CANADIAN WILDLAND FIRE & SMOKE

NEWSLETTER

FALL 2025

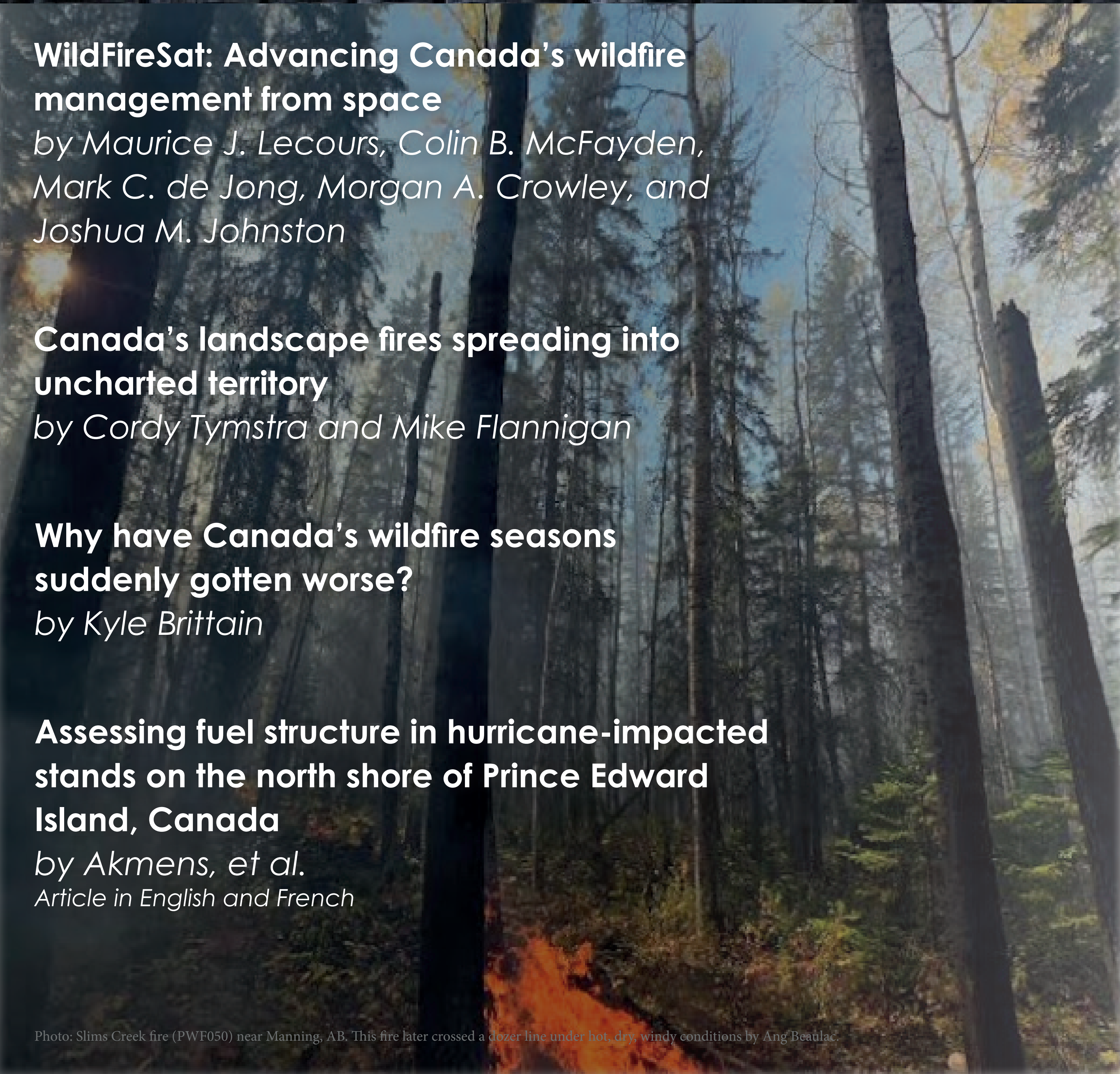

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Photo: Slims Creek fire (PWF050) near Manning, AB. This fire later crossed a dozer line under hot, dry, windy conditions by Ang Beaulac.

WildFireSat: Advancing Canada's wildfire management from space

By Maurice J. Lecours[1*], Colin B. McFayden[1], Mark C. de Jong[1], Morgan A. Crowley[1], and Joshua M. Johnston[1]
[1]Great Lakes Forestry Centre, Canadian Forest Service, Natural Resources Canada, Sault Ste. Marie, Ontario, Canada. *Corresponding author: maurice.lecours@nrcan-rncan.gc.ca

When wildfires are burning across Canada, decision-makers need reliable, timely intelligence to maintain awareness on a local and national scale. This is what the WildFireSat (WFS) mission aims to do. Targeted to launch around 2029, the WFS Canadian Operational Mission is designed to enhance situational awareness for fire management and support fire managers in making important decisions with reliable and quality information in extreme and uncertain conditions.

Traditionally, people in aircraft do reconnaissance flights to visually assess, map and report on fires, in many cases with hand-drawn maps. Monitoring wildfires with aircraft is increasingly challenging due to the incredible number of fires in recent fire seasons, and is further complicated by unsafe flying conditions (such as thick smoke and high winds). Given the vastness of Canada, satellite observation is the only feasible way to monitor fires across the entire country daily.

In this article, we discuss the WFS mission, some of the technology behind it, explore the WFS satellite constellation, and uncover key insights about how the satellites will detect wildfires.

Canada's First Government-owned Operational Wildfire Satellite Mission

WFS is the world's first government-owned satellite mission specifically designed to monitor all active wildfires across Canada daily. The end-to-end mission is a Government of Canada initiative between Natural Resources Canada, the Canadian Space Agency, and Environment and Climate Change Canada. It includes building the spacecraft, mission operations, ground segments (i.e., antennas to downlink the data), data processing, and a suite of scientific products and software designed for use by fire managers.

For fire managers to fully benefit from WFS, the scientific products must be usable and useful. The adoption of new technologies in fire management is not straightforward—fire managers need reliable tools that they can trust and that are tailored to their operational needs. As such, WFS has prioritized knowledge exchange with fire managers from the onset of the mission. More information on the implementation and uptake for fire managers can be found in the WildFireSat pathway for implementation and uptake in provincial and territorial fire management agencies. Collaborating with fire managers will also help them develop the capabilities to adopt WFS data products and use them in their decision-making. Additional details on the suite of scientific products are available in the WildFireSat Science and Applications Plan.

The WFS journey has been decades in the making. Since the 1980s, scientists have recognized that satellites could measure wildfires. By the 2010s, feasibility studies under the "Canadian Wildland Fire Monitoring System" led to the development of user requirements for WFS. More information on this journey can be found here: WildFireSat e-Bulletin, Issue 2.

How Will WildFireSat Work?

A Change in Fire Monitoring Technology

Wildfires release energy through convection, conduction, and radiation (Figure 1). WFS focuses on the measurement of the radiative component of a wildfire (10-20% of total fire energy).

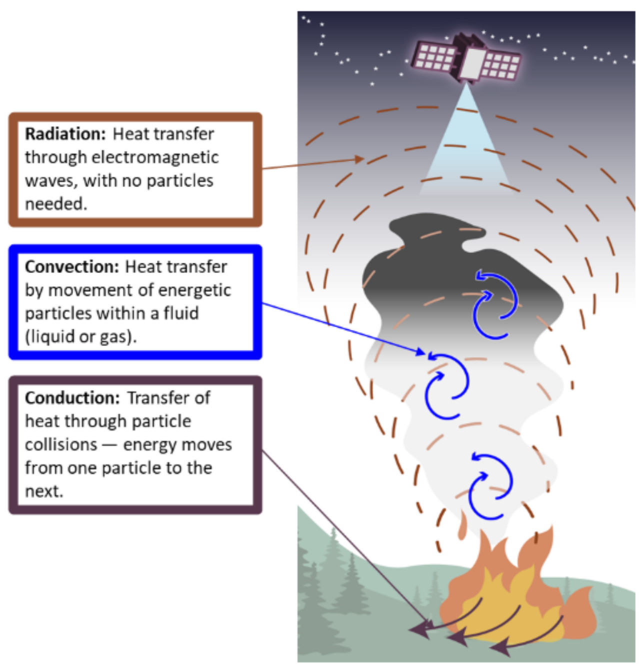


Figure 1. Wildfires release energy through three primary mechanisms: convection, conduction, and radiation. While convection and conduction transfer heat through air movement and direct contact, WildFireSat (WFS) focuses on detecting radiation, which accounts for about 10-20% of the total fire energy. Radiative energy travels at the speed of light, allowing space-based infrared sensors to detect wildfires in near real-time.

Travelling at the speed of light, radiation allows for detection via mid-wave infrared sensors in space.

Traditionally, satellites with infrared sensors required bulky, power-hungry cooling systems (-200°C) to operate. As a result, conventional satellites were relatively large (some as large as a school bus) and costly. To justify the expense, most satellite missions prior to WFS had to be designed with many different applications in mind. These multi-purpose needs inevitably led to mission compromises, such as overpass times that don't align well for wildfire monitoring in Canada.

Nowadays, the development of microbolometers (compact, uncooled detectors) are reducing power consumption to just 4 watts, which is similar to a strand of LED Christmas lights. This technology allows for much smaller, lower-cost satellites (e.g. the size of a briefcase) with mid- and long-wave infrared monitoring capabilities. This advancement changes the game for fire monitoring satellites, making missions with narrow applications such as WFS feasible.

WildFireSat: Tailored for Operational Wildfire Monitoring

WFS's orbit and sensor design are optimized for fire monitoring. By operating in a polar orbit, which is best suited for monitoring fires at higher latitudes, WFS ensures high-resolution coverage of Canada's entire landmass. While other polar-orbiting satellites currently provide valuable wildfire data, their overpasses do not align with the driest part of the day, typically around 17:00-18:00 daylight saving time (DST), when fires have the highest potential to spread (peak burn). WFS plans to fill this gap and synthesize data from multiple satellite sources, including VIIRS, which provides data around 13:00 DST, to create a 'virtual constellation.' This approach supports the development of products such as fire progression mapping, enhancing wildfire monitoring and decision-making.

The WFS constellation will consist of seven satellites, with spares for rapid deployment if needed, as shown in Figure 2. As a Class-B operational mission, WFS is designed for >90% availability and incorporates extensive redundancies, including both hot and cold spare satellites. Hot spare satellites will be in orbit, ready to be used, while a cold spare will be on the ground, ready to be launched if required. This level of reliability is among the highest for satellite missions, second only to human spaceflight missions. The WFS constellation will be preceded by the launch of a single precursor satellite in 2027 to thoroughly test the operational mission.

A Clearer View of Wildfire Activity

Travelling at Mach 23 (28,400 km/hr or 7.8 km/s), WFS constellation satellites will each complete an orbit around the Earth every ~90 minutes. When all seven satellites' overpasses are combined, WFS will ensure daily coverage of all active wildfires in Canada. With the constellation positioned in an evenly spaced ring at an altitude of approximately 475 km (about 75 km higher than the International Space Station), the satellites will provide national coverage with overlapping swaths for high-resolution monitoring. Star trackers will, in turn, pinpoint satellite location and orientation information, much like ancient sailors navigating by the stars. WFS will deliver Canadian coverage twice daily (every 12 hours), with more frequent overpasses in northern regions where certain areas may be revisited every six hours or less.

WFS will regularly cross-calibrate sensors using the moon to ensure consistent thermal readings across satellites. By narrowing the field of view and removing distortion, WFS will improve the accuracy of fire monitoring. For example, multipurpose satellites, like VIIRS, typically capture data in a single 3,000 km swath. Large swath size can lead to image distortion near the periphery due to the Earth's curvature, and mapping errors due to wide viewing angles. For a visual explanation, see the 'Impact of Viewing Angles on Wildfire Detection' sidebar.

Another key advantage of WFS is its ability to accurately measure very hot temperatures. Many other sensors frequently

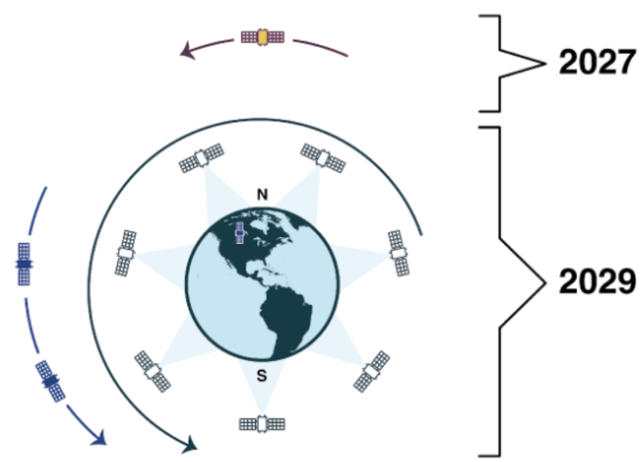
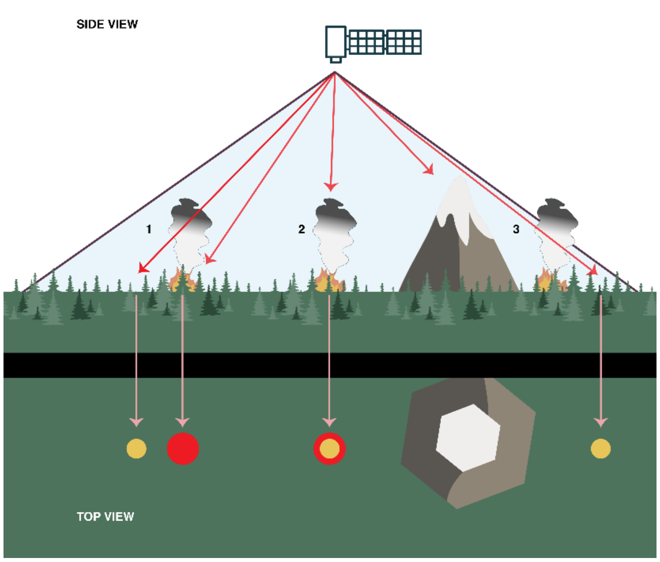


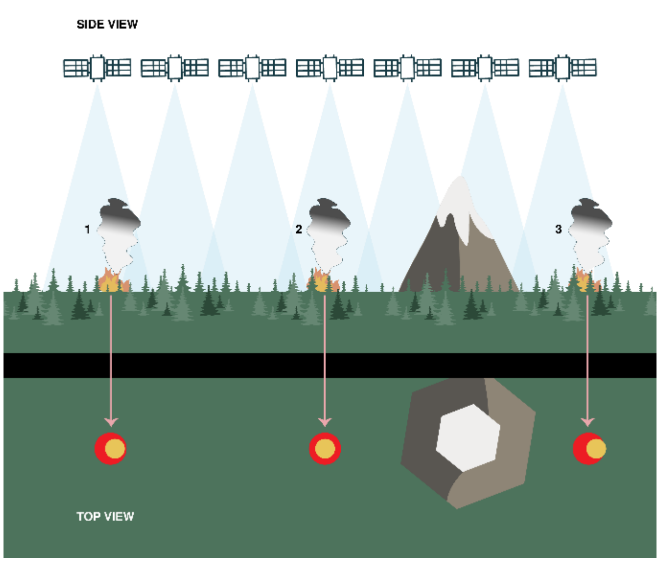
Figure 2. An illustration of the locations and general timelines of WildFireSat (WFS) satellites. The yellow satellite represents the single precursor satellite, scheduled for launch around 2027. The white satellites indicate the seven operational satellites of the WFS constellation, expected to be fully operational by 2029. The blue satellites represent three spare satellites: two hot spares already in orbit and one cold spare remaining on the ground in Canada.

The Impact of Viewing Angles on Wildfire Detection

A) Multi-Purpose Satellite



B) Purpose-Built Satellite



This illustration demonstrates how (A) wide angle multi-purpose satellites (e.g., VIIRS, MODIS, or Sentinel-3) and (B) purpose-built satellites (e.g., WildFireSat) observe three wildfires, highlighting how WFS is designed to minimize detection errors caused by higher viewing angles. Each panel includes a side view (top) of the satellite detection geometry and a corresponding top-down map (bottom) showing satellite-detected heat signatures. In the top-down map view, red dots represent wildfire heat signatures, and yellow dots represent detected hot smoke plumes. Note: only sufficiently intense wildfires generate smoke plumes hot enough to be detected by satellite sensors. WFS satellites operate in a constellation, each with a viewing angle of about 22°, compared to 56° for multi-purpose satellites like VIIRS. The narrower WFS viewing angle is intentional, reducing geometric errors that occur when satellites observe fires at steep angles near the edge of their swath.

Wildfire 1 is viewed at a steep angle by the multi-purpose satellite, near the edge of its swath. Here, the heat from the smoke plume may be mistakenly projected onto the ground outside the fire perimeter, creating a false positive, a detected "fire" that doesn't exist, which could distort fire maps or be misidentified as a new ignition. In contrast, WFS views Wildfire 1 near-nadir due to its restricted swath, so the smoke plume heat signature remains closely aligned within the fire's boundary, eliminating the false positive.

Wildfire 2 is viewed near-nadir (almost directly below) by both satellites. As a result, any heat signature from the fire or smoke plume is projected onto the Earth's surface close to the actual wildfire location. In this case, both systems perform well, and the chance of detection error is low.

Wildfire 3 is in complex terrain (e.g., mountainous regions). WFS, with its lower viewing angle, successfully detects the fire's on-ground location. The multi-purpose satellite, viewing from a steep angle, may have its line of sight blocked by terrain, leading to a false negative and, completely missing the fire. However, the satellite may still detect heat from the smoke plume and, like Wildfire 1, mistakenly assign it to the wrong location on the ground.

saturate over intense wildfires, preventing accurate measurement of Fire Radiative Power (FRP). FRP is crucial for quantifying several fire characteristics, including fire intensity, severity, and growth. Since WFS always observes fires from an angle relatively close to nadir (looking straight down), the satellites will avoid the directional bias in emitted energy that occurs with off-nadir observations.

Fires radiate different amounts of energy depending on the viewing angle. This causes the accuracy of FRP measurements to vary across the swath on most satellites. Thanks to thoughtful design planning, this is not the case with WFS. Consistent viewing geometry makes WFS's FRP measurements more accurate and comparable over time and space.

WFS will mark a major step forward in wildfire monitoring, providing fire managers with the data they need when they need it most. By leveraging improvements in satellite technology with decades of fire research, WFS can provide information to enhance decision-making and support wildfire response across Canada.

Canada's landscape fires spreading into uncharted territory

By Cordy Tymstra[1] and Mike Flannigan[1]
[1]Natural Resource Science, Thompson Rivers University, Kamloops, BC, Canada
Corresponding author: mflannigan@tru.ca

Author's Note: This article draws heavily from the perspective paper by Cordy Tymstra and Mike Flannigan, published in Environmental Research Letters (2025, Environ. Res. Lett. 20 111003, https://doi.org/10.1099/1748-9326/ae1495).

On average, during the 1983–2024 period, 7,400 wildfires burned about 2.8 million ha annually across Canada (Natural Resources Canada 2025a) (Figure 1), the second largest country in the world and custodian of 25% of the global boreal forest (UNECE 2025). In comparison, approximately 70,000 wildfires on average burned about 730,000 ha annually in the United States for the same period (NIFC 2025).

Wildfire is an integral ecological process in the boreal forests of North America (Heinselman and Wright 1973). In Canada, big land with contiguous fire-dependent forests, equates to big wildfires. Extremes drive the fire world. Each spring new wildfires arrive, and a few over-winter (holdover) wildfires awake. About 3% of the wildfires in Canada account for 97% of the area burned, with most of this burning occurring during a relatively small number of spread days, when extreme fire weather supports very high to extreme rates of wildfire spread.

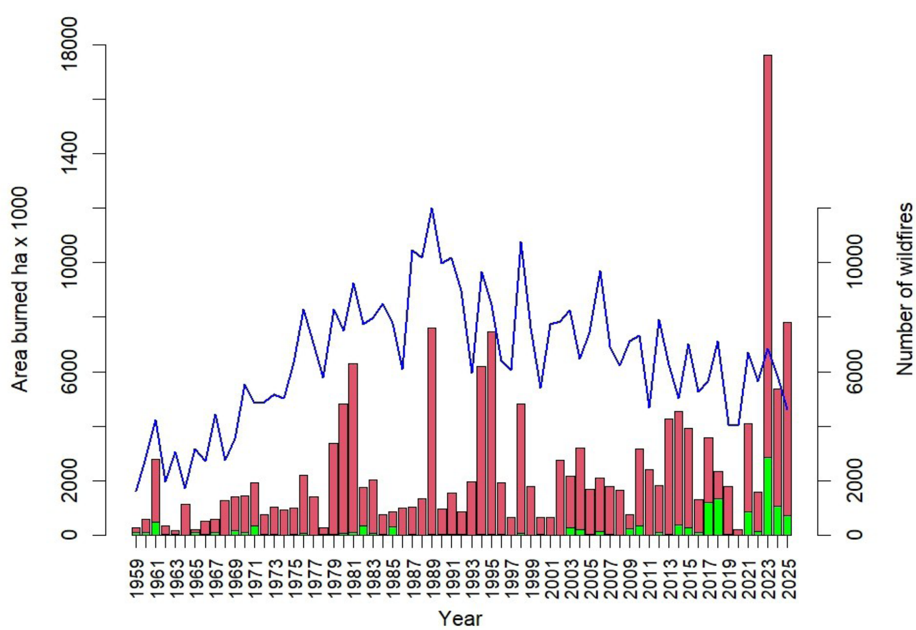


Figure 1. Area burned (red bar), number of wildfires (blue line) in Canada 1959–2025 (as of June 27, 2025), with British Columbia data highlighted separately (green bar).

A notable shift, however, in wildfire activity in western Canada started in 2017, when the province of British Columbia experienced a disastrous wildfire season, with new records being set (Figure 1). During a three-day period (6-8 July), over 190 new wildfires started (CIFFC 2017), many close to communities. This resulted in the displacement of a record number of evacuees (65,000), and the 545,151 ha Plateau Wildfire becoming, at that time, the largest wildfire in the province's history.

A comparison of fire weather and fire behaviour metrics with and without anthropogenic influence (event attribution) suggests human induced climate change strongly influenced the extremeness of the 2017 wildfire season in southern British Columbia (Kirchmeier-Young et al. 2019).

British Columbia's 2018 wildfire season had even more wildfires and area burned than in 2017. Numerous wildfires also burned uncontrolled in the provinces of Alberta (late May), Saskatchewan (early May), Manitoba (early May, late June), Ontario (July), and Quebec (July). In early August, all available resources in Canada mobilized to assist British Columbia during a late second wave of wildfire activity in that province.

Persistent drought conditions in British Columbia from 2017 to 2019 contributed to sustain extremely dry fuel (vegetation) conditions. Listed in order of size, the five most severe wildfire seasons in British Columbia during the 1959–2024 period are 2023, 2018, 2017, 2024, and 2021 (Figure 1). The area burned in the recent nine-year period of 2017–2025 (as of August 21) is about 3 million ha more than during the 1950–2016 period (Figure 1).

In 2021, the Lytton Wildfire in British Columbia destroyed the village of Lytton and caused two civilian fatalities, the first in Canada since 1938, when brush fires started by settlers escaped and killed 17 people in Ontario. The day before the wildfire, the temperature in Lytton reached a Canadian record high of 49.60°C due to the occurrence of a strong heat dome over the Pacific northwest (Jain et al. 2024a).

Canada's most destructive wildfire season occurred two years later when 6,000 wildfires burned about 15 million ha and impacted all provinces and two territories (Northwest Territories and Yukon). The 2023 wildfire season was unprecedented in extent, scale, intensity, duration, and impact (Jain et al. 2024b). Just over 4% of Canada's forested lands burned in one year. The alignment of environmental factors (i.e., early snow melt and arrival of wildfires, multi-year drought, prolonged extreme fire weather conditions) resulted in the high fire load across Canada in 2023. Wildfire management agencies are increasingly experiencing more days when forests are conducive to high severity wildfires (Wang et al. 2025) and their suppression efforts are overwhelmed and ineffective (Wotton et al 2017). During the 2023 wildfire season, Canada experienced a record 120 consecutive days at National Preparedness Level 5 (CIFFC 2023), indicating the country had insufficient available resources to meet agency needs and international assistance was needed.

The 2023 Grouse Complex and Bush Creek East Wildfires in British Columbia, the Enterprise Wildfire in the Northwest Territories, and the Barrington and Tantallon Wildfires in Nova Scotia caused significant community impacts, including property loss, damage, and evacuations. The Baie-James, Caniapiscau, and Senneterre Complexes in Quebec and the Red Lake 12 and Long Lake Wildfires in Ontario resulted in evacuations from northern communities. The 4.5 million ha burned in Quebec impacted the forest sector and important caribou range habitat. Although no civilian deaths occurred during the catastrophic 2023 wildfire season, when 232,000 people from over 200 communities were evacuated, eight firefighters died.

Seventy percent of First Nations communities in Canada live in and depend on the boreal forest (Natural Resources Canada 2025b). These communities experience disproportionately higher impacts from wildfire. Reduced air quality from smoke events often trigger northern community evacuations, which occur at a rate eight times higher than southern non-Indigenous communities.

Smoke also, impacts distant communities. On June 19, 2025, air quality alerts were issued in cities in the Midwest and Northeast regions of the United States because of smoke from aggressive wildfires in northern British Columbia, Alberta, and Saskatchewan. The 2025 wildfire season in Canada started early. On May 14, two civilians trapped in the Wendigo Wildfire in southeast Manitoba lost their lives. By 21 August 2025, 4,621 wildfires already burned 7.8 million ha (CIFFC 2025a) and surpassed 1989 as the second worst wildfire season on record (Figure 2). The European Union (EU) was also setting records. By 12 August 2025, over 1 million hectares — a new EU — record burned and released an estimated 37 megatons of CO_2 (EFFIS 2025).

The amount of emissions released by wildfires and the subsequent health impacts are staggering. The 2023 wildfire season in Canada alone released 647 megatons of carbon (Byrne et al. 2024), which accounted for about 31% of the global emissions from wildfires. An estimated 1,400 deaths annually in Canada from 2020 to 2024 are linked to increased smoke emissions from wildfires during that five-year period (Romanello et al. 2025).

Globally, 1.53 million deaths are attributable from landscape fires for the period 2000–2019 (Xu et al. 2024). The health impacts of exposure to wildfire-related $PM_{2.5}$ (particulate matter ≤ 2.5 microns in diameter) compared to non-fire-related wildfire-related $PM_{2.5}$ have, however, been significantly underestimated (Alari et al. 2025). This is worrisome because observed increases in wildfire severity—including impacts on plants and organic biomass (see Whitman et al. 2022)—suggest there may be associated increases in particulate emissions.

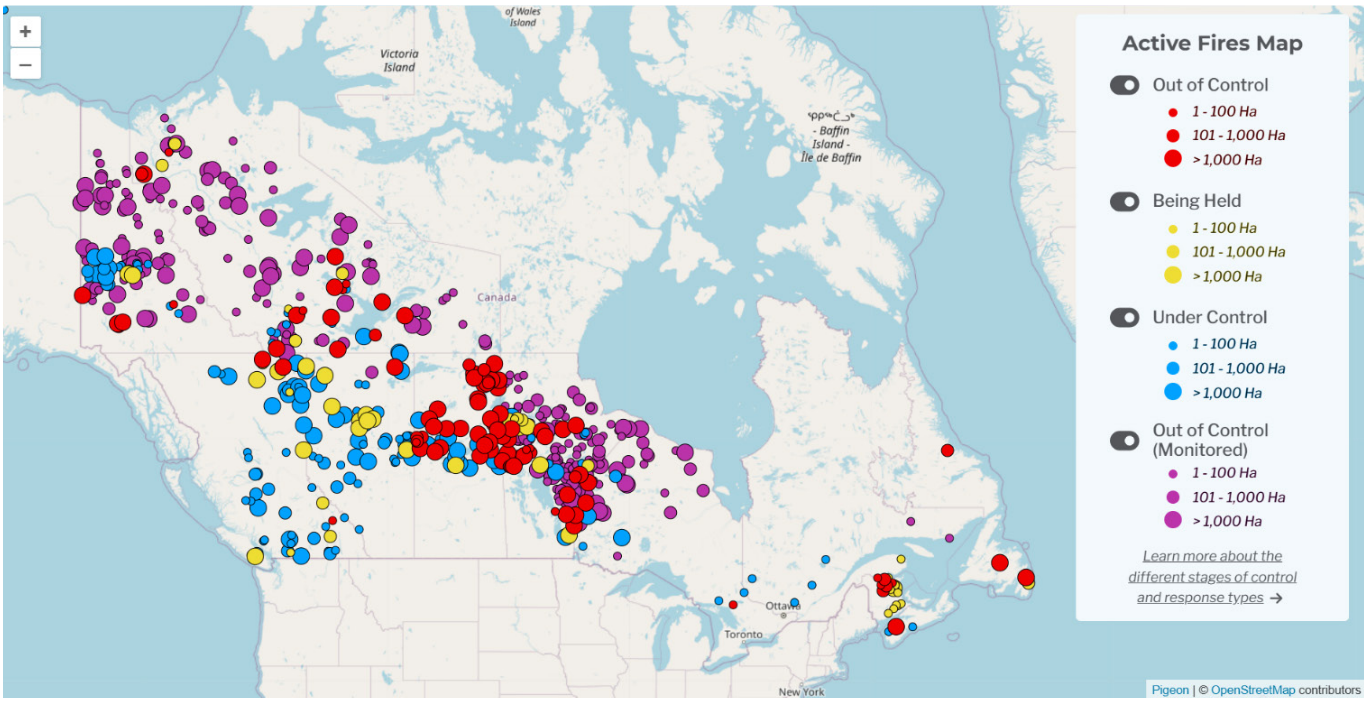


Figure 2. CIFFC map of active wildfires in Canada on August 21, 2025 (CIFFC 2025b).

The record-setting 2023 wildfire season extended into 2024 and became, at that time, the second-worst wildfire season in Canada this century when 5,581 wildfires burned 5.3 million ha. On 14 May 2024, British Columbia had 130 active wildfires. Hotspots smouldering in deep forest organic layers through the winter and then resurfacing in the spring, accounted for 85 of these wildfires.

The World Meteorological Organization confirmed 2023 was the hottest year on record (1.48°C above the preindustrial average for the 1850–1900 period). During the 2023 wildfire season (May–October), the average temperature was 2.2°C warmer than the average temperature for the same duration during the 1991–2020 period (Jain et al. 2024b). The record set in 2023 was surpassed in 2024, the first year with a global average surface temperature surpassing the 1.5 ^{C} threshold above the preindustrial average for the 1850–1900 period. Some areas in Northern Canada are warming 2-3 times faster than the global average (Copernicus Climate Change Service 2025).

Global warming affects the wildfire environment in many ways. When temperatures increase, the atmosphere can hold more water from the evaporation of moisture from soil, litter, duff, vegetation and water bodies. For every degree of warming, precipitation must increase 15% to compensate for the drying of fine surface fuels, and 10% for the drying of organic duff layers in the forest (Flannigan et al. 2016). Drier fuels mean it is easier for wildfires to start, and more fuel becomes available, which leads to higher intensity wildfires that can be difficult to impossible to manage.

The heating of the Earth is also lengthening the wildfire season (Wotton et al. 1993, Jolly et al. 2015). April is the new May, and wildfires now burn into October. Further challenging wildfire management agencies is night-time burning. The traditional expectation of reduced burning conditions at night can no longer be counted on, as drought and prolonged periods of drying sustain night-time wildfire activity (Luo et al. 2024).

Wildfire activity in Canada and the United States in recent years—including California's 2025 Palisades, Eaton, and Hurst wildfires; the 2023 Lahaina wildfire in Hawaii; California's 2020 Fire Siege; and the state's 2018 Woolsey and Camp, 2017 Tubbs, and 2015 Valley wildfires—may be without historical precedent. We are in uncharted territory. The climate change impact from increased boreal forest wildfires, particularly in northern Canada, is currently unpredictable and unknown. Global warming is contributing to larger and more intense and severe wildfires, and the most intense wildfires are becoming more intense (Cunningham et al. (2024) .

The potential power of wildfire was evident during the 2024 Jasper Wildfire in Alberta. At about 1300 h (Mountain Daylight Time), on 24 July 2024, a 10,000-ha wildfire in majestic Jasper National Park blew up and spread quickly north. Five hours later, the wildfire entered the world-renowned tourist town of Jasper and destroyed 358 structures. This wildfire and the weather it itself created produced fire-induced thunderstorms (called pyrocumulonimbus clouds or PyroCBs) that easily overcame the limited available wildland and structural firefighting resources.

The unfortunate Jasper Wildfire in 2024 and the other noted wildfire disasters in North America are a warning of our inability to manage all wildfires all the time. Despite wildfire management agencies across North America being among the best in the world, they are powerless when confronted with a firestorm. Tymstra et al. (2020) suggested wildfire management agencies are at a tipping point. We are now past the tipping point.

Although there is no one solution, we know how to build community wildfire resiliency. Both FireSmart incentives and mandatory FireSmart community certification based on FireSmart building codes and the seven disciplines of FireSmart (firesmartcanada.ca) are required. We need to harden structures to withstand ember attacks ahead of the advancing firestorm. This includes having defensible space. The immediate ignition zone around a structure (0 -1.5 m) should be non-combustible. The intermediate zone (1.5–10 m) should mitigate ember ignition and sever fire pathways to the structure. Ember entry into homes (e.g., vents) needs to be mitigated. Sprinkler systems work. Homeowners in central British Columbia who reduced surface fuels around their homes and used sprinklers returned to their homes still standing after the devastating Grouse Mountain and Bush Creek East Wildfire Complexes in 2023.

FireSmart alone, however, cannot solve the problem. Wildfire is a multi-faceted issue requiring a multi-pronged approach. Increased effort, for example, to reduce the number of human-caused wildfires will pay significant dividends because humans cause most of the wildfires globally. Managing entire fire-prone landscapes is also not economically feasible nor ecologically desirable. We therefore need to focus on mitigating the risk to high value assets and moving outward to manage the surrounding fuels. Increased prescribed and cultural burning will help to achieve the goal of community wildfire resiliency. Strategic fuel treatments were effective in helping protect the First Nation community of Nicomen in British Columbia from a 2021 wildfire by mitigating crown fire and providing a suppression advantage through improved access and ability to burn out fuels (FPInnovations 2024).

Strengthening wildfire detection and initial response is urgently needed because the quick and early containment of wildfire arrivals provides the highest return on investment. When wildfires escape initial attack and blow up during extreme wind events, they typically generate massive ember attacks on communities. Once structures become fully engaged in fire, it is difficult to stop structure to structure ignition.

The 2006 Canadian Wildland Fire Strategy provided a pathway towards achieving the goal of coexisting with wildfire. However, a 10-year Review and Renewed Call to Action published in 2016 reported that Canada had fallen short in implementing the strategy. Moving forward with the strategy requires a comprehensive and multi-dimensional approach and a commitment of time, resources, and support from all levels of government.

The 2024 Canadian Wildland Fire Prevention and Mitigation Strategy provided another path forward, but with a focus on wildland fire prevention and mitigation efforts to achieve a more wildland fire resilient society. This is a positive step forward, but the increasing trend in the number of days when Canada does not have sufficient resources to manage wildfires (Figure 3) suggests Canada clearly needs to do more.

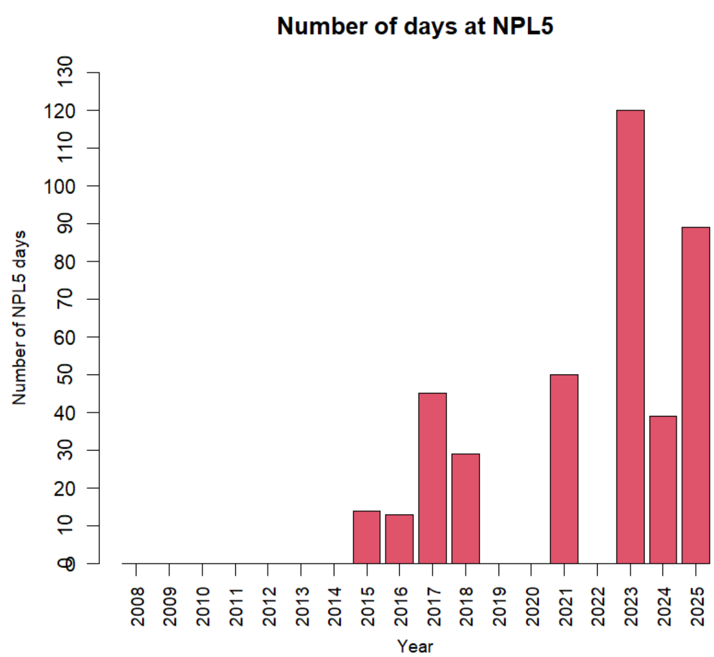


Figure 3. Number of days at National Preparedness Level (NPL) 5 in Canada for the period 2008–2025.

After the 2024 Jasper Wildfire, the Senate Standing Committee on Agriculture and Forestry held hearings on the state of wildfire management in Canada. The Committee was told that Canada must be better prepared to address a future with more wildfire. In his speech to the Senate on 10 June 2025, the Honourable David M. Arnot, Senator (Saskatchewan), noted that the United States has the Federal Emergency Management Agency (FEMA) and Australia has the National Emergency Management Agency (NEMA), but Canada has no equivalent. He stated, "a uniquely Canadian and equally robust national response mechanism"[1] is needed in Canada. In a recent poll by Abacus Data, 3 in 4 Canadians agreed with Senator Arnot.

While more needs to be done to prevent and mitigate wildfires, there is also a need to increase our initial response capacity and capability to protect communities and critical infrastructure. Preventing, mitigating and responding to threatening wildfires requires a whole-of-government, society, and industry approach.

Substantive discussions across Canada are needed. Should Canada have national resources to help manage potentially disastrous wildfires, i.e., firefighting crews and air tanker groups (one fleet in the west and another in the east)? Is it time to establish a Canada-made national emergency response agency? These are important and urgent questions because climate change impacts on wildfires in Canada are accelerating at a much faster rate than forecasted.

The 2025 Global Assessment Report on Disaster Risk Reduction (UNDRR 2025) identified the need for smart risk-informed investments to reduce and prevent disaster losses. Building capacity, capability and resilience can yield high benefit-cost ratios. We will see increasing evacuations and community losses if we fail to build affordable and sustainable resilience and learn to live with increasing wildfire and smoke on the landscape while also addressing human-caused climate change.

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Why have Canada's wildfire seasons suddenly gotten worse?

By Kyle Brittain, Weather Specialist and Freelance Video Journalist, Calgary, thegreatbrittain1@gmail.com

Canada's wildfire seasons are getting worse. Of the past five wildfire seasons, four have seen well-above-average area burned across the country. There have been several wildland urban interface disasters. Wildfire smoke has plagued millions across the continent with poor air quality for days on end.

So, what is driving the recent change?

In this article, the case will be made that rapidly changing ocean temperature patterns across the North Pacific – influenced in large part by human activities — are playing a key role in increasing fire weather conditions in much of Canada.

Natural climate variability influences area burned in Canada

Climate change occurs over long periods of time. Recent trends are typically assessed by comparing the 30-year averages of certain atmospheric and oceanic variables. Within those longer timeframes exist periods of shorter-term but significant variability. For instance, some years may be much warmer in certain areas of Canada than others. Such effects are often tied to oscillating patterns of sea surface temperature (SST) in different areas of the world, which can influence the weather thousands of kilometres away.

The El Niño-Southern Oscillation (ENSO), occurring in the tropical Pacific, is the most important climate driver influencing year-to-year variability in Earth's climate system. Outside the tropics, the Pacific Decadal Oscillation (PDO) plays a significant role in climate variability across the North Pacific –and will be very important in our current discussion. The PDO occurs on longer time scales and has a warm (positive) phase, along with a cold (negative) phase.

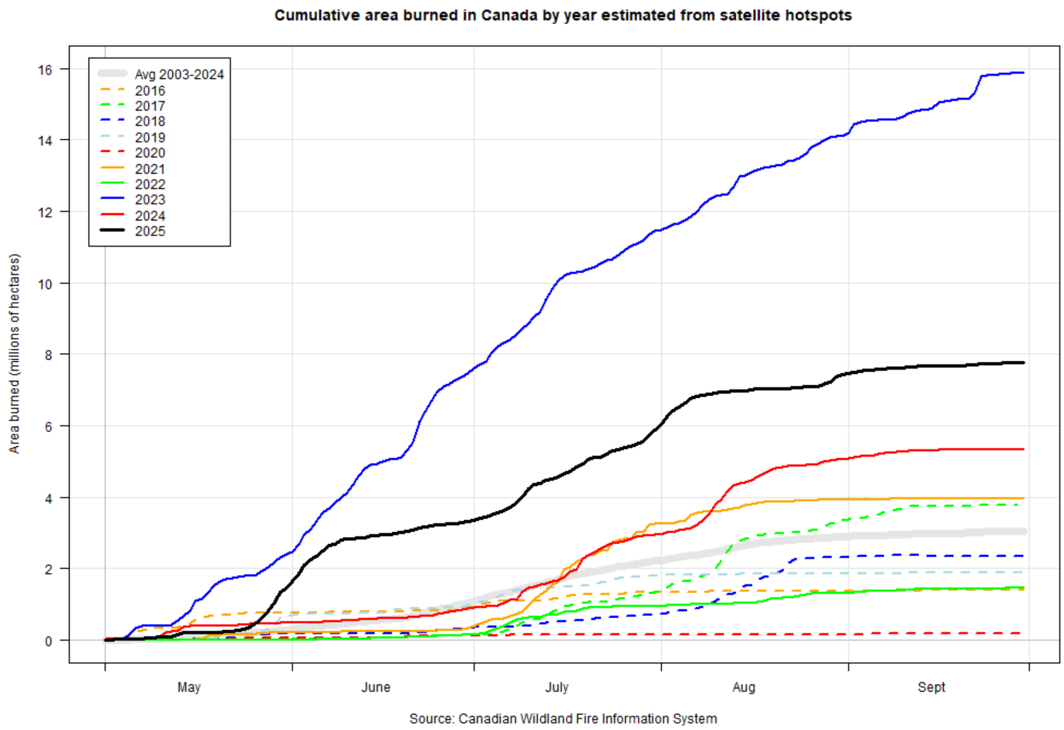

Figure 1. Four of the past five wildfire seasons have seen well above the 2003-2024 average of area burned in Canada, including 2021, 2023, 2024, and 2025. (Natural Resources Canada).

Warm PDO phases are "El Niño-like" and have warmer-than-average sea surface temperatures along the west coast of North America, with cooler-than-average sea surface temperatures across the western and central North Pacific. Cold PDO phases are "La Niña-like" and present with the opposite pattern of sea surface temperature anomalies. This image from the National Oceanic and Atmospheric Administration (NOAA) shows the typical SST patterns associated with the warm PDO on the left, and the cold PDO on the right.

Both patterns can influence the atmosphere in ways that make fire weather (meteorological conditions conducive to ignition and spread of wildfires - typically hot, dry, and windy) more or less common across Canada in a given season.

Research has shown that in the past, warm PDO (+PDO) conditions generally led to greater area burned east of the Rockies in Canada. Conversely, cold PDO (-PDO) conditions generally led to less area burned east of the Rockies, with more area burned west of the Rockies in British Columbia.

Where we are at now

We are presently in a cold PDO regime, with the PDO index becoming increasingly negative since about 2020. In July 2025, it hit an all-time record low of -4.12 – likely driven largely by the extreme warmth in the western Pacific near Japan and eastward along the Kuroshio Extension. Except for the strong El Niño in the winter of 2023/24 (out of phase with the strongly negative background PDO), ENSO has frequently been in cool neutral or La Niña territory.

In this current climate regime, widespread drought and national area burned have increased since 2021.

Unlike the typical -PDO sea surface temperature anomaly pattern, much of the eastern North Pacific has also frequently been warmer than normal during the summertime, resulting in basin-wide warmth. In addition to the western Pacific, there have been several marine heat waves, or "blobs" of anomalously warm water, that have formed in the eastern North Pacific, near the west coast of North America.

Finally, despite typical patterns of area burned during -PDO regimes, there has been significant area burned on both sides of the Rockies in recent years. This has especially been the case in the western half of the country.

Broadly speaking, sea surface temperature anomaly patterns across the North Pacific have been quite consistent since 2021. These have also had a fairly consistent influence on patterns of winds and pressure in the atmosphere above, which have been influencing the weather downstream in North America.

Let's look at the average position of some of these key features in the oceans and atmosphere during the summers of 2021-2025, using ERA5 reanalysis data as visualized on the Climate Reanalyzer website.

How the oceans are influencing the atmosphere

During boreal summer in recent years, the warmest sea surface temperature anomalies have been focused in the western and central Pacific. This has largely been driven by the Kuroshio Current (a climatologically warm, western boundary current east of Japan), which has been much warmer and farther north than normal. This is pumping warmth eastward across the ocean along the North Pacific Current.

This sea surface temperature pattern has influenced the summertime jet stream, initiating a wave train that frequently sets up across the North Pacific and North America.

The result is mean, positive geopotential height anomalies ("ridging") at 500mb in areas east of Japan, over western Canada, and just east of Newfoundland. Mean troughing centres exist at higher latitudes, near Beringia and over Baffin Bay.

The pattern of 500mb wind speed anomalies reveals a summertime jet stream that is further north than normal.

The overall pattern of upper height and wind anomalies has important implications for prevailing weather conditions during the summer across North America.

Perhaps the most critical atmospheric feature in influencing the severity of fire seasons in Canada has been the strong, mean upper ridging over the western half of the country. This causes large-scale sinking air and an abundance of hot and dry weather, while also blocking the flow of Pacific moisture from the west. This sets the stage for drought development over much of Canada, and we have learned through time that drought tends to beget more drought in continental climates.

ERA5 reanalysis of temperature reveals that summers since 2021 have been much warmer than normal across western and northern areas of North America. Skies have also been clearer than normal during the summers across much of Canada, with less precipitation than normal in central and western areas of the country.

The mean upper ridging and poleward-shifted storm track has resulted in clearer skies and lighter winds across much of the North Pacific, as well as east of Atlantic Canada. This results in a higher frequency of marine heat waves in these regions. This is reflected in the SST anomaly pattern, with the North Pacific warm pool extending toward the west coast of North America in the summer.

Extreme fire weather has become more common in the West

Rapid wildfire growth is favoured when fuels are dry and the weather is hot, dry, and windy. Wildfire seasons in regions with large area burned tend to have excess fire weather conditions.

However, area burned can be a tricky metric to gauge the overall severity of a wildfire season. Fire managers in some areas may utilize modified suppression approaches that result in large area burned. Some years may see fewer human-caused fires, which may reduce area burned, despite otherwise great potential for massive spread. And of course, a year with less area burned overall may still be remembered for a single, disastrous urban interface event.

Still, large area burned won't occur without ample fire weather conditions. Therefore, it can be helpful to look at other metrics, such as anomalies in the Fire Weather Index (FWI), to get a sense of overall fire weather trends across North America.

The current climate regime has resulted in excess extreme fire weather days across much of western Canada in recent years. This

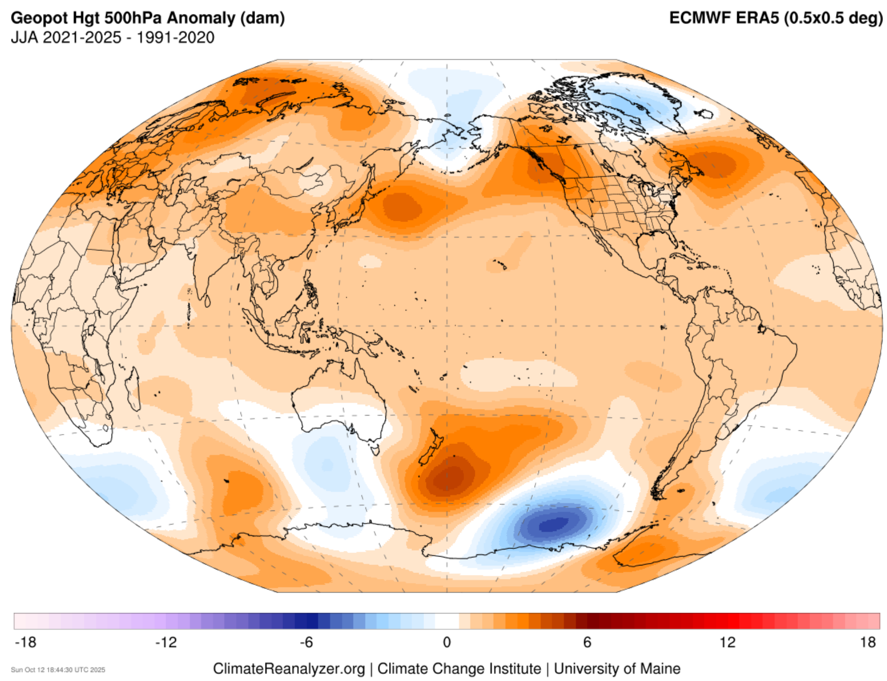

Figure 2. Global 500mb geopotential height anomaly during June, July, and August 2021-2025. (Climate Reanalyzer).

has been especially true in much of northeastern British Columbia, northwestern Alberta, and southern Northwest Territories – a significant percentage of which has burned in recent, multi-year fires. Lesser but still significant anomalies have also occurred across other parts of western North America, including from southern British Columbia down the west coast of the United States.

It comes as no surprise, then, that national area burned has greatly increased since 2021.

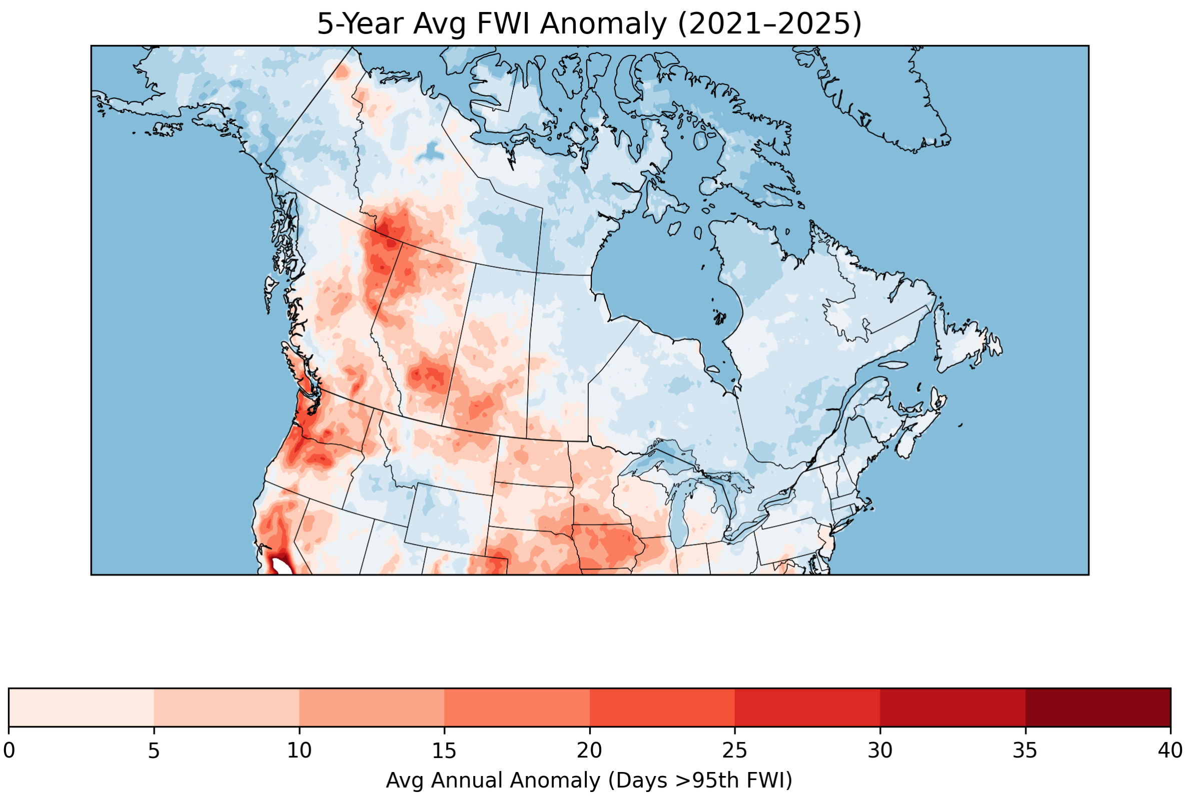

Figure 3. 5-year average FWI anomaly in Canada from 2021-2025 based on ERA5 reanalysis data, using 1991-2020 as a baseline.

Reductions in air pollution are warming the ocean

In recent years, the North Pacific has been rapidly warming. In fact, as of the end of summer 2025, it was the warmest ever recorded.A major driver in recent North Pacific warming has been the sudden reduction of sulphate aerosol pollution.

When fossil fuels are burned, they give off greenhouse gases (like CO_2) that have a warming effect on the atmosphere — along with gases (like SO_2) that are the precursor of aerosol pollution (like sulphate aerosols), which have a cooling effect. The latter "hides" some of the warming from greenhouse gases through the aerosol masking effect. Aerosols have a cooling effect by increasing the scattering of sunlight and increasing the albedo (brightness) of clouds, so that less of the sun's energy is absorbed at the surface.

However, the microscopic airborne particles that comprise aerosol pollution are one of the leading causes of premature death in the world. Scrubbing them from fossil fuel emissions is therefore desirable. But it comes at the expense of potentially rapid warming due to its unmasking of the warming effect of greenhouse gases. Because aerosols have a much shorter residence time in the atmosphere than greenhouse gases, their sudden removal can result in rapid, observable changes. There are few better examples of the direct impact of human actions on Earth's climate system.

In recent years, emissions of sulphur dioxide have been drastically cut. Two notable examples include the recent cleanup of East Asian air pollution, and the 2020 IMO regulatory cap on sulphur in shipping fuels.

One of the effects that has been observed since IMO2020 is a significant reduction in ship track clouds, as seen in this image of the eastern North Atlantic from NASA on 16 January 2018. Sulphate aerosols act as cloud condensation nuclei on which water vapour can condense into cloud droplets. When removed from the atmosphere, fewer clouds form. This results in more absorption of the sun's energy by the oceans, and more warming with the effect being maximized near the world's busiest shipping lanes. Elsewhere, clouds that do form (like marine stratocumulus) are dimmer and reflect less light. While the overall effect may be relatively small in the global system, it's playing a role in the warming of the oceans.

Perhaps a more significant example of SO2 reductions has come from China and, more broadly, East Asia in recent years. Between 2013 and 2019, China's clean air action plan resulted in massive reductions of sulphur dioxide, bringing about significant declines of aerosol pollution over East Asia and downwind areas of the Pacific. This can regionally reduce albedo, resulting in warmer sea surface temperatures across much of the North Pacific. In fact, research has shown that reductions in East Asian air pollution can even increase the frequency of marine heat waves as far away as near the North American coast.

That better air quality may come at the expense of rapid global warming is a concerning dilemma. Indeed, it has motivated efforts to research certain geoengineering schemes that could reintroduce the aerosol masking effect, such as stratospheric aerosol injection or marine cloud brightening. However, these have not yet been implemented on a large scale due to the concerns of negative, unintended consequences on the global climate system.

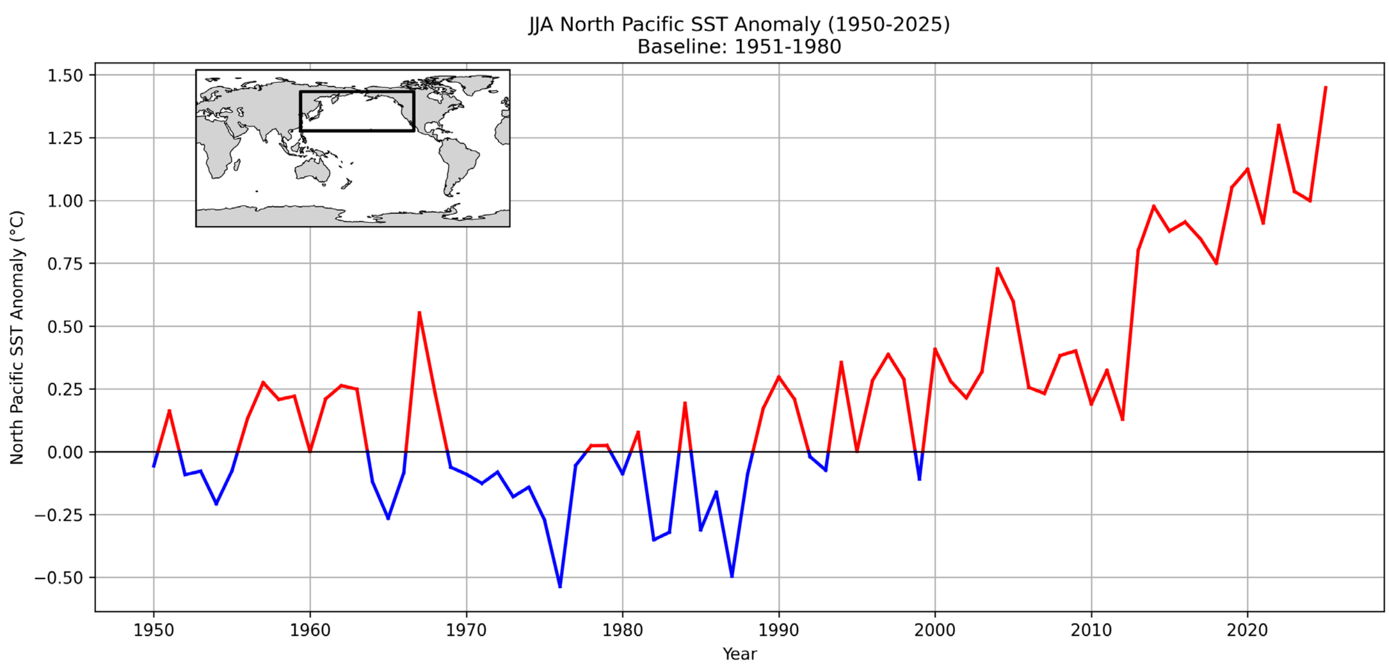

Figure 4. North Pacific sea surface temperature anomaly during June, July and August 1950-2025, based on the 1951-1980 baseline, using the NOAA ERSSTv5 dataset.

Pacific Ocean warming appears to be influencing Canadian wildfire seasons

It is interesting to note how different the current, cold PDO regime looks compared with others in the recent past. This includes 1998–2002 and 2007–2013, when temperatures in the eastern North Pacific and over adjacent areas of western North America tended to be cooler than normal during the summer. It is clear that in recent years, something has changed—and that this change likely can't be accounted for by natural climate variability alone.

If we step back to look at the big picture for a moment, global average surface temperature has really begun to increase since the late 1970s or early 1980s — around the time that SO2 emissions (and sulphate aerosol pollution) had peaked and began to decline. These reductions occurred in Europe and the Americas first, with later declines truly beginning in Asia since about 2013. This has occurred at the same time that global CO2 emissions continue to rise. The removal of cooling aerosols is therefore playing a significant role in unmasking the warming caused by greenhouse gases like carbon dioxide.

So, when we see significant, so-called "termination shocks" caused by sudden reductions in aerosol pollution, as we have seen across the North Pacific region since 2013, widespread, observable impacts to the climate system are likely.

These effects appear to be changing the typical expression of the PDO in the North Pacific, with more expansive and intense warmth amplifying the overall pattern — which may be shifting and strengthening patterns of mean atmospheric blocking. Indeed, it's been found that human forcing (through greenhouse gas warming and reduction of air pollution) is causing a +PDO-like warming pattern in the North Pacific. At the same time, human forcing may reduce the PDO signal and shorten the duration of its phases, with some speculation that it could significantly reduce its predictability overall. All of this could influence Canadian wildfire seasons in unexpected ways.

The way forward

It is unknown to what extent the current pattern will continue in the future, and to what extent it is tied to the current PDO sea surface temperature regime. How might things change when the PDO swings positive again, bringing warmer-than-normal sea surface temperatures along the west coast of North America? How might these changes influence patterns of wind and pressure throughout the atmosphere? Recent research suggests that marine heat waves in the northeast Pacific are more common during +PDO phases, but we've been seeing marine heat waves persisting in this region even though the PDO has been strongly negative. In any case, the persistence of the current climate regime and its widespread warmth across the North Pacific—along with its associated atmospheric wave train—are clearly contributing to worsened Canadian wildfire seasons since 2021.

Though the average summertime atmospheric wave train through much of the Northern Hemisphere seems to be forced primarily by the extreme warmth in the western and central North Pacific, it's unknown to what extent episodes of shallower warmth (associated with marine heat waves) in the eastern Pacific may also be forcing the jet stream. In any case, the entire North Pacific is rapidly warming, and a warmer ocean overall leads to warmer adjacent landmasses.

A warming climate increases the potential for wildfire spread in Canada by lengthening fire seasons, increasing the drying power of the atmosphere, increasing the risk of lightning at higher latitudes, and increasing the frequency and intensity of extreme heat and flash drought events. Combined, these play a major role in the amount of annual area burned, along with the severity of individual wildfire events like Lytton or Jasper. It is, therefore, no surprise that things have been unfolding as they have in recent years.

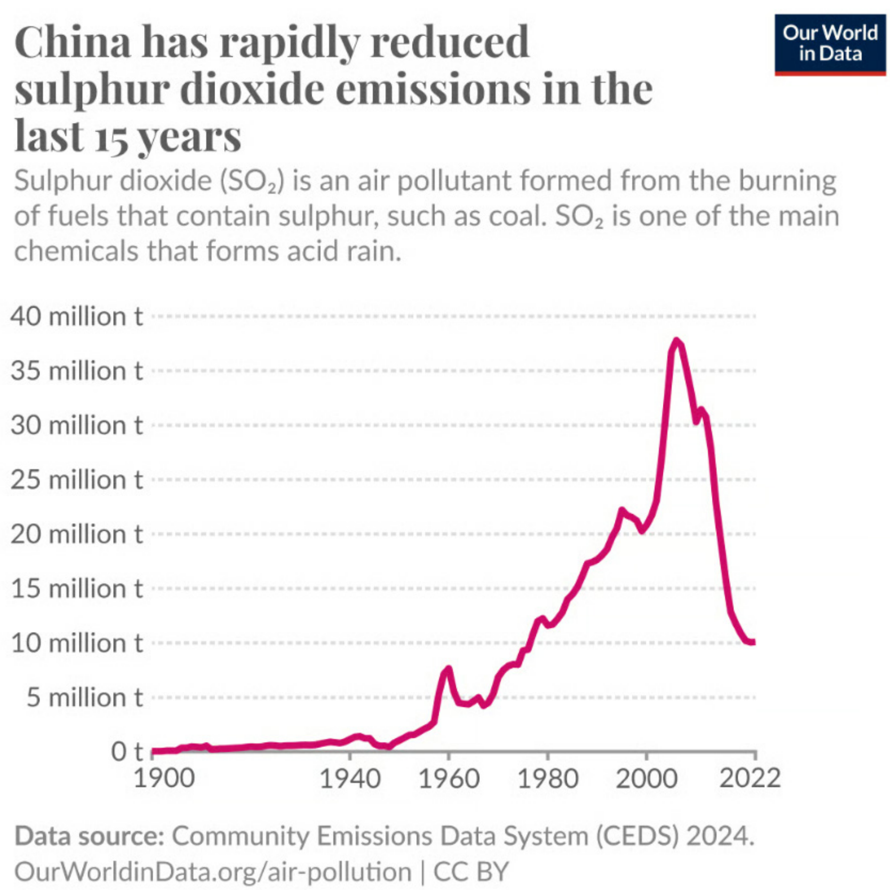

Figure 5. Emissions of sulphur dioxide (SO2) in China, from 1900-2022. (Our World in Data).

The way forward is complex. Many aspects of this discussion warrant much further research and are emerging topics in climate and wildfire science. And while there is much uncertainty about how things could pan out in the near and distant future, it appears very likely that human influence is changing and amplifying natural climate variability in a way that makes drought and fire weather more likely across Canada. In the meantime, adaptation to the emerging reality of living with more fire is essential – even as we continue to work toward solutions to decelerate the warming of our climate.

Kyle Brittain is a weather specialist and freelance video journalist based in Calgary. You can find more of his work on Bad Weather Kyle - Severe Weather Journalist and his YouTube channels: Kyle's Forecasts - YouTube and Bad Weather Kyle - YouTube

NEW WEBINARS

Two new webinars are now available on the Canada Wildfire YouTube channel, providing scientific insight into the Jasper 2024 Wildfire Complex from both operational and analytical perspectives.

Jasper 2024 Wildfire: Fire Behaviour Documentation and Reconstruction, and Structure Loss Analysis
Daniel Perrakis (Canadian Forest Service) and Luke Collins (FPInnovations) present findings from two major reports on the fire’s spread and impacts. Topics include fire behaviour reconstruction, predictive modelling, and structure loss within the Jasper townsite.

The Jasper Wildfire Complex: Insights from the First Two Weeks of Response
Incident Commander Landon Shepherd shares lessons from the first two weeks of wildfire response—covering ignition context, early fire behaviour, and initial suppression strategies.

Watch now: youtube.com/@CanadaWildfire

Assessing fuel structure in hurricane-impacted stands on the north shore of Prince Edward Island, Canada

By Kyle E. Akmens[1], Madisyn Harper[2], Robyn Caissie[2], Hailey Paynter[2], Kim Gamble[2], Andrew Ing[3], Matt Angus[3], Matt McIver[3], Zora Wendt[3], Tim Bernard[4], Nicole Bernard[4], Ethan Shea[4], Blake Bernard[4], Luke Arsenault[4], Cheryl Bernard[4], Tommy Labobe[4], Mary Knockwood[1], Sherilyn Young[5], Emma Ladouceur[6,7,8], Brooke Foster[2], Matthew Smith[9], James MacKinnon[10], Jonathan Boucher[11], Anne Cotton-Gagnon[11], Douglas Piercey[12], Andrew Penney[12], Rodney J. Foster[1], Raphaël D. Chavardès[1]

[1]Atlantic Forestry Centre, Canadian Forest Service, Natural Resources Canada, Fredericton, NB, Canada

[2]Prince Edward Island National Park, Parks Canada, Dalvay, PE, Canada

[3]Department of Environment, Energy and Climate Action, Government of Prince Edward Island, Charlottetown, PE, Canada

[4]Natural Resource Department, Lennox Island First Nation, Lennox Island, PE, Canada

[5]Kwilmu'kw Maw-Klusuaqn, Truro, NS, Canada

[6]Department of Biology, University of Prince Edward Island, Charlottetown, PE, Canada

[7]Canadian Centre for Climate Change and Adaptation, University of Prince Edward Island, Charlottetown, PE, Canada

[8]School of Climate Change and Adaptation, University of Prince Edward Island, Charlottetown, PE, Canada

[9]Kejimkujik National Park and National Historic Site, Parks Canada, Maitland Bridge, NS, Canada

[10]Department of Natural Resources and Renewables, Government of Nova Scotia, Shubenacadie, NS, Canada

[11]Laurentian Forestry Centre, Canadian Forest Service, Natural Resources Canada, Quebec City, QC, Canada

[12]Atlantic Forestry Centre, Canadian Forest Service, Natural Resources Canada, Corner Brook, NL, Canada

Corresponding author: raphael.chavardes@nrcan-rncan-gc.ca

English version (French version below)

During spring and early summer 2025, staff from the Canadian Forest Service (CFS) worked with staff from Parks Canada, the Prince Edward Island Department of Environment, Energy and Climate Action, and the Lennox Island First Nation Natural Resource Department to collect Next Generation (NG) Fuels data at eight plots in hurricane-impacted stands on the north shore of PEI (Figure 1). The collection of the fuels data followed the NG Fuels protocol (Boucher et al. 2024) of the NG Canadian Forest Fire Danger Rating System (Canadian Forest Service Fire Danger Group 2021). The dataset is available on the Open Government Portal website (link; Akmens et al. 2025) and represents an addition to the nationwide effort towards measuring NG Fuels across different forest types that can be impacted by disturbances.

The NG Fuels dataset from north shore PEI hurricane-impacted stands, along with more extensive datasets in Canada (e.g., Zerb et al. 2025; Skretting et al. 2025; Chavardès et al. 2025, in press), can help researchers and fire managers gain a more comprehensive understanding of fuel complexes and potential fire behaviour when the datasets are used as inputs in fire simulation models. For example, ongoing research with these datasets aims to help estimate fire behaviour metrics like flame length and rate of spread, supporting decision-making for fuel hazard mitigation. This effort is critical in PEI, and more generally in the Maritimes, given the extensive wildland–urban interface (Johnston and Flannigan 2018) and severe blowdown impacts on many stands by recent hurricanes like Dorian in 2019 and Fiona in 2022.

Acknowledgments

We respectfully acknowledge that the research was conducted in the district of Epekwitk aq Piktuk within Mi'kma'ki, which is the ancestral and unsurrendered territory of the Mi'kmaq People. This territory is covered by the "Treaties of Peace and Friendship," which were signed by Mi’kmaq, Wolastoqiyik (Maliseet), and Peskotomuhkatiyik Peoples, and the British Crown. We aim to walk lightly, harvest with respect, and learn from local knowledge-keepers of every Nation. For permitting work at field sites, we thank Kerry-Lynn Atkinson (Parks Canada - PC), Tim Bernard (Lennox Island First Nation Natural Resource Department), and Christopher Kirby (Agriculture and Agri-Food Canada - AAFC). We thank Alexis MacIntyre (PC), Gaëtan Leclair (CFS), and Dan MacEachern, Myles Gallant, Steven Meerburg (AAFC) for logistical support.

Figure 1. Leaf off (left) and leaf on (right) 360º photos taken at 1.5 m above the ground from the centre of one plot located on the north shore of Prince Edward Island. The photos show elevated woody debris exposed to drying environmental conditions, including wind and solar radiation, and little contact with the ground, which limits the absorption of moisture by the wood and slows its decomposition. Photo credit: K.E. Akmens.

Version française - Évaluation de la structure des combustibles dans des peuplements impactés par ouragan sur la côte nord de l’Île-du-Prince-Édouard, Canada

Au printemps et au début de l’été 2025, du personnel du Service canadien des forêts (SCF) a collaboré avec du personnel de Parcs Canada, du ministère de l’Environnement, de l’Énergie et de l’Action climatique de l’Île-du-Prince-Édouard et du Lennox Island First Nation Natural Resource Department afin de recueillir des données sur les combustibles de prochaine génération (PG) dans huit placettes situées dans des peuplements impactés par ouragan sur la côte nord de l’Île-du-Prince-Édouard (Figure 1). La collecte des données sur les combustibles s’est déroulée conformément au protocole des combustibles PG (Boucher et al. 2024) de la PG de la Méthode canadienne d’évaluation des dangers d’incendie de forêt (Canadian Forest Service Fire Danger Group 2021). L’ensemble de données est disponible sur le site web du Portail gouvernemental ouvert (link; Akmens et al. 2025) et s’inscrit dans le cadre d’un effort national visant à mesurer les combustibles PG dans différents types de forêts susceptibles d’être impactés par des perturbations.

L’ensemble de données sur les combustibles PG provenant de peuplements impactés par ouragan sur la côte nord de l’Île-du-Prince-Édouard, ainsi que des ensembles de données plus extensifs provenant du Canada (p. ex. Zerb et al. 2025; Skretting et al. 2025; Chavardès et al. 2025, sous presse), peuvent aider les chercheur.euses.s et les gestionnaires des incendies à mieux comprendre les complexes de combustibles et le comportement potentiel du feu lorsque les ensembles de données sont utilisés comme intrants dans les modèles de simulation d’incendies. Par exemple, des recherches en cours avec ces données visent à estimer les paramètres de comportement d’incendie, tels que la longueur des flammes et la vitesse de propagation, afin de faciliter la prise de décisions en matière d’atténuation des aléas liés aux combustibles. Cet effort est essentiel à l’Île-du-Prince-Édouard et, plus généralement, dans les Maritimes, compte tenu de l’étendue du milieu périurbain (Johnston et Flannigan 2018) et des impacts de chablis sévères sur de nombreux peuplements à cause d’ouragans récents comme Dorian en 2019 et Fiona en 2022.

Remerciements

Nous reconnaissons respectueusement que la recherche a été menée dans le district d’Epekwitk aq Piktuk, au sein du Mi’kma’ki, qui est le territoire ancestral et non cédé du peuple Mi’kmaq. Ce territoire est couvert par les « Traités de paix et d’amitié », qui ont été signés par les peuples Mi’kmaq, Wolastoqiyik (Malécites) et Peskotomuhkatiyik, ainsi que par la Couronne britannique. Nous nous efforçons d’agir avec discrétion, de récolter avec respect et d’apprendre des gardiens du savoir locaux de chaque nation. Nous remercions Kerry-Lynn Atkinson (Parcs Canada - PC), Tim Bernard (Lennox Island First Nation Natural Resource Department) et Christopher Kirby (Agriculture et Agroalimentaire Canada - AAC) pour nous avoir permis de travailler sur le terrain. Nous remercions Alexis MacIntyre (PC), Gaëtan Leclair (SCF) et Dan MacEachern, Myles Gallant, Steven Meerburg (AAC) pour leur soutien logistique.

Figure 1. Photos à 360º prises à 1,5 m au-dessus du sol depuis le centre d'une placette située sur la côte nord de l'Île-du-Prince-Édouard, sans feuilles (à gauche) et avec feuilles (à droite). Les photos montrent des débris ligneux surélevés exposés à des conditions environnementales asséchantes, notamment au vent et au rayonnement solaire, et peu en contact avec le sol, ce qui limite l'absorption d'humidité du bois et ralenti sa décomposition. Crédit photo : K.E. Akmens.

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