Forest Fire Activity in Canada during the 2030s-2050s

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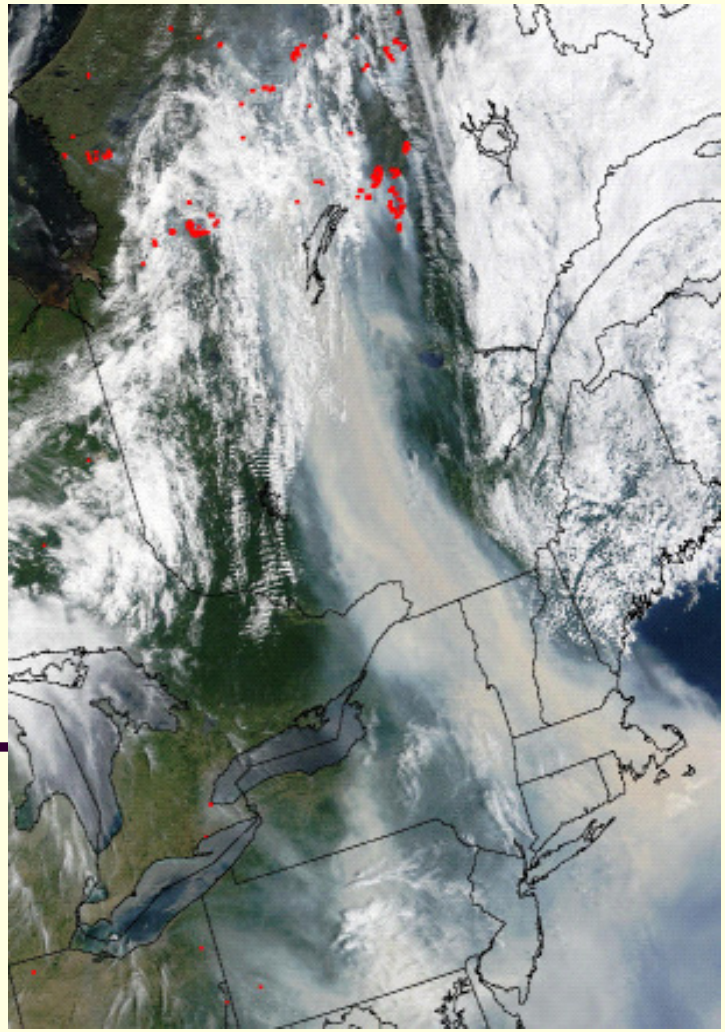
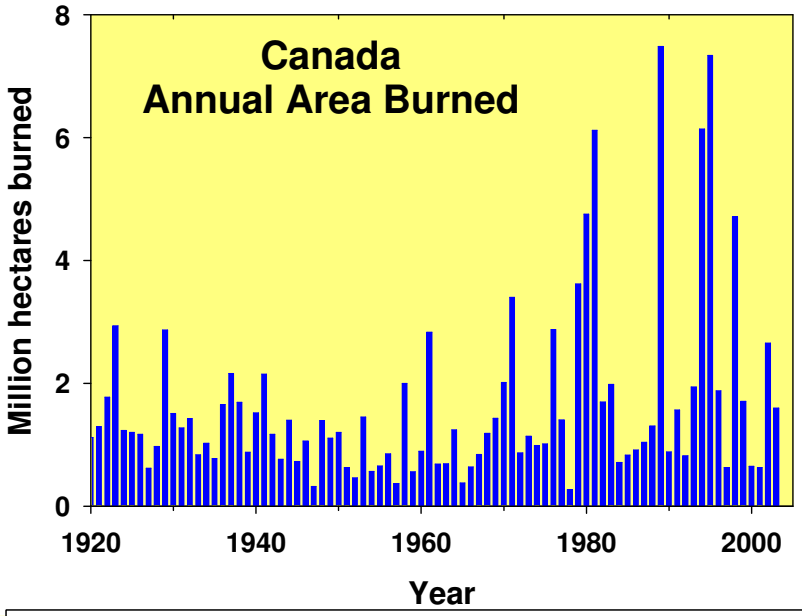
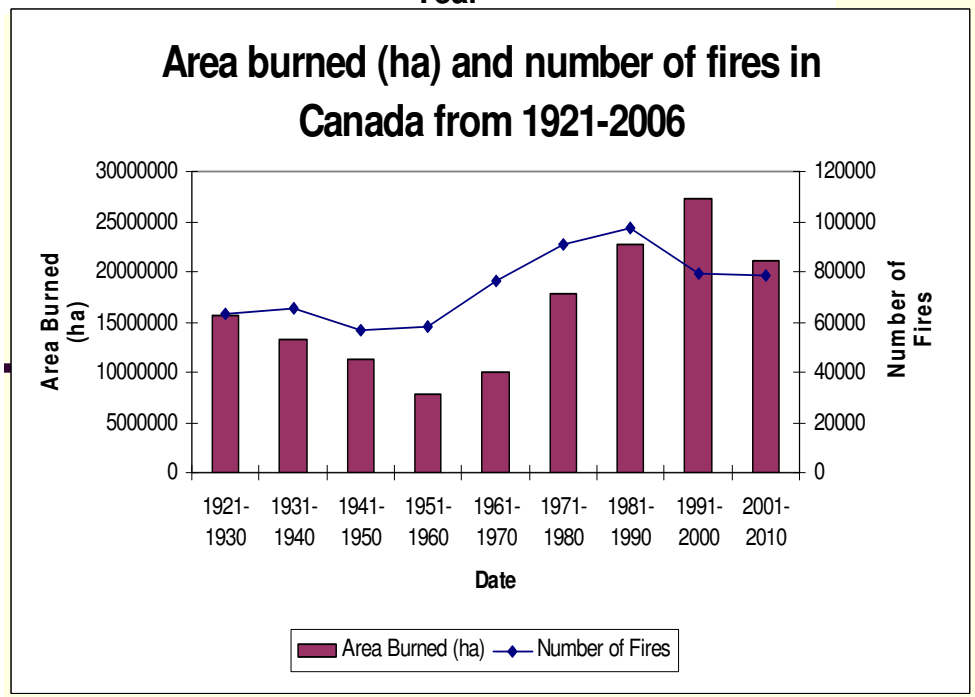
Outline



- Fire background
- Climate change
- Impacts of climate change on fire activity
- What will be the 2030s-2050s be like
- Options

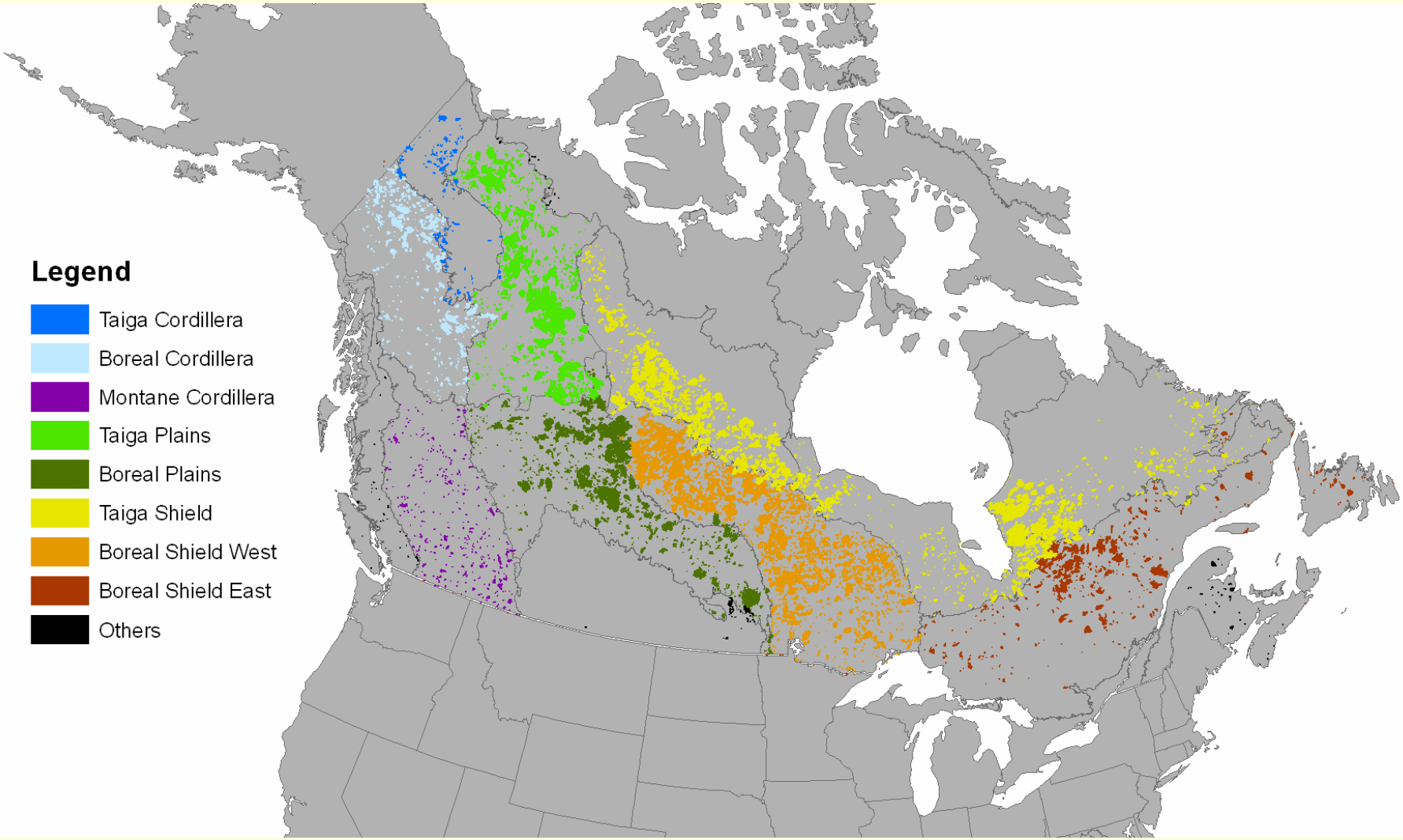
Canadian Fire Statistics





- Incomplete prior to 1970
- Currently - average of 9000 fires a year burn 2 million ha – 1 million ha in the early 70s
- Primarily crown fires
- Area burned is highly episodic
  - 0.4 to 7.6 million ha
- Lightning fires
  - 35% of total fires
  - represent 85% of area burned
- Fire size
  - 3% of fires are >200 ha
  - represent 97% of area burned

The boreal forest is dominated by fire 1980-1999



The fire polygons were kindly provided by Canadian fire agencies (provinces, territories, national parks)

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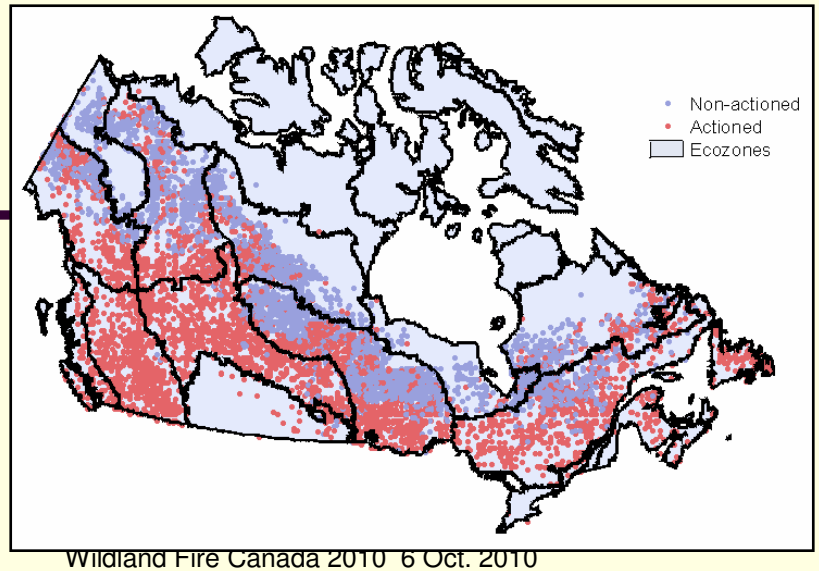
Fire Issues



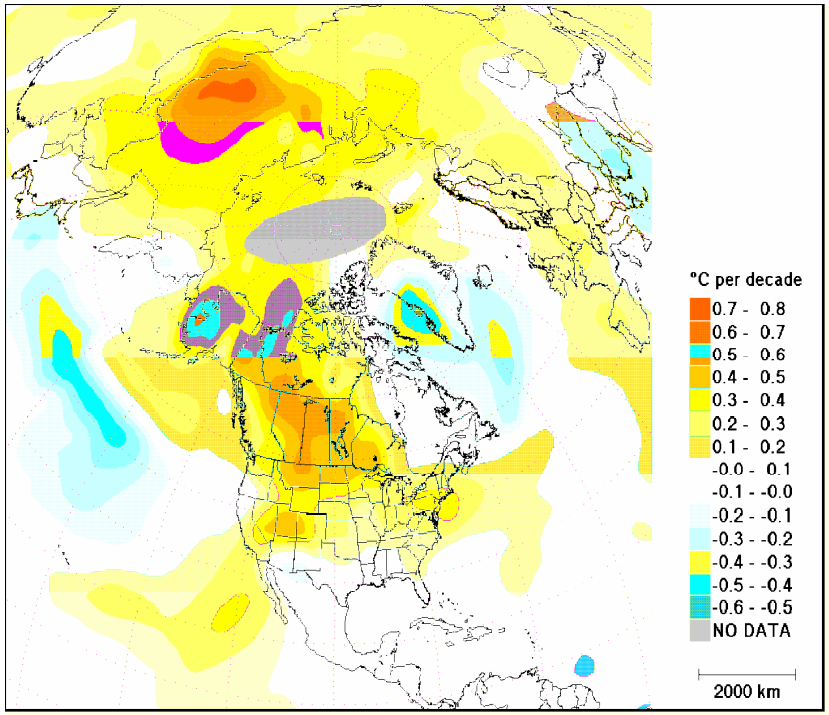
- An average of $800 million spent by fire management agencies in Canada a year on direct fire fighting costs
- Health and safety of Canadians – evacuations – smoke (mercury)
- Property and timber losses due to fire
- Balancing the positive and negative aspects of fire
- Traditional approaches to fire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

Wildland Urban Interface

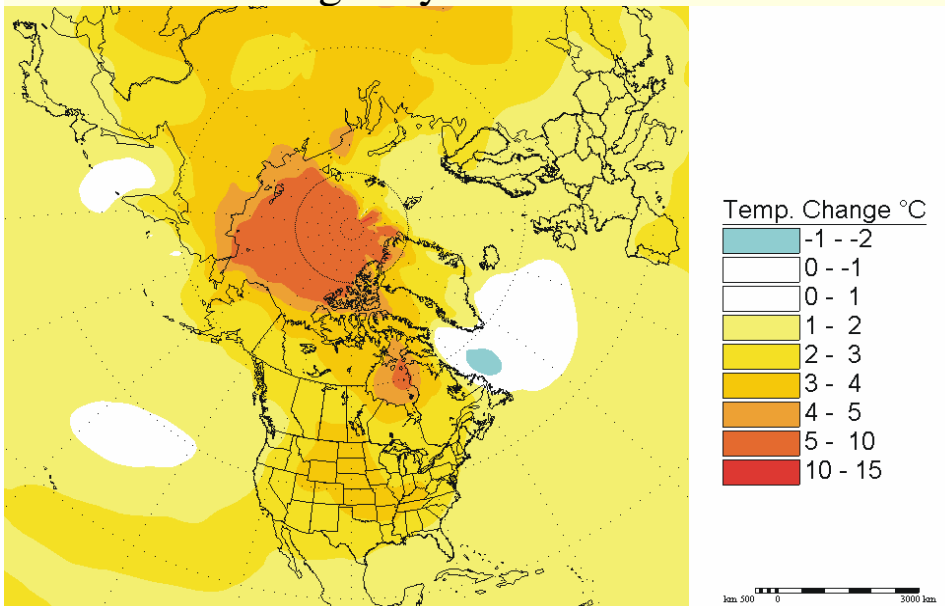
- On average a total of 5500 people are evacuated from 10 communities per year
- On average 20 communities with about 70000 people are threatened by large fires each year
- Reasons for evacuations
  - Threat life/property 62%
  - Smoke and health 14%
  - Transportation 3%
  - Unknown 21%

Forest Fires – 4 Key Factors

- Fuel - loading, moisture, structure etc.
- Ignition - human and lightning
- Weather - temperature, precipitation atmospheric moisture and wind; upper atmospheric conditions (blocking ridges)
- Humans - land use, fragmentation, fire management etc.



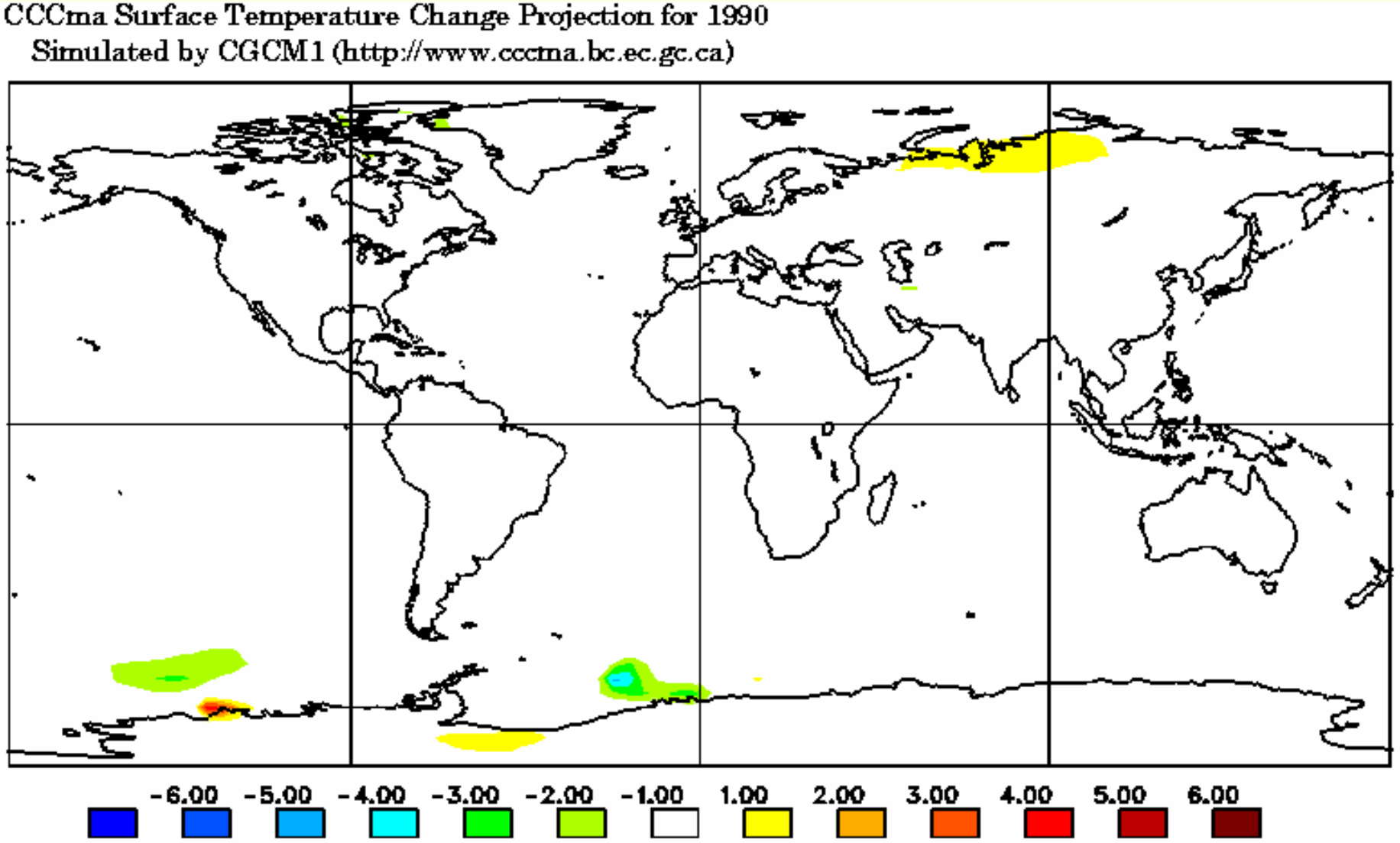
Observations above – temperature changes by 2050 below



Climate Change Projections

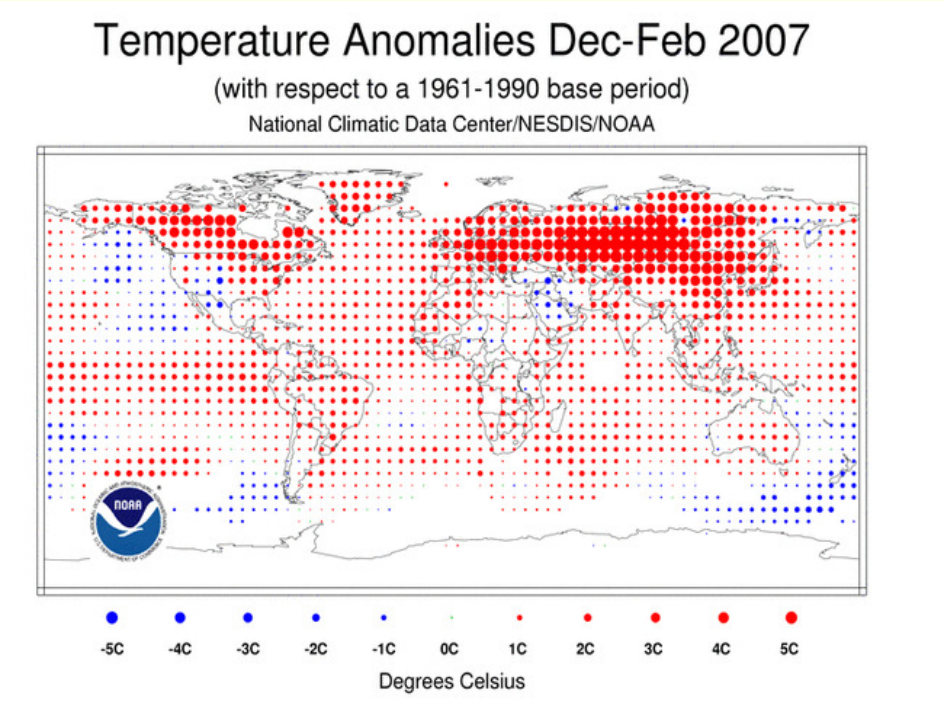
- GCMs project 1.4 – 5.8^0 C increase in global mean temperature by 2100
- Greatest increases will be at high latitudes, over land and winter/spring
- Projected increases in extreme weather(e.g., heat waves, drought, floods, wind storms and ice storms)
- Observed increases across west-central Canada and Siberia over past 40 years

Projected temperature changes vary considerably from year to year

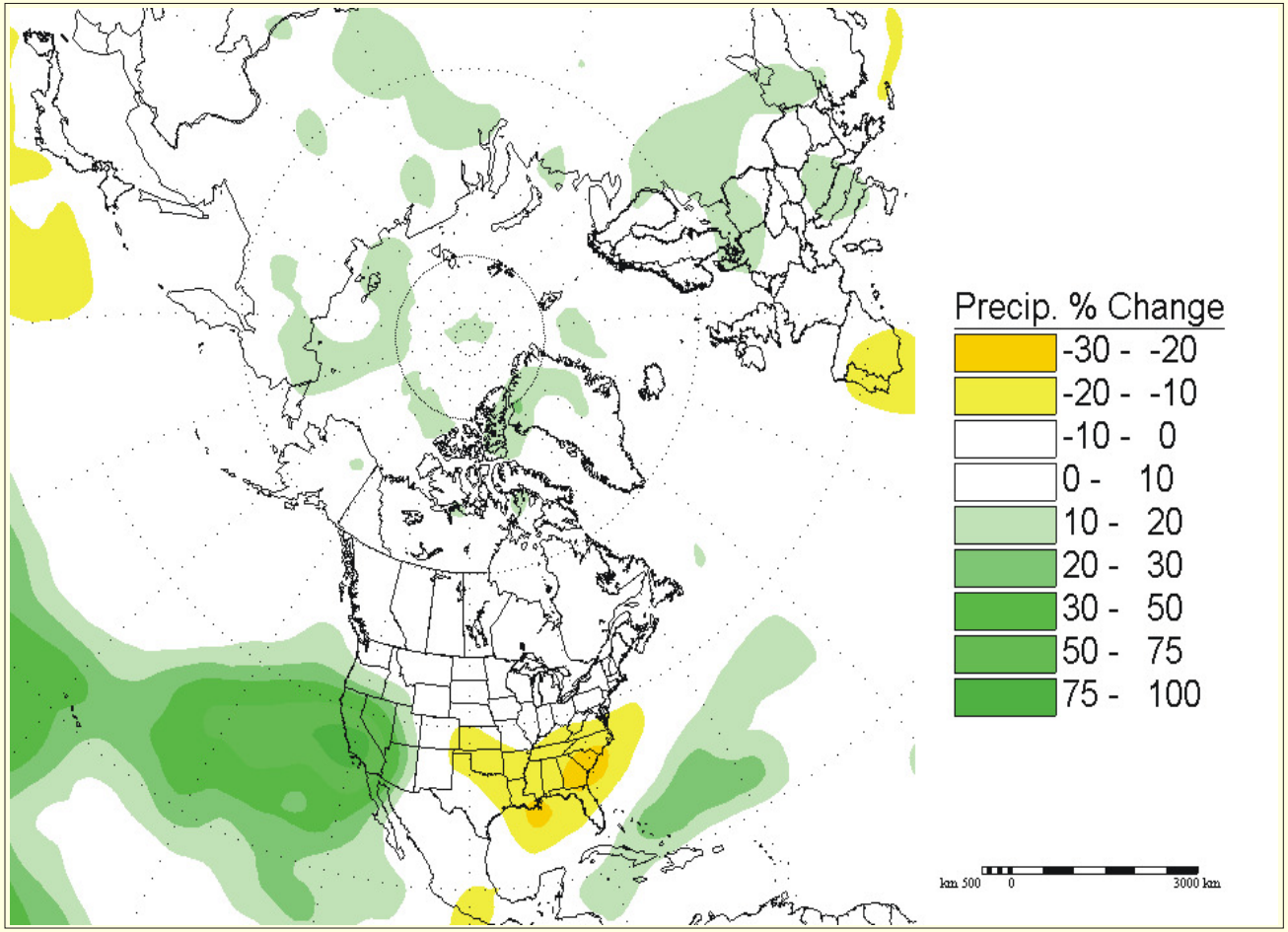


Fire & Temperature

- Key variable in fire activity for 3 reasons
- First, the amount of moisture the atmosphere can hold is highly sensitive to temperature. This drives fuel moisture; if temperature increases then significant increases in precipitation are needed to compensate.
- Second, temperature has a strong positive correlation with lightning…the warmer it is the more lightning we have.
- Third, the warmer it is the longer the fire season; particularly important at high northern latitudes.



Precipitation Change by 2050



Fire and Carbon

Fire plays a major role in carbon dynamics: it can determine the magnitude of net biome productivity

1) combustion: *direct loss*

2) decomposition of fire-killed vegetation

3) Change in vegetation type : *different sink potential when there is a change in vegetation type. Example forest stand renewal – young successional stands have potential to be greater sinks than mature stagnant forests*

The role of Peat

- 700 Pg carbon stored in the boreal forest ~30-35 % of the global terrestrial biosphere.. peat is a major component.

- Climate change will mean the melting of permafrost, more droughts which suggest peat fires will be more common.

-Peat fires can release significant amounts of GHGs for example peat fires in Indonesia during 1997 released the equivalent of 20-50% of global fossil fuel emissions. Peat in the boreal dwarfs the amount of peat in tropical regions

-Difficult to extinguish; can burn through winter under the right conditions

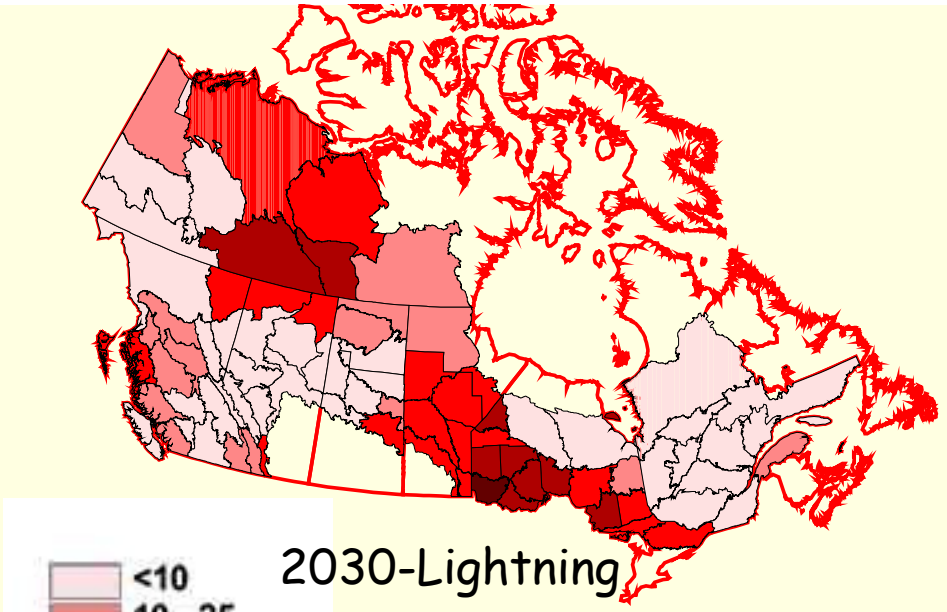
Future Fire

- Changes in climate (including warmer temperatures, changes in precipitation, atmospheric moisture, wind, and cloudiness) affect wildfires

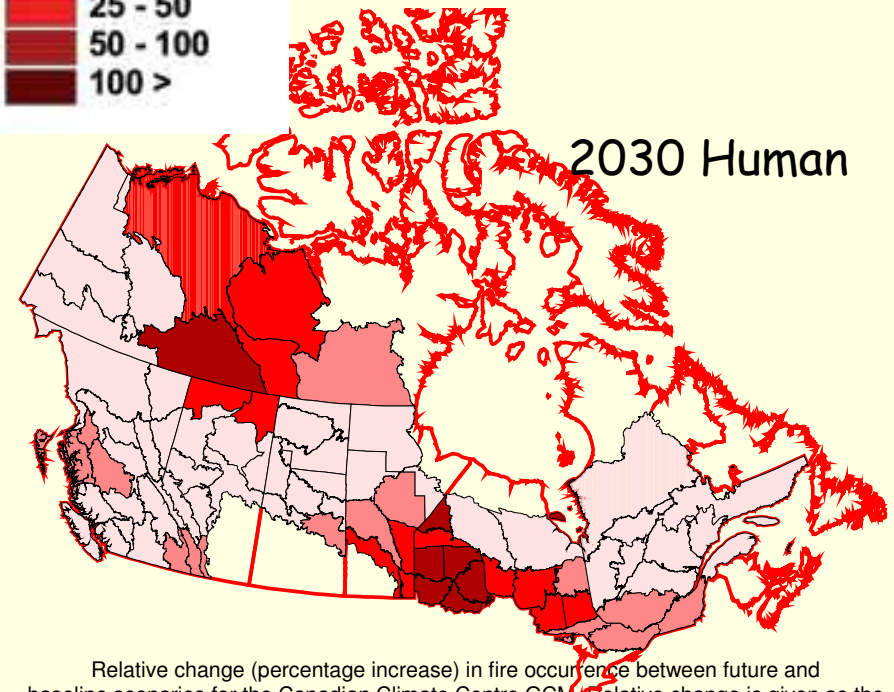
- Direct, indirect, and interactive effects of weather/climate, fuels, and people will determine future fire activity

  - Area burned
  - Fire occurrence
  - Fire season
  - Fire intensity
  - Fire severity

- Recent trends – see IJWF Flannigan et al. (2009) review paper 18:483-507.



2030-Lightning



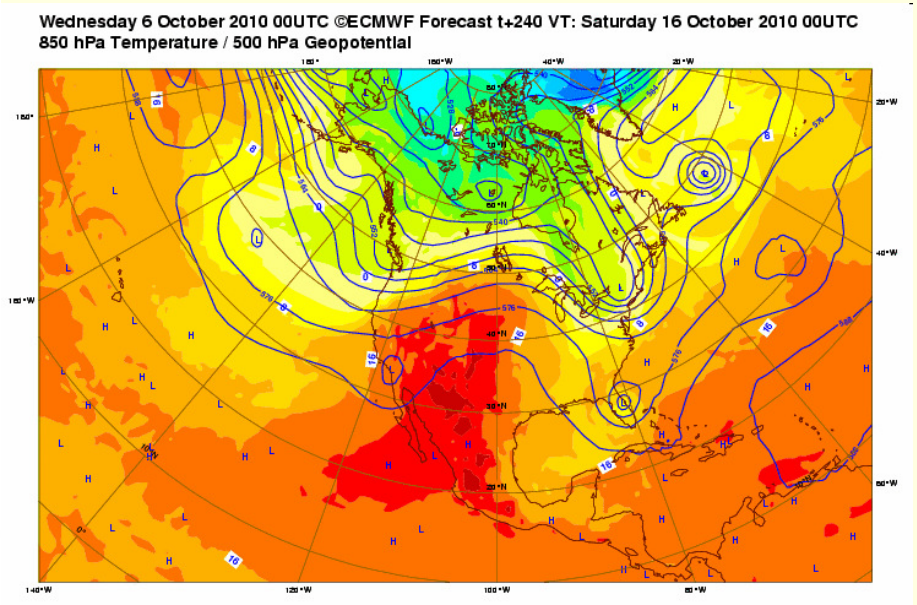
2030 Human

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.

Fire – weather/climate Interactions

- We still have a lot to learn about climate patterns and fire activity
- There are definite linkages between sea surface temperatures and patterns and fire activity at scales of 2-50 years
- Understanding these relationships will help for seasonal forecasts as well as multi-year forecasts
- Climate oscillations/patterns such as ENSO, PDO, AO and AMO influence climate and weather and thereby fire activity
- Just starting to understand the relationships – interactions between these processes

Blocking (Stationary) Ridges

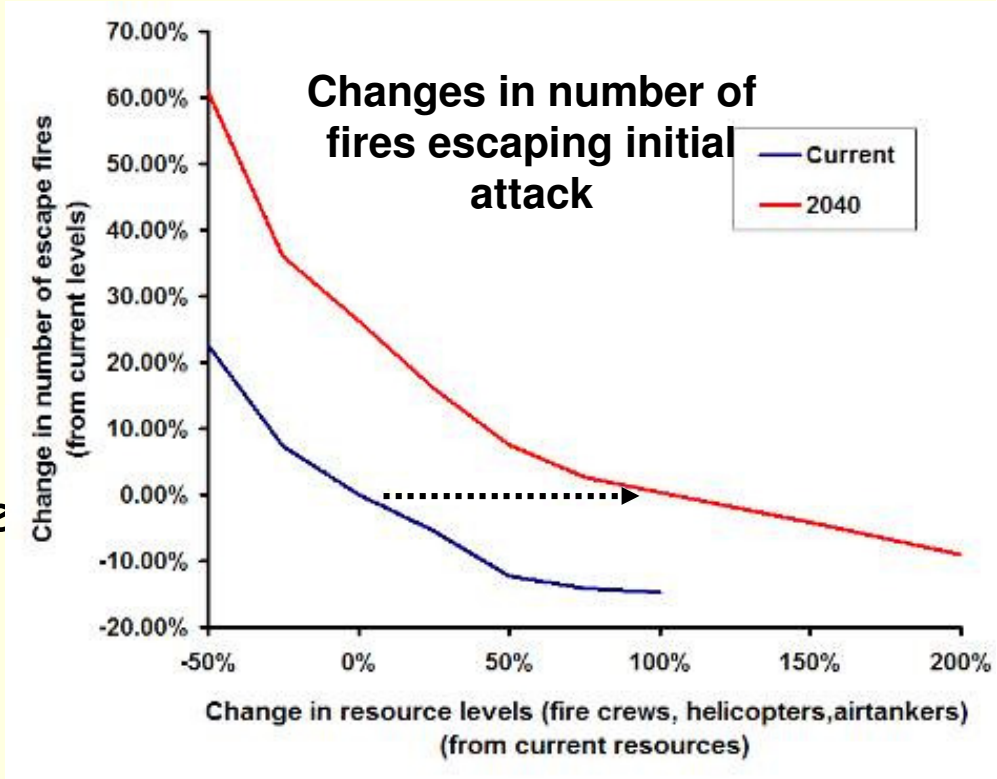


- Important to fire activity because descending air associated with upper ridges -warm/hot, sunny and dry conditions
- Last 7- 10 days or more and allows the forest fuels to dry out (FFMC and DMC to increase significantly)
- When the upper ridge breaks down there can be thunderstorms with strong gusty winds and often have a change in wind direction
- Models suggest that in the future there will be stronger blocking ridges that may last longer than present day

Climate Change & Fire Protection

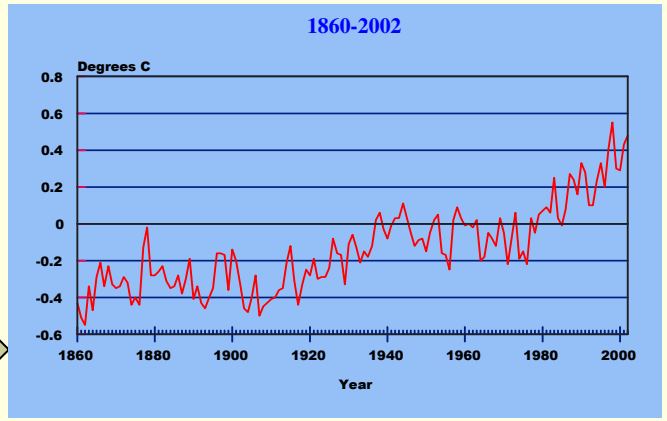
- A simple level of protection experiment
  - Used Ontario's level of protection analysis system
  - Climate change scenarios for 2040 ($2\times CO_2$)
    - Increased fire occurrence
    - Increased spread potential
  - A range of resource increases over current levels

- Results:
  - To maintain current level of fire escapes – must double the fire suppression resources in Ontario



Fire and Weather Feedbacks: *potentially positive*

Fossil Fuel emissions: increase greenhouse gases



Cause warmer conditions

Weather becomes more conducive to fire: more fire

Carbon released from more fire enhances greenhouse gases further

Options and Adaptations

- Health and safety of Canadians through improved fire weather and fire behaviour systems. The Canadian Forest Fire Danger Rating System is used across Canada and in many part of the world.
- Adaptation options for fire management agencies with respect to climate change altered fire regimes including community protection
- Inputs for decisions on International Agreements – forest fire is a critical element in determining if our forests are carbon sinks or sources?

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 and will impose an increased threat to our communities and forests

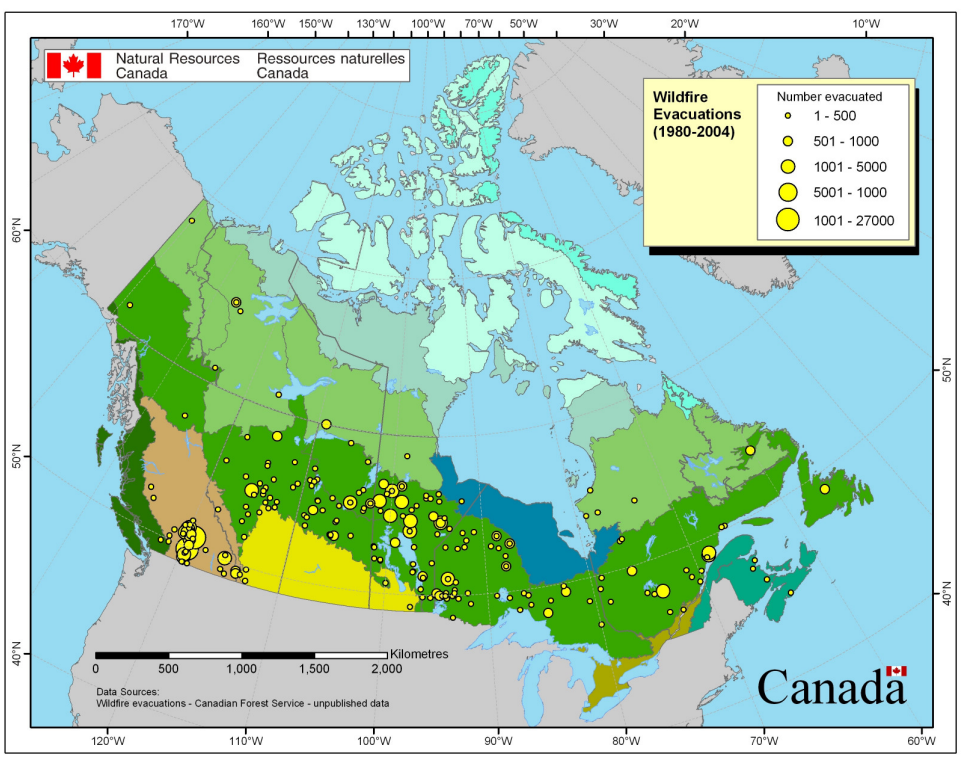
- Need for cooperation
  - Adaptation strategies
  - Cooperative research

Options

- Mitigate human-caused climate change ?
- Adapt by protecting Canadians, communities, infrastructure and forests through fuel management and through enhanced and expanded fire weather and fire behaviour systems
- Develop strategic plans for landscape management and sustainable forests that included the dynamic influences of climate and disturbance
- Adaptation options for fire management agencies with respect to climate change altered fire regimes

Context

- Management of wildland fire is largely within provincial/territorial jurisdiction but also involves the federal government
  - Emergency Preparedness Act
  - Emergency assistance (mostly DND) during major fire events
  - Insurer of last resort following
  - natural disasters
  - Federal lands/Aboriginal
  - communities
  - Air quality/public health

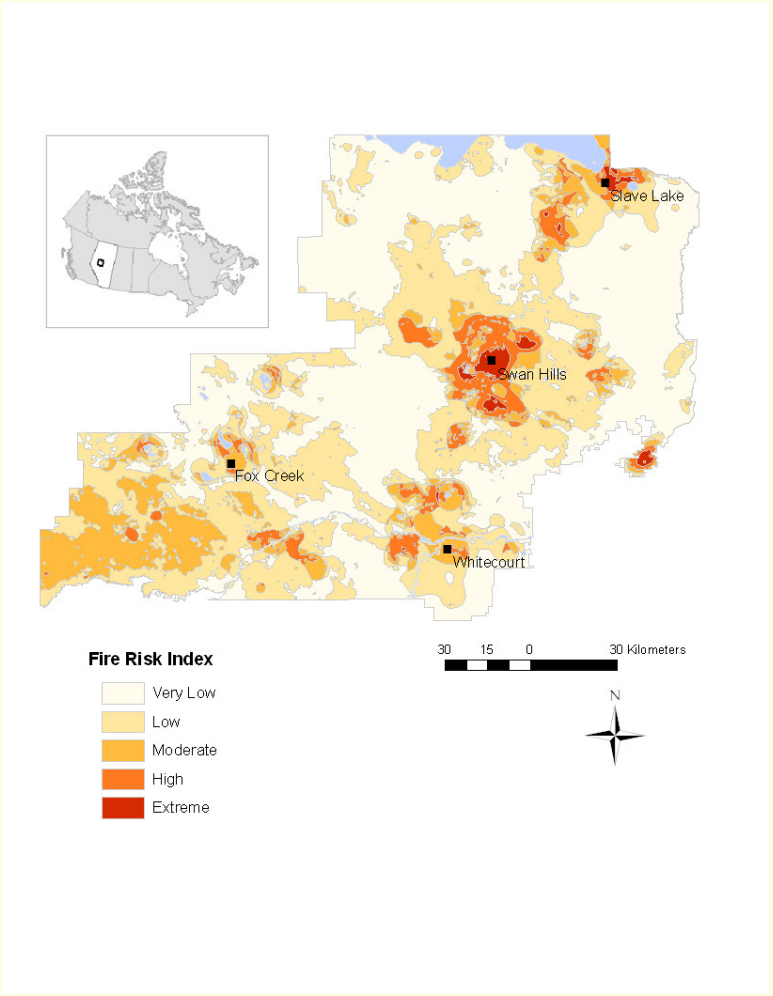


Collaborators/Partners

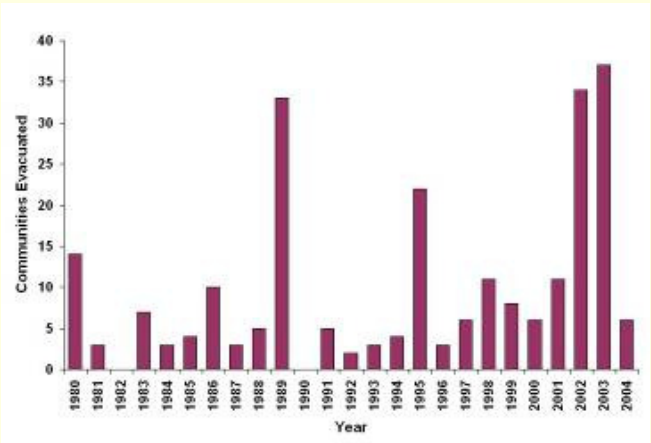
- Universities – Arizona, Australian National University, Manitoba, Montana, Toronto and UQAM/UQAT
- BC Ministry of Forests, Environment Canada, NRCan, Ontario MNR and USDA Forest Service,
- GCTE & IGBP
- Action Plan 2000, Climate Change Action Fund, NCE – SFMN, National Center for Ecological Analysis and Synthesis, PERD

Expanding WUI

- Expanding WUI
  - Rapid recent increase in expansion of communities into the WUI
    - Unquantified for Canada overall but in US its estimated that 60% of new homes are in WUI
  - On average a total of 5500 people are evacuated from 10 communities per year
  - On average 20 communities with about 70000 people are threatened by large fires each year



Communities evacuated



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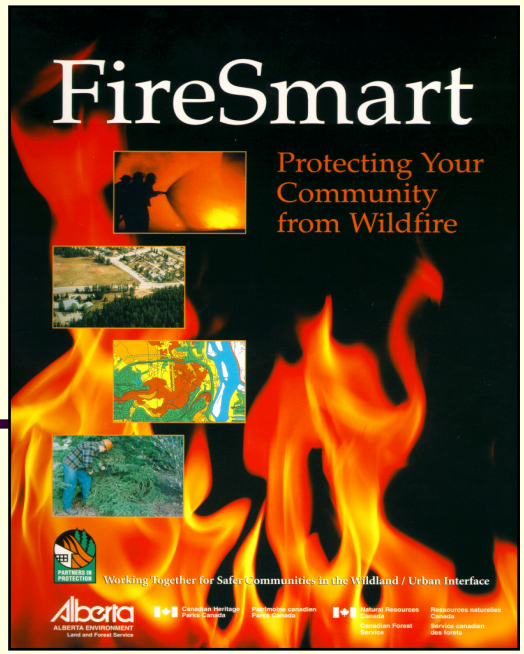
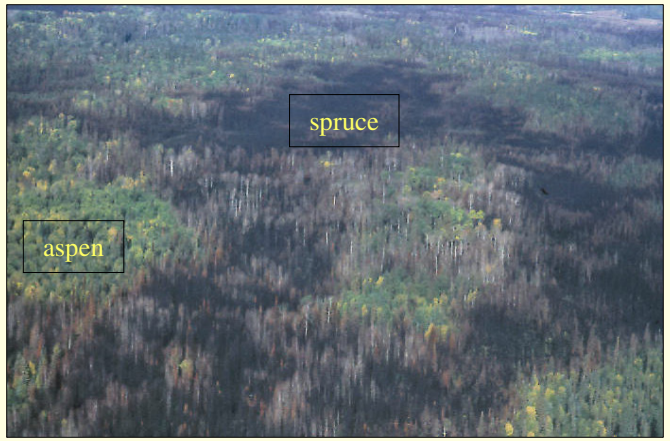
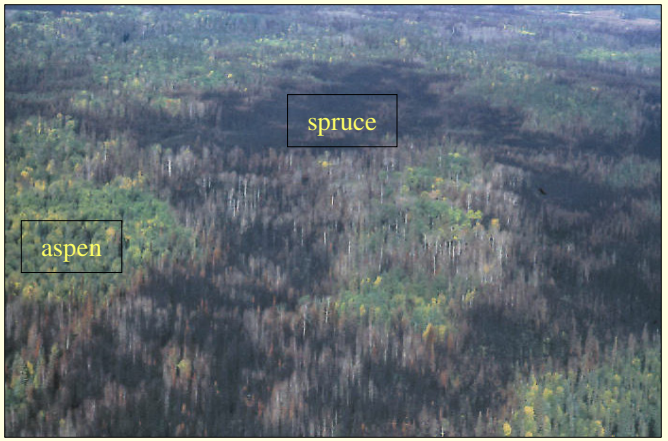
Adaptation Strategies

- Fire exclusion not an option in many regions
- Landscape fuels management
  - Fuel conversion
  - Fuel reduction
  - Fuel isolation
- “FireSmart” landscapes
  - Strategically located firebreaks
  - Education, prevention
  - Emergency planning
- Level of protection studies



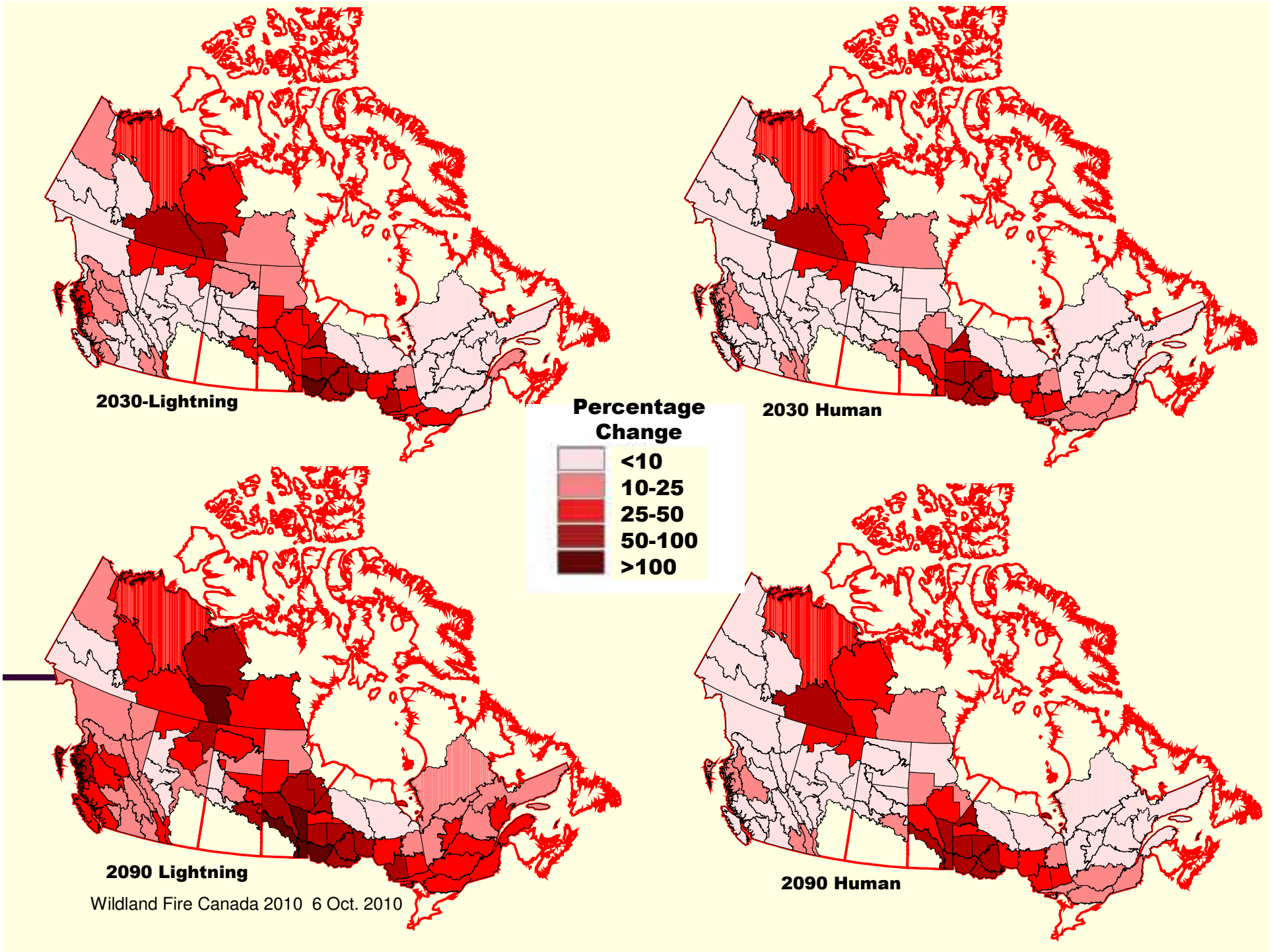


Adaptation and Mitigation:



Challenges to improve:

- Prevention
- Detection
- Suppression – exclusion not an option
- Fuels Management
- Protection of values (e.g., construction, social)



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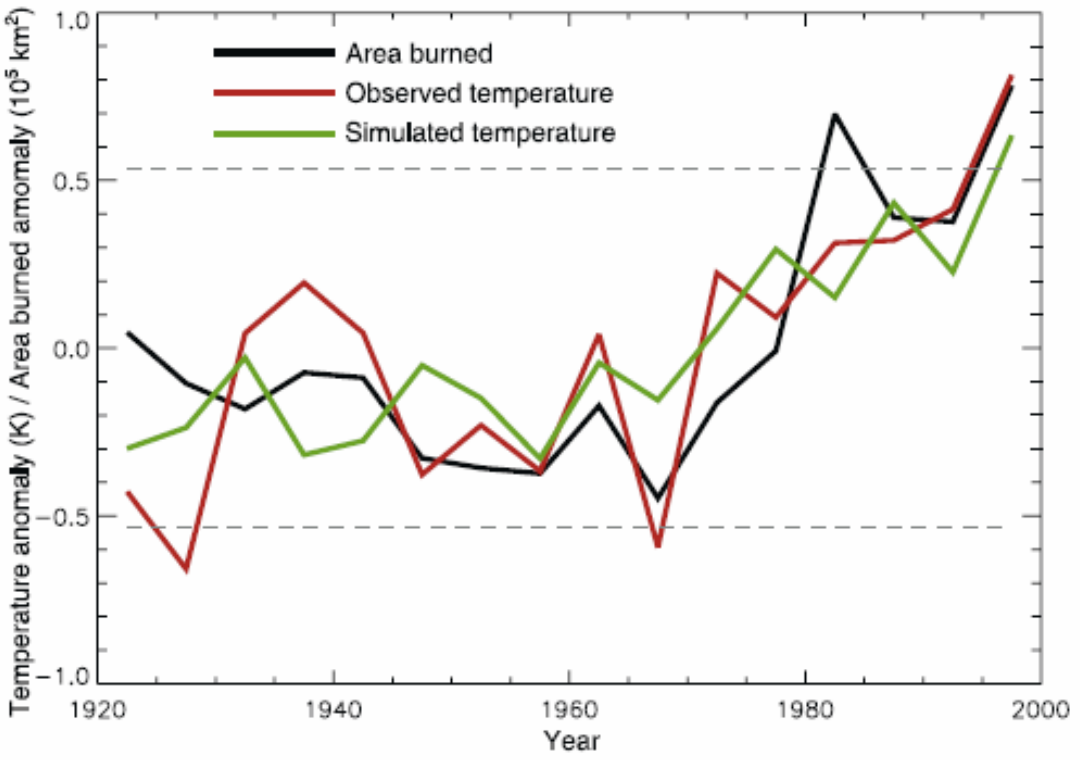
Trend Observations

- Is area burned correlated with increasing temperature?
- Is this caused by anthropogenic effects?



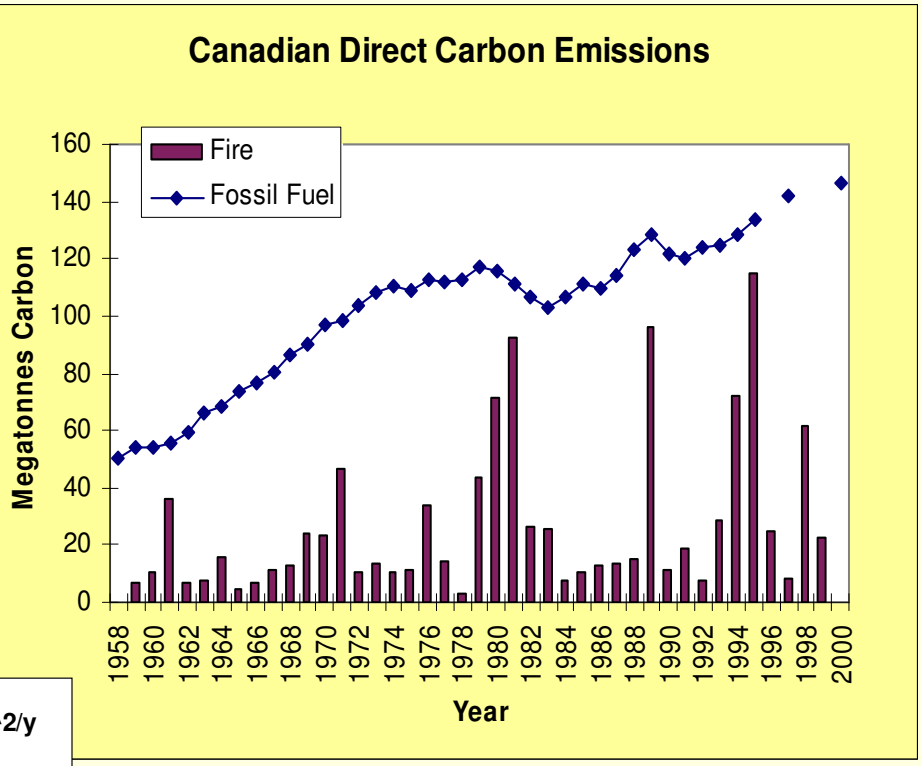
Future Fire:

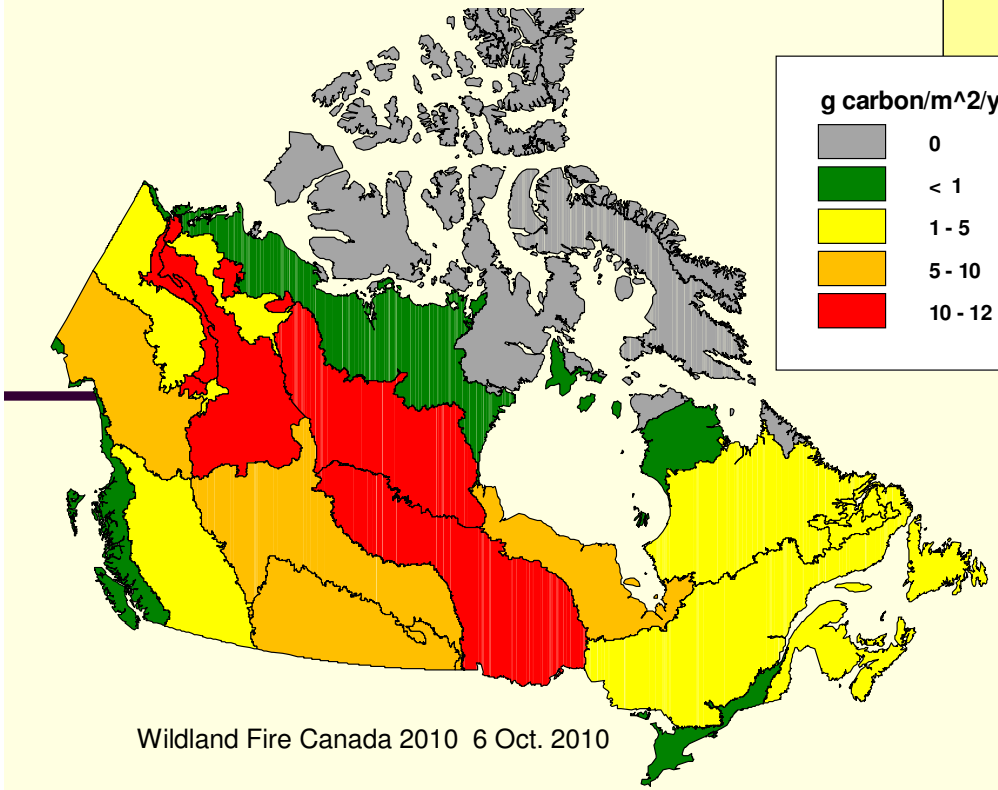
- More fire activity, longer fire seasons
- More ignitions (human, lightning)
- Fuel effect uncertain
- Suppression effectiveness uncertain
- Will the warming cause more fire; increasing CO_2 emissions; and further the warming?

But, many of our forest ecosystems have evolved with fire. How much fire do our forests need? And how much can they handle?

Direct Emissions

Combustion from forest fires
average 27 Tg carbon/yr
~ 20% of carbon from fossil fuels in Canada





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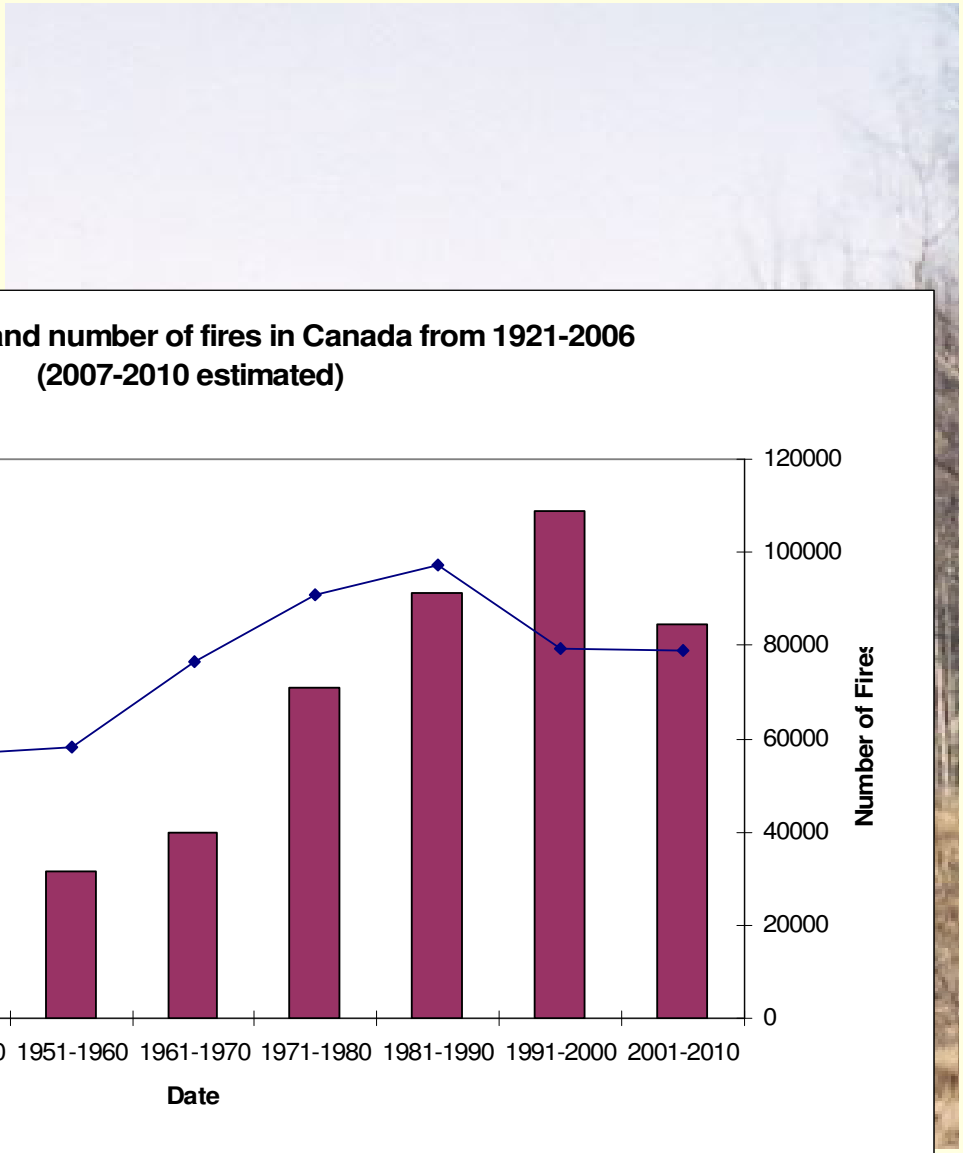
Forest Fire Danger Rating Systems

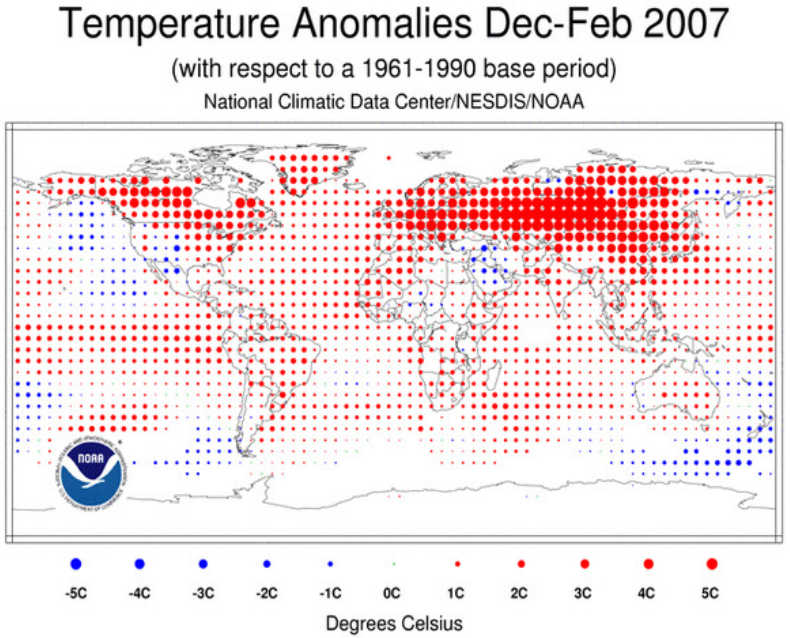
- Fire research has been ongoing since the 1920s in the CFS
- Fire Weather Index (FWI) System and the Fire Behaviour Prediction (FBP) System
- These systems were not developed with peatlands and wetlands in mind



Area burned (ha) and number of fires in Canada from 1921-2006
(2007-2010 estimated)
Area Burned (ha)
30000000
25000000
20000000
15000000
10000000
5000000
0
Number of Fires
120000
100000
80000
60000
40000
20000
0
1921-1930
1931-1940
1941-1950
1951-1960
1961-1970
1971-1980
1981-1990
1991-2000
2001-2010
Date
Area Burned (ha)
Number of Fires

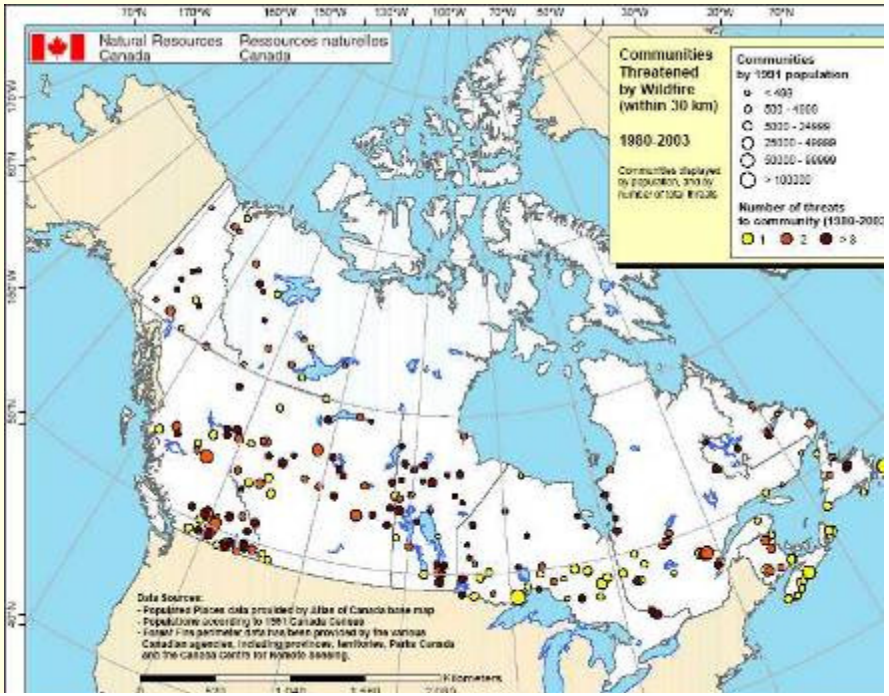
Emerging Fire Management Challenges

- Climate change
- Expanding Wildland Urban Interface (WUI)
- Deteriorating fire management infrastructure
- Forest fire smoke/public health
- Forests under stress
  - Mountain Pine Beetle
- Competition for forest land base
- Public expectation



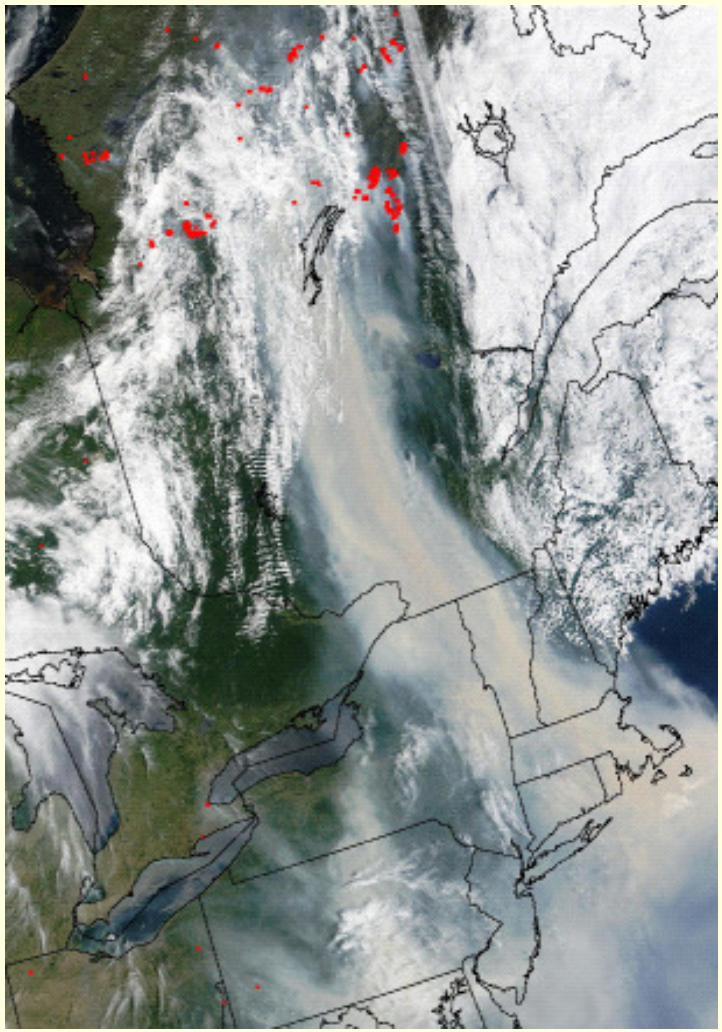
Wildland-Urban Interface (WUI)

- **Managing Public Risk and Expectations in the Wildland-Urban Interface**
  - Lack of building codes requiring fire-resistant structures
  - Hazard mitigation programs (communities and homes) just beginning – no pan-Canadian technical standard
  - Evacuations of northern aboriginal communities increasing – major smoke/health issues



Smoke/Public Health Issues

- Impact in terms of evacuations of nearby communities (particularly northern)
- Long-range impact as CDN fire smoke increasingly affecting air quality in urban centres (often far-removed from fires)
- Growing acceptance that smoke mixed with urban pollution creates a significant health risk in highly populated cities

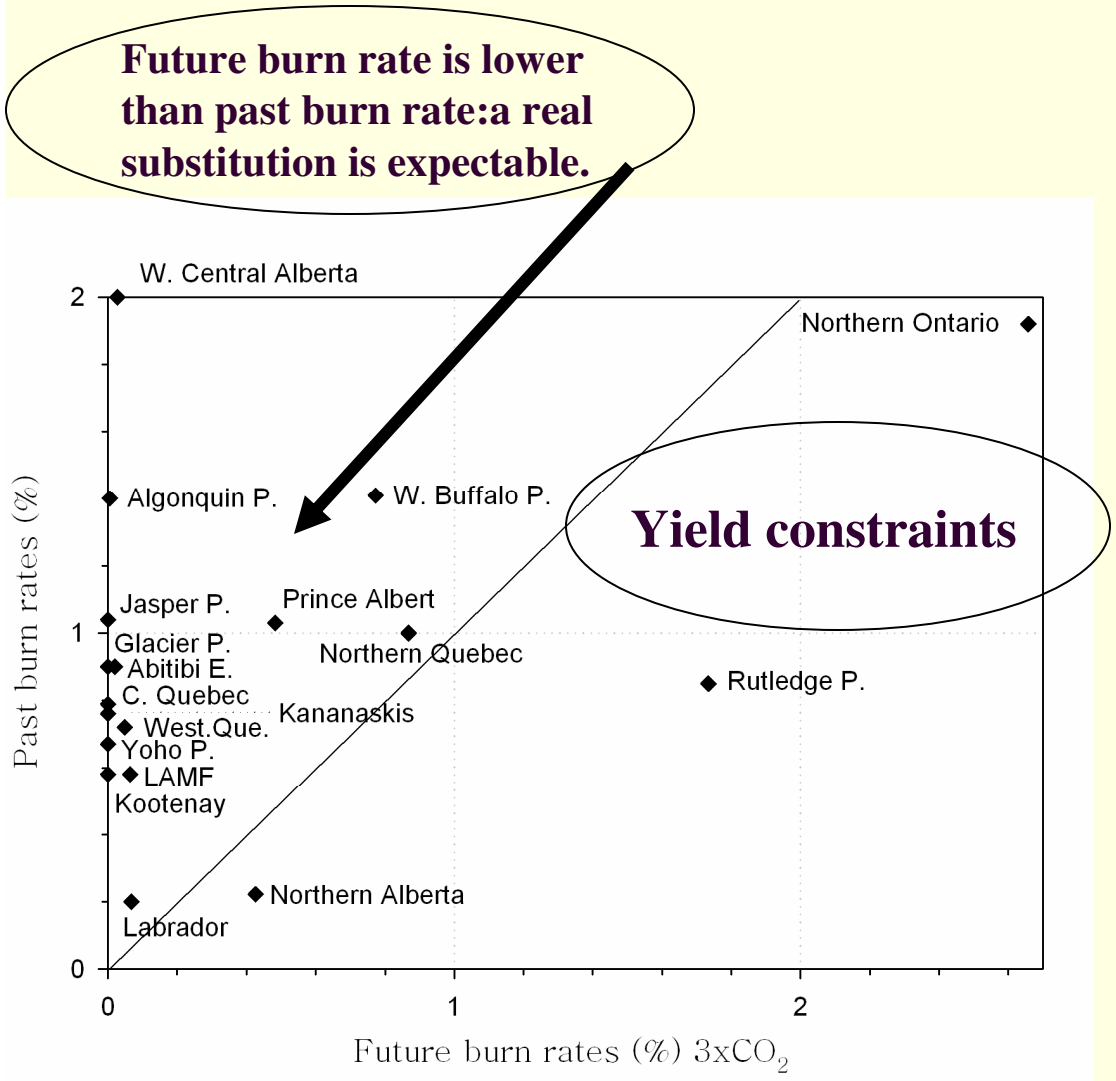


Wildl

The P Factor…Peat

700 Pg carbon stored in the boreal forest ~30-35 % of the global terrestrial biosphere

Sustainable Forest Management

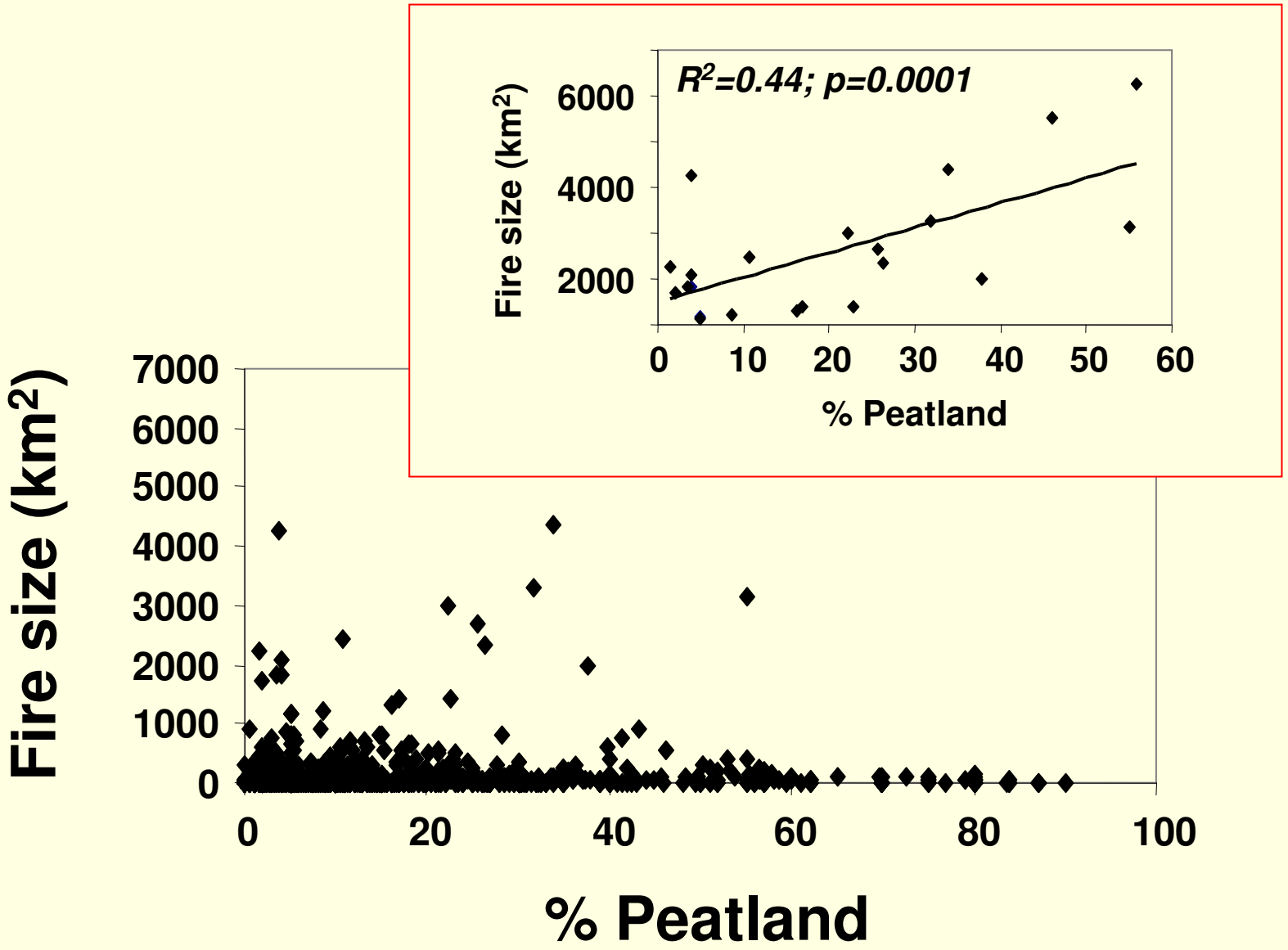


- Future area burned may be less than historical area burned in some regions
- Natural Disturbance based Forest management could be used to recreate the forest age structure of fire-controlled pre-industrial landscapes

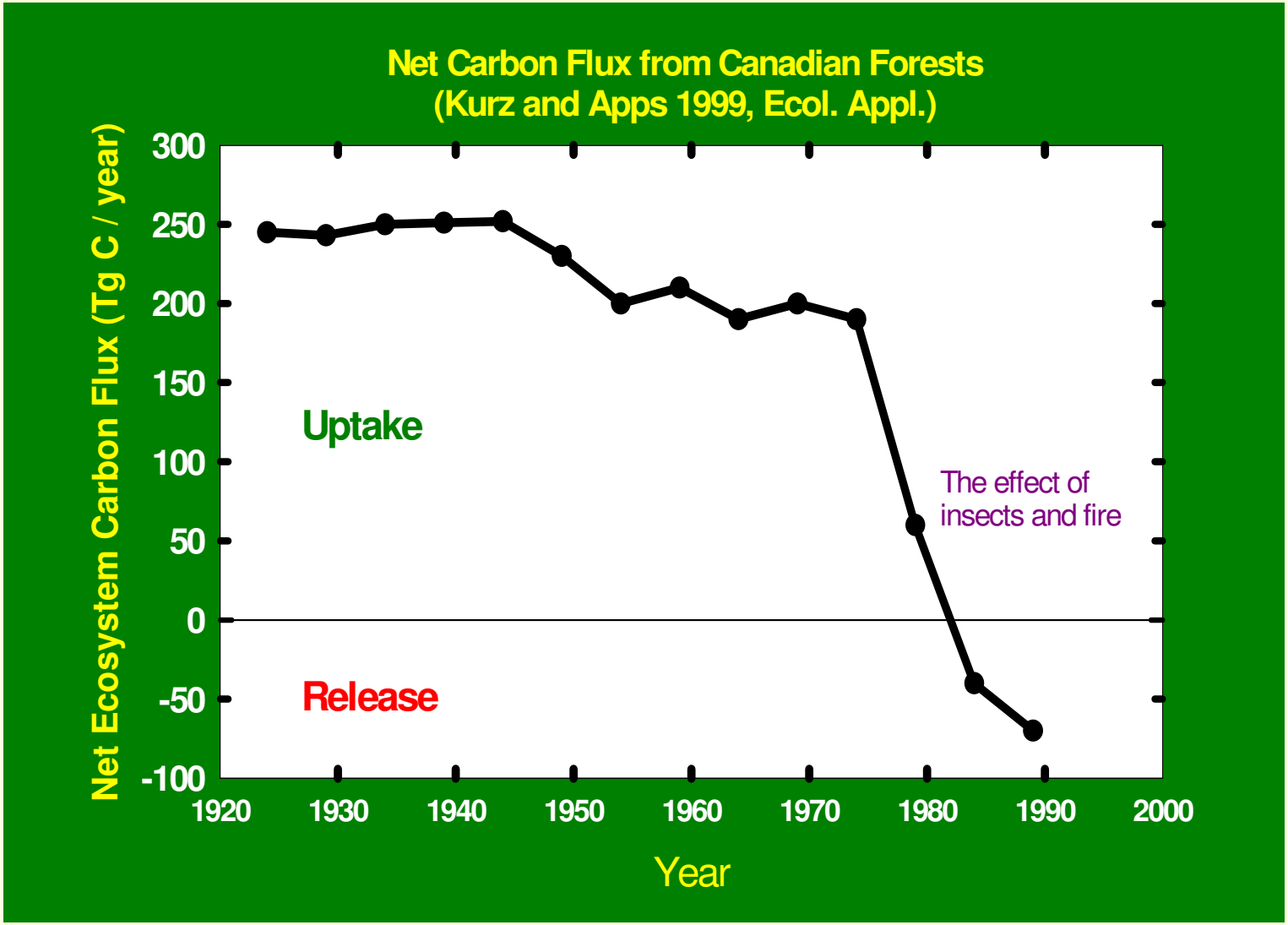
Bergeron, Y., Flannigan, M., Gauthier, S., Leduc, A. and Lefort, P. 2004. Past, current and future fire frequency in the Canadian boreal forest: implications for sustainable forest management. Ambio. 33:356-360

Fire Ecology

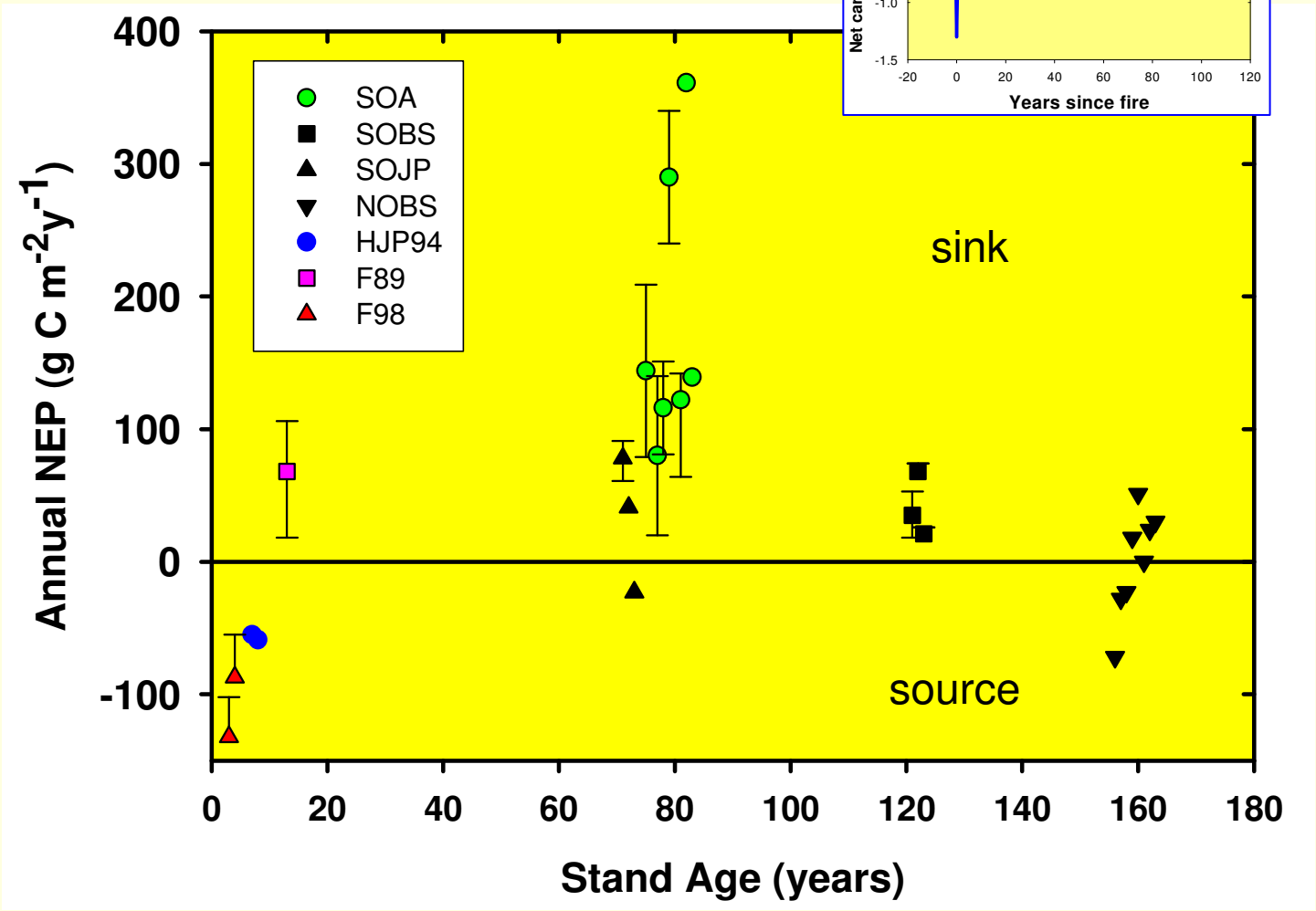
- Boreal forests survive and even thrive in semi-regular high intensity fires (stand renewal)
- Removes competition
- Prepares seedbed
- Survival strategies - Cone serotiny, vegetative reproduction and bark thickness
- Role of fire suppression – Smokey syndrome


R^2=0.44; p=0.0001
Fire size (km^2)
6000
4000
2000
0
10
20
30
40
50
60
% Peatland
Fire size (km^2)
7000
6000
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
% Peatland

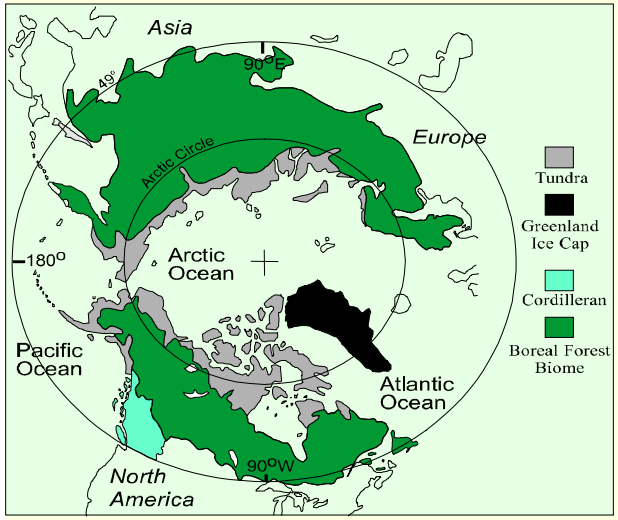
Models estimate that Canadian forests have changed from net carbon sinks to sources, because of enhanced disturbance



Annual Net Ecosystem Production (NEP) in Canadian Boreal Forests and Stand Age



NOBS=Northern Old Black Spruce; data provided by A. Dunn & S. Wofsy

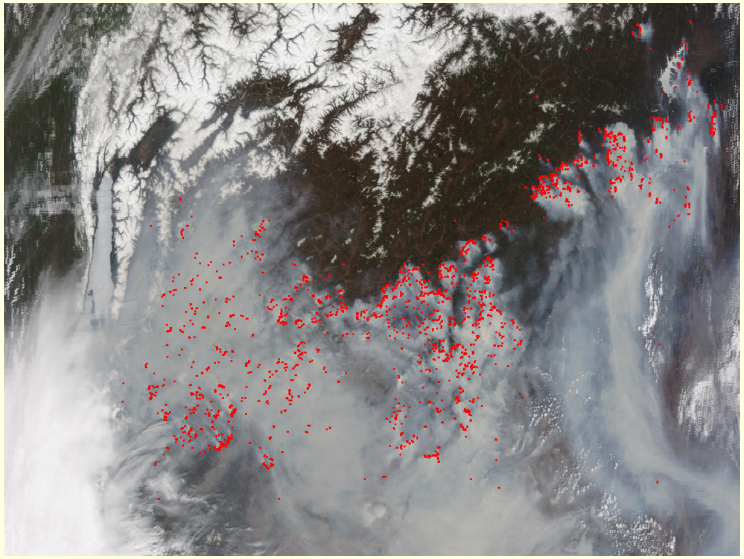


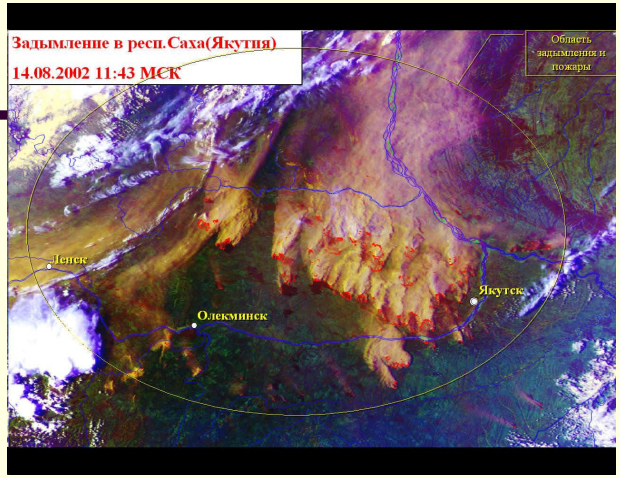
Circumboreal Forest Fire Activity

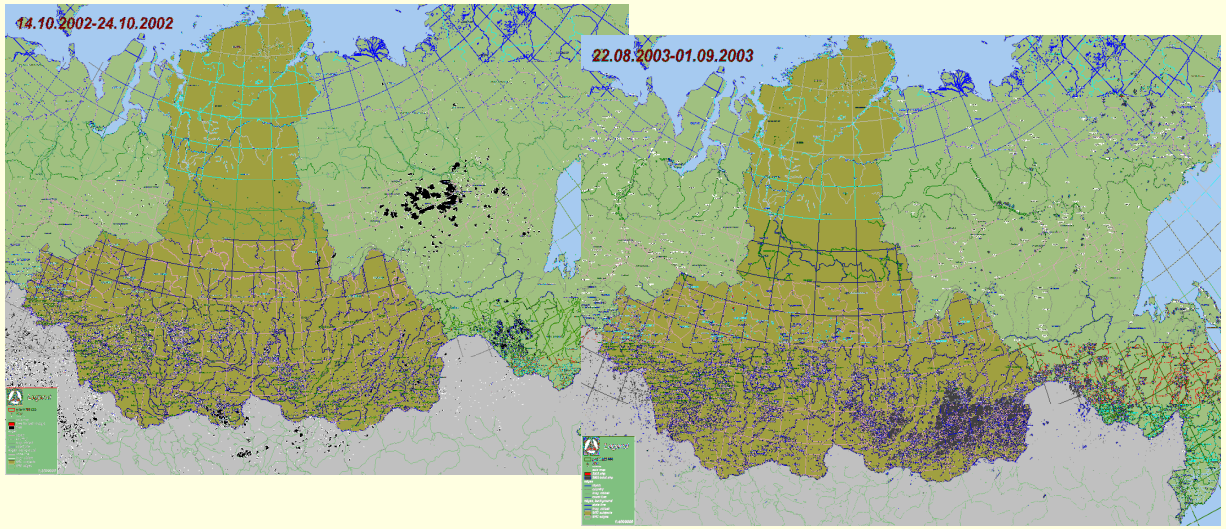
- Annual burned area - 5-15 million hectares (large fires dominate)
- Natural / essential to Boreal ecosystems
- Primarily Canada, Russia and Alaska – historically crown fires in North America and surface fires in Russia
- Russian statistics may be underestimates
- Area burned shows great inter-annual variability
- Continental climate, extreme weather, multiple ignitions

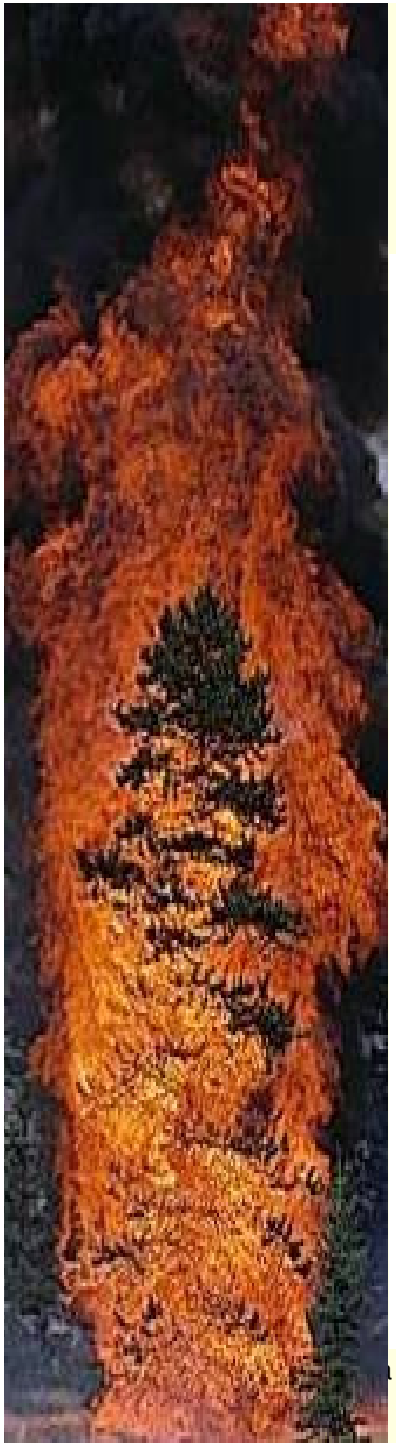
Russia -Increasing Fire Activity/Severity

- ~20 million ha in 2003, 12 million ha in 2002
- More crown fires where surface fires once common
- More C loss, economic impacts
- Smoke transport issues

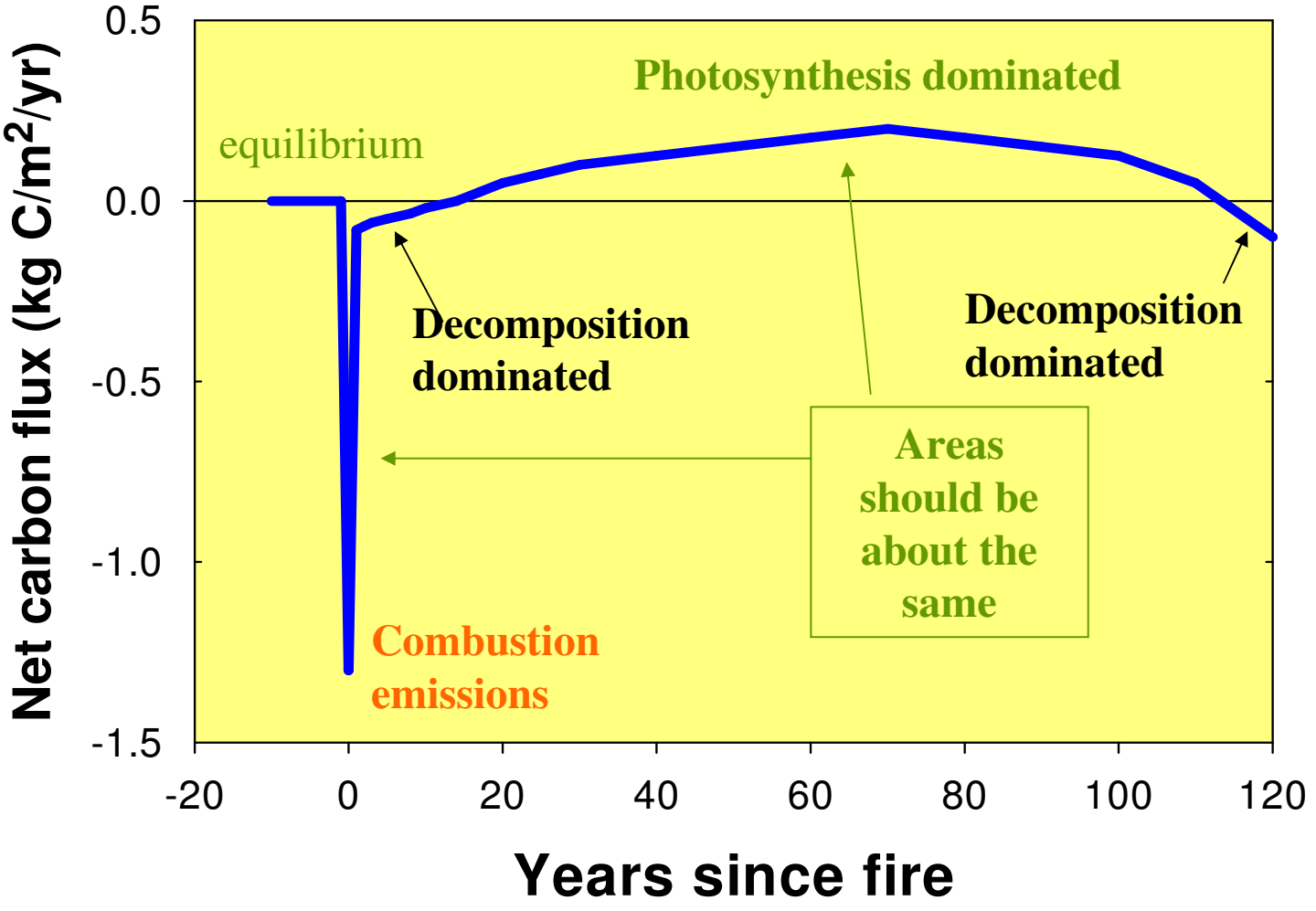




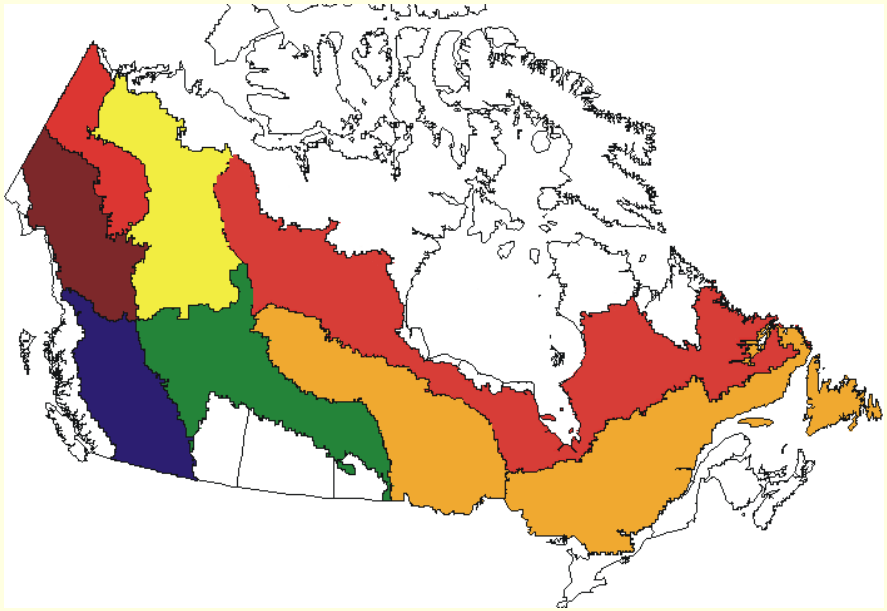




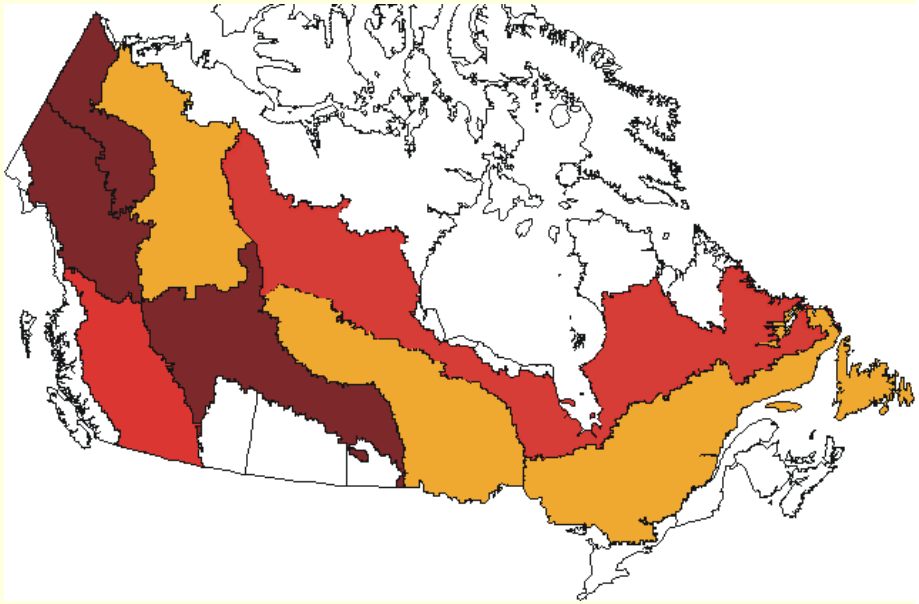
Stylized concept of forest carbon life cycle with fire



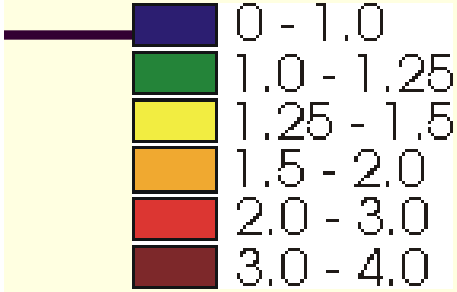
Area Burned Projections: GCM estimates



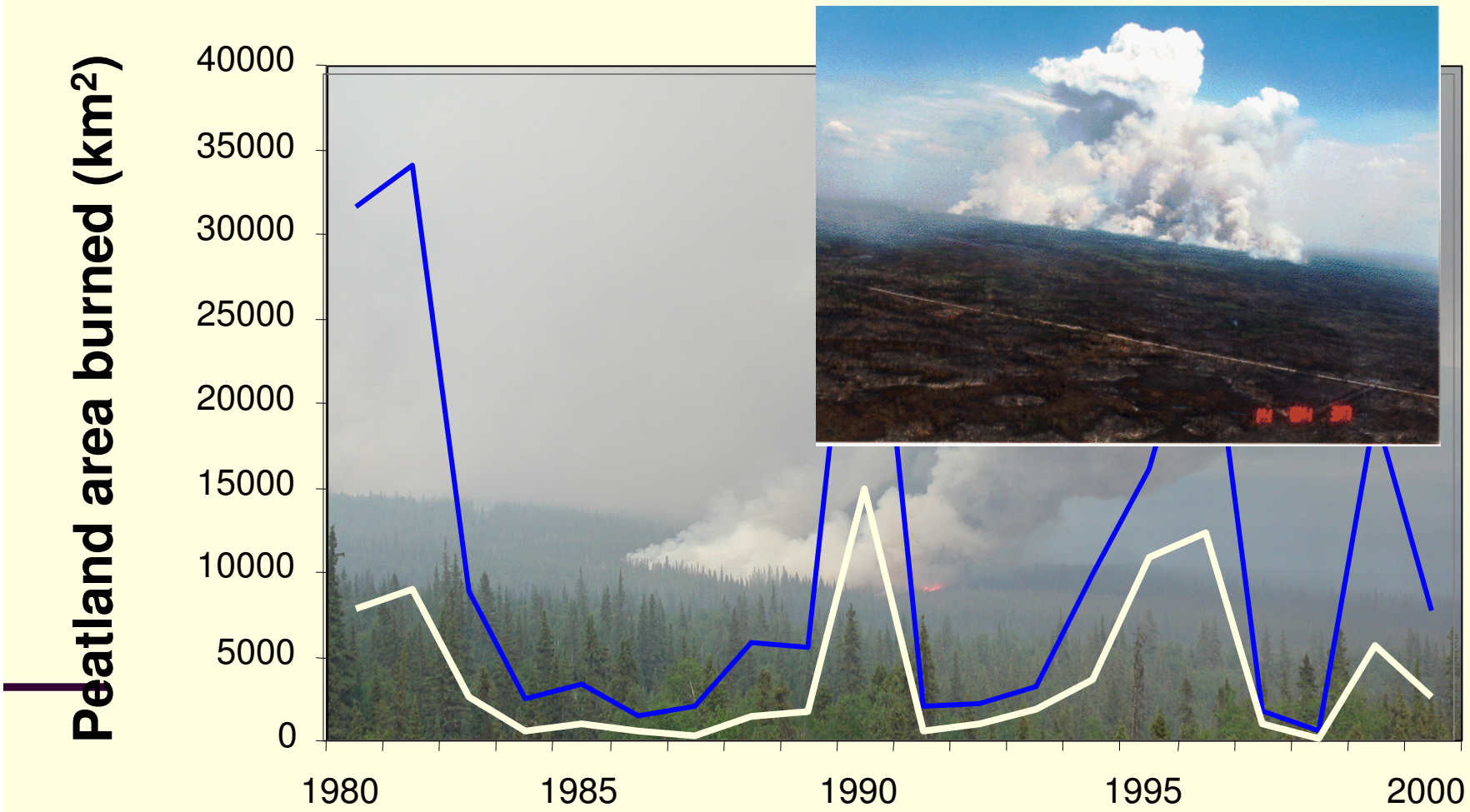
CCC –3xCO_2



Hadley –3xCO_2

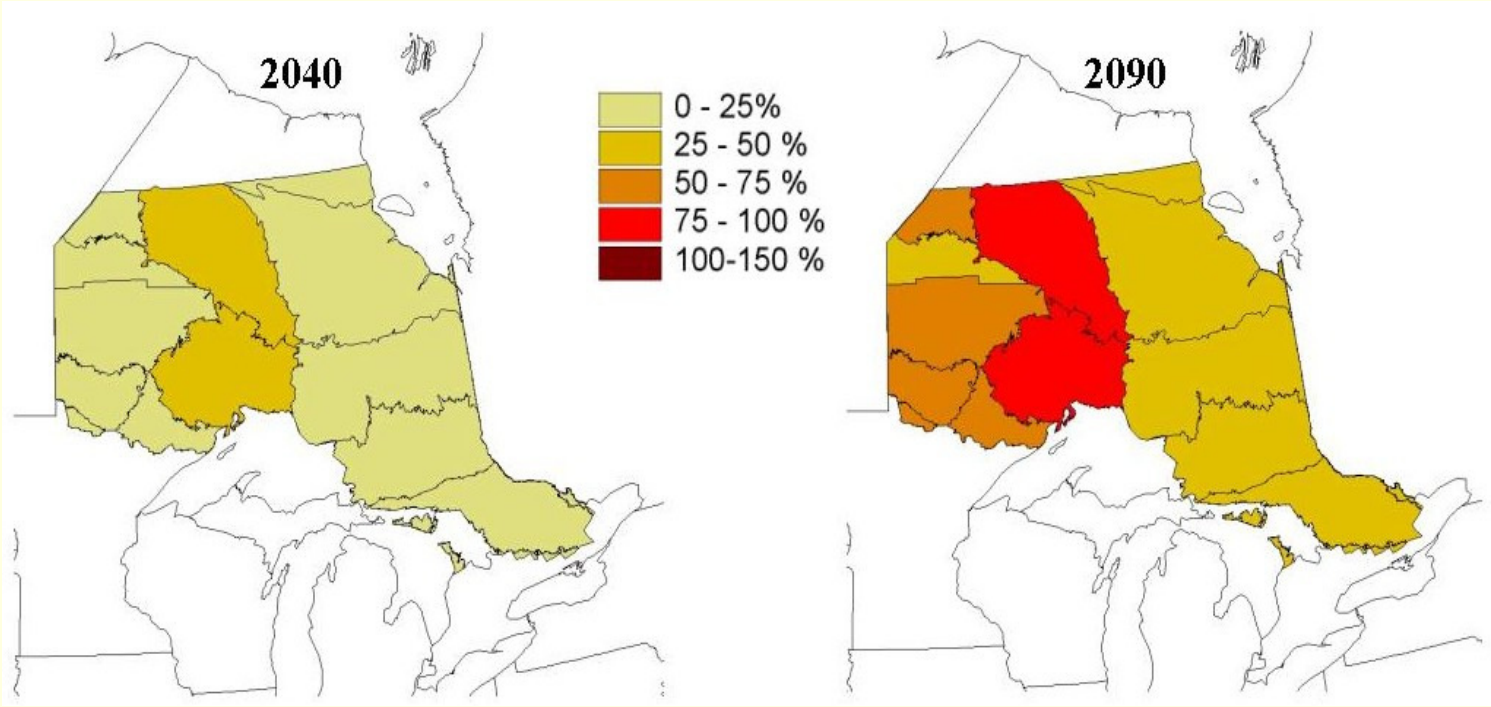


Area burned projections based on weather/fire danger relationships suggest a 75-120% increase in area burned by the end of this century according to the Canadian and Hadley models respectively

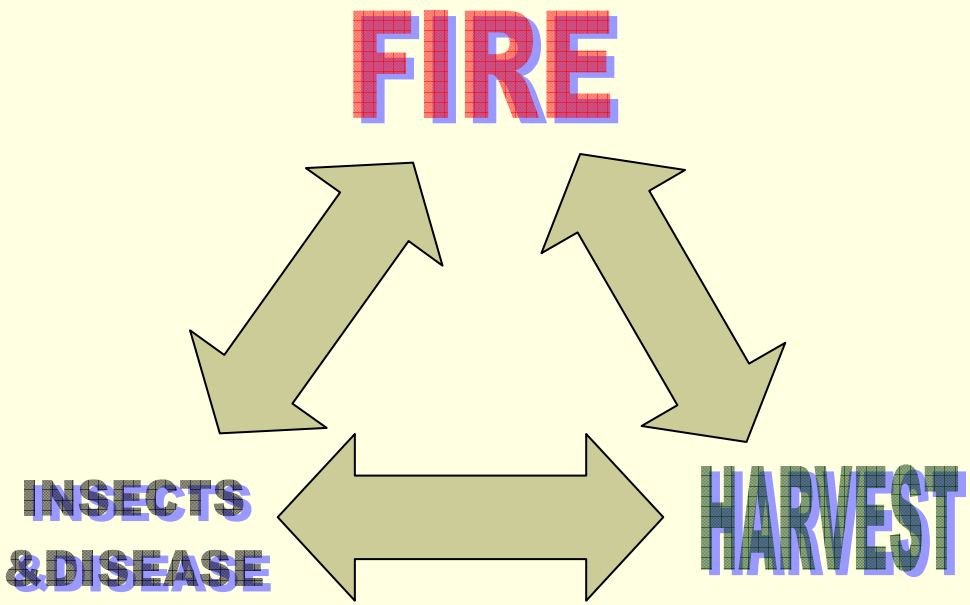

Peatland area burned (km²)
40000
35000
30000
25000
20000
15000
10000
5000
0
1980
1985
1990
1995
2000

Fire Occurrence Prediction

- People-caused and lightning-caused fire occurrence
- Models for Ontario suggest 25-100% increase in fire starts by 2090

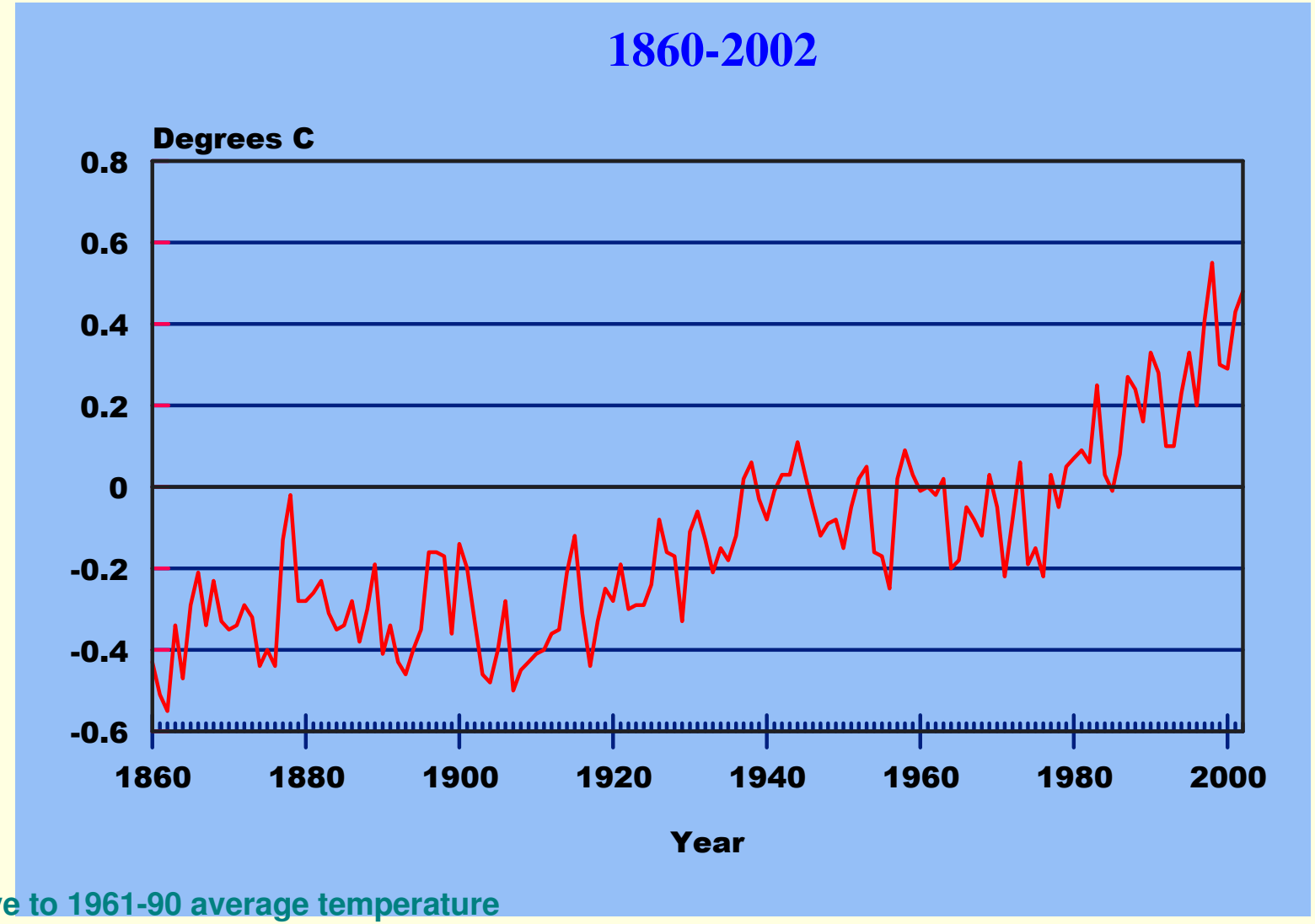


Disturbance Compensation: Can we win?



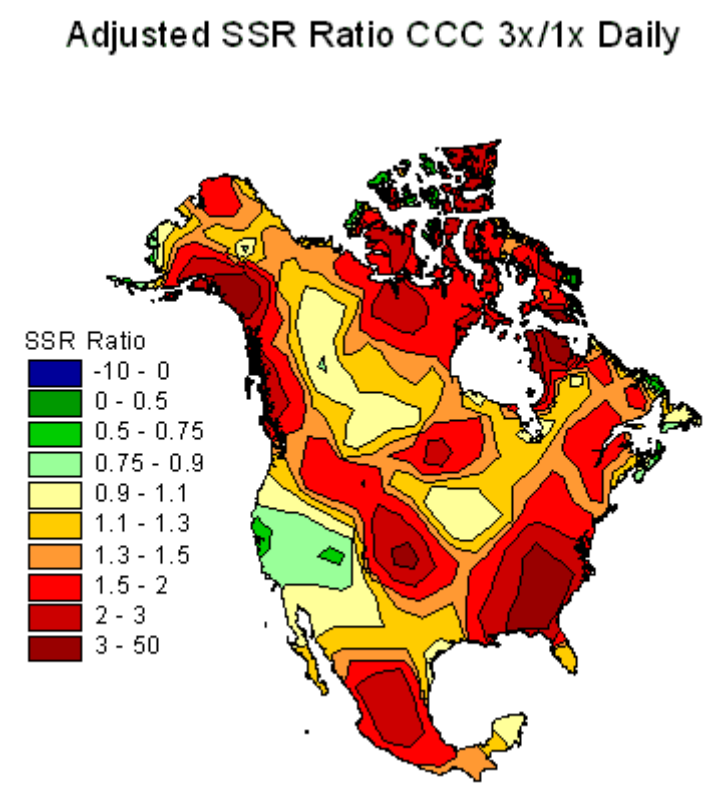
Our management strategies buy time!?

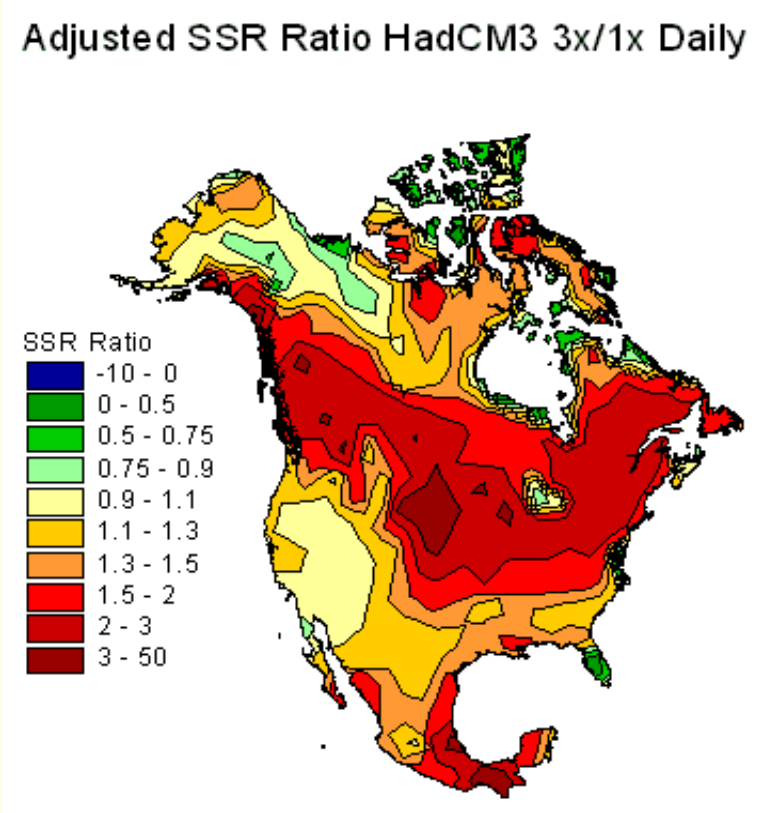
Global surface temperatures are rising



Relative to 1961-90 average temperature

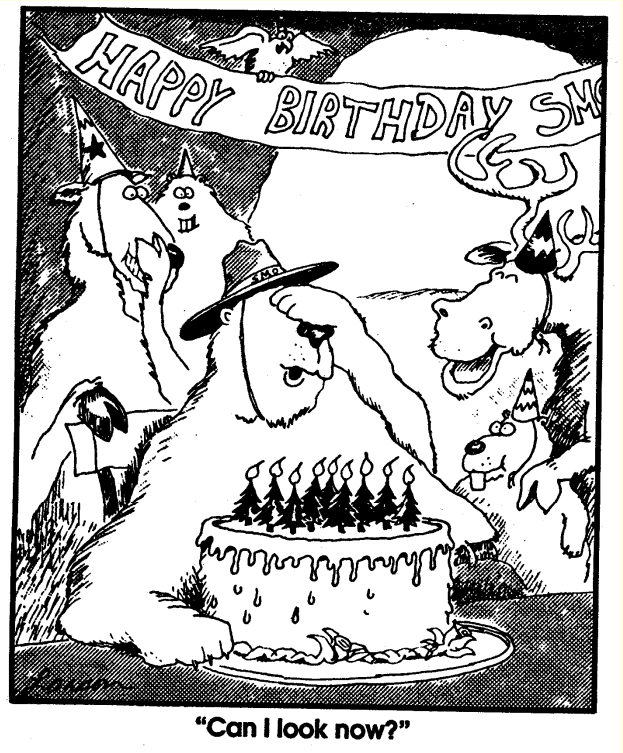
GCMs Seasonal Severity Rating





Summary

- **Weather/Climate and fire are strongly linked**
- **Fire activity is likely to increase significantly with climate change although the response will have large temporal and spatial variability**



"Can I look now?"

- **Are we reaching a tipping point?**
- **Integrated approaches will be required to adapt to climate-change altered fire activity in terms of social, economic and ecological policies and practices**

What will the future be like?

- Longer fire seasons
- More area burned
- More intense fires
- More ignitions – human and lightning-caused
- Fire suppression effectiveness uncertain

But, many of our forest ecosystems have evolved with fire. How much fire do our forests need? And how much can they handle?

Potential Impacts

- Health and safety of Canadians
- Threats to communities and infrastructure
- Sustainable forest management could be jeopardized by increased disturbances
- Fire management agencies may become overwhelmed with respect to climate change altered fire regimes

Fire and Climate Change Research – where we are going

- Better estimates of future area burned and GHG emissions
- Fire Occurrence prediction – lightning and human-caused
- Dynamic vegetation, fire and climate models
- Interactions with other disturbances
- Understanding the effects of atmospheric and oceanic circulations on fire activity
- Understanding processes & interactions using historical data

Disturbances in Canada annually:

418 million ha of total forest (60% is productive timber)

Harvesting: 1 million ha

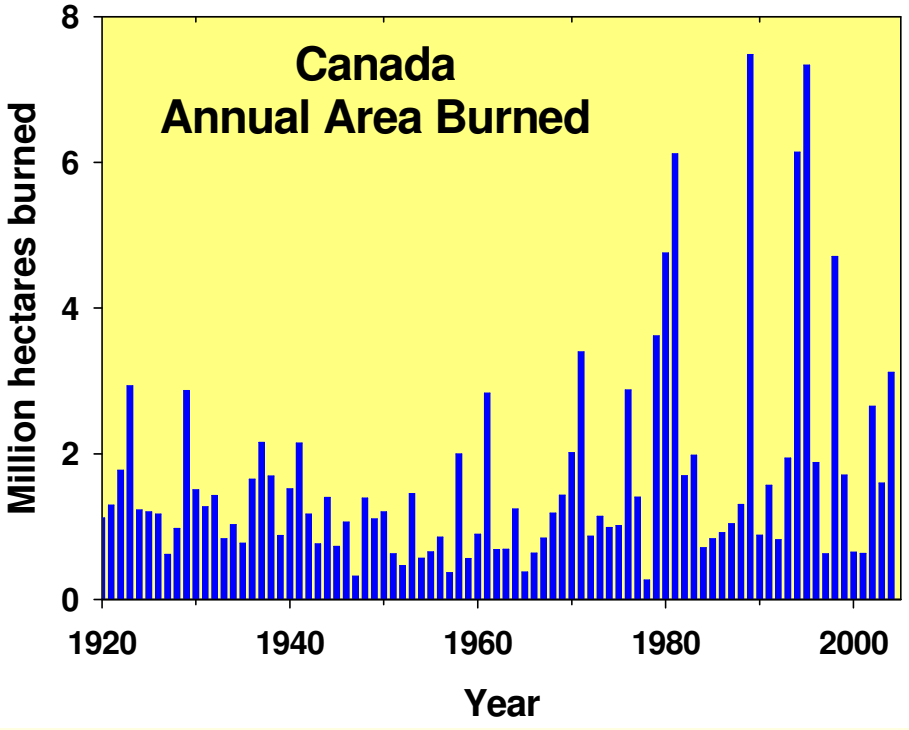
Fire: 1 to 8 million ha

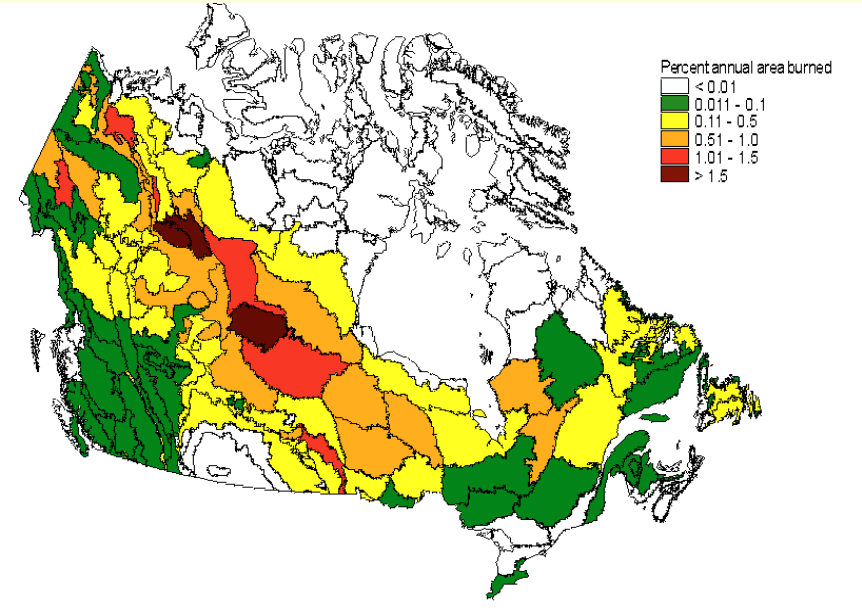
Insects: 10 to 25 million ha

Mike Maksimchuk Alberta SRD

Canadian Fire Statistics

- Incomplete prior to 1970
- Area burned is highly episodic
  - 0.2 to 7.6 million ha
- Lightning fires
  - 35% of total fires
  - represent 85% of area burned
- Fire size
  - 3% of fires are >200 ha
  - represent 97% of area burned





Combustion losses
CO_2, CO, CH_4

Decomposition

Decomposition
CWD,
regeneration

Successional
vegetation to crown
closure

Renewed
mature
forest stand

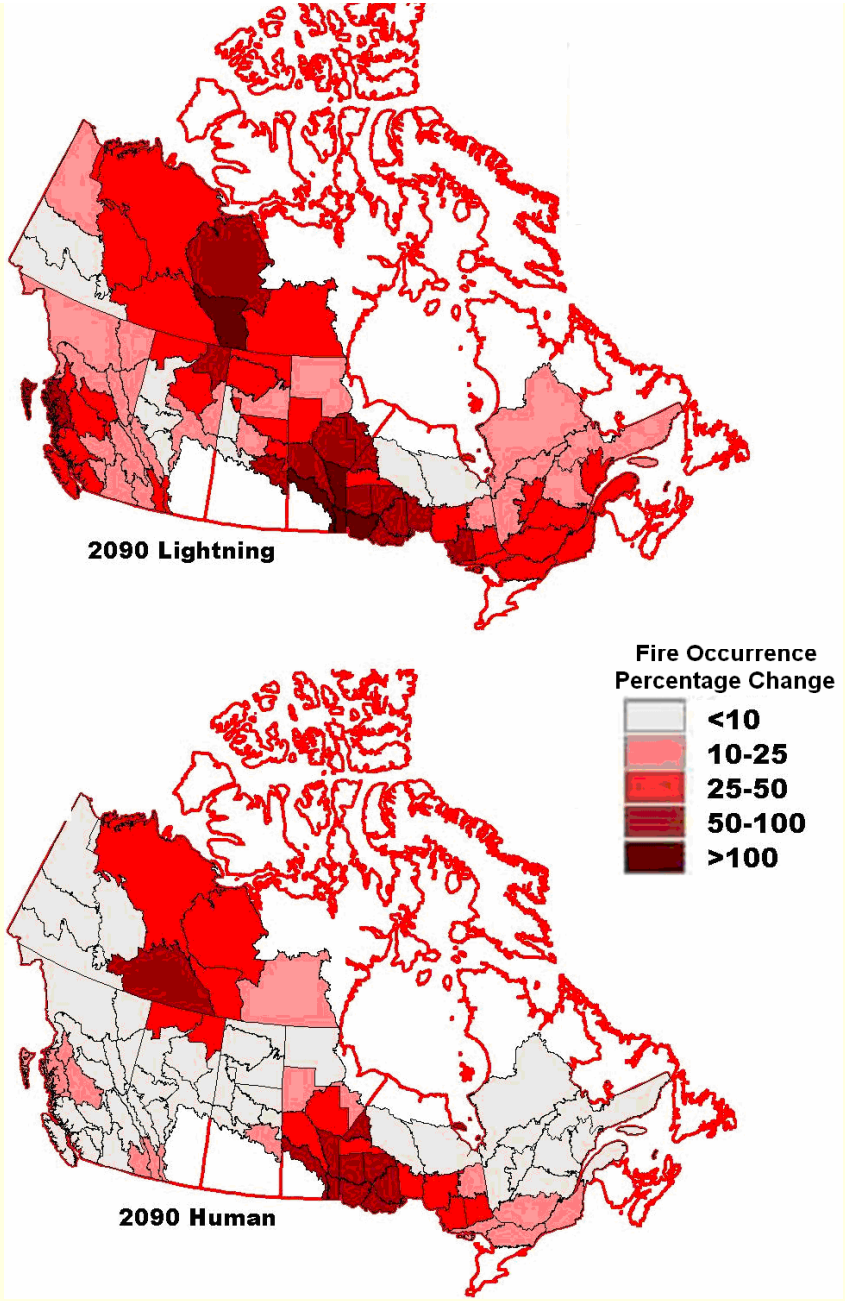
Future Fire

- 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

- Recent trends – see IJWF Flannigan et al. (2009) review paper 18:483-507.



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.