Block CN01 (Central North 01)

GRAV-D Airborne Data Release User Manual

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Version Notes

12/2017 BETA #1: First release

Introduction to GRAV-D and Data User Manuals

NOAA's National Geodetic Survey (NGS) launched the Gravity for the Redefinition of the American Vertical Datum (GRAV-D) program in 2007. This program is designed to replace the current national vertical datum (NAVD 88) with a datum based upon a gravimetric geoid by 2022. To produce the geoid with 1-2 cm accuracy (where possible), an airborne campaign has been launched to measure the gravity field over all of the US and its holdings.

A more comprehensive description of the GRAV-D project is available in the "GRAV-D General Airborne Gravity Data User Manual." The version of that manual that applies to this release is manual v. 2.X. That manual also describes general details of the nominal airborne field operations, data post-processing software specifics, data naming schemes and distribution, data formats, and how to calculate other commonly-used gravity values from the released data. This manual relates details for this block of data that are in addition to the General User Manual.

GRAV-D uses some specific terminology (e.g. "block" for a geographic area with enough flown data and tie lines to provide error statistics, and "survey" for an occupation by the field team of a particular airport, at a particular time, and with a particular aircraft and instrument suite). For a full list of terminology, refer to the Glossary in the Appendices of the "GRAV-D General Airborne Gravity Data User Manual."

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1. Block Description

GRAV-D Block **CN01** is located in the **C**entral Time Zone, in the **N**orth half (south of 40° latitude). This was the first (**01**) block of data completed in that region. Block CN01 is 876 km by 447 km, covering areas of Minnesota, North Dakota and Canada (Figure 1). The corner coordinates defining Block CN01 are listed in Table 1.

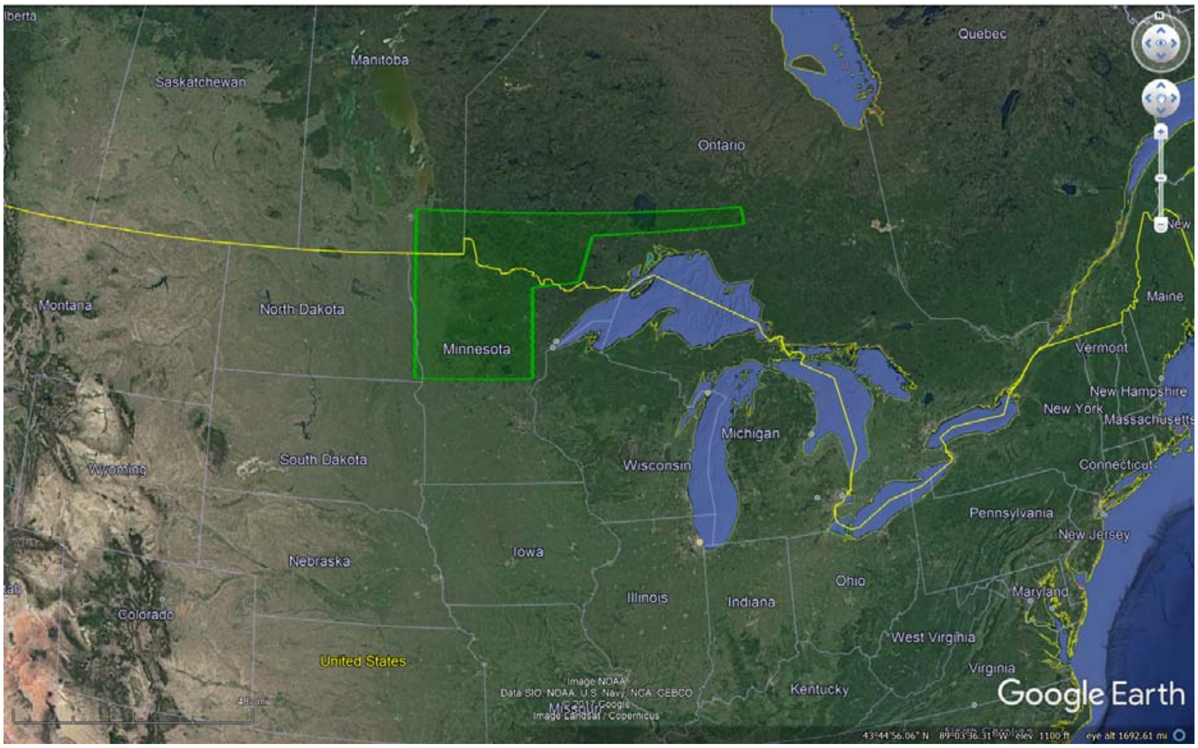

Figure 1: Google Earth Image of the Location of Block CN01

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block CN01

Latitude (decimal degrees)	Longitude (decimal degrees)
46.016092643	-96.835891049
45.993043672	-92.780227821
48.170292202	-92.687035117
48.243317825	-91.040362386
49.335384523	-90.462037615
49.292327986	-84.892006736
49.713539070	-84.927910478
50.086874006	-96.964263918

2. Survey Design and Execution

Airborne gravity data in Block CN01 were collected during five surveys: MN12-1 (Minnesota 2012, first occupation), MN13-1 (Minnesota 2013, first occupation), MN15-1 (Minnesota 2015, first occupation), MN15-2 (Minnesota 2015, second occupation) and MN16-1 (Minnesota 2016, first occupation). All data and cross flights were done at approximately 20,000 ft with two different aircraft and two different relative gravimeters. Supplementary data from transit (target of opportunity) flights may be made available at a future date. Table 3, Table 4, and

Table 5 give a synopsis of survey layout and execution for the data. Figure 2: shows the data coverage, plotted in Google Earth.

In CN01 some data lines are East-West and some are North-South. Cross lines were flown diagonally to the block in a Northwesterly or Southeasterly direction. The block consists of 20 data lines and 7 cross lines from MN12-1; 26 data lines and 5 cross lines from MN13-1; 13 data lines and 1 cross line from MN15-1; 2 data lines from MN15-2; and 28 data lines from MN16-1. Two data lines were reflown: Line 109 from MN12-1 and line 209 from MN15-1; and line 125 from MN13-1 and line 225 from MN16-1. Cross lines CN01509 and CN01609 data are collinear, but do not overlap at all so are not considered a reflight of a cross line. The usual line numbering scheme used by GRAV-D (see "General User Manual") was used for this survey. In the data file, line numbers are preceded by the block name (i.e. CN01101= block CN01's line 101).

Several cross lines were originally used for block EN05, but intentionally flown long enough to act as cross lines for the north eastern "pan handle" of CN01 as well. To reduce confusion in processing and in this manual, these cross lines were each given a unique CN01 designation as well. Table 2 shows the lines EN05 designation and their corresponding CN01 designation.

Table 2 Equivalent cross lines from EN05 and CN01

EN05	CN01
EN05501	CN01507
EN05502	CN01508
EN05503	CN01509
EN05603	CN01609
EN05504	CN01510
EN05505	CN01511
EN05506	CN01512

Table 3: Survey Overview

Conducting Organization	Fugro Earth Data	NOAA-National Geodetic Survey
Survey Name	MN12-1	MN13-1
Airport Base of Operations	Range Regional Airport (HIB) Hibbing, MN FBO: Range Regional	Duluth International Airport (DLH) Duluth, MN FBO: Monaco
Geographic Location	Minnesota, Wisconsin, and Canada	
Dates of Airborne Operations	May 2 – Jul. 2, 2012	Aug. 19 - 28, 2012
Coducting Organization	NOAA- National Geodetic Survey	
Survey Name	MN15-1	MN15-2
Airport Base of Operations	Duluth International Airport (DLH) Duluth, MN FBO: Monaco	Flying Cloud Airport (FCM) Eden Prairie, MN FBO: Executive Aviation
Geographic Location	Minnesota, Wisconsin, and Canada	Iowa, Michigan, Minnesota, and Wisconsin
Dates of Airborne Operations	Jul. 16 – Aug. 1, 2015	Aug. 9 – Sep. 13, 2015
Coducting Organization	NOAA- National Geodetic Survey	
Survey Name	MN16-1	
Airport Base of Operations	Flying Cloud Airport (FCM) Eden Prairie, MN FBO: Executive Aviation	
Geographic Location	Iowa, Michigan, Minnesota, and Wisconsin	
Dates of Airborne Operations	Jul. 28 – Aug. 31, 2016	

Table 4: Aircraft and Instrumentation

Aircraft	Dynamic Aviation King Air E90A (N23W)
Engines, number and type	2, Turboprop
Gravity Instrumentation	Micro-g LaCoste (MGL) TAGS S-160 & S-161 (relative) (MN12-1) MGL A-10 (absolute) LaCoste and Romberg G-6 (relative)
GPS Instrumentation	NovAtel DL-4 Plus NovAtel SPAN-SE with Honeywell µIRS (GPS + IMU)
Aircraft	NOAA Turbo Commander (N45RF)
Engines, number and type	2, Turboprop
Gravity Instrumentation	Micro-g LaCoste (MGL) TAGS S-137 (relative) (MN13-1, MN16-1) Micro-g LaCoste (MGL) TAGS S-161 (relative) (MN15-1, MN15-2) MGL A-10 (absolute) LaCoste and Romberg D-43 and G-6 (relative)
GPS Instrumentation	NovAtel DL-4 Plus NovAtel SPAN-SE with Honeywell µIRS (GPS + IMU)

Table 5: Survey Design and Execution

Line Spacing	Data Lines: 10 km Cross Lines: ~80 km
Type of Layout	Regular data lines & regular cross lines
Nominal Survey Altitude	20,000 ft
Nominal Aircraft Ground Speed	250 knots
Number of Lines Released	Data Lines: 20 (MN12-1), 26 (MN13-1), 13 (MN15-1), 2 (MN15-2), 28 (MN16-1) Cross Lines: 7 (MN12-1), 5 (MN13-1), 1 (MN15-1) Repeat Lines: 2 data lines (Cross lines 509 and 609 are collinear but do not overlap)
Number of Crossovers	257

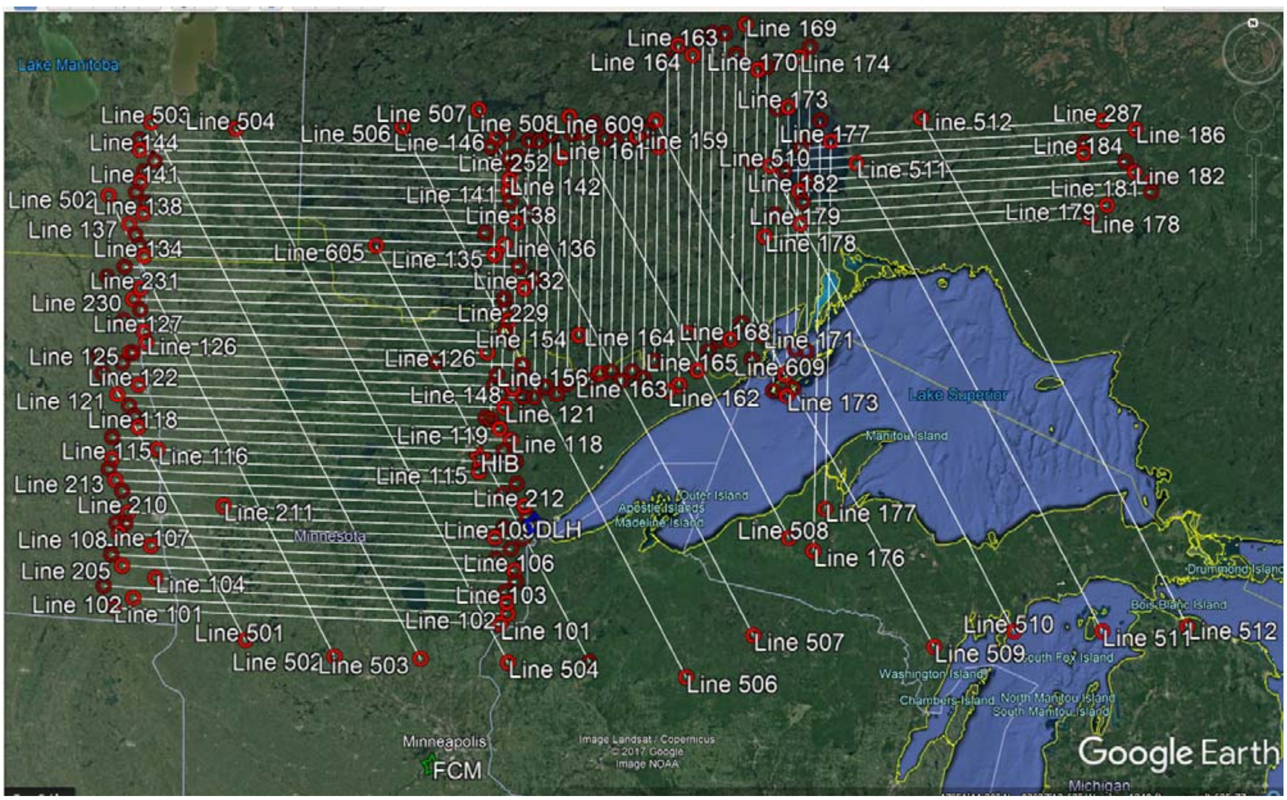

Figure 2: Data Coverage for CN01. Data lines range from 101 to 187. Range Regional Airiport (HIB) is marked with a red star, Duluth International Airport (DLH) is marked with a blue star, and Flying Cloud Airport (FCM) is marked with a green star.

2.1 GPS/IMU Instrumentation

The Dynamic Aviation King Air and the NOAA Turbo Commander had one GPS antenna available for scientific measurements. Two geodetic-quality GPS receivers shared the antenna: one NovAtel DL-V3 or NovAtel DL-4 Plus (included as part of the TAGS gravimeter timing unit) and a NovAtel SPAN-SE. The NovAtels' had a data rate of 1 Hz. The NovAtel SPAN-SE system included a Honeywell Inertial Measurement Unit (IMU) that recorded aircraft orientation information at 200 Hz during the flight, including pitch, roll, yaw, and heading.

On the ground, two or three Ashtech Z-Surveyor antenna/receivers for the following surveys: MN12-1, MN13-1, MN15-1, and MN15-2, recording at 1 Hz served as GPS base stations throughout the survey. For MN16-1 two NovAtel PP6 recording at 1Hz were used. See Section 3.3.1 GPS processing- by flight for a table of GPS data available for each flight and processing details.

2.2 Gravity Instrumentation

The Micro-g LaCoste TAGS (Turn-key Airborne Gravimetry System) was mounted in the cargo area of the Turbo Commander. The TAGS records data at 1 Hz and has a NovAtel timing unit mounted on the gravimeter. The gravimeter also records an environmental file at 0.1 Hz. For more information on the instrument, refer to its user manual (Micro-g LaCoste, 2010).

The TAGS was mounted to the seat tracks in the center of the fuselage of the aircraft. The IMU was mounted on top of the TAGS and in the center of the frame. Table 6 lists the lever arm measurements between the TAGS and other instruments (distances are measured along the body of the aircraft: X positive toward the right, Y positive toward the nose, and Z positive up.)

Table 6: Lever Arm Measurements FROM the SPAN TO the Other Instruments

MN12-1 Instrument/Location	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter (TAGS 137)	-0.011	0.015	-0.527
Aircraft GPS Antenna	-0.125	-0.364	0.52
MN13-1 Instrument/Location	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter (TAGS 137)	-0.011	0.015	-0.527
Aircraft GPS Antenna	0.092	0.143	0.616
MN15-1 Instrument/Location	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter (TAGS 161)	-0.017	0.019	-0.433
Aircraft GPS Antenna	0.092	0.143	0.616
MN15-2 Instrument/Location	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter (TAGS 161)	-0.017	0.019	-0.433
Aircraft GPS Antenna	0.092	0.143	0.616
MN16-1 Instrument/Location	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter (TAGS 137)	-0.011	0.015	-0.527
Aircraft GPS Antenna	0.092	0.143	0.616

3. GPS and Gravity Data Processing

3.1 Whole-Survey Applicable Details

3.1.1 GPS

Table 7: GPS High Rate Data Availability (1 Hz or higher)

Airport	Type	Receiver	Flight Available	Day of Year Available (UTC)
HIB MN12-1	Kinematic	NovAtel (SPAN)	f01, f02, f04, f06, f09, f11, f14-f16, f19, f21, f22, f24, f25	146, 150, 151, 152, 154, 157, 160, 161, 167, 169, 173, 174, 176
	Static	Ashtech 2807	f01, f02, f04, f06, f09, f11, f14-f16, f19, f21, f22, f24, f25	146, 150, 151, 152, 154, 157, 160, 161, 167, 169, 173, 174, 176
		Ashtech 3402	f01, f02, f04, f09, f11, f14-f16, f19, f21, f22, f24, f25	146, 150, 151, 154, 157, 160, 161, 167, 169, 173, 174, 176
		Ashtech 3901	f01, f02, f04, f06, f09, f11, f14-f16, f19, f21, f22, f24, f25	146, 150, 151, 152, 154, 157, 160, 161, 167, 169, 173, 174, 176
DLH MN13-1	Kinematic	NovAtel (SPAN)	f01, f03, f05-f16	231-240
	Static	Ashtech 3613	f05, f07, f09-f11, f13, f15, f16	232, 233, 235, 237-240
		Ashtech HELA	f01, f03, f05-f16	231-240
DLH MN15-1	Kinematic	NovAtel (SPAN)	f04-f11	204, 207-209, 213
	Static	Ashtech EAST	f04-f11	204, 207-209, 213
		Ashtech WEST	f05, f07, f09-f11	204, 207-209, 213
FCM MN15-2	Kinematic	NovAtel (SPAN)	f01	221
		Ashtech WEST	f01	221
FCM MN16-1	Kinematic	NovAtel (SPAN)	f03, f09, f23, f32, f34, f36, f38, f40	211, 214, 226, 240-244
	Static	NovAtel North	f03, f09, f23, f32, f34, f36, f38, f40	211, 214, 226, 240-244
		NovAtel South	f03, f23, f32, f34, f36, f38, f40	211, 226, 240-244

Data were processed using GRS80 and ITRF08. After post-processing the GPS-only kinematic data (before processing with coupled IMU), average position accuracy for the data block is calculated. Position standard deviation is estimated by the GPS processing programs for each flight and those numbers are averaged to provide a survey-wide estimate of GPS position accuracy. For the data lines, the average horizontal position accuracy is ±0.055 m and the average vertical position accuracy is ±0.090 m (95% confidence interval).

3.1.2 Ground Gravity Tie

Absolute gravity measurements were performed by NGS with a Micro-g LaCoste A-10 gravimeter in April 2012 (HIB), August 2013 (DLH), and September 2015 (FCM). The A-10 was set up at the exact location of the aircraft: Dynamic Aviation's King Air E90 and NOAA's Turbo Commander. The positions were determed from the GPS collected during the gravity survey while the plane was parked. Table 8 is a summary of the point ID, location and gravity tie from each of the airports.

Table 8: Gravity Ties at the height of the TAGS Gravimeter in the airplane.

Airport	Point ID	Latitude	Longitude	Tie height above mark (cm)	Gravity Tie (mGal)
HIB	KHIB TAGS	47.39216758°N	92.84433465°W	162.56	980687.028 ± 0.008
DLH	KDLH TAGS	46.83877300°N	92.19219228°W	80.6	980694.359 ± 0.008
FCM	KFCM TAGS	44.82422686°N	93.45237376°W	80.6	980572.819 ± 0.008

3.1.3 Gravity Filtering

For block CN01, flights were accomplished in two surveys and were filtered the same way. Newton v1.4 uses a time-domain Gaussian filter that is applied three times to the data during final filtering. The Gaussian filter chosen for this survey has a 6-sigma of 120s, i.e. a 2-sigma of only 40s. Applying the filter three times provides superior noise reduction compared to a single application of the filter. Although the triple application provides better noise reduction, the filter is tailored to best preserve the amplitudes of the long wavelength signal, while allowing some short wavelength noise to remain in the final product. For suggestions on data handling, including on further noise suppression, see Section 4.1 Suggested Data Handling.

3.2 Whole-Block Applicable Details

3.2.1 Gravity Error Analysis

Crossover error analysis was done by identifying the crossing points of the data lines and cross lines and then applying the standard free-air correction to bring all points to the average altitude of the block. There was an unidentified bias in all flight lines, so an additional correction was applied before the crossover analysis to adjust each line's median airborne gravity value to the median gravity value of EGM08 along the line. The bias-corrected difference between the cross line gravity value and data line gravity value is the residual. The square root of the RMS of the residuals yields the total RMS error. For CN01, the result of the crossover analysis is shown in

Table 9 and in Figure 3.

Table 9: Gravity Crossover Error Analysis

Nominal Altitude (ft)	Nominal Altitude (m)	Altitude for Analysis (m)	Number of Crossovers	RMS Of Residuals (mGal)	Std. Dev. Of Residuals (mGal)	Mean Crossover Difference (mgal)	RMS Error (mGal)
20,000	6,096	6,351	257	2.38	2.32	-0.54	1.68

One assumption of crossover analysis is that the quality of the cross lines are high and that the crossover difference reflects only the error in the data lines. This is not necessarily the case. This means that the crossover statistics do not accurately reflect the quality of the data lines, due to the errors in the cross lines. One way to quantify this problem is by reporting the standard deviation and mean of the crossover residuals for each cross line, as in Table 10. The higher the standard deviation of the residuals, the more likely that the cross line was noisy. Also, a non-zero mean could indicate a cross-line bias with respect to the data lines (unlikely here because of the bias correction applied), which would produce false crossover statistics that indicate poor data line quality.

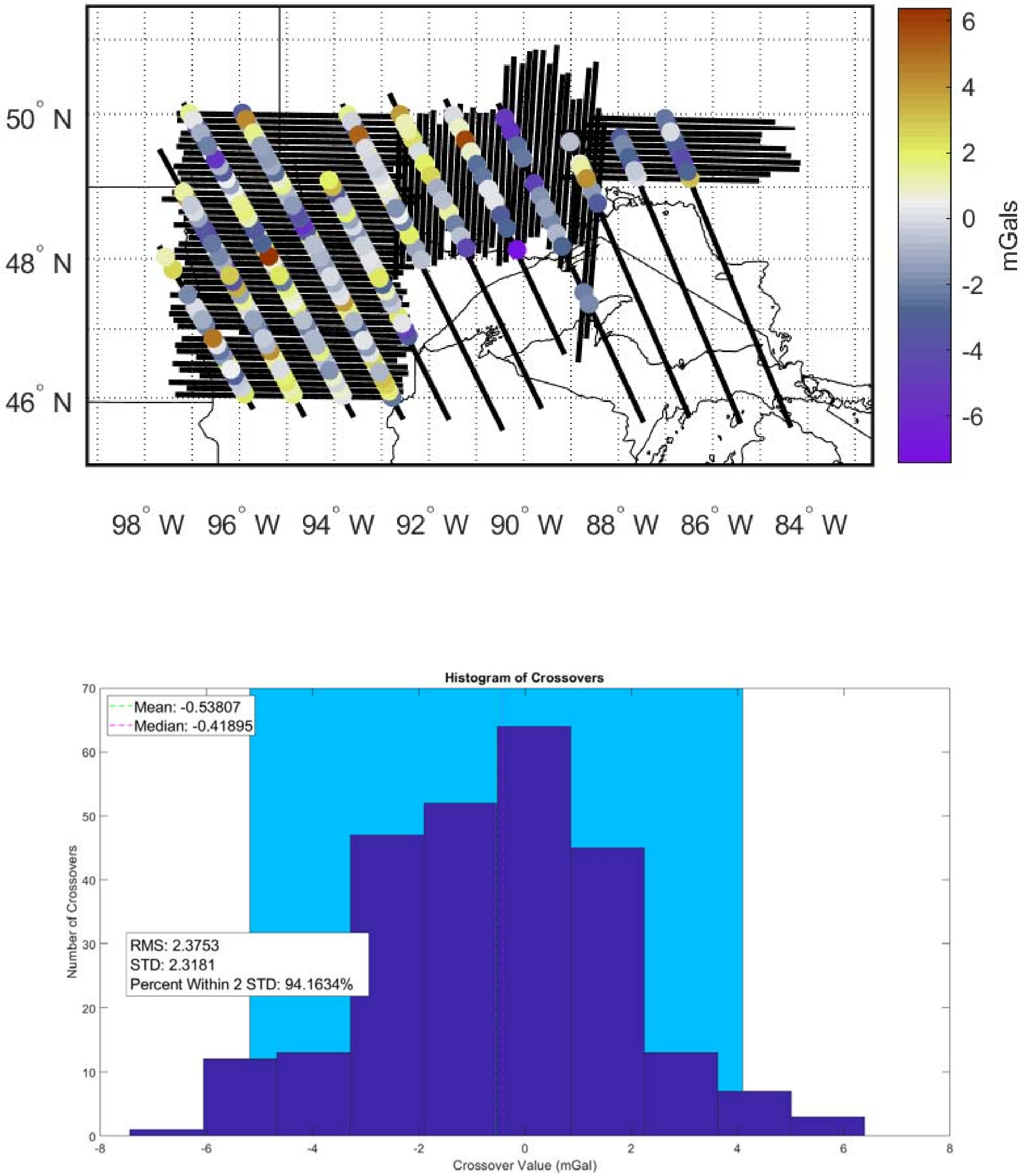

Figure 3: Crossover Residuals, Histogram, and Statistics for Block CN01.

Table 10: Quality of Cross Lines Used in Crossover Analysis

Cross Line Number	Standard Deviation of Residuals Along Line (mGal)	Mean of Residuals Along Line (mGal)
501	2.01	0.07
502	2.63	-0.50
503	2.07	-0.37
504	2.10	-0.34
605	2.15	-0.44
506	1.92	0.04
507	2.45	0.012
508	3.35	-0.91
509	0.18	-2.11
609	1.66	-2.91
510	2.45	0.42
511	1.91	-2.32
512	2.41	-2.38

Another way to evaluate the quality of gravity data is to calculate the correlation of the gravity values along two adjacent data lines. Average correlation and statistics on the spread of correlations can yield information about the quality of the data lines (Table 11) This technique works well as a measure of data quality in areas with little lateral variability in the gravity field (such as the Gulf of Mexico). But the technique doesn't work well when the correlations are not expected to be high, such as in areas with large changes in topography and/or density from data line to data line. Line correlations were calculated for adjacent lines and then averaged to give an overall quality measurement. Correlations > 80% mean the lines are very highly correlated, 70% - 80% mean the lines are highly correlated, 50% - 70% mean the lines are more correlated than not, and <50% are more uncorrelated than correlated.

Table 11: Average Data Line Correlation

Number of Correlations	Average Data Line Correlation	Standard Deviation of Correlations
90	91.31%	10.71%

A fourth way of gauging data quality is by calculating the repeatability of the gravity signal along reflown lines of good quality. Reflight analysis can also help to pinpoint the lightest filtering that produces highly-correlated results. In CN01 two data lines had re-flights: CN01109 and CN01125. The correlations between these re-flown lines are found in (Table 12).

Table 12: Correlations between reflown lines

Survey	Line Track Number	Correlation
MN12-1	109	86.11%
MN15-1	209	
MN13-1	125	98.11%
MN16-1	225	

3.3 Flight- and Line-Specific Details

3.3.1 GPS processing- by flight

GPS data were processed in Inertial Explorer (IE) v. 8.7. A lever arm correction (to move the position solution from that of the GPS antenna to that of the center of the gravimeter) was applied within the IE software and included in the GPS+IMU solution. In the case of the GPS-only solution, no IMU data were available and a translation-only, vertical lever arm correction was instead applied by the Newton gravity code to translate the GPS-only positions to the center of the gravimeter.

NGS has developed an independent method of measuring the quality of GPS position solutions based on information available from both Inertial Explorer. For the GPS-only part of the position solution, the quality analysis takes into account the following: whether a fixed or float solution was achieved, the magnitude of the combined separation between forward and reverse solutions (a measure of precision), and the estimated position accuracy. For details on the calculation, please refer to the “GRAV-D General Airborne Gravity Data User Manual.”

3.3.2 Gravity processing- by line

All gravity processing was done with NGS’ Newton v1.4 software. For a description of the package, refer to the “GRAV-D General Airborne Gravity Data User Manual.” The final gravity data file contains full-field gravity at altitude (Figure 4), although other gravity products such as free-air anomalies or free-air disturbances (Figure 5) can be easily calculated by following directions in Section 4 of the “GRAV-D General Airborne Gravity Data User Manual”.

Table 13: GPS+IMU and GPS-only Kinematic Processing Results

Survey	Flight Num.	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Quality Grade
MN12-1	1	SPAN	GPS+IMU	5	211	100
	2	SPAN	GPS+IMU	7.5	106	100
					107	100
					108	100
	4	SPAN	GPS+IMU	7.5	121	100
					122	100
	6	SPAN	GPS+IMU	7.5	114	100
	9	SPAN	GPS+IMU	5	132	100
					133	100
					134	100
	11	SPAN	GPS+IMU	5	124	100
	14	SPAN	GPS+IMU	5	115	100
					116	100
					117	100
					118	100
	15	SPAN	GPS+IMU	5	101	100

					102	100
					103	100
					104	100
	16	SPAN	GPS+IMU	7.5	109	100
	19	SPAN	GPS+IMU	7.5	507	100
					508	100
	21	SPAN	GPS+IMU	5	512	100
	22	SPAN	GPS+IMU	5	509	100
					510	100
	24	SPAN	GPS+IMU	5	511	100
	25	SPAN	GPS+IMU	7.5	609	100
MN13-1	1	SPAN	GPS+IMU	7.5	146	100
					147	100
					148	100
					149	100
	3	SPAN	GPS+IMU	7.5	119	100
					120	100
	5	SPAN	GPS+IMU	5	154	100
					155	100
					156	100
					157	100
	6	SPAN	GPS+IMU	7.5	250	100
					251	100
					252	100
					253	100
	7	SPAN	GPS+IMU	5	145	100
					502	100
	8	SPAN	GPS+IMU	7.5	503	100
	9	SPAN	GPS+IMU	7.5	504	100
	10	SPAN	GPS+IMU	5	501	100
	11	SPAN	GPS+IMU	5	143	100
					144	100
	12	SPAN	GPS+IMU	5	141	100
					142	100
	13	SPAN	GPS+IMU	5	158	100
					159	100
					160	100
					161	100
	14	SPAN	GPS+IMU	5	506	100
	15	SPAN	GPS+IMU	7.5	139	100
	16	SPAN	GPS+IMU	7.5	125	100

					126	100
MN15-1	4	SPAN	GPS+IMU	7.5	212	100
					213	100
	5	SPAN	GPS+IMU	7.5	209	100
					210	100
	6	SPAN	GPS+IMU	5	186	100
					287	100
	7	SPAN	GPS+IMU	5	184	100
	8	SPAN	GPS+IMU	7.5	605	100
	9	SPAN	GPS+IMU	7.5	162	100
					163	100
	10	SPAN	GPS+IMU	7.5	182	100
					183	100
	11	SPAN	GPS+IMU	7.5	180	100
					181	100
MN15-2	1	SPAN	GPS+IMU	7.5	127	100
					128	100
MN16-1	3	SPAN	GPS+IMU	5	178	100
					179	100
					285	100
	9	Span	GPS+IMU	5	176	100
					177	100
	23	Span	GPS+IMU	5	205	100
					223	100
	32	SPAN/Differential Base 47	GPS+IMU	7.5	164	100
					165	100
					166	100
					167	100
	34	SPAN	GPS+IMU	5	170	100
					171	100
					172	100
					173	100
	36	SPAN	GPS+IMU	5	135	100
					136	100
					137	100
					138	100
	38	SPAN	GPS+IMU	7.5	168	100
					169	100
					174	100
					175	100
	40	SPAN	GPS+IMU	5	225	100

					229	100
					230	100
					231	100
					240	100

Table 14: Gravity Processing Results

Survey	Flight Num.	Line Num.	Time of Deleted Data Section (s)	Comments
There were no deleted sections in this block				

Table 15 Bias from EGM08 by Line

Survey	Flight Num.	Line Num.	Bias from EGM08
MN12-1	1	211	1.49
	2	106	-0.58
		107	0.05
		108	-0.36
	4	121	0.87
		122	-0.42
	6	114	-0.97
	9	132	-0.98
		133	-0.32
		134	-1.64
	11	124	2.43
	14	115	-0.52
		116	-1.09
		117	-0.06
		118	-1.5
	15	101	-0.42
		102	-2.28
		103	-1.7
		104	-1.08
	16	109	3.17
	19	507	0.03
		508	-0.1
	21	512	-1.25
	22	509	0.18
		510	0.16
	24	511	-0.38
	25	609	-1.02
MN13-1	1	146	0.21

		147	1.39
		148	0.69
		149	1.17
	3	119	0.33
		120	-1.14
	5	154	-0.65
		155	0.16
		156	-0.32
		157	-0.15
	6	250	-1.4
		251	-0.71
		252	-0.98
		253	-0.31
	7	145	-0.96
		502	0.07
	8	503	-0.25
	9	504	0.1
	10	501	0.1
	11	143	0.36
		144	-0.6
	12	141	0.19
		142	-0.23
	13	158	-0.57
		159	0.35
		160	0.57
		161	0.28
	14	506	0.07
	15	139	1.06
	16	125	1.36
		126	-0.06
MN15-1	4	212	3.55
		213	1.15
	5	209	2.03
		210	0.31
	6	186	1.05
		287	1.24
	7	184	2.81
	8	605	-0.02
	9	162	3.25
		163	3.07
	10	182	3.57

		183	1.28
	11	180	5.34
		181	4.8
MN15-2	1	127	3.75
		128	3.34
MN16-1	3	178	-0.05
		179	1.76
		285	-0.83
	9	176	1.83
		177	2.1
	23	205	0.82
		223	-0.43
	32	164	1.41
		165	2.12
		166	3.5
		167	3.77
	34	170	1.04
		171	1.07
		172	0.84
		173	0.66
	36	135	-1.18
		136	0.56
		137	0.02
		138	1.71
	38	168	1.62
		169	1.22
		174	1.32
		175	1.37
	40	225	0.74
		229	1.18
		230	-0.17
		231	1.06
		240	-0.54

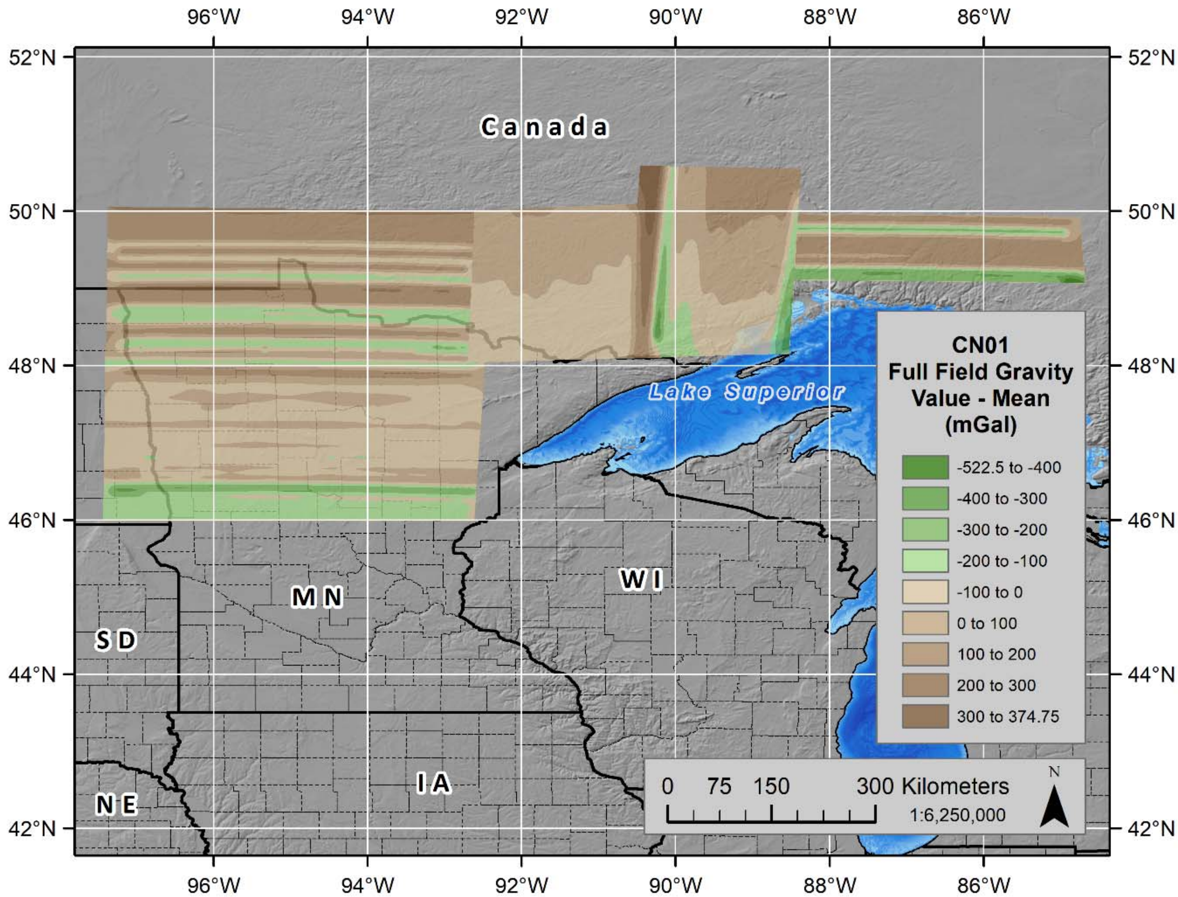

Figure 4: Full-field gravity at altitude (mean removed) for Block CN01. This is the data in the gravity release ".txt" file and includes the effects of differing altitudes along flight lines.

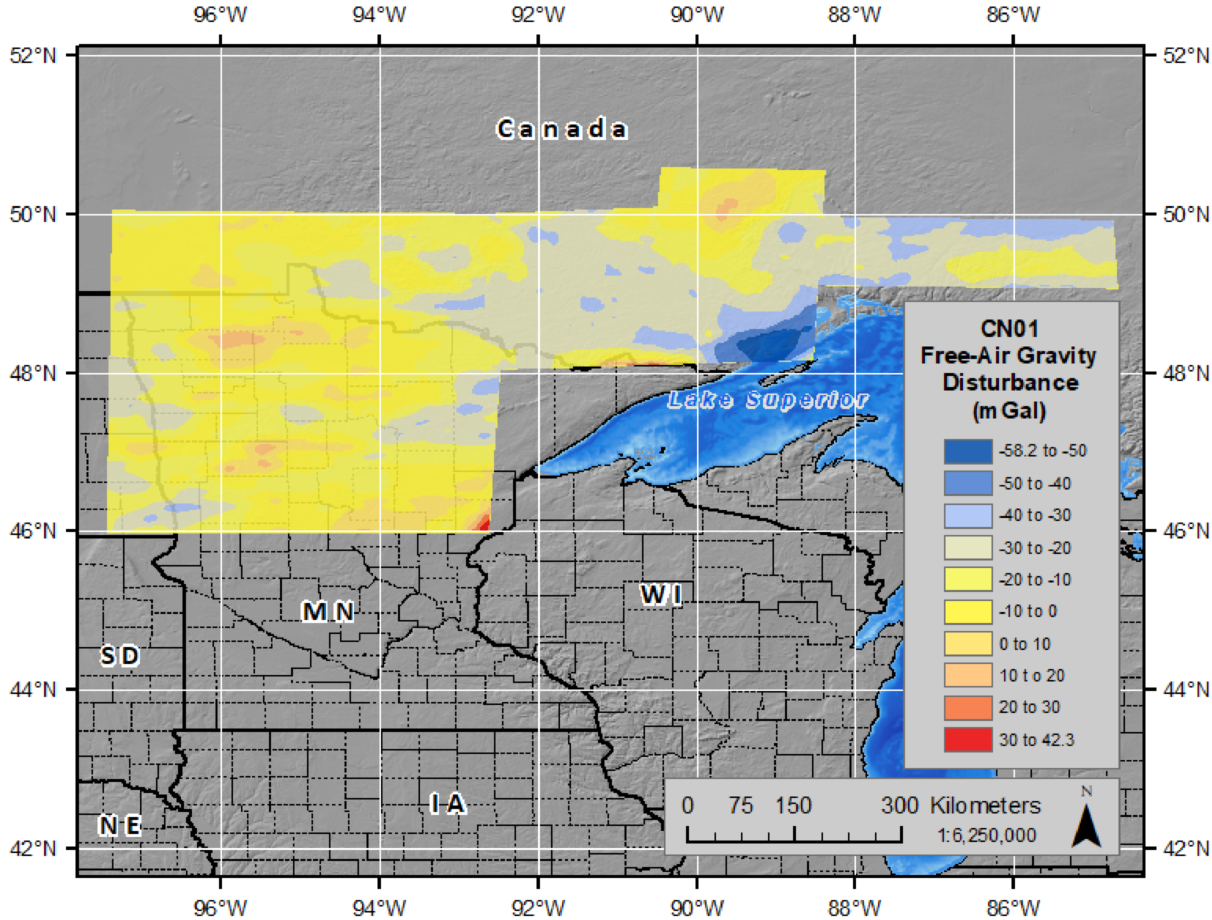

Figure 5 Free-air gravity disturbance for Block CN01 with respect to the GRS80 ellipsoid

4. Data Usage Guidelines

4.1 Suggested Data Handling

This data product was purposefully filtered to preserve the amplitude of the long-wavelength gravity signal. As a trade-off, the filter allows some short wavelength noise to remain in the product. Prior to use for geophysical purposes, the data should be run through a frequency-domain low-pass filter to remove that excess short wavelength noise. For geodetic purposes, higher frequencies can be damped during inclusion into a spherical harmonic model. In any case where downward continuation will be done with this data, the high frequency noise should first be filtered out, damped, or otherwise dealt with so that the downward continuation does not amplify the noise.

4.2 Documentation

The survey block User Manual, the general GRAV-D User Manual, and metadata for the block should all be downloaded with the data and kept in the same directory. The contents of the manuals are critical to understanding the quality of the data and using the data properly.

4.3 How to Cite These Data

The following citations should be used in all presentations or publications that reference the GRAV-D work. Please replace the *DATE* tag in the following references with the date you downloaded the data or reports from the NGS website.

The GRAV-D Team, in alphabetical order, are: Vicki A. Childers, Justin Dahlberg, Theresa M. Damiani, Jeff Kanney, Jeffery A. Johnson, Chris Villarreal, Derek van Westrum, and Monica A. Youngman.

To reference the CN01 data file, reference the webpage:
GRAV-D Science Team (2017). "Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project, Airborne Gravity Data; Block CN01". Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_CN01.shtml

To reference the block and survey details, reference the block user manual:
GRAV-D Science Team (2017). "Block CN01 (Central North 01); GRAV-D Airborne Gravity Data User Manual." Monica A. Youngman and Jeffery A. Johnson, ed. Version BETA. Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_CN01.shtml

To reference the general GRAV-D project operations, reference the General User Manual:
GRAV-D Science Team (2017). "GRAV-D General Airborne Gravity Data User Manual." Theresa Damiani, Monica Youngman, and Jeffery Johnson, ed. Version 2.1. Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_products.shtml

5. References

Micro-g LaCoste, 2010. "TAGS Turnkey Airborne Gravity System AIR III Hardware & Operations Manual."