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Characterization of Ground Displacement Sources from Variational Bayesian Independent Component Analysis of Space Geodetic Time Series

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A critical point in the analysis of ground displacement time series, as those measured by modern space geodetic techniques (primarly continuous GPS/GNSS and InSAR) is the development of data driven methods that allow to discern and characterize the different sources that generate the observed displacements. A widely used multivariate statistical technique is the Principal Component Analysis (PCA), which allows to reduce the dimensionality of the data space maintaining most of the variance of the dataset explained. It reproduces the original data using a limited number of Principal Components, but it also shows some deficiencies, since PCA does not perform well in finding the solution to the so-called Blind Source Separation (BSS) problem. The recovering and separation of the different sources that generate the observed ground deformation is a fundamental task in order to provide a physical meaning to the possible different sources. PCA fails in the BSS problem since it looks for a new Euclidean space where the projected data are uncorrelated. Usually, the uncorrelation condition is not strong enough and it has been proven that the BSS problem can be tackled imposing on the components to be independent. The Independent Component Analysis (ICA) is, in fact, another popular technique adopted to approach this problem, and it can be used in all those fields where PCA is also applied. An ICA approach enables us to explain the displacement time series imposing a fewer number of constraints on the model, and to reveal anomalies in the data such as transient deformation signals. However, the independence condition is not easy to impose, and it is often necessary to introduce some approximations. To work around this problem, we use a variational bayesian ICA (vbICA) method, which models the probability density function (pdf) of each source signal using a mix of Gaussian distributions. This technique allows for more flexibility in the description of the pdf of the sources, giving a more reliable estimate of them. Here we introduce the vbICA technique and present its application on synthetic data that simulate a GPS network recording ground deformation in a tectonically active region, with synthetic time-series containing interseismic, coseismic, and postseismic deformation, plus seasonal deformation, and white and coloured noise. We study the ability of the algorithm to recover the original (known) sources of deformation, and then apply it to a real scenario: the Emilia seismic sequence (2012, northern Italy), which is an example of seismic sequence occurred in a slowly converging tectonic setting, characterized by several local to regional anthropogenic or natural sources of deformation, mainly subsidence due to fluid withdrawal and sediments compaction. We apply both PCA and vbICA to displacement time-series recorded by continuous GPS and InSAR (Pezzo et al., EGU2015-8950).