Block PN03 (Pacific North 03)

GRAV-D Airborne Data Release User Manual

Applies to Data Release BETA #1, 10/2018

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Version Notes

10/2018 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 **PN03** is located in the **P**acific Time Zone, in the **N**orth half (north of 63° latitude). This was the third (**03**) block of data completed in that region. Block PN03 is 400 km by 460 km, covering parts of Idaho, Washington, Montana, and Canada (Figure 1). The corner coordinates defining Block PN03 are listed in Table 1.

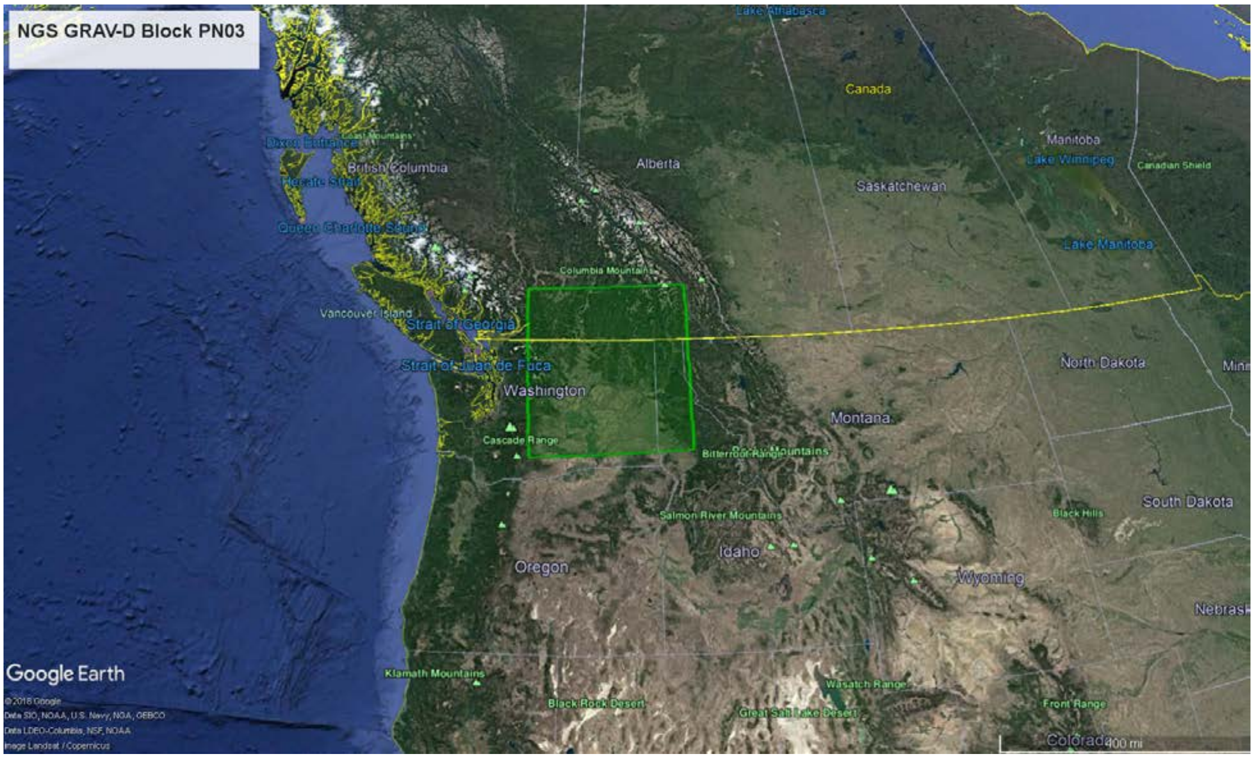

Figure 1: Google Earth Image of the Location of Block PN03

Table 1: Latitude and Longitude Coordinates of Corner Points Defining Block PN03

Latitude (decimal degrees)	Longitude (decimal degrees)
46.193772692	-121.137282470
46.346693542	-115.889744265
50.422551694	-115.860577564
50.337492054	-121.573520657

2. Survey Design and Execution

Airborne gravity data in Block PN03 were collected during 4 surveys: OR17-2 (Oregon 2017, second occupation), ID17-1 (Idaho 2017, first occupation), WA18-1 (Washington 2018, first occupation), and WA18-2 (Washington 2018, second occupation). Data lines from the four surveys were flown at approximately 23,000-24,000 ft. PN03 was surveyed with three different aircraft and three relative gravimeters. 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 PN03, data lines are north/south and cross lines are east/west. The block consists of 4 data lines from ID17-1, 2 data lines and 7 cross lines from OR17-2, 10 data lines from WA18-1, and 26 data lines from WA18-2. Two data lines, PN03102 and PN03127, from OR17-1 were reflown as PN03202 in WA18-2 and PN03227 in WA18-1. 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. PN03101= block PN03's line 101).

Table 2: Survey Overview

Survey	Conducting Organization	Airport Base of Operations	Geographic Location	Survey Dates
OR17-2	NOAA-National Geodetic Survey	Hillsboro Airport (HIO) Hillsboro, OR FBO: Aero Air, LLC	Idaho, Washington and Canada	Aug 17 - Aug 30, 2017
ID17-1	NOAA-National Geodetic Survey	Boise Airport (BOI) Boise, ID FBO: BLM/NIFC National Interatgency Fire Center	Idaho, Washington and Canada	Nov 4 - Nov 24, 2017
WA18-1	NOAA-National Geodetic Survey	Tri-Citites Airport (PSC) Pasco, WA FBO: Bergstrom Aircraft, Inc.	Idaho, Washington and Canada	Jul 31 - Aug 6, 2018
WA18-2	NOAA-National Geodetic Survey	Tri-Citites Airport (PSC) Pasco, WA FBO: Bergstrom Aircraft, Inc.	Idaho, Washington and Canada	Jul 31 - Sep 3, 2018

Table 3: Aircraft and Instrumentation

Survey	Aircraft	Engines: Number, and Type	Gravity Instrumentation	GPS Instrumentation
OR17-1	NOAA Turbo Commander	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-137	NovAtel DL-V3 or DL-4 Plus NovAtel SPAN-SE with Honeywell µIRS (GPS + IMU)
OR17-2	NOAA Turbo Commander	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-161	NovAtel DL-V3 or DL-4 Plus NovAtel SPAN-SE with Honeywell µIRS (GPS + IMU)
ID17-1	BLM Pilatus	1, Turboprop	Micro-g LaCoste (MGL) TAGS S-161 and S-211	NovAtel DL-V3 or DL-4 Plus NovAtel SPAN-SE with Honeywell µIRS (GPS + IMU)
WA18-1	NOAA Turbo Commander	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-161	NovAtel DL-V3 or DL-4 Plus NovAtel PP7 with Honeywell µIRS (GPS + IMU)
WA18-2	Dynamic Aviation King Air (N43U)	2, Turboprop	Micro-g LaCoste (MGL) TAGS S-161 and S-211	NovAtel DL-V3 or DL-4 Plus NovAtel SPAN-SE or PP7 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	23,000-24,000 ft.
Nominal Aircraft Ground Speed	250 knots
Number of Lines Released	Data Lines: 4 (ID17-1), 2 (OR17-2), 10(WA18-1), 26 (WA18-2) Cross Lines: 5 (AK18-1), 8 (AK18-2) Repeat Lines: 2 lines
Number of Crossovers	285

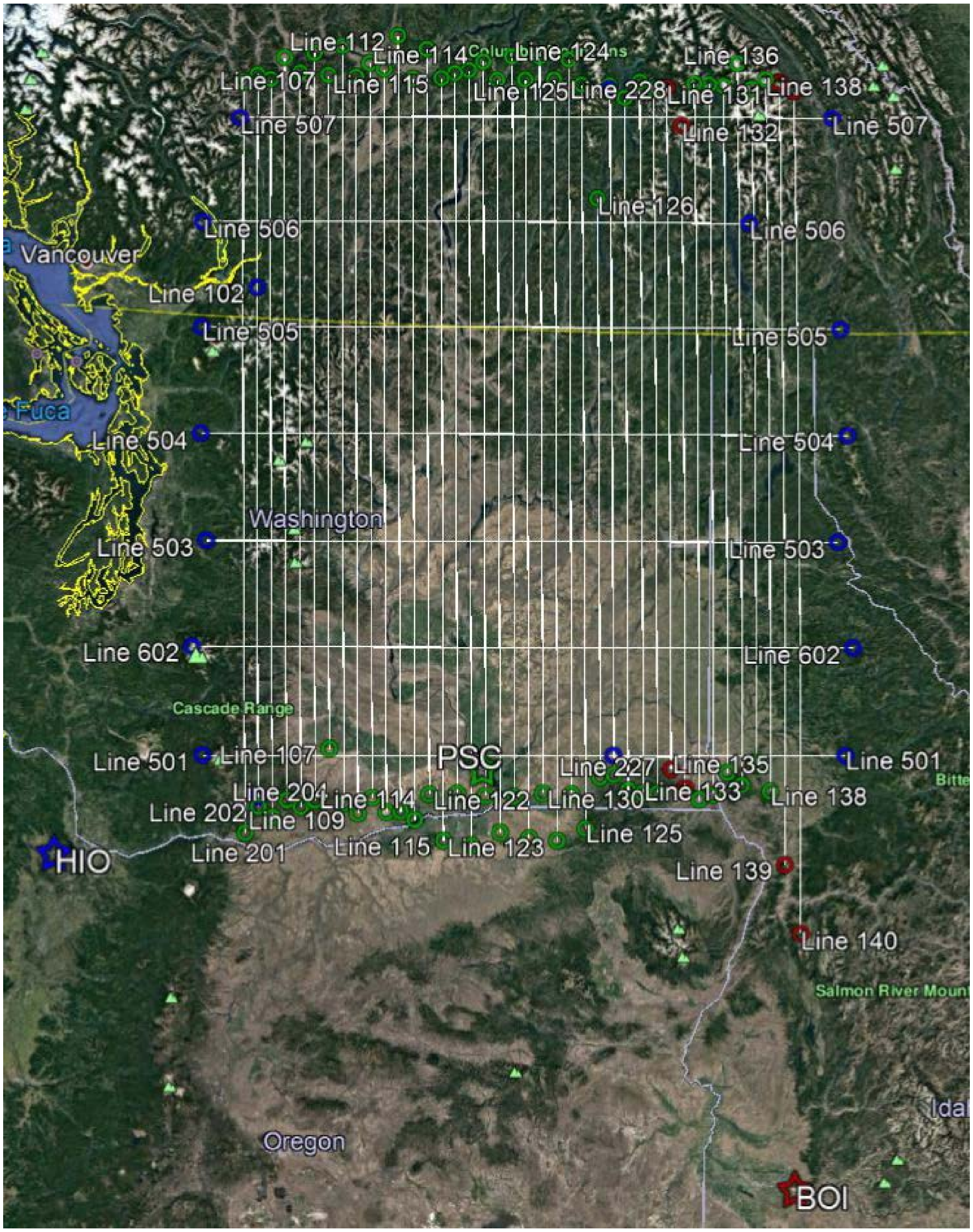

Figure 2: Data Coverage for PN03. Data lines range from 101 to 140. Hillsboro Airport (HIO) and lines flown from there are marked with blue. Boise Airport (BOI) and lines flown from there are marked with Red. Tri-Cities Airport (PSC) and lines flown from there are marked in green.

2.1 GPS/IMU Instrumentation

The aircraft 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 or PP7 (included as part of the Inertial Navigation System). The NovAtels related to TAGS S-161 had a data rate of 1 Hz, and the NovAtels related to TAGS S-211 had a data rate of 20 Hz. The NovAtel SPAN-SE/PP7 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, a variety of different GPS receivers operated at either 20 Hz or 1 Hz to act as base stations. See Table 6 and Table 12 for information regarding 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-161 and TAGS S-137 record data at 1 Hz and have a Novatel timing unit mounted on the gravimeter. S-161 and S-137 also record a separate environmental file at about 1 Hz (Micro-g LaCoste, 2010). 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 IMU 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 IMU TO the Other Instruments

Instrument/Location	X (m)	Y (m)	Z (m)
S-211 Gravimeter	-0.001	-0.002	-0.453
S-161 Gravimeter	-0.016	0.021	-0.503
S-137 Gravimeter	-0.011	0.036	-0.514
GNSS antenna on NOAA Turbo Commander (S-137 and S-161)	0.092	0.143	0.616
GNSS antenna on Dynamic Aviation King Air (S-161)	-0.133	0.389	0.538
GNSS antenna on Dynamic Aviation King Air (S-211)	-0.139	0.38	0.665
GNSS antenna on BLM Pilatus PC-12 (S-161)	0.005	0.681	0.611
GNSS antenna on BLM Pilatus PC-12 (S-211)	0.01	0.56	0.732

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)
ID17-1 BOI	Kinematic	NovAtel SPAN	f01, f02	321-323
ID17-1 BOI	Static	NovAtel PP6 (44)	f01, f02	321-323
ID17-1 BOI	Static	NovAtel DLV	f01, f02	321-323
OR17-2 HIO	Kinematic	NovAtel SPAN	f20, f26, f28, f30, f33	230, 237, 238, 239, 242
OR17-2 HIO	Static	NovAtel PP6 (49)	f20, f26, f28, f30, f33	230, 237, 238, 239, 242
OR17-2 HIO	Static	NovAtel PP6 (47)	f20, f26, f28, f30, f33	230, 237, 238, 239, 242
WA18-1 PSC	Kinematic	NovAtel SPAN	f01, f02, f04	214, 216, 217
WA18-1 PSC	Static	NovAtel PP6 (44)	f01, f02, f04	214, 216, 217
WA18-2 PSC	Kinematic	NovAtel	f05-f07, f10, f11, f14-f21	218, 219, 223-225, 227, 228, 230, 231, 234-236
WA18-2 PSC	Static	NovAtel DLV3	f05-f07	218, 219
WA18-2 PSC	Static	NovAtel PP6 (44)	f10, f11	223-225
WA18-2 PSC	Static	Trimble R8	f19-f21	234-236

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 ±0.047 m and the average vertical position accuracy is ±0.076 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 on May 2017 (BOI, called KBOI TAGS), April 2016 (HIO, called KHIO TAGS), and August 2018 (PSC, called KPSC TAGS). The A-10 was set up at the exact location of the aircraft. 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/ Airplane	Point ID	Latitude	Longitude	Tie height above mark (cm)	Gravity Tie (mGal)
BOI/ BLM Pilatus	KBOI TAGS	43.56437161°N	-116.21225695°W	163.7	980191.678 ± 0.008
HIO/ NOAA Turbo Commander	KHIO TAGS	45.54142798°N	-122.95422647°W	80.6	980590.417 ± 0.008
PSC/ NOAA Turbo Commander	KPSC TAGS	46.26209664°N	-119.104325750°W	80.6	980646.737 ± 0.008
PSC/ Dynamic Aviation King Air (N43U)	KPSC TAGS	46.26209664°N	-119.104325750°W	162.5	980646.737 ± 0.008

3.1.3 Gravity Filtering

For block PN03, 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 PN03, 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)
24,000	7,300	7,254	285	4.00	4.00	0.27	2.83

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.

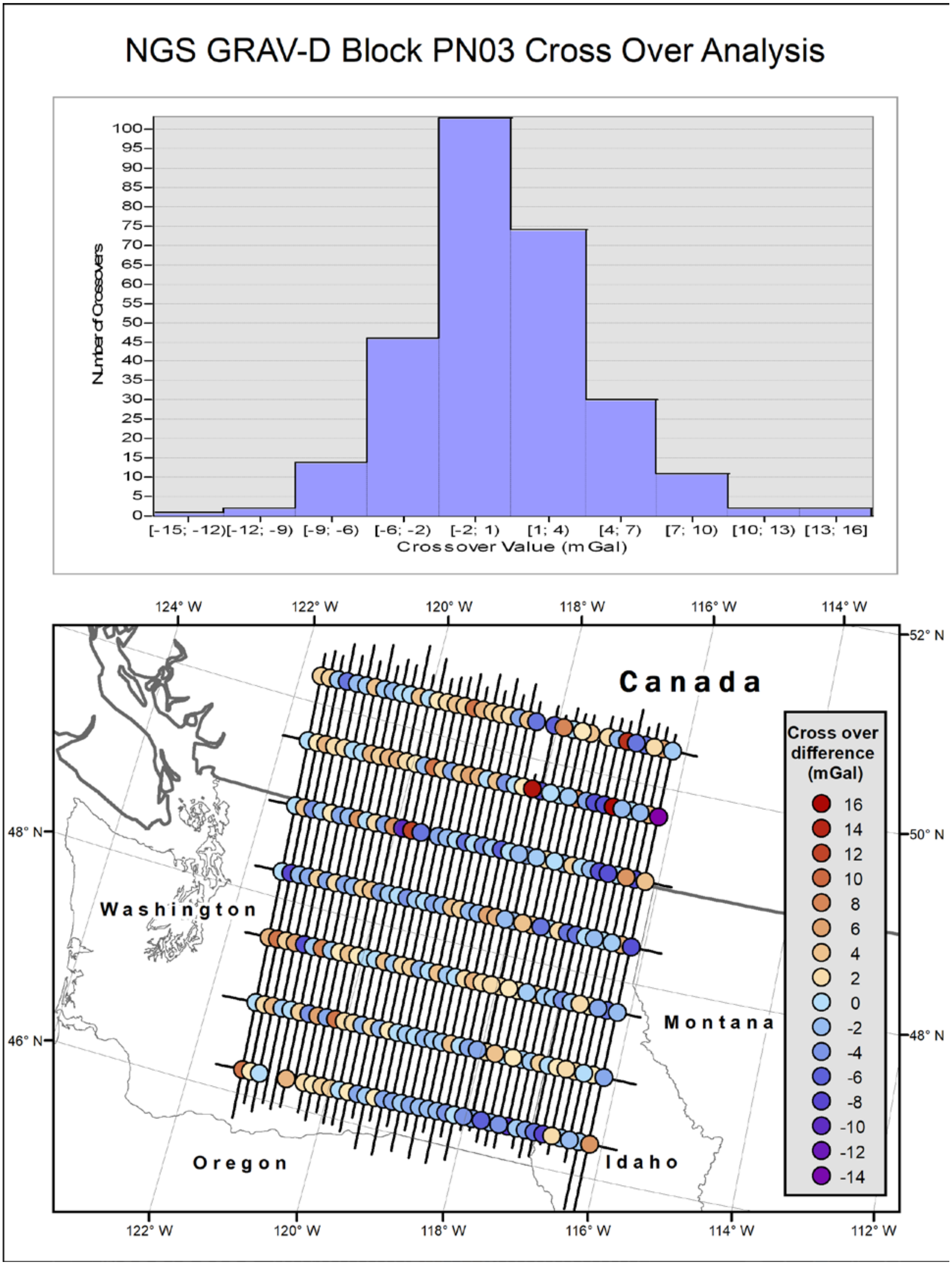

Figure 3: Crossover Residuals, Histogram, and Statistics for Block PN03

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)
PN03501	3.62	-0.91
PN03602	2.65	0.57
PN03503	3.31	1.15
PN03504	3.49	-0.65
PN03505	4.28	-0.70
PN03506	5.58	1.23
PN03507	4.01	1.13

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
45	99.59%	0.22%

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 PN03, two data lines were re-flown as PN03102/PN03202 and PN03127/PN03227. Table 11 shows the correlation between these two sets of repeat lines.

Table 11: Repeat Line Correlations

Repeat Lines	Correlation
PN03102	99.97%
PN03202	
PN03127	99.98%
PN03227	

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
ID17-1	f01	SPAN	GPS+IMU	7.5	139	100
ID17-1	f01	SPAN	GPS+IMU	7.5	140	100
ID17-1	f02	SPAN	GPS+IMU	5	131	100
ID17-1	f02	SPAN	GPS+IMU	5	132	100
OR17-2	f20	SPAN	GPS+IMU	5	501	100
OR17-2	f26	SPAN	GPS+IMU	7.5	102	100
OR17-2	f28	SPAN	GPS+IMU	5	504	100
OR17-2	f28	SPAN	GPS+IMU	5	505	100
OR17-2	f30	SPAN	GPS+IMU	5	503	100
OR17-2	f30	SPAN	GPS+IMU	5	506	100
OR17-2	f30	SPAN	GPS+IMU	5	507	100
OR17-2	f30	SPAN	GPS+IMU	5	602	100
OR17-2	f33	SPAN	GPS+IMU	5	127	100
WA18-1	f01	SPAN	GPS+IMU	5	137	100
WA18-1	f01	SPAN	GPS+IMU	5	138	100
WA18-1	f02	SPAN	GPS+IMU	5	133	100
WA18-1	f02	SPAN	GPS+IMU	5	134	100
WA18-1	f02	SPAN	GPS+IMU	5	135	100
WA18-1	f02	SPAN	GPS+IMU	5	136	100
WA18-1	f04	SPAN	GPS+IMU	5	129	100
WA18-1	f04	SPAN	GPS+IMU	5	130	100
WA18-1	f04	SPAN	GPS+IMU	5	227	100
WA18-1	f04	SPAN	GPS+IMU	5	228	100
WA18-2	f05	SPAN	GPS+IMU	5	201	100
WA18-2	f05	SPAN	GPS+IMU	5	202	100
WA18-2	f06	PP7	GPS+IMU	5	203	100
WA18-2	f06	PP7	GPS+IMU	5	204	100
WA18-2	f07	PP7	GPS+IMU	5	205	100
WA18-2	f07	PP7	GPS+IMU	5	206	100
WA18-2	f10	PP7	GPS+IMU	5	107	100
WA18-2	f10	PP7	GPS+IMU	5	108	100
WA18-2	f11	PP7	GPS+IMU	5	109	100
WA18-2	f11	PP7	GPS+IMU	5	110	100
WA18-2	f14	PP7	GPS+IMU	5	111	100
WA18-2	f14	PP7	GPS+IMU	5	112	100
WA18-2	f15	PP7	GPS+IMU	5	113	100
WA18-2	f15	PP7	GPS+IMU	5	114	100

Survey	Flight	Rover GPS Unit	Solution Type	Elevation Mask (deg)	Line Num.	NGS Qualtiy Grade
WA18-2	f16	PP7	GPS+IMU	5	115	100
WA18-2	f16	PP7	GPS+IMU	5	116	100
WA18-2	f17	PP7	GPS+IMU	5	117	100
WA18-2	f17	PP7	GPS+IMU	5	118	100
WA18-2	f18	PP7	GPS+IMU	5	119	100
WA18-2	f18	PP7	GPS+IMU	5	120	100
WA18-2	f19	PP7	GPS+IMU	5	121	100
WA18-2	f19	PP7	GPS+IMU	5	122	100
WA18-2	f20	PP7	GPS+IMU	5	123	100
WA18-2	f20	PP7	GPS+IMU	5	124	100
WA18-2	f21	PP7	GPS+IMU	5	125	100
WA18-2	f21	PP7	GPS+IMU	5	126	100

Table 13: Gravity Processing Results

Survey	Flight Num.	Line Num.	Time of Deleted Data	Comments
OR17-2	f20	501	2017-08-18 19:33:46- 2017-08-18 19:36:03	Bump Removed
OR17-2	f28	505	2017-08-26 18:03:22- 2017-08-26 18:04:50	Bump Removed
WA18-2	f20	124	2018-08-23 16:41:16- 2018-08-23 16:47:07	Bump Removed

Table 14: Bias from EGM08 by Line

Survey	Flight Num.	Line	EGM08 mean
ID17-1	f01	139	3.57
ID17-1	f01	140	4.34
ID17-1	f02	131	4.11
ID17-1	f02	132	3.99
OR17-2	f20	501	8.39
OR17-2	f26	102	4.33
OR17-2	f28	504	3.22
OR17-2	f28	505	3.79
OR17-2	f30	503	4.73
OR17-2	f30	506	2.8
OR17-2	f30	507	1.92
OR17-2	f30	602	3.54
OR17-2	f33	127	5.95
WA18-1	f01	137	4.03
WA18-1	f01	138	3.45
WA18-1	f02	133	2.67
WA18-1	f02	134	4.28
WA18-1	f02	135	0.74
WA18-1	f02	136	3.34
WA18-1	f04	129	3.58
WA18-1	f04	130	3.13
WA18-1	f04	227	2.57
WA18-1	f04	228	4.42
WA18-2	f05	201	3.15
WA18-2	f05	202	3.19
WA18-2	f06	203	5.34
WA18-2	f06	204	4.14
WA18-2	f07	205	2.9
WA18-2	f07	206	0.83
WA18-2	f10	107	1.5
WA18-2	f10	108	1.73
WA18-2	f11	109	-0.44
WA18-2	f11	110	-2.12
WA18-2	f14	111	-1.68
WA18-2	f14	112	-1.28
WA18-2	f15	113	-0.29
WA18-2	f15	114	-0.08
WA18-2	f16	115	0.47

Survey	Flight Num.	Line	EGM08 mean
WA18-2	f16	116	-0.76
WA18-2	f17	117	2.63
WA18-2	f17	118	0.2
WA18-2	f18	119	3.29
WA18-2	f18	120	0.89
WA18-2	f19	121	1.13
WA18-2	f19	122	0.42
WA18-2	f20	123	1.01
WA18-2	f20	124	-0.27
WA18-2	f21	125	0.75
WA18-2	f21	126	1.08

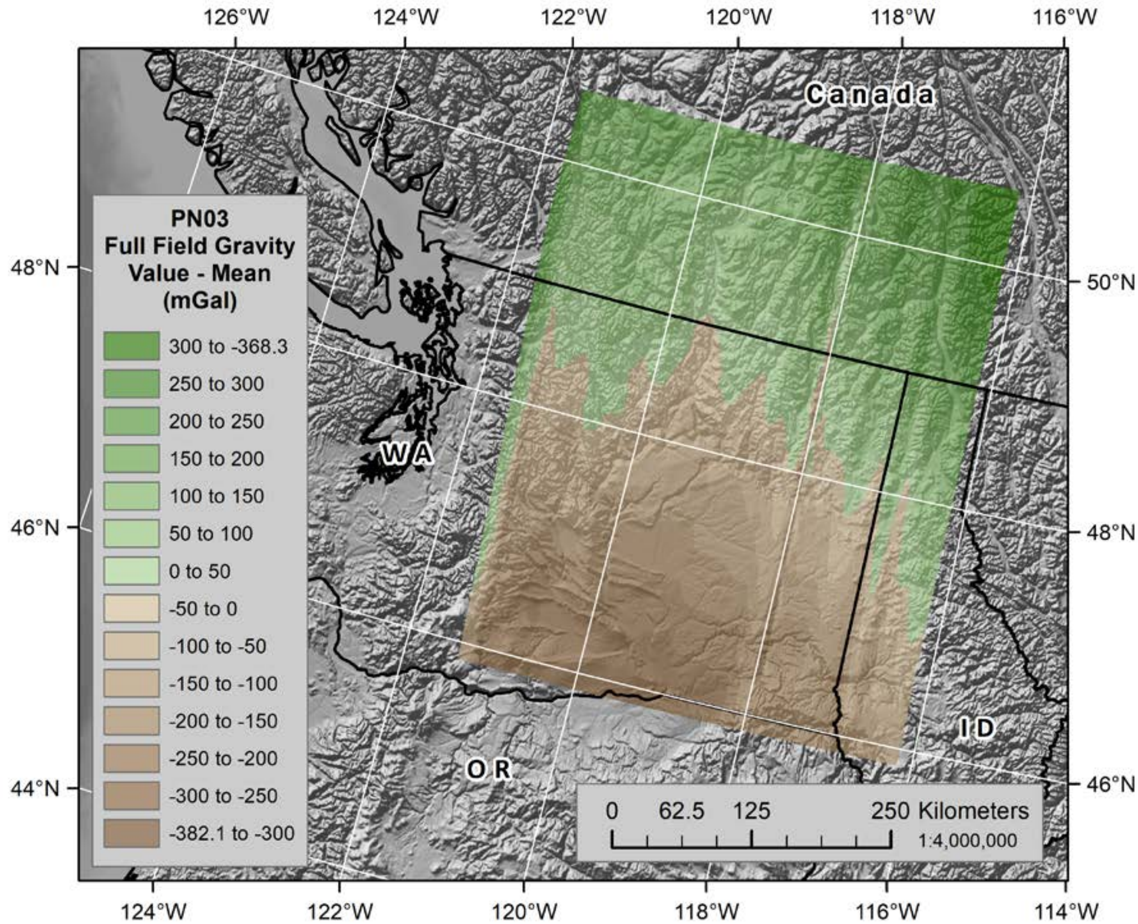

Figure 4: Full-field gravity at altitude (mean removed) for Block PN03. This is the data in the gravity release ".txt" file and includes the effects of differing altitudes along flight lines.

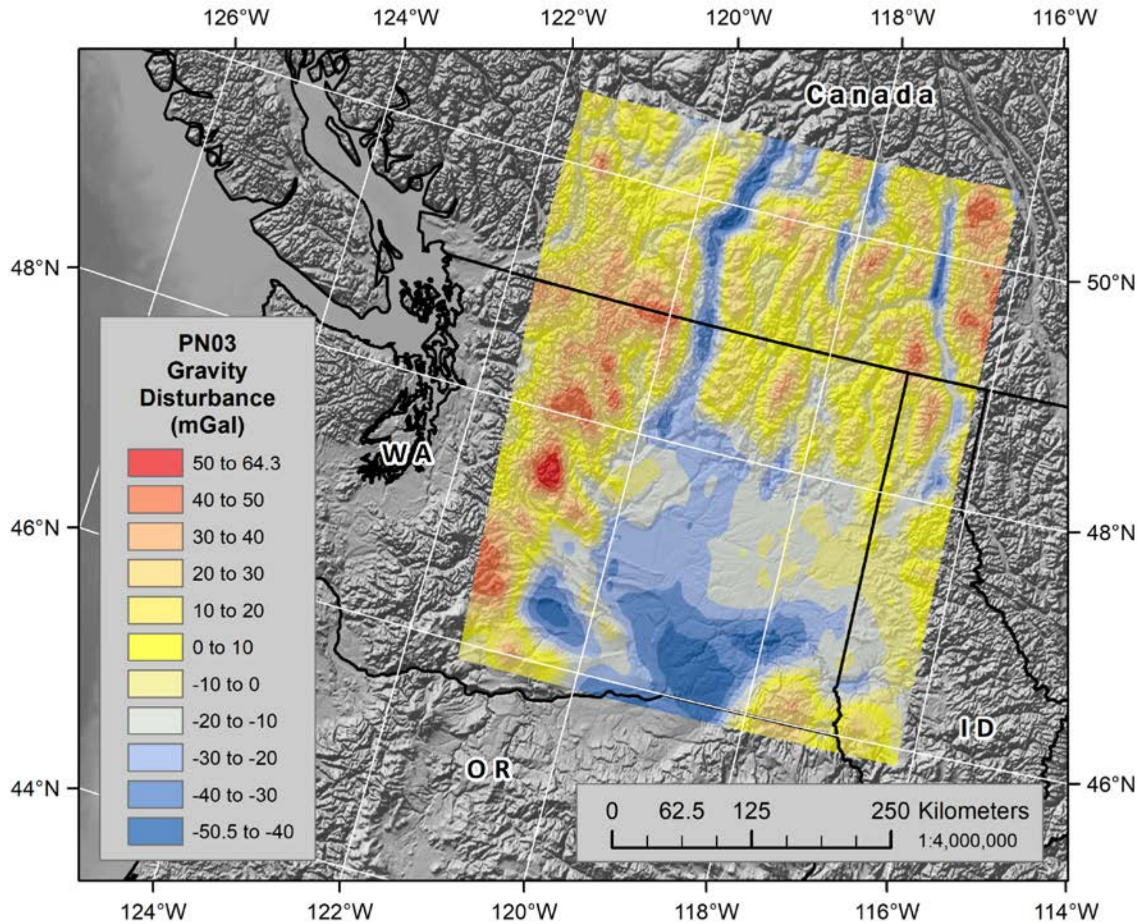

Figure 5: Gravity disturbance for Block PN03 with respect to the GRS80 ellipsoid. Calculated with the confocal ellipsoid method of calculating normal gravity.

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 PN03". Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_PN03.shtml

To reference the block and survey details, reference the block user manual:
GRAV-D Science Team (2018). "Block PN03 (Pacific North 03); GRAV-D Airborne Gravity Data User Manual." Jeffery A. Johnson, ed. Version BETA. Available *DATE*. Online at: http://www.ngs.noaa.gov/GRAV-D/data_PN03.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."

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