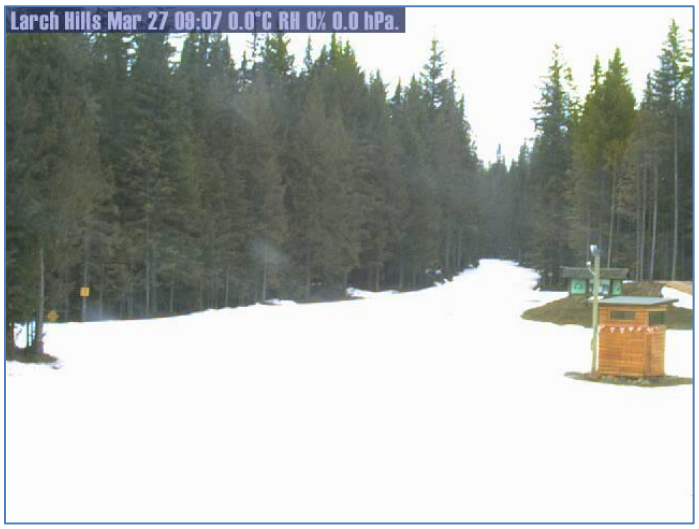
An Assessment of Potential Climate Change Impacts on Skiing Viability at Larch Hills Nordic Ski Club

April 7, 2016



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Acknowledgements

Alan Bates, PEng provided valuable review and comments during the development of this report. While his input was instrumental in finalizing the report, the author alone takes responsibility for all content and conclusions found in the report.

1 Introduction

A Strategic Plan[1] was completed for the Larch Hill Nordic Society in 2015 and included direction to assess climate change in support of decisions around infrastructure investment. Specifically, Section 4.3 of the Strategic Plan addresses Infrastructure & Capital Expenditures and includes the following direction:

2. Prepare a climate change adaptation plan as part of preliminary work for all infrastructure planning.

3. Present a chalet plan and preliminary budget to the membership. The plan will consider the needs of LHNS user groups and the interests of members, the effects of climate change, and regulatory requirements.

As part of the chalet expansion committee's work, a motion to expand the chalet was voted on in Jan 2016 and passed subject to the following condition:

> "The Climate Update Study suggests a reasonable likelihood of skiable conditions through most of the existing Larch Hills Recreation Area for an average of 60 days per season for most of the seasons during the next fifteen years. "

This report has been prepared to provide a general overview of climate change implications on future skiing at Larch Hills and provide an answer the specific question contained in the chalet expansion motion. While this report provides context for future climate change adaptation by presenting expected future climate trends, it does not explore any specific adaptation actions.

2 Climate vs Weather

When considering climate change, it is important to separate the ideas of weather vs climate. Weather is the short-term atmospheric conditions that we experience over minutes, hours, or days, while climate is looking at average daily conditions for an extended period of time (years to decades) for a specific location. We don't experience climate averages, only daily weather.

Both climate and weather are based on temperature and precipitation but the much finer scale timing of weather requires the consideration of additional factors like cloudiness, wind, air pressure, etc in order to make forecasts. Climate is the weather of a place, averaged over a period of time, typically decades. Climate information includes statistics on historical trends that tells us about typical weather for a location, as well as the range of weather extremes for that location. Climate forecasts aim to provide this information for future decades using global models that consider changes in atmospheric conditions, wind patterns, ocean surface temperatures, etc.

When a climate forecast provides 'average winter temperature' for different periods, it helps us to understand likely trends over time, but it does little to tell us about what is going to happen in any specific day, month, or single ski season. In fact, climate change is widely expected to deliver increased variation around average conditions.

[1] Larch Hills Strategic Plan Report, 2015 http://skilarchhills.ca/wp/wp-content/uploads/2015/01/Strategic-Plan-public-input-summary.doc

3 Historic Snow Depths

Snow depth (snow pack) measurements have been taken at consistent locations and time frames in the Larch Hills area since 2007 as result of the dedication of several club volunteers (Pat Hutchinson, Keith Cox, George Zorn). The data and graphs presented in this section were sourced from their material posted on the Larch Hills Nordic website (http://skilarchhills.ca/snow-depth-measurements/). The full set of snow depth measurement collected since 2007 can be found in Appendix A of this report.

Historical snow depth measurements are useful as part of a climate change study addressing 'skiable conditions' because they help to provide a link between climate model statistics (predicted average snow fall) and localized outcomes (snowpack) that translate into skiable conditions. Snowpack measurements will always be less than 'fallen snow' measurements due to melt, compaction, etc.

To illustrate the challenge of looking at average conditions over many seasons (as climate models do), vs a single years outcomes, the early March snow depth measurements can analyzed. They are graphed below for the period 2007-2015 and indicate that on average, snow depth at the Chalet/Parking Lot elevation was 54.6cm over the 9 years assessed, with a peak of 87cm in 2007 and a low of 4cm in 2010. Clearly a wide range in snow depths occurred, and these had implications on annual skiing conditions.

- Both 2010 and 2015 are memorable for their poor snow years and lack of snow to ski on in late March/April. However, they were still successful ski seasons for the club with reasonable (sometimes poor) conditions present for the core skiing months (Dec-Feb). [Note: BC Midget Championships were hosted in March 2010 and did require some snow shoveling onto the race course in places].
- If conditions in 2010 could be considered a minimum for skiable conditions, and represent an extreme low within a 9 year period, comparisons can be made to this time period using future climate predictions.

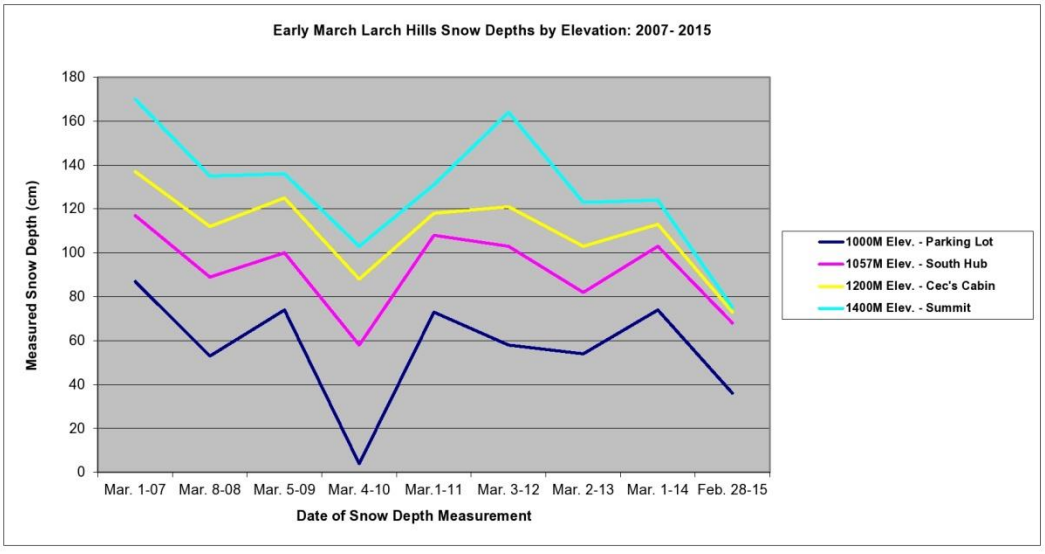


Figure 1. Early march snow depths at various Larch Hill locations for the years 2007-2015 (Source: Larch Hills website)

4 Climate Models and Scenarios

Climate forecasts for this report have been obtained using UBC's Climate WNA (Western North America) model which takes Global Climate Model data and downscales it to be relevant to specific geographic locations / elevations. A web based version of the model is shown below and can be found here: http://www.climatewna.com/ClimateWNA.aspx .

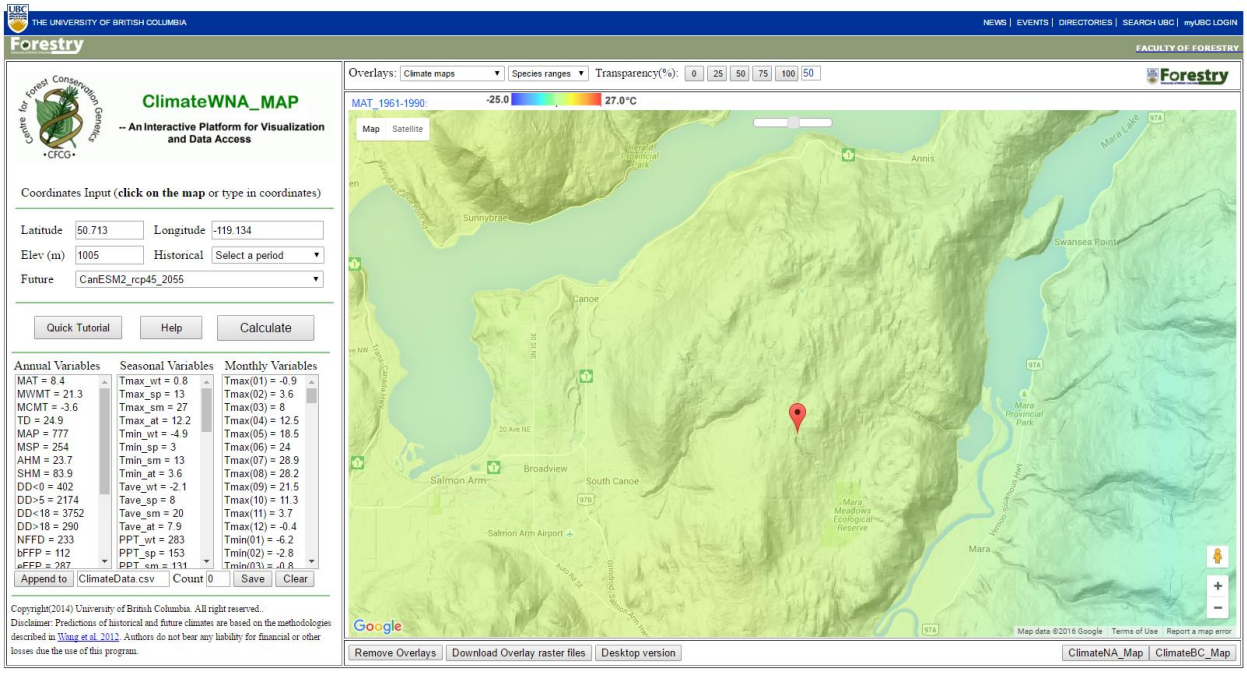


Figure 2. Example of UBC's interactive web-based version of its Climate WNA model (map pointer on chalet location).

The following climate change scenarios were used:

- Canadian Ensemble 2 Dataset, Emissions scenario 4.5 - CanESM2_RCP45 **[Moderate Change]**
  a. Assumes moderate emissions mitigation occurs in the future and the rise in total radiative forcing reaches 4.5 watts/m^2 by 2100.
- Canadian Ensemble 2 Dataset, Emissions scenario 8.5 - CanESM2_RCP85 **[Significant Change]**
  a. Assumes little to no emissions mitigation occurs in the future and the rise in total radiative forcing reaches 8.5 watts/m^2 by 2100.

5 Climate Forecasts

In general, climate forecasts for the Larch Hills Chalet area suggest the following trends (see Figure 3):

1) Average winter (Dec-Feb) temperatures will rise:
    a. from -4.2 to -2.1 in the next 50 years under the Moderate Change scenario
    b. from -4.2 to -1.1 in the next 50 years under the Significant Change scenario.
2) Precipitation will increase in the fall, winter, and spring – but decrease in summer.
3) The increased precipitation will fall more often as rain at lower elevations as temperatures are more often above zero. Thus, the precipitation expected to fall as snow will decline over time. Relative to what has been experienced in the last decade (2001-2010), precipitation falling as snow during winter months will decline by:
    a. 3% in the next 50 yrs and 20% in the next 80 years under the Moderate Climate Change scenario,
    b. 22% in the next 50 yrs and 58% in the next 80 years under the Significant Climate Change scenario
    c. The increase in snow in 2025 (relative to 2001-2010) is not expected to occur. It is more appropriate to look at the declining snow relative to the longer term historic average. The single decade of 2001-2010 is considered an anomaly within the longer term trend.
    d. In addition, much less snow is expected to fall in spring so skiing during this time of year will be increasingly dependent on the snowpack accumulated prior to March.
4) Similar trends were seen at the elevation of Cec's cabin, however as there is typically more snow at this elevation to start with, so reductions in snowfall will take longer to impact ski conditions.

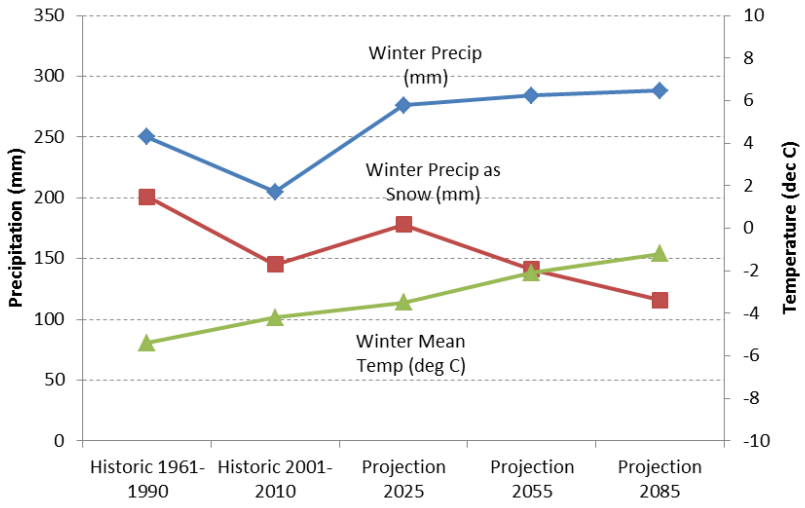


Figure 3. Winter Months (Dec-Feb) climate - historic vs predicted (Moderate Climate Change Scenario)

It should be noted that the climate change modeling community has indicated that they have the highest confidence in projected temperature changes (vs precipitation changes) so to put the projected temperature changes in perspective, a range of local sites/elevations and their 2001-2010 average winter (Dec-Feb) temperatures are provided below.

Table 1. Elevation / Temperature gradient for 2001-2010 Average Winter Temperatures

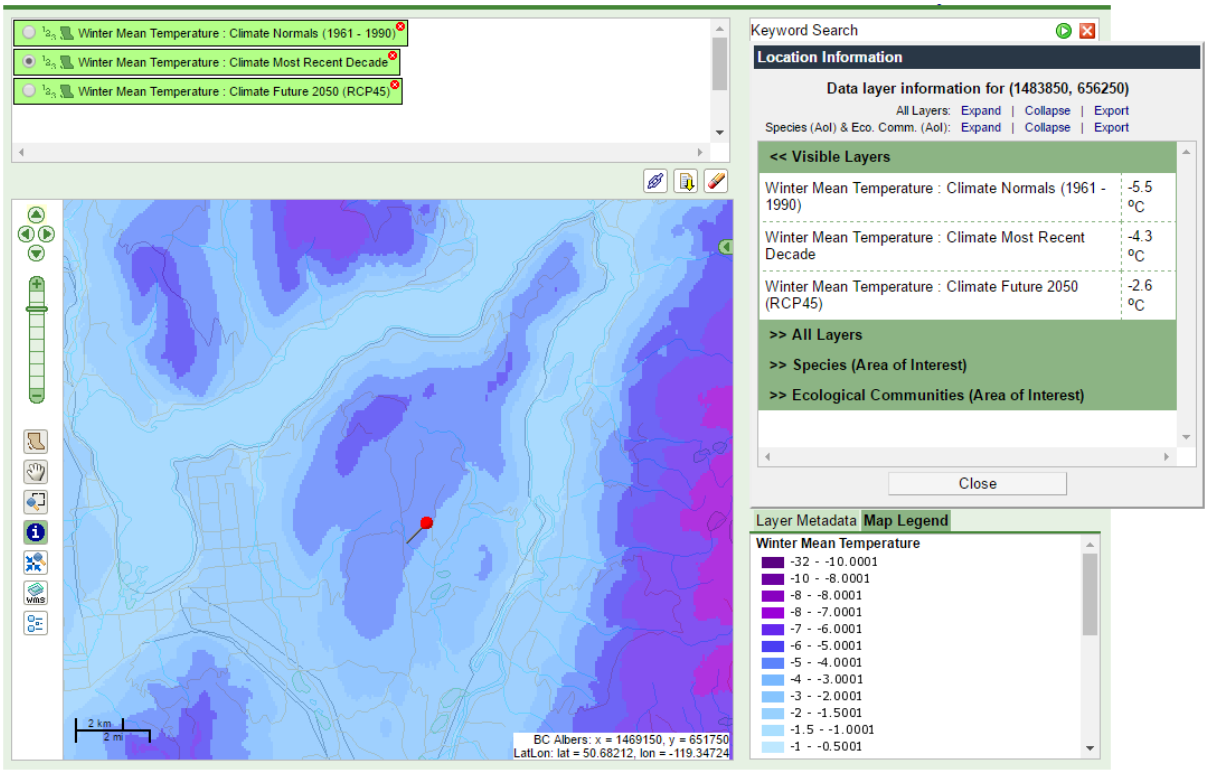
Location	Elevation (m)	2001-2010 Average Winter (Dec-Feb) Temperature (deg C)
Salmon Arm Wharf	349	-1.9
City Hall	359	-1.9
RMCP /Bastion School	435	-2.2
Field Of Dreams	520	-2.4
Hwy 97 / Grandview Brench Rd	526	-2.4
Grandview Brench Rd / Edgar Rd	660	-2.9
Johns Ski Shack	792	-3.5
Chalet/Parking Lot	**1000**	**-4.2**
South Hub	1055	-4.4
Cec's Cabin	1220	-4.9

Source: http://www.climatewna.com/ClimateWNA.aspx

Based only on the projected temperature shifts from the Moderate Climate Change scenario, this table would suggest that the chalet will experience winter temperatures more like Johns Ski Shack (-3.5) by 2025 and RCMP/Bastion School (-2.2) by 2055. This simplified comparison does not consider the projected increases in precipitation (rain and snow) that climate change is expected to deliver, however it can provide a sense of what future average temperature conditions might look like at the chalet.

To further illustrate projected climatic changes across the Larch Hills area, maps are provided below depicting average winter temperatures and annual precipitation falling as snow in the 2000's and in the 2050's. The temperature maps show warming across elevation bands throughout the ski area, while the snowfall maps show a similar trend but with a less dramatic shift.

Map 1A: Average Winter Temperature for (2000-2010) for Larch Hill Ski Area (Pin = Chalet Location)



Map 1B: Predicted Average Winter Temperature (2050's) for Larch Hill Ski Area (Pin = Chalet Location)

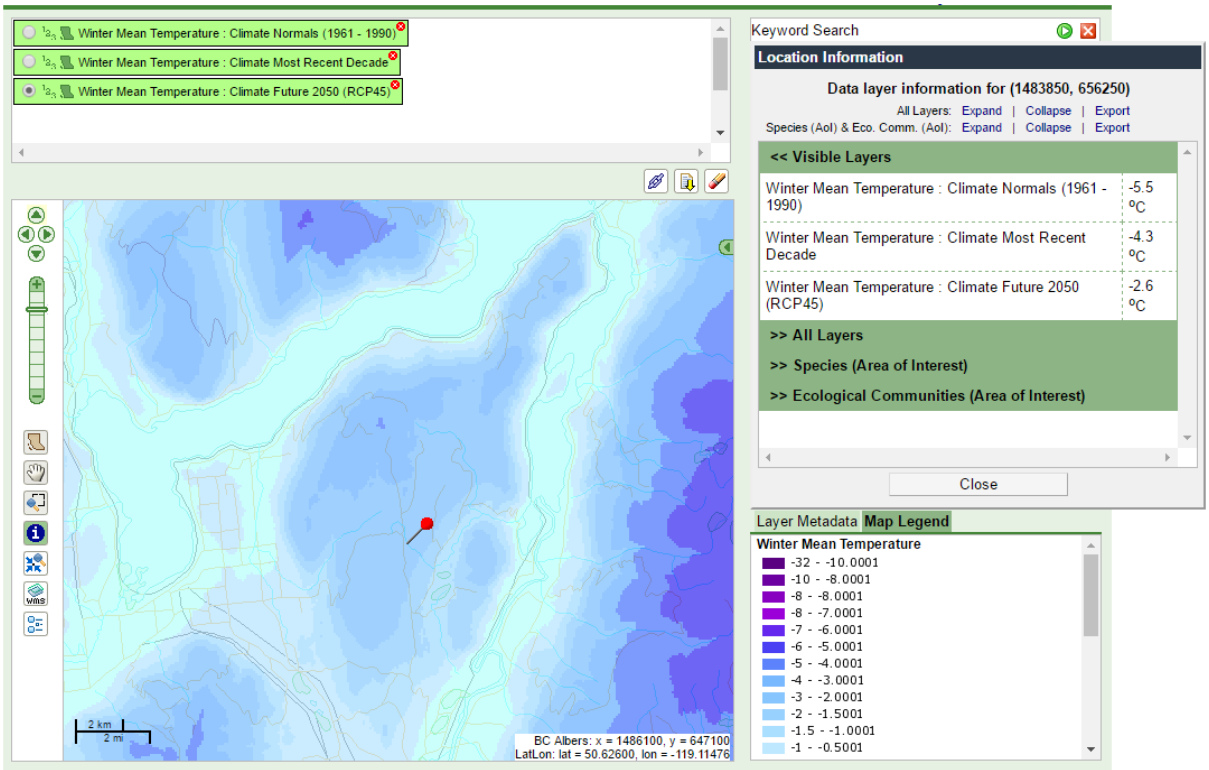
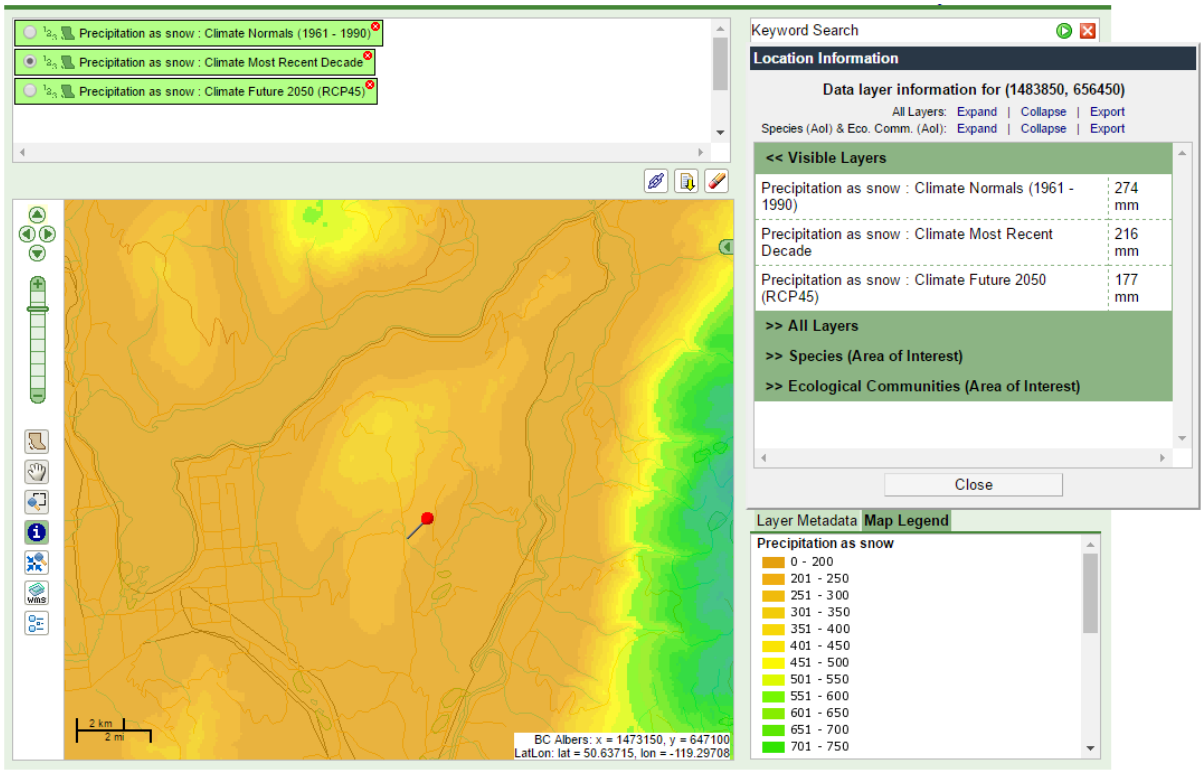
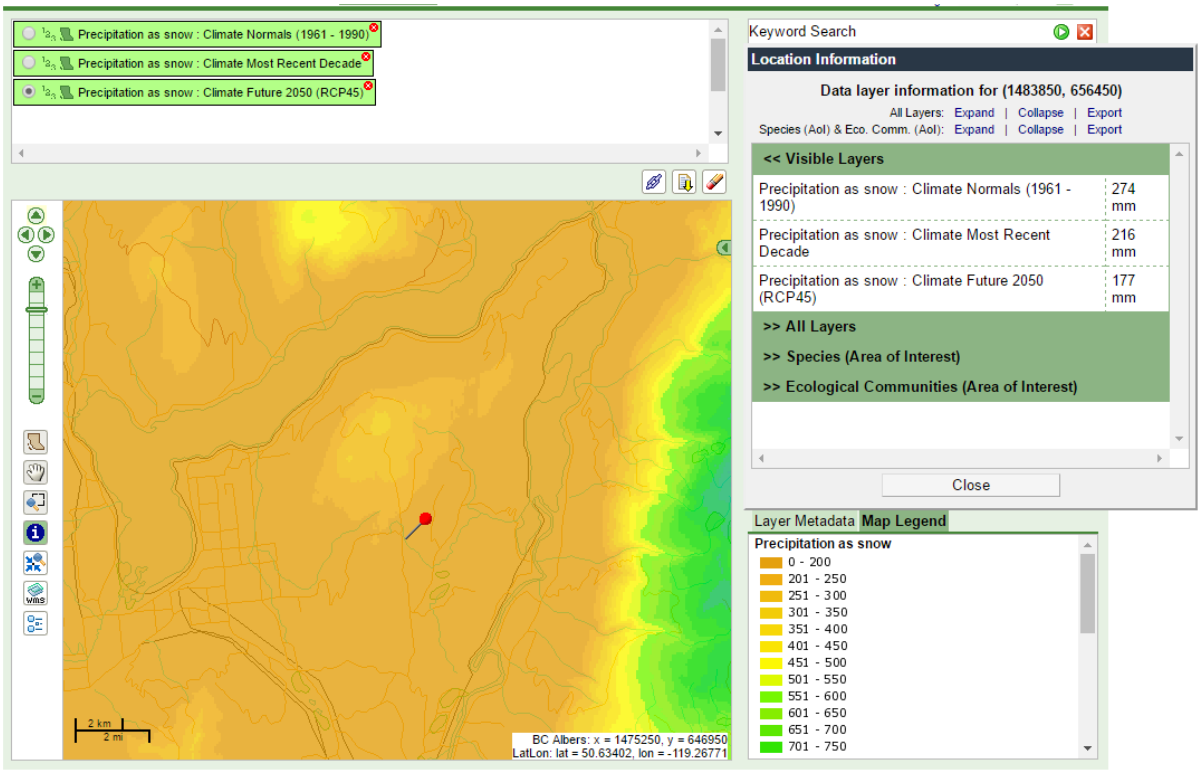


Image Sources: Hectare BC Webmap (http://www.hectaresbc.org/app/habc/HaBC.html)

Map 2A: Annual Precipitation Falling as Snow (2000-2010) for Larch Hill Ski Area (Pin = Chalet Location)



Map 2B: Annual Predicted Average Winter Temperature (2050's) for Larch Hill Ski Area (Pin = Chalet)



Map Image Sources: Hectare BC Webmap (http://www.hectaresbc.org/app/habc/HaBC.html)

In order to provide a more detailed assessment of skiable conditions in the future, climate statistics for years with known snowpacks (2007-2015) have been compared to projected future climate statistics. Table 2 and Figure 4 show the measured climate attributes associated with a known 'good' snow year (2007), a poor year (2010), and an average year (2013) as defined in the Historic Snow Depth section of this report. This correlation between known skiing conditions (snowpack) and climate attributes (snow fall) provide a basis for evaluating future climate predictions.

Table 2. Historic and projected future climate for the Larch Hills chalet location (Source: UBC's Climate WNA model)

		Winter (Dec-Feb) Precip (mm)	Winter Precip as Snow (mm)	Winter Mean Temp (deg C)	Winter Max Temp (deg C)	Winter Min Temp (deg C)	Larch Hills Chalet Snow Depth Measured in Jan (cm)	Larch Hills Chalet Snow Depth Measured in Mar(cm)
Historic	Historic 1961-1990	250	201	-5.4	-2.0	-8.8		
	Historic 2001-2010	205	145	-4.2	-0.9	-7.6		
	Historic 2007	215	136	-3.6	-0.5	-6.7	61	87
	Historic 2010	153	87	-4.1	-0.9	-7.2	36	4
	Historic 2013	135	101	-4.0	-0.8	-7.2	33	54
Projection: Mod Change	Projection 2025	276	178	-3.5	-0.4	-6.7	CanESM2 RCP45 Scenario	
	Projection 2055	284	141	-2.1	0.8	-4.9		
	Projection 2085	288	116	-1.2	1.5	-3.8		
Projection: Significant Change	Projection 2025	278	174	-3.3	-0.2	-6.5	CanESM2 RCP85 Scenario	
	Projection 2055	294	113	-1.1	1.5	-3.7		
	Projection 2085	293	61	1.0	3.1	-1.1		

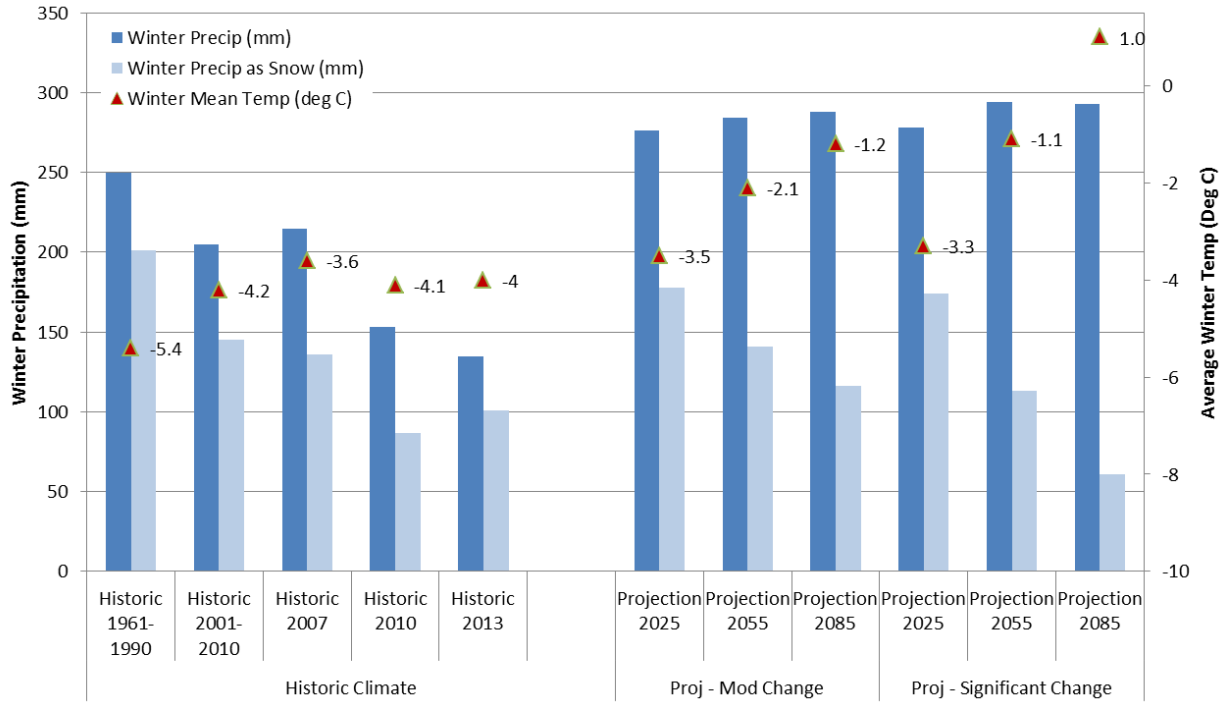


Figure 4. Historic and projected future climate for the Larch Hills chalet location (Source: UBC's Climate WNA model using the Canadian Ensemble2 dataset, RCP45 and RCP85 Scenarios)

General Observations:

Historically (1961-1990), approximately 80% of the precipitation that fell between Dec-Feb came in the form of snow due to temperatures largely being below freezing during those months (251mm of precip, 201mm fell as snow, avg temp of -5.4 deg C). Future projections show that the amount of precipitation in the winter will increase but that it will fall more often as rain:

- 2001-2010: 71% of winter precipitation has fallen as snow,
- By 2025, total precipitation increases but only 65% will fall as snow, and
- By 2055 total precipitation again increases but only 50% will fall as snow.
- Keep in mind, these are long term averages so realistically, some years will be excellent snow years while others could be quite poor.
- The chalet area/elevation typically experiences temperatures that are slightly below freezing so annual variations of a few degrees could have a significant impact on snow accumulation and retention (see elevation/temperature gradient discussed above).

Observations for the current chalet location:

- The precipitation that fell as snow in 2010 (poor year) is lower than any projected future average condition up to 2055. While that does not mean that years like 2010 will not occur in the future, it does indicate that the average conditions for future decades are predicted to be better than 2010.
- If 2001-2010 can be considered to have provided reasonable skiing conditions, then the average precipitation falling as snow for 2001-2010 can be compared to the forecast for 2055. The Moderate Change scenario can be seen to be quite similar (slightly lower) than 2001-2010 but the significant change scenario is considerably lower (worse).
- While the Moderate Change scenario suggests that average winter snowfall in 4 decades (2055) may be similar to what occurred in 2001-2010, this result occurs largely because overall precipitation is increasing. Average temperatures will be warmer by 1.9 degrees and result in a higher proportion of precipitation falling as rain. This is concerning because the snowfall would be eroded by the increase in rain and generally warmer temperatures, requiring more snowfall to sustain the same skiing conditions. Thus, 2055 snowpack and skiing conditions are expected to be worse than the 2001-2010 average condition – potentially more like the 2010 season.
- In the shorter term, the projections for 2025 suggest that we will have very similar skiing conditions to what has been experienced in the last decade – but with the expectation that poor snow years will occur more often.
- In the longer term, the projections for 2085 suggest that skiing will become increasing difficult under continually reducing snowfall and increasing rain at the chalet location (1000m elevation). If the Significant Change scenario were to play out, there would almost certainly be no reasonable skiing at the chalet by 2085 (only 20% of winter precip would fall as snow).

6 Conclusions

While it is not possible to make definitive statements about the quality of future skiing at Larch Hills from climate projections, interpretation of climate modeling and historical snowfall trends point to future ski seasons with increasingly lower snowpacks at the current chalet location. While the amount of winter precipitation is expected to increase, warmer temperatures will cause less of it to fall as snow and produce conditions that melt snow more frequently. It is the timing and rate of this predicted change that is of interest to the ski club.

It is the author's conclusion that the site of the chalet is likely to experience conditions that limit skiing from occurring well before 2085 under worst case climate change projections (i.e. limited mitigation of global emissions occur in the future). If global mitigation efforts are more successful (i.e. the Moderate Change Scenario transpires), there is a reasonable chance that skiing can continue out of the chalet location for several decades to come – while recognizing that poor years / shorter seasons will become increasingly common as decades pass. The long term (50+ year) viability of skiing at the chalet location appears questionable.

Specific to the chalet expansion motion question, there would appear to be a very high likelihood of skiable conditions existing throughout most of the Larch Hills' trails for an average of 60 days per season for most of the seasons during the next fifteen years (e.g. until 2030).

It should be noted that while Cec's cabin is 220m higher in elevation (0.7 deg cooler), it is projected to experience a similar future to the current chalet location, just delayed by 20-30 years.

For reference, both Telemark and Blackjack chalet locations are projected to have degraded skiing conditions sooner than Larch Hills, while Sovereign Lake is projected to have little to no degradation of skiing conditions for the foreseeable future due to its high elevation.

Appendix A: Larch Hills Nordic Club Snow Measurements (http://skilarchhills.ca/snow-depth-measurements/)

Larch Hills Snow Depths Measurements: 2007 - 2015

Snow depth measurements have been recorded at four different elevations on the Larch Hills Ski Trails network. Measurements are taken each year in early January and early March. Measurements are the average of two fixed points at each elevation which are relatively similar in forest canopy closure and slope. Contact: Pat Hutchins (832-7242), Keith Cox (832-7768) or George Zorn (832-9335) if you have questions.

	Parking Lot (1000 M elev.)	South Hub (1057 M elev.)	Cec's Cabin (1200 M elev.)	The Summit (1400 M elev.)
Jan. 5, 2007	61 cm	71 cm	102 cm	115 cm
March 1, 2007	87 cm	117 cm	137 cm	170 cm
Jan. 12, 2008	58 cm	71 cm	102 cm	110 cm
March 8, 2008	53 cm	89 cm	112 cm	135 cm
Jan. 12, 2009	71 cm	89 cm	114 cm	137 cm
March 5, 2009	74 cm	100 cm	125 cm	136 cm
Jan. 9, 2010	36 cm	63 cm	89 cm	104 cm
March 4, 2010	4 cm	56 cm	88 cm	103 cm
Jan. 1, 2011	39 cm	57 cm	76 cm	76 cm
March 1, 2011	73 cm	108 cm	118 cm	131 cm
Jan. 7, 2012	28 cm	47 cm	62 cm	70 cm
Feb. 2, 2012	52 cm	82 cm	98 cm	113 cm
Mar. 3, 2012	58 cm	103 cm	121 cm	164 cm
Jan. 2, 2013	33 cm	50 cm	66 cm	82 cm
Feb. 2, 2013	54 cm	77 cm	89 cm	110 cm
March 2, 2013	54 cm	82 cm	103 cm	123 cm
Jan. 4, 2014	53 + 70 = **62 cm**	73 + 77 = **75 cm**	82 + 83 = **83 cm**	84 + 115 = **100 cm**
Mar. 1, 2014	65 + 83 = **74 cm**	101 + 104 = **103 cm**	112 + 114 = **113 cm**	113 + 134 = **124 cm**
Jan. 3, 2015	41 + 44 = **43 cm**	56 + 57 = **57 cm**	61 + 62 = **62 cm**	54 + 65 = **60 cm**
Feb. 28-15	30 + 43 = **36 cm**	70 + 66 = **68 cm**	75 + 70-= **73 cm**	67 + 82 = **75 cm**
March 16-15	0 + 28 = **14cm**	62 + 62 = **62 cm**	60 + 66 = **63 cm**	**Not measured**
April 2-15	0 + 0 = 0 cm	50 + 45 = 48 cm	57 + 46 = 52 cm	36 + 65 = 51 cm

Feb. 2/13: Keith

- each end of Grouse Track on Raven's Ridge: 65 cm (1083M elev.)
- near Sentinel – Townview/Lakeview Junction: 63 cm (1089M elev.)

Jan. 5/15: snowed approx. 45 cm at Larch Hills 1000M elevation today. Schools in area and Okanagan closed 2 days.

On track set snow depths Feb. 28/15:
1000M, Chalet area: 28 + 41 = **35cm**, 1057M, S. Hub area: **34cm**, 1200M Cec's: **42cm**,

Note: Maximum snow depth at chalet in March was 2007 (87 cm), Min was in 2010 (4cm). 2015 was also a generally poor snow year with an early spring.