MINING RELATED GROUND MOVEMENT DETECTION BY COMBINATION OF MULTI-TEMPORAL AND MULTI-SENSORAL DINSAR AND PSI ANALYSES

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ABSTRACT

Purpose of the research project "MultiSAR" is the determination of height changes by application of two different interferometric analysis approaches to data originating from three different SAR missions. The main project aim is to combine all results in order to gain as much information as possible about height changes, both in space and time.

In the investigation area slight subsidences and uplifts of below 1 cm/year occur in the vicinity of lignite open pit mines and abandoned open pits. Radar interferometric analyses are further limited due to the rural character of the region. Currently only intermediate results will be shown due to the ongoing acquisition of TerraSAR-X data.

1. RESEARCH PROJECT "MULTISAR"

Due to restrictions of differential interferometry in rural regions it is not possible to make area-wide statements about ground movements without any gaps. In order to gain as much information as possible about height changes (both in space and time) we use data from three different SAR missions (TerraSAR-X, ENVISAT ASAR, and ALOS PALSAR). For their diverse characteristics in resolution, repeat interval and wavelength, they are applicable for different regions (e.g. rural, urban, woodland) and height changes (different rates or dimensions). It is intended to utilize the advantages of every sensor to complement information and for cross-checking of the results.

Results will be derived using the two different analysis approaches PSI (point based Persistent Scatterer Interferometry) and DInSAR (raster based Differential SAR Interferometry). They will be applied on all data sets (cf. also Fig. 1) and combined subsequently using GIS (cf. chapter 4).

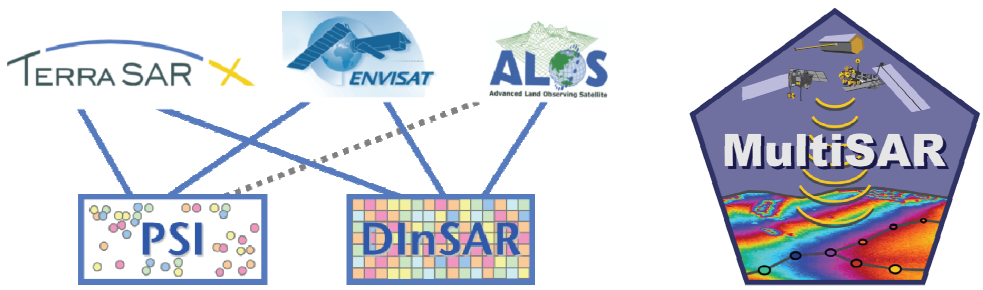

Figure 1: Visualisation of analysis approach used in the research project "MultiSAR". Data originating from three SAR sensors are analysed using two different approaches (point and raster based). Due to an insufficient number of ALOS acquisitions only DInSAR is used for this sensor. Right side: Project logo.

2. INVESTIGATION AREA

The investigation area is situated south the city of Leipzig, Germany. In this area several abandoned open pit mines lie in spatially close neighbourhood of two active lignite open pits (see Fig. 2). Due to the since decades ended dewatering within large parts of the area in conjunction with an active flooding of selected open pit sites, a rising of the groundwater occurs, resulting in a slight uplift of the topographic surface. On the other hand the operating mining sites relocate slowly and likewise the dewatering of the ground water moves forward, resulting in ground subsidence. Both effects cause only slight ground deformation rates of 1 cm per year maximum.

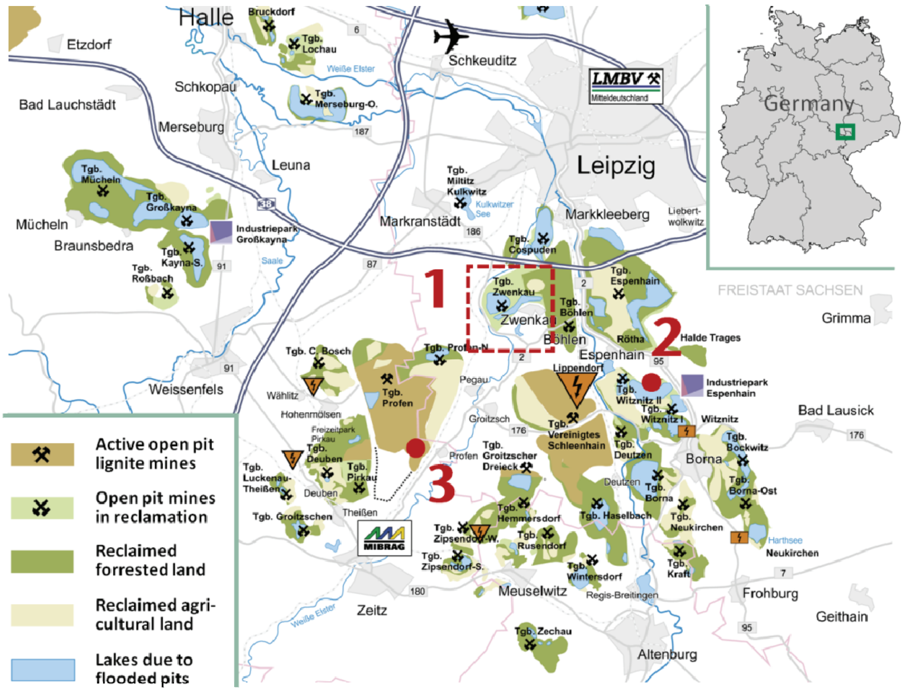

Figure 2: Map of investigation area south of the city of Leipzig. Red box (1) shows extent of Fig. 4 (Zwenkau lake), red dots show locations used for Fig. 5 top (2, Witznitz lake) and bottom (3, Profen mine). Source: http://www.debriv.de

Nevertheless a detailed monitoring of ground movements is compulsory for both mining and reclamation companies for legal demands originating from mining authorities. For this reason mining industry is supporting the research by providing extensive reference data measurements (e.g. levelling data). In the area of interest a levelling network consisting of more than one thousand points plus additional object measurements exists. The reference data will allow an intensive checking and ascertainment of the accuracy of the interferometric results.

3. PRELIMINARY RESULTS

Data acquisition for the investigation area started in 2005. In 2007 first ALOS PALSAR scenes could be obtained. Since May 2009 Stripmap mode SAR data of TerraSAR-X completes the aims of the research project MultiSAR. Fig. 3 shows a visualisation of all available SAR acquisitions since 2005. For the long repeat interval of ALOS and the PALSAR observation strategy by JAXA, which is disadvantageous for the area of interest, it will not be possible to perform PSI analyses with PALSAR data (only DInSAR analyses possible). Data acquisition of TerraSAR-X and ALOS PALSAR data will be continued till October 2011.

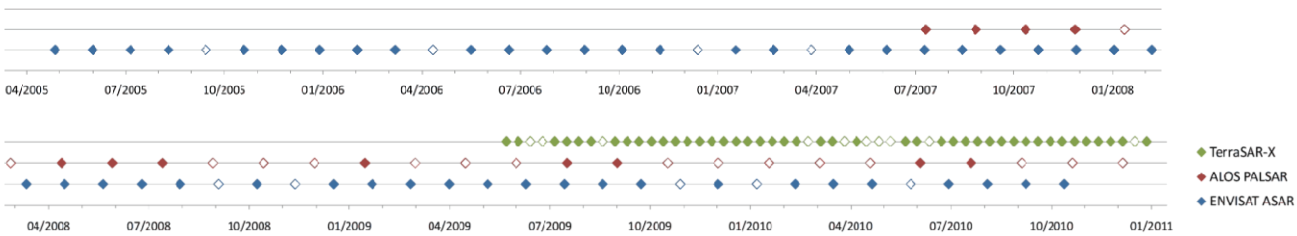

Figure 3: Illustration of temporal availability of TerraSAR-X, ENVISAT ASAR, and ALOS PALSAR data for time span 2005 – 2010. Unfilled points indicate an unintended loss of the particular acquisition.

Fig. 4 shows a comparison of areas with radar interferometric information, obtained by all available sensors. Note that the results are based on different total amounts of scenes and unequal time spans (see also Tab. 1 for details).

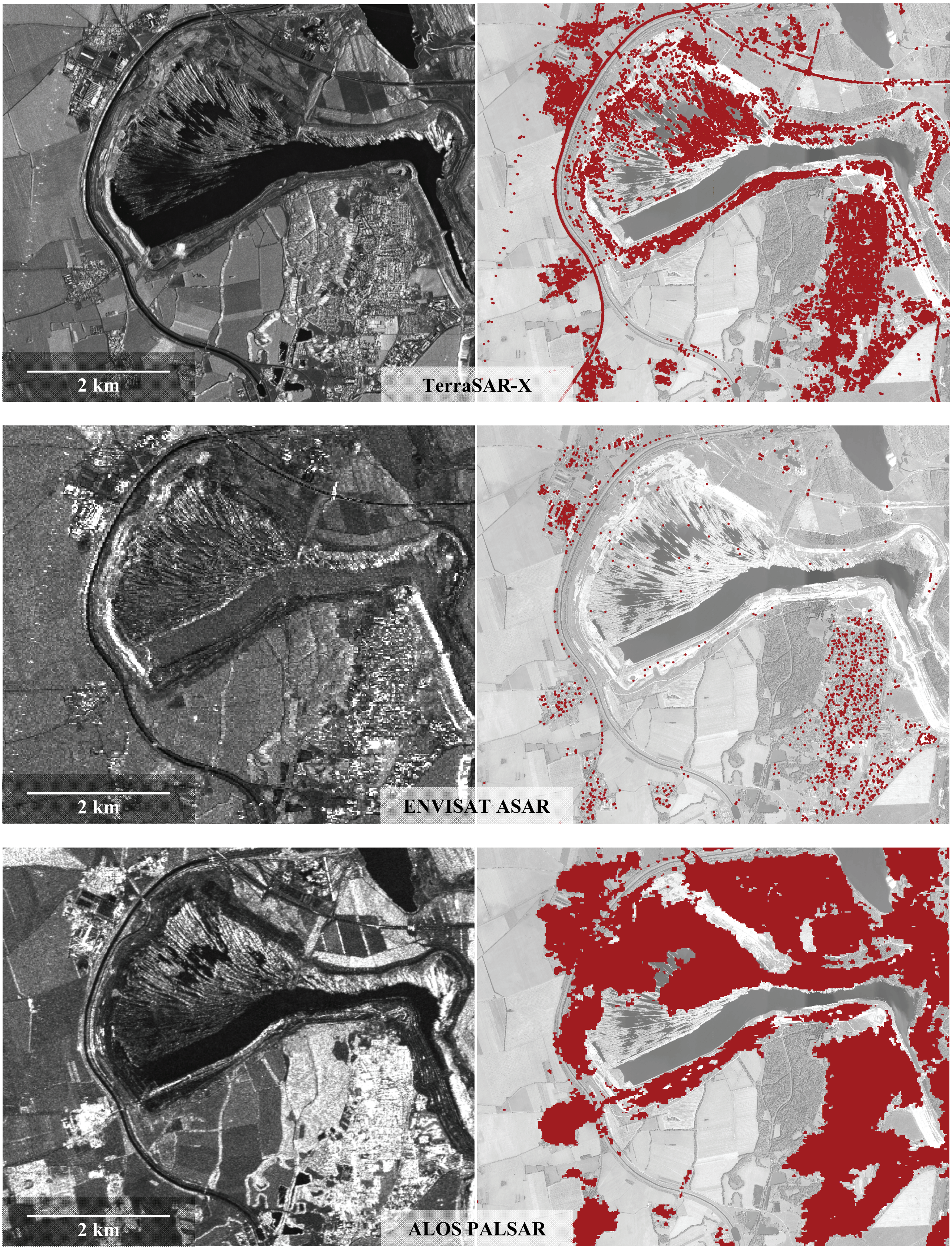

Figure 4: Radar intensity pictures of the three SAR sensors in the vicinity of abandoned open pit mine Zwenkau (left). Right: Comparison of areas with radar interferometric information generated by PSI (based on 35 TerraSAR-X scenes over 1.5 years and 49 ENVISAT ASAR scenes over 5.5 years), and by DInSAR stacking (based on 13 ALOS PALSAR scenes over 3 years). Background on the right shows aerial photograph.

The comparison shows that information obtained from ALOS PALSAR DInSAR stacking covers the largest area. Nevertheless at some places TerraSAR-X results were available for small (or narrow) man-made objects like streets, railways or pylons, which often disappear in DInSAR analysis due to filtering, coherence estimation and masking steps. ENVISAT ASAR PSI result evidently shows much sparser information than TerraSAR-X result. However, areas providing information are nearly the same as with TerraSAR-X PSI. In relation to the total amount of theoretically possible PSI points (i.e. all SLC pixels) an ENVISAT ASAR PSI analysis provides nearly the same percentage of useful PSI points (see Tab. 1), although total point numbers are much lower due to the coarser ground resolution of ASAR.

Table 1: Detailed information about analysed SAR data stacks and preliminary results concerning different areas and time spans.

		TerraSAR-X	ENVISAT ASAR	ALOS PALSAR
Analysis method used		PSI	PSI	DInSAR
Acquisition time span	start date	24.05.2009	28.04.2005	13.07.2007
	end date	09.09.2010	14.10.2010	21.07.2010
Number of scenes analyzed		35	49	13
PSI points per km^2	urban (Leipzig)	18'189 points	752 points	-
	rural area	1'427 points	62.6 points	-
	extent of fig. 4	86'221 points	3'227points	-
SLC pixel ground resolution	range x azimuth	2.2m x 3.3m	24.2m x 5.0m	8.6m x 5.1m
PSI points / DInSAR pixels in % of all pixels	urban (Leipzig)	7.31%	6.11%	73.1%
	rural area	0.57%	0.51%	28.0%
	extent of fig. 4	0.69%	0.52%	35.9%

Future DInSAR analyses with ENVISAT ASAR and TerraSAR-X will allow a better comparison between PSI and DInSAR results. Current experiences show, that the combination of DInSAR and PSI results will not only bring benefits in increasing the area of information, but also in reducing errors of the final result. This is due to the fact that phase unwrapping errors in PSI results occur over time on a point-by-point basis, while DInSAR results possess spatial phase unwrapping errors in single dates. The combination of results originating from different sensors will bring additional benefits, since phase-to-deformation factors are different for the three sensors. This will allow the detection of phase unwrapping errors by exploiting different phase ambiguities.

4. GIS BASED ANALYSIS AND FUSION

Main project aim is the creation of area-wide information of ground movement time series without gaps in an area of rural character. This means it should be possible to declare vertical ground movements of user-defined time spans for any arbitrary point in the area of investigation. The result will be based upon diverse interferometric measurements using different analysis approaches, also including terrestrial information (if desired). For this purpose a database system for all measurements (interferometric and terrestrial) has been developed. This also implies the development of software tools for data analysis, fusion, mathematical modeling, visualisation and comparison of data originating from diverse sources. Main problems were the unequal time points of the time series and differing locations where results can be obtained.

DInSAR results have the specific characteristic, that many pixels in the stack can provide useful information about height changes, although it was not possible to determine the deformation history over the complete time span for them. Fig. 5 shows the loss of ALOS DInSAR coherence over the whole time span of 3 years. Areas delivering information for all 13 time points are displayed in purple colour, corresponding to red areas in Fig. 4 bottom right. Beside of these areas (mainly villages and open pits), many agricultural areas are losing coherence after some time. All raster based DInSAR results are converted to the same data format used for PSI results. Every DInSAR pixel becomes one PSI point with its deformation history, allowing the application of the existing GIS based analysis tools.

Currently intermediate results and visual comparisons of the single results can be shown. Fig. 6 shows typical examples of time-series plots of height changes in the investigation area. For comparison reasons extensive reference data measurements (eg. levelling) are available. This is an important factor for boosting the acceptance of DInSAR in the range of mining, geodesy, mine surveying, and for local authorities. Therefore an intensive ascertainment of the accuracy of the radar interferometric results (both raster-based and point-based) will be performed in future.

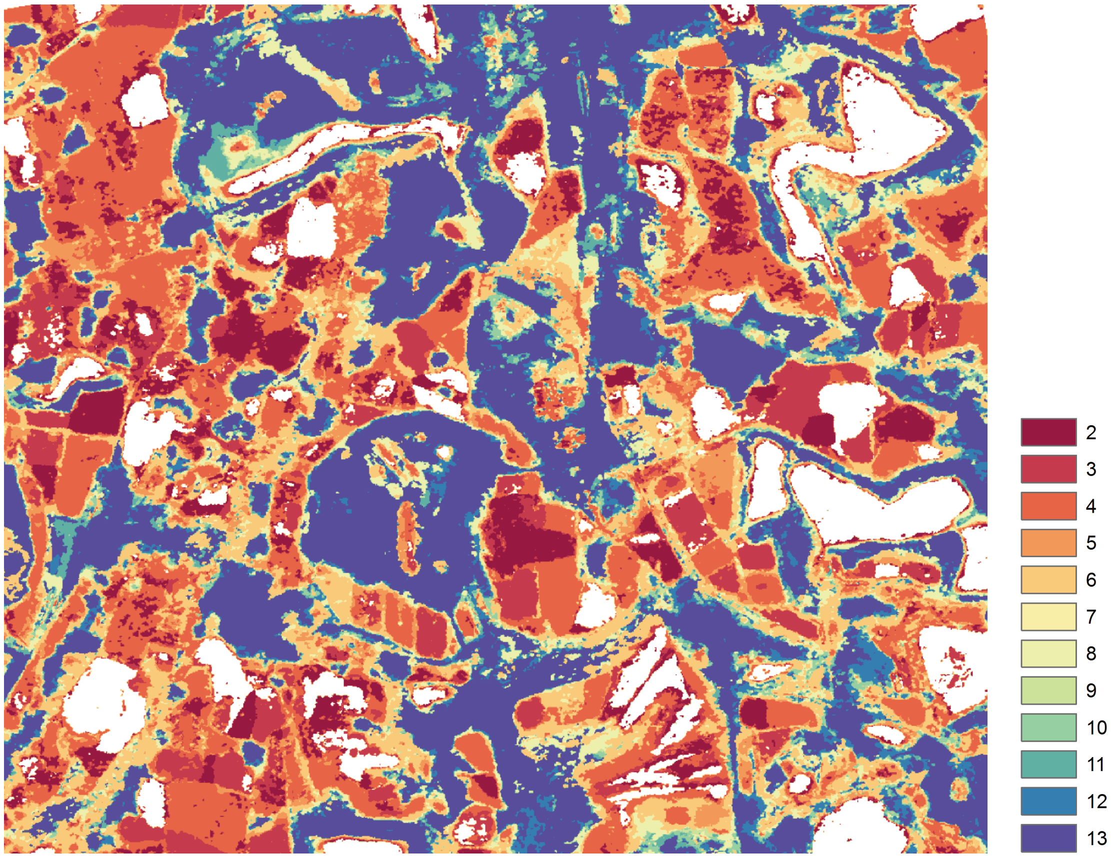

Figure 5: Raster-based DInSAR stack result based on ALOS PALSAR data, showing which pixels remain coherent after n timepoints. Purple areas of long-time coherence are mainly villages and sparsely vegetated open pit mines. Agricultural areas are clearly visible with reddish to yellow colours. White areas correspond to water bodies.

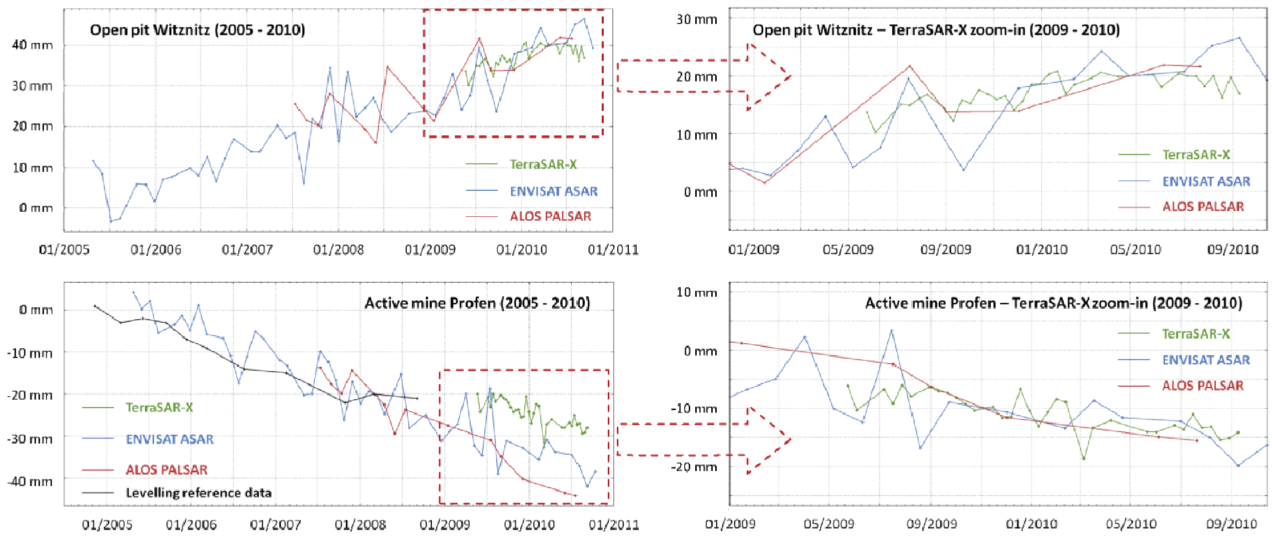

Figure 6: Time-series examples of typical height changes in the investigation area. Top diagrams show uplift at abandoned open pit lake Witznitz (see point 2 in Fig. 2), bottom diagrams show subsidence within active lignite mine Profen (point 3 in Fig. 2) in comparison with levelling reference data.

5. ACKNOWLEDGEMENTS

The research work is funded by budget of the German Federal Ministry of Economics and Technology (BMWi) via the German Federation of Industrial Research Associations "AiF" (Arbeitsgemeinschaft industrieller Forschungsvereinigungen Otto von Guericke e.V.) under project no. 15880 N.

TerraSAR-X StripMap mode data is provided by German Aerospace Center (DLR e.V.) through TerraSAR-X AO project no. MTH0528.

ENVISAT ASAR image mode data was provided by European Space Agency (ESA) in the frame of Category-1 proposal no. 3085. ALOS PALSAR data was also provided by ESA via JAXA ALOS ADEN AO proposal no. 3576.

Reference data was kindly provided by Mitteldeutsche Braunkohlengesellschaft (MIBRAG) mbH.