UPLIFT ANALYSIS IN THE CITY OF BÖBLINGEN USING PS-INSAR

Bence Ambrus, PhD student, Department of Geodesy and Surveying, Budapest University of Technology and Economics

Email: ambrus.bence@epito.bme.hu Website: www.geod.bme.hu/ambrus-bence

Karlsruher Institut für Technologie

BUDAPESTI MŰSZAKI
ÉS GAZDASÁGTUDOMÁNYI EGYETEM
Építőmérnöki Kar - építőmérnöki képzés 1782 óta
Általános és Felsőgeodézia Tanszék

Abstract

During the period between 2006 and 2008, geothermal drillings were carried out in the city of Böblingen in Baden-Württemberg, Germany. Because of presumable faulty execution, groundwater was leaked into layers with considerable clay content prone to expansion. The uplift generated by the expanding clay quickly reached the order of 5 cm/year and resulted in significant damage to residential buildings and other structures. By using the PS-InSAR technique and processing archived Envisat data acquired between 2002 and 2010, our task was to help identify the uplift's spatial and temporal point of origin.

Introduction and objectives

Residents of Böblingen (located in the state of Baden-Württemberg, south-west Germany) started experiencing structural damages in their buildings in early 2011 (see *Figure 1*). As the number of reports began to pile up in mid-2011, the authorities lead an investigation into the phenomenon which showed that in total more than 40 cm of uplift had taken place. Suspicions arose that the surface movement was somehow tied to the geothermal drillings carried out in the area between 2006 and 2008. Namely, that faulty execution of the drillings led to water leakage into the gypsum layers beneath the surface. These layers expanded, leading to the uplift of the ground and as a consequence, structural damage in the buildings.

A project, funded by the Ministry of Environment, Climate Protection and the Energy Sector in Baden-Württemberg, was created with the objective of using SAR data and the PS-InSAR processing technique to investigate the temporal and spatial starting point of the uplift and whether the phenomenon has any correlation with the geothermal drillings in the area.

The main data processing and interpretation were carried out by a team consisting of researchers and PhD students from the Institute of Geodesy at the Karlsruhe Institute of Technology (GIK-KIT).

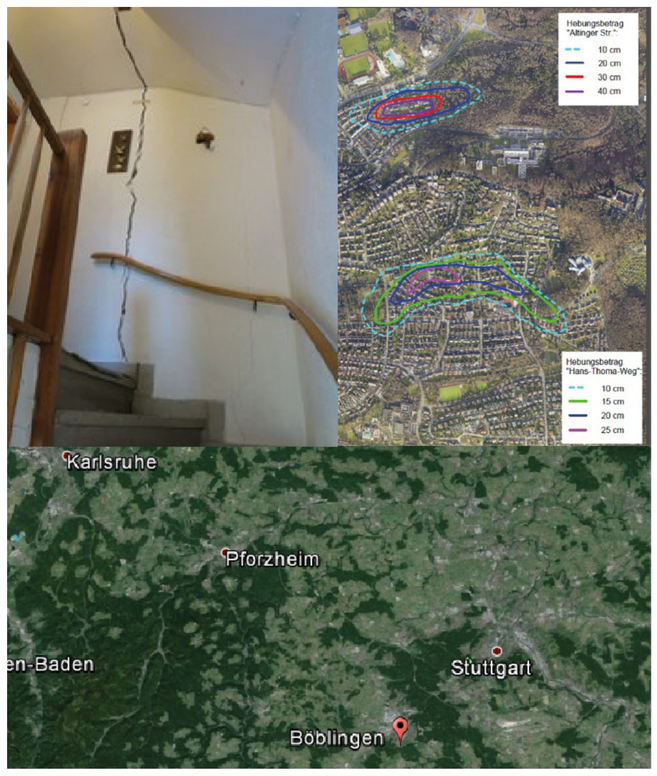


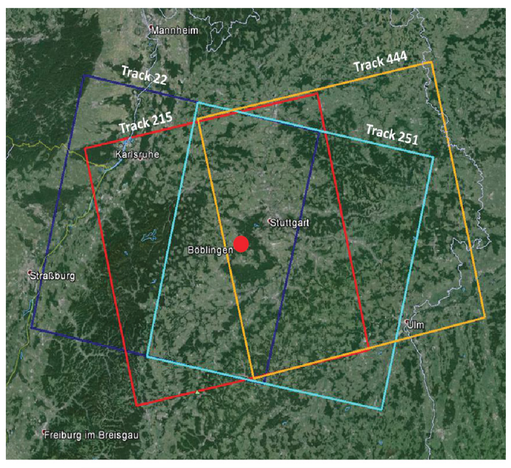
Figure 1. An example of the structural damages (upper left), the uplift area inside the city (upper right) and the location of Böblingen (bottom). Source: Thomas Fuhrmann (GIK-KIT).

Data used in the project

Starting from mid-2011, the uplifting areas as well as the uplift rates are well documented with data from several surveying methods. However, preceding this period, little to no information is available about the sites. In a situation like this, the application of previously acquired and archived SAR data can prove to be invaluable if acquisitions with sufficient temporal resolution are available that cover the area of interest.

Inside the frame of the project, data acquired by ESA's Envisat satellite between 2002 and 2010 were used, two tracks from both ascending and descending orbits with 104 SLC scenes spread throughout the acquisition period (as shown in *Figure 2*). The two different orbits allowed for a multi-track processing approach with the advantages of denser PS points, more reliable assessment of deformation and the separation of the vertical and horizontal components of the ground movement.

In the earlier part of the project, only the data from two tracks were processed (tracks no. 22 and 251). The results shown here are solely from track 22.



Track	Period	No.
22	2003/03 – 2010/09	32
251	2002/10 – 2010/10	36
215	2004/10 – 2008/09	17
444	2002/10 – 2010/08	15

Figure 2. The location, number and time period of the Envisat scenes used in the project. Source: Thomas Fuhrmann (GIK-KIT).

Data processing

The main data processing was carried out using the DORIS and the StaMPS software packages. Using a single scene as the master, first preliminary coherence was calculated between each master-slave combination according to [Kampes, 2005]. Basic intuition would suggest that the ideal master scene is located in the middle of the acquired SLC stack to reduce the temporal baseline.

However, during the project, we wanted to maximize the number of data points inside the time interval of the geothermal drillings which would result in a master scene outside of the middle of the stack. After initially taking this approach, the master scene for the particular track had to be changed to 31/10/2007, which unfortunately meant one less scene inside the interval of interest. Two additional scenes had to be excluded from the processing due to their low preliminary coherence, making the total number of scenes 30 (including the master).

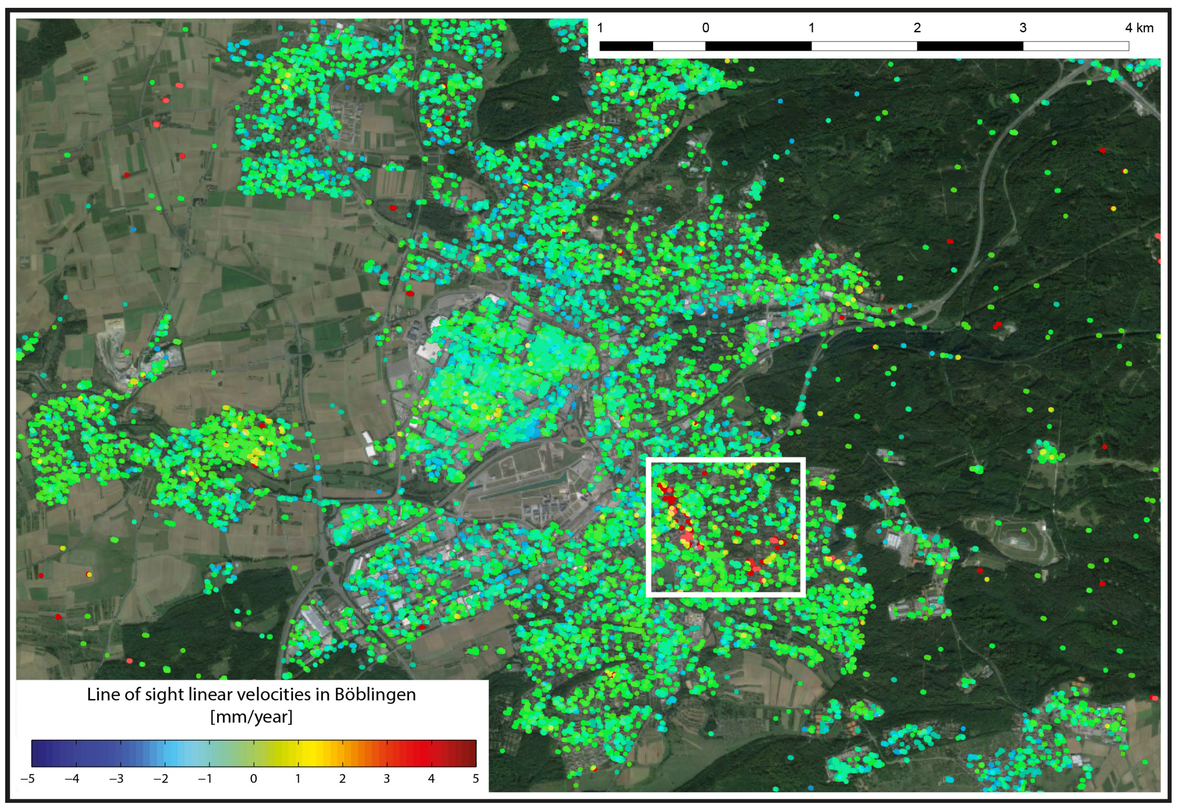


Figure 3. Linear velocity of each PS-point inside the city after the processing.

Discussion and conclusion

On the left, *Figure 3* shows the results of the PS-processing for the entire area of the city. In the middle, marked with a white rectangle, two uplift zones can be distinguished. Taking a closer look (*Figure 4*), we can see that the areas 1, 2 and 3 are located rather close to the drillings (marked with blue star symbols) and according to the PS time series on *Figure 5*, show considerable uplift taking place. The time series also indicate, that in areas 2 and 3 the deformation has a distinct temporal starting point that can be placed between mid-2006 and early 2007, coinciding with the period of the geothermal drillings. However, area 1 appears to show a linear deformation trend, the starting point of which cannot be concluded from the time series as it seems to predate the earliest data acquisition available for the processing. Moreover, area 4, which has geothermal drilling locations spread all over it, shows little to no sign of any uplift or any kind of significant movement for that matter.

The reason behind these peculiar deformation figures is speculated to be of geological origin, namely, the location of the gypsum layers with expanding capabilities is definitely not homogeneous underneath the city. Unfortunately, the geological maps of the surrounding area cannot provide the sufficient resolution and accuracy to completely back up these speculations, still, the geological reasons seem to be the most logical.

Nevertheless, the results from areas 2 and 3 clearly demonstrate that the uplift in these zones started after the drillings began to take place in the area.

Major references

Ferretti A., Prati C., & Rocca F. (2001). Permanent scatterers in SAR interferometry. Ieee Transactions on Geoscience and Remote Sensing, 39(1). doi: Doi 10.1109/36.898661

Kampes B. M. (2005). Displacement parameter estimation using permanent scatterer interferometry. (PhD thesis), Delft University of Technology, The Netherlands.

Anderssohn J. (2014, September). Bodenbewgungsmonitoring, Böblingen. [Monitoring of surface movement, Böblingen]. Conference proceedings, Stuttgart.

Westerhaus M. (2015). Einsatz der Multi-track SAR-Interferometrie zur Bestimmung von Beginn und Ausgangspunkt des Hebungssignales in Böblingen. [The use of Multi-track SAR-Interferometry to determine the spatial and temporal starting point of the uplift signal in Böblingen]. Geodetic Institute, Karlsruhe Institute of Technology.

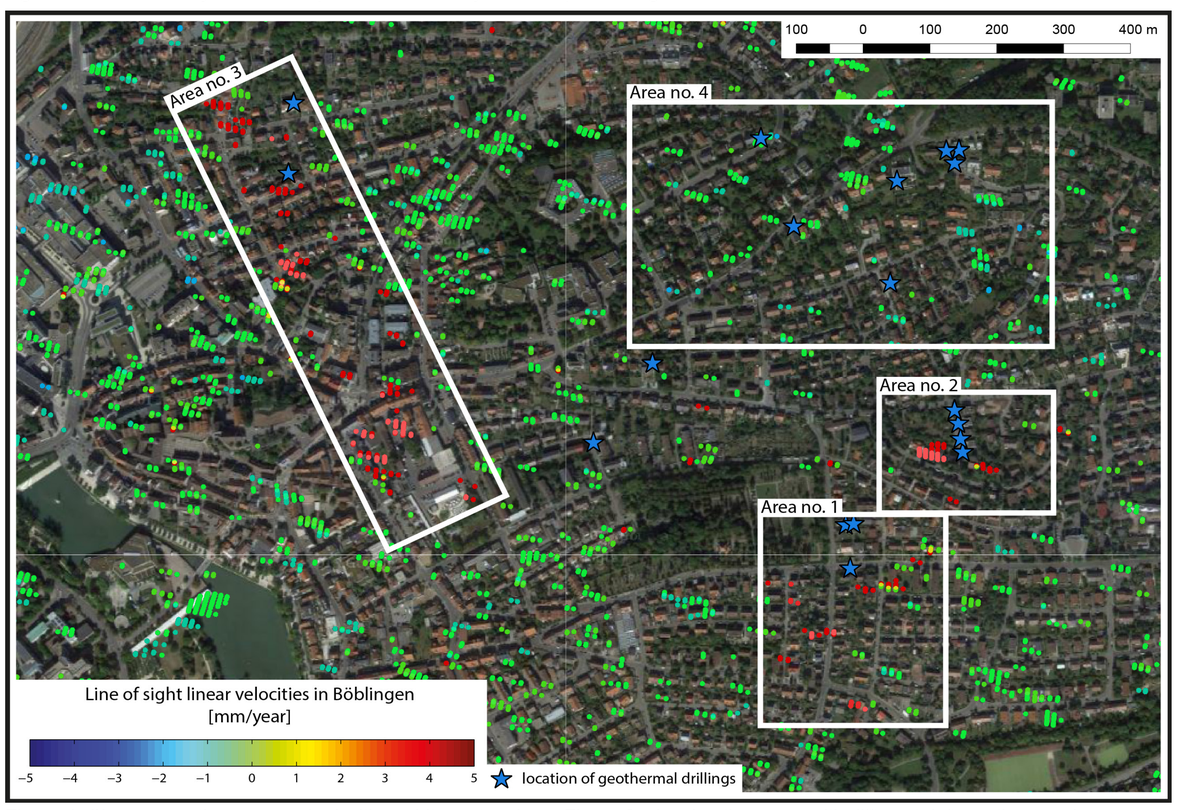


Figure 4. Close-up on the area marked with a white rectangle on Figure 3, showing the areas with different deformation trends.

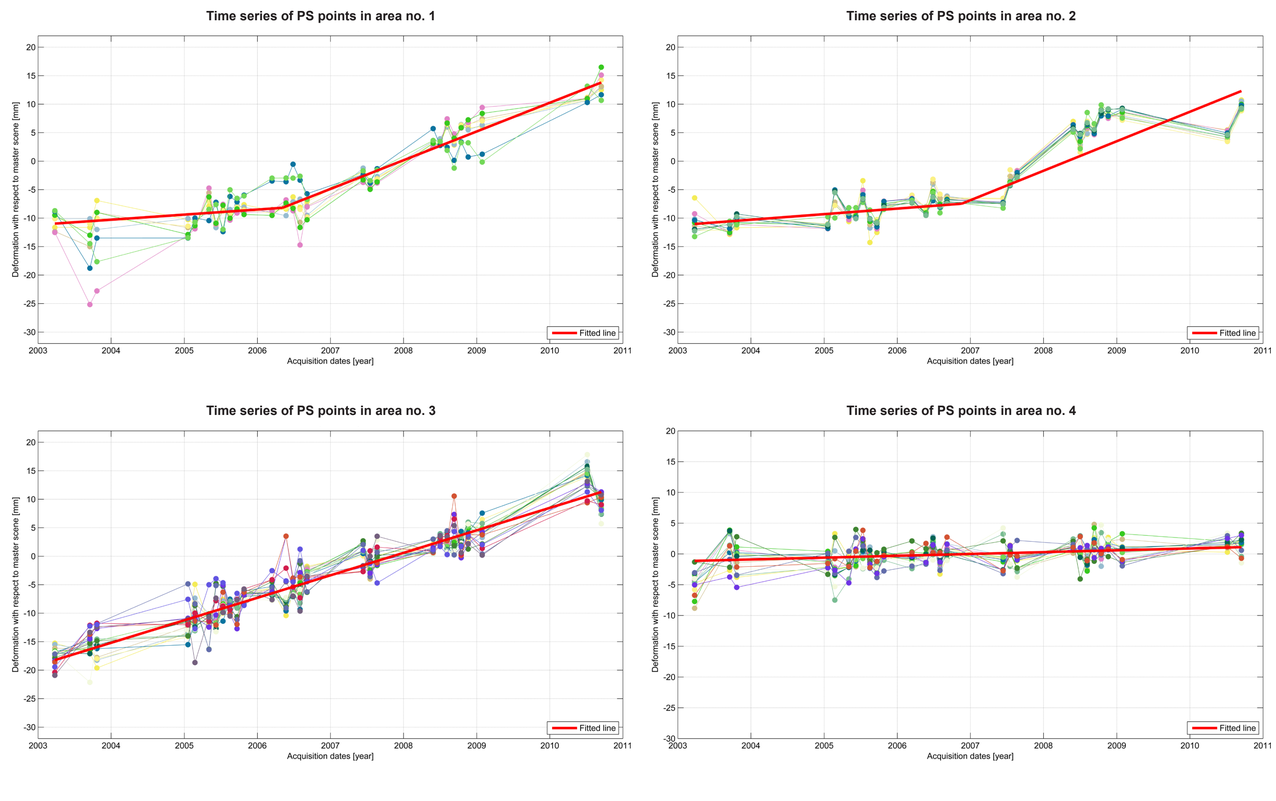


Figure 5. PS time series of the areas marked in Figure 4. The red lines are linearly fitted using the least squares method.