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Data-Adaptive Detection of Transient Deformation in GNSS Networks

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Transient deformation of the Earth surface are now commonly measured by dense and continuously operating GNSS networks. Such transients are however challenging to extract from the backgroung noise inherent to GNSS time series and to unravel from other geophysical signals such as seasonal oscillations caused by mass variations of the atmosphere, ocean and the hydrological reservoirs. In addition, because of the very large number of GNSS stations now available, it has become impossible to systematically inspect each time series and visually compare them at all neighboring sites. The issue is then to efficiently comb through large amounts of GNSS data to extract signals of geophysical importance.

Here we show that the Multichannel Singular Spectrum Analysis (M-SSA), a method derived from the analysis of dynamical systems, can be used to automatically extract transient deformation, seasonal oscillations, and noise present in GNSS time series. The M-SSA is a multivariate non-parametric statistical method which exploit simultaneously the spatial and temporal correlations of geophysical fields. It consists in estimating Spatio-Temporal Empirical Orthogonal functions (ST-EOFs) onto which the GNSS time series can be projected and represented. It allows for the extraction of common modes of variability such as non-linear trends and oscillations shared across time series. Contrary to other methods that first clean the data assuming some a priori stochastic structure then search for transients using a library of a priori functions, the M-SSA allows for the extraction of transients without a priori hypothesis about their spatio-temporal structure or the noise characteristics of the time series.

We illustrate our results using synthetic examples and show applications examples of the M-SSA to real data in Alaska and southern California to detect seasonal signals and micro-inflation/subsidence events.