Rapport d'activité

Etude de la génération de séismes et la propagation des ondes sismique

- Study on the earthquake generation and seismic wave propagation processes -

Projet : A0030406700
Responsable : AOCHI Hideo

Allocation

CINES BULL noeuds fins Occigen : 215 000 heures scalaires

Consommation

CINES BULL noeuds fins Occigen : 179 865 heures scalaires, soit 83.66% par rapport à 71.7% de temps passé (20/07/2018)

Scientific Results (below is written in English)

As planned in the scientific description of the current project (November 2017 to Ocober 2018), the numerical simulations of dynamic rupture process and seismic wave propagation were carried out mainly for

- the 2016 Amatrice, Italy, earthquake
- the 2015 Illapel, Chile, earthquake

First of all, although both earthquakes are different in terms of geology, tectonics and seismic magnitude, these experiences allowed to discuss the physical condition of stress field for normal/reverse fault. It is found that normal faulting is less favorable especially in the shallow crust from the point of view of possible initial stress loading and dynamic interaction with the ground surface (***Figure 1***). This is summarized in **Aochi (in revision, Geophys. J. Int., 2018)** and the second paper is in preparation according to the extended abstract in a workshop **(Aochi and Miyake, 2018)**. A new **Boundary Domain Method** was applied to include more precisely the ground surface effects on the rupture process. It is worth citing the numerical capacity. One simulation takes about 11 hours using 30 nodes (x 28 cores = 840 cores in total) for a domain of 60 km x 60 km x 30 km (grid size of 200 m) including a fault of 13 km x 30 km (element size of 300 m).

The first attempt to find a better earthquake model among about 100 simulations for the 2016 Amatrice earthquake is very successful, through the comparison with the kinematic finite source model of other researchers (***Figure 2****; the very early results were previously presented in IASPEI 2017*). This was numerically a hard work, because the preparation of successful dynamic rupture models needs experimental calibration of the parameters, especially in the case where determining the location of asperities and their frictional characteristics are too many parameters to handle automatically. Now that the asperities' locations are sufficiently good enough for the known finite source model, we will be able to explore the frictional parameters by systematical search (scientific description for the year 2018-2019) and hopefully finalize during the year 2018.

The modeling of the 2015 Illapel earthquake opens a new collaboration with the University of Chile, when H. Aochi was invited there in March 2018. We started working on foreshock- mainshock modeling of this large earthquake (about Mw8.2). This large earthquake is important in terms of different scales (high-frequency seismic wave radiation, seismogenic asperities detected by teleseismic data and continuous GPS). We have tested only several models to have research perspectives (see an example in ***Figure 3***). As the earthquake is too large to model using Boundary Domain Method. The simulations are held using a boundary integral equation method and finite difference method, sequentially. Typical dimension of the modeling is a fault of 175 km x 130 km (reduced resolution of a fault element of 2 km) and a volume of 300 km x 450 km x 50 km (still reduced resolution of grid of 500 m). Both calculation take less than 1 hour on 10 nodes (x 28 cores = 280 cores in total). This reduction of the resolution is necessary to calibrate faster the model parameters before carrying out high resolution simulations. An abstract is going to be submitted to AGU Fall Meeting (deadline : the beginning of August 2018). We hope to continue collaborating on this topic with Chilean colleagues.

Besides the main topics presented above, it is worth mentioning other contributions.

- The ground motion simulations of finite source models for a moderate earthquake were added to our previous study of the 2016 ML4.0 Lacq (SW France) earthquake, according to the reviewer's comment (**Aochi and Burnol, J. Seismol., 2018**). The contribution on the calculations of Green's function were already reported last year.
- The simulations using a Boundary Integral Equation Method are carried out for sequential coupling with the TOUGH2 code (Suite of Simulators for Nonisothermal Multiphase Flow and Transport in Fractured Porous Media by Lawrence Berkeley National Laboratory) for simulating the faulting induced by the pore pressure change. TOUGH2 code is launched in advance on PC and its outputs are implemented in boundary integral equation method (**Aochi et al., 2018**).

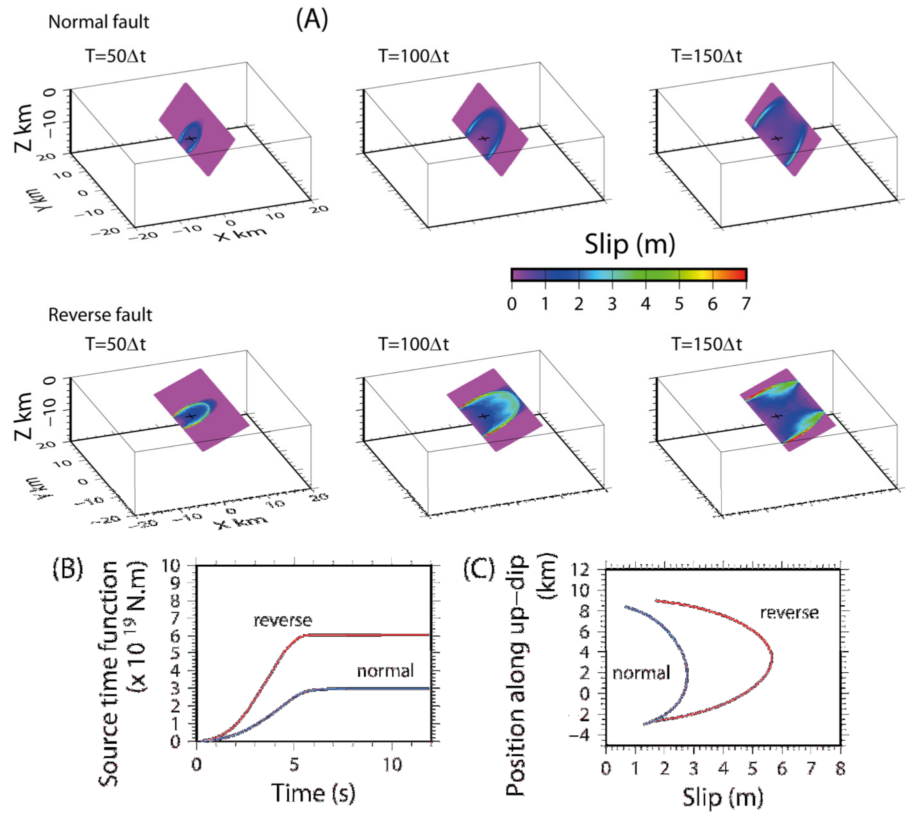

Figure 1 : Comparison of normal and reverse faults simulated by Boundary Domain Method (Aochi, GJI, 2018). (A) Snapshot of rupture propagation at different time steps. (B) Comparison of source time functions. (C) Comparison of fault slip along fault dip.

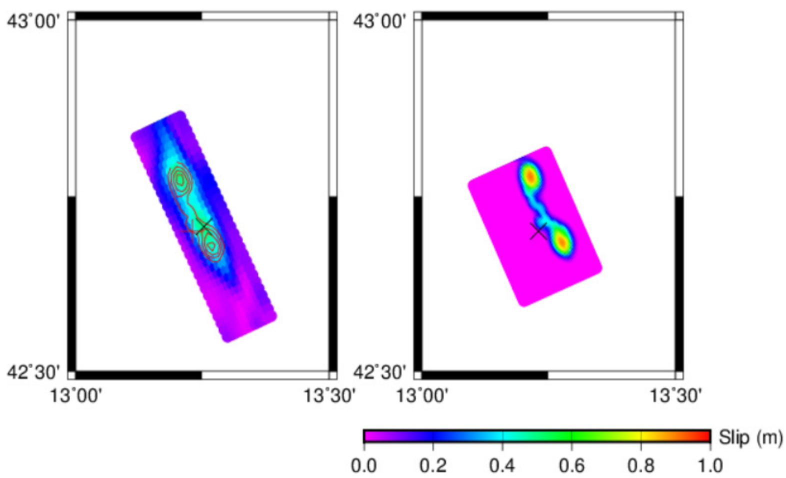

Figure 2: Comparison of kinematic finite source model (Pizzi et al., 2017) (left panel in color) and inverted dynamic rupture model (right panel in color ; also contour on the left). Cross and plus marks represent the hypocenter position of each model.

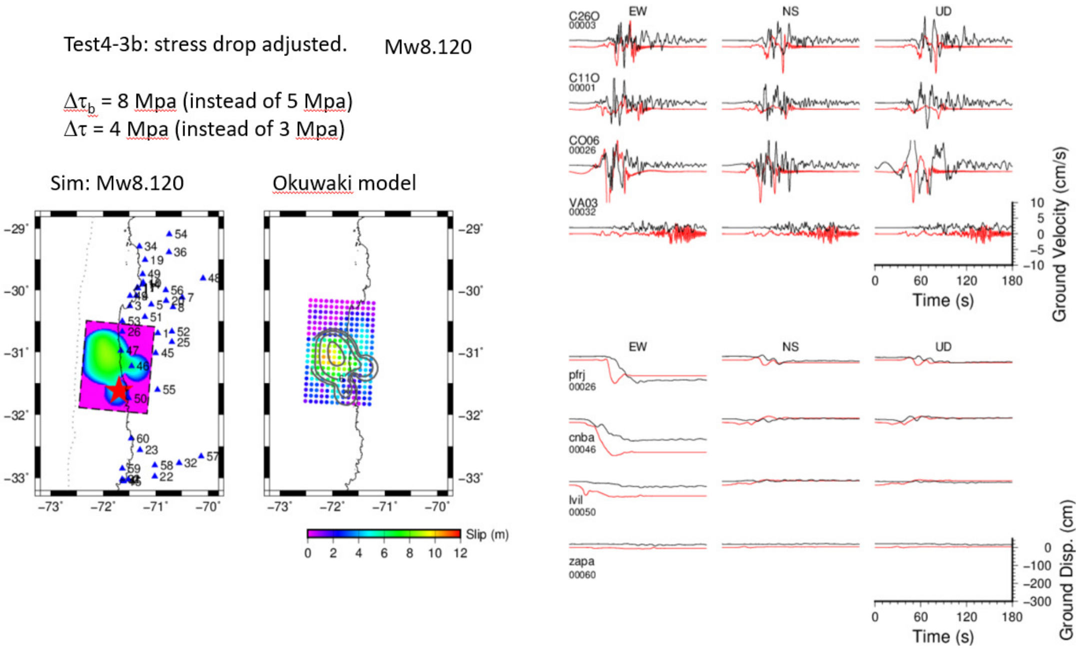

Figure 3: An example of the numerical simulation of 2015 Illapel, Chile, earthquake from boundary integral equation and finite difference methods. (left) comparison of source model with a kinematic source model of Okuwaki et al. (2016). On the right, the comparisons of seismograms in velocity and cGPS in displacement at different stations. Observations in black and simulations in red.

Publications submitted or in preparation

Aochi, H. and H. Miyake, On near-field ground motions of normal and reverse faults from viewpoint of dynamic rupture model – insights from the 2017 Amatrice earthquake, in preparation for Pageoph according to the extended abstract of the workshop held in May 2018.

Publications in 2018

Aochi, H., Dynamic asymmetry of normal and reverse faults due to constrained depth-dependent stress accumulation, in revision, Geophys. J. Int., 2018.

Aochi, H. and A. Burnol, Mechanism of the ML4.0 25th April 2016 earthquake in southwest of France in the vicinity of the Lacq gas field, J. Seismol., published on line, 2018. doi: 10.1007/s10950-018-9758-5.

Conferences with extended abstracts

Aochi, H. and H. Miyake, On near-field ground motions of normal and reverse faults from viewpoint of dynamic rupture model, In the proceedings for the 2nd IAEA workshop on Best Practice in Physics-based Fault Rupture Models for Seismic Hazard Assessment of Nuclear Installations, Cadarache-Château, France, 14-16 May 2018 (extended abstract).

Aochi, H., F. Smai and J. Rutqzist, Repeating earthquake behavior due to fluid circulation through TOUGH-BIEM simulation, TOUGH Symposium 2018, Berkeley, CA, USA, 8-10 October 2018 (extended abstract).