Change point in log-periodic power law time series of atmospheric radon concentration

*Daichi Iwata[1], Hiroyuki Nagahama[1], Jun Muto[1], Yumi Yasuoka[2]

1. Dept. Geol., Grad. Sch. Sci., Tohoku Univ., 2. Inst. Radioisot. Res., Kobe Pharm. Univ.

Radon is a radioactive element which belongs to uranium series with a half-life of about 3.8 days. Radon (^{222}Rn) is produced by alpha decay of radium (^{226}Ra). Anomalies in atmospheric radon concentration related to earthquake occurrence have been reported. For example, it has been reported that anomalous increase in atmospheric radon concentration observed in Kobe Pharmaceutical University before 1995 Kobe earthquake (Yasuoka and Shinogi, 1997). It is considered that stress change in the crust causes exhalation of radon from the ground surface resulting in anomalous atmospheric radon concentration (Yasuoka et al., 2009). Moreover the increase before the earthquake according to the log-periodic power law has also been reported (Yasuoka et al., 2006). The log-periodic power law is one of the critical phenomena models, and it is characterized by the fluctuation (logarithmic periodic oscillation) toward the critical point. In addition to the case of atmospheric radon concentration, the power law is also reported in cumulative benioff strain (Newman et al., 1995), chloride ion concentration in ground water (Johansen et al., 1996) and relative ground level (Igarashi, 2000). For fitting the power law model to observed data, it is necessary to analyze by nonlinear least squares method and to define a period for estimating parameters of the model. In previous studies, the periods were selected arbitrarily (e.g., Igarashi, 2000). In this research, we apply a recurrence plot to evaluate nonstationarity of the data to define the fitting period as a non-change of data structure.
We used atmospheric radon data observed at Fukushima Medical University (FMU) from January 2003 to February 2011. As a result, structural change in data of cumulative atmospheric radon concentration after the 2008 Ibaraki-ken Oki earthquake (*Mw* 6.8) was revealed. The power law observed in the cumulative atmospheric radon concentration diverges towards the 2011 Tohoku Oki earthquake. Regarding the 2011 Tohoku Oki earthquake, an increase in the power law has also been reported in cumulative benioff strain (Xue et al., 2012). Cumulative atmospheric radon concentration observed at FMU and benioff strain (Xue et al., 2012) with log-periodic power law seem to indicate critical phenomena of the 2011 Tohoku-Oki earthquake. Beside, application of the recurrence plot to Earth science data has a benefit to know the structural change-point in nonstationarity data.

Keywords: atmospheric radon concentration, earthquake precursor events, log-periodic power law, recurrence plot

