Supplement of

Recent hydrological response of glaciers in the Canadian Rockies to changing climate and glacier configuration

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Supplementary Tables

Table S1: Changes in precipitation for annual, seasonal, and monthly time periods [Comparison C1]. Highlighted bold numbers are significant at 95% confidence level.

| Season/month | AGRB | PGRB |
|--------------|------|------|
|              | p-value Wilcoxon test | p-value t-test | Past (mm) | Present (mm) | Difference (mm) | p-value Wilcoxon test | p-value t-test | Past (mm) | Present (mm) | Difference (mm) |
| Annual       | 0.912 | 0.683 | 611.4 | 626.6 | 15.2 | 0.143 | 0.121 | 697.0 | 768.7 | 71.7 |
| Winter       | 0.043 | 0.037 | **254.5** | **205.0** | **-49.5** | 0.436 | 0.223 | 272.2 | 237.0 | -35.2 |
| Spring       | 0.089 | 0.191 | 115.0 | 128.1 | 13.1 | 0.064 | 0.057 | 152.4 | 182.1 | 29.7 |
| Summer       | 0.052 | 0.020 | **132.9** | **171.4** | **38.5** | 0.009 | 0.006 | **146.2** | **196.4** | **50.2** |
| Fall         | 0.481 | 0.468 | 109.0 | 122.1 | 13.1 | 0.218 | 0.260 | 126.2 | 153.2 | 27 |
| January      | 0.123 | 0.056 | 92.9 | 58.2 | -34.7 | 0.089 | 0.060 | 94.6 | 60.7 | -33.9 |
| February     | 0.821 | 0.882 | 32.5 | 31.5 | -1 | 1.000 | 0.613 | 48.8 | 43.4 | -5.4 |
| March        | 0.436 | 0.313 | 40.1 | 45.1 | 5 | 0.165 | 0.069 | 61.2 | 77.2 | 16 |
| April        | 0.496 | 0.356 | 34.6 | 39.6 | 5 | 0.280 | 0.259 | 40.7 | 48.3 | 7.6 |
| May          | 0.436 | 0.571 | 40.4 | 43.5 | 3.1 | 0.393 | 0.420 | 50.6 | 56.5 | 5.9 |
| June         | 0.043 | 0.095 | **47.1** | **61.0** | **13.9** | 0.029 | 0.076 | **61.9** | **80.0** | **18.1** |
| July         | 0.054 | 0.055 | 39.0 | 55.0 | 16 | 0.089 | 0.064 | 45.1 | 63.6 | 18.5 |
| August       | 0.353 | 0.319 | 46.7 | 55.4 | 8.7 | 0.123 | 0.103 | 39.2 | 52.8 | 13.6 |
| September    | 0.280 | 0.227 | 48.0 | 63.6 | -15.6 | 0.315 | 0.288 | 66.2 | 85.5 | 19.3 |
| October      | 0.739 | 0.814 | 60.9 | 58.5 | -2.4 | 0.529 | 0.497 | 60.0 | 67.7 | 7.7 |
| November     | 0.579 | 0.462 | 53.9 | 58.8 | 4.9 | 0.063 | 0.067 | 73.7 | 93.7 | 20 |
| December     | 0.082 | 0.086 | 75.3 | 56.5 | -18.8 | 0.035 | 0.032 | **55.1** | **39.3** | **-15.8** |
Table S2: Changes in daily maximum temperature for annual, seasonal, and monthly periods [Comparison C1]. Highlighted bold numbers are significant at 95% confidence level.

| Season/month | AGRB       | PGRB       |
|--------------|------------|------------|
|              | p-value    | p-value    | Past (°C) | Present (°C) | Difference (°C) | p-value | p-value    | Past (°C) | Present (°C) | Difference (°C) |
|              | Wilcoxon test | t-test |           |            |               | Wilcoxon test | t-test |           |            |            |                |
| Annual       | 0.002      | 0.002     | 2.1       | 3.1        | 1             | 0.000       | 0.000     | 1.3        | 2.8        | 1.5           |
| Winter       | 0.009      | 0.009     | -7.2      | -5.3       | 1.9           | 0.001       | 0.001     | -0.2       | 1.7        | 1.9           |
| Spring       | 0.052      | 0.044     | 1.5       | 2.6        | 1.1           | 0.043       | 0.016     | 11         | 12.1       | 1.1           |
| Summer       | 0.796      | 0.979     | 12.3      | 12.3       | 0             | 0.315       | 0.358     | 5.3        | 5.9        | -0.6          |
| Fall         | 0.436      | 0.529     | 5.9       | 6.3        | 0.4           | 0.007       | 0.005     | -6.8       | -5         | 1.8           |
| January      | 0.000      | 0.001     | -10.1     | -5.0       | 5.1           | 0.000       | 0.000     | -9.4       | -4.6       | 4.8           |
| February     | 0.579      | 0.668     | -6.0      | -5.4       | 0.6           | 0.579       | 0.740     | -5.9       | -5.5       | -0.4          |
| March        | 0.075      | 0.023     | -3.9      | -1.9       | 2             | 0.015       | 0.008     | -5.0       | -2.7       | 2.3           |
| April        | 0.063      | 0.054     | 0.7       | 2.2        | 1.5           | 0.003       | 0.002     | -1.1       | 1.2        | 2.3           |
| May          | 0.684      | 0.878     | 7.5       | 7.4        | -0.1          | 0.165       | 0.110     | 5.4        | 6.5        | 1.1           |
| June         | 0.631      | 0.546     | 10.3      | 9.9        | -0.4          | 0.393       | 0.405     | 8.7        | 9.2        | 0.5           |
| July         | 0.739      | 0.723     | 13.3      | 13.5       | 0.2           | 0.015       | 0.012     | 12.0       | 13.4       | 1.4           |
| August       | 0.631      | 0.771     | 13.1      | 13.3       | 0.2           | 0.123       | 0.070     | 12.2       | 13.4       | 1.2           |
| September    | 0.912      | 0.986     | 8.9       | 8.9        | 0             | 0.853       | 0.809     | 8.5        | 8.8        | 0.3           |
| October      | 0.218      | 0.230     | 3.0       | 3.7        | 0.7           | 0.105       | 0.157     | 2.2        | 3.1        | 0.9           |
| November     | 0.105      | 0.081     | -4.2      | -2.6       | 1.6           | 0.029       | 0.032     | -4.3       | -2.5       | 1.8           |
| December     | 1.000      | 0.870     | -8.4      | -8.2       | 0.2           | 0.912       | 0.980     | -7.6       | -7.6       | 0             |
Table S3: Changes daily minimum temperature for annual, seasonal, and monthly periods [Comparison C1]. Highlighted bold numbers are significant at 95% confidence level.

| Season/month | AGRB | PGRB |
|--------------|------|------|
| p-value Wilcox test | p-value t-test | Past (°C) | Present (°C) | Difference (°C) | p-value Wilcox test | p-value t-test | Past (°C) | Present (°C) | Difference (°C) |
| Annual       | 0.190 | 0.081 | -4.5 | -4.0 | 0.5 | 0.000 | 0.001 | -4.9 | -3.8 | 1.1 |
| Winter       | 0.971 | 0.671 | -12.3 | -12  | 0.3 | 0.853 | 0.673 | -11.2 | -10.9 | 0.3 |
| Spring       | 0.089 | 0.077 | -5.7 | -4.9 | 0.8 | 0.001 | 0.001 | -7.0 | -5.5 | 1.5 |
| Summer       | 0.043 | 0.023 | **4.5** | **5.2** | **0.7** | 0.000 | 0.000 | 3.7  | **5.0** | 1.3 |
| Fall         | 0.247 | 0.384 | -1.1 | -0.7 | 0.4 | 0.009 | 0.008 | -2.0 | -0.6 | 1.4 |
| January      | 0.007 | 0.012 | **-15.0** | **-11.4** | **3.6** | 0.001 | 0.003 | **-13.3** | **-9.8** | 3.5 |
| February     | 0.796 | 0.517 | -12.1 | -13.1 | -1  | 0.739 | 0.382 | -11.5 | -12.8 | -1.3 |
| March        | 0.684 | 0.490 | -9.8  | -9.2  | 0.6 | 0.089 | 0.067 | -10.8 | -9.3  | 1.5 |
| April        | 0.029 | 0.018 | **-6.9** | **-5.3** | **1.6** | 0.015 | 0.008 | **-7.9** | **-6.2** | 1.7 |
| May          | 1.000 | 0.699 | -0.5  | -0.3  | 0.2 | 0.004 | 0.004 | **-2.4** | **-1.0** | 1.4 |
| June         | 0.853 | 0.734 | 2.9   | 3.1   | 0.2 | 0.739 | 0.516 | 1.9   | 2.2   | 0.3 |
| July         | 0.043 | 0.023 | **5.4** | **6.4** | **1** | 0.000 | 0.000 | **4.3** | **6.2** | **1.9** |
| August       | 0.019 | 0.020 | **5.1** | **6.1** | **1** | 0.000 | 0.000 | **4.8** | **6.6** | **1.8** |
| September    | 0.280 | 0.169 | 0.7   | 1.6   | 0.9 | 0.190 | 0.182 | 0.8   | 1.6   | 0.8 |
| October      | 0.853 | 0.937 | -2.9  | -2.9  | 0   | 0.004 | 0.004 | **-4.7** | **-2.8** | **1.9** |
| November     | 0.631 | 0.807 | -9.2  | -9.4  | -0.2 | 0.739 | 0.985 | -8.5  | -8.5  | 0   |
| December     | 0.280 | 0.393 | -12.7 | -13.9 | -1.2 | 0.190 | 0.251 | -11.4 | -12.7 | -1.3 |
Table S4: Changes daily mean temperature in annual, seasonal, and monthly periods [Comparison CI]. Highlighted bold numbers are significant at 95% confidence level.

| Season | AGRB | PGRB |
|--------|------|------|
|        | p-value Wilcoxon test | p-value t-test | Past (°C) | Present (°C) | Difference (°C) | p-value Wilcoxon test | p-value t-test | Past (°C) | Present (°C) | Difference (°C) |
| Annual | 0.105 | 0.089 | -1.1 | -0.6 | 0.5 | 0.001 | 0.001 | -1.6 | -0.6 | 1 |
| Winter | 0.481 | 0.336 | -9.7 | -9 | 0.7 | 0.529 | 0.342 | -8.9 | -8.4 | 0.5 |
| Spring | 0.165 | 0.119 | -2 | -1.2 | 0.8 | 0.003 | 0.003 | -3.4 | -2 | 1.4 |
| Summer | 0.393 | 0.392 | 8.7 | 9 | 0.3 | 0.003 | 0.002 | 7.6 | 8.7 | 1.1 |
| Fall | 0.529 | 0.799 | 2.4 | 2.6 | 0.2 | 0.28 | 0.23 | 1.7 | 2.4 | 0.7 |
| January | 0.004 | 0.006 | -12.5 | -8.6 | 3.9 | 0.000 | 0.001 | -11.3 | -7.6 | 3.7 |
| February | 0.912 | 0.704 | -9.1 | -9.7 | -0.6 | 0.796 | 0.537 | -8.7 | -9.6 | -0.9 |
| March | 0.353 | 0.234 | -6.8 | -5.8 | 1 | 0.075 | 0.058 | -7.9 | -6.3 | 1.6 |
| April | 0.063 | 0.054 | -2.9 | -1.6 | 1.3 | 0.007 | 0.007 | -4.3 | -2.6 | 1.7 |
| May | 0.579 | 0.943 | 3.8 | 3.8 | 0 | 0.105 | 0.044 | 1.8 | 3.0 | 1.2 |
| June | 0.912 | 0.754 | 7.0 | 6.8 | -0.2 | 0.436 | 0.507 | 5.7 | 6.0 | 0.3 |
| July | 0.190 | 0.214 | 9.7 | 10.3 | 0.6 | 0.002 | 0.001 | 8.4 | 10.1 | 1.7 |
| August | 0.631 | 0.373 | 9.3 | 9.8 | 0.5 | 0.019 | 0.010 | 8.6 | 10.1 | 1.5 |
| September | 0.739 | 0.727 | 4.8 | 5.1 | 0.3 | 0.631 | 0.727 | 4.7 | 5.0 | 0.3 |
| October | 0.853 | 0.991 | 0.1 | 0.1 | 0 | 0.052 | 0.089 | -1.2 | -0.2 | 1 |
| November | 0.853 | 0.870 | -6.5 | -6.4 | 0.1 | 0.971 | 0.632 | -6.2 | -5.8 | 0.4 |
| December | 0.436 | 0.499 | -10.4 | -11.2 | -0.8 | 0.247 | 0.285 | -9.4 | -10.5 | -1.1 |
Table S5: Results of Student's t-test for changes in annual mean values of water fluxes. Highlighted bold numbers are significant at the 95% confidence level. The comparisons are defined in Table 1.

| Comparisons | Fluxes          | AGRB     | PGRB     |
|-------------|----------------|----------|----------|
|             | p-value t-test | Mean 1 (mm) | Mean 2 (mm) | Difference (mm) | p-value t-test | Mean 1 (mm) | Mean 2 (mm) | Difference (mm) |
| C1          | Snowfall       | 0.443    | 911      | 866      | -45     | 0.121    | 1135      | 919      | -216     |
|             | Rainfall       | 0.001    | 175      | 262      | 87      | 0.304    | 310       | 362      | 52       |
|             | Rainfall ratio | 0.001    | 0.161    | 0.232    | 0.071   | 0.047    | 0.220     | 0.283    | 0.063    |
|             | Snowmelt       | 0.223    | 687      | 723      | 36      | 0.309    | 1105      | 974      | -131     |
|             | Firn melt      | 0.652    | 275      | 307      | 32      | 0.806    | 163       | 146      | -17      |
|             | Ice melt       | 0.537    | 532      | 501      | -31     | 0.000    | 265       | 667      | 402      |
|             | Runoff         | 0.578    | 1320     | 1365     | 45      | 0.005    | 1581      | 1888     | 307      |
| C2          | Snowfall       | 0.892    | 911      | 901      | -10     | 0.591    | 1135      | 1060     | -75      |
|             | Rainfall       | 0.983    | 175      | 175      | 0       | 0.923    | 310       | 313      | 3        |
|             | Rainfall ratio | 0.918    | 0.161    | 0.163    | 0.002   | 0.601    | 0.220     | 0.234    | 0.014    |
|             | Snowmelt       | 0.432    | 687      | 661      | -26     | 0.683    | 1105      | 1056     | -49      |
|             | Firn melt      | 0.930    | 275      | 267      | -8      | 0.095    | 163       | 39       | -124     |
|             | Ice melt       | 0.245    | 532      | 470      | -62     | 0.225    | 265       | 364      | 99       |
|             | Runoff         | 0.279    | 1320     | 1236     | -84     | 0.499    | 1581      | 1524     | -57      |
| C3          | Snowfall       | 0.546    | 911      | 876      | -35     | 0.292    | 1135      | 986      | -149     |
|             | Rainfall       | 0.001    | 175      | 175      | 0       | 0.923    | 310       | 313      | 3        |
|             | Rainfall ratio | 0.001    | 0.161    | 0.229    | 0.068   | 0.117    | 0.220     | 0.268    | 0.048    |
|             | Snowmelt       | 0.827    | 687      | 669      | -18     | 0.613    | 1105      | 1041     | -64      |
|             | Firn melt      | 0.587    | 275      | 314      | 39      | 0.015    | 163       | 414      | 251      |
|             | Ice melt       | 0.460    | 532      | 571      | 39      | 0.003    | 265       | 537      | 272      |
|             | Runoff         | 0.125    | 1320     | 1452     | 132     | 0.000    | 1581      | 2069     | 488      |
| C4          | Snowfall       | 0.545    | 901      | 866      | -35     | 0.287    | 1060      | 919      | -141     |
|             | Rainfall       | 0.001    | 175      | 262      | 87      | 0.340    | 313       | 362      | 49       |
|             | Rainfall ratio | 0.001    | 0.163    | 0.232    | 0.069   | 0.118    | 0.234     | 0.283    | 0.049    |
|             | Snowmelt       | 0.035    | 661      | 723      | 62      | 0.527    | 1056      | 974      | -82      |
|             | Firn melt      | 0.581    | 267      | 307      | 40      | 0.008    | 39        | 146      | 107      |
|             | Ice melt       | 0.454    | 470      | 501      | 31      | 0.006    | 364       | 667      | 303      |
|             | Runoff         | 0.101    | 1236     | 1365     | 129     | 0.001    | 1524      | 1888     | 364      |
| C5          | Snowfall       | 0.785    | 876      | 866      | -10     | 0.606    | 986       | 919      | -67      |
|             | Rainfall       | 0.986    | 262      | 262      | 0       | 0.974    | 360       | 362      | 2        |
|             | Rainfall ratio | 0.895    | 0.163    | 0.232    | 0.069   | 0.645    | 0.268     | 0.283    | 0.015    |
|             | Snowmelt       | 0.504    | 669      | 723      | 54      | 0.621    | 1041      | 974      | -67      |
|             | Firn melt      | 0.908    | 314      | 307      | -7      | 0.003    | 414       | 146      | -268     |
|             | Ice melt       | 0.111    | 571      | 501      | -70     | 0.192    | 537       | 667      | 130      |
|             | Runoff         | 0.295    | 1452     | 1365     | -87     | 0.124    | 2069      | 1888     | -181     |
Table S6: Results of paired Student's t-test and Wilcoxon test for changes in monthly values of water fluxes. Highlighted bold numbers are significant at the 95% confidence level. The comparisons are defined in Table 1.

| Comparisons | Fluxes | AGRB | PGRB |
|-------------|--------|------|------|
|              |        | p-value | p-value | p-value | p-value |
|              |        | t-test | Wilcoxon test | t-test | Wilcoxon test |
| C1          | Snowfall | 0.424 | 0.986 | 0.028 | 0.018 |
|             | Rainfall | **0.000** | **0.000** | 0.141 | 0.000 |
|             | Snowmelt | 0.525 | 0.109 | 0.303 | 0.922 |
|             | Firn melt | 0.540 | 0.181 | 0.741 | 0.552 |
|             | Ice melt | 0.437 | 0.859 | **0.000** | **0.000** |
|             | Runoff | 0.500 | 0.059 | **0.000** | **0.000** |
| C2          | Snowfall | **0.000** | **0.000** | **0.000** | **0.000** |
|             | Rainfall | **0.003** | **0.000** | 0.100 | **0.000** |
|             | Snowmelt | **0.000** | **0.000** | **0.028** | 0.262 |
|             | Firn melt | **0.029** | **0.027** | **0.001** | **0.000** |
|             | Ice melt | **0.000** | **0.000** | **0.000** | **0.000** |
|             | Runoff | **0.000** | **0.000** | **0.023** | 0.057 |
| C3          | Snowfall | 0.538 | 0.839 | 0.138 | 0.113 |
|             | Rainfall | **0.000** | **0.000** | 0.162 | **0.001** |
|             | Snowmelt | 0.312 | 0.097 | 0.604 | 0.897 |
|             | Firn melt | 0.460 | 0.125 | **0.003** | **0.002** |
|             | Ice melt | 0.336 | 0.072 | **0.000** | **0.000** |
|             | Runoff | 0.061 | **0.003** | **0.000** | **0.000** |
| C4          | Snowfall | 0.531 | 0.851 | 0.135 | 0.113 |
|             | Rainfall | **0.000** | **0.000** | 0.170 | **0.001** |
|             | Snowmelt | 0.265 | **0.013** | 0.496 | 0.613 |
|             | Firn melt | 0.453 | 0.160 | **0.002** | **0.000** |
|             | Ice melt | 0.346 | 0.078 | **0.000** | **0.000** |
|             | Runoff | **0.048** | **0.004** | **0.000** | **0.000** |
| C5          | Snowfall | **0.000** | **0.000** | **0.000** | **0.000** |
|             | Rainfall | 0.234 | **0.000** | 0.511 | **0.000** |
|             | Snowmelt | **0.000** | **0.003** | **0.006** | 0.288 |
|             | Firn melt | **0.035** | 0.062 | **0.000** | **0.000** |
|             | Ice melt | **0.000** | **0.000** | **0.000** | **0.000** |
|             | Runoff | **0.000** | **0.000** | **0.000** | **0.018** |
**Table S7: Results of Student’s t-test and Wilcoxon test for changes in glacier mass balances. Highlighted bold numbers are significant at 95% confidence level. The comparisons were as per the Scenarios defined in Table 1.**

| Comparisons | Mass Balance | AGRB | PGRB |  |
|--------------|--------------|------|------|---|
|              |              | Mean 1 (mm) | Mean 2 (mm) | Difference (mm) | Mean 1 (mm) | Mean 2 (mm) | Difference (mm) | p-value Wilcoxon test | p-value t-test | p-value Wilcoxon test | p-value t-test |  |
| C1 Winter    | 0.029        | 474   | 417   | -57 | 0.007 | 0.009 | 586   | 324   | -262 |
| Summer       | 0.796        | -176  | -133  | 43  | 0.123 | 0.149 | -857  | -1056 | -199 |
| Annual       | 0.579        | -701  | -716  | -15 | 0.029 | 0.019 | -271  | -733  | -462 |
| C2 Winter    | 0.280        | 474   | 447   | -27 | 0.043 | 0.059 | 586   | 401   | -185 |
| Summer       | 0.247        | -176  | -1083 | 93  | 0.123 | 0.249 | -857  | -709  | 148  |
| Annual       | 0.315        | -701  | -636  | 65  | 0.739 | 0.830 | -271  | -308  | -37  |
| C3 Winter    | 0.353        | 474   | 444   | -30 | 0.315 | 0.278 | 586   | 474   | -112 |
| Summer       | 0.481        | -176  | -1229 | -53 | 0.011 | 0.010 | -857  | -1306 | -449 |
| Annual       | 0.529        | -701  | -785  | -84 | 0.023 | 0.016 | -271  | -832  | -561 |
| C4 Winter    | 0.247        | 447   | 417   | -30 | 0.315 | 0.266 | 401   | 324   | -77  |
| Summer       | 0.481        | -1083 | -1133 | -50 | 0.007 | 0.008 | -709  | -1056 | -347 |
| Annual       | 0.529        | -636  | -716  | -80 | 0.023 | 0.014 | -308  | -733  | -425 |
| C5 Winter    | 0.218        | 444   | 417   | -27 | 0.089 | 0.075 | 474   | 324   | -150 |
| Summer       | 0.218        | -1229 | -1133 | 96  | 0.105 | 0.114 | -1306 | -1056 | 250  |
| Annual       | 0.436        | -785  | -716  | 69  | 0.481 | 0.625 | -832  | -733  | 99   |