Eulerian numerical procedure for large deformation of visco-elasticfluid: Toward plate-mantle simulation

Mikito Furuichi[1]; Masanori Kameyama[2]; Akira Kageyama[3]

[1] Earth simulator; [2] ESC/JAMSTEC; [3] JAMSTEC

http://www.es.jamstec.go.jp/esc/research/Solid/index.ja.html

It is well known that the tectonic plate shows strongly nonlinear behaviors as the cool surface layer in a convecting mantle. For the purpose of simulating the realistic mantle convection which includes the plate tectonics, one needs to take into account not only the motion of viscous fluids but also the large deformation of the elastic plates over the timescale of mantle convection. We have developed the method for solving the finite deformation of visco-elastic fluids based on the Eulerian finite volume method. This technique solves the force balance equation and the Maxwell visco-elastic constitutive equation for large deformation in following three steps.

First, the advection term of constitutive equation is evaluated by semi-Lagrangian scheme. Our calculation scheme, combined with CIP-CSLR (CIP-Conservative Semi-Lagrangian by using rational function), turned out not only to yield rather low diffusive solution in the advection phase, but also to advect the tensor terms with the Jaumann corotational effect which states the principle of material objectivity. Secondly, the non-advection terms of constitutive equation are analytically updated under the assumption that strain rate tensor does not change in the time step $¥Delta t$. Finally, the force balance equations are solved by our developed algorithm, ACuTE method, for a convective motion of highly viscous fluids.

One of the major advantages of our method is that it can naturally handle both the two- and three-dimensional models. We will present some numerical tests to demonstrate the not only qualitative but also quantitative validity of our method, and will further discuss the application of the method toward the large scale three dimensional plate-mantle simulation.