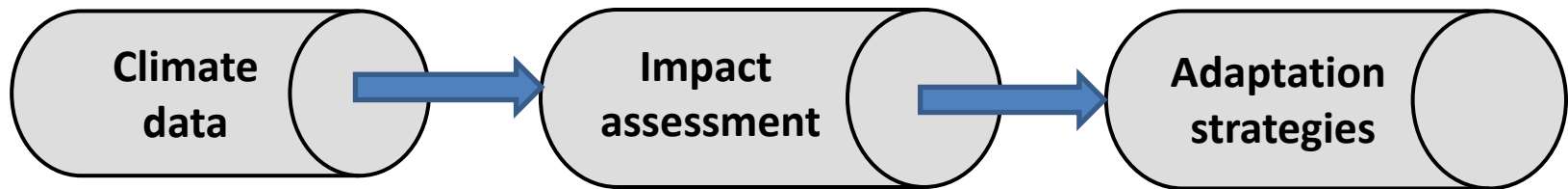


ClimateWNA, consensus projections for BEC and a climate-based seed transfer system

Tongli Wang and Sally Aitken, UBC
Dave Spittlehouse, Elizabeth Campbell and
Greg O'Neill, BC FS
Andreas Hamann, UofA
Trevor Murdock, PCIC



A simplified framework for climate change studies in forestry



Climate data for
the past and the
future

Plant-climate
relationships

Impacts on
ecosystems,
Species ranges
Insects, fire,
Communities, etc.

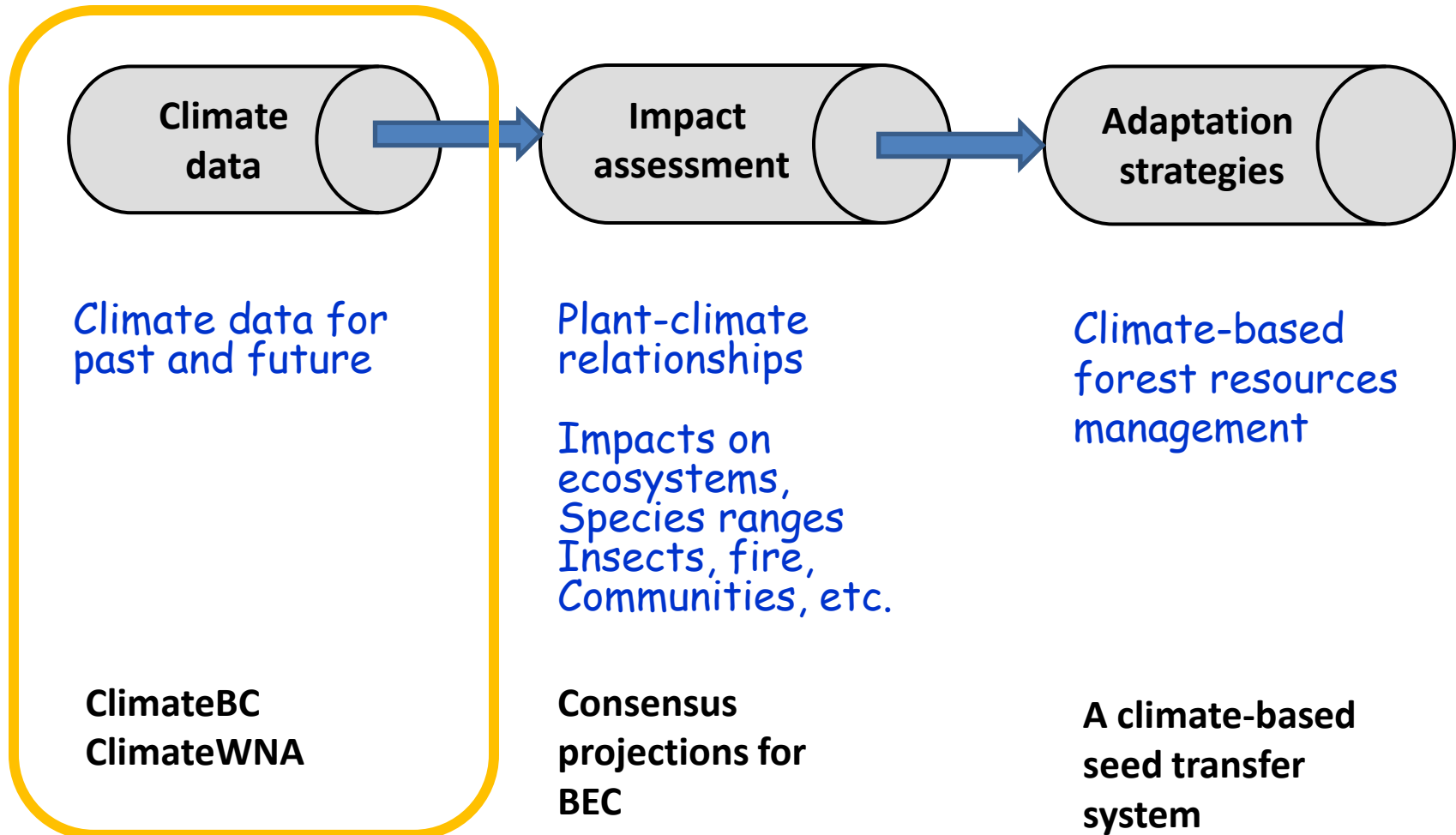
Climate based
resources
management

**ClimateBC
ClimateWNA**

**Consensus
projections for
BEC**

**A climate-based
seed transfer
system**

A simplified framework for climate change studies in forestry



ClimateBC/ClimateWNA

- Challenges in getting climate data
 - Not easy to access for specific locations
 - Not at the desirable and consistent resolutions
 - Not at the expected accuracies
 - Not have enough biological relevant climate variables

Features of ClimateBC/WNA

1. Based on high quality baseline data
2. Effective downscaling algorithms
3. Many calculated and derived variables (85)
4. Integrated and improved historical and future climate data
5. Easy access

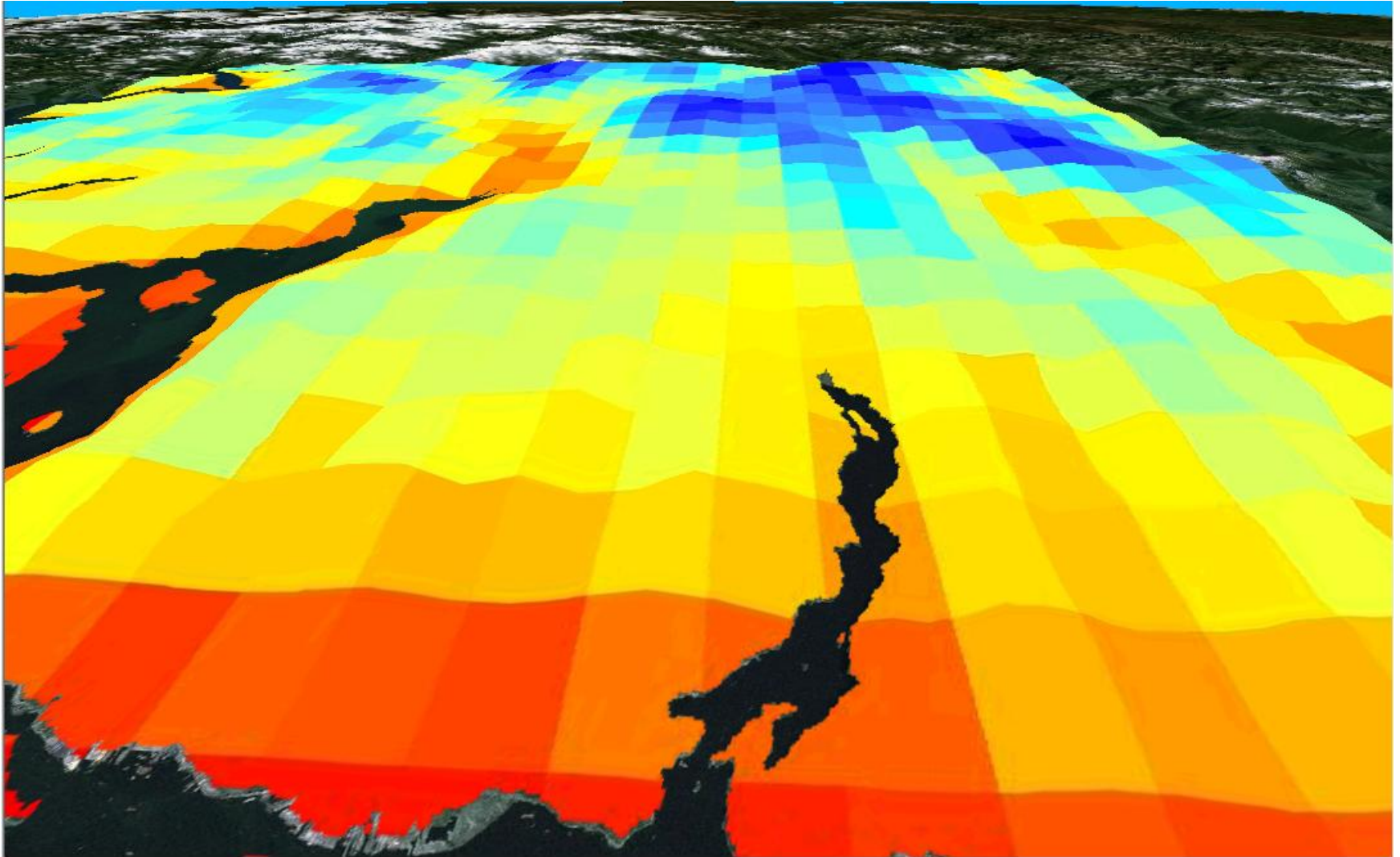
Features of ClimateBC/WNA

1. High quality baseline data
2. Effective downscaling algorithms
3. Many calculated and derived variables (85)
4. Integrated and improved historical and future climate data
5. Easy access

An example: effectiveness of downscaling

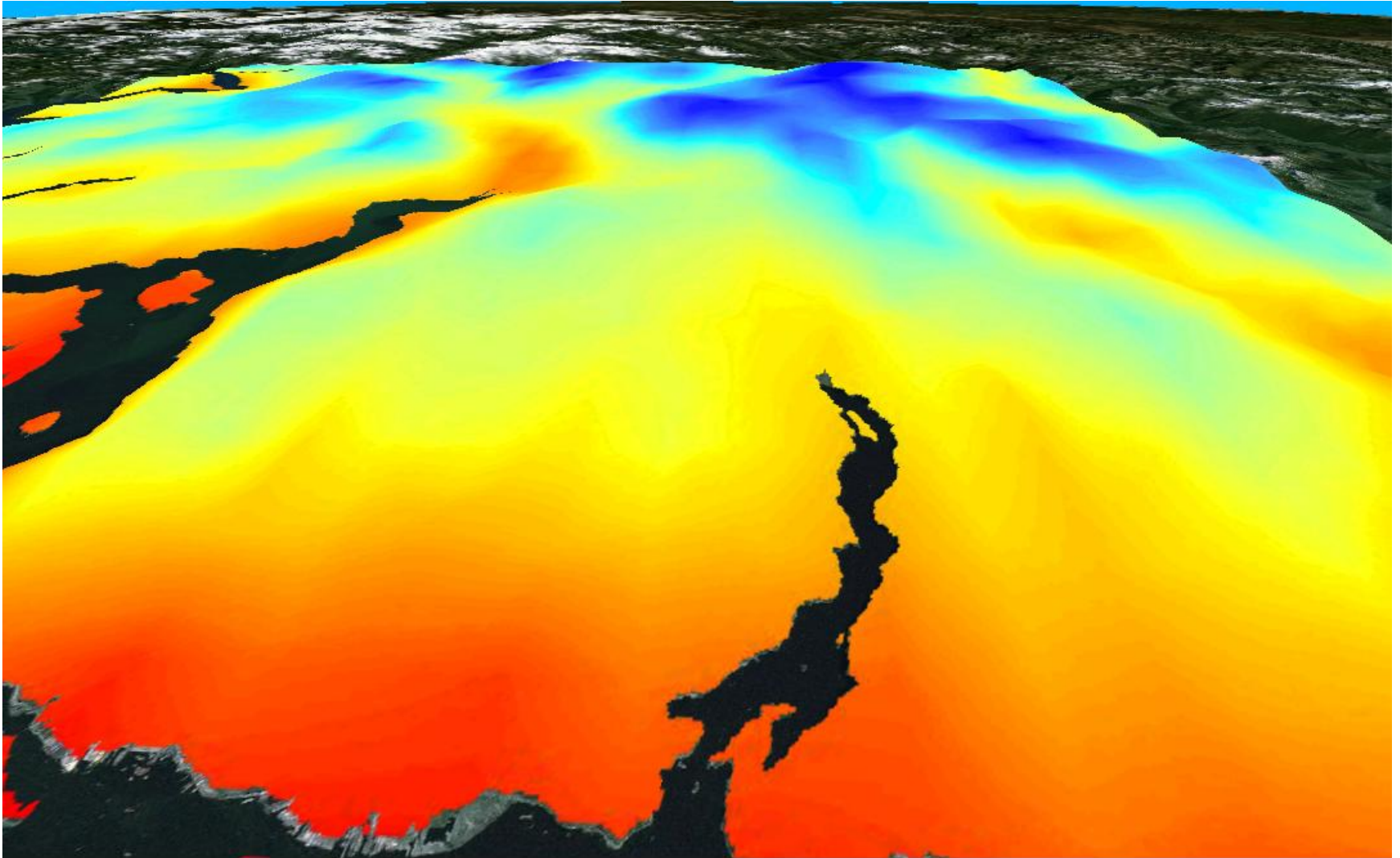


Mean Annual Temperature (MAT) by PRISM (4 x 4 km)



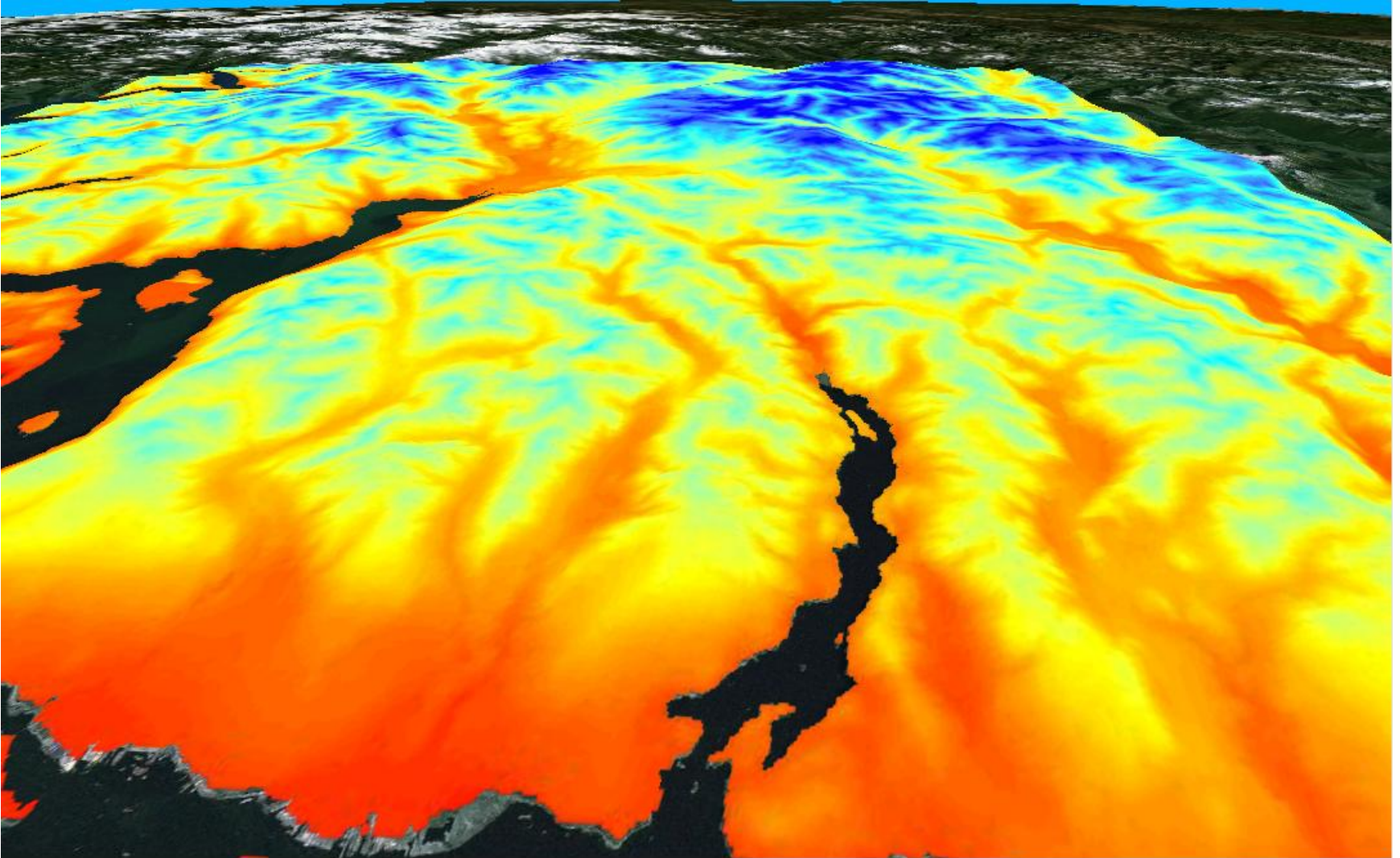
A mountain area near North Vancouver

Downscaled MAT by GIS interpolation tools (90m)



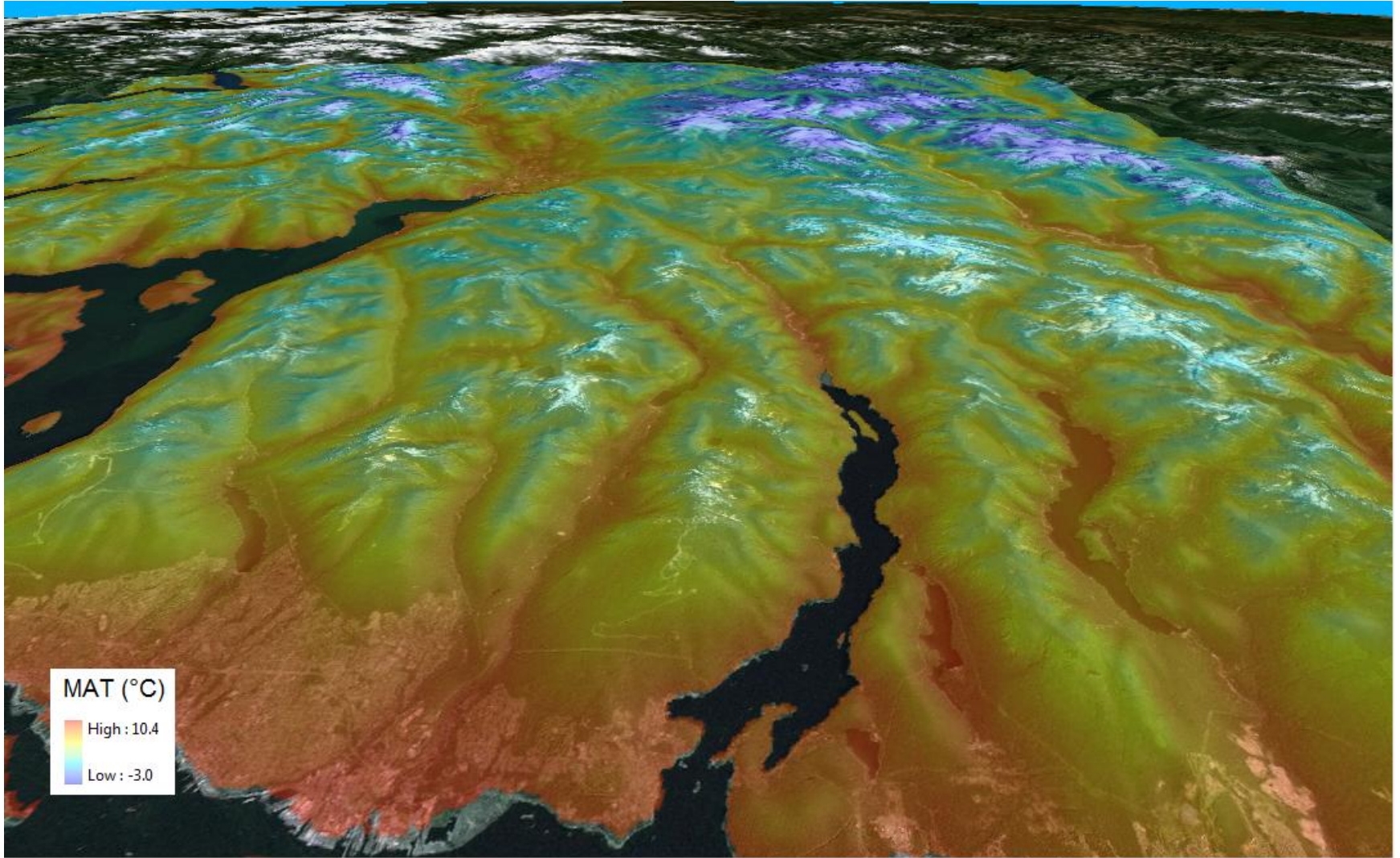
A mountain area near North Vancouver

Downscaled MAT by ClimateWNA (90m)



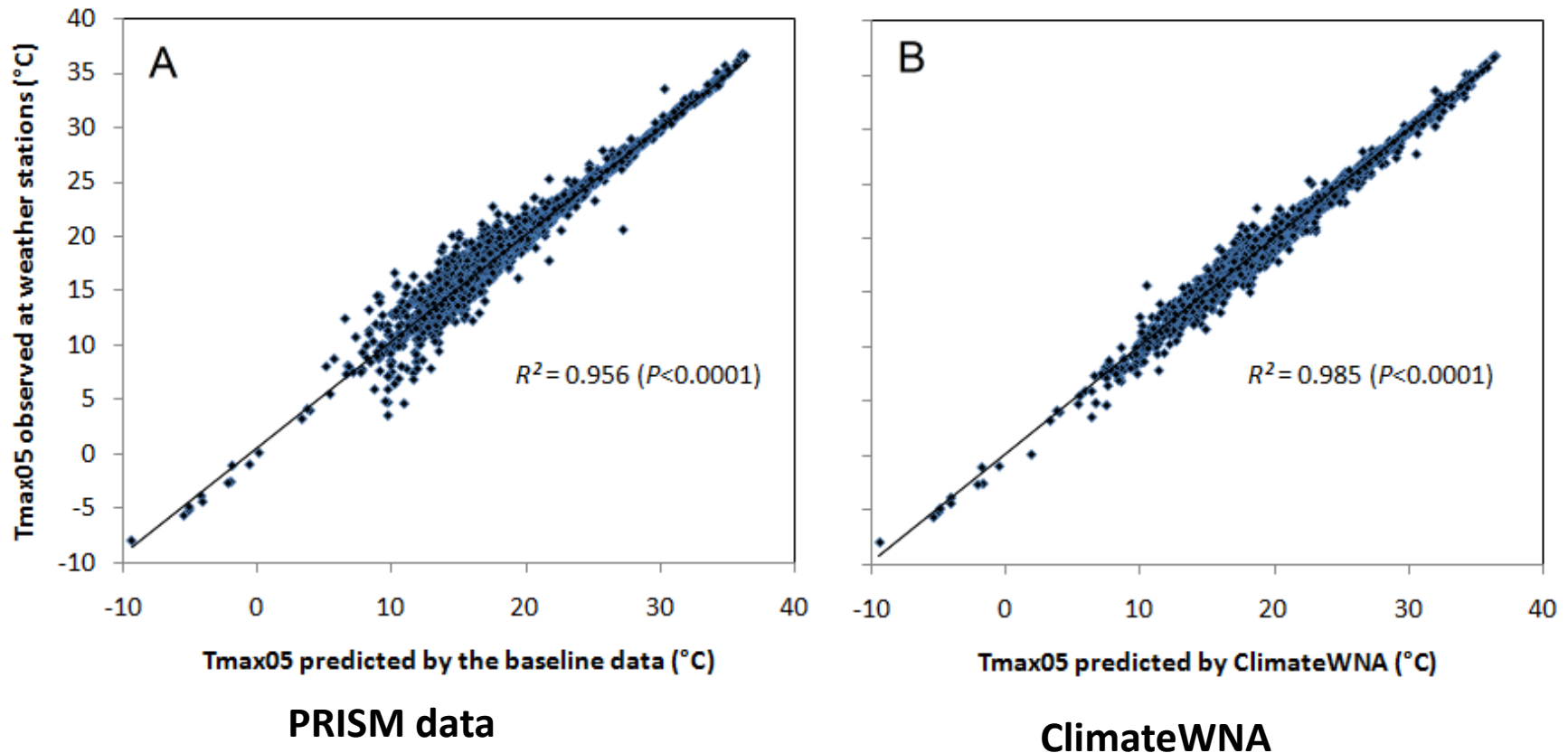
A mountain area near North Vancouver

ClimateWNA improves spatial resolution



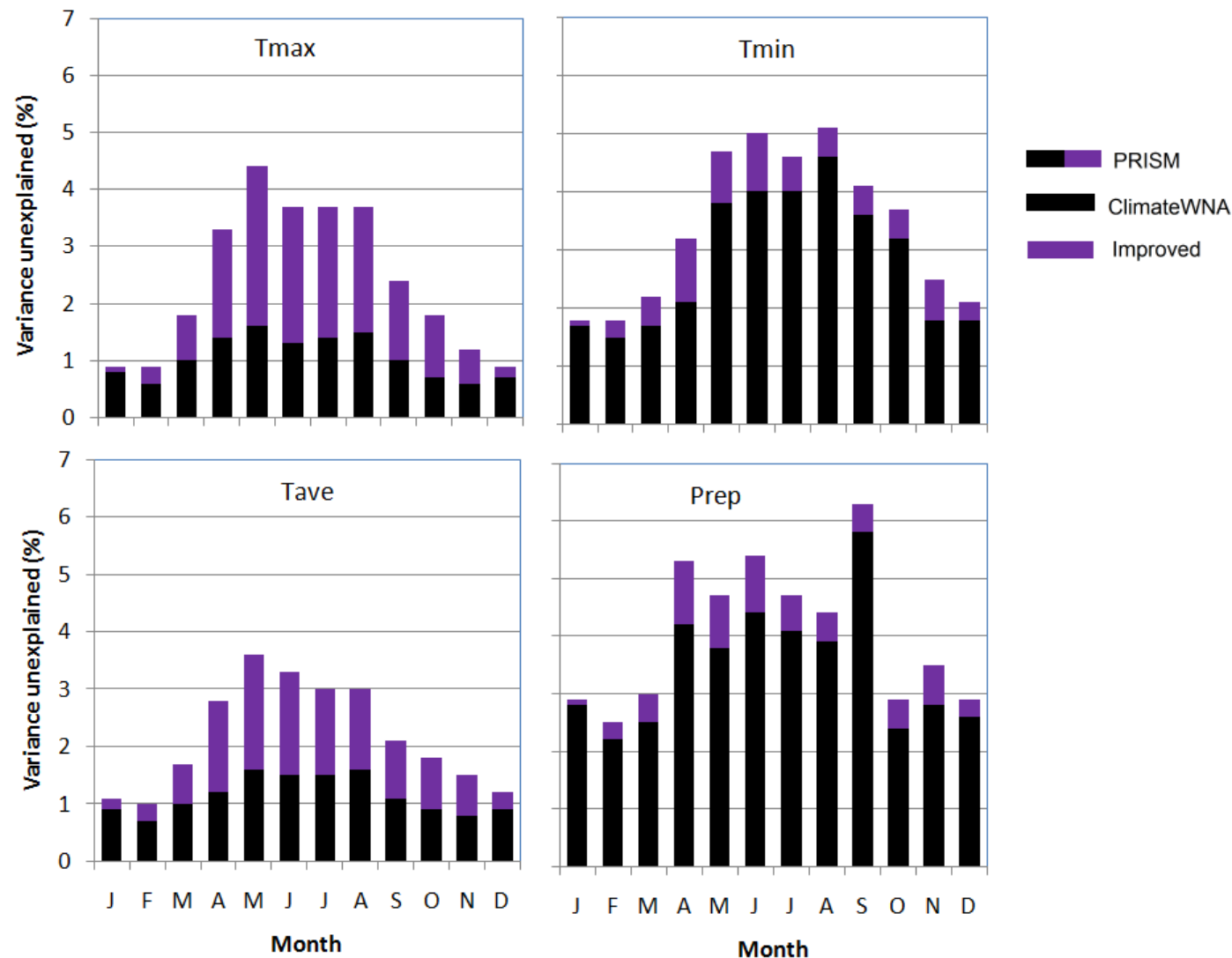
A mountain area near North Vancouver

ClimateWNA improves prediction precisions



Data from 3,353 weather stations were used to evaluate the predictions

ClimateWNA improves prediction precisions

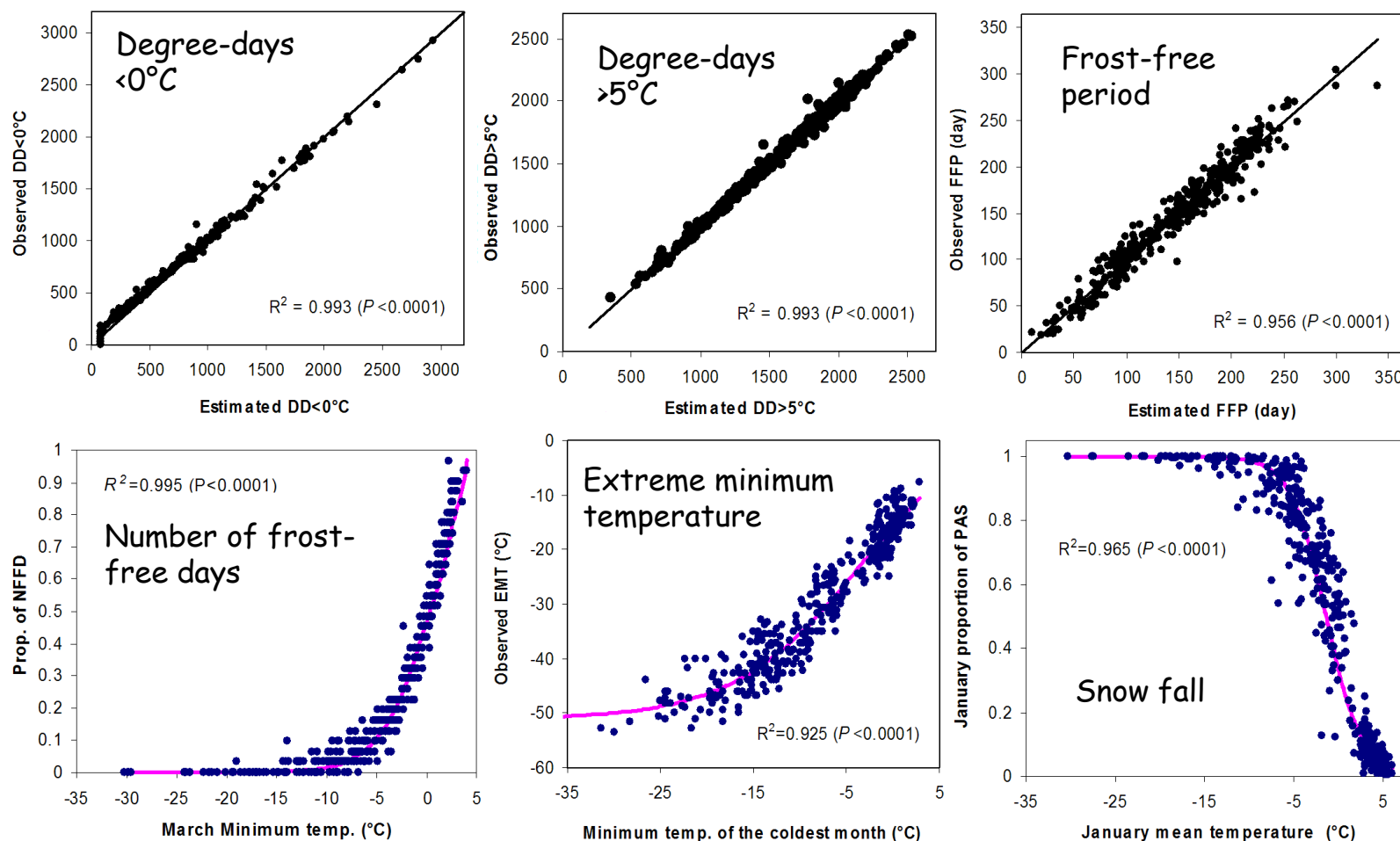


Data from 3,353 weather stations were used to evaluate the predictions

Features of ClimateBC/WNA

1. High quality baseline data
2. Effective downscaling algorithms
3. Many calculated and derived variables (85)
4. Integrated and improved historical and future climate data
5. Easy access

Many derived climate variables in ClimateBC/WNA



Features of ClimateBC/WNA

1. High quality baseline data
2. Effective downscaling algorithms
3. Many calculated and derived variables (85)
4. Integrated and improved historical and future climate data
5. Easy access

It predicts climate data for the future periods

ClimateWNA_v4.60 Copyright (2010) Wang T, Hamann A and Spittlehouse D. All rig...

Select Output Variables
Annual variables

Select Period
Future Periods [Select a GCM](#)

Coordinate Input ☒ Decimal ☐ DMS

Latitude
Longitude
Elevation (m)

Output of annual variables

MAT	MWMT	MCMT	TD	M
<input type="text" value="12"/>	<input type="text" value="25.4"/>	<input type="text" value="-1"/>	<input type="text" value="26.4"/>	<input type="text"/>
DD<0	DD>5	DD<18	DD>18	N
<input type="text" value="211"/>	<input type="text" value="3068"/>	<input type="text" value="2854"/>	<input type="text" value="763"/>	<input type="text"/>

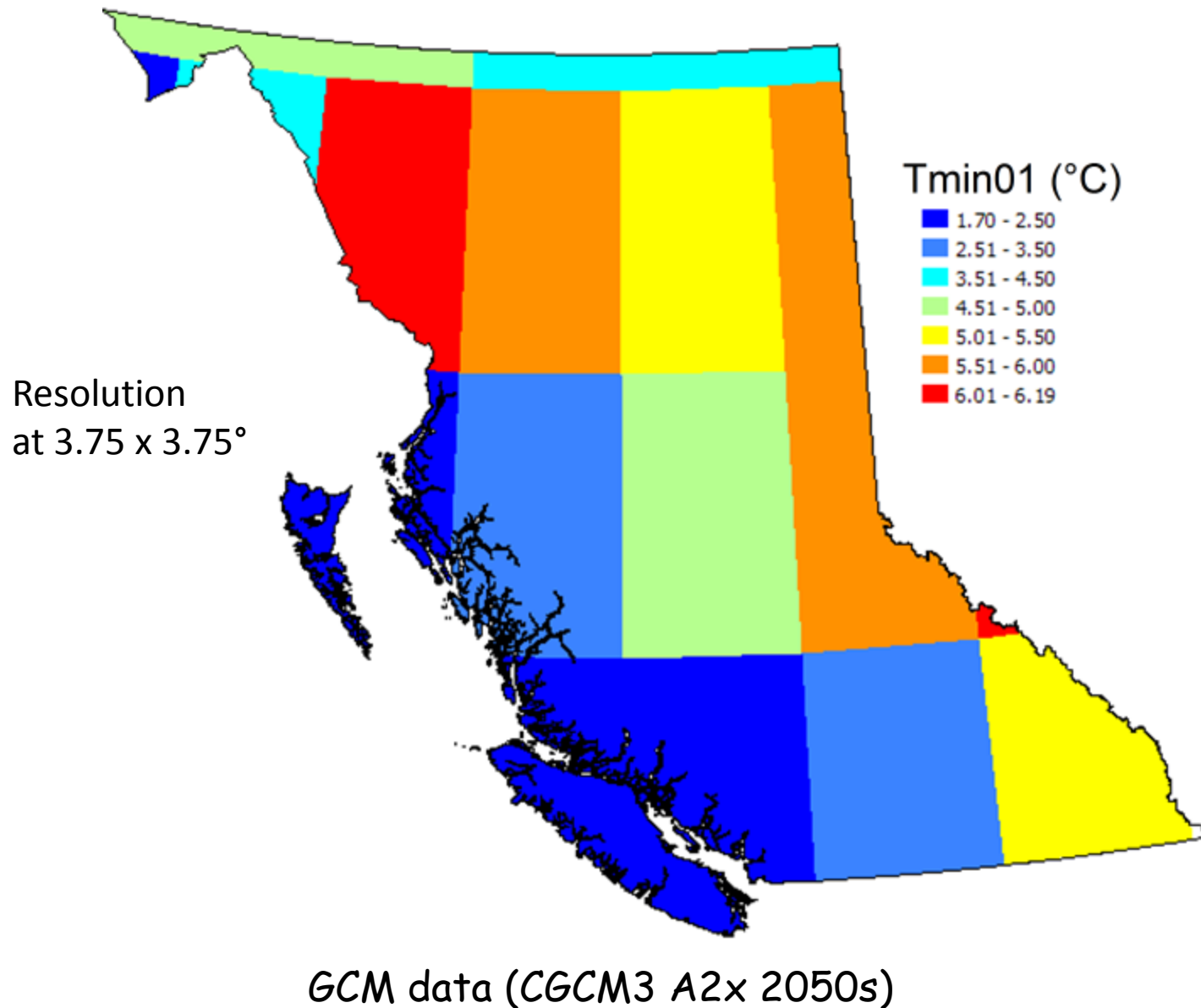
Multi-location

Select input file Sp

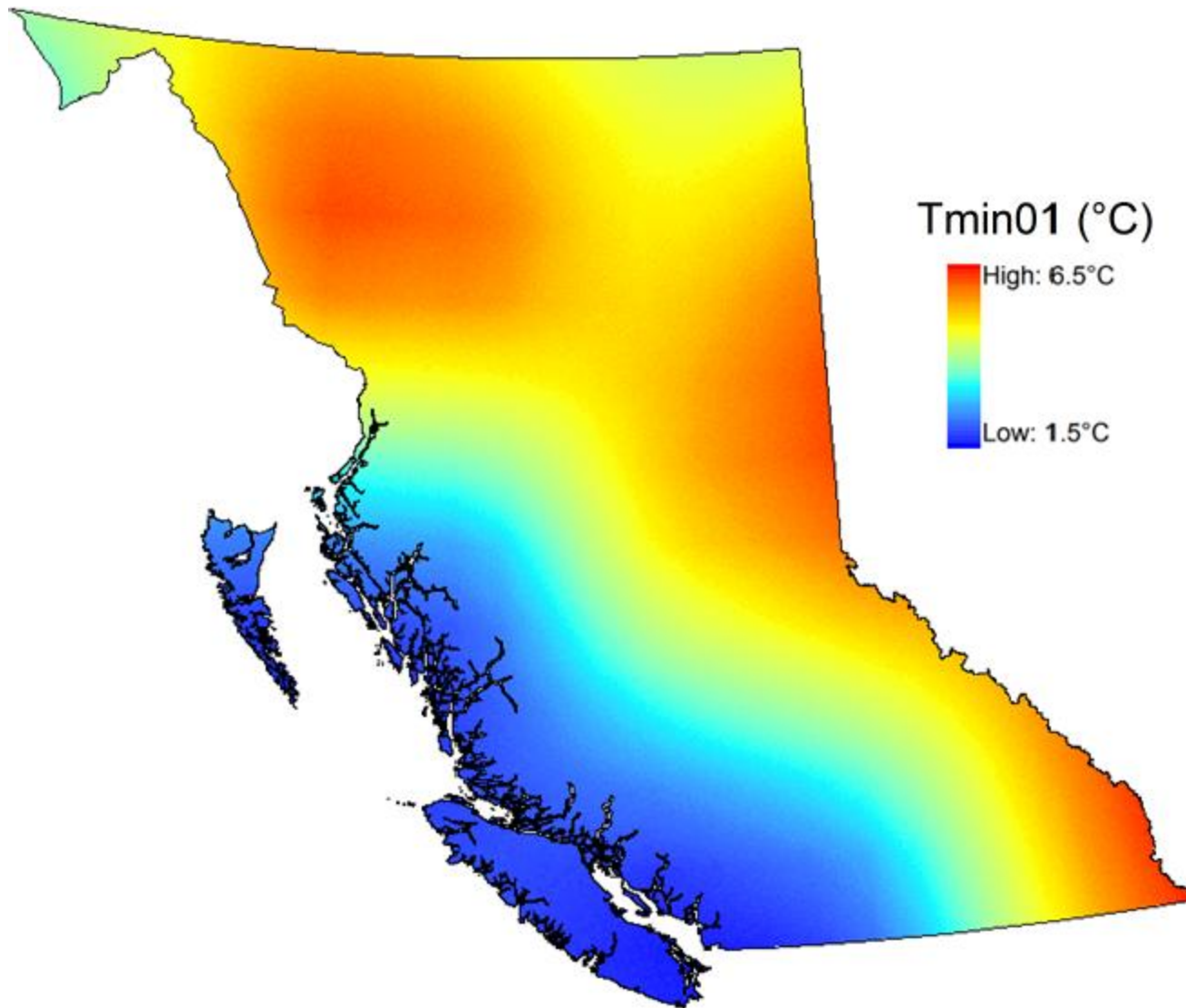
Status

AR4_BCCR_BCM20_A2-run1_2020.gcm
AR4_BCCR_BCM20_A2-run1_2050.gcm
AR4_BCCR_BCM20_A2-run1_2080.gcm
AR4_CCCMA_CGCM3_A1B-run1_2020.gcm
AR4_CCCMA_CGCM3_A2-run4_2020.gcm
AR4_CCCMA_CGCM3_A2-run4_2050.gcm
AR4_CCCMA_CGCM3_A2-run4_2080.gcm
AR4_cccma_cgcm3_A2-run5_2020.gcm
AR4_cccma_cgcm3_A2-run5_2050.gcm
AR4_cccma_cgcm3_A2-run5_2080.gcm
AR4_csiro_mk30_B1-run1_2020.gcm
AR4_csiro_mk30_B1-run1_2050.gcm
AR4_csiro_mk30_B1-run1_2080.gcm
AR4_gfdl_cm21_A2-run1_2020.gcm
AR4_gfdl_cm21_A2-run1_2050.gcm
AR4_gfdl_cm21_A2-run1_2080.gcm
AR4_giss_ah_A1B-run3_2020.gcm
AR4_giss_ah_A1B-run3_2050.gcm
AR4_giss_ah_A1B-run3_2080.gcm
AR4_miroc32_Hires_B1_run1_2020.gcm
AR4_miroc32_Hires_B1_run1_2050.gcm
AR4_miroc32_Hires_B1_run1_2080.gcm
AR4_MIROC32_MEDRES_A2-run2_2020.gcm
AR4_MIROC32_MEDRES_A2-run2_2050.gcm
AR4_MIROC32_MEDRES_A2-run2_2080.gcm
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AR4_mpi_echam5_B1-run1_2050.gcm
AR4_mpi_echam5_B1-run1_2080.gcm
AR4_mri_cgcm232a_B1-run5_2020.gcm
AR4_mri_cgcm232a_B1-run5_2050.gcm

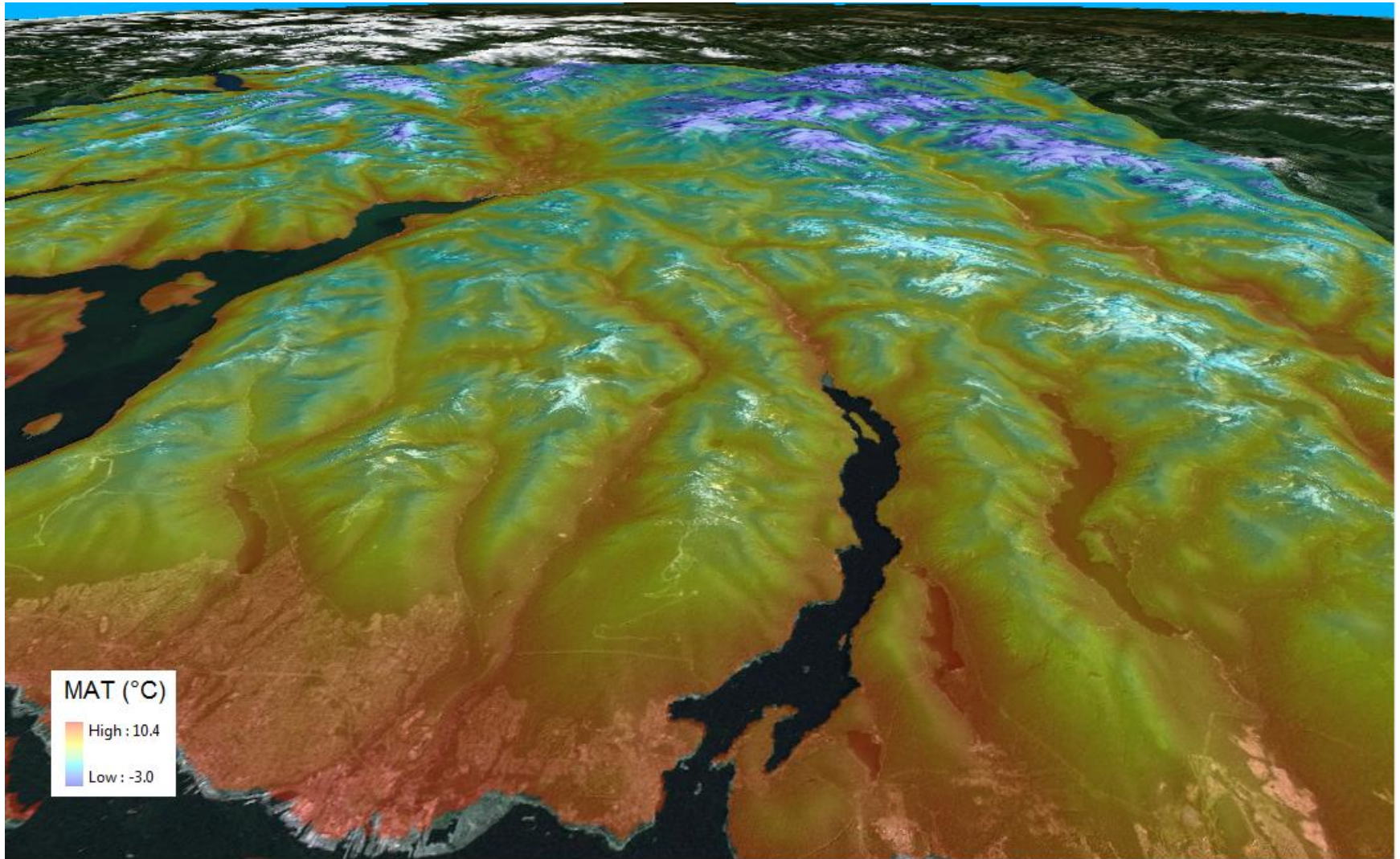
GCMs are in low spatial resolution



GCM data downscaled to points by ClimateBC in run-time

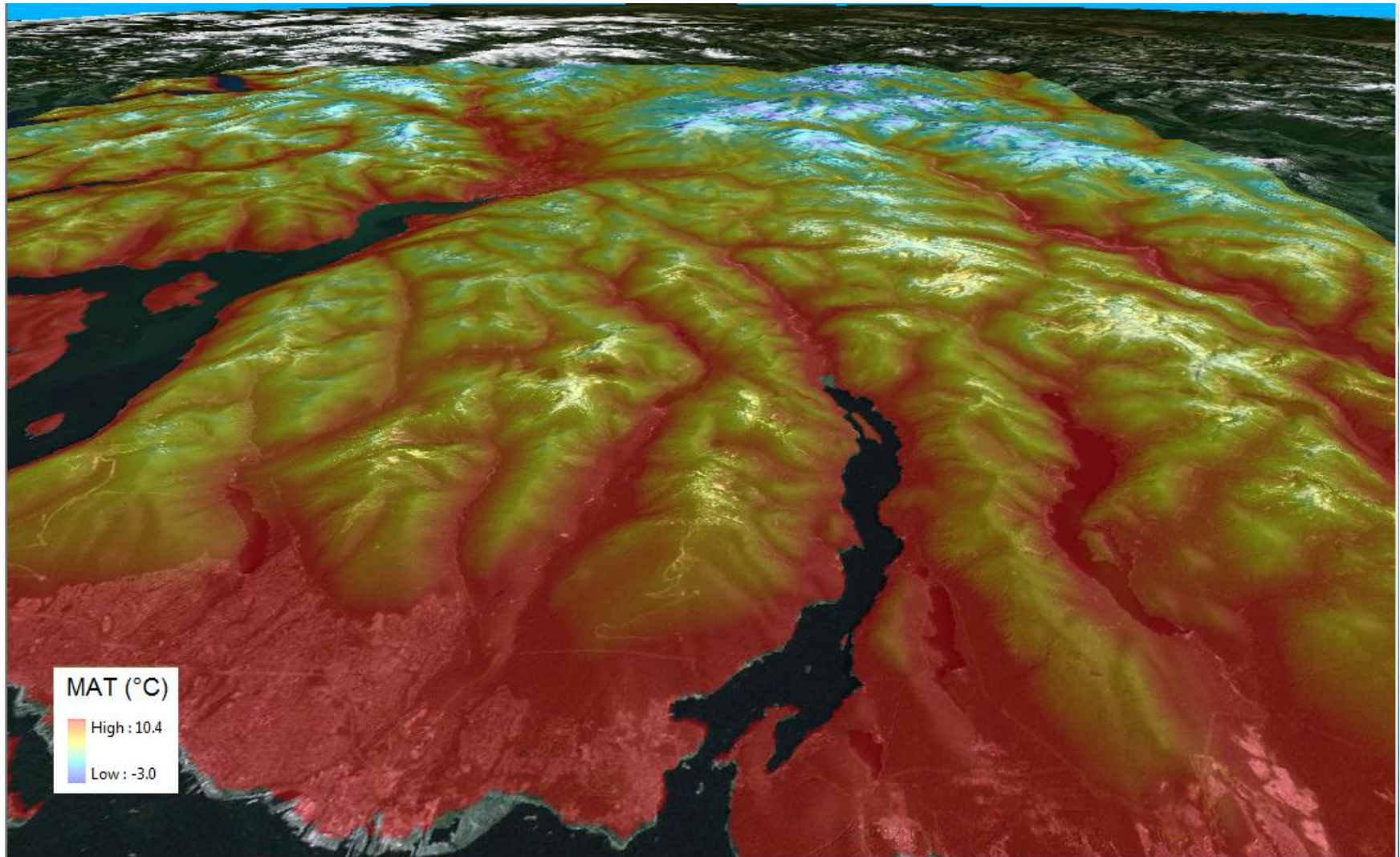


Spatial pattern of temperature for baseline period



ClimateBC output (90m) overlaid on a satellite image (1970s)

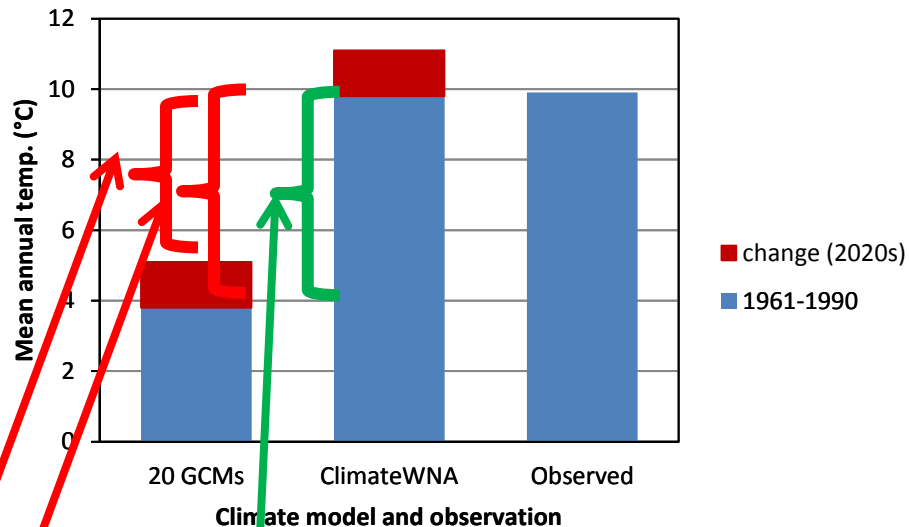
GCM changes added onto the baseline data



ClimateBC output (90m) overlaid on a satellite image (CGCM2 A2_2050s)

It improves future predictions

--An example at the Vancouver Airport



5°C cooler than the observation
Error: -6°C

ClimateWNA eliminates the error of -6°C
in the 1961-1990 normal data



ClimateWNA generates climate data for the past years (1901 - 2009)

ClimateWNA_v4.60 Copyright (2010) Wang T, Hamann A and Spittlehouse D. All rig...

Select Output Variables
Annual variables

Select Period
Annual Data [Select a year](#)

Coordinate Input ☒ Decimal ☐ DMS

Latitude
Longitude
Elevation (m)

Output of annual variables

MAT	MVMT	MCMT	TD	M
<input type="text" value="12"/>	<input type="text" value="25.4"/>	<input type="text" value="-1"/>	<input type="text" value="26.4"/>	<input type="text"/>
DD<0	DD>5	DD<18	DD>18	N
<input type="text" value="211"/>	<input type="text" value="3068"/>	<input type="text" value="2854"/>	<input type="text" value="763"/>	<input type="text"/>

Multi-location

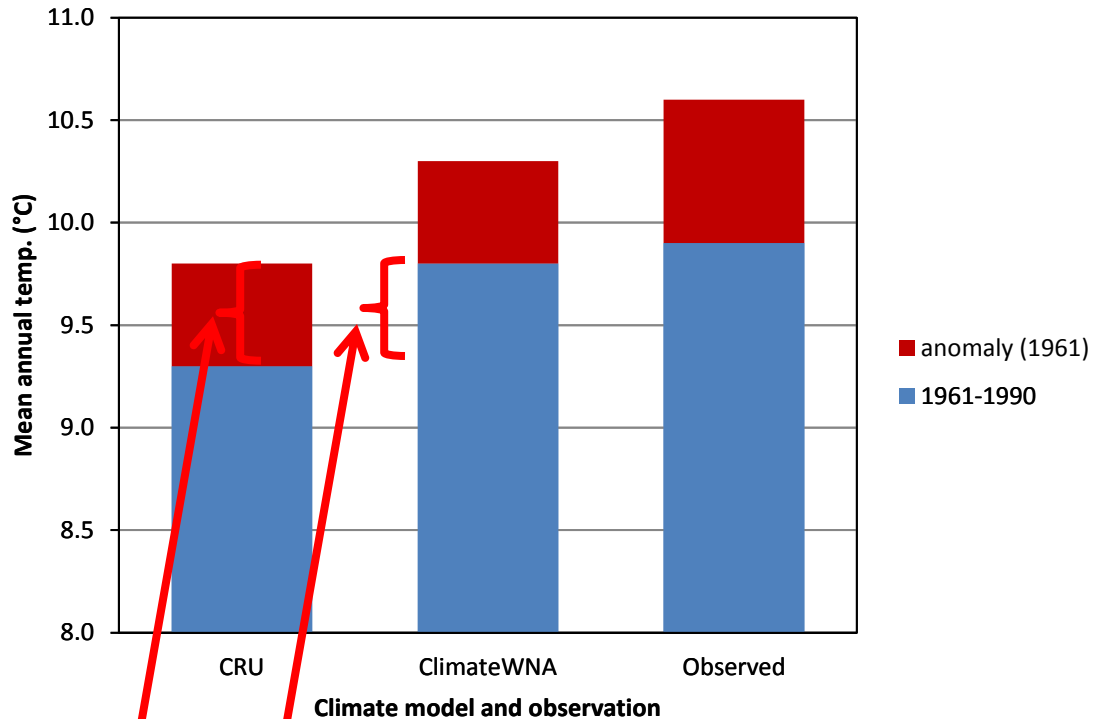
Select input file Sp

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
year_1912.ann
year_1913.ann
year_1914.ann
year_1915.ann
year_1916.ann
year_1917.ann
year_1918.ann
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

It improves historical data

--An example at the Vancouver Airport for 1961



Error in 1961-1990 normal data
ClimateWNA eliminates most of the error
in the 1961-1990 normal data

Data access for time series

ClimateWNA_v4.62 Copyright (2010) Wang T, Hamann A and Spittlehouse D. All ri...

Select Output Variables

All variables for multiple years

Annual variables

Seasonal variables

Monthly variables

All variables

All variables for multiple years

Longitude 115.02

Elevation (m) 1000

Select Period

Time series Normal 1961 - 1990

Calculate

About

Help

Output of annual variables

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

Save

Multi-location

Select input file

Specify output file

Calculate TS

Status

Features of ClimateBC/WNA

1. High quality baseline data
2. Effective downscaling algorithms
3. Many calculated and derived variables (85)
4. Integrated and improved historical and future climate data
5. Easy access

Desktop version

ClimateWNA_v4.52 Copyright (2008) Wang T, Hamann A and Spittlehouse D. All right...

Select Output Variables
Annual variables

Select Period
Normal 1961-1990 Normal 1961 - 1990

Coordinate Input ☒ Decimal ☐ Degree

Latitude: 47.98
Longitude: 115.02
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	DD<18	DD>18	NFFD	FFP	bFFP	eFFP	Eref	CMD

Save

Multi-location

Select input file Specify output file **Calculate**

Status

ClimateWNA provides easy access to over 20,000 climate surfaces

Wang et al. 2012, J. Appl. Meteor. Clim

Web version

UBC THE UNIVERSITY OF BRITISH COLUMBIA

Forestry

Centre for Forest Conservation Genetics •CFCG•

Welcome to ClimateWNA Web Version

Coordinates Input: ☒ Decimal ☐ Degree

Latitude: 50.50833 Longitude: 120.50833

Elevation: 500 m Time Period: Normal_1961_1990

Calculate [Help](#)

Output:

Annual Variables:	Seasonal Variables:	Monthly Variables:
MAT = 6.6	Tave(12-2) = -3.5	Tave(1) = -4.9
MWMT = 17.5	Tave(3-5) = 6.7	Tave(2) = -1.3
MCMT = -4.9	Tave(6-8) = 16.6	Tave(3) = 2.2
TD = 22.4	Tave(9-11) = 6.7	Tave(4) = 6.6
MAP = 451	Tmax(12-2) = 0.3	Tave(5) = 11.2
MSP = 216	Tmax(3-5) = 12.5	Tave(6) = 15.1
AHM = 36.9	Tmax(6-8) = 24.0	Tave(7) = 17.5
SHM = 81.0	Tmax(9-11) = 12.0	Tave(8) = 17.3
EMT = -32.8	Tmin(12-2) = -7.3	Tave(9) = 12.3
PAS = 98	Tmin(3-5) = 0.8	Tave(10) = 7.4
DD<0 = 491	Tmin(6-8) = 9.3	Tave(11) = 0.5
DD>5 = 1711	Tmin(9-11) = 1.5	Tave(12) = -4.3
DD<18 = 4190	PPT(12-2) = 121	Tmax(1) = -1.2
DD>18 = 93	PPT(3-5) = 87	Tmax(2) = 2.9
NFFD = 204	PPT(6-8) = 126	Tmax(3) = 7.4

Copyright(2009) Wang, T., Hamann, A., and Spittlehouse, D. All right reserved.

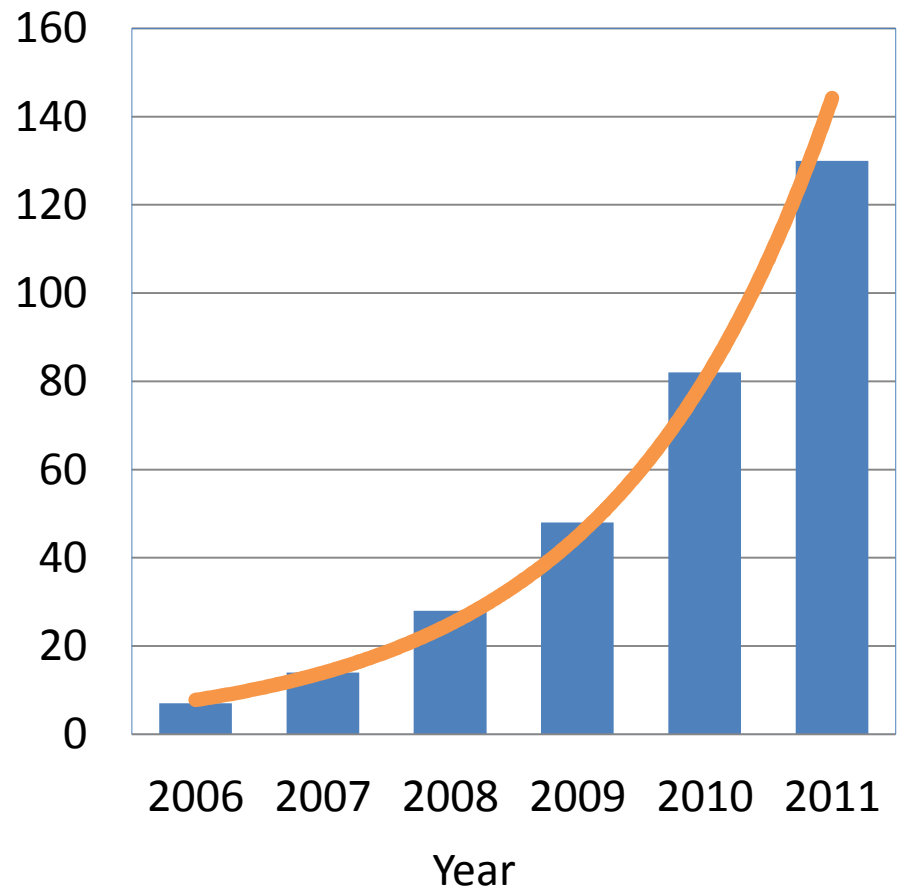
Disclaimer: Predictions of baseline and future climates are based on downscaled PRISM and predictions from various global circulation models. Authors do not bear any liability for financial or other losses due the use of this program.

Contact: [Tongli Wang](#)

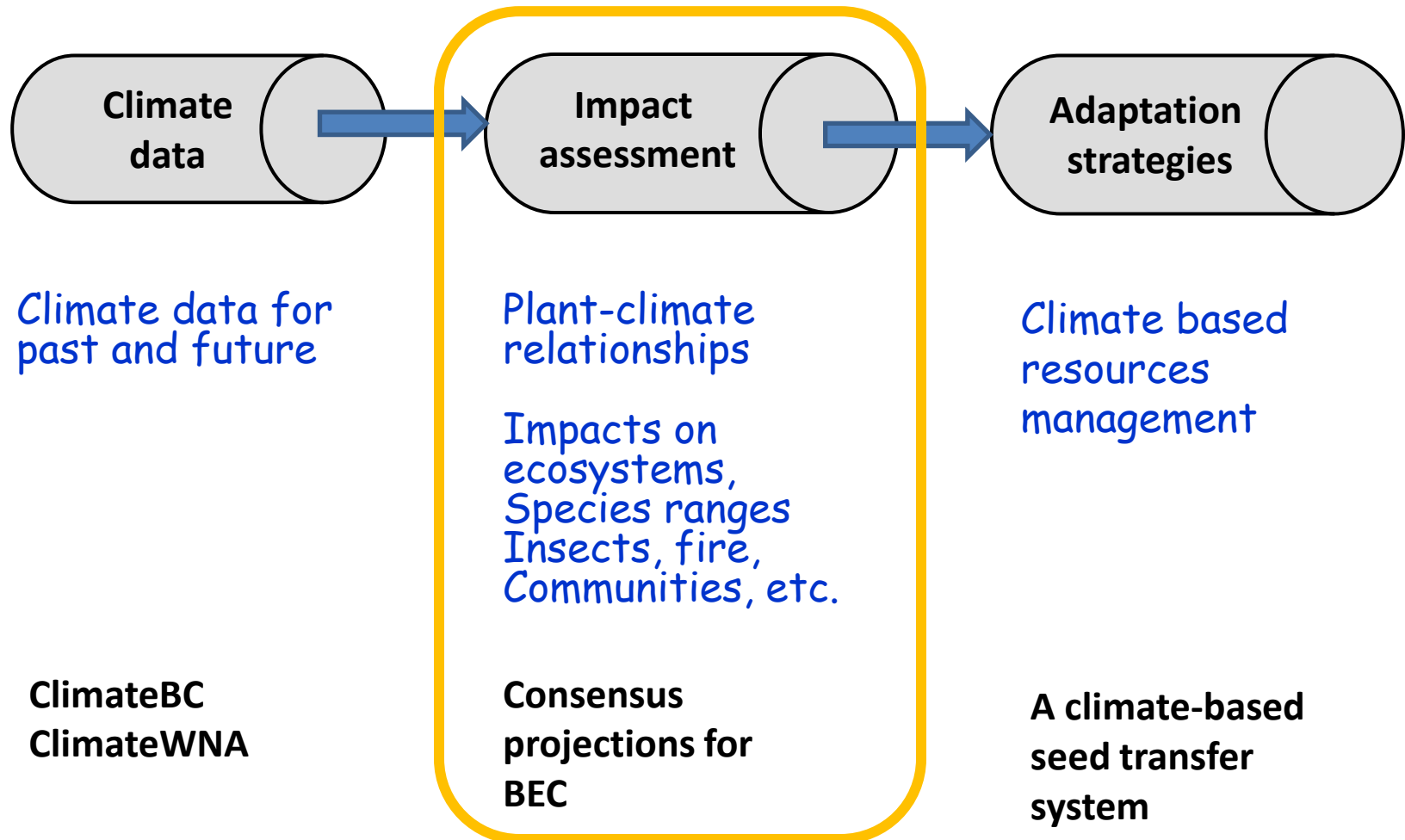
Widely used for climate related studies



Supported SCI journal papers



A simplified framework for climate change studies in forestry

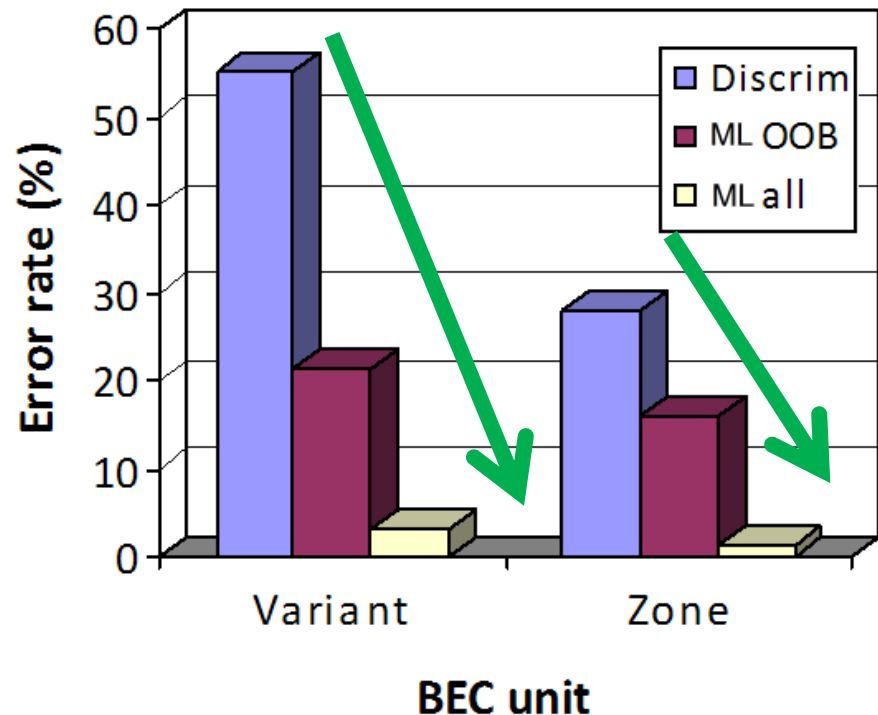


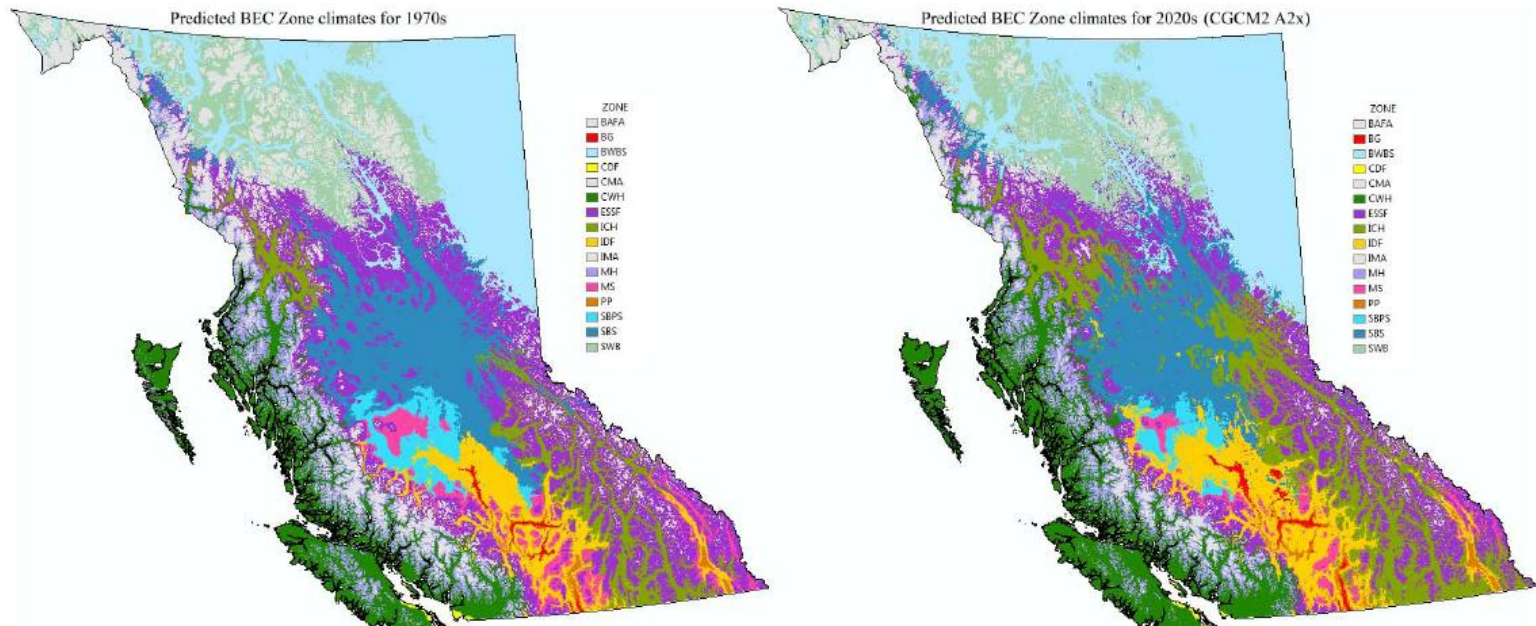
Consensus projections of future climate habitats for BC ecosystems

- Two major challenges
 - Model accuracy
 - Uncertainty associated with uncertain future climates

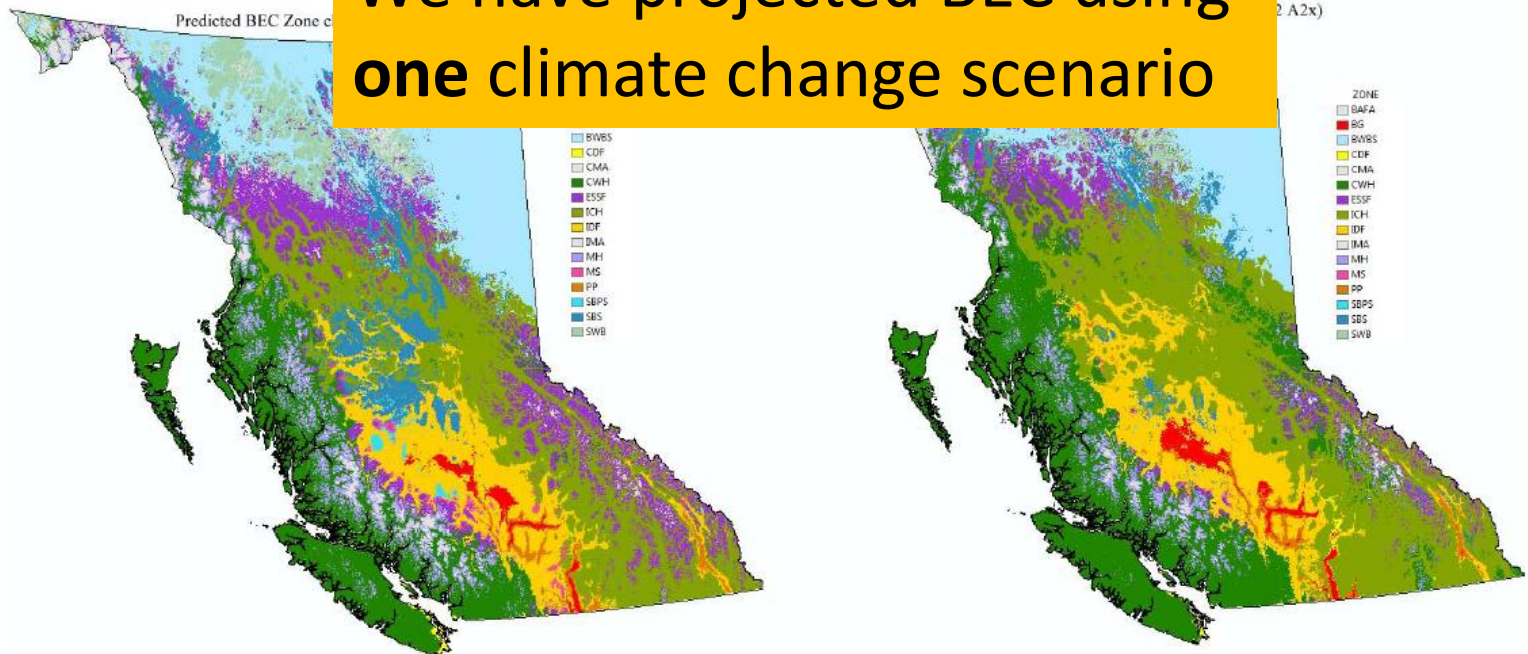
Improvement in model accuracy

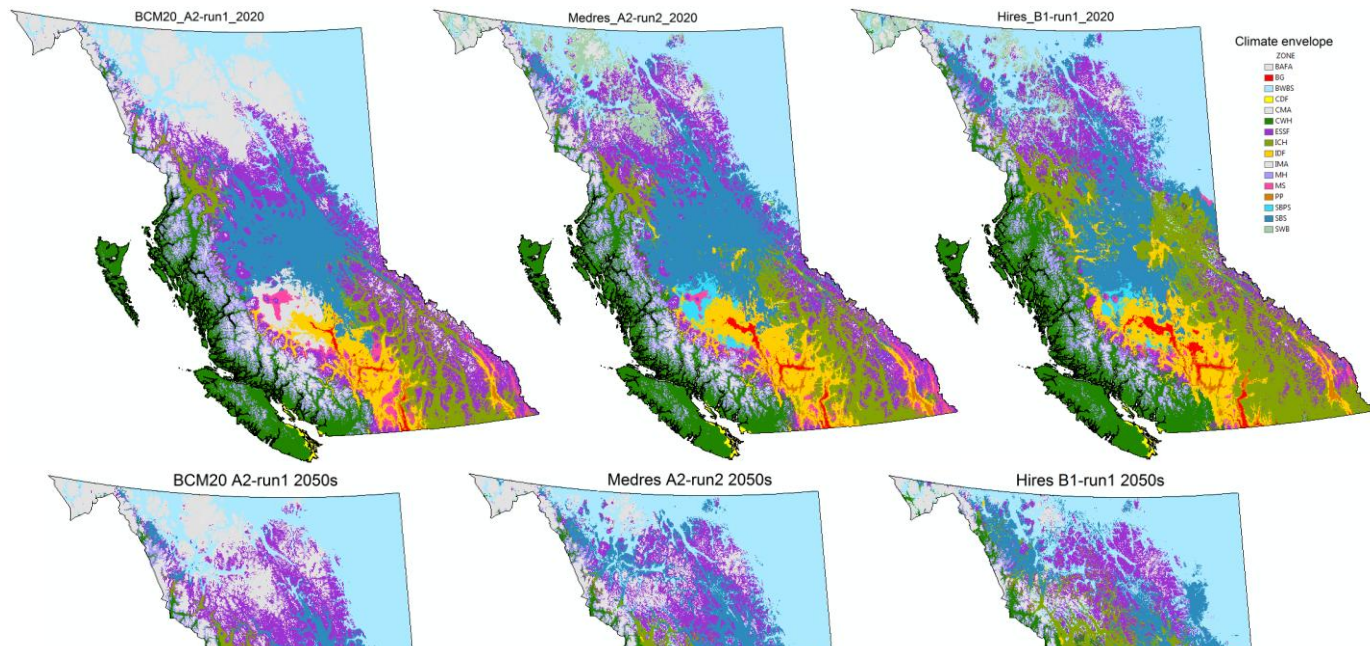
- PCA
- Discriminant analysis
- Machine-learning methods
 - Neural network
 - Random Forest



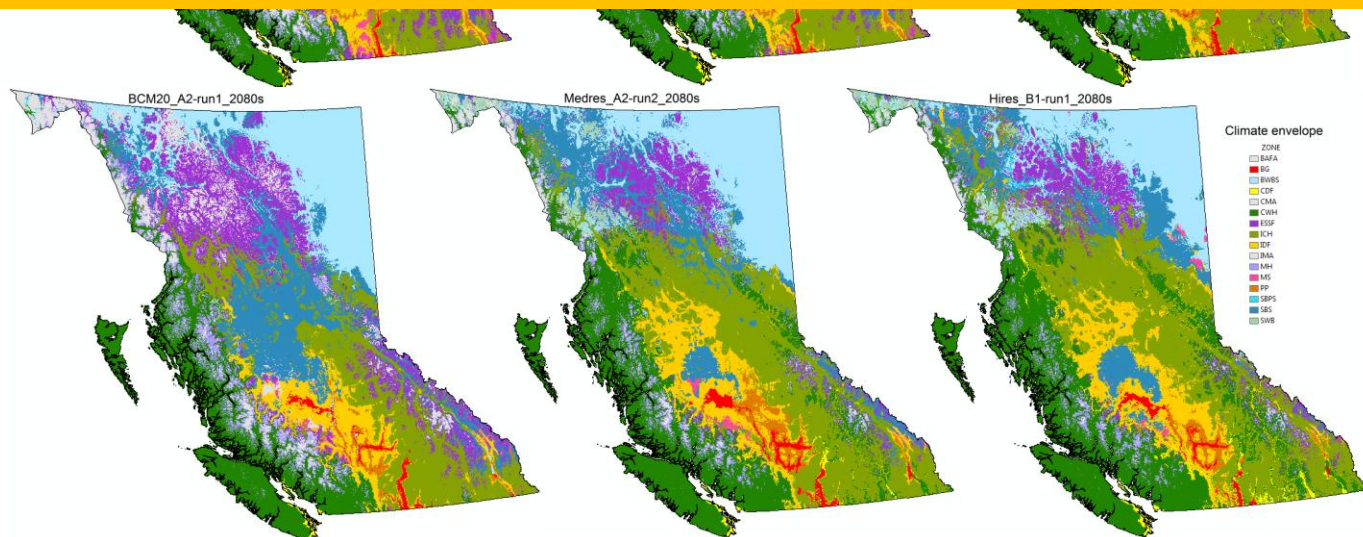


We have projected BEC using
one climate change scenario





and projections using **three** climate change scenario.
However, ...

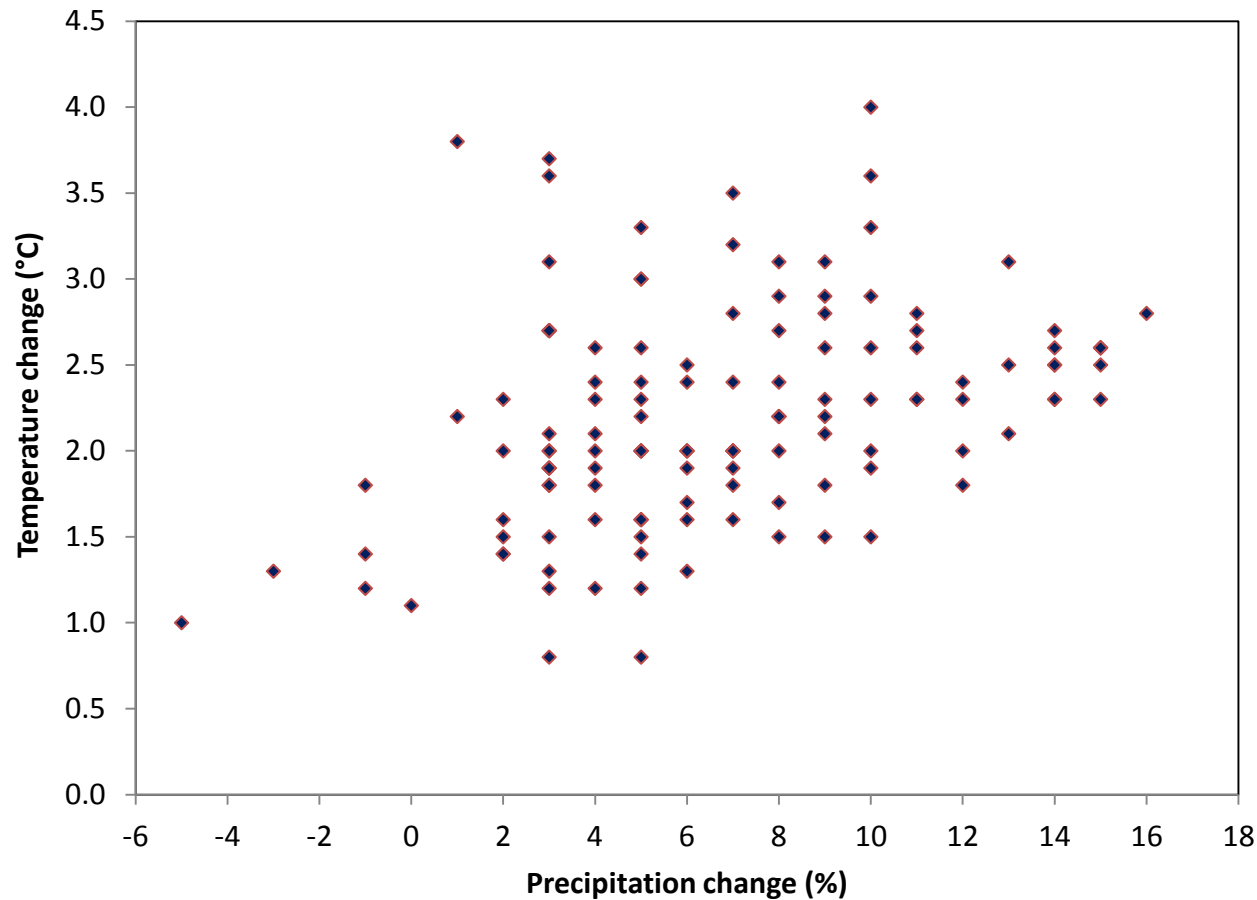


A large number of GCM projections for future climates from IPCC AR4

Center	Center Acronym	Model	COM-MIT	PI-cntrl	20C3M	A2	A1B	B1	1%-2X	1%-4X	add. data
Beijing Climate Center China	BCC	CM1		run_1 run_2	run_1		run_1	run_1	run_1		
Bjerknes Centre for Climate Research Norway	BCCR	BCM2.0	run_1	run_1	run_1	run_1	run_1	run_1	run_1		
Canadian Center for Climate Modelling and Analysis Canada	CCCma	CGCM3 (T47 resolution)	run_1 run_2 run_3	run_1	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3	run_1	run_1	
		CGCM3 (T63 resolution)		run_1	run_1		run_1	run_1	run_1		
Centre National de Recherches Meteorologiques France	CNRM	CM3	run_1	run_1	run_1	run_1	run_1	run_1	run_1	run_1	
Australia's Commonwealth Scientific and Industrial Research Organisation Australia	CSIRO	Mk3.0	run_1	run_1 run_2	run_1 run_2 run_3	run_1	run_1	run_1	run_1		
Max-Planck-Institut for Meteorology Germany	MPI-M	ECHAM5-OM	run_1 run_2	run_1	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3	run_1	compl. set of md"
Meteorological Institute, University of Bonn Meteorological Research Institute of Kyoto Model and Data Groupe at MPI-M, Germany									run_1 run_2	run_1	
Institute of Atmospheric Physics China	LASG	FGOALS-g1.0	run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3		run_1 run_2 run_3	run_1 run_2 run_3	run_1 run_2 run_3		
Geophysical Fluid Dynamics Laboratory USA	GFDL	CM2.0	run_1	run_1	run_1 run_2 run_3	run_1	run_1	run_1	run_1	run_1	
		CM2.1	run_1	run_1	run_1 run_2 run_3	run_1	run_1	run_1	run_1	run_1	
Goddard Institute for Space Studies USA	GISS	AOM		run_1 run_2	run_1 run_2		run_1 run_2	run_1 run_2			
		E-H		run_1	run_1 run_2 run_3		run_1 run_2 run_3		run_1		
		E-R	run_1	run_1	run_1 run_2 run_3	run_1	run_1 run_2 run_3	run_1	run_1	run_1	
Institute for Numerical Mathematics Russia	INM	CM3.0	run_1	run_1	run_1	run_1	run_1	run_1	run_1	run_1	
Institut Pierre Simon Laplace France	IPSL	CM4	run_1	run_1	run_1 run_2	run_1	run_1	run_1	run_1	run_1	
National Institute for Environmental Studies Japan	NIES	MIROC3.2 hires		run_1	run_1		run_1	run_1	run_1		
		MIROC3.2 medires			run_1	run_1	run_1	run_1	run_1	run_1	

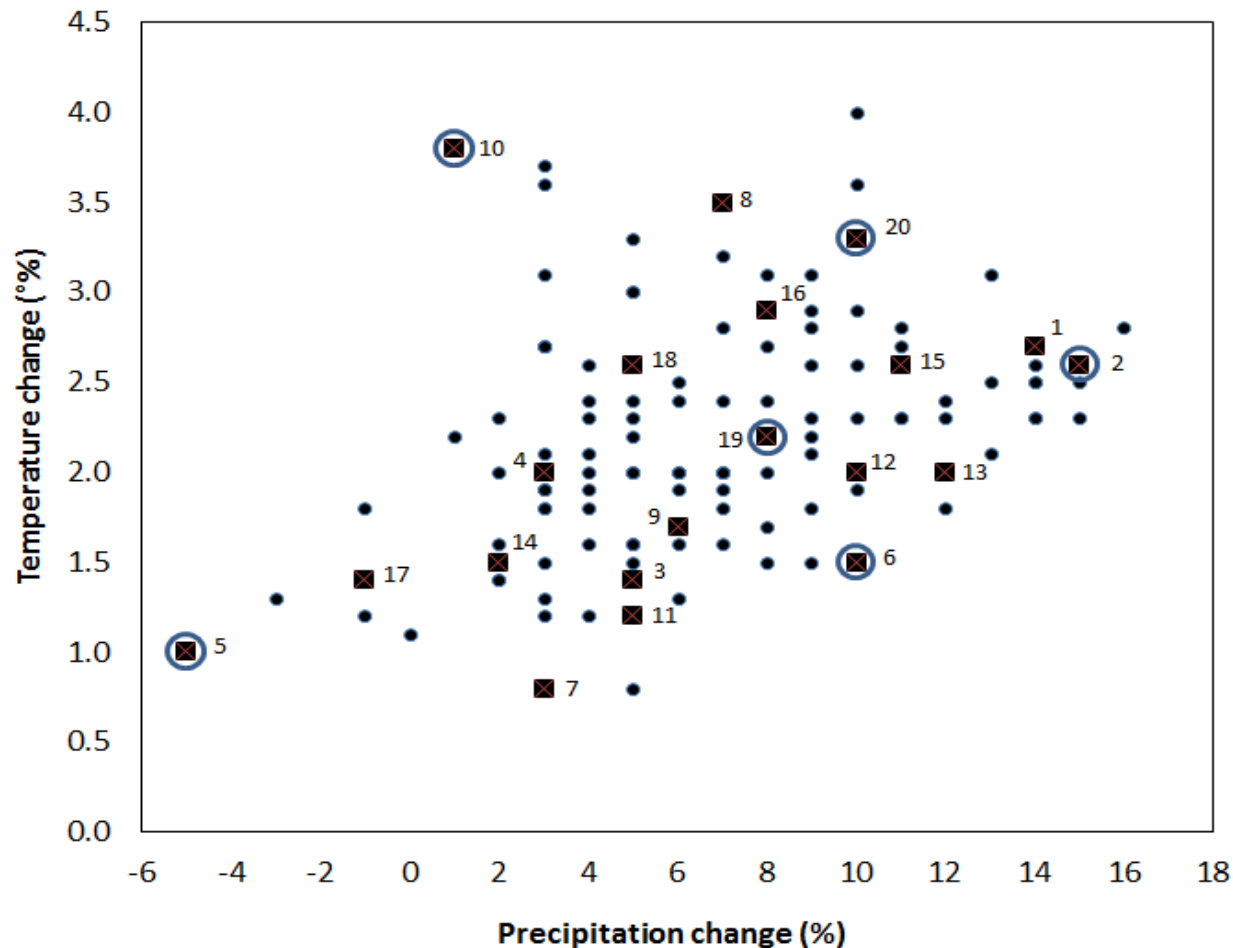
There are over 100 scenarios!

A wide range of climate conditions are projected for the future

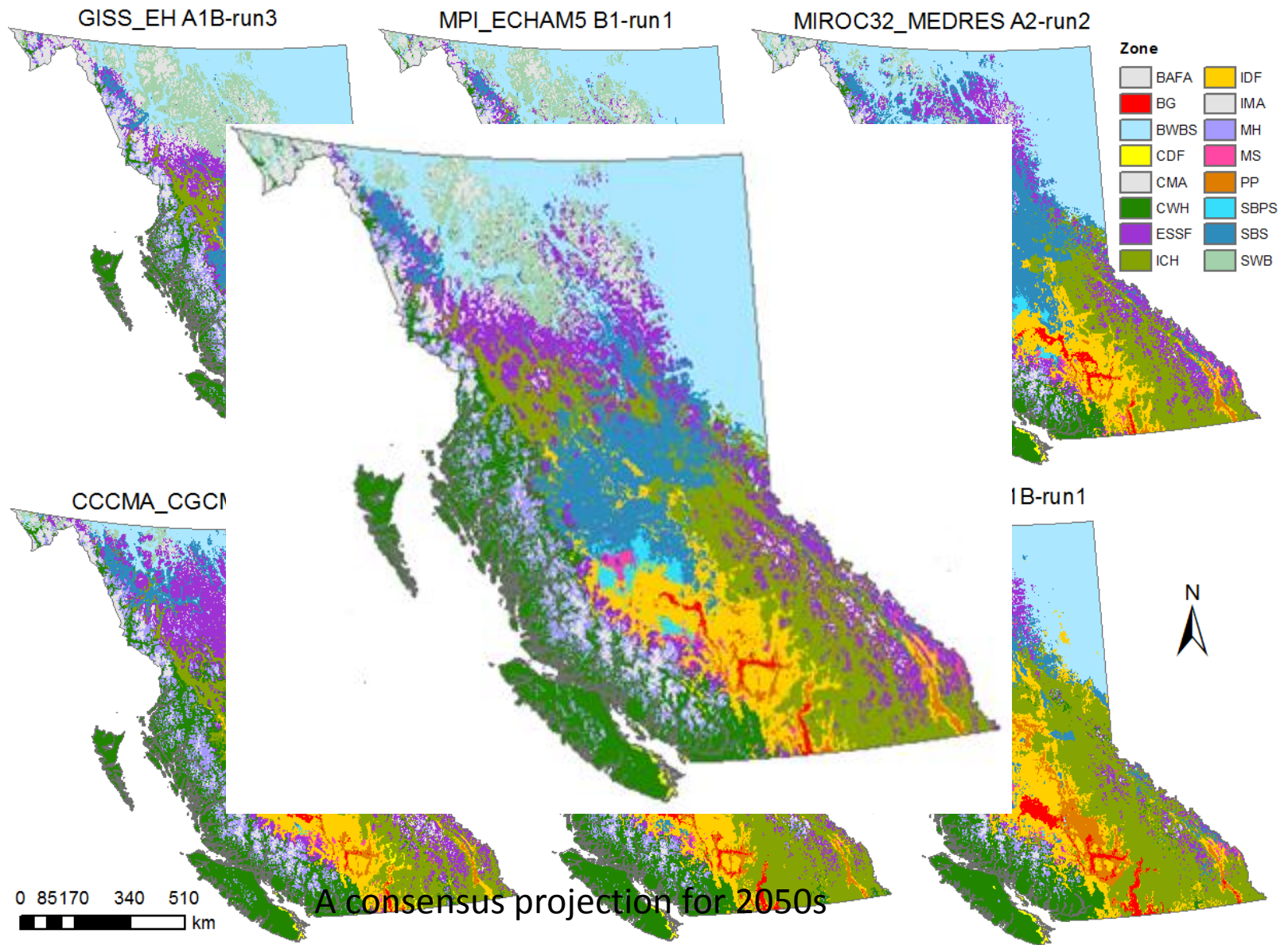


134 climate projections for BC for 2050s (Data source: PCIC)

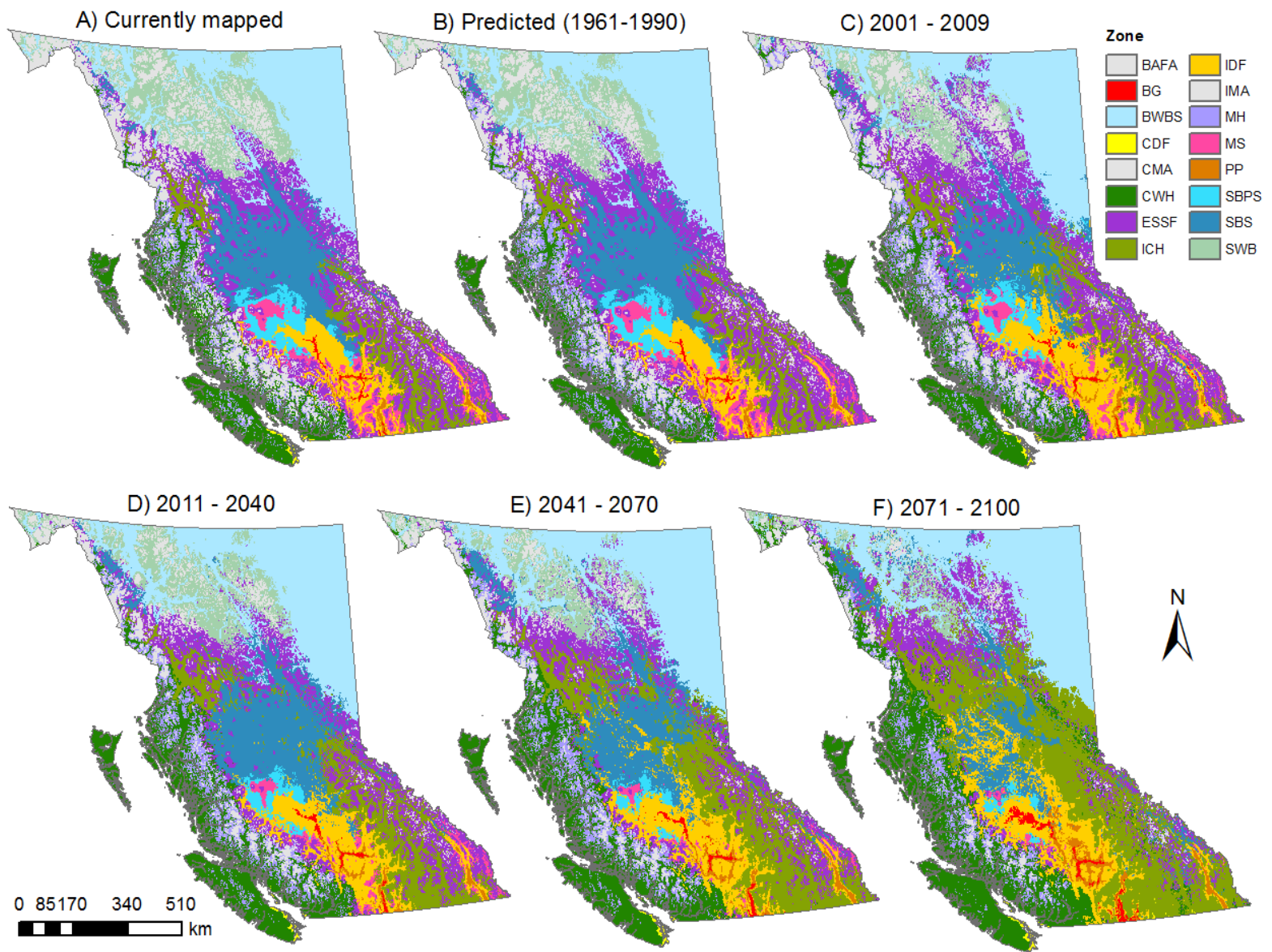
We chose 20 scenarios to represent the range and distribution



Predicted changes in temp. and precip. for BC by 134 climate changes scenarios for 2050s

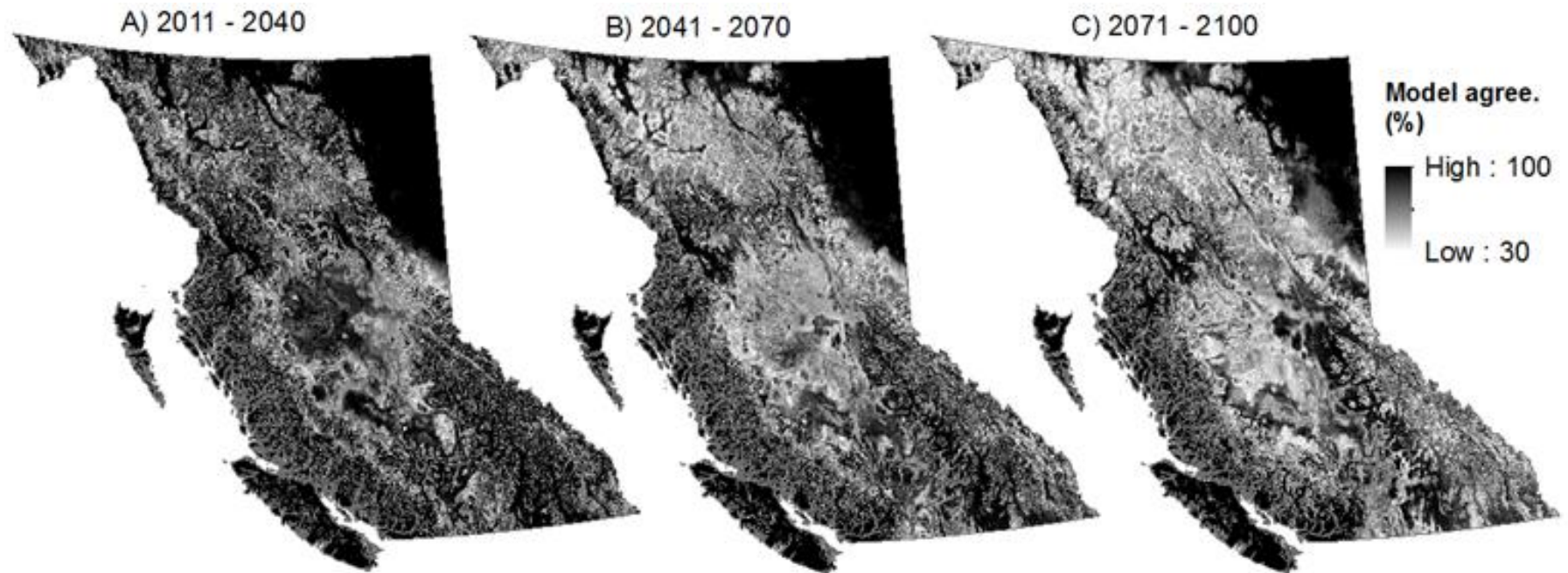


Projected ecological responses to six selected climate change scenarios for 2050s

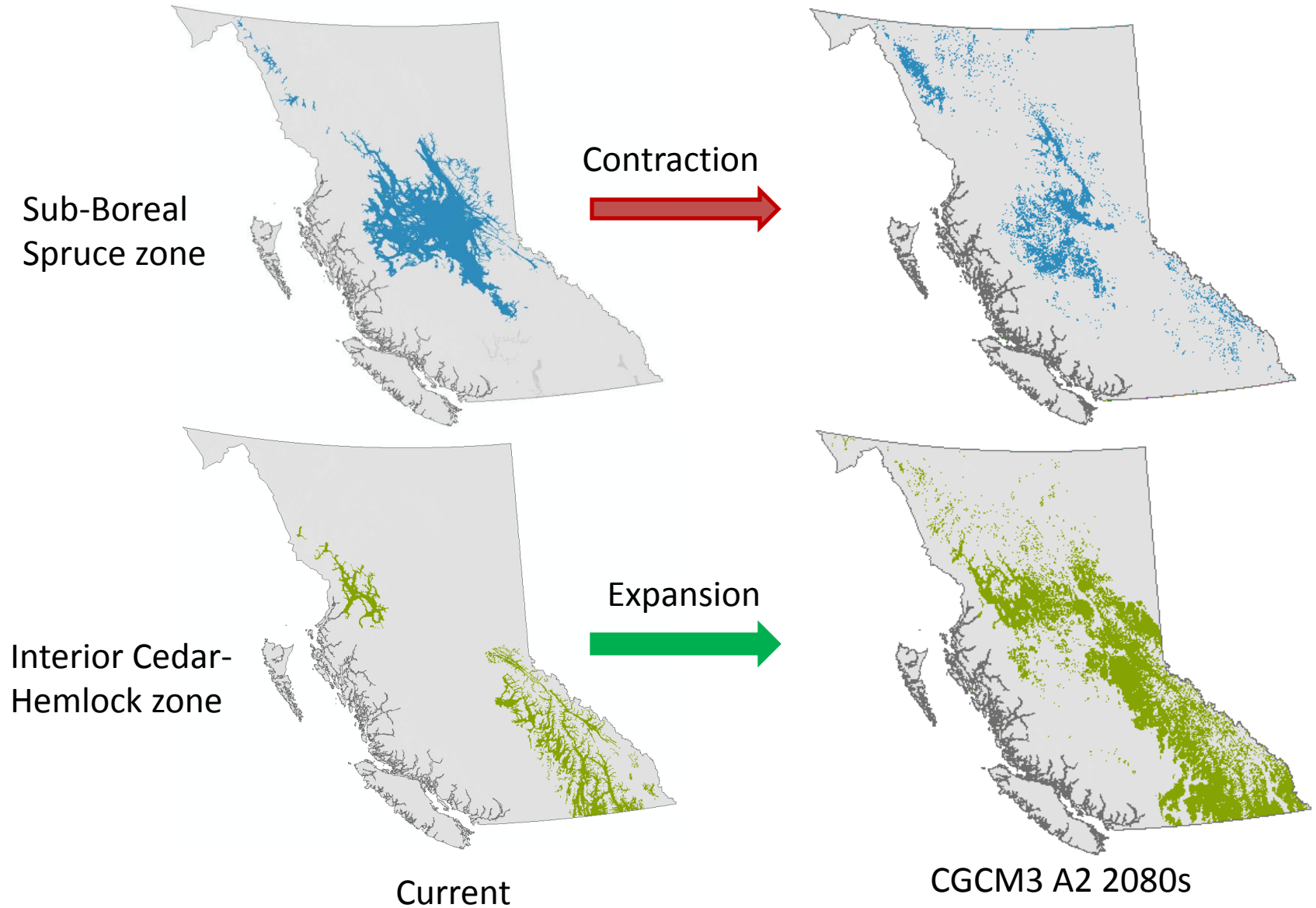


Consensus predictions with the best-model agreement among 20 selected climate change scenarios

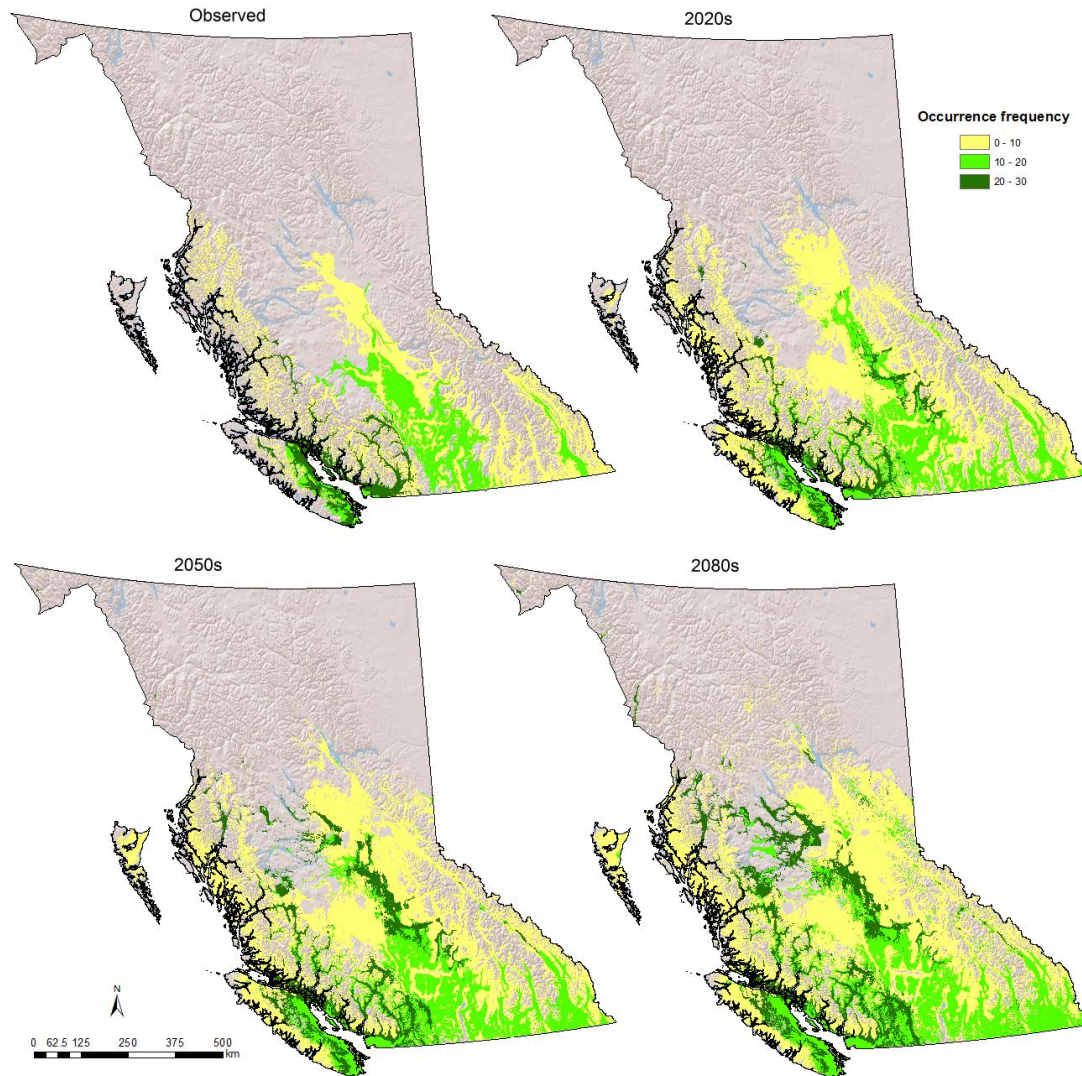
Model-agreement among the projections based the 20 selected climate change scenarios



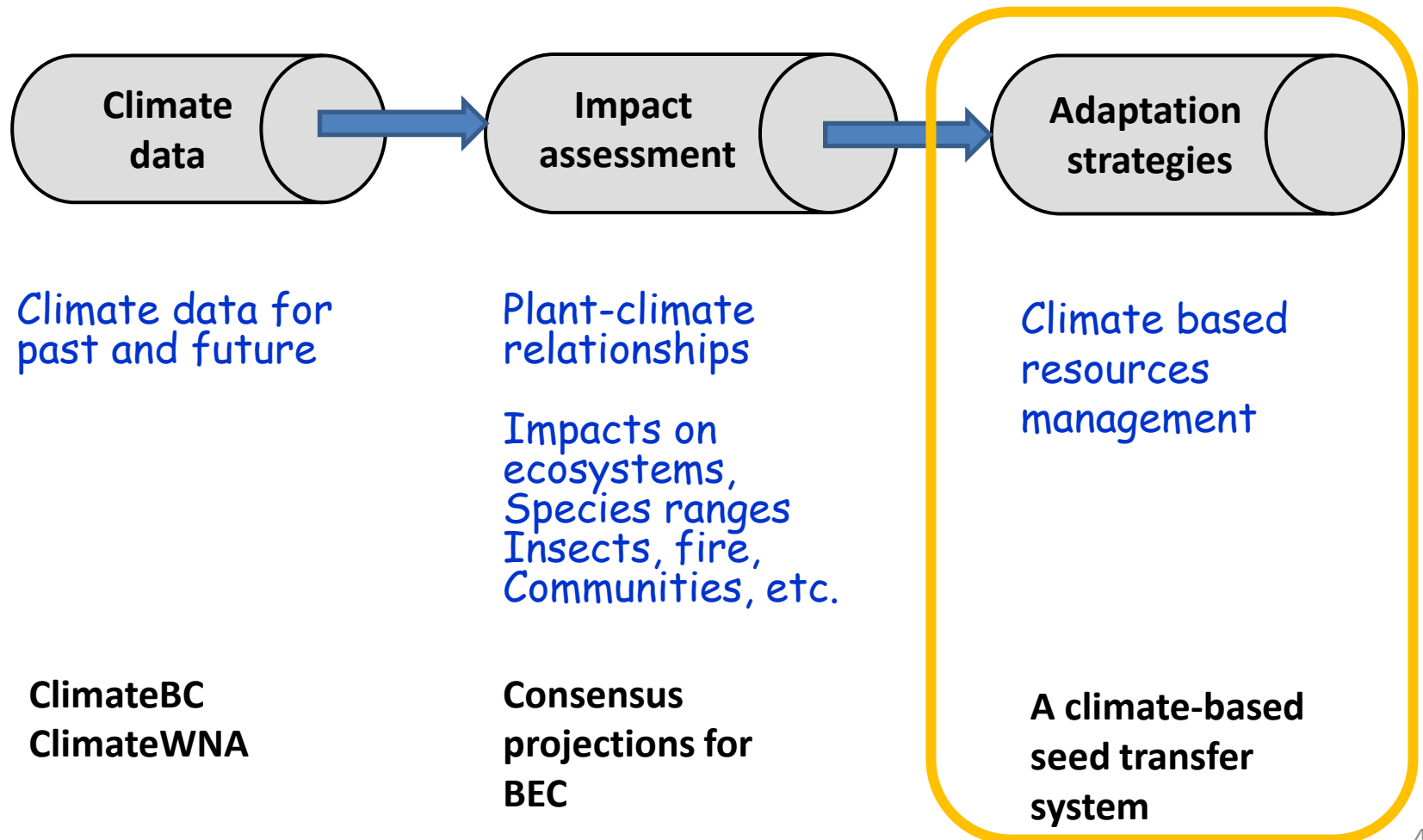
CC Impacts differ among ecological zones



Application of the “flying BEC” in species range projections – Douglas-fir



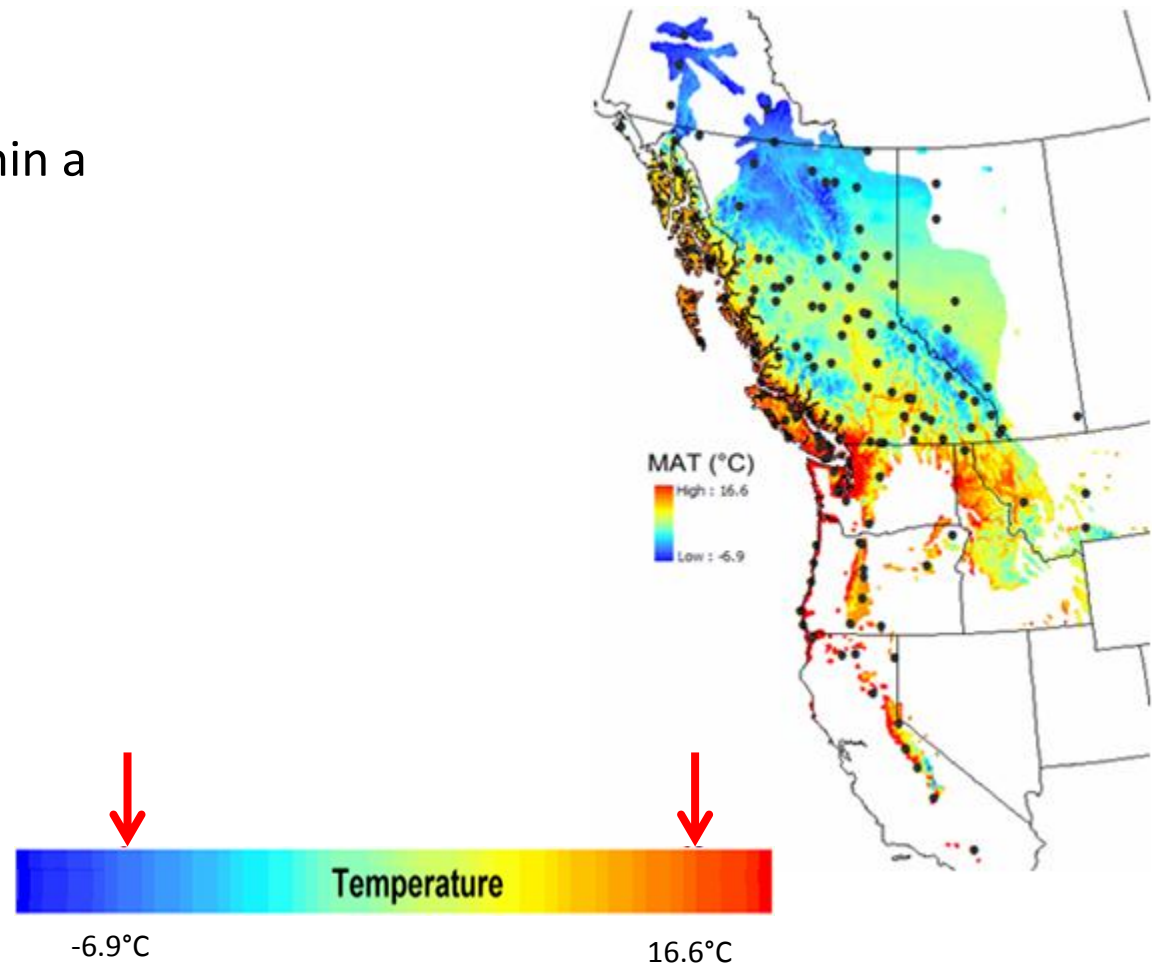
A simplified framework for climate change studies in forestry



Development of a climate-based seed transfer system

Why a seed transfer system?

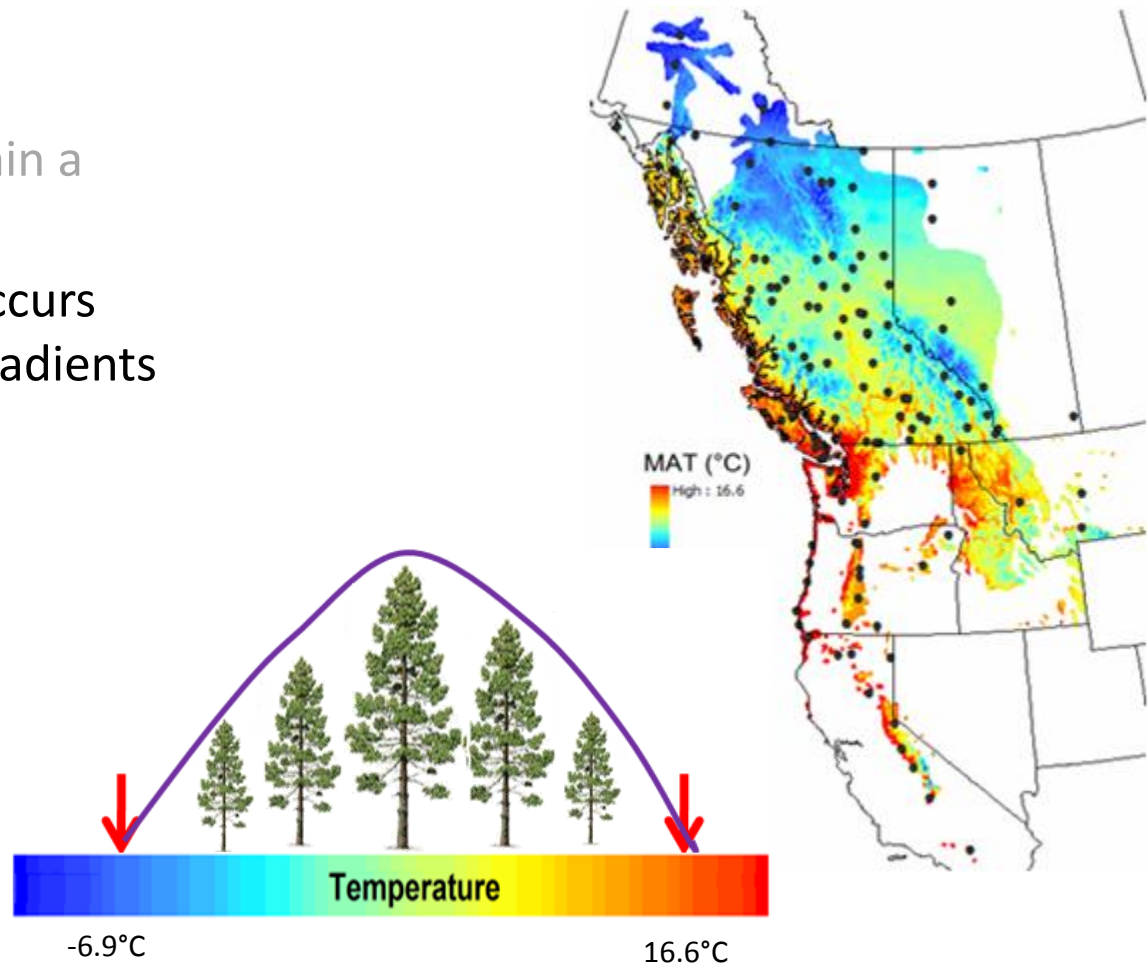
- Substantial climatic variation exists within a species range



Geographic and climatic distributions of Lodgepole pine

Why a seed transfer system?

- Substantial climatic variation exists within a species range
- Genetic variation occurs following climate gradients



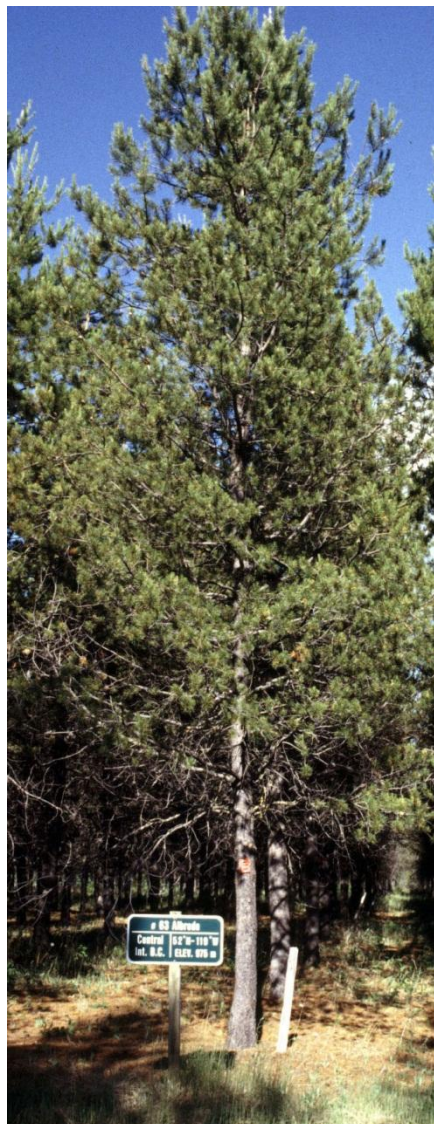
Geographic and climatic distributions of Lodgepole pine

Lodgepole pine

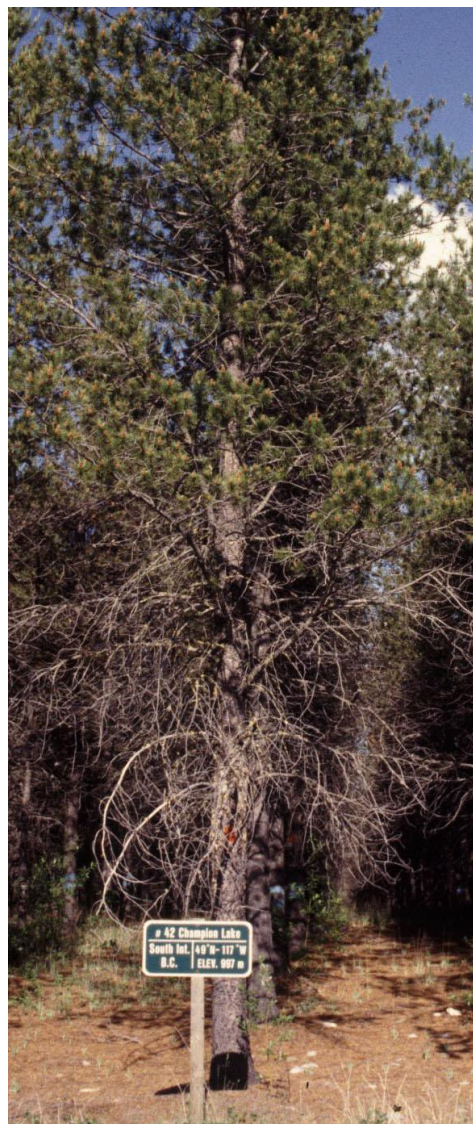
Photos from Sally Aitken



Manning
49 N



Albreda
52 N



Champion
59 N



Takhini
60 N

Western hemlock



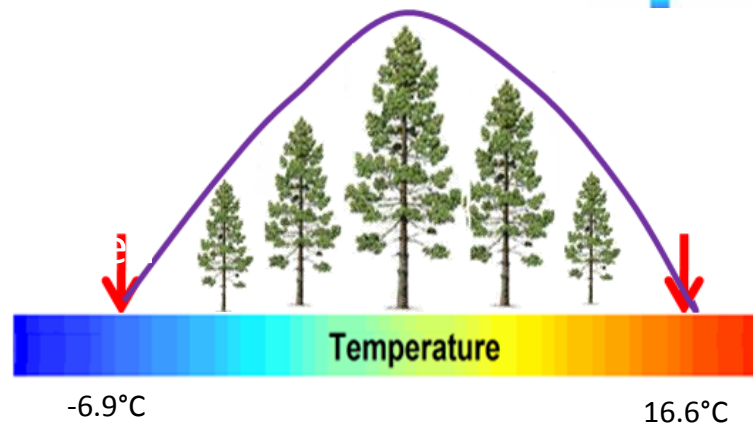
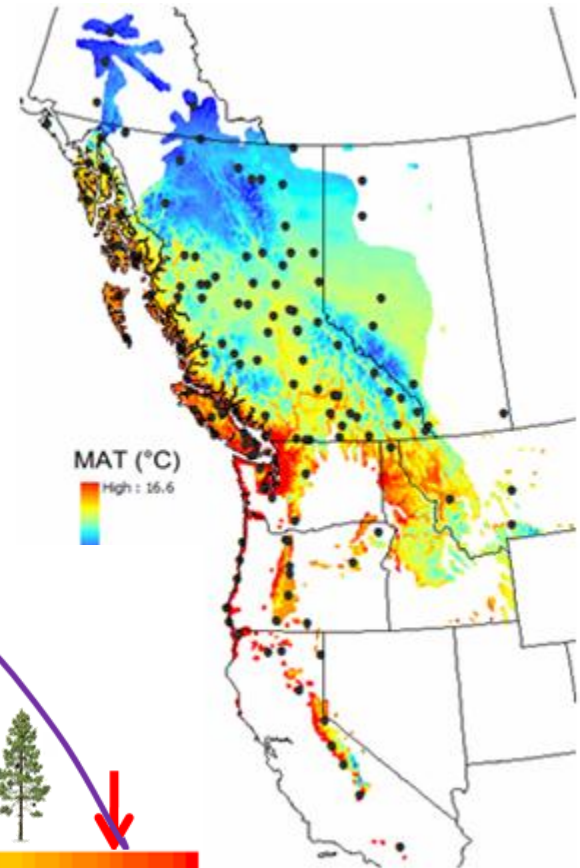
Photo from Sally Aitken

Sitka Spruce



Why a seed transfer system?

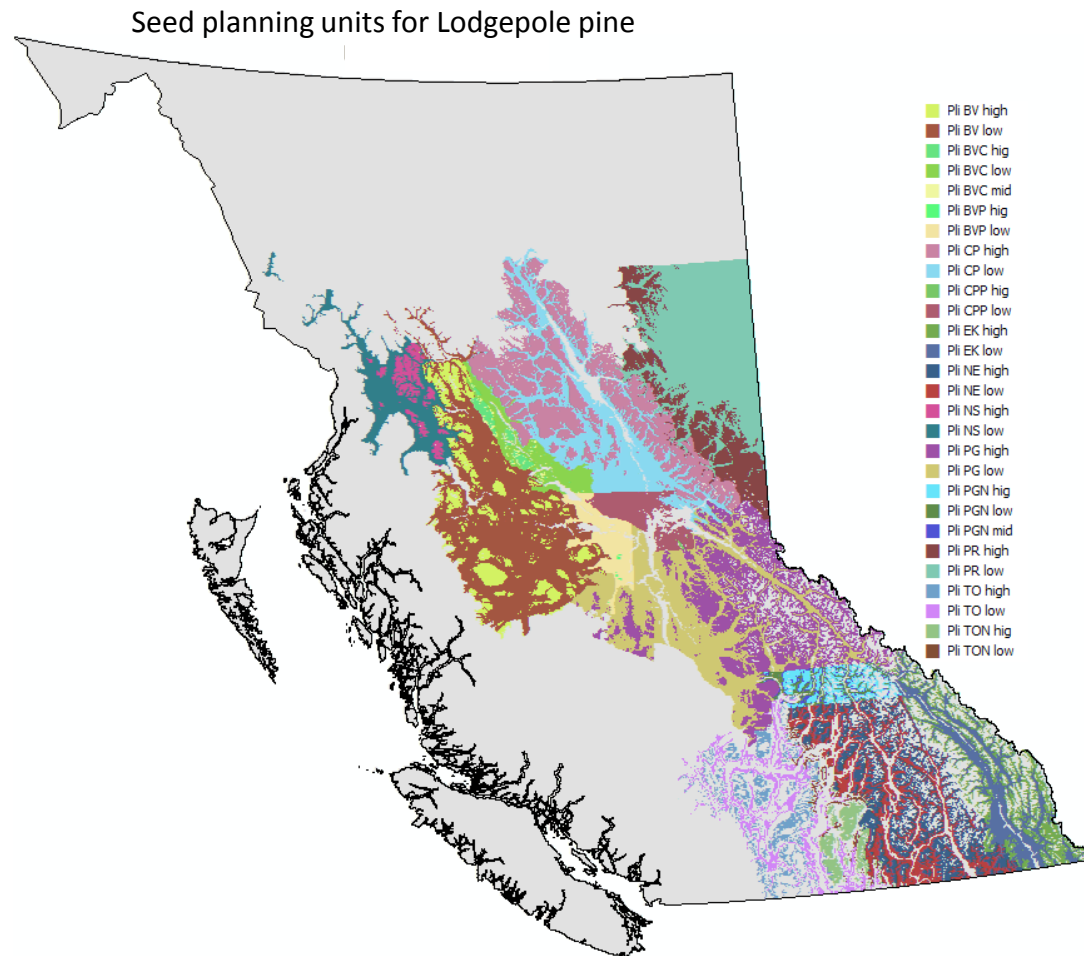
- Substantial climatic variation exists within a species range
- Genetic variation occurs following climate gradients
- Using local seed has been a general guideline



Geographic and climatic distributions of Lodgepole pine

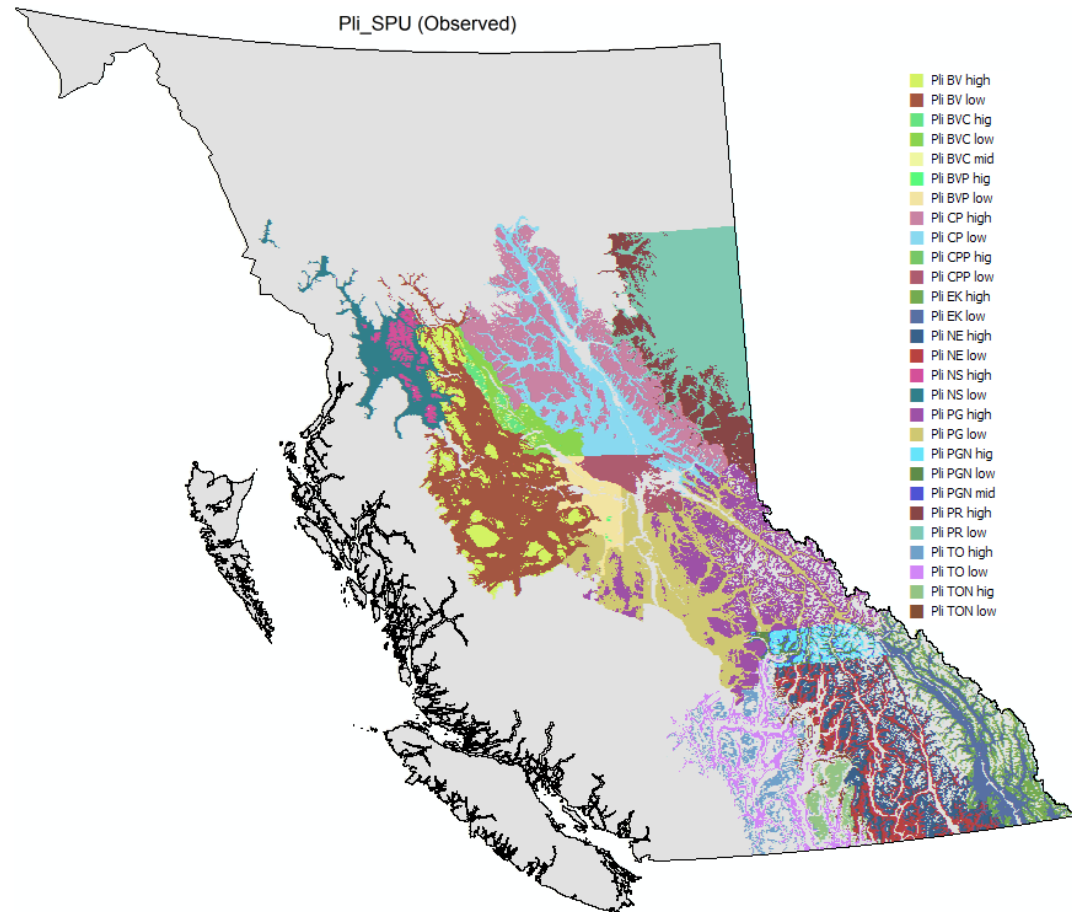
Why a seed transfer system?

- Substantial climatic variation exists within a species range
- Genetic variation occurs following climate gradients
- Using local seed has been a general guideline
- Grouping areas with similar climatic conditions is effective for seed planning
 - Current Seed Planning Units (SPUs)



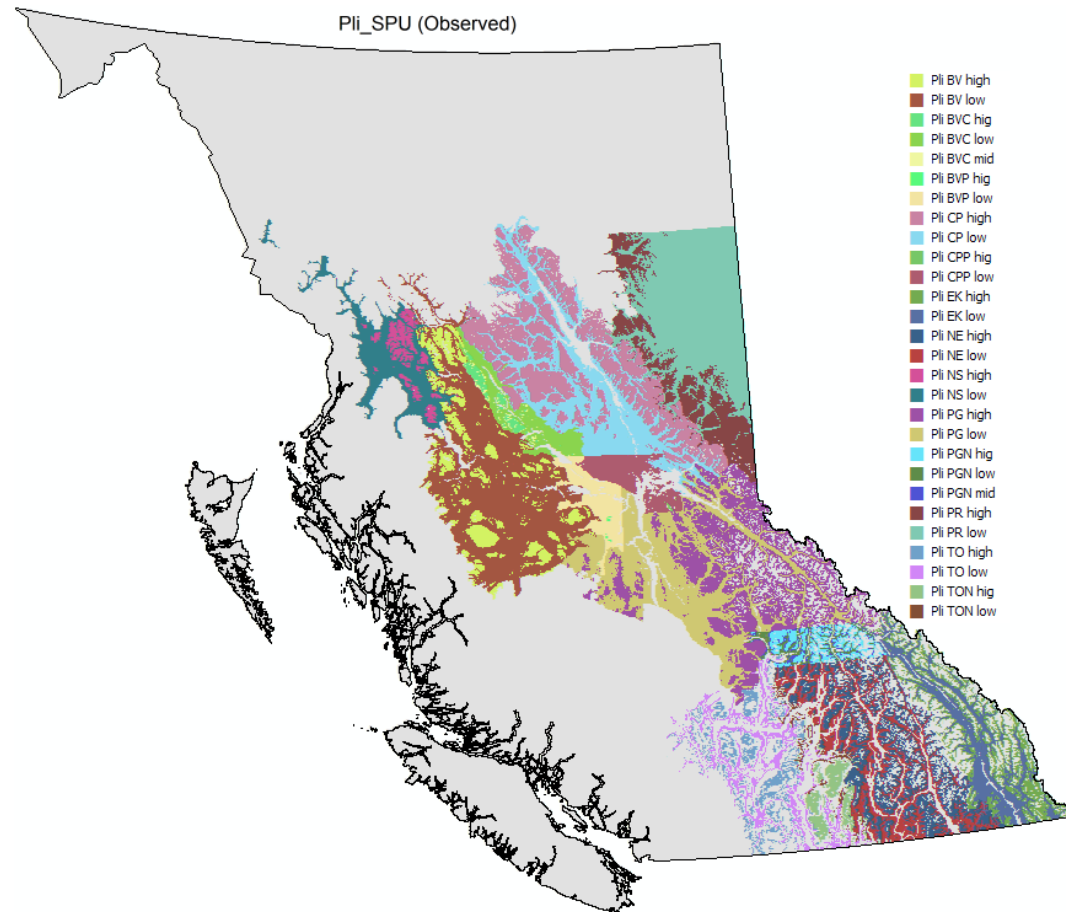
Features and limits of the current SPU

- Geographic-based and easy to use



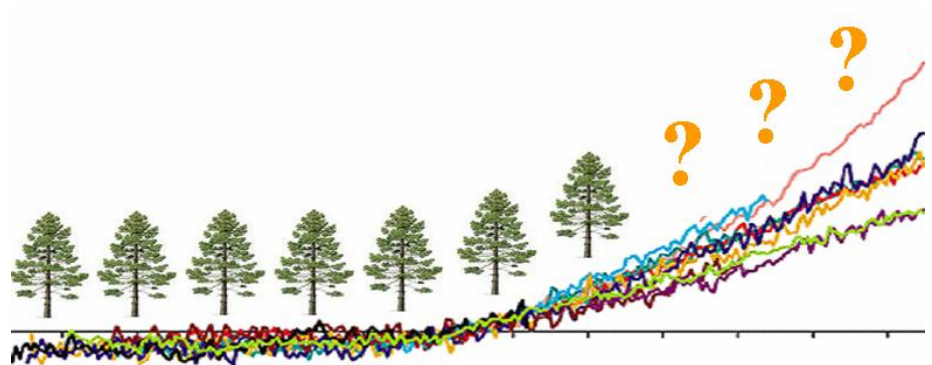
Features and limits of the current SPU

- Geographic-based and easy to use
- Effective for local adaptation

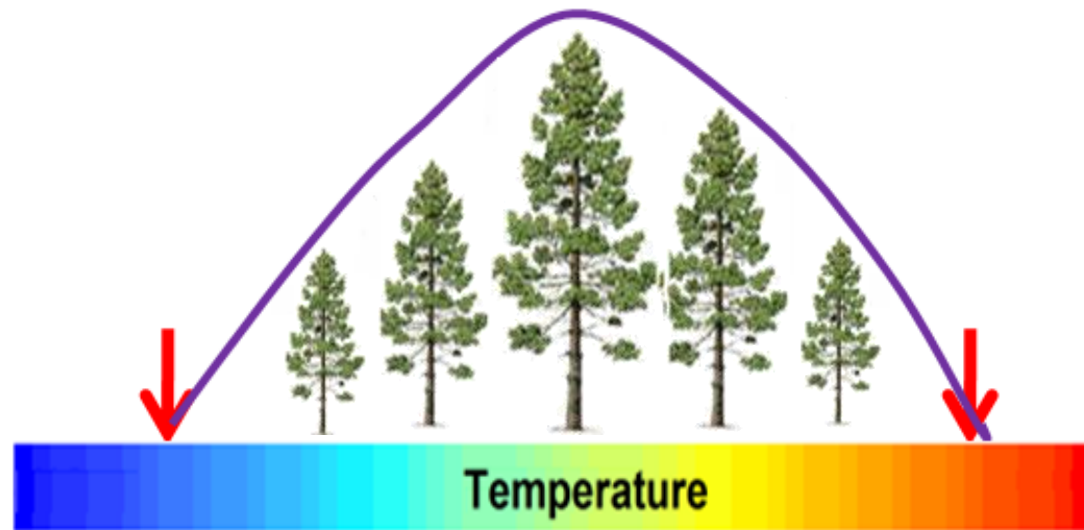


Features and limits of the current SPU's

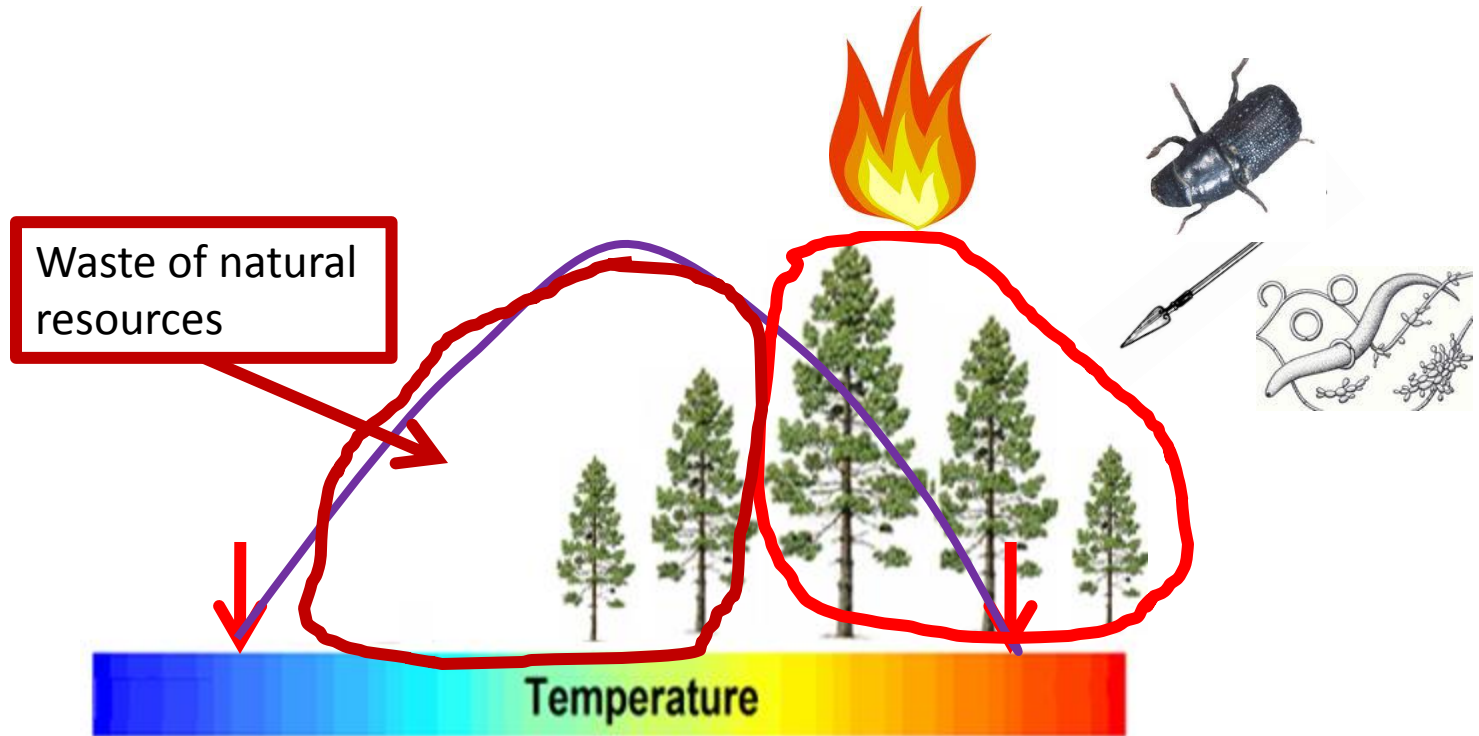
- Geographic-based and easy to use
- Effective for local adaptation
- Not suitable for a changing climate because “the local climate” is moving away



Climate changes causes mismatches between
the climate that trees adapted and
the climate that trees are going to experience



Some existing trees will move out
their suitable climate habitat



We need a system that can help trees matching their suitable climate

Objectives

- To develop a climate-based seed transfer system (CSTS) that can
 - Take advantage of the current seed transfer system;
 - Consider the shifts in climate envelopes under climate change;
 - Can be dynamically adjusted with time.

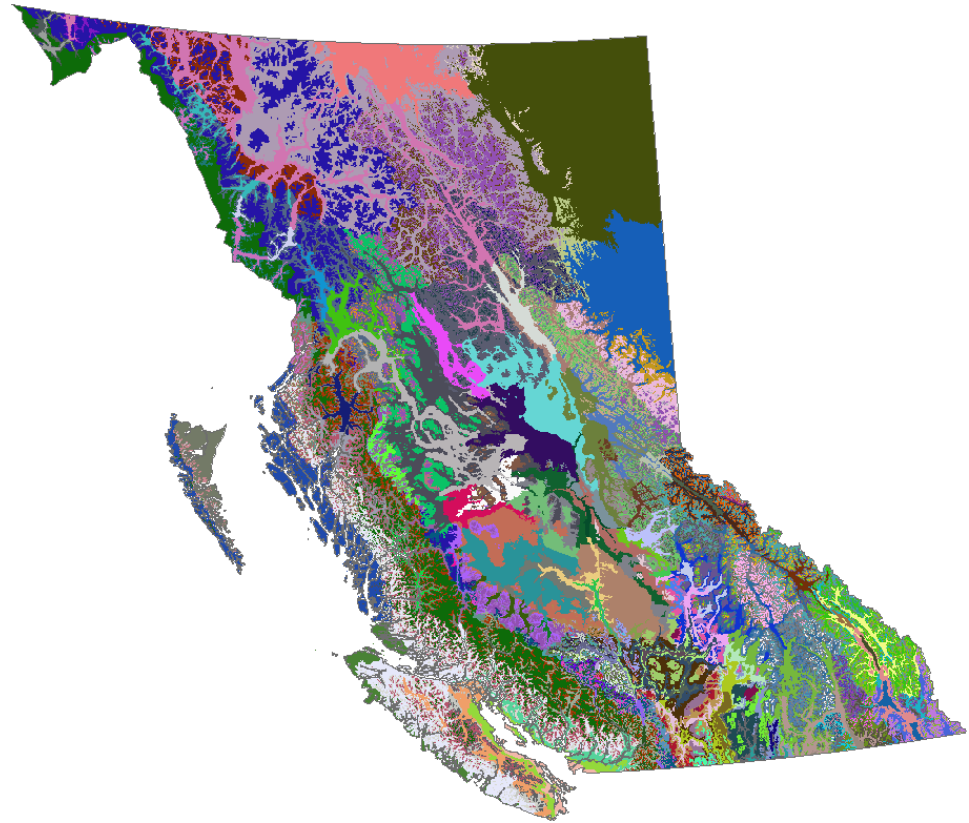
The approach:

--Put the SPUs on the “flight” of BEC zones

- What we need to do:
 - To find the right “seats” – BEC units
 - To fine tune the “seats” – modifications of the BEC units
 - To educate the “passengers” – modelling the climate envelopes for the SPUs

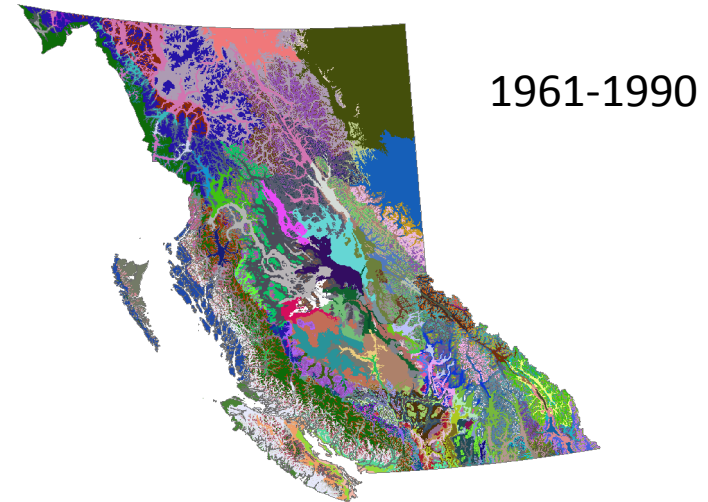
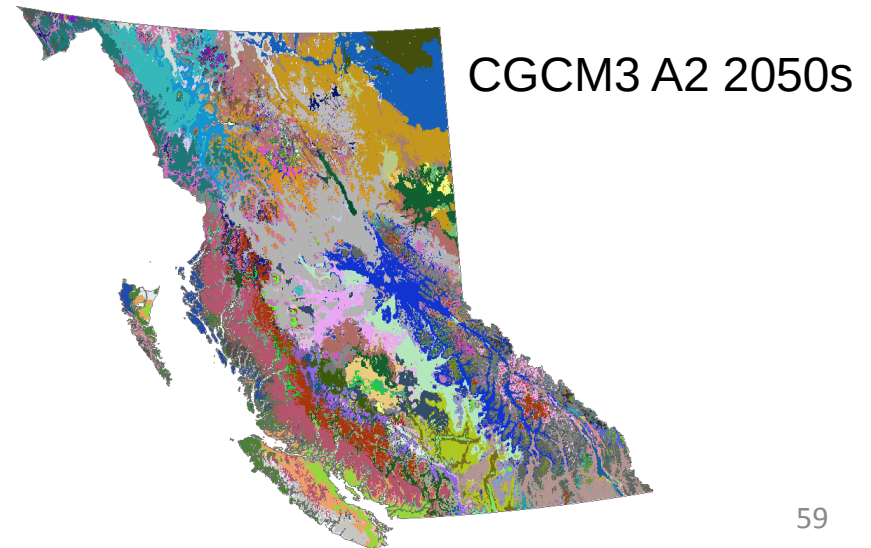
Climate envelopes for BEC variants are the right “seats” for SPUs

- Climatically uniform within each unit in term of supporting the same plant community
- A reasonable number (205) of units
- Some variants need to be modified
 - ESSF wcp: 2, 3, 4, 6
 - ESSF wcw: 2, 3, 4, 6
 - ESSF.mvp: 1, 2, 3, 4
 - ESSF.xvp: 1, 2
- We have 215 Climate-based Seed Transfer Units (CSTUs) ([Thanks to Adrian Walton for generating the GIS layer](#))



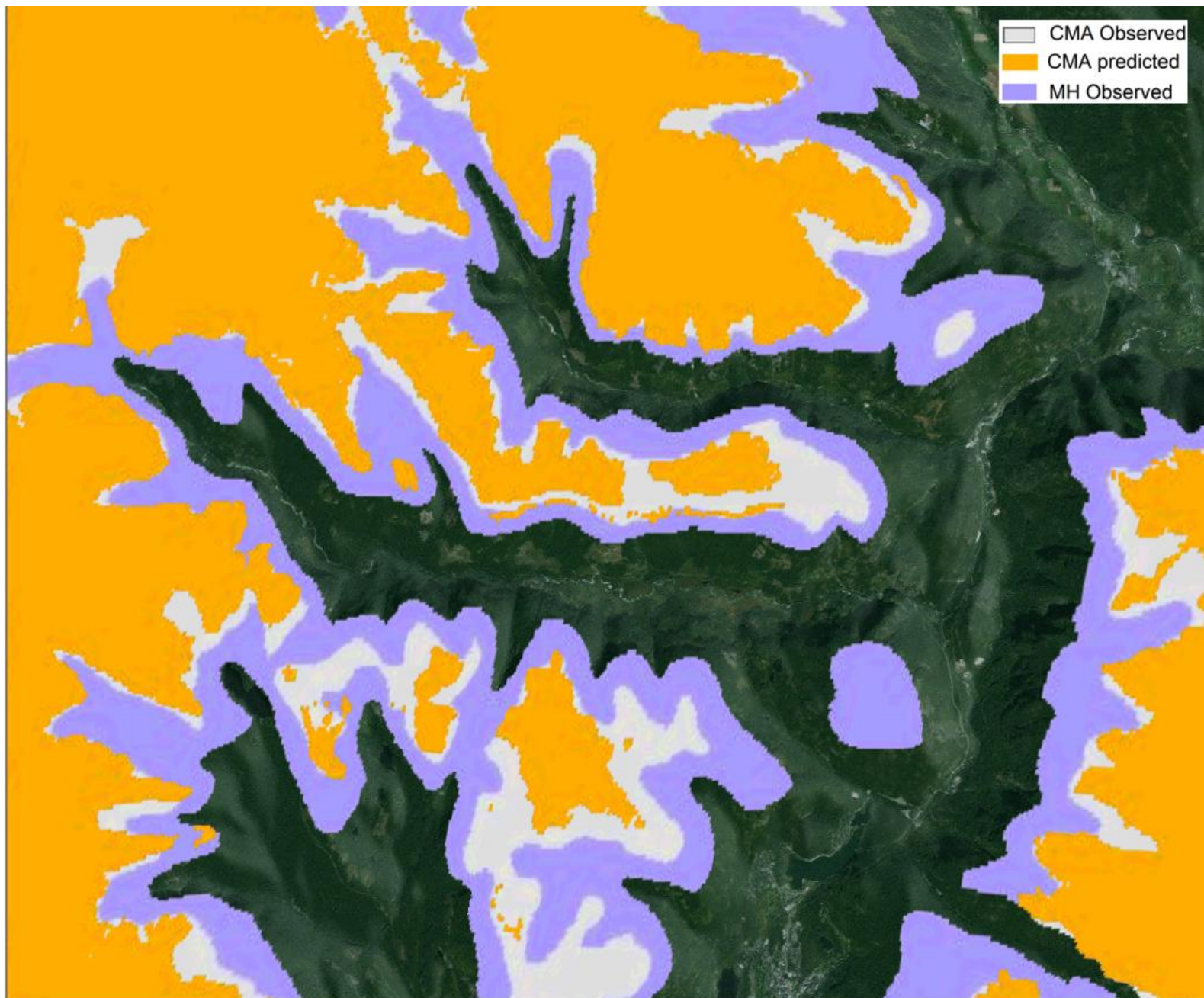
Modeling and projecting the CSTUs

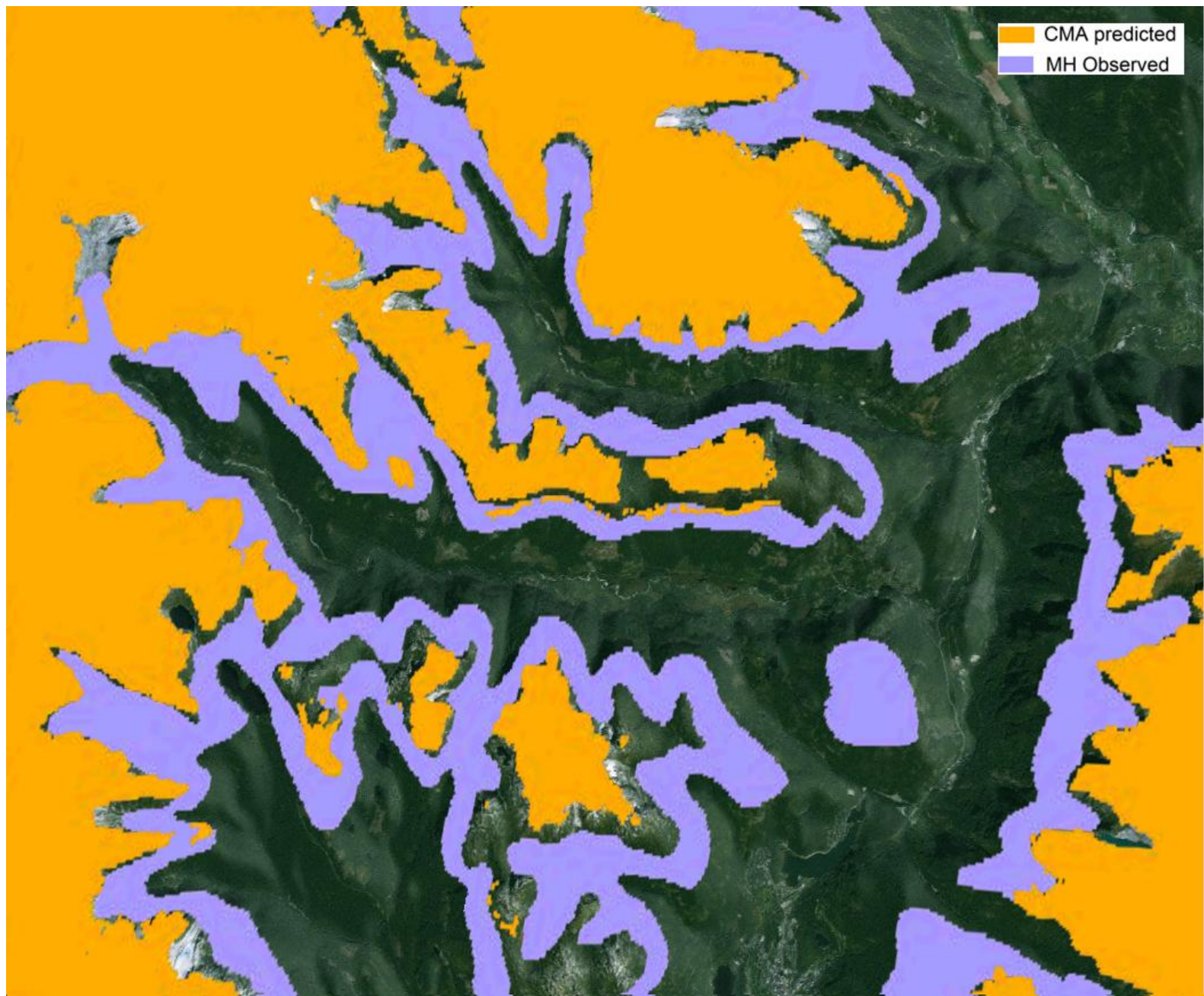
- Bioclimate envelopes were modeled using Random Forest for CSTUs
- And projected for future periods
 - E.g., CGCM3 A2 run4 for demonstration



To educate the “passenger”: We converted current SPUs to climate based SPUs

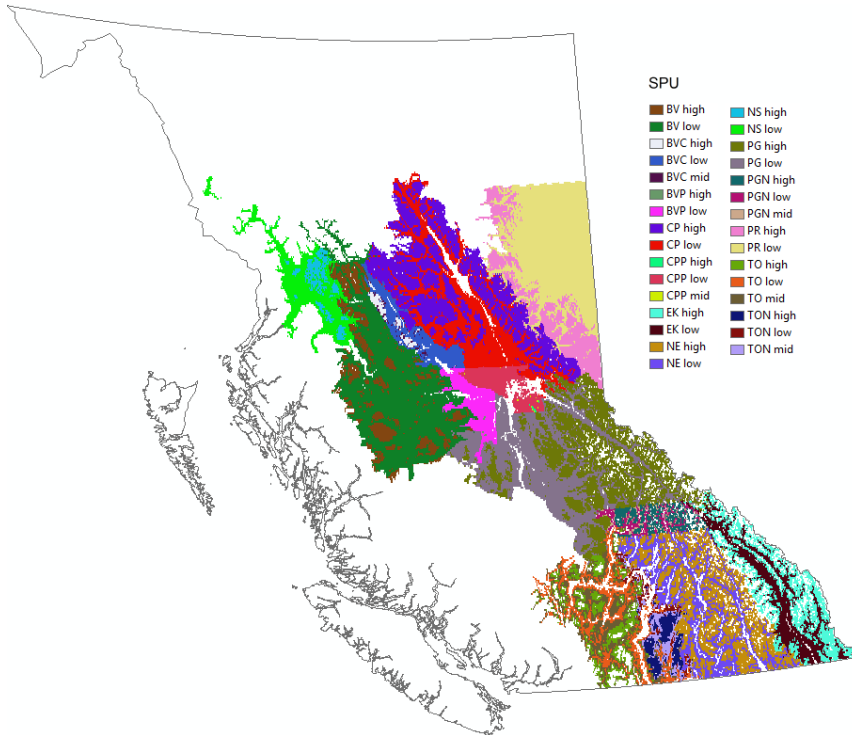
- Approach:
 - Model the climate envelopes of the current SPUs using Random Forest
- Assumptions:
 - Current SPUs are, in general, reasonably delineated and effective for local adaptation
- Expectations
 - To correct some errors in current SPUs
 - To expand ranges beyond current SPUs
 - These expectations are based on the power of Random Forest predictions in modeling the BEC variants



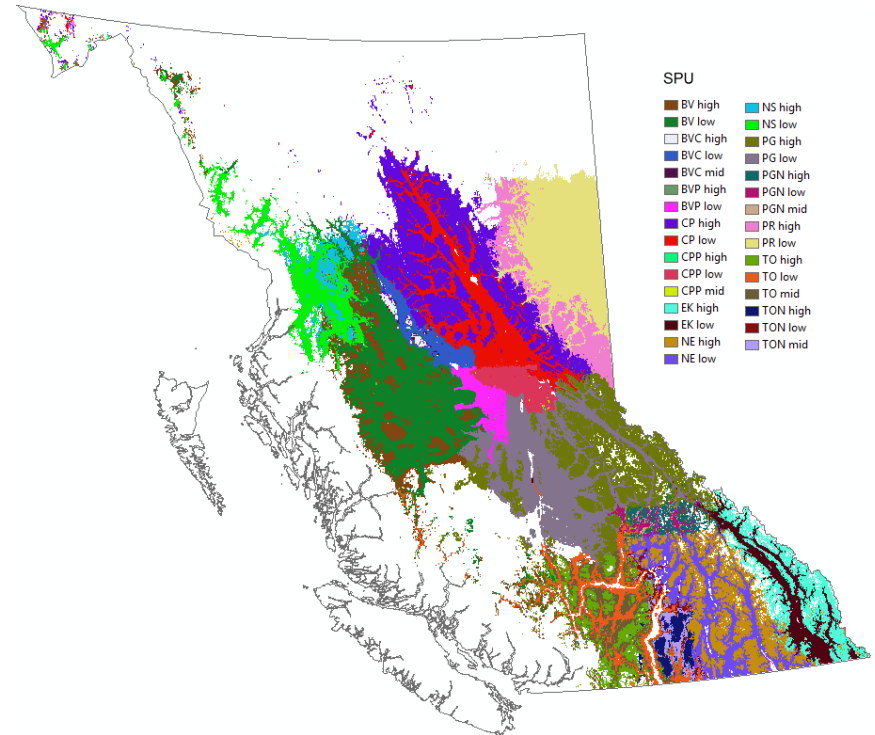


Climate envelopes of the SPUs are predicted using Random Forest

Current SPUs

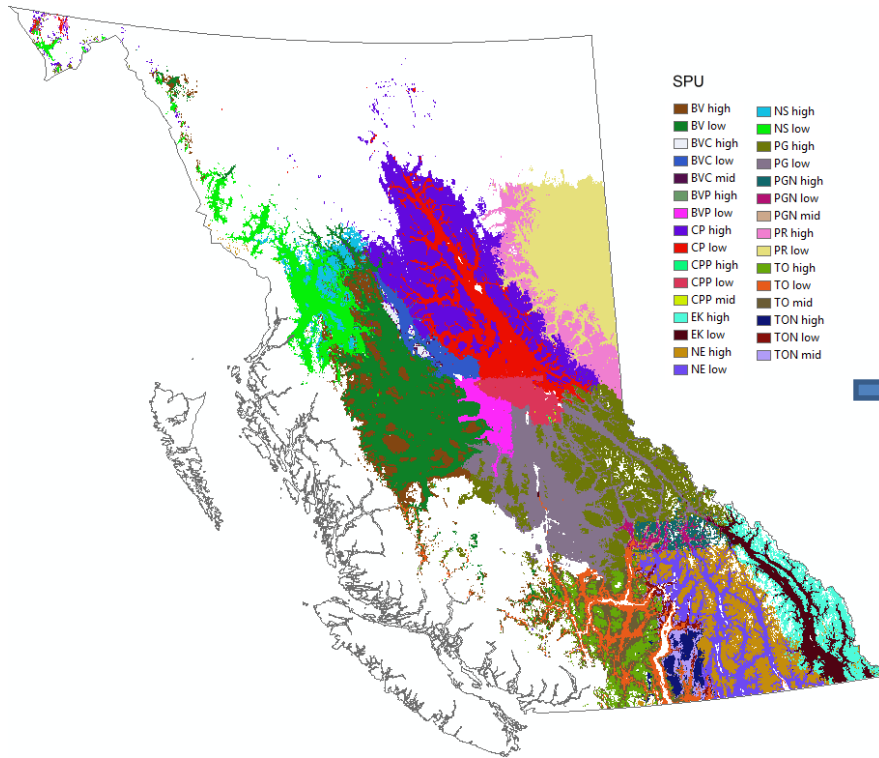


Climate envelopes of SPUs

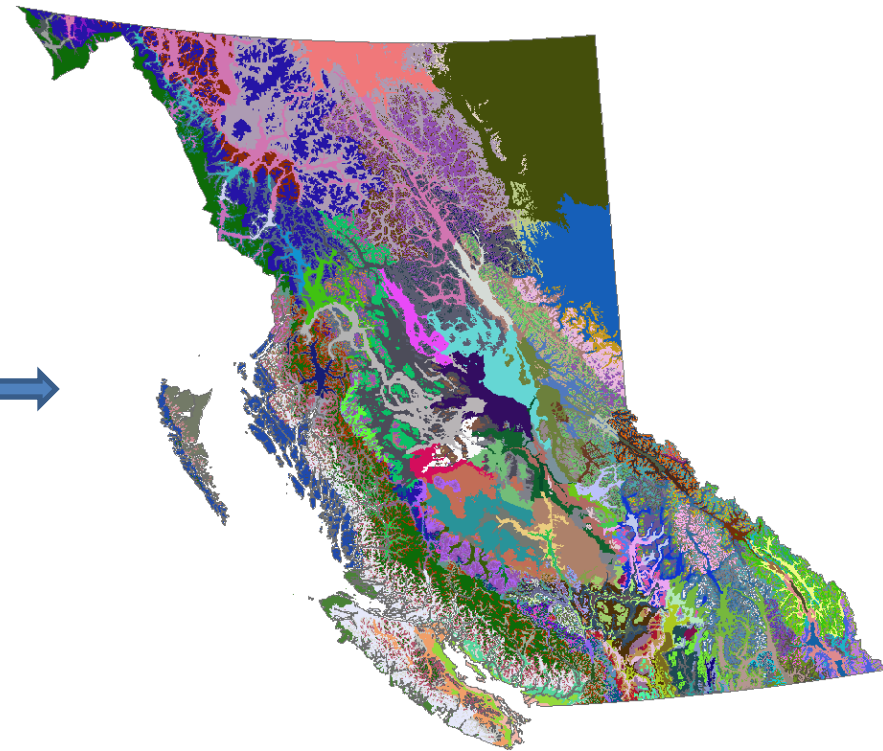


Migrating climate based SPUs to CSTUs

Climate envelopes for
current SPUs



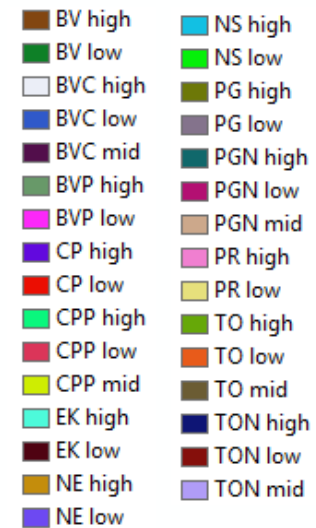
Modified BEC variants (CSTUs)



A maximum probability approach is used to deal with multiple matches

Lodgepole pine

SPU



Climate-based seed transfer
Units for 1961-1990

NS low

PR high

SPU

- | | |
|----------|----------|
| BV high | NS high |
| BV low | NS low |
| BVC high | PG high |
| BVC low | PG low |
| BVC mid | PGN high |
| BVP high | PGN low |
| BVP low | PGN mid |
| CP high | PR high |
| CP low | PR low |
| CPP high | TO high |
| CPP low | TO low |
| CPP mid | TO mid |
| EK high | TON high |
| EK low | TON low |
| NE high | TON mid |
| NE low | |

NE low

CGCM3 A2 run4 2050s

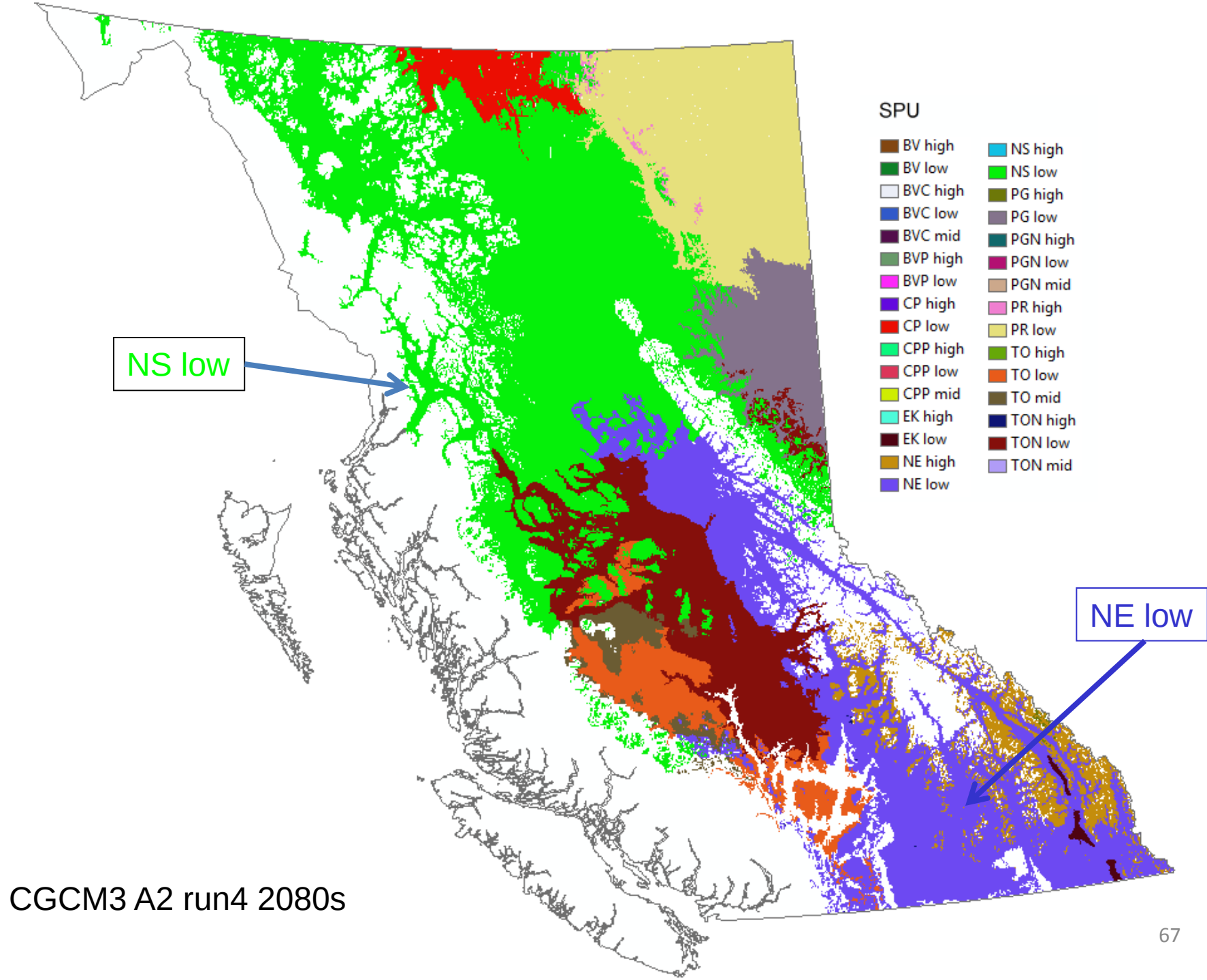


Table 1. List of CSTUs for each SPU of Lodgepole pine (Pli) for **2010-2039**.

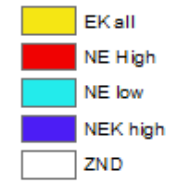
Pli SPU	CSTU (BEC variant)
BV high	BAFAun, BAFAunp, BWBSun, ESSFmcp, ESSFmvp1, ESSFmvp3, ESSFmvp4, ESSFwv, ESSFwvp, SWB mk, SWB mks
CP low	BWBSdk 2
EK high	ESSFdku
EK low	IDF dm 2, IDF xk, MS dk 2, PP dh 2
NE high	ESSFdk 1, ESSFdk 2, ESSFdkp, ESSFdkw, ESSFdmp, ESSFdmw, ESSFvc, ESSFvcp, ESSFvcw, ESSFwc 1, ESSFwc 4, ESSFwc 5, ESSFwc 6, ESSFwcp2, ESSFwcp4, ESSFwcp6, ESSFwcw4, ESSFwcw6, ESSFwm, ESSFwmp, ESSFwmw
NE low	ESSFdm, ESSFmm 1, ESSFmm 2, ESSFmmw, ESSFwc 2, ESSFwc 3, ESSFwcw2, ESSFwk 2, ICH dm, ICH dw 1, ICH dw 2, ICH dw 3, ICH mk 4, ICH mm, ICH mw 1, ICH mw 2, ICH mw 3, ICH mw 4, ICH vk 1, ICH vk 2, ICH wk 1, ICH wk 2, ICH wk 3, ICH wk 4, ICH xw, IDF un, MS dk 1, SBS dh 2, SBS vk, SBS wk 1
NS low	BWBSvk, BWBSwk 1, ESSFmc, ESSFmv 1, ESSFmv 2, ESSFmv 3, ESSFmvp2, ICH mc 1, ICH mc 2, ICH vc, SBS mc 2, SBS mk 1, SBS mk 2, SBS wk 2, SBS wk 3
PG high	ESSFdcp, ESSFmmp, ESSFwcp3, ESSFwcw3, IMA un
PG low	SBPSdc, SBPSmc, SBPSmk, SBS mc 3
PGN low	SBS dh 1, SBS dw 3
PR high	BWBSwk 2, BWBSwk 3, ESSFmv 4
PR low	BWBSmw 1, BWBSmw 2
TO high	ESSFdc 3, ESSFxc 1, ESSFxc 3, MS xk 1, MS xk 3, SBS mc 1, SBS mm
TO low	BG xh 3, BG xw 1, IDF dc, IDF dk 1, IDF dk 2, IDF dk 5, IDF dm 1, IDF mw 2, IDF xc, IDF xh 1, IDF xh 2, IDF xh 4, IDF xw, MS dc 1, MS dc 3, MS dm 1, MS xk 2, PP xh 3, SBS dk, SBS dw 1, SBS dw 2, SBS mh, SBS mw
TO mid	ICH mk 2, IDF dk 3, MS dm 2, MS dm 3
TON high	ESSFdc 1, ESSFdcw, ESSFwk 1, ESSFxc 2
TON low	ICH dk, ICH mk 3, IDF mw 1
TON mid	ICH mk 1

Table 3. A matrix showing the shift in SPUs in future climates

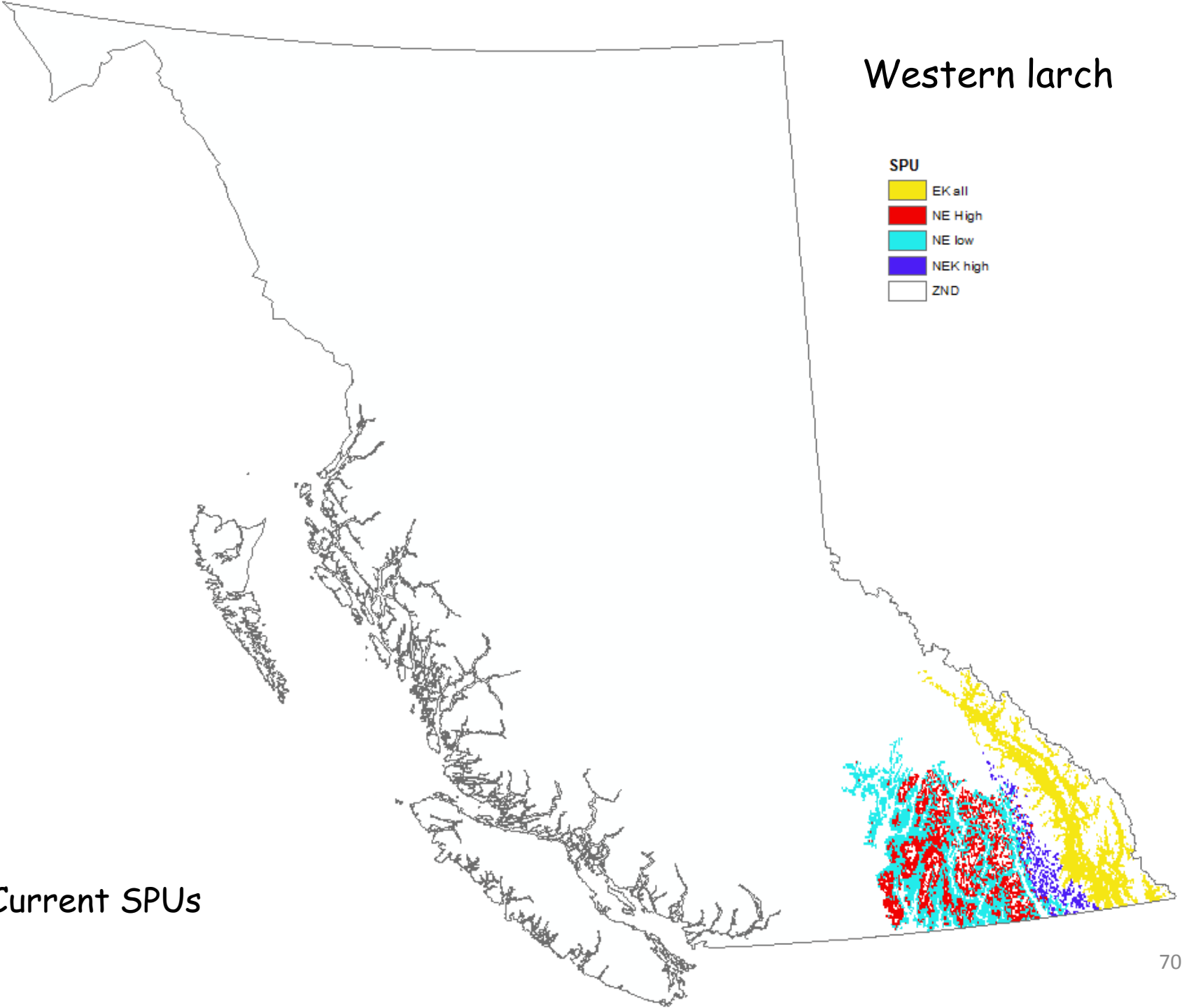
CSTU (variant)	spu1975	spu2001-2009	spu2020s	spu2050s	spu2080s
BAFAun	ZND	CP high	BV high	PR high	NS low
BAFAunp	ZND	ZND	BV high	ZND	ZND
BG xh 1	ZND	ZND	ZND	ZND	ZND
BG xh 2	ZND	ZND	ZND	ZND	ZND
BG xh 3	TO low	TO low	TO low	ZND	ZND
BG xw 1	TO low	TO low	TO low	ZND	ZND
BG xw 2	ZND	ZND	ZND	TO low	ZND
BWBSdk 1	ZND	ZND	ZND	ZND	NS low
BWBSdk 2	ZND	ZND	CP low	CP low	CP low
BWBSmw 1	PR low	PR low	PR low	PG low	PG low
BWBSmw 2	ZND	ZND	PR low	PR low	PR low
BWBSun	ZND	ZND	BV high	ZND	ZND
BWBSvk	NS low	ZND	NS low	ZND	ZND
BWBSwk 1	PR high	PR high	NS low	NS low	TON low
BWBSwk 2	PR high	PR high	PR high	PR high	NS low
BWBSwk 3	ZND	PR high	PR high	PR high	PR high
CWH vh 2	ZND	ZND	ZND	ZND	ZND
CWH vm	ZND	ZND	ZND	ZND	ZND
CWH xm 2	ZND	ZND	ZND	ZND	ZND
ESSFdc 1	TON high	TON mid	TON high	TON mid	NE low
ESSFdc 2	TO high	TO high	ZND	ZND	ZND
ESSFdc 3	PG high	NS low	TO high	TON mid	NE low
ESSFdcp	NE high	PG high	PG high	TON high	TON high
ESSFdcw	TON high	TON high	TON high	TON high	NE low
ESSFdk 1	EK high	NE high	NE high	NE low	NE low
ESSFdk 2	EK high	EK high	NE high	NE high	NE high

Western larch

SPU

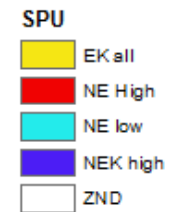
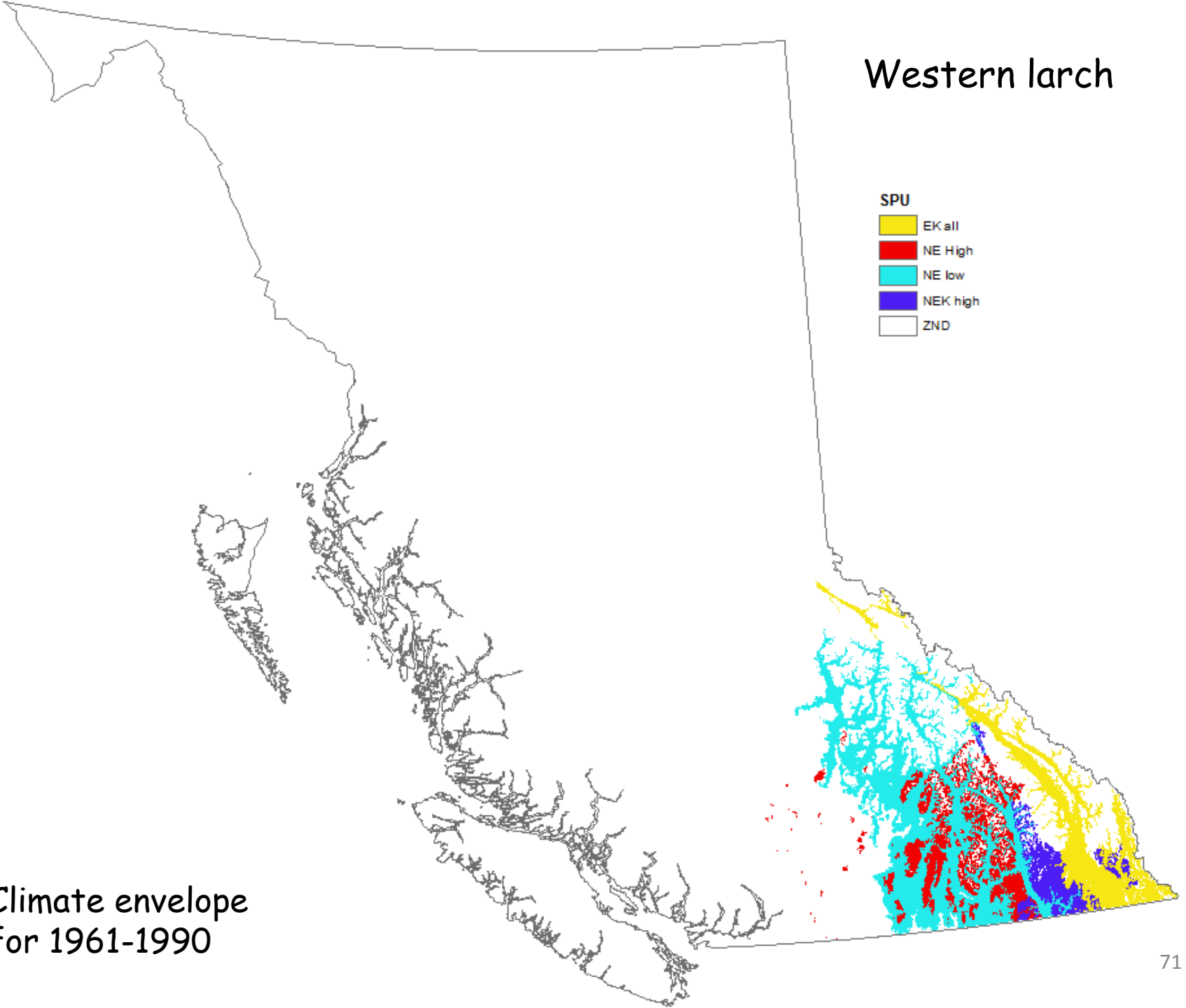


Current SPUs



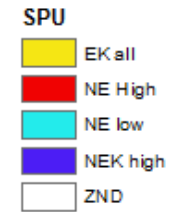
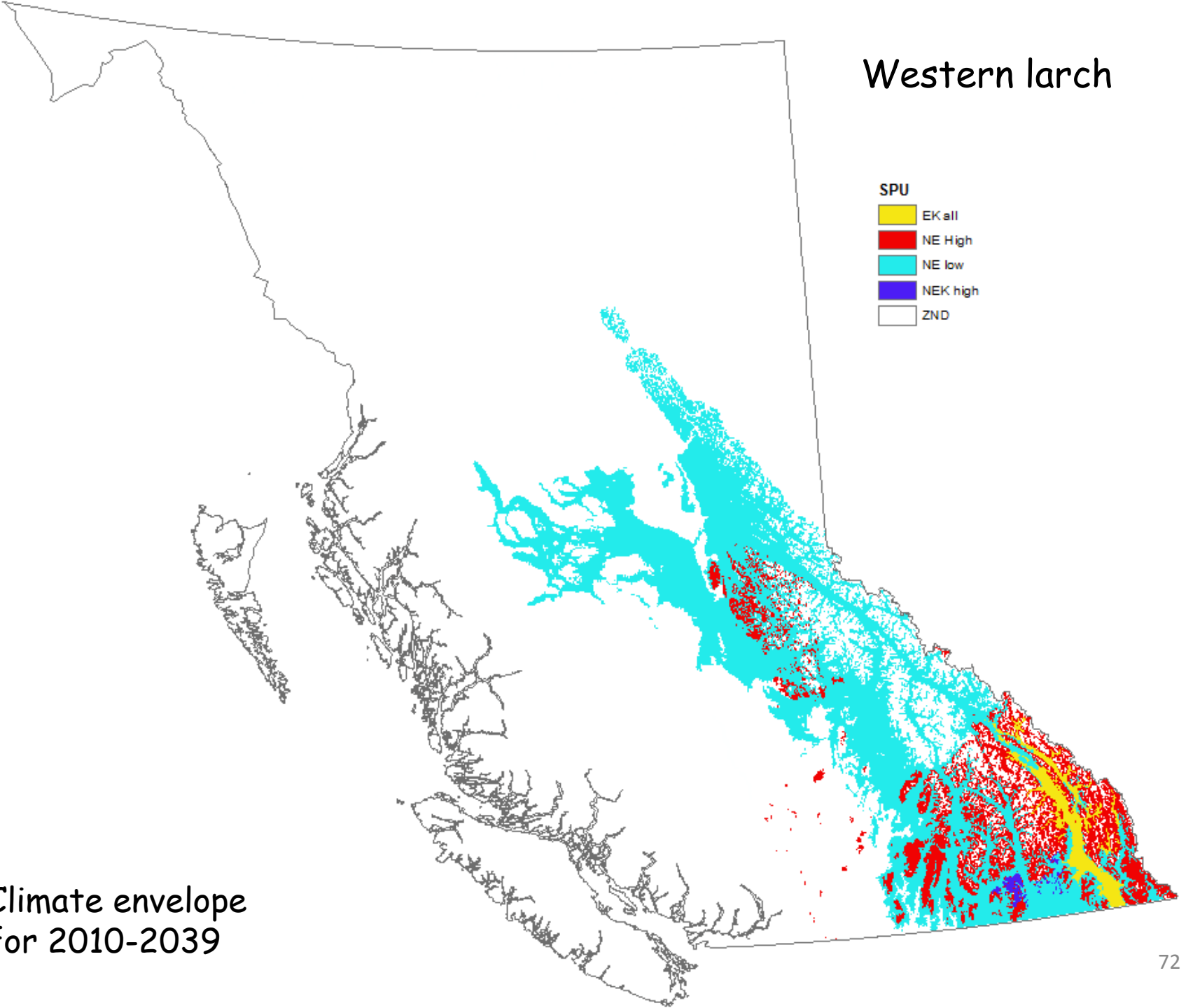
Western larch

Climate envelope
for 1961-1990



Western larch

Climate envelope
for 2010-2039



Western larch

SPU

- EK all
- NE High
- NE low
- NEK high
- ZND

Climate envelope
for 2040-2069

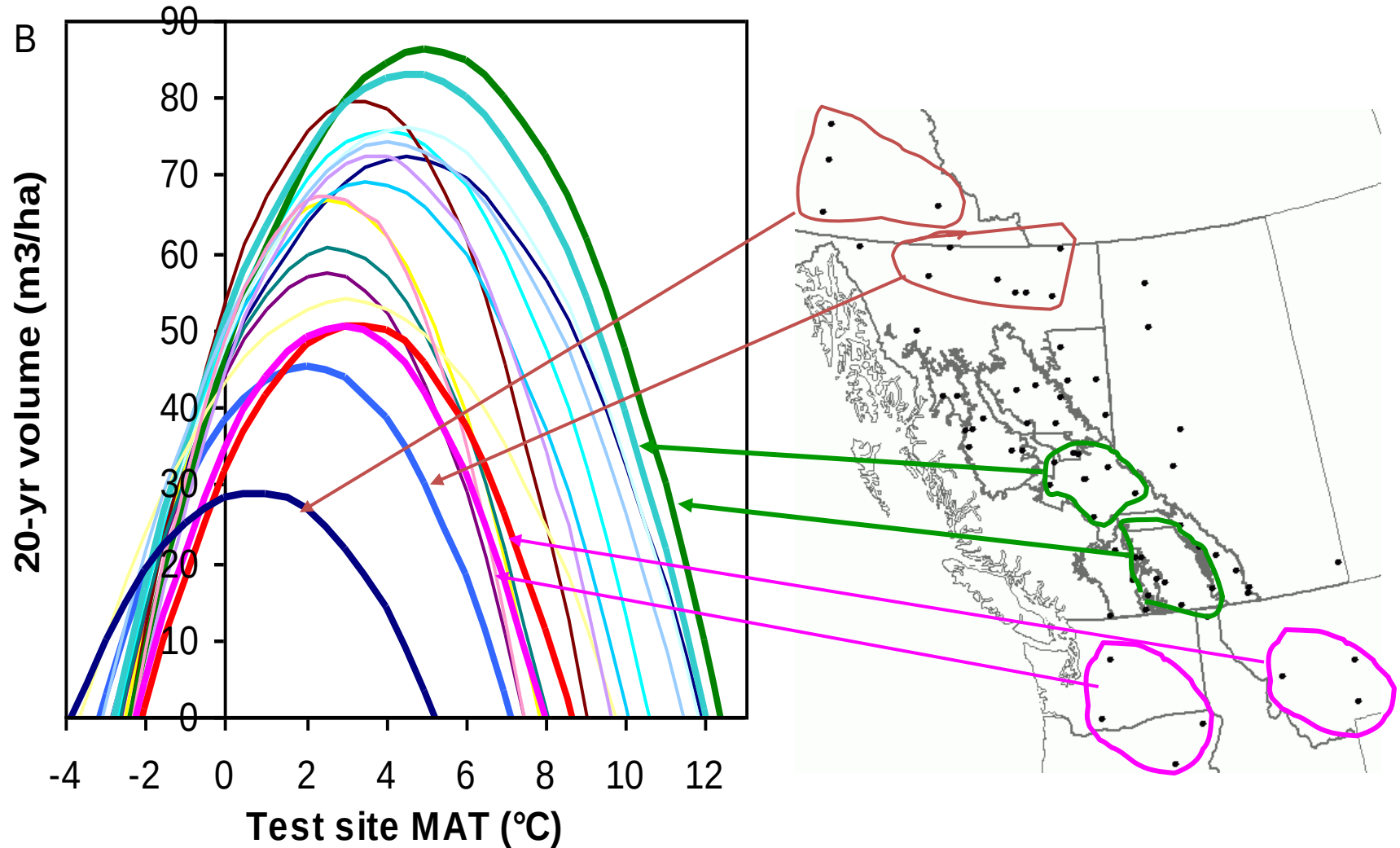
Summary of the CST system

- Maintain “local is the best”, but in term of climate rather than geographic locations
 - Use local seed to match the “flying” local climate
- Can be dynamically adjusted under a changing climate
- Easy to implement: using either a matrix or maps

What is the next?

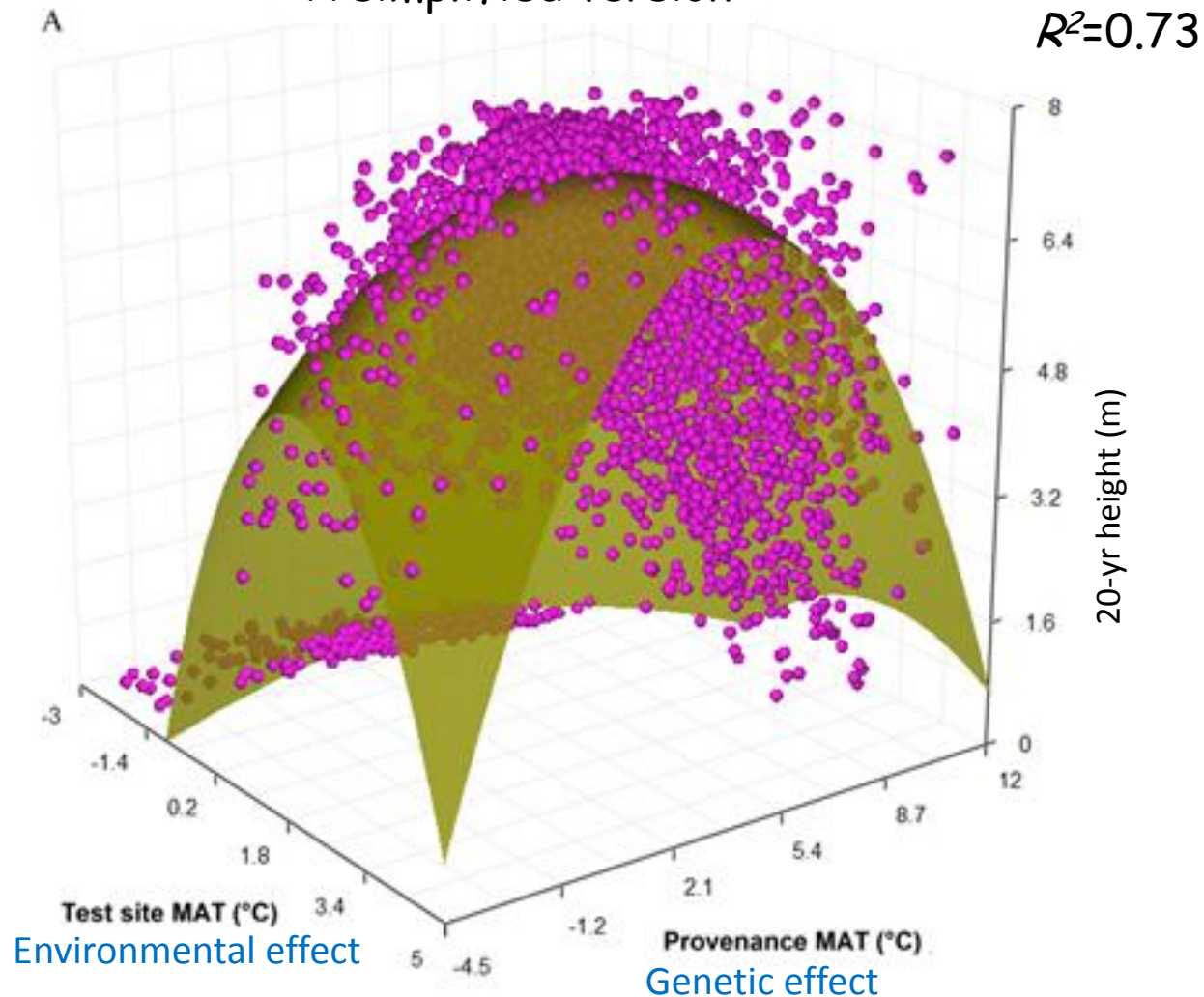
- Apply consensus projections
 - In progress
- Move from “local is the best” to an optimal seed transfer system
 - Integrating genecology results

To incorporate climate response functions of SPUs into the system



For the populations not tested, the universal response function can be used

A simplified version



What is the next?

- Apply consensus projections
 - In progress
- Move from “local is the best” to an optimal seed transfer system
 - Integrating genecology results
- A multi-million Genome Canada project, led by Aitken and Hamann, to improve the climate-based seed transfer system



Acknowledgements

- People:
 - Jack Woods, Adrian Walton, Will MacKenzie and Alvin Yanchuk
- Funding:
 - BC Seed Transfer TAC
 - FGC
 - BC FFESC