

SUPPLEMENTAL MATERIAL 1.

Climate Trends From the Government Camp Weather Station and Snowpack Depth From the Mt Hood Test Site SNOTEL Station

The Government Camp Station (NCDC COOP number 353402) is located at 45°18’N 121°145’W, 1213 m asl. The Mt Hood Test Site SNOTEL Station (SNOTEL site number 651) is located at 45°19’N 121°43’W, 1637 m asl. Monthly, seasonal, and annual temperature (mean, min, max), snowfall, and Julian day of last measurable snowpack were regressed over the 1950 - 2008 time period (except last snowpack, regressed over 1981 to 2011 time period) to determine if there were significant climate trends over time (SM1 Table 1-2). The dominant trends are an increase in minimum temperatures and a decrease in snow fall, while date of last measurable snowpack has been variable but does not display any significant trends (SM1 Fig. 1)

SM1 Table 1. Summary of linear regressions of snowfall and last day of measureable snowpack variables over the 1950-2008 (Government Camp weather station) and 1981 to 2001 (Mt Hood test site SNOTEL station) time period.

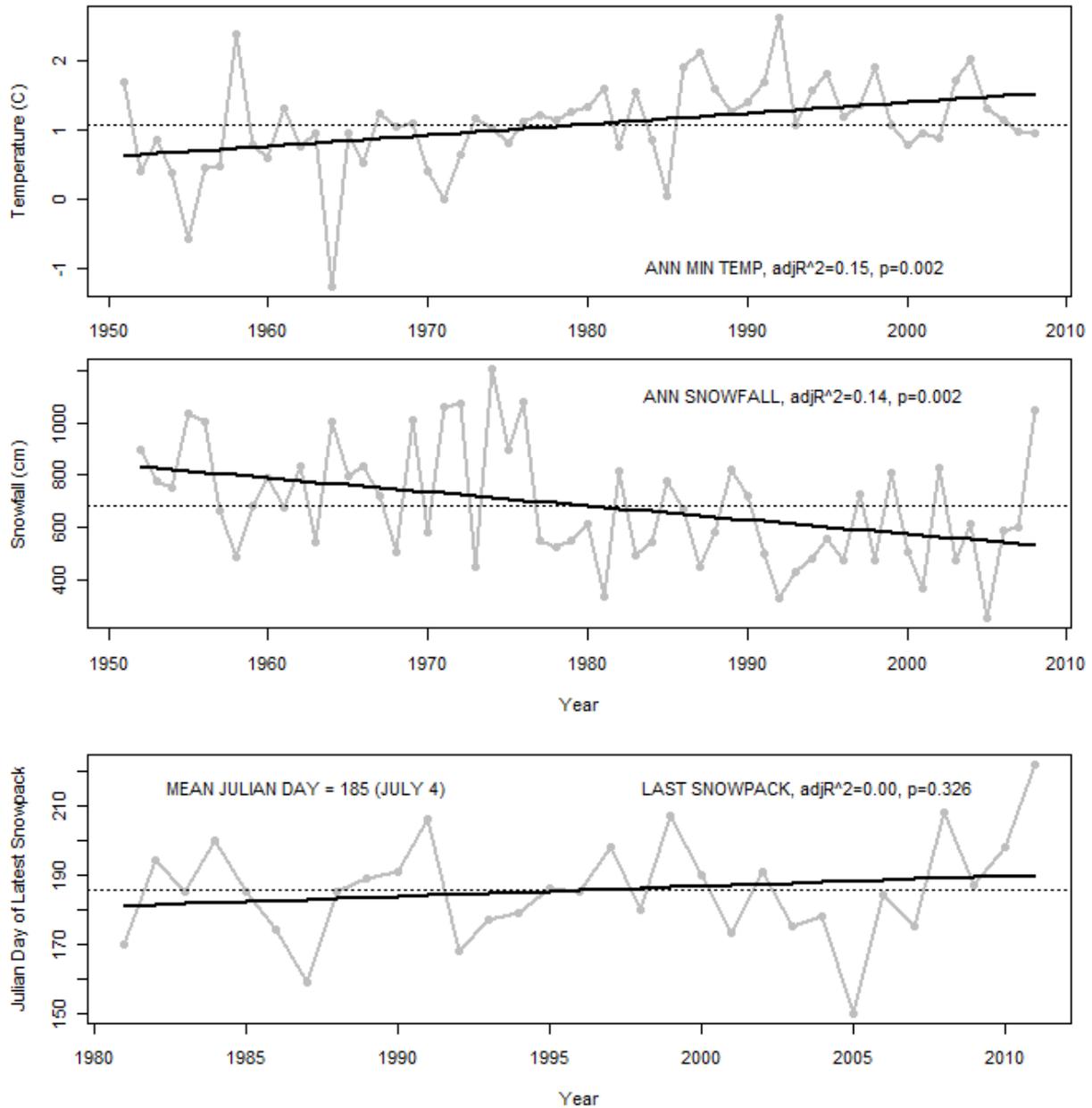
Climate Variable	Parameter Estimate (SE)	adj. R ²	p
JUL snowfall	-	-	-
AUG snowfall	-	-	-
SEP snowfall	-0.0048 (0.0145)	-0.0162	0.7426
OCT snowfall	-0.1893 (0.1681)	0.0048	0.2649
NOV snowfall	0.5979 (0.5268)	0.0051	0.2613
DEC snowfall	-0.6416 (0.5777)	0.0041	0.2716
JAN snowfall	-1.0615 (0.7428)	0.0183	0.1587
FEB snowfall	-1.0063 (0.487)	0.0552	0.0435*
MAR snowfall	-2.1442 (0.5899)	0.1791	0.0006*
APR snowfall	-0.7141 (0.3334)	0.0602	0.0367*
MAY snowfall	-0.1713 (0.1515)	0.0049	0.2631
JUN snowfall	-0.0023 (0.0394)	-0.0181	0.9535
ANN snowfall	-5.3374 (1.6522)	0.1442	0.0021*
AJ snowfall	-0.8877 (0.4048)	0.0637	0.0326*
Last snowpack	0.2984 (0.2986)	0.0000	0.3259

Note: ANN, AJ, and JS refer to annual, spring (April – June), and summer (July – Sept). Last snowpack refers to the latest Julian date of measurable snowpack. Parameter estimates are the fitted climate trend (cm yr⁻¹). There were not enough years of JUL and AUG snowfall for analyses.

SM1 Table 2. Summary of linear regressions of mean, minimum, and maximum temperatures at the Government Camp Weather Station over the 1950-2008 time period.

Time Period	Mean Temperature			Minimum Temperature			Maximum Temperature		
	Parameter Estimate (SE)	adj. R ²	p	Parameter Estimate (SE)	adj. R ²	p	Parameter Estimate (SE)	adj. R ²	p
JAN	0.0198 (0.0154)	0.0115	0.2040	0.0299 (0.0171)	0.0356	0.0856	0.0096 (0.0149)	-0.0105	0.5215
FEB	-0.007 (0.0155)	-0.0144	0.6508	0.0055 (0.015)	-0.0157	0.7159	-0.018 (0.0172)	0.0018	0.2981
MAR	0.0327 (0.0128)	0.0898	0.0134*	0.0406 (0.0116)	0.1670	0.0009*	0.025 (0.0152)	0.0294	0.1062
APR	0.0075 (0.0126)	-0.0116	0.5515	0.0161 (0.01)	0.0274	0.1140	-0.001 (0.0165)	-0.0181	0.9532
MAY	0.0044 (0.0136)	-0.0162	0.7469	0.0146 (0.0097)	0.0218	0.1395	-0.0058 (0.019)	-0.0165	0.7610
JUN	0.0047 (0.0134)	-0.0159	0.7264	0.0078 (0.0113)	-0.0095	0.4939	0.0017 (0.017)	-0.0180	0.9221
JUL	0.0421 (0.0348)	0.0081	0.2315	0.0287 (0.0094)	0.1301	0.0034*	-0.0048 (0.017)	-0.0167	0.7797
AUG	0.0255 (0.0116)	0.0628	0.0324*	0.0311 (0.0093)	0.1508	0.0015*	0.0204 (0.0159)	0.0113	0.2038
SEP	0.0066 (0.015)	-0.0144	0.6633	0.0194 (0.0109)	0.0366	0.0806	-0.0062 (0.0202)	-0.0161	0.7595
OCT	-0.0088 (0.0139)	-0.0106	0.5290	0.004 (0.01)	-0.0150	0.6947	-0.0219 (0.0188)	0.0064	0.2475
NOV	-0.0031 (0.0141)	-0.0170	0.8282	0.0133 (0.0132)	0.0004	0.3164	-0.0205 (0.0168)	0.0085	0.2271
DEC	-0.0054 (0.0171)	-0.0161	0.7546	0.0053 (0.0156)	-0.0158	0.7370	-0.0159 (0.0198)	-0.0063	0.4268
ANN	0.0037 (0.0052)	-0.0086	0.4769	0.0158 (0.0047)	0.1499	0.0016*	-0.0036 (0.006)	-0.0114	0.5531
AJ	0.0055 (0.009)	-0.0112	0.5407	0.0128 (0.008)	0.0271	0.1152	-0.0017 (0.0111)	-0.0177	0.8790
JS	0.0247 (0.014)	0.0356	0.0837	0.0273 (0.0057)	0.2772	0.0000*	0.0043 (0.0104)	-0.0148	0.6808

Note: ANN, AJ, and JS refer to annual, spring (April – June), and summer (July – Sept). Parameter estimates are the fitted climate trend (degrees C yr⁻¹).



SM1 Figure 1. Trends in annual minimum temperature (ANN MIN TEMP) and annual snowfall (ANN SNOWFALL) from the Government Camp weather station, and the latest date of measurable snowpack (LAST SNOWPACK) from the Mt Hood test site SNOTEL station. Gray points and lines are annual temperature, snowfall and date of last snowpack, black dotted lines are mean values for time period, and solid black lines are fitted regression lines of climate variables over time.

SM1 Table 3. List of statistical analyses performed in this study.

Analysis	Analysis Type	Response Variables	Explanatory Variables
Proportion of meadow occupied	Linear regression	Proportion of plots occupied, based on aged trees	time (years)
Tree invasion in relation to climate	Pearson correlation	Landscape invasion rate, based on aged trees	PDO, PDO_MAX, PDO_MIN, ANN_T, ANN_T_MAX, ANN_T_MIN, ANN_S, ANN_S_MAX, ANN_S_MIN, AJ_T, AJ_T_MAX, AJ_T_MIN, AJ_S, AJ_S_MAX, AJ_S_MIN, JS_T, JS_T_MAX, JS_T_MIN
Differences in snow depth on plots in glacial versus debris flow landforms	Satterthwaite t tests for samples with unequal variances	Snow depth	Landforms (glacial versus debris flow)
Snow depth in relation to biotic and topographic factors	Nonparametric multiplicative regression (NPMR)	Snow depth	ELEV, TOPO, RAD, CANDIST, CANDIRECT
Tree abundance in relation to biotic and topographic factors	General linear mixed model with AIC model selection	Abundance (count data) of mountain hemlock and Pacific silver fir	ELEV, TOPO, RAD, CANDIST, CANDIRECT, ABAM_DIST, TSME_DIST
Interactive effect of climate and microtopography on tree invasion	Wilcoxon-Mann-Whitney test	Counts of tree invasion, based on aged trees	Years classified as cool and snowy versus warm and less snowy.
Interactive effect of climate and microtopography on tree invasion	Contingency tables and Fisher's exact test	Counts of tree invasion, based on aged trees	High versus low TOPO, high versus low ELEV, cool and snowy versus warm and less snowy years.

Note: See Table 1 and methods section for descriptions of response and explanatory variables.