A First Evaluation of the new GNSS Station Installations at the Tide Gauges of Walvis Bay and Lüderitz in the Republic of Namibia

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Abstract

During September 2015 the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in collaboration with the University of Luxembourg (UL) installed two state-of-the-art continuous GNSS stations adjacent to the tide gauges of Walvis Bay and Lüderitz in the Republic of Namibia. These installations are the culmination of a four-year effort to get the stations established and the help of the Namibian Port Authority (Namport) in this endeavour is much appreciated. The tide gauge at Walvis Bay (Global Sea Level Observing System (GLOSS) number 314) has a record in the Permanent Service for Mean Sea Level (PSMSL) Revised Local Reference (RLR) database (number 914) dating back to 1958 (data completeness 54%). The tide gauge at Lüderitz is not a GLOSS station but also has a PSMSL RLR record (number 911) since 1958 (data completeness 67%). Both tide gauges currently use a radar measurement unit and are operated by the Hydrographic Office of the South African Navy. They are the only sea level observations along a more than 3000 km stretch of the West African coast from Pointe Noire in the Republic of the Congo to Port Nolloth in the Republic South Africa, hence they form an important data source for sea level studies.
The two continuous GNSS stations record observations from all visible GNSS satellites (GPS, GLONASS, BDS and Galileo) with a 1 second recording interval. The current installations support hourly data downloads, which are sufficient for most activities within the IGS, while the data have great potential to contribute not only to the TIGA working group but also to MGEX. In this study we present the first evaluation of the quality of the GNSS observations from the two new continuous GNSS stations for the first three months of operation. In the future we plan to make the data available to the scientific community.

Introduction

Tide gauges provide an important source of information for sea level science in our changing world. As these instruments measure sea level with respect to the land or structure they are located on, it is essential that their records are corrected for any vertical land movements (VLM) so that geocentric sea level estimates can be obtained [Teferle et al., 2002; Wöppelmann and Marcos, 2015]. The International GNSS Service (IGS) has been at the forefront in developing GNSS as a tool for monitoring tide gauges under its Tide Gauge Benchmark Monitoring (TIGA) Working Group [Schöne et al., 2009]. The community has made great efforts over the past decades to equip tide gauges with continuous GNSS stations and develop the necessary methods for this challenging task.

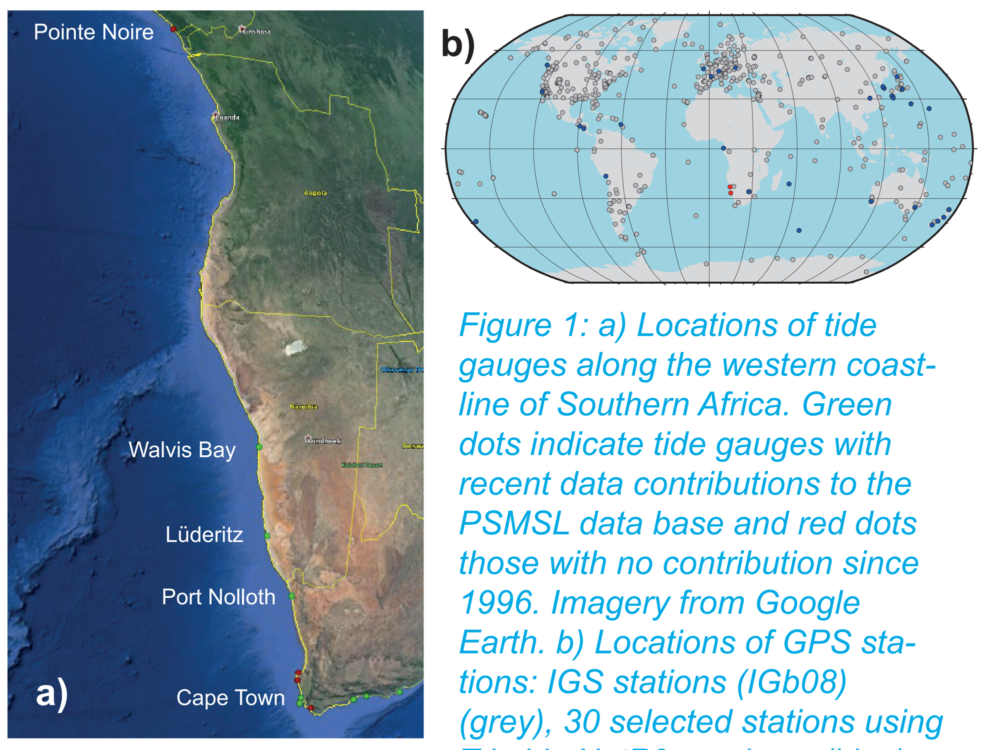

Figure 1: a) Locations of tide gauges along the western coastline of Southern Africa. Green dots indicate tide gauges with recent data contributions to the PSMSL data base and red dots those with no contribution since 1996. Imagery from Google Earth. b) Locations of GPS stations: IGS stations (IGb08) (grey), 30 selected stations using Trimble NetR9 receivers (blue) and LZTA and WBTA (red).

Here we report on two recent installations in Lüderitz and Walvis Bay in the Republic of Namibia. This region is largely undersampled, as can be seen from Figure 1a, and lacks both in sea level and GNSS observations. The new stations will reduce the hemispheric in-balance in the number of GNSS stations (Figure 1b) and have the potential to contribute to the global reference frame but also the local communities in Namibia. In this presentation we will first introduce the two new GNSS stations, then we will evaluate their data quality and finally we will present the first position estimates from 17 October 2015 to 20 January 2016. In our evaluations and processing we will use 30 selected IGS GNSS stations using the same receiver type to compare our metrics (Figure 1b).

GNSS Installations

The GNSS stations were installed adjacent to the existing tide gauges in the Port of Lüderitz and the Port of Walvis Bay, which are both hosted by the Namibian Port Authority (Namport). Although other locations nearby may have been better for GNSS observations, we wanted to keep any regular leveling work between the GNSS antenna and the tide gauge benchmark to a minimum and for the site to be situated within the security fence of the port area. As Figure 2a shows the area around LZTA is fairly open with only one building close to the station and small vessels mooring nearby. For WBTA the situation is different (Figure 2b). The antenna had to be placed fairly close to a fence running along the quayside edge to the east of the antenna while to the west huge container ships may be berthed during shipping operations. This means that there is a changing electromagnetic environment, which is less suitable for GNSS observations.

The GNSS stations are equipped with similar configurations. The antenna is mounted on a 2.5-m stainless steel mast, which is bolted onto the concrete ground (Figures 2a and 2b). The receiver and electronics are housed in a large equipment enclosure, which is attached to the mast. In order to be independent of mains power the GNSS stations were equipped with 150W solar panels that sit above and opposite to the enclosure. Communications to both stations are provided via a USB HSPA modem connected to a router and an external antenna. Further details on both GNSS stations and their configurations are in Table 1 and Figure 3.

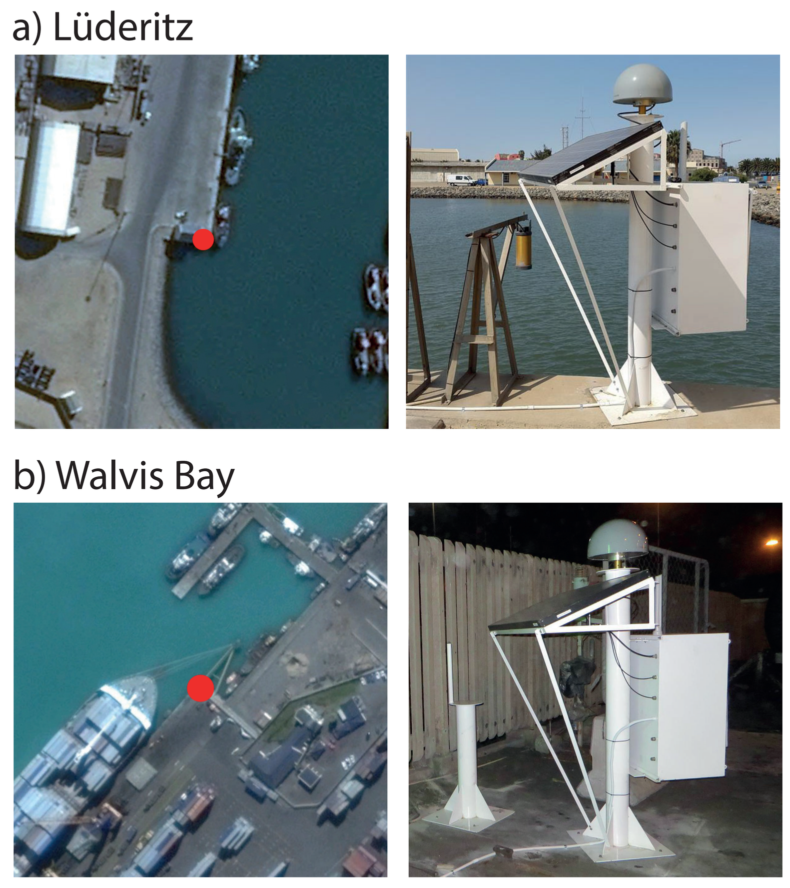

Figure 2: New continuous GNSS @ tide gauge stations in Lüderitz (a) and Walvis Bay (b). Marine-grade stainless steel monument and enclosure.with electronics and auxiliary equipment.

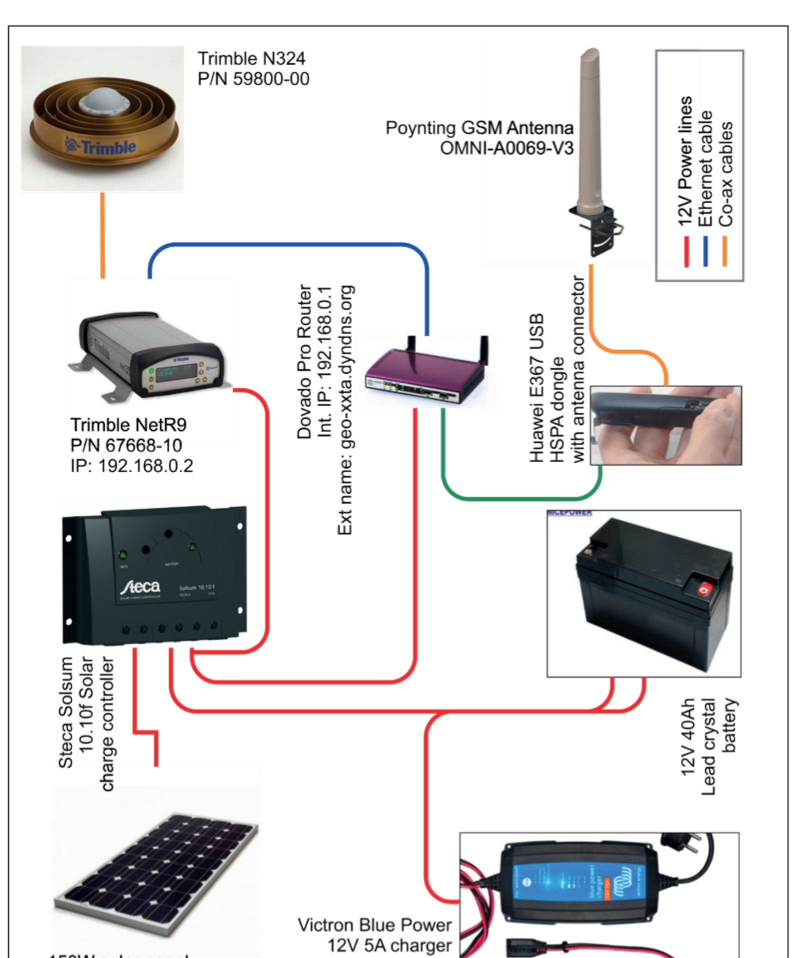

Figure 3: Generic continuous GNSS station layout and diagram.

Table 1: Equipment details for continuous GNSS stations LZTA (31103M001) and WBTA (31102M002).

GNSS Equipment	Trimble NetR9 Trimble Choke Ring TRM59800.00 SCIS Robot antenna calibration by Geo++, Germany
GNSS Data/Archive	1s and 30s GPS, GLONASS, Galileo and BDS hourly/daily download, HartRAO
Power System	12V DC from one solar panels with 150 Watts Steca Solsum Solar charge controller 1x 40Ah lead crystal battery Victron Blue Power 12V 5A Charger
Communications	Dovado Pro Router Huawei E367 USB HSPA Dongle Poynting GSM Antenna OMNI-A0069-V3

GPS Data Quality

The Teqc software [Estey & Meertens, 1999] allows the computation of a number of quality control metrics of which the most important ones include code-multipath on L1 and L2, denoted as MP1 and MP2, the number of predicted and recorded observations, and the number of observations per cycle slips. The latter ratio can be expressed in terms of cycle slips per observations in 1000, leading to a number close to zero for the optimal case.

Using the 30 IGS stations along LZTA and WBTA the quality control metrics were computed on a daily basis for 17 October 2015 to 20 January 2016. Figure 4 shows the time series and cumulative distribution for each metric and Figure 5 shows skyplots of the MP1 values for LZTA and WBTA for 26 December 2015.

The metrics indicate the LZTA and WBTA have relatively high MP values, a low percentage of observations and a high and varied number of cycle slips, with LZTA performing slightly better than WBTA.

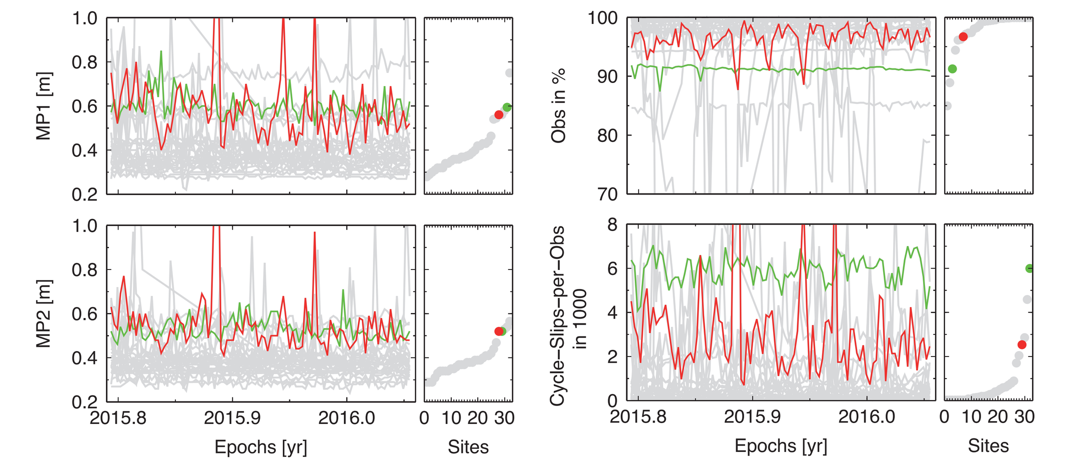

Figure 4: Time series and cumulative distributions of quality control metrics: MP1, MP2, percentage of observations and cycle-slips-per-observations in 1000 for 30 IGS stations (grey), LZTA (green) and WBTA (red) for 17 October 2015 to 20 January 2016.

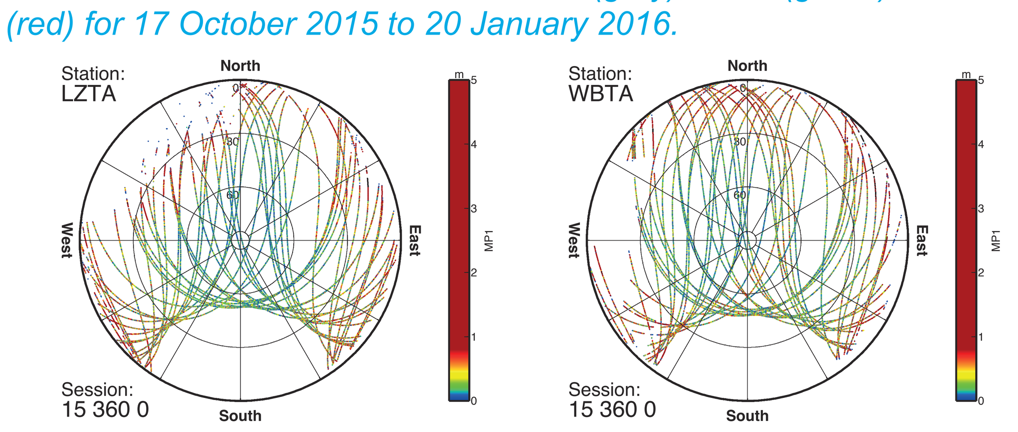

Figure 5: Skyplots of MP1 values for LZTA and WBTA for 26 December 2015.

Although both stations suffer from signal obstructions the larger variations in the quality metrics for WBTA suggest that the installation suffers due to arrivals of large vessels or loading operations close-by.

Position Estimates

Using the 30 IGS stations along LZTA and WBTA daily position estimates were obtained using the Bernese GNSS Software v 5.2 [Dach et al., 2015] in precise point positioning (PPP) mode [Teferle et al., 2007] for 17 October 2015 to 20 January 2016. We use the final satellite orbit and clock as well as the Earth rotation products from the Centre for Orbit Determination in Europe (CODE) IGS Analysis Center, which are also based on the Bernese GNSS software, avoiding effects arising from the use of different software and model implementations during product generation and user application in PPP. In this analysis only the GPS observations were employed and an elevation cut off angle of 3 degrees was applied. Figure 6 shows the computed position time series for LZTA and WBTA.

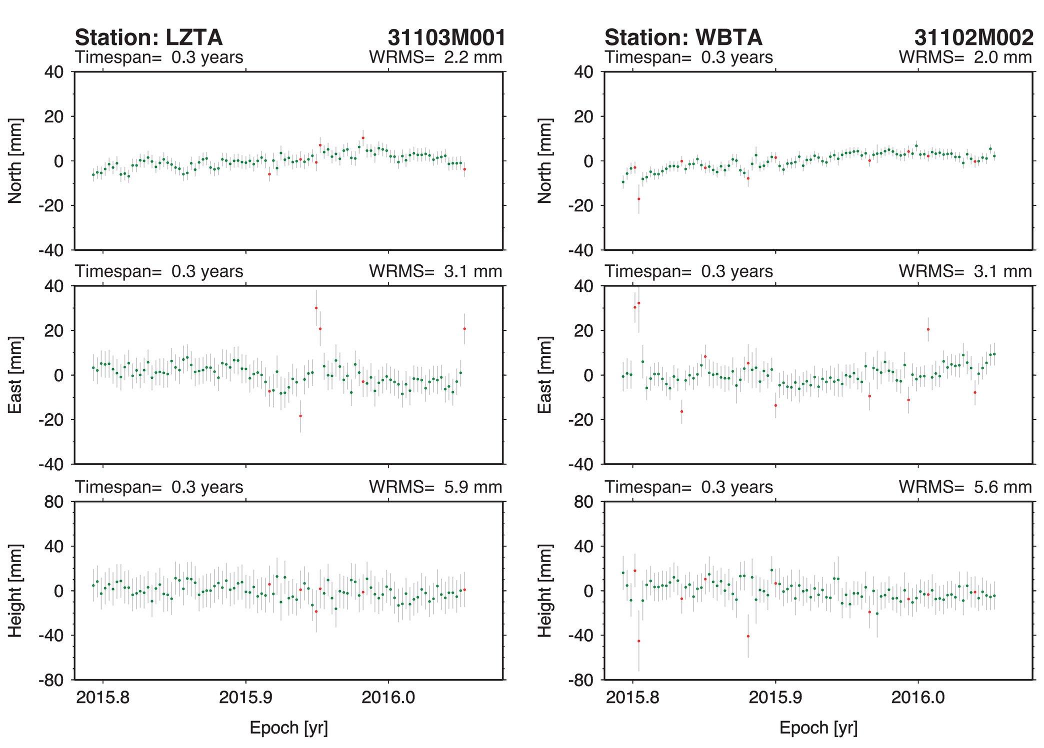

Figure 6: Position time series for LZTA and WBTA from PPP from 17 October 2015 to 20 January 2016. Position outliers are indicated by the red circles and uncertainties are three times the daily standard error from the GPS processing.

Table 2 shows the number of computed solutions, the number of outliers and the percentage of outliers for the 30 IGS stations and LZTA and WBTA for 17 October 2015 to 20 January 2016. From the table it can be seen that both new stations perform well and their number of outliers is only slightly larger than the average for the 30 stations. Considering the standard deviation of 3 (not shown), LZTA is well within the normal range associated with IGS stations while WBTA is slightly above.

From both Figure 6 and Table 3 it can be seen that the position time series for LZTA and WBTA show a day-to-day scatter, as indicated by the WRMS values computed with respect to a linear trend, which is equivalent to the average values for the 30 IGS stations. Only the WRMS for the North component is slightly beyond the 1-sigma standard deviation.

Table 2: Solution statistics: number of computed solutions, the number of outliers and the percentage of outliers for the 30 IGS stations and LZTA and WBTA for 17 October 2015 to 20 January 2016.

	Solutions	Outliers	[%]
30 Stations	91,6	4,3	4,0
LZTA	96	6	5,8
WBTA	96	10	9,6

Table 3: Weighted root-mean square (WRMS) statistics for the 30 IGS stations and for LZTA and WBTA for the North, East and Up position component time series for 17 October 2015 to 20 January 2016. The uncertainties of the mean WRMS values are the standard deviations.

	North	East	Up
30 stations	1,6 ± 0,4	2,8 ± 1,0	4,8 ± 1,4
LZTA	2,2	3,1	5,9
WBTA	2,0	3,1	5,6

Conclusions

The new continuous GNSS stations in Lüderitz (LZTA) and Walvis Bay (WBTA) were introduced and their data quality and position estimates were evaluated by comparison to 30 IGS stations, all using the same receiver type, for 17 October 2015 to 20 January 2016. Although the GNSS stations are located in the busy harbor environments, the Port of Walvis Bay is a large container terminal, the data quality and the positioning results so far exhibit only little degradation. Some permanent signal obstructions are present in both locations while WBTA also suffers from temporal obstructions from large ships being berthed close-by. The two GNSS stations are the second and third installations, besides the IGS station in Windhoek (WIND), in the Republic of Namibia. Their data will be highly valuable for scientific use in this under sampled region of the Southern Hemisphere and will be of benefit for the IGS working groups, for example, TIGA and MGEX

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