Geophysical Research Abstracts
Vol. 13, EGU2011-6440, 2011
EGU General Assembly 2011

Robust identification of phase synchronization clusters via multivariate singular spectrum analysis

Andreas Groth (1) and Michael Ghil (1,2)

(1) Environmental Research and Teaching Institute and Laboratoire de Météorologie Dynamique (CNRS and IPSL), Ecole Normale Superieure, Paris, France (andreas.groth@ens.fr), (2) Department of Atmospheric & Oceanic Sciences and Institute of Geophysics & Planetary Physics, University of California, Los Angeles, USA

In numerous applications over the last two decades, multivariate singular spectrum analysis (M-SSA) has proven its usefulness in the spatio-temporal analysis of short and noisy time series (for an overview see e.g. Ghil et al., Rev. Geophys., 2002). M-SSA provides insight into the unknown or partially known dynamics of the underlying system by decomposing the delay-coordinate phase space of a given multivariate time series into a set of data-adaptive orthonormal components and allows one to reconstruct a robust "skeleton" of the dynamical system's structure.

M-SSA is able, in particular, to detect oscillatory modes that can be attributed to unstable periodic orbits (UPOs), and which leave their imprint on the system's observed time series. UPOs are road posts on the way from simple to complex dynamics, and play an important role in the synchronization process. In this talk, we demonstrate that M-SSA provides considerable insight into the mechanism of phase synchronization within a chain of coupled chaotic oscillators. Without having to rely on detailed knowledge of individual subsystems, nor on a suitable phase definition for each of them, M-SSA is able to automatically identify common oscillatory modes and to detect clusters of synchronized oscillators. This makes M-SSA superior to methods that require an explicit and a priori phase definition in the analysis of high-dimensional systems contaminated by observational noise.

Assuming that there exists an appropriate phase definition, Allefeld et al. (Int. J. Bif. Chaos, 2007) have demonstrated the usefulness of an eigenvalues decomposition of the corresponding phase coupling matrix in the detection of synchronization clusters. The appearance of degenerate eigenvectors, however, is a general problem in the eigenvalue decomposition of large matrices and it impedes correct cluster identification (Bialonksi & Lehnertz, Phys. Rev. E, 2006). For this reason, Vejmelka & Palus (Chaos, 2010) have recently proposed subsequent varimax rotation of eigenvectors.

We show in this talk that a modified form of varimax rotation also improves the M-SSA results greatly. M-SSA analysis goes in fact beyond a pure classification of oscillators into clusters by means of a participation index, and allows furthermore to reconstruct the dynamical behavior that participating oscillators share. Even in the presence of contamination by high noise levels, e.g. when Gaussian noise with the same standard deviation as the signal is added, the M-SSA results are robust. M-SSA thus provides a robust identification and reconstruction of synchronization mechanisms from high-dimensional and noisy observations.