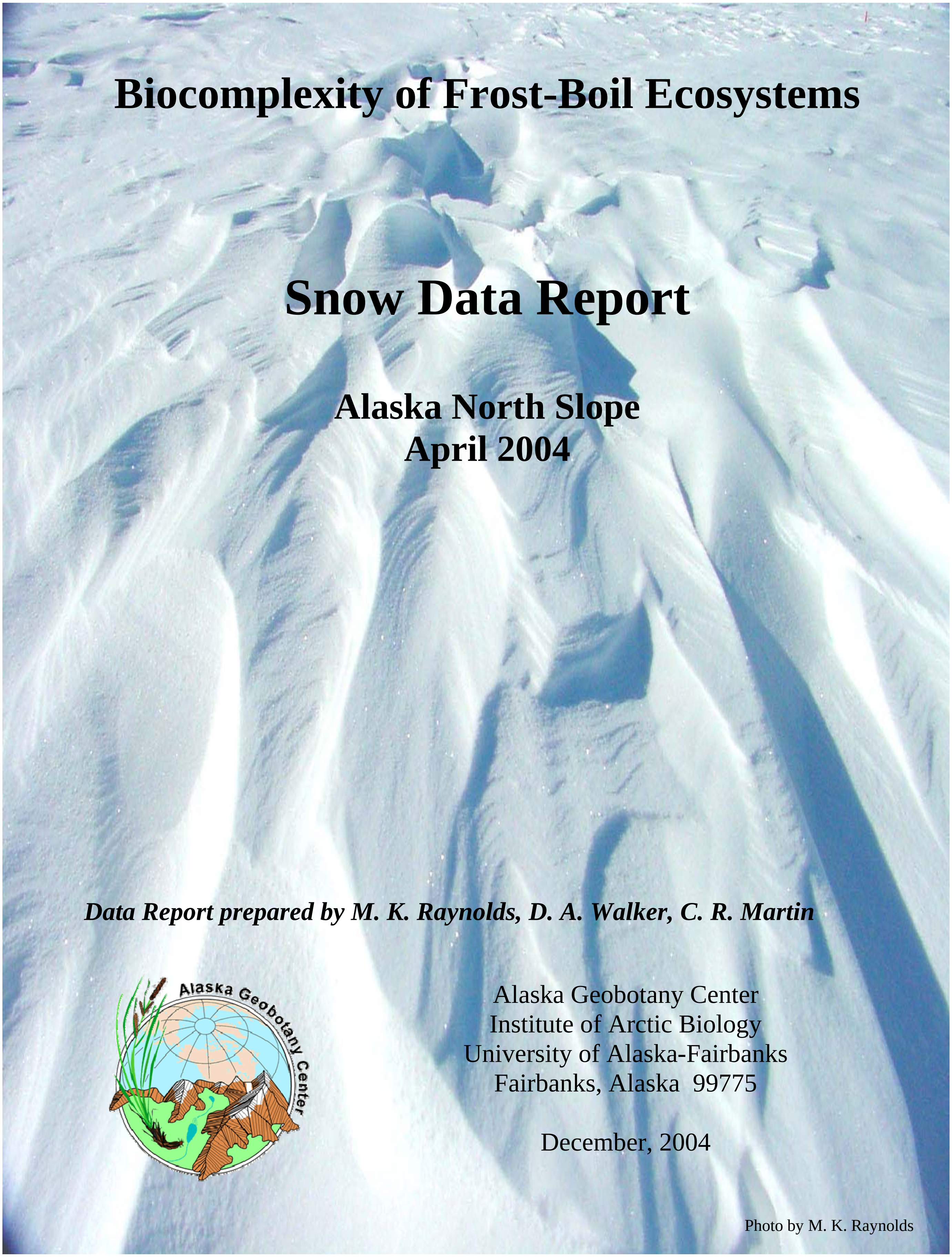

# Biocomplexity of Frost-Boil Ecosystems

# Snow Data Report

## Alaska North Slope
## April 2004

*Data Report prepared by M. K. Raynolds, D. A. Walker, C. R. Martin*

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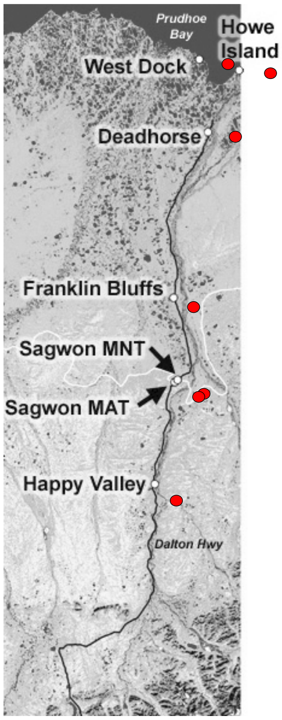
December, 2004

Photo by M. K. Raynolds

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# Alaska North Slope, April 2004

M. K. Raynolds, D. A. Walker, and C. R. Martin

## Introduction

This data report is a summary of snow-survey information collected during a trip to the Arctic Slope April 12-15, 2004. The data were all collected as part of the Biocomplexity of Frost-Boil Ecosystems study (Walker et al. 2004). Snow is an important factor affecting soil-surface temperatures during the winter. These data will be used to help model the influence of snow on frost heave.

Members of the survey team included Martha Raynolds, Anja Kade, and Christine Martin, all from the Alaska Geobotany Center and UAF student volunteer Nathan Shoutis, The data collected included

1. Snow depth and soil temperature information from 97 of the 117 permanent plots (relevés) that are part of a vegetation classification study.
2. Snow density and snow-water-equivalent (SWE) measurements from the midpoints of the four sides of each of ten 10x10-m grids at Happy Valley, Sagwon, Franklin Bluffs, and Deadhorse. We were not able to access the grids on B.P.-leased lands atWest Dock, and Howe Island, because we did not have B.P.'s "authorization to proceed".
3. Snow depths at every meter within each of the ten grids.
4. Snow profile descriptions from each of the ten grids.
5. Heave measurements from iron re-bar at relevé sites and V. Romanovsky heave meters
6. Snow depth measurements every 100 m within 1 x 1 km plot and at 45 permanent plots at Happy Valley.

Information from this data report and other information from the grids are available on the Alaska Geobotany Center web site: http://www.geobotany.uaf.edu/cryoturbation/index.html. Photos from the survey are in Appendix A.

## Methods

### Relevé snow depth

Snow depth was measured at each relevé at the plot marker using a stainless steel T-bar rod. One measurement was taken at each plot marker.

### Grid snow depths

Snow depth was measured at every meter in each grid (Appendix A, Photo 1). If the pin flag marking the grid point location was visible, the measurement was taken immediately adjacent to the pin flag. If the flag was buried by snow, a meter tape was stretched first between A1 and A11 and the snow depth measured at the meter intervals along the tape. The tape was then moved to the next row and the process repeated, until all the rows were completed. Appendix B contains the data sheet used for the grid snow depths. Snow depth maps of the grids were made using the program Transform PPC, version 3.4, by Fortner Software.

### Snow density and snow water equivalent (SWE) at the grids

Snow density and water equivalent were measured using a “federal sampler” with a cross section area of 11.464 $cm^2$ (Appendix A, Photo 2). One sample was taken at the midpoint of each side of the grids (4 samples per grid). The coring device had a toothed bit, and was inserted first to the soil surface to note the snow depth. It was then cored into the soil to the point where a small sample of soil was included in the core to keep the loose snow from falling out of the corer. The snow was removed from the corer, placed into a plastic bag and weighed (Appendix A, Photo 3). Appendix B contains the data sheets used for the data collection. The federal sampler was borrowed from Matthew Sturm, US Army CRREL, Ft. Wainwright, AK.

### Heave

Heave was measured at each of the relevés, and at the heave-meters installed by Vladimir Romanovsky adjacent to the grids (Appendix A, Photos 4, 5).

### Snow profiles

Snow trenches were dug at each grid, approximately 3 m long and 2 m wide. Snow surface characteristics were noted (roughness, nature of surface irregularities, depth of irregularities, average wavelength, and compass direction of sastrugi features). The various layers in the snow were described according to thickness of the layer, grain shape (Colbeck et al 1992), grain size (mm), and hardness (fist, 4 fingers, 1 finger, pencil, knife blade; Colbeck et al. 1992). See Appendix B for the snow profile data sheet and Appendix C for classification of snow characteristics.

### Happy Valley 1 x 1 km grid and permanent plots

During 22-24 April 2004, snow depths were measured every 100 m within a 1 x 1 km grid at Happy Valley. The large grid includes the dry, moist and wet 10 x 10 m grids. At each site, marked by a 2 m-tall plastic pipe, depth was measured at 4 sites around the stake. Snow depth at three sites could not be measured because seismic vehicle traffic had compacted the snow. Snow depths were also measured at permanent plots which had been subjectively chosen to represent the range of vegetation types occurring in the Happy Valley area. Forty-five of the original 55 permanent plots were located, and five depth measurements were taken at each plot, one at the stake marking the plot and four surrounding it.

## Results

Table 1 contains the relevé snow depths. Table 2 (a - j) contains the data and a summary of the mean snow depth, standard deviation, and standard error for each grid. Mean grid snow depths are shown in Figure 1. The deepest snow occurred at the Happy Valley moist and wet grids (mid- and toeslope, 69 and 68 cm, respectively), and the shallowest snow was at the Franklin Bluff dry grid (25 cm). Snow depths generally increased from the coast inland, but as in 2003, deeper snow was encountered at Deadhorse (52 cm). Maps of the snow depths on each grid are shown in Figure 5.

Snow density measurements of each grid are in Table 3 (a-f), and a summary of the average snow depths, snow densities and snow-water equivalents at the grids is in Table 4. The snow density was greatest at Deadhorse, and least at the Happy Valley wet grid (Figure 2). Snow water equivalent was plotted as a function of snow depth (Figure 3). Snow water equivalent was highest at the Happy Valley moist grid (where average snow depth was greatest), and at Deadhorse (where density was highest) (Figure 4).

Heave results are available from Anja Kade (for relevés) and Vladimir Romanovsky (for heave-meters).

Table 5 (a-e), contains the snow profile descriptions for the five sites samples. The Deadhorse site had depth hoar, which was thicker in the interboil (Appendix A, Photo 6). The difference in the depth hoar compensated for the difference in surface elevation between the frost boil and interboil areas. The survace had a 5-8 cm thick wind-packed slab. This slab resulted in the higher snow density values recorded at Deadhorse (Table 4). The Franklin Bluff site had less dense snow than Deadhorse, but the same pattern of shallower depth hoar on the frost boil was evident (Appendix A, Photo 7). The Happy Valley site had the deepest snow, with a 15 cm layer of metamorphosed crystals above the hoar frost layer (Appendix A, Photo 8).

Table 6 contains the snow depths measured on the 1 km x 1 km Happy Valley grid. The mean snow depth on the grid was 68.0 +/- 1.2 cm. A map of the snow depths is shown in Figure 6. Table 7 lists the snow depths measured at the permanent relevé plots at Happy Valley.

## Literature cited

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## Acknowledgements

Thanks to Anja Kade and Nathan Shoutis for data collection, and Matthew Sturm and Jon Holmgren for providing the sampling equipment and advice on sampling methods. Thanks to VECO for providing the logistic support. Funds for the data collection and report preparation came from the National Science Foundation grant no. OPP-0120736.

# Tables

**Table 1. Relevé snow depths , North Slope, 13-15 April 2004 (measured by Anja Kade).**

| Relevé | Location | Type | Snow depth (cm) | GPS (dd mm ss.s) |
|---|---|---|---|---|
| 106 | Deadhorse | bare frost boils | 16 | 70 09 37.0 148 28 07.1 |
| 49 | Deadhorse | interboil moist | 19 | 70 09 42.6 148 28 00.5 |
| 51 | Deadhorse | interboil moist | 20 | 70 09 38.2 148 28 08.1 |
| 105 | Deadhorse | interboil moist | 21 | 70 09 38.2 148 28 09.5 |
| 44 | Deadhorse | bare frost boils | 29 | 70 09 38.6 148 28 08.6 |
| 43 | Deadhorse | bare frost boils | 32 | 70 09 41.5 148 27 59.7 |
| 50 | Deadhorse | interboil moist | 38 | 70 09 38.3 148 28 09.2 |
| 41 | Deadhorse | vegetated boils | 40 | 70 09 41.9 148 27 59.5 |
| 45 | Deadhorse | bare frost boils | 40 | 70 09 42.5 148 28 00.0 |
| 48 | Deadhorse | interboil moist | 40 | 70 09 41.6 148 28 00.0 |
| 42 | Deadhorse | vegetated boils | 42 | 70 09 38.5 148 28 08.7 |
| 39 | Deadhorse | vegetated boils | 44 | 70 09 37.2 148 28 10.05 |
| 104 | Deadhorse | bare frost boils | 47 | 70 09 41.3 148 28 02.5 |
| 40 | Deadhorse | vegetated boils | 52 | 70 09 41.5 148 27 59.0 |
| 38 | Deadhorse | vegetated boils | 59 | 70 09 40.8 148 28 00.5 |
| 32 | Franklin Bluffs | vegetated boil, dry | 6 | 69 40 28.2 148 43 14.0 |
| 6 | Franklin Bluffs | bare boil, dry | 7 | 69 40 29 148 43 16 |
| 31 | Franklin Bluffs | bare boil, dry | 8 | 69 40 28.9 148 43 15.7 |
| 9 | Franklin Bluffs | bare boil, dry | 10 | 69 40 27.4 148 43 13.9 |
| 10 | Franklin Bluffs | bare boil, dry | 10 | 69 40 26.3 148 43 13.7 |
| 33 | Franklin Bluffs | bare boil, dry | 10 | 69 40 28.4 148 43 14.5 |
| 8 | Franklin Bluffs | vegetated boil, dry | 11 | 69 40 27.5 148 43 13.9 |
| 5 | Franklin Bluffs | vegetated boil, dry | 14 | 69 40 28 148 43 13 |
| 35 | Franklin Bluffs | interboil dry | 14 | 69 40 28.5 148 43 14.4 |
| 97 | Franklin Bluffs | vegetated boil, moist | 18 | 69 40 29.3 148 43 18.0 |
| 36 | Franklin Bluffs | bare boil, wet | 19 | 69 40 25.7 148 43 28.4 |
| 118 | Franklin Bluffs | bare boil, wet | 19 | 69 40 26.6 148 43 27.4 |
| 141 | Franklin Bluffs | vegetated boil, moist | 19 | 69 40 28.8 148 43 16.7 |
| 30 | Franklin Bluffs | vegetated boil, dry | 20 | 69 40 28.9 148 43 15.7 |
| 11 | Franklin Bluffs | interboil dry | 21 | 69 40 27.4 148 43 13.8 |
| 96 | Franklin Bluffs | vegetated boil, moist | 21 | 69 40 29.1 148 4318.4 |
| 117 | Franklin Bluffs | bare boil, wet | 22 | 69 40 26.1 148 43 29.0 |
| 142 | Franklin Bluffs | vegetated boil, moist | 22 | 69 40 29.3 148 43 17.8 |
| 34 | Franklin Bluffs | interboil dry | 28 | 69 40 28.9 148 43 14.8 |
| 140 | Franklin Bluffs | vegetated boil, moist | 29 | 69 40 28.8 148 43 19.1 |
| 7 | Franklin Bluffs | vegetated boil, dry | 30 | 69 40 30 148 43 16 |

**Table 1. (continued)**

| Relevé | Location | Type | Snow depth (cm) | GPS (dd mm ss.s) |
|---|---|---|---|---|
| 3 | Franklin Bluffs | bare boil, wet | 32 | 69 40 27.1 148 43 02.4 |
| 12 | Franklin Bluffs | interboil dry | 32 | 69 40 28 148 43 14 |
| 20 | Franklin Bluffs | interboil, moist | 33 | 69 40 29.5 148 43 18.2 |
| 19 | Franklin Bluffs | interboil, moist | 34 | 69 40 29.2 148 43 17.5 |
| 2 | Franklin Bluffs | bare boil, wet | 35 | 69 40 25.9 148 43 01.8 |
| 46 | Franklin Bluffs | interboil, moist | 36 | 69 40 28.4 148 43 16.5 |
| 1 | Franklin Bluffs | bare boil, wet | 37 | 69 40 26.7 148 42 58.4 |
| 13 | Franklin Bluffs | interboil dry | 41 | 69 40 29 148 43 15 |
| 37 | Franklin Bluffs | interboil wet | 41 | 69 40 25.9 148 43 28.8 |
| 47 | Franklin Bluffs | interboil, moist | 41 | 69 40 20.3 148 43 29.8 |
| 15 | Franklin Bluffs | interboil wet | 51 | 69 40 27.1 148 43 02.4 |
| 16 | Franklin Bluffs | interboil wet | 51 | 69 40 26.7 148 42 58.4 |
| 4 | Franklin Bluffs | bare boil, wet | 57 | 69 40 26.3 148 43 07.5 |
| 18 | Franklin Bluffs | interboil, moist | 57 | 69 40 28.4 148 43 18.2 |
| 14 | Franklin Bluffs | interboil wet | 67 | 69 40 25.9 148 43 01.8 |
| 17 | Franklin Bluffs | interboil wet | 83 | 69 40 26.3 148 43 07.5 |
| 70 | Sagwon MNT | bare boil | 32 | 69 25 56.1 148 40 19.3 |
| 63 | Sagwon MNT | bare boil | 34 | 69 25 58.8 148 40 23.1 |
| 61 | Sagwon MNT | vegetatated boil | 35 | 69 25 57.5 148 40 23.2 |
| 72 | Sagwon MNT | bare boil | 37 | 69 25 58.2 148 40 23.4 |
| 64 | Sagwon MNT | vegetatated boil | 39 | 69 25 58.3 148 40 23.8 |
| 68 | Sagwon MNT | interboil moist | 39 | 69 25 59.8 148 40 19.5 |
| 60 | Sagwon MNT | vegetatated boil | 40 | 69 25 59.3 148 40 21.7 |
| 29 | Sagwon MNT | interboil moist | 41 | 69 26 00.9 148 40 16.8 |
| 69 | Sagwon MNT | bare boil | 41 | 69 25 59.1 148 40 22.3 |
| 59 | Sagwon MNT | vegetatated boil | 42 | 69 25 58.8 148 40 23.8 |
| 71 | Sagwon MNT | bare boil | 44 | 69 25 56.5 148 40 21.6 |
| 55 | Sagwon MNT | interboil moist | 47 | 69 25 59.8 148 40 22.0 |
| 65 | Sagwon MNT | interboil moist | 47 | 69 25 58.5 148 40 23.3 |
| 67 | Sagwon MNT | interboil moist | 48 | 69 25 54.1 148 40 22.5 |
| 58 | Sagwon MNT | vegetatated boil | 62 | 69 25 58.7 148 40 23.9 |
| 73 | Sagwon MAT | vegetated boil (mound) | 18 | 69 25 32.1 148 41 44.3 |
| 80 | Sagwon MAT | vegetated boil (mound) | 20 | 69 25 33.1 148 41 51.1 |
| 78 | Sagwon MAT | vegetated boil (mound) | 22 | 69 25 33.2 148 41 43.2 |
| 74 | Sagwon MAT | vegetated boil (mound) | 24 | 69 25 32.2 148 41 43.2 |
| 76 | Sagwon MAT | vegetated boil (mound) | 29 | 69 25 32.4 148 41 43.6 |
| 62 | Sagwon MAT | interboil moist | 44 | 69 25 32.0 148 41 45.3 |
| 79 | Sagwon MAT | interboil moist | 44 | 69 25 33.0 148 41 44.9 |

**Table 1. (continued)**

| Relevé | Location | Type | Snow depth (cm) | GPS (dd mm ss.s) |
|---|---|---|---|---|
| 75 | Sagwon MAT | interboil moist | 45 | 69 25 32.0  148 41 43.5 |
| 77 | Sagwon MAT | interboil moist | 52 | 69 25 32.5  148 41 43.6 |
| 81 | Sagwon MAT | interboil moist | 53 | 69 25 33.2  148 41 51.2 |
| | | | | |
| 89 | Happy Valley | vegetated boil | 28 | 69 08 48.6  148 51 07.1 |
| 90 | Happy Valley | vegetated boil | 28 | 69 08 48.6  148 51 08.4 |
| 57 | Happy Valley | bare frost boil, wet | 32 | 69 08 49.1  148 50 49.3 |
| 91 | Happy Valley | vegetated boil | 33 | 69 08 48.2  148 51 07.8 |
| 88 | Happy Valley | vegetated boil | 43 | 69 08 48.7  148 51 05.9 |
| 92 | Happy Valley | vegetated boil | 43 | 69 08 47.6  148 51 08.5 |
| 82 | Happy Valley | vegetated boil (mound) | 55 | 69 08 48.7  148 50 54.3 |
| 94 | Happy Valley | vegetated boil (mound) | 55 | 69 08 48.7  148 50 54.0 |
| 93 | Happy Valley | vegetated boil (mound) | 60 | 69 08 48.9  148 50 53.0 |
| 52 | Happy Valley | bare frost boil, wet | 61 | 69 08 49.8  148 50 49.1 |
| 54 | Happy Valley | bare frost boil, wet | 63 | 69 08 48.8  148 50 49.7 |
| 56 | Happy Valley | bare frost boil, wet | 64 | 69 08 48.7 148 50 48.9 |
| 85 | Happy Valley | interboil moist | 65 | 69 08 49.4  148 50 52.4 |
| 53 | Happy Valley | bare frost boil, wet | 66 | 69 08 50.1  148 50 48.7 |
| 83 | Happy Valley | vegetated boil (mound) | 67 | 69 08 49.9  148 50 53.6 |
| 95 | Happy Valley | vegetated boil (mound) | 70 | 69 08 50.1  148 50 54.4 |
| 84 | Happy Valley | interboil moist | 71 | 69 08 49.1  148 50 52.9 |
| 87 | Happy Valley | interboil moist | 73 | 69 08 49.0  148 50 51.6 |
| 66 | Happy Valley | interboil moist | 77 | 69 08 48.6  148 50 52.4 |
| 86 | Happy Valley | interboil moist | 77 | 69 08 49.8  148 50 53.4 |

Remarks:  Relevés on Howe Island and West Dock were not accessible due to BP restrictions. Snow depths were measured next to plot markers.

**Table 2. Snow depth measurements (cm) on the 10 x 10 m Biocomplexity Grids, April 2004.**
Measurements were made at the pinflags when they were visible or at 1-m intervals along a tape stretched across the grid when the snow depth was deeper than the pin flag height.

**a) Location: Howe Island** No data gathered due to oilfield access denied.

**b) Location: West Dock** No data gathered due to oilfield access denied.

**c) Location: Deadhorse**
Photos: Roll 04-01:1 to 9 Date: 15 April 2004
Observers: Martha Raynolds, Nathan Shoutis Weather: sunny, no wind, 5 $^0$F, ice crystals in air

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 49 | 54 | 56 | 58 | 43 | 46 | 38 | 45 | 49 | 50 | 46 |
| J | 59 | 51 | 55 | 50 | 48 | 48 | 50 | 44 | 42 | 50 | 50 |
| I | 56 | 51 | 40 | 46 | 50 | 48 | 51 | 50 | 50 | 50 | 36 |
| H | 52 | 46 | 48 | 47 | 40 | 37 | 50 | 50 | 46 | 50 | 39 |
| G | 37 | 42 | 48 | 45 | 43 | 40 | 51 | 52 | 45 | 47 | 47 |
| F | 45 | 48 | 49 | 50 | 56 | 49 | 46 | 56 | 58 | 65 | 41 |
| E | 56 | 45 | 58 | 60 | 59 | 56 | 57 | 48 | 59 | 62 | 60 |
| D | 53 | 54 | 60 | 53 | 61 | 58 | 61 | 62 | 56 | 61 | 65 |
| C | 58 | 63 | 56 | 53 | 65 | 65 | 64 | 58 | 60 | 55 | 57 |
| B | 61 | 62 | 48 | 60 | 62 | 58 | 59 | 56 | 55 | 51 | 52 |
| A | 54 | 53 | 56 | 50 | 52 | 49 | 57 | 48 | 54 | 48 | 48 |

| | |
|---|---|
| mean = | 51.9 |
| SD = | 6.8 |
| n = | 121.0 |
| SE = | 0.6 |

**d) Location: Franklin Bluffs, dry**
Date: 14 April 2004
Observers: Nathan Shoutis, Christine Martin Weather: sunny, windy

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 39 | 29 | 34 | 22 | 32 | 29 | 24 | 31 | 26 | 20 | 25 |
| J | 46 | 32 | 38 | 30 | 38 | 30 | 29 | 31 | 24 | 21 | 22 |
| I | 50 | 31 | 21 | 37 | 34 | 33 | 24 | 14 | 20 | 18 | 12 |
| H | 49 | 37 | 22 | 25 | 35 | 33 | 23 | 11 | 17 | 21 | 19 |
| G | 40 | 41 | 34 | 25 | 33 | 14 | 22 | 29 | 25 | 18 | 20 |
| F | 28 | 33 | 27 | 33 | 34 | 22 | 13 | 26 | 17 | 19 | 26 |
| E | 32 | 33 | 32 | 27 | 33 | 23 | 27 | 26 | 28 | 25 | 18 |
| D | 27 | 20 | 18 | 10 | 20 | 22 | 18 | 14 | 32 | 37 | 13 |
| C | 33 | 26 | 27 | 18 | 25 | 19 | 26 | 19 | 28 | 31 | 20 |
| B | 24 | 18 | 18 | 9 | 22 | 12 | 19 | 23 | 20 | 17 | 13 |
| A | 7 | 17 | 21 | 19 | 19 | 19 | 22 | 30 | 19 | 10 | 10 |

| | |
|---|---|
| mean = | 24.9 |
| SD = | 8.4 |
| n = | 121.0 |
| SE = | 0.8 |

**Table 2. (continued)**

**e) <u>Location</u> Franklin Bluffs, moist**

<u>Date</u>: 14 April 2004
<u>Observers</u>: Nathan Shoutis, Christine Martin <u>Weather</u>: sunny, still

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 22 | 25 | 33 | 31 | 18 | 41 | 38 | 46 | 33 | 36 | 48 | | |
| J | 24 | 29 | 24 | 39 | 34 | 28 | 39 | 46 | 52 | 52 | 55 | | |
| I | 28 | 28 | 35 | 34 | 32 | 48 | 47 | 50 | 55 | 46 | 39 | mean = | 39.1 |
| H | 40 | 35 | 46 | 28 | 31 | 45 | 48 | 47 | 58 | 38 | 34 | SD = | 8.6 |
| G | 39 | 36 | 28 | 39 | 39 | 34 | 44 | 51 | 36 | 34 | 48 | n = | 121 |
| F | 43 | 39 | 42 | 40 | 37 | 54 | 48 | 50 | 35 | 45 | 43 | SE = | 0.8 |
| E | 37 | 35 | 49 | 38 | 51 | 39 | 37 | 51 | 25 | 42 | 54 | | |
| D | 29 | 33 | 47 | 49 | 34 | 40 | 43 | 44 | 46 | 48 | 40 | | |
| C | 26 | 25 | 19 | 41 | 31 | 39 | 50 | 42 | 33 | 48 | 46 | | |
| B | 31 | 36 | 32 | 41 | 34 | 47 | 33 | 47 | 26 | 35 | 35 | | |
| A | 34 | 40 | 39 | 48 | 43 | 49 | 23 | 33 | 48 | 31 | 41 | | |

**f) <u>Location</u>: Franklin Bluffs, wet**

<u>Date</u>: 14 April 2004
<u>Observers</u>: Nathan Shoutis, Christine Martin <u>Weather</u>: sunny, still

| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K** | 28 | 29 | 25 | 39 | 44 | 44 | 47 | 45 | 40 | 44 | 34 | | |
| **J** | 29 | 30 | 34 | 39 | 45 | 48 | 49 | 41 | 42 | 47 | 43 | | |
| **I** | 39 | 38 | 37 | 40 | 48 | 53 | 48 | 44 | 41 | 41 | 44 | mean = | 43.2 |
| **H** | 42 | 35 | 32 | 33 | 42 | 49 | 49 | 48 | 41 | 42 | 39 | SD = | 7.5 |
| **G** | 41 | 35 | 32 | 31 | 42 | 46 | 48 | 45 | 33 | 37 | 27 | n = | 121 |
| **F** | 38 | 42 | 39 | 39 | 44 | 46 | 44 | 32 | 33 | 30 | 40 | SE = | 0.7 |
| **E** | 46 | 48 | 40 | 38 | 39 | 47 | 43 | 41 | 32 | 26 | 36 | | |
| **D** | 48 | 46 | 42 | 47 | 43 | 48 | 31 | 42 | 47 | 40 | 46 | | |
| **C** | 46 | 44 | 47 | 46 | 45 | 46 | 42 | 47 | 50 | 53 | 47 | | |
| **B** | 52 | 50 | 47 | 51 | 50 | 52 | 59 | 64 | 52 | 57 | 50 | | |
| **A** | 49 | 52 | 51 | 49 | 61 | 56 | 53 | 53 | 52 | 48 | 53 | | |

**Table 2. (cont.)**

**g) Location: Sagwon grid: MNT-1 (old)**

Date: 14 April 2004

Observers: Nathan Shoutis, Christine Martin

Weather: sunny, slight wind, -5 $^0$ C

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K** | 29 | 41 | 39 | 41 | 37 | 44 | 23 | 38 | 28 | 26 | 32 | | |
| **J** | 48 | 49 | 52 | 34 | 36 | 49 | 41 | 37 | 30 | 42 | 39 | | |
| **I** | 46 | 52 | 65 | 55 | 58 | 42 | 53 | 36 | 38 | 35 | 42 | mean = | 48.0 |
| **H** | 51 | 51 | 48 | 59 | 42 | 51 | 54 | 40 | 37 | 40 | 32 | SD = | 9.0 |
| **G** | 46 | 51 | 60 | 59 | 47 | 54 | 43 | 54 | 45 | 53 | 61 | n = | 121 |
| **F** | 37 | 46 | 64 | 42 | 64 | 46 | 63 | 57 | 43 | 48 | 56 | SE = | 0.8 |
| **E** | 50 | 54 | 43 | 53 | 48 | 56 | 60 | 61 | 49 | 45 | 60 | | |
| **D** | 54 | 49 | 58 | 40 | 59 | 60 | 52 | 50 | 46 | 60 | 51 | | |
| **C** | 63 | 38 | 55 | 51 | 47 | 49 | 51 | 54 | 53 | 58 | 44 | | |
| **B** | 48 | 52 | 53 | 51 | 44 | 47 | 55 | 60 | 65 | 52 | 42 | | |
| **A** | 40 | 50 | 48 | 36 | 51 | 45 | 55 | 44 | 46 | 45 | 56 | | |

**h) Location: Sagwon grid: MNT 2 (new)**

Date: 14 April 2004

Observers: Nathan Shoutis, Christine Martin, Martha Raynolds, Anja Kade

Weather: sunny, slight wind -5˚ C

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K** | 28 | 34 | 43 | 44 | 54 | 31 | 41 | 60 | 61 | 55 | 55 | | |
| **J** | 45 | 45 | 21 | 40 | 35 | 32 | 56 | 41 | 51 | 54 | 59 | | |
| **I** | 40 | 42 | 33 | 30 | 39 | 52 | 41 | 50 | 62 | 38 | 50 | mean = | 45.1 |
| **H** | 32 | 31 | 38 | 40 | 49 | 44 | 58 | 51 | 45 | 48 | 40 | SD = | 8.9 |
| **G** | 28 | 41 | 46 | 35 | 43 | 51 | 43 | 54 | 58 | 46 | 44 | n = | 121 |
| **F** | 35 | 45 | 44 | 37 | 44 | 36 | 42 | 52 | 37 | 54 | 34 | SE = | 0.8 |
| **E** | 37 | 39 | 39 | 46 | 41 | 42 | 39 | 56 | 47 | 56 | 35 | | |
| **D** | 47 | 57 | 50 | 52 | 56 | 45 | 54 | 49 | 38 | 72 | 41 | | |
| **C** | 39 | 50 | 35 | 52 | 40 | 48 | 42 | 49 | 34 | 40 | 36 | | |
| **B** | 42 | 49 | 46 | 60 | 61 | 54 | 49 | 48 | 48 | 34 | 47 | | |
| **A** | 51 | 38 | 43 | 41 | 66 | 58 | 50 | 44 | 44 | 55 | 36 | | |

Remarks: Grid is oriented incorrectly, N is to left (not up).

**Table 2. (cont.)**

**i) Location: Sagwon MAT**

Date: 16 April 2004

Observers: Nathan Shoutis, Martha Raynolds
Weather: sunny, 10 mph breeze

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 34 | 43 | 39 | 41 | 43 | 38 | 48 | 50 | 67 | 63 | 52 | | |
| J | 36 | 48 | 60 | 43 | 48 | 40 | 47 | 51 | 48 | 49 | 58 | | |
| I | 38 | 30 | 31 | 46 | 30 | 49 | 51 | 50 | 50 | 52 | 49 | mean = | 47.4 |
| H | 42 | 51 | 46 | 54 | 51 | 56 | 30 | 56 | 57 | 52 | 49 | SD = | 8.2 |
| G | 33 | 45 | 38 | 45 | 54 | 50 | 51 | 40 | 52 | 49 | 42 | n = | 121 |
| F | 32 | 52 | 44 | 36 | 42 | 56 | 58 | 49 | 54 | 53 | 55 | SE = | 0.7 |
| E | 41 | 22 | 47 | 46 | 50 | 50 | 52 | 51 | 53 | 51 | 50 | | |
| D | 40 | 42 | 56 | 41 | 55 | 53 | 61 | 41 | 51 | 49 | 49 | | |
| C | 41 | 42 | 35 | 39 | 41 | 55 | 47 | 48 | 43 | 44 | 48 | | |
| B | 48 | 48 | 57 | 40 | 56 | 59 | 48 | 49 | 55 | 55 | 51 | | |
| A | 42 | 24 | 36 | 55 | 59 | 53 | 56 | 42 | 56 | 58 | 60 | | |

**j) Location: Happy Valley grid: Hilltop (dry)**

Date: 16 April 2004

Observers: Nathan Shoutis, Martha Raynolds
Weather: sunny, slight breeze

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 35 | 29 | 52 | 57 | 44 | 39 | 49 | 38 | 36 | 43 | 48 | | |
| J | 59 | 52 | 51 | 41 | 48 | 61 | 49 | 51 | 53 | 61 | 45 | | |
| I | 42 | 39 | 46 | 46 | 58 | 35 | 44 | 36 | 33 | 55 | 55 | mean = | 50.3 |
| H | 47 | 55 | 50 | 49 | 51 | 37 | 44 | 43 | 56 | 48 | 50 | SD = | 7.7 |
| G | 51 | 49 | 50 | 59 | 54 | 44 | 53 | 30 | 50 | 51 | 53 | n = | 121 |
| F | 47 | 58 | 50 | 48 | 48 | 50 | 49 | 51 | 50 | 64 | 68 | SE = | 0.7 |
| E | 58 | 35 | 54 | 58 | 47 | 53 | 51 | 53 | 55 | 68 | 50 | | |
| D | 48 | 49 | 48 | 51 | 56 | 42 | 43 | 55 | 60 | 55 | 63 | | |
| C | 50 | 37 | 58 | 53 | 45 | 59 | 48 | 55 | 53 | 60 | 44 | | |
| B | 52 | 56 | 58 | 54 | 39 | 57 | 40 | 48 | 47 | 60 | 60 | | |
| A | 51 | 59 | 55 | 58 | 55 | 50 | 57 | 47 | 53 | 60 | 64 | | |

**Table 2. (cont.)**

**k) Location: Happy Valley grid: Mid-slope (moist)**

Date: 16 April 2004
Observers: Nathan Shoutis, Martha Raynolds
Weather sunny, slight breeze

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 78 | 75 | 75 | 64 | 52 | 65 | 72 | 61 | 74 | 61 | 58 | | |
| J | 79 | 73 | 62 | 65 | 72 | 73 | 71 | 66 | 64 | 73 | 75 | | |
| I | 73 | 68 | 60 | 77 | 66 | 65 | 71 | 71 | 81 | 75 | 70 | mean = | 68.9 |
| H | 71 | 61 | 61 | 76 | 72 | 69 | 80 | 77 | 62 | 42 | 60 | SD = | 7.2 |
| G | 66 | 71 | 79 | 81 | 78 | 67 | 70 | 82 | 77 | 54 | 75 | n = | 121 |
| F | 56 | 70 | 79 | 66 | 79 | 66 | 66 | 63 | 64 | 59 | 72 | SE = | 0.7 |
| E | 75 | 73 | 77 | 70 | 73 | 66 | 74 | 68 | 71 | 60 | 69 | | |
| D | 81 | 70 | 82 | 64 | 75 | 69 | 62 | 69 | 56 | 68 | 61 | | |
| C | 85 | 74 | 77 | 71 | 68 | 57 | 61 | 65 | 66 | 66 | 60 | | |
| B | 69 | 75 | 65 | 76 | 62 | 63 | 65 | 73 | 67 | 62 | 62 | | |
| A | 77 | 72 | 69 | 77 | 63 | 68 | 67 | 64 | 72 | 67 | 62 | | |

**l) Location: Happy Valley, grid: Toe slope (wet)**

Date: 16 April 2004
Observers: Nathan Shoutis, Martha Raynolds
Weather: sunny, slight breeze

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K | 78 | 78 | 64 | 71 | 78 | 56 | 60 | 63 | 71 | 63 | 67 | | |
| J | 62 | 71 | 70 | 76 | 72 | 60 | 71 | 64 | 70 | 63 | 63 | | |
| I | 53 | 71 | 78 | 74 | 83 | 84 | 79 | 59 | 64 | 71 | 62 | mean = | 67.1 |
| H | 71 | 77 | 71 | 62 | 60 | 79 | 65 | 65 | 77 | 61 | 65 | SD = | 6.6 |
| G | 69 | 62 | 52 | 67 | 68 | 77 | 62 | 62 | 53 | 58 | 62 | n = | 121 |
| F | 77 | 67 | 73 | 74 | 61 | 65 | 69 | 66 | 58 | 74 | 72 | SE = | 0.6 |
| E | 64 | 65 | 68 | 75 | 78 | 67 | 66 | 61 | 69 | 64 | 74 | | |
| D | 63 | 65 | 63 | 60 | 72 | 63 | 65 | 77 | 67 | 56 | 62 | | |
| C | 65 | 68 | 62 | 62 | 63 | 61 | 76 | 72 | 73 | 74 | 67 | | |
| B | 65 | 65 | 73 | 63 | 59 | 70 | 66 | 71 | 66 | 60 | 51 | | |
| A | 58 | 67 | 72 | 67 | 68 | 64 | 70 | 68 | 62 | 68 | 64 | | |

**Table 3. Detailed depth and density measured on the four sides of the 10 x 10 m Biocomplexity grids, April 2004.**

Density was measured with a Federal snow corer (cross-sectional area of 11.464 $cm^2$). For sites listing more than one measurement, density was obtained by averaging the depths and weights before calculating the snow density.

**a) Location: Howe Island** No data gathered due to oilfield access denied.

**b) Location: West Dock** No data gathered due to oilfield access denied.

**c) Location: Deadhorse**

Observers: Martha Raynolds, Nathan Shoutis Date: 14 April 2004

| Site | Orientation | Snow depth (cm) | Snow weight (g) | Snow density ($g/cm^3$) |
|---|---|---|---|---|
| **DH** | N | 40 | 154 | 0.34 |
| | E | (58, 53) | (227, 204) | 0.34 |
| | S | 59 | 240 | 0.35 |
| | W | 53 | 160 | 0.26 |
| ***site average:*** | | | | ***0.32*** |

**d) Location: Franklin Bluffs**

Observer: Martha Raynolds Date: April 13, 2004

| Site | Orientation | next to | Snow depth (cm) | Snow weight (g) | Snow density($g/cm^3$) |
|---|---|---|---|---|---|
| **FB dry** | N | K5 | 35 | 123 | 0.31 |
| | E | F11 | (42, 41) | (145, 136) | 0.30 |
| | S | A5 | 24 | 70 | 0.25 |
| | W | F1 | (30, 29) | (97, 98) | 0.29 |
| ***site average*** | | | | | ***0.29*** |
| **FB moist** | N | K5 | (30,31) | (71, 83) | 0.22 |
| | E | F11 | 42 | 127 | 0.26 |
| | S | A5 | 38 | 101 | 0.23 |
| | W | F1 | 36 | 91 | 0.22 |
| ***site average*** | | | | | ***0.23*** |
| **FB wet** | N | K5 | (48, 48) | (192, 183) | 0.34 |
| | E | F11 | (40,42,41) | (174, 135,153) | 0.33 |
| | S | A5 | (42, 43) | (105, 100) | 0.21 |
| | W | F1 | (40, 41) | (108, 117) | 0.24 |
| ***site average:*** | | | | | ***0.28*** |

**Table 3.** (continued)

**e) <u>Location</u>: Sagwon MNT**

<u>Observer</u>: Martha Raynolds    <u>Date</u>: 13 April 2004

| Site | Orientation | next to | Snow depth (cm) | Snow weight (g) | Snow density(g/cm$^3$) |
|---|---|---|---|---|---|
| **SagMNT1** | N | K5 | (31, 31) | (102, 108) | 0.30 |
| | E | F11 | (50, 46, 46) | (196, 159, 169) | 0.32 |
| | S | A5 | (50, 45) | (151, 152) | 0.28 |
| | W | F1 | 60 | 216 | 0.31 |
| ***site average:*** | | | | | ***0.30*** |
| **SagMNT2** | N | F1 | (30, 29) | (70, 75) | 0.21 |
| | E | K5 | (44, 43) | (163, 150) | 0.31 |
| | S | F11 | (35, 36) | (105, 119) | 0.28 |
| | W | A5 | 29 | 116 | 0.35 |
| ***site average:*** | | | | | ***0.29*** |
| **Sagwon MAT** | N | F11 | 35 | 100 | 0.25 |
| | E | A5 | 45 | 115 | 0.22 |
| | S | F11 | 46 | 132 | 0.25 |
| | W | K5 | 39 | 101 | 0.23 |
| ***site average:*** | | | | | ***0.24*** |

**f) <u>Location</u>: Happy Valley**

<u>Observer</u>: Christine Martin    <u>Date</u>: April 15, 2004

| Site | Orientation | next to | Snow depth (cm) | Snow weight (g) | Snow density(g/cm$^3$) |
|---|---|---|---|---|---|
| **HV dry** | N | K5 | 48 | 109 | 0.20 |
| | E | F11 | 45 | 137 | 0.27 |
| | S | A5 | 29 | 112 | 0.34 |
| | W | F1 | 38 | 99 | 0.23 |
| ***site average:*** | | | | | ***0.26*** |
| **HV moist** | N | K5 | 66 | 200 | 0.26 |
| | E | F11 | 70 | 252 | 0.31 |
| | S | A5 | 66 | 190 | 0.25 |
| | W | F1 | 61 | 175 | 0.25 |
| ***site average:*** | | | | | ***0.27*** |
| **HV wet** | N | K5 | 66 | 165 | 0.22 |
| | E | F11 | 49 | 141 | 0.25 |
| | S | A5 | 71 | 162 | 0.20 |
| | W | F1 | 57 | 127 | .19 |
| ***site average:*** | | | | | ***0.22*** |

**Table 4. Depth, snow water equivalent (SWE), and snow density at the Biocomplexity grids, April 2004.**

| Site | depth (cm) ± s.e. | density ($g/cm^3$) ± s.e. | SWE snow-water equivalent $cm^3$ (density*depth) ± s.e. |
|---|---|---|---|
| DH | 51.9 ± 4.4 | 0.32 ± 0.02 | 16.8 ± 1.8 |
| FBd | 32.5 ± 3.7 | 0.29 ± 0.01 | 9.4 ± 1.3 |
| FBm | 36.6 ± 2.4 | 0.23 ± 0.01 | 8.6 ± 0.9 |
| FBw | 43.0 ± 1.7 | 0.28 ± 0.03 | 12.1 ± 1.7 |
| SN1 | 46.5 ± 5.9 | 0.30 ± 0.01 | 14.1 ± 2.0 |
| SN2 | 34.4 ± 3.4 | 0.29 ± 0.03 | 10.0 ± 1.5 |
| SA | 41.3 ± 2.6 | 0.24 ± 0.01 | 9.8 ± 0.7 |
| HVd | 40.0 ± 4.2 | 0.26 ± 0.03 | 10.0 ± 0.7 |
| HVm | 65.8 ± 1.8 | 0.27 ± 0.02 | 17.8 ± 1.5 |
| HVw | 60.8 ± 4.9 | 0.22 ± 0.01 | 13.0 ± 0.8 |

Remarks:
Measurements taken at 4 sides of each grid.

**Table 5. Snow profiles at Biocomplexity grids, April 2004.**

a) **Location: Deadhorse** Observer: Anja Kade Date: 14 April 2004
Sky conditions: clear Air temperature: -20°C
Snow surface: rippled, sastrugi Snow depth (cm): boil = 27, interboil = 39
Surface roughness: random furrows, 15 cm depth, 4 m between ridges, E-W direction

| Layer thickness (cm) | Grain shape | Grain size (mm) | Density ($g/cm^3$) | Temp (°C) | Hardness index | Remarks |
|---|---|---|---|---|---|---|
| **Frost boil** | | | | | | |
| 0-7 | Hollow cup crystal | 7 | | -19 | Fist | Depth hoar |
| 7-12 | Rounded poly-crystal | 1-2 | | -21 | Knife | Wind slab? Refrozen! |
| 12-27 | Small rounded particle | 0.5 | 0.38 | -25 | 1 finger | |
| | | | | | | |
| **Interboil** | | | | | | |
| 0-12 | Hollow cup crystal | 7 | | -19 | Fist | Depth hoar |
| 12-20 | Rounded poly-crystal | 1-2 | | -21 | Knife | Hard layer, some metamorphosis |
| 20-39 | Small rounded particle | 0.5 | 0.38 | -25 | 1 finger | |

**Table 5 (continued)**

b) **<u>Location:</u> Franklin Bluffs moist grid** <u>Observer</u>: Anja Kade <u>Date:</u> 13 April 2004
<u>Sky conditions:</u> no clouds, little wind, sunny <u>Air temperature</u>: -13$^{o}$C
<u>Snow surface:</u> sastrugi <u>Snow depth (cm):</u> boil = 24, interboil = 36
<u>Surface roughness:</u> random furrows, 5 cm depth, 1 m between ridges, E-W direction

| Layer thickness (cm) | Grain shape | Grain size (mm) | Density (g/cm$^3$) | Temp ($^{o}$C) | Hardness index | Remarks |
|---|---|---|---|---|---|---|
| **Frost boil** | | | | | | |
| 0-2 | Faceted with recent rounding | 2 | | -16 | Pencil | Hard - particles frozen together |
| 2-23 | Rounded particles with few facetsl\ | 1 | | -18 | Fist | Main snow pack |
| 23-24 | Wind crust - well sintered particles | 0.5 | 0.26 | -12 | 4 finger | Soft slab |
| | | | | | | |
| **Interboil** | | | | | | |
| 0-9 | Hollow cup crystal | 7 | | -16 | Fist | Depth hoar |
| 9-13 | Hollow cup crystal | 5 | | -16 | 1 finger | Refrozen depth hoar |
| 13-34 | Rounded particles with few facets | 1 | | -18 | fist | Main snow pack |
| 34-36 | Wind crust - well sintered particles | 0.5 | 0.26 | -12 | 4 finger | Soft slab |

c) **<u>Location:</u> Sagwon MNT 1** <u>Observer</u>: Anja Kade <u>Date:</u> 13 April 2004
<u>Sky conditions:</u> sunny, mild <u>Air temperature</u>: -3$^{o}$C
<u>Snow surface:</u> pitted <u>Snow depth (cm):</u> 42
<u>Surface roughness:</u> smooth overall with random furrows, 2 cm depth, 0.5 m between ridges, E-W direction

| Layer thickness (cm) | Grain shape | Grain size (mm) | Density (g/cm$^3$) | Temp ($^{o}$C) | Hardness index | Remarks |
|---|---|---|---|---|---|---|
| 0-6 | Hollow cup crystal | 8 | | -14 | Fist | Loose depth hoar |
| 6-8 | Rounded particles with few facets | 2 | | -15 | Knife | Hard layer |
| 8-11 | Hollow cup crystal | 7 | | -14 | fist | Some loose depth hoar |
| 11-19 | Faceted with recent rounding | 2 | 0.33 | -13 | 4 fingers | Some plates, signs of metamorphosis |
| 19-42 | Well-rounded particles | 0.5-1 | 0.37 | -13 | pencil | |

**Table 5 (continued)**

**<u>Location:</u> Sagwon MAT** Observer: Anja Kade Date: 15 April 2004

Sky conditions: clear Air temperature: -9°C

Snow surface: rippled Snow depth (cm): 43

Surface roughness: random furrows, 4 cm depth, 0.4 m between ridges, E-W direction

| Layer thickness (cm) | Grain shape | Grain size (mm) | Density ($g/cm^3$) | Temp (°C) | Hardness index | Remarks |
|---|---|---|---|---|---|---|
| 0-16 | Large cup-shaped hollow crystals in columns | 10-20 | 0.26 | -14 | 4 fingers | Depth hoar, clustered in columns |
| 16-22 | Faceted with recent rounding | 2 | | -14 | Pencil | Hard windslab |
| 22 | Horizontal buried ice layer | | | | | Ice layer, 0.5 cm thick |
| 22-28 | Hollow cup crystal | 7 | | -13 | 4 fingers | Depth hoar |
| 28-30 | Faceted with recent rounding | 2 | | -12 | pencil | Hard windslab |
| 30-43 | Well-rounded particles | 1 | 0.29 | -11 | 4 fingers | Same surface snow as other sites |

d) **<u>Location:</u> Happy Valley** Observer: Anja Kade Date: 15 April 2004

Sky conditions: sunny, mild Air temperature: -5°C

Snow surface: smooth with few ripples Snow depth (cm): 65

Surface roughness: smooth with slight E-W ridges, 5 cm depth

| Layer thickness (cm) | Grain shape | Grain size (mm) | Density ($g/cm^3$) | Temp (°C) | Hardness index | Remarks |
|---|---|---|---|---|---|---|
| 0-20 | Hollow cup crystal, some arranged in columns | 8 | 0.29 | -10 | 4 fingers | Depth hoar |
| 20-34 | Hollow cup crytals and columns | 1 | 0.31 | -11 | Fist | Metamorphosed crystals, but more compact and less "refrozen" than depth hoar |
| 34-64 | Well-rounded particles | 1 | 0.29 | -13 | 4 fingers | Same surface snow as other sites |
| 64-65 | Surface hoar frost | 3 | | -7 | Fist | Very pretty surface hoar |

**Table 6. Snow depths at Happy Valley 1 x 1 km grid, April 2004.**

| Northing | Easting | Stake | 1 | 2 | 3 | 4 | Mean | S.E | Northing | Easting | Stake | 1 | 2 | 3 | 4 | Mean | S.E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7,671,500 | 426,000 | 90 | 92 | 89 | 88 | 90 | 90 | 0.7 | 7,672,000 | 426,500 | 84 | 81 | 82 | 85 | 86 | 84 | 0.9 |
| 7,671,500 | 426,100 | 78 | 77 | 73 | 75 | 60 | 73 | 3.3 | 7,672,000 | 426,600 | 48 | 51 | 61 | 54 | 53 | 53 | 2.2 |
| 7,671,500 | 426,200 | 50 | 69 | 70 | 72 | 62 | 65 | 4.0 | 7,672,000 | 426,700 | 72 | 74 | 87 | 75 | 64 | 74 | 3.7 |
| 7,671,500 | 426,300 | 80 | 77 | 79 | 73 | 78 | 77 | 1.2 | 7,672,000 | 426,800 | 57 | 53 | 53 | 58 | 52 | 55 | 1.2 |
| 7,671,500 | 426,400 | 50 | 60 | 62 | 67 | 60 | 60 | 2.8 | 7,672,000 | 426,900 | 94 | 100 | 120 | 100 | 107 | 104 | 4.5 |
| 7,671,500 | 426,500 | 68 | 64 | 70 | 72 | 73 | 69 | 1.6 | 7,672,100 | 427,000 | 68 | 66 | 64 | 66 | 74 | 68 | 1.7 |
| 7,671,500 | 426,600 | 83 | 80 | 69 | 70 | 73 | 75 | 2.8 | 7,672,100 | 426,000 | 67 | 73 | 73 | 65 | 64 | 68 | 1.9 |
| 7,671,500 | 426,700 | 76 | 76 | 76 | 75 | 69 | 74 | 1.4 | 7,672,100 | 426,100 | 83 | 72 | 76 | 71 | 79 | 76 | 2.2 |
| 7,671,500 | 426,800 | 52 | 62 | 63 | 68 | 67 | 62 | 2.8 | 7,672,100 | 426,200 | 60cm 4m N of stake | | | Destroyed by seismic train | | | |
| 7,671,500 | 426,900 | 132 | 130 | 117 | 136 | 126 | 128 | 3.2 | 7,672,100 | 426,300 | 72 | 83 | 67 | 70 | 85 | 75 | 3.6 |
| 7,671,500 | 427,000 | 57 | 35 | 53 | 47 | 37 | 46 | 4.3 | 7,672,100 | 426,400 | 85 | 84 | 84 | 81 | 73 | 81 | 2.2 |
| 7,671,600 | 426,000 | 100 | 105 | 102 | 89 | 99 | 99 | 2.7 | 7,672,100 | 426,500 | 43 | 55 | 48 | 45 | 59 | 50 | 3.0 |
| 7,671,600 | 426,100 | 74 | 84 | 82 | 84 | 84 | 82 | 1.9 | 7,672,100 | 426,600 | 67 | 65 | 55 | 61 | 61 | 62 | 2.1 |
| 7,671,600 | 426,200 | 60 | 60 | 56 | 56 | 58 | 58 | 0.9 | 7,672,100 | 426,700 | 72 | 65 | 72 | 63 | 70 | 68 | 1.9 |
| 7,671,600 | 426,300 | 68 | 71 | 65 | 68 | 68 | 68 | 0.9 | 7,672,100 | 426,800 | 53 | 46 | 62 | 55 | 65 | 56 | 3.4 |
| 7,671,600 | 426,400 | 72 | 72 | 72 | 69 | 71 | 71 | 0.6 | 7,672,100 | 426,900 | 75 | 73 | 78 | 63 | 72 | 72 | 2.5 |
| 7,671,600 | 426,500 | 53 | 63 | 58 | 64 | 69 | 61 | 2.7 | 7,672,200 | 426,000 | 62 | 71 | 64 | 65 | 69 | 66 | 1.7 |
| 7,671,600 | 426,600 | 92 | 88 | 90 | 79 | 86 | 87 | 2.2 | 7,672,200 | 426,100 | 74 | 65 | 66 | 67 | 62 | 67 | 2.0 |
| 7,671,600 | 426,700 | 80 | 73 | 72 | 70 | 70 | 73 | 1.8 | 7,672,200 | 426,200 | 69 | 68 | 71 | 66 | 70 | 69 | 0.9 |
| 7,671,600 | 426,800 | 62 | 65 | 72 | 71 | 65 | 67 | 1.9 | 7,672,200 | 426,300 | 50 | 65 | 57 | 58 | 57 | 57 | 2.4 |
| 7,671,600 | 426,900 | 42 | 40 | 33 | 40 | 41 | 39 | 1.6 | 7,672,200 | 426,400 | 64 | 62 | 66 | 64 | 62 | 64 | 0.7 |
| 7,671,600 | 427,000 | 64 | 42 | 52 | 47 | 65 | 54 | 4.6 | 7,672,200 | 426,500 | 67 | 64 | 65 | 60 | 65 | 64 | 1.2 |
| 7,671,700 | 426,000 | 39 | 29 | 51 | 27 | 34 | 36 | 4.3 | 7,672,200 | 426,600 | 52 | 62 | 62 | 56 | 55 | 57 | 2.0 |
| 7,671,700 | 426,100 | 59 | 68 | 67 | 60 | 73 | 65 | 2.6 | 7,672,200 | 426,700 | 59 | 51 | 67 | 64 | 68 | 62 | 3.1 |
| 7,671,700 | 426,200 | 70 | 75 | 76 | 70 | 71 | 72 | 1.3 | 7,672,200 | 426,800 | 69 | 70 | 76 | 64 | 69 | 70 | 1.9 |
| 7,671,700 | 426,300 | 43 | 46 | 41 | 47 | 51 | 46 | 1.7 | 7,672,200 | 426,900 | 73 | 67 | 76 | 72 | 68 | 71 | 1.7 |
| 7,671,700 | 426,400 | 64 | 55 | 72 | 66 | 62 | 64 | 2.8 | 7,672,200 | 427,000 | 80 | 79 | 77 | 72 | 69 | 75 | 2.1 |
| 7,671,700 | 426,500 | 90 | 84 | 85 | 85 | 85 | 86 | 1.1 | 7,672,300 | 426,000 | 68 | 69 | 70 | 62 | 60 | 66 | 2.0 |
| 7,671,700 | 426,600 | 72 | 69 | 77 | 70 | 63 | 70 | 2.3 | 7,672,300 | 426,100 | 76 | 74 | 80 | 74 | 77 | 76 | 1.1 |
| 7,671,700 | 426,700 | 67 | 71 | 85 | 72 | 66 | 72 | 3.4 | 7,672,300 | 426,200 | 69 | 69 | 67 | 70 | 74 | 70 | 1.2 |
| 7,671,700 | 426,800 | 57 | 63 | 57 | 56 | 59 | 58 | 1.2 | 7,672,300 | 426,300 | 66 | 64 | 58 | 66 | 64 | 64 | 1.5 |
| 7,671,700 | 426,900 | 57 | 58 | 63 | 64 | 56 | 60 | 1.6 | 7,672,300 | 426,400 | 64 | 66 | 68 | 64 | 64 | 65 | 0.8 |
| 7,671,700 | 427,000 | 48 | 45 | 58 | 57 | 47 | 51 | 2.7 | 7,672,300 | 426,500 | 66 | 64 | 70 | 69 | 66 | 67 | 1.1 |
| 7,671,800 | 426,000 | 57 | 43 | 56 | 53 | 67 | 55 | 3.9 | 7,672,300 | 426,600 | 59 | 64 | 62 | 57 | 58 | 60 | 1.3 |
| 7,671,800 | 426,100 | 58 | 62 | 56 | 66 | 70 | 62 | 2.6 | 7,672,300 | 426,700 | 59 | 58 | 58 | 57 | 67 | 60 | 1.8 |
| 7,671,800 | 426,200 | 60 | 61 | 56 | 64 | 71 | 62 | 2.5 | 7,672,300 | 426,800 | 69 | 80 | 73 | 60 | 66 | 70 | 3.4 |
| 7,671,800 | 426,300 | 70 | 63 | 70 | 63 | 78 | 69 | 2.8 | 7,672,300 | 426,900 | 74 | 70 | 70 | 74 | 76 | 73 | 1.2 |
| 7,671,800 | 426,400 | 59 | 62 | 60 | 58 | 62 | 60 | 0.8 | 7,672,300 | 427,000 | 79 | 77 | 78 | 73 | 77 | 77 | 1.0 |
| 7,671,800 | 426,500 | 80 | 80 | 73 | 83 | 83 | 80 | 1.8 | 7,672,400 | 426,000 | 70 | 64 | 73 | 68 | 68 | 69 | 1.5 |
| 7,671,800 | 426,600 | 84 | 78 | 72 | 73 | 70 | 75 | 2.5 | 7,672,400 | 426,100 | 73 | 77 | 58 | 68 | 68 | 69 | 3.2 |
| 7,671,800 | 426,700 | 117 | 98 | 99 | 114 | 97 | 105 | 4.3 | 7,672,400 | 426,200 | 72 | 59 | 67 | 61 | 64 | 65 | 2.3 |
| 7,671,800 | 426,800 | 70 | 65 | 66 | 63 | 67 | 66 | 1.2 | 7,672,400 | 426,300 | 69 | 75 | 68 | 66 | 73 | 70 | 1.7 |

**Table 6 (continued)**

| Northing | Easting | Stake | 1 | 2 | 3 | 4 | Mean | S.E | Northing | Easting | Stake | 1 | 2 | 3 | 4 | Mean | S.E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7,671,800 | 426,900 | **NA** | **NA** | **NA** | **NA** | **NA** | Snowcat trail | | 7,672,400 | 426,400 | 67 | 67 | 63 | 68 | 70 | 67 | 1.1 |
| 7,671,800 | 427,000 | 51 | 50 | 53 | 50 | 48 | 50 | 0.8 | 7,672,400 | 426,500 | 59 | 59 | 60 | 61 | 50 | 58 | 2.0 |
| 7,671,900 | 426,000 | 84 | 74 | 73 | 83 | 78 | 78 | 2.2 | 7,672,400 | 426,600 | 70 | 67 | 65 | 59 | 67 | 66 | 1.8 |
| 7,671,900 | 426,100 | 65 | 66 | 77 | 77 | 70 | 71 | 2.6 | 7,672,400 | 426,700 | 71 | 66 | 76 | 69 | 73 | 71 | 1.7 |
| 7,671,900 | 426,200 | 79 | 75 | 79 | 67 | 72 | 74 | 2.3 | 7,672,400 | 426,800 | 64 | 66 | 69 | 58 | 62 | 64 | 1.9 |
| 7,671,900 | 426,300 | 66 | 64 | 68 | 71 | 72 | 68 | 1.5 | 7,672,400 | 426,900 | 67 | 63 | 65 | 61 | 69 | 65 | 1.4 |
| 7,671,900 | 426,400 | 64 | 68 | 66 | 56 | 64 | 64 | 2.0 | 7,672,400 | 427,000 | 76 | 77 | 72 | 77 | 82 | 77 | 1.6 |
| 7,671,900 | 426,500 | 61 | 62 | 63 | 68 | 70 | 65 | 1.8 | 7,672,500 | 426,000 | 65 | 60 | 71 | 62 | 62 | 64 | 1.9 |
| 7,671,900 | 426,600 | 63 | 62 | 65 | 58 | 60 | 62 | 1.2 | 7,672,500 | 426,100 | 76 | 59 | 59 | 67 | 59 | 64 | 3.4 |
| 7,671,900 | 426,700 | 49 | 56 | 49 | 46 | 48 | 50 | 1.7 | 7,672,500 | 426,200 | 70 | 64 | 64 | 62 | 55 | 63 | 2.4 |
| 7,671,900 | 426,800 | 73 | 70 | 72 | 73 | 75 | 73 | 0.8 | 7,672,500 | 426,300 | 62 | 45 | 67 | 57 | 64 | 59 | 3.9 |
| 7,671,900 | 426,900 | 85 | 81 | 80 | 80 | 78 | 81 | 1.2 | 7,672,500 | 426,400 | 71 | 70 | 69 | 70 | 65 | 69 | 1.0 |
| 7,671,900 | 427,000 | 27 | 26 | 29 | 23 | 29 | 27 | 1.1 | 7,672,500 | 426,500 | 65 | 65 | 61 | 58 | 53 | 60 | 2.3 |
| 7,672,000 | 426,000 | 75 | 76 | 72 | 69 | 70 | 72 | 1.4 | 7,672,500 | 426,600 | 76 | 75 | 85 | 67 | 78 | 76 | 2.9 |
| 7,672,000 | 426,100 | 71 | 63 | 70 | 82 | 77 | 73 | 3.2 | 7,672,500 | 426,700 | 75 | 77 | 71 | 70 | 71 | 73 | 1.4 |
| 7,672,000 | 426,200 | 71 | 73 | 80 | 80 | 71 | 75 | 2.1 | 7,672,500 | 426,800 | 73 | 71 | 67 | 69 | 72 | 70 | 1.1 |
| 7,672,000 | 426,300 | 65 | 63 | 73 | 65 | 66 | 66 | 1.7 | 7,672,500 | 426,900 | 88 | 72 | 67 | 73 | 75 | 75 | 3.5 |
| 7,672,000 | 426,400 | 60 cm 2 m N of stake | | | Destroyed by seismic train | | | | 7,672,500 | 427,000 | 88 | 72 | 74 | 74 | 77 | 77 | 2.9 |

Grid mean = 68.0 +/- 1.2 cm

**Table 7. Snow depths at Happy Valley permanent plots, April 2004.**

| Relevé | Latitude (mm d ss.s) | Longitude (mm dd ss.s) | Stake | 1 | 2 | 3 | 4 | Mean | Standard Error |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 69 9 28.6 | 148 49 13.8 | 42 | 49 | 48 | 43 | 44 | 45 | 1.4 |
| 2 | 69 9 28.4 | 148 49 18.3 | 30 | 28 | 33 | 35 | 32 | 31.6 | 1.2 |
| 3 | 69 9 37.5 | 148 49 28.4 | 75 | 81 | 73 | 75 | 70 | 74.8 | 1.8 |
| 4 | 69 9 29.7 | 148 49 29.8 | 74 | 80 | 83 | 84 | 71 | 78.4 | 2.5 |
| 5 | 69 9 28.8 | 148 49 31.7 | 80 | 83 | 80 | 80 | 100 | 84.6 | 3.9 |
| 6 | 69 9 24.8 | 148 49 25.5 | 47 | 48 | 50 | 47 | 49 | 48.2 | 0.6 |
| 7 | Unable to locate | | | | | | | | |
| 8* | | | 17 | 23 | 23 | 28 | 25 | 23.2 | 1.8 |
| 9 | 69 8 48.3 | 148 49 44.2 | 45 | 49 | 37 | 43 | 46 | 44 | 2.0 |
| 10 | 69 8 48.4 | 148 49 38.6 | 47 | 45 | 47 | 53 | 52 | 48.8 | 1.6 |
| 11 | Unable to locate | | | | | | | | |
| 12 | | | Approx. 100 | | | | | | |
| 13 | Unable to locate | | | | | | | | |
| 14* | 69 8 16.3 | 148 49 59.1 | 40 | 48 | 50 | 50 | 54 | 48.4 | 2.3 |
| 15 | Unable to locate | | | | | | | | |
| 16 | Unable to locate | | | | | | | | |
| 17 | 69 7 31.2 | 148 49 57 | 53 | 57 | 53 | 42 | 33 | 47.6 | 4.4 |
| 18 | 69 7 23.6 | 148 49 56.6 | 45 | 45 | 48 | 45 | 45 | 45.6 | 0.6 |

**Table 7 (continued)**

| Relevé | Latitude (mm d ss.s) | Longitude (mm dd ss.s) | Stake | 1 | 2 | 3 | 4 | Mean | Standard Error |
|---|---|---|---|---|---|---|---|---|---|
| 19 | Unable to locate | | | | | | | | |
| 20 | 69 9 30 | 148 50 13.8 | 66 | 63 | 59 | 72 | 53 | 62.6 | 3.2 |
| 21 | 69 9 33.3 | 148 50 14.7 | 70 | 70 | 60 | 72 | 72 | 68.8 | 2.2 |
| 22* | 69 9 34.1 | 148 50 15.3 | 240 | | | | | | |
| 23* | 69 9 35.3 | 148 50 15.3 | 61 | 66 | 62 | 65 | 70 | 64.8 | 1.6 |
| 24* | 69 9 36.3 | 148 50 74.9 | 92 | 90 | 100 | 97 | 102 | 96.2 | 2.3 |
| 25 | 69 9 36.7 | 148 50 15 | 67 | 66 | 75 | 68 | 71 | 69.4 | 1.6 |
| 26 | 69 9 37.1 | 148 50 15.1 | 55 | 58 | 58 | 60 | 54 | 57 | 1.1 |
| 27 | 69 9 39.7 | 148 50 15 | 69 | 65 | 67 | 74 | 65 | 68 | 1.7 |
| 28 | 69 9 42.2 | 148 50 16.1 | 78 | 66 | 76 | 81 | 74 | 75 | 2.5 |
| 29 | 69 9 48.3 | 148 50 18.9 | 71 | 68 | 70 | 73 | 81 | 72.6 | 2.2 |
| 30 | 69 9 68.1 | 148 50 34.5 | 55 | 42 | 41 | 50 | 51 | 47.8 | 2.7 |
| 31 | 69 8 55.7 | 148 50 44.3 | 69 | 67 | 63 | 67 | 63 | 65.8 | 1.2 |
| 32 | 69 8 46.5 | 148 50 21.1 | 62 | 63 | 66 | 60 | 64 | 63 | 1.0 |
| 33 | 69 8 47 | 148 51 24.3 | 51 | 55 | 55 | 55 | 57 | 54.6 | 1.0 |
| 34 | 69 8 47.9 | 148 51 27.9 | 67 | 68 | 71 | 66 | 67 | 67.8 | 0.9 |
| 35 | 69 8 48.9 | 148 51 28.5 | 57 | 61 | 57 | 58 | 58 | 58.2 | 0.7 |
| 36 | 69 8 48.5 | 148 51 29 | 65 | 61 | 63 | 58 | 62 | 61.8 | 1.2 |
| 37 | 69 8 48.6 | 148 51 29.8 | 59 | 56 | 66 | 61 | 64 | 61.2 | 1.8 |
| 38 | 69 8 48.6 | 148 51 30.4 | 53 | 61 | 62 | 56 | 59 | 58.2 | 1.7 |
| 39 | 69 8 49.4 | 148 51 33.2 | 76 | 70 | 77 | 71 | 65 | 71.8 | 2.2 |
| 40 | 69 8 45.6 | 148 51 40.2 | 62 | 59 | 54 | 58 | 60 | 58.6 | 1.3 |
| 41 | Unable to locate | | | | | | | | |
| 42 | 69 8 44.2 | 148 51 4.3 | 80 | 80 | 71 | 76 | 86 | 78.6 | 2.5 |
| 43 | 69 8 41.1 | 148 50 50.6 | 95 | 78 | 82 | 82 | 88 | 85 | 3.0 |
| 44 | 69 8 40.6 | 148 50 33.9 | 48 | 44 | 56 | 55 | 66 | 53.8 | 3.8 |
| 45 | 69 8 45.9 | 148 50 35 | 40 | 51 | 51 | 31 | 42 | 43 | 3.8 |
| 46 | 69 9 56.2 | 148 51 19.4 | 61 | 58 | 60 | 62 | 59 | 60 | 0.7 |
| 47 | 69 9 55.1 | 148 51 19.6 | 49 | 47 | 50 | 49 | 49 | 48.8 | 0.5 |
| 48 | Unable to locate | | | | | | | | |
| 49 | 69 9 56.2 | 148 51 32.1 | 35 | 39 | 31 | 36 | 36 | 35.4 | 1.3 |
| 50 | 69 9 57.3 | 148 51 37.5 | 40 | 42 | 42 | 41 | 39 | 40.8 | 0.6 |
| 51 | Unable to locate | | | | | | | | |
| 52 | 69 9 54.1 | 148 52 3.6 | 63 | 62 | 62 | 56 | 64 | 61.4 | 1.4 |
| 53 | 69 9 53.2 | 148 52 6.5 | 61 | 58 | 58 | 60 | 64 | 60.2 | 1.1 |
| 54 | 69 9 56.5 | 148 51 44.2 | 48 | 48 | 49 | 46 | 46 | 47.4 | 0.6 |
| 55 | 69 9 57.3 | 148 51 42.7 | 42 | 41 | 42 | 38 | 41 | 40.8 | 0.7 |

# Figures

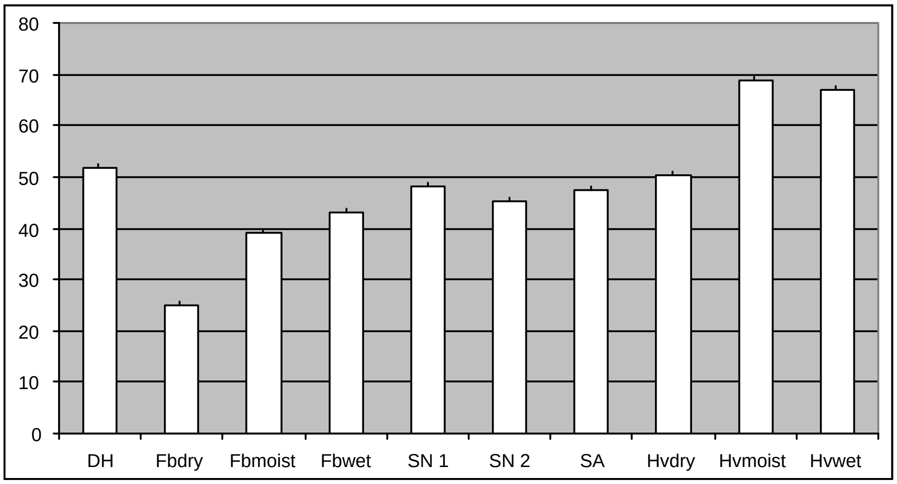


**Figure 1. Mean snow depth (cm) on 10 x 10 m grids, North Slope, Alaska, April 2004 (n = 121).**

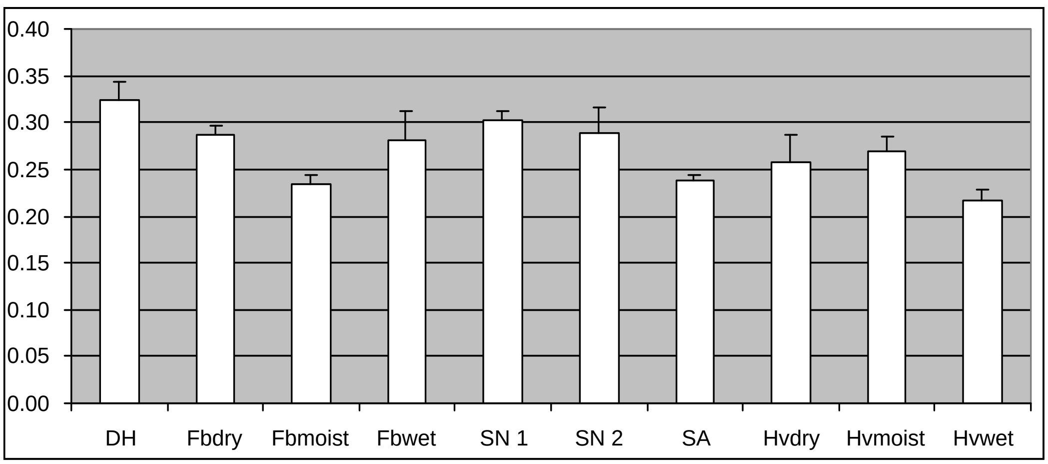


**Figure 2. Mean snow density (g/cm$^3$ +/- s.e.) on 10 x 10 m grids, North Slope, Alaska, April 2004 (n = 4).**

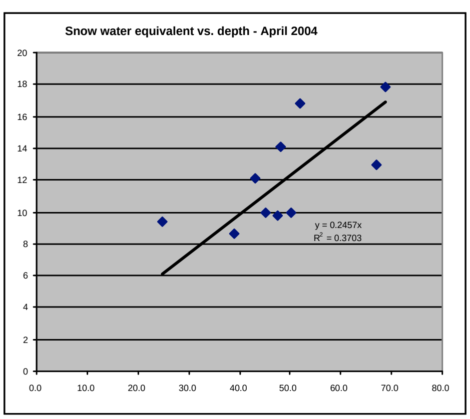


**Figure 3. Snow water equivalent vs. snow depth from ten 10 x 10 m grids on the North Slope, Alaska, April 2004.**

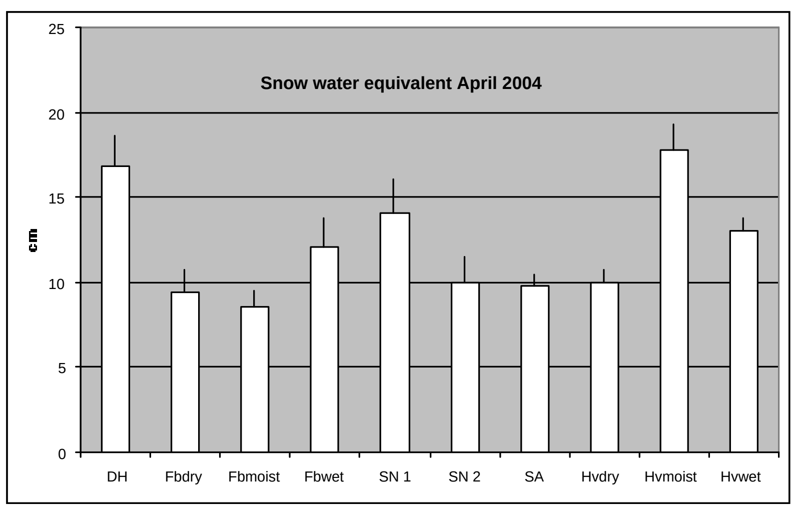


**Figure 4. Snow water equivalent on 10 x 10 m grids on the North Slope, Alaska, April 2004 (n = 4).**

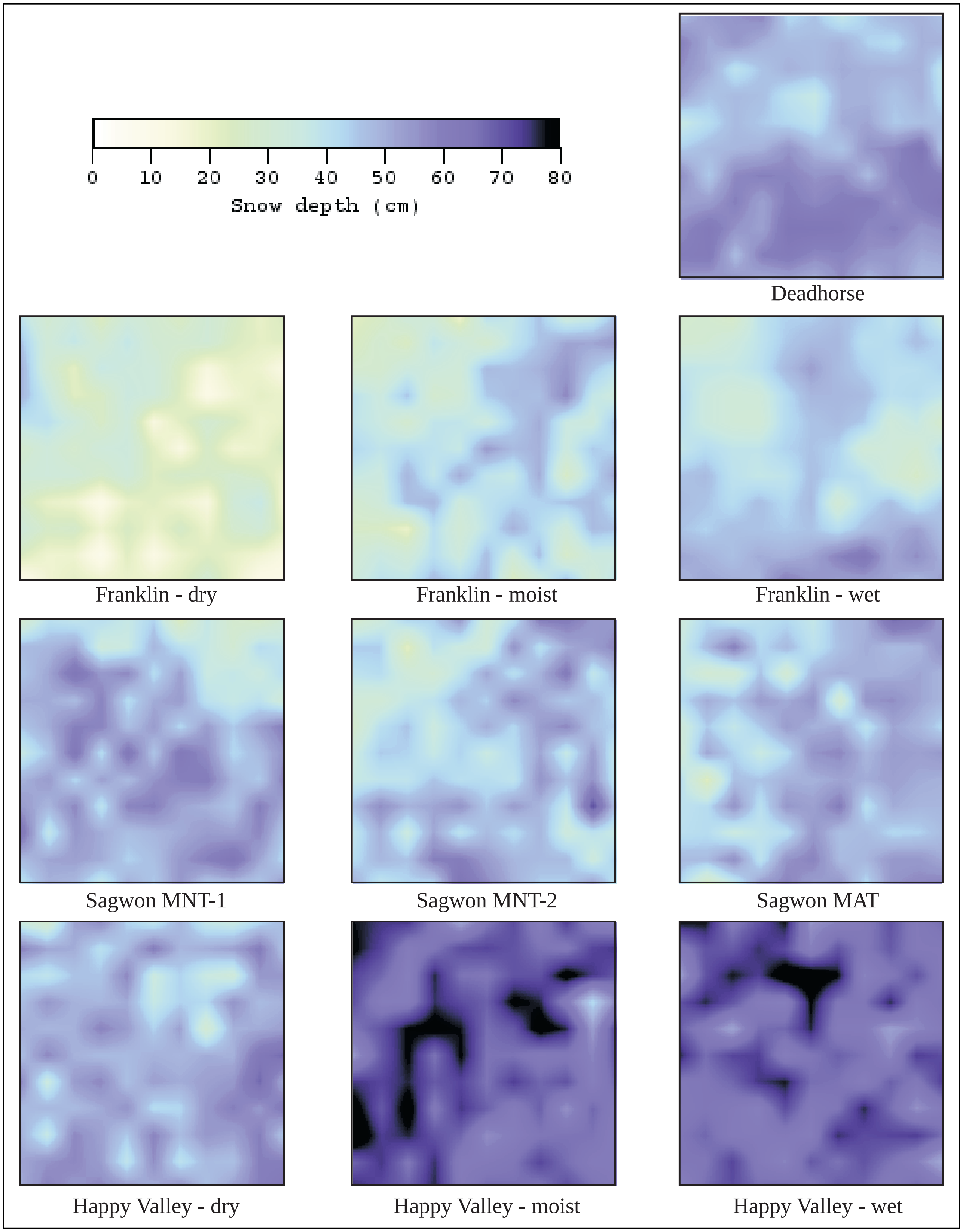


**Figure 5. Snow depths of the 10 x 10 m grids, North Slope, Alaska, April 2004.**

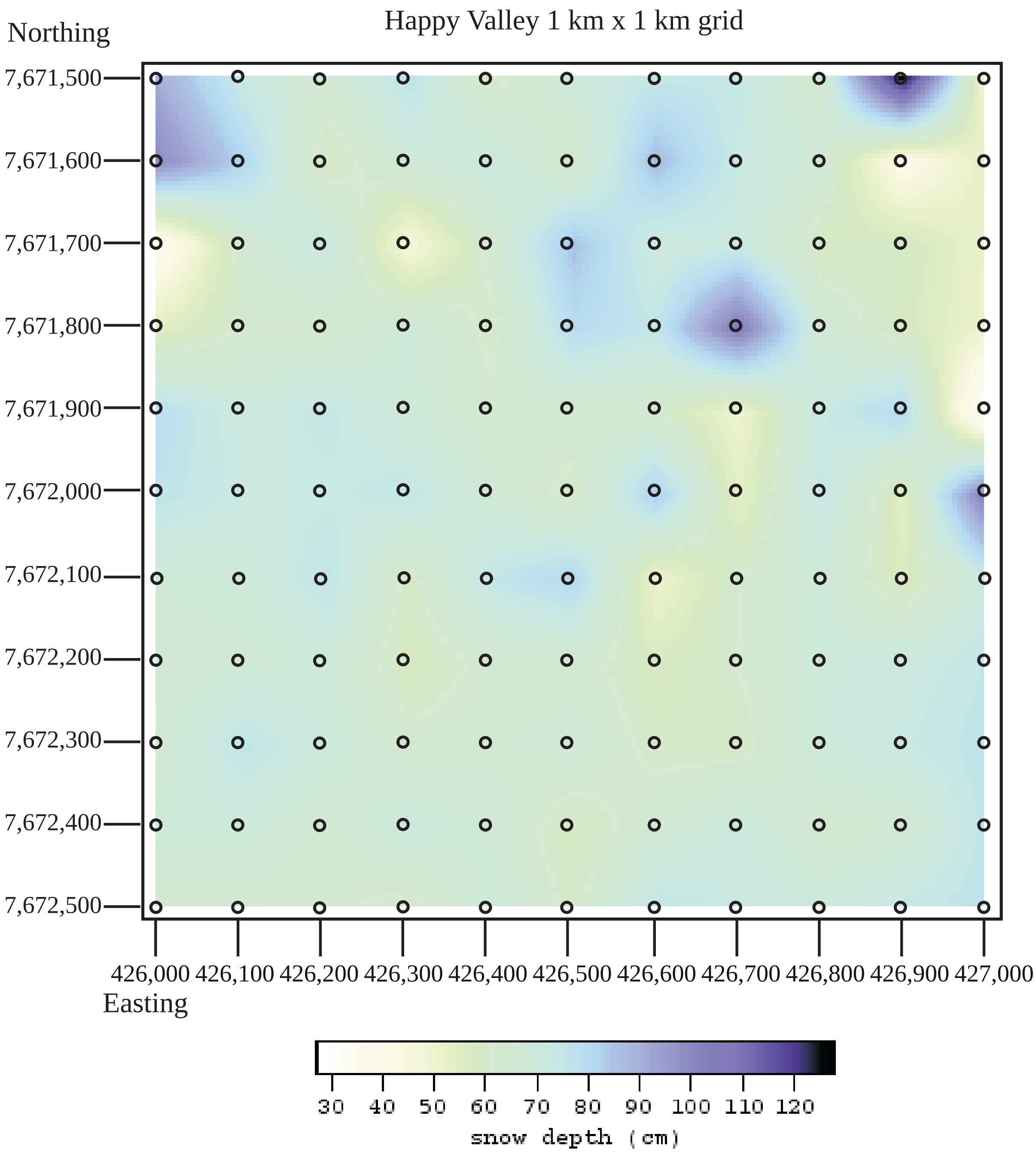


**Figure 6. Snow depths on Happy Valley 1 km x 1 km grid, May 2004**

# Appendix A. Photographs

Photo 1. Christine Martin measuring snow depth. Photo by M.K. Raynolds

Photo 2. Martha Raynolds coring snow for density measurements. Photo by C. R. Martin.

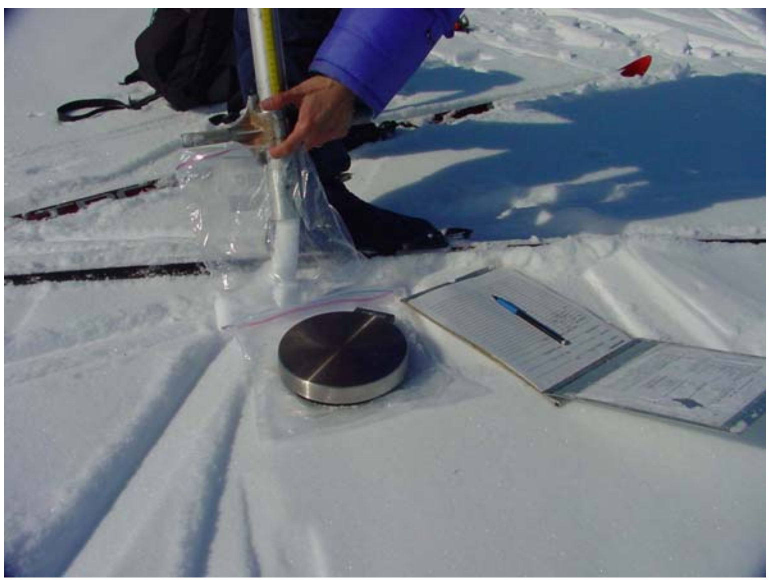

Photo 3. Christine Martin weighing snow from corer. Photo by M. K. Raynolds

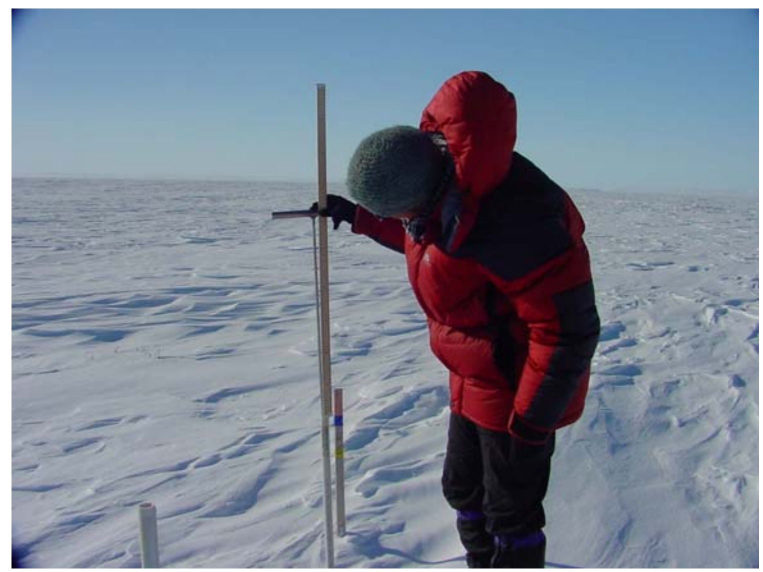

Photo 4. Anja Kade measuring heave at frost boil. Photo by M. K. Raynolds



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Photo 5.  Heave-meter at Franklin Bluff moist grid.  Photo by M. K. Raynolds

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Photo 6. Snow pit at Deadhorse grid; note hard snow slab on surface with depth hoar below.  Photo by M. K. Raynolds

Photo 7.  Snow pit at Franklin Bluff moist grid; note depth-hoar layer, which is shallower on top of the frost boil on the right.  Photo by M. K. Raynolds

Photo 8.  Snow pit at Happy Valley; note deep, light snow.  Photo by M. K. Raynolds

## Appendix B. Data collection forms

### SNOW DENSITY

Location: ______________________________ Grid: ______________________________

Observers: ______________________________ Date: ______________________________

Coring equipment: ______________________________ Corer cross-section: ______________________________

| Sample site | Snow depth (cm) | Snow weight (g) | Notes |
|---|---|---|---|
| | | | |
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**SNOW DEPTH (cm) - GRID SAMPLE**

Location: ______________________ Grid: ______________________

Observers: ______________________ Date: ______________________

Weather: ______________________ Photo: ______________________

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **K** | | | | | | | | | | | | **K** |
| **J** | | | | | | | | | | | | **J** |
| **I** | | | | | | | | | | | | **I** |
| **H** | | | | | | | | | | | | **H** |
| **G** | | | | | | | | | | | | **G** |
| **F** | | | | | | | | | | | | **F** |
| **E** | | | | | | | | | | | | **E** |
| **D** | | | | | | | | | | | | **D** |
| **C** | | | | | | | | | | | | **C** |
| **B** | | | | | | | | | | | | **B** |
| **A** | | | | | | | | | | | | **A** |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | |

*Note: be careful about putting data in correct order/location, with A1 in lower left*
*this will match maps of the grid, and put approximate North to the top of the page*

Remarks:

## SNOW PROFILE

Location: ______________________ Grid: ______________________

Observers: ______________________ Date & Time: ______________________

Sky conditions: ______________________ Air Temp (°C): ______________________

| SNOW SURFACE (Circle one) |
|---|
| Smooth Rippled Pitted Gullied |

Total snow depth (cm): __________

| SURFACE ROUGHNESS (circle one) |
|---|
| Smooth Wavy Concave furrows Convex furrows Random furrows |
| Average depth of surface irregularities: |
| Average wavelength (distance between ridges): |
| Compass direction of ridges: |

| Layer | Thickness (cm) | Grain Shape (see crystal classification table) | Grain Size (mm) | Density (g/cm3) | Temp ( °C) | Hardness Index (see table) | Remarks |
|---|---|---|---|---|---|---|---|
| Top 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

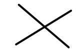
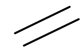
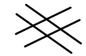
# Appendix C. Classification of snow crystals (Colbeck et al. 1992)

Classification of snow crystals (Colbeck et al. 1992)



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Precipitation particles** | Columns | Short prismatc crystal, solid or hollow | **Decomposing and fragmented precipitation particles** | Partly decomposed particles | Partly rounded, characteristic shapes of precip. particles still recognizable | **Cup-shaped crystals, depth hoar** | Cup crystal | Cup-shaped, striated crystals, usually hollow | **Ice masses** | Ice layer | Horizontal buried ice layer |
| | Needles | Needle-like, approx. cylindrical | | Highly broken particles | Packed, shards or rounded fragments of precip. particles | | Columns of depth hoar | Large cup-shaped striated hollow crystals arranged in columns <10mm | | Ice column | Vertical ice body |
| | Plates | Plate-like, mostly hexagonal | **Rounded grains** | Small rounded particles | Well rounded particles, <0.5 mm, often well bonded | | Colunmnar crystals | Very large columnar crystals, 10-20 mm | | Basal ice | Basal ice layer |
| | Stellar dendrites | Six-fold, star-like, planar or spatial | | Large rounded particles | Well rounded particles > 0.5 mm | **Wet grains** | Clustered rounded grains | Clustered rounded crystals held by large ice-ice bonds, water in veins between grains | **Surface deposits and crusts** | Rime | Soft rime: irregular<br>Hard rime: small super-cooled water droplets frozen in place |
| | Irregular crystals | Cluster of very small crystals | | Mixed form | Rounded particles, with few developing facets | | Rounded poly-crystals | Individual crystals frozen into solid poly-crystaline grain, wet or re-frozen | | Rain crust | Thin, transparent glaze or clear surface layer |
| | Graupel | Heavily rimed particles | **Faceted crystals** | Solid faceted particles | Solid faceted crystals, usually hexagonal prisms | | Slush | Separate rounded crystals completerly immersed in water | | Sun crust, firn-spiegel | Thin, transparent glaze or surface film |
| | Hail | Laminar internal structure, translucent or milky, glazed surface | | Small faceted particles | Small faceted crystals in surface layer; <0.5 mm | **Feathery crystals** | Surface hoar frost | Striated, usually feathery crystal; aligned; ususally flat, sometimes needle-like | | Wind crust | Small, broken or abraded, closely-packed particles, well-sintered |
| | Ice pellets | Transparent, mostly small spheroids | | Mixed forms | Faceted particles with recent rounding of facets | | Cavity hoar | Striated, planar or feathery crystals grown in cavity, random orientation | | Melt-freeze crust | Crust of recognizable melt-freeze polycrystals |

Hardness of deposited snow (Colbeck et al. 1992)

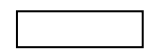
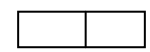
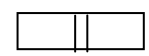
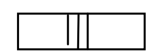
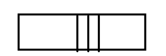
| *Term* | *Swiss Rammsonde* *(newtons)* | *Order of magnitude stress (Pa)* | *Hand test* | *Symbol* | *Graphic symbol* |
|---|---|---|---|---|---|
| Very low | 0-20 | 0-103 | Fist | R1 | |
| Low | 20-150 | 103-104 | 4 fingers | R2 |  |
| Medium | 150-500 | 104-105 | 1 finger | R3 |  |
| High | 500-1000 | 105-106 | Pencil | R4 |  |
| Very high | > 1000 | > 106 | Knife blade | R5 |  |
| Ice | | | | R6 |  |

Load-bearing capacity of the snow surface (Colbeck et al. 1992)

| |
|---|
| Depth of ski track (skier supported on one ski) in mm |
| Depth of footprint (person standing on one foot) in mm |
| Penetration of a Swiss Rammsonde (first element by its own weight) |



Liquid water content (Colbeck et al. 1992)

| *Term* | *Remarks* | *Approximate Range* | *Symbol* |
|---|---|---|---|
| Dry | Dry snow can occur at any temperature up to $0^{o}$C. Disaggregated snow grains have little tendency to adhere to each other when pressed together, as in making a snowball. | 0% |  |
| Moist | T = $0^{o}$C. Water is not visible even at 10 x magnification. When lightly crushed, the snow has a distinct tendency to stick together. | < 3% |  |
| Wet | T = $0^{o}$C. Water can be recognized at 10 x magnification by its meniscus between adjacent snow grains, but water cannot be pressed out by moderately squeezing the snow in the hands. | 3-8% |  |
| Very wet | T = $0^{o}$C. Water can be pressed out by moderately squeezing the snow in the hands, but there is an appreciable amount of air confined within the pores. | 8-15% |  |
| Slush | T = $0^{o}$C. Snow is flooded with water and contains relatively small amounts of air. | > 15% |  |