

Original Surface GPS Data Collected by K. Jezek at OSU Cluster Sites: Years 2003, 2004, 2005  
 Data processed by J. Sonntag  
 Note that data were subsequently corrected for local slopes for elevation change comparisons

Year:2003						
Station	2001	2002	2003	2004	2005	2006
Lat	65 06 30.74771	65 04 02.49242	64 55 58.04774	64 58 53.86262	65 08 56.81268	65 17 35.10058
Long	45 41 12.70018	45 17 14.58329	45 35 46.24260	46 01 35.06830	46 06 13.32414	45 50 02.17894
Surface Elevation	2526.907	2594.598	2575.4273	2493.988	2451.285	2465.695

Year:2004							
Station	1001		1003			1006	1007
Lat	65 23 16.27305		65 14 13.76876			65 32 49.48577	65 32 24.51312
Long	312 19 35.84841		312 32 21.95937			312 6 15.42224	312 32 12.95967
Surface Elevation	2031.39		2135.36			1913.44	2033.81

Station	2001	2002	2003	2004	2005	2006
Lat	65 6 30.89714	65 4 2.64626	64 55 58.18229	64 58 54.01177	65 8 56.97243	65 17 35.28739
Long	314 18 46.61795	314 42 44.93101	314 24 13.15826	313 58 24.11803	313 53 45.82488	314 9 57.06943
Surface Elevation	2527.16	2594.83	2575.46	2494.29	2451.42	2465.9

Year:2005							
Station	1001		1003			1006	1007
Lat	65 23 16.64613		65 14 14.17703			65 32 49.84334	65 32 24.92086
Long	312 19 33.23243		312 32 19.29587			312 6 12.05403	312 32 13.25639
Surface Elevation	2031.66		2135.12			1913.24	2033.79
Station	2001				2005	2006	
Lat	65 6 31.04769				65 8 57.12736	65 17 35.47246	
Long	314 18 45.93146				313 53 44.97529	314 9 56.31762	
Surface Elevation	2527.37				2451.71	2465.96	

Coordinates referenced to ITRF 2000, WGS-84 ellipsoid  
 Surface Heights in meters  
 GPS data processed by J. Sonntag  
 Note that local slope corrections were subsequently applied based on offset between GPS antenna position and original OSU coordinate. Data shown here are GPS antenna positions and do not include slope correction.

Cluster Elevation Data Summary: ITRF 1993 Coordinates/WGS 84 Ellipsoid; Comparison between ITRF 93 and 2000 Geographic positions is less than 1 m  
 So, reference frames taken to be equivalent for this analysis. Elevations slope corrected to original OSU position  
 1980/81 from Whillans; 2003/04/05 Collected by Jezek using Surface GPS and processed by J. Sonntag; other values are combined surface GPS and/or ATM data obtained from W. Krabill and E. Fredericks

**Lower Cluster**

Station	Lat 1980	Long 1980	1980	1981	1993	1994	1995	1997	1998	2003	2004	2005	2011
1001	65.387647	312.327239	2029.103	2028.813	2030.736	2030.887			2031.03		2031.487	2031.899	2031.3247
1002	65.386762	312.762313	2170.423		2170.967	2171.031			0				2171.561
1003	65.23707	312.540178	2133.089	2133.169	2134.708	0			2135.31		2135.945	2136.304	2135.233
1004	65.242286	312.129507	1995.31		1997.047	1996.968			1997.451				1996.731
1005	65.390374	311.890526	1866.984		1869.062	1868.921			1869.427				1868.174
1006	65.546866	312.104823	1910.978	1912.698	1913.24	0			1913.813		1913.467	1913.312	1911.88
1007	65.539912	312.537651	2032.457	2032.639	2034.191	2034.349			2034.201		2034.534	2034.587	2033.153

**Central Cluster**

Station	Lat 1980	Long 80	1980	1981	1993	1994	1995	1997	1998	2003	2004	2005	2011
2001	65.108176	314.313638	2525.649	2525.259	2526.3735	2526.425	2526.502		2526.536	2527.031	2527.327	2527.579	2527.39
2002	65.067255	314.713182	2592.989	2592.769	2593.997	2593.932			2594.05	2594.633	2594.876	NaN	2594.85
2003	64.932856	314.403601	2572.934	2573.534	2574.539	2574.637		2574.766	2574.732	2575.334	2575.428	NaN	2575.54
2004	64.981484	313.973897	2491.794	2491.704	2493.315				2493.424	2494.033	2494.354	NaN	2494.42
2005	65.149097	313.896816	2448.78	2449.38	2450.2955	2450.444	2450.582		2450.756	2451.371	2451.542	2451.869	2451.57
2006	65.292962	314.166266	2463.456	2463.466	2464.691	2464.804	2464.882	2464.984	2465.049	2465.746	2465.992	2466.094	2465.98
2007	65.246832	314.591373	2536.415	2536.745	2537.682				2538.051				2538.9

**Dye-3**

Station	Lat 1980	Long 1980	1980	1981	1993	1994	1995	1997	1998	2003	2004	2005	2011
3001	65.258899	316.533129	2421.37			2420.088			2419.446				2418.49
3002	65.106181	316.534737	2481.756			2479.746		2478.874					2478.44
3003	65.201544	316.160011	2529.128		2528.507	2528.652			2528.17				2527.64
3004	65.025476	316.152189	2562.714			2562.625		2562.169					2561.65
3005	65.118702	315.802468	2598.036		2597.821	2597.713			2597.465				2597.22
3006	64.926553	315.820358	2654.971			2654.522		2654.166					2654.29
3007	65.014155	315.357009	2672.413		2672.354	2671.697			2672.195				2672.76
3008	64.849788	315.347001	2707.539		2708.316	2708.026		2708.336					2708.99

Average ICESat Elevations Computed Using Data Extracted from NSIDC and Provided by B. Smith  
 Elevations Slope Corrected to OSU Station Location  
 Elevations referenced to ITRF 2000 WGS 84

osunum	Lat	Long		2004	2005	2006	2007	2008	
1001	65.387647	312.327239		2031.308	2031.34	2031.895	2031.08	2031.085	
osunum	Lat	Long		2004	2005	2006	2007	2008	2009
2001	65.10818488	314.3136512		2527.2	2527.3	2527.505	2527.363	2527.36	2527.58
osunum	Lat	Long	2003	2004	2005				
3001	65.258899	316.533129	2419.125	2419.1	2419.228				

Lower Cluster Velocity

	2004/05		1980/81	
Station	Speed (m/yr)	Azimuth (degrees)	Speed (m/yr)	Azimuth (degrees)
1001	35.7	288	35.76	288
1003	36.83	290	36.07	290
1006	44.63	284	44.05	285

note that errors at Lower Cluster are large (1 m/yr at least) because of pole tilt uncertainty between 2004 and 2005

Central Cluster Velocity

	1980/81		1993		2003/04		2004/05	
Station	Speed	Azimuth	Speed	Azimuth	Speed	Azimuth	Speed	Azimuth
2001	9.32	298			10.08526171	297	10.12784753	298
2002	7.55	309			7.983746556	307		
2003	8.58	298			8.959090909	298		
2004	11.38	293			11.69407713	293		
2005	11.56	295			12.20688705	294	12.09944918	293
2006	10.95	302	11.19	299	11.39242424	301	11.33575687	300

1980/81 data from Whillans

1993 data from van der Veen and others

2003-05 data from Jezek and computed using Vincenty formula applied to GPS data

2004-2005 Accumulation Rates at Central Cluster, Greenland

Station	2004 Pole Ht	2005 Pole Ht	Accum (cm)	Delta T (days)	A (cm/yr)	Water Eq (cm/yr)	Average Accumulation rates from Whillans (cm/yr)
2001	190.00	82.00	108.00	364.00	108.30	42.24	38.30
2005	180.00	71.00	109.00	364.00	109.30	42.63	36.90
2006	178.00	92.50	85.50	364.00	85.73	33.44	35.60

2002 corrected for tilted pole

Average density in upper 1 m taken as 0.39 gm/cc

Whillans Data quoted from van der Veen et al 2001 table 6

2004 results are systematically higher, this could be the result of too high an average density. Density chosen on basis of a core collected at 2006 in 1993.

2003-2004 Accumulation Rates at Central Cluster, Greenland

Station	2003 Pole Ht	2004 Pole Ht	Accum (cm)	Delta T (days)	A (cm/yr)	Water Eq (cm/yr)	Average Accumulation rates from Whillans (cm/yr)
2001	292.10	190.00	102.10	364.00	102.38	39.93	38.30
2002	314.88	205.00	109.88	364.00	110.18	42.97	36.10
2003	308.88	204.00	104.88	364.00	105.17	41.02	40.70
2004	297.88	179.00	118.88	364.00	119.21	46.49	37.20
2005	281.94	180.00	101.94	364.00	102.22	39.87	36.90
2006	284.48	178.00	106.48	364.00	106.77	41.64	35.60

1980 data are bomb horizon estimated

2004 data are one year differences in pole heights

	Accumulation cm/yr water equivalent		
	1980	2003	2004
2001	38.3	39.9	42.2
2002	36.1	43.0	
2003	40.7	41.0	
2004	37.2	46.5	
2005	36.9	39.9	42.6
2006	35.6	41.6	33.4
ave	37.47	41.99	39.40

Surface Gravimetry at Central Cluster using LaCoste Romberg Meters  
 Relative gravity measurements were tied to IGSN stations in Sondrestrom and Jacobshavn

Year	Station	Abs g (mgal)
1981	2001	981604.287
1993	2001	981603.827
1995	2001	981604.26
2003	2001	981604.03
1981	2002	981581.464
1993	2002	
1995	2002	
2003	2002	981581.275
1981	2003	981580.775
1993	2003	
1995	2003	
2003	2003	981580.33
1981	2004	981605.03
1993	2004	
1995	2004	
2003	2004	981604.73
1981	2005	981617.24
1993	2005	
1995	2005	981616.67
2003	2005	981616.98
1981	2006	
1993	2006	981610.359
1995	2006	981610.35
2003	2006	981610.517

Data were also collected in 2004 and 2005 at Central and Lower Cluster using a Scintrex gravimeter. The data in 2004 were corrupted by incorrect calibration data from the manufacturer. Scintrex data in 2005 were uniformly less than earlier data (about 0.4 mgal) and the difference is unexplained. Scintrex data may be recoverable

July 6, 1993 2006 Jezek

Thickness	Descript	0	Depth	Grain Size
4	new snow	4	0	0.2
1	bonded co:	5	4	0.2
1	ice	6	4	1
4	fine	10	5	1
1	ice	11	5	0
4	fine	15	6	0
0.5	ice	15.5	6	0.4
11.5	fine	27	10	0.4
1	ice	28	10	0
4	medium	32	11	0
4	massive fir	36	11	0.5
11	fine	47	15	0.5
0.2	wind crust	47.2	15	0
6.8	fine	54	15.2	0
0.2	wind crust	54.2	15.2	0.5
4.8	fine	59	27	0.5
0.2	wind crust	59.2	27	0
5.8	fine	65	28	0
3	massive fir	68	28	0.6
5	fine	73	32	0.6
7	coarse	80	32	0.5
10	massive fir	90	65	0.5
0.2	wind crust	90.2	65	0.55
2.8	fine	93	73	0.55
3	DH	96	73	1
0.2	wind crust	96.2	80	1
1.8	DH	98	80	0.4
4	fine	102	93	0.4
2	bonded me	104	93	1
16	medium	120	98	1
5	massive fir	125	98	0.5
			102	0.5
			102	0.7
			104	0.7
			104	0.8
			120	0.8
			120	0.5

fine  
 massive fine 0<grain size<=0.5 mm  
 wet, fine fine grains that are consolidated, need a shovel to chop out blocks  
 dense, hard fine qualitatively more consolidated than massive fine, need a saw  
 medium grain 0.5<grain size <1mm  
 bonded, medium medium grains bonded into a brittle matrix  
 coarse 1 mm<=grain size <2mm  
 bonded coarse coarse grains bonded together in a brittle matrix  
 very coarse grain size >=2 mm  
 ice lense horizontal lense  
 ice pipe vertical  
 ice crust/DH wind or melt crust underlain by depth hoar  
 laminar ice fine filament or web of very thin (mm) ice layers  
 Loose, Granular similar to dry sugar, finer grains than depth hoar  
 DH Depth hoar  
 ice layers thicker less frequent ice layers than laminar ice layers  
 massive laminar ice solid matrix of layers interspersed with medium to coarse, bonded grains  
 wind crust very thin crust/ice layer (1mm or less)  
 new snow fresh layer of very fine (.2-.3 mm) grains

Depth	Temperature	Depth	Wt	Wt-bag	Density
0	-4	5	189.5	179.5	0.351961
1	-2	10	196.5	186.5	0.365686
10	-6.5	20	199.5	189.5	0.371569
20	-6.5	30	210	200	0.392157
30	-7	40	202.5	192.5	0.377451
40	-7.5	50	209.5	199.5	0.391176
50	-8.5	60	215	205	0.401961
60	-9	70	198	188	0.368627
70	-9.5	80	202.5	192.5	0.377451
80	-10	90	183.5	173.5	0.340196
90	-10.5	100	199	189	0.370588
100	-11.5	110	177.5	167.5	0.328431
110	-12.5	120	225	215	0.421569
120	-13.5				
130	-14.5				

DATE	6-Jul-93
Time	14:14
Label in Log	2006 Pit
KM from CP	
KM from Dye 2	
Lat	65.2932
Long	314.1662
Elevation	







Station 2004

8-Jun-03

Stratigraphy

Layer Thickness	snow type
5	medium snow
6	ice layers
3	medium snow
5.2	ice layers
27.8	massive fine
4	ice layers
12	fine snow
2	ice layers
13	fine snow
10	medium snow

Temperature

Depth	Temp
0	-4
1.6	-3.8
5	-4.9
25	-8.5
50	-10
76	-11

Station 2001  
7-Jun-03

2001

Stratigraphy

thickness	Type
5	snow
0.1	ice
0.9	snow
0.1	ice
2.9	snow
0.1	ice
3.9	snow
0.5	ice
19.5	snow

Temperature

depth	temp
0	-1
5	-3
30	-8