Investigation of Blind Source Separation Technique for Transients in GPS Time-Series

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Introduction

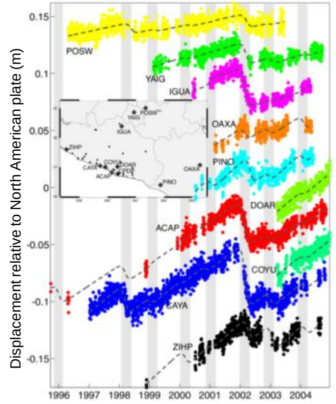
The Residual GPS time series (N, E, U)$_{res}$: (N, E, U) → (N, E, U)$_{res}$

Transients: → Tectonic (Post-Seismic Deformation, Slow Slip Event)
→ Non-tectonic (Hydrological loading)

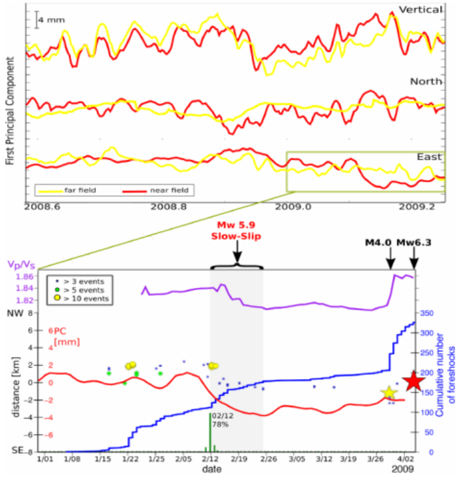
(N, E, U)$_{res}$ could be spatially correlated due to: →
- Common Mode Error (CME)
- Transient Signals

Transient Signals ➢ Non-secular strain accumulation in the crust

In most of the cases, transient signals are not noticeable in the GPS time series → 2009 April 6 (Mw) 6.3 L'Aquila Earthquake



SSE observed in Guerrero Gap, Mexico (modified from Radiguet et al. (2012))



Zoomed first PC along east component (red), V_p/V_s ratio (purple), and cumulative number of foreshocks (blue)

- *Montillet and Bos (2019)*
- *Borghi et al. (2016)*

Methods

Principal Component Analysis (PCA)

- ➢ Transforms the large number of intercorrelated variables into smaller number of uncorrelated variables.
- ➢ Uses the Eigenvalue Decomposition by maximizing the variances (**$\Sigma = XX^T = V\Lambda V^T$**) with Lagrange's Undetermined Multiplier.
- ➢ Principle Component (PC) is the projection of observed variable into the eigenvector (**PC** = **VX**).

Independent Component Analysis (ICA)

- ➢ Observed data variables are a linear mixture of latent variables (also called source or factor).
- ➢ Observed data (**X**) = **AS**, **A** = Mixing Matrix, **IC = A^{-1}X.**

- *Hyvarinen and Oja (2020)*
- *Choudrey (2002)*

Abstract

Fourteen different residual time series have been simulated using the Gauss-white noise and heavy-side step function to represent the discontinuity in the GPS time series. We used blind source separation techniques (PCA, and ICA) to identify the simulated transients. Although discontinuities in the simulated signals are perfectly extracted by both the techniques, we need station's contribution to PC to get more insights into the stations which will be helpful to better constrain the data-processing of real geodetic data sets without a priori information about the data.

Results and Analysis

Simulation of input signal: To know the ability of the different algorithms for retrieving the known sources, we have performed a series of tests on synthetic time series. For the synthetic signal, we input source (S) and noises (N). We have introduced Gaussian White Noise (as noise) and Heavy-side step function (as discontinuity for transient representation).

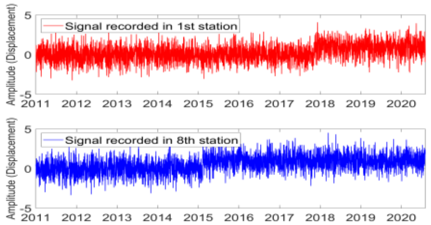
Simulation: Test-1

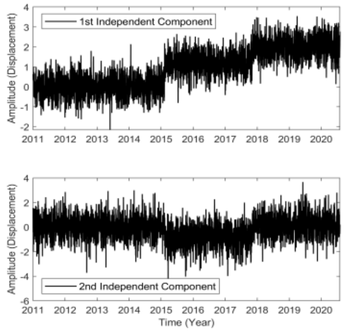
Gaussian-white noise with mean "0" and standard deviation "1" is used for all the fifteen stations. Heavy-side step function of magnitude "1" is employed as the discontinuity from the epochs 2500 (around 2018 in the year) and above for all the stations.

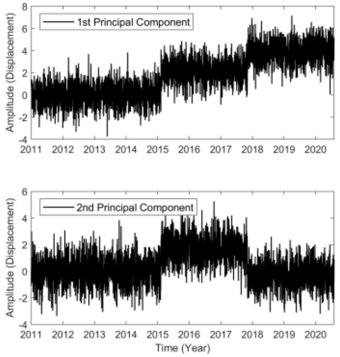
➢ Discontinuity is identified by both PCA and ICA (figure in the central right box).

Simulation: Test-11

Two different amplitudes of step function are applied. One with "1" from 2018 for the first seven stations and amplitude "1.2" from 2015 for the remaining last eight stations. Both the perturbations are in upward direction.



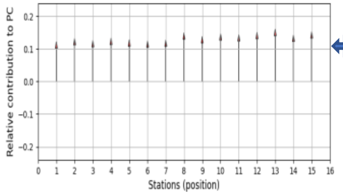




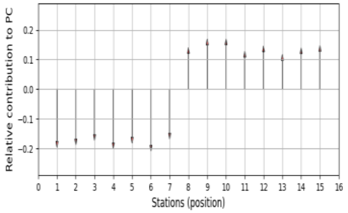
- ❖ Principal components are able to identify both discontinuities in the signal.
- ❖ ICA shows a mixed effect in picking the discontinuity.
- ❖ Stations show their contribution mainly in two ways meaning data can divide into two clusters for further processing.

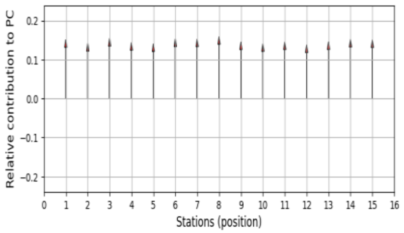
Station contribution to:

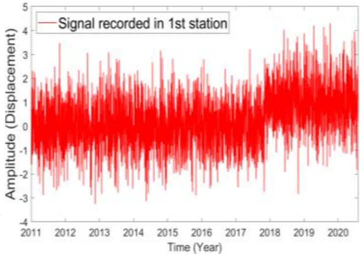
1st PC



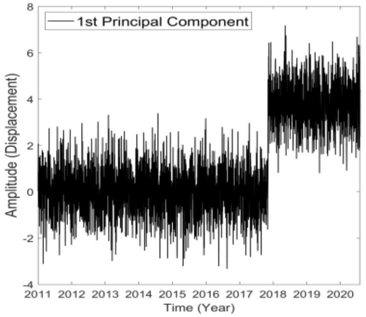
2nd PC



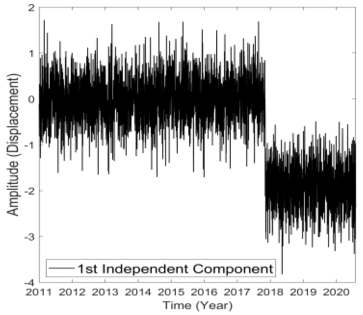




PCs from PCA



ICs from fastICA



Conclusion

- ➢ All the BSS techniques are able to identify the discontinuity however we require the contribution plot for proper interpretation.
- ➢ Noise in data influences the results (for discontinuity identification with the contribution of PC).
- ➢ The contribution plot further gives the eventual local or spatial effects and clustering in the stations which is important to understand which stations have more/less contribution to the signal.
- ➢ The BSS techniques help to better understand the input data without a priori information but 'colored noise' is necessary to mimic the real geophysical signal.