A detection of substorm precursors on geomagnetic data at auroral latitudes by SSA-based change-point analysis

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Until now, several studies have shown about substorm precursors, which are observed in the auroral region and preceded to onset of substorm expansion phase by 1-3 minutes. Kepko et al., [2004] indicated that high-latitude magnetogram shows a very small negative deflection in the H-component before auroral arc brightening. Morioka et al. [2008] reported the dH/dt component from a search-coil magnetometer at ground shows that a few minutes prior to high-altitude AKR breakup, the quasi-DC component begins a negative exclusion that is nearly synchronized with the start of the gradual enhancement of the low-altitude AKR. Although these observations suggest that the precondition of ionosphere before onset of substorm expansion phase plays an essential role to drive a sudden formation of a parallel electric filed, more detailed analysis is needed to elucidate spatio-temporal evolutions of the substorm precursors. In this paper, we will present a new algorithm based on Singular Spectrum Analysis (SSA), described in the next paragraph, to detect substorm precursors from high-latitude ground magnetometer data.

Singular Spectrum Analysis (SSA), used as a powerful technique in time series analysis, has been developed and applied in the field of geophysics. The original aim of SSA is to reconstruct principal structures of time series and make a decomposition of the original time series into the sum of a small number of uncorrelated and interpretable components such as slowly varying trend, oscillatory components and a structureless noise. In recent years, SSA has been applied for failure diagnosis of engineering systems in the field of data mining. Ide and Inoue [2005] demonstrated the effectiveness of a SSA based change-point detection method to detect a structure change of various types of time series. Since this approach is completely data adaptive, it is probably a powerful method for our aim: to detect a small and irregular perturbation such as substorm precursors on the geomagnetic data observed in the auroral region.

We have applied SSA-based change-point analysis for a substorm event occurred on January 8, 1997 around 14:35UT. We used ground-magnetometer data from the Circum-Pan Pacific Magnetometer Network (CPMN) [Yumoto et al., 2001]. As a result, two clear change-points were detected from H-component of KTN data at 14:35:25UT and 14:37:25UT. These two change-points remain their essential structure over a wide range of window lengths, which should be pre-adjusted. By comparison with auroral global image provided by Polar/UVI and AKR wave spectrograms provided by Polar/PWI electric field observations, it is confirmed that the first change-point appeared almost synchronized with an initial brightening of aurora and an enhancement of low-altitude AKR. In addition, it is confirmed that the second change-point appeared almost synchronized with the auroral breakup and an enhancement of high-altitude AKR.