



Uplift around the geothermal power plant of Landau (Germany) observed from InSAR monitoring

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1. ABSTRACT

Modern geodetic measures provide information on surface deformation at high accuracy. Using radar remote sensing techniques, we image an uplift of several centimeters over a square kilometer area around the geothermal power plant of Landau (Germany). The surface deformation affects a large part of the city. The persistent scatterers interferometry (PSI) processing of the synthetic aperture radar (SAR) images shows that the displacement initiates in the summer 2013 and increased during the whole production time, until March 2014. Results from modeling suggest that a significant injection of fluid occurred around 400 meters depth below the geothermal plant during the first phase of deformation.

2. DATA AND METHOD

Since 2012, we acquire synthetic aperture radar (SAR) images from TerraSAR-X satellite. We process the images using SAR interferometry (InSAR) (e.g. Massonnet, et al., 1997) and persistent scatterer interferometry (Ferretti et al., 2001; Hooper et al., 2004) processing. The interferometry technique measures the change in the distance between the ground and the satellite. The repeat time between two pass of the TerraSAR-X satellite is of 11 days. But gaps exists in our dataset. The wavelength of the X-band is 3.1 cm. The images are acquired in the descending orbit at an incidence angle of 21° over Landau. The pixels have a metric resolution.

The measures correspond to a deformation in the Line of Sight (LOS) direction that is mainly sensitive to the vertical component of displacement. We use PSI process to establish the time series of the surface displacement over the city of Landau. And we compare our results to the leveling results made by the city of Landau (www.bodenhebungen-landau.de).

3. RESULTS

We observe a quasi-circular displacement pattern on the South of Landau around the geothermal plant during the April 2012-April 2014 period. The quasi-circular pattern of displacement occurs during the summer 2013-spring 2014 period (figure 1). The deformation pattern is typical of uplift displacement. The radius of the area affected by the displacement extends to 1000 meters. However we observe a large north-south elongated area of moderate uplift up to the North of Landau.

Time evolution analysis shows that we can distinguish four main periods. 1) First, we see a continuous uplift in the North of Landau located in the area of oil field exploitation (figure 2, time series A and B). The uplift rate is of 1.5 cm/yr. 2) A new displacement field appears in the South of Landau in the vicinity of the geothermal plant in July 2013. This event is clearly visible in the time series between July and September 2013 (figure 2, time series C, D, E and F). The amplitude of displacement decreases with the distance from the power plant. 3) A deformation extends in the city in a North-South direction. 4) In the middle of March 2014 a subsidence initiates in the vicinity of the geothermal power plant.

4. MODEL

According to the linear evolution of the deformation in time and the smooth evolution in space, we propose that the dominant response of the underground is elastic. We inverted the results of PSI and test several models of reservoir deformations: e.g. simple point source model, ellipsoid model (Mogi, 1958; Segall, 2009). The results of the Mogi point source model inversion from the PSI displacement between the 30th July 2013 and 23 September 2013 is presented figure 3. Results of the tests give deepness around 400 meters below the geothermal plant.

5. CONCLUSION

Our study demonstrates the importance of geodetic methods to find out the origin of surface deformation. The PSI results give information about the time evolution of the surface displacement. Four main periods are proposed and 3 pattern of surface deformation are detected: the first one in the oil field area, the second one centered on the geothermal field and the last one over Landau in a North-South direction.

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FIGURES

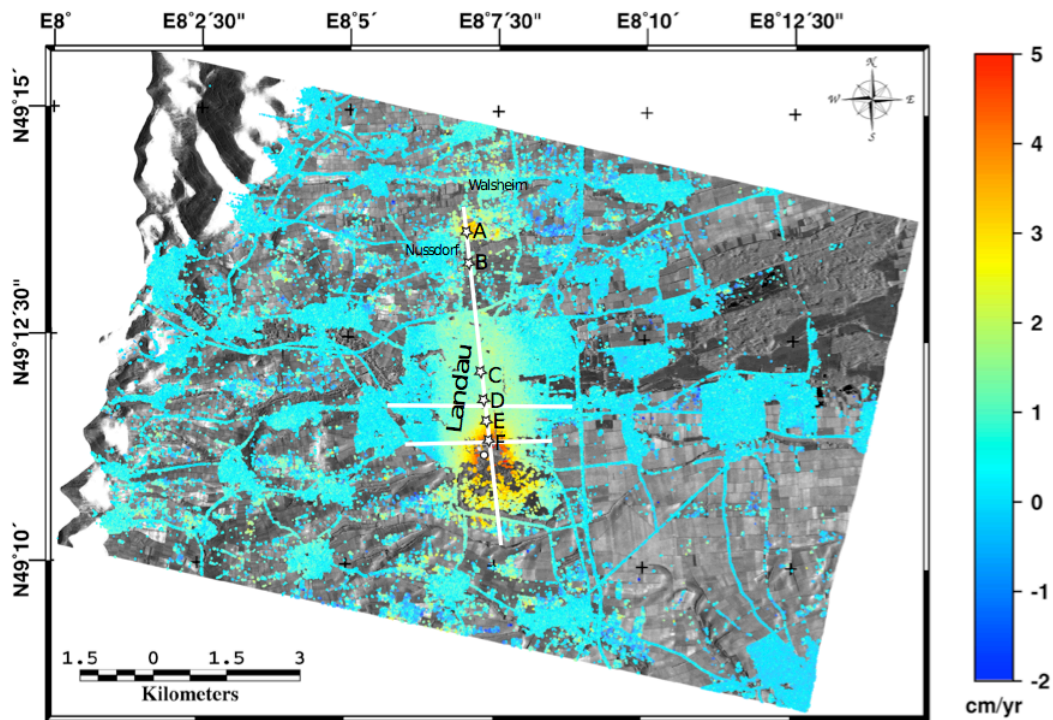


Figure 1: Mean displacement velocity (cm/yr) in LOS direction (positive towards the satellite) over the city of Landau between 8th July 2013 and 9th April 2014 obtained from the PSI results analysis. White lines, profiles; white stars, location of the time series results (figure 2); white circle, location of the geothermal power plant.

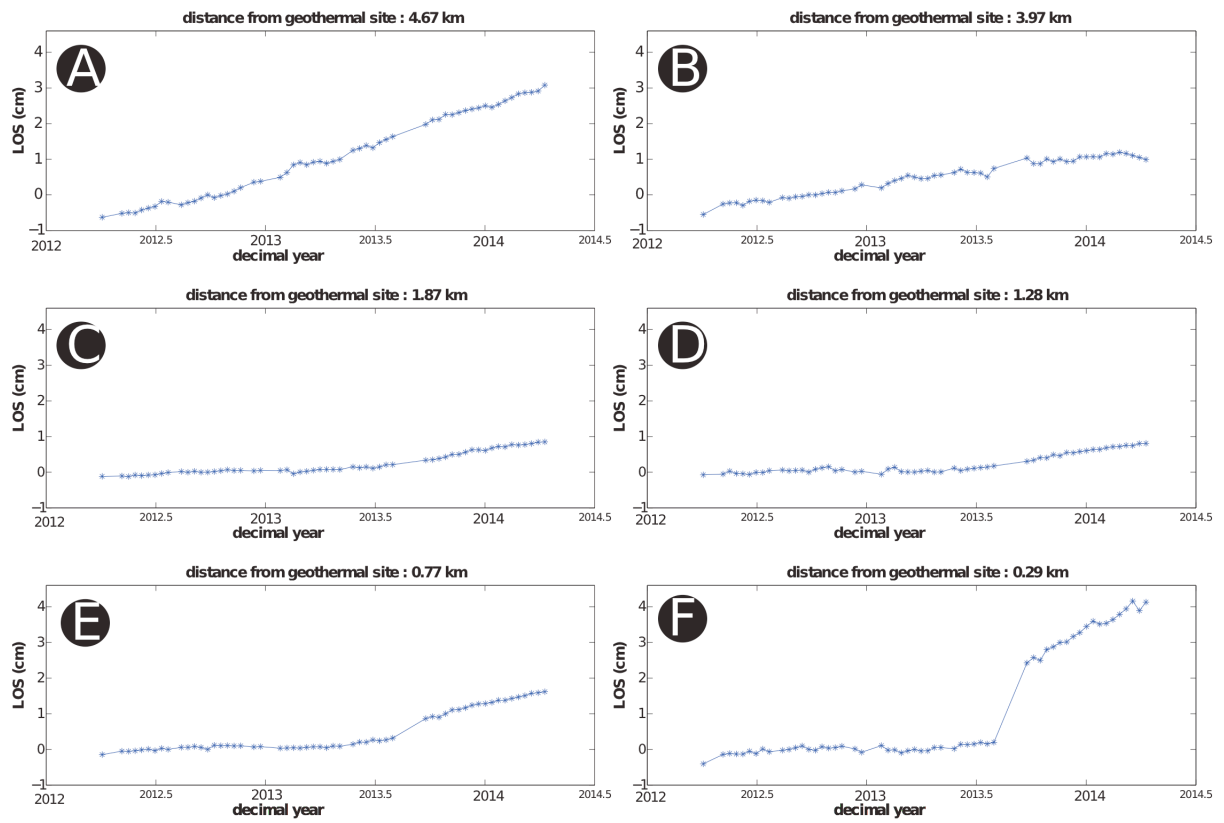


Figure 2: Time series of the LOS displacement toward the satellite at the 6 points area located figure 1 on the North-South profile.

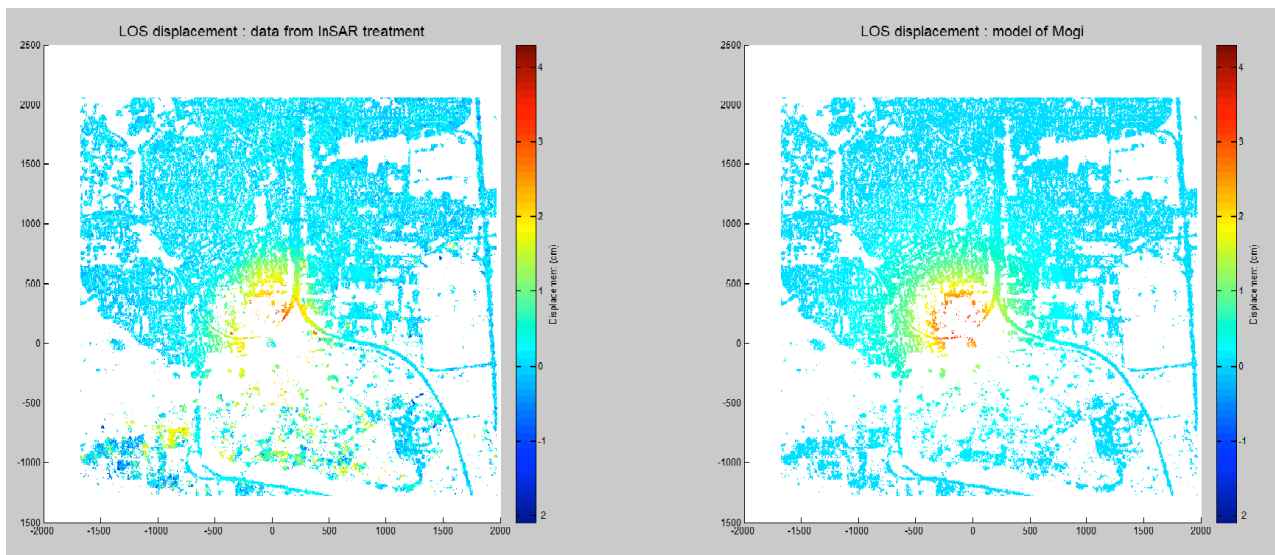


Figure 3: LOS displacement (cm) between the 30th July 2013 and 23 September 2013. Left, PSI results; right, results from inversion using a simple source model (Mogi, 1958).