Application of Permanent Scatterers on Mining-Induced Subsidence

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ABSTRACT
We have derived a subsidence estimate by means of differential SAR-interferometry in a rural area in the lower rhine embayment, Germany. This area is affected by large scale groundwater drawdown during mining. We have compared the results from interferometric point target analysis (IPTA) with leveling measurements. The focus of our current research is the verification and validation of our interferometric deformation estimates. The displacement observation from both techniques (IPTA and leveling) is very promising and can compliment each other in further technical interpretation.

INTRODUCTION
The area of our investigation is located in the lower rhine embayment between Aachen and Cologne in Germany. This region is recognized as the third biggest brown coal deposit of the world. During mining in open cast pits, the groundwater level is lowered below the mining level [1]. The effects of the drawdown in and around the open cast pits are also observabel on the earth's surface. In this area a drawdown of the groundwater level by 1m leads to 1-3 mm subsidence on the surface [2].
In this paper we focus on the accuracy of our interferometric observations. For this reason we have compared the IPTA with ground truth.

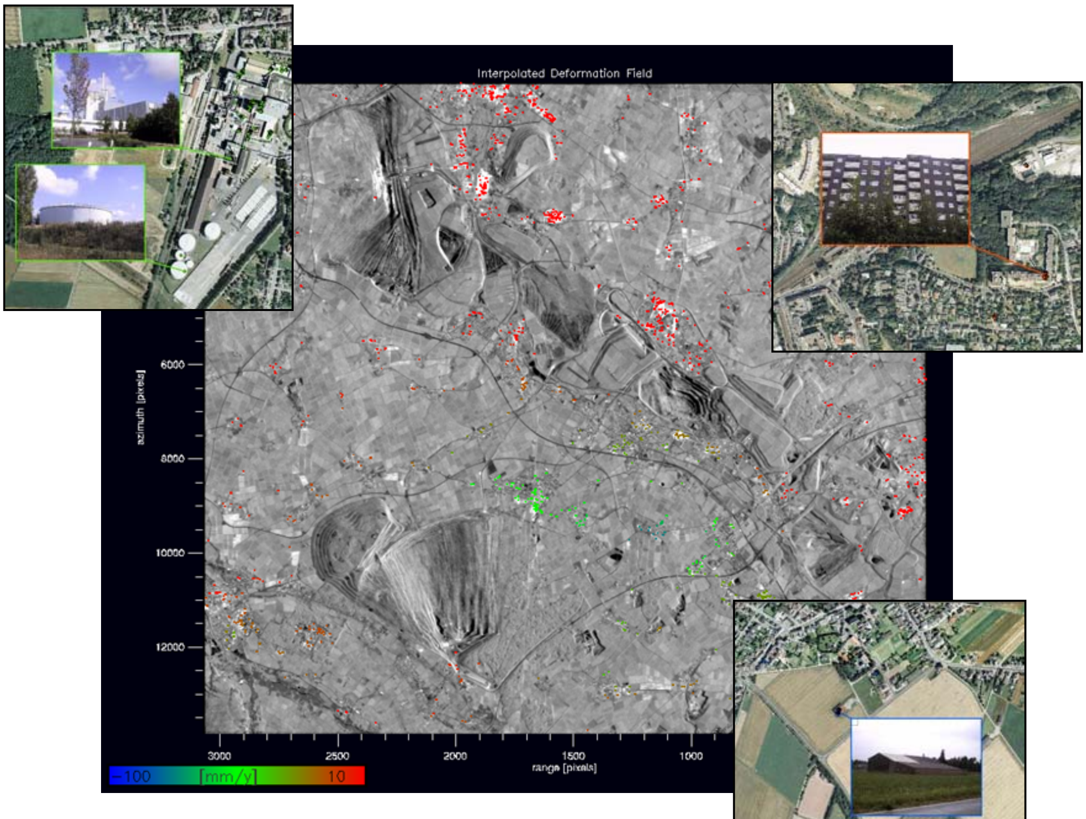

Fig. 1: Estimated IPT values with arial views of identified IPTs

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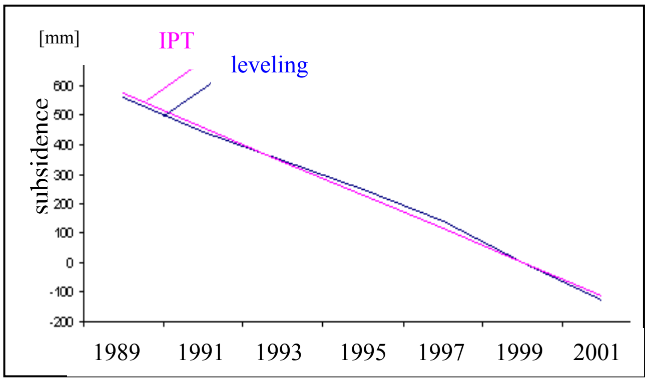
Data Processing

We analyzed differential interferometric phases on point targets using a research system developed by the Institute of Remote Sensing Technology (IMF) of the German Aerospace Center (DLR). Forty differential interferograms from May 1992 until December 2000 were computed. The scenes with a perpendicular baseline up to 1158 m were coregistered for a single master grid. IPTs are choosen by their amplitude statistics and a reference network is constructed between them. Elevation differences and differential linear deformation rates are estimated between the identified points and are integrated to elevation and deformation difference rates at the points with respect to a reference point [3].
The ground truth data consists of leveling measurements. The benchmarks are mostly along streets and have been measured bi-annually since 1989. The leveling observations are made relative to reference points.

Analysis and Results

In the IPTA we have derived a map of points stable over 8 years (1992-2000) and have estimated elevation and linear vertical displacement rates. Fig. 1 presents the IPTs with subsidence rates between -100 and 10 mm/y. This study was the first application of the IPTA technique in a rural test site. However the identification of some IPTs (Fig. 1) demonstrates, that longtime stable backscatterers may be found on industrial buildings, large apartment buildings or sheds for agricultural machines, for example.
After identifing the IPTs and estimating the displacement rates the quality of our IPTA results must be analyzed.

To verify the reliability of the derived deformation rates we compared the estimated values with ground truth data (leveling data between 1989 and 2001 of the Land Surveying Office of NRW, Germany).



First we compared the number of IPTs and leveling points in an defined area. Despite clustering of the IPTs (one big building can have ceveral IPTs) the number of IPTs is about 10 times bigger than the number of leveling points.
The comparison between subsidence rates at the IPT and nearby leveling points shows a very good agreement (Fig. 2). The estimated deformation at the IPTs is assumed to be linear. Also the leveling shows a linear subsidence trend, supporting thisassumption.

Fig. 2: Pointwise comparison between one IPT and a neighboring leveling point (distance 136 m)

The comparison along a profile is displayed in Fig. 3. The curves are the deformation rates in mm/y with error bars indicating the standard deviation due to the kriging variance. The two measurements correspond very well.

	Leveling:	IPT :
Max.	-80.25 mm/y	-86.96 mm/y
Min.	-4.58 mm/y	1.27 mm/y
Mean	-35.78 mm/y	-35.67 mm/y

The measured and the estimated maximum values have a difference of about 6.5 mm/y, the mean deformation rates are nearly equal.

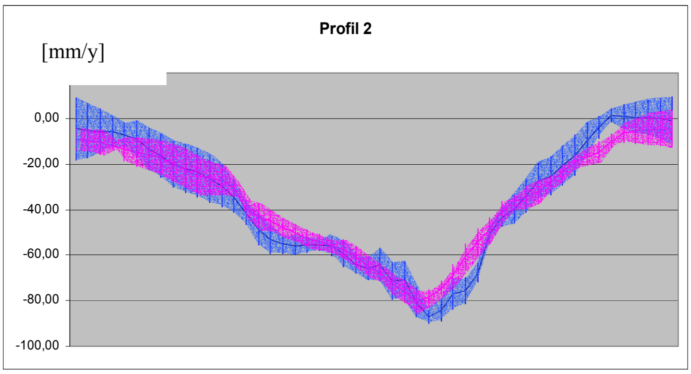


Fig. 3: Comparison of levelling and IPTs along a profile

After analyzing and comparing the IPT with the ground truth we interpolated displacement maps of the leveling data (Fig. 4) and the IPTs (Fig. 5). The interpolation was made by ordinary kriging. As well the structure as the motion rates are similar in a first comparison.

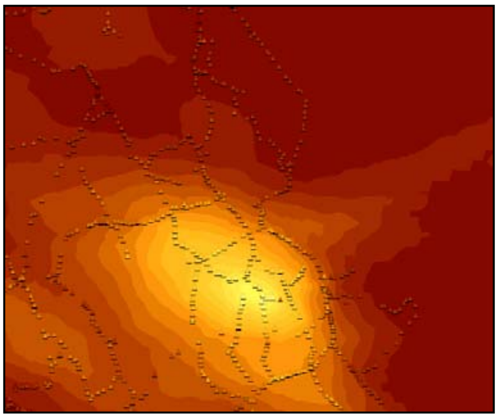
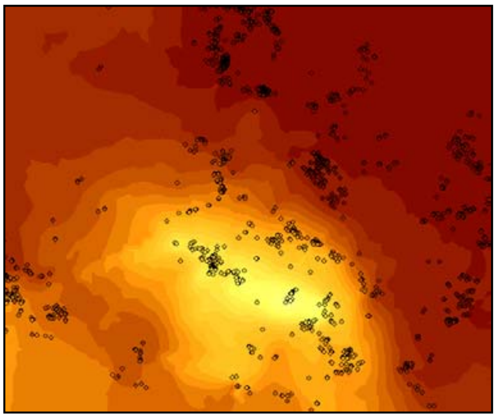


Fig. 4: Interpolation of leveling data



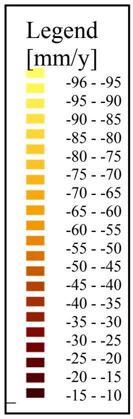


Fig. 5: Interpolation of IPT

The difference between the two interpolation maps (Fig. 4 and 5) is shown in Fig. 6. Differences in most areas are less than 10 mm/y. The largest differences occur where the interpolation is less constrained by the data.

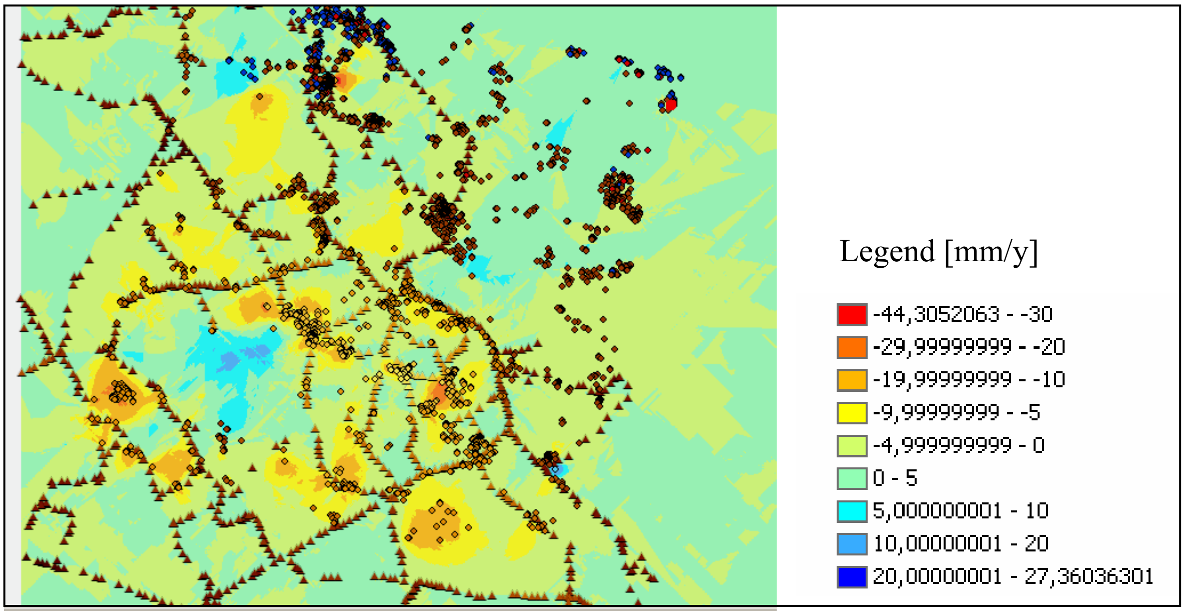


Fig. 6: Difference map between the interpolation of the leveling data and the interpolation of the IPT

The standard error estimated for the linear deformation rates of the IPTs is 0,9 mm/y and 1-2 mm/y for the leveling measurements. The error due to the interpolation has to be added to this values.

Discussion

The comparison at points, profiles and spatially between IPTA and ground truth showed a good agreement and support the reliability of the IPTA, so that the datasets can compliment each other for further subsidence interpretation in that area.

The residual phase of the IPTs still contains phase noise, rest-atmosphere and non-linear deformation contributions [4]. The current focus of our research is to separate the residues in the different phase parts and to analyze the differences of the non-linear deformation from the linear trend. First analysis of the non-linear phase part indicates that the deviation from the linear trend is very small. But If we could exactly seperate the phase parts, primarily the non-linear phase, we could further improve our deformation estimates.

References

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