Development of Monitoring and Forecasting Methods for Crustal Activity Utilizing Large-Scale High-Fidelity Finite Element Simulations with 3D Heterogeneous Medium

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To analyze crustal activity in the Earth's interior, such as spatio-temporal variation in slip velocity on the plate interface including ordinary and slow earthquakes, we need to use the data observed mostly on the Earth's surface. If the data are limited on land that is far from the deformation sources, it would be enough to use simple model as elastic homogeneous half space. However, it is becoming intrinsic to consider 3D heterogeneous structure of the interior, especially in subduction zones, since we can obtain dense surface deformation data on land and partly on the seafloor. Thus, to fully utilize such fruitful data, it is necessary to develop physics-based data analysis methods including (1) a structural model with the 3D geometry of the plate interface and the material properties such as elasticity and viscosity, (2) calculation codes for crustal deformation and seismic wave propagation using (1), (3) inverse analysis or data assimilation codes both for structure and fault slip using (1) and (2). To accomplish this, it is at least necessary to develop highly reliable large-scale simulation code to calculate crustal deformation and seismic wave propagation for 3D heterogeneous structure. Unstructured finite element (FE) non-linear seismic wave simulation code has been developed (Ichimura et al. [2015]). This achieved physics-based urban earthquake simulation enhanced by 1.08 T DOF x 6.6 K time-step. A high-fidelity FE simulation code with mesh generator has also been developed to calculate crustal deformation in and around Japan with complicated surface topography and subducting plate geometry for 1 km mesh (Ichimura et al. [2016]). This code has been improved for higher resolution in calculation of crustal deformation and achieved 2.05 T-DOF with 45 m resolution on the plate interface (Fujita et al. [2016]. This high-resolution analysis enables evaluation of change in the stress acting on the plate interface. For inverse analyses, a waveform inversion code for modelling 3D crustal structure has been developed (Ichimura et al. [2017]). Furthermore, such large-scale simulation codes have been implemented on a GPU cluster and analysis tools have been developed to estimate fault slip distribution with considering uncertainty in structural models (Yamaguchi et al. [2017a, 2017b]). Utilizing them, we are developing the data assimilation method for monitoring and forecasting the slip velocity variation on the plate interface with 3D heterogeneous structure.

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