Detecting (very slow) natural ground motion in Schleswig-Holstein from radar satellite data

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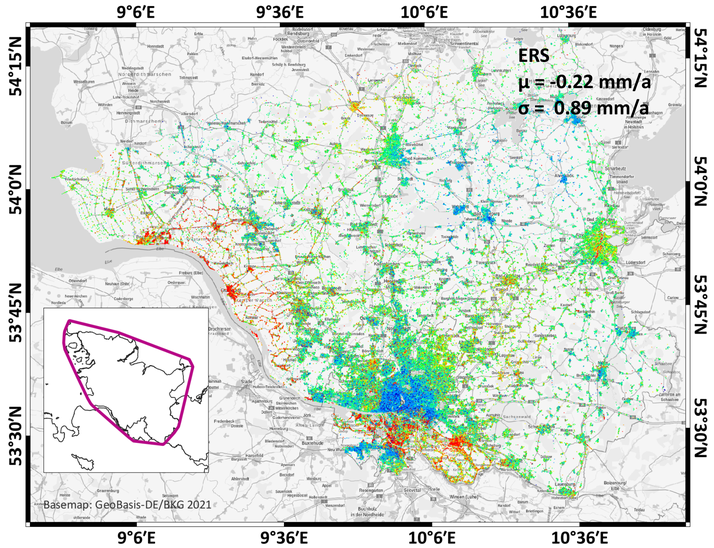

Introduction

The near-surface geology of Schleswig-Holstein is characterized by glacial deposits, deformed by rising Permian and Upper Triassic salt structures. Ground motions potentially associated with these processes are extremely slow and are superimposed by signals of e.g. hydrological and anthropogenic sources.

To measure ground motion, we use radar interferometric time series data provided by the German Aerospace Center and the Federal Institute for Geosciences and Natural Resources' Ground motion service. These data are based on Synthetic Aperture Radar images acquired by ESA's ERS and Sentinel satellites. Time-series analyses are possible for temporally stable backscattering objects (persistent scatterers[i]) on the ground. Here we present results of an InSAR time series analysis over Schleswig-Holstein from ERS satellite date that spans the time between 1991 and 2001 (Fig. 1), supplemented by results derived from Sentinel-1 data (Fig. 4-6).

Fig. 2: Ground motion rates calculated from ERS data and extent of ERS data acquisition area over Schleswig-Holstein (colored dots). and extent of Sentinel-1 data qcquistion area over Schleswig-Holstein (small map).

Methods

We measure ground motion with InSAR-satellite data, where the distance, χ, in line of sight ist given as a change in phase, Φ, by $\Phi = 4\chi\pi/\lambda$ (λ = wavelength of the signal) and ground motion is calculated as the difference between the distances measured during two distinct overflights (Fig. 2). Where applicable, the motion rates measured at high voltage AC transmission towers are used to calibrate the data. To assess ground motion rates over a region like Schleswig-Holstein, where ground motion is more a variation of nothing than a fast process, a relative scale of sigma-classes is used instead of an absolute scale[ii] (Fig. 3). The basis distribution of those sigma-scales is the distribution of ground motion rates over the hydrogeological region, in which an area of interest is located.

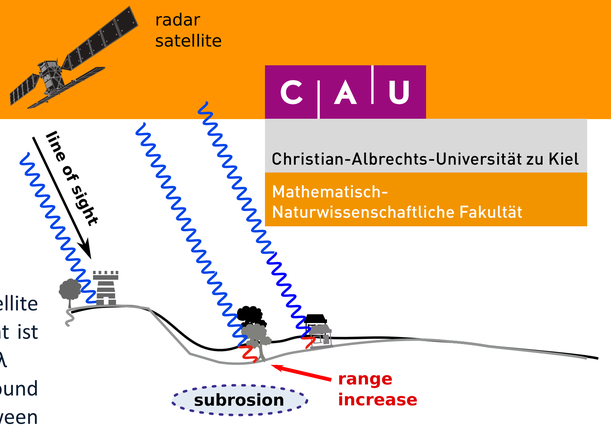

Fig. 2: The basic principle of the SAR acquisition geometry and InSAR method

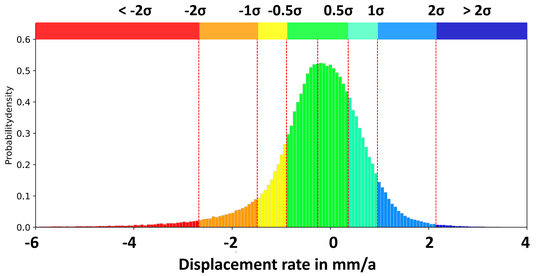

Fig. 3: Scale of sigma-classes over the hydrological region Neustadt-Lübecker Becken.

Preliminary Results

Lübeck's Historic City

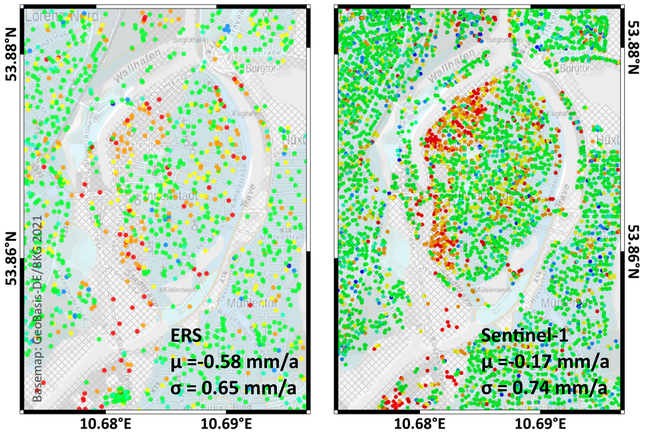

Fig. 4: Lübeck's old town seen from ERS satellite (left) and Sentinel-1 (right).

An area of increased subsidence runs along the west of Lübeck's old town, tracing regions where fills were placed over moorlands (Fig. 4).

Elbemarshlands/Nuclear Plant Brunsbüttel

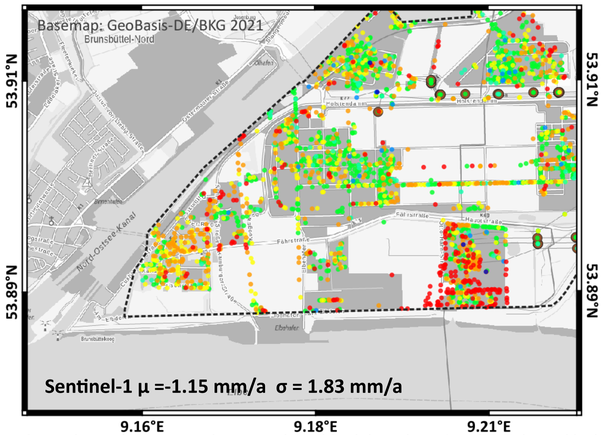

Fig. 5: The nuclear power plant Brunsbüttel (red dotted area) at the Kiel Canal locks.

The ERS data show a vast region of increased subsidece along the river Elber (Fig. 1) with particularly high sudsidence rates at industrial buildings like the nuclear plant at Brunsbüttel (Fig.5).

Kalkberg Bad Segeberg

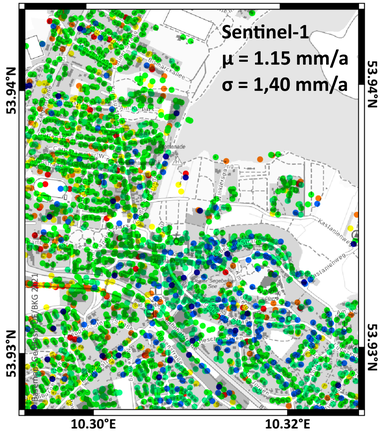

Fig. 6: The Kalkberg in Bad Badsegeberg

The swelling of Permian anhydrite causes upward movements at the "Kalkberg" in Bad Segeberg (Fig.6).

Conclusions and outlook

PS-InSAR measurements ar a valuable tool to detect ground motion even over regions where such geological processes extremely slow. The most challenging tasks are the leveling of data from different satellites and different satellite tracks to a common reference point and the dcomposition of signal in order to distinguish anthropogenic from geological and hydrogeological causes.

References

The work on the ERS data is based data provided bei the German Aerospace Center (DLR), processed in connection with the development of the Wide Area Product (WAP) by Nico Adam[iii].

i Ferretti, A., Prati, C., & Rocca, F. L. (1999). Permanent scatterers in SAR interferometry. https://doi.org/10.1117/12.373150

ii Hoogestraat, D. H. (2019). Auswertung von Zeitreihen stabiler Streupunkte (persistent scatterer) aus InSAR-Satellitenaufnahmen hinsichtlich Bodenbewegungen im Raum Hamburg und Schleswig-Holstein. BSc-Thesis, Kiel University (DE), Inst. f. Geosciences

iii Adam, N., Rodriguez Gonzalez, F., Parizzi, A., & Liebhart, W. (2011). Wide area persistent scatterer interferometry. https://doi.org/10.1109/IGARSS.2011.6049347