Precursory signals from GPS data for short-term earthquake forecasts: signal processing and assessment

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It has been shown by many studies on catalog-based probabilistic forecasting of earthquakes that only a certain amount of precursory information (probability gain) is available in earthquake catalogs. Borrowing strength from non-catalog measurements for earthquake forecasting became important if we can extract additional precursory information from these measurements. There have been many studies aiming to look for precursory signals in various non-catalog data such as GPS measurements of ground deformation, strain time series, and magnetic or electric fields. It is crucial to assess the performance of these signals as precursors to large earthquakes and test them in different regions.

We developed a filtering technique called moving rate of variation (MRV) to extract short-term signals from the time series of GPS measurements of ground deformation. We applied this technique to the GPS time series from the North Island of New Zealand to extract short-term precursory information for large earthquakes and evaluated the forecasts using Molchan's error diagram.

After that, we tested the statistical significance of these signals by applying the filtering method to different regions with different tectonic settings, Southern California and the Kanto Region of Japan, and examining whether the filtered GPS signals can be used to improve earthquake forecasts in those regions. The results suggest that the GPS signals extracted in the two regions do contain precursory information for predicting large earthquakes, with a probability gain of 2 ~ 4 against a Poisson model and a false alarm rate lower than 50%.

Two further tests were conducted to eliminate the possibility that the precursory information in the GPS signals is due to their occurrence after large earthquakes and before later large aftershocks. Swapping the roles of GPS signals and earthquakes in the Molchan error diagram, the first test shows that the GPS signals are not triggered by large earthquakes. Using earthquakes as both signal and targets in the Molchan error diagram, the second test shows that the selected catalogs in this study are not clustered. These results imply that precursory information in the GPS data can be used to augment probabilistic models based on seismic catalog data, in order to improve forecasting of large earthquakes