Block CS10 (Central South 10)

GRAV-D Airborne Data Release User Manual

Applies to Data BETA1 Release, 4/2020

BETA 1 edited by Jeffery A Johnson

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 **CS10** is located in the **C**entral Time Zone, in the **S**outh half (south of 40° latitude). This was the tenth (**10**) block of data completed in that region. Block CS10 is about 550 km by 400 km over central CONUS including Kansasa, and northern Oklahoma (Figure 1). The corner coordinates defining Block CS10 are listed in Table 1.

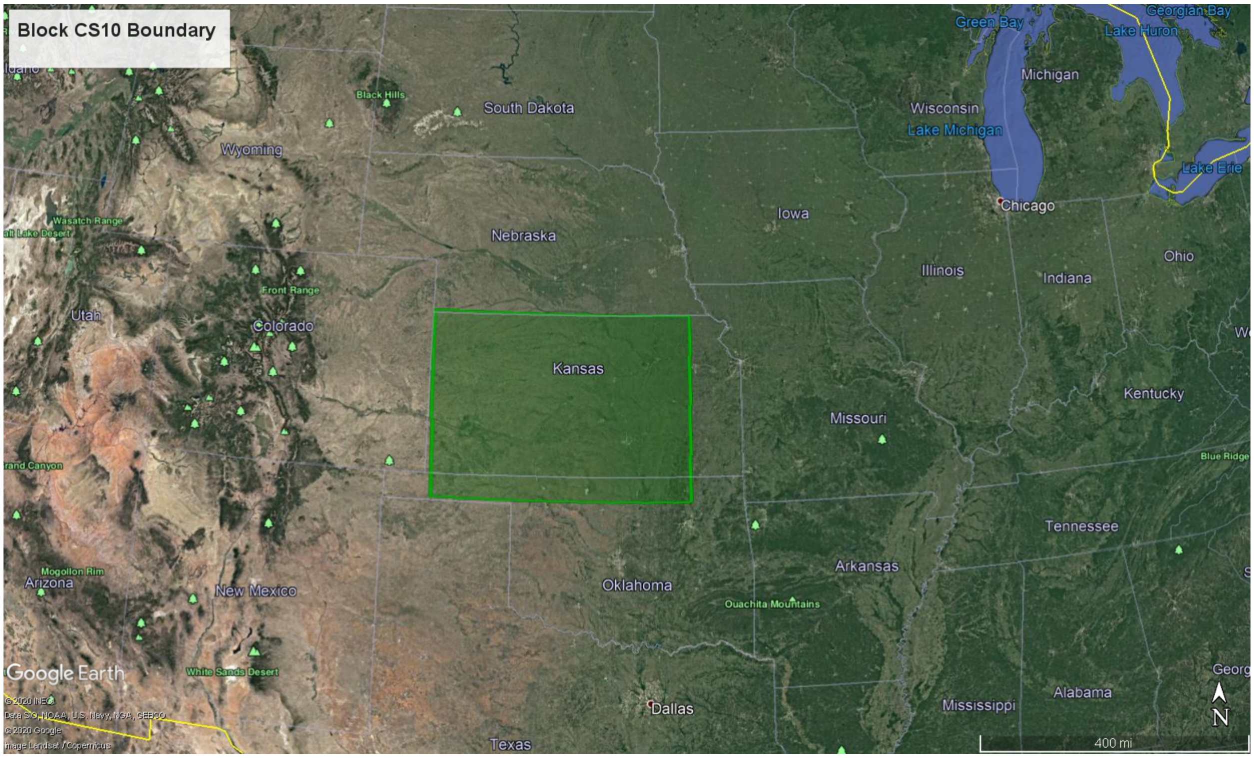

Figure 1: Google Earth Image of the Location of Block CS10.

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block CS10

Latitude (decimal degrees)	Longitude (decimal degrees)
36.534706759	-95.845480124
39.990536051	-95.799968853
40.054436658	-102.013001868
36.563106547	-101.888394352

2. Survey Design and Execution

Airborne gravity data in Block CS10 were collected during eight surveys: OK18-1 (Oklahoma 2018, first occupation), OK18-2 (Oklahoma 2018, second occupation), OK18-3 (Oklahoma 2018, third occupation), OK18-4 (Oklahoma 2018, fourth occupation), TX18-1 (Texas 2018, first occupation), OK19-1 (Oklahoma 2019, first occupation), OK19-2 (Oklahoma 2019, second occupation), and OK20-1 (Oklahoma 2020, first occupation). For all eight surveys, data and cross line flights were flown at about 20,000 - 21,000 ft. Three different aircraft and two different airborne gravimeters were used to collect CS10 data. Table 3, Table 4, and Table 5 give a synopsis of survey layout and execution for the data. Figure 2 shows a map of the data coverage.

In CS10 all data lines are East-West and cross lines are North-South. The block consists of 2 cross lines from OK18-1; 2 cross lines from OK18-2; 9 data lines and 2 cross lines from OK18-3; 16 data lines from OK18-4; 2 cross lines from TX18-1; 6 data lines from OK19-1; 8 data lines from OK19-2; and 4 data lines from OK20-1. Three data lines, CS10123, CS10125, and CS10126 were flown twice with good data collected both times. 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. CS10101= block CS10's line 101).

Table 2: Survey Overview

Survey	Conducting Organization	Airport Base of Operations	Geographic Location	Survey Dates
OK18-1	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Jan 7 - Jan 30, 2018
OK18-2	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Jan 7 - Jan 31, 2018
OK18-3	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Feb17 - Mar 18, 2018
OK18-4	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Oct 9 - Nov 14, 2018
TX18-1	NOAA- National Geodetic Survey	Rick Husband Amarillo International Airport (AMA) Amarillo, Texas FBO: TAC Air	Central CONUS	Sep 19 - Oct 1, 2018
OK19-1	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Oct 15 - Nov 6, 2019
OK19-2	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Dec 7 - Dec 20, 2019
OK20-1	NOAA- National Geodetic Survey	Tulsa International Airport (TUL) Tulsa, Oklahoma FBO: Atlantic Aviation	Central CONUS	Feb 13 - Mar 9, 2020

Table 3: Aircraft and Instrumentation

Survey	Aircraft	Engines: Number, and Type	Gravity Instrumentation	GPS Instrumentation
OK18-1 (TUL)	DOI Pilatus PC12 (N190PE)	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK18-2 (TUL)	King Air 200T (N43U)	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-161 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK18-3 (TUL)	DOI Pilatus PC12 (N190PE)	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK18-4 (TUL)	DOI Pilatus PC12 (N190PE)	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
TX18-1	DOI Pilatus PC12 (N190PE)	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) L&R G-Meter	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK19-1	DOI Pilatus PC12 (N190PE)	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK19-2	NOAA King Air 350 (N68RF)	2, Turbo Prop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (GPS + IMU)
OK20-1	King Air 200T (N54F)	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-211 (relative) MGL A-10 25 (absolute) Scintrix CG6 (relative)	NovAtel DL-4 Plus NovAtel SPAN-SE (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 - 21,000 ft.
Nominal Aircraft Ground Speed	250 knots
Number of Lines Released	Data Lines: 43 Cross Lines: 8 Repeat Lines: 3
Number of Crossovers	330

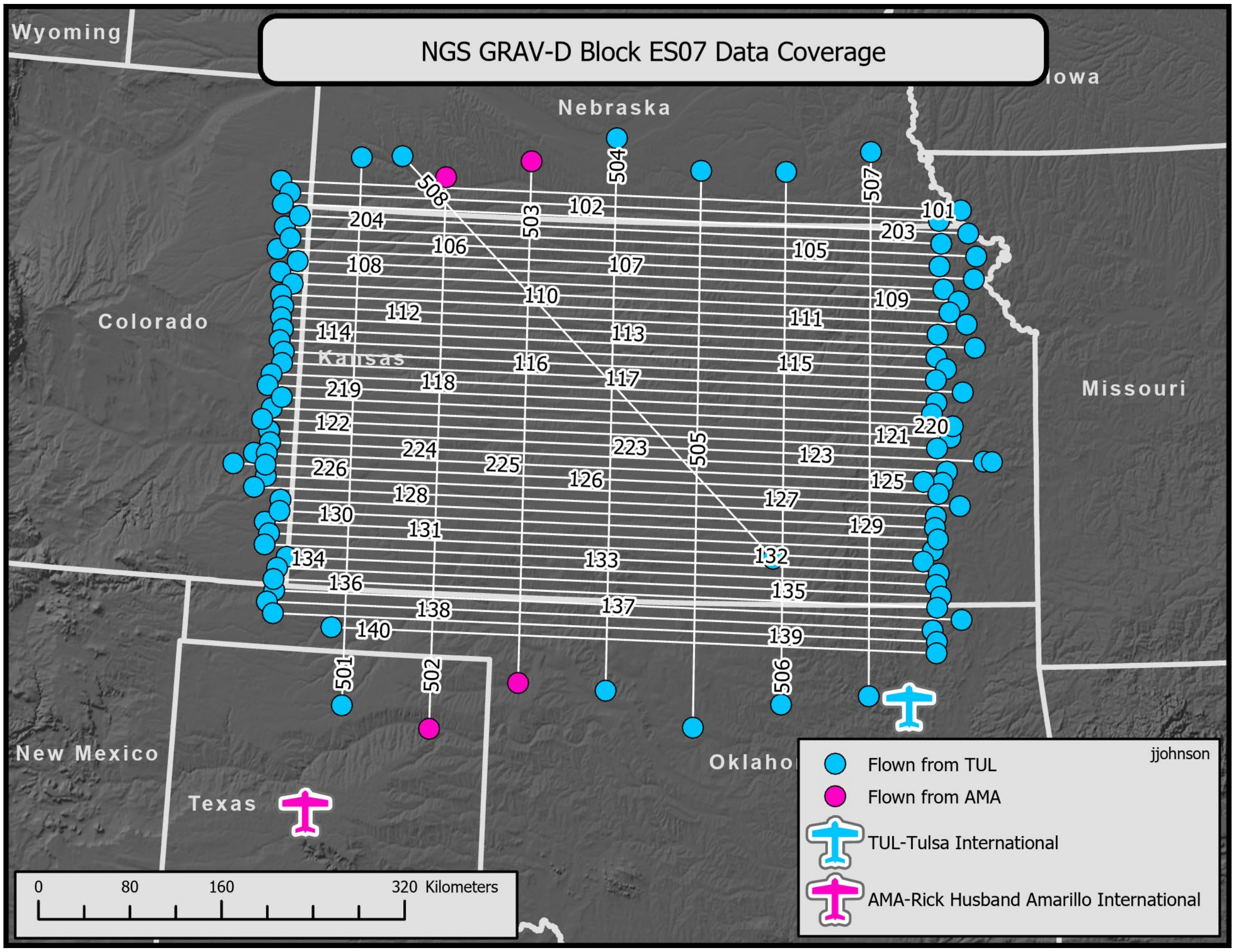

Figure 2: Data Coverage for CS10. Data lines start in the north at 101 and continue south to 140. Lines marked with a blue dot are flown from Tulsa International Airport (TUL). Lines marked with a pink dot are flown from Rick Husband Amarillo International Airport (AMA).

2.1 GPS/IMU Instrumentation

The aircraft each had one GPS antenna available for scientific measurements. Two geodetic-quality GPS receivers shared the antenna: NovAtel DL-4 Plus (included as part of the TAGS gravimeter timing unit) and a NovAtel (inside the SPAN-SE system). The NovAtels had a data rate of either 20 Hz or 1 Hz to match the gravimeter data collection rate. The NovAtel μIMU system also contained an 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 GPS base stations recorded at 1 Hz or 20 Hz (for TAGS S-211 observations) throughout the survey. 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. The TAGS S-137 and S-161 records data at 1 Hz and has a NovAtel timing unit mounted on the gravimeter. These gravimeters also record an environmental file at 0.1 Hz. For more information on the instrument, refer to its user manual (Micro-g LaCoste, 2010). The TAGS S-211 records data at 20 Hz and has a NovAtel timing unit mounted on the gravimeter. S-211 records environmental data along with the raw gravity data at 20 Hz. (Micro-g LaCoste, 2015)

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 IMU and the TAGS (distances are measured along the body of the aircraft: X positive toward the right, Y positive toward the nose, and Z positive up). Table 7 lists the lever arm measurement between the IMU and the GPS antenna (distances 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 Center of the IMUs Sensor TO the Center of the TAGS Sensor

Instrument/Location	X (m)	Y (m)	Z (m)
TAGS S-161	-0.016	0.021	-0.503
TAGS S-211	-0.001	-0.002	-0.453

Table 6: Lever Arm Measurements FROM the Center of the IMU's sensor TO the GPS Antenna

Instrument/Location	X (m)	Y (m)	Z (m)
GPS Antenna N43U (S-161)	-0.133	0.389	0.538
GPS Antenna N190PE (S-211)	0.010	0.560	0.732
GPS Antenna N54F (S-211)	-0.143	0.409	0.664
GPS Antenna N68RF (S-211)	-0.244	-1.643	0.583

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 (Survey)	Type	Receiver	Flight Available	2013-2014 Day of Year Available
OK18-1 TUL	Kinematic	NovAtel (SPAN)	f01	12,13
	Static	DLV	f01	12,13
		NovAtel (49)	f01	12,13
OK18-2 TUL	Kinematic	NovAtel (SPAN)	f02	19
	Static	NovAtel (47)	f02	19
OK18-3 TUL	Kinematic	NovAtel (SPAN)	f01, f02, f04-f06, f08	62, 63, 68, 71, 72, 74
	Static	NovAtel (46)	f01, f02, f04-f06, f08	62, 63, 68, 71, 72, 74
		DLV	f01, f02, f04-f06, f08	62, 63, 68, 71, 72, 74
OK18-4 TUL	Kinematic	NovAtel (SPAN)	f01, f03-f05, f08, f10, f11, f13	286, 290, 293-295, 314, 315, 317
	Static	DLV	f01, f03-f05, f08, f10, f11, f13	286, 290, 293-295, 314, 315, 317
TX18-1 AMA	Kinematic	NovAtel (SPAN)	f03	272
		DLV	f03	272
OK19-1 TUL	Kinematic	NovAtel (SPAN)	f04, f07, f08	299, 300, 304, 305, 307
	Static	DLV	f04, f07, f08	299, 300, 304, 305, 307
		Trimble netR9	f04, f07, f08	299, 300, 304, 305, 307
OK19-2 TUL	Kinematic	NovAtel (SPAN)	f01, f03-f05	345, 351-353
	Static	DLV	f01, f03-f05	345, 351-353
		Trimble netR9	f01, f03-f05	345, 351-353
OK20-1 TUL	Kinematic	NovAtel (SPAN)	f04	61, 62
	Static	Trimble R8	f04	61, 62
		Trimble netR9	f04	61, 62

Data were processed using GRS80 and IGS08. Average position accuracy for the data block is calculated from the final GPS position solution. 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 0.015 m and the average vertical position accuracy is 0.026 m.

3.1.2 Ground Gravity Tie

Absolute gravity measurements at each airport were performed by NGS with a Micro-g LaCoste A-10 gravimeter. The A-10 was set up at the exact location of the aircraft. The positions were determed from the GPS collected during the gravity survey while the plane was parked. See Table 9 for more information about each of the gravity ties.

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

Airport/ Airplane	Point ID	Latitude	Longitude	Tie height above mark (cm)	Gravity Tie (mGal)
TUL/ King Air 200T N43U and N54F	TAGS_North	36.19306504°N	95.89407556°W	162.5	979762.677 ± 0.008
TUL/ Pilatus PC12 N190PE	TAGS_North	36.19306504°N	95.89407556°W	163.7	979762.692 ± 0.008
TUL/ Pilatus PC12 N190PE	TAGS_South	36.19306504°N	95.89407556°W	163.7	979762.679 ± 0.008
TUL/King Air 350 N68RF	TAGS_North	36.19306504°N	95.89407556°W	157.6	979762.710 ± 0.008
AMA/Pilatus PC12 N190PE	KAMA TAGS	35.21689382°N	101.7085789°W	163.7	979406.431 ± 0.006

3.1.3 Gravity Filtering

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 CS10, the result of the crossover analysis is shown in Table 10 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	6,137	330	1.30	1.30	-0.11	0.92

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 11. 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.

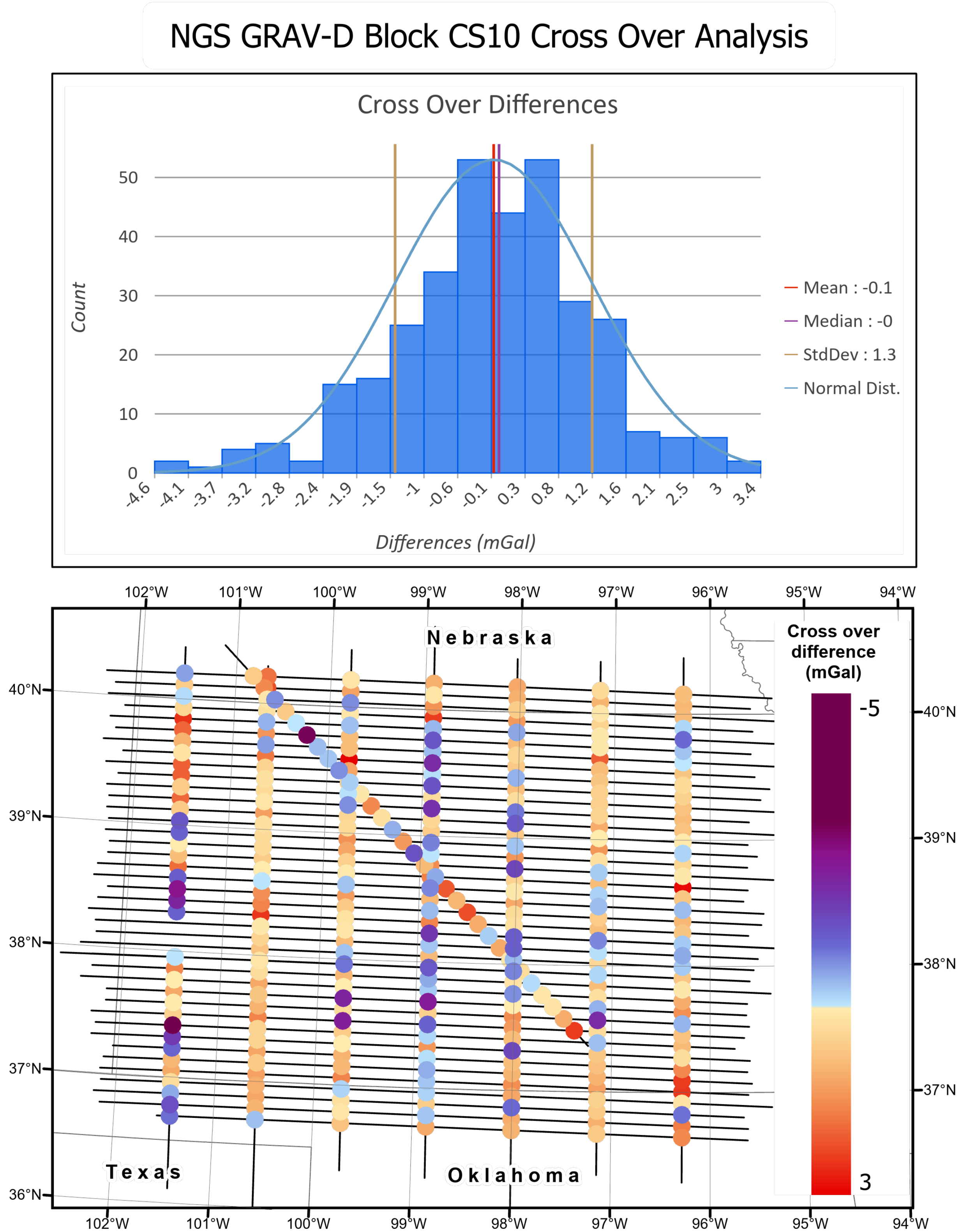

Figure 3: Crossover Residuals, Histogram, and Statistics for Block CS10. Color scale in mGals.

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	1.80	-0.42
502	0.93	0.41
503	1.21	-0.12
504	1.47	-0.56
505	1.21	-0.29
506	0.90	-0.06
507	1.15	0.25
508	1.41	-0.09

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 12) 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
49	95.15%	5.9%

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. Table 13 shows the correlation of lines flown twice with a significant amount of overlap.

Table 12: Reflown Line Correlations

<table>
<tr><th>Line</th><th>Correlation</th></tr>
<tr><td>CS10123</td><td rowspan="2">99.58%</td></tr>
<tr><td>CS10223</td></tr>
<tr><td>CS10125</td><td rowspan="2">99.81%</td></tr>
<tr><td>CS10225</td></tr>
<tr><td>CS10126</td><td rowspan="2">99.66%</td></tr>
<tr><td>CS10226</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) 8.50-8.80. 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 IE. 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	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
OK18-1	f01	SPAN	GPS+IMU	5	506	100
OK18-1	f01	SPAN	GPS+IMU	5	507	100
OK18-2	f02	SPAN	GPS+IMU	5	504	100
OK18-2	f02	SPAN	GPS+IMU	5	505	100
OK18-3	f01	SPAN	GPS+IMU	5	123	100
OK18-3	f02	SPAN	GPS+IMU	5	107	100
OK18-3	f02	SPAN	GPS+IMU	5	108	100
OK18-3	f04	SPAN	GPS+IMU	5	501	100
OK18-3	f04	SPAN	GPS+IMU	5	508	100
OK18-3	f05	SPAN	GPS+IMU	5	127	100
OK18-3	f05	SPAN	GPS+IMU	5	128	100
OK18-3	f06	SPAN	GPS+IMU	5	223	100
OK18-3	f06	SPAN	GPS+IMU	5	224	100
OK18-3	f08	SPAN	GPS+IMU	7.5	109	100
OK18-3	f08	SPAN	GPS+IMU	7.5	110	100
OK18-4	f01	SPAN	GPS+IMU	5	105	100

Survey	Flig ht	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
OK18-4	f01	SPAN	GPS+IMU	5	106	100
OK18-4	f03	SPAN	GPS+IMU	5	101	100
OK18-4	f03	SPAN	GPS+IMU	5	102	100
OK18-4	f04	SPAN	GPS+IMU	5	203	100
OK18-4	f04	SPAN	GPS+IMU	5	204	100
OK18-4	f05	SPAN	GPS+IMU	5	111	100
OK18-4	f05	SPAN	GPS+IMU	5	112	100
OK18-4	f08	SPAN	GPS+IMU	5	113	100
OK18-4	f08	SPAN	GPS+IMU	5	114	100
OK18-4	f10	SPAN	GPS+IMU	5	121	100
OK18-4	f10	SPAN	GPS+IMU	5	122	100
OK18-4	f11	SPAN	GPS+IMU	5	137	100
OK18-4	f11	SPAN	GPS+IMU	5	138	100
OK18-4	f13	SPAN	GPS+IMU	5	125	100
OK18-4	f13	SPAN	GPS+IMU	5	126	100
OK19-1	f04	SPAN	GPS+IMU	5	225	100
OK19-1	f04	SPAN	GPS+IMU	5	226	100
OK19-1	f07	SPAN	GPS+IMU	5	115	100
OK19-1	f07	SPAN	GPS+IMU	5	116	100
OK19-1	f08	SPAN	GPS+IMU	5	131	100
OK19-1	f08	SPAN	GPS+IMU	5	132	100
OK19-2	f01	SPAN	GPS+IMU	5	133	100
OK19-2	f01	SPAN	GPS+IMU	5	134	100
OK19-2	f03	SPAN	GPS+IMU	5	135	100
OK19-2	f03	SPAN	GPS+IMU	5	136	100
OK19-2	f04	SPAN	GPS+IMU	5	139	100
OK19-2	f04	SPAN	GPS+IMU	5	140	100
OK19-2	f05	SPAN	GPS+IMU	5	129	100
OK19-2	f05	SPAN	GPS+IMU	5	130	100
OK20-1	f04	SPAN	GPS+IMU	5	117	100
OK20-1	f04	SPAN	GPS+IMU	5	118	100
OK20-1	f04	SPAN	GPS+IMU	5	219	100
OK20-1	f04	SPAN	GPS+IMU	5	220	100
TX18-1	f03	SPAN	GPS+IMU	5	502	100
TX18-1	f03	SPAN	GPS+IMU	5	503	100

Table 14: Gravity Processing Results

Survey	Flight Num.	Line Num.	Time of Deleted Data	Comments
OK18-3	f04	501	2018-03-09 20:59:11-2018-03-09 21:03:18	Large Bump Removed
OK19-2	f01	133	2019-12-11 18:20:32-2019-12-11 18:27:48	Large Bump Removed

Table 15: Bias from EGM08 by Line

Survey	Flight Num.	Line	EGM08 mean
OK18-1	f01	506	1.94
OK18-1	f01	507	2.93
OK18-2	f02	504	1.23
OK18-2	f02	505	1.3
OK18-3	f01	123	2.83
OK18-3	f02	107	3.39
OK18-3	f02	108	1.63
OK18-3	f04	501	5.11
OK18-3	f04	508	2.13
OK18-3	f05	127	1.54
OK18-3	f05	128	-0.11
OK18-3	f06	223	1.59
OK18-3	f06	224	0.04
OK18-3	f08	109	2.07
OK18-3	f08	110	0.79
OK18-4	f01	105	1.03
OK18-4	f01	106	1.06
OK18-4	f03	101	2.19
OK18-4	f03	102	1.49
OK18-4	f04	203	3.27
OK18-4	f04	204	0.71
OK18-4	f05	111	1.4
OK18-4	f05	112	0.23
OK18-4	f08	113	2.17
OK18-4	f08	114	-0.04
OK18-4	f10	121	2.62
OK18-4	f10	122	1.92
OK18-4	f11	137	2.23
OK18-4	f11	138	1.42
OK18-4	f13	125	2.44

Survey	Flight Num.	Line	EGM08 mean
OK18-4	f13	126	-0.23
OK19-1	f04	225	1.21
OK19-1	f04	226	0.66
OK19-1	f07	115	0.83
OK19-1	f07	116	-0.03
OK19-1	f08	131	1.26
OK19-1	f08	132	1.35
OK19-2	f01	133	-0.16
OK19-2	f01	134	0.39
OK19-2	f03	135	0.32
OK19-2	f03	136	-0.02
OK19-2	f04	139	-0.83
OK19-2	f04	140	-1.03
OK19-2	f05	129	0.18
OK19-2	f05	130	0.46
OK20-1	f04	117	1.13
OK20-1	f04	118	0.95
OK20-1	f04	219	-0.15
OK20-1	f04	220	0.1
TX18-1	f03	502	1.04
TX18-1	f03	503	1.92

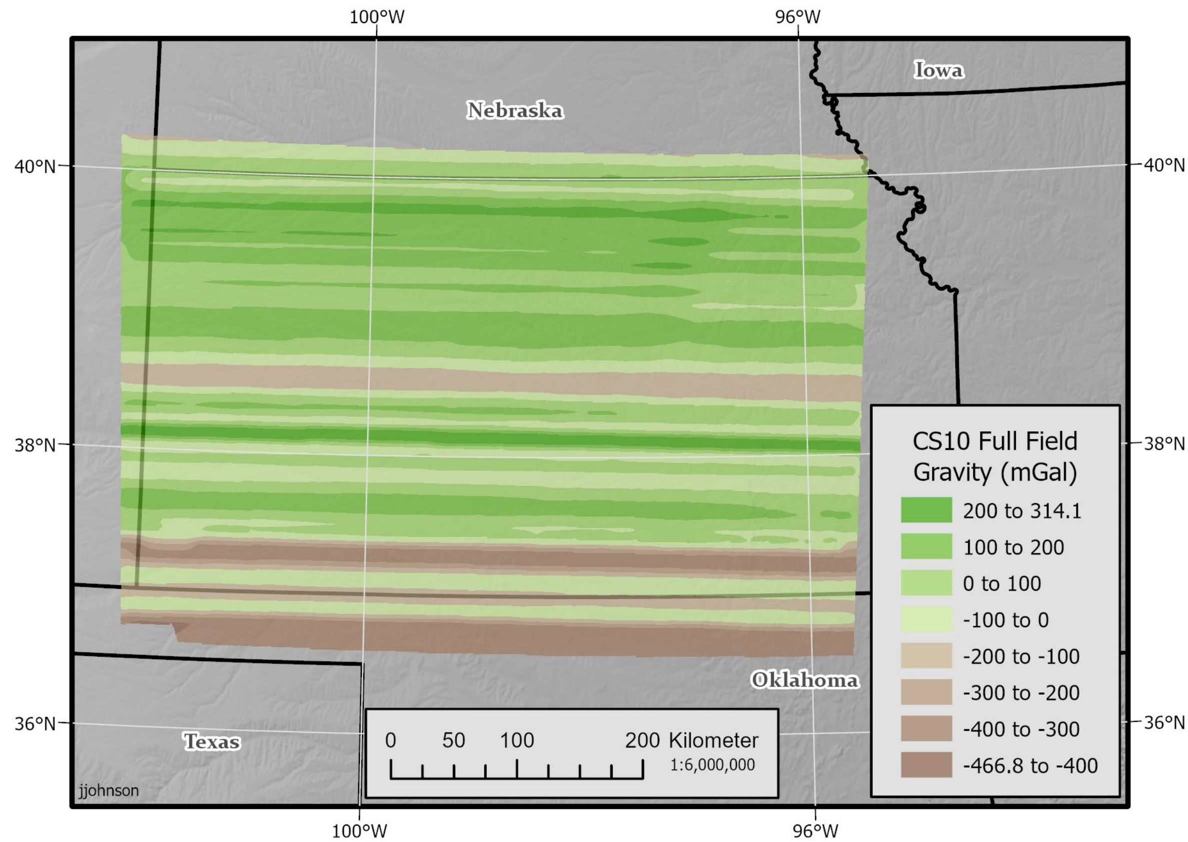

Figure 4: Full-field gravity at altitude (mean removed) for Block CS10. This is the data in the gravity release ".txt" file and includes the effects of differing altitudes along flight lines.

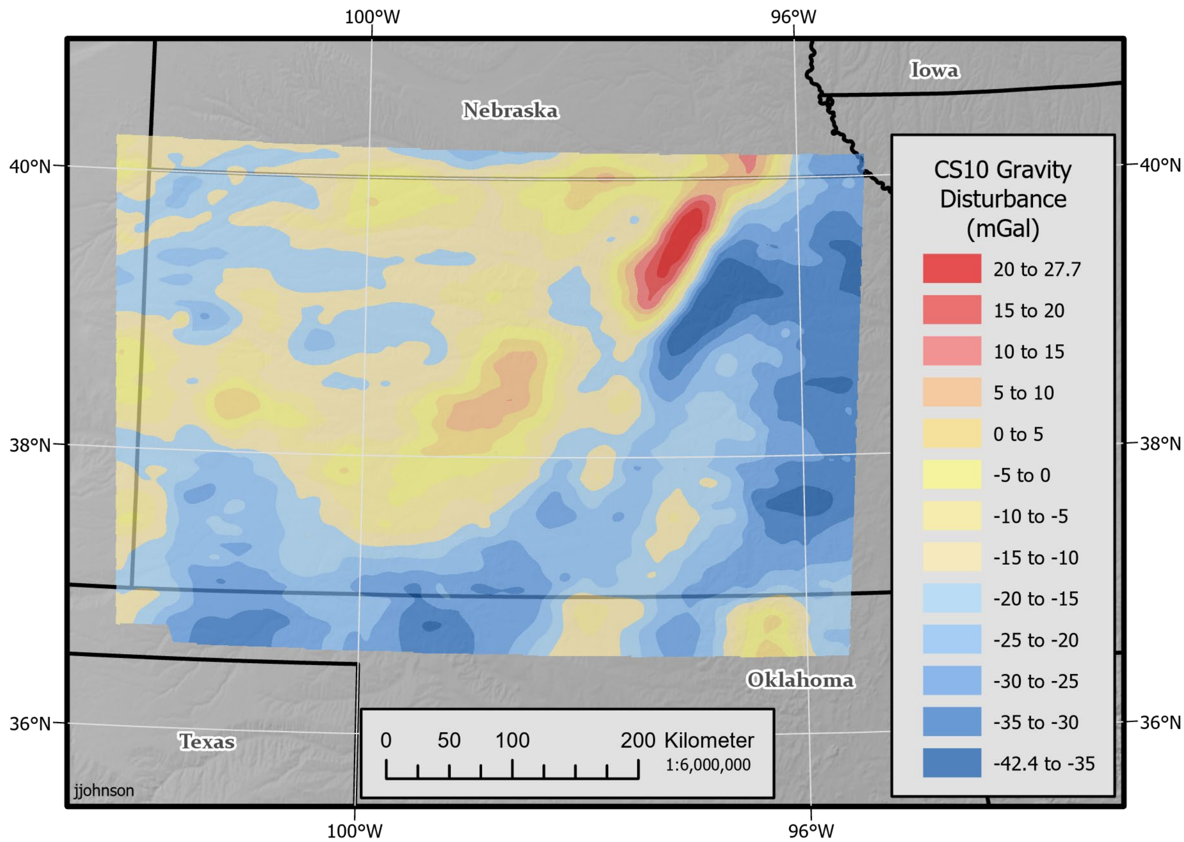

Figure 5: Gravity disturbance for Block CS10 with respect to the GRS80 ellipsoid.

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 correctly 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 E. Dahlberg, Theresa M. Damiani, Jeff Kanney, Jeffery A Johnson, Chris Villarreal, and Derek van Westrum.

To reference the CS10 data file, reference the webpage:
GRAV-D Team (2020). "Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project, Airborne Gravity Data; Block CS10". Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_CS10.shtml

To reference the block and survey details, reference the block user manual:
GRAV-D Team (2020). "Block CS10 (Central South 10); GRAV-D Airborne Gravity Data User Manual." Jeff Johnson, ed. Version BETA1. Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_CS10.shtml

To reference the general GRAV-D project operations, reference the General User Manual:
GRAV-D Team (2017). "GRAV-D General Airborne Gravity Data User Manual." Theresa Damiani, Monica Youngman, and Jeff Johnson, ed. Version 2.1 Available *DATE*. Online at: https://www.ngs.noaa.gov/GRAV-D/data/NGS_GRAV-D_General_Airborne_Gravity_Data_User_Manual_v2.1.pdf

5. References

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

Micro-g LaCoste, 2015. “TAGS-6 Turnkey Airborne Gravity System 6 User’s Manual.”