

Planning for a New Climate

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The Issue

- Global climate is **changing rapidly**
 - Major climate **change is coming** to the Prairie Provinces
 - We must **reduce our emissions** and we must prepare **adaptation strategies**
-
- Adaptation strategies must be based on **informed decision making**
 - The planning community must **envision and build resilient futures**

1880-2015 Global Temperature Change (°C)

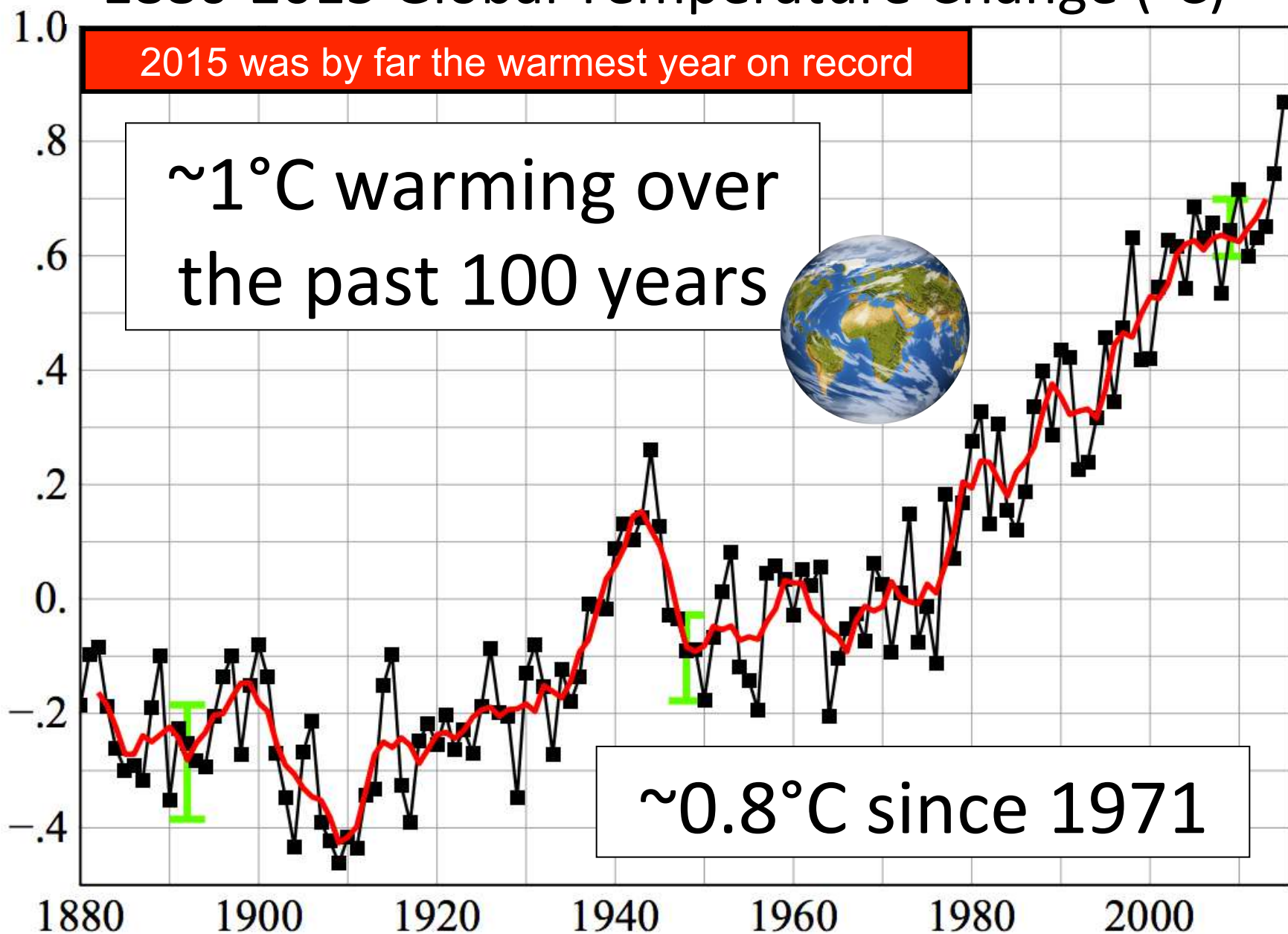
2015 was by far the warmest year on record

~1°C warming over
the past 100 years

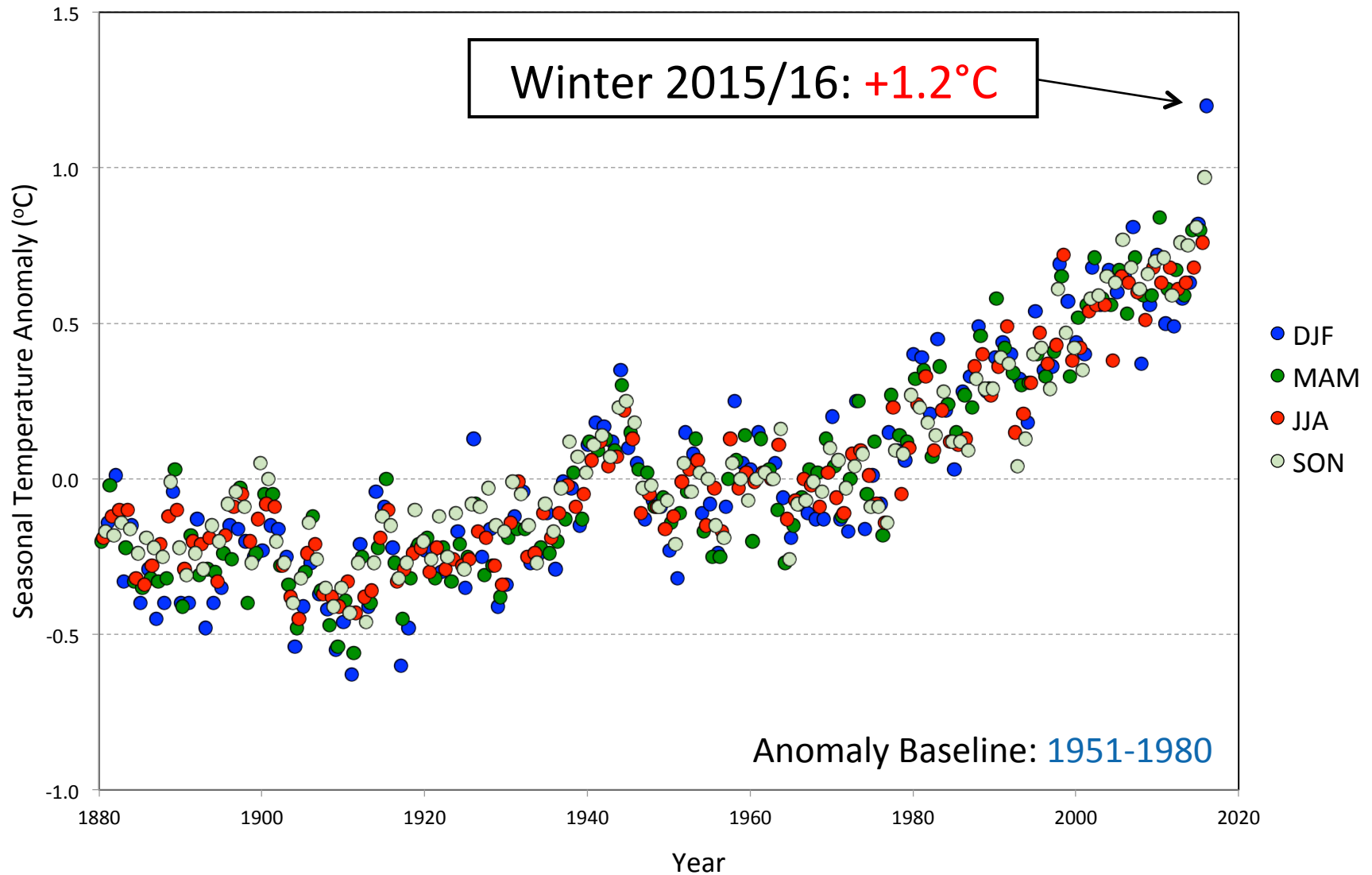


~0.8°C since 1971

Temperature Anomaly (°C)

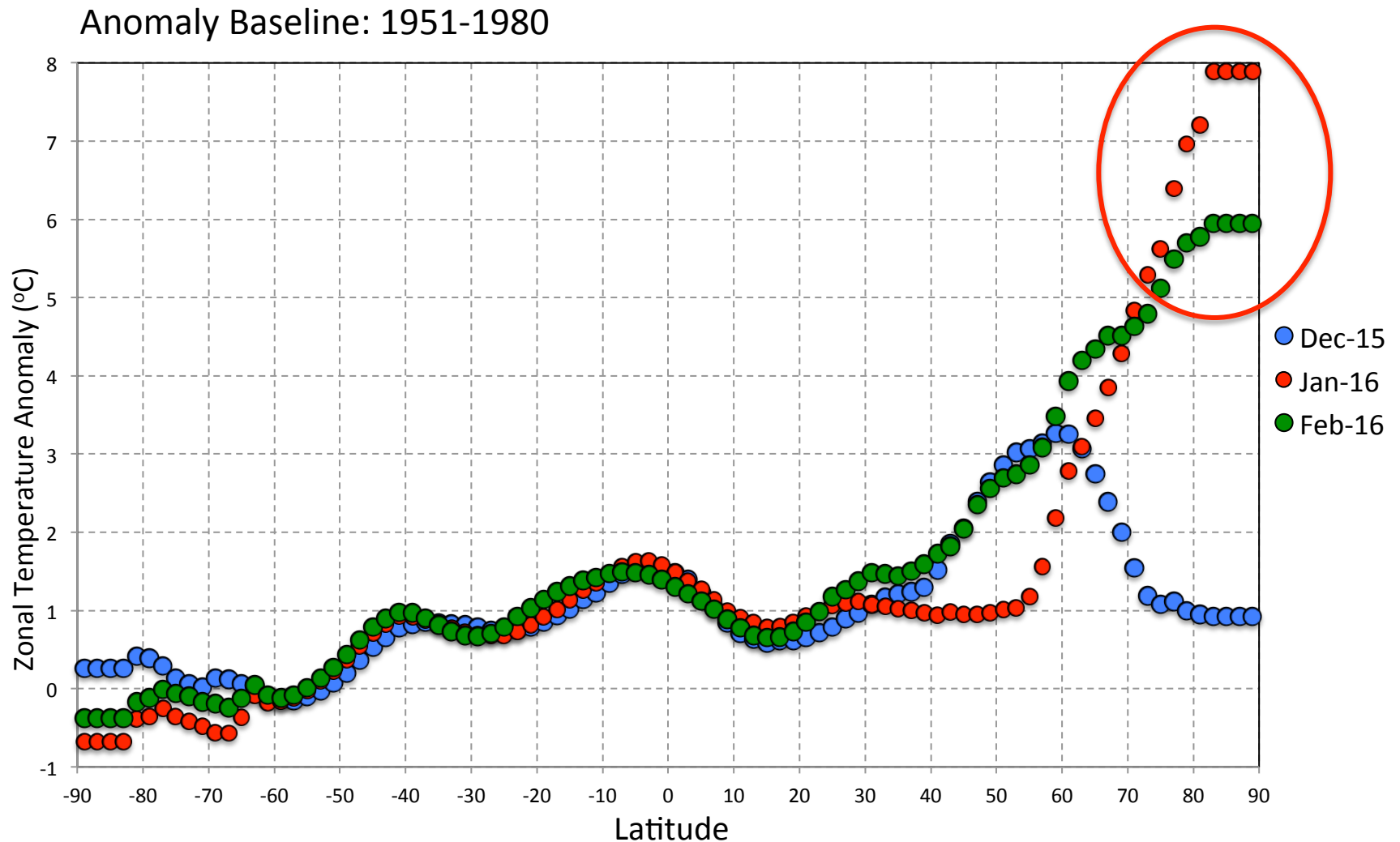


Seasonal Global Temperature Anomalies: 1880-2016



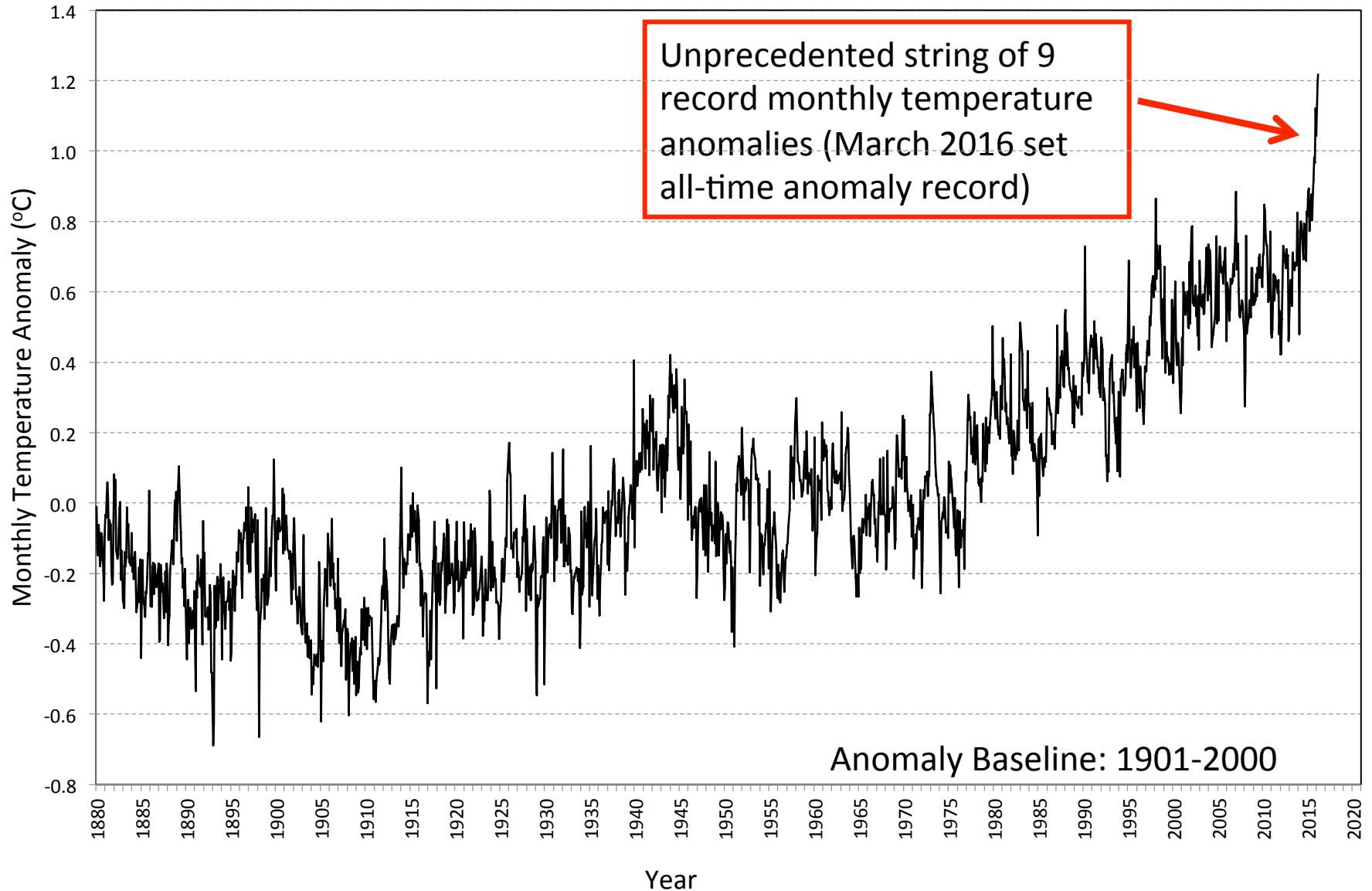
Data source: <http://data.giss.nasa.gov/gistemp/>

Monthly Zonal Temperature Anomalies: Winter 2015/16



Data Source: <http://data.giss.nasa.gov/gistemp/maps/>

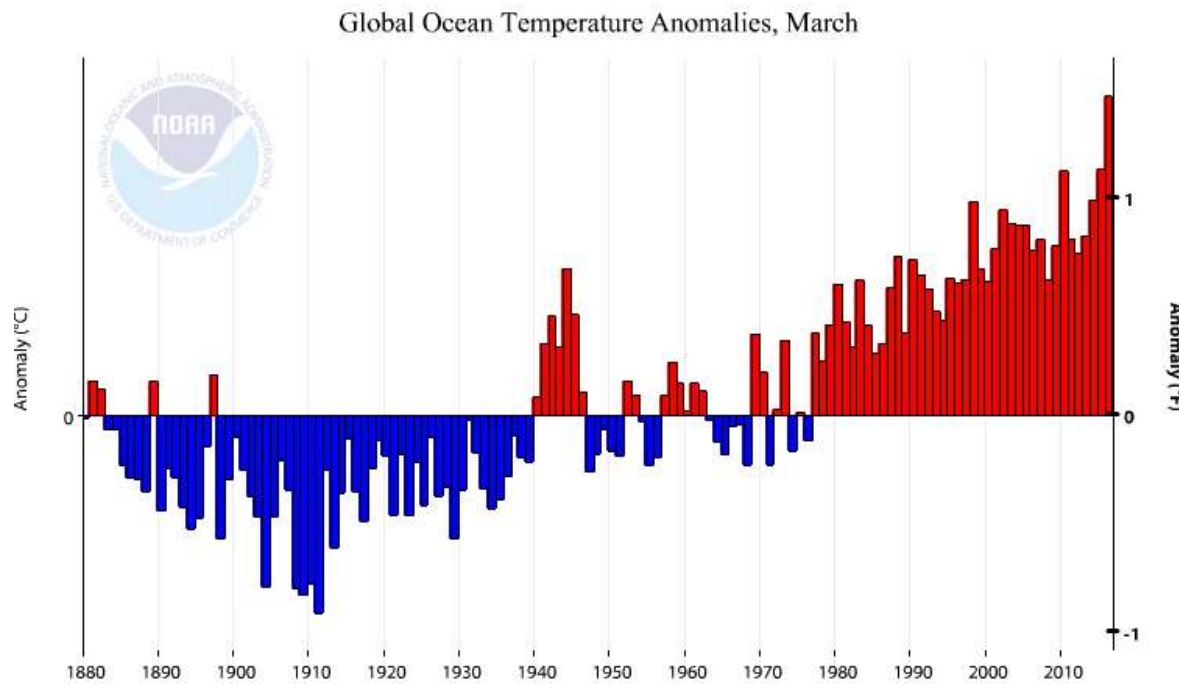
Monthly Global Temperature Anomalies: 1880-2016



March Sea Surface Temperature (SST)

- Globally-averaged SST was **higher than in any other March** (1880-2016)
- SST departure from normal in March was **6th highest** out of all 1,635 months
- The **7 highest** monthly global ocean temperature departures have all occurred in **last 7 months**

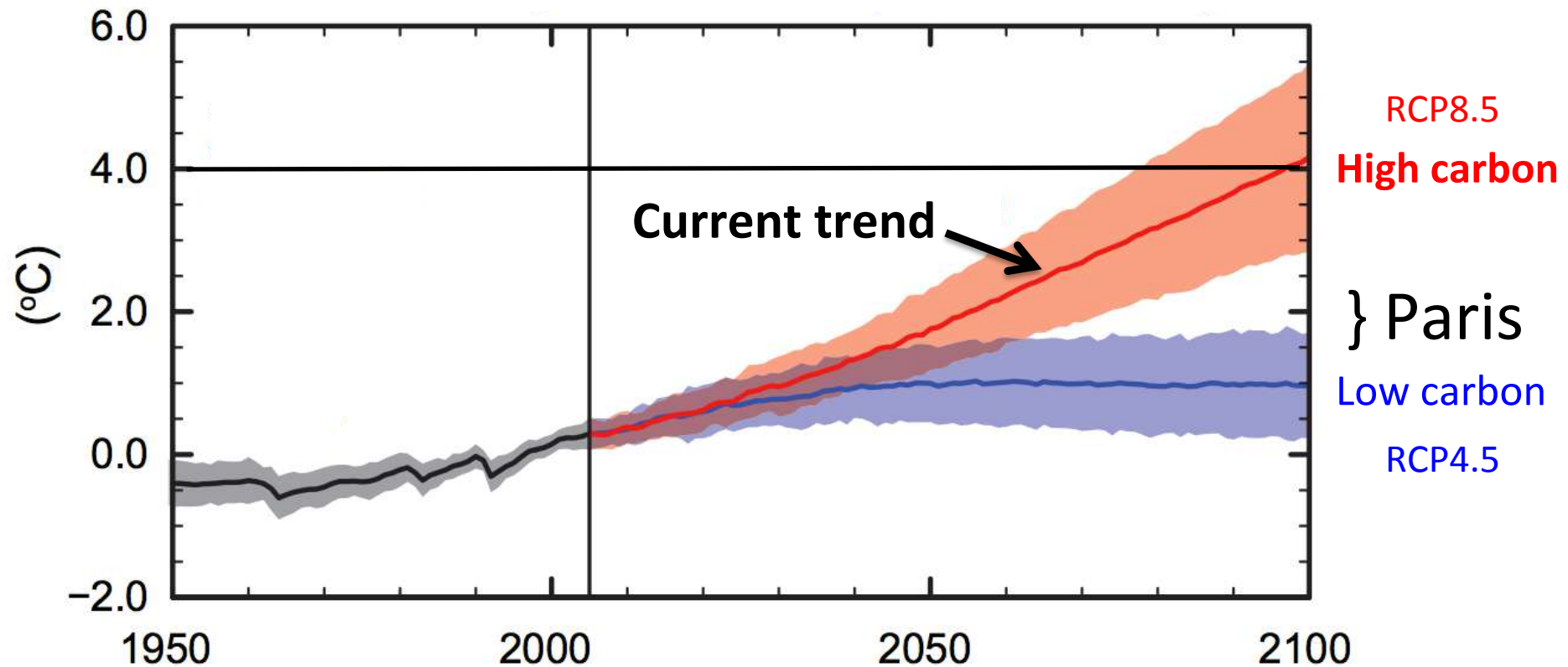
<https://www.ncdc.noaa.gov/sotc/global/201603>



April 2016 was
warmest April
on record

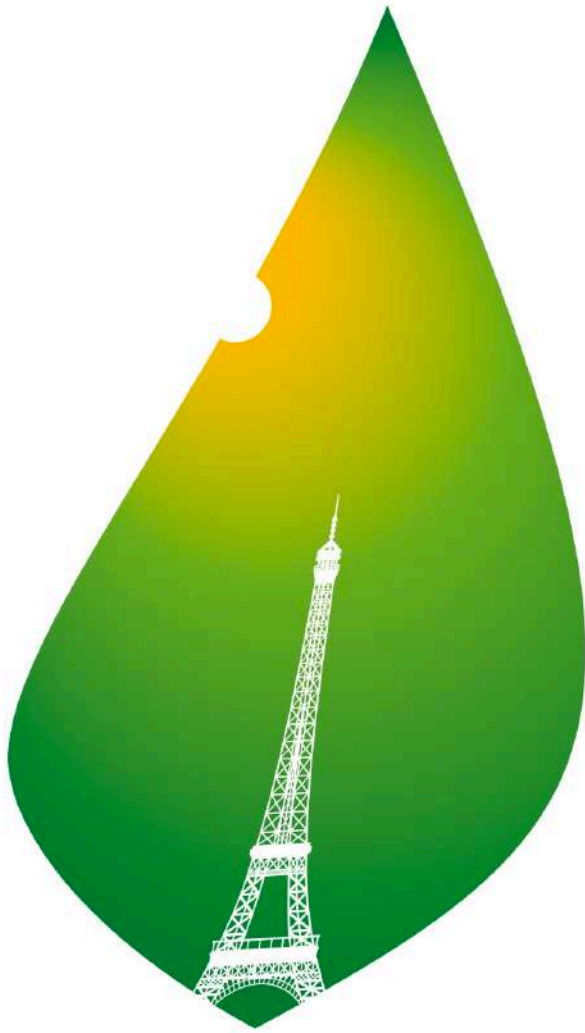
<https://www.ncdc.noaa.gov/cag/time-series/global/globe/ocean/1/3/1880-2016>

Global Average Surface Temperature Change for High and 'Low' Carbon Emissions Scenarios



Source: Adapted from IPCC's latest report





The Paris Agreement's goal is **to limit *additional* global warming to 1 °C** and ideally 0.5 °C.

To do so, we must drastically reduce our global carbon emissions.

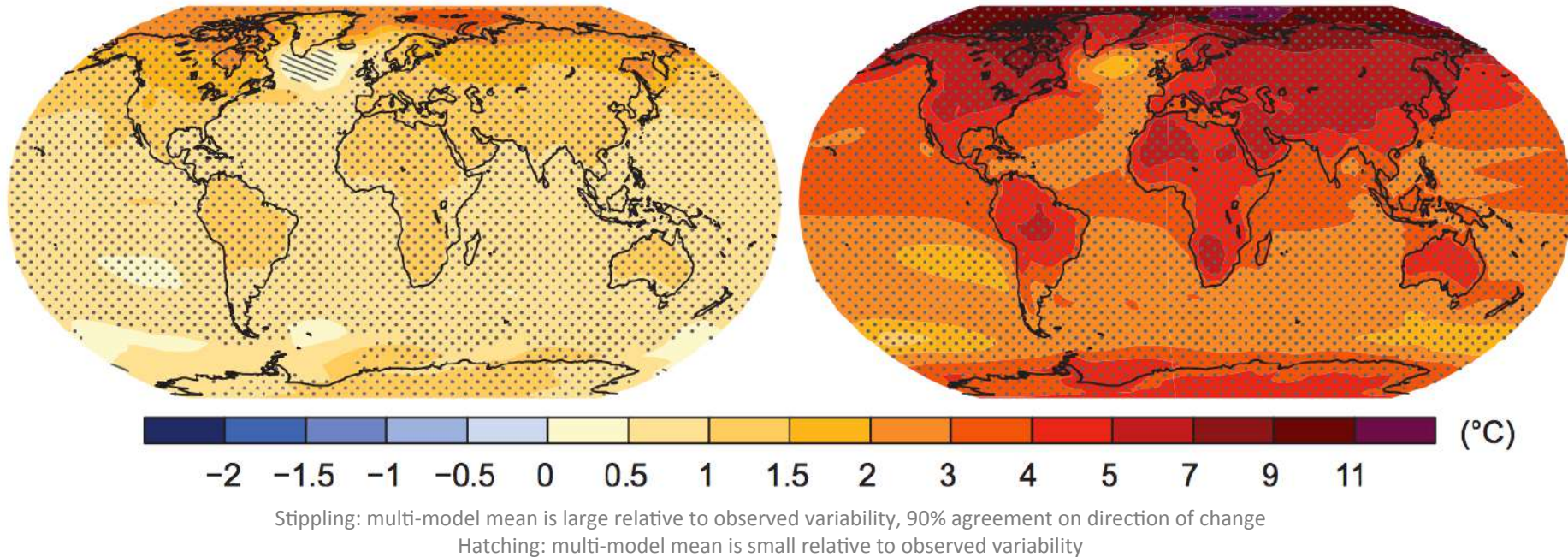
COP21 • CMP11

PARIS 2015

UN CLIMATE CHANGE CONFERENCE

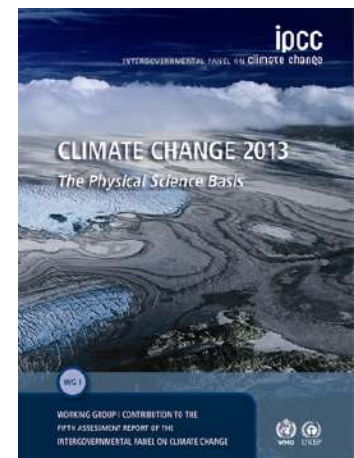
**We need to reduce our
global emissions.**

Very low carbon High carbon
Change in average surface temperature (1986–2005 to 2081–2100)



Largest amount of warming
projected in higher
latitudes and over land.

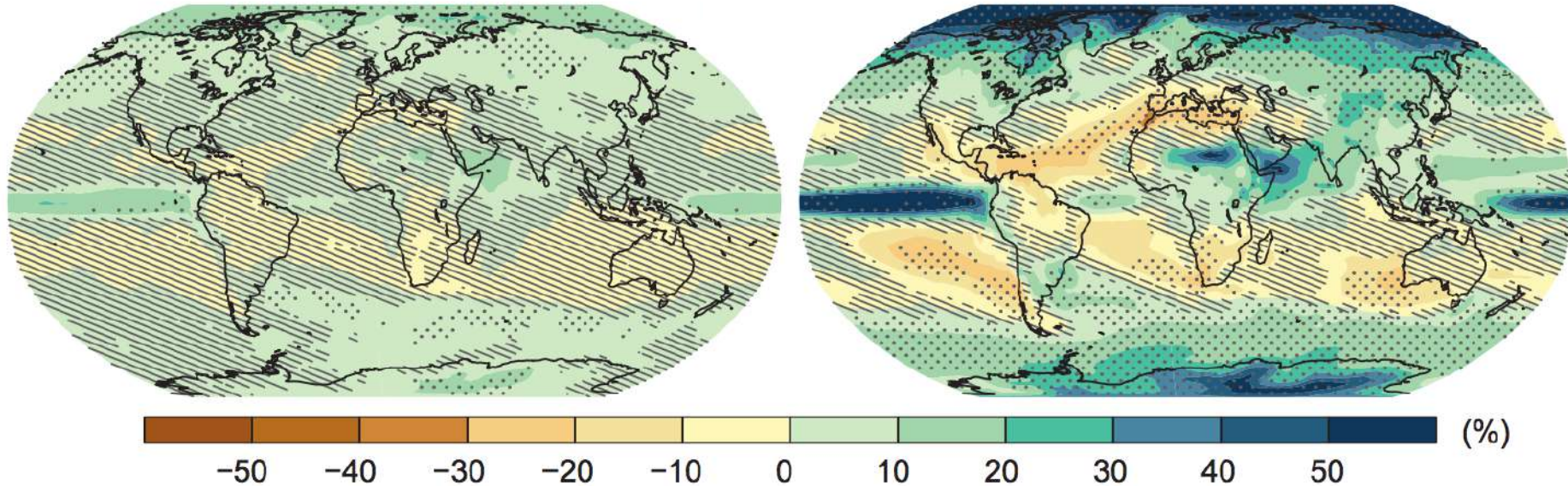
Source: Adapted from IPCC's latest report



Very low carbon

High carbon

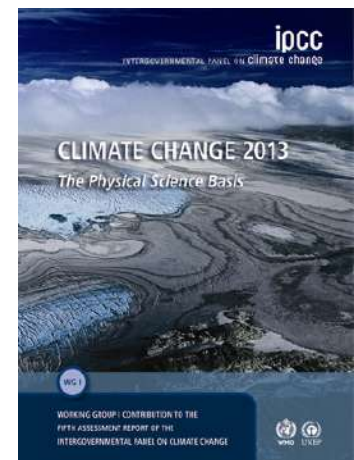
Change in average precipitation (1986–2005 to 2081–2100)



Stippling: multi-model variability is large relative to observed variability, 90% agreement on direction of change
Hatching: multi-model variability is small relative to observed variability

In general, wet areas
projected to get wetter,
and dry areas get drier.

Source: Adapted from IPCC's latest report



Not many people really
understand what all of this
means to them,
in part because it is *too*
far away, spatially and
temporally.

Many think that climate
change *so far* has generally
been a *good thing*.

Recent improvement and projected worsening of weather in the United States

Patrick J. Egan^{1*} & Megan Mullin^{2*}

Here we show that in the United States from 1974 to 2013, the weather conditions experienced by the vast majority of the population improved. Using previous research on how weather affects local population growth to develop an index of people's weather preferences, we find that 80% of Americans live in counties that are experiencing more pleasant weather than they did four decades ago. Virtually all Americans are now experiencing the much milder winters that they typically prefer, and these mild winters have not been offset by markedly more uncomfortable summers or other negative changes.



21 April 2016

If we want government,
communities, industry, citizens,
and planners to prepare...

they need to know
what to expect

We need to bring climate
change information *home*.

Prairie Climate Centre and the Prairie Climate Atlas

Visualizing Climate Change Projections for the
Canadian Prairie Provinces



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Acknowledgements



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THE
Great-West Life
ASSURANCE  COMPANY

Manitoba



About Us



Dr. Danny Blair

- Science Director, Prairie Climate Centre
- Climatologist
- Associate Dean, Faculty of Science
- Principal, Richardson College for the Environment
- Professor, Department of Geography
- University of Winnipeg



Dr. Ian Mauro

- Communications Director, Prairie Climate Centre
- Film maker, environmental scientist
- Associate Professor, Department of Geography
- University of Winnipeg



Ryan Smith, MSc

- Research Associate, Prairie Climate Centre
- Climate researcher, computer programmer and map designer
- University of Winnipeg



Dr. Hank Venema

- Planning Director, Prairie Climate Centre
- Policy analyst, International Institute for Sustainable Development
- Professional engineer
- Climate, water, energy, ecosystem management, environmental economics, agriculture policy expert

Role of the Prairie Climate Centre

- Mobilize knowledge about climate change
- To translate the science of climate change into language that can be understood by all
- To make the climate data relevant and engaging:
 - Localize and visualize the data
 - Tell stories using words and film

Role of the Prairie Climate Centre

- Make climate change data **accessible** to all
- Inform **policy** and develop **solutions**
- Inspire **adaptation** and **mitigation**
- Build decision making **tools**
- Produce peer-reviewed **research** results
- Foster Prairie-wide **collaborations** and **partnerships**
- Conduct workshops and **training** sessions

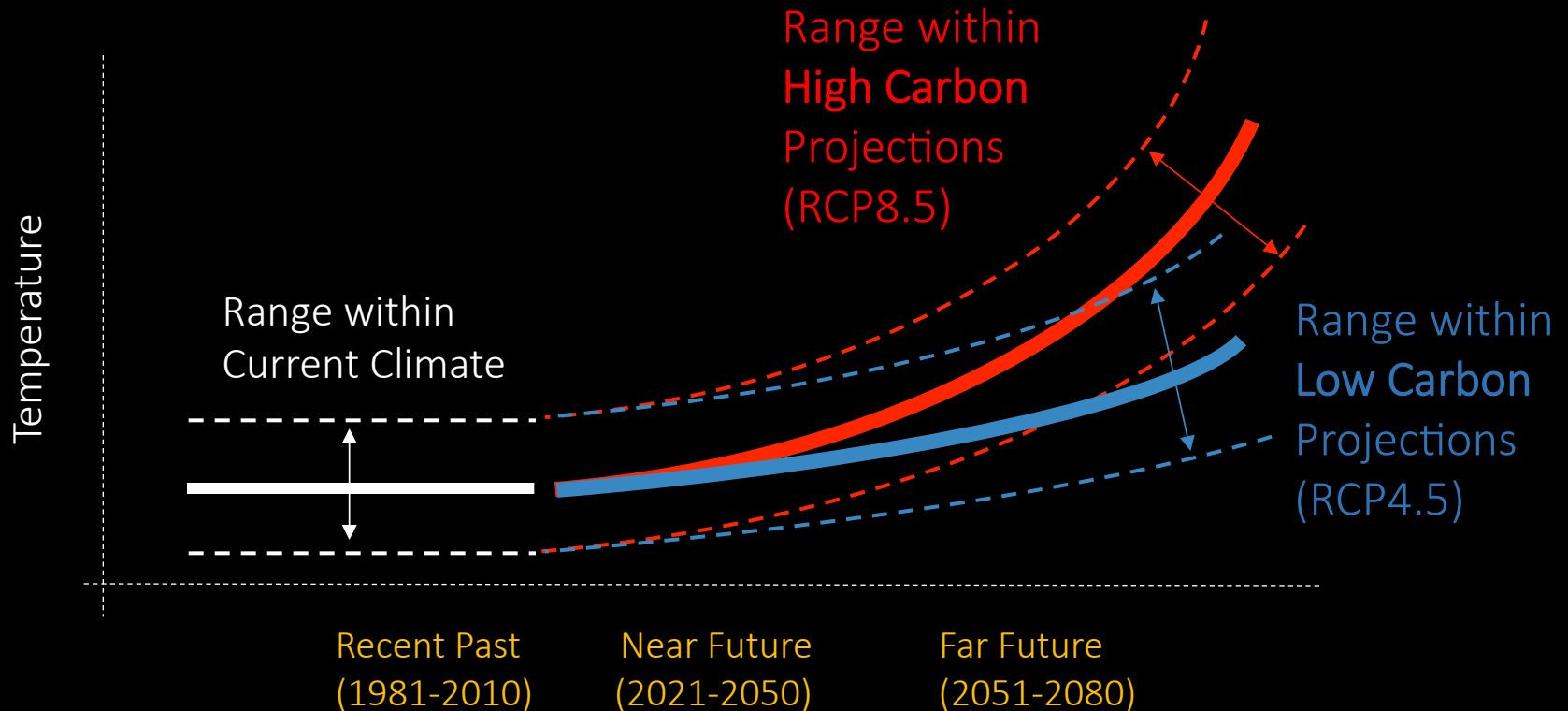
How is the prairie climate expected to change?

It depends on:
models, emissions, time.

- We use data from 12 downscaled global climate models to produce ensemble (average) projected conditions for the region
- Downscaled data was produced by the Pacific Climate Impacts Consortium (PCIC) in Victoria, BC
- Projections using two Carbon Emissions Scenarios are used to represent the uncertainty associated with future concentrations of greenhouse gases
- Projections are shown for two future time periods: near future (2021-2050) and far future (2051-2080). Changes often shown relative to 1981-2010 baseline period (modeled).

Projections Summary

- Climate projections were extracted from:
 - 12 Global Climate Models, each using
 - 2 Carbon Emissions Scenarios



References

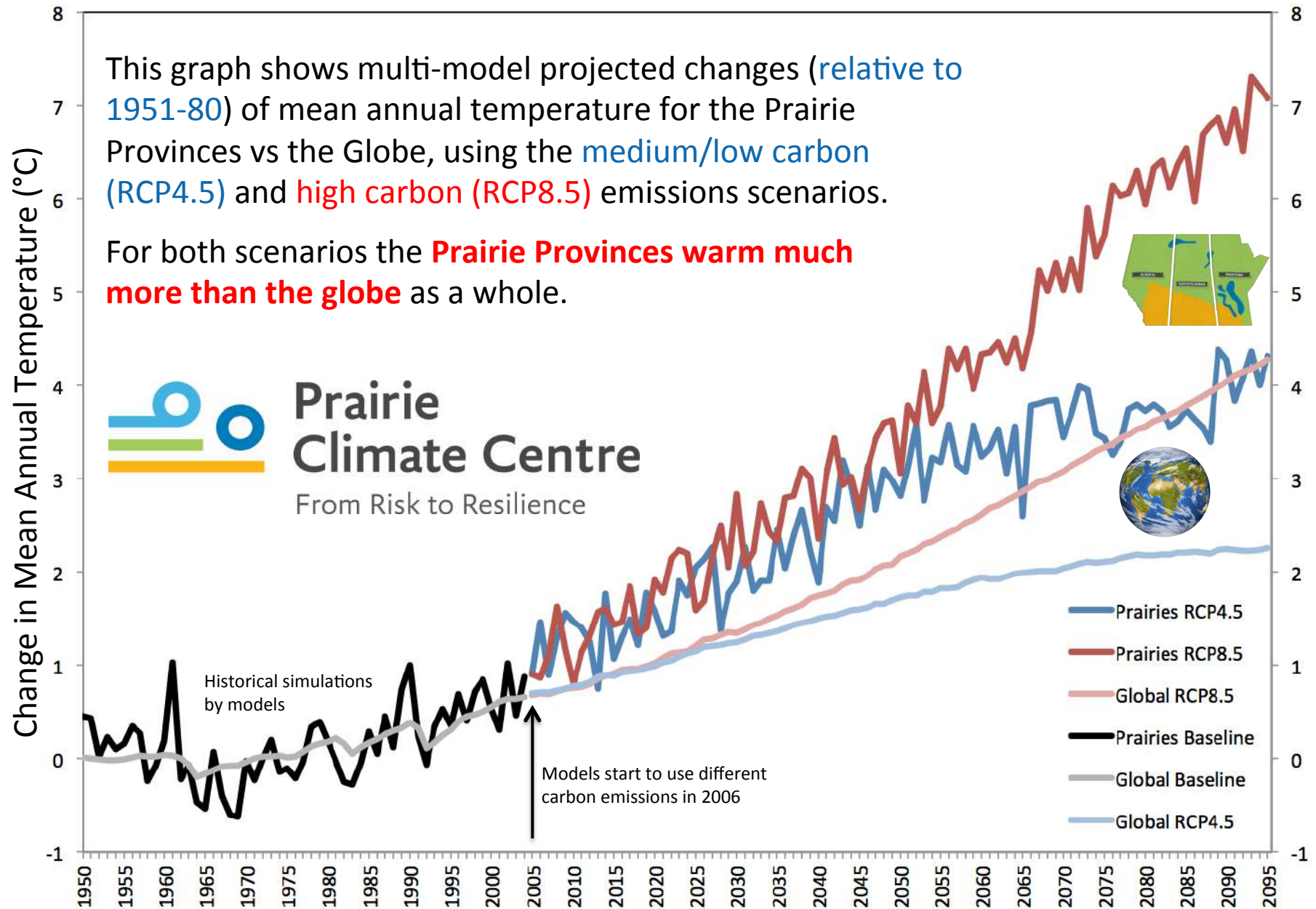
BCSD-downscaled climate data supplied by:

Pacific Climate Impacts Consortium, University of Victoria, (Jan. 2015). Statistically Downscaled Climate Scenarios. Downloaded from *pacificclimate.org*

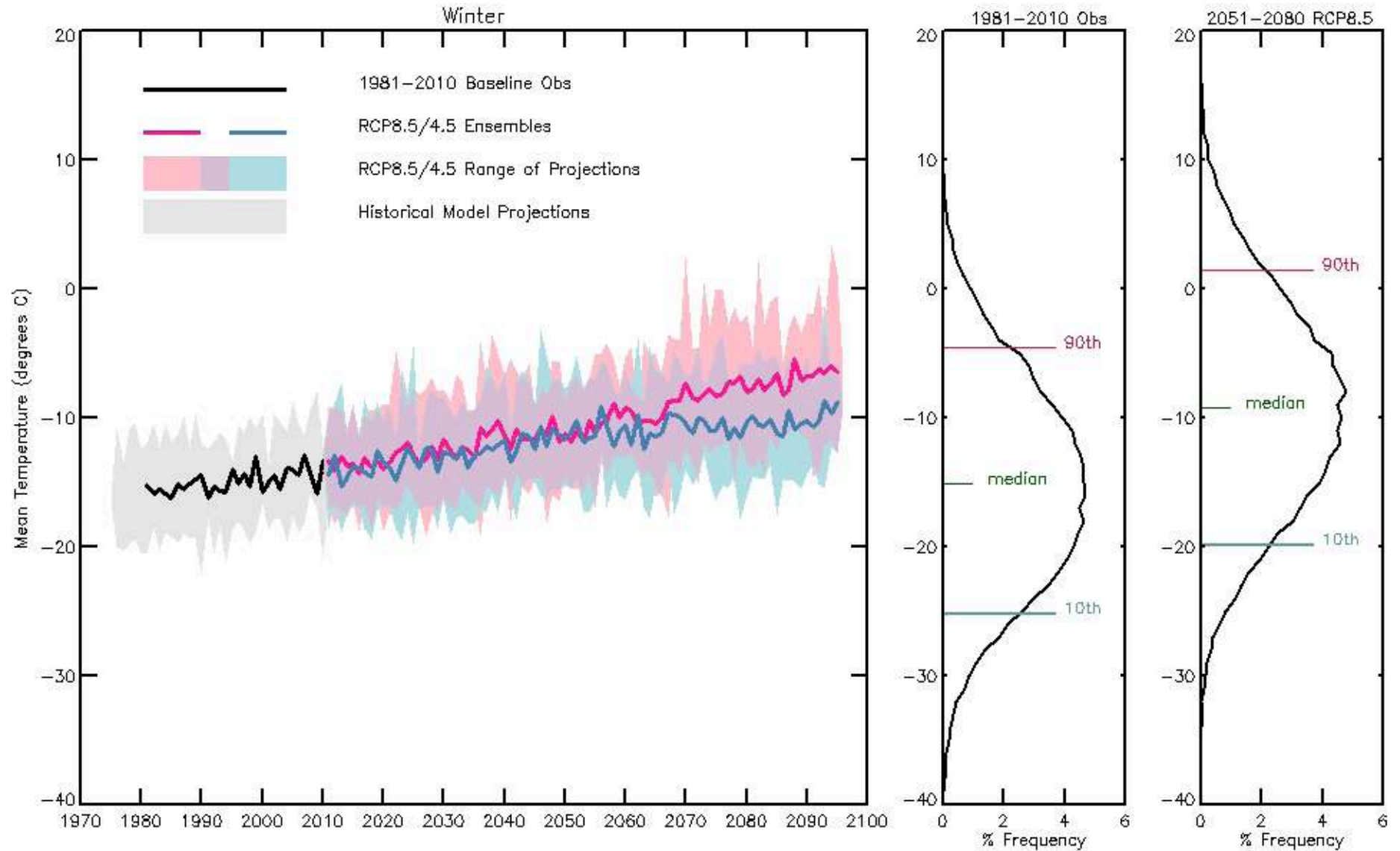
THANK YOU PCIC

AdaptWest Project. 2015. Gridded current and projected climate data for North America at 1km resolution, interpolated using the ClimateNA v5.10 software (T. Wang et al., 2015). Available at *adaptwest.databasin.org*

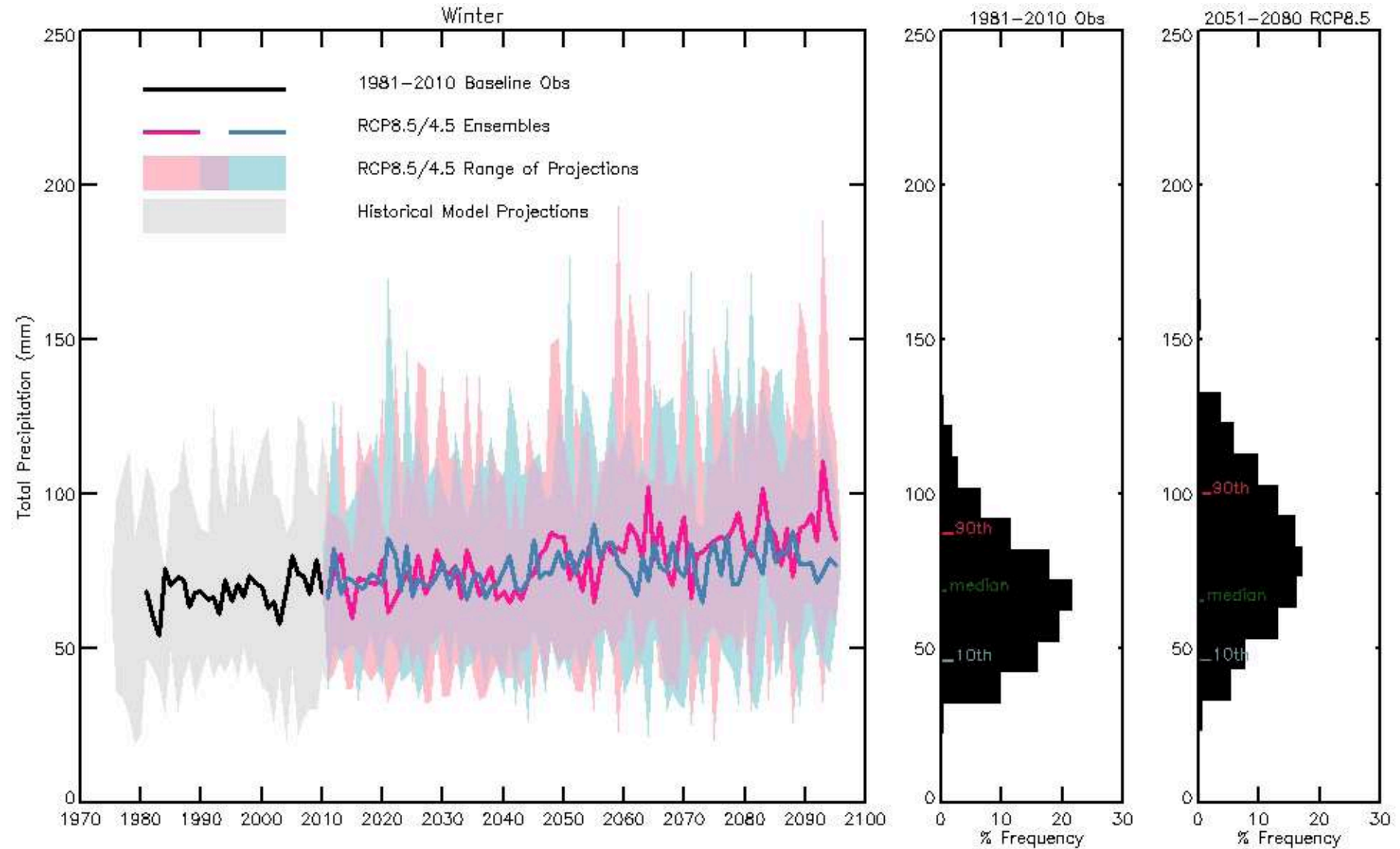
Projected Change of Annual Temperature in Prairie Provinces vs Globe



Historic and Projected (RCP4.5/8.5) Winter Temperature: Winnipeg



Historic and Projected (RCP4.5/8.5) Winter Precipitation: Winnipeg



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Spring Precipitation



Prairie Precipitation

Projected Changes in Total Spring Precipitation

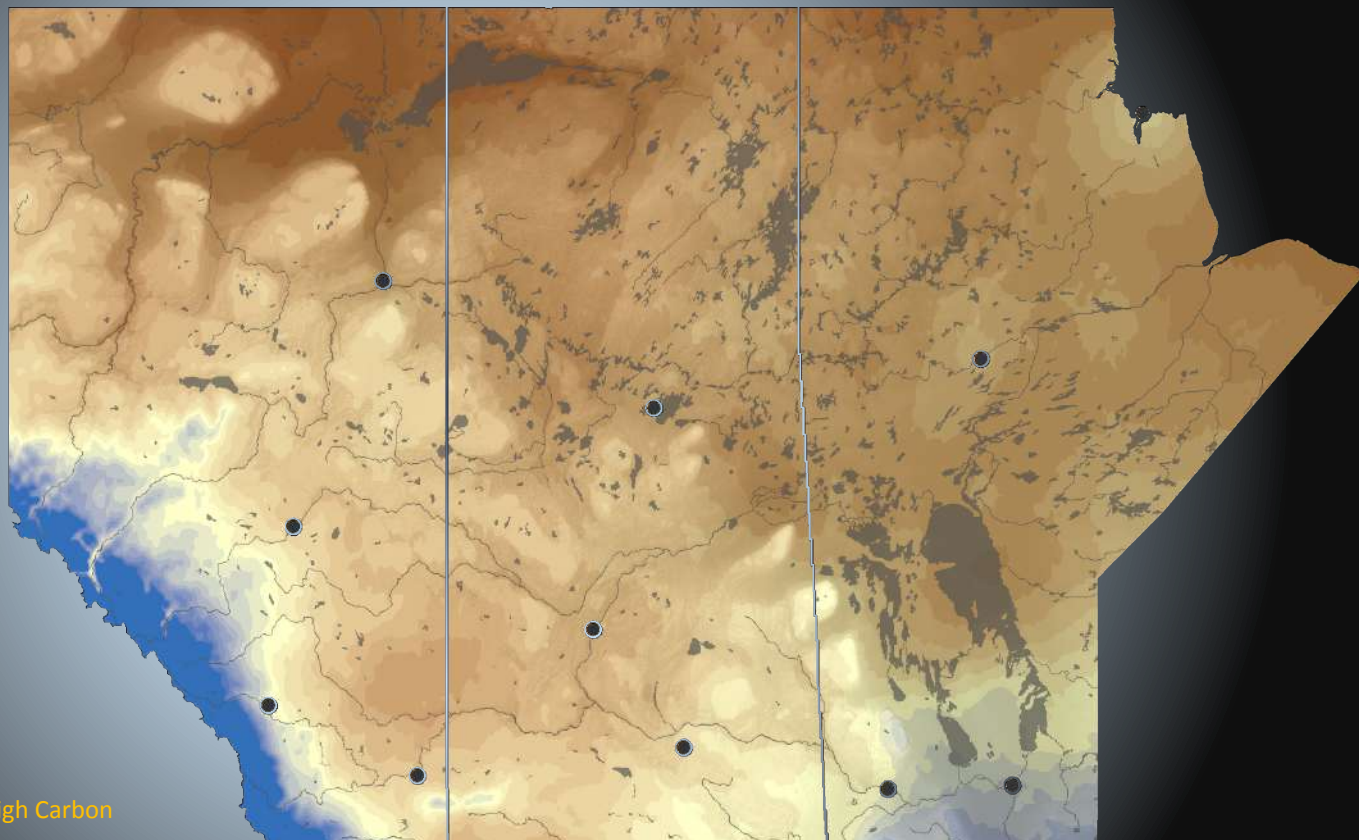


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Climate Centre

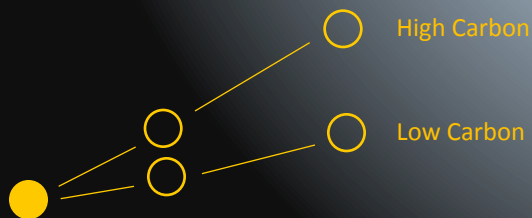
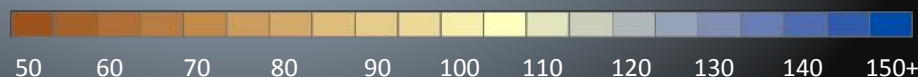
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1981-2010 Total Spring Precipitation (mm)



Recent Past Near Future Far Future

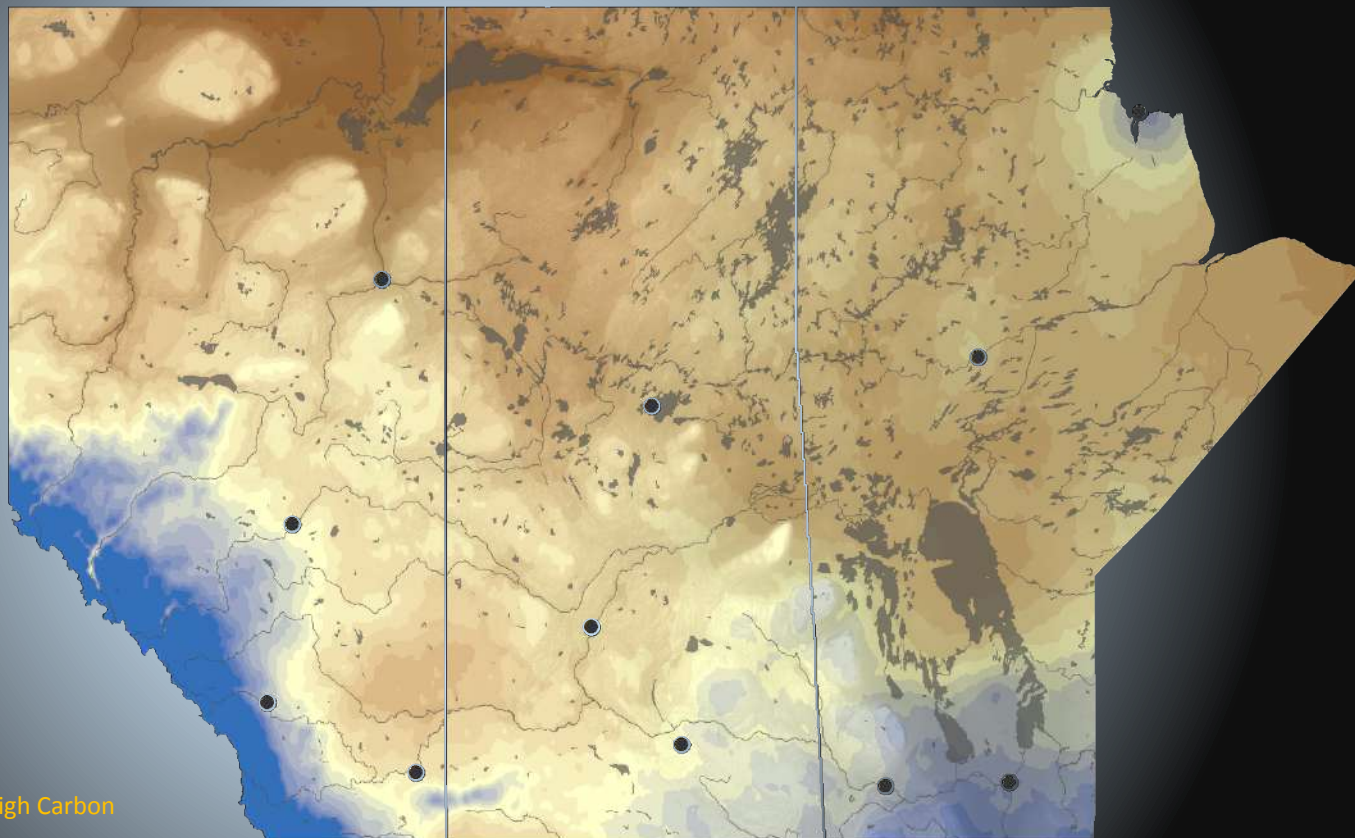
Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
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Prairie Precipitation

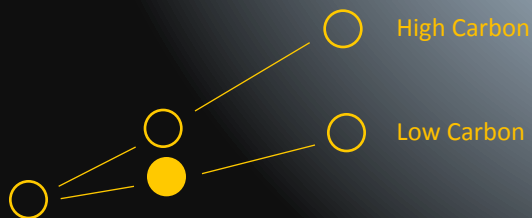
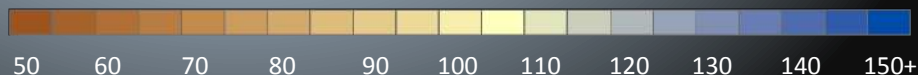
Projected Changes in Total Spring Precipitation



Prairie
Climate Centre



2021-2050 Total Spring Precipitation (mm)



Recent Past Near Future Far Future

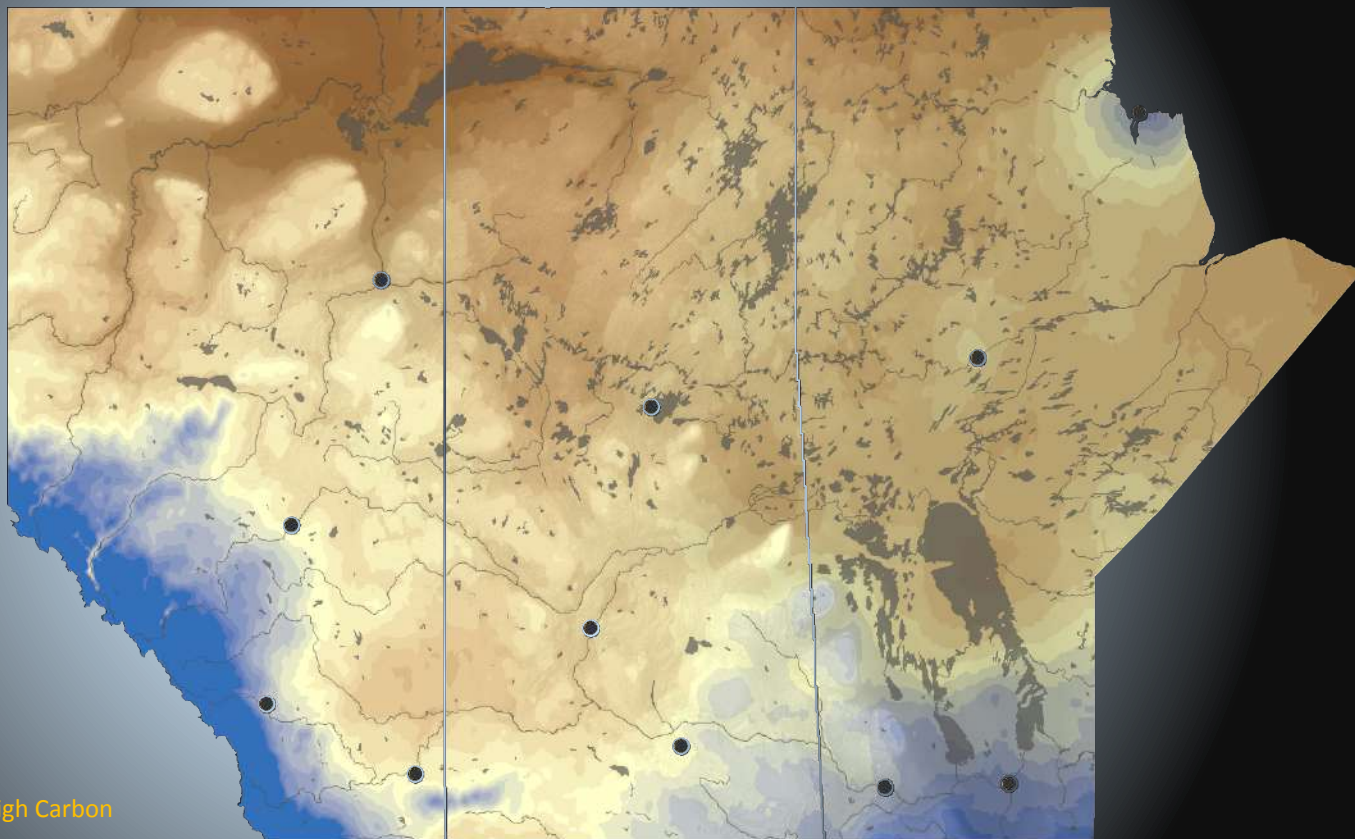
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Prairie Precipitation

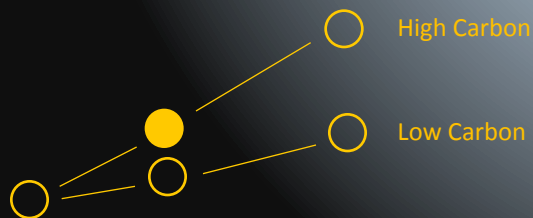
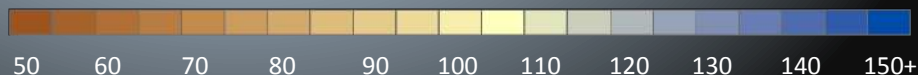
Projected Changes in Total Spring Precipitation



Prairie
Climate Centre



2021-2050 Total Spring Precipitation (mm)



Recent Past Near Future Far Future

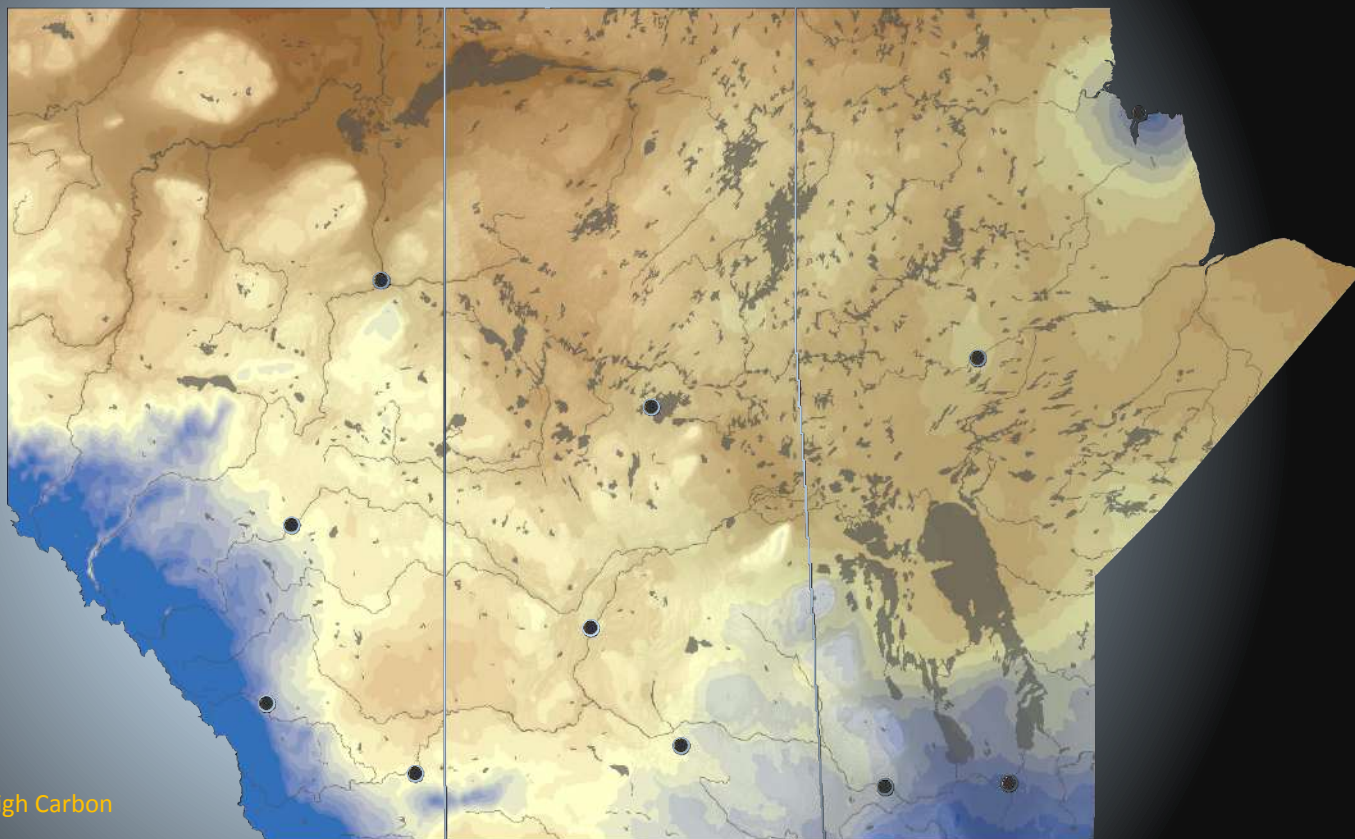
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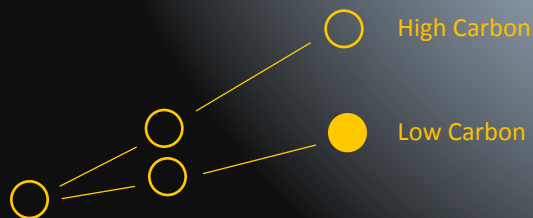
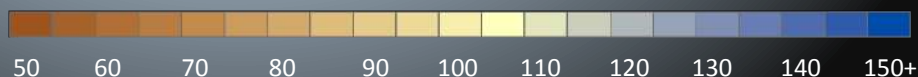
Projected Changes in Total Spring Precipitation



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Climate Centre



2051-2080 Total Spring Precipitation (mm)

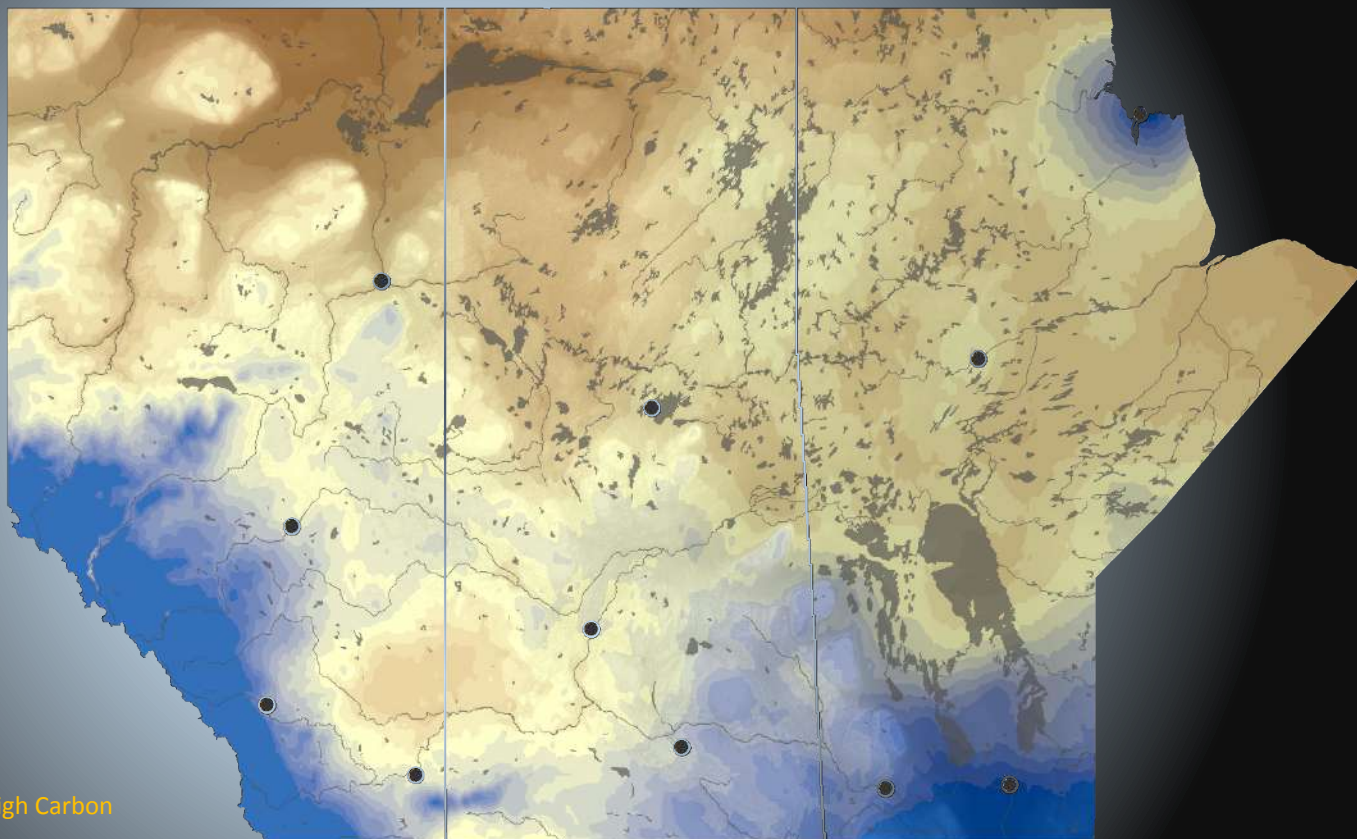


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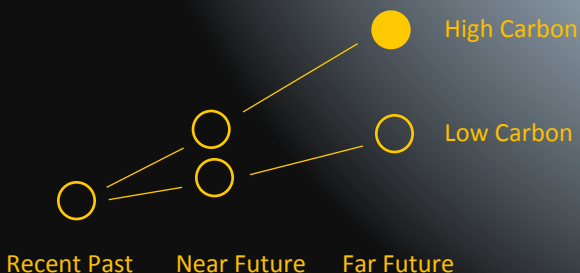
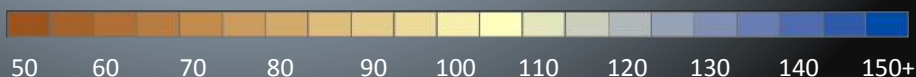
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Prairie Precipitation

Projected Changes in Total Spring Precipitation



2051-2080 Total Spring Precipitation (mm)



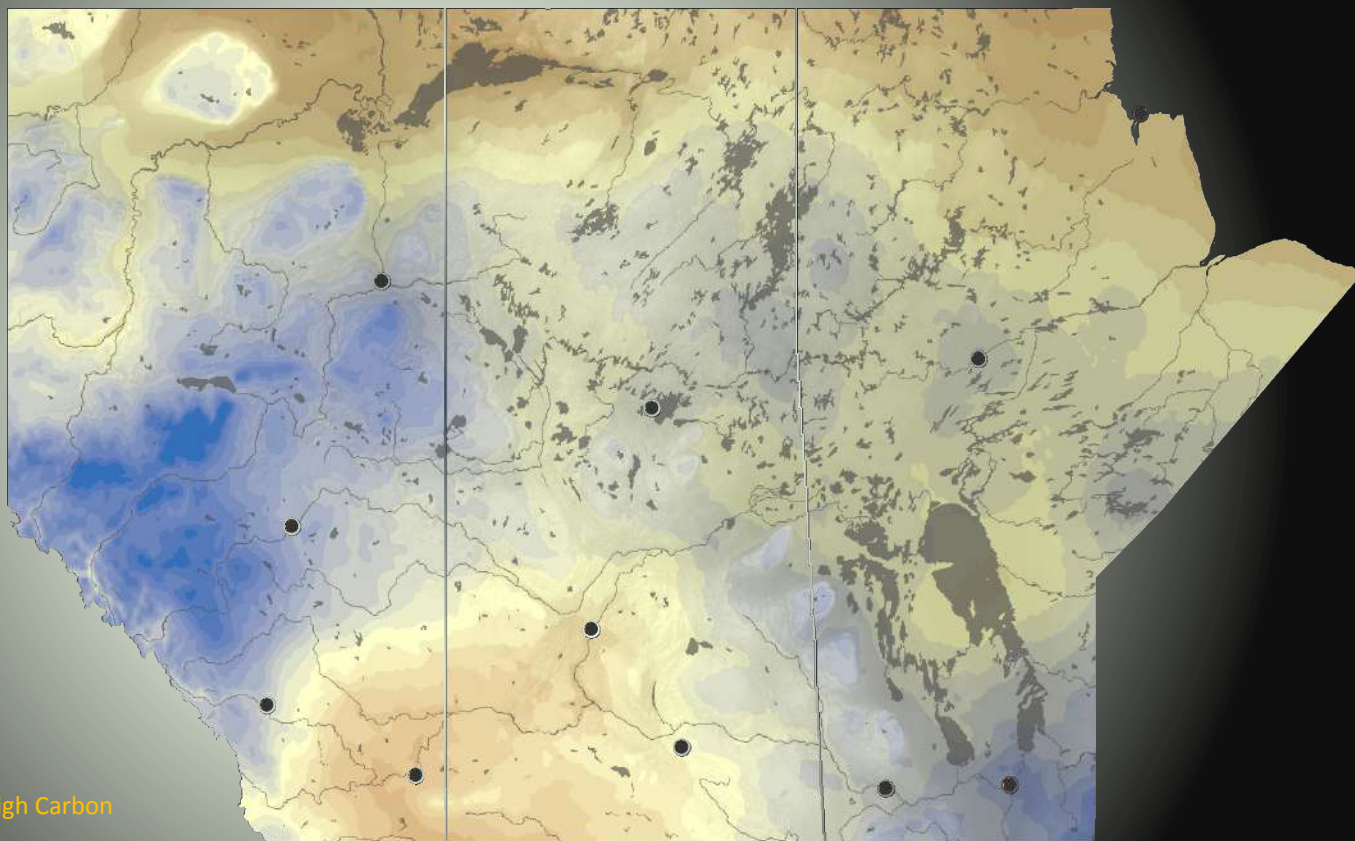
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Summer Precipitation

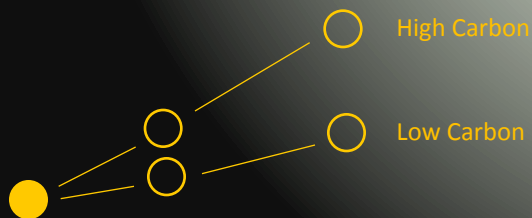
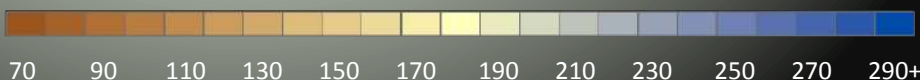


Prairie Precipitation

Projected Changes in Total Summer Precipitation



1981-2010 Total Summer Precipitation (mm)

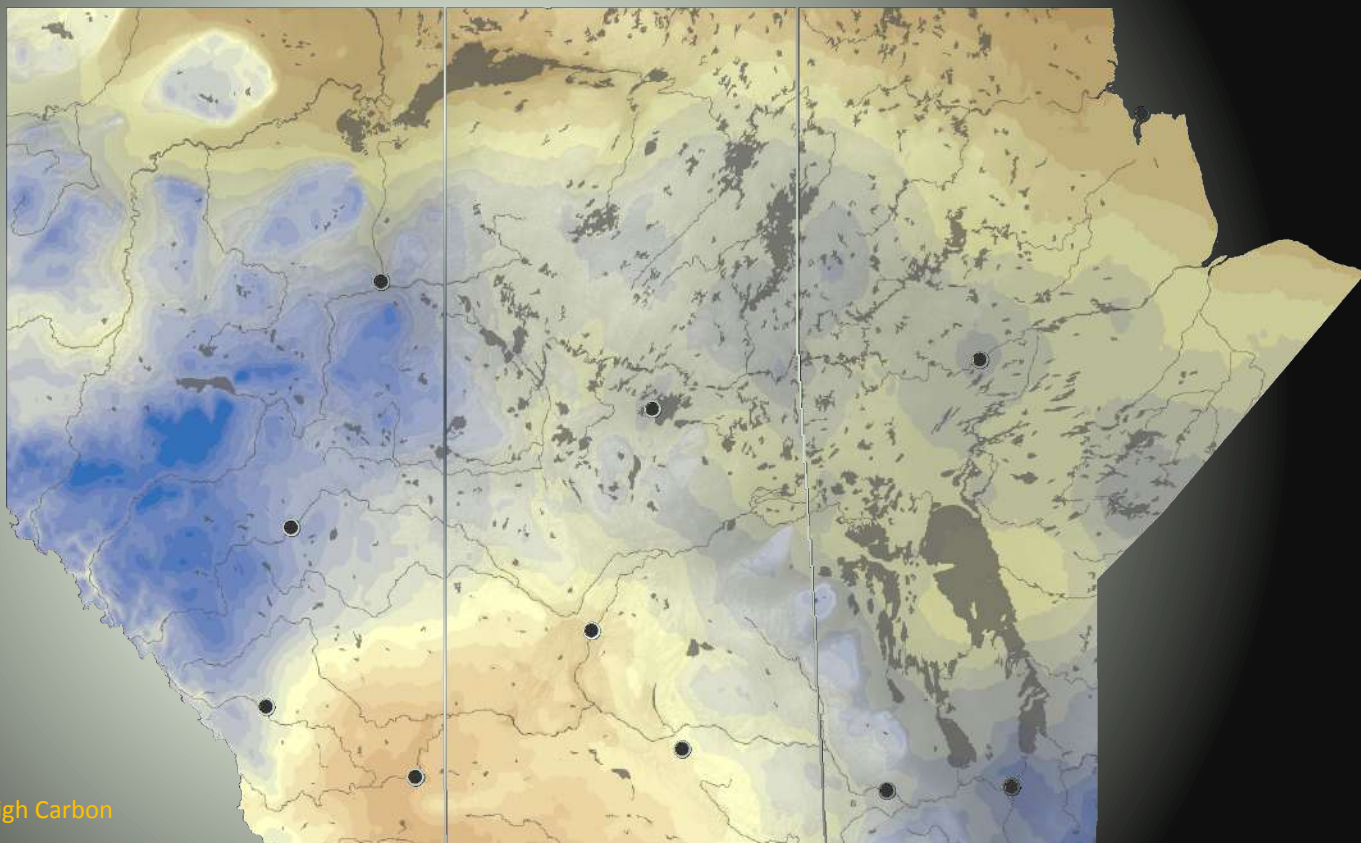


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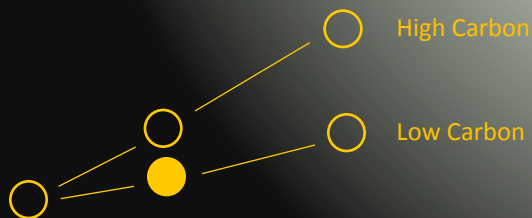
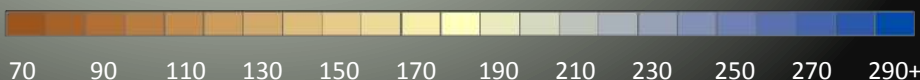
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Prairie Precipitation

Projected Changes in Total Summer Precipitation



2021-2050 Total Summer Precipitation (mm)



Recent Past Near Future Far Future

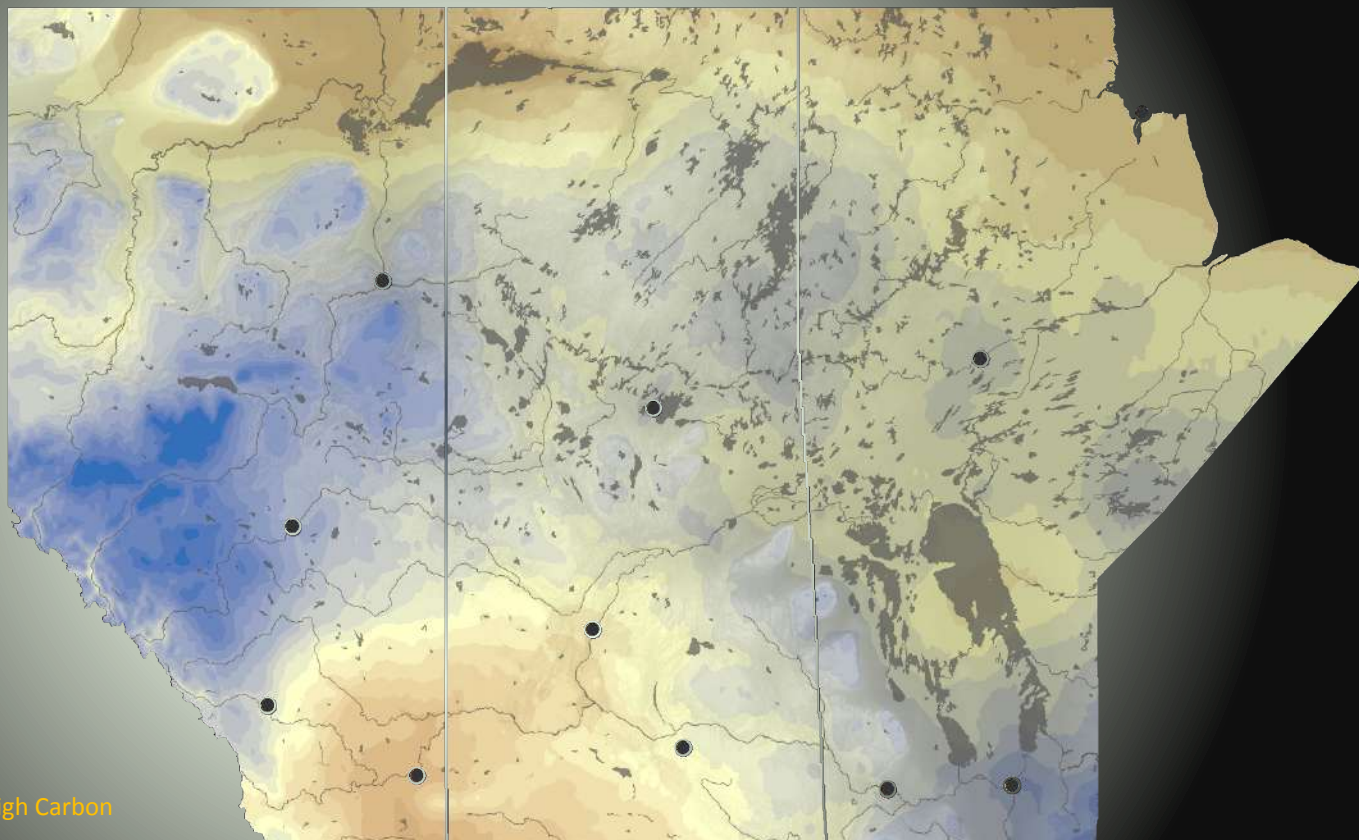
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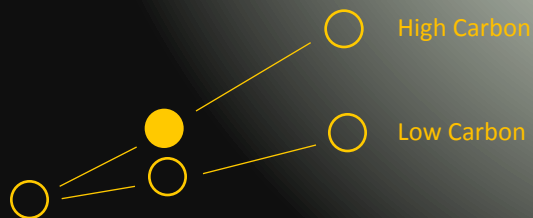
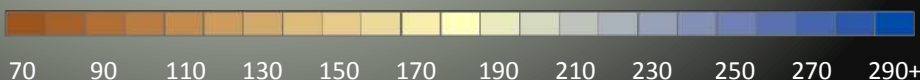
Projected Changes in Total Summer Precipitation



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2021-2050 Total Summer Precipitation (mm)

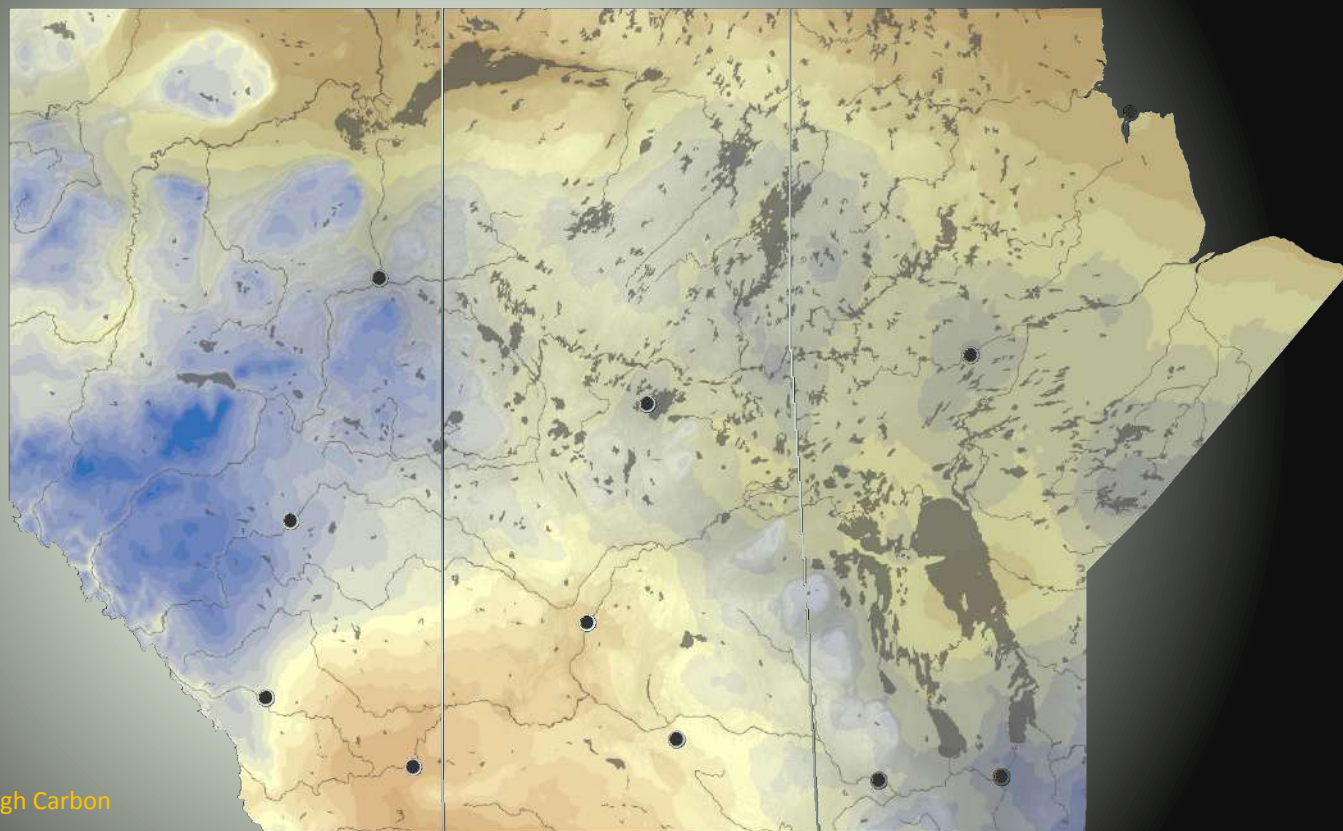


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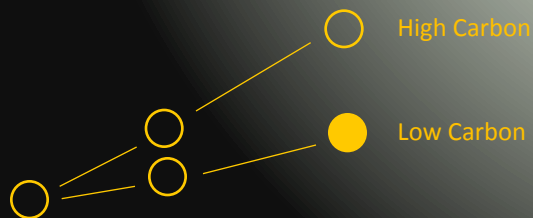
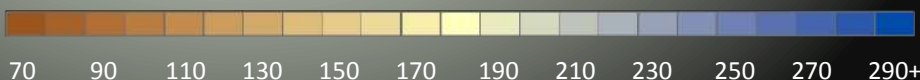
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Prairie Precipitation

Projected Changes in Total Summer Precipitation



2051-2080 Total Summer Precipitation (mm)

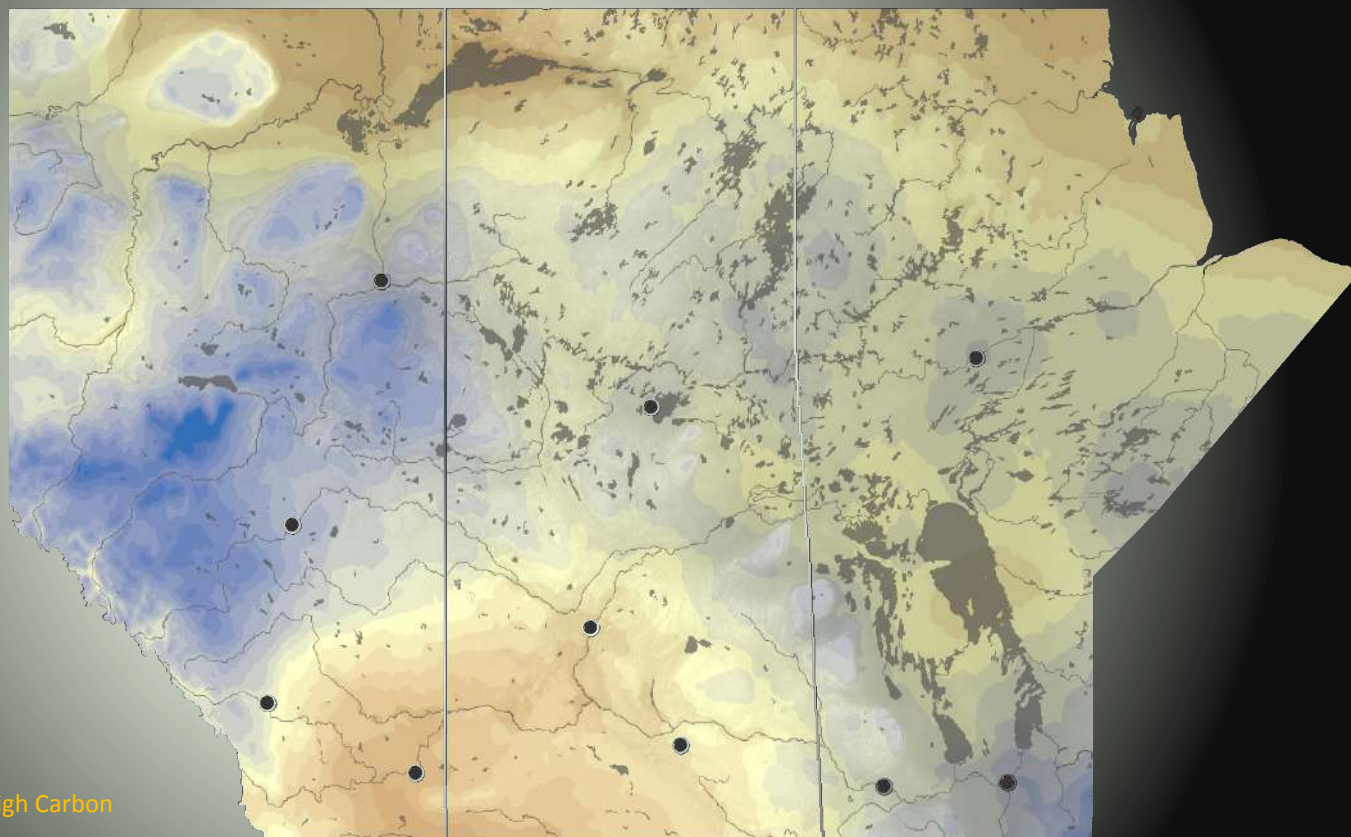


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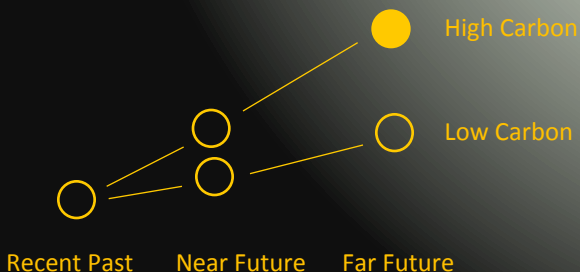
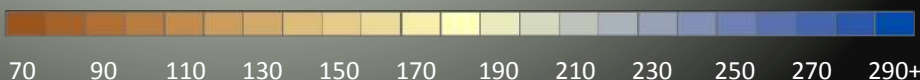
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Prairie Precipitation

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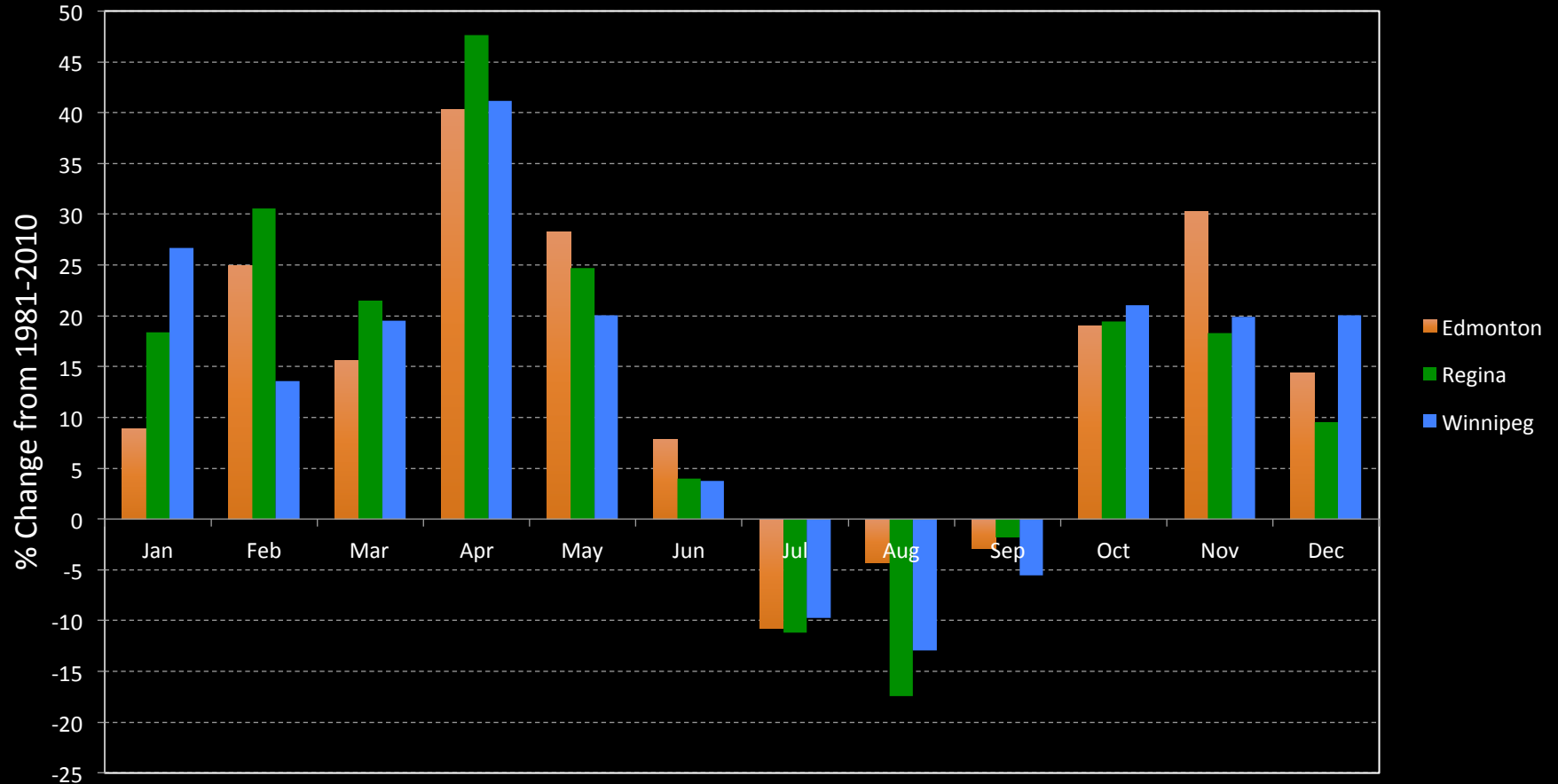


2051-2080 Total Summer Precipitation (mm)

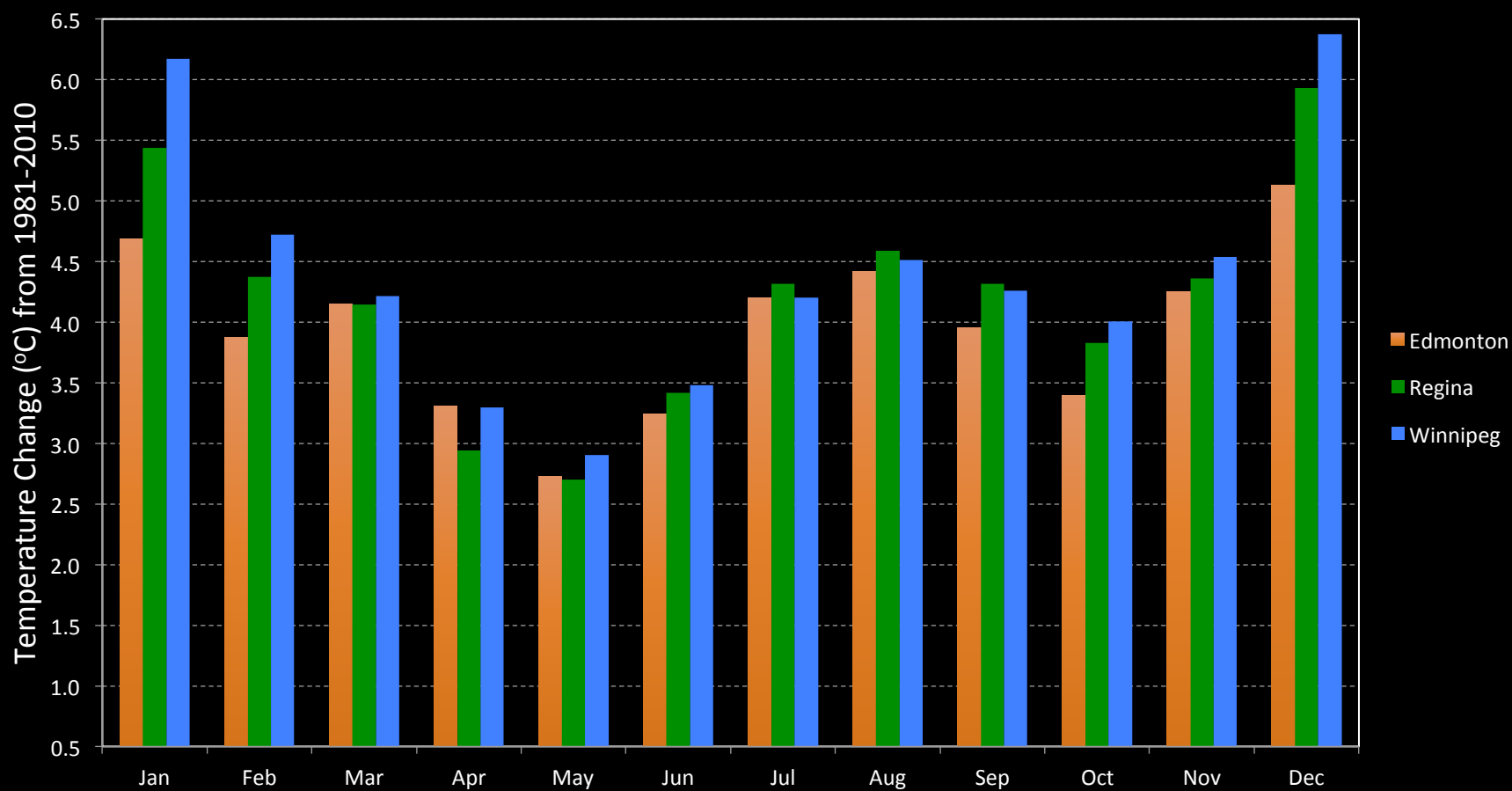


Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
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2051-2080 Δ PPT: RCP8.5



2051-2080 ΔT : RCP8.5



**Days -30°
or Colder**



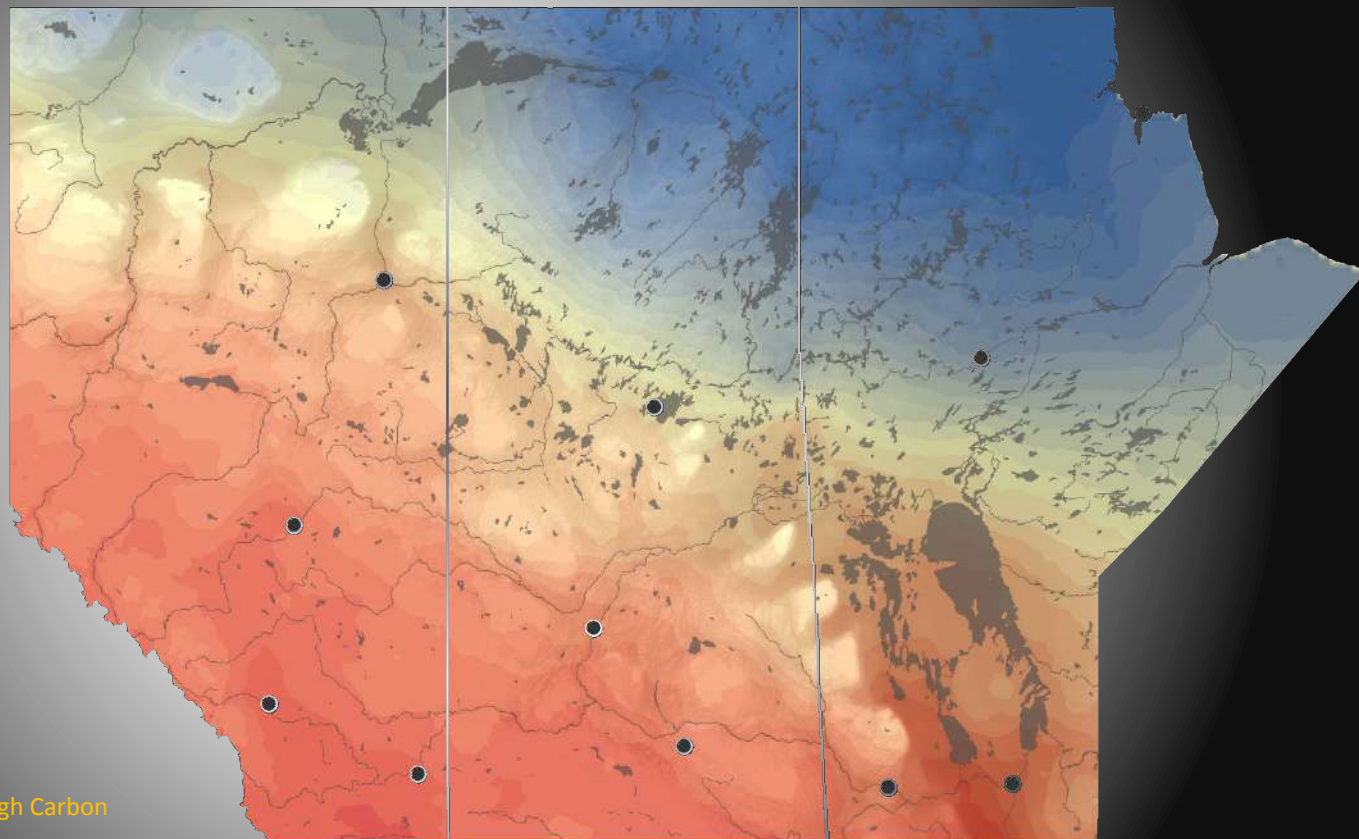
Shifting Extremes

Change in the Number of Very Cold Days

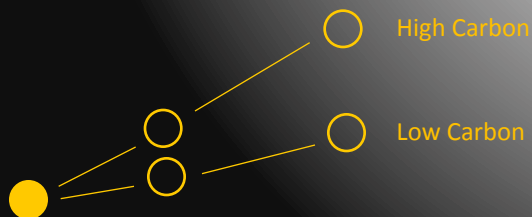
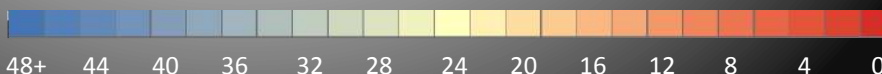
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1981-2010 Annual number of days $\leq -30^{\circ}\text{C}$



Recent Past Near Future Far Future

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Shifting Extremes

Change in the Number of Very Cold Days

Five different versions of maps for each variable will be presented:

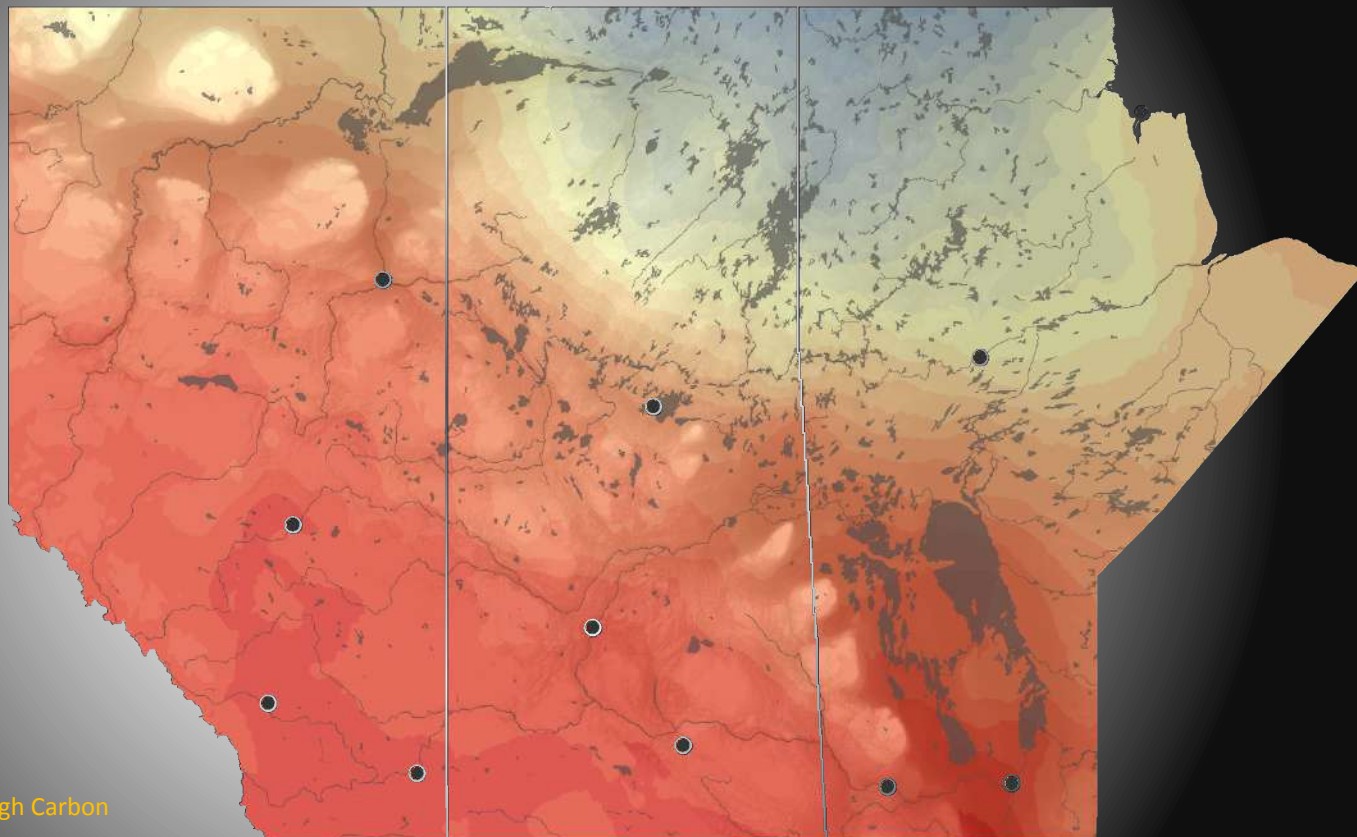
1981-2010

2021-2050 (RCP4.5)

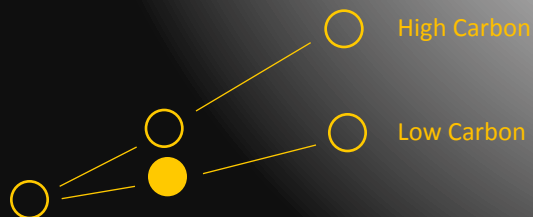
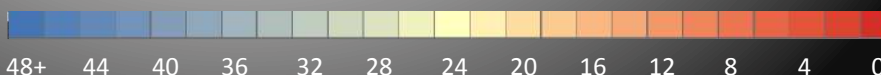
2021-2050 (RCP8.5)

2051-2080 (RCP4.5)

2051-2080 (RCP8.5)



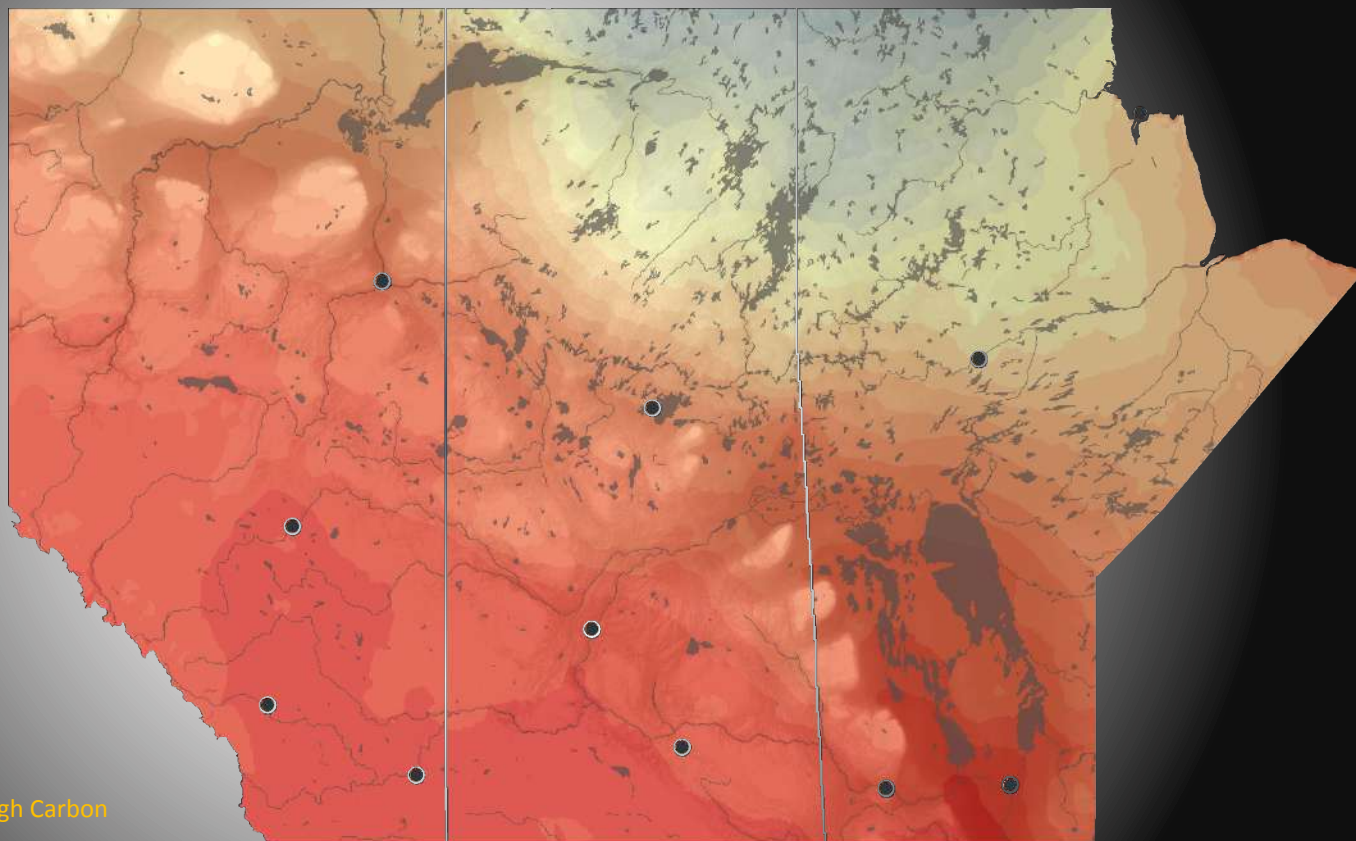
2021-2050 Annual number of days $\leq -30^{\circ}\text{C}$



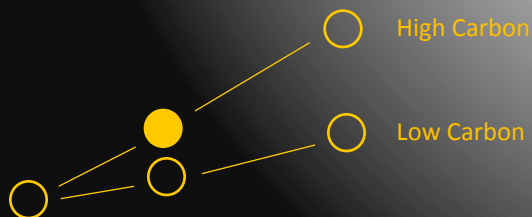
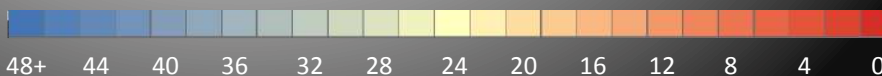
Recent Past Near Future Far Future

Shifting Extremes

Change in the Number of Very Cold Days



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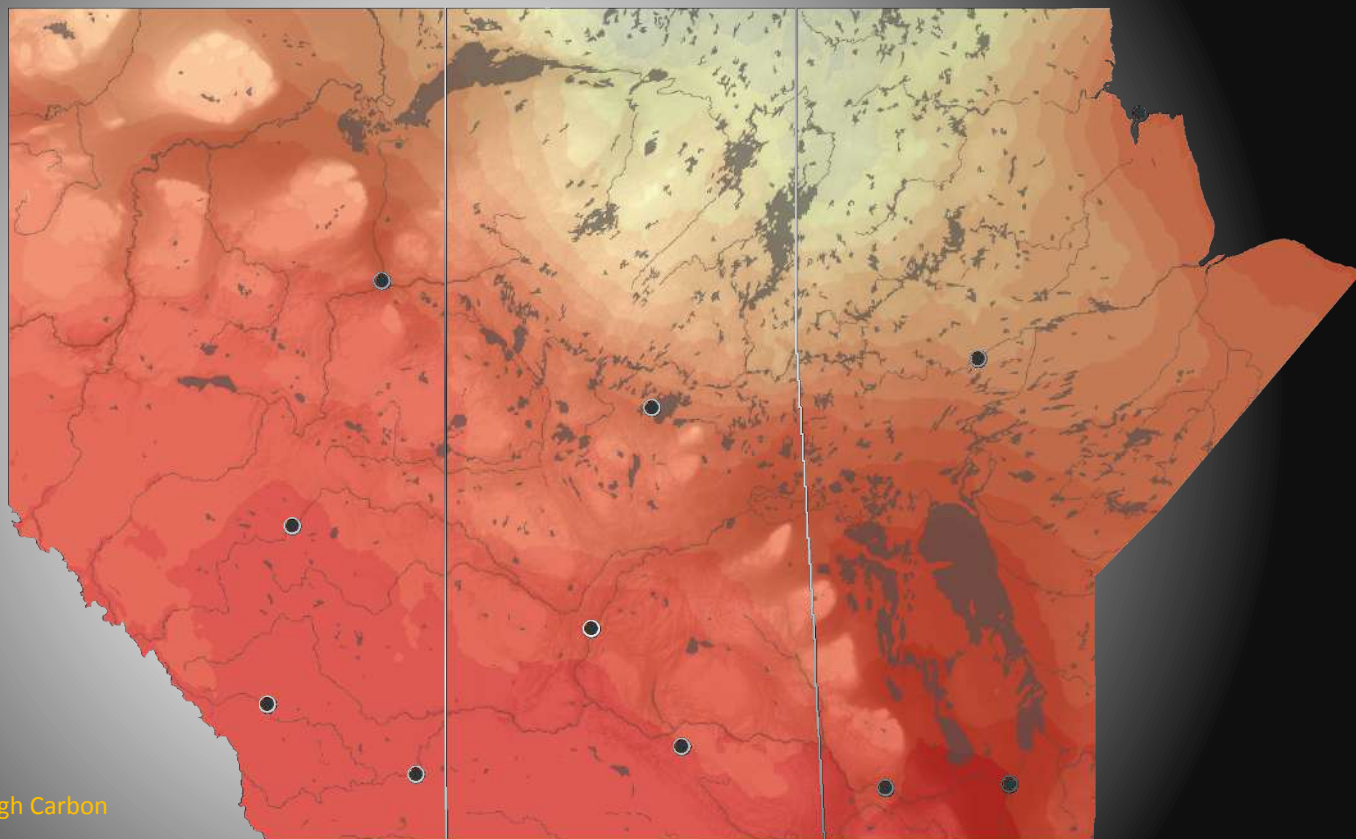


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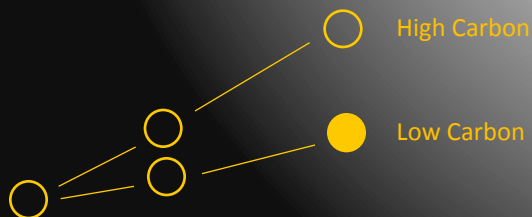
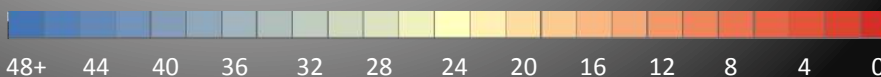
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Shifting Extremes

Change in the Number of Very Cold Days



2051-2080 Annual number of days $\leq -30^{\circ}\text{C}$

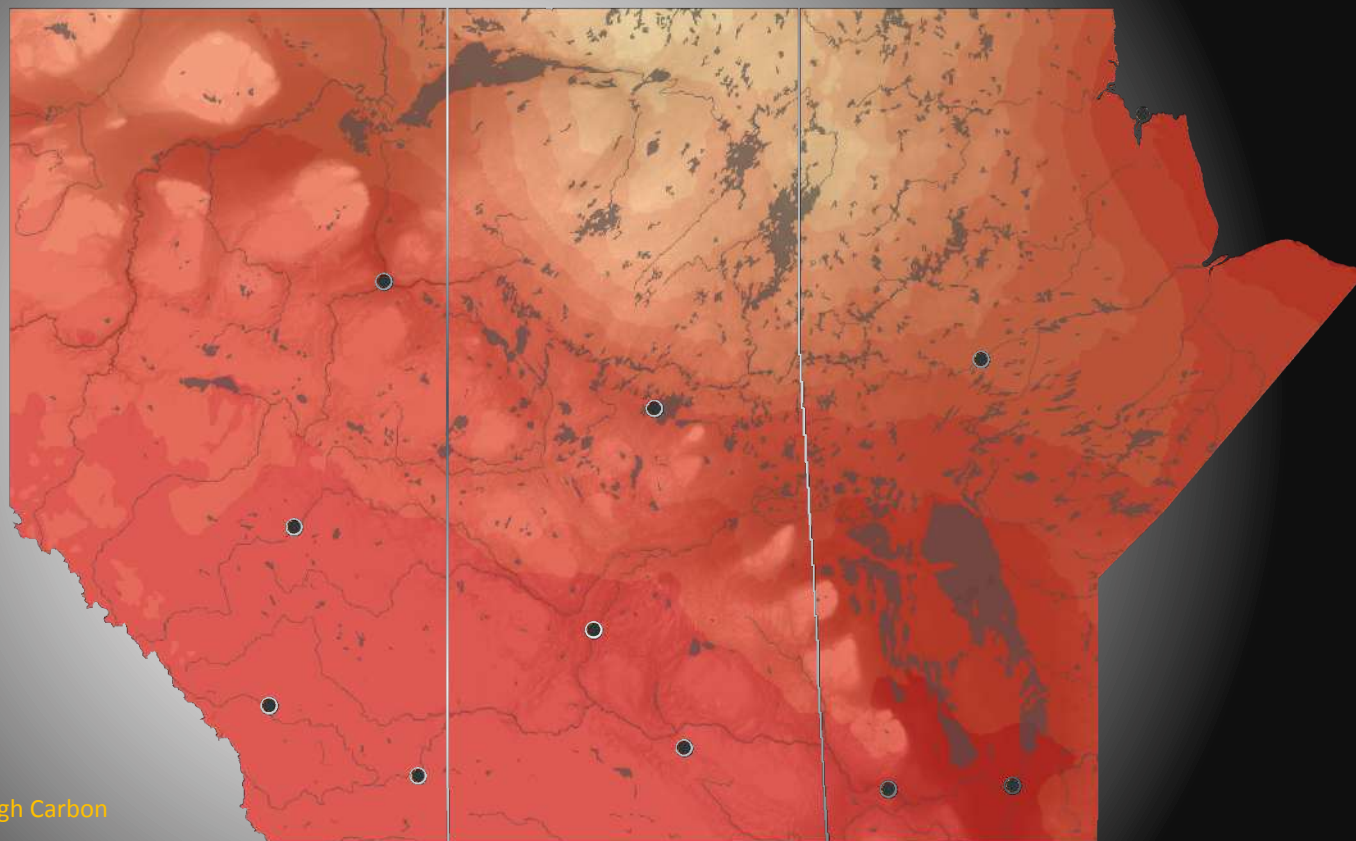


Recent Past Near Future Far Future

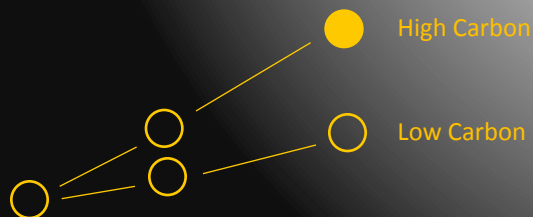
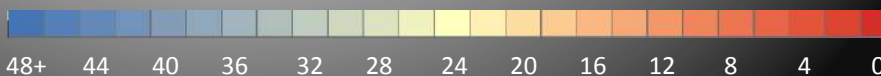
Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

Shifting Extremes

Change in the Number of Very Cold Days



2051-2080 Annual number of days $\leq -30^{\circ}\text{C}$



Recent Past Near Future Far Future

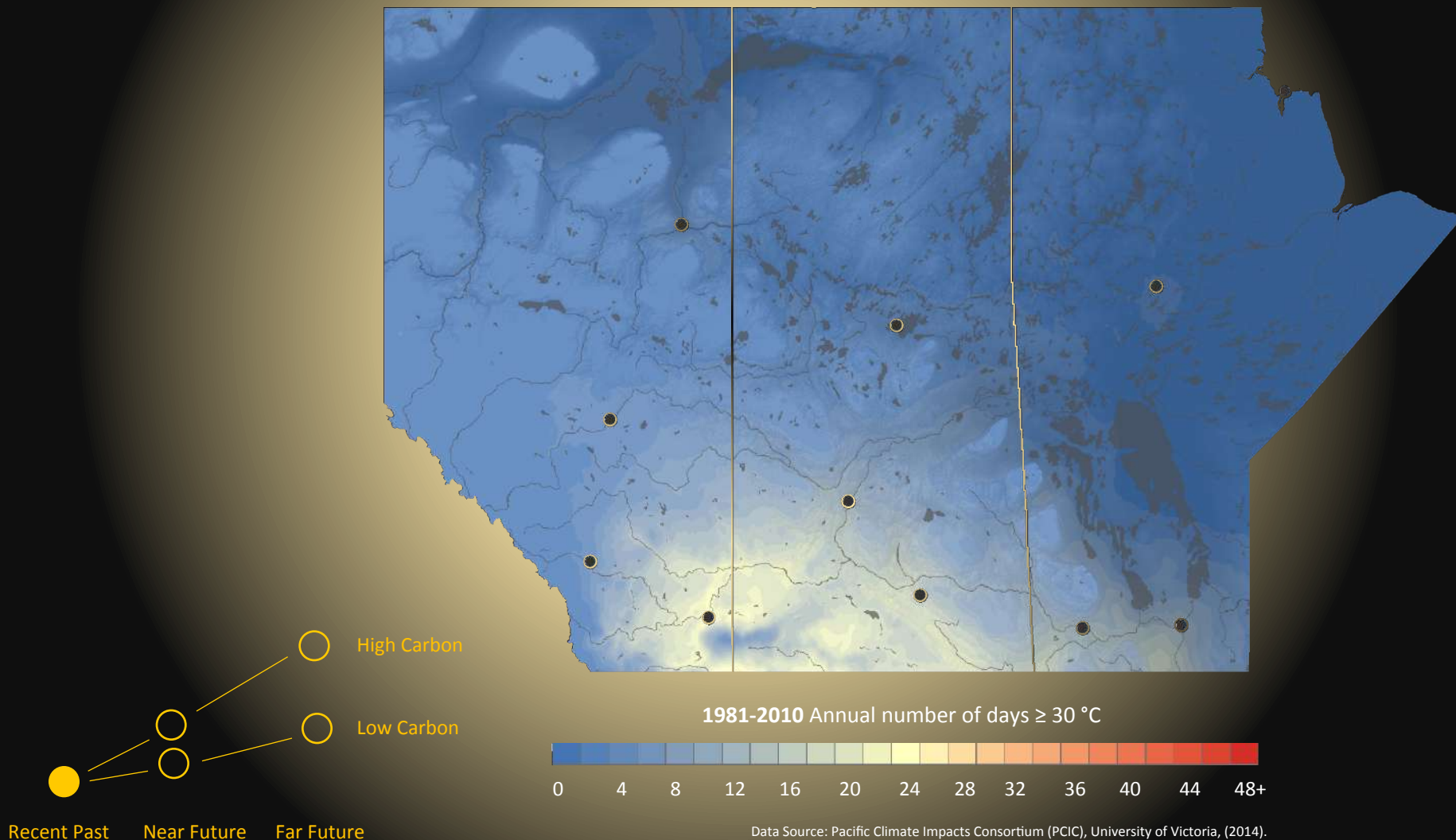
Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

**Days +30°
or Warmer**



Shifting Extremes

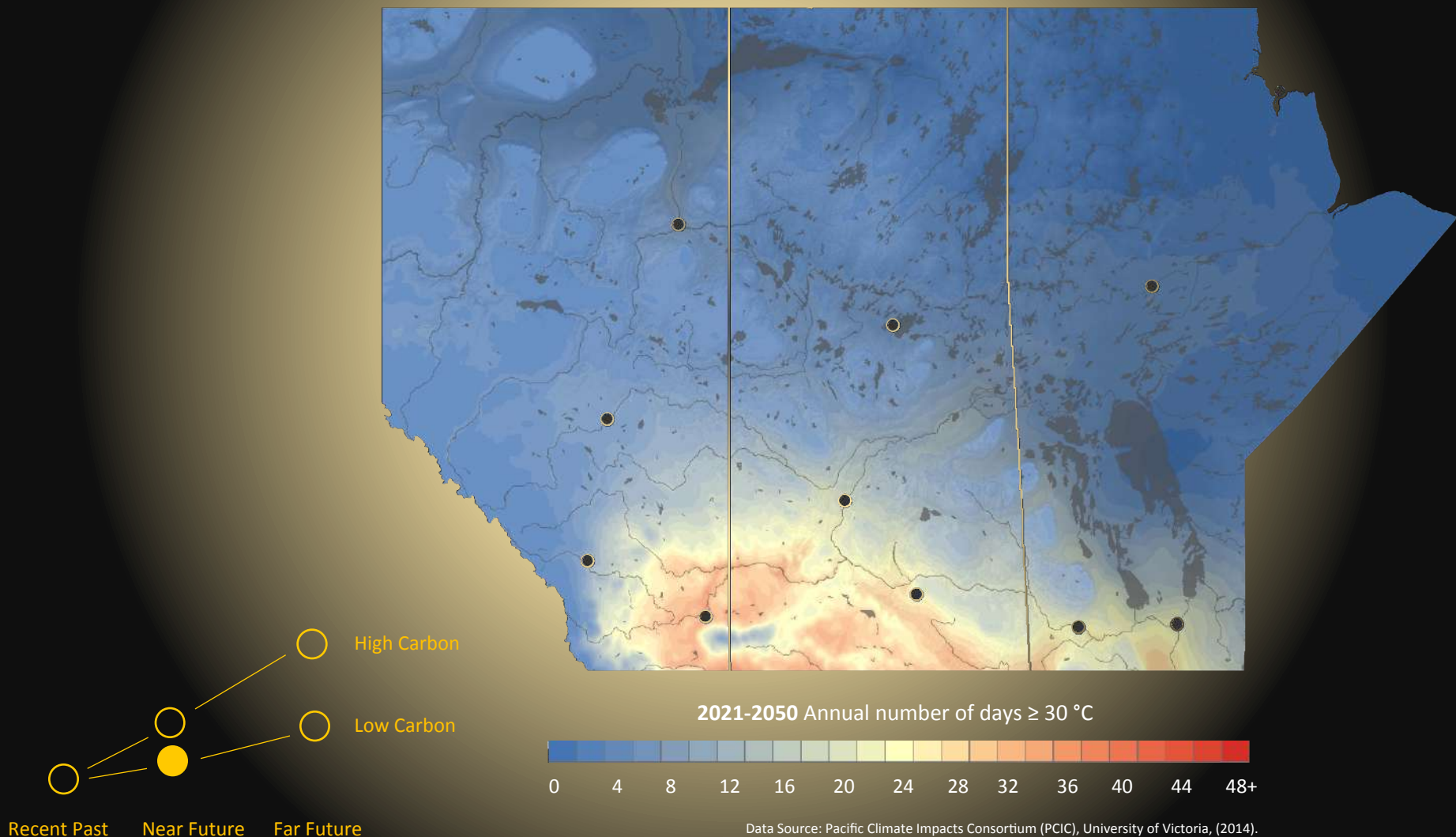
Change in the Number of Very Hot Days



Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

Shifting Extremes

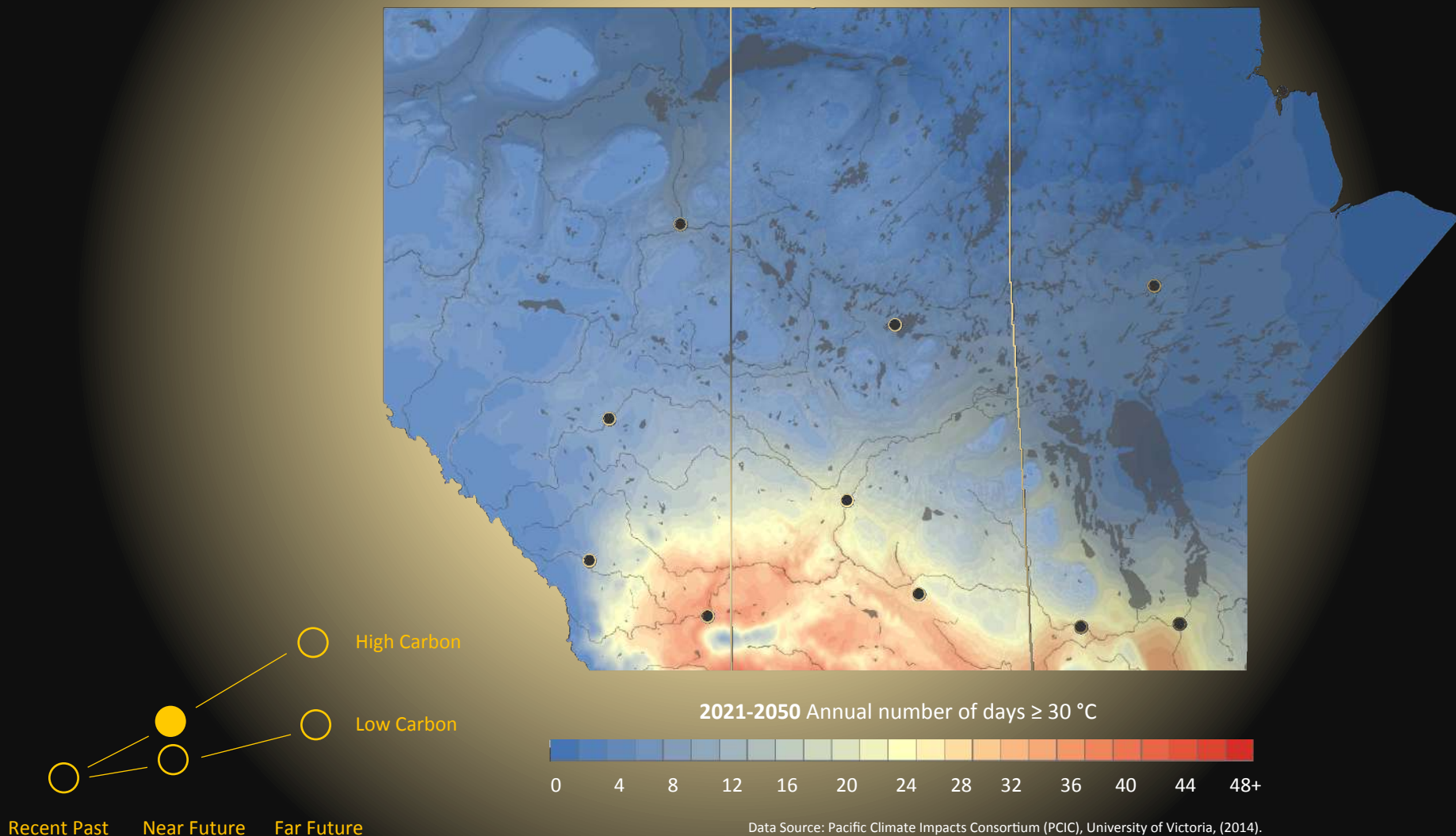
Change in the Number of Very Hot Days



Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

Shifting Extremes

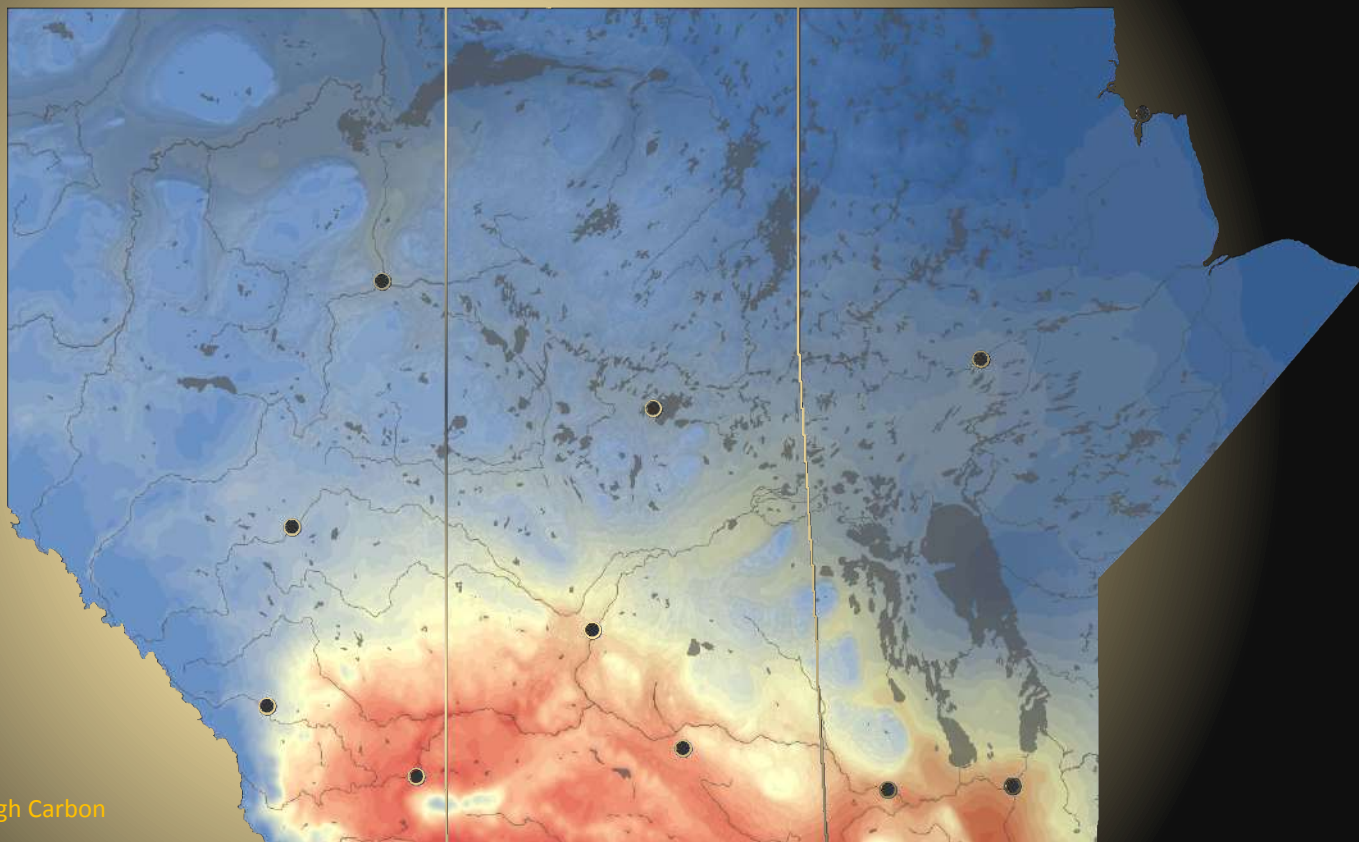
Change in the Number of Very Hot Days



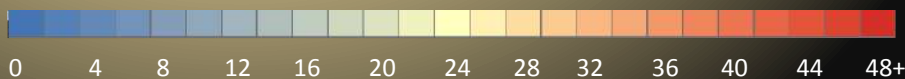
Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

Shifting Extremes

Change in the Number of Very Hot Days



2051-2080 Annual number of days $\geq 30^\circ\text{C}$



Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

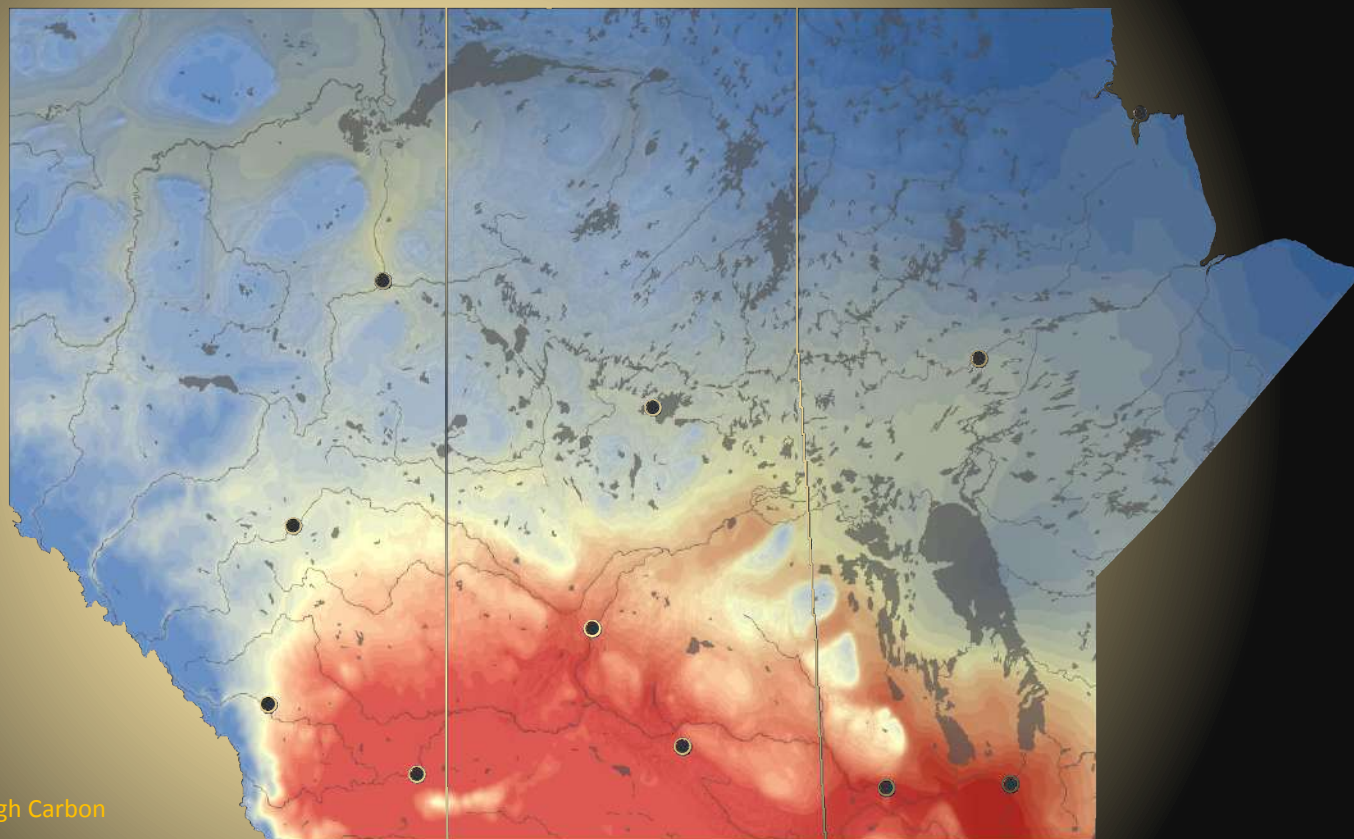
Recent Past Near Future Far Future

Near Future

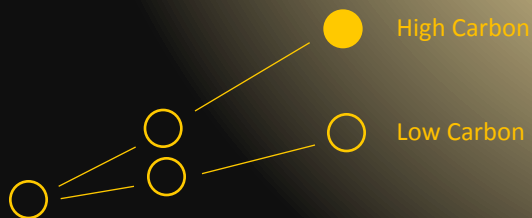
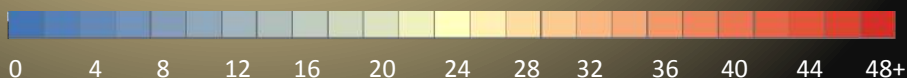
Far Future

Shifting Extremes

Change in the Number of Very Hot Days



2051-2080 Annual number of days $\geq 30^{\circ}\text{C}$



Recent Past Near Future Far Future

Data Source: Pacific Climate Impacts Consortium (PCIC), University of Victoria, (2014).
Statistically Downscaled Climate Scenarios. Downloaded from pacificclimate.org.

Tailor-made Reports

Winnipeg

High Carbon Emissions (RCP8.5)

Climate Variable	Season	1981-2010 (Baseline)	2021-2050 Projections			2021-2050 +/-	2051-2080 Projections			2051-2080 +/-
			L	M	H		L	M	H	
Mean Temperature	Annual	2.9 °C	4.3 °C	5.1 °C	5.8 °C	+2.2 °C	6.1 °C	7.3 °C	8.5 °C	+4.4 °C
	Winter	-15.0 °C	-13.2 °C	-12.0 °C	-10.9 °C	+3.0 °C	-11.1 °C	-9.3 °C	-7.4 °C	+5.7 °C
	Spring	3.0 °C	3.9 °C	4.7 °C	5.6 °C	+1.7 °C	5.3 °C	6.4 °C	7.6 °C	+3.5 °C
	Summer	18.6 °C	20.0 °C	20.5 °C	21.1 °C	+1.9 °C	21.7 °C	22.7 °C	23.7 °C	+4.1 °C
	Fall	4.9 °C	6.1 °C	7.0 °C	7.8 °C	+2.1 °C	8.0 °C	9.1 °C	10.2 °C	+4.3 °C
	January	-17.7 °C	-16.2 °C	-14.7 °C	-13.3 °C	+3.0 °C	-13.7 °C	-11.5 °C	-9.4 °C	+6.2 °C
	February	-13.9 °C	-13.6 °C	-11.6 °C	-10.1 °C	+2.3 °C	-11.3 °C	-9.2 °C	-6.9 °C	+4.7 °C
	March	-6.7 °C	-6.4 °C	-4.5 °C	-2.8 °C	+2.2 °C	-4.4 °C	-2.4 °C	-0.5 °C	+4.2 °C
	April	3.9 °C	4.6 °C	5.5 °C	6.3 °C	+1.6 °C	6.3 °C	7.2 °C	8.1 °C	+3.3 °C
	May	11.6 °C	12.3 °C	13.1 °C	13.8 °C	+1.5 °C	13.4 °C	14.5 °C	15.6 °C	+2.9 °C
	June	17.2 °C	18.0 °C	18.8 °C	19.7 °C	+1.6 °C	19.7 °C	20.6 °C	21.6 °C	+3.5 °C
	July	19.8 °C	21.2 °C	21.8 °C	22.7 °C	+2.0 °C	22.9 °C	24.0 °C	24.9 °C	+4.2 °C
	August	18.8 °C	20.2 °C	20.9 °C	21.8 °C	+2.1 °C	22.0 °C	23.3 °C	24.6 °C	+4.5 °C
	September	12.8 °C	14.2 °C	14.9 °C	15.8 °C	+2.1 °C	15.8 °C	17.1 °C	18.7 °C	+4.3 °C
	October	6.1 °C	7.0 °C	8.0 °C	9.0 °C	+1.9 °C	9.2 °C	10.1 °C	11.2 °C	+4.0 °C
	November	-4.4 °C	-3.5 °C	-2.0 °C	-0.5 °C	+2.3 °C	-1.0 °C	0.2 °C	1.6 °C	+4.5 °C
	December	-13.4 °C	-11.0 °C	-9.7 °C	-8.3 °C	+3.7 °C	-8.3 °C	-7.0 °C	-5.7 °C	+6.4 °C

Tailor-made Reports

Winnipeg

High Carbon Emissions (RCP8.5)

Climate Variable	Season	1981-2010 (Baseline)	2021-2050 Projections			2021-2050 +/-	2051-2080 Projections			2051-2080 +/-
			L	M	H		L	M	H	
Precipitation	Annual	524.7 mm	511.1 mm	552.6 mm	590.0 mm	+5.3 %	528.2 mm	564.7 mm	598.5 mm	+7.6 %
	Winter	66.2 mm	64.8 mm	72.3 mm	84.7 mm	+9.2 %	69.8 mm	80.8 mm	90.8 mm	+22.0 %
	Spring	116.8 mm	109.4 mm	128.0 mm	145.3 mm	+9.6 %	132.4 mm	146.7 mm	163.1 mm	+25.6 %
	Summer	227.9 mm	212.2 mm	226.1 mm	247.3 mm	-0.8 %	189.4 mm	214.2 mm	233.5 mm	-6.0 %
	Fall	112.9 mm	109.7 mm	125.2 mm	135.8 mm	+10.8 %	110.0 mm	122.9 mm	139.0 mm	+8.8 %
	January	24.5 mm	22.6 mm	26.7 mm	31.1 mm	+9.1 %	24.3 mm	31.0 mm	35.8 mm	+26.7 %
	February	18.9 mm	15.7 mm	19.5 mm	25.0 mm	+3.3 %	15.4 mm	21.4 mm	27.4 mm	+13.6 %
	March	23.7 mm	20.1 mm	26.0 mm	30.6 mm	+9.8 %	23.0 mm	28.3 mm	34.1 mm	+19.5 %
	April	31.3 mm	31.8 mm	37.5 mm	44.0 mm	+19.8 %	32.0 mm	44.2 mm	55.3 mm	+41.2 %
	May	61.8 mm	53.9 mm	64.5 mm	75.1 mm	+4.4 %	60.8 mm	74.2 mm	88.9 mm	+20.0 %
	June	80.2 mm	73.3 mm	86.6 mm	102.7 mm	+8.0 %	68.8 mm	83.2 mm	99.2 mm	+3.7 %
	July	75.5 mm	59.8 mm	70.6 mm	82.1 mm	-6.6 %	55.1 mm	68.2 mm	75.7 mm	-9.7 %
	August	72.2 mm	55.0 mm	69.0 mm	84.5 mm	-4.5 %	48.2 mm	62.9 mm	74.6 mm	-13.0 %
	September	50.7 mm	41.9 mm	51.8 mm	63.4 mm	+2.0 %	39.3 mm	48.0 mm	57.1 mm	-5.5 %
	October	34.3 mm	32.0 mm	41.6 mm	51.6 mm	+21.1 %	28.7 mm	41.5 mm	56.0 mm	+21.0 %
	November	27.9 mm	24.3 mm	31.8 mm	43.8 mm	+14.2 %	25.5 mm	33.4 mm	43.5 mm	+19.9 %
	December	23.8 mm	23.3 mm	27.1 mm	30.3 mm	+14.0 %	25.0 mm	28.5 mm	31.1 mm	+20.1 %

Tailor-made Reports

Winnipeg

High Carbon Emissions (RCP8.5)

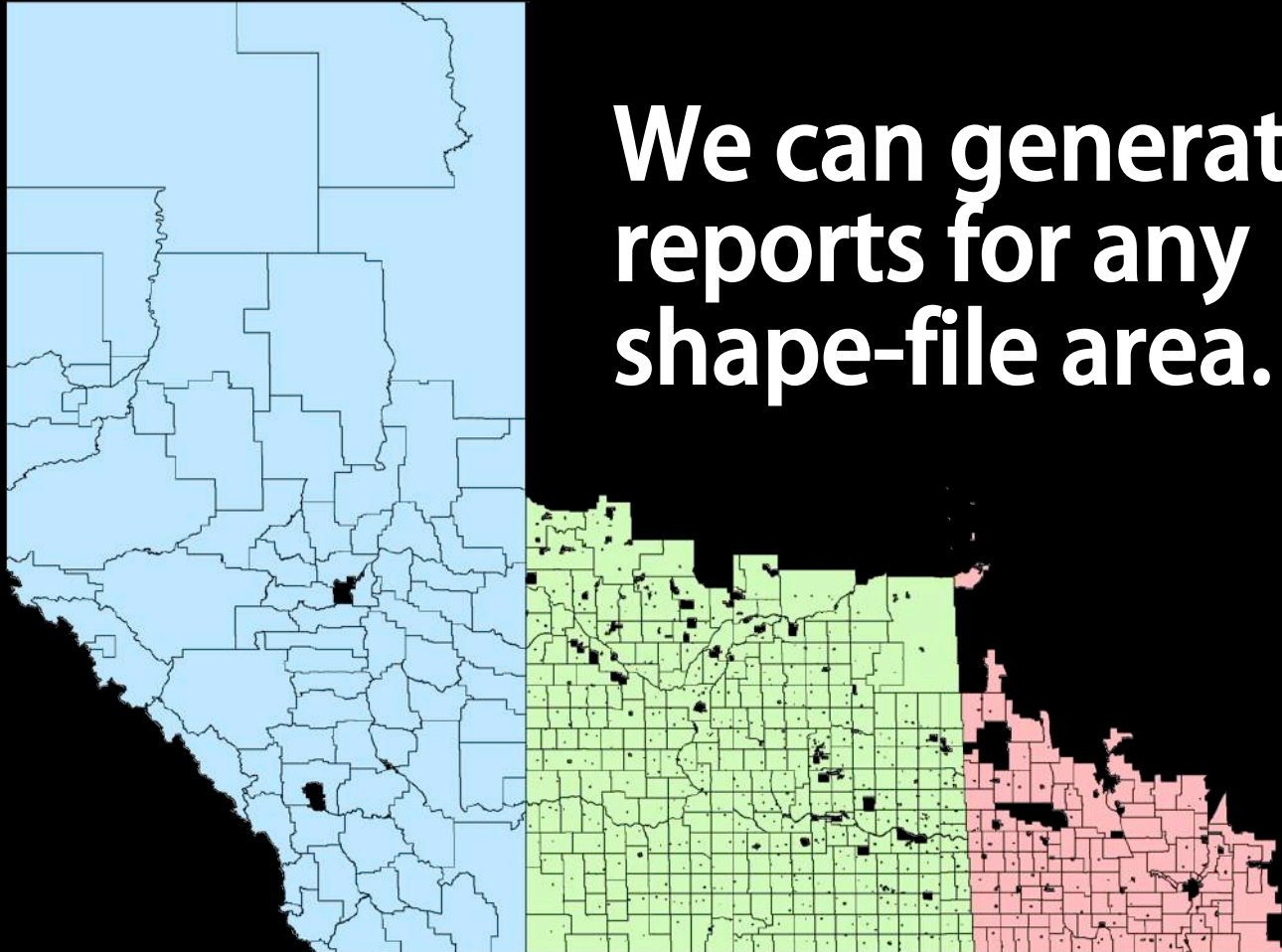
Climate Variable	Season	1981-2010 (Baseline)	2021-2050 Projections				2021-2050 +/-	2051-2080 Projections				2051-2080 +/-
			L	M	H			L	M	H		
Days $\geq 30^{\circ}\text{C}$	Annual	11.0 days	19.0 days	25.6 days	36.0 days		+14.6 days	34.0 days	46.4 days	60.0 days		+35.4 days
Nights $\geq 20^{\circ}\text{C}$	Annual	1.0 days	2.0 days	5.1 days	9.0 days		+4.1 days	10.0 days	15.8 days	22.0 days		+14.8 days
Days $\leq -30^{\circ}\text{C}$	Annual	8.2 days	1.0 days	2.9 days	5.0 days		-5.3 days	0.0 days	0.7 days	2.0 days		-7.5 days
Last Spring Frost	-	May-19	May-02	May-11	May-20		-8 days	Apr-24	May-02	May-11		-17 days
Frost-Free Period	Annual	128.4 days	128.0 days	145.8 days	162.0 days		+17.4 days	147.0 days	161.4 days	177.0 days		+33.1 days
First Fall Frost	-	Sep-24	Sep-23	Oct-04	Oct-19		+9 days	Oct-02	Oct-10	Oct-22		+16 days
Frost Period	Annual	211.2 days	150.0 days	165.2 days	178.0 days		-45.9 days	145.0 days	157.7 days	174.0 days		-53.5 days
Frost Days	Annual	186.2 days	157.0 days	167.0 days	179.0 days		-19.2 days	134.0 days	148.2 days	159.0 days		-38.0 days
Icing Days	Annual	117.8 days	92.0 days	104.2 days	115.0 days		-13.6 days	71.0 days	86.7 days	98.0 days		-31.1 days
Freeze-Thaw Cycles	Annual	58.7 cycles	45.0 cycles	54.1 cycles	61.0 cycles		-4.6 cycles	46.0 cycles	53.1 cycles	58.0 cycles		-5.6 cycles
5 $^{\circ}\text{C}$ Degree Days	Annual	1826.1	2086.9	2188.9	2314.7		+362.9	2402.5	2601.5	2807.6		+775.4
10 $^{\circ}\text{C}$ Degree Days	Annual	1015.7	1225.9	1301.6	1401.8		+285.9	1490.1	1640.7	1823.2		+624.9
16 $^{\circ}\text{C}$ Degree Days	Annual	325.6	453.3	506.1	563.1		+180.5	641.9	748.8	881.4		+423.2
Max 1-day Precip	Annual	67.0 mm	54.7 mm	75.3 mm	99.2 mm		+12.5 %	50.9 mm	77.4 mm	108.6 mm		+15.6 %
Max 3-day Precip	Annual	139.9 mm	118.2 mm	160.4 mm	198.4 mm		+14.6 %	102.8 mm	168.3 mm	226.8 mm		+20.3 %
PET	Annual	632.2 mm	658.7 mm	672.3 mm	684.1 mm		+6.3 %	689.1 mm	714.1 mm	737.1 mm		+12.9 %
P/PET Ratio	Annual	0.83	0.76	0.82	0.88		-0.01	0.74	0.79	0.83		-0.04

L = Low Projection (10th Percentile)

M = Mean Projection

H = High Projection (90th Percentile)

Tailor-made Reports

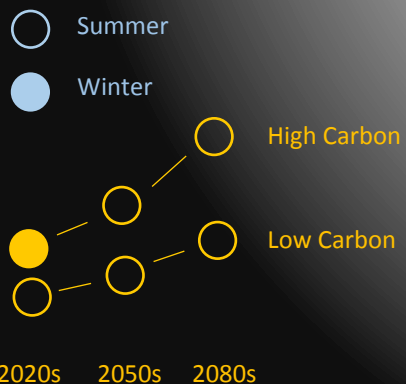


Climate Analogues

Winnipeg

Winter Climate Analogues

AdaptWest data was used to identify whose climates we will have in the future, using seasonal temperature and precipitation projections.

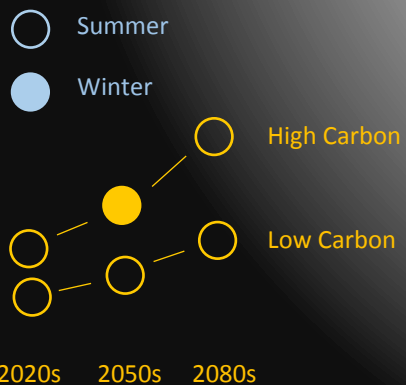


Winnipeg

Winter Climate Analogues

Similarity index:

- Mean temperature within 1 °C
- Total snow within 15%

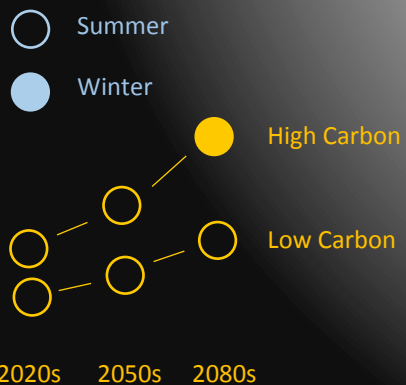
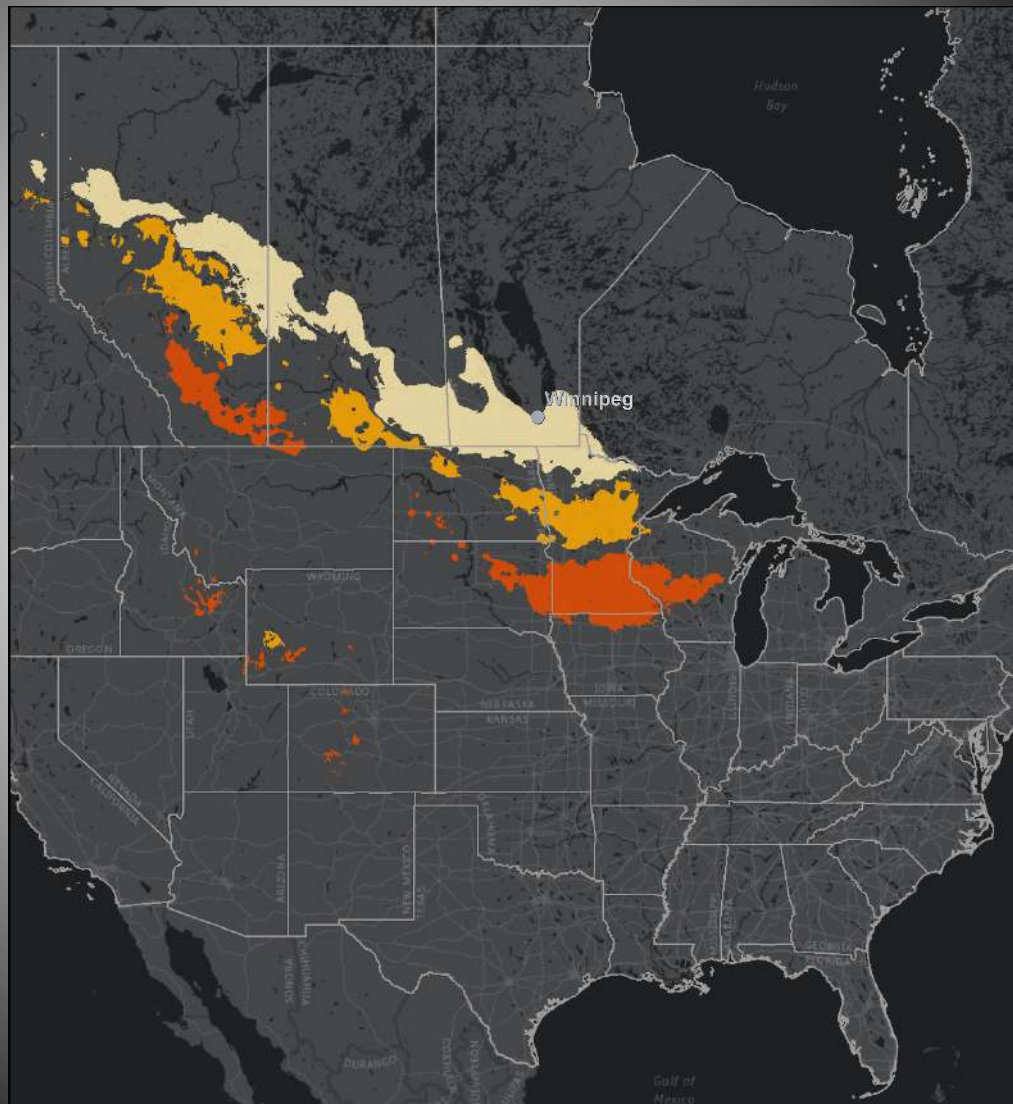


Winnipeg

Winter Climate Analogues

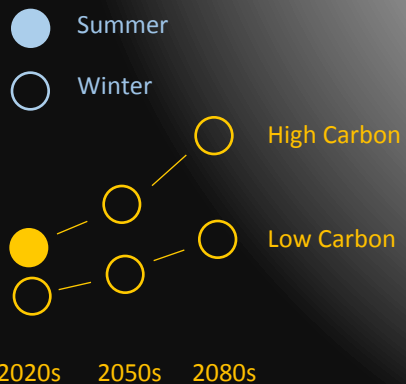
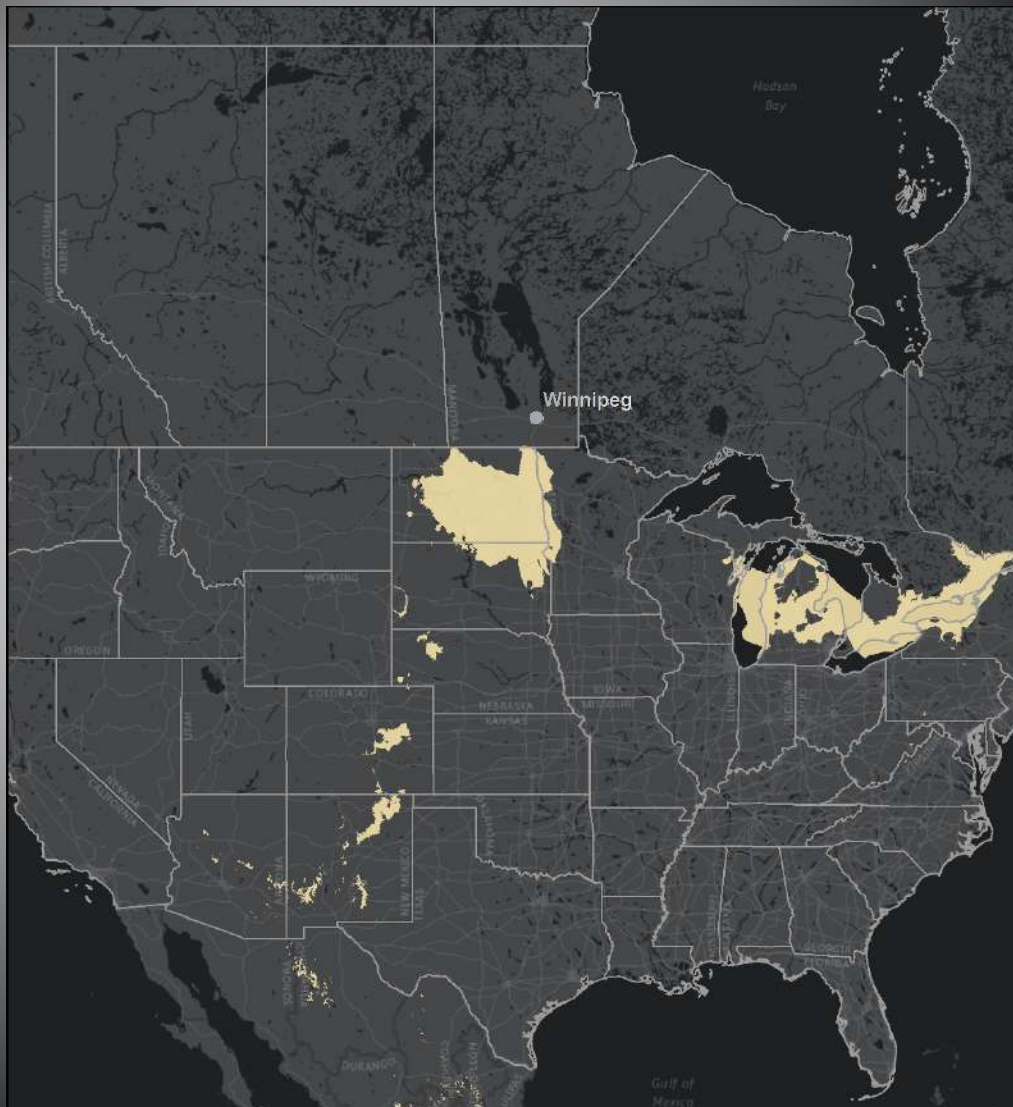
Similarity index:

- Mean temperature within 1 °C
- Total snow within 15%



Winnipeg

Summer Climate Analogues

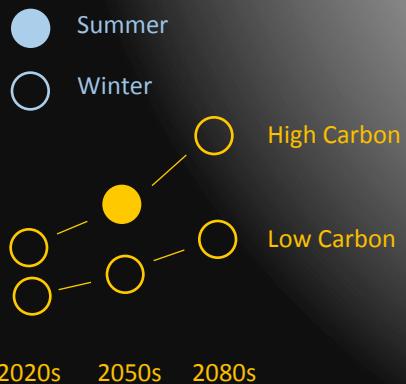
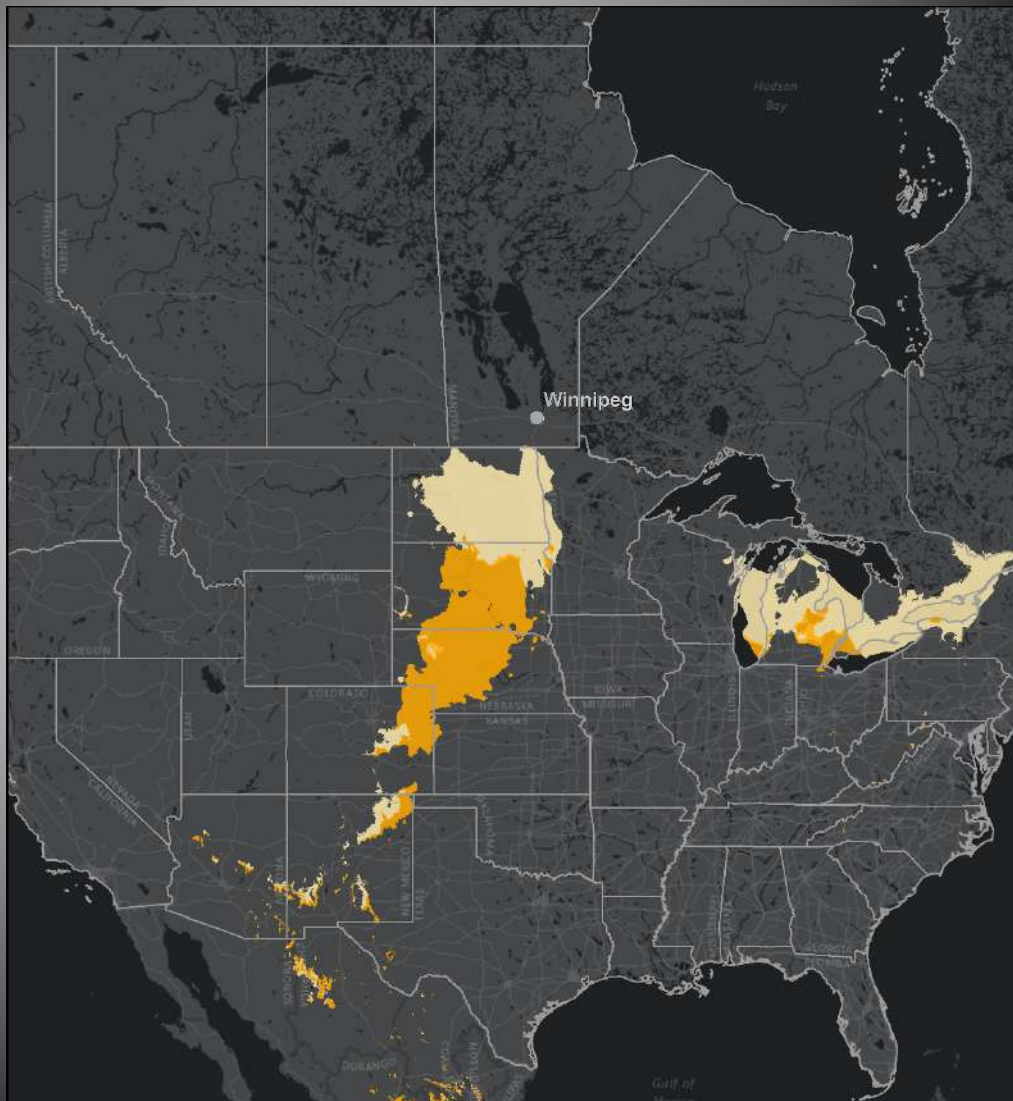


Winnipeg

Summer Climate Analogues

Similarity index:

- Mean temperature within 1 °C
- Total precipitation within 20%



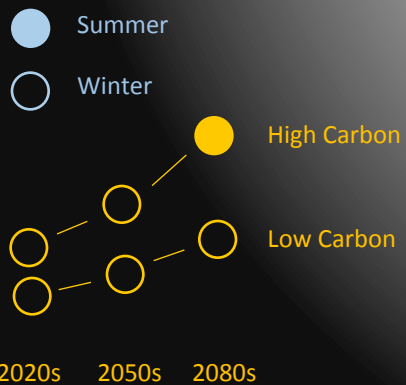
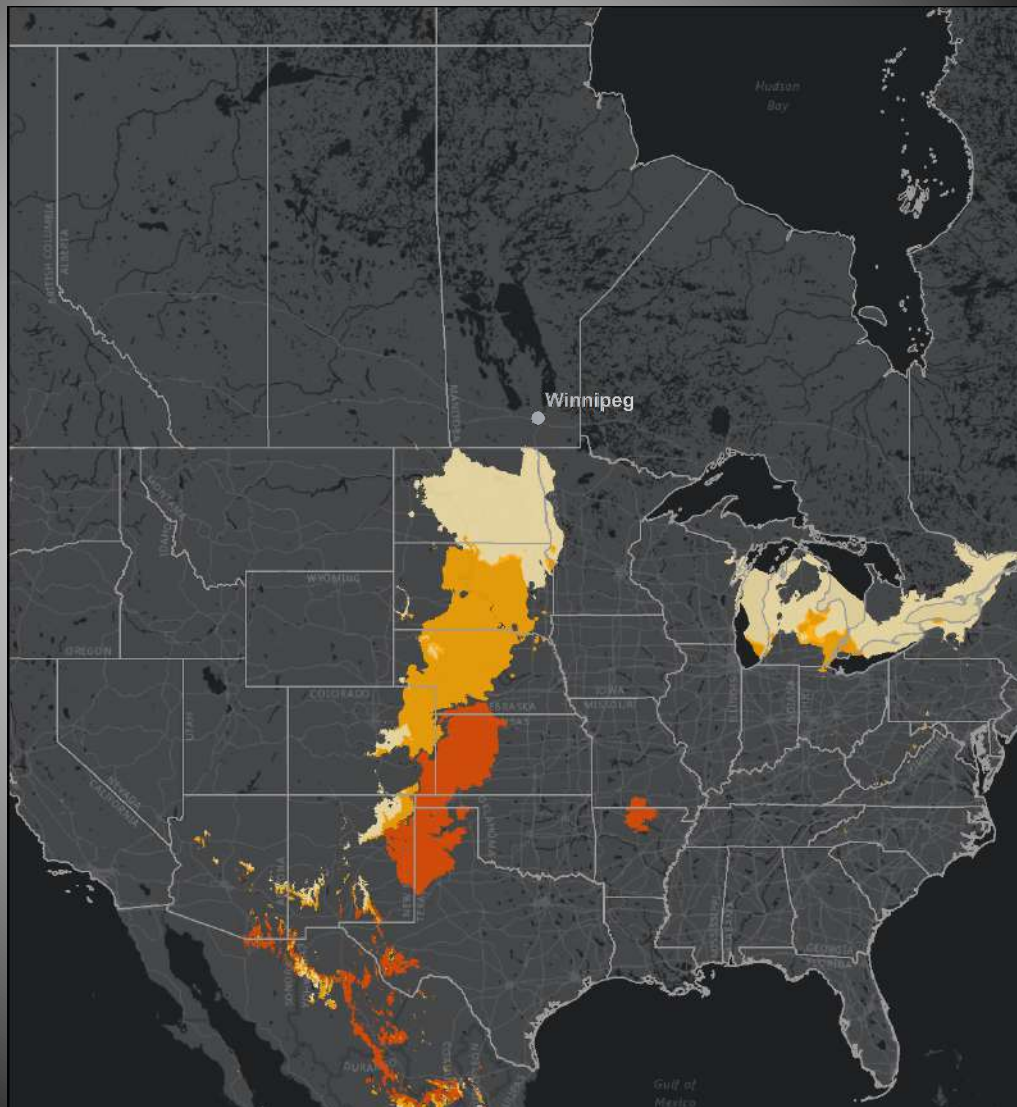
Winnipeg

Summer Climate Analogues



Similarity index:

- Mean temperature within 1 ° C
- Total precipitation within 20%



2020s 2050s 2080s

A New Climate

- Shifting **seasons**
- Shorter, warmer **winters**
- Longer, hotter **summers**
- **More precipitation** in winter, spring, fall
- **Less precipitation** in summer
- More **intense precipitation** events
- More **severe** weather
- More **heat** waves

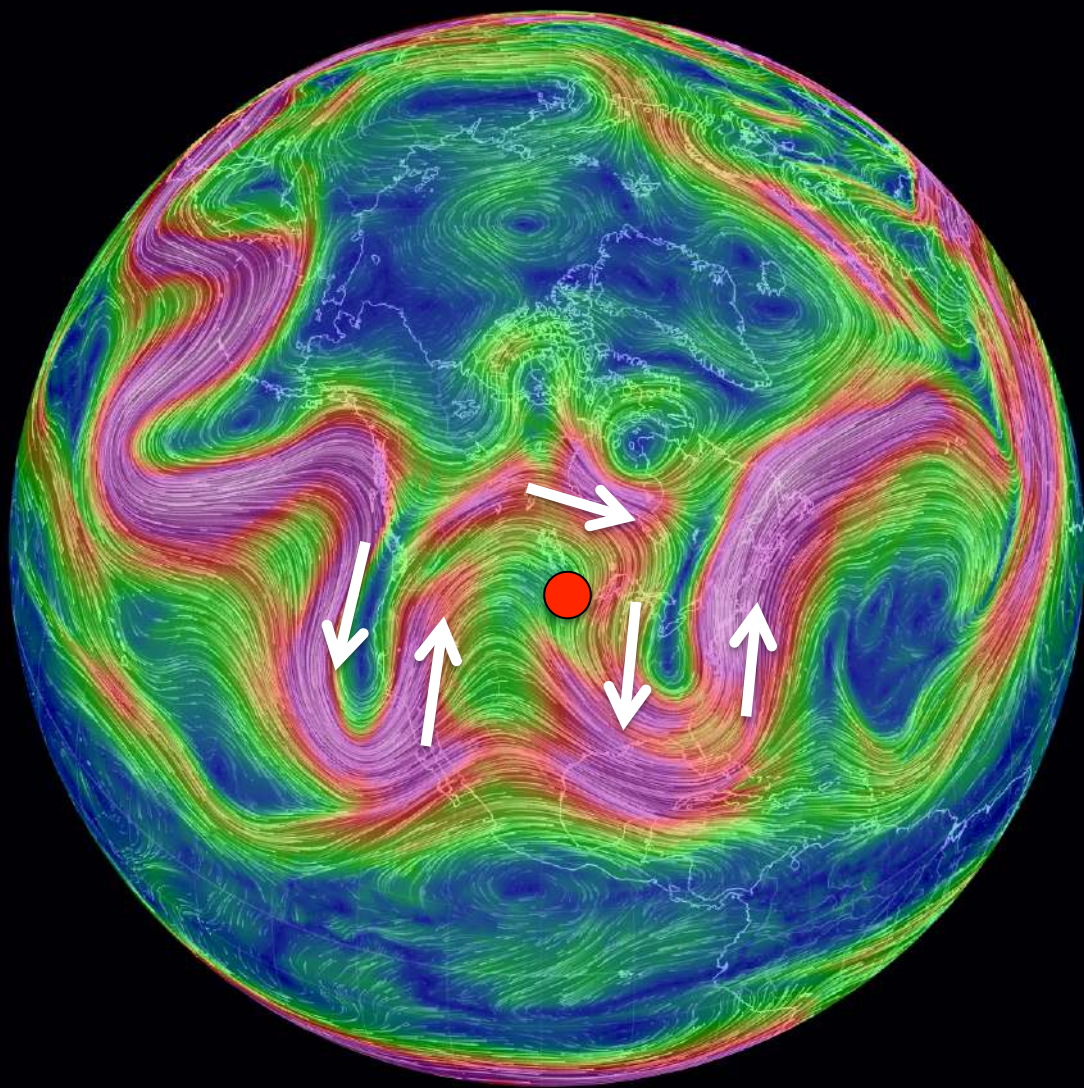
Some Benefits

- Longer **growing** season
- New **crop** varieties
- Lower winter **heating** costs
- Fewer extreme **cold** events

Many Risks

- Floods and droughts
- Water resource management
- Shortening of return periods
- Winter melting
- Extreme heat events
- Human health
- Crop failure
- Invasive species
- Forest fires
- Even more variability and instability

Exceptionally meridional jet stream on 5 May 2016



Record May 5
temperatures of
35.2 °C in
Winnipeg and
34.3 °C in
Brandon

Planning Issues

- Infrastructure resilience
- Urban design
- New building codes
- Disaster management and response
- Heating and cooling
- Summer energy demand
- Winter roads
- Freeze/thaw cycles
- Wind loads?
- Insurance
- Litigation?

Integrating
Mitigation

Thank You

