**Title**

An analysis of the InSAR displacement vector decomposition: InSAR fallacies and the strap-down solution

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**Abstract**

Satellite radar interferometry (InSAR) is a powerful technique for monitoring deformation phenomena. While deformation phenomena occur in a three-dimensional (3D) world, one of the limitations of the InSAR phase observations is that they are only sensitive to the projection of the 3D displacement vector onto the radar line-of-sight (LoS) direction. To uniquely estimate the three displacement components, we would require at least three sets of spatiotemporally coinciding independent (STCI) LoS observations, (i.e., scatterers on an object that is not subject to internal deformations, observed at the same time) available over the same Region of Uniform Motion (RUM). More importantly, the system of equations needs to have a full rank coefficient matrix. Unfortunately, in most practical situations at most two sets of STCI LoS observations are available, resulting in an underdetermined system with an infinite amount of possible solutions.

Within the InSAR literature we encounter different approaches to address the underdeterminancy problem, unfortunately often with either mathematical or semantic flaws. We concluded that the InSAR community has no uniform way of addressing the underdeterminancy problem. We developed a taxonomy for the different fallacious approaches that can help by evaluating InSAR results and reviewing InSAR papers.

Moreover, using the east-north-up (ENU) reference frame for decomposing the LoS observations provides results that are not tuned to the needs of the end-user of an InSAR product. Therefore, we developed an alternative solution to the underdetermined problem, in the form of a `strap-down' approach, which uses a local strap-down reference system that is fixed to the deformation phenomenon with transversal, longitudinal, and normal (TLN) components. For many practical cases, such as line-infrastructure, landslides, or subsidence bowls, analysis of the main driving forces supports the assumption that significant deformations in the longitudinal direction are unlikely.

We found that using the strap-down approach gives physically more relevant estimates. Moreover, it results in more relevant estimates since it properly includes all uncertainties. We can further conclude that the conventional way of communicating (PS)-InSAR results by means of a `dot distribution map' is sub-optimal when considering the quality of the estimates. For many cases, `vector arrow maps', or traditional geodetic vector-based visualizations, including error ellipses are a viable and more optimal alternative.