Online Journal of Space Communication

Volume 5
Issue 9 *Global Navigation Satellite System (Winter 2006)*

Article 18

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Elliot N. Arroyo-Suarez

Deborah L. Mabey

Vic Hsiao

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Recommended Citation

Arroyo-Suarez, Elliot N.; Mabey, Deborah L.; Hsiao, Vic; and Phillips, Reo () "Implementation of a Positioning and Telemetry Buoy to Determine Chart Datum for Hydrographic Survey Applications," *Online Journal of Space Communication*: Vol. 5 : Iss. 9 , Article 18.
Available at: https://ohioopen.library.ohio.edu/spacejournal/vol5/iss9/18

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Implementation of a Positioning and Telemetry Buoy to Determine Chart Datum for Hydrographic Survey Applications

Elliot N. Arroyo-Suarez
Naval Oceanographic Office, Stennis Space Center, Mississippi

LT Deborah L. Mabey, USN
Fleet Survey Team, Stennis Space Center, Mississippi

Vic Hsiao
NavCom Technology, Inc., Torrance, California

Reo Phillips
AXYS Technologies Inc., Sidney, BC, Canada

ABSTRACT

The Naval Oceanographic Office (NAVOCEANO) and the U. S. Navy's Fleet Survey Team (FST) conduct worldwide hydrographic surveys in accordance with International Hydrographic Organization (IHO) S-44 standards. The current concept of operations (CONOPS) requires that tide gauges be installed in-shore to define the local vertical chart datum. This requires clearances and permissions from national and local authorities as well as landowners in order to establish and access these shore stations. Substantial effort to establish and maintain security for shore parties and equipment left behind is also required. The recent implementation of real-time Global Differential GPS (GDGPS) point positioning technology presents an opportunity to change and greatly simplify the current CONOPS.

I. INTRODUCTION

When access to land is not feasible, hydrodynamic models are run to determine tidal constituents and correctors at the survey site. An accurate hydrodynamic modeling result requires accurate boundary conditions, provided by well-known bathymetry, coastlines, and tidal constituents. Due to the uncertainty of the model input, the current error caused by water level is about 40–60% of the total depth solution. Occasionally, the bathymetry error can be as high as the total tide amplitude.

GDGPS will enable bathymetric positions to be measured on the absolute three-dimensional WGS-84 Earth Centered Earth Fixed (ECEF) reference frame at the decimeter level globally and, when required, at the centimeter level on baselines of less than 20 km utilizing GPS real-time kinematic (RTK) and/or post-processed kinematic (PPK) techniques. This will eliminate the uncertainty introduced by changes of water level due to tides and vessel dynamics.

The measurement of water levels tied to an ECEF coordinate system and the derivation of chart datum from a GPS equipped buoy are possible, as proved by a number of studies. Research showed that the utilization of high-accuracy GPS buoys to derive chart datum increases the accuracy of the reduced depths on nautical charting products [1]. The objective of the positioning and telemetry buoy (P&TB) is to make enough water level observations to derive a localized chart datum within each survey zone.

The system architecture and system integration of the P&TB are described herein. Results from observations and a comparison with a land-based tide gauge are also discussed. Additionally, future plans for testing and improved processing methods are addressed.

II. SYSTEM ARCHITECTURE AND INTEGRATION

NAVOCEANO's P&TB (Fig. 1) uses the NCT-2050G GPS receiver to provide real-time accurate three-dimensional positions generated by the GDGPS solution, which includes solid earth tide corrections. Synchronously, position along with tilt (pitch, roll) and heading data is supplied to the P&TB processors, which perform the necessary tilt corrections, averaging and filtering. GPS data observation intervals, logging, filtering and averaging are fully user-configurable, allowing for an optimum water level position solution in real-time.

Processed data is provided to the user over an Iridium satellite link. All data is also logged internally for the duration of any data collection period, allowing post-processing of the GPS and motion data for further analysis and to increase the position accuracy. In addition to the fully configurable onboard processing scheme, a power saving scheme was implemented, optimizing the life cycle of each deployment.

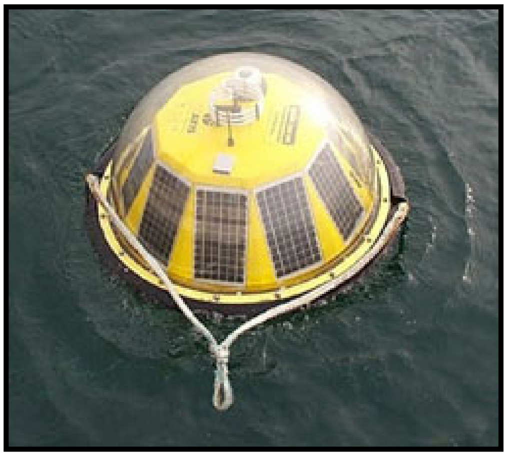

Fig. 1. NAVOCEANO's positioning and telemetry buoy

The P&TB provides the ability to measure the water elevation for a period of at least 240 hours continuously and for a lifetime of at least 5 years. It is capable of operating in any climate and location in the world that allows the moorage of a measurement buoy. The buoy is fitted with a Navigation Obstruction light programmed with the Ocean Data Acquisition System flash sequence for Coast Guard compliance and navigation and operational safety. A power switch allows the light to be disabled if necessary.

The system is completely configurable and controlled using a wireless setup interface via a secure BlueTooth® link, allowing setup and configuration of the system remotely without the need to open or connect to the buoy. This includes the ability to configure both the operational parameters for the P&TB processors and for the NCT-2050G. Power is supplied with rechargeable lead acid batteries and solar cells, requiring no additional or environmentally harmful waste during operation and life of the buoy.

The complete buoy system is 0.9 m in diameter, weighs less than 216 kg, and is able to withstand impact, shock and spinning experienced during normal deployment, operational and recovery cycles. The system is serviceable without the requirement of any special tools or equipment, and can be maintained by general technically-trained staff.

III. OBSERVATIONS AND COMPARISON WITH A LAND-BASED TIDE GAUGE

NAVOCEANO's P&TB was deployed in Patricia Bay, Sydney, B.C., Canada from June 21, 2005 to July 10, 2005. The buoy was anchored within 500 meters of a permanent tide gauge owned and maintained by the Canadian Hydrographic Service (CHS).

A. Ellipsoid-chart datum separation

In order to make direct comparisons between the buoy data and the tide gauge data, it was necessary to establish the separation between chart datum and the WGS84 ellipsoid. CHS provided elevations of tidal benchmarks above chart datum. National Resources Canada, Geodetic Survey Division, provided geodetic positions for these same benchmarks. The separation (SEP) between chart datum and the WGS84 ellipsoid was calculated for two benchmarks as shown in Table 1.

	Benchmark 78C9501	Benchmark 867001
Elevation above chart datum (m)	5.431	22.701
Ellipsoidal height (m)	-15.645	1.625
SEP (m)	-21.076	-21.076

Table 1. Ellipsoid-chart datum separation

B. Tide gauge data

Tide gauge data obtained from CHS was referenced to chart datum. All values shown have been converted to height from the WGS84 ellipsoid by adding SEP to the tidal time series. Daily high and low values were manually selected (Fig. 2). NAVOCEANO's NAVOTAS software was used to calculate Mean Higher High Water (MHHW), Mean Lower Low

Water (MLLW), Mean Tide Range, and Mean Sea Level (MSL) for the observation period (Table 2).

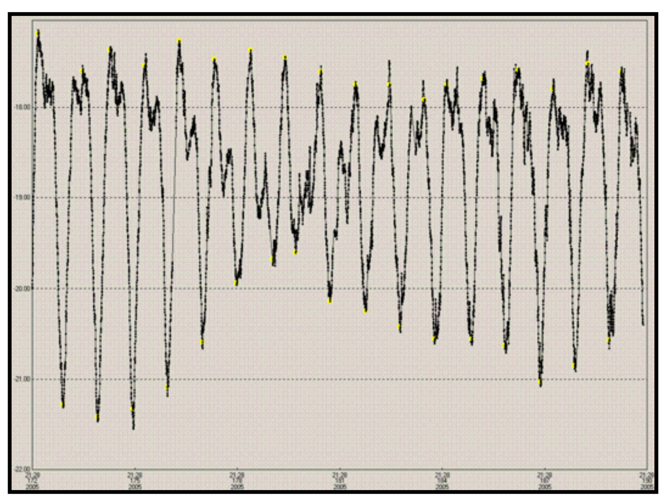

Fig. 2. Yellow dots show manual selection of daily highs and lows for tide gauge data

MHHW (m)	-17.64
MLLW (m)	-20.55
Mean Tide Range (m)	2.91
MSL (m)	-18.78

Table 2. NAVOTAS tide record analysis for tide gauge data

C. P&TB data

Daily high and low values were manually selected from the buoy height record (Fig. 3). NAVOCEANO's NAVOTAS software was used to calculate MHHW, MLLW, Mean Tide Range, and MSL for the observation period (Table 3).

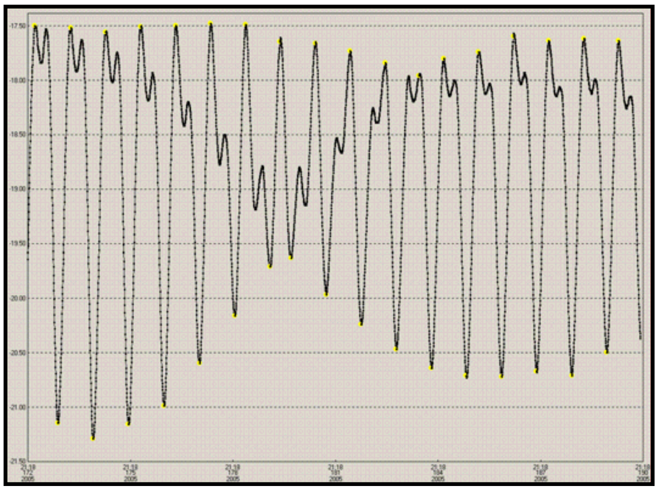

Fig. 3. Yellow dots show manual selection of daily highs and lows for buoy data

MHHW (m)	-17.57
MLLW (m)	-20.59
Mean Tide Range (m)	3.02
MSL (m)	-18.79

Table 3. NAVOTAS tide record analysis for buoy data

D. Comparison

The tide gauge and GDGPS height records are shown together in Fig. 4. The tide record analyses from Tables 2 and 3 are summarized in Table 4.

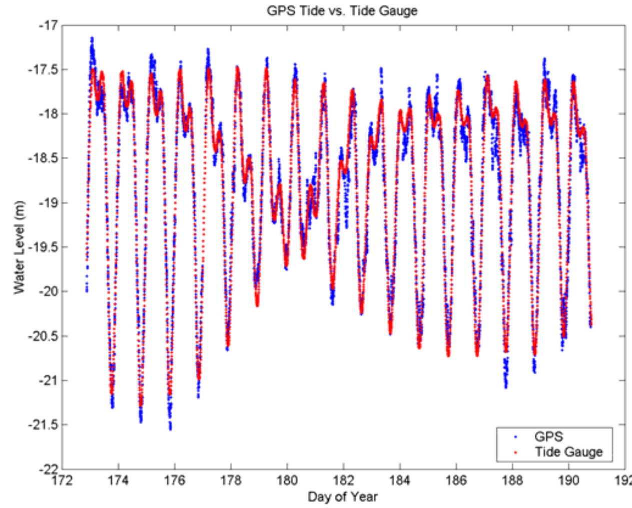

Fig. 4. CHS tide gauge data (red) and NAVOCEANO's P&TB data (blue)

	CHS Tide Gauge (m)	*P&TB (m)*	*Difference (m)*
MHHW (m)	-17.64	-17.57	-0.07
MLLW (m)	-20.55	-20.59	0.04
Mean Tide Range (m)	2.91	3.02	-0.11
MSL (m)	-18.78	-18.79	0.01

Table 4. NAVOTAS tide record analyses for tide gauge and buoy data

IV. FUTURE PLANS

A. Testing

Two additional tests of NAVOCEANO's P&TB are currently planned. The first involves simultaneous collection of raw GPS data for post-processing, real-time GDGPS data, and tide gauge data for intercomparison. The second is an operational scenario in which the seabed will be mapped from a seamless reference, the WGS84 ellipsoid [2]. Depths measured from the ellipsoid will be reduced to chart datum by substracting the P&TB-produced SEP. The SEP-reduced depths will then be compared with depths reduced using traditional tidal methods.

B. Processing Methods

Traditional tide gauges use a combination of mechanical and numerical filters to remove the unwanted effects of high frequency wind waves and currents. These filters are part of the physical design of the sensor and the data collection algorithm in the data collection platform [3]. An optimal filter to extract the water levels due to astronomic, hydrodynamic and atmospheric effects, eliminating the noise from the GDGPS height solution, is yet to be determined. Signal processing and harmonic analysis techniques will be applied to the P&TB-produced

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water level data, with the goal of consistently producing SEP values within 10 cm of those calculated using established land-based gauges.

ACKNOWLEDGMENT

D.L.M. thanks LT James Coleman and LCDR Christopher Sterbis of FST for their willingness to investigate new technologies and to operationalize these technologies once their value has been demonstrated. E.A.S. thanks his wife Maria de Lourdes for her support and understanding. The authors also thank Mr. Neil Sutherland of CHS, Tidal Survey Division, for providing the tidal and geodetic data and Ms. Jeannette Bedard of AXYS Technologies for providing the P&TB data and Mr. Jim Mattock for his contribution to the design and implementing the algorithms.

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DISCLAIMER

The mention of a commercial product or company name in this paper does not constitute an endorsement by the Naval Oceanographic Office or the U. S. Navy's Fleet Survey Team.