Scenario Earthquake Shaking Maps in Japan

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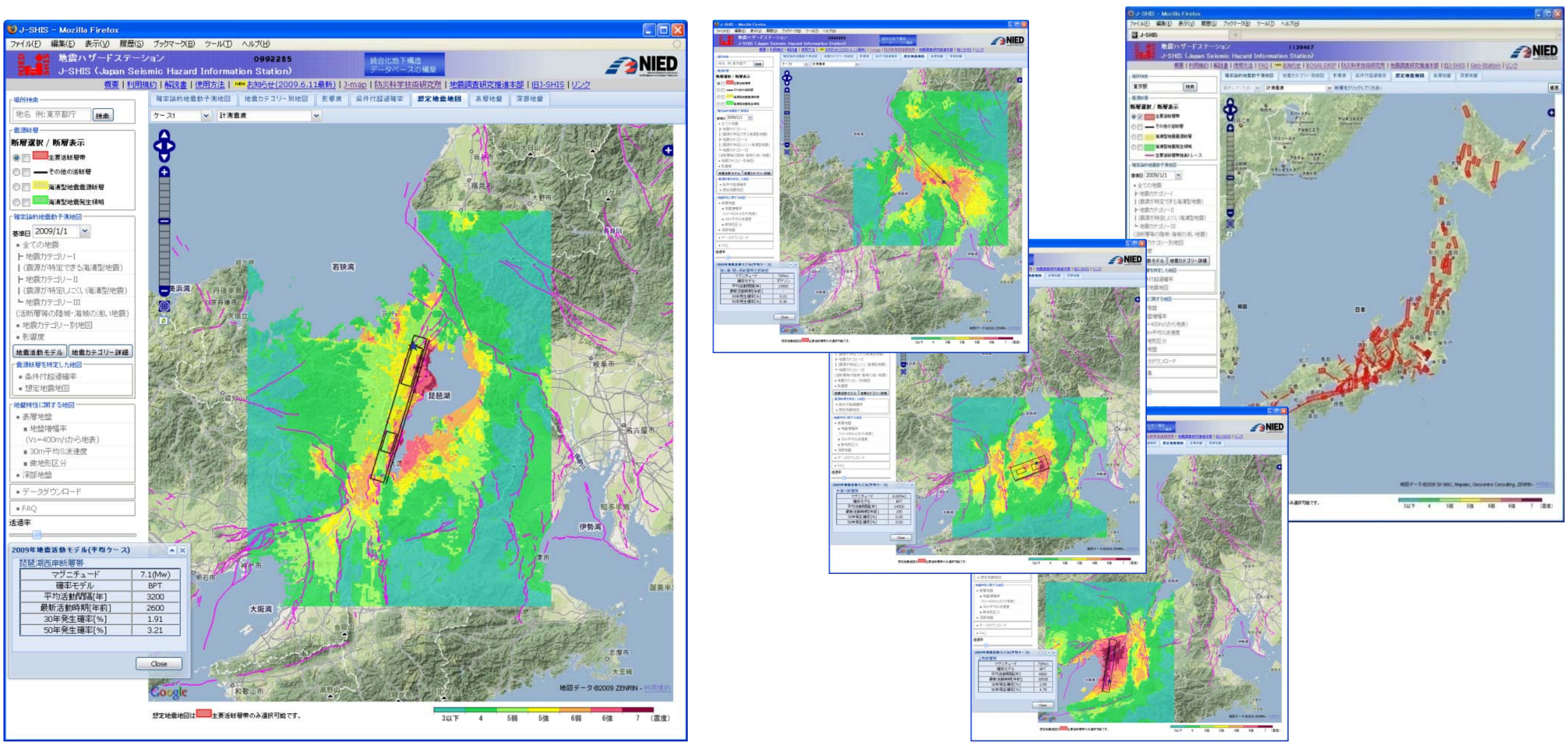
Scenario Earthquake Shaking Maps (SESMs)

The shaking maps are evaluated for about 500 scenario earthquakes of almost all of major active faults in Japan.



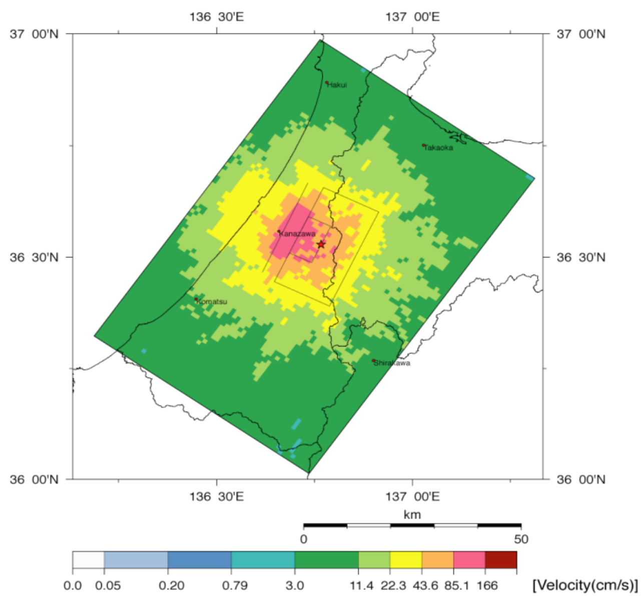
Selection of a specified scenario is essential to make a shaking map. The basic policy of the selection of a scenario earthquake is that we choose the most probable case.

For treatment of uncertainties, we assume several cases of source model and compare the results of them to show deviation of strong-motion evaluation due to uncertainties.

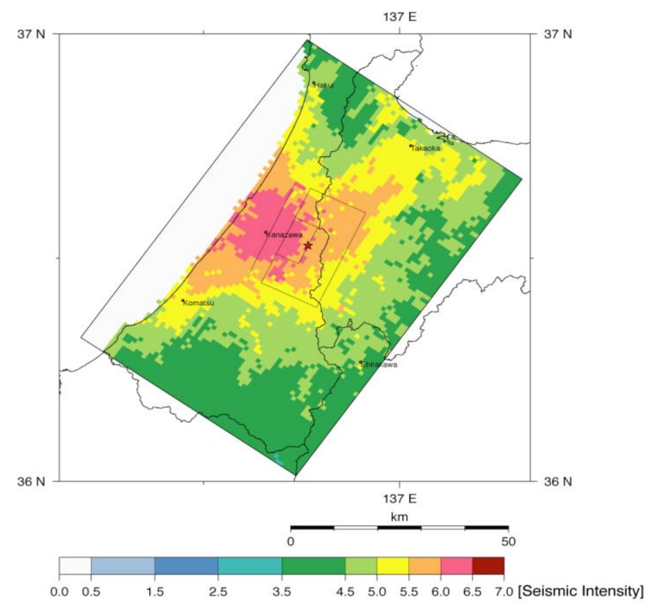
Scenario Earthquake Shaking Maps

for specified seismic-source fault

	on the engineering bedrock	on the ground surface
Mesh size	**1 km × 1km**	**0.25 km × 0.25 km**
Peak acceleration	△	×
Peak velocity	○	△
Spectrum	△	×
JMA seismic intensity (I_{JMA})	○	○
Time history of waveform	○	×



Peak velocity on the engineering bedrock.



JMA seismic intensity on the ground surface.

Strong-motion evaluation method (Recipe)

Modeling of source fault
(Characterized source model)
- Outer source parameters
- Inner source parameters
- Other source parameters

Modeling of underground structure
- Deep underground structure from the crust up to seismic bedrock
- Structure of sediments from the seismic bedrock up to the engineering bedrock

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Waveform simulation (Hybrid method)
- Finite difference method (for low frequency range)
- Stochastic Green's function method (for high frequency range)

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Waveforms on the engineering bedrock

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Amplification factor based on subsurface shallow structure from the engineering bedrock to the ground surface

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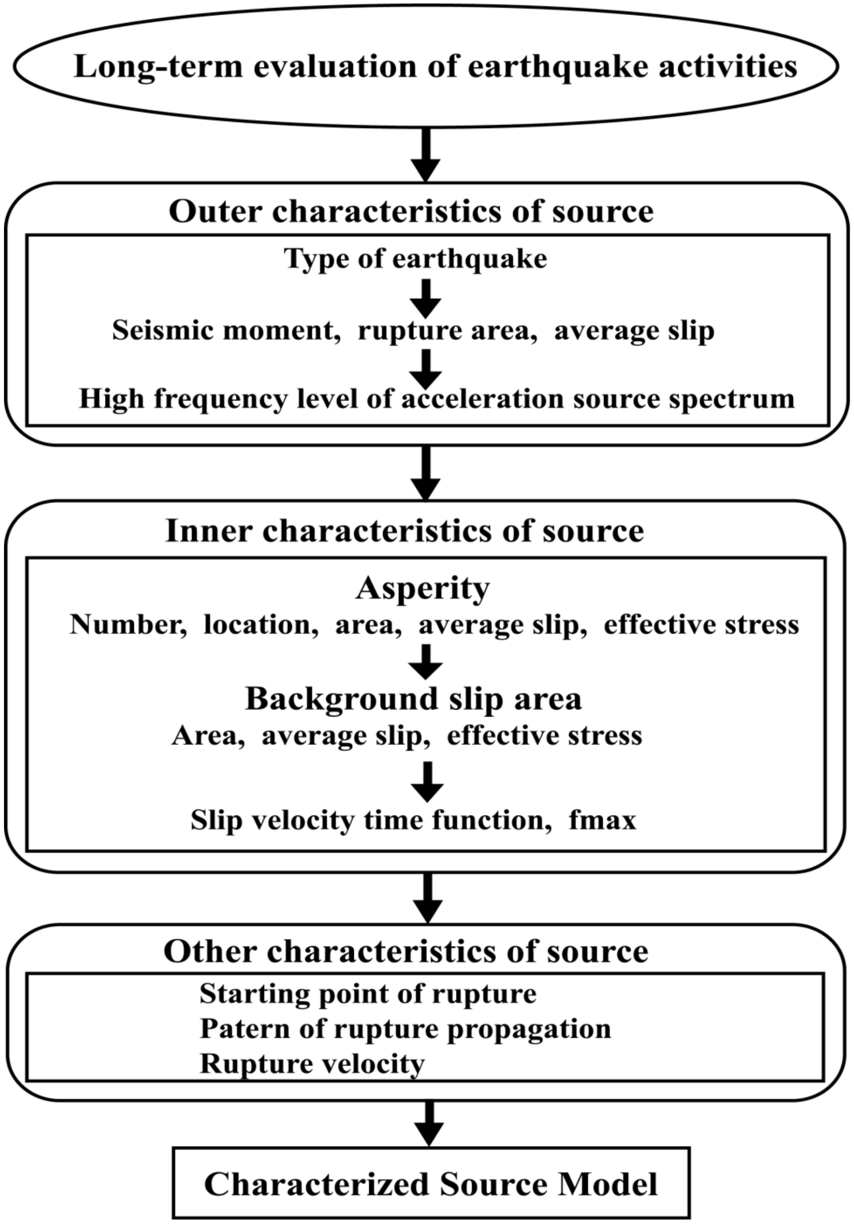
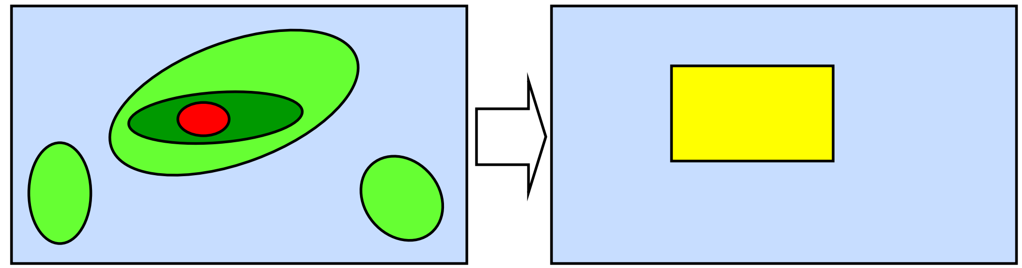
JMA seismic intensity on the ground surface

Characterized source model



Complicated source model



The complicated source model is simplified by the characteristic source model for strong-motion prediction.

Characterized source models are composed of asperities and a background slip area surrounding the asperities. Asperities are the main rupture areas in the fault zone.

Source parameters required to evaluate strong-motions by using the characterized source model are classified into three parts.

The first part is the set of outer parameters that show the magnitude and the fault shape of the earthquake.

The second part is the set of the parameters that describe the degree of fault heterogeneity.

The third part is the set of the parameters to define the characteristics of the rupture propagation.

Determination of outer source parameters

Fault length (L) by the long-term evaluation ⇒ Outer source parameters

Formulae

$$M = (\log L + 2.9) / 0.6 \quad \text{(Matsuda, 1975)}$$

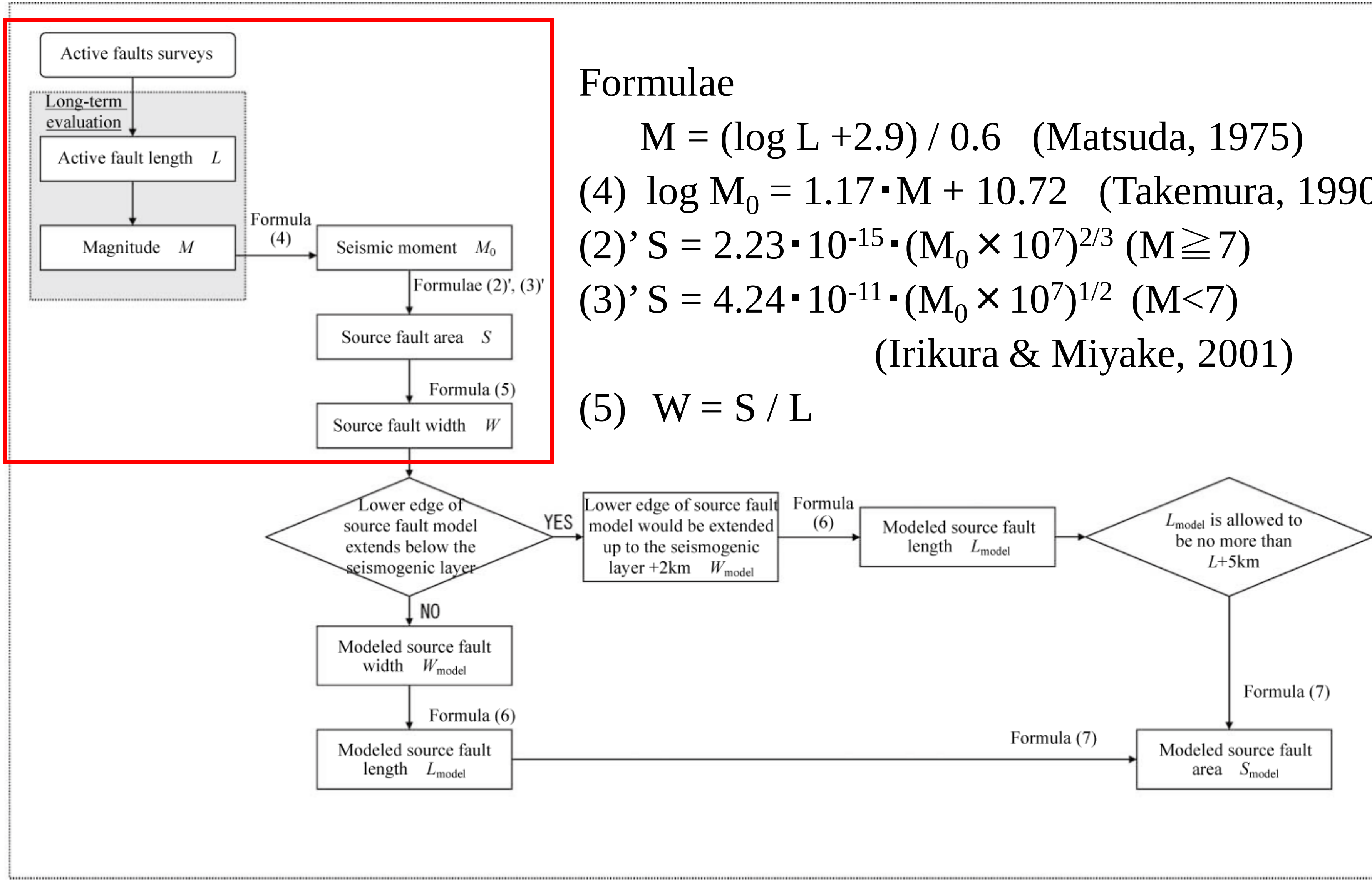
(4) $\log M_0 = 1.17 \cdot M + 10.72$ (Takemura, 1990)

(2)' $S = 2.23 \cdot 10^{-15} \cdot (M_0 \times 10^7)^{2/3}$ $(M \geqq 7)$

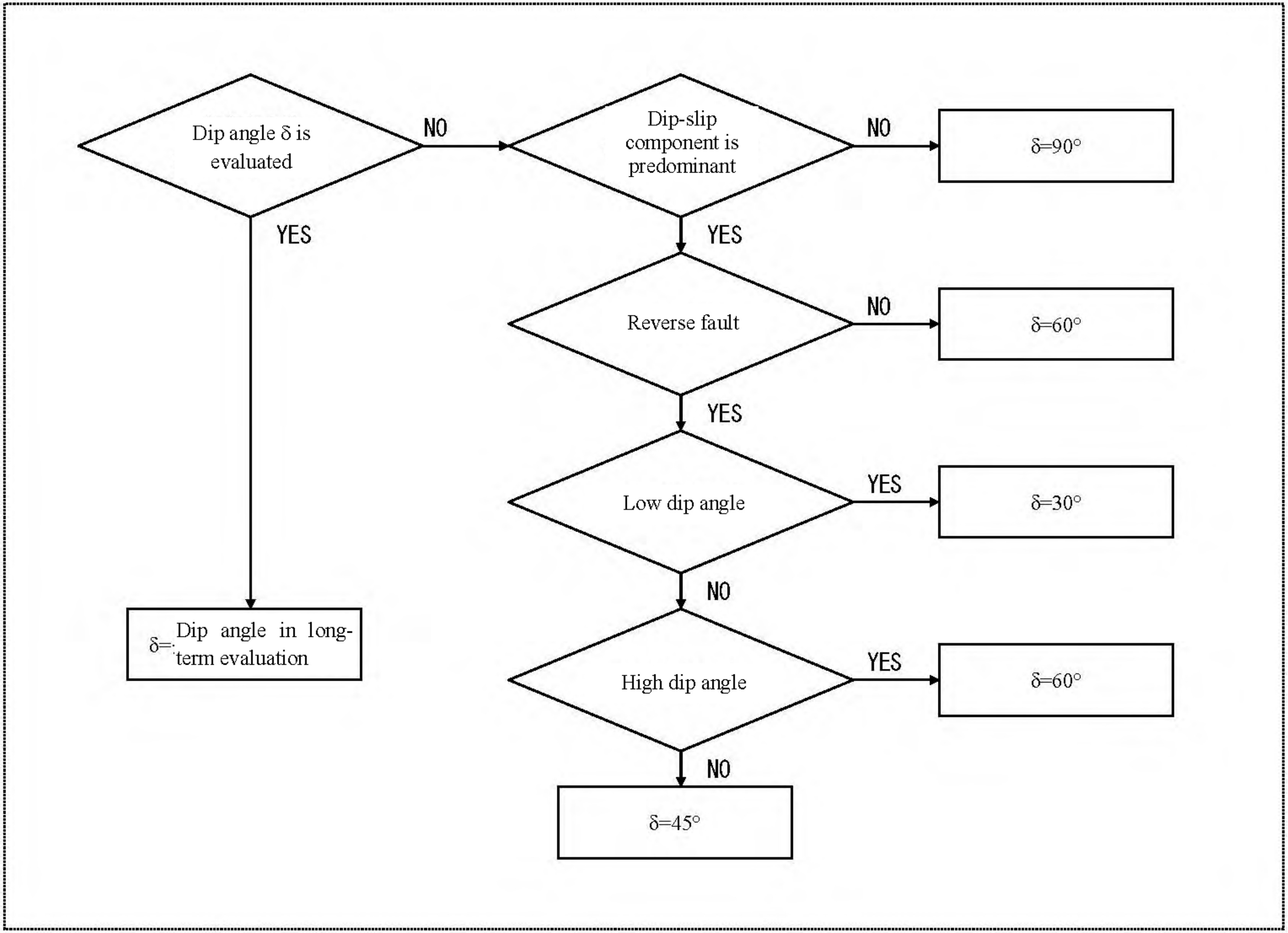
(3)' $S = 4.24 \cdot 10^{-11} \cdot (M_0 \times 10^7)^{1/2}$ $(M<7)$

(Irikura & Miyake, 2001)

(5) $W = S / L$



Determination of dip angle



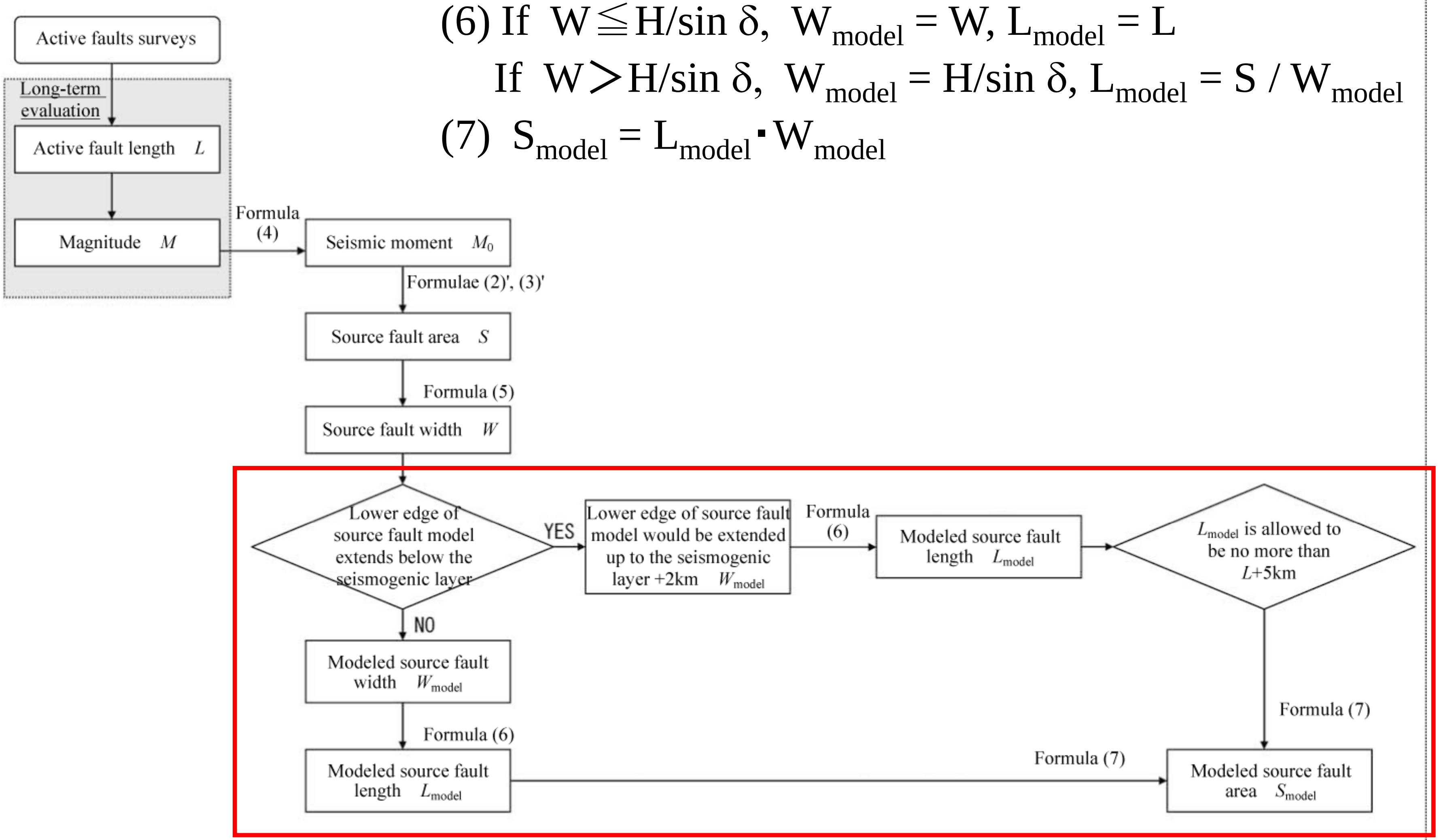
Determination of outer source parameters

Thickness of seismogenic zone (H) is mainly determined from activities of small or micro earthquakes

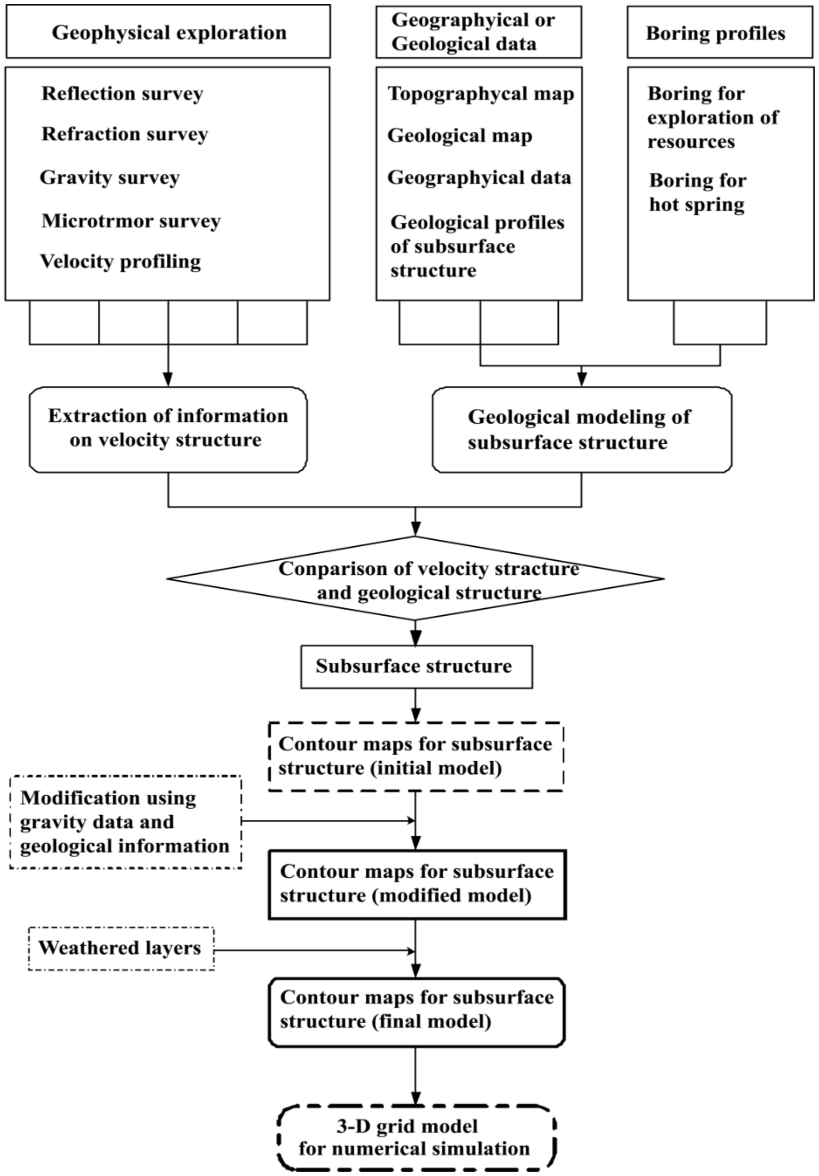
(6) If $W \leqq H/\sin\delta$, $W_{model} = W$, $L_{model} = L$

If $W > H/\sin\delta$, $W_{model} = H/\sin\delta$, $L_{model} = S / W_{model}$

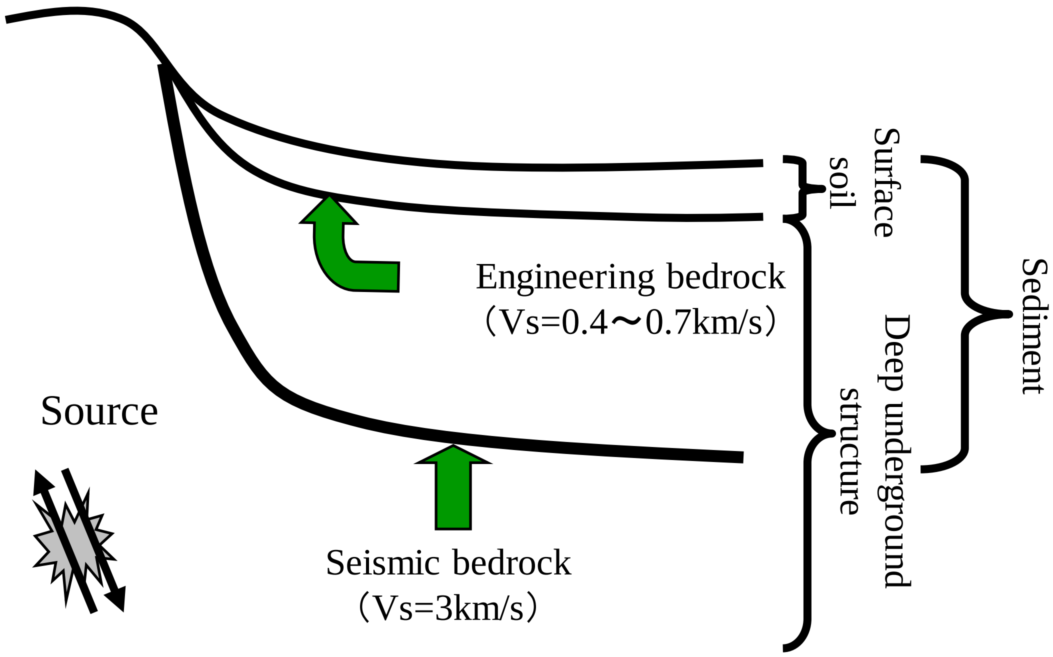
(7) $S_{model} = L_{model} \cdot W_{model}$



Modeling of underground structure



Flowchart of structure modeling



•The deep underground structure from the crust and plates up to seismic bedrock;

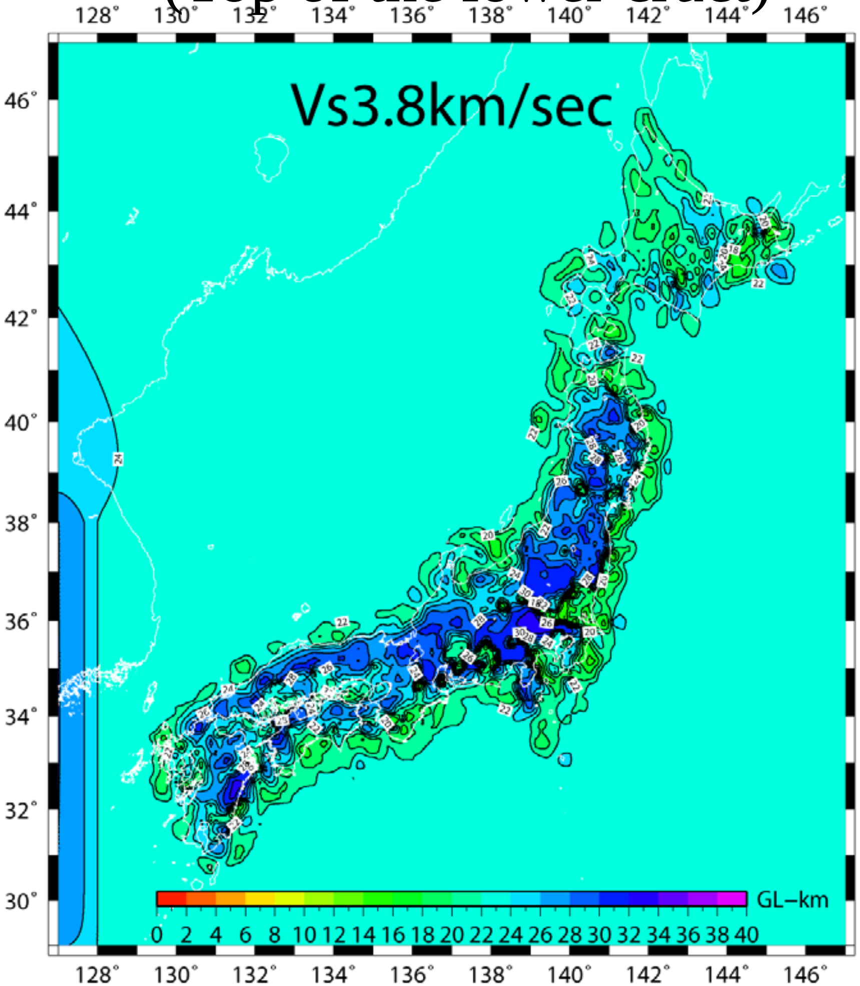
•The structure of sediments from the seismic bedrock up to engineering bedrock (Vs=0.4km/s～0.7m/s);

•The structure of surface soils from the engineering bedrock up to the ground surface.

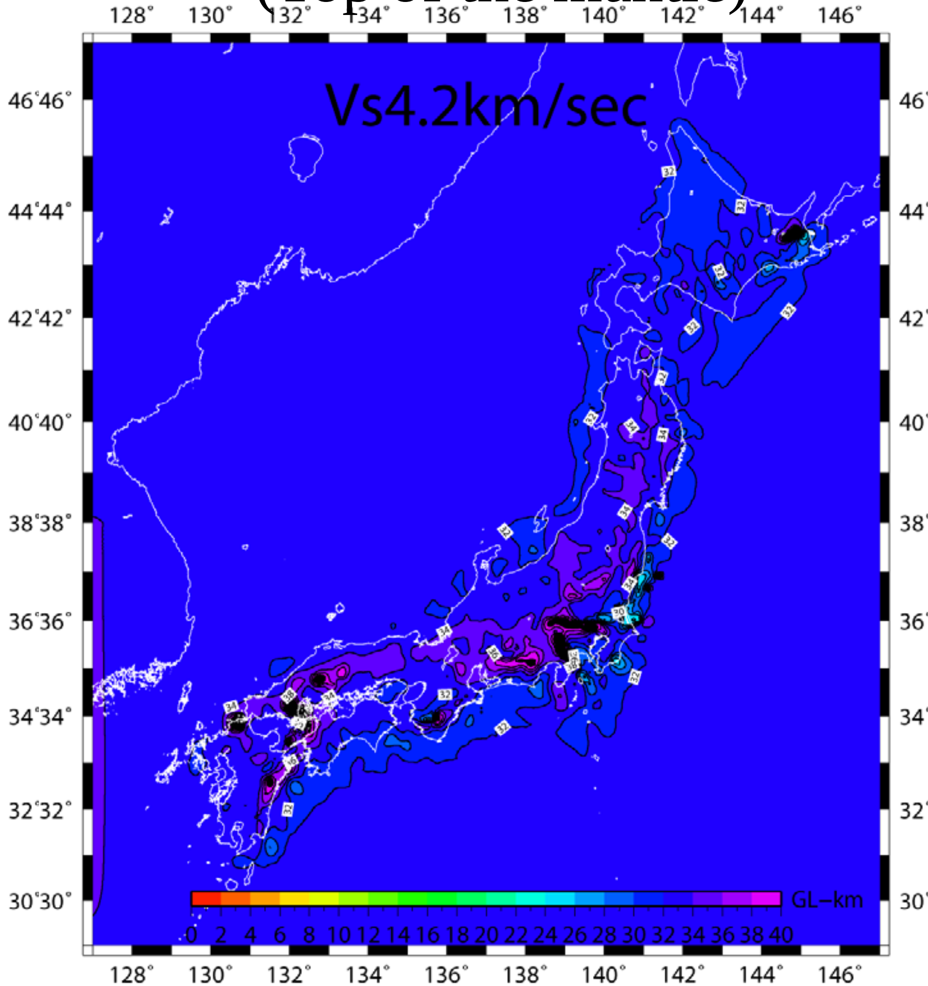
Structure model deeper than the seismic bedrock

Contour of the top depth of each velocity layer based on the 3D velocity structure by Matsubara et al. (2008)

(Top of the lower cruct)



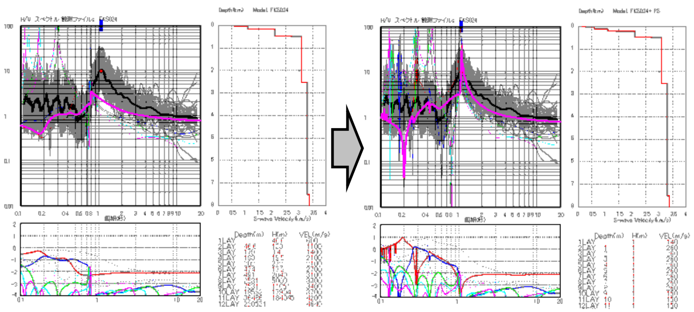
(Top of the mantle)

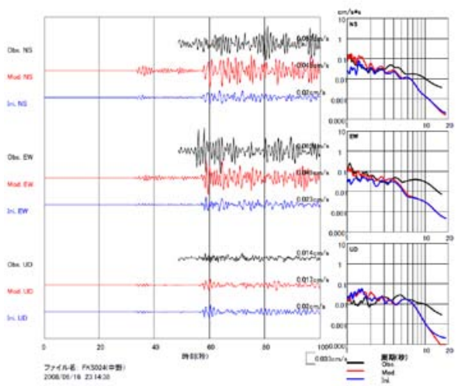


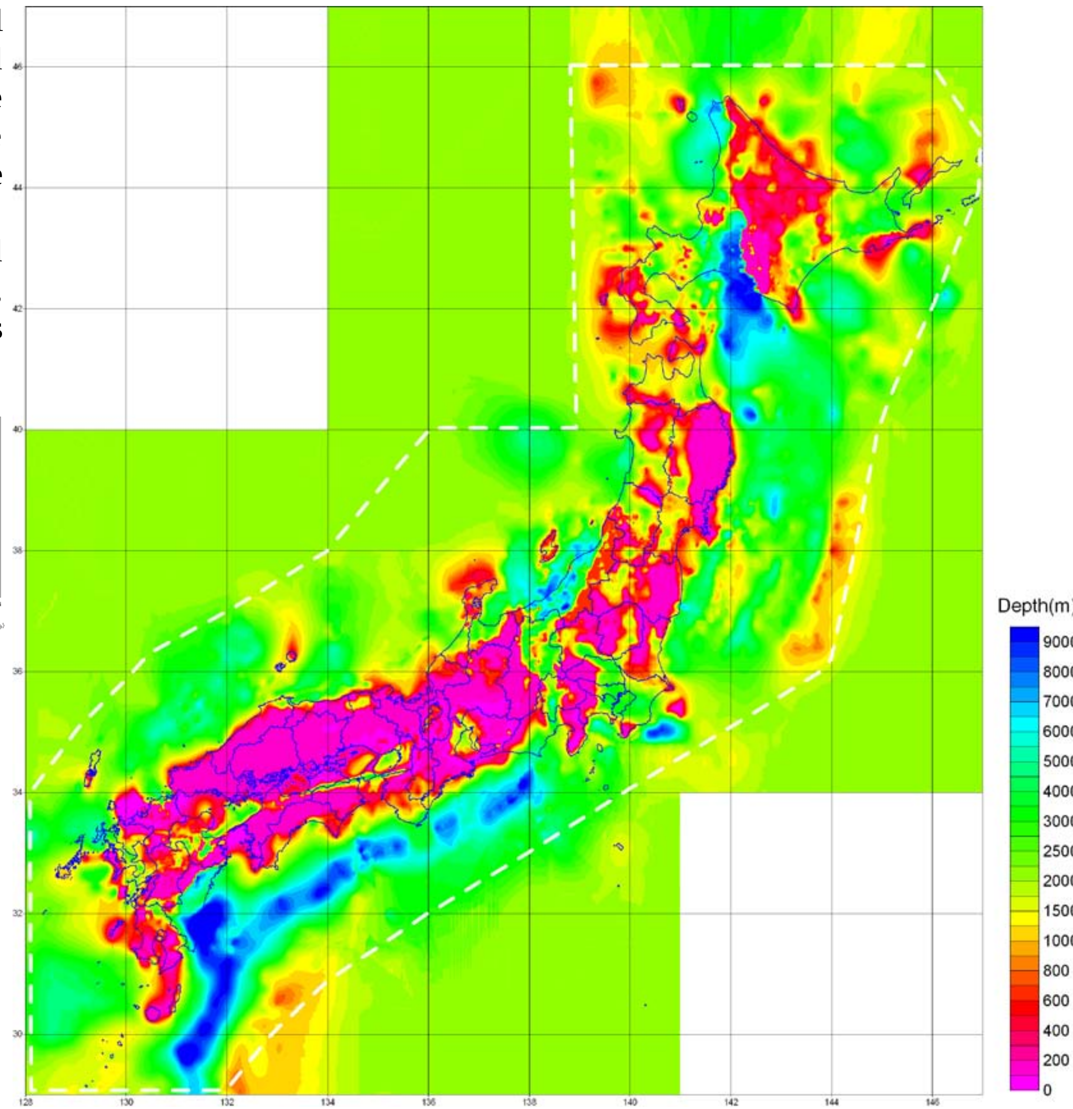
Structure model for deep sedimentary layers

To improve the initial model, with a focus on predominant periods, by comparing the H/V spectral ratio of seismic records (for M5.5 or greater) obtained by the Kyoshin Network (K-NET, KiK-net) and the H/V spectral ratio of fundamental to 4th higher-mode Rayleigh waves obtained from velocity structure models.

Comparing calculated waveforms with observed waveforms for middle-scale earthquakes (around M5), the validity of adjustments using H/V spectral ratios was reviewed.

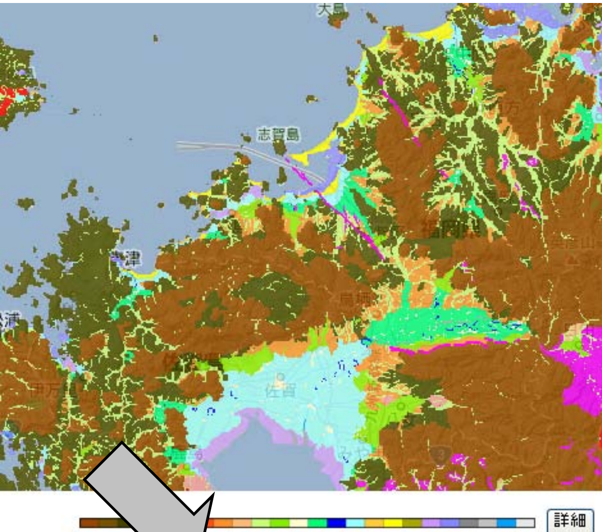




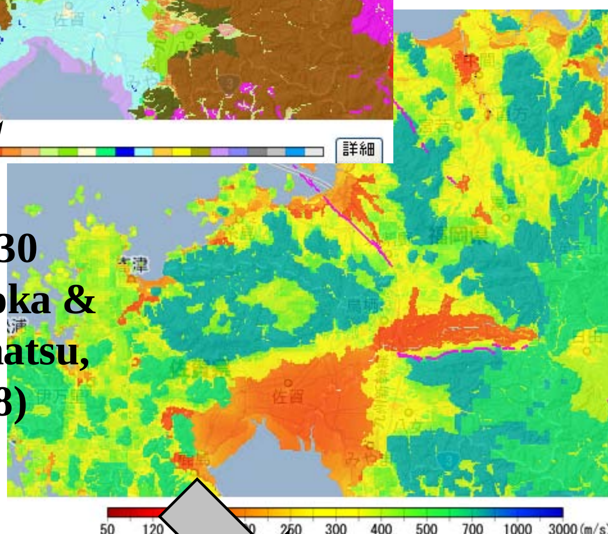


Depth contour of seismic bedrock

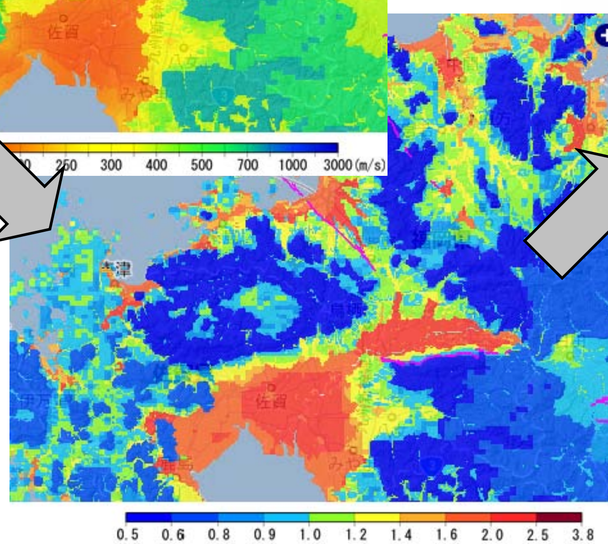
Subsurface shallow structure model



Engineering geomorphologic Classification (Wakamatsu & Matsuoka, 2008)

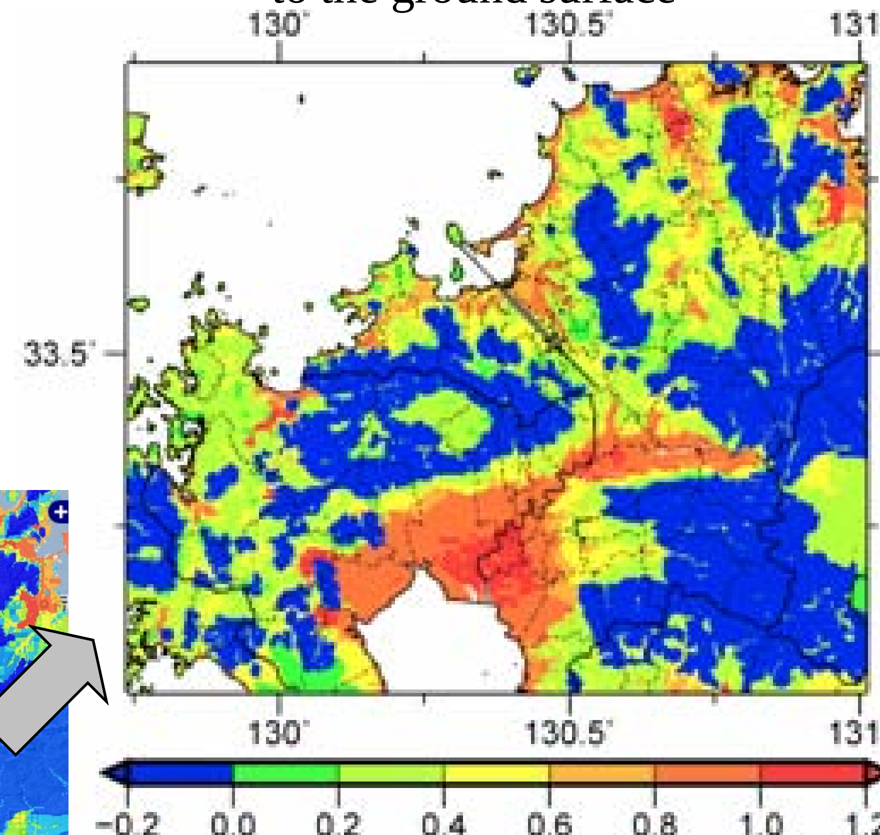


AVS30 (Matsuoka & Wakamatsu, 2008)

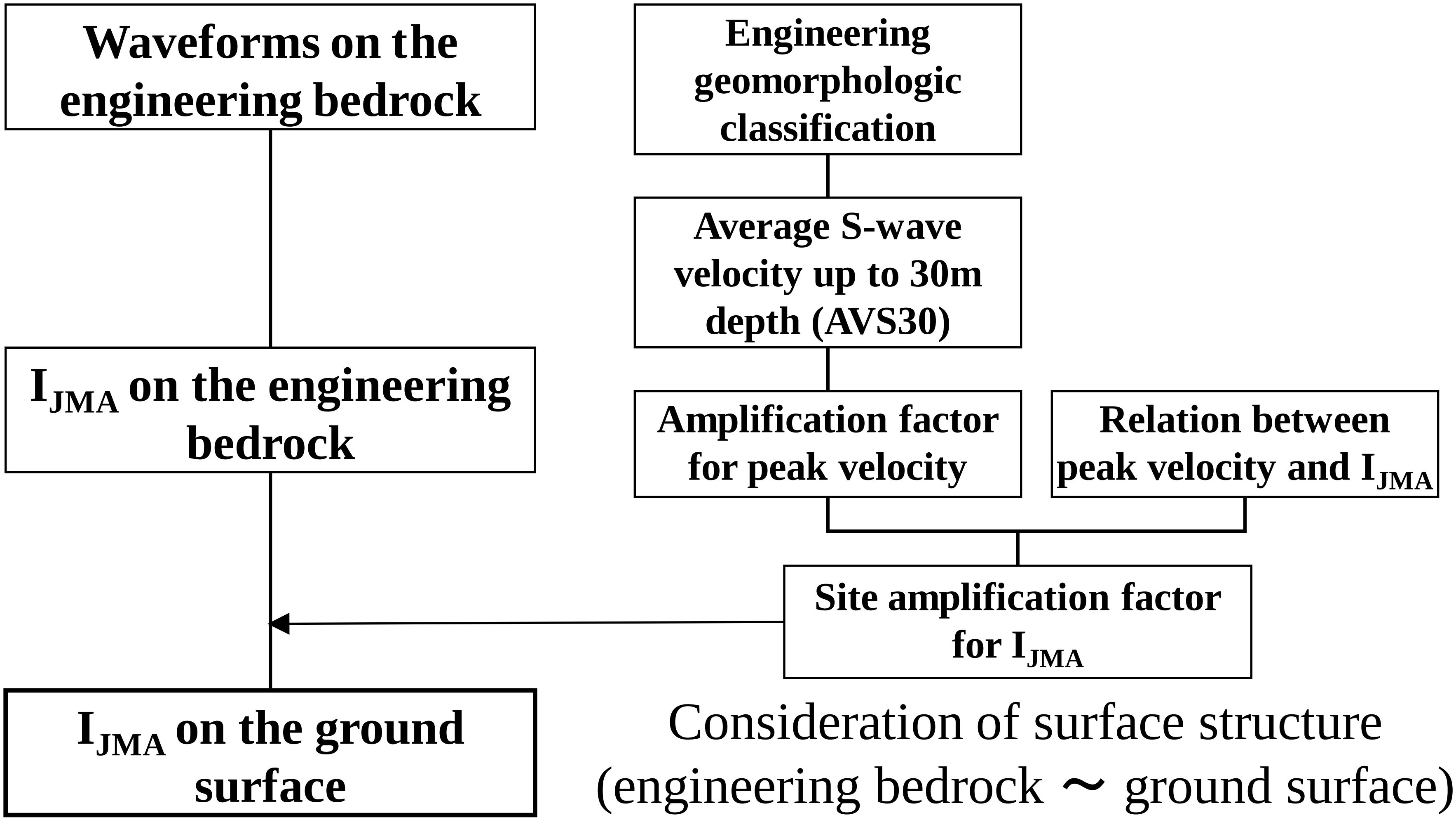


Amplification factor for peak velocity (Fujimoto & Midorikawa, 2006)

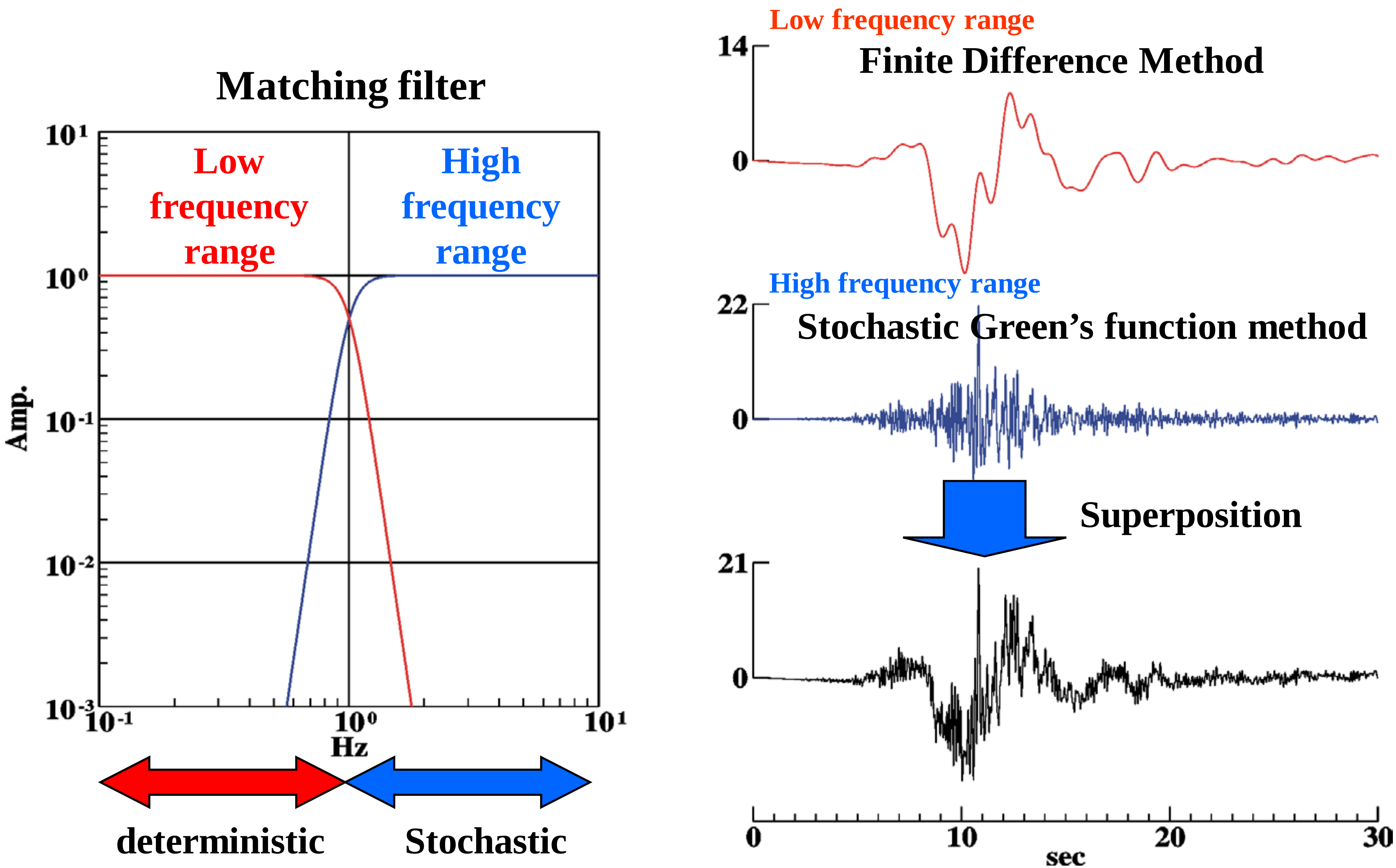
Site amplification factor for I_{JMA}
from engineering bedrock (Vs=0.6km/s)
to the ground surface



Calculation of JMA seismic intensity (I_{JMA}) on the ground surface



Hybrid method for evaluation of strong-motion



The technical details on the hybrid method are summarized as the 'Recipe for strong-motion evaluation', which are published by the earthquake research committee of Japan.

Verification of the 'Recipe'

For inland crustal earthquakes

- The 2000 western Tottori earthquake on October 6, 2000
  (M_{JMA} = 7.3, Mw = 6.8, Depth = 9 km)
- The 2005 west off Fukuoka earthquake on March 20, 2005
  (M_{JMA} = 7.0, Mw = 6.6, Depth = 9 km)

↓

- Simulated strong-motion intensity distribution matched well to observed one.
- Simulated spectral level also matched well to observed one if the location of asperity and velocity structure model could be set up appropriately.

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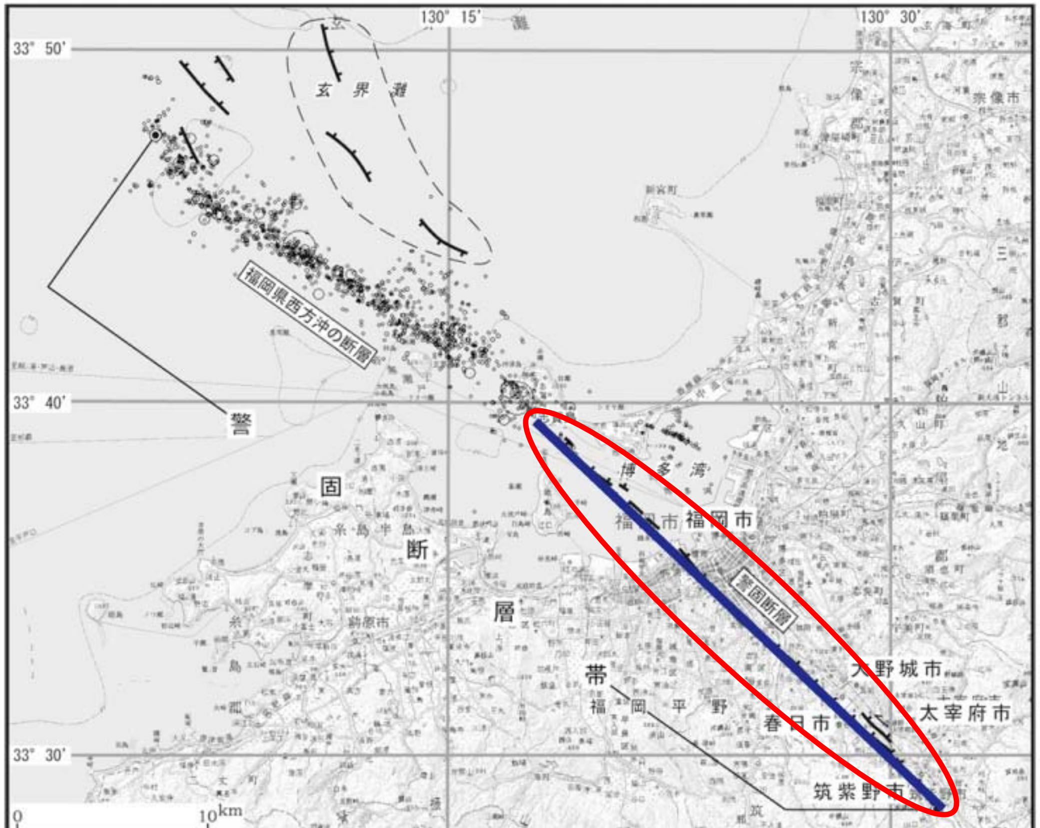
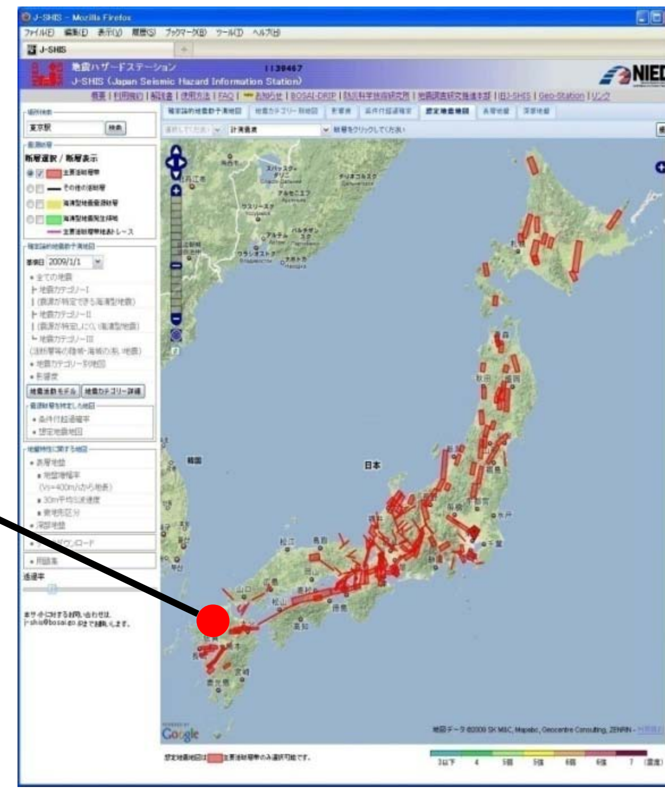
Uncertainty of asperity location should be considered because it is very difficult to know the location in advance.

Example of SESMs

Southeastern part of the Kego fault zone

- Fault length = 27km (⇒ M = 7.2)
- Strike-slip fault



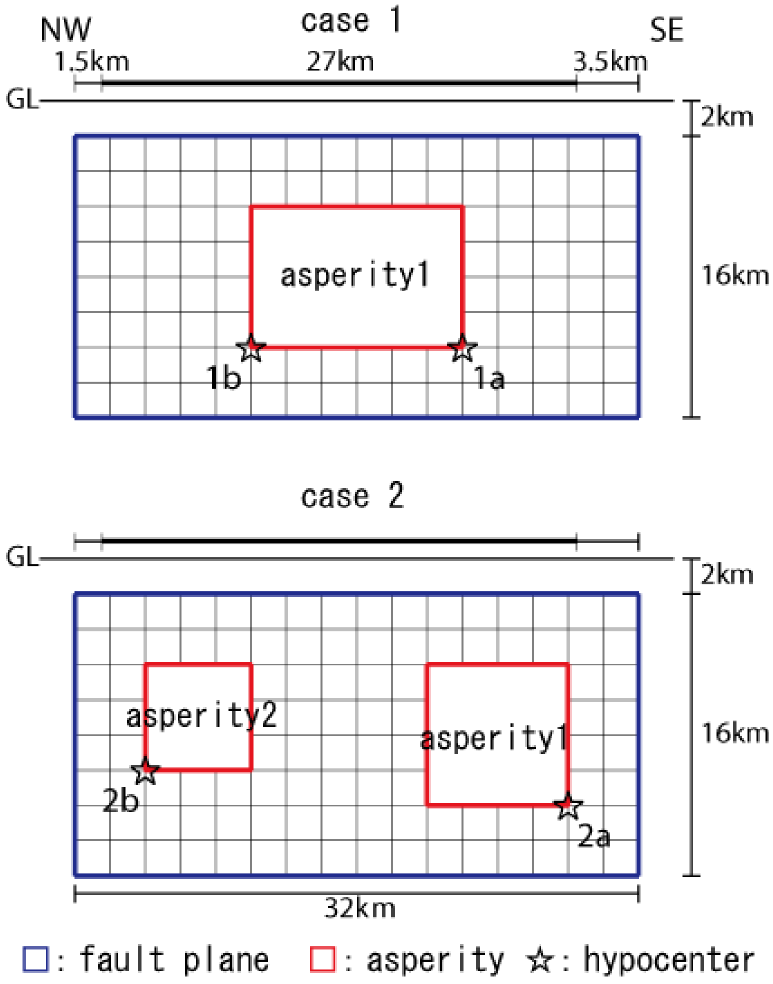


Characterized source model

Outer source parameters ⇒ Inner source parameters

For details, see 'Recipe'

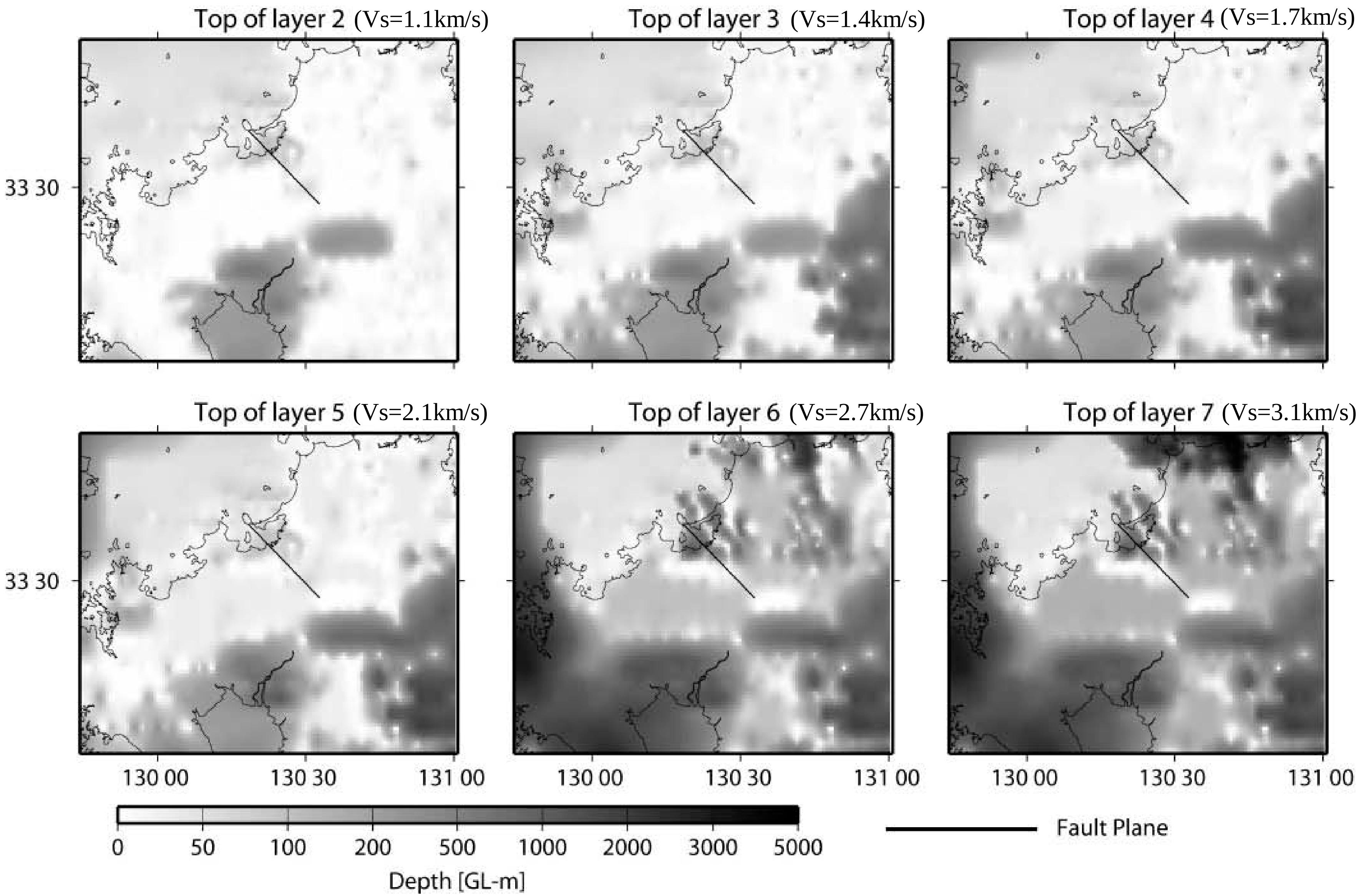
(http://www.j-shis.bosai.go.jp/map/JSHIS2/text/news_en.html)



	case 1	case 2
Outer source parameters		
Seismic moment [Nm]	1.47×10^{19}	
L_{model} [km]	32	
W_{model} [km]	16	
Innter source parameters		
Asperity 1		
Area [km^2]	96	64
Average slip [m]	1.8	2.0
Effective stress [MPa]	16	16
Asperity 2		
Area [km^2]	—	36
Average slip [m]	—	1.4
Effective stress [MPa]	—	16
Background region		
Area [km^2]	416	412
Average slip [m]	0.7	0.7
Effective stress [MPa]	2.8	2.8
Other source parameters		
Rupture velocity [km/s]	2.4	

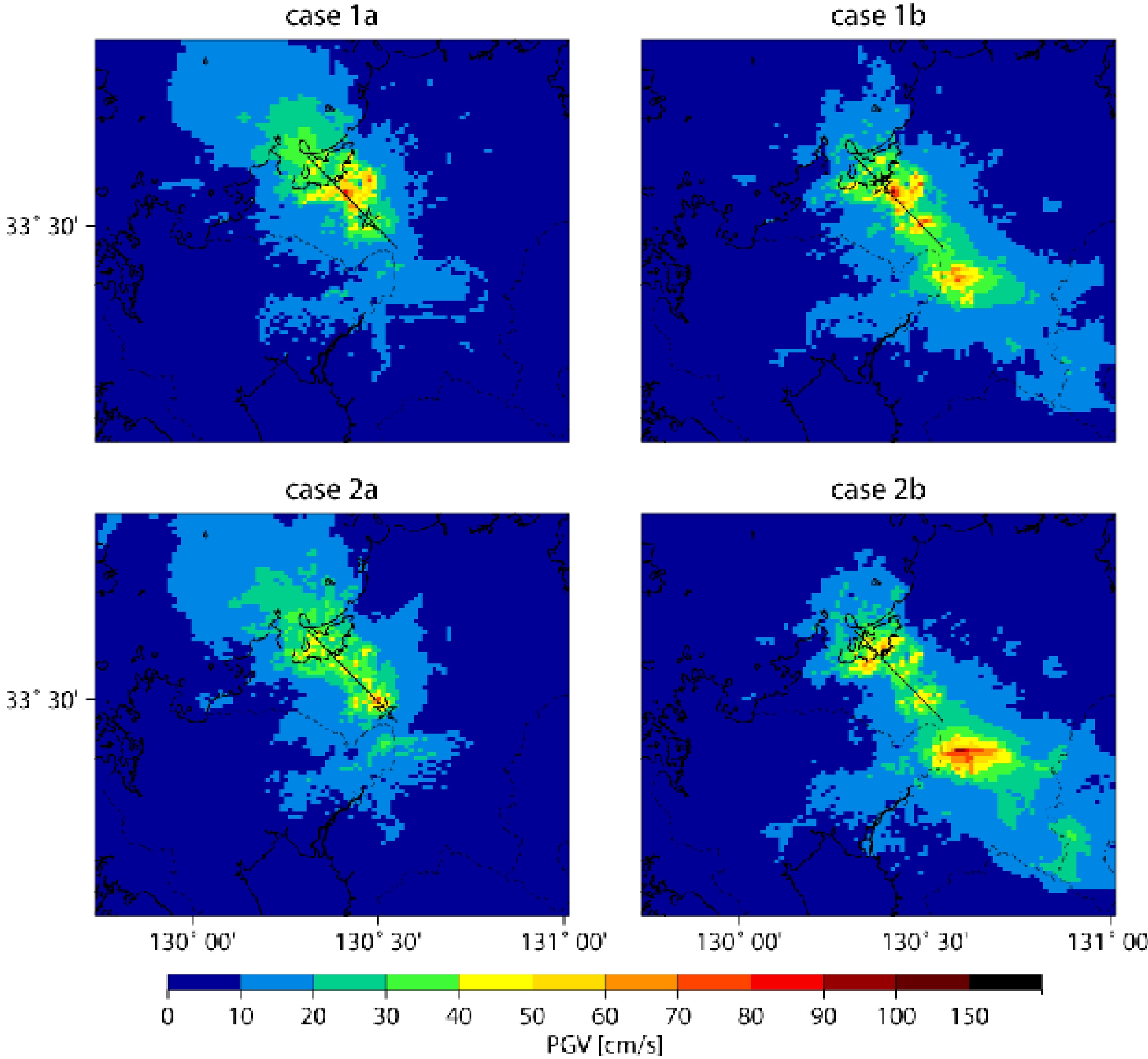
Deep sediments structure model

Seismic bedrock (Vs=3.1 km/s) ~ engineering bedrock (Vs = 0.6 km/s)



Results-1

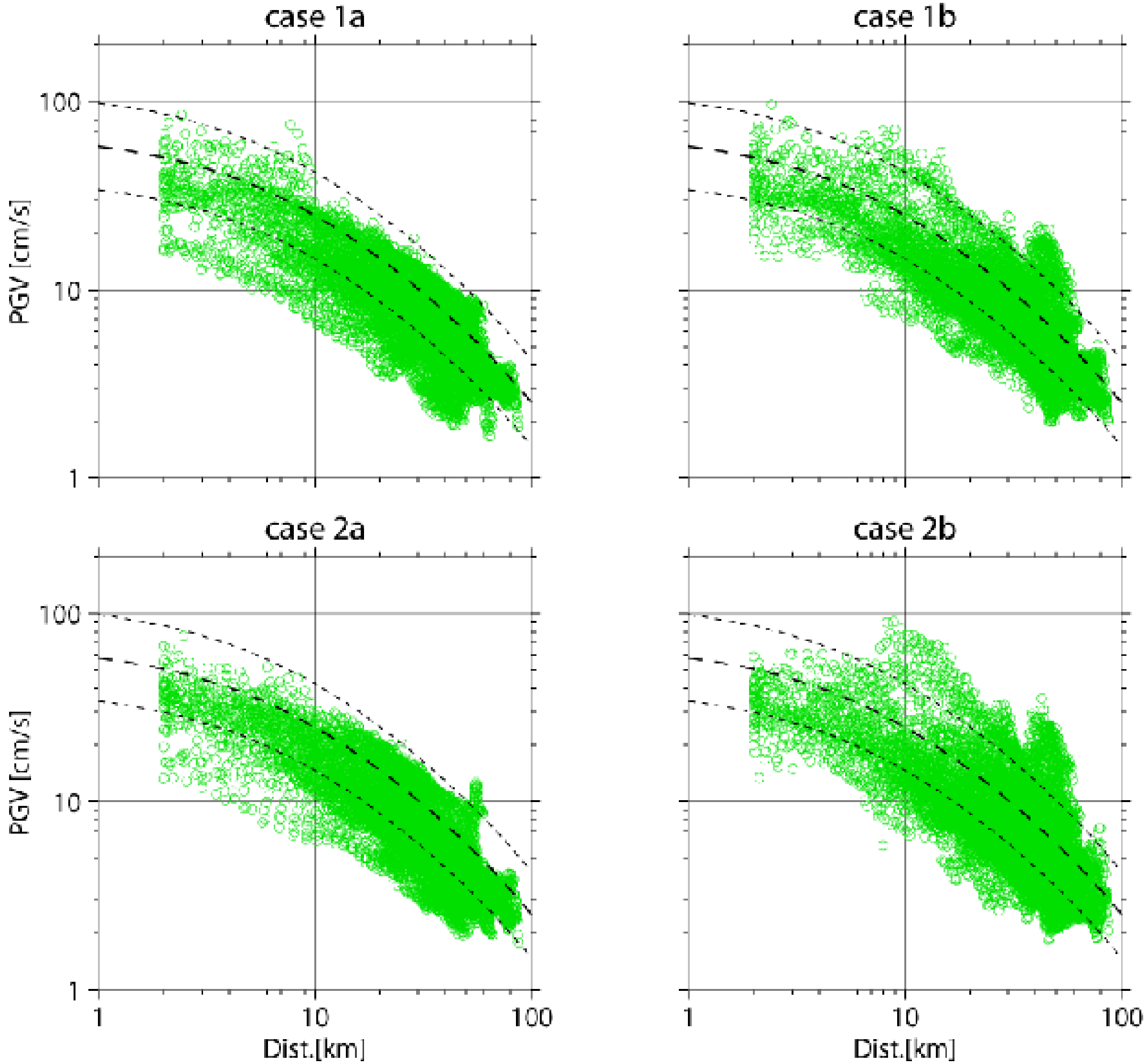
Peak velocity distribution on the engineering bedrock (Vs=0.6km/s)



- peak velocities at near source fault in cases 1a and 1b are larger than cases 2a and 2b
- large peak velocity region extends to southeastern of the source fault in cases 1b and 2b (forward directivity effect and amplifications by sediments)

Results-2

Comparison of simulated peak velocity on the engineering bedrock with an empirical attenuation relation by Si and Midorikawa (1999)

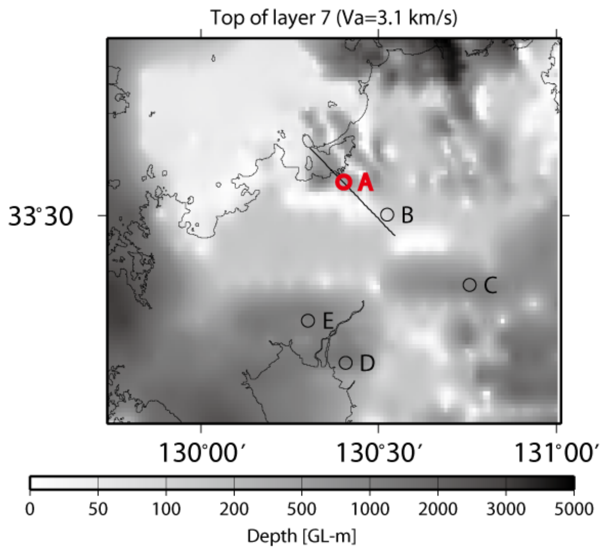


・Simulated peak velocities have a tendency small compared with the attenuation relation. The depth to seismic bedrock is shallow (200m or less) at the near fault region.

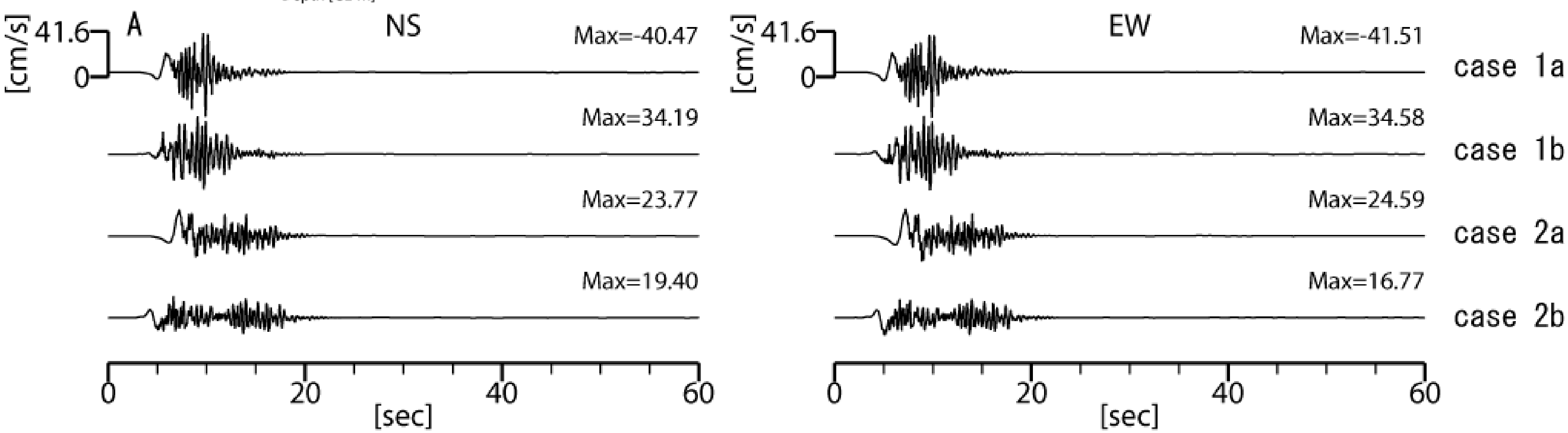
・Extremely large peak velocities are simulated in cases 1b and 2b.

Results-3

Examples of velocity waveforms on the engineering bedrock (site A located just on the source fault)

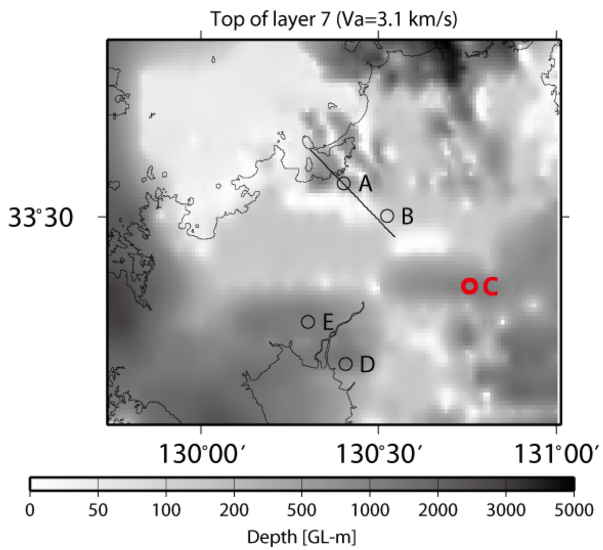


- ○ cases 1a & 1b (1 asperity model) large amplitudes with a short duration
- ○ cases 2a & 2b (2 asperities model) relatively small amplitudes with a long duration



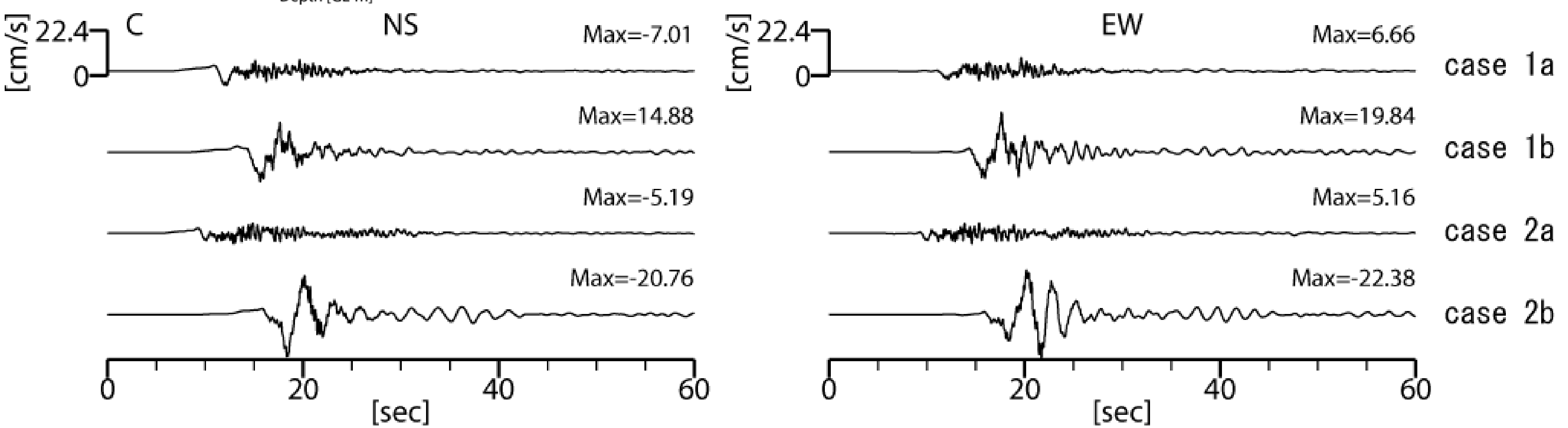
Results-4

Examples of velocity waveforms on the engineering bedrock
(site C located on a direction extending from the source fault)



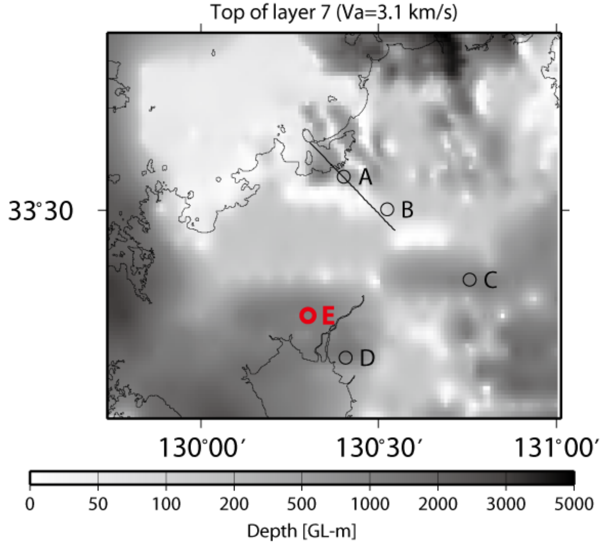
○ cases 1a & 2a
small amplitudes

○ cases 1b & 2b
large pulse with period of about 3s
(forward directivity effect
+ amplification by sediments)



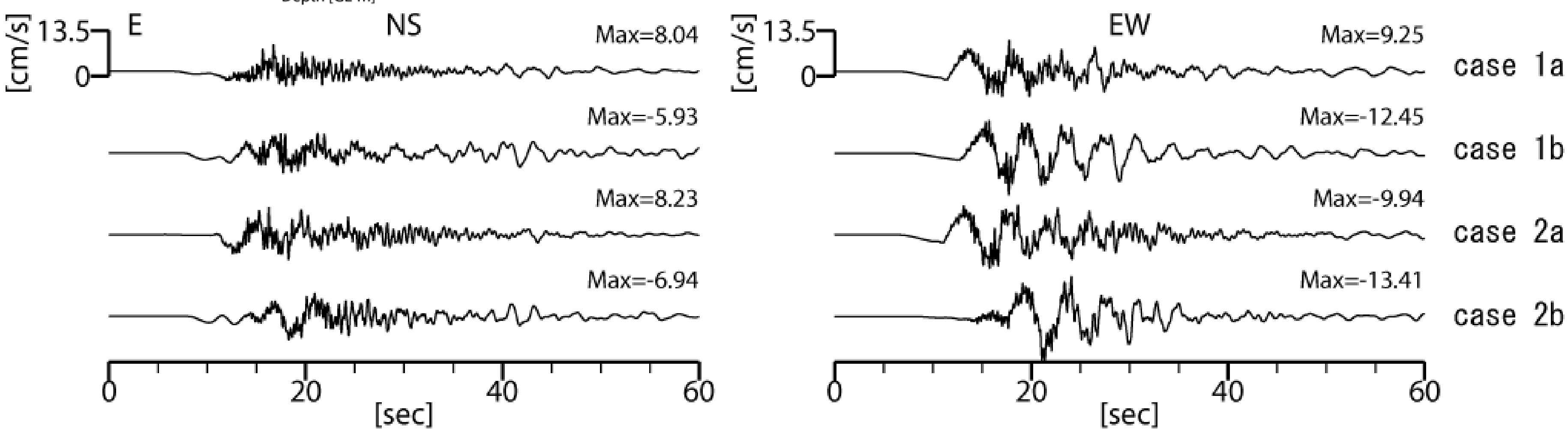
Results-5

Examples of velocity waveforms on the engineering bedrock
(site E located on very thick sediments)



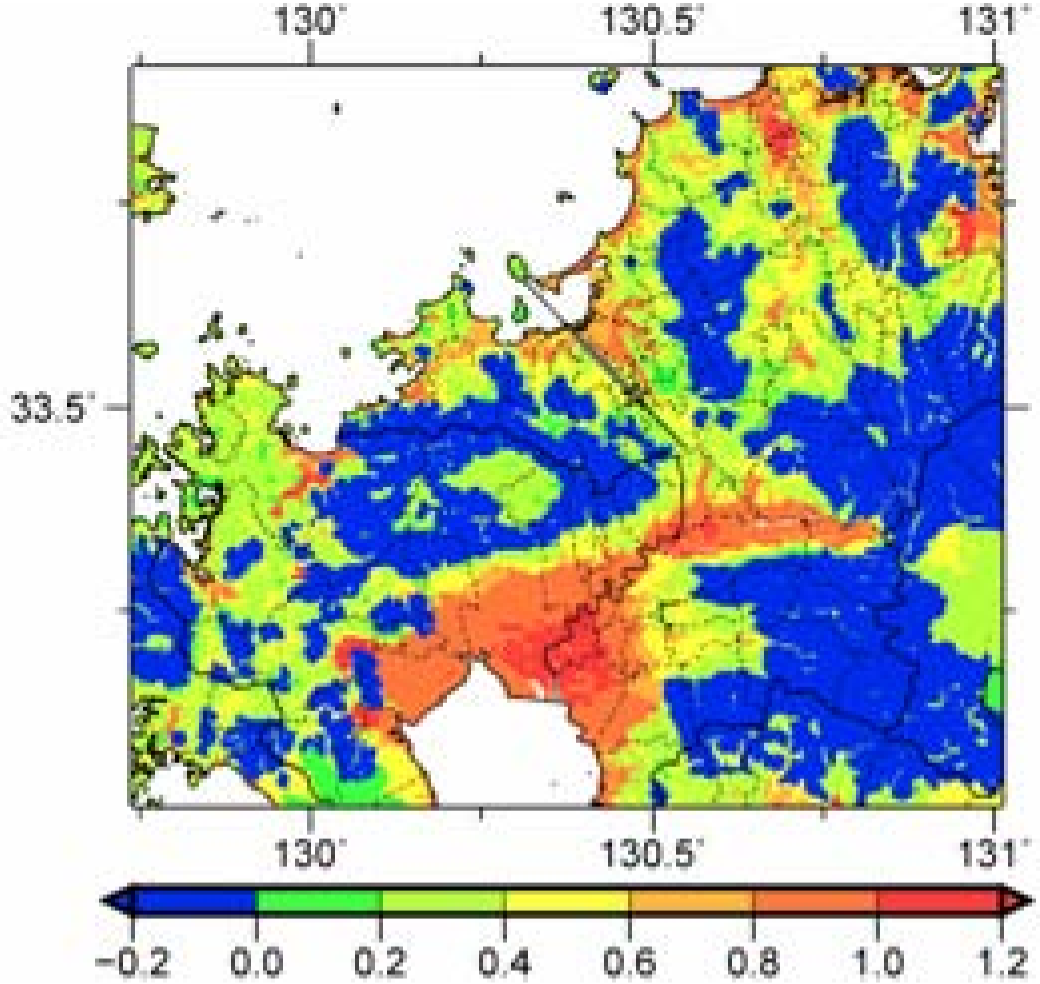
○ all cases
remarkable later phases with large amplitudes

○ cases 1b & 2b
relatively large peak amplitude
(forward directivity effect)



Site amplification factor for I_{JMA}

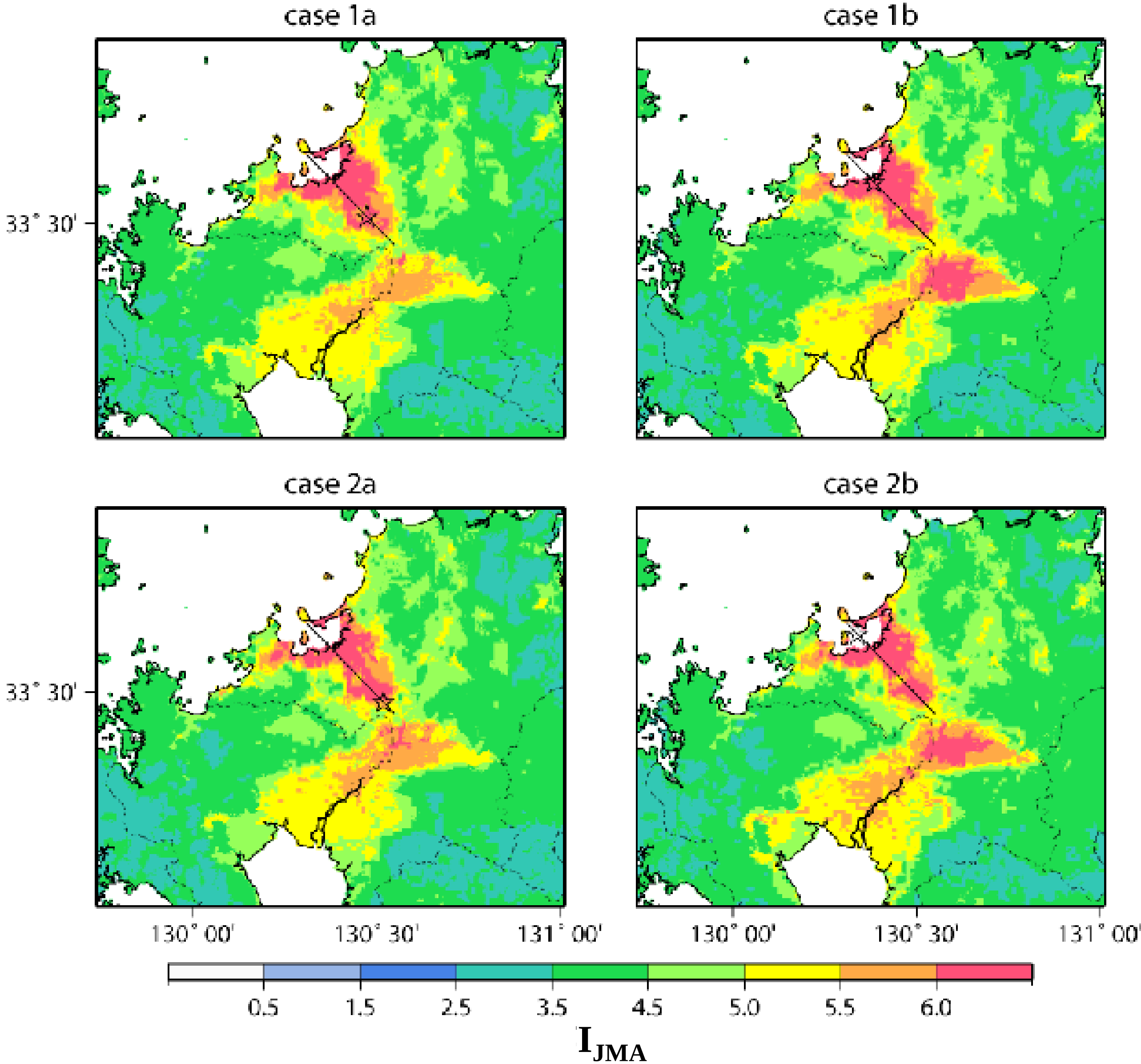
from engineering bedrock (Vs=0.6km/s)
to the ground surface



I_{JMA} on the ground surface can be obtained by adding the value to the I_{JMA} on the engineering bedrock calculated from simulated waveforms

Results-6

JMA seismic intensity distribution on the ground surface



- Large amplification in basins causes very large JMA seismic intensity on the ground surface for all cases.

- Difference between basin and mountain regions is more remarkable compared with peak velocity on the engineering bedrock.

Conclusions

Scenario Earthquake Shaking Maps can understand strong ground motion distribution if the target earthquake occurs. The maps have an advantage that the influences of the rupture processes of the source fault and detail underground structure, especially the deep sedimentary layers structure, are expressed.

Problems remain:

･It is not enough to consider uncertainties because only one or few cases have been carried out for each fault.

･The underground structure models should be improved much more.

･SESMs for huge subduction-zone earthquakes are also required.

･Forward directivity effect may be overestimated because simple rupture propagation (circular rupture propagation with a constant rupture velocity) is assumed in the simulation.

Thank you for your attention !