Strong motion simulation of the hypothetical Tonankai earthquake using the empirical Green's function method

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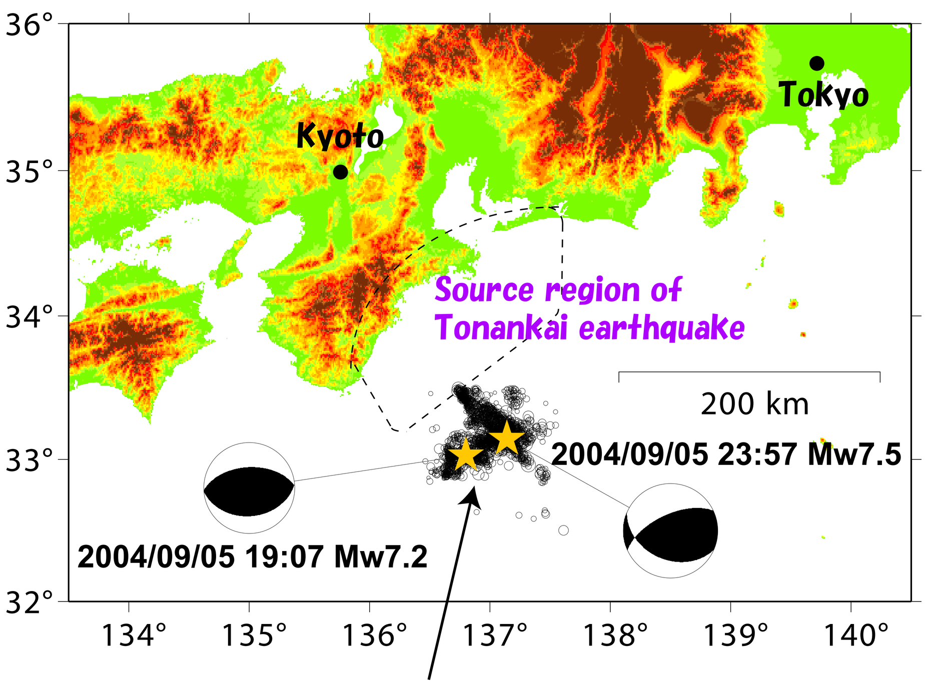
Tonankai earthquake and the 2004 southeast off ot the Kii peninsula earthquakes



Seismic activities related to the 2004 southeast off of the Kii peninsula earthquakes

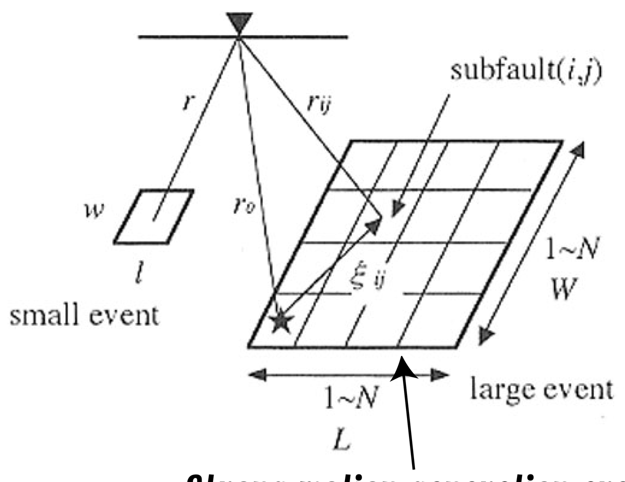
Large interplate earthquake (its magnitude is about 8.1), Tonankai earthquake is expected to occur in the near future. It is important to know the characteristics of strong motions caused by the future earthquake in order to mitigate seismic hazards. In this source region, the seismicity was not so high. In September 2004, two M7 class earthquakes took place in the subducting Philippine sea plate near this region (the 2004 southeast off of the Kii peninsula earthquakes). Recordings of these earthquakes would tell us precious information about propagation characteristics of Tonankai earthquake. We try to simulate the strong motions caused by the hypothetical Tonankai earthquake using these records.

10 years	20 years	30 years	40 years	50 years
10–20%	40%	60%	70–80%	90%

Probabilities of Tonankai earthquake occurrence for next 10-50 years since January 1st, 2005 (The Headquarters for Earthquake Research Promotion, hereinafter HERP, 2005)

Empirical Green's function (EGF) method

EGF method is a technique to synthesize the waveforms of an earthquake (target event) using records of a small earthquake (element event) which occurred near the target event. This method enables broadband strong motion simulation including higher frequency (> 1 Hz) component which is difficult for the theoretical approach. We employed the EGF method proposed by Irikura (1986) which is based on the self-similar relationship of fault parameters and the omega-square law of source spectra.



Strong motion generation area (**SMGA**, defined by Miyake *et al.*, 2003)

Formulation

Waveform of target event *U(t)* is synthesized by summing up the waveform of element event *u(t)*

$$U(t)=\sum_{i=1}^{N}\sum_{j=1}^{N}(r/r_{ij})\cdot F(t)*(C\cdot u(t-t_{ij}))$$

$$t_{ij}=(r_{ij}-r_0)/V_s+\xi_{ij}/V_r$$

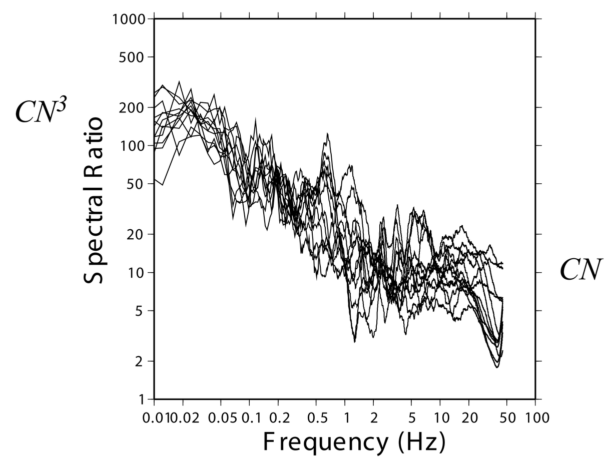
N, the integer to divide large events to space and the time

C, the ratio of the stress drop between the target and element events

$$N = L/l = W/w = T/t = (M_0/Cm_0)^{1/3}$$

Length **Width** **Rise time** **Seismic moment**

N,C are related to the spectral ratio of target and element events as below.

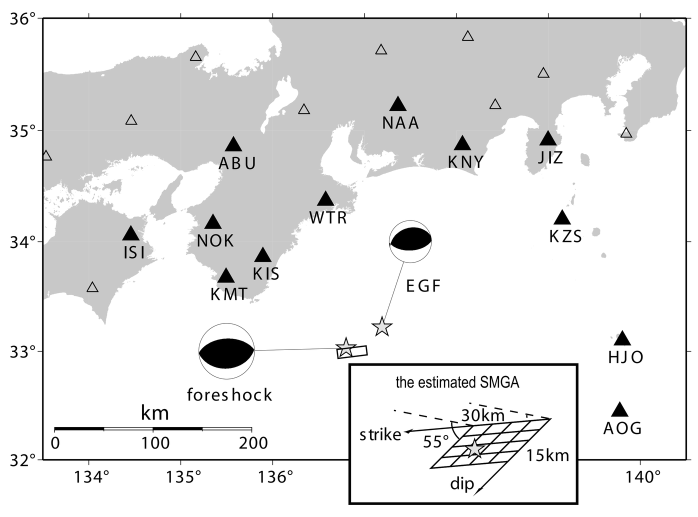


Spectral ratios of S-wave portions of the target event (Mw7.2) and the element event (Mw5.5) of the 2004 southeast off of the Kii peninsula earthquake. From high and low-frequency flat levels , C and N are estimated to be 2.5 and 4, respectively.

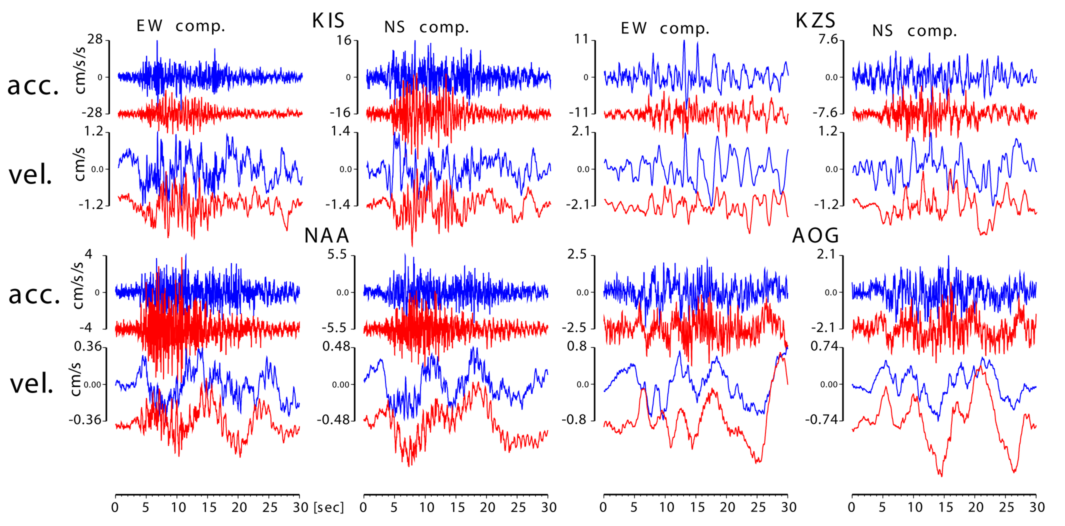
	Date	Mw	Seismic moment (F−net)	Estimated SMGA paramters	
				size	stress drop
Target event	2004/09/05 19:07	7.2	7.73×10^{19} Nm	450 km^2	8.3 MPa
Element event	2004/09/08 03:36	5.5	2.06×10^{17} Nm	28.1 km^2	3.3 MPa

Estimation of the size and the stress drop of the EGF event

We estimated the size and the location of the SMGA of the foreshock (Mw7.2 event) by fitting the synthetic waveforms of EGF simulation to the observed broadband waveforms. Model parameters which give the minimum residual value of the velocity waveforms and the acceleration envelopes are searched using the genetic algorithm. Size and stress drop for both target and element events are estimated as shown in right table.



Twelve F-net stations used to estimate the foreshock SMGA

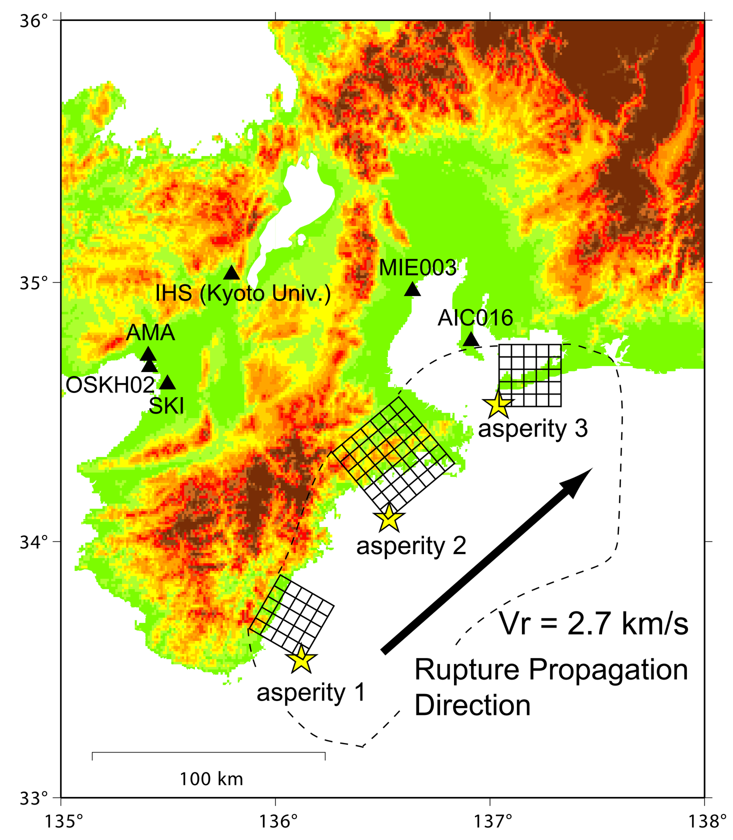


Examples of waveform fittings.

Observation
Simulation

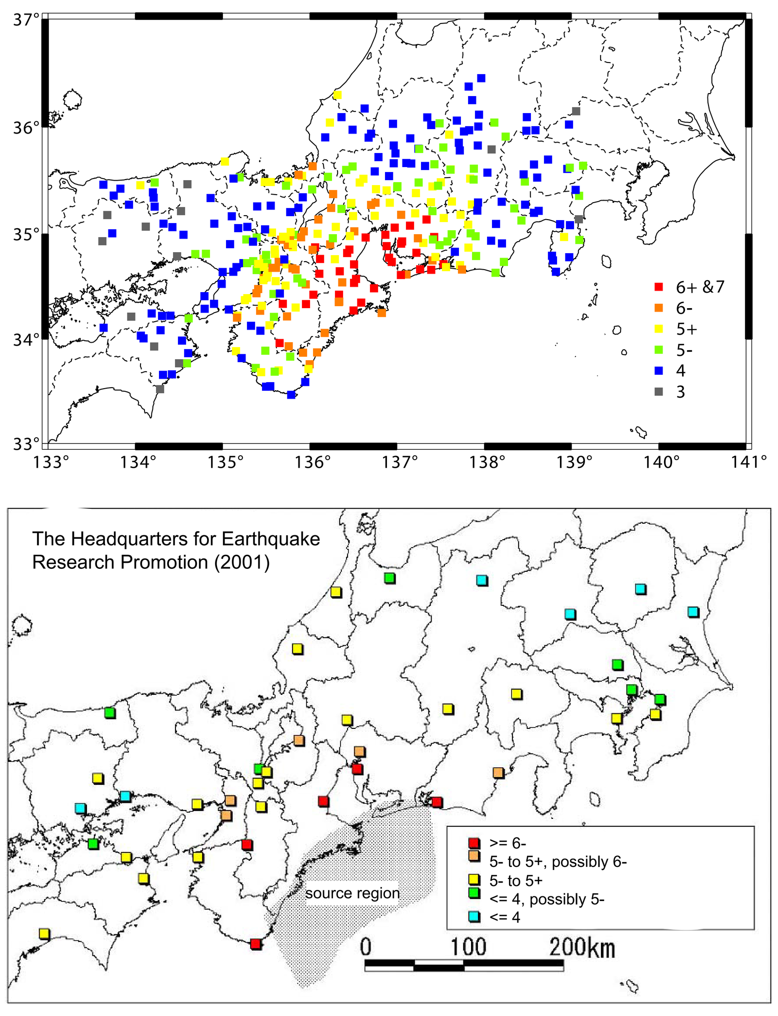
Strong motion simulation of the hypothetical Tonankai earthquake

Using records of Mw5.5 event whose size and stress drop are estimated 28.1km² and 3.3 MPa as an EGF, we simulated the broadband (0.05-20 Hz) strong motions of the hypothetical Tonankai earthquake. Following the source model for strong motion simulation by HERP (2001), we assumed the source model which consists of three asperities. Geometry and parameters of each asperity are shown in figure and table below. Asperities are discretized by subfaults which are as large as the EGF event (28.1 km²). We simulated strong motion waveforms radiated from the asperity area.



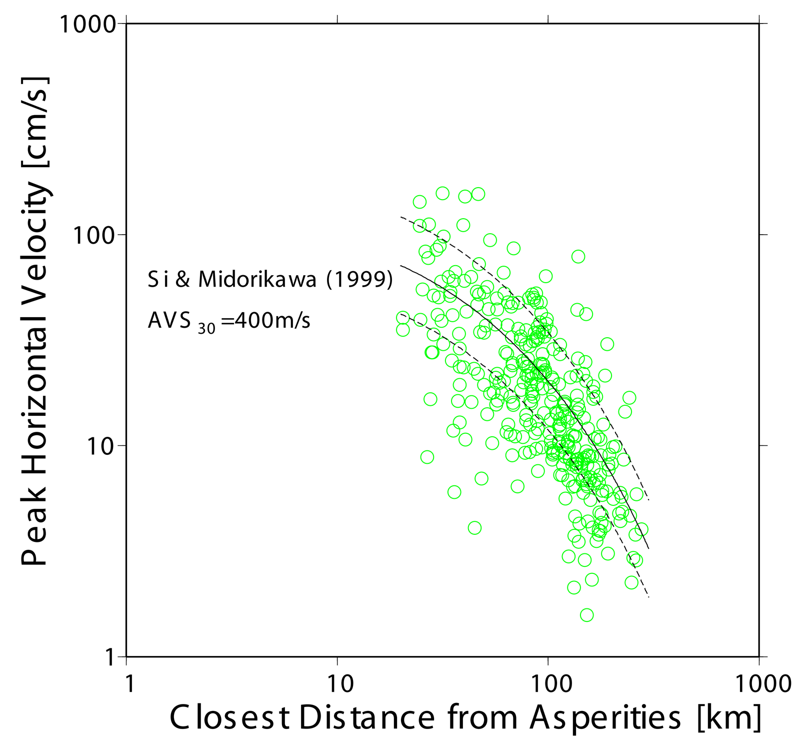
	Strike	Dip	Rupture starting point		Size	Seismic moment	Stress drop
			Depth	Delay time			
Asperity 1	210°	15°	23.1 km	0.0 seconds	702 km^2	1.40×10^{20} Nm	21.9 MPa
Asperity 2	230°	15°	20.4 km	26.6 seconds	1376 km^2	3.75×10^{20} Nm	20.1 MPa
Asperity 3	270°	15°	23.1 km	51.7 seconds	702 km^2	1.40×10^{20} Nm	21.9 MPa

Spatial distribution of seismic intensity



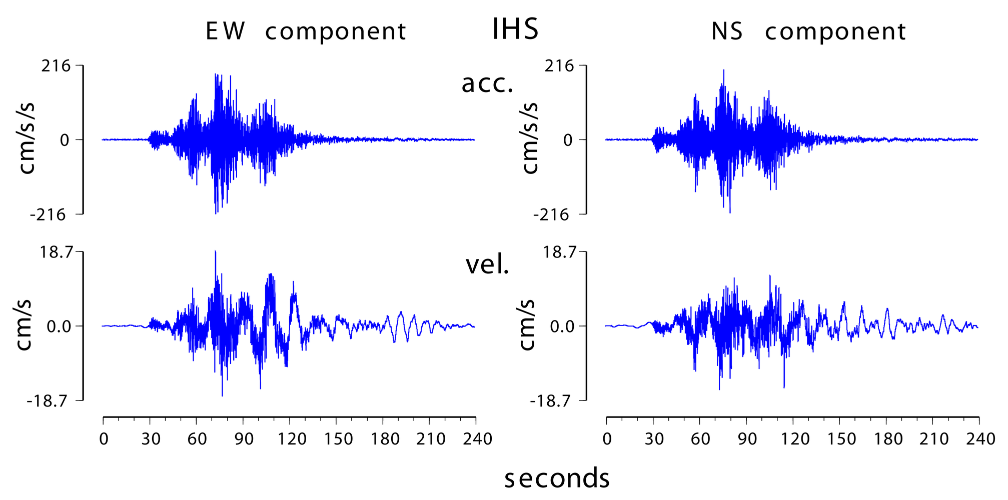
Seismic intensity distribution of the hypothetical Tonankai earthquake calculated in this study (upper) and that calculated in HERP (2001, lower) which used the stochastic Green's function method to simulate waveforms. These distributions are similar to each other. Large seismic intensities (>= 6-) are predicted for the near-source stations.

Attenuation of peak horizontal velocity

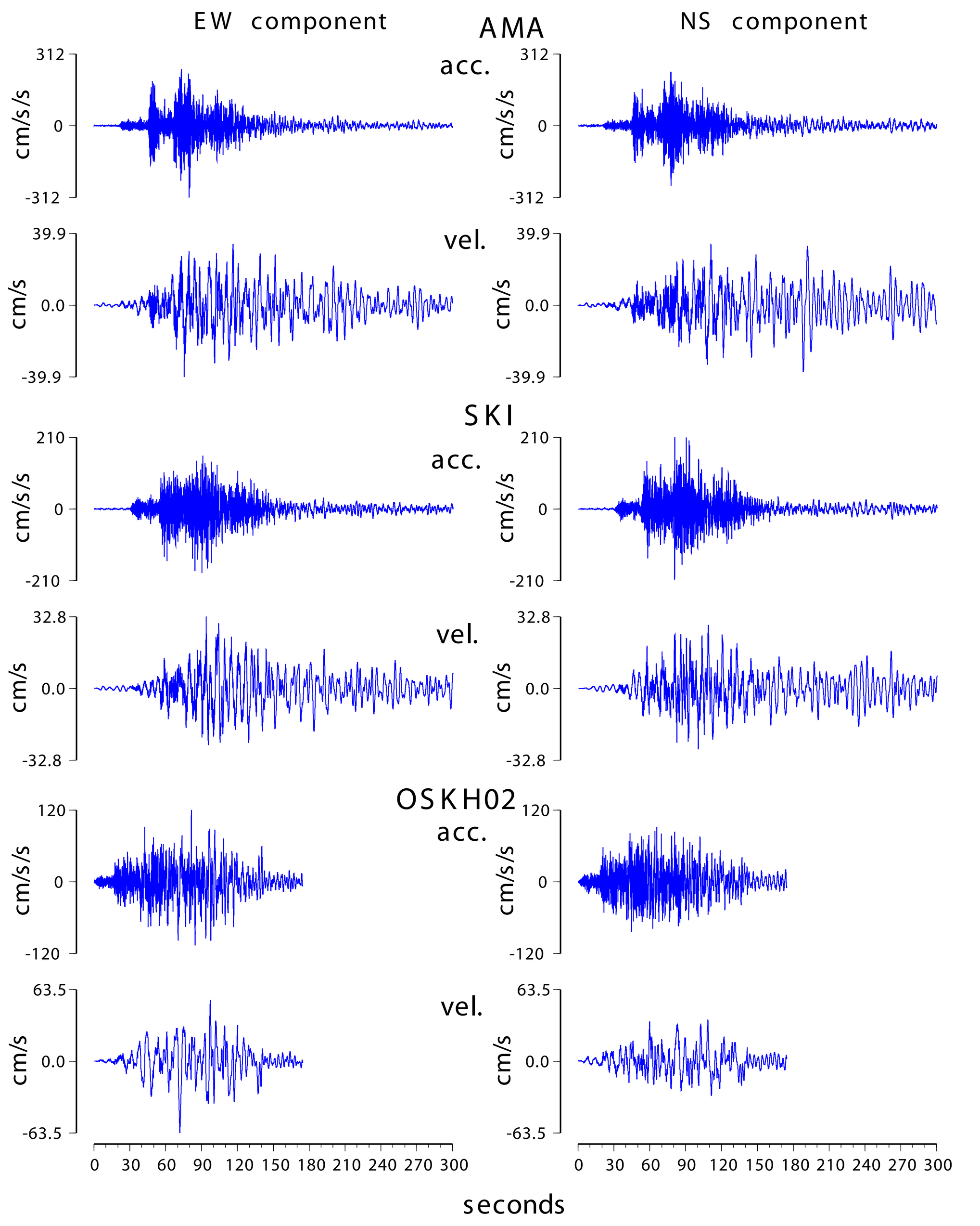


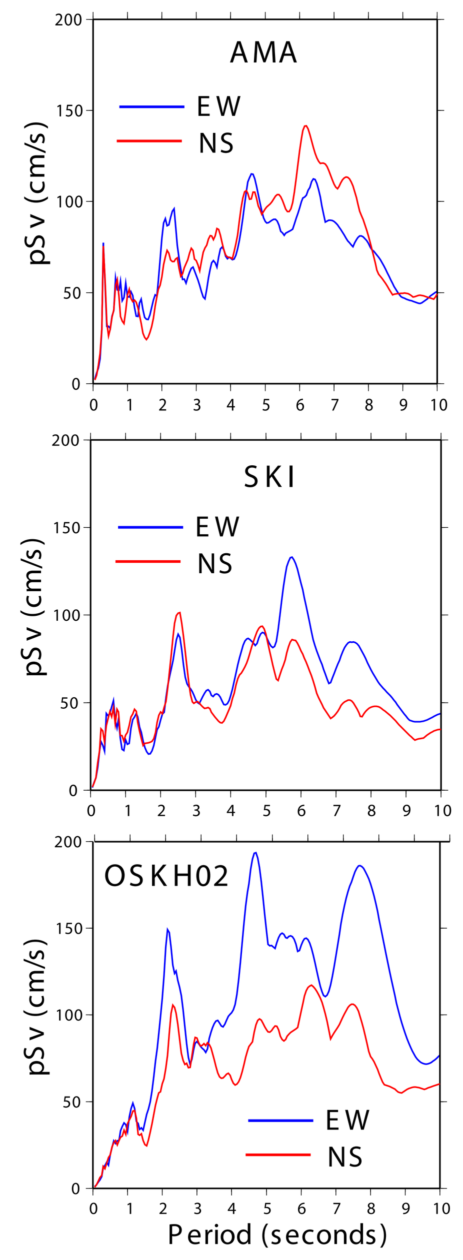
Predicted peak horizontal velocity compared with the empirical attenuation relationship derived by Si and Midorikawa (1999) for sites where AVS30 is 400 m/s. Predicted values more or less follows this empirical relationship.

Waveforms at Kyoto University (main campus)



Waveforms and pseudo velocity response spectra in the Osaka basin

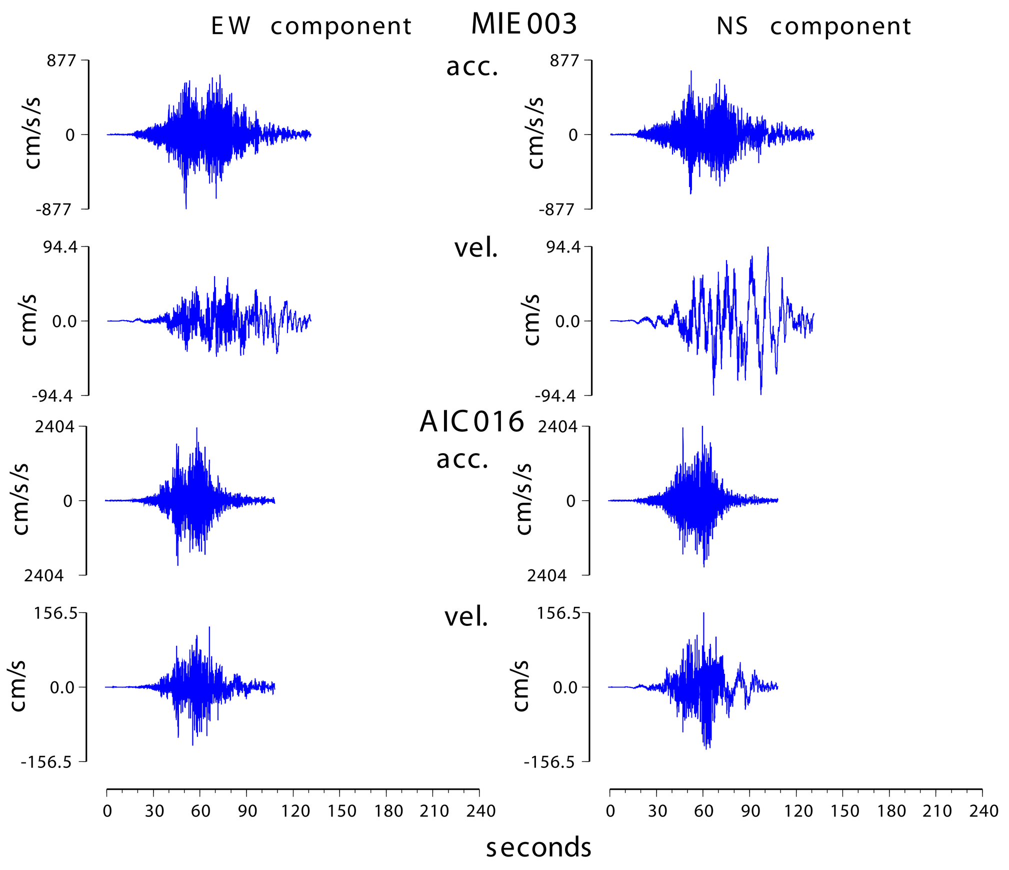




Left figures:
Later phases last for long duration in the velocity waveforms predicted for stations in the Osaka basin. Pseudo velocity response spectra (pSv) of 5% dumping show that long period ground motions (4-7 seconds) are dominant for these stations.

Right figures:
Acceleration and velocity waveforms with large amplitude are predicted for the stations in the Nobi basin, which is located in the forward direction of rupture propagation.

Waveforms in the Nobi basin



Conclusion

We performed strong motion simulation of the hypothetical Tonankai earthquake assuming the source model comprised of only three asperities using Mw5.5 aftershock of the 2004 southeast off of the Kii peninsula earthquakes as an EGF. Predicted distribution of seismic intensity and peak horizontal velocity are similar to those expected by previous study and the empirical relationship. For near-source regions, large seismic intensity more than 6- and large amplitude waveforms are predicted. For stations in the Osaka basin, long period ground motions dominate and last after direct waves for long duration. Our simulation will give the main characteristics of broadband strong motions caused by the hypothetical Tonankai earthquake.

References
Irikura, 1986, Prediction of strong acceleration motions using empirical Green's function.
Miyake *et al.*, 2003, Source characterization for broadband ground-motion simulation: kinematic heterogeneous source model and strong motion generation area.
Si and Midorikawa, 1999, New attenuation relationships for peak ground acceleration and velocity considering effects of fault type and site condition.
The Headquarters for Earthquake Research Promotion, 2001, The interim report on strong ground motion evaluation methods for projected earthquakes in the Nankai trough.
The Headquarters for Earthquake Research Promotion, 2005, http://www.jishin.go.jp/main/chousa/05jan_kakuritsu/p04_kaikou.pdf.

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