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A BROADBAND SOURCE MODELING OF INTERPLATE EARTHQUAKES, METHOD AND APPLICATION

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ABSTRACT:
A method to model broadband source process of hypothetical interplate earthquakes is validated through comparing predicted ground motion with observation of a recent interpolate earthquake in Japan. The method (Sekiguchi et al., 2008) modifies a so-called characteristic asperity model with very long-wavelength heterogeneity by adding adequate amount of shorter wavelength heterogeneity so that the model can generate a broadband ground motion. This method was applied to construct a broadband source model for the 2003 Tokachi-oki earthquake using an inverted source model as a base source model. Synthesized broadband ground motion reconstructed spectra level similar to the observation in the frequency range even above that constrained by the source inversion, which shows the adequacy of the method.

KEYWORDS: source model, ground motion prediction, 2003 Tokachi-oki earthquake, multi-scale heterogeneity, rupture process

1. INTRODUCTION

What size of asperities (patches with relatively large slip) and where to locate them is one of the most important subjects in modeling a hypothetical earthquake source for ground motion prediction. Because, as former studies have shown, strong ground motions and resultant damages are often characterized by microscopic features of source process, especially ruptures of asperities. Diverse range of geologic, geophysical, geomorphologic, and seismological data (e.g. slip distribution of past earthquakes on the same source fault, geometry of fault plane, displacement distribution along surface traces of active faults, estimated locked zone on source faults) are taken into account to model asperities under an assumption that asperities are fault specific characteristics.

For great interplate earthquakes, available information for estimating characteristic slip distribution is rough and sparse because rupture areas are quite large and often far offshore. For example, scale of asperities estimated for interpolate earthquakes on Nankai trough is about several tens to a hundred km (Headquarters for Earthquake Research Promotion of Japan (HERP), 2001; Central Disaster Management Council of Japan (CDMC), 2003). If no heterogeneities smaller than these asperities are given, calculated ground motions are limited to a period range longer than ten or several tens seconds. In order to predict ground motion in the period range affective to damages of most buildings and engineering structures (0.5-10s), smaller scale heterogeneity is necessary.

Sekiguchi et al. (2008) has proposed a method to modify a characteristic asperity model with only very long-wavelength heterogeneity into a multi-scale heterogeneous model which can generate appropriate level of ground motion in broadband period range. In this study, first I outline the method and then apply this method to 2003 Tokachi-oki earthquake, an interplate earthquake along Japan trench, to examine the appropriateness of generating high frequency ground motion.

2. BROADBAND SOURCE MODELING OF HYPOTHETICAL INTERPLATE EARTHQUAKE, METHODOLOGY

In this chapter, I explain the outline of the methodology of broadband source modeling by Sekiguchi et al. (2008).

First, we prepare initial source model from a long-wavelength heterogeneous source model, either so-called asperity-background model or inverted source model for previous earthquakes at the target source area. Slip, rupture time, stress drop and rise time on grids at proper intervals are derived from the base model.

Multi-scale heterogeneity is introduced to both the slip distribution and the rupture velocity distribution of the initial source model by increasing or decreasing the values in randomly-distributed, various-size patches. The amount of the increase/decrease of the slip is set proportional to the radius of the patch and that for the rupture velocity is set to a constant. These fluctuations are given so that the slip and rupture propagation earn adequate variation seen in many source inversion results. The amplitude of slip spectrum is adjusted to decay as $k^{-1.75}$, which was derived by Mai and Beroza (2002) who conducted stochastic analysis of earthquake slip complexity using many published source models. The variation of rupture speed is made comparable to the amount found by a stochastic analysis (Miyakoshi and Petukhin, 2005).

Slip velocity time functions on grids are generated following Nakamura and Miyatake (2000) reflecting the spatially variable slip, stress drop and rise time.

3. APPLICATION TO 2003 TOKACHI-OKI EARTHQUAKE

3.1. Source model

An initial model is constructed based on a source model derived by the waveform inversion by Aoi et al. (2008). This model was obtained with 7km squares subfaults and seismic waveforms longer than 2.5 s (lower than 0.4 Hz). Intending to extend the period range down to 0.5 s (up to 2.0 Hz), the initial model is expressed by 1km interval point sources. Slip, rupture time, stress drop and rise time at finer grids of the initial model are given interpolating the distributions of the inverted source model (Figure 1). Stress drop distribution is computed from the slip distribution. Rupture time is defined as the time for local slip to archive 10 % of the final slip. Rise time is defined as the time for the local slip to take from 10 to 90 % of the final amount. Figure 2 illustrates the distributions of the slip and rupture time of the multi-scale heterogenized source model. Modification from what show in Figure 1 to what shown in Figure 2 is done as explained in Chapter 2. Figure 3 shows slip velocity time functions generated following Nakamura and Miyatake (2000) using the source parameters of the initial model, i.e. of the inversion model.

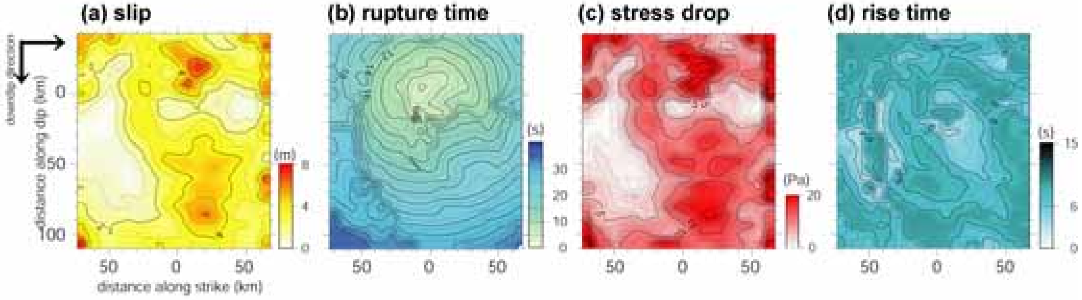

Figure 1 Distributions of source parameters of initial source model given based on inverted source model by Aoi et al.(2008).

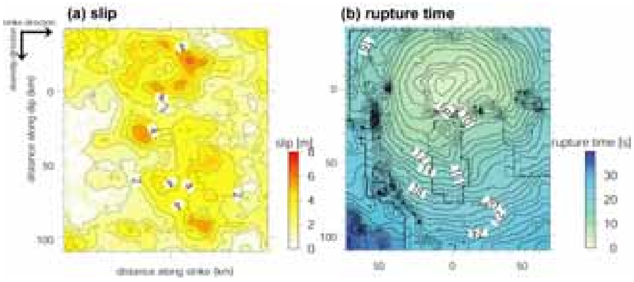

Figure 2 Multi-scale heterogeneous distributions of slip and rupture time.

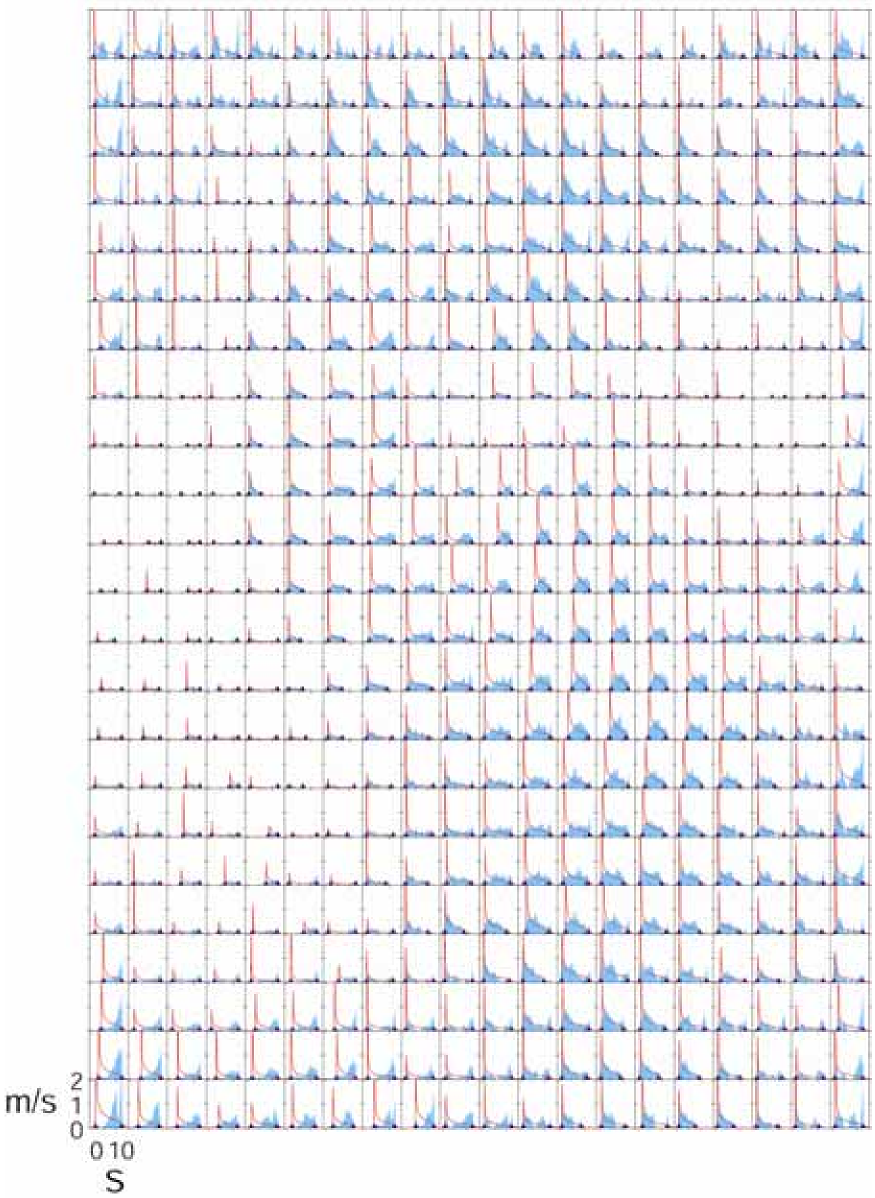

Figure 3 Slip velocity time functions on the fault plane of the inverted source model (blue) and generated using spatially heterogeneous source parameters following Nakamura and Miyatake (2000) function (red). The comparison is done at location of subfaults of the inversion analysis (Aoi et al., 2008).

3.2. Computation of synthetics

Ground motions are computed assuming a stratified media which was also used by Aoi et al. (2008). Theoretical Green's functions are calculated using the discrete wavenumber method (Bouchon, 1981) and the Reflection/Transmission coefficient matrix method (Kennett, 1983).

3.3. Comparison of the observation and the synthetics

Waveforms and Fourier spectrum of (1) synthetics with this multi-scale heterogeneous source model, (2) synthetics with the inversion source model and (3) the observation at several KiK-net stations with relatively hard basement are compared (Fig. 4). Synthetics with the multi-scale heterogeneous source model are richer in high frequency components than the synthetics with the inversion source model. As seen in the comparison of the Fourier amplitude spectra, in the frequency range of the waveform inversion analysis (0.1-0.4 Hz), spectrum for the two synthetics (and observation) match. Above that frequency range, the spectra of the synthetics with the inversion source model abruptly drops while that of the multi-scale heterogeneous source model keeps the level of the observation.

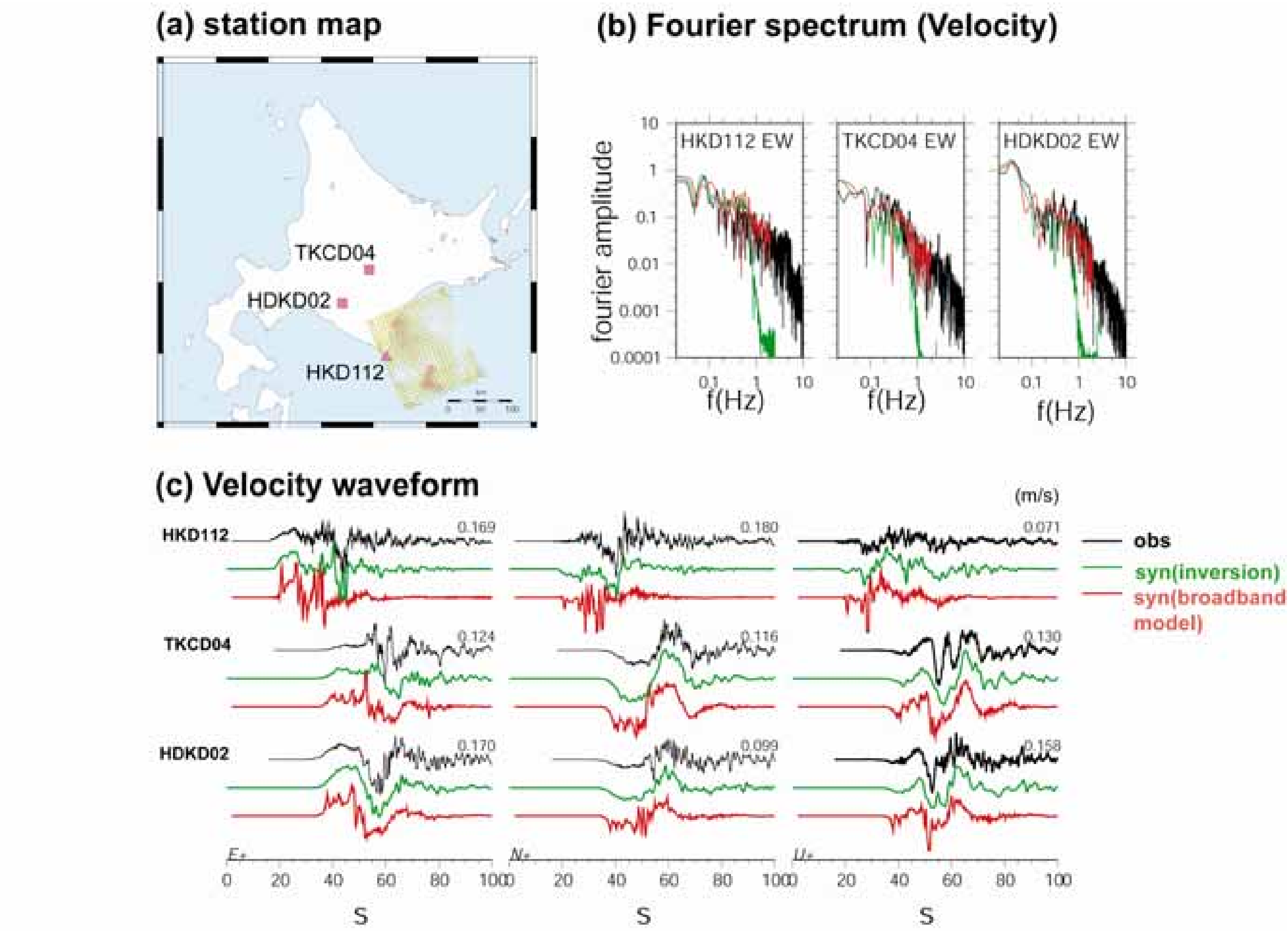

Figure 4 Comparison of the observation and synthetics. (a) Station map. (b) Fourier spectrum amplitudes. (c)Waveforms.

4. CONCLUSIONS

A method to model broadband source process of hypothetical interplate earthquakes by Sekiguchi et al. (2008) was validated through comparing predicted ground motion with observation of Tokachi-oki earthquake, an interpolate earthquake in Japan. As shown in Chapter 3, similar amount of high frequency compared to the observation was generated by the broadband source model. I can conclude this methodology of modifying long-wavelength heterogeneous source model (i.e. long-period source model) to broadband source model is valid.

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