The Onsala tide gauge station: experiences from the first three years of operation

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Introduction

The location of the Onsala geodetic VLBI telescopes close to the coast line motivates continuous and accurate sea level observations, especially given the recent finding of an accelerating global sea level rise (Nerem et al., 2018). A tide gauge station (Fig. 1) was developed and constructed in house, with advise from the Swedish Meteorological and Hydrological Institute (SMHI). Since the end of June 2015 it is an official site in SMHI's national monitoring network of the sea level.

Sensors

The official tide gauge station has several independent sensors: one radar (Fig. 2) and three pneumatic sensors (Fig. 3, also referred to as bubblers). Now in March 2019 there are one laser (Fig. 4) and two more radars installed in the well for quality assessment of the official data. One of the bubblers is mounted outside the well. The sketch shown in Fig. 5 gives an overall impression of the design and the locations of the sensors.

We compare the four official sensors and the laser sensor. The latter was installed in April 2016 (Börjesson et al., 2016). In fact the expected accuracy (one standard deviation, SD) for all of these sensors is approximately 3 mm, estimated from the data-sheet specifications.

Results

The official time series, based on the radar sensor, from the start in June 2015 until the beginning of March 2019 is shown in Fig. 6. An example of sea level observations with the radar and the laser for the month of December 2018 is shown in Fig. 7. The corresponding differences are shown in Fig. 8. Monthly biases and SDs between the radar and four other sensors have been calculated from samples with the temporal resolution of 1 min and are summarised in the following table:

Radar vs.	Monthly Bias (mm)	Monthly SD (mm)
Laser	3 – 4	2 – 5
USGS1	1 –10	2 – 5
USGS2	1 – 9	2 – 6
USGS3	6 –14	2 –14

Biases are caused by uncertainties of the reference level of the sensors, plus the salinity and temperature determining the density of the water for the bubblers, multipath effects for the radar, and an uncertainty of the reference level of the floating reflector for the laser. In terms of their monthly biases it is clear that the laser and radar show superior stability compared to the bubblers.

The USGS3 bubbler, mounted outside the well is expected to show a larger variability given that the well acts as a low-pass filter. However, we have noted, apart from just looking at the SDs, that a systematic negative bias sporadically occurs, compared to the other sensors. We have no obvious explanation for this behaviour and the sensor shall be taken out of operation and be examined.

Conclusions and future work

We find that the different sensors roughly perform according to their specifications. The radar and the laser sensor appear to be more stable in terms of long term systematic errors. Therefore, future work will focus on these two sensors, plus the additional two radar sensors installed in the well.

Figure 1. The tide gauge station.

Figure 2. The radar sensor, CS476, operating at 26 GHz.

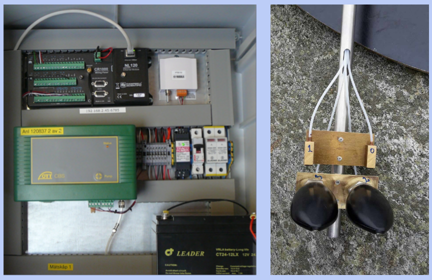

Figure 3. The pneumatic sensors, CS471, have a compressor located in the hut (green unit, left). Each compressor is connected to a nozzle (right) at the bottom of the well via a plastic pipe.

Figure 4. The laser sensor is mounted on the wall of the well. A reflecting target is floating in the pipe.

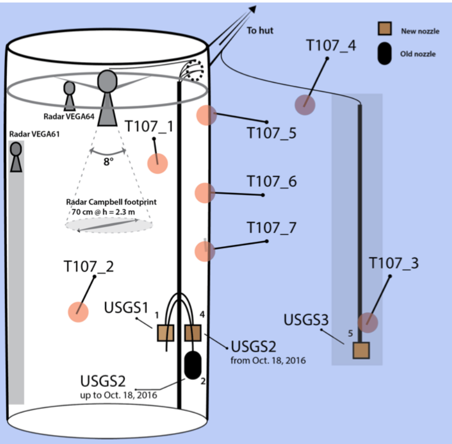

Figure 5. Design of the tide gauge well. The official sensors are the Campbell radar CS476, mounted at the top in the centre and the three USGS bubblers. Additionally two radar sensors, VEGA61, where the signal is propagating in a circular waveguide, and the high frequency, VEGA64, plus one laser sensor (not shown here, see Fig. 4) are used for assessment of the data quality. The pink circles denote temperature sensors.

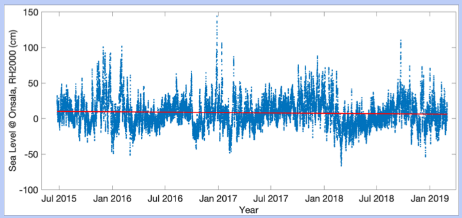

Figure 6.The official time series, based on the radar sensor, is available from the SMHI web page. The sea level at Onsala is mainly determined by the weather. The highest sea level value during this period, approximately +1.5 m, was during the storm Urd in December 2016.

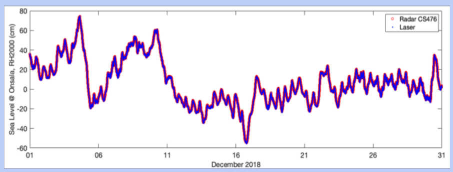

Figure 7. Sea level observations during Dec. 2018.

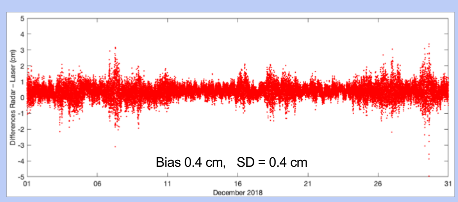

Figure 8. Time series of the difference between the radar and the laser sensor.

References

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Nerem, R. S., B. D. Beckley, J. T. Fasullo, B. D. Hamlington, D. Masters, and G. T. Mitchum (2018). Climate-change—driven accelerated sea-level rise detected in the altimeter era, PNAS, 115(9), 122-125, www.pnas.org/cgi/doi/10.1073/pnas.1717312115.

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