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Developing a complex independent component analysis technique to extract non-stationary patterns from geophysical time-series

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Geodetic/geophysical observations, such as the time series of global terrestrial water storage change or sea level and temperature change, represent samples of physical processes and therefore contain information about complex physical interactionswith many inherent time scales. Extracting relevant information from these samples, for example quantifying the seasonality of a physical process or its variability due to large-scale ocean-atmosphere interactions, is not possible by rendering simple time series approaches. In the last decades, decomposition techniques have found increasing interest for extracting patterns from geophysical observations. Traditionally, principal component analysis (PCA) and more recently independent component analysis (ICA) are common techniques to extract statistical orthogonal (uncorrelated) and independent modes that represent the maximum variance of observations, respectively. PCA and ICA can be classified as stationary signal decomposition techniques since they are based on decomposing the auto-covariance matrix or diagonalizing higher (than two)-order statistical tensors from centered time series. However, the stationary assumption is obviously not justifiable for many geophysical and climate variables even after removing cyclic components e.g., the seasonal cycles.

In this paper, we present a new decomposition method, the complex independent component analysis (CICA, Forootan, PhD-2014), which can be applied to extract to non-stationary (changing in space and time) patterns from geophysical time series. Here, CICA is derived as an extension of real-valued ICA (Forootan and Kusche, JoG-2012), where we (i) define a new complex data set using a Hilbert transformation. The complex time series contain the observed values in their real part, and the temporal rate of variability in their imaginary part. (ii) An ICA algorithm based on diagonalization of fourth-order cumulants is then applied to decompose the new complex data set in (i). (iii) Dominant non-stationary patterns are recognized as independent complex patterns that can be used to represent the space and time amplitude and phase propagations. We present the results of CICA on simulated and real cases e.g., for quantifying the impact of large-scale ocean-atmosphere interaction on global mass changes.

Forootan (PhD-2014) Statistical signal decomposition techniques for analyzing time-variable satellite gravimetry data, PhD Thesis, University of Bonn, http://hss.ulb.uni-bonn.de/2014/3766/3766.htm

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