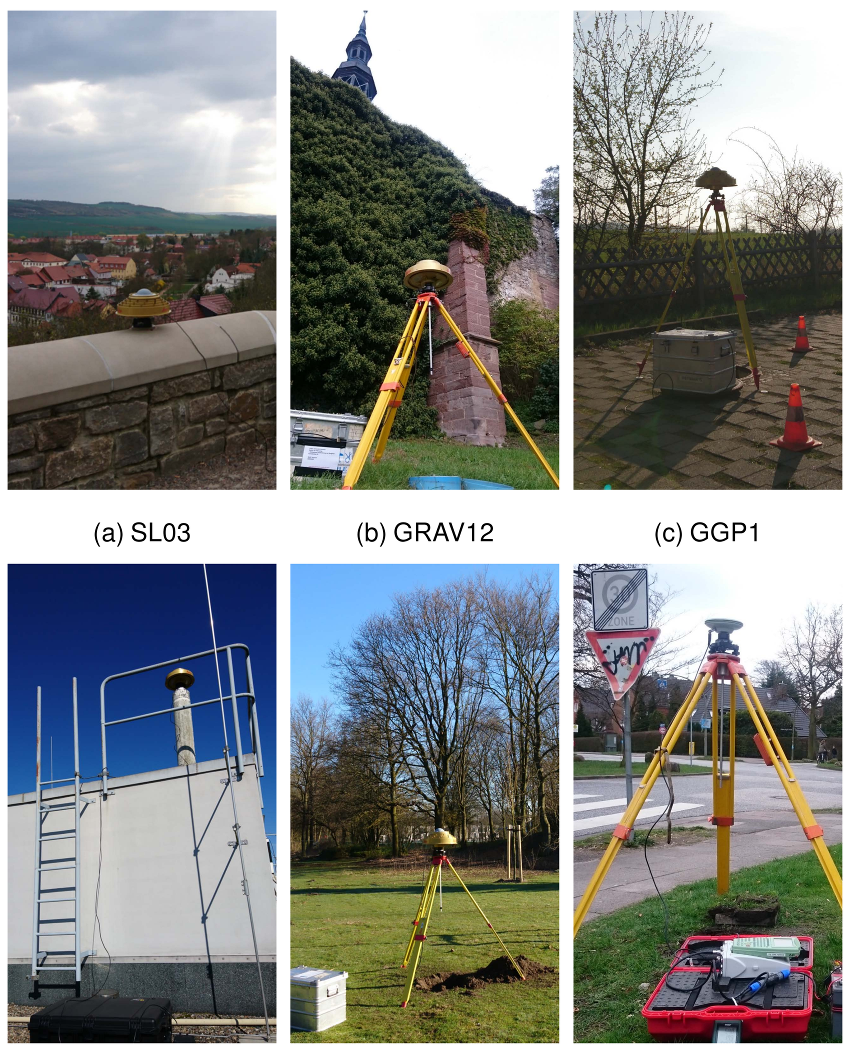
# The Joint Research Project SIMULTAN
# WP3.1: GNSS Campaigns and Research


Tobias Kersten and Steffen Schön

Institut für Erdmessung | Leibniz Universität Hannover | {kersten, schoen}@ife.uni-hannover.de


## Urban GNSS Sites and Campaign Design


(a) SL03 (b) GRAV12 (c) GGP1

(d) HHDE (e) HH01 (f) HH09

**Figure 1:** Co-located urban GNSS sites as part of geo-monitoring networks to control and observe subsidence processes, (a-c) Bad Frankenhausen (Thuringia), (d-f) Hamburg Groß-Flottbek.

### SIMULTAN-Project

- **S**inkhole **I**nstability, **MULT**iscale monitoring and **AN**alysis: gain a deeper understanding of the complex processes, interactions and characteristics of the underground and the surface interaction in urban environments, [Kersten et al., 2017].

### GNSS-Campaign Design in SIMULTAN

- Multi-GNSS equipment (Leica GRX1200+GNSS, Novatel 703GGG, Leica AR25.R3) with height adaptor FG ANA 100B for precise height determination.
- Four hour sessions, at least 3 independent repetitions per site.
- Data recording (1 Hz) at co-located sites (GNSS, levelling, gravimetry).
- Star-like GNSS monitoring network, fixed in local reference stations.

### Urban GNSS Sites

- Urban infrastructure yields to variable and high multipath as well as challenging satellite geometry at each co-located site.
- Short baselines of approx. 700-1800 m.

## Hamburg - Network

- **HHDE:** Local reference station at DESY (Deutsches Elektronen-Synchrotron), stability check by SA*POS*® stations (Lower Saxony) Buchholz (0680), Stade2 (1662), Lüneburg (0660).
- **HH01:** Co-located site in a park with several trees which reduces satellite visibility at low elevations.
- **HH05:** Site located in proposed stable environment, northern part, close to DESY. Used to monitor subsidence in Wobbe-See (HH02-HH04) and the old storage basin (HH08).
- **HH03:** Co-located site to monitor subsidence; challenging satellite visibility, cf Fig. 3.

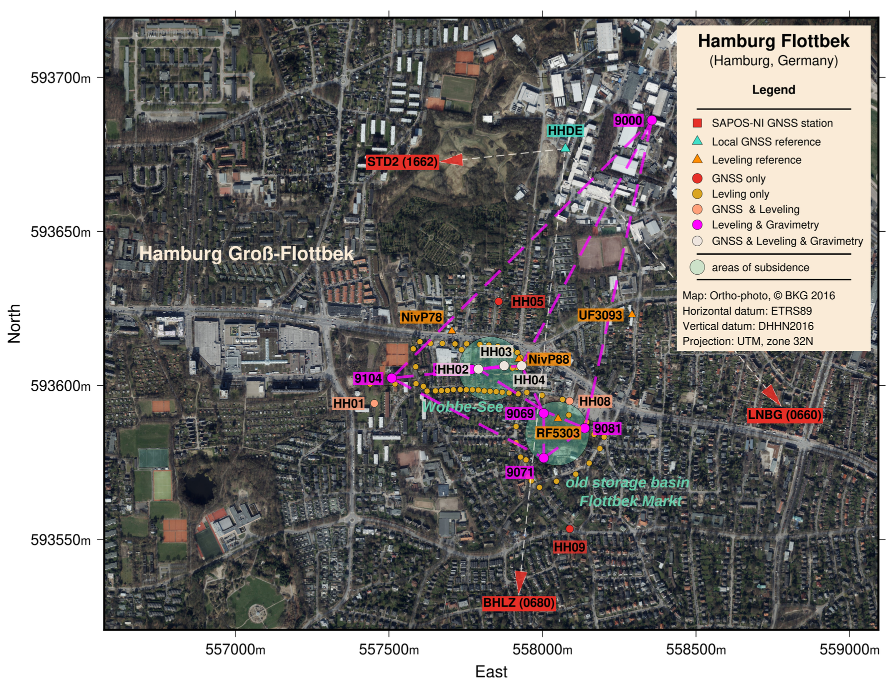
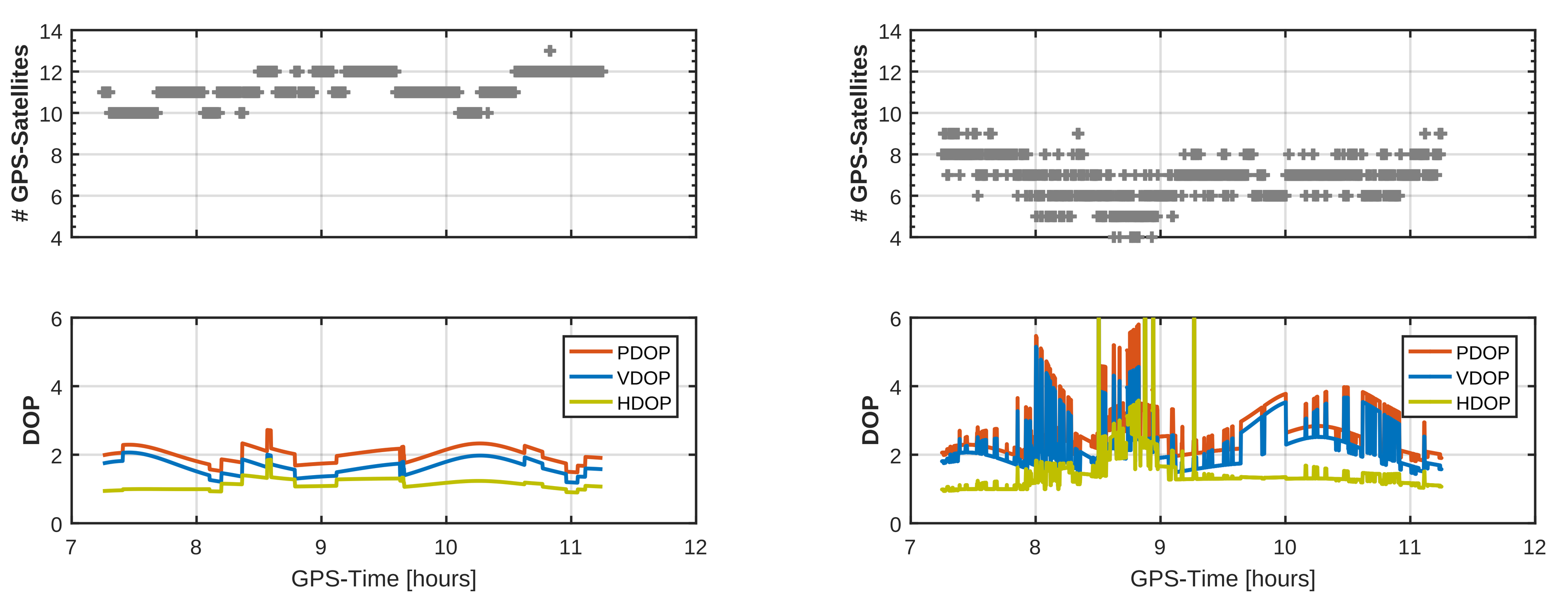



**Figure 2:** Combined geophysical network in Hamburg, Groß-Flottbek.




(a) DOP values at HHDE (b) DOP values at HH03

**Figure 3:** Comparison of several DOP-Values (dilution of precision) and overall satellite visibility as quality indicators for characteristic sites of he monitoring network for the local Reference HHDE (a) and a site in the Wobbe-See subsidence area HH03 (b).

## Hamburg - Details

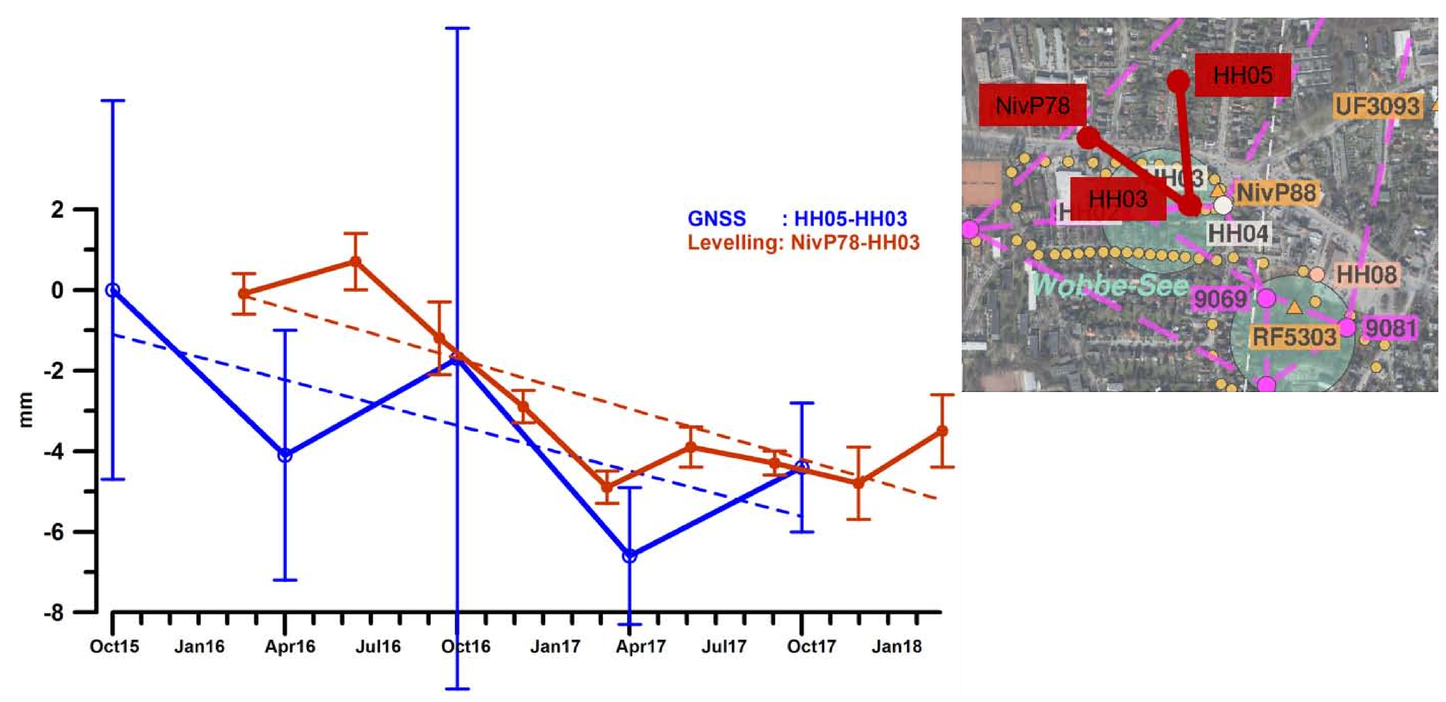



**Figure 4:** Temporal variation for specific height difference in the vicinity of Wobbe-See (HH03) by leveling (ref. to Niv.P78) and by GNSS (ref. to HH05). Both points are located in the north of the subsidence area.

- Subsidence processes observed although the scale of drift is very small (1.5-2 mm).
- Independent methods (leveling and GNSS) agree very well and show drift in the areas of interest.
- Results evaluated in cooperation with AP/WP 3.2 and 3.3, gravity changes between sites indicate furthermore mass transport (separation from seasonal signals), [Weise et al., 2017a, Weise et al., 2018].

## Hamburg - GNSS Repeatability

### Findings

- Generally, repeatability with magnitudes of 2 mm achieved, higher values caused by vegetation and frequent traffic at sites.
- Optimal location for co-location sites of interest (leveling, gravimetry) not at any time feasible, cf. Fig. 3, [Icking et al., 2016].
- Magnitudes of RMS generally at 0.3-0.4 mm and 0.2-0.3 mm (optimal sites), respectively (cf. Fig. 5).

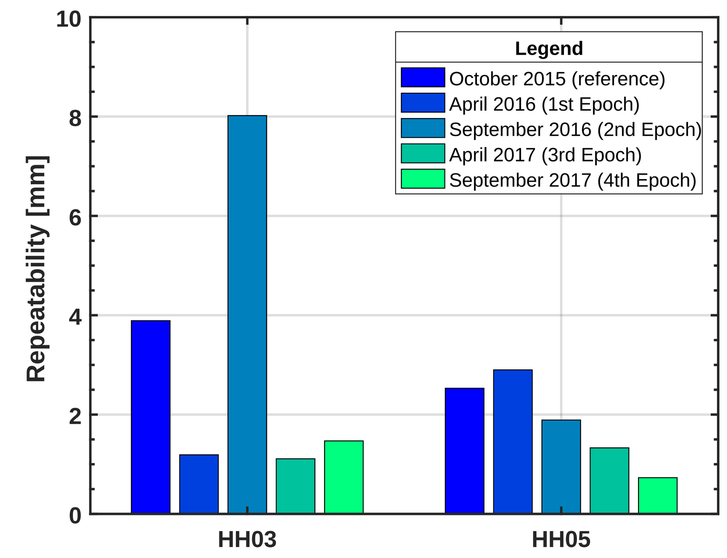
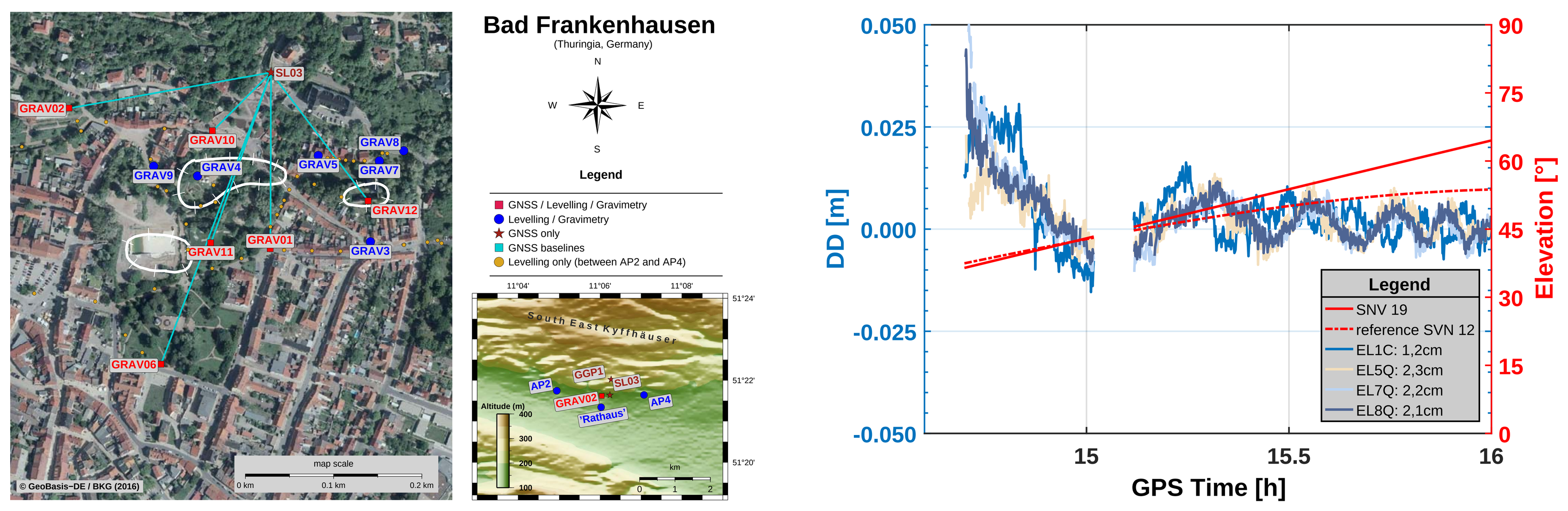



**Figure 5:** Characteristic repeatability of co-located sites to monitor subsidence in different scales (time, depth, spartial).

## Bad Frankenhausen - Network




(a) GNSS network Bad Frankenhausen (b) SL-12: DD and elevation versus GPS Time

**Figure 6:** Analysis of Galileo GNSS sites, (a) network with indicated baseline, (b) double difference residuals for four hour session captured at GRAV12 (cf. Fig. 1b).

- **SL03:** Local reference station (stability check by SA*POS*® stations Erfurt (0209), Buttstädt (0221), Sondershausen (0200), Mühlhausen (0214)).
- **GRAV12:** Co-located point in close vicinity to a concrete wall (located in the north of the GNSS site), challenging obstruction geometry present.
- **Baseline SL03-GRAV12 (SL-12):** 190 m, significant impact of multipath detectable.
- Multipath signatures detectable (sinusoidal) with frequencies of ≈20 minutes that lead to amplitudes in Galileo DDs (E5a, E5b and AltBOC E5a+b) although low noise is present. Highest noise on Galileo E1 signal detected, [Ruwisch et al., 2016].

## Conclusions and Further Steps

- Study of Galileo observations in challenging, urban environments by [Ruwisch et al., 2016].
- Challenging satellite geometry improved by applying adaptive dynamic elevation masks (dynMsk) studied by [Icking et al., 2016].
- Campaigns finished and processing of epoch comparisons ongoing; solutions published frequently.
- Data provided through WebDAV server for both projects (HHX and BFH) for dedicated WP partners.

### Ongoing and further steps

- Development and evaluation of integrated model for leveling and gravimetric data sets, [Kersten et al., 2017, Weise et al., 2017b].
- Quantification and separation of superimposed signals as e.g. hydrological, atmospheric, seasonal variations and tidal effects.
- Studies and application of GNSS low-cost reference stations in combination with urban infrastructure as street furniture like, e.g. streetlamps etc., [Kröger et al., 2017] to gain consistent and longer time series.


### Acknowledgement & Funding

**Acknowledgement** The authors thank the TLVerm Thuringia, the Glückauf Vermessung GmbH Sondershausen, the MEA2 Group of the German Electron Synchrotron (DESY) and the city of Bad Frankenhausen for their kind and friendly cooperation. Additional FG ANA 100B GNSS height adaptors and corresponding accessories were provided by the LGLN (Lower Saxony). The Center of Orbit Determination in Europe (CODE) is grateful acknowledged for providing freely high precise orbits and corresponding products.

**Funding** The work in the project of SIMULTAN is funded under the grant 03G0843D by the Federal Ministry of Education and Research, based on a resolution by the German Bundestag.


### References


Icking, L., Kersten, T., und Schön, S. (2016). Dynamische und adaptive Elevationsmasken zur Optimierung von GNSS-Netzen. In *Geodätische Woche 2016, 11.-13. Oktober, Hamburg.*

Kersten, T., Kobe, M., Timmen, L., Schön, S., and Vogel, D. (2017). Geodetic Monitoring of Subrosion-Induced Subsidence Processes in Urban Areas - Concept and Status Report. *Journal of Applied Geodesy*, 11(1):21–30. DOI: 10.1515/jag-2016-0029.

Kröger, J., Kersten, T., und Schön, S. (2017). GPS/GNSS Low Cost Permanent-Stationen für urbane Monitoringnetze. In *Geodätische Woche 2016, 26.-28. September, Berlin.*

Ruwisch, F., Kersten, T., und Schön, S. (2016). GNSS-Doppeldifferenzanalyse für urbane Monitoring-Ansätze. In *Geodätische Woche 2016, 11.-13. Oktober, Hamburg.*

Weise, A., Gabriel, G., Kersten, T., Schön, S., Timmen, L., und Vogel, D. (2017a). Deformationsüberwachung mit Gravimetrie? Ein Experiment im Erdfallgebiet in Hamburg-Flottbek. In *Jahrestagung der Deutschen Geophysikalischen Gesellschaft, March 27-30, Potsdam, Germany.*

Weise, A., Kersten, T., Schön, S., Timmen, L., und Vogel, D. (2017b). Deformationsüberwachung mit Gravimetrie? Ein Experiment im Erdfallgebiet in Hamburg-Flottbek. In *Proceedings of 77. Jahrestagung der Deutschen Geophysikalischen Gesellschaft, March 27.-30., Potsdam, Germany.*

Weise, A., Kersten, T., Timmen, L., Gabriel, G., Schön, S., und Vogel, D. (2018). Ein integrativer geodätisch-gravimetrischer Ansatz zur Erkundung von Subrosion im Erdfallgebiet Hamburg Flottbek – Oberflächendeformation und Massentransfer. *Allgmeeine Vermessungsnachrichten - Sonderheft Geomonitoring, Seiten 1–16. (accepted).*



(Projektträger Jülich :: Status-Seminar Dresden, Grant-ID: 03G0843D) Created with LaTeX


SIMULTAN Research Group