A STUDY ON RESPONSE DURATION TIME SPECTRA OF EARTHQUAKE MOTIONS IN TOKYO

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ABSTRACT :

The Response Duration Time Spectrum is newly defined as a duration time where the cumulative squared amplitudes increase from 5% to 95% of the one for the total duration of the response motion of a single degree of freedom system with damping factor h and natural period T. The velocity response spectra S_V and the velocity response duration time spectra TS_V with damping factors 0.05 and 0.01 are calculated and examined, by using the earthquake ground motion records in Tokyo. In the period range less than 1 second, TS_V gradually increases with the period and seems not so different between the earthquakes. However, in the period range more than 1 second, TS_V increases suddenly with the period, contains a spectral peak especially for a shallow earthquake, which is characteristic of long period seismic waves due to the hypocentral fault and the underground structure. It seems that the characteristics of TS_V highly depend on the hypocentral direction and on the hypocentral depth. S_V and TS_V are also calculated by using the mended record and the evaluated ground motions in Tokyo for the inter-plate great earthquakes along the Sagami trough, and compared to each other.

KEYWORDS: Tokyo metropolitan area, regional characteristics, source, propagation, response duration time spectrum, long period earthquake ground motion

1. INTRODUCTION

Many works have been performed concerning the amplitudes and their spectral characteristics of the ground motions over broad period ranges, including long period ranges. There are also earthquake ground motion records which have long duration times. However the spectral characteristics of duration times have not been investigated yet. In this study, the Response Duration Time Spectrum is newly defined and examined by using the earthquake ground motion records at Etchujima, Tokyo, where Yokota *et al.*(1989) has pointed out that the characteristics of the response spectra of the records are different depending on the hypocentral regions.

2. RESPONSE DURATION TIME SPECTRUM

Figure 1 shows the procedure to calculate the response duration time spectrum which is proposed in this study. The response duration time spectrum is newly defined as a duration time where the cumulative squared amplitudes increase from 5% to 95% of the one for the total duration of the response motion of a single degree of freedom system with damping factor h and natural period T [s]. The response spectrum is the maximum amplitude of the response motion. So it is valuable to examine and to discuss both spectra together.

3. ANALYSES OF EARTHQUAKE GROUND MOTION RECORDS IN TOKYO

Figure 2 shows the location of Etchujima recording station in Tokyo and the earthquakes selected in this study. In this study, the velocity response spectra S_V [cm/s] and the velocity response duration time spectra TS_V [s] with damping factors 0.05 and 0.01 are calculated and examined, by using the earthquake ground motions recorded at G.L.-100m depth of Etchujima station from 1983 to 2004. Each record has been selected on condition that the magnitude of the earthquake is 5.5 or over, the hypocenter is shallower than 100 km, the peak acceleration of is 1 cm/s^2 or over, and it is not an irregular data. Each earthquake noted in gray letters in Figure

2 has only about 1 minute or shorter records, which may not be sufficient to discuss in the longer period range.

Figure 3 shows the velocity response spectra S_V and the velocity response duration time spectra TS_V with damping factor 0.05, calculated by using the horizontal ground motion records (NS and EW components). In each hypocentral region, the hypocentral distances are similar between the earthquakes. Therefore S_V in the long period range generally increases with the magnitude. TS_V in the period range less than 0.5 second is almost constant or gradually increases with the period and seems not so much different between the earthquakes. However, TS_V in the period range more than 0.5 second increases suddenly with the period, and contains large spectral peaks especially for a shallow earthquake. Such characteristics are supposed to be influenced by the long period seismic waves due to the hypocentral fault and the underground structure beneath the Kanto plain. For the earthquakes in southeast Yamanashi, TS_V increase with the period from 0.5 second, and reach 50 to 180 seconds in the period range longer than 2 second, approximately. In the hypocentral direction between SSE and SW, both the peak value of TS_V and its period are increasing for the west. In the hypocentral direction between SSE and ENE, both values are increasing for the north. In the hypocentral direction between ENE and N, the spectral peak is not clear, so TS_V is almost flat in the long period range. It suggests that the propagation characteristics of seismic waves through the underground structure are dominant. It also seems TS_V decreases (or increases) at the period where S_V increases (or decreases), that might corresponds to the concentration (or dispersion) of the arriving seismic waves, mainly surface waves. Figure 4 is in case with damping factor 0.01 using horizontal records and Figure 5 is in case with damping factor 0.05 using vertical records. For each earthquake, S_V changes according to the damping (0.05 or 0.01) or the component (horizontal or vertical), but TS_V is not influenced by them so much.

Figure 6 shows the normalized velocity response duration time spectra ${}^{N}TS_V$ with damping factors 0.05 and 0.01 (plotted together since both are similar) calculated by using horizontal records. Each spectrum is normalized by the average of the spectral amplitudes in the period range between 0.1 and 0.5 seconds. It is an index of length of the duration time compared with the one in the short period range. The results mean that the response duration time of a long period structure could reach at least several times to ten times of the one of a short period structure even if it is not induced by a large earthquake.

4. DISCUSSION ON DESIGN MOTIONS FOR LONG PERIOD STRUCTURES IN TOKYO

Figure 7 shows the velocity response spectra S_V and the velocity response duration time spectra TS_V with damping factor 0.05, calculated by using the conventional design standard motions (El Centro NS, Taft EW, Hachinohe SN and EW) which have been normalized by the maximum velocity 50 cm/s, and by using the mended record (Yokota *et al.*,1989) and the evaluated ground motions (Ishii and Sato,1994; Sato *et al.*,1998,1999) in Tokyo for the inter-plate great earthquakes along the Sagami trough. TS_V of the conventional design standard motions are almost constant and less than 50 seconds. S_V of the evaluated motions explain well the 1.5 times one of the mended EW component records of the 1923 Kanto earthquake, which is considered to correspond to the saturated NS component, and are almost as much as those of the design standard motions. However TS_V of the evaluated motions stay less than only half the one of the mended record, though they are three or four times as much as those of the design standard motions in the period range more than 1 second.

5. CONCLUSIONS

It seems that the characteristics of velocity response duration time spectra TS_V highly depend on the hypocentral direction and on the hypocentral depth. The azimuthal characteristics of TS_V have been got together in Figure 8. The duration times of ground motions in the long period range especially more than 1 second could be much longer than the ones in the short period range or the ones evaluated by some past studies, and TS_V could have dominant peaks. It should be taken into account in examining structural performances or in the structural design of long period structures, for example tall buildings, base-isolated buildings, or some equipment inside.

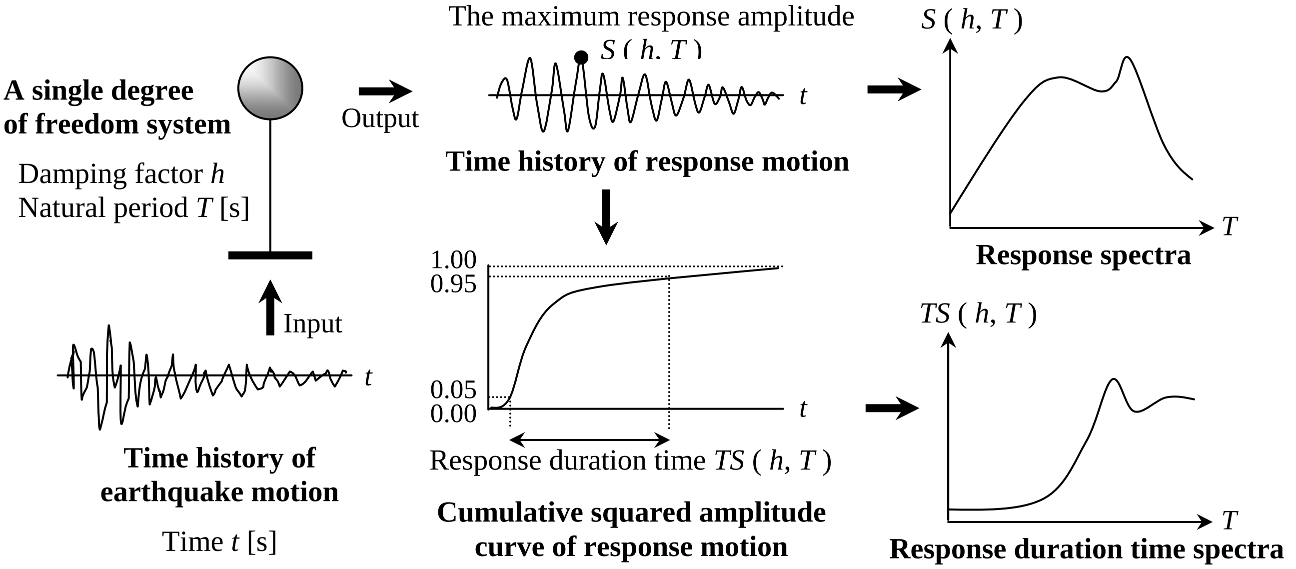
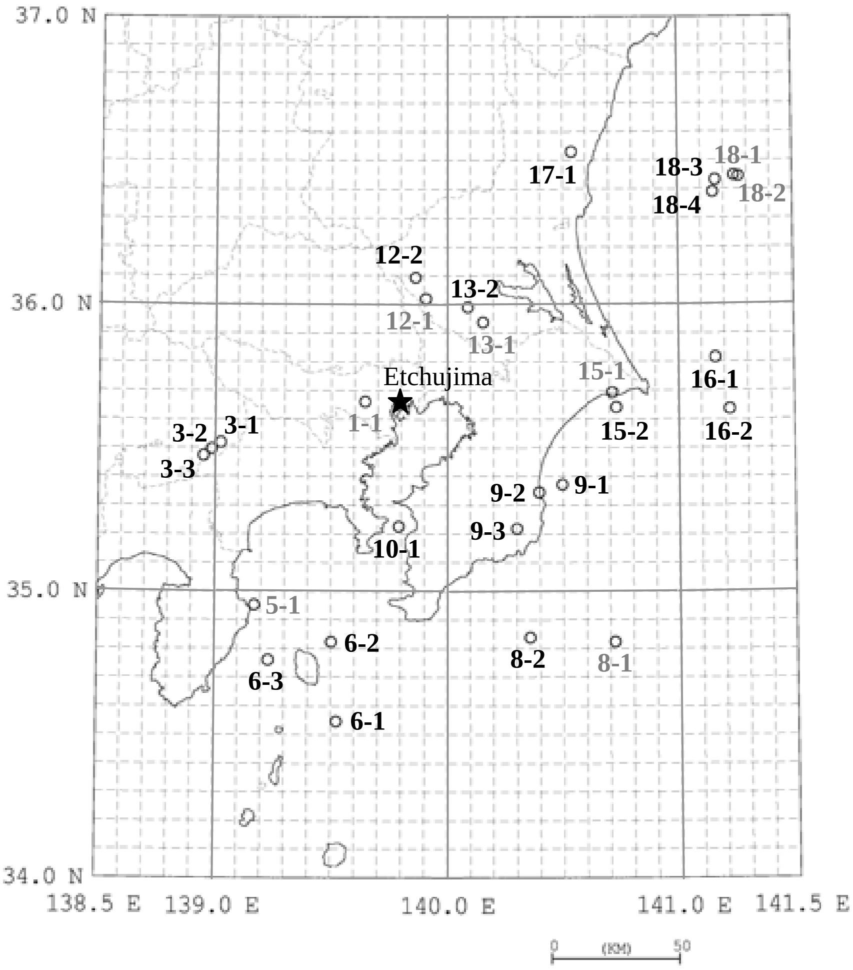


Figure 1 Procedure to calculate the response duration time spectrum which is proposed in this study



Region	EQ. No.	Date	Depth [km]	*M*
Tokyo	1-1	1988.03.18	96.1	5.8
Southeast Yamanashi	3-1	1983.08.08	22.0	6.0
	3-2	1988.09.05	29.6	5.6
	3-3	1996.03.06	19.6	5.5
Near Ito	5-1	1997.03.04	2.6	5.9
Near Izu-Oshima	6-1	1986.11.22	15.1	6.0
	6-2	1989.10.14	21.2	5.7
	6-3	1990.02.20	5.8	6.5
Off Boso Peninsula	8-1	1986.06.24	73.3	6.4
	8-2	2004.07.17	68.7	5.5
Sotobo	9-1	1987.12.17	57.9	6.7
	9-2	1990.08.23	49.9	5.5
	9-3	2003.09.20	70.0	5.8
Uchibo	10-1	1992.02.02	92.3	5.7
Southwest Ibaragi	12-1	1989.02.19	55.3	5.6
	12-2	1996.12.21	53.1	5.6
	13-1	1983.02.27	72.0	6.0
	13-2	2004.10.06	66.0	5.7
Near Choshi	15-1	1989.03.06	55.7	6.0
	15-2	1990.06.01	59.3	6.0
Off Choshi	16-1	1991.08.06	42.5	5.9
	16-2	1996.09.11	52.0	6.4
Near Hitachi	17-1	1992.05.11	56.2	5.6
Off Ibaragi	18-1	1984.01.17	43.0	5.6
	18-2	1984.01.18	43.0	5.9
	18-3	2003.11.15	48.4	5.8
	18-4	2004.04.04	49.0	5.8

(from 1983 to 2004, magnitude 5.5 or over, shallower than 100 km, peak acceleration of each record is 1 cm/s^2 or over)
Each earthquake noted in gray letters has only about 1 minute or shorter records.

Figure 2 Location of Etchujima recording station in Tokyo and the earthquakes selected in this study

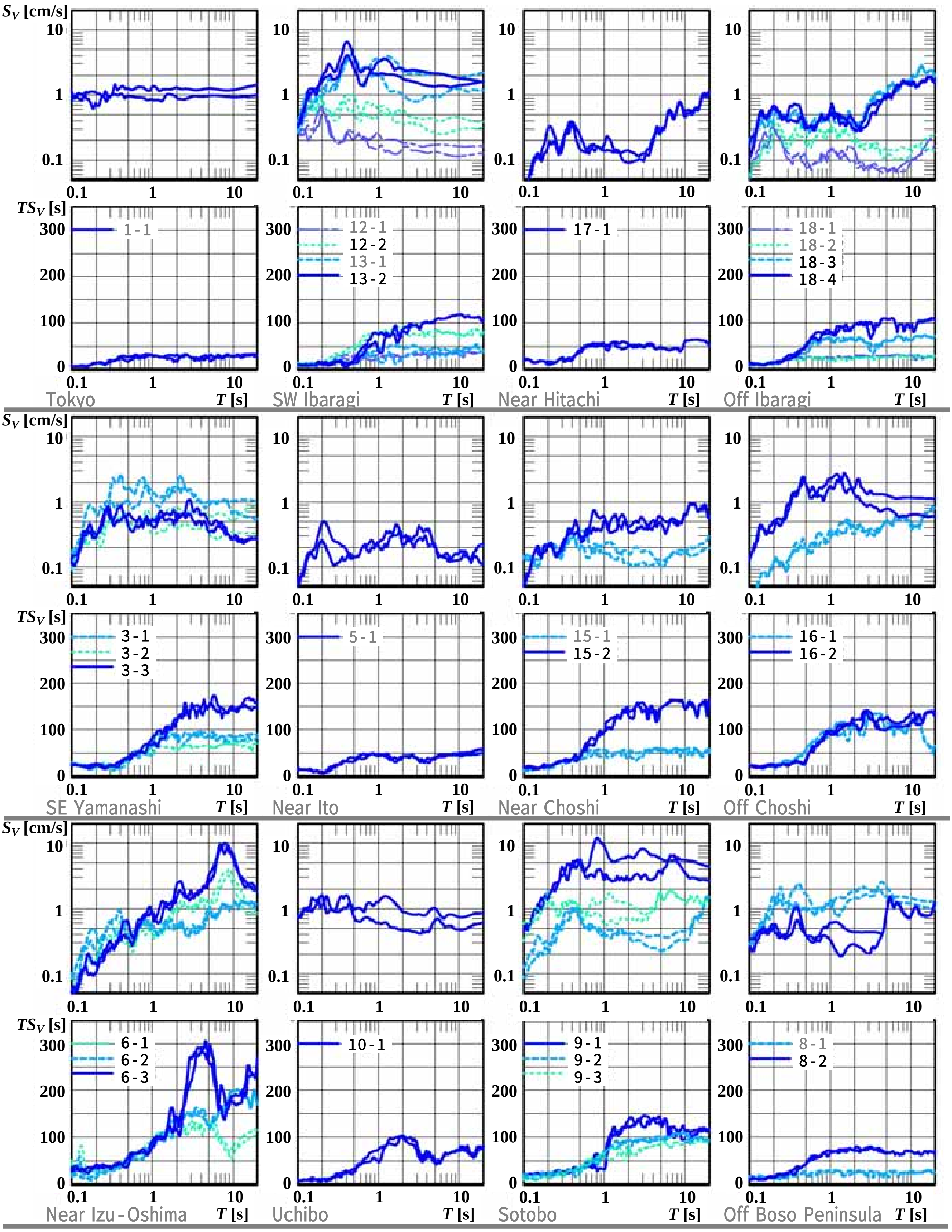


Figure 3 Velocity response spectra S_V [cm/s] and velocity response duration time spectra TS_V [s] with damping factor 0.05 calculated by using horizontal ground motion records at Etchujima, Tokyo

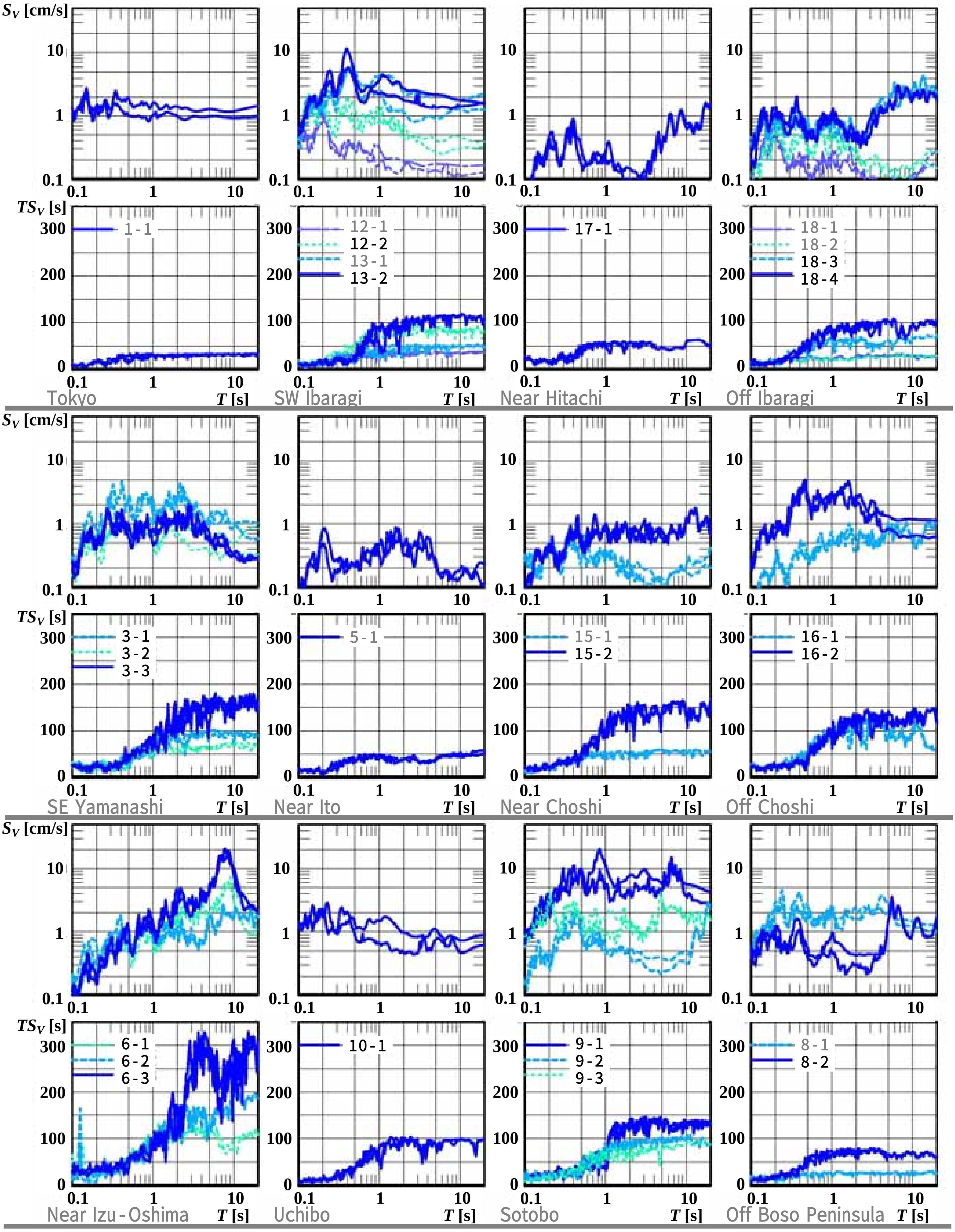


Figure 4 Velocity response spectra S_V [cm/s] and velocity response duration time spectra TS_V [s] with damping factor 0.01 calculated by using horizontal ground motion records at Etchujima, Tokyo

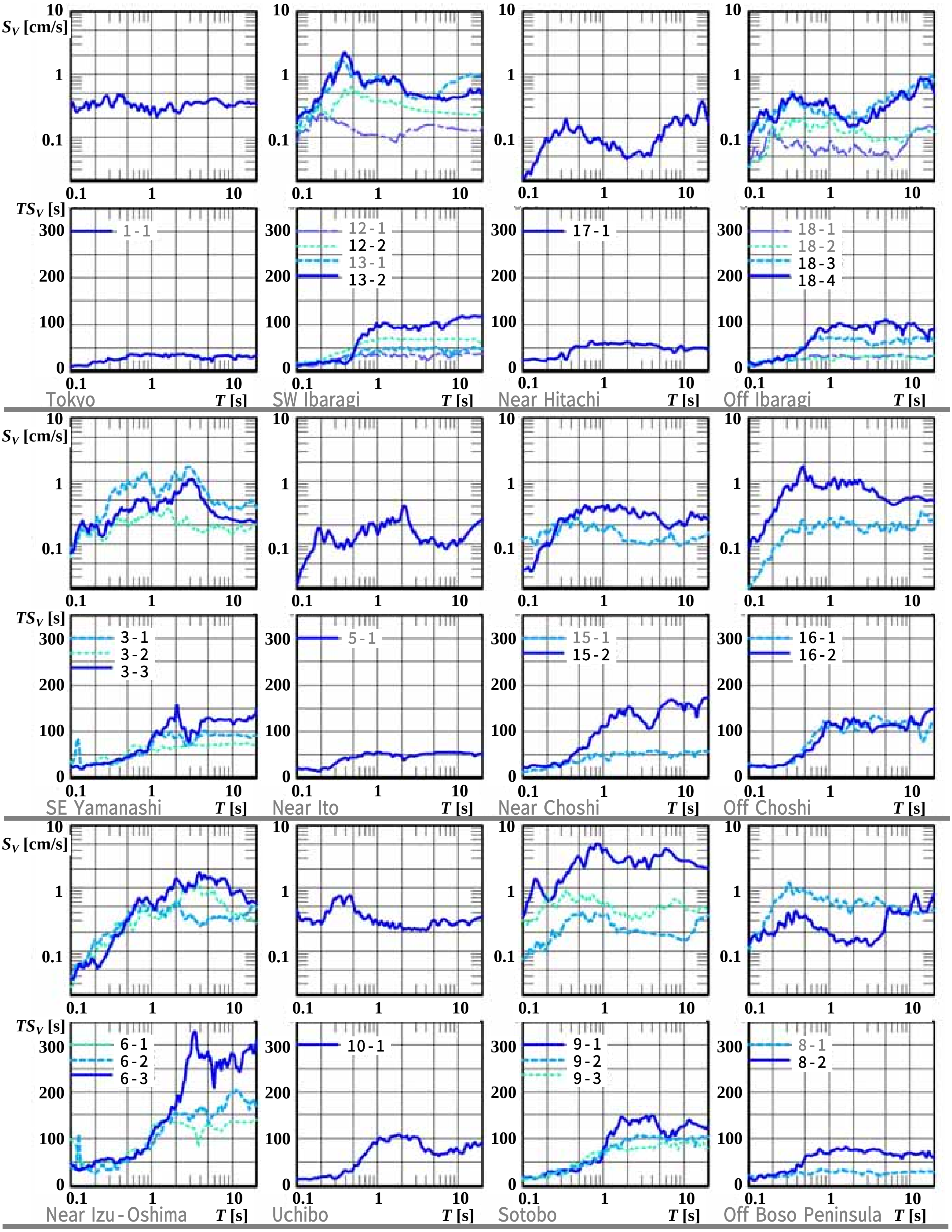


Figure 5 Velocity response spectra S_V [cm/s] and velocity response duration time spectra TS_V [s] with damping factor 0.05 calculated by using vertical ground motion records at Etchujima, Tokyo

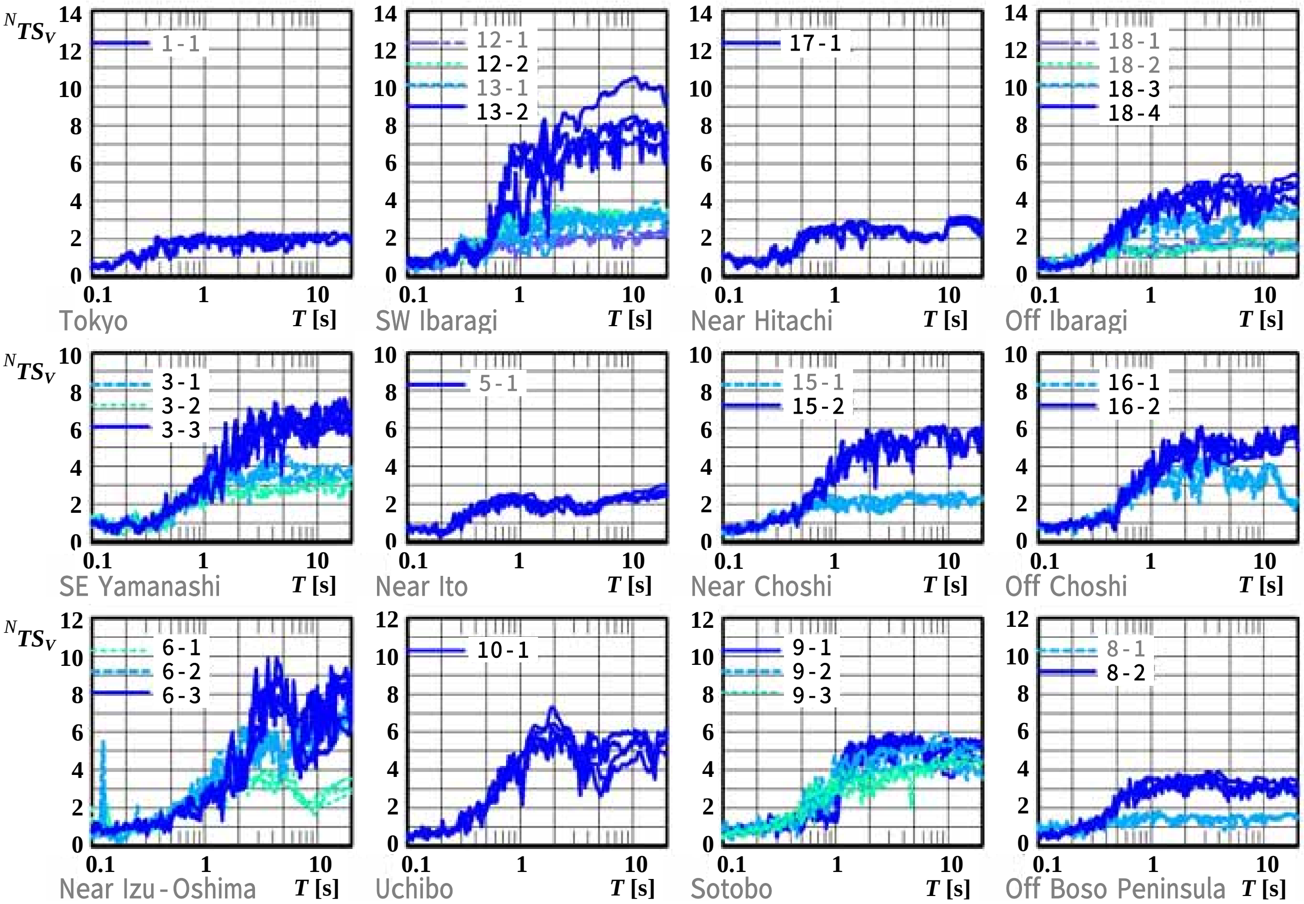


Figure 6 Normalized velocity response duration time spectra ${}^{N}TS_V$ with damping factors 0.05 and 0.01 (plotted together) calculated by using horizontal ground motion records at Etchujima, Tokyo

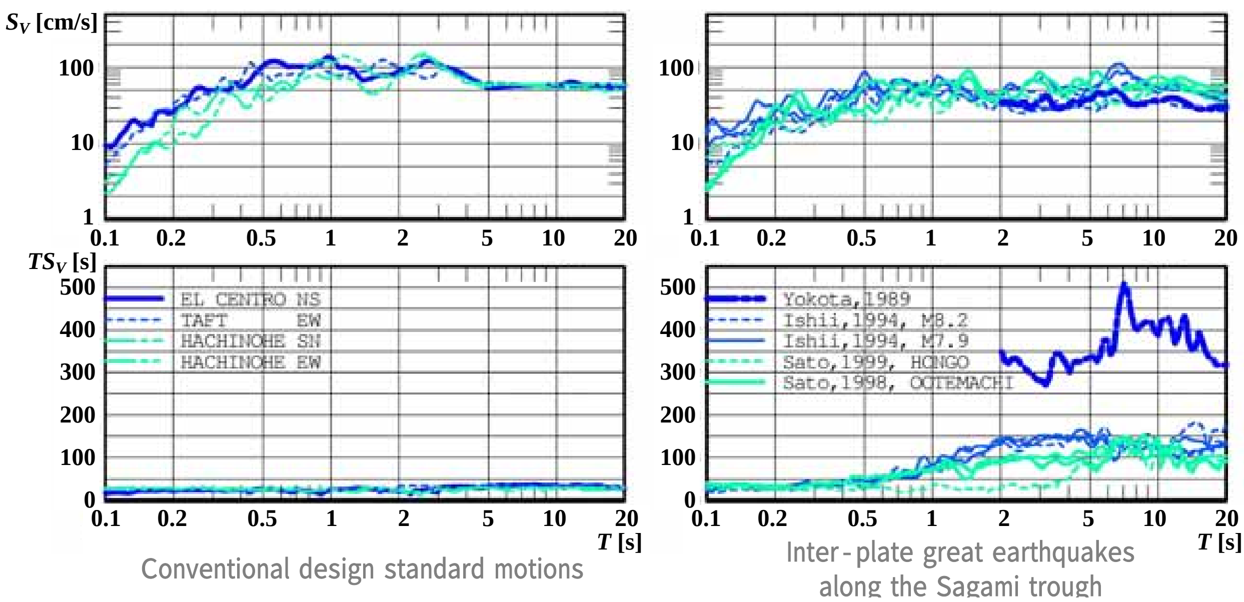


Figure 7 Velocity response spectra S_V [cm/s] and velocity response duration time spectra TS_V [s] with damping factor 0.05 calculated by using the conventional design standard motions (*left*), and the mended record (Yokota *et al.*,1989) and the evaluated ground motions (Ishii and Sato,1994; Sato *et al.*,1998,1999) in Tokyo for the inter-plate great earthquakes along the Sagami trough (*right*)

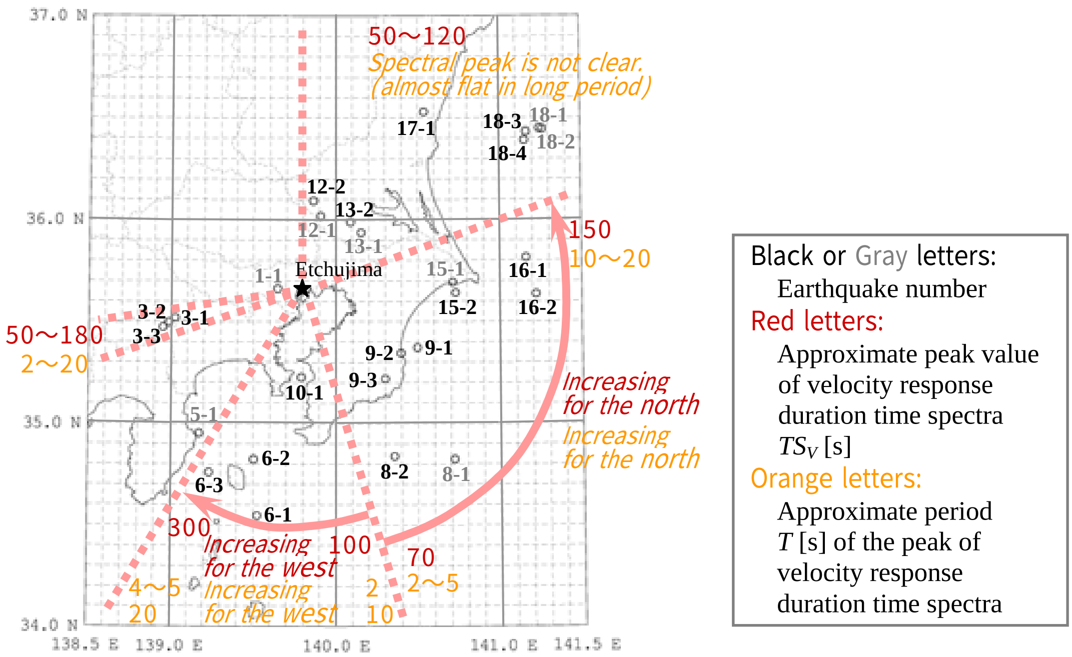


Figure 8 Azimuthal characteristics of velocity response duration time spectra

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