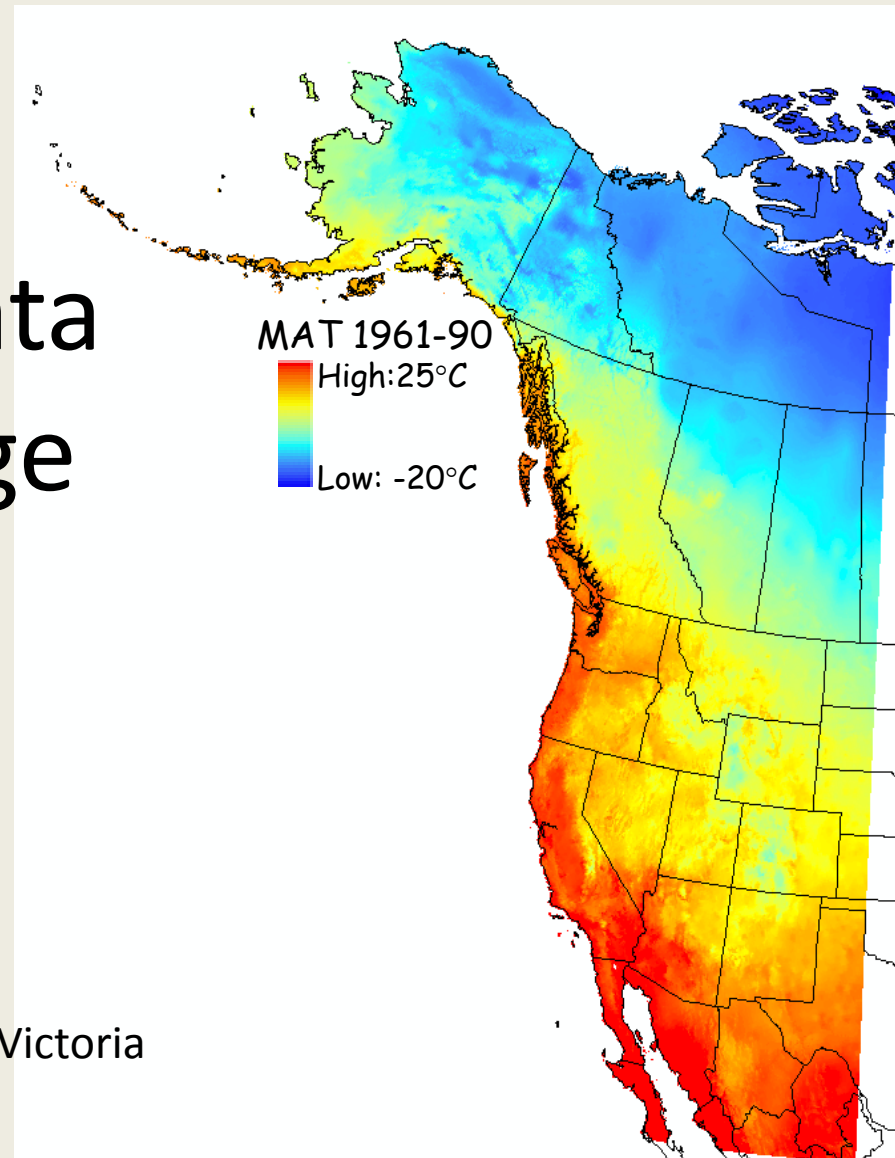


# Spatial Climate Data for Climate Change Studies – *caveat emptor*

Dave Spittlehouse

Research, BC Ministry of Forests and Range, Victoria



# Acknowledgements

Trevor Murdock & Gerd Buerger, Pacific Climate Impacts Consortium, U. Victoria



Future Forest Ecosystems Scientific Council Project 014



FIA, Forest Science Program, Projects F090116, F100215



Tongli Wang, UBC  
Andreas Hamann, U Alberta



# Key messages

- Embrace uncertainty
- You can't always get what you want
- Keep it simple

# Future BC Climate

- 2050s Temperature
  - Mean annual temperature 1 to 4°C warming
  - Increase in occurrence of warm extremes
- 2050s Precipitation
  - Winter: up to 20% wetter throughout BC
  - Summer: North from 10% drier to 10% wetter  
South up to 15% drier
  - Increase in precipitation intensity

Based on PCIC regional analysis tool <http://pacificclimate.org/tools/regionalanalysis/> and IPCC AR4

# Why spatial climate data?

- Climate data to match mapping scale of forest and range resources
- Provide appropriate variables
- Provide climate change data for use in impact and adaptation studies

# Outline

- Definitions
- Spatial data bases
- Uncertainty in spatial climate change data
- Examples of using climate change data
- Summary

# Definitions

- Climate model (e.g., GCM, RCM, EMIC..): physical and chemical representation of the climate system within a computer
- Emissions scenario (e.g., A2, A1B, B1..):
  - Representation of possible future emissions of greenhouse gases (e.g., CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CFCs) and particulates (e.g., soot).
  - Based on assumptions about future population growth, technological development, sources of energy, global cooperation.
- IPCC AR4: Intergovernmental Panel on Climate Change 4<sup>th</sup> Assessment Report

# Definitions (continued...)

- Climate projection/scenario:
  - One “run” from one climate model using one emissions scenario, e.g., CGCM3 A2 run 4
  - 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

# What is spatial data?

- Point or gridded temperature and precipitation data and other variables
- Locations with no measured data
- At scales from 0.1 to 100's km
- Adjusted for elevation
- Does not account for effects of small-scale topographic features on climate
- Does not describe microclimates within and below canopies

# Limitations of spatial data

- Sparse measurement locations for historic climate
- Station density changed with time
- Interpolation in mountainous terrain
- Low spatial resolution of climate change data

# First steps in using spatial data

Consider:

- Geographical area: e.g. GVRD, Okanagan
- Subject: e.g. water supply, tree growth
- Relevant climate variables: e.g. average temperature, summer precipitation, spring snowpack
- Spatial resolution (do you *really* need high resolution?)
- Output required – maps, graphs, tables
- Availability of data
- Capacity to obtain and analyse data

# Spatial data bases – Historic climate

- Cangrid – 50 km, monthly
- ANUSPLIN – 10 km, daily
- PRISM – 4 km, 0.8 km, climatology, monthly
- WORLDCLIM – 1 km, 50-y climatology
- ClimateBC, ClimateWNA – scale free, climatology, monthly
- BioSim – scale free, monthly

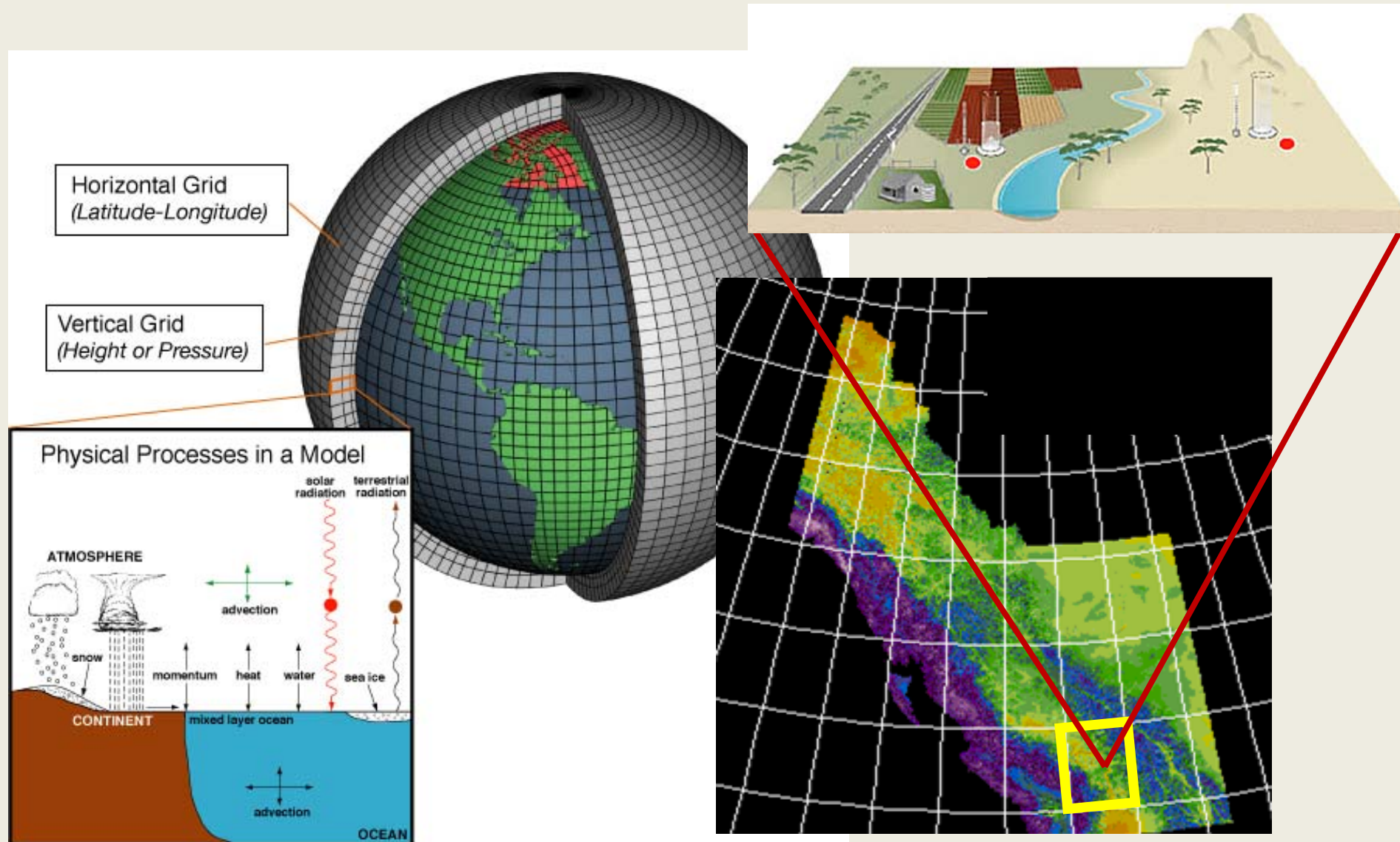
# Spatial data - Climate projections

- Global climate models
    - Plan2Adapt, PCIC Regional Analysis Tool
  - Regional climate models
    - NARCCAP, CRCM (Ouranos), PCIC
  - Elevation corrected GCM and RCM projections
    - ClimateWNA, Plan2Adapt, Climate Wizard, HectaresBC
  - Statistical downscaling of GCM and RCM projections
    - EDS, TreeGEN, SDSM, BCSD
- 
- ~300 km
- ~10 - 50 km
- ~0.1 – 40 km
- ~ 0.1 km

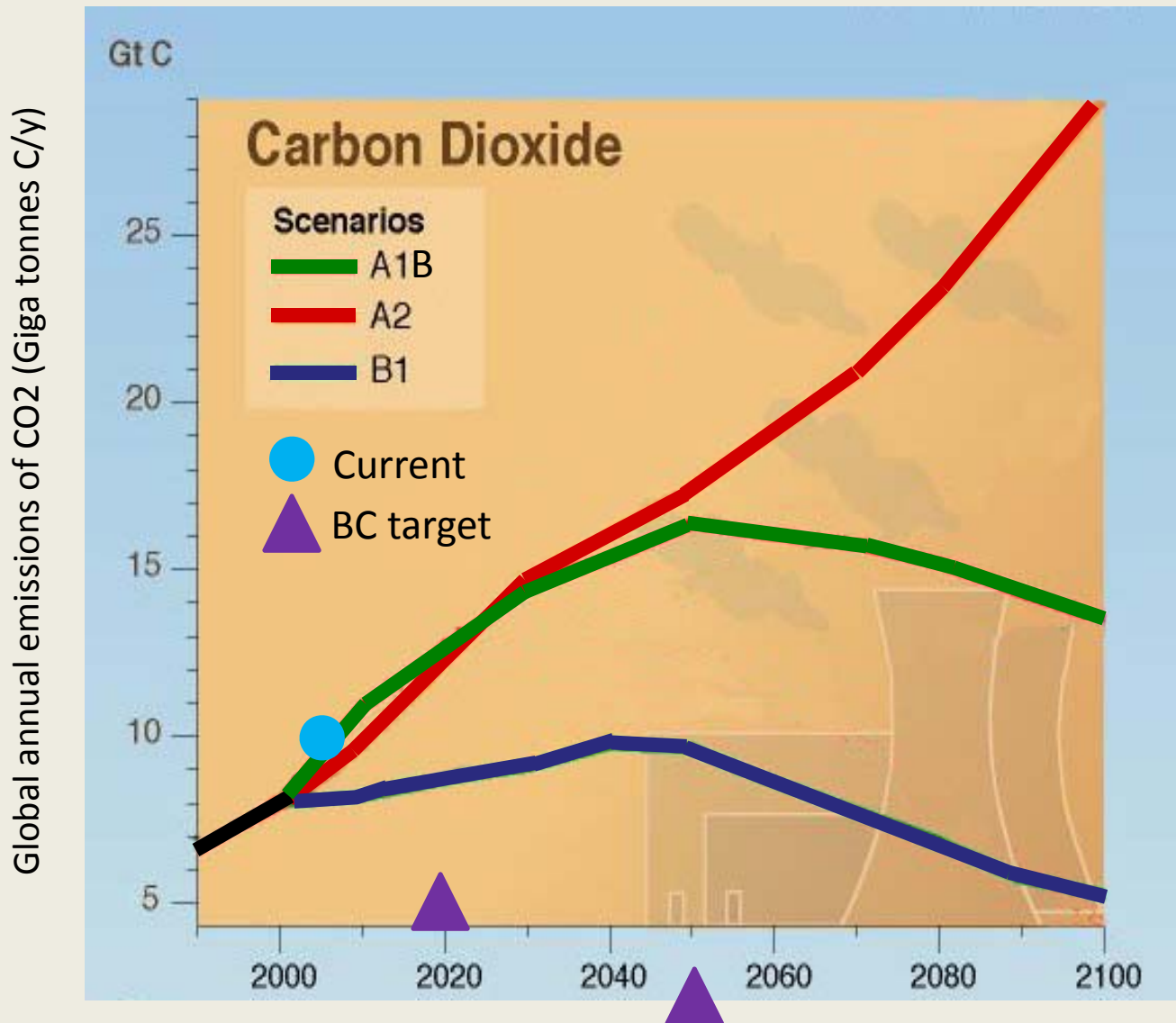
# Sources of uncertainty in applying climate change projections

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

# Uncertainty in using GCM climate projections

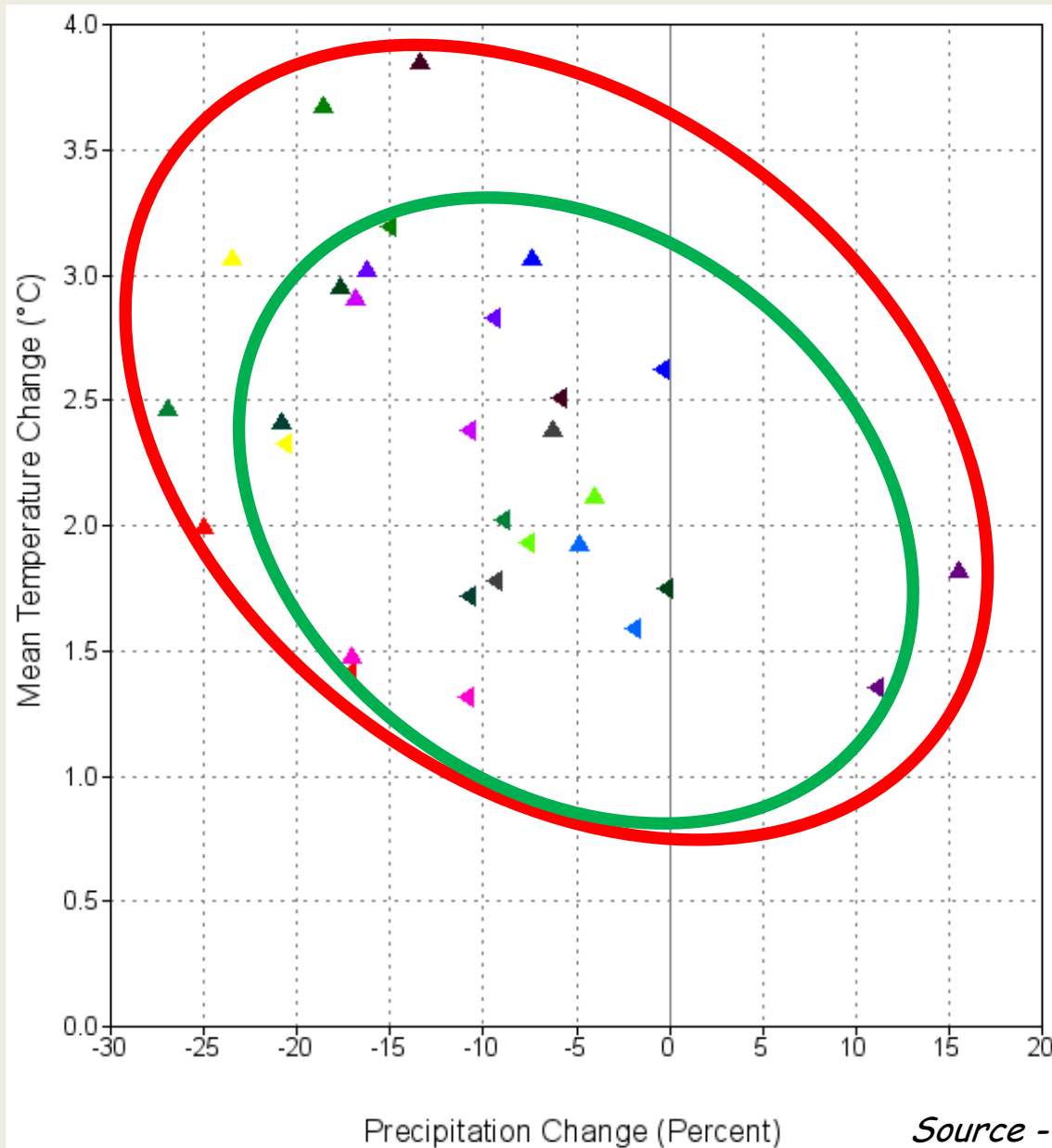


# Global emissions scenarios - CO<sub>2</sub>



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

# Differences between GCMs and emission scenarios



Change in temperature  
and precipitation

15 GCMs, AR4

A2 and B1 Scenarios

Summer 2050s

Thompson Nicola

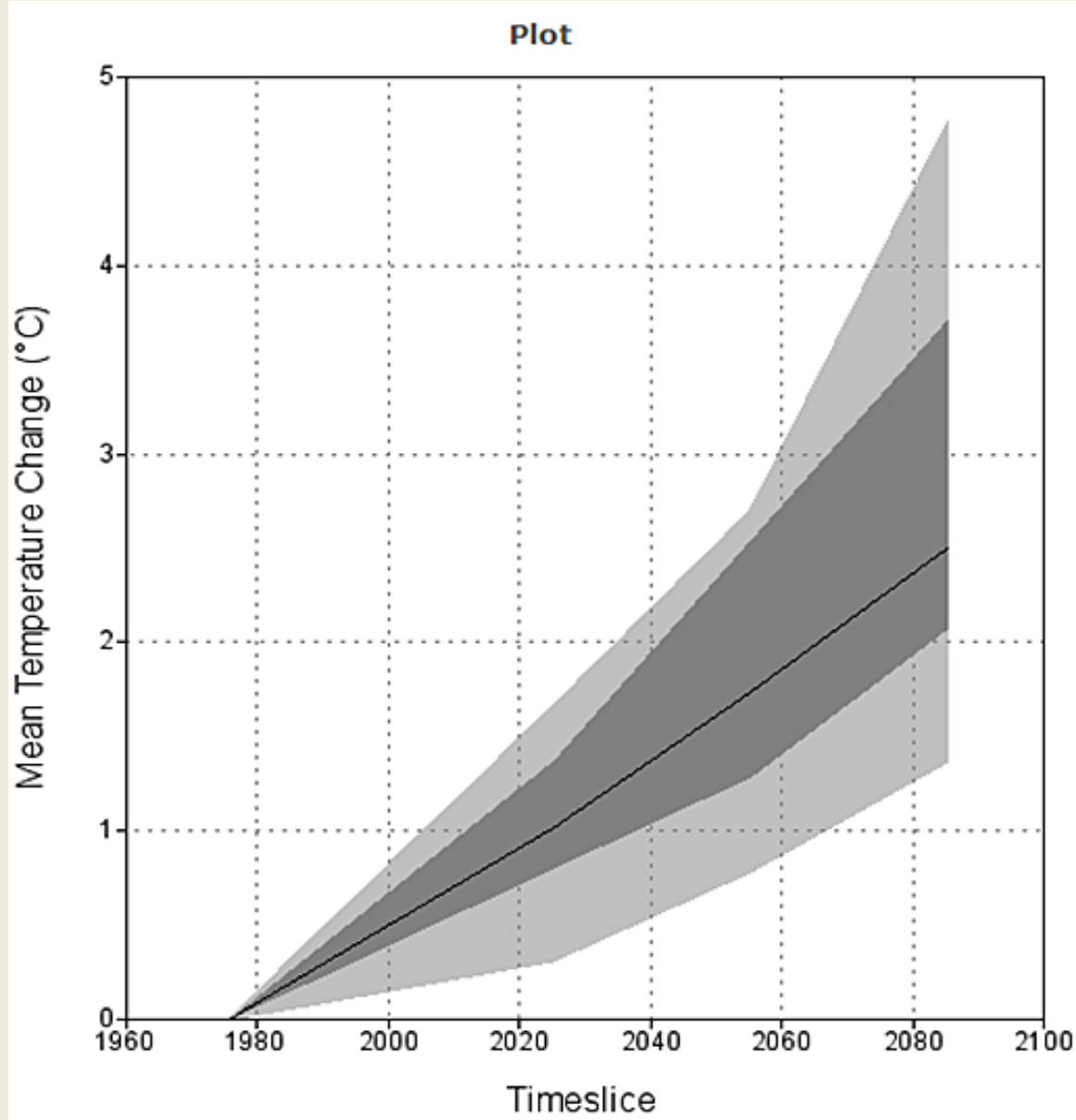


Source - PCIC Regional Analysis Tool

# Uncertainty Increases...

1. As time period of interest becomes smaller
  - 30-year average (2020s, 2050s, 2080s)
  - Year
  - Month
  - Day
  - Extreme weather events
2. As distance into the future increases
  - e.g. 2080s more uncertain than 2020s

# More uncertainty with increased distance into the future



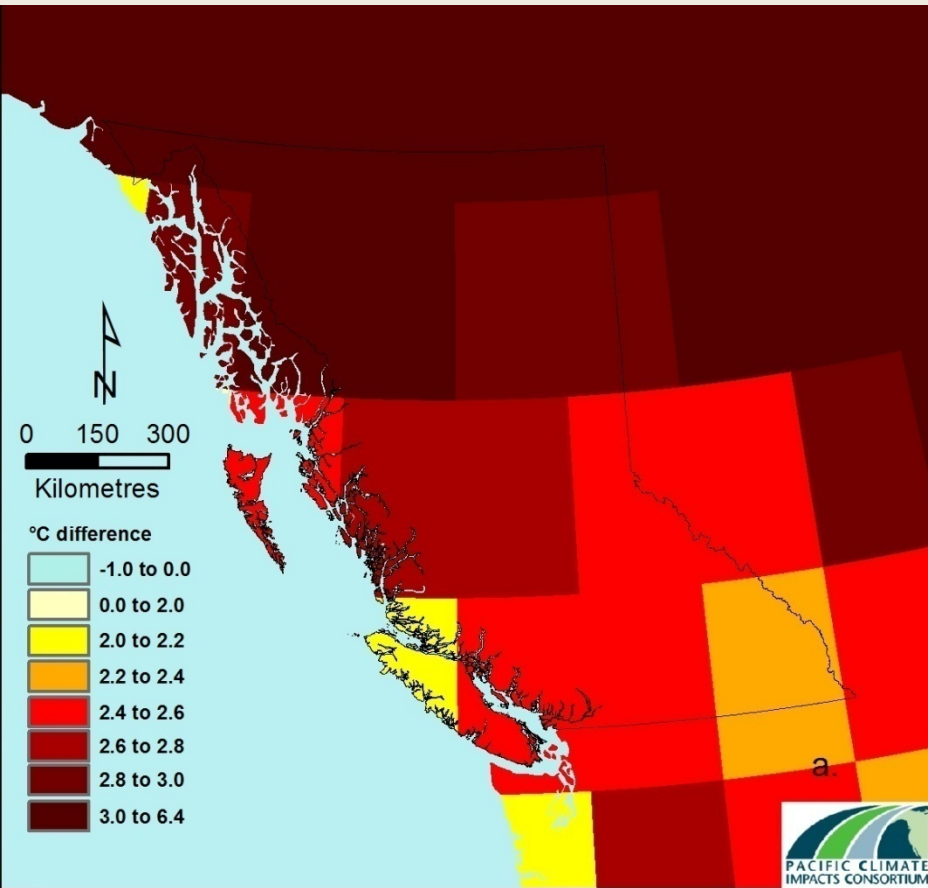
Winter temperature change  
Central Kootenay region, 2020s,  
2050s, 2080s , 15 GCMs , AR4  
A2 and B1 scenarios

Line – Median  
Dark grey 25<sup>th</sup> & 75<sup>th</sup> percentiles  
Light grey 10<sup>th</sup> & 90<sup>th</sup> percentiles

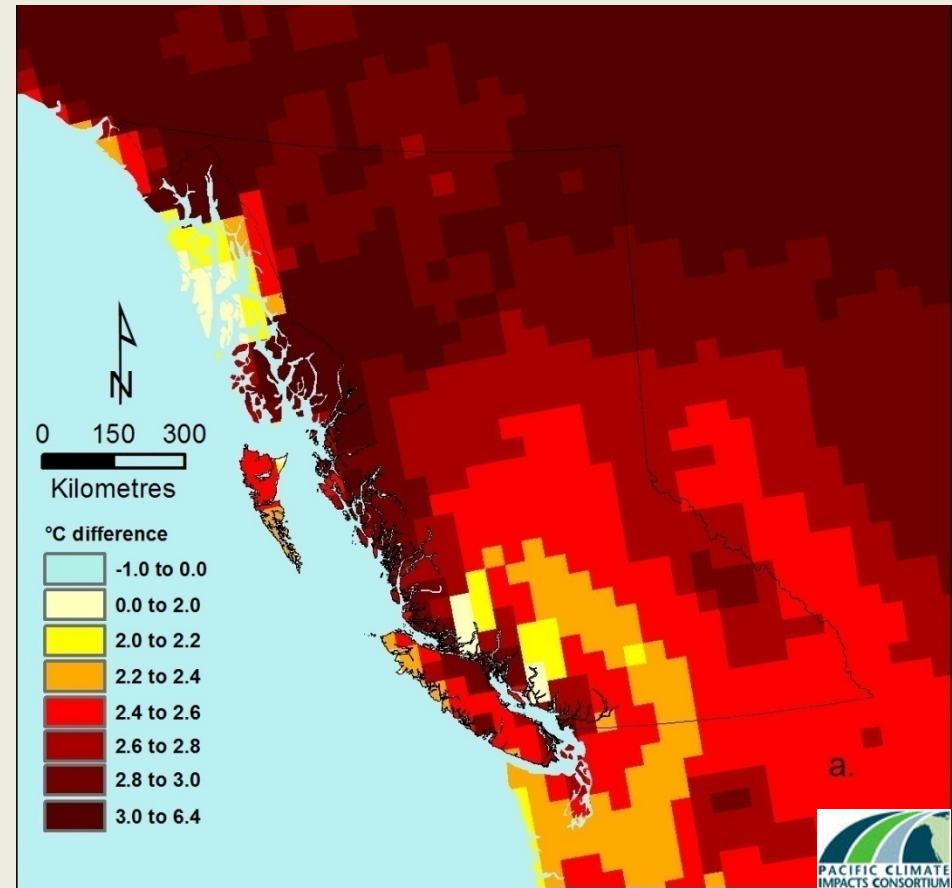
Source: Pacific Climate Impacts  
Consortium, [www.Plan2Adapt.ca](http://www.Plan2Adapt.ca)

# Regional Climate Models increase the resolution (dynamical downscaling) of the GCM projection

Change in mean annual temperature between now and 2050s

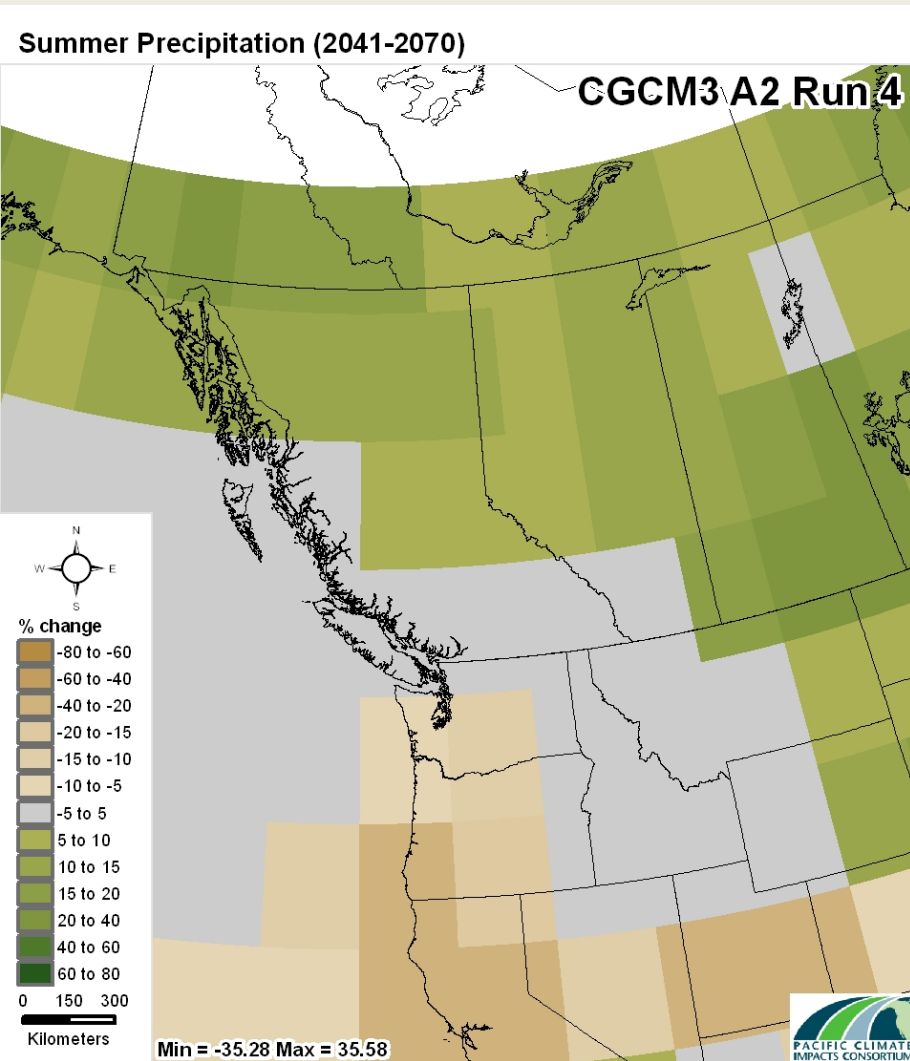


CGCM3 A2 run 4

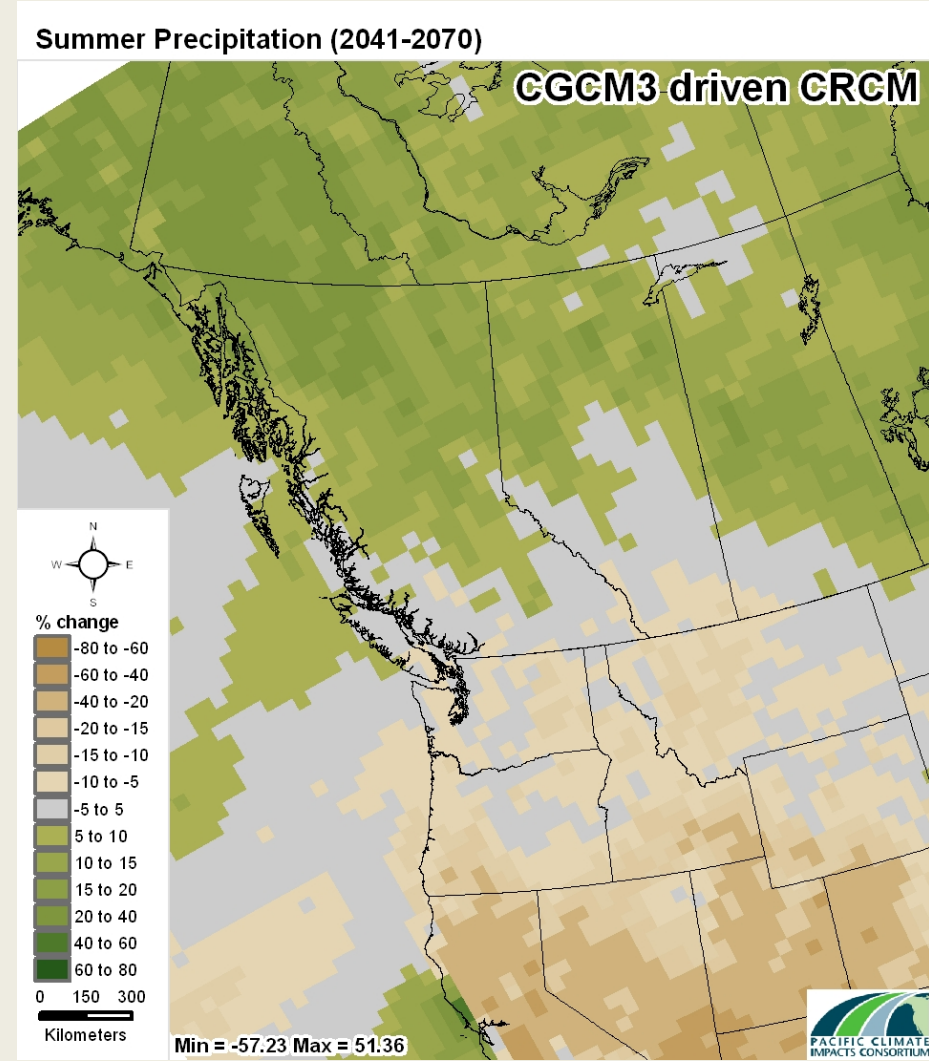


CRCM 4.1.1 forced by CGCM3 A2 run 4

# RCM downscale of GCM projection – Change in summer precipitation between now and 2050s



CGCM3 A2 run 4



CRCM forced by CGCM3 A2 run 4

# Downscaling with ClimateBC/ClimateWNA

- Based on PRISM 1961-90 normals
- Interpolate 4-km-gridded monthly temperature and precipitation data to specified locations
- Adjust for elevation of locations
- Weather station climate
- Calculate derived variables (e.g., GDD, FFP)
- Historic monthly data and climate change scenarios downscaled with Delta method

# ClimateWNA

ClimateWNA\_v4.52 Copyright (2008) Wang T, Hamann A and Spittlehouse D. All rights reserved

**Select Output Variables**

Annual variables

Seasonal variables

Monthly variables

All variables

All variables for multiple years

Longitude

Elevation (m)

**Select Period**

Future Periods

Select a GCM

AR4\_bcm20\_A2-run1\_2050.gcm

AR4\_bcm20\_A2-run1\_2080.gcm

AR4\_cgcm3\_A2\_mean\_2020.gcm

AR4\_cgcm3\_A2\_mean\_2050.gcm

AR4\_cgcm3\_A2\_mean\_2080.gcm

AR4\_cgcm3\_A2-run1\_2020.gcm

AR4\_cgcm3\_A2-run1\_2050.gcm

AR4\_cgcm3\_A2-run1\_2080.gcm

AR4\_cgcm3\_B1\_mean\_2020.gcm

AR4\_cgcm3\_B1\_mean\_2050.gcm

AR4\_cgcm3\_B1\_mean\_2080.gcm

AR4\_cgcm3\_B1-run1\_2020.gcm

AR4\_cgcm3\_B1-run1\_2050.gcm

AR4\_cgcm3\_B1-run1\_2080.gcm

AR4\_Hires\_B1\_run1\_2020.gcm

AR4\_Hires\_B1\_run1\_2050.gcm

AR4\_Hires\_B1\_run1\_2080.gcm

AR4\_hirs\_B1-run1\_2020.gcm

AR4\_hirs\_B1-run1\_2050.gcm

AR4\_hirs\_B1-run1\_2080.gcm

AR4\_bcm20\_A2-run1\_2020.gcm

AR4\_bcm20\_A2-run1\_2050.gcm

AR4\_bcm20\_A2-run1\_2080.gcm

AR4\_cgcm3\_A1B\_mean\_2020.gcm

AR4\_cgcm3\_A1B\_mean\_2050.gcm

AR4\_cgcm3\_A1B\_mean\_2080.gcm

AR4\_cgcm3\_A1B-run1\_2020.gcm

AR4\_cgcm3\_A1B-run1\_2050.gcm

AR4\_cgcm3\_A1B-run1\_2080.gcm

AR4\_cgcm3\_A2-run1\_2020.gcm

About

Help

PAS

CMD

Save

ate

**Output of annual variables**

|                                  |                                  |                                   |                                 |                      |
|----------------------------------|----------------------------------|-----------------------------------|---------------------------------|----------------------|
| MAT                              | MWMT                             | MCMT                              | TD                              | M                    |
| <input type="text" value="2.6"/> | <input type="text" value="13"/>  | <input type="text" value="-7"/>   | <input type="text" value="20"/> | <input type="text"/> |
| DD<0                             | DD>5                             | DD<18                             | DD>18                           | N                    |
| <input type="text" value="854"/> | <input type="text" value="874"/> | <input type="text" value="5638"/> | <input type="text" value="0"/>  | <input type="text"/> |

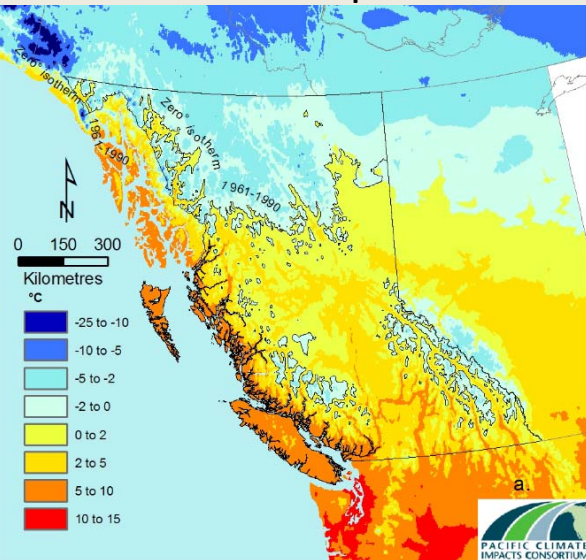
**Multi-location**

Select input file

Status

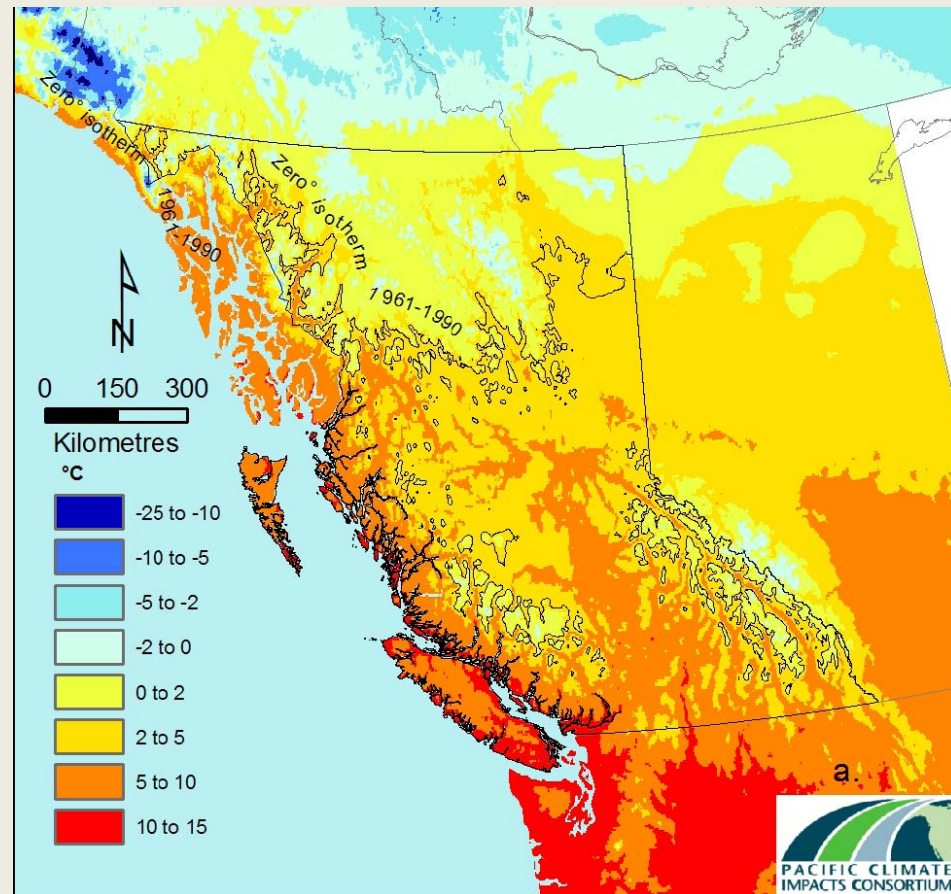
# ClimateWNA increases the resolution of the GCM/RCM change projection

Mean annual temperature 1961-90

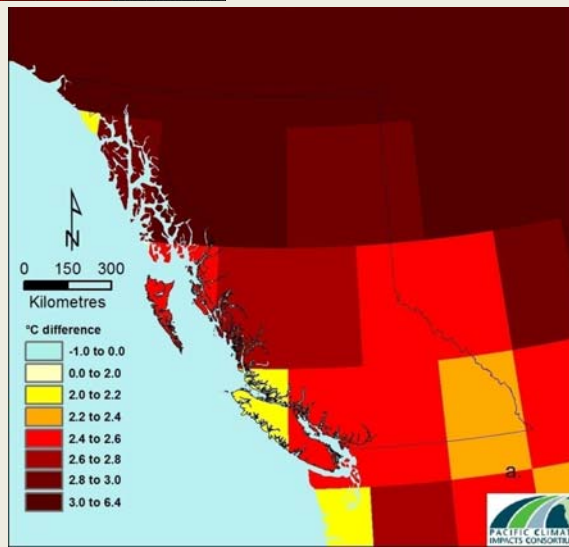


ClimateWNA  
interpolated  
from PRISM

Mean annual temperature 2050s



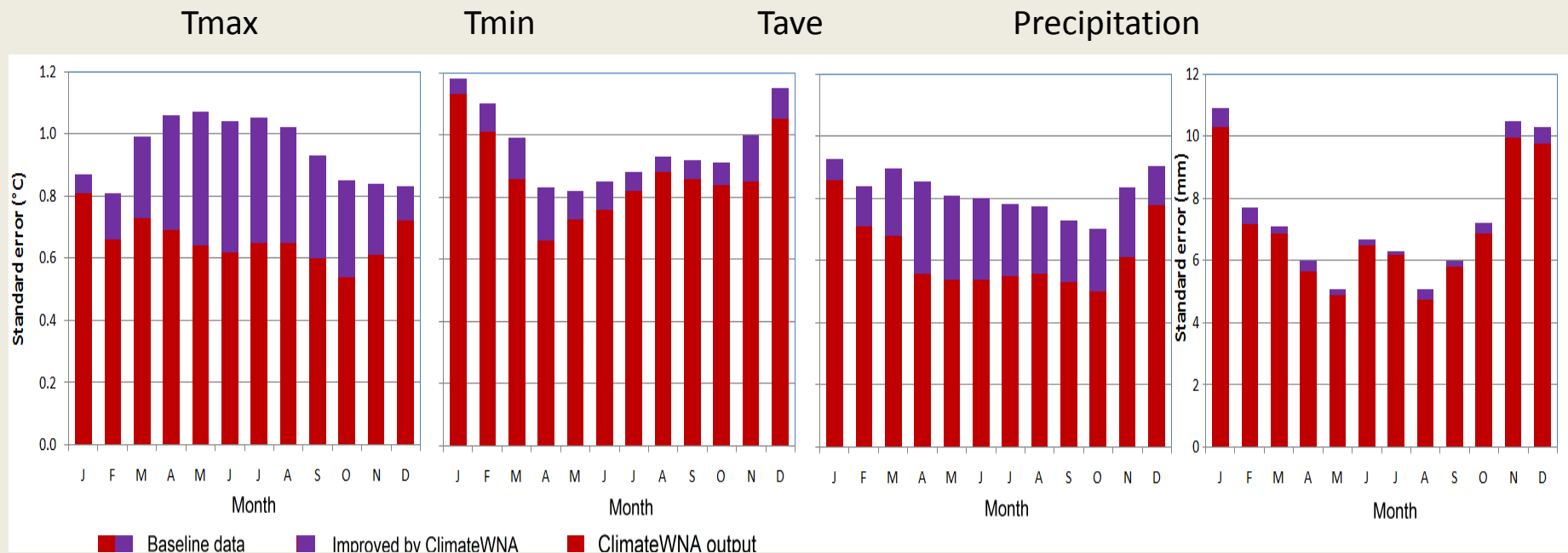
GCM change in  
temperature



ClimateWNA interpolation of  
CGCM3 A2 run 4

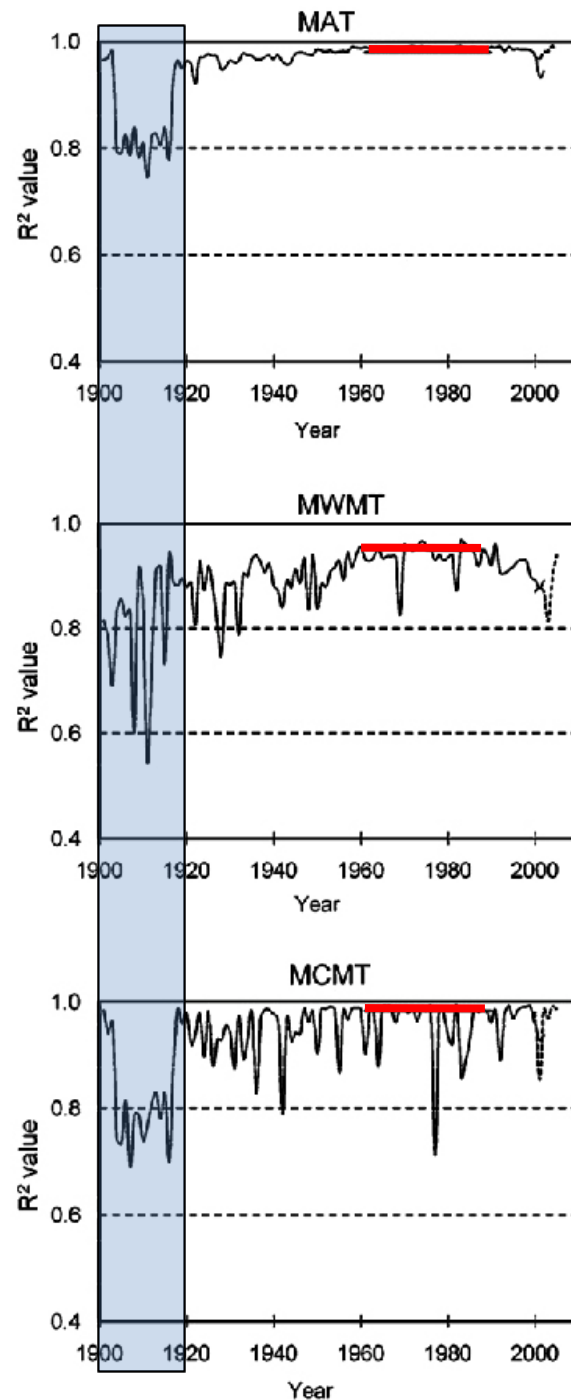
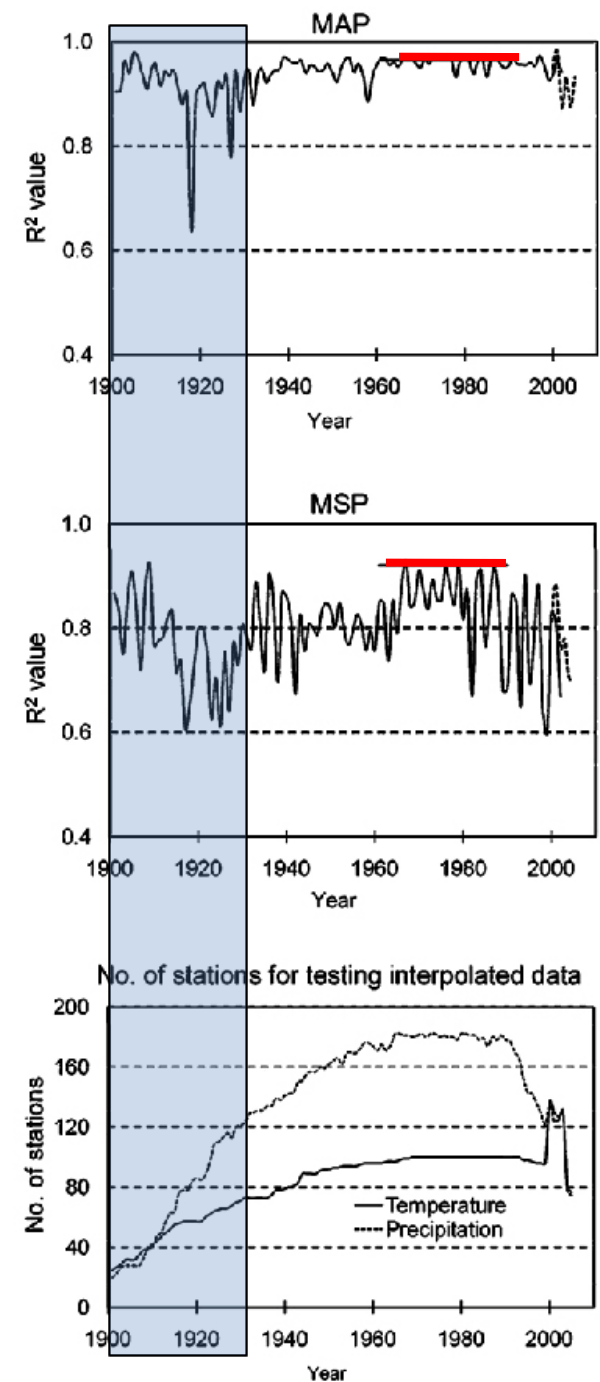
# Evaluation of ClimateWNA predictions of monthly temperature and precipitation - 1049 US, 1122 CAN weather stations

Standard error of predicted monthly values



(Wang et al. in preparation)

$R^2$  between observed and interpolated variables for 1900-2006 monthly data for weather stations in western Canada  
(Mbogga et al. 2009)



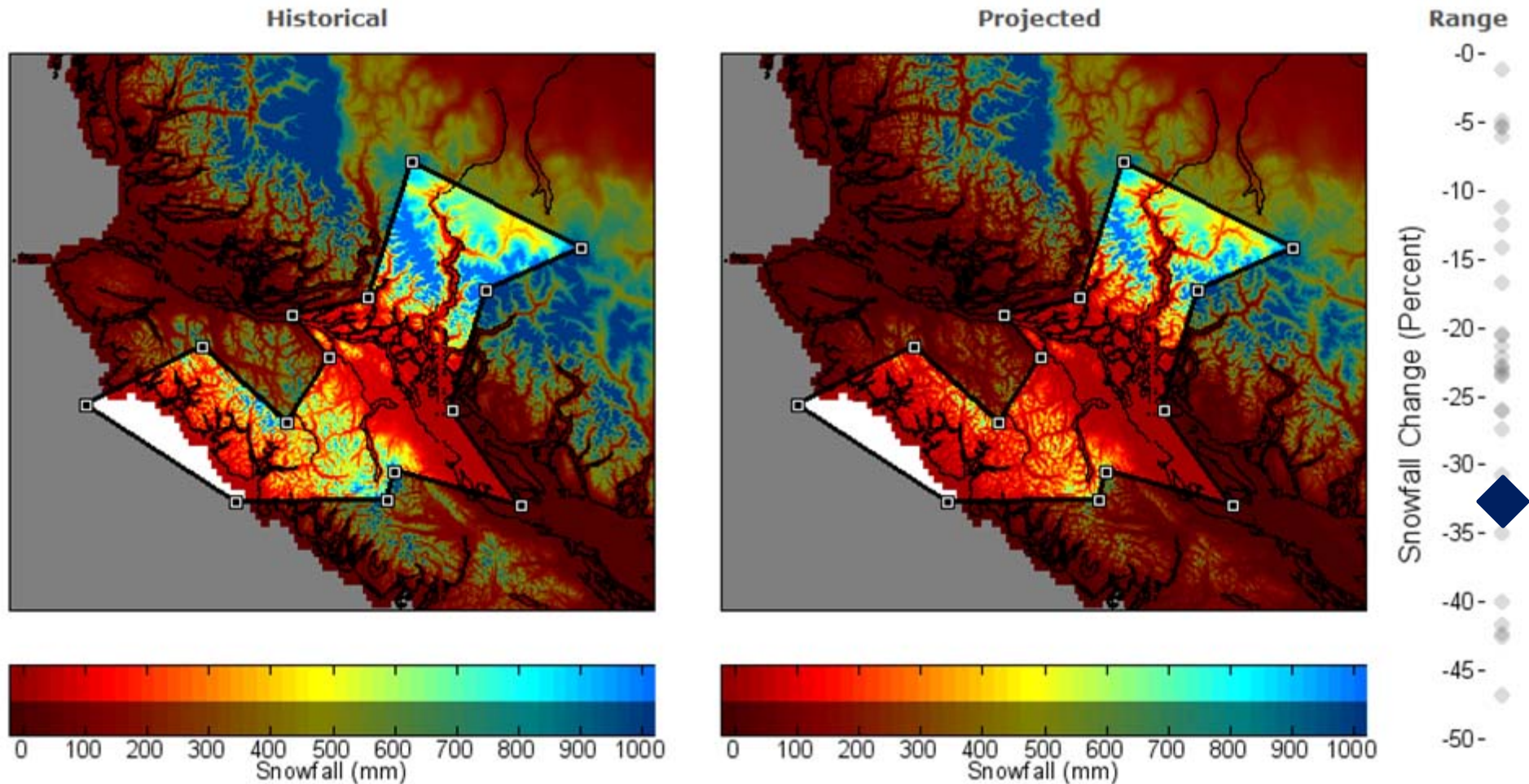
# Statistical downscaling

- Extremes of temperature and precipitation
- Link probability of specific events at a location to regional atmospheric conditions
- Resulting functions used with RCM projections to generate probability of events at a location

# Using climate change scenarios

- Spatially and temporally consistent set of weather conditions
- Regional and seasonal differences
- Illustrate how much the climate might change in a geographical area
- Assess impacts of a range of climate change scenarios on a system (e.g., species, forest growth)
- Identify impact of specific GHG emissions scenarios on climate for a geographical area
- Analyze sensitivity of a system (e.g., stream flow, tree regeneration) to specific changes in a climate parameter (e.g., 2°C warmer, 20% drier)

# Illustrative: Winter Snowfall – Historical and 2050s Comox-Strathcona Region

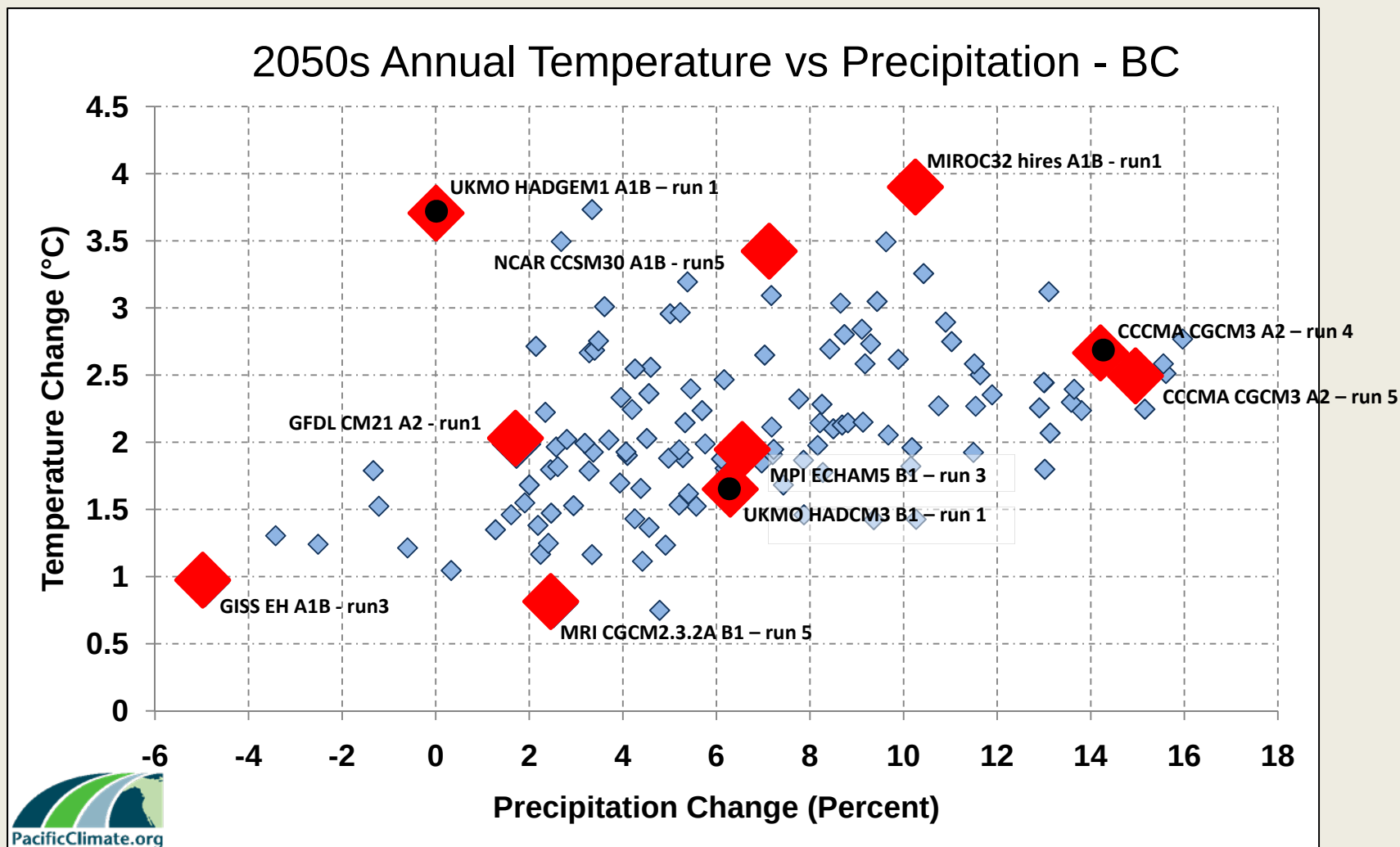


Source: Pacific Climate Impacts Consortium, [www.Plan2Adapt.ca](http://www.Plan2Adapt.ca)

# Scenarios – Minimal set of climate projections

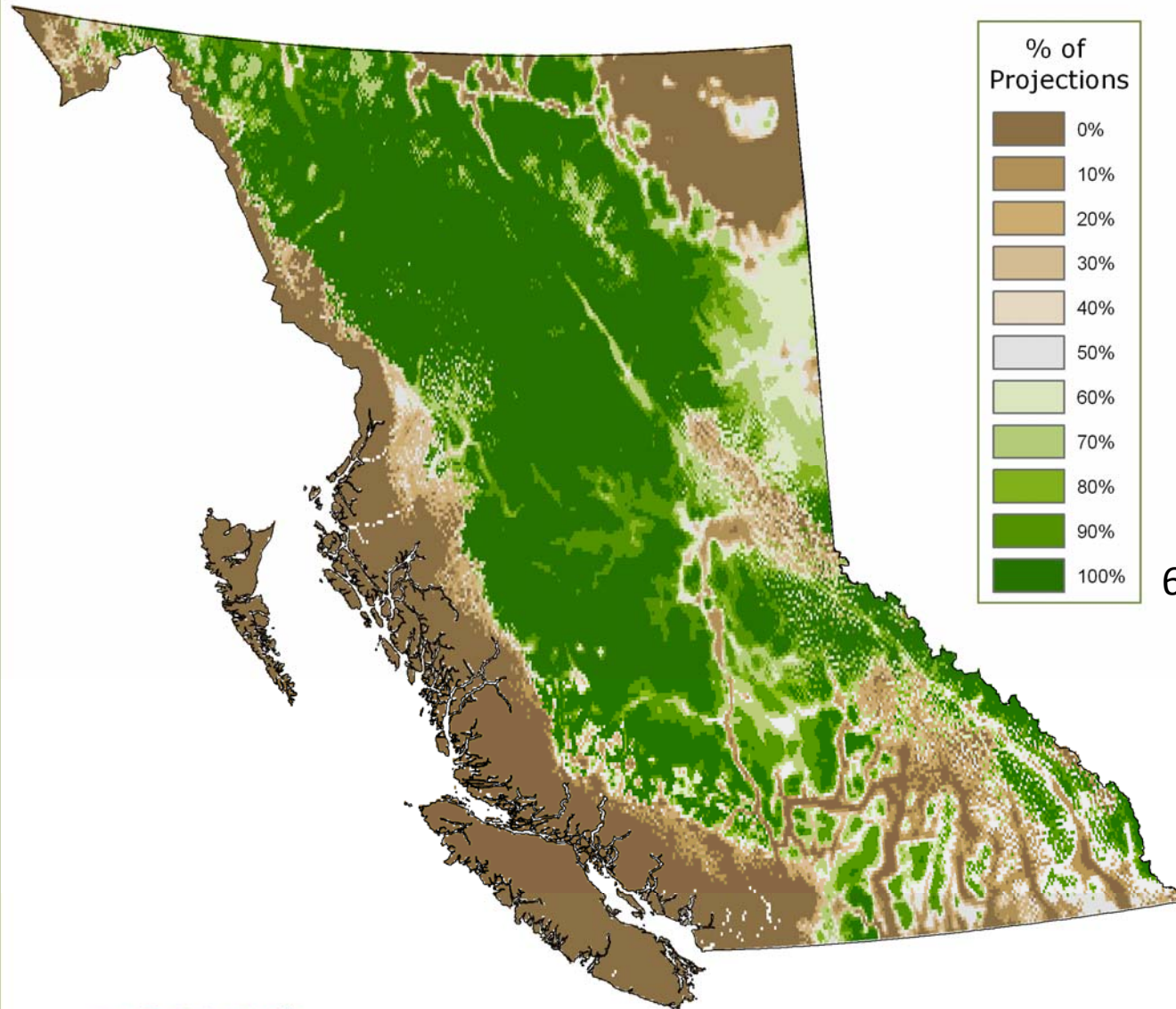
- Hot and dry – HadGEM A1B run 1
- Warm and wet – CGCM3 A2 run 4
- Cooler and less dry – HadCM3 B1 run 1
- Extensively used, RCMs available

# Selecting GCMs and emission scenarios that bound the range of climates



# 2050s Spruce Suitability

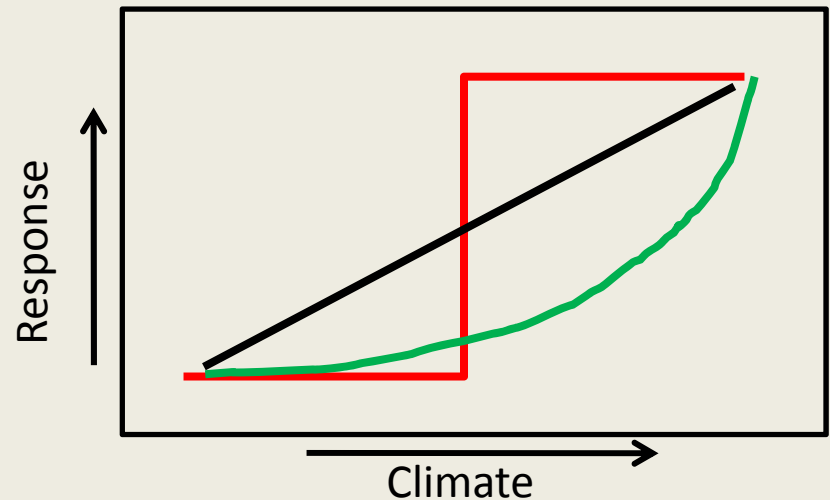
Percent of Climate Projections Indicating Climatic Suitability



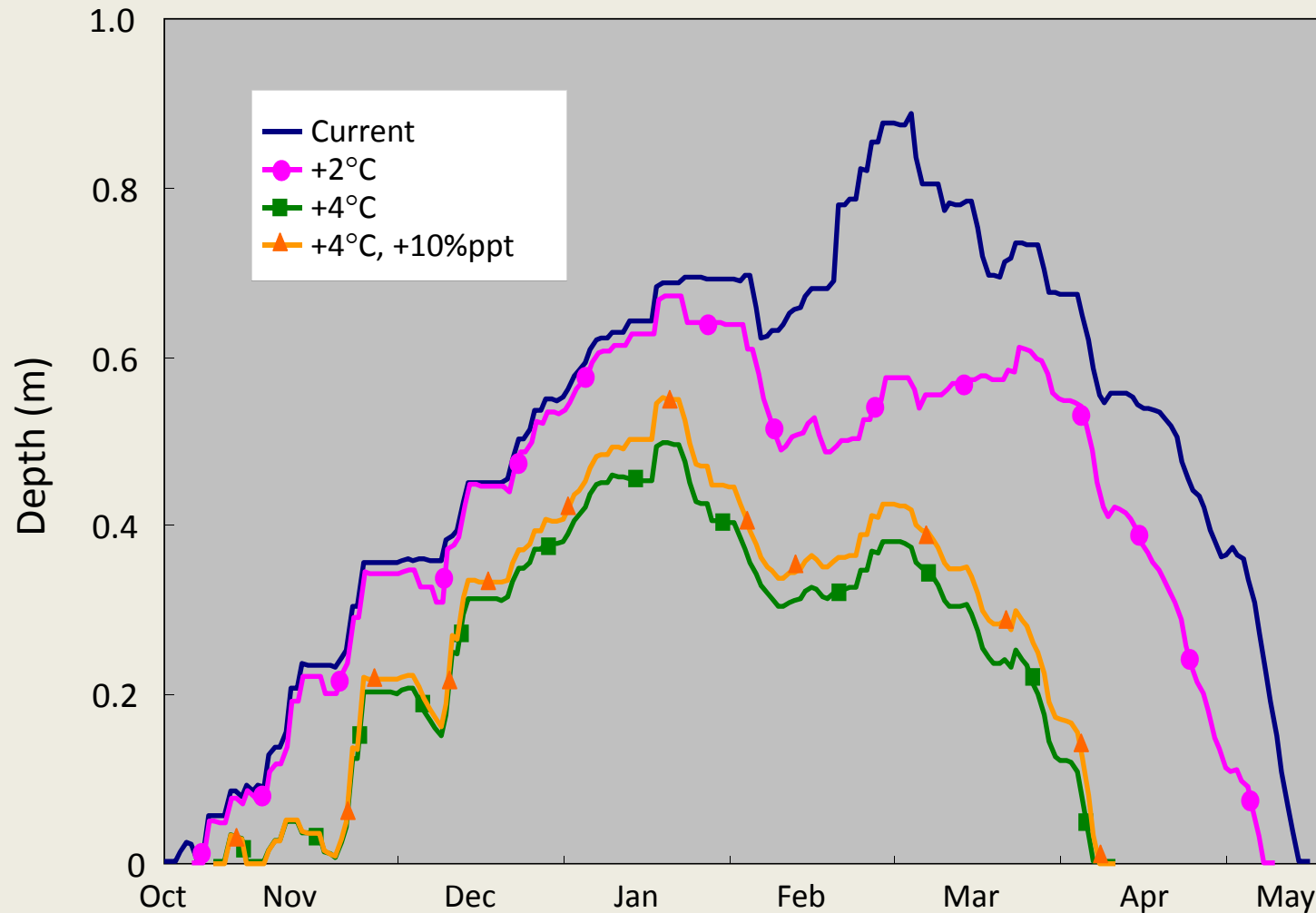
61% of BC

# Sensitivity to change in climate

- Temperature: 1°C, 2°C, 4°C
- Winter precipitation: 0%, +10%, +30%
- Summer precipitation: -30%, -10%, 0%, +10%
- Chose GCM projections to fit these conditions
- Adjust historical data



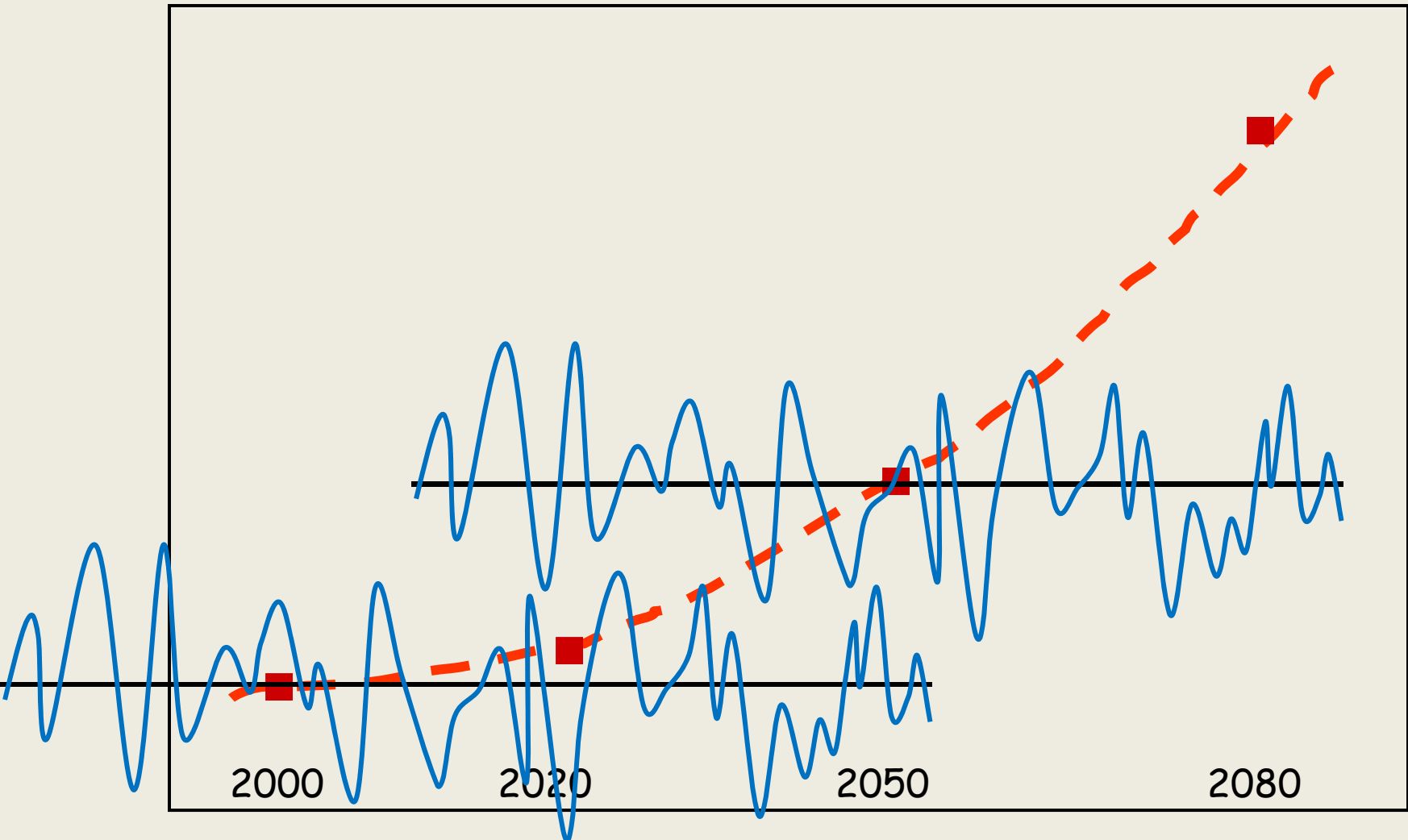
# Sensitivity analysis: Snow depth - Upper Penticton Creek



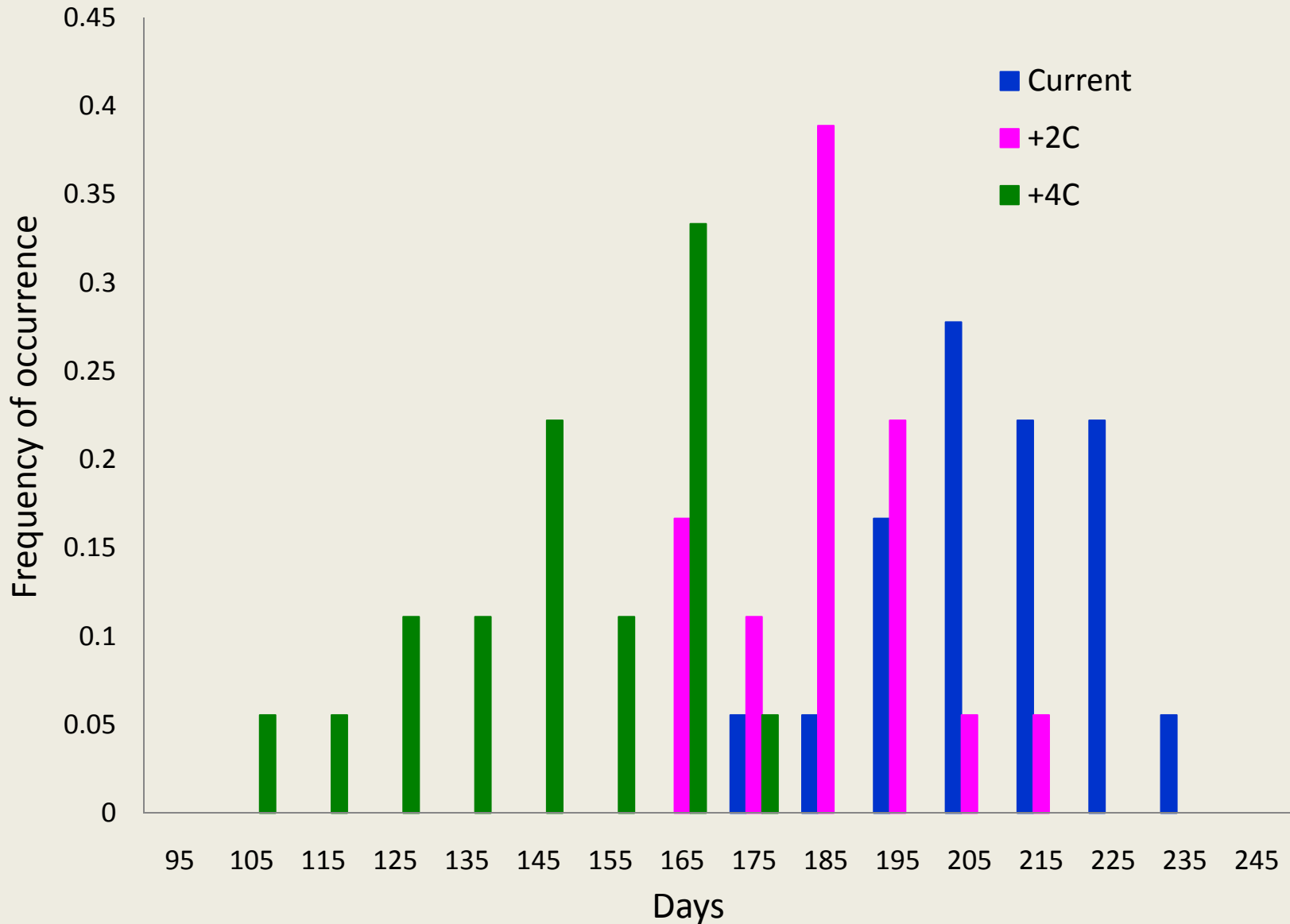
# Time series

- Data for assessing risk.
- GCM data not readily available.
- Shift existing time series by change indicated by GCM – e.g., temperature: change mean, same variance and temporal trend.
- Weather generator (e.g., LARSWG5) - equations simulating a time-series of daily weather at a site - change mean, same or different variance.
- Computationally inexpensive ways to produce daily and monthly site-specific climate change scenarios.

# Time series - inter-annual variability

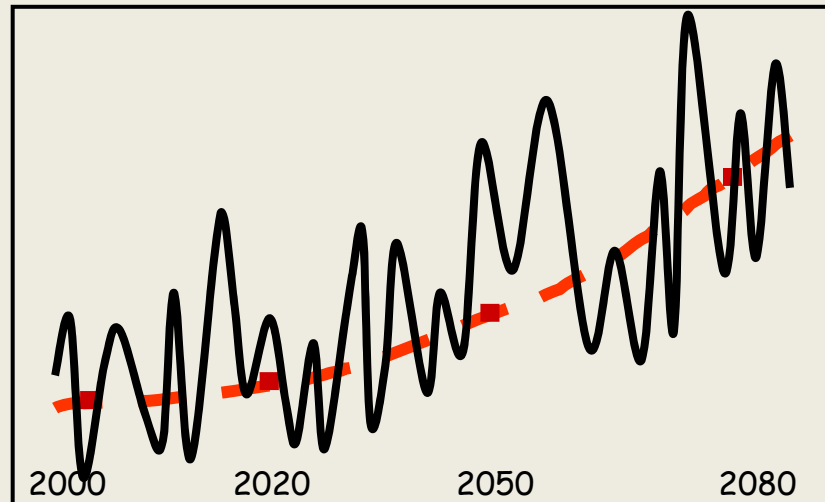


# Length of snow season - UPC



# Variability & extreme events

- Global summaries of GCMs
- Downscaling from RCMs
- Active research area – FFESC project 014, Pacific Climate Impacts Consortium
- Non-stationary time series



# Summary – using spatial data

- Before selecting scenarios, identify what you want to do with the data and determine data availability.
- Use scenarios with spatial data at a resolution suited to the task.
- Minimal “set” of projections: 1) warmer & wetter, 2) hotter & dryer, and 3) medium climate change
- Assessing sensitivity to specific climate changes provides greatest flexibility.

# Summary (continued...)

- View climate forecasts at PCIC RAT and Plan2Adapt web sites
- Guidelines on using climate scenarios - Recommended scenario/GCM combinations
- ClimateWNA for monthly point and gridded data
- PCIC RAT source for gridded data
- Time series - Delta method and weather generators
- Downscaling for extremes – lot of work to do
- Uncertainty is not an excuse for inaction