes to extreme weather events rather than the general temperature of the climate. *Canada's Changing Climate Report* finds "Annual and seasonal mean temperatures across Canada have increased, with the greatest warming occurring in winter. Between 1948 and 2016, the best estimate of mean annual temperature increase is 1.7°C for Canada as a whole and 2.3°C for northern Canada" (Bush and Lemmen, 2019).

## Drought

The IPCC claims "medium confidence" that drought has increased around the world. The underlying evidence is clearly mixed and inconsistent. AR6, Section 11.6.2.1 refers to the World Meteorological Organization Standardized Precipitation Index (SPI) data base which covers 1901-2017. That data set indicates no significant trend in drought has occurred. Likewise, Vincente-Serrano et al. (2022) concludes that the SPI data "shows a dominance of non-significant trends between 1900 and 2020." While they agree with the IPCC that there has been some increased drought in some places, they add:

In the vast majority of the world, trends in meteorological drought duration and

magnitude are not statistically significant, with the exception of some small regions of Africa and South America, which is also where data uncertainty is greater... In summary, trends in meteorological drought severity in the last few decades are not observed globally based on precipitation data, and very few areas are showing changes in the severity of meteorological droughts (Vincente-Serrano et al., 2022).

The International Energy Agency (IEA) in a 2021 report, suggests that drought severity in Canada from 2000–2020 was only slightly above the global average.

## Flooding

The IPCC assesses that it is *likely* floods have increased globally since 1950. AR6, section 11.5.2 says: "Peak flow trends are characterized by high regional variability and lack overall statistical significance of a decrease or an increase over the globe as a whole. Of more than 3,500 streamflow stations in the USA, central and northern Europe, Africa, Brazil, and Australia, 7.1% stations showed a significant increase, and 11.9% stations showed a significant decrease in annual maximum peak flow during 1961–2005" (2021b)

The IPCC also states that "In North America (Table 11.20), there is robust evidence that the magnitude and intensity of extreme precipitation has very likely increased since the 1950s... There is, however, regional diversity. In Canada, there is a lack of detectable trends in observed annual maximum daily (or shorter duration)

4 Internal referencing omitted from quoted material.

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precipitation” (IPCC 2021a).<sup>4</sup> *Canada’s Changing Climate Report* finds that “Extreme precipitation is also projected to increase in the future, although the observational record has not yet shown evidence of consistent changes in short-duration precipitation extremes across the country” (Bush and Lemmen, 2019).

However, it is unclear that the observed changes described above, for the United States (and probably Canada) may or may not be related to human-caused climate change. The United States Global Change Research Program, in its 2017 National Climate Assessment, found “Detectable changes—a mix of increases and decreases—in some classes of flood frequency have occurred in parts of the United States,” although attribution studies have not established a robust connection between increased riverine flooding and human-induced climate change. They also observed that “While by some measures drought has decreased over much of the continental United States in association with long-term increases in precipitation, neither the precipitation increases nor inferred drought decreases have been confidently attributed to anthropogenic forcing” (Wuebbles et al., 2017).<sup>5</sup>

Another study (Do et al., cited by the IPCC above), published in the *Journal of Hydrology* in 2017 casts further doubt on the IPCC’s assessment that it is ‘likely’ that flooding has been increasing, and that it is attributable to climate change. Do et al., studied global streamflow data from the Global Runoff Data Centre database, which

contains records from 9,213 streamflow recording stations across the globe. Increased streamflows would be a potential indicator of elevated flood risk (Do et al., 2017). Their conclusions<sup>6</sup> were:

Importantly, for almost all datasets considered, and regardless of whether the stations were filtered by the presence of dams, catchment area, or forest cover changes, there were more stations exhibiting significant decreasing trends than increasing trends. In particular, decreasing trends were observed for a large number of stations in western North America and the data-covered regions of Australia, and increasing trends in parts of Europe, eastern North America, parts of South America and southern Africa (Do et al., 2017).

With regard to increasing flood risk, Do et al. (2017), found that “...though there may be evidence of regional increasing trends in flood hazard, the hypothesis that there is a significant increase in flood hazard when averaged over all the data-covered regions of the globe is not supported by this analysis.”

*Canada’s Changing Climate Report* also finds no clear evidence of increasing extreme precipitation, stating,

There do not appear to be detectable trends in short-duration extreme precipitation in Canada for the country as a whole based on available station data. More stations have

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<sup>5</sup> A Fifth National Climate Assessment is pending publication at this time, but not available at time of writing.

<sup>6</sup> Internal referencing omitted from quoted material.

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experienced an increase than a decrease in the highest amount of one-day rainfall each year, but the direction of trends is rather random over space. Some stations show significant trends, but the number of sites that had significant trends is not more than what one would expect from chance (Bush and Lemmen, 2019).

In short, the IPCC asserts only medium confidence that compound flooding risk has increased in some locations, and low confidence that human influence has contributed to changes in compound events leading to flooding. Contradictory, and even negating evidence from the real world suggests globally, flood risk had decreased since the 1950s, and has not clearly been shown to be increasing.

## Hurricanes and Cyclones

Hurricanes and tropical cyclones are also frequently tied to climate change in the popular media. Confidence levels for different dimensions of hurricane range from low for detection of severe convective storms—tornadoes, hail, rainfall, wind, lightning—to likely with medium confidence for most other observations in changes of extremes over the last 50 years related to hurricanes and tropical cyclones.

Roger Pielke Jr. is a professor at the University of Colorado Boulder, where, in 2002, he founded and directed the Center for Science and Technology Policy Research. He also created and led the university's Graduate Certificate Program in Science and Technology Policy from 2003–2020. Pielke has made the study of hurricanes a critical

focus in his work for over three decades, publishing a book in 1997 (co-authored with his father Roger Pielke Sr., also a noted climate researcher) titled *Hurricanes: Their Nature and Impacts on Society* (Pielke, 1997). Pielke and colleagues would publish the first peer-reviewed paper with a comprehensive dataset of tropical hurricane landfalls (Weinkle et al., 2012). The work would be updated in 2019 (Knutson et al., 2019), at the request of the World Meteorological Organization, and in 2023, Pielke et al. published still another update to his Substack outlet, *The Honest Broker* (Pielke and Maue, 2023).

Weinkle et al. (2012), presents a comprehensive dataset of tropical hurricane landfalls. In the latest update (Pielke et al. 2023) Pielke finds no long-term trends in hurricanes or major hurricanes recorded globally going back to 1980. In fact, counter to the “things are getting worse narrative,” Pielke observes that, based on 12-month running sums, the most recent two years have had “close to the least overall global activity of the past 40+ years, for both hurricanes and major hurricanes.”

Pielke and Maue et al. also take the data back to the UN's starting point of 1950, finding variability in cyclone landfalls, but no apparent trend. Pielke and Maue show that approximately 16 Category 1 cyclones made landfall in 1960, which rose only to 17 by 2022. Pielke and Maue's review of the data found that approximately 6 Category 3+ cyclones (more severe) made landfall in 1960, and the overall average trend was stable at six from 2020–2022. Pielke and Maue delves further into hurricane trends, looking at accumulated

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cyclone energy (ACE)—an indexed “integrated value of frequency and intensity of global tropical cyclones”—finding no overall trend. The global accumulated cyclone energy average over 1980 to 2022 is flat at an accumulated cyclone energy index level of 16, ranging from an ACE index low of 12 in 1981 to an index high of 20 in 1992, 1994, 1996, and 2004. (Pielke and Maue, 2023).

The US National Climate Assessment (NCA) agrees that hurricane activity in the Atlantic has increased, but attribution to climate change is not currently possible. They observe,

Atlantic hurricane activity has increased since the 1970s, but the relatively short length of high-quality hurricane records do not yet allow us to say how much of that increase is natural and how much may be due to human activity. With future warming, hurricane rainfall rates are likely to increase, as will the number of very intense hurricanes, according to both theory and numerical models. However, models disagree about whether the total number of Atlantic hurricanes will increase or decrease. Rising sea level will increase the threat of storm surge. Hurricane activity is undeniably linked to sea surface temperatures... Other influences being equal, warmer waters yield stronger hurricanes with heavier rainfall. The tropical Atlantic Ocean has warmed over the past century, at least partly due to human-caused emissions of greenhouse gases. However, high-quality records of Atlantic hurricanes are too short to reliably separate any long-term trends in

hurricane frequency, intensity, storm surge, or rainfall rates from natural variability (NCA, 2019).

In sum, with regard to hurricanes, cyclones, and the like, while the IPCC suggests that there is likely an increase in certain tropical cyclone characteristics. These include greater likelihood of increased intensities (categories 3-5), likely increase in rapidly intensifying tropical cyclones, and medium-high likelihood of human contribution to the trend. Evidence that hurricanes, or tropical cyclones are either growing more frequent, or are clearly attributable to climate change or human activities either contradicts the IPCC’s narrative, or reveals no trends in the data.

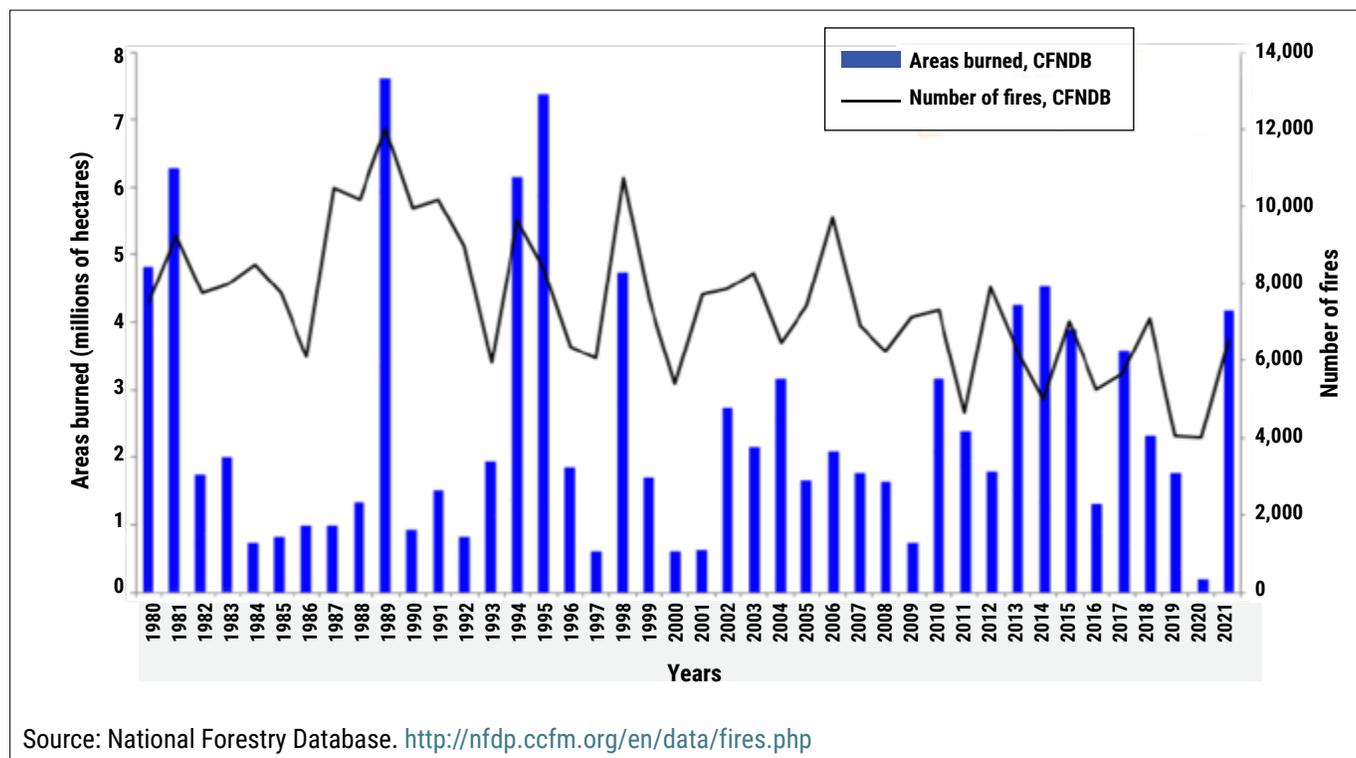
## Wildfires

The IPCC asserts medium confidence that there has been some increase in fire weather in “some regions” since 1950. Further, per IPCC, some of the most worrisome extreme weather events that might aggravate fire weather such as wind and lightning are portrayed with “low confidence in past trends in hail and winds and tornado activity due to short length of high-quality data records” (IPCC, 2021b).

Fire weather is only one factor in the evolution of wildfires but the linkage between the two in the popular imagination has been fueled by politicians tying isolated seasons with high wild-fire numbers—or the extent of areas burned—to increasing ‘fire weather’ caused by human-induced climate change. Figure 1 shows the number, and areas burned across Canada from 1983–2022. As one can see from the data, forest

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Figure 1: Number and extent of forest fires in Canada, 1980–2021



Source: National Forestry Database. <http://nfdp.ccfm.org/en/data/fires.php>

fires have been declining in terms of both frequency and magnitude in Canada.

A recent blog post, published by the Royal Society, an independent scientific academy in the United Kingdom, summarizes in a 2020 blog post updating 2016 research on global wildfire extent, “...when considering the total area burned at the global level, we are still not seeing an overall increase, but rather a decline over the last decades. This has been confirmed in a series of subsequent studies, using data up to 2017 or 2018.”

The 2016 report was more explicit, finding: “Instead, global area burned appears to have overall declined over past decades, and there is increasing evidence that there is less fire in

the global landscape today than centuries ago” (Doerr and Santin, 2016).

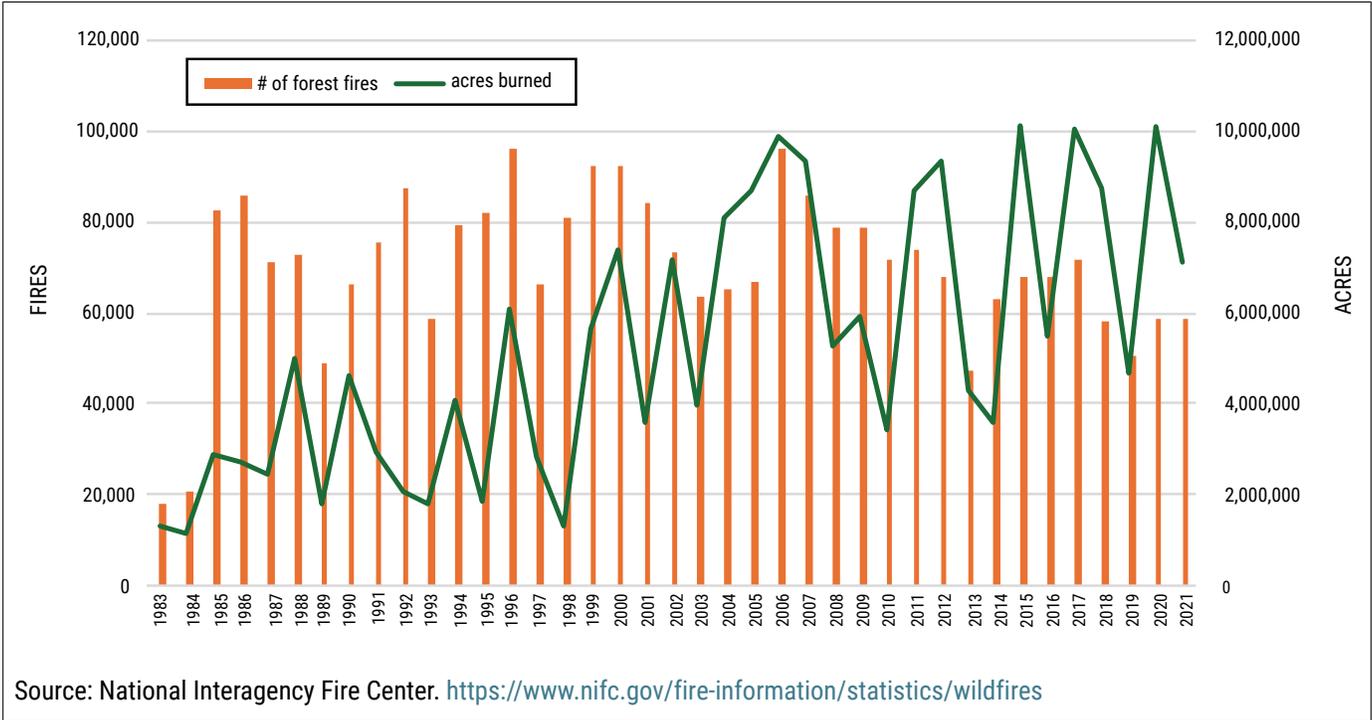
University of Guelph professor Ross McKittrick also documented Canada’s declining wildfire trends based on data in the Canadian Wildland Fire Information System. McKittrick shows that

Wildfires have been getting less frequent in Canada over the past 30 years. The annual number of fires grew from 1959 to 1990, peaking in 1989 at just over 12,000 that year, and has been trending down since. From 2017 to 2021 (the most recent interval available), there were about 5,500 fires per year, half the average from 1987 to 1991. The annual area burned also peaked 30 years

7 The blog post “Global trends in wildfire and its impacts,” from The Royal Society (October 1, 2020), <https://royalsociety.org/blog/2020/10/global-trends-wildfire/>, is an interview in which the authors of the 2016 study characterize their latest findings (Doerr and Santin, 2016).

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**Figure 2: Number of Fires, Acres Burned, United States, 1983–2022**



ago. It grew from 1959 to 1990, peaking in 1989 at 7.6 million hectares before declining to the current average of 2.4 million hectares per year over 2017–21. And 2020 marked the lowest point on record with only 760,000 hectares burned (McKittrick, 2023).

Figure 2 shows similar data for the United States, from 1983–2022. In the US data, while extent of area burned seems to show a significant upward trend, the number of fires does not show a clear trend.

In sum, while the IPCC asserts medium confidence that there has been some increase in fire weather in “some regions” since 1950, a variety of real-world measurements of wild fire trends suggests that confidence may be overstated (IPCC, 2021a).

## Conclusion

As mentioned in the introduction to this brief, Carl Sagan, noted astrophysicist, philosopher of science, and one of the first science popularizers to rise to significant renown once wrote that “Extraordinary claims require extraordinary evidence” (Sagan, 1986).

World leaders are making extraordinary claims about the Earth’s climate with increasing regularity, and demanding extraordinary actions in response to those claims. Actions such as abandoning capitalism (Beals, 2023), and the economic system that lifted much of humanity out of primitive modes of living that were “solitary, poor, nasty, brutish, and short,” as Thomas Hobbes characterized the state of nature (Munro, 2024). Other world leaders demand the end to the use of fossil fuels (Milman, 2023; Dlouhy,

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2023). The very fuels that took humanity out of an oppressive social structure based on manual labor in agriculture and enabled the development of technological societies which have lengthened human life expectancy, drastically reduced infant mortality and child mortality, enabled the rise of non-labor-based jobs suitable to women's greater entry into the workforce, and hence participation and influence in democratic societies. Truly extraordinary claims to action.

Is there, correspondingly, extraordinary evidence to back up the claim that climate change is so severe, and growing still more severe that such extraordinary actions are justifiable or warranted? Certainly, government leaders say so, speaking in absolutes about the climate and how it is changing. Their language in promoting climate policies has ratcheted up over the years from simply "climate change is happening," to "climate change is speeding up," to a proclaimed "climate crisis" that has dragged the deadlines for proposed stabilization of the Earth's climate by the year 2050—little more than 25 years away.

But a bit of digging into the scientific literature, and more importantly, a review of actual measured trends in potentially dangerous climate changes suggests that this Orwellian absolutism is unjustified. It does seem clear that the Earth's atmosphere has warmed, at least since the 1970s, when satellite measurements allowed the creation of a reliable global average temperature assessment (IPCC, 2021a; Christy and Spencer, 2024). Similarly, it seems clear that the weather patterns one would expect to be most closely tied to a change in average temperatures also seem to

have increased, including more heat waves, less cold snaps, more hot days and nights, fewer cold days and nights. But beyond these most global, most generalized measures of the climate—changes to the Earth's weather patterns, particularly extreme weather of most concern to those most fearful of climate change—the state of knowledge becomes increasingly blurry. There is only medium confidence that many extreme weather patterns have been seen to increase since 1950. Other claims to have observed extreme weather changes since 1950 are given even less confidence by the IPCC. It is only deemed "likely," that there has been an observed increase in the likelihood that a tropical cyclone will be at major intensity (category 3-5); that there has been an observed change in the frequency of rapidly intensifying tropical cyclones; and that a decrease in tropical cyclone forward motion has been observed over the United States. IPCC notes that there is mostly only medium confidence in the increase of "compound events such as fire weather, and compound flooding risk" (IPCC, 2021a), as discussed above.

And as we discussed above, there is reason to believe that these levels of confidence in having observed sharp, clear increases in extreme weather that might justify language like "climate crisis," or calls for extreme actions to "combat" climate change are overstated. Evidence for observed changes in drought, flooding, tropical cyclones and hurricanes, fire weather, and others is spotty, globally non-uniform, of varying levels of quality, duration, and areal coverage. Measured trends in flooding, drought, wildfires and hurricanes, have in fact, been seen to decline over

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all or parts of the time period IPCC claims to have observed increases (IPCC, 2021a).

Again, extraordinary claims require extraordinary evidence. While there is good evidence that Earth's atmosphere is warming moderately, and that there are some sequelae to that which humans will have to accommodate, evidence for

greater climate threats is overstated. The evidence does not reach the level of "extraordinary evidence" to justify claims of a "climate crisis," or demands for the effective end of modern civilization: an abandonment of capitalism and the use of fossil fuels.

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