

SALT MINING INDUCED SUBSIDENCE MAPPING OF LUENEBURG (GERMANY) USING PSI AND SBAS TECHNIQUES EXPLOITING ERS AND TERRASAR-X DATA

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ABSTRACT

This paper is a comparative study of the salt mining induced subsidence analysis of Lueneburg (Germany) exploiting ERS and TerraSAR-X SAR data using the techniques Persistent Scatterer Interferometry (PSI) and the Small Baseline Subset Algorithm (SBAS). We demonstrate the applicability of differential SAR interferometry for observing such phenomena as salt mining induced subsidence and similar applications.

Index Terms— ERS, Lueneburg (Germany), Persistent Scatterer Interferometry (PSI), Small Baseline Subset Algorithm (SBAS), TerraSAR-X.

1. INTRODUCTION

We present here the deformation mapping results for Lueneburg, located in Germany, exploiting ERS and TerraSAR-X data using Persistent Scatterer Interferometry (PSI) [1]-[3] and the Small Baseline Subset Algorithm (SBAS) [4].

Lueneburg is a town situated in the German state of Lower Saxony. Due to constant salt mining dating back to the 19th century and continuing till 1980, various areas of the town experienced a gradual or high subsidence, became unstable and had to be demolished. The sinking still continues even today. Many ground stations have been established since 1946 to monitor the deformation, but due to the changing subsidence patterns and locations, space-borne differential SAR interferometric technique has been applied for deformation mapping of Lueneburg.

First, we present results using C-band ERS satellites' data from 1992 to 2003. We estimate the deformation time series using PSI as well as the SBAS technique, and compare the results. PSI focuses on resolution cells characterized by a single dominant scatterer and makes use of interferograms generated using a single master scene. In comparison, SBAS concentrates on a distributed scattering model and makes use of small baseline interferograms not limited to a single master. For PSI processing, we assume a linear deformation model. For SBAS, we estimate the non-linear deformation time series without any modelling. The subsidence phenomenon is observable using both the

techniques and the results are similar and consistent with the ground based measurements. However, due to the low resolution of the C-band ERS sensors, the highly localized subsidence phenomenon cannot be detected sometimes.

Thus, since October 2010, stacks of the X-band SAR satellite TerraSAR-X have been ordered to monitor the subsidence at high resolution [2], [3]. TerraSAR-X provides a resolution of 0.6 m in the slant range direction and 1.1 m in the azimuth direction in the High Resolution Spotlight mode and even single buildings can be mapped from space. With a short repeat cycle of 11 days, stack of acquisitions can be acquired rapidly for time series analysis. We have processed a small dataset of 7 images from October, 2010 to February, 2011 and have generated 21 small baseline differential interferograms. In most of the interferograms, the deformation fringes are clearly visible in the area of interest, and confirm to the ground based observations. We present the first TerraSAR-X interferograms for the above mentioned time period. TerraSAR-X data looks ideal for the application and we are now collecting a larger stack of High Resolution Spotlight data for PSI and/or SBAS processing.

2. ERS DATASET

We performed eleven years of subsidence analysis for Lueneburg using ERS dataset from 1992 to 2003. We applied two approaches for the subsidence mapping, namely, PSI and SBAS.

PSI is a technique for generating deformation time series, wherein, a stack of SAR images are used and long time span differential interferograms with respect to a single master image are formed. Very stable and long time coherent persistent scatterers (PSs) are exploited. For PSI processing, we employed DLR's operational PSI-GENESIS processor [5], [6]. ERS track 22 consisting of 71 ERS images was used for the processing. We split the dataset into two (1992-1997, 1998-2003) because of the high data amounts. A linear deformation model assumption was made. Fig. 1 shows the deformation velocity estimation results for the considered time period and an example of deformation time series for a point.

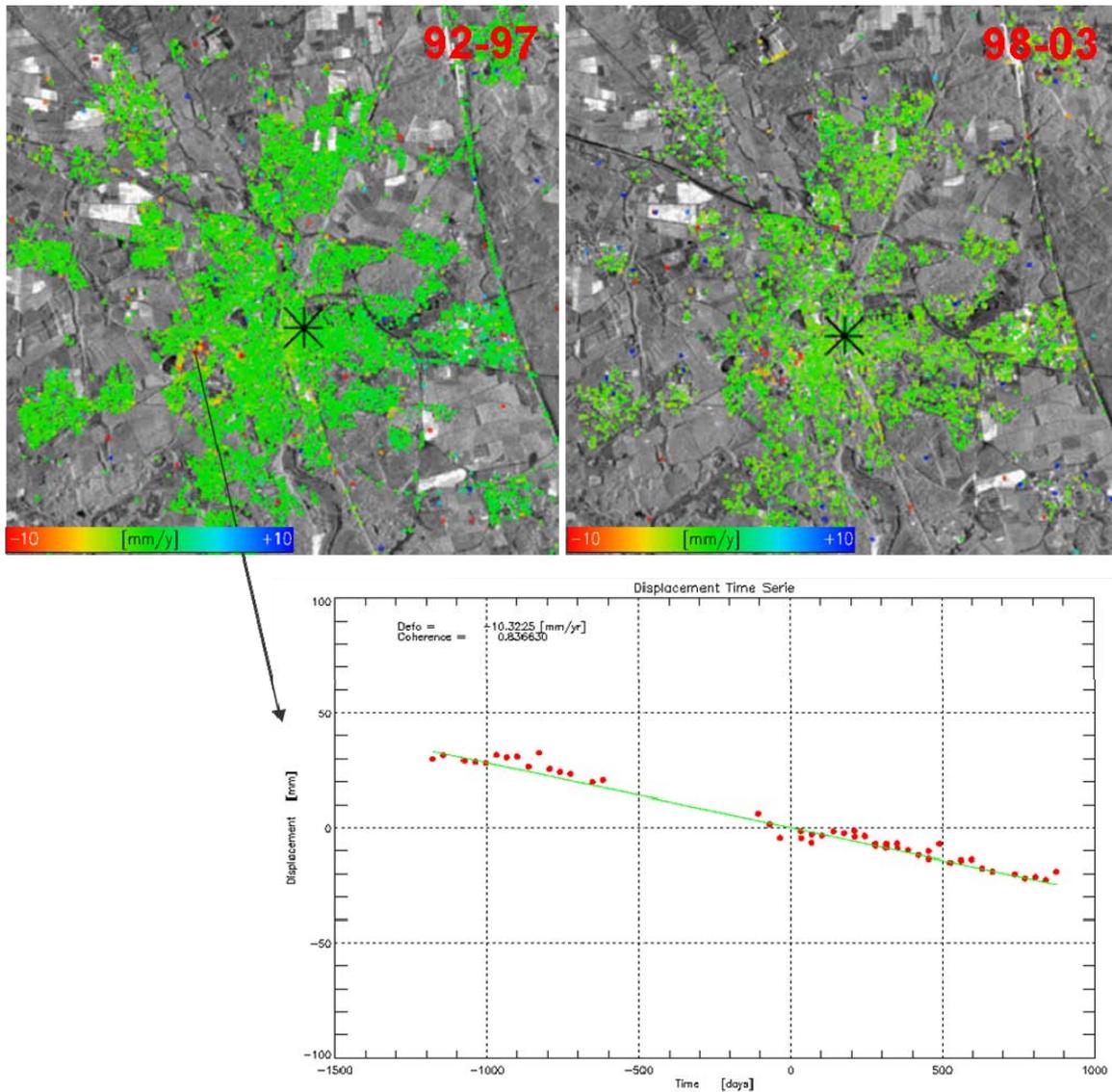


Figure 1. PSI deformation estimation results for Lueneburg from 1992-1997 and 1998-2003 using 71 ERS images. The reference point is marked in black.

We also used the SBAS approach to retrieve the LOS deformation. It exploits Distributed Scatterers (DSs) and makes use of small baseline differential interferogram subsets. Singular Value Decomposition (SVD) is applied to link independent subsets separated by large baselines. Non-linear deformation is estimated without any prior knowledge. We again used ERS track 22 for the SBAS processing. 71 ERS images from 1992-2003 were used to generate 172 small baseline differential interferograms based on spatial (perpendicular) baseline threshold of 150 m and temporal baseline threshold of 700 days. No dataset partition was required. Fig. 2 shows the covariance matrix for Lueneburg. Fig. 3 shows the baseline time plot for the dataset. Fig. 4 shows the cumulative deformation estimation results using SBAS processing

and an example of non-linear deformation time series for a point.

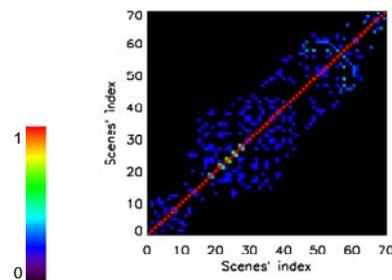


Figure 2. Covariance matrix for Lueneburg. It shows the average coherence of the small baseline interferometric pairs used in the SBAS processing.

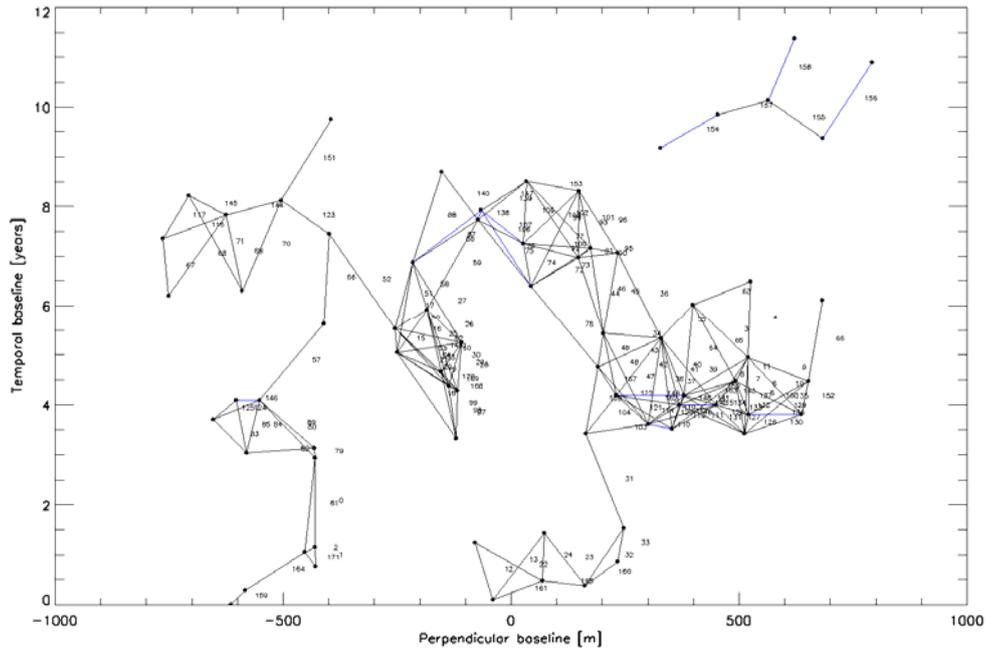


Figure 3. Baseline-time plot for Lueneburg. each dot corresponds to a SAR image and each line corresponds to an interferogram used in the SBAS processing (blue lines represent those interferograms that have an average coherence greater than 0.3).

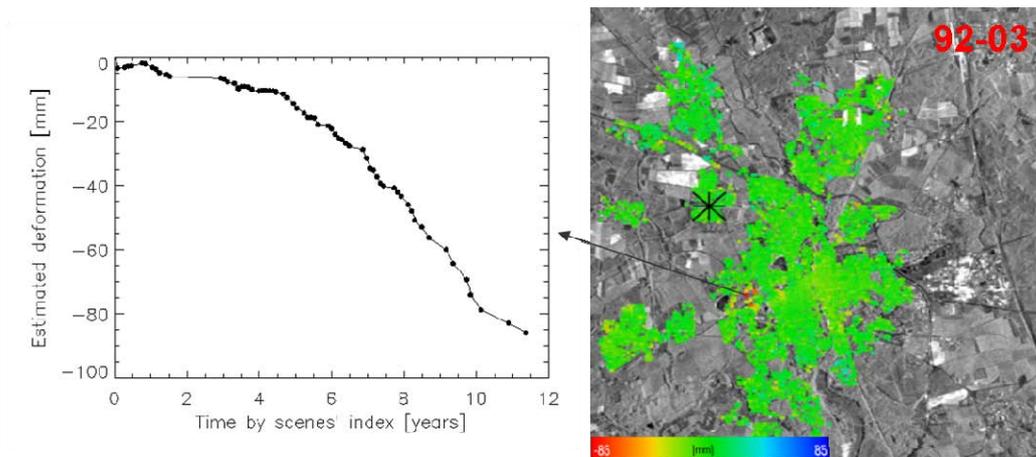


Figure 4. SBAS deformation estimation results for Lueneburg from 1992-2003 using 71 ERS images and 172 small baseline differential interferograms. The reference point is marked in black.

The subsidence is detectable using both PSI and SBAS and the results are comparable as shown in Fig. 5, where, the estimated deformation has been geocoded and visualized in Google Earth.

3. TERRASAR-X DATASET

The C-band ERS sensors have a low resolution and the highly localized subsidence occurring in Lueneburg is sometimes not detectable. As a consequence, since October 2010, high resolution X-band data from

TerraSAR-X is being used for deformation monitoring. We used a small dataset of 7 TerraSAR-X images to generate 21 small baseline differential interferograms. The deformation fringes are clearly visible in these interferograms and confirm to the ground based measurements. In Fig. 6, we can see examples of 3 such differential interferograms. The TerraSAR-X data has high potential for such applications and we are now collecting a bigger stack of High Resolution Spotlight data of Lueneburg for PSI and/or SBAS processing.

PSI

SBAS

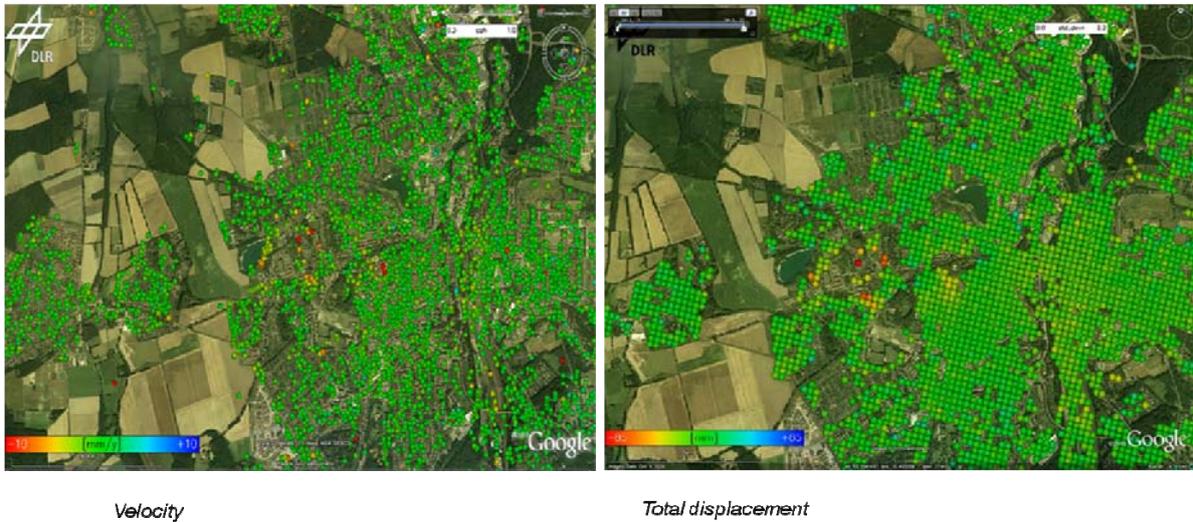


Figure 5. Comparison of PSI and SBAS deformation estimates using ERS data.

4. CONCLUSION

This paper demonstrates the applicability of differential SAR interferometry for observing such phenomena as salt mining induced subsidence and similar applications. The PSI and SBAS techniques provide comparable results in identifying the salient deformation patterns for Lueneburg using ERS data and further comparative studies could be performed to better understand the limitations of these two techniques. Additionally, higher resolution satellites such as TerraSAR-X have a high potential for monitoring the deformation time series and the results can be used for further risk assessment.

5. REFERENCES

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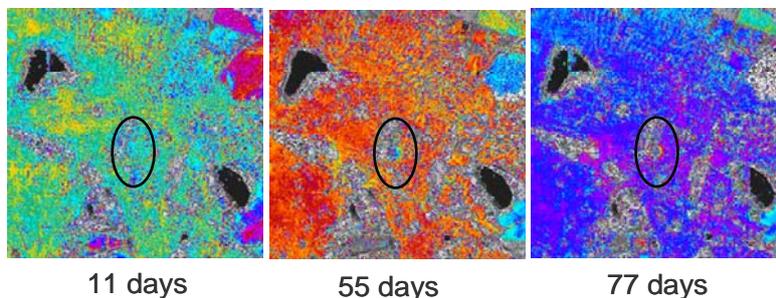


Figure 6. Small baseline differential interferograms of Lueneburg using TerraSAR-X data. Deformation fringes are encircled in black.