Climate change: the science and implications for life in Canada.

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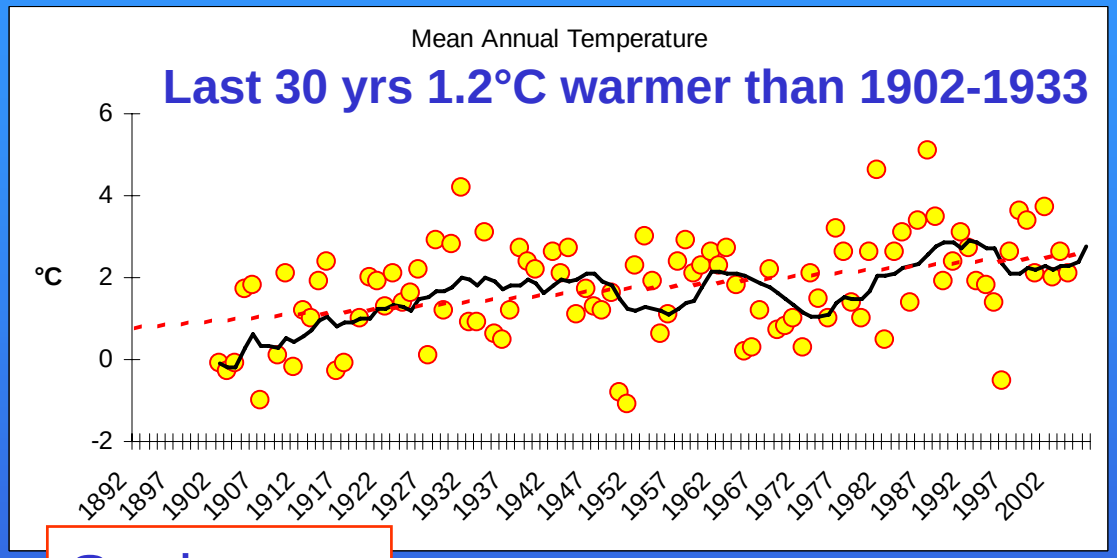
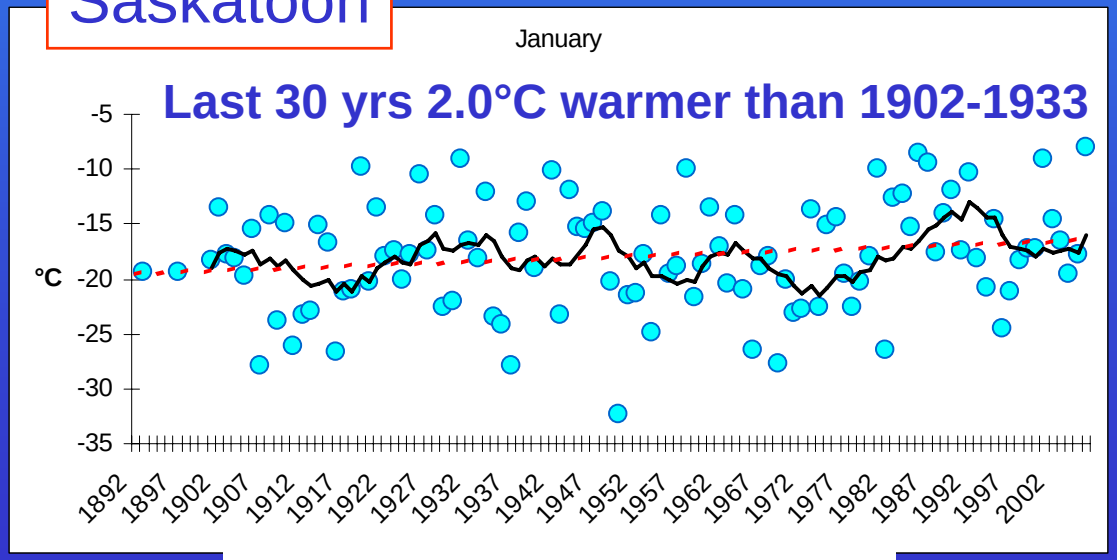
Founded 1899

‘global warming’ is topical



Saskatoon



Data from Environment Canada Environnement Canada

Global average warming of 0.63°C

0.2°C / decade

Brandon & Winnipeg have warmest Jan since 1941

2006 Canada’s 2nd hottest summer

winnipegfreepress.com A9

Temperature of Earth at level not seen for millennia

WASHINGTON — The Earth’s temperature has climbed to levels not seen in thousands of years, warming that has begun to affect plants and animals, researchers report in today’s issue of *Proceedings of the National Academy of Sciences*.

The Earth has been warming at a rate of 0.2 degrees Celsius per decade for the last 30 years, according to the research team led by James Hansen of NASA’s Goddard Institute for Space Studies in New York. That brings the overall temperature to the warmest in the current interglacial period, which began about 12,000 years ago.

The researchers noted that a report in the journal *Nature* found that 1,700 plant, animal and insect species moved poleward at an average rate of about 6.5 kilometres per decade in the last half of the 20th century.

The warming has been stronger in the far north, where melting ice and snow expose darker land and rocks beneath allowing more warmth from the sun to be absorbed, and more over land than water.

Water changes temperature more slowly than land because if its great capacity to hold heat, but the researchers noted that the warming has been marked in the Indian and western Pacific Oceans. Those oceans have a major effect on climate and warming there could lead to more El Nino episodes affecting the weather.

“This evidence implies that we are getting close to dangerous levels of human-made pollution,” Hansen said in a statement.

Few scientists doubt that the planet has warmed, though some question the causes of the change.

— *Associated Press*

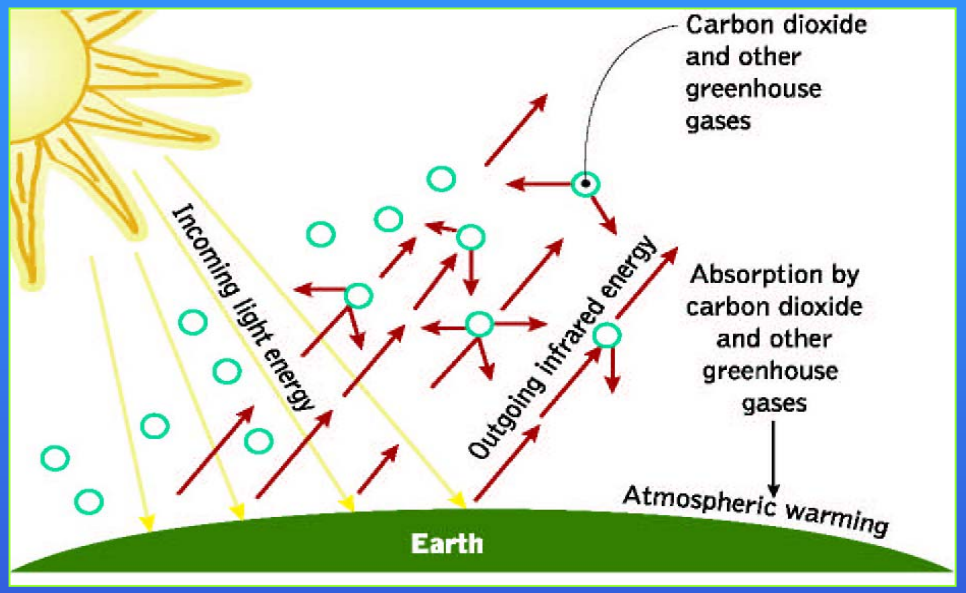
***Winnipeg Free Press*, Sept. 26, 2006**

The science of climate change

- Greenhouse effect - combined effects of ***natural processes <u>and</u> human activities*** (fossil fuels, biomass, agriculture).
- Not ‘global warming’, but ***climate change*** - yes, global average temp. changes, but also changes in precipitation amounts & seasonality.
- ***Climate models*** beset with uncertainty – complex & chaotic systems, but getting better; forecasts for 2020 to 2050.
- Consequences for Canada:
  - ***Arctic sea ice;*** rising sea levels and other effects.
  - ***Altered climate zones*** will affect what we grow and where, and the distribution of plants and animals *<u>and</u>* our water supply.

‘greenhouse’ – a poor analogy

1. *Radiation from the sun* either reaches the surface, or is *reflected* back into space by *clouds*, and also by *dust* in the upper atmosphere and by *high albedo land surfaces* (grasslands, ice, snow).
2. *GHGs absorb* (or ‘trap’) short-wave radiation *and re-radiate it as long wave radiation* (= heat).



Dearden & Mitchell, 2005

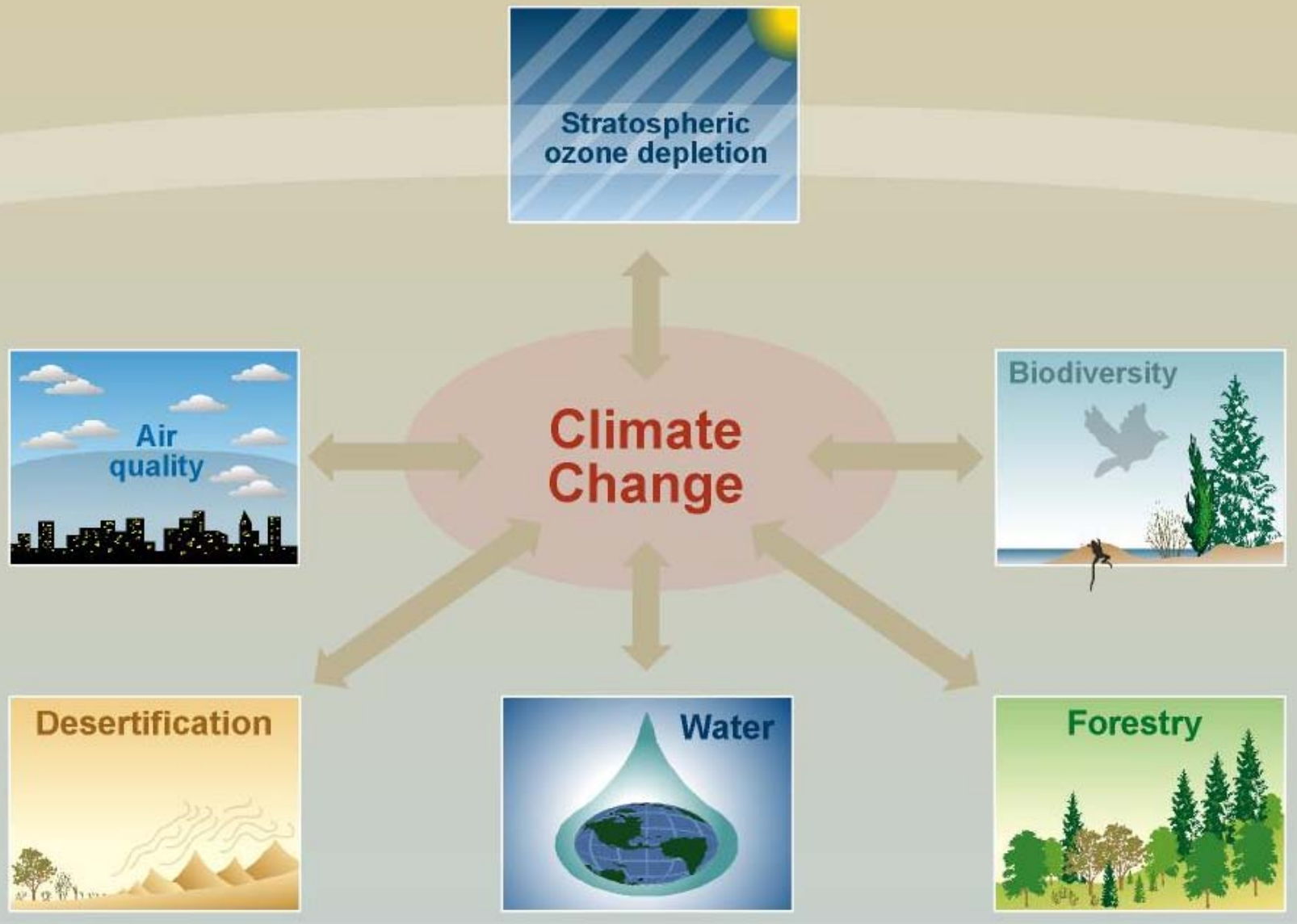
3. *At night, the land and ocean re-radiate heat into the atmosphere*. This radiation may be reflected back to the surface by clouds or dust, be lost into space (on clear nights). Some is absorbed by GHGs and retained in the atmosphere.
4. *A natural process* - in its absence, the earth’s oceans would be frozen solid and life would not be possible.

Greenhouse: an old idea

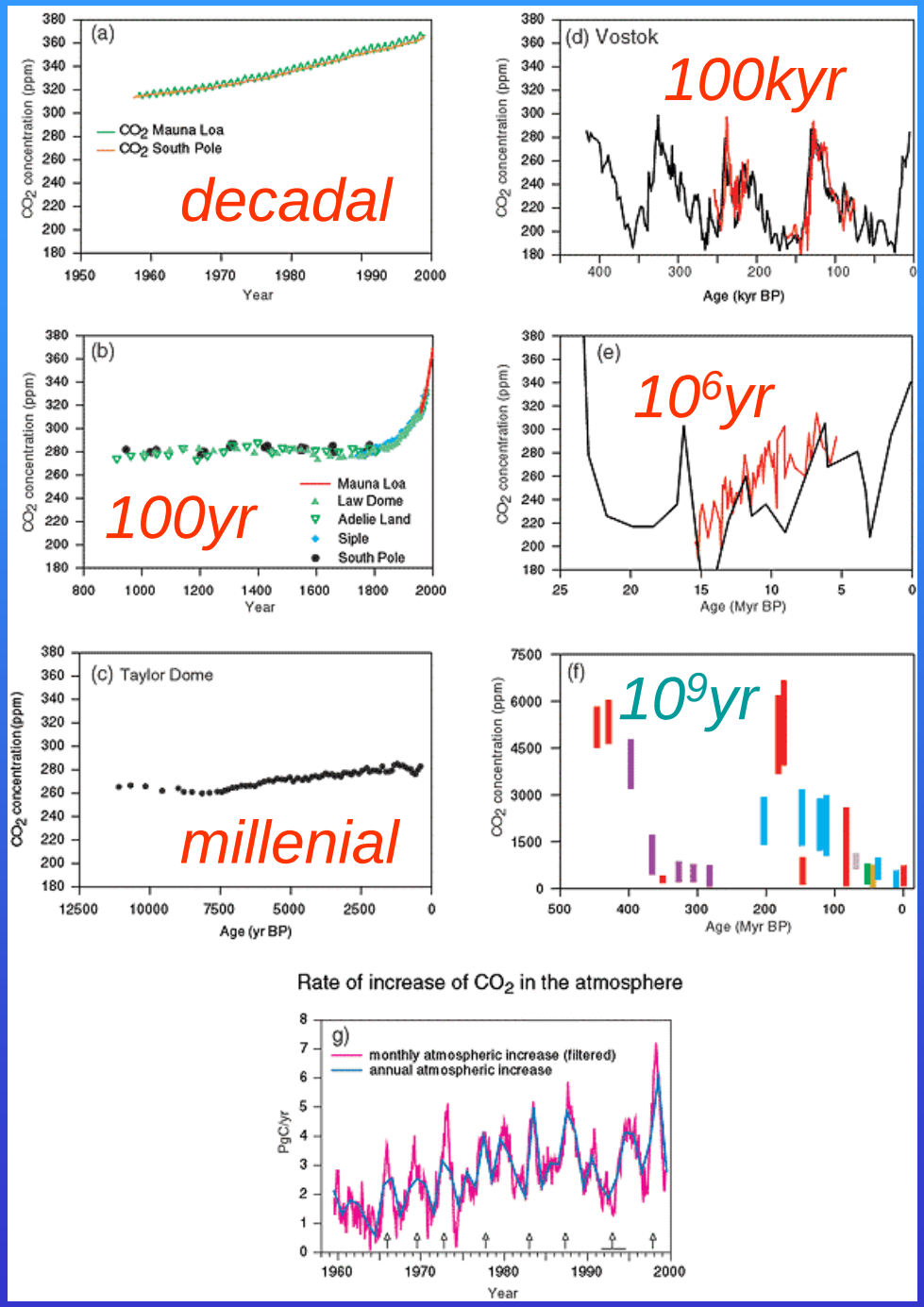
- Fourier, 1824: hypothesized the atmosphere blocks outgoing radiation, and warms it by reradiating some of this radiation.
- Arrhenius, 1896: CO_2 traps and reradiates heat.
- Callendar, 1938: since 1880 the Earth has warmed by 1°F, and will warm by double this in next 100 years.
- Revelle & Suess, 1957: the oceans could not absorb human emissions of CO_2 as fast as they were produced – *"Human beings are now carrying out a large-scale geophysical experiment … we are returning to the atmosphere and oceans the … carbon stored in the sedimentary rocks over hundreds of millions of years."*

Source: Coward & Weaver (eds), 2004. *See ch. 2*.

Linkages between climate change and other environmental issues



Variation in CO_2 at different time scales



- CO_2 levels (pCO_2) have varied due to natural processes (e.g. volcanoes, tectonics)
- Past $\Delta\ pCO_2$ have caused climate change (↓ cooler; ↑ warmer)
- Current rate of $\Delta\ pCO_2$ is > than in the past

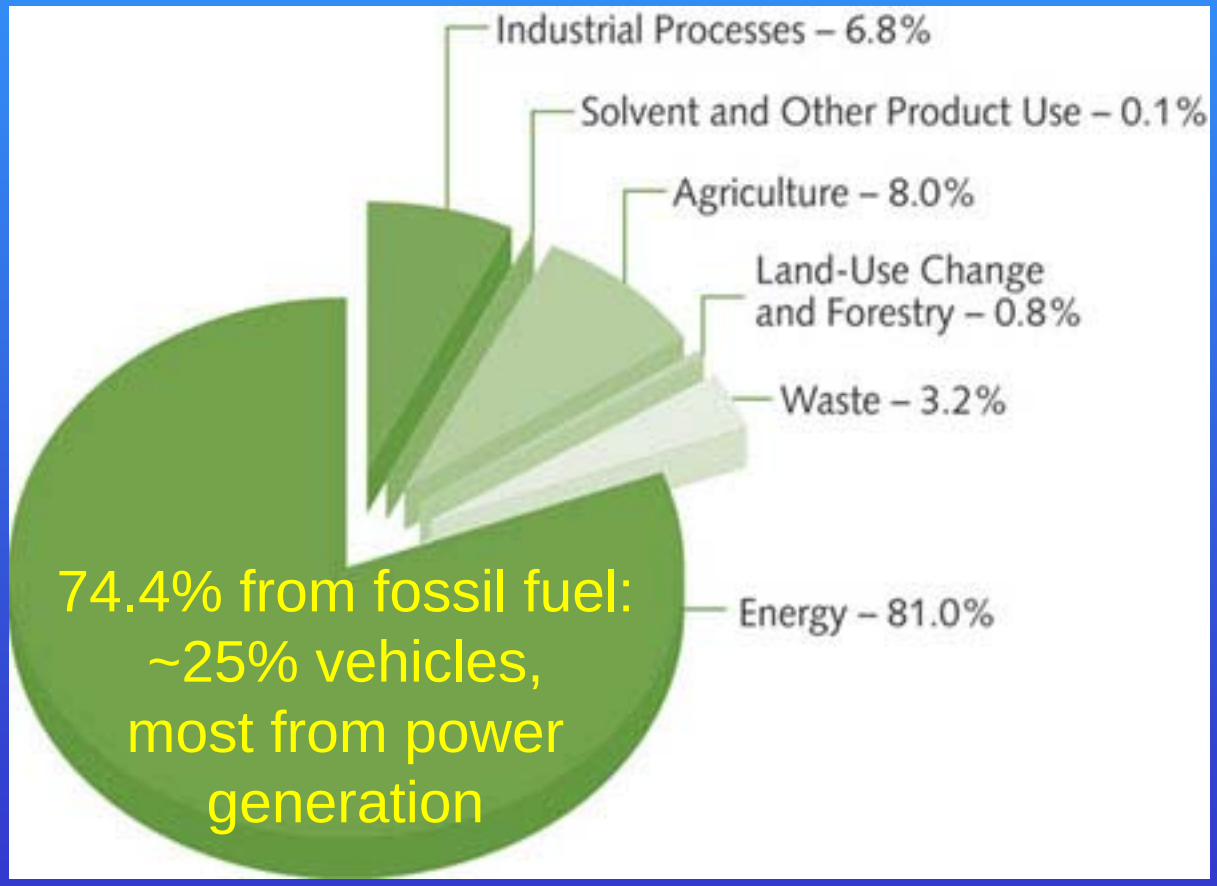
GHGs affected by human activity

	CO_2 (ppm)	CH_4 (ppb)	N_2O (ppb)	CFC-11 (ppt)	HFC-23 (ppt)
Pre-industrial atmos. conc.*	~280 (180-300)[1]	~700	~270	zero	zero
1998 (2005)	365 (380)	1745	314	268	14
Rate of change	1.5 ppm/yr	7.0 ppb/yr	0.8 ppb/yr	-1.4 ppt/yr	0.55 ppt/yr
Atmospheric lifetime (yrs)	5 - 200	12	114	45	260

* pre-1860s

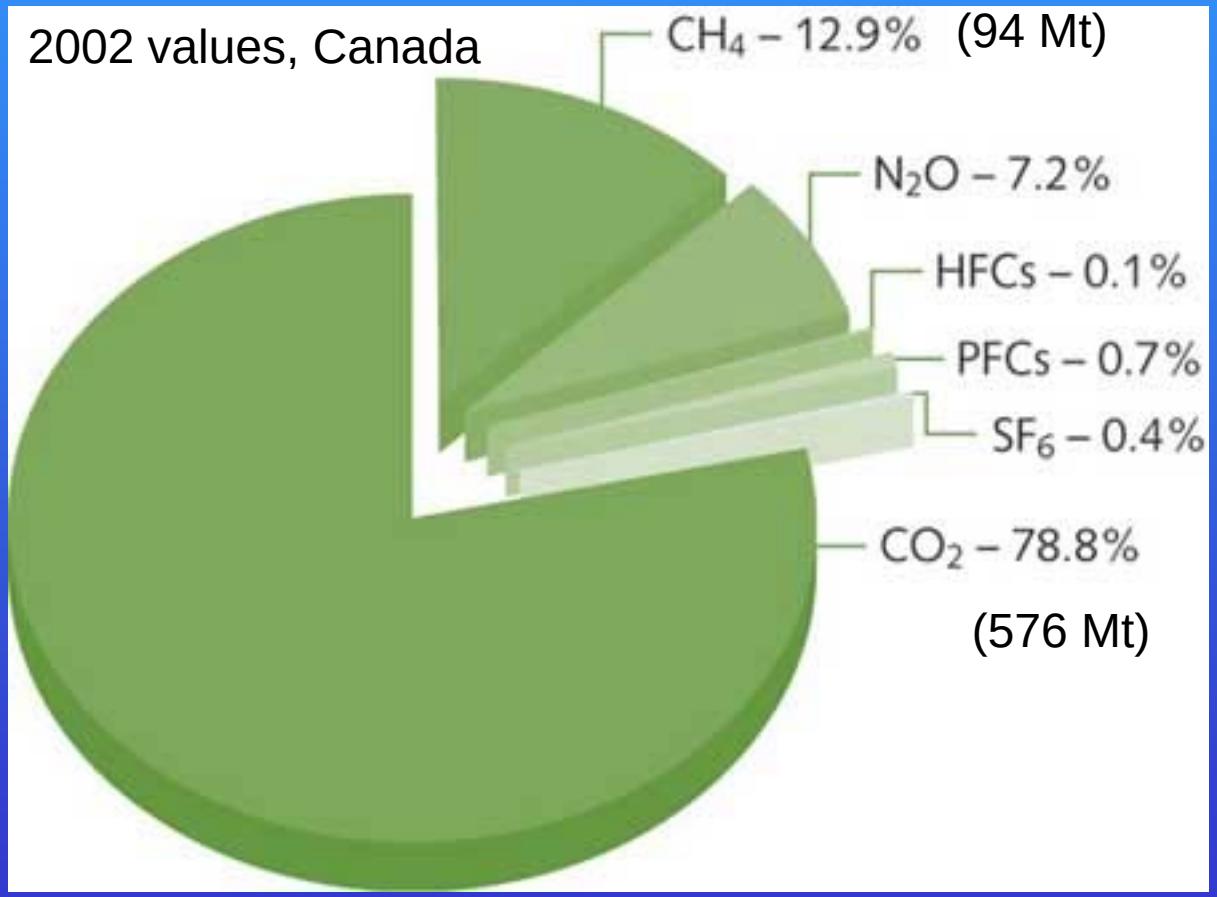
[1] last 650,000 yrs

Canadian sources of GHGs



- fossil fuels as an energy source the primary source of GHGs in western society
- Canada one of the top GHG sources, per capita & national (USA #1)
  - cold winters require heating
  - A/C in summer
  - big cars, SUVs & pick-up trucks

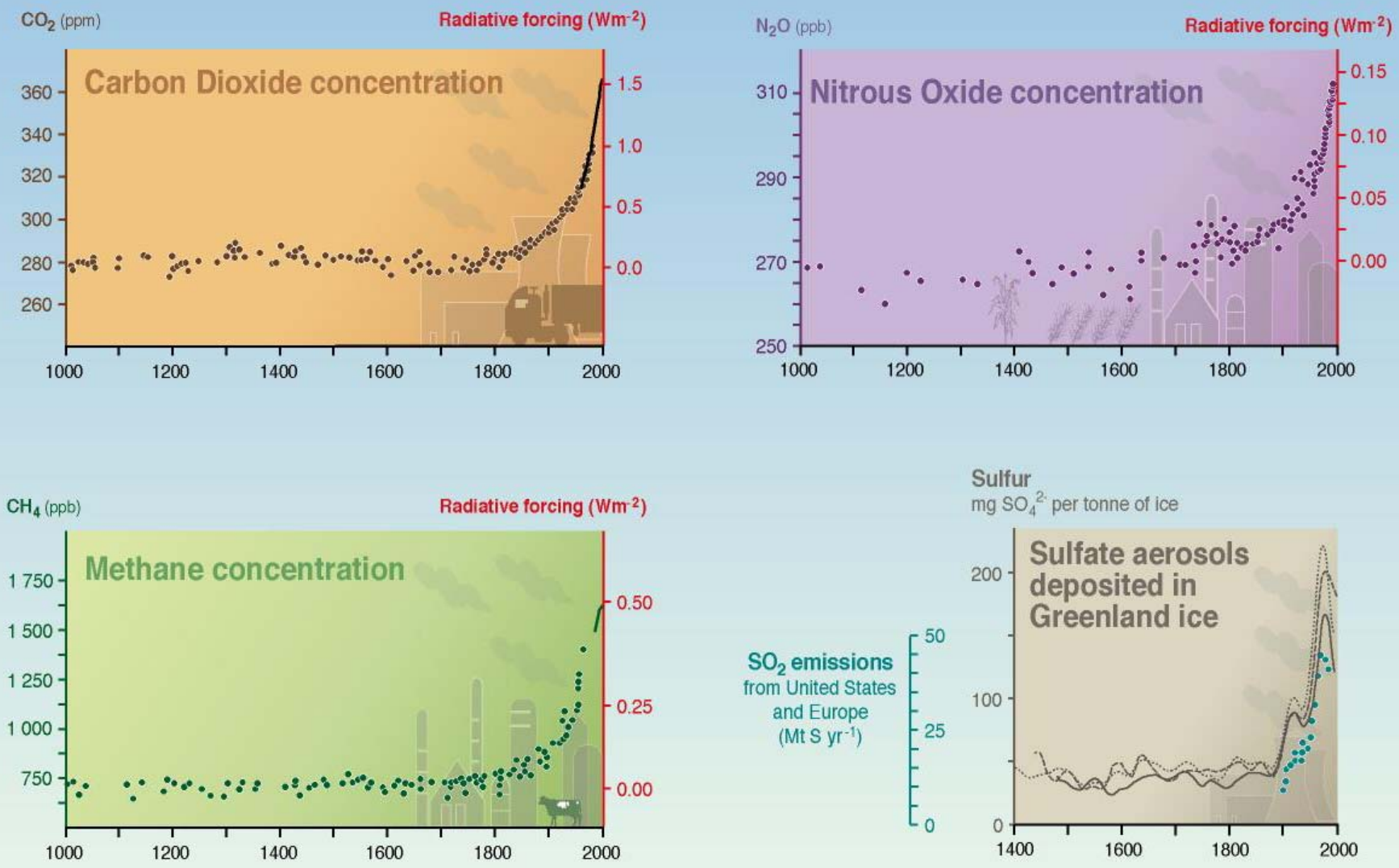
GHGs – not just carbon dioxide



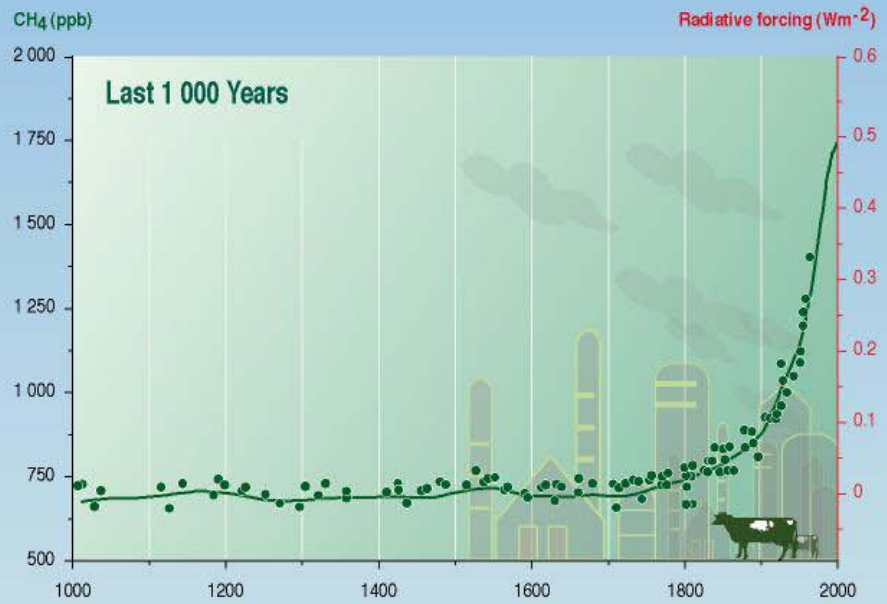
GHGs vary in concentration *and* the amount of heat absorbed per molecule of gas

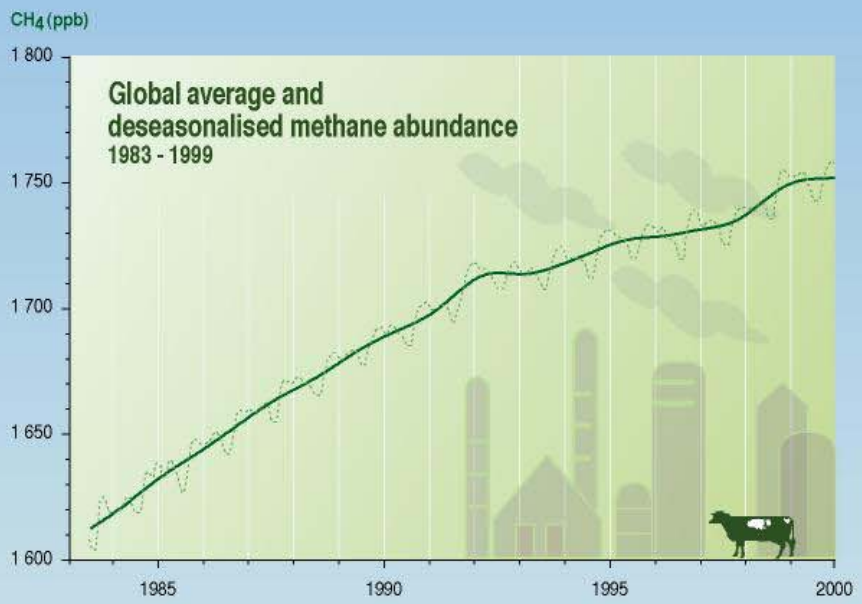
1. Fluorocarbons
2. Water vapour
3. Nitrous oxide
4. Methane
5. Carbon dioxide

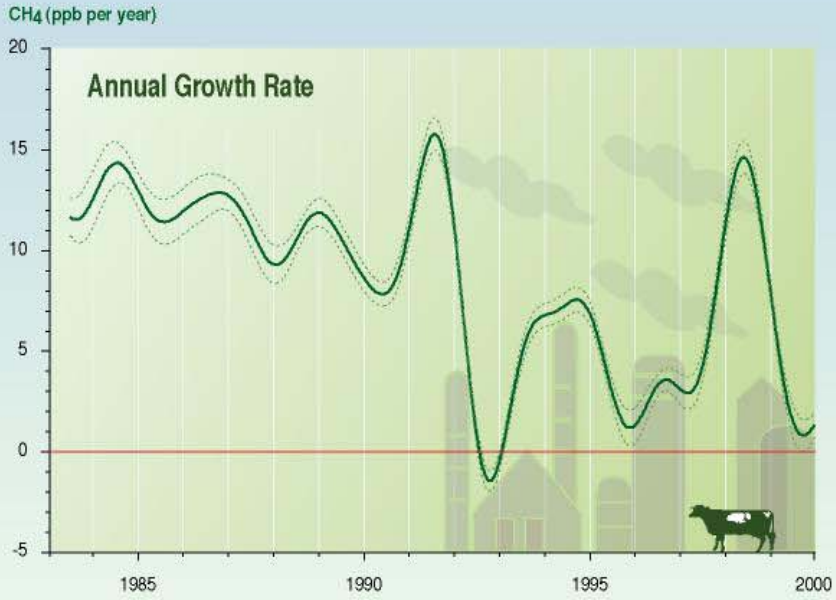
Indicators of the human influence on the atmosphere during the Industrial era



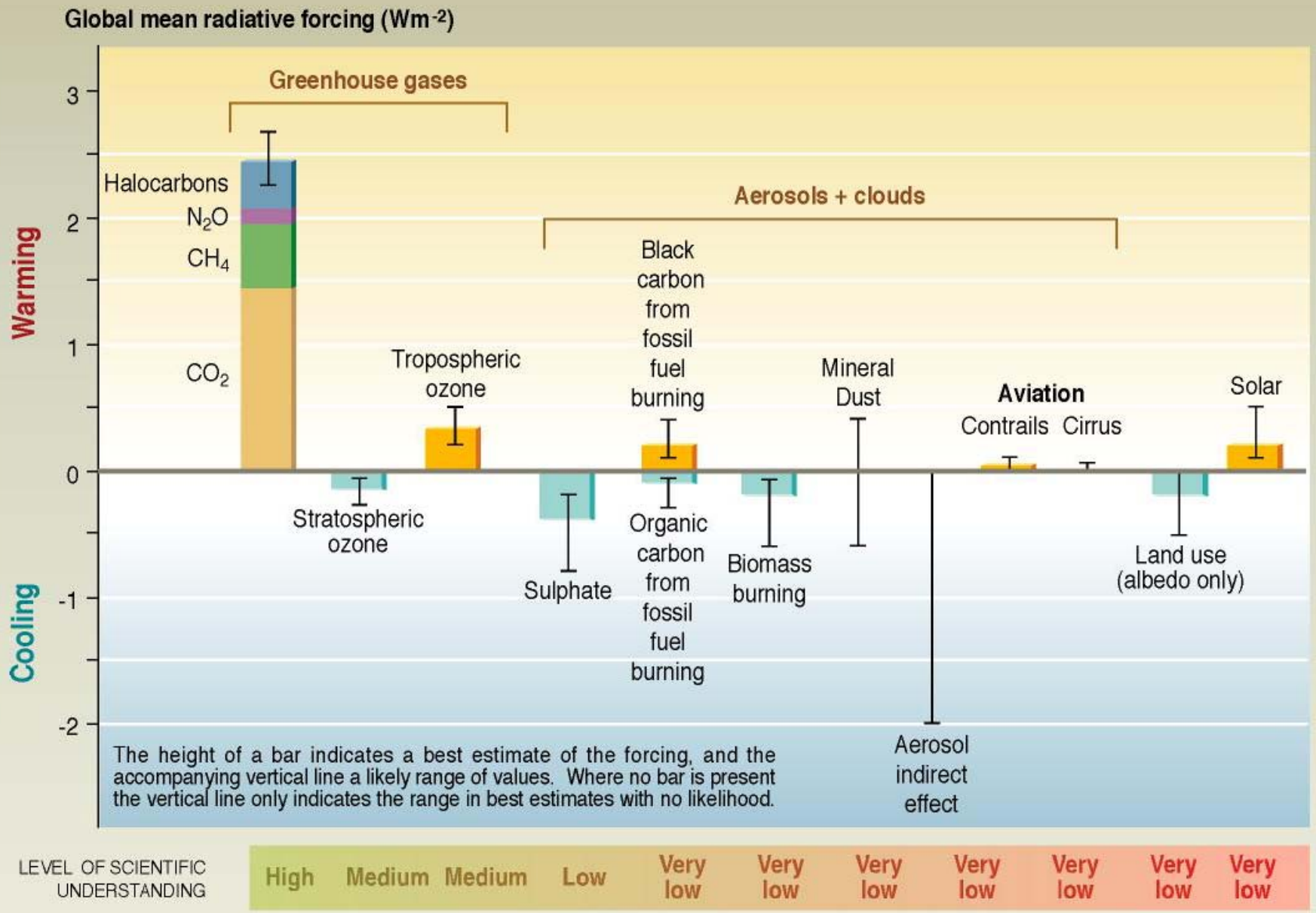
Change in methane abundance







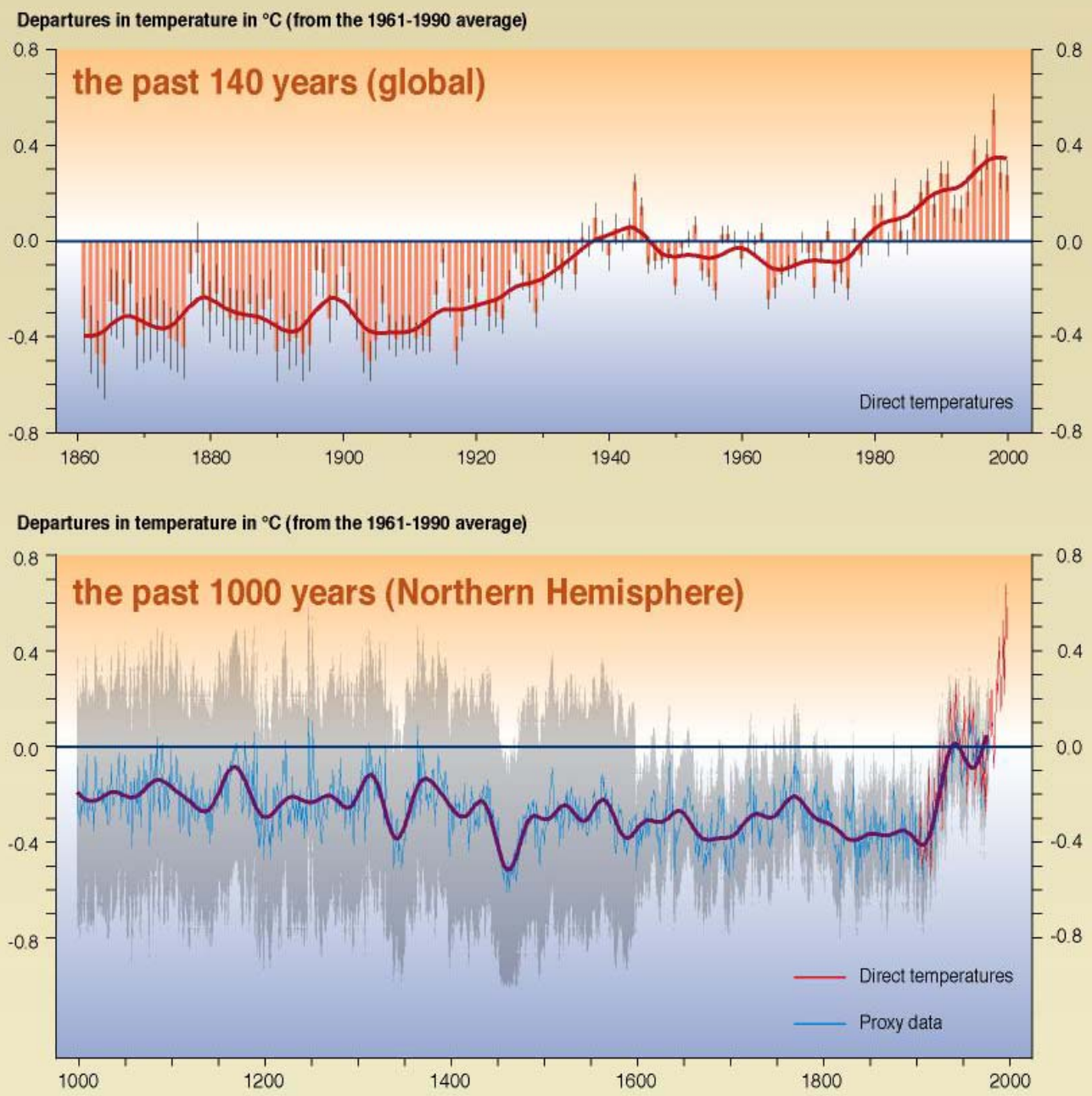
Anthropogenic and natural forcing of the climate for the year 2000, relative to 1750



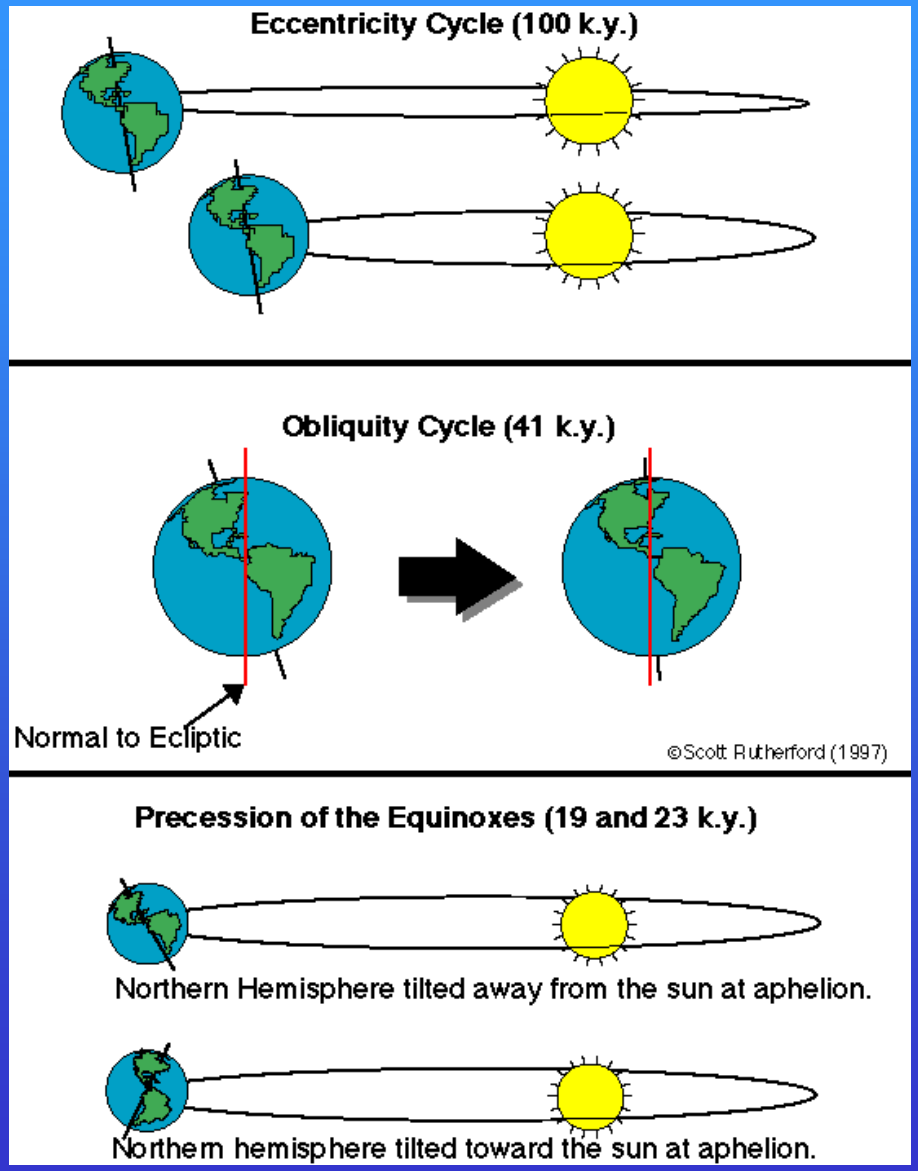
SY

Temperature is naturally variable at several scales.

- decades
- millennia &
- geological (ice ages & longer)
- ΔT° last 60 yrs exceeds past 1000yrs

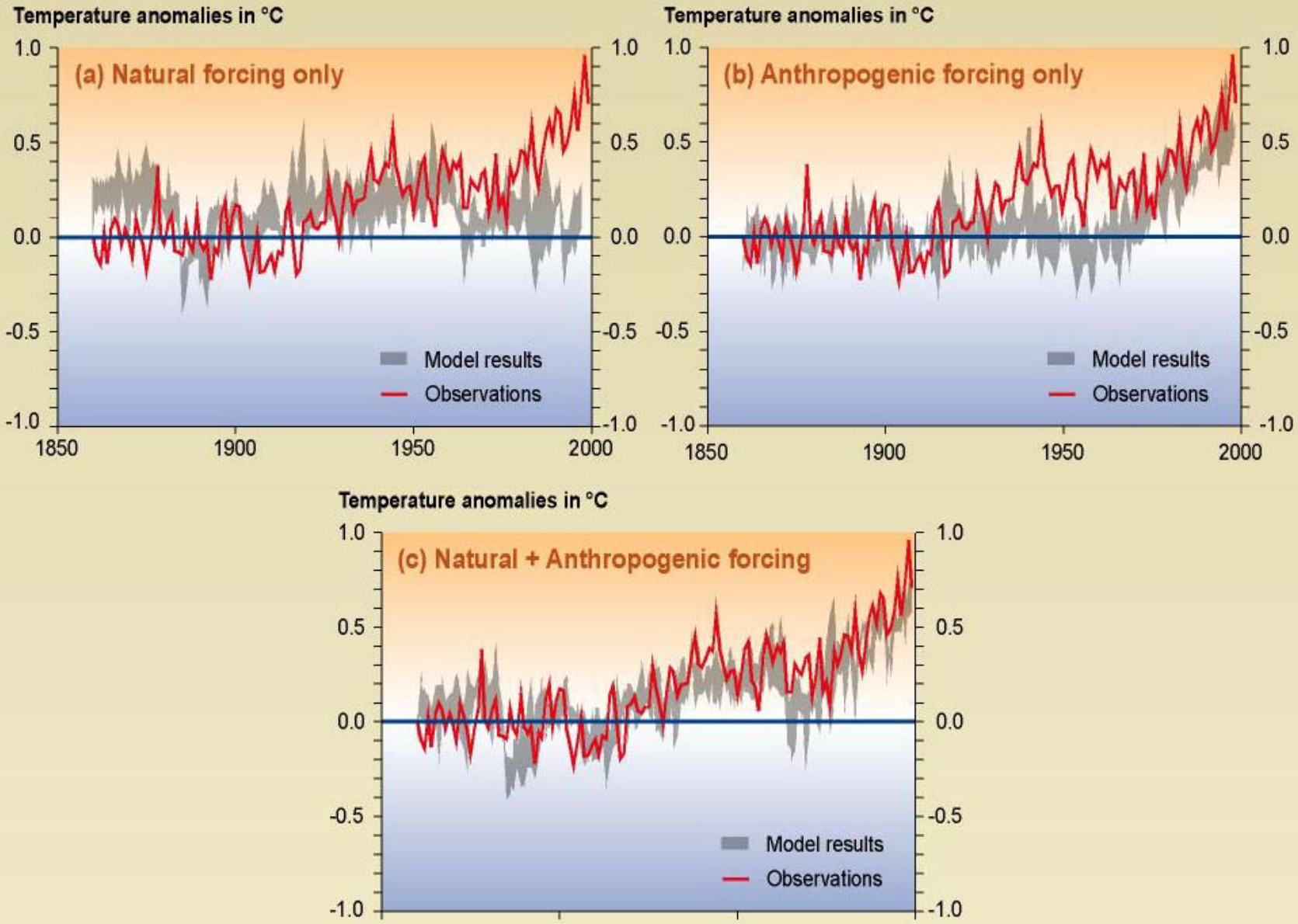


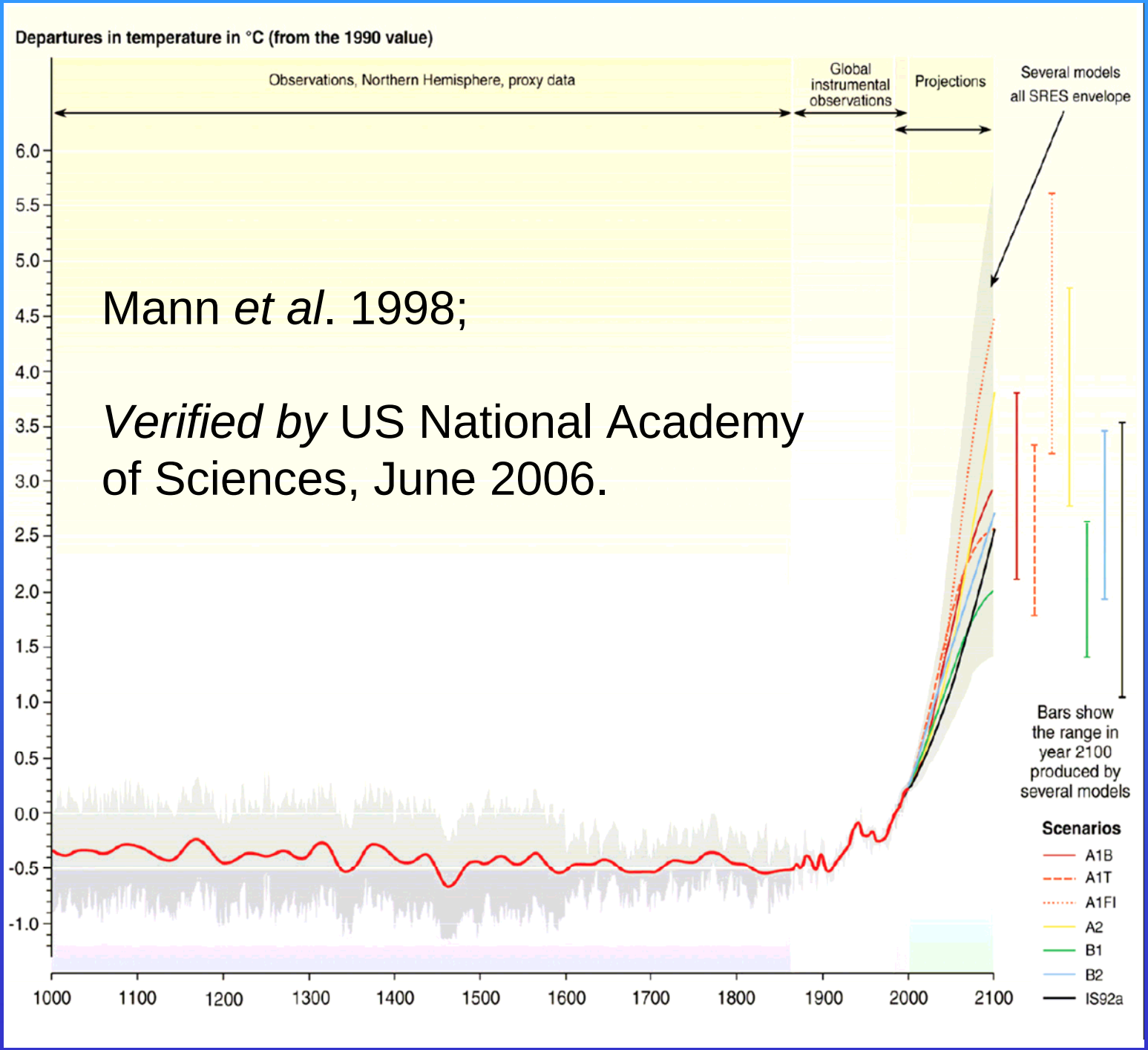
Sources of climate variability (forcings)



- GHG levels (volcanoes & forest fires emit GHGs and also produce dust)
- Solar output varies (sunspot activity)
- Orbital changes (earth's distance from the sun; axial tilt)
- El niño / la niña

Comparison between modeled and observations of temperature rise since the year 1860





Mann *et al*. 1998;

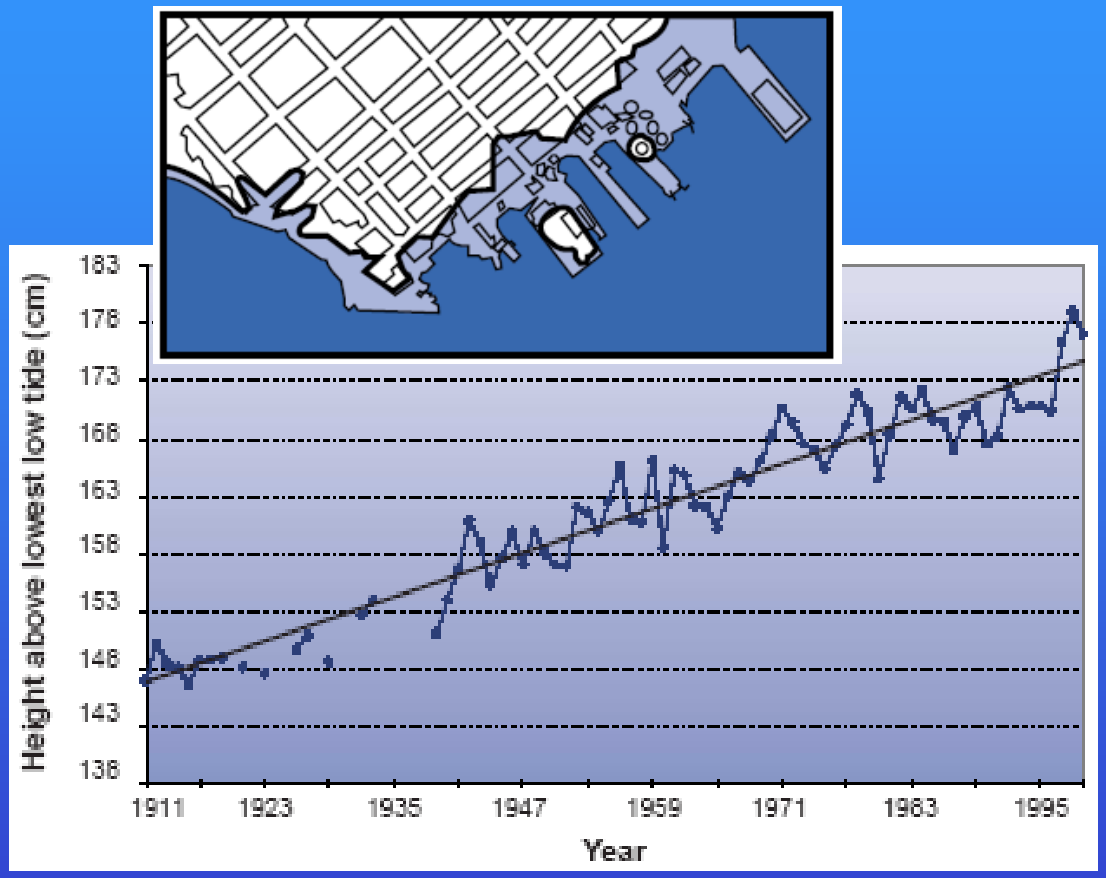
Verified by US National Academy of Sciences, June 2006.

Effects of climate change

Some of the expected consequences of climate change are already being observed.

1. Receding mountain glaciers.
2. Early and longer break-up of Arctic & Antarctic sea ice.
3. Rising sea level.
4. Plants flowering earlier (earlier spring).
5. The 1st two have affected sea levels, but also wildlife populations.

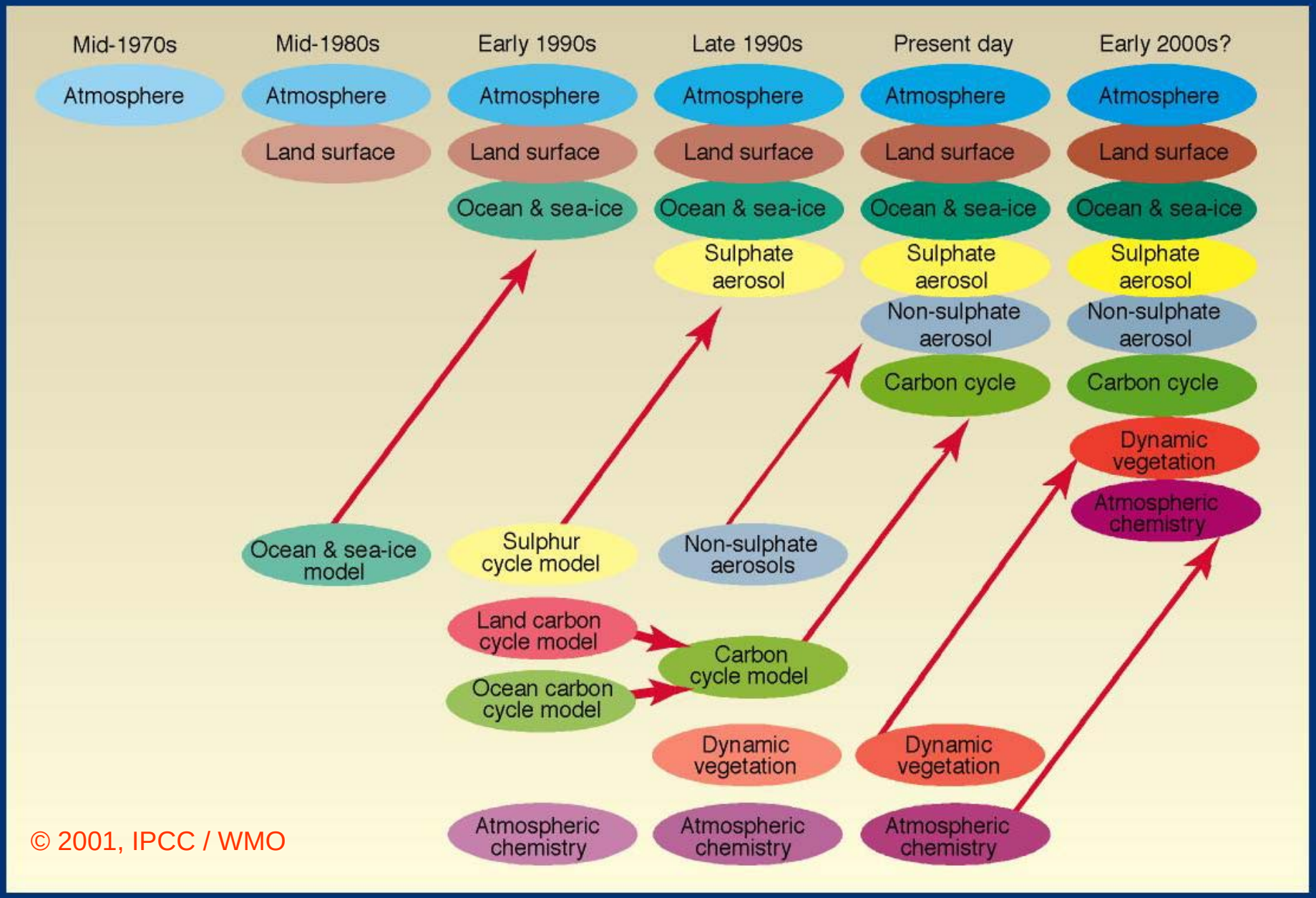
Consequences in Canada



The annual sea level at Charlottetown (PEI) between 1911 and 1998 above the lowest expected low tide level.

- Charlottetown (PEI) is seriously threatened by rising sea levels.
- Its historic core lies just a few m a.s.l., and over the past 100yrs the city's average sea level rose by ~ 30 cm.
- ~20 cm probably due to local sinking of the land after the last ice age
- rest can be linked to global sea level changes resulting from a warmer climate.

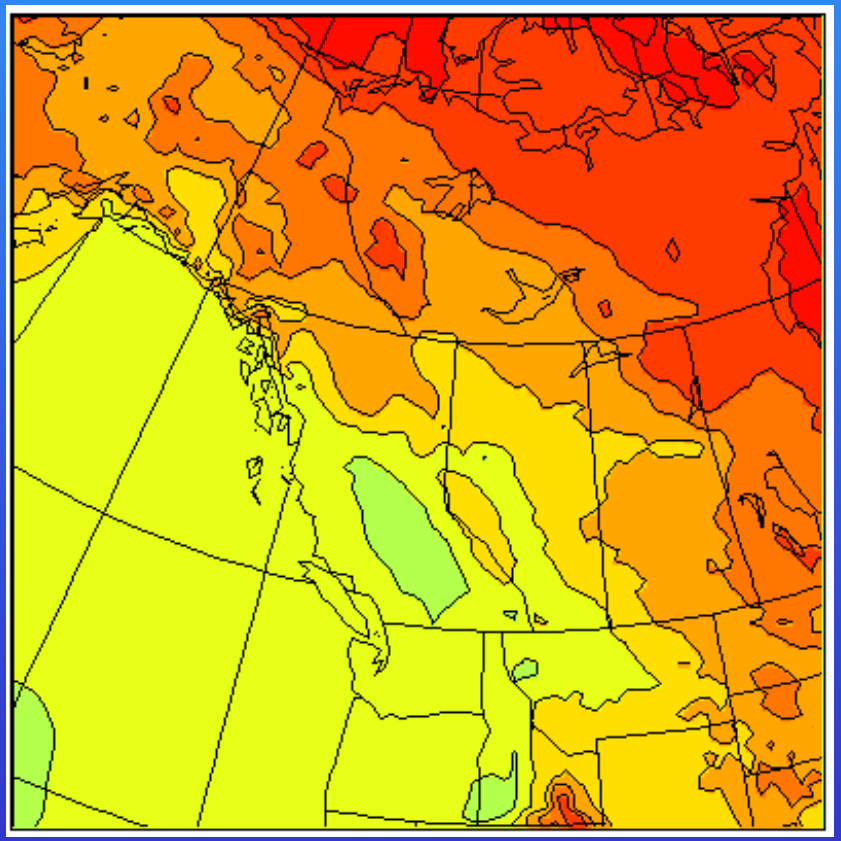
The development of climate models, past, present and future



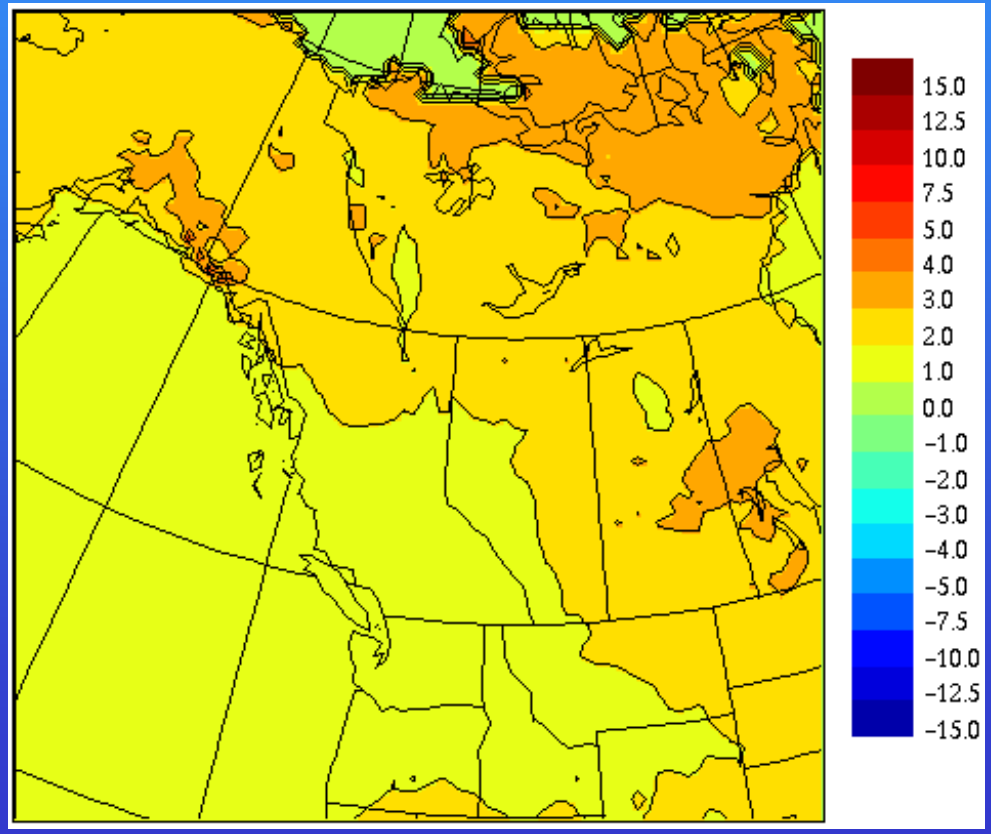
Diagnostic Plots from CRCM

Change in screen (2m) temperature in 2040-49 vs. 1975-84 (°C)

DJF (winter)



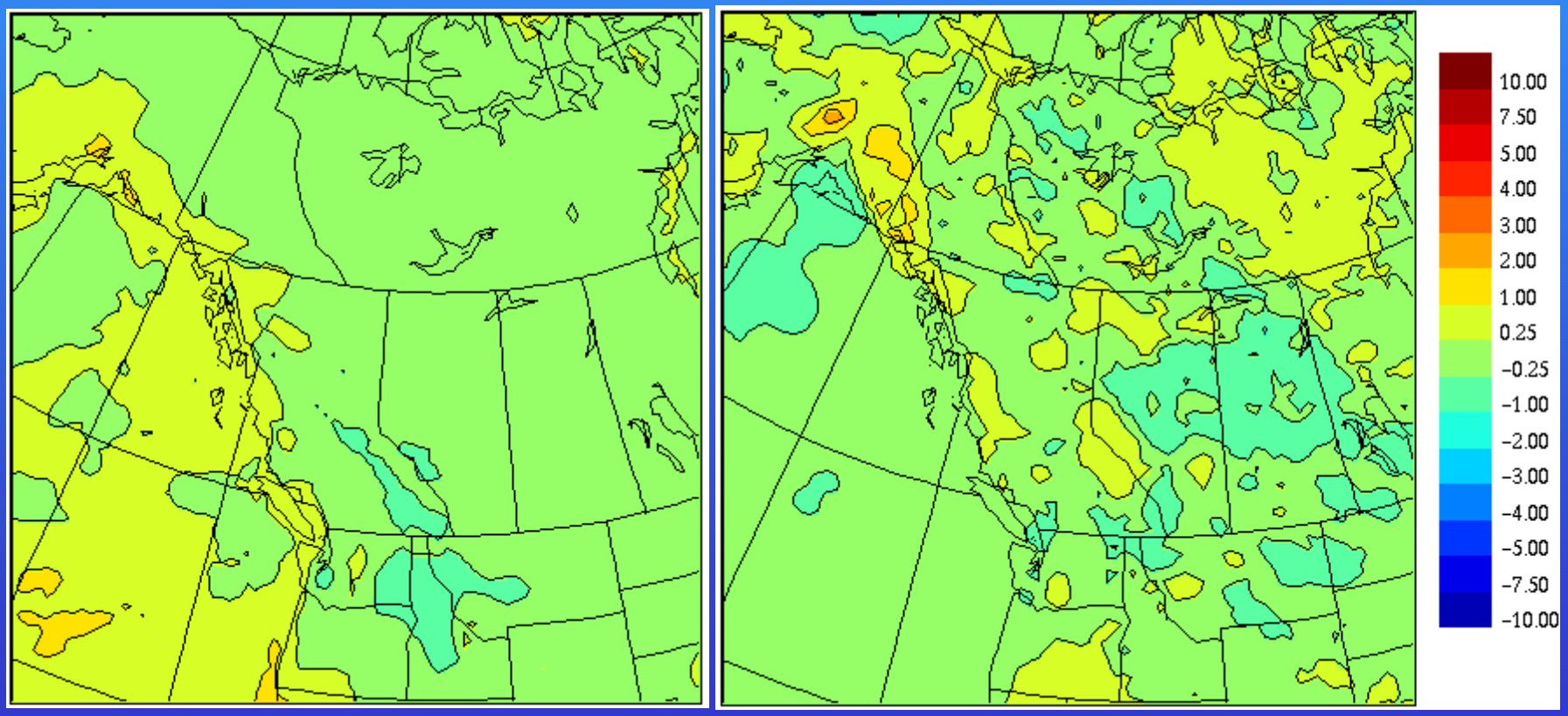
JJA (summer)



Diagnostic Plots from CRCM

Change in precipitation in 2040-49 vs. 1975-84 (mm/day)

DJF (winter) JJA (summer)



Prairie Adaptation Research Collaborative

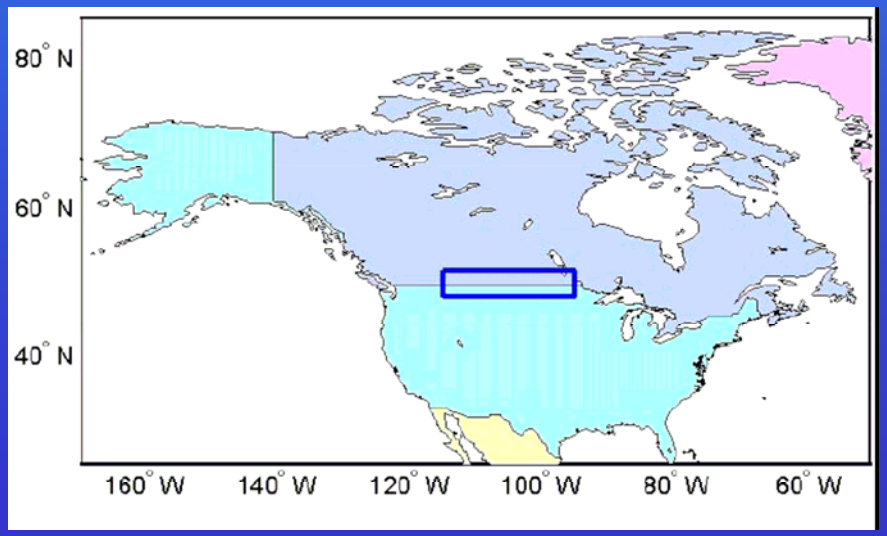
National Assessment of Climate Change
Prairies Chapter

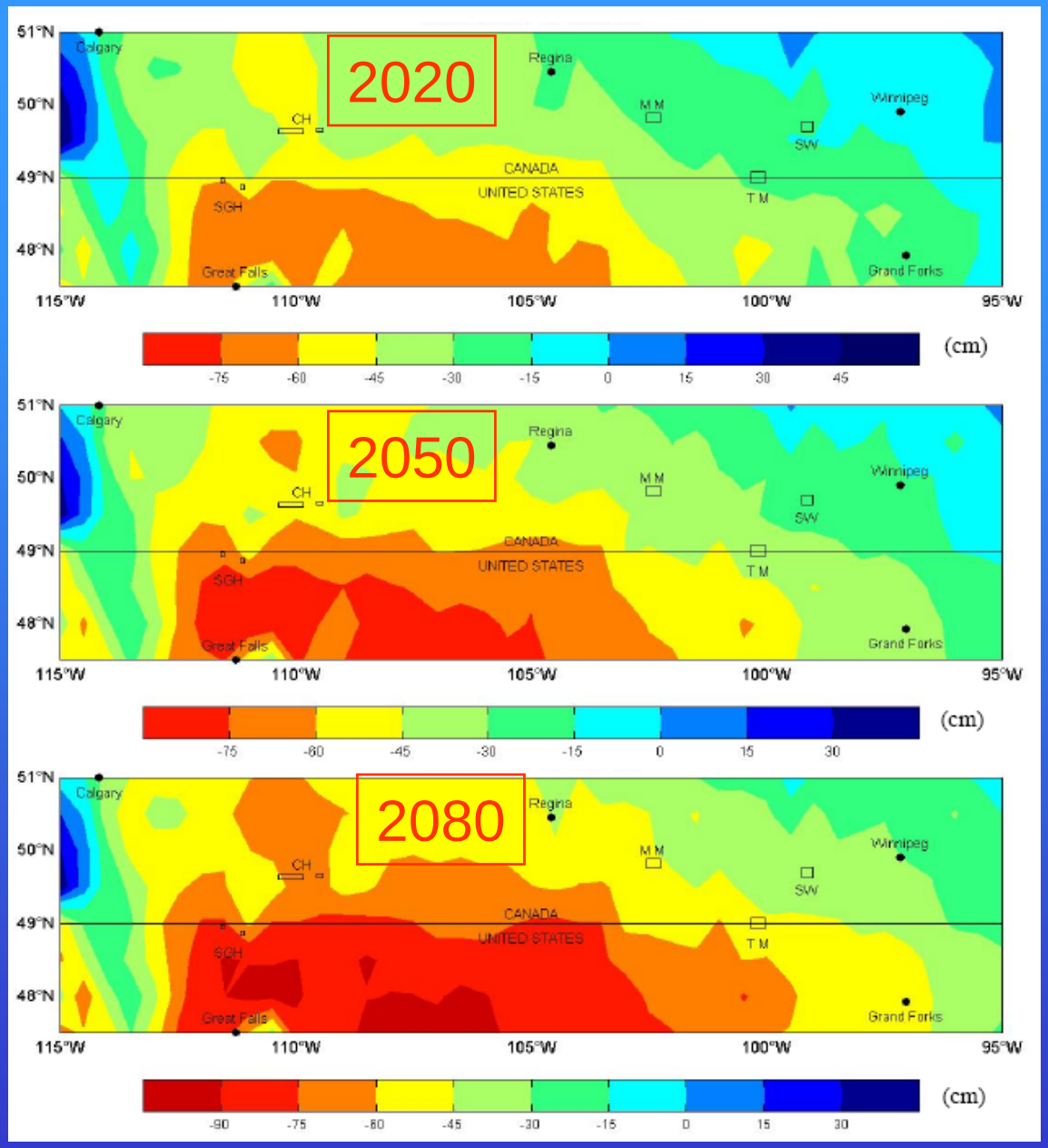
Dave Sauchyn
University of Regina

- GCMs forecast a median annual increases of 2 to 5°C and 2-12% in precipitation;
  - with the exception of a few scenarios for the 2020s, all models forecast climates that outside the range of natural variability.
- increase in temp. and precipitation mostly in winter and spring in both forest and grassland regions, with increases of close to 4°C and 15% in winter.

- Changes in the availability of water resources represent the most serous climate risk.
- Lower summer stream flows, lake levels, retreating glaciers;
  - increasing soil and surface water deficits, as more water is lost by evaporation.
- Higher forest, grassland & crop productivity from increased heat and CO_2 limited by available soil moisture.

Climate Change Impacts on the Island Forests of the Great Plains and the Implications for Nature Conservation Policy:

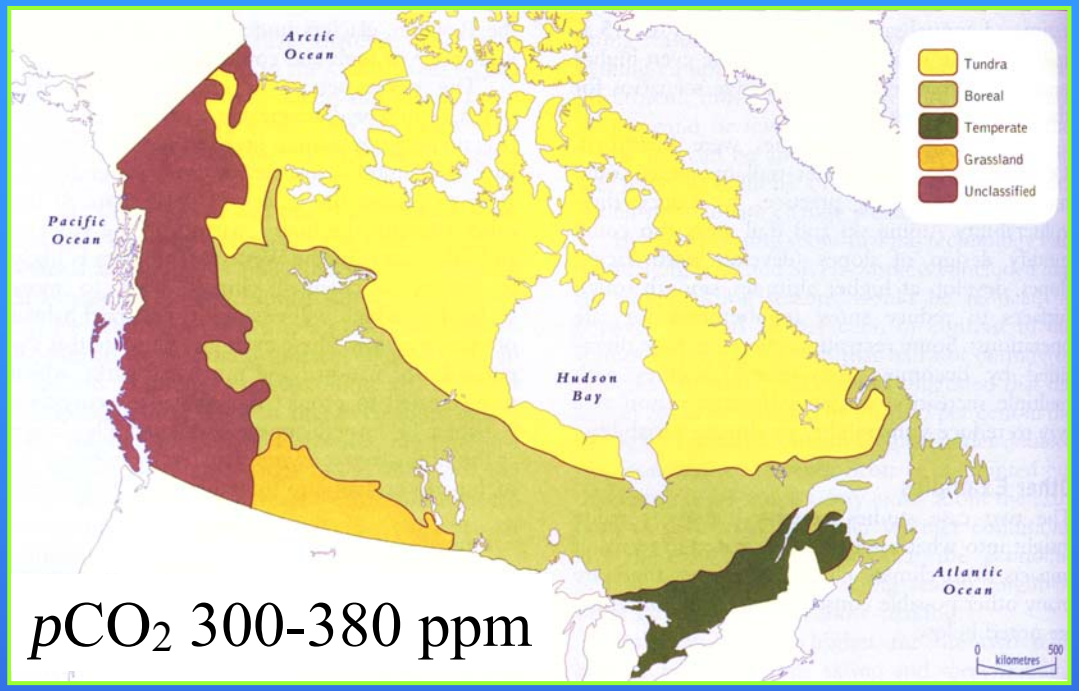


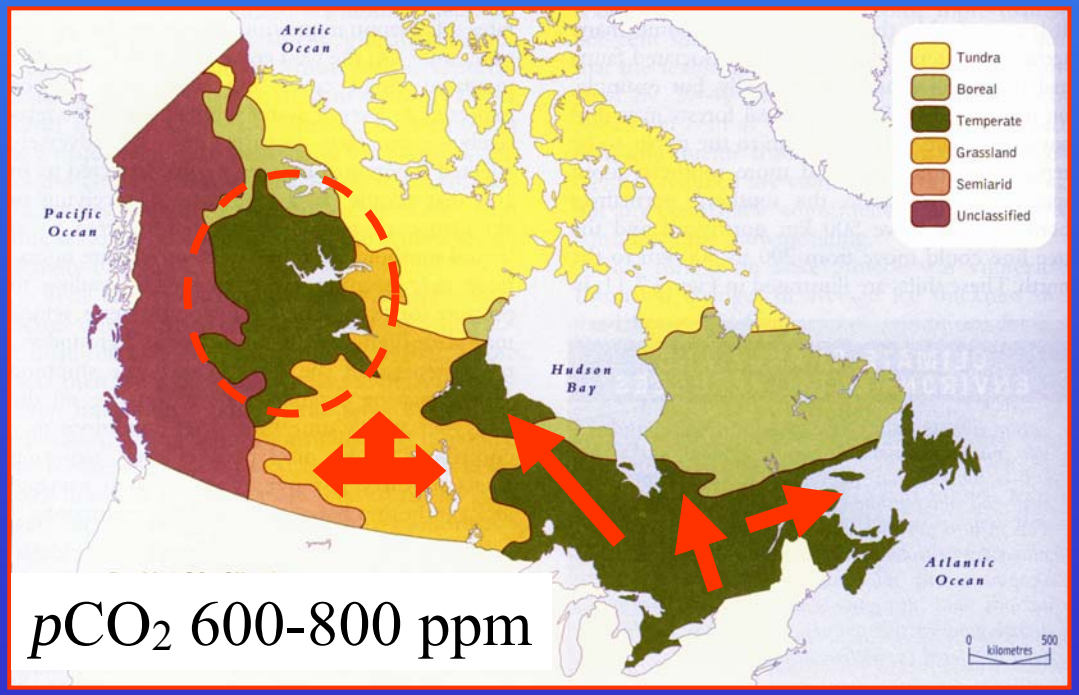


Soil moisture: light blue to red excludes conifers.

- Major ecosystem changes are expected.
- Most visible in isolated forests and forest fringe areas.
  - Cypress Hills and Moose Mtn (SK), Spruce Woods (MB), Turtle Mtn (MB, ND).
  - trees will give way to shrub or grassland landscapes.
  - Major loss of forests in the southern boreal forest is possible.
- We will see new ecosystems develop..

Consequences in Canada





Changes in forest & grassland boundaries due to doubling of CO_2

- reduction in tundra;
- loss of boreal forest across much of the Prairie provinces;
- expansion of semi-arid areas & grasslands, and;
- expansion of temperate deciduous forests.

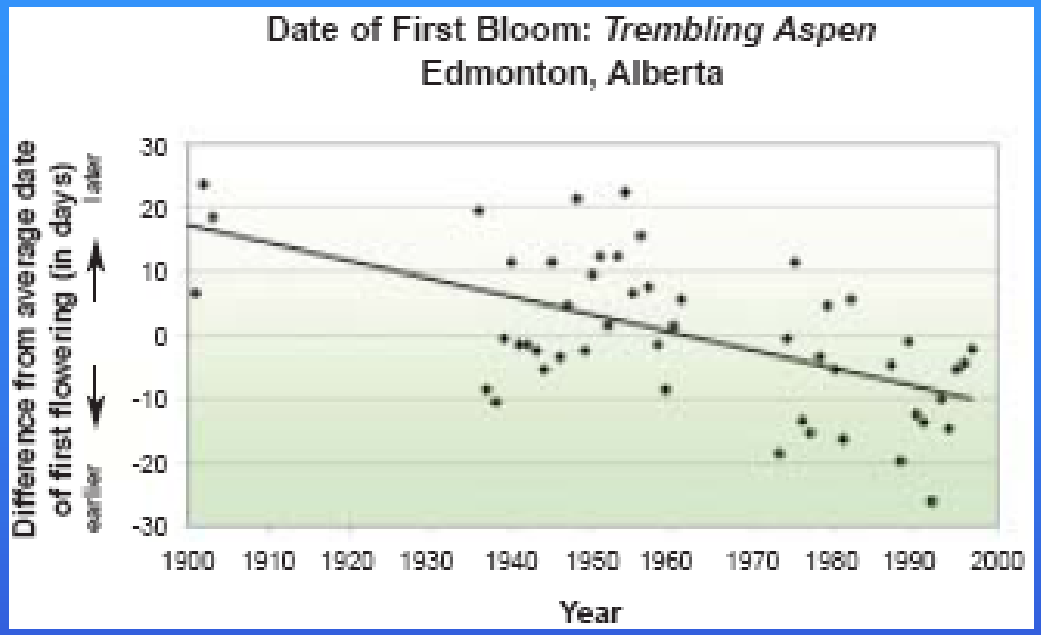
Dearden & Mitchell, 2005

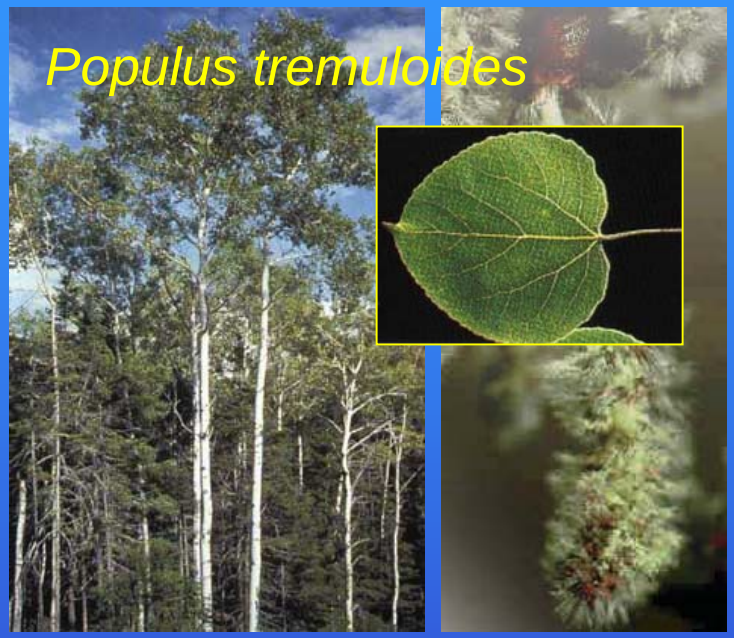
Consequences in Canada

- ‘Balmy weather breaks record’ *Winnipeg Free Press*, Feb. 1.
- “(January) Average temperatures 10°C warmer than normal.”

place	*Jan. 2006*	*Year of 1st record*	*30 yr mean (1971-2000)*	*anomaly*
Brandon	–7.3°C	1941	-17.9°C	↑ 10.6°C
Winnipeg	–7.5°C	1938	-17.8°C	↑ 10.3°C
Dauphin	–7.4°C	1942	-17.3°C	↑ 9.9°C
The Pas	–11.2°C	1943	-20.6°C	↑ 9.4°C
Thompson	–17.3°C	1967	-24.9°C	↑ 7.6°C
Churchill	–21.5°C	1943	-26.7°C	↑ 5.2°C

Consequences in Canada



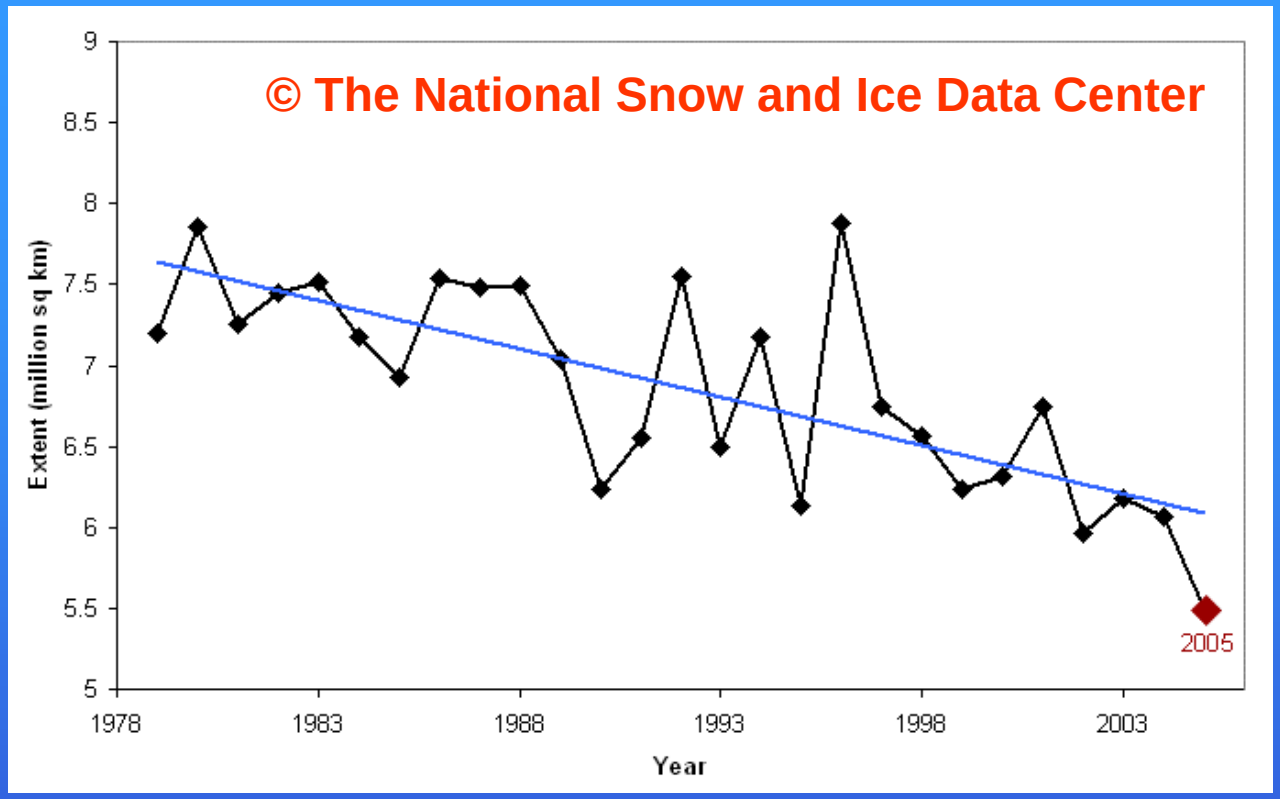


- 1901-1997 the ***average flowering date shifted ~26 days*** – early May to early April.
- ***Warmer and earlier springs on the Prairies.***
- During the 20th Century ***daily spring high T°C increased by > 2ºC***, and overnight lows increased even more.
- The earlier flowering of the trembling aspen in Edmonton ***may have been in part due*** to an ***'urban effect'*** (or 'heat island') – greater urban warming than in nearby rural areas because Edmonton has less green space and more asphalt and buildings.

Consequences in Canada

Seal pups are born on the ice and must stay there until they can swim. In early 2002, many harp seal pups were lost in the Gulf of St. Laurence when a mild winter resulted in a lack of sea ice.

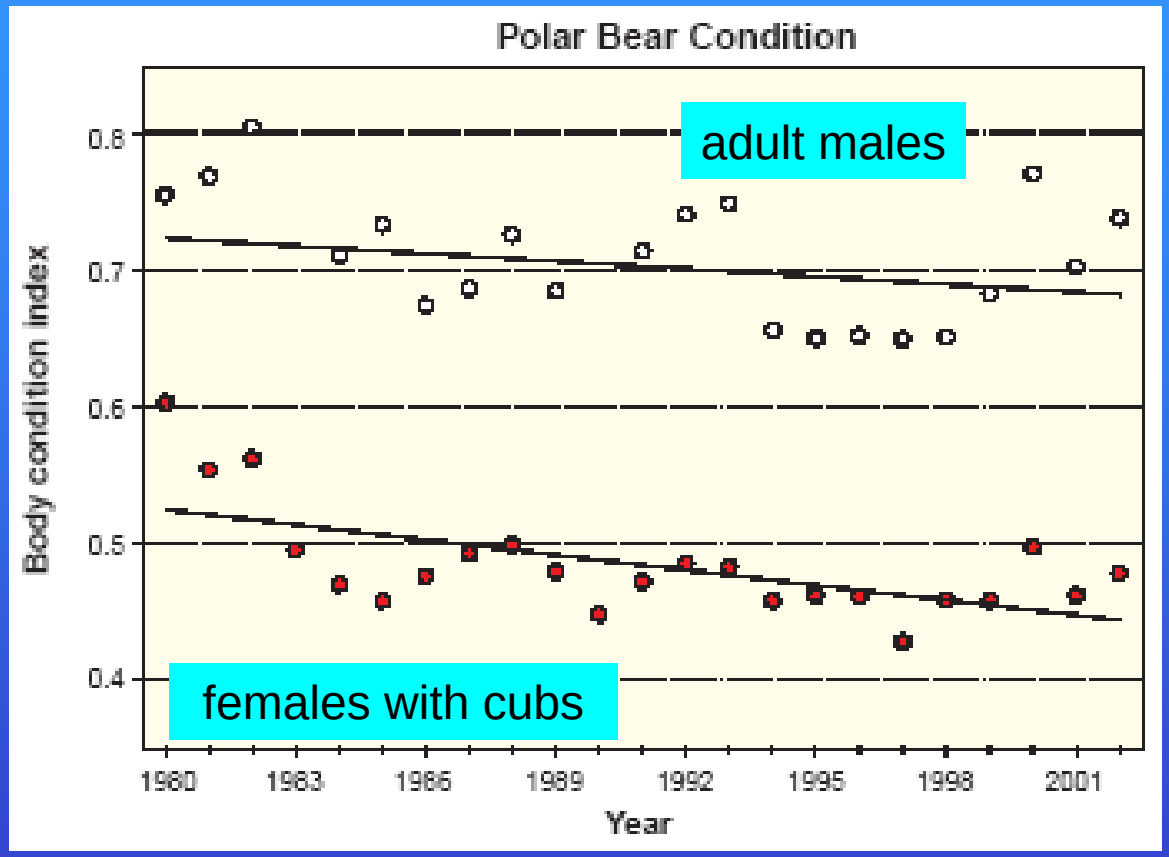
- Seals and polar bears need sea ice to breed or to hunt.
- The extent and persistence of Arctic sea ice is affected by a number of factors, but mainly air temperature.



© BBC

- Permanent sea ice doesn't melt in summer.
- has decreased by 25% since 1969.
- average thickness decreased ~ 45% between 1958-1976 and 1993-1997 (US nuclear submarines).
- only 25-year record, so some uncertainty whether due to climate change or natural variation … but seems to be accelerating.

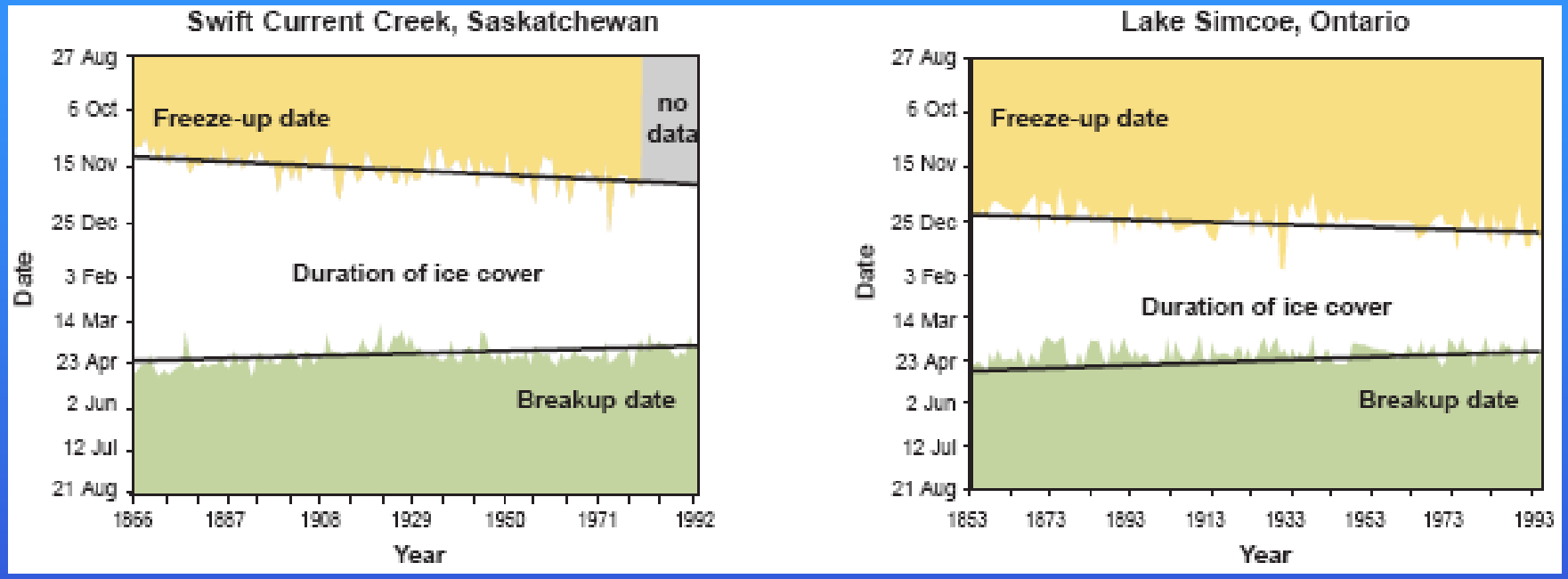
Consequences in Canada



The body condition index measures the relationship between weight & body length. It provides good evidence of the general health of polar bears.

- The decline since the early 1980s appears to be caused by the trend towards earlier breakup of the sea ice (previous slide).
- Related to a 0.2–0.3°C increase in spring T°C per decade since 1950.
- Only 25-year record, so some uncertainty whether due to climate change or natural variation.

Consequences in Canada



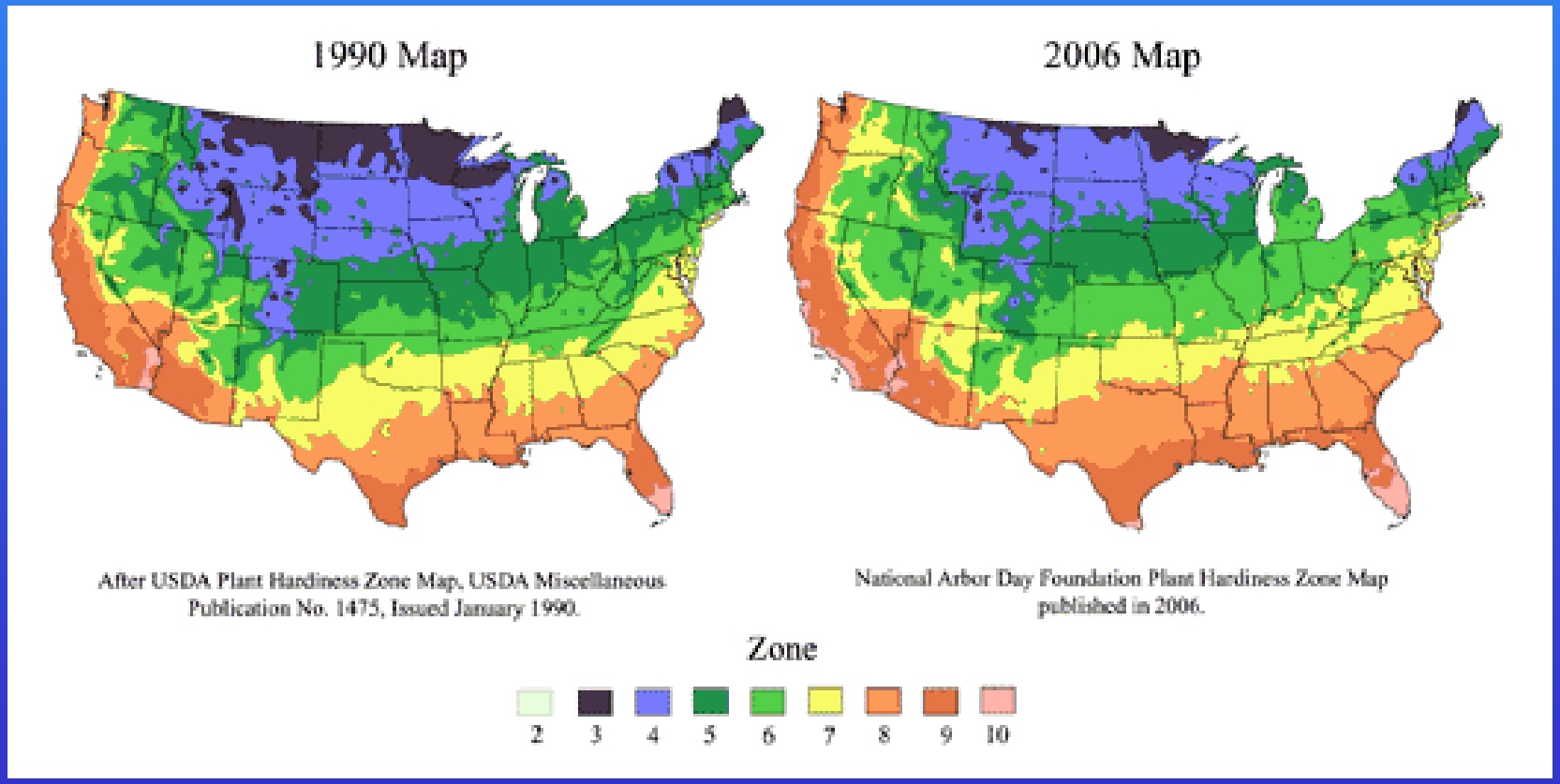
- The average freeze-up date for Lake Simcoe (ON) is about 13 days later than it was 140 years ago, and the average break-up date is about 4 days earlier.
- For Swift Current Creek (SK) freeze-up is now about 24 days later and break-up about 14 days earlier than 115 years ago.
- These results are what might be expected from the temperature record of the past century, which shows more warming in southern Saskatchewan than in southern Ontario.

Consequences in Canada

- Winter roads rely on permafrost & lake ice
- Shifting vegetation zones
  - Loss of tundra, change in resource base for Arctic people
  - Loss of boreal forest / forest ‘islands’ in Prairies?
- Pests / new species further north
  - e.g., pine bark beetle in BC
  - New diseases / disease vectors (e.g., malaria)
- Water flowing down rivers (e.g., Saskatchewan R)
  - dependent on glacial melt and Rockies snow-pack / effect of erratic rainfall patterns (can’t rely on flows)
  - Water-supply *AND* hydroelectricity
- North-west passage
  - geopolitical tensions, cost of sovereignty & sea route

Consequences for North America

- US plant hardiness zones were adjusted in Dec. 2006 to compensate for climate change since the 1990 maps were made (see National Arbor Day Foundation website)
- Much of Illinois, Indiana & Ohio have shifted from Zone 5 to 6.



Summary

- Climate is naturally variable, and can sometimes shift dramatically within a few hundred or thousand years (climate change is not 'new').
  - **Past climate change is linked to ↑↓GHGs and other forcings.**
  - **However, over the past 60-100 years, the rate at which climate has been changing appears to exceed the natural rate of change.**
- Scientific evidence for global climate change includes:
  - **increasing concentrations of greenhouse gases (CO_2, CH_4, NO_x, CFCs) in the atmosphere due to human activity;**
  - **shrinking glaciers, sea ice & snow cover throughout the world;**
  - **and increases in sea level.**
- Climate models are used to explore past and present climate trends.
  - **There are many limitations associated with the models, and much uncertainty under different scenarios.**
- The impacts of climate change will be variable around the globe.
  - **Impacts are already being felt in the Canadian Prairies and Arctic.**
  - **Many US states have shifted at least one full plant hardiness zone. Some areas around the US have even warmed two full zones.**

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