SINGLE-BEAM BATHYMETRIC DATA NEAR TUNTUTULIAK, ALASKA, COLLECTED JUNE 8, 2023

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Raw Data File 2024-3

Photo of M2Ocean Hydroball sensor towed behind a boat near Tuntutuliak, Alaska, on June 8, 2023. Photo: Alaska Division of Geological & Geophysical Surveys.

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SINGLE-BEAM BATHYMETRIC DATA NEAR TUNTUTULIAK, ALASKA, COLLECTED JUNE 8, 2023

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data along the Kinak River near Tuntutuliak, Alaska, on June 8, 2023 (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. Coincident Global Navigation Satellite System (GNSS) base station and water level time series data were collected using Trimble survey equipment and a Solinst Levelogger pressure and temperature sensor 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/10.14509/31148.

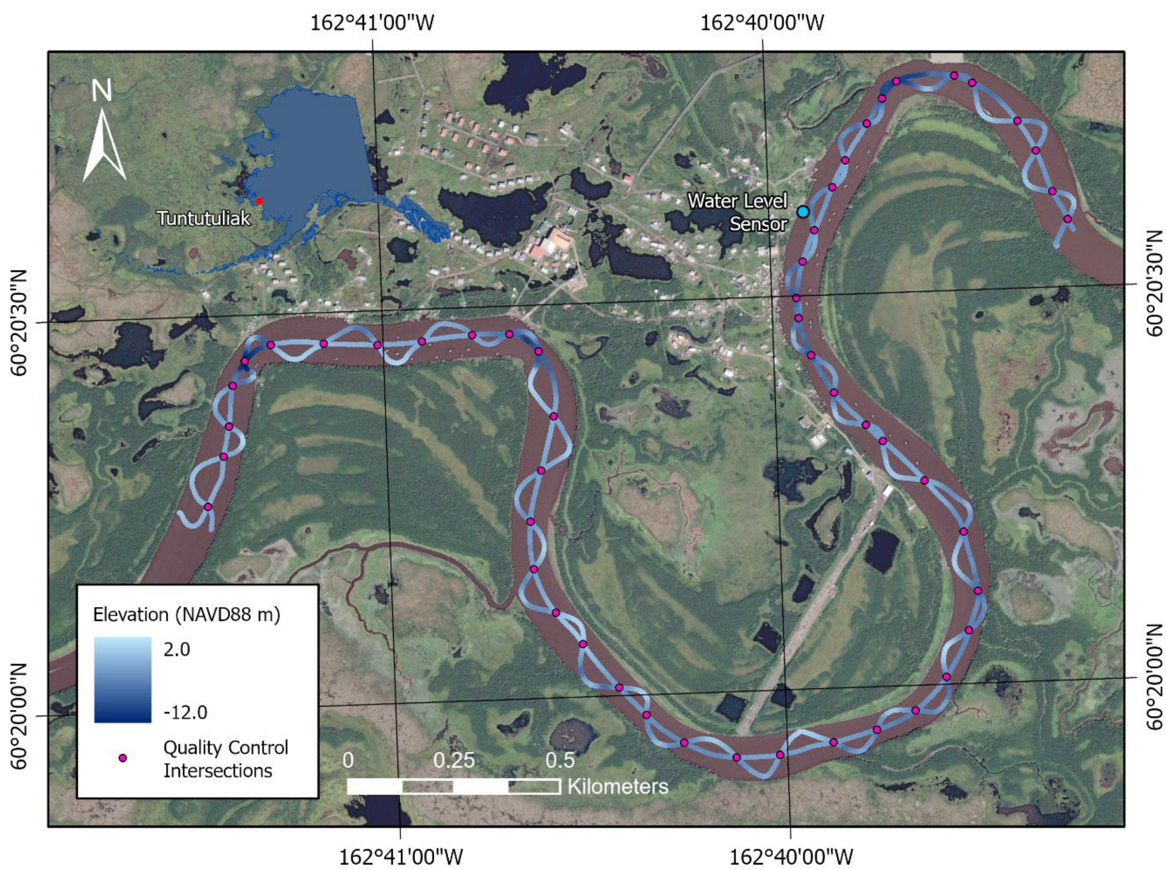

Figure 1. Map of bathymetric soundings along the Kinak River near Tuntutuliak, Alaska.

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LIST OF DELIVERABLES

- Bathymetric sounding data
- Data dictionary
- Metadata

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 August 17, 2022, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over a temporary benchmark. Base station data were used to correct the Hydroball sensor positions. To provide water level corrections, DGGS collected derived water level time series data from two temporarily installed Solinst model 3001 Levelogger Edge LT M10/F30 pressure and temperature sensors, one fully submerged approximately 1 m off the western bank of the Kinak River (fig. 2) and the other placed in a dry, shaded location on land.

Figure 2. Solinst Levelogger installation near Tuntutuliak, Alaska.

Survey Details

The bathymetric survey was performed on June 8, 2023, from 3:45 PM to 6:00 PM AKDT. The weather throughout the survey was mostly cloudy, with light wind and little to no wave action. 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 11.6 km of riverine 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 100/100. Final corrected data were exported as time-stamped position files in the WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS collected temperature-compensated pressure-time series data on June 8 and 9, 2023, from 1:30 PM to 10:30 AM AKDT, at synchronized five-minute intervals on the two Levelogger sensors. Using a barometric (millibar) to water column equivalent (meter) conversion of 1.0 mb = 0.0101972 m, DGGS converted both the submerged Levelogger and the dry air Levelogger data. Subtracting the dry air pressures in water column equivalent pressures from the submerged water column equivalent pressures provides the barometrically compensated water level. These data were then adjusted to the vertical datum NAVD88 (GEOID12B) elevation of the submerged sensor location, converted to Coordinated Universal Time (UTC) and interpolated to the second using a 4-degree Lagrange interpolating polynomial,

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

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

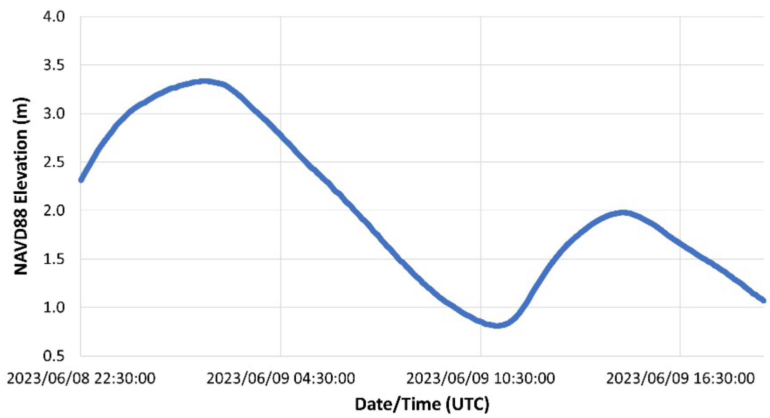

Figure 3. Observed and interpolated water level elevation data during this survey.

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 data. The final soundings were exported with WGS84 horizontal coordinates and NAVD88 (GEOID12B) elevations. These data were projected to 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 a data dictionary detailing the header names, definitions, and applicable units.

Coordinate System and Datum

All data were processed in horizontal coordinate system WGS84 and vertical datum NAVD88 (GEOID12B). All data were delivered in 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 an order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards to avoid misinterpretation (table 1). These accuracy criteria are unique to this survey because they are site-specific and depth-dependent. The reported accuracy of these data is intended to express quality only and should not be considered sufficient for safe navigation.

Table 1. DGGS order of accuracy criteria for this survey.

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	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.127 m**	**5.063 m**	**2.000 m**	**1.000 m**
$\boldsymbol{TVU_{max}}$	**1.000 m**	**0.500 m**	**0.250 m**	**0.150 m**

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 2). 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 1) with a 2-dimensional (position) 95 percent confidence level of 0.043 m.

Table 2. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation (m)	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
629173.071	6692778.576	8.341	0.016	0.007	0.063

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 root-mean-square (RMS) error supplied by NOAA's Vertical Datum Transformation software (table 2). 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 of the Imagenex 852 single-beam echosounder, 50.00 m. 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 1) 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 50 times in total (fig. 1 and table 3), with a separation range between 0.000 m and 0.618 m, average separation of 0.167 m, and median separation of 0.157 m (fig. 4). Overall vertical error is calculated as the RMS error of the offsets at these intersection points, with a total vertical error of 0.139 m (table 3). These data meet DGGS 3rd Order standards (table 1) with a 1-dimensional (depth) 95 percent confidence level of 0.276.

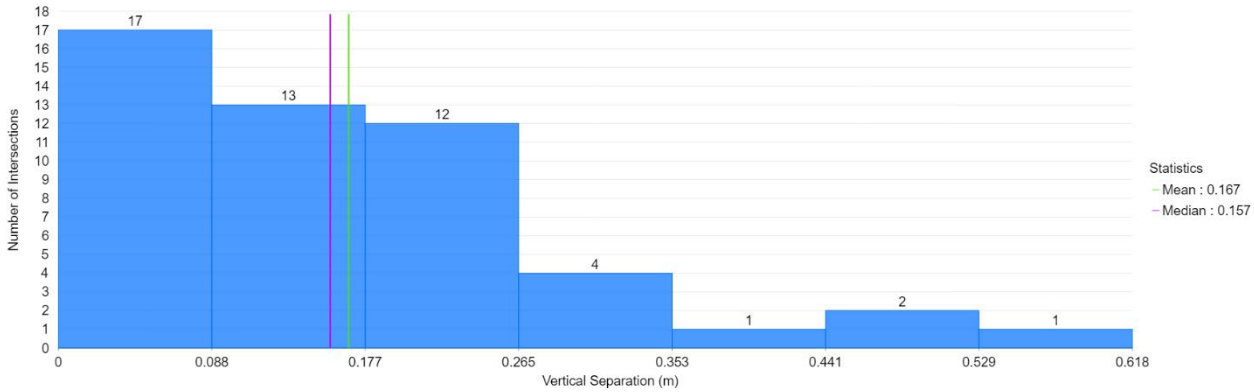

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 2. Survey intersection locations and vertical separations.

NAD83 (2011) Northing	NAD83 (2011) Easting	NAVD88 Vertical Separation (m)
6691246.736	627454.734	0.036
6691364.949	627492.437	0.018
6691435.733	627504.429	0.043
6691532.383	627513.456	0.212
6691590.008	627542.449	0.188
6691628.945	627603.507	0.334
6691631.740	627727.906	0.192
6691628.750	627855.448	0.202
6691636.803	627960.019	0.153
6691651.866	628078.936	0.347
6691654.256	628166.228	0.162
6691211.614	628215.666	0.155
6691099.327	628224.415	0.260
6691613.384	628235.410	0.117
6691332.212	628241.876	0.023
6691460.032	628270.940	0.258
6690996.369	628276.485	0.168
6690922.297	628340.435	0.130
6690820.023	628425.519	0.167
6690755.102	628490.127	0.042
6690689.382	628578.982	0.000
6690654.606	628703.402	0.322

NAD83 (2011) Northing	NAD83 (2011) Easting	NAVD88 Vertical Separation (m)
6690661.379	628806.075	0.215
6691739.496	628843.595	0.111
6691692.271	628848.993	0.001
6691824.934	628858.099	0.207
6691604.614	628878.896	0.067
6691899.792	628886.417	0.074
6692001.416	628928.742	0.381
6690690.682	628931.546	0.161
6691515.998	628932.199	0.618
6692064.331	628958.638	0.015
6691440.059	629007.410	0.098
6692150.856	629009.583	0.345
6690720.782	629034.029	0.204
6692210.607	629045.804	0.257
6691402.407	629047.834	0.043
6692251.281	629079.212	0.005
6690765.864	629125.648	0.018
6691309.113	629146.814	0.029
6690845.467	629198.250	0.513
6692264.376	629215.947	0.506
6691188.002	629238.801	0.136
6690954.936	629251.570	0.158
6692248.008	629258.652	0.044
6691048.623	629272.733	0.118
6692157.950	629365.199	0.191
6692088.097	629408.699	0.046
6691991.032	629447.881	0.226
6691925.883	629483.768	0.043
	Mean	**0.167**
	Median	**0.157**
	Standard Deviation	**0.141**
	95% Confidence Level	**0.276**
	Root-Mean-Square Error	**0.139**

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 both 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 orthometric height ranges are estimated using the same calculations applied to horizontal error reporting, typically resulting in a much larger potential error than the ellipsoid height peak-to-peak error. For more accurate orthometric height error reporting, DGGS used NOAA's Vertical Datum Transformation software for final elevation conversions from NAD83 (2011) ellipsoidal heights to NAVD88 (GEOID12B) orthometric 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).

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