BC's Changing Climate and Projections for the In-SHUCK-ch FSR

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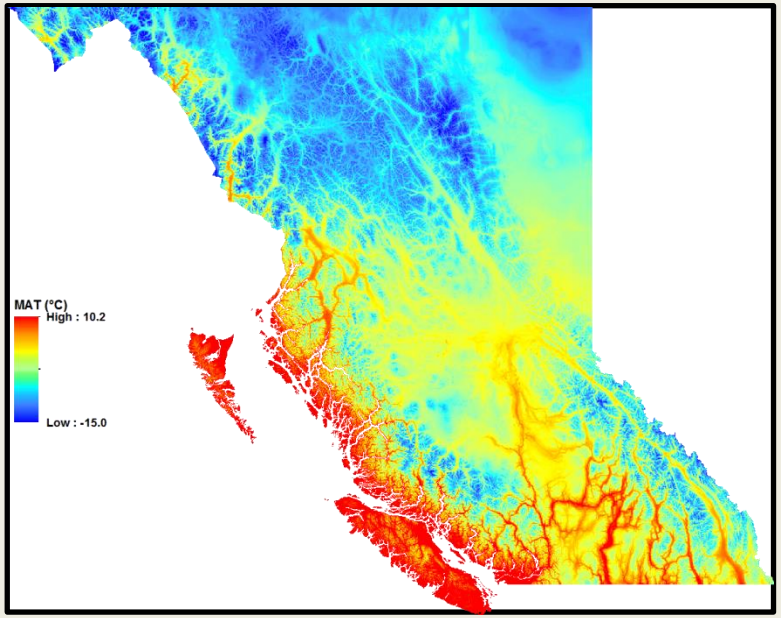
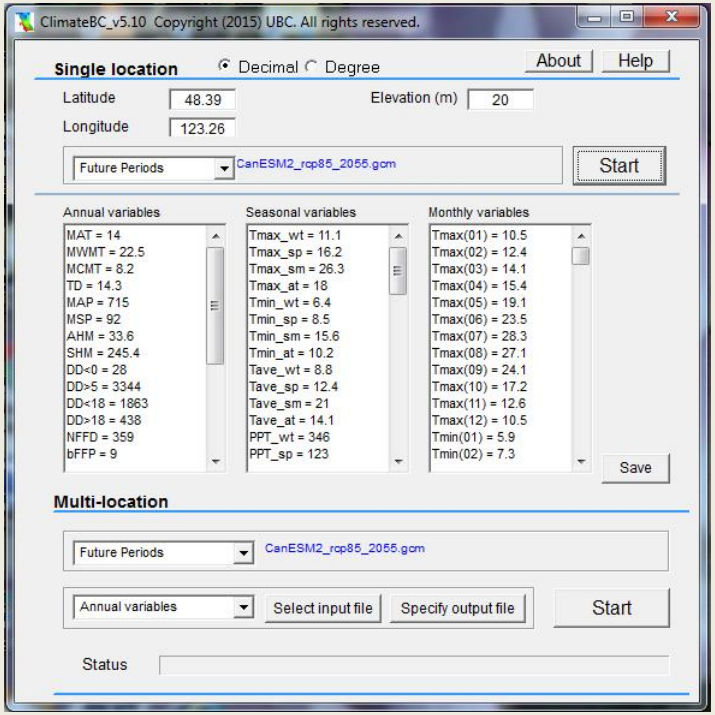
Acknowledgements

- Trevor Murdock et al., PCIC
- Tongli Wang, UBC





Outline

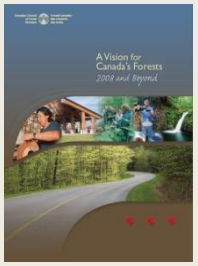
- IPCC 5th Assessment report
- Weather and climate
- Past changes in BC's climate
- Climate change – the science
- Projections for the 21st century
- Sources of climate change information
- Summary
- Projections for the In-shuck-ch

IPCC 5th Assessment – the past

- Warming of the climate is unequivocal – atmosphere and ocean
- Increase in mid latitude NH precipitation
- Glacier retreat, decrease in Arctic sea ice
- Sea level rise of ~0.19 m in last 110 years
- Ocean acidification – surface water pH ↓ 0.1
- CO_2, CH_4, N_2O highest levels in last 800,000 y
- Human influence on the climate is clear and it is the dominant cause of recent observed warming

Canadian Council of Forest Ministers (2008)

The impacts of a changing climate have to be considered in every aspect of managing Canada's forests... Climate change adaptation and mitigation strategies will reduce the effects of climate change on forests and communities.



Commissioner of Environmental and Sustainable Development – House of Commons (2010)

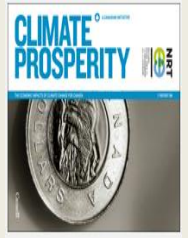
The government acknowledges that climate change is inevitable and that we must adapt to its impacts in order to reduce their severity.

Professional Engineers and Geoscientists of BC Climate Change Task Force (2010)

Climate change is a public safety issue.

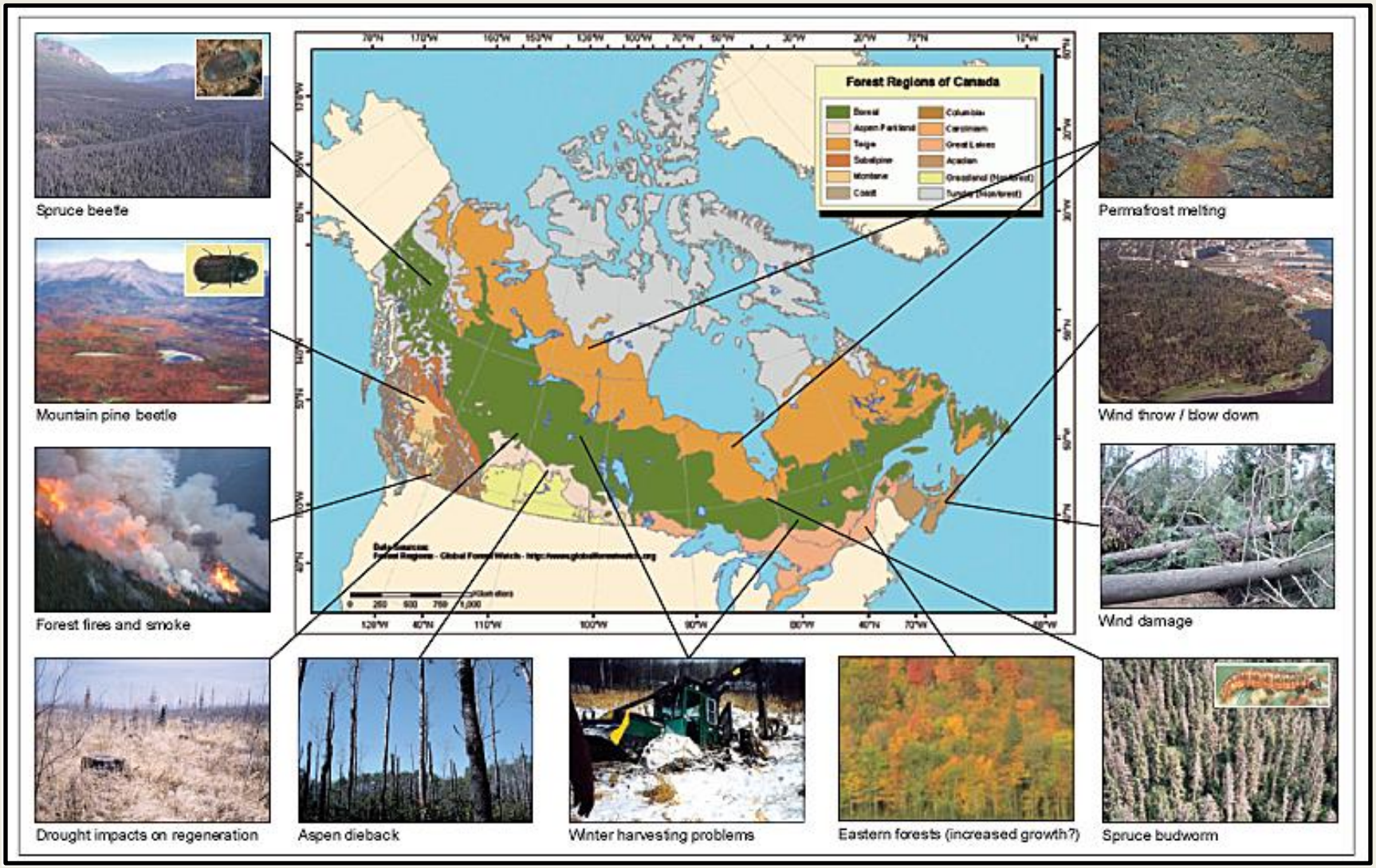
National Round Table on the Environment and the Economy (2011)

British Columbia could also face costs from the effect of climate change on forest productivity, forest fires, and pest disturbance.



(Pearce 2012, Duinker 2012)

Impacts of weather/climate on forests



(Williams et al. 2009)

Weather v. Climate

Daily maximum air temperature in January

1 day

Victoria

5°C -2°C

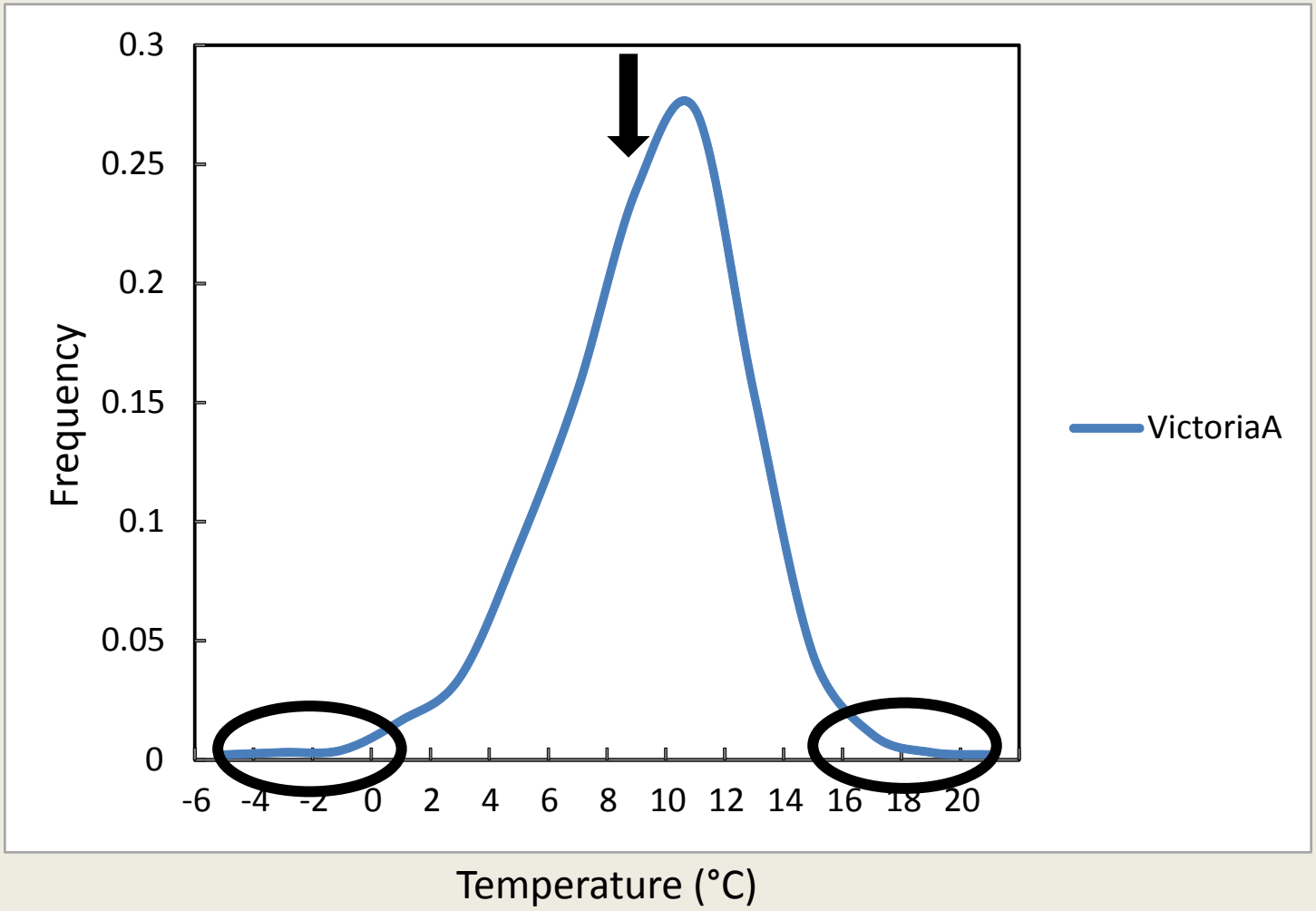
Montreal

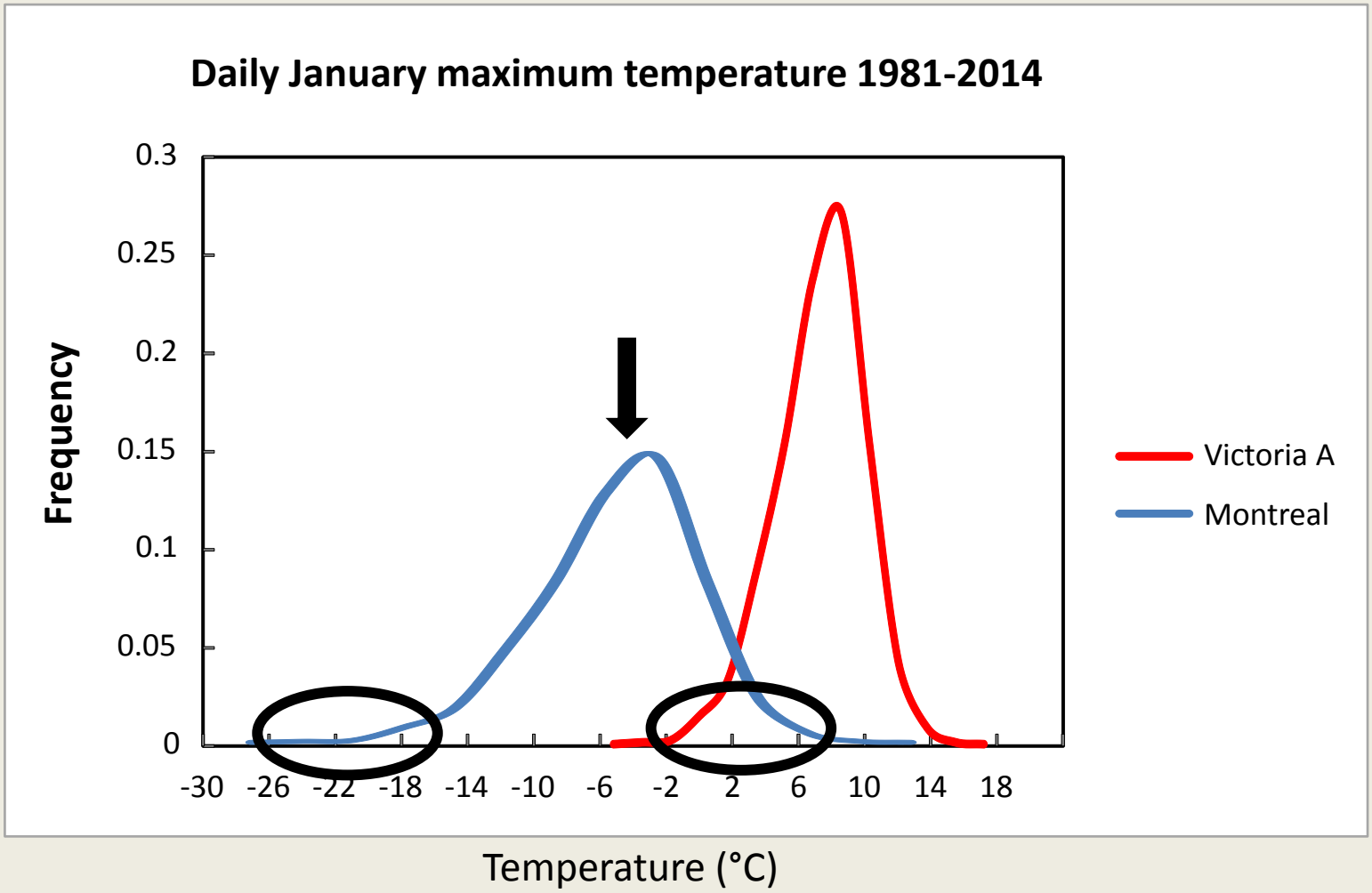
Weather v. Climate

Daily maximum air temperature in January

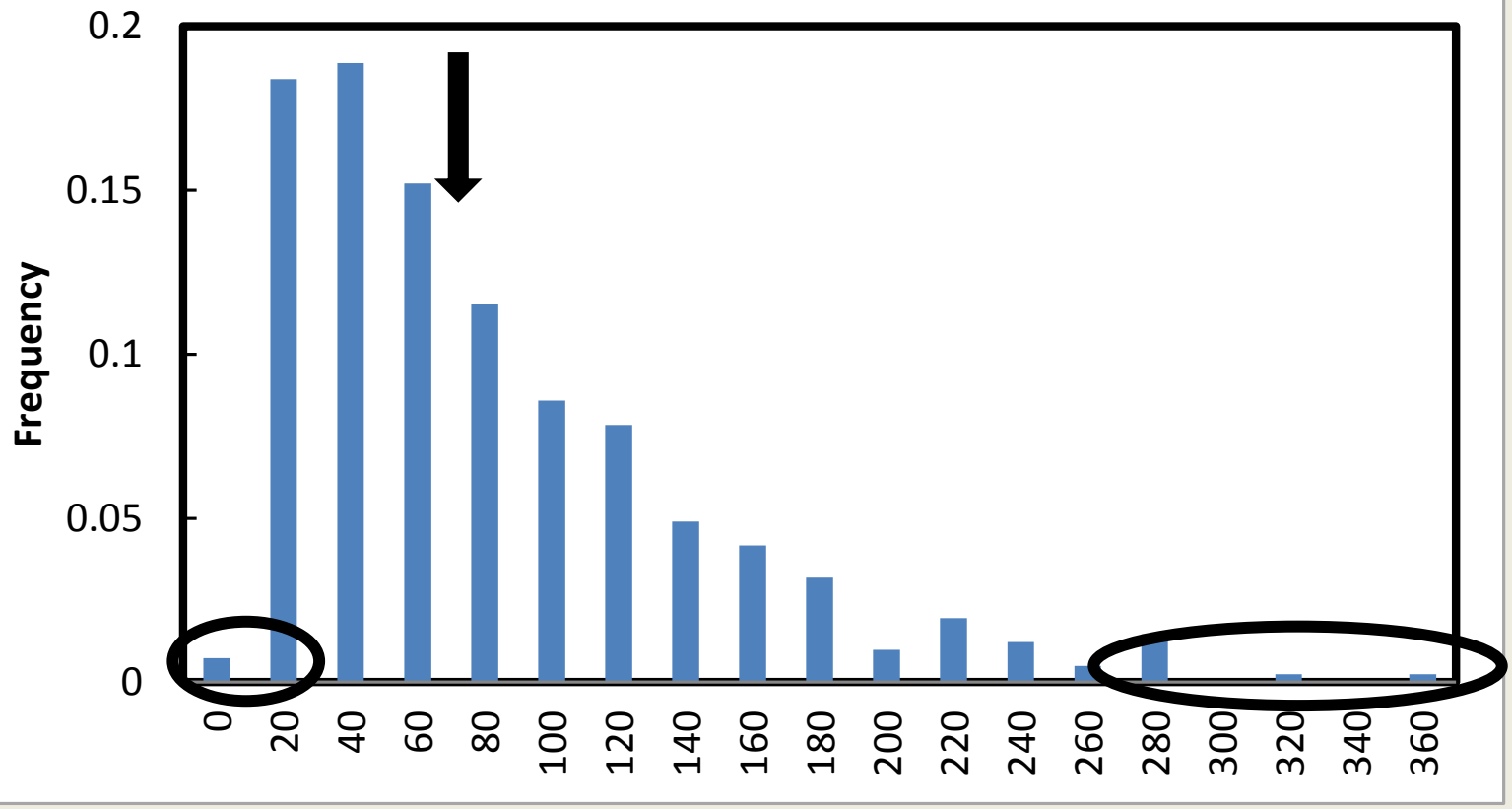
	1 day	Monthly average Tmax
Victoria	-2°C	7.5°C
Montreal	5°C	-5.2°C

Distribution of January daily maximum temperature 1981-2014

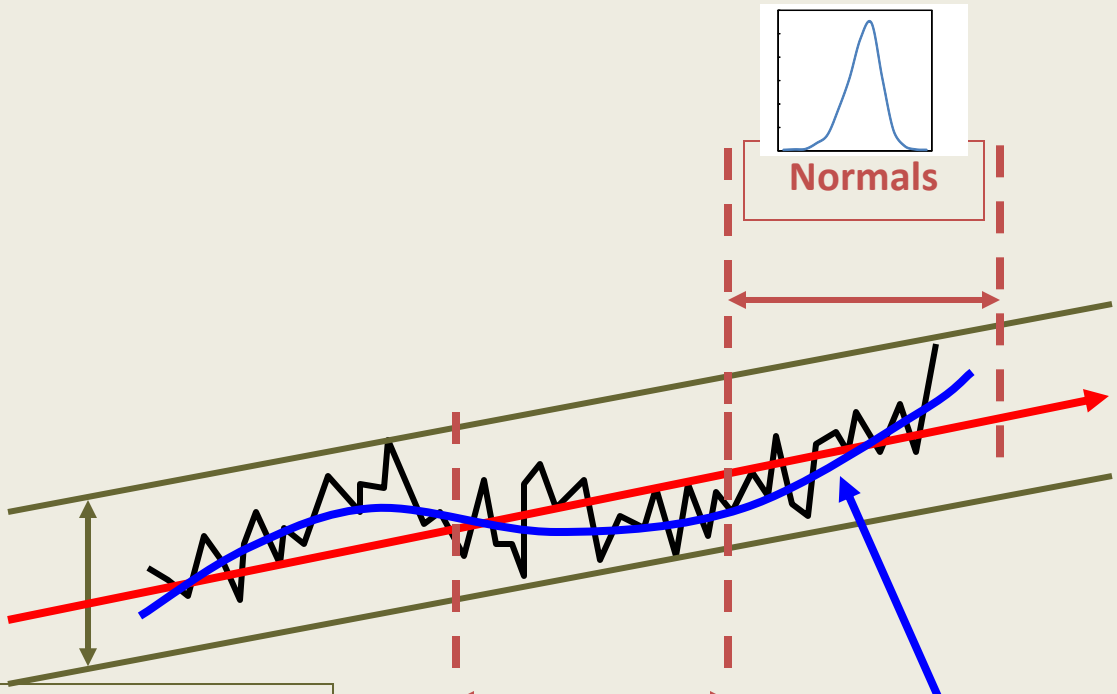



Daily January maximum temperature 1981-2014
Frequency
0.3
0.25
0.2
0.15
0.1
0.05
0
-30
-26
-22
-18
-14
-10
-6
-2
2
6
10
14
18
Victoria A
Montreal
Temperature (°C)

Victoria A monthly precipitation 1981-2014



Climate Variability & Climate Change



Year-to-year variability

Year to decadal rise and fall about the trend line (e.g., ENSO, volcanoes)

Climate change

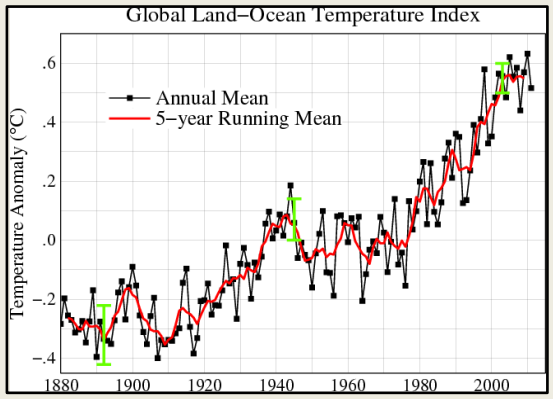
Long term trends and major shifts in climate (centuries, millennia…): orbital variations, atmospheric chemistry

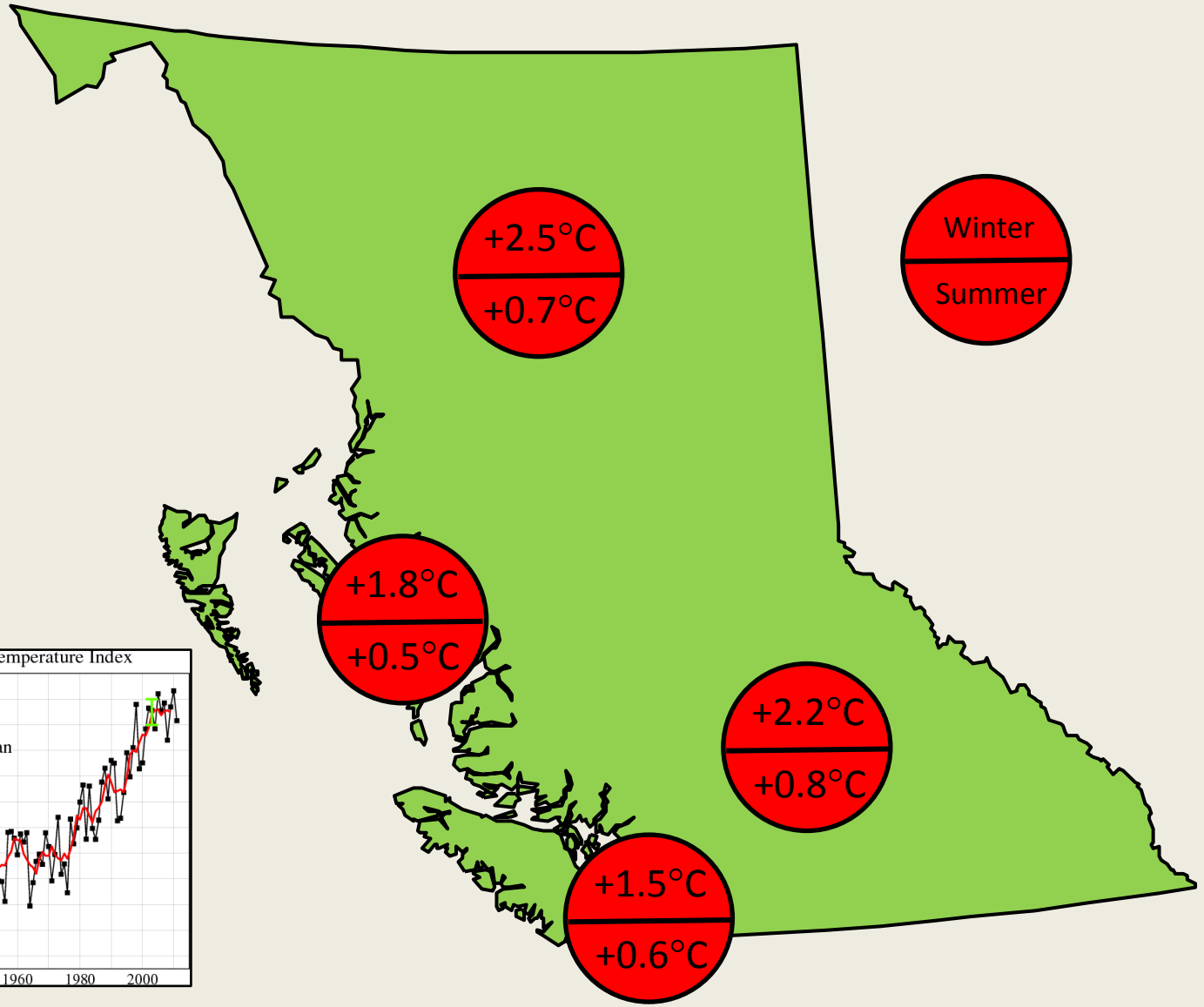
Climate oscillation

Multi-decadal variations in regional climate: (e.g. PDO, NAO)

(Adapted from Murdock 2012, PCIC)

Increase in winter and summer air temperature in BC 1901-2013





(Adapted from Zhang et al. 2000, Moore et al. 2010, Pike et al. 2010, Environment Canada 2014, http://data.giss.nasa.gov/gistemp/graphs_v3/)

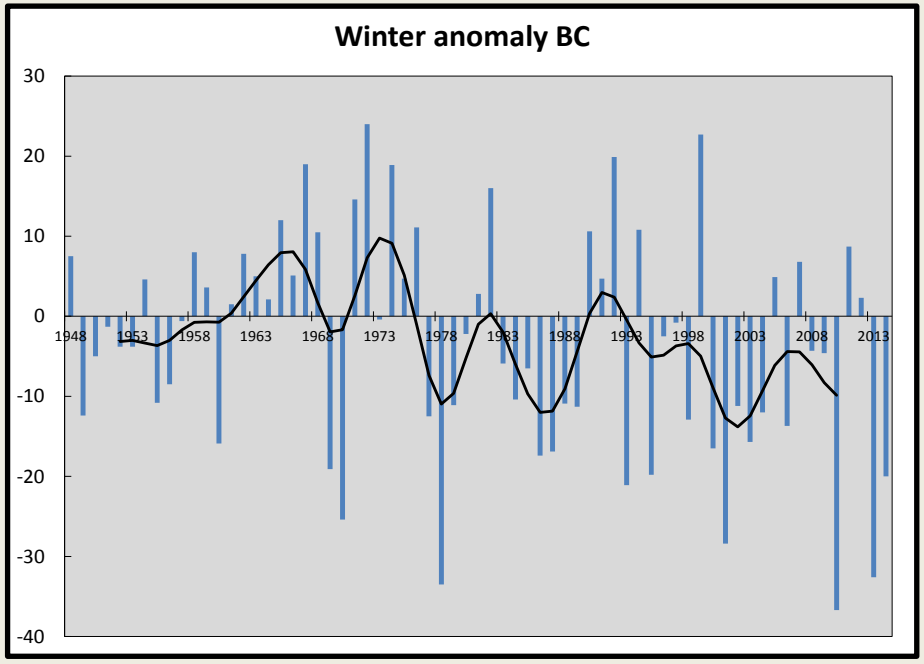
Precipitation

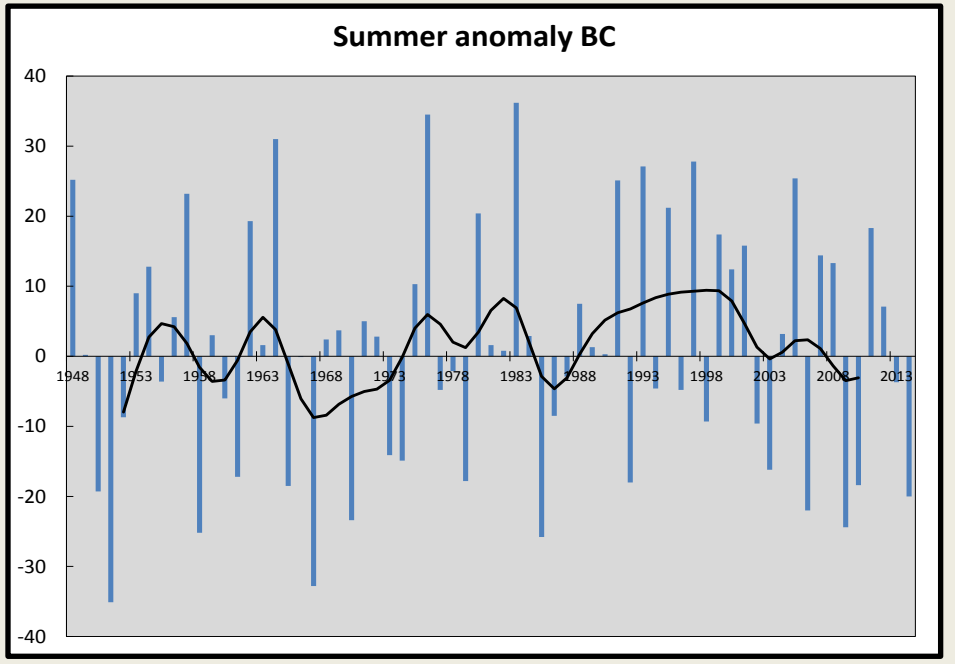
- Trend to increase over 20th century
- Uncertainty on trends is high

BC precipitation trend 1948-2014

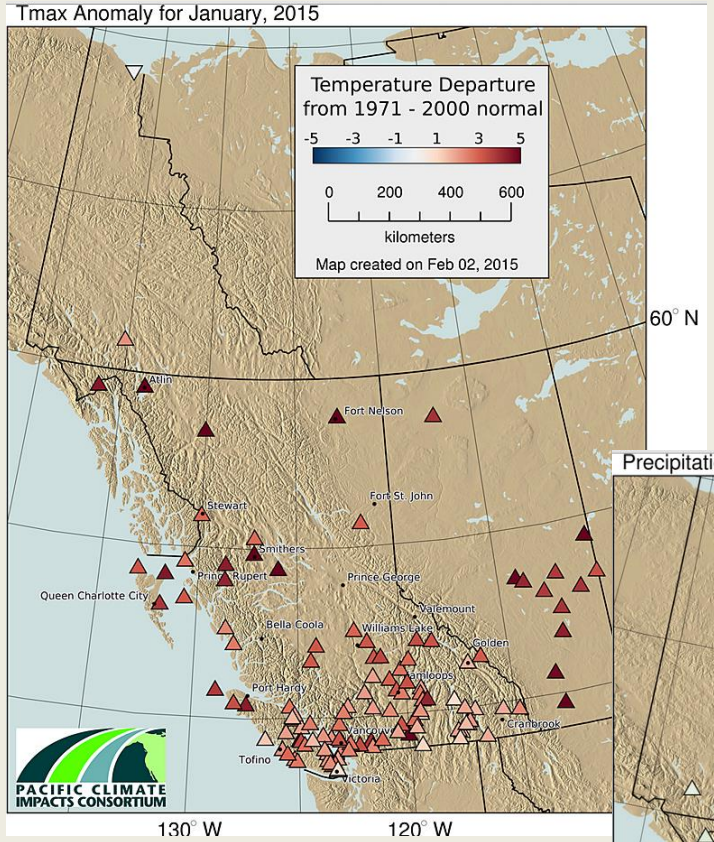
% difference in precipitation from 1961-90 normals

Anomaly — Moving average

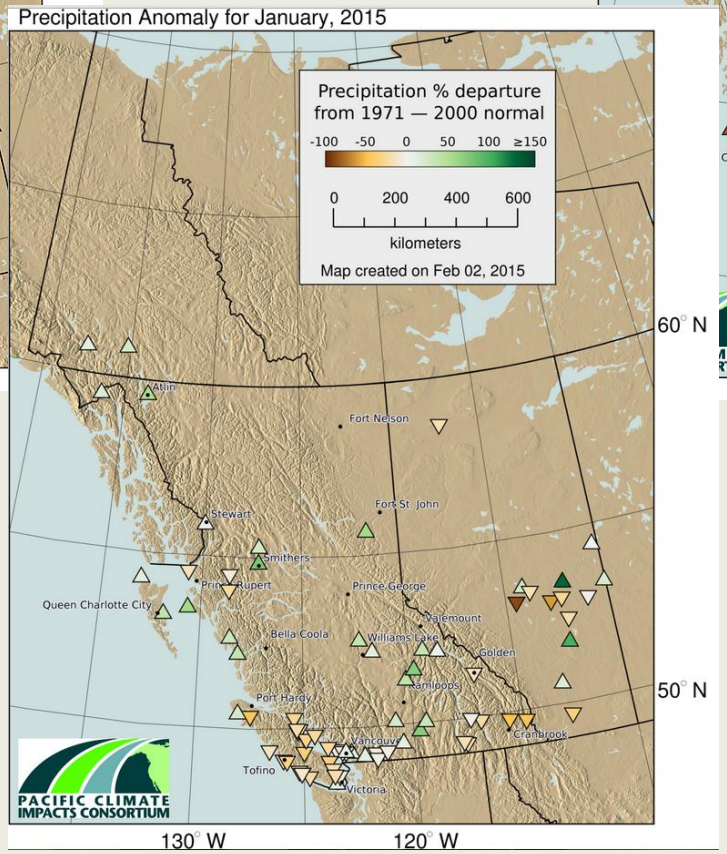




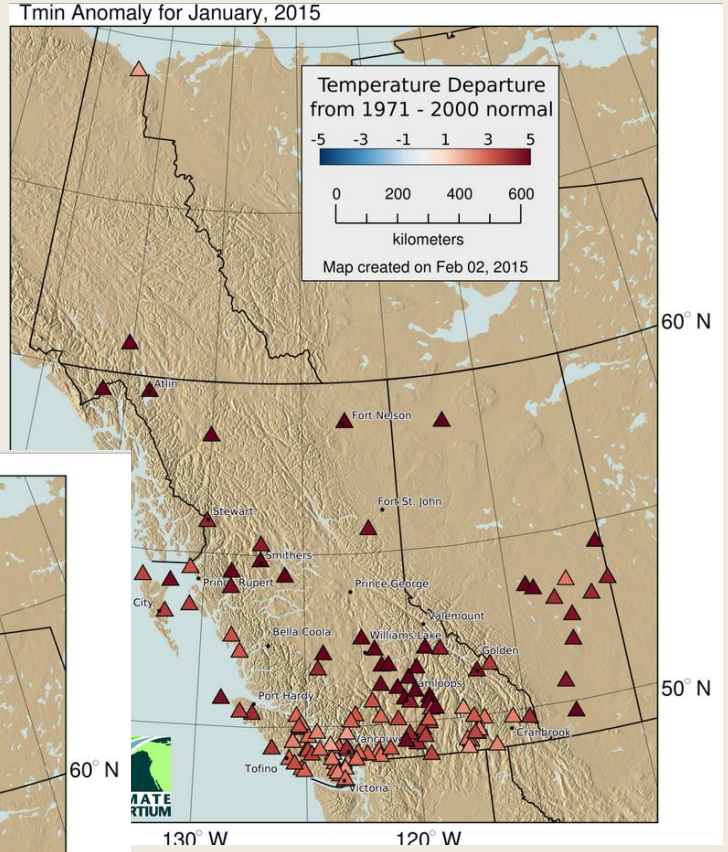
January 2015 difference from 1971-2000



Maximum temperature



Precipitation



Minimum temperature

(http://www.pacificclimate.org/analysis-tools/seasonal-maps)

Definitions

- Climate model

  - Biological, physical and chemical representation of the climate system within a computer

- Emissions scenario (e.g., rcp 4.5, 8.5)

  - Representation of possible future emissions of greenhouse gases (e.g., CO2, CH4, N2O, CFCs) and particulates (e.g., soot).

  - Based on assumptions about future population growth, technological development, sources of energy, global cooperation and proscribed temperature change.

- IPCC AR5 - Intergovernmental Panel on Climate Change 5th Assessment Report

Definitions (continued…)

- Climate projection/scenario
  - One “run” from one climate model using one emissions scenario, e.g., CanESMr1 rcp8.5
  - A representation of a possible future climate
- Ensemble mean
  - Average of a number of climate projections from multiple runs, models, and/or emissions scenarios
- Downscaling
  - Applying global scale climate change data at the local scale

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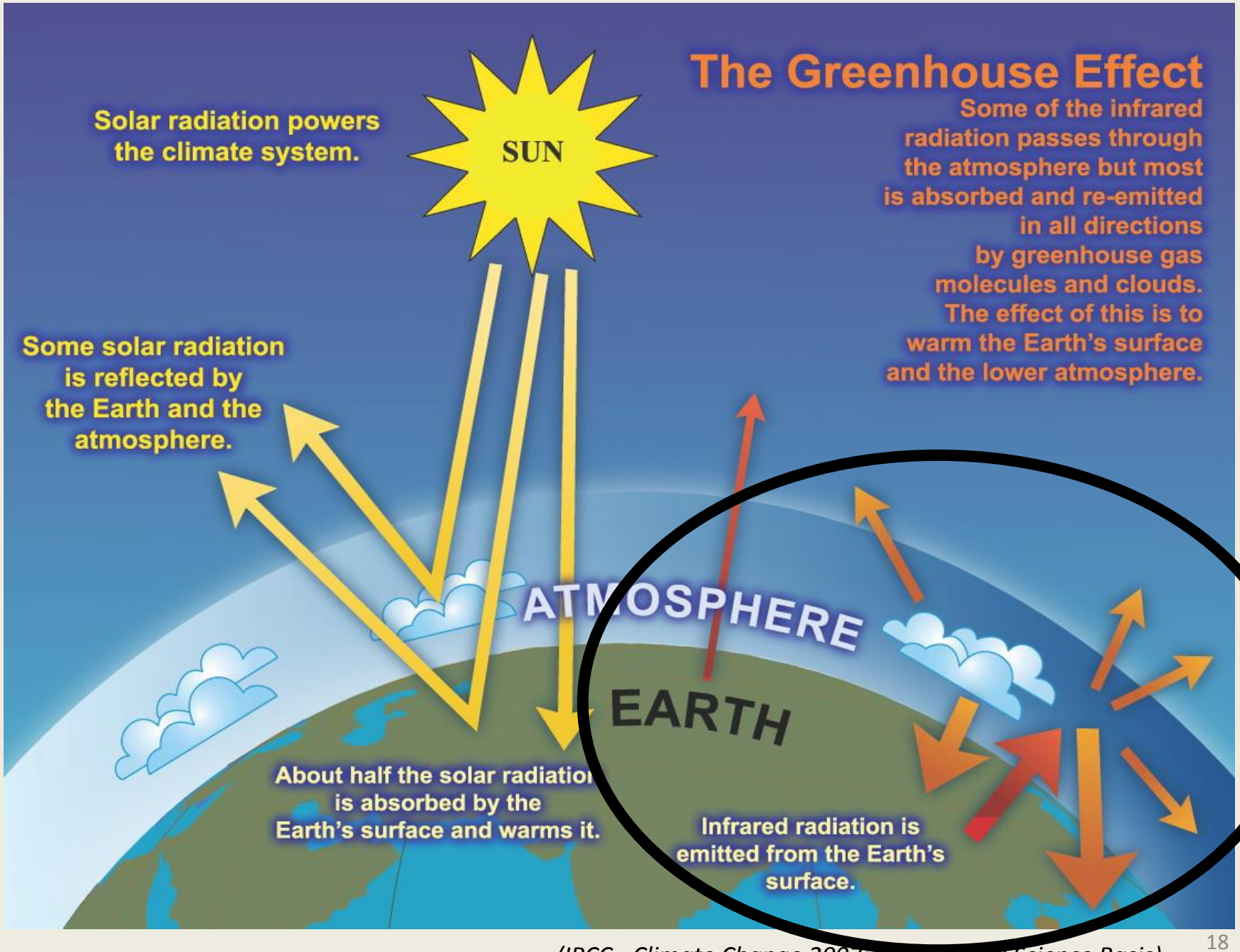
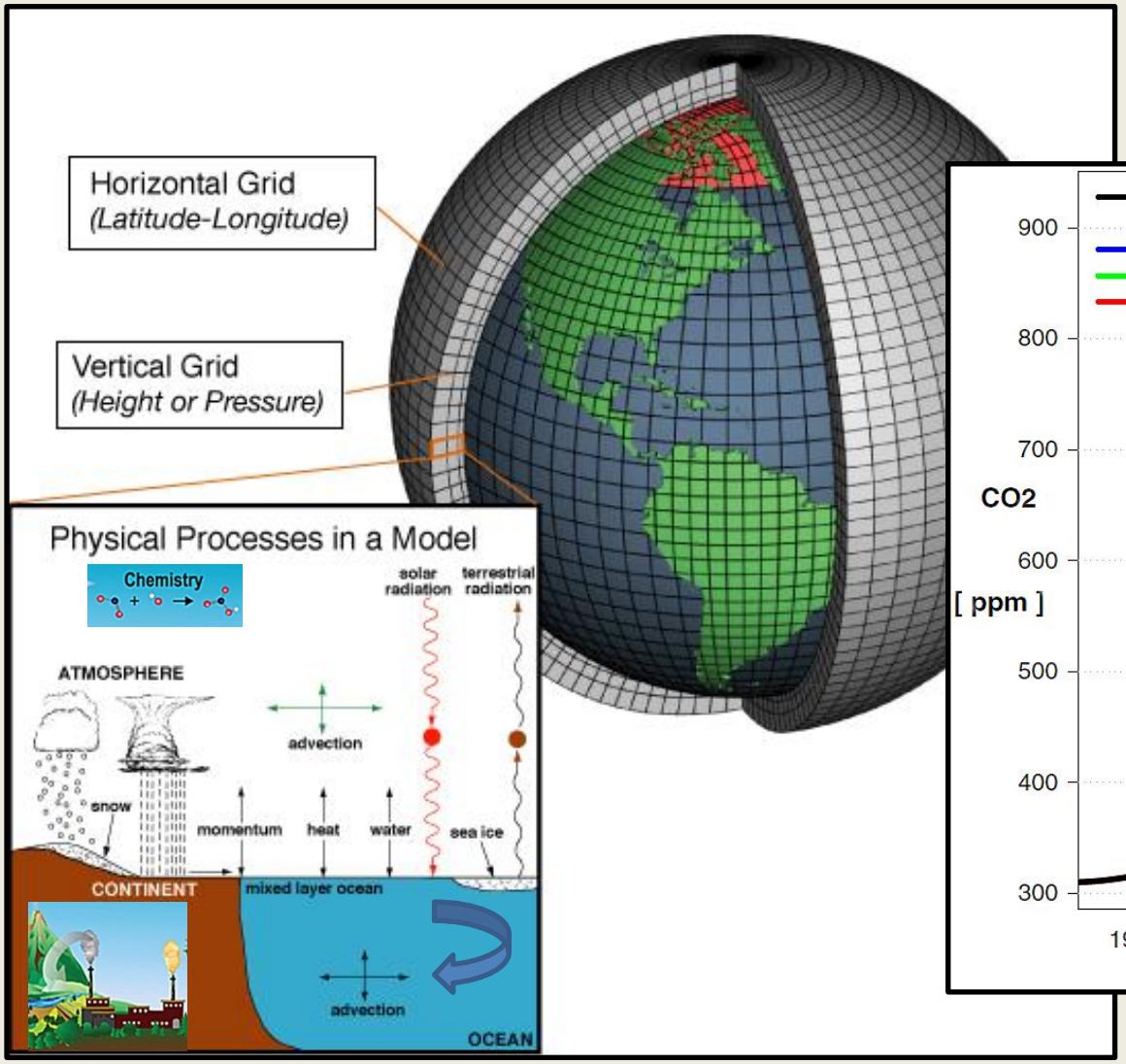


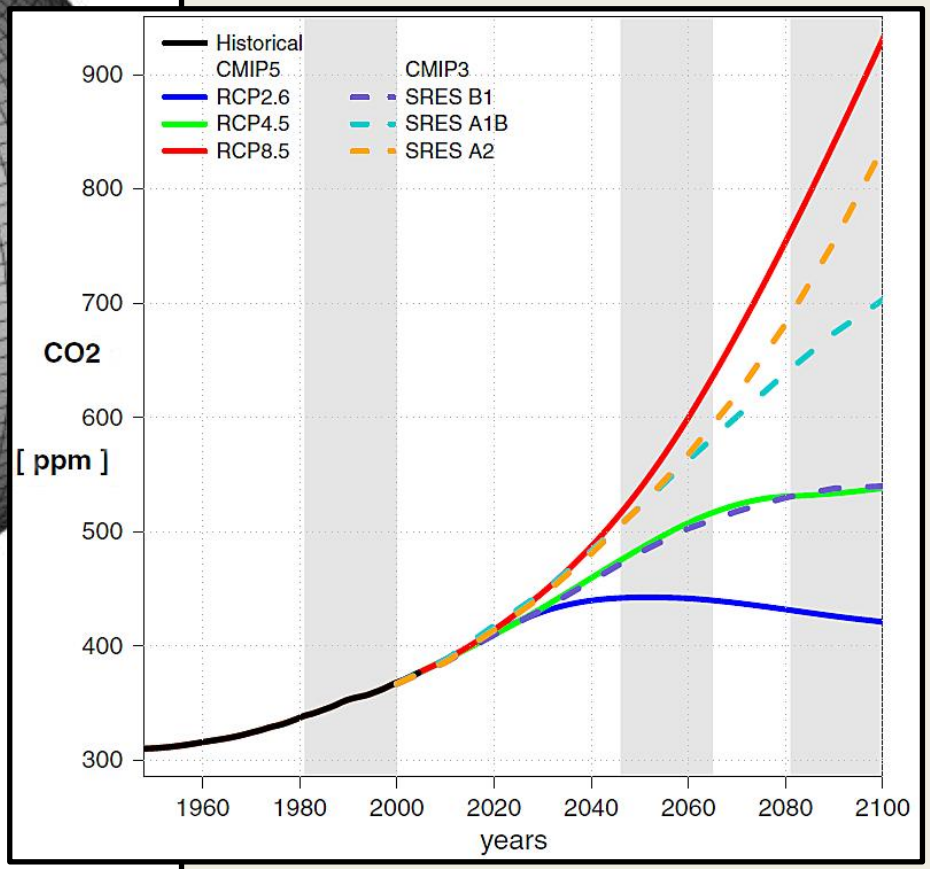
(IPCC - Climate Change 2007: The Physical Science Basis)

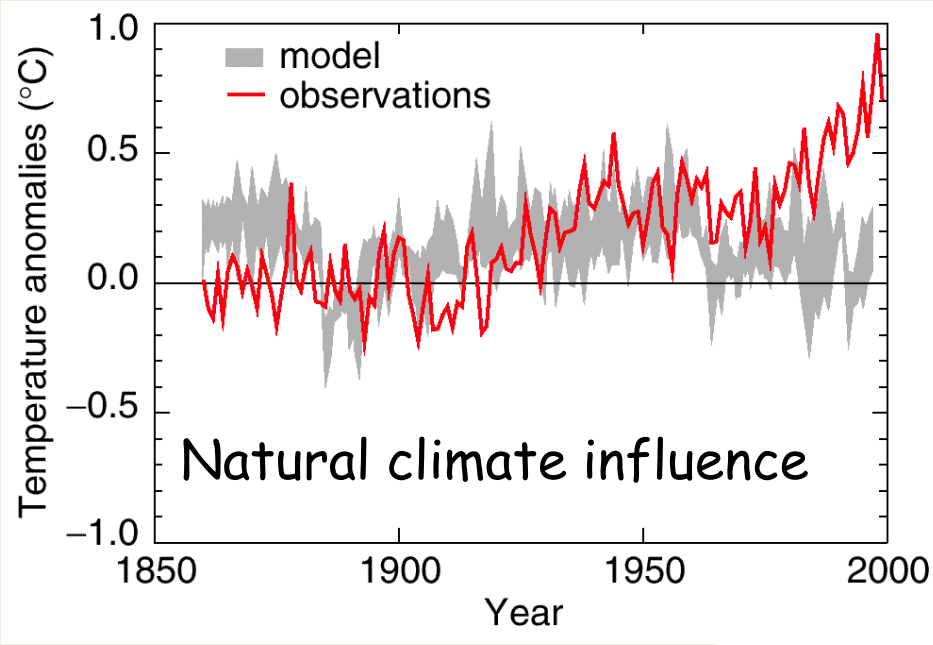
Projections of future climate

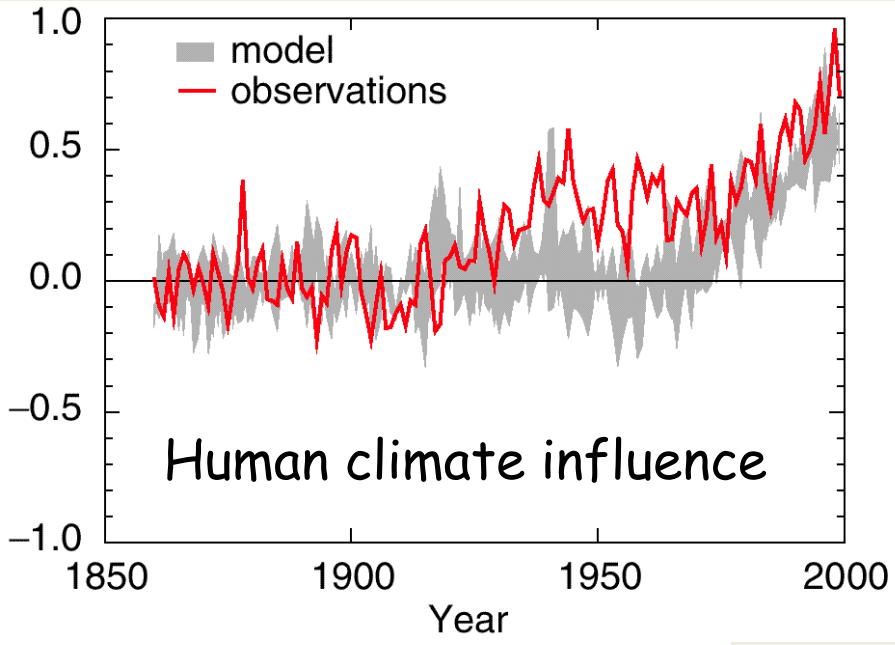
Global climate models



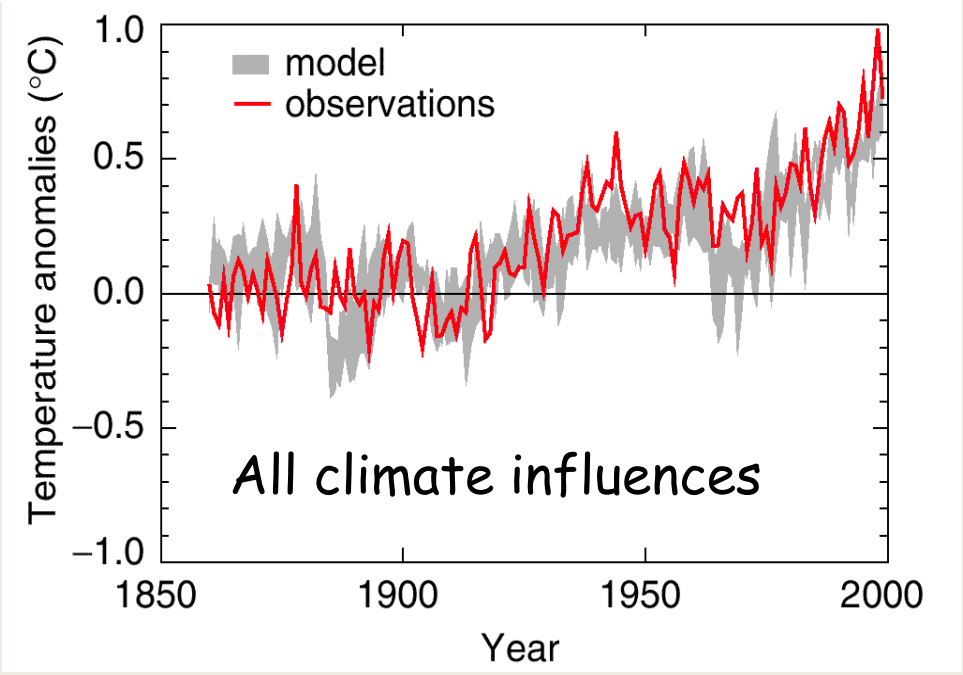
Greenhouse gas emissions scenarios







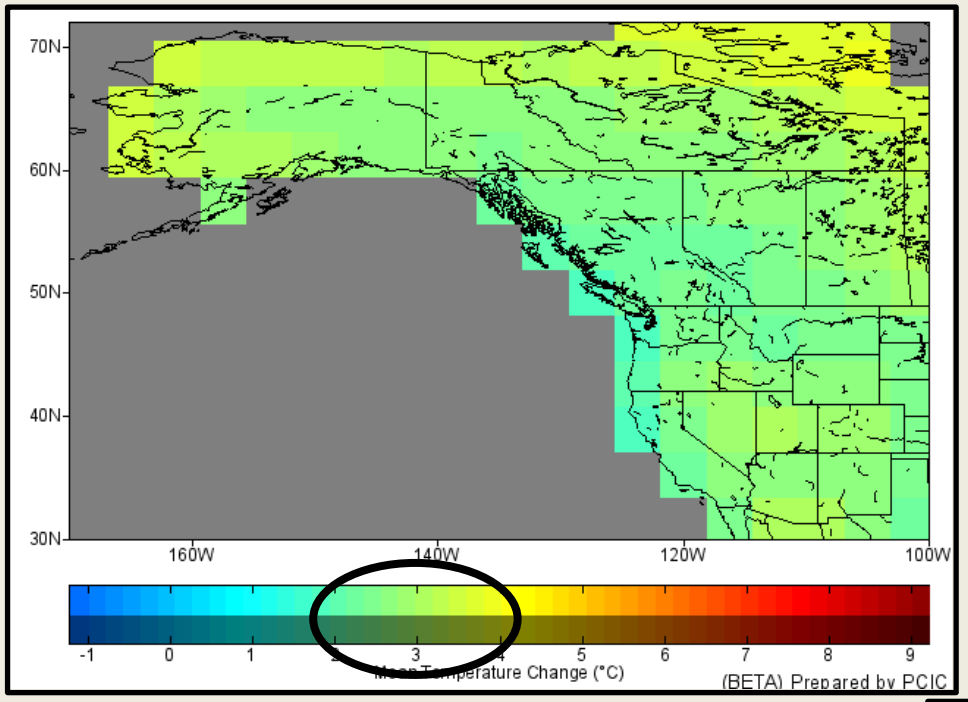
Simulating the future climate - do the models work?



IPCC 5th Assessment – the future

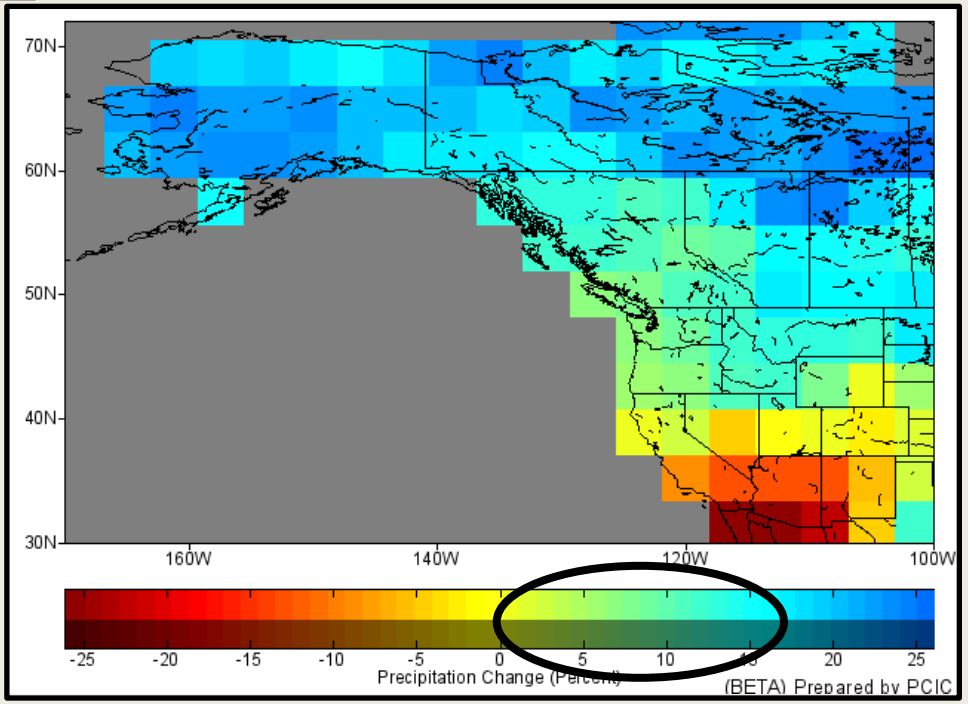
- Continued emissions of greenhouse gases will cause further warming in all components of the climate
- By end of 21 century the global surface temperature will likely warm by 1.5 to 4.5°C
- Increased contrast in precipitation between wet and dry seasons and wet and dry regions
- Sea level rise of 0.3 to 0.9 m; ocean pH ↓ 0.1 to 0.3
- Most aspects of climate change will persist even if emissions of GHGs are stopped
- AR5 reinforces the conclusions presented in AR4

Examples of projected change by 2050s from CGCM3r1 A2



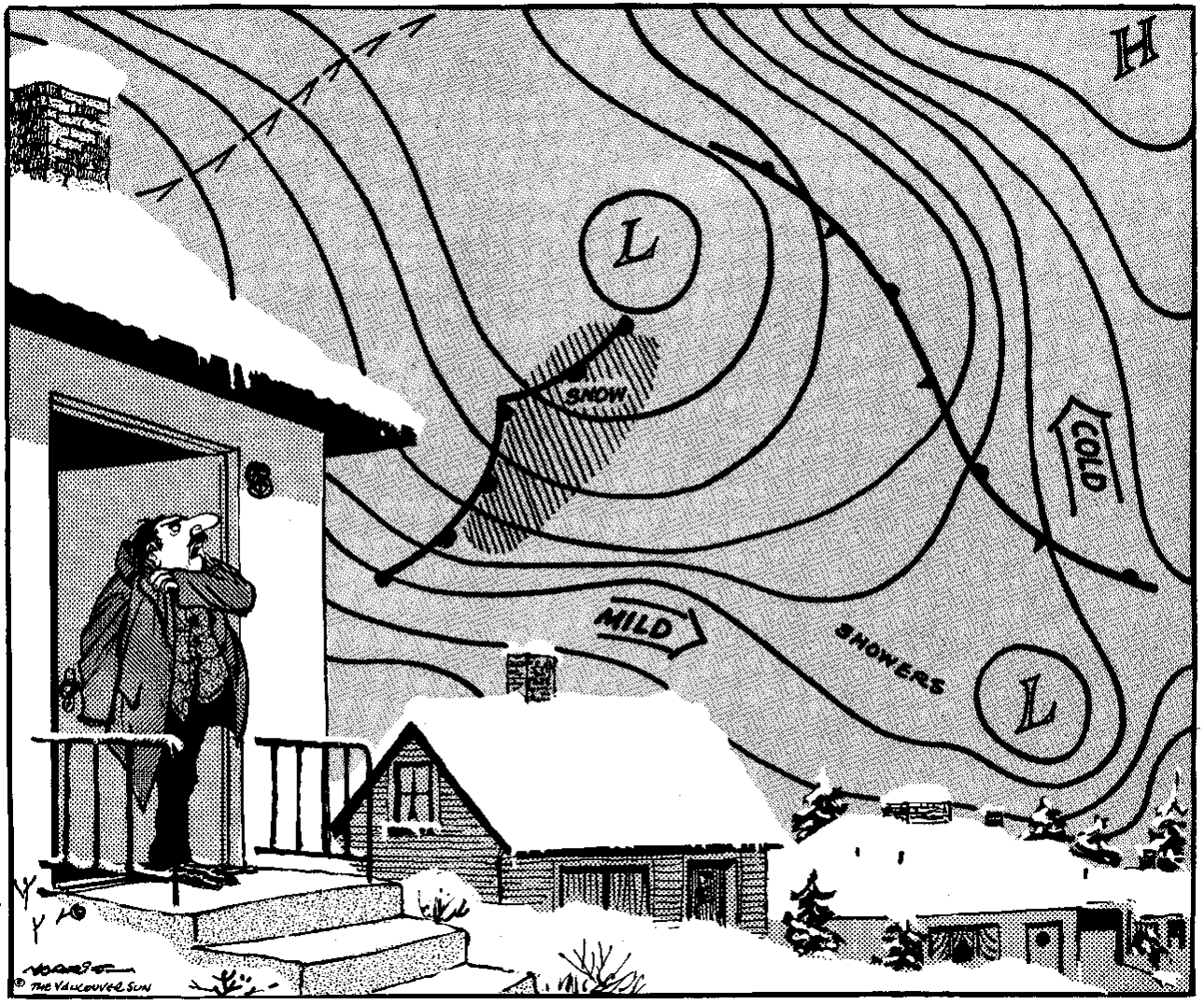
Mean annual temperature change (°C)

Mean annual precipitation change (%)



(http://pacificclimate.org)

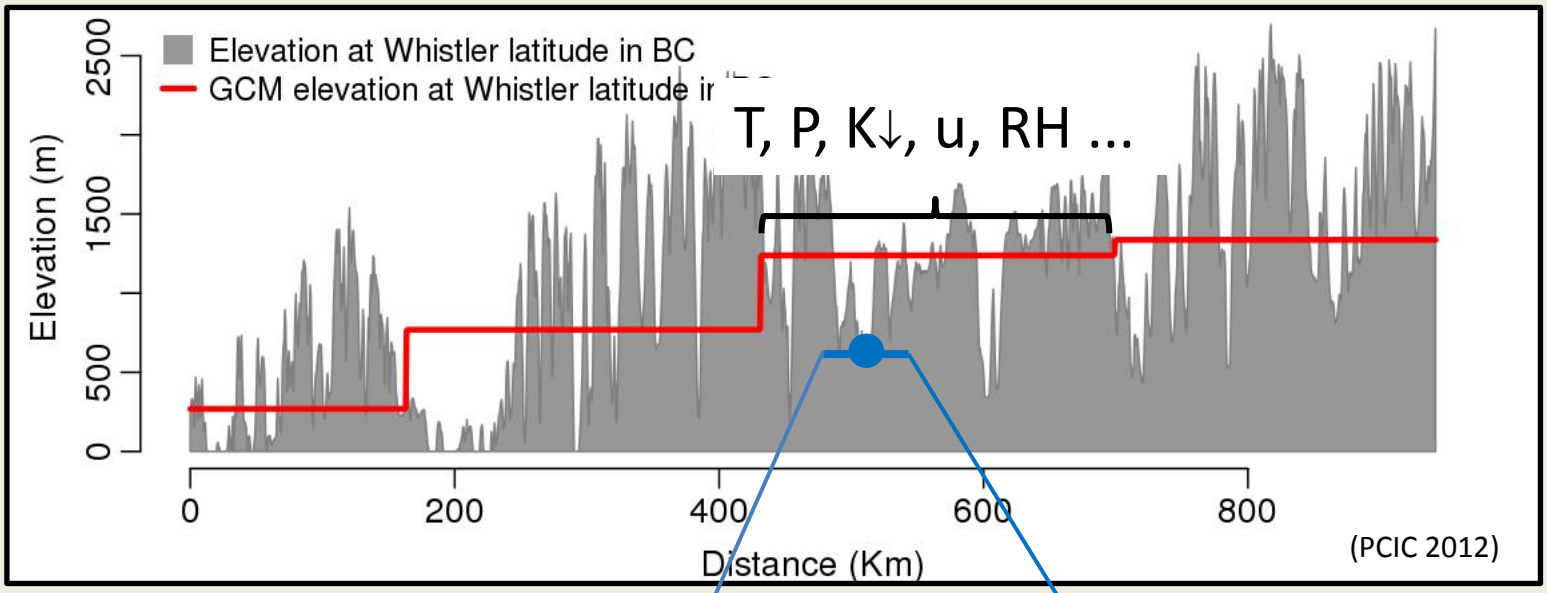
Downscaling – from global to local



"Frankly, I don't like the look of the climate."

(Hare and Thomas 1974)

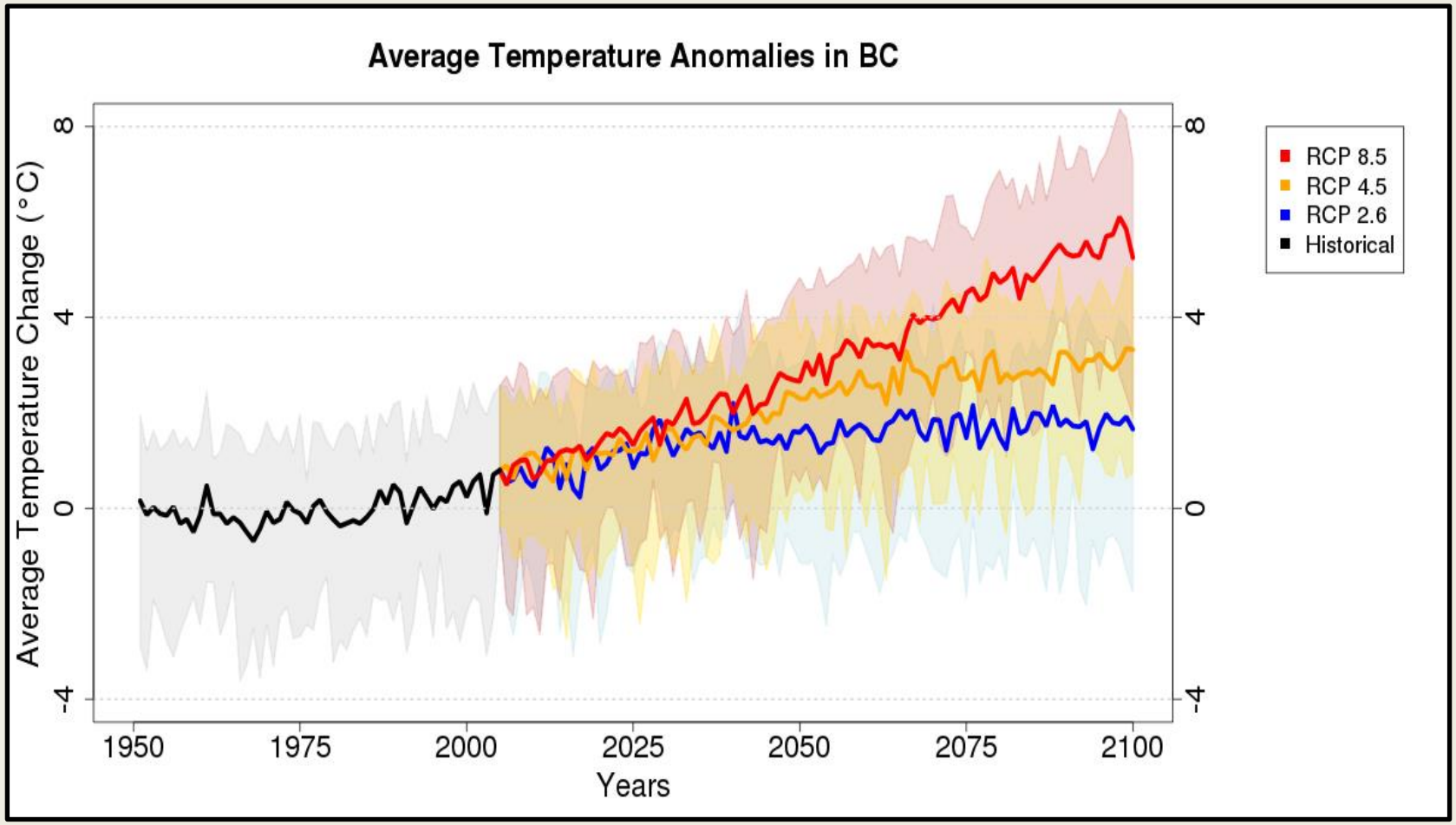
Downscaling global climate models to small areas or specific locations



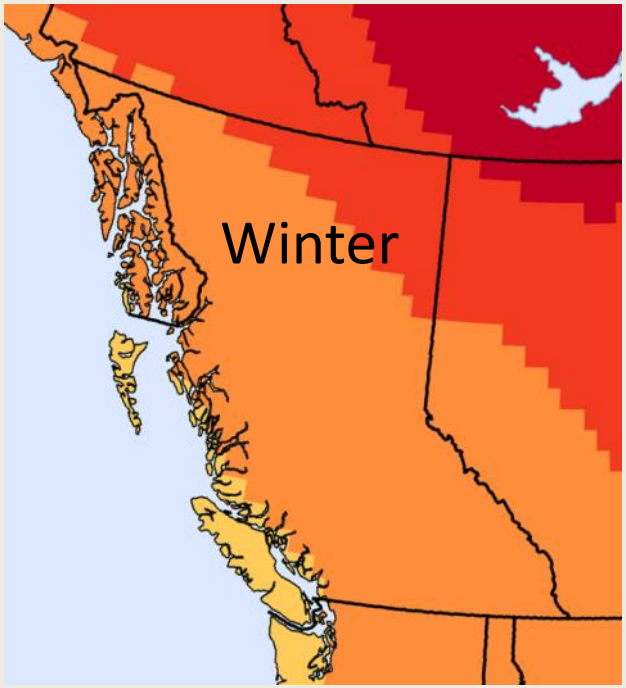
Delta method: Difference between location data and GCM for 1961-90 normals used to adjust projections to specific elevations.

Sources of uncertainty in applying climate change projections

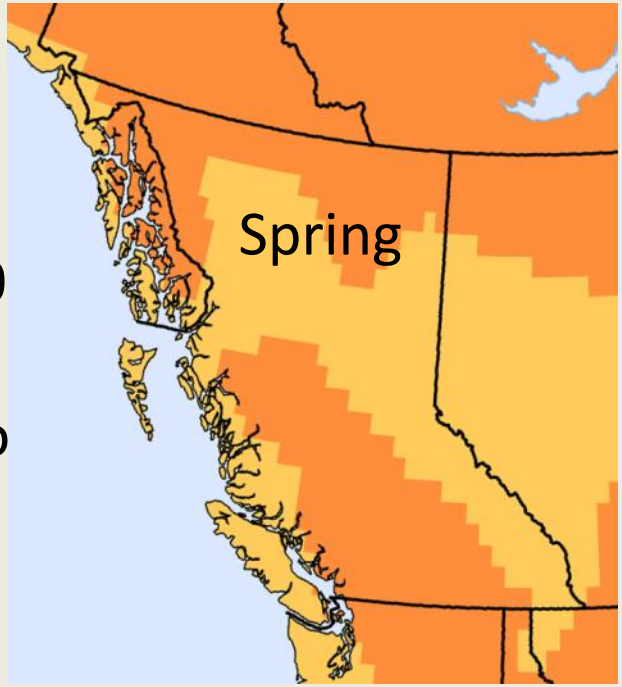
- Global climate models – representation of chemistry, physics, biology, topography
- Greenhouse gas emissions scenarios
- Downscaling – methods, spatial and temporal scales
- Impact assessment models

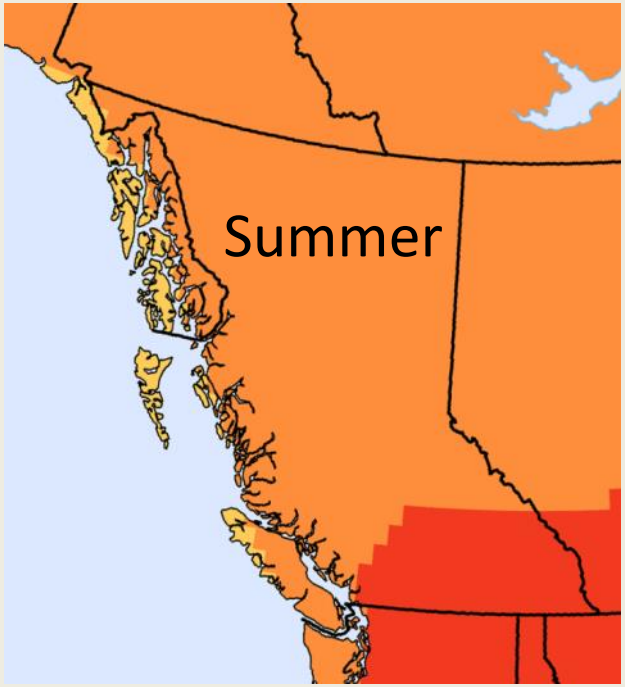

Average Temperature Anomalies in BC
Average Temperature Change (°C)
8
4
0
-4
1950
1975
2000
2025
2050
2075
2100
Years
RCP 8.5
RCP 4.5
RCP 2.6
Historical

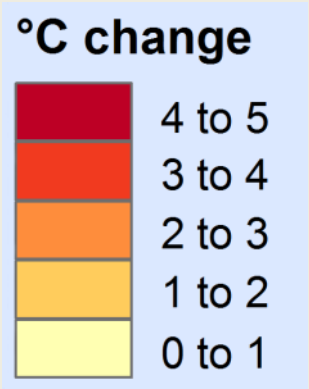
(PCIC 2014)

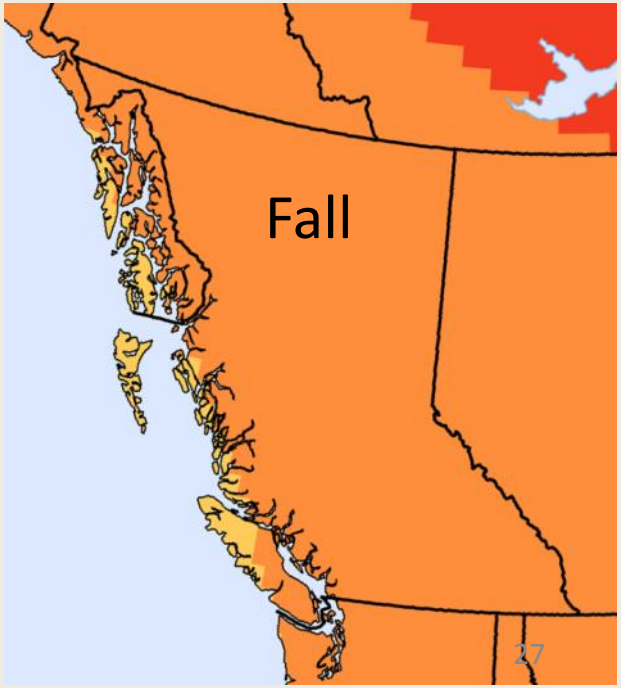


Median temperature change (°C) by season in 2050s from 1961-90 normals – 13 GCMs + BAU emission scenario

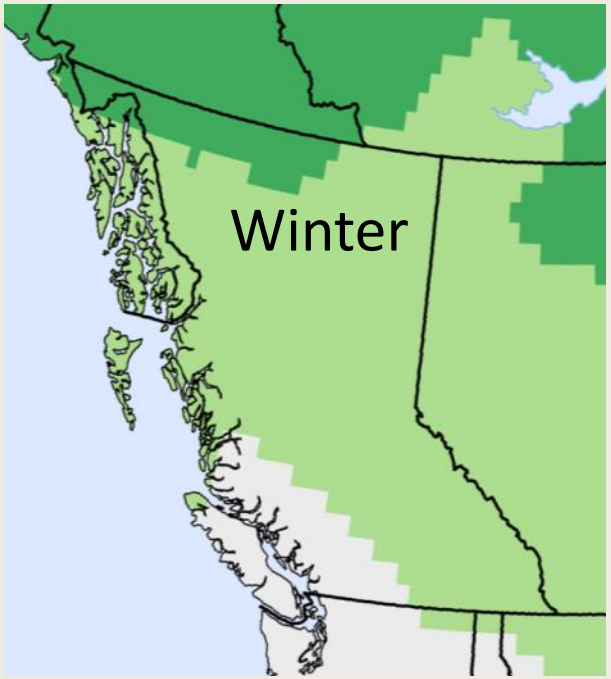




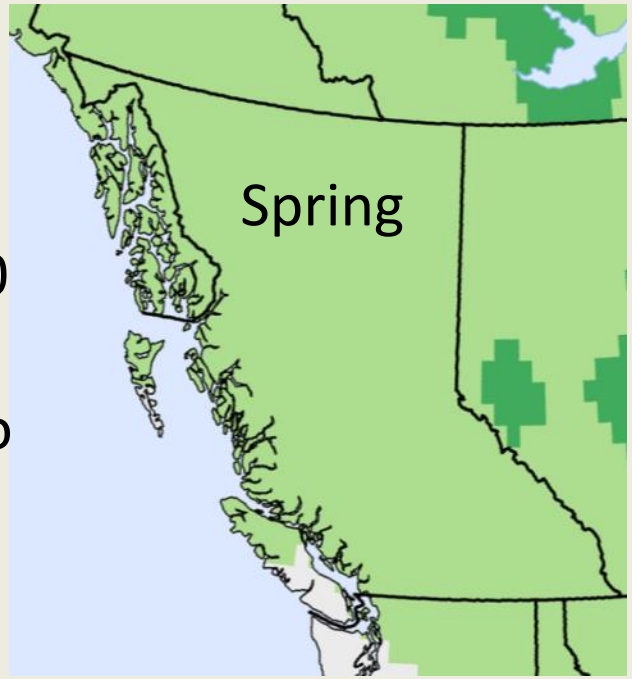


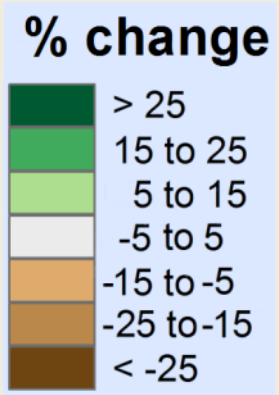


(Adapted from Fettig et al. 2013)



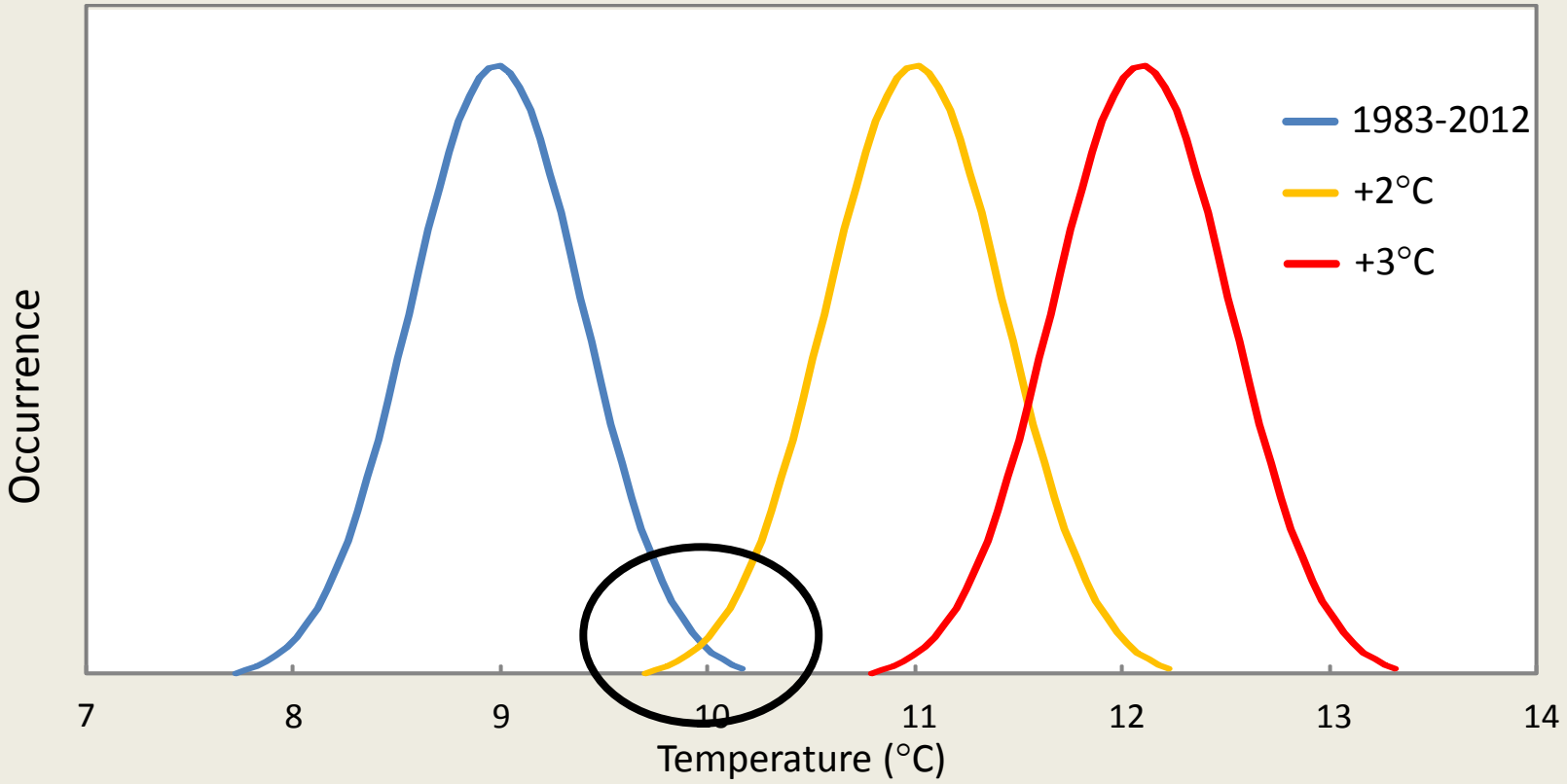
Median precipitation change (%) by season in 2050s from 1961-90 normals – 13 GCMs + BAU emission scenario





(Adapted from Fettig et al. 2013)

Mean annual air temperature – Campbell River Airport



Temperature and precipitation extremes for BC

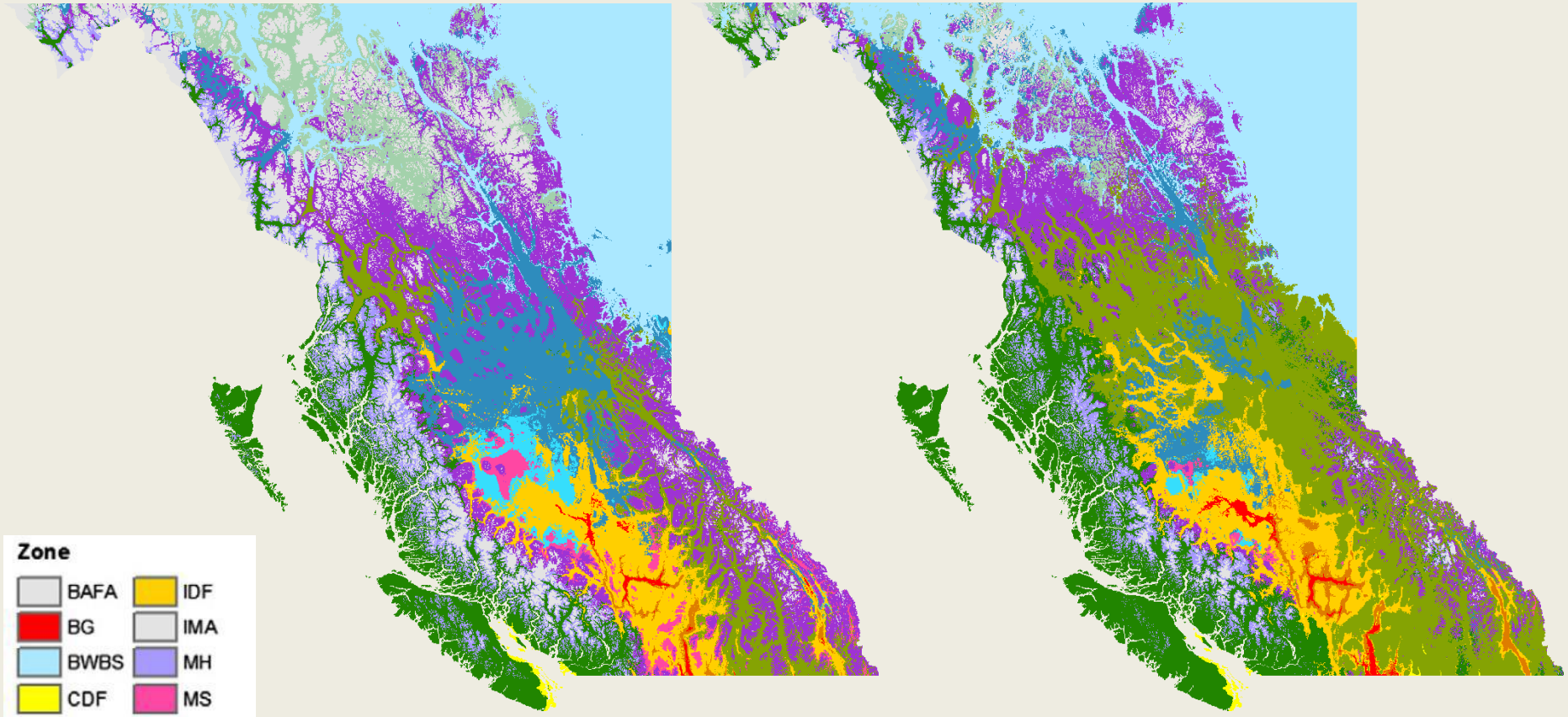
- 1 in 20 year warm temperature extremes become 1 in 5 years by 2050s
- Cold extremes show a corresponding decrease in frequency or cease
- 1 in 20 year precipitation extremes become 1 in 10 year events by 2050s
- July-August dry periods likely more intense for southern BC

(Kharin et al. 2007, Bürger et al. 2012, Silmann et al. 2013)

Change in ecosystem-based climate zones

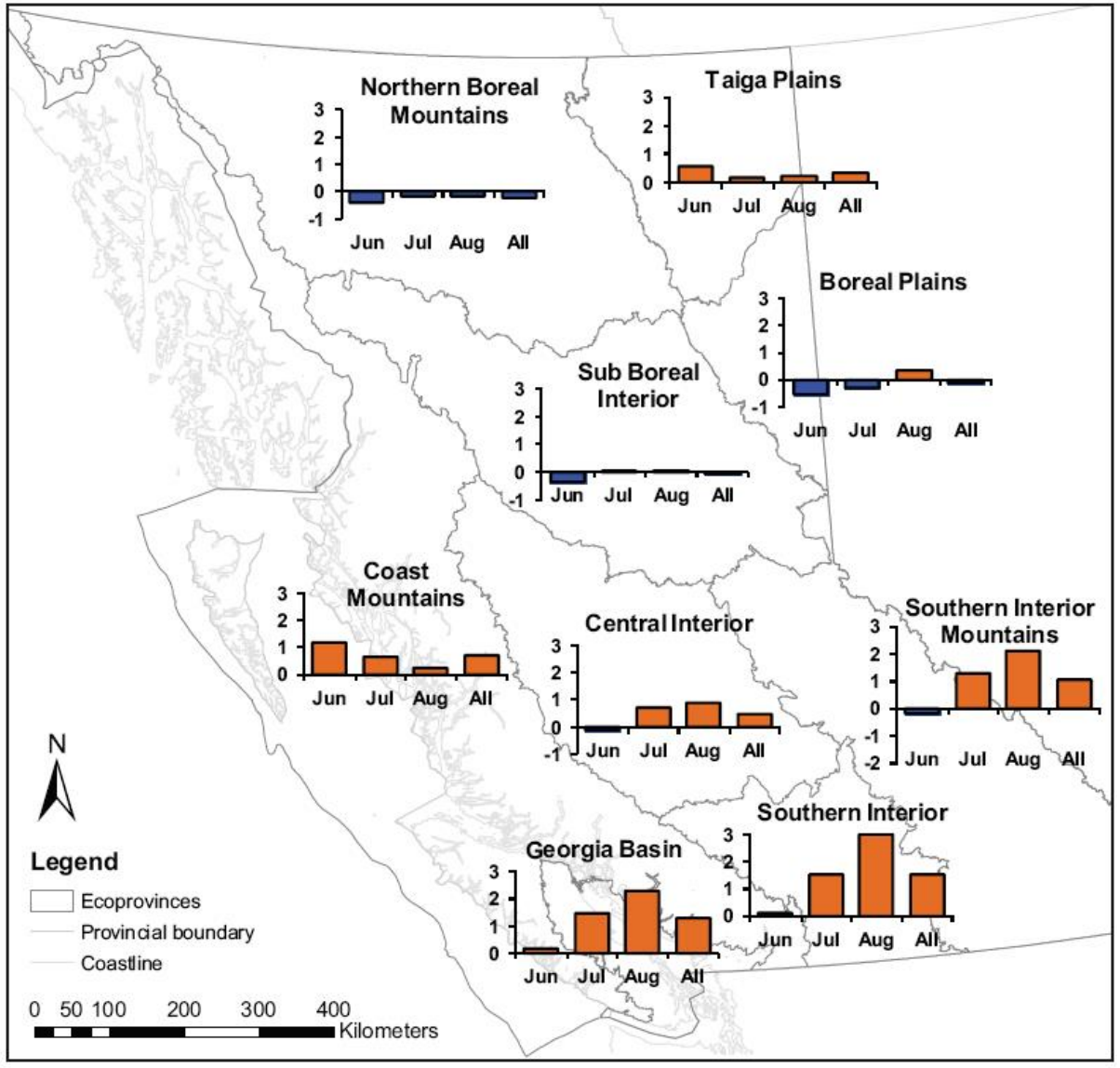
Current

2080s



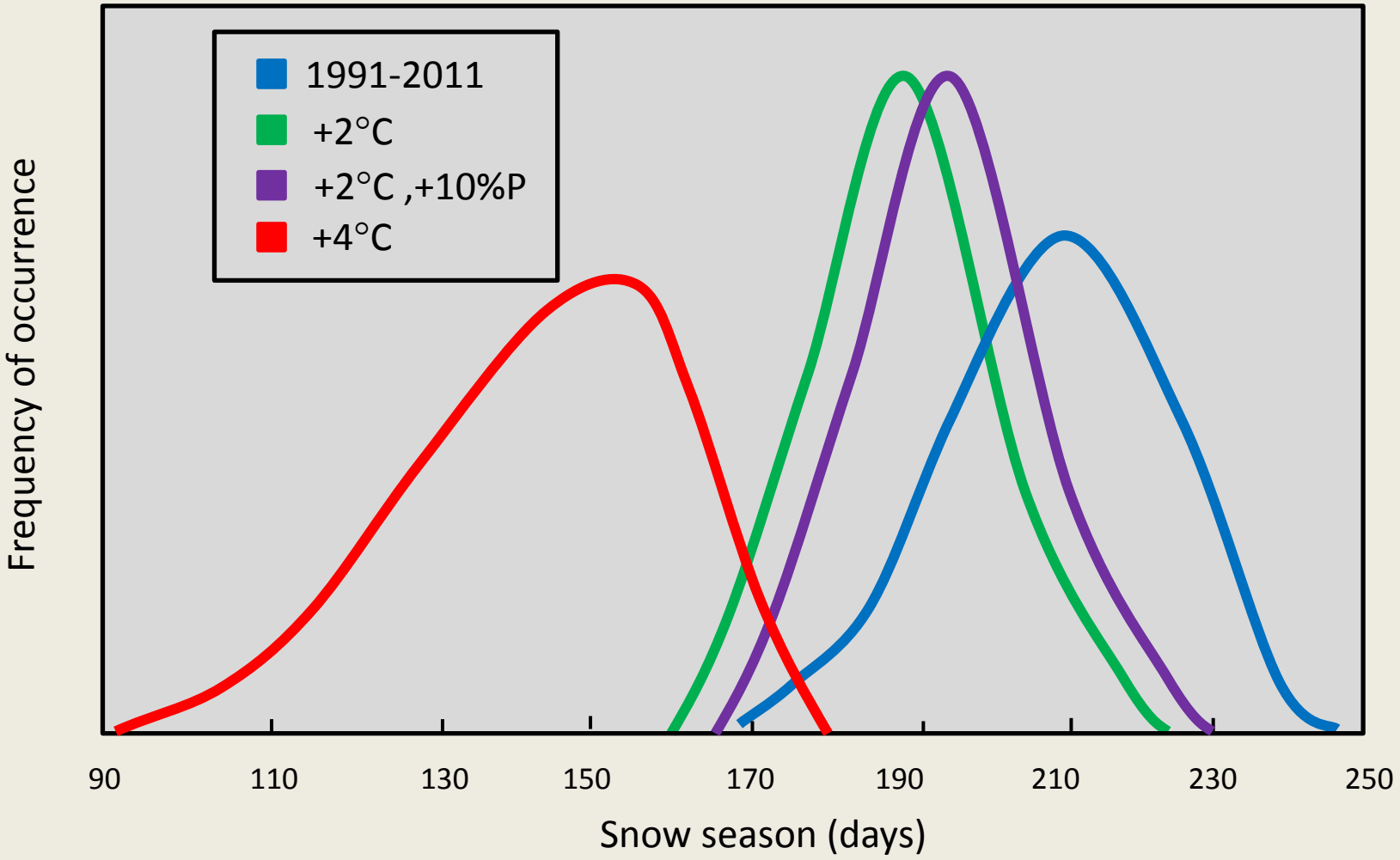
(Wang et al. 2012)

Change in monthly fire severity ratio by 2080s based on the CRCM4.2 A2



(Haughain et al. 2012)

Length of snow season and warming – ~1600 m on Okanagan Plateau



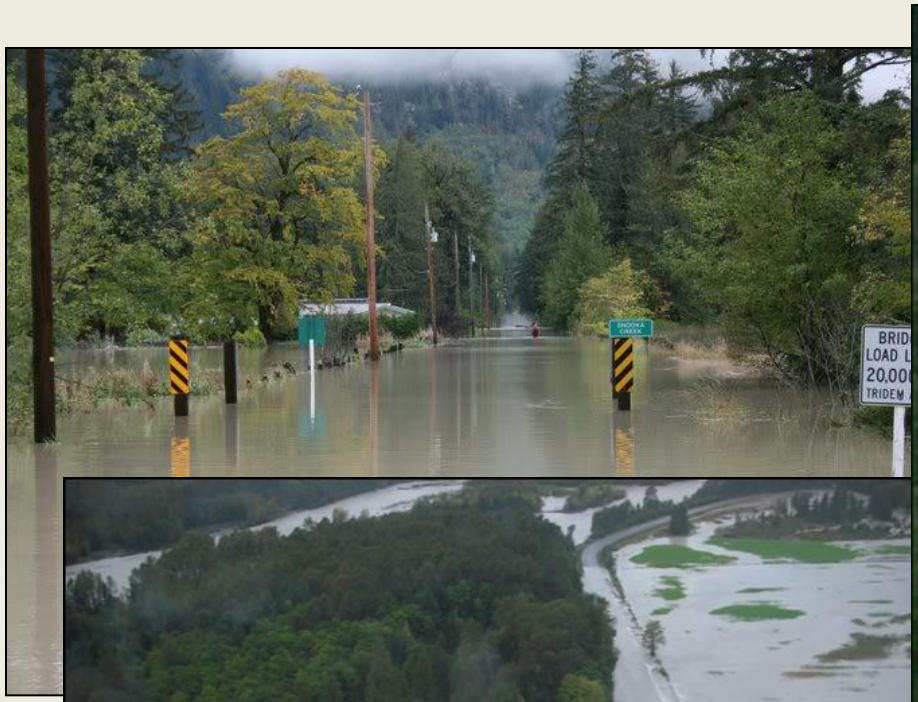
(Adapted from Murdock and Spittlehouse 2011)

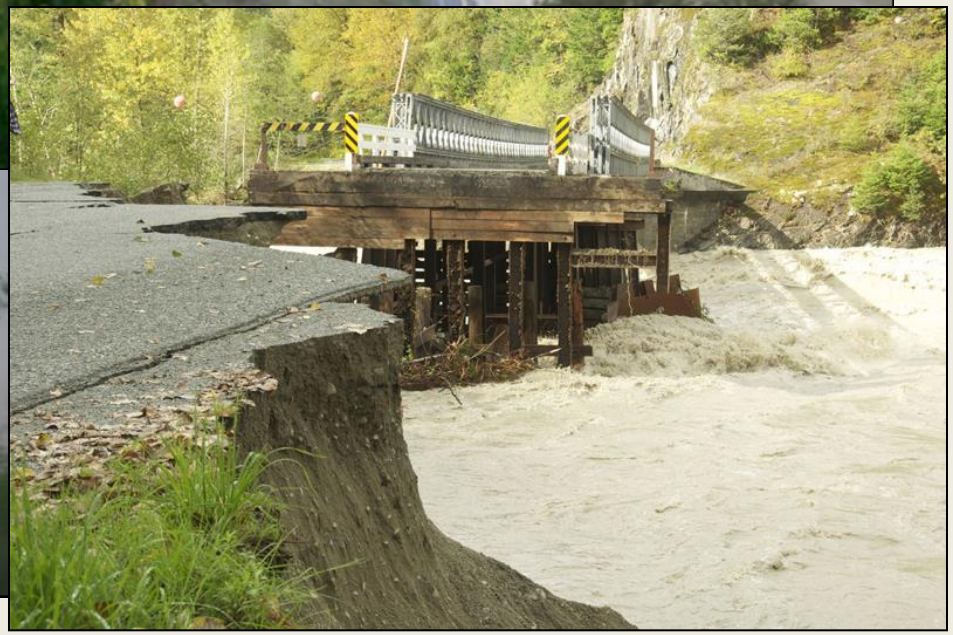
Hydrological changes

- *Snow dominated systems*
  - More winter precipitation as rain
  - Shorter snow season, shallower snow pack
  - Earlier peak flow
  - Decrease summer low flows
- *Rain dominated systems*
  - Increase in winter peak flow
  - Decrease/increase in summer low flows
- *Hybrid systems*
  - Move toward rain dominated mode
- *Glacier augmented*
  - Increase/reduce summer flows

(Pike et al. 2008, 2010)

Extreme events – Bella Coola





Climate change information

- Pacific Climate Impacts Consortium - Plan2Adapt; Regional Analysis Tool
  http://www.pacificclimate.org/
- Regional climate summaries
- ClimateBCv5.1 – stand alone software;
  http://cfcg.forestry.ubc.ca/projects/climate-data/climatebcwna/#ClimateBC
- ClimateBCv5.1 – web-based software;
  http://climatewna.com/climatena_map/ClimateBC_Map.aspx

PACIFIC CLIMATE IMPACTS CONSORTIUM

PLAN2ADAPT

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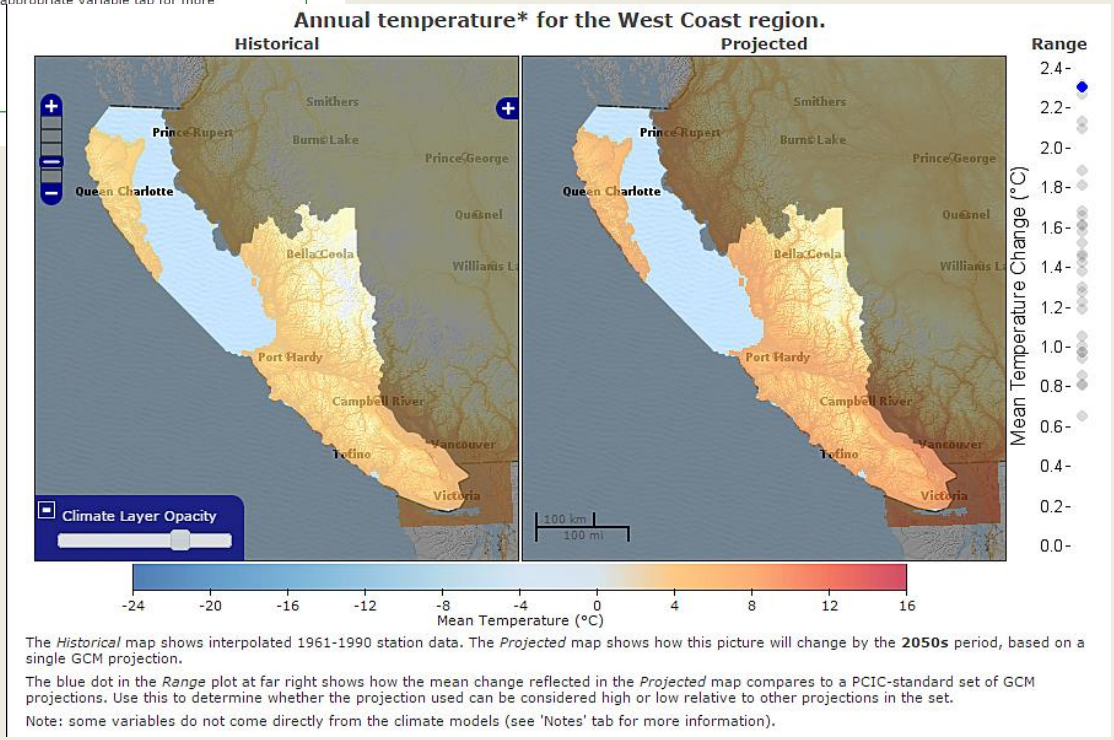
Summary
Region & Time
Temperature
Precipitation
Snowfall
Growing DD
Heating DD
Frost-Free Days
Impacts
Notes
References

Summary of Climate Change for West Coast in the 2050s

Climate Variable	Season	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Mean Temperature (°C)	Annual	+1.4 °C	+0.8 °C to +2.2 °C
Precipitation (%)	Annual	+6%	-0% to +11%
	Summer	-10%	-18% to +2%
	Winter	+6%	-2% to +12%
Snowfall* (%)	Winter	-28%	-46% to -10%
	Spring	-51%	-72% to -14%
Growing Degree Days* (degree days)	Annual	+327 degree days	+204 to +506 degree days
Heating Degree Days* (degree days)	Annual	-534 degree days	-816 to -318 degree days
Frost-Free Days* (days)	Annual	+22 days	+13 to +32 days

The table above shows projected changes in average (mean) temperature, precipitation and several derived climate variables from the baseline historical period (1961-1990) to the **2050s** for the **West Coast** region. The ensemble median is a mid-point value, chosen from a PCIC standard set of Global Climate Model (GCM) projections (see the 'Notes' tab for more information). The range values represent the lowest and highest results within the set. Please note that this summary table does not reflect the 'Season' choice made under the 'Region & Time' tab. However, this setting does affect results obtained under each variable tab.

* These values are derived from temperature and precipitation. Please select the appropriate variable tab for more information.



The *Historical* map shows interpolated 1961-1990 station data. The *Projected* map shows how this picture will change by the **2050s** period, based on a single GCM projection.

The blue dot in the *Range* plot at far right shows how the mean change reflected in the *Projected* map compares to a PCIC-standard set of GCM projections. Use this to determine whether the projection used can be considered high or low relative to other projections in the set.

Note: some variables do not come directly from the climate models (see 'Notes' tab for more information).

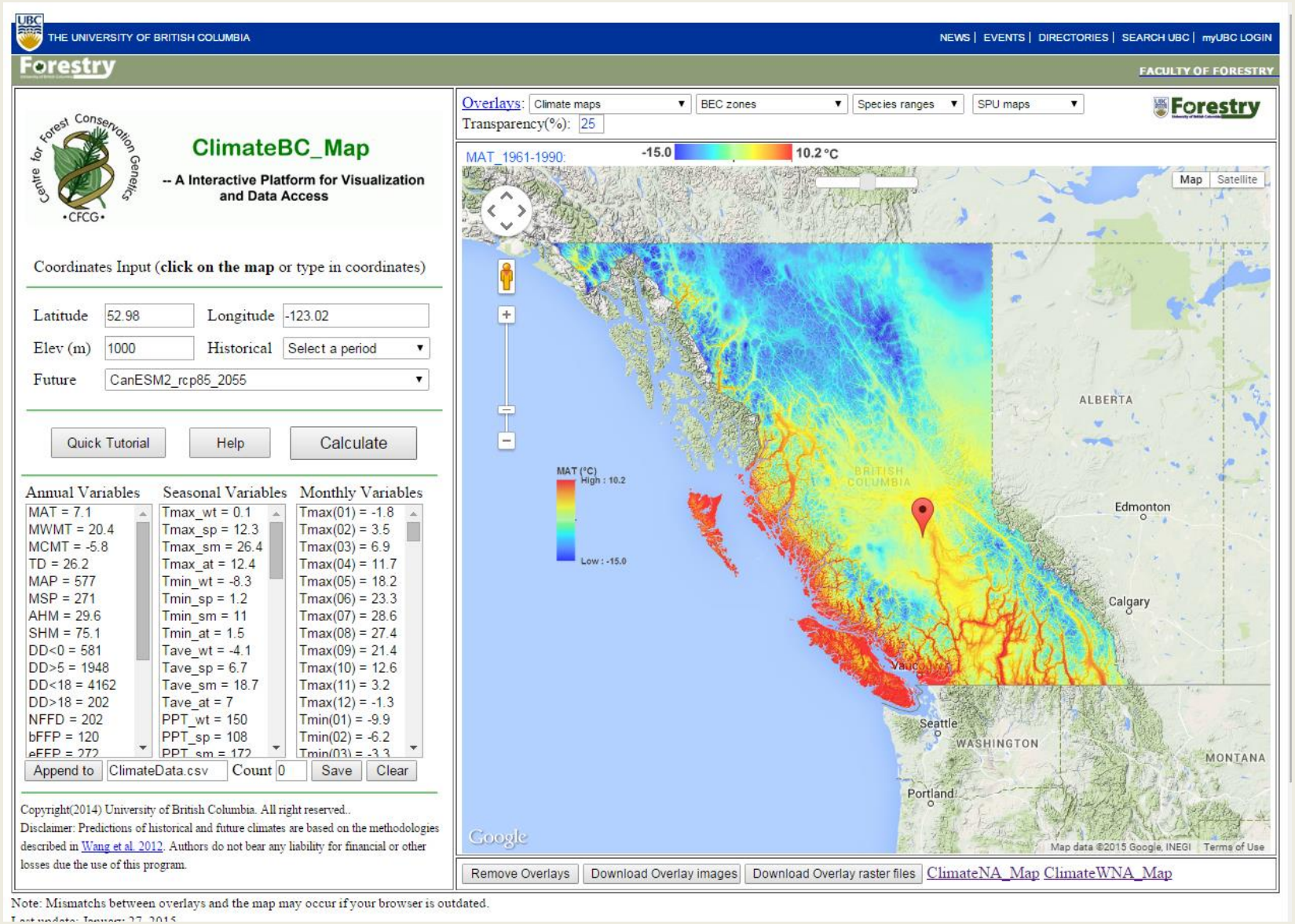
Plan2Adapt

http://www.pacificclimate.org/analysis-tools/plan2adapt

Resource Regions Climate Summaries

(http://www.pacificclimate.org/resources/publications)

ClimateBC v5.1- web application



(http://climatewna.com/climatena_map/ClimateBC_Map.aspx)

FLNRO Climate Change Strategy 2013-2018

- Climate change is integrated into ministry core business
- Climate science and knowledge help guide actions
- Actions are taken in collaboration with all stakeholders

Adaptation

- Reduce vulnerability of an entity to climate change
- Vulnerabilities vary with the entity -
  uncertainty, timeframe, exposure, sensitivity, adaptive capacity, knowledge
- Management = Juggling vulnerabilities and values to maintain resilience of forest resources and communities

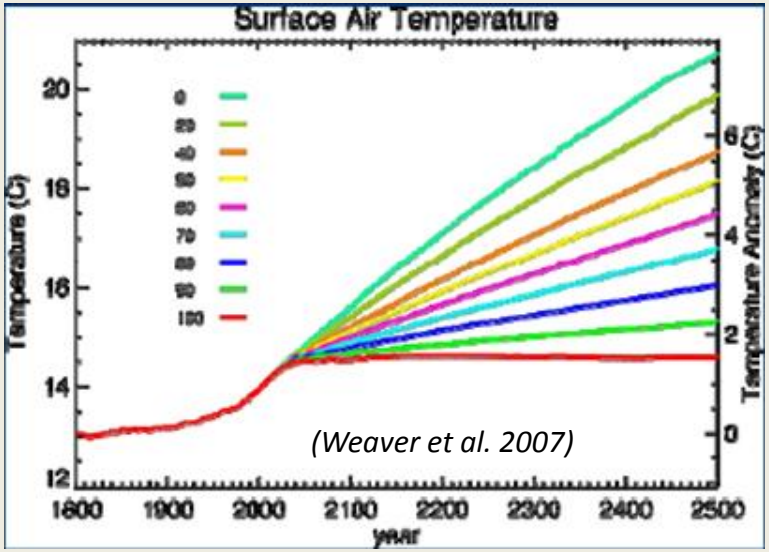
Adaptation

- Biological - Adapt forests to the changing climate - Influence the direction and timing of the response
- Technological - Adapt technology and practices to the forest response to the changing climate
- Societal – Adapt our values and how we use forest resources

(Spittlehouse and Stewart 2003, Spittlehouse 2005)

2°C global temperature change goal

- Proposed to restrict global temperature change to 2°C by 2100 through emissions reduction
- Limit degree of “dangerous” change to the global environment
- All emission scenarios with <60% reduction in emissions break the 2°C threshold by 2100



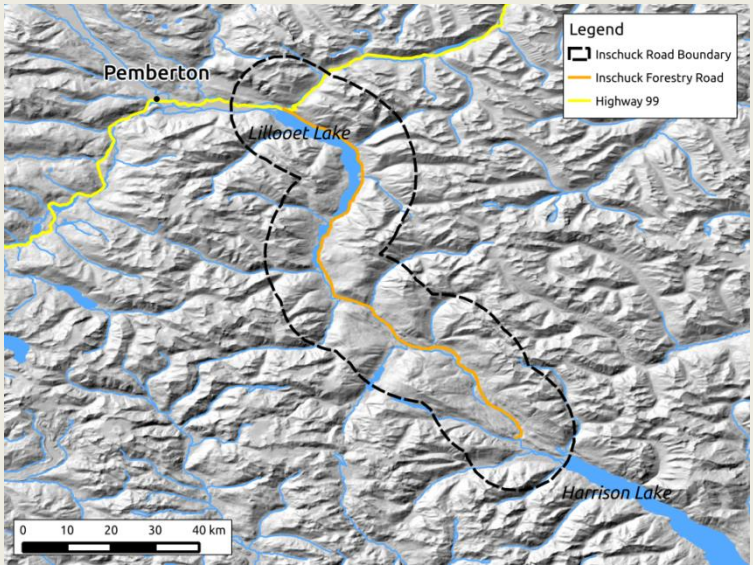
- GDP, quality of life = emissions

Summary

- **Climate is changing**
- **And it will continue to change**
- **Uncertainty in the amount and timing of change**
- **Tools available to obtain information on historic and projected change**

Climate change and the In-shuck-ch

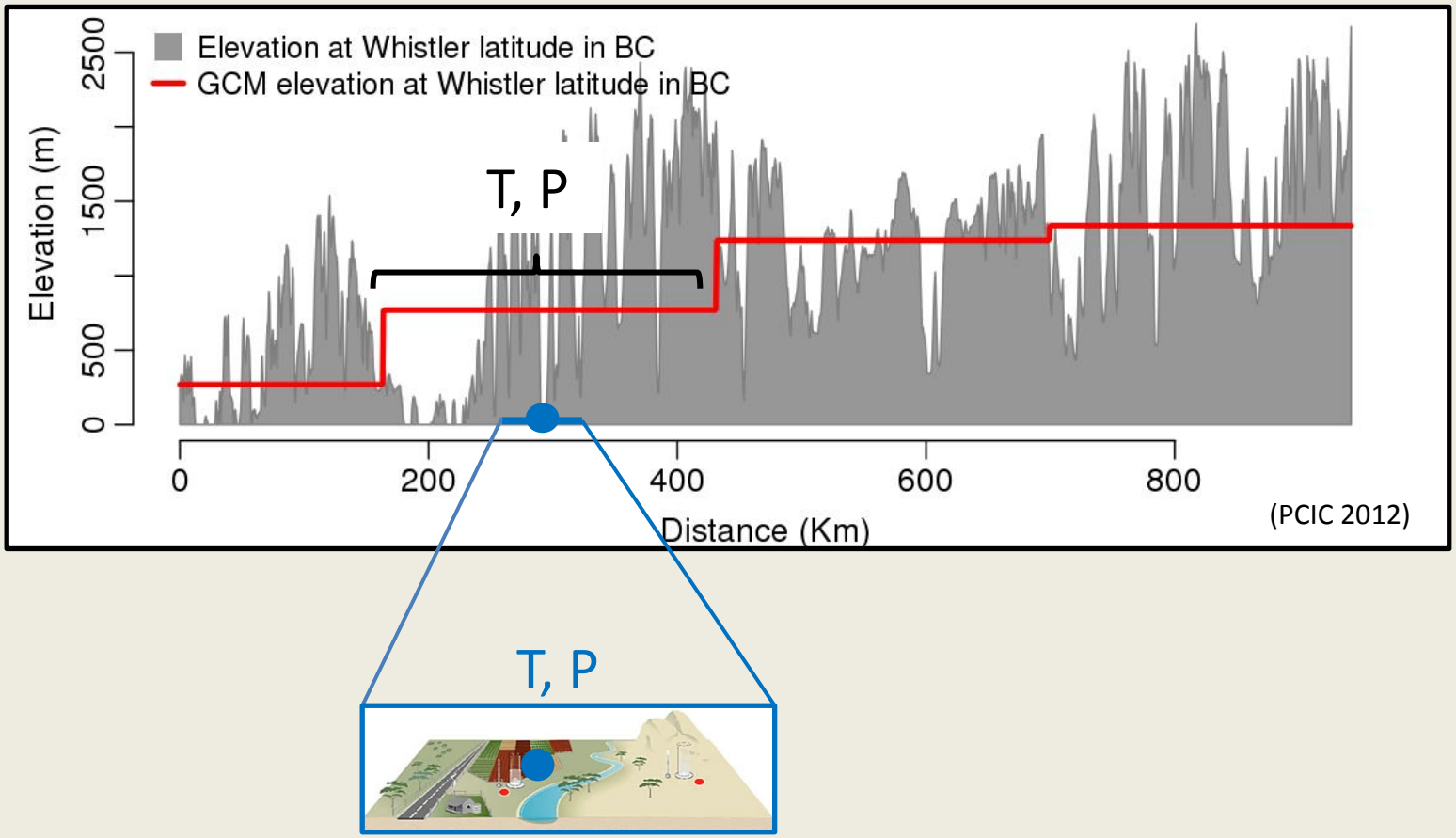
- Objective: Provide historic climate and projections of future climate to inform the PIEVC analysis
- Climate variables: Temperature and precipitation – seasonal means and daily extremes, return periods



Climate and infrastructure

#	Climate Parameter	Infrastructure Indicator
1	High Temperature	Number of Days with max. temp. exceeding 30ºC
2	Low Temperature	Days with min. temp. below -24ºC
3	Temperature Variability	Daily temperature variation of more than 24ºC
4	Freeze / Thaw	17 or more days where max. temp. > 0ºC and min. temp < 0ºC
5	Frost Penetration	Assessed through empirical analysis of forecast climate conditions
6	Frost	47 or more days where min. temp <0ºC
7	Extreme Rainfall Intensity Over One Day	Determined empirically. PCIC used . 76mm over 24 hrs.
8	Magnitude of Severe Storm Driven Peak Flows	Determined empirically. PCIC used directional wind speed, temperature and precipitation all > median values.
9	Frequency of Severe Storm Driven Peak Flow Events	Determined empirically. PCIC used directional wind speed, temperature and precipitation all>. median value for three consecutive days in autumn.
10	Rain on Snow	10 or more days where rain falls on snow
11	Freezing Rain	1 or more days with rain that falls as liquid and freezes on contact
12	Snow Storm / Blizzard	8 or more days with blowing snow
13	Snow (Frequency)	Days with snowfall > 10 cm
14	Snow Accumulation	5 or more days with a snow depth > 20 cm
15	High Wind / Downburst	Wind speed > 80.5 km/hr
16	Visibility due to Fog	Decrease in stopping sigh distance < 245 m

Downscaling daily climate change data for the In-shuck-ch



Data sources

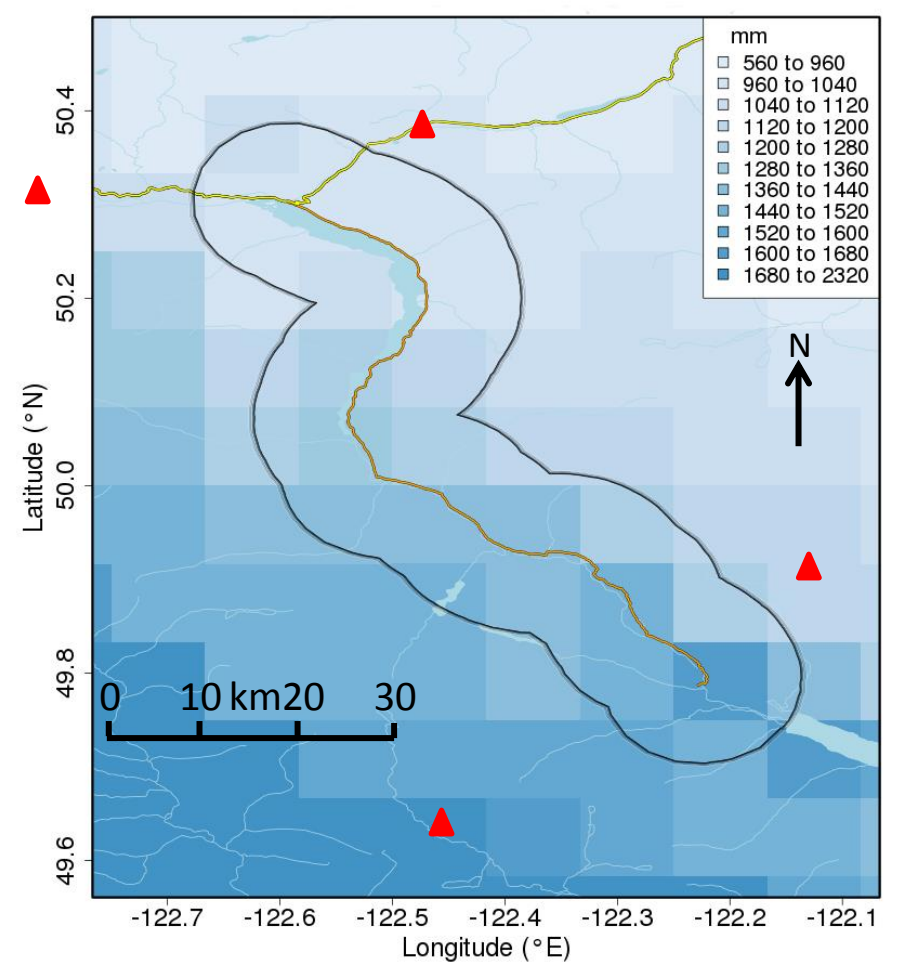
- No long term weather stations in the valley
- Interpolated temperature and precipitation
  - BCCAQ: Historic and projected daily values – 10 km grid PCIC
  - ClimateBC: Annual historic monthly values and projected monthly normals – point based, derived variables
  - PRISM 1971-2000 normals
- Climate change scenarios: 12 GCMs and rcp 4.5 and 8.5

Methods

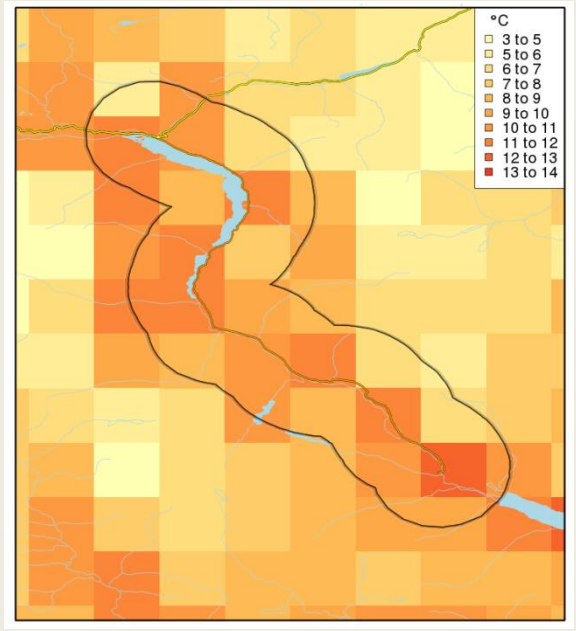
- Evaluate historic daily gridded BCCAQ data using nearby weather stations and ClimateBC data
  - normals, distributions and extremes
- Determine adjustments to BCCAQ data and to downscale BCCAQ to finer grid where necessary
- 1971-2000 is reference, 2011-2040, 2041-2070 and 2071-2100 are future time periods evaluated
- Changes in means and distribution of extremes and return periods in the future

Mean annual precipitation and temperature 1971-2000

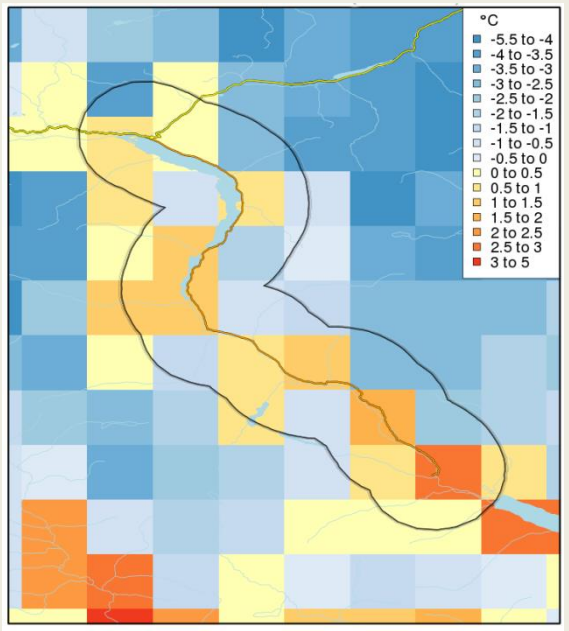
Precipitation



TMax



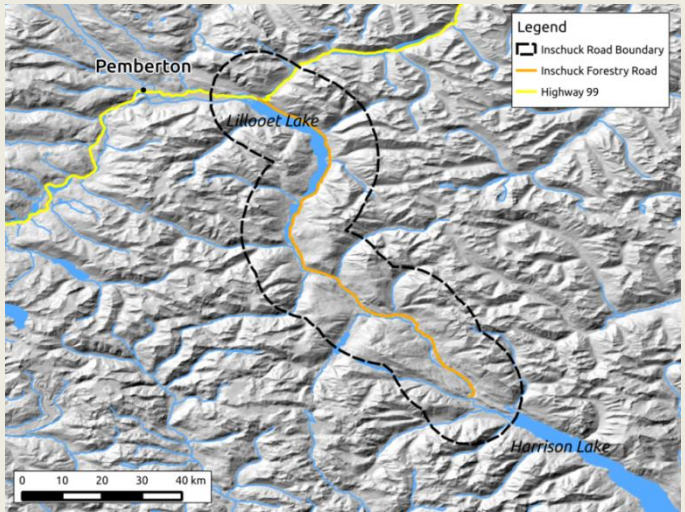
TMin



(BCCAQ data - PCIC 2015)

Mean annual temperature change (°C) from 1971-2000 - BAU scenario (rcp8.5)

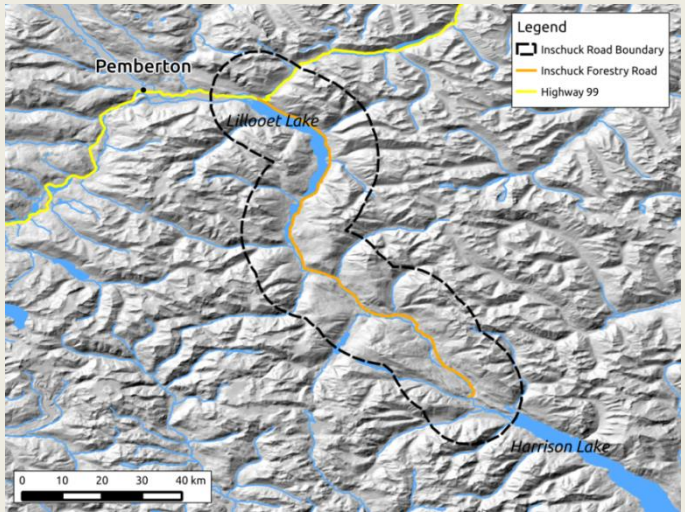
Period	Winter	Summer
2041-2070	2.7±1°C	3.6±2°C
2071-2100	4.8±1.5°C	5.8±2°C



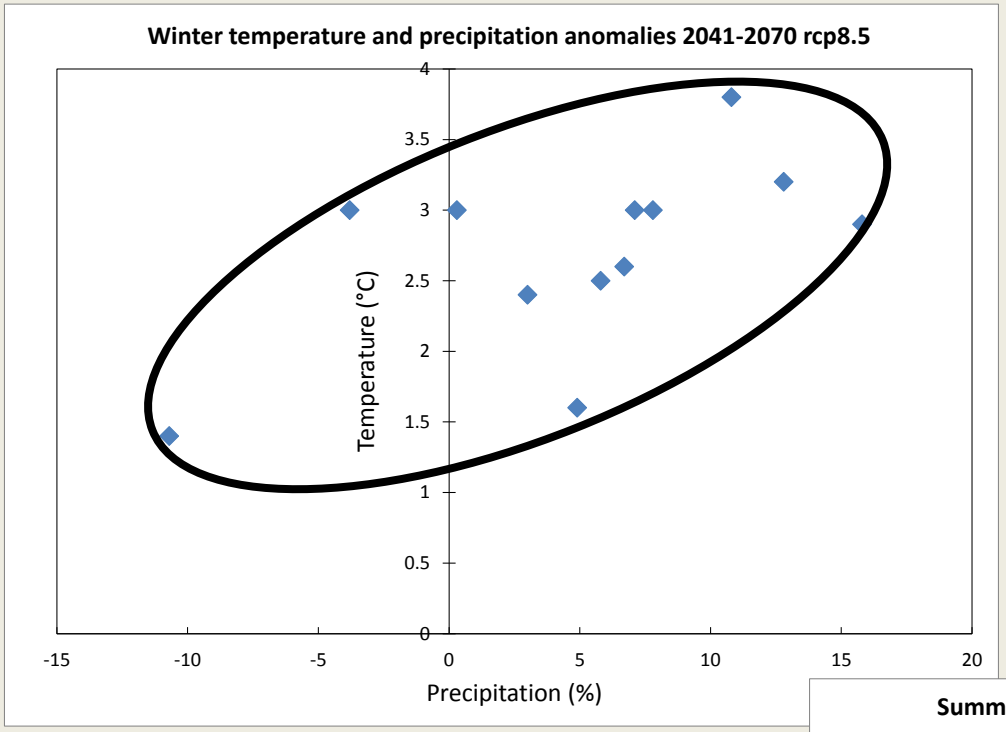
(PCIC 2015)

Mean annual precipitation change (%) from 1971-2000 - BAU scenario (rcp8.5)

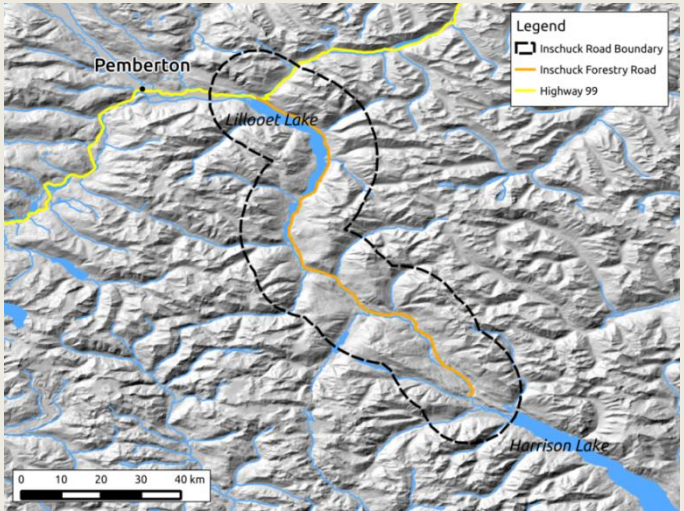
Period	Winter	Summer
2041-2070	+6±6%	-16±15%
2071-2100	+14±12%	-25±25%

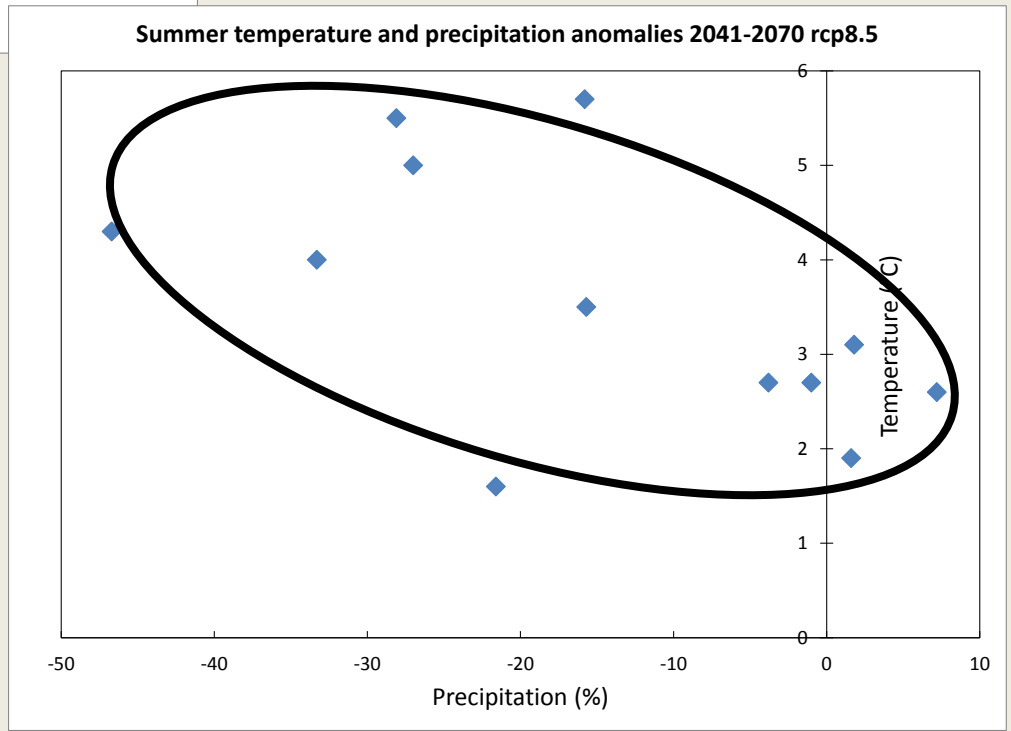


(PCIC 2015)



Winter and summer projections for 2041-2070 period, difference from 1970-2000 period.
12 GCMs rcp8.5





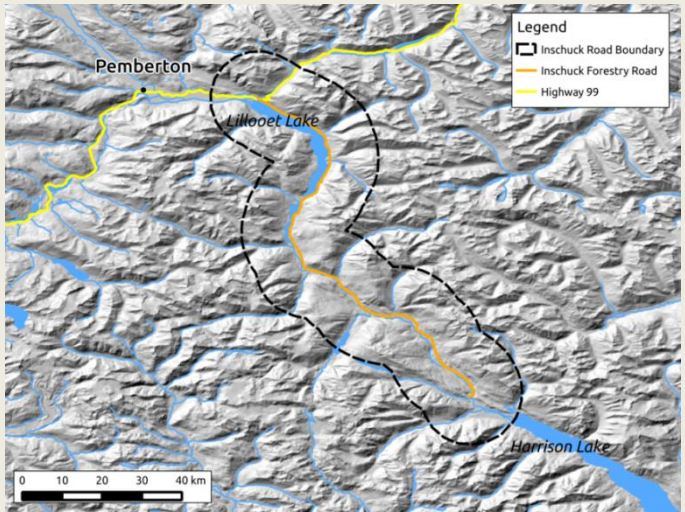
Precipitation

	1971-2000	2041-2070	2071-2100
Annual (mm)	1510	1630	1670
20-yr return period (mm)			
1-day max	90	105	105
5-day max	180	210	220

(CanESM rcp 8.5, 49.875°N, 123.291°W)

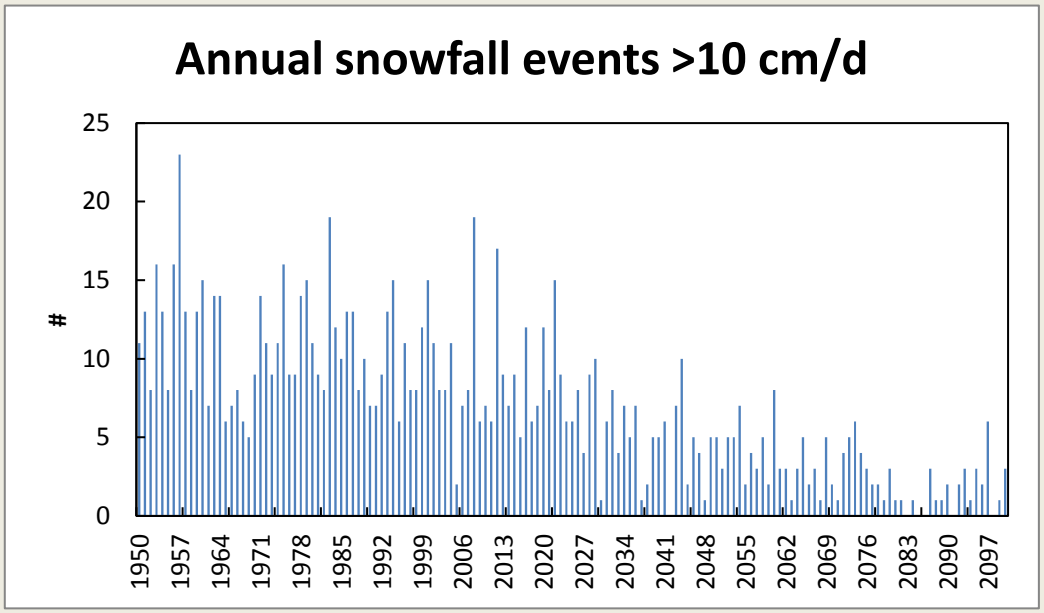
20 year return period temperature extremes – average for rcp8.5 projections

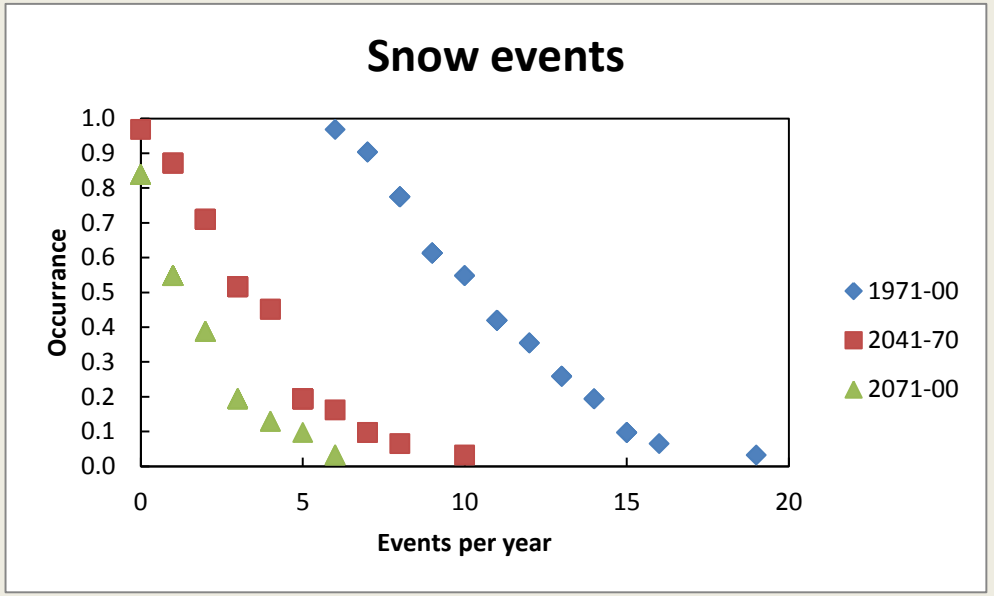
		1971-2000	2041-2070	2071-2100
Maximum temperature		34°C	39°C	41°C
Minimum temperature		-32°C	-26°C	-22°C
GCMs	Max		±2°C	±3°C
	Min		±3°C	±4°C



(PCIC 2015)

Influence of warming on snowfall





(CanESM rcp 8.5, 49.875°N, 123.291°W)

Summary

- GCMs project a continuation of trends seen in the past century
- Further warming of 3 to 6°C over this century
- Changes to precipitation – winter increase, summer decrease
- Increase in magnitude of extremes
- Substantial decrease in snow cover

FLNR Engineering, Roads and Bridges Climate Adaptation PIEVC Pilot Project

Part 2
Climate Change and Projections for In-SHUCK ch FSR

QUESTIONS/DISCUSSION

Teleconference call

1-877-353-9184 participant code 2043433#