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GNSS-IR LOW COST SYSTEMS

GNSS-IR LOW COST SYSTEMS : RATIONALE

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- Commercial Off The Shelf geodetic quality Receivers and Antennas are relatively expensive
- They are “designed” to suppress multipath
- Modern receivers are designed so they can record multi-GNSS and multi-frequencies at high rate
- Generally very robust system, they will keep running

HOWEVER

- With the advent of low-cost GNSS chips, often designed for phones or drones etc researchers have been looking at ways to use these in GNSS-IR application
- Apart from the appeal of low-cost there is a belief that the cheaper antennas will not suppress multipath as much leading to a better signal

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I am only going to talk about low cost systems that have been used to measure sea level

There are other systems that have been built for soil moisture etc

I am only going to show results from my own work (mainly)

I am not going to show you how to build a low cost system

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General set up : We need

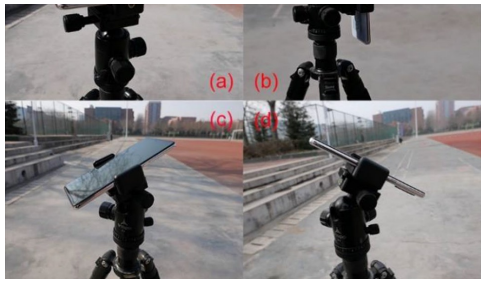
- Something with a GNSS chip – often UBLOX
  - Could be a phone or a tablet
  - Modern ones now track all GNSS and dual frequency
- Antenna although the built in one can be used.
- Some sort of computer to record the data (Raspberry Pi, arduino)
  - Either you can record raw data that can be converted to RINEX
  - Or record NMEA signals*
- You need some way of powering the system
- You need some way of recording or transmitting the data
- After that its pretty much the same as a COTS GPS receiver

Can We Measure Sea Level With a Tablet Computer?

Joakim Strandberg and Rüdiger Haas

Performance assessment of GNSS-IR altimetry using signal-to-noise ratio data from a Huawei P30 smartphone

Zhihao Liu · Lan Du · Peiyuan Zhou · Zejun Liu · Zhongkai Zhang · Zheyu Xu



An open-source low-cost sensor for SNR-based GNSS reflectometry: design and long-term validation towards sea-level altimetry

M. A. R. Fagundes · I. Mendonça-Tinti · A. L. Iescheck · D. M. Akos · F. Geremia-Nievinski

*NOTE NMEA message give integer SNR, elevation and azimuth values

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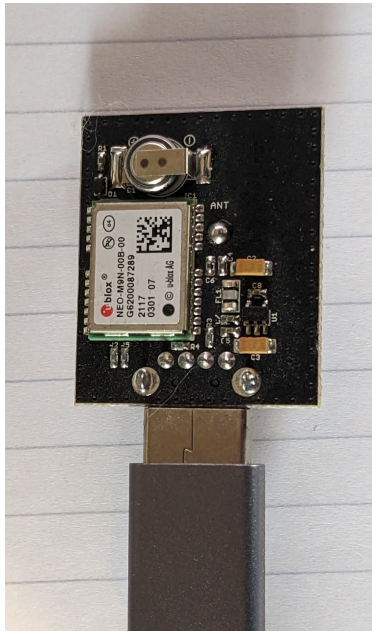
If you really want to try this simply….

RECENT ANDROID PHONE
And an app like GEO++ RINEX Logger



Overview | Release Notes | Support | Documents | References | Porting to BB | To Do | Statistics | SDR Receiver

RTKLIB: An Open Source Program Package for GNSS Positioning

GNSS chip plugged into a laptop and RTKLIB

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- **Fagundes, M. A. R., I. Mendonca-Tinti, A. L. Iescheck, D. M. Akos, and F. Geremia-Nievinski. 2021. 'An open-source low-cost sensor for SNR-based GNSS reflectometry: design and long-term validation towards sea-level altimetry', GPS Solutions, 25.**
- Li, Yunwei, Kegen Yu, Taoyong Jin, Xin Chang, Qi Wang, and Jiancheng Li. 2021. 'Development of a GNSS-IR instrument based on low-cost positioning chips and its performance evaluation for estimating the reflector height', GPS Solutions, 25: 127.
- Li, Yunwei, Kegen Yu, Taoyong Jin, Xin Chang, Qiang Zhang, Changhui Xu, and Jiancheng Li. 2021. "Soil moisture estimation using amplitude attenuation factor of low-cost GNSS receiver based SNR observations." In 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, 7654-57. IEEE.
- Purnell, D. J., N. Gomez, W. Minarik, D. Porter, and G. Langston. 2021. 'Precise water level measurements using low-cost GNSS antenna arrays', Earth Surf. Dynam., 9: 673-85.
- Rover, S., and A. Vitti. 2019. 'GNSS-R with Low-Cost Receivers for Retrieval of Antenna Height from Snow Surfaces Using Single-Frequency Observations', Sensors (Basel, Switzerland), 19.
- Williams, Simon D. P., Paul S. Bell, David L. McCann, Richard Cooke, and Christine Sams. 2020. 'Demonstrating the Potential of Low-Cost GPS Units for the Remote Measurement of Tides and Water Levels Using Interferometric Reflectometry', Journal of Atmospheric and Oceanic Technology, 37: 1925-35.
- Altuntas, Cemali, and Nursu Tunalioglu. 2021. 'Feasibility of retrieving effective reflector height using GNSS-IR from a single-frequency android smartphone SNR data', Digital Signal Processing, 112: 103011.
- Liu, Zhihao, Lan Du, Peiyuan Zhou, Zejun Liu, Zhongkai Zhang, and Zheyu Xu. 2022. 'Performance assessment of GNSS-IR altimetry using signal-to-noise ratio data from a Huawei P30 smartphone', GPS Solutions, 26: 42.
- Strandberg, J., and R. Haas. 2020. 'Can We Measure Sea Level With a Tablet Computer?', Ieee Geoscience and Remote Sensing Letters, 17: 1876-78.

MPHW: AN OPEN-SOURCE GNSS-IR SENSOR

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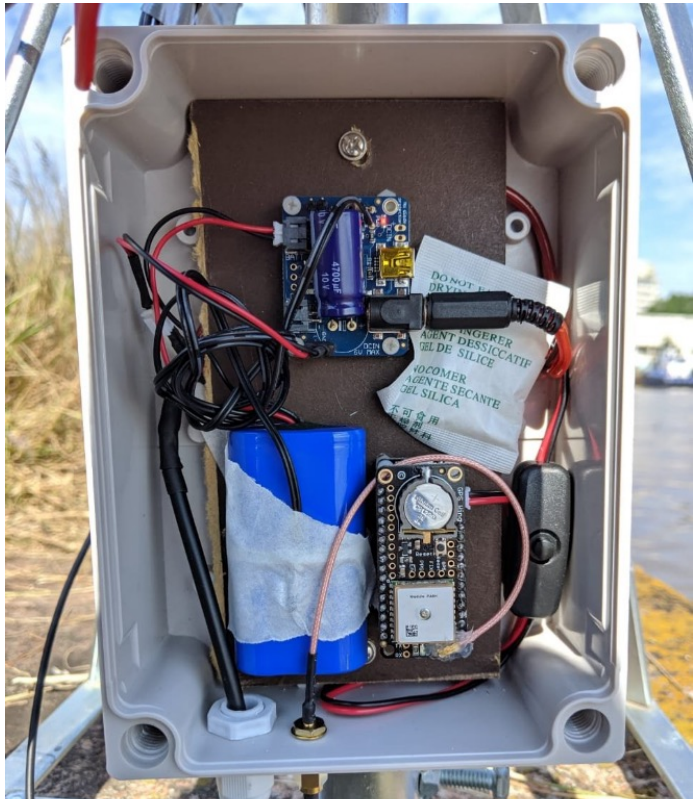
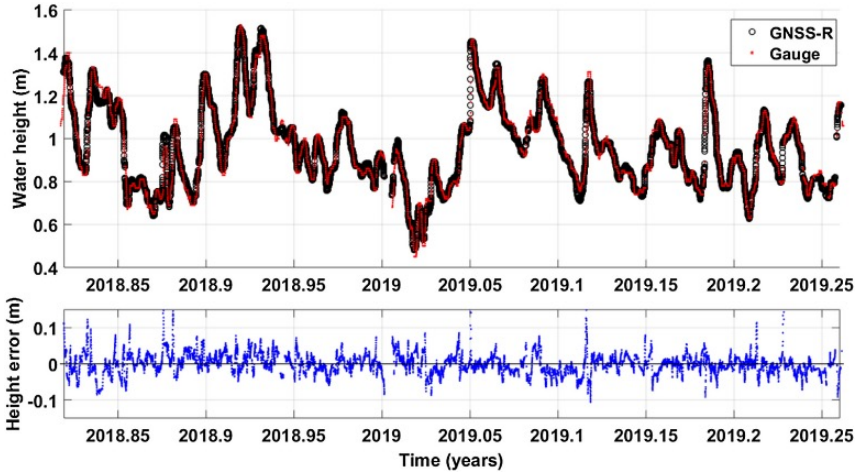
- Arduino based
  - USD200 bill of materials
- NMEA format
  - 0.1 dB resolution!
- Solar powered
  - With 3-day battery
- Validated
  - 3 cm RMS, 0.9 correlation
- Build tutorial
  - Step by step
- New: high rate (10 Hz)





https://github.com/fgnievinski/mphw

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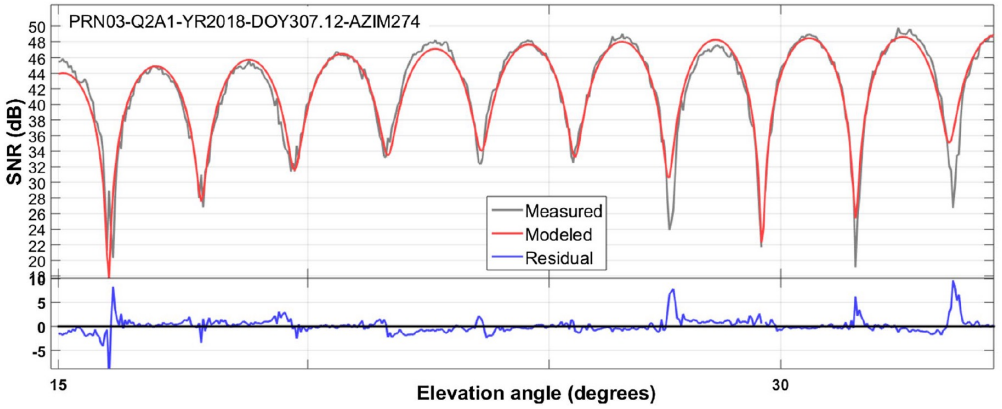
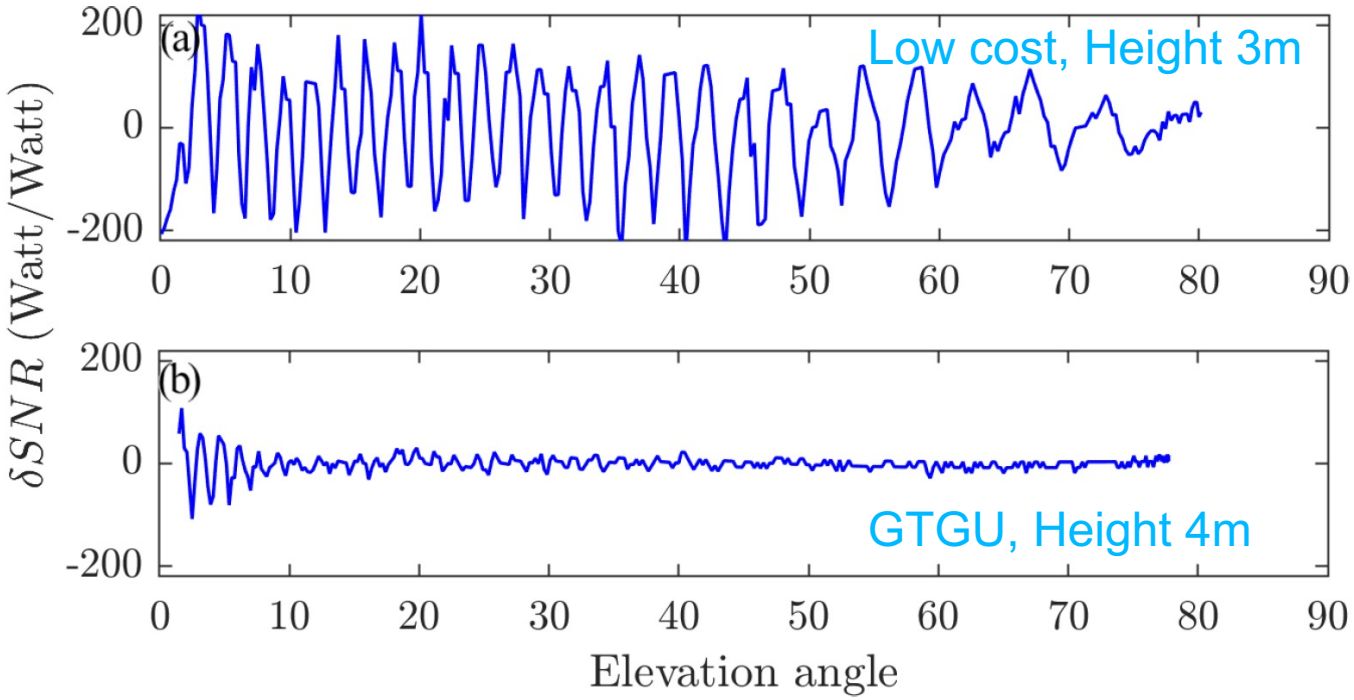
Apart from the appeal of low-cost there is a belief that the cheaper antennas will not suppress multipath as much leading to a better signal

An open-source low-cost sensor for SNR-based GNSS reflectometry: design and long-term validation towards sea-level altimetry

M. A. R. Fagundes[1] · I. Mendonça-Tinti[2] · A. L. Iescheck[3] · D. M. Akos[4] · F. Geremia-Nievinski[3]



D. J. Purnell et al.: Precise water level measurements using low-cost GNSS antenna arrays



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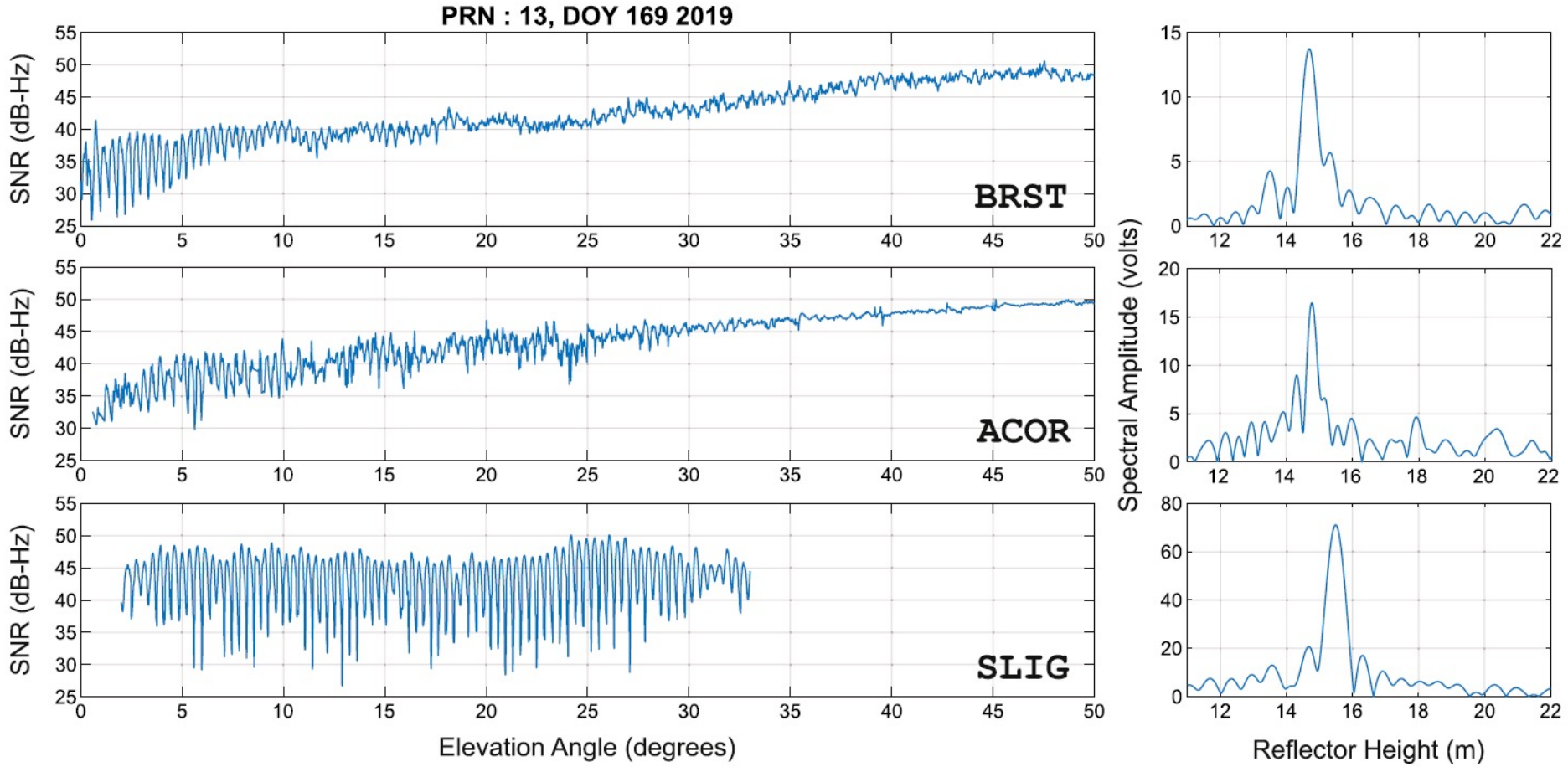

FIG. 4. (left) Example of SNR vs elevation angle for PRN 13 on DOY 169 during 2019 at three sites: BRST (top) Brest, France (BRST); (middle) A Coruña, Spain (ACOR); and (bottom) Sligo, Ireland (SLIG). (right) Periodograms for these records. Note the difference in scale on the *y* axes of the right panels.

GNSS-IR LOW COST SYSTEMS : EXAMPLES

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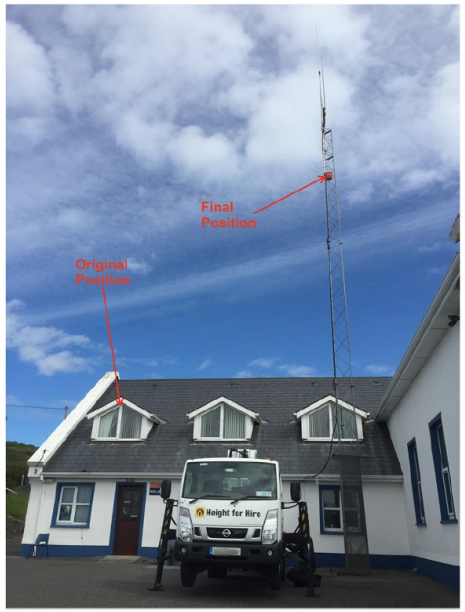


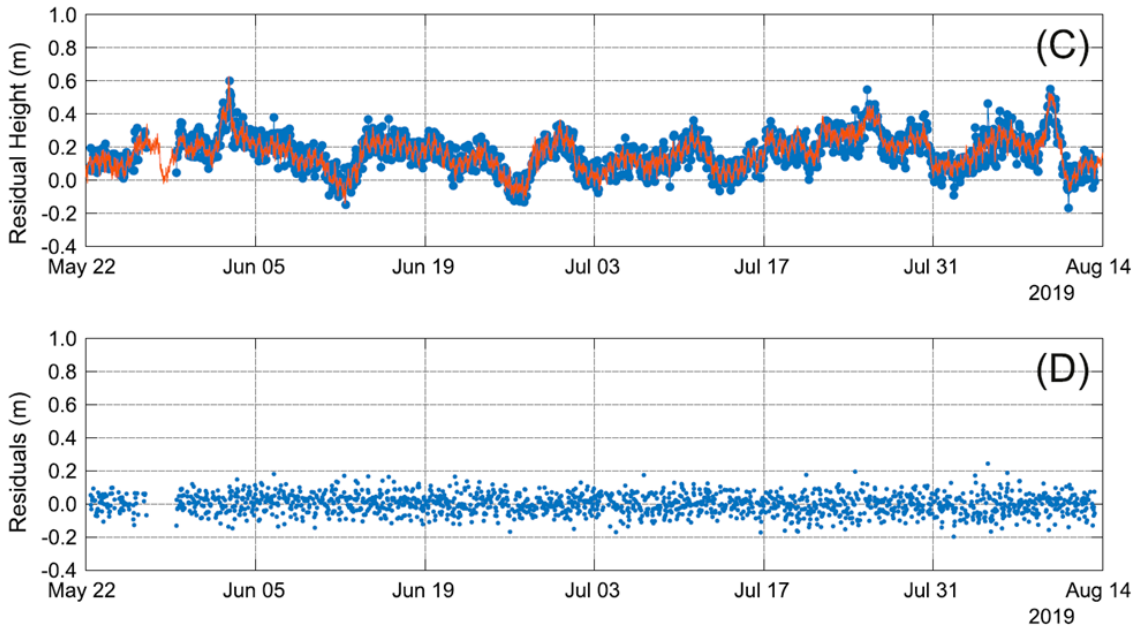
FIG. 2. Northward view of the RNLI Station at Sligo, Ireland. The labels indicate the original and final locations of the GPS antennas.

Maestro
A2200A SiRFstar IV module with Xbee wireless transmitter back to the building

Low Cost GPS tide gauge

We achieved results comparable or better than a conventional GNSS-IR for a fraction of the cost
5-6 cm residuals, 1.7 cm daily averages.

In fact the results were so good we identified a potential scale issue in the co-located tide gauge.



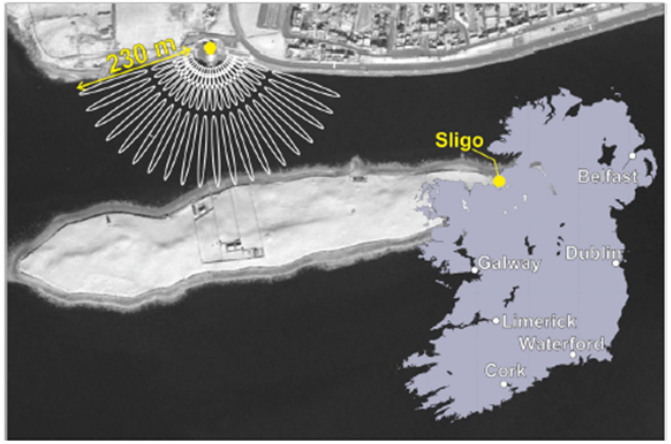


FIG. 1. Satellite view of the Sligo test site (solid yellow circle) with Fresnel zones for a reflector height of 16 m and elevation angles of 5° (largest white ellipses), 10°, 15°, and 20° (smallest ellipses) within the azimuth range 110°–251°.

Demonstrating the Potential of Low-Cost GPS Units for the Remote Measurement of Tides and Water Levels Using Interferometric Reflectometry

SIMON D. P. WILLIAMS,[a] PAUL S. BELL,[b] DAVID L. MCCANN,[c] AND RICHARD COOKE
National Oceanography Centre, Liverpool, United Kingdom

CHRISTINE SAMS
National Oceanography Centre, Southampton, United Kingdom

ALFRED DOCK TIDE GAUGE, LIVERPOOL

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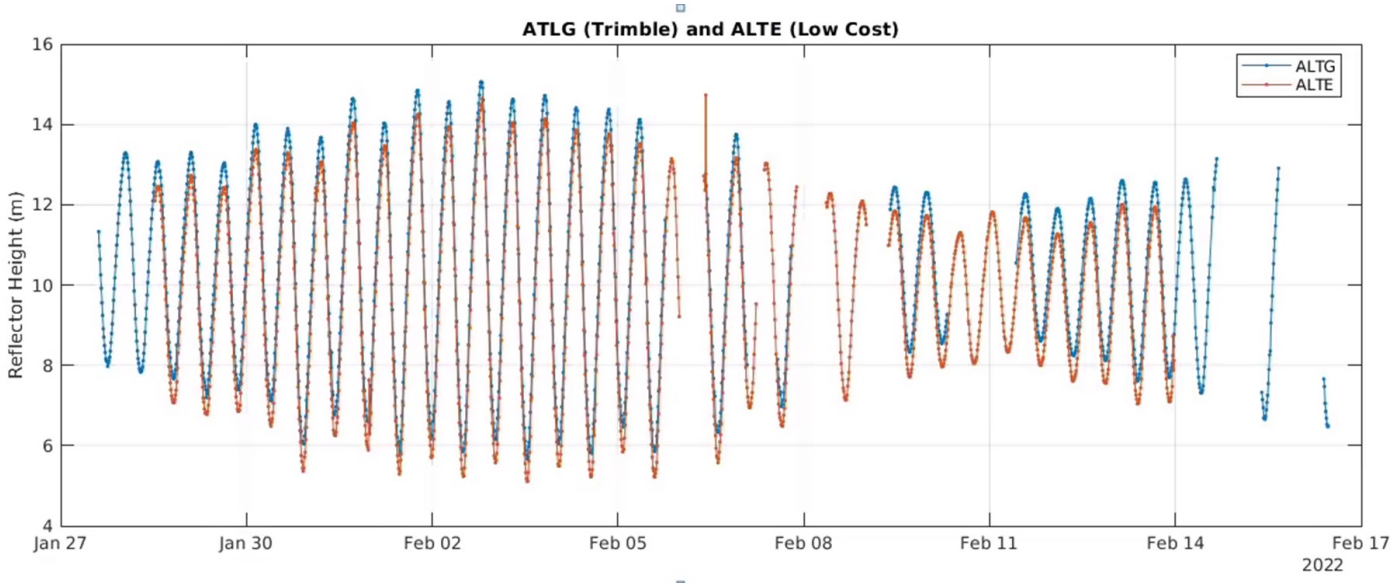
New tide gauge installation with twin radar and trimble GNSS
Also includes a “not quite” low cost GNSS in the form of an EMLID REACH M2 (500 GBP) which uses the same UBLOX chips we are using elsewhere.

The extra cost is because it is an all in one system so incorporates a Raspberry Pi and can transmit via Bluetooth etc and the years of design time in building a system



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- Example of a low cost system deployed in the Severn Estuary on Clevedon Pier
- Currently running to support the SWOT mission by supplementing the tide gauges in the area.
- There are two other low-cost systems deployed in the area
- We have several versions:
  - solar/battery/mains,
  - Logging/transmitted
  - older chip using NMEA
  - newer using RINEX

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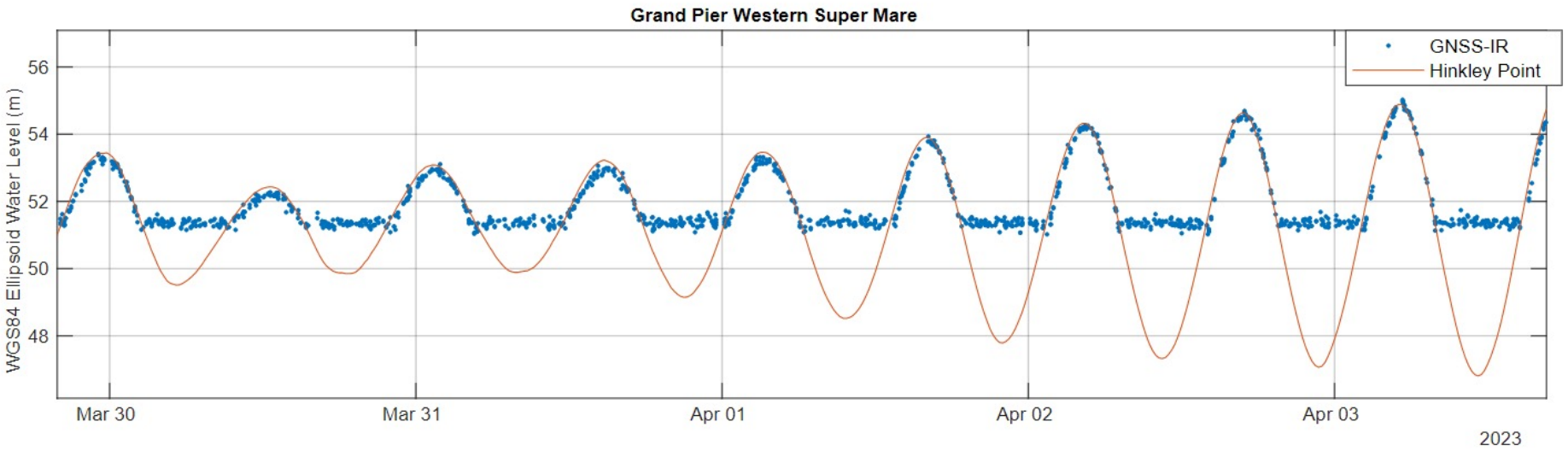

The GNSS-IR is not in the same place as the tide gauge which is downstream and we can see a phase shift that is consistent with their locations.

We can see that the results “dry out” at low tide.

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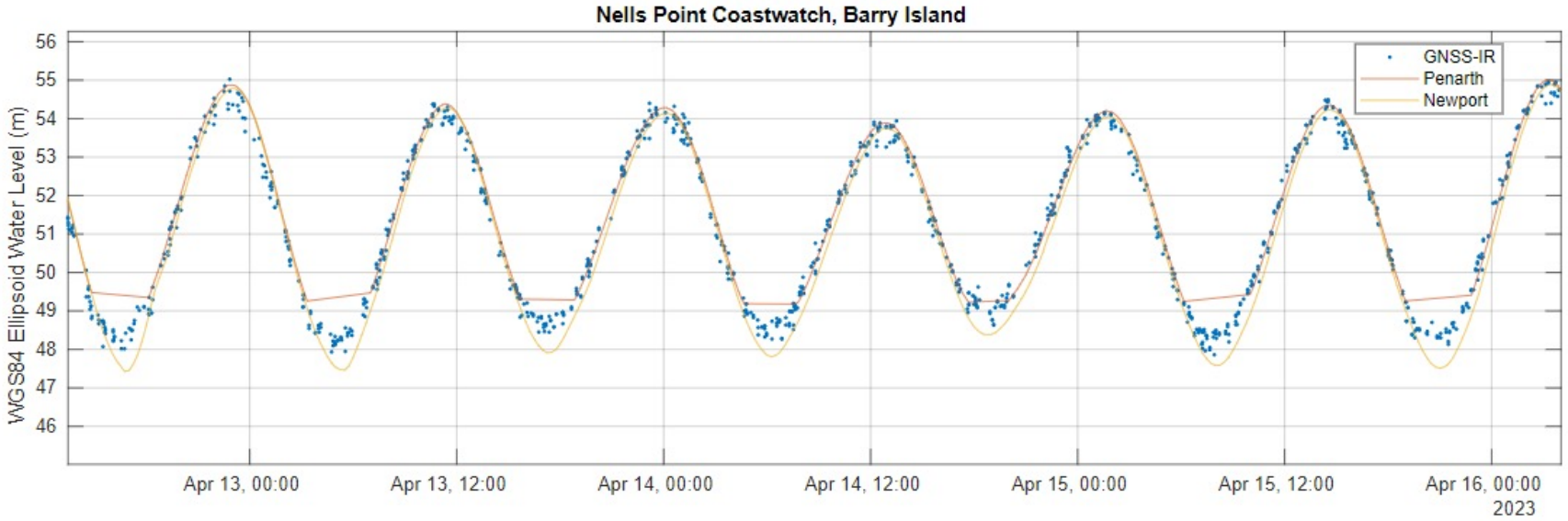

Again we can see a phase shift between the gauges which are either side of the GNSS-IR

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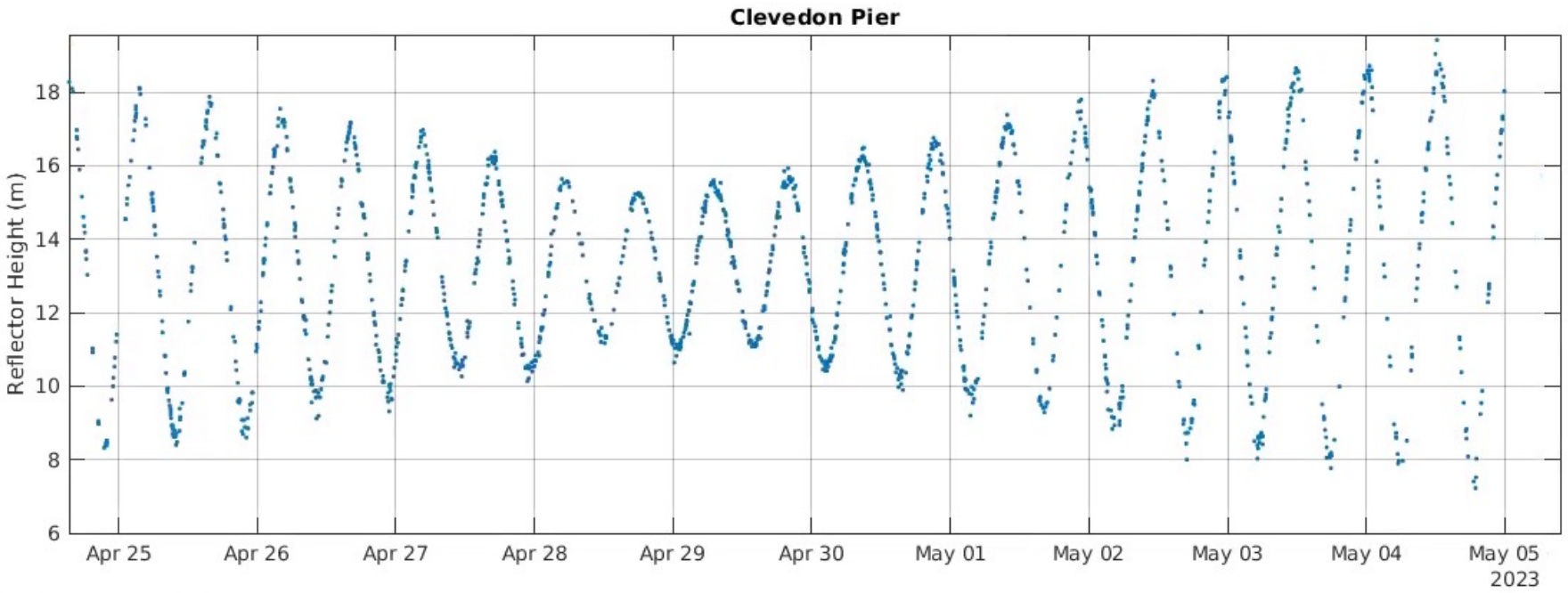

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EXAMPLES FROM ALFRED DOCK

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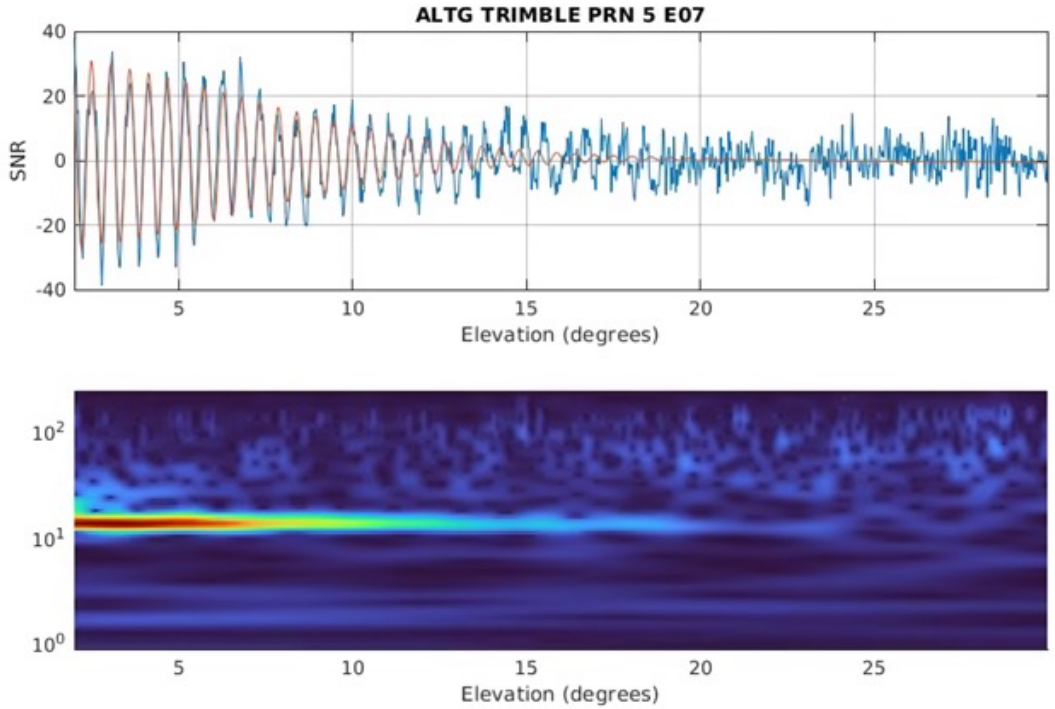

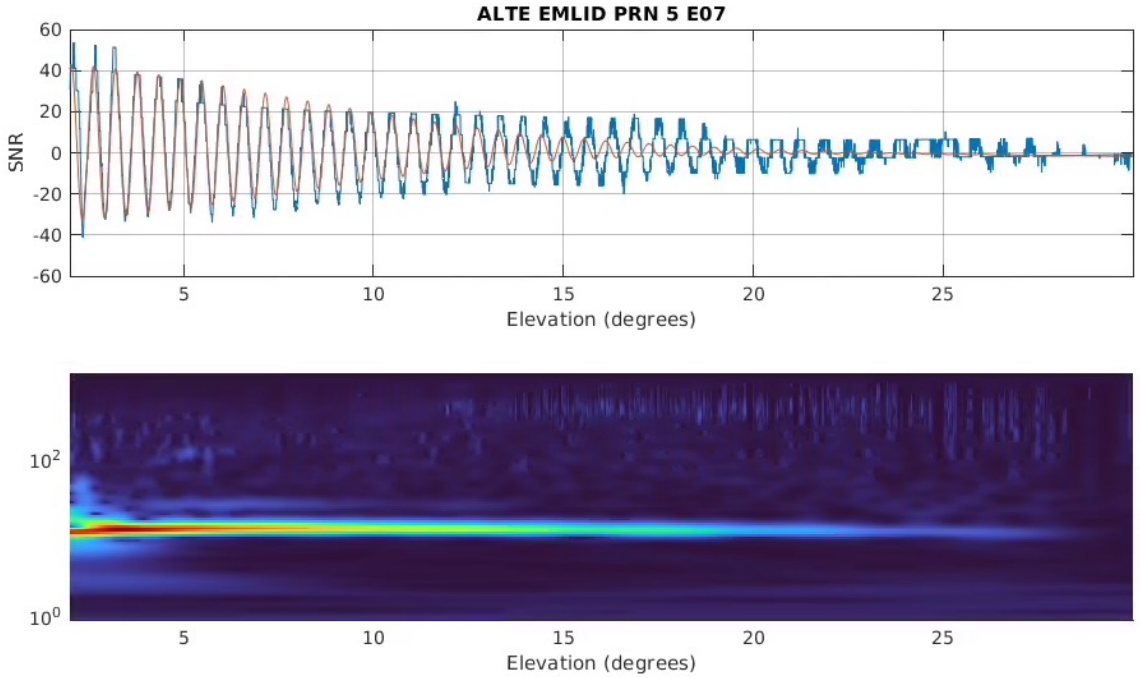

SEVERN ESTUARY EXAMPLES