Block AS08 (Alaska South 08)

GRAV-D Airborne Data Release User Manual

Applies to Data Release BETA #1, 9/2018

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Version Notes

9/2018 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."

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1. Block Description

GRAV-D Block **AS08** is located in the **A**laskan Time Zone, in the **S**outh half (south of 63° latitude). This was the eighth (**08**) block of data completed in that region. Block AS08 is 500 km by 440 km, covering parts of Alaska, the Gulf of Alaska and Bristol Bay (Figure 1). The corner coordinates defining Block AS08 are listed in Table 1.

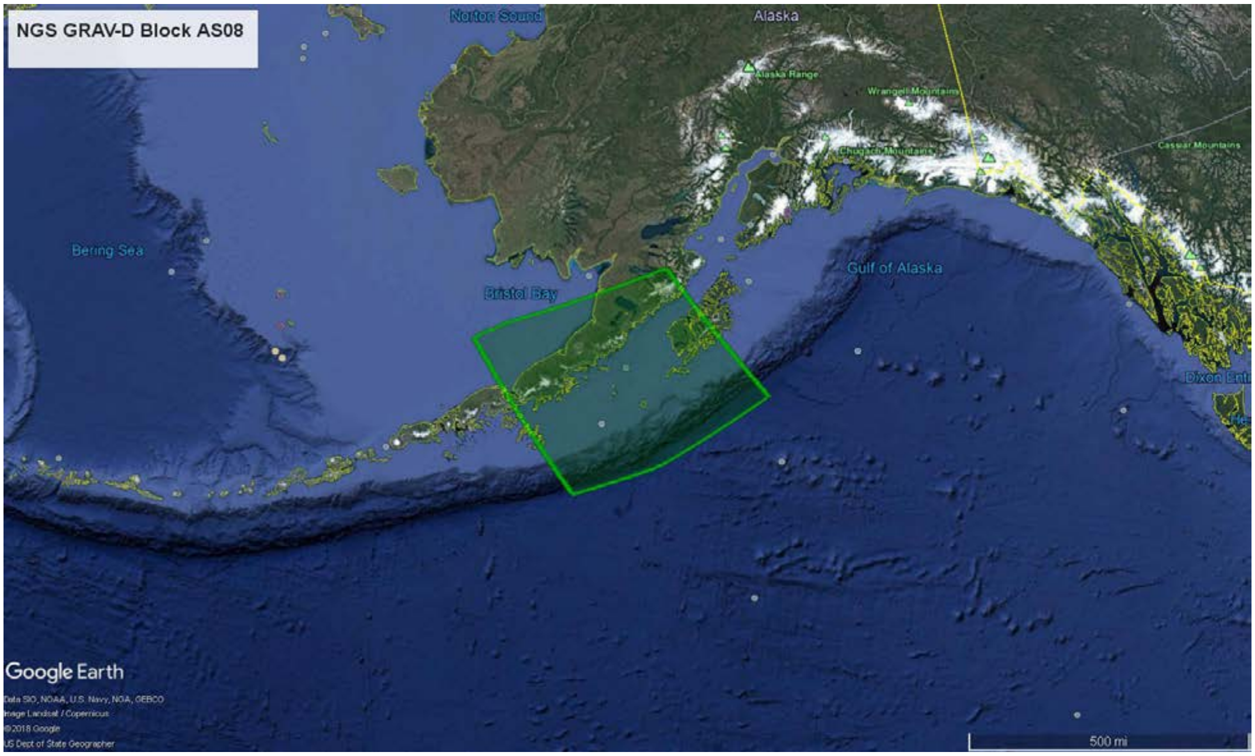

Figure 1: Google Earth Image of the Location of Block AS08

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block AS08

Latitude (decimal degrees)	Longitude (decimal degrees)
58.711759044	-154.836088629
57.343613105	-161.126665214
56.965483891	-162.295379418
53.846734589	-158.065327959
54.486956751	-155.086587023
55.967297372	-150.861731124

2. Survey Design and Execution

Airborne gravity data in Block AS08 were collected during two surveys: AK18-1 (Alaska 2018, first occupation), and AK18-2 (Alaska 2018, second occupation). Data lines from the two surveys were flown at approximately 22,000 ft. AS08 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 AS08, data lines are northeasterly/southwesterly and cross lines are east/west. The block consists of 5 cross lines from AK18-1 (Two cross lines from AK18-1 are shared with block AS07 and labeled AS07503 and AS07504), and 48 data lines and 8 cross lines from AK18-2 (One cross line from AK18-2 are shared with block AS07 and labeled as AS07505). Two cross lines, AS08501 and AS08508, from AK18-1 were reflown in AK18-2 as AS08601 and AS08608. 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. AS08101= block AS08's line 101).

Table 2: Survey Overview

Coducting Organization	NOAA- National Geodetic Survey	NOAA- National Geodetic Survey
Survey Name	AK18-1	AK18-2
Airport Base of Operations	Dillingham Airport (DLG) Dillingham, AK FBO: Alaska Cargo Services	Kodiak Airport (ADQ) Kodiak, AK FBO: Island Air Services
Geographic Location	Southwest Alaska	Southwest Alaska
Dates of Airborne Operations	Apr 16 - May 21, 2018	May 22 - July 30, 2018

Table 3: Aircraft and Instrumentation

Aircraft (Surveys)	Dynamic Aviation King Air (N43U)
Engines, number and type	2, Turboprop
Gravity Instrumentation	Micro-g LaCoste (MGL) TAGS S-211 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	22,000 ft.
Nominal Aircraft Ground Speed	250 knots
Number of Lines Released	Data Lines: 48 (AK18-2) Cross Lines: 5 (AK18-1), 8 (AK18-2) Repeat Lines: 2 lines
Number of Crossovers	302

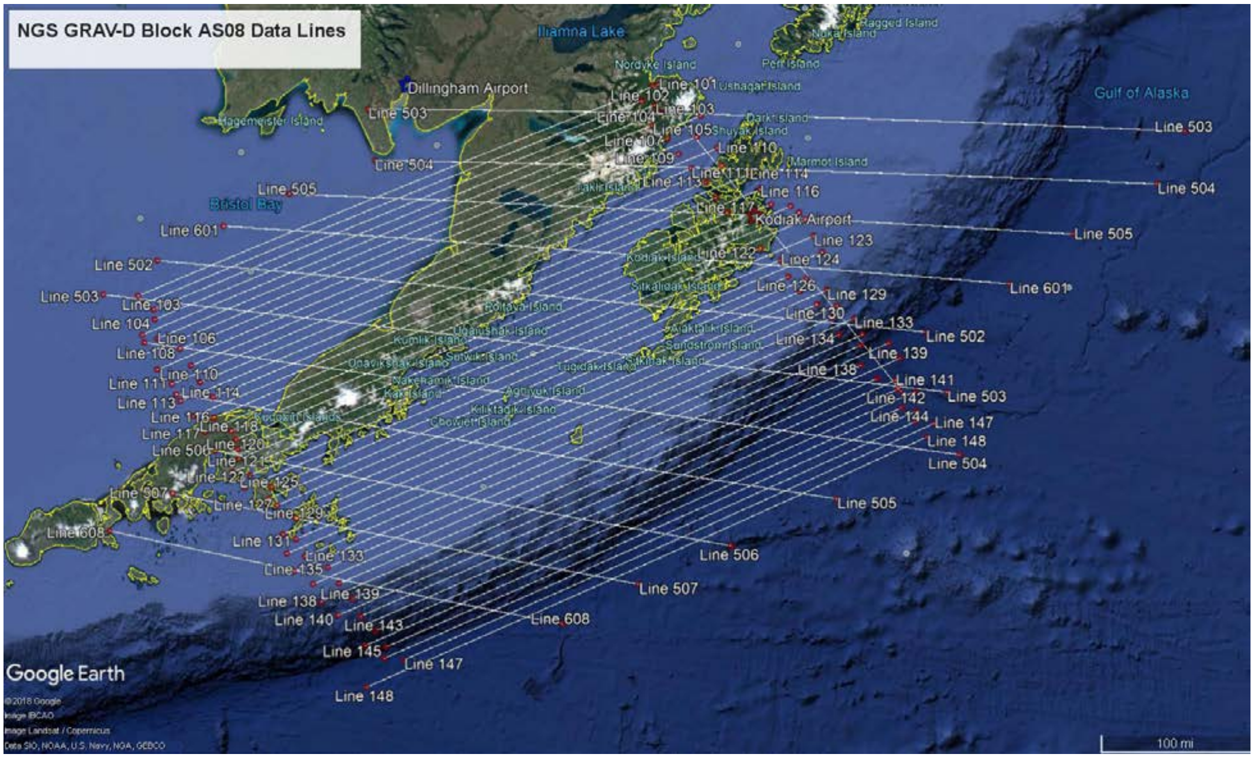

Figure 2: Data Coverage for AS08. Data lines range from 101 to 148. Dillingham Airport (DLG) is marked with a blue star. Kodiak Airport (ADQ) is marked with a red star.

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, one NovAtel PP6 receiver operating at 1 Hz and one DLV3 operating at 20 Hz served as GPS base stations throughout the AK18-1, however, only the DLV3 was operating in AK18-2. 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 Dynamic Aviation. The TAGS S-211 records data at 20 Hz and has a NovAtel timing unit mounted on the gravimeter. The gravimeter includes environmental information in the same file as the gravity data at 20 Hz (Micro-g LaCoste, 2015).

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 (N43U)	**X (m)**	**Y (m)**	**Z (m)**
Gravimeter	-0.001	-0.002	-0.453
Aircraft GPS Antenna	-0.139	0.38	0.665

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)
AK18-1 DLG	Kinematic	NovAtel (SPAN)	f01, f10, f23	108, 116, 117, 128
AK18-1 DLG	Static	NovAtel PP6	f01, f10, f23	108, 116, 117, 128
AK18-1 DLG	Static	NovAtel DLV3	f01, f10, f23	108, 116, 117, 128
AK18-2 ADQ	Kinematic	NovAtel	f14, f21, f23, f24, f27, f29, f30, f33-f42, f44, f47-f55	157, 158, 162, 163, 169, 170, 173-177, 179-184, 186, 191-193, 195, 196, 202, 210, 211
AK18-2 ADQ	Static	NovAtel DLV3	f14, f21, f23, f24, f27, f29, f30, f33-f42, f44, f47-f55	157, 158, 162, 163, 169, 170, 173-177, 179-184, 186, 191-193, 195, 196, 202, 210, 211

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 ±0.032 m and the average vertical position accuracy is ±0.056 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 (DLG, called PADL TAGS). The A-10 was set up at the exact location of the aircraft. The absolute gravity measurement for ADQ TAGS was transferred with a CG6 relative gravimeter from a nearby monument. The positions were determed from the GPS data 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)
DLG	PADL TAGS	59.0440870°N	-165.4361187°W	162.5	982259.520 ± 0.009
ADQ	KADQ TAGS	57.7535183°N	-152.5176100°W	162.5	981731.410 ± 0.007

3.1.3 Gravity Filtering

For block AS08, 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 confocal ellipsoid normal gravity free-air correction method 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 AS08, 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)
22,000	6,706	6,783	302	2.51	2.51	0.02	1.77

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.

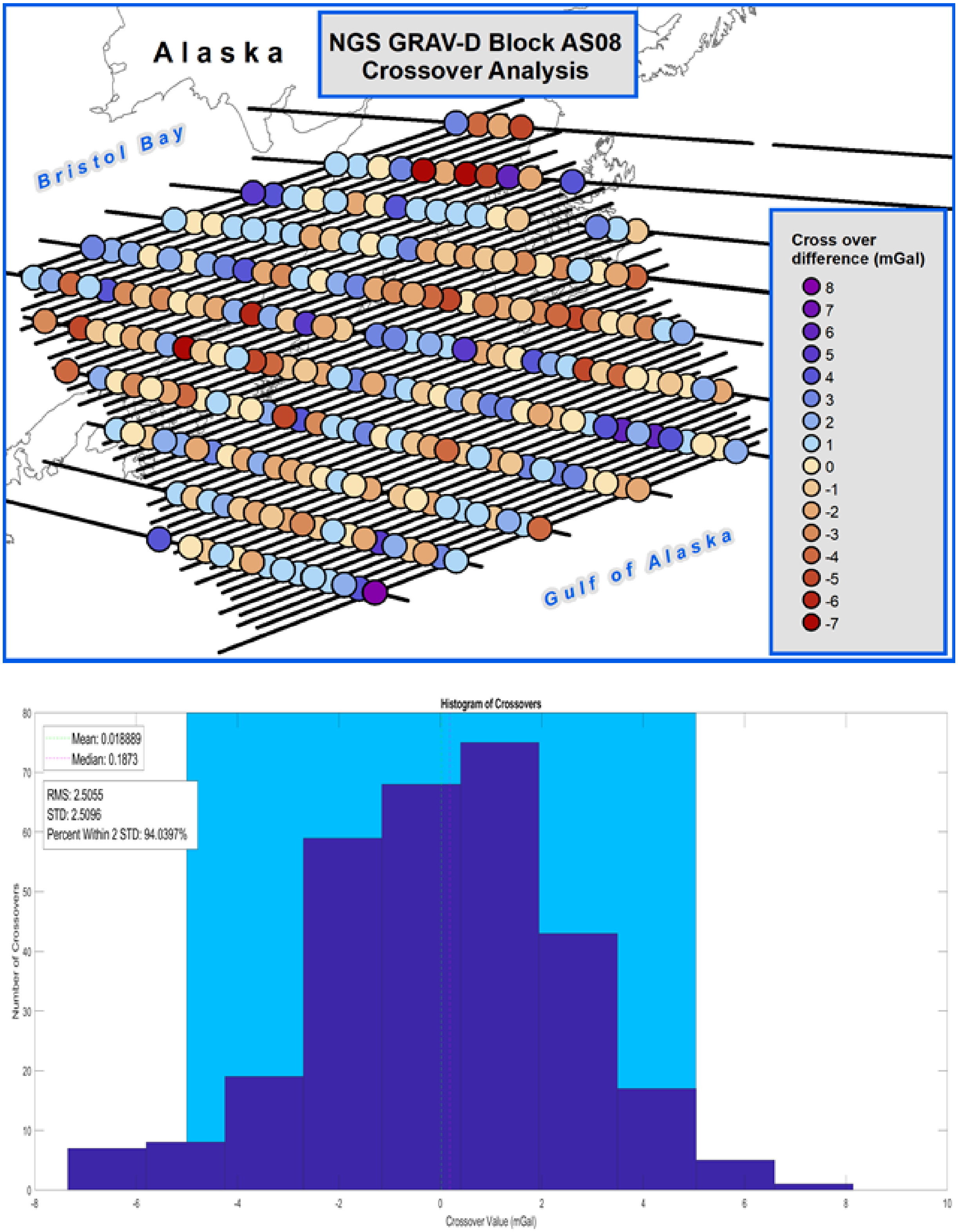

Figure 3: Crossover Residuals, Histogram, and Statistics for Block AS08

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)
AS07503	3.59	-2.44
AS07504	4.51	-0.80
AS07505	1.88	1.04
AS08501	1.71	-0.13
AS08601	1.55	-0.34
AS08502	2.64	-0.66
AS08503	2.69	0.11
AS08504	2.81	0.11
AS08505	2.32	-0.31
AS08506	1.72	-0.06
AS08507	2.13	0.07
AS08508	2.79	1.49
AS08608	2.52	1.54

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
47	98.15%	2.16%

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 AS08, two data lines were re-flown as AS08501/AS08601 and AS08508/AS08608. Table 11 shows the correlation between these two sets of repeat lines.

Table 11: Repeat Line Correlations

<table>
<tr><th>Repeat Lines</th><th>Correlation</th></tr>
<tr><td>AS08501</td><td rowspan="2">99.38%</td></tr>
<tr><td>AS08601</td></tr>
<tr><td>AS08508</td><td rowspan="2">99.92%</td></tr>
<tr><td>AS08608</td></tr>
</table>

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	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
AK18-1	f01	SPAN	GPS + IMU	5	AS07505	100
AK18-1	f10	SPAN	GPS + IMU	5	501	100
AK18-1	f11	SPAN	GPS + IMU	5	508	100
AK18-1	f23	SPAN	GPS + IMU	5	AS07503	100
AK18-1	f23	SPAN	GPS + IMU	5	AS07504	100
AK18-2	f14	SPAN	GPS + IMU	5	147	100
AK18-2	f14	SPAN	GPS + IMU	5	148	100
AK18-2	f21	SPAN	GPS + IMU	5	145	100
AK18-2	f21	SPAN	GPS + IMU	5	146	100
AK18-2	f22	SPAN	GPS + IMU	7.5	127	100
AK18-2	f22	SPAN	GPS + IMU	7.5	128	100
AK18-2	f23	SPAN	GPS + IMU	5	102	100
AK18-2	f23	SPAN	GPS + IMU	5	502	100
AK18-2	f24	SPAN	GPS + IMU	5	103	100
AK18-2	f24	SPAN	GPS + IMU	5	503	100
AK18-2	f27	SPAN	GPS + IMU	5	125	100
AK18-2	f27	SPAN	GPS + IMU	5	126	100
AK18-2	f29	SPAN	GPS + IMU	5	129	100
AK18-2	f29	SPAN	GPS + IMU	5	130	100
AK18-2	f30	SPAN	GPS + IMU	5	131	100
AK18-2	f30	SPAN	GPS + IMU	5	132	100
AK18-2	f33	SPAN	GPS + IMU	7.5	143	100
AK18-2	f33	SPAN	GPS + IMU	7.5	144	100
AK18-2	f34	SPAN	GPS + IMU	5	141	100
AK18-2	f34	SPAN	GPS + IMU	5	142	100
AK18-2	f35	SPAN	GPS + IMU	5	106	100
AK18-2	f35	SPAN	GPS + IMU	5	107	100
AK18-2	f36	SPAN	GPS + IMU	5	108	100
AK18-2	f36	SPAN	GPS + IMU	5	109	100
AK18-2	f37	SPAN	GPS + IMU	5	123	100
AK18-2	f37	SPAN	GPS + IMU	5	124	100
AK18-2	f38	SPAN	GPS + IMU	5	110	100
AK18-2	f38	SPAN	GPS + IMU	5	111	100
AK18-2	f39	SPAN	GPS + IMU	5	121	100
AK18-2	f39	SPAN	GPS + IMU	5	122	100
AK18-2	f40	SPAN	GPS + IMU	5	112	100
AK18-2	f40	SPAN	GPS + IMU	5	113	100

Survey	Flight	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
AK18-2	f41	SPAN	GPS + IMU	5	120	100
AK18-2	f41	SPAN	GPS + IMU	5	608	100
AK18-2	f42	SPAN	GPS + IMU	5	114	100
AK18-2	f42	SPAN	GPS + IMU	5	115	100
AK18-2	f44	SPAN	GPS + IMU	5	119	100
AK18-2	f44	SPAN	GPS + IMU	5	507	100
AK18-2	f47	SPAN	GPS + IMU	5	116	100
AK18-2	f47	SPAN	GPS + IMU	5	117	100
AK18-2	f48	SPAN	GPS + IMU	5	118	100
AK18-2	f48	SPAN	GPS + IMU	5	506	100
AK18-2	f49	SPAN	GPS + IMU	5	101	100
AK18-2	f49	SPAN	GPS + IMU	5	601	100
AK18-2	f50	SPAN	GPS + IMU	5	139	100
AK18-2	f50	SPAN	GPS + IMU	5	140	100
AK18-2	f51	SPAN	GPS + IMU	5	137	100
AK18-2	f51	SPAN	GPS + IMU	5	138	100
AK18-2	f52	SPAN	GPS + IMU	5	104	100
AK18-2	f52	SPAN	GPS + IMU	5	105	100
AK18-2	f53	SPAN	GPS + IMU	7.5	133	100
AK18-2	f53	SPAN	GPS + IMU	7.5	134	100
AK18-2	f54	SPAN	GPS + IMU	5	135	100
AK18-2	f54	SPAN	GPS + IMU	5	136	100
AK18-2	f55	SPAN	GPS + IMU	5	504	100
AK18-2	f55	SPAN	GPS + IMU	5	505	100

** AS07503, AS07504, and AS07505 are crosslines that are in common between blocks AS07 and AS08.*

Table 13: Gravity Processing Results

Survey	Flight Num.	Line Num.	Time of Deleted Data	Comments
AK18-1	f01	AS07505*	2018-04-18 19:46:37 - 2018-04-18 19:55:47	Bump Removed
AK18-1	f10	501	2018-04-27 00:35:19 - 2018-04-27 00:39:23	Bump Removed
AK18-1	f11	508	2018-04-27 23:45:59 - 2018-04-27 23:50:38	Bump Removed
AK18-1	f23	AS07503*	2018-05-08 18:52:57 - 2018-05-08 18:56:12	Bump Removed
AK18-2	f27	126	2018-06-23 01:25:15 - 2018-06-23 01:29:45	Bump Removed
AK18-2	f41	120	2018-07-02 18:19:16 - 2018-07-02 18:22:23	Bump Removed
AK18-2	f51	138	2018-07-14 20:45:17 - 2018-07-14 20:50:39	Bump Removed

* Lines AS07503 and AS07505 are crosslines in common between AS07 and AS08

Table 14: Bias from EGM08 by Line

Survey	Flight Num.	Line	EGM08 mean
AK18-1	f01	AS07505	0.73
AK18-1	f10	501	3.31
AK18-1	f11	508	5.42
AK18-1	f23	AS07503	1.08
AK18-1	f23	AS07504	2.89
AK18-2	f14	147	5.04
AK18-2	f14	148	2.28
AK18-2	f21	145	1.82
AK18-2	f21	146	0.59
AK18-2	f22	127	1.93
AK18-2	f22	128	1.33
AK18-2	f23	102	1.58
AK18-2	f23	502	2.44
AK18-2	f24	103	2.75
AK18-2	f24	503	2.68
AK18-2	f27	125	3.24
AK18-2	f27	126	1.89
AK18-2	f29	129	0.67
AK18-2	f29	130	1.51
AK18-2	f30	131	2.51
AK18-2	f30	132	1.77
AK18-2	f33	143	2.29
AK18-2	f33	144	1.5
AK18-2	f34	141	1.8
AK18-2	f34	142	1.67
AK18-2	f35	106	3.77
AK18-2	f35	107	0.14
AK18-2	f36	108	3.26
AK18-2	f36	109	1.68
AK18-2	f37	123	1.51
AK18-2	f37	124	0.24
AK18-2	f38	110	1.13
AK18-2	f38	111	-0.17
AK18-2	f39	121	1.19
AK18-2	f39	122	0.19
AK18-2	f40	112	1.01
AK18-2	f40	113	1.45
AK18-2	f41	120	0.59

Survey	Flight Num.	Line	EGM08 mean
AK18-2	f41	608	0.7
AK18-2	f42	114	2.32
AK18-2	f42	115	0.63
AK18-2	f44	119	3.58
AK18-2	f44	507	1.74
AK18-2	f47	116	3.44
AK18-2	f47	117	1.27
AK18-2	f48	118	2.45
AK18-2	f48	506	1.41
AK18-2	f49	101	2.71
AK18-2	f49	601	1.6
AK18-2	f50	139	0.34
AK18-2	f50	140	0.45
AK18-2	f51	137	-0.15
AK18-2	f51	138	0.73
AK18-2	f52	104	2.38
AK18-2	f52	105	0.92
AK18-2	f53	133	1.66
AK18-2	f53	134	-0.53
AK18-2	f54	135	2.75
AK18-2	f54	136	1.33
AK18-2	f55	504	4.65
AK18-2	f55	505	1.12

* AS07503, AS07504, and AS07505 are crosslines that are in common between blocks AS07 and AS08.

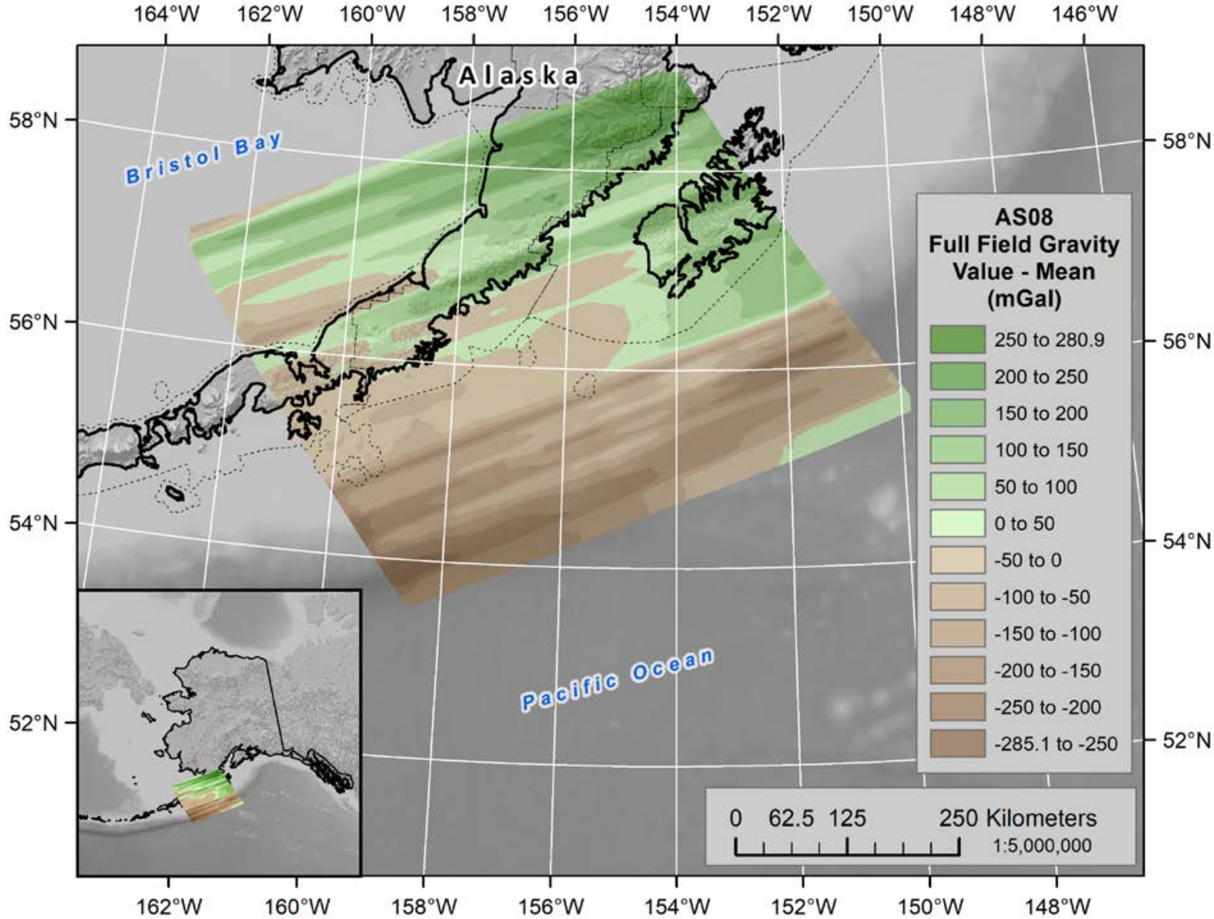

Figure 4: Full-field gravity at altitude (mean removed) for Block AS08. This is the data in the gravity release ".txt" file and includes the effects of differing altitudes along flight lines.

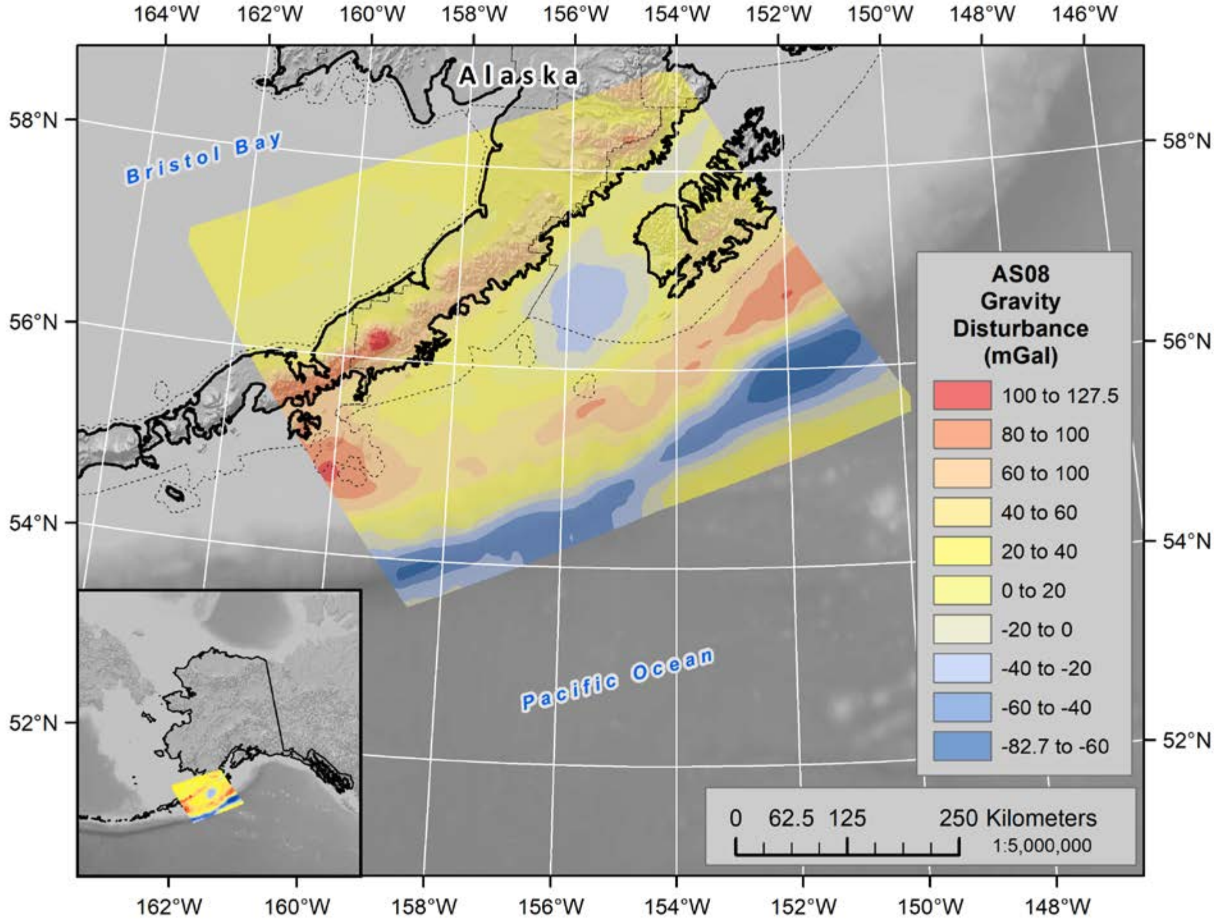

Figure 5: Gravity disturbance for Block AS08 with respect to the GRS80 ellipsoid. Calculated with the confocal ellipsoid method of calculating normal gravity.

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 AS08 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 AS08". Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_AS08.shtml

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