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 -

1. General Information

Projet : A0150406700
Responsable : AOCHI Hideo

Allocation

TGCC BULL Joliot Curie/Irene Rome : 350 000 heurs scalaires
IDRIS Jean Zay CSL : 200 000 heures scalaires.

Consommation

TGCC BULL Joliot Curie/Irene Rome : 354 610 heures scalaires (13/08/2024), soit 101 % des heures accordées.
IDRIS Jean Zay CSL : 182 406 heures scalaires (20/08/2024), soit 91 %.

2. Scientific Results (below is written in English)

First, we have followed the work of numerical simulation of dynamic rupture process and ground motion for the 6th Feburary 2023 Mw7.8 Kahramanmaraş, Türkiye earthquake, the first one of the doublets. This earthquake was recorded at least by 11 near-fault accelerometric stations. It is the first case to allow the researchers studying along-strike variation of rupture process and ground motion from the observations. Aochi & Cruz-Atienza (**submitted to Seismica, 2024**) propose the comprehensible dynamic model of the earthquake, considering non-planar fault strike, regional stress variation, and data-driven frictional parameters. We brought a lot of parameter studies through a combination of boundary integral equation method (BIEM) and finite difference method (FDM). We also compared our simulation with a published kinematic finite source model to understand the role of the heterogeneity, especially by fitting the non-uniform rupture front propagation containing local super-shear rupture propagation (***Figure 1***). High rupture speed area is characterized also by high slip rate and the radiation efficiency of seismic waves, then the peak ground velocity distribution along the fault strike (***Figure 2***). The deployed parameterization approach is valid for reproducing the comprehensive earthquake scenarios, so that would be useful for further seismic hazard application brought by many numerical simulations.

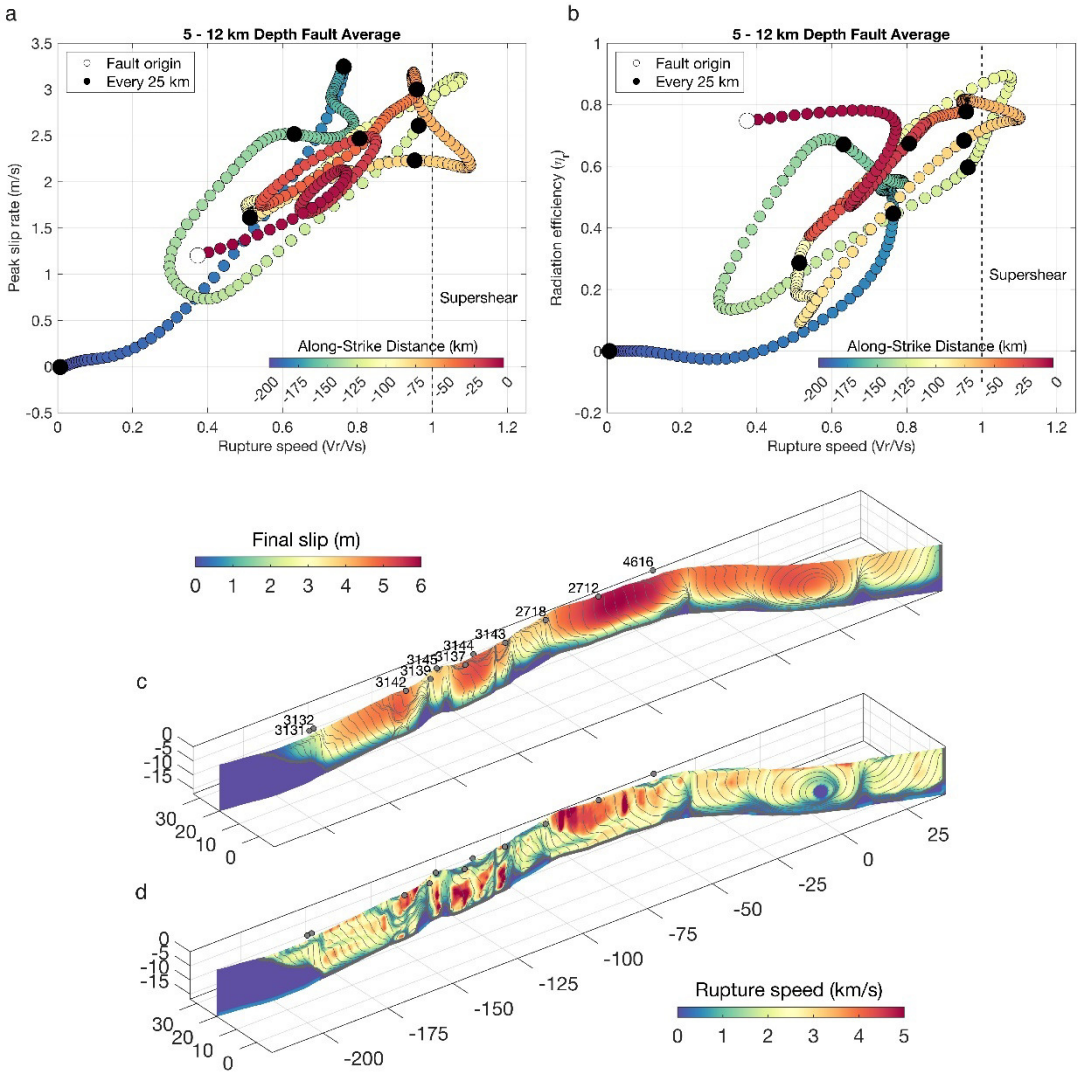

*Figure 1: A simulation result of dynamic rupture simulation along East Anatolian fault. (a) Peak slip rate in function of rupture speed. (b) Radiated energy in function of rupture speed. (c) Final slip distribution and (d) rupture speed. (After **Aochi & Cruz-Atienza, 2024**).*

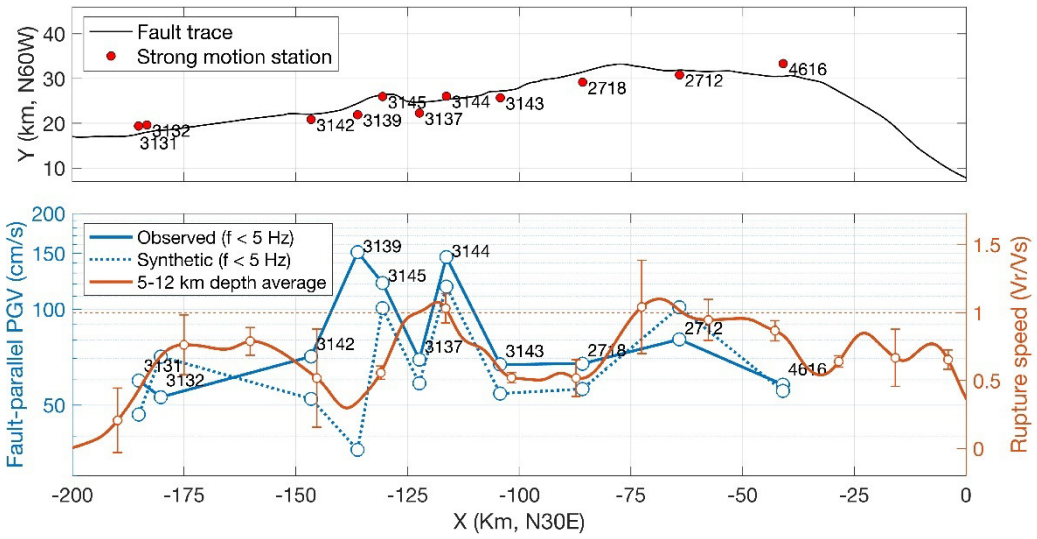

Figure 2: Along-strike distribution of rupture speed and the observed and simulated fault parallel PGV. Rupture speed is averaged between 5-12 km depth. The seismographs in velocity are filtered up to 5 Hz. The station positions are shown on top. After ***Aochi & Cruz-Atienza (2024)****.*

This work is further extended to study the medium heterogeneity of the seismic wave propagation. In fact, the velocity spectra at near-fault stations at low frequencies between 0.1 and 1 Hz can be explained by the 1D structure or even by the fault zone model (low seismic velocity associated to fault zone) (**Aochi & Fukuyama, ESC, 2024**; See ***Figure 3***). The numerical simulation of ground motions are held using a finite difference method (FDM) by introducing the earthquake scenario already computed previously (e.g. **Aochi & Atienza, 2024**). If the shear velocity reduction occurred during the earthquake, fault zone helps to amplify the low frequency amplitude and this is observable at the near-fault stations. We need to further explore this hypothesis from the mechanical point of view and the observations.

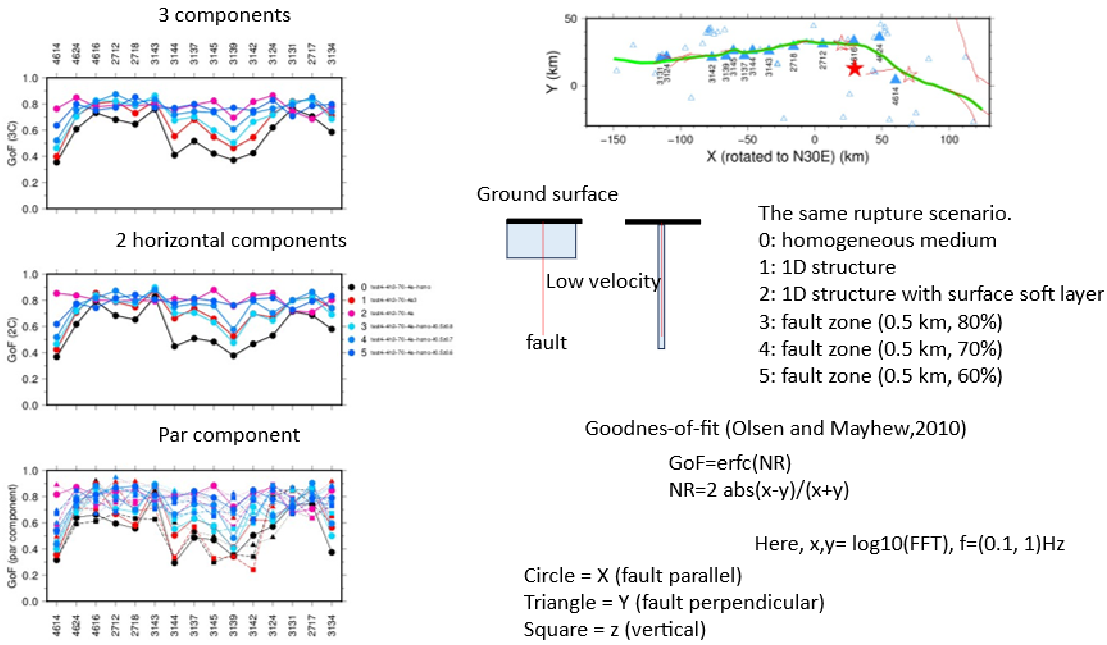

*Figure 3: Numerical simulations of ground motions for the 2023 Turkish earthquake. We prepare different structure models, 1D structure and fault zone models. The ground motions at different seismic station positions are compared with the observation in terms of FFT amplitude through a Goodness-of-fit factor. (**Aochi & Fukuyama, 2024**)*

Second, we have been working on the 2024 Noto Peninsula earthquake sequence (Mw7.6 at maximum). We have particularly focused on the pre-events of M5.5-6 before the Mw7.6 mainshock. One occurred four minutes earlier and another only 13 seconds earlier. The latter can be only recognized at the near stations, otherwise the wave radiation of the prevent is hidden by the mainshock (**Figure 4**). **Aochi (submitted to EPS, 2024)** held dynamic rupture inversion by patch description. Many simulations of BIEM and FDM were carried out. After this analysis, we conclude that the ruptured area of the pre-earthquake is superposed on a map with the mainshock ruptured area, however they may be different fault structure in 3D medium (**Figure 5**). The pre-event runs away from the mainshock hypocenter. Thus, this pre-event does not trigger directly the mainshock rupture. This would be an important remark to understand how this earthquake occurs, as its mechanism is in question (the sequence started since the end of 2020).

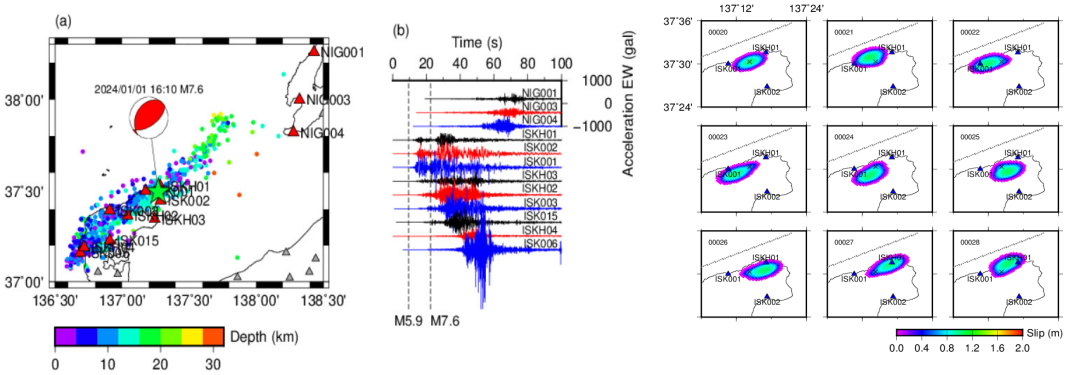

Figure 4 *: Left: (a) Map for the 2024 Noto peninsula earthquake sequences. The seismicity on the 1st January 2024 on the same day of the mainshock after JMA catalog. (b) the acceleration ground motions aligned along the fault line. Only a few stations near the epicenter show the distinguishable seismic waves from the pre-event. Right: Examples of dynamic rupture inversion model to find a position of the target patch and its mechanical parameters. After* ***Aochi (2024)****.*

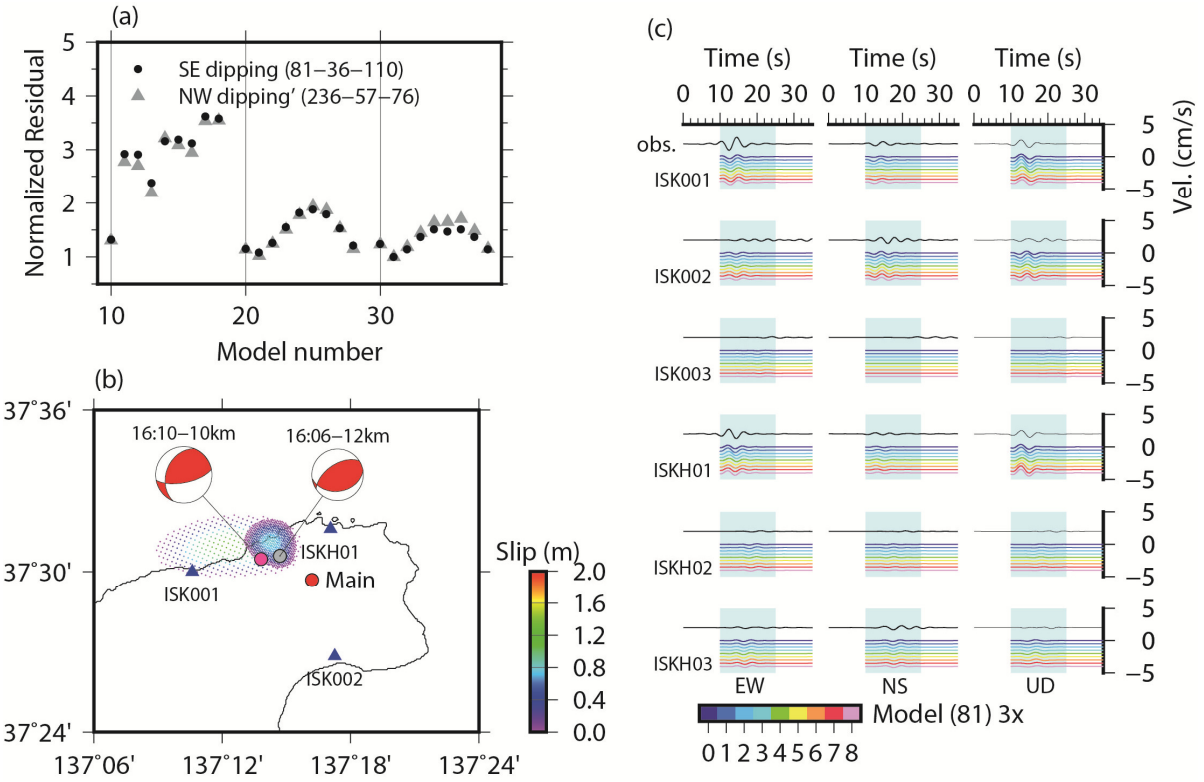

Figure 5 *: Dynamic rupture inversion results for the M5.5 pre-event. (a) Normalized residual for fixed fault parameters. See also Figure 6 caption. (b) Ruptured area obtained for a better model 00031 (southeast-dipping fault, with a high stress case). (c) Comparison between observed (in black) and synthetic (in color) waveforms filtered between 0.03 and 0.3 Hz. Models from 00030 to 00038 on a southeast-dipping fault with a high stress case are shown. A 15-second section is used to calculate residuals. After* ***Aochi (2024)****.*

3. Publications submitted

Aochi, H. and V. M. Cruz-Atienza, Rupture Dynamics and Near-Fault Ground Motions of the Mw7.8 Kahramanmaraş, Turkey earthquake of February 6, 2023, submitted Seismica, 2024.

Aochi, H., Dynamic rupture inversion on the M5.9 pre-event before the 2024 Mw7.6 Noto-Peninsula, Japan, earthquake, submitted to Earth, Planets and Space, 2024.

4. Conferences and posters

Aochi, H., & E. Fukuyama, On the near-fault ground motion from the observation and simulation, European Seismological Commission, Corfu, Greece, September 2024.

Aochi, H., Dynamic inversion of the moderate earthquakes before the mainshock of the 2024 Noto Peninsula, Japan, earthquake, European Seismological Commission, Corfu, Greece, September 2024.

Aochi, H., Dynamic rupture on the ore-events prior to the 2024 Mw 7.6 Noto Peninsula, Japan, earthquake, Japan Geoscience Union Meeting, Chiba, Japan, May 2024.

Aochi, H., V. M. Cruz-Atienza, Characterization of shallow fault parameters from the near-field ground motion data and non-planar dynamic rupture simulations for the Mw7.8 February 6th Pazarcık, Turkey, earthquake, European Geoscience Union General Assembly, Vienna, Austria, April 2024.