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Subject
MSc Project: GPS Interferometric Reflectometry and land subsidence

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Short summary:

We propose an MSc project topic on GPS Interferometric Reflectometry and land subsidence. The project will be executed at TNO AGE and GM in collaboration with and supervised by TU Delft Geoscience and Remote Sensing research group. We aim for a master's student from TU Delft's Geoscience and Remote Sensing master track or from Faculty of Aerospace Engineering, who are familiar with space-based earth observation methods. The student will work closely with the Bonn University, Institute of Geodesy and Geoinformation research group.

Project Synopsis:

The Netherlands is subject to anthropogenic and natural subsidence with present rates, which are an order of magnitude higher than sea-level rise. Subsidence threatens the country's viability and has significant socio-economic consequences: it may increase flood risks during storm surges and high river water levels, damage infrastructures and houses, and causes saline water intrusion.

Processes that cause anthropogenic subsidence are generally divided into deep (ca. >500 m), middle-deep (ca. >20 m and <500 m) and shallow sourced (ca. <20 m), roughly corresponding to depth intervals of hydrocarbon extraction and salt mining, groundwater pumping, and surficial processes respectively. The latter comprises various processes, such as phreatic groundwater lowering, excess overburden by man-made ground, and mining-related sinkholes. Furthermore, besides sometimes occurring all together at the same location, these processes are superimposed on naturally occurring subsidence processes related to tectonic movements and glacial isostatic adjustments. Anthropogenic causes of subsidence at different depths and natural subsidence accumulate and are expressed as total surface elevation lowering.

A critical step in mitigating anthropogenically caused subsidence is disentangling subsidence rates of processes at different depths. New advancements in geodesy[1,2] enable disentangling the contribution of surficial and deeper surface displacement-related processes. With GPS Interferometric Reflectometry (GPS-IR) subsidence rates can be identified from processes deeper and shallower than the GPS foundation level respectively (Fig. 1). This is a relatively new application as GPS-IR has mostly been used for sea-level measurements[1] once a single GNSS station has proven the capability of reproducing tide-gage measurement accuracies. Since GPS station foundation depths are typically in the upper tens of meters of the subsurface (either direct or attached to buildings), we hypothesize that this method can be deployed in the Netherlands to distinguish subsidence by shallow soil compaction and oxidation from deeper processes.

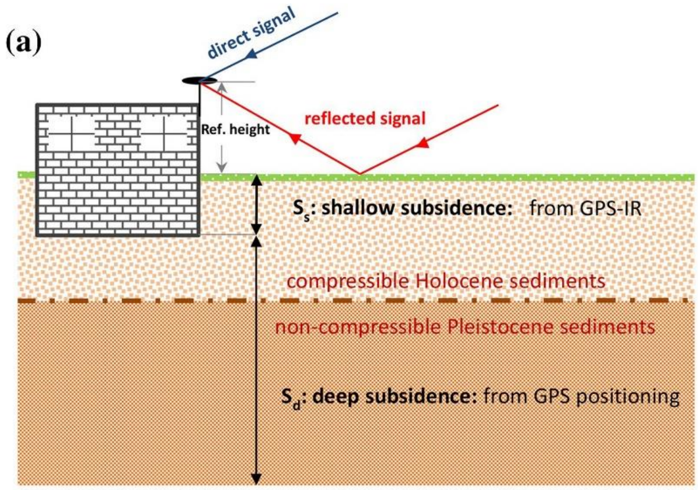

Figure 1 – Schematic overview of subsidence measurements using GPS IR[1].

The GPS-IR technique uses two signals received at the GPS antenna (direct and reflected - Fig 1) to allow the estimation of the vertical component of the shallow subsidence. We can extract the three displacement components at the antenna position estimated between the GPS satellites and the antenna from the direct signal. From the interference reflected signal with the direct signal, a characteristic oscillation pattern emerges on top of a long-time trend in the SNR data from which the shallow sources of surface displacement can be estimated.

At TNO, we are developing model approaches to forecast subsidence, which comprises forward and inverse modelling techniques, and uses a suit of subsurface information as input (Fig. 2). It is essential to incorporate observed subsidence derived from geodetic information such as GPS stations in the workflow to confront the subsidence predictions. Therefore, the potential of the new advancements made with GPS IR and shallow subsidence estimation could be a critical step forward in this part of TNO's modelling workflow.

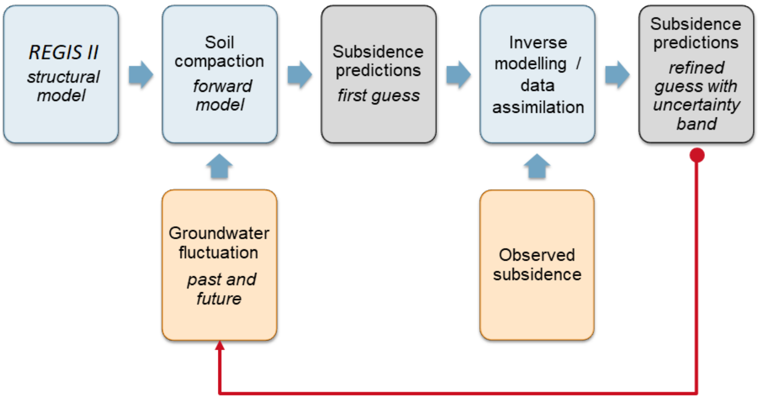

Figure 2 - Overview of the main steps of the workflow developed at TNO. Observed subsidence comprises geodetic information[2].

Application in the Netherlands

The application of GPS-IR will be performed on all GPS stations operating in the Netherlands.
Some locations may be better than others for the application IR, especially concerning the surroundings of the GNSS antenna. One exciting test site is the continuous GNSS station Zegveld which shows good reflection zones (Figure 3). This site does not have environmental interference (e.g. buildings), but the high vegetation density makes it equally interesting as the reflection is also sensitive to vegetation growth. At the antenna location, two corner reflectors are also oriented to ascending and descending geometry of SAR acquisitions. These corner reflectors (CR) allow the retrieval of the time series of displacements at the CR location from InSAR and, therefore, confirm the displacements derived from GNSS-IR.

For more challenging sites, complementing the GPS with Glonass and Galileo satellite data might help narrow down the detected signal's error bar.

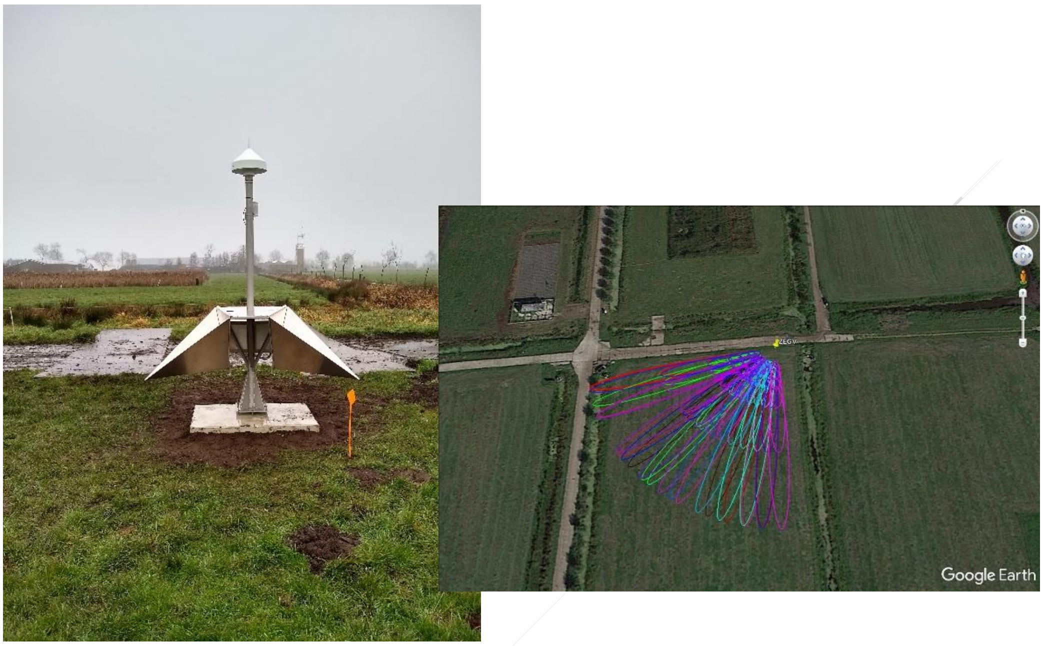

Figure 3 – Left: Picture of the ZGVLD GSNN antenna and two corner reflectors. Right: Reflection sensing zones, Zegveld.

The preliminary research questions we would like to be answered are:

- What are the necessary requirements and tools to deploy and process GPS-IR techniques to measure shallow subsidence processes such as due to peat oxidation?
- What are the estimated accuracies, and how are the estimated subsidence rates comparable with other measurements?
- Can the GPS-IR accuracies be improved using Galileo and Glonass satellites - GNSS-IR?
- How can GNSS and InSAR time series be compared/combined to obtain a realistic total subsidence rate, along with its uncertainty, for the area of interest?

Trainee:	TNO supervisor:	TU Delft supervisor:	Bonn supervisor
Signature:	Signature:	Signature:	Signature:
Date:	Date:	Date:	Date:

References

[1]Larson KM, Löfgren JS, Haas R (2013a) Coastal sea level measurements using a single geodetic GPS receiver. Adv Space Res 51(8):1301–1310

[2]Karagar et al. (2020), Novel quantification of shallow sediment compaction by GPS Interferometric Reflectometry and implications for flood susceptibility. GRL 47(14)

[3]Candela et al. (2020), Towards regionally forecasting shallow subsidence. PIAHS 382