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Raw Data File 2023-7

M2Ocean Hydroball sensor being towed behind a boat near Kwigillingok, Alaska, on June 19, 2022. Photo: Alaska Division of Geological & Geophysical Surveys.

This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

2023
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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Suggested citation:
Horen, K.C., Buzard, R.M., Overbeck, J.R., Poisson, A.C., and Siemsen, Z.J., 2023, Single-beam bathymetric data near Kwigillingok, Alaska, collected June 18-19, 2022: Alaska Division of Geological & Geophysical Surveys Raw Data File 2023-7, 9 p.
https://doi.org/10.14509/31005

SINGLE-BEAM BATHYMETRIC DATA NEAR KWIGILLINGOK, ALASKA, COLLECTED JUNE 18–19, 2022

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data near Kwigillingok, Alaska, on June 18 and 19, 2022 (fig. 1). The purpose of this survey is to provide bathymetric data for the assessment of coastal hazards and riverine erosion studies. These data were collected using an M2Ocean Hydroball integrated bathymetric sensor and processed using CIDCO DepthStar software. DGGS collected coincident Global Navigation Satellite System (GNSS) base station and water-level time series data using Trimble survey equipment and a Stilltek iGage radar sensor, respectively, to correct horizontal and vertical positions. This data product does not meet the International Hydrographic Organization (IHO) bathymetric coverage standard (IHO, 2022), is not intended to determine navigability, and is released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31005.

Figure 1. Map of bathymetric soundings near Kwigillingok, Alaska.

LIST OF DELIVERABLES

- Bathymetric sounding data
- Data dictionary
- Metadata

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METHODS

Field Collection

DGGS used an M2Ocean Hydroball bathymetric sensor composed of an Imagenex 852 single-beam echosounder (SBES), a Tallysman TW3972 GNSS antenna, and a Honeywell HMR3000 inclinometer to collect field data. On June 18, 2022, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over known benchmark 946 5911 B with a published solution available from https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBGM53&ts=19297165248. On June 19, 2022, DGGS temporarily installed the GNSS base station over a found Bureau of Land Management (BLM) brass-cap monument stamped "S4098." Base station data were used to correct the Hydroball sensor positions. DGGS collected water-level time series data from a permanently installed Stilltek iGage Stream Gauge on a metal bridge over a navigable tributary of the Kwigillingok River (fig. 2) to provide water level corrections.

Figure 2. Stilltek iGage radar sensor installation in Kwigillingok, Alaska.

Survey Details

The bathymetric survey was performed on June 18 and 19, 2022, from 1:50 PM to 7:50 PM and 1:00 PM to 4:40 PM AKDT, respectively. The weather throughout the survey was fair, with scattered cloud cover, little to no wind, and calm waters. The Hydroball was attached to a catamaran configuration and towed behind a small boat equipped with an outboard motor at speeds below 4 knots. The Imagenex 852 SBES was configured with a maximum range of 20 m, gain of 5 dB, and pulse length of 120 microseconds. Due to time and vessel constraints, the bathymetric survey was performed using a survey pattern inconsistent with the requirements outlined in the IHO standards (IHO, 2022). Approximately 24.1 km of riverine and 15.9 km of near-shore marine bathymetry were surveyed.

Data Processing

Base positions were corrected using Online Positioning User Service (OPUS) solutions, which were used to update the Hydroball sensor positions using post-processed kinematic (PPK) adjustments from RTKLIB version 2.4.2 software with the following settings applied: L1+L2 frequencies forward and backward filtered; a 10-degree elevation mask; broadcast ionosphere and Saastamoinen troposphere corrections; a minimum fixed ambiguity ratio of 3; and L1/L2 code/carrier-phase error ratios of 100. During post-processing, DGGS applied International GNSS Service (IGS) precise orbits and final clock solutions retrieved from the Crustal

Dynamics Data Information System (CDDIS) available from urs.earthdata.nasa.gov/. Final corrected data were exported as time-stamped position files in the WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS retrieved hourly water-level time series data collected by the Stilltek iGage from 12:00 PM on June 18 to 6:00 PM AKDT on June 19, 2022. These data are available from https://water-level-watch.portal.aoos.org/#metadata/110872/station/data in the Mean Higher High Water (MHHW) datum described by National Oceanic and Atmospheric Administration (NOAA) tide station 946 5911 available from tidesandcurrents.noaa.gov/benchmarks.html?id=9465911. The water level elevations were converted to the NAVD88 (GEOID12B) vertical datum using the Alaska Tidal Datum Portal available from dggs.alaska.gov/hazards/coastal/ak-tidal-datum-portal.html. These data were then adjusted to Coordinated Universal Time (UTC) and interpolated to the second using a 4-degree Lagrange interpolating polynomial,

$$z = \sum_{j}^{4} f_j(t), \qquad f_j(t) = z_j \prod_{\substack{k=1 \\ k \neq j}}^{4} \frac{t - t_k}{t_j - t_k}$$

where z_j is the observed water level elevation, t_j is the observation time, t_k represents the other three primary times used in the calculation, and z is the interpolated water level elevation at time t (fig. 3).

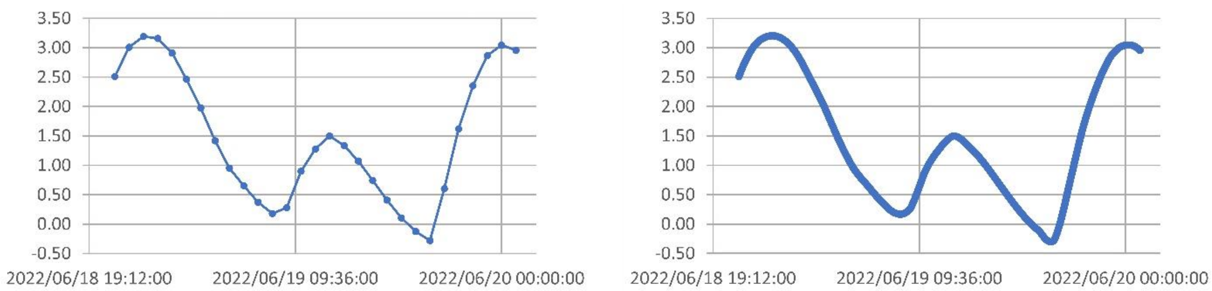

Figure 3. Comparison of per hour and per second (interpolated) water level elevation data.

Using CIDCO DepthStar software, DGGS imported the Hydroball device file containing raw GNSS position, SBES depth, and inclinometer gyrocompass data. These data were corrected to the 0.115 m catamaran draft and 0.364 m GNSS antenna reference point offset from the SBES acoustic center. These data were then georeferenced to the corrected PPK positions and interpolated water level time series using the water level reference survey (WLRS) sounding reduction method, applying a sound velocity correction of 1450 m/s (fresh-water default value) to all riverine data and 1500 m/s (salt-water default value) to all near-shore marine data. The final soundings were exported with WGS84 horizontal coordinates and NAVD88 (GEOID12B) elevations. These data were projected to the horizontal coordinate system NAD83 (2011) UTM Zone 3 North using Esri ArcGIS Pro version 3.0.2 software.

Data Formatting

All data were delivered in comma-delimited (CSV) format with column headers and accompanied by a data dictionary detailing the header names, definitions, and applicable units.

Coordinate System and Datum

All data were processed in the horizontal coordinate system WGS84 and vertical datum NAVD88 (GEOID12B). All data were delivered in the horizontal coordinate system NAD83 (2011) UTM Zone 3 North and vertical datum NAVD88 (GEOID12B).

ACCURACY REPORT

Using the IHO minimum bathymetric standards (IHO, 2022) would be inappropriate for assessing these data, which do not meet the IHO-prescribed systematic survey pattern criteria. DGGS has developed order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards to avoid misinterpretation. The reported accuracy of these data is intended to express quality only and should not be considered sufficient for safe navigation.

Horizontal Accuracy

We quantified the horizontal accuracy of the GNSS position data using the latitudinal and longitudinal peak-to-peak errors provided by OPUS (table 1). Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have latitudinal and longitudinal errors less than or equal to 0.04 m.

We quantified the horizontal accuracy of individual depth soundings using the maximum manufacturer-reported angular accuracy of the Honeywell HMR3000 inclinometer, 0.6 degrees. DGGS applied the following formula to determine the horizontal accuracy for each depth sounding,

$$\pm\Delta(d) = d \tan 0.6°$$

where $\pm\Delta$ is the horizontal uncertainty, and d is the sounding depth at a given location.

We categorized the quality of depth-sounding data by order of accuracy based on the maximum Total Horizontal Uncertainty (THU) derived from the following formula (IHO, 2022),

$$THU_{max} = \min_{i \in [1,n]} (a + bd_i)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient that represents the portion of uncertainty that varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 2-dimensional (position) 95 percent confidence level of 0.052 m.

Vertical Accuracy

We quantified the vertical accuracy of the GNSS position data using the combined ellipsoidal height peak-to-peak errors provided by OPUS and ortho height RMS error provided by NOAA's Vertical Datum Transformation software. Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have vertical errors less than or equal to 0.08 m.

We quantified the vertical accuracy of individual depth soundings using the manufacturer-reported range resolution, 0.02 m, as a percentage of the maximum range, 50.00m, of the Imagenex 852 single-beam echosounder. DGGS applied the following formula to determine the vertical accuracy for each depth sounding,

$$\pm\Delta(d) = \frac{0.02}{50.00}d$$

where $\pm\Delta$ is the vertical uncertainty and d is the sounding depth at a given location.

We categorized the quality of depth sounding data by order of accuracy based on the maximum Total Vertical Uncertainty (TVU) derived from the following formula (IHO, 2022),

$$TVU_{max} = \min_{i \in [1,n]} \left(\sqrt{a^2 + (bd_i)^2}\right)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient that represents the portion of uncertainty that varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.002 m.

Overall Accuracy

We quantified the overall accuracy of the bathymetric data using the vertical separation of overlapping point-to-point 3-dimensional lines within the data. These data intersected 69 times in total, with a separation range between 0.001 m and 0.882 m, average separation of 0.238 m, and median separation of 0.158 m (fig. 4). Overall vertical error is calculated as the root-mean-square (RMS) error of the offsets at these intersection points, with a total vertical error of 0.236 m (table 2). These data meet DGGS 3rd Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.465 m.

Table 1. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
602670.520	6639531.038	4.111	0.005	0.014	0.071
604236.993	6637715.523	3.669	0.005	0.014	0.063

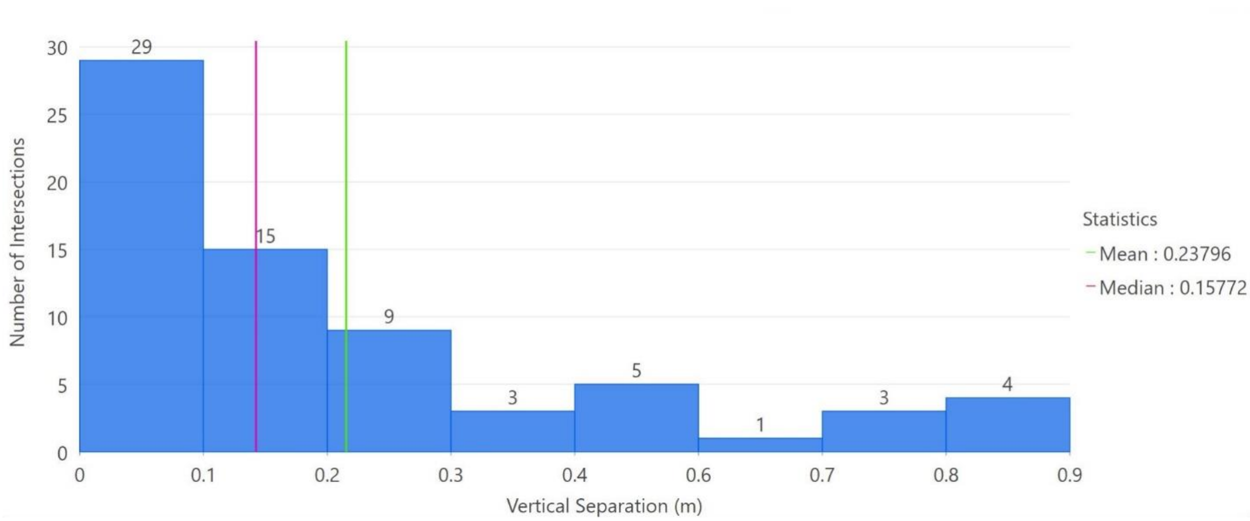

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 2. Survey intersection locations and vertical separations.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
602968.6471	6639877.7833	0.001
603416.7924	6639952.7407	0.002
604762.1033	6636797.5563	0.003
603790.2579	6638883.0331	0.015
602755.9323	6640120.8284	0.019
604502.7633	6637509.1547	0.020
603724.5068	6639671.9240	0.023
603561.8377	6639954.8341	0.027
604074.1061	6638906.9518	0.048
604496.5238	6637555.7654	0.049
603999.5604	6638656.2687	0.051
603469.6483	6639927.9317	0.051
603955.2905	6638495.8912	0.053
604542.3812	6637523.8540	0.058
602738.6465	6640126.2521	0.058
604252.6901	6638907.6515	0.063
604403.5748	6638049.9660	0.070
604141.0844	6638283.2628	0.081
603922.6416	6638502.2157	0.082
602969.0290	6639894.7300	0.085
603572.4284	6639968.0368	0.088
603279.9018	6639705.6383	0.090
603664.0590	6639879.6698	0.093
602973.0980	6639992.9586	0.096
603778.7272	6638968.5482	0.097
604095.5367	6638358.5219	0.100
603736.6821	6639929.2385	0.104
603584.8467	6639181.1696	0.110
603264.8214	6639769.5951	0.110
603854.7456	6638841.3315	0.115
605803.0753	6634990.2959	0.118
603994.2826	6638562.8328	0.133
602945.9460	6640087.5963	0.151
603907.8591	6638466.8724	0.157
604169.3730	6638351.5214	0.158
604240.4551	6638936.5762	0.163

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
602905.7560	6640129.6942	0.164
604190.0875	6638939.1272	0.171
603671.9047	6639368.1949	0.179
603651.0717	6639857.2308	0.197
604353.2075	6638227.1041	0.207
603247.9568	6639796.6249	0.213
602932.2311	6639662.2901	0.214
606636.8688	6634538.6619	0.220
603448.7874	6639936.1760	0.223
603613.6799	6639166.1691	0.229
606140.5015	6634295.5886	0.235
605552.3926	6634773.7650	0.237
605330.4653	6634605.5991	0.242
603928.0036	6638429.1906	0.267
603763.8599	6639657.3607	0.269
603916.5462	6638472.3537	0.287
603648.0762	6639358.7704	0.304
603739.5233	6639372.1376	0.334
603955.1241	6638336.6983	0.387
603667.2378	6639053.4107	0.415
603763.9726	6639613.2912	0.456
602978.2004	6639921.4441	0.478
603660.4543	6639066.8406	0.509
603900.5909	6638503.7150	0.527
603759.9802	6639486.7155	0.535
603661.8609	6639110.9497	0.598
603994.8270	6638681.0665	0.665
602934.5782	6639633.2183	0.701
605330.5455	6635411.3919	0.715
602933.0624	6639735.8233	0.868
602933.0494	6639736.9317	0.871
602933.0601	6639736.0204	0.876
602857.1388	6640102.9242	0.882
	Mean	**0.238**
	Median	**0.158**
	Standard Deviation	**0.237**
	95% Confidence Level	**0.465**
	Root-Mean-Square Error	**0.236**

Table 3. DGGS order of accuracy criteria.

Criteria	4th Order	3rd Order	2nd Order	1st Order
THU	$a = 20\ m$ $b = 0.10$	$a = 5\ m$ $b = 0.05$	$a = 2\ m$ $b = 0.00$	$a = 1\ m$ $b = 0.00$
TVU	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.082 m**	**5.041 m**	**2.000 m**	**1.000 m**
$\boldsymbol{TVU_{max}}$	**1.000 m**	**0.500 m**	**0.250 m**	**0.150 m**

Data Consistency and Completeness

DGGS filtered out low-quality, non-differential (single) GNSS position data using standard categorization (single, float, fixed). All 0.0 m depth soundings, excessive noise, and vertical anomalies were removed through visual inspection. DGGS used time series data for depth and attitude (pitch and yaw) to manually remove anomalous soundings and any sounding reporting an attitude deviation larger than twenty degrees. No significant erroneous areas requiring repair were identified during this quality control process.

Base station data were processed using the OPUS static processing service, which derives GNSS coordinates from the average of three independent, single-baseline solutions, each computed by double-differenced carrier-phase measurements from three nearby National Continuously Operating Reference Stations (CORS). OPUS provides the range of the three individual single baselines, known as the peak-to-peak error. These ranges include errors from the CORS during processing (NOAA, 2022).

OPUS ortho height ranges are estimated using the same calculations applied to horizontal error reporting, typically resulting in a much larger potential error compared to the peak-to-peak error of the ellipsoid height. For more accurate ortho height error reporting, DGGS used NOAA's Vertical Datum Transformation software for final elevation conversions from NAD83(2011) ellipsoidal heights to NAVD88 (GEOID12B) ortho heights. This software employs accurate, multi-parameter mathematical equations and location-specific grid models to perform vertical transformations and report the total root-mean-square error (NOAA, 2016).

ACKNOWLEDGMENTS

We thank the Native Village and City of Kwigillingok for supporting the creation of these data products, made possible with the National Fish and Wildlife Foundation's National Coastal Resilience Funding through our partners at the Alaska Native Tribal Health Consortium. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the Alaska Division of Geological & Geophysical Surveys, the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources. Mention of trade names or commercial products does not constitute endorsement by the Alaska Division of Geological & Geophysical Surveys, the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources.

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