Summary of Session 3.1: Macroscopic methods (FEM, FD, PS, SE) of earthquake faulting and waves

Kazuro Hirahara

Department of Earth and Planetary Science, Nagoya University, Chikusa, Nagoya, 464-0814, Japan (e-mail: hirahara@eps.nagoya-u.ac.jp; phone: +81-52-789-3651; fax: +81-52-789-3033).

Session 3.1 was mainly focussed on a technical discussion of macroscopic methods for wave propagation in geological structures, and fault rupture modeling. The main macroscopic methods that have been discussed are the Finite Difference method (FDM), the Finite Element method (FEM), global pseudo-spectral methods (GPM) and spectral element methods (SEM). Convenors of the session were Prof. K. Hirahara (convenor, Japan) and Dr. D. Komatitsch (co-convenor, USA). The main points that have been discussed during the session are:

1. Evolution towards larger-scale computing.
2. Evolution towards more realistic simulations of the earthquake cycle and of the different processes involved in fault rupture.
3. Evolution towards numerical simulation of wave propagation in large-scale complex media, e.g., basins, site effects.

The key points discussed and the main conclusions were that:

- Efficient algorithms are now available, including with a parallel implementation, most of the time using message passing (MPI). This has been underlined by some speakers of the Geofem group, and by Prof. J. Bielak.
- Very large systems can now be solved efficiently. Typically, problems involving one hundred million degrees of freedom (DOF) or more can now be addressed. Solving big linear systems is difficult, in particular regarding the efficient preconditioning of the system.
- Complex media, including for instance viscoelasticity, anisotropy, fluid and solid regions, can now be studied with efficient algorithms.
- The main problem for basin simulations is now more to have a good geological model of the basin than to do the computations themselves.

Among the issues addressed by the different speakers, let us mention some particularly important points that have been mentioned:

- Prof. J. Bielak showed that classical FEM methods can be used efficiently to model wave propagation in basins. Some points that are usually considered to be technical details (e.g., mesh generation) can become bottlenecks for very big models. FEM is a very flexible method for this problem.

- Several speakers of the Geofem group insisted on the fact that a huge computer is currently being built in Japan (the "Earth Simulator"), with 5120 nodes and 10 Terabytes of memory. It should be available at the end of 2001. There is also a big effort to develop portable parallel software based upon message passing (MPI). Solving big linear systems in this context is difficult (in particular the preconditioning) because no global information is stored. This group plans to put the code on the Web at the end of March, and is interested in standardizing some "plug-ins" for their solver.

- Three talks about FEM applied to the study of faults have shown that complex friction laws (with also viscoelastic or elasto-plastic materials, and/or gravity) can be included in the simulation.

- Finally a talk by D. Komatitsch about the spectral element method has shown that this method is very efficient for modeling wave propagation in basins. It leads to a diagonal mass matrix, and therefore to a very efficient code to deal with systems of several hundred million degrees of freedom. Anisotropy and acoustic (fluid) layers among the elastic model can be handled easily. A very good fit with the reference solution is obtained in validation tests, but meshing is difficult due to the use of hexahedral elements only.