

Supplementary materials

Table S1. Information about the three mountain watersheds, USGS gauges and SNOTEL stations used in this study.

Watershed	USGS Gauge Number	SNOTEL Station	Elevation (m)		Average Annual Rainfall (mm/y)	Annual Mean Temperature (°C)	Drainage Area (km ²)
			USGS Gauge	SNOTEL station			
Cleve Creek	10243700	Berry Creek	1889.8	2773.7	765	2.9	82.3
Twin River	10249300	Big Creek	1950.7	2651.8	712	5.9	51.8
Incline Creek	10336700	Mountain Rose Ski Area	1904.1	2697.5	858	7.1	17.5

Table S2. Trends of daily mean, minimum and maximum temperature in three watersheds during the 1990-2016 period.

	Cleve Creek	Twin River	Incline Creek
T_{mean}	0.073**	0.085***	0.009
T_{max}	0.041*	0.095***	-0.013
T_{min}	0.103***	0.074***	0.038*

Note: The asterisk *, ** and *** indicate the statistics are significant at 0.05, 0.01 and 0.001 level, respectively.

Table S3. General shifts of streamflow timing metrics with snow metrics during period 1990-2016.

Indices	SMR (mm/d)	SP (%)	SRT	SSL (d)
Cleve Creek	Slope	Slope	Slope	Slope
Q25	17.11***	2.70**	0.81***	0.67**
Q50	8.42***	1.61***	0.45***	0.36***
PQD	5.96**	1.86	0.28	0.38
PQ	1.56***	0.18*	0.06*	0.04
ASF	38.53***	7.77***	1.63**	1.17*
SBF	11.10***	2.47***	0.53***	0.42**
Twin River				
Q25	22.78***	3.03***	0.65***	0.63***
Q50	11.60***	1.58***	0.41***	0.30**
PQD	6.34	1.05	0.24	0.18
PQ	1.02***	0.14***	0.02*	0.03***
ASF	38.99***	5.14***	0.74*	1.09***
SBF	8.19***	1.10***	0.20**	0.21***

Incline Creek				
Q25	16.78***	3.08**	1.01***	0.72**
Q50	6.94***	1.85***	0.49***	0.43***
PQD	5.36	2.42***	0.46	0.51**
PQ	1.73***	0.34***	0.08***	0.07***
ASF	101.81***	19.83***	4.61***	4.40***
SBF	17.48***	4.08***	0.94***	0.90***

Note: The asterisk *, ** and *** indicate the statistics are significant at 0.05, 0.01 and 0.001 level, respectively.

Table S4. Average, minimum and maximum value of the snow and streamflow metrics during period 1990-2016.

	Cleve Creek	Twin River	Incline Creek
SMR (mm/d)	3.22 [1.54,5.71]	2.78 [1.55,4.4]	3.82 [1.4,6.33]
SP	0.68 [0.6,0.76]	0.64 [0.55,0.76]	0.59 [0.49,0.7]
SRT	79.11 [46.42,105.66]	62.46 [21.36,90.44]	99.09 [49.56,135.29]
SSL (d)	232.77 [207,273]	220.23 [168,262]	202.12 [152,248]
Q25	195.96 [120,233]	194.85 [149,227]	172.27 [65,226]
Q50	233.38 [210,256]	230 [211,251]	223.5 [191,257]
PQD	231.31 [210,256]	232.92 [205,258]	223.96 [171,268]
PQ (mm)	1.43 [0.4,10]	1.07 [0.22,3.32]	3.7 [0.6,10.04]
ASF (mm)	116.4 [61.73,224.75]	68.62 [24.86,140.75]	334.29 [104.77,660.77]
SBF (mm)	27.3 [13.93,59.69]	12.38 [3.54,31.21]	63.57 [15.86,118.74]

Note: The value in the table is displayed as the “average [minimum, maximum]”.

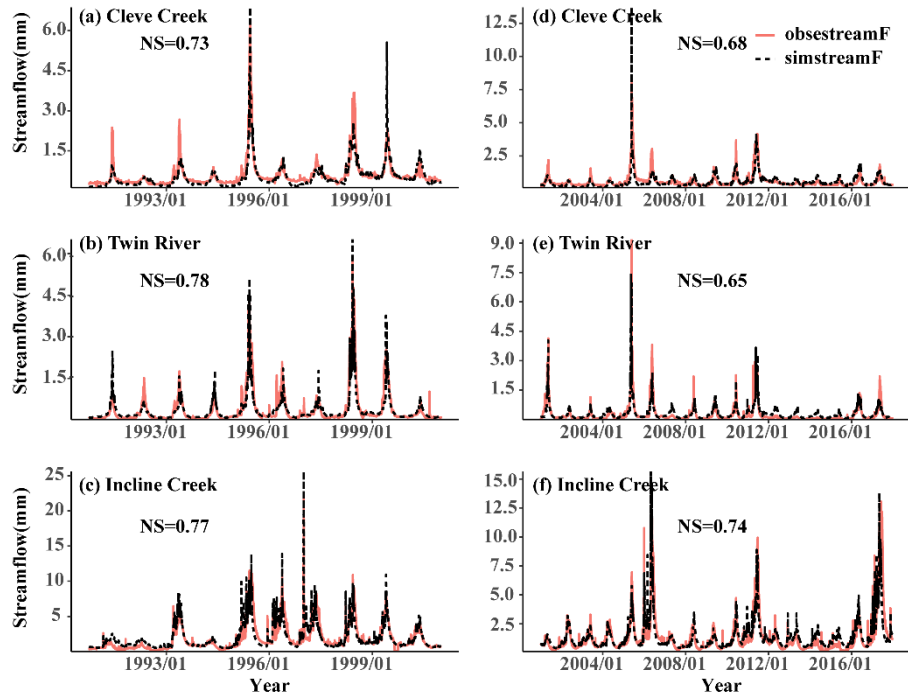


Figure S1. Calibration (for 1990-2000 period) and evaluation (for 2001-2016 period) of observed daily streamflow (red line) and simulated streamflow (black dotted line) in the three watersheds. (a-c) for calibration periods; (d-f) for evaluation periods; and NS is Nash-Sutcliff coefficient. All the NS results are greater than 0.73 in calibration periods, and greater than 0.65 in evaluation periods, expressing that applying CHESS model to simulate streamflow is reliable.

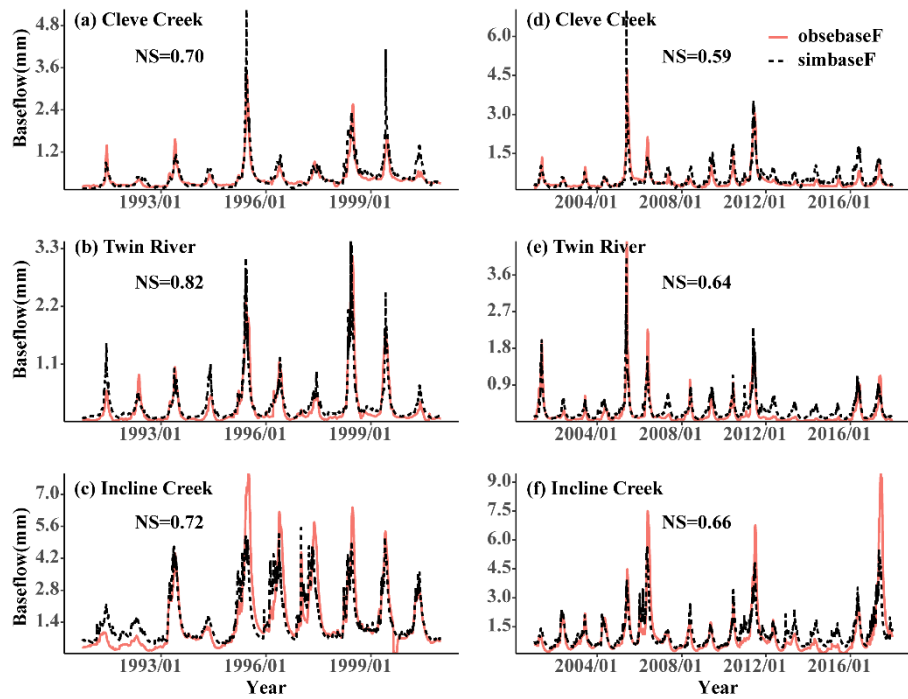


Figure S2. Calibration (for 1990-2000 period) and evaluation (for 2001-2016 period) of observed daily baseflow (red line) and simulated baseflow (black dotted line) in the three watersheds. (a) and (d) for Cleve Creek; (b) and (e) for Twin River; (c) and (f) for Incline Creek; and NS is Nash-Sutcliff coefficient.

Similarly, all the NS results are greater than 0.70 in calibration periods, and greater than 0.59 in evaluation periods, expressing that applying CHES model to simulate base flow is reliable.

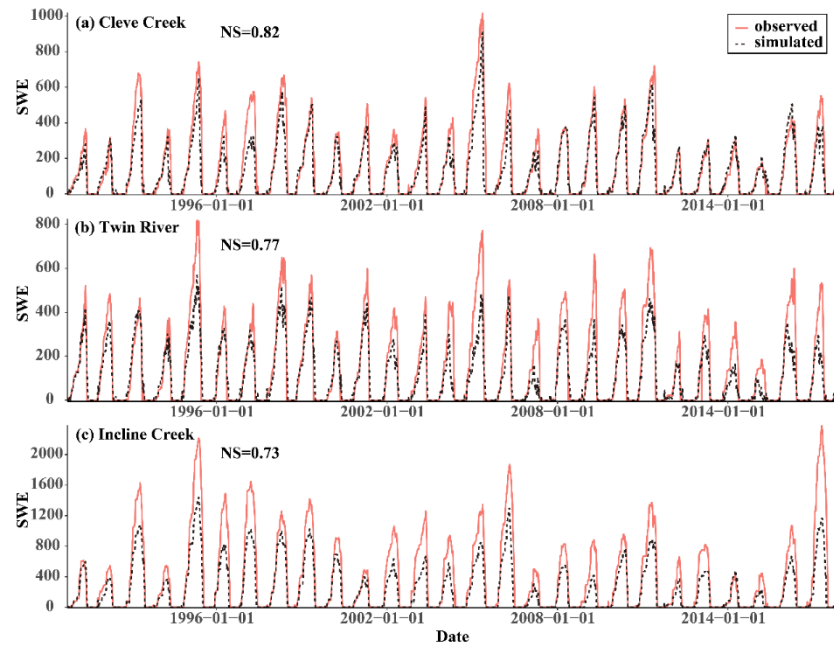


Figure S3. Observed daily SWE (red line) and simulated SWE (black dotted line) in the three watersheds. (a) for Cleve Creek; (b) for Twin River; (c) for Incline Creek; and NS is Nash-Sutcliff coefficient. The NS results are all greater than 0.73 in three watersheds, showing that the simulation results of SWE are investigable.

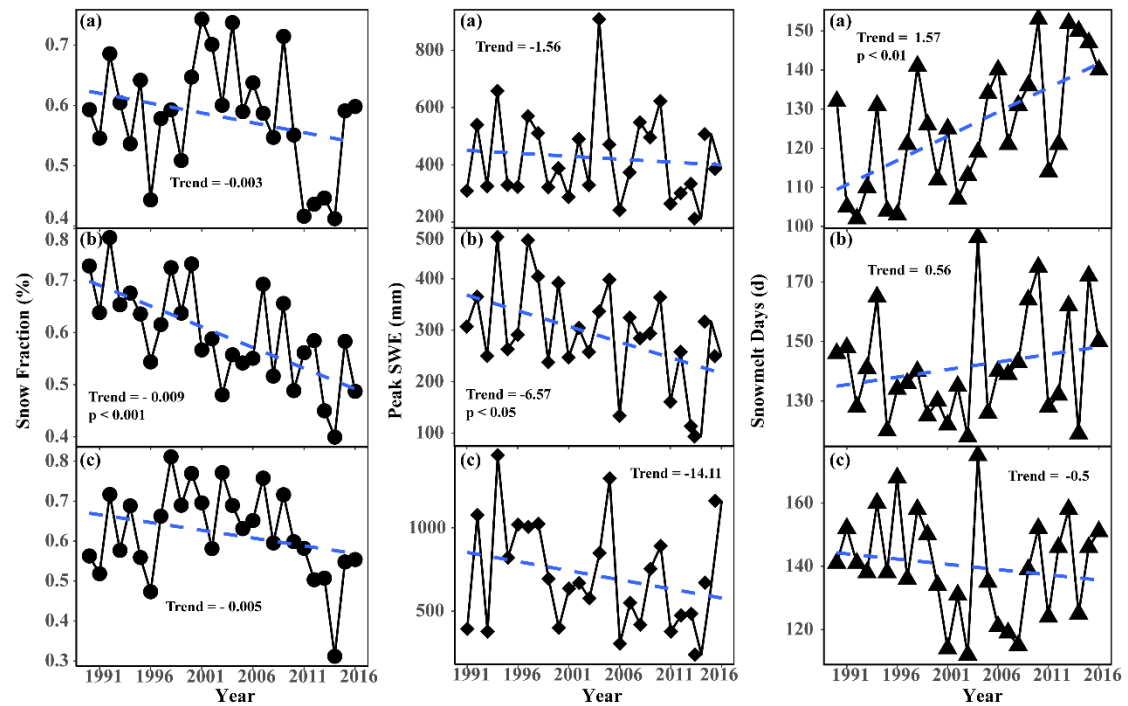


Figure S4. Trends of snow fraction, peak SWE and snowmelt days in the (a) Cleve Creek, (b) Twin River and (c) Incline Creek during 1990-2016.

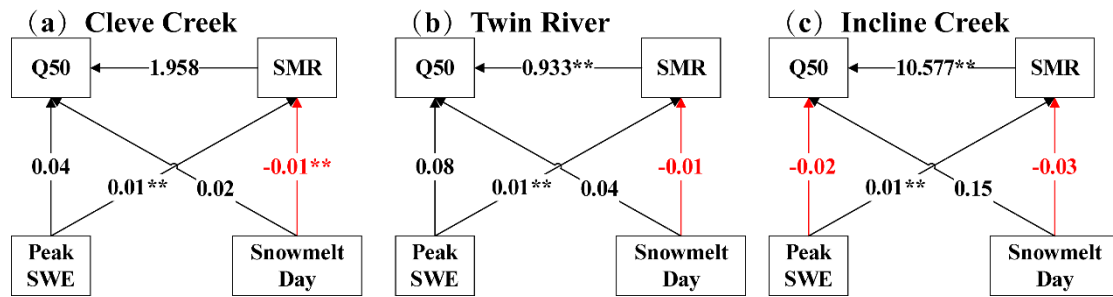


Figure S5. Structural equation model examining the multivariate effects on Q50. Black arrows and red arrows represent positive and negative effects, respectively. The asterisk symbols *, ** indicate that effects are significant at 0.01, 0.05 levels, respectively.

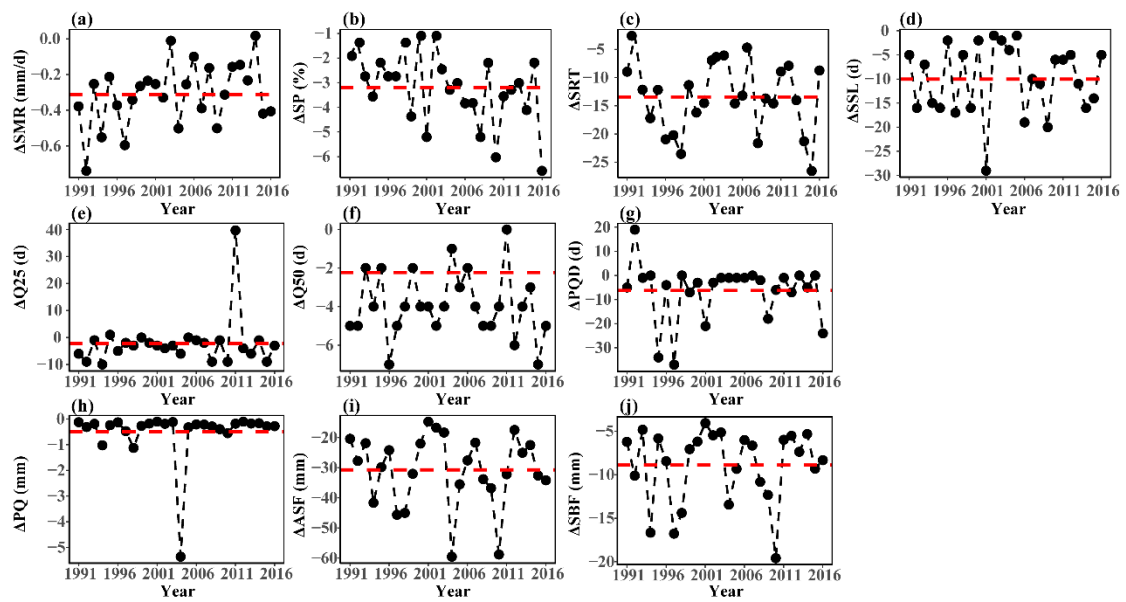


Figure S6. Differences in metrics between simulation under warming scenario with daily minimum and maximum temperature increasing by 1°C increase and that under the reference scenario in the Cleve Creek watershed during 1990 to 2016. Red line represents a multi-year average difference.