Nonlinear PCA for Spatio-Temporal Analysis of Earth Observation Data
Supplementary material

Here we extend the spatial-temporal decomposition of the global Soil Moisture (SM) explained in the paper with the ROCK PCA method and we performed the decomposition with PCA and PCA with a VARIMAX rotation. The comparison with a real data experiment will show how a complex nonlinear rotated method could perform a better spatial-temporal decomposition.

PCA decomposition:

Temporal components are coupled as, for example, PC3 have a periodic signal with an annual period as the PC1 and PC4 have a long trend

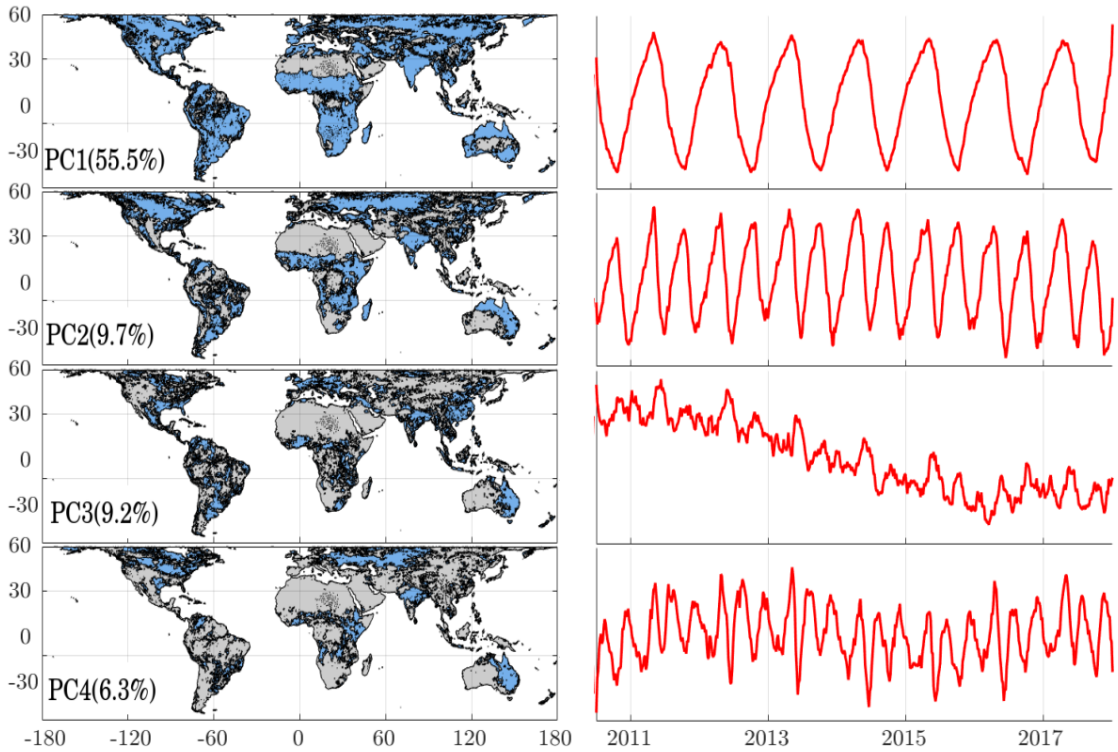

Fig.1 Spatio-Temporal decomposition of global SM obtained with PCA.

A linear PCA, perform a decomposition of data that results in a set of four variability modes but obtaining a mixed component set. This issue is fixed with the VARIMAX rotation, where the rotation unmix the components and allow to obtain a set of signals with different periodicity.

The kernel extension allow to find a nonlinear decomposition that unmixed better the principal components. I was our case, the nonlinear decomposition is almost linear but still nonlinear. In fig. 4, we illustrate the scatter plot between the covariance matrix (linear case) and the estimated kernel matrix with the real and imaginary components, in each case. The dispersion from the linear case show the nonlinear decomposition, where we can conclude that the variability modes of global SM are quasi-linearly separable.

PCA decomposition with VARiMAX rotation:

Temporal components are desacoupled in comparison with PCA. Some periodic signals still mixed with the PC3. Spatial distribution of components represents acurately the main variability modes of the global SM.

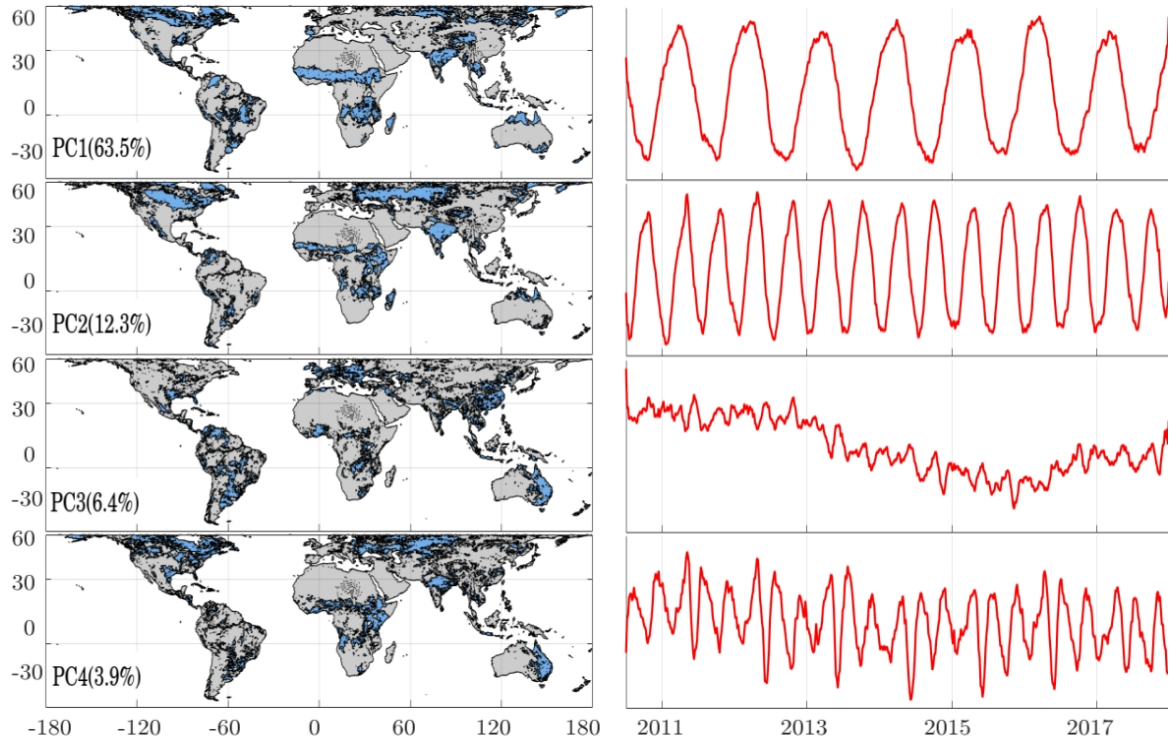

Fig.2 Spatio-Temporal decomposition of global SM obtained with PCA and VARIMAX rotation.

ROCK PCA decomposition:

Temporal components are desacoupled in comparison with PCA and VARIMAX rotation. PC3 appears completely unmixed with other periodic signals and also is represented at the spatial distribution. Spatial distribution of components represents acurately the main variability modes of the global SM.

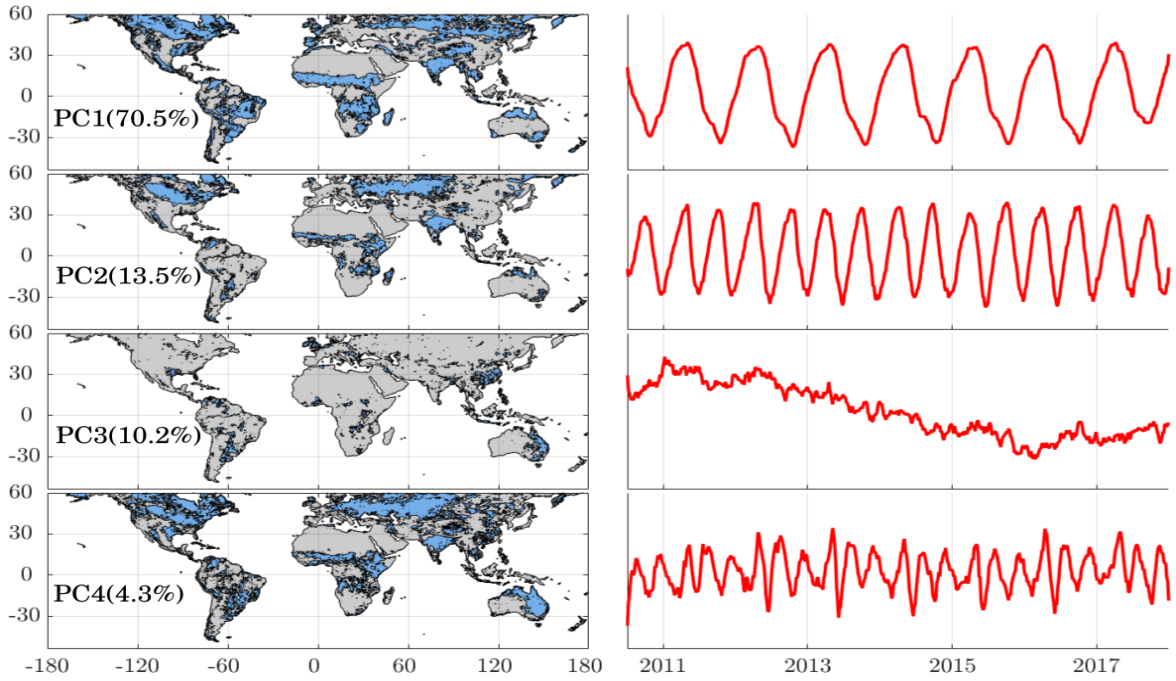

Fig.3 Spatio-Temporal decomposition of global SM obtained with ROCK PCA.

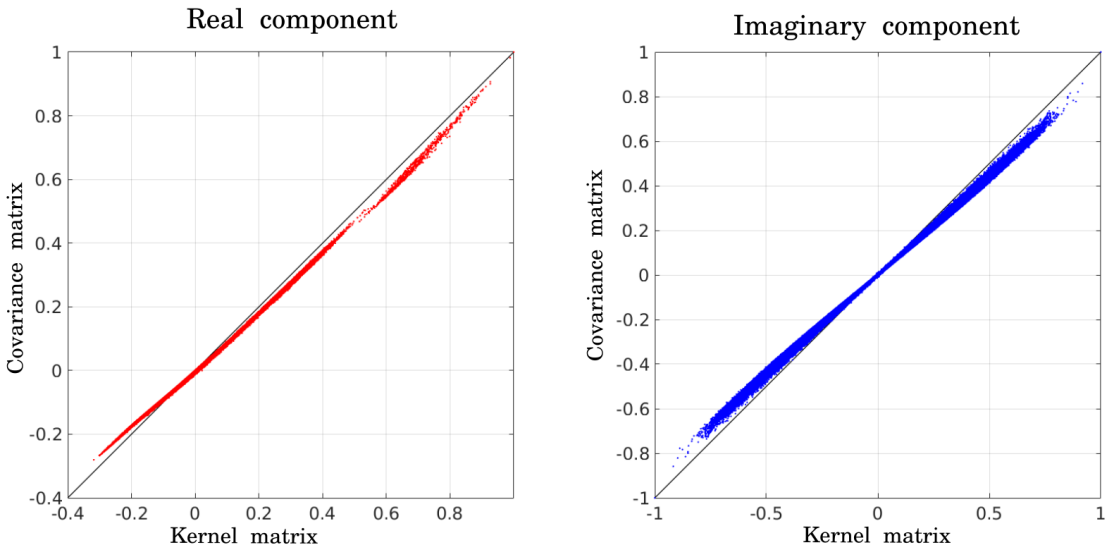

Fig.4 Scatter plot between thew covariance matrix (linear case) and the estimated kernel matrix (nonlinear case) element-by-element.

In the fig. 5, we compare the estimated time series and his respective power spectrum for each method. The varimax rotation and the ROCK PCA sharper accurately each component in the frequency domain, as for example PC1 with the 6 month period signal. Between Varimax and ROCK PCA, the difference is lower, but still significant, as, for example, the ROCK PCA can remove the 4 months signal from the PC3 and also remove the long trend term from the PC4.

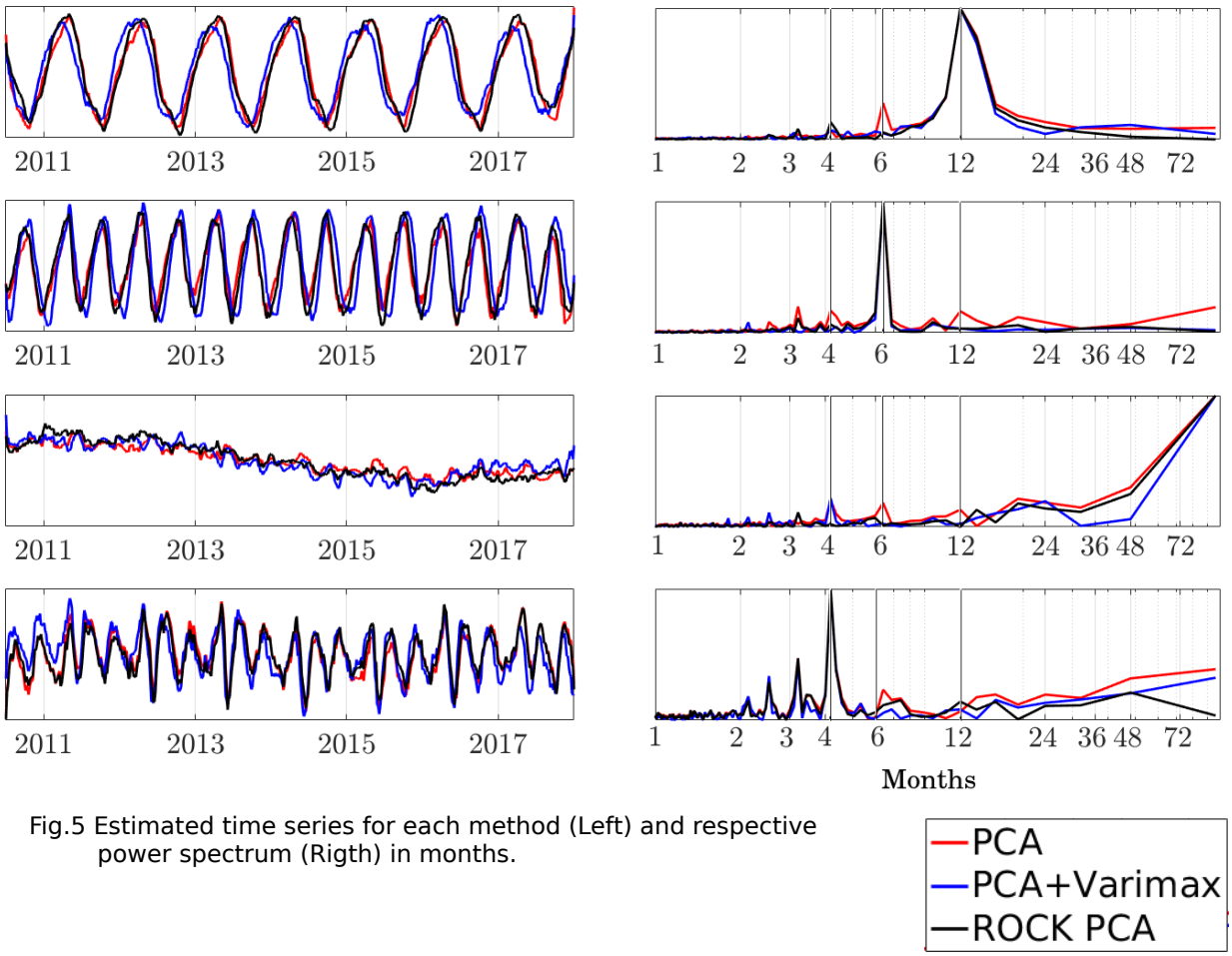

Fig.5 Estimated time series for each method (Left) and respective power spectrum (Rigth) in months.