

# **Modeling the Future Impacts of Climate Change on Douglas Fir and Spruce Forests in British Columbia**

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Ministry of Forests and Range Climate Change Seminar Series

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**Pacific Climate Impacts Consortium**

## Introduction

This MoFR Forest Science Program funded project is focused on examining the impact of projected climate change on spruce and Douglas fir forests in British Columbia.

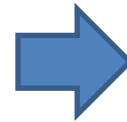
Research is focused on the impacts of climate change on:

- 1) Climatic suitability for these tree species
- 2) The occurrence of outbreaks of relevant forest pests
- 3) Forest health in economic terms



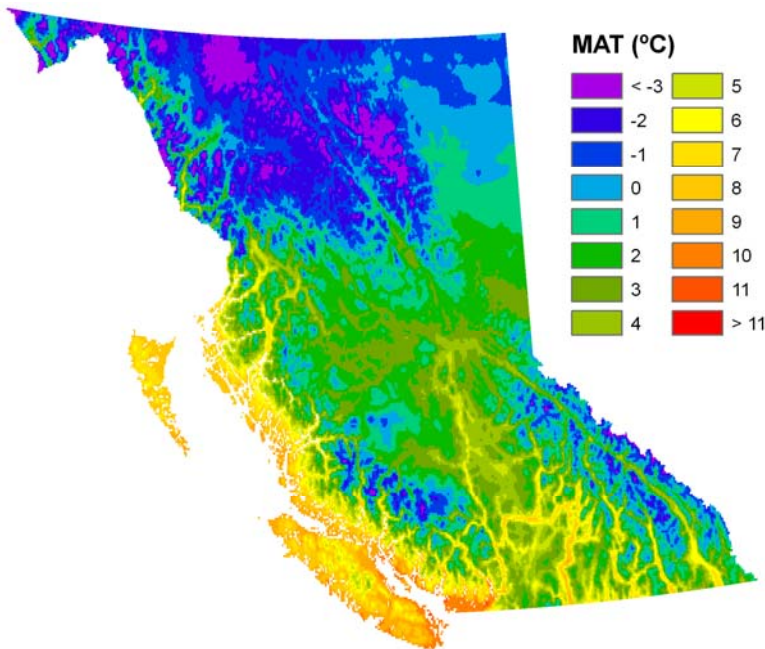
# Changing Climates

- Increasing temperatures in all seasons
- Increasing winter precipitation
- Decreasing summer precipitation

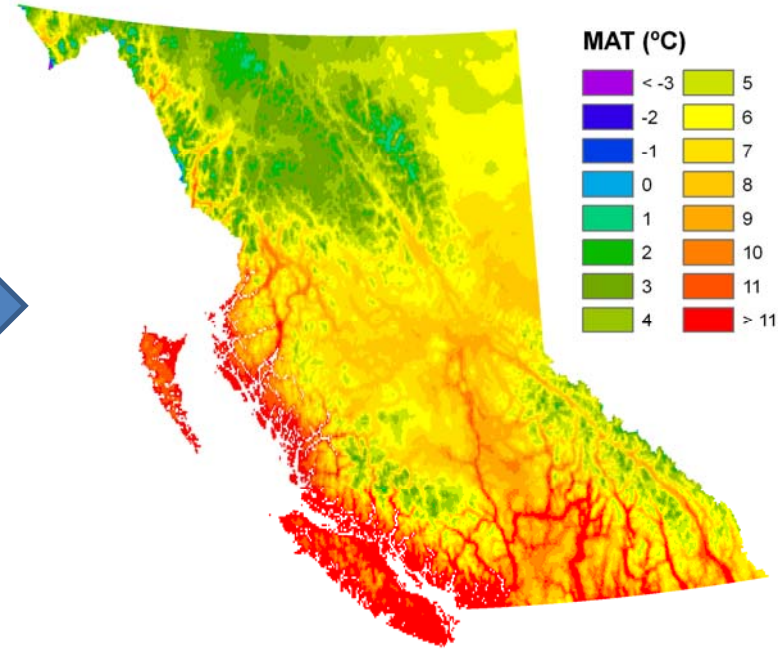


**What does this  
mean for species  
and ecosystems?**

1961-1990 Mean Annual Temperature

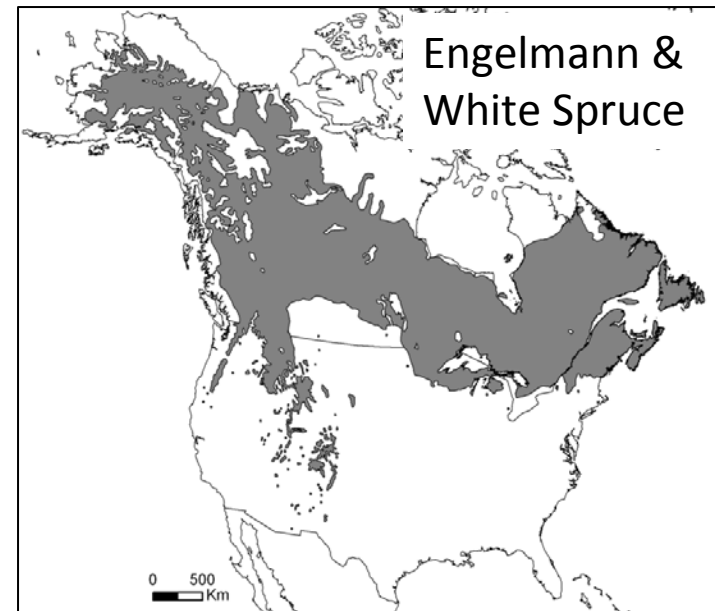
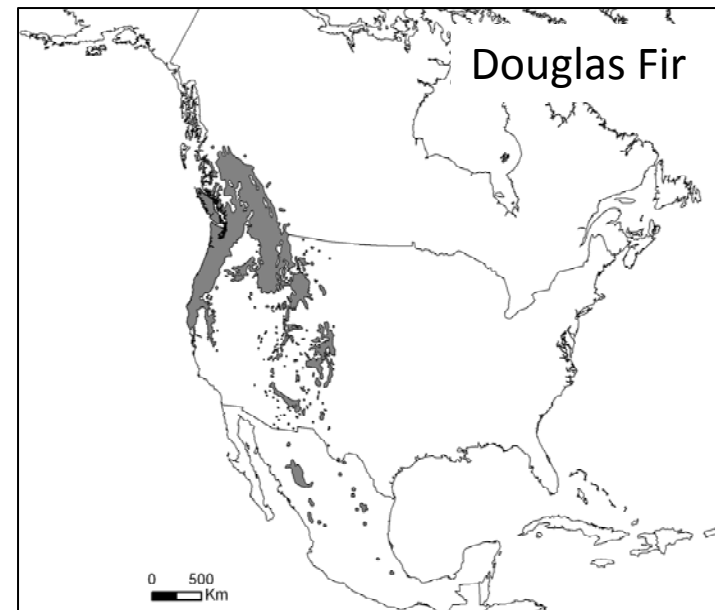


2080s Mean Annual Temperature

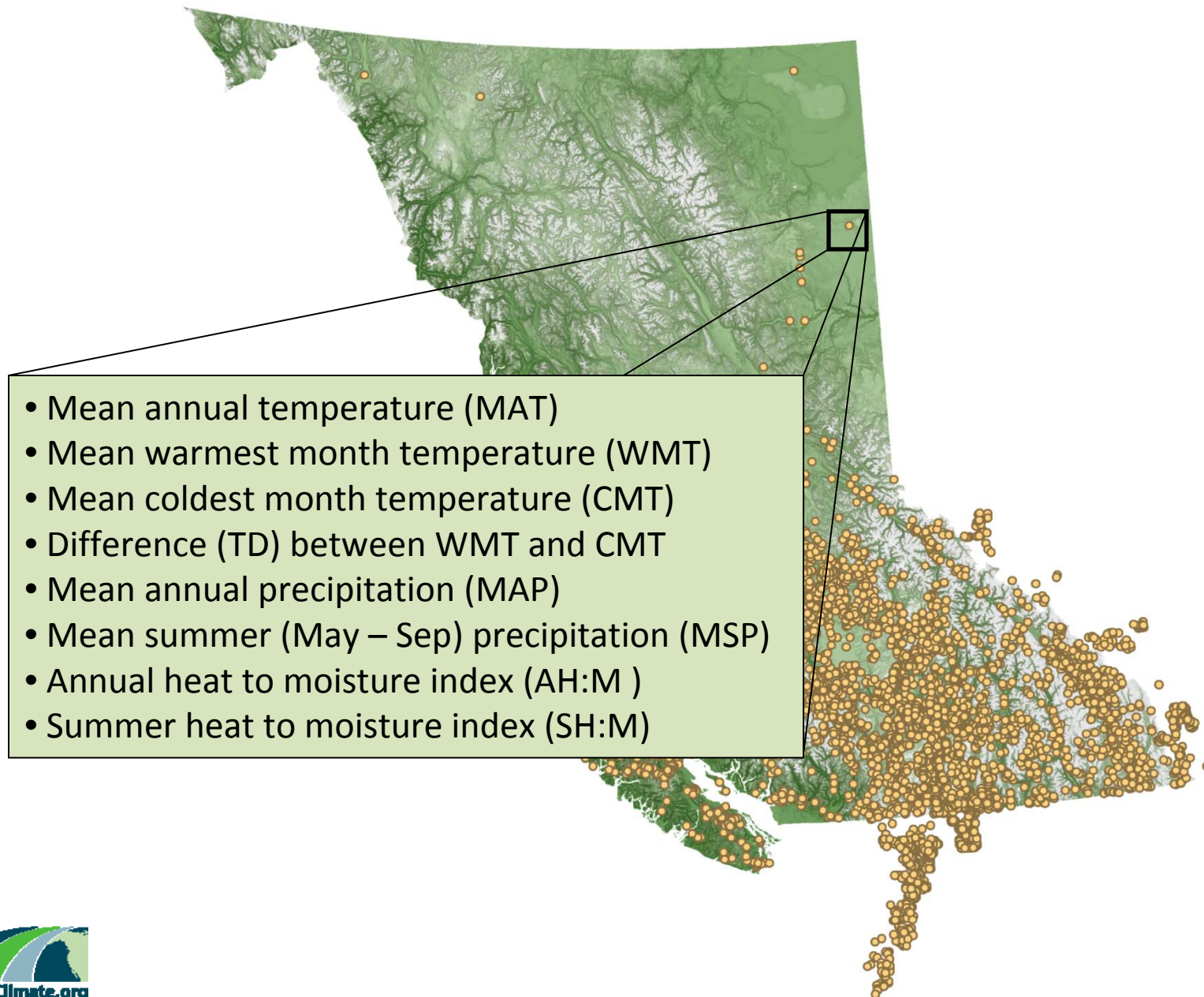


## Bioclimatic Envelope Models

- Use historical climate data to define species' ranges
- Climate projections can be used to find where these climate envelopes will exist in the future
- Based on climate data only; soils, competition, etc. not included
- General Linear Models, RandomForests, simple quantile envelopes, Principal Component / Factor Analysis

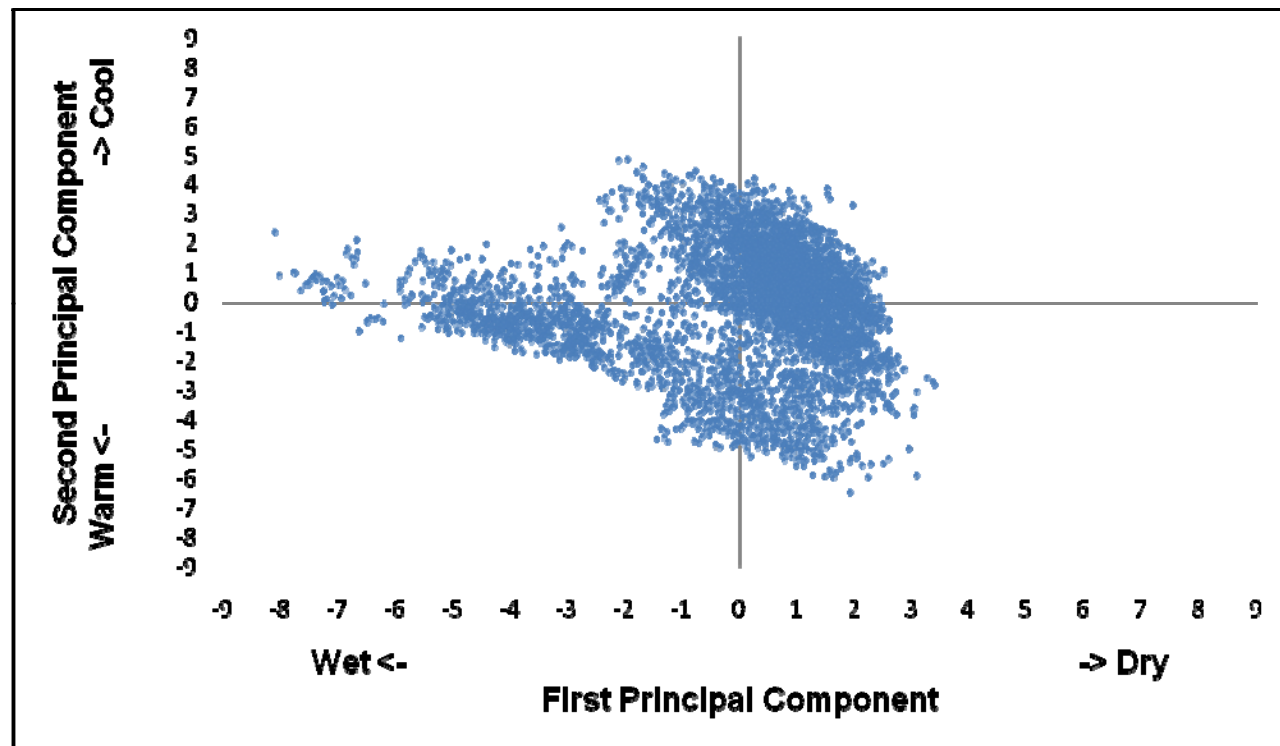


## Douglas Fir (*Pseudotsuga menziesii*) Vegetation Survey Plots

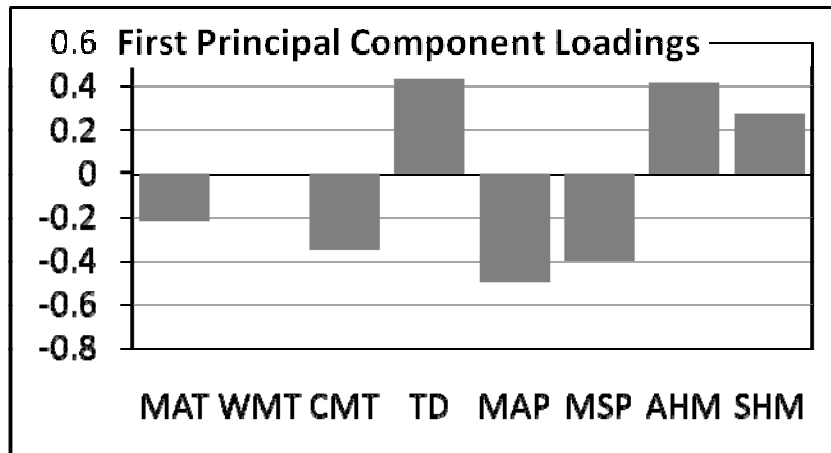


## Bioclimatic Envelope Modelling Methods

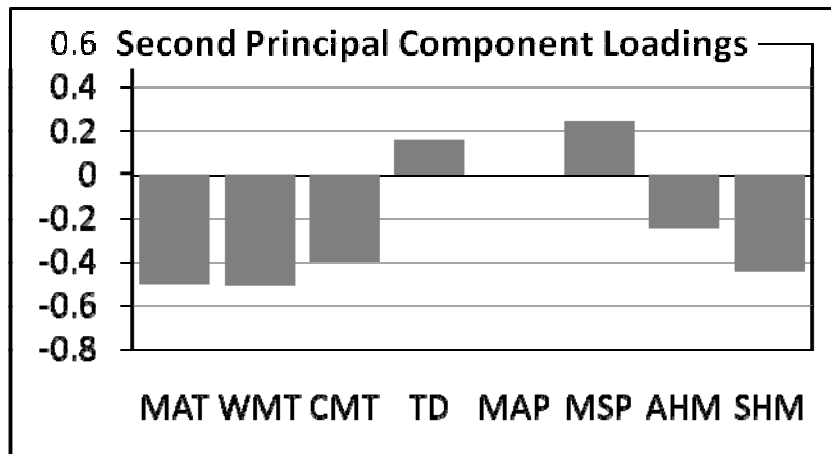
- Followed methods outlined in Robertson *et al.* 2001
- Principal components analysis (PCA) used to define the climatic envelopes
- Uses presence-only species records
- Multivariate approach, PCs are linear re-combinations of the eight climate variables



## Douglas Fir Model Component Loadings

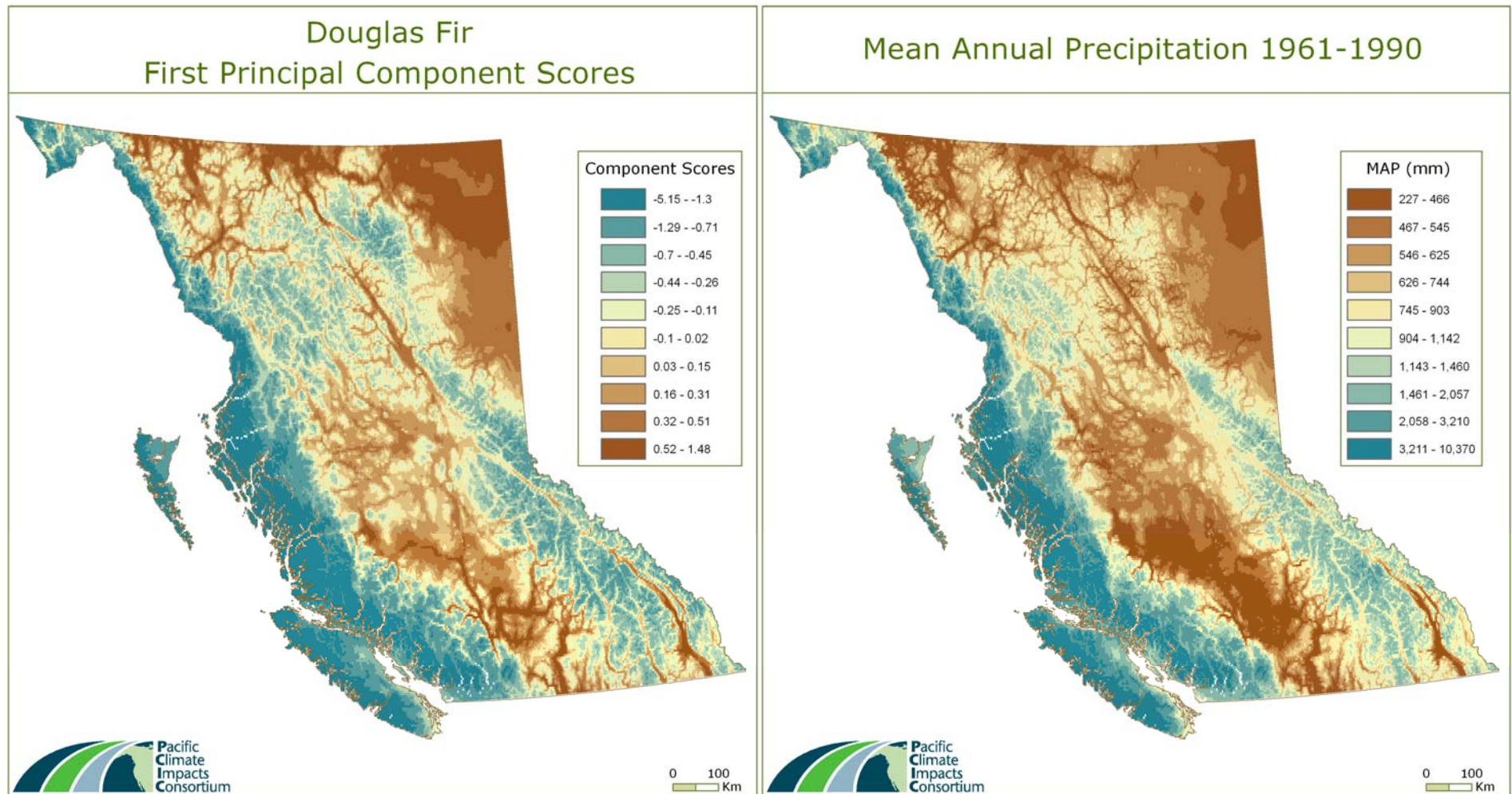


The first principal component primarily represents a southwest-northeast **precipitation gradient**, and can be interpreted as reflecting the differences in the precipitation regimes of the coastal maritime climates and the interior continental climates.

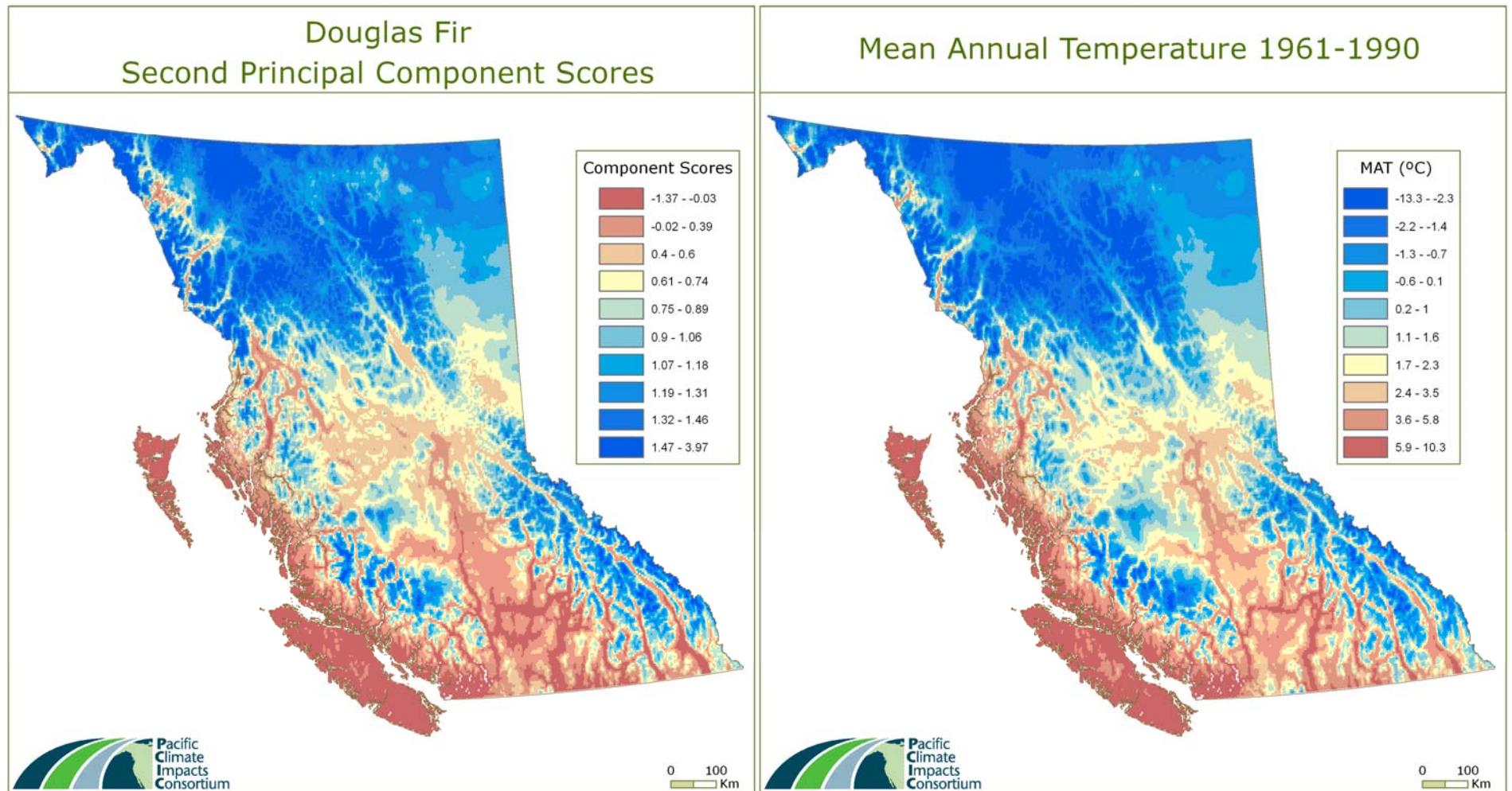


The second principal component primarily represents a **temperature gradient** and can be interpreted as reflecting elevational and latitudinal gradients between warmer valley bottoms (and coastal areas) and colder mountainous and northern interior regions.

# Douglas Fir Bioclimatic Envelope Model – First Principal Component



## Douglas Fir Bioclimatic Envelope Model – Second Principal Component

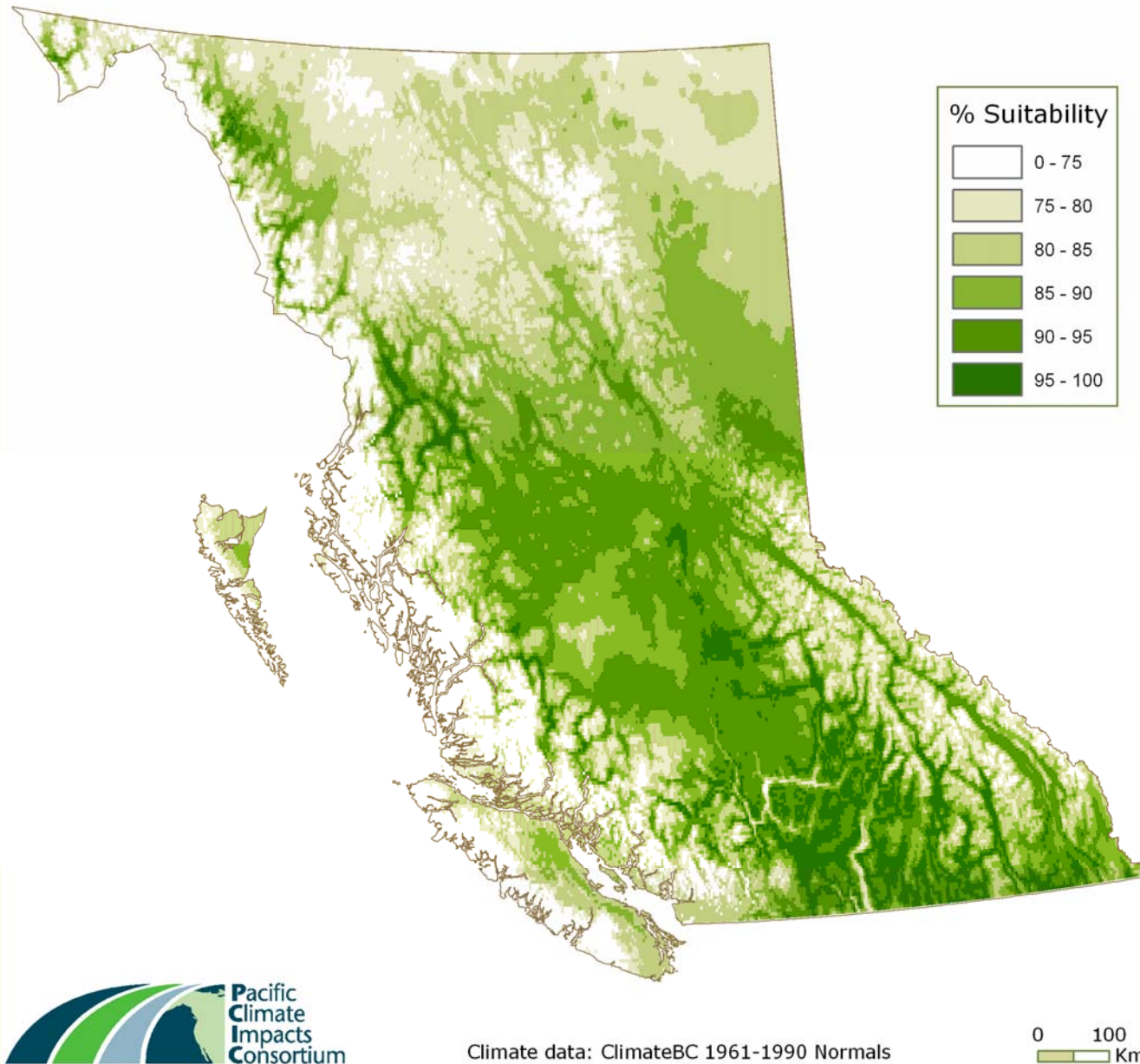


## Bioclimatic Envelope Modelling Methods

- **Eight climate variables extracted at ~4 kilometer resolution for the entire province**
- **Distance from the center of the envelope calculated for each grid cell**
  - Climate variables standardized using the mean & S.D. calculated from presence records
  - Variables multiplied by their loading on each component and divided by the associated eigenvalue, giving a standardized score on each component
  - Scores for each component are squared and summed
  - Square root of scores taken, giving Euclidian distance from the centre of the envelope
  - **Percent suitability calculated** as:  $(1 - (\text{Euclidian distance} / \text{maximum 1961-1990 Euclidian distance}))$
- **Results calculated and mapped using ArcCatalog and ArcMap software**

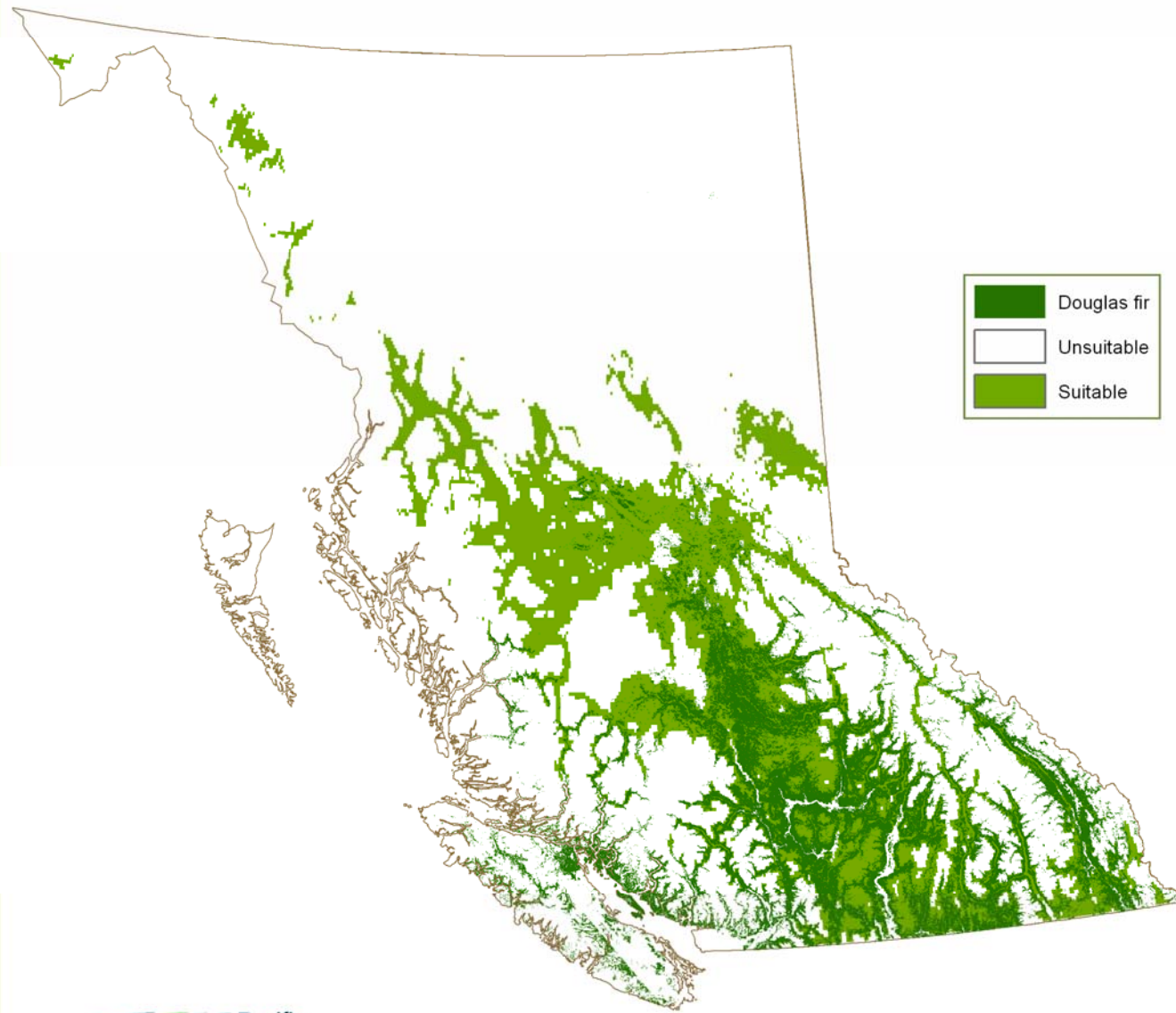
# Present Day Douglas Fir Suitability

Relative 1961-1990 Climatic Suitability



# Present Day Douglas Fir Suitability

Relative 1961-1990 Climatic Suitability Compared to Actual Distribution

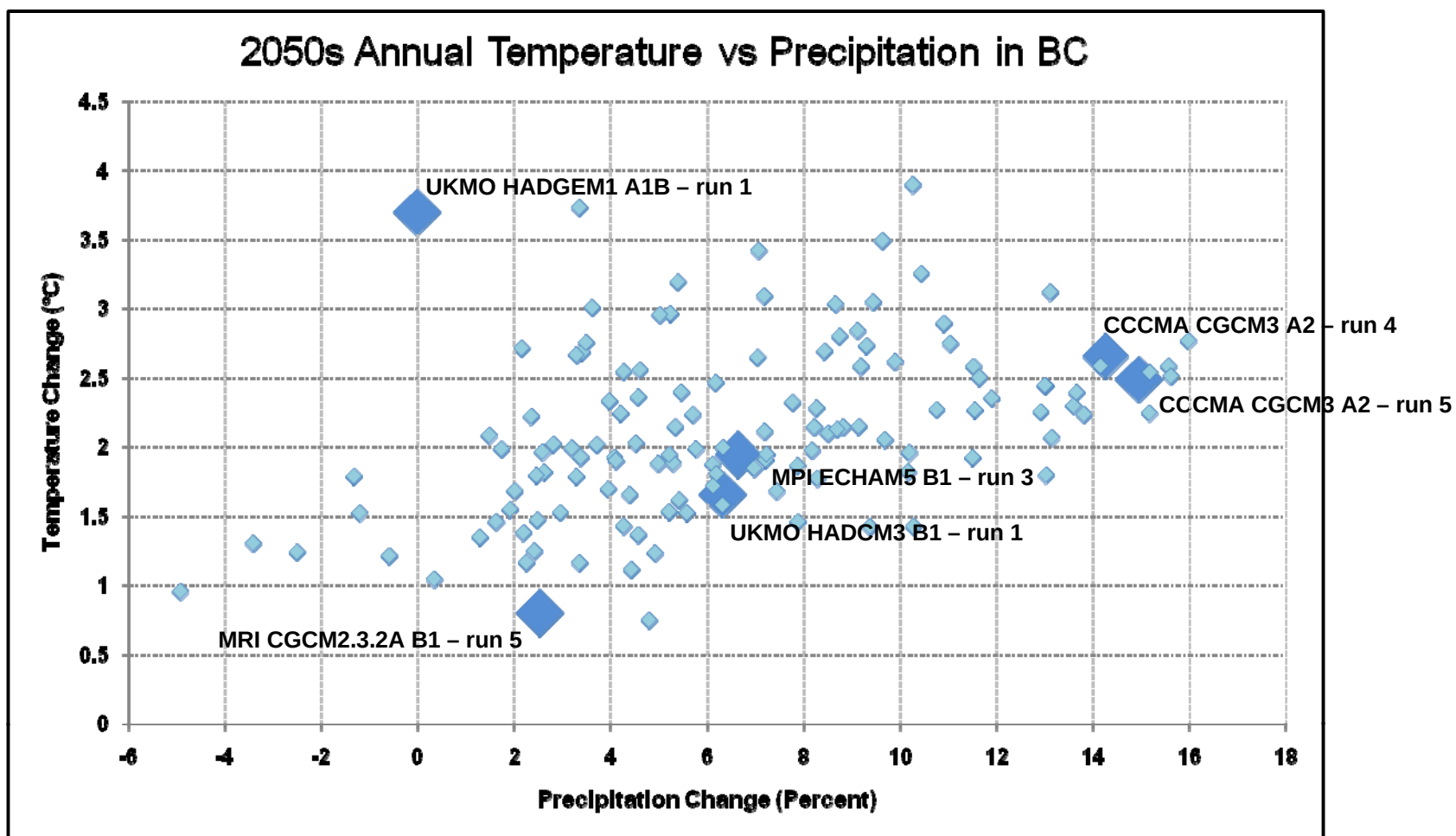


## Projected Climate Data

| Climate Model                                              | Emissions scenario / run | BC 2050s Temperature change (°C) | BC 2050s Precipitation change (%) |
|------------------------------------------------------------|--------------------------|----------------------------------|-----------------------------------|
| Meteorological Research Institute of Japan: MRI_CGCM2.3.2A | B1 – run 5               | <b>0.8</b>                       | <b>3</b>                          |
| Hadley Centre Coupled Model: UKMO_HADCM3                   | B1 – run 1               | <b>1.7</b>                       | <b>6</b>                          |
| European Centre Hamburg Model: MPI_ECHAM5                  | B1 – run 3               | <b>1.9</b>                       | <b>7</b>                          |
| Canadian Global Climate Model: CCCMA_CGCM3                 | A2 – run 5               | <b>2.5</b>                       | <b>15</b>                         |
| Canadian Global Climate Model: CCCMA_CGCM3                 | A2 – run 4               | <b>2.7</b>                       | <b>14</b>                         |
| Hadley Centre Global Environmental Model: UKMO_HADGEM      | A1B – run 1              | <b>3.7</b>                       | <b>0</b>                          |

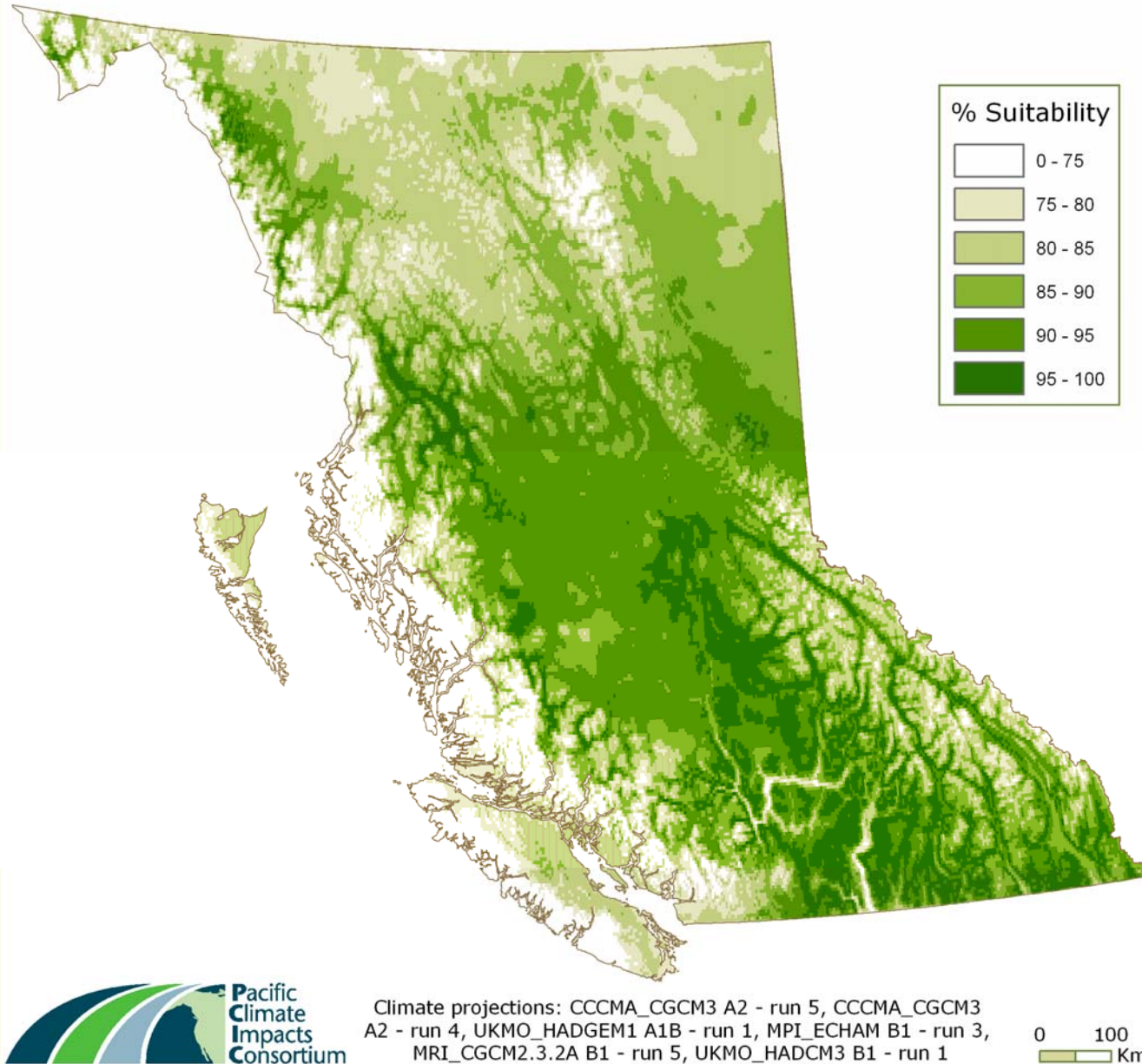
| All SRES AR4     | BC 2050s Temperature change (°C) | BC 2050s Precipitation change (%) |
|------------------|----------------------------------|-----------------------------------|
| 90 <sup>th</sup> | <b>3.0</b>                       | <b>13%</b>                        |
| Median           | <b>2.0</b>                       | <b>6%</b>                         |
| 10 <sup>th</sup> | <b>1.3</b>                       | <b>2%</b>                         |

## Projected Climate Data



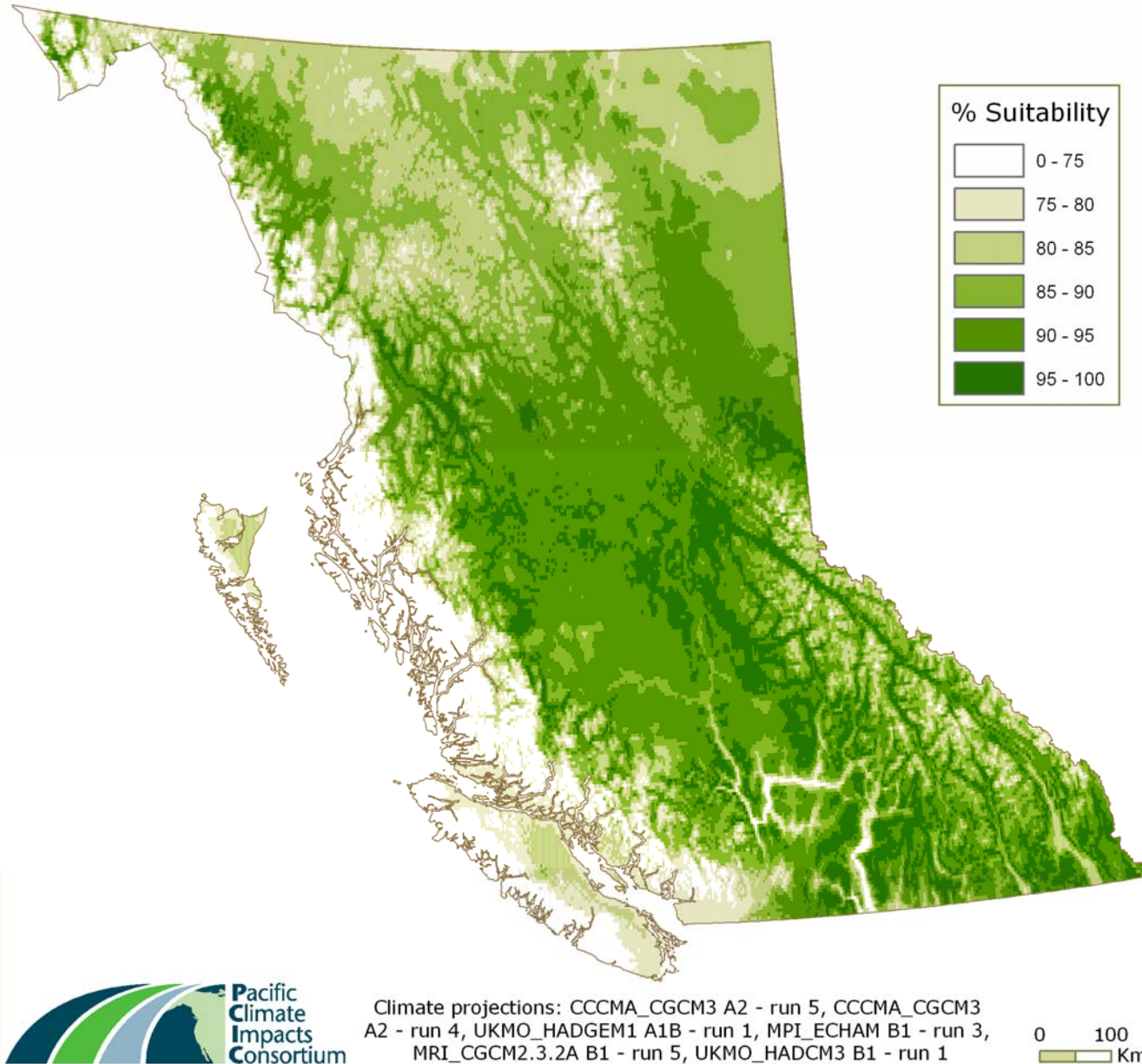
# 2020s Douglas Fir Suitability

Relative Climatic Suitability Based on Six Climate Projections



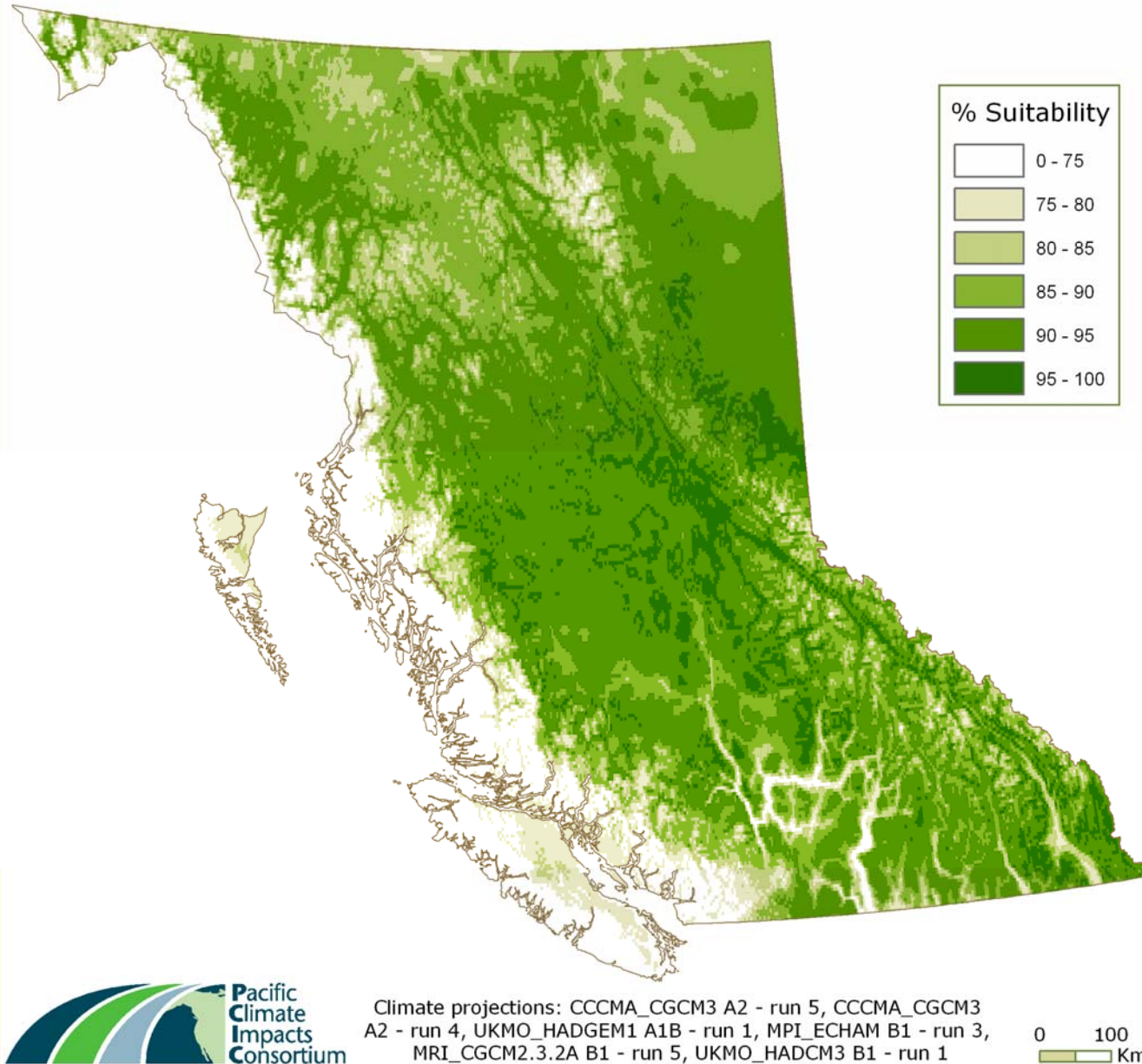
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Relative Climatic Suitability Based on Six Climate Projections



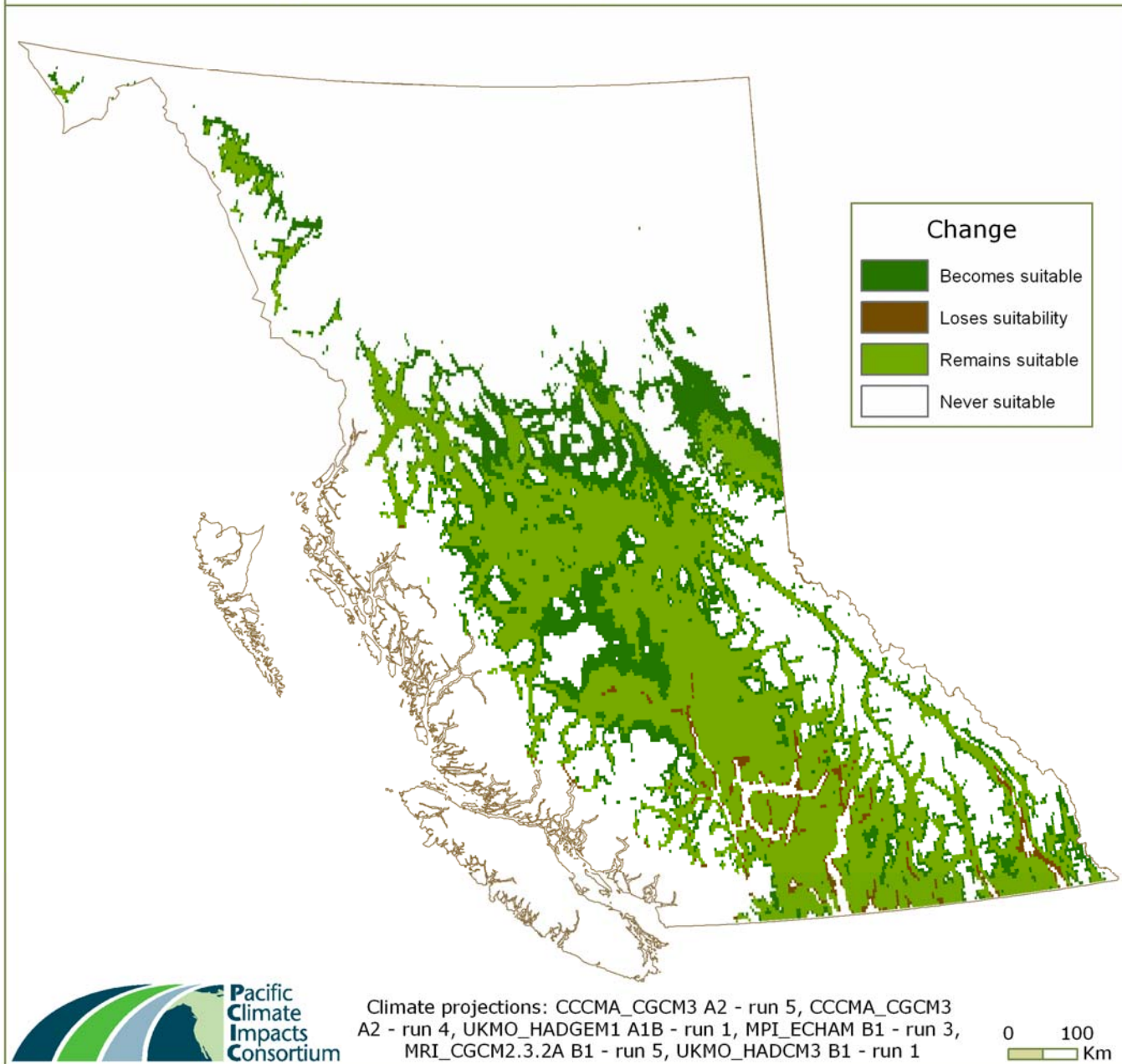
# 2080s Douglas Fir Suitability

Relative Climatic Suitability Based on Six Climate Projections



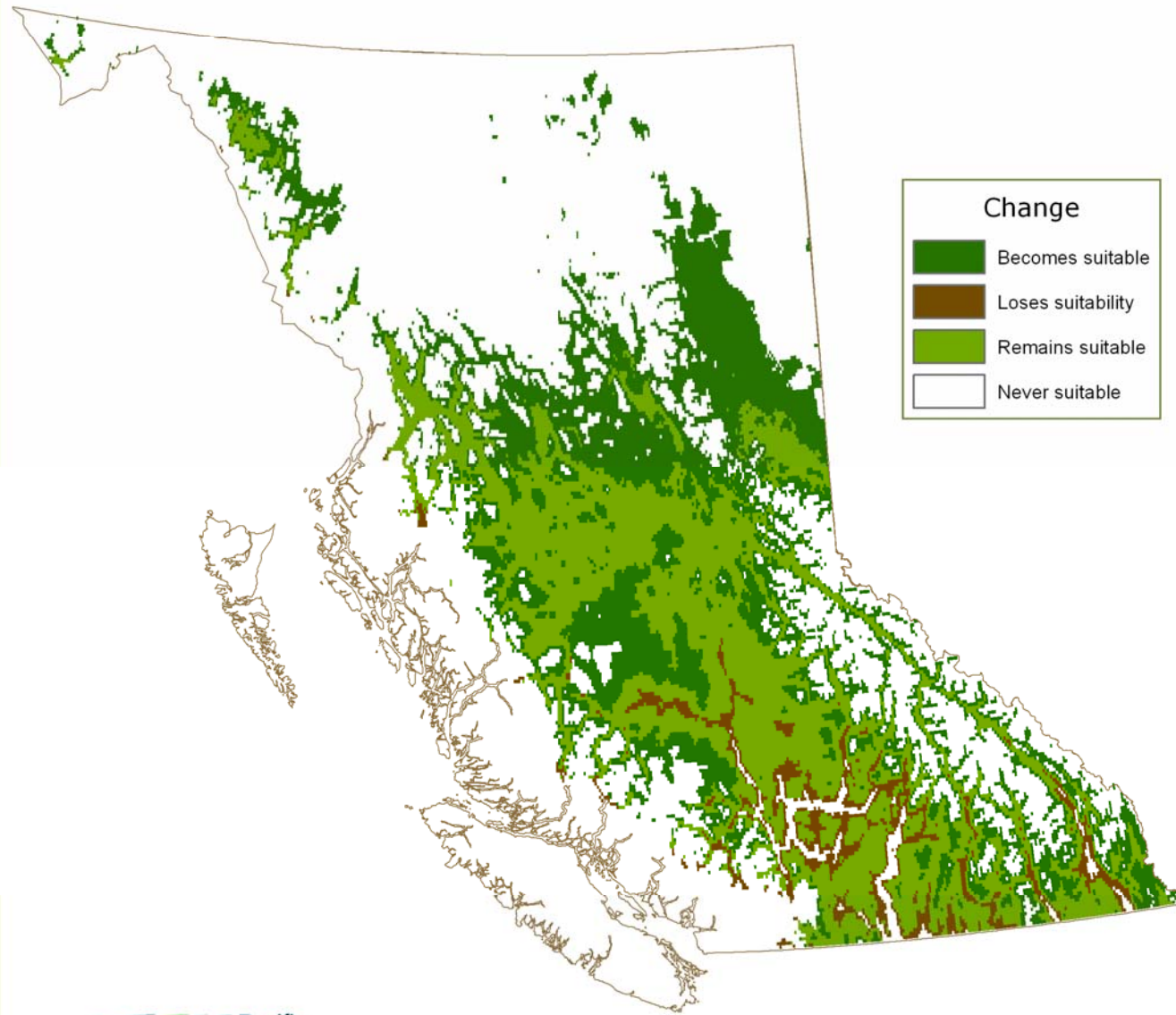
# 2020s Douglas Fir Suitability

Change in Climatic Suitability Relative to 1961-1990



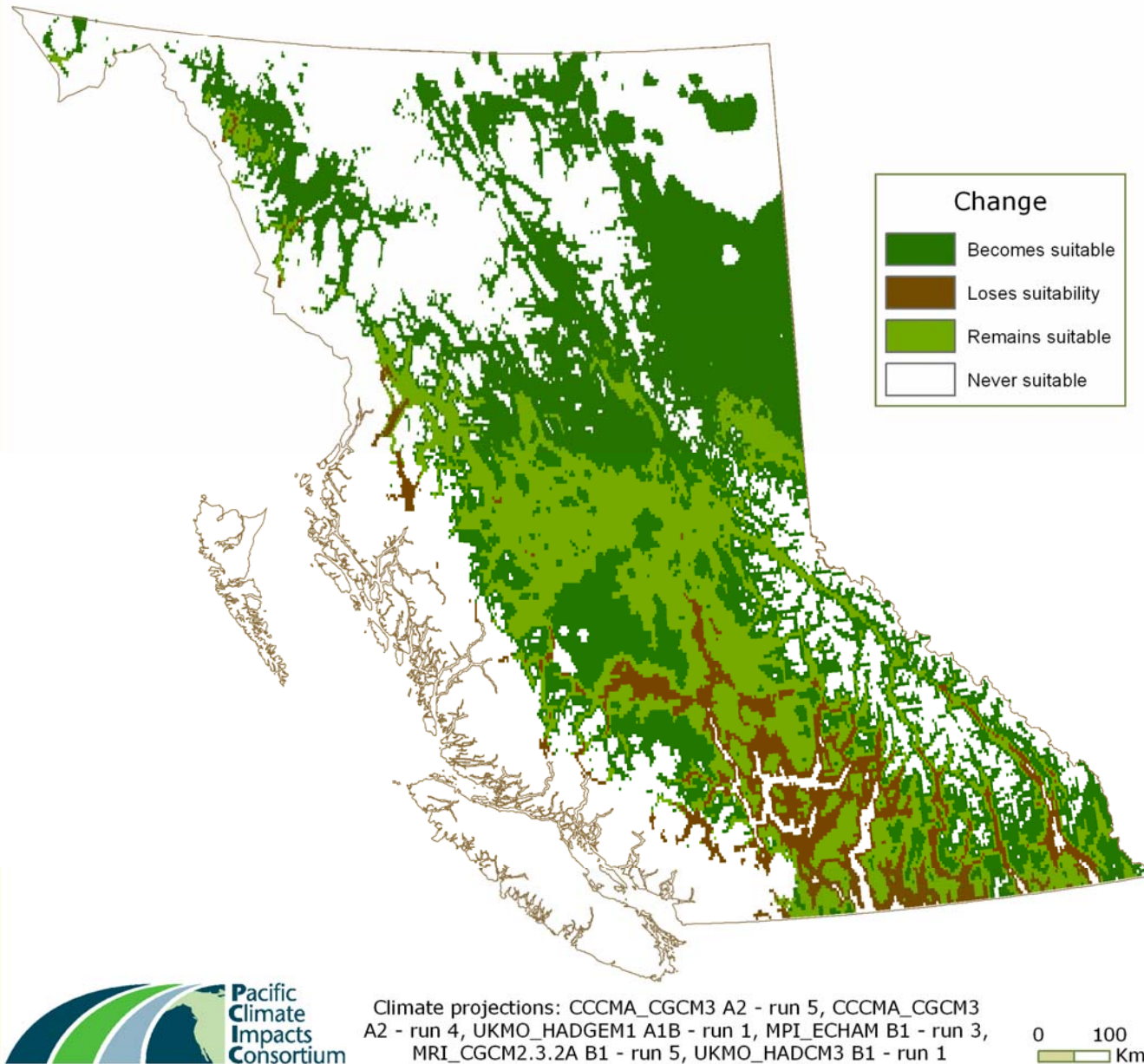
# 2050s Douglas Fir Suitability

Change in Climatic Suitability Relative to 1961-1990

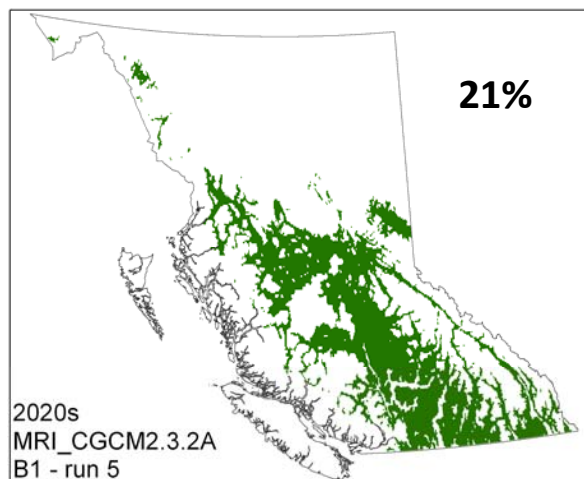
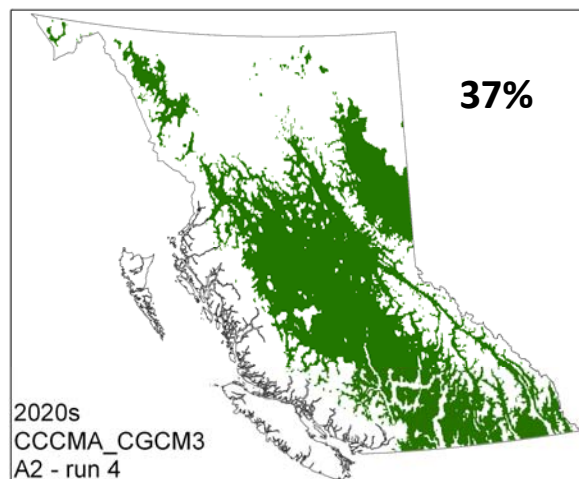
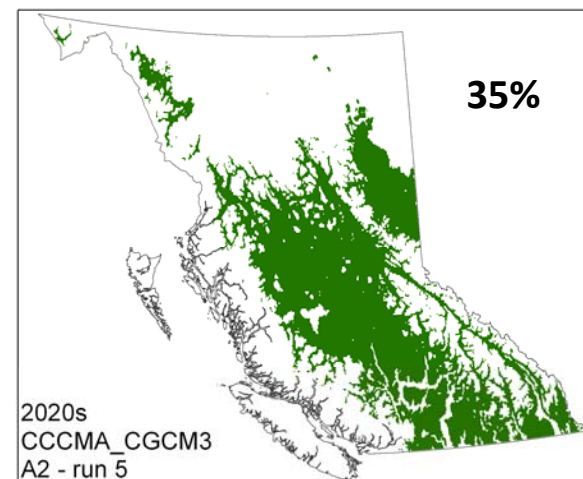
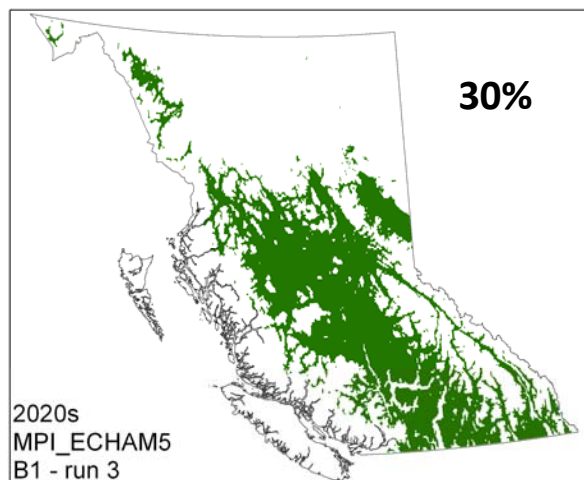
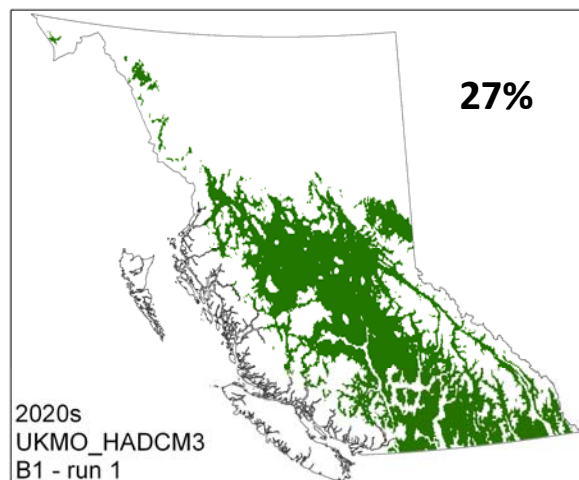
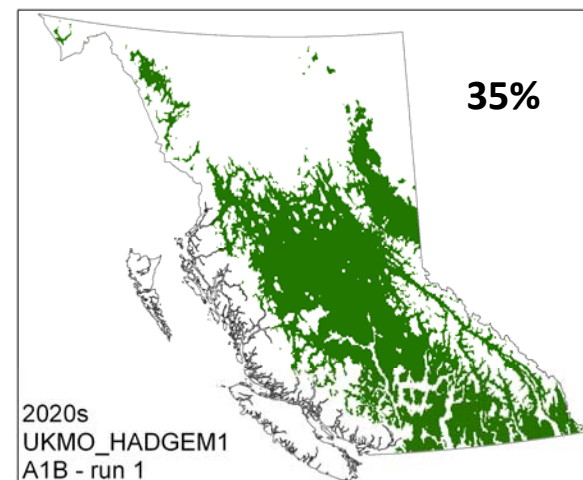


# 2080s Douglas Fir Suitability

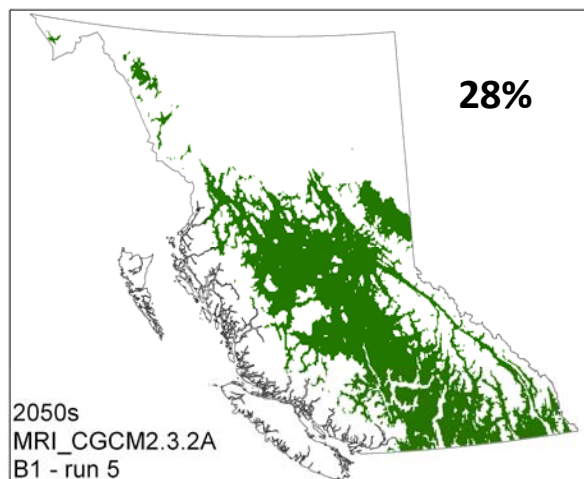
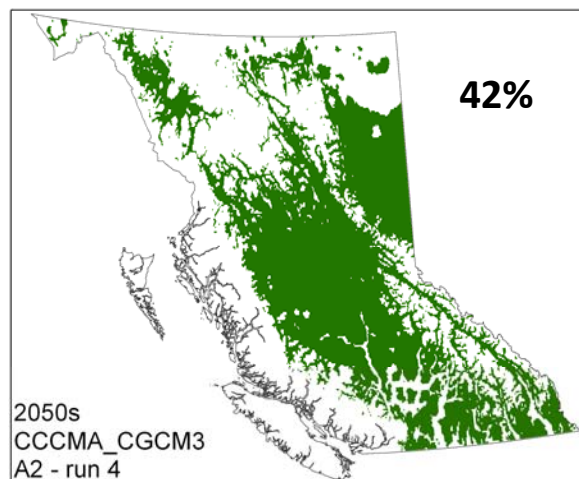
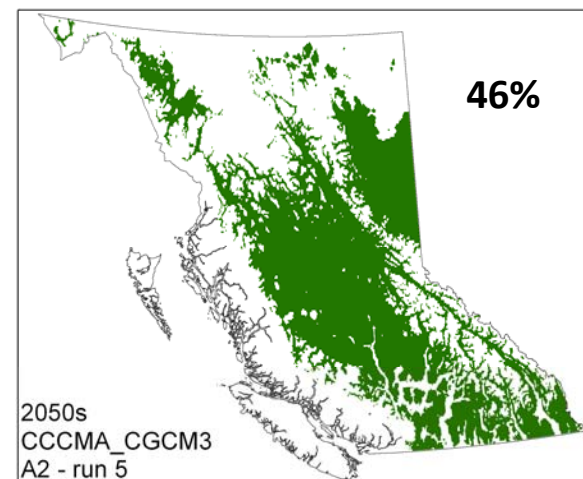
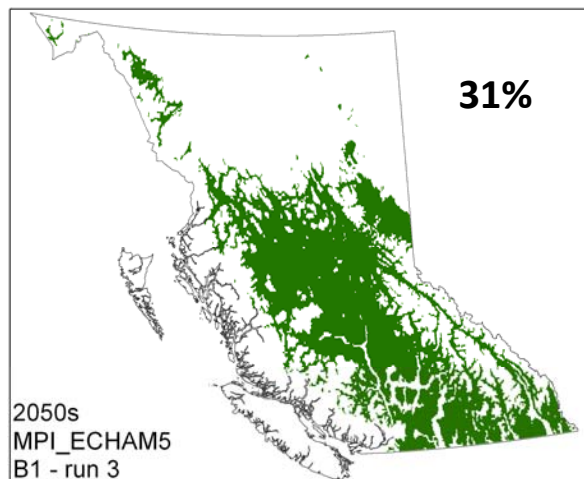
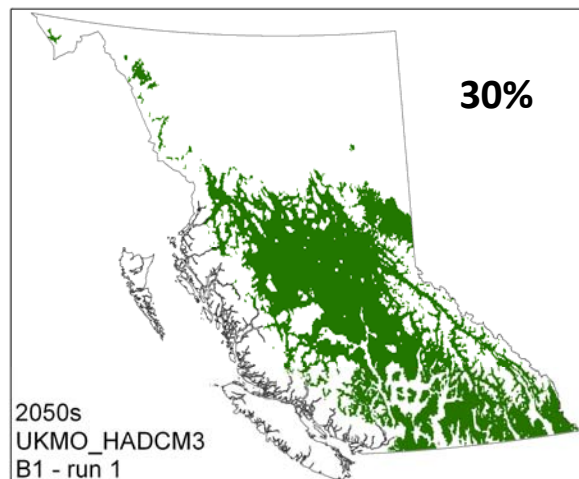
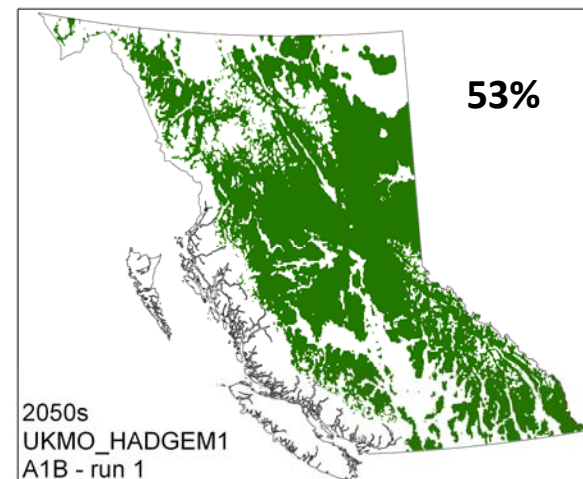
Change in Climatic Suitability Relative to 1961-1990



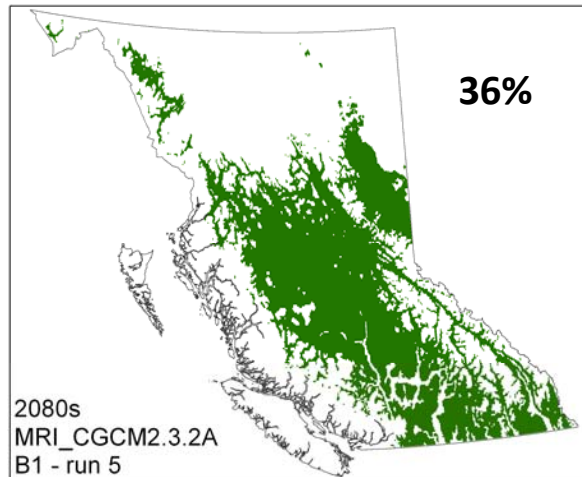
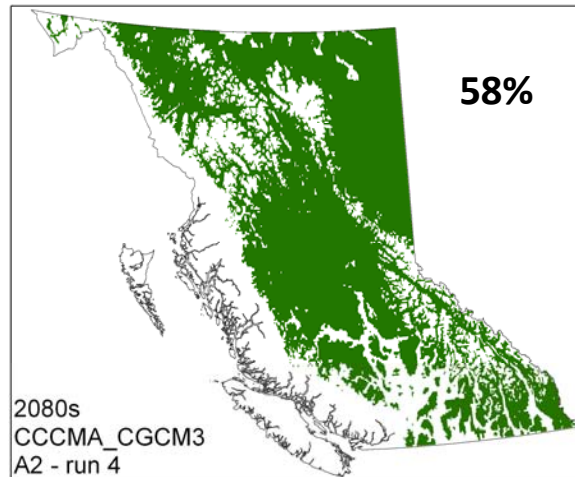
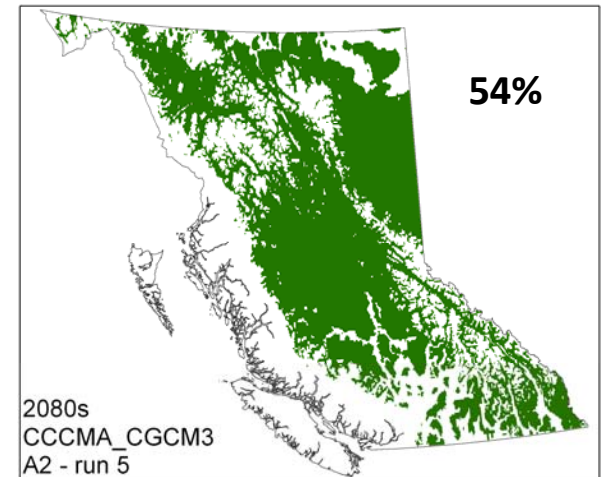
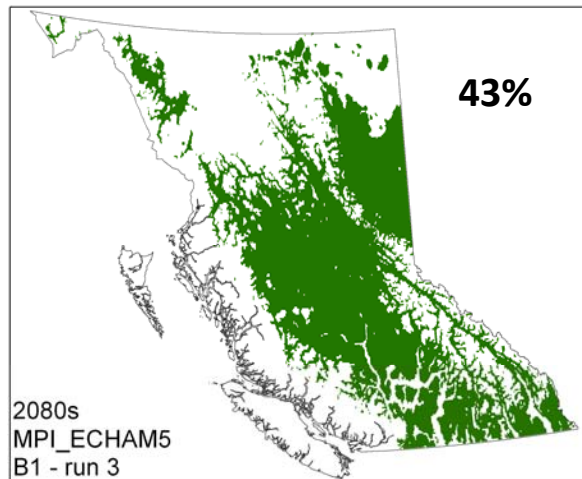
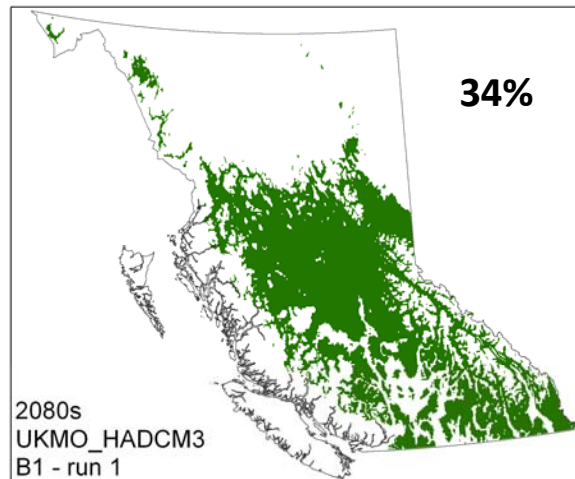
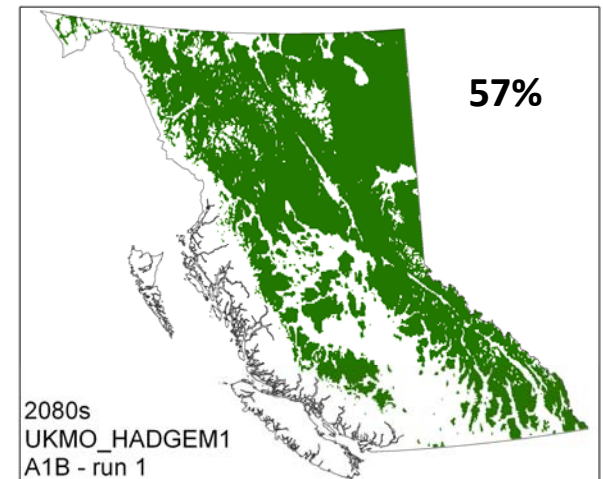
## Comparison of Climate Projections – 2020s Douglas Fir Suitability



## Comparison of Climate Projections – 2050s Douglas Fir Suitability

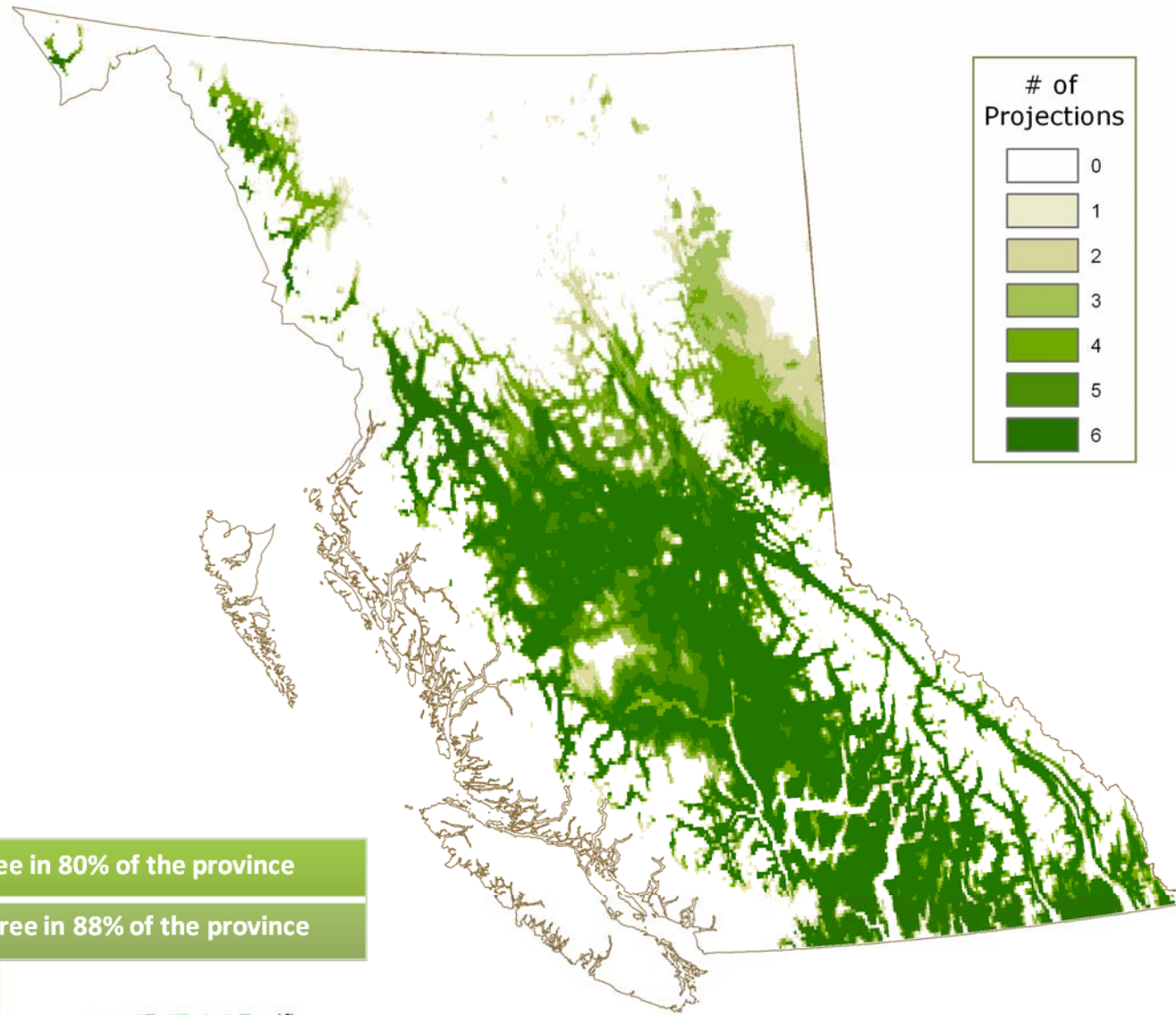


## Comparison of Climate Projections – 2080s Douglas Fir Suitability



# 2020s Douglas Fir Suitability

Number of Climate Projections Indicating Climatic Suitability

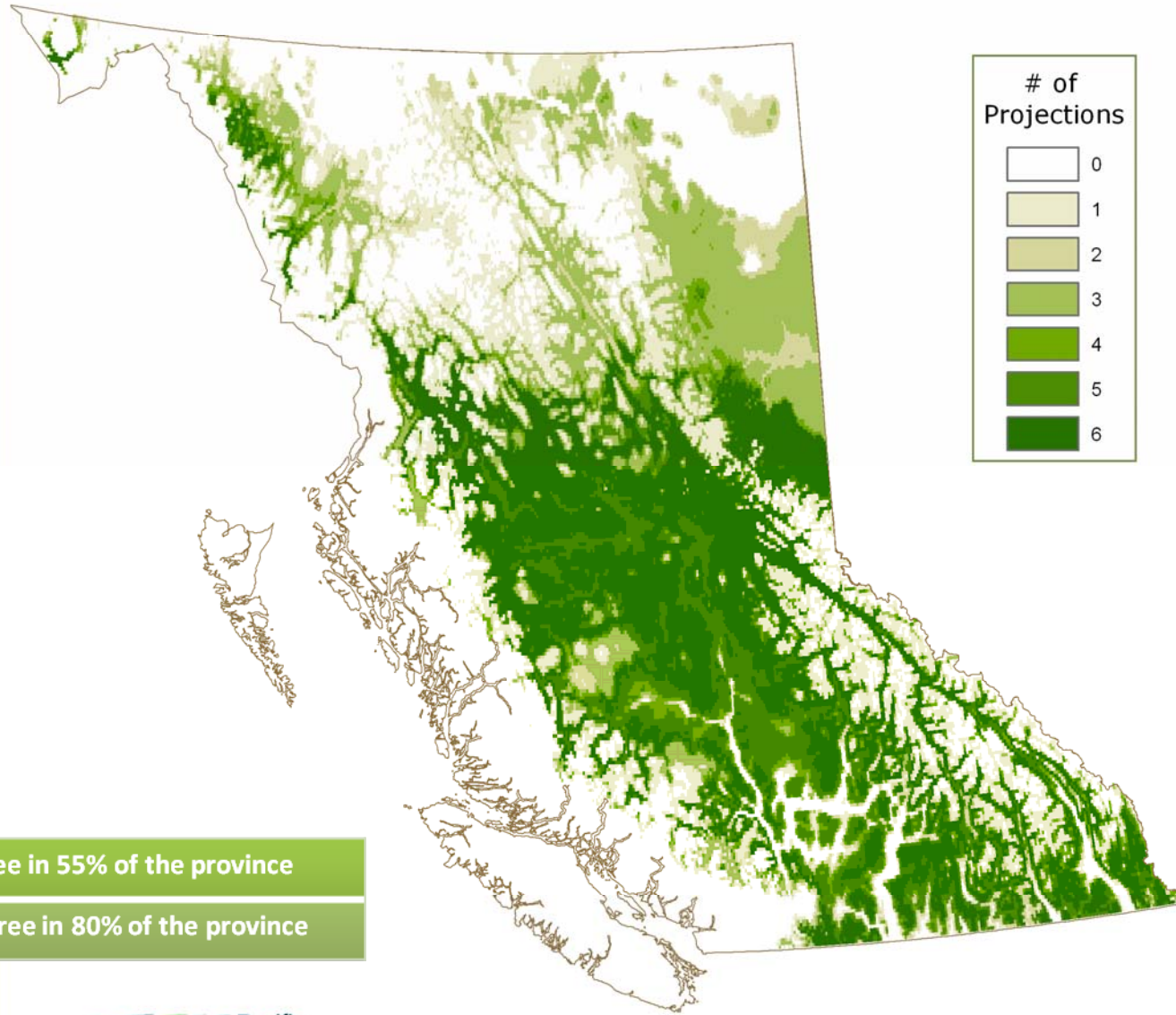


6 projections agree in 80% of the province

5+ projections agree in 88% of the province

# 2050s Douglas Fir Suitability

Number of Climate Projections Indicating Climatic Suitability



6 projections agree in 55% of the province

5+ projections agree in 80% of the province

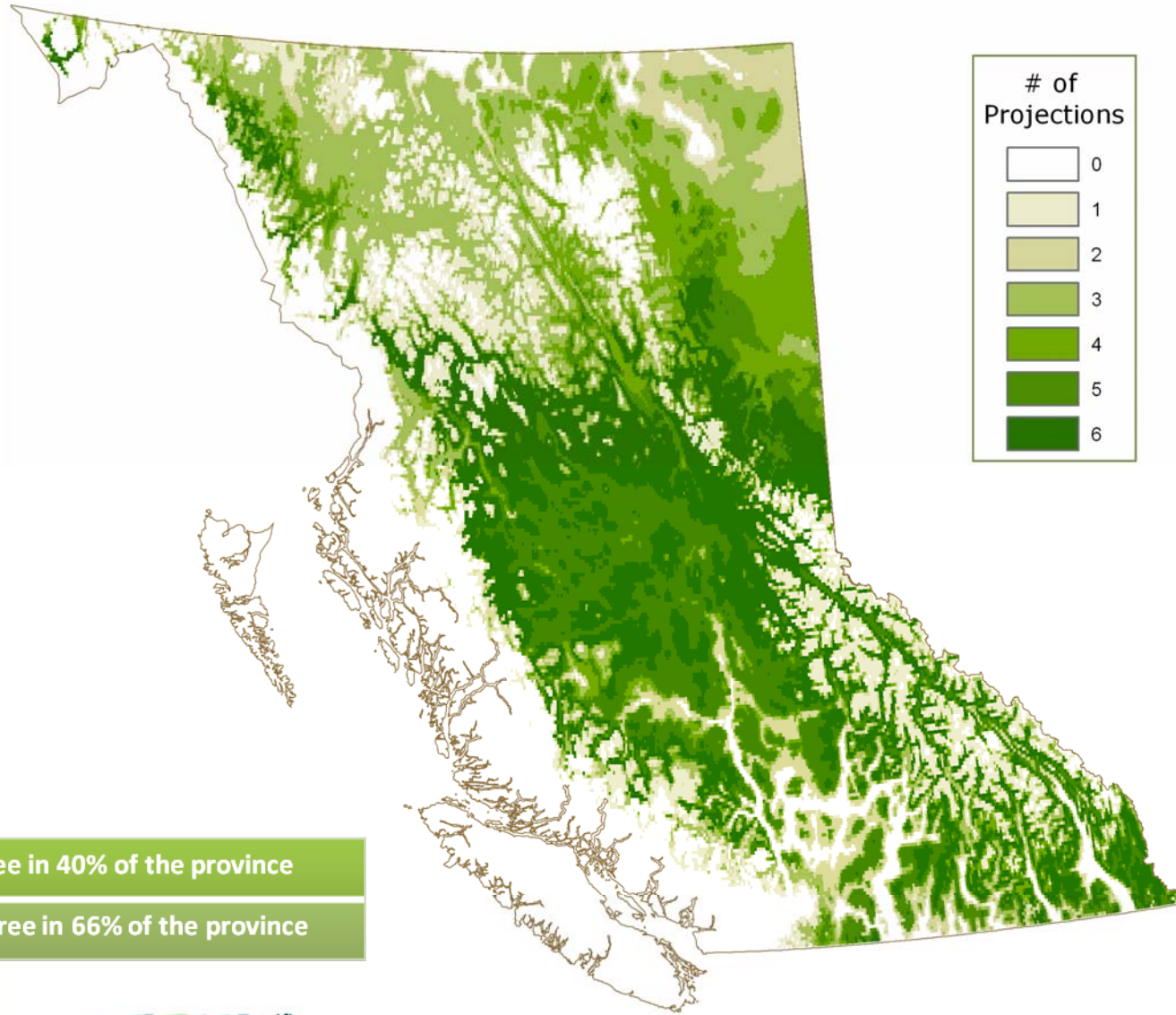


Climate projections: CCCMA\_CGCM3 A2 - run 5, CCCMA\_CGCM3 A2 - run 4, UKMO\_HADGEM1 A1B - run 1, MPI\_ECHAM B1 - run 3, MRI\_CGCM2.3.2A B1 - run 5, UKMO\_HADCM3 B1 - run 1

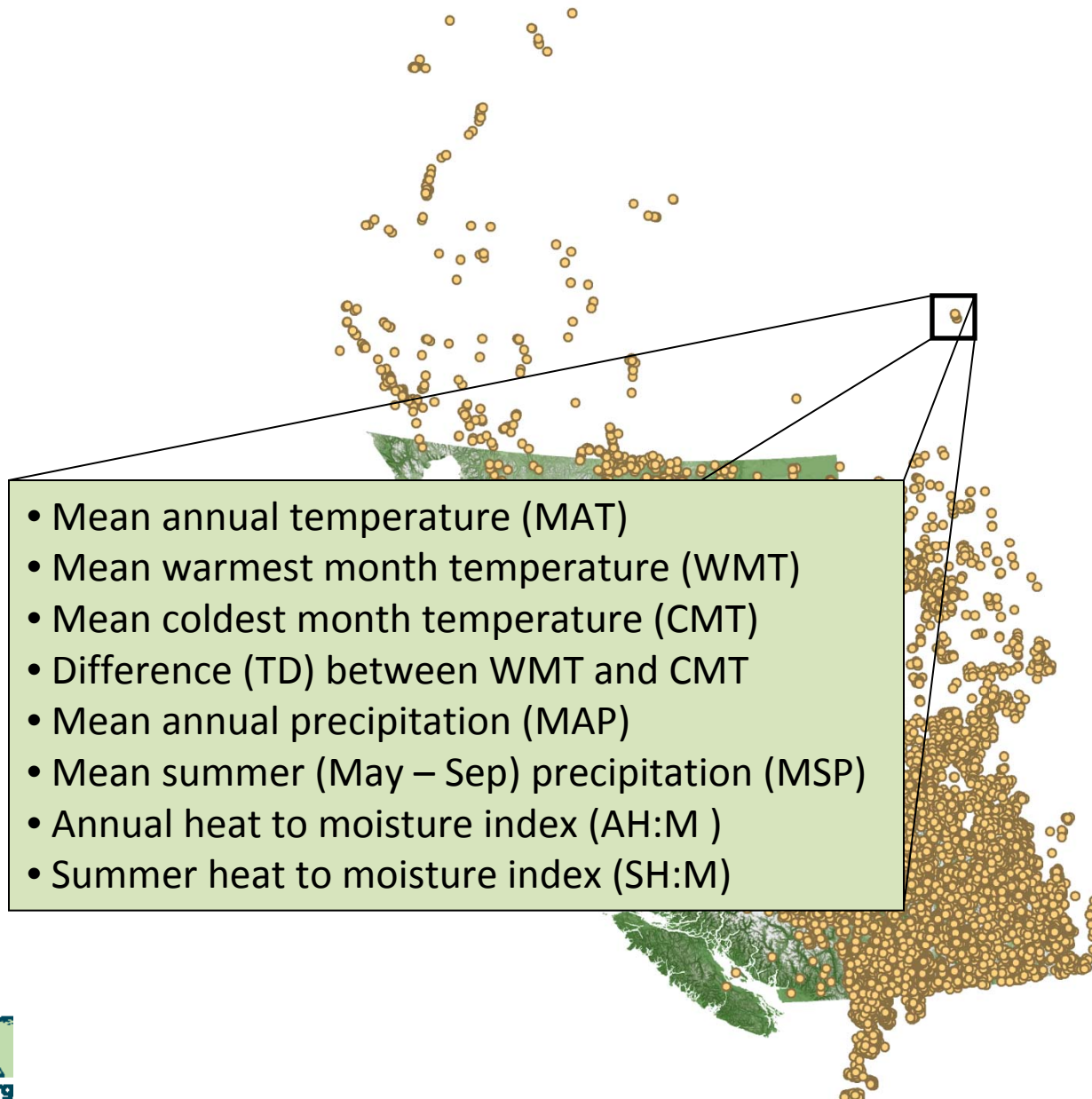
0 100 Km

# 2080s Douglas Fir Suitability

Number of Climate Projections Indicating Climatic Suitability



## White Spruce (*Picea glauca*), Engelmann Spruce (*Picea engelmannii*), and Hybrid Spruce (*Picea glauca* x *engelmannii*) Vegetation Survey Plots

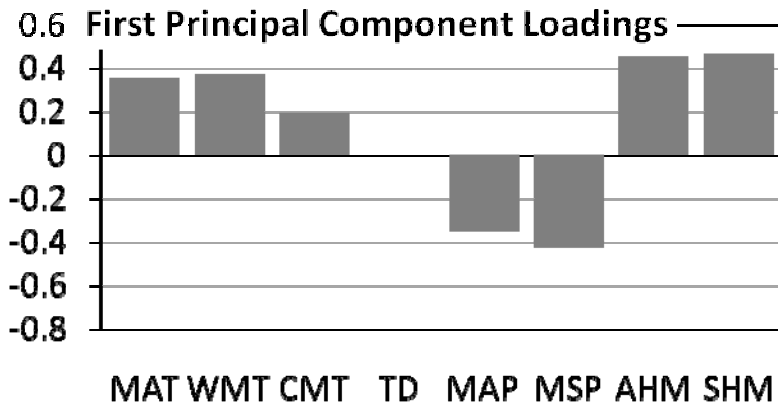
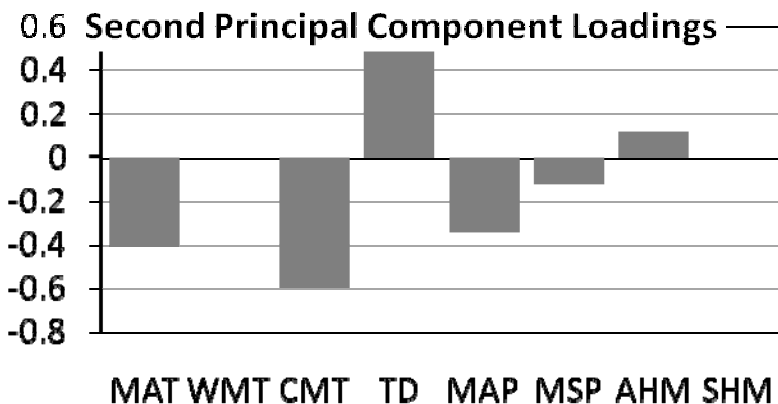
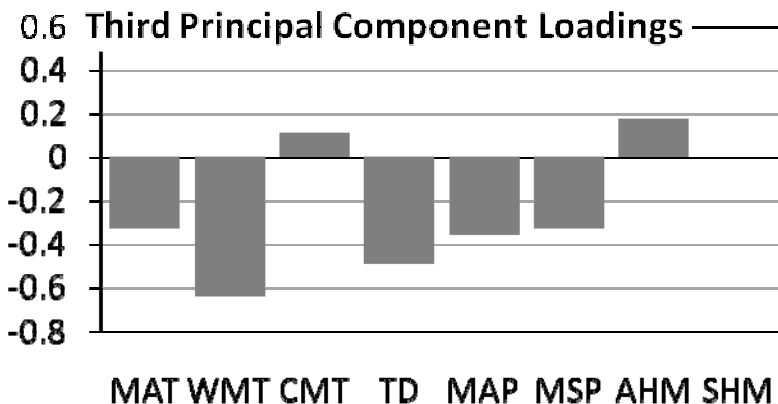


## Spruce Model Component Loadings

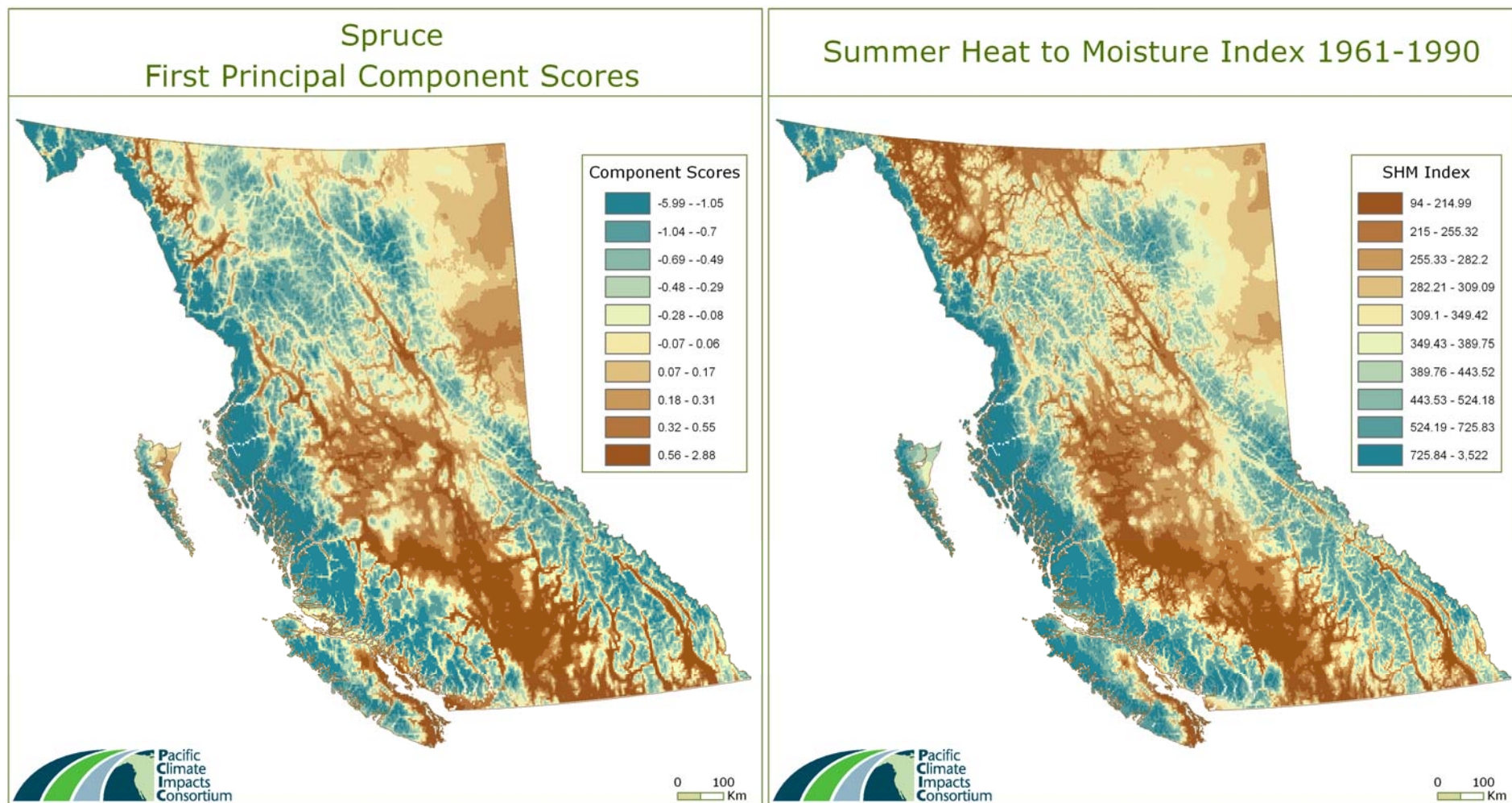
The first principal component can be interpreted as primarily representing a **summer moisture balance gradient** reflecting the differences between the dry, hot summers of interior valleys and the wet, cool summers of high-elevation and/or coastal regions.

The second principal component represents a **gradient between maritime and continental winter climates** and can be interpreted as reflecting the differences between the cold, dry winters of lower elevations in northern British Columbia and the wetter and/or warmer winters of the rest of the province.

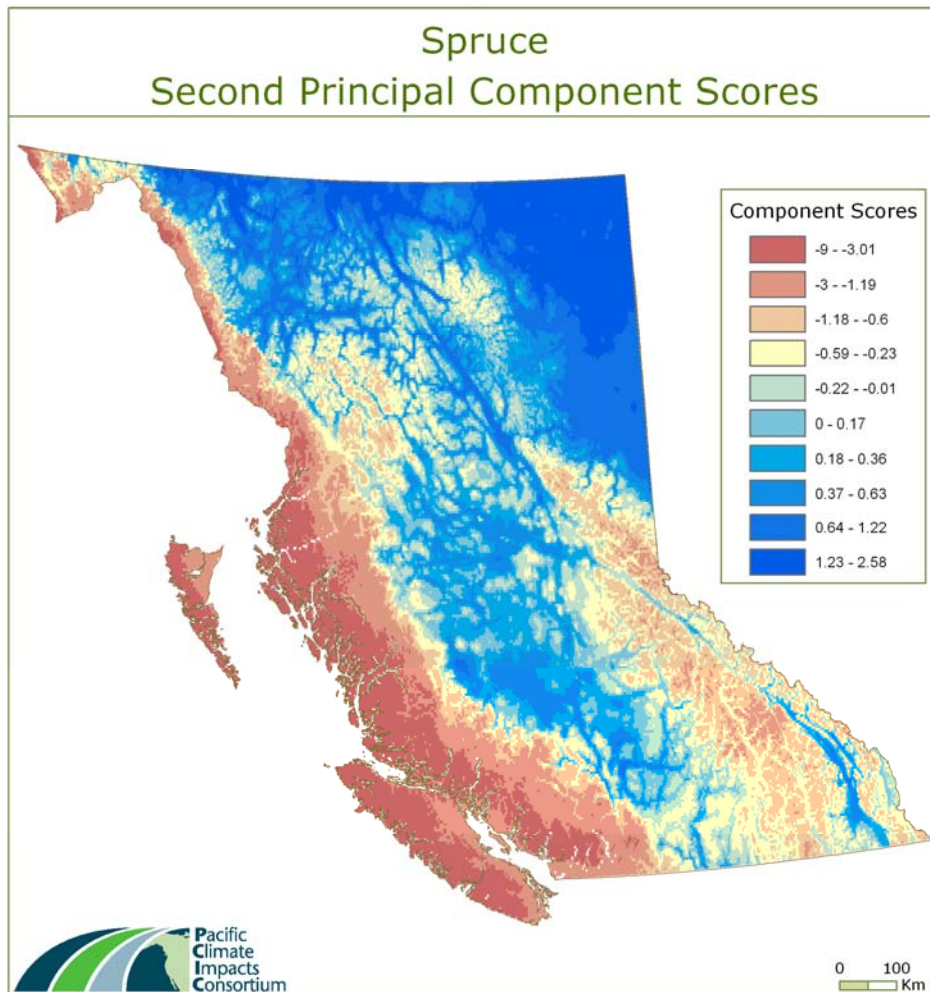
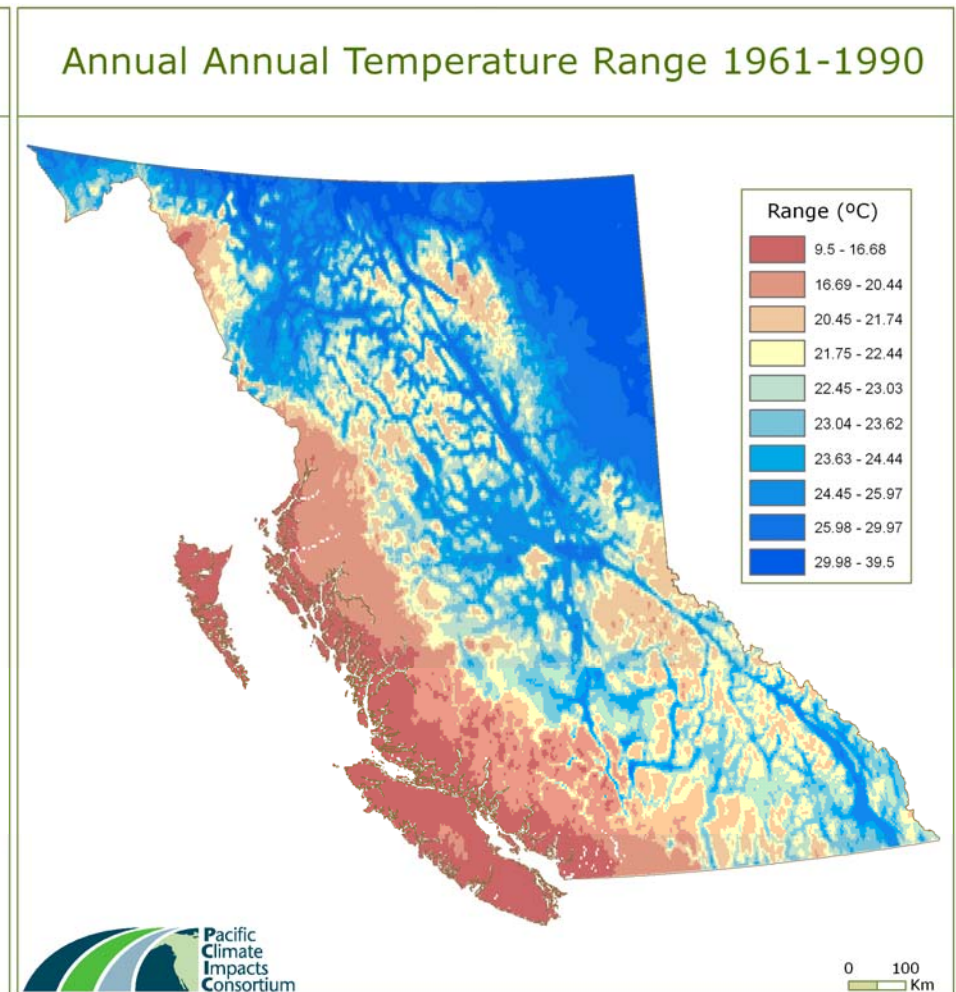
The third principal component can be interpreted as a **summer temperature gradient** reflecting the differences between the cool, moderately dry summers of high elevations in the interior and the warmer and/or wetter summers of both coastal areas and lower elevations in the interior.



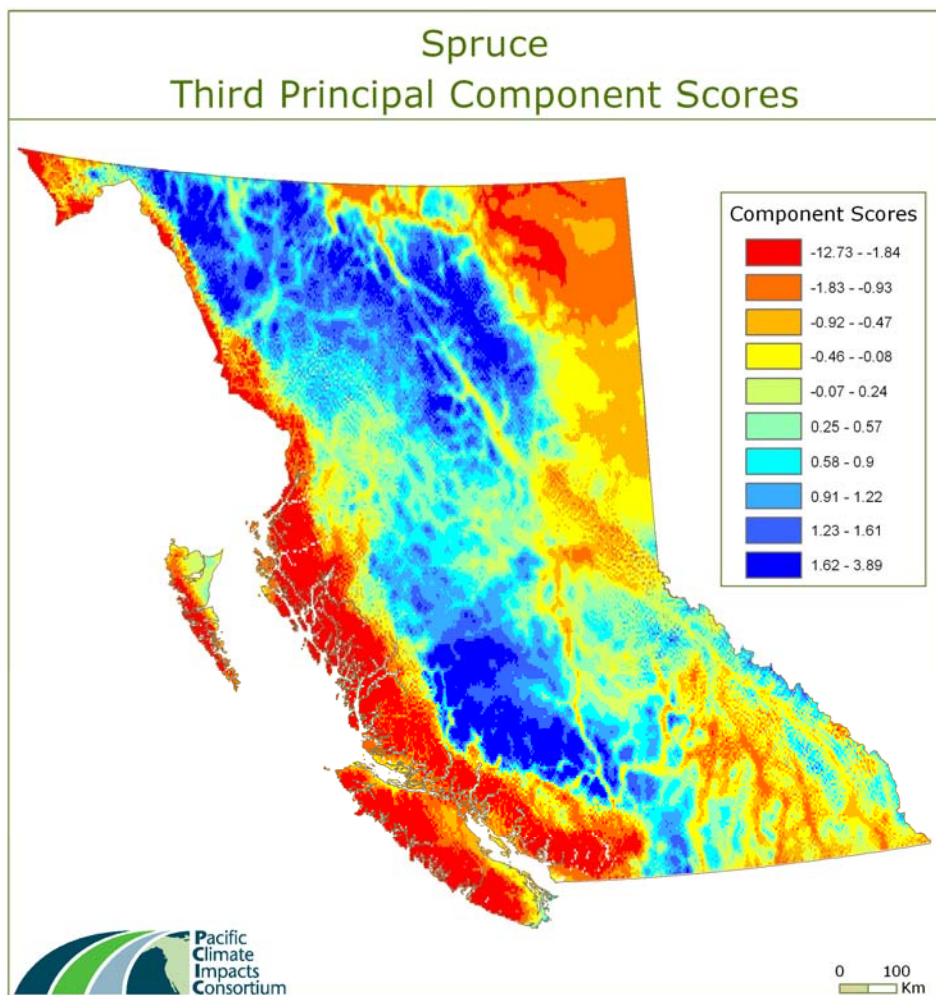
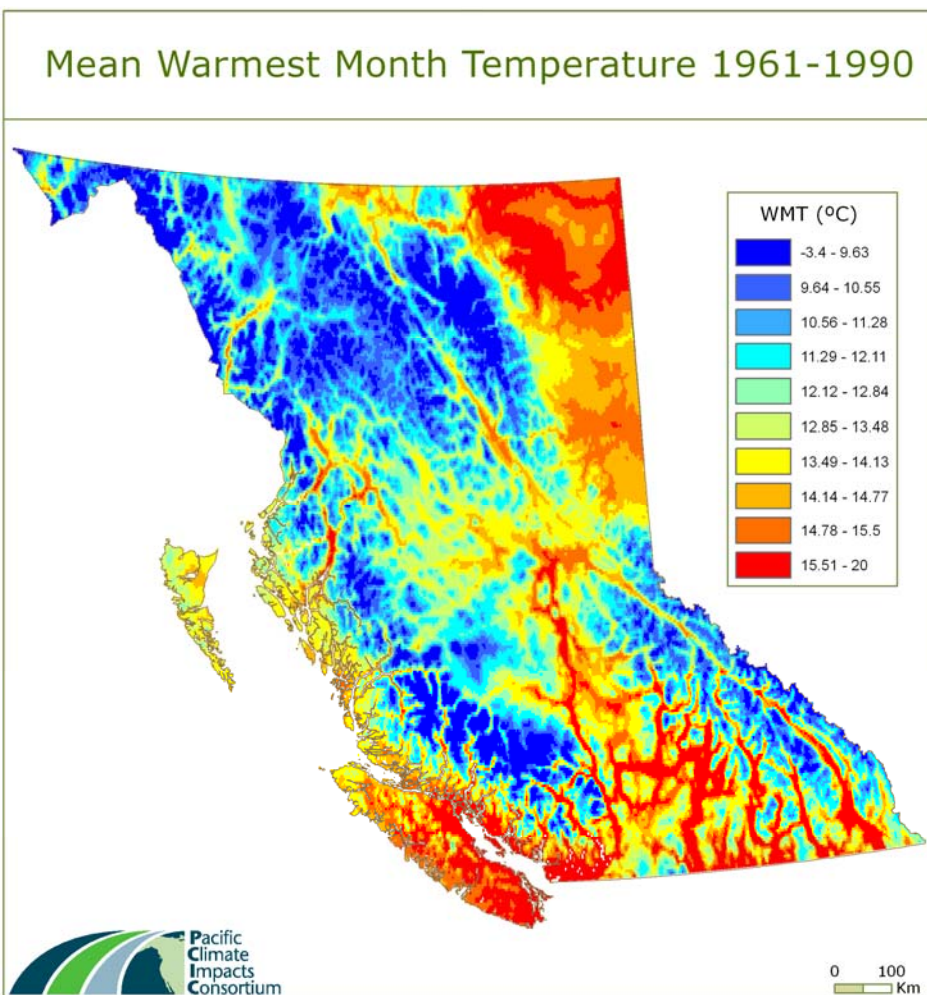
# Spruce Bioclimatic Envelope Model – First Principal Component



## Spruce Bioclimatic Envelope Model – Second Principal Component

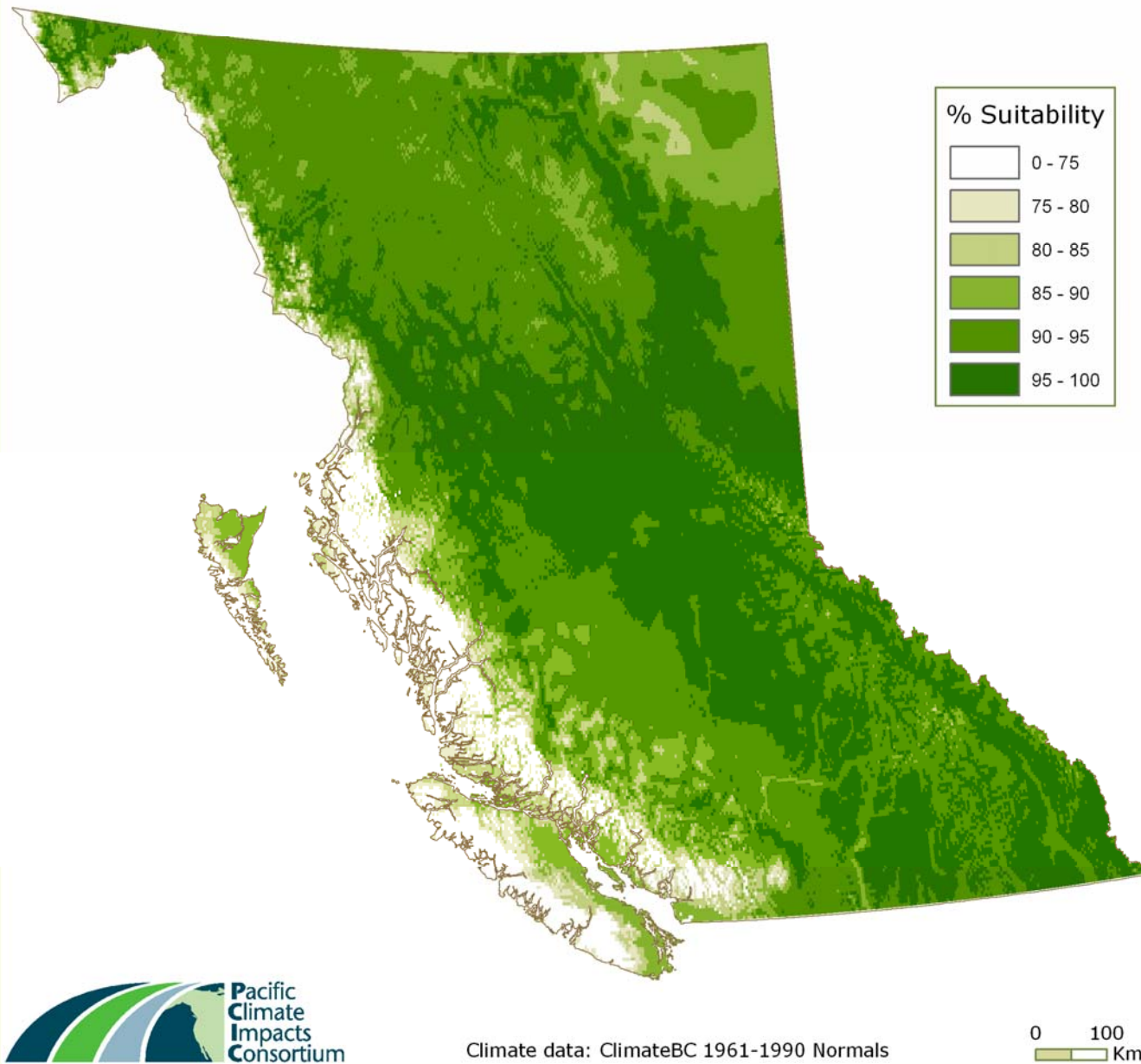


## Spruce Bioclimatic Envelope Model – Third Principal Component



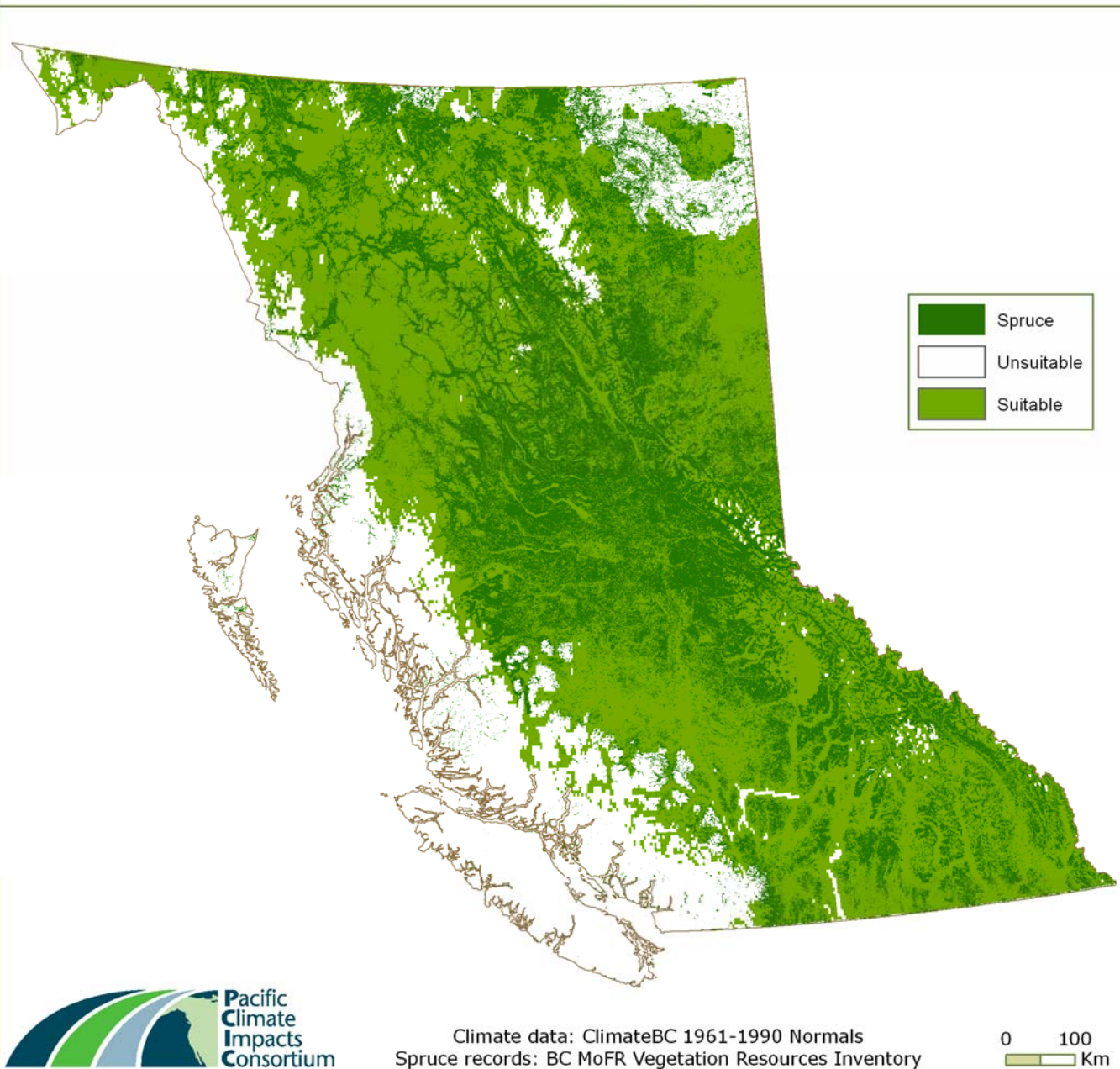
# Present Day Spruce Suitability

Relative 1961-1990 Climatic Suitability



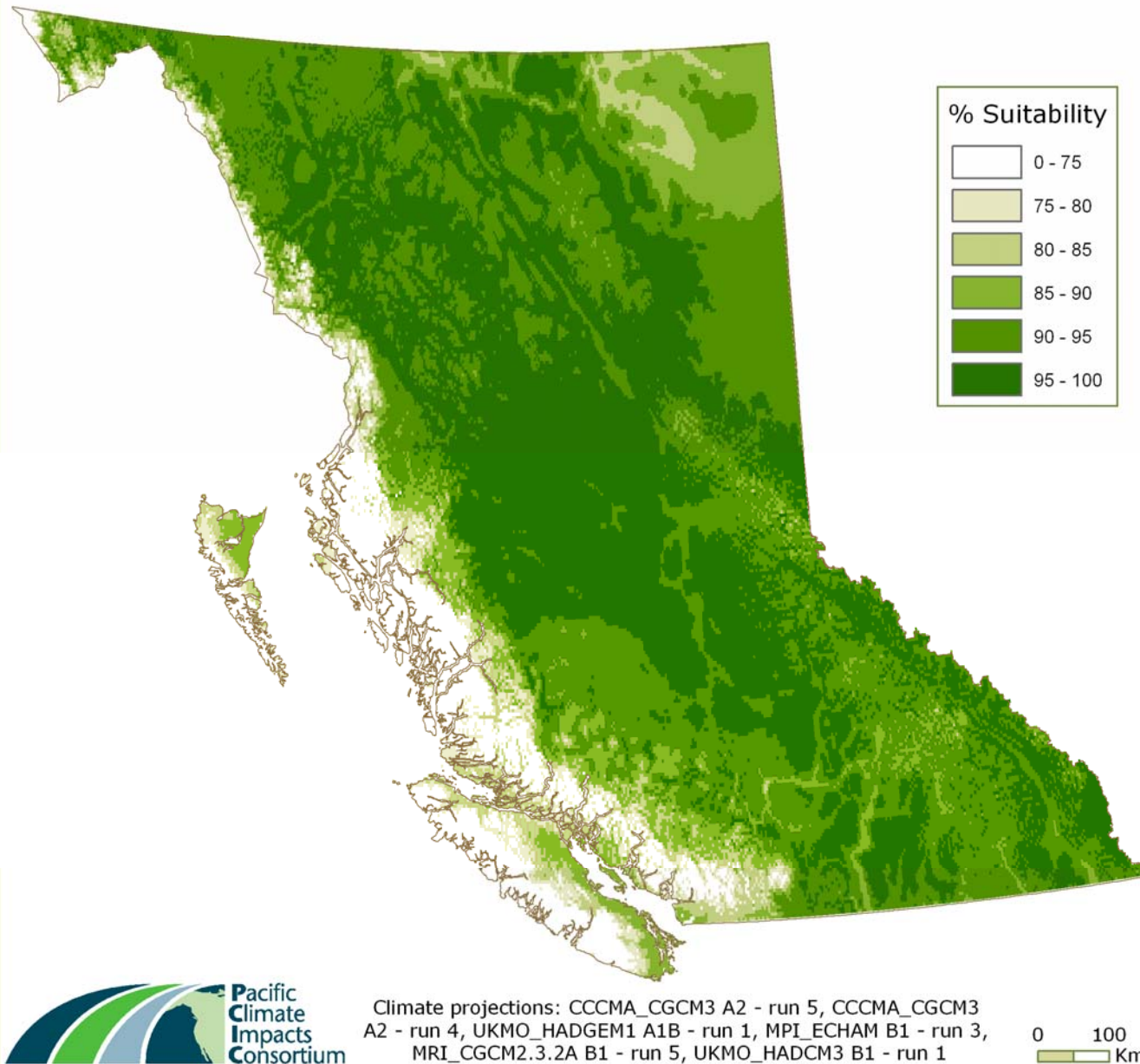
# Present Day Spruce Suitability

Relative 1961-1990 Climatic Suitability Compared to Actual Distribution



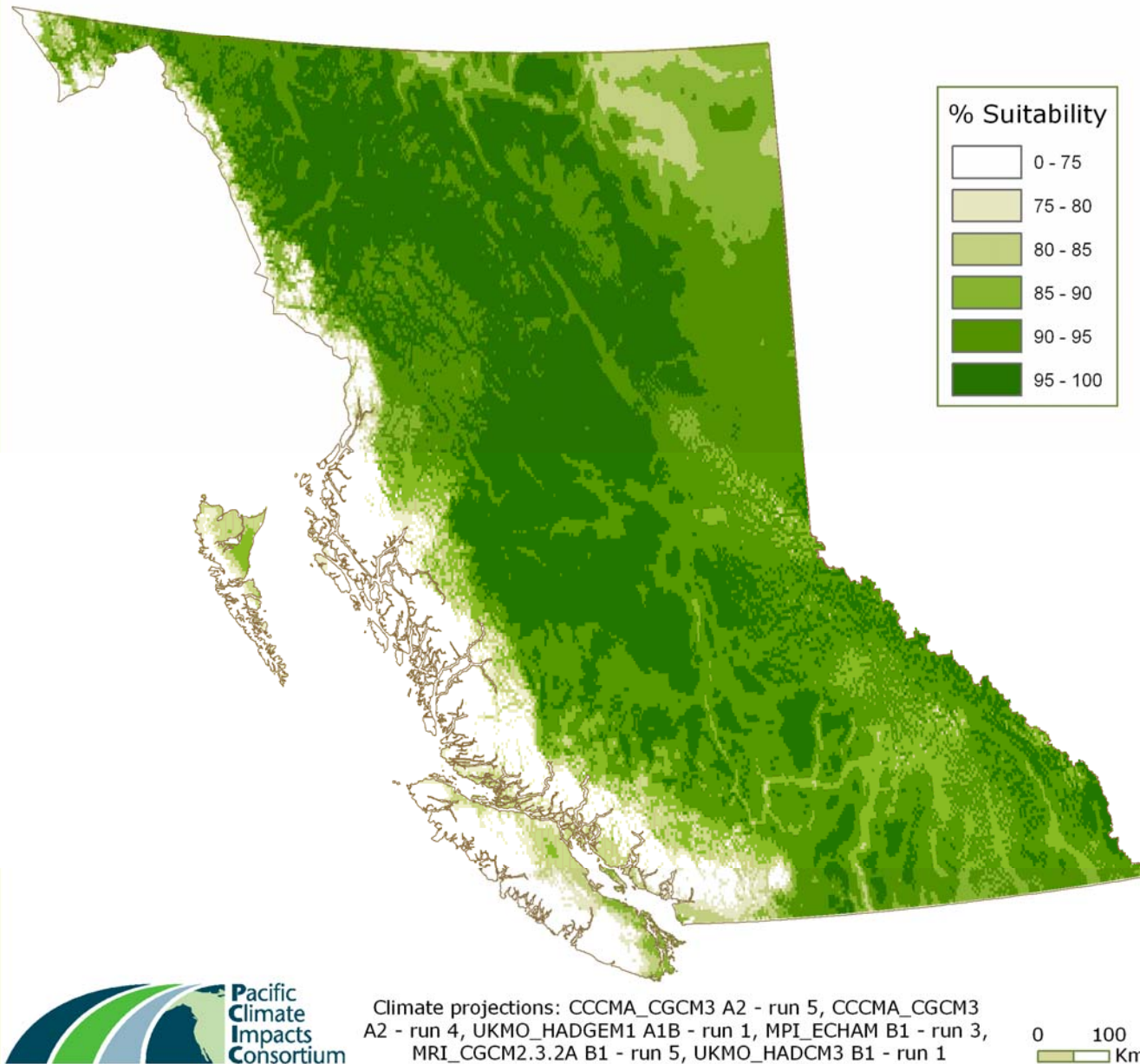
# 2020s Spruce Suitability

Relative Climatic Suitability Based on Six Climate Projections



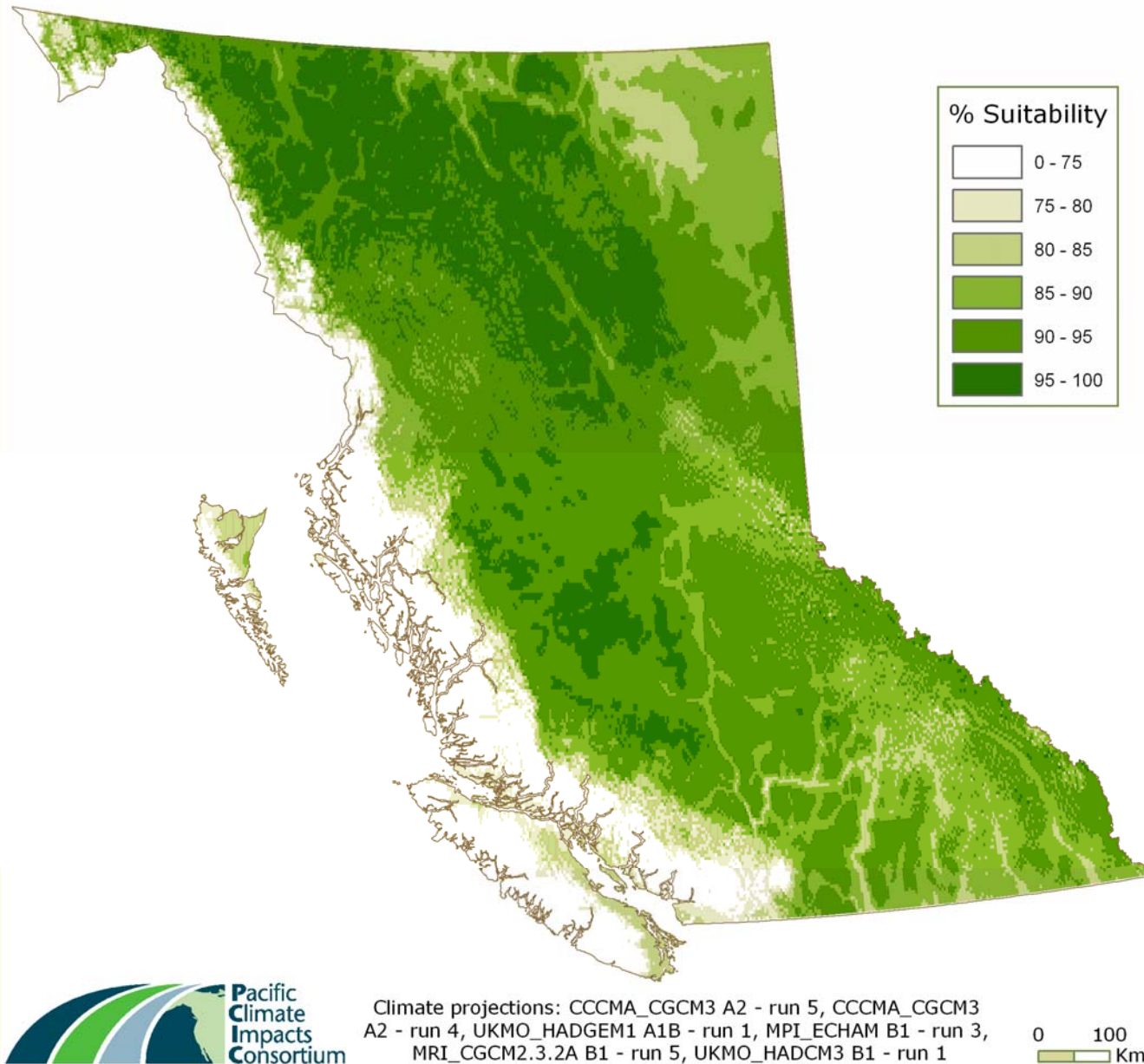
# 2050s Spruce Suitability

Relative Climatic Suitability Based on Six Climate Projections



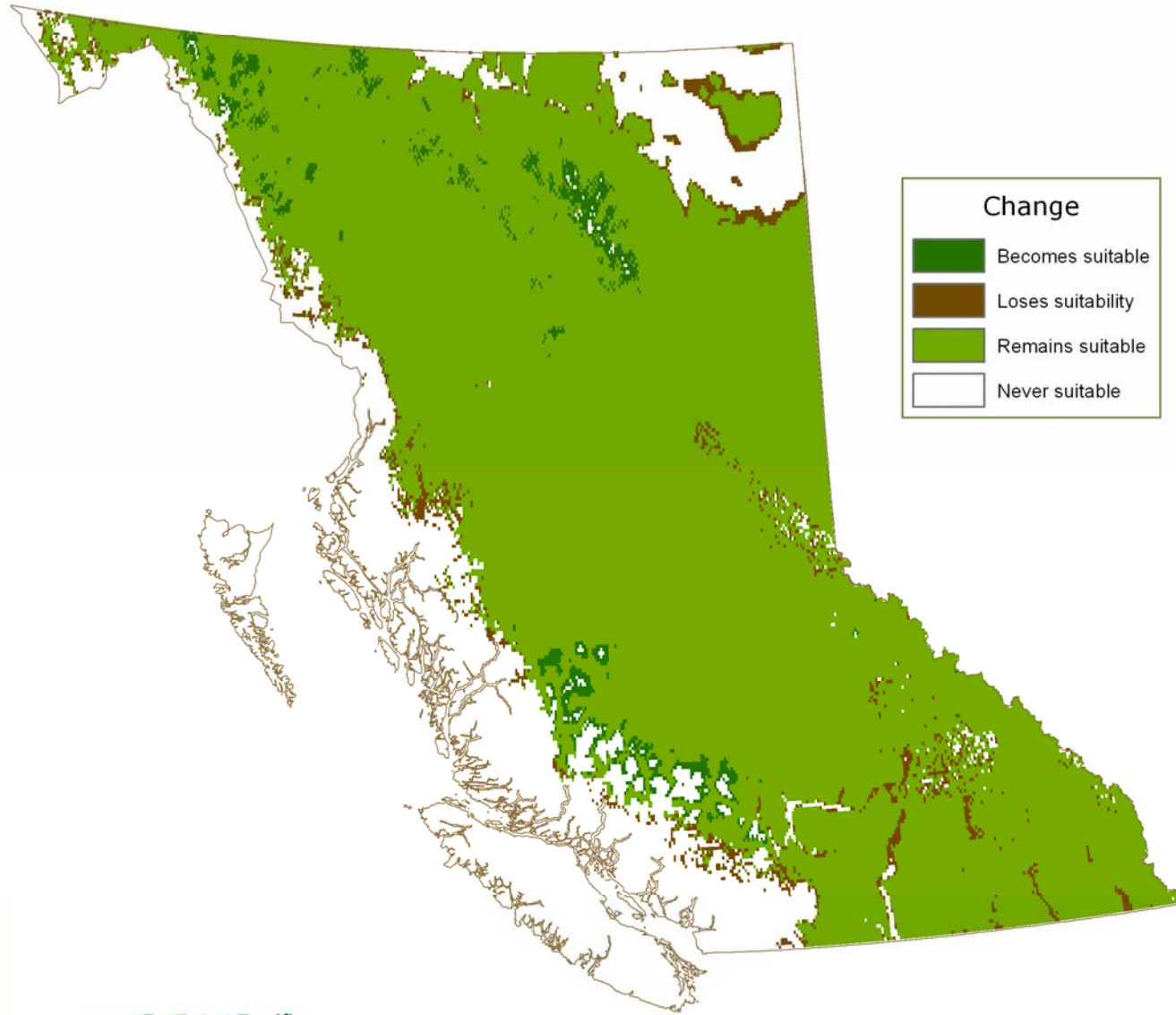
# 2080s Spruce Suitability

Relative Climatic Suitability Based on Six Climate Projections



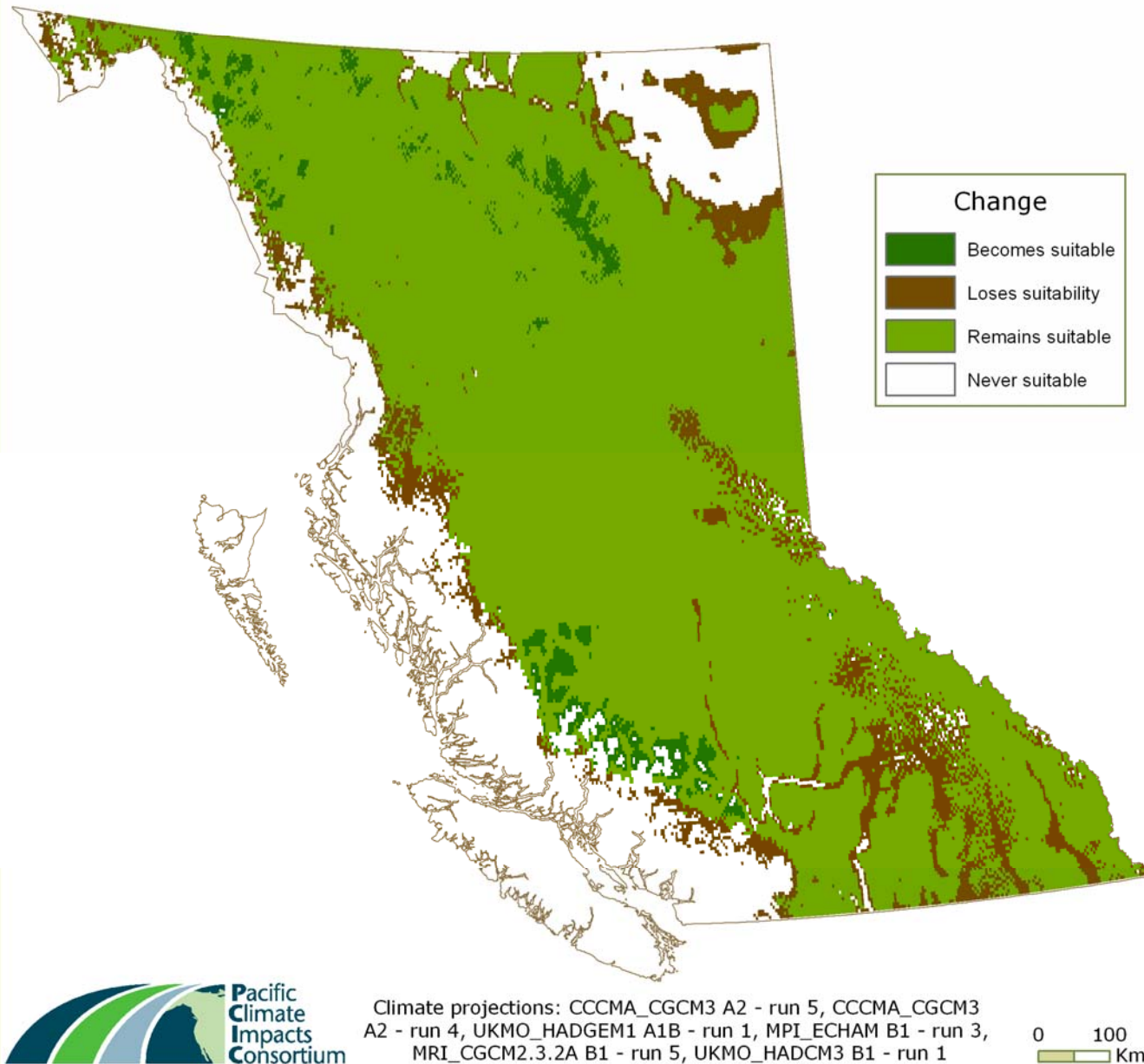
# 2020s Spruce Suitability

Change in Climatic Suitability Relative to 1961-1990



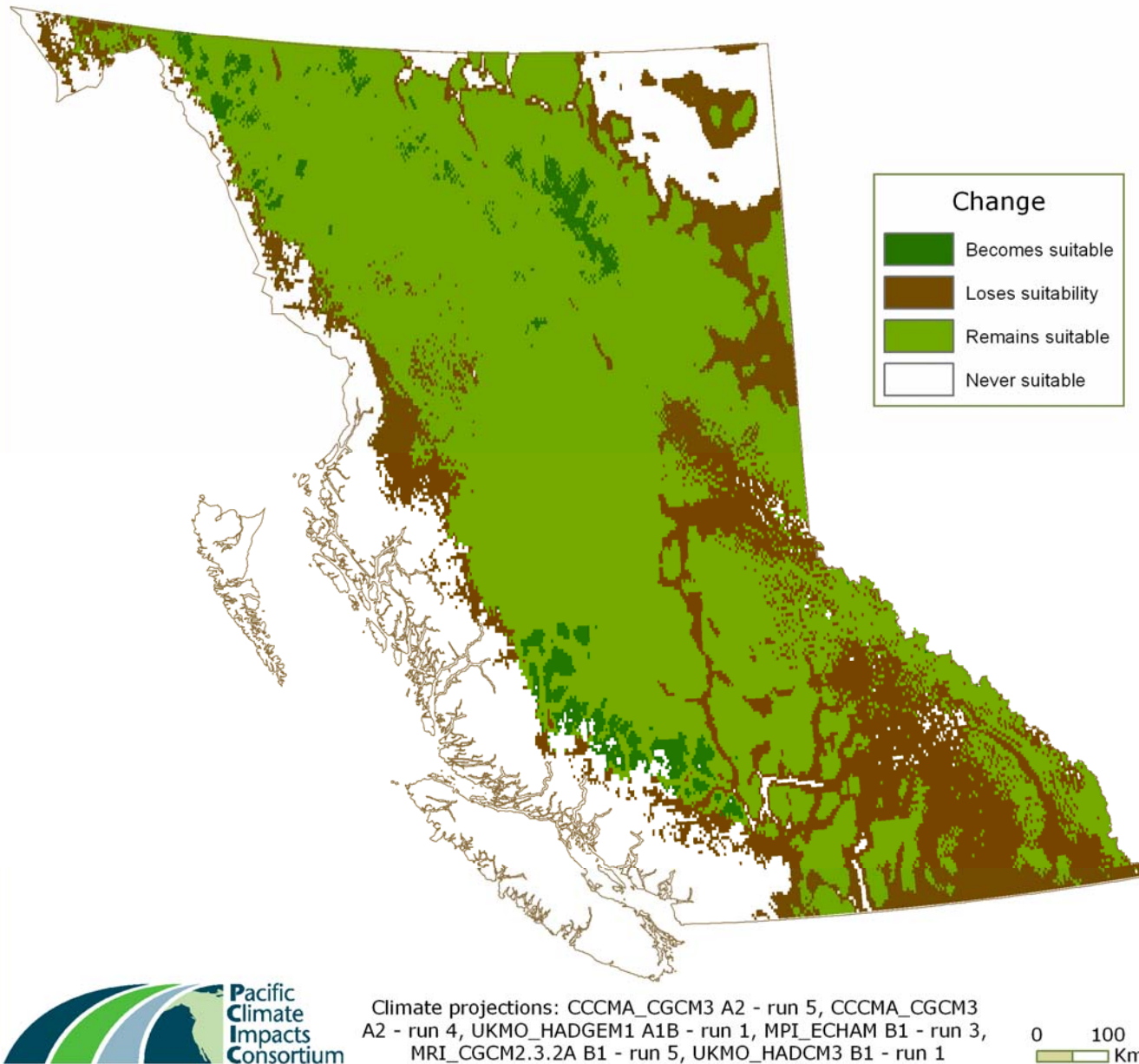
# 2050s Spruce Suitability

Change in Climatic Suitability Relative to 1961-1990

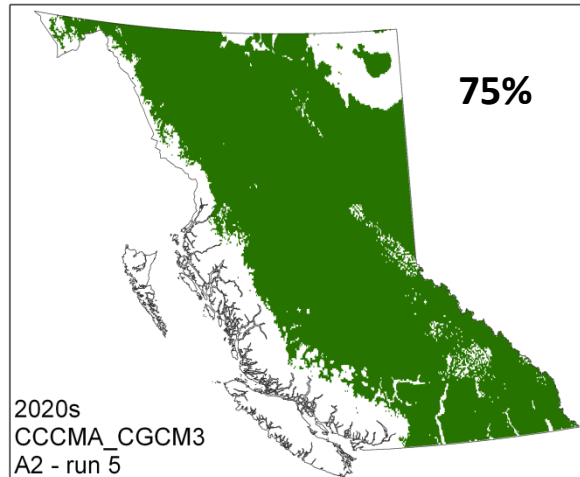
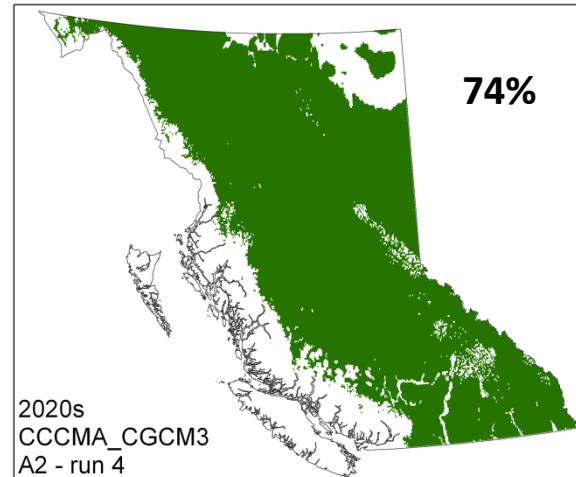
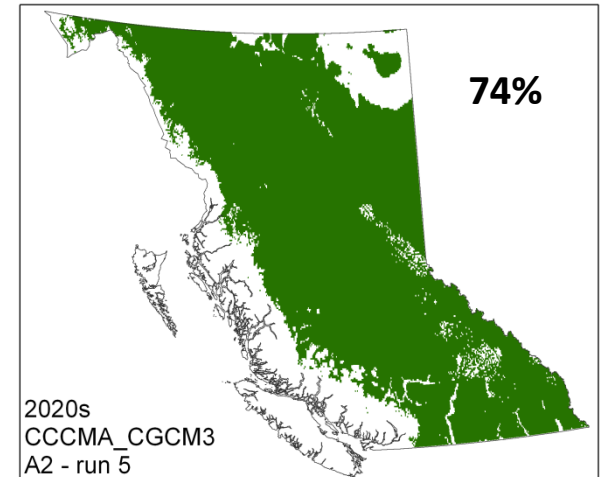
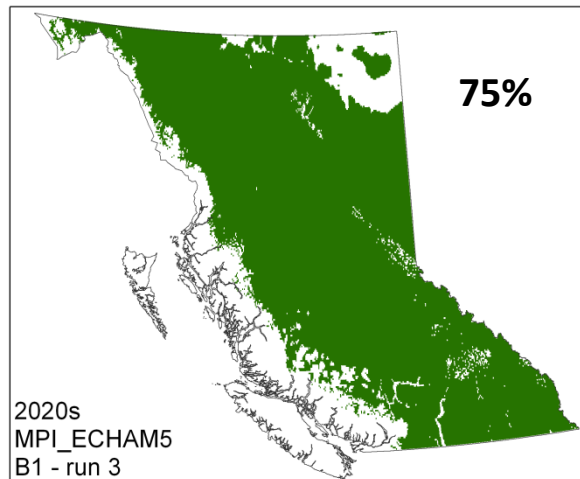
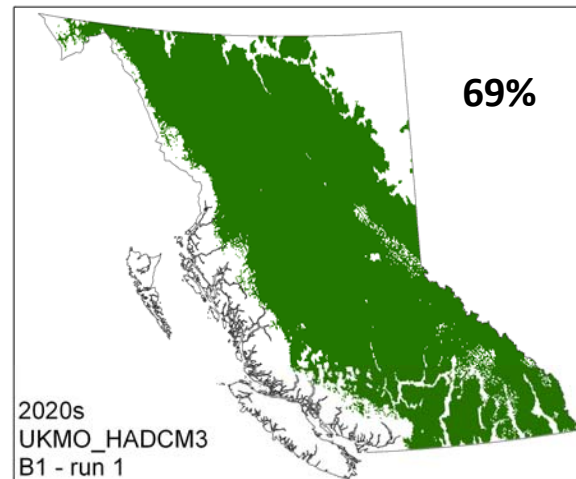
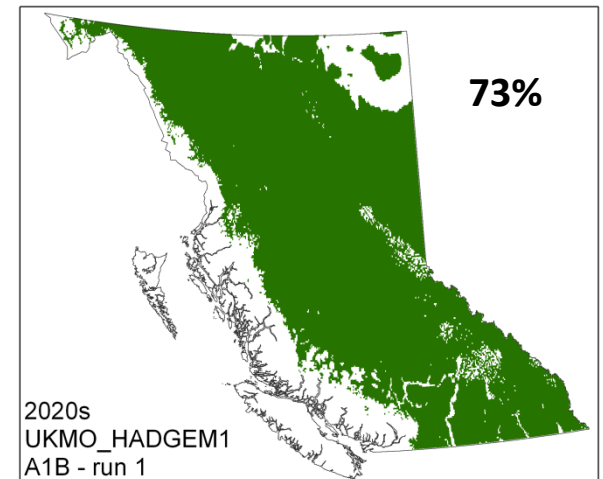


# 2080s Spruce Suitability

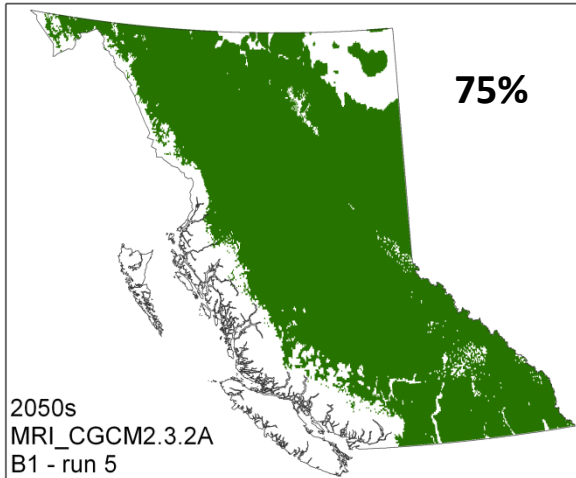
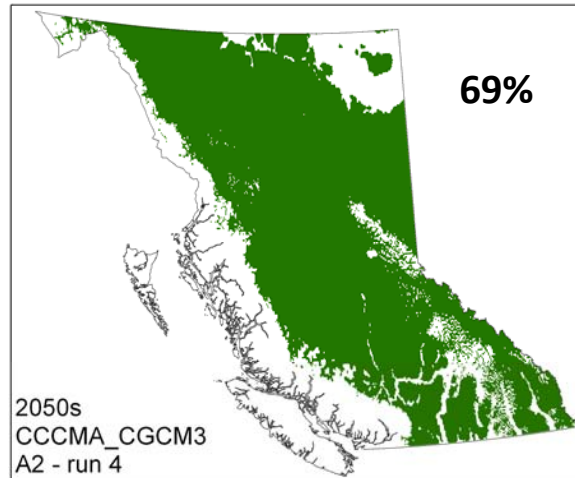
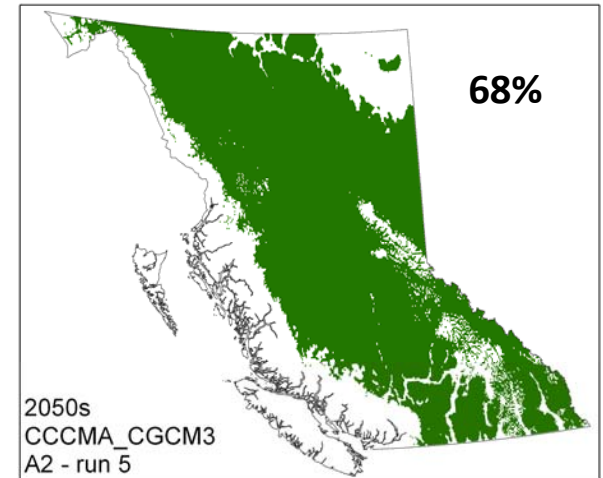
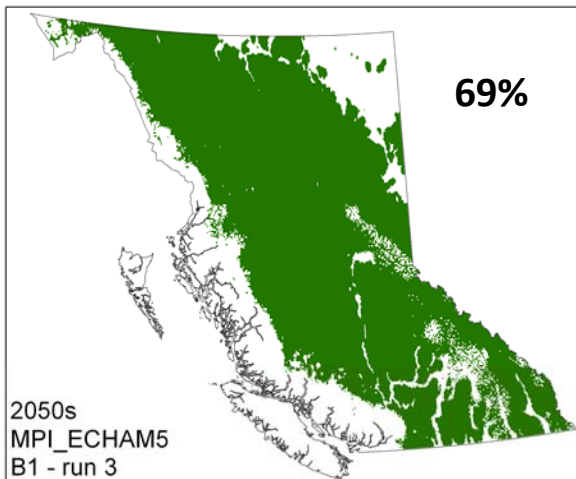
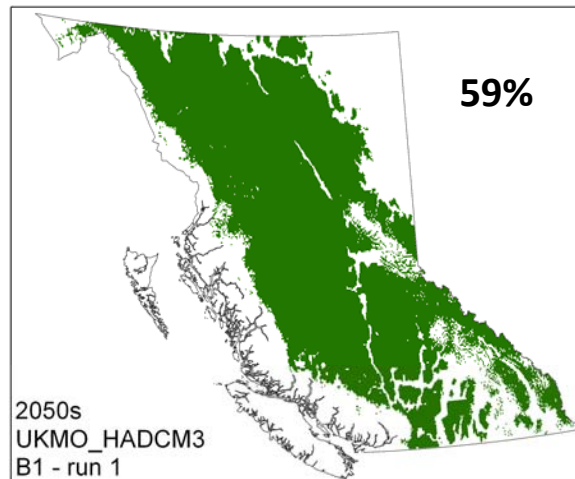
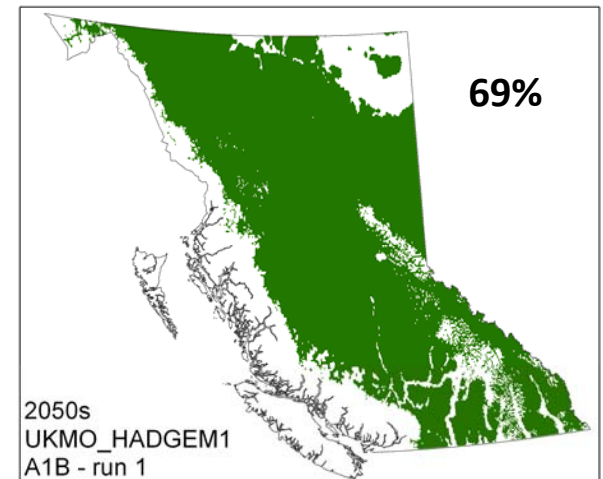
Change in Climatic Suitability Relative to 1961-1990



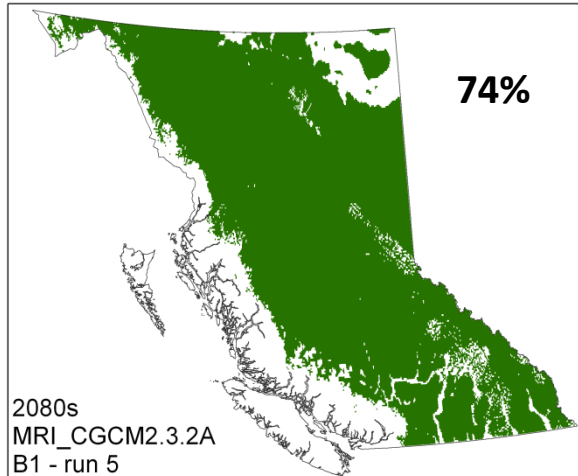
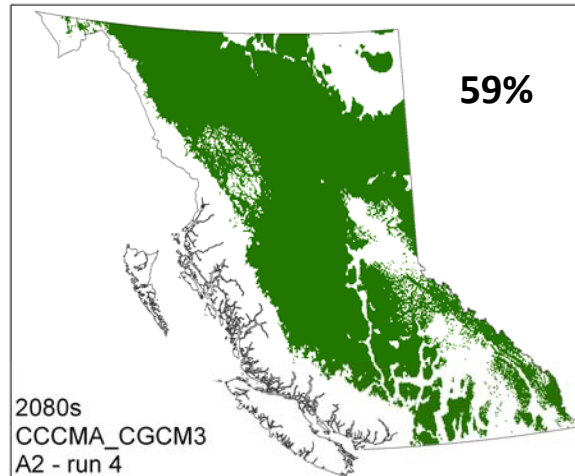
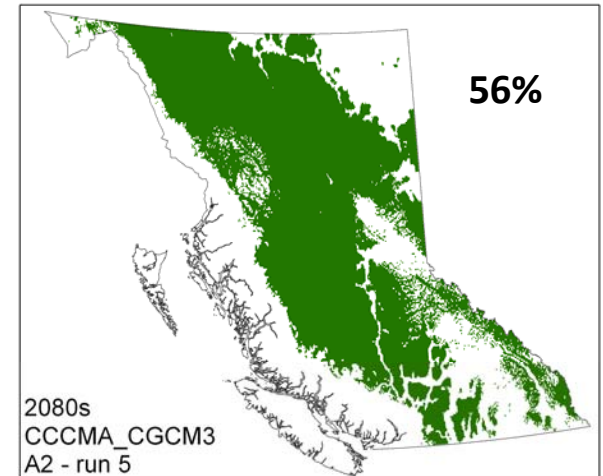
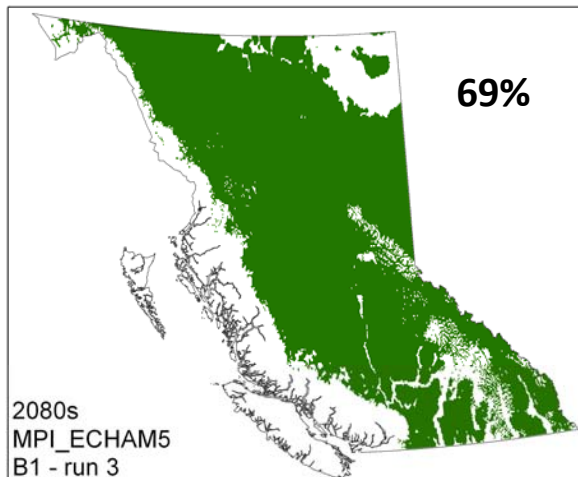
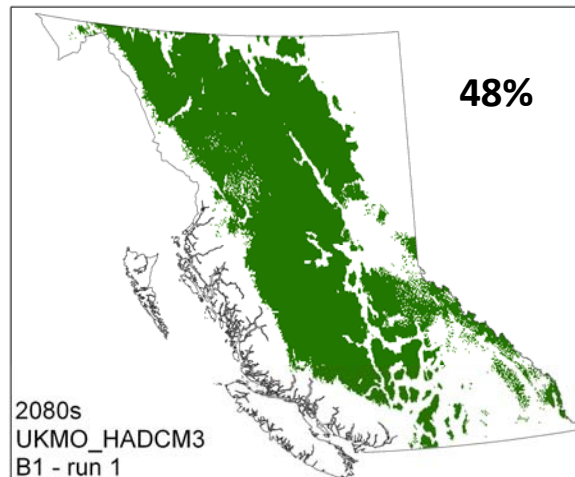
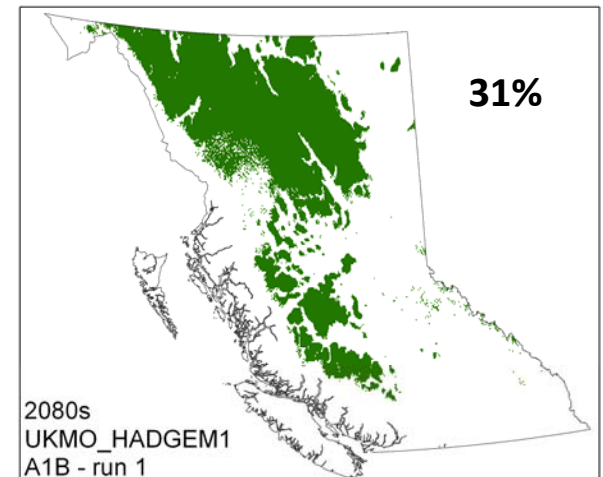
## Comparison of Climate Projections – 2020s Spruce Suitability



## Comparison of Climate Projections – 2050s Spruce Suitability

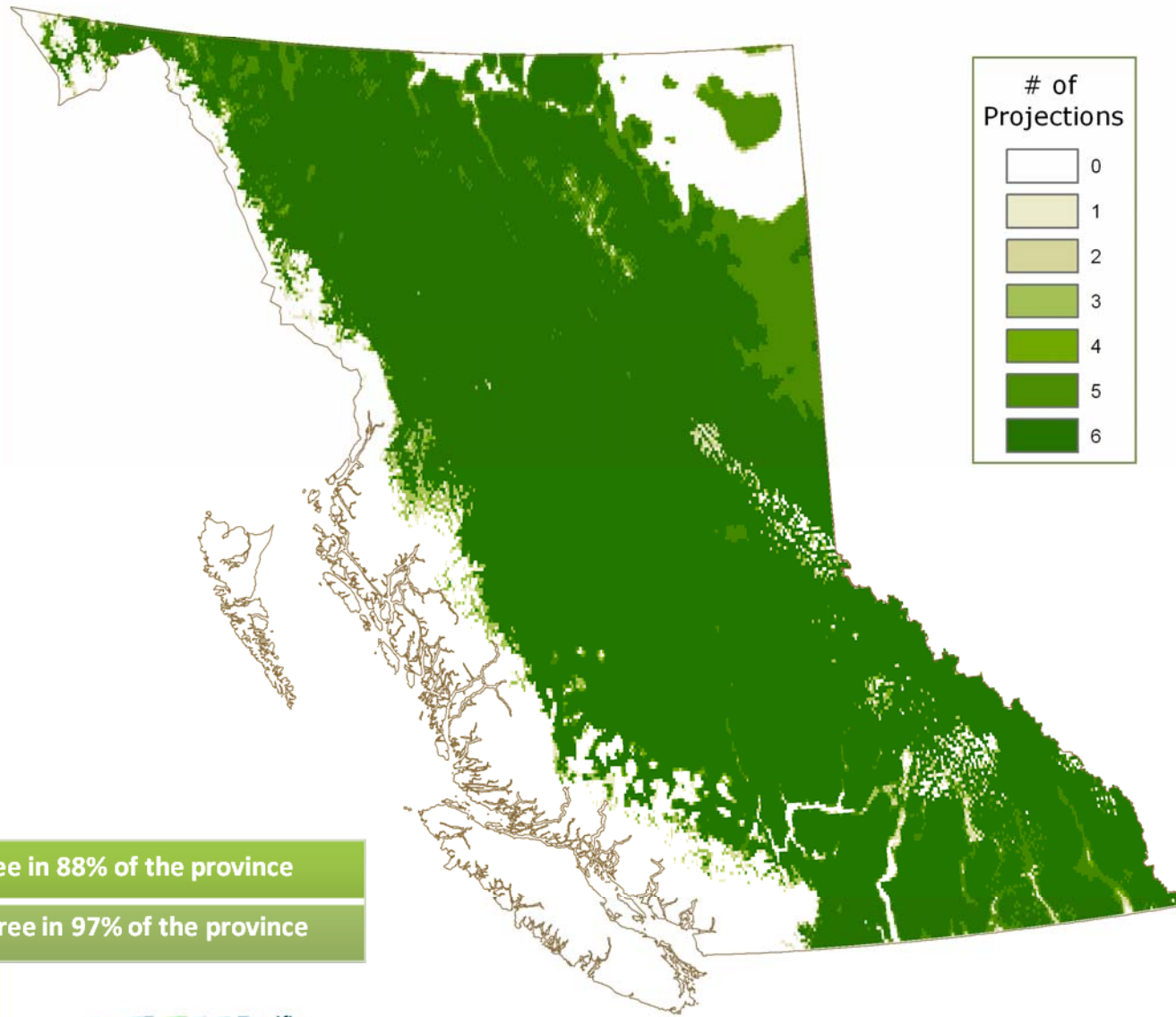


## Comparison of Climate Projections – 2080s Spruce Suitability



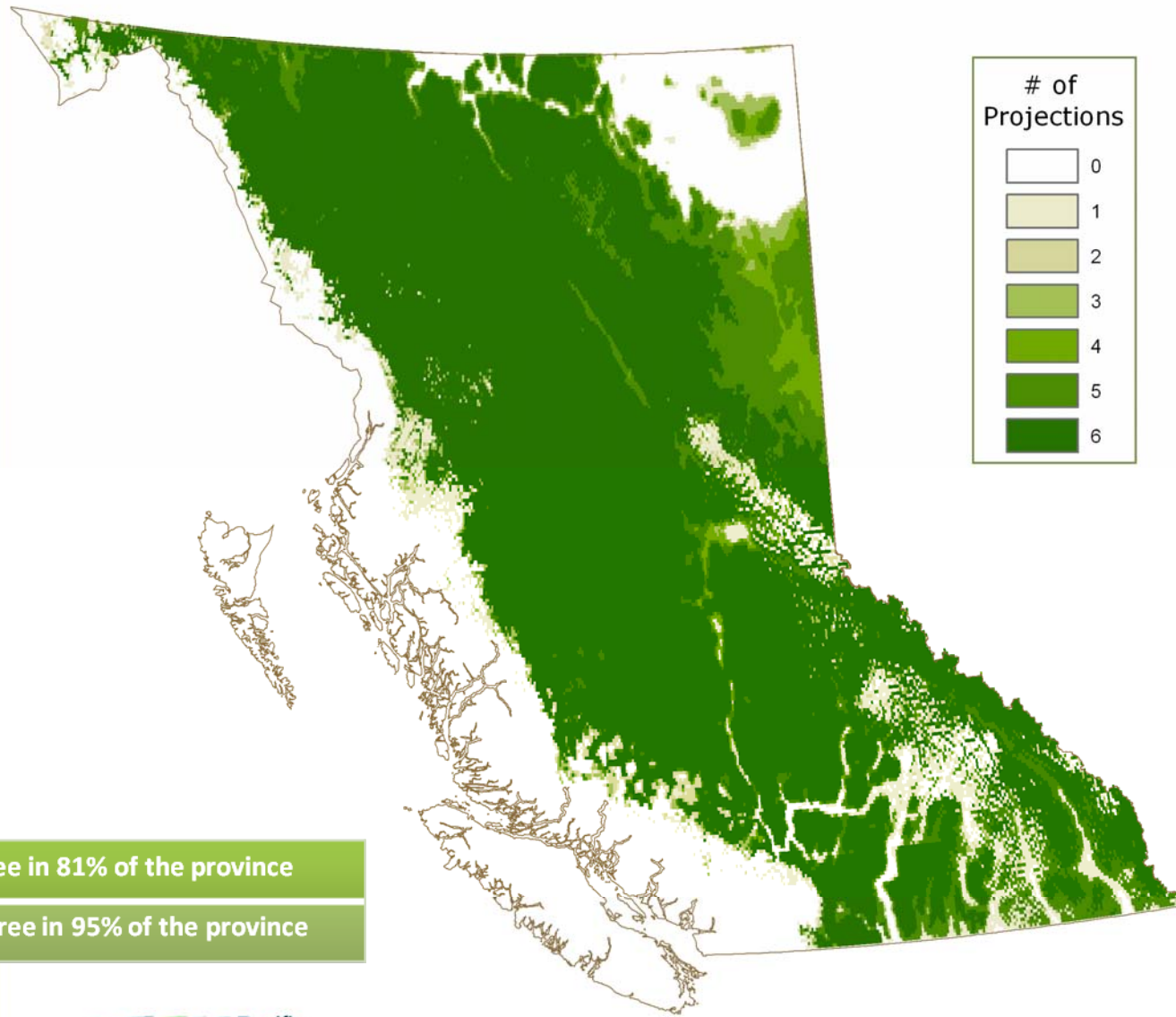
# 2020s Spruce Suitability

Number of Climate Projections Indicating Climatic Suitability



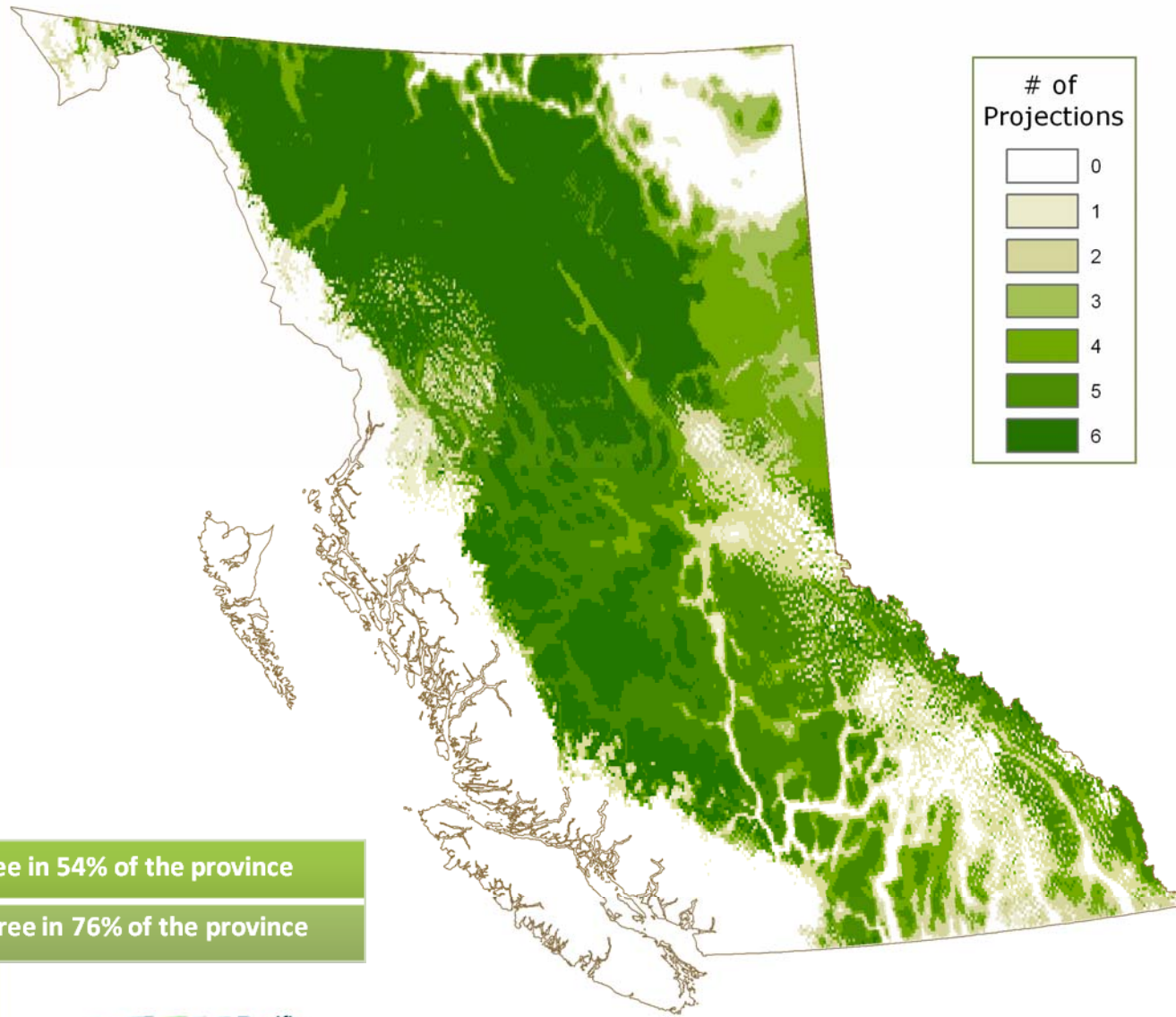
# 2050s Spruce Suitability

Number of Climate Projections Indicating Climatic Suitability



# 2080s Spruce Suitability

Number of Climate Projections Indicating Climatic Suitability



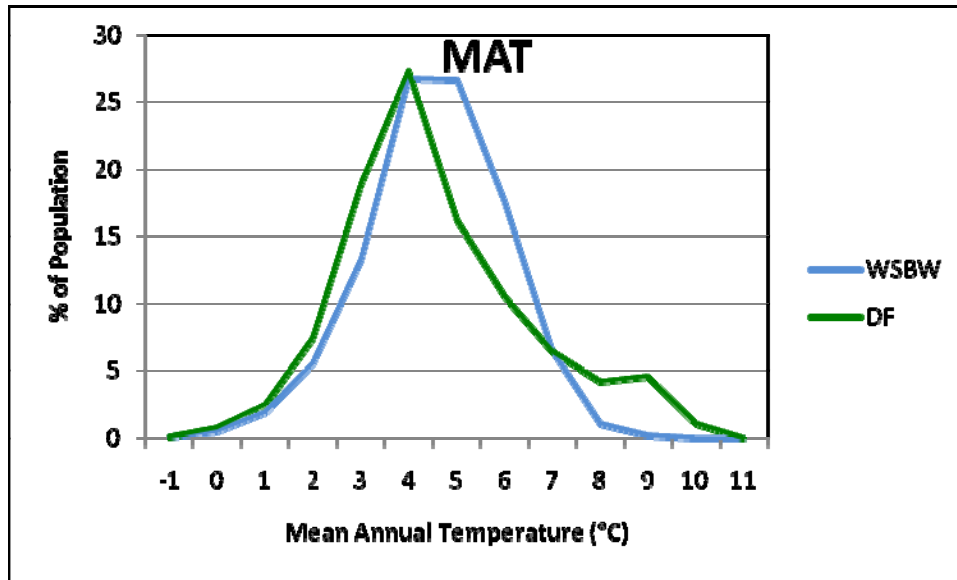
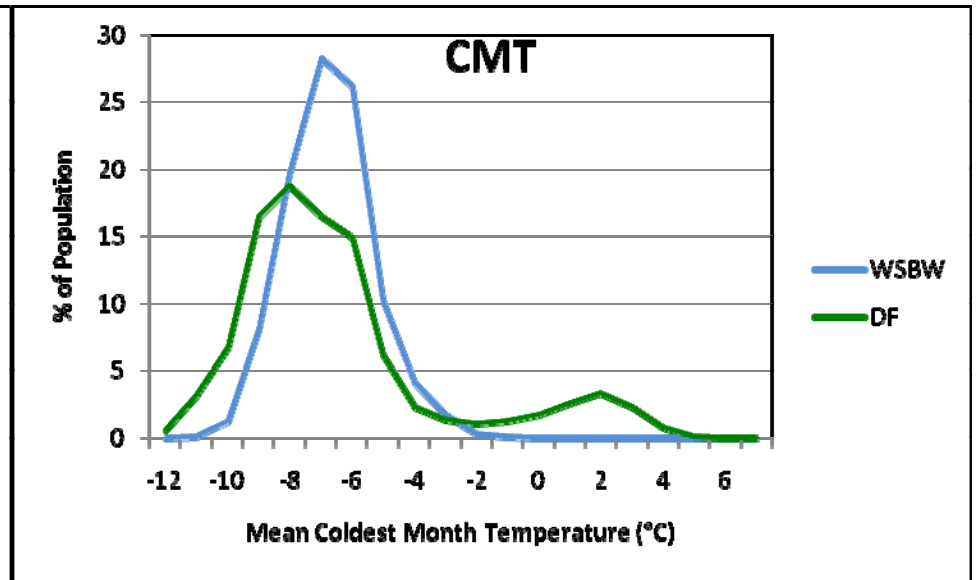
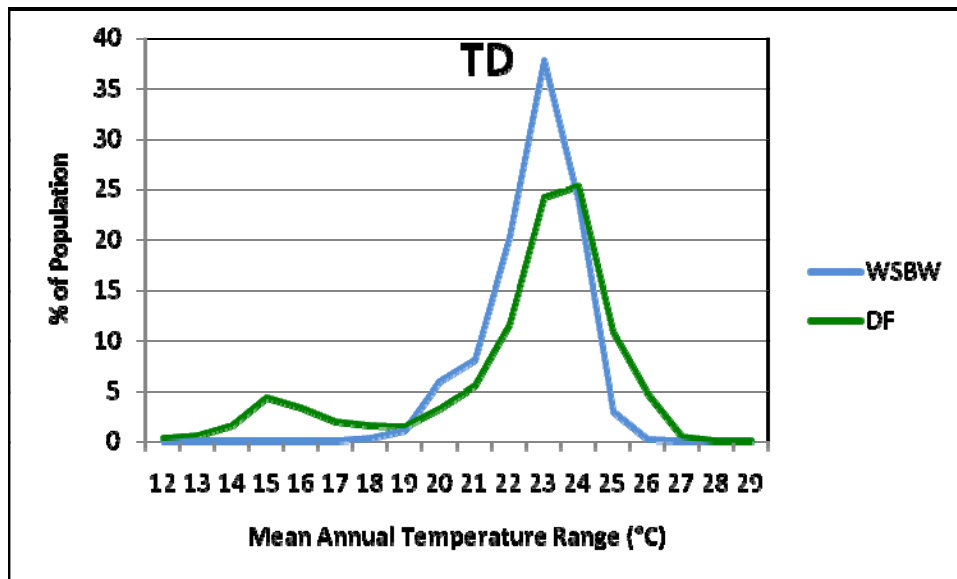
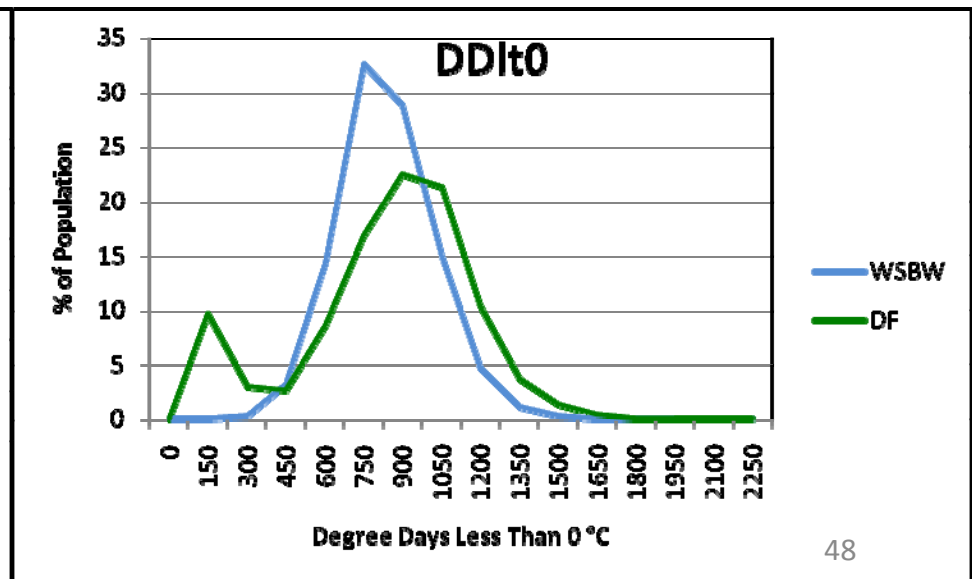
## Bioclimatic Envelope Models: Summary & Conclusions

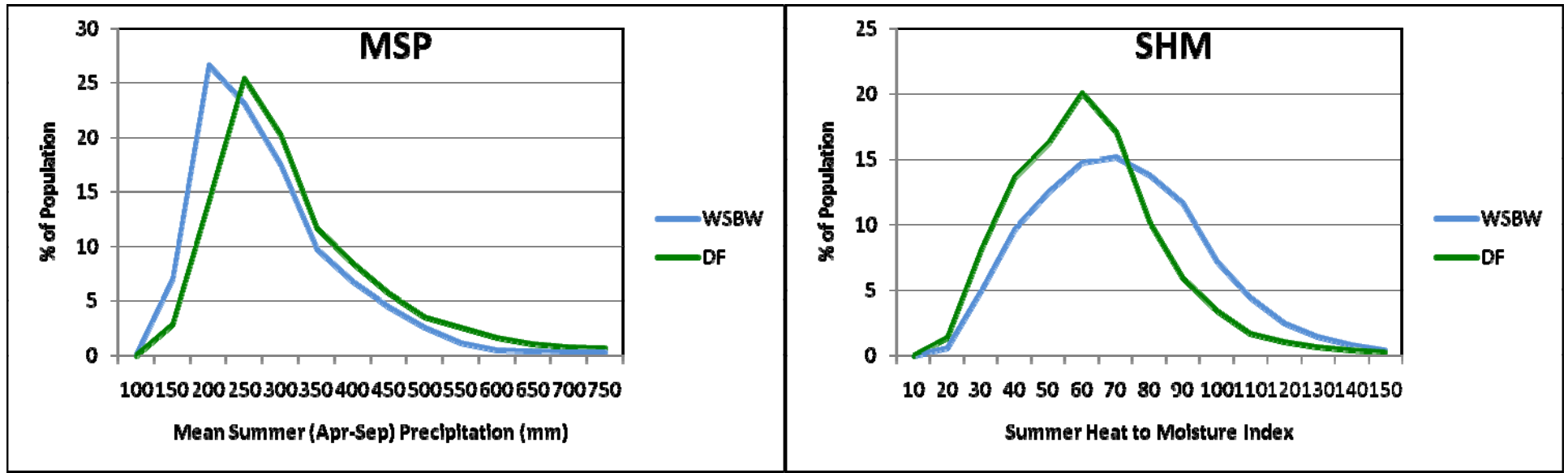
- PCA-based model offers a valuable presence-only approach
- Model limited by distribution of presence records
- Climatic suitability for both species decreases in valleys, increases upslope and to the north over the next century
- Uncertainty in climate projections increases as we look further into the future
- Important to look at a suite of climate projections to assess uncertainty inherent in GCM projections

# Western Spruce Budworm

## *Choristoneura occidentalis*

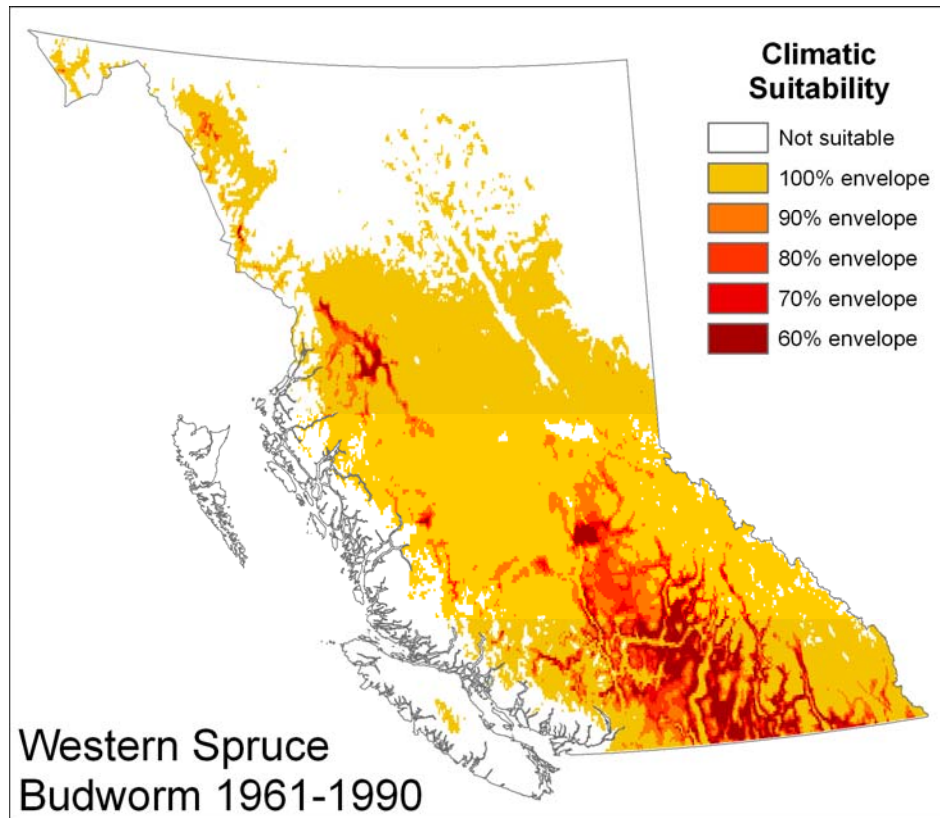
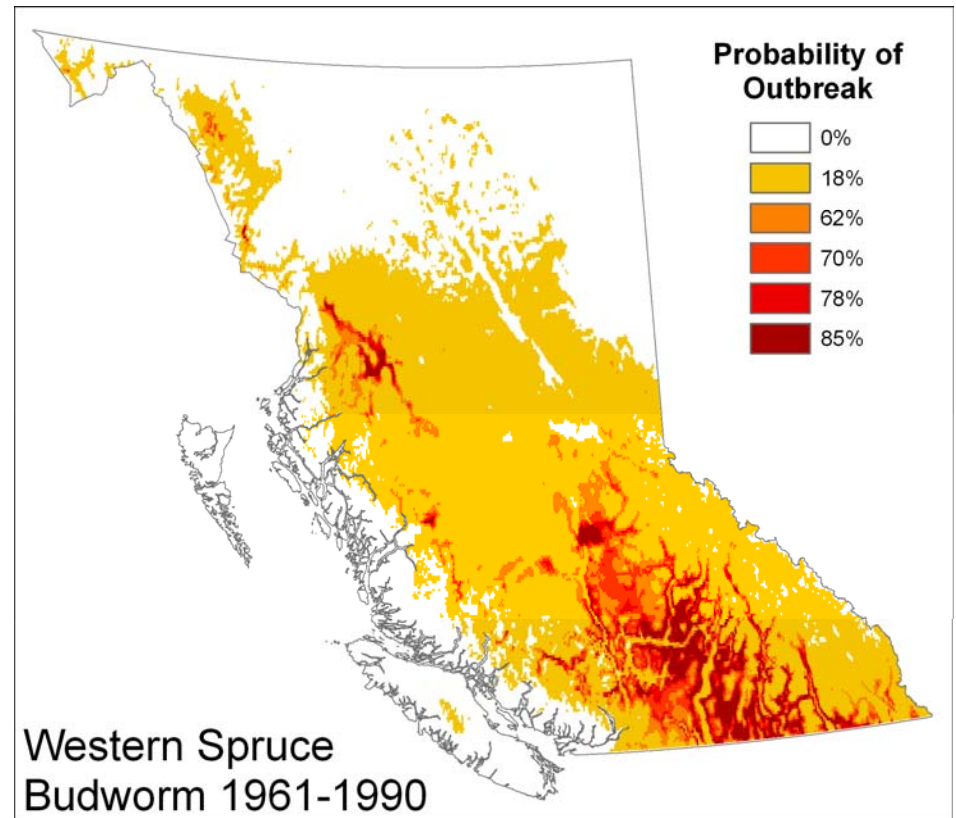






### Summary:

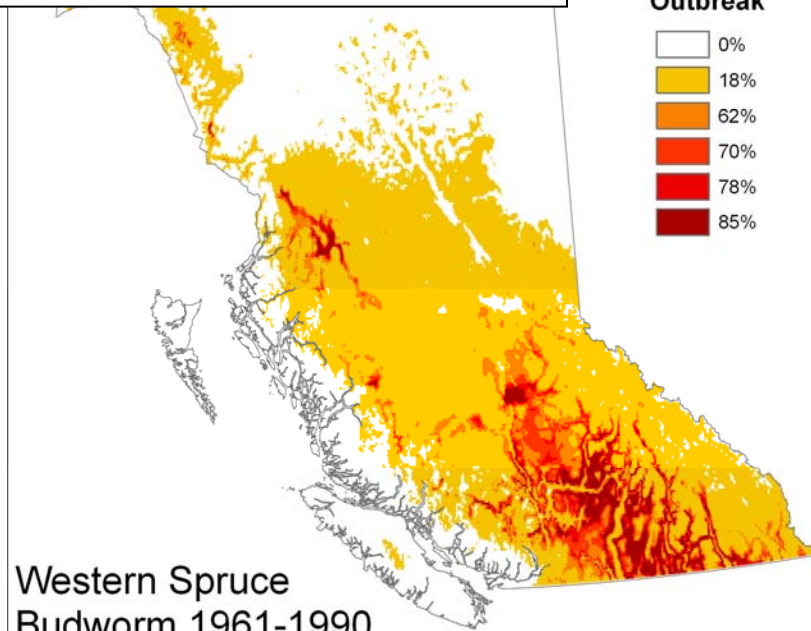
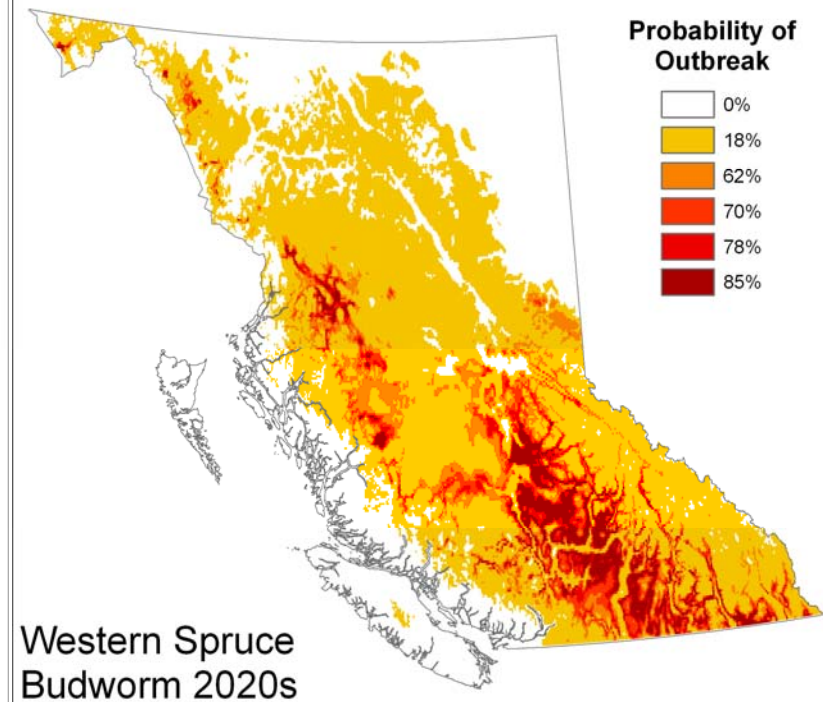
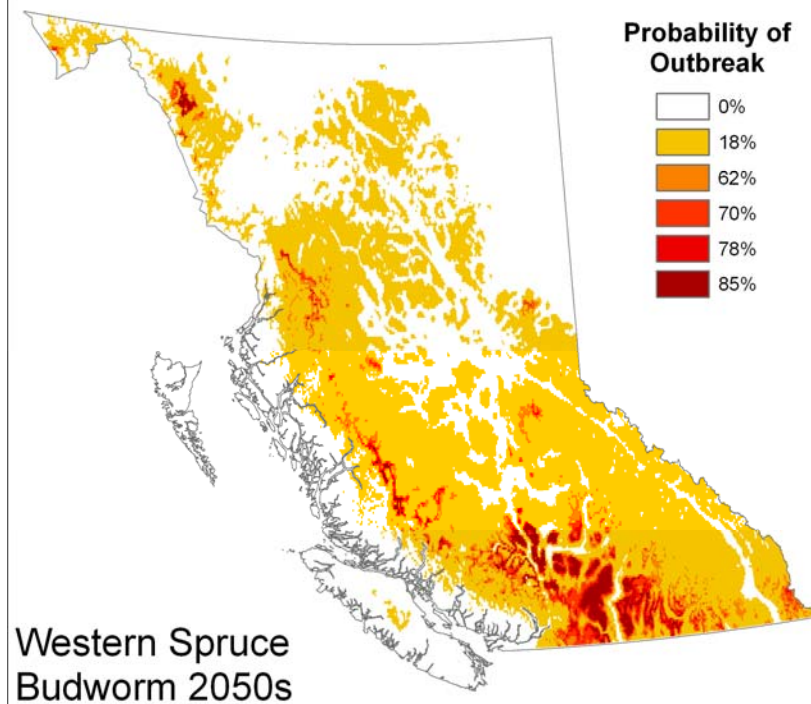
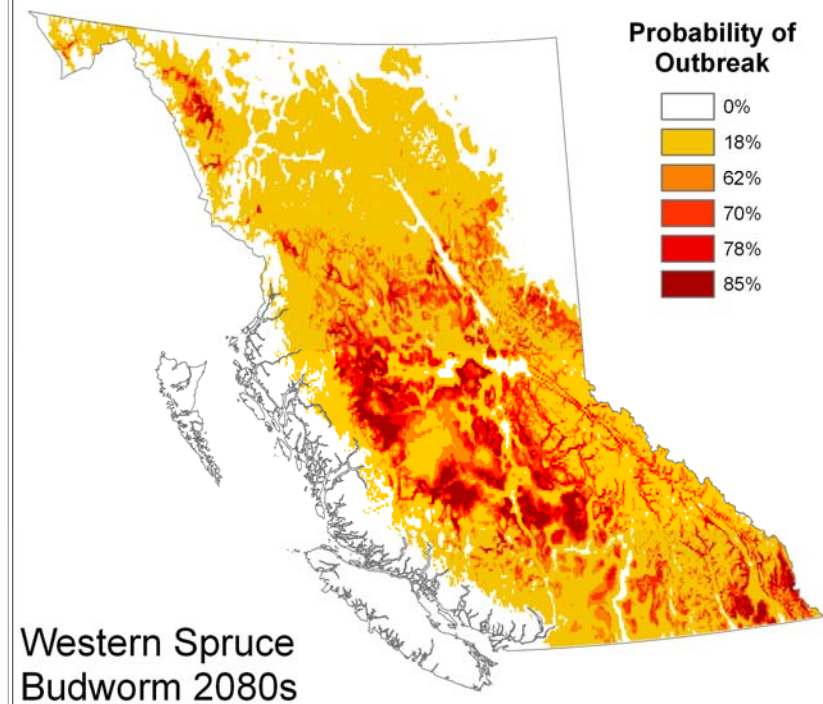
WSBW outbreaks occur in the warmer, drier parts of the range of Douglas Fir



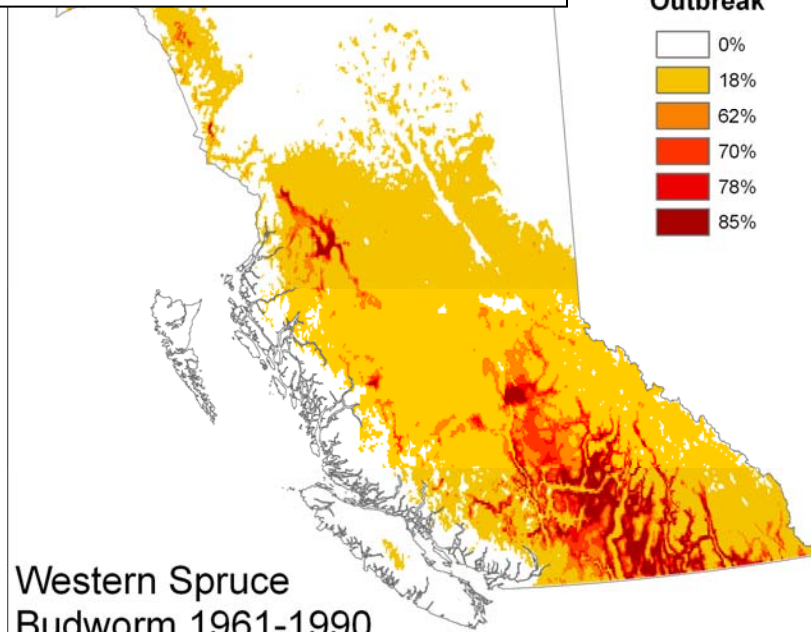
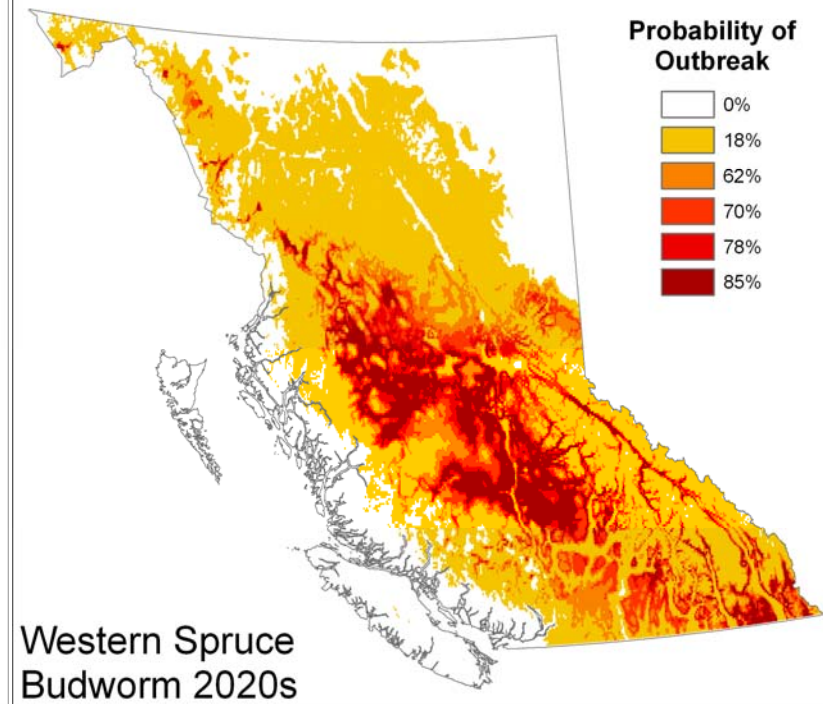
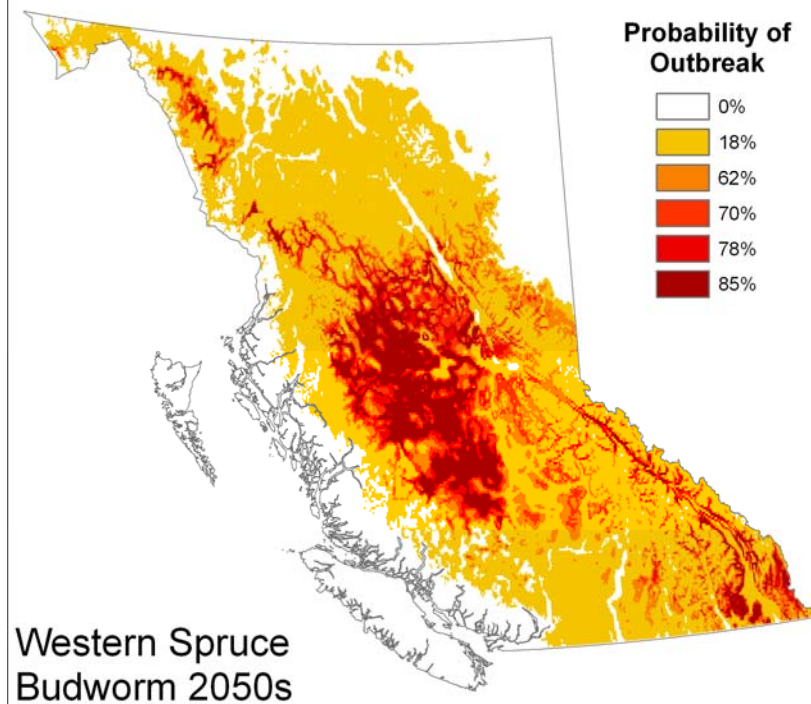
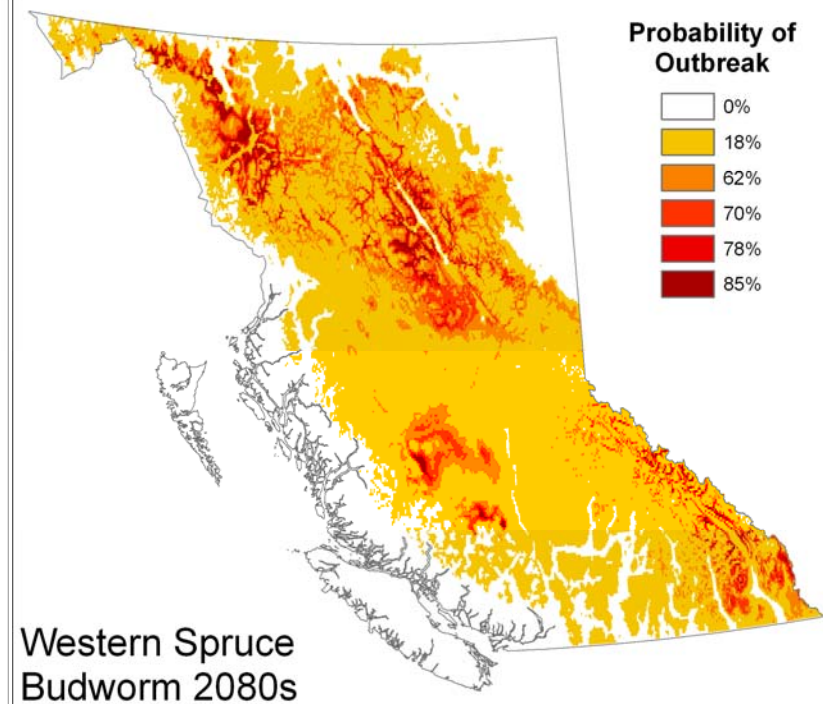
**Climatic suitability envelope:** the area with climatic conditions within the range that 100%, 90%, etc. of WSBW outbreaks occurred during the 1961-1990 period.

**Probability of outbreak:** the number of suitable (climatically suitable, Douglas fir present) grid cells that experienced an outbreak, divided by the total number of suitable grid cells. Calculated for 30-year periods for each climatic envelope. Ignores spatial autocorrelation.

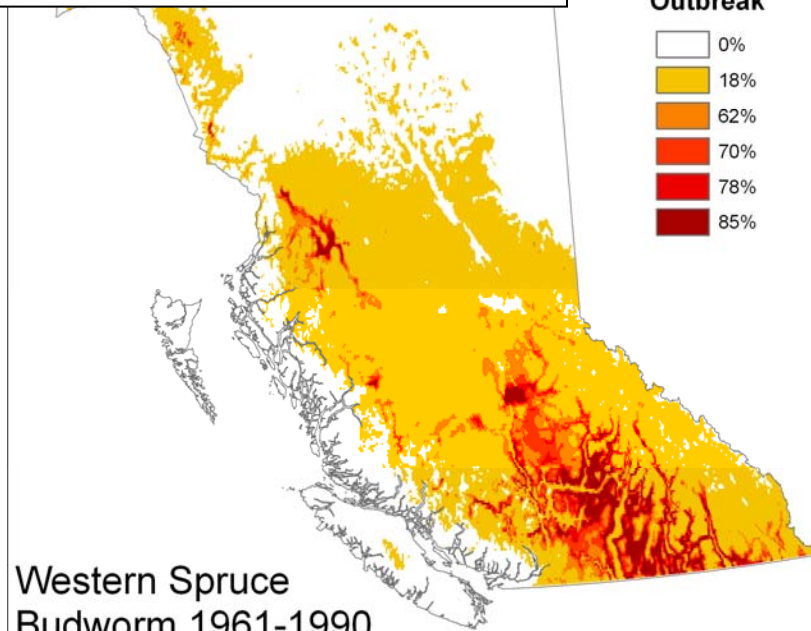
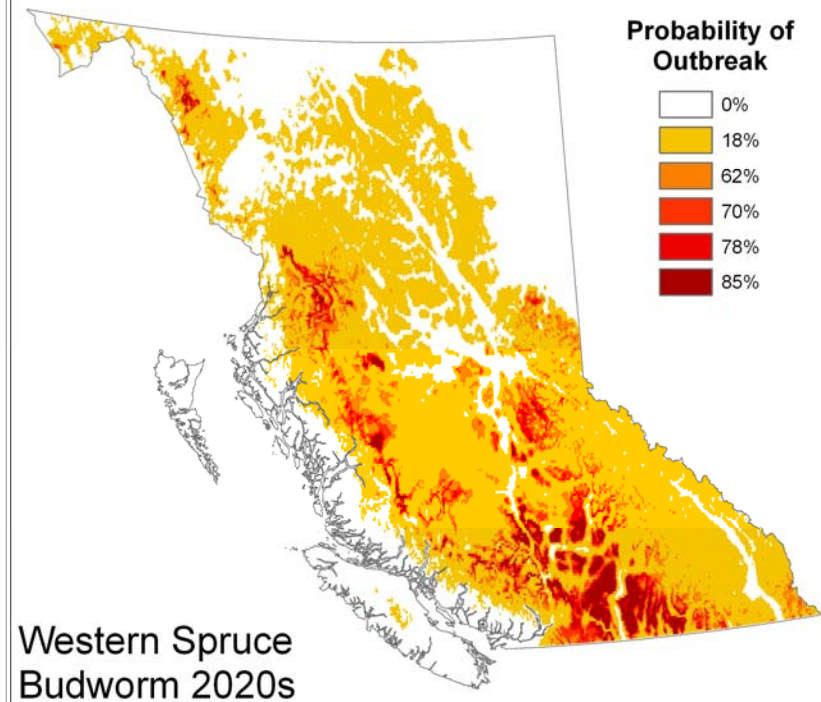
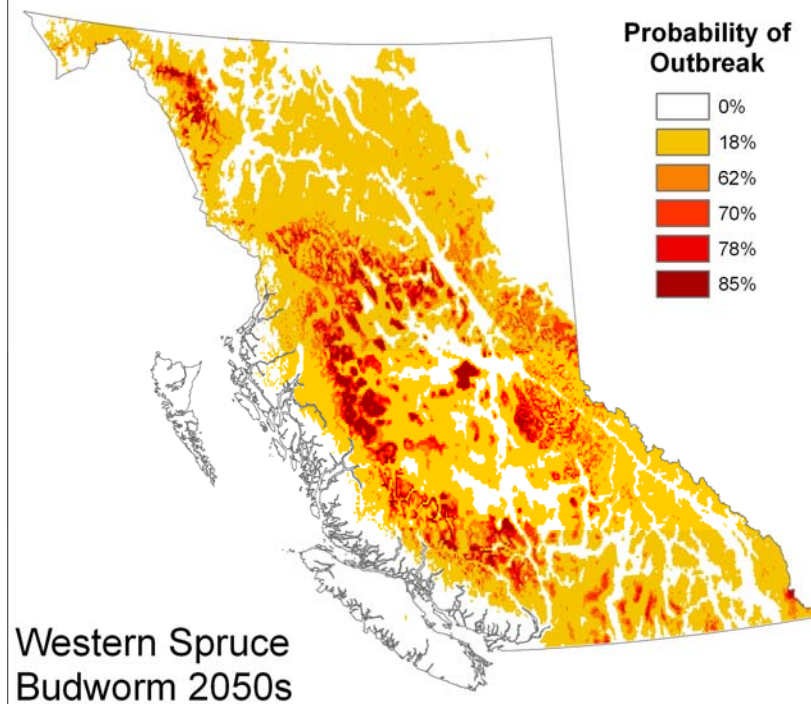
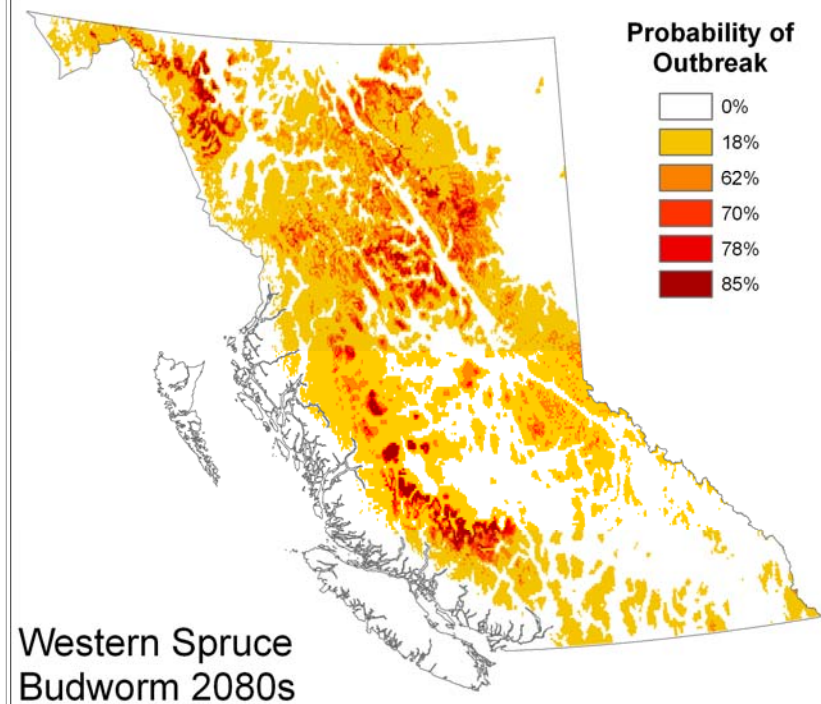
## ECHAM 5 B1 – run 3



## CGCM3 A2 – run 5



# HADGEM1 A1B – run 1

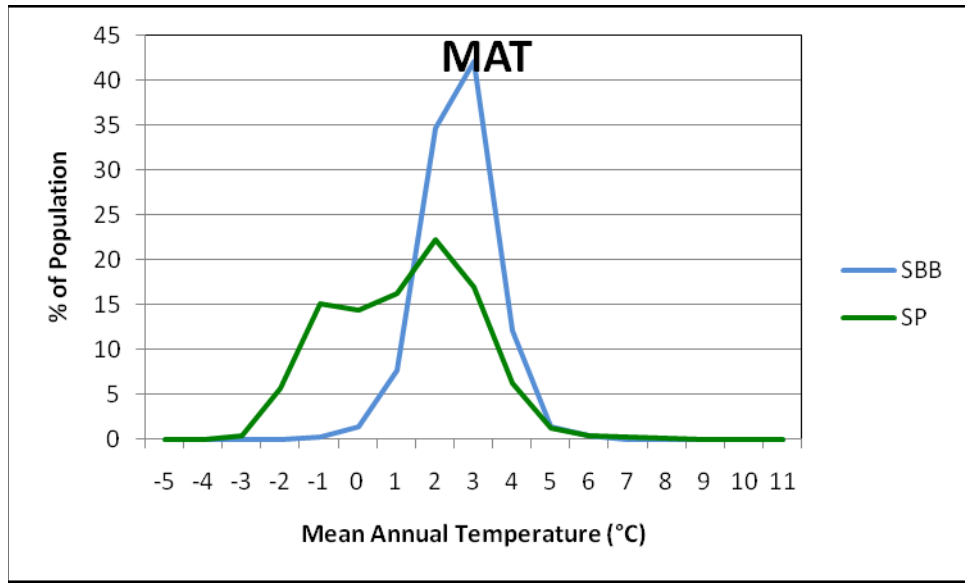
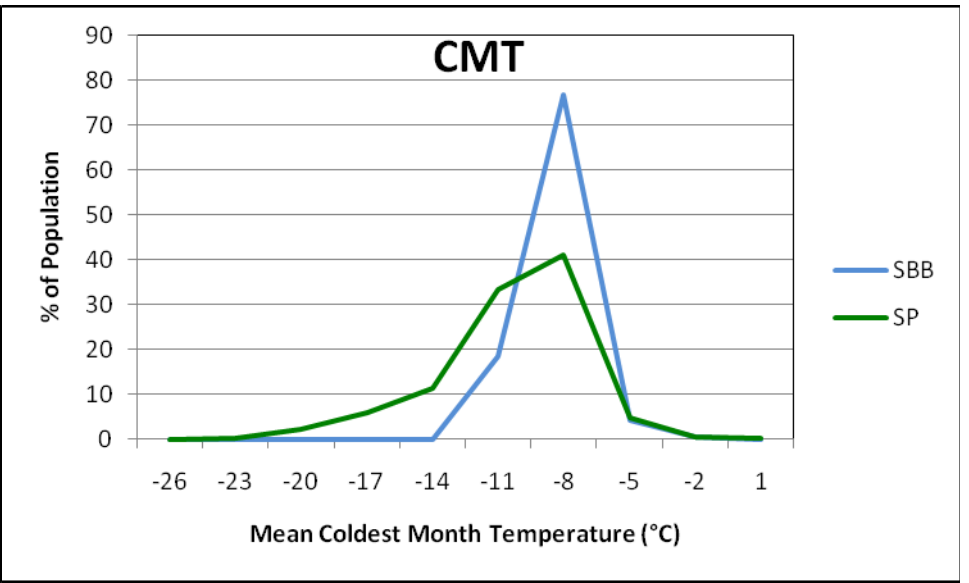
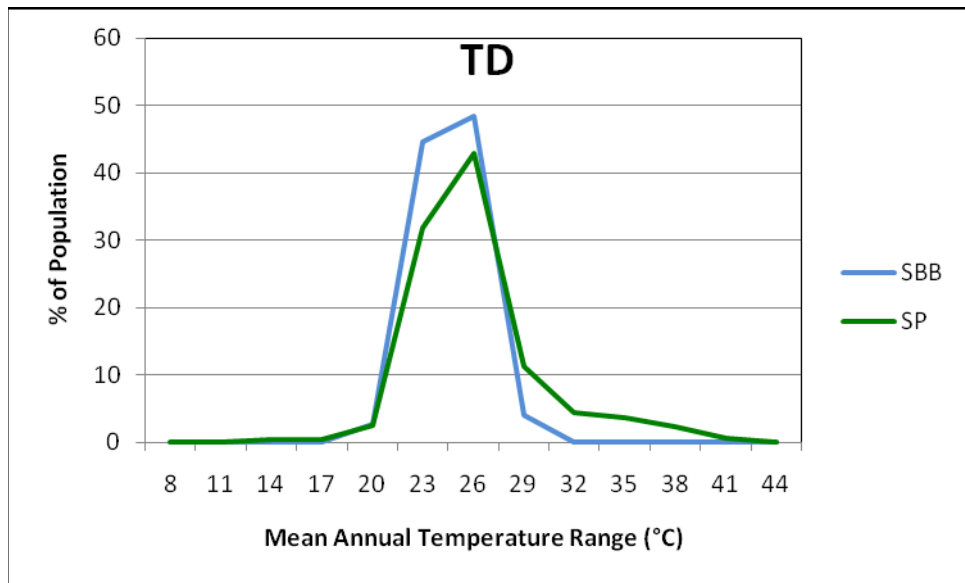
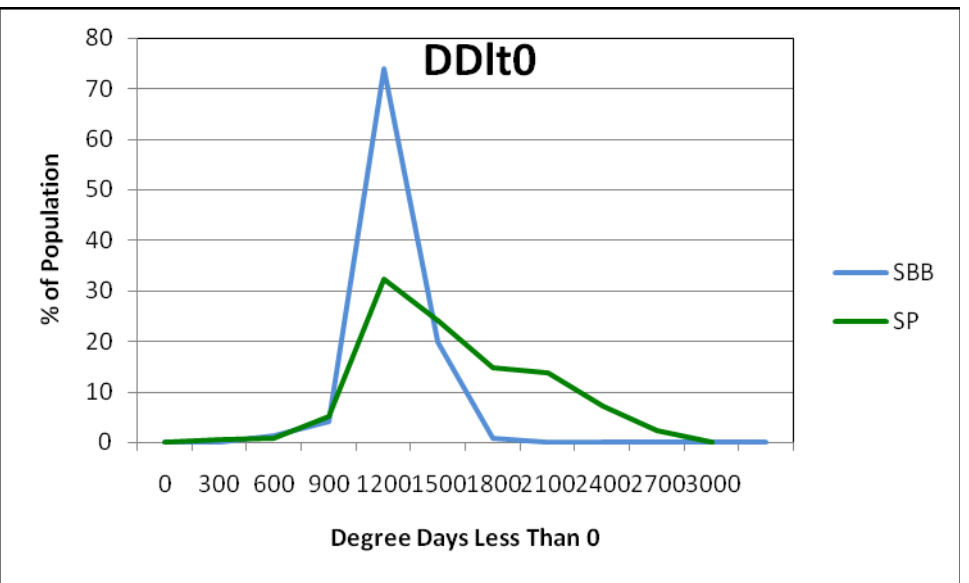


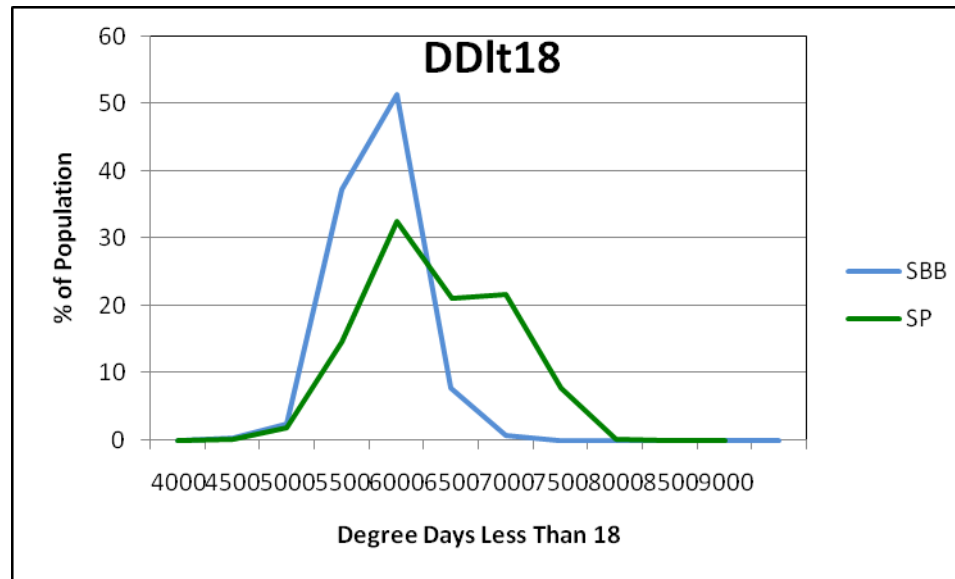
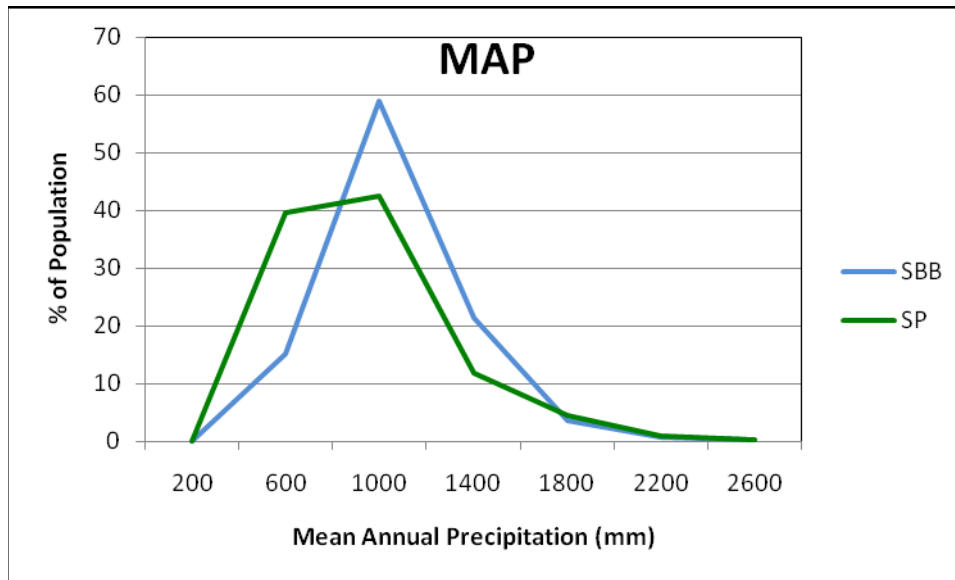
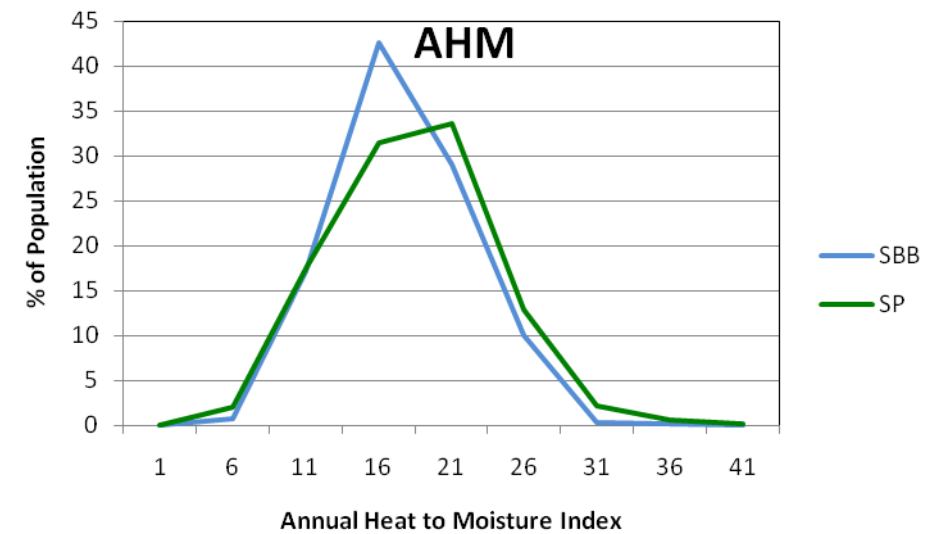
# Spruce Bark Beetle

## *Dendroctonus rufipennis*



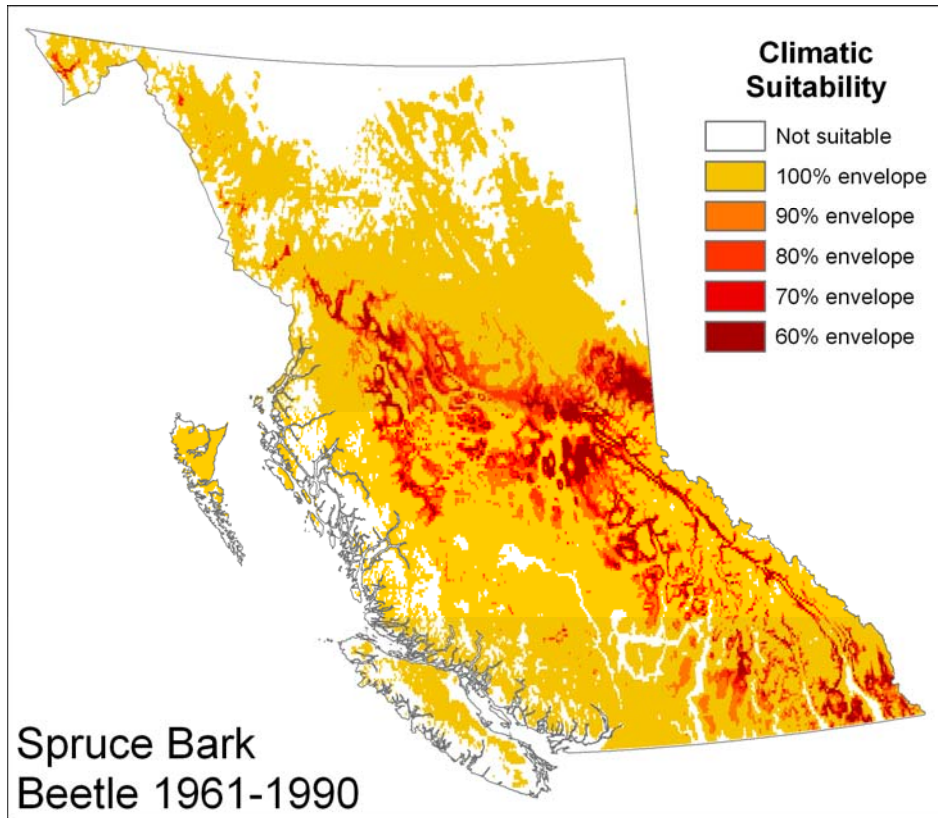
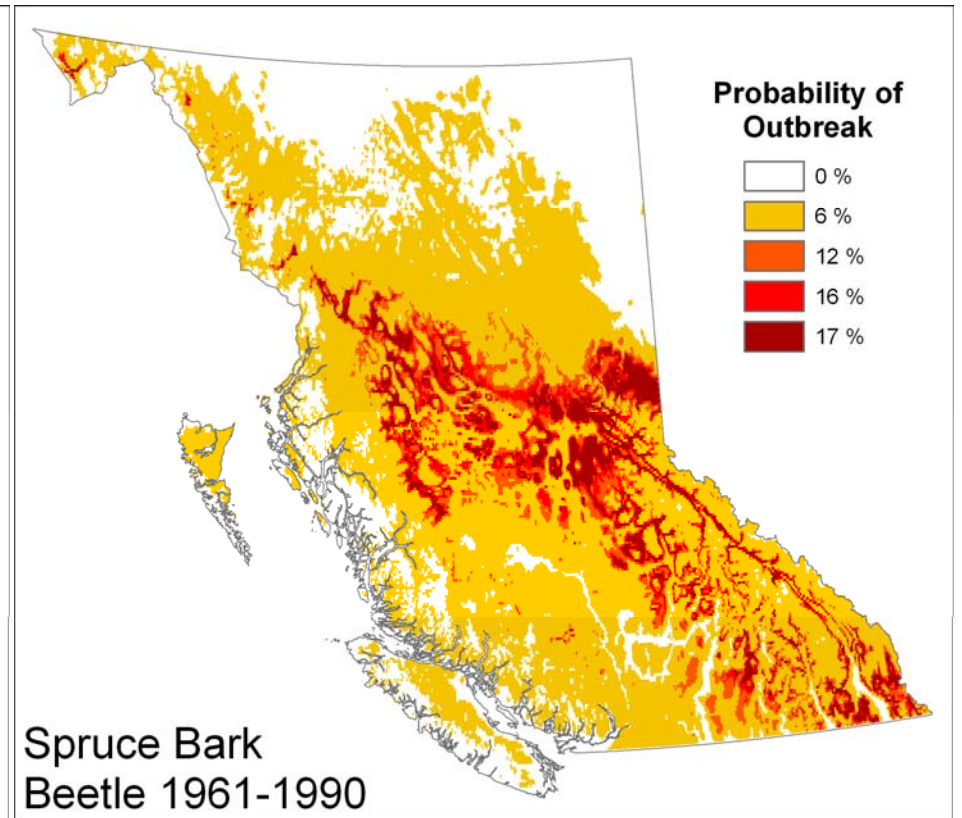
Photos from the BC Ministry of Forests and Range



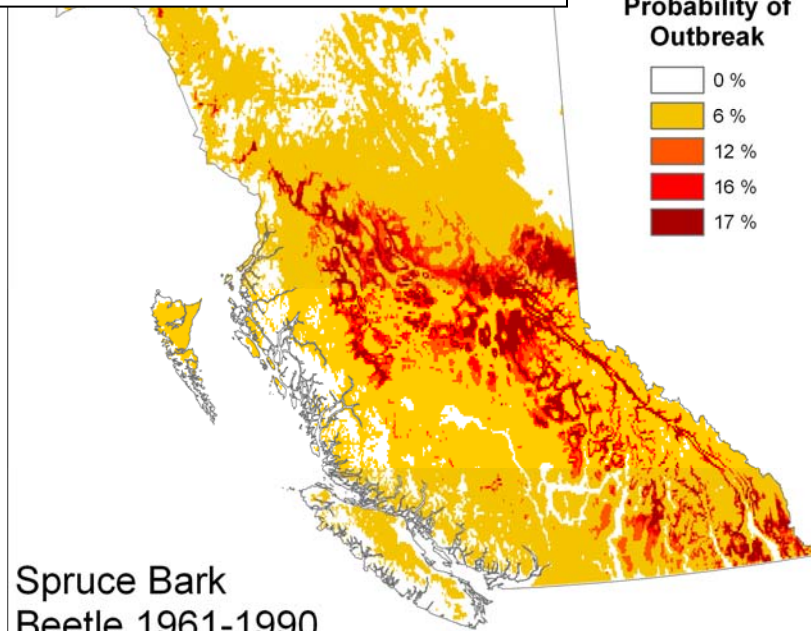
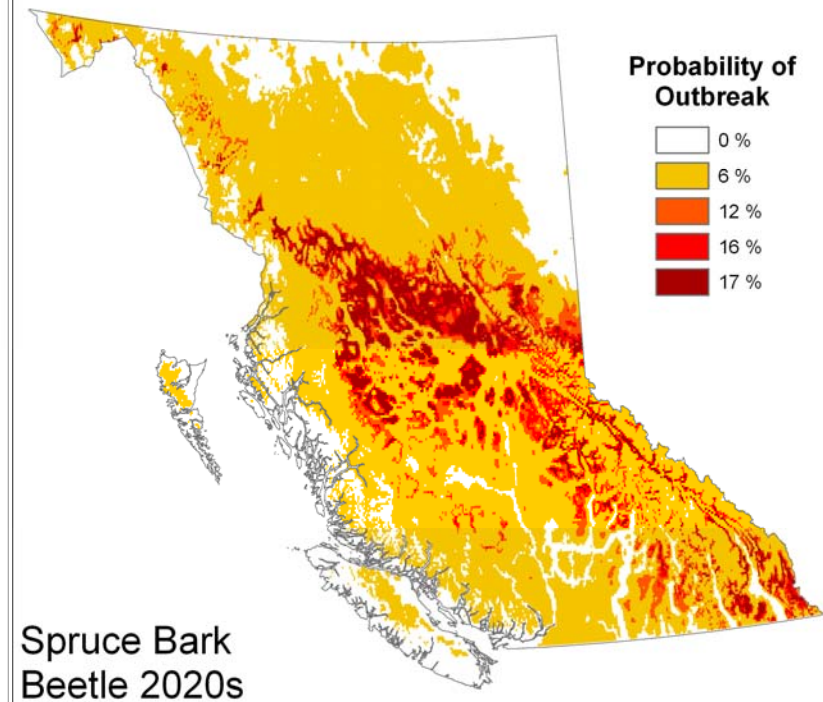
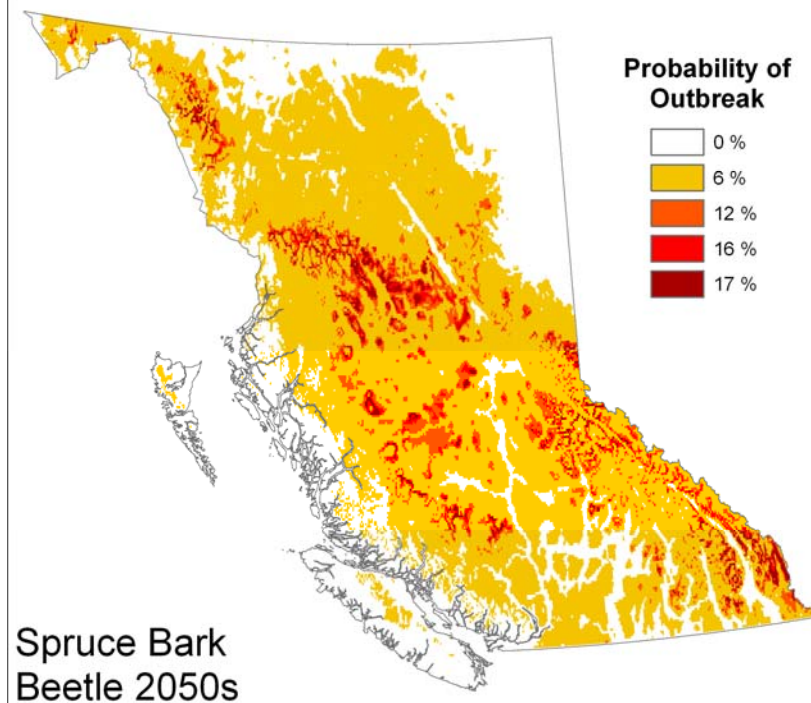
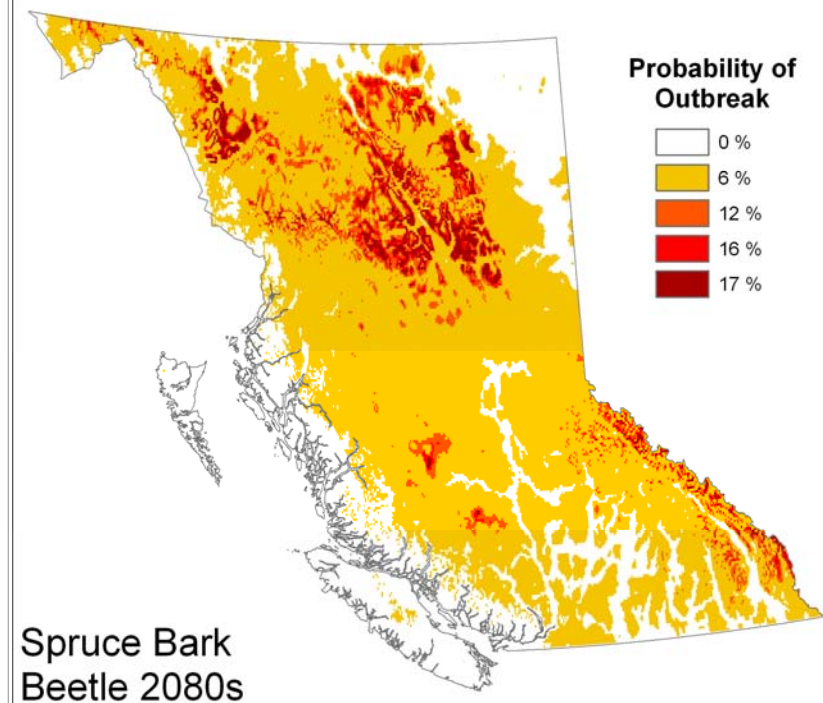


## Summary:

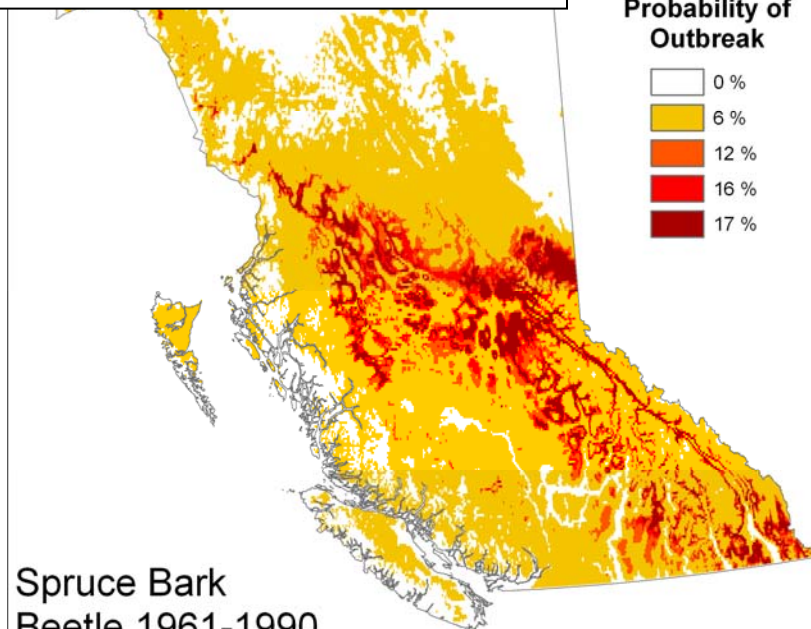
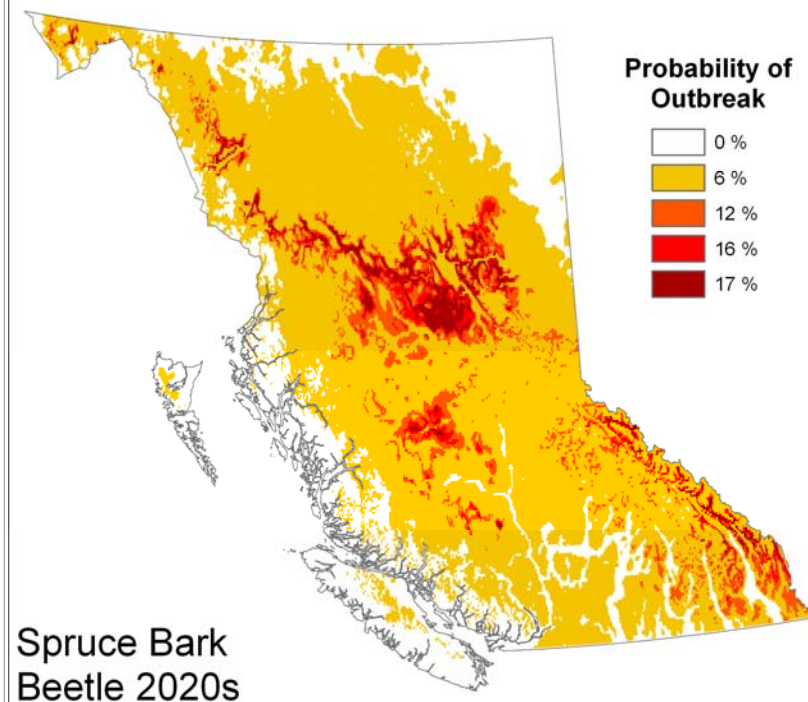
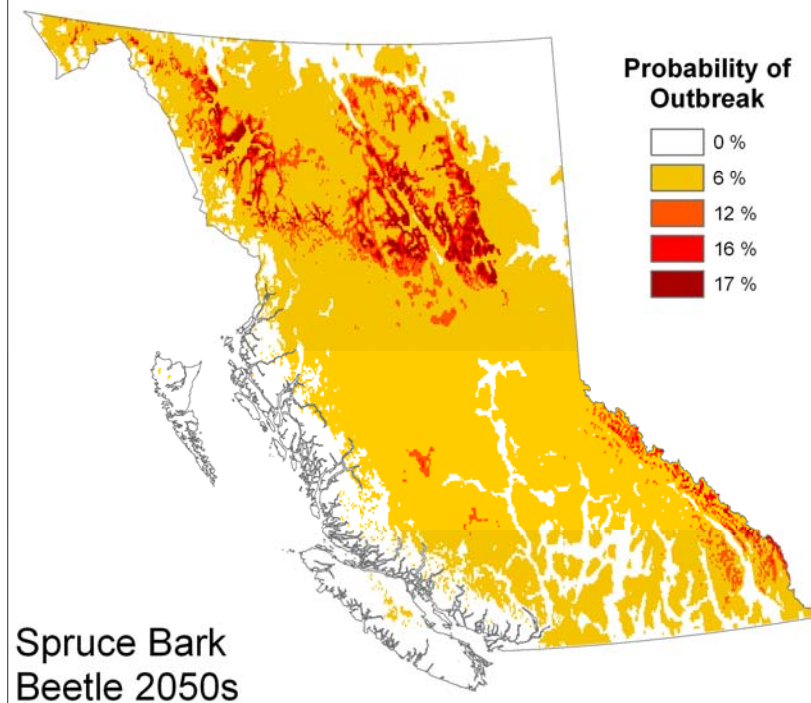
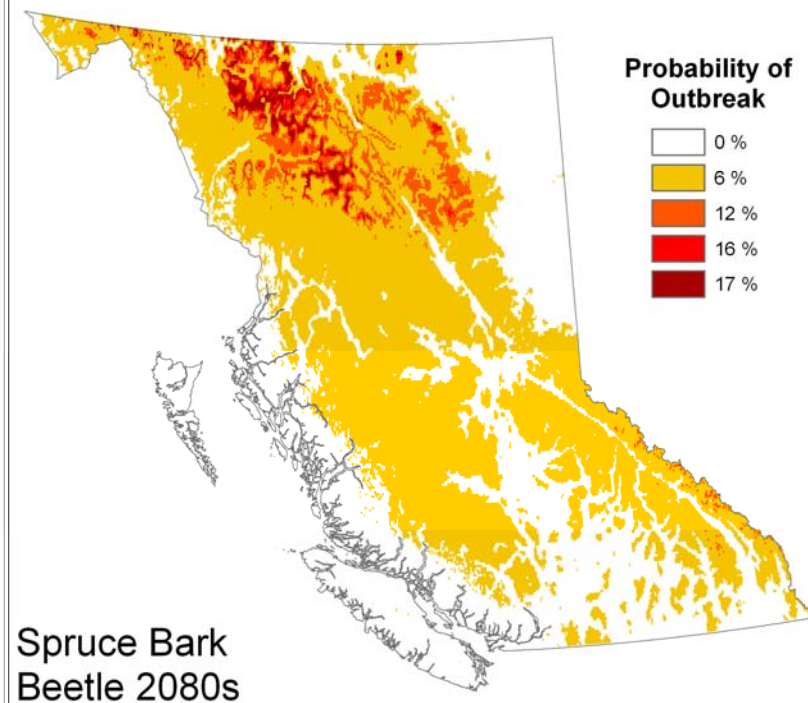
SBB outbreaks occur in the warmer, wetter parts of the range of spruce forests



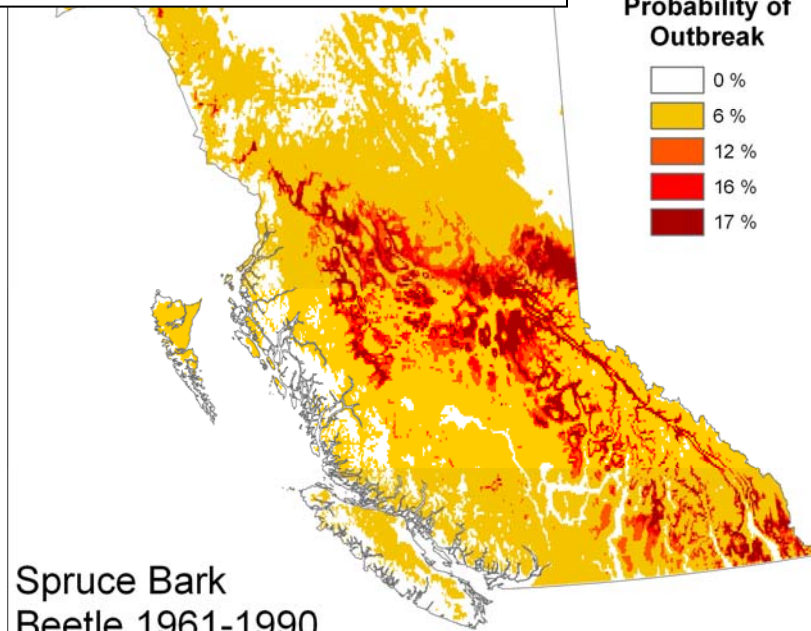
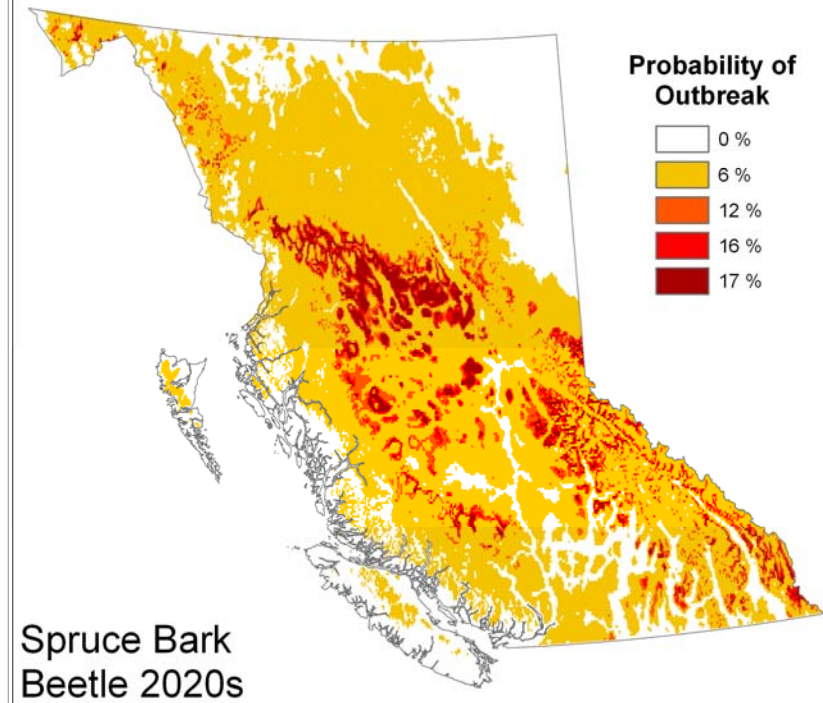
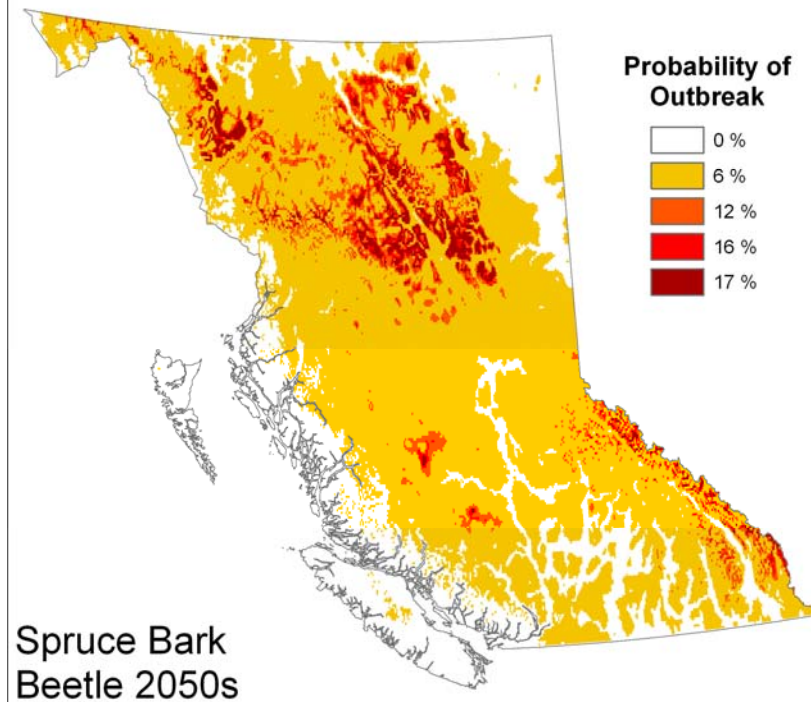
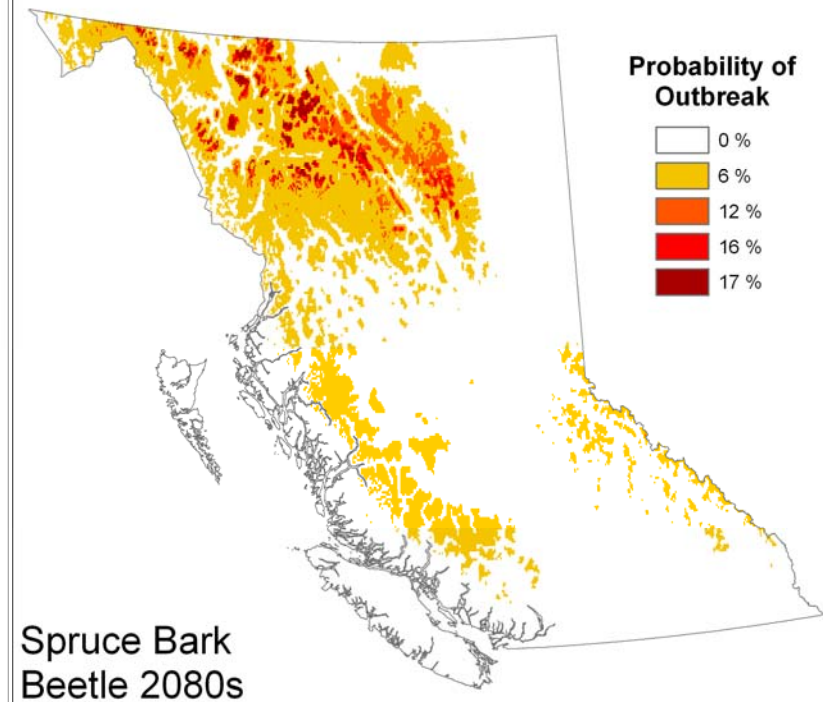
## ECHAM 5 B1 – run 3



## CGCM3 A2 – run 5



# HADGEM1 A1B – run 1



## Pest Outbreak Projections: Summary & Conclusions

- Simple climate envelopes offer conservative projections
- Western spruce budworm outbreaks have historically occurred in the warmer, drier portions of their host's distribution
- Spruce bark beetle outbreaks have historically occurred in the warmer, wetter parts of their host's distribution
- Projections indicate a northward and/or eastward shift and overall decrease in areas with a high probability of SBB and WSBW outbreaks over the next century

# Thank you

For more information

[www.PacificClimate.org](http://www.PacificClimate.org)

