Calculation of heights for local datum points of tide gauges in Albania referred to the average sea level and Albageo program

Bledar Sina[1], *Gezim* Hasko[2], *Eduart* Blloshmi[3],

[1]*Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania*
[2] *Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania*
[3] *Faculty of Civil Engineering, Polytechnic University of Tirana, Tirana, Albania*

[#]*Corresponding author: bledar.sina@fin.edu.al*

ABSTRACT

The accurate measurement and monitoring of sea levels are of paramount importance, especially for coastal regions like Albania, where sea level changes can have significant impacts on various aspects of life, including coastal infrastructure, ecosystems, and human settlements. This abstract provides an in-depth overview of a study focused on the calculation of heights of local datum points at tide gauges in Albania with reference to the average sea level, using the ALBAGEO3 program. Tide gauges play a crucial role in understanding the dynamic nature of sea levels. These instruments measure the height of the sea surface relative to a reference point, which is typically known as the local datum. The calculation of heights of local datum points is crucial for several reasons. Firstly, it provides insights into the relative sea level changes at different locations in Albania. It allows for the identification of areas that may be more vulnerable to such events, enabling better-informed decision-making in terms of coastal management and disaster preparedness. Furthermore, accurate knowledge of local datum heights is essential for navigation and maritime activities. It ensures that nautical charts are up to date and that ships can safely navigate Albanian waters without the risk of running aground or encountering obstacles related to sea level changes. In summary, the study on the calculation of heights of local datum points at tide gauges in Albania, utilizing the ALBAGEO3 program, plays a pivotal role in advancing our understanding of sea level variations in this coastal nation. The accurate and reliable data generated through this research benefits not only the scientific community but also provides actionable insights for policymakers, urban planners, and other stakeholders involved in the sustainable development and protection of Albania's coastal areas.

Keywords: gnss, tide gauges, albageo3, sea level, albcors.

1. Introduction

The measurement and monitoring of sea level have always been critical components of understanding coastal dynamics, assessing climate change impacts, and ensuring coastal infrastructure resilience. In coastal nations like Albania, where maritime activities are integral to the economy and the safety of coastal communities is paramount, accurate data on sea level variations is indispensable. Tide gauges serve as indispensable instruments in this endeavor, providing continuous records of sea level changes over time. However, ensuring the accuracy of these measurements requires meticulous calibration against a reliable reference, often the average sea level.

In Albania, the determination of local datum points for tide gauges, referenced to the average sea level, is a vital undertaking. These datum points serve as the baseline for measuring sea level fluctuations along the Albanian coast, aiding in various applications, including navigation, coastal management, and disaster preparedness. The Calculation of Heights for Local Datum Points of Tide Gauges is a meticulous process that involves precise measurements, geodetic calculations, and the utilization of advanced technologies to establish accurate reference points.

At the forefront of this endeavor in Albania is the Albageo program, a comprehensive initiative aimed at advancing geodetic and geospatial capabilities in the country. Albageo, short for Albanian Geospatial and Earth Observation Program, encompasses a range of activities geared towards enhancing

Albania's capacity in geodesy, cartography, and earth observation. Spearheaded by governmental agencies, academic institutions, and international partners, Albageo represents a collaborative effort to modernize Albania's geospatial infrastructure and harness geospatial data for sustainable development.

The integration of tide gauge measurements into the Albageo program underscores its significance in coastal management and disaster risk reduction strategies. By incorporating precise measurements of sea level variations into Albania's geospatial framework, the Albageo program facilitates informed decision-making processes, enables early warning systems for coastal hazards, and supports adaptive planning in response to climate change impacts.

The calculation of heights for local datum points of tide gauges within the framework of the Albageo program involves a multidisciplinary approach, drawing upon expertise from geodesy, oceanography, hydrography, and geospatial technology. Geodetic surveys are conducted to establish precise elevation benchmarks, which are then correlated with sea level observations obtained from tide gauges. Advanced geodetic techniques, such as Global Navigation Satellite Systems (GNSS) and satellite altimetry, are employed to ensure the accuracy and reliability of the calculated heights.

The computation of a local datum point for tide gauges is a critical aspect of ensuring the accuracy and reliability of sea level measurements. Various techniques have been developed to determine this essential reference point, each tailored to the unique geographical and environmental characteristics of the observation site. In this introduction, we explore the diverse methodologies and technologies employed in the computation of local datum points for tide gauges, highlighting their significance in facilitating precise and consistent sea level monitoring along coastal regions worldwide.

Methodology

The State Network of Tide Gauges is the network that enables the collection, processing, storage and access of information related to sea level change. This network consists of 4 tide gauges with Radar Sensors of the "Open Water" type, located in Shengjin, Durrës (Bishti i Palla), Orikum and Sarandë, which collect information related to sea level changes and send it to the processing center and sea level data storage built near ASIG.

To determine the impact of vertical movements of the earth on the measurement of the sea level around each tide station, Local Datums consisting of three points have been constructed.

At a distance of 10-30 m from the tide gauge, the tide gauge benchmarks have been built, which are simultaneously points of the "Albanian Geodetic Datum" of 42 points of the first order networks of the KRGJSH.

These benchmarks will also be points (Ground Type) of the Active GPS Network.

In order to monitor the stability of the Benchmarks near the tide gauge stations, a Microgrid with 3 monumentalized points located at a distance of 2-5 km from them will be built.

Figure 1. Tide gauges in Albania.

1.1 Benchmark Survey

We conducted an initial geodetic survey along the Albanian coast to establish primary benchmarks with known elevations. These benchmarks served as reference points for subsequent height calculations.

We used precise geodetic techniques such as GNSS (Global Navigation Satellite Systems) to determine the coordinates of these benchmarks with high accuracy.

GNSS monitoring of the Local Datum of the Mareograph was carried out according to the following methodology:

1. To enable the evidence of the contribution of vertical movements of the place where tide gauges are installed.

2. To enable calculation of mean sea level in a Global Geocentric Reference.

GNSS monitoring of the Local Tide Datum consists of:

1. Determining the ellipsoidal heights of this datum point with the Post Processing method (PP) using data measured in two 2-hour sessions, one in the morning and one in the afternoon, during which the precise leveling of the network connecting the local datum points will be carried out.

2. The determination of the ellipsoidal height of the GNSS Benchmark will refer to the ARP (Antenna Reference Point), which is calculated with an accuracy of ≤ 1cm and will be performed periodically according to the requirements used for the measurements and calculations performed to determine the 3D position of the base stations of the ALBCORS system.

To determine the impact of vertical movements of the earth on the measurement of sea level around each tide gauge station, a Local Gauge Datum is constructed.

Local Tide Datum consists of at least 3 benchmarks built at a distance of about 100 m from the mounting point of the tide gauge and connected between them with Precise Leveling - First Class, using digital levels combined with bar-code bars.

The main benchmarks will be considered:

1. TGBM (Tide Gauge Benchmark), which represents the point to which the measured sea level change is referenced.

2. GNSSBM (GNSS Benchmark), which enables the permanent control of the TGBM through the calculation of the ellipsoidal height referred to the ARP (Antenna Reference Point), which are calculated with an accuracy of ≤ 1 cm, with the PP (Post Processing) method using data obtained from IGS (International GNSS Service).

Part of the datum will also be considered the line of the State Leveling Network - First Class that connects TGBM with at least two intermediate benchmarks located at a distance of up to 5 km from it.

Datum points are also considered:

1. RSM (Reference Survey Mark), which is represented by the point identified by the manufacturer on the tide gauge sensor itself or determined during assembly.

2. TGZ (Tide Gauge Zero) is the level for which the tide gauge would record the zero value for the sea level referenced TGBM. This point is chosen in such a way that the sea water level never falls below this point.

1.2 Data collection

We collected continuous data from the tide gauges, recording sea level measurements over extended periods. Ensure data integrity and quality control procedures are in place to mitigate errors and anomalies. Then, we integrated the tide gauge data with existing geodetic reference networks to correlate sea level measurements with precise elevation benchmarks established during the initial survey.

1.3 Integration with Albageo program

We incorporated the calculated heights of local datum points into the broader framework of the Albageo program, ensuring seamless integration with existing geospatial databases and infrastructure. Then, standardized formats and metadata conventions were utilized to facilitate interoperability and data sharing among relevant stakeholders within the Albageo network. We established data dissemination protocols to make the calculated heights accessible to government agencies, research institutions, and other end-users involved in coastal management and decision-making processes.

2. Results

2.1 Results of GNSS measurements carried out in October – December.

As mentioned above, the GNSS monitoring of the local datum of the tide gauges was carried out through the Post-Processing method with sessions over 2 hours. In the following table, the results obtained from the processing of the measurements are given.

Table 1 shows the coordinates processed in the KRGJSH framework for the benchmarks located near the Durrës tide gauge station, which constitute the leveling microgrid in this tide gauge.

It should be noted that the static measurements performed near the Durrës tide gauge station were processed using several active CORS stations of the ALBCORS network as fixed points.

Tab 1. GNSS measurements in mareograph of Durres.

Nr	**Name**	**N (m)**	**E (m)**	**h(m)**	**H-ALBA GEO3(m)**
1	Wood_Top (nails)	4586257.044	449587.044	35.999	**1.247**
2	BM_1	4586257.193	449587.363	36.423	**1.671**
3	BM_2	4586270.784	449598.646	36.539	**1.786**
4	BM_3	4586302.56	449648.731	36.751	**1.996**
5	D17 HaHpVG	4586244.345	449583.868	45.747	**10.995**

Figure 2. Mareograph of Durres.

Table 2 shows the coordinates processed in the KRGJSH framework for the benchmarks located near the Orikum tide gauge station, which constitute the leveling microgrid in this tide gauge.

The static measurements performed near the Orikum tide gauge station were processed using several active CORS stations of the ALBCORS network as fixed points.

Tab 2. GNSS measurements in mareograph of Orikum.

IR	Name	ISS measurements_Static and RTK methods (08-12.2020)			
		TMzn			
		N (m)	E (m)	h(m)	H-LBAGEO3(m)
1	Wood_Top (nails)				
2	BM_1	630836.28	65507.58	8.765	**1.883**
3	BM_2	630926.85	65534.55	9.824	**2.936**
4	D08 HaHpVG	630837.81	65538.74	3.203	**6.319**

Figure 3. Mareograph of Orikum.

Table 3 shows the coordinates processed in the KRGJSH framework for the benchmarks located near the Shengjin tide gauge station, which constitute the leveling microgrid in this tide gauge.

It should be noted that the static measurements performed near the Shengjin tide gauge station were processed using several active CORS stations of the ALBCORS network as fixed points.

Tab 3. GNSS measurements in mareograph of Shengjin.

NR	Name	GNSS measurements_Static and RTK methods (08-12.2020)			
		TMzn			
		N (m)	E (m)	h(m)	H-ALBAGEO3(m)
1	Wood_Top (nails))				
2	BM_1	4630836.28	465507.58	38.765	**1.883**
3	BM_2	4630926.85	465534.55	39.824	**2.936**
4	D08 HaHpVG	4630837.81	465538.74	43.203	**6.319**

Figure 4. Mareograph of Shengjin.

Table 4 shows the coordinates processed in the KRGJSH framework for the benchmarks located near the Sarande tide gauge station, which constitute the leveling microgrid in this tide gauge.

It should be noted that the static measurements performed near the Sarande tide gauge station were processed using several active CORS stations of the ALBCORS network as fixed points.

Tab 4. GNSS measurements in mareograph of Sarande.

NR	Name	GNSS measurements_Static and RTK methods (08-12.2020)			
		TMzn			
		N (m)	E (m)	h(m)	H-ALBAGEO3(m)
1	Wood_Top (nails)				
2	BM_1	4630836.28	465507.58	38.765	**1.883**
3	BM_2	4630926.85	465534.55	39.824	**2.936**
4	D08 HaHpVG	4630837.81	465538.74	43.203	**6.319**

Figure. 5 Mareograph of Sarande.

3. Conclusions

The ALBAGEO3 software gives geoid heights (N) and Orthometric Height for the entire Albanian territory with calculated errors in the order:

- 20 cm with a security level of 68%

- 40 cm with a 95% confidence level.

GNSS measurements according to the Static method were carried out with an error of gmk ± 1-2 cm (due to the fact that during the 2-hour measurement period the signals received from the satellite systems were not very frequent.

For a very accurate and reliable determination of the measured sea level, a long-term average sea level is needed (the most accurate is found for a period of 18.6 years) due to the undulation of the sea surface by many natural factors as follows:

The temporal and positional change in the attraction of the sun and the moon to the earth, which cause the natural phenomenon of tides (contribution to the lunar cycle -18.6 years)

Due to the influence of the above factors, the average sea level is constantly changing and these changes are grouped into:

- 24 hour shift,

- monthly change,

- annual change,

- perennial (century) change.

4. References

Barbosa S. M., Fernandes M. J., and Silva M. E. Nonlinear sea level trends from European tide gauge records. Annales Geophysicae, 22:1465_1472, 2004.

Berwin R. Topex/Poseidon Sea Surface Height Anomaly Product. User's Reference Manual. NASA JPL Physical Oceanography DAAC, Pasadena, CA., January 2003.

Box G. E. P. and Jenkins G. M. Time series analysis: Forecasting and Control.

Church, J. A. and White, N. J. (2006). A 20th century acceleration in global sea-level rise. Geophysical research letters, 33(1).

Uysal Church, J. A. dhe White, N. J. (2011). Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics.

Douglas, B. C. (2001). Sea level change in the era of the recording tide gauge. Sea level rise: history and consequences, 75:37-64.

Pugh, D. dhe Woodworth, P. (2014). Sea-Level science - Understanding Tides, Surges, Tsunamies and Mean Sea-Level Changes. Faqja:22-23, 36-58, 60-63, 99, 103-106, 257.

PSMSL.org (2014). Permanent service for mean sea level. Accessed: 05.11.14.

Nerem, R. (1995). Global mean sea level variations from topex/poseidon altimeter data. Science.