

CLIMATE VARIABLE MAPPING AND AGRICULTURE – METRO VANCOUVER

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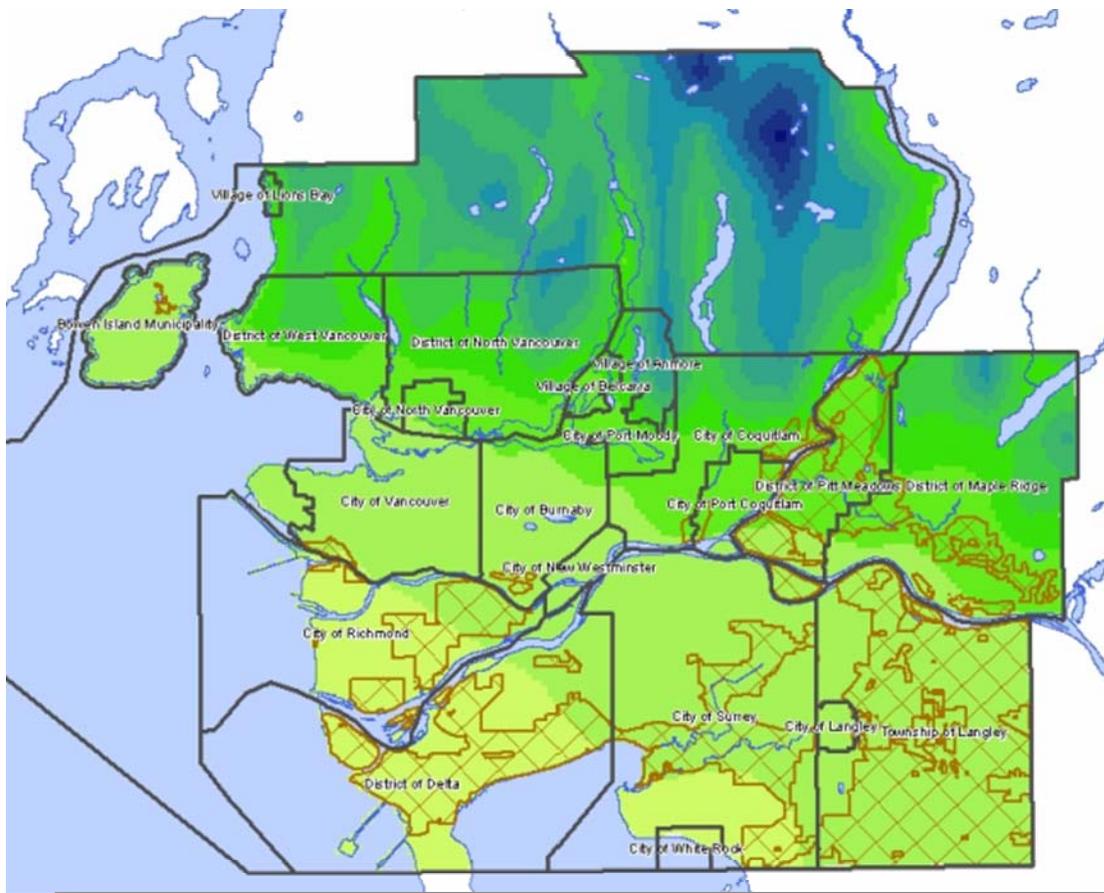


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INTRODUCTION

This document provides information to Metro Vancouver regarding select climate variables associated with agriculture in the regional district. These variables are discussed in the context of historical data as well as predictive data associated with two different climate change scenarios. Climate variable information is conveyed using regional maps produced using data generated by ClimateBC, a computer/web based application that integrates climate scenarios with topographical data sets to produce spatial information for map production. Interpretations of the maps and historical data are provided from an agricultural production perspective.

METRO VANCOUVER'S CLIMATE

INSIGHTS FROM HISTORICAL DATA



Metro Vancouver has a maritime temperate climate characterized by changeable, often overcast weather with significant precipitation in all seasons. The moderating influence of the ocean results in cooler summers and warmer winters than other locations at a similar latitude.

A weather station within Metro Vancouver at Vancouver International Airport has a 70 year record of weather observation data. This data, collected over the past seven decades and analyzed by the authors, indicate changes that are occurring to the Metro Vancouver climate. These climate changes are reflected in attributes of both temperatures and precipitation. These changes that are occurring provide context to potential climate change scenarios reflected in climate variable maps later in this report.

TEMPERATURE

Figure 1 indicates the trends in average annual maximum (brown) temperatures and average annual minimum (blue) temperatures since 1937. Both graphs indicate an increase in average temperatures. It is interesting to note that the climate is getting warmer more as a result of higher night temperatures than higher day temperatures. This is consistent with either an increase in greenhouse gas concentrations or an increase in cloud cover, since both of these phenomena will diminish the amount of overnight cooling.

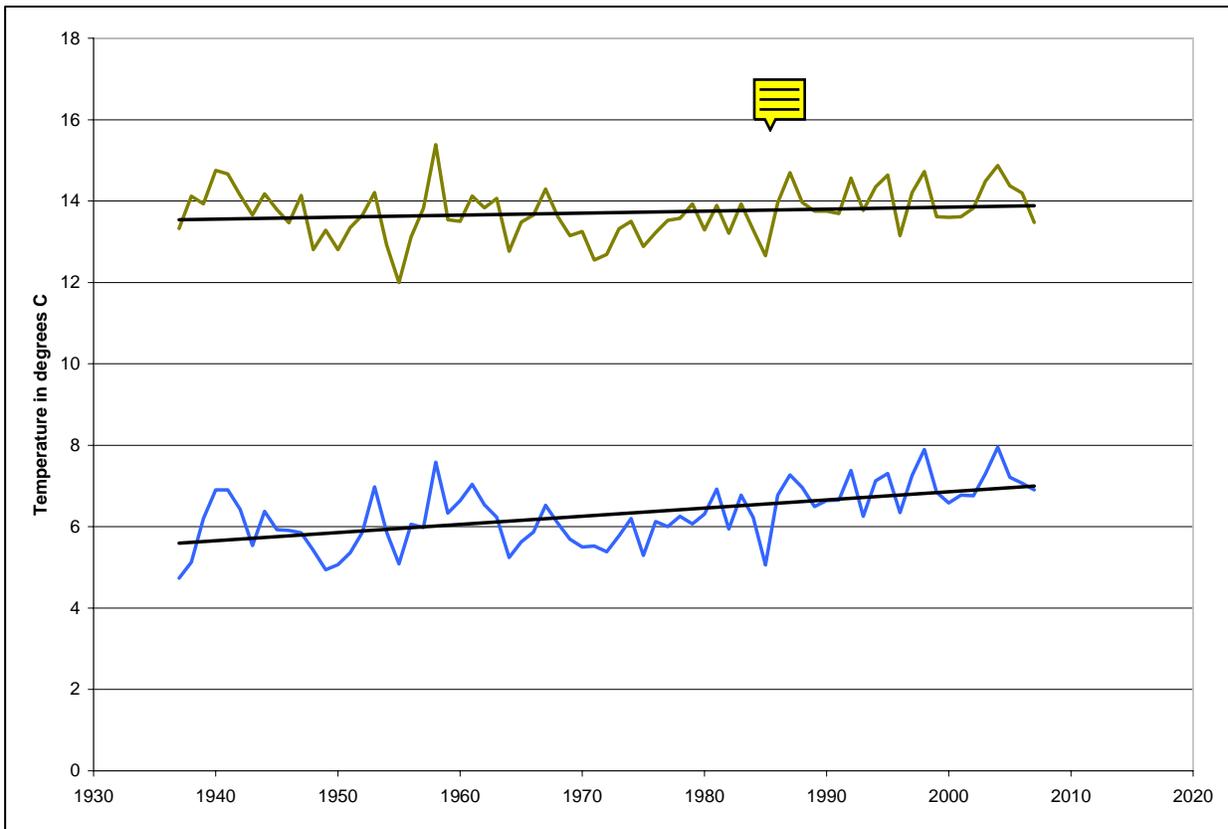


Figure 1 Trends in Annual Average Max. and Min. Temperatures at Vancouver International Airport

TEMPERATURE VARIABILITY

Deriving average temperatures is independent of the variation in the measurements. Over a period of time, average temperatures can remain constant while there can be changes to the variability of the data reflecting an increased magnitude of extreme temperature events. To ascertain if the variability of temperature has changed over time, an analysis has been undertaken to determine if the magnitude of the difference of extreme high and low temperature events from historical climate normals are increasing or decreasing.

Using the temperature data recorded at Vancouver International Airport, records of the extreme maximum temperature for August and the extreme minimum temperature for January were selected for each year from 1937 to 2008. The difference between each maximum and minimum temperature value and a constant value (in this case the 1965-1990 climate normal of Average August Maximum temperature and Average January Minimum temperature respectively) was derived. These values are plotted in Figures 2 and 3 respectively.

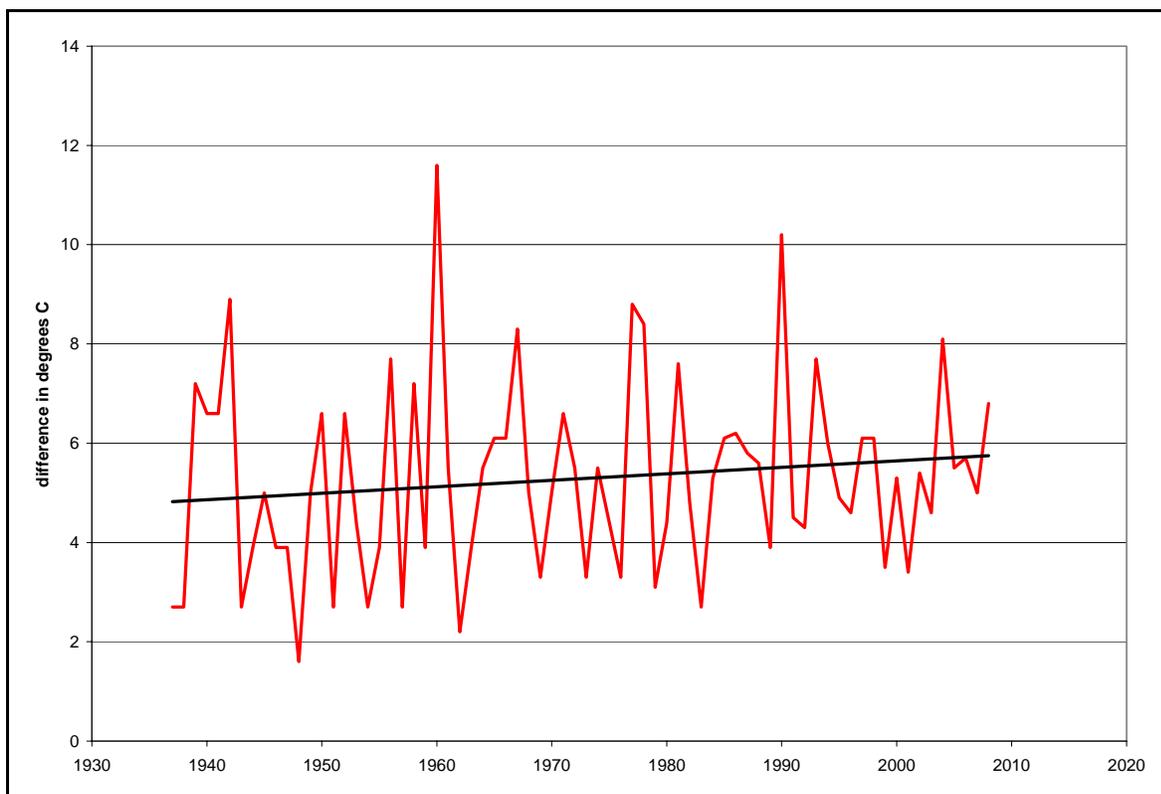


Figure 2 Variability in Extreme Maximum August Temperatures at Vancouver International Airport

The analysis reveals that the variability of extreme maximum temperatures in August is increasing. In the 1940's, the extreme maximum temperature was, on average, approximately 5 Celsius degrees higher than the climate normal for the average maximum August temperature. In the past decade the extreme maximum temperatures in August are averaging almost 6 Celsius degrees higher than the climate normal.

A similar analysis for extreme minimum temperatures for January is shown in Figure 3. In this case, the variability of extreme minimum temperatures is decreasing. On average, extreme January minimum temperatures are now 2.5 Celsius degrees closer to the climate normal. Again this phenomenon may be attributed to the increase in cloud cover and associated insulating effect.

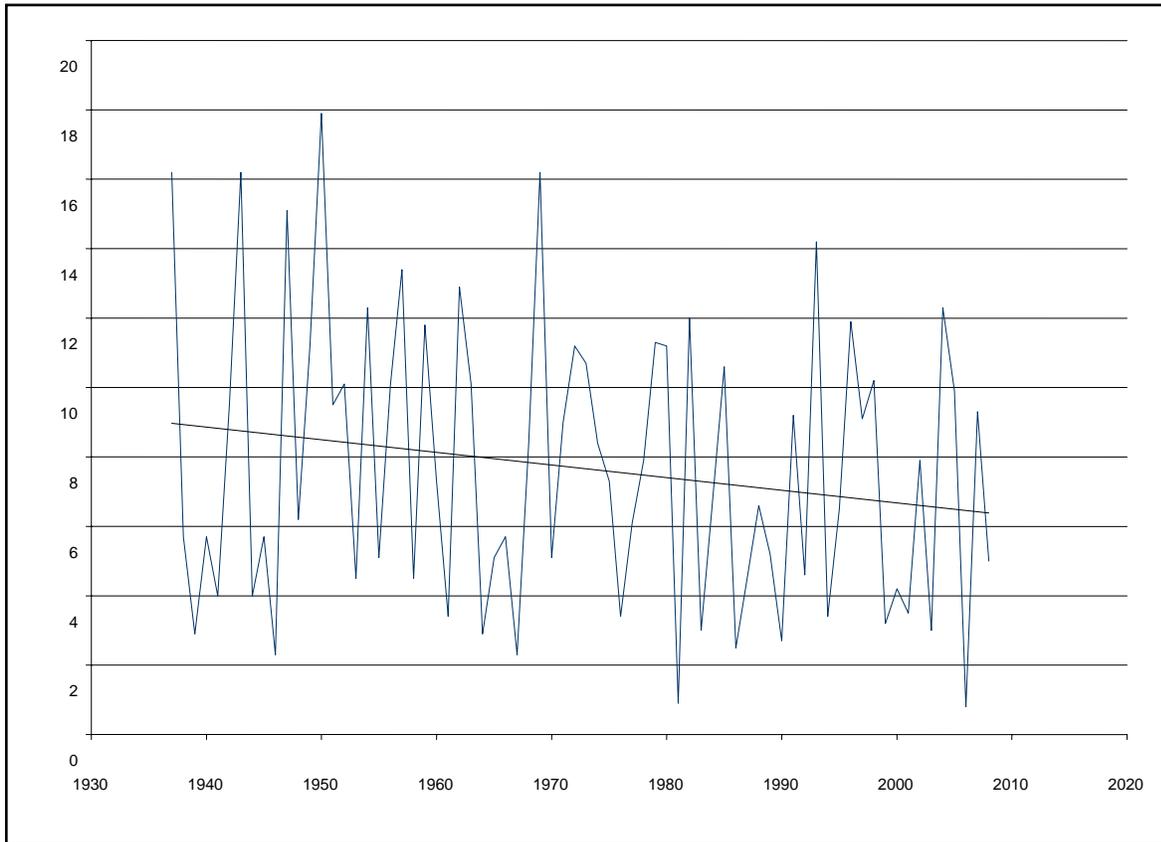


Figure 3 Variability in Extreme Minimum January Temperatures at Vancouver International Airport

PRECIPITATION

As well as getting warmer, Metro Vancouver's climate is also getting wetter. This may reflect a larger global trend towards an increase in precipitation believed to be a natural consequence of the hydrological cycle in response to rising temperatures. Figure 4 shows an approximate 20% increase in annual precipitation over the past 70 years at the Vancouver International Airport.

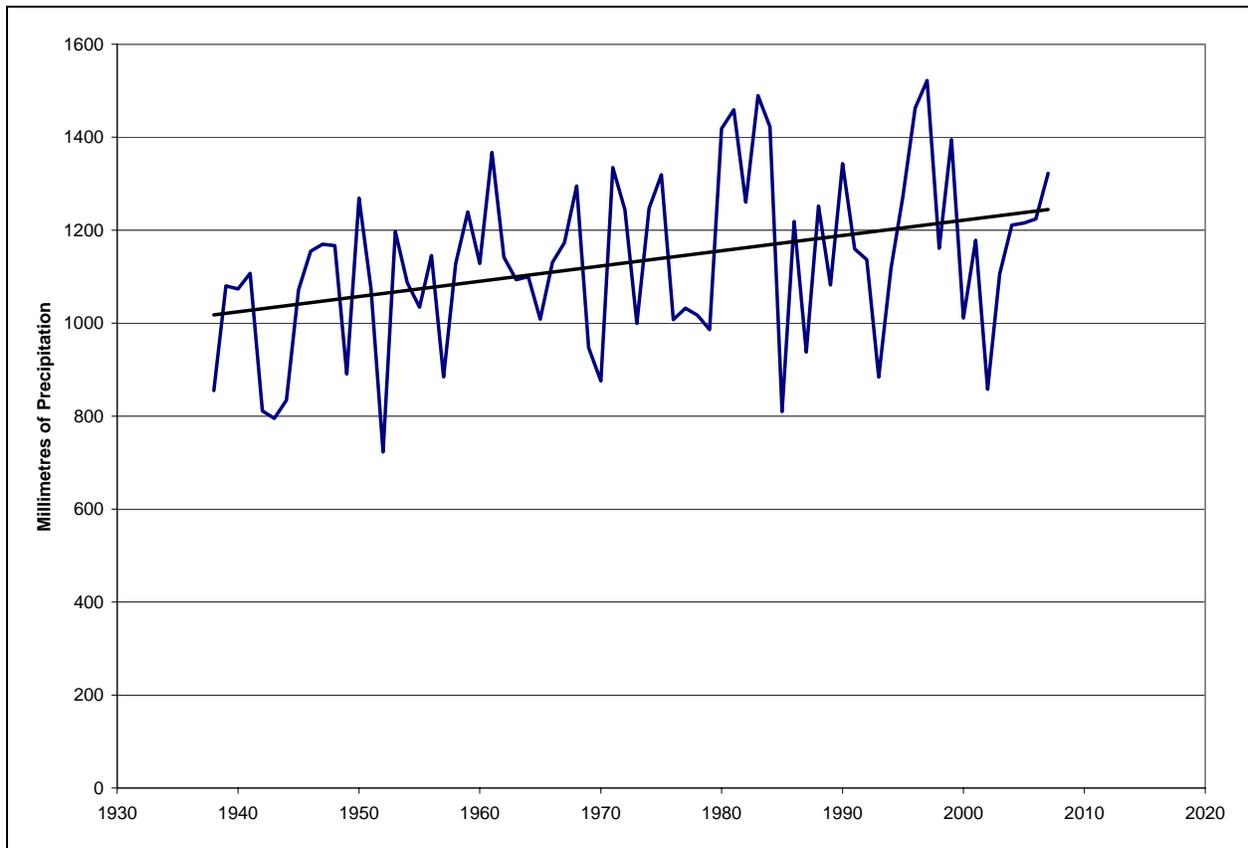


Figure 4 Annual Precipitation at Vancouver International Airport

The following chart shows how the precipitation record has been distributed over the four seasons: winter (December-February), fall (September-November), spring (March-May) and summer (June-August). It is interesting to note that all seasons are showing a trend of increased precipitation; however, the trend is most pronounced in Spring and Fall records.

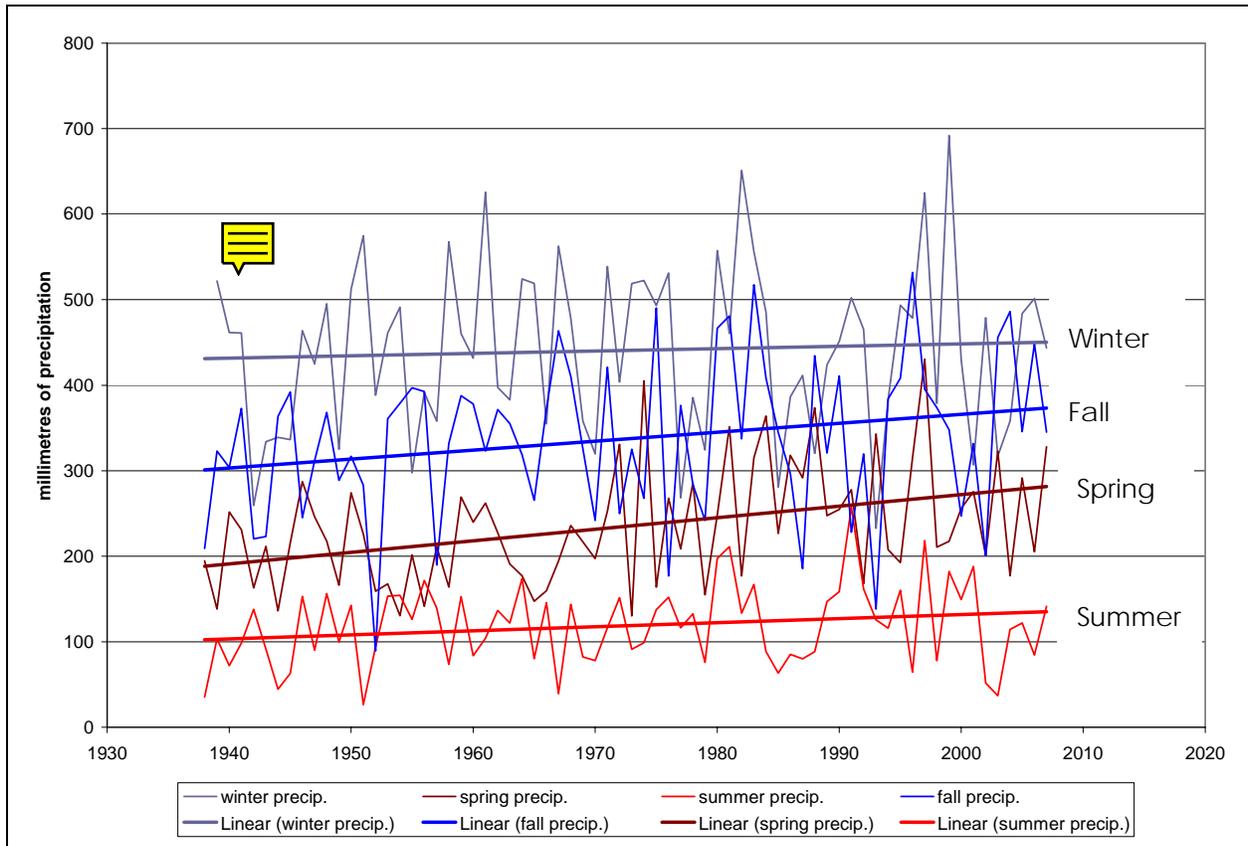


Figure 5 Seasonal Precipitation at Vancouver International Airport

The relative contribution of precipitation to the annual total from each season is reflected in Figure 6. It shows how the relative contribution of the seasons to annual precipitation is changing. The proportion of the contribution to the annual total from the spring is increasing at the expense of the winter proportion of the contribution to the annual total.

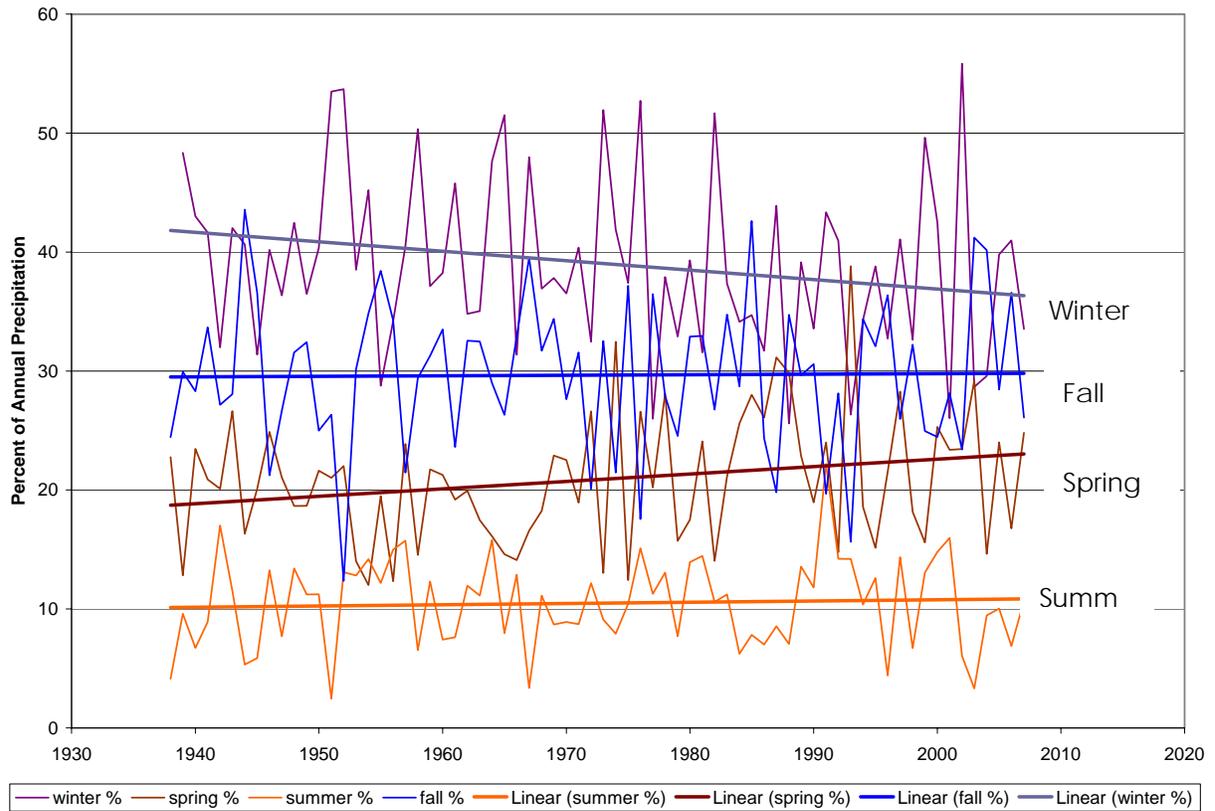


Figure 6 Relative Contribution of Seasonal Precipitation to Annual Precipitation

THE CLIMATE BC APPLICATION TOOL

The following maps are derived from historic climate data associated with temperature and precipitation between 1961 and 1990 and predictive climate data using the ClimateBC v 3.2 programⁱⁱ jointly developed by the Province of British Columbia and University of British Columbia scientists. The program allows for a number of different climate variables pertinent to agricultural production to be calculated or derived for a geographical area. The program also provides for the production of climate variables based on future climate data sets generated by various global circulation models and climate change scenarios.



Four sets of maps produced by the Climate BC program follow, each reflecting the regional distribution of a climate variable important to Metro Vancouver agriculture:

- Mean Annual Temperature
This climate variable is calculated by averaging the twelve monthly average temperatures. The average monthly temperatures are calculated by determining the mean of the daily temperatures within the month. Mean daily temperature is the average of the highest and lowest temperature in a 24-hour period.
- Number of Frost Free Days
Frost-free period can be defined as the number of days between the average last spring frost date and the average first fall frost date.
- Spring Precipitation
This is the average total precipitation for the months of March, April and May
- Summer Precipitation
This is the average total precipitation for the months of June, July and August

The predictive maps reflect the 2050s time period (2040 – 2069).

Each group of maps contains a map showing the climate variable based on historical data (1961-1990 Normals) and two maps of predicted climate data based on two global climate change storylines-scenarios , A2 and B1, being applied to the Canadian Global Circulation Model 2 (CGCM2).

The storylines/scenarios are a tool to explore how developments in the global environment in the 21st century will affect the production of greenhouse gases. Each storyline/scenario represents different demographic, social, economic, technological, and environmental development.

The A2 storyline emphasizes a future world of strong economic development and increasing regionalization. Global greenhouse gas emissions would significantly increase. The B1 storyline



emphasizes a future world of strong environmental values and increasing globalization. Greenhouse gas emissions would increase at a moderate rate. The two storylines are considered equally valid with no assigned probabilities of occurrence.

Characteristics of the two storylines are summarized in the table belowⁱⁱⁱ:

	Global Climate Storyline A2	Global Climate Storyline B1
World	<ul style="list-style-type: none"> • Very heterogeneous 	<ul style="list-style-type: none"> • Convergent
Economy	<ul style="list-style-type: none"> • Regionally orientated and fragmented economic growth • Lowest per capita growth 	<ul style="list-style-type: none"> • Rapid changes in economic structures to service and information based
Population	<ul style="list-style-type: none"> • Continuously increasing global population 	<ul style="list-style-type: none"> • 2050 peak, then declining global population
Governance	<ul style="list-style-type: none"> • Self-reliance with preservation of local identities 	<ul style="list-style-type: none"> • Global solutions to economic, social and environmental sustainability
Technology	<ul style="list-style-type: none"> • Slowest and most fragmented development 	<ul style="list-style-type: none"> • Clean and resource-efficient

The ClimateBC tool allows the users to input single or multiple geographic locations that generates spatial data that can be used for producing maps or graphs.. This information can be displayed on maps and interpreted broadly at a regional scale but caution should be exercised when interpreting these maps for small specific areas such as a farm or community.

When interpreting the maps from an agricultural production perspective, it is important to note that soil types and topography are significant factors that affect the agricultural potential of land. These factors are not reflected in the maps.

CLIMATE VARIABLE MAPS



The following maps are derived by displaying the data generated by the ClimateBC tool in a Geographical Information System (GIS). One of the inputs into the ClimateBC model is land elevation. This study used a 20 metre interval. For land areas below 20 metres, which constitutes the Fraser delta in Richmond and portions of Delta, an elevation of 4 metres was assumed (the elevation of the weather station at the Vancouver International Airport).

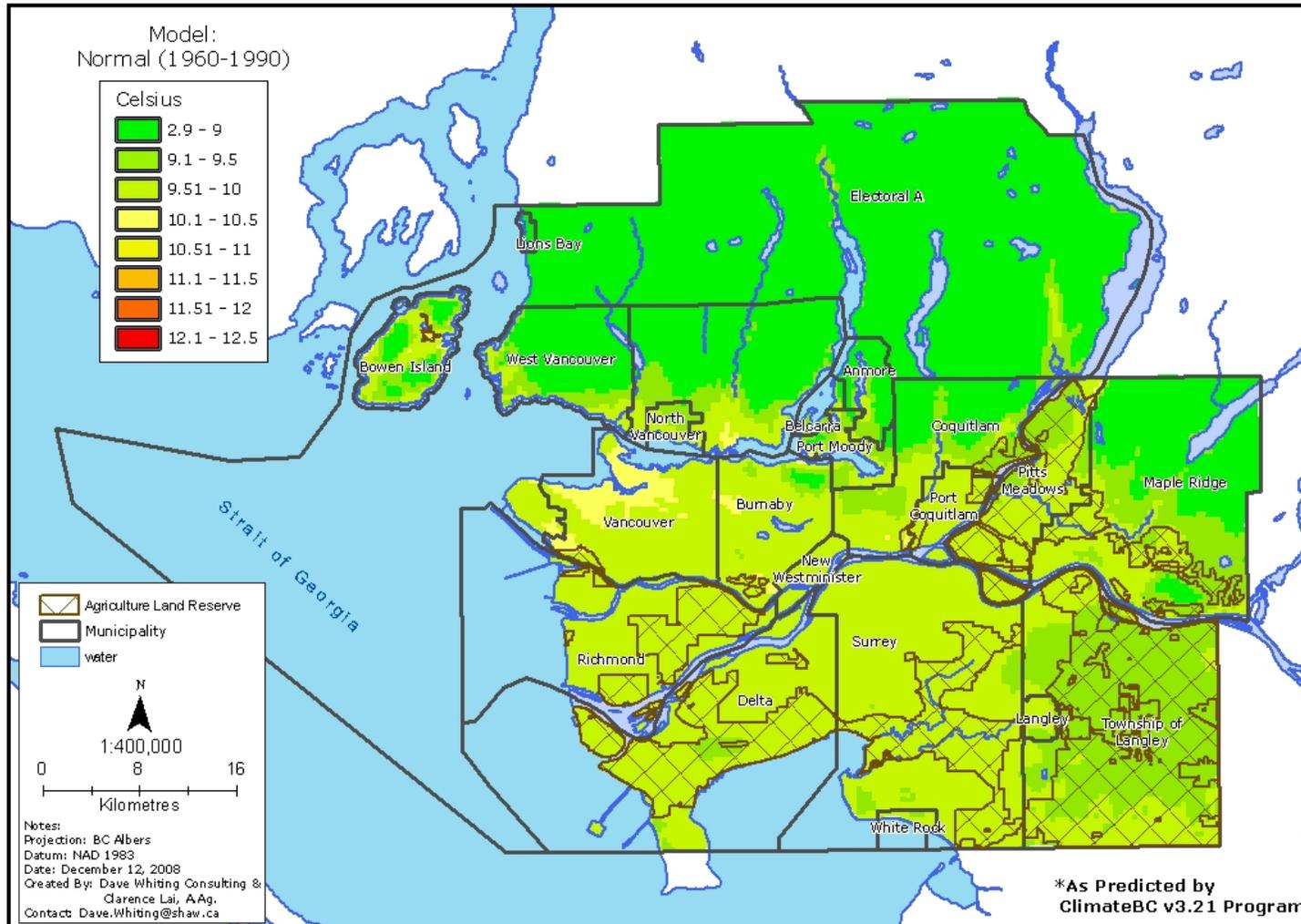
Two climate variables, Mean Annual Temperature and Number of Frost Free Days, are associated with temperature. Two climate variables, Spring Precipitation and Summer Precipitation are associated with precipitation. For each climate variables three maps have



been produced – Climate Normal (1960 – 1990) which is based on historical information and two potential global climate change models (A2 and B1) which are based on predictive information.



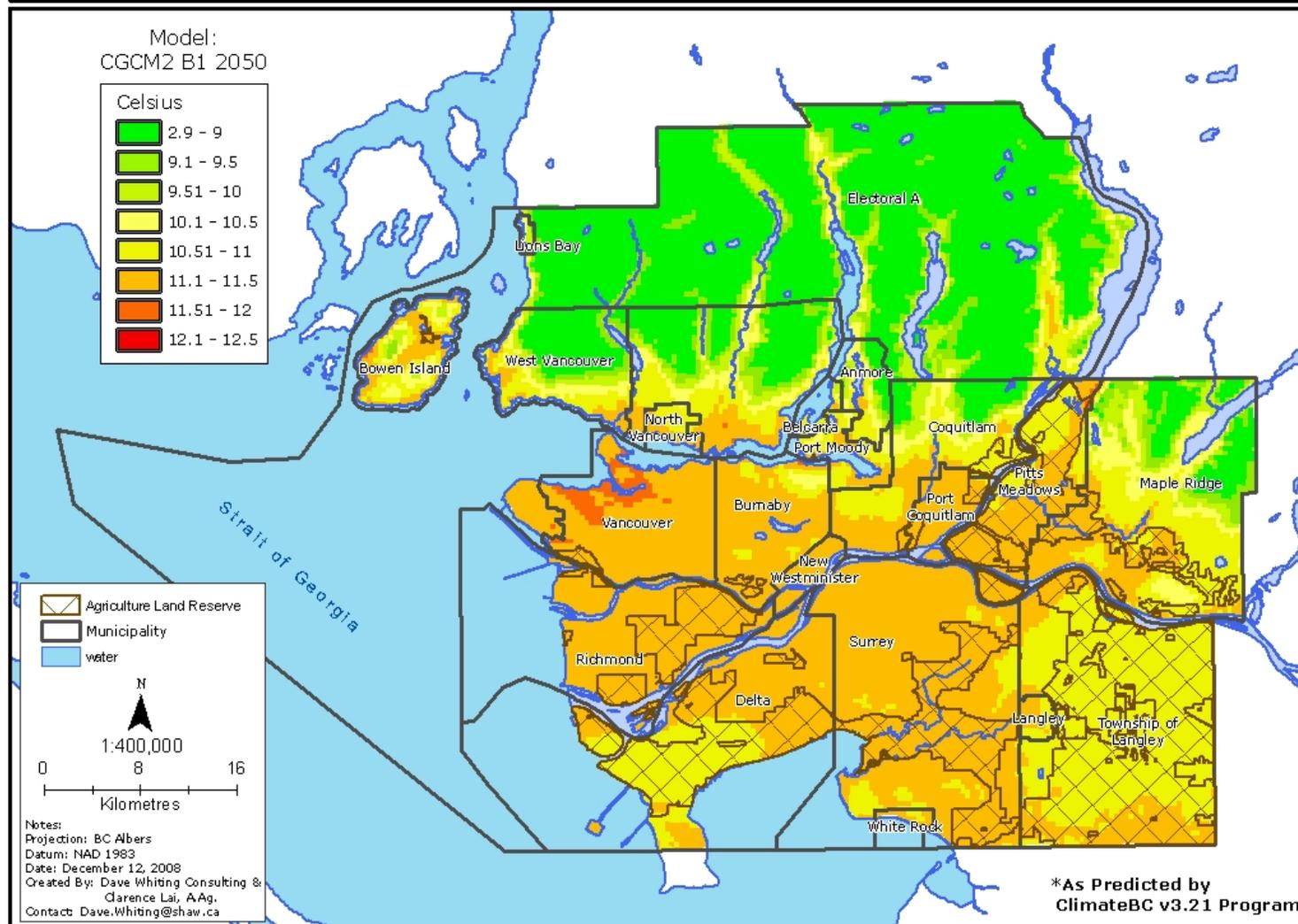
Annual Temperature (1960-1990)



Map 1 Mean Annual Temperature Normal (1960 - 1990)



Predicted Annual Temperature (CGCM2 B1 2050)

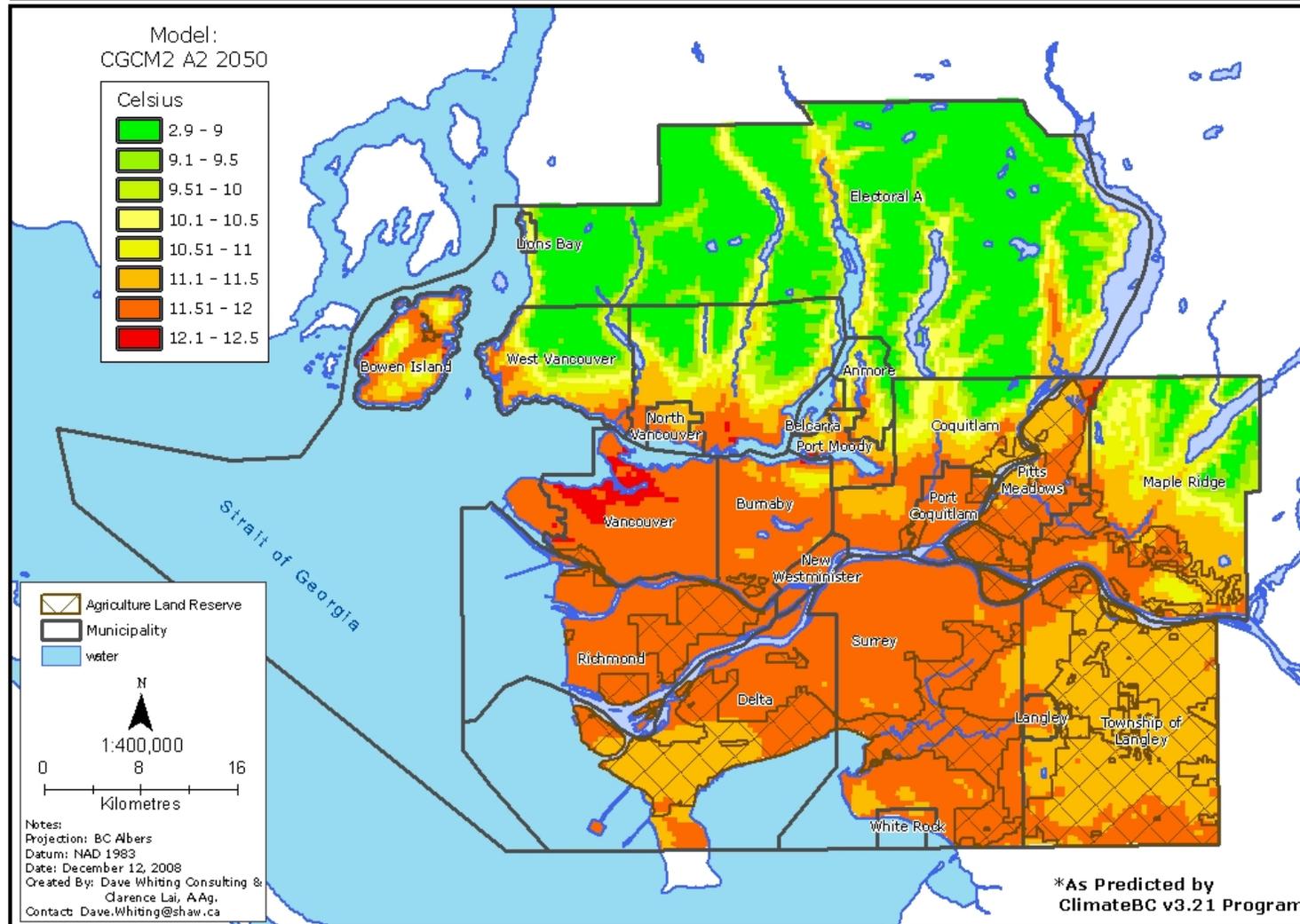


Map 2 Predicted Mean Annual Temperature CGCM2 B1 (2050)





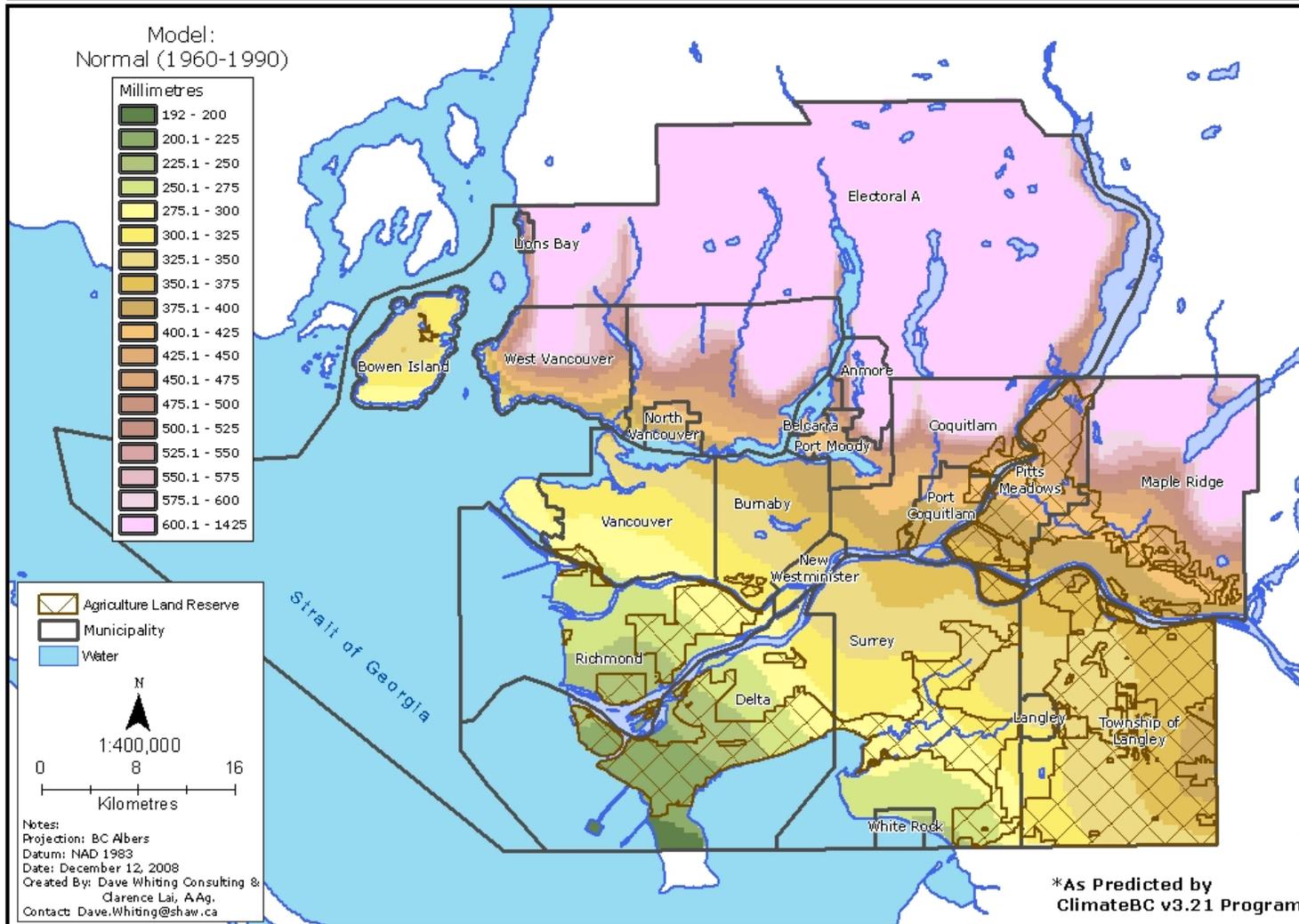
Predicted Annual Temperature (CGCM2 A2 2050)



Map 3 Predicted Mean Annual Temperature CGCM2 A2 (2050)



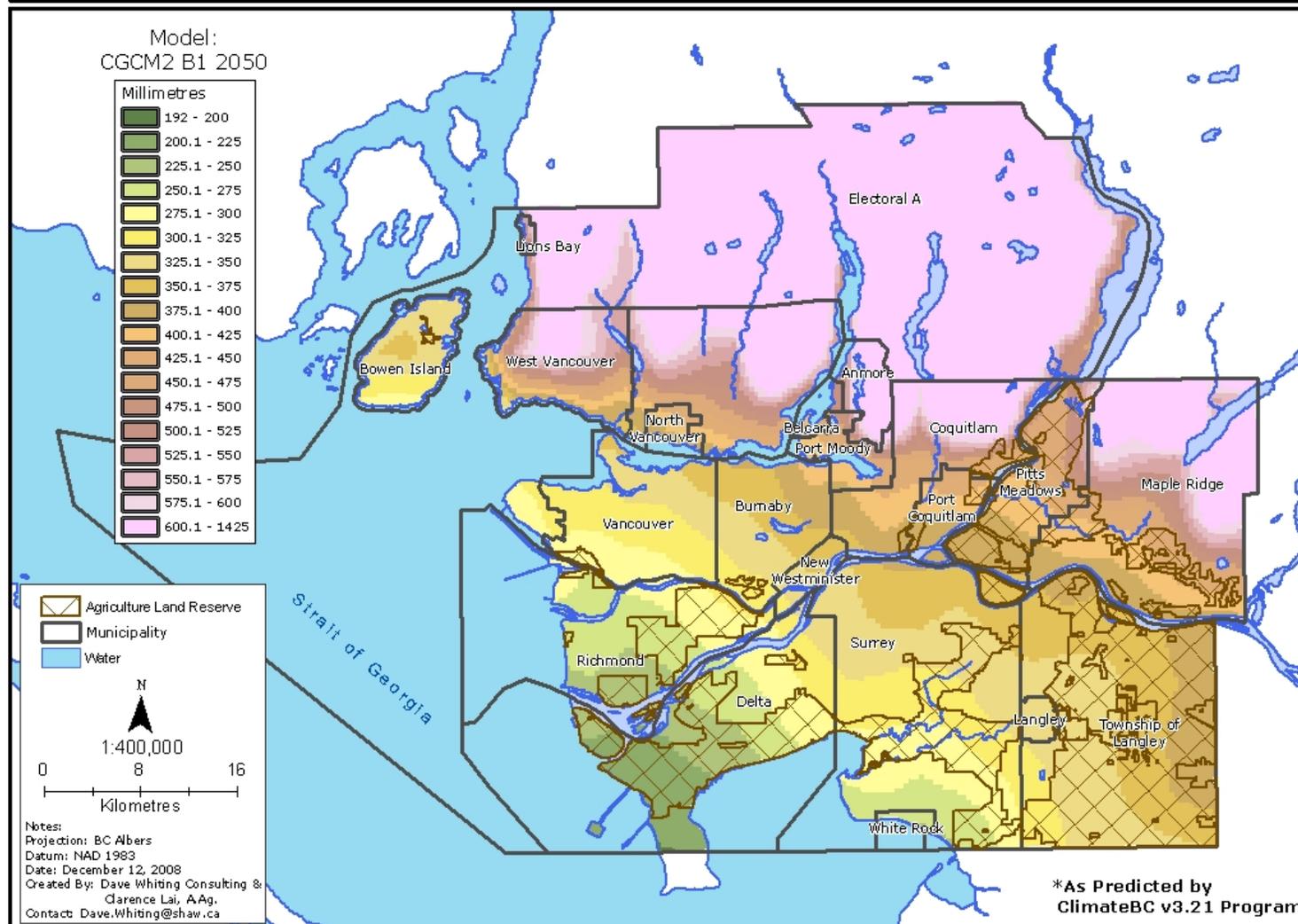
Spring Precipitation (1960-1990)



Map 4 Spring Precipitation Normal (1960 - 1990)



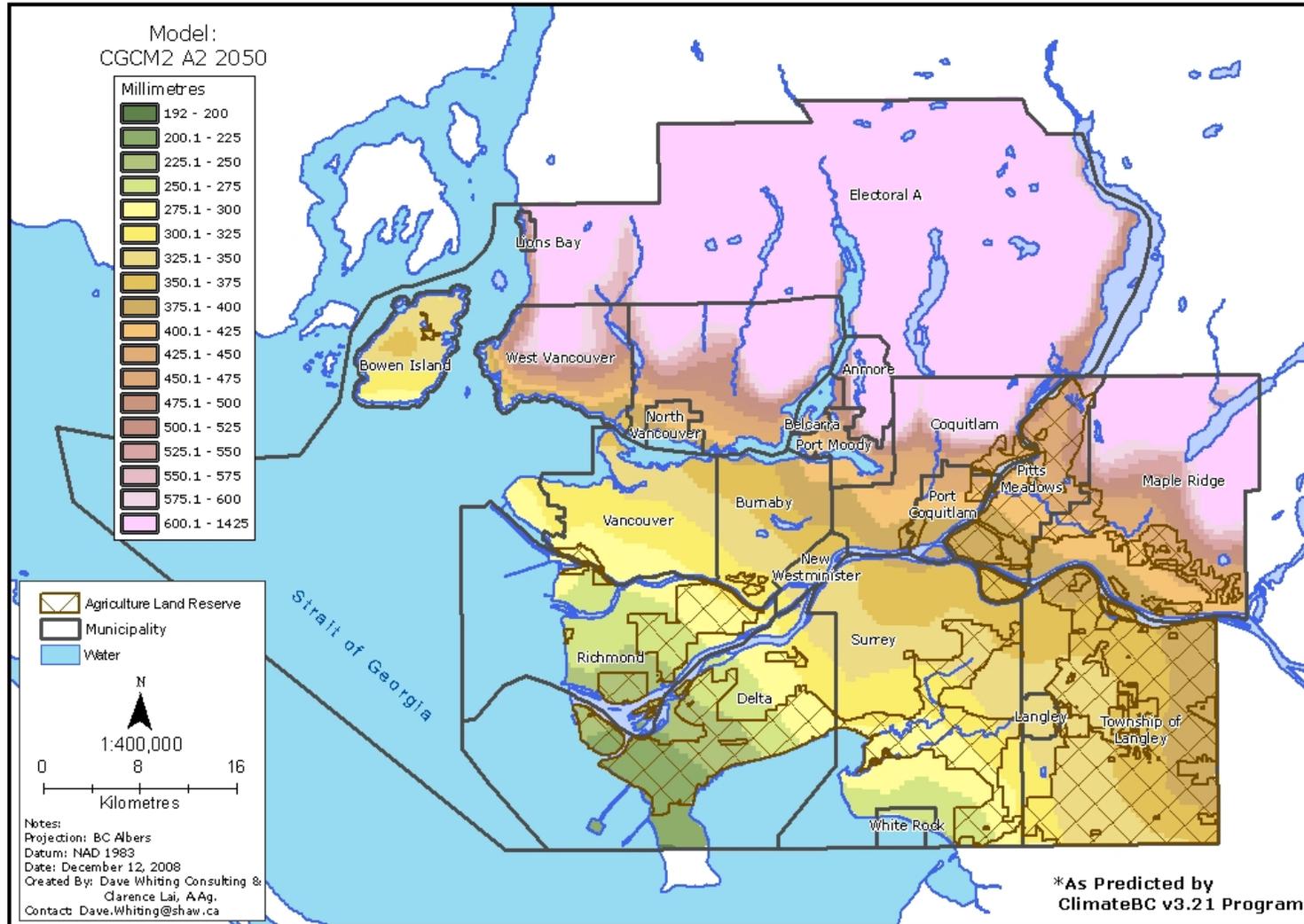
Predicted Spring Precipitation (CGCM2 B1 2050)



Map 5 Predicted Spring Precipitation CGCM2 B1 (2050)



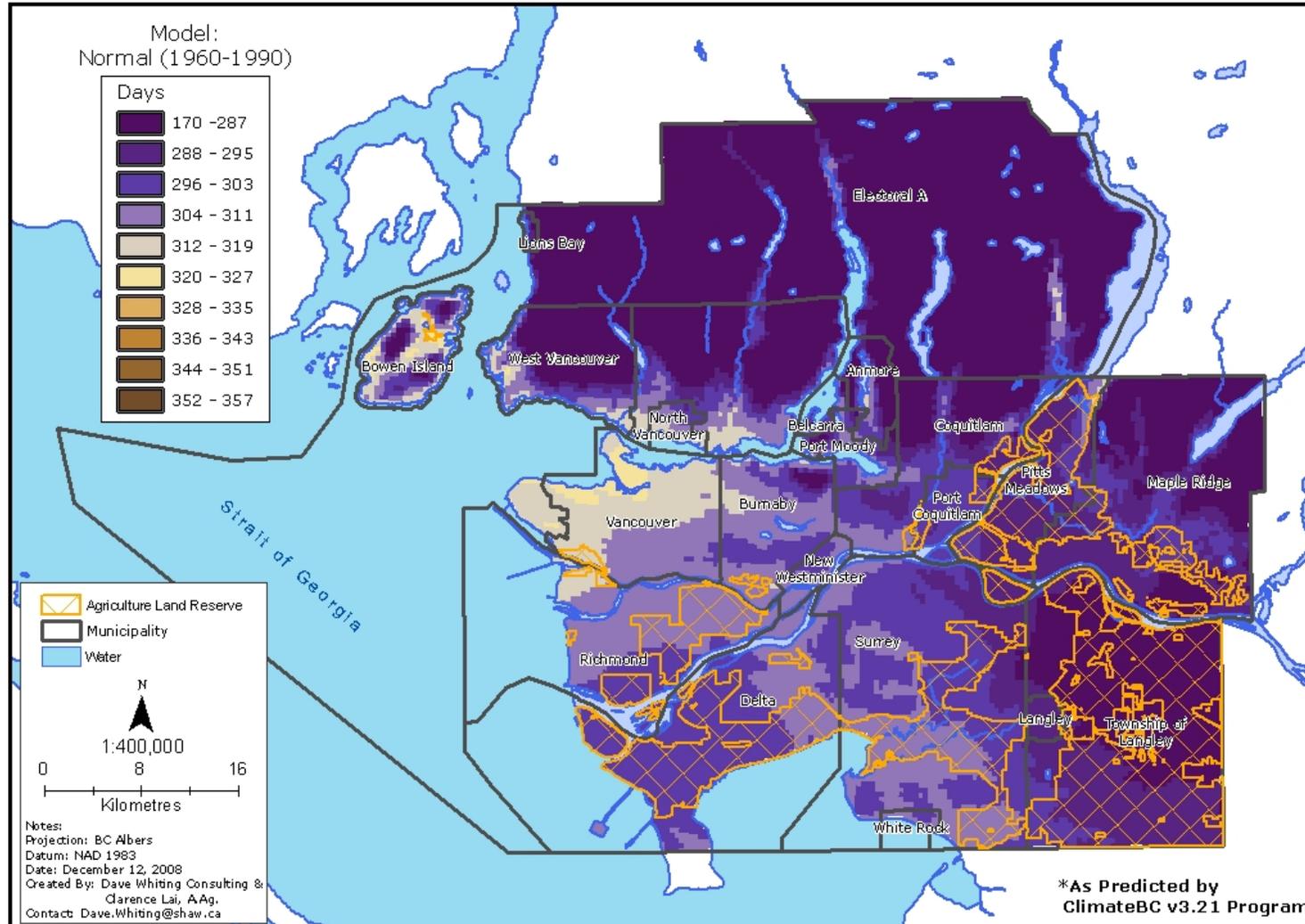
Predicted Spring Precipitation (CGCM2 A2 2050)



Map 6 Predicted Spring Precipitation CGCM2 A2 (2050)



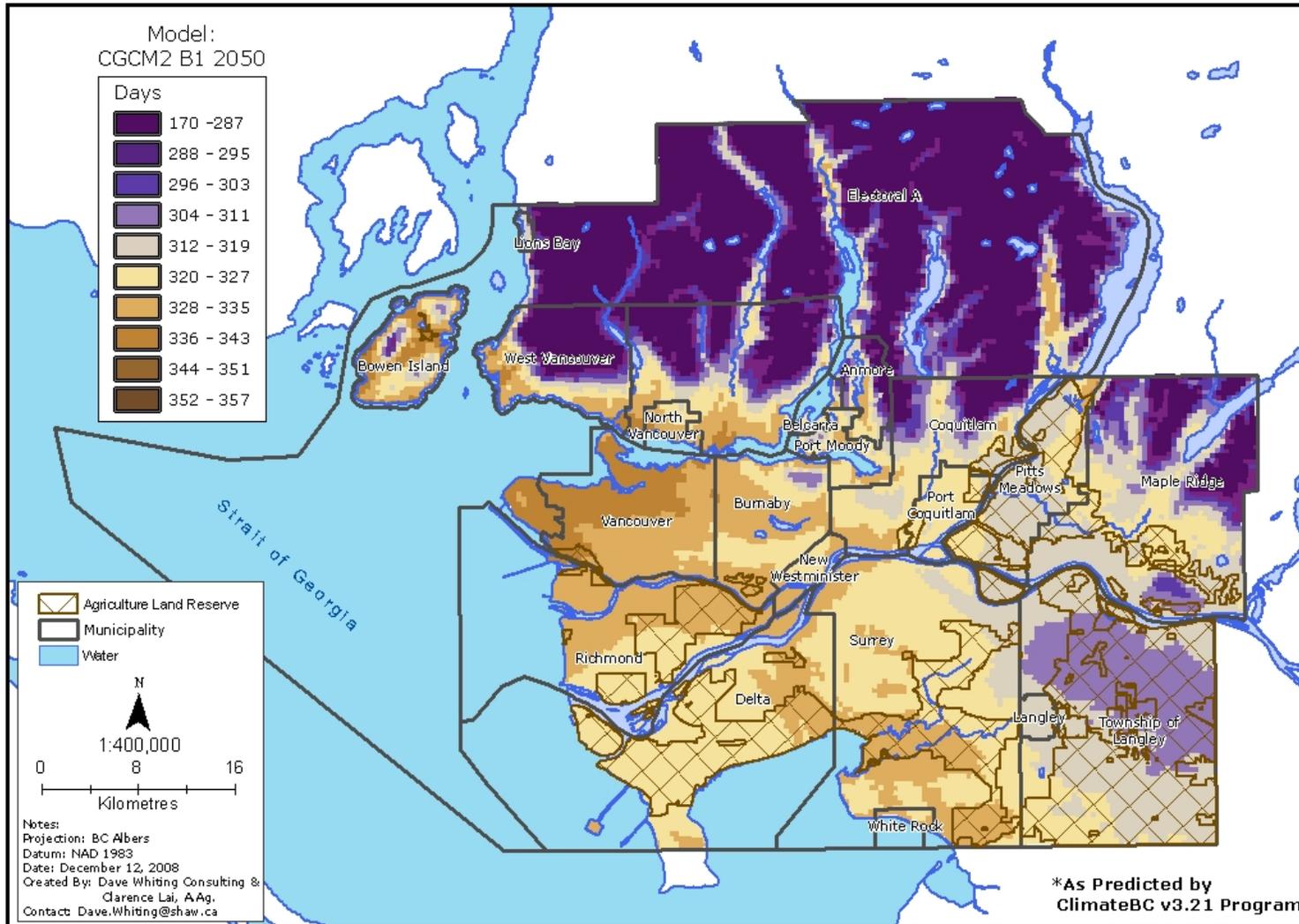
Frost Free Days (1960-1990)



Map 7 Frost Free Days Normal (1960 - 1990)



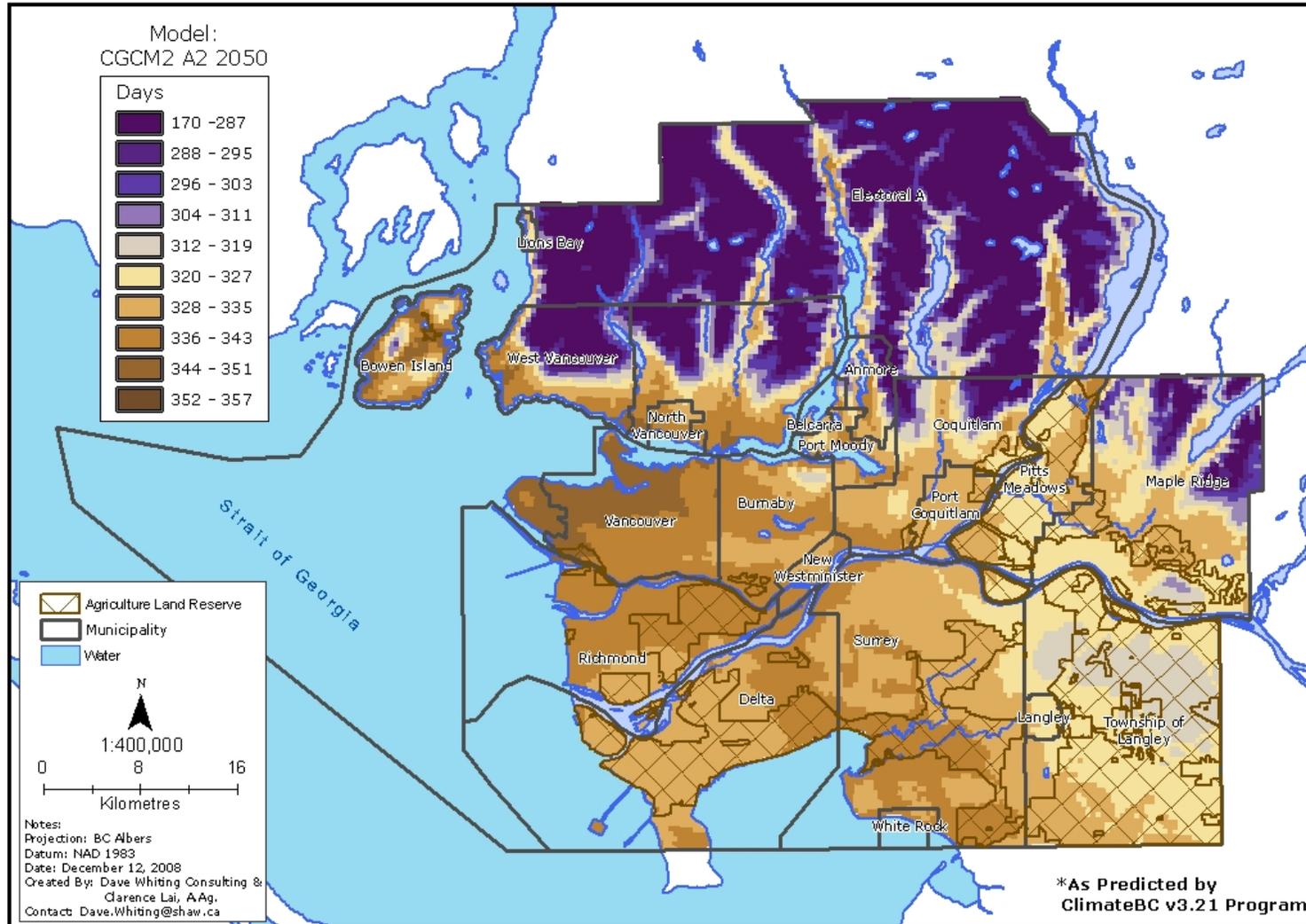
Predicted Frost Free Days (CGCM2 B1 2050)



Map 8 Predicted Frost Free Days CGCM2 B1 (2050)



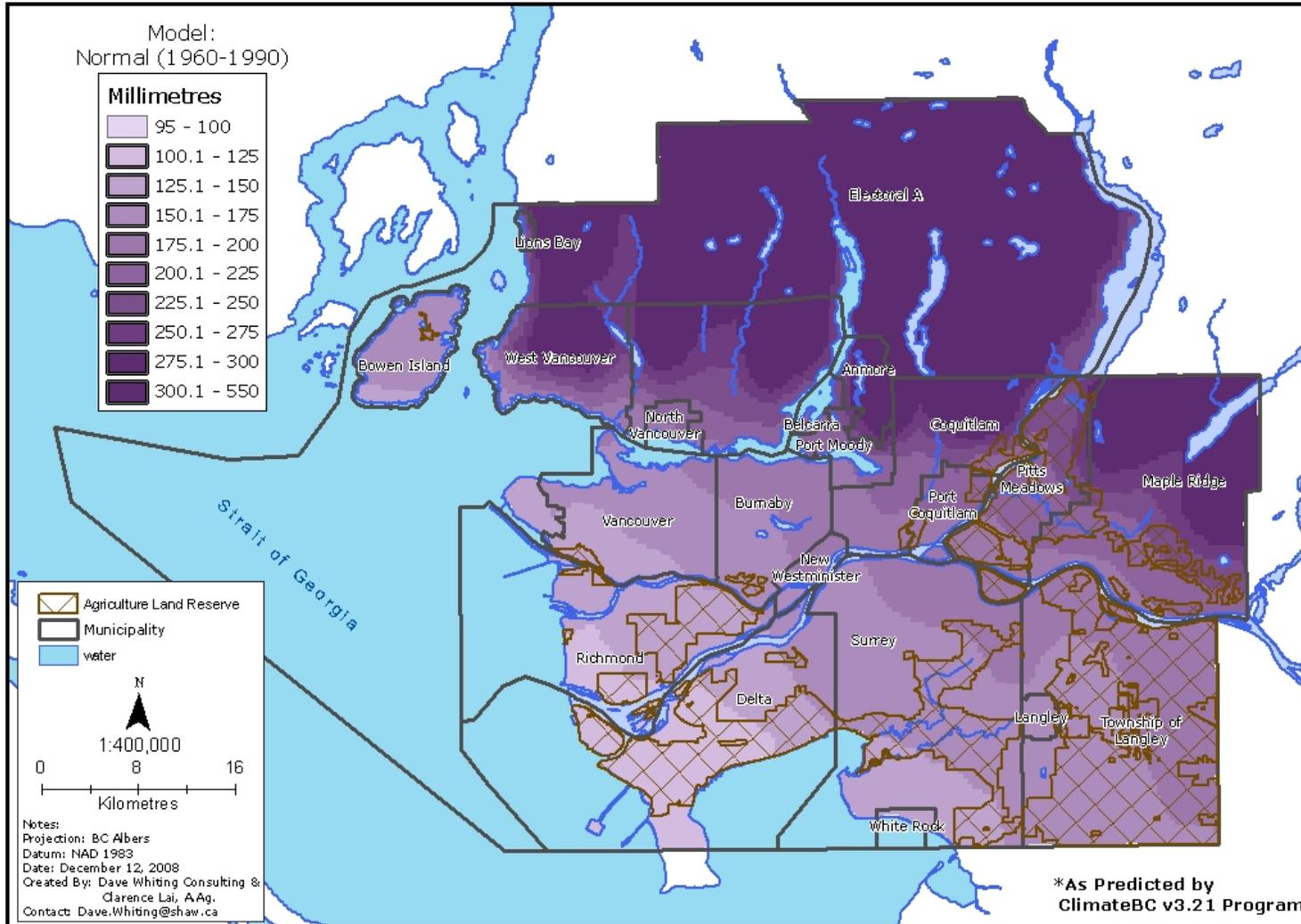
Predicted Frost Free Days (CGCM2 A2 2050)



Map 9 Predicted Frost Free Days CGCM2 A2 (2050)



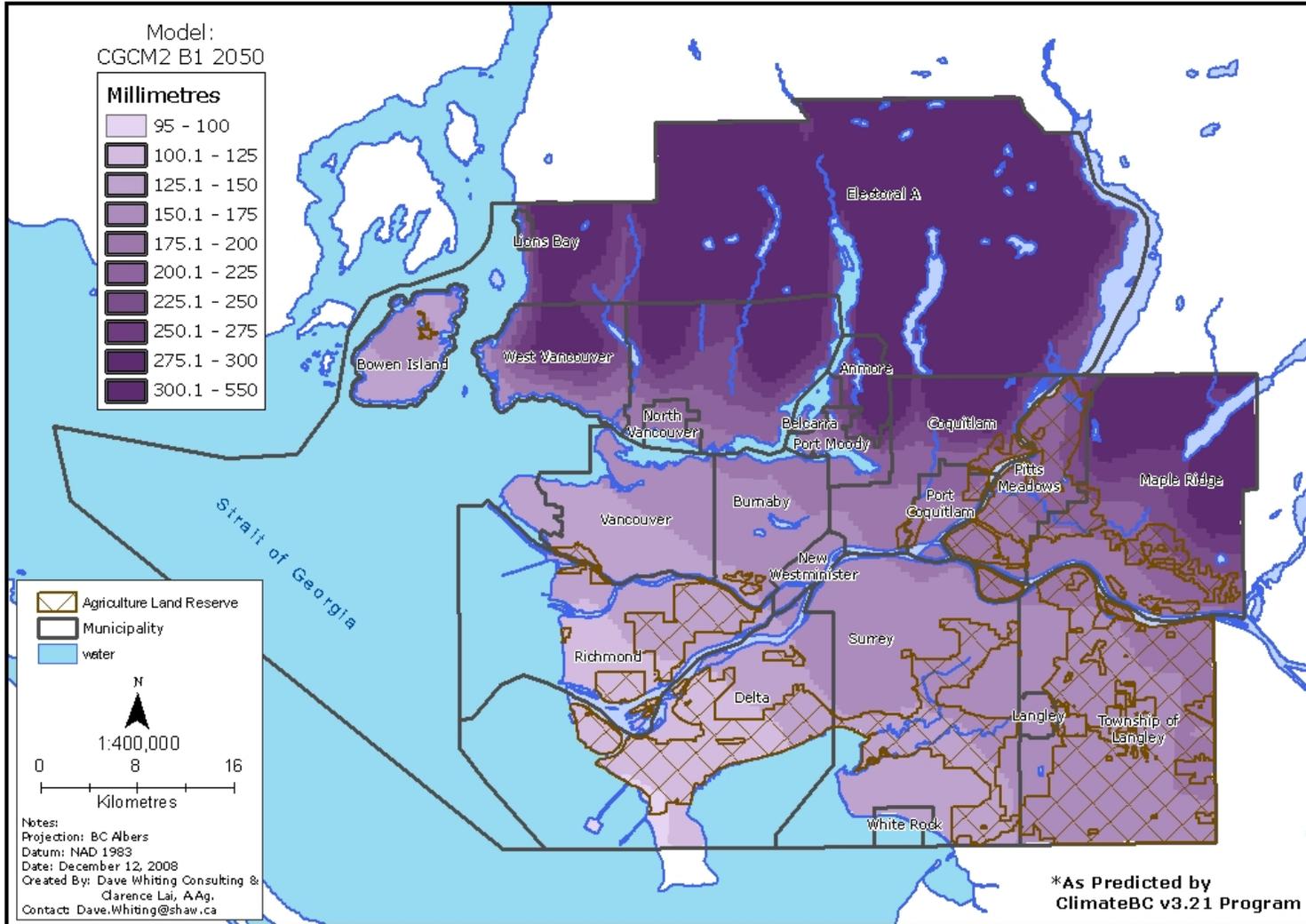
Summer Precipitation (1960-1990)



Map 10 Summer Precipitation Normal (1960 - 1990)



Predicted Summer Precipitation (CGCM2 B1 2050)

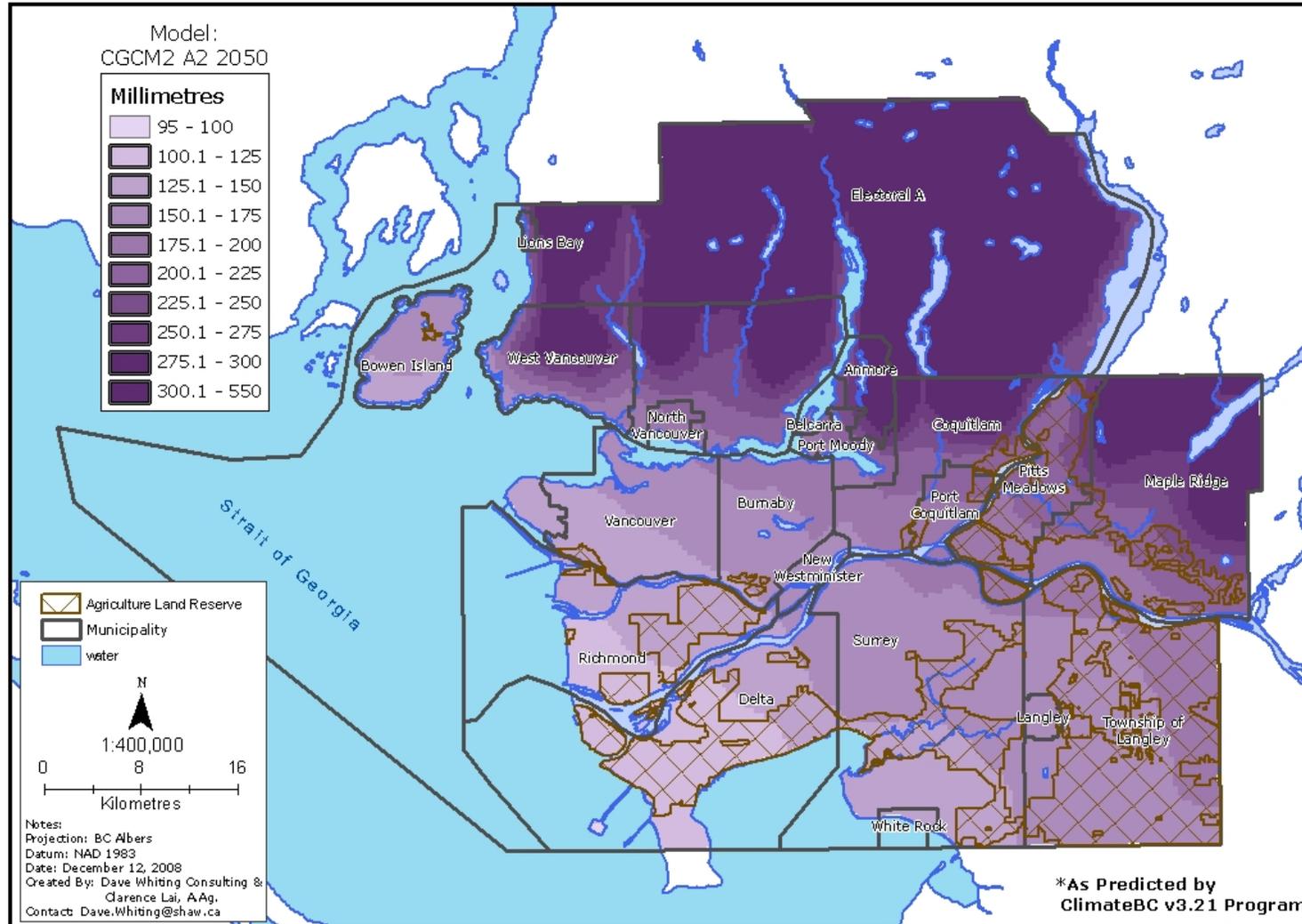


Map 11 Predicted Summer Precipitation CGCM2 B1 (2050)



metro

Predicted Summer Precipitation (CGCM2 A2 2050)



Map 12 Predicted Summer Precipitation CGCM2 A2 (2050)

POTENTIAL CHANGES TO CLIMATE OF AGRICULTURAL LAND IN METRO VANCOUVER

How climate variables differ from the maps of climate normals (1960 – 1990) under a “conservative” climate change scenarios (B1) and under a more drastic scenario (A2) are reflected in a general manner in the table below. The focus of the summary is the significant areas of land that are currently within the Agricultural Land Reserve (ALR).

		Normal (1960-1990)	Future Scenario B1	Future Scenario A2
Burnaby	Mean Annual Temperature (°C)	9.5 – 10.0	11.1 – 11.5	11.5 – 12.0
	Number of Frost Free Days	304 – 311	328 - 335	336 - 343
	Spring Precipitation (mm)	300 - 325	300 - 325	300 - 325
	Summer Precipitation (mm)	150 -175	125 - 175	150 - 175
Richmond	Mean Annual Temperature (°C)	9.5 – 10.0	11.1 – 11.5	11.5 – 12.0
	Number of Frost Free Days	North 304 – 311 South 296 - 303	North 328 - 335 South 320 - 327	336 - 343
	Spring Precipitation (mm)	NE 275 – 300 Central 250 – 275 SW 225 - 250	NE 275 – 300 Central 250 – 275 SW 225 - 250	NE 275 – 300 Central 250 – 275 SW 225 - 250
	Summer Precipitation (mm)	North 125 – 150 South 100 - 125	North 125 – 150 South 100 - 125	North 125 – 150 South 100 - 125
Delta	Mean Annual Temperature (°C)	9.5 – 10.0	North 11.1 -11.5 South 10.5 – 11.0	North 11.5 – 12.0 South 11.1- 11.5
	Number of Frost Free Days	SW 296 – 303 NE 304 – 311	320 - 327	336 - 343
	Spring Precipitation (mm)	NE 250 – 300 Central 225 – 250 SW 200 -225	NE 250 – 300 Central 225 – 250 SW 200 -225	NE 250 – 300 Central 225 – 250 SW 200 -225
	Summer Precipitation (mm)	North 125 – 150 South 100 - 125	North 125 – 150 South 100 - 125	North 125 – 150 South 100 - 125
Surrey	Mean Annual Temperature (°C)	9.5 – 10.0	11.1 – 11.5	11.5 – 12.0

		Normal (1960-1990)	Future Scenario B1	Future Scenario A2
	Number of Frost Free Days	North 296 – 303 South 304 - 324	North 320 - 327 South 328 - 335	North 328 – 335 South 336 - 343
	Spring Precipitation (mm)	North 325 – 350 Central 300 - 325 South 250 - 300	North 325 – 350 Central 300 - 325 South 250 - 300	North 325 – 350 Central 300 - 325 South 250 - 300
	Summer Precipitation (mm)	150 - 175	North 150 – 175 South 125 – 150	North 150 – 175 South 125 – 150

		Normal (1960-1990)	Future Scenario B1	Future Scenario A2
Langley	Mean Annual Temperature (°C)	9.1 – 9.5	10.5– 11.0	11.1 – 11.5
	Number of Frost Free Days	North 288 - 295 South 296 - 303	North 304 - 311 South 312 -319	North 312 – 319 South 320 - 335
	Spring Precipitation (mm)	West 300 – 350 East 350 - 400	West 300 – 350 East 350 - 400	West 300 – 350 East 350 - 400
	Summer Precipitation (mm)	North 175 – 200 South 150 - 175	North 175 – 200 South 150 - 175	North 175 – 200 South 150 - 175
Pitt Meadows	Mean Annual Temperature (°C)	9.5 – 10.0	North 10.5 – 11.0 South 11.1 – 11.5	11.5 – 12.0
	Number of Frost Free Days	288 - 295	312 - 319	320 - 335
	Spring Precipitation (mm)	North 400 – 450 South 350 - 400	North 400 – 450 South 375 - 400	North 400 – 450 South 375 - 400
	Summer Precipitation (mm)	North 225 – 250 South 200 - 225	North 175 – 200 South 150 – 175	North 175 – 200 South 150 – 175
Maple Ridge	Mean Annual Temperature (°C)	9.1 – 10.0	11.1 – 12.0	11.1 – 11.5
	Number of Frost Free Days	288 - 303	328 - 335	320 - 327
	Spring Precipitation (mm)	North 400 – 475 South 375 -425	North 400 – 475 South 375 -425	North 400 – 475 South 375 -425
	Summer Precipitation (mm)	North 225– 250 South 200 - 225	North 225– 250 South 200 - 225	North 225– 250 South 200 - 225

CONCLUSION

Agriculture is often considered to be among one of the most vulnerable economic sectors to the risks and impacts of climate change.^{iv} For agricultural producers in general, climate change impacts can be summarized as:

- Crop/livestock losses due to extreme events
- Crop/livestock losses due to altered levels of soil moisture
- Crop/livestock losses due to change and severity of pests
- Crop/livestock losses due to increased variability in weather
- Increased opportunities for growing new varieties and finding new markets

The climate variable maps in this study inform decision makers regarding some climate change impacts associated with some of the above impact categories. Other potential impacts of climate change on Metro Vancouver agriculture could be investigated in further research.

KEY FINDINGS

Based on the observations of the historical data from Vancouver International Airport and on the predictive climate variable maps and associated table, some potential impacts of climate change on future agricultural production in the region can be identified.

- The climate of Metro Vancouver will continue to become warmer. The ClimateBC model predicts an increase from historical normals in Mean Annual Temperature of between 1.5 and 2.0 C° by the 2050s across Metro Vancouver depending on the climate change scenario and local micro-climates. The warming climate is primarily as a result of warmer nights resulting from increased cloud cover. Potential impacts on agriculture include:
 - Higher crop productivity
 - Greater range of potential crops (including increase of tropical species in greenhouse operations)
 - Decreased heating costs associated with greenhouse operations and poultry and livestock facilities
 - Increased summer cooling costs associated with greenhouse operations and poultry and livestock facilities
- High temperatures appear to be becoming more variable with an increasing frequency in extreme events. Variability of high temperature appears to be increasing at different temporal scales – annual, seasonal and daily. The potential impacts of high temperature variability on agriculture could be more significant than the impacts of higher mean annual temperatures. Potential impacts on agriculture include:
 - Increased potential for crop damage from sun scald
 - Demand for heat tolerant forage species
 - Increased potential for summer drought conditions and increased demand for supplementary irrigation

- Low temperatures appear to be becoming less variable and there is a reduced frequency of extreme cold events. Variability of low temperature appears to be decreasing at different temporal scales – annual, seasonal and daily. The potential impacts of low temperature variability on agriculture include:
 - Decreased potential for crop damage from extreme cold
 - Winter survival, and more life cycles, of pests and diseases
 - Greater variety of pests and diseases
- The frost free period will be extended by approximately 24 to 32 days depending on the climate change scenario and the topography of the land. In effect, by the 2050s the models predict that the growing season within the region will start approximately 2 weeks earlier and extend a further 2 weeks. Potential impacts on agriculture include:
 - Earlier harvest of forage crops
 - Increased viability of bell pepper, melon, overwintering cabbage family crops and double cropping
- Spring precipitation, as predicted by the climate variable maps, is not consistent with the historical trend graphs at Vancouver International Airport, nor with the literature^v. The two predictive spring precipitation maps show little difference between the 1960 – 1990 climate normals. The graphs showing historical records indicate an increasing amount of spring precipitation over the past 70 years as well as an increased proportion of annual precipitation occurring in the spring. Potential impacts of increased spring precipitation on agriculture include:
 - Limited forage harvesting
 - Reduced forage quality
 - Increased potential for water logged soils limiting annual crop production
 - Increased potential for flooding, inadequate soil drainage, soil compaction, leaching of agricultural chemicals
- Summer precipitation, as predicted by the climate variable maps, shows little change from the map showing 1960 – 1990 normals. This is consistent with the graphs of historical data of summer precipitation over the past 70 years and is consistent with the literature. Consistent precipitation, in conjunction with higher summer temperatures, will result in an increase in evapo-transpiration and the summer moisture deficit. This could result in an increased demand for supplementary irrigation of agricultural crops.

POTENTIAL TOPICS FOR FURTHER STUDY

- **Spring Precipitation Trends**

As noted above, the discrepancy between the historical spring precipitation trends at Vancouver International Airport with the predicted spring precipitation trends from the ClimateBC program should be addressed in further research. Increasing spring precipitation could have a significant impact on agricultural operations within Metro Vancouver and the trend and extent of spring precipitation change should be confirmed.

- **Analyses of historical data from other weather stations**

Vancouver International Airport was selected for this study due to the extensive historical records (70 years) the quality of data, and its location within Metro Vancouver. This record may be influenced by the “heat sink” affect associated with the climate record of large urban areas. These records may be representative of the agricultural areas of Burnaby and Richmond in close proximity to the airport weather station. The climate of other agriculture areas of Metro Vancouver may not be changing in the same way as that of Vancouver International Airport. An analysis of other regional weather records could inform climate change decision making.

- **Variability of precipitation**

It appears in Figures 4 and 5 that the variability of annual and seasonal precipitation is increasing. Agricultural operations can be significantly impacted by either too much water in some seasons, or too little in others. In addition, at a daily temporal scale, extreme precipitation events, including hail, can have dramatic impacts on agricultural operations. Climate change may be increasing the frequency of extreme precipitation events. Further research of variability of precipitation at all temporal scales, and the resulting impact on agricultural operations, is warranted.

- **Precipitation as snow**

Climate change is resulting in a climate that is both warmer and wetter. Both of these elements contribute to whether precipitation occurs as snow. Snow can have dramatic impacts on some agricultural operations such as greenhouses. Warmer temperatures at lower elevations (including the agricultural areas) may result in a greater proportion of precipitation as rain. Higher levels of precipitation (providing the temperature is low enough such as an extreme temperature event) may result in higher levels of precipitation as snow.

In the North Shore Mountains, there may be higher snow levels at some elevations and lower snow levels at others. This in turn, could affect the quantity and timing of flows (the hydrograph) of streams and the management of reservoirs. Further research on the potential for snow and severe snow storms in agricultural areas is warranted. In addition, the effects of changing snow accumulations on the hydrographs of key watersheds in Metro Vancouver would help inform decisions associated with water allocation and storage decisions for potential agricultural irrigation.

- **Indirect impacts of climate change**

Much of the agricultural areas of Metro Vancouver is at risk from indirect climate change impacts associated with flooding.

- Much of the agricultural land is at low elevation on the Fraser Delta and is protected by dikes. These lands are drained by drainage infrastructure including ditches and pumping stations. As the sea level rises as a result of glacier melting,

this infrastructure will be less effective at reducing the risk of flooding, and the effectiveness and cost of drainage will increase.

- o Increased risk of spring freshet flood on Fraser River due to climate change impacts on watershed characteristics and extreme event frequency.

These two risk factors are cumulative and warrant research.

ⁱ Environment Canada Climate Data

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

ⁱⁱ A description of the ClimateBC program is available in The Climate Network, Vol 10, No.1, April 2005 published by the Canadian Institute for Climate Studies

http://www.genetics.forestry.ubc.ca/cfcg/res_climate-models/CICS%20Newsletter%200405%5B1%5D.pdf

ⁱⁱⁱ IPCC Special Report on Emissions Scenarios www.grida.no/climate/ipcc/emission/003.htm

^{iv} Agricultural Adaptation in a Changing Climate, Summary Report for March 1, 2002 Workshop, University of Guelph

^v Walker, I.J. and Sydneysmith, R. (2008): British Columbia; *in* From Impacts to Adaptation: Canada in a Changing Climate 2007, *edited by* D.S. Lemmen, F.J. Warren, J.Cacroix and E.Bush; Government of Canada, Ottawa ON p329 - 386