Study on Propagation Characteristics of Long-period Seismic Motion

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ABSTRACT

In this paper, the long period seismic motion is simulated by 3D finite difference method. It is known that the propagation characteristics of the seismic motion are different depending on the relation between the source model and geological structure. Therefore it is important to propose the hazard areas by considering the source model and geological structure when the great earthquake will occur in the future. For that purpose, first of all, basic propagation characteristics of seismic motion are investigated by the simplified ground models, and then the ground model of Kanto Plain is evaluated and discussed. The two simplified ground models which we call "Basin model" and "Slope model" are employed to consider the ground model of Kanto Plain, and propagation characteristics of seismic motion in two models are analyzed by the seismic source models in the 1923 Kanto earthquake, the 1931 west Saitama earthquake and 1987 east off Chiba Prefecture earthquake that have occurred in Kanto Plain in the past. As the propagation characteristics of the source model and the geological structure, the similar features are become clear between simplified ground models and the ground model of Kanto Plain. These similar features are that the characteristics of "Basin model" can be seen in the vicinity of Chiba Prefecture and the characteristics of "Slope model" can be seen in the entire area of Kanto Plain. It becomes clear that there is a possibility having these two features in the ground model of Kanto Plain.

INTRODUCTION

Recently, the occurrence of a great earthquake in Tokyo area is worried, and a lot of researches are conducted (e.g.[1]). It is known that the significant differences of damages are caused by seismic source, propagation path and characteristic of site. Because geological structure has severe effect in a case of strong earthquake, it is necessary to propose the hazard areas. In this paper, the ground motion is simulated by 3D finite difference method[2] using two simplified ground models. As a result, fundamental characteristics are clarified. Then, based on the fundamental results, and utilizing a ground model of the Kanto Plain, the long period seismic motion is simulated using earthquakes occurring in this region in past years.

Propagation Characteristics of Seismic Motion in Simple Basin Models

To investigate the basic propagation characteristics of seismic motion, and to compare it with propagation characteristics in the ground model of Kanto Plain used in the next chapter, two simplified ground models which we call "Basin model (Figure 1)" and "Slope model (Figure 2)" are proposed. And the propagation characteristics are examined in this chapter.

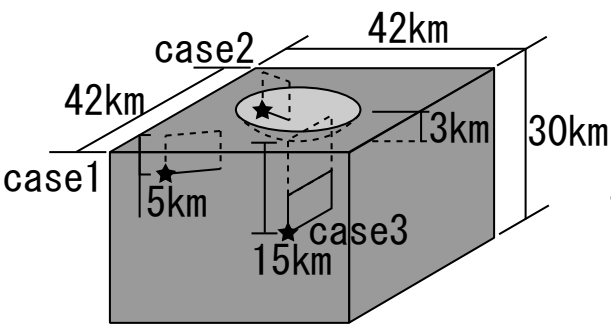


Figure 1 Basin model

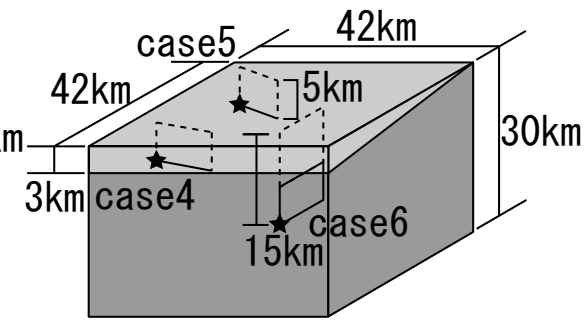


Figure 2 Slope model

Table 1 Physical properties

	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Q
	2300	1000	2100	120
	5200	3000	2600	300

Table 1 shows the physical properties of each model, and indicates these values of the grounds by gray scale. Vp expresses pressure wave velocity, Vs expresses shear wave velocity, ρ expresses density, Q value which has a linear dependence on frequency is account for the effect of anelastic attenuation. The analytical period is 1.5 seconds or more. The source models are proposed giving a mind to the 1923 Kanto earthquake[3], the 1931 west Saitama earthquake[4] and 1987 east off Chiba Prefecture earthquake[5] examined in the next chapter, and they are shown as cases 1 ~ 6 in Figure 1 and Figure 2. The symbols ★ show starting point of rupture, and the solid lines show the fault.

The two source models of case 1 and case 4 are corresponding to the source model of the 1923 Kanto earthquake. The source parameter of case 1 is (strike, dip, rake) = (60º, 20º, 80º), and that of case 4 is (strike, dip, rake) = (100º, 20º, 80º). Two source models are set in the line of 8.5km in length in the position of 5km in depth. The two source models of case 2 and case 5 are corresponding to the source model of the 1931 west Saitama earthquake. The source parameter of both cases is (strike, dip, rake) = (120º, 90º, 0º), and two source models are set in the line of 6km in length in the position of 5km in depth. The two source models of case 3 and case 6 are corresponding to the source model of the 1987 east off Chiba Prefecture earthquake. The source parameter of both cases is (strike, dip, rake) = (0, 70, 160), and two source models are set in plane of 5×6km in size of the position of 15km in depth. The positions of the source models and the seismic source parameters are made similar to three kinds of the earthquake for each source model.

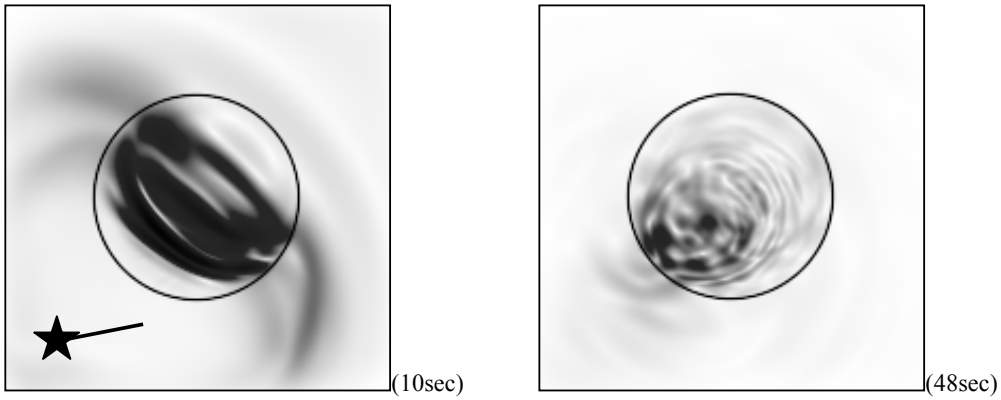


Figure 3 Basin model (case 1)

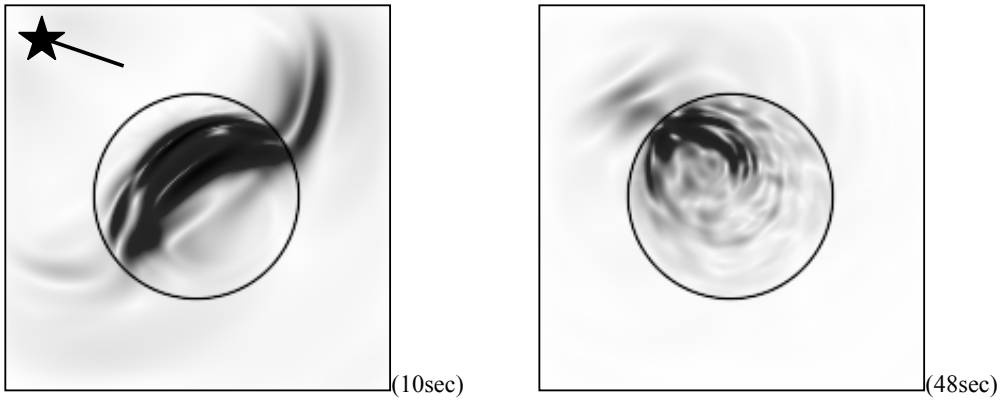


Figure 4 Basin model (case 2)

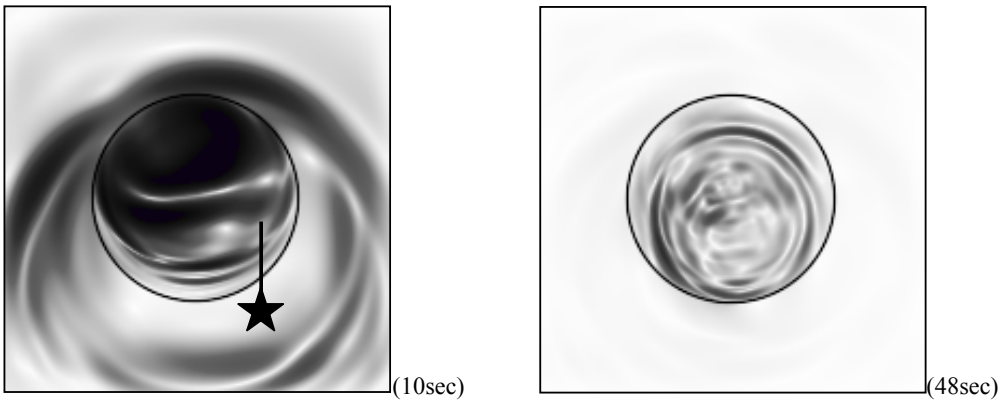


Figure 5 Basin model (case 3)

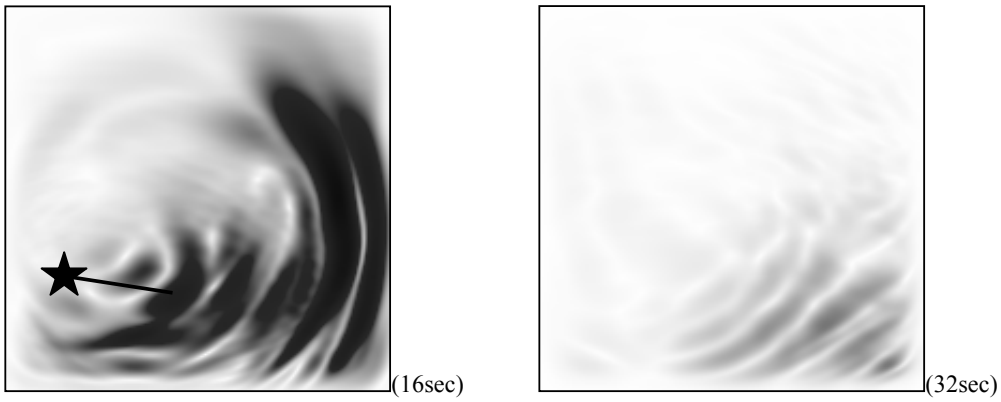


Figure 6 Slope model (case 4)

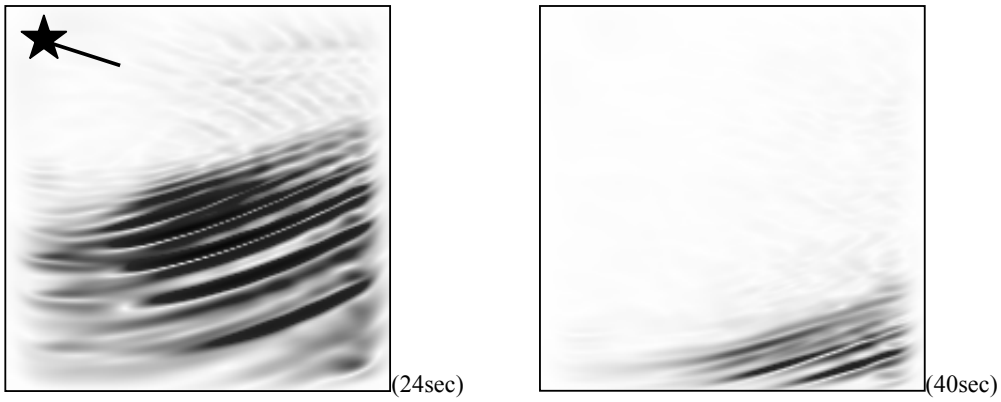


Figure 7 Slope model (case 5)

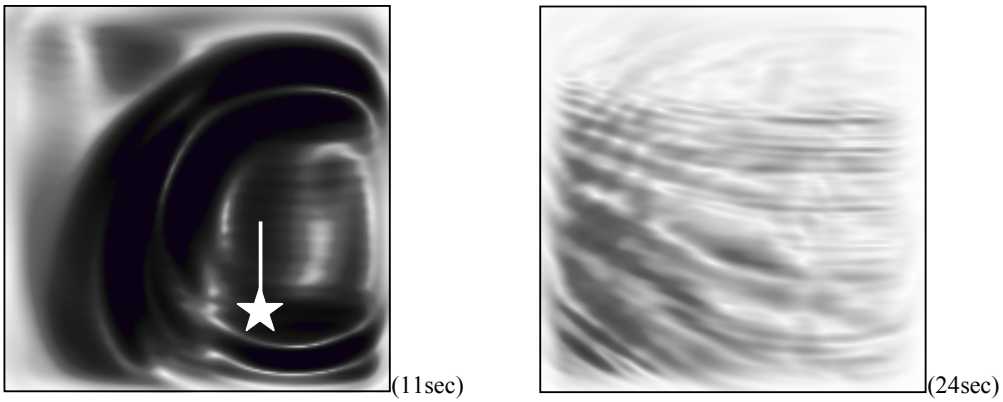


Figure8 Slope model (case 6)

Figures 3 ~ 8 indicate the velocity amplitude of surface layer of cases 1 ~ 6 by gray scale. The number of the inside of parentheses represents passed period from starting time of analysis.

In the basin model of cases 1 ~ 3 in Figures 3 ~ 5, similar characteristics appear in all source models. The seismic wave concentrates the center of basin in around 10 second, because the seismic wave turns around hard ground layer

and propagates soft ground layer. Moreover, there are characteristics that the seismic wave propagating inside of the basin reflects repeatedly and large amplitude wave remains for long time(see 48sec). In the Slope model of case 4 in Figure 6, large seismic wave propagates from thick sedimentary layer to thin one(16sec), and moreover the wave reflects to the sedimentary layer and remains for long time(32sec). In the case 5 in Figure 7, the seismic wave which propagates from thin sedimentary layer propagates to the direction of slope(24sec). And, the seismic wave remains for long time in the part of thick sedimentary layer(40sec). In the case 6 in Figure 8, large amplitude wave propagates to the direction of rupture propagation(11sec). And then, large amplitude wave propagates to the orthogonal direction of rupture propagation(24sec).

Propagation Characteristics of Seismic Motion in Ground Model of Kanto Plain

The 8th layers model is proposed as ground model of Kanto Plain referring to the ground data which Central Disaster Prevention Council is making public. And the scale of ground model is 200km×204km×75km(depth). Table 2 shows the physical properties of ground model of Kanto Plain from surface layer to the depth direction. Figure 9 shows the altitude of 3rd layer (Vs = 1400m/sec) in Kanto Plain. It can be seen from Figure 9 that the basin structure is chiefly located in Chiba Prefecture, and opened from Kanagawa Prefecture to Chiba Prefecture. Moreover, the sedimentary layer becomes thick while going from the north to the south in the macro. It is regarded that the ground model of Kanto plain has similar features of both "Basin model" (Figure 1) and "Slope model" (Figure 2).

Figure 10 shows the three source models of the 1923 Kanto earthquake[3], the 1931 west Saitama earthquake[4] and the 1987 east off Chiba Prefecture earthquake[5]. The symbols ★ represent the starting points of rupture and the solid lines represent the fault. The hypocenters of the 1923 Kanto earthquake and the 1931 west Saitama earthquake are assumed the 10km depth from surface layer. And the hypocenter of the 1987 east off Chiba Prefecture earthquake is assumed the 40km depth, and the scale of fault is set as 20km×20km. The source parameters are shown in Figure 10. The division interval of finite difference analysis is 400m and the analytical period is 4.0seconds or more.

Table 2 Physical properties

Layers	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Q
1	1500	500	1900	90
2	1800	700	2000	100
3	2900	1400	2200	150
4	4200	2400	2400	200
5	5000	2900	2600	300
6	6000	3400	2600	300
7	6800	4000	3000	500
8	7800	4500	3300	500

Figure 11 shows the normalized velocity amplitude on 45seconds and 90seconds from starting time of analysis in the 1923 Kanto earthquake. Figure 12 shows the normalized velocity amplitude on 70seconds and 140seconds in the 1931 west Saitama earthquake. Figure 13 shows the normalized velocity amplitude on 29seconds and 42seconds in the 1987 east off Chiba Prefecture earthquake.

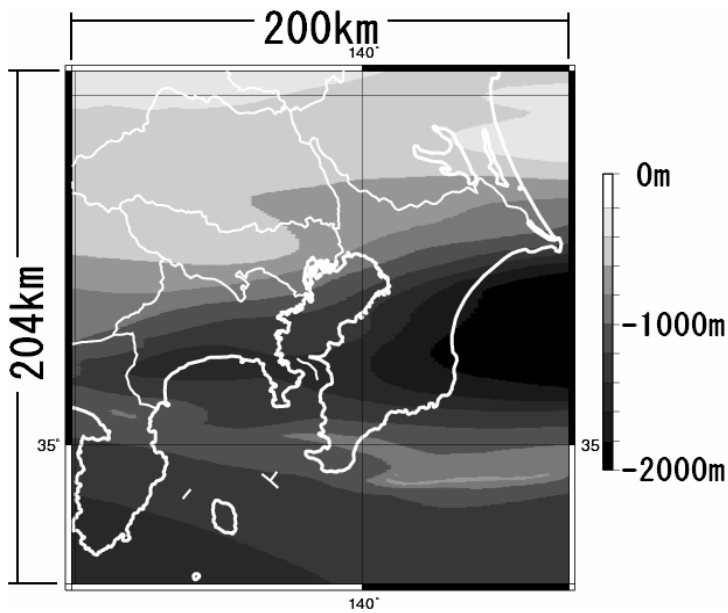
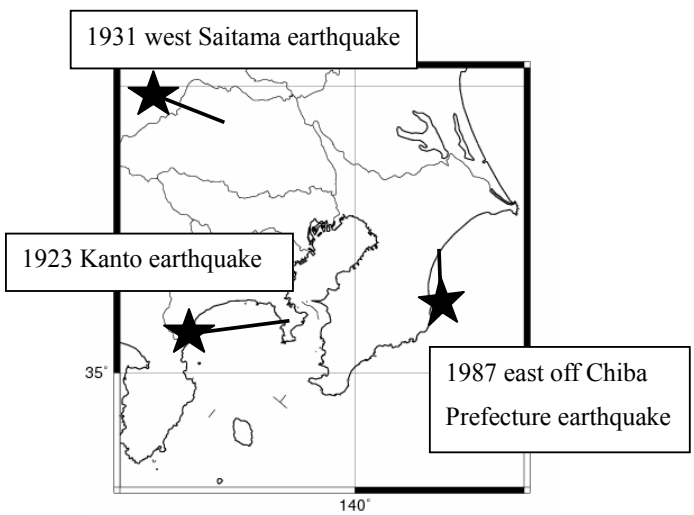


Figure 9 Geological structure of Kanto Plain



1923 Kanto earthquake:
t = 0sec ~ 13sec
Mo = 8.9×10^{20}Nm
(Strike, Dip, Rake)= (120º, 20º, 80º)

1931 west Saitama earthquake:
t = 0sec ~ 6sec
Mo = 2.8×10^{19}Nm
(Strike, Dip, Rake)= (108º, 80º, 0º)

1987 east off Chiba Prefecture earthquake:
t = 0sec ~ 6sec
Mo = 1.4×10^{19}Nm
(Strike, Dip, Rake) = (355º, 69º, 163º)

t: rupture duration
Mo: seismic moment

Figure 10 Seismic source data

In the 1923 Kanto earthquake, the seismic wave propagates to the wide area after 45seconds in Figure 11. Especially, the large amplitude wave can be seen in Chiba Prefecture and Kanagawa Prefecture. In 90seconds, it can be seen that the seismic wave appears to remain for long time in the inside of basin depending on basin geological structure in Chiba Prefecture. In the 1931 west Saitama earthquake, the seismic wave widely propagates from Chiba Prefecture to Kanagawa Prefecture after 70seconds in Figure 12. And then, the wave appears to remain for long time in Chiba Prefecture after 140seconds. In the 1987 east off Chiba Prefecture earthquake, it can be seen from 29seconds of Figure 13 that the large amplitude wave propagates to Chiba Prefecture and Ibaraki Prefecture which are the rupture direction of fault. And, after 42seconds, the wave propagates to Kanagawa Prefecture that is the orthogonal direction of rupture propagation. Similar characteristics appear respectively in the “Basin model” and “Slope model” of preceding chapter for all the seismic source models.

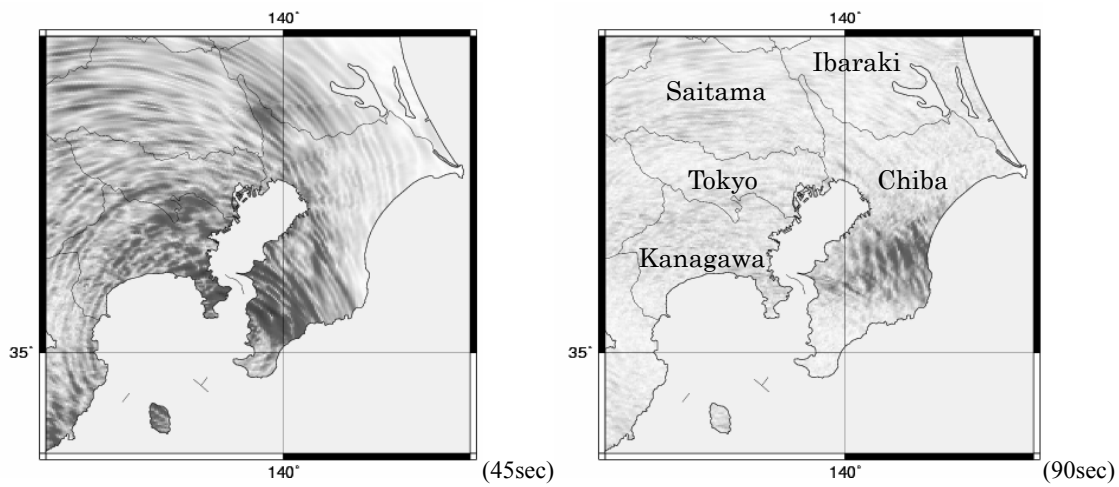


Figure 11 Snapshots of velocity amplitude concerning the seismic source model of 1923 Kanto earthquake

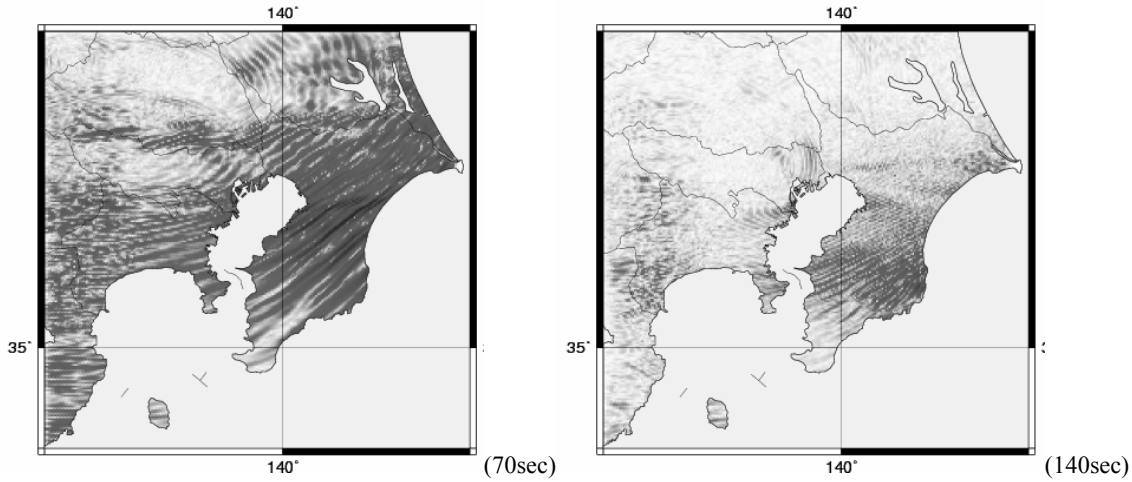


Figure 12 Snapshots of velocity amplitude concerning the seismic source model of 1931 west Saitama earthquake

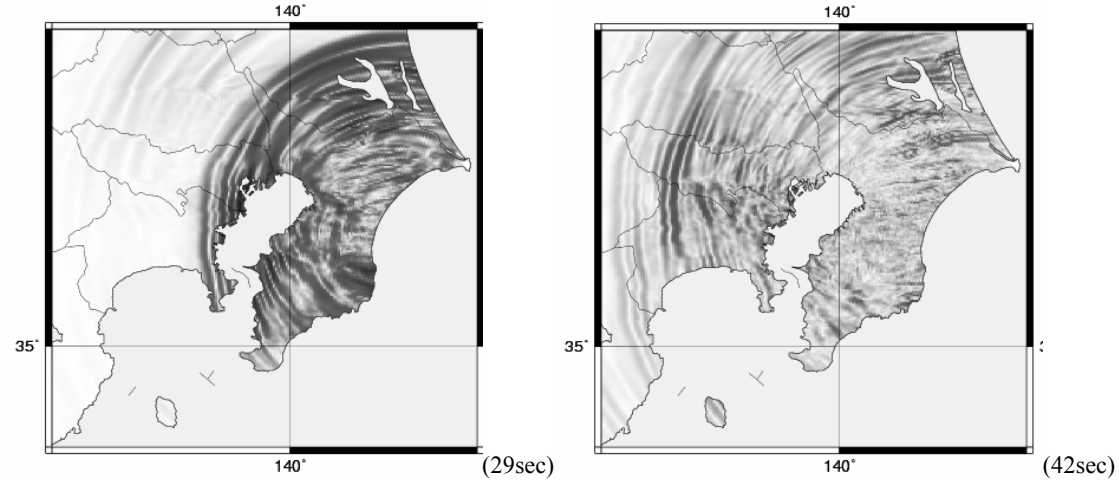


Figure 13 Snapshots of velocity amplitude concerning the seismic source model of 1987 east off Chiba Prefecture earthquake

CONCLUSIONS

The ground model of Kanto Plain is proposed, and propagation characteristics of seismic motion are analyzed using the seismic source models in the 1923 Kanto earthquake, the 1931 west Saitama earthquake and 1987 east off Chiba Prefecture earthquake that have occurred in Kanto Plain in the past. The similar features for the propagation characteristics based on the source models and the geological structures are become clear in simplified ground models and the ground model of Kanto Plain. These similar features are summarized as follows. The characteristics of "Basin model" can be seen in the vicinity of Chiba Prefecture, and the characteristics of "Slope model" can be seen in the entire area of Kanto Plain. Therefore it becomes clear that there is a possibility having these two features in the ground model of Kanto Plain.

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