Site-Dependent Effects in GNSS-Observations

─ Reflections as Disturbances and/or Signals ─

Johan Löfgren, Rüdiger Haas, Jan Johansson, Tong Ning, Hans-Georg Scherneck
Department of Radio and Space Science, Chalmers University of Technology, Göteborg, Sweden

Introduction

GNSS-observations are today used to investigate a variety of research topics in geosciences, including e.g. monitoring of crustal deformations and the amount of tropospheric water vapor. These applications require high accuracy for the results, e.g., millimeter-accuracy for positioning. During the last years so-called absolute antenna calibrations for GNSS-antennas on the satellites and on the ground have been implemented. These absolute antenna calibrations increase the accuracy of the GNSS-results. However, unmodeled error sources in the results still remain due to the electromagnetic coupling of the GNSS-antennas with their surroundings, in particular in connection to reflections at different surfaces and objects.

Signal reflections can be looked at in two different ways:

- On one hand, the site-dependent error sources can be seen as limiting factors for the traditional GNSS-applications. To further improve the accuracy, these effects and their dependency on the direction of the observation need to be identified and removed in the GNSS data analysis.
- On the other hand, reflected signals offer opportunities for new applications of GNSS, e.g., sea level monitoring.

We present a study of multipath effects on GNSS-observations, including different antenna surroundings, e.g., with and without absorbing material. Furthermore, we report on observations of GNSS-signals reflected from the sea surface. Both investigations were performed at the Onsala Space Observatory (OSO) which is located on a peninsula at the Swedish West Coast. Since many years it hosts a GNSS-monument and equipment that contribute to the International GNSS Service (IGS) and the Swedish Network of Permanent GNSS Stations (SWEPOS). In recent years, OSO established an additional GNSS-monument that allows a variety of configurations. Furthermore, in 2008 a project was started to install a GNSS-based tide gauge.

References

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For further information

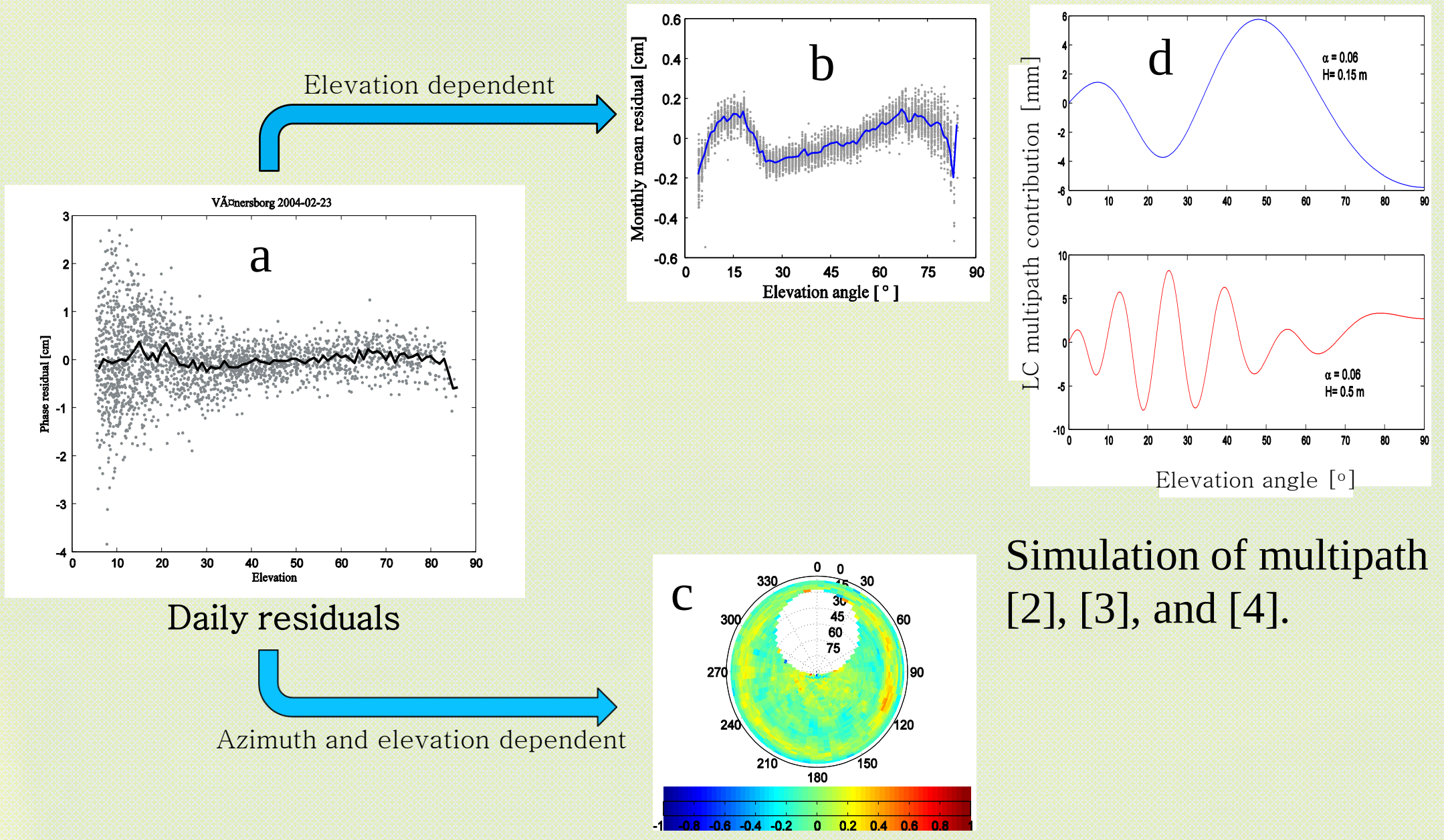
Please contact the following for more information:

Johan Löfgren johan.lofgren@chalmers.se, Tong Ning tong.ning@chalmers.se

Multipath Reflections: Disturbances for GNSS-Observations

Background

The accuracy of GNSS-results have increased during recent years due to so called absolute antenna calibrations of GNSS-antennas on satellites and at ground stations. However, site-dependent unmodeled error sources still effect the results [1]. This is visible for example in Fig.1 that shows post-fit phase residuals from GIPSY-OASIS II Precise Point Positioning (PPP) analysis of six years of data for the SWEPOS station Vänersborg. The residuals are shown as daily (a) and monthly mean (b) values, and as a function of azimuth and elevation (c). The shape of the residual curve corresponds reasonably well to multipath simulations (d).



Simulation of multipath [2], [3], and [4].

Figure 1: GNSS-post-fit residuals and multipath simulations.

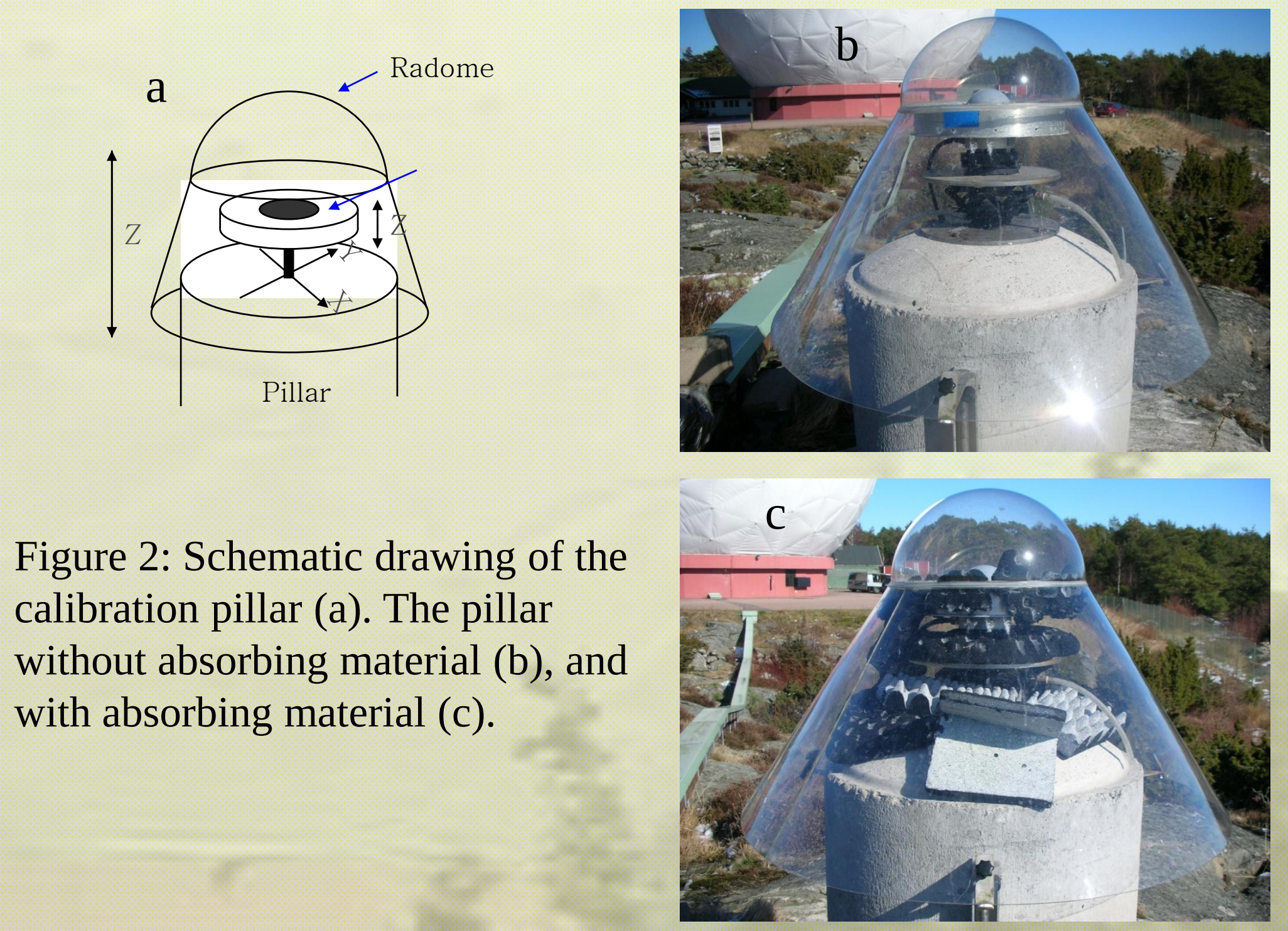


Figure 2: Schematic drawing of the calibration pillar (a). The pillar without absorbing material (b), and with absorbing material (c).

The calibration pillar

To be able to investigate the impacts of site-dependent electromagnetic environment on a GNSS-antenna, an experimental pillar was constructed at OSO (Fig. 2). It allows to move the antenna in X, Y, and Z direction inside the radome (a), to remove the radome, and to add microwave absorbing material, e.g., eccosorb (b, c). The pillar is located approximately 20 m from the permanent IGS station ONSA and a water vapor radiometer.

Calibration measurements

The impact of microwave absorbing material on GNSS-measurements was investigated systematically. GNSS-data was recorded during two weeks for two different configurations, with and without microwave absorbing material. The data were analyzed with GIPSY-OASIS II using the PPP strategy and the standard deviation of the station coordinates are shown in Fig. 3. It becomes clear that adding micro-wave absorbing material below the antenna decreases the standard deviation of the station position.

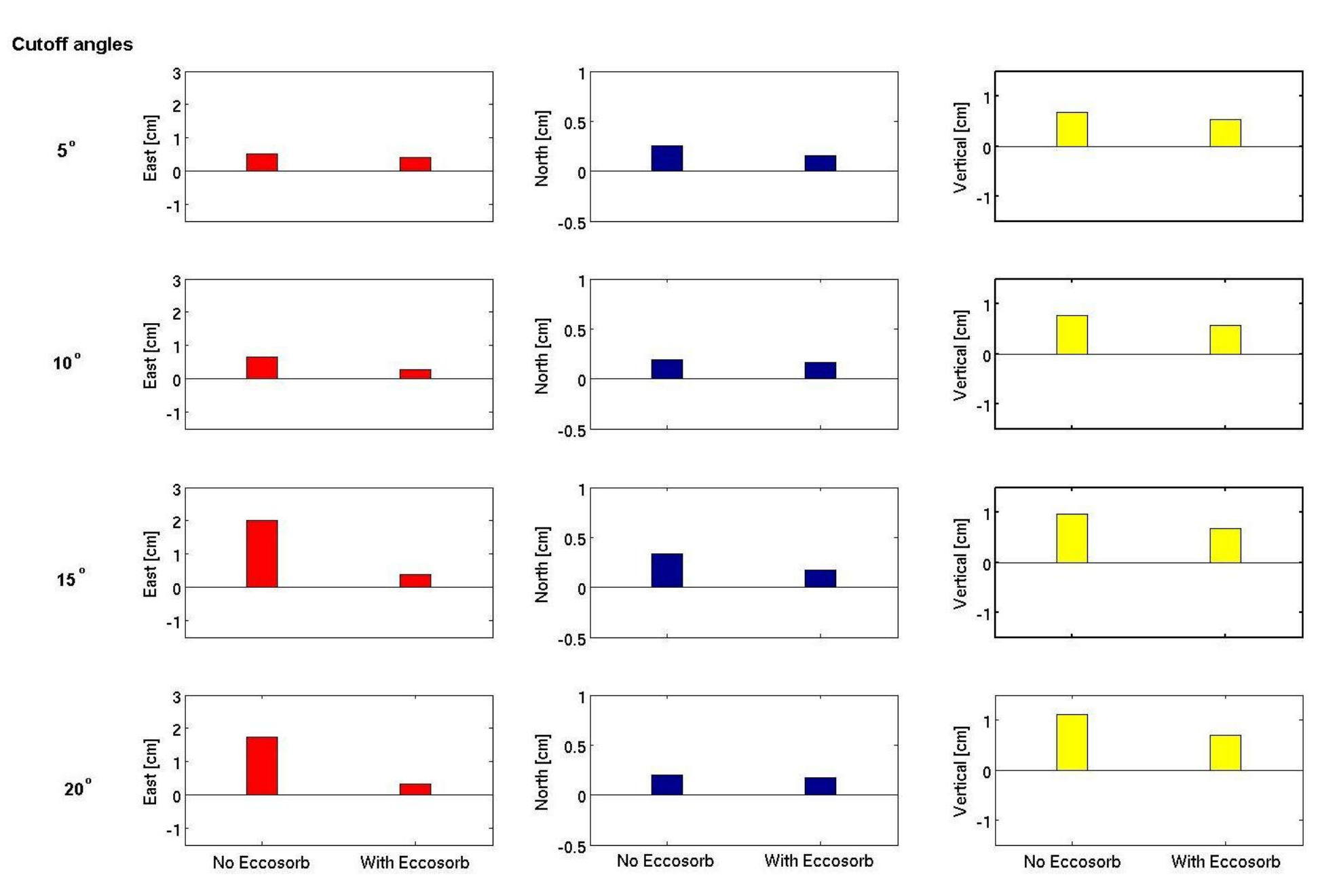


Figure 3:The standard deviation (std) of the coordinates for four different cutoff angles and two different pillar configurations.

Results and conclusions

Our measurements demonstrate that some of the site-dependent effects, i.e., multipath reflection, are reduced by using microwave absorbing material.

The measurement using the new calibration station at OSO will continue and hopefully lead to better understanding of the GNSS-antenna's electro-magnetic environment, and the influence of eccosorb.

Sea Surface Reflections: Signals for GNSS-based Tide Gauge

Background

Global climate change is believed to result in the melting of large masses of ice in Polar Regions, bringing freshwater into the ocean [5], and changing the sea level [6]. The traditional way to measure the sea level, by a tide gauge, results in measurements relative to the Earth's crust [7]. However, in order to fully understand the process, these measurements together with absolute measurements (change in sea level in relation to the Earth's center of gravity) are necessary. This is especially important in regions affected by so-called isostatic uplift, e.g., Fennoscandia. The motion of the Earth's crust in relation to the center of gravity can be determined by satellite techniques, e.g., GPS [8] and therefore a GNSS-based tide gauge is proposed.

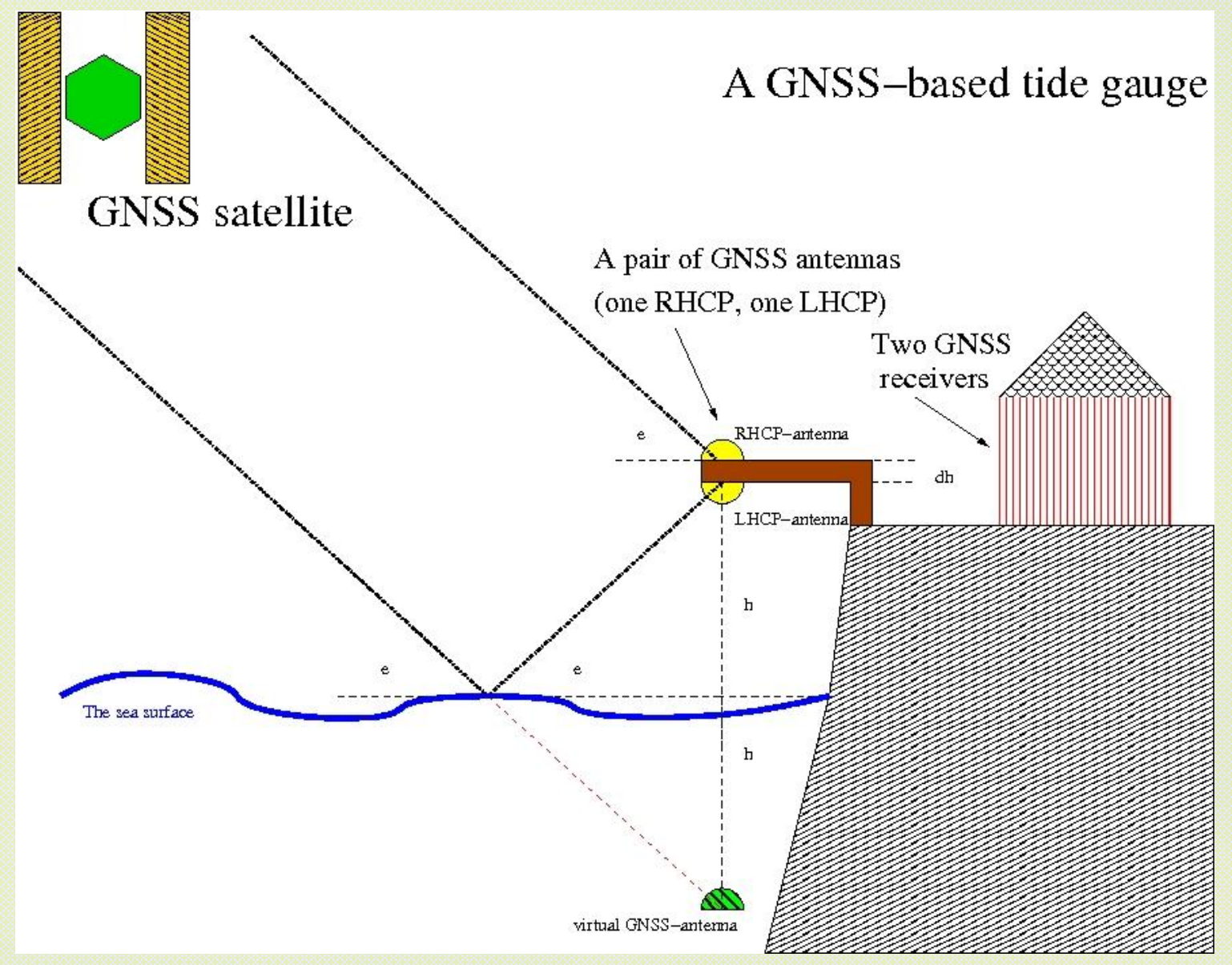


Figure 4: A GNSS-based tide gauge installation.

Figure 5: Experimental setup for the GNSS-based tide gauge.

Installation

The planned GNSS-tide gauge installation consists of two antennas, one upward looking right hand circular polarized (RHCP) and one downward looking left hand circular polarized (LHCP), mounted on a beam over the water. The RHCP antenna receives the GNSS-signals directly, whereas the LHCP antenna receives the signals reflected from the sea surface. Because of the additional path delay of the reflected signal, the LHCP antenna will appear to be a virtual GNSS-antenna located below the sea surface (Fig.4). When the sea level changes, the path delay of the reflected signal changes, thus the LHCP antenna will appear to be in a new position, and therefore monitor sea level changes. Fig. 5 shows an experimental setup and Fig. 6 the received SNR recorded with receivers connected to the antennas.

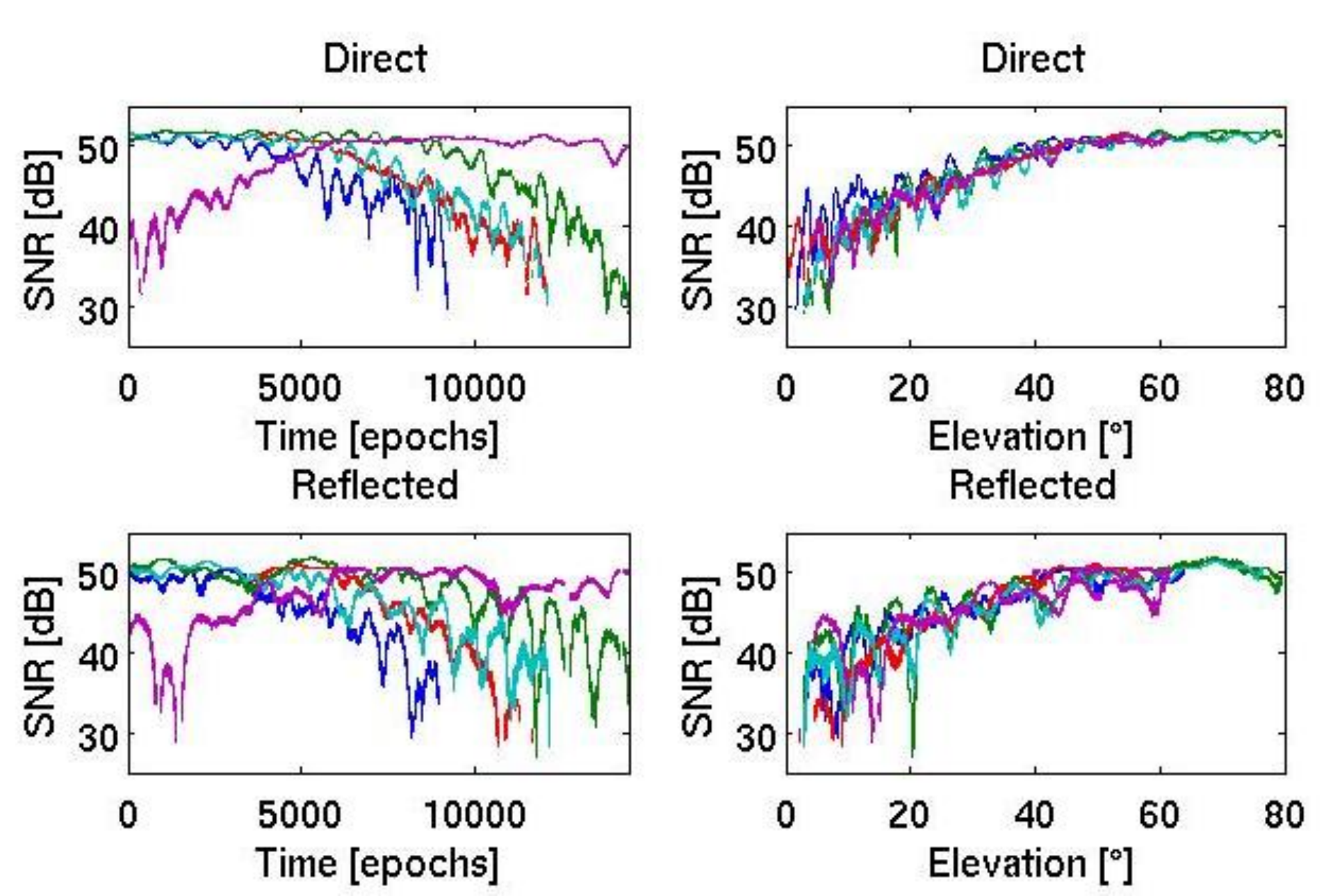


Figure 6: SNR for the direct and reflected signals from 5 satellites.

Data Analysis

We analyzed 40 hours of continuous 1 Hz data from the two receivers using an in-house developed software in MATLAB. The software used L_1 phase delays for relative positioning to solve for differences in the local vertical components, receiver clocks, and phase ambiguities. Each solution was made using 20 minutes of data every full hour. The resulting time-series for the vertical differences is compared to data from two traditional tide gauges at Ringhals and Göteborg, about 18 km south of and 33 km north of OSO, respectively (Fig.7).

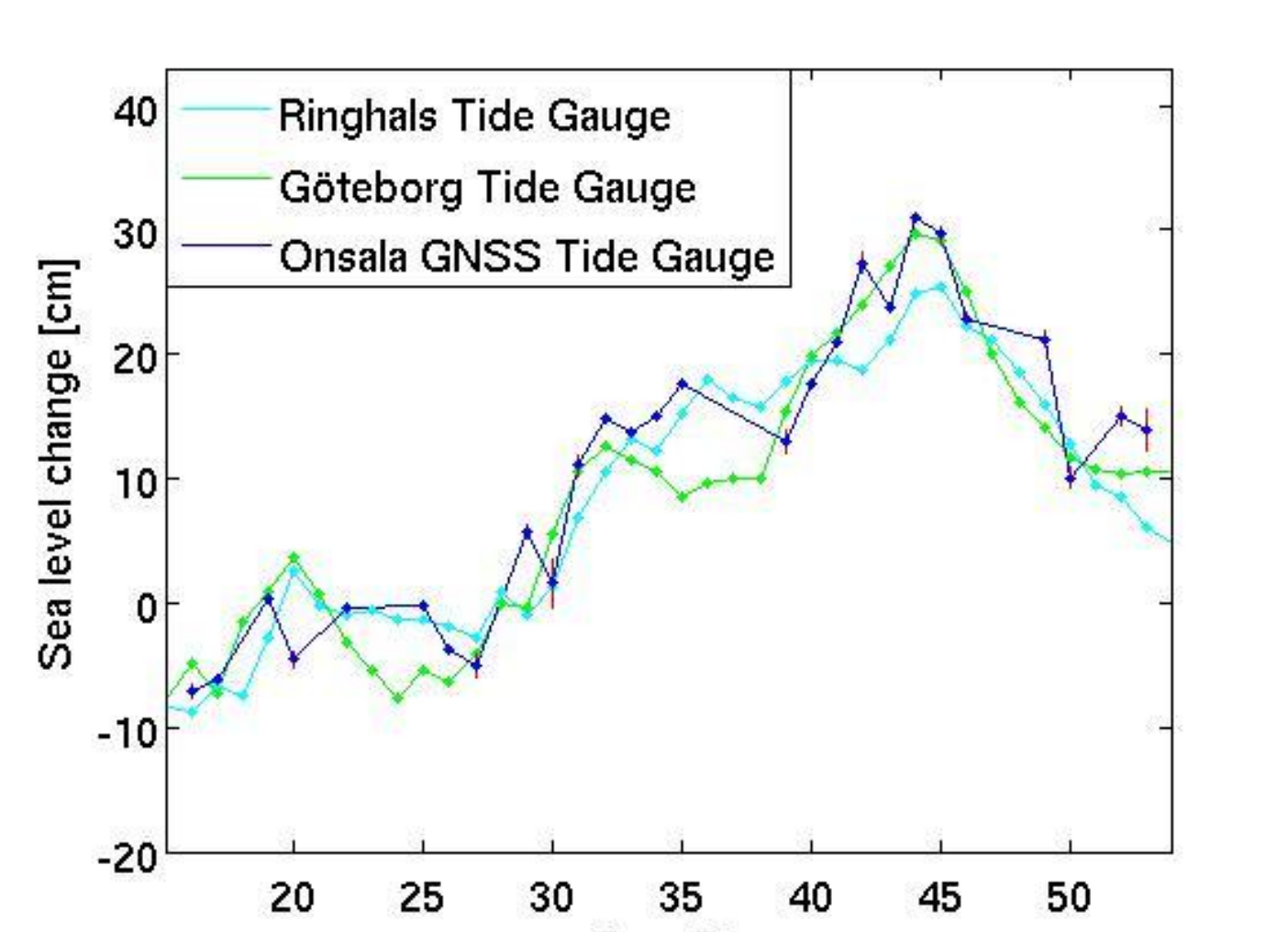


Figure 7: Sea level change from the GNSS-based tide gauge and traditional tide gauges.

Results and conclusions

The quality of the reflected signals is surprisingly good, in particular above 20° elevation (Fig.6). However, below 20° elevation the SNR of the reflected signals fluctuates more than for the direct signals, indicating more complicated reflections.

The derived vertical difference between the two antennas resembles reasonably well the independently observed sea level changes (Fig.7). This indicates that the GNSS-tide gauge gives valuable results for sea level monitoring.