Hohonu

Tidal Datum Calculation Procedures

Date	Revision Description	Notes
March 2024	• Clarified input data details • Add established methodology for MMSC • Additional Hohonu/TAD comparison data	• Data more closely aligned with NOAA published methodologies • Datum histories now available
November 2023	• Original document	• Deep dive into Hohonu's tidal datum calculation methodology and comparison to NOAA protocols and TAD calculator • Identified future upgrades to methodology to increase alignment with NOAA methods, specifically in optimizing calculation record length and the MHHW calculation

Purpose and Scope

Hohonu provides precision water level monitoring and forecasting to help communities prepare for and respond to flooding. The organization maintains a network of over 100 water level sensors located in 14 states, and it uses the latest technologies in hardware, software, and data science in order to deliver reliable and accessible water level data to its customers.

Tidal datums are standard elevations referenced to a certain tidal stage and can be used as a baseline for measuring local water levels. It is essential to accurately and reproducibly establish tidal datums for usage by both the data provider (e.g. for QA/QC of raw data, for comparison to control stations) and public stakeholders (e.g. for navigation, setting acute event thresholds, etc.). While long records (i.e. greater than 19 years) of water levels are needed to establish a primary estimate of a tidal datum, shorter records can be used to establish National Tidal Datum Epoch

(NTDE)-equivalent datums given there is a control station with a sufficient record nearby. NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) is the authoritative source for accurate water level data, maintaining dozens of such control stations (i.e. NWLON) and providing methodology for calculating local tidal datums.[1] Hohonu implements these procedures within its own data program to ensure accurate datum calculations.

This document provides an overview of the calculation methodology used by Hohonu to establish NTDE-equivalent tidal datums for its stations. ***It is intended as technical support for users of Hohonu's data, providing identification of the origin of Hohonu's public data as well as context when converting between datums.*** While related to tidal datums, Hohonu maintains procedures for assessing geodetic datums (e.g. NAVD 88) elsewhere. As per the NOAA technical documentation, determination and use of tidal datums can be considered independent of geodetic datums.[1]

Datum Calculation

Once a record of at least 35 days has been established at a Hohonu station, tidal datum calculations are performed once per month for the first year of a station's establishment, and once per year thereafter. These frequencies were selected based on the asymptotic convergence of datums after one year observed in Hohonu data and by NOAA.[1] Calculations are performed using all data available at a station. Metadata related to the data record used and the datum uncertainty (as estimated by NOAA based on record length[1]) are provided on the Hohonu Dashboard.

The procedures for calculating tidal datums are outlined below (Figure 1). **Estimation of tidal datums closely follows the procedures outlined by NOAA and utilized in the Tidal Analysis and Datum (TAD) calculator.**[1,2]

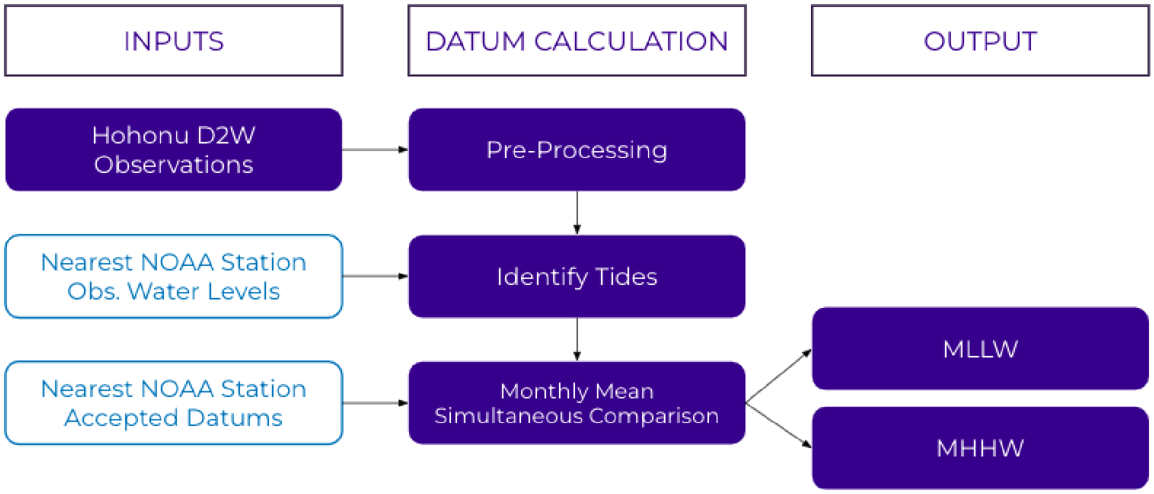

Figure 1. Overview of the Hohonu tidal datum calculation methodology

Data Input and Pre-Processing

The input to the tidal datum calculation is a cleaned water level observation dataset collected at a Hohonu station. Cleaned data are used to avoid bias from noise and outliers; details on the QA/QC process used to clean Hohonu data are provided elsewhere.[3] When fetched from the Hohonu server, these data are initially referenced to the station datum, referred to as the measurement of distance to the water (D2W). For many use cases, this relative, hyper-localized measurement in locations filling gaps between NWLON stations is proving valuable to communities. Prior to performing tidal datum calculations, cleaned D2W data are further pre-processed by aligning them to the nearest six-minute mark and removing any duplicate measurements. Finally, all measurements are inverted to properly facilitate identification of high and low tides.

Identifying Tidal Signals

The first step in the tidal datum calculation involves joining the inverted D2W data with data collected simultaneously at an associated NOAA control station. Control stations are matched to each Hohonu sensor based primarily on proximity and similarity of tidal conditions. NOAA data are fetched referenced to the station datum (STND). Water level data from both stations are then processed using a sixth-order Butterworth digital filter to remove high frequency (> 4 cycles/day) water level variability. This filter is robust to gaps in the dataset. Local extrema are then identified from the filtered water level data, and tidal high and low waters by day in the record are assigned. High and low selections that are less than 0.03 m different in height or 2 hours apart from the subsequent or preceding selections are removed per the NOAA procedure.[1] Finally, the times in which high and low tides occurred in both station’s signals are used to mark the original observed data points in the prefiltered signals.

Monthly Mean Simultaneous Comparison (MMSC)

Hohonu calculates NTDE-equivalent datums using the monthly mean simultaneous comparison (MMSC) method.[1] In short, monthly average tide values are calculated for the Hohonu and control stations’s daily extrema time series, resulting in values for mean lower low water (MLLW), mean low water (MLW), mean high water (MHW), and mean higher high water (MHHW) by each calendar month in the dataset. Remaining ‘principal’ datums and ranges (e.g. MTL, Mn, DTL, Gt, etc.)[1] are subsequently calculated for each calendar month. Depending on the station’s coastal location (US Pacific, West, Gulf, or East coast), these principal datums and ranges are used to calculate mean monthly differences and ratios between the Hohonu and control stations. Accepted datum values for the NOAA control stations are applied to the difference/ratio estimations to arrive at NTDE-equivalent datums for the Hohonu station.

Hohonu primarily uses the MLLW and MHHW datum values to reference station data. MLLW and MHHW example comparisons between Hohonu and NOAA are shown in the below table (Table 1).

Datum Usage and Review

Upon calculation, tidal datums for each station (and associated metadata) are saved in the Hohonu server to be utilized for efficient conversion of water level data and comparison to nearby stations. Error estimates are based on those provided in NOAA’s computation techniques document[1]. Users can access and manipulate the datum of sensor data via the user interface on the Hohonu Dashboard and mobile app or through the Hohonu Public API.[4] References for data access are provided below. Tidal datums undergo consistent review. Hohonu regularly performs random manual comparison to nearby control stations and to datums calculated using the online TAD calculator[2] provided by NOAA CO-OPS (Table 1).

Hohonu Node	Nearest NOAA	MLLW			MHHW		
		Hohonu (m)	TAD (m)	Error (m)	Hohonu (m)	TAD (m)	Error (m)
DeBordieu Colony, SC	Springmaid's Pier	-3.65	-3.61	-0.04	-2.19	-2.23	0.04
GMRI Pier, Portland, ME	Portland	-5.30	-5.30	-0.01	-2.27	-2.25	-0.01
Fernandina 1, FL	Fernandina	-4.00	-3.99	-0.01	-1.99	-2.00	0.00
Cape Lookout, NC	Beaufort, Duke	-2.71	-2.70	-0.01	-1.54	-1.54	0.00
SF Tidal Marina, CA	San Francisco	-3.01	-2.98	-0.03	-1.09	-1.10	0.01
Ashley River, SC	Charleston	-3.71	-3.71	-0.01	-1.94	-1.95	0.02
Bath, ME	Portland	-4.45	-4.44	-0.01	-2.29	-2.27	-0.02
Washington Boat Ramp, NC	Wrightsville Beach	-4.67	-4.66	-0.01	-3.53	-3.52	-0.01
Salem Harbor Ferry, MA	Boston	-5.52	-5.53	0.01	-2.56	-2.55	-0.01
Kiawah Island, SC	Charleston	-3.50	-3.49	-0.01	-1.72	-1.72	0.00
Quissett Harbor, MA	Woods Hole	-2.52	-2.51	-0.02	-1.33	-1.36	0.02
Steilacoom, WA	Tacoma	-6.67	-6.66	-0.01	-2.68	-2.69	0.01

Table 1. Example comparisons between the Hohonu procedures and NOAA's online TAD calculator show methodology alignment. Input data for each methodology were a record of cleaned D2W measurements collected at various Hohonu stations of varying record length up to February 2024.

References

1. National Ocean Service, Computational Techniques For Tidal Datums Handbook, NOAA Technical Report NOS COOPS 2, Center For Operational Oceanographic Products and Services, Silver Spring, MD, 2003. https://www.tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf
2. Tidal Analysis Datum Calculator. NOAA Center For Operational Oceanographic Products and Services. https://access.co-ops.nos.noaa.gov/datumcalc/
3. Hohonu's Quality Control Procedures for Real-Time Water Level Data. https://www.hohonu.io/_files/ugd/fb3fef_c3beefab943842d49ab71608f4f8c1bb.pdf
4. Hohonu Public API. https://hohonu.readme.io/reference/getting-started-with-your-api