# Wildfire, Fuels and Management in Canada

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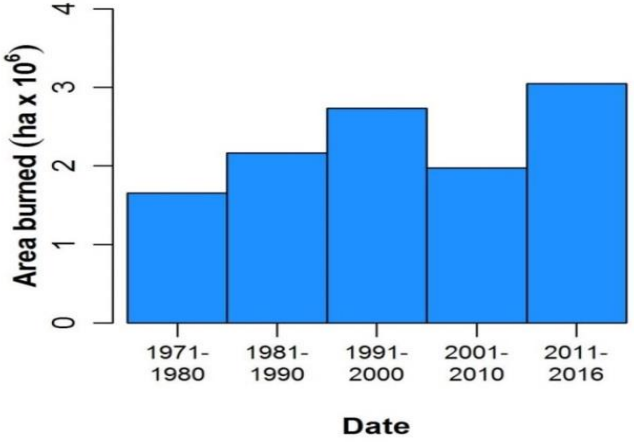
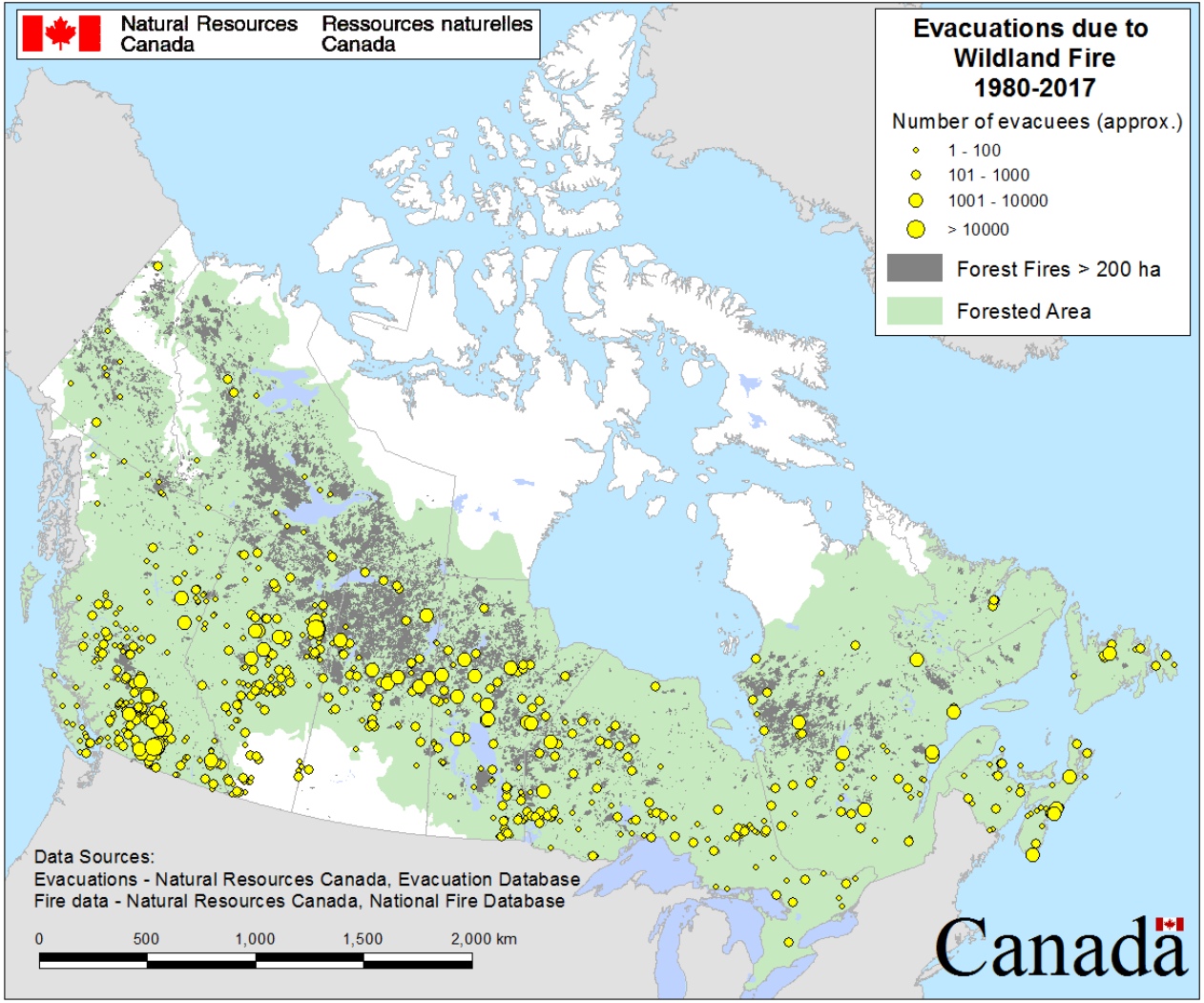
Canadian Partnership for Wildland Fire Science

2019 Air Quality and Health Workshop 6 February 2019

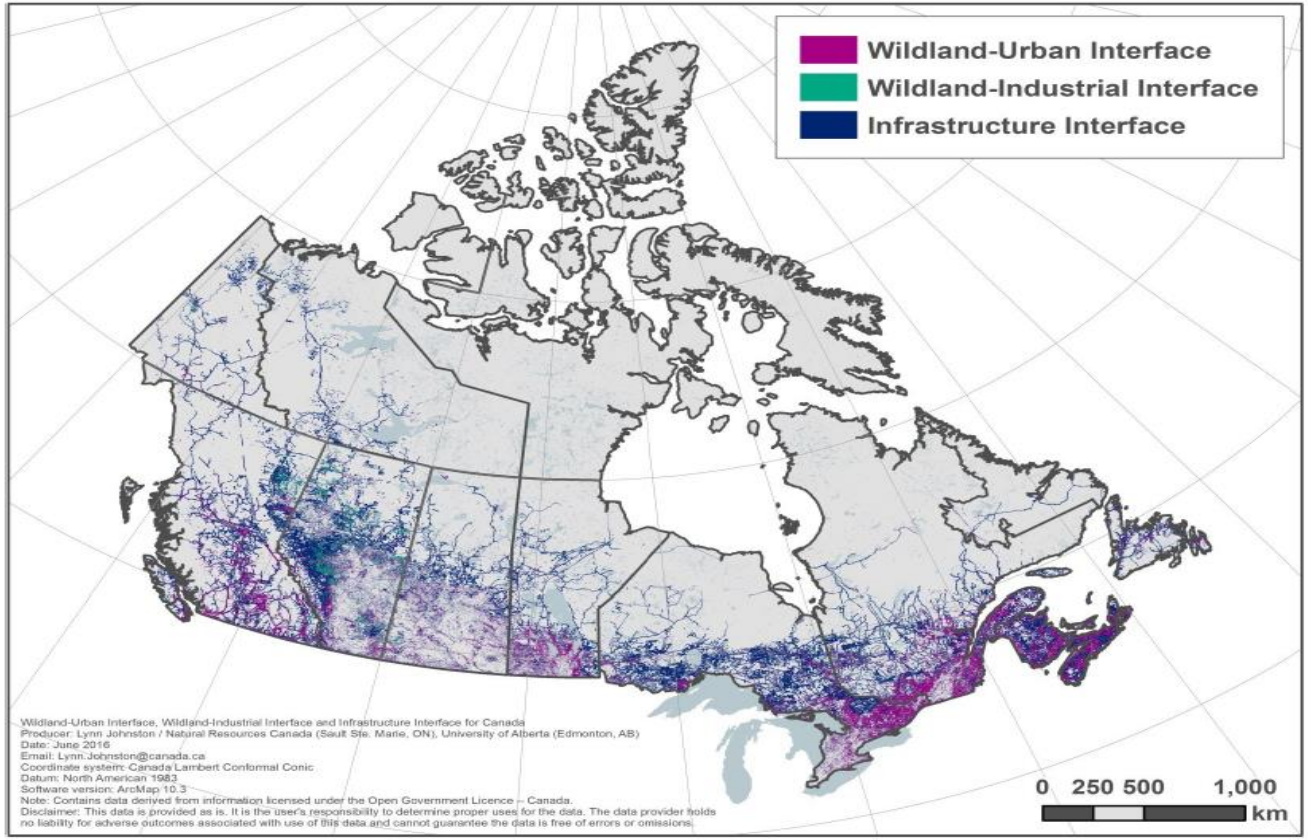
# Canadian Fire Statistics



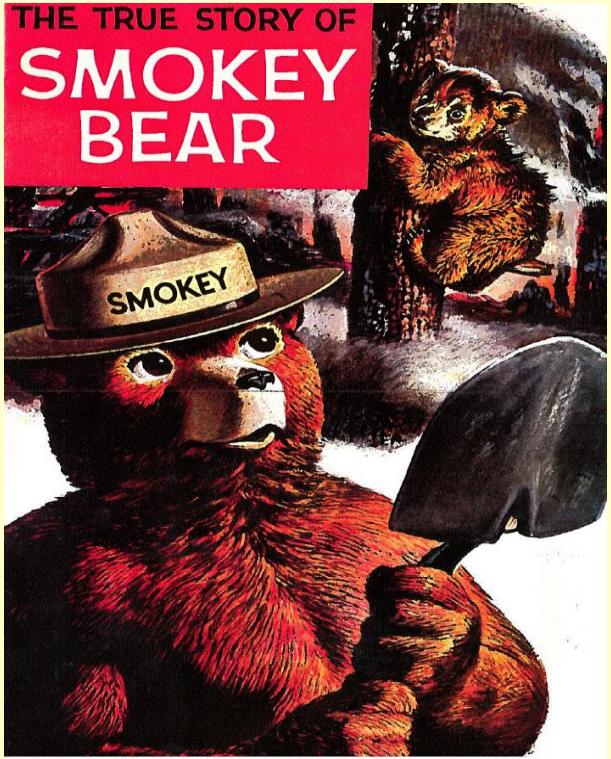

- Incomplete prior to 1970.
- Currently - average of 7000 fires a year burn 2.5 - 3 million ha – doubled since the 1970s.
- BC averages 1600 fires that burn nearly 400,000 hectares a year
- Often high intensity/high severity crown fires.
- Area burned is highly episodic:
  - 0.4 to 7.6 million ha
- Lightning fires:
  - 40% of total fires (BC ~60%)
  - represent 80-90% of area burned
- Fire size:
  - 3% of fires are >200 ha
  - represent 97% of area burned


Natural Resources Canada
Ressources naturelles Canada
Evacuations due to Wildland Fire 1980-2017
Number of evacuees (approx.)
1 - 100
101 - 1000
1001 - 10000
> 10000
Forest Fires > 200 ha
Forested Area
Data Sources:
Evacuations - Natural Resources Canada, Evacuation Database
Fire data - Natural Resources Canada, National Fire Database
0
500
1,000
1,500
2,000 km
Canada

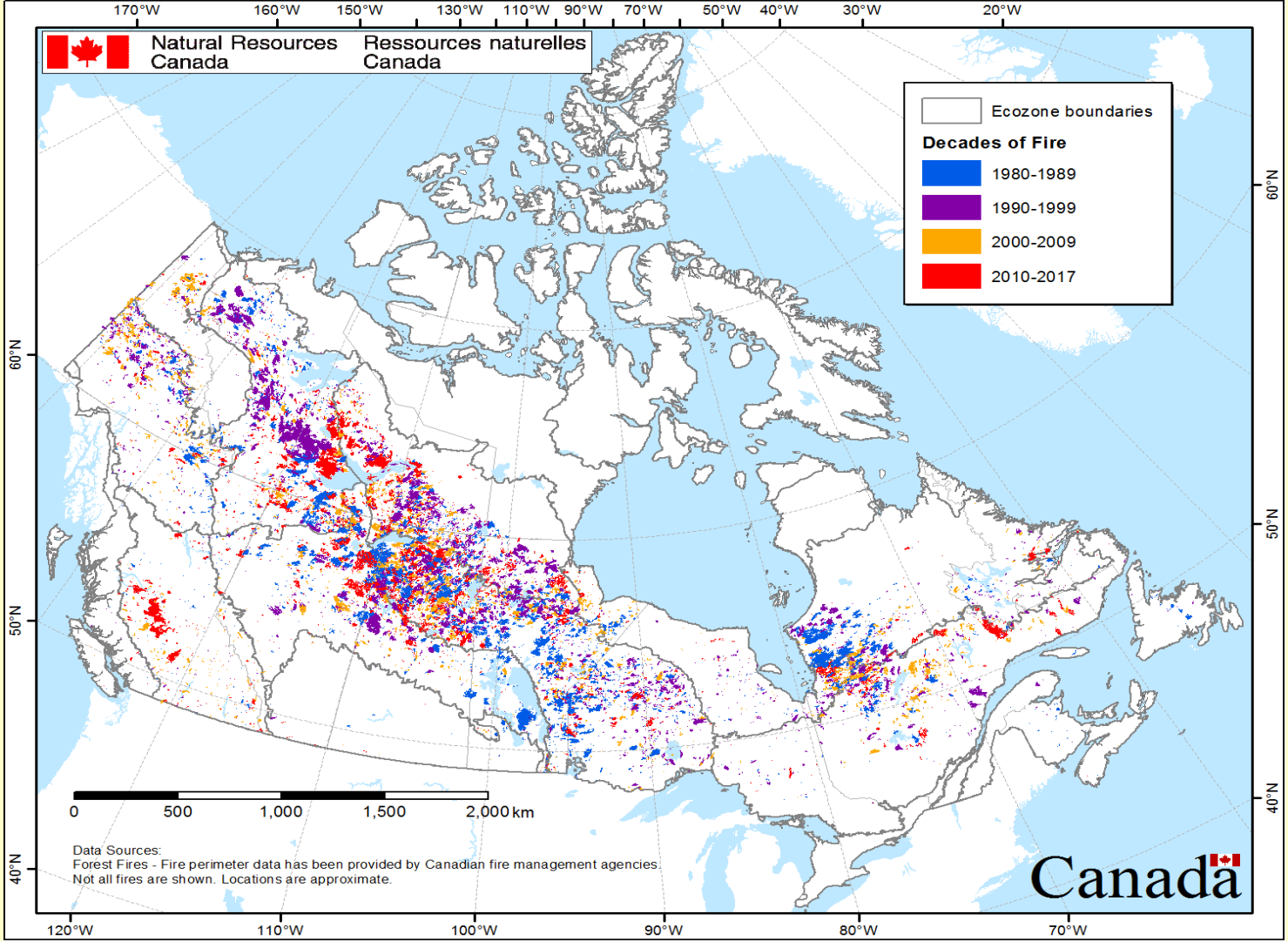
# National map of the “human-wildland interface”

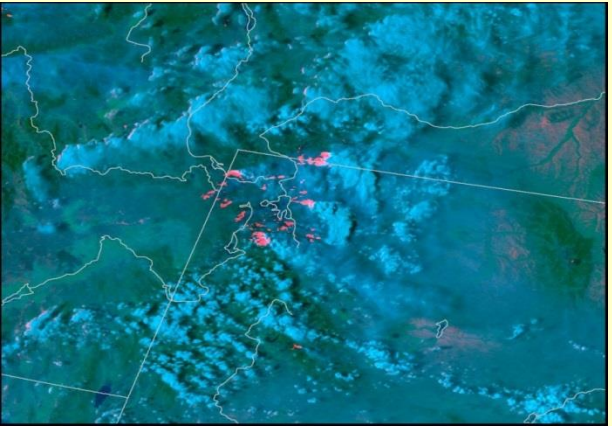


# Fire Management




- Canadian fire management agencies among best in the world.
- Canadian Forest Fire Danger Rating System.
- Initial attack but if fire escapes…
- Traditional approach has been total fire suppression – now some regions use appropriate response.


Natural Resources Canada
Ressources naturelles Canada
Ecozone boundaries
Decades of Fire
1980-1989
1990-1999
2000-2009
2010-2017
170°W
160°W
150°W
130°W
110°W
90°W
70°W
50°W
40°W
30°W
20°W
60°N
50°N
40°N
120°W
110°W
100°W
90°W
80°W
70°W
0
500
1,000
1,500
2,000 km
Data Sources:
Forest Fires - Fire perimeter data has been provided by Canadian fire management agencies.
Not all fires are shown. Locations are approximate.
Canada



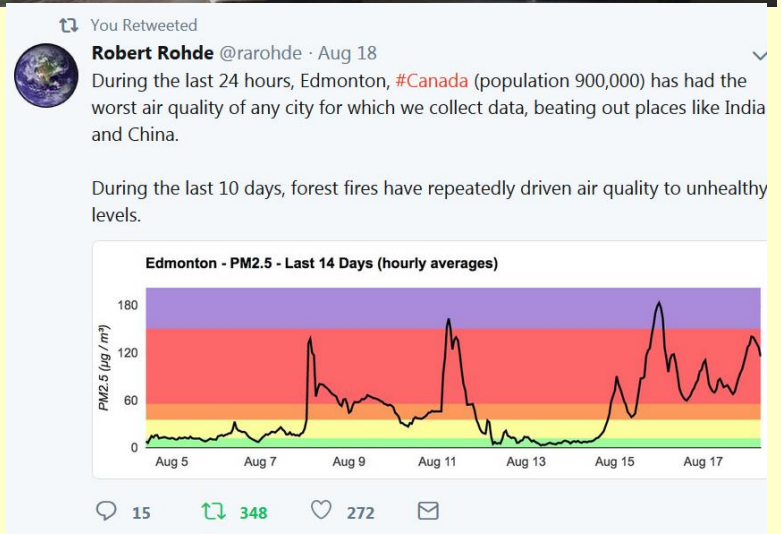
# Forest Fires – 3 Ingredients

- Fuel – type, loading, moisture, structure.
- Ignition - human and lightning
- Weather – hot, dry windy.  Extreme weather

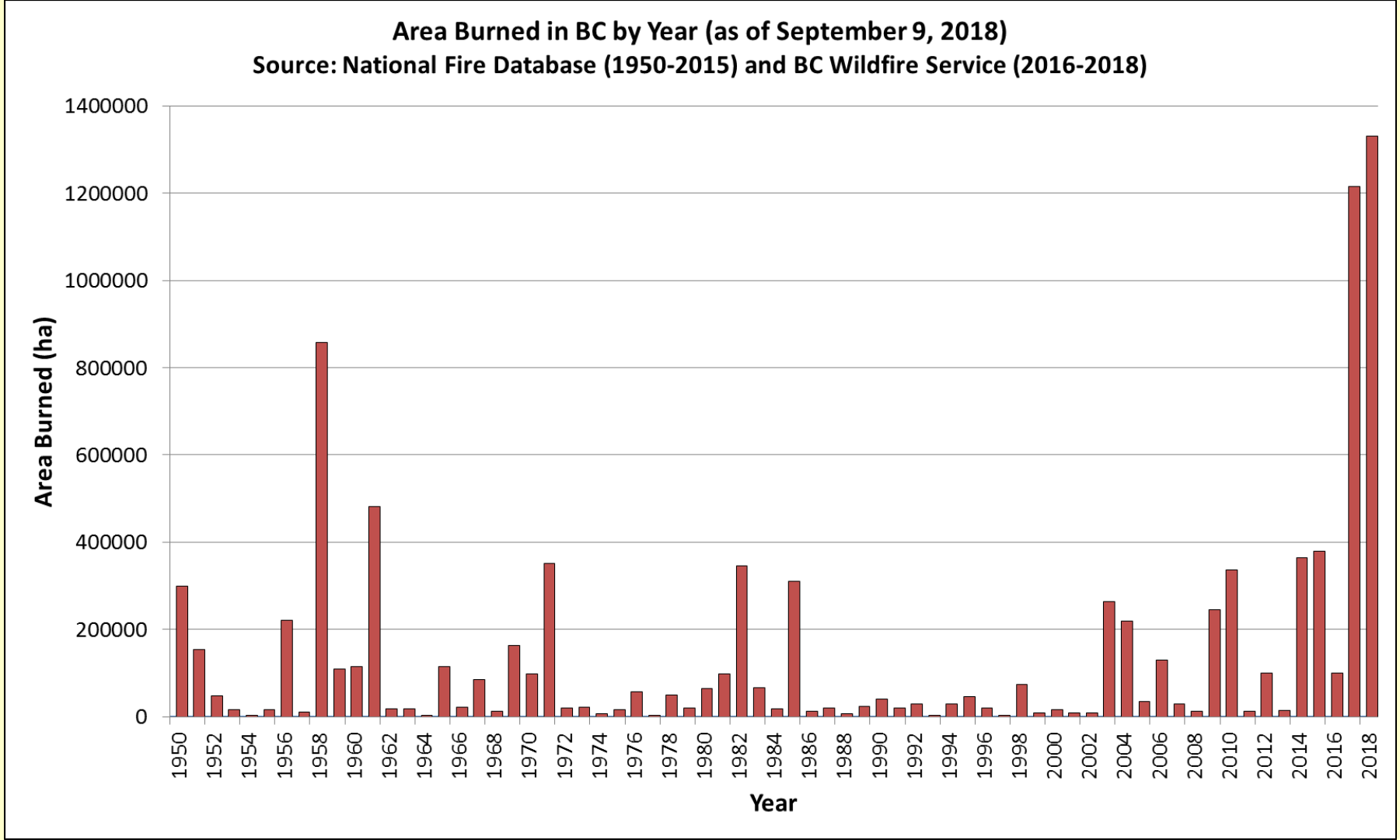

# Fire Issues

- An average of $800 million spent by fire management agencies in Canada a year on direct fire fighting costs. These costs are rising
- Health and safety of Canadians – evacuations – smoke.
- Property and timber losses due to fire.
- Balancing the positive and negative aspects of fire.
- Traditional approaches to fire suppression (e.g., crews, air tankers) may be reaching their limit of economic and physical effectiveness.

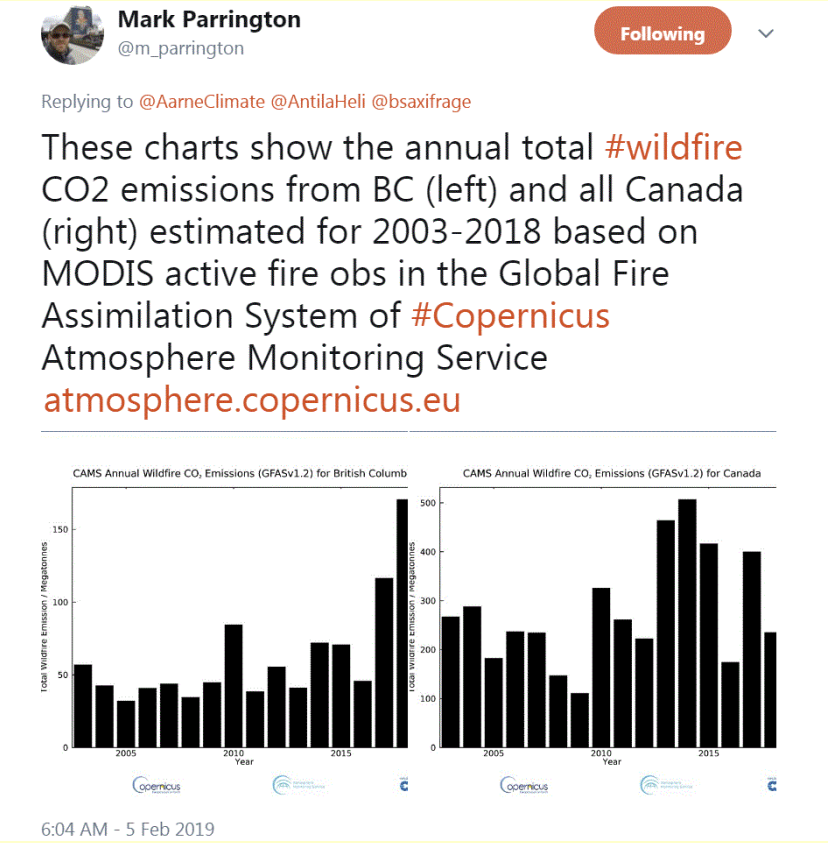
# Fire Impacts



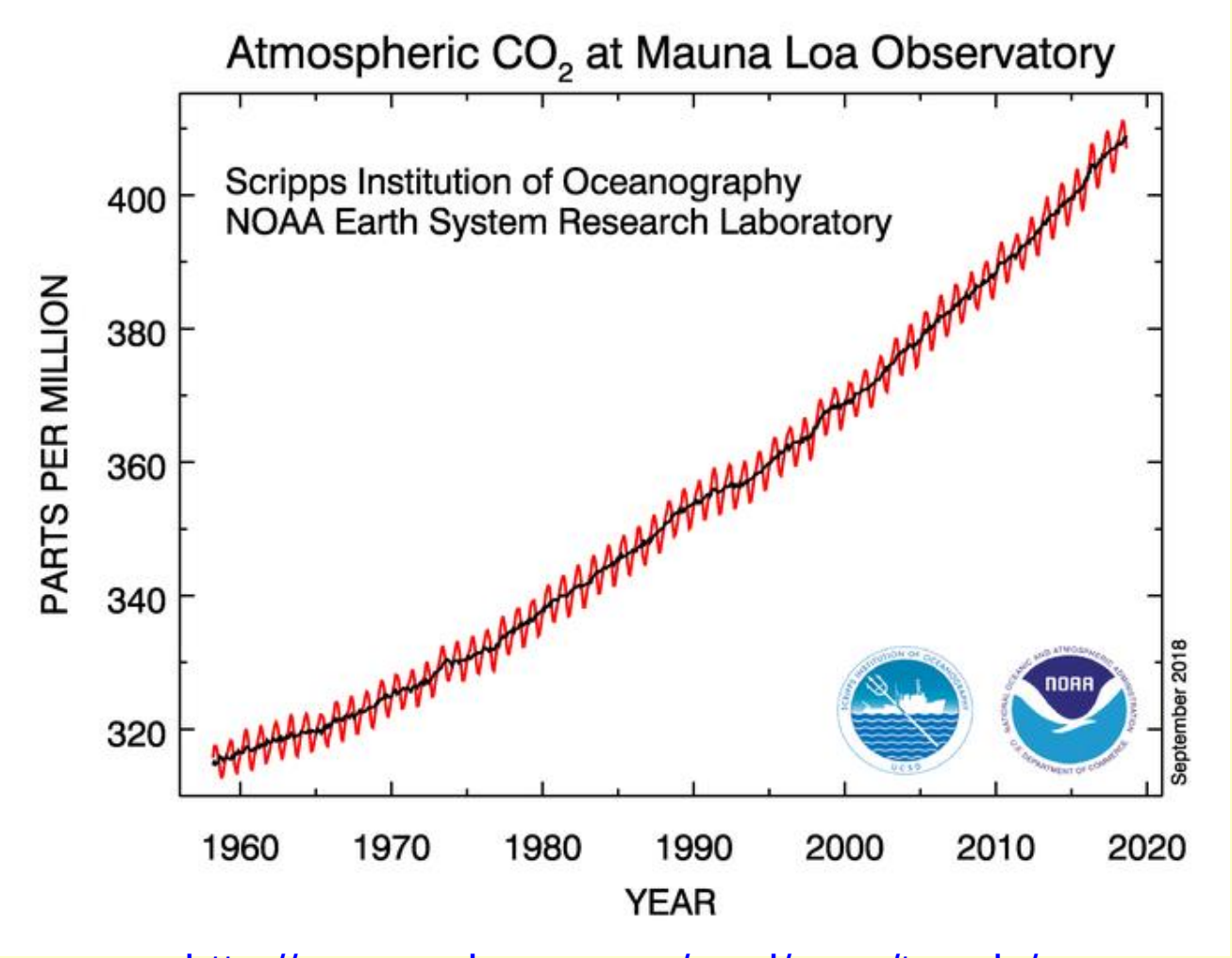

- Location, location location
- Slave Lake May 2011
- Fort McMurray 2016.
- 2017 Chile, Portugal, Spain, South Africa, Ireland, Greenland, USA (CA) and Canada (BC, AB, NT, SK and MB).
- 2018 Greece, California, England, Sweden, ON and BC
- Globally, smoke related fatalities estimated at 330,000 per year


Area Burned in BC by Year (as of September 9, 2018)
Source: National Fire Database (1950-2015) and BC Wildfire Service (2016-2018)
Area Burned (ha)
1400000
1200000
1000000
800000
600000
400000
200000
0
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year

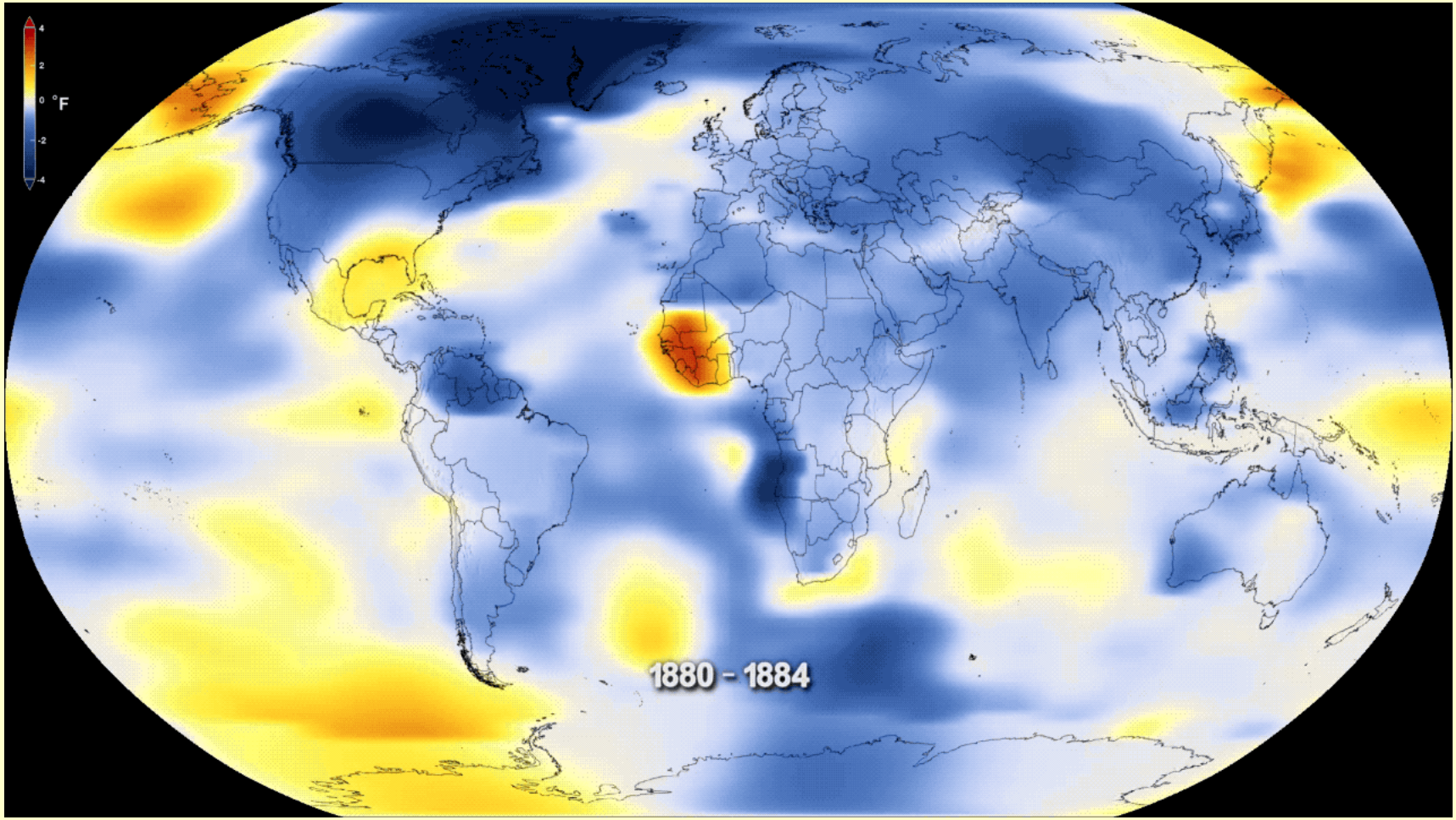
# Wildfire Emissions

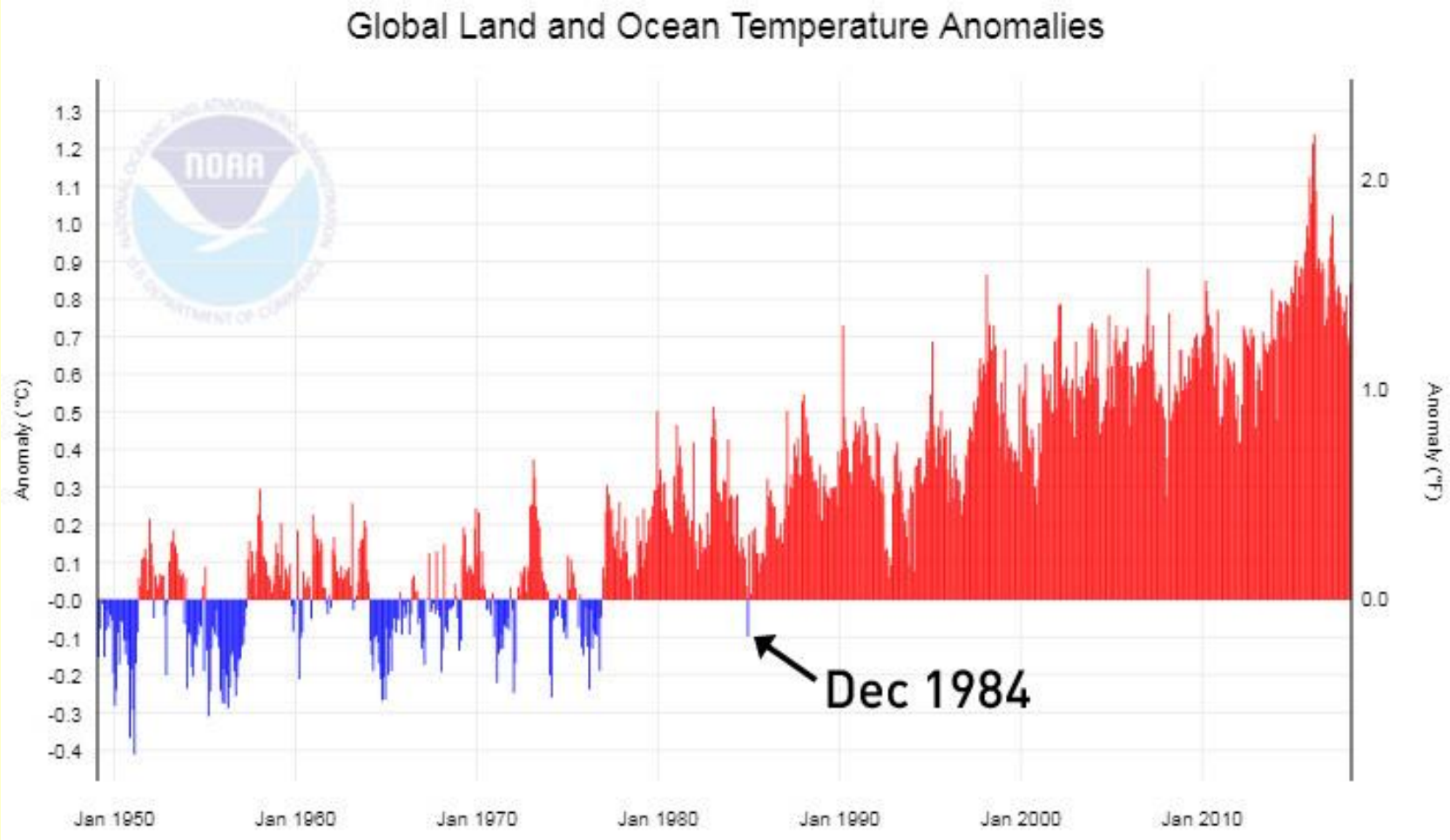



- **Wildfire emission depend on the area burned, fuel consumed, combustion completeness (efficiency) and Emission Factor (amount of pollutant released (g per kg))**
- **Significant variations over time and space.**
- **Combustion – flaming and smouldering give rise to this variability.**
- **Major pollutant is PM. Particulates can be transported over long distances. Aged smoke particles often pose a greater health risk.**
- **Forests recently carbon sources not sinks**

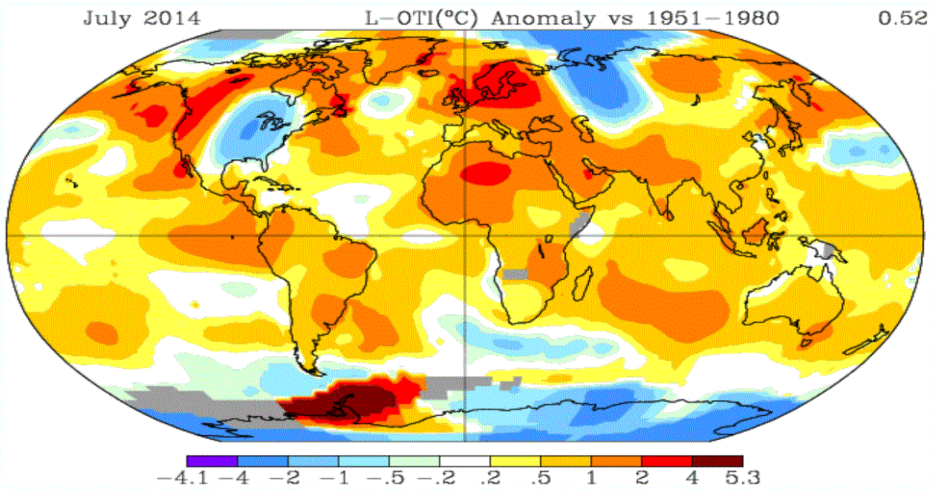


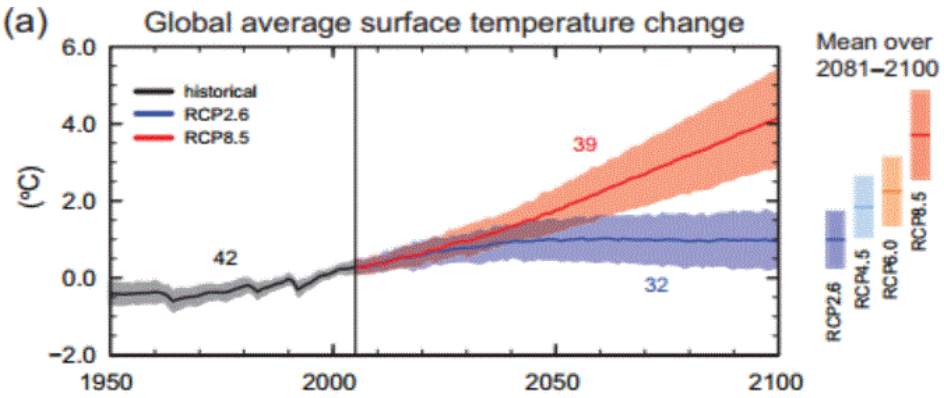

http://www.esrl.noaa.gov/gmd/ccgg/trends/


4
2
0
-2
-4
°F
1880 – 1884


Global Land and Ocean Temperature Anomalies
Anomaly (°C)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
-0.1
-0.2
-0.3
-0.4
Anomaly (°F)
2.0
1.0
0.0
Dec 1984
Jan 1950
Jan 1960
Jan 1970
Jan 1980
Jan 1990
Jan 2000
Jan 2010

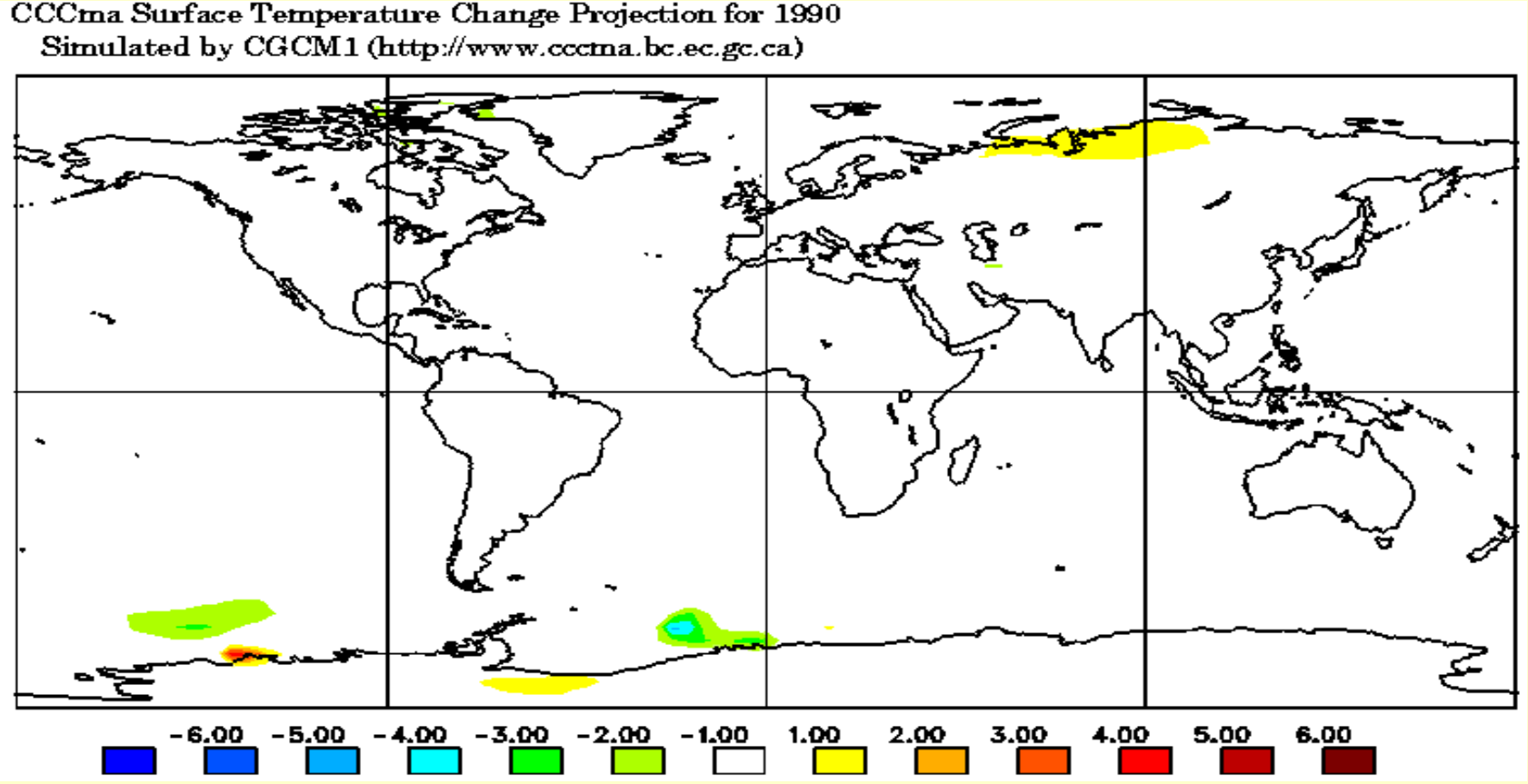
# Climate Change Projections



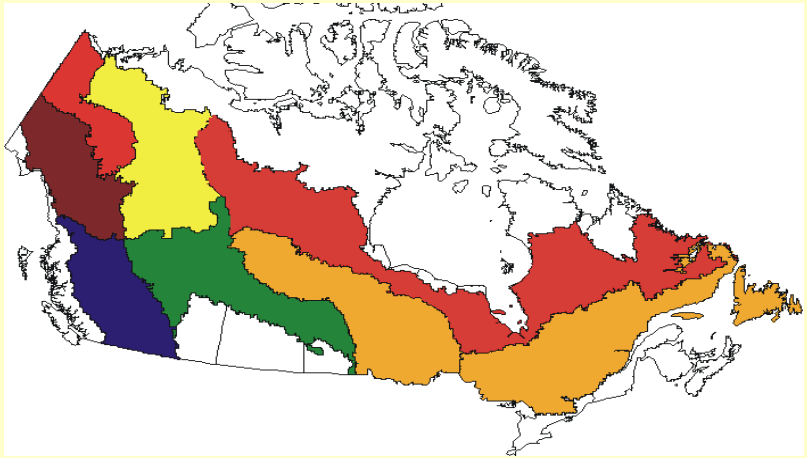




- GCMs project up to a $6^0$ C increase in global mean temperature by 2100.
- Greatest increases will be at high latitudes, over land and in winter/spring except the Arctic Ocean when seasonally ice-free.
- Projected increases in extreme weather(e.g., heat waves, drought, floods, wind storms and ice storms).
- Spatial and temporal variability in climate change.

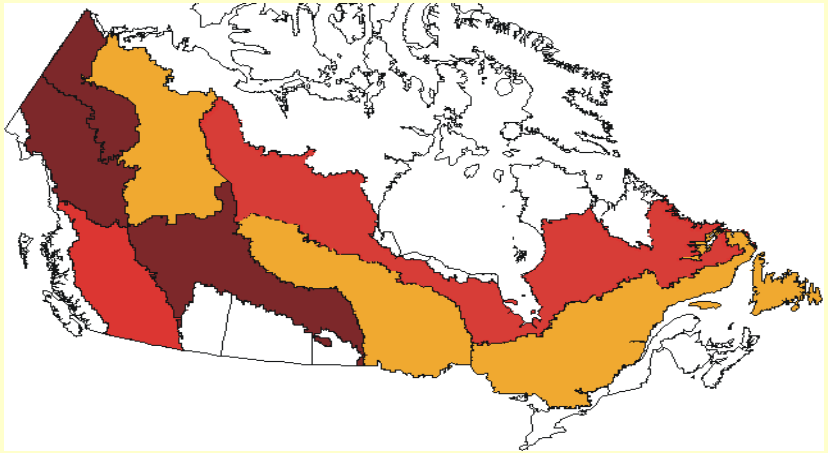
# Projected temperature changes vary considerably from year-to-year



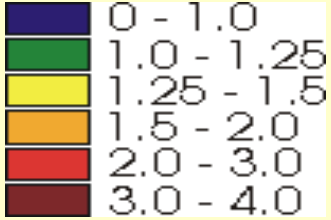
# Area Burned Projections



Canadian –3x$CO_2$



Hadley –3x$CO_2$

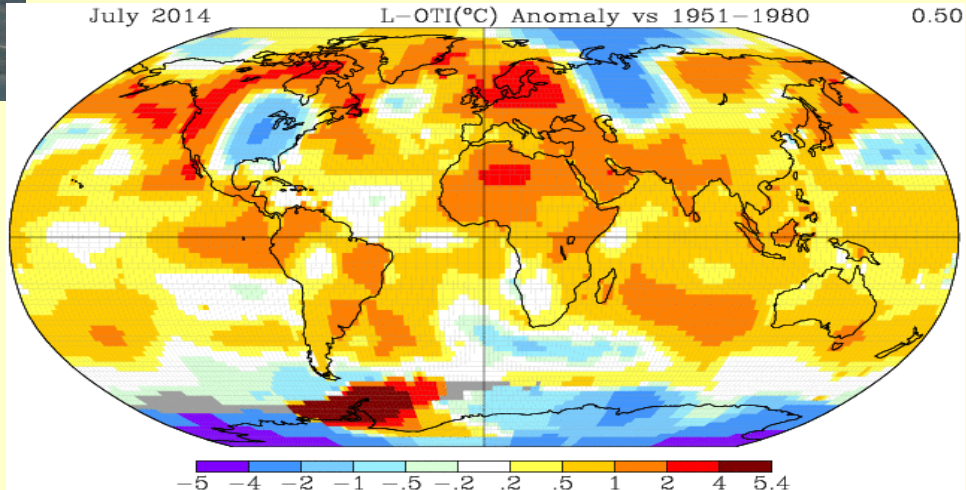



**Projections of area burned based on weather/fire danger relationships suggest a 75-120% increase in area burned by the end of this century according to the Canadian and Hadley models respectively**

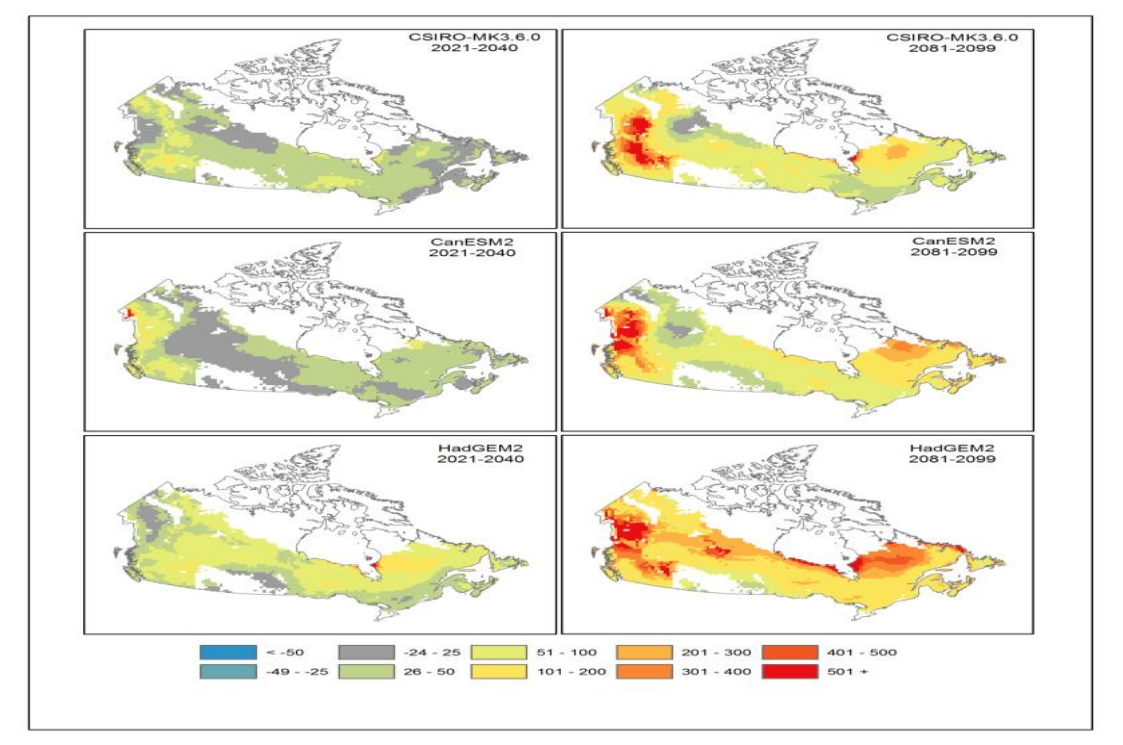
# Fire & Temperature

Photo credit: Government of the Northwest Territories

- Drier fuels
- Lightning
- Fire season



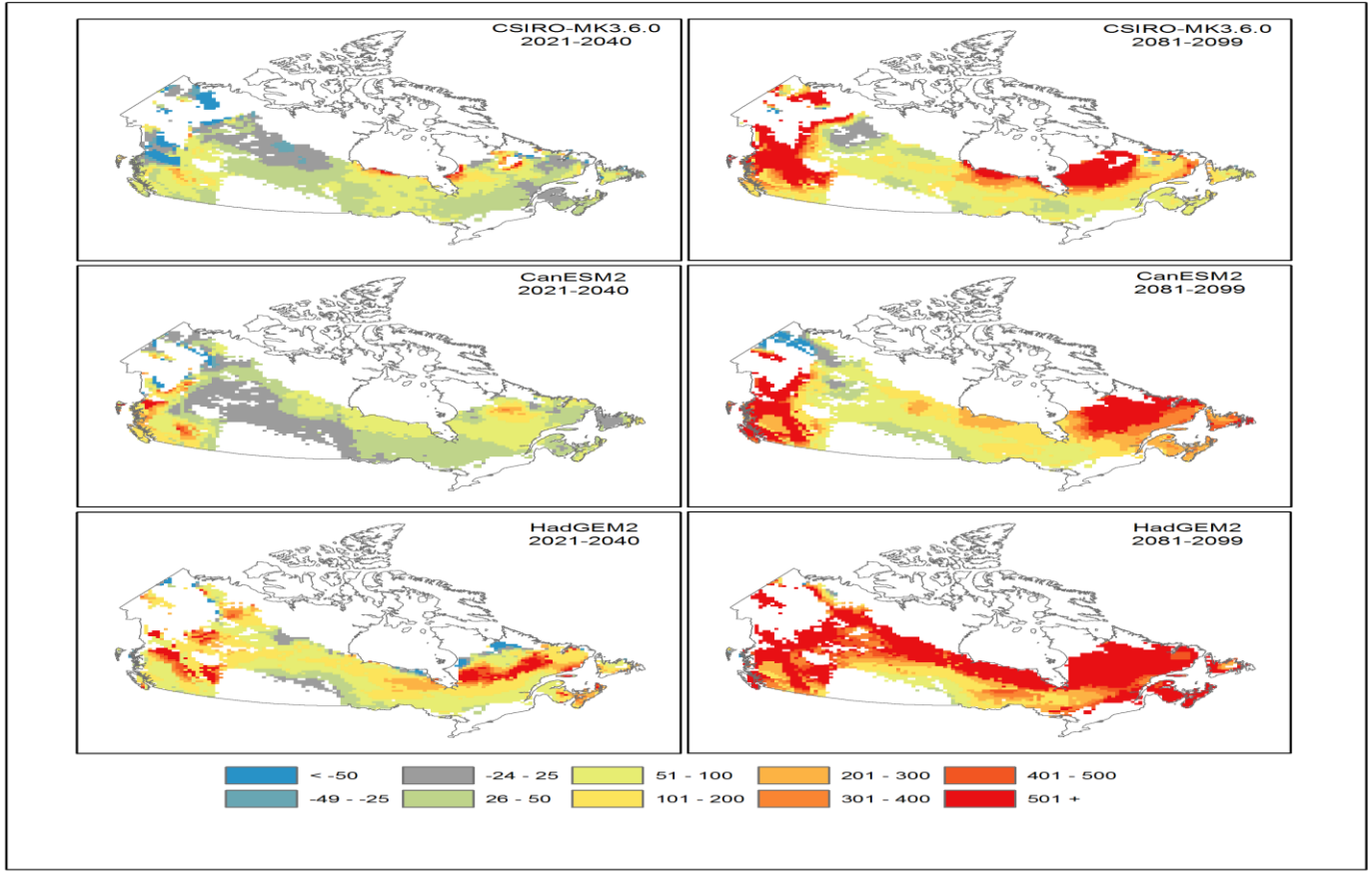
# Surface Fuel Consumption




Earlier work suggested that most of the increase in wildfire emissions were due to increased area burned. This more recent work suggests that fire intensity and fuel consumption will increase significantly.

Wotton, B.M., Flannigan, M.D. and Marshall, G. 2017. Potential climate change impacts on fire intensity and key wildfire suppression thresholds in Canada. Environmental Research Letters. 12 (2017) 095003, https://doi.org/10.1088/1748-9326/aa7e6e

# Crown Fuel Consumption

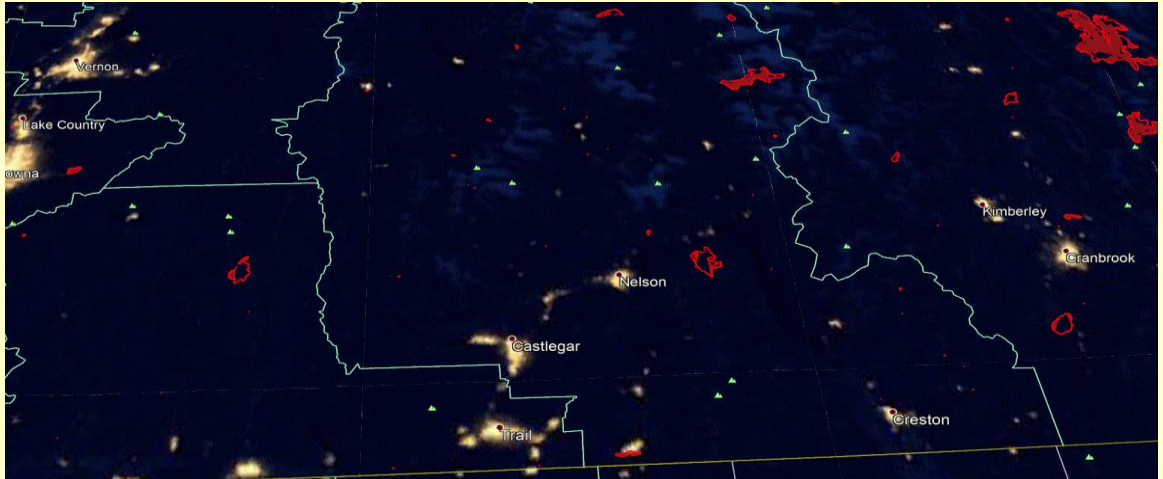


# How can we manage wildland fire

- Fuel, ignitions and hot, dry windy weather are part of our future so we need to learn to live with fire.
- That is, we have to allow fire on the landscape but when and where we want it (Appropriate Response).
- From the wildland fire perspective 3 ingredients but we can only manage the fuel and human-caused fires.
- Context for Canada – climate change = more extreme weather = more fire on the landscape.
- FireSmart Canada – fuel management, planning, education, cooperation, training and development.

# Manage wildland fire in the future

- Update the Canadian Forest Fire Danger Rating System.
- Need for an Early Warning System
- -Use machine learning (AI) to identify severe fire weather episodes (Self Organized Maps).
- Use machine learning in building fire occurrence prediction systems.
- Enhance existing fire decision support systems
- More remote sensing
- Focus on community zones( sprinklers) and Initial Attack
- Explore fuel management, in concert with harvesting, grazing  and carbon management.
- Role of forest management and other disturbances for fire management?
- Emergency management phases – prevention, mitigation, preparedness, response, recovery (review)

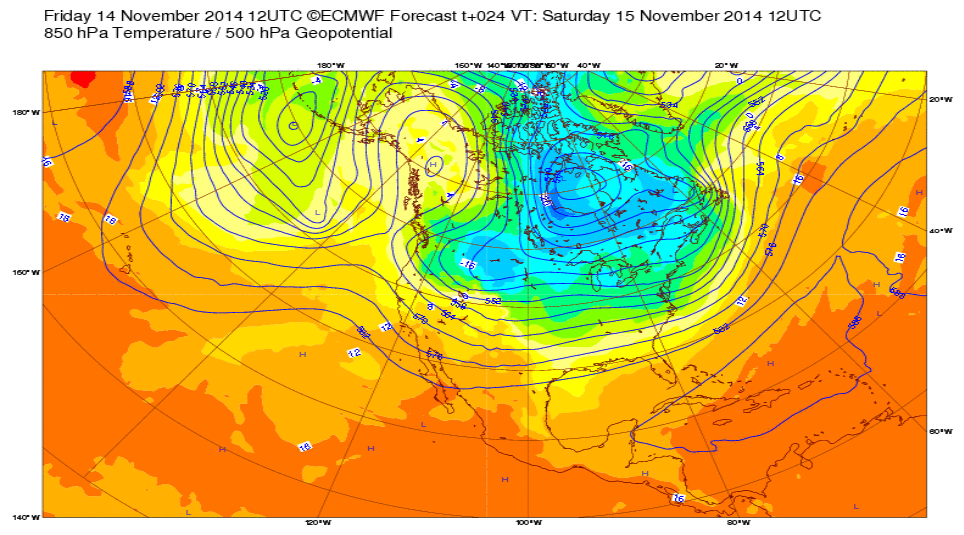



Courtesy of Steve Taylor CFS

# Prescribed burns versus wildfires

- Fire people argue for PBs -Little smoke under controlled conditions or lots of smoke - uncontrolled
- Where are the PBs located can be problematic. Even if it is a little smoke if it is close to the community that could be a problem. Alternate approaches include mechanical or grazing could be used.
- Balance – PBs away from communities and other approaches near communities
- Complicated - Needs more research

# A wild card – the Jet Stream


- **Band of fast moving air – energy derived from the temperature difference between equatorial regions and polar regions.**
- **Jet streams determine the strength and movement of the synoptic weather systems.**
- **Climate change is causing a weakened of the jet stream as the temperature difference between the equator and poles decreases.**
- **Atmospheric patterns – stagnate, meandering – more extremes – droughts, floods, heat and cold.**
- **Important for BC as recent suggests a strengthening and persistence of a west coast ridge…**
- **Can BC have 3 bad fire seasons in a row? Over 4% of the forested area of BC burned in the last 2 years.**

# Summary

- Fire and weather are strongly linked
- Changes in forest fires may be the greatest early impact of climate change on forests
- Fire activity will increase in a changing climate, but will be variable in time and space
- Longer fire season.

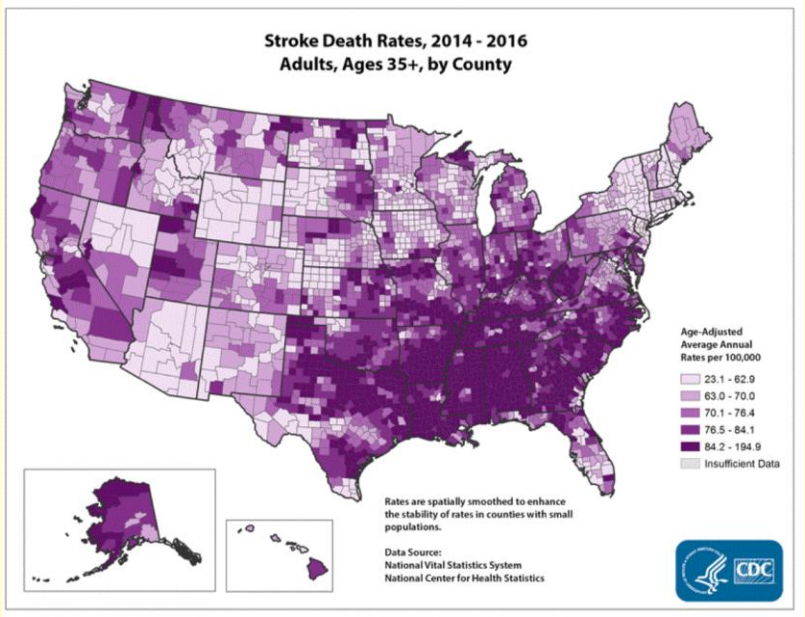
# Summary - 2

- More fire occurrence, more crown fires (higher intensity), increased fuel consumption and more area burned leading significantly more emissions.
- More fire activity in the future and our fire management approaches have to adapt to this new reality.
- May be entering new territory with no historical analogues. The unknown unknowns. We can not rely on only our experience.
- Fire and society interactions will increase in the future. We need to learn to live with fire and smoke.



@CanadaWildfire https://www.canadawildfire.org/

# Wildfire Emissions




- **Wildfire emission depend on the area burned, fuel consumed, combustion completeness (efficiency) and Emission Factor (amount of pollutant released (g per kg))**
- **Significant variations over time and space.**
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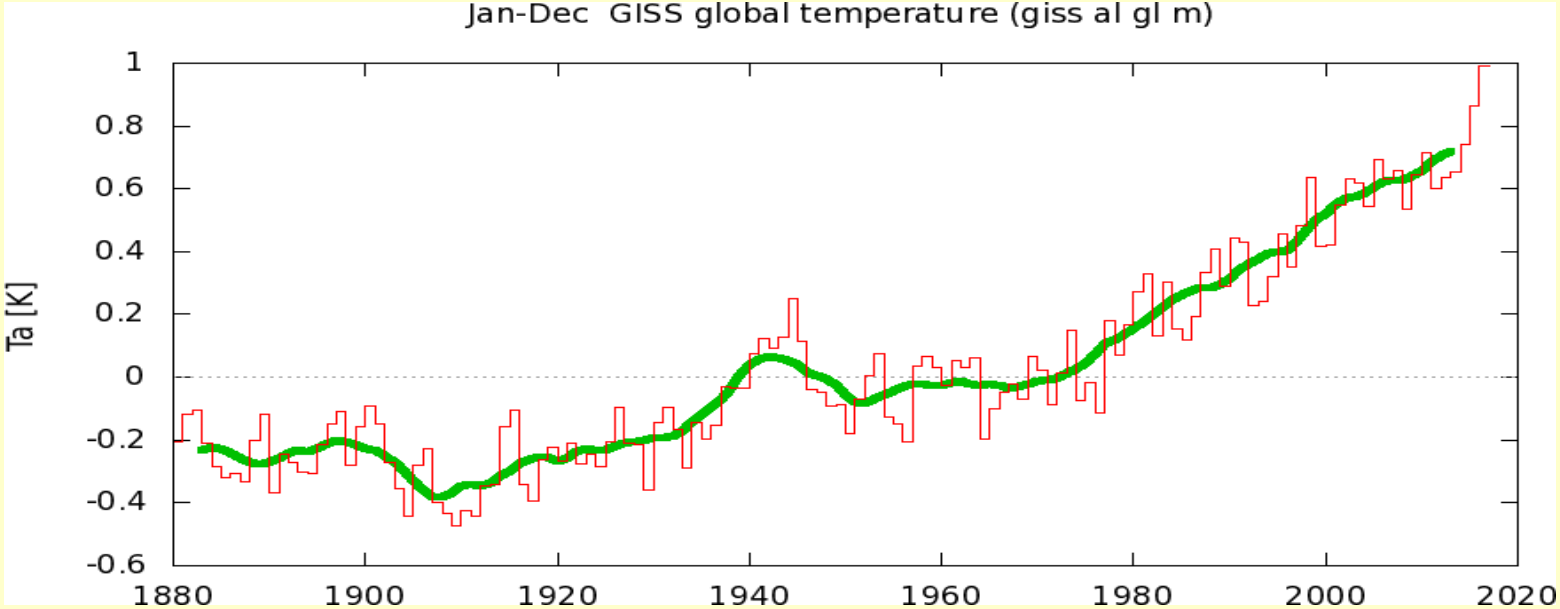
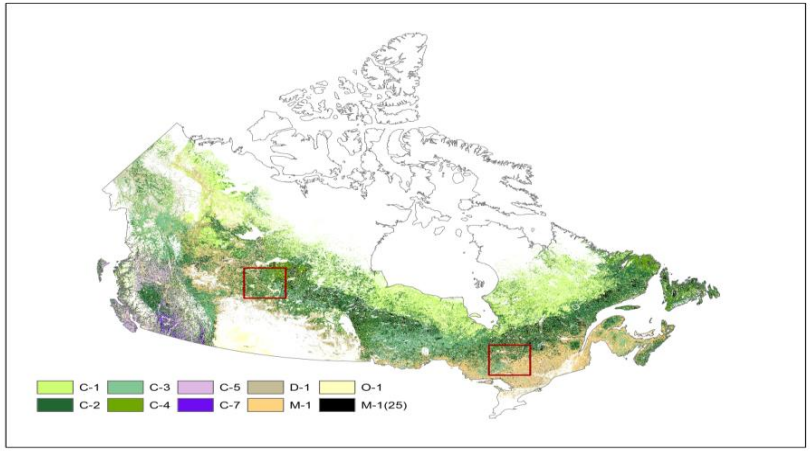
https://eos.org/articles/stroke-deaths-rise-life-expectancy-falls-with-polluted-air?utm_source=eos&utm_medium=email&utm_campaign=EosBuzz020119

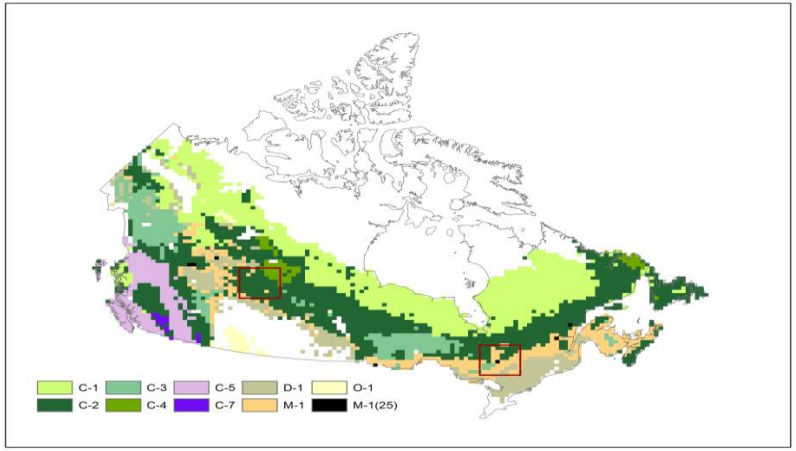

Jan-Dec GISS global temperature (giss al gl m)
Ta [K]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1880
1900
1920
1940
1960
1980
2000
2020

# Methods - 1

- Three GCMs – CanESM2, HadGEM2-ES, CSIRO-Mk3.6.0
- Three RCPs – RCP2.6, RCP4.5, RCP8.5
- Calculated the Canadian Fire Weather Index (FWI) System indexes for the period 1970 - 2099. Baseline 1971-2000.
- Canadian FWI System is a weather based system – temperature, relative humidity, wind speed and precipitation.

# Methods - 2




- **Calculate the fire intensity, rate of spread, depth of burn, fuel consumption, crown fraction burned using the Canadian Fire Behaviour Prediction (FBP) System as well as days above specified thresholds (e.g., HFI > 2,000 and 10,000 KW/m)**

- **Fuels – used a national fuel classification (250 m) for the forested regions of Canada. Aggregated fuels to a predominate fuel type for 40 km by 40 km cells.**

- **Time periods include baseline as well as 2021-2040 and 2081-2099.**

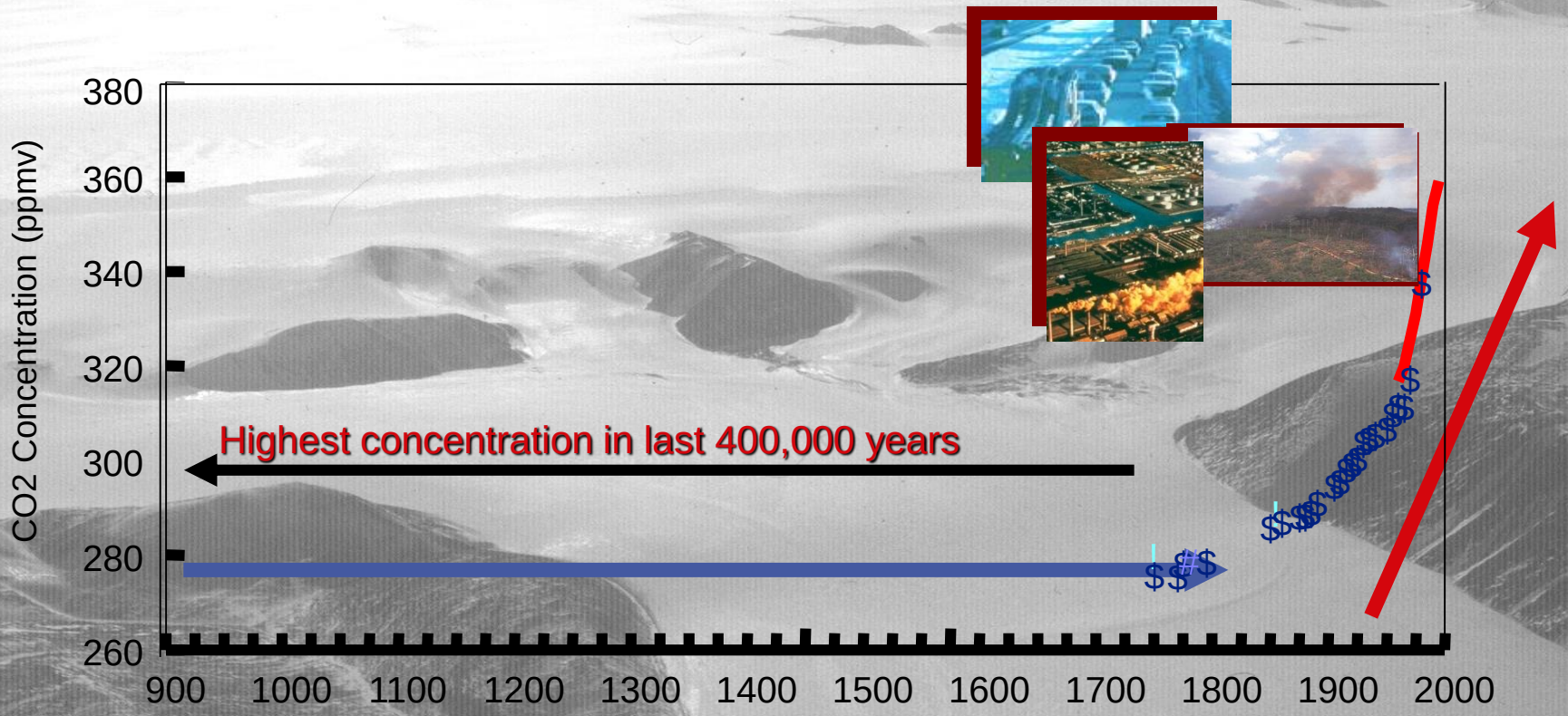
# Escaped Fires….

- Increased fire intensity may lead to more escapes

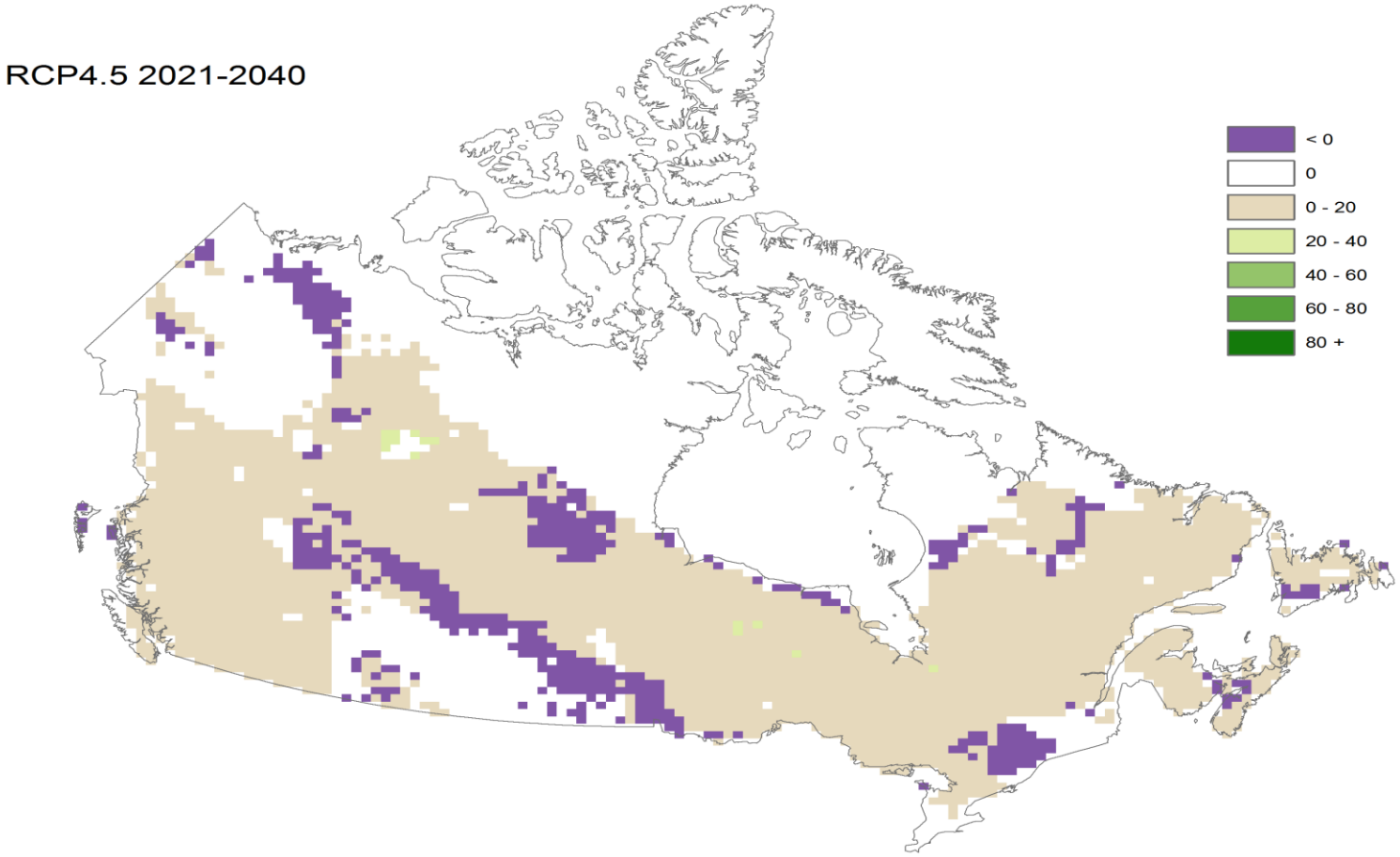
Extended attack simulation showed that projected intensity increases resulted in very substantial increases in burned area

  – Driven by the change in frequency of being above suppression intensity thresholds

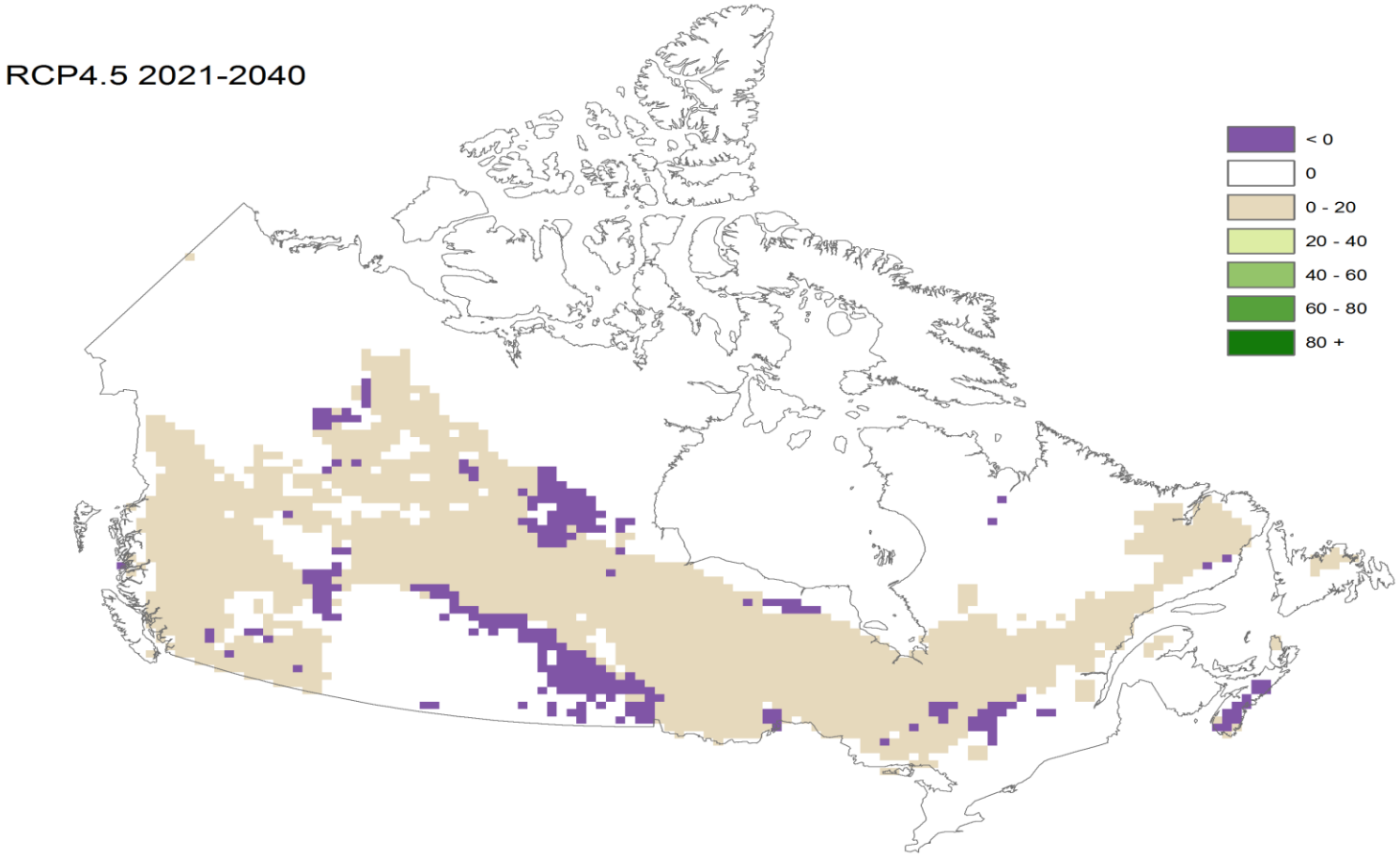
# CO2 concentrations are now unprecedented in at least the past 400,000 years



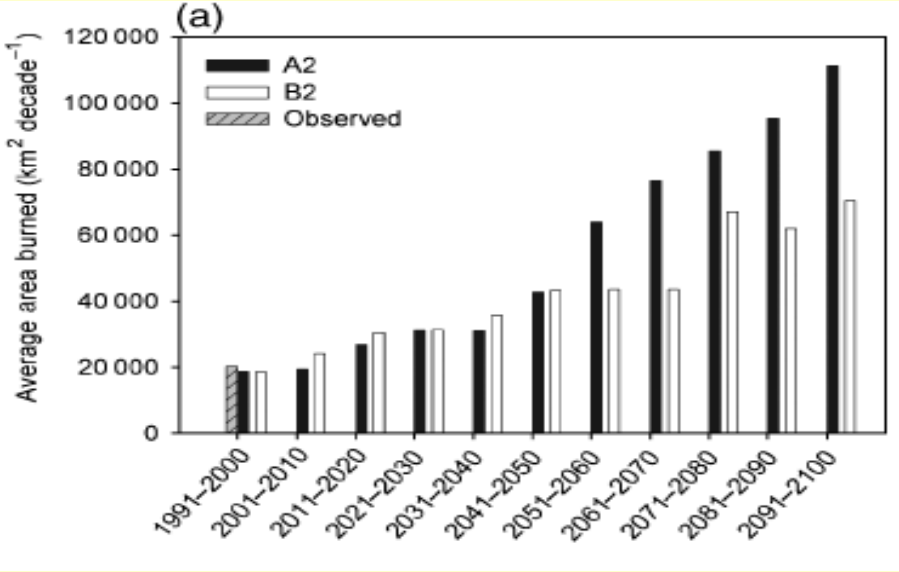
# Change in days with HFI > 2,000 kW/m



# Change in days with HFI > 10,000 kW/m



# Area Burned – Alaska W. Canada




- Predicted mean annual area burned (km$^2$/yr) per decade for Alaska and western Canada driven ( by the NCEP model development datasets(1990–2005) and the CGCM2 A2 and B2 climate scenarios (2006–2100).

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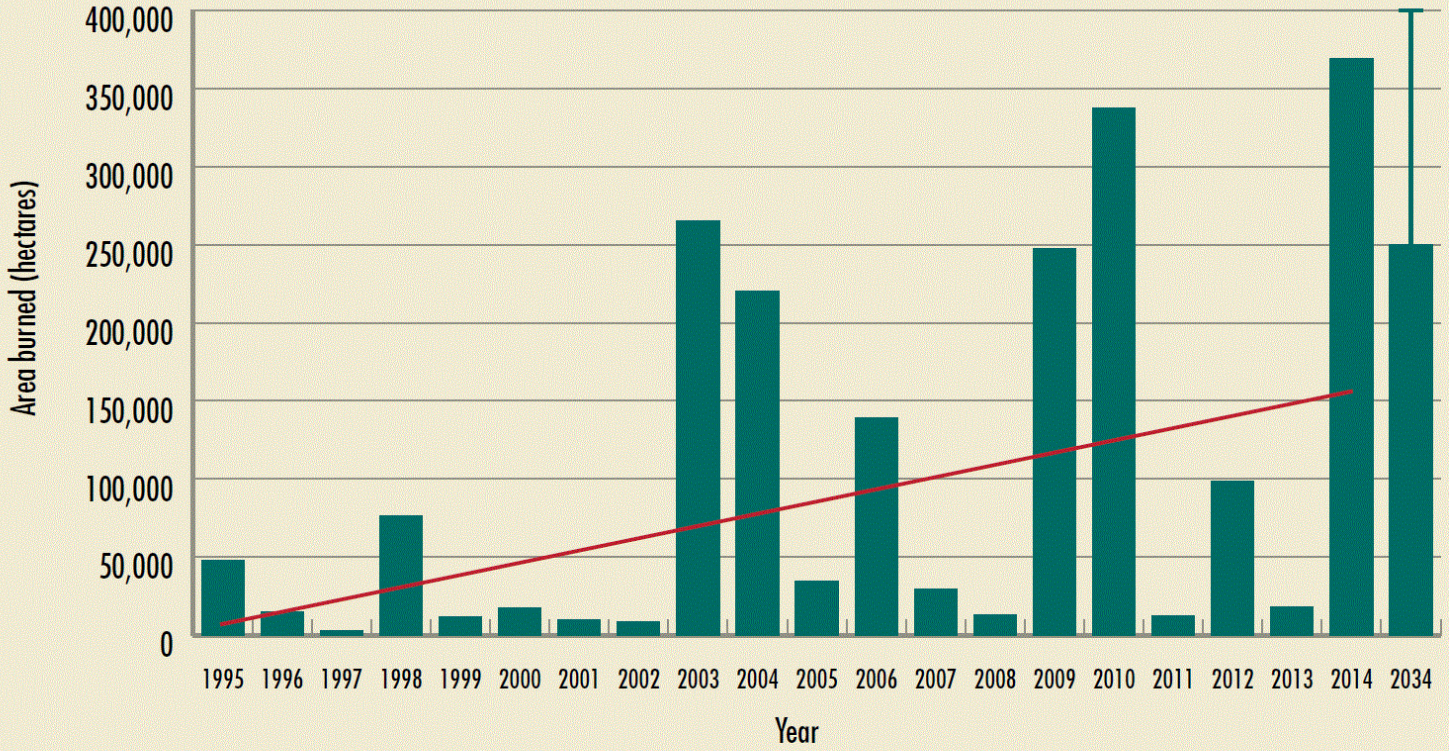
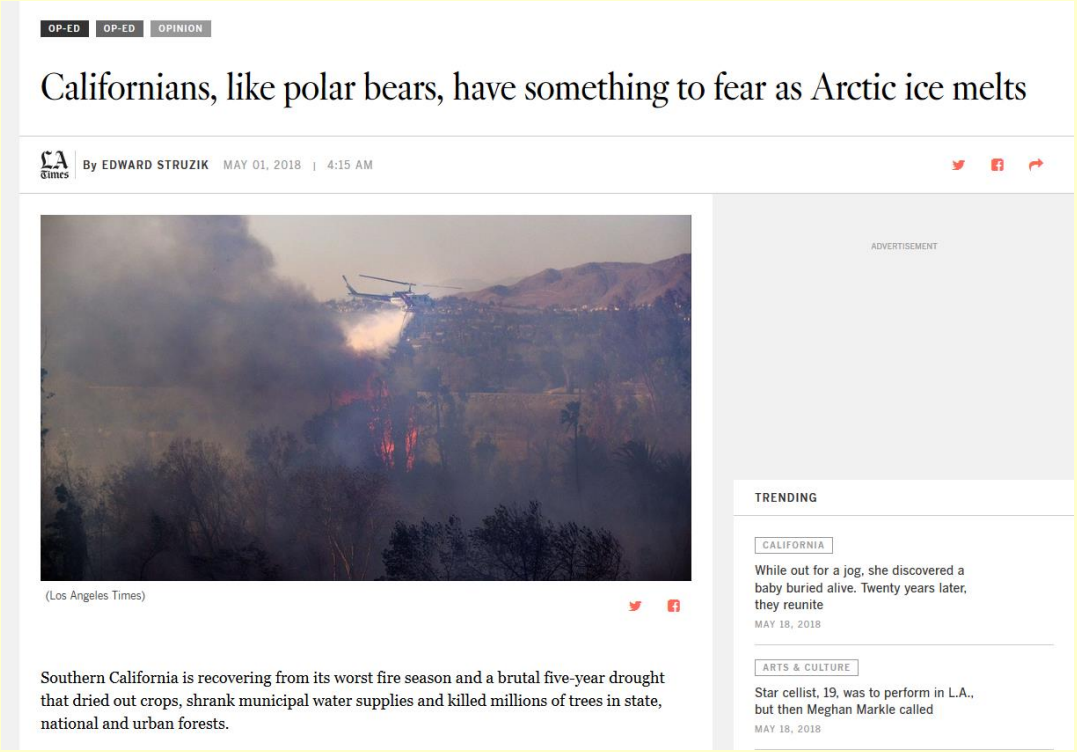
- http://rammb.cira.colostate.edu/ramsdis/online/loop.asp?data_folder=loop_of_the_day/goes-16/20170811000000&number_of_images_to_display=200&loop_speed_ms=100
- https://www.vox.com/science-and-health/2017/11/17/16665966/nasa-visualization-aerosols-hurricanes

**Exhibit 21:** Area burned from B.C. wildfires 1995-2014, projection to 2034




Source: British Columbia Wildfire Service, Ministry of Forests, Lands, Natural Resource Operations and Rural Development

# Regional Variability



OP-ED OP-ED OPINION

Californians, like polar bears, have something to fear as Arctic ice melts

LA Times | By EDWARD STRUZIK MAY 01, 2018 | 4:15 AM

(Los Angeles Times)

Southern California is recovering from its worst fire season and a brutal five-year drought that dried out crops, shrank municipal water supplies and killed millions of trees in state, national and urban forests.

ADVERTISEMENT

TRENDING

CALIFORNIA

While out for a jog, she discovered a baby buried alive. Twenty years later, they reunite

MAY 18, 2018

ARTS & CULTURE

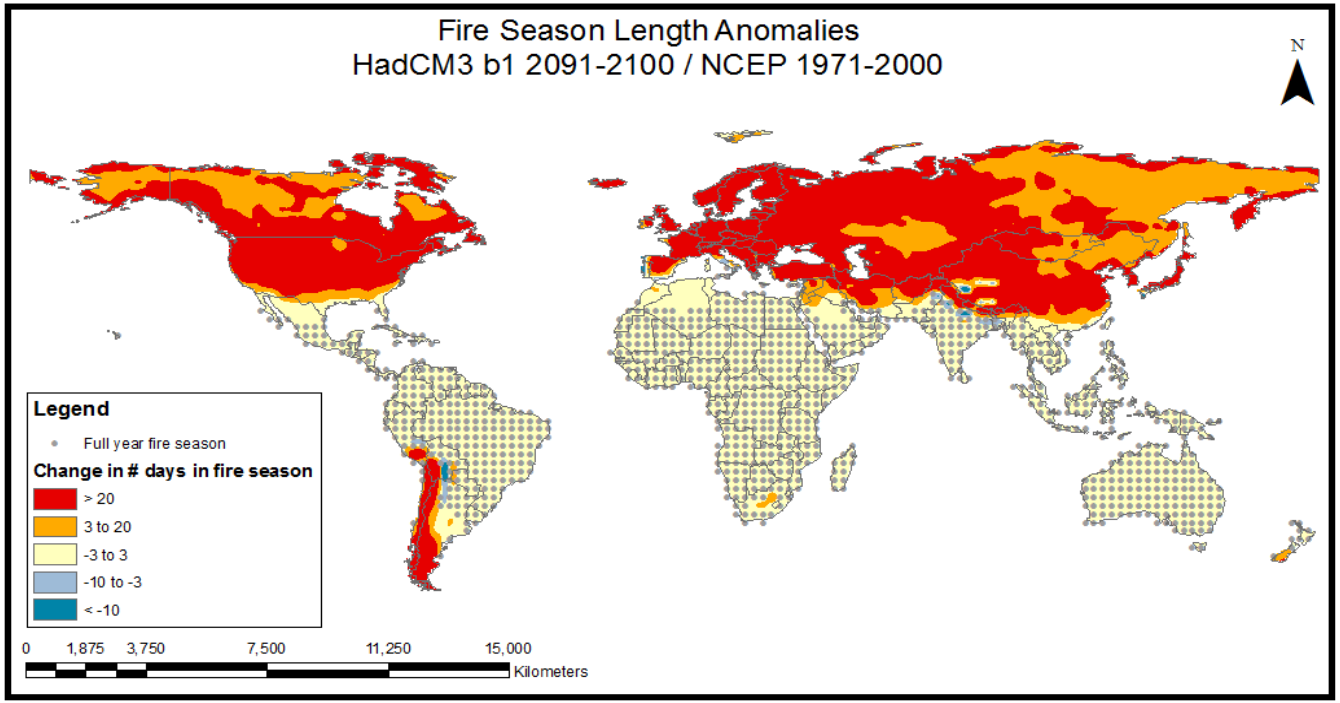
Star cellist, 19, was to perform in L.A., but then Meghan Markle called

MAY 18, 2018

- **Possibility of semi-permanent (blocking) patterns of the synoptic weather systems.**
- **More extremes – drought and fire and precipitation and flooding depending on where the ridges and troughs are.**

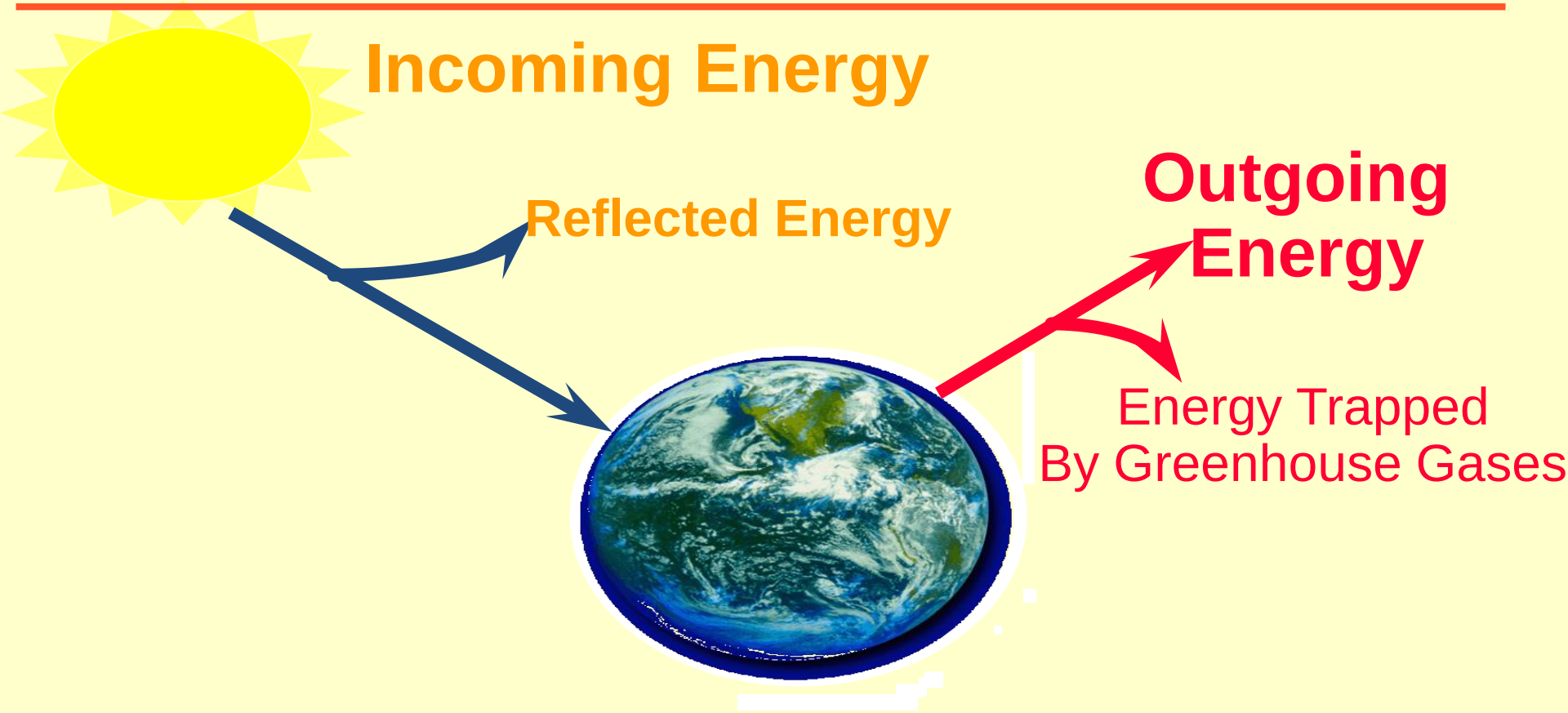
# Fire Regime

- Extent/size
- Intensity
- Type (surface, ground, crown)
- Frequency
- Seasonality
- Severity (impact on the ecosystem, mortality, depth of burn, fuel consumption)

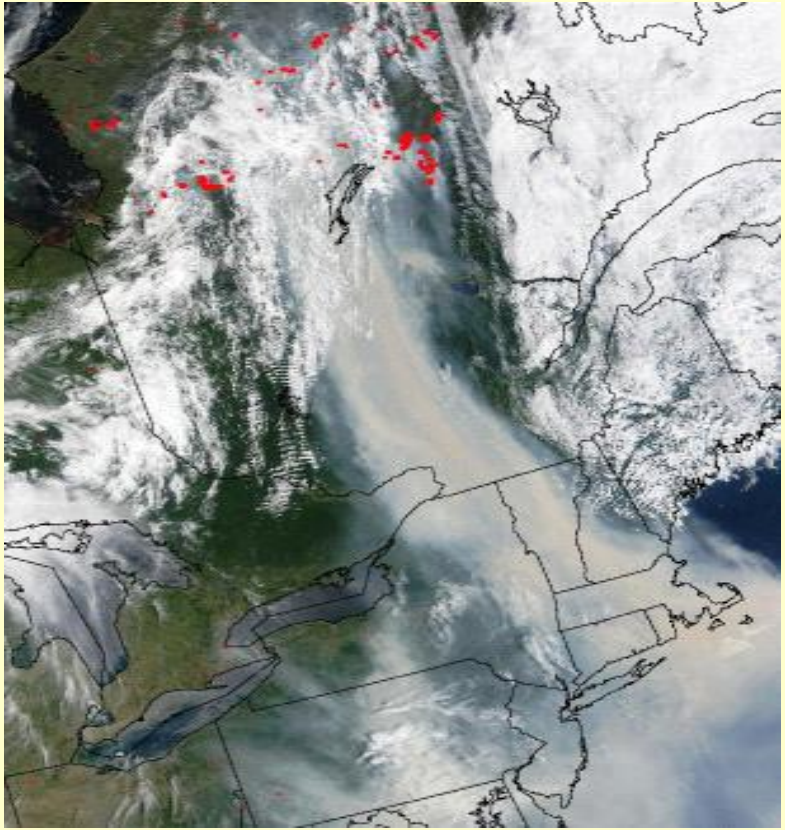



Jain, P., Wang, X. and Flannigan, M. 2017.Trend analysis of fire season length and extreme fire weather in North America between 1979-2015. International Journal of Wildland Fire. 26:1009-1020. https://doi.org/10.1071/WF17008.

# Incoming solar energy heats the Earth, and outgoing heat radiation cools it off



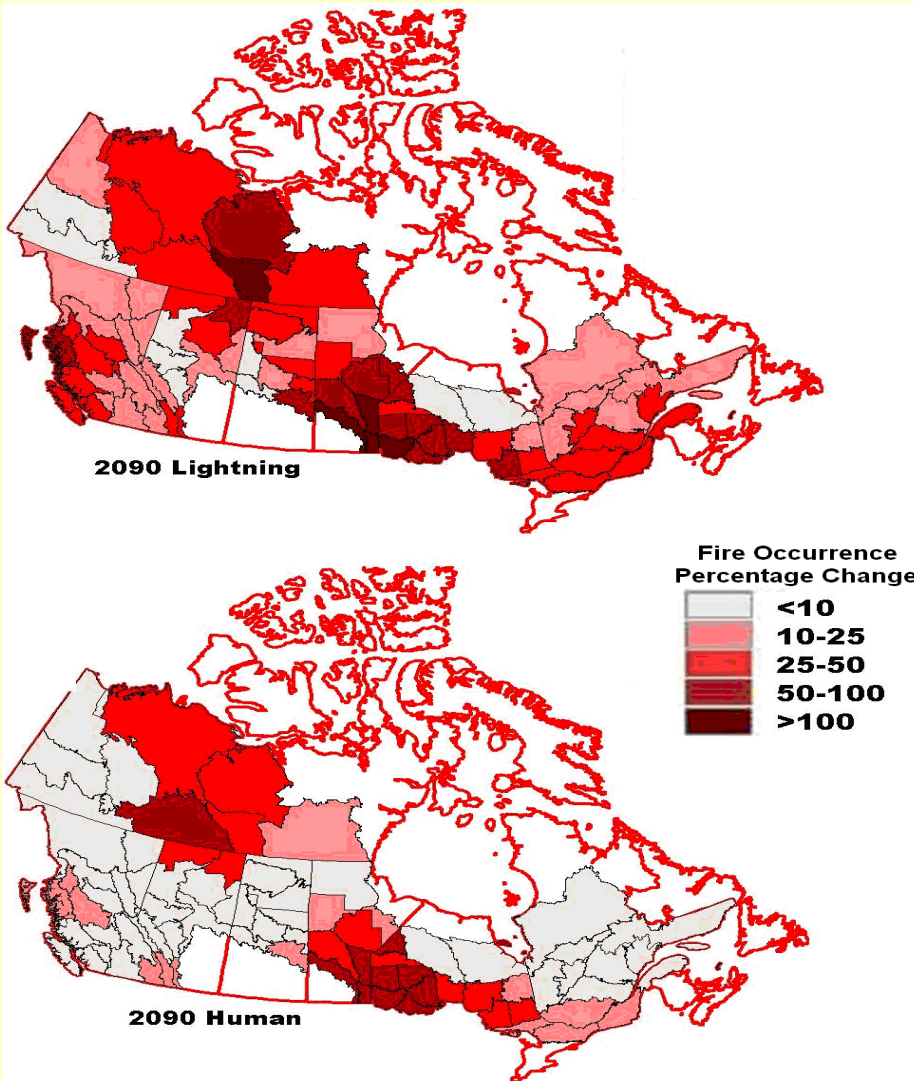
# Future Fire Seasons



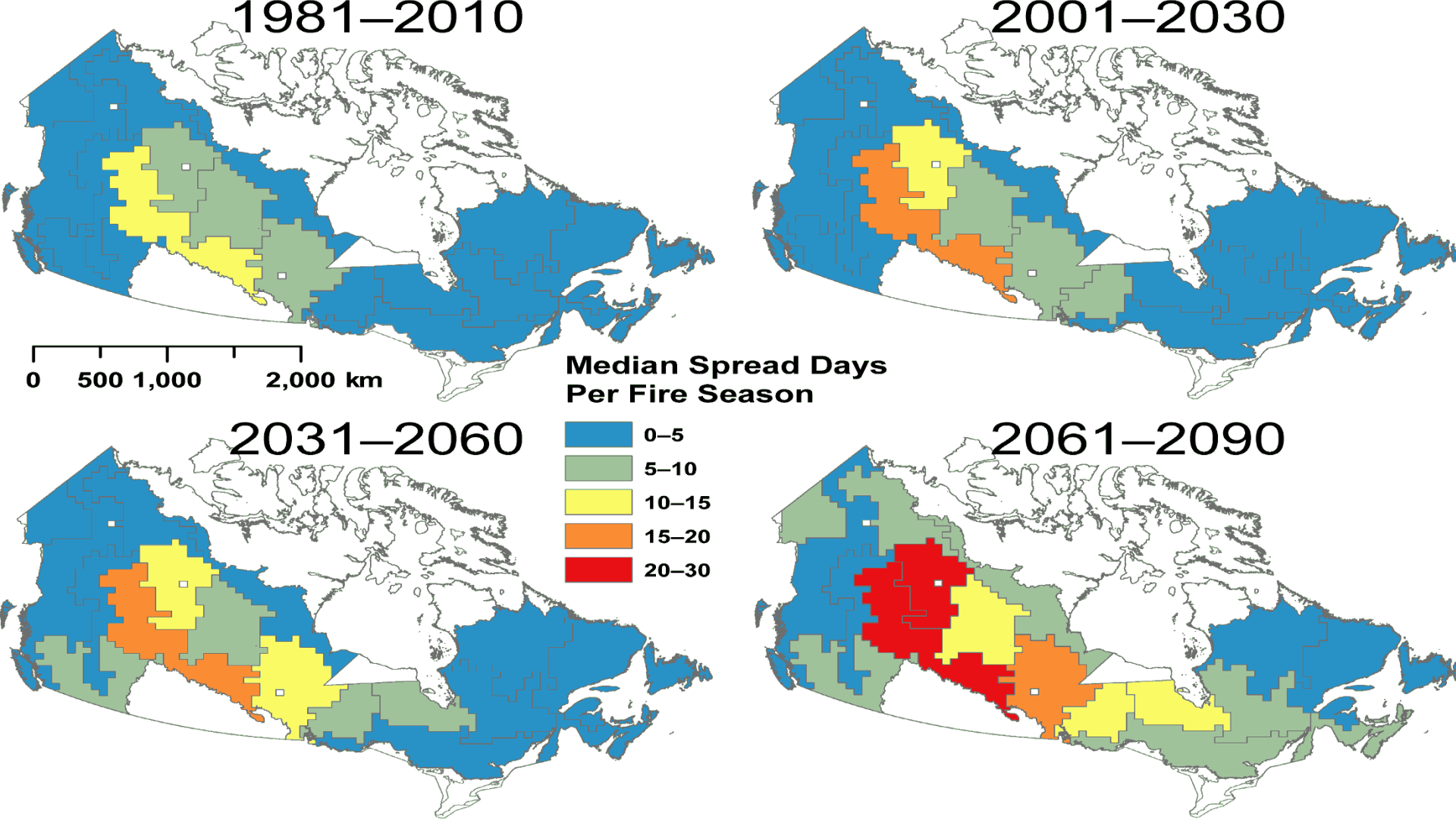
- **Used NCEP reanalysis data to calculate the Canadian Fire Weather Index System components including DSR for the world 1971-2000. As well as the fire season length using a temperature threshold.**
- **Three emission scenarios –A1B, A2, B1 from three GCMS – Canadian, Hadley and French IPSL.**

# Future Fire Occurrence

- Increases in human and lightning-caused fires
- Conservative as these changes driven by fuel moisture changes alone.
- Significant regional variation.




Wotton, B.M., Nock, C.A. and Flannigan, M.D. (2010). Forest fire occurrence and climate change in Canada. *International Journal of Wildland Fire*,19,253-271.


1981–2010
2001–2030
2031–2060
2061–2090
0 500 1,000 2,000 km
Median Spread Days
Per Fire Season
0–5
5–10
10–15
15–20
20–30

# February 2018 heatwave across the Far North

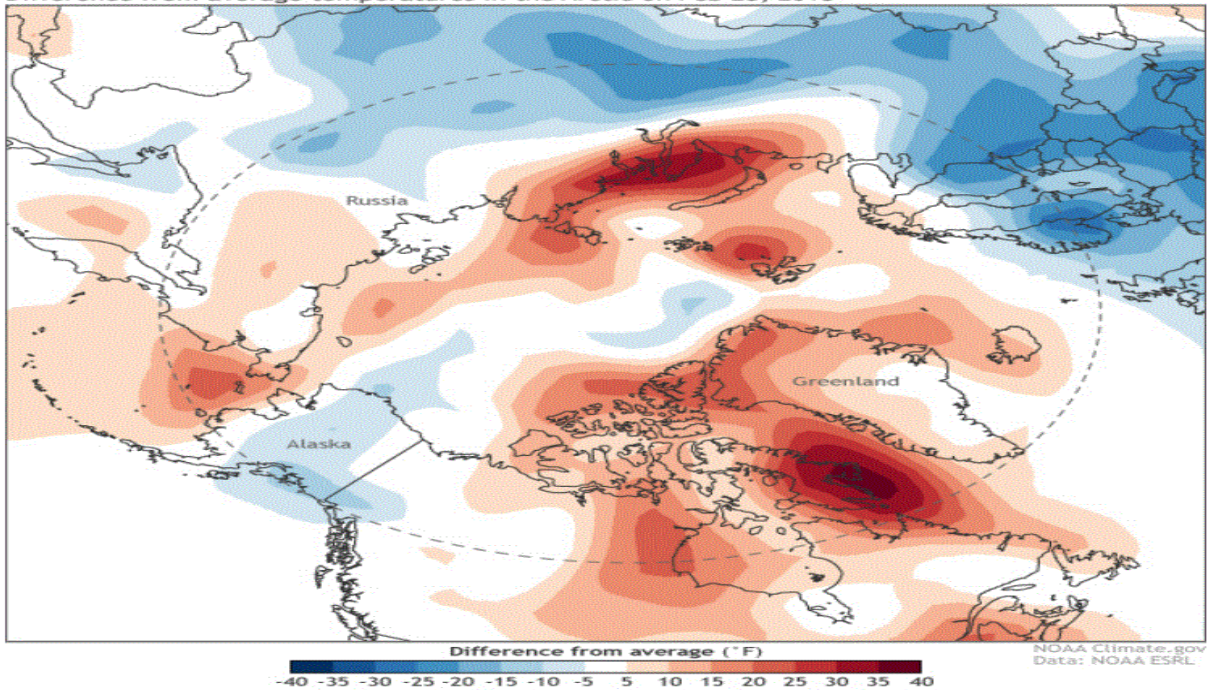
*Author:* Michon Scott

*March 20, 2018*

Print

Sea ice melts in the spring and summer, and grows in the autumn and winter. Arctic sea ice typically reaches its maximum extent sometime between late February and early April, and since the start of the twenty-first century, those winter maximums have declined. Although Arctic sea ice in 2018 hasn't broken all previous records for its low wintertime extent, it is still trending well below the 1981–2010 average. But as researchers watched Arctic sea ice in early 2018, they marveled at the high air temperatures over parts of the Arctic. In late February 2018, at Cape Morris Jesup, Greenland, the weather station closest to the North Pole (maintained by the Danish Meteorological Institute), temperatures climbed 45°F above normal for that time of year.

Difference from average temperatures in the Arctic on Feb 28, 2018



# Future Fire

- Changes in climate (including warmer temperatures, changes in precipitation, atmospheric moisture, wind, and cloudiness) affect wildfires
- Direct, indirect, and interactive effects of weather/climate, fuels, and people will determine future fire activity

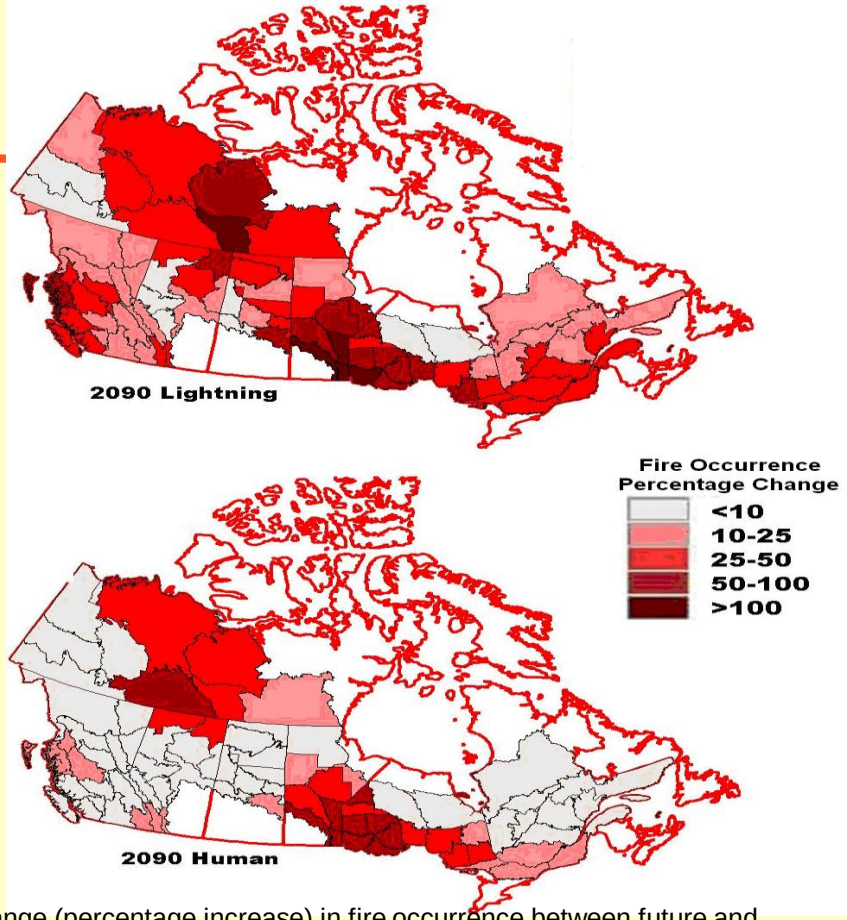
  Area burned

  Fire occurrence

  Fire season

  Fire intensity

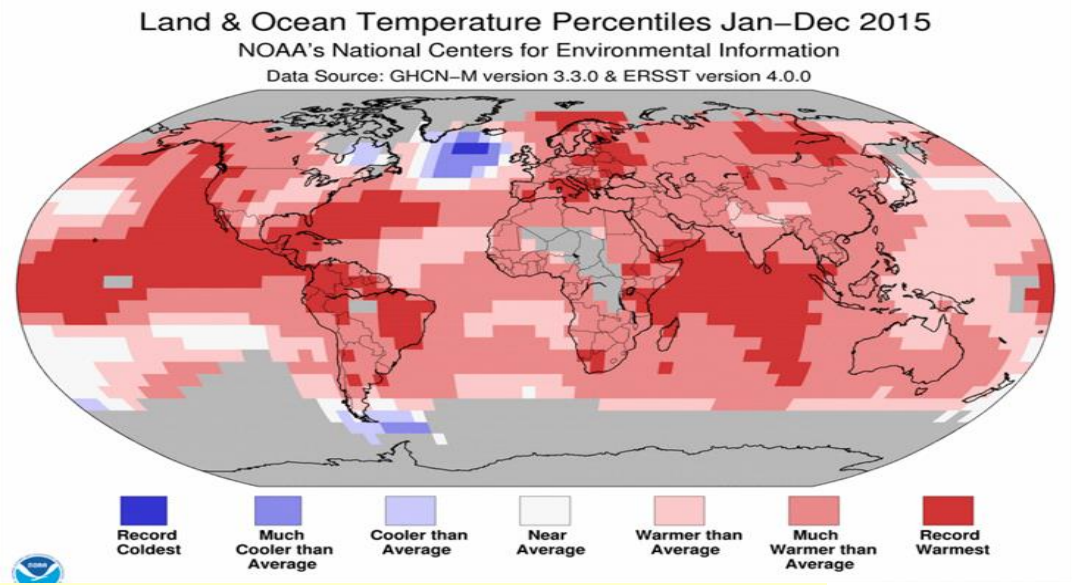
  Fire severity

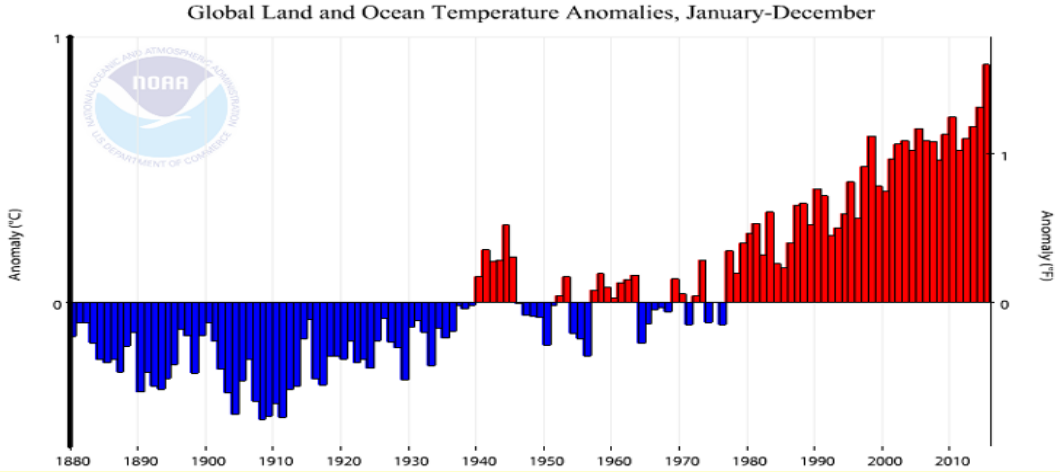



Relative change (percentage increase) in fire occurrence between future and baseline scenarios for the Canadian Climate Centre GCM. Relative change is given as the percentage increase in number of fires predicted by the GCM (future scenario minus baseline scenario) divided by the total number of fires in the baseline scenario ( i.e., (N2020-2040 – N1975-1995)/ N1975-1995 ); “no data” is shown in white.

Flannigan, M.D., Krawchuk, M.A., de Groot, W.J., Wotton, B.M. and Gowman, L.M. (2009). Implications of changing climate for global wildland fire. *International Journal of Wildland Fire*,18, 483-507.

Wotton, B.M., Nock, C.A. and Flannigan, M.D. (2010). Forest fire occurrence and climate change in Canada. *International Journal of Wildland Fire*,19,253-271.

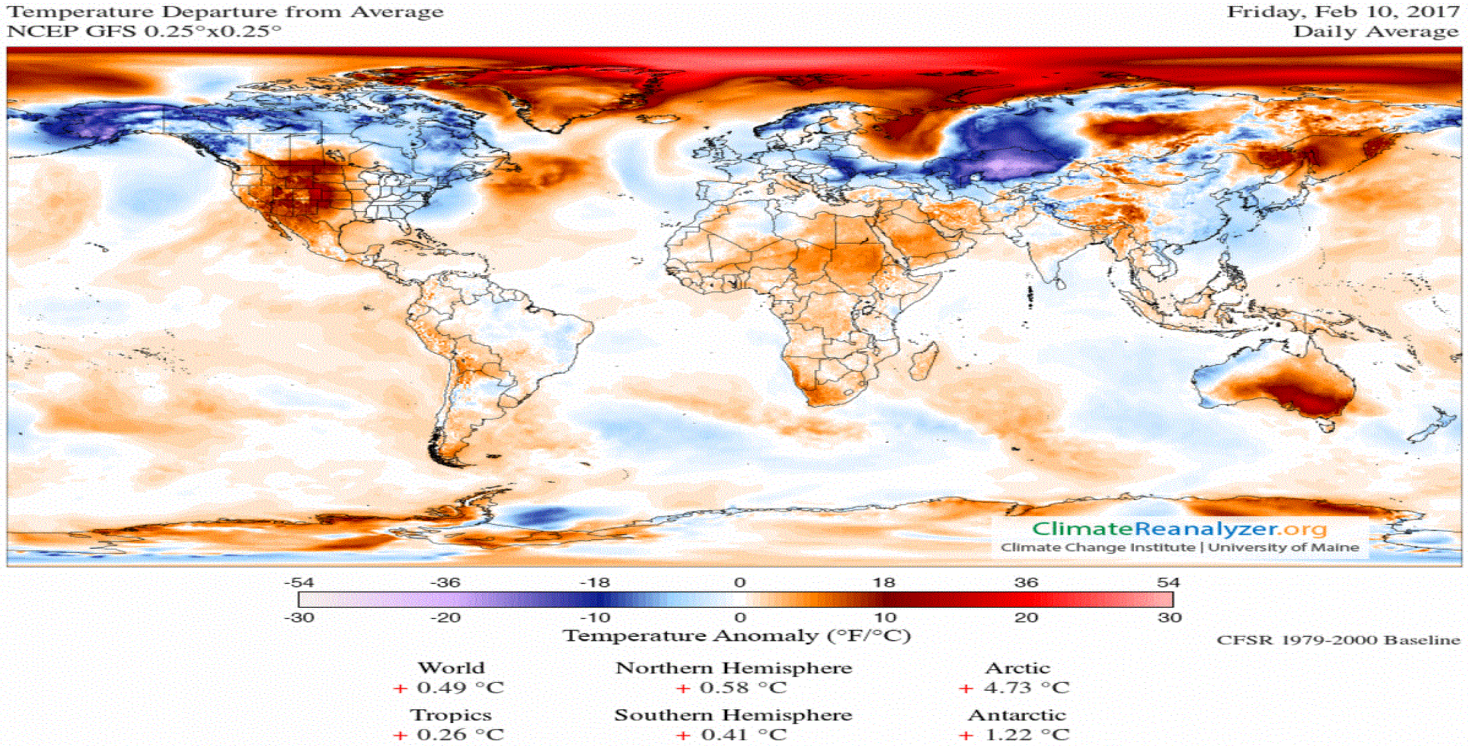

Land & Ocean Temperature Percentiles Jan–Dec 2015
NOAA's National Centers for Environmental Information
Data Source: GHCN–M version 3.3.0 & ERSST version 4.0.0
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest


Global Land and Ocean Temperature Anomalies, January-December
Anomaly (°C)
Anomaly (°F)
1
0
1
0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Capital Weather Gang

# It's about 50 degrees warmer than normal ne Pole, yet again

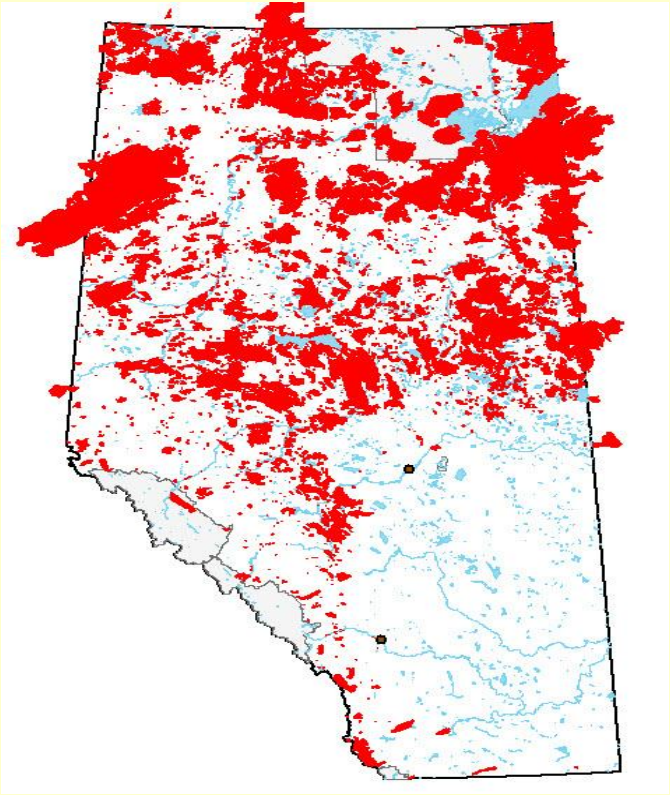
By Jason Samenow February 10




Temperature difference from normal, Feb. 10, 2017. (University of Maine Climate Re-analyzer)

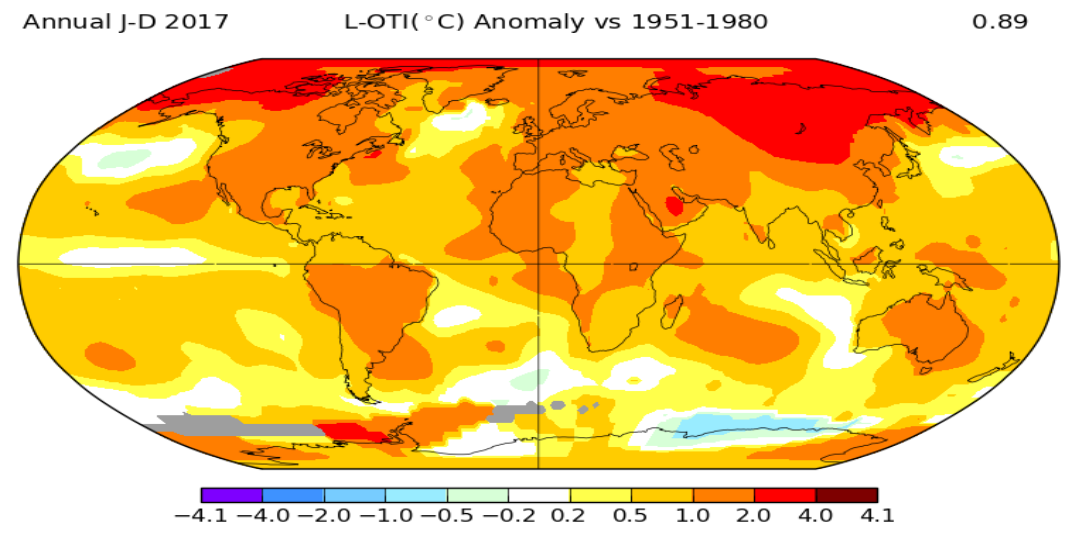
Peer at a map of the Arctic and it glows fluorescent red. The warmth, compared to normal, is again nearly off the charts.

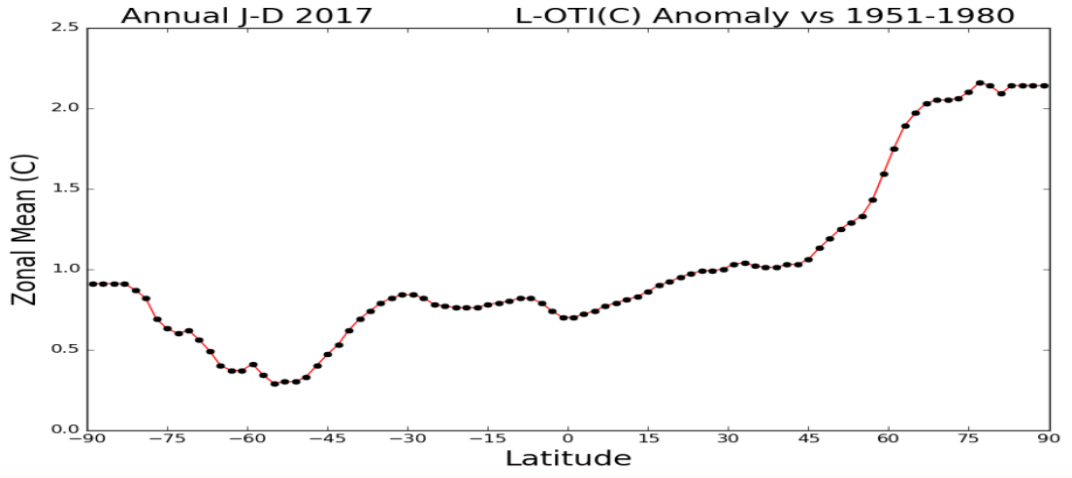
# Alberta is Different

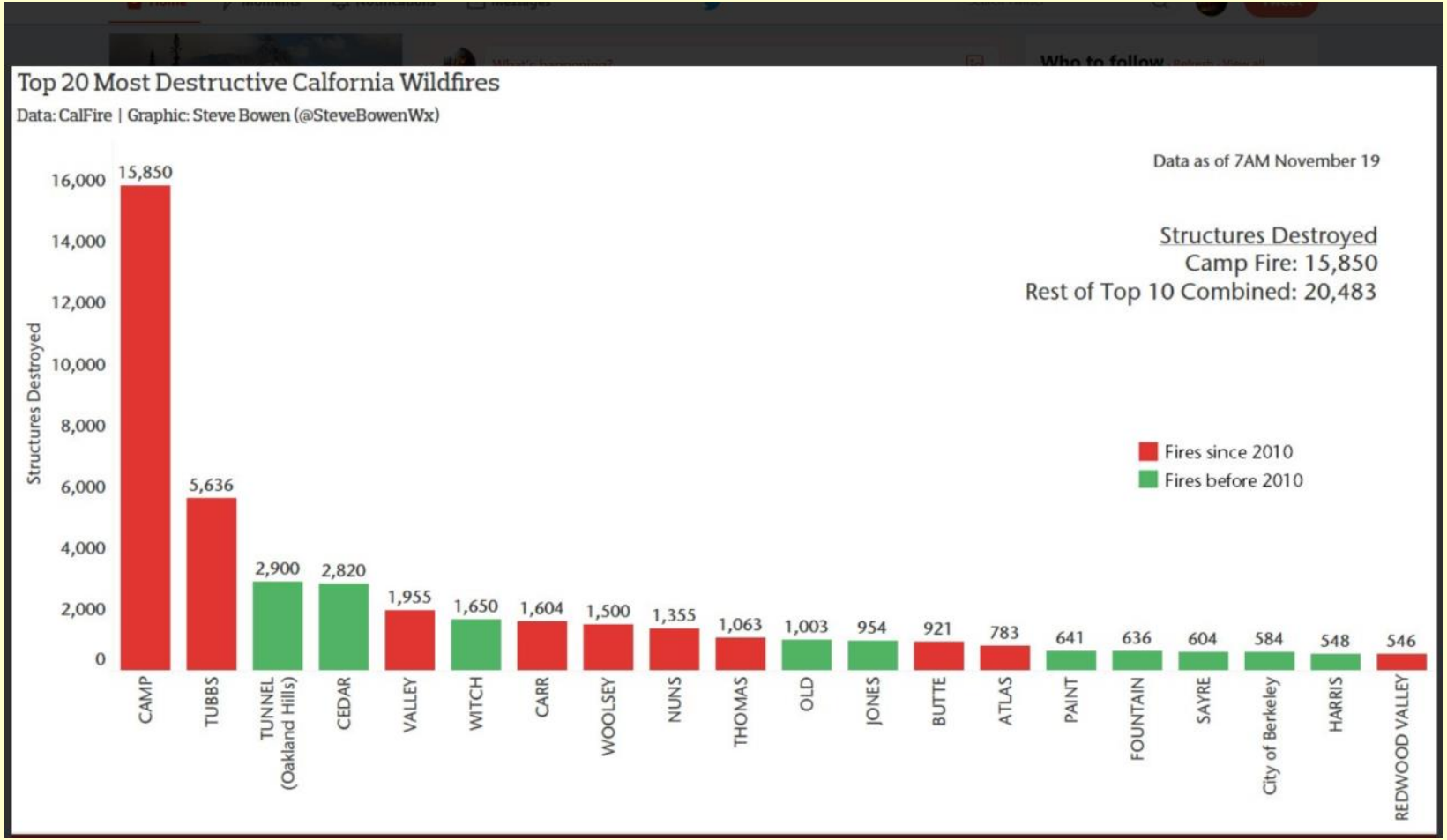


**1931 - 2015**

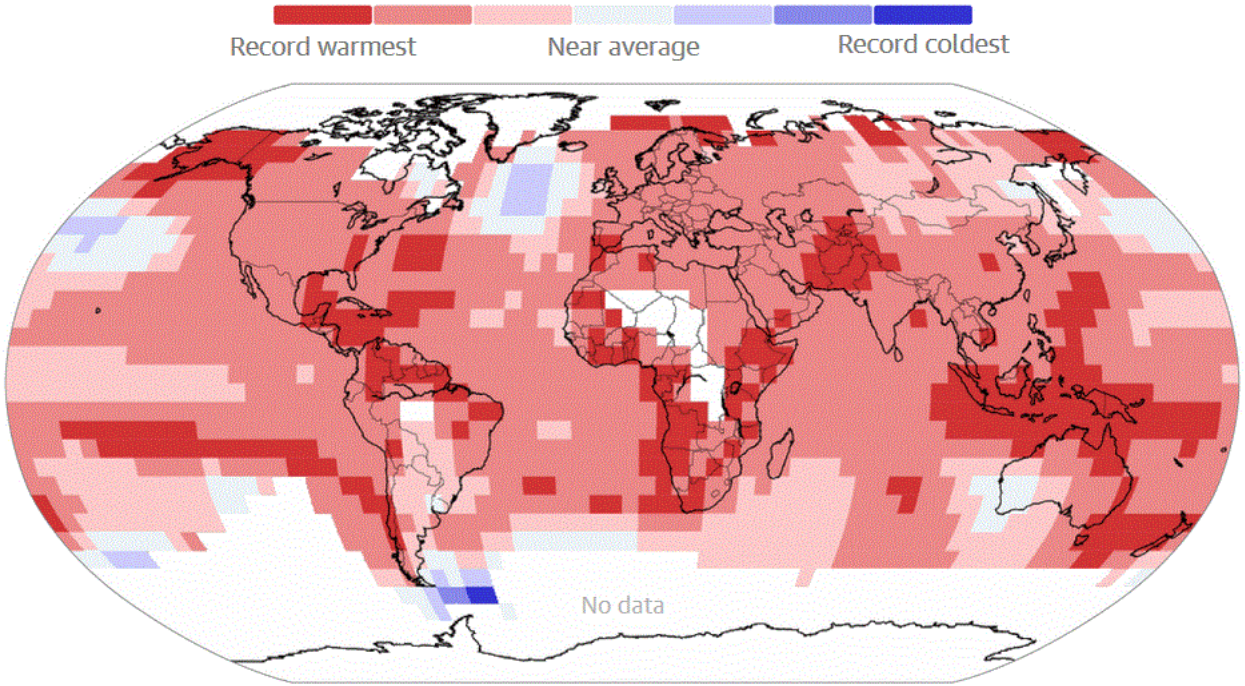
- Spring fires – 51% of the annual area burned is from May fire starts
- 82% of the fires in May are human-caused
- 10 year average of 1500 fires burning 280,000 ha


Annual J-D 2017
L-OTI(°C) Anomaly vs 1951-1980
0.89
−4.1 −4.0 −2.0 −1.0 −0.5 −0.2 0.2 0.5 1.0 2.0 4.0 4.1

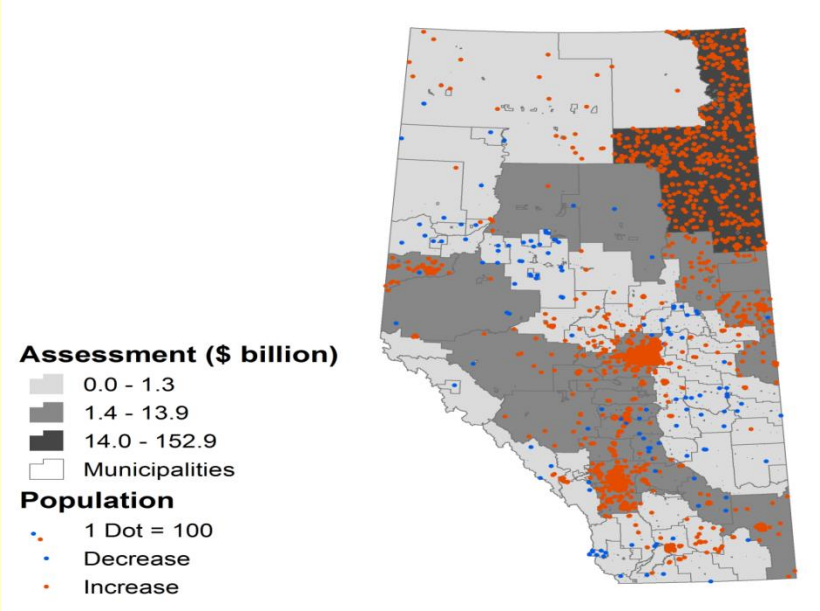

Annual J-D 2017
L-OTI(C) Anomaly vs 1951-1980
Zonal Mean (C)
2.5
2.0
1.5
1.0
0.5
0.0
−90 −75 −60 −45 −30 −15 0 15 30 45 60 75 90
Latitude


Top 20 Most Destructive Calfornia Wildfires
Data: CalFire | Graphic: Steve Bowen (@SteveBowenWx)
Data as of 7AM November 19
Structures Destroyed
Camp Fire: 15,850
Rest of Top 10 Combined: 20,483
Fires since 2010
Fires before 2010
Structures Destroyed
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
15,850
5,636
2,900
2,820
1,955
1,650
1,604
1,500
1,355
1,063
1,003
954
921
783
641
636
604
584
548
546
CAMP
TUBBS
TUNNEL (Oakland Hills)
CEDAR
VALLEY
WITCH
CARR
WOOLSEY
NUNS
THOMAS
OLD
JONES
BUTTE
ATLAS
PAINT
FOUNTAIN
SAYRE
City of Berkeley
HARRIS
REDWOOD VALLEY

## 2016 saw record highs for both land and ocean surface temperatures and set a combined global record for the third year in a row



# Development




- Now more than ever Canadians live and work in the forest.
- Development increasing in parts of the country.
- More people = more fire and more exposure to fire.
- We can make communities more fire-resistant but not fire-proof


**In the last 10 years, 60% of new homes in the U.S. have been built on lands adjacent to fire-prone public lands.**