Open-source hardware options for SNR-based GPS/GNSS reflectometry – Proof-of-concept and initial validation

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1. Introduction

Monitoring the sea level is fundamental due to climate change (Figure 1). Unfortunately, satellite altimeters do not work well in coastal regions and tide gauges are not as numerous as necessary and may be affected by vertical land motion (Figure 2).

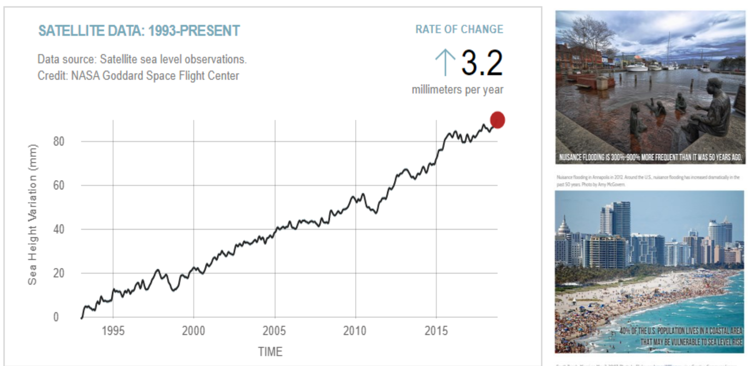

Figure 1: Rising sea leve (left) and consequences (right).

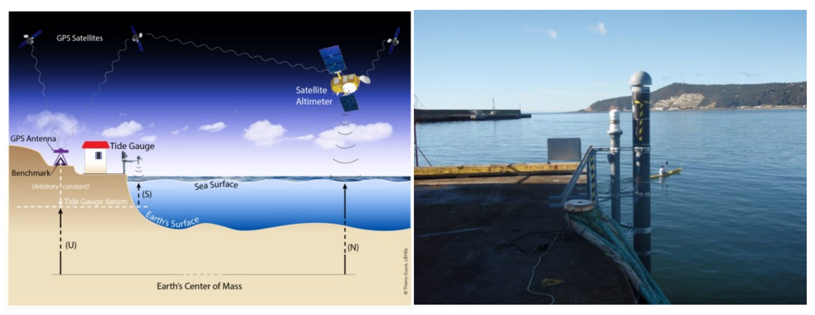

Figure 2: Satellite altimeres (left) and tide gauge with GNSS.

Ground-based GNSS Reflectometry allows geocentric sea-level sensing (Figures 3 and 4). Geodetic-quality receivers and antennas are expensive; here, a lower-cost and open-source hardware alternative is presented (Figures 5 and 6).

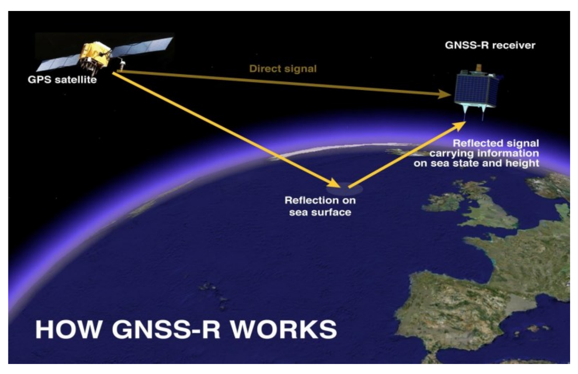

Figure 3: Principles of the GNSS-R technique.

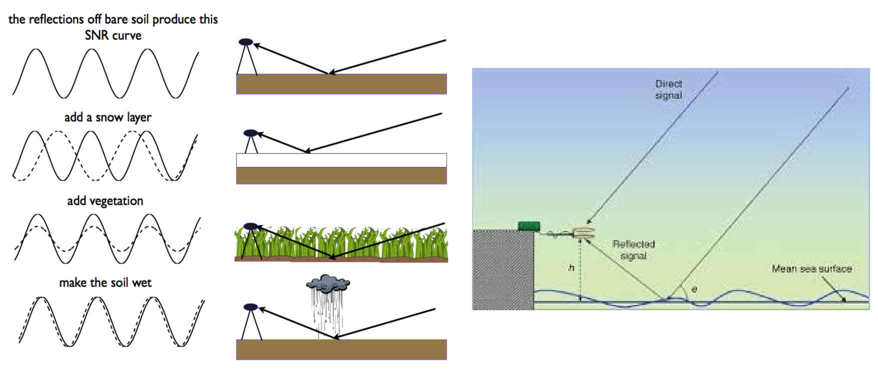

Figure 4: Applications of GNSS-R .

Figure 5: Geodetic equipment.

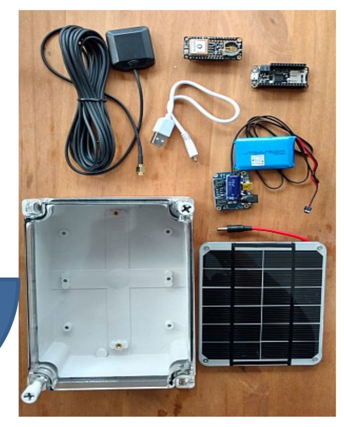

Figure 6: Experimental device.

2. Materials and methods

2.1 Hardware

The main electronic components employed are shown in Figure 7: an Arduino board integrated with SD card reader/writer (Adafruit Feather Adalogger), a single-frequency GPS L1 C/A add-on (Adafruit GPS FeatherWing), and an external GPS antenna (active 28-dB, Chang Hong GPS-01-174-1M-0102). A complete solar power system was also developed (Figure 8).

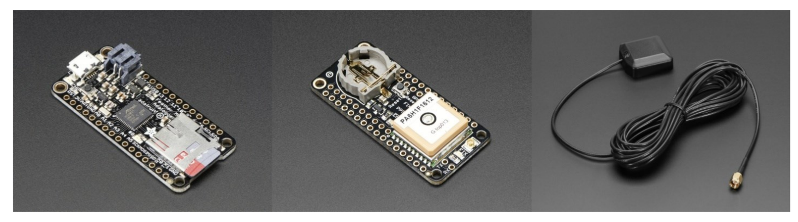

Figure 7: Main sensor components: Arduino device with integrated SD-card interface (left); GPS shield with internal GPS antenna (middle); external antenna (right).

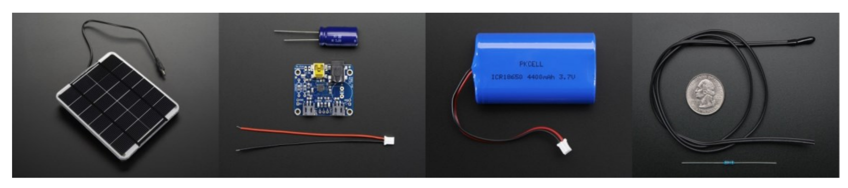

Figure 8: Solar power system: solar panel (far left); solar charge (center left); battery (center right); thermistor (far right).

2.2 Software

We have developed two pieces of software, both available as open source. One piece runs onboard the Arduino and another runs in Matlab on a PC. They can be download from GitHub, at https://git.io/fjCnp.

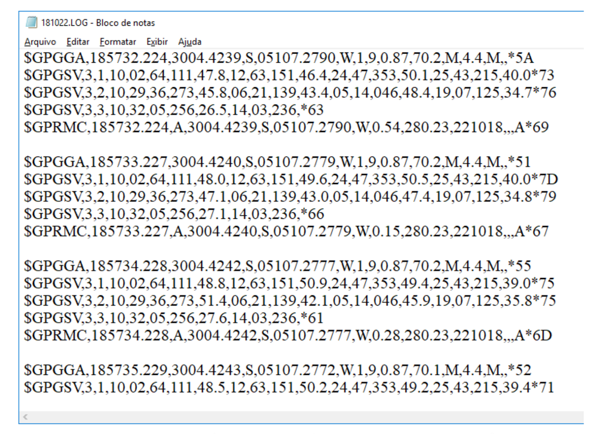

Figure 9: Sample SNR data in NMEA format.

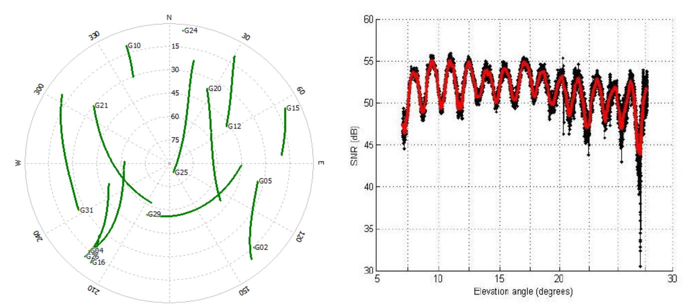

Figure 10: Skyplot (left) and pattern of interference fringes (right)

$$dSNR \approx A \cdot \cos(2\pi\lambda^{-1} \cdot 2H \cdot \sin e + \phi$$

The total cost is US$205 as of January 2019; the complete bill of materials is publicly available at: http://www.adafruit.com/wishlists/469752

3. Field validation

3.1 Location

On October 26th, 2018 a unit was installed at the Mauá Wharf by the Guaíba River in the city of Porto Alegre, Brazil (30.0277°S, 51.2287°W), shown in Figures 11 and 12.

Figure 11: Map indicating the site location (red dot).

3.2 Installation

Our GNSS-R station has been running uninterruptedly for more than six months (Figure 13).

Figure 13: GNSS-R experimental station.

Figure 12: Site panoramic view; inset: existing tide gauge.

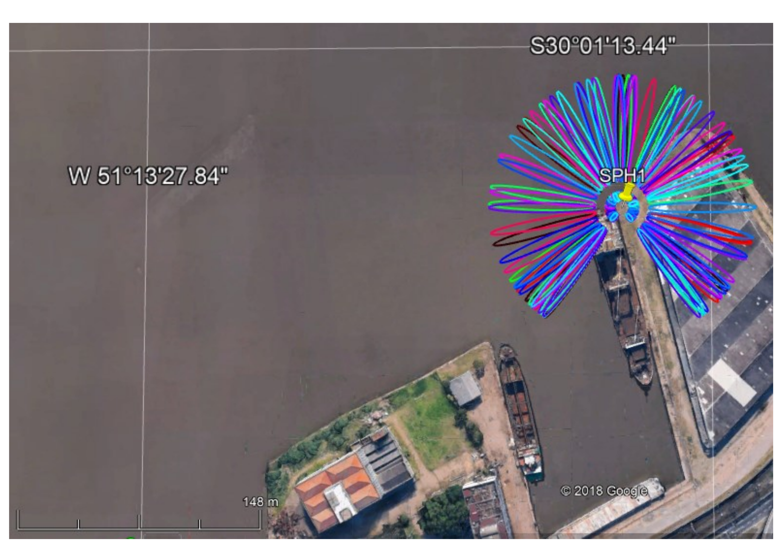

Figure 14: Reflection Fresnel zones for elevation angles between 5° – 30° and antenna height equal to 3 m.

4. Initial results

We performed inversion for the estimation of the water surface height at the Mauá Wharf applied to several satellite tracks (Figure 15).

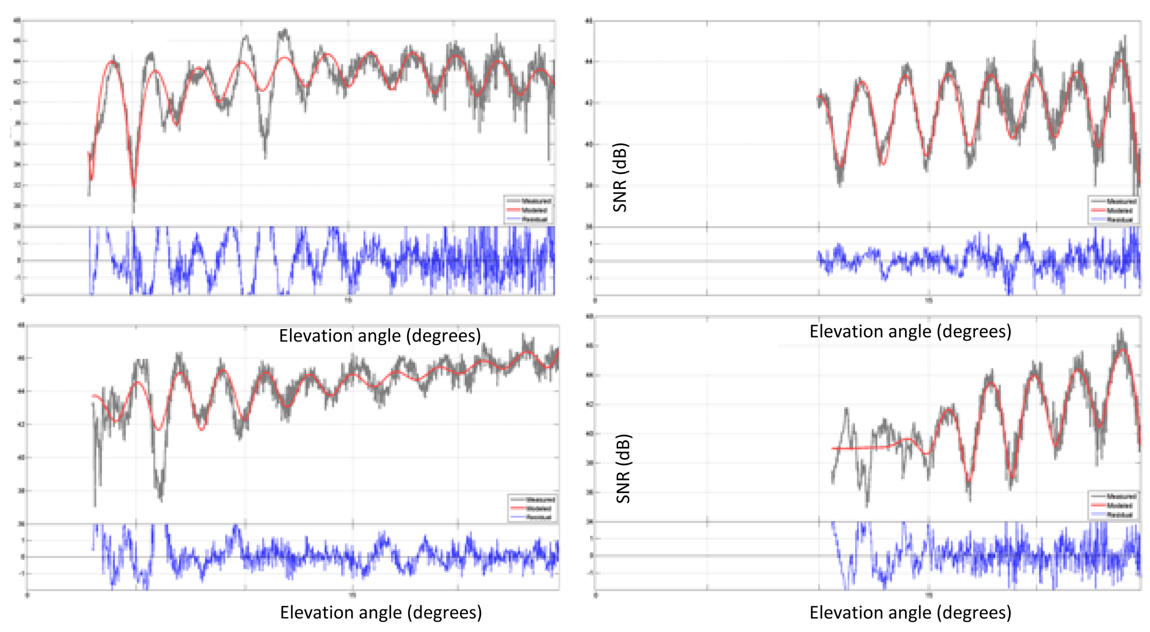

Figure 15: Inversion results: measurements are in gray, model fit in red, and residuals in blue (bottom panels).

Parameter estimates for the six satellite tracks shown resulted in a mean reflector height of 3.191 m with a standard deviation of 20 cm. For validation, we surveyed the water level and the antenna phase center, resulting in an average of 3.128 m with standard deviation of 2.4 cm, mainly caused by the small waves. The discrepancy of 6.3 cm amounts to approximately 2% of the reflector height.

5. Ongoing and future work

We are in the process of analyzing several months of data collected since installation.

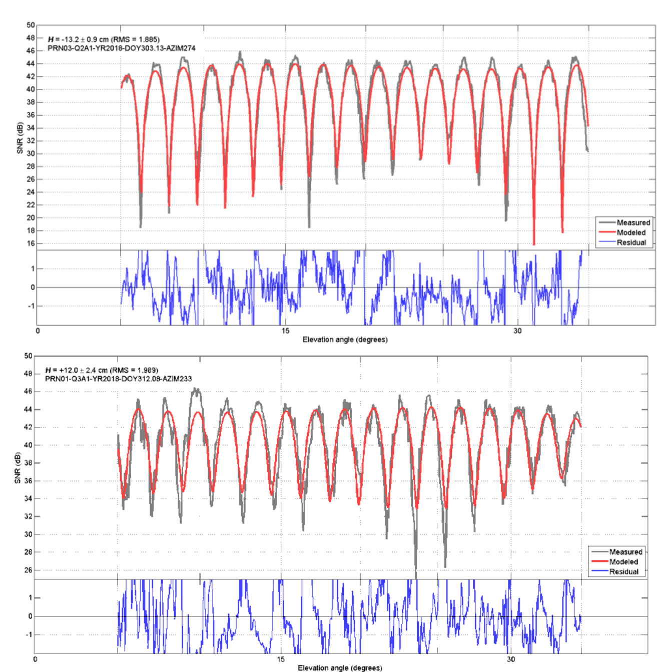

Figure 16: Sample SNR results from river-facing site.

Figure 17: Location of future sea-facing installation.

We are also planning an installation by the sea, at the Imbituba Port (Santa Catarina state), where several tide gauges exist.

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