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Signal decomposition of multi-source displacement fields with component analysis methods, applied to InSAR time series of the Epe gas storage cavern field (Germany)

Alison Seidel, Markus Even, Malte Westerhaus, and Hansjörg Kutterer
Karlsruhe Institute of Technology, Geodetic Institute Karlsruhe, Geodetic Earth System Sciences, Germany
(alison.seidel@kit.edu)

Time series of interferometric SAR (InSAR) images offer the potential to detect and monitor surface displacements with high spatial and temporal resolution, even for small and slow deformation processes. Yet, due to the nature of InSAR, the interferometric signal can contain a multitude of contributions. Different displacement source mechanisms could superpose each other, signals that are residuals of atmospheric and topographic effects could not be completely removed during processing of the time series or non-coherent noise could exist. Therefore, the criteria for the selection of temporally stable pixels are often rather strict, leading to significant reduction of the spatial resolution density.

However, to understand the underlying processes of a deformation field, it is important to extract the displacement signals from the data at the best resolution possible and differentiate signals from different source mechanisms. Furthermore, being able to describe the displacement field as superposition of several simple mechanisms is a possible answer to the general question how the information content from tens of thousands of points each coming with a time series over hundreds of acquisitions can be extracted and comprehended.

We address these issues, by determining the dominant displacement signals of different sources in a subset of reliable pixels of InSAR time series datasets with data driven component analysis methods. Subsequently we use models of these signals to identify their displacement patterns in previously not regarded pixels. We utilize the statistical principal component analysis for removing uncorrelated signal contributions and compare different blind source separation methods, such as independent component analysis and independent vector analysis for differentiating between displacements of different origin.

We apply our method to a dataset of multiple orbits of Sentinel-1 InSAR time series from 2015 to 2022 above the gas storage cavern field Epe in NRW, Germany. Epe displays a complex surface displacement field, consisting of trends caused by cavern convergence, cyclic gas pressure dependent contributions, as well as ground water dependent seasonal displacements. With our approach, we can successfully distinguish the signals of the different source mechanisms and obtain a dense spatial sampling of these signals. Our results show good agreement with geodetic

measurements from GNSS and levelling and show a strong correlation to cavern filling levels and groundwater levels, suggesting causal relations.