Analysis of anomalousness of atmospheric radon concentration with singular spectrum transformation

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Radon is a natural radioactive gas, which belongs to uranium series and has a half-life of about 3.8 days. Radium (^{226}Ra) decays to radon (^{222}Rn) by emitting an alpha particle. Radon (^{222}Rn) is released from the ground and observed as atmospheric radon concentration in radioisotope institutes.
It is known that the anomalous change in atmospheric radon concentration with earthquakes can be observed. For example, prior to the 1995 Kobe earthquake, the anomalous increase in atmospheric radon concentration was observed at Kobe Pharmaceutical University (Yasuoka and Shinogi, 1997). It is considered that the changes in atmospheric radon concentration related to large earthquakes are caused by the crustal strain enhancing radon exhalation from the ground (Yasuoka et al., 2009). Observed data of atmospheric radon concentration contains many components: seasonal variation, linear trend and anomalous changes. In conventional method, anomalous changes in atmospheric radon concentration are calculated as a residual by removing a seasonal component and the linear trend from data. But it is necessary to know underlying physical relationships among them.
In this study we applied singular spectrum transformation (SST) to atmospheric radon concentration data. SST is a method for calculating a degree of anomalousness directly from observed raw data without any knowledge or physical models about the variation of the data. We calculated degrees of anomalousness using data of atmospheric radon concentration measured at the radioisotope institutes of Sapporo Medical University (SMU) and Fukushima Medical University (FMU) (Kobayashi et al., 2015). Then, we compared them with the results calculated by conventional method assuming seasonal variation and linear trends. We detected the high degrees of anomalousness around 2003 Tokachi oki earthquake (September 26, 2003, Mw 8.0) and 2011 off the Pacific coast of Tohoku Earthquake (March 11, 2011, Mw 9.0) in the data from January 2000 to December 2011 observed at SMU. Moreover we detected high degrees of anomalousness around Ibaraki-ken oki earthquake (May 8, 2008, Mw 6.8), Fukushima-ken oki earthquake (July 19, 2008, Mw 6.9), 2010 Fukushima-ken oki earthquake (March 14, 2010, Mw 6.5) and 2011 off the Pacific coast of Tohoku Earthquake (March 11, 2011, Mw 9.0) in the data from January 2003 to March 2011 observed at FMU. The atmospheric radon concentration calculated by conventional method also increased in these periods. The periods of high degrees of anomalousness coincides with those of high concentration of residual atmospheric radon. This indicates that radon exhalation from the ground increased due to non-seasonal environmental changes in the above periods. Finally, this study also indicates that SST is a powerful method to detect anomalous changes in atmospheric radon concentration.

Keywords: atmospheric radon concentration, detecting anomaly, singular spectrum transformation

