Analysis of 30 Minute Resolution GPS Time Series from the Tohoku-Oki Earthquake via Statistical Modeling

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A 30 minute time resolution GPS displacement measurement product has recently been developed from data collected by the Japanese GEONET GPS network for a time period of several days before and after the March 11th, 2011 M9.0 Tohoku-Oki earthquake. This data set shows clear signals of pre- co- and post-seismic displacement, as well as a number of more ambiguous signals.

We applied three different time series analysis methods to this data set in order to further explore the time evolution of the GEONET GPS signals in the period leading up to and following the main shock event. All three of these techniques were statistical in nature: data driven, rather than model driven, deriving their insights only from the measurements themselves. The first was analysis based on fitting hidden Markov models (HMMs) to the data; the optimal model fit to the data implicitly segments each time series into a number of distinct discrete states. When stations change states, how those state changes are geographically distributed, and what underlying measurements generate those state changes all provide insight into the underlying system. The second was analysis based on fitting a Bayesian graphical model to the entire network; the fitted model learns the probabilistic relationships between GPS station measurements. This provides a mechanism for determining the degree to which observations on a particular station or sub-network are anomalous and how that measure of anomaly evolves over time, both in isolation and in the context of the larger network. The third method was that of covariance descriptor analysis, which allows for comparison of time series and time series segments via a covariance distance metric. When the distance between particular set of measurements and a set of nominal data is large, an anomaly is indicated. We discuss the pros and cons of each approach and present preliminary analysis results for the Tohoku-Oki data set.