Coupled Gravity and Elevation Measurements of Ice Sheet Mass Change

Final Report

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Abstract

We measured surface gravity and position at ten locations about two glaciological measurement networks located on the South-central Greenland Ice during June 2004. Six of the individual sites of the first network were occupied the previous year. At the repeat sites we were able to measure annual accumulation rate and surface displacement by referencing measurements to aluminum poles left in the firn the previous year. We occupied 4 additional sites at a second measurement network for the first time since initial observations were last made at the network in 1981. At each individual site, we operated a GPS unit for 90 minutes – the unit was operated simultaneously with a base station unit in Sondrestrom Fjord so as to enable differential, post-processing of the data. We installed an aluminum, accumulation-rate-pole at each site. The base section of the pole also served as the mount for the GPS antenna. A new, Scintrex gravimeter was used at each site and relative gravity measurements were tied to the network of absolute gravity stations in Sondrestrom. We measured snow physical properties in two shallow pits. This report summarizes our observations and data analysis.

1 Introduction

Airborne topographic lidar data collected over south-central Greenland indicate that ice sheet thickening continued at least through 1998 at a rate between 5 to 10 cm per year. We believe it is important to understand the significance of ice sheet elevation change in terms of ice sheet mass change. Combining repeat altimeter and gravity data provides a mechanism to separate actual mass changes on the ice sheet from changes in near surface density.

During June 2004, we measured surface gravity at ten locations about two glaciological measurement sites located on the South-central Greenland Ice Sheet (figures 1 and 2). Ian Whillans who first established the sites in 1980 designated the sites as Central and Western Cluster. Previously, gravity observations were made at the 5 of the Upper Cluster sites in 1981 (Jezek and others, 1985), at two of the sites in 1993, at two of the sites in 1995, and 6 of the sites in 2003 (figures 3 and 4). Four of the Lower Cluster sites were occupied in 1981. We made measurements on the hexagonal networks with vertices spaced at 20 km from the center point (van der Veen and others, 2000). Gravity data were collected in conjunction with Doppler satellite measurements of position in 1981 and global positioning system measurements in 1993, 1995, 2003, and 2004.

The measurements were made to investigate whether temporal decreases in gravity observed between 1981 and 1995 (Jezek and others, 2002) continued to the present. The goal of the measurements is to determine whether changes in gravity can be used to estimate changes in the local ice sheet mass. Three-dimensional GPS measurements were simultaneously made at each site so as to remove the free-air gravity anomaly from the gravity observations.

Repeat GPS measurements in 2004 of aluminum poles deployed in 2003 enable us to compute horizontal and vertical surface displacement as well as annual accumulation rate. We completed our observations by noting firn stratigraphy and firn temperature in two shallow pits excavated at Central Cluster sites.

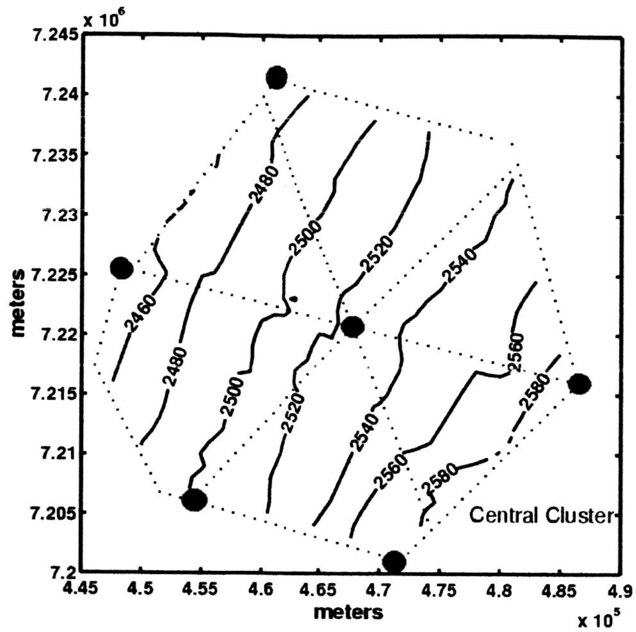

Figure 1. Upper Cluster surface elevation measured in 1981. Red circles show gravity sites occupied with gravimeters and GPS units in 2003 and 2004. Blue dots show shallow pit sites sampled in 2003 and 2004.

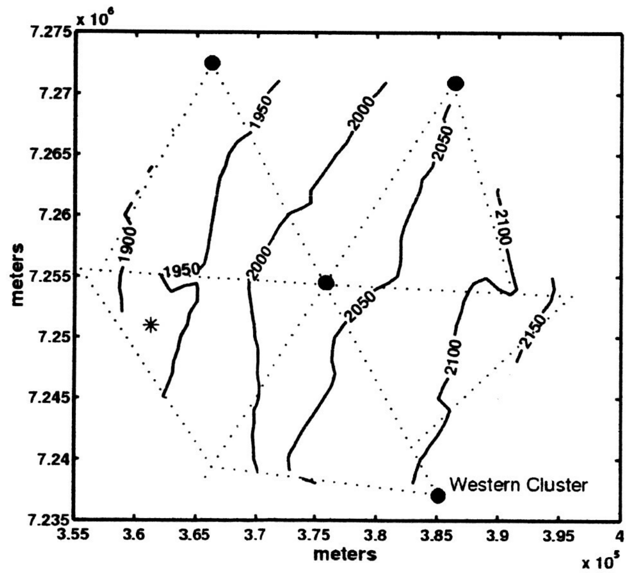

Figure 2. Lower Cluster surface elevation measured in 1981. Filled circles show gravity sites occupied with the gravimeter and GPS units in 2004. These were the only sites where there was coincident Doppler satellite tracking data and gravity data in 1981. Asterisk shows site occupied in 1995.

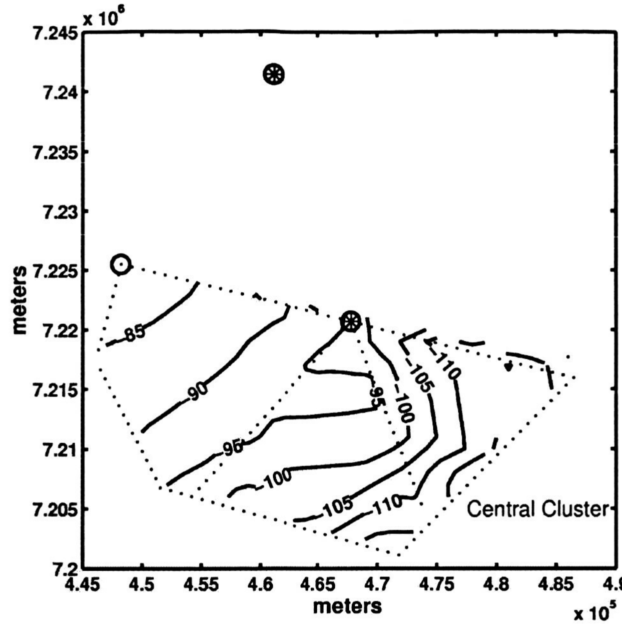

Figure 3. Upper Cluster relative gravity contours measured in 1981. Black dots show locations of gravity sites in 1981. Circles and asterisks show gravity sites in 1993 and 1995 respectively.

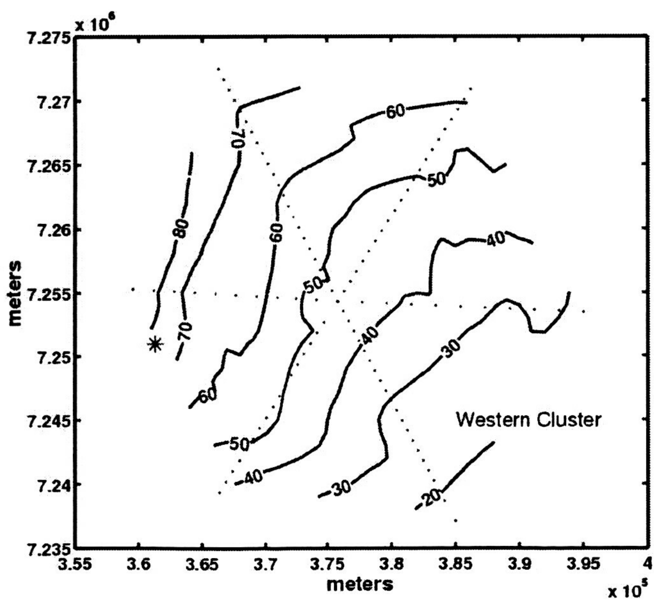

Figure 4. Western Cluster relative gravity contours measured in 1981. Black dots show locations of gravity sites in 1981. Gravity site in 1995 shown by asterisk.

2 Measurement Time-line

We arrived in Sondrestrom Fjord on June 1. We organized equipment and met with the local VECO representatives and the flight crew. We also began monitoring gravity at the local IGSN stations (see section 4). We established a GPS base station at the Met Shack on June 2. Due to favorable weather conditions and advantageous scheduling, we were able to begin observations early on June 3. Prior to departure, we tied the gravity meters to the Arctic Hotel and began recording GPS data at the base station in Sondrestrom located at the Met Shack (see section 3). We flew to our four western cluster sites using a Twin Otter aircraft. The flight time was approximately 1 hour. We noticed little melting on the ice sheet surface on the way to the sites (figure 5). We did observe slight surface melting and crusting at several of our field sites. It was easy to drive aluminum poles for antenna mounts into the snow suggesting there was significant snowfall and little melting during the preceding year. We benefited from exceptional weather conditions (unlimited visibility, cloud-free skies, no wind, and warm temperatures) and we were able to complete all four of our sites (1001, 1003, 1006, 1007). We optimized our time on the ground by retrieving the receiver at station 1001 after deploying receivers at 1003 and 1006. We then redeployed this receiver at 1007 before picking up the remaining two on the way back to Sondrestrom. We made gravity measurements upon arrival and attached an extra 6' aluminum pole extension to the antenna mount before departing. We attached flags to the top of the extension. We reoccupied the Arctic Hotel IGSN gravimetric base station upon return to Sondrestrom.

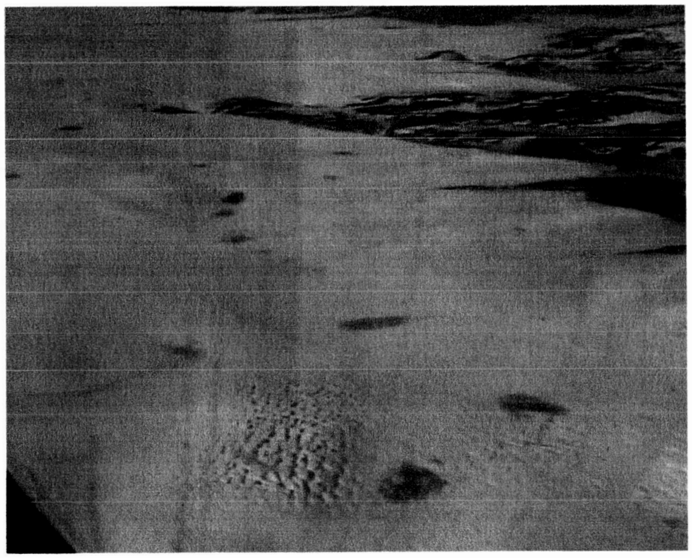

Figure 5. Ice sheet and surface lakes in early June 2004.

We began remeasurements at the Central Cluster on June 4. Our procedure was largely the same except that we measured the height of the aluminum poles left behind last year. We used the lower section of the pole (sometimes augmented with a stub) for the antenna mount. We occupied sites 2006, 2001 and 2005 in an order determined by low clouds that moved through the region. At site 2001, we found only a small section of pole protruding from the snow. Presumably the upper section blew away during the winter.

We excavated a 1-m pit at site 2005 and measured temperature and noted visible stratigraphy. We did not extend the aluminum pole, however we believe the pole tops will still be above the snow level in 2005 should there be reason to remeasure these sites.

We followed the same procedure on June 5 when we completed measurements at the remaining Central Cluster sites (2004, 2003, 2002). We excavated a second shallow pit at 2002. We found the site 2002 aluminum pole was no longer vertical (Figure 6). However it was still firmly in the snow and we estimated the approximate location of the nadir point. We drove a second pole into this point to use as the antenna mount.

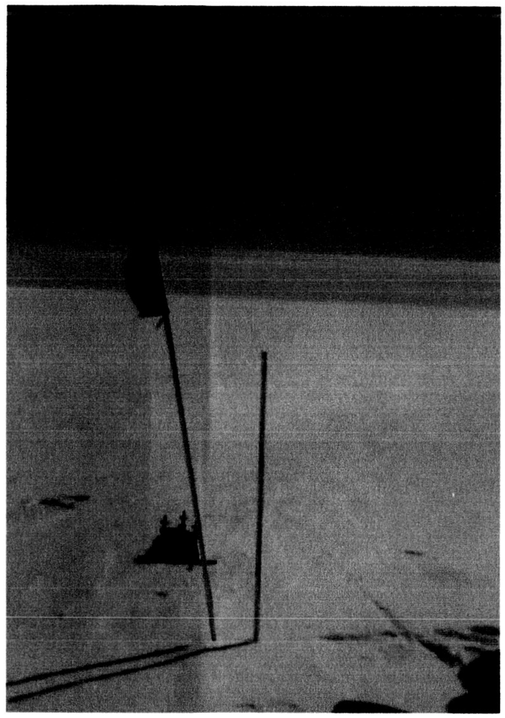

Figure 6. The aluminum pole left at site 2002 in year 2003 was tilted in year 2004. The pole without any flags indicates our best estimate of the position of the based of the pole.

We readied our equipment for return shipment on June 6. In addition we made gravity ties between the Arctic Hotel IGSN site and the old MAC Terminal site. MAC terminal was the primary IGSN station for the 1981 field campaign. We attempted to find the Wharf IGSN station but could not locate it even with GPS navigation. We departed Sondrestrom on June 7 after making a final gravity tie to the Arctic Hotel.

3 GPS Observations

We operated an Ashteck GPS base station at the Met Shack in Sondrestrom. The base station antenna and the Met Shack are shown in figures 7 and 8. The antenna is located directly above a fiducial mark.

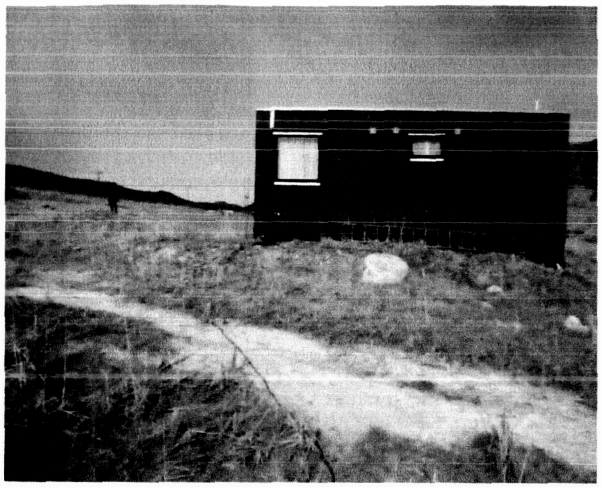

Figure 7. Met Shack located just down the fjord from the Arctic Hotel.

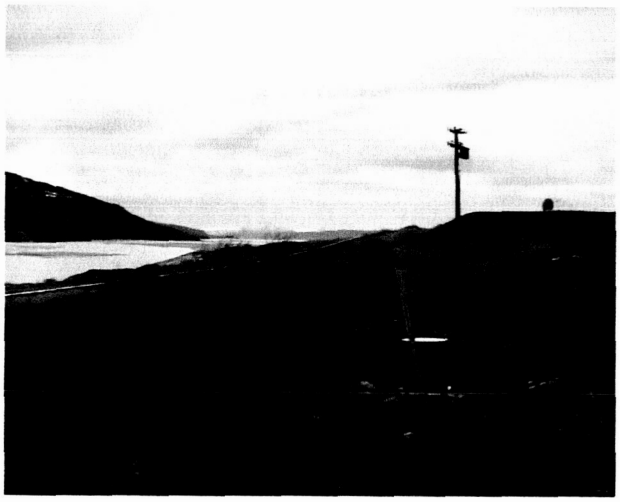

Figure 8. GPS base station antenna set up above the fiduical mark near the Met Shack.

We recorded data once every 30 seconds at the base station and at the field sites.

At the field sites, we drove a 6-foot aluminum pipe into the snow and mounted an antenna atop it (figure 9). We operated the GPS unit for about 90 minutes at each site. At the conclusion of the measurements, we attached a second 6-foot length of pipe to the top of the first, and measured the total height above the snow surface.

A summary of the GPS data files is given in Table 1.

Table 1. GPS file summary

File Name	Date	Time	Site	Ant Height (cm)	Start Time GMT	Record Rate	Lat	Long	Elev	Accum Pole	Comments
B001	1-Jun		Sonde base 61388 KMS	Measured 136.8 cm diagonal - vertical height computed to be 142.1		1/30 sec				none	test record
B002	2-Jun		Sonde base 61388 KMS	Measured136.8 cm diagonal - vertical height computed to be142.1		1/30				none	test record
B003	3-Jun	6:40 Local	Sonde base 61388 KMS	Measured 136.75 cm diagonal vertical height computed to be 142.0	8:45	1/30 sec	67 00.35944	50 42.19484	82.5	none	first complete data set
1001	3-Jun	10:06 Local	1001	E83.5, H84.2, B83.7	12:07	1/30	65 23.27129	47 40.40292	2043	261 CM	
1003	3-Jun	10:55 loc	1003	D85.0, B86.0, C84.6	112:56:00	1/30	65 14.22975	47 27.63264	7039 ft	261	NOTE: Antenna cable was loose upon return
1006	3-Jun	11:45 loc	1006	H87.4, G87.4, C87.4	13:46	1/30	65 32.82603	47 53.74050	1922	264	Surface was starting to melt
1007	3-Jun	12:39 loc	1007	H103.4, C99.4, E101.0	14:40	1/30	65 32.40871	47 27.78466	2040	276	
B004	4-Jun	06:32 loc	Sonde base 61388 KMS	Measured 136.75 cm diagonal vertical height computed to be 142.0	06:32 loc	1/30	67 00.35664	50 42.19138	71.45	none	2nd day of observations

2006	4-Jun 9:49 lo	2006	187.8, 189.0, 187	11:49 1/30	65 17.587	45 50.05	2476	178 cm	accumulation pole not extended
2001	4-Jun 10:31 loc	2001	E108.7, H110.1, B110.1	12:32 1/30	65 06.513	45 41.224	2536	190 CM	Upper part of accumulation pole missing. Installed half section for the antenna. Replaced with full section for accumulation next year
2005	4-Jun 11:13 loc	2005	187.4, 189.9, 188.0	13:15 1/30	65 08.950	46 06.235	8098 ft	180 cm	accumulation pole not extended
B005	5-Jun 6:32	Sonde base 61388 KMS	Measured 136.70 cm diagonal/ vertical height computed to be 142.0	8:35 1.30	67 00.35763	50 42.19570	74.01	none	3rd day of observations
2004	5-Jun 9:54 loc	2004	189.4, 187.4, 189.8	11:54 1/30	64 58.899	46 01.60	2503	179 cm	accumulation pole not extended
2003	5-Jun 10:37 loc	2003	D125.5, C126.0, B123.9	12:37 1/30	64 56.012	45 35.782	2585	204	used a half section of pole for the antenna
2002	5-Jun 11:25 loc	2002	F136.8, A138.0, D138.2	13:26 1/30	65 04.044	45 17.248	8530 ft	128 cm	The pole was tilted so a second pole was inserted at the approximate position of the base of the tilted pole. The offset at the surface was about 22 cm

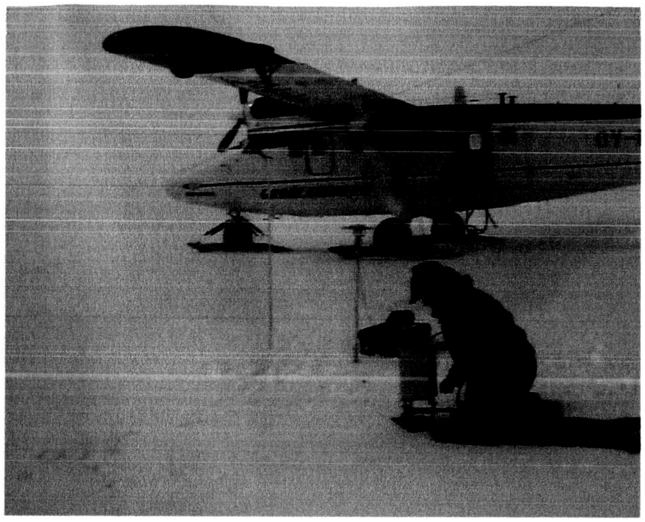

Figure 9. Gravity and GPS measurements at the field site.

4 Gravity Measurements

We used a new Scintrex model CG5 Autograv gravity meter (serial number 40300063). We tied our surveys to two IGSN stations in Sondrestrom, the Arctic Hotel (figure 10) and the SAS Garage. At the end of the campaign, we also tied the Arctic Hotel IGSN gravity site into the old MAC terminal IGSN site. We did this because MAC terminal served as the primary absolute gravity site for the 1981 campaign. For the same reason, we attempted to occupy the Wharf site but were unable to locate the fiducial mark.

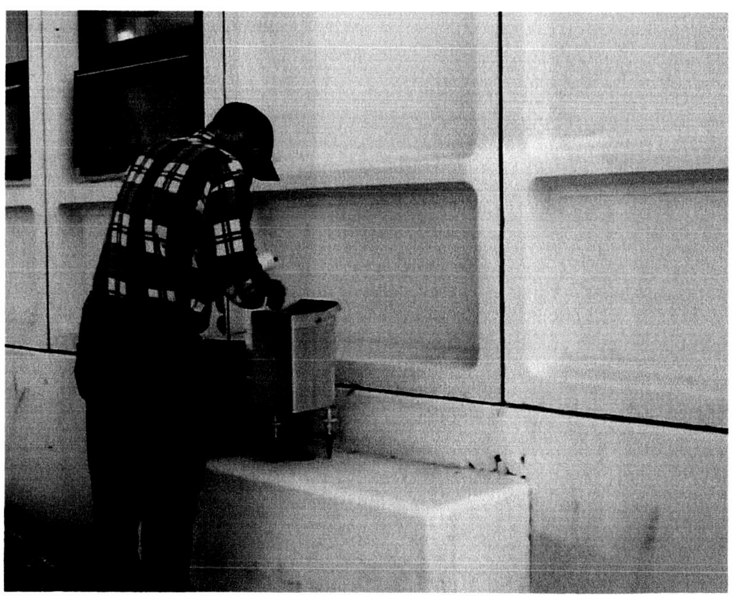

Figure 8. Arctic Hotel IGSN station nr. 68202, EPB 9143-82. A brass fiducial marker indicates the site.

We made measurements with the gravity meter at the base stations and at the field sites. At the base stations, we placed the Scintrex tripod directly over the fiducial (figure 8). At the field sites, we used a fiberglass platform leveled and mounted flush with the snow surface. We mounted the Scintrex tripod on top of the fiberglass platform. The gravity measurements were made within about 1 m of the GPS antenna in the field. We were able to maintain gravity meter temperatures throughout the campaign.

Gravity data entries into the June 9 data file are summarized in table 2. We began the gravity survey by making several measurements around Sondrestrom. In all cases, the CG5 parameter settings were: tide correction, yes; cont. tilt, yes, auto rejection, yes; terrain correction, no; seismic filter, yes; raw data, no. We used a secure, stable location in the VECO warehouse to check the drift correction. The absolute gravity at the site was unknown. We did a local survey between two IGSN stations to check the meter calibration. We checked the Arctic Hotel and SAS Garage sites. We found that that the expected difference between the two sites was 5.335 mgal based on quoted values of absolute gravity. Using the CG5 gravimeter, we found a difference of 5.313 mgal (both at the beginning and the end of our field study). This good agreement gave us confidence in the meter. However as noted later, we do not believe this good agreement persists over large changes in gravity. Finally, we monitored drift and changed the drift constant which enabled us to obtain very consistent ties back to our base station.

Table 2. Gravity file summary (color bands indicate gravity loops)

June 9 data file

Survey Name		Station	Date	Time	Long	Lat	Line Num	Comments
Sonde61			1-Jun	17:41	50.7	67	1	VECO Warehouse, Drift check
							2	VECO Warehouse, Drift Check
		1001	2-Jun	13:44	50.7	67	3	VECO Warehouse, Drift check
		1002	2-Jun	13:55	50.7	67	4	VECO Warehouse, Drift check
s62		3	2-Jun	14:00	50.7	67	1	VECO Warehouse, Drift check
		3	2-Jun	14:08	50.7	67	2	VECO Warehouse, Drift check
		4	2-Jun	14:15	50.7	67	1	VECO Warehouse, Drift check
[redacted]								
a62b		1.1	2-Jun	21:55	50.7	67	1.1	Arctic Hotel IGSN Change Drift Rate and Reset Drift
a63a		1	3-Jun	8:21	50.7	67	1	Arctic Hotel IGSN
	1001	1001	3-Jun	11:43	47.4	65	1001	1001 Field Site
	1001	1001.1	3-Jun	11:59	47.4	65	1001.1	1001 Field Site
	1003	1003	3-Jun	12:50	47.5	65	1003	1003 Field Site
	1006	1006	3-Jun	13:38	47.9	65	1006	1006 Field Site
	1007	1007	3-Jun	14:46	47.5	65	1007	1007 Field Site
	1007	1007.1	3-Jun	14:55	47.5	65	1007.1	1007 Field Site
a63b		1	3-Jun	18:55	50.7	67	1	Arctic Hotel IGSN
a63b		10	3-Jun	19:03	50.7	67	10	Arctic Hotel IGSN
a64a		1	4-Jun	8:15	50.7	67	1	Arctic Hotel IGSN
	2006	2006	4-Jun	11:28	45.83	65.3	2006	2006 Field Site
	2001	2001	4-Jun	12:38	45.69	65.1	2001	2001 Field Site
	2005	2005	4-Jun	13:24	46.1	65.2	2005	2005 Field Site
	2005	2005.1	4-Jun	13:29	46.1	65.2	2005.1	2005 Field Site
a64b		1	4-Jun	19:12	50.7	67	1	Arctic Hotel IGSN
a65a		1	5-Jun	8:15	50.7	67	1	Arctic Hotel IGSN
a65a		1.1	5-Jun	8:20	50.7	67	1.1	Arctic Hotel IGSN
	2004	2004	5-Jun	12:02	46.03	65	2004	2004 Field Site
	2004	2004.1	5-Jun	12:07	46.03	65	2004.1	2004 Field Site
2003a		2003	5-Jun	12:45	45.6	64.9	2003	2003 Field Site
2003a		2003.1	5-Jun	12:52	45.6	64.9	2003.1	2003 Field Site
	2002	2002	5-Jun	13:33	45.29	65.1	2002	2002 Field Site
a65b		1	5-Jun	17:48	50.7	67	1	Arctic Hotel IGSN
[redacted]								

Occasionally, we decided to record a second set of data at the same site. Generally we simply changed the station and line number by a decimal value to indicate the second set of observations.

5 Shallow Pits

We sampled the near surface snow on June 4 at 2005 and dug a shallow pit at 2002 on June 5. At site 2005, we observed about 86 cm of very uniform, fine-grained snow pack with not ice lenses or visible stratigraphy. Below 86 cm, we observed a thick ice layer. The snow temperature decreased from –6° C at the surface to –14° C at the base. At site 2002, we observed 61 cm of uniform, fine-grained snow overlaying an ice layer. The surface temperature was –5° C and the temperature at the base was –12° C.

6 Analysis

Accumulation Rate

Based on the repeat measurements of aluminum pole height, we are able to calculate the accumulation rate in water equivalent for our Center Cluster Sites (Table 3) The 1980 data are from Whillans (van der Veen and others 2001 table 6) and the analysis is based on bomb horizons. The 2004 data are from accumulation pole height difference over a 1-year period. Differences between 1980 estimate and 2004 estimate could plausibly be explained by interannual variations.

Table 3. Accumulation Rate At Central Cluster

Station\year	1980	2004	Delta	% Change Rel 1980
2001	38.3	39.9	1.6	4.3
2002	36.1	43.0	6.9	19.0
2003	40.7	41.0	0.3	0.8
2004	37.2	46.5	9.3	25.0
2005	36.9	39.9	3.0	8.0
2006	35.6	41.6	6.0	17.0
			ave %	12.3

Central Cluster Velocity 1980-2004

Surface displacements are computed using code available from the USGS which computes distance along a geodesic given the initial and final geocentric coordinates. 2003-04 displacements were determined from GPS derived data processed by J. Sonntag in 2003 and 2003. WGS-84 ellipsoid parameters were used. The 1980 data are from

Whillans and the 1993 data from Thomas and others as quoted in van der Veen and others (2000), tables 5 and 13. Surface speeds are about 10 m/yr. There is a statistically significant increase in speed for all sites. The direction of motion has remained nearly constant.

Table 4. Surface Speed and Direction at Central Cluster

Station	80 Speed	80 Dir	93 Speed	93 Dir	04 Speed	04 Dir
2001	9.32	298			10.03	297
2002	7.55	309			7.94	307
2003	8.58	298			8.91	298
2004	11.38	292			11.63	293
2005	11.56	294			12.14	294
2006	10.95	302	11.19	299	11.33	301

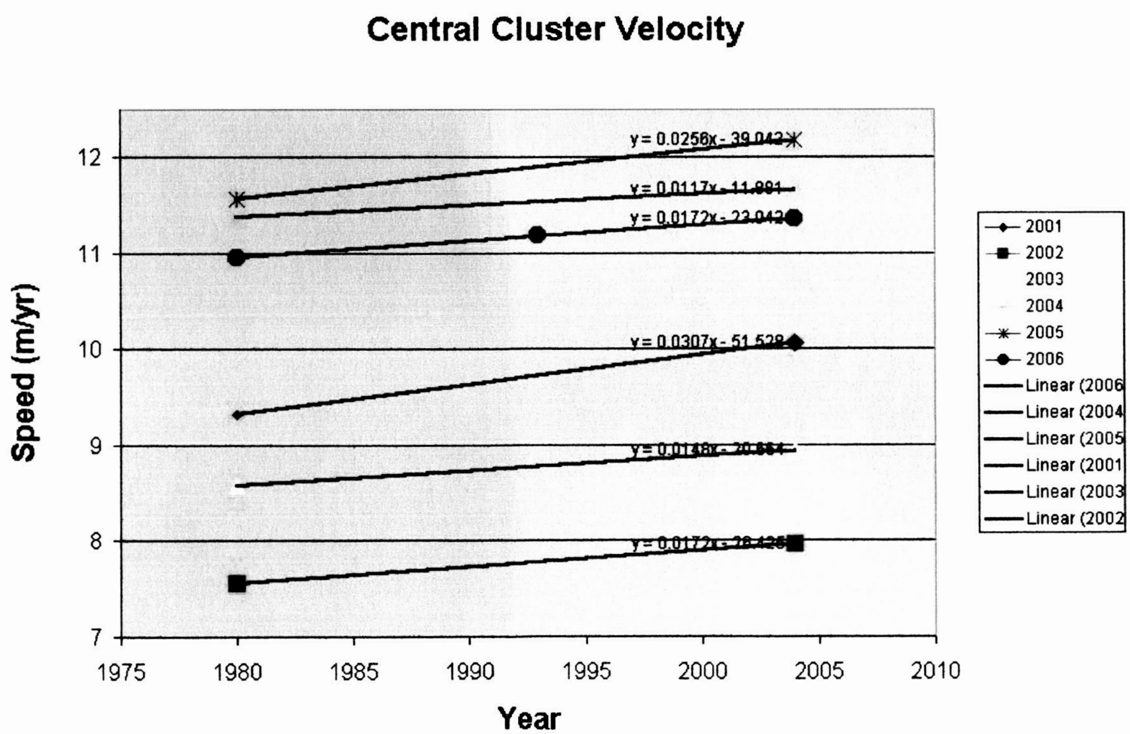

Figure 9. Speed at Central Cluster Sites in 1980/81 and 2003/04.

Elevation Change (1980-2004) at OSU Central Cluster

Elevation steadily increases at the OSU Central Cluster site from 1980 to 2004 (Figure 10) as determined by in situ observations using Doppler Satellites (1980, 1981) and GPS (all subsequent years). This is consistent with independent observations made using an airborne lidar system operated by the Wallops Flight Facility. Table 5 shows that elevation increases at a rate of about 9 cm/yr.

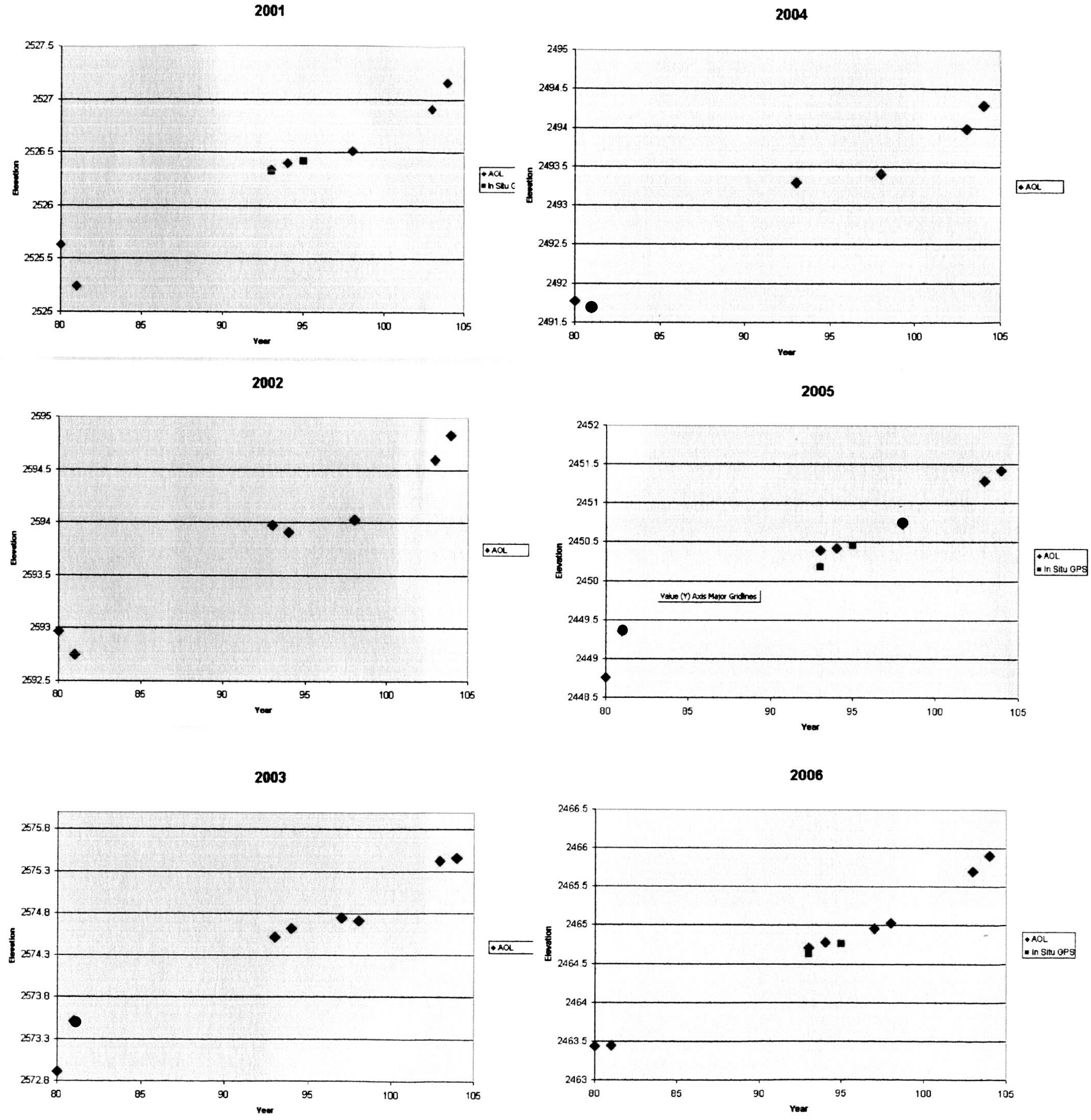

Figure 10. Elevation observations in meters at the Central Cluster sites from 1980 to 2004.

Table 5 Elevation Change Rate (1980-2004) : Linear Fit to All Data

Station	Thickness Change (cm/yr)
2001	6.6
2002	7.3
2003	9.3
2004	10.3
2005	9.8
2006	9.3

Note that elevation change observations are not at precisely the same spot. A small, local-slope correction should be applied before the results are considered final.

Gravity

Gravity data culled from the June 9 data file download are shown in Appendix 1. Note that the base station readings all agree to within 0.01 mgal demonstrating that the drift correction is working properly. However, appendix 1 also shows something worrisome. Data collected in 2003 and data collected in 2004 at the same Central Cluster locations differ systematically by about 3.6 mgal. Given that the surface displacement is only about 10 m, the surface gravity gradients are small, and the elevation change is less than 10 cm, this value is too large to be explained by physical change in the ice sheet. Instead it suggests that the meter calibration is not correct over large changes in gravity relative to a base station. There is a further indication that there is an instrumental problem. Figure 11 shows 24 years of gravity change at the Central Cluster site constructed from observations made using several different LaCoste Romberg gravity meters. Over that period, gravity has decreased by about 0.5 mgal at the most. The 2003-2004 comparison exceeds the 20-year trend by a factor of 6.

Suspecting a problem with the gravity meter calibration, I visited Scintrex Corporation, which is the manufacturer of the equipment, on November 4.

After this introduction, I reviewed the problems with Andrew Hugil who designed the instrument. The first step was to determine if the meter calibration was off. To check the meter, a technician performed a tilt reading and sensitivity adjustment and then we went off to make 5 measurements on the local gravity range.

The range spans the distance from Scintrex to Georgian Bay on Lake Huron. It winds through various rural terrains and small towns. We spent about 5 hours total making measurements on the way out and then on the way back. The meter readings were repeatable to about 1 microgal. There was virtually no drift discernable from readings at the start and end of the survey. Based on the reading, we determined that the calibration had changed by a factor of 0.999514. This explains only about 10% (0.3 mgal) of the observed discrepancy in the field data.

We concluded from the calibration survey that there could either be a problem with the meter or the meter is non-linear over large variations in gravity. Hugil produced data that showed that for a previous meter the non-linearities where only about 0.02 mgal over 2000 milligals. This is small – but still larger than expected based on the meter specifications. Consequently, Scintrex proposed doing a series of tests. These began with a pressure test which he started while I was still on site. The pressure tests were to be followed by a linearization test which I understand is primarily an electrical adjustment.

Hugil also contacted the Canadian Geological Survey to determine if they would be able to take the meter over a gravity course from Toronto to Innuvik on the Arctic Ocean. The great advantage of this idea is that it will operate the meter at sites with known gravity and over a very large range of absolute gravity. (This infact was completed in early 2005 with highly satisfactory results.)

I subsequently learned that there was indeed a problem with the meter linearization. Scintrex is trying to design an approach for measuring the proper value that will retain the integrity of my data – though the chances of reliably correcting my data to useful accuracies are small. The long-line calibration run was completed in April 2005 and the analysis and Scintrex has provided new calibration constants. Based on the results of a more recent gravity survey, the new calibration seems quite good. Analysis of the 2004 data and attempts to retrieve the gravity data are ongoing and will be combined with the data processing from a follow-on project funded in 2005.

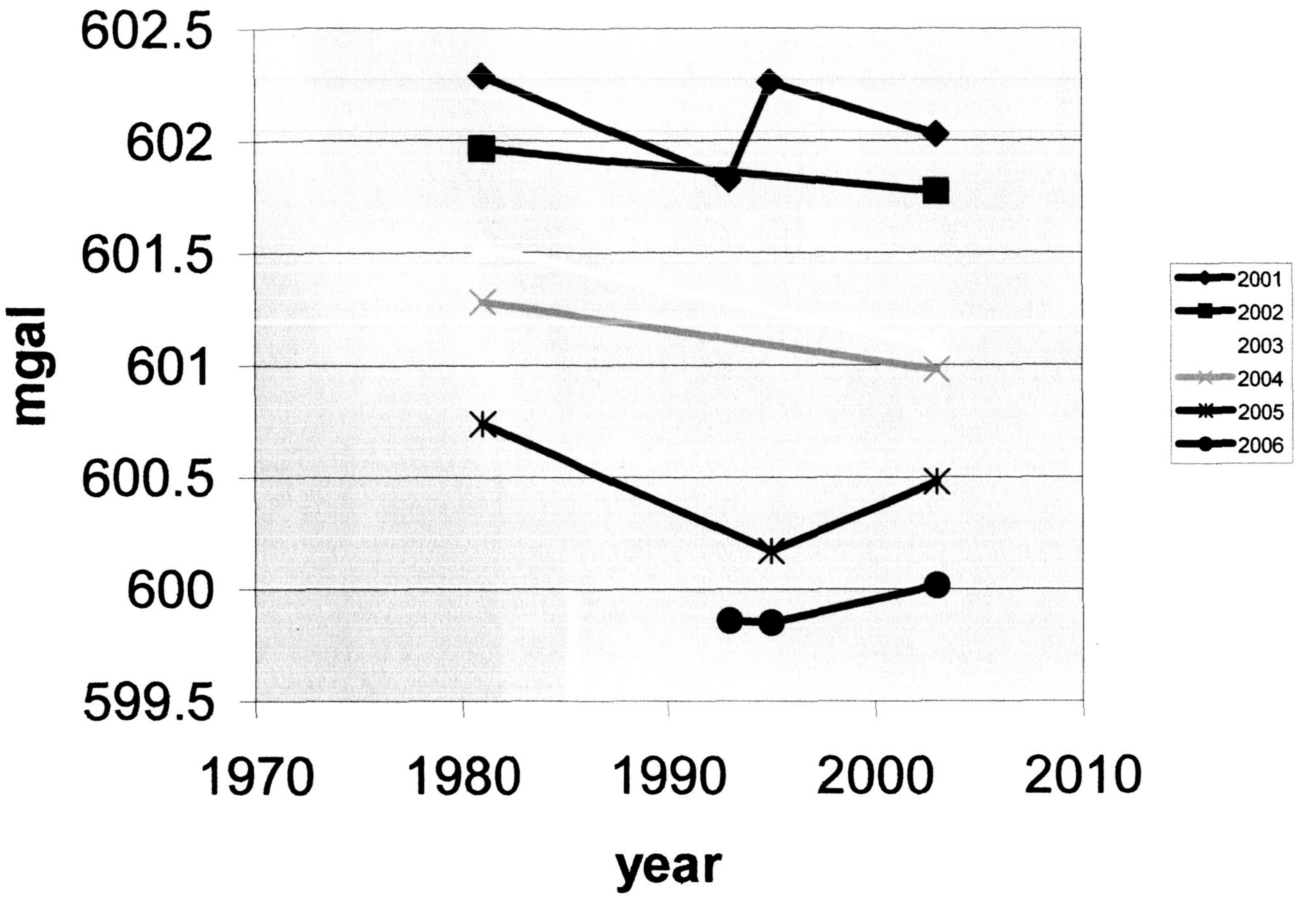

Figure 11. 24 years of gravity observations at Central Cluster

7 Summary

We completed all of our gravity and GPS measurement goals. Initial results suggest that the GPS data are of excellent quality. We are concerned about the gravity data because of an apparently large discrepancy between the 2003 and 2004 results. We also measured snow physical properties at two-sites. We were limited in physical property measurements by a competing demand to maintain short intervals between gravity base station readings and to keep the meters on heat.

8 Acknowledgements

Rosanne Jezek ably assisted with all of the field measurements. We thank Robin Abbot from VECO for logistical help. We also appreciate efforts of the Greenland Air flight crew. Finally we thank the Danish Polar Center for help in securing access to Greenland and our field sites.

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Appendix 1

[redacted]

/	Date:	2004/	6/	3
/	Time:	0.34794		
/	LONG:	50.7 W		
/	LAT:	67 N		
Line	1.000N			

Line	Station	Alt	Grav	Dec Time	Reading - base	IGSN Base+reading-base (mgal)	2003 Value (mgal)	2004-2003 (mgal)
1	1	50	4899.894	1581.354	-0.01	982372.94		
1	1	50	4899.896	1581.355	-0.008	982372.942		
1	1	50	4899.899	1581.355	-0.005	982372.945		
1	1	50	4899.901	1581.355	-0.003	982372.947		
1	1	50	4899.904	1581.356	0	982372.95		

/	Survey	name:	1001	
/	Date:	2004/	6/	3
/	Time:	0.48821		
/	LONG:	47.4 W		
/	LAT:	65 N		
Line	1001.000N			

1001	1001	2028	4270.823	1581.495	-629.081	981743.869
1001	1001	2028	4270.823	1581.495	-629.081	981743.869
1001	1001	2028	4270.824	1581.495	-629.08	981743.87
1001	1001	2028	4270.825	1581.496	-629.079	981743.871
1001	1001	2028	4270.825	1581.496	-629.079	981743.871

Line 1001.100N

1001.1	1001.1	2028	4270.805	1581.499	-629.099	981743.851
1001.1	1001.1	2028	4270.804	1581.499	-629.1	981743.85
1001.1	1001.1	2028	4270.803	1581.5	-629.101	981743.849
1001.1	1001.1	2028	4270.805	1581.5	-629.099	981743.851
1001.1	1001.1	2028	4270.806	1581.501	-629.098	981743.852

/	Survey	name:	1003	
/	Date:	2004/	6/	3
/	Time:	0.53329		
/	LONG:	47.5 W		
Line	1003.000N			

1003	1003	2028	4239.094	1581.534	-660.81	981712.14
1003	1003	2028	4239.096	1581.535	-660.808	981712.142
1003	1003	2028	4239.095	1581.535	-660.809	981712.141
1003	1003	2028	4239.098	1581.535	-660.806	981712.144
1003	1003	2028	4239.094	1581.536	-660.81	981712.14

/	Survey	name:	1006	
/	Date:	2004/	6/	3
/	Time:	0.56808		
/	LONG:	47.9 W		

/	LAT:	65 N					
Line	1006.000N						
	1006	1006	1912	4299.457	1581.569	-600.447	981772.503
	1006	1006	1912	4299.456	1581.569	-600.448	981772.502
	1006	1006	1912	4299.456	1581.57	-600.448	981772.502
	1006	1006	1912	4299.457	1581.57	-600.447	981772.503
	1006	1006	1912	4299.458	1581.571	-600.446	981772.504
/	Survey	name:	1007				
/	Date:	2004/	6/		3		
/	Time:	0.61581					
/	LONG:	47.5 W					
Line	1007.000N						
	1007	1007	2032	4286.101	1581.617	-613.803	981759.147
	1007	1007	2032	4286.1	1581.617	-613.804	981759.146
	1007	1007	2032	4286.1	1581.617	-613.804	981759.146
	1007	1007	2032	4286.102	1581.618	-613.802	981759.148
	1007	1007	2032	4286.101	1581.618	-613.803	981759.147
Line	1007.100N						
	1007.1	1007.1	203	4286.087	1581.621	-613.817	981759.133
	1007.1	1007.1	203	4286.088	1581.621	-613.816	981759.134
	1007.1	1007.1	203	4286.087	1581.621	-613.817	981759.133
	1007.1	1007.1	203	4286.086	1581.622	-613.818	981759.132
	1007.1	1007.1	203	4286.09	1581.622	-613.814	981759.136
[redacted]							
/	Date:	2004/	6/		3		
/	Time:	0.78851					
/	LONG:	50.7 W					
Line	1.000N						
	1	1	50	4899.905	1581.789	0.001	982372.951
	1	1	50	4899.905	1581.789	0.001	982372.951
	1	1	50	4899.907	1581.79	0.003	982372.953
	1	1	50	4899.904	1581.79	0	982372.95
	1	1	50	4899.903	1581.791	-0.001	982372.949
Line	10.000N						
	10	10	50	4899.908	1581.793	0.004	982372.954
	10	10	50	4899.908	1581.793	0.004	982372.954
	10	10	50	4899.907	1581.793	0.003	982372.953
	10	10	50	4899.906	1581.794	0.002	982372.952
	10	10	50	4899.907	1581.794	0.003	982372.953
[redacted]							
/	Date:	2004/	6/		4		
/	Time:	0.34404					
/	LONG:	50.7 W					
/	LAT:	67 N					
Line	1.000N						
	1	1	50	4899.911	1582.344	0	982372.95
	1	1	50	4899.911	1582.345	0	982372.95

	1	1	50	4899.914	1582.345	0.003	982372.953		
	1	1	50	4899.915	1582.346	0.004	982372.954		
	1	1	50	4899.915	1582.346	0.004	982372.954		

[redacted]

/	Date:	2004/	6/	4					
/	Time:	0.47844							
/	LONG:	45.83 W							
/	LAT:	65.3 N							
Line	2006.000N								
	2006	2006	2466	4133.897	1582.5	-766.014	981606.936	981610.51	3.577
	2006	2006	2466	4133.897	1582.5	-766.014	981606.936		
	2006	2006	2466	4133.902	1582.5	-766.009	981606.941		
	2006	2006	2466	4133.901	1582.501	-766.01	981606.94		
	2006	2006	2466	4133.902	1582.501	-766.009	981606.941		

[redacted]

/	Date:	2004/	6/	4					
/	Time:	0.52685							
/	LONG:	45.69 W							
/	LAT:	65.1 N							
Line	2001.000N								
	2001	2001	2527	4127.418	1582.529	-772.493	981600.457	981604.09	3.629
	2001	2001	2527	4127.418	1582.529	-772.493	981600.457		
	2001	2001	2527	4127.419	1582.529	-772.492	981600.458		
	2001	2001	2527	4127.42	1582.53	-772.491	981600.459		
	2001	2001	2527	4127.421	1582.53	-772.49	981600.46		

[redacted]

/	Date:	2004/	6/	4					
/	Time:	0.53743							
/	LONG:	46.1 W							
/	LAT:	65.2 N							
Line	2005.000N								
	2005	2005	2451	4140.351	1582.557	-759.56	981613.39	981616.96	3.572
	2005	2005	2451	4140.352	1582.558	-759.559	981613.391		
	2005	2005	2451	4140.351	1582.558	-759.56	981613.39		
	2005	2005	2451	4140.352	1582.559	-759.559	981613.391		
	2005	2005	2451	4140.351	1582.559	-759.56	981613.39		
Line	2005.100N								
	2005.1	2005.1	2451	4140.335	1582.561	-759.576	981613.374		
	2005.1	2005.1	2451	4140.335	1582.562	-759.576	981613.374		
	2005.1	2005.1	2451	4140.336	1582.562	-759.575	981613.375		
	2005.1	2005.1	2451	4140.335	1582.562	-759.576	981613.374		
	2005.1	2005.1	2451	4140.335	1582.563	-759.576	981613.374		

[redacted]

/	Date:	2004/	6/	4
/	Time:	0.80064		
/	LONG:	50.7 W		
/	LAT:	67 N		

Line	1.000N									
		1	1	50	4899.896	1582.801	-0.015	982372.935		
		1	1	50	4899.9	1582.801	-0.011	982372.939		
		1	1	50	4899.898	1582.802	-0.013	982372.937		
		1	1	50	4899.9	1582.802	-0.011	982372.939		
		1	1	50	4899.9	1582.802	-0.011	982372.939		
[redacted]										
/	Date:	2004/	6/		5					
/	Time:	0.34286								
/	LONG:	50.7 W								
/	LAT:	67 N								
		1	1	50	4899.941	1583.344	-0.004	982372.946		
		1	1	50	4899.941	1583.344	-0.004	982372.946		
		1	1	50	4899.944	1583.344	-0.001	982372.949		
		1	1	50	4899.943	1583.345	-0.002	982372.948		
		1	1	50	4899.942	1583.345	-0.003	982372.947		
Line	1.100N									
		1.1	1.1	50	4899.948	1583.347	0.003	982372.953		
		1.1	1.1	50	4899.95	1583.347	0.005	982372.955		
		1.1	1.1	50	4899.949	1583.348	0.004	982372.954		
		1.1	1.1	50	4899.95	1583.348	0.005	982372.955		
		1.1	1.1	50	4899.952	1583.349	0.007	982372.957		
/	Survey name:	2004								
/	Date:	2004/	6/		5					
/	Time:	0.45156								
/	LONG:	46.03 W								
/	LAT:	65 N								
Line	2004.000N									
		2004	2004	2494	4128.104	1583.501	-771.841	981601.109	981604.74	3.631
		2004	2004	2494	4128.104	1583.501	-771.841	981601.109		
		2004	2004	2494	4128.106	1583.501	-771.839	981601.111		
		2004	2004	2494	4128.11	1583.502	-771.835	981601.115		
		2004	2004	2494	4128.109	1583.502	-771.836	981601.114		
Line	2004.100N									
		2004.1	2004.1	2494	4128.093	1583.505	-771.852	981601.098		
		2004.1	2004.1	2494	4128.095	1583.505	-771.85	981601.1		
		2004.1	2004.1	2494	4128.095	1583.505	-771.85	981601.1		
		2004.1	2004.1	2494	4128.096	1583.506	-771.849	981601.101		
		2004.1	2004.1	2494	4128.096	1583.506	-771.849	981601.101		
/	Survey name:	2003a								
/	Date:	2004/	6/		5					
/	Time:	0.51156								
/	LONG:	45.6 W								
/	LAT:	64.9 N								
Line	2003.000N									
		2003	2003	2575	4103.706	1583.531	-796.239	981576.711	981580.33	3.619
		2003	2003	2575	4103.708	1583.531	-796.237	981576.713		

		2003	2003	2575	4103.709	1583.532	-796.236	981576.714		
		2003	2003	2575	4103.711	1583.532	-796.234	981576.716		
		2003	2003	2575	4103.71	1583.533	-796.235	981576.715		
Line	2003.100N									
		2003.1	2003.1	2575	4103.699	1583.535	-796.246	981576.704		
		2003.1	2003.1	2575	4103.697	1583.535	-796.248	981576.702		
		2003.1	2003.1	2575	4103.697	1583.536	-796.248	981576.702		
		2003.1	2003.1	2575	4103.698	1583.536	-796.247	981576.703		
		2003.1	2003.1	2575	4103.698	1583.537	-796.247	981576.703		
/	Survey	name:		2002						
/	Date:	2004/	6/		5					
/	Time:	0.54211								
/	LONG:	45.29 W								
/	LAT:	65.1 N								
Line	2002.000N									
		2002	2002	2595	4104.557	1583.564	-795.388	981577.562	981581.28	3.718
		2002	2002	2595	4104.558	1583.564	-795.387	981577.563		
		2002	2002	2595	4104.56	1583.565	-795.385	981577.565		
		2002	2002	2595	4104.559	1583.565	-795.386	981577.564		
		2002	2002	2595	4104.558	1583.565	-795.387	981577.563		
[redacted]										
/	Date:	2004/	6/		5					
/	Time:	0.73992								
/	LONG:	50.7 W								
/	LAT:	67 N								
Line	1.000N									
		1	1	50	4899.939	1583.741	-0.006	982372.944		
		1	1	50	4899.938	1583.741	-0.007	982372.943		
		1	1	50	4899.939	1583.742	-0.006	982372.944		
		1	1	50	4899.94	1583.742	-0.005	982372.945		
		1	1	50	4899.938	1583.742	-0.007	982372.943		