Precise ground-based GNSS-Reflectometry sea level measurements using low-cost antennas

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We are developing a new technique to precisely monitor sea level using multiple low-cost GNSS antennas. These instruments could be used as a much less-expensive alternative to acoustic or pressure tide gauges, with similar precision for hourly sea level measurements. In order to validate the technique, we installed an experimental configuration of antennas at the Port of Trois-Rivières and will compare sea level measurements to a co-located tide gauge. We plan to install more instrumentation at various locations along the Saint Lawrence river.

Keywords—GNSS-Reflectometry; sea level; low-cost instrumentation; geodesy

I. INTRODUCTION

GNSS-Reflectometry (GNSS-R) techniques rely on analyzing the interference caused by signals reflecting off the sea surface prior to reaching a coastal GNSS antenna. Sea level measurements may be retrieved via spectral analysis of the Signal-to-Noise Ratio (SNR) data of a particular signal from a GNSS satellite. It has been shown that GNSS-R sea level measurements are highly correlated to measurements from a co-located tide gauge. However, GNSS stations that have been used for reflectometry purposes thus far are designed for monitoring land motion and may cost more than $10,000 each. We have found that a low-cost GNSS antenna (< $100) can be used to make equally precise sea level measurements. Additionally, we propose a technique to improve the precision of GNSS-R sea level measurements, which varies between a few centimeters to half a meter in current literature with high cost stations.

II. ERROR ANALYSIS

We have developed a modelling technique to estimate the precision and sources of error in GNSS-R sea level measurements by creating and analyzing a time series of synthetic SNR data. Our modelling work demonstrates that two of the dominant sources of error are the effects of random noise in the SNR data and atmospheric refraction. In light of this, we have designed a new technique to precisely monitor sea level by using multiple low-cost GNSS antennas in the same location. Initial results from modelling indicate that multiple antennas can be used to reduce the effect of noise. Furthermore, the antennas can be oriented to increase the amplitude of interference and reduce the error due to atmospheric refraction.

III. FIELD WORK

In collaboration with the Port of Trois-Rivières and the Canadian Hydrographic Service, we have installed an experimental setup of low-cost GNSS antennas to monitor sea level (Figure 1). GNSS-R sea level measurements will be compared to measurements from the co-located tide gauge and the precision will be quantified using the RMSE. The Saint Lawrence river is an ideal testing ground for tide gauges due to the large range of forcing from both tidal and non-tidal sources. Therefore we plan to install more instrumentation on the island of Montreal and near Quebec city.

Figure 1: Experimental configuration of four low-cost GNSS antennas being installed by William Minarik at the Port of Trois-Rivières in September 2019