GNSS REFLECTOMETRY FOR TIDE GAUGE LEVELLING

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What is this about?

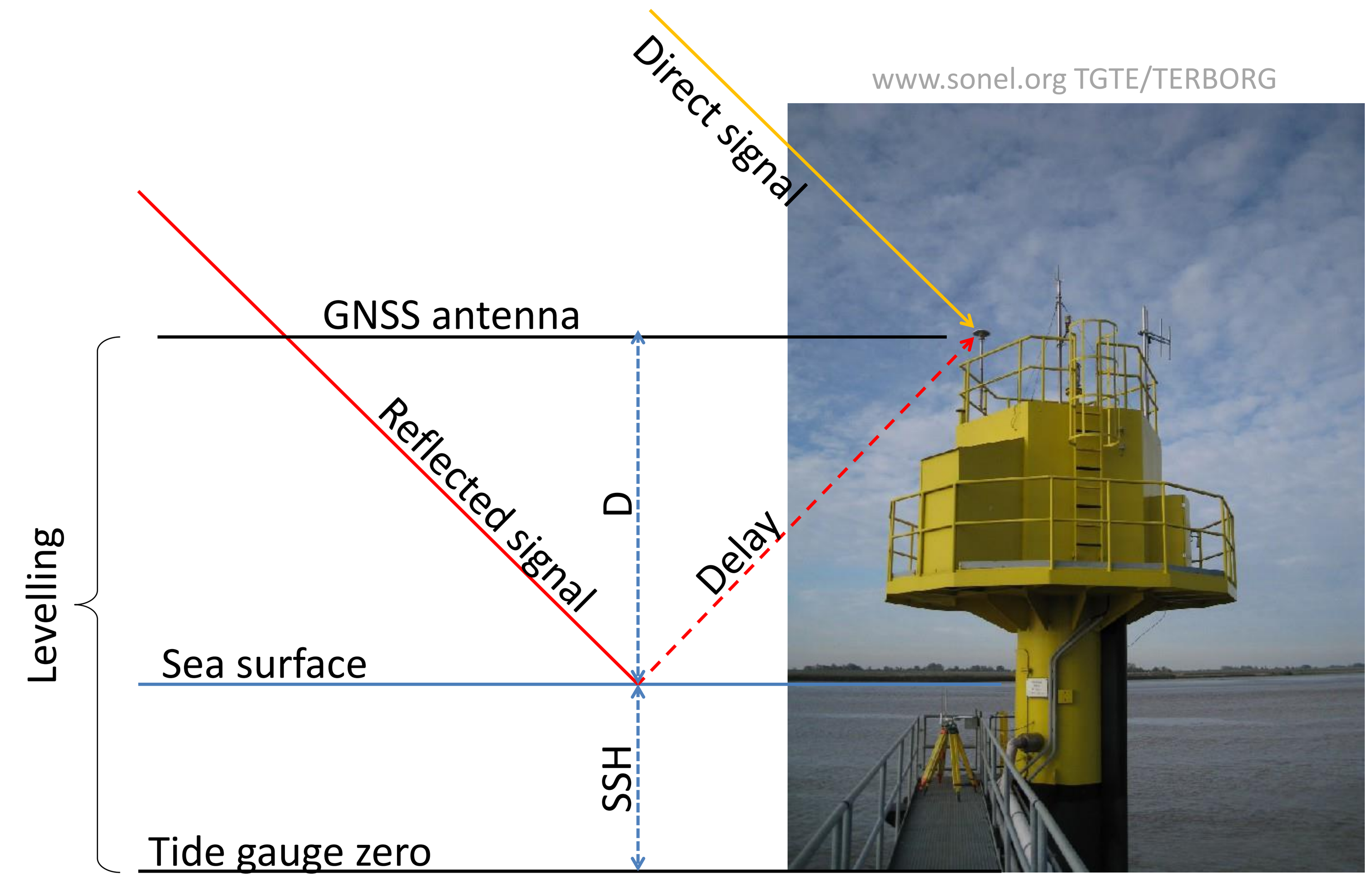
New technique to estimate the vertical distance (levelling) between the tide gauge zero and a co-located GNSS antenna using reflections of GNSS signals from the sea surface.

Advantages

- It uses already installed instruments (no levelling campaign needed).
- Levelling can be done continuously and remotely.
- It avoids errors in the true location of the GNSS and TG height references
- It enables monitoring of the relative stability between the GNSS and tide gauge

How does it work?

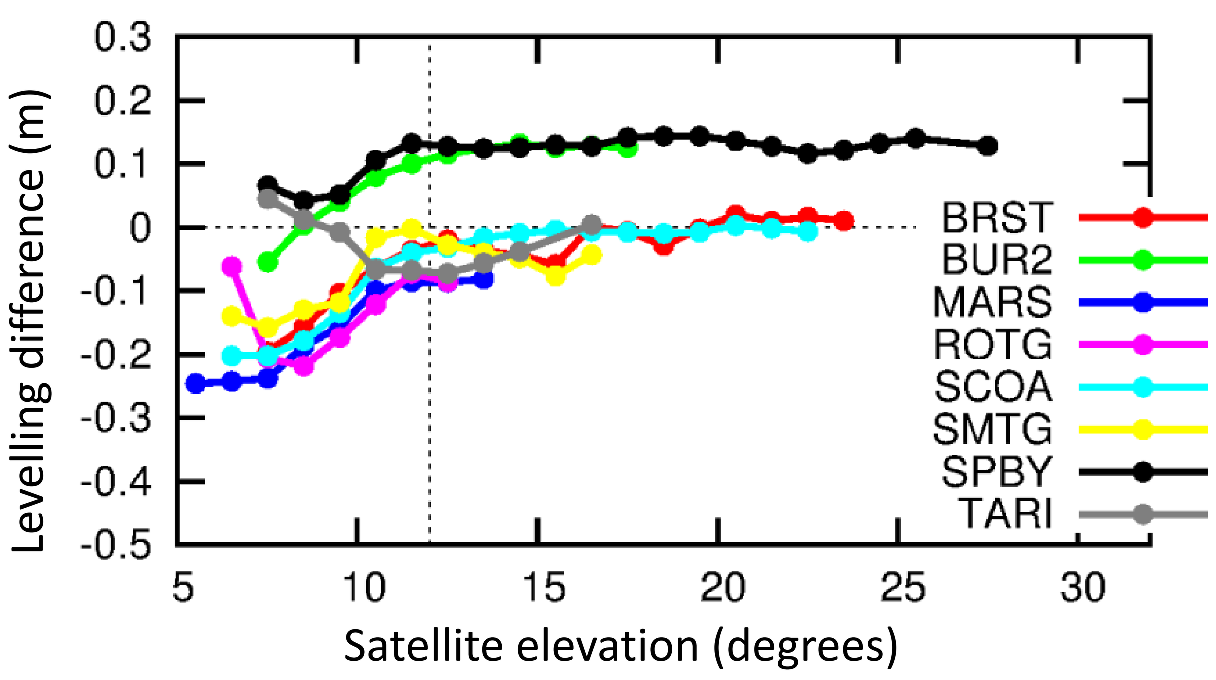
Reflected signals reaching the GNSS antenna (red) are delayed with respect to the direct signals (orange) and cause measurable interference. By analysing the rate of change of the interference, we can estimate the vertical distance from the reflecting surface to the antenna (D). The tide gauge observations remove the sea-surface height variations (SSH) and translate the measured distance from the sea surface to the tide gauge zero, i.e., the levelling distance.



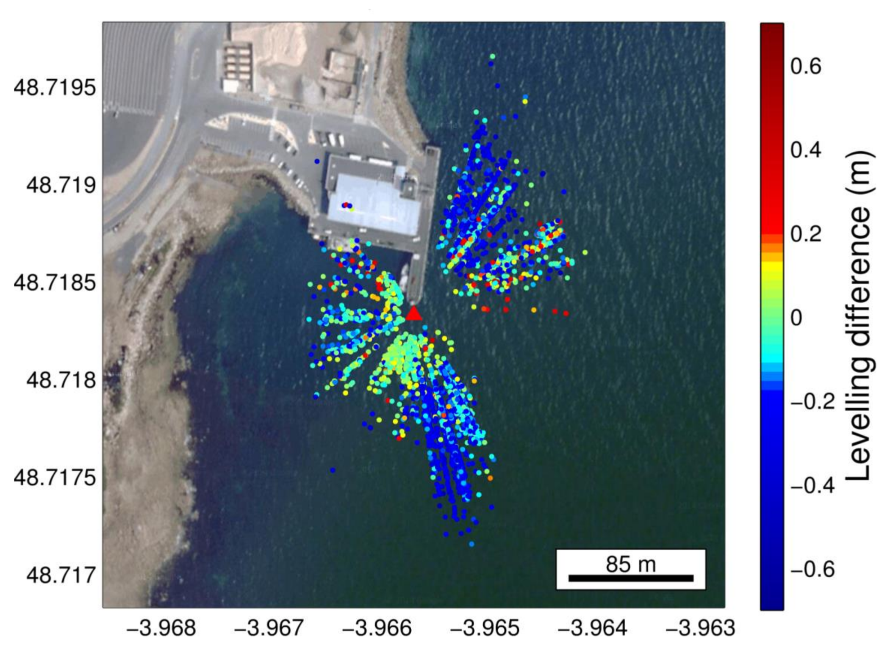
Schematic figure showing how the reflected GNSS signals can be used to estimate the levelling between the tide gauge zero and a co-located GNSS antenna.

1) First experiment: eight sites analysed

- **Systematic error for satellite observations below 12 degrees elevation.**
- Above 12 degrees elevation, differences with in situ levelling less than 3 cm at 4 sites.
- Two sites with obstructed reflections: requirements on GNSS antenna location.
- Quality of GNSS measurements: requirement on signal-to-noise ratio (SNR) resolution better than 1 dB-Hz.
- Biased results by 11-13 cm at two sites (see right panel).



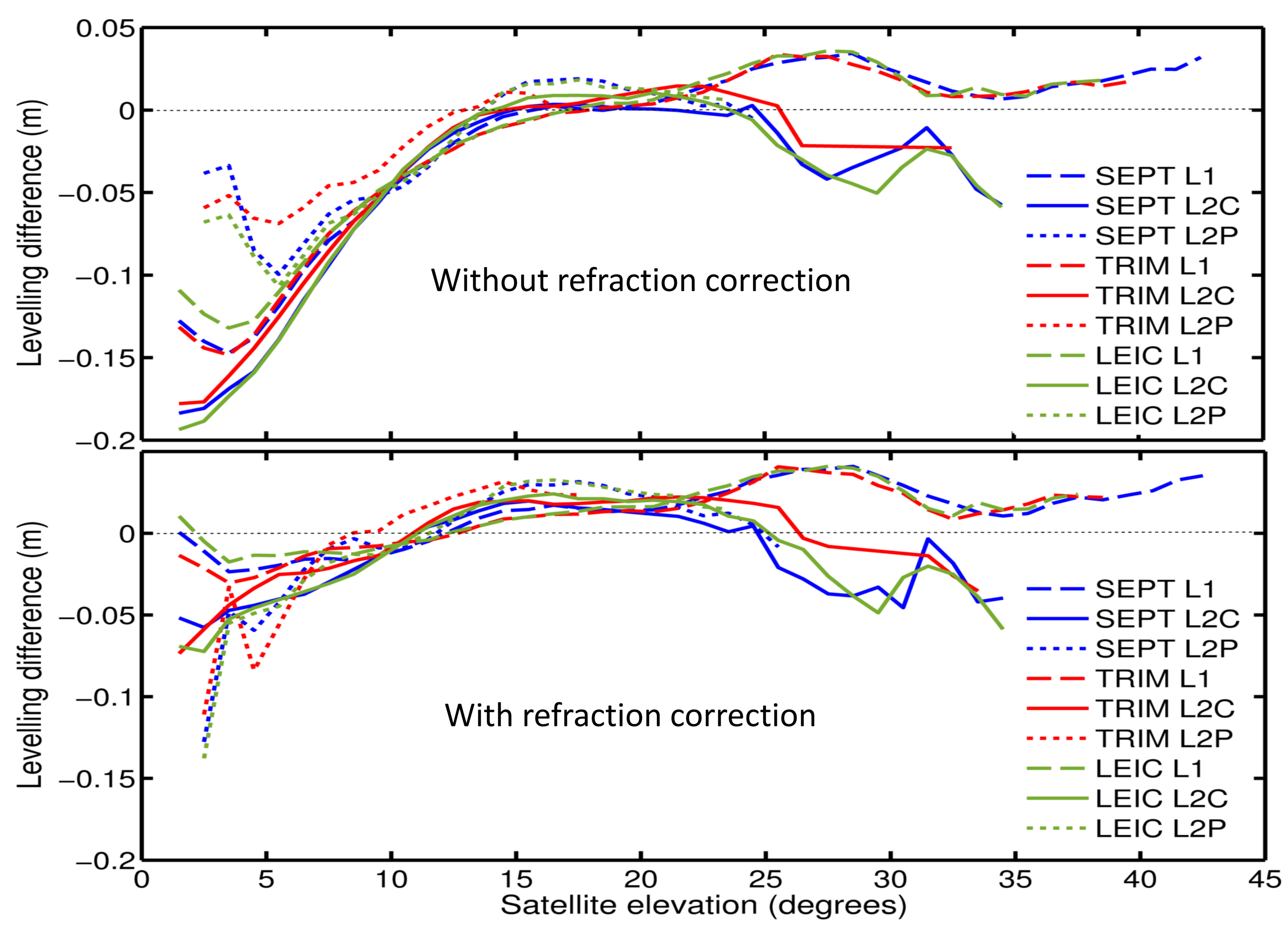
Moving average of levelling differences wrt to in situ values at eight different sites using the GPS L1 signal.



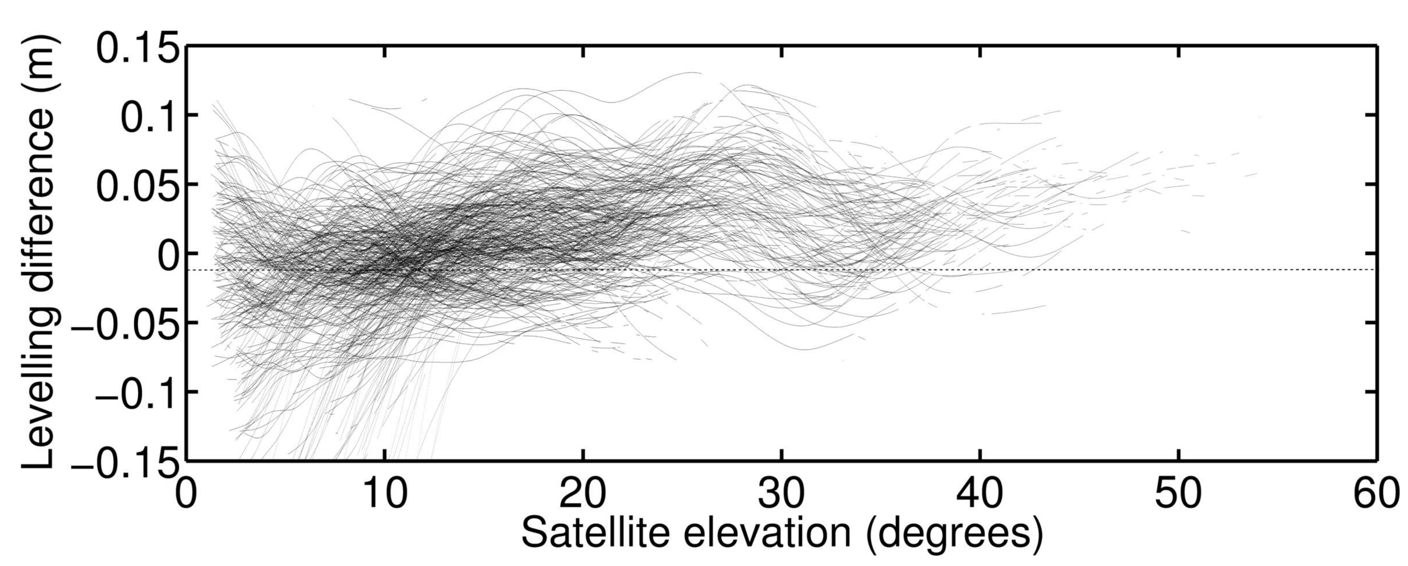
Scatter of satellite ground tracks used to estimate the levelling at Roscoff (France). By using the tide gauge observations, the sea-surface reflections can be isolated from other reflectors near the antenna.

2) Follow up experiment: Spring Bay, Australia

- Difference with in situ levelling of 11 cm at this site (receiver or tide gauge or sea-surface problem?)
- New experiment: observations with three different receivers connected to same antenna placed sideways.
- All receivers and signals provide consistent results between 5 and 25 degrees elevation.
- Elevation-dependent error reduced when correcting for atmospheric refraction.
- **Above 5 degrees elevation, mean differences with in situ levelling less than 1 cm and repeatability of levelling estimates of 3 cm.**
- GPS L2P provides good results when L1 interference is filtered out.



Moving average of levelling differences wrt to in situ values at Spring Bay from three different receivers (Septentrio, Trimble, Leica) and different GPS signals (L1, L2C, L2P)



Scatter of levelling differences at Spring Bay for all observed satellites in January 2015 using L1 signal from a Leica receiver.

Further work and problems still to solve

- Tropospheric refraction at low elevation needs accurate modelling.
- Differences between upright and sideways antenna: antenna & surface response still to be better understood.

More details and information

Santamaría-Gómez et al. 2015. Levelling co-located GNSS and tide gauge stations using GNSS reflectometry. J. of Geodesy, 89.

The authors thank Geoscience Australia for providing the receivers used at the Spring Bay experiment.