Summary of Session 3:

Physically-based simulation of earthquake generation and the earthquake cycle

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Session issues and questions

The entire processes of earthquake generation cycle consists of several stages such as tectonic loading due to relative plate motion, quasi-static rupture nucleation, dynamic rupture propagation and stop, and fault healing. Development of a realistic computer simulation for earthquake generation cycle requires both the physically-based model including proper fault constitutive laws and highly sophisticated numerical techniques such as solving techniques of non-linear constitutive equations and super-parallel computing techniques for performing realistic large-scale computations. Session 3 aims at exploring the essence of earthquake generation and earthquake cycles, developing new computing techniques to solve non-linear and large capacity calculation, and examining the present status of the physically-based macroscopic simulation of earthquake generation and earthquake cycle including real data analyses, and the further directions are discussed.

Major questions considered were:

- What are the dynamics of earthquake cycles and what are the factors affecting earthquake generation? How can we understand earthquake generation and earthquake cycles by using macroscopic simulation methods?
- How to establish physical models to solve some nonlinear problems such as rate and state or slip and time dependent constitutive laws and 3D viscoelastic modeling in macroscopic simulations?
- How to improve computing techniques such as fast multipoles and parallel computings What are the possibilities, challenges and potential limitations of microscopic simulation approaches?

The questions were considered in three subdivisions of session 3:

Session II1-I: Access to realistic large-scale modeling -multi-scale modeling and super-parallel computing, etc.

Ideally, the earthquake generation cycle in a regional scale should be considered in a framework of larger scale flow or of convection system in the global scale mantle. However, it seems to be difficult to simulate the detailed processes of the earthquake generation cycle in the whole mantle convection system at present. Therefore we need a multi-scale analysis, simulating the earthquake cycle in a limited region which is connected to the whole mantle system through appropriate boundary conditions. Even in such cases, extremely large-scale computations are required for realistic simulations, which is not realized without sophisticated numerical techniques such as supper-parallel computing. We discuss these two aspects of simulation.

Session II1-II: .Modeling of earthquake cycle
For a realistic modeling of earthquake cycle in a regional scale, we need to model the processes of tectonic loading due to relative plate motion, the earthquake generation and the fault healing specifying a fault constitutive law on interfaces of plates or faults. Simulation of earthquake generation cycles at transcurrent and subduction zones are presented employing the advanced techniques of two methods, BIE with green functions and FEM, in elastic or a viscoelastic medium. Further, earthquake cycles in a multi-fault system with complex fault interaction are discussed based on a real earthquake sequence or simplified stress transfer models.

Session II1-III: Simulation of earthquake generation.
This process is indeed included in a part of earthquake cycle simulation, but we are especially focusing on the earthquake generation. A real data analysis on triggering earthquakes is performed, and the effects of the structural heterogeneity and the fault creep on the earthquake generation are examined through laboratory experiments and FEM simulations. Finally, the rate and state friction law and its implementation in earthquake generation simulation through dynamic FD and quasi-static FEM simulations are discussed.

Summary of activities

Working Group 3 (WG3) had six formal activities at the 2nd ACES workshop: Session 3-I, Session 3-II, Session 3-P, Session 3-III, session 3-IV, and Session 3-V. All of them were on Wednesday, 18 October 2000, at which all in attendance at the ACES meeting were present, and a smaller Working Group Meeting of all interested participants on the night of that day. During Session II and Session III, a brief overview of each poster to be presented in Session 3-P was also given.

1. Papers presented

Access to realistic large-scale modeling

- Mantle convection models with viscoelastic, brittle lithosphere numerical methodology and plate tectonic modeling, Louis Moresi, H.Muhlhaus and F. Dufour
- Large-scale viscoelastic analysis, M Iiruka, H.Suito, M.Hyodo and K.Hirahara

Modeling of earthquake cycle

- Physical modelling of earthquake generation cycles at transcurrent plate boundaries, C. Hashimoto and M.Matsu'ura
- Elastodynamic analysis of earthquake sequences on slowly loaded faults with rate and state friction, N. Lapusta and J.R.Rice
- Use of fast multipoles for earthquake modeling, T.E.Tullis, J. Salmon and N.Kato
- Quasi-static FEM modeling of earthquake cycle at a subduction zone based on a laboratory derived law in a laterally heterogeneous viscoelastic medium under gravitation, Kazuro Hirahara
- Stress change in a subducting plate, due to large thrust earthquakes, viscoelastic relaxation and plate convergence, and possible Interaction to intraplate faulting earthquake, Takeshi Mikumo
- San Francisco Bay area earthquake simulations: A step toward a standard physical model ,Steven Ward

Simulation of earthquake generation

- Characterization of fault zones, Y Ben-zion and C. Sammis
- The role of transient deformation in triggering earthquakes, Fred Pollitz
- Rupture sequence with single and double events in a laboratory experiment, S Yoshida and A.Kato
- Effects of subducted seamounts on the source process of the 1946 Nankai earthquake, SW Japan, T Hori, T.Baba, P.R.Cummins and Y.Kaneda
- Simulation of the effects of fault creep on the stress field of its neighbor faults, Yong-xian Zhang and Xiang-chu Yin
- On the slip weakening in rate and state dependent constitutive Law, M Cocco and Bizzarri
- Finite element modeling of seismic faulting with a laboratory-derived rate and state dependent friction law, H-L Xing and A.Makinouchi

2 Poster Part

- Parallel performance of the tectonic loading process model at transcurrent plate boundaries, K. Nakajima, C.Hashimoto and M.Matsu'ura
- Modeling 3-D configuration of plate boundaries in and around Japanese islands, K.Fukui, T.Sato and T.Iwasaki
- 3-D Viscoelastic FEM modeling of kinematic earthquake cycle in Northeast Japan, H.Suito, M.Iizuka and K.Hirahara
- 3-D visco-elastic FEM modeling of kinematic earthquake cycle in Southwest Japan, M.Hyodo, K.Hirahara and M.Iizuka
- Earthquake cycles and rupture patterns: models and insights from paleoseismic data, L.B.Grant
- Simulation of complex recurrence behavior of earthquakes with an interacting fault system model, Manabu Hashimoto