Block AN09 (Alaska North 09)

GRAV-D Airborne Data Release User Manual

Applies to Data Release BETA #1, 1/2018

Edited by Monica A. Youngman and Jeffery A. Johnson

Version Notes

1/2018 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."

Contents

Introduction to GRAV-D and Data User Manuals 1
Figure List 3
Table List 3
1. Block Description 4
2. Survey Design and Execution 5
  2.1 GPS/IMU Instrumentation 7
  2.2 Gravity Instrumentation 7
3. GPS and Gravity Data Processing 8
  3.1 Whole-Survey Applicable Details 8
    3.1.1 GPS 8
    3.1.2 Ground Gravity Tie 8
    3.1.3 Gravity Filtering 9
  3.2 Whole-Block Applicable Details 9
    3.2.1 Gravity Error Analysis 9
  3.3 Flight- and Line-Specific Details 12
    3.3.1 GPS processing- by flight 12
    3.3.2 Gravity processing- by line 12
4. Data Usage Guidelines 21
  4.1 Suggested Data Handling 21
  4.2 Documentation 21
  4.3 How to Cite These Data 21
5. References 21

Figure List

Figure 1: Google Earth Image of the Location of Block AN09 4
Figure 2: Data Coverage for AN09 6
Figure 3: Crossover Residuals, Histogram, and Statistics for Block AN09. 10
Figure 4: Full-field gravity at altitude (mean removed) for Block AN09 19
Figure 5 Free-air gravity disturbance for Block AN09 with respect to the GRS80 ellipsoid 20

Table List

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block AN09 4
Table 2: Survey Overview 5
Table 3: Aircraft and Instrumentation 6
Table 4: Survey Design and Execution 6
Table 5: Lever Arm Measurements FROM the SPAN TO the Other Instruments 7
Table 6: GPS High Rate Data Availability (1 Hz or higher) 8
Table 7: Gravity Ties at the height of the TAGS Gravimeter in the airplane. 9
Table 8: Gravity Crossover Error Analysis 9
Table 9: Quality of Cross Lines Used in Crossover Analysis 11
Table 10: Average Data Line Correlation 11
Table 11: Correlations between Reflown Lines 11
Table 12: GPS+IMU and GPS-only Kinematic Processing Results 13
Table 13: Gravity Processing Results 15
Table 14: Bias from EGM08 by Line 17

1. Block Description

GRAV-D Block **AN09** is located in the **A**laska Time Zone, in the **N**orth half (north of 63° latitude). This was the ninth (**09**) block of data completed in that region. Block AN09 is 460 km by 360 km, covering areas of Alaska and its coast (Figure 1). The corner coordinates defining Block AN09 are listed in Table 1.

Figure 1: Google Earth Image of the Location of Block AN09

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block AN09

Latitude (decimal degrees)	Longitude (decimal degrees)
64.635933267	-168.620937629
59.643779730	-168.110432624
61.457581023	-157.239346265
63.311793671	-157.760897726
63.331292070	-157.422456293
65.523414919	-158.363899732

2. Survey Design and Execution

Airborne gravity data in Block AN09 were collected during three surveys: AK16-2 (Alaska 2016, second occupation), AK17-2 (Alaska 2017, second occupation), and AK17-3 (Alaska 2017, third occupation). Data lines from AK16-2 were flown at approximately 20,000 ft, and data lines and cross lines from AK17-2 and AK17-3 were flown at approximately 24,000 ft. AN09 was surveyed with one aircraft and one relative gravimeter. Supplementary data from transit (target of opportunity) flights may be made available at a future date. Table 2, Table 3, and Table 4 give a synopsis of survey layout and execution for the data. Figure 2: shows the data coverage, plotted in Google Earth.

In AN09, data lines are North-South and cross lines are East-West. The block consists of 31 data lines and 1 cross line from AK16-2, 18 data lines and 5 cross line from AK17-2, and 20 data lines from AK17-3. Four data lines were reflown: Line AN09119 from AK17-2 and line AN09219 from AK17-3; line AN09229 from AK17-3 and line AN09329 from AK17-3, AN09143 from AK16-2 and AN09243 from AK17-2, and line AN09162 from AK16-2 and line AN09262 from AK17-2. 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. AN09101= block AN09's line 101).

Table 2: Survey Overview

Coducting Organization	NOAA- National Geodetic Survey	
Survey Name	AK16-2	AK17-2
Airport Base of Operations	Nome Airbort (OME) Nome, AK FBO: Bering Air, Inc.	Nome Airbort (OME) Nome, AK FBO: Bering Air, Inc.
Geographic Location	Coastal Alaska	
Dates of Airborne Operations	May 15 - July 9, 2016	May 16 - June 9, 2017
Coducting Organization	NOAA- National Geodetic Survey	
Survey Name	AK17-3	
Airport Base of Operations	Dilingham Airport (DLG) Dillingham, AK FBO: Alaska Cargo Services	
Geographic Location	Coastal Alaska	
Dates of Airborne Operations	June 10 – July 2017	

Table 3: Aircraft and Instrumentation

Aircraft	Dynamic Aviation King Air (N43U)
Engines, number and type	2, Turboprop
Gravity Instrumentation	Micro-g LaCoste (MGL) TAGS S-161 (relative) MGL A-10 (absolute) LaCoste and Romberg D-43 and G-6 (relative)
GPS Instrumentation	NovAtel DL-V3 or DL-4 Plus NovAtel SPAN-SE with Honeywell μIRS (GPS + IMU)

Table 4: 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 (AK16-2), 24,000 ft (AK17-2 and AK17-3)
Nominal Aircraft Ground Speed	250 knots
Number of Lines Released	Data Lines: 31 (AK16-2), 18 (AK17-2), 20 (AK17-3) Cross Lines: 1 (AK16-2), 5 (AK17-2) Repeat Lines: 4 data lines
Number of Crossovers	389

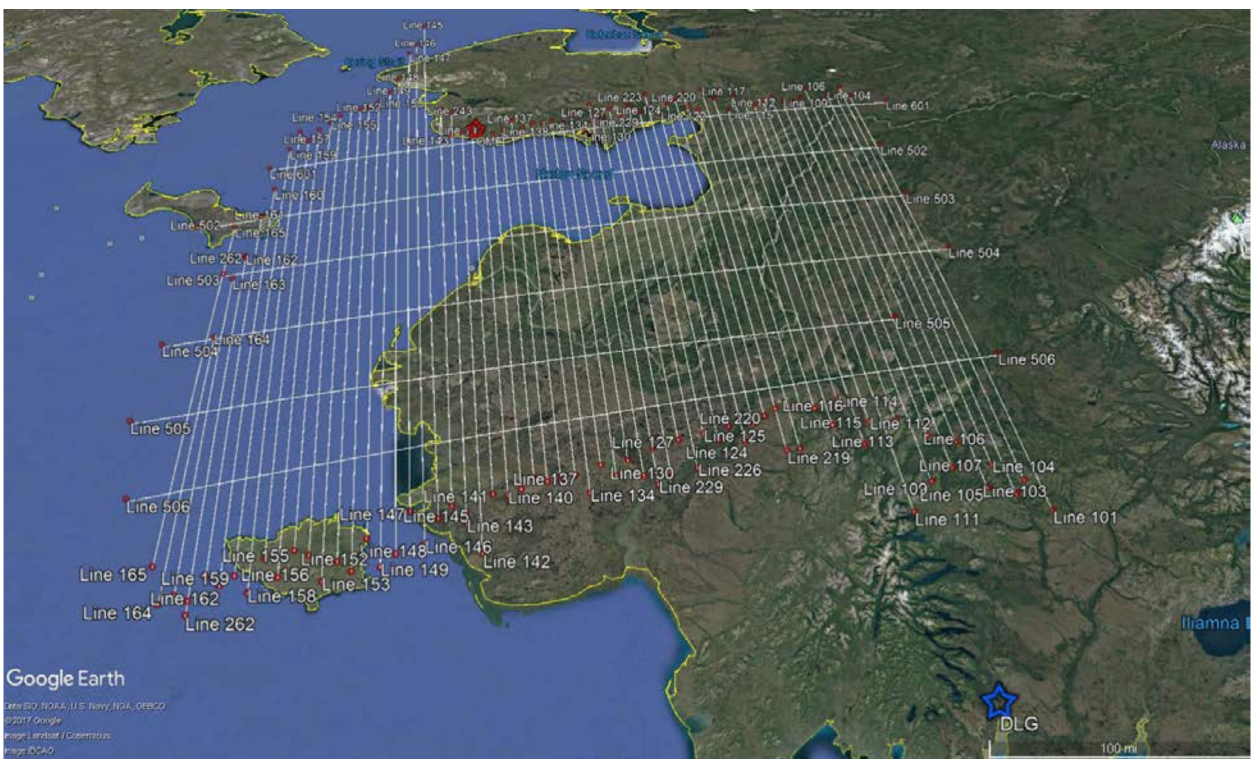

Figure 2: Data Coverage for AN09. Data lines range from 101 to 165. Nome Airport (OME) is marked with a red star, and Dillingham Airport (DLG)is marked with a blue star.

2.1 GPS/IMU Instrumentation

The Dynamic Aviation King Air had one GPS antenna available for scientific measurements. Two geodetic-quality GPS receivers shared the antenna: either a 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 Ashtech Z-Extreme antenna/receivers for AK16-2 recording at 1 Hz served as GPS base stations throughout the survey. And for AK17-2 and AK17-3, one NovAtel PP6 and one Ashtech Z-Extreme antenna/receivers served as base stations recording at 1 Hz. See Section 3.2.1 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 King Air and Pilatus. 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 5 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 5: Lever Arm Measurements FROM the SPAN TO the Other Instruments

Instrument/Location	X (m)	Y (m)	Z (m)
Gravimeter (TAGS 161)	-0.017	0.019	-0.433
Aircraft GPS Antenna	-0.132	0.360	0.463

3. GPS and Gravity Data Processing

3.1 Whole-Survey Applicable Details

3.1.1 GPS

Table 6: GPS High Rate Data Availability (1 Hz or higher)

Airport	Type	Receiver	Flight Available	Day of Year Available (UTC)
OME AK16-2	Kinematic	NovAtel (SPAN)	f01-f04, f10, f13, f16, f18-f20, f22-f24, f28, f30, f31, f41, f43, f46	138-140, 149, 153-163, 166, 167, 180-184
OME AK16-2	Static	Ashtech EAST	f01-f04, f10, f13, f16, f18-f20, f22-f24, f28, f30, f31, f41, f43, f46	138-140, 149, 153-163, 166, 167, 180-184
OME AK16-2	Static	Ashtech WEST	f01, f16, f19, f20, f22, f24, f28, f31, f41, f43, f46	138, 154-163, 166, 167, 180-184
OME AK17-2	Kinematic	NovAtel (SPAN)	f01, f02, f04, f06-f11, f13-f15	139-140, 142, 143, 148-152, 158-160
OME AK17-2	Static	Ashtech EAST	f02, f04, f06-f11, f14, f15	139-140, 142, 143, 148-152, 158-160
OME AK17-2	Static	NovAtel 44	f01, f02, f04, f06-f11, f13-f15	139-140, 142, 143, 148-152, 158-160
DLG AK17-3	Kinematic	NovAtel (SPAN)	f01, f02, f04, f06, f08, f09, f13-f15, f23	166-172, 175, 176, 196
DLG AK17-3	Static	Ashtech South	f01, f02, f09, f14, f23	166-168, 171, 172, 175, 176, 196
DLG AK17-3	Static	NovAtel 44	f01, f02, f04, f06, f08, f09, f13-f15, f23	166-172, 175, 176, 196

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 ±0.042 m and the average vertical position accuracy is ±0.074 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 July 2015 (OME and DLG). The A-10 was set up at the exact location of Dynamic Aviation's King Air. The positions were determed from the GPS collected during the gravity survey while the plane was parked. Table 7 is a summary of the point ID, location and gravity tie from each of the airports.

Table 7: 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)
OME	KDLH OME	64.51183726°N	165.4361187°W	159.385	981754.452 ± 0.008
DLG	PADL TAGS	59.04408698°N	159.5127957°W	159.385	981851.093 ± 0.008

3.1.3 Gravity Filtering

For block AN09, flights were accomplished in three 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 AN09, the result of the crossover analysis is shown in Table 8 and in Figure 3.

Table 8: 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	7,053	389	3.78	3.39	1.68	2.67

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 9. 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.

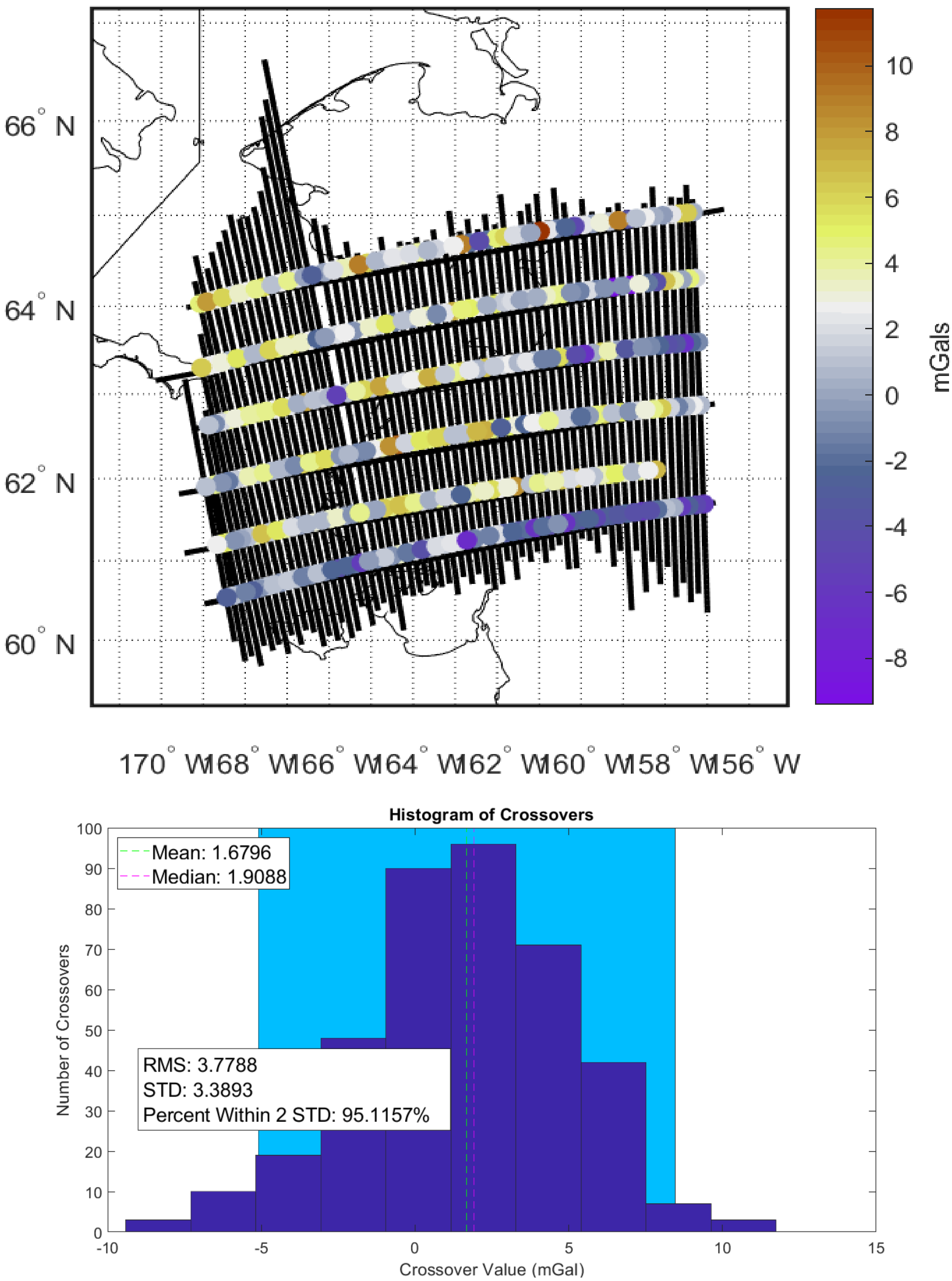

Figure 3: Crossover Residuals, Histogram, and Statistics for Block AN09

Table 9: Quality of Cross Lines Used in Crossover Analysis

Cross Line Number	Standard Deviation of Residuals Along Line (mGal)	Mean of Residuals Along Line (mGal)
601	3.29	2.50
502	3.30	1.96
503	3.42	1.76
504	2.78	2.66
505	2.33	3.14
506	2.74	-1.65

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 10) 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 10: Average Data Line Correlation

Number of Correlations	Average Data Line Correlation	Standard Deviation of Correlations
76	99.91%	0.07%

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 AN09 four data lines had re-flights: AN09119, AN09129, AN09143, and AN09162. The correlations between these re-flown lines are found in (Table 11).

Table 11: Correlations between Reflown Lines

Survey	Line Track Number	Correlation
AK17-2	AN09119	100.00
AK17-3	AN09219	
AK17-3	AN09229	99.97
AK17-3	AN09329	
AK16-2	AN09143	99.95
AK17-2	AN09243	
AK16-2	AN09162	99.95
AK17-2	AN09262	

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 12: GPS+IMU and GPS-only Kinematic Processing Results

Survey	Flight Num.	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
OME AK16-2	1	SPAN	GPS + IMU	7.5	141	100
					142	100
	2	SPAN	GPS + IMU	7.5	139	100
					140	100
	3	SPAN	GPS + IMU	5	137	100
					138	100
	4	SPAN	GPS + IMU	5	135	100
					136	100
	10	SPAN	GPS + IMU	5	133	100
					134	100
	13	SPAN	GPS + IMU	5	143	100
	16	SPAN	GPS + IMU	5	130	100
	18	SPAN	GPS + IMU	5	127	100
					128	100
	19	SPAN	GPS + IMU	5	125	100
	20	SPAN	GPS + IMU	5	506	100
	22	SPAN	GPS + IMU	5	124	100
	23	SPAN	GPS + IMU	5	163	100
					164	100
	24	SPAN	GPS + IMU	5	162	100
	28	SPAN	GPS + IMU	5	159	100
					160	100
	30	SPAN	GPS + IMU	5	157	100
					158	100
	31	SPAN	GPS + IMU	5	155	100
					156	100
	41	SPAN	GPS + IMU	5	153	100
					154	100
	43	SPAN	GPS + IMU	7.5	151	100
					152	100
	46	SPAN	GPS + IMU	5	149	100
					150	100
OME AK17-2	1	SPAN	GPS + IMU	7.5	231	100
					232	100
	2	SPAN	GPS + IMU	5	223	100
					226	100
	4	SPAN	GPS + IMU	5	505	100

	6	SPAN	GPS + IMU	5	161	100
					262	100
	7	SPAN	GPS + IMU	5	147	100
					148	100
	8	SPAN	GPS + IMU	7.5	144	100
					146	100
	9	SPAN	GPS + IMU	7.5	243	100
					145	100
	10	SPAN	GPS + IMU	5	502	100
					601	100
	11	SPAN	GPS + IMU	5	165	100
					503	100
					504	100
	13	SPAN	GPS + IMU	5	121	100
					122	100
	14	SPAN	GPS + IMU	5	119	100
	15	SPAN	GPS + IMU	5	117	100
					118	100
DLG AK17-3	1	SPAN	GPS + IMU	5	113	100
					114	100
	2	SPAN	GPS + IMU	5	219	100
					220	100
	4	SPAN	GPS + IMU	5	101	100
					102	100
	6	SPAN	GPS + IMU	5	115	100
					116	100
	8	SPAN	GPS + IMU	5	111	100
					112	100
	9	SPAN	GPS + IMU	5	109	100
					110	100
	13	SPAN	GPS + IMU	5	103	100
					104	100
	14	SPAN	GPS + IMU	5	105	100
					106	100
	15	SPAN	GPS + IMU	5	107	100
					108	100
	23	SPAN	GPS + IMU	5	229	100
					329	100

Table 13: Gravity Processing Results

Survey	Flight Num.	Line Num.	Time of Deleted Data	Comments
OME AK16-2	1	141		
		142		
	2	139		
		140		
	3	137		
		138		
	4	135		
		136		
	10	133		
		134		
	13	143		
	16	130		
	18	127		
		128		
	19	125		
	20	506		
	22	124	90471-90857	Bump Removed
	23	163		
		164		
	24	162		
	28	159		
		160	91876-92121	Bump Removed
	30	157		
		158		
	31	155		
		156		
	41	153		
		154		
	43	151		
		152		
	46	149		
		150		
OME AK17-2	1	231		
		232		
	2	223		
		226		
	4	505		
	6	161		

		262		
	7	147		
		148		
	8	144		
		146		
	9	243		
		145	71472-71673	Bump Removed
	10	502		
		601		
	11	165		
		503		
		504		
	13	121		
		122		
	14	119		
	15	117		
		118		
DLG AK17-3	1	113		
		114		
	2	219	85090-85267	Bump Removed
		220		
	4	101		
		102		
	6	115		
		116		
	8	111		
		112		
	9	109		
		110		
	13	103		
		104		
	14	105		
		106		
	15	107		
		108		
	23	229		
		329		

Table 14: Bias from EGM08 by Line

Survey	Flight Num.	Line	EGM08 mean
OME AK16-2	1	141	2.14
		142	3.3
	2	139	0.85
		140	2.02
	3	137	2.69
		138	4.01
	4	135	1.14
		136	2.17
	10	133	2.2
		134	1.83
	13	143	0.62
	16	130	0.67
	18	127	2.82
		128	2.33
	19	125	1.57
	20	506	2.5
	22	124	0.97
	23	163	2.03
		164	3.43
	24	162	0.6
	28	159	1.54
		160	3.36
	30	157	2.88
		158	1.9
	31	155	2.9
		156	1.55
	41	153	3.96
		154	3.73
	43	151	2.02
		152	1.66
	46	149	3.29
		150	4.23
OME AK17-2	1	231	3.96
		232	7.09
	2	223	5.19
		226	6.3
	4	505	7.06
	6	161	6.6

		262	6.15
	7	147	5.26
		148	3.91
	8	144	6.42
		146	8.5
	9	243	5.23
		145	6.55
	10	502	4.87
		601	5.42
	11	165	5.6
		503	5.29
		504	6.76
	13	121	4.18
		122	3.5
	14	119	4.43
	15	117	4.32
		118	3.88
DLG AK17-3	1	113	3.08
		114	3.35
	2	219	3.53
		220	3.3
	4	101	5.36
		102	4.04
	6	115	6.57
		116	6.1
	8	111	4.1
		112	2.98
	9	109	4.85
		110	4.11
	13	103	2.9
		104	3.07
	14	105	2.37
		106	1.71
	15	107	2.5
		108	3.37
	23	229	2.61
		329	1.71

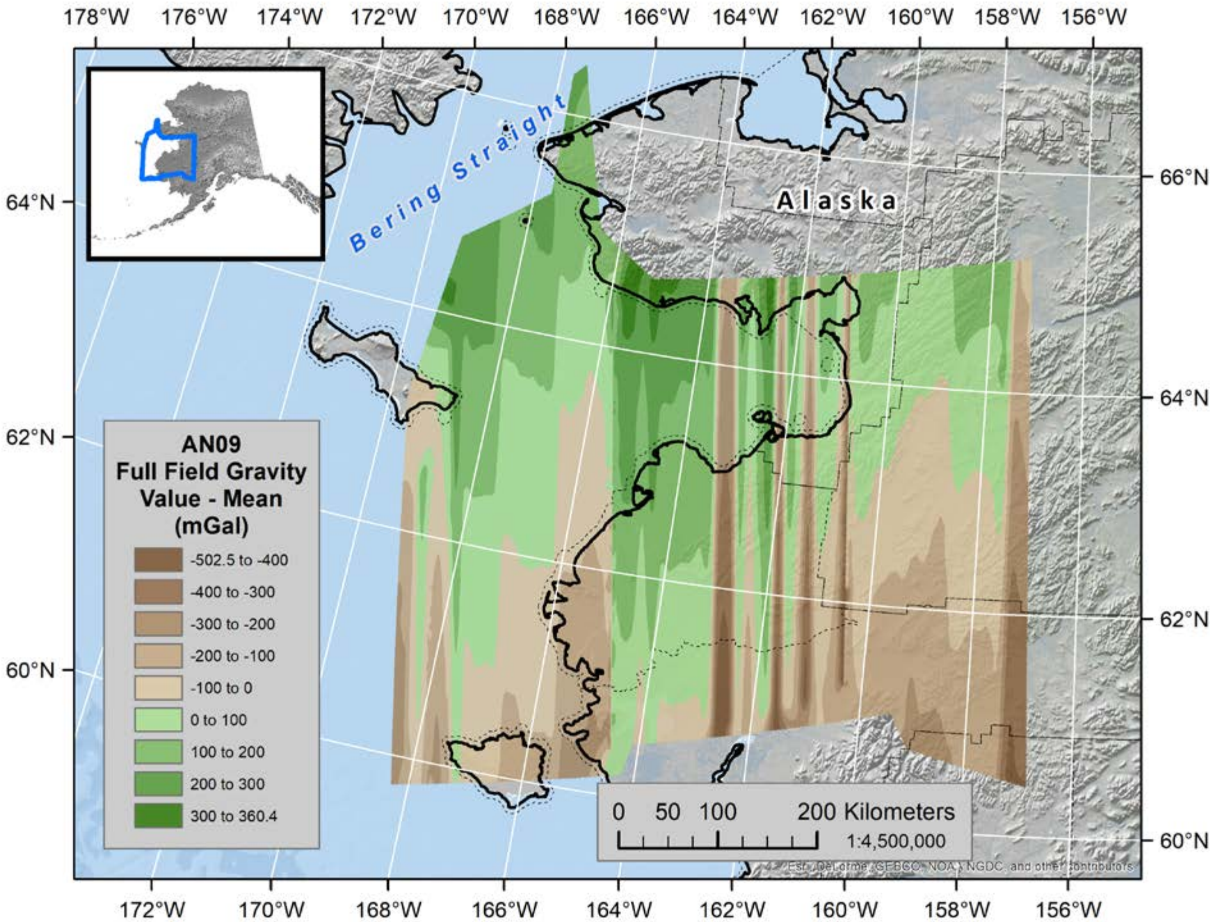

Figure 4: Full-field gravity at altitude (mean removed) for Block AN09. This is the data in the gravity release ".txt" file and includes the effects of differing altitudes along flight lines.

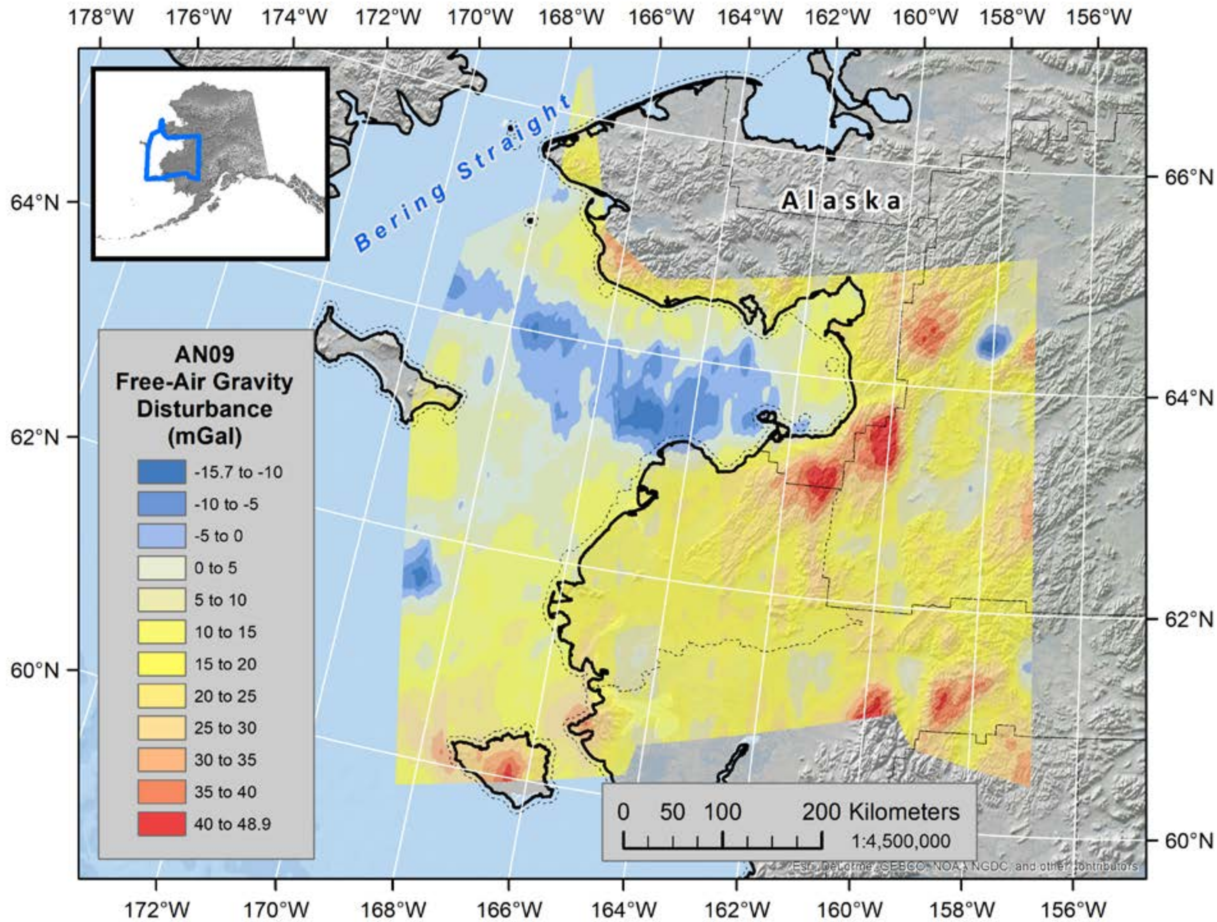

Figure 5 Free-air gravity disturbance for Block AN09 with respect to the GRS80 ellipsoid

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 AN09 data file, reference the webpage:
GRAV-D Science Team (2018). "Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project, Airborne Gravity Data; Block AN09". Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_AN09.shtml

To reference the block and survey details, reference the block user manual:
GRAV-D Science Team (2018). "Block AN09 (Alaskal North 09); 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_AN09.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."