On the Deviation of Tide Measured from Multiple Gauges

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Key words: Pressure Sensor, Acoustic Sensor, RADAR sensor

SUMMARY

The measurement technology for tides has been through a long evolution. From the tide poles used prior to the invention of self-recording gauges around 1830 to the float gauges that followed for 150 years, the most common gauges at present include those based on pressure sensors, acoustic sensors, and RADAR sensors. At the tide station established near the national Height Origin located in Keelung, Taiwan, these three types of gauge were all deployed. This tide station, located inside the campus of the National Museum of Marine Science and Technology, has two major functions, namely, public education and serving as the reference tide station of the Height Origin. In this writing, the comparison of tide heights observed from these three different types of gauges are reported. While the trend of these tide measurements appears similar, the individual observations in the same time epoch differ. This is likewise true for the Mean Sea Level derived from the three gauges as well. These indicate that there are not only random components, but also systematic deviations. From the tide observed from 2015 to 2019, the MSL deviation is about +0.012 m for the pressure sensor, -0.006 m for the RADAR sensor, as compared to the acoustic sensor. Besides the potential deviation resulting from the physical measurements, sensor calibration may be a critical issue.

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1. INTRODUCTION

Orthometric height system is adopted in Taiwan as a vertical control. The current datum, TWVD 2001 (TaiWan Vertical Datum 2001), is defined with the reference zero established by the MSL (Mean Sea Level) of Keelung tide station. Besides the reference tide station, TWVD 2001 includes a height origin which includes two monuments. Due to the construction of an elevated highway that extends the transportation network, the original height origin established with monuments K999 and K998 was demolished. A new origin was established several kilometres away from the original. This newly established height origin is on the other side of the road to the Museum of Marine Science and Technology (MMST) and is shown in Figure 1, denoted with a blue arrow. Consequently, a new tide station is established inside the campus of MMST, as denoted by a red arrow in Figure 1. The purpose of this tide station is twofold. First of all, it serves as a part of the public education utilities of MMST. Secondly, this tide station is nearby the height origin and potentially could serve as the reference tide station of the height system in the future.

Figure 1: The location of height origin and MMST tide station (Source: “National Museum of Marine Science and Technology, Keelung.” 25°8'25.96"N, 121°48'3.87"E, Google Earth. Oct. 3, 2012. Jul. 9, 2015)

Three different types of tide gauge, namely, the pressure, acoustic, and RADAR, were implemented in the MMST tide station. This writing reports the comparison of the MSL derived from these gauges.

2. THE GAUGES

The tide station initially became operational with a pressure sensor activated on Sept. 23, 2014. Subsequently, an acoustic and a RADAR gauge were installed in 2015. Besides these three types of tide gauges, meteorological instruments including barometers, thermometers, wind direction and speed measurement units, rain gauges, are also a part of this station. A GNSS unit was also installed to link the tide levels to the ellipsoid height. Figure 2 shows these instruments in 2015. The RADAR gauge installation is shown in Figure 3. The cantilever design imposes a low level definition of the height and is subsequently under critical review. The acoustic gauge is shown in Figure 4. The metal plate that is shown by the finger in Figure 4 is the surface that sets zero as a reference for the gauge. To ensure a strong connection of the tide readings to TWVD2001, a TGBM (Tide Gauge Bench Mark), TG997, is established, as shown in Figure 5. The corresponding location of the current Height Origin, K997, K996, and TG997 is shown in Figure 6. Based on the annual survey with precise differential levelling by National Land Surveying and Mapping Center (NLSC) from 2010 to 2017, the stability of K997 is high and the changes are all less than 2mm. The elevation changes of TG997 with respect to K997 has also been less than 2mm since its deployment.

Figure 2: The MMST tide station in 2015

Figure 3: RADAR gauge (left) and tide staff (right)

Figure 4: The acoustic gauge

Figure 5: The tide gauge benchmark, TG997

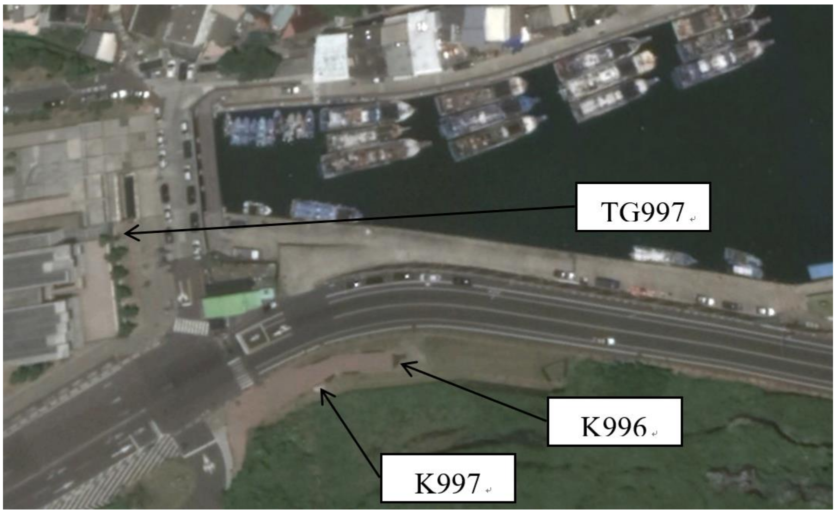

Figure 6: The locations of K997, K996 and TG997

The waterbody which the tide station in MMST deployed is connected with the sea water of Chang-Tan-Li fishery harbour. As shown in Figure 1 and 6, there are two bridges, one for vehicle and one for passenger separated the harbour and the waterbody. But, the waters are connected under the bridges.
The model and specification of the three tide gauges are listed in Table 1.

Table 1: The gauge specification
(Aquatrak, 2006; Druck, 2002; B.M. Tecnologie, 2016)

Gauge	Maker	Model	Specification
Acoustic	Aquatrak	3000XDCR and 4110 Controller	±0.025%（FS）
Pressure	GE Druck	PTX 1830	±0.1%（FS）
RADAR	BM Tecnologie Industriali S.R.L.	Radar Level Meter CW 56 -26GHz	3 mm

3. THE MEAN SEA LEVELS

The pressure gauge started recording on Sept. 25, 2014; the acoustic gauge on Feb. 3, 2015; and RADAR on April 10, 2015. In order to compare the Mean Sea Level (MSL) derived for the same period, the data collected between April 10, 2015, 15:54 to Oct. 31, 2019, 20:42 are used for this study. The sampling interval is six minutes. There are two approaches devised for deriving MSL. The first one is the direct average of the observations. The second is the average of the resampled tide from harmonic analysis (Foreman, 1977). For both approaches, the tide collected while the gauges were miss-functioning are removed. UTide (Codiga, 2011) is applied for the harmonic analysis and SNR threshold is set to 20. With the same setting, the numbers of significant constituents derived were 60 for both acoustic and RADAR, and 59 for pressure gauge. Most constituents are the same, but six of them appeared only in one or two.
The two averages and their deviations are listed in Table 2. Physically, the differences between the direct average and the average after harmonic analysis is the exclusion of non-astronomic components. For all three gauges, the direct averages are higher. Among the three gauges, the deviation between the pressure and acoustic is 0.0117m for the average after harmonic analysis, 0.0063m between acoustic and RADAR, 0.018m between pressure and RADAR.

Table 2: The MSL derived from three gauges (Unit: m)

Tide period: 2014/4/10 15:54-2019/10/31 20:42	Pressure	Acoustic	RADAR
Direct Average	0.0972	0.0865	0.0776
Average from Harmonic Analysis	0.0845	0.0728	0.0665
Differences between two averages	**0.0127**	**0.0137**	**0.0111**

4. CONCLUDING REMARKS

Three types of gauges: pressure, acoustic, and RADAR, are deployed in the tide station inside MMST. From the MSL analysis, the deviations among the three gauges reached 0.018m between pressure and RADAR. While the physical definition sensed by the three type gauges are different, how well the sensor zero is defined also plays an important role in the cause of MSL deviations. Regarding the procedure of deriving MSL, the approach with harmonic analysis could remove the non-astronomic components fairly effective. For all three gauges in the year 2018, the MSL from direct average is higher.

REFERENCES

Aquatrak, 2006. User's Guide Model 4100/4110 Series, http://www.aquatrak.com/Downloads/Models_4100_&_4110_Manual.pdf, last accessed on 20191124.

B.M. Tecnologie, 2016. BM Compact Wave 26 GHz –CW Series, http://www.bmtecnologie.it/wp-content/uploads/downloads/2016/06/RADAR-LT-BM-26GHZ.pdf, last accessed on 20191114.

Codiga, D. L., 2011, Unified Tidal Analysis and Prediction Using the UTide Matlab Functions, Technical Report 2011-01, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, pp.59.

Druck, 2002. PTX1835/1235 Depth/Level Pressure Transmitter with Internal Lightning Protection, Druck Incorporated, PDS-A148 5/02.

Foreman, M. G. G., 1977. Manual for Tidal Heights Analysis and Prediction, Pacific Marine Science Report 77-10, Institute of Ocean Science, Patricia Bay, Sidney, BC, Canada, 97.

BIOGRAPHICAL NOTES

Peter T.Y. Shih completed his PhD study in the Department of Surveying Engineering, University of New Brunswick, Fredericton, Canada in 1989. Since 1992, he has been teaching in the Department of Civil Engineering, National Chiao Tung University, Taiwan.

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