Detecting the Precursor of Auroral Substorms in Ground-magnetometer Data by Applying Singular Spectrum Analysis

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To predict an occurrence of extraordinary phenomena, such as earthquakes, failures of engineering system and financial market crushes, it is important to identify precursory events in time series. However, existing methods are limited in their applicability for real world precursor detections. Moskvina and Zhigljavsky [2003] used the singular spectrum analysis (SSA) technique for change detection in time series, based on the SVD on the Hankel matrix generated by original time series. The original aim of the SSA is to reconstruct principal structures of time series and make a decomposition of an original time series into the sum of a small number of uncorrelated and interpretable components. It has been applied to forecast various phenomena, such as industrial production, daily exchange rates and hydrological variations. Ide and Inoue [2005] have developed an SSA-based change-point detection method, called singular spectrum transformation (SST). In this paper, we extend the SST so that it is applicable for real world precursor detections, focusing on the wide applicability of the conventional SST. Although the SST is suitable for detecting various types of change-points, detecting precursors can be far more difficult than expected because, in general, real world time series contains measurement noise and non-stationary trends. Furthermore, precursory events are usually observed as minute and less-visible fluctuations preceding an onset of massive fluctuations of extraordinary phenomena and therefore they are easily over-looked. To overcome this, we extend the conventional SST to the multivariable SST, focusing on the synchronism detection of precursory events in multiple sequences of univariate time series. First, we would like to define the problem setting of real world precursory detections and consider its difficulties. Second, the multivariable SST is introduced. Third, we apply SST to geomagnetic time series data and show the multivariable SST is more suitable than the conventional SST for real world precursor detections. Finally, we show further experimental results using artificial data to evaluate the reliability of SST-based precursor detections.

Keywords: substorm, precursor detection, time series analysis, singular spectrum analysis