Appendix 1. Supplemental Methods: A detailed description of climate data and statistical models compared for model fit.

Climate data

We used the following equations to relate temperature and precipitation at PRISM grid cells to values at the Longmire climate station, based on a calculated adjustment factor:

$$T_i = T_{station} + Ta_i \qquad \text{(A.1)}$$

$$P_i = P_{station} \times Pa_i \qquad \text{(A.2)}$$

where T_i represents mean temperature at grid cell i, $T_{station}$ represents mean temperature recorded at the Longmire climate station and Ta_i is the adjustment factor that relates the two temperature values. Likewise, P_i represents total precipitation at grid cell i, $P_{station}$ represents total precipitation recorded at the Longmire climate station and Pa_i is the factor that relates the two precipitation values. We calculated the value of Ta_i and Pa_i for each month of the year using Equations A.1 and A.2, the monthly mean temperature (estimated by averaging the mean maximum and mean minimum temperatures) and total precipitation normals (1971-2000) for each grid cell from the PRISM estimates, and the monthly mean temperature and total precipitation normals (1971-2000) calculated from Longmire data. Next, we used Equations A.1 and A.2, the adjustment factors (Ta_i and Pa_i), and the daily mean temperature and total precipitation values for 1914-2007 from Longmire to estimate daily mean temperature and total precipitation for each grid cell in the Park for 1914-2007. For days with missing data at Longmire, Longmire climate was estimated based on values at a nearby climate stations and the relationship between climate variables at Longmire and the nearby climate station. Longmire was missing temperature data for only 1.39% of days and precipitation data for only 1.44% of days.

For each sampling location, we picked the grid cell in which the sampling location was located to represent the climate of that sampling location. These climate estimates were then used to calculate seasonal and annual values for temperature and precipitation for each sampling location. We then input the daily temperature and precipitation estimates into the SNOW-17 snow model (Anderson 1976) to calculate annual snowpack variables for each sampling location.

Statistical models compared for fit

Below is a list of the 32 mixed effects models compared for fit in our analyses. For all models, we designated both individual tree and year as random effects to account for non-independence of data from the same individual or within years (Crawley 2007); climate variables were fixed effects. Models with * between explanatory variables include the interaction term. The response variable for all models was ring width index (rwi), a measure of annual tree growth. There were nine potential explanatory variables: mean growing season temperature (GST), growing degree days (GDD), mean dormant season temperature (DST), mean annual temperature (MAT), total growing season precipitation (GPT), total annual precipitation (PPT), total dormant season precipitation (DPT), snow water equivalent (SWE), and snow duration (SNDR).

Null Model: rwi ~ 1 (intercept only)

Model 1: rwi ~ MAT

Model 2: rwi ~ PPT

Model 3: rwi ~ MAT + PPT

Model 4: rwi ~ MAT * PPT

Model 5: rwi ~ GST

Model 6: rwi ~ DST

Model 7: rwi ~ GPT

Model 8: rwi ~ DPT

Model 9: rwi ~ GST + DST

Model 10: rwi ~ GPT + DPT

Model 11: rwi ~ GST + DST + GPT + DPT

Model 12: rwi ~ GST + GPT

Model 13: rwi ~ GST * GPT

Model 14: rwi ~ DST + DPT

Model 15: rwi ~ DST * DPT

Model 16: rwi ~ SWE

Model 17: rwi ~ SNDR

Model 18: rwi ~ GDD

Model 19: rwi ~ SWE + GST

Model 20: rwi ~ SNDR + GST

Model 21: rwi ~ SWE + GPT

Model 22: rwi ~ SNDR + GPT

Model 23: rwi ~ SWE + GST * GPT

Model 24: rwi ~ SWE + GST + GPT

Model 25: rwi ~ SNDR + GST * GPT

Model 26: rwi ~ SNDR + GST + GPT

Model 27: rwi ~ GDD + DST + GPT + DPT

Model 28: rwi ~ GDD + GPT + DPT

Model 29: rwi ~ GDD + GPT

Model 30: rwi ~ GDD * GPT

Model 31: rwi ~ GDD + SWE

LITERATURE CITED

Anderson, E.A. 1976. A point energy and mass balance model of a snow cover. NOAA Technical Report NWS 19. U.S. Department of Commerce, Silver Spring, MD.

Appendix 2. Supplemental figures showing relationships between climate variables.

Supplemental Figure Legends

Figure 1S. Climate variables are highly correlated among stations near sampling locations at Mt. Rainier. We used climate estimates derived from Longmire (842 m) for our analyses because this station had the longest climate records. Location-specific adjustments were based on elevational differences between the sampling location and Longmire (i.e. temperature and precipitation lapse rates). Here we show correlations between temperature (A&B) and precipitation (C&D) from Longmire as compared to a climate station above (Paradise, 1654 m) and below (La Grande, 243 m) our sampling locations. Correlations are similarly high when comparing mean annual temperature (MAT) and cumulative precipitation (PPT) among the three climate stations. Correlations are based on data from all available years for which there was overlap (Longmire: 1909-2009; La Grande: 1954-1983; Paradise: 1931-2009).

Figure 2S. Some temperature-related climate variables are highly correlated with one another within years. All pairwise relationships between mean annual temperature (MAT), growing season temperature (GST), dormant season temperature (DST), potential evapotranspiration (PET) and growing degree days (GDD) from the Longmire climate station. Correlations between climate variables are similar for other location-specific climate data. Correlation coefficients are shown in the upper panel (** indicates $P<0.001$; * indicates $0.001< P<0.05$). We did not simultaneously include highly correlated explanatory variables in linear mixed effects models ($r>0.6$).

Figure 3S. Some precipitation-related climate variables are highly correlated with one another within years. All pairwise relationships between cumulative annual precipitation (PPT), growing season precipitation (GSP), dormant season precipitation (DSP), maximum snow pack measured as snow water equivalent (SWE) and the number of days with snow cover (SNDR) from the Longmire climate station. Correlation coefficients are shown in the upper panel (** indicates $P<0.001$; * indicates $0.001< P<0.05$). We did not simultaneously include highly correlated explanatory variables in the same linear mixed effects models ($r>0.6$).

Figure 1S.

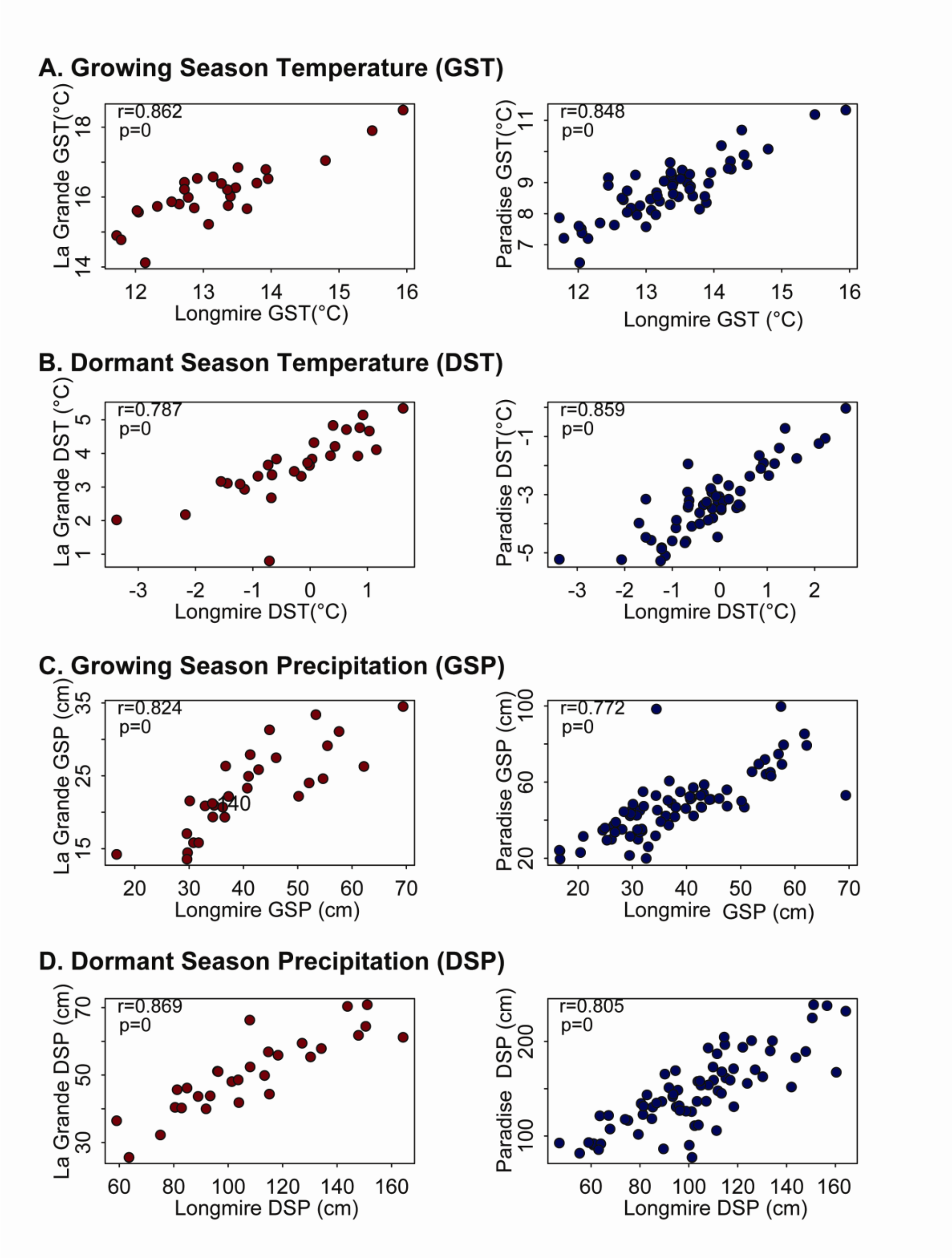

A. Growing Season Temperature (GST)
r=0.862
p=0
La Grande GST(°C)
Longmire GST(°C)
r=0.848
p=0
Paradise GST(°C)
Longmire GST (°C)
B. Dormant Season Temperature (DST)
r=0.787
p=0
La Grande DST (°C)
Longmire DST(°C)
r=0.859
p=0
Paradise DST(°C)
Longmire DST(°C)
C. Growing Season Precipitation (GSP)
r=0.824
p=0
La Grande GSP (cm)
Longmire GSP (cm)
r=0.772
p=0
Paradise GSP (cm)
Longmire GSP (cm)
D. Dormant Season Precipitation (DSP)
r=0.869
p=0
La Grande DSP (cm)
Longmire DSP (cm)
r=0.805
p=0
Paradise DSP (cm)
Longmire DSP (cm)

Figure 2S.

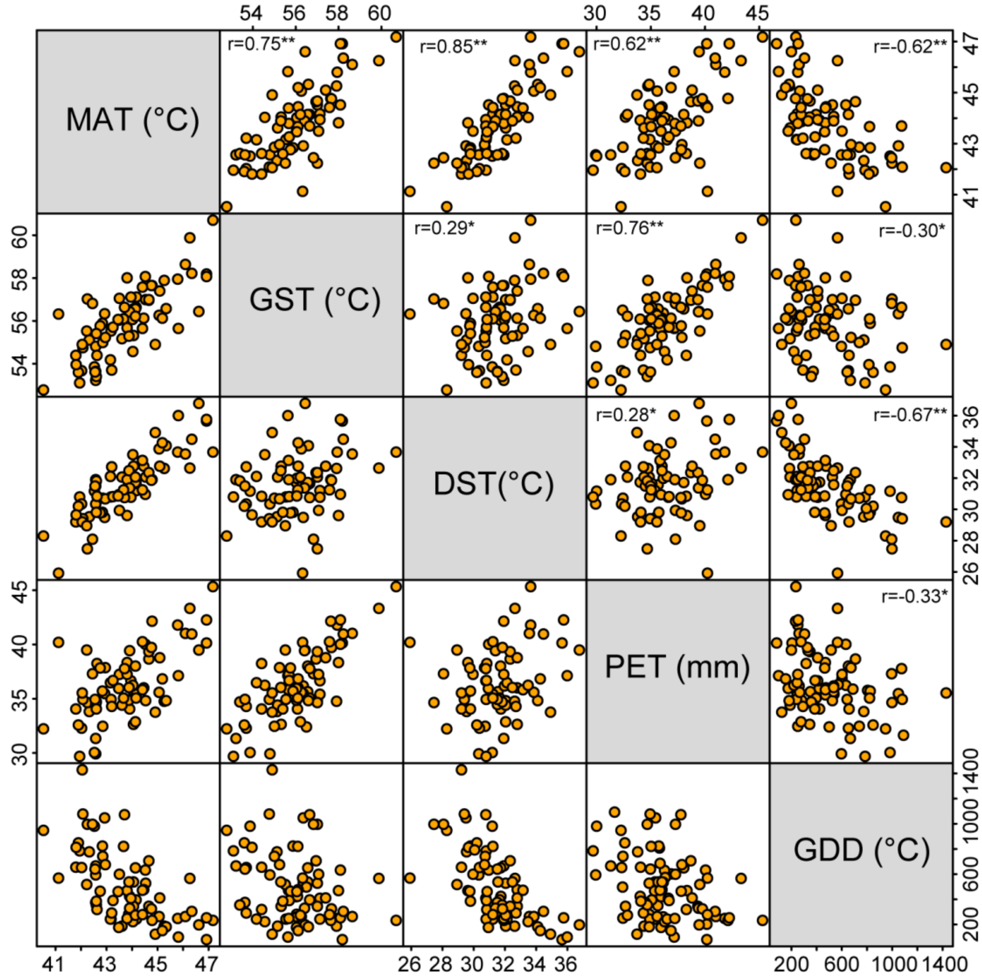
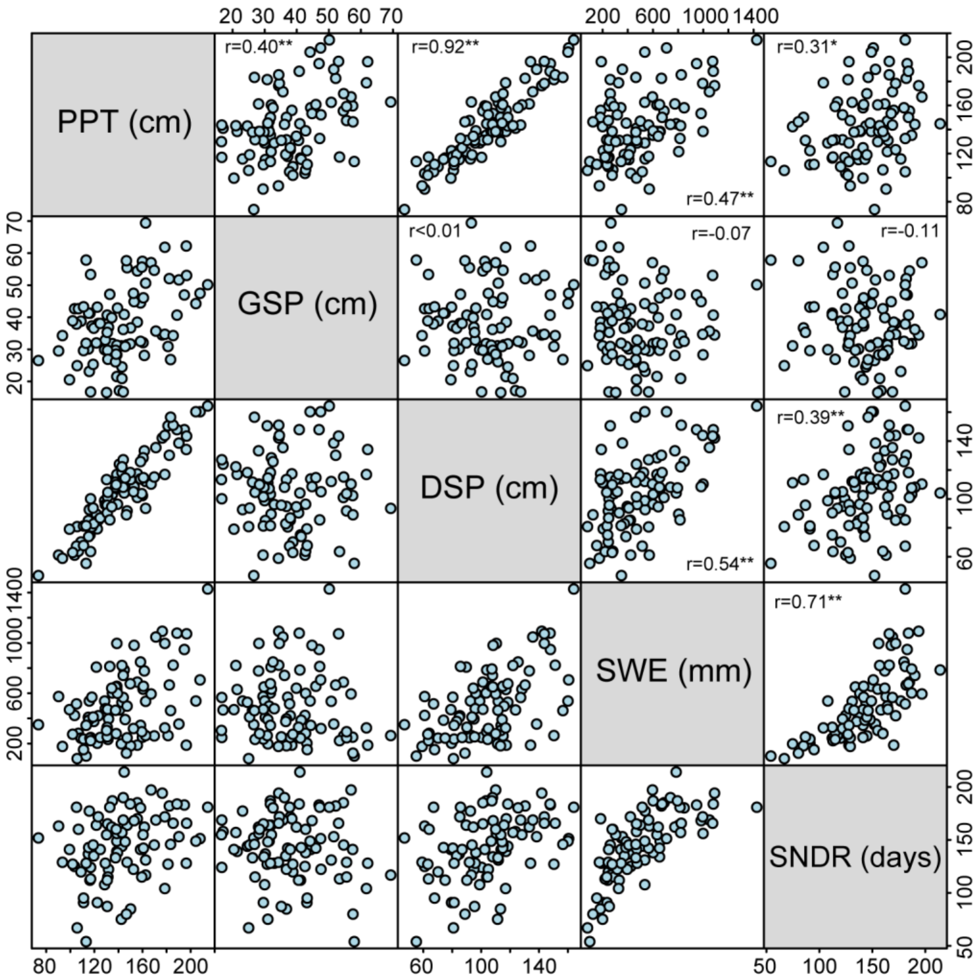

MAT (°C)
GST (°C)
DST(°C)
PET (mm)
GDD (°C)
r=0.75**
r=0.85**
r=0.62**
r=-0.62**
r=0.29*
r=0.76**
r=-0.30*
r=0.28*
r=-0.67**
r=-0.33*

Figure 3S.


PPT (cm)
GSP (cm)
DSP (cm)
SWE (mm)
SNDR (days)
r=0.40**
r=0.92**
r=0.47**
r=0.31*
r<0.01
r=-0.07
r=-0.11
r=0.54**
r=0.39**
r=0.71**
20 30 40 50 60 70
200 600 1000 1400
80 120 160 200
60 100 140
50 100 150 200