

Use of genetic variation in forest trees to adapt to changing climate



Tongli Wang and Sally Aitken --

Centre for Forest Conservation Genetics, University of British Columbia

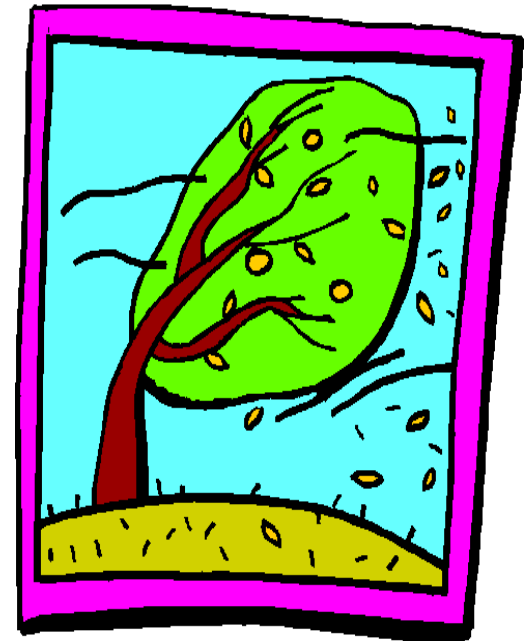
Greg O'Neill, Alvin Yanchuk, Dave Spittlehouse and Elizabeth Campbell – *Research Branch, Ministry of Forests and Range*

Andreas Hamann – *University of Alberta*

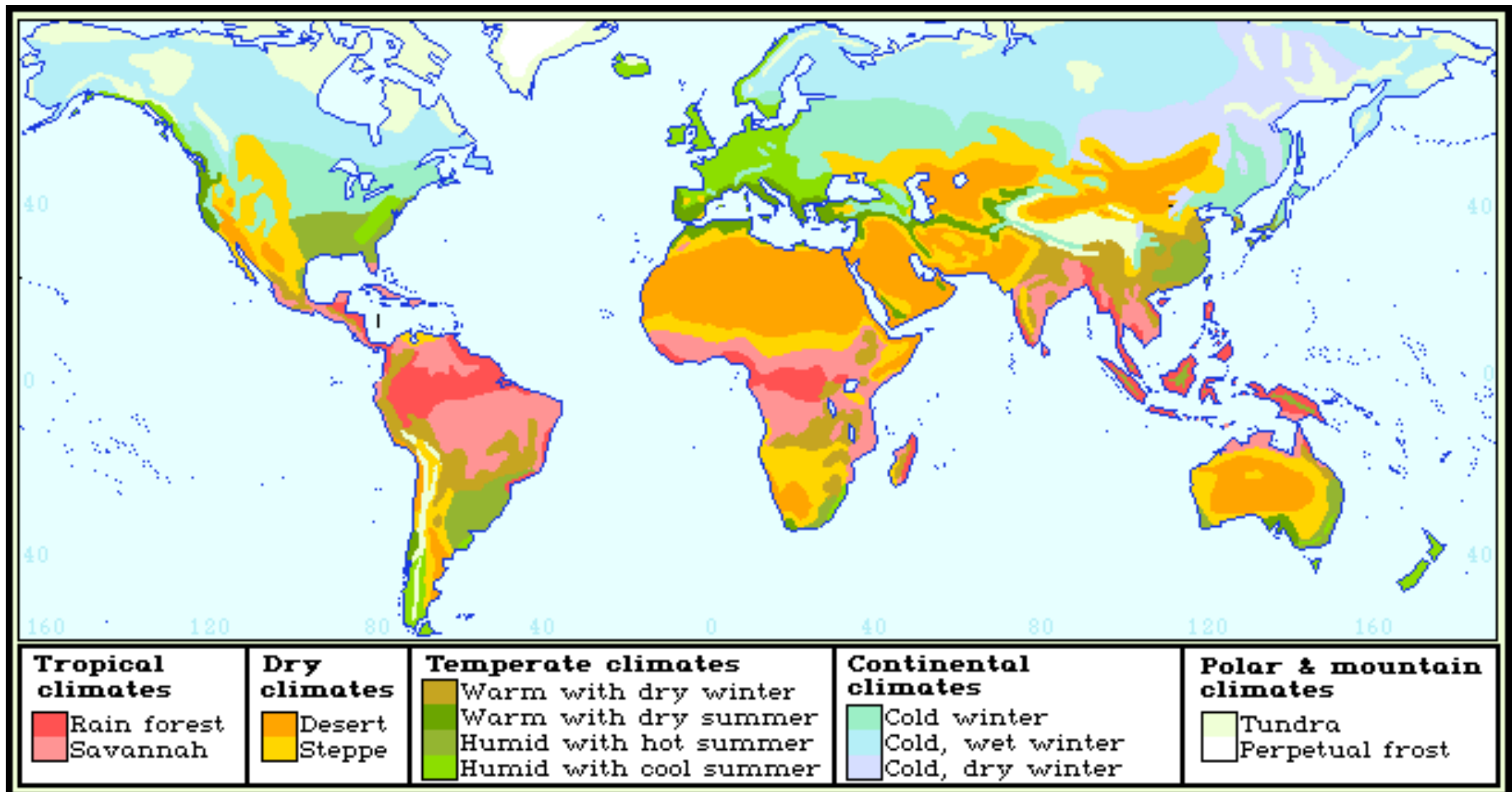


Effects of climate on forest trees

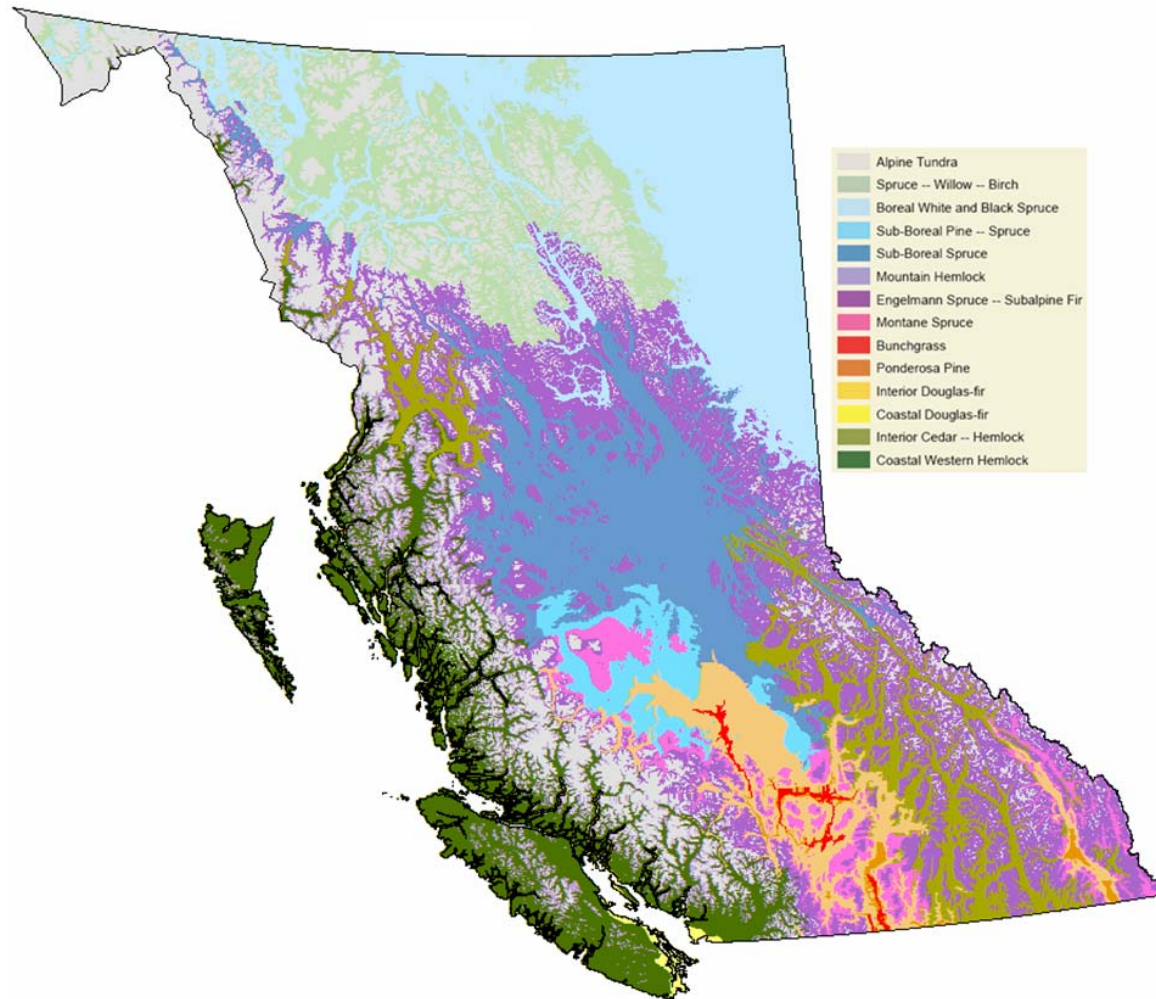
- Climate is a major environmental factor affecting the performance of trees (**environmental effect**)
- Climate is also the most important evolutionary force molding among- and within-species variation (**genetic effect**)



Climate determines forest types (**among-species variation**) at the global scale



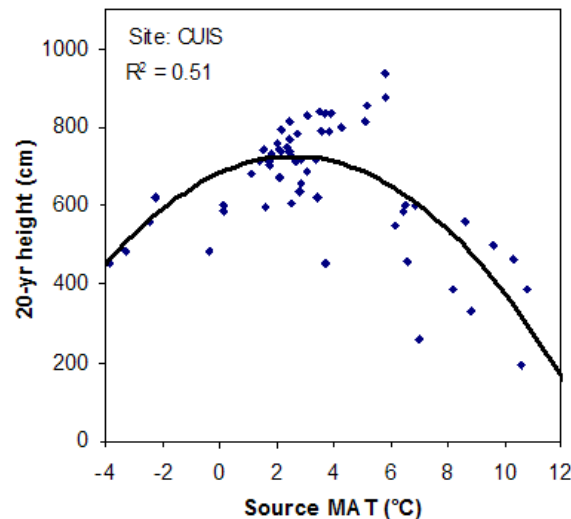
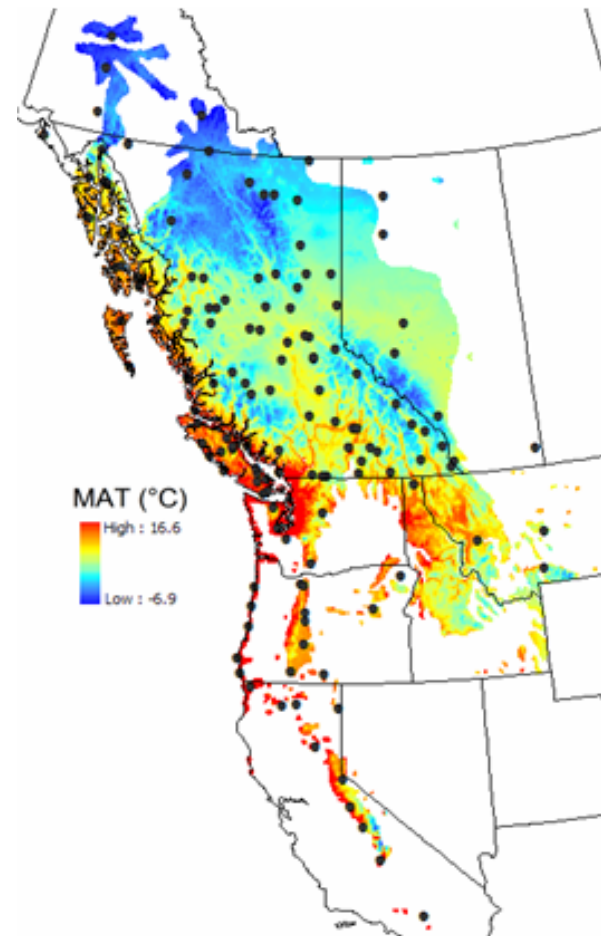
Climate controls species distribution (among-species variation) in a region



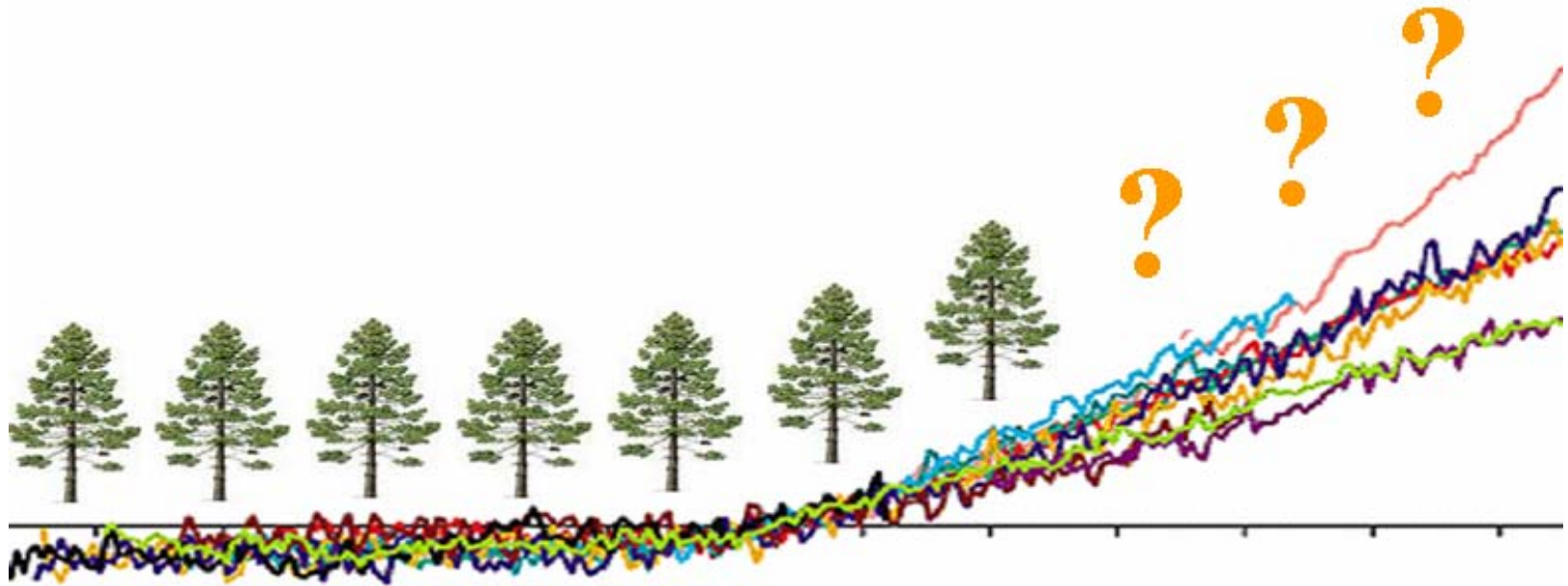
Biogeoclimatic Ecosystem Classification (BEC) in British Columbia

Climate also drives **among-population variation** within a species

- Among-population variation is often observed along climatic gradients



Can our trees adapt to their new climates?

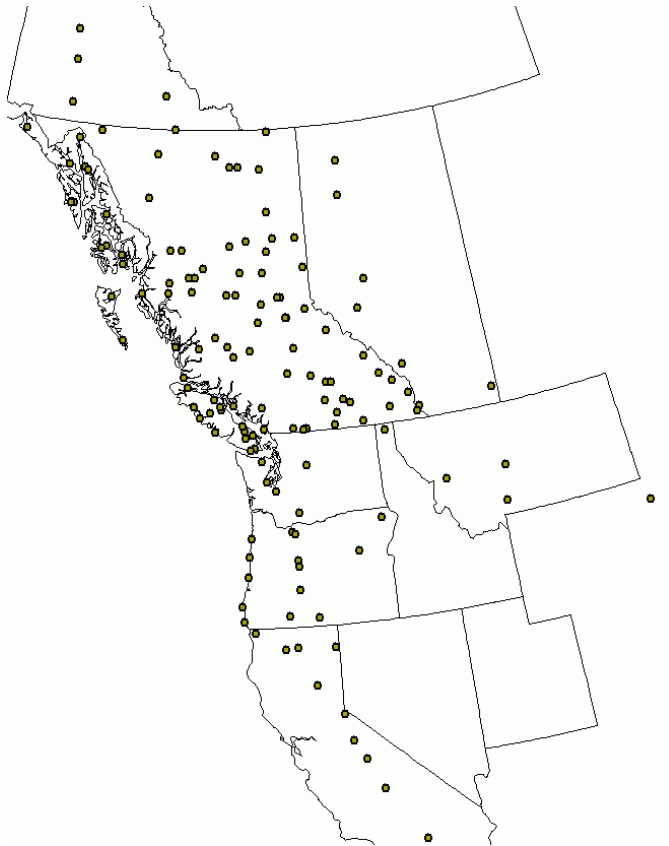


To help trees to adapt to climate change

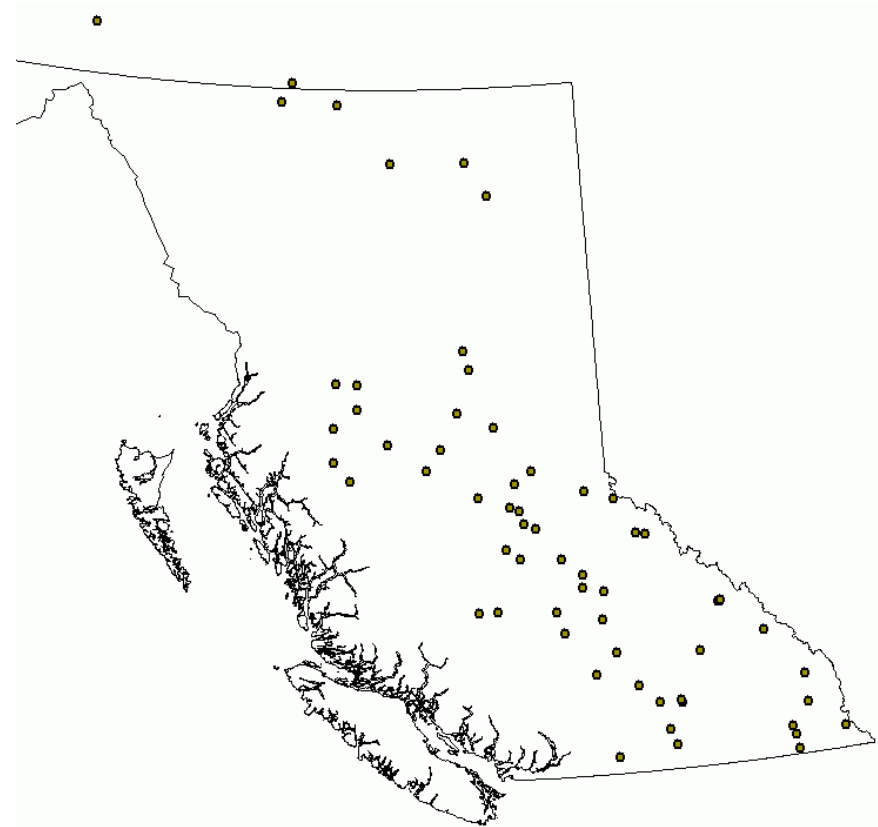
- Determine plant-climate relationships
- Predict responses of trees to climate change
- Develop management strategies to adapt to climate change

Provenance trials are used in climate change studies

140 provenances

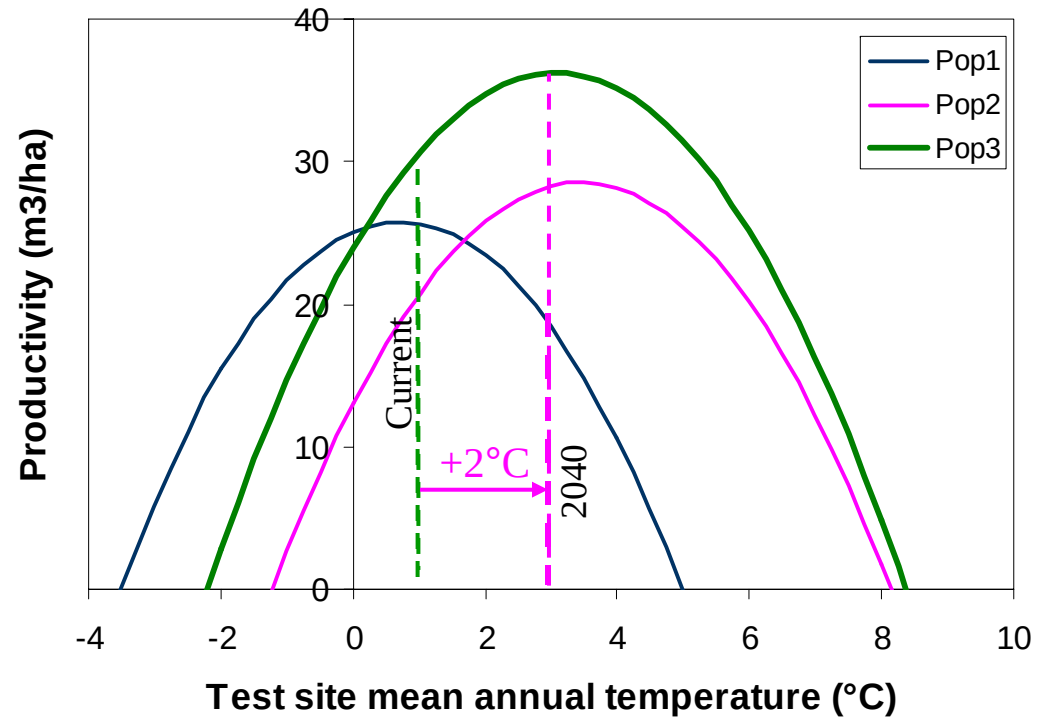


60 test sites

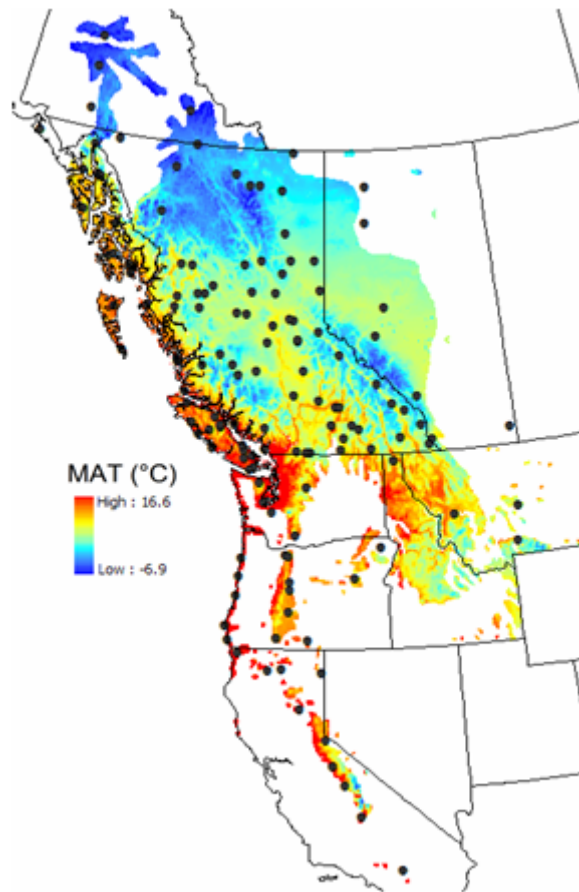


Lodgepole pine provenance trial in BC (established in 1974)

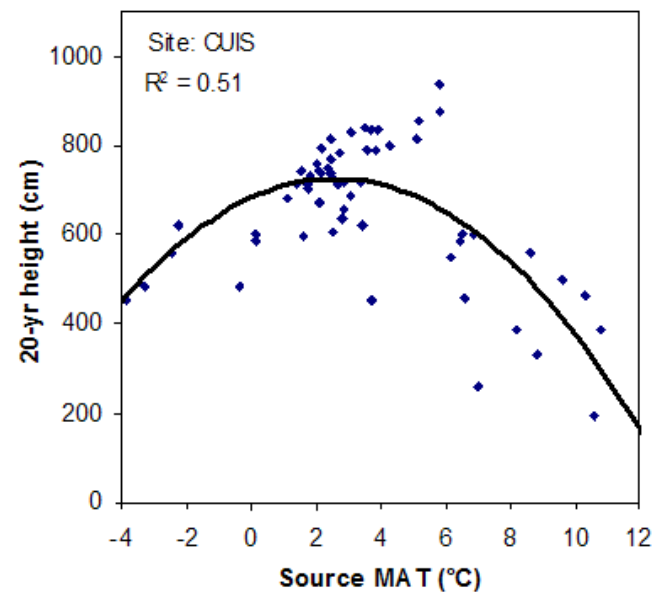
Among-population variation in response to climate



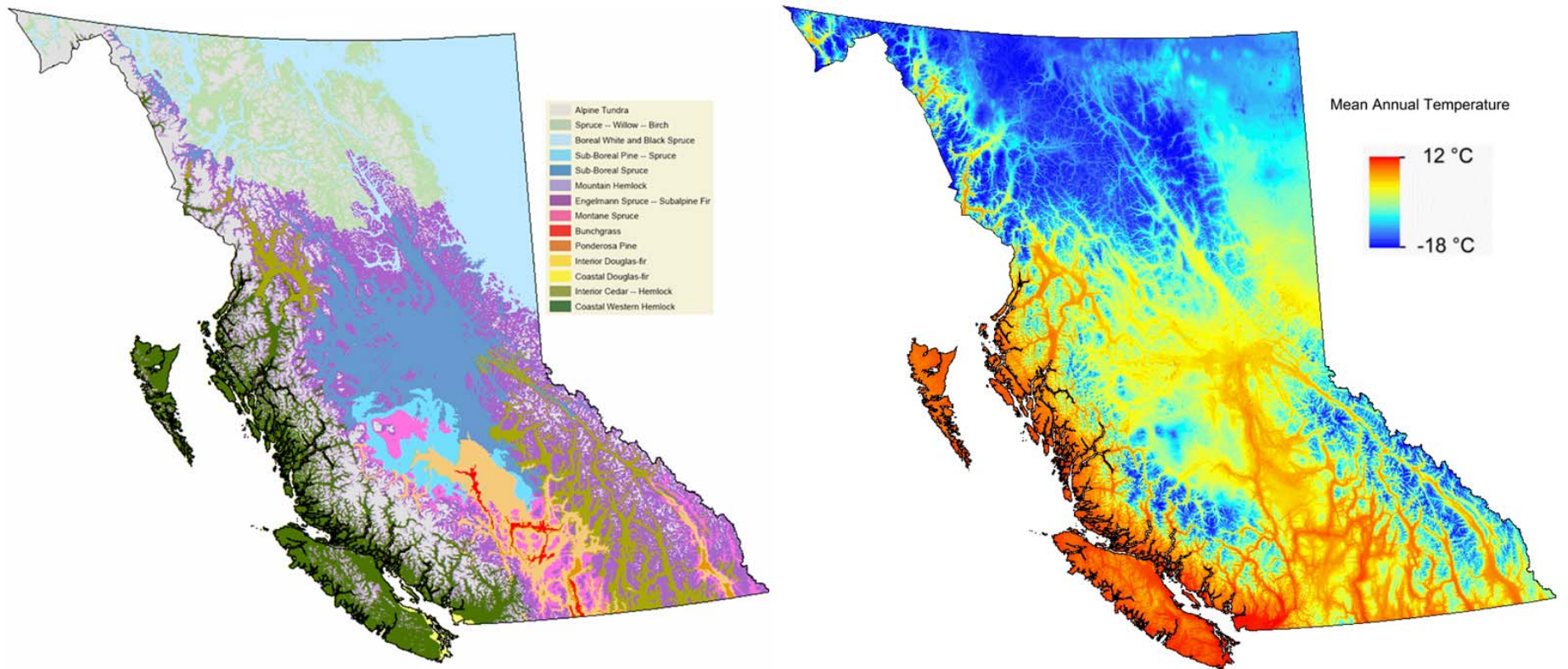
Among-population variation at a test site



An individual transfer function



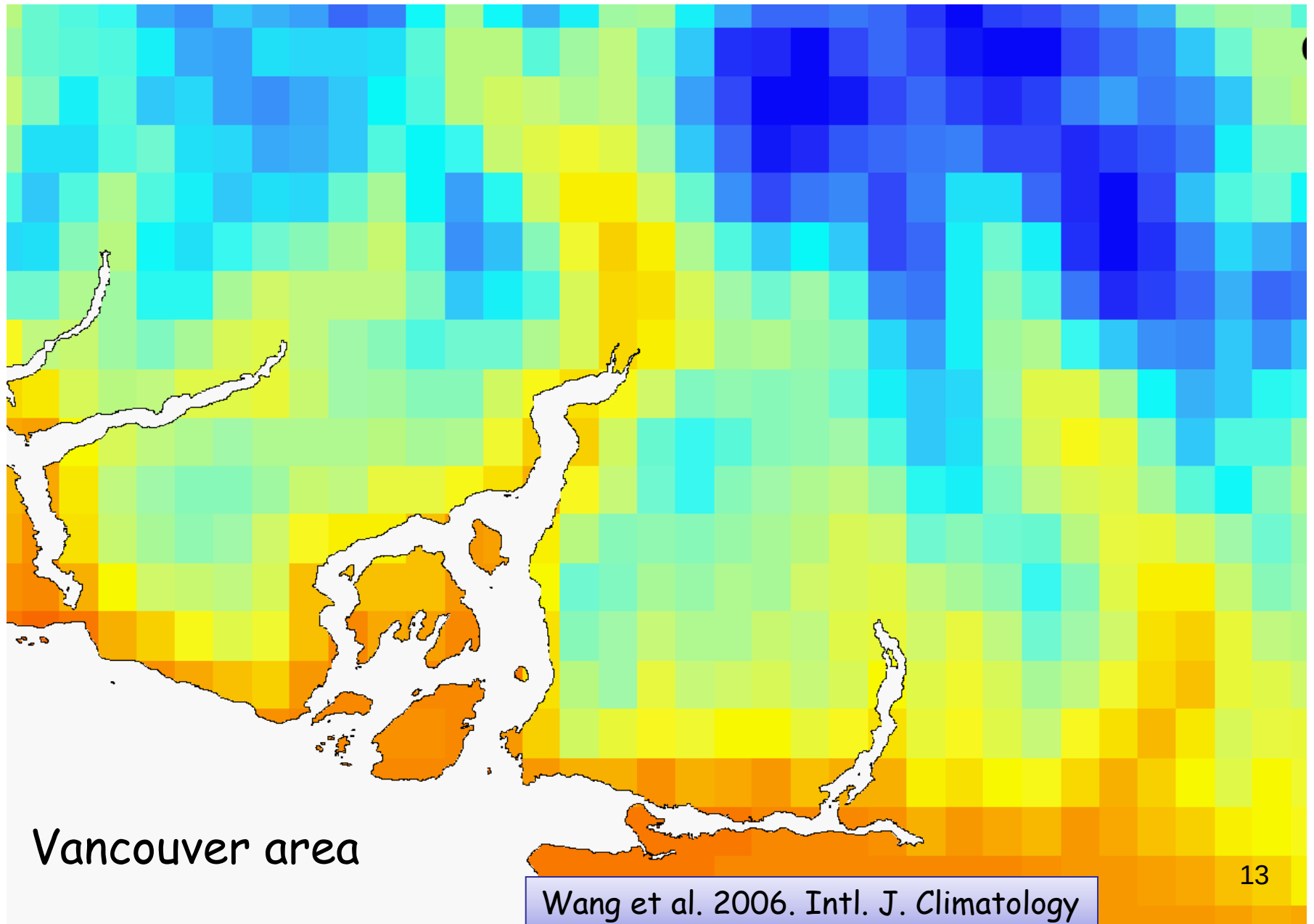
Use of plant-climate relationships to predict future climate envelopes for ecosystems and species ranges



Objectives

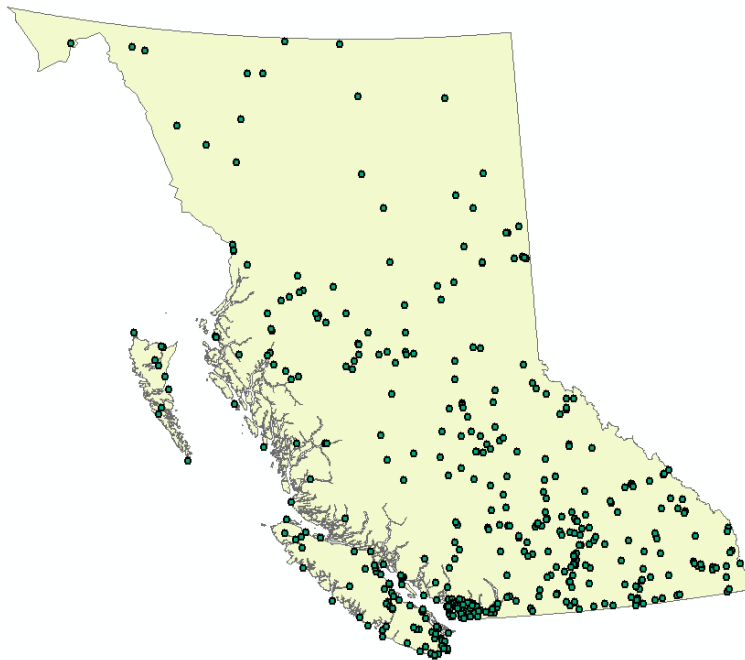
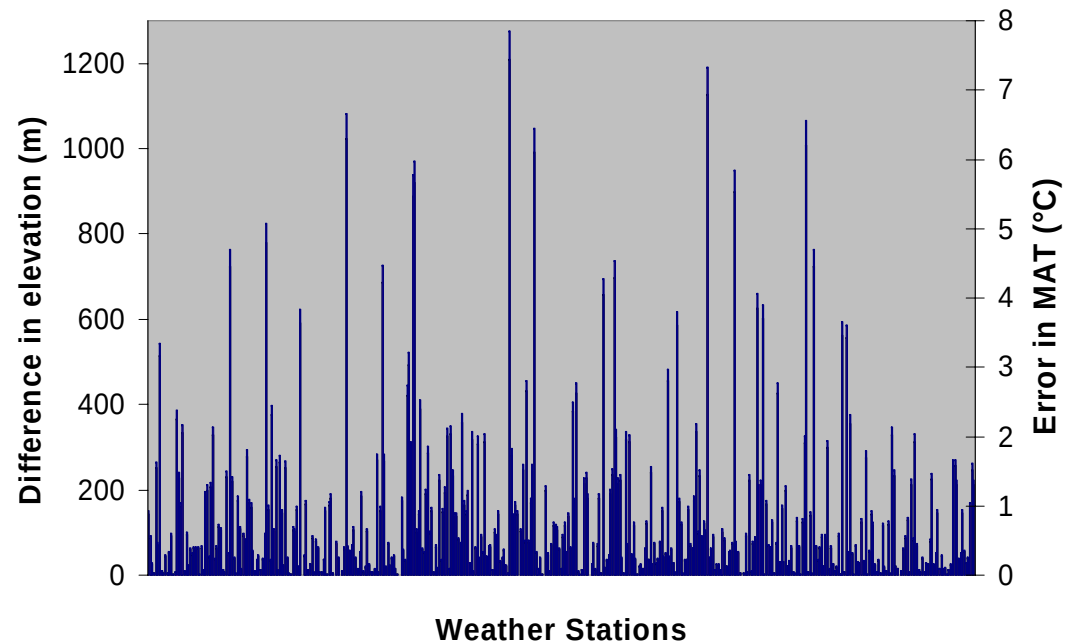
- Development of high-resolution climate model
- Development of population response functions to climate
- Predict future climatic envelopes for BC ecosystems and species ranges

The resolution of PRISM data is low: 4 x 4 km



The low resolution can result in huge amount of error in predictions for temperatures

493 Weather stations



ClimateBC - a computer program for predicting current and future climate data

ClimateBC_v3.2 Copyright (2006) Wang, Hamann, Spittlehouse and Aitken. All...

Select Time Scale
☒ Annual ☐ Season ☐ Monthly

Select Period
Normal 1961-1990 Period: Normal 1961 - 1990

Coordinate Input ☒ Decimal ☐ Degree

Latitude: 46.98
Longitude: -113.02
Elevation (m): 1000

Calculate **About** **Help**

Output of annual variables

MAT	MWMT	MCMT	TD	MAP	MSP	AH:M	SH:M	EMT	PAS
DD<0	DD>5	DD5 ₁₀₀	DD<18	DD>18	NFFD	FFP	bFFP	eFFP	

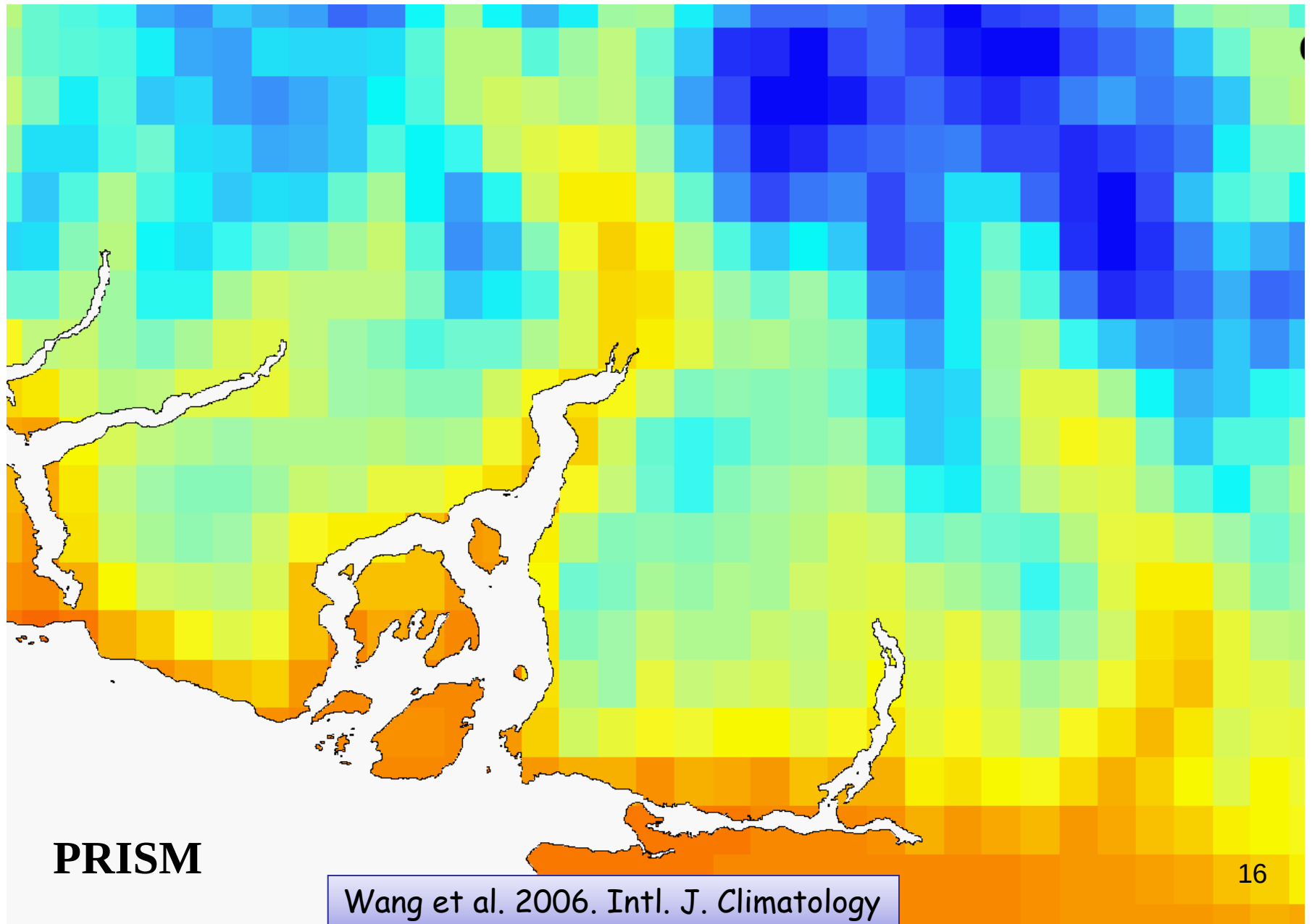
Save

Multi-location

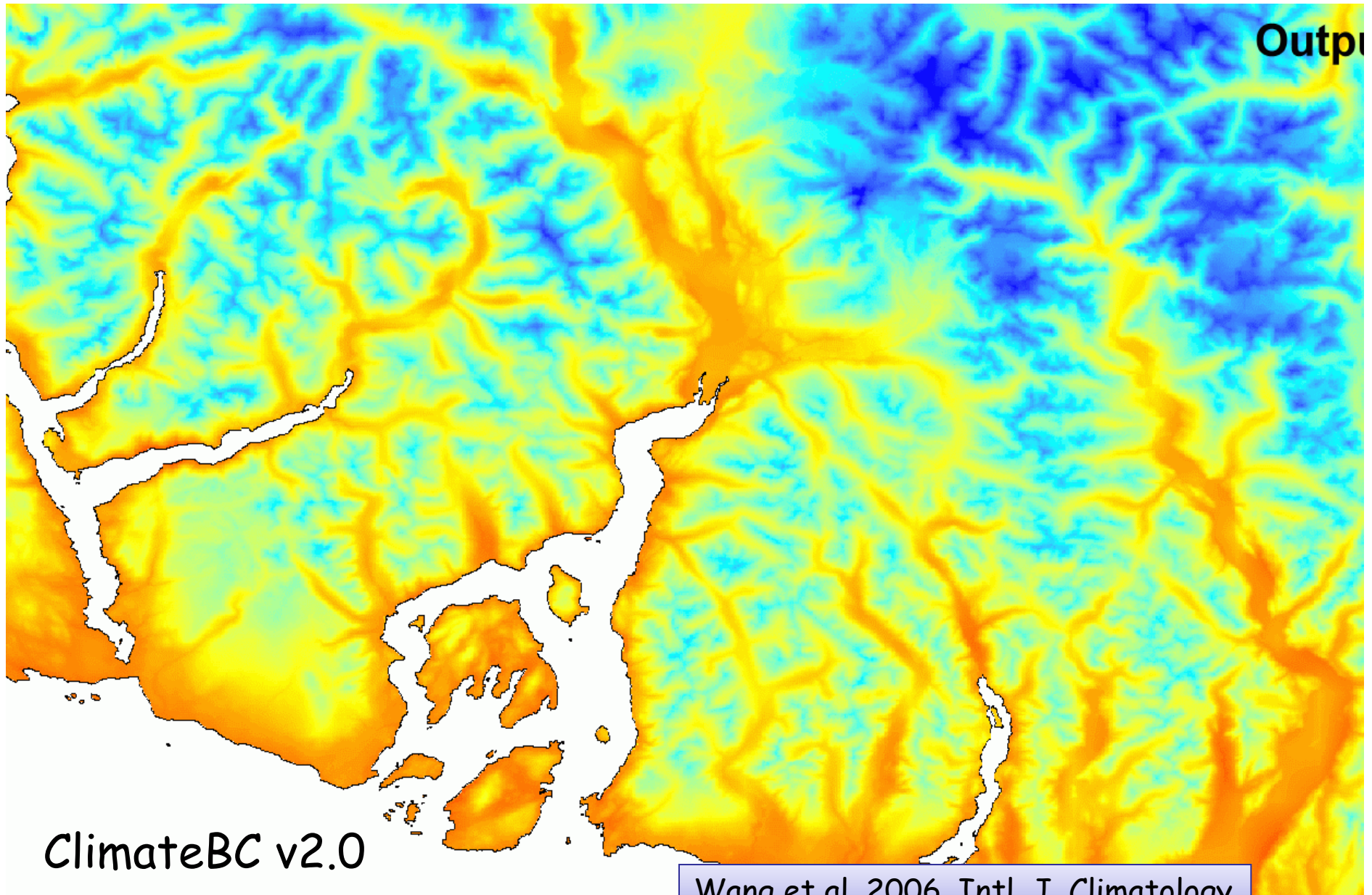
Select input file Specify output file Calculate

Status

Mean annual temperature for Vancouver area



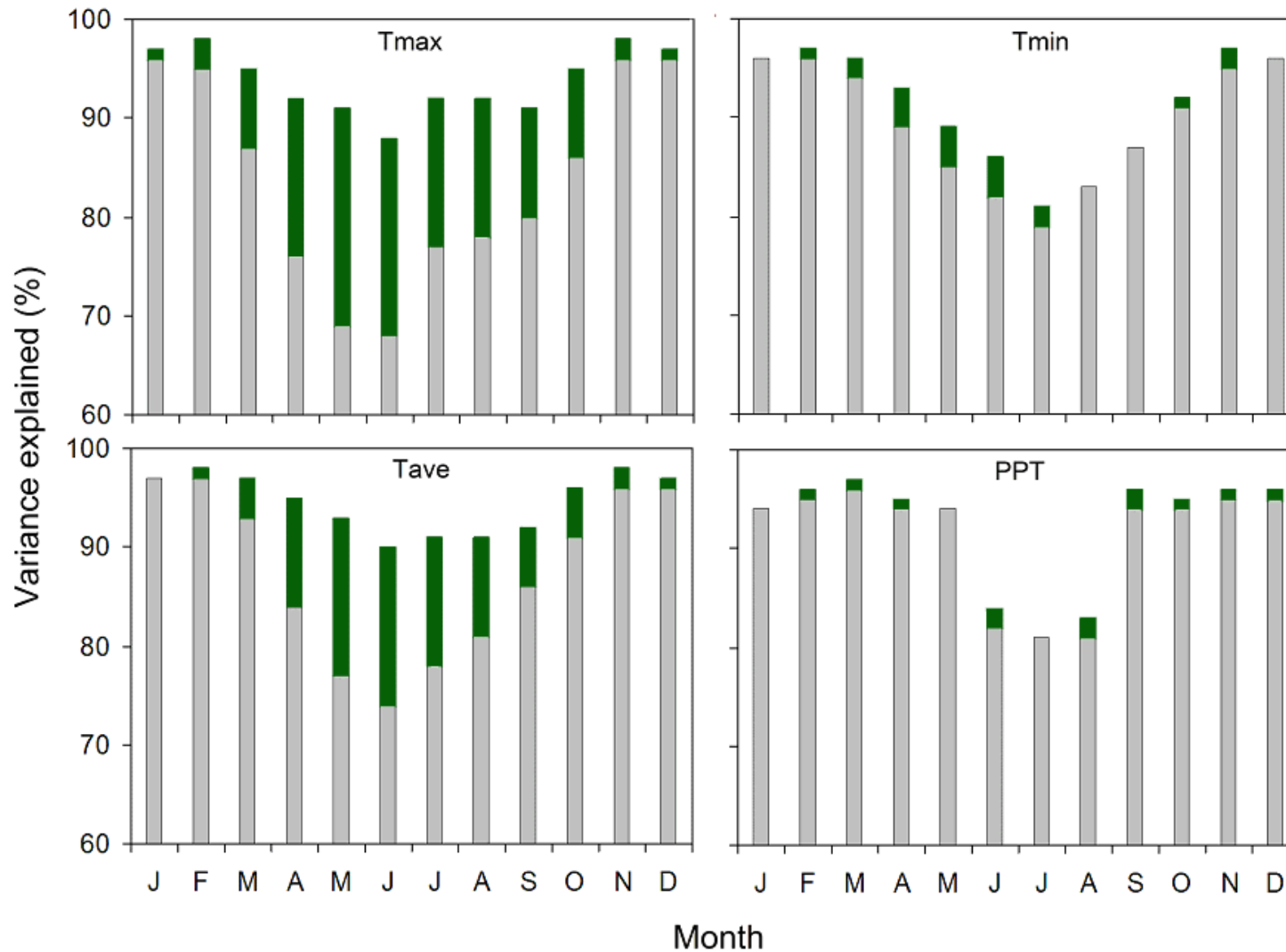
ClimateBC output (100m x100m)



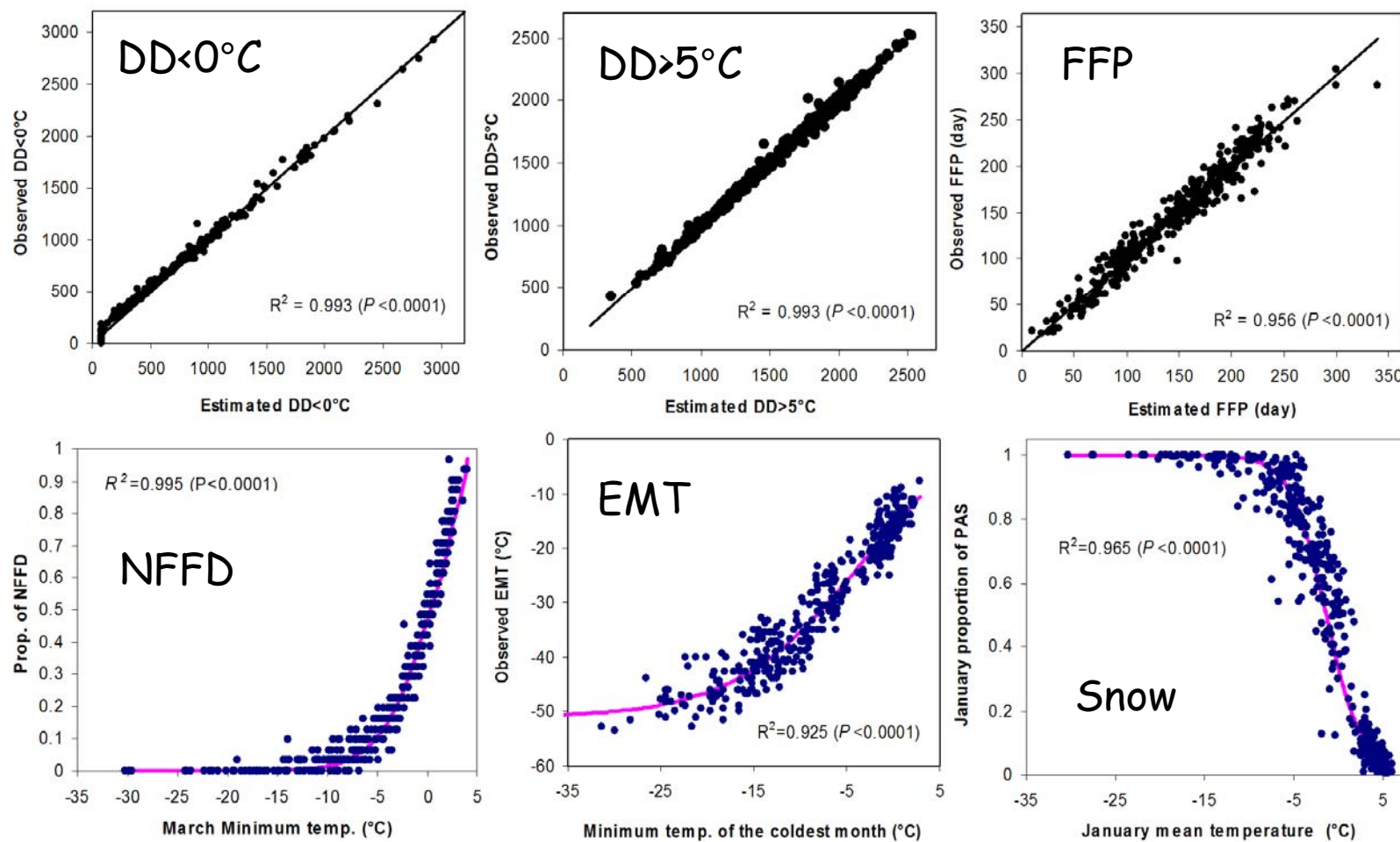
ClimateBC v2.0

Wang et al. 2006. Intl. J. Climatology

Predictions improved



Relationships used to predict derived variables



It generates climate data for past 102 years

ClimateBC_v3.2 Copyright (2006) Wang, Hamann, Spittlehouse and Aitken. All...

Select Time Scale
☒ Annual ☐ Season ☐ Monthly

Select Period
Annual Data Period: Select a year

Coordinate Input ☒ Decimal ☐
Latitude: 46.98
Longitude: -113.02
Elevation (m): 1000

Output of annual variables
MAT MWMT MCMT TD MA
DD<0 DD>5 DD5₁₀₀ DD<18 DD

Multi-location
Select input file Sp
Status

year_1901.ann
year_1902.ann
year_1903.ann
year_1904.ann
year_1905.ann
year_1906.ann
year_1907.ann
year_1908.ann
year_1909.ann
year_1910.ann
year_1911.ann
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year_1919.ann
year_1920.ann
year_1921.ann
year_1922.ann
year_1923.ann
year_1924.ann
year_1925.ann
year_1926.ann
year_1927.ann
year_1928.ann
year_1929.ann
year_1930.ann

About
Help
SH:M EMT PAS
bFFP eFFP Save
Calculate

It predicts climate data for the next 100 years using results from global circulation models

ClimateBC_v3.2 Copyright (2006) Wang, Hamann, Spittlehouse and Aitken. All...

Select Time Scale
☒ Annual ☐ Season ☐ Monthly

Coordinate Input ☒ Decimal ☐
Latitude: 46.98
Longitude: -113.02
Elevation (m): 1000

Output of annual variables
MAT MWMT MCMT TD MA
DD<0 DD>5 DD5₁₀₀ DD<18 DD

Multi-location
Select input file Sp

Status

Select Period
Future Periods
CGCM1_gax_2020s.gc
CGCM1_gax_2050s.gc
CGCM1_gax_2080s.gc
CGCM2_A1FI_2000s.gi
CGCM2_A1FI_2010s.gi
CGCM2_A1FI_2020s.gi
CGCM2_A1FI_2030s.gi
CGCM2_A1FI_2040s.gi
CGCM2_A1FI_2050s.gi
CGCM2_A1FI_2060s.gi
CGCM2_A1FI_2070s.gi
CGCM2_A1FI_2080s.gi
CGCM2_A1FI_2090s.gi
CGCM2_A2_2020s.gcn
CGCM2_A2_2050s.gcn
CGCM2_A2_2080s.gcn
CGCM2_A2x_2020s.gc
CGCM2_A2x_2050s.gc
CGCM2_A2x_2080s.gc
CGCM2_B1_2020s.gcn
CGCM2_B1_2050s.gcn
CGCM2_B1_2080s.gcn
CGCM2_B2_2000s.gcn
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CGCM2_B2_2060s.gcn
CGCM2_B2_2070s.gcn

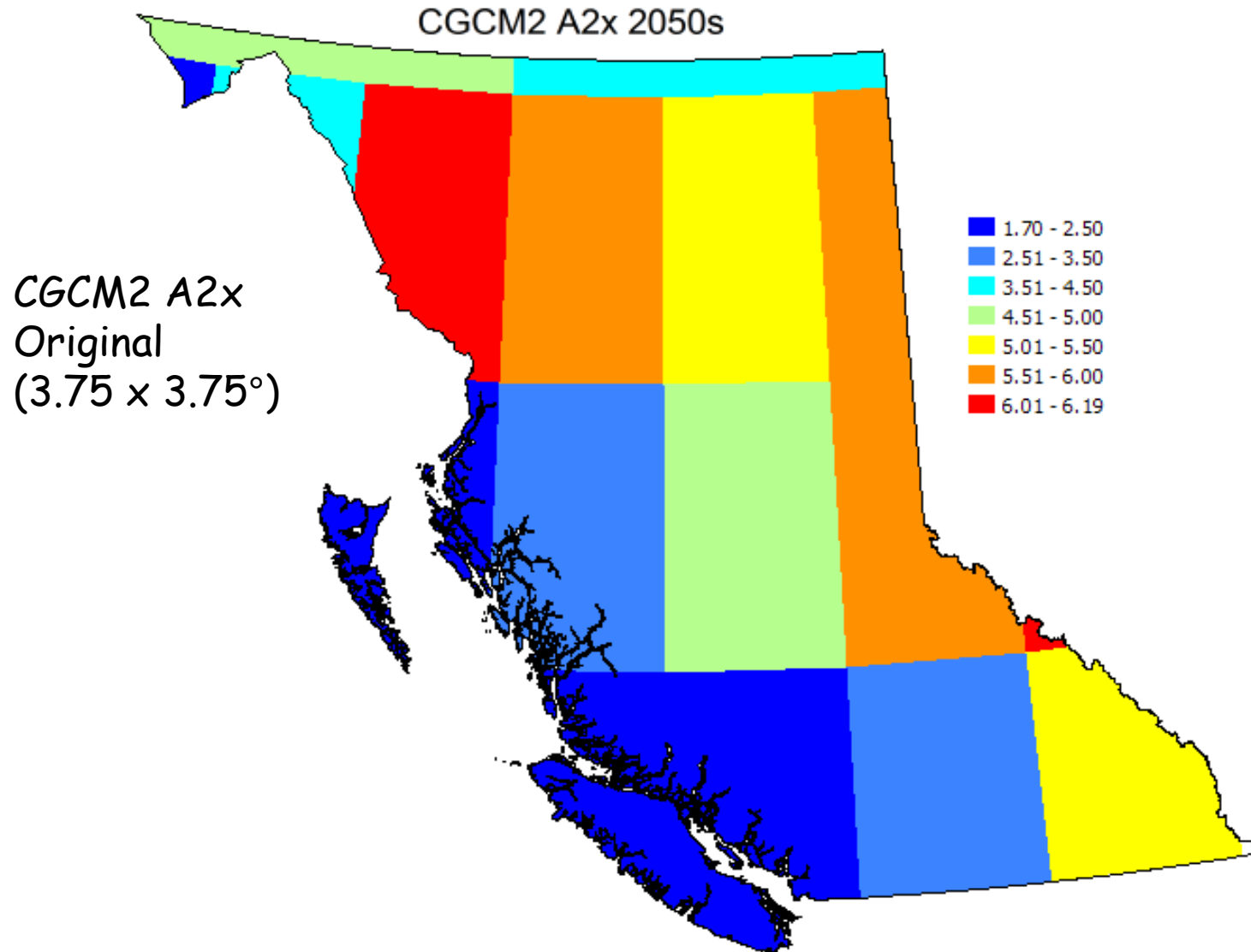
GCM: Select a GCM

About Help

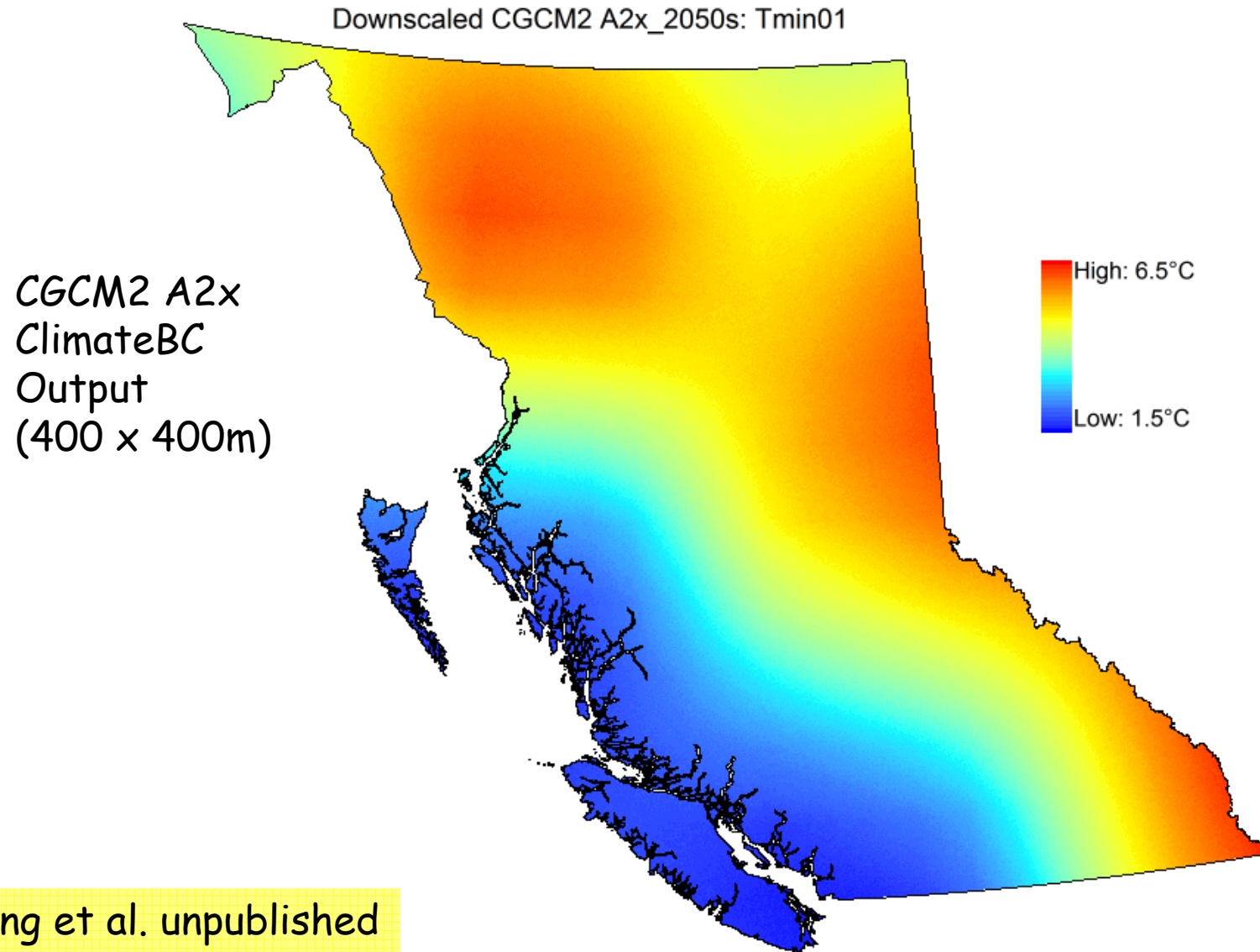
SH:M EMT PAS
bFFP eFFP Save

Calculate

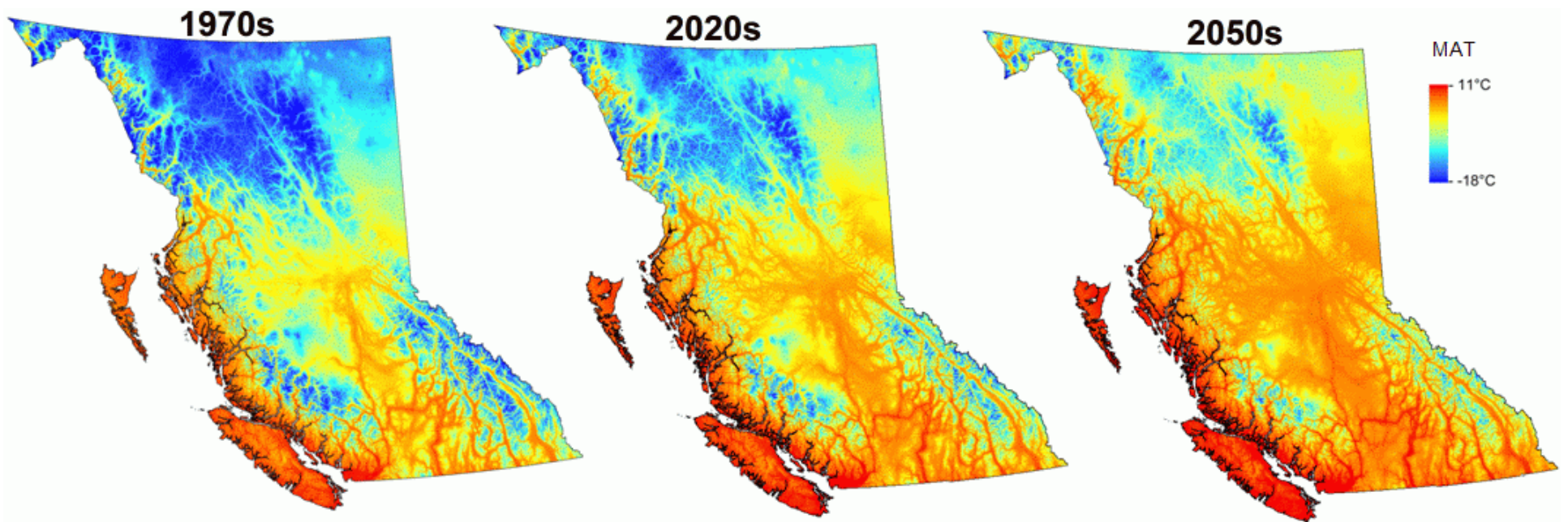
Downscaling of GCM data (CGCM2 A2x 2050s)



Downscaling of GCM data (CGCM2 A2x 2050s)



ClimateBC outputs



Maps of Mean Annual Temperature



B.C.'S FUTURE CARDINAL?
WESTCOAST NEWS | B1



CRUISE SHIP ANATOMY
BUSINESS BC | D1



MOZART FROM MADRAS
ARTS & LIFE | F1



CRUNCH TIME IN OTTAWA
SPORTS | H1

WEEKEND EDITION

THE VANCOUVER SUN

FINAL EDITION

www.vancouver.sun.com

SERIOUSLY WESTCOAST SINCE 1912

SATURDAY, JUNE 2, 2007

B.C. 2050 What climate change will do to our province



How trees can fuel cars

BY GORDON HAMILTON
and SCOTT SIMPSON
VANCOUVER SUN

At a pilot plant located on an isolated corner of the University of B.C. campus, researchers are converting trees killed by the mountain pine beetle into high-grade ethanol, a green alternative to gasoline.

Four hundred kilometres away, north of Kamloops, waste bark fed into a high-tech burner comes out as synthetic natural gas for heating water and drying veneer at a plywood mill.

And in B.C. Hydro's Vancouver office, staff are sorting through more than 80 expressions of interest from energy and forest companies. They want to produce power from mountains of wood going to waste alongside British Columbia's logging roads.

Calling timber-rich B.C. the new green Saudi Arabia without its polluting fossil fuels and gushing oil wells isn't just wild fantasy.

All over the world, scientists, businesses and governments are looking for ways to produce energy without increasing greenhouse gas emissions that are contributing to global warming.

Over the past few weeks, a Vancouver Sun team of reporters, editors and graphic artists has been sifting through interviews, scientific journals, government reports and private sector studies, asking how our province will be transformed in the coming decades by climate change.

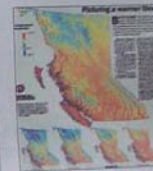
We've chosen 2050 as our target date because scientists say it's a pivotal moment in the history of humanity — if we haven't curtailed our fossil fuel emissions by then, warming will be an irreversible trend.

"Whether or not you believe in global warming, we cannot afford to take that risk," deputy forests minister Doug Koskoff told a recent Vancouver audience.

"We have to start preparing for this. The fact is, be it short term, be it long term, our climate has changed right now."

WEEKEND EXTRA
CONTINUES ON A6

WEEKEND
EXTRA



Forecasting a hotter future

What the province may be like at mid-century

WEEKEND REVIEW | C6-7



Picture of hope

Artist Robert Bateman refuses to give in to global-warming gloom

WEEKEND REVIEW | C1

Quebec revolution

Quebec's mayor is determined to change her city's image. B1

INSIDE



Firing a \$400,000 ticket for lotto head

BY CHAD SKELTON

executive officer Vic Polischuk. He also suggested more heads could roll after the conclusion...

Champions of the poor or just malcontents?

Its website says it exists to give a voice to the city's underprivileged — the poor, the drug-addicted and the homeless. Its members oppose capitalism and...

B.C. 2050 OUR CH

What will the province look like at mid-century? To answer that question, the Sun's B.C. 2050 sources. The stark picture that emerges on these pages will come as a shock to anyone expect

Climate change is about more than just longer summers and warmer winters. A transformation has begun that goes right to the heart of who we are and where we live. Icons of the West Coast – the rainforests we fought so hard to preserve, the salmon whose annual migration to our shores and rivers we celebrate – will be dying or dead. Our winters will no longer be cold enough to discourage diseases like malaria and dengue fever from finding a niche in new eco-systems. Massive dyking projects like those in Holland will be needed to keep Delta, Richmond and Vancouver International Airport from being inundated by rising sea levels. If climate change

models are accurate, temperatures in B.C. actually 3.5 degrees C. That's the difference between the upper Fraser River ice taken place. Eco-systems that have been the void is anybody's guess.

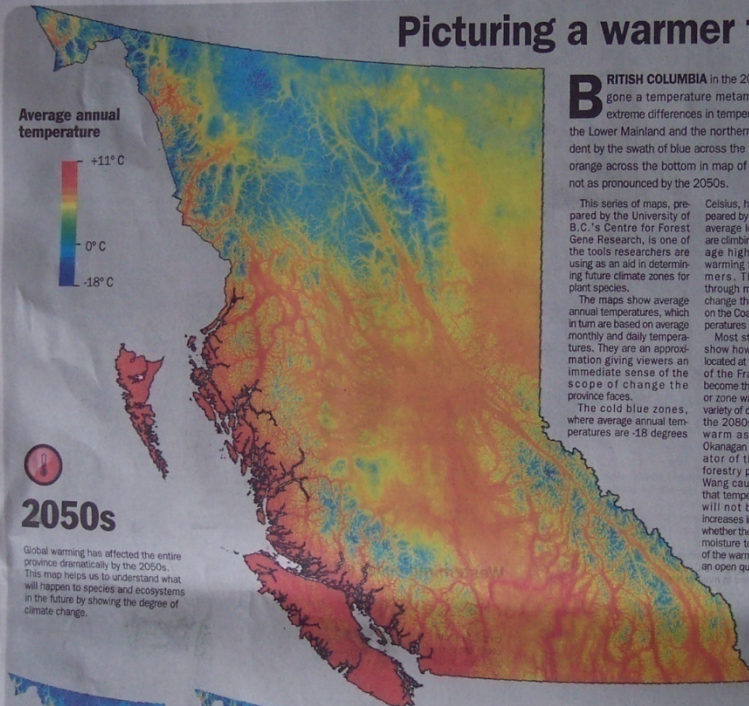
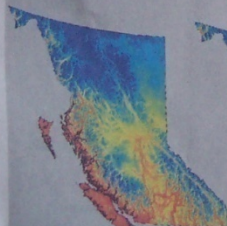
Picturing a warmer time

Average annual temperature



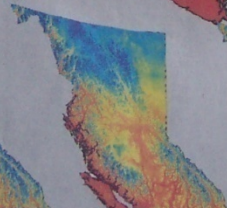
2050s

Global warming has affected the entire province dramatically by the 2050s. This map helps us to understand what will happen to species and ecosystems in the future by showing the degree of climate change.



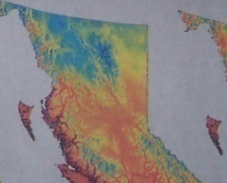
1970s

The north is noticeably cooler in this snapshot of average annual temperatures from 1961 to 1990.

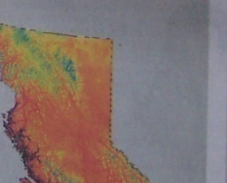


2020s

The trend to higher temperatures, which will affect distribution of plants and animals, is already evident in this map of the near future.



2050s



2050s

Climate zones will no longer fall within the climatic envelope of many of the species they currently support.

BRITISH COLUMBIA in the 2050s has undergone a temperature metamorphosis. The extreme differences in temperatures between the Lower Mainland and the northern Interior so evident by the swath of blue across the top and band of orange across the bottom in map of the 1970s, are not as pronounced by the 2050s.

This series of maps, prepared by the University of B.C.'s Centre for Forest Gene Research, is one of the tools researchers are using as an aid in determining future climate zones for plant species.

The maps show average annual temperatures, which in turn are based on average monthly and daily temperatures. They are an approximation giving viewers an immediate sense of the scope of change the province faces.

The cold blue zones, where average annual temperatures are -18 degrees Celsius, have almost disappeared by 2050, a sign that average low temperatures are climbing faster than average highs. Winters are warming faster than summers. The North goes through more temperature change than the South and on the Coast, mountain temperatures are climbing.

Most striking, the maps show how Prince George, located at the northern bend of the Fraser River, has become the hub of an interior zone warm enough for a variety of crops by 2050. By the 2080s, the land is as warm as the southern Okanagan is today. The creator of the maps, UBC forestry professor Tongli Wang cautions, however, that temperature increases will not be matched by increases in precipitation, so whether there will be enough moisture to take advantage of the warmer climate is still an open question.

Human health



Forestry

Rising temperatures will disrupt the equilibrium of forest eco-systems that have taken millennia to fine-tune. From Victoria to Haida Gwaii, the giant cedars will be dying of thirst during the longer, drier summers. In the Interior, fires will be more frequent and more intense. In the north, a host of new fungi and insect pests will flourish in the warmer, moister winters.

Grasslands overtake previously forested lands. Deciduous trees take over coastal rainforest regions because the climate is not longer suited to evergreens.

Snowpack

Snowfall will continue to vary from year to year as the climate naturally fluctuates, but the International Panel on Climate Change predicts decreasing snow cover in the Northern Hemisphere during the 21st century.



These maps show the projected snow cover in the northern part of the province. Higher temperatures mean the snowpack builds later in the year.

2007/02/06

Free to download



THE UNIVERSITY OF BRITISH COLUMBIA

Forestry
University of British Columbia

Centre for Forest Conservation Genetics • Home • About • People • Projects • Resources • Publications

- ◆ Overview
- ◆ Web-based
- ◆ ClimateBC v3
- ◆ References
- ◆ Predictions
- ◆ Monthly data



ources

ClimateBC: A program to generate climate normal data for genecology and climate change studies in western Canada

Overview

ClimateBC extracts and downscales PRISM ([Daly et al. 2002](#)) monthly data (2.5 x 2.5 arcmin) for the reference period (1961-1990), and calculates seasonal and annual climate variables for specific locations based on latitude, longitude and elevation (optional) for British Columbia, Yukon Territories, the Alaska Panhandle, and part of Alberta and US. This program also downscales and integrates historical (1901-2002) ([Mitchell and Jones 2005](#)) and future climate datasets (2020s, 2050s and 2080s) generated by various global circulation models. The output includes both directly calculated and derived climate variables. Methodologies are described in [Wang et al. \(2006\)](#) and [Hamann and Wang \(2005\)](#).

An overview of the ClimateBC is given in Climate Network Vol.10 No.1, April 2005, published by the Canadian Institute for Climate Studies [[download](#)] and in TICtalk December 2006 [[download](#)]. A recent Vancouver Sun article features output ClimateBC ([open pdf](#)).





THE UNIVERSITY OF BRITISH COLUMBIA

Forestry



Welcome To ClimateBC Web Version

A web version is
also available

Coordinates Input:

Latitude in Degree: ° ' " Longitude: ° ' "

Elevation: m Select Period: ▾

Calculate

[Help](#)

Output:

Annual Variables:

MAT= 6.6
MWMT= 17.5
MCMT= -4.9
TD= 22.4
MAP= 451
MSP= 216
AHM= 36.9
SHM= 81.0
EMT= -33.1
PAS= 107
DD<0= 453
DD>5= 1756
DD5_100= 119
DD<18= 3972
DD>18= 89
NFFD= 206
FFP= 131
bFFP= 134

Seasonal Variables:

Tave(12-2)= -4
Tave(3-5)= 7
Tave(6-8)= 17
Tave(9-11)= 7
Tmax(12-2)= 0
Tmax(3-5)= 12
Tmax(6-8)= 24
Tmax(9-11)= 12
Tmin(12-2)= -7
Tmin(3-5)= 1
Tmin(6-8)= 9
Tmin(9-11)= 2
PPT(12-2)= 121
PPT(3-5)= 87
PPT(6-8)= 136
PPT(9-11)= 107

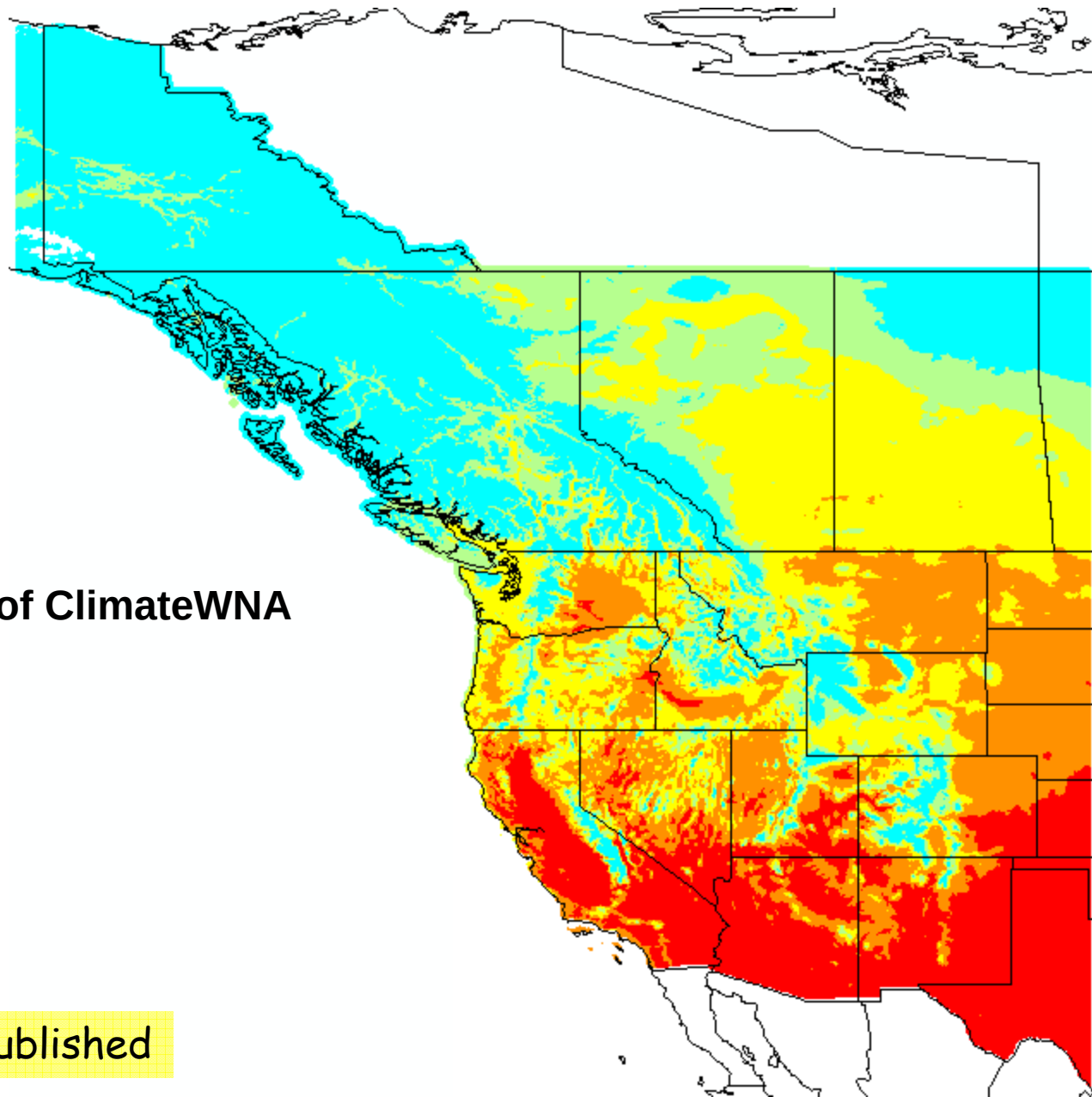
Monthly Variables:

Tave(1)= -4.9
Tave(2)= -1.3
Tave(3)= 2.2
Tave(4)= 6.6
Tave(5)= 11.2
Tave(6)= 15.1
Tave(7)= 17.5
Tave(8)= 17.3
Tave(9)= 12.3
Tave(10)= 7.4
Tave(11)= 0.5
Tave(12)= -4.3
Tmax(1)= -1.2
Tmax(2)= 2.9
Tmax(3)= 7.1
Tmax(4)= 12.5
Tmax(5)= 18.0
Tmax(6)= 22.2

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Coverage of ClimateWNA

Wang et al. unpublished

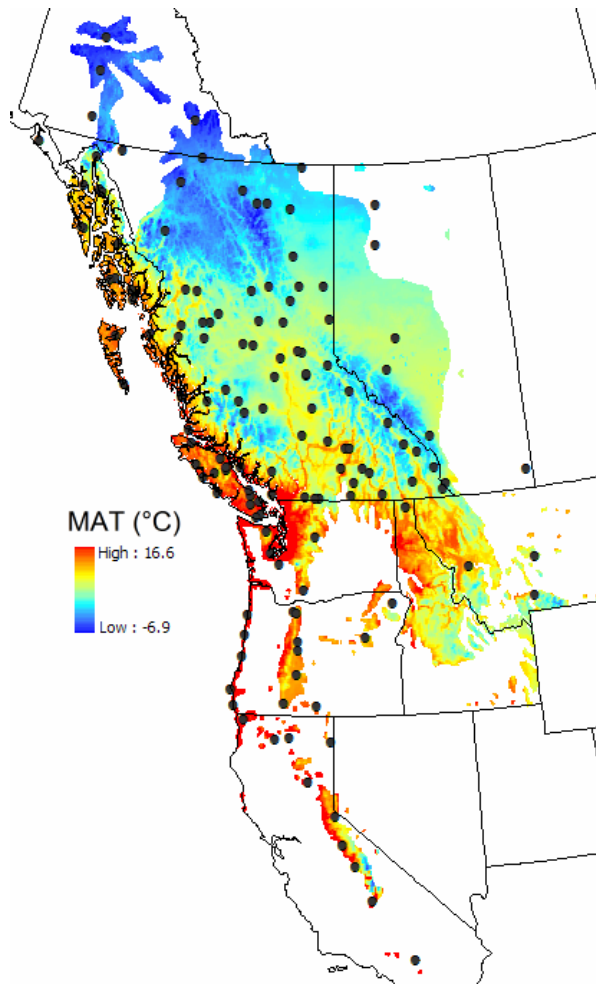


Objectives

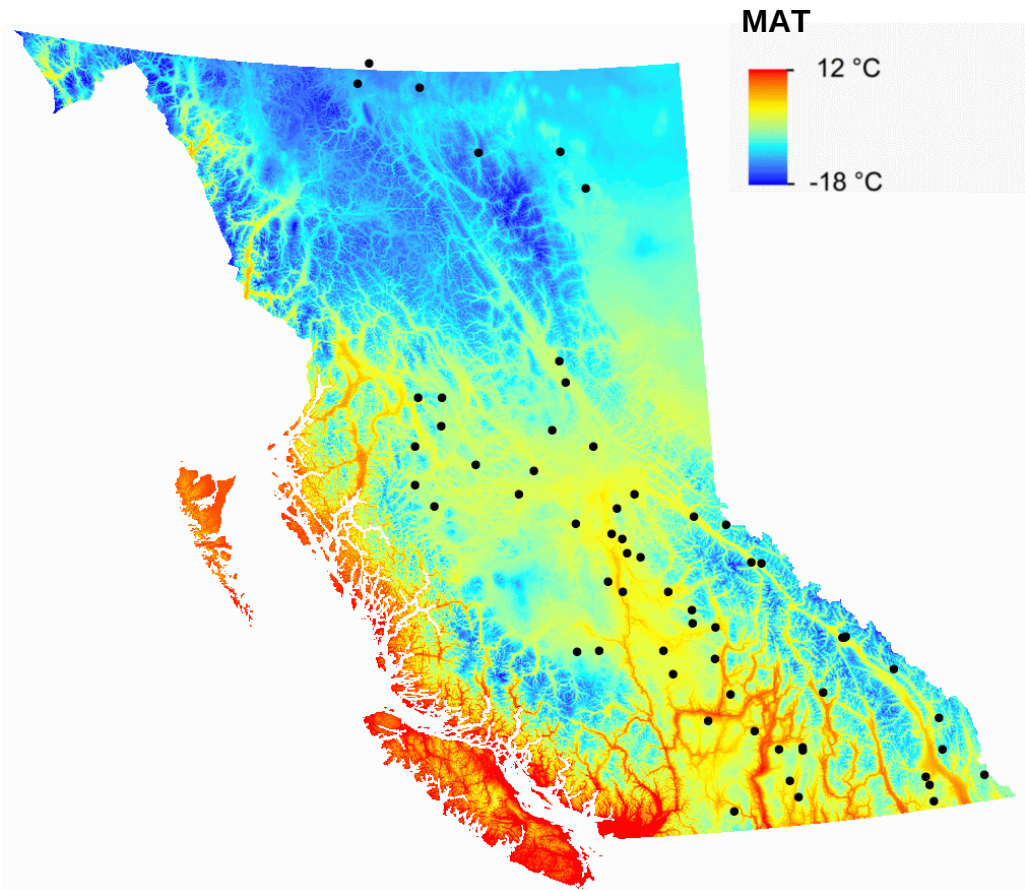
- Development of high-resolution climate model
- Development of population response functions to climate
- Predict future climatic envelopes for BC ecosystems and species ranges

Plant materials

140 provenances



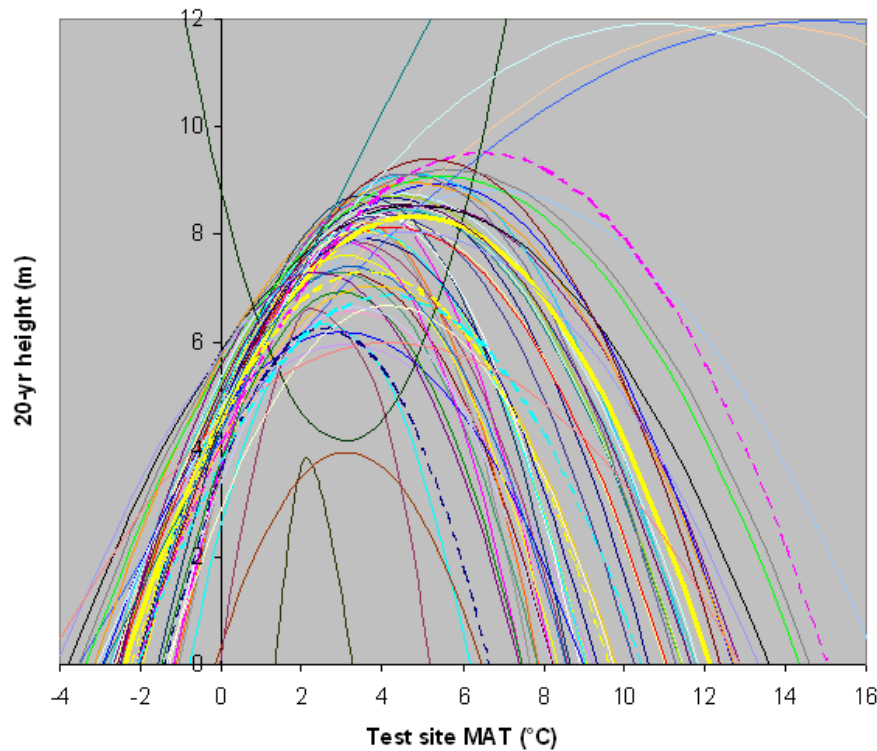
60 test sites



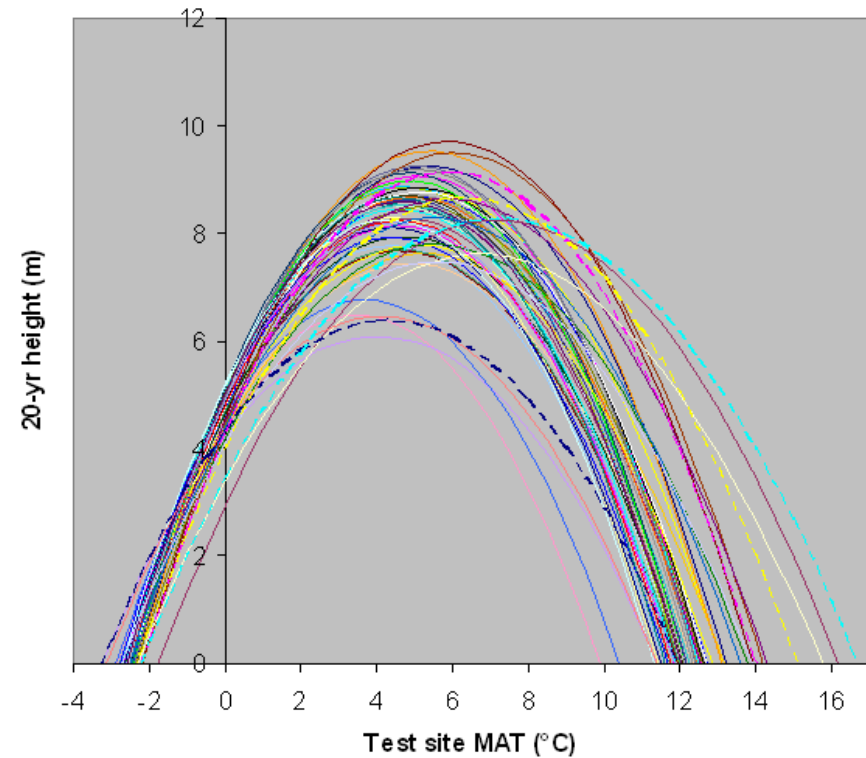
Lodgepole pine provenance trial in BC
established in 1974 (Illingworth 1978)

Effects of predicted anchor points on climatic response functions

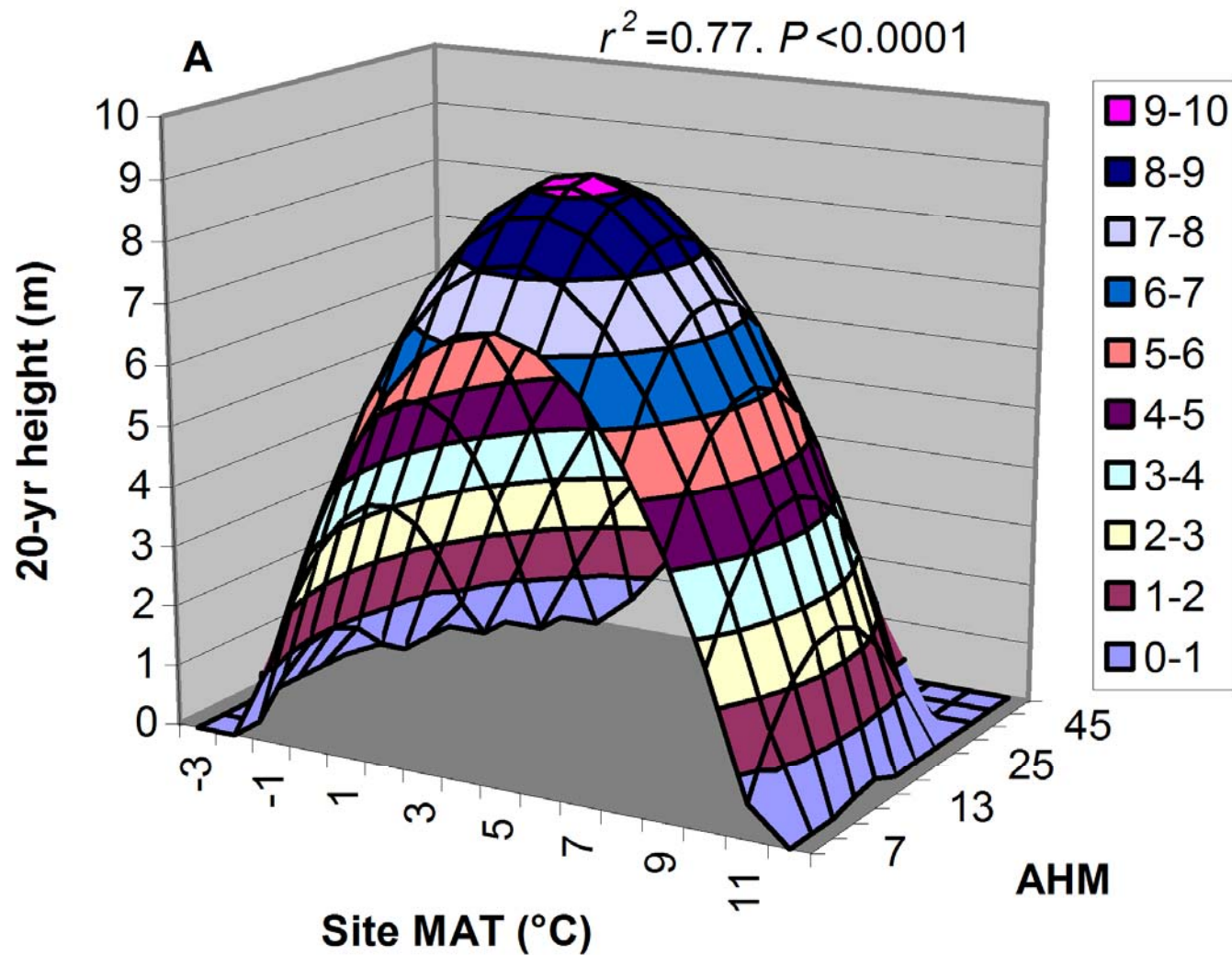
Without predicted anchor points



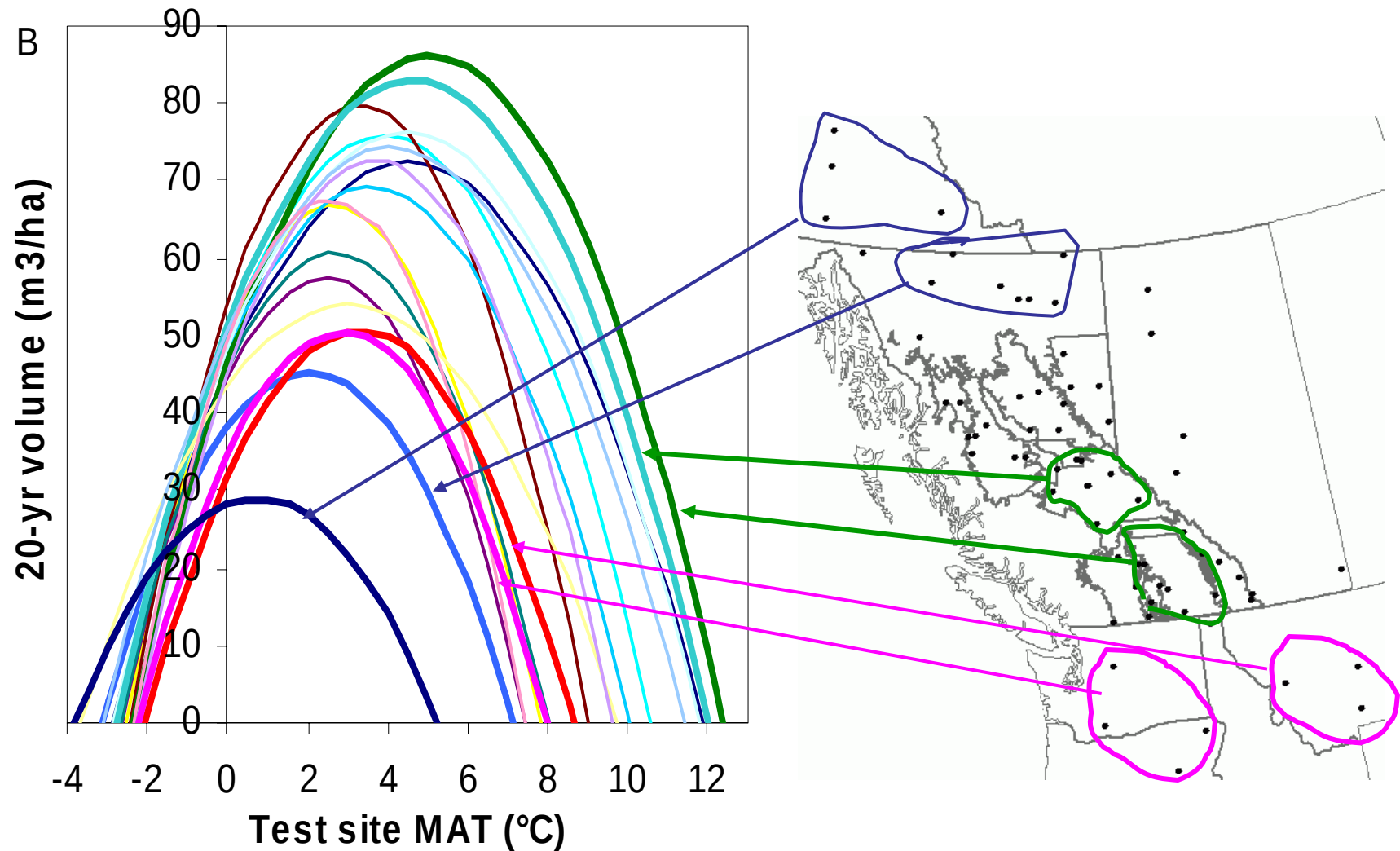
With predicted anchor points



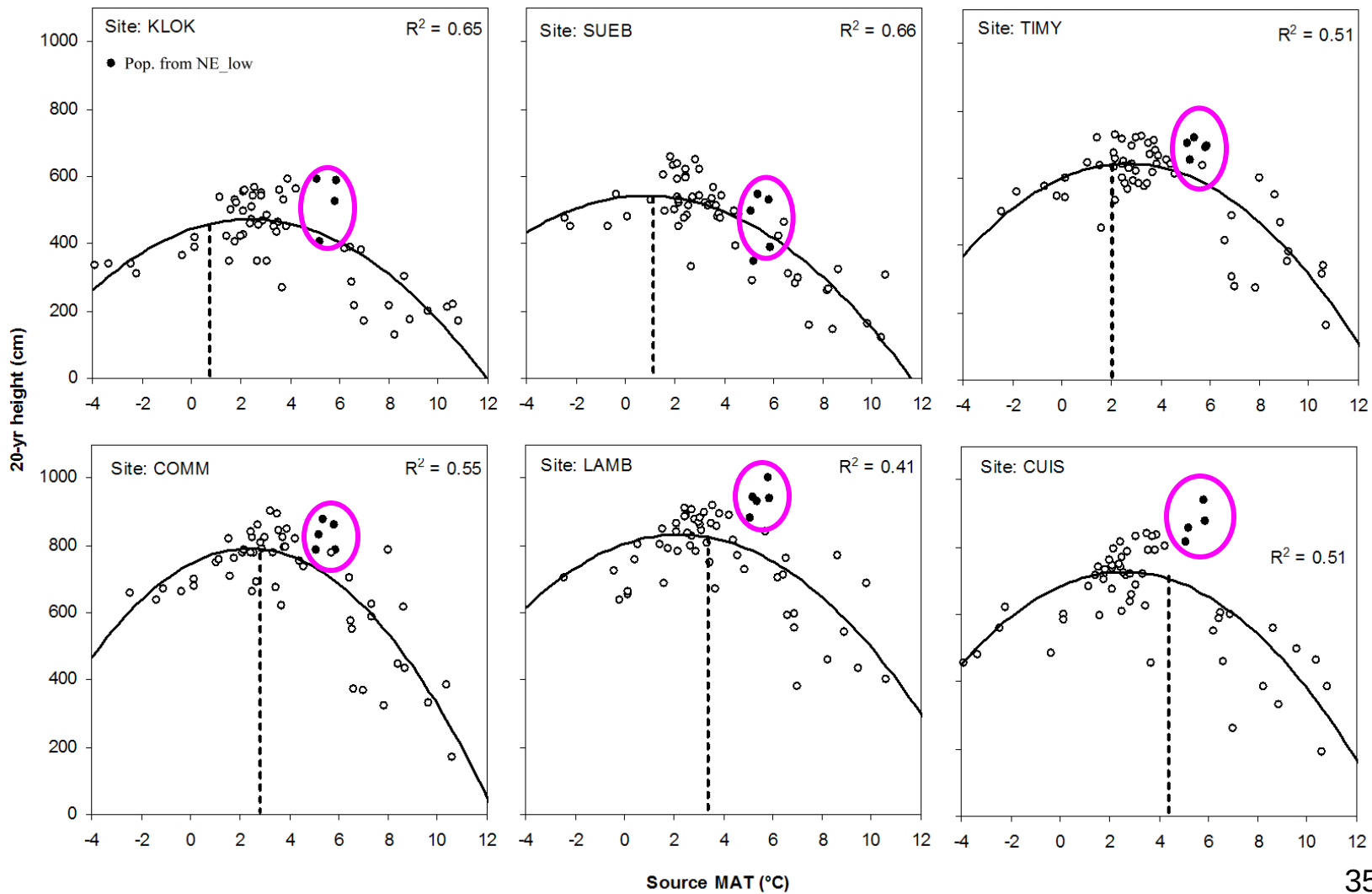
Multivariate approach further improved response functions



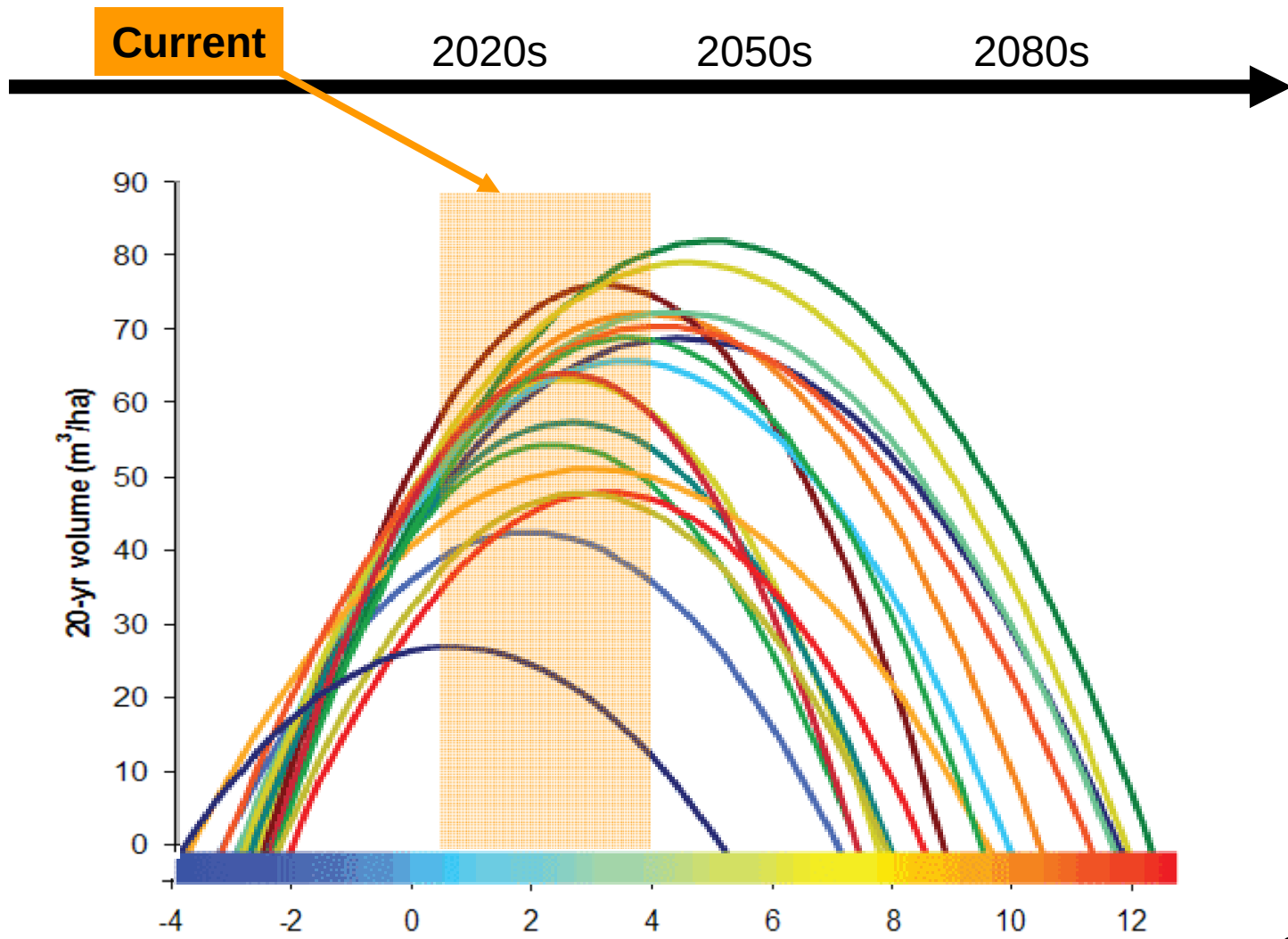
Variation in response of lodgepole pine populations to climate change



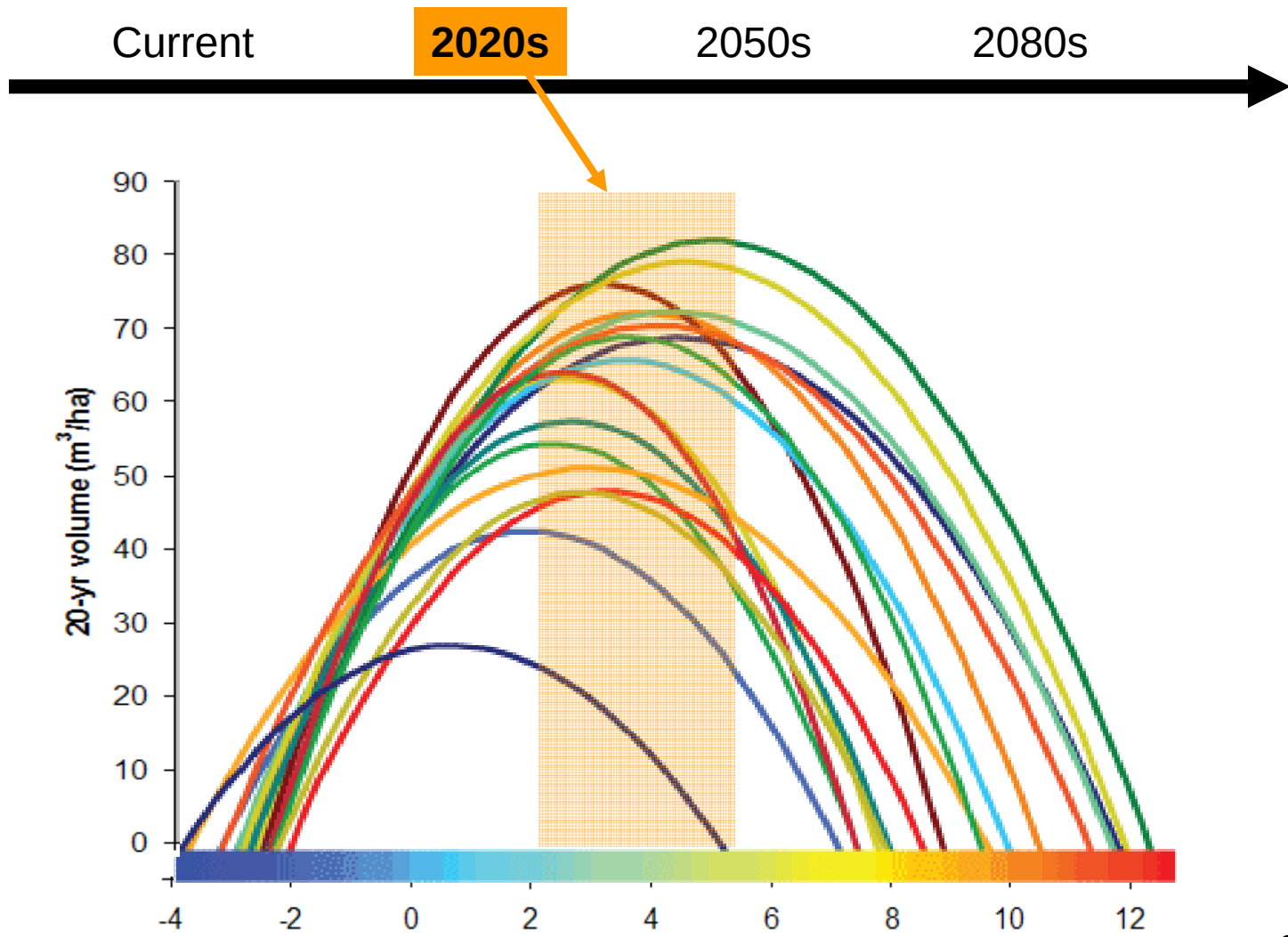
The performance of populations from the best SPU at individual sites



Response of lodgepole pine populations to climate change

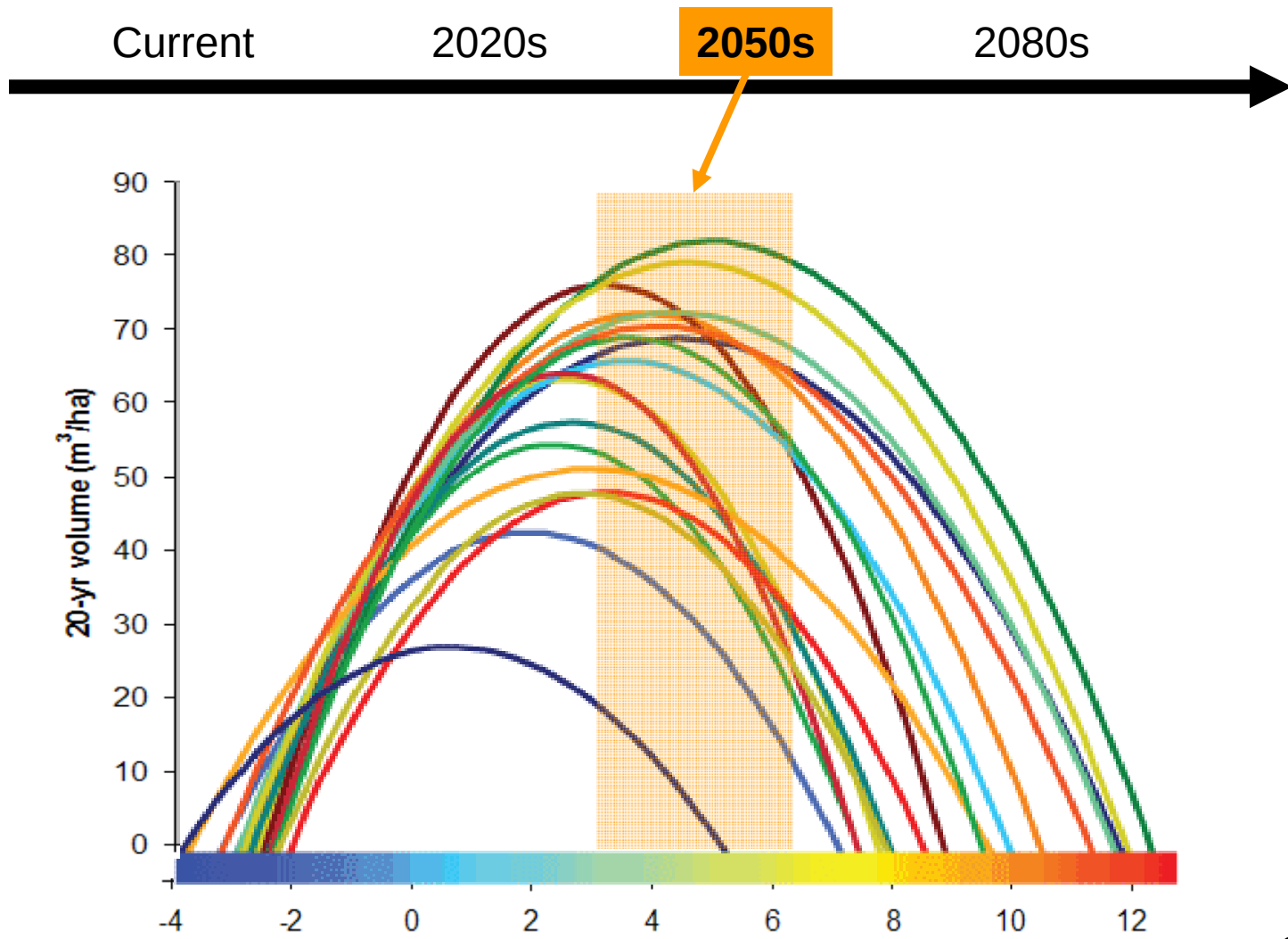


Response of lodgepole pine populations to climate change

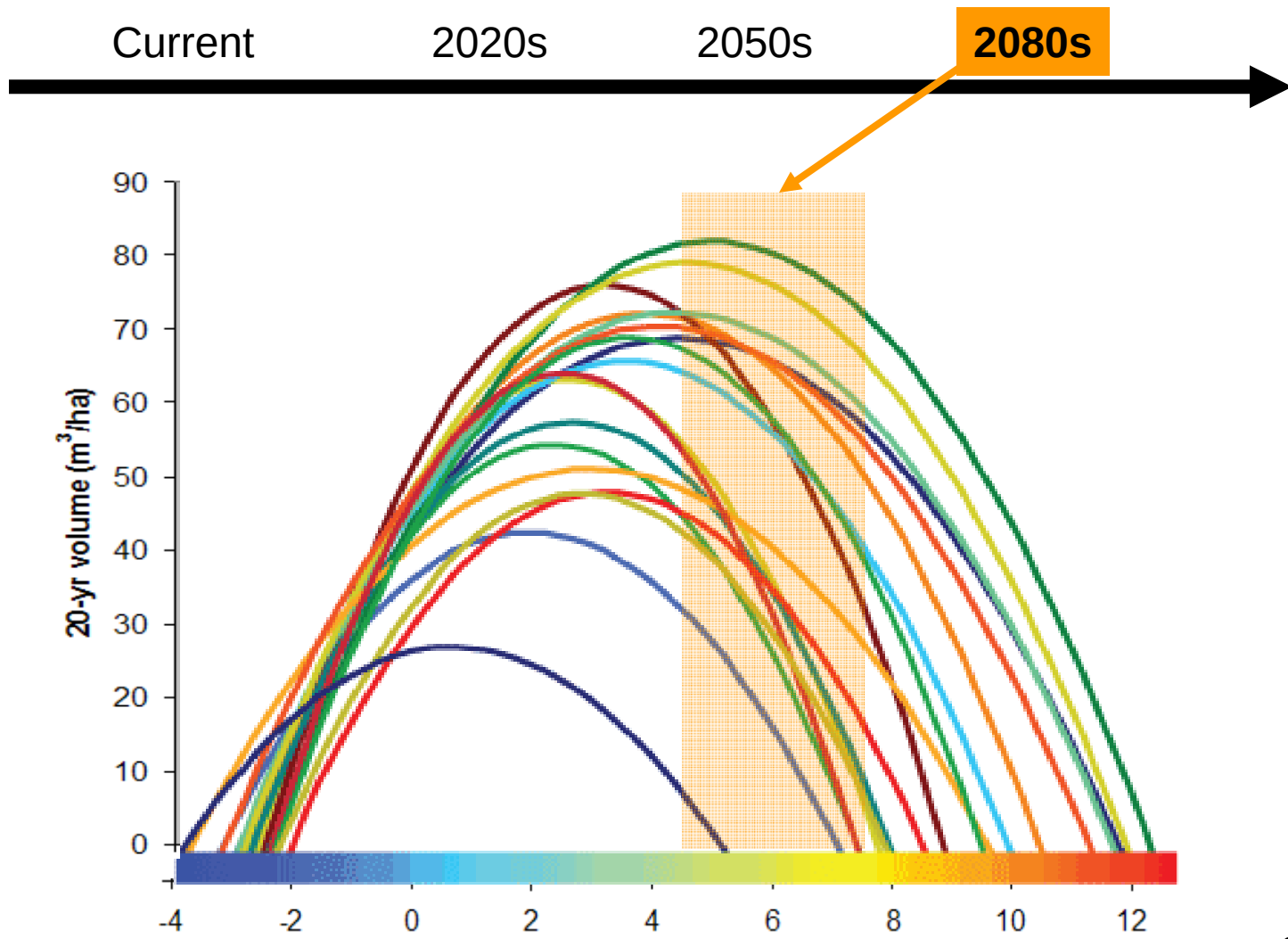


Future climates are based on CGCM2Ax2

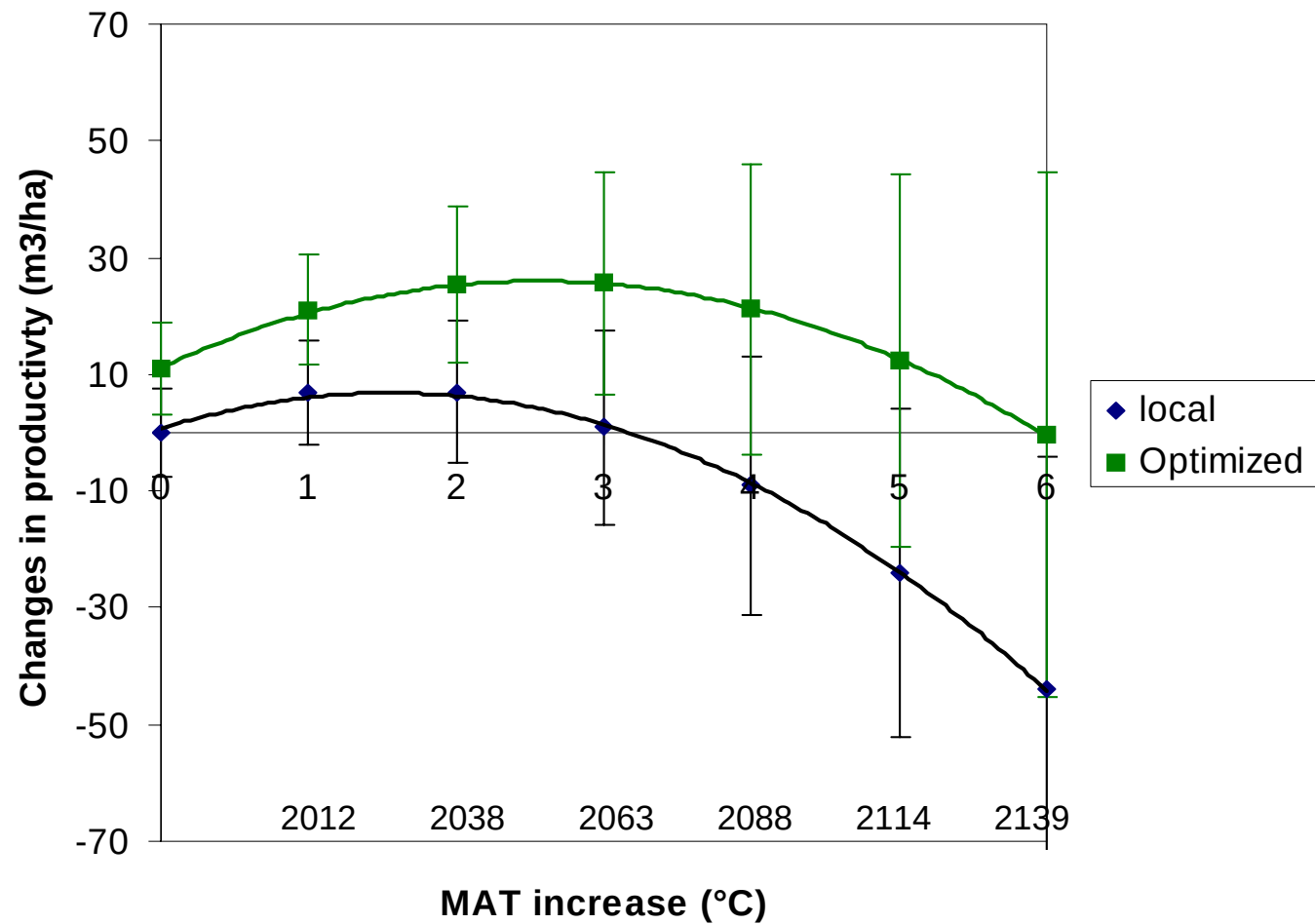
Response of lodgepole pine populations to climate change



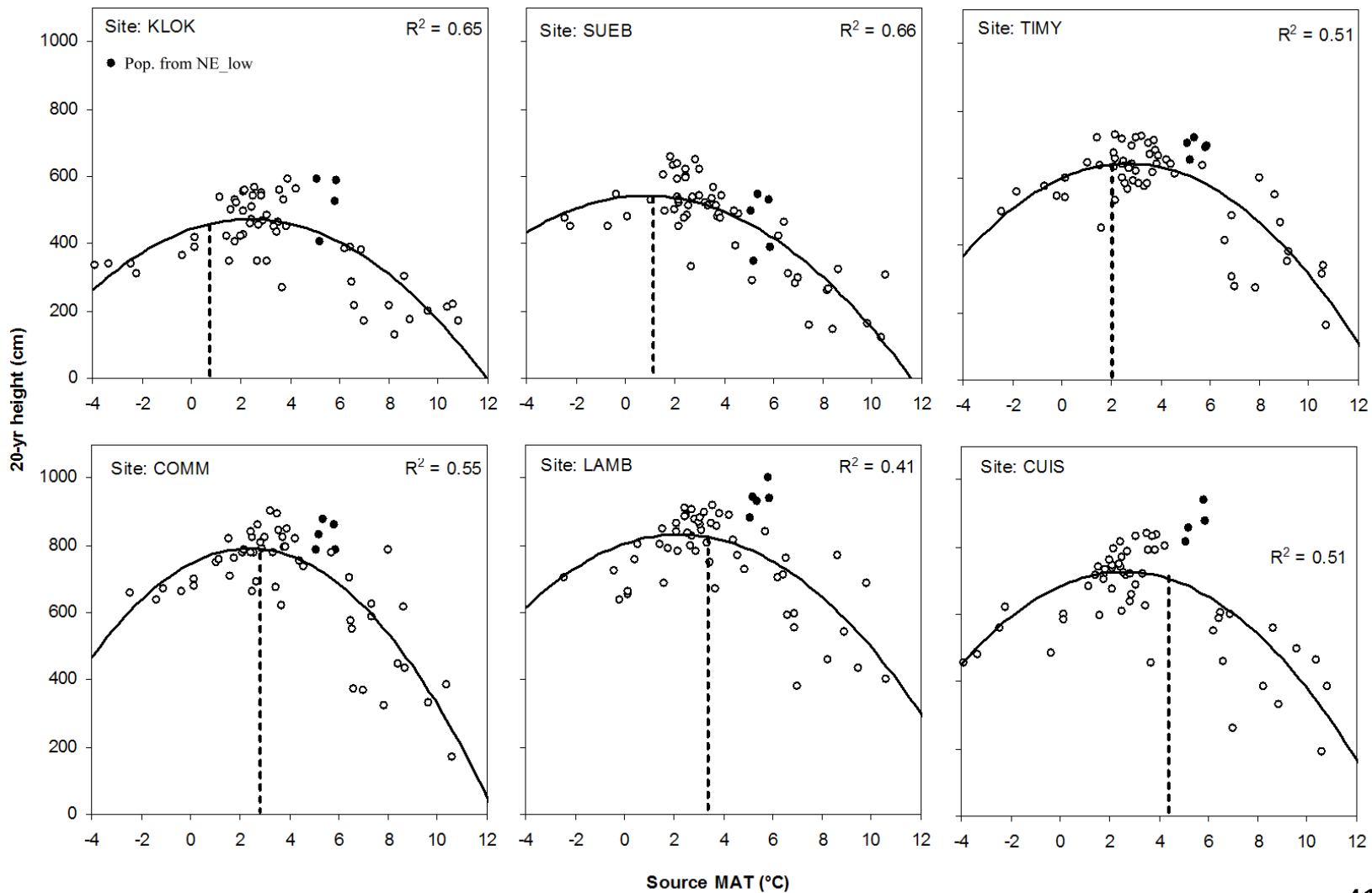
Response of lodgepole pine populations to climate change



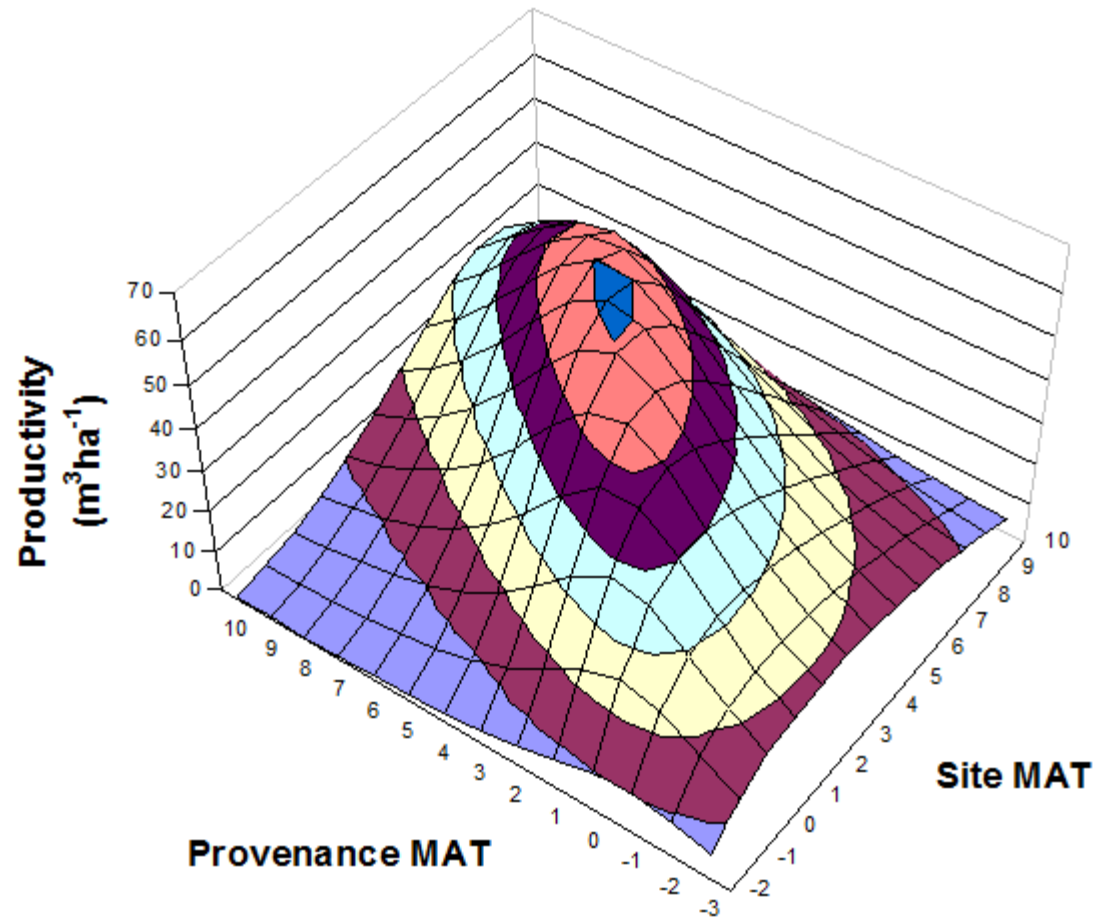
Optimization predicted to be effective, but uncertainty exists



Individual transfer functions

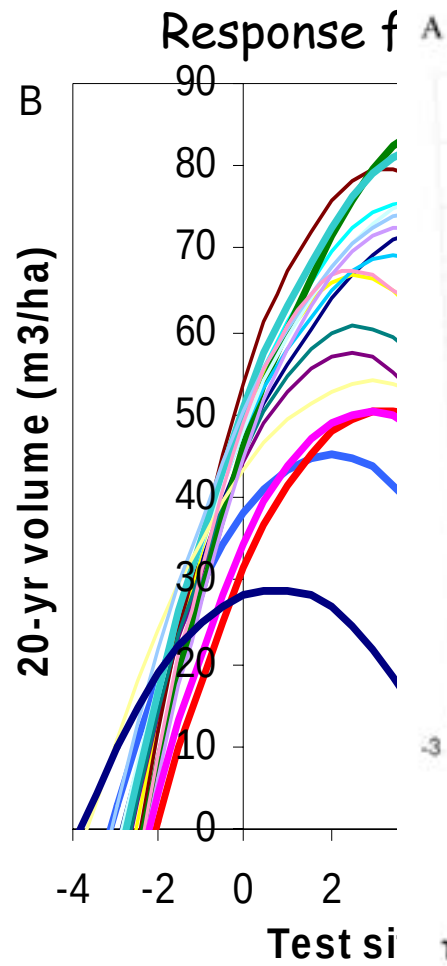
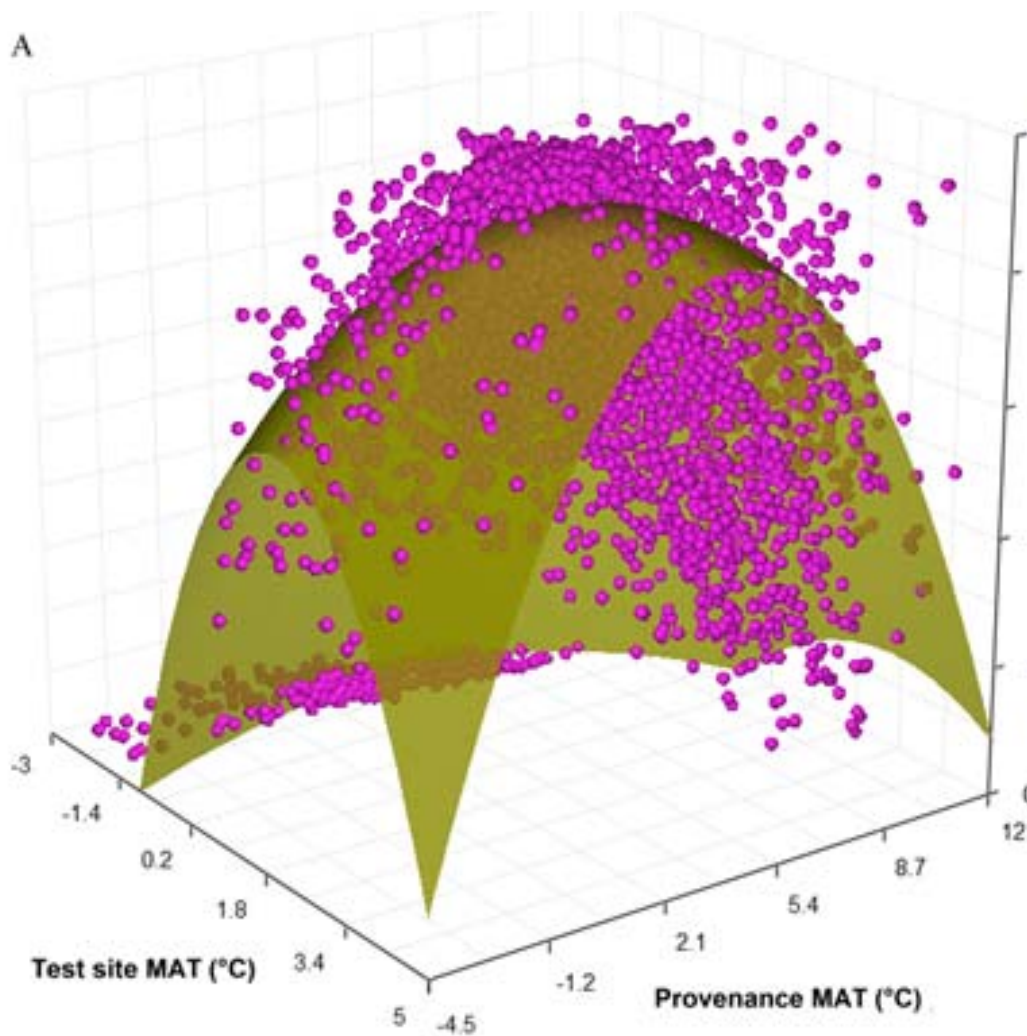


A universal transfer function

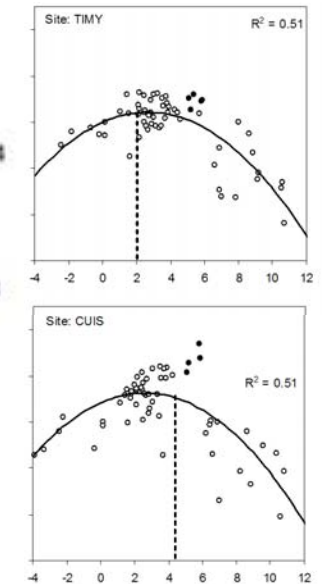


Integration

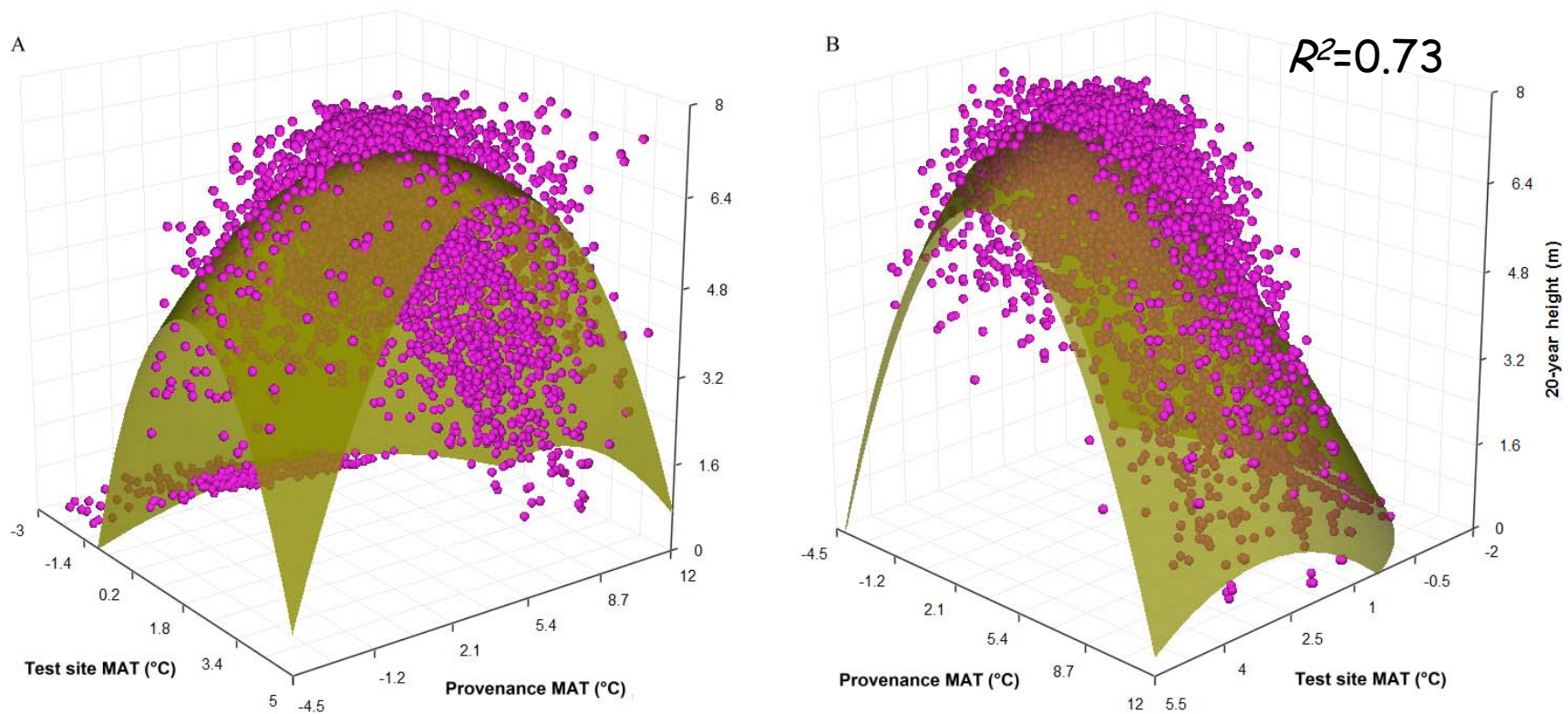
Universal response function



unctions



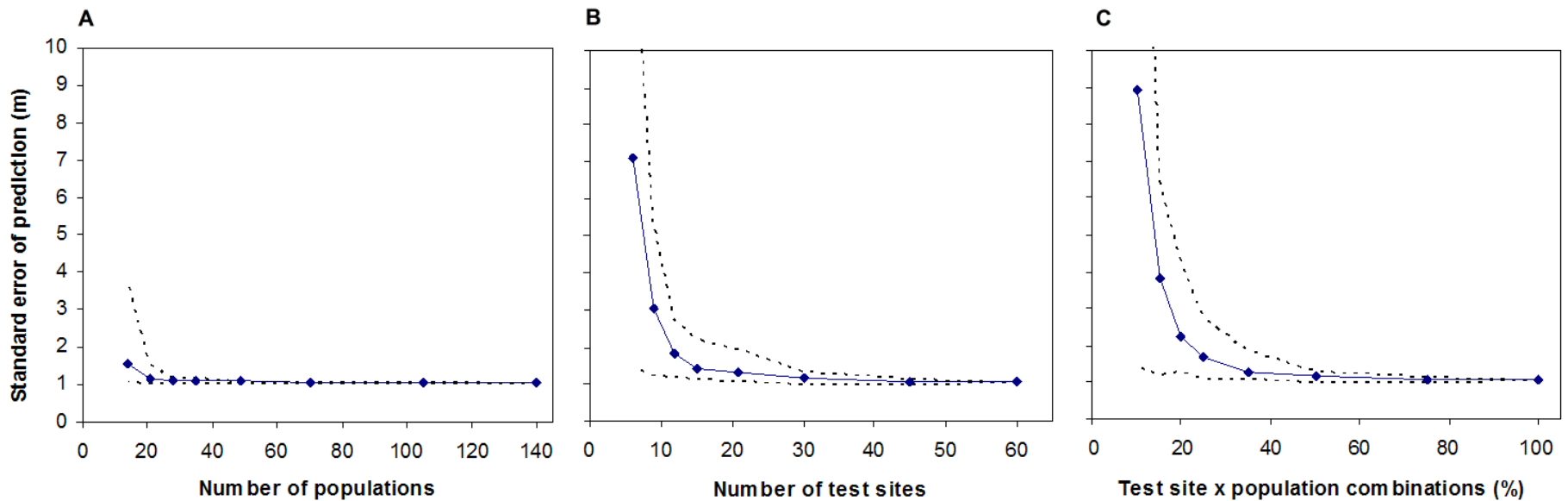
A universal response function



The surfaces were generated by a simplified version of the URF

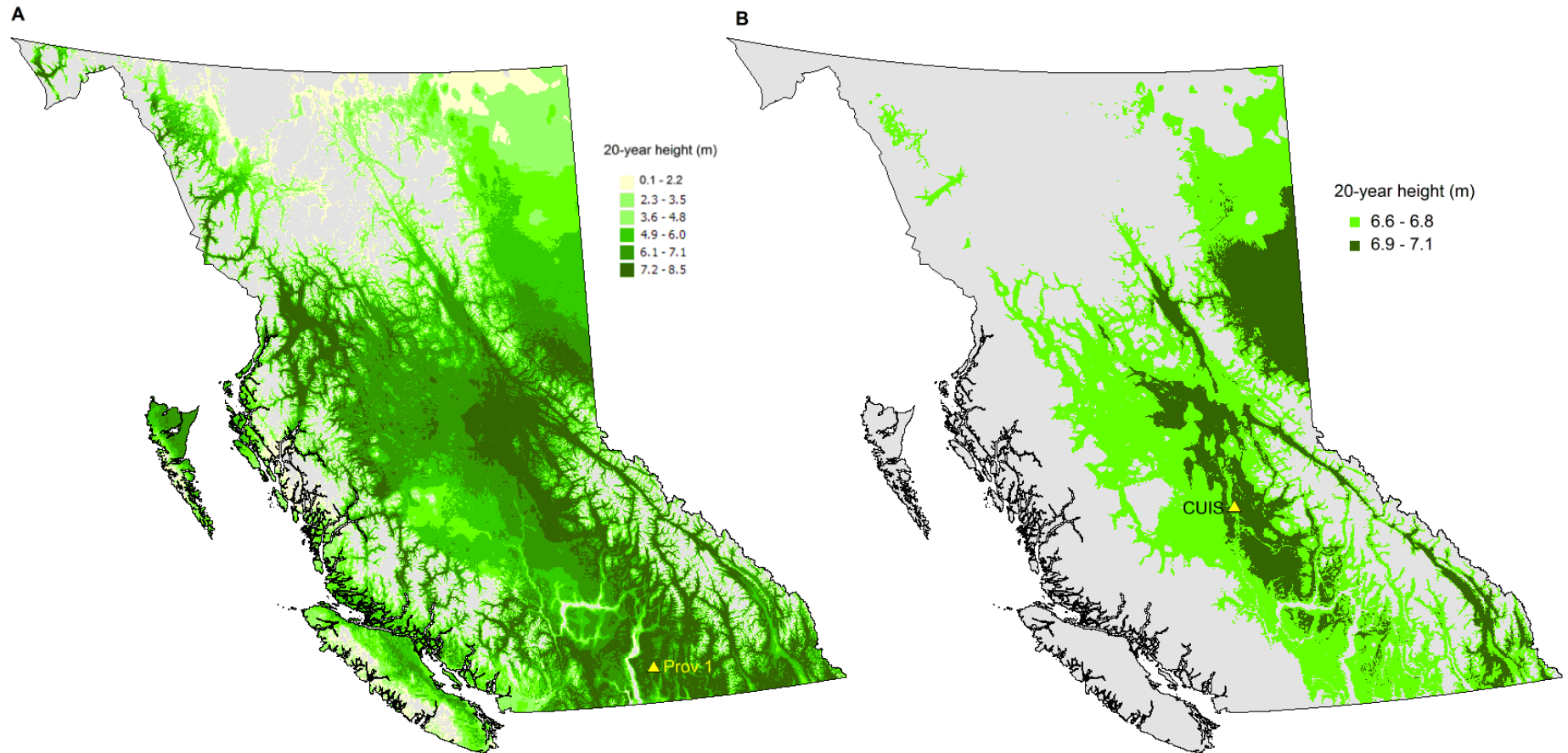
Wang et al. unpublished

A URF needs a much smaller sample size



Wang et al. unpublished

Applications of URF



Predicted performance of a population

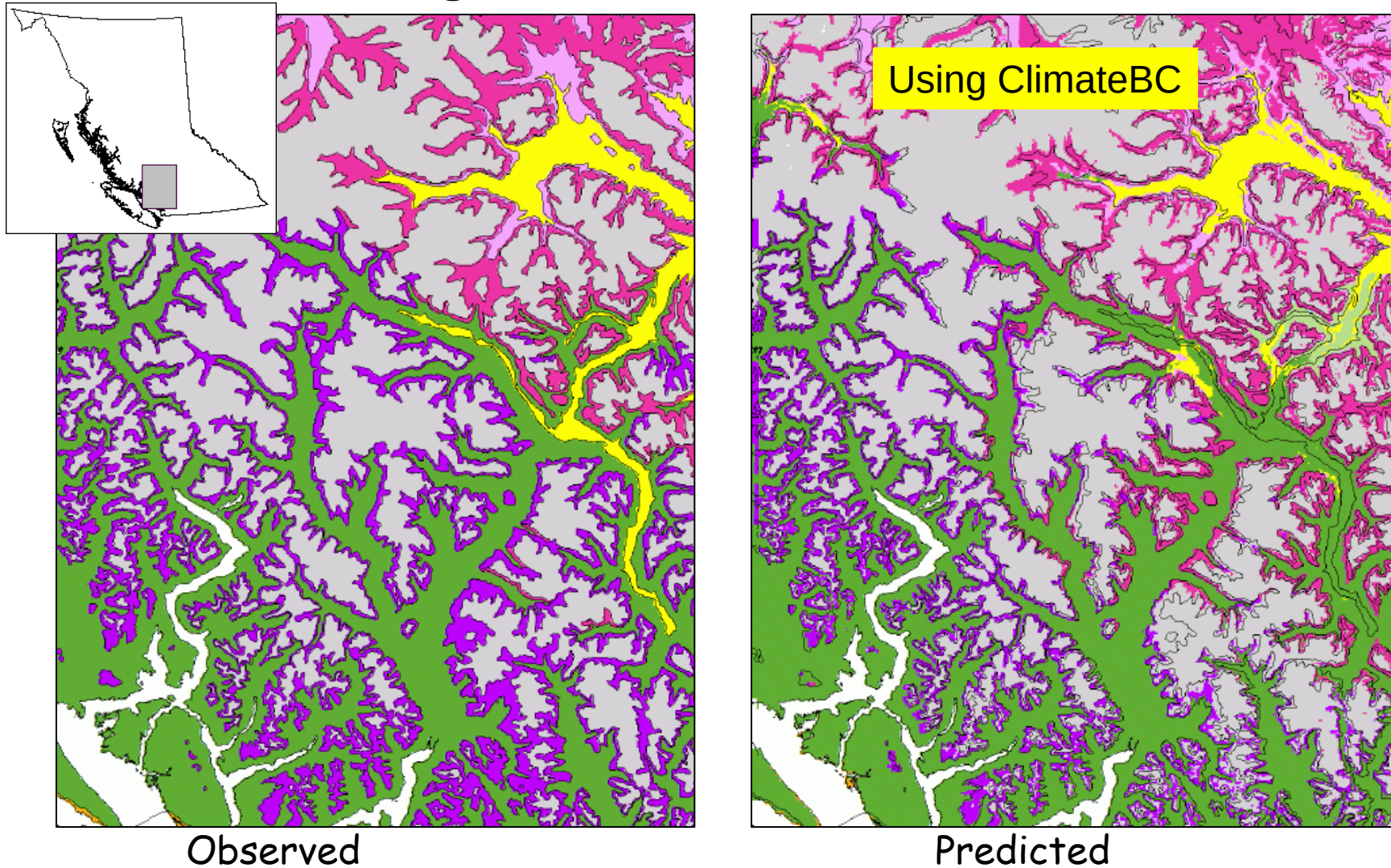
Predicted best provenances for a site

Wang et al. unpublished

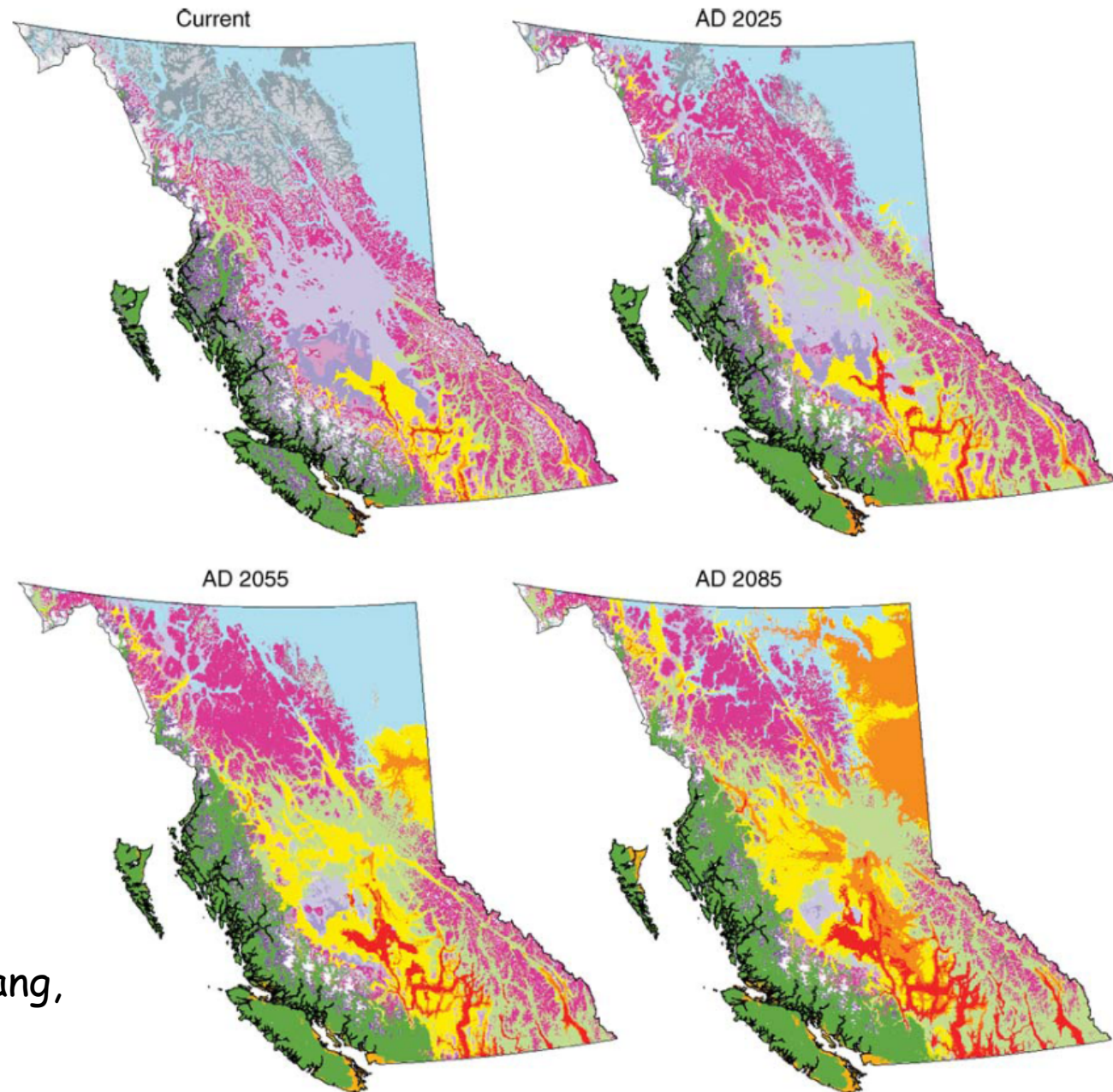
Objectives

- Development of high-resolution climate model
- Development of population response functions to climate
- Predict future climatic envelopes for BC ecosystems and species ranges

ClimateBC is critical for climatic mapping of Biogeoclimatic Ecological Classification (BEC) zones



Source: Hamann & Wang. 2005. *Agricultural and Forest Meteorology* **128**: 211-221 ⁴⁸



Hamann and Wang,
Ecology 2006

On average, expected climate change will equal a seven-degree shift north in latitude, meaning a tree that does well today in Prince George, the heart of B.C.'s forest industry, will grow best north of the Yukon border in 80 years.

Forest for the trees

BY MATTHEW VANDERKLEEF
in Vancouver

Sirra Carlio-McLane spent much of this week shimmying up whitebark pine trees, wearing a blue raincoat, industrial-strength rubber gloves and, for a splash of something completely out of place, crime goggles and a vest.

Not exactly fashion's finest, but for Ms. Carlio-McLane the point was less about looking good than about trying to understand if she could use a complex new British Columbia climate model to save a species of tree.

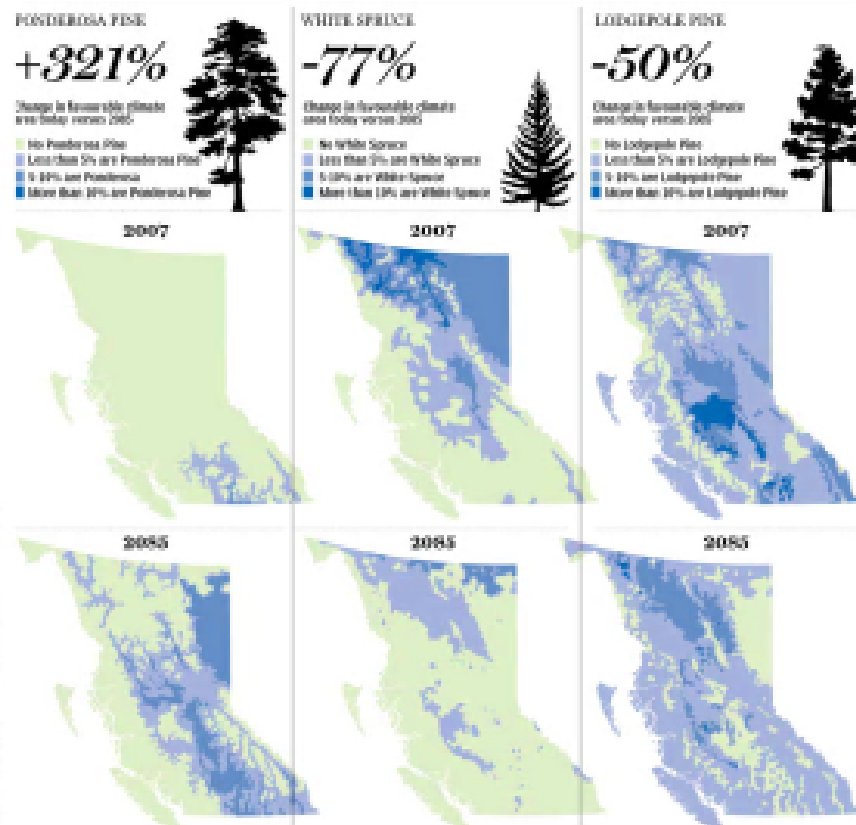
That model, developed by the UBC Centre for Forest Gene Conservation, allows research-

ers to enter into the far north-eastern corner of the province Coastal Douglas fir will see a 77% growth in its area, Western red cedar 33%.

Still, the news is not good. It's especially bad for Ms. Carlio-McLane's whitebark pine, which according to the model will see fully 99% of its area disappear.

Whitebark pine has already served as a kind of early warning system for climate change problems. In recent years, some of its B.C. populations have been cut in half. South of the U.S. border, populations have been almost completely wiped out in a scenario that could be replicated among other species in a warming climate. As the climate warms, trees lose their ability to repel attackers in ways already being seen in the whitebark, which has been

BRITISH COLUMBIA'S SHIFTING TREES



SOURCE: AMERICAN FOREST AND PAPER RESEARCH

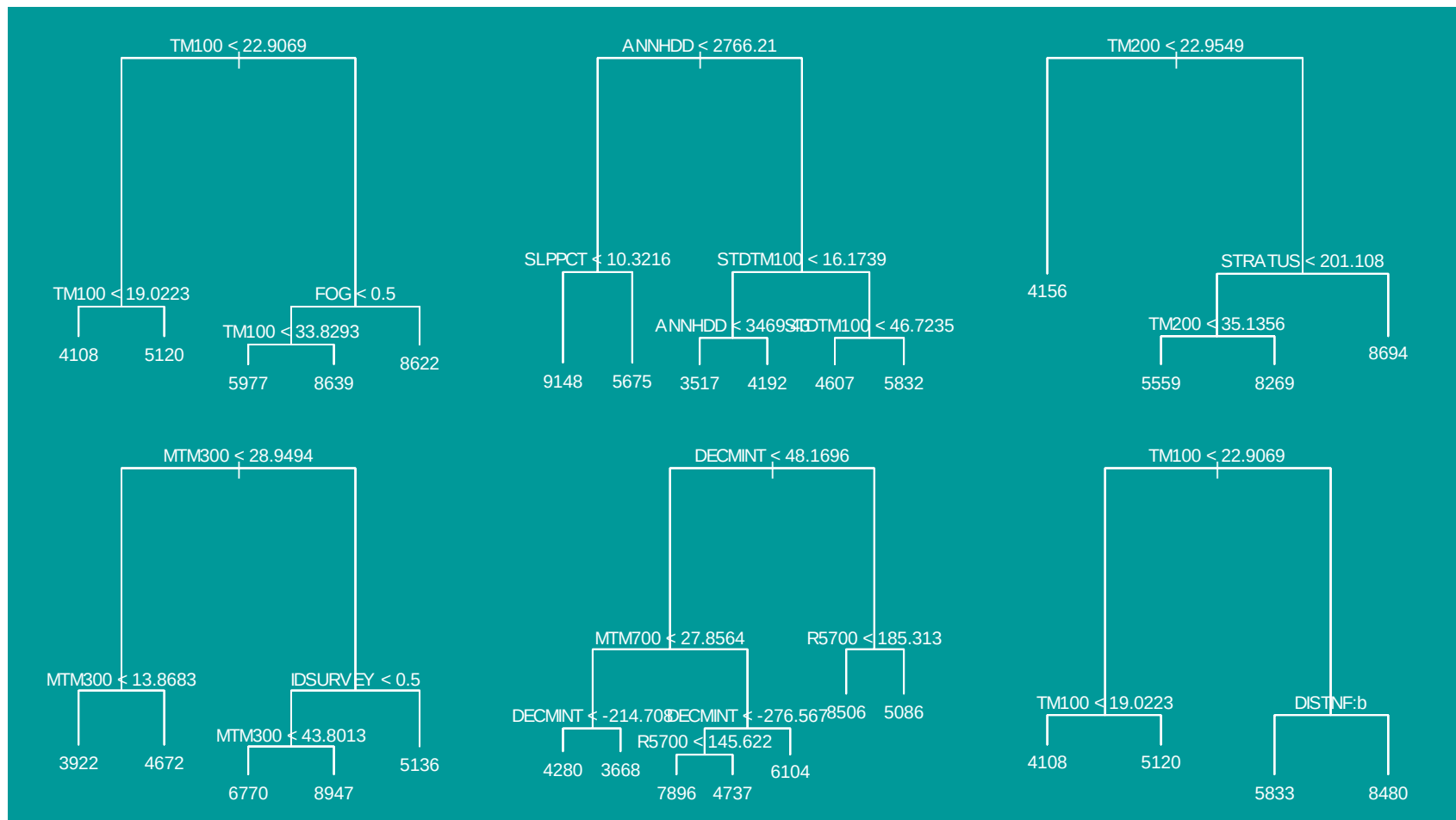
BRITISH REPORT AND MODEL COURTESY: JACQUES POIR

Use of Random Forest to predict climate envelopes of BEC zones in the future

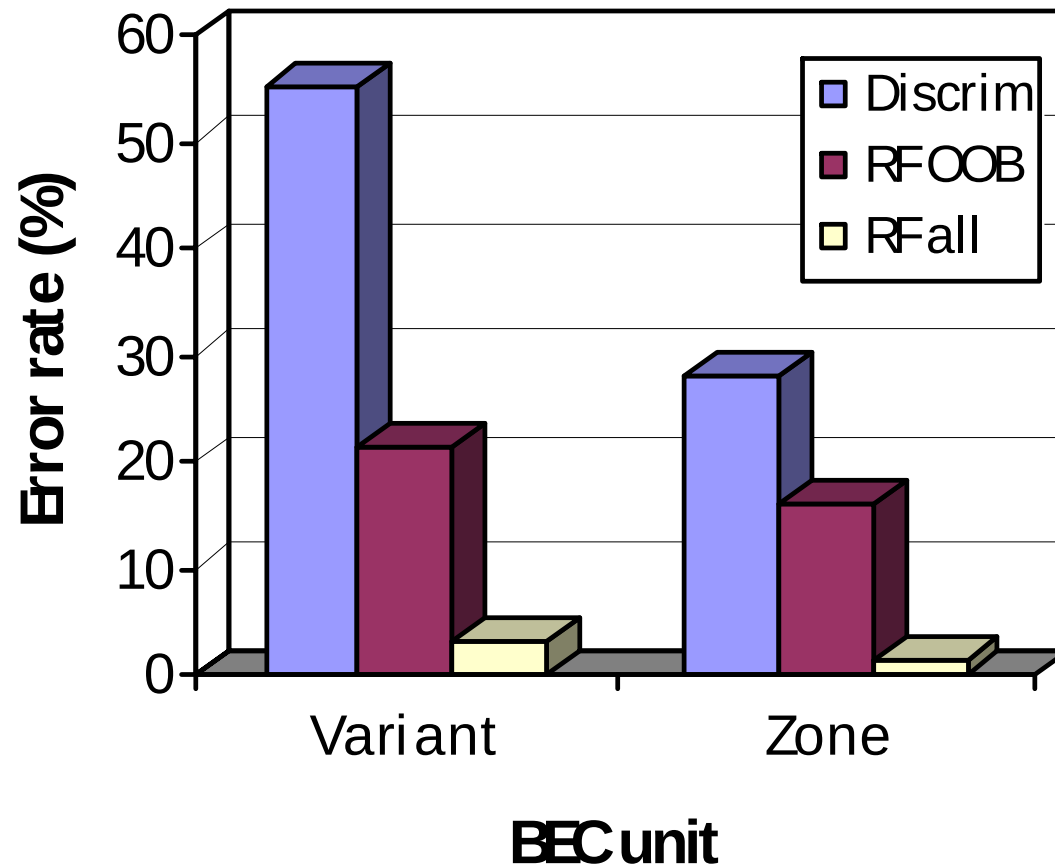
Centre for Forest Conservation Genetics



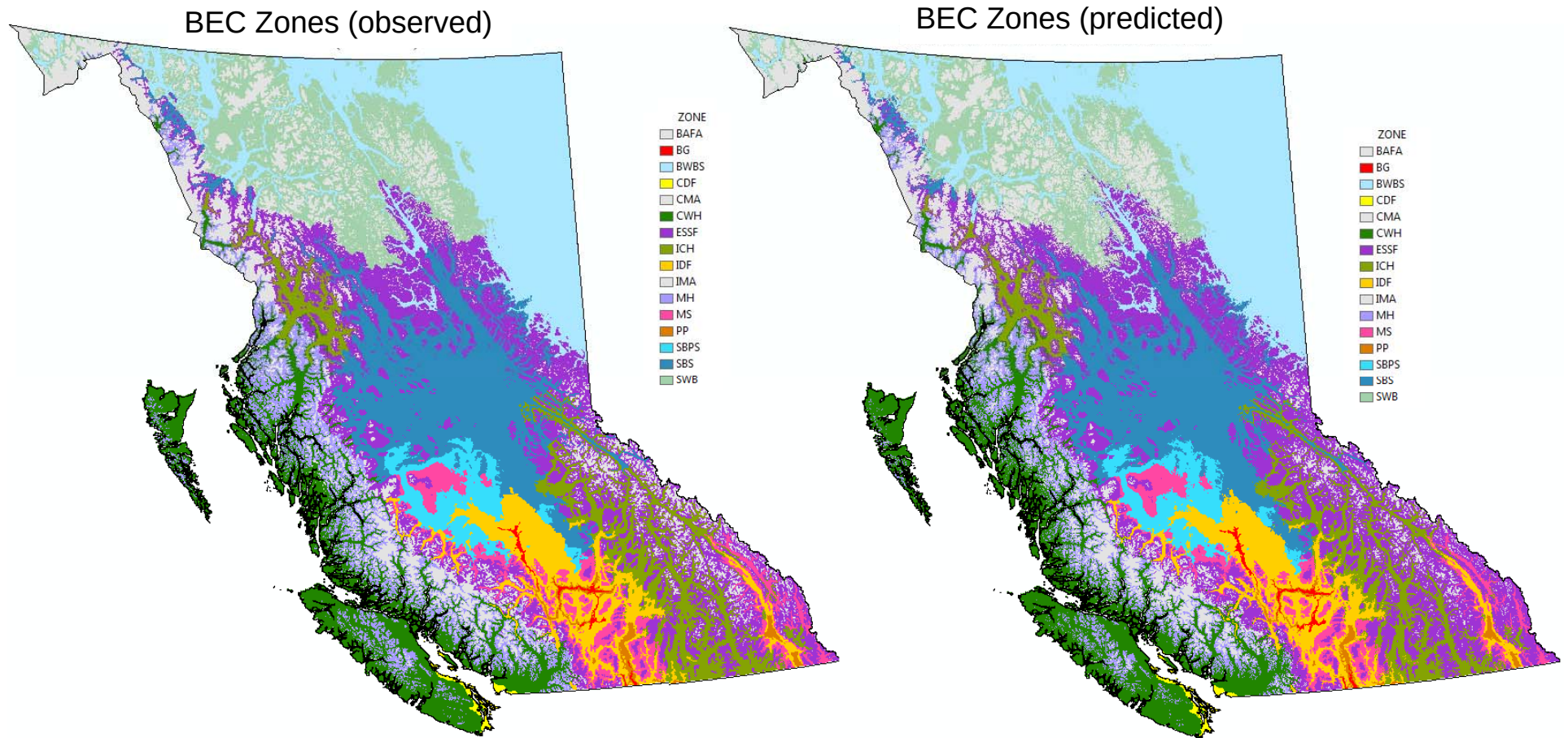
A forest of classification trees



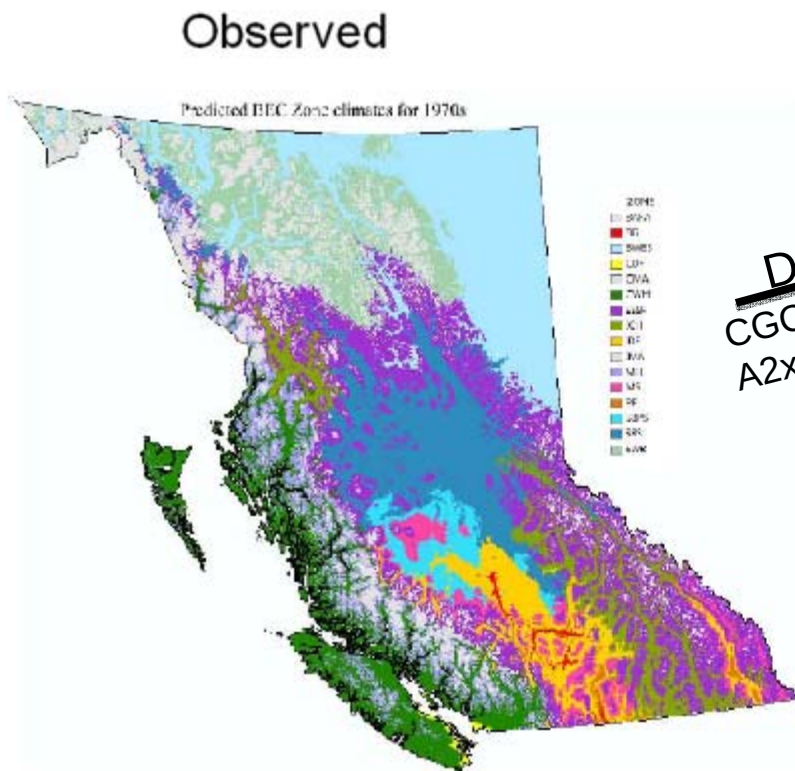
Comparisons between modeling approaches



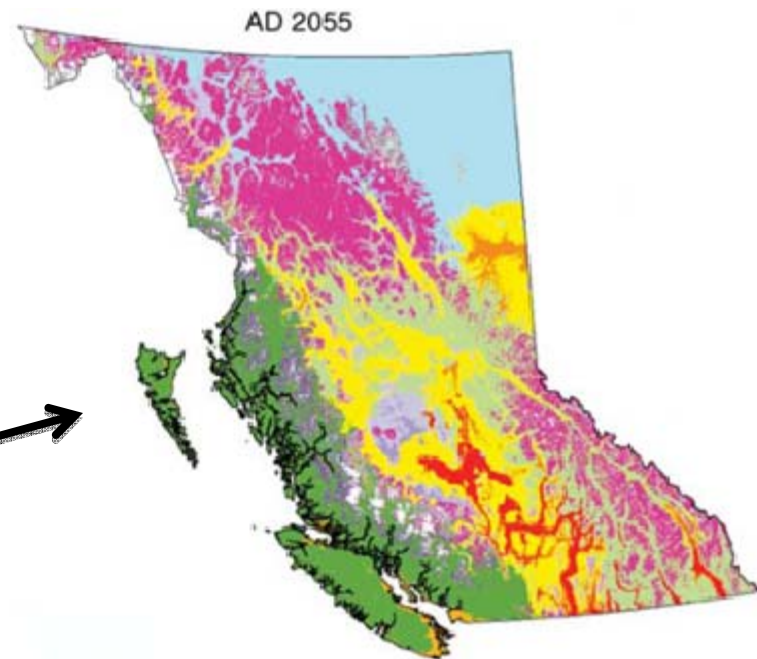
Observed vs. predicted BECs



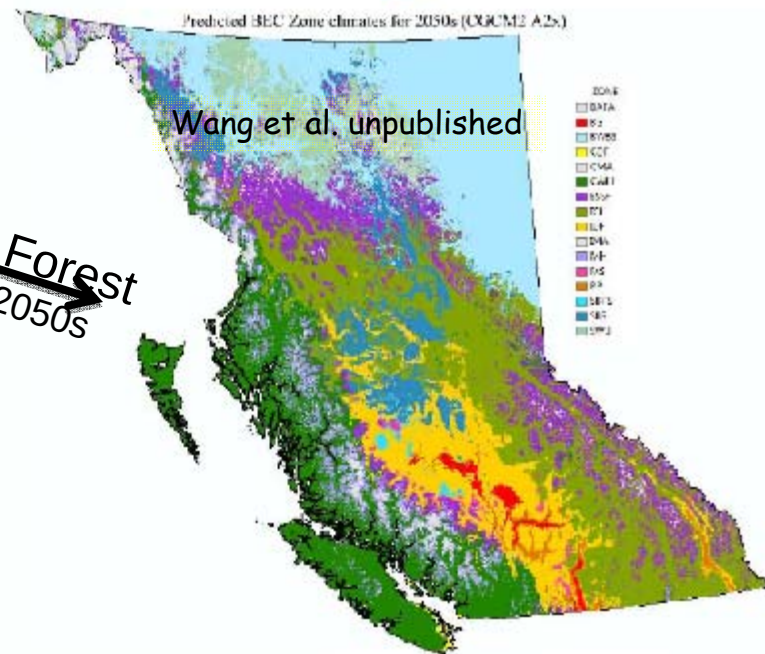
Wang et al. unpublished



Discrim
CGCM
A2x_2050s



Random Forest
CGCM A2x_2050s



Wang et al. unpublished

Current

2020s

2050s

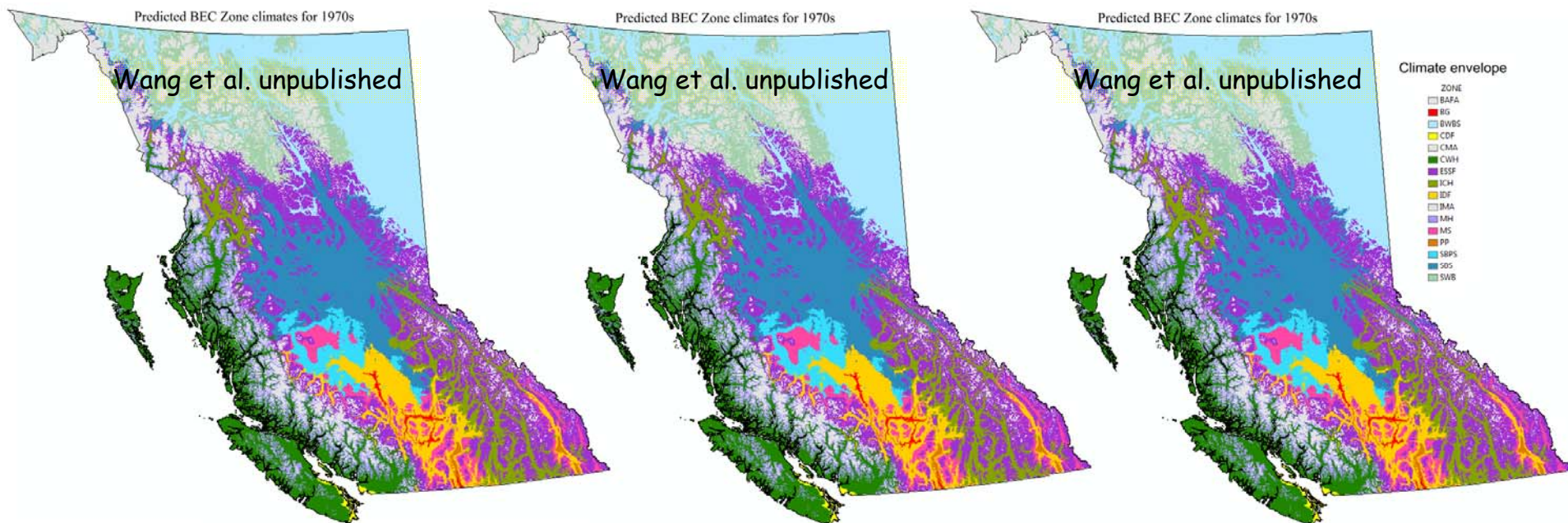
2080s

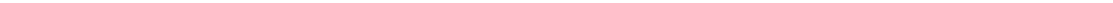


Baseline

Baseline

Baseline





2020s

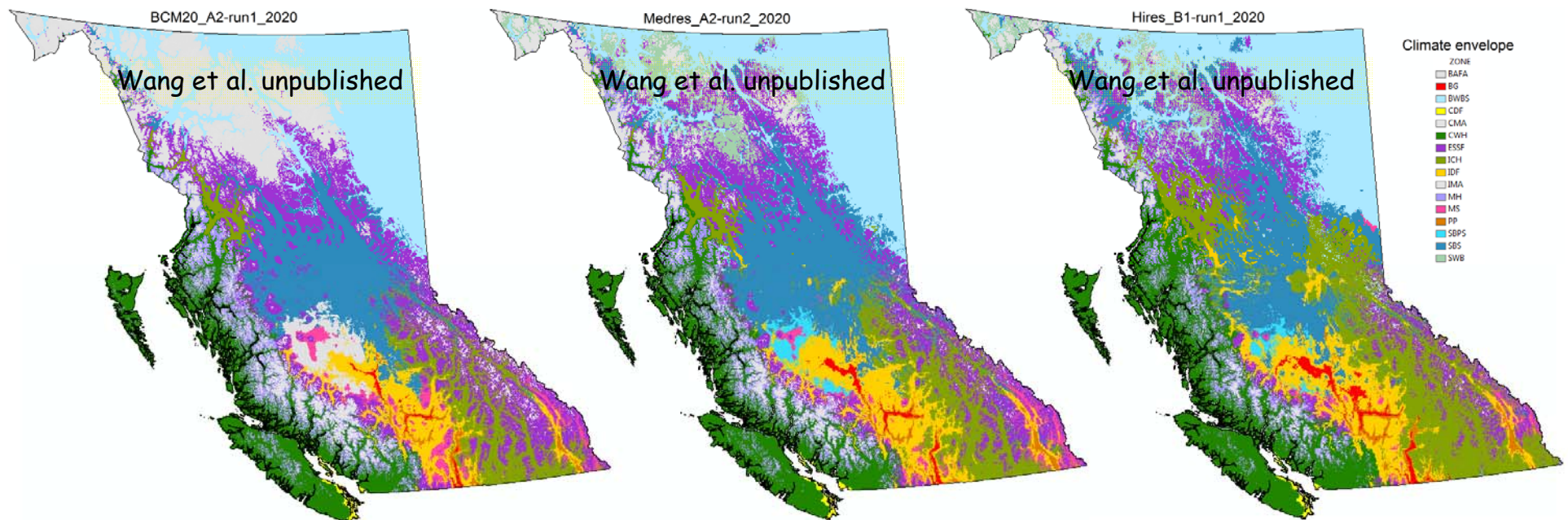
2050s

2080s

Least

Mid-road

Most



Current

2020s

2050s

2080s



Least

Mid-road

Most

BCM20_A2-run1_2050s

Medres_A2-run2_2050s

Hires_B1-run1_2050s

Wang et al. unpublished

Wang et al. unpublished

Wang et al. unpublished

Climate envelope

- ZONE
- WASA
- SG
- SWBS
- CDP
- CMA
- CWH
- ESSP
- KCH
- KDF
- MAA
- MH
- MS
- PP
- SBPS
- SBS
- SWB

Current

2020s

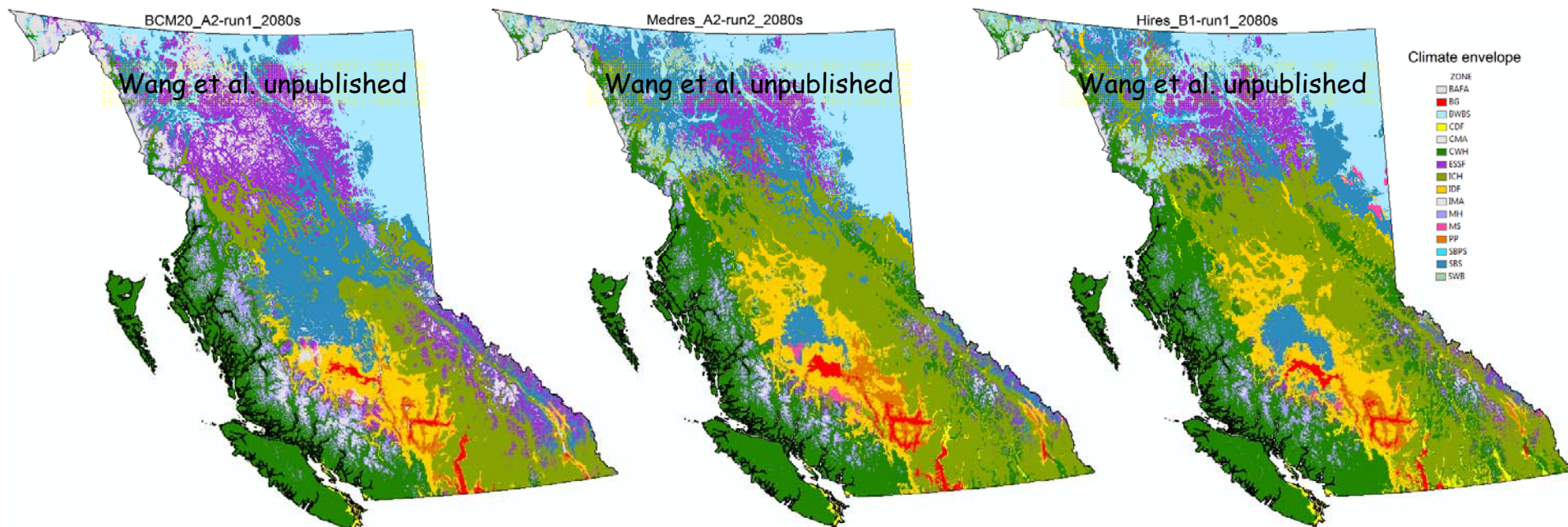
2050s

2080s

Least

Mid-road

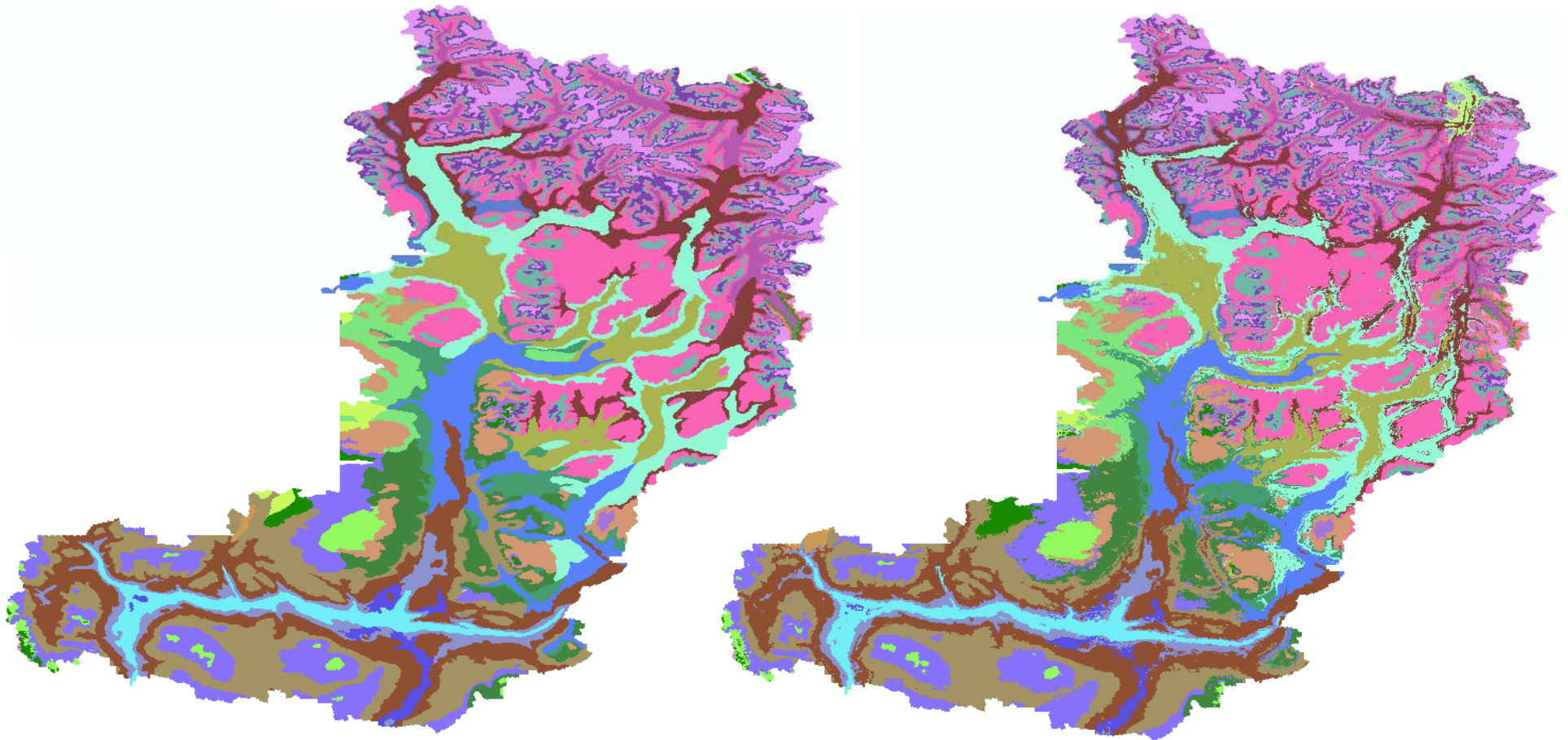
Most



A local application the predictions at Subzone level

Current Subzone

Predicted Subzone (Current)



Wang et al. unpublished

Kamloops Timber Supply Area

Predictions of species distributions

Two approaches

- Associate species distributions with BEC Variants
 - Species climate envelopes shift with BEC Variant climate
- Model and predict species climate habitats based on ecological plot data
 - BC ecological plot data (Elizabeth)
 - US FIA data

Current

2020s

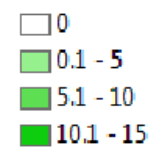
2050s

2080s

Ponderosa pine Climate envelope shift

Wang et al. unpublished

Frequency (%)



Current

2020s

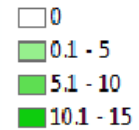
2050s

2080s

Ponderosa pine
Climate envelope shift

Wang et al. unpublished

Frequency (%)



Current

2020s

2050s

2080s

Ponderosa pine
Climate envelope shift

Wang et al. unpublished

Frequency (%)

0

0.1 - 5

5.1 - 10

10.1 - 15

Current

2020s

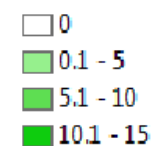
2050s

2080s

Ponderosa pine
Climate envelope shift

Wang et al. unpublished

Frequency (%)



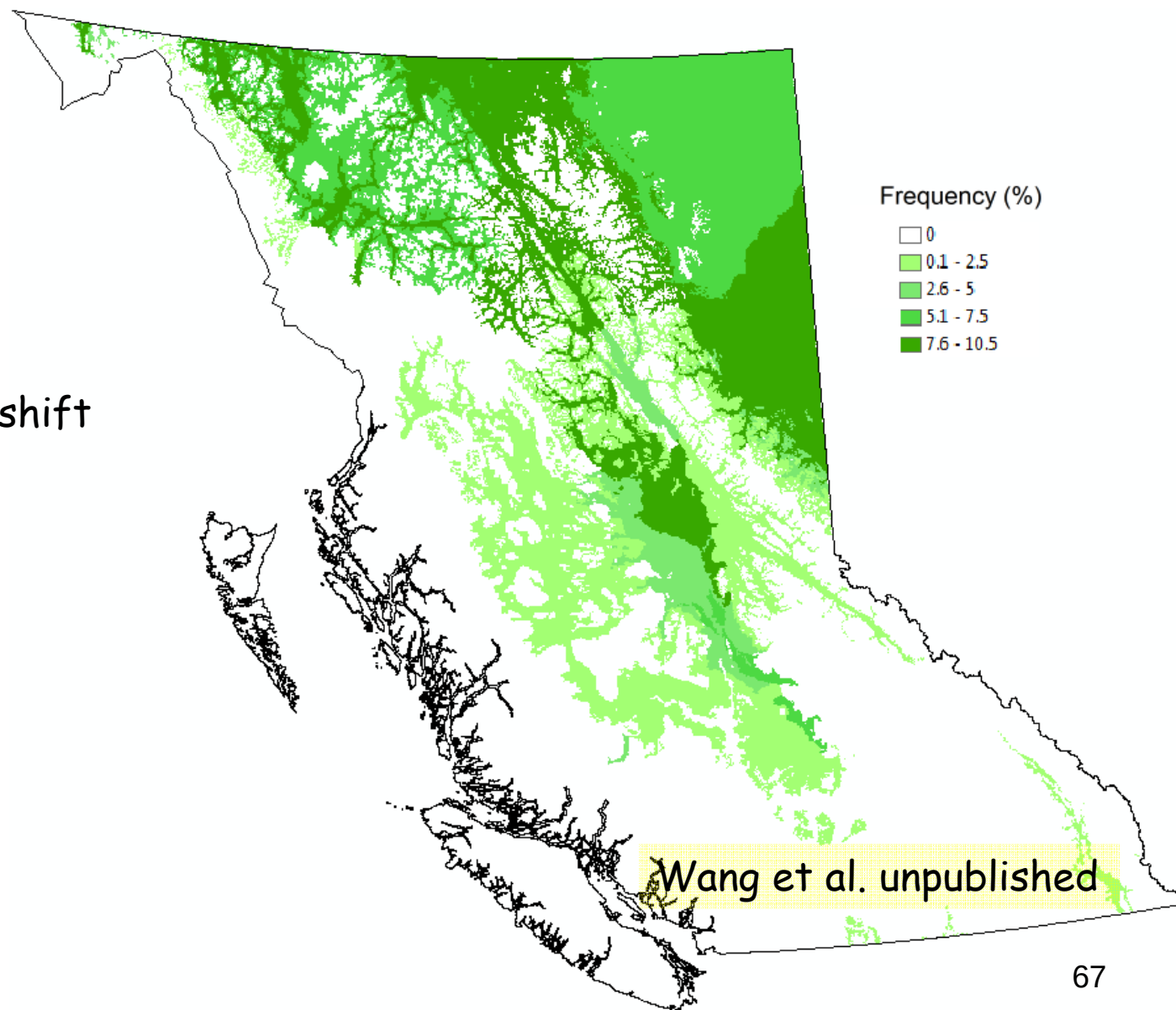
Current

2020s

2050s

2080s

White spruce
Climate envelope shift



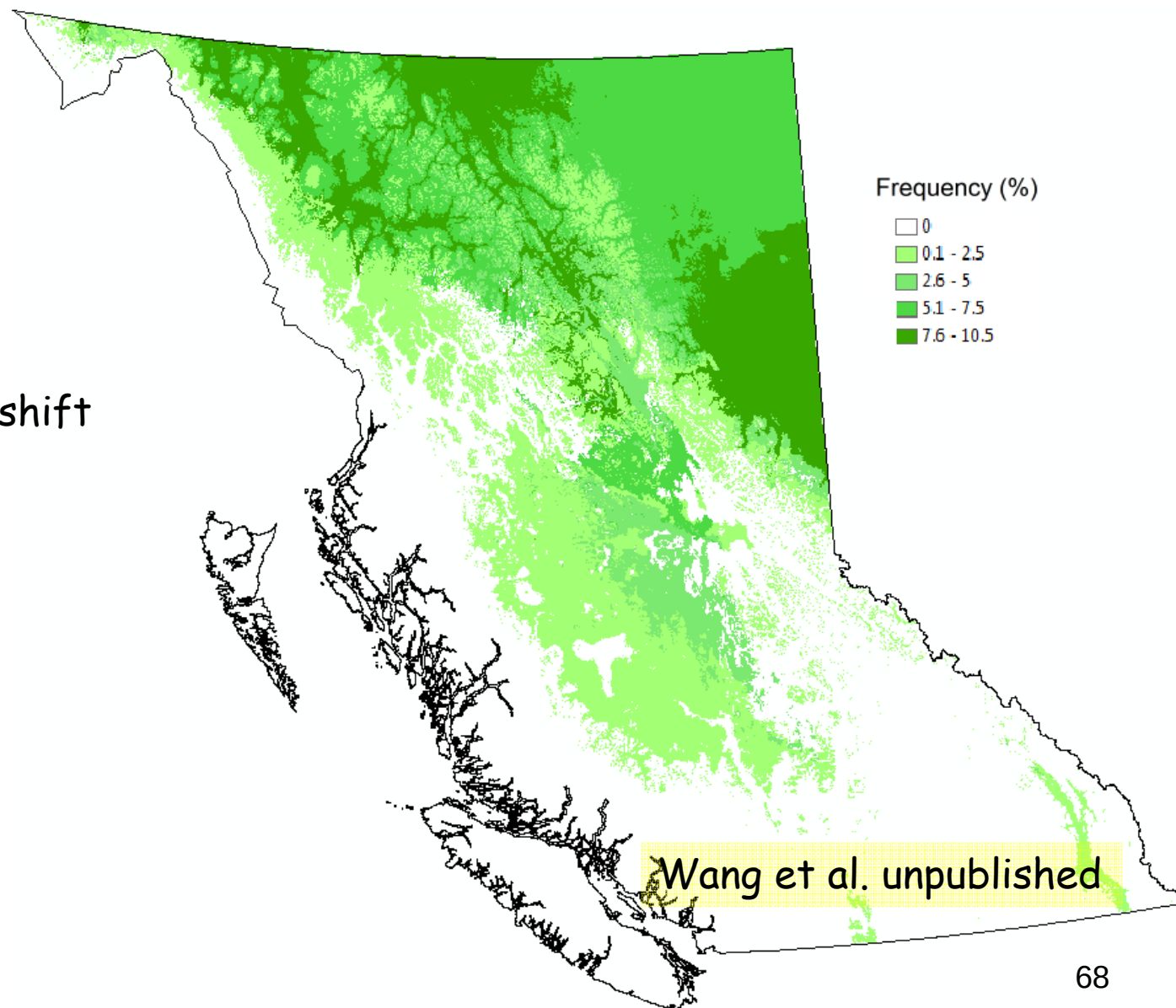
Current

2020s

2050s

2080s

White spruce
Climate envelope shift



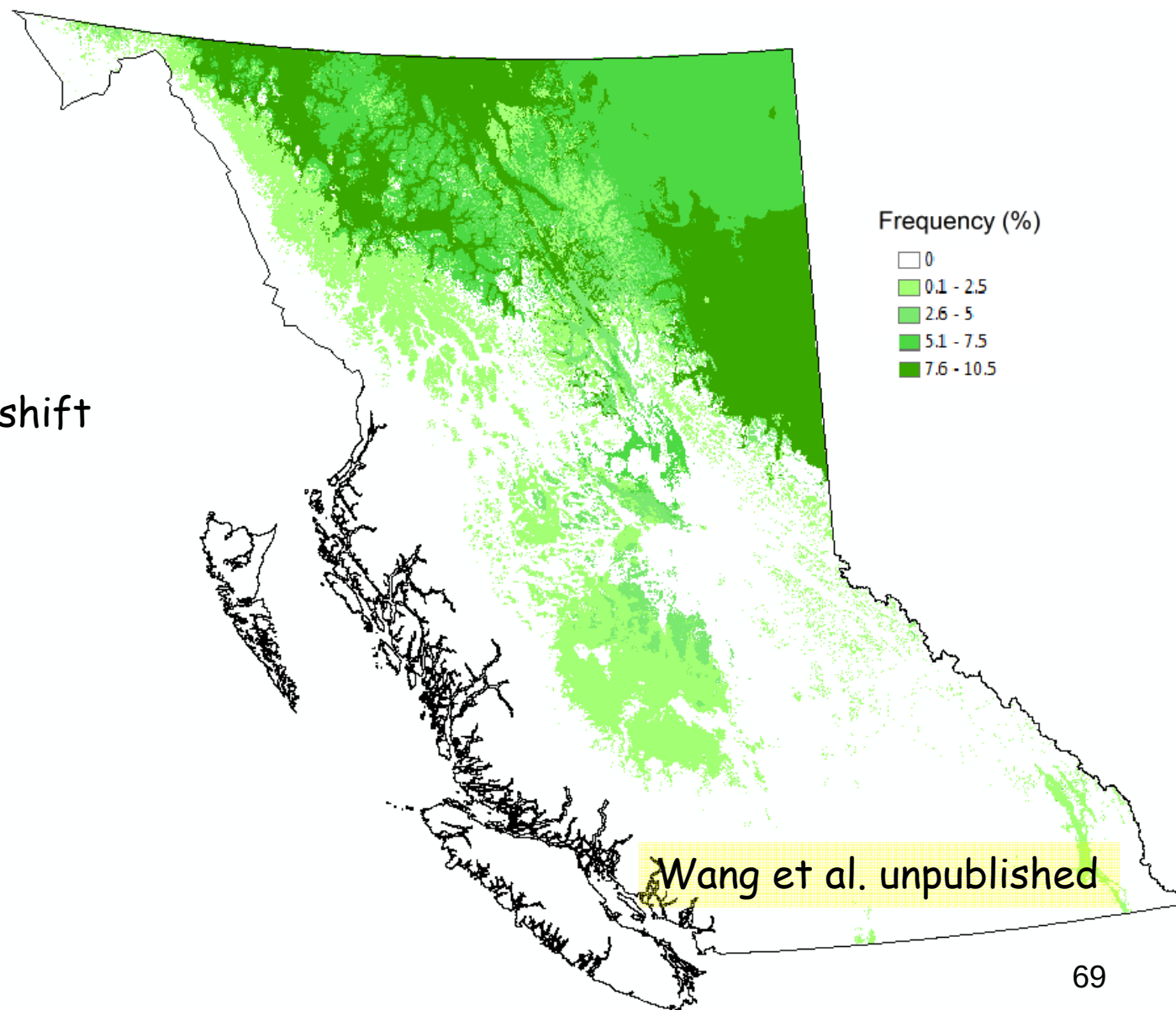
Current

2020s

2050s

2080s

White spruce
Climate envelope shift



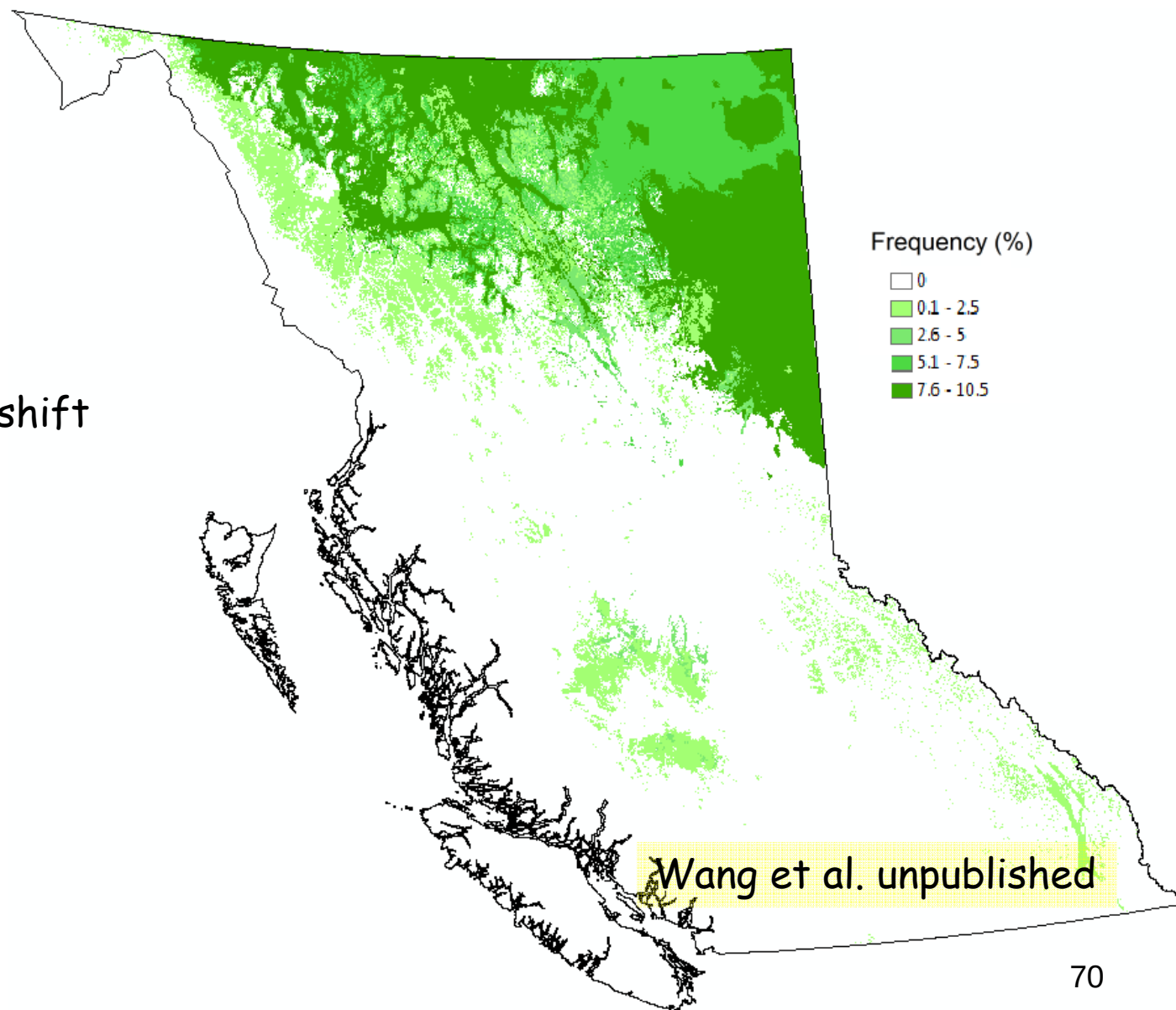
Current

2020s

2050s

2080s

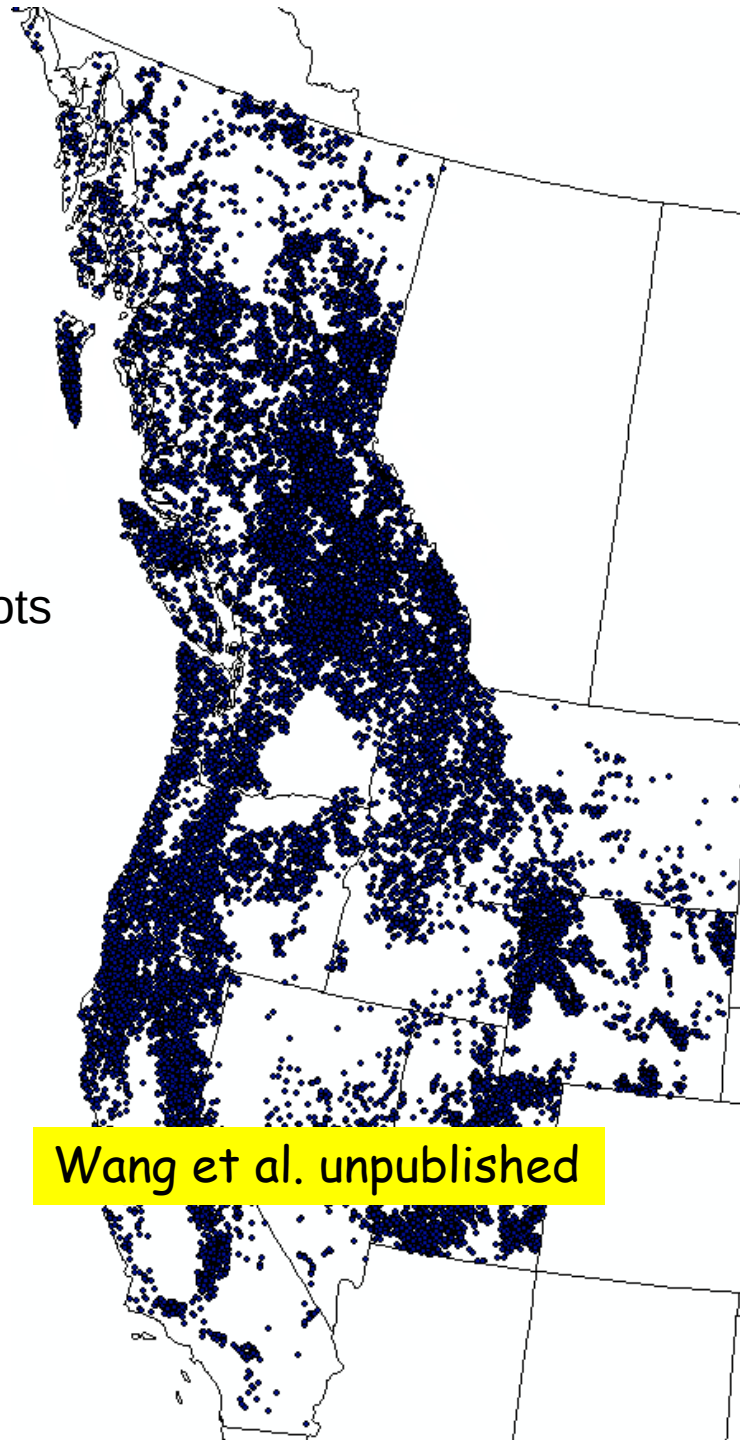
White spruce
Climate envelope shift



Two approaches

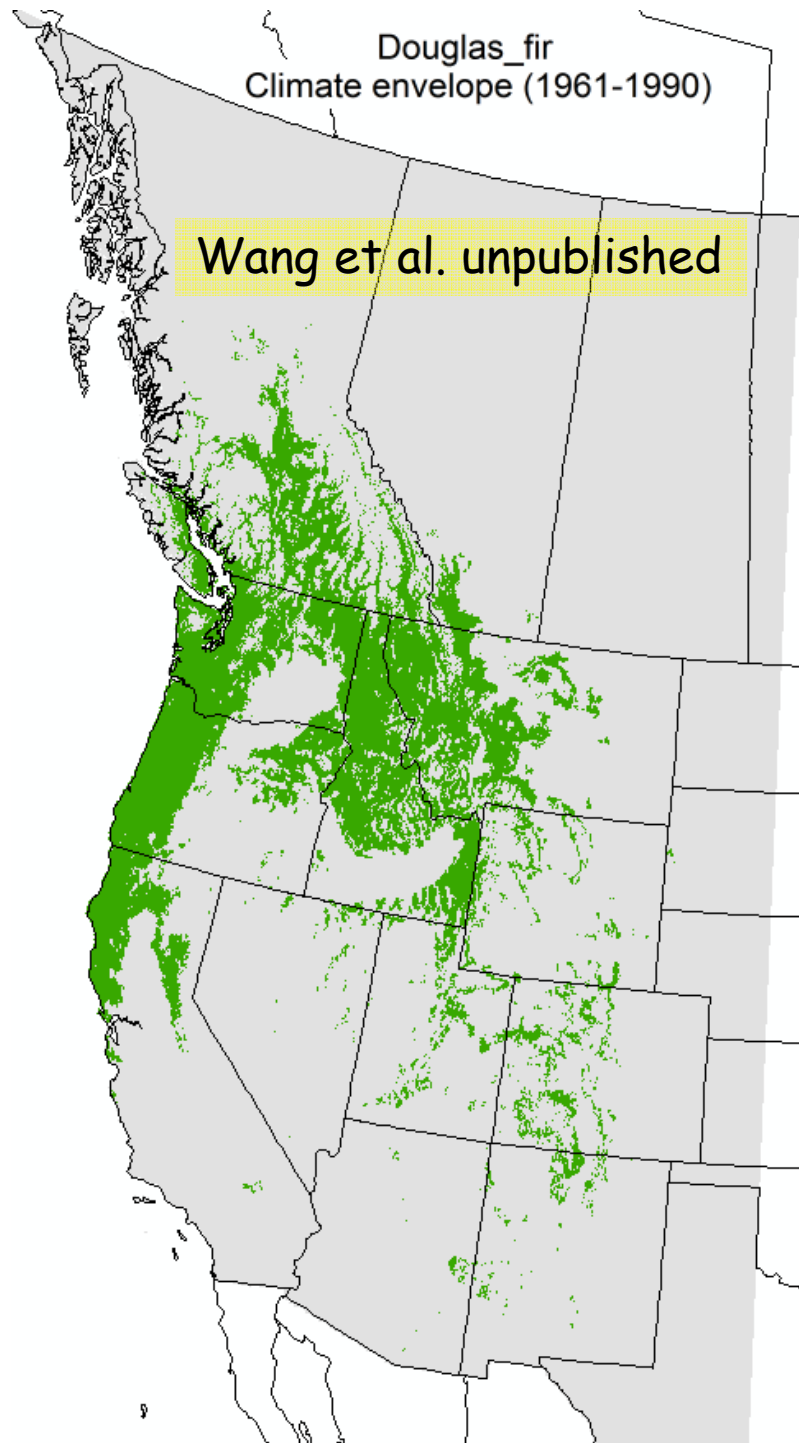
- Associate species distributions with BEC Variants
 - Species climate envelopes shift with BEC Variant climate
- Model and predict species climate habitats based on ecological plot data
 - BC ecological plot data (Elizabeth)
 - US FIA data

Distribution of the sample plots
(over 35,000 plots)

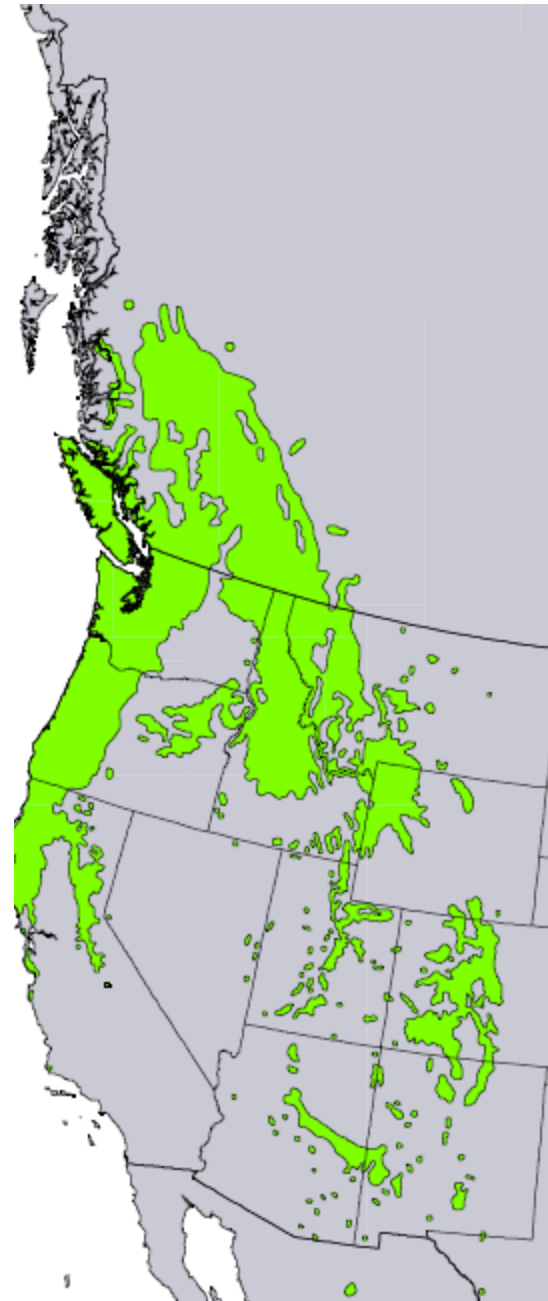


Wang et al. unpublished

Predictions of climate
envelopes for Douglas-fir

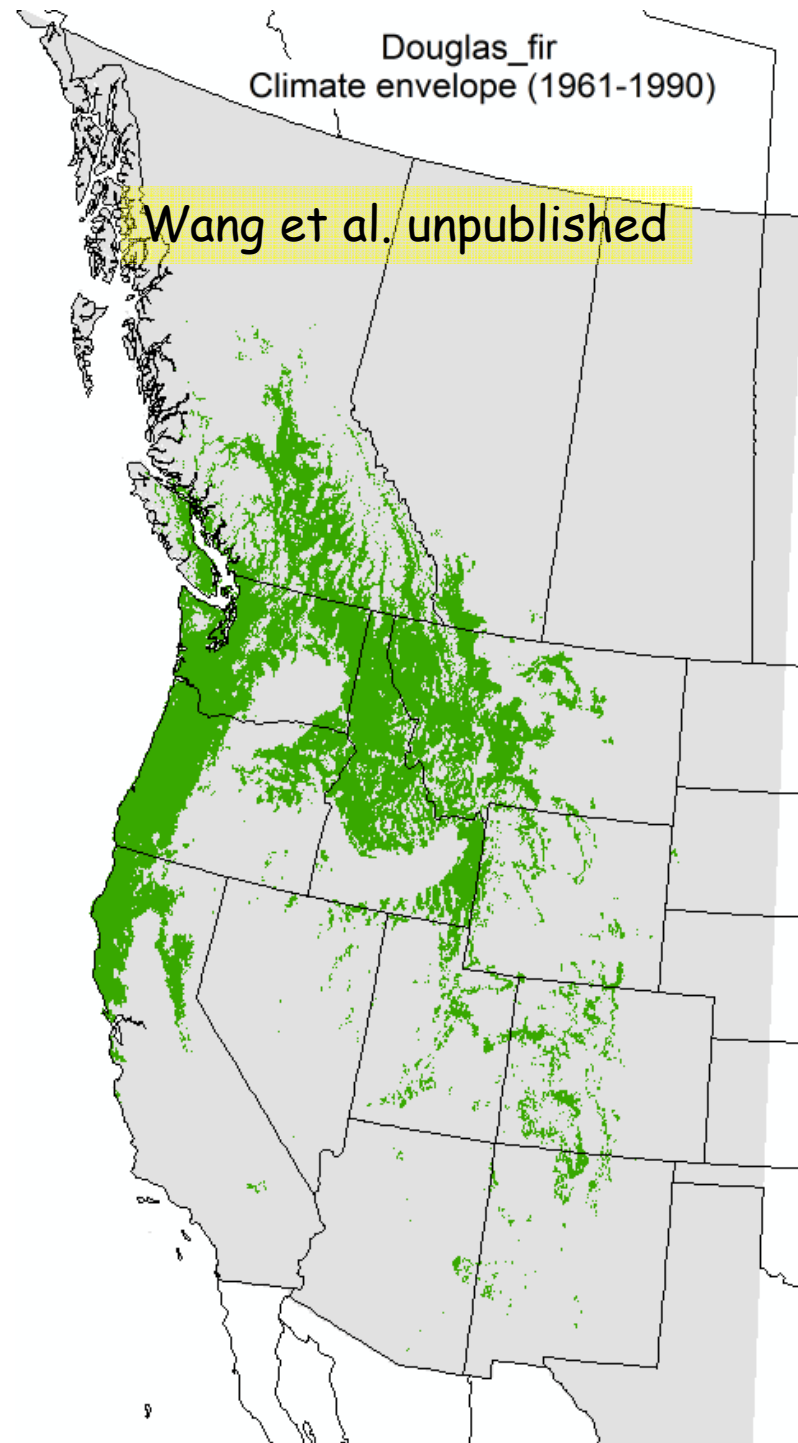


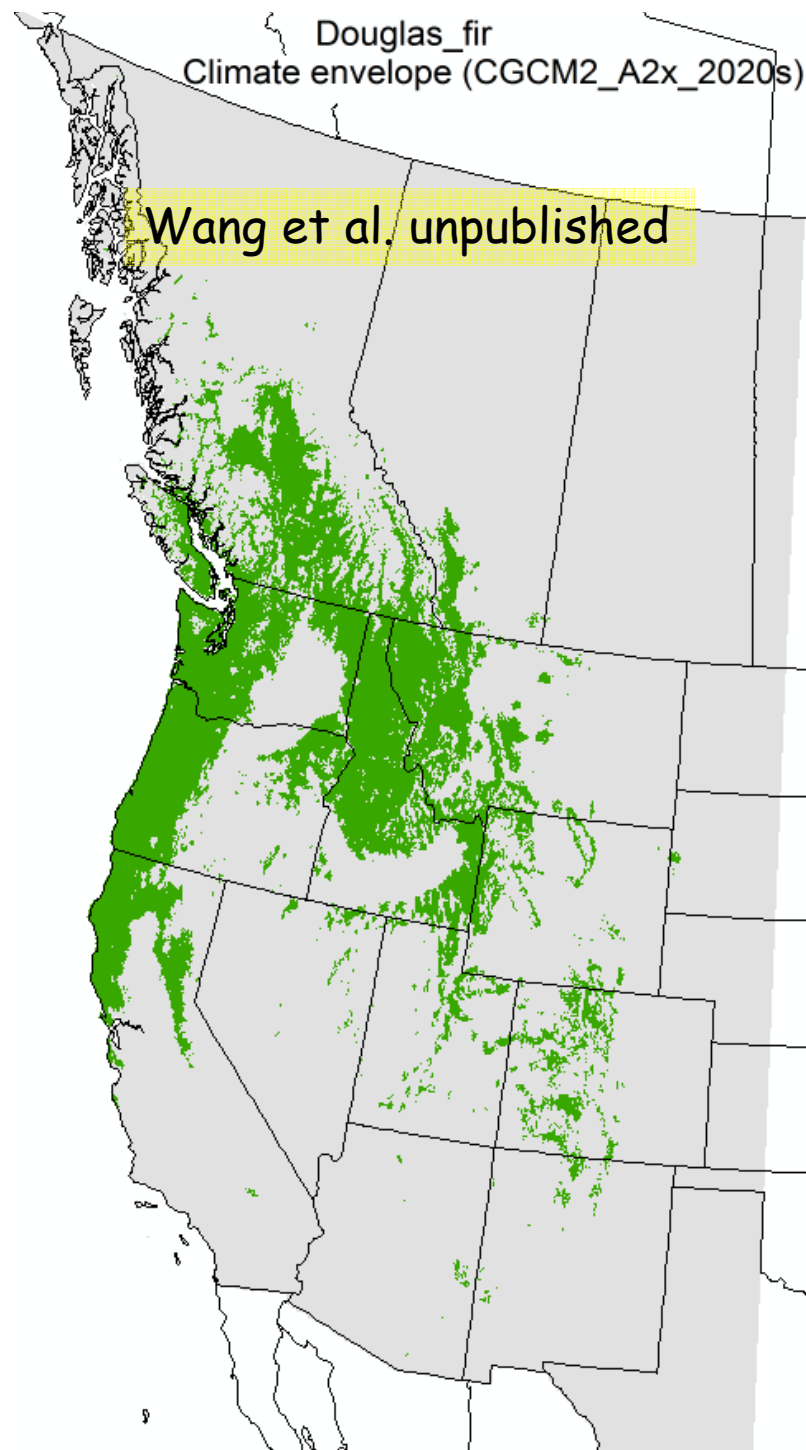
Douglas_fir distribution

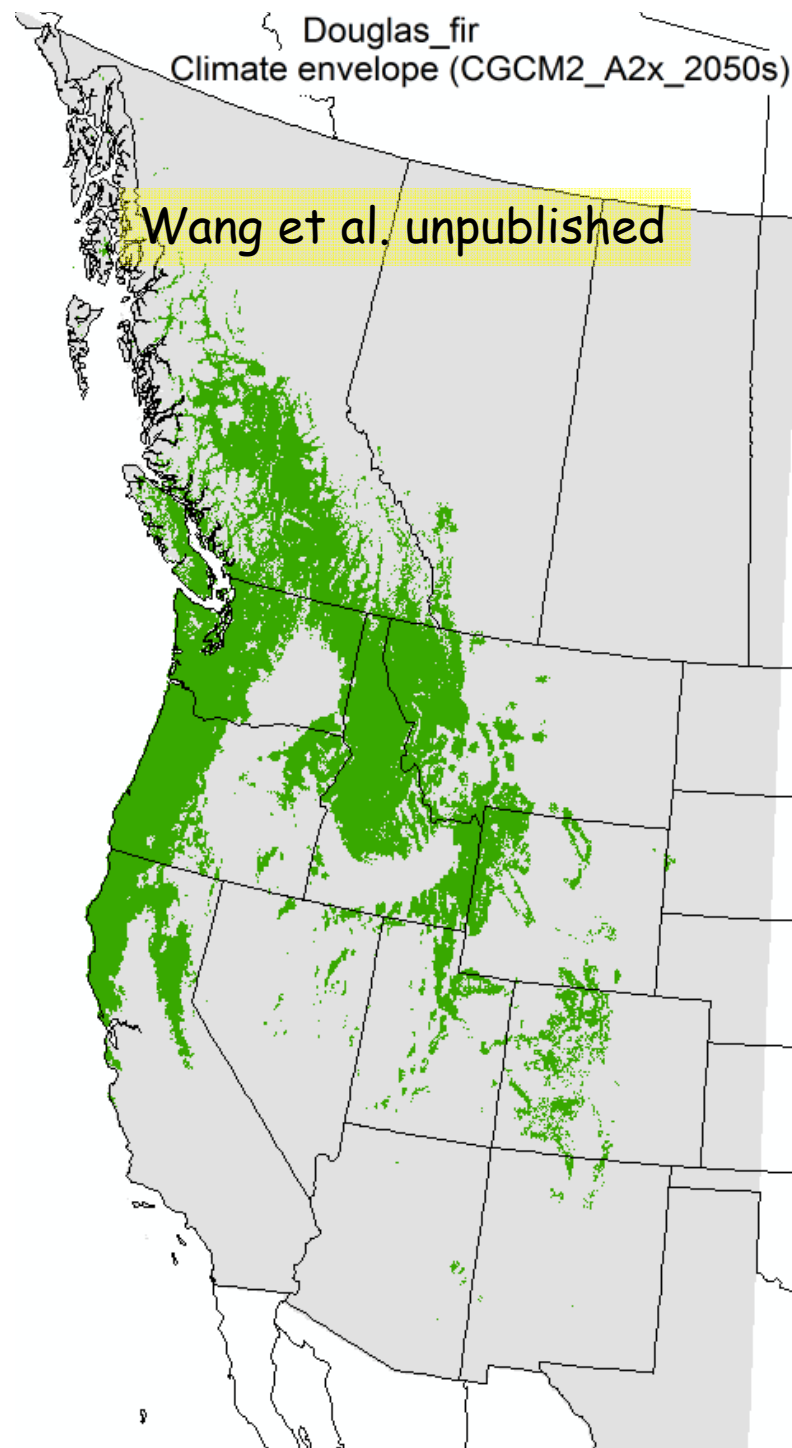


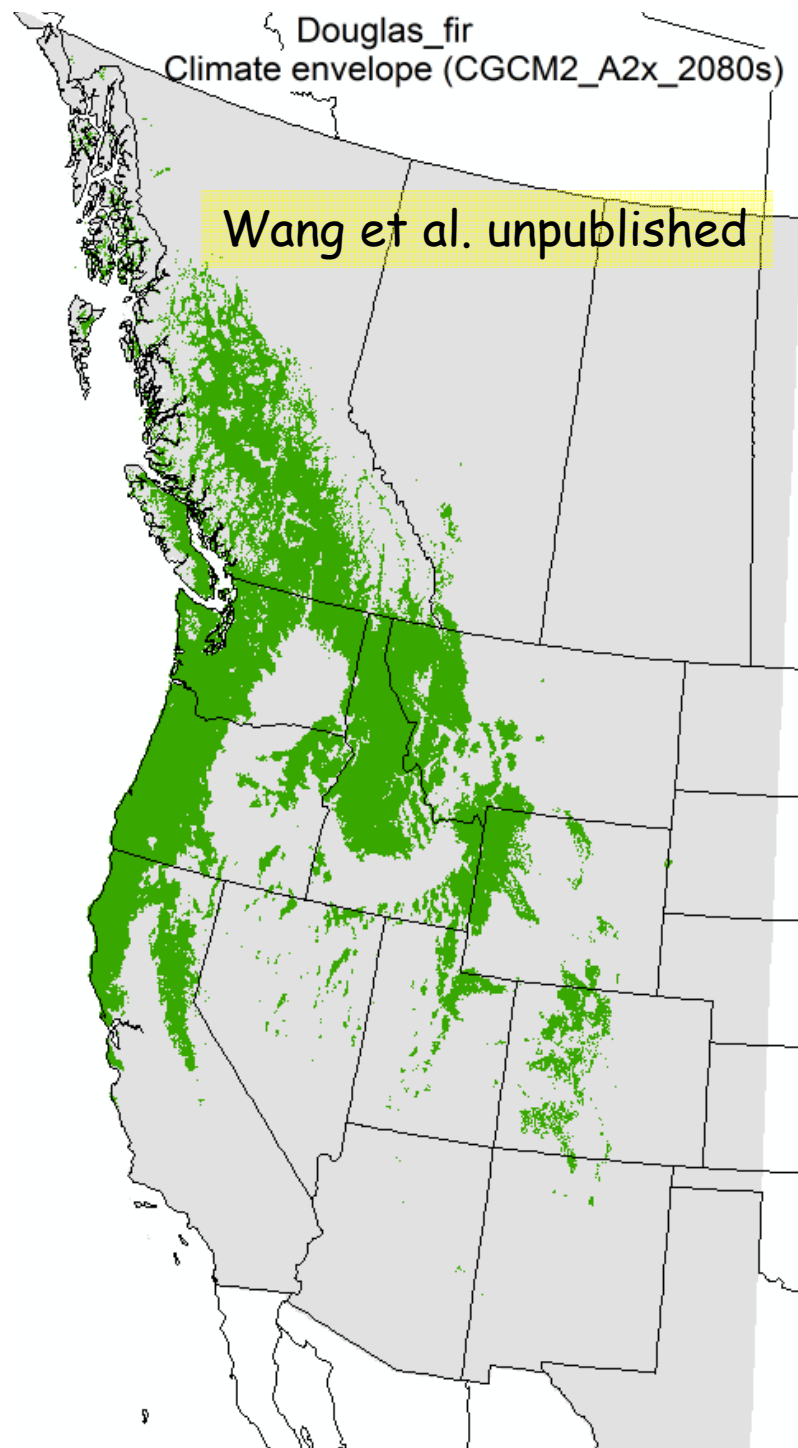
Source:











Acknowledgements

- Funding:
 - Forest Genetics Council of BC
 - BC Forest Science Program
 - Future Forest Ecosystem Initiative