**Supplementary materials for**

**Using beryllium-10 dating to determine when the Cordilleran Ice Sheet stopped flowing over the Canadian Rocky Mountains**

Helen E. Dulfer, Martin Margold, Zbynĕk Engel, Régis Braucher, and Aster

Team

**This pdf file includes:**

Section S1: Snow cover correction

**Other supplementary Material for this manuscript includes:**

Data file D1 (Excel format): Data input file.

Data file D2 (Excel format): Calculated dRSL values.

Data file D3 (Excel format): Recalculated 10Be cosmogenic nuclide ages.

Data file D4 (Excel format): Calculating the degree of scatter in ages.

**Section S1: Snow cover correction**

The monthly snow depth and density data used to calculate the snow shielding factor at each sample site is shown in the table below. The data for the months of January to May has been obtained from manual snow stations located at Mt Morfee (at the Mt Morfee sample site) and Monkman Creek (approx. 50 km south of the Mt Spieker sample site). The average snow depth for the months of October to December was estimated from the closest automated snow weather stations. The data is available for download from the provincial government of British Columbia at <https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=c15768bf73494f5da04b1aac6793bd2e> (Government of Canada, 2019).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Snow station** | **Location**  | **Elevation (m)** | **Measurement period** | **Month** | **Average snow depth (cm)** | **Average snow density (g/cm-3)** |
| **Mt. Morfee** | 55 25' N, 123 02' W | 1,430 | 1968 - 2019 | October | 100 | 0.3 |
| November | 107 | 0.3 |
| December | 109 | 0.3 |
| January  | 162 | 0.31 |
| February | 190 | 0.34 |
| March | 218 | 0.37 |
| April | 193 | 0.42 |
| May | 153 | 0.44 |
| **Monkman Creek** | 54 44' N, 121 13' W | 1,570 m | 1974 - 2019 | October | 60 | 0.3 |
| November | 67 | 0.3 |
| December | 69 | 0.3 |
| January | 120 | 0.3 |
| February | 147 | 0.31 |
| March | 164 | 0.34 |
| April | 157 | 0.38 |
| May | 129 | 0.42 |

**Calculation for snow shielding**

The annual snow shielding factor is calculated according to the equation below

$f\_{snow}= \frac{1}{12}\sum\_{i}^{12}e^{-(Z\_{snow}-Z\_{boulder})ρ\_{snow}/Λ}$ Gosse and Phillips (2001)

Where $Z\_{snow}$ is the monthly average snow height (cm), $ρ\_{snow}$ is the average monthly snow density (g/cm3), $Z\_{boulder}$ is the height (cm) of the sampled boulder and Λ is the attenuation length (g/cm2).

**Mt Morfee**

|  |
| --- |
| RM18-01 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 62 | 0.31 | 160 | 0.8868096 |
| Feb | 90 | 0.34 | 160 | 0.8259261 |
| Mar | 118 | 0.37 | 160 | 0.7611879 |
| Apr | 93 | 0.42 | 160 | 0.7833897 |
| May | 53 | 0.44 | 160 | 0.8643738 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 7 | 0.3 | 160 | 0.9869608 |
| Dec | 9 | 0.3 | 160 | 0.9832666 |
| $$f\_{snow}$$ |  |  |  | **0.924326** |

|  |
| --- |
| RM18-02 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 97 | 0.31 | 160 | 0.8286665 |
| Feb | 125 | 0.34 | 160 | 0.7667266 |
| Mar | 153 | 0.37 | 160 | 0.7020066 |
| Apr | 128 | 0.42 | 160 | 0.7146231 |
| May | 88 | 0.44 | 160 | 0.7850562 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 35 | 0.3 | 160 | 0.936482 |
| Nov | 42 | 0.3 | 160 | 0.924271 |
| Dec | 44 | 0.3 | 160 | 0.9208114 |
| $$f\_{snow}$$ |  |  |  | **0.881554** |

|  |
| --- |
| RM18-03 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 92 | 0.31 | 160 | 0.8367332 |
| Feb | 120 | 0.34 | 160 | 0.7749165 |
| Mar | 148 | 0.37 | 160 | 0.7101706 |
| Apr | 123 | 0.42 | 160 | 0.7240644 |
| May | 83 | 0.44 | 160 | 0.7959253 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 30 | 0.3 | 160 | 0.9453028 |
| Nov | 37 | 0.3 | 160 | 0.9329767 |
| Dec | 39 | 0.3 | 160 | 0.9294846 |
| $$f\_{snow}$$ |  |  |  | **0.887465** |

|  |
| --- |
| RM18-04 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 42 | 0.31 | 160 | 0.9218479 |
| Feb | 70 | 0.34 | 160 | 0.8617845 |
| Mar | 98 | 0.37 | 160 | 0.7972197 |
| Apr | 73 | 0.42 | 160 | 0.8256164 |
| May | 33 | 0.44 | 160 | 0.913246 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 0 | 0.3 | 160 | 1 |
| Dec | 0 | 0.3 | 160 | 1 |
| $$f\_{snow}$$ |  |  |  |  **0.94331** |

**Mt Spieker**

|  |
| --- |
| RM18-05 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 50 | 0.3 | 160 | 0.9105104 |
| Feb | 77 | 0.31 | 160 | 0.8614076 |
| Mar | 94 | 0.34 | 160 | 0.8189355 |
| Apr | 87 | 0.38 | 160 | 0.8133246 |
| May | 59 | 0.42 | 160 | 0.8565222 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 0 | 0.3 | 160 | 1 |
| Dec | 0 | 0.3 | 160 | 1 |
| $$f\_{snow}$$ |  |  |  | **0.938392** |

|  |
| --- |
| RM18-06 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 70 | 0.3 | 160 | 0.8769985 |
| Feb | 97 | 0.31 | 160 | 0.8286665 |
| Mar | 114 | 0.34 | 160 | 0.7848599 |
| Apr | 107 | 0.38 | 160 | 0.7755948 |
| May | 79 | 0.42 | 160 | 0.8127148 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 10 | 0.3 | 160 | 0.9814247 |
| Nov | 17 | 0.3 | 160 | 0.9686277 |
| Dec | 19 | 0.3 | 160 | 0.9650021 |
| $$f\_{snow}$$ |  |  |  | **0.916157** |

|  |
| --- |
| RM18-07 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 80 | 0.3 | 160 | 0.860708 |
| Feb | 107 | 0.31 | 160 | 0.8127656 |
| Mar | 124 | 0.34 | 160 | 0.7683576 |
| Apr | 117 | 0.38 | 160 | 0.7573915 |
| May | 89 | 0.42 | 160 | 0.7916586 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 20 | 0.3 | 160 | 0.9631944 |
| Nov | 27 | 0.3 | 160 | 0.9506351 |
| Dec | 29 | 0.3 | 160 | 0.9470769 |
| $$f\_{snow}$$ |  |  |  | **0.904316** |

|  |
| --- |
| RM18-08 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 85 | 0.3 | 160 | 0.8526765 |
| Feb | 112 | 0.31 | 160 | 0.80493 |
| Mar | 129 | 0.34 | 160 | 0.760237 |
| Apr | 122 | 0.38 | 160 | 0.7484507 |
| May | 94 | 0.42 | 160 | 0.781336 |
| Jun | 0 | 0 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 25 | 0.3 | 160 | 0.9542067 |
| Nov | 32 | 0.3 | 160 | 0.9417645 |
| Dec | 34 | 0.3 | 160 | 0.9382395 |
| $$f\_{snow}$$ |  |  |  | **0.898487** |

**Telkwa Range**

|  |
| --- |
| mar-10-08 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 60 | 0.26 | 160 | 0.9071023 |
| Feb | 90 | 0.29 | 160 | 0.849485 |
| Mar | 130 | 0.32 | 160 | 0.7710516 |
| Apr | 160 | 0.35 | 160 | 0.7046881 |
| May | 90 | 0.41 | 160 | 0.7940372 |
| Jun | 10 | 0.46 | 160 | 0.9716593 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 0 | 0.3 | 160 | 1 |
| Dec | 0 | 0.3 | 160 | 1 |
| $$f\_{snow}$$ |  |  |  | **0.916502** |

|  |
| --- |
| mar-10-11 AND 12 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 50 | 0.26 | 160 | 0.9219632 |
| Feb | 80 | 0.29 | 160 | 0.8650223 |
| Mar | 120 | 0.32 | 160 | 0.7866279 |
| Apr | 150 | 0.35 | 160 | 0.720273 |
| May | 80 | 0.41 | 160 | 0.8146473 |
| Jun | 0 | 0.46 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 0 | 0.3 | 160 | 1 |
| Dec | 0 | 0.3 | 160 | 1 |
| $$f\_{snow}$$ |  |  |  | **0.9257111** |

|  |
| --- |
| mar-10-13 |
| MONTH | $$Z\_{snow}-Z\_{boulder}$$(cm) | Ρ (g/cm^3) | Λ (g/cm^2) | $$f\_{snow}$$ |
| Jan | 20 | 0.26 | 160 | 0.9680224 |
| Feb | 50 | 0.29 | 160 | 0.9133602 |
| Mar | 90 | 0.32 | 160 | 0.8352702 |
| Apr | 120 | 0.35 | 160 | 0.7691264 |
| May | 50 | 0.41 | 160 | 0.8797434 |
| Jun | 0 | 0.46 | 160 | 1 |
| Jul | 0 | 0 | 160 | 1 |
| Aug | 0 | 0 | 160 | 1 |
| Sep | 0 | 0 | 160 | 1 |
| Oct | 0 | 0.3 | 160 | 1 |
| Nov | 0 | 0.3 | 160 | 1 |
| Dec | 0 | 0.3 | 160 | 1 |
| $$f\_{snow}$$ |  |  |  | **0.9471269** |

**References:**

Gosse, J.C., and Phillips, F.M., 2001. Terrestrial in situ cosmogenic nuclides: theory and application. *Quaternary Science Reviews* 20, 1475-1560.

Government of Canada, 2019. Snow stations interactive map. Available at https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=c15768bf73494f5da04b1aac6793bd2e. Accessed on 17 January 2020.