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CGPS Station Collocated at Split Tide Gauge

Introduction

The sea level data measured at the tide gauges are important for a wide range of activities related to the sea. These activities include the safety of navigation (especially at harbours), hydrographic survey, geodesy (definition of vertical datums and maritime law terminology), coastal oceanography, scientific and expert analysis of sea level changes (Vilibić et al., 2005). Hydrographic Institute of the Republic of Croatia owns and operates six tide gauges at the time (Rovinj, Zadar, Split-harbour, Split-MedGLOSS, Ploče and Dubrovnik). The data are collected in agreement with the recommendations of International Hydrographic Organization and other maritime management organisations.

European Sea Level Service (ESEAS) is a regional sea level network initiated in 2001. Croatian institutions actively participate in the programme and follow the trends which are present in worldwide sea level monitoring and research activities. In order to improve sea level monitoring and research and to provide access to various sea level databases in Europe, ESEAS – Research Infrastructure project (ESEAS-RI) was launched in 2002 and lasted until 2005. The partners in the project included national authorities responsible for tide gauge operation and/or the geodetic control of tide gauges as well as research institutes involved in research and operational activities related to sea level (Vilibić et al., 2005). In the framework of the project a Continuous GPS antenna and receiver (CGPS – Continuous Global Positioning System) have been installed in 2004 at the roof of the Split Harbour tide gauge. This paper brings an overview of the collocation with special emphasis on the selection of the observing site and problems which have been encountered during collocation and maintenance of the site and the equipment.

Collocation of the Split tide gauge with a CGPS

The collocation effort was carried out in the frame of Work package 2 (Absolute sea level variations) and Work package 4 (Improving the sea level observing system; Task 4.3 - Co-location of Tide Gauge Stations with GPS) within the ESEAS-RI project. Split-harbour tide gauge is located in

the town's port, on a small peer near Harbour Master building (Fig. 1), and it operates continuously from 1956. The tide gauge benchmark (TGBM) PN-165 was installed on the Master's building, which had been erected on the bedrock near a city centre. Beside TGBM, an auxiliary benchmark exists on the eastern wall of the tide gauge edifice (R-1).

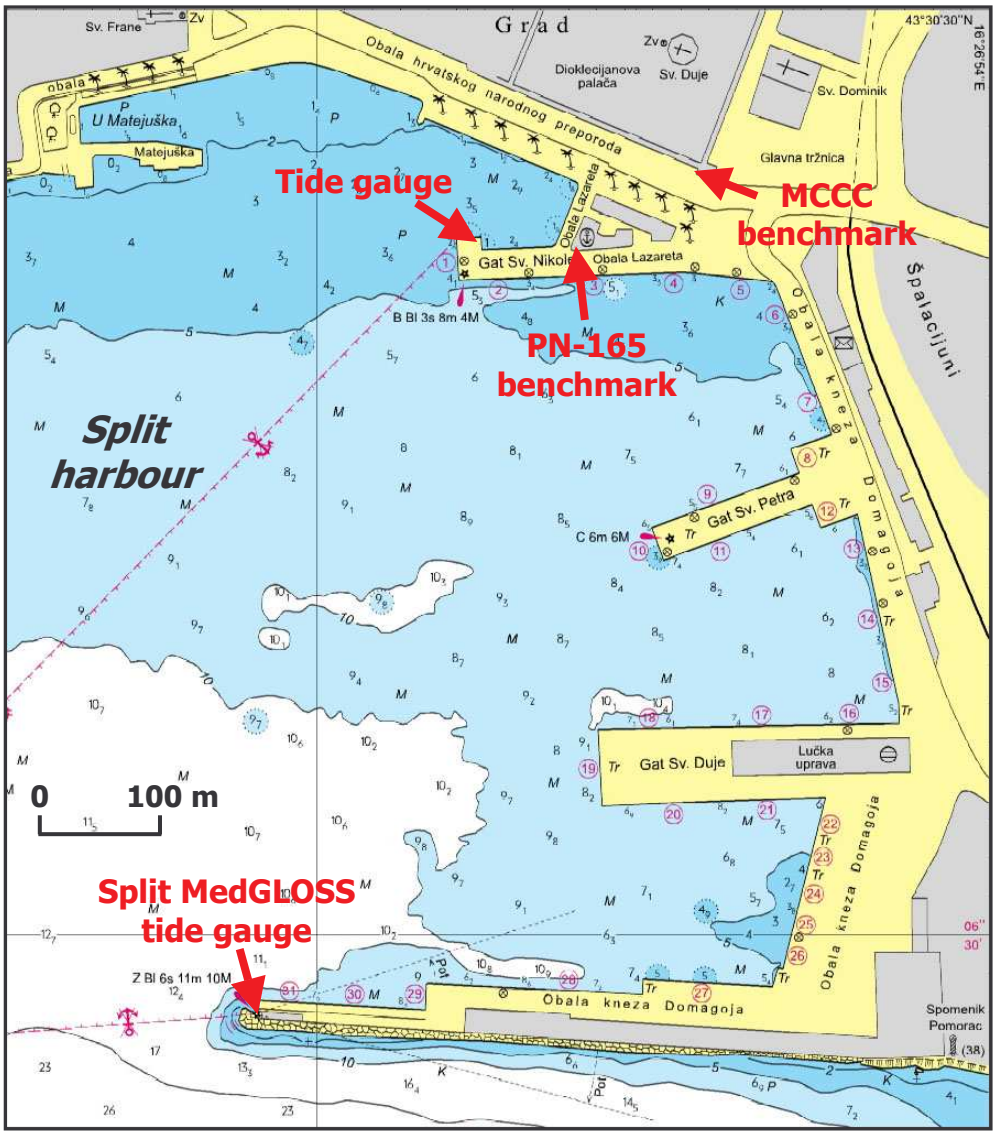

Figure 1. The location of tide gauges and benchmarks at Split harbour. Background map is a part of navigation plan no. 47 (Split – Kaštela bay), issued by the Hydrographic Institute of the Republic of Croatia.

The CGPS station was installed on the roof of Split harbour tide gauge on 4 May 2004 (Fig. 2). The instrument will enable determination of the absolute sea level changes, along with the tide gauge measurements and satellite altimetry. Satellite altimeters measure absolute sea level height which is defined as the position of the sea surface with respect to a global datum, such as the ITRF

ellipsoid (Bevis et al., 2002). CGPS data provide information about vertical velocity at a certain point of the coastline, while tide gauge at the same or nearby point measures relative sea level. By using this collocated information, relative sea level can be transformed into absolute sea level. The goal of the collocation programme is to determine vertical velocity of a tide gauge with accuracy better than 1 mm/year. This is a very demanding task, and at least a decade of CGPS observations is needed. Still, these calculations and transformations need to be examined very carefully.

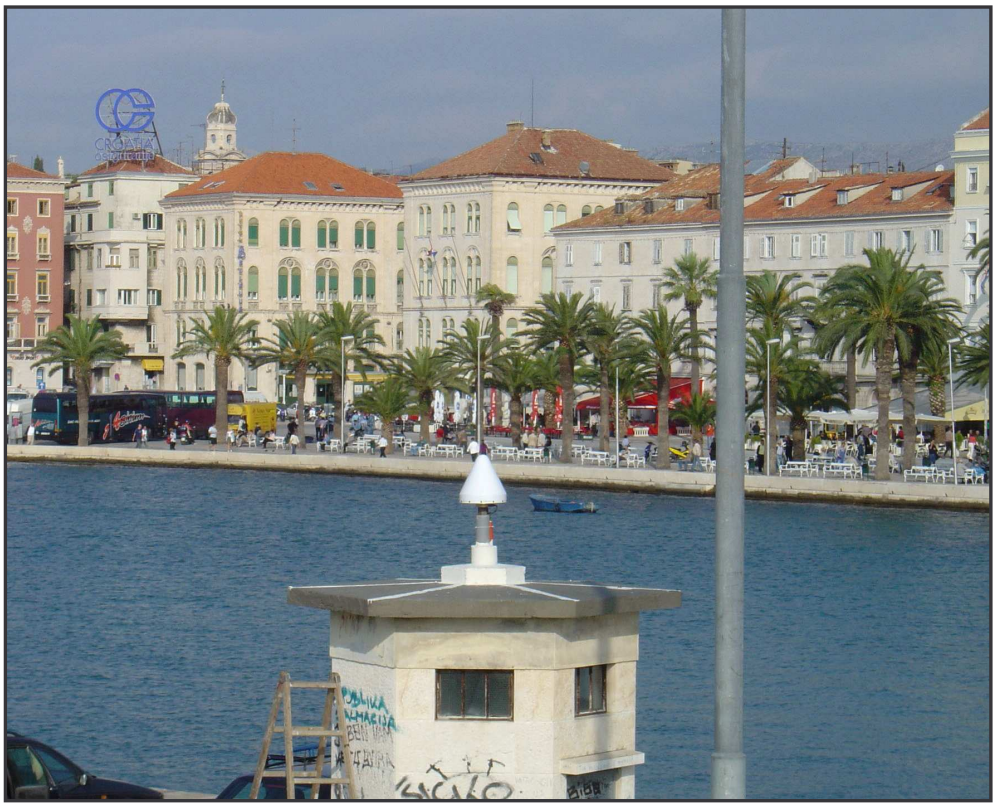

Figure 2. CGPS antenna mounted on the roof of Split-harbour tide gauge.

The first important thing that has to be taken into account is the site selection for CGPS station. There are several important requirements that have to be followed. First of all, it is crucial that the GPS antenna has a clear view of the sky in all directions for elevation angles above 15 degrees, and, ideally, a clear view down to 10 degrees elevation. This is a very demanding task since a considerable part of tide gauges and tide gauge benchmarks are located in places with poor sky view. Other factors that need to be considered are the security of the equipment, accessibility of the electrical power and telecommunication networks, etc. A very important matter that has to be carefully studied when selecting proper site is the local ground stability. If the ground is stable, the antenna can be placed near the tide gauge and vertical offset between the antenna and the gauge can be considered as constant. In that case vertical motion of the CGPS station represents the motion of the region close

to the tide gauge and precise levelling is easy to perform and doesn't need to be very frequent. However, in many cases it is not possible to collocate tide gauge with CGPS because underlying bedrock is not stable, so the station has to be moved further away and frequent levelling between CGPS and tide gauge has to be done (Bevis et al., 2002).

These requirements were carefully followed during the selection of the best site for collocation of the Split Harbour tide gauge with CGPS station. Tide gauge building was the first choice for CGPS antenna, but knowing the recommendations given by Bevis et al. (2002) several matters had to be examined. The highest obstacle obscuring the view at the tide gauge is a Harbour Master building. The measurements showed that the elevation angle between the roof of the tide gauge and the highest point on the Master's building was around 12.7 degrees.

Another essential problem that had to be examined was local ground stability. Since the tide gauge became operational in 1956 several precise levelling campaigns were preformed in order to check the stability of the terrain surrounding the tide gauge. The results from these campaigns are reviewed and summarized in Table 1. They represent the height differences between three benchmarks in the vicinity of the tide gauge, i.e. R-1 (tide gauge auxiliary benchmark), PN-165 (tide gauge benchmark) and MCCC (benchmark at the south-eastern corner of the Diocletian's palace – Fig. 1). Historical precise levelling of these benchmarks showed that there were no significant changes in height during last 50 years (Mihanović et al., 2004). Hence, an antenna monument was constructed on the roof of the tide gauge building, since there were no obstacles around the gauge with elevation angle above 15 degrees and the ground proved to be stable. The site selection had an important impact on the instrumentation selection as well. Since the building could easily be equipped with electrical power, whilst the internet connection wasn't available, the receiver and the antenna needed to have a GSM modem. Therefore, Ashtech Micro-Z CGRS receiver with Dorne-Margolin antenna offered an optimal choice for our tide gauge, and the receiver was placed in the tide gauge building, powered by batteries and equipped with GSM modem for communication with the instrument and downloading the data. CGPS station was installed on 4 May 2004, and daily files (station name SPLT) are available starting from 5 May 2004 (day 126).The station was provided with electrical power in March 2005, so that the instruments are autonomous and GSM modem enables communication with the receiver. Nevertheless, since the tide gauge building is located in the centre of the city, at a very active harbour's peer, the maintenance of the site and instrument check is performed on weekly basis.

RINEX files obtained from the instruments are compressed using Hatanaka compression software (version 2.4) and uploaded to ESEAS-RI Data Archive. Preliminary analysis of the data, carried at the Norwegian Mapping Authority, showed that:

– the number of measurements and the number of outliers is normal,

– the mean residual for the code measurements is very good,

– the mean residual for the phase measurements is acceptable (Kierulf et al., 2005).

Table 1. The results of precise levelling campaigns performed after 1956 in the vicinity of Split-harbour tide gauge.

Stand point	End point	Difference (m)	Distance (km)	Epoch of observation
R1	PN165	0.4191	0.09	1963.500
R1	PN165	0.4184	0.09	1966.500
R1	PN165	0.4188	0.09	1967.500
R1	PN165	0.4185	0.09	1968.500
R1	PN165	0.4185	0.09	1969.500
R1	PN165	0.4185	0.09	1970.500
R1	PN165	0.4180	0.09	1983.500
R1	PN165	0.4169	0.09	1988.500
R1	PN165	0.4176	0.09	1992.500
R1	PN165	0.4168	0.09	2000.470
R1	PN165	0.4190	0.09	2004.822
MCCC	R1	-0.3375	0.21	1963.500
MCCC	R1	-0.3384	0.21	1966.500
MCCC	R1	-0.3374	0.21	1967.500
MCCC	R1	-0.3376	0.21	1968.500
MCCC	R1	-0.3375	0.21	1969.500
MCCC	R1	-0.3374	0.21	1970.500
PN165	MCCC	-0.0811	0.13	1966.500
PN165	MCCC	-0.0815	0.13	1967.500
PN165	MCCC	-0.0808	0.13	1968.500
PN165	MCCC	-0.0807	0.13	1969.500
PN165	MCCC	-0.0815	0.13	1970.500
PN165	MCCC	-0.0808	0.13	1983.500
PN165	MCCC	-0.0803	0.13	1988.500

It is also important to emphasize that during CROREF96-CRODYN96 GPS campaign new benchmark was established on the concrete roof of the tide gauge, and precise levelling was performed. This benchmark was used to determine the height of Antenna Reference Point (ARP) above the national geodetic datum, equalling 6.1251 m (Fig. 3).

Figure 3. Antenna Reference Point of the Split-harbour CGPS antenna and GPS point from CROREF96-CRODYN96 GPS campaign.

Problems encountered from May 2004 to May 2006

It was very hard to presume the extent of problems which would be encountered after the collocation of the tide gauge with CGPS. First of all, the Harbour Master building was renovated in 2003, and during this the TGBM was hidden on the southern wall. We needed to use the historical benchmark description and a large magnet in order to retrieve the benchmark and to uncover that specific part of the façade without damaging it.

A satellite telephony antenna was installed on the roof of the Split harbour tide gauge during International Boat Show in April 2005. Between 2 and 11 April CGPS data quality was very poor, since the CGPS antenna was almost completely covered by a satellite dish fixed on the roof (Fig. 4), without any notice to HHI or approval by HHI. The influence of the satellite dish on the Split CGPS data at the beginning of April 2005 can be seen in Fig. 5 (Domijan et al., 2005).

Figure 4. CGPS antenna covered by a satellite dish in April 2005.

At the end of February 2006 a window above the entrance on the eastern side of the tide gauge building was broken. The rock used to damage it flew over the tide gauge instrument and almost smashed the CGPS receiver. At the same time we noticed that the cable connecting the antenna and the receiver was shifted for about 180 degrees at the bottom of the antenna. It seems like somebody climbed the roof and tried to unscrew the antenna from the antenna monument. It is very hard to prevent these actions, since the tide gauge represents a part of the protected architectural and cultural area, hence no fences or similar protections can be used to protect the roof and the antenna.

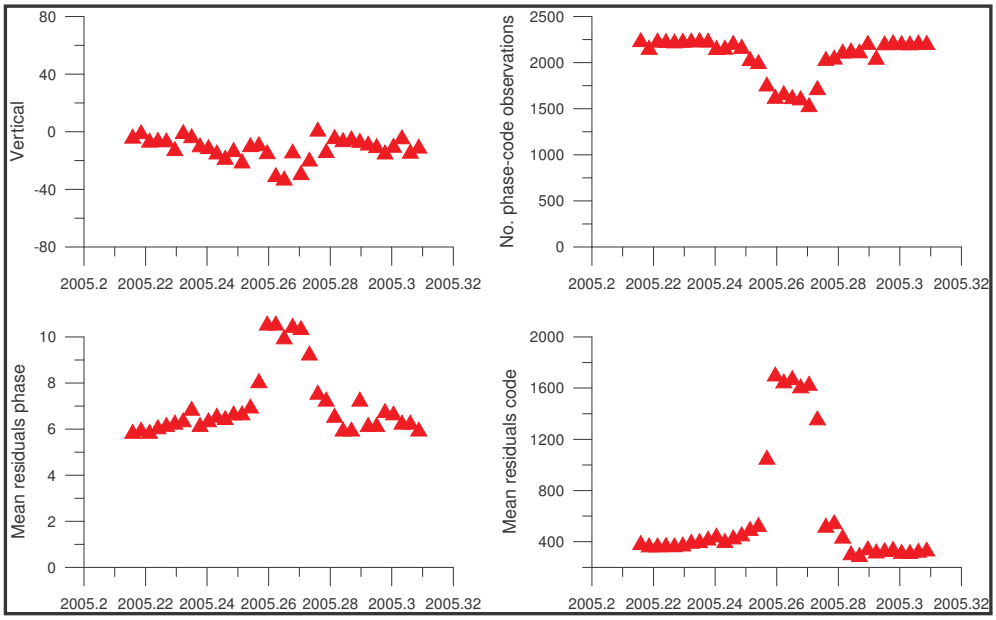

Figure 5. CGPS data influenced by unauthorized instalment of satellite dish at the roof of the tide gauge building at the beginning of April 2005.

Conclusions

Installation of the CGPS station in Split represents a new important step in sea level related measurements in Croatia. It will take some time until the data will enable estimates of absolute sea level changes, but so far it can be concluded that the site selection was optimal with respect to location, levelling procedures and data transmission possibilities. The data collected need to be processed in appropriate centres because of the complex nature of these measurements. At the moment the CGPS station installed at the Split Harbour tide gauge can be maintained by Croatian personnel, but the processing and the determination of absolute sea level heights should be performed in the regional centres which processed the data within ESEAS-RI or through International Geodetic Service (IGS). However, such a process will be done in the national centres in the future, especially after the initiation of vertical land-movement measurements at other Croatian tide gauges and other sites in Croatia. This will enable proper computation of absolute sea level changes in the Adriatic Sea, followed by the projections of sea level behaviour and risk/vulnerability analyses in the future (Vilibić et al., 2005).

Precise levelling also needs to be continued in order to verify local network stability of the site. The instruments and the site have to be checked frequently, since the building is located in the centre of the city and vulnerable to vandalism and other unauthorized activities that might influence the quality of the data.

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Abstract

Split tide gauge is located in the town's port, on a small peer near Harbour-Master building. The tide gauge benchmark PN-165 (TGBM) was installed on the Master's building, which had been erected on the bedrock near a city centre. There is an auxiliary benchmark (R-1) on the tide gauge edifice. Historical precise levelling that took place during last 50 years did not show any significant changes in height between Harbour-Master TGBM, tide-gauge auxiliary benchmark and benchmark (MCCC) located in the south-eastern part of Diocletian's palace. The benchmark established on the concrete roof of the tide gauge during CROREF96-CRODYN96 GPS campaign was used to determine the height of Antenna Reference Point (ARP) above the national geodetic datum.

An optimal choice for Split CGPS station was Ashtech Micro-Z CGRS receiver with Dorne-Margolin antenna. The station is powered by external power supply and equipped with GSM modem for communication with the instrument and downloading the data. CGPS station was installed on 4 May 2004 and daily files (station name SPLT) are available starting from 5 May 2004. RINEX files obtained from the instruments are compressed using Hatanaka compression software, version 2.4 and uploaded to the ESEAS-RI Data Server (European Sea Level Service). Preliminary analysis of the data showed that the observing site was well selected, and that the measurements will enable long-term analysis of the vertical land movements in this region. The problems which have been encountered during different stages CGPS collocation and maintenance are also stressed and presented.

Sažetak

Mareografska postaja Split-luka nalazi se u gradskoj luci, na lukobranu u blizini zgrade Lučke kapetanije. Zgrada Lučke kapetanije izgrađena je na stijeni u centru grada, a na njoj je postavljen i glavni reper mareografa (TGBM), oznake PN-165. Na mareografskoj kućici se nalazi pomoćni reper (R-1). Precizno niveliranje obavljano tijekom zadnjih 50 godina nije pokazalo značajne razlike između visina ovih dvaju repera, kao i u odnosu na reper koji se nalazi na zidu u jugoistočnom dijelu Dioklecijanove palače (MCCC). Na krovu mareografske kućice je za vrijeme CROREF96-CRODYN96 kampanje postavljen još jedan reper, koji je korišten pri određivanju visine referentne točke antene (Antenna Reference Point – ARP) u odnosu na nacionalnu geodetsku nulu.

Uzevši u obzir karakteristike same lokacije na koju se trebala postaviti CGPS postaja, izabran je Ashtech Micro-Z CGRS prijemnik s Dorne-Margolin antenom. Postaja ima vanjsko napajanje te je opremljena GSM modemom koji omogućuje komunikaciju s instrumentom i skidanje podataka. Uređaji su postavljeni 4. svibnja 2004. godine, a dnevne datoteke postaje Split (kratica postaje SPLT) dostupne su od 5. svibnja 2004. Originalne RINEX datoteke se komprimiraju korištenjem Hatanaka programskog paketa (verzija 2.4), te se putem FTP-a prebacuju na server ESEAS-RI projekta (European Sea Level Service). Preliminarna analiza podataka pokazala je da je lokacija za CGPS postaju dobro izabrana, te da će omogućiti dugoperiodičku analizu vertikalnih gibanja u ovom području. U radu su predstavljeni i problemi koji su se pojavili u raznim stadijima postavljanja i upravljanja CGPS postajom.