The Science of Climate Change

Presentation to ICLR Friday Forum
October 14, 2011

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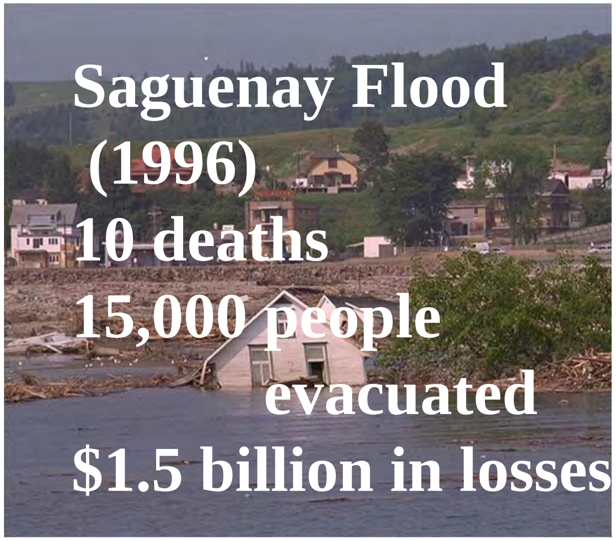
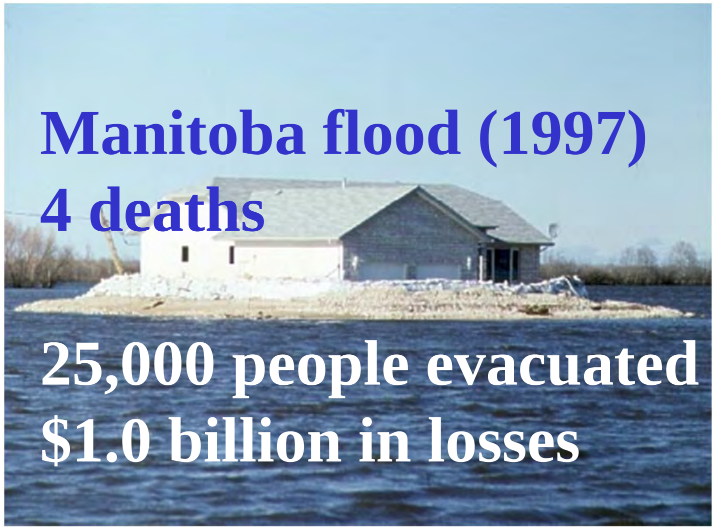
Canada has had an increasing toll in the the past decades





The Eastern Canada Ice storm - 1998

30+ deaths
$5B + damages
Months of impact

Barrie 1985

Durham, Vaughan

Tornadoe , 2009

Barrie 1985

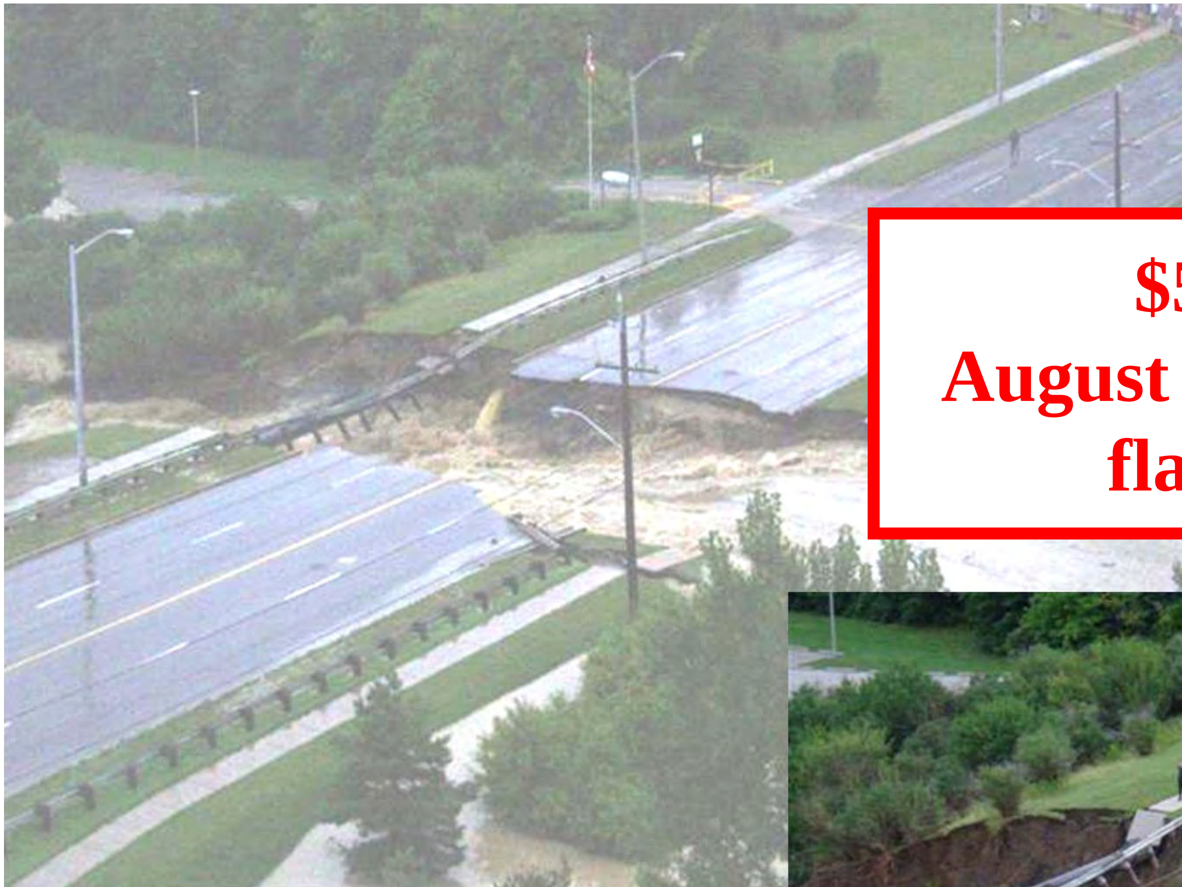
12 people killed

- **800 people homeless**
- **$300M damages**

Historical occurrences of urban flooding
1980, 1996, 2002, 2004
1 in 100 year event in 2002


August 19, 2005

$500M for the August 19, 2005 wind, rain flash flood event



Wind Damage to Infrastructure

Severe Storm	Loss of Service
Sept. 29, 2005	93,000
Nov. 6, 2005	120,000
Nov. 16, 2005	50,000
Feb. 4, 2006	100,000
July 17, 2006	170,000
Aug. 2, 2006	150,000
Sept. 24+27, 2006	93,000

HAZARD: ***potentially damaging physical event, phenomenon or human activity that* MAY *cause the loss of life or injury, property damage, social and economic disruption or environmental degradation."***

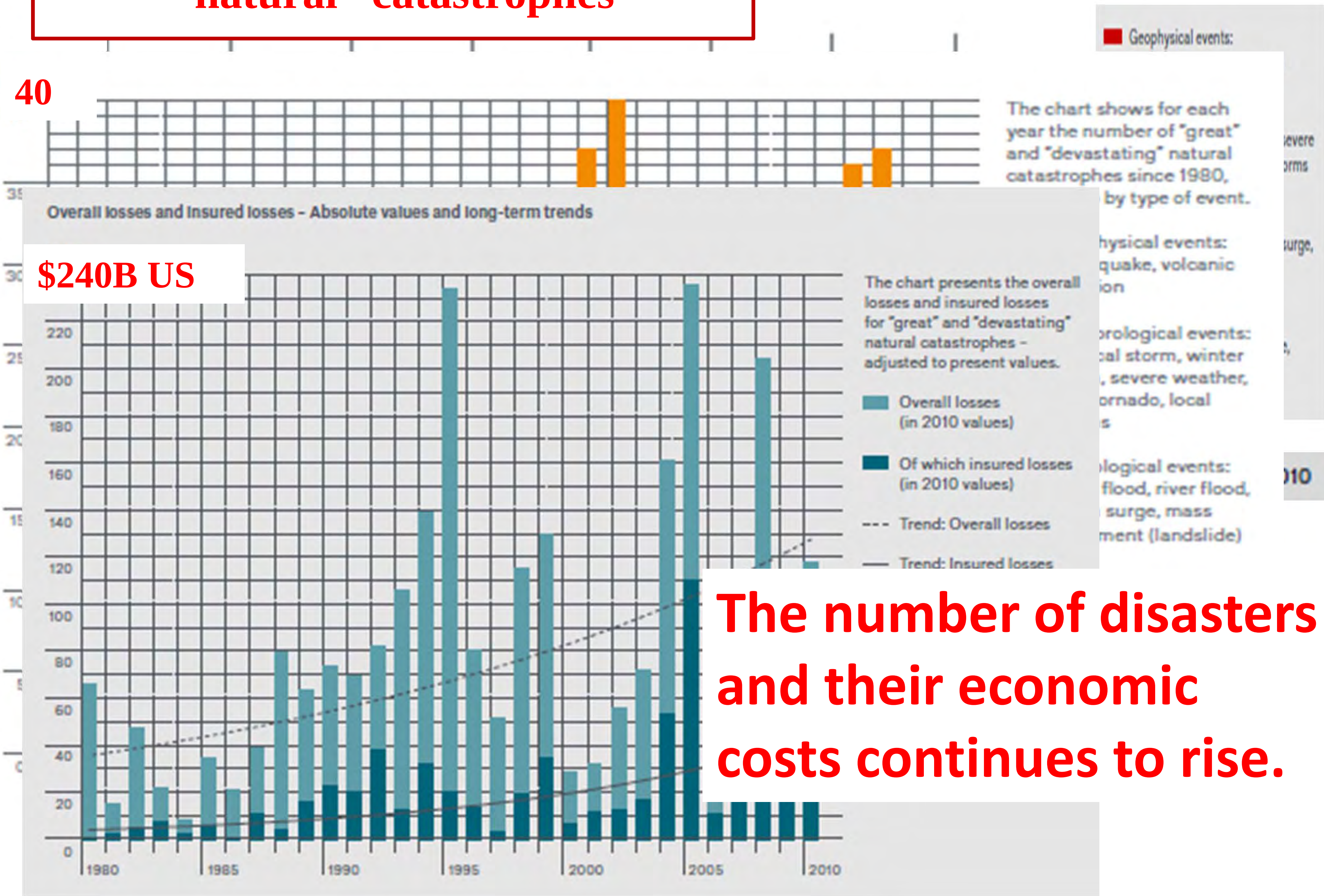
VULNERABILITY: ***conditions determined by physical, social, economic, and environmental factors or pro[...] the susceptibility of a community to the[...]***

A natural disaster –
"serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources."

Disasters result when there is the intersection of a hazard and a vulnerability

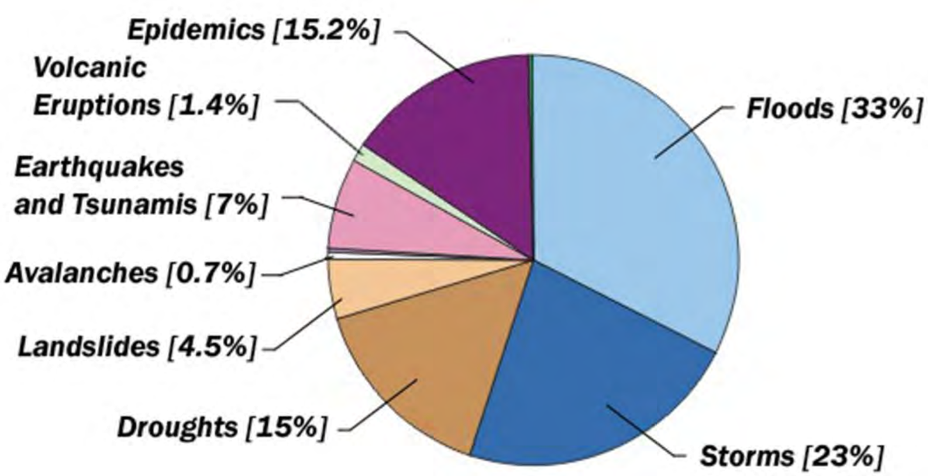
Research on both hazard and vulnerability

Number of great and devastating “natural” catastrophes



The number of disasters and their economic costs continues to rise.

Floods, storms, droughts, …>75%



Earthquakes, tsunamis -7% - horrific

Epidemics – 15%

Global Impacts of Hazards

"Over the last two decades (1988-2007), 76% of all disaster events were hydrological, meteorological or climatological in nature; these accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards."

"The real tragedy is that many of these deaths can be avoided."

Mega-Disasters – > 10,000 fatalities

2003-2008

Year	Country	Disaster	Fatalities
1983	Ethiopia	Ethiopian drought	300,000
1976	China	Tangshan earthquake	242,000
2004	South Indian Ocean	Indian Ocean tsunami	226,408
1983	Sudan	Sudan drought	150,000
1991	Bangladesh	Cyclone Gorky	138,866
2008	Myanmar	Cyclone Nargis	133,655
1981	Mozambique	Southern Mozambique drought	100,000
2008	China	Sichuan earthquake	87,476
2005	India, Pakistan	Kashmir earthquake	73,338
2003	Europe	European heat wave	56,809
1990	Iran	Manjil-Rudbar earthquake	40,000
1999	Venezuela	Vargas floods	30,000
2003	Iran	Bam earthquake	26,796
1978	Iran	Tabas earthquake	25,000
1988	Soviet Union	Spitak earthquake	25,000
1976	Guatemala	The Guatemala earthquake	23,000
1985	Colombia	Nevado Del Ruiz volcano	21,800
2001	India	Gujarat earthquake	20,005
1999	Turkey	Izmit earthquake	17,127
1998	Honduras	Hurricane Mitch	14,600
1977	India	Andhra Pradesh cyclone	14,204
1985	Bangladesh	Bangladesh cyclone	10,000
1975	China	Haicheng earthquake	10,000

Climate related

Table 1.1: Disasters with more than 10,000 fatalities, January 1975 – June 2008 4

(Highlighting denotes disasters within the five-year period, 2003–2008.) EMDAT; Analysis by ISDR, 2008

2003-2008

Mega-Disasters – > $US 10 B in losses

Year	Country	Hazard	Total loss (billion US$)
2005	United States of America	Hurricane Katrina	125
1995	Japan	Kobe earthquake	100
2008	China	Sichuan earthquake	30
1998	China	Yangtze flood	30
2004	Japan	Chuetsu earthquake	28
1992	United States of America	Hurricane Andrew	26.5
1980	Italy	Irpinia earthquake	20
2004	United States of America	Hurricane Ivan	18
1997	Indonesia	Wild fires	17
1994	United States of America	Northridge earthquake	16.5
2005	United States of America	Hurricane Charley	16
2004	United States of America	Hurricane Rita	16
1995	Democratic People's Republic of Korea	Korea floods	15
2005	United States of America	Hurricane Wilma	14.3
1999	Taiwan (China)	Chichi earthquake	14.1
1988	Soviet Union	Spitak earthquake	14
1994	China	China drought	13.8
1991	China	Eastern China floods	13.6
1996	China	Yellow River flood	12.6
2007	Japan	Niigataken Chuetsu-oki earthquake	12.5
1993	United States of America	Great Midwest flood	12
2002	Germany	River Elbe floods	11.7
2004	United States of America	Hurricane Frances	11
1991	Japan	Typhoon Mireille	10
1995	United States of	Major west coast wind storm	10

Climate related

Table 1.2 Disasters leading to losses of more than US$ 10 billion, January 1975 – June 2008
(Highlighting denotes disasters within the five-year period, 2003–2008.) Source: EMDAT; Analysis by ISDR

Why the increasing trends?

- Social and demographic characteristics
  - More people and more complex societies
  - Growing inequality - Poverty
- Choices or necessity– where to live, work, play and travel
  - Urbanization of societies – most along coasts and rivers
  - Great concentrations of people in communities
  - More exposure
- Built and commercial environments
  - Growing density
  - Dependence – vulnerability
  - Transportation – people and goods

- **More structure – much of its aging**
  - **Particularly in urban areas**
- **Human intervention in the environment**
  - **Changing landscapes**
    - **Development along rivers – changing flood risks**
    - **Destruction of forest and mangroves – changing risk of floods and impacts of storm surges, tsunamis**
  - **Emission of pollutants and greenhouse gases**
    - **Changing threats from air and water pollution**
    - **Changing the climate**

The Climate System and its Science

The system is complex and our understanding is based on decades of scientific study

- **Archimedes, Newton, …**
- **1824 – Fourier – first paper on greenhouse effect**
- **1896 – Arrhenius- theoretical model of Greenhouse effect**
- **1957 - International Geophysical Year - 1957**
    - **carbon cycle, ozone and oceans**
- **1960's**
    - **First earth observation satellites**
- **1980 – start of World Climate Research Program**

Climate Science Assessment

- **The Intergovernmental Panel on Climate Change**
    - **Established in 1988 by the World Meteorological Organization and the United Nations Environmental Programme**
- **Science Assessments – 1990, 1995, 2001, 2007**

Time Scales for Climate System

• Water cycle	10 days
• Ocean response	years to centuries
• Emissions to globe	years
• Methane gas	10 years
• Carbon dioxide	100 years
• End-use technologies	years
• Supply technologies	decades
• Social standards	decades
• Infrastructure, …	decades

Oceans control the response time and magnitude

global issues

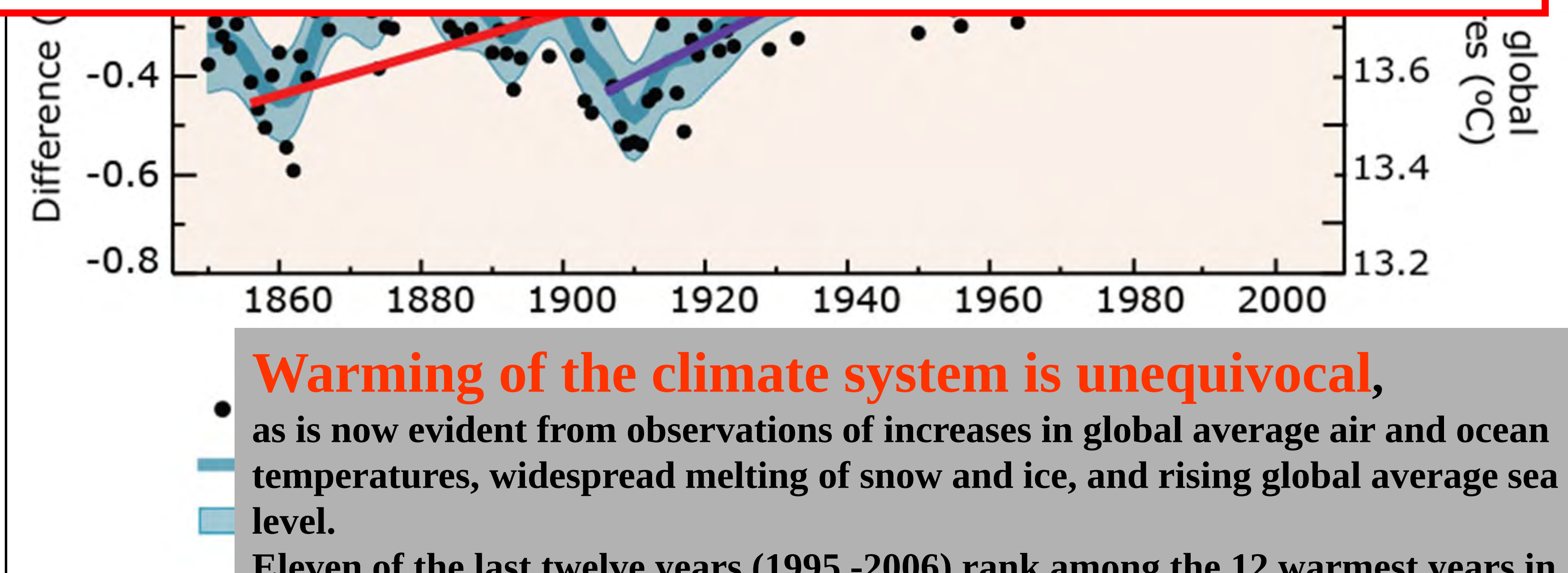
responding


Is the climate changing?

WMO-

"2010 ranked as the warmest year on record, together with 2005 and 1998."

"The ten warmest years on record have all occurred since 1998. Over the ten years from 2001 to 2010, global temperatures have averaged 0.46°C above the 1961-1990 average, and are the highest ever recorded for a 10-year period since the beginning of instrumental climate records."

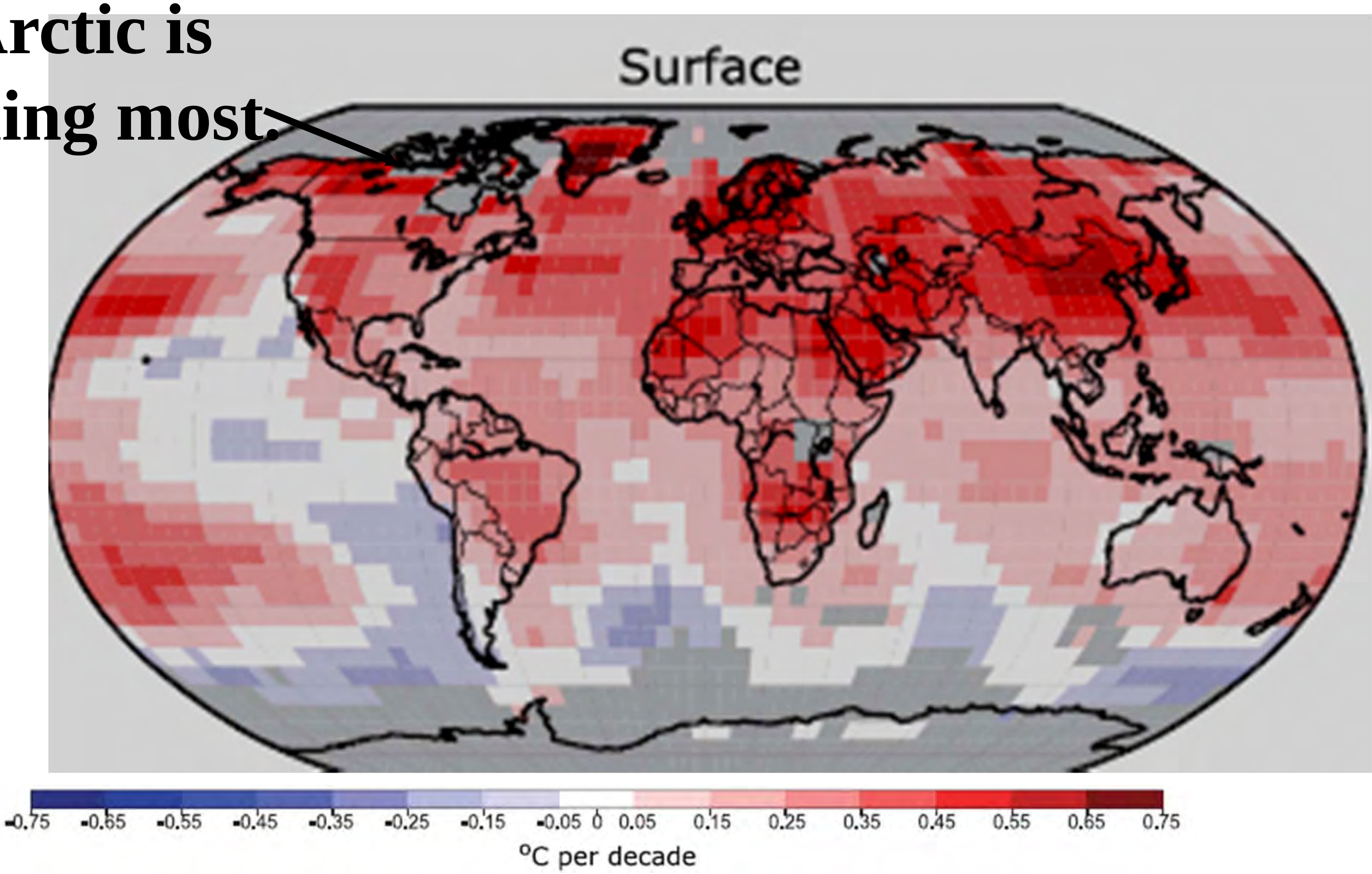


Warming of the climate system is unequivocal,

as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.

Eleven of the last twelve years (1995 -2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850).

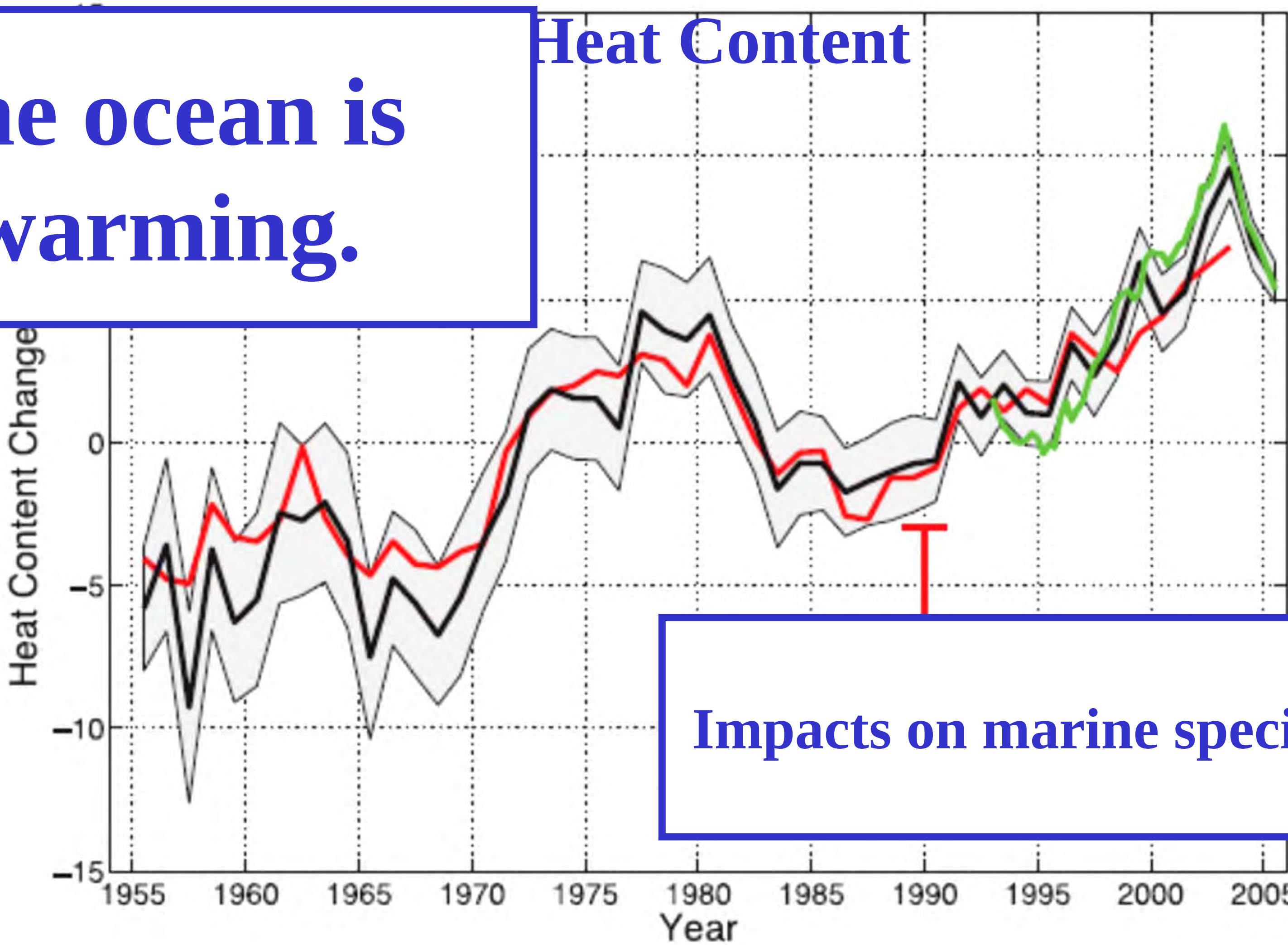
The Arctic is warming most.



Patterns of linear global temperature trends from 1979 to 2005 estimated at the surface

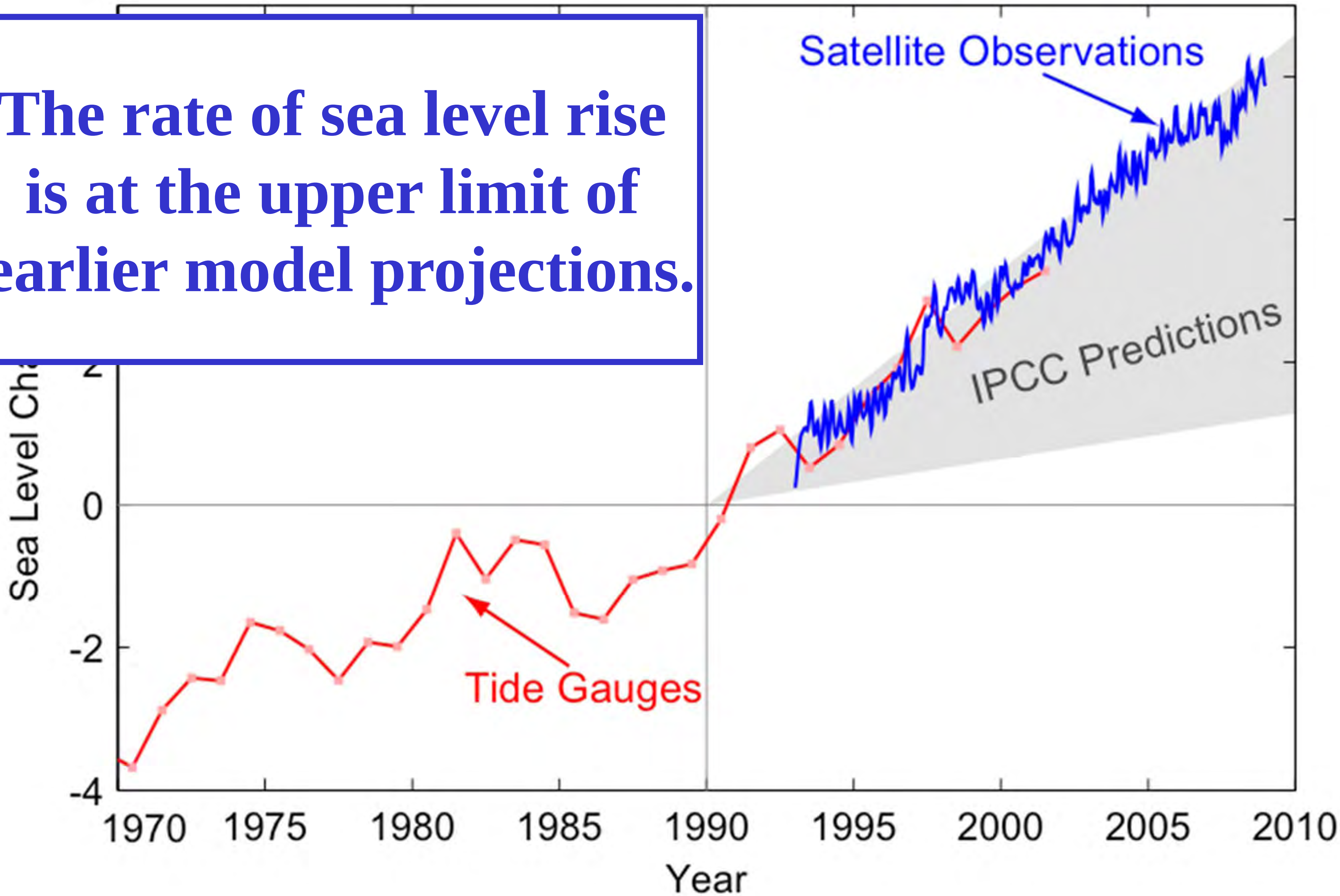
The ocean is warming.

Heat Content



Time series of global annual ocean heat content (10^{22} J) for the 0 to 700 m layer.

The rate of sea level rise is at the upper limit of earlier model projections.

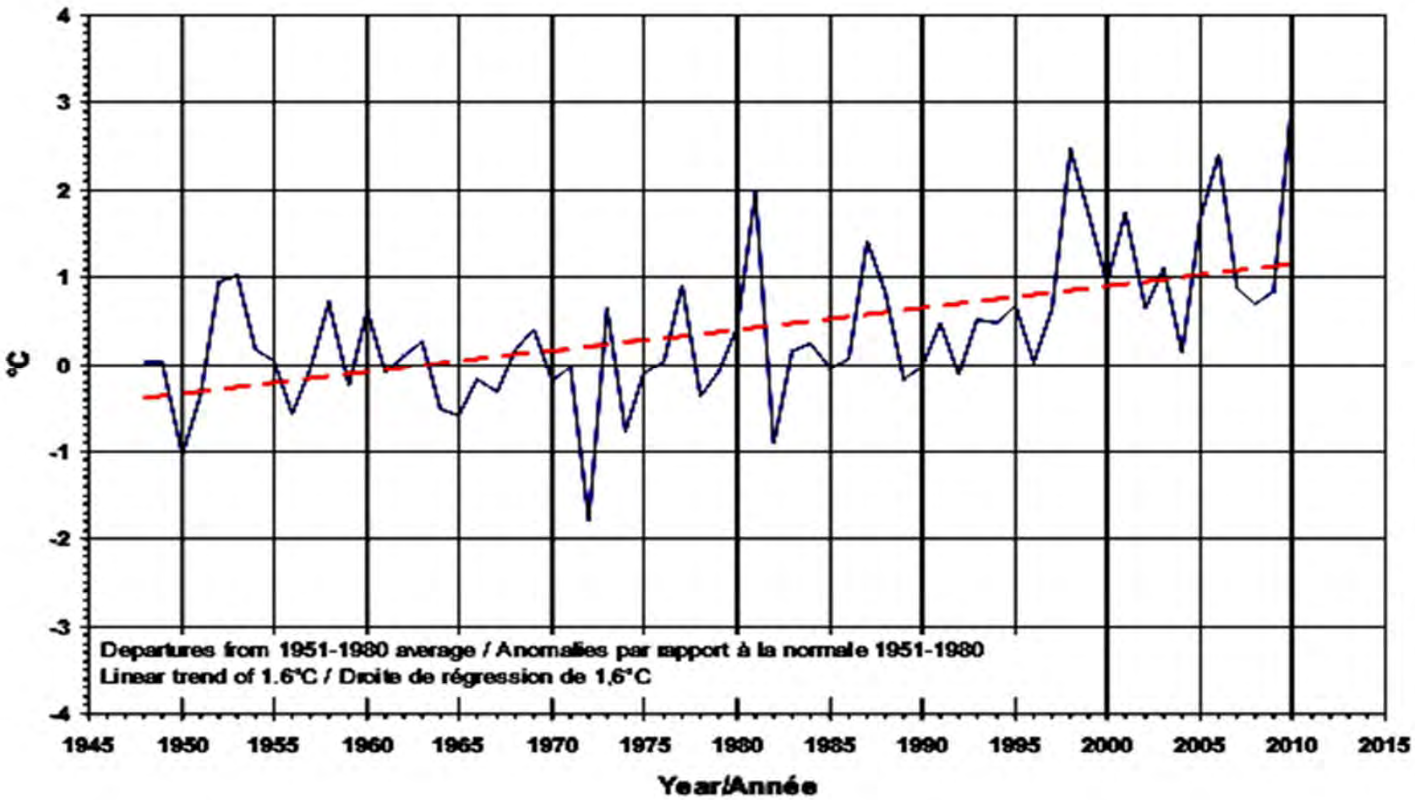



Climate Change in Canada

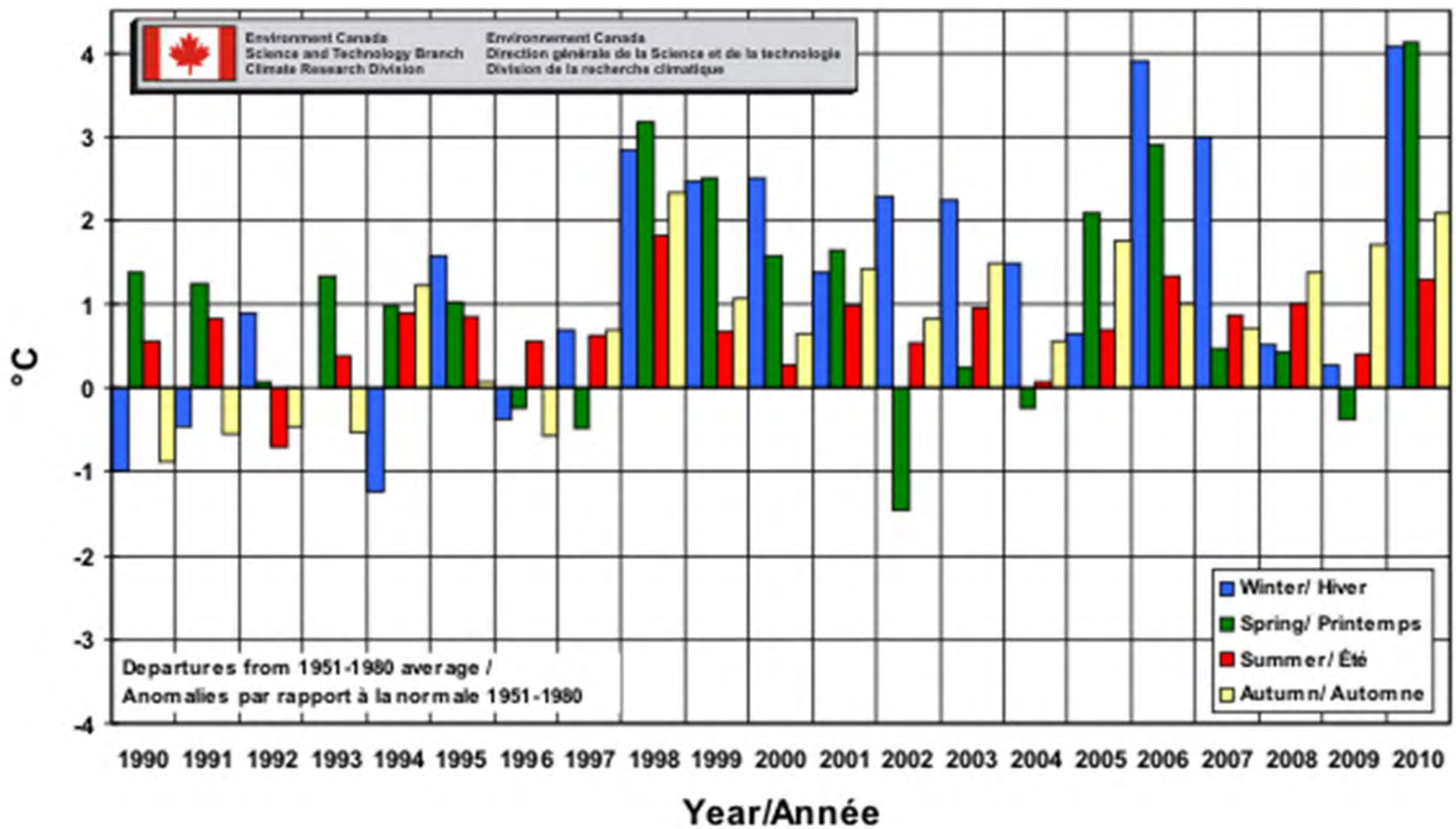
Canadian National Temperature

The national average temperature for the year 2010 was 3.0°C above normal, based on preliminary data, which makes this the warmest year on record since nationwide records began in 1948. The previous warmest year was 1998, 2.5°C above normal. At 1.8°C below normal 1972 was the coolest.

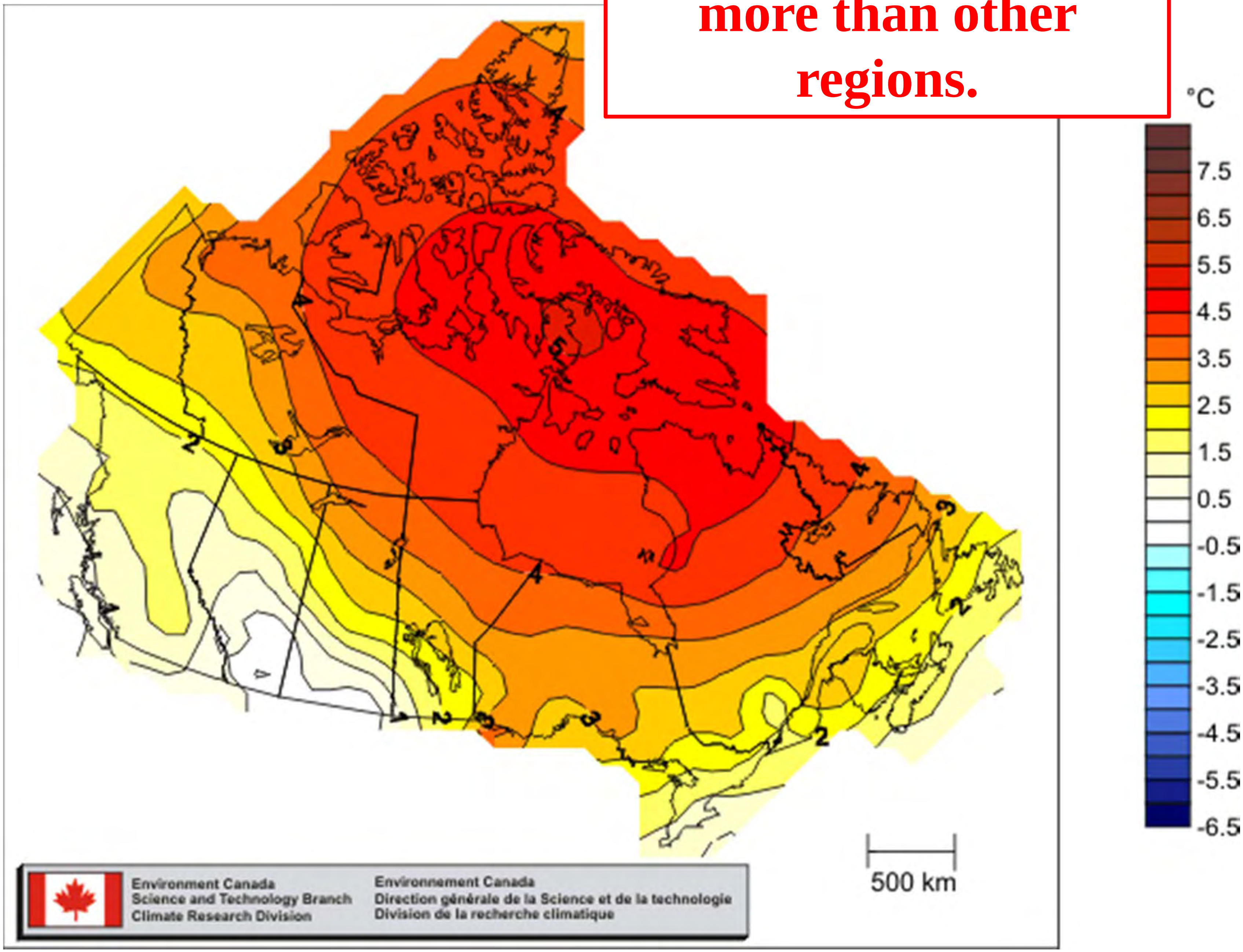
http://www.ec.gc.ca/adsc-cmda/default.asp?lang=En&n=77842065-1



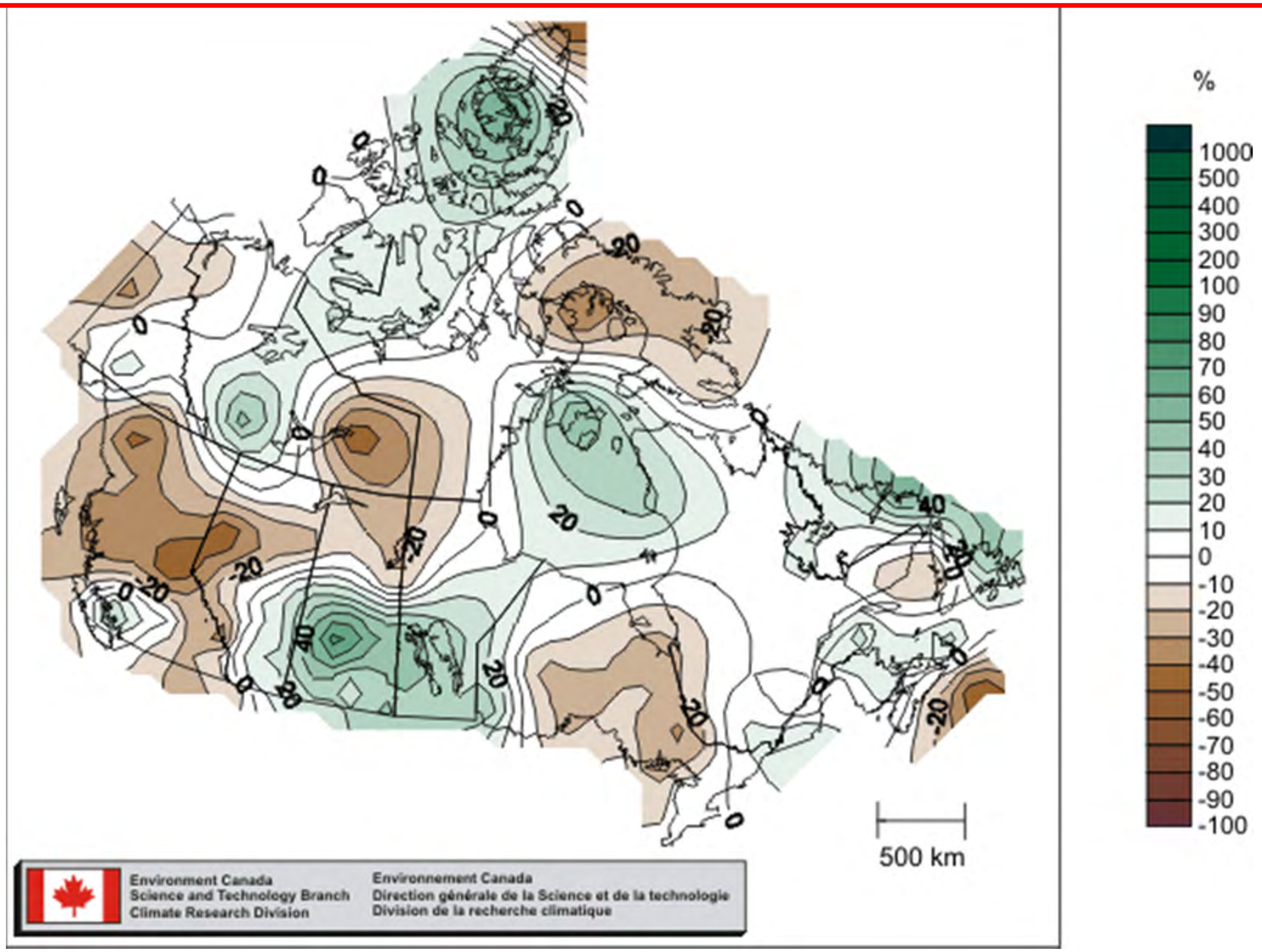
Winters are warming more than other seasons.



The Arctic is warming more than other regions.



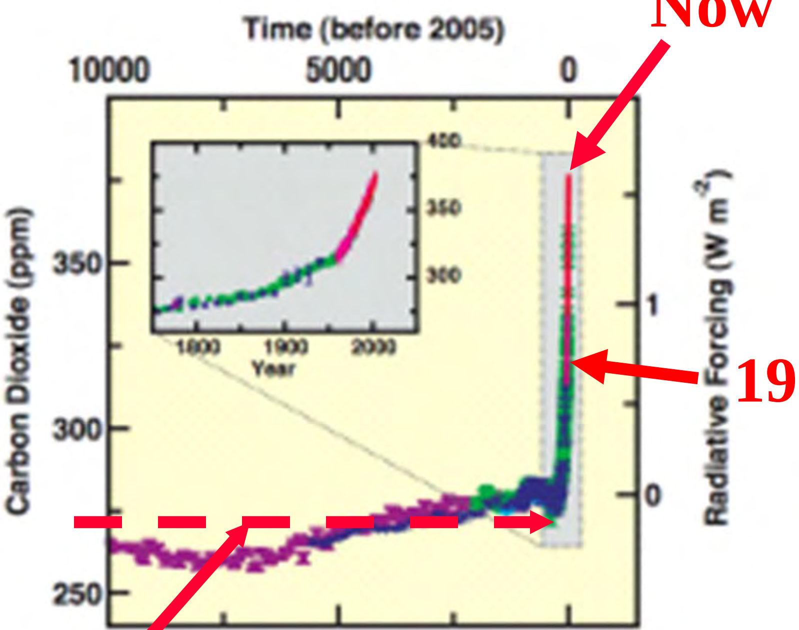
Precipitation in 2010 was “near” normal with major regional variations.




Why is the climate changing?

Changing Greenhouse Gas Concentrations from ice cores and modern data

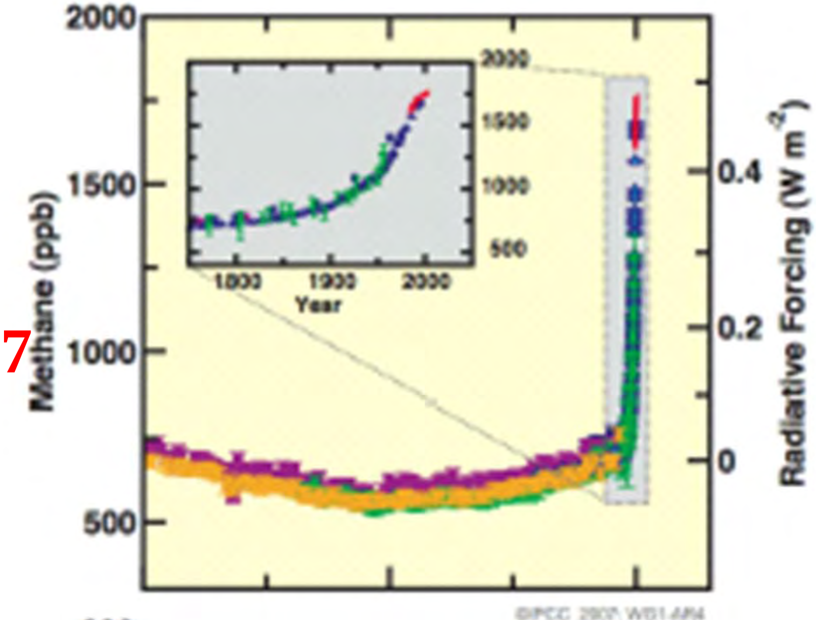
Now



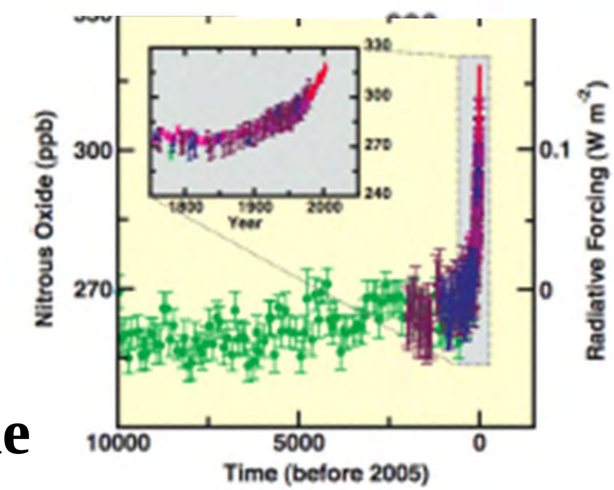
1957

Carbon dioxide

Last 10,000 y

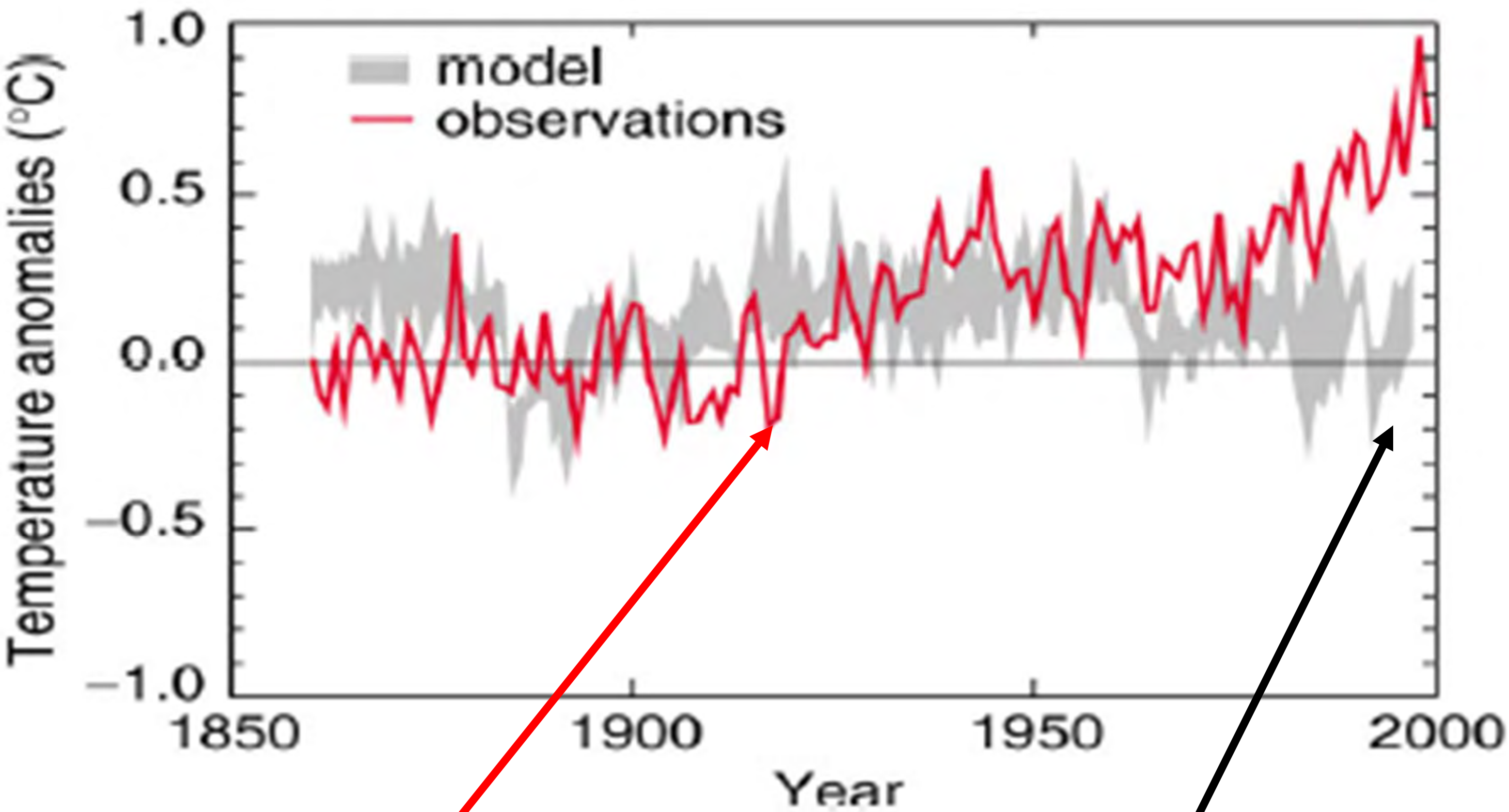


Methane



Nitrous oxide

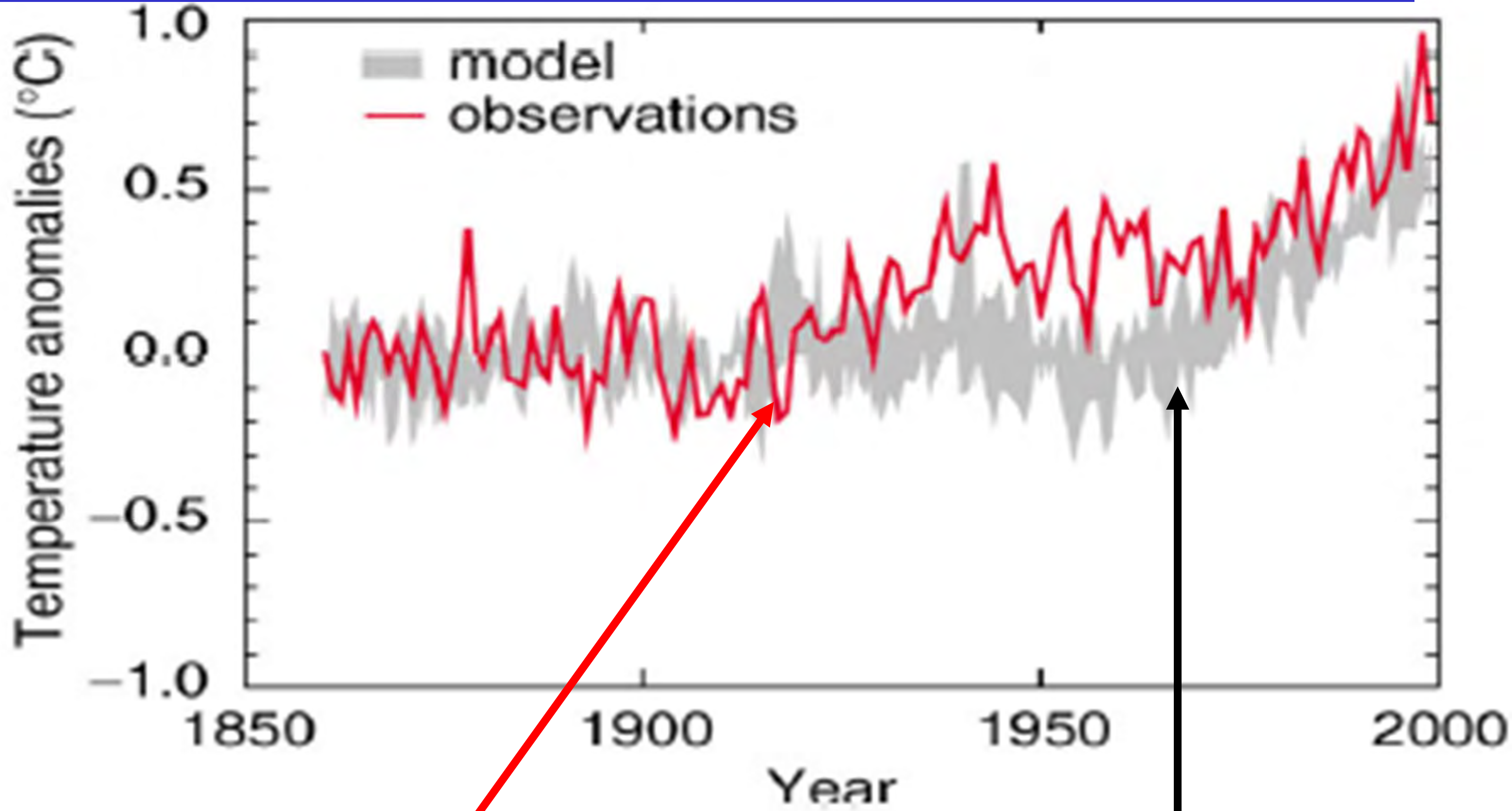
Compare observations with model simulations



Observations

Climate simulated by model with volcanoes, solar variations and other natural factors included.

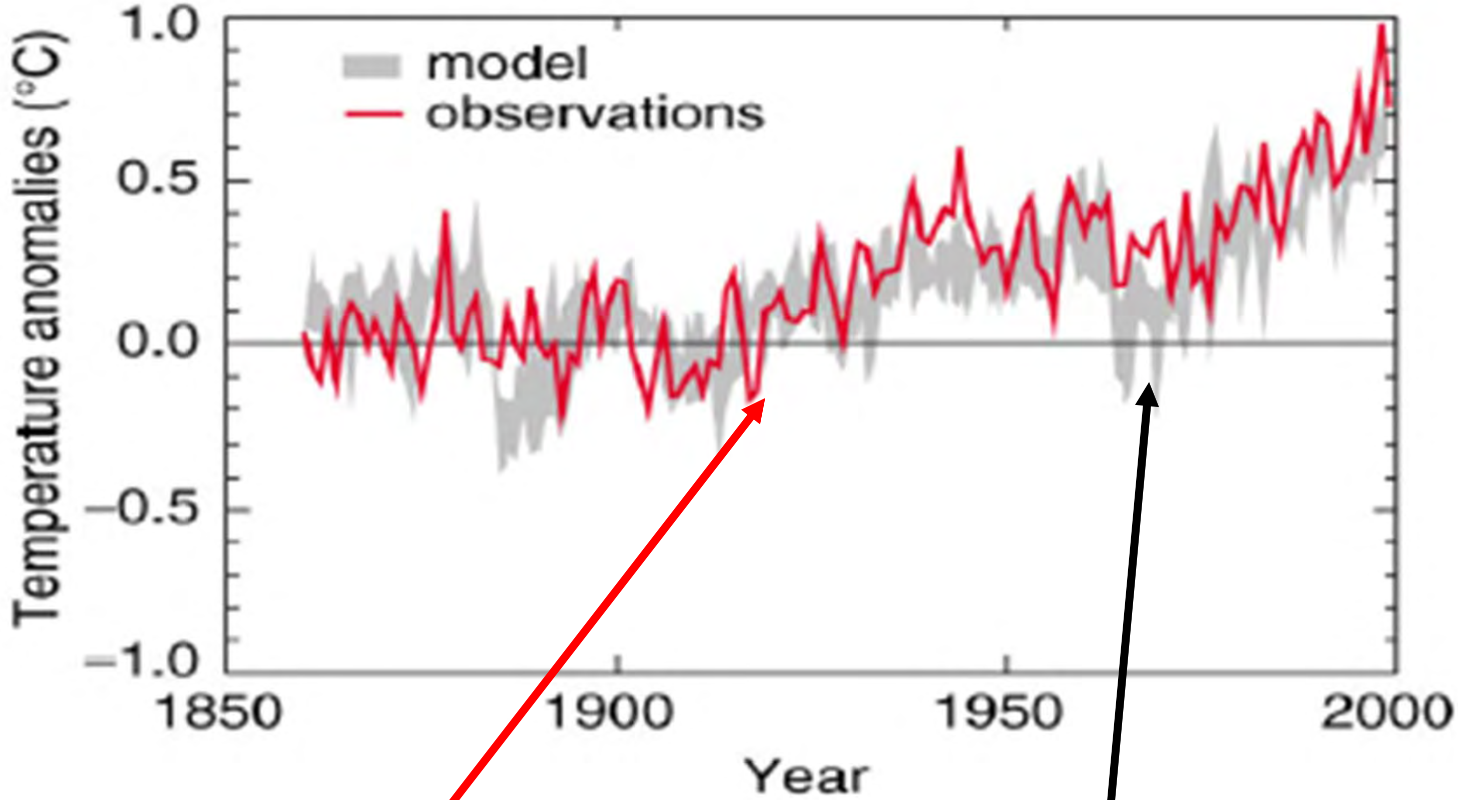
Compare observations with model simulations



Observations

Climate simulated by model with greenhouse gases, aerosols, "anthropogenic factors" included.

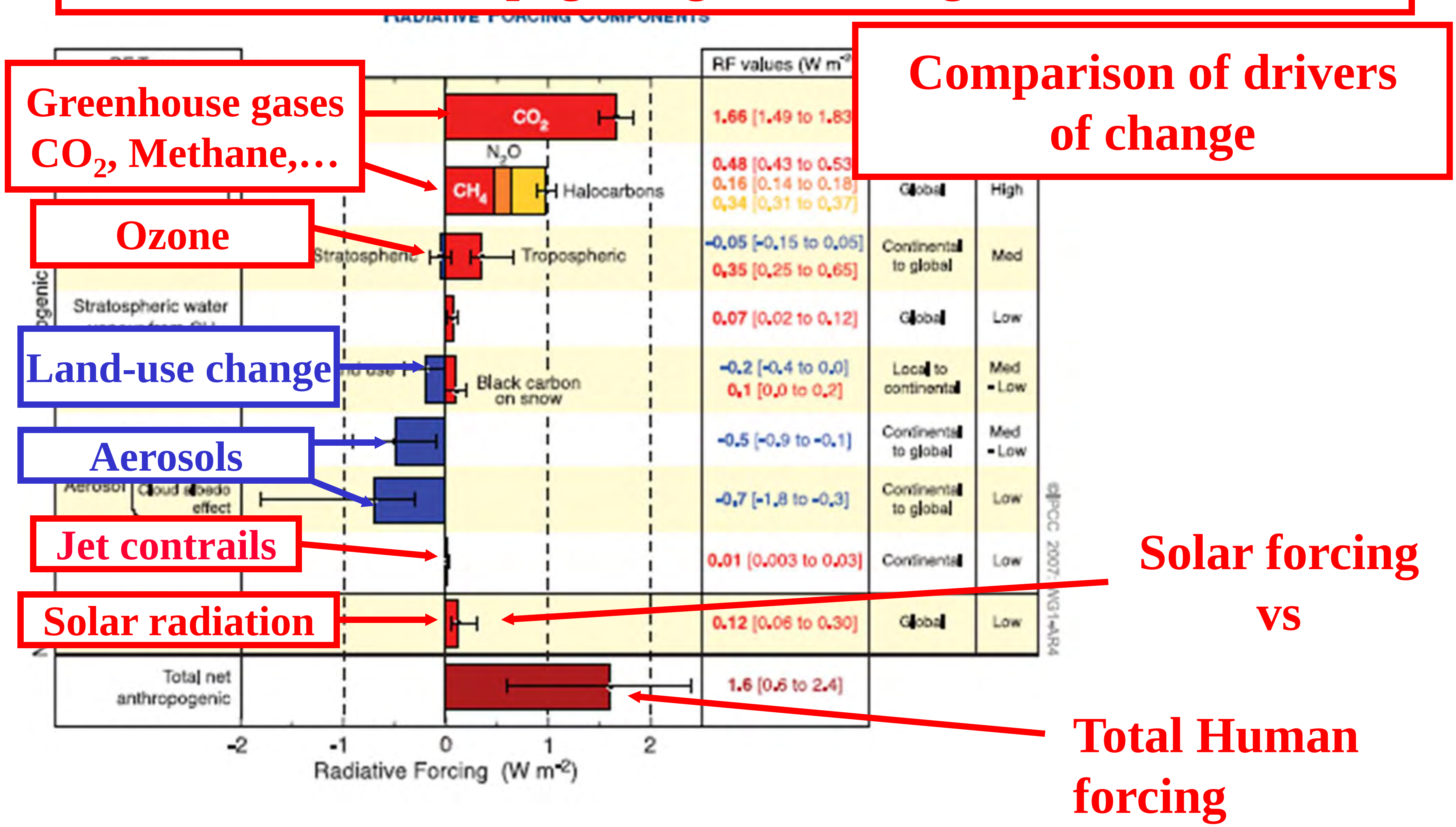
Compare observations with model simulations



Observations

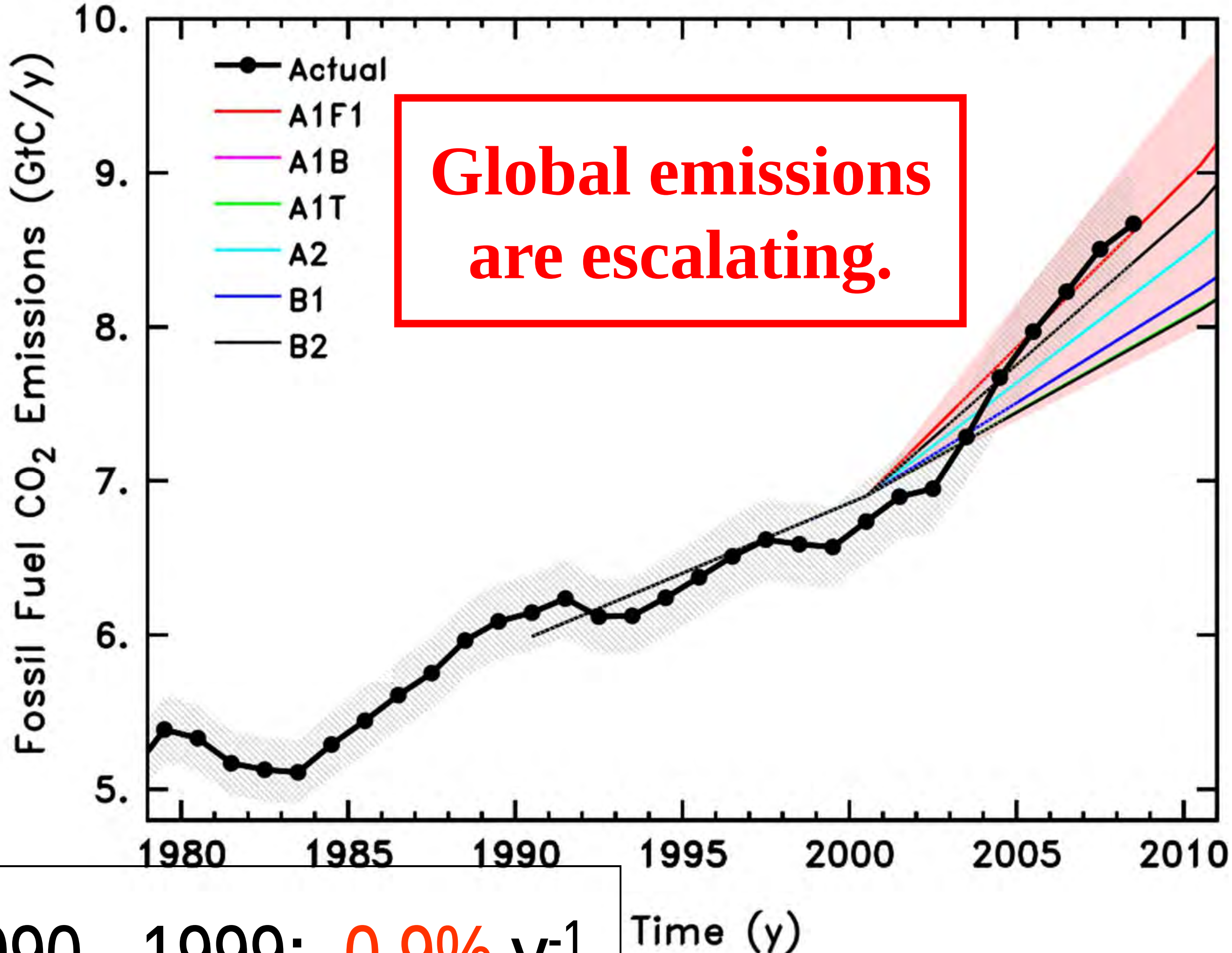
Climate simulated by model with natural and anthropogenic **all** factors included.

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.




Projections for future

Global CO_2 Emissions from Fossil Fuels



ES (2000) aver. growth rates in % y^{-1} for 2000-2010:

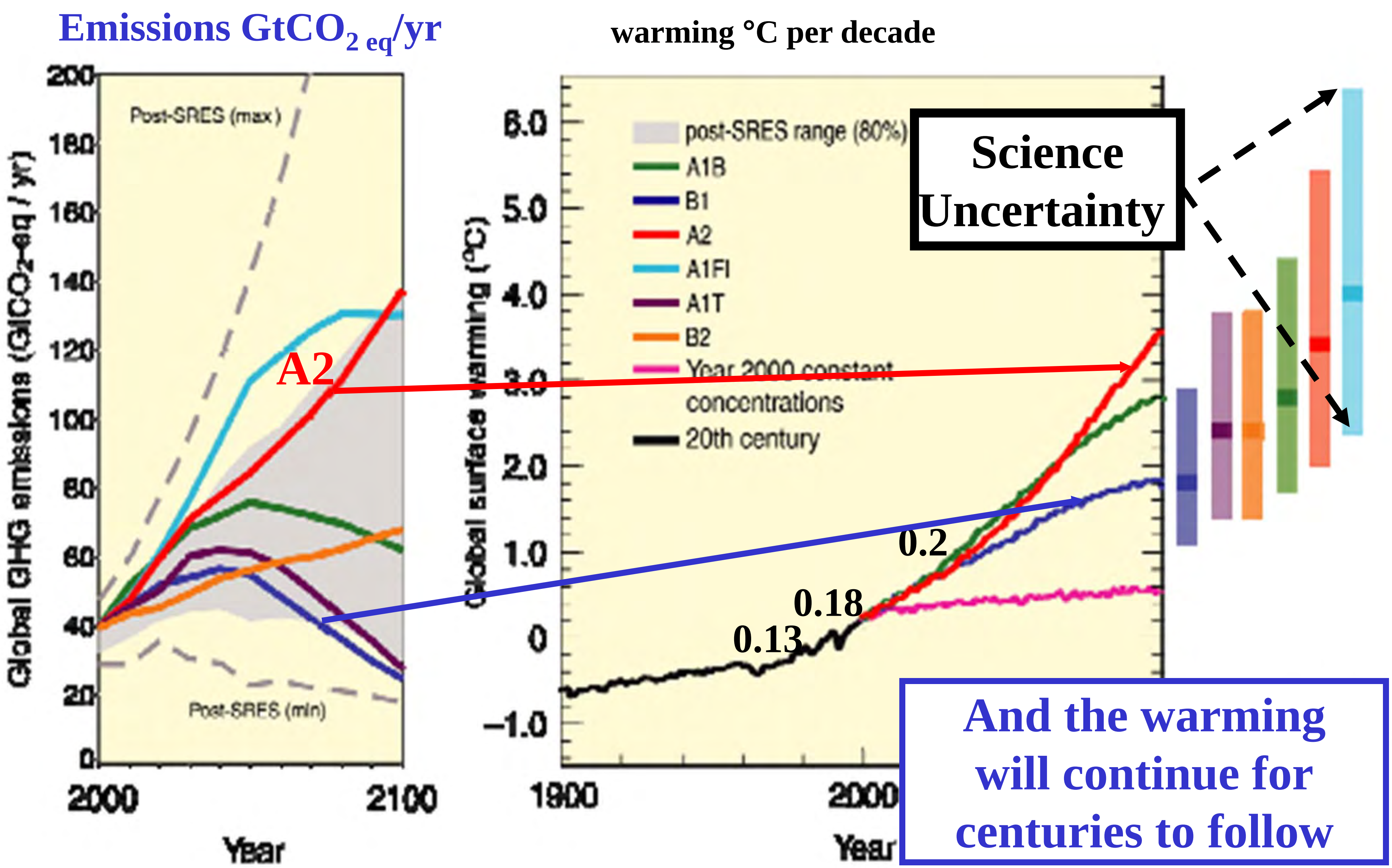
A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Growth Rates

1990 - 1999: 0.9% y^{-1}

2000 - 2007: 3.5% y^{-1} x4

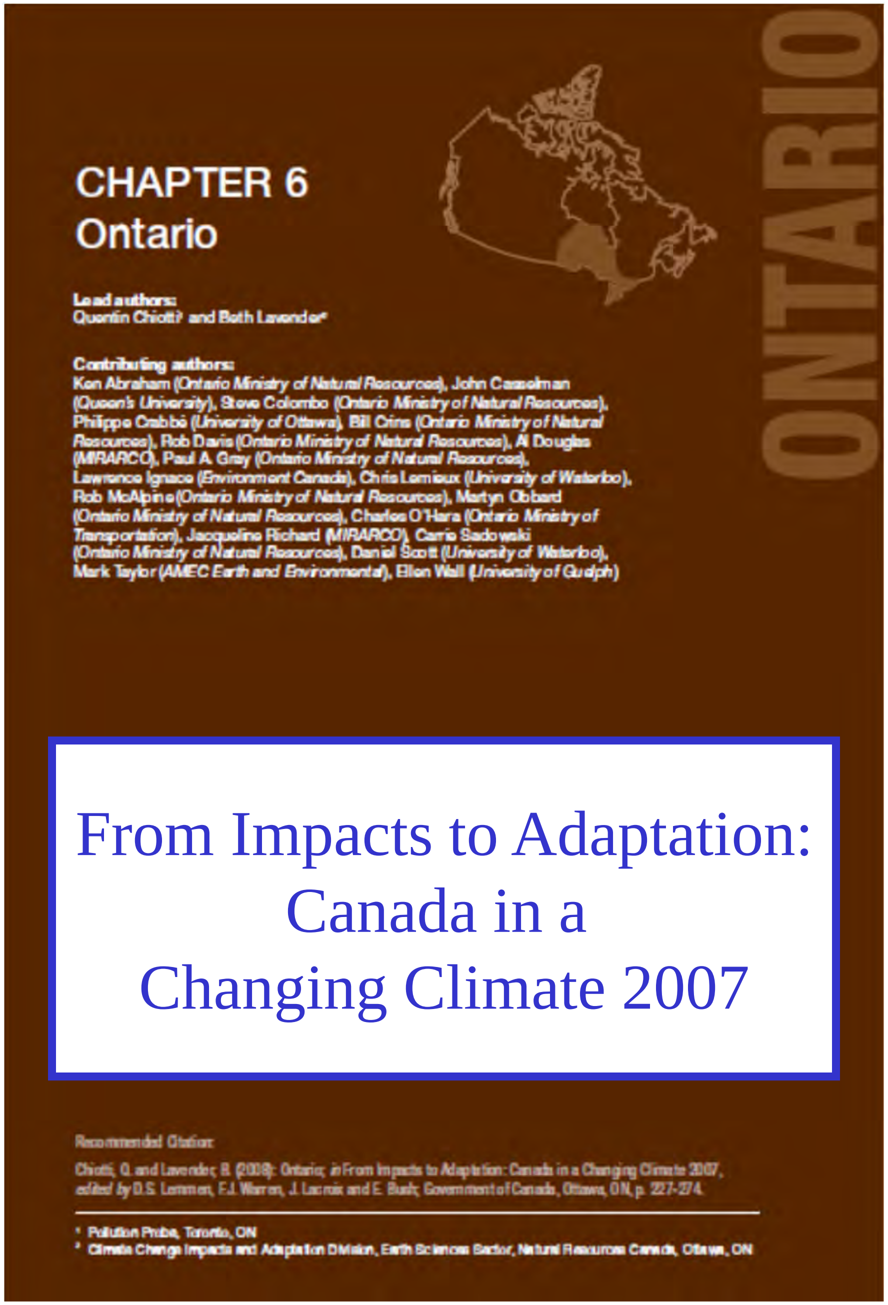
Future climate change



Climate change adaptation

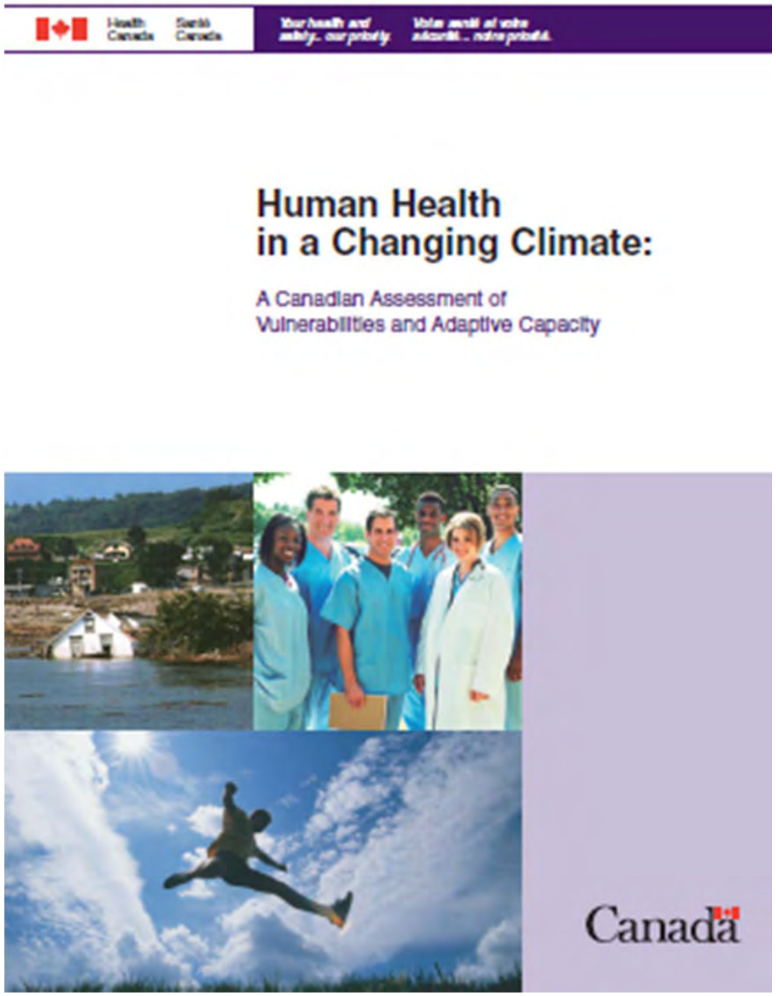
- ***"the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."***
- **Canadian National Assessment: *"making adjustments in our decisions, activities and thinking because of observed or expected changes in climate, in order to moderate harm or take advantage of new opportunities."***


What Canadians will have to
“adapt” to.



- **Projections - intense rainfall events, heat waves and smog episodes are likely to become more frequent.**
- **Heat-related mortality could more than double in southern and central Ontario by the 2050s, while air pollution mortality could increase about 15 to 25% during the same interval.**
- **The health of Ontario residents has been at risk … extreme weather, heat waves, smog episodes and ecological changes that support the spread of vector-borne diseases.**
- **Walkerton, Ontario**

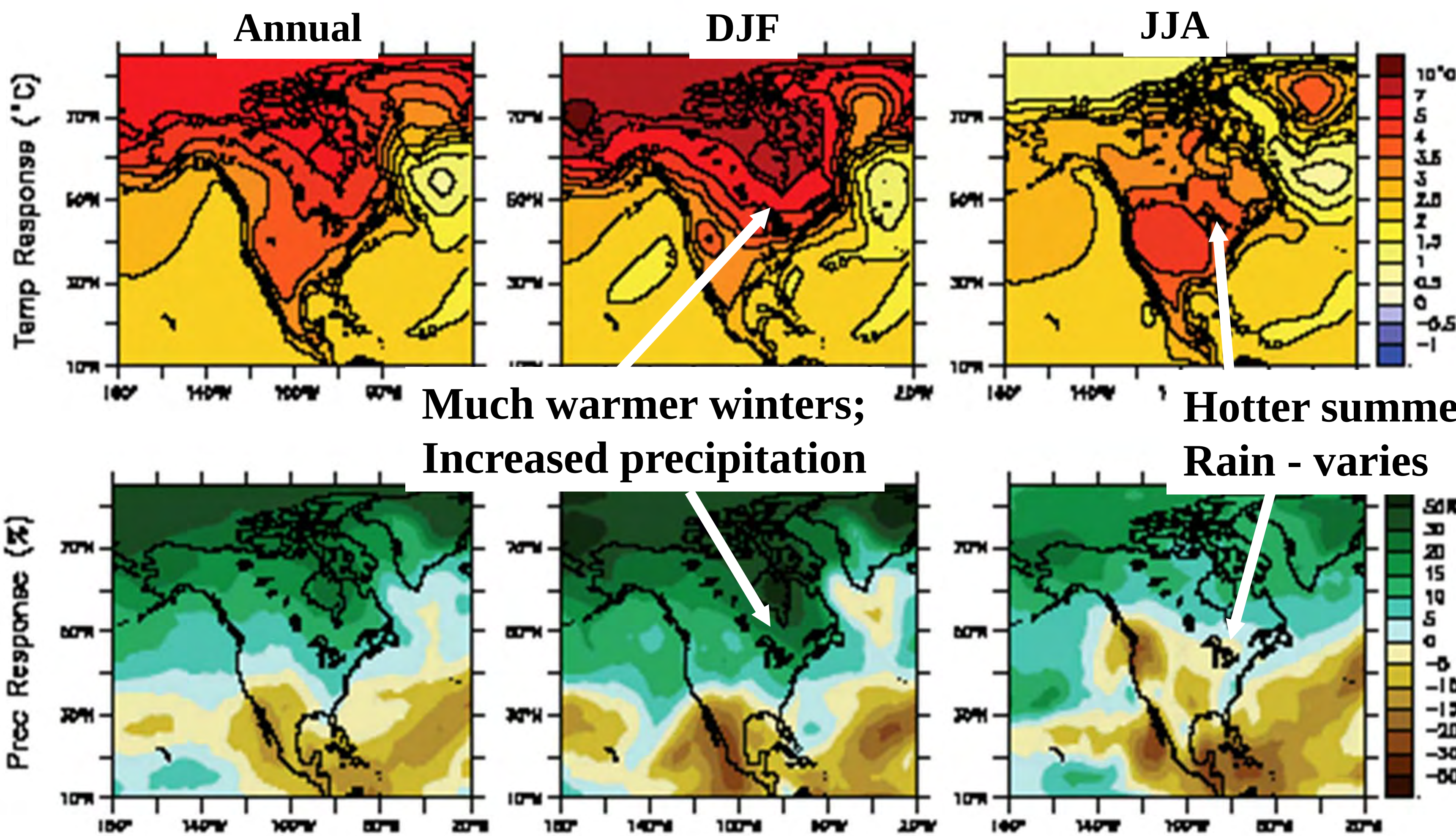
Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity (2008)



- **“Climate change is expected to increase risk to the health of Canadians through many pathways: they food they eat, the air they breathe, the water they drink, and their exposure to extreme weather events and infectious diseases found in nature.”**

No one lives at the global average

Medium (A1B) scenario (2090-2099): Global mean warming 2.8°C; Much of land area warms by ~3.5°C; Arctic warms by ~6°C.

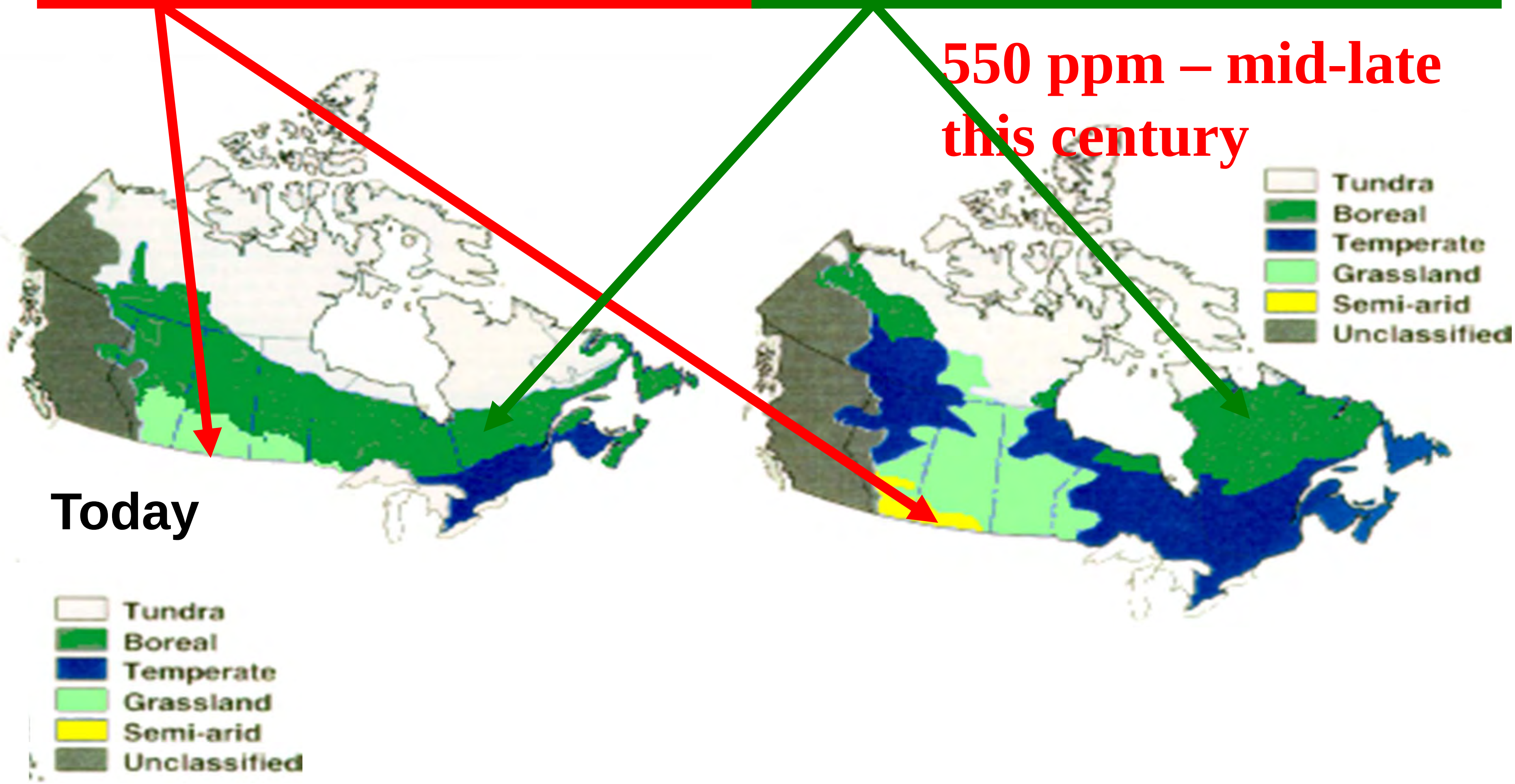


Changing Precipitation

Water-sewage, agriculture
Forestry, floods, droughts

Increased risk of drought Is Likely

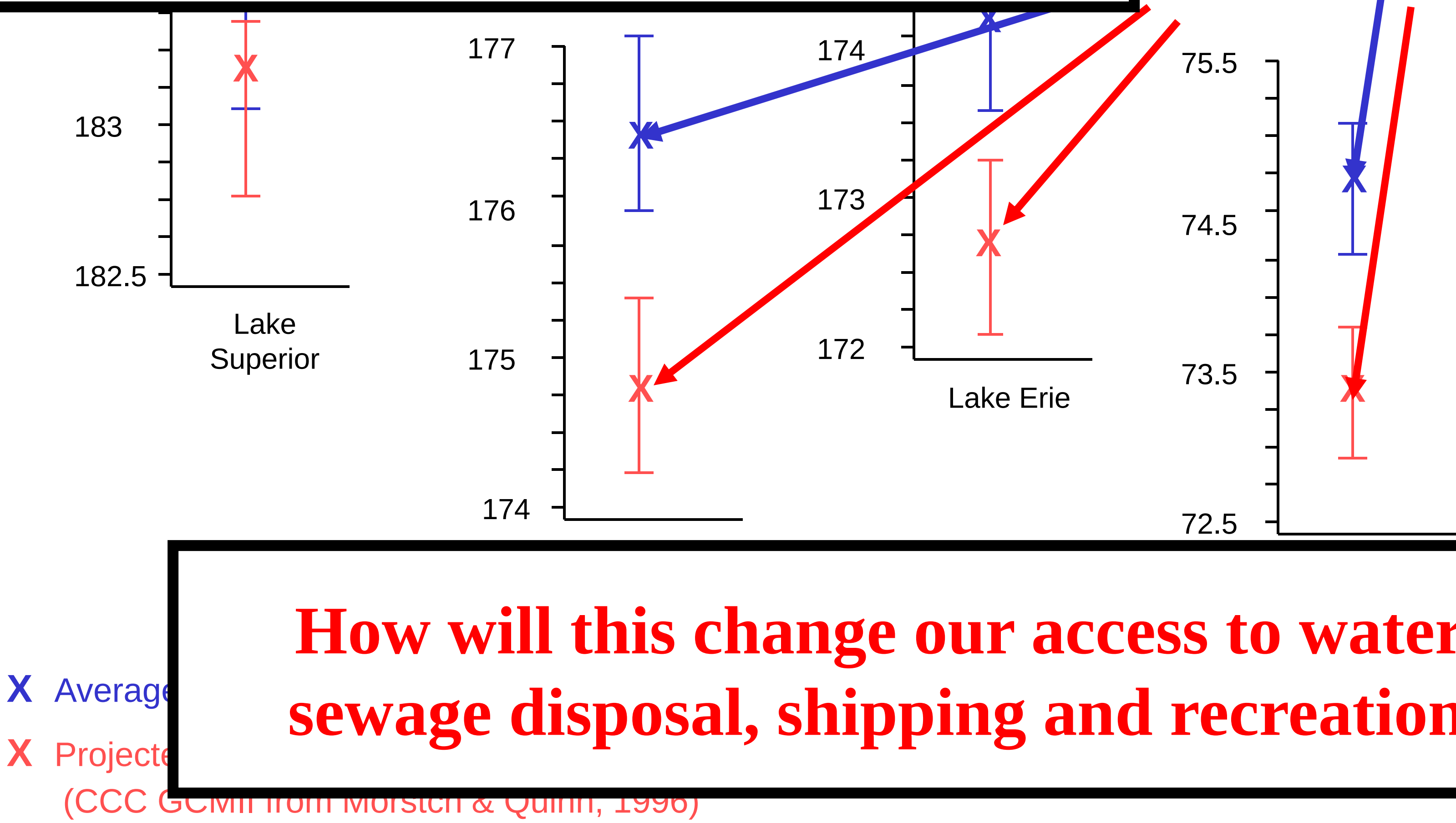
Boreal forest under stress
Climate moves north faster than the trees



Warmer temperatures

Warmer lakes and changing climate resulting in more invasive species in lakes and ecosystems

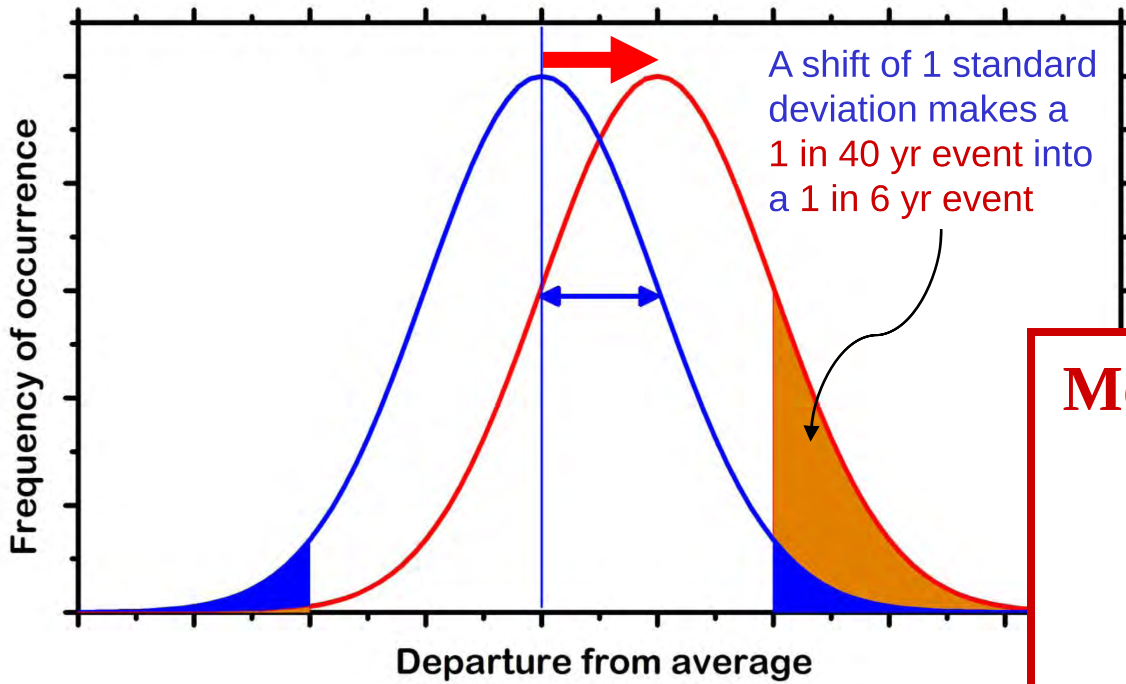
1 metre drop in lake level possible



How will this change our access to water, sewage disposal, shipping and recreation?

Calculus of extremes

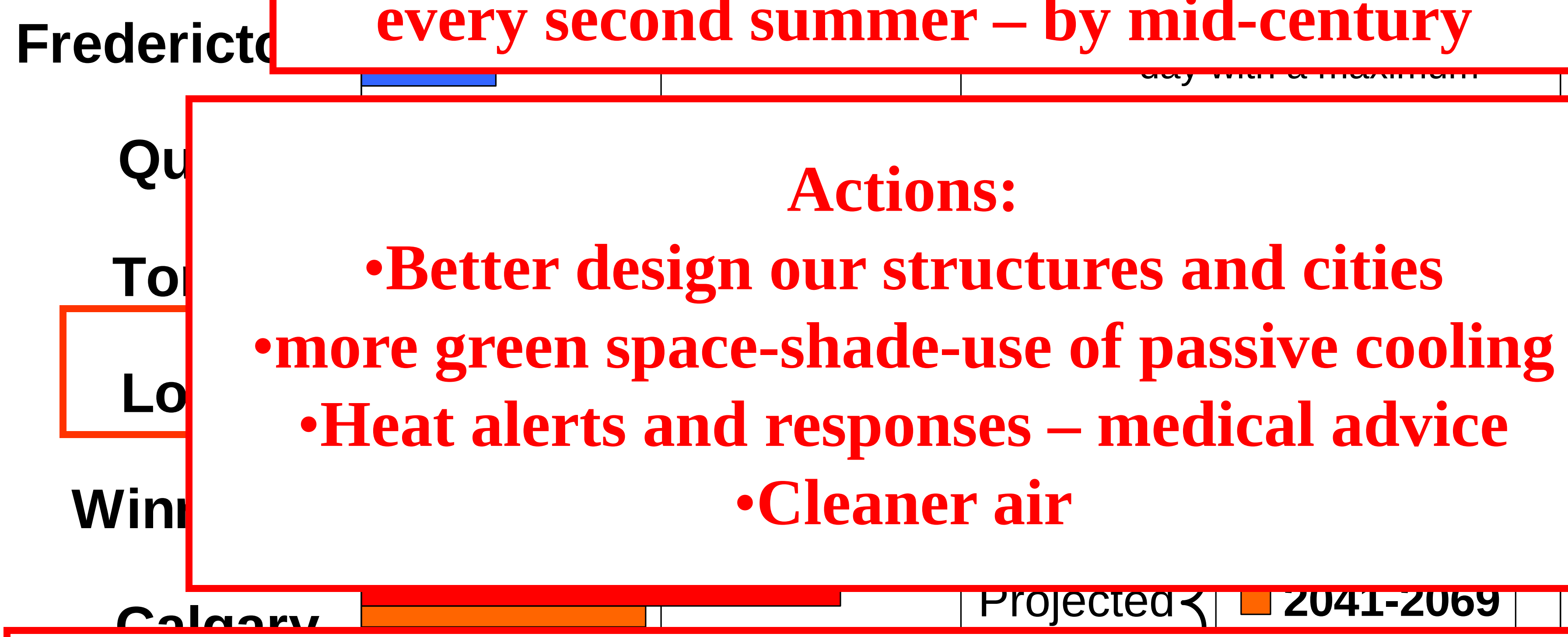
The distribution of weather events around the climatic average follows a 'bell-shaped' curve.



Climate change can involve change in the average, or the spread around the average (standard deviation), or both.

Most of our infrastructure is designed for the extremes of the past. Need to look to future and re-evaluate risk.

In Europe - Record setting August 2003 (more than 70,000 deaths) will be every second summer – by mid-century



Actions:

- **Better design our structures and cities**
- **more green space-shade-use of passive cooling**
- **Heat alerts and responses – medical advice**
- **Cleaner air**

More frequent hot days – virtually certain
Warm spells – very likely

No Breathing Room
National Illness Costs of Air Pollution

Canadian Medical Association (CMA) August 2008

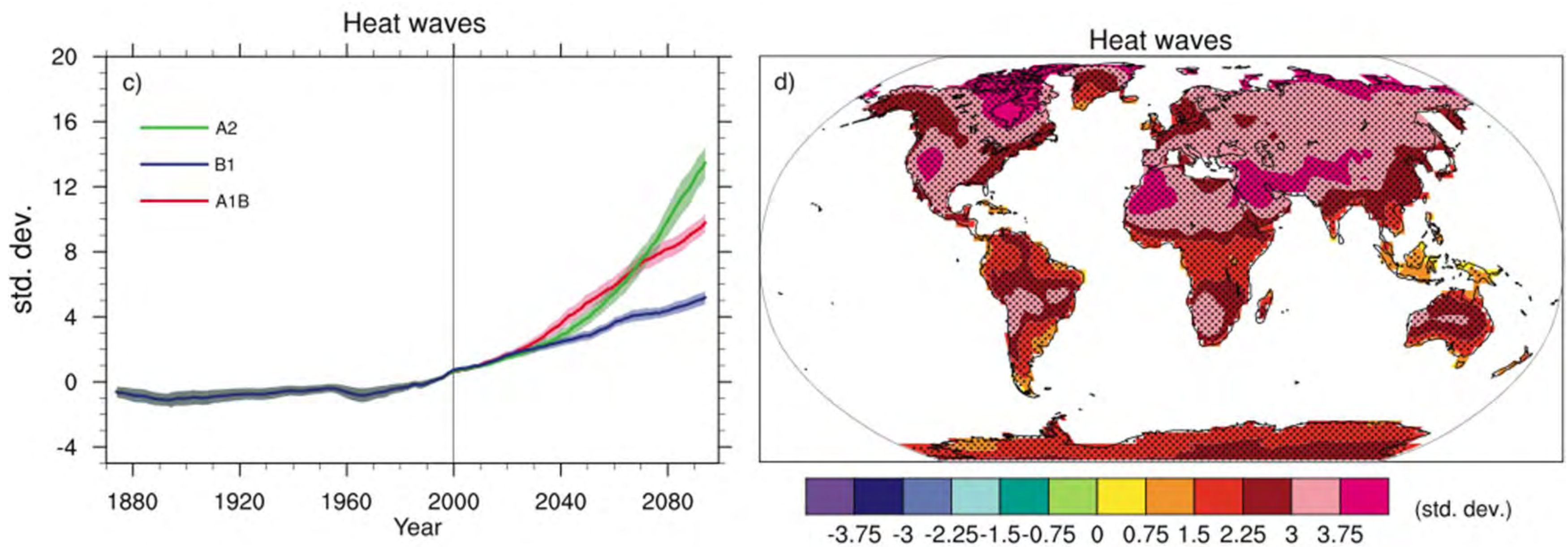
1. **In 2008, 21,000 Canadians will die from the effects of air pollution.**
2. **By 2031, almost 90,000 people will have died from the acute effects of air pollution. The number of deaths due to long-term exposure to air pollution will be 710,000. …**

10. 11. In 2008, economic costs of air pollution will top $8 billion. By 2031, these costs will have accumulated to over $250 billion.

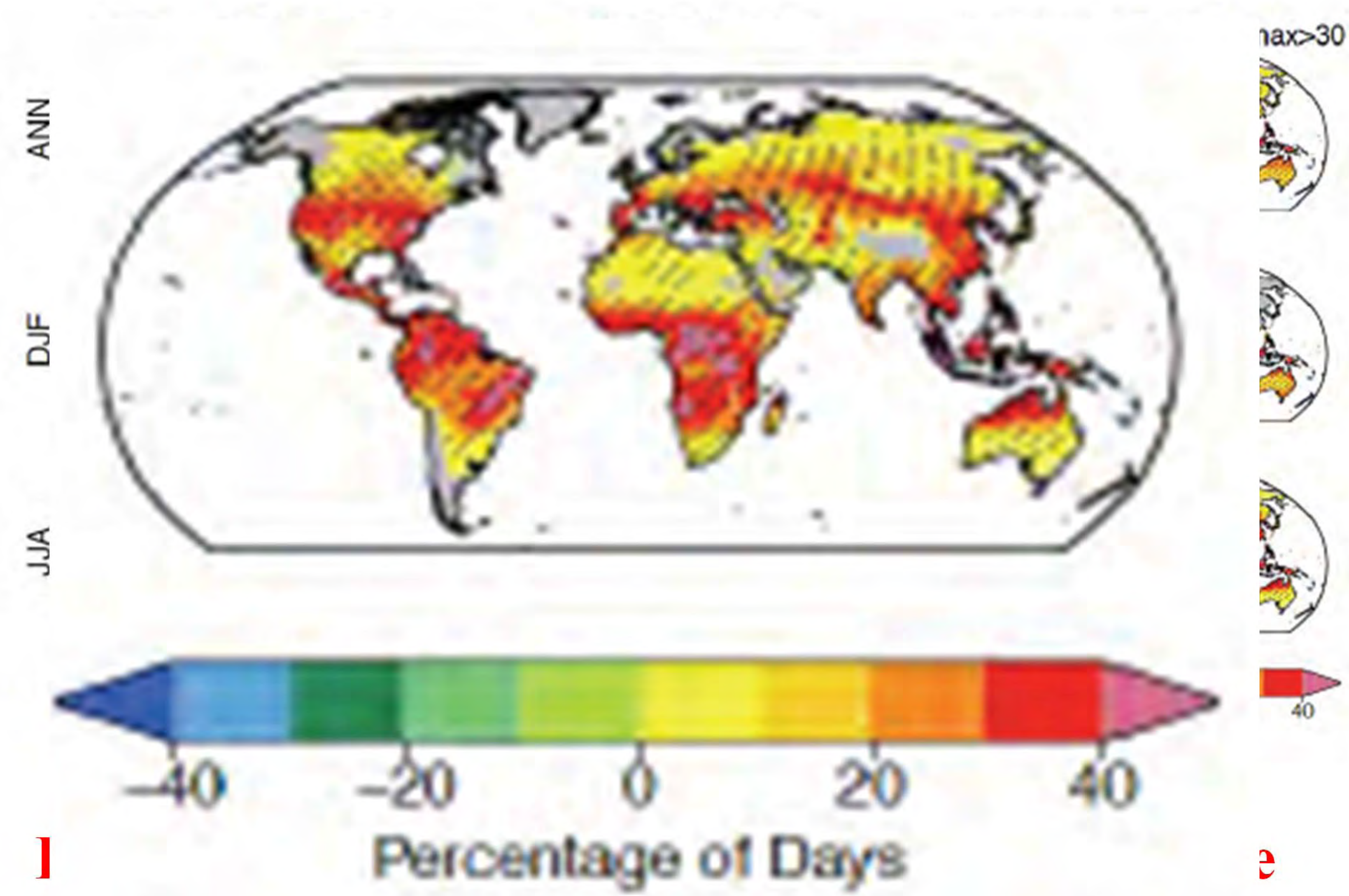
With warming and more smoggy days – these numbers will increase.

The processes that result in air pollution are much the same as those that produce greenhouse gases.

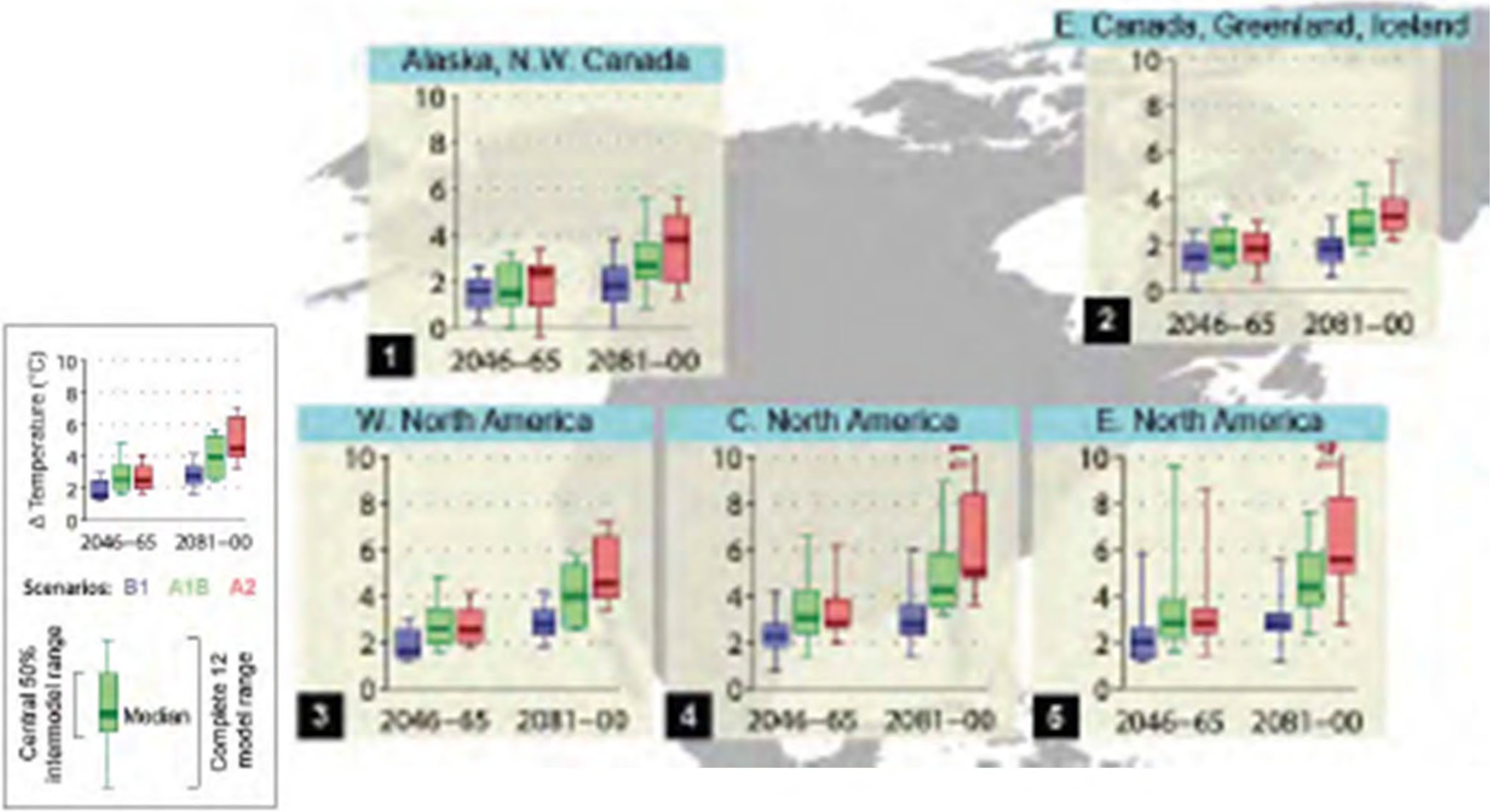
Projected changes with respect to standard deviation of the parameter--sense of extremes Heat Waves



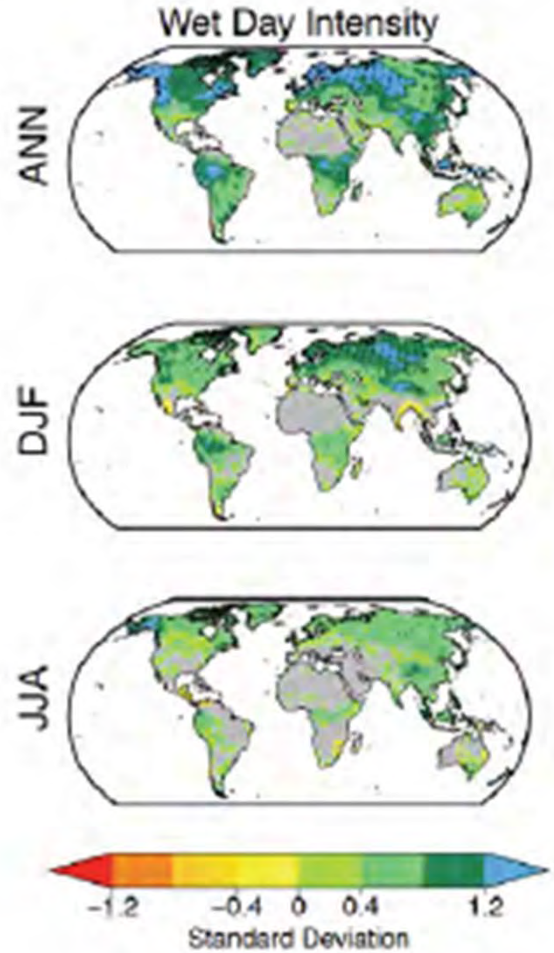
More frequent hot days – virtually certain
Warm spells – very likely

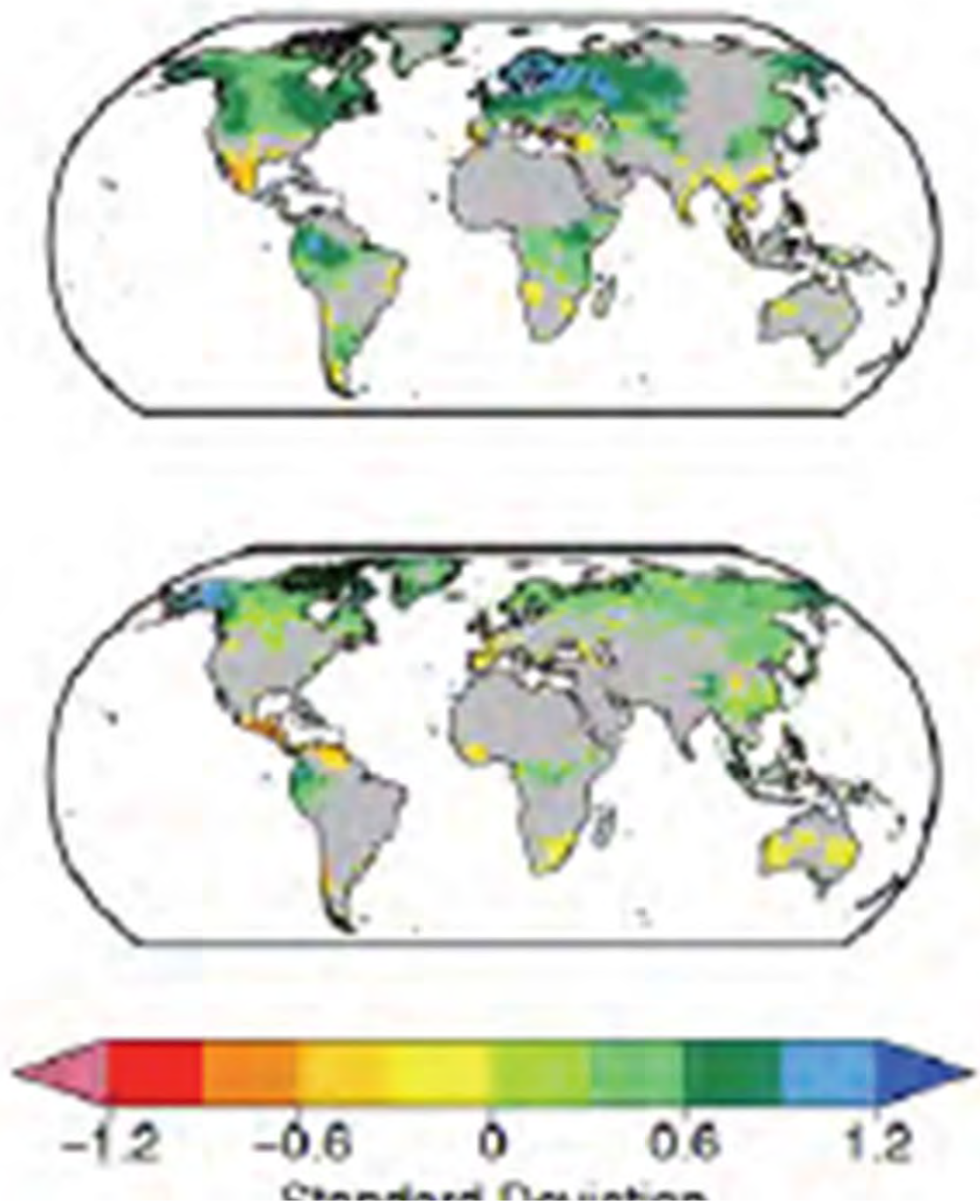


indices for daily Tmax for 2081-2100 with respect to 1980-1999.

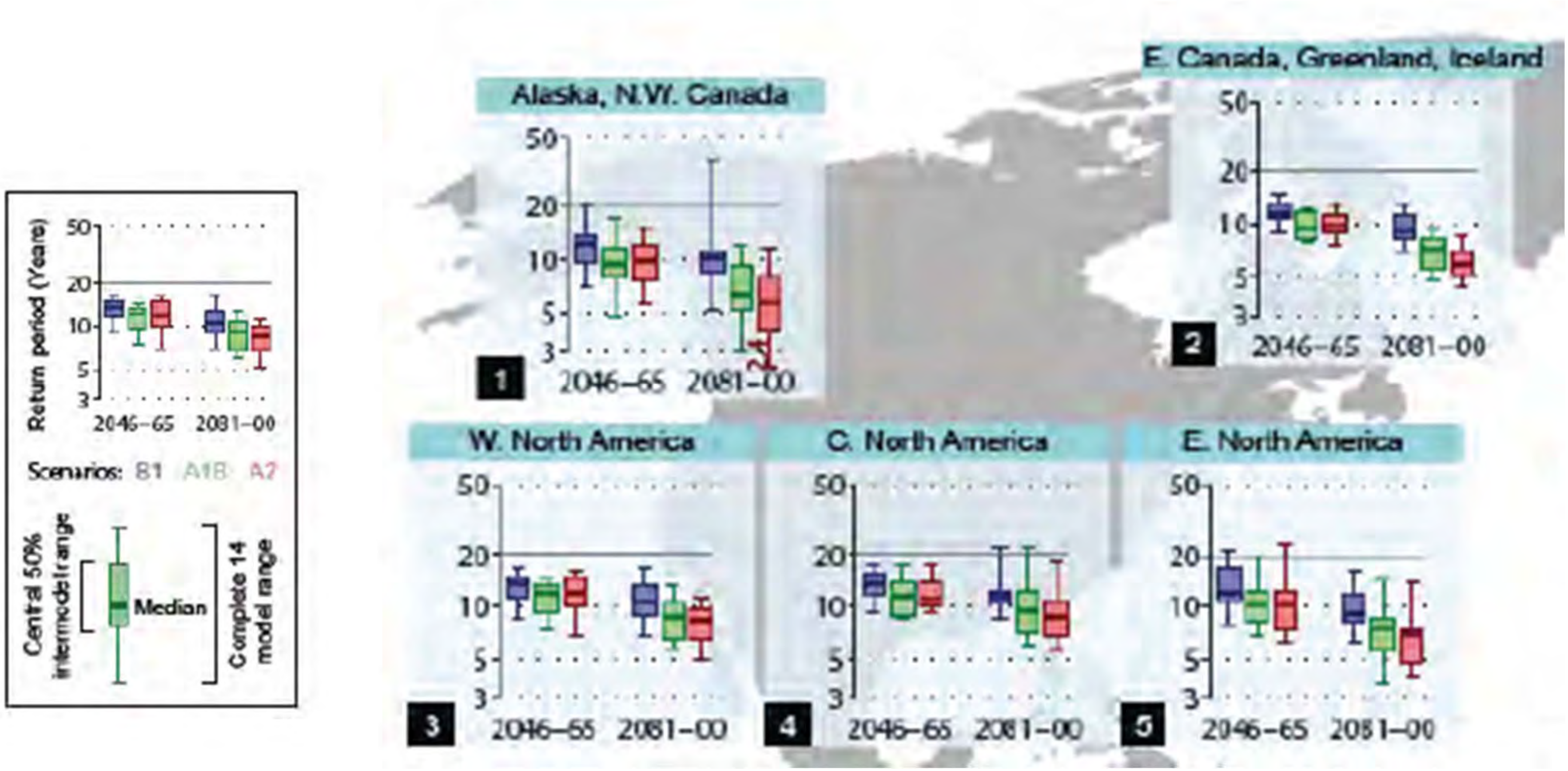


Projected changes (in degrees C) in 20-year return values of annual maximum of the daily maximum temperature. The bar plots (see legend for more information) show results for regionally averaged projections for two time horizons, 2046 to 2065 and 2081 to 2100, as compared to the late-20th-century,.



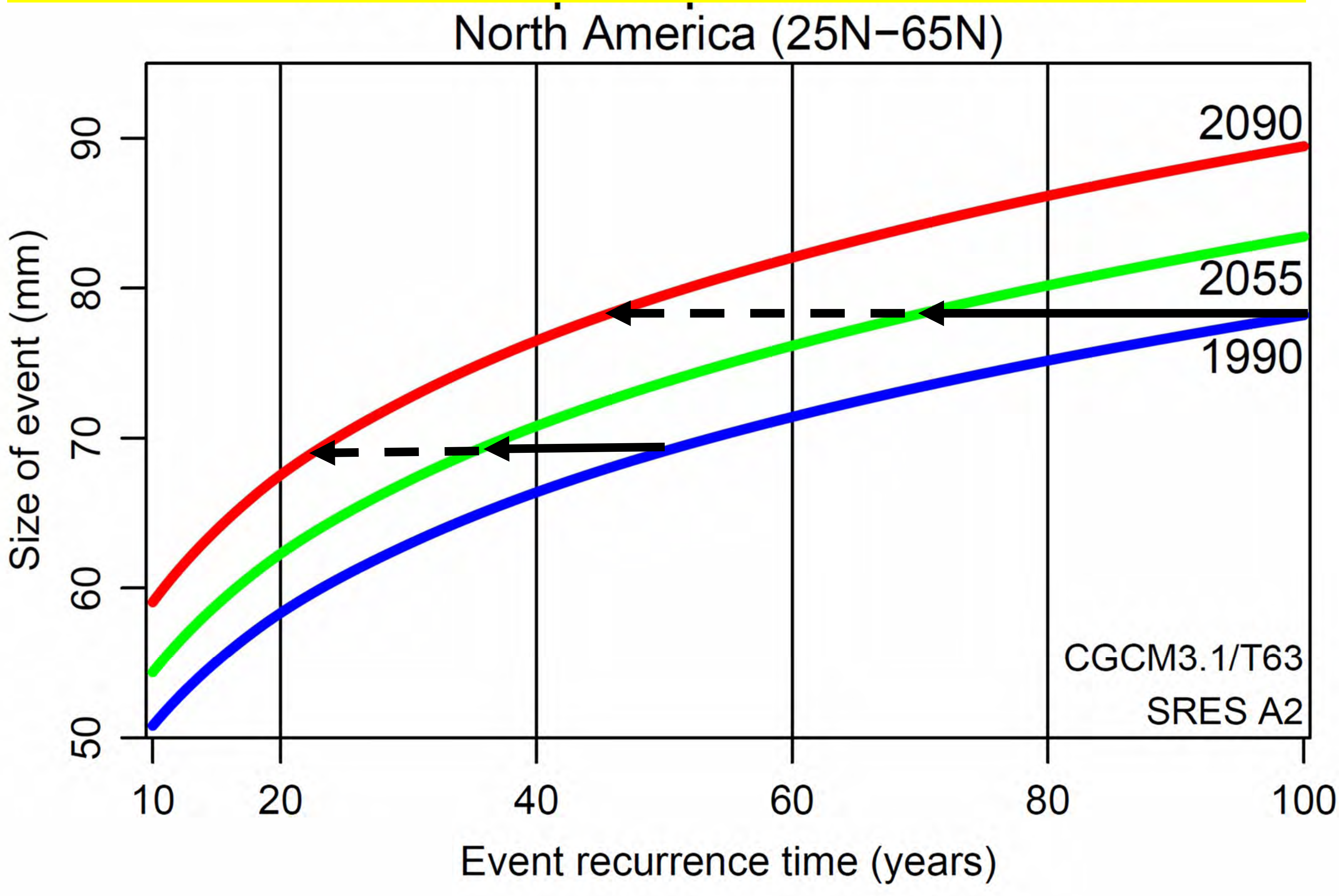


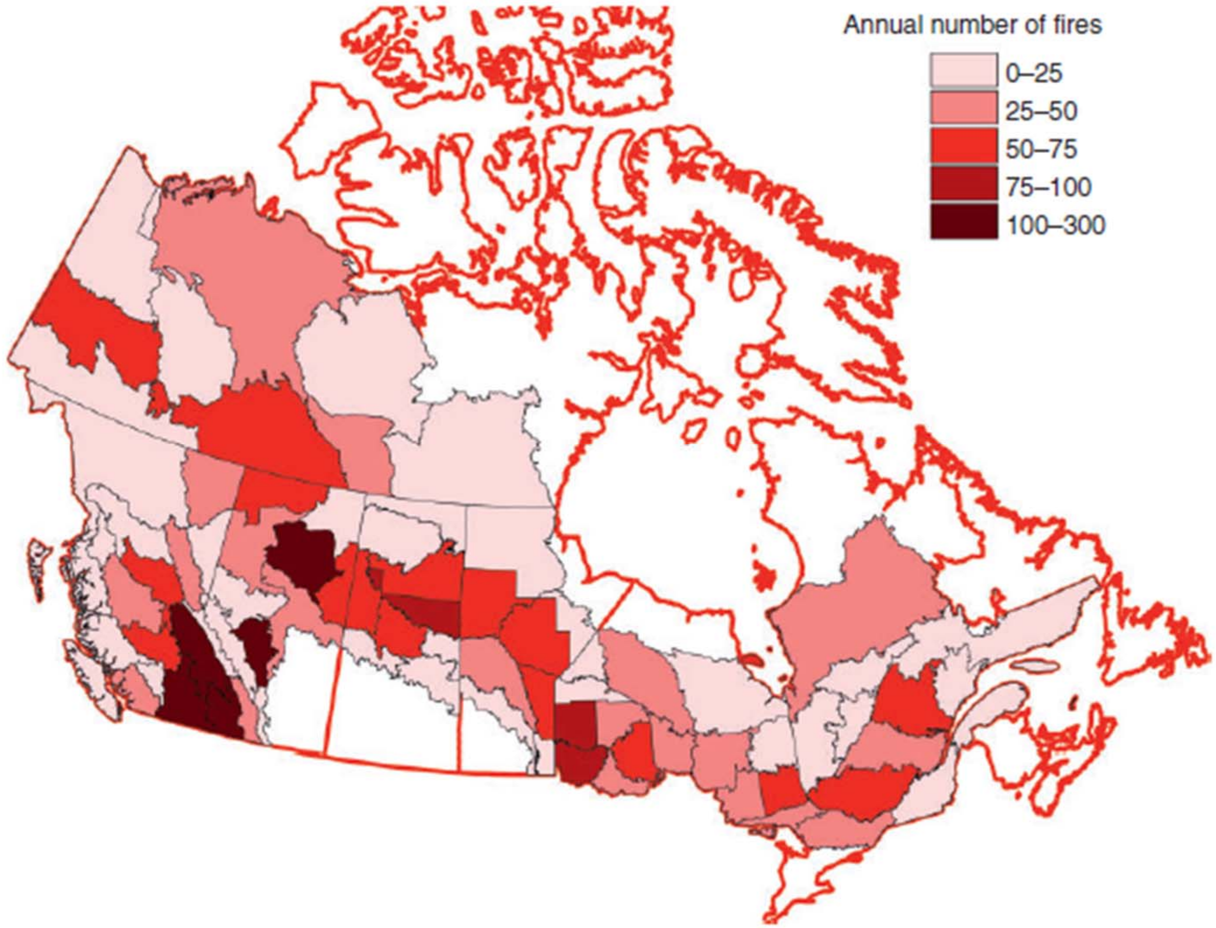
Projected annu
indices for daily
with



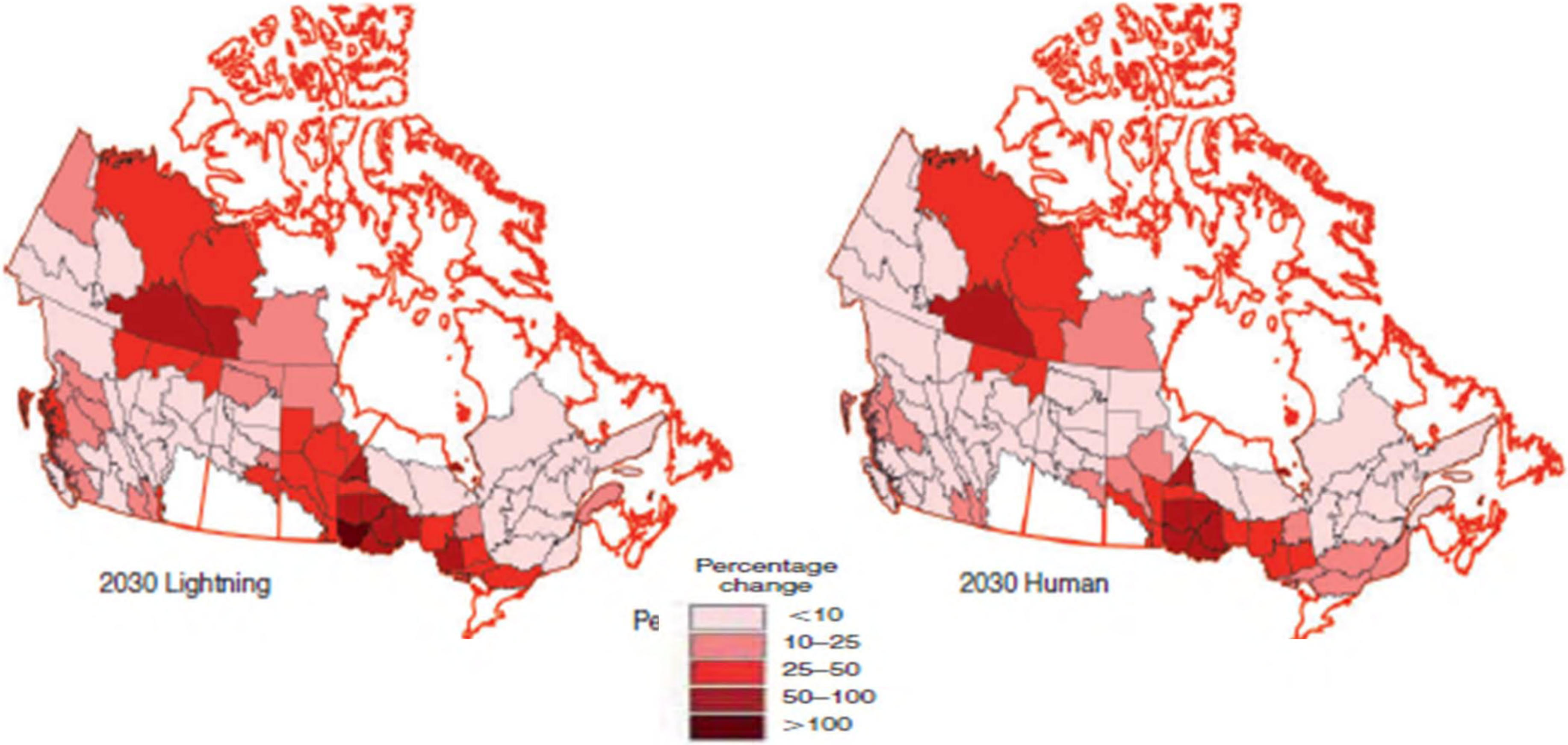
Projected return period (in years) of late 20th-century 20-year return values of annual maximum 24-hour precipitation rates. The bar plots (see legend for more information) show results for regionally averaged projections for two time horizons, 2046 to 2065 and 2081 to 2100,

Projected changes in extreme 24-hr precip events

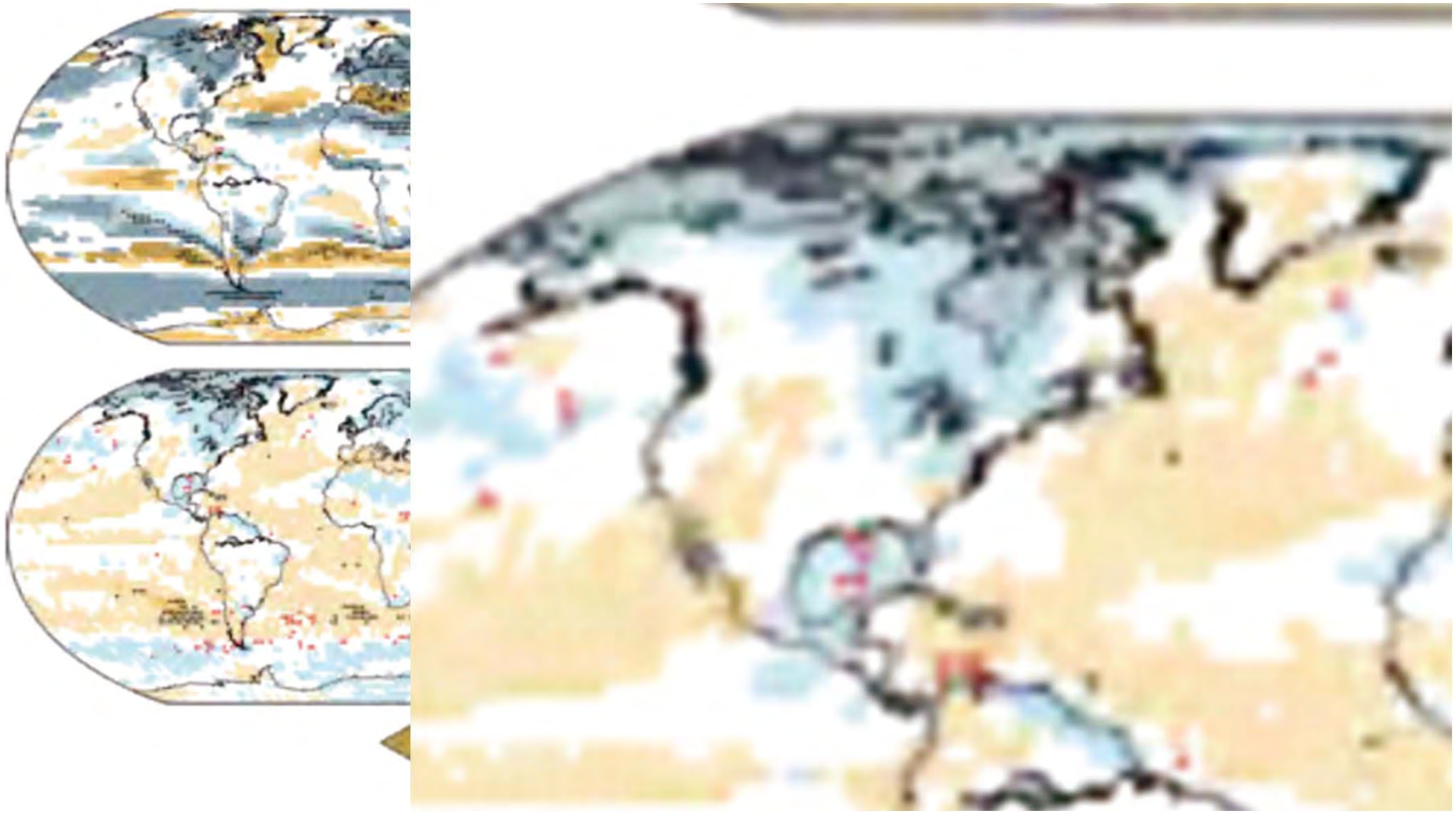




Annual lightning-caused fire occurrence rates (number of fires per year) for ecoregions throughout the study area. Numbers in the legend represent mean annual number of fires.



Relative change (percentage increase) in fire occurrence between future and baseline scenarios for the Canadian Climate Centre general circulation model (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.



Averaged changes from a 19-member ensemble of CMIP3 GCMs in the mean of the daily-averaged 10-m (top) and 99th percentile of the daily-averaged 10-m wind speeds (bottom) for the period 2081–2100 relative to 1981–2000 (% change) for December to February (left) and June to August (right)

IPCC SREX Summary for Policymakers

- **Exposure and vulnerability are key determinants of disaster risk.**
- **A changing climate leads to changes in the frequency, intensity, spatial extent, and duration of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.**
- **The severity of the impacts of extreme and non-extreme weather and climate events depends strongly on the level of vulnerability and exposure to these events.**
- **There is evidence from observations gathered since 1950 of changes in some extremes. Confidence in observed changes in extremes depends on the quality and quantity of data and the availability of studies analyzing these data. It consequently varies across regions and for different extremes.**

SREX - DISASTER LOSSES

- **Economic losses from weather- and climate-related disasters are increasing, but with large interannual variability (*high confidence*).**
- **Measured economic and insured losses from disasters are largest in developed countries. Fatality rates and economic losses as a proportion of GDP are higher in developing countries (*high confidence*).**
- **Increasing exposure of people and economic assets is the major cause of the long-term changes in economic disaster losses (*high confidence*).**
- ***Long-term trends in normalized economic disaster losses cannot be reliably* attributed to natural or anthropogenic climate change, particularly for cyclones and floods (*medium evidence, high agreement*).**

CLIMATE EXTREMES

IPCC 2007 – Synthesis Report: Changes in extreme weather and climate events, based on projections to the mid- to late 21st century

Phenomenon and Direction of trend	Likelihood of Future trend
Warm spells/heat waves. Frequency increases over most land areas	Very likely
Heavy Precipitation Events. Frequency increases over most areas	Very likely
Area affected by drought increases	Likely
Intense tropical cyclone activity increases	Likely
Increased incidence of extreme high sea level (excludes tsunamis)	Likely

Western

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The End

Thank you for your attention