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Can Canada’s Forests Adapt to a Changing Climate, and How?

David Price

Canadian Forest Service, Edmonton

Up North on Climate Conference
Thunder Bay, 24 April 2018

Canada

Topic Guide

- Is the global climate changing?
- Are humans causing climate change?
- How will Canada (Ontario) be affected?
- What are effects on forests?
- What are effects on communities?
- What can be done?

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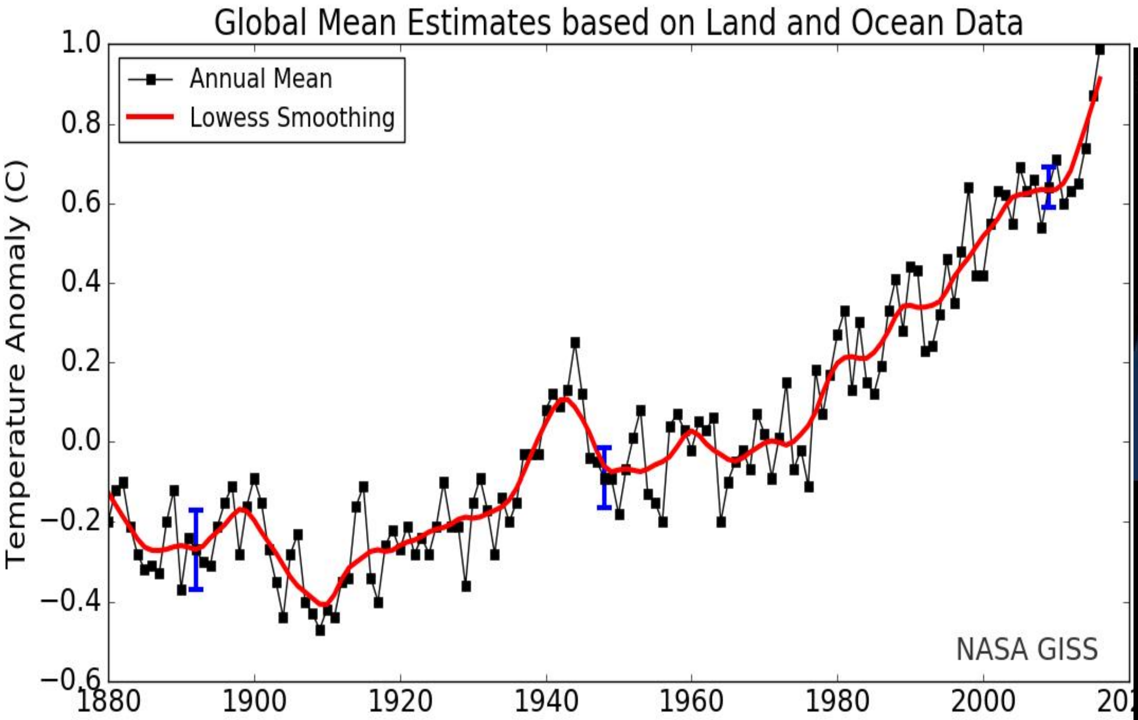
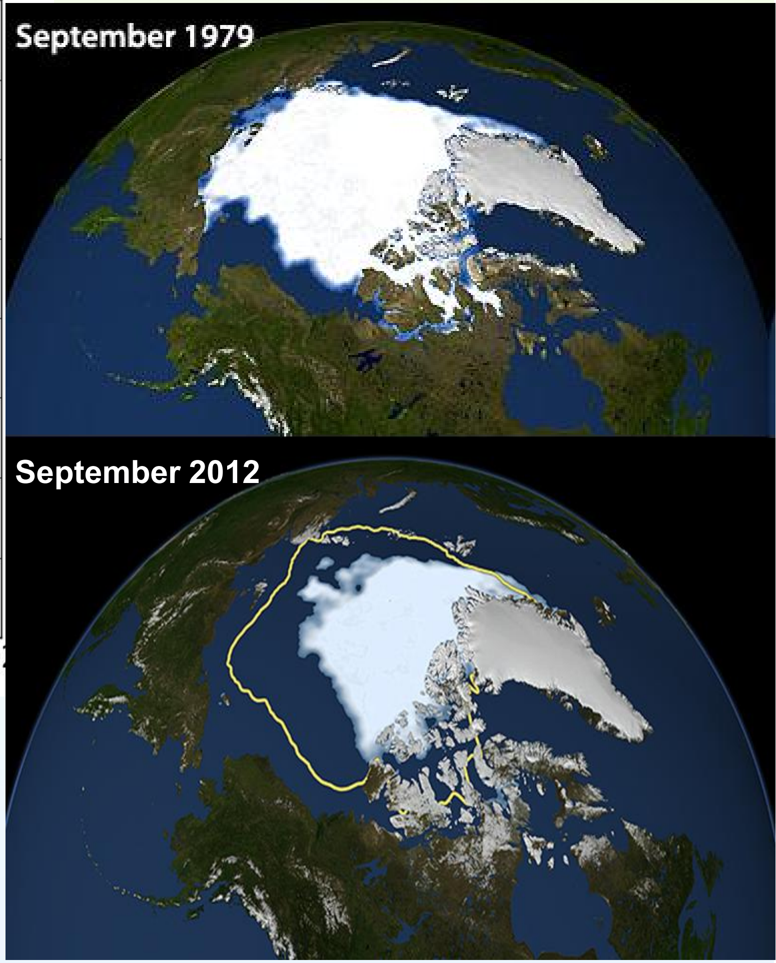
Global temperature record



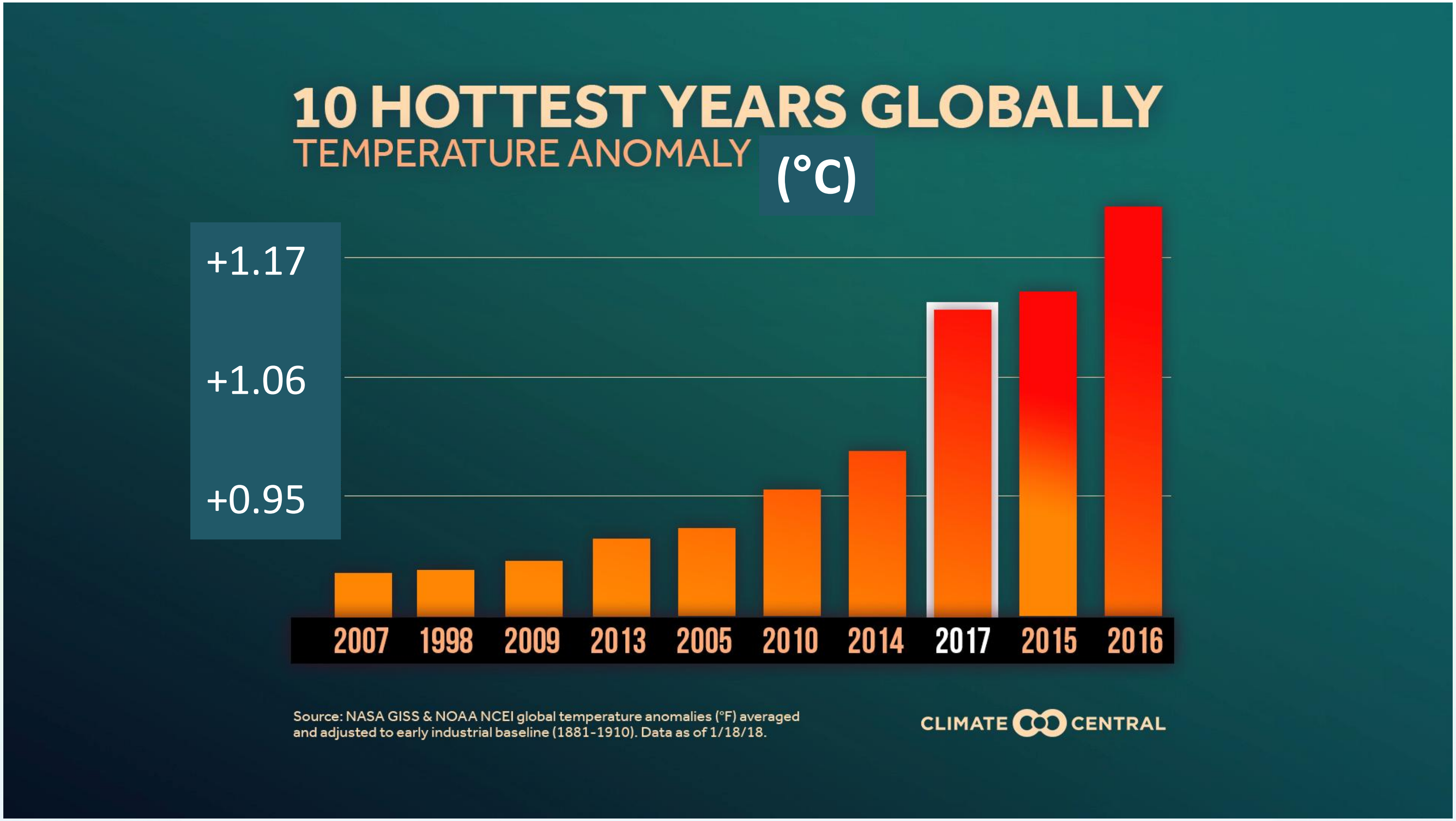


From NASA web site at: http://data.giss.nasa.gov/gistemp/graphs/

- **Warming of more than 1°C over the past century**
- **Year 2016 was the warmest on record**

see: http://www.ncdc.noaa.gov/sotc/global/201612

http://www.nasa.gov/topics/earth/features/2012-seaicemin.html



http://www.climatecentral.org/gallery/graphics/the-10-hottest-global-years-on-record

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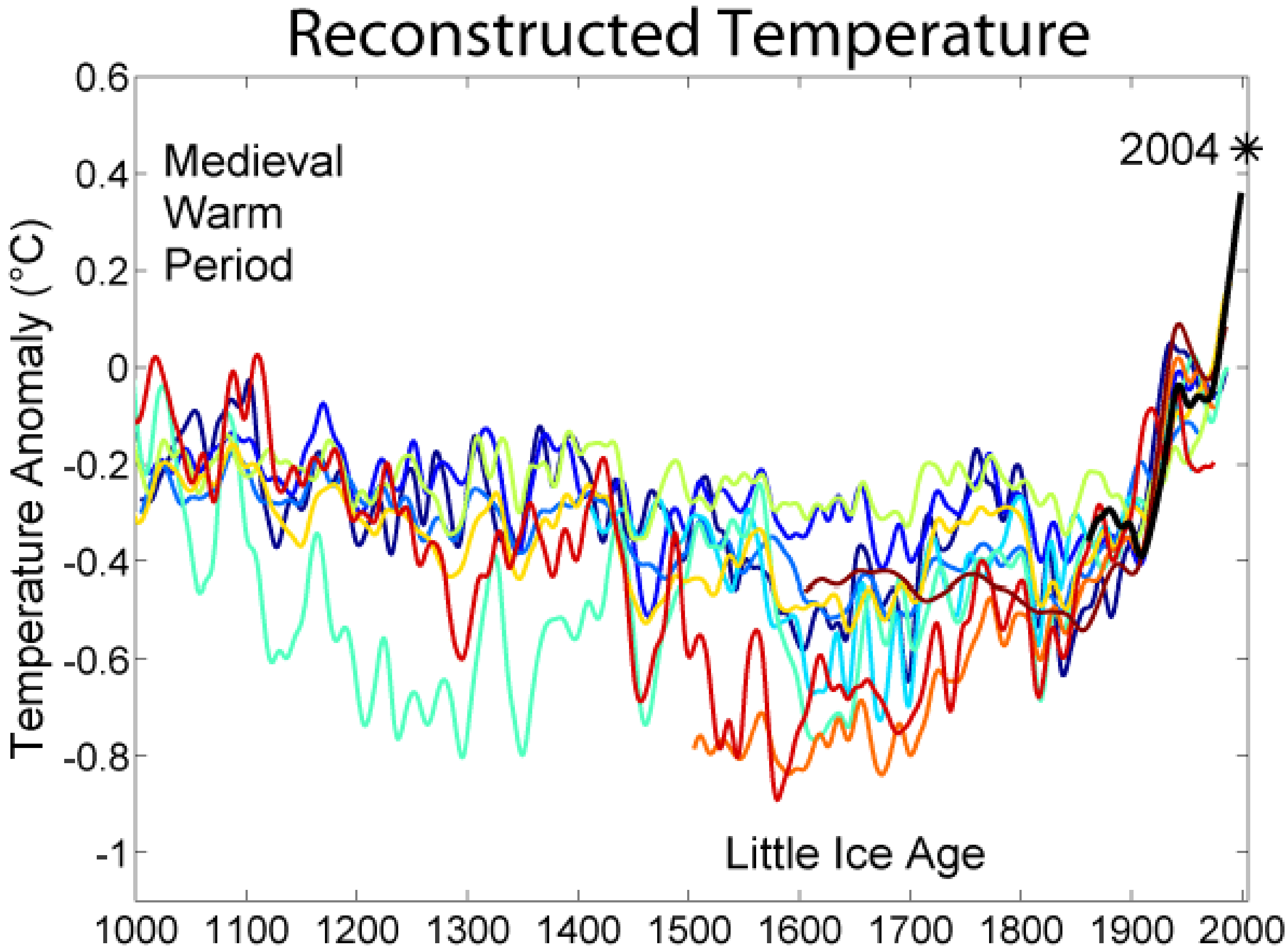

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Image from: Global Warming Art: http://www.globalwarmingart.com/wiki/Image:1000_Year_Temperature_Comparison_png

Questions?

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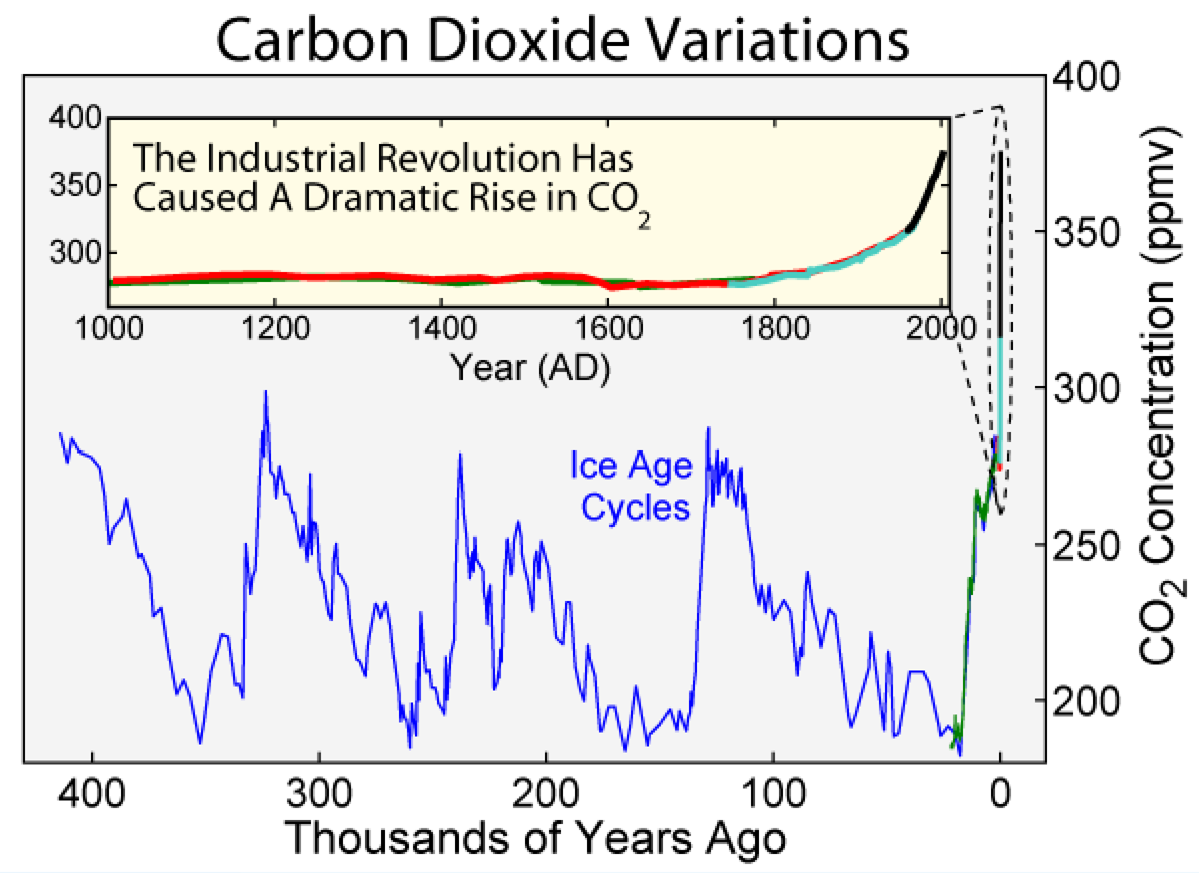
Global temperature record correlates with CO_2 Emissions



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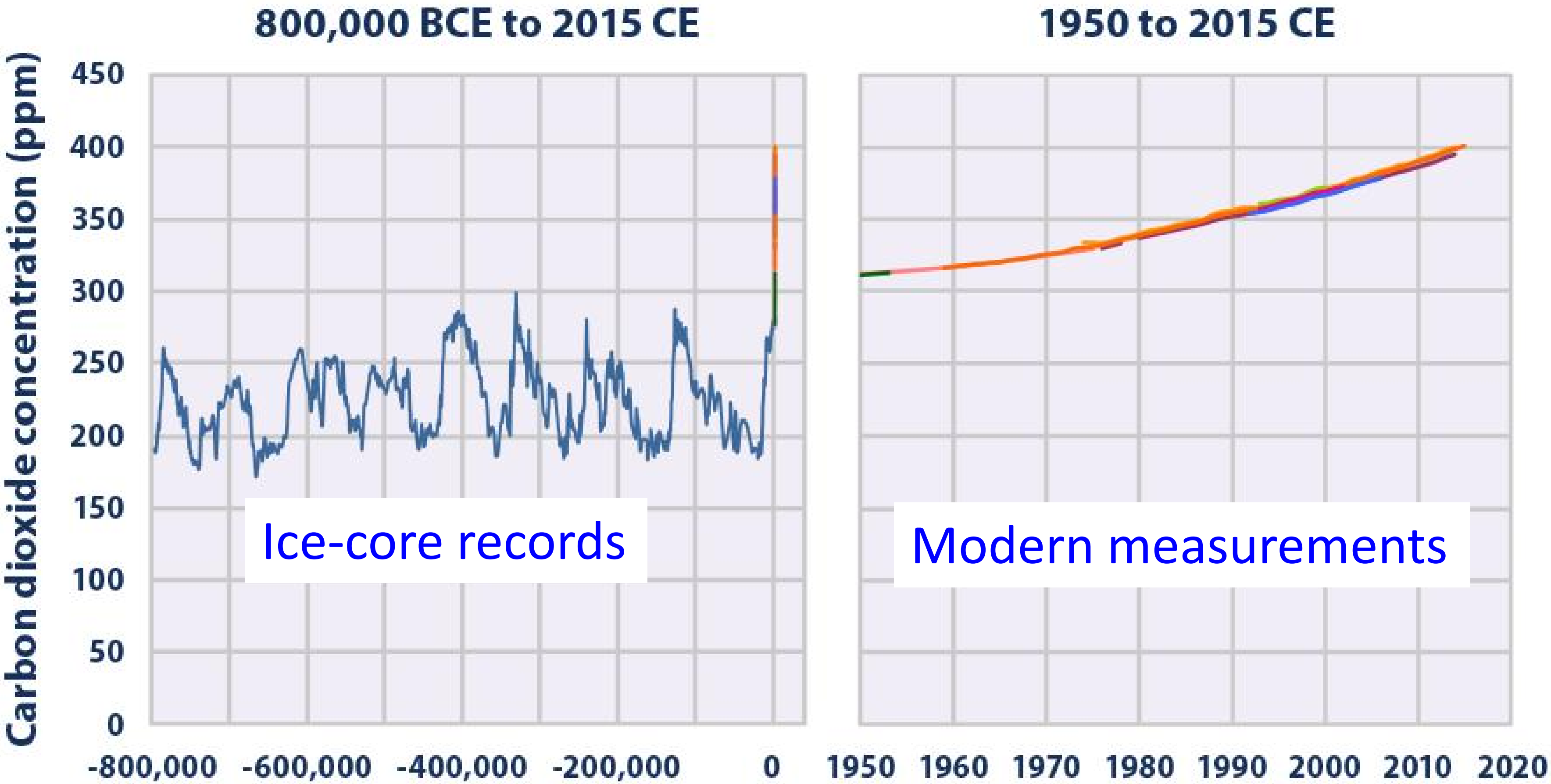
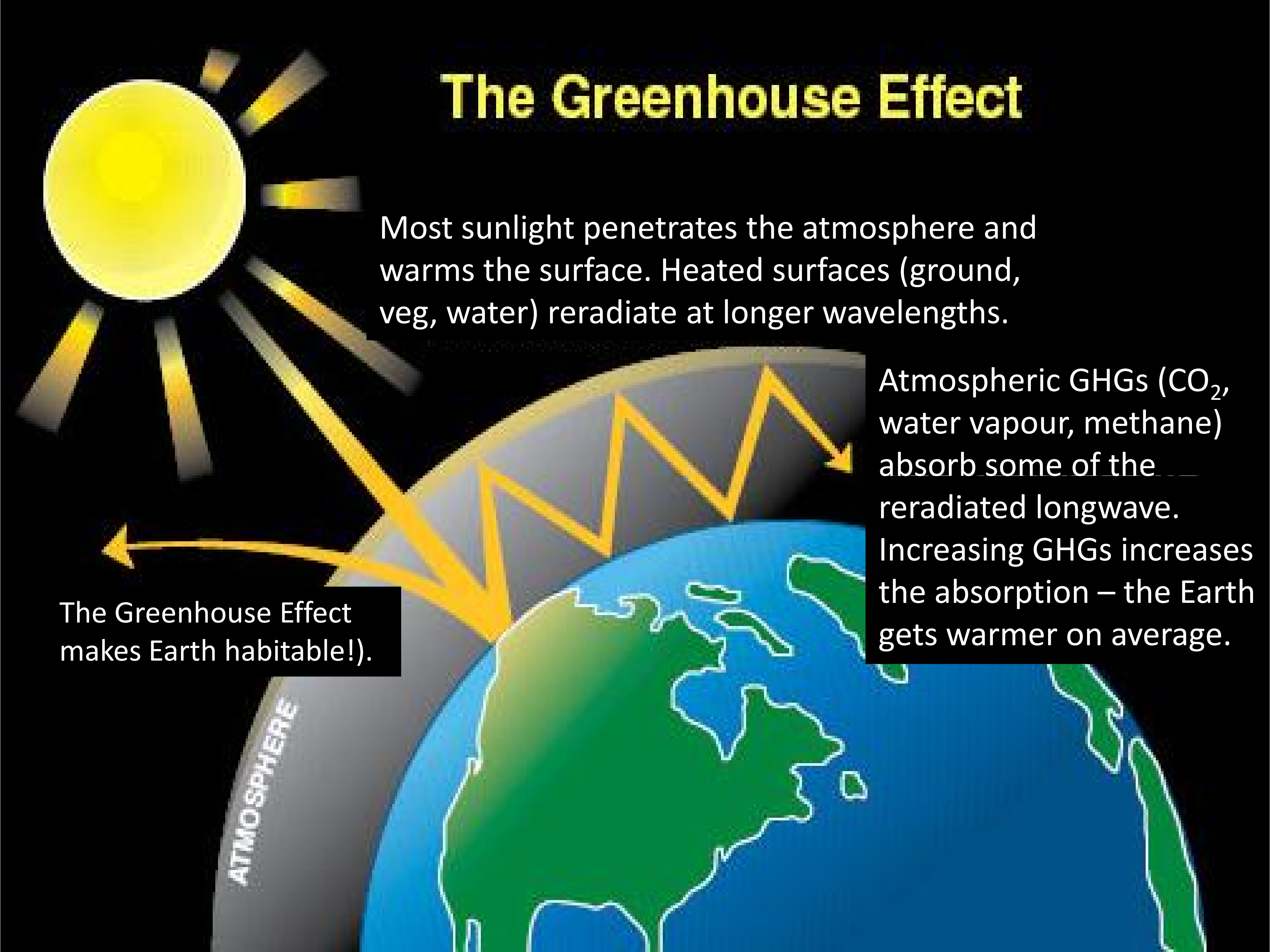
Global temperature record correlates with average CO_2 Concentration Increase

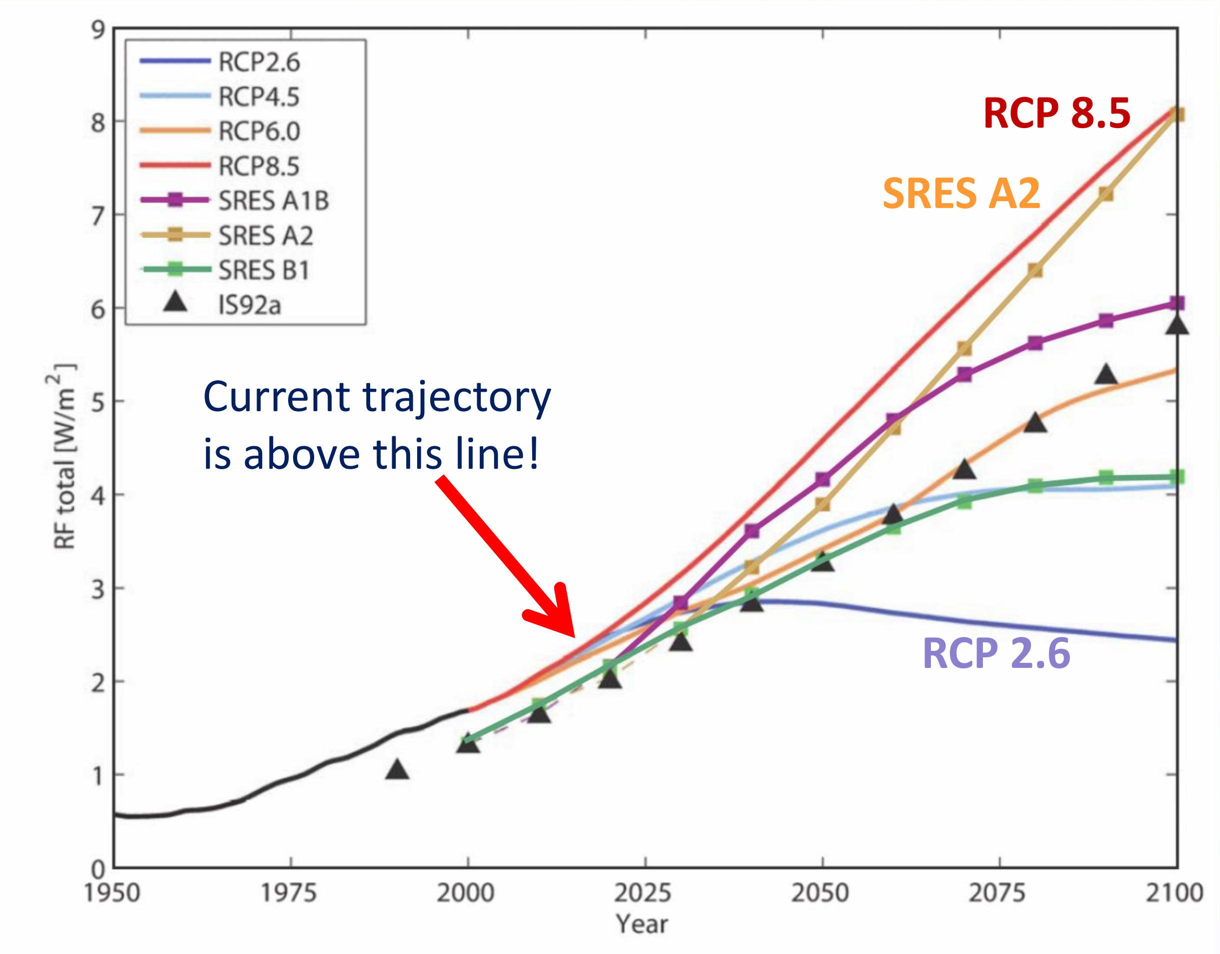


Data source: EPA (2016): Compilation of 10 underlying datasets.



The Greenhouse Effect
Most sunlight penetrates the atmosphere and warms the surface. Heated surfaces (ground, veg, water) reradiate at longer wavelengths.
Atmospheric GHGs (CO_2, water vapour, methane) absorb some of the reradiated longwave. Increasing GHGs increases the absorption – the Earth gets warmer on average.
The Greenhouse Effect makes Earth habitable!).
ATMOSPHERE

IPCC radiative forcing (RF) scenarios



For the IPCC's Fifth Assessment Report (AR5) a new set of "radiative forcing" scenarios were developed. These "RCP" scenarios supersede the "SRES" scenarios used in the Third and Fourth Assessments. This Figure 1.15 appears in the AR5 WG1 report to compare the SRES and RCP scenarios.

© http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_All.pdf

Questions?

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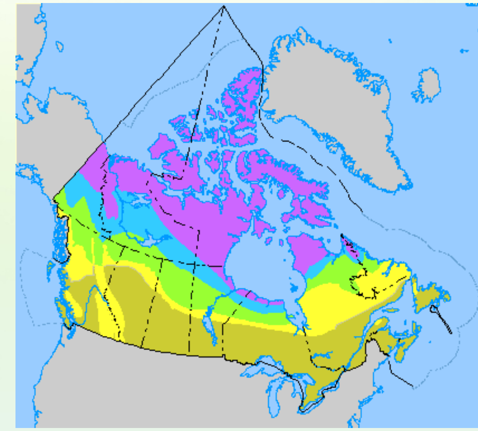
Some effects of climate warming
(already seen to be happening)

Thawing of permafrost
- mainly northern boreal forest & Arctic
- profound changes to ecosystems
- poses problems for existing infrastructure

Glacier melting
- implications for water supply to the prairies

Shorter winter period of frozen ground
- poses major challenges for winter access to forested land base & remote communities



Permafrost zones

- Continuous (>90%)
- Extensive (50-90%)
- Sporadic (10-50%)
- Isolated (<10%)
- None

From National Atlas of Canada http://atlas.gc.ca/site/english/maps/environment/land/permafrost

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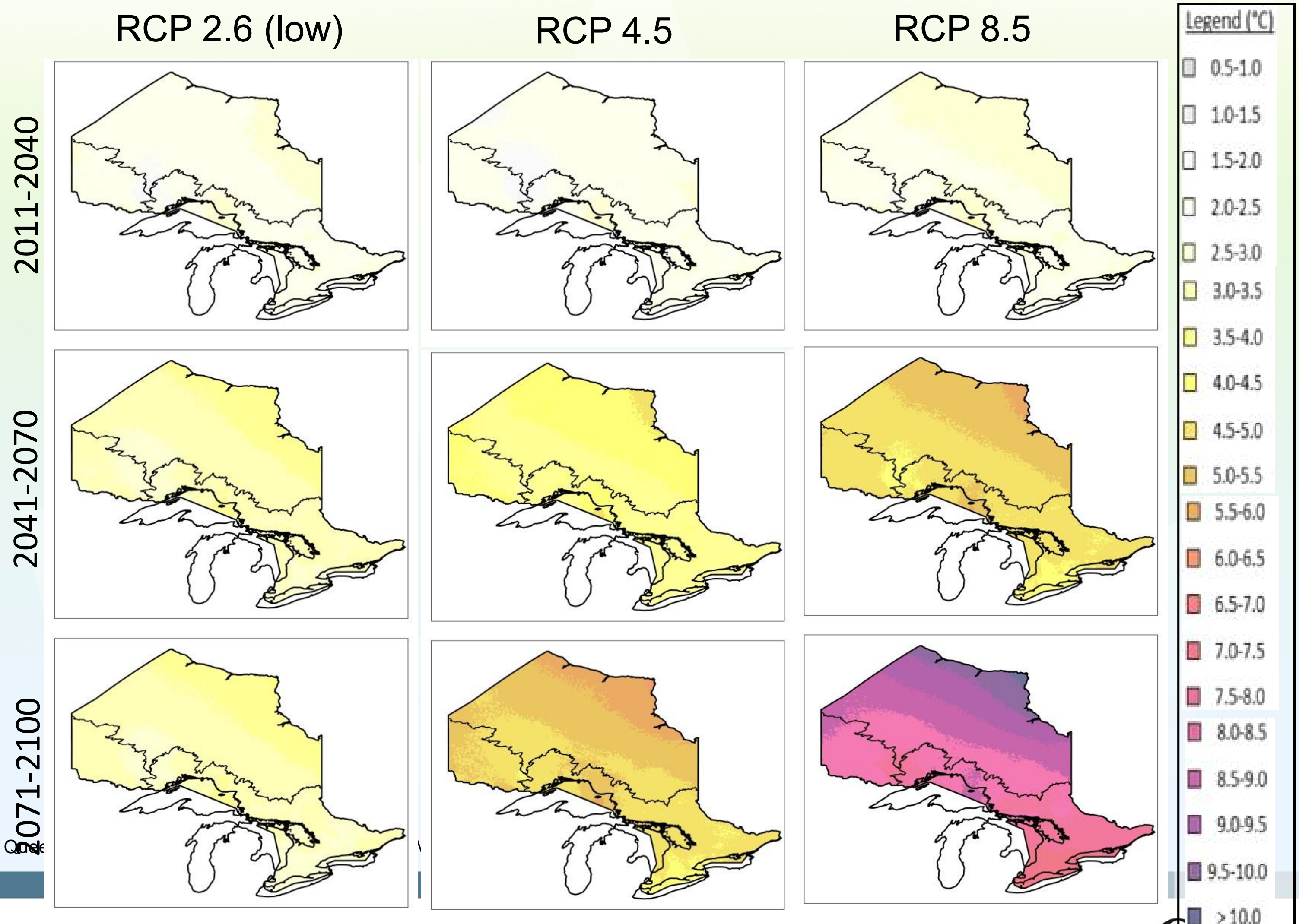
Slide from: Ted Hogg, CFS-NoFC

Climate Change in Ontario

(Projected Change in Mean Annual Temperature; Composite GCM)



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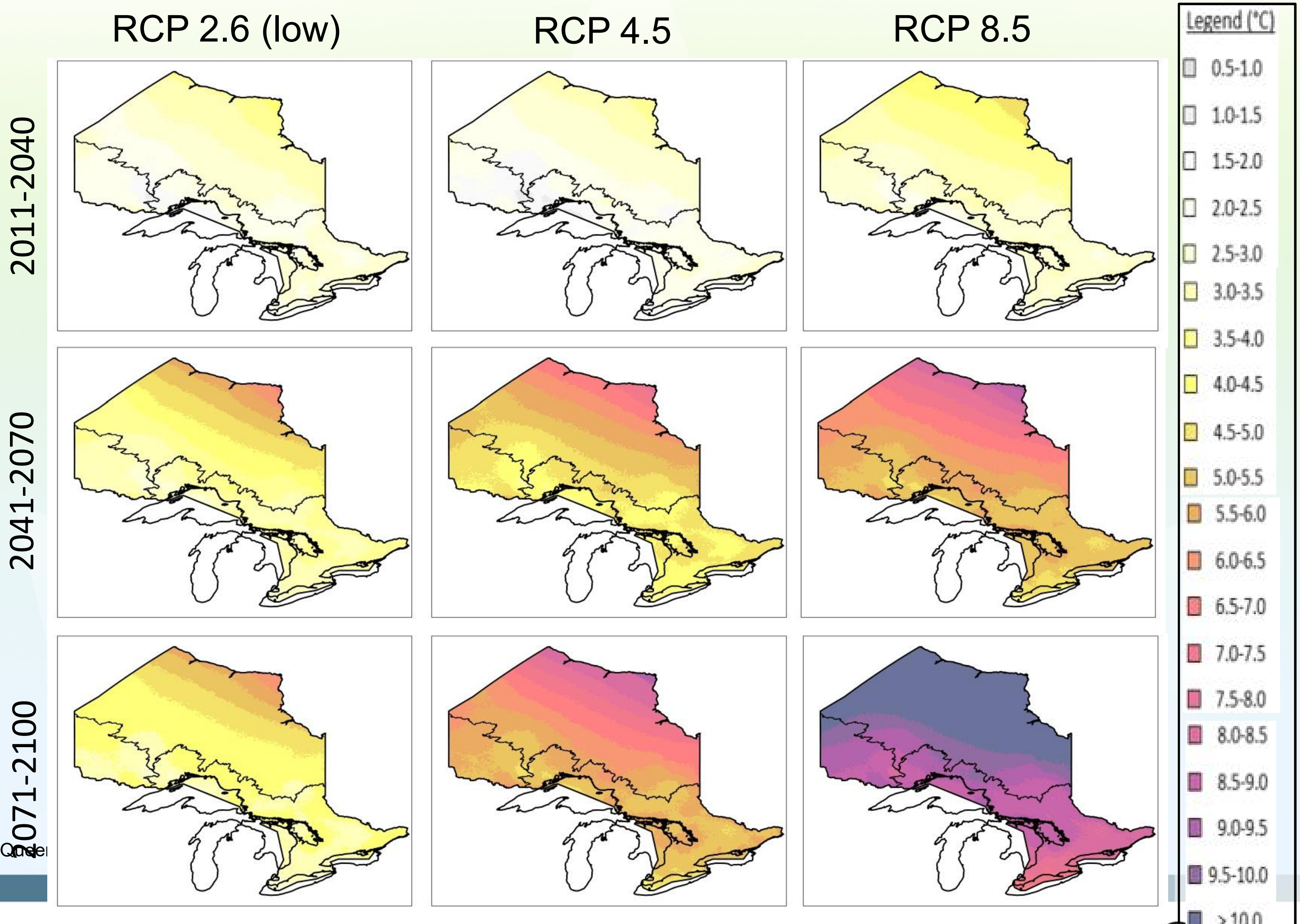
Climate Change in Ontario

(Projected Change in Winter Temperature; Composite GCM)



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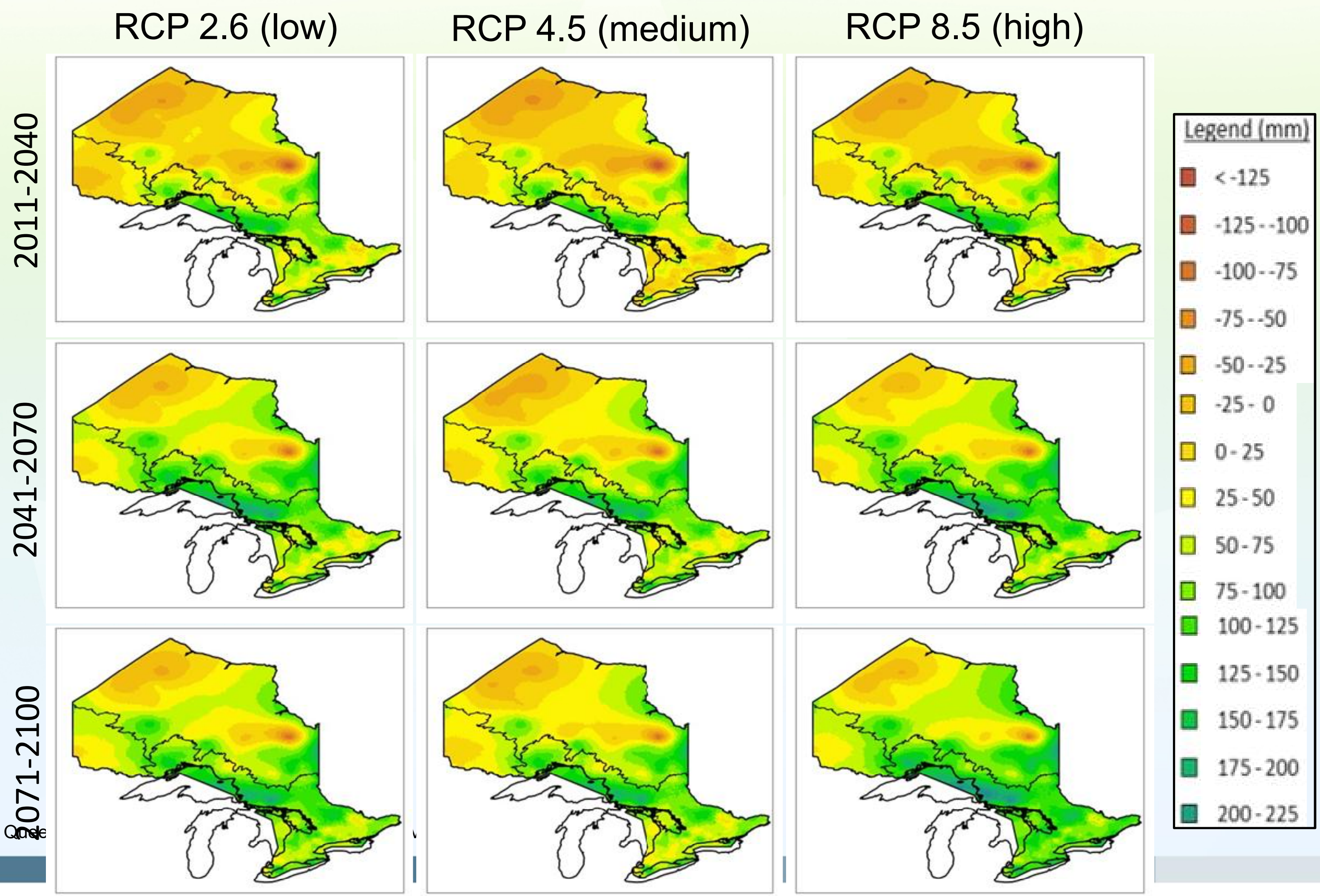
Climate Change in Ontario

(Projected Change in Annual Precipitation; Composite GCM)



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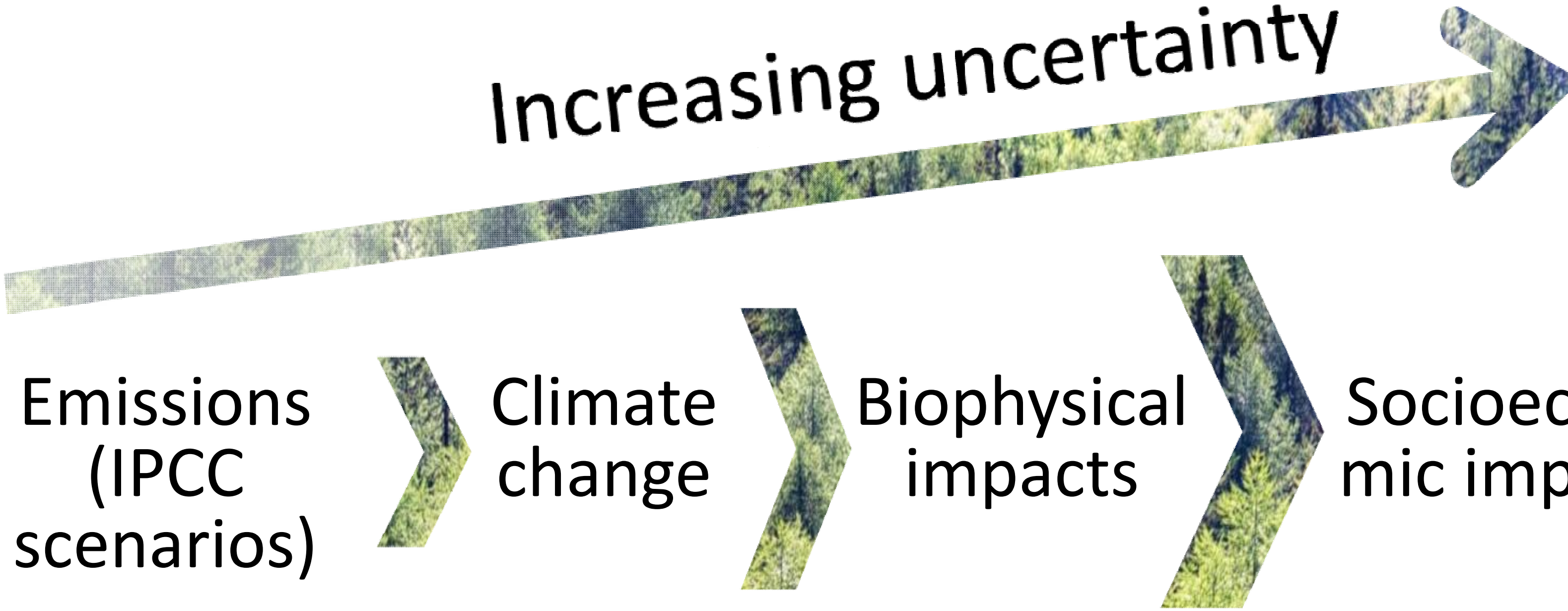
Why Is Future Climate Uncertain?



The climate models make projections, not predictions

Questions?

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Topic Guide

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- How do we know humans are involved?
- Are humans causing climate change?
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Forest dieback in Alberta and Saskatchewan

Major cause: Prolonged drought (1998 and 2001-2003)

- Severe aspen mortality in the parkland (resembling fire in some areas!)
- Other species also affected (white spruce, jack pine, urban trees)

Drought-damaged aspen foliage

Drought-induced mortality of white spruce, Battle River valley near Alliance, Alberta (Photo by Ted Hogg, July 2004)

Severe aspen mortality following drought near North Battleford, Saskatchewan (Photo by M. Michaelian, August 2004)

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Fire and climate effects on conifers

- Expected increases in fire occurrence (annual area burned)
- Will conifers be able to regenerate naturally under a drier future climate?

Conversion of jack pine forest to grassland following fire near Prince Albert, SK (Hyde & Smith 1996, SERM report)

Conversion of mature white spruce forest to prairie-like vegetation 45 years after the Takhini burn near Whitehorse, YT

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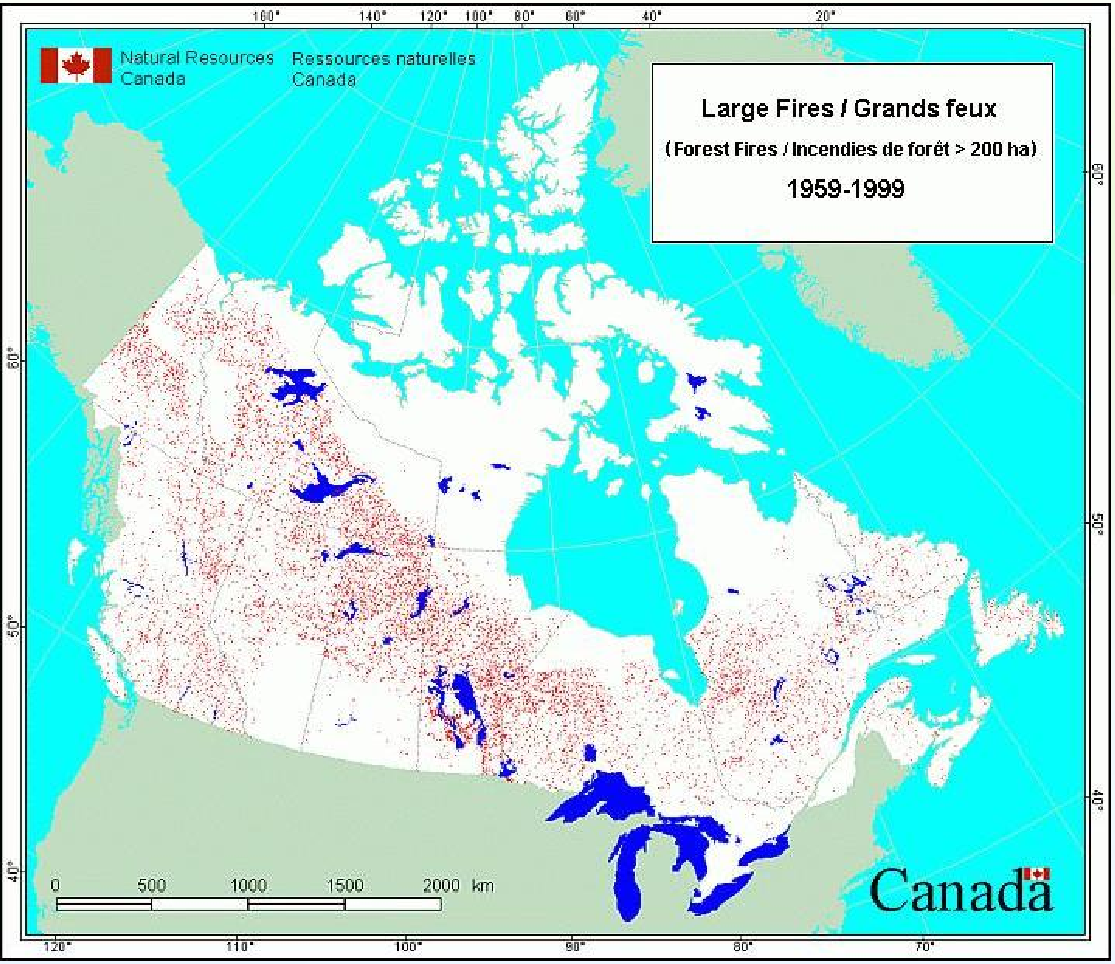
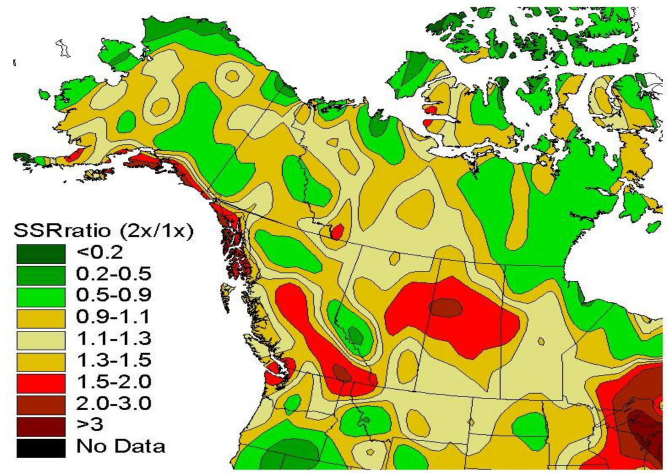
Slide from: Ted Hogg, CFS-NoFC

Future climate effects on fire occurrence



From Amiro et al., 2001
Canadian Forest Service

Predicted changes in fire under doubling of CO_2



From Flannigan et al.,
Canadian Forest Service

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Potential impacts of a drier climate

A not-so-gradual transformation of the forest?

	Boreal forest	**? →** **Parkland & Prairie**
Climate:	Moist	Dry
Runoff:	Significant	Minimal in most years
Lake levels:	Stable	Variable
Wetlands:	Bogs and fens	Marshes and sloughs
Conifers:	Several species	Rare or absent
Aspen:	Productive stands	Stunted patches

Water is critical to all aspects of ecosystem functioning!

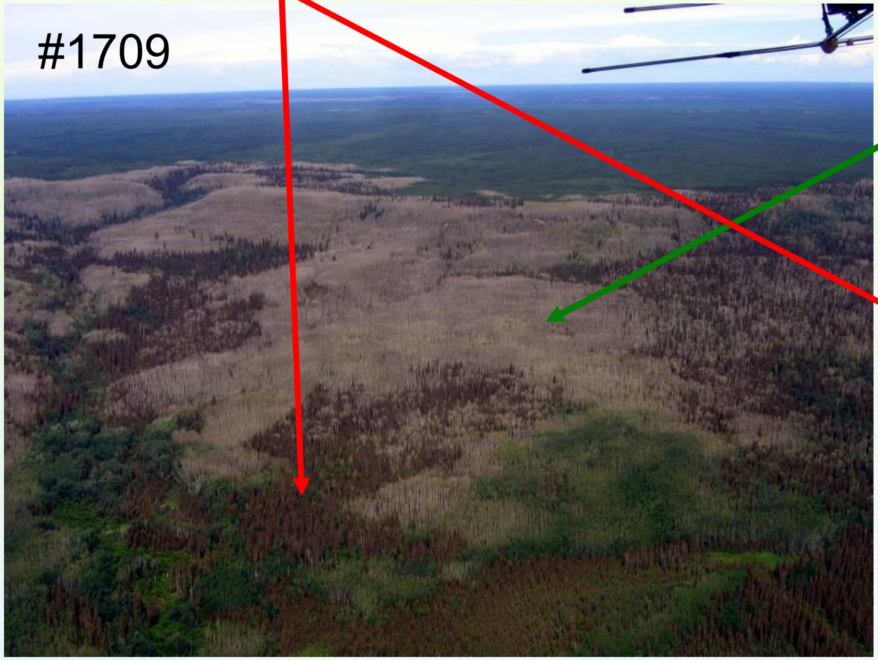
From Hogg and Hurdle (1995) Water, Air and Soil Pollution 82: 391-400.

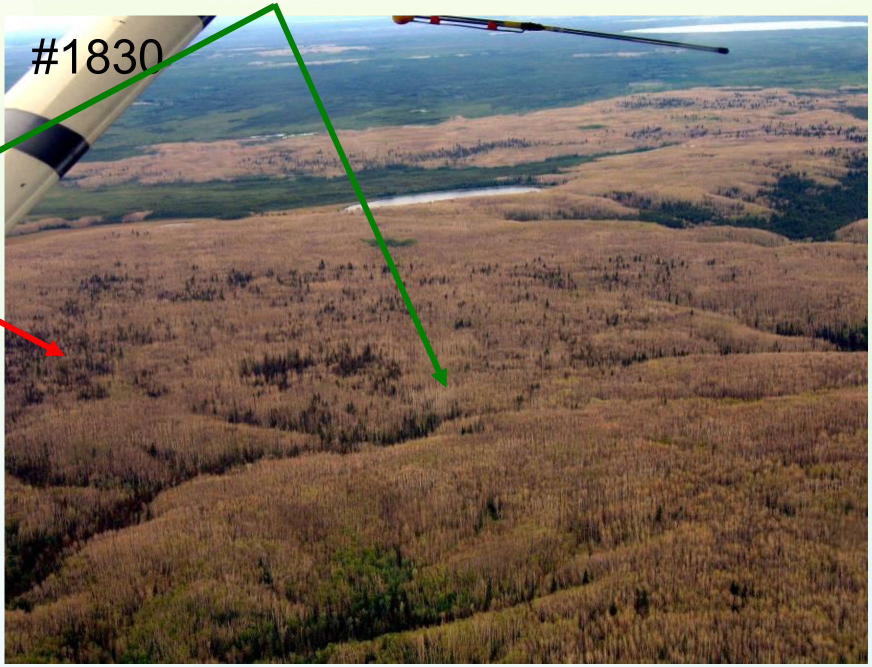
Slide from: Ted Hogg, CFS-NoFC

East of Fort McMurray, AB. 26 June 2008

Spruce Budworm (SBW)

Forest Tent Caterpillar (FTC)





From overview flight for remote sensing research by Ron Hall et al., CFS & CCRS (photos by Eric Arsenault & Mike Michaelian, CFS Northern Forestry Centre)

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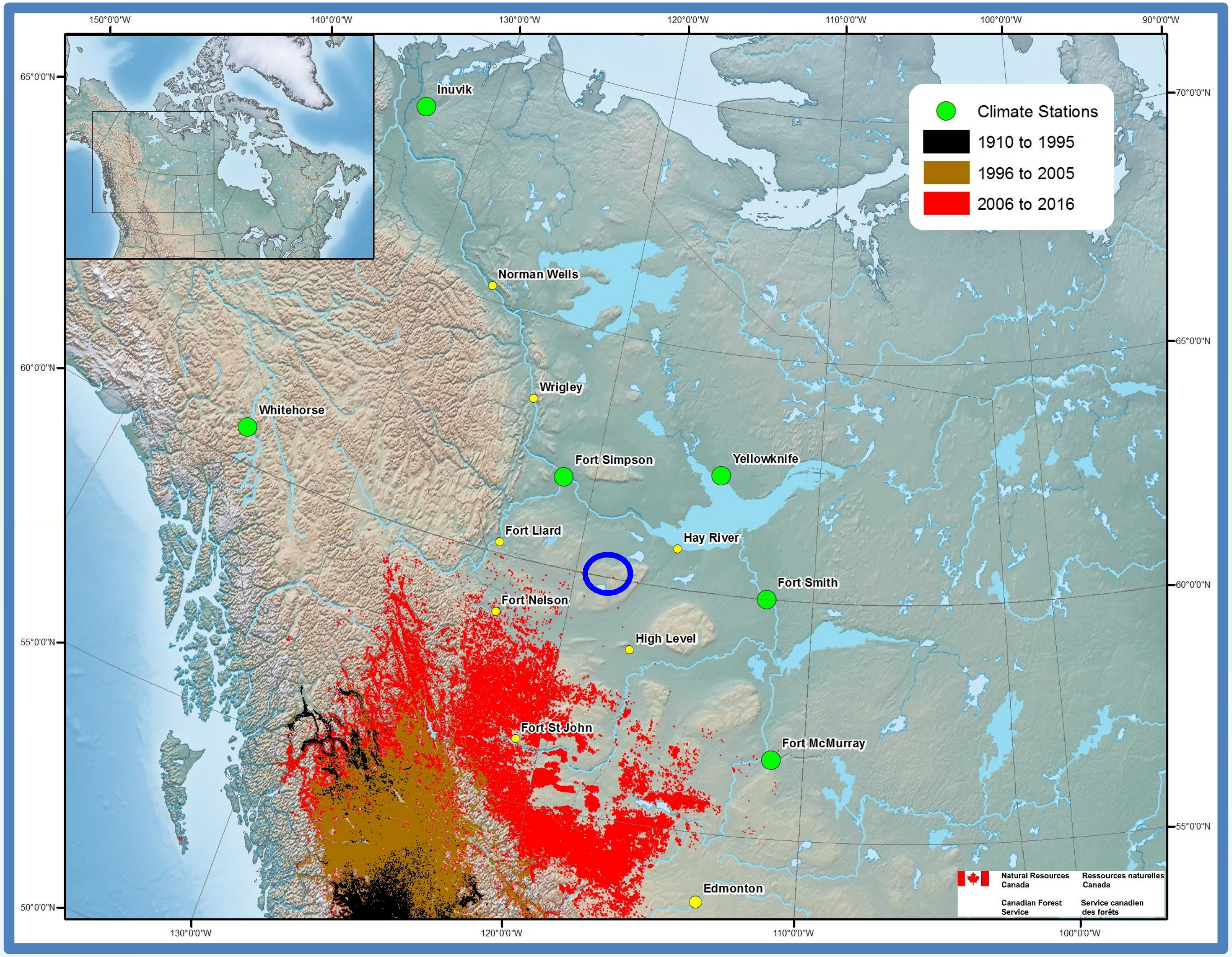
Mountain Pine Beetle!

Spread of Mountain Pine Beetle 1910-2016



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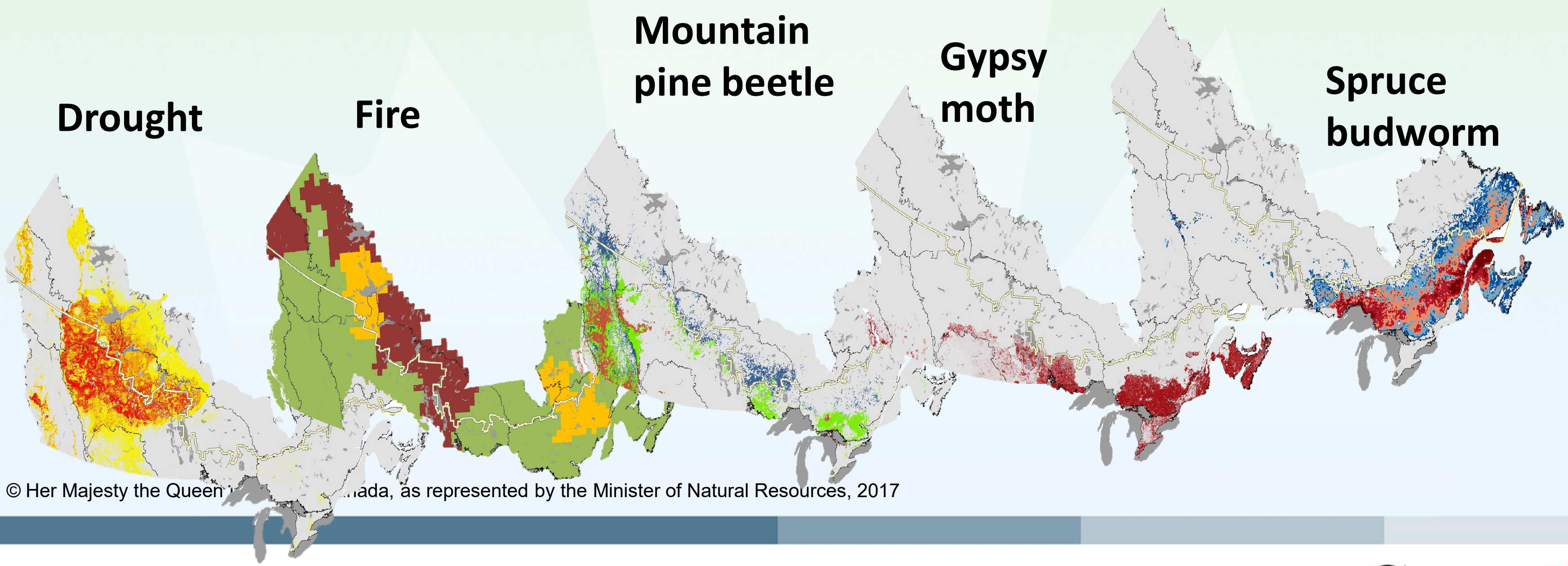
The cumulative effects of disturbances and other changes to the forest will be complex

- Pests, such as mountain pine beetle, and drought may leave trees more susceptible to fire, and could lead to a doubling of the annual area burned by the end of this century.
- Projected changes to forest productivity and tree species composition will

Short-term impact projections (2011-2040)



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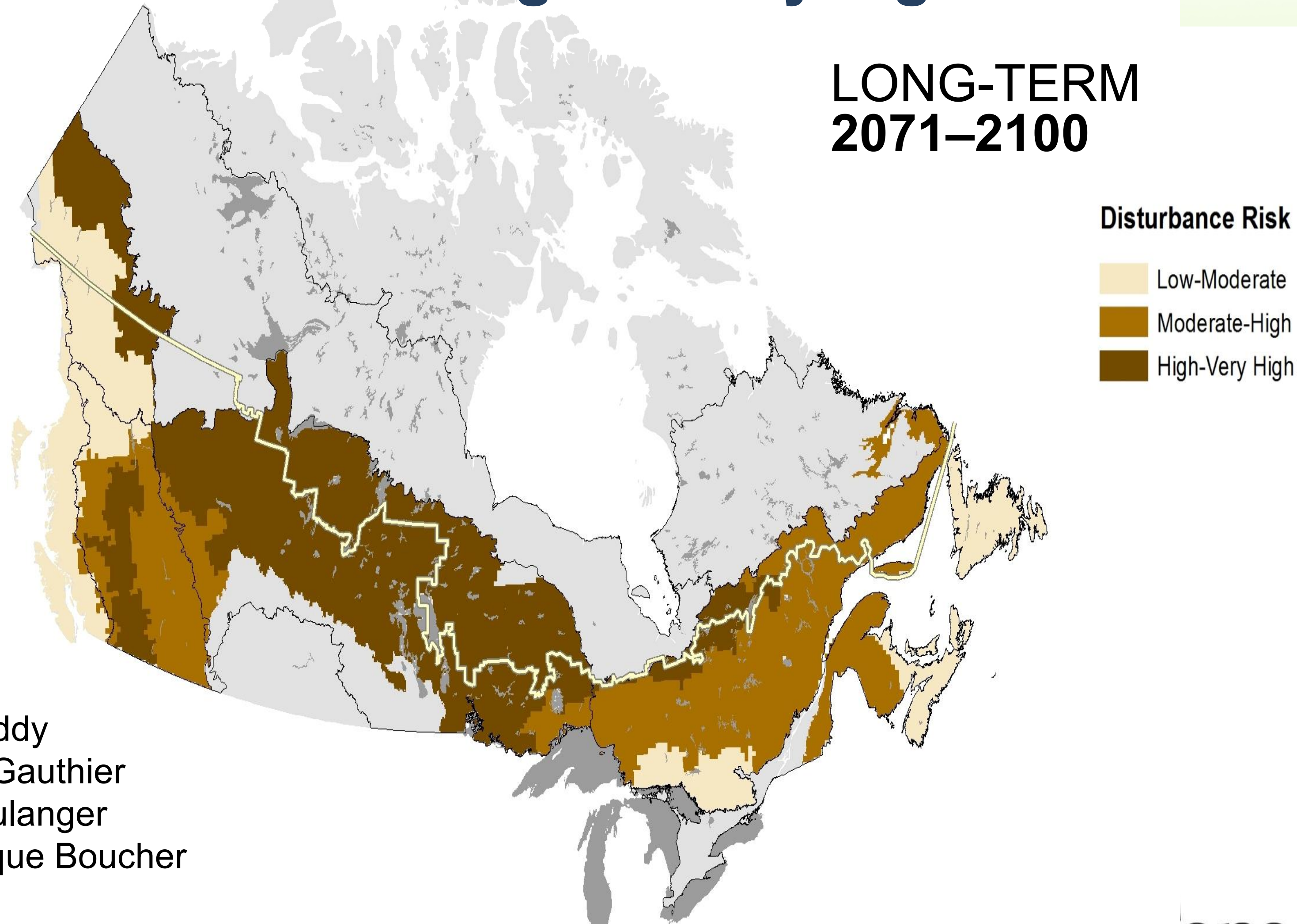
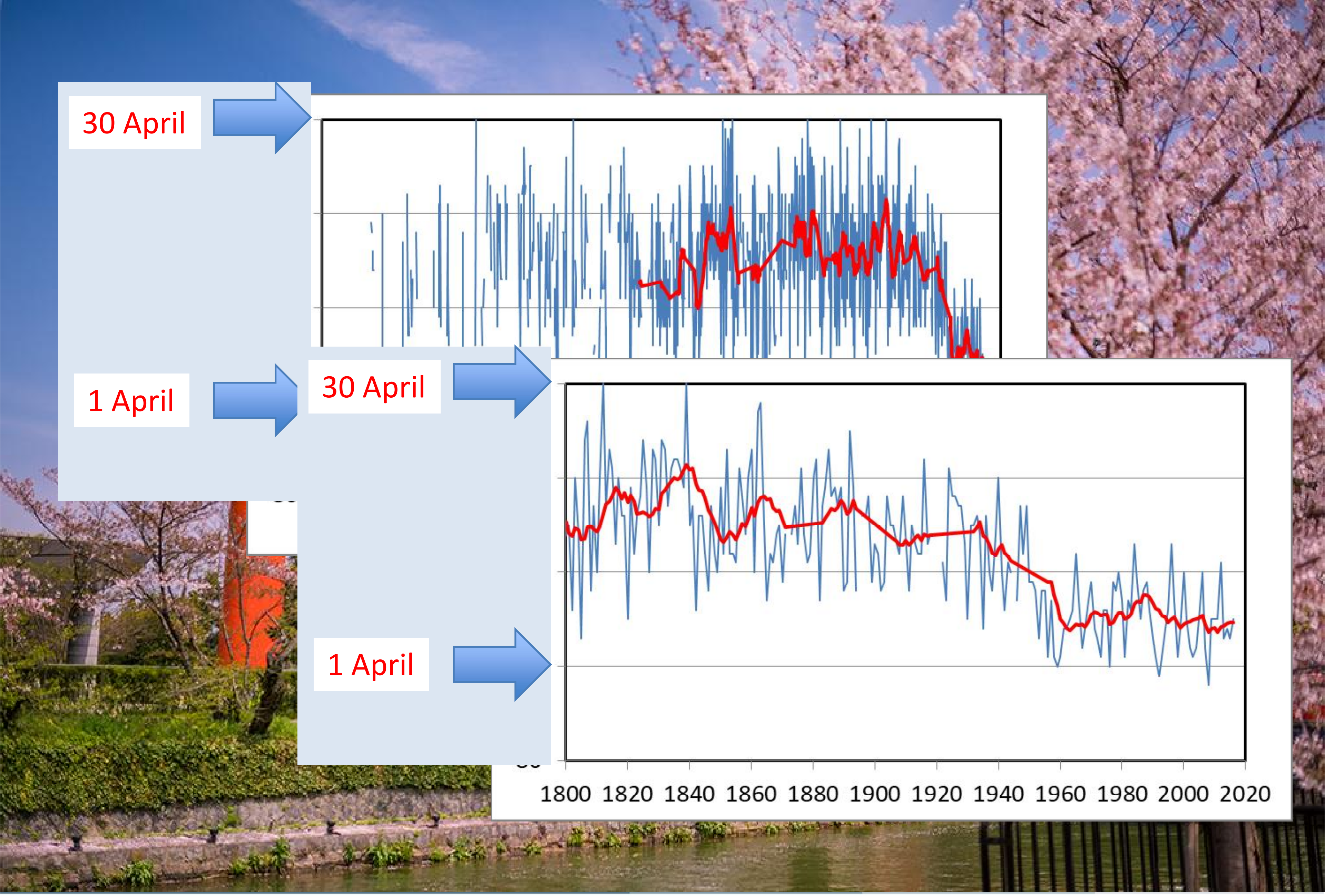
Cumulative disturbances of fire, pests, and drought are projected to place vast areas of Canada’s forests at high to very high risk



By:
Brian Eddy
Sylvie Gauthier
Yan Boulanger
Dominique Boucher


30 April
1 April
30 April
1 April
1800 1820 1840 1860 1880 1900 1920 1940 1960 1980 2000 2020

Panel 3-4 - Mountin Pine Beetle (MPB)

Author(s): Gauthier, S.; Boulanger, Y.; Cooke, B.J., Price, D.T.

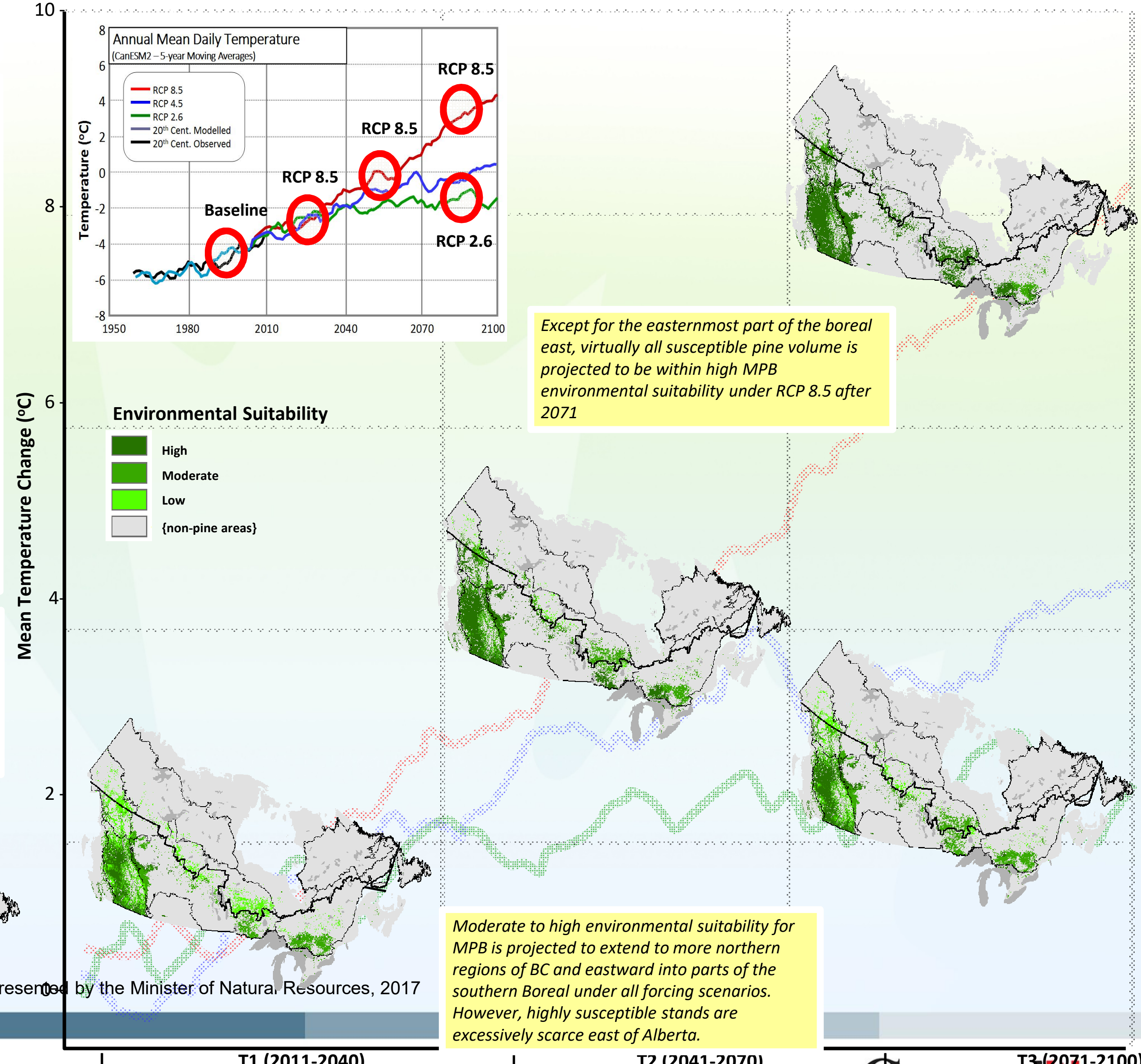
Model Description:

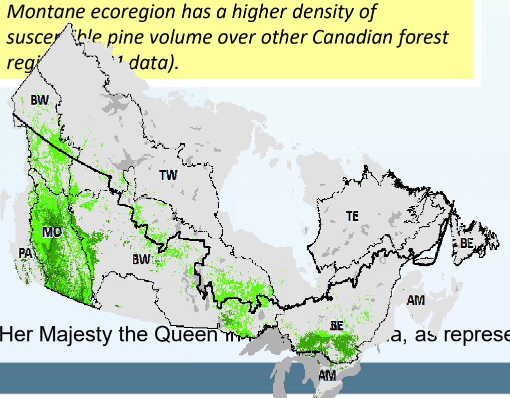
Current and future environmental suitability for mountain pine beetle was assessed by overlaying the Safranyik et al. (Carroll et al. 2004) climate suitability model outputs with susceptible pine stands. The Safranyik et al. model use heat accumulation during the growing season (univoltinism), minimum temperature during winter (winter survival), maximum August temperature (adult flight activity) and various moisture-related variables (tree vigour) to estimate climate suitability for MPB. Susceptible pine stands were defined using the Beaudoin et al. forest cover maps as pixels where current (2001) pine species volume was higher than 40 m3.ha-1 and comprised more than 50% of the total pixel's volume.

References:

- Carroll, A.L., Taylor, S.W., Re´gnière, J., and Safranyik, L. 2004. Effects of climate and climate change on the mountain pine beetle. In Challenges and Solutions: Proceedings of the Mountain Pine Beetle Symposium, Kelowna, British Columbia, 30 and 31 October 2003. Edited by T.L. Shore, J.E. Brooks, and J.E. Stone. Information Report BC-X-399, Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, British Columbia.pp. 221–230.
- Beaudoin A, Bernier PY, Guindon L, Villemaire P, Guo XJ, Stinson G, Bergeron T, Magnussen S, Hall RJ (2014) Mapping attributes of Canada's forests at moderate resolution through kNN and MODIS imagery. Can J For Res 44:521–532.

Historically, MPB outbreaks have been confined to southwest and interior BC; however outbreaks have spread to northern BC and into Alberta in the last decade.
Montane ecoregion has a higher density of suscer ble pine volume over other Canadian forest regi 1 data).





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T0 - Baseline (1981-2010)

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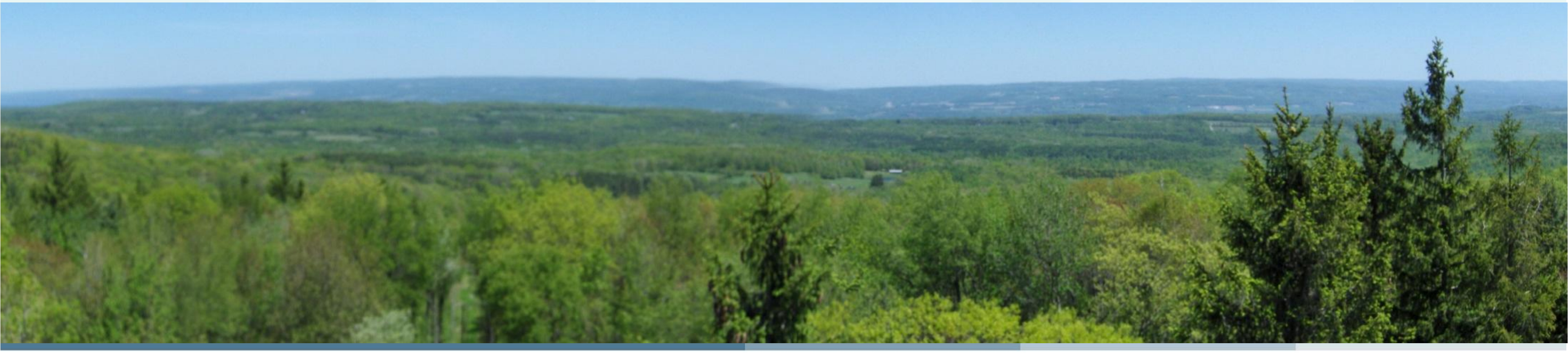
Canada

Summary
- Climate and Climate Change in Ontario -

- Ontario has been getting warmer and wetter over the past century
- These trends are expected to continue in the future
- Warmness expected to outpace wetness = drier in the future
- These changes will have big implications for forests, including susceptibility to MPB



Questions?

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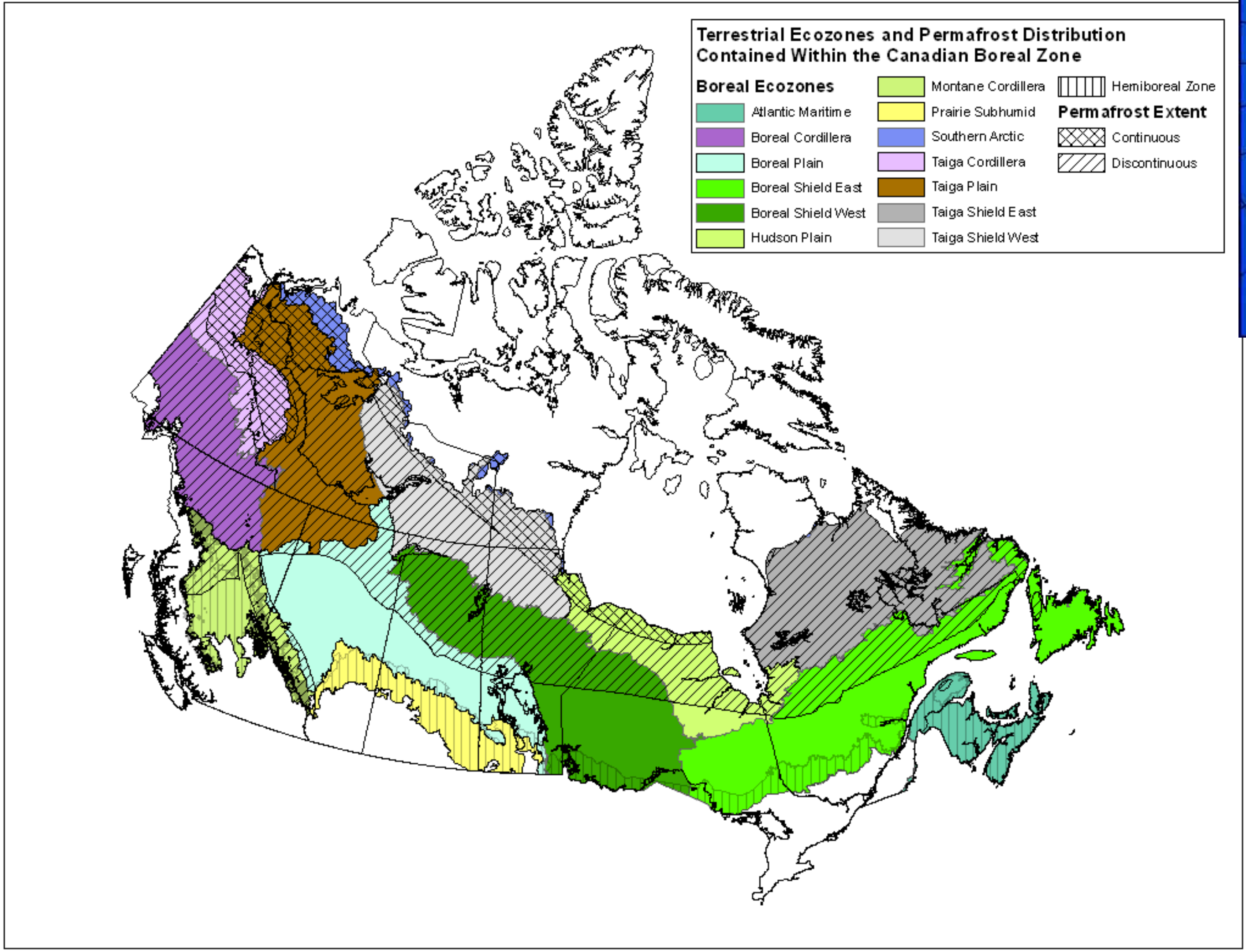
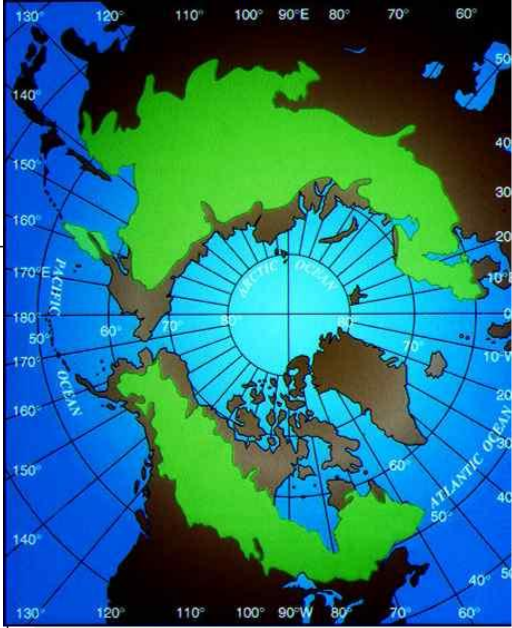
The Canadian Boreal Forest





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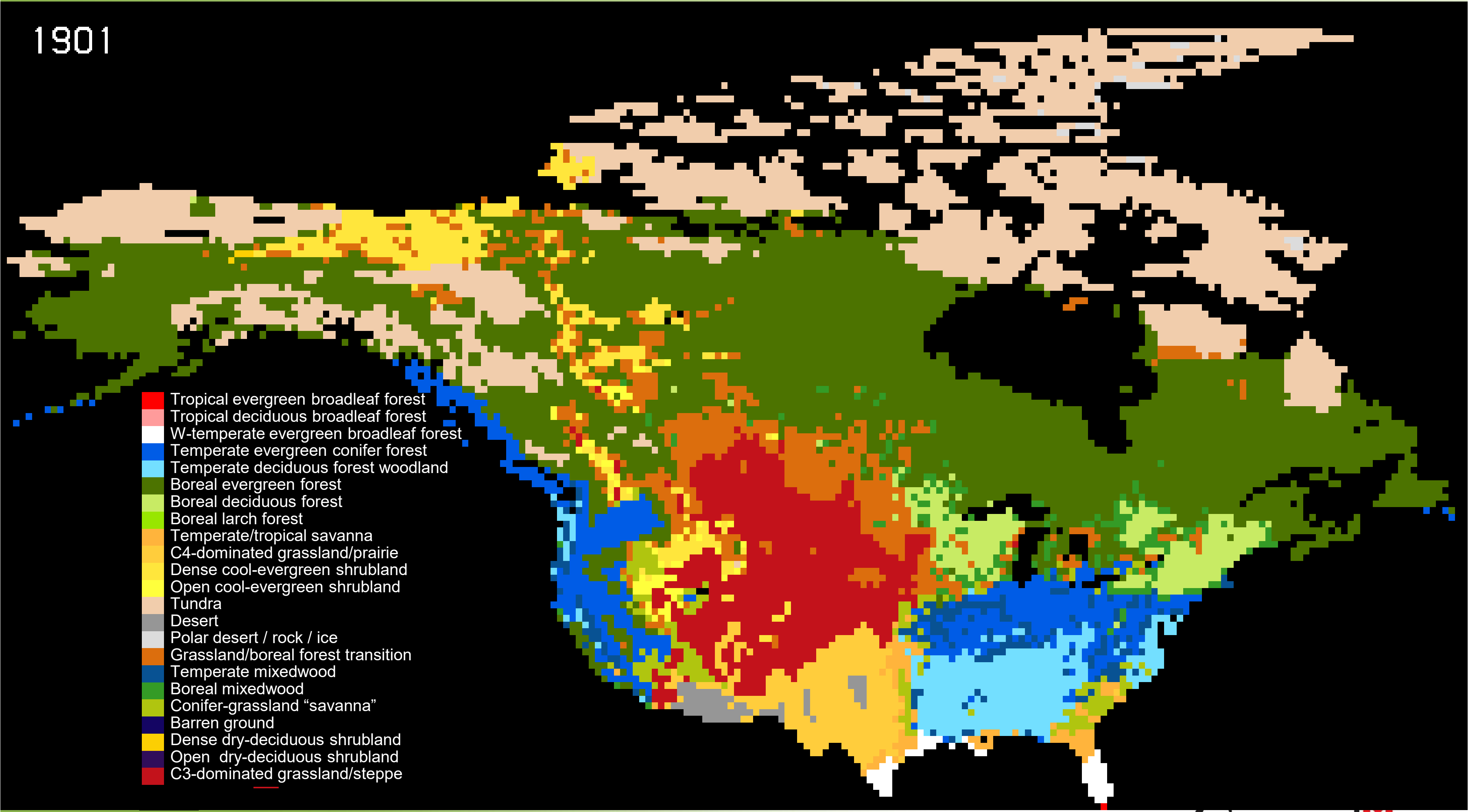
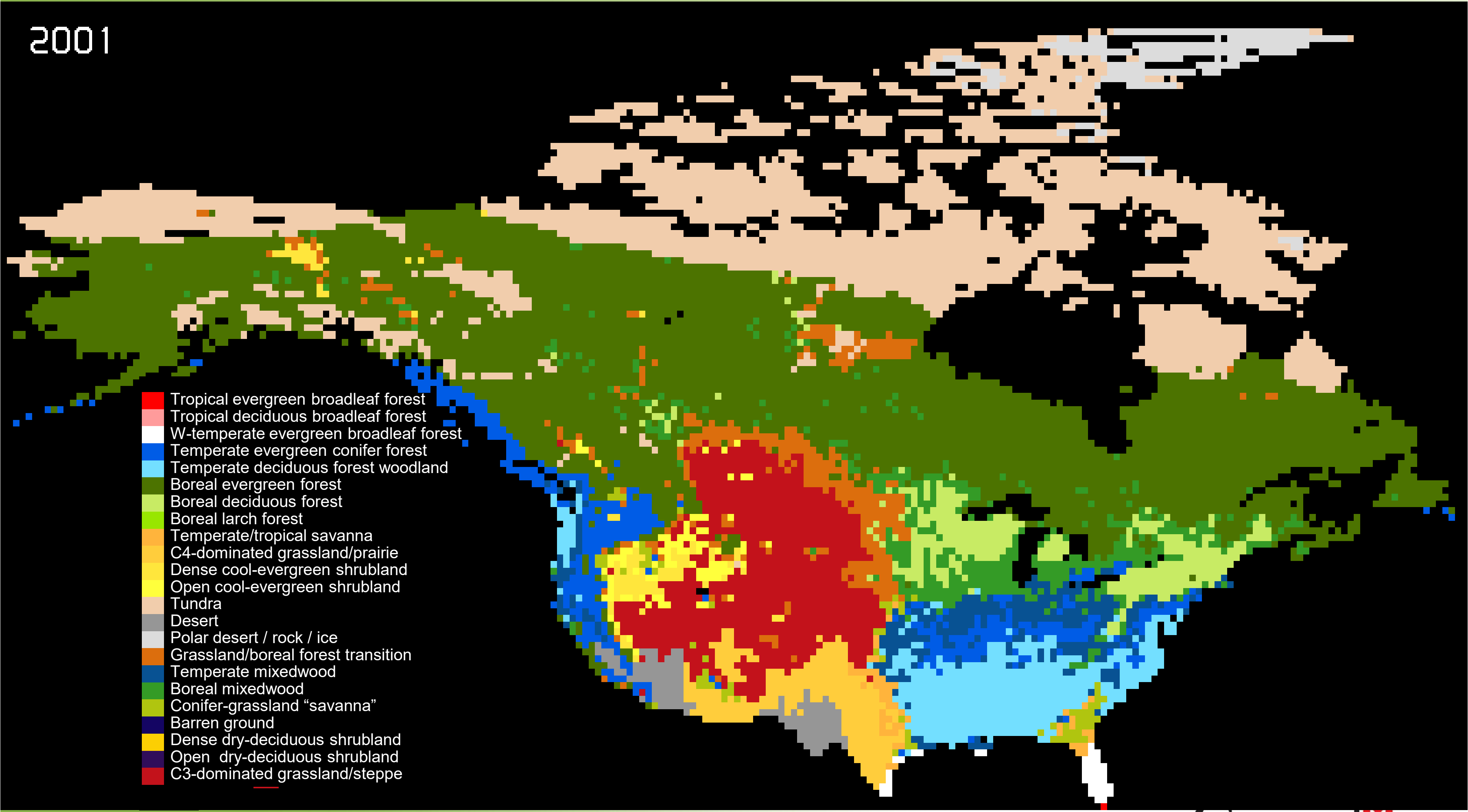
Canada

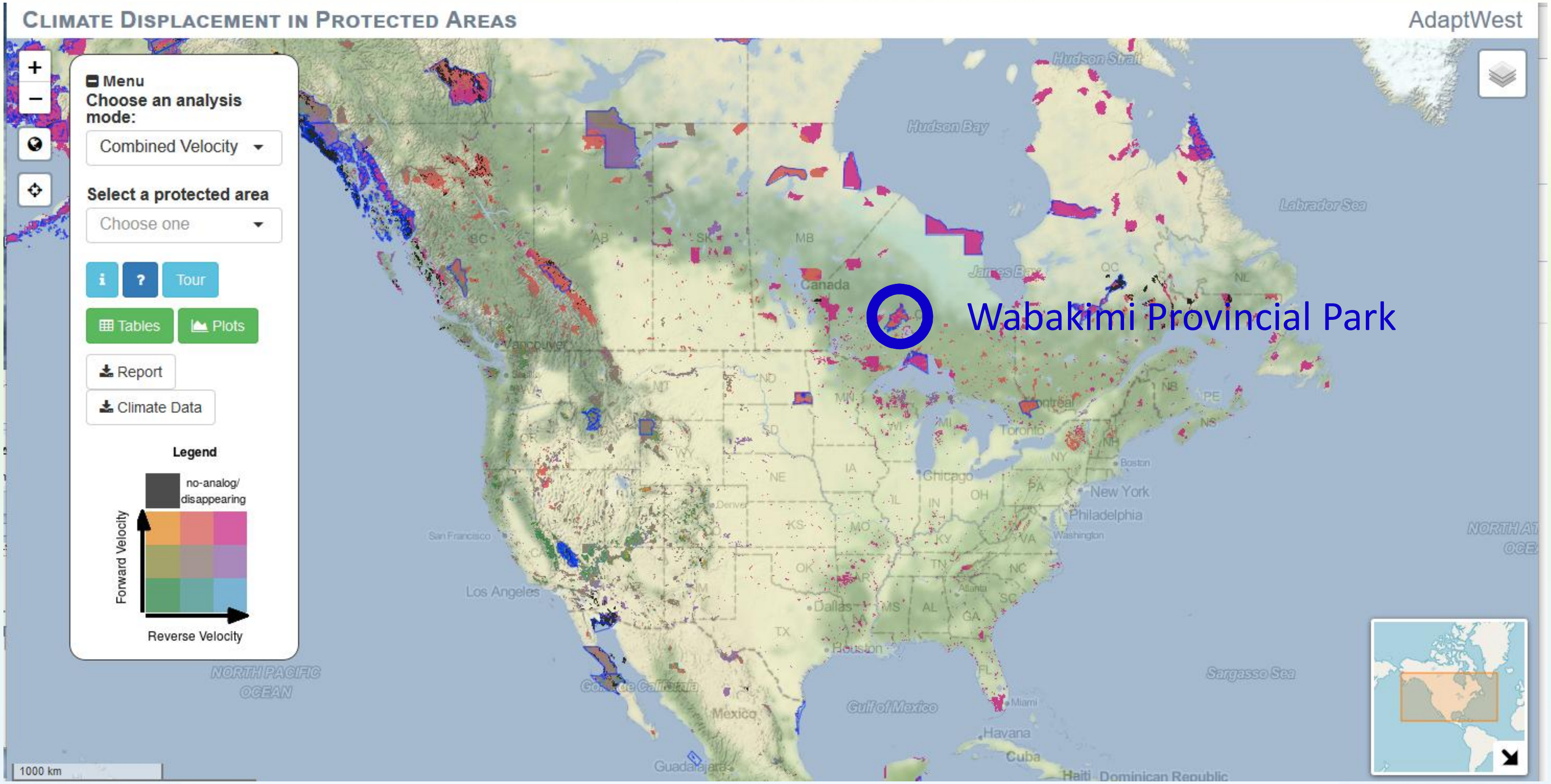
Can-IBIS Run #309: Dominant vegetation types



Can-IBIS Run #309: Dominant vegetation types (CGCM2-A2)



North American Protected Areas



Batilori et al. 2017, *Global Change Biology*; Parisien et al. 2018 (W.I.P.)

https://adaptwest.databasin.org/pages/climate-displacement-protected-areas

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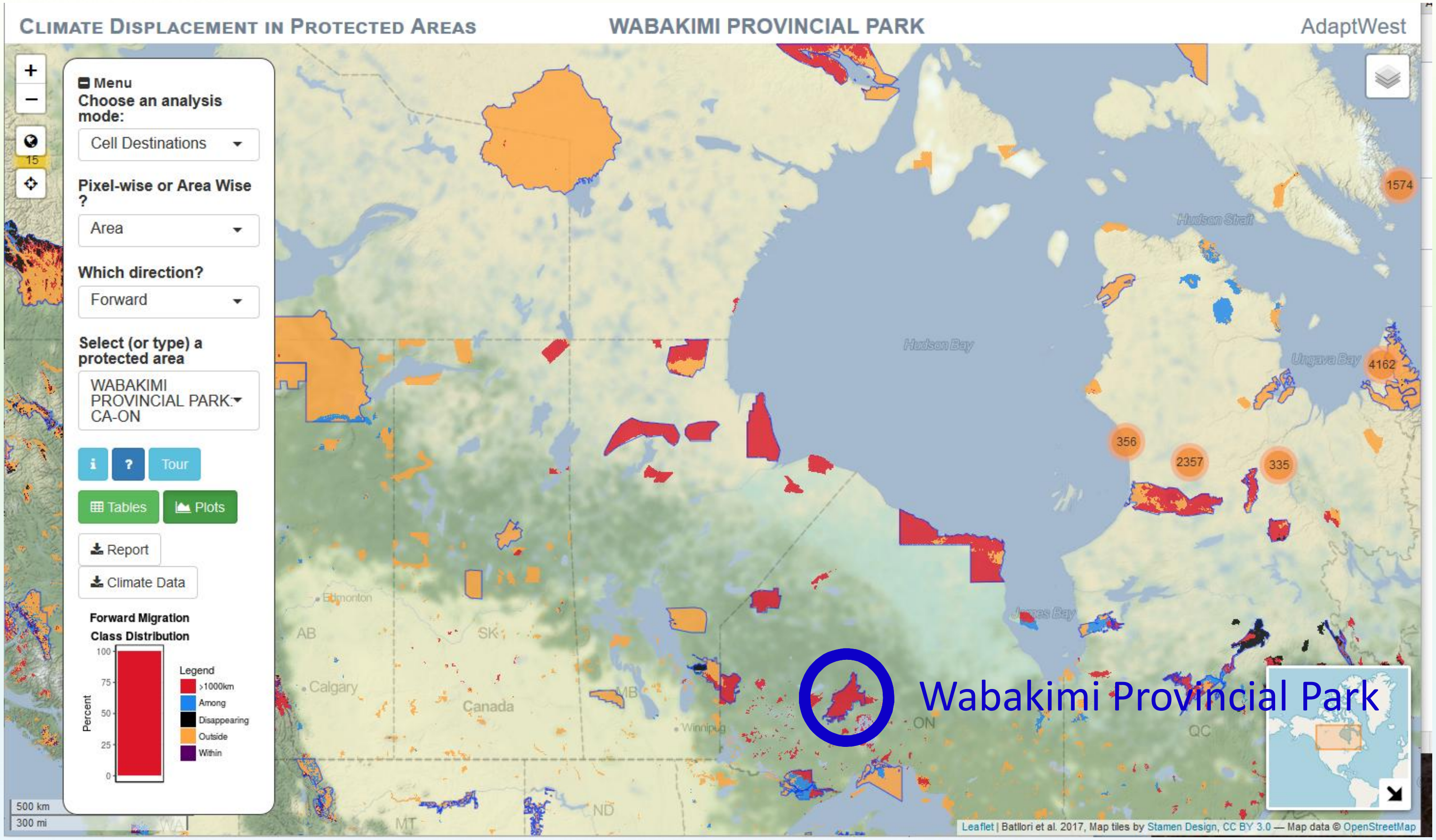

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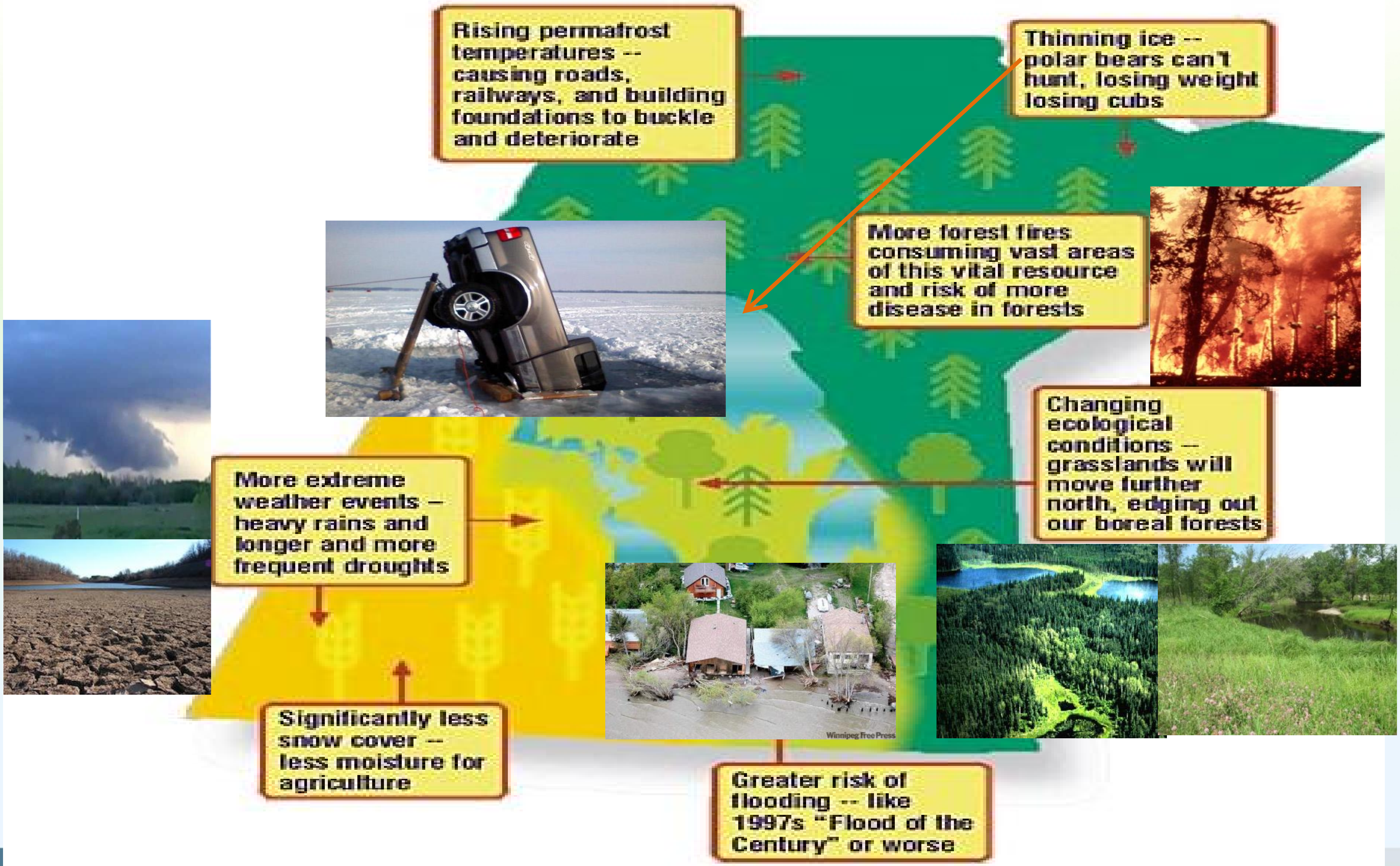
How Will Climate Change Affect Manitoba?



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Two ways to deal with Climate Change…

Green House Gas Emissions → **Changing Climate** → Ecosystem Changes and Impacts

MITIGATION

Avoid the unmanageable

Globally responsible

ADAPTATION

Managing the unavoidable

Locally responsible

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Two ways to deal with Climate Change…

Mitigation

Human actions to stabilize levels of greenhouse gases (GHG) in the atmosphere (e.g., carbon dioxide) to slow down the rate of global climate change

Adaptation

Human actions to minimize negative impacts of global climate change (and take advantage of potential benefits)

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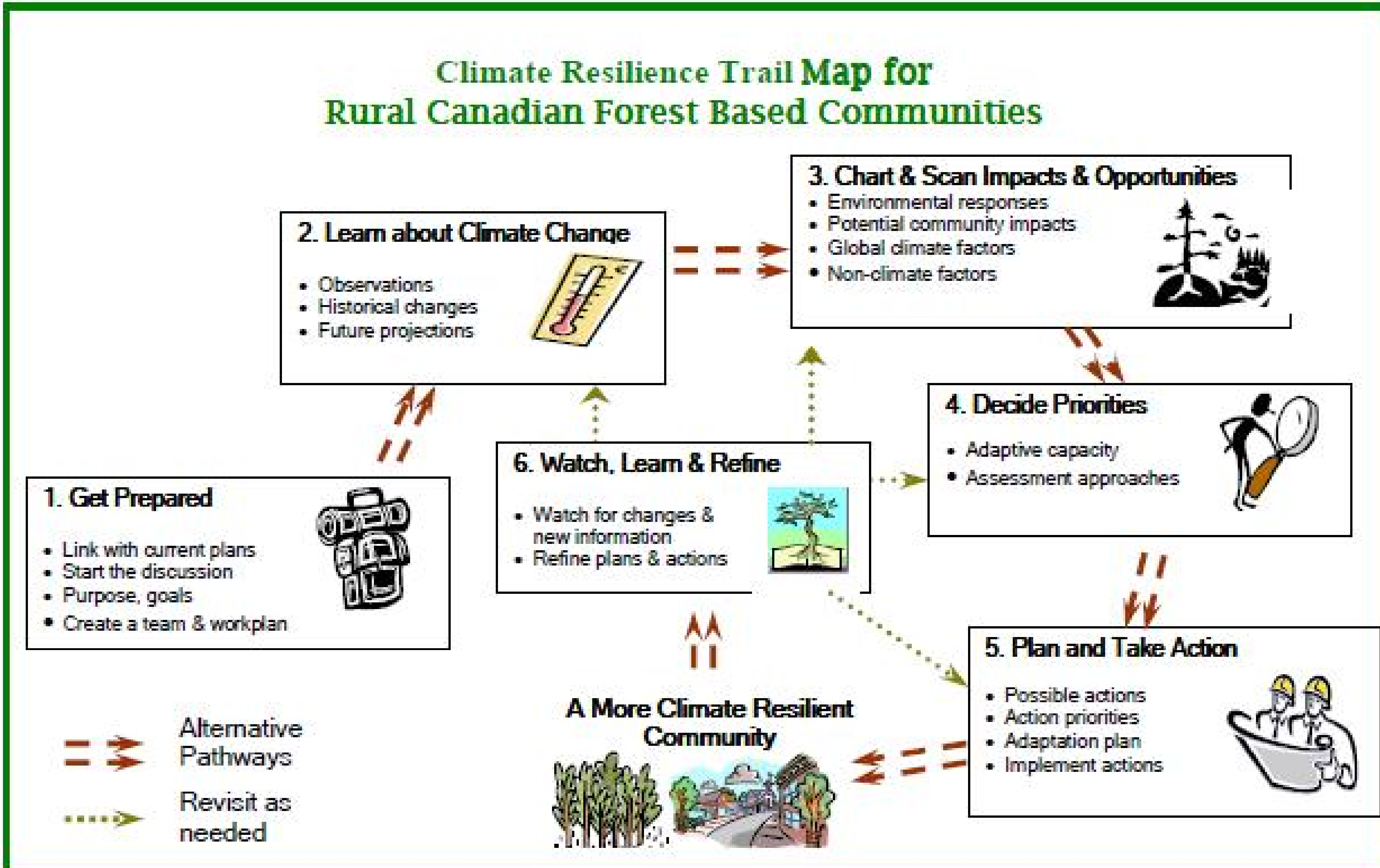
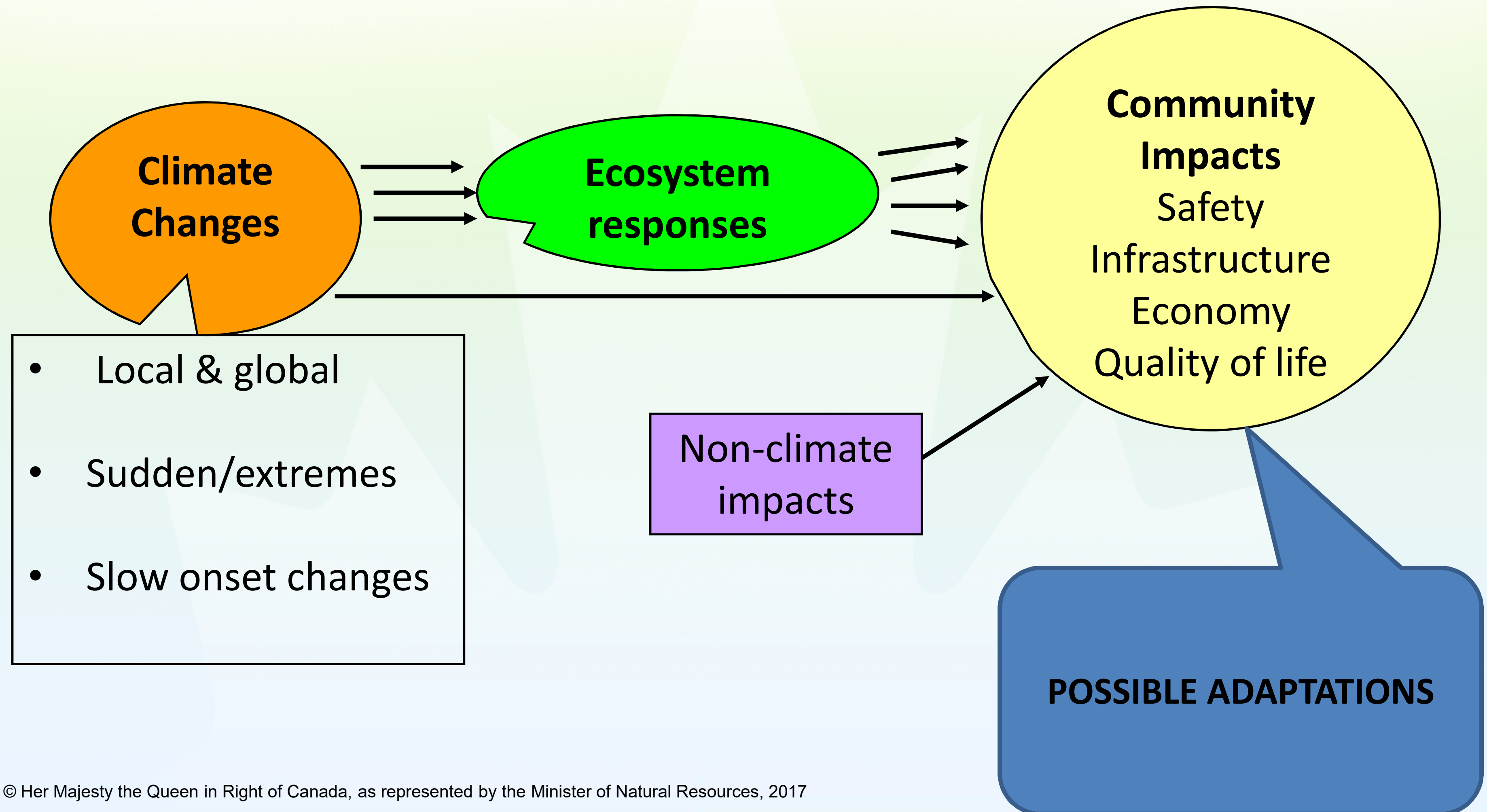
Slide from: Ted Hogg, CFS-NoFC

Adaptation Trail Map



Impact Charting



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PRIORITY	Does a Community Process Exist?	
	NO	**YES**
High	***Highest priority for this phase of adaptation planning!***	*Support existing process to add climate change implications. If not possible, then include in this phase of adaptation planning.*
Lower	Assess in *next* phase of adaptation planning. Continue to watch new information and local conditions to verify low implications.	Encourage existing process to include climate change. If not possible, assess in *next* phase of adaptation planning. Continue to watch new information and local conditions to verify low implications.

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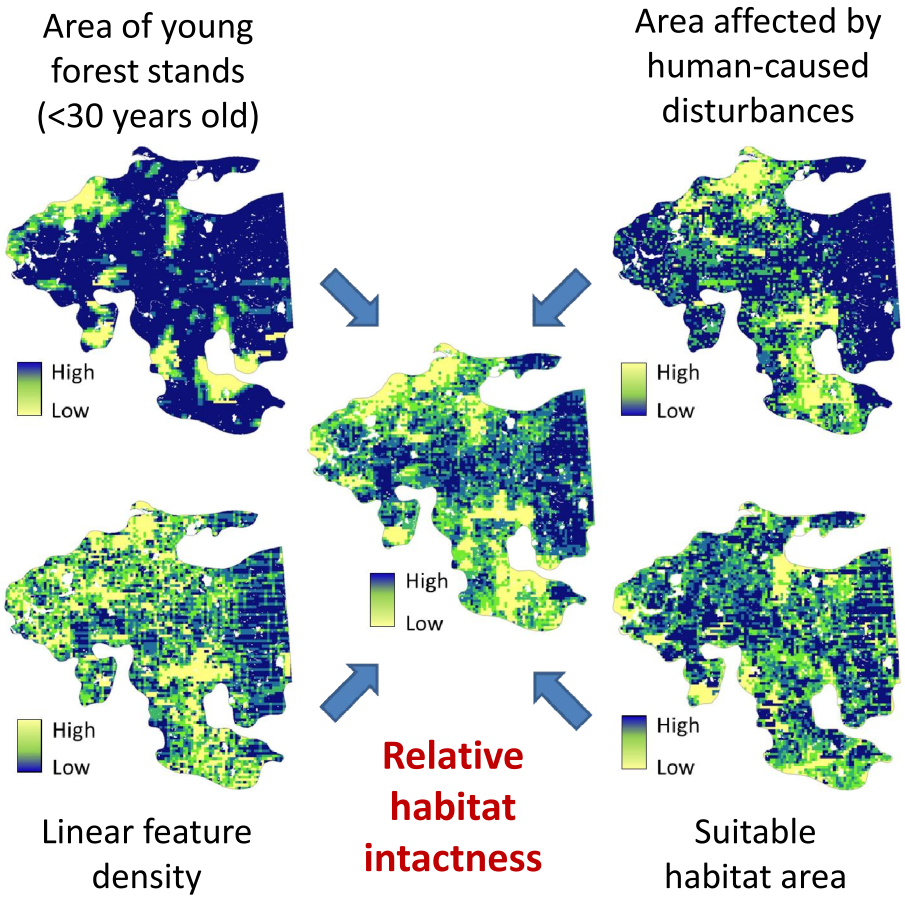
Slide modified from Cindy Pearce

Plan PD2 landscape restoration efforts using multi-criteria analytic tools



What is needed:

- Spatial prioritization of multiple restoration objectives in fragmented landscapes
- Aggregation of qualitatively different objectives (like "apples" and "oranges")
- Multi-criteria aggregation tool for handling large-scale uncertain data

Proposed Approach:

- A multi-attribute frontier (MAF) aggregation with a hypervolume metric PD1
- Aggregate multiple restoration objectives into a single-dimensional priority metric

Results:

- Software tool for multi-criteria aggregation (MAF Mapper 1.1)
- Apply the tool to generate maps of relative habitat intactness

Slide 51

PD1 What is a "hypervolume metric"? I think I understand but it's not clear. How about "multi-dimensional"? This fits better wtih the next bullet.
Price, David, 2017-11-21

PD2 I have changed "Manage" to "Plan" here because (a) we are not managing and (b) even managers will need to plan (and make compromises) when making decisions
Price, David, 2017-11-21

Restoring connectivity and intactness of fragmented landscapes

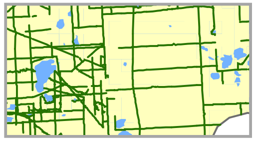
Economic resource allocation model for seismic line restoration and caribou protection

- Maximizes habitat connectivity and intactness in fragmented boreal landscapes
- Based on graphical theory approach (generalized Steiner Network type model)
- Mixed integer programming formulation with cost, budget PD3 and connectivity constraints
- Uses spatial data on habitat / species availability, intactness and restoration costs
- Incorporates costs, budgets and potentially other economic assumptions
- Can be generalized for adaptation to other regions / economic scenarios

PD4

Conceptualize study area as a landscape scale “network of habitats”

Seismic lines → Habitat network



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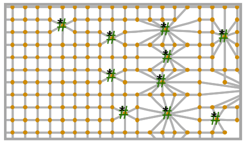
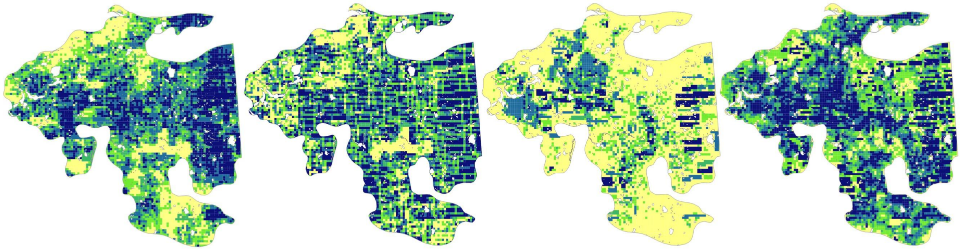
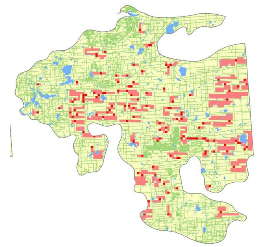


Input data on costs, budget, and habitat / species availability



Resource allocation mixed integer programming model



Optimal restoration strategies

Slide 52

PD3 do you need both "cost and budget" in these sentences? What is the difference from a model constraint veiewpoint? And in the one two lines further down?
Price, David, 2017-11-21

PD4 I like this but I hope this says it more clearly.
Price, David, 2017-11-21

Tracey/David, may I be excused? My brain is full."

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Questions?

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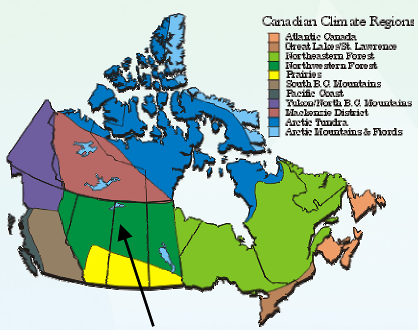
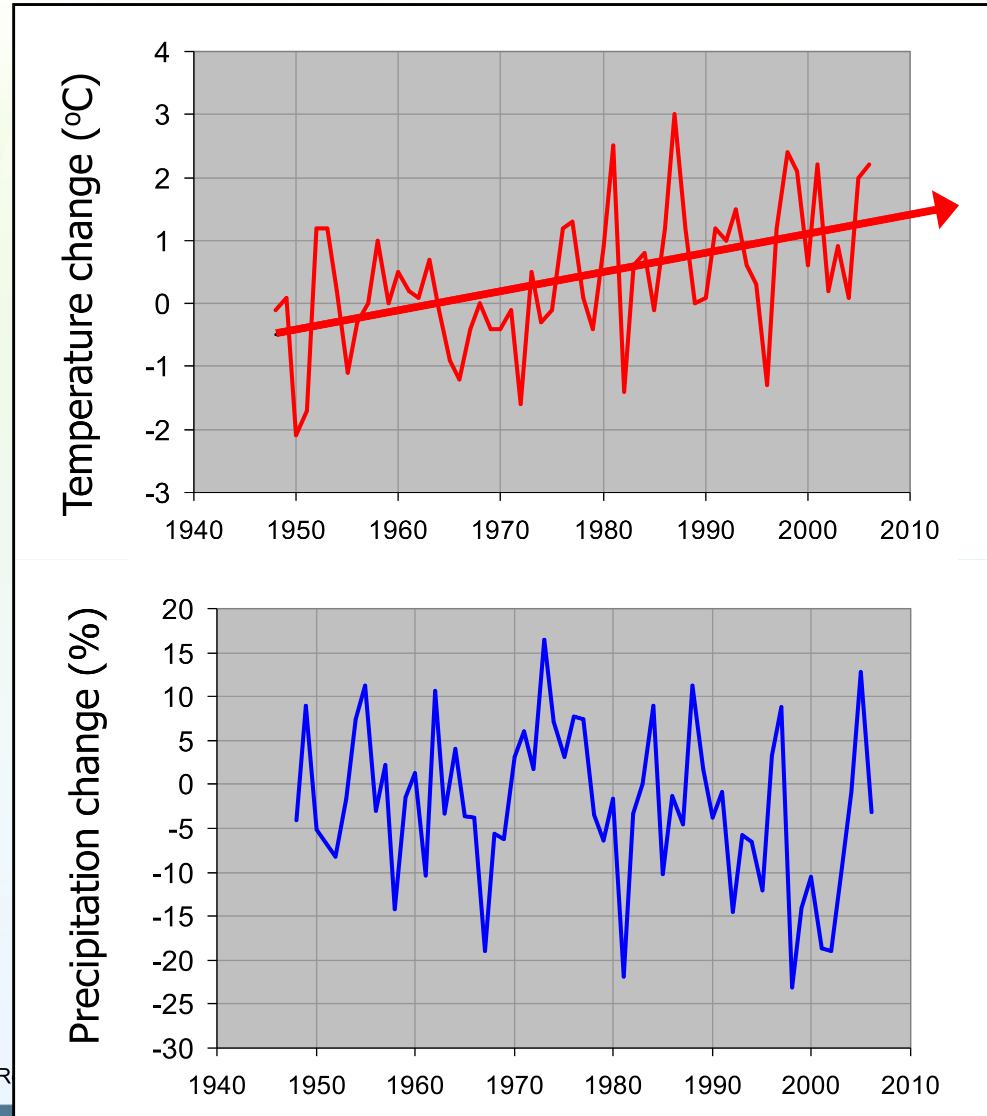
Regional climate trends

- Significant warming (+1.8°C since 1948)
- Faster warming for nightly minimums and in winter
- No apparent trend yet for precipitation (highly variable)



Northwestern Forest region



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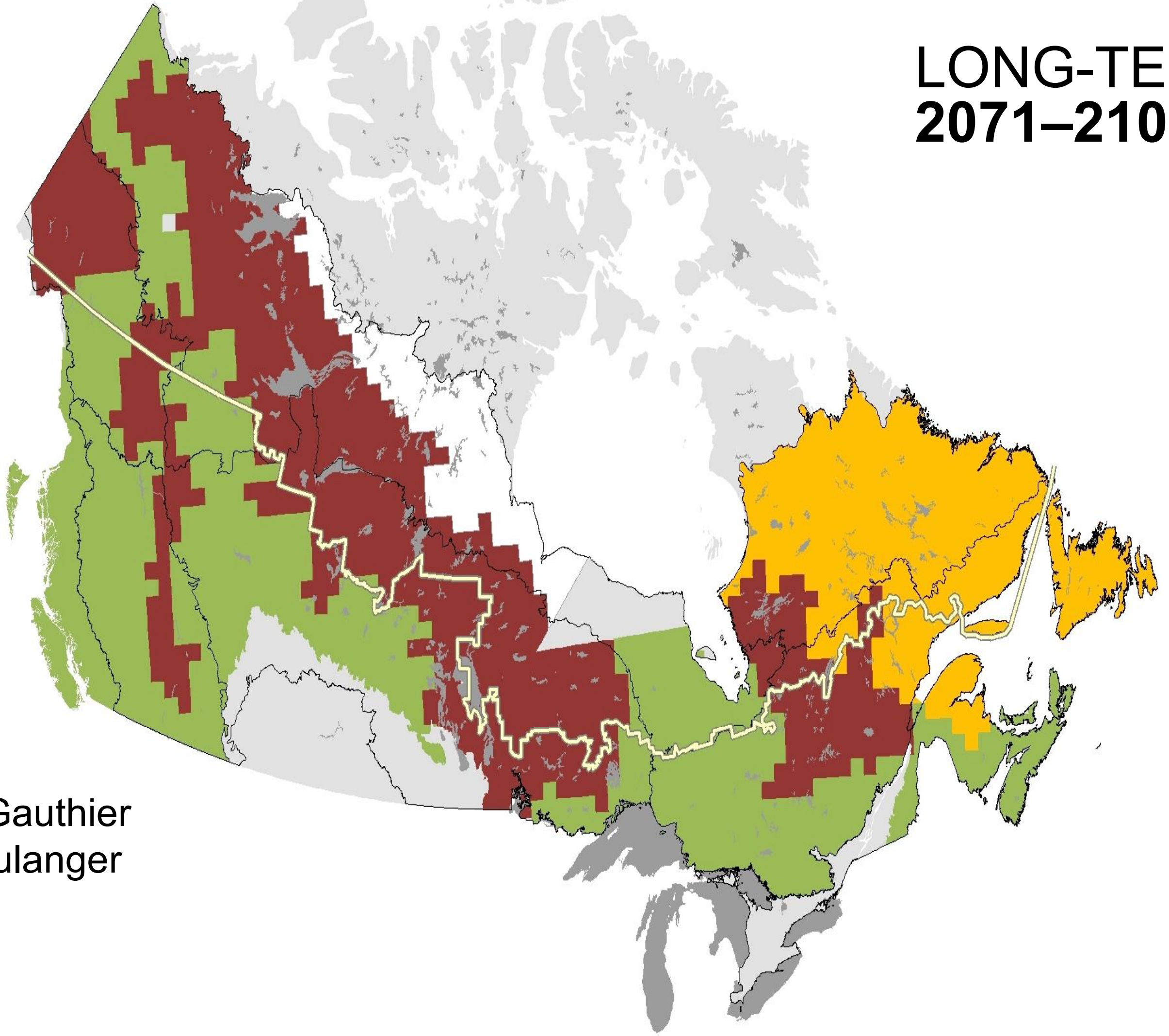
Slide from: Ted Hogg, CFS-NoFC

Data from Climate Trends & Variations Bulletin, Environment Canada
http://www.msc-smc.ec.gc.ca/ccrm/bulletin/archive_e.cfm

Fires are projected to affect key natural resource development areas



By:
Sylvie Gauthier
Yan Boulanger

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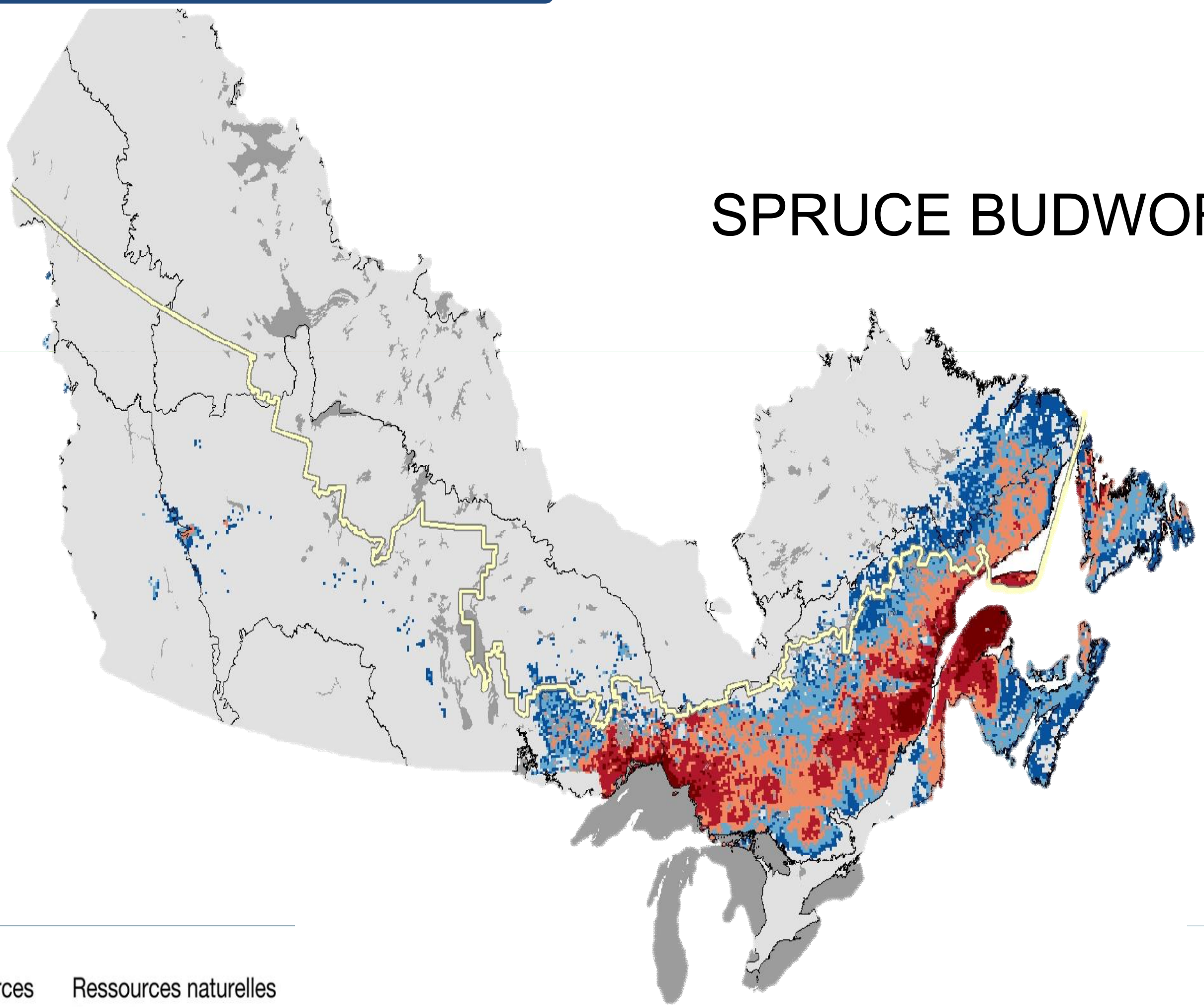
The cumulative effects of disturbances and other changes to the forest will be complex

Short-term impact projections (2011–2040)



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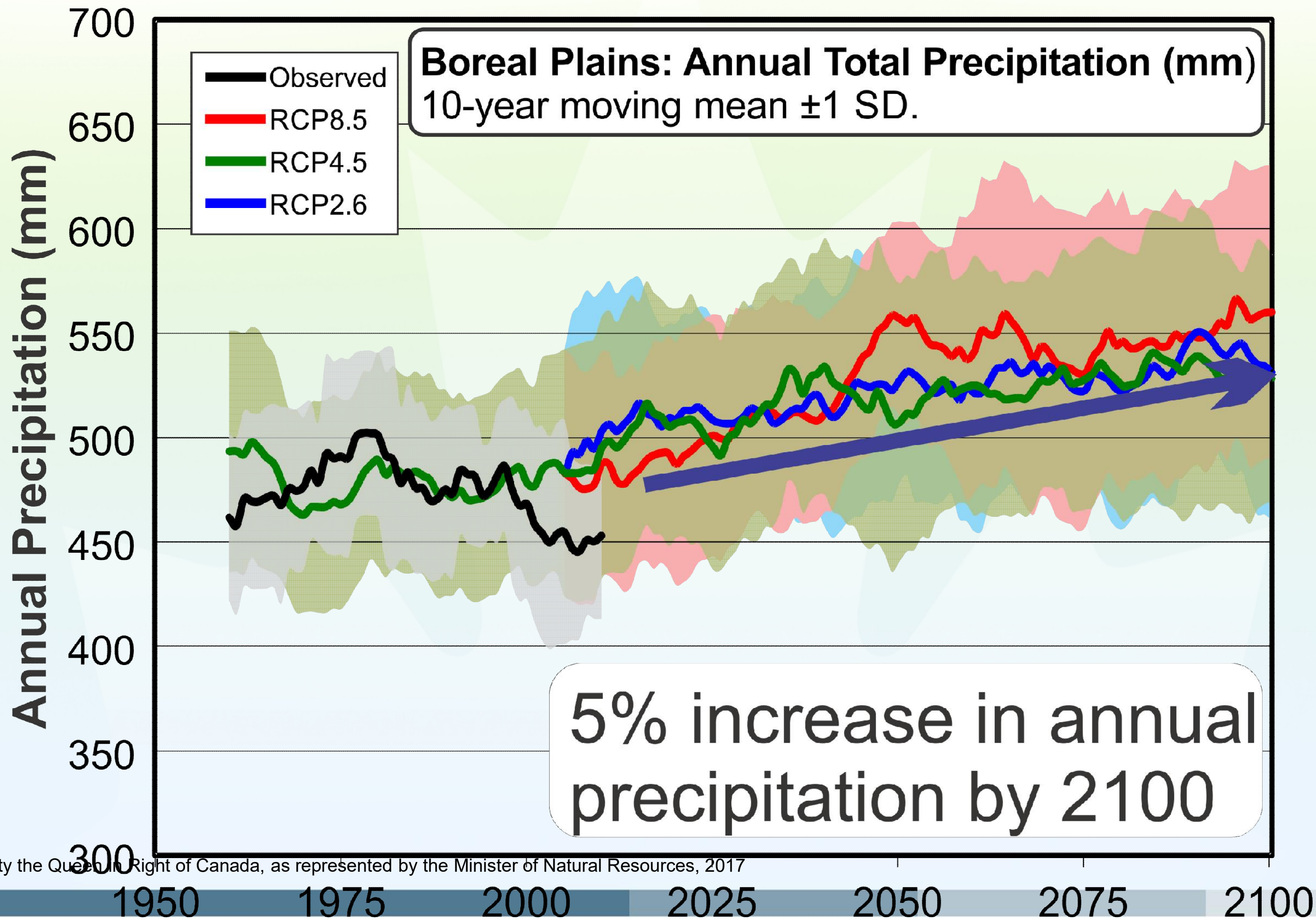
Climate scenarios for the Boreal Plains



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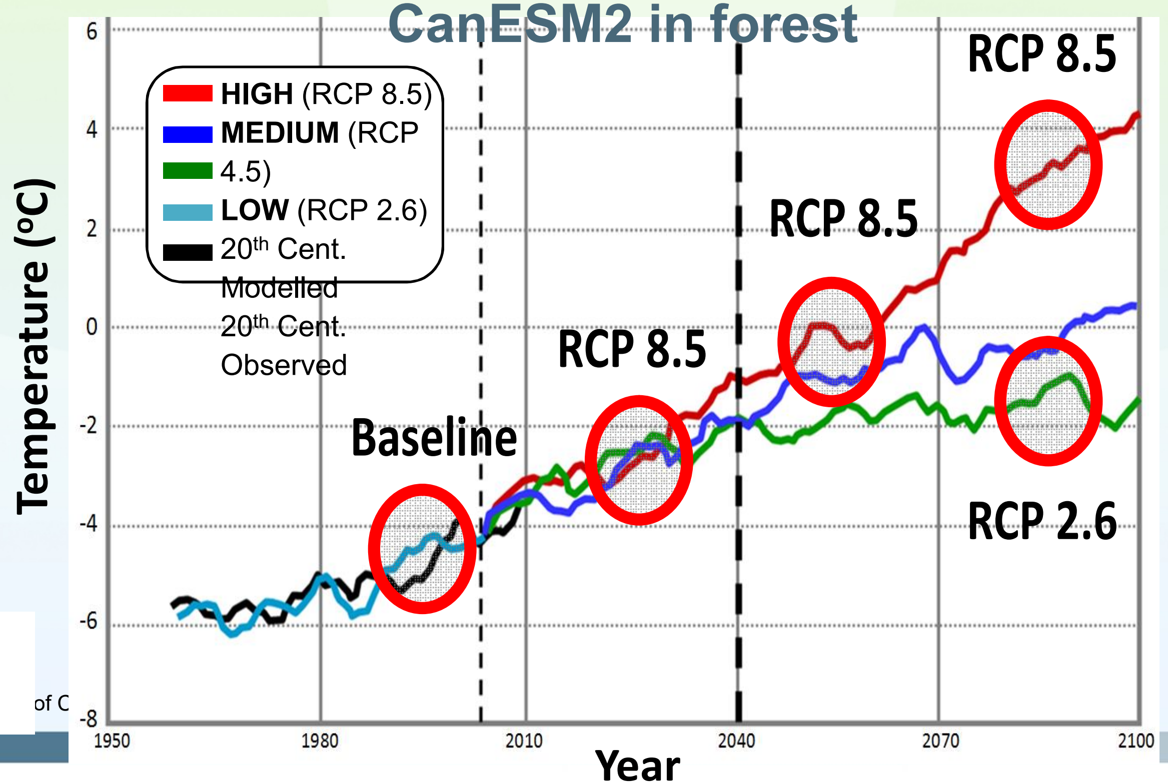
Scenarios help to cope with uncertainty

- The biophysical analysis was done for three time periods and on different scenarios

Temperature projections based on CanESM2 in forest



By:
David Price

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‘Primary’ Climate Variables

Parameter	Units	Time step[a]	Type[b]	Period covered	Area covered[c]
Minimum and maximum temperature	°C	m	n	1931–60, 1961–90, 1971–2000	CA, NA
			h	1901–2008	CA, NA
		w	n	1961–90, 1971–2000	CA
			h	1961–2003	CA
		d	h	1950–2008	CA
Precipitation	mm	m	n	1931–60, 1961–90, 1971–2000	CA, NA
			h	1901–2008	CA, NA
		w	n	1961–90, 1971–2000	CA
			h	1961–2003	CA
		d	h	1950–2008	CA
Solar radiation	$MJ\ m^{-2}$	m	n	1961–1990	CA, NA
Photovoltaic potential	$MJ\ m^{-2}$	m	n,h	1971–1994	CA
Sunshine	h	m	n	1961–1990; 1971–2000	CA
Potential evapotranspiration	mm	m	n	1961–1990, 1971–2000	CA, NA
Climate moisture index[d]	cm	m	n	1961–1990, 1971–2000	CA, NA
Relative humidity	%	m	n	1961–1990	CA, NA
Vapor pressure	kPa	m	n	1961–1990	CA
Evaporation (pan and lake)	mm	m,w	n,h	1961–1990	CA
Extreme minimum and maximum temperature	°C	a,m	n	1961–1990, 1971–2000	NA
		a,m	h	1961–2000	NA
Frost-free days	d	a	n	1961–1990	CA
Avg wind speed	$km\ h^{-1}$	m	n	1961–1990	CA, NA
Maximum wind gust	$km\ h^{-1}$	m	n	1961–1990, 1971–2000	CA
Rainfall	mm	m	n	1931–60, 1961–90, 1971–2000	CA
Snow depth	cm	m	n	1961–90, 1971–2000	CA
			h	1955–2008	

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“Derived” Climate Variables

Bioclimatic Variables	Units	Description
Annual mean temperature	°C	Average of mean monthly temperatures
Mean diurnal range	°C	Average of monthly temperature ranges
Isothermality		Variable 2 ÷ Variable 7
Temperature seasonality	%	Standard deviation of monthly-mean temperature estimates expressed as a percent of their mean
Max temperature of warmest month	°C	Highest monthly maximum temperature
Min temperature of coldest month	°C	Lowest monthly minimum temperature
Temperature annual range	°C	Variable 5 – Variable 6
Mean temperature of wettest quarter	°C	Average temperature during 3 wettest months
Mean temperature of driest quarter	°C	Average temperature during 3 driest months
Mean temperature of warmest quarter	°C	Average temperature during 3 warmest months
Mean temperature of coldest quarter	°C	Average temperature during 3 coldest months
Annual precipitation	mm	Sum of monthly precipitation values
Precipitation of wettest month	mm	Precipitation of the wettest month
Precipitation of driest month	mm	Precipitation of the driest month
Precipitation seasonality	mm	Standard deviation of the monthly precipitation estimates expressed as a percent of their mean
Precipitation of wettest quarter	mm	Total precipitation of 3 wettest months
Precipitation of driest quarter	mm	Total precipitation of 3 driest months
Precipitation of warmest quarter	mm	Total precipitation of 3 warmest months
Precipitation of coldest quarter	mm	Total precipitation of 3 coldest months
Growing Season Variables	**Units**	**Description**
Start	days	Julian day of the start of the growing season
End	days	Julian day of the end of the growing season
Length	days	Duration of the growing season
Degree days over 0°C	°C	Sum of temperatures over 0°C during the growing season
Degree days over 5°C	°C	Sum of temperatures over 5°C during the growing season
Degree days over 10°C	°C	Sum of temperatures over 10°C during the growing season
Precipitation	mm	Total precipitation during the growing season
Mean temperature	°C	Average daily temperature during the growing season
Temperature range	°C	Range in daily temperatures during the growing season

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Small Changes in Climate Matter

Where	Winter Average Temp.	Summer Average Temp.	Average annual precipitation (mm)
Thompson	-22.7	13.9	535
Black River	-17.7	16.8	520
Winnpeg	-16.0	18.3	504
Emerson	-14.6	19.0	547

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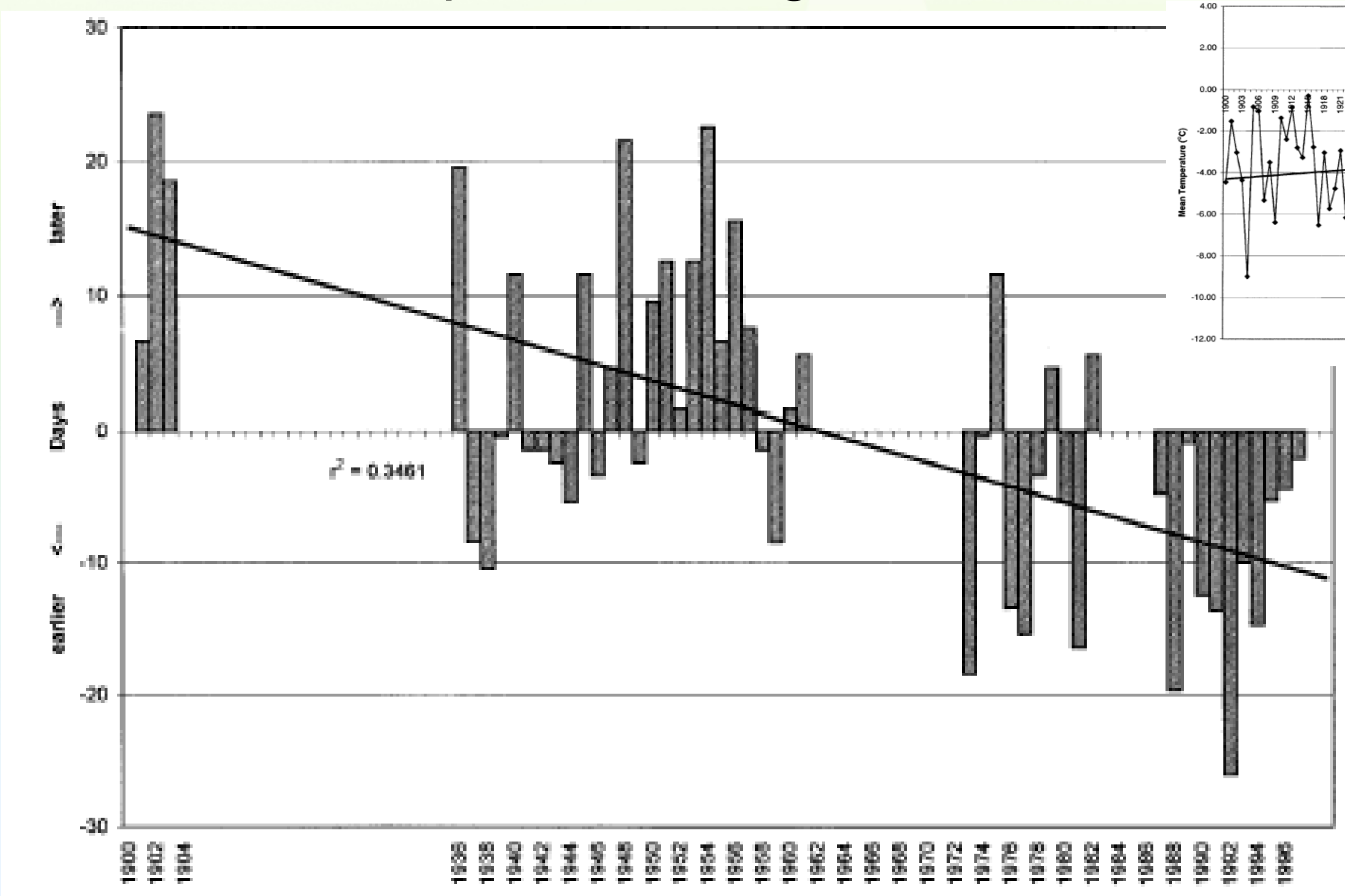
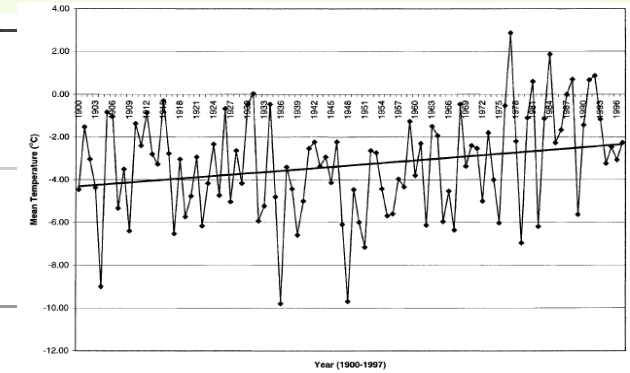
Climate Change Effects on Plants

Variations in aspen flowering date at Edmonton, 1901-1997





Late winter air temp. Edmonton Municipal Airport 1900-1997

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From: Beaubien and Freeland, 2000, Int. J. Biometeorol. 44: 53-59 http://plantwatch.sunsite.ualberta.ca/

Some "Unexpected Guests"…

Gypsy moth

Asian long-horn beetle

Emerald Ash-borer

Recent introductions of exotic insect defoliators to Edmonton's urban forest:
http://www.gov.edmonton.ab.ca

- Ash leaf-tier
- Cottony psyllid, ash
- Elm leafminer
- Gypsy moth
- Pine false webworm
- Red-headed ash borer
- Satin moth
- Yellowheaded spruce sawfly

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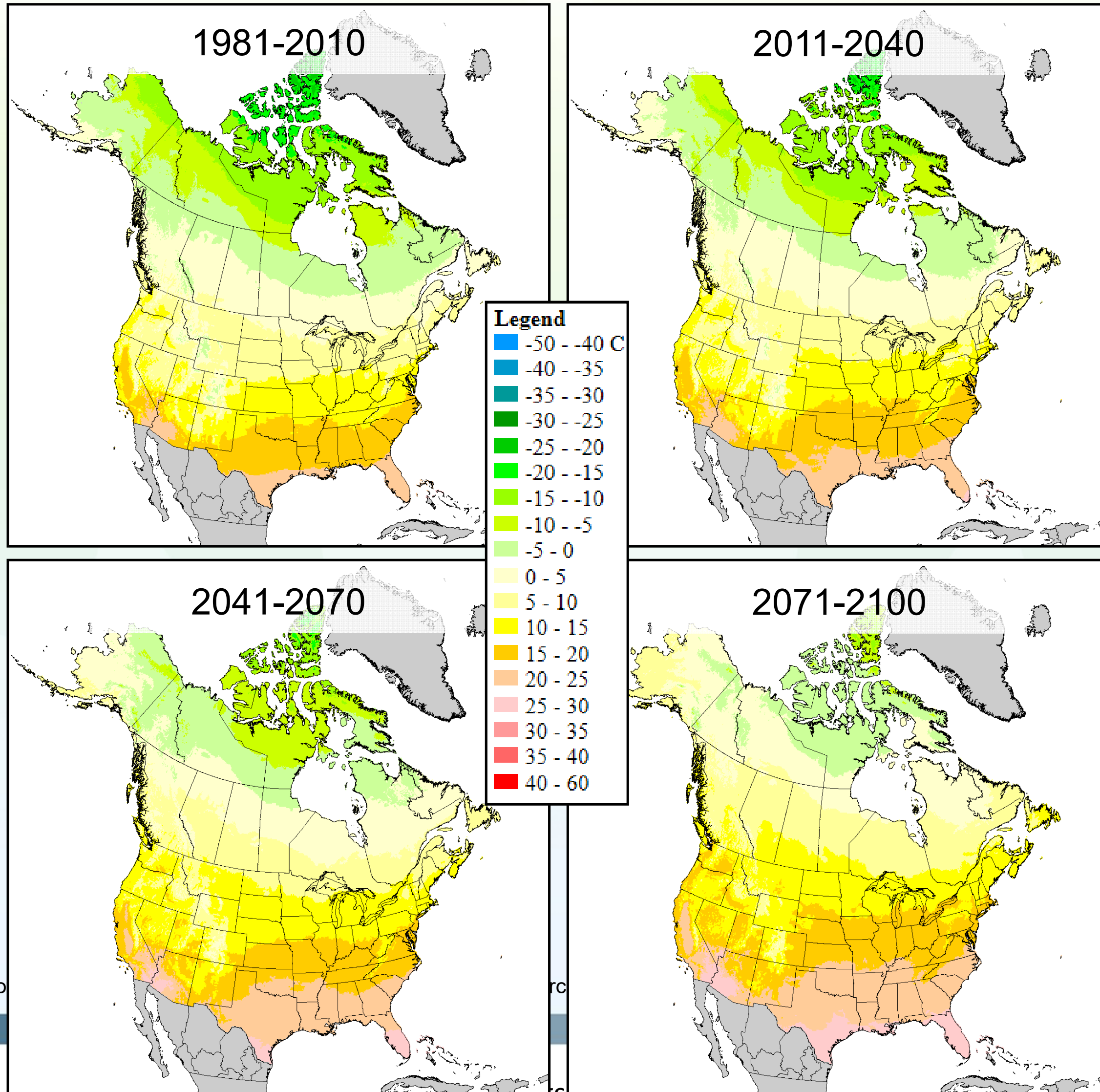
Slide from: Ted Hogg, CFS-NoFC

Future Climate Projections, Cont'd

(Mean Annual Temperature; Composite GCM; RCP8.5)



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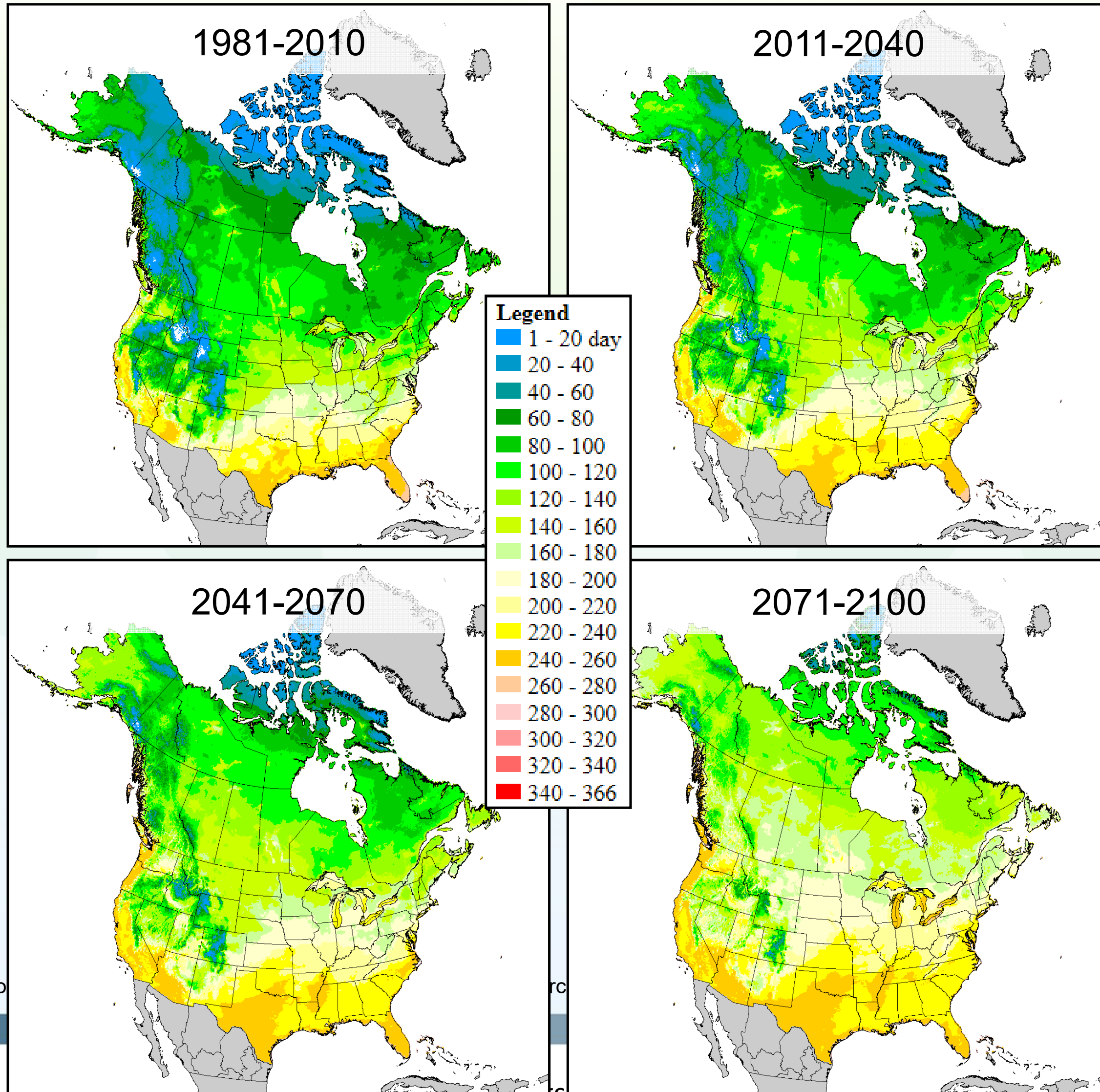
Future Climate Projections, Cont'd

(Growing Season Length; Composite GCM; RCP8.5)



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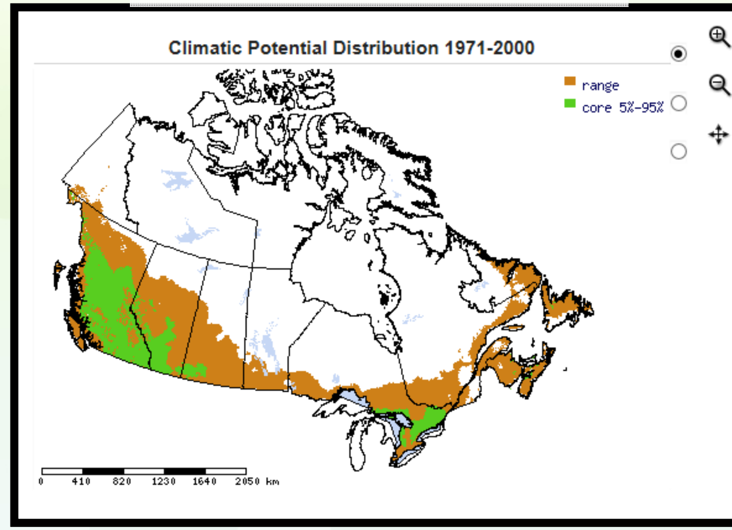
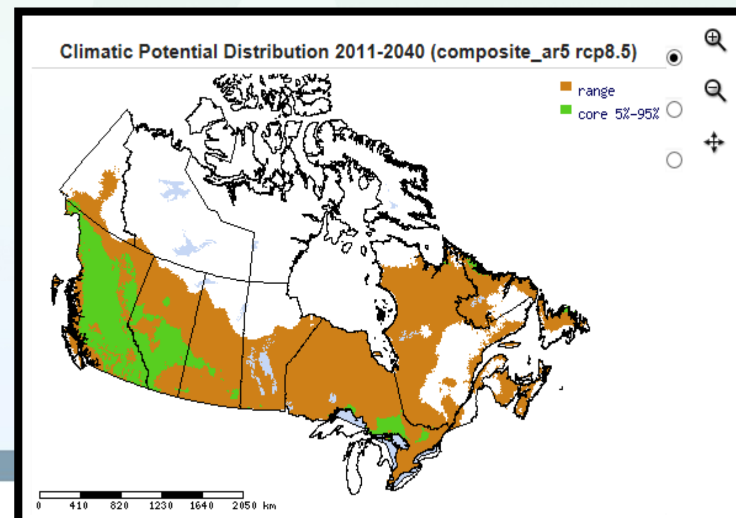
Climate Applications, *Cont’d*

- Pest Risk Mapping -

- Based on insect and disease occurrence data (e.g., FIDS, private collections, GBIF)
- Climate-based species distribution models for more than 1500 insect and disease species
- Available for current and future time periods
- Overlaid host distributions to get a sense of area and wood volumes at risk
- Limitations: little data outside of Canada and expert knowledge

Mountain Pine Beetle





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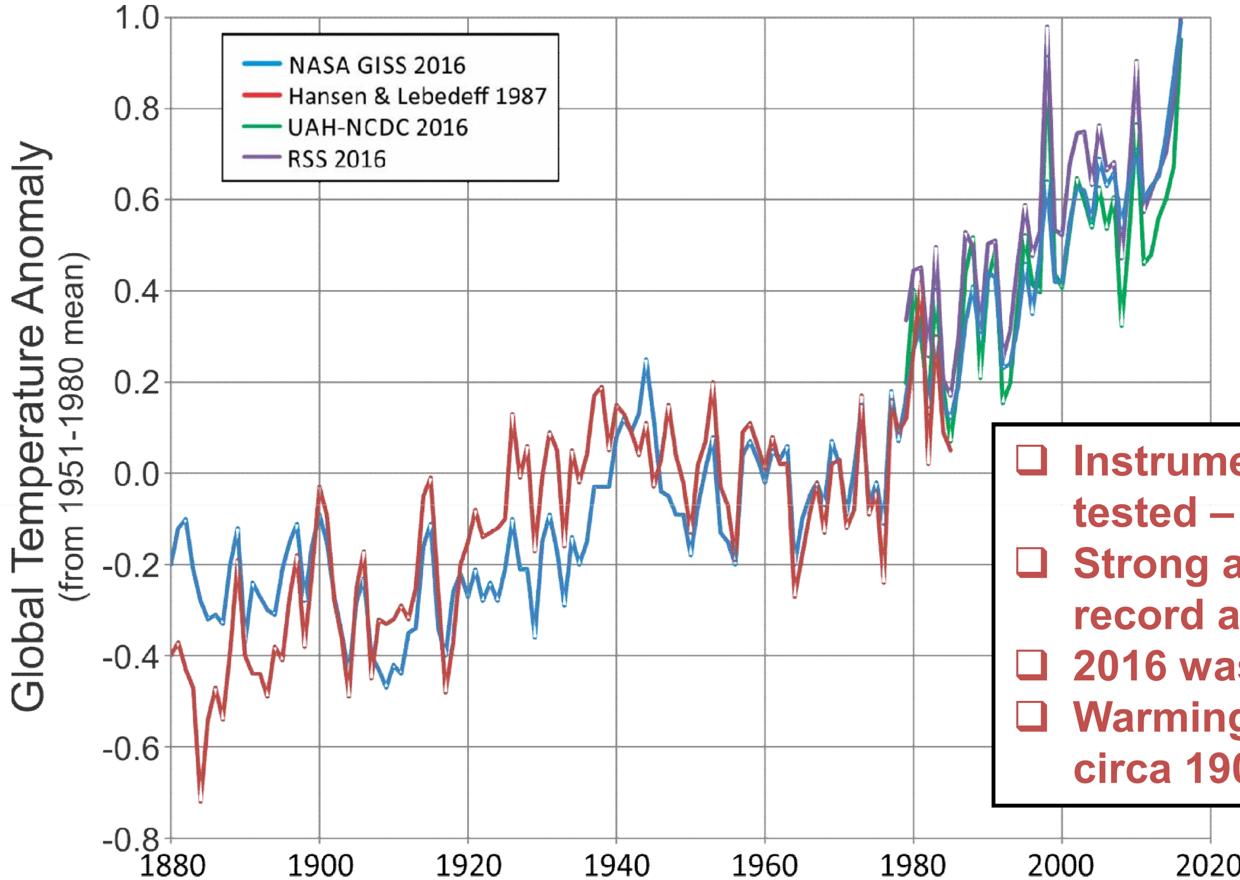

- Instrument record (since 1880) is well-tested – and cannot be ignored!
- Strong agreement between instrument record and satellite data (since 1978)
- 2016 was the warmest year on record
- Warming is approaching 1.5 ºC since circa 1900)

http://data.giss.nasa.gov/gistemp/
https://pubs.giss.nasa.gov/abs/ha00700d.html
http://www.nsstc.uah.edu/data/msu/v6.0beta/tlt//uahncdc_lt_6.0beta5.txt
http://data.remss.com/msu/graphics/TLT/RSS_TS_channel_TLT_Global_Land_And_Sea_v03_3.txt

Splatsin Community Area Climate Change Profile

Climate Element	Past climate trends (1950s to 2000s)	Future Climate (change from 2000s)		
		2050s	2080s	Snapshot
SPRING (March to May				
Average temperature (°C)	+0.6	+3.0 to 3.6	+3.6 to 5.5	Much Warmer
Average precipitation (%)	+28	+6 to 8	+8 to 14	Wetter
SUMMER (June to August)				
Average temperature (°C)	+0.8	+2.5 to 3.5	+3.2 to 6.0	Much Warmer
Average precipitation (%)	No trend	+7 to 9	-2 to +9	Slightly Wetter
FALL (September to November)				
Average temperature (°C)	+0.4	+1.8 to 2.7	+2.5 to 4.6	Warmer
Average precipitation (%)	+16	-1 to +1	+1 to 6	Little change
WINTER (December to February)				
Average temperature (°C)	+1.3	+1.5 to 2.1	+2.0 to 4.1	Warmer
Average precipitation (%)	-17	+29 to 30	+33 to 39	Much Wetter
The past and future changes presented here are based on decadal averages and do not take into account changes in extreme events s that can occur at various time scales. For example there is mounting evidence of increasing extremes in rainfall intensity for periods as short as a few minutes, to as long as days and even months.				

Source: Cindy Pearce

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