Future Changes in Winter Snowfall and Rainfall Under SSP2-4.5 and SSP5-8.5 Emission Scenarios at Eight Ski Resorts in British Columbia, Canada

MICHAEL PIDWIRNY and SIERRA COLLINS - Department of Earth, Environmental and Geographic Sciences, Irving K. Barber School of Science,
University of British Columbia, Science Building, 1177 Research Road, Kelowna, British Columbia, Canada, V1V 1V7; Michael.Pidwirny@ubc.ca

ABSTRACT

The purpose of our research was to determine the impact of future climate change on winter precipitation for eight major ski resorts in British Columbia, Canada. Data for this study was generated by the database ClimateBC which can produce high quality historical data and future predicted data from eight specifically selected IPCC AR6 climate models (GCMs) at the local scale. WInter season (December, Janaury, and February) data generated included precipitation, snowfall, rainfall, and mean temperature. For these climate variables, we used the normal period 1971-2000 as a baseline comparing it to future predictions based on the SSP2-4.5 and SSP5-8.5 emission scenarios for the year 2085. Increases in winter mean temperatures for the eight ski resorts were between 2.2° to 2.9°C for SSP2-4.5 and 3.7° to 4.3°C for SSP5-8.5 relative to the 1971-2000 baseline. All of the resorts saw increases in the quanity of winter precipitation as would be expected in a warming atmosphere. Mt. Washington, Cypress, and Sasquatch ski resorts, saw significant future declines in snowfall (39 to 59% with SSP2-4.5 and 59 to 70% with SSP5-8.5) and subsequent large increases in rainfall (67 to 90% with SSP2-4.5 and 97 to 160% with SSP5-8.5) by 2085. Sun Peaks was predicted to have a 4% increase in snowfall under SSP2-4.5.

INTRODUCTION

Several studies have shown that the winter recreational activities of skiing and snowboarding will be severely impacted by changes in temperature and precipitation driven by future human caused climate change. Skiing and snowboarding are activities normally done in the winter season when temperatures are below freezing and precipitation mainly falls as snow. Climate change will cause warmer temperatures which in turn should cause more of the precipitation to fall as rain, less as snow. This research examines this hypothesis for eight ski resorts in British Columbia, Canada under SSP2-4.5 and SSP5-8.5 emission scenario for the year 2085.

METHODS

1) Eight ski resorts in British Columbia were identified for this research. These resorts are at roughly the same latitude but each has a different longitude along a gradient from the western to the eastern border of the province.

2) The ski resorts examined were Mt. Washington (1336 m), Cypress (1124 m), Whistler (1682 m), Sasquatch (1174 m), Sun Peaks (1639 m), Big White (1930 m), Revelstoke (1508 m), and Whitewater (1728 m). Mid-elevation of teh ski resort is given in the brackets.

3) Using Google Earth we determined, for each ski resort, the decimal degree latitudinal and longitudinal location (to 4 decimals) for a point on the resort that was roughly at mid-elevation and at its geographic center. This information was required for steps 4 and 5 and to help construct **Figure 1**.

4) ClimateBC (Wang et al., 2016) was used to generate statistically downscaled, spatially interpolated, and altitude adjusted winter season (December, January, and February) mean temperature, precipitation, and snowfall data for the thirty-year climate normal period 1971-2000. Average winter season rainfall was determined by the difference between winter season precipitation and snowfall.

5) ClimateBC was also used to produce future forecasted winter season mean temperature, precipitation, and snowfall for the year 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios for eight selected GCMs used in the IPCC's 6th Assessment Report. Winter season rainfall was determined by the difference between predicted winter season precipitation and snowfall. Models used were: ACCESS-ESM1-5, CNRM-ESM2-1, EC-Earth3, GFDL-ESM4, GISS-E2-1-G, MIROC6, MPI-ESM1-2-HR, and MRI-ESM2-0.

6) A graph was generated with the X-axis showing the longitudinal location of each ski resort and the Y-axis displayed the winter **mean temperatures** associated with the 1971-2000 average and the eight climate model average for 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios (**Figure 1**). Error bars were drawn to show the range of model predictions for SSP2-4.5 and SSP5-8.5.

7) Bar charts were created with the X-axis showing changes in winter **precipitation**, **snowfall**, and **rainfall** for the 1971-2000 average and the eight climate model average for 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios (**Figures 2, 3, and 4**). Error bars were drawn to show the range of model predictions associated with the SSP2-4.5 and SSP5-8.5 emission scenarios.

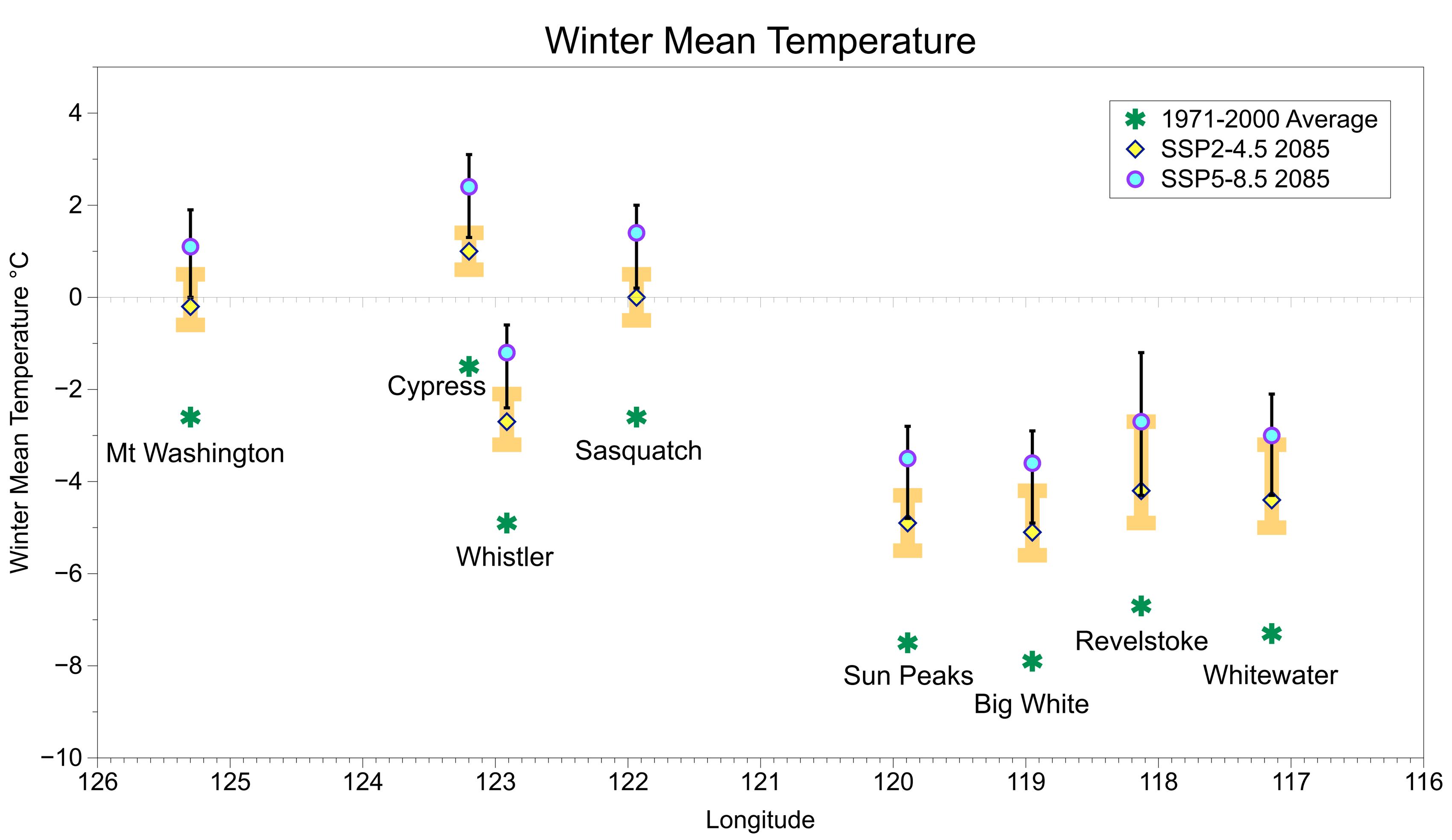

Figure 1. Change in winter mean temperature from the 1971-2000 climate normal average to the eight model average for the year 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios. Error bars indicate the range of model predictions.

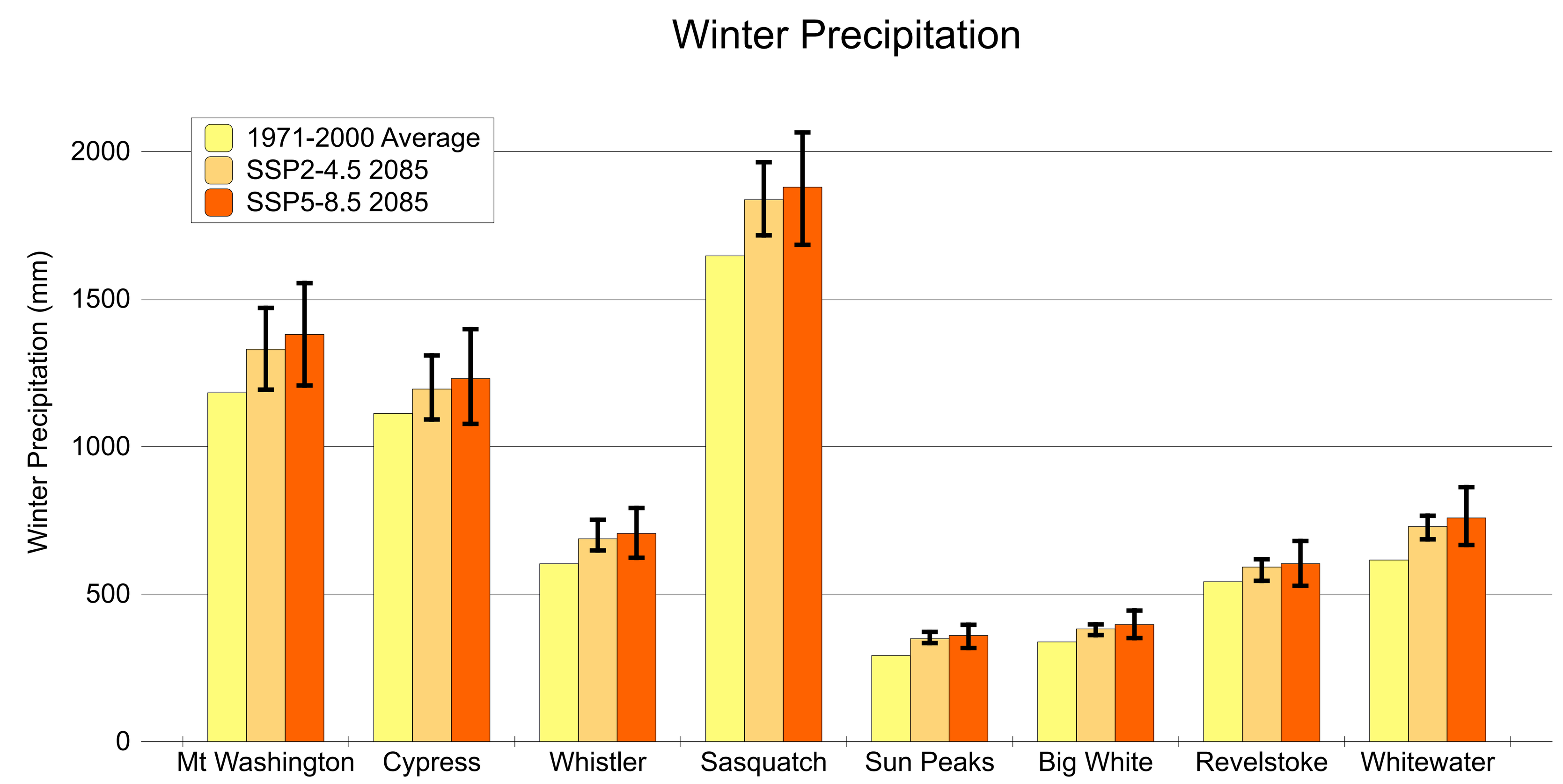

Figure 2. Change in winter precipitation from the 1971-2000 climate normal average to the eight model average for the year 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios. Error bars indicate the range of model predictions.

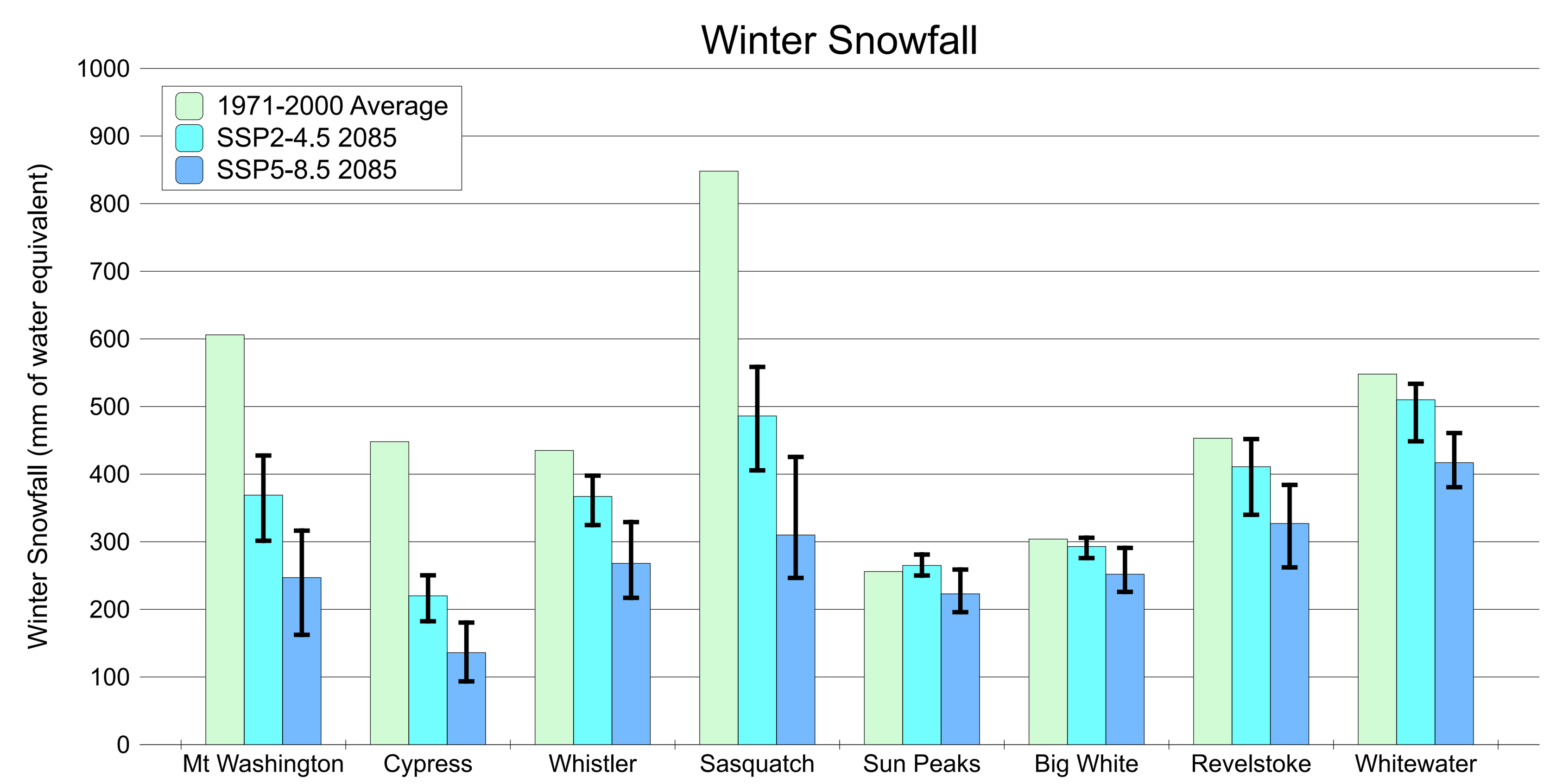

Figure 3. Change in winter snowfall from the 1971-2000 climate normal average to the eight model average for the year 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios. Error bars indicate the range of model predictions.

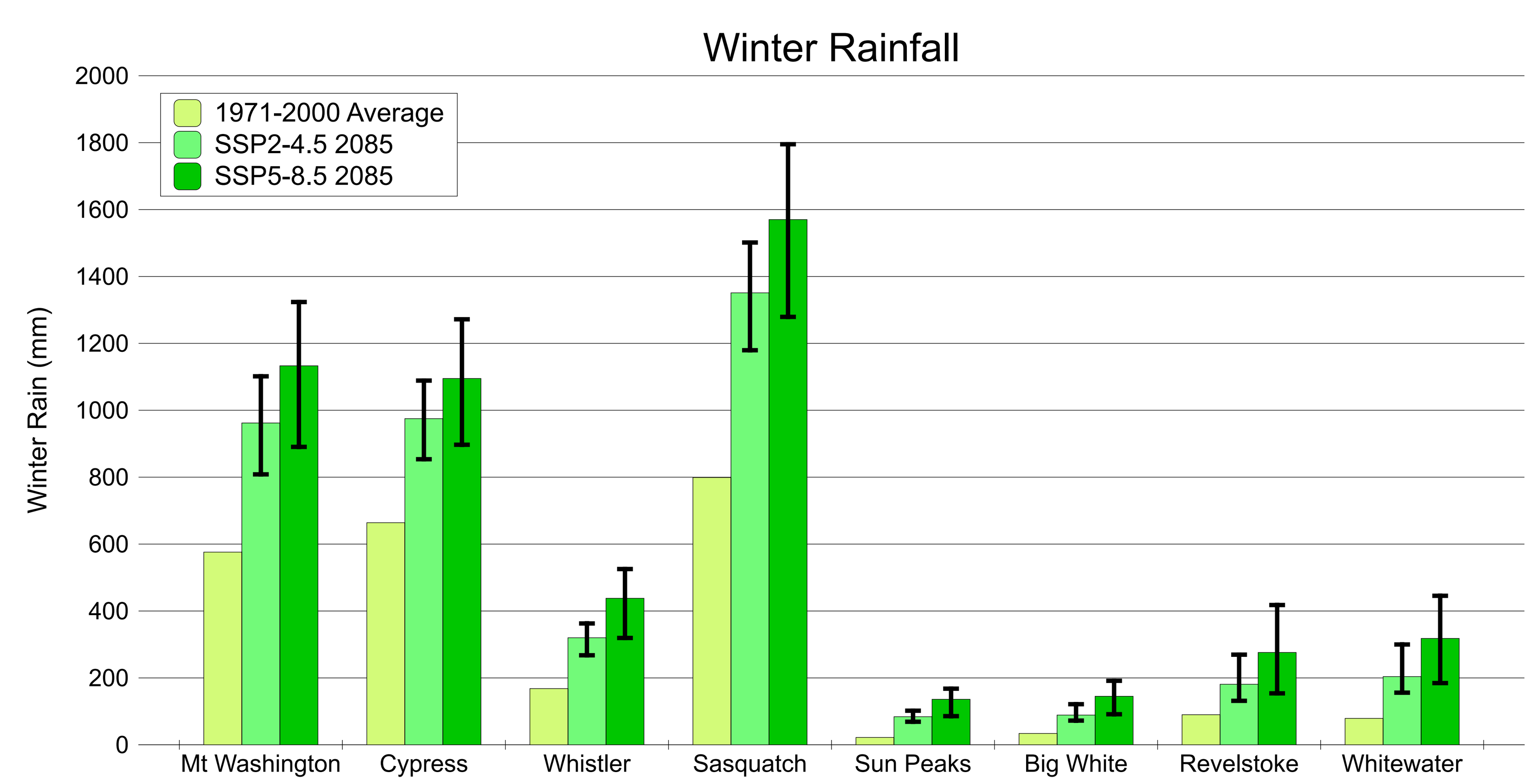

Figure 4. Change in winter rainfall from the 1971-2000 climate normal average to the eight model average for the year 2085 under SSP2-4.5 and SSP5-8.5 emission scenarios. Error bars indicate the range of model predictions.

RESULTS and DISCUSSION

Figure 1 describes the forecasted change in winter mean temperature for the eight ski resorts examined. According to the model average predicted future warming will cause Mt. Washington, Cypress, and Sasquatch, to cross the 0°C threshold under the SSP5-8.5 emission scenario by 2085. Resorts closer to the coast, Mt. Washington, Cypress, Whistler, and Sasquatch see winter mean temperatures increase by 2.4, 2.5, 2.2, and 2.6 °C under SSP-4.5 and 3.7, 3.9, 3.7, and 4.0 °C under SSP5-8.5, respectively, relative to the 1971-2000 average. Interior Resorts, Sun Peaks, Big White, Revelstoke and Whitewater see winter mean temperatures increase by 2.6, 2.8, 2.5, and 2.9 °C under SSP2 -4.5 and 4.0, 4.3, 4.0, and 4.3 °C under SSP5-8.5, respectively.

All of the ski resorts are forecasted to have increases in winter precipitation by 2085 under both emission scenarios relative to 1971-2000 average according to the model average (**Figure 2**). For the coast resorts, winter precipitation will increase by 148, 83, 85, and 190 mm under SSP2-4.5 and by 198, 118, 103, and 233 mm under SSP5-8.5 (Mt. Washington > Cypress > Whistler > Sasquatch). For the interior resorts, winter precipitation will increase by 57, 44, 50, and 114 mm under SSP2-4.5 and by 68, 59, 61, and 143 mm under SSP5-8.5 (Sun Peaks > Big White > Revelstoke > Whitewater).

Relative to the 1971-2000 average, winter snowfall will decrease by 238, 228, 67, and 361 mm (water equivalent) under SSP2-4.5 and 360, 312, 167, and 538 mm under SSP5-8.5 for the coastal resorts (Mt. Washington > Cypress > Whistler > Sasquatch) according to the model average (**Figure 3**). By 2085, Sun Peaks will see their winter snowfall increase by 9 mm under SSP2-4.5 and decrease by 33 mm under SSP5-8.5 compared to the 1971-2000 average. The remaining interior ski resorts, Big White, Revelstoke, and Whitewater will see a decrease in winter snowfall by 11, 41, and 38 mm under SSP2-4.5 and 52, 126, and 131 mm under SSP5-8.5, respectively.

For the period 1971-2000, the winter rainfall average was 576, 664, 168, and 799 mm for Mt. Washington, Cypress, Whistler, and Sasquatch, respectively (**Figure 4**). Under the SSP2-4.5 emission scenario, winter rainfall will increase for these four coastal resorts to 962, 975, 320, and 1351 mm and 1133, 1095, 438, and 1570 mm for SSP5-8.5 based on the model average by 2085, respectively. Because of much colder winter temperatures, the interior resorts have less winter rainfall: Sun Peaks – 22 mm, Big White – 34 mm, Revelstoke – 90 mm, and Whitewater – 79 mm. Under the SSP2-4.5 emission scenario, winter rainfall will increase for these four resorts to 84, 89, 181, and 204 mm and 136, 145, 276, and 318 mm for SSP5-8.5 based on the model average by 2085, respectively.

CONCLUSIONS

While both emission scenarios will cause significant changes in winter mean temperature, winter precipitation, winter snowfall, and winter rainfall, the best-case SSP2-4.5 scenario is clearly a better outcome for the British Columbian ski resorts examined here. Under this emission scenario Whistler, Sun Peaks, Big White, Revelstoke, and Whitewater should be able to support skiing and snowboarding in 2085, albeit at a somewhat reduced capacity.

REFERENCES

Wang, T., A. Hamann, D. Spittlehouse, and C. Carrol 2016. Locally downscaled and spatially customizable climate data for historical and future periods for North America. ***PLos ONE*** 11(6) doi:10.1371/journal.pone.0156720.