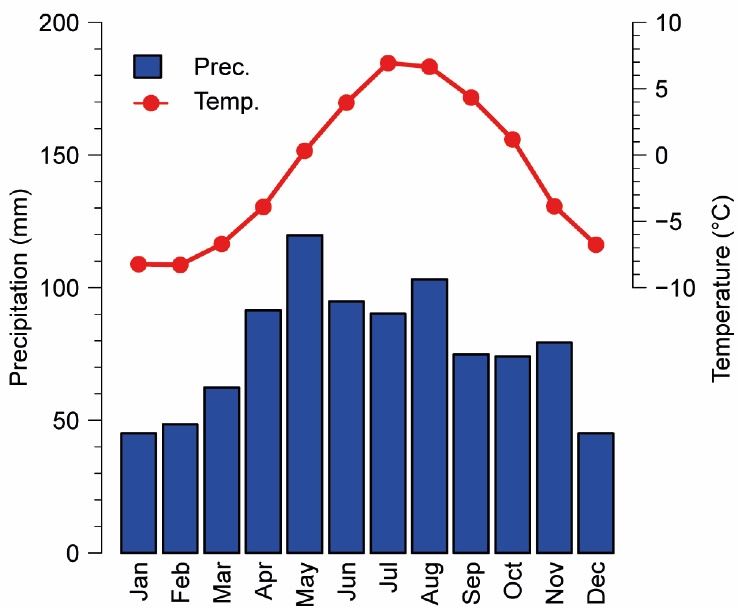
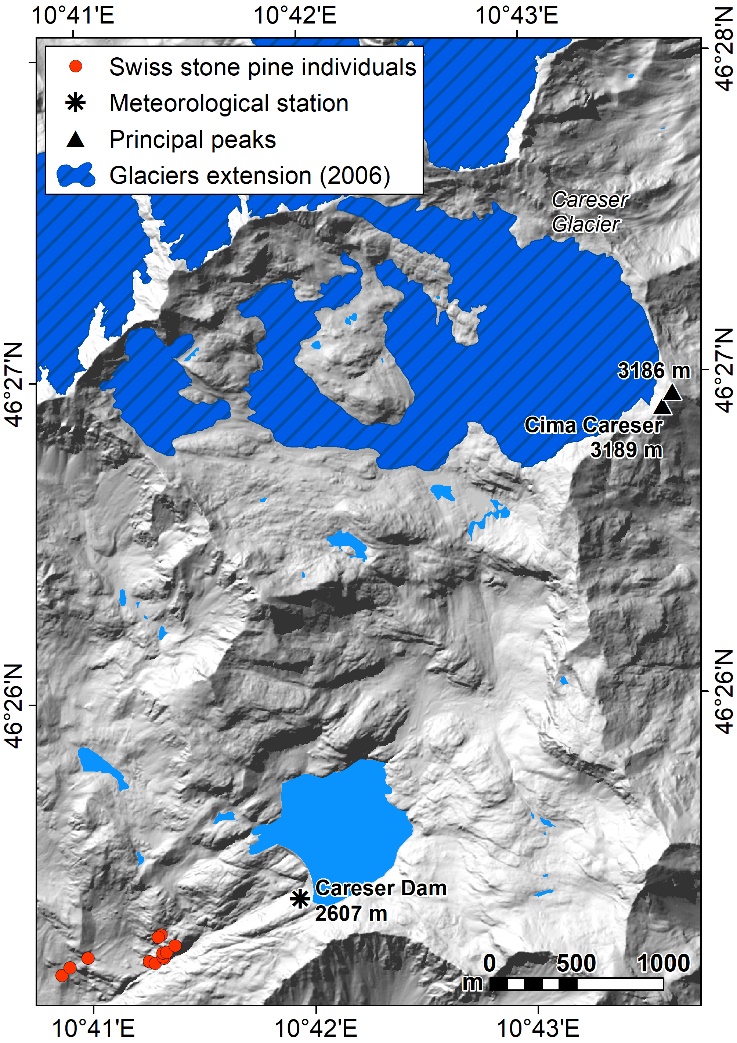
***Pinus cembra* L. tree-ring data as a proxy for summer mass-balance variability of the Careser Glacier (Italian Rhaetian Alps)**

Riccardo Cerrato1, Maria Cristina Salvatore1, 2, Björn E. Gunnarson3, Hans W. Linderholm4, Luca Carturan5, Michele Brunetti6 and Carlo Baroni1, 2

**SUPPLEMENTARY MATERIAL**

****

**Fig. S1**: Mean monthly temperature and precipitation values recorded at the Careser dam meteorological station (2607 m a.s.l.) during the 1961–90 period (data accessed on www.meteotrentino.it).

****

**Fig. S2**: Details of the locations of individual Swiss stone pines.

****

**Fig. S3**: Linear regression Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the MXD and Bs. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of the 1st half and 2nd half, please refer to Table S1.

****

**Fig. S4:** Linear regression Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the MJJAS temperatures and Bs. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of the 1st half and 2nd half, please refer to Table S2.

****

**Fig. S5:** Linear regression Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the previous October to the current May for the precipitation and Bw. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of the 1st half and 2nd half, please refer to Table S3.

****

**Fig. S6**: Scaling Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the MXD and Bs. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of th e1st half and 2nd half, please refer to Table S4.



**Fig. S7:** Scaling Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the MJJAS temperatures and Bs. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of the 1st half and 2nd half, please refer to Table S5.

****

**Fig. S8:** Scaling Pearson’s (r) and Spearman (ρ) correlation indexes of the referenced calibration windows and validation halves between the previous October to the current May for the precipitation and Bw. The ΔRMSE reports the difference between the δRMSE of the 1st and 2nd halves. For the definitions of the 1st half and 2nd half, please refer to Table S6.

**Table S1**: Linear regression correlation indexes and associated errors of the evolutionary correlation analysis between the MXD and Bs. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

**Table S2:** Linear regression correlation indexes and associated errors of the evolutionary correlation analysis between the MJJAS temperatures and Bs. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

**Table S3:** Linear regression correlation indexes and associated errors of the evolutionary correlation analysis between the previous October and the current May for the sums of precipitation and Bw. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

**Table S4**: Scaling correlation indexes and associated errors of the evolutionary correlation analysis between the MXD and Bs. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

**Table S5:** Scaling correlation indexes and associated errors of the evolutionary correlation analysis between the MJJAS temperatures and Bs. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

**Table S6:** Scaling correlation indexes and associated errors of the evolutionary correlation analysis between the previous October and the current May for the sums of precipitation and Bw. R2: explained variance; p-value: significance of the R2 index; ρ: Spearman’s rank correlation index; RMSE: root mean squared error; δRMSE: difference between the calibration RMSE and validation RMSE; ΔRMSE: difference between δRMSE values; MAE: mean absolute error.

Table S1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  |  |  |  |  |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **slope** | **intercept** | **slope.tot** | **intercept.tot** |
| 10 | 1967 - 1976 | 0.27 | 0.146 | 0.56 | 370.98 | 1977 - 1986 | 0.55 | 0.019 | 0.66 | 427.90 | 56.92 | *NA* | *NA* | *NA* | *NA* | -5686.747 | 4330.442 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.55 | 0.019 | 0.66 | 306.32 | 1967 - 1976 | 0.27 | 0.146 | 0.56 | 448.39 | 142.07 | 0.45 | 364.89 | 291.26 | -85.15 | -7696.287 | 6047.140 | -7594.461 | 6066.361 |
| 11 | 1967 - 1977 | 0.30 | 0.097 | 0.63 | 354.21 | 1978 - 1988 | 0.42 | 0.039 | 0.54 | 456.60 | 102.39 | *NA* | *NA* | *NA* | *NA* | -5465.325 | 4109.641 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.42 | 0.039 | 0.54 | 302.20 | 1967 - 1977 | 0.30 | 0.097 | 0.63 | 436.12 | 133.92 | 0.50 | 355.27 | 284.15 | -31.53 | -7583.018 | 5919.735 | -8000.660 | 6452.347 |
| 12 | 1967 - 1978 | 0.30 | 0.078 | 0.60 | 339.36 | 1979 - 1990 | 0.21 | 0.153 | 0.43 | 456.47 | 117.11 | *NA* | *NA* | *NA* | *NA* | -5468.007 | 4115.974 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.21 | 0.153 | 0.43 | 312.63 | 1967 - 1978 | 0.30 | 0.078 | 0.60 | 529.25 | 216.62 | 0.50 | 357.28 | 282.22 | -99.51 | -4255.635 | 2540.232 | -7154.997 | 5634.175 |
| 13 | 1967 - 1979 | 0.30 | 0.063 | 0.59 | 326.05 | 1980 - 1992 | 0.21 | 0.131 | 0.33 | 524.28 | 198.23 | *NA* | *NA* | *NA* | *NA* | -5461.052 | 4109.765 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.21 | 0.131 | 0.33 | 335.40 | 1967 - 1979 | 0.30 | 0.063 | 0.59 | 573.27 | 237.87 | 0.55 | 368.78 | 291.24 | -39.64 | -4483.245 | 2692.455 | -7737.756 | 6195.092 |
| 14 | 1967 - 1980 | 0.31 | 0.046 | 0.59 | 315.25 | 1981 - 1994 | 0.11 | 0.266 | 0.21 | 602.90 | 287.65 | *NA* | *NA* | *NA* | *NA* | -5223.533 | 3886.377 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.11 | 0.266 | 0.21 | 413.85 | 1967 - 1980 | 0.31 | 0.046 | 0.59 | 642.17 | 228.32 | 0.50 | 411.96 | 322.95 | 59.33 | -3584.994 | 1736.988 | -7429.466 | 5897.821 |
| 15 | 1967 - 1981 | 0.30 | 0.041 | 0.55 | 312.00 | 1982 - 1996 | 0.10 | 0.269 | 0.20 | 589.59 | 277.59 | *NA* | *NA* | *NA* | *NA* | -5271.414 | 3914.858 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.10 | 0.269 | 0.20 | 392.68 | 1967 - 1981 | 0.30 | 0.041 | 0.55 | 673.23 | 280.55 | 0.48 | 406.84 | 320.85 | -2.96 | -3030.984 | 1144.751 | -7191.779 | 5637.661 |
| 16 | 1967 - 1982 | 0.33 | 0.024 | 0.61 | 373.50 | 1983 - 1998 | 0.06 | 0.378 | 0.11 | 539.22 | 165.72 | *NA* | *NA* | *NA* | *NA* | -6723.846 | 5273.148 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.06 | 0.378 | 0.11 | 431.97 | 1967 - 1982 | 0.33 | 0.024 | 0.61 | 695.00 | 263.03 | 0.44 | 441.73 | 342.27 | -97.31 | -2689.219 | 772.650 | -7259.770 | 5676.551 |
| 17 | 1967 - 1983 | 0.42 | 0.006 | 0.67 | 373.04 | 1984 - 2000 | 0.09 | 0.258 | 0.23 | 493.66 | 120.62 | *NA* | *NA* | *NA* | *NA* | -7692.345 | 6197.722 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.09 | 0.258 | 0.23 | 424.64 | 1967 - 1983 | 0.42 | 0.006 | 0.67 | 616.15 | 191.51 | 0.44 | 428.82 | 326.00 | -70.89 | -3197.321 | 1339.952 | -7216.196 | 5632.842 |
| 18 | 1967 - 1984 | 0.38 | 0.008 | 0.61 | 376.90 | 1985 - 2002 | 0.03 | 0.506 | 0.05 | 489.71 | 112.81 | *NA* | *NA* | *NA* | *NA* | -7292.310 | 5781.087 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.03 | 0.506 | 0.05 | 419.96 | 1967 - 1984 | 0.38 | 0.008 | 0.61 | 681.20 | 261.24 | 0.44 | 427.19 | 329.37 | -148.43 | -2309.284 | 376.691 | -7369.974 | 5767.974 |
| 19 | 1967 - 1985 | 0.41 | 0.004 | 0.64 | 367.22 | 1986 - 2004 | 0.13 | 0.140 | 0.24 | 701.64 | 334.42 | *NA* | *NA* | *NA* | *NA* | -7133.929 | 5629.767 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.13 | 0.140 | 0.24 | 616.51 | 1967 - 1985 | 0.41 | 0.004 | 0.64 | 515.70 | -100.81 | 0.46 | 523.80 | 379.82 | 435.23 | -6745.783 | 4886.902 | -9145.015 | 7507.384 |
| 20 | 1967 - 1986 | 0.45 | 0.002 | 0.68 | 364.89 | 1987 - 2006 | 0.09 | 0.211 | 0.14 | 742.70 | 377.81 | *NA* | *NA* | *NA* | *NA* | -7594.461 | 6066.361 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.09 | 0.211 | 0.14 | 644.44 | 1967 - 1986 | 0.45 | 0.002 | 0.68 | 616.56 | -27.88 | 0.44 | 548.52 | 404.73 | 405.69 | -5681.270 | 3692.332 | -9383.913 | 7706.629 |
| 21 | 1967 - 1987 | 0.49 | 0.001 | 0.71 | 363.52 | 1988 - 2008 | 0.11 | 0.152 | 0.21 | 736.43 | 372.91 | *NA* | *NA* | *NA* | *NA* | -8056.556 | 6505.665 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.11 | 0.152 | 0.21 | 646.21 | 1967 - 1987 | 0.49 | 0.001 | 0.71 | 593.57 | -52.64 | 0.47 | 546.63 | 404.60 | 425.55 | -6344.119 | 4351.677 | -9783.435 | 8095.044 |
| 22 | 1967 - 1988 | 0.50 | 0.000 | 0.71 | 355.27 | 1989 - 2010 | 0.12 | 0.123 | 0.23 | 731.44 | 376.17 | *NA* | *NA* | *NA* | *NA* | -8000.660 | 6452.347 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.12 | 0.123 | 0.23 | 626.50 | 1967 - 1988 | 0.50 | 0.000 | 0.71 | 597.15 | -29.35 | 0.48 | 535.17 | 392.85 | 405.52 | -6426.108 | 4418.738 | -9872.565 | 8179.280 |
| 23 | 1967 - 1989 | 0.45 | 0.001 | 0.70 | 364.58 | 1990 - 2012 | 0.16 | 0.064 | 0.29 | 823.33 | 458.75 | *NA* | *NA* | *NA* | *NA* | -7027.621 | 5510.767 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.16 | 0.064 | 0.29 | 606.67 | 1967 - 1989 | 0.45 | 0.001 | 0.70 | 644.00 | 37.33 | 0.48 | 547.72 | 409.82 | 421.42 | -7463.137 | 5413.144 | -10301.962 | 8584.348 |

Table S2

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  |  |  |  |  |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **slope** | **intercept** | **slope.tot** | **intercept.tot** |
| 10 | 1967 - 1976 | 0.59 | 0.013 | 0.73 | 277.52 | 1977 - 1986 | 0.74 | 0.002 | 0.79 | 463.84 | 186.32 | *NA* | *NA* | *NA* | *NA* | -584.017 | 2713.684 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.74 | 0.002 | 0.79 | 232.44 | 1967 - 1976 | 0.59 | 0.013 | 0.73 | 488.12 | 255.68 | 0.56 | 325.26 | 248.32 | -69.36 | -491.786 | 1696.916 | -530.787 | 2158.318 |
| 11 | 1967 - 1977 | 0.59 | 0.008 | 0.76 | 269.09 | 1978 - 1988 | 0.65 | 0.004 | 0.80 | 491.46 | 222.37 | *NA* | *NA* | *NA* | *NA* | -548.029 | 2458.108 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.65 | 0.004 | 0.80 | 234.93 | 1967 - 1977 | 0.59 | 0.008 | 0.76 | 534.03 | 299.10 | 0.56 | 334.85 | 249.34 | -76.73 | -435.165 | 1253.131 | -548.061 | 2246.551 |
| 12 | 1967 - 1978 | 0.53 | 0.010 | 0.65 | 276.79 | 1979 - 1990 | 0.58 | 0.005 | 0.78 | 490.09 | 213.30 | *NA* | *NA* | *NA* | *NA* | -482.708 | 1996.481 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.58 | 0.005 | 0.78 | 227.78 | 1967 - 1978 | 0.53 | 0.010 | 0.65 | 540.57 | 312.79 | 0.57 | 329.37 | 247.26 | -99.49 | -418.331 | 1111.188 | -567.932 | 2360.302 |
| 13 | 1967 - 1979 | 0.53 | 0.006 | 0.66 | 267.14 | 1980 - 1992 | 0.39 | 0.028 | 0.56 | 581.79 | 314.65 | *NA* | *NA* | *NA* | *NA* | -483.396 | 1993.645 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.39 | 0.028 | 0.56 | 296.59 | 1967 - 1979 | 0.53 | 0.006 | 0.66 | 634.73 | 338.14 | 0.54 | 373.69 | 275.7 | -23.49 | -355.100 | 580.215 | -579.426 | 2406.744 |
| 14 | 1967 - 1980 | 0.50 | 0.006 | 0.63 | 267.88 | 1981 - 1994 | 0.38 | 0.023 | 0.59 | 582.07 | 314.19 | *NA* | *NA* | *NA* | *NA* | -471.091 | 1892.365 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.38 | 0.023 | 0.59 | 346.89 | 1967 - 1980 | 0.50 | 0.006 | 0.63 | 584.08 | 237.19 | 0.58 | 375.74 | 281.98 | 77.00 | -402.117 | 922.844 | -608.549 | 2612.776 |
| 15 | 1967 - 1981 | 0.50 | 0.004 | 0.63 | 262.92 | 1982 - 1996 | 0.36 | 0.022 | 0.59 | 580.84 | 317.92 | *NA* | *NA* | *NA* | *NA* | -479.750 | 1936.769 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.36 | 0.022 | 0.59 | 329.84 | 1967 - 1981 | 0.50 | 0.004 | 0.63 | 610.68 | 280.84 | 0.56 | 374.95 | 285.39 | 37.08 | -371.914 | 680.554 | -596.655 | 2509.136 |
| 16 | 1967 - 1982 | 0.64 | 0.000 | 0.69 | 274.65 | 1983 - 1998 | 0.33 | 0.024 | 0.56 | 544.80 | 270.15 | *NA* | *NA* | *NA* | *NA* | -580.303 | 2574.505 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.33 | 0.024 | 0.56 | 365.64 | 1967 - 1982 | 0.64 | 0.000 | 0.69 | 589.08 | 223.44 | 0.57 | 385.4 | 296.28 | 46.71 | -388.260 | 789.900 | -619.391 | 2655.269 |
| 17 | 1967 - 1983 | 0.69 | 0.000 | 0.74 | 274.65 | 1984 - 2000 | 0.17 | 0.111 | 0.32 | 533.80 | 259.15 | *NA* | *NA* | *NA* | *NA* | -620.758 | 2828.147 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.17 | 0.111 | 0.32 | 404.84 | 1967 - 1983 | 0.69 | 0.000 | 0.74 | 599.03 | 194.19 | 0.51 | 401.52 | 313.43 | 64.96 | -271.948 | 5.710 | -548.434 | 2192.295 |
| 18 | 1967 - 1984 | 0.51 | 0.001 | 0.62 | 335.11 | 1985 - 2002 | 0.14 | 0.138 | 0.30 | 488.58 | 153.47 | *NA* | *NA* | *NA* | *NA* | -498.657 | 1963.102 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.14 | 0.138 | 0.30 | 396.23 | 1967 - 1984 | 0.51 | 0.001 | 0.62 | 553.64 | 157.41 | 0.52 | 393.72 | 308.34 | -3.94 | -318.142 | 340.083 | -561.472 | 2271.691 |
| 19 | 1967 - 1985 | 0.53 | 0.001 | 0.68 | 326.84 | 1986 - 2004 | 0.53 | 0.001 | 0.37 | 580.06 | 253.22 | *NA* | *NA* | *NA* | *NA* | -505.826 | 2005.985 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.53 | 0.001 | 0.37 | 451.88 | 1967 - 1985 | 0.53 | 0.001 | 0.68 | 408.34 | -43.54 | 0.66 | 414.36 | 319.76 | 296.76 | -634.168 | 2635.868 | -665.676 | 2975.637 |
| 20 | 1967 - 1986 | 0.56 | 0.000 | 0.72 | 325.26 | 1987 - 2006 | 0.55 | 0.000 | 0.50 | 581.85 | 256.59 | *NA* | *NA* | *NA* | *NA* | -530.787 | 2158.318 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.55 | 0.000 | 0.50 | 453.26 | 1967 - 1986 | 0.56 | 0.000 | 0.72 | 409.08 | -44.18 | 0.68 | 414.61 | 318.69 | 300.77 | -653.875 | 2753.428 | -688.710 | 3121.127 |
| 21 | 1967 - 1987 | 0.54 | 0.000 | 0.73 | 342.70 | 1988 - 2008 | 0.52 | 0.000 | 0.48 | 596.41 | 253.71 | *NA* | *NA* | *NA* | *NA* | -549.440 | 2255.044 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.52 | 0.000 | 0.48 | 476.80 | 1967 - 1987 | 0.54 | 0.000 | 0.73 | 418.99 | -57.81 | 0.67 | 433.14 | 330.16 | 311.52 | -671.361 | 2850.723 | -708.510 | 3232.712 |
| 22 | 1967 - 1988 | 0.56 | 0.000 | 0.75 | 334.85 | 1989 - 2010 | 0.51 | 0.000 | 0.48 | 585.25 | 250.40 | *NA* | *NA* | *NA* | *NA* | -548.061 | 2246.551 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.51 | 0.000 | 0.48 | 468.59 | 1967 - 1988 | 0.56 | 0.000 | 0.75 | 425.41 | -43.18 | 0.67 | 426.2 | 325.2 | 293.58 | -637.673 | 2598.866 | -693.366 | 3131.607 |
| 23 | 1967 - 1989 | 0.55 | 0.000 | 0.75 | 329.06 | 1990 - 2012 | 0.51 | 0.000 | 0.53 | 593.72 | 264.66 | *NA* | *NA* | *NA* | *NA* | -547.214 | 2233.961 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.51 | 0.000 | 0.53 | 462.56 | 1967 - 1989 | 0.55 | 0.000 | 0.75 | 420.64 | -41.92 | 0.69 | 420.16 | 317.89 | 306.58 | -647.455 | 2659.917 | -707.436 | 3226.381 |

Table S3

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  |  |  |  |  |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **slope** | **intercept** | **slope.tot** | **intercept.tot** |
| 10 | 1967 - 1976 | 0.56 | 0.017 | 0.49 | 122.02 | 1977 - 1986 | 0.58 | 0.014 | 0.37 | 228.75 | 106.73 | *NA* | *NA* | *NA* | *NA* | 1.503 | 205.546 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.58 | 0.014 | 0.37 | 226.62 | 1967 - 1976 | 0.56 | 0.017 | 0.49 | 127.08 | -99.54 | 0.62 | 182.62 | 134.56 | 206.27 | 1.533 | 155.528 | 1.474 | 206.621 |
| 11 | 1967 - 1977 | 0.87 | 0.000 | 0.62 | 118.88 | 1978 - 1988 | 0.36 | 0.063 | 0.42 | 252.00 | 133.12 | *NA* | *NA* | *NA* | *NA* | 1.744 | 93.177 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.36 | 0.063 | 0.42 | 218.92 | 1967 - 1977 | 0.87 | 0.000 | 0.62 | 169.32 | -49.60 | 0.62 | 186.44 | 140.87 | 182.72 | 1.318 | 224.383 | 1.553 | 142.320 |
| 12 | 1967 - 1978 | 0.86 | 0.000 | 0.68 | 117.07 | 1979 - 1990 | 0.45 | 0.022 | 0.57 | 257.82 | 140.75 | *NA* | *NA* | *NA* | *NA* | 1.758 | 94.320 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.45 | 0.022 | 0.57 | 202.93 | 1967 - 1978 | 0.86 | 0.000 | 0.68 | 196.18 | -6.75 | 0.63 | 183.56 | 142.16 | 147.50 | 1.398 | 141.118 | 1.592 | 108.331 |
| 13 | 1967 - 1979 | 0.86 | 0.000 | 0.70 | 114.43 | 1980 - 1992 | 0.43 | 0.019 | 0.59 | 243.97 | 129.54 | *NA* | *NA* | *NA* | *NA* | 1.740 | 97.944 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.43 | 0.019 | 0.59 | 195.70 | 1967 - 1979 | 0.86 | 0.000 | 0.70 | 189.29 | -6.41 | 0.63 | 176.48 | 132.54 | 135.95 | 1.341 | 177.428 | 1.587 | 112.026 |
| 14 | 1967 - 1980 | 0.81 | 0.000 | 0.68 | 134.59 | 1981 - 1994 | 0.56 | 0.003 | 0.62 | 243.04 | 108.45 | *NA* | *NA* | *NA* | *NA* | 1.760 | 108.479 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.56 | 0.003 | 0.62 | 144.10 | 1967 - 1980 | 0.81 | 0.000 | 0.68 | 239.56 | 95.46 | 0.63 | 170.60 | 126.07 | 12.99 | 1.313 | 165.503 | 1.575 | 115.118 |
| 15 | 1967 - 1981 | 0.59 | 0.001 | 0.50 | 201.72 | 1982 - 1996 | 0.83 | 0.000 | 0.85 | 150.50 | -51.22 | *NA* | *NA* | *NA* | *NA* | 1.559 | 177.085 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.83 | 0.000 | 0.85 | 93.38 | 1967 - 1981 | 0.59 | 0.001 | 0.50 | 233.59 | 140.21 | 0.66 | 167.71 | 124.08 | -191.43 | 1.566 | 55.472 | 1.612 | 89.514 |
| 16 | 1967 - 1982 | 0.62 | 0.000 | 0.55 | 195.34 | 1983 - 1998 | 0.83 | 0.000 | 0.88 | 156.46 | -38.88 | *NA* | *NA* | *NA* | *NA* | 1.566 | 172.204 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.83 | 0.000 | 0.88 | 93.80 | 1967 - 1982 | 0.62 | 0.000 | 0.55 | 231.26 | 137.46 | 0.66 | 165.38 | 123.48 | -176.34 | 1.674 | -8.349 | 1.634 | 74.275 |
| 17 | 1967 - 1983 | 0.65 | 0.000 | 0.62 | 190.11 | 1984 - 2000 | 0.26 | 0.042 | 0.73 | 345.80 | 155.69 | *NA* | *NA* | *NA* | *NA* | 1.527 | 189.997 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.26 | 0.042 | 0.73 | 268.02 | 1967 - 1983 | 0.65 | 0.000 | 0.62 | 282.20 | 14.18 | 0.47 | 255.31 | 171.40 | 141.51 | 1.739 | -132.953 | 1.735 | -28.222 |
| 18 | 1967 - 1984 | 0.65 | 0.000 | 0.62 | 184.90 | 1985 - 2002 | 0.49 | 0.002 | 0.73 | 345.56 | 160.66 | *NA* | *NA* | *NA* | *NA* | 1.523 | 193.579 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.49 | 0.002 | 0.73 | 283.35 | 1967 - 1984 | 0.65 | 0.000 | 0.62 | 264.41 | -18.94 | 0.53 | 258.02 | 174.25 | 179.60 | 2.030 | -255.535 | 1.79 | -42.152 |
| 19 | 1967 - 1985 | 0.65 | 0.000 | 0.60 | 180.53 | 1986 - 2004 | 0.49 | 0.001 | 0.73 | 336.27 | 155.74 | *NA* | *NA* | *NA* | *NA* | 1.517 | 193.594 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.49 | 0.001 | 0.73 | 278.61 | 1967 - 1985 | 0.65 | 0.000 | 0.60 | 254.93 | -23.68 | 0.53 | 252.13 | 169.97 | 179.42 | 2.024 | -247.522 | 1.783 | -37.488 |
| 20 | 1967 - 1986 | 0.62 | 0.000 | 0.51 | 182.62 | 1987 - 2006 | 0.48 | 0.001 | 0.70 | 321.28 | 138.66 | *NA* | *NA* | *NA* | *NA* | 1.474 | 206.621 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.48 | 0.001 | 0.70 | 273.42 | 1967 - 1986 | 0.62 | 0.000 | 0.51 | 238.92 | -34.50 | 0.53 | 246.02 | 162.99 | 173.16 | 2.031 | -231.248 | 1.775 | -31.05 |
| 21 | 1967 - 1987 | 0.63 | 0.000 | 0.56 | 187.93 | 1988 - 2008 | 0.50 | 0.000 | 0.69 | 311.19 | 123.26 | *NA* | *NA* | *NA* | *NA* | 1.546 | 153.334 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.50 | 0.000 | 0.69 | 268.42 | 1967 - 1987 | 0.63 | 0.000 | 0.56 | 237.55 | -30.87 | 0.54 | 243.69 | 165.68 | 154.13 | 2.071 | -256.396 | 1.824 | -65.67 |
| 22 | 1967 - 1988 | 0.62 | 0.000 | 0.56 | 186.44 | 1989 - 2010 | 0.54 | 0.000 | 0.75 | 299.32 | 112.88 | *NA* | *NA* | *NA* | *NA* | 1.553 | 142.320 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.54 | 0.000 | 0.75 | 265.12 | 1967 - 1988 | 0.62 | 0.000 | 0.56 | 227.94 | -37.18 | 0.56 | 238.90 | 160.76 | 150.06 | 2.075 | -249.350 | 1.823 | -62.284 |
| 23 | 1967 - 1989 | 0.61 | 0.000 | 0.56 | 186.36 | 1990 - 2012 | 0.48 | 0.000 | 0.73 | 291.00 | 104.64 | *NA* | *NA* | *NA* | *NA* | 1.560 | 130.091 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.48 | 0.000 | 0.73 | 275.21 | 1967 - 1989 | 0.61 | 0.000 | 0.56 | 204.85 | -70.36 | 0.54 | 239.22 | 160.38 | 175.00 | 1.832 | -94.123 | 1.728 | -2.131 |

Table S4

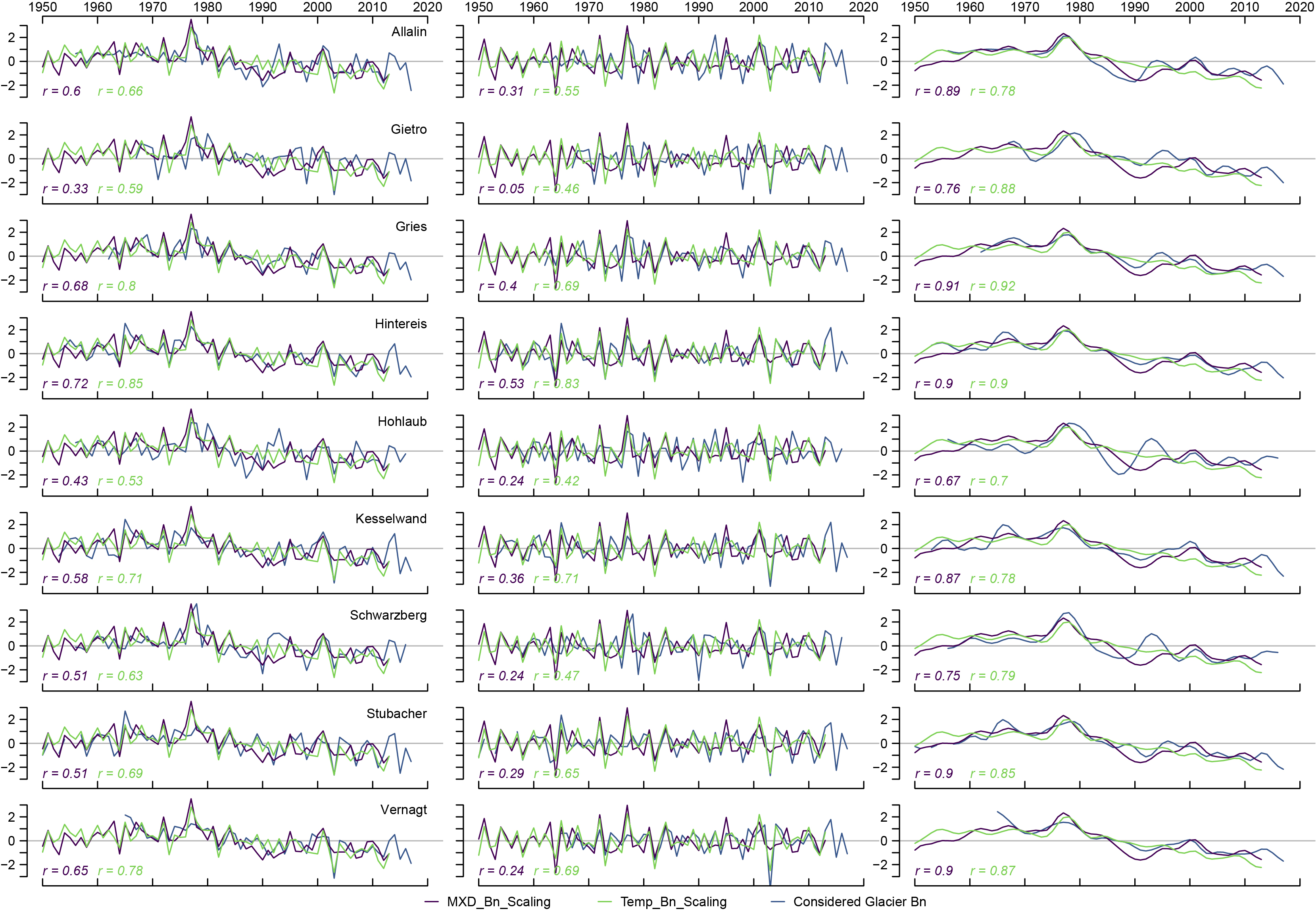
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  | **Glacier** | | **Glacier** | |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **scale** | **centre** | **scale.tot** | **centre.tot** |
| 10 | 1967 - 1976 | 0.27 | 0.146 | 0.56 | 425.76 | 1977 - 1986 | 0.55 | 0.019 | 0.66 | 525.96 | 100.20 | *NA* | *NA* | *NA* | *NA* | 457.302 | -1203.900 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.55 | 0.019 | 0.66 | 328.28 | 1967 - 1976 | 0.27 | 0.146 | 0.56 | 604.10 | 275.82 | 0.45 | 399.30 | 342.27 | -175.62 | 481.165 | -1620.671 | 504.417 | -1412.285 |
| 11 | 1967 - 1977 | 0.30 | 0.097 | 0.63 | 403.02 | 1978 - 1988 | 0.42 | 0.039 | 0.54 | 676.63 | 273.61 | *NA* | *NA* | *NA* | *NA* | 443.036 | -1176.818 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.42 | 0.039 | 0.54 | 332.60 | 1967 - 1977 | 0.30 | 0.097 | 0.63 | 702.52 | 369.92 | 0.50 | 384.39 | 327.92 | -96.31 | 417.562 | -1759.794 | 515.273 | -1468.306 |
| 12 | 1967 - 1978 | 0.30 | 0.078 | 0.60 | 386.13 | 1979 - 1990 | 0.21 | 0.153 | 0.43 | 771.62 | 385.49 | *NA* | *NA* | *NA* | *NA* | 422.683 | -1172.500 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.21 | 0.153 | 0.43 | 366.15 | 1967 - 1978 | 0.30 | 0.078 | 0.60 | 755.45 | 389.30 | 0.50 | 387.03 | 325.96 | -3.81 | 367.347 | -1834.561 | 514.131 | -1503.531 |
| 13 | 1967 - 1979 | 0.30 | 0.063 | 0.59 | 370.53 | 1980 - 1992 | 0.21 | 0.131 | 0.33 | 880.65 | 510.12 | *NA* | *NA* | *NA* | *NA* | 405.889 | -1181.154 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.21 | 0.131 | 0.33 | 392.09 | 1967 - 1979 | 0.30 | 0.063 | 0.59 | 866.28 | 474.19 | 0.55 | 395.22 | 339.21 | 35.93 | 393.972 | -1966.672 | 560.366 | -1573.913 |
| 14 | 1967 - 1980 | 0.31 | 0.046 | 0.59 | 357.55 | 1981 - 1994 | 0.11 | 0.266 | 0.21 | 950.11 | 592.56 | *NA* | *NA* | *NA* | *NA* | 393.211 | -1194.628 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.11 | 0.266 | 0.21 | 506.66 | 1967 - 1980 | 0.31 | 0.046 | 0.59 | 910.70 | 404.04 | 0.50 | 446.15 | 370.49 | 188.52 | 455.718 | -2017.781 | 591.698 | -1606.205 |
| 15 | 1967 - 1981 | 0.30 | 0.041 | 0.55 | 354.50 | 1982 - 1996 | 0.10 | 0.269 | 0.20 | 930.78 | 576.28 | *NA* | *NA* | *NA* | *NA* | 386.437 | -1214.228 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.10 | 0.269 | 0.20 | 484.74 | 1967 - 1981 | 0.30 | 0.041 | 0.55 | 890.67 | 405.93 | 0.48 | 442.22 | 365.14 | 170.35 | 427.893 | -2022.021 | 573.794 | -1618.124 |
| 16 | 1967 - 1982 | 0.33 | 0.024 | 0.61 | 421.10 | 1983 - 1998 | 0.06 | 0.378 | 0.11 | 937.15 | 516.05 | *NA* | *NA* | *NA* | *NA* | 470.865 | -1285.964 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.06 | 0.378 | 0.11 | 546.92 | 1967 - 1982 | 0.33 | 0.024 | 0.61 | 863.59 | 316.67 | 0.44 | 484.74 | 397.33 | 199.38 | 460.477 | -2042.457 | 597.968 | -1664.210 |
| 17 | 1967 - 1983 | 0.42 | 0.006 | 0.67 | 410.79 | 1984 - 2000 | 0.09 | 0.258 | 0.23 | 860.37 | 449.58 | *NA* | *NA* | *NA* | *NA* | 505.582 | -1338.966 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.09 | 0.258 | 0.23 | 526.33 | 1967 - 1983 | 0.42 | 0.006 | 0.67 | 767.09 | 240.76 | 0.44 | 470.33 | 382.78 | 208.82 | 459.123 | -1997.110 | 581.126 | -1668.038 |
| 18 | 1967 - 1984 | 0.38 | 0.008 | 0.61 | 418.91 | 1985 - 2002 | 0.03 | 0.506 | 0.05 | 901.64 | 482.73 | *NA* | *NA* | *NA* | *NA* | 493.793 | -1352.412 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.03 | 0.506 | 0.05 | 545.14 | 1967 - 1984 | 0.38 | 0.008 | 0.61 | 797.31 | 252.17 | 0.44 | 468.47 | 379.80 | 230.56 | 439.896 | -2042.797 | 578.779 | -1697.604 |
| 19 | 1967 - 1985 | 0.41 | 0.004 | 0.64 | 405.56 | 1986 - 2004 | 0.13 | 0.140 | 0.24 | 1061.33 | 655.77 | *NA* | *NA* | *NA* | *NA* | 490.889 | -1376.127 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.13 | 0.140 | 0.24 | 746.22 | 1967 - 1985 | 0.41 | 0.004 | 0.64 | 976.03 | 229.81 | 0.46 | 572.08 | 442.03 | 425.96 | 680.388 | -2207.176 | 720.947 | -1791.652 |
| 20 | 1967 - 1986 | 0.45 | 0.002 | 0.68 | 399.30 | 1987 - 2006 | 0.09 | 0.211 | 0.14 | 1118.75 | 719.45 | *NA* | *NA* | *NA* | *NA* | 504.417 | -1412.285 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.09 | 0.211 | 0.14 | 799.11 | 1967 - 1986 | 0.45 | 0.002 | 0.68 | 1003.06 | 203.95 | 0.44 | 601.45 | 472.87 | 515.50 | 693.280 | -2280.103 | 742.440 | -1846.194 |
| 21 | 1967 - 1987 | 0.49 | 0.001 | 0.71 | 394.56 | 1988 - 2008 | 0.11 | 0.152 | 0.21 | 1135.17 | 740.61 | *NA* | *NA* | *NA* | *NA* | 519.972 | -1449.225 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.11 | 0.152 | 0.21 | 791.43 | 1967 - 1987 | 0.49 | 0.001 | 0.71 | 1017.44 | 226.01 | 0.47 | 595.66 | 471.31 | 514.60 | 702.342 | -2339.858 | 758.721 | -1894.542 |
| 22 | 1967 - 1988 | 0.50 | 0.000 | 0.71 | 384.39 | 1989 - 2010 | 0.12 | 0.123 | 0.23 | 1121.60 | 737.21 | *NA* | *NA* | *NA* | *NA* | 515.273 | -1468.306 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.12 | 0.123 | 0.23 | 764.00 | 1967 - 1988 | 0.50 | 0.000 | 0.71 | 1006.79 | 242.79 | 0.48 | 582.13 | 451.54 | 494.42 | 683.167 | -2357.592 | 748.266 | -1912.949 |
| 23 | 1967 - 1989 | 0.45 | 0.001 | 0.70 | 398.60 | 1990 - 2012 | 0.16 | 0.064 | 0.29 | 1171.65 | 773.05 | *NA* | *NA* | *NA* | *NA* | 504.107 | -1473.771 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.16 | 0.064 | 0.29 | 726.52 | 1967 - 1989 | 0.45 | 0.001 | 0.70 | 1091.50 | 364.98 | 0.48 | 595.32 | 473.04 | 408.07 | 675.084 | -2448.784 | 768.106 | -1961.277 |

Table S5

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  | **Glacier** | | **Glacier** | |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **scale** | **centre** | **scale.tot** | **centre.tot** |
| 10 | 1967 - 1976 | 0.59 | 0.013 | 0.73 | 295.11 | 1977 - 1986 | 0.74 | 0.002 | 0.79 | 478.96 | 183.85 | *NA* | *NA* | *NA* | *NA* | 457.302 | -1203.900 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.74 | 0.002 | 0.79 | 240.98 | 1967 - 1976 | 0.59 | 0.013 | 0.73 | 515.60 | 274.62 | 0.56 | 347.73 | 248.89 | -90.77 | 481.165 | -1620.671 | 504.417 | -1412.285 |
| 11 | 1967 - 1977 | 0.59 | 0.008 | 0.76 | 285.97 | 1978 - 1988 | 0.65 | 0.004 | 0.80 | 636.59 | 350.62 | *NA* | *NA* | *NA* | *NA* | 443.036 | -1176.818 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.65 | 0.004 | 0.80 | 247.13 | 1967 - 1977 | 0.59 | 0.008 | 0.76 | 646.16 | 399.03 | 0.56 | 358.30 | 257.38 | -48.41 | 417.562 | -1759.794 | 515.273 | -1468.306 |
| 12 | 1967 - 1978 | 0.53 | 0.010 | 0.65 | 297.64 | 1979 - 1990 | 0.58 | 0.005 | 0.78 | 713.37 | 415.73 | *NA* | *NA* | *NA* | *NA* | 422.683 | -1172.500 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.58 | 0.005 | 0.78 | 242.68 | 1967 - 1978 | 0.53 | 0.010 | 0.65 | 719.81 | 477.13 | 0.57 | 351.50 | 250.66 | -61.40 | 367.347 | -1834.561 | 514.131 | -1503.531 |
| 13 | 1967 - 1979 | 0.53 | 0.006 | 0.66 | 287.36 | 1980 - 1992 | 0.39 | 0.028 | 0.56 | 853.79 | 566.43 | *NA* | *NA* | *NA* | *NA* | 405.889 | -1181.154 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.39 | 0.028 | 0.56 | 329.41 | 1967 - 1979 | 0.53 | 0.006 | 0.66 | 835.06 | 505.65 | 0.54 | 401.43 | 291.4 | 60.78 | 393.972 | -1966.672 | 560.366 | -1573.913 |
| 14 | 1967 - 1980 | 0.50 | 0.006 | 0.63 | 289.94 | 1981 - 1994 | 0.38 | 0.023 | 0.59 | 899.96 | 610.02 | *NA* | *NA* | *NA* | *NA* | 393.211 | -1194.628 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.38 | 0.023 | 0.59 | 386.25 | 1967 - 1980 | 0.50 | 0.006 | 0.63 | 882.41 | 496.16 | 0.58 | 400.22 | 291.82 | 113.86 | 455.718 | -2017.781 | 591.698 | -1606.205 |
| 15 | 1967 - 1981 | 0.50 | 0.004 | 0.63 | 284.35 | 1982 - 1996 | 0.36 | 0.022 | 0.59 | 881.33 | 596.98 | *NA* | *NA* | *NA* | *NA* | 386.437 | -1214.228 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.36 | 0.022 | 0.59 | 368.46 | 1967 - 1981 | 0.50 | 0.004 | 0.63 | 862.36 | 493.90 | 0.56 | 401.17 | 294.93 | 103.08 | 427.893 | -2022.021 | 573.794 | -1618.124 |
| 16 | 1967 - 1982 | 0.64 | 0.000 | 0.69 | 289.65 | 1983 - 1998 | 0.33 | 0.024 | 0.56 | 863.88 | 574.23 | *NA* | *NA* | *NA* | *NA* | 470.865 | -1285.964 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.33 | 0.024 | 0.56 | 412.39 | 1967 - 1982 | 0.64 | 0.000 | 0.69 | 808.97 | 396.58 | 0.57 | 411.33 | 312.39 | 177.65 | 460.477 | -2042.457 | 597.968 | -1664.210 |
| 17 | 1967 - 1983 | 0.69 | 0.000 | 0.74 | 287.25 | 1984 - 2000 | 0.17 | 0.111 | 0.32 | 830.61 | 543.36 | *NA* | *NA* | *NA* | *NA* | 505.582 | -1338.966 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.17 | 0.111 | 0.32 | 480.96 | 1967 - 1983 | 0.69 | 0.000 | 0.74 | 714.22 | 233.26 | 0.51 | 433.88 | 332.02 | 310.10 | 459.123 | -1997.110 | 581.126 | -1668.038 |
| 18 | 1967 - 1984 | 0.51 | 0.001 | 0.62 | 361.80 | 1985 - 2002 | 0.14 | 0.138 | 0.30 | 857.69 | 495.89 | *NA* | *NA* | *NA* | *NA* | 493.793 | -1352.412 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.14 | 0.138 | 0.30 | 477.80 | 1967 - 1984 | 0.51 | 0.001 | 0.62 | 772.00 | 294.20 | 0.52 | 424.08 | 319.26 | 201.69 | 439.896 | -2042.797 | 578.779 | -1697.604 |
| 19 | 1967 - 1985 | 0.53 | 0.001 | 0.68 | 351.47 | 1986 - 2004 | 0.53 | 0.001 | 0.37 | 945.98 | 594.51 | *NA* | *NA* | *NA* | *NA* | 490.889 | -1376.127 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.53 | 0.001 | 0.37 | 485.73 | 1967 - 1985 | 0.53 | 0.001 | 0.68 | 946.51 | 460.78 | 0.66 | 435.23 | 327.04 | 133.73 | 680.388 | -2207.176 | 720.947 | -1791.652 |
| 20 | 1967 - 1986 | 0.56 | 0.000 | 0.72 | 347.73 | 1987 - 2006 | 0.55 | 0.000 | 0.50 | 979.10 | 631.37 | *NA* | *NA* | *NA* | *NA* | 504.417 | -1412.285 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.55 | 0.000 | 0.50 | 485.72 | 1967 - 1986 | 0.56 | 0.000 | 0.72 | 976.31 | 490.59 | 0.68 | 434.07 | 324.16 | 140.78 | 693.280 | -2280.103 | 742.440 | -1846.194 |
| 21 | 1967 - 1987 | 0.54 | 0.000 | 0.73 | 367.68 | 1988 - 2008 | 0.52 | 0.000 | 0.48 | 1010.34 | 642.66 | *NA* | *NA* | *NA* | *NA* | 519.972 | -1449.225 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.52 | 0.000 | 0.48 | 514.39 | 1967 - 1987 | 0.54 | 0.000 | 0.73 | 1003.75 | 489.36 | 0.67 | 454.54 | 343.94 | 153.30 | 702.342 | -2339.858 | 758.721 | -1894.542 |
| 22 | 1967 - 1988 | 0.56 | 0.000 | 0.75 | 358.30 | 1989 - 2010 | 0.51 | 0.000 | 0.48 | 1005.58 | 647.28 | *NA* | *NA* | *NA* | *NA* | 515.273 | -1468.306 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.51 | 0.000 | 0.48 | 506.45 | 1967 - 1988 | 0.56 | 0.000 | 0.75 | 993.96 | 487.51 | 0.67 | 447.11 | 335.40 | 159.77 | 683.167 | -2357.592 | 748.266 | -1912.949 |
| 23 | 1967 - 1989 | 0.55 | 0.000 | 0.75 | 352.31 | 1990 - 2012 | 0.51 | 0.000 | 0.53 | 1079.39 | 727.08 | *NA* | *NA* | *NA* | *NA* | 504.107 | -1473.771 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.51 | 0.000 | 0.53 | 499.73 | 1967 - 1989 | 0.55 | 0.000 | 0.75 | 1069.97 | 570.24 | 0.69 | 438.87 | 328.22 | 156.84 | 675.084 | -2448.784 | 768.106 | -1961.277 |

Table S6

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Calibration** | | | | | **Validation** | | | | |  | **Whole period** | | |  | **Glacier** | | **Glacier** | |
| **win.length** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **year** | **R2** | **p.value** | **ρ** | **RMSE** | **δRMSE** | **R2** | **RMSE** | **MAE** | **ΔRMSE** | **scale** | **centre** | **scale.tot** | **centre.tot** |
| 10 | 1967 - 1976 | 0.56 | 0.017 | 0.49 | 130.47 | 1977 - 1986 | 0.58 | 0.014 | 0.37 | 313.68 | 183.21 | *NA* | *NA* | *NA* | *NA* | 194.294 | 929.600 | *NA* | *NA* |
| 10 | 1977 - 1986 | 0.58 | 0.014 | 0.37 | 241.66 | 1967 - 1976 | 0.56 | 0.017 | 0.49 | 315.60 | 73.94 | 0.62 | 193.19 | 145.52 | 109.27 | 366.842 | 1131.271 | 303.858 | 1030.435 |
| 11 | 1967 - 1977 | 0.87 | 0.000 | 0.62 | 120.95 | 1978 - 1988 | 0.36 | 0.063 | 0.42 | 276.21 | 155.26 | *NA* | *NA* | *NA* | *NA* | 344.277 | 1017.273 | *NA* | *NA* |
| 11 | 1978 - 1988 | 0.36 | 0.063 | 0.42 | 244.77 | 1967 - 1977 | 0.87 | 0.000 | 0.62 | 128.86 | -115.91 | 0.62 | 197.19 | 154.47 | 271.17 | 286.953 | 979.521 | 309.879 | 998.397 |
| 12 | 1967 - 1978 | 0.86 | 0.000 | 0.68 | 119.17 | 1979 - 1990 | 0.45 | 0.022 | 0.57 | 271.59 | 152.42 | *NA* | *NA* | *NA* | *NA* | 332.652 | 1032.833 | *NA* | *NA* |
| 12 | 1979 - 1990 | 0.45 | 0.022 | 0.57 | 222.05 | 1967 - 1978 | 0.86 | 0.000 | 0.68 | 168.95 | -53.10 | 0.63 | 193.74 | 152.28 | 205.52 | 285.676 | 913.145 | 309.340 | 972.989 |
| 13 | 1967 - 1979 | 0.86 | 0.000 | 0.70 | 116.55 | 1980 - 1992 | 0.43 | 0.019 | 0.59 | 273.62 | 157.07 | *NA* | *NA* | *NA* | *NA* | 319.084 | 1038.231 | *NA* | *NA* |
| 13 | 1980 - 1992 | 0.43 | 0.019 | 0.59 | 215.10 | 1967 - 1979 | 0.86 | 0.000 | 0.70 | 177.79 | -37.31 | 0.63 | 186.23 | 143.24 | 194.38 | 269.718 | 904.518 | 297.386 | 971.374 |
| 14 | 1967 - 1980 | 0.81 | 0.000 | 0.68 | 138.09 | 1981 - 1994 | 0.56 | 0.003 | 0.62 | 270.98 | 132.89 | *NA* | *NA* | *NA* | *NA* | 320.022 | 1062.771 | *NA* | *NA* |
| 14 | 1981 - 1994 | 0.56 | 0.003 | 0.62 | 154.00 | 1967 - 1980 | 0.81 | 0.000 | 0.68 | 231.10 | 77.10 | 0.63 | 180.05 | 136.25 | 55.79 | 226.452 | 884.495 | 286.777 | 973.633 |
| 15 | 1967 - 1981 | 0.59 | 0.001 | 0.50 | 214.52 | 1982 - 1996 | 0.83 | 0.000 | 0.85 | 225.31 | 10.79 | *NA* | *NA* | *NA* | *NA* | 326.310 | 1035.228 | *NA* | *NA* |
| 15 | 1982 - 1996 | 0.83 | 0.000 | 0.85 | 95.49 | 1967 - 1981 | 0.59 | 0.001 | 0.50 | 267.45 | 171.96 | 0.66 | 176.09 | 134.10 | -161.17 | 236.486 | 860.154 | 293.817 | 947.691 |
| 16 | 1967 - 1982 | 0.62 | 0.000 | 0.55 | 206.64 | 1983 - 1998 | 0.83 | 0.000 | 0.88 | 211.33 | 4.69 | *NA* | *NA* | *NA* | *NA* | 327.246 | 1013.276 | *NA* | *NA* |
| 16 | 1983 - 1998 | 0.83 | 0.000 | 0.88 | 96.01 | 1967 - 1982 | 0.62 | 0.000 | 0.55 | 249.12 | 153.11 | 0.66 | 173.61 | 133.23 | -148.42 | 232.689 | 860.582 | 289.885 | 936.929 |
| 17 | 1967 - 1983 | 0.65 | 0.000 | 0.62 | 200.10 | 1984 - 2000 | 0.26 | 0.042 | 0.73 | 438.09 | 237.99 | *NA* | *NA* | *NA* | *NA* | 330.445 | 1036.025 | *NA* | *NA* |
| 17 | 1984 - 2000 | 0.26 | 0.042 | 0.73 | 308.90 | 1967 - 1983 | 0.65 | 0.000 | 0.62 | 363.69 | 54.79 | 0.47 | 278.11 | 204.82 | 183.20 | 320.241 | 730.463 | 355.971 | 883.244 |
| 18 | 1967 - 1984 | 0.65 | 0.000 | 0.62 | 194.63 | 1985 - 2002 | 0.49 | 0.002 | 0.73 | 367.55 | 172.92 | *NA* | *NA* | *NA* | *NA* | 320.762 | 1033.468 | *NA* | *NA* |
| 18 | 1985 - 2002 | 0.49 | 0.002 | 0.73 | 307.17 | 1967 - 1984 | 0.65 | 0.000 | 0.62 | 330.89 | 23.72 | 0.53 | 277.68 | 205.49 | 149.20 | 409.311 | 801.630 | 381.011 | 917.549 |
| 19 | 1967 - 1985 | 0.65 | 0.000 | 0.60 | 190.10 | 1986 - 2004 | 0.49 | 0.001 | 0.73 | 355.95 | 165.85 | *NA* | *NA* | *NA* | *NA* | 311.736 | 1034.075 | *NA* | *NA* |
| 19 | 1986 - 2004 | 0.49 | 0.001 | 0.73 | 302.04 | 1967 - 1985 | 0.65 | 0.000 | 0.60 | 320.14 | 18.10 | 0.53 | 271.38 | 200.61 | 147.75 | 401.757 | 814.439 | 371.733 | 924.257 |
| 20 | 1967 - 1986 | 0.62 | 0.000 | 0.51 | 193.19 | 1987 - 2006 | 0.48 | 0.001 | 0.70 | 353.35 | 160.16 | *NA* | *NA* | *NA* | *NA* | 303.858 | 1030.435 | *NA* | *NA* |
| 20 | 1987 - 2006 | 0.48 | 0.001 | 0.70 | 297.09 | 1967 - 1986 | 0.62 | 0.000 | 0.51 | 322.29 | 25.20 | 0.53 | 264.78 | 194.14 | 134.96 | 389.605 | 809.003 | 362.634 | 919.719 |
| 21 | 1967 - 1987 | 0.63 | 0.000 | 0.56 | 198.60 | 1988 - 2008 | 0.50 | 0.000 | 0.69 | 342.67 | 144.07 | *NA* | *NA* | *NA* | *NA* | 314.684 | 1007.225 | *NA* | *NA* |
| 21 | 1988 - 2008 | 0.50 | 0.000 | 0.69 | 290.82 | 1967 - 1987 | 0.63 | 0.000 | 0.56 | 311.78 | 20.96 | 0.54 | 261.58 | 192.67 | 123.11 | 387.179 | 798.239 | 364.165 | 902.732 |
| 22 | 1967 - 1988 | 0.62 | 0.000 | 0.56 | 197.19 | 1989 - 2010 | 0.54 | 0.000 | 0.75 | 312.35 | 115.16 | *NA* | *NA* | *NA* | *NA* | 309.879 | 998.397 | *NA* | *NA* |
| 22 | 1989 - 2010 | 0.54 | 0.000 | 0.75 | 284.85 | 1967 - 1988 | 0.62 | 0.000 | 0.56 | 290.71 | 5.86 | 0.56 | 255.73 | 188.37 | 109.30 | 398.638 | 834.183 | 362.495 | 916.290 |
| 23 | 1967 - 1989 | 0.61 | 0.000 | 0.56 | 197.38 | 1990 - 2012 | 0.48 | 0.000 | 0.73 | 316.55 | 119.17 | *NA* | *NA* | *NA* | *NA* | 306.254 | 988.771 | *NA* | *NA* |
| 23 | 1990 - 2012 | 0.48 | 0.000 | 0.73 | 299.28 | 1967 - 1989 | 0.61 | 0.000 | 0.56 | 281.61 | -17.67 | 0.54 | 257.08 | 188.39 | 136.84 | 389.413 | 836.610 | 354.834 | 912.690 |

****

**Fig. S9:** Comparison between the Z-scores of the reconstructed MXD/prec-based and temp/prec-based Bn and the Bn values of other glaciers in the area for the total frequency (left column), high frequency (central) and mid frequency (right column). Numbers identify Pearson’s correlation index values. The glacier name is reported in the first plot of each row.

**Table S7:** Comparison among Alpine glacier Bn values in the high-frequency domain over the 1966/67–87/88 (upper right half) and 1988/89–2012/13 (lower left half) periods

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Allalin | Claridenfirn | Gietro | Gries | Hintereis | Hohlaub | Kesselwand | Schwarzberg | Silvretta | Stubacher | Vernagt | Careser | MXD\_Bn1 | Temp\_Bn1 | MXD\_Bn2 | Temp\_Bn2 |
| Allalin |  | 0.48 | 0.57 | 0.83 | 0.67 | 0.83 | 0.59 | 0.82 | 0.61 | 0.38 | 0.40 | 0.65 | 0.55 | 0.66 | 0.56 | 0.66 |
| Claridenfirn | 0.62 |  | 0.57 | 0.72 | 0.72 | 0.20 | 0.67 | 0.60 | 0.67 | 0.75 | 0.72 | 0.43 | 0.14 | 0.56 | 0.13 | 0.57 |
| Gietro | 0.61 | 0.81 |  | 0.69 | 0.44 | 0.43 | 0.44 | 0.69 | 0.52 | 0.46 | 0.50 | 0.45 | 0.17 | 0.40 | 0.18 | 0.40 |
| Gries | 0.64 | 0.78 | 0.74 |  | 0.77 | 0.61 | 0.69 | 0.87 | 0.61 | 0.54 | 0.60 | 0.76 | 0.42 | 0.69 | 0.43 | 0.69 |
| Hintereis | 0.61 | 0.77 | 0.68 | 0.69 |  | 0.35 | 0.95 | 0.59 | 0.78 | 0.73 | 0.84 | 0.81 | 0.56 | 0.94 | 0.57 | 0.94 |
| Hohlaub | 0.79 | 0.66 | 0.60 | 0.60 | 0.56 |  | 0.23 | 0.67 | 0.35 | 0.09 | 0.03 | 0.36 | 0.39 | 0.36 | 0.41 | 0.35 |
| Kesselwand | 0.61 | 0.77 | 0.76 | 0.59 | 0.93 | 0.57 |  | 0.55 | 0.80 | 0.79 | 0.89 | 0.73 | 0.45 | 0.86 | 0.47 | 0.86 |
| Schwarzberg | 0.76 | 0.54 | 0.50 | 0.79 | 0.55 | 0.80 | 0.46 |  | 0.64 | 0.49 | 0.45 | 0.50 | 0.24 | 0.47 | 0.25 | 0.47 |
| Silvretta | 0.60 | 0.86 | 0.83 | 0.77 | 0.89 | 0.66 | 0.88 | 0.58 |  | 0.81 | 0.76 | 0.58 | 0.21 | 0.64 | 0.21 | 0.64 |
| Stubacher | 0.44 | 0.69 | 0.55 | 0.58 | 0.84 | 0.49 | 0.76 | 0.44 | 0.75 |  | 0.90 | 0.49 | 0.14 | 0.61 | 0.14 | 0.62 |
| Vernagt | 0.60 | 0.81 | 0.85 | 0.71 | 0.86 | 0.61 | 0.93 | 0.51 | 0.90 | 0.77 |  | 0.66 | 0.35 | 0.76 | 0.35 | 0.77 |
| Careser | 0.70 | 0.69 | 0.65 | 0.66 | 0.94 | 0.55 | 0.88 | 0.62 | 0.82 | 0.78 | 0.81 |  | 0.60 | 0.83 | 0.61 | 0.83 |
| MXD\_Bn1 | 0.22 | 0.21 | -0.07 | 0.31 | 0.40 | 0.09 | 0.29 | 0.26 | 0.20 | 0.33 | 0.18 | 0.41 |  | 0.74 | 1.00 | 0.74 |
| Temp\_Bn1 | 0.57 | 0.58 | 0.53 | 0.69 | 0.80 | 0.56 | 0.75 | 0.62 | 0.82 | 0.64 | 0.72 | 0.80 | 0.39 |  | 0.75 | 1.00 |
| MXD\_Bn1 | 0.23 | 0.20 | -0.07 | 0.33 | 0.40 | 0.09 | 0.28 | 0.28 | 0.20 | 0.33 | 0.17 | 0.42 | 1.00 | 0.41 |  | 0.75 |
| Temp\_Bn1 | 0.57 | 0.58 | 0.53 | 0.69 | 0.81 | 0.56 | 0.75 | 0.62 | 0.82 | 0.64 | 0.72 | 0.80 | 0.39 | 1.00 | 0.40 |  |

1 identifies reconstructed Bn values obtained by scaling; 2 identifies reconstructed Bn values obtained by regression. Glacier data were downloaded from the WGMS database (Huss et al., 2015; WGMS, 2017, 2015)

**Table S8**: Comparison among Alpine glacier Bn values in the mid-frequency domain over the 1966/67–87/88 (upper right half) and 1988/89–2012/13 (lower left half) periods

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Allalin | Claridenfirn | Gietro | Gries | Hintereis | Hohlaub | Kesselwald | Schwarzberg | Silvretta | Stubacher | Vernagt | Careser | MXD\_Bn1 | Temp\_Bn1 | MXD\_Bn2 | Temp\_Bn2 |
| Allalin |  | 0.86 | 0.68 | 0.96 | 0.92 | 0.88 | 0.93 | 0.95 | 0.76 | 0.95 | 0.91 | 0.97 | 0.97 | 0.90 | 0.96 | 0.90 |
| Claridenfirn | 0.56 |  | 0.83 | 0.89 | 0.95 | 0.76 | 0.87 | 0.85 | 0.91 | 0.93 | 0.93 | 0.85 | 0.82 | 0.83 | 0.82 | 0.83 |
| Gietro | 0.48 | 0.90 |  | 0.69 | 0.75 | 0.75 | 0.53 | 0.75 | 0.84 | 0.76 | 0.64 | 0.57 | 0.62 | 0.79 | 0.64 | 0.79 |
| Gries | 0.66 | 0.85 | 0.87 |  | 0.95 | 0.76 | 0.94 | 0.88 | 0.81 | 0.93 | 0.93 | 0.97 | 0.93 | 0.90 | 0.93 | 0.90 |
| Hintereis | 0.52 | 0.87 | 0.68 | 0.81 |  | 0.78 | 0.93 | 0.89 | 0.90 | 0.94 | 0.97 | 0.93 | 0.93 | 0.91 | 0.93 | 0.91 |
| Hohlaub | 0.58 | 0.37 | 0.56 | 0.65 | 0.33 |  | 0.72 | 0.91 | 0.75 | 0.87 | 0.74 | 0.75 | 0.86 | 0.79 | 0.87 | 0.79 |
| Kesselwald | 0.57 | 0.89 | 0.70 | 0.75 | 0.94 | 0.24 |  | 0.84 | 0.74 | 0.93 | 0.98 | 0.97 | 0.90 | 0.79 | 0.89 | 0.79 |
| Schwarzberg | 0.49 | 0.36 | 0.53 | 0.70 | 0.43 | 0.94 | 0.26 |  | 0.73 | 0.92 | 0.87 | 0.89 | 0.93 | 0.93 | 0.93 | 0.93 |
| Silvretta | 0.66 | 0.91 | 0.79 | 0.85 | 0.87 | 0.37 | 0.91 | 0.38 |  | 0.83 | 0.81 | 0.71 | 0.78 | 0.78 | 0.79 | 0.78 |
| Stubacher | 0.23 | 0.88 | 0.84 | 0.67 | 0.72 | 0.07 | 0.75 | 0.10 | 0.76 |  | 0.95 | 0.93 | 0.89 | 0.85 | 0.89 | 0.86 |
| Vernagt | 0.38 | 0.89 | 0.76 | 0.69 | 0.85 | 0.15 | 0.94 | 0.15 | 0.88 | 0.86 |  | 0.95 | 0.89 | 0.83 | 0.89 | 0.83 |
| Careser | 0.26 | 0.58 | 0.65 | 0.81 | 0.70 | 0.61 | 0.54 | 0.76 | 0.65 | 0.48 | 0.55 |  | 0.93 | 0.86 | 0.92 | 0.87 |
| MXD\_Bn1 | 0.68 | 0.57 | 0.28 | 0.39 | 0.54 | -0.04 | 0.66 | -0.10 | 0.74 | 0.39 | 0.56 | 0.08 |  | 0.90 | 1.00 | 0.90 |
| Temp\_Bn1 | 0.13 | 0.63 | 0.75 | 0.62 | 0.49 | 0.51 | 0.38 | 0.56 | 0.60 | 0.63 | 0.51 | 0.75 | 0.08 |  | 0.91 | 1.00 |
| MXD\_Bn1 | 0.67 | 0.55 | 0.26 | 0.37 | 0.53 | -0.03 | 0.64 | -0.09 | 0.73 | 0.36 | 0.54 | 0.07 | 1.00 | 0.09 |  | 0.91 |
| Temp\_Bn1 | 0.13 | 0.64 | 0.75 | 0.62 | 0.49 | 0.51 | 0.38 | 0.56 | 0.60 | 0.63 | 0.51 | 0.75 | 0.07 | 1.00 | 0.08 |  |

1 identifies reconstructed Bn values obtained by scaling; 2 identifies reconstructed Bn values obtained by regression. Glacier data were downloaded from the WGMS database (Huss et al., 2015; WGMS, 2017, 2015).