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GROUND MOTION SIMULATIONS OF ASHIGARA VALLEY, JAPAN DURING THE 1990 ODAWARA EARTHQUAKE USING THREE-DIMENSIONAL VELOCITY STRUCTURE MODELS

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SUMMARY

We tried to simulate the strong ground motion of Ashigara Valley, Japan during the 1990 Odawara earthquake of M_{JMA}5.1 using three-dimensional velocity structure models. Pseudo spectral method was used for numerical calculation. We studied the effects of basin structure on later arrival excitation by comparing basin model and flat-layered model. The flat-layered model did not simulate the later arrivals at sediment stations and basin model simulated the excitation of later arrivals at sediment stations better than flat-layered model. Next, we studied the effects of source parameters on waveforms by comparing simulated motion for two source models. We realized that the excitation of later arrivals was affected by source parameters significantly. We also checked whether upper boundary shape of layer with Vs=3.5km/s affected later arrival excitation or not. The calculated waveforms showed that the effects of modeling of layers with Vs=3.5km/s was less significant than that of shallow layers.

INTRODUCTION

Successive later arrivals forming long duration of strong motion has been a great interest in the field of engineering seismology, since the 1985 Michoacan, Mexico earthquake and the basin effects is considered to be a reason of later arrivals excitation. Both of observational and numerical studies are necessary to convince the basin effect to ground motions. Ashigara Valley, Japan is a sediment filled valley located in the west part of Kanagawa Prefecture, Japan and the valley was suffered a great damage during the 1923 Great Kanto earthquake. Earthquake Research Institute (ERI), The University of Tokyo deployed strong motion observation network in Ashigara Valley to study the effects of surface geology (ESG) on seismic motions [e.g. Kudo[1]]. Observational studies using the array data revealed that later arrivals of ground motions are composed of basin induced or transduced surface waves [e.g. Kawase[2]; Higashi[3]; Uetake[4]] and numerical studies tried to simulate the later arrivals excitation [e.g. Kawase[2], Pitarka[5,6], Uetake[7]]. The models used in these numerical studies were two-dimensional model of a part of the valley. In this article, we try to simulate the strong ground motions whale of Ashigara Valley using three-dimensional basin model. The 1990 Odawara, Japan earthquake of M_{JMA}5.1 was selected for simulation. Using this event provides two merits in numerical modeling. The hypocenter of the event is so

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close to the valley that we don't need so large velocity structure model to numerical simulation. Small magnitude makes it possible to suppose simple source process.

DATA

Ashigara Valley is a sediment filled valley with middle-sized dimension as the long axis of 12 km and the short one of 5 km. It is located in the western part of Kanagawa Prefecture, Japan. The valley is surrounded by Hakone Volcano, Tanzawa Mountains and Oiso Hills, and opened to Sagami Bay in the south. The Kozu-Matsuda and Kannawa active faults [e.g. Yamazaki[8]] are indicated at the east and north margins of the basin. ERI has deployed strong motion observation array in the sedimentary basin as well on rock outcrops in surrounding mountains to study ESG. The stations of KNO, KNP, and KNS were selected as the international test site of ESG study and the strong motion records of the 1990 Odawara earthquakes (M_{JMA}5.1) were used in the blind prediction studies [e.g. Kudo[9]]. The instruments of ERI stations are force-balance accelerometers. They have flat response from DC to 30 Hz (100 Hz sampling) and their clipping levels are 2000 cm/s/s.

The 1990 Odawara earthquake occurred on August 5, 1990 just below Hakone Mountain in the neighborhood of the Ashigara Valley. Strong ground motion records were obtained at five rock sites and eight sediment sites. Location of these stations is shown in Figure 1. Two epicenters for one event are plotted in Figure 1. These epicenters are used in the numerical studies of Pitarka[6] and Sato[10]. The source parameters are shown in Table 1. Pitarka[5,6] simulated the ground motions at stations of KNO, KNP, and KNS by two dimensional model considering with radiation pattern from the hypocenter. Sato[10] determined the source mechanism of this event from regional rock site data to simulate waveforms of Kanto area. In Sato[10], only KNO station was used in Ashigara valley network. We study the effects of source mechanisms by comparing the ground motions from these two source models.

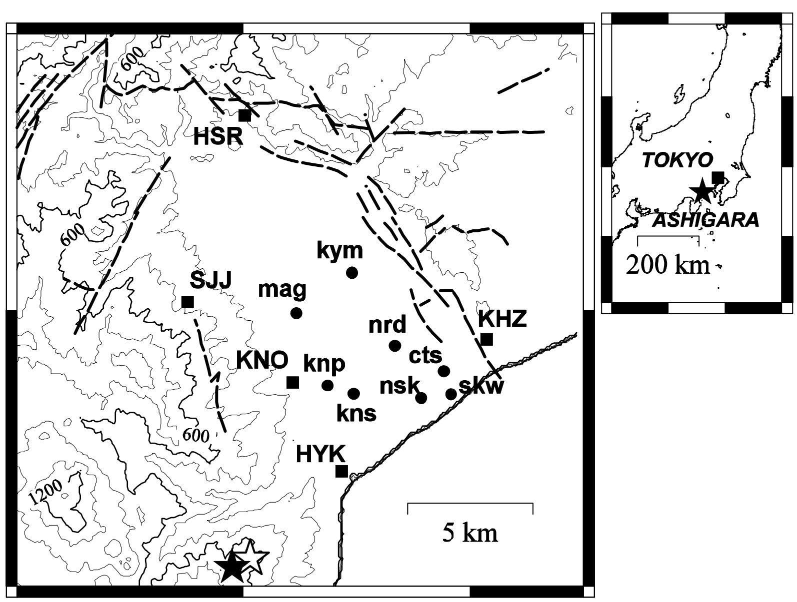

Figure 1 Epicenter of the 1990 Odawara, Japan earthquake and observation stations of Ashigara Valley. Black star and white star shows epicenters of Pitarka et al (1996) and Sato et al.(1998), respectively. Broken lines denote active fault lines.

Table 1 Source parameters of the 1990 Odawara Earthquake

Model	Lat.	Long.	Depth (km)	Strike (deg.)	Dip (deg.)	Rake (deg.)	Moment (Nm)	Source Time(s)
Pitarka et al. (1996)	35.207	139.095	13.7	239	32	54	4.7e+16	0.50
Sato et al.(1998)	35.210	139.103	15.3	215	35	40	3.3e+16	0.65

Velocity waveforms observed in Ashigara Valley strong motion network during the 1990 Odawara event are shown in Figure 2. Upper seven traces are records of sediment sites and lower five traces are that of rock sites. These waveforms were integrated from original acceleration records. Rock site motions show relatively simple feature and its S-wave portions are composed from a clear single pulse with period of 0.5 s and small coda part. Sediment site motions show large amplitude and excitation of later arrivals. The stations of KNO, KNP, and KNS are located within a few km but the waveforms changes significantly.

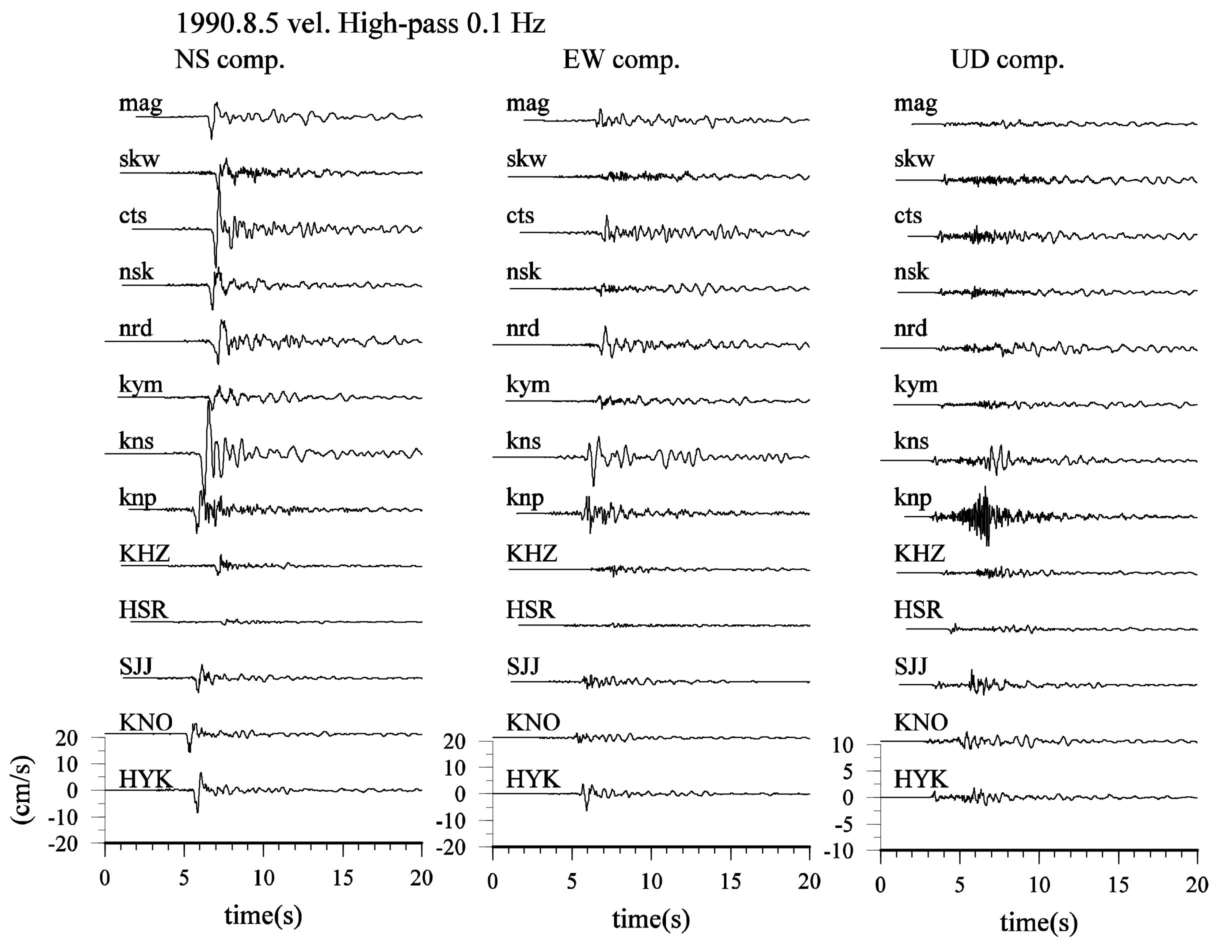

Figure 2 Velocity seismograms observed in Ashigara Valley network for the 1990 Odawara Earthquake. Site name written in capital letter and small letter denote rock site and sediment site, respectively.

NUMERICAL MODELING

In Ashigara Valley, many geophysical surveys were performed. Seismic refraction survey [e.g. Higashi [11]] and seismic reflection survey [e.g. Ikawa[12], Sato[13]] proposed section models of the valley. Microtremor prospecting [e.g. Kanno[14]] revealed shallow sediment structure. Surface wave dispersion analysis [Higashi[3], Uetake[15]] were also used for modeling of sediment structure. We constructed the 3-D basin model based on the result of Love wave dispersion analysis with referencing other geophysical prospecting results. The 3-D model was composed of 8 layers with curved boundary. The boundaries of layers are shown in Figure 3 and properties of layers are shown in Table 2. Bottoms of low velocity layers with Vs=0.6–1.2 km/s are deep in South-East part of the Valley but bottoms of layers with Vs=2.0-2.4 km/s have a trench along the basin axis. The boundary of Vs=2.8km/s and 3.6km/s was assumed considering with subduction of Philippine Sea plate. We also used flat layered model shown in Table 3 after Sato[10] as a reference of basin effects. Sato[10] made this model for KNO to evaluate source mechanism.

Table 2 Properties of each layer in basin model

No.	Vp(km/s)	Vs(km/s)	Density(g/cm3)	Q
1	1.8	0.6	1.8	30
2	2.2	1.0	2.0	50
3	2.4	1.2	2.1	50
4	3.0	1.5	2.2	100
5	4.0	2.0	2.3	150
6	4.4	2.4	2.5	200
7	5.5	2.8	2.7	300
8	6.2	3.6	3.0	400

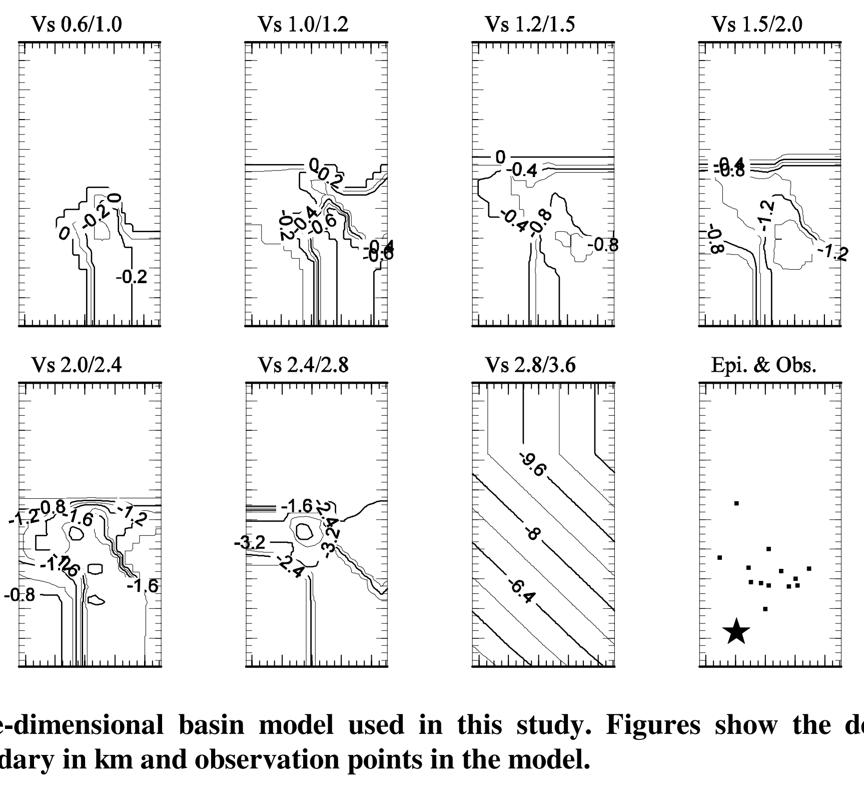

Figure 3 Three-dimensional basin model used in this study. Figures show the depth of layer's boundary in km and observation points in the model.

Table 3 Flat-layered model for KNO after Sato et al.(1998)

No.	Thickness(km)	Vp(km/s)	Vs(km/s)	Density(g/cm3)	Q
1	0.25	2.2	0.7	2.1	30
2	1.0	3.0	1.5	2.3	75
3	0.75	4.2	2.4	2.4	100
4	3.0	5.6	3.26	2.6	150
5	5.0	6.1	3.53	2.6	150
6	5.0	6.4	3.7	2.7	150
7	--	6.9	3.92	2.9	250

Regular grid pseudo spectral method after Furumura[16] was used for numerical calculation. Since spatial differentiation is analytically done in wave-number domain, this method needs smaller grid number relative to Finite Differential Method. Q-values of media were considered after Graves[17]. The model size is 38.4km in NS and 19.2km in EW and in depth direction with grid spacing of 0.15km. Time step of calculation is 0.006s. Pseudo delta function after Herrmann[18] with 0.5 s is used as source time function.

RESULT

To study the effects of basin structure and source mechanisms, we compare the simulation result from some combination of sub-surface structure model and source model. Basin and flat layered models are used for structure model and two sets of parameters after Pitarka[6] and Sato[10] are used for source models. The calculation cases are shown in Table 4.

Table 4 Study cases for numerical simulations

	Sub-surface structure	Source model
Case 1	Flat layered model	Sato et al.(1998)
Case 2	Basin model	Sato et al.(1998)
Case 3	Basin model	Pitarka et al.(1996)

Velocity waveforms calculated for each case are shown in Figure 4 comparing with observed ones. Each waveform was band-pass filtered between 0.1 and 0.7 Hz. Calculated waveforms for Case 1 showed the good agreement for ground motion at KNO and KNP but did not simulate other stations. Since this model was originally constructed for rock site KNO, it is natural not to reproduce later arrivals excitation at sediment stations. Case 1 did not reproduce other rock site motion too. Basin models of Case 2 and 3 generate later arrivals of waveforms at sediment sites but waveforms characteristics are different. Waveforms of Case 3 show better agreement about amplitude and phases for several sediment sites and rock sites such as KYM, NSK, CTS, SKW, HYK, SJJ, and KHZ. Waveforms of Case 2 show better agreement for KNO and KNP. UD components of simulated motions are too large at several sediment sites. Generally it is seen, source parameters after Pitarka[6] were better for simulation of Ashigara Valley data than those after Sato[10]. Two source models resembled each other but the strike angles were different by 25 degrees. This shows that the excitation of latter arrivals was also affected by the difference of source parameters. The waveforms at NRD, MAG, and KNP in Case 3 show too large later arrival's excitation. EW- and UD-components show less agreement than NS-components. We have to tune up the basin model. It is important to use proper combinations of sub-surface structure and source model to simulate ground motion.

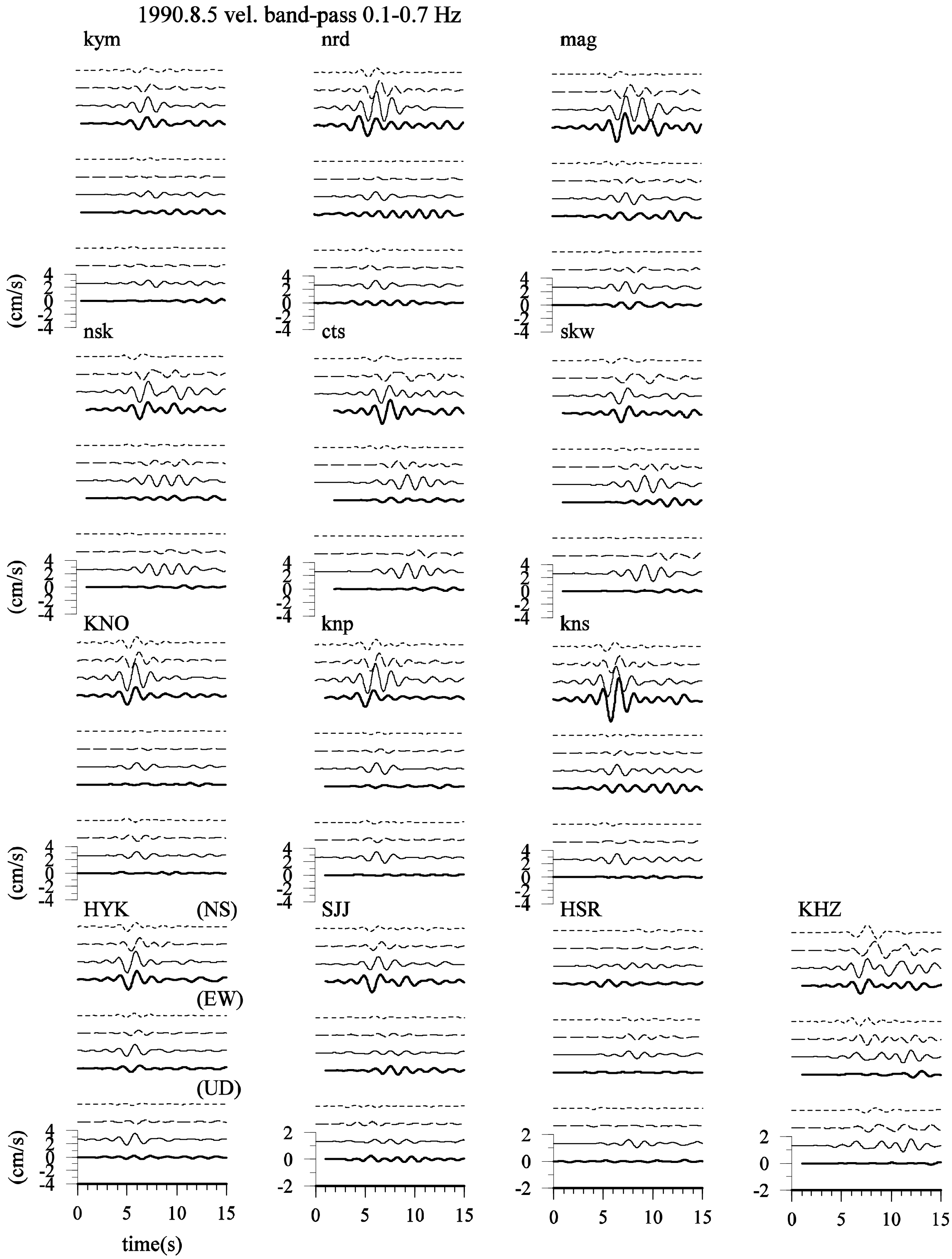

Figure 4 Comparison of Observed and Calculated ground motion waveforms. Bold line denotes observed data. Thin solid line denotes the calculation results for basin model with Source model after Pitarka et al.(1996). Broken line denotes calculated one for basin model with source model after Sato et al.(1998). Dotted line denotes the result for flat-layered model with Sato's source model.

DISCUSSIONS

The basin model used for simulation was constructed after geophysical prospecting or observation data basically but the upper boundary of the layer with Vs=3.6km/s was assumed to be an oblique plane considering to subduction of Philippine Sea plate. To confirm the effect of this layer on ground motion characteristics, we modified the oblique upper boundary of 3.6km/s fixed to 5.2km in depth and compared the calculated waveforms with those from the original basin model. Source parameters are after Pitarka[6]. Band-pass velocity waveforms for two models are shown in Figure 5. The waveform characteristics are all most the same. The phases of waveforms of horizontally flat model a little ahead compared with that of oblique model. Phase foreword is significant at initial S-arrival not at later arrivals as shown at SKW and KHZ. This may be because initial S arrivals of flat model are earlier than that of oblique model. The layer with Vs=3.6km/s is less important than shallow layers for later arrival excitation characteristics.

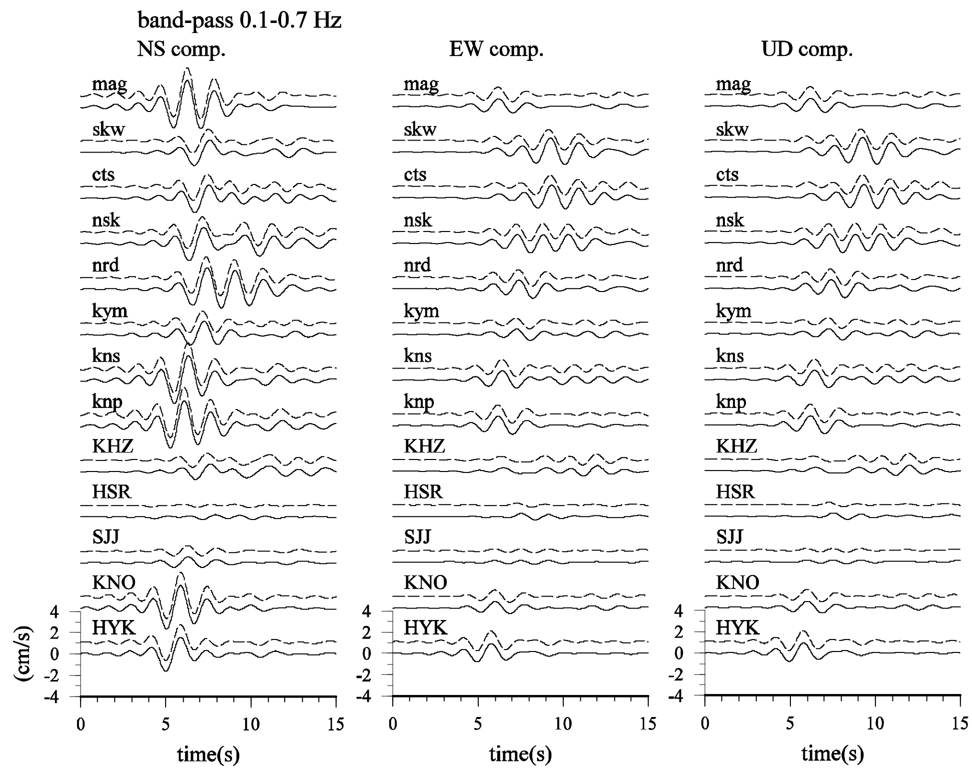

Figure 5 Comparison of waveforms calculated from oblique and flat upper boundary of Vs= 3.6km/s. Band-pass velocity waveforms in filter range between 0.1 and 0.7 Hz are shown in this figure. Solid line and broken line show oblique case and flat case, respectively.

CONCLUSION

We studied the basin effects through the numerical simulations of observed data in Ashigara valley network during the 1990 Odawara earthquake. First, we show the effects of basin structure on later arrival excitation by comparing the ground motion calculated for basin model to that for flat-layered model. The waveforms for basin model simulate the excitation of later arrivals at sediment stations better than flat-layered model. Next, we studied the effects of source parameters on waveforms by comparing waveforms calculated for two source mechanisms after Pitarka[6] and Sato[10]. The excitation of later arrivals was affected by difference of source parameters significantly and the source model after Pitarka[6] give a better result for Ashigara Valley network except for KNO area than that after Sato[10]. It is important to use proper combinations of sub-surface structure and source model to simulate ground motion.

We compared waveforms calculated from two models that have different upper boundary shape of the layer with Vs=3.5km/s. The one is oblique model the other is horizontally flat model. The calculated ground motion waveforms from two models were almost the same in frequency range between 0.1 and 0.7 Hz. The modeling of deep layer with Vs=3.6km/s was less important than that of shallow layers about excitation of later arrivals.

The simulation waveforms in this study did not fully reproduce observation data. We have to improve the basin model of Ashigara Valley, Japan to predict strong ground motions by large earthquakes expected in near future.

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