A Physics-based Predictive Simulation Model for Crustal Activity in and around Japan

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In the last decade there has been great progress in the physics of earthquake generation; that is, the introduction of laboratory-based fault constitutive laws as a basic equation governing earthquake rupture and the quantitative description of tectonic loading driven by plate motion. Now we can quantitatively describe the entire earthquake generation process by a coupled nonlinear system, which consists of an elastic/viscoelastic slip-response function and a fault constitutive law. The driving force of this system is observed relative plate motion. The system to describe the earthquake generation cycle is conceptually quite simple. The complexity in practical modelling mainly comes from complex structure of the real earth. Since 1998 our research group has conducted the Crustal Activity Modelling Program (CAMP), which is one of the three main programs composing the Solid Earth Simulator project promoted by MEXT. The aim of CAMP is to develop a physics-based predictive simulation model for crustal activity in and around Japan. The total simulation system is divided into three components: a crust-mantle structure model, a tectonic loading model and a dynamic rupture model. For the present we have developed a 3-D standard model of plate interfaces in and around Japan, the viscoelastic slip-response functions for this structure model, and the slip- and time-dependent fault constitutive law with an inherent strength-restoration mechanism. Combining all these elements, we can construct a quasi-static tectonic loading model. We have also developed a simulation algorithm for dynamic rupture propagation on a 3-D curved fault surface by applying BIEM. In the last stage of CAMP the quasi-static loading model and the dynamic rupture model are connected with each other through a simulation platform on the Earth Simulator, which is a high performance, massively parallel-processing computer system with 10 TB memories and 40 TFLOPS peak speed. Outputs of the simulation system are the crustal deformation, internal stress change and seismic wave radiation associated with seismic and/or aseismic slip at the plate interfaces. From comparison of these computed data and observed data, we can extract useful information to estimate the past slip history and the present stress state at the plate interfaces by using an inversion technique. Given the past slip history and the present stress state, we can predict the next step fault slip motion and stress change through computer simulation.