SINGLE-BEAM BATHYMETRIC DATA NEAR KIPNUK, ALASKA, COLLECTED JUNE 21, 2022

Keith C. Horen, Richard M. Buzard, Jacquelyn R. Overbeck, Autumn C. Poisson, and Zachary J. Siemsen

Raw Data File 2023-9

M2Ocean Hydroball sensor towed behind a boat near Kipnuk, Alaska on June 21, 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.

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SINGLE-BEAM BATHYMETRIC DATA NEAR KIPNUK, ALASKA, COLLECTED JUNE 21, 2022

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data near Kipnuk, Alaska on June 21, 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 for use in determining navigability, and is released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31007.

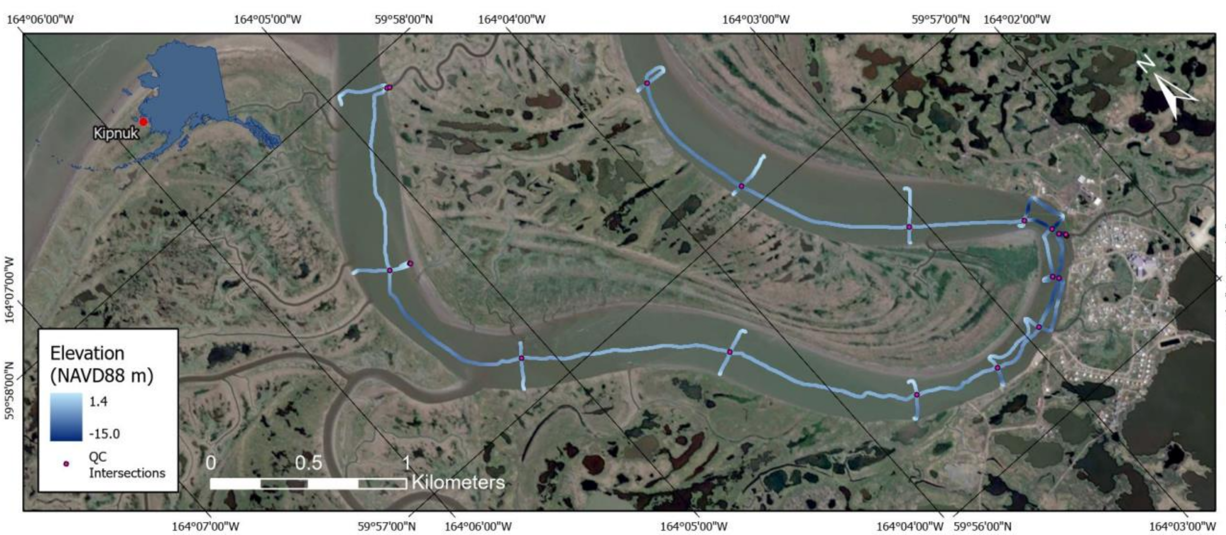

Figure 1. Map of bathymetric soundings near Kipnuk, Alaska.

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 21, 2022, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over a found stainless steel rod in a lidded case stamped "AIRPORT GEODETIC CONTROL MARK LS11797 2015 IIK-A." Base station data were used to correct the HydroBall sensor positions. To provide water level corrections, 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 Kuguklik River (fig. 2).

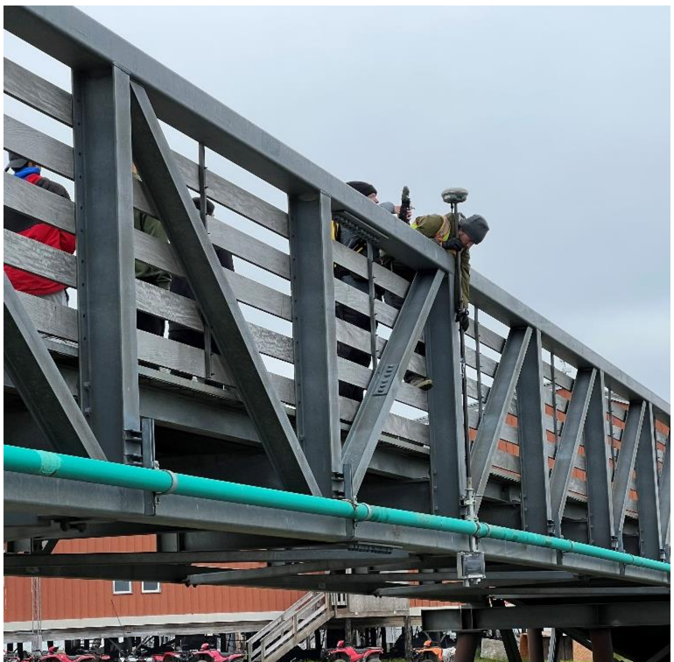

Figure 2. Stilltek iGage radar sensor installation in Kipnuk, Alaska.

Survey Details

The bathymetric survey was performed on June 21, 2022, from 5:25 PM to 8:45 PM AKDT. The weather throughout the survey was overcast, with intermittent showers, light wind, and wave heights under 0.3 m. 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 12.1 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. 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 WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS retrieved hourly water level time series data collected by the Stilltek iGage from 4:00 PM to 10:00 PM AKDT on June 21, 2022. These data are available from https://water-level-watch.portal.aoos.org/#metadata/119627/station/data in the Mean Higher High Water (MHHW) datum described by National Oceanic and Atmospheric Administration (NOAA) tide station 946 5951 available from tidesandcurrents.noaa.gov/benchmarks.html?id=9465951. 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).

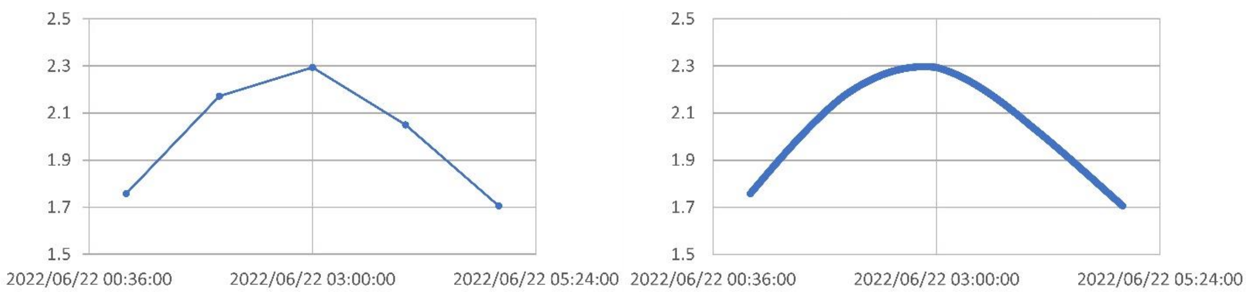

Figure 3. Comparison of per hour and per second (interpolated) water level elevation data.

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 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 accompanied by 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

The use of the IHO minimum bathymetric standards (IHO, 2022) would be inappropriate for assessment of these data, which do not meet the IHO prescribed systematic survey pattern criteria. To avoid misinterpretation, DGGS has developed order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards. 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, 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 which 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 0.073 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, 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 which 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 23 times in total, with a separation range between 0.001 m and 0.811 m, average separation of 0.179 m, and median separation of 0.103 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 0.187 m (table 2). These data meet DGGS 3rd Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.374.

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)
554135.137	6644568.574	4.451	0.008	0.011	0.077

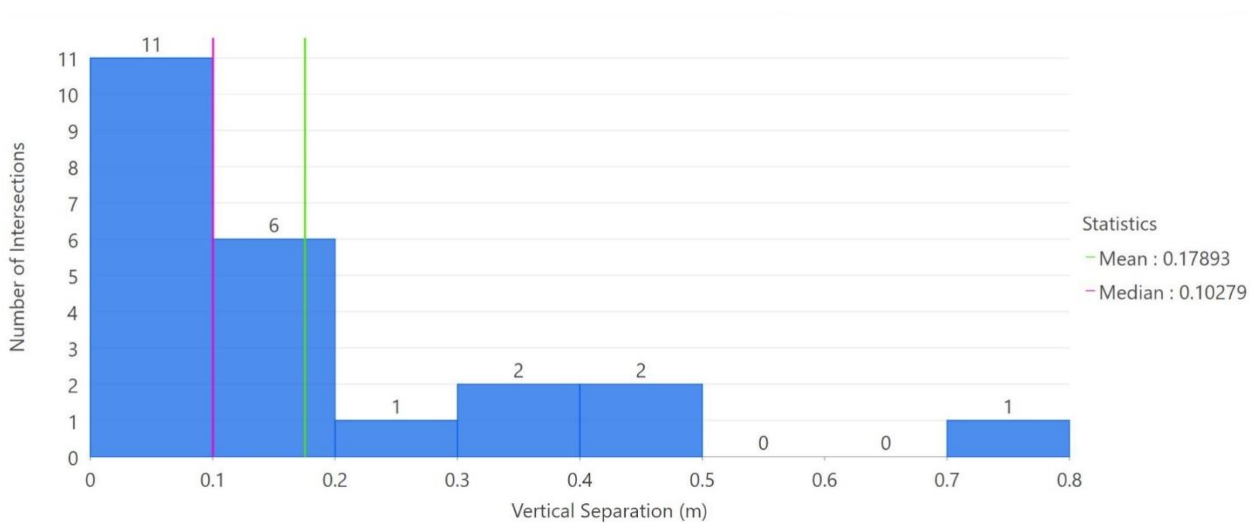

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 2. Survey intersection locations and vertical separations.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
6647907.1402	551453.5128	0.001
6647907.0714	551453.6595	0.011
6646417.7943	551067.7738	0.016
6644800.5411	553169.7672	0.057
6645621.8748	553006.7046	0.064
6647155.9380	550956.8015	0.065
6647196.8417	550855.1433	0.077
6645260.0190	553470.6676	0.084
6646340.8959	552493.7857	0.087
6644950.4742	553391.3520	0.089
6645739.3595	551893.6099	0.102
6644923.4598	553409.6240	0.103
6647155.9834	550956.1805	0.110
6647052.9345	552474.0331	0.123
6644784.0277	552872.3007	0.142
6645068.3142	553582.4432	0.175
6647155.8075	550955.3315	0.176
6647902.5154	551465.1471	0.222
6644949.8941	552470.9659	0.322
6645135.5296	553547.6283	0.346
6647155.4689	550953.6347	0.462
6645092.5409	553559.1182	0.472
6645060.3719	553580.6093	0.811
	Mean	**0.179**
	Median	**0.103**
	Standard Deviation	**0.191**
	95% Confidence Level	**0.374**
	Root-Mean-Square Error	**0.187**

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	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.083 m**	**5.042 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 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 any errors from the CORS used during processing.

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.

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REFERENCES

International Hydrographic Organization, 2022, Standards for hydrographic surveys (S-44), Edition 6.1.0, 51 p.

National Oceanic and Atmospheric Administration, 2016, Estimation of vertical uncertainties in VDatum, retrieved from https://vdatum.noaa.gov/docs/est_uncertainties.html.

National Oceanic and Atmospheric Administration, 2022, About OPUS, retrieved from https://geodesy.noaa.gov/OPUS/about.jsp.