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Upgrading InSAR observations by combination with leveling data to understand small scale deformation processes

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Estimation of surface displacements by InSAR methods has been steadily improved in recent years, mainly by innovative SAR sensors like TerraSAR-X, but also through constantly enhanced processing techniques like persistent scatterer interferometry. Despite its high accuracy plus favorable spatial resolution and coverage, InSAR observation is merely the one dimensional line of sight mapping of the true surface displacement. Thus a combination of InSAR with additional geodetic methods or a precise geodynamic model is inevitable to obtain the full displacement vector.

We use leveling data in combination with TerraSAR-X persistent scatterer stacks observed in ascending and descending mode to retrieve the full surface displacement vector. A thin plate spline approximation is modeled for each scalar displacement field to allow for a continuous description of the discrete scattered data set. The thin plate spline model is advantageous as it makes use of general physical properties of deformation processes, like minimum bending energy, without the need for specific deformation geometries and processes.

We apply the proposed method to the anthropogenic deformation phenomenon in the city of Staufen (Germany). The city is strongly affected by small scale surface movements with comparably large displacement rates up to 14 mm per month. Well drillings in late 2008 caused mineral conversion of anhydrite layers in depths between 60 and 130 m. The concurrent volume increase causes vertical surface uplift but also horizontal displacements in radial direction. The latter is significant as the inflation source is in comparably shallow depth.

With the proposed method we determine the full displacement vector of the Staufen deformation without the use of a geodynamic model. The results of horizontal displacement rates are largely consistent with independent terrestrial observations, whereas some points reveal an overestimation of the westward component due to the glancing intersection of the satellites line of sight in ascending and descending mode. The proposed method allows a combination of one dimensional displacement observations to retrieve the full displacement vector by means of thin plate spline modeling. This approach is also valuable in case of sparse GNSS observations and missing geodynamical models.