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Multivariate singular spectrum analysis and phase synchronization: An application to U.S. business cycles

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Over the last two decades, singular spectrum analysis (SSA) and multivariate SSA (M-SSA) have proven their power in the temporal and spatio-temporal analysis of short and noisy time series in numerous fields of the geosciences and of other disciplines. 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. These components can be classified essentially into trends, oscillatory patterns and noise, and allow one to reconstruct a robust "skeleton" of the dynamical system's structure. For an overview we refer to Ghil et al. (Rev. Geophys., 2002).

We first present M-SSA in the context of synchronization analysis and illustrate its ability to unveil information about the mechanisms behind the adjustment of rhythms in coupled dynamical systems. This poster deals with the special case of phase synchronization between coupled chaotic oscillators (Rosenblum et al., PRL, 1996). Several ways of measuring phase synchronization are in use, and the robust definition of a reasonable phase for each oscillator is critical in each of them. We illustrate here the advantages of M-SSA in the automatic identification of oscillatory modes and in drawing conclusions about the transition to phase synchronization. Without using any a priori definition of a suitable phase, we show that M-SSA is able to detect phase synchronization in a chain of coupled chaotic oscillators (Osipov et al., PRE, 1996).

The key application of these theoretical results in this poster is to U.S. macroeconomic data for 1954–2005. M-SSA helps us draw conclusions about the cyclical behavior of the U.S. economy and its underlying dynamical properties. The recurrence of expansions and recessions, at approximately 5–6-year intervals, is referred to as business cycles; their origin is still a matter of considerable controversy. Our analysis sheds light on the question whether this behavior is of a randomly forced, but essentially linear nature, or whether it can be attributed to the endogenously produced oscillations of the underlying, nonlinear system. The presence of such oscillatory modes in the present analysis of U.S. macroeconomic indicators has important consequences for the net impact of natural disasters on the U.S. economy: Hallegatte and Ghil (Ecol. Econ., 2008) have shown that the presence of business cycles modifies substantially this impact with respect to their impact on an economy in or near equilibrium.