# IS ALASKA PREPARED FOR EXTREME WILDFIRES?

**1** Heatwaves in Alaska in late spring and summer

Heatwaves characterized by high temperatures and dry vegetation

**2** Many wildfire outbreaks in the summer

Higher than average fire danger followed by an above average amount of wildfires in summer

**3** Air pollution and greenhouse gas emissions

Impacts on:

- Local communities
- Climate change
- Forest management

Wildfires are a natural part of the *boreal forest*[A] ecosystem, which is largely present in Alaska. However, in recent years, the fires seem to be more frequent and intense due to human-forced warming and an overall lengthening of the fire season, which affects local communities, flora and fauna. Alaskan ecosystems are already significantly exposed to impacts of climate change, not least due to temperature increase, which is almost twice the global average rate, largely due to a phenomenon known as *Arctic amplification*[B] (US Global Change Research Program). Summer 2019 recorded some of the highest temperatures and lowest moisture levels since records are kept (1952) (NASA Earth Observatory). This led to an extreme fire season in the northern state, burning an area of over 1 million hectares. This situation additionally contributed to exacerbating climate change, since the $CO_2$ stored in the soil and permafrost of these ecosystems had been released. Keeping forest fires under control is becoming an urgent and challenging task for the Arctic region. Predicting this type of events could improve preparedness and help to better protect the towns and communities that are at risk of destruction, e.g. help authorities make evacuations in time or allow the relocation of firefighting resources.

## GLOSSARY

A

**Boreal forest:**

A forest growing in high latitude environments, characterized by coniferous trees; also known as taiga.

B

**Arctic amplification:**

A phenomenon in which Arctic temperatures increase faster than in the rest of the world. This reduces the temperature difference between the equator and the North Pole, with potential consequences for weather and climate at lower latitudes.

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## THE EVENT: Above average amount of wildfires in the summer 2019

It is not unusual for the state of Alaska to experience wildfires, as they are a natural part of the boreal forest ecosystem. However, in July and August 2019, the number of fires burning in Alaska was much higher than average, and the burnt area was very large. This was reflected in the *Fire Weather Index (FWI)*[C]. Anomalous high conditions of FWI were present over Alaska in the period April-September. Fire danger was particularly high in the south coast of Alaska during July and August (Fig. 1).

C

**Fire Weather Index (FWI):**

A meteorologically based index used worldwide to estimate fire danger. It consists of different components that account for the effects of fuel moisture (obtained from precipitation) and the drying rate (computed from temperature, humidity, wind speed and time of year) on fire behaviour and spread. The higher the FWI is, the more favorable the meteorological conditions to trigger a wildfire are. It is used widely in Canada and Alaska, as it has been developed for boreal ecosystems.

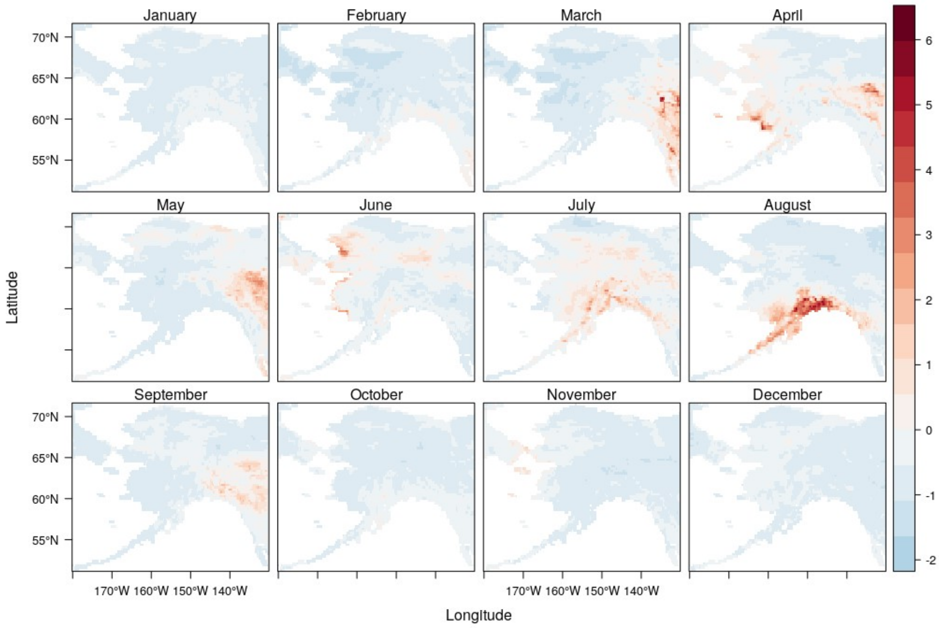



Fig.1. Fire Weather Index for Alaska in 2019. Source: Fire danger indices historical data from the Copernicus Emergency Management Service (CEMS), ECMWF (Vitolo et al. 2020). Credit: Claudia Vitolo.

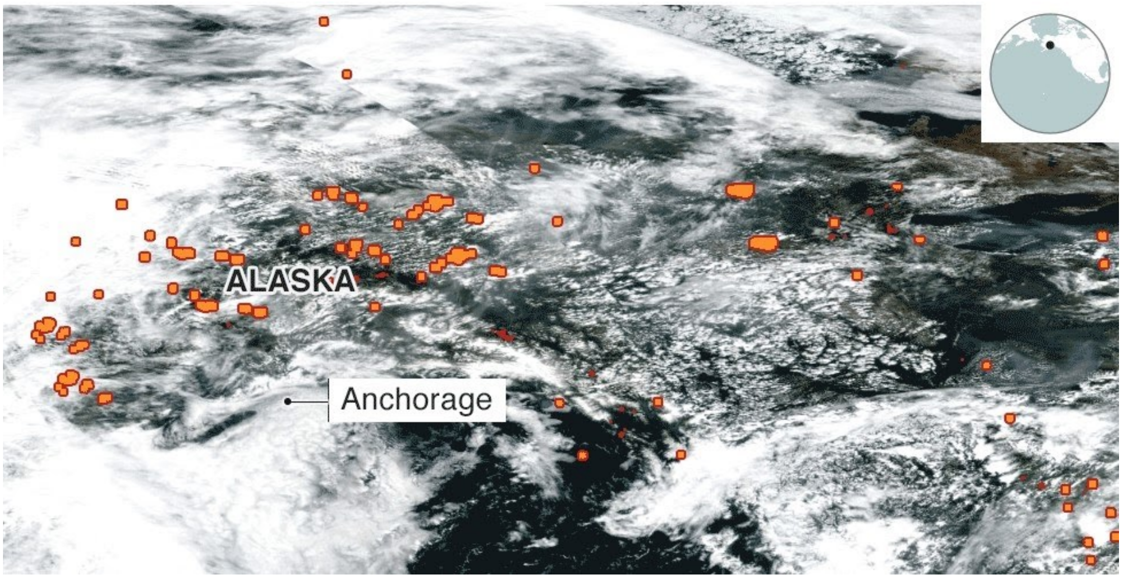



Fig.2. Fires and "thermal anomalies" (can include volcanoes and gas flares) between 31 July and 1 August 2019. Source: NASA FIRMS.

D

**Heatwave**

A prolonged period of abnormally hot weather.

The conditions that show an anomalous high FWI often coincide with *heatwaves*[D] and droughts. This combination, that was present in Alaska at the time, is sometimes called "fire -weather" because it increases the probability of a wildfire happening. Fire-weather also makes it easy for fire to spread once it is ignited because the soil and above-ground vegetation are dried out (Phillips, 2019). In such dry conditions, fire spreads fast, and even faster when aided by the wind. Indeed in 2019, Alaska saw what is considered to be an "extreme" fire season, with over 2.5 million acres (1 million hectares) burned (Fig. 2). Some of the wildfires, such as the McKinley, Deshka Landing, and Swan Lake wildfires were particularly large and destructive. Out of all the wildfires recorded in Alaska during summer 2019 (719), 339 were caused by humans (intentionally or unintentionally), 8 had undetermined causes, while the majority of them (372) were caused by lightning (AICC, 2020).

## THE IMPACT: Air pollution and greenhouse gas emissions

### Air pollution from smoke affecting local communities

Intense fire seasons can create dangerous conditions for everybody who visits or lives in Alaska. Some communities have already been evacuated in the past, and many more were affected by the smoke from these wildfires, which can pollute the air even in areas very distant from the burning ground (Fig. 3). The black soot can harm both people and ecosystems' health. For many Alaskans, staying indoors with closed windows in high summer temperatures to avoid the air pollution is not an option because they do not have air conditioning in their homes. Fires can also contribute, along with industrial pollution, to the creation of acid rain. This can dry up plants that people and animals eat, resulting in food security issues.

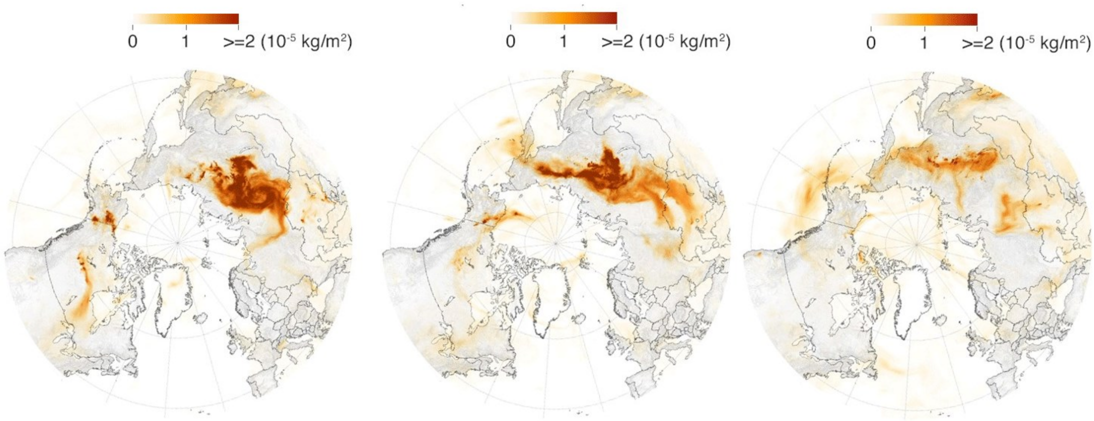



Fig.3. Soot (black carbon) concentration on the 24, 26 and 29 July. Dark red marks a high concentration. Source: NASA, Aqua/Modis, GEOS-FP.

APPLICATE User Group members pointed out that wildfires are a major issue for villages in Alaska, especially since many houses are under-insured or not insured for fire loss, resulting in losses of homes. Insurance companies could grasp this as a business opportunity for property insurance, which would help the affected villagers in the future. Besides houses, effects were felt on state infrastructure, such as communications and utility lines.

### Greenhouse gas emissions contributing to climate change

Burning of trees and foliage during a wildfire releases carbon dioxide into the atmosphere, which contributes to global warming. Other than in trees and foliage, Alaska's ecosystems also store huge quantities of carbon, that has accumulated over millennia, in permafrost and soil. When a wildfire appears in such an ecosystem, it combusts soil and accelerates permafrost thaw, both of which release additional *heat trapping gases*[E] to the atmosphere. That is why northern wildfires have a bigger impact on global warming than wildfires in midlatitudes. Besides Alaska, such ecosystems are present in other areas of the Arctic circle, many of them also affected by an extreme wildfire season in 2019. In June 2019, the

E

**Heat trapping or greenhouse gases:**

Any of various gaseous compounds (such as carbon dioxide or methane) that absorb infrared radiation, trap heat in the atmosphere, and contribute to the greenhouse effect.

**INTERESTING FACT**

The global northern permafrost zone stores around 1 500 billion tonnes of organic carbon (Schuur et al., 2015), which is almost twice as much as currently stored in the atmosphere. Alaska, as well as the Arctic in general, normally act as a net sink of atmospheric $CO_2$ (Schuur, 2019). As the climate becomes warmer and wildfires more frequent and intense, permafrost thaws more quickly and challenges the global carbon balance.

Arctic circle fires emitted more carbon dioxide than all the Arctic circle fires in the same month from 2010 to 2018 together (CAMS). In addition, in the case of intensive forest fires in the Arctic region, black soot settles on sea ice, which decreases the albedo effect and further adds to the warming.

Interestingly, members of the APPLICATE User Group from Alaska noticed that summer 2019 had much more lightning than usual, and that they occurred in places where they do not usually happen. This crowd-sourced information supports the research stating that lightning strikes are becoming more common due to climate change (Veraverbeke et al., 2017; Romps et al., 2014), thus increasing the possibility of ignition and adding to the carbon release loop. Accordingly, if the trend of global warming continues, an increase in the frequency of lightning strikes could make the fire season in Alaska even worse.

## Maintenance of boreal forests' health

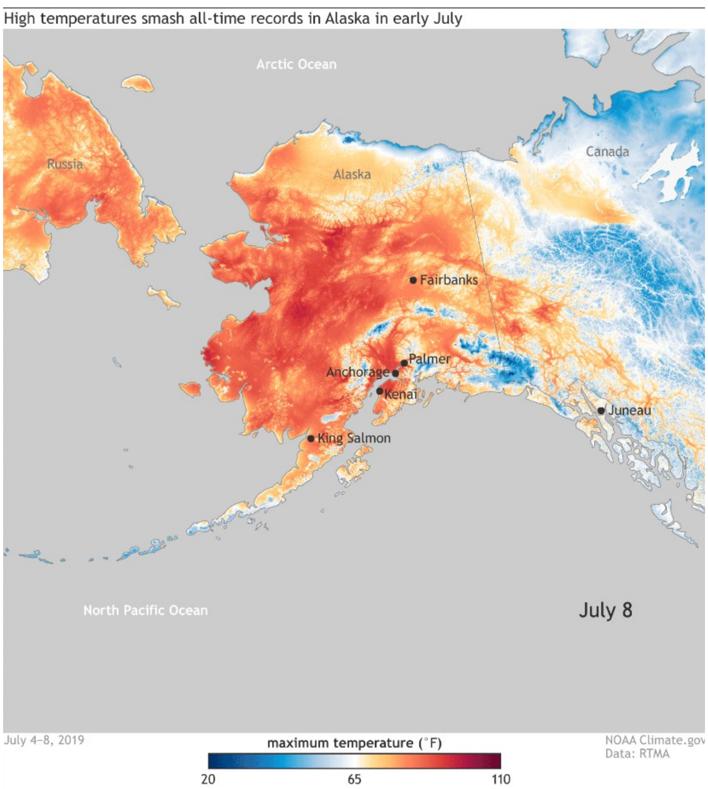
Forest fires in the Arctic can also involve burning of *peatland*[F]. Under normal conditions and in a healthy ecosystem, there is a balanced forest age distribution and the ground is covered with mosses. This cover keeps humidity and acts as a fire break. The change in disturbance regime can decrease the extent of older forest, i.e. it increases the proportion of early-successional, regenerating forest stands (Kuuluvainen and Gauthier, 2018). These changes can also affect peatland that dries more easily and becomes a very flammable substance. Once ignited, peat gradually burns deeper and deeper into the ground, moving laterally across the ecosystem. These fires are very persistent and can last for months or even years. Peat fire leads to massive carbon emissions, while damaging the soil and the tree root systems. Thus, the moss at the surface of peatland is important to keep a healthy ecosystem. It is particularly important on the surface of permafrost ground because it keeps it from melting and releasing the captured carbon (Jean et al., 2018). Wildfires can therefore cause much more damage to forests than meets the eye, emphasizing the importance of maintaining healthy forests.

F

**Peatland**

Ground made from slowly decomposing organic matter, like moss, that gradually builds up into a layer up to several meters thick. Given enough time and enough pressure, it will eventually harden into the undisputed heavyweight champion of carbon emissions: coal. Peatlands are the largest natural terrestrial carbon store on Earth.

## THE CAUSE: Heatwaves in Alaska in late spring and summer 2019




Globally, July 2019 was the hottest month ever measured (NOAA). This trend was apparent even in the world's most northern regions. The Arctic circle, including Alaska, Siberia and Greenland, experienced heatwaves during the summer of 2019, which were characterized by higher than average temperatures (Fig. 4) and dry vegetation (i.e. higher fuel availability).

Fig.4. Temperatures on July 8th in Alaska. Temperatures cooler than 18°C are shades of blue; those warmer than 18°C go from yellow to red. Source: NOAA Climate.gov, based on RTMA data.

## Higher than normal temperatures

Alaska's average temperature in July was 14.5°C, which is higher than the previously highest recorded temperature in July 2004 of 14.05°C, and almost 2°C higher than the long-term average (NOAA). The duration of this heatwave was an important factor in setting the conditions that favour wildfires, as above average temperatures were observed from June to August.

## Dry vegetation

A prolonged period of abnormally high temperatures contributed to a low level of air humidity, which increased evapotranspiration and left the vegetation extremely dry. Additionally, much of the South-eastern coast of Alaska (the Northeast Gulf and Panhandle regions) experienced below average precipitation during the summer months (NOAA), which enhanced the drought conditions, favouring the spread of wildfires (Fig. 5).

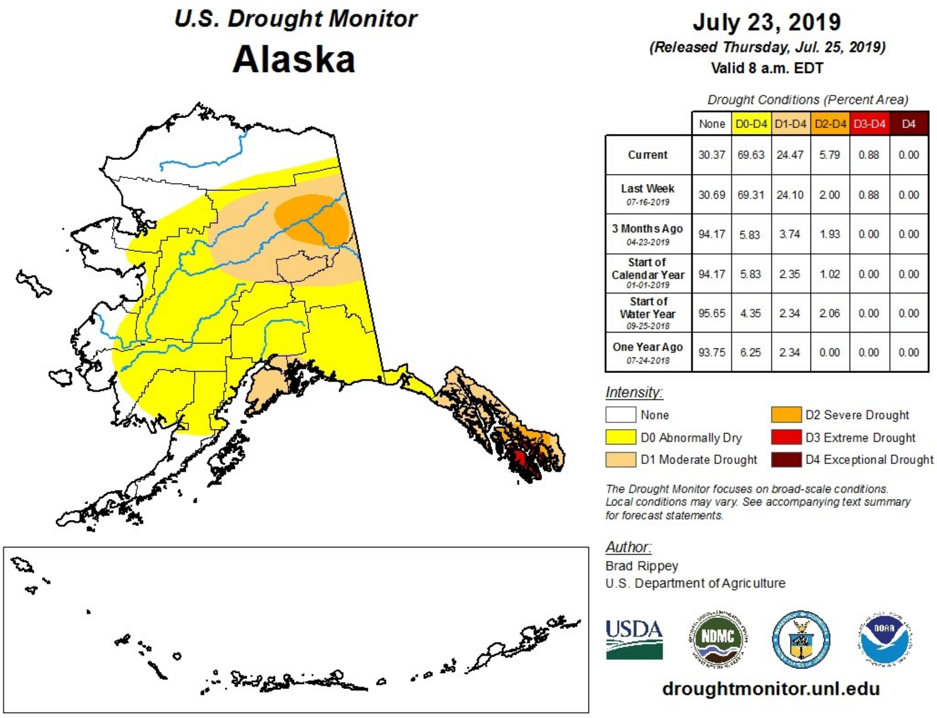



Fig.5. Drought in Alaska during the week 16-23 July, 2019. Shades of yellow and red mark abnormally dry areas, with dark red marking exceptional drought. Source: U.S. Drought Monitor. Credit: Brad Rippey, U.S. Department of Agriculture.

## What was going on in the atmosphere?

A high pressure system was present over Alaska in the beginning of July, keeping clouds away and maintaining dry weather. That is what allowed for such high temperatures to persist in Alaska during many consecutive days.

## What was going on in the ocean?

Sea surface temperature as well as the interaction between the atmosphere and the ocean both have a major influence on Alaska's weather and climate. Therefore it should be noted that while the air temperatures were above average, the temperatures of the ocean around Alaska were also much higher than usual. Additionally, the sea ice extent was on a record-low level in the Bering and Chukchi seas which separate Alaska from Russia (Fig. 6). Both the high ocean temperatures and the low sea ice extent potentially influenced the high air temperatures recorded in Alaska.

**INTERESTING FACT**
Heatwaves in high latitudes mean that more sea ice will be melting, which contributes to more global warming. 2019 sea ice extent closely approached that of 2012, which was the lowest sea ice extent on satellite record (NOAA).

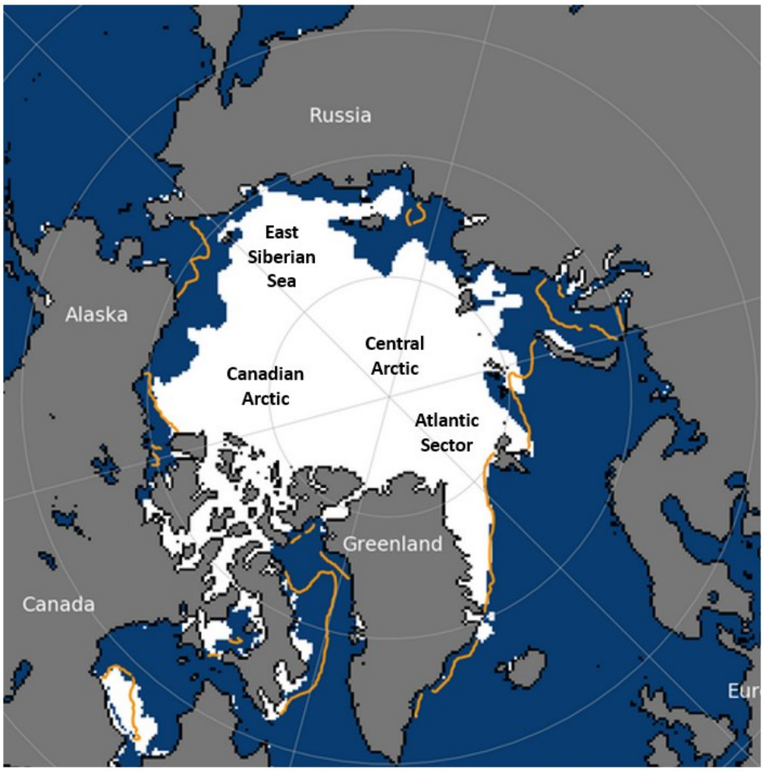



Fig.6. Arctic sea ice extent on 15th July 2019, with 1981-2010 average extent indicated in orange. Underlying map and data courtesy of the US National Snow and Ice Data Center (NSIDC). Source: Met Office UK.

G

**Numerical Weather Prediction (NWP)**

Most familiar form of weather model data on a day-to-day basis. NWP focuses on taking current observations of weather and processing them using computer models to forecast the future state of weather for the next few days.

H

**Extreme Forecast Index (EFI)**

Index highlighting regions that are forecasted to have potentially anomalous, extreme or severe weather conditions compared to local climate (e.g. heavy precipitation, strong winds, heavy snowfall, extreme temperatures, etc.). EFI values higher than 0.8 indicate a likely very unusual or extreme weather.

## APPLICATE PREDICTIONS

As the impacts and dangers of wildfires are growing, scientific contribution is becoming crucial in producing information regarding wildfire activity and developing operational models that could help to predict it. In this sense, the European Centre for Medium-Range Weather Forecasts (ECMWF) has developed wildfire danger indices providing global information extending back 40+ years. Apart from wildfire activity, ECMWF provides forecasts of extreme weather that can be used as a proxy for fire risk. For instance, *Numerical Weather Prediction*[G] models (for the next few days) predicted extremely high values of temperature for 7-9 July 2019 over Alaska already one week in advance of the drought, as shown by the *Extreme Forecast Index*[H] (EFI, Fig. 7). The forecast shows the likelihood for extreme temperatures over large parts of the north-eastern Pacific.

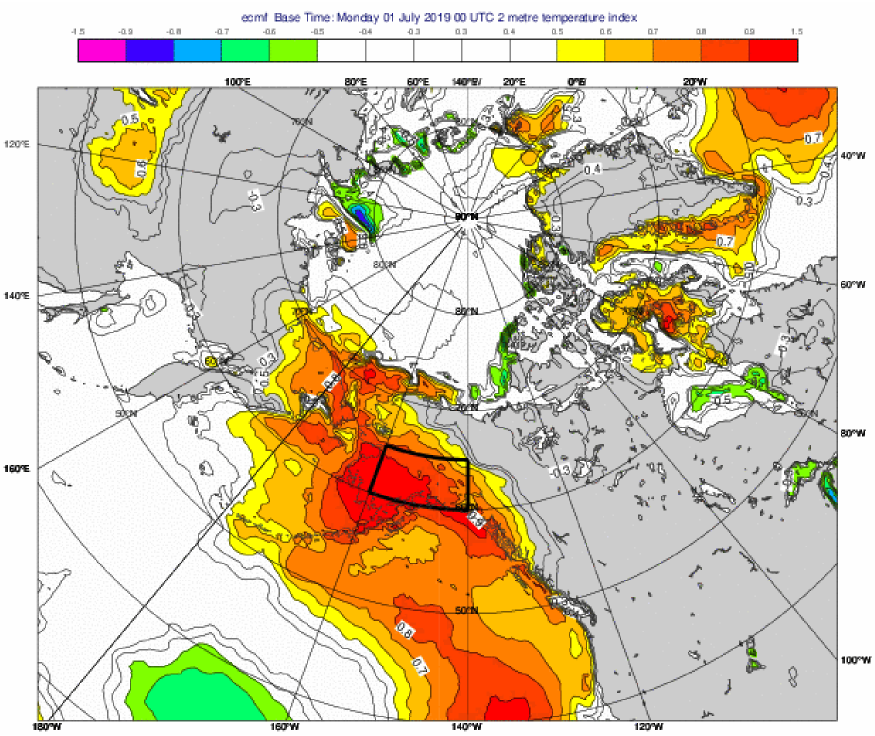



Fig.7. Predicted Extreme Forecast Index (EFI) for 3-day average temperature for 7-9 July 2019. Red colours mark a high likelihood of extreme temperatures. The black box highlights the region of interest in Southern Alaska. Source: ECMWF ensemble forecast issued on 1 July. Credit: Linus Magnusson, ECMWF

Additionally, the Copernicus Climate Change Service (C3S) provides seasonal forecasts of fire danger (for the next few months and seasons) as well as longer term projections of future fire danger (for the next few decades), which allow to adapt investments or management plans to future climate conditions. More precisely, Copernicus Emergency Management Service (CEMS) integrates the European Forest Fire Information System for monitoring forest fire activity in Europe and the Mediterranean, while its extension, the Global Wildfire Information System, is available for doing so on a global level.

Fire danger high resolution forecasts (HRES) estimate the Fire Weather Index (FWI) 10 days in advance. The following figure shows FWI forecast evolution compared to the observed *Fire Radiative Power (FRP)* for the region around Anchorage from mid June to mid July 2019.

**Fire Radiative Power (FRP)**

A measure of the rate of heat output from a fire. It is related to the rate at which fuel (e.g. dry vegetation) is being consumed and smoke emissions released to the atmosphere.

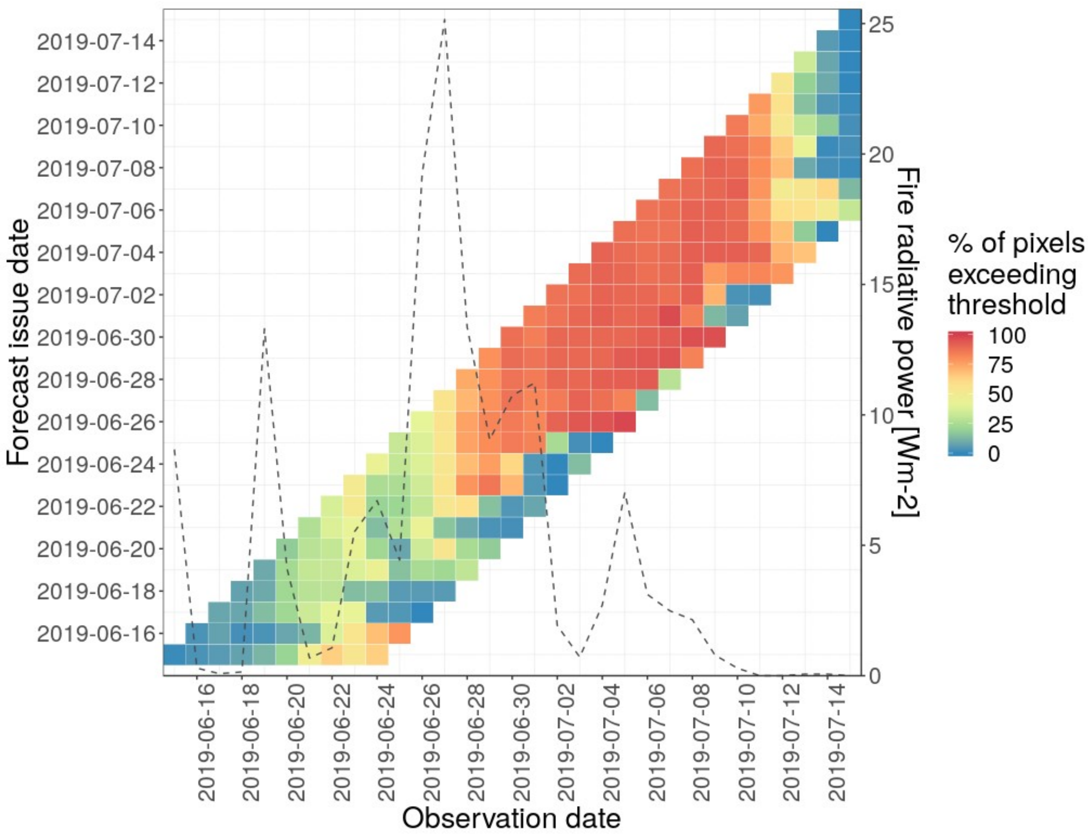



Fig.8. Fire Weather Index (FWI) forecast evolution against observed Fire Radiative Power (FRP) for Anchorage. On the x-axis are the dates in which FRP was observed and on the y-axis the dates forecasts were issued. The square cells represent the forecasts and the dashed line shows the observed FRP. The cell in the bottom left corner refers to day 1 of the forecast issued on 2019-06-15 and it is color-coded to show the percentage of pixels in the study area above the high danger threshold (90th percentile of the FWI climatology for that pixel and day of the year). The forecasts for day 2 to day 10 follow on the right hand side on the same row. The forecasts issued on the following day are in the row above. The dashed line shows the observed FRP (see also secondary y-axis). Orange-to-red cells signal situations in which 75-100% of the area of interest is above the high danger threshold (90th percentile of climatology). Credit: Claudia Vitolo, ECMWF.

For the selected region and time (Fig. 8), the peak in fire activity was observed around 27-28 June (see highest peak of dashed grey line). A sharp increase in fire danger was evident 6 days ahead (see days 5-7 for the FWI issued on 23rd June), and the high danger period lasted until 11 July. This forecast would have given local authorities a significant amount of time to prepare. That is why an accurate prediction of fire weather is instrumental for early-warning of the risk of wildfires.

## CONSIDERATIONS

APPLICATE does not directly provide predictions of wildfires, but it does provide the prediction of essential climate variables (temperature and precipitation) and indices (EFI for precipitation and temperature) that are highly related to the risk of wildfires occurrence. These predictions can be related to the likelihood of wildfire outbreaks, but the relationship is not linear.

## FIRE MANAGEMENT UNDER THE CHANGING CLIMATE

Forest fires of low intensity are good for the boreal forest ecosystem because they help maintain the forest's composition and structure in balance. However, in the past three decades wildfires have been drastically increasing in intensity (AICC, 2020). This could affect boreal forests' health and shift the carbon balance of the boreal ecosystem from net accumulation to net loss (Bond-Lamberty et al., 2007; Walker et al., 2019).

F

**Seasonal Climate Forecast:**

Prediction of average seasonal conditions for different climate variables for the upcoming seasons.

The year 2019 has been marked by unusually extreme fires. The fires were taking place in parallel in forests that are not accustomed to seeing such extreme wildfires, and in regions where large-scale forest fires are more common, such as South America, Australia and western North America.

In the future, the fire season is expected to start earlier and last longer because of an earlier snowmelt and start of the growing season (Lehtonen et al., 2015). This means that the period in which ignitions are likely to occur would be longer and within that period soil and vegetation would be drier (Westerling et al., 2006). If decreasing trends of summer precipitation continue, the result will likely be a continuing pattern of dry, warm summers that result in increasingly severe wildfires.

Wildfires have already been extending over a larger area during fire seasons of the past decade, raising concerns among fire managers about competition and overlap in firefighting resources. If in the future fires occur at the same time in areas that usually step in for each other when one of them is affected by a strong wildfire, the result may be a lack of resources to put out the fire. These concerns point to the importance of predicting fire weather more accurately, so that firefighting resources can be relocated and on standby near the areas where fire danger is high.

Even though the Federal firefighting costs have been steadily increasing (NIFC, 2020) and fire management could be calling for additional resources in the near future, it also presents an overlooked opportunity: it is a known and applicable technique of reducing the amount of carbon released from wildfires (Phillips, 2019). Seeing that large fire seasons might become more common in Alaska and thus emit more carbon dioxide into the atmosphere, authorities could reconsider fire management as a relevant approach to mitigate climate change.

## OUTCOMES FROM THE CASE STUDY

With the effect of global warming, heat waves are now longer, hotter and more frequent. This was a contributing factor in the extreme wildfire season Alaskan boreal forests have seen in summer 2019. Although these forests are used to wildfire as a part of their natural cycle, this was an extreme year with over 700 fires in Alaska and more than a million hectares of land burned. The event on such a scale heavily impacted the Alaskan community and their environment. With the wildfire activity increasing and becoming more intense even in places that are not used to seeing fire, it is becoming urgent to develop and use accurate prediction systems to allow towns and communities to be better prepared. This also needs to go hand in hand with improved planning that allows us to more efficiently manage our forests in order to protect the communities and ecosystems locally and, on a larger scale, to reduce greenhouse gases emitted from wildfires.

## REFERENCE LIST


Bond-Lamberty, B. et al. (2007) Fire as the dominant driver of central Canadian boreal forest carbon balance. *Nature* 450, 89–92, https://doi.org/10.1038/nature06272

Forkel et al. (2012) Extreme fire events are related to previous-year surface moisture conditions in permafrost-underlain larch forests of Siberia. *Environ. Res. Lett.* 7 044021, https://doi.org/10.1088/1748-9326/7/4/044021

Jean et al. (2018) Spatial and temporal variation in moss-associated dinitrogen fixation in coniferous- and deciduous-dominated Alaskan boreal forests. *Plant Ecol* 219, 837–851 https://doi.org/10.1007/s11258-018-0838-y

Kuuluvainen & Gauthier (2018) Young and old forest in the boreal: critical stages of ecosystem dynamics and management under global change. *For. Ecosyst.* 5, 26. https://doi.org/10.1186/s40663-018-0142-2

Lehtonen et al. (2015) Risk of large-scale fires in boreal forests of Finland under changing climate, *Nat. Hazards Earth Syst. Sci.* 16, 239-253, https://doi.org/10.5194/nhess-16-239-2016

Phillips (2019) How Alaska's recent heat wave may worsen climate warming, https://blog.ucsusa.org/carly-phillips/how-alaskas-recent-heat-wave-may-worsen-climate-warming; What do Alaska Wildfires Mean for Global Climate Change? https://blog.ucsusa.org/carly-phillips/alaska-wildfires-climate-change, *Union of concerned scientists (UCSUSA)*

Romps et al. (2014) Projected increase in lightning strikes in the United States due to global warming. *Science* 346, 851-854, https://doi.org/10.1126/science.1259100

Schuur, E. et al. (2015) Climate change and the permafrost carbon feedback. *Nature* 520, 171–179, https://doi.org/10.1038/nature14338

Schuur, T. (2016) Permafrost and the Global Carbon Cycle Terrestrial carbon cycle. *Arctic Report Card 2019,* J. Richter-Menge, M. L. Druckenmiller, and J. Mathis, Eds. http://www.arctic.noaa.gov/Report-Card.

Veraverbeke et al. (2017) Lightning as a major driver of recent large fire years in North American boreal forests. *Nature Climate Change* 7, 529–534, https://doi.org/10.1038/nclimate3329

Walker, X.J. et al. (2019) Increasing wildfires threaten historic carbon sink of boreal forest soils. *Nature* 572, 520–523 https://doi.org/10.1038/s41586-019-1474-y

Westerling et al. (2006) Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity, *Science* 313, 940-943, https://doi.org/10.1126/science.1128834

Ziel et al. (2020) A Comparison of Fire Weather Indices with MODIS Fire Days for the Natural Regions of Alaska. *Forests* 11, 516, https://doi.org/10.3390/f11050516

Alaska Interagency Coordination Center (AICC) (2020) https://fire.ak.blm.gov/predsvcs/fuelfire/fwidefined.php; AICC Situation Report, https://fire.ak.blm.gov/content/aicc/sitreport/AICC%20Situation%20Report.pdf

Copernicus Atmosphere Monitoring Service (CAMS), https://atmosphere.copernicus.eu/cams-monitors-unprecedented-wildfires-arctic

Copernicus Emergency Management Service (CEMS), https://emergency.copernicus.eu/, https://cds.climate.copernicus.eu/cdsapp#!/dataset/cems-fire-historical?tab=overview

European Centre for Medium-Range Weather Forecasts (ECMWF), https://www.ecmwf.int/en/about/media-centre/news/2019/worlds-first-wildfire-and-river-flow-reanalyses-be-updated-near-real

NASA Earth Observatory, https://earthobservatory.nasa.gov/images/145294/historic-heat-in-alaska

National Interagency Fire Center (NIFC), External Affairs Office: Federal Firefighting Costs, updated 3/11/20 https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf

National Oceanic and Atmospheric Administration (NOAA) US Department of Commerce, https://www.noaa.gov/news/july-2019-was-hottest-month-on-record-for-planet; NOAA Climate.gov, https://www.climate.gov/news-features/event-tracker/high-temperatures-smash-all-time-records-alaska-early-july-2019;

NOAA's National Centers for Environmental Information (NCEI) National Climate Report 2019, https://www.ncdc.noaa.gov/sotc/national/201913

United States Drought Monitor, https://droughtmonitor.unl.edu/Maps/MapArchive.aspx, https://droughtmonitor.unl.edu/Summary.aspx

University of Alaska Fairbanks (2008) Alaska's permafrost map, https://permafrost.gi.alaska.edu/sites/default/files/AlaskaPermafrostMap_Front_Dec2008_Jorgenson_etal_2008.pdf

US Global Change Research Program, Fourth National Climate Assessment, Alaska 2018, https://nca2018.globalchange.gov/chapter/26/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