Classification of sediments in the Nankai Trough accretionary prism by Principal Component Analysis

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The Nankai Trough has been studied extensively for understanding the plate boundary process as the society is threatened by upcoming great earthquake. Nankai Trough Seismogenic Zone Experiments (NanTroSEIZE) in the framework of the Integrated Ocean Drilling Program (IODP) have been obtained seismological and geological data from direct sampling and in-situ measurement by drilling into the shallow accretionary prism. The feature of sediments forming the accretionary prism have been figured out based on analyses of drilled core and drill cuttings. Classification of the sediments by defining lithological units has been performed by mainly synthesis of observational results and log data. Analyses of mineral and chemical composition and gas composition were also important auxiliary data.
Here we try to classify the sediments based on the chemical composition using Principal Component Analysis (PCA), and estimate chemical processes relate to the depositional and diagenetic process of sediments and the formation process of the accretionary prism. We used major chemical compositions data of 6 IODP drill sites situated in Kumano forearc Basin, Slope sediment, Frontal thrust zone and Subduction input in the Nankai accretionary prism. The PCA results show that the sediments from the Kumano forearc Basin and accretionary prism were obviously distinguished in terms of chemical composition. Classification of the sediments is firstly sensitive to LOI, CaO and SiO_2 contents, and secondary relate to metallic elements such as MgO, Fe_2O_3 and TiO_2. It implies that the abundance in LOI and CaO is linked to diagenesis of sediments, and so does metallic components to their depositional source.

Keywords: the Nankai Trough accretionary prism, Chemical composition, Principal Component Analysi

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

Geodetic inversion for spatial distribution of slow earthquakes under sparsity constraint (Fused Lasso)

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In geodetic data inversion, insufficient observational data and smoothness constraints for model parameters make it difficult to clearly resolve small-scale heterogeneous structures with discontinuous boundaries. Therefore, we have developed a novel regularization scheme for the inversion problem that uses smoothness, discontinuity, and sparsity constraints [Nakata et al., 2016]. We have applied the inversion method to synthetic displacements due to the simulated afterslip on the plate interface. The method accurately reproduces the slip distribution. However, the proposed method have some problems in terms of calculation cost and applicability. Then, we are now improving the method to treat more realistic and larger scale problem than our previous study. We are investigating other mathematical algorithms as the sparsity constraint, such as Fused Lasso, Adaptive Lasso, and Relaxed Lasso for evaluation function. And we prepare analyzing realistic displacement data observed at GEONET stations around the Bungo channel on 1997, 2003, and 2010. By using an improving method, we will show inversion results using sparsity constraint for the three slow slip events occurred beneath the Bungo channel.

Joint estimation of parameters and initial conditions of numerical models of fault slip using data assimilation methods

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Numerical models of the evolution of fault slip based on rate- and state-dependent friction laws have been widely used to simulate variety of seismic and aseismic fault slip behavior during the earthquake cycle, including earthquakes, afterslip, slow slip events, and steady aseismic creep. In these numerical models, the evolution of slip and shear stress on faults are governed by the force balance equations and friction law equations for many subdivided fault patches. The friction law equations include parameters that describe frictional properties of the fault. Previous studies have shown that these parameters, which are often called friction parameters, as well as initial conditions of the model, are one of the major governing factors in determining the evolution of fault slip. Although several studies have proposed methods to estimate friction parameters with fixed initial conditions based on GNSS data [Fukuda et al., 2009; Kano et al., 2013, 2015], it has been difficult to constrain the friction parameters and initial conditions simultaneously. In this study, we develop methods to simultaneously estimate the friction parameters and initial conditions of the rate-state friction model of fault slip using data assimilation methods.
In this study, we employ a two-dimensional planar fault in a three-dimensional elastic half-space. The evolution of slip rate and shear stress on the fault is governed by the force balance equation and rate- and state-dependent friction law. We assume that time-series of displacements at stations on the ground surface are observable. We employ the ensemble Kalman filter and smoother (EnKF) and adjoint method to simultaneously estimate cumulative slip, slip rate, and frictional state variable for each subdivided fault patch and friction parameters.
We conduct synthetic tests to assess the validity of the proposed methods. In these synthetic tests, we focus on afterslip, which is transient, decelerating, aseismic slip triggered by stress changes due to a large earthquake. We impose an earthquake using a circular crack with constant stress drop and calculate coseismic shear stress changes on the fault. Slip rate and frictional state variables immediately after the earthquake are determined based on the calculated coseismic shear stress changes. Using these slip rate and frictional state variables as the initial condition, we employ the rate-state friction model to simulate the evolution of afterslip assuming that the fault has a velocity-strengthening frictional property. We then compute displacement time series at stations on the ground surface using the simulated slip history. Finally, we add normally distributed observation errors to generate simulated data. This simulated data set is used in the synthetic tests.
For the case of the EnKF, we find that the prediction step of the EnKF becomes numerically unstable if some of the initial ensemble members have values significantly different from the true values. These numerical instabilities occur when, for example, the initial ensemble members are randomly generated. In contrast, if the initial ensemble members have similar values to the true values, such numerical instabilities do not occur and consequently the EnKF can successfully be implemented. These results indicate that it is important to develop a method to generate appropriate initial ensemble to successfully implement the EnKF for our model. We will also show the results obtained from the adjoint method in the presentation.

Keywords: data assimilation, fault slip, friction parameters

