Arctic Wildfires at a Tipping Point

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1. Introduction

I have written on this subject before. Arctic amplification is a secondary effect of climate change, where global warming in the summer increases the temperature by more than twice as much in Polar Regions.[1] A major concern from this is that it accelerates melting of the polar ice caps. See the recent post described and linked below on this subject.

Too Much Water! *If we are taking about the Planet-Earth, the title of this paper is absurd. In general, our planet has an almost fixed amount of water over any reasonably short period (say centuries to millennia). But what isn't static is the water's state. At any given time, it may be solid, liquid) or gas (water-vapor), and it has a habit of changing from one to the others at all times. Even though we've been studying this for decades to centuries, fully understanding this still challenges our best climatologists. However we are making progress, and we'd better: a large percentage of people on our planets live in coastal areas and other regions beset by floods. All too soon an increasing percent of these people will get to experience the title of this paper firsthand.*

This post will explore immediate threats, specifically how and when sea level will rise. Also, I'm not looking at coastal floods happening centuries in the future, but those ranging from a few decades hence to the end of this century. In other words, where we still have time to mitigate the severity.

https://energycentral.com/c/ec/too-much-water

Unfortunately, rising oceans are not the end-points of the risk from arctic amplification. Another effect, with a strong positive feedback element, may even be worse in the long run. Two recent articles and papers in Science describe this effect. The following section is from a summary of the main paper.

2. Summary of Paper by Descals et al.

Vast amounts of organic carbon are stored in Arctic soils. Much of this is in the form of peat, a layer of decomposing plant matter. Arctic wildfires release this carbon to the atmosphere as carbon dioxide (CO_2) and contribute to global warming. This creates a feedback loop in which accelerated Arctic warming dries peatland soils, which increases the likelihood of bigger, more frequent wildfires in the Arctic and releases more CO_2, which further contributes to warming. Although this feedback mechanism is qualitatively understood, there remain uncertainties about its details...[2]

Assessment of the relationship between climate warming and the frequency and extent of Arctic wildfires is complicated by several factors. Satellite data of the annual area burned by wildfires in the Arctic may require difficult-to-obtain ground-based validation to improve accuracy. Moreover, multiple factors may interact with warming in complex ways to influence fire occurrence, severity, and extent, such as lightning strikes, rainfall, and fuel load (vegetation cover).

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[1] See https://earthobservatory.nasa.gov/images/81214/arctic-amplification

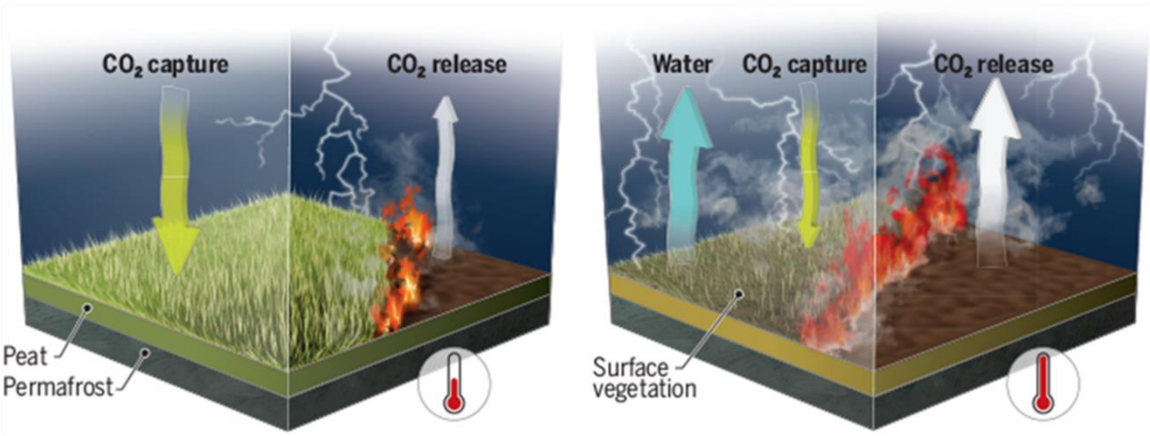
[2] Eric Post1 and Michelle C. Mack, Science, "Arctic wildfires at a warming threshold," Nov 4, 2022, https://www.science.org/doi/10.1126/science.ade9583# Note that access is limited.

Add to this mix the uncertainty that derives from gaps in the geographic representation of data across the Arctic and the challenges seem almost insurmountable. The Siberian Arctic, for example, represents as much as 70% of the terrestrial Arctic, but year-to-year records of its burned area are sparse.

Descals et al. compiled multiple satellite-based estimates of the annual burned area for the Siberian Arctic from 1982 to 2020 to analyze associations between burned area and several factors (see the figure). According to their analysis across all sources of satellite data, 2019 and 2020 emerge as the biggest fire years for the Siberian Arctic, accounting for nearly half of the area burned for that region over the entire 39-year period and releasing nearly 150 million tonnes of carbon to the atmosphere. On 20 June 2020, the Russian town of Verkhoyansk set the record for the highest single-day temperature measured above the Arctic Circle (38°C / 100°F). On average, the Arctic region has warmed faster than the rest of the globe. Northern peatlands—including those in Asia, North America, and Europe—currently account for an annual carbon sink of ~100 million tonnes. The enormous carbon release of 150 million tonnes (165 million tons) from the 2019 and 2020 Siberian fires demonstrates how quickly northern ecosystems can switch from carbon sinks to carbon sources under the continuous warming of the Arctic.

The effect of Arctic wildfires on carbon release

Arctic wildfires accelerate the release of organic carbon from the soil into the atmosphere, which can strengthen the feedback to warming.



Past
Arctic peatlands, forests, and tundra are generally carbon sinks. Cold temperatures and wet soils keep the land relatively moist, which reduces wildfire activity.

Present
Higher temperatures dry the peat layer and drive more active weather systems, which lead to larger fires that release more carbon to the atmosphere.

The authors started with individual single-predictor models, which mostly show exponential increases in burnt area across the Siberian Arctic for each of the individual drivers. These include the increases in temperature, vapor-pressure deficit (the ability of the air to dry the land surface), climatic water deficit (more water being evaporated relative to precipitation), and the number of ignition events presumably related to lightning strikes. Building on the single-predictor models, the authors then created a multivariate model, which revealed that some of the single-predictor drivers can themselves be driven by an increase in temperature.

For example, warming can directly increase the number of ignition events and indirectly increase plant water stress by increasing the vapor-pressure deficit. This in turn can dry deeper soil layers and contribute to plant water stress. By linking these processes and identifying the direct and indirect effects of warming on increasing burn area, Descals et al. provide insights into what the future of Arctic wildfires may look like under accelerating warming.

According to their analysis, warming of mean summer air temperature past a threshold of 10°C (50°F), or of mean summer surface temperature above 17°C (63°F), would cause disproportionately large increases in the extent of carbon-rich soils burned in the Siberian Arctic. However, patterns of both local warming and vegetation change are highly variable across the Arctic. Therefore, additional studies in other regions of the Arctic that harbor vast expanses of peatland, such as Canada and Alaska, are needed to test these hypotheses and their general applicability to the Arctic region…

3. Additional Material from Paper by Descals et al.

Arctic fires can release large amounts of carbon from permafrost peatlands. Satellite observations reveal that fires burned ~4.7 million hectares (11.6 million acres) in 2019 and 2020, accounting for 44% of the total burned area in the Siberian Arctic for the entire 1982–2020 period. The summer of 2020 was the warmest in four decades, with fires burning an unprecedentedly large area of carbon-rich soils. We show that factors of fire associated with temperature have increased in recent decades and identified a near-exponential relationship between these factors and annual burned area. Large fires in the Arctic are likely to recur with climatic warming before mid-century, because the temperature trend is reaching a threshold in which small increases in temperature are associated with exponential increases in the area burned...[3]

Wildfires are common in the Arctic and Subarctic, but their size, frequency, and intensity are expected to increase as the climate warms. Extreme weather, such as that in 2020 in the Siberian Arctic, is expected to become more severe as Arctic oscillations weaken over time. Previous research in the Alaskan tundra suggests that the annual burned area might be two times greater than in the 1950–2010 period by the end of the century as warmer and drier conditions coincide more frequently. The conditions that affected the Arctic fire seasons of 2019 and 2020 in the Siberian Arctic have provided new empirical observations between climatic factors and burn extent and may already be indicating the changes in fire regimes expected by the end of the century. The fire seasons of 2019 and 2020, however, raised two uncertainties—first, whether the annual burned area above the Arctic Circle was actually increasing. Satellite-derived burned-area products tend to underestimate the true extent of burning, and rigorous validation techniques are required. Second, even if the burned areas in 2019 and 2020 were the largest yet observed, the links to other trends required evaluation.

Author's comment: Note the following excerpt near the beginning of the above paragraph: "*Extreme weather, such as that in 2020 in the Siberian Arctic), is expected to become more severe as Arctic oscillations weaken over time."* I dug into this and found scant information to link Arctic oscillations (AO) and Arctic amplification (AA). The best

[3] Adrià Descals, David L. A. Gaveau, Aleixandre Verger, Douglas Sheil, Daisuke Naito and Josep Peñuelas, Science, "Unprecedented fire activity above the Arctic Circle linked to rising temperatures," Nov 4, 2022, https://www.science.org/doi/10.1126/science.abn9768 Access is limited

explanation I found said: *"Recently, extensive research has been performed to determine whether there is a relationship between AA and the AO… Specifically, multiple studies have tried to link these two phenomena by examining the frequency of extreme events. However, the impacts of AA on the AO are still uncertain, as definitive signals cannot be distinguished from historical variability at this point in time."*[4]

Back to reference 3.

We assessed annual burned area in the Siberian Arctic (latitudes >66.5°N) for 1982–2020 using six satellite-derived maps of burned areas. We investigated the Siberian Arctic because it is where most burning occurs above the Arctic Circle and fire frequency appeared to be increasing. We investigated 10 factors associated with the likelihood of fire: six climatic variables [air and surface temperature, total precipitation, wind speed and direction, and vapor-pressure deficit (VPD, or the ability of the air to dry the land surface)], three variables describing the vegetation conditions [length of the growing season, mean normalized difference vegetation index (NDVI), and climatic water deficit (CWD)], and the number of ignitions, a factor associated with the likelihood of fires.

We evaluated how these factors have varied over the past four decades and their relationships with satellite-derived estimates of annual burned areas. Lastly, we investigated the future trends of annual burned area and fire emissions under future Representative Concentration Pathways.

Author's comment: Greenhouse gasses (GHGs) cause radiative forcing (a.k.a. forcing), which quantifies this change in net heat-energy flows in watts per square meter (W/m^2) at the top of the atmosphere. Positive forcing warms the surface, and negative forcing cools the surface.

In order to have a common framework for future scenarios, climate scientists have created representative concentration pathways (RCPs) – a set of scenarios representing different levels of forcing. The forcing is estimated for year 2100. Four scenarios are used: 2.6 W/m^2 for RCP2.6, 4.5 W/m^2 for RCP4.5, 6.0 W/m^2 for RCP6.0, and 8.5 W/m^2 for RCP8.5. Note that we have already exceeded RCP2.6. [5]

Trends of the fire factors for 1982–2020: *Various factors that may exacerbate the risk of fire have increased significantly over the past four decades in the Siberian Arctic. Air temperature, NDVI, the length of the growing season, and VPD have steadily risen. The average increase in summer air temperature was 0.66°C per decade. In 2019 and 2020, the mean summer air temperature was 11.35° and 11.53°C, which was 2.65° and 2.82°C higher than the 1982–2020 average, respectively. Climatic water deficit (CWD), a proxy of plant water stress defined as the difference between potential and actual evapotranspiration, also increased between 1982 and 2020, although the linear trend likely began in the 2000s.*

More surprising, however, was the abrupt increase in CWD in 2019 and 2020. The estimated number of ignitions, total precipitation, and wind speed all had strong

[4] Great Lakes Integrated Sciences and Assessments, "Arctic Amplification and Arctic Oscillation," 2023, https://glisa.umich.edu/arctic-amplification-and-arctic-oscillation/

[5] See https://energycentral.com/c/ec/climate-and-energy-part-1-future-rev-c, subsection 2.3

interannual variations, and the slope of their trends was not significantly different from zero.

The annual number of detected ignitions was relatively consistent, with a median of 143, but high counts were observed in specific years, peaking at 423 in 2020. Seventy-two percent of these 2020 ignitions were detected within 20 days, between 13 June and 3 July, reaching Siberian Arctic regions as far north as 72.9°. Notably, these ignitions coincided with anomalously high values of convective available potential energy (CAPE), an indicator of convective storms and lightning. Between 13 June and 3 July, satellite thermal sensors registered a rapid increase in the number of active fire detections, which accounts for 40.6% of all hot spots detected in 2020. By contrast, hot spots detected before 13 June represented only 1.1%. Similar peaks in the number of detected ignitions, preceding high rates of active fire detection, occurred concurrently with high CAPE values in 2002, 2005, 2013, and 2018.

Sensitivity of the burned area to the fire factors: *Linear and exponential regressions were used to analyze the best association between the annual burned area (aggregated with the median across available satellites for each year) and the factors of fire regime. An exponential regression was the best regression model; the annual burned area accelerated when specific thresholds were exceeded. For example, the four years with the largest mapped burned areas (2001, 2018, 2019, and 2020) had a mean summer air temperature >10°C (>50°F). The best fit was for climatic water deficit (CWD), which explained 92% of the interannual variability in the burned area. Other factors with a high determination were summer air temperature (87%), vapor-pressure deficit (VPD, 89%), and number of ignitions (87%)...*

Projections of annual burned area and carbon emissions under warming scenarios: *Annual burned area in 2018, 2019, and 2020 more than doubled the long-term average for the period 1982–2020 in the Siberian Arctic. Summer 2001, with a mean temperature nearing 10°C, was the first year on record to have a mapped burned area over twice that of the long-term average. The exponential regression between the burned area and temperature indicated that an annual burn of 0.5 Mha (1.24 million acres) occurred at a mean summer temperature of 10.2°C. The 10°C threshold also indicated the rapid growth of the annual burned area in 2018, 2019, and 2020. This indicates that small increases in summer mean temperature above the 10°C threshold tend to be associated with extensive annual burned areas.*

The linear trend of mean summer air temperature indicated that temperatures would reach 10.2°C by 2024 and reach the levels in 2020 by 2045 if mean summer temperatures continued to increase linearly at the current rate. The RCP 4.5 and 8.5 scenarios also indicated an increase in temperatures that could substantially expand the burned area in the Siberian Arctic; annual burned area could range from 0.5 to 2.5 Mha (Million hectares, each Mha = 2.5 million acres) or before the middle of the century under RCP 4.5 and RCP 8.5…

4. Other Information

The above post is a scientifically rigorous explanation of this climate change effect, but I have covered this subject earlier. Even though the prior (2019) post (described and linked below) was less rigorous, it was more wide-ranging and amusing.

Positive Feedback Accelerates Sea Level Rise: Mother Nature seems to have many surprises for climatologists and many of these involve positive feedback, and one of these involves beavers' revenge. This paper will look at the positive feedback loops

https://www.energycentral.com/c/ec/positive-feedback-accelerates-sea-level-rise