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# Parallel 3D Simulation of Seismic Wave Wave Propagation: Observations and Simulations

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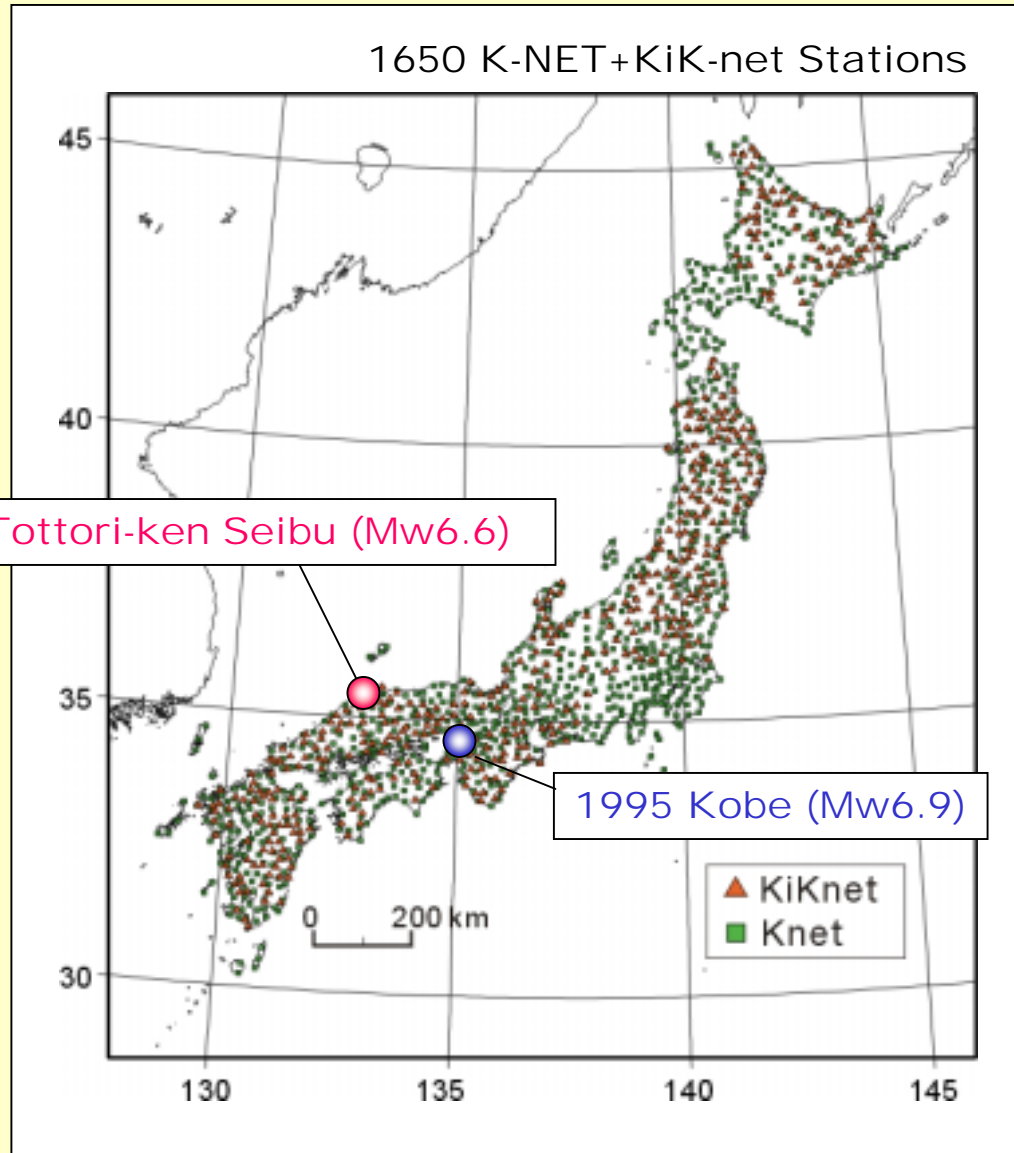


## Outline

**I. Strong Ground Motions from the 2000 Tottori-ken  
Seibu (Mw6.6) Earthquake: *Obs. and Simu.***

**II. Strong Motion Simulation  
for the Nankai Subduction Earthquakes**

# Strong Motion Network, NIED, Japan (1995- )



- 3-Comp. Acc.
- 100/200Hz, 24bit
- 20km Interval

K-NET (1100 stations)



KiK-net (550 stations)



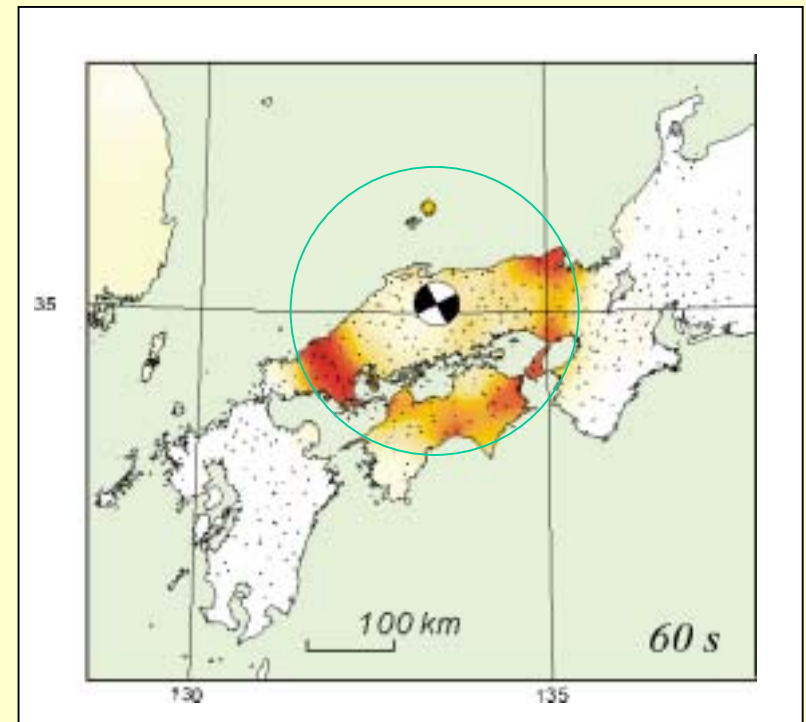
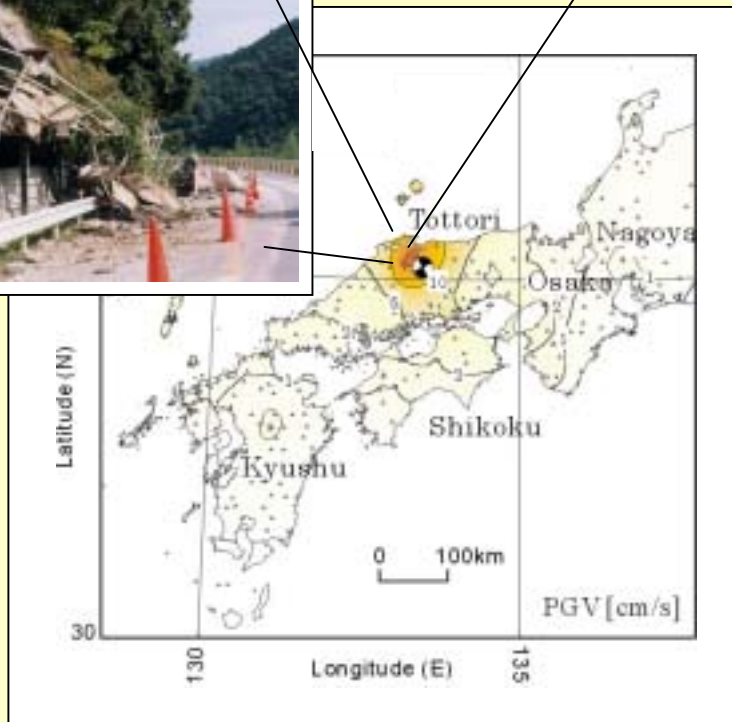
# Strong Ground Motions from the 2000 Tottori-ken Seibu Earthquake (Mw6.6)

Photos: Shimane Univ

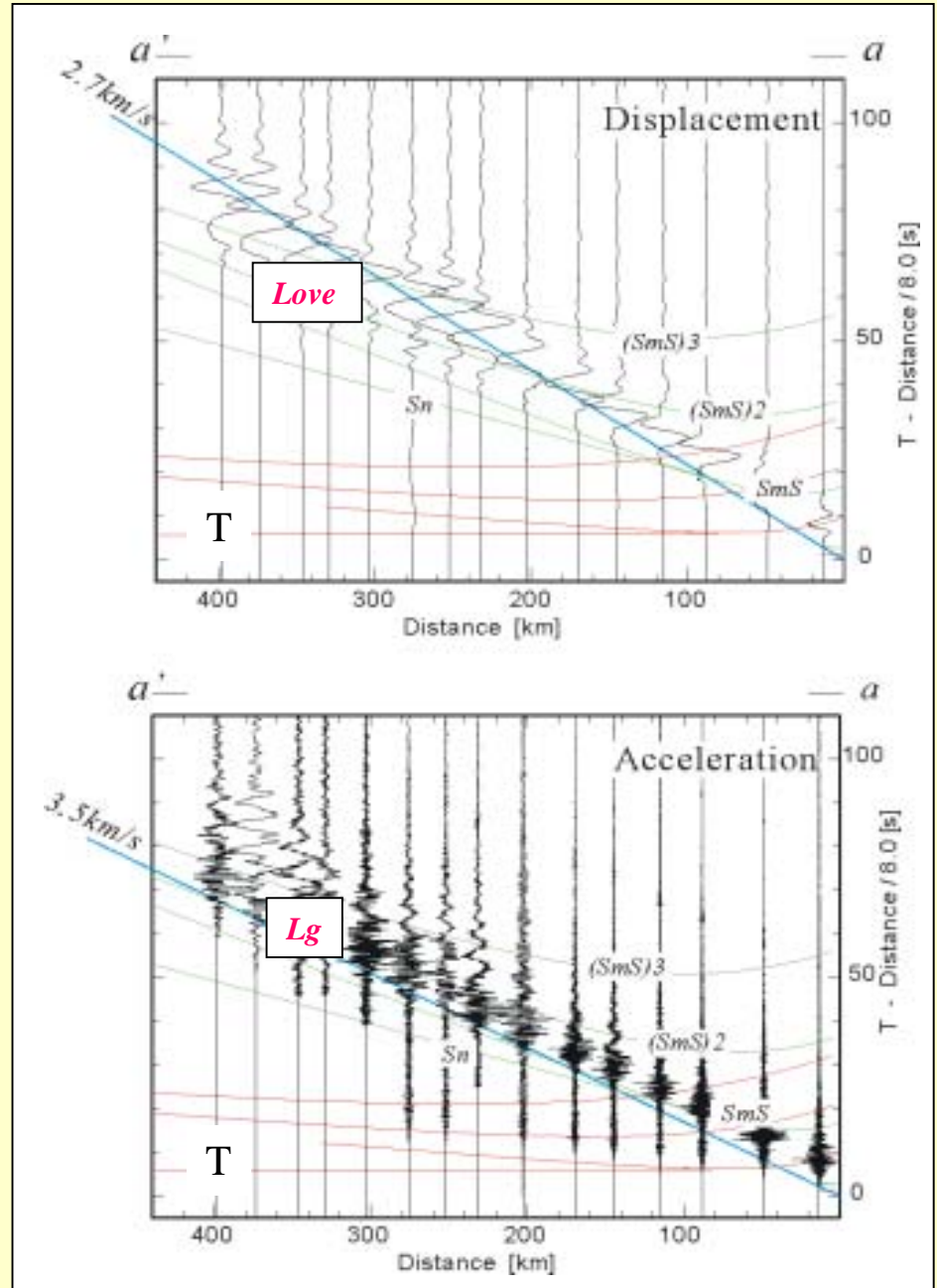
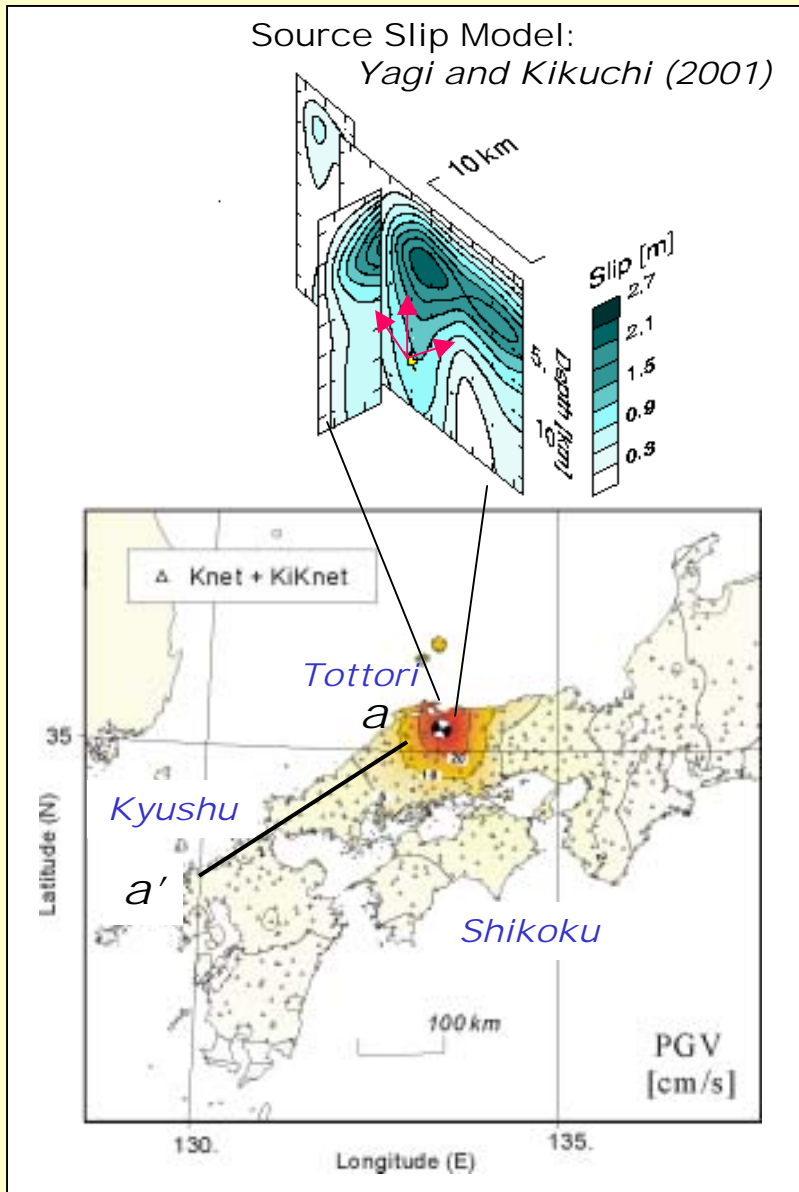


Ground Velocity Motion ( $f < 0.25\text{Hz}$ )

2.7 km/s

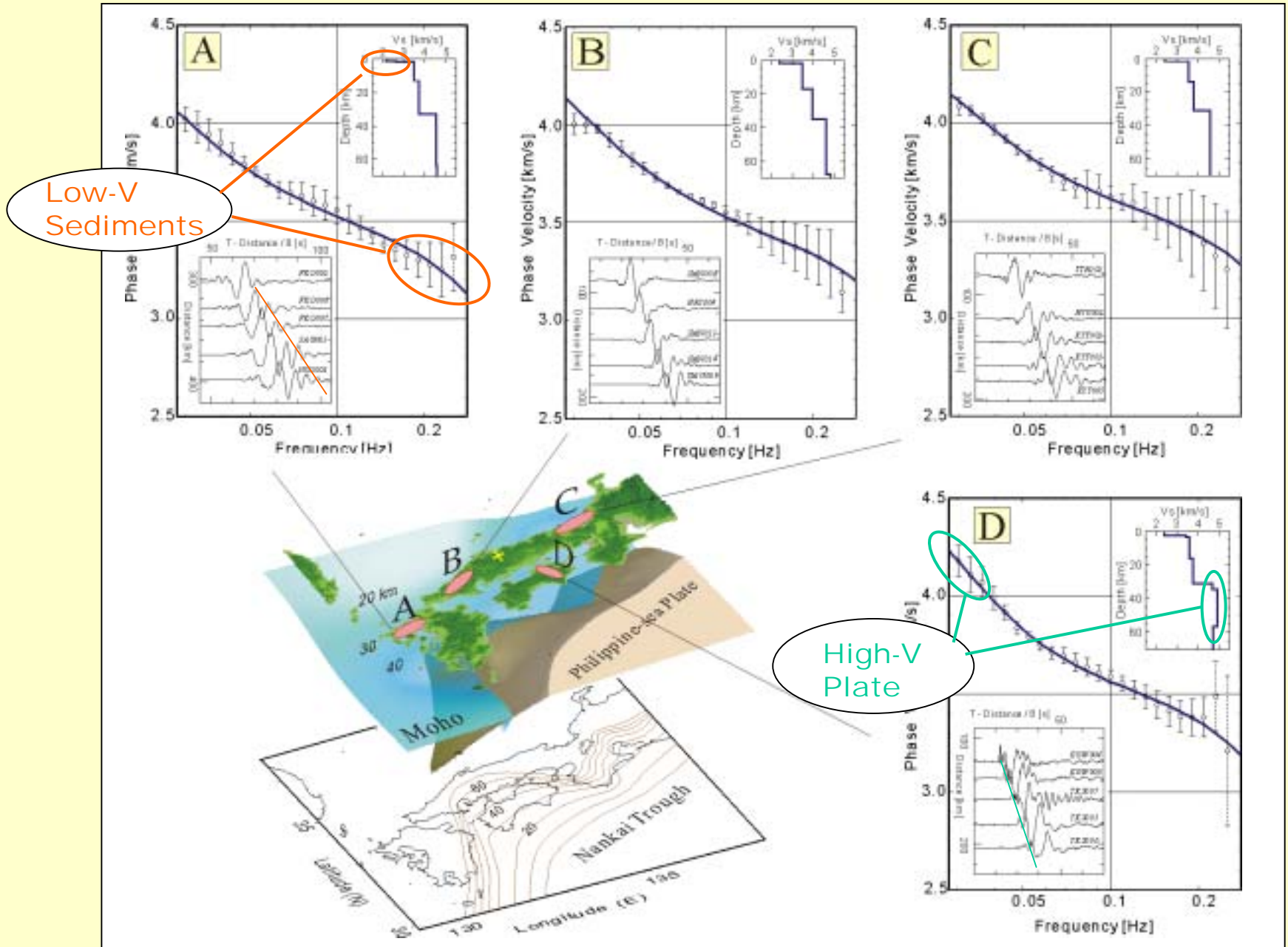


# Observed Waveforms



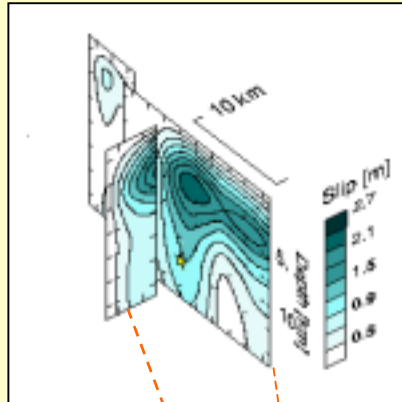


# 3D Vs Structure: Phase Velocities of the Love Waves



# 3D Simulation of the 2000 Tottori-ken Seibu Earthquake

Source Slip model



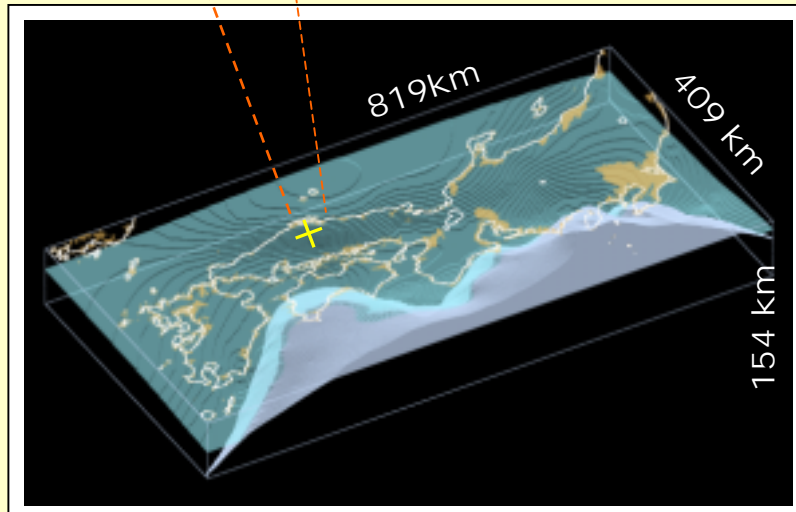
Yagi and Kikuchi  
(2001)

Hybrid PSM/FDM Code

Furumura et al. (2000,2002)

Horizontal (x,y):	PSM (Fourier)
Vertical (z):	4 <sup>th</sup> -order FDM

3D Structural Model ( $V_p$ ,  $V_s$ ,  $R_o$ ,  $Q$ )



Model Specifications

Grid Points:	33 million
Grid Size:	0.8-1.6 / 0.4-0.8 km
Resolution:	$f < 0.5 \text{ Hz}^*$

\* $V_s < 1.6 \text{ km/s}$

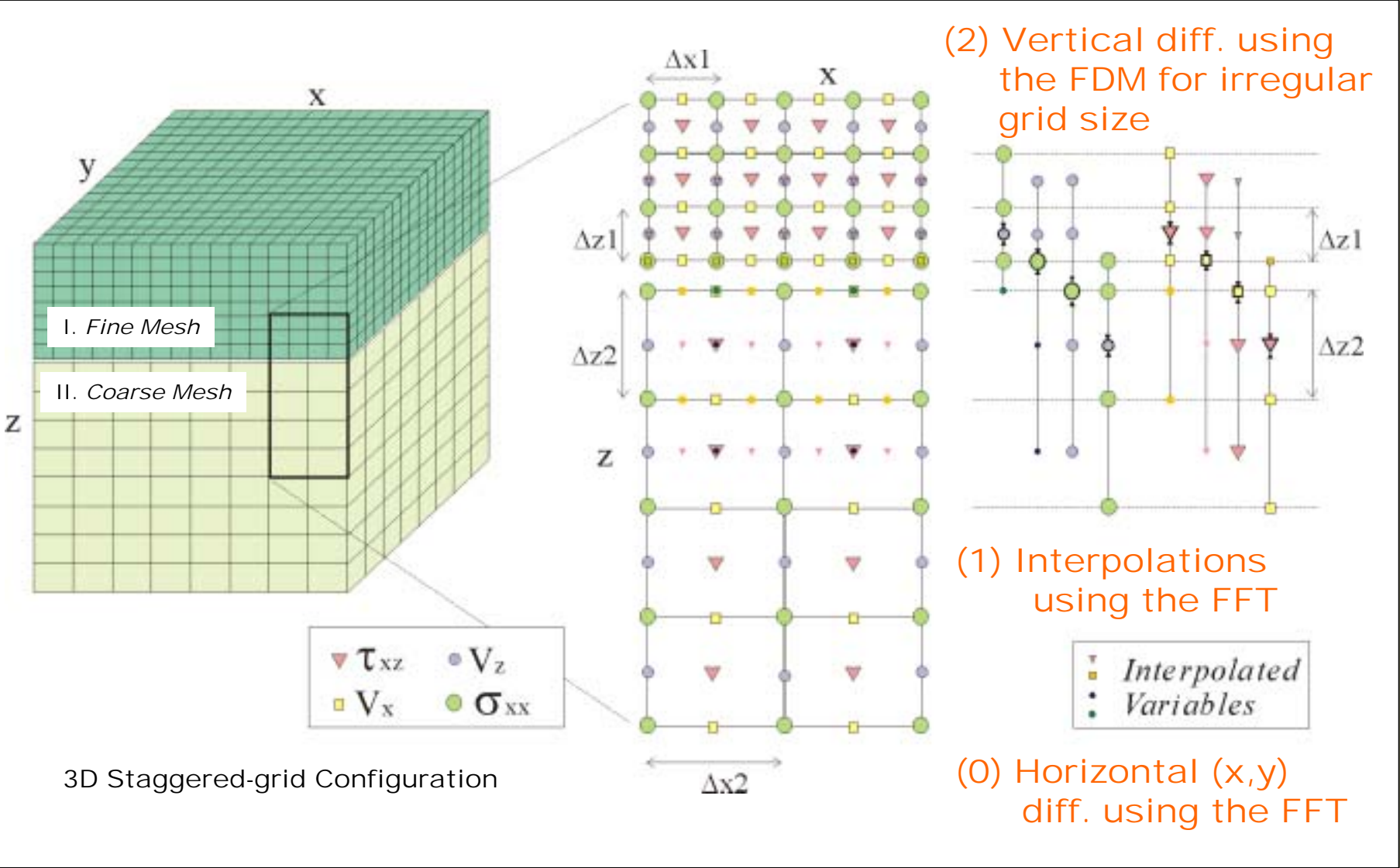
Moho: Ryoki (1999)

PHP: Ishida (1982)

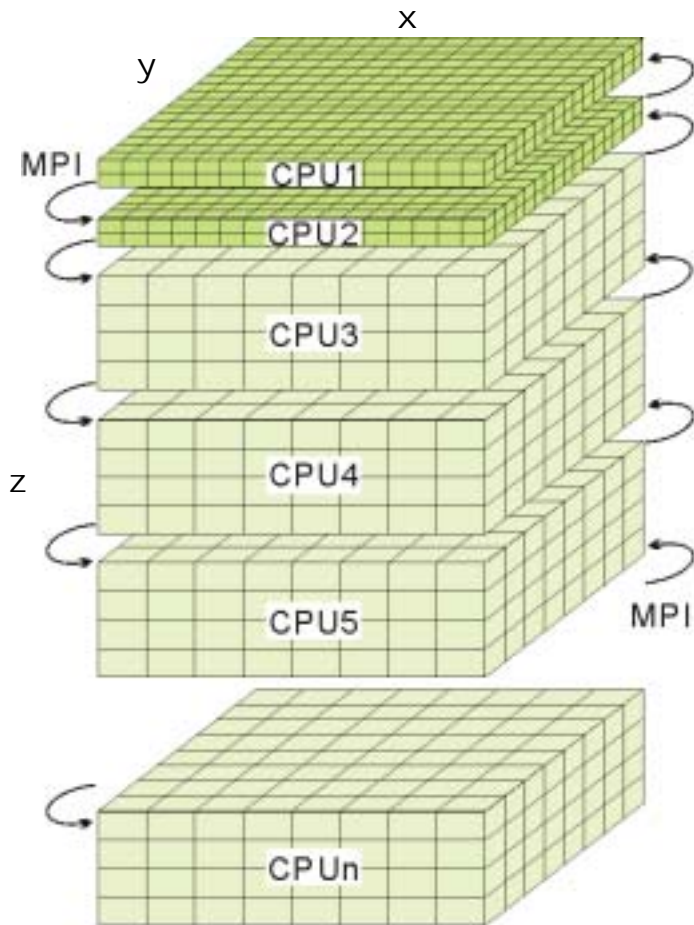
$V_p$ : Zhao et al. (1992)

$V_s$ : *this study*

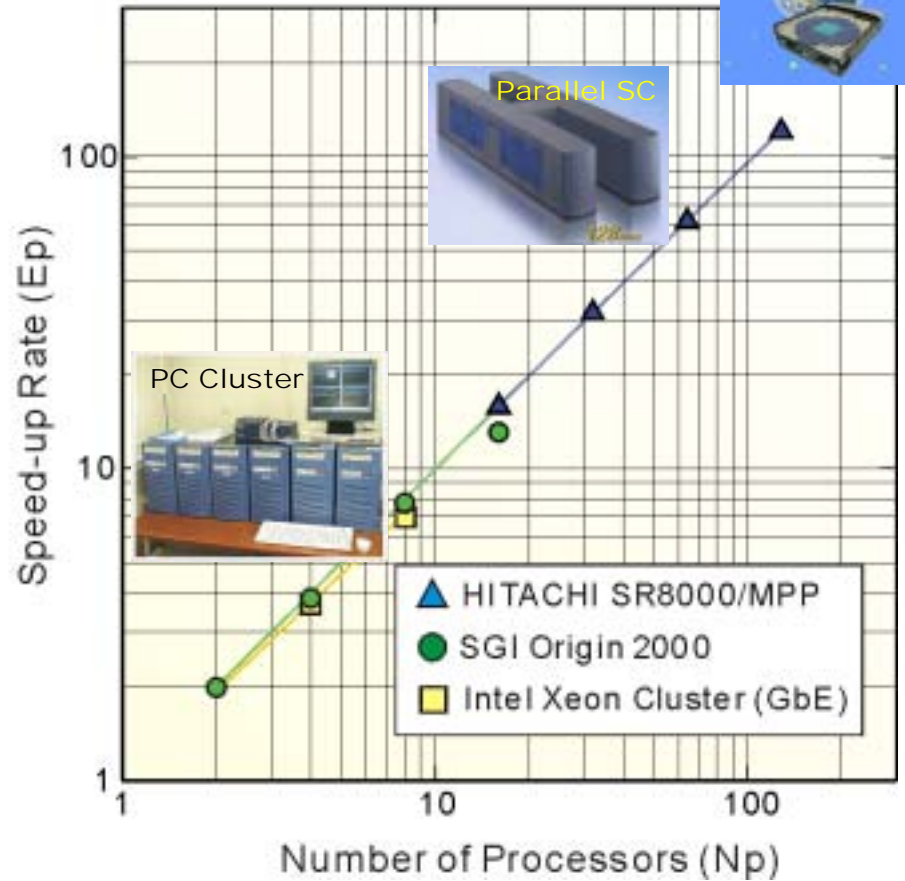
# Hybrid PSM/FDM, Multi-grid Model



# Multi-grid Parallel PSM/FDM: Efficiency and Scalability



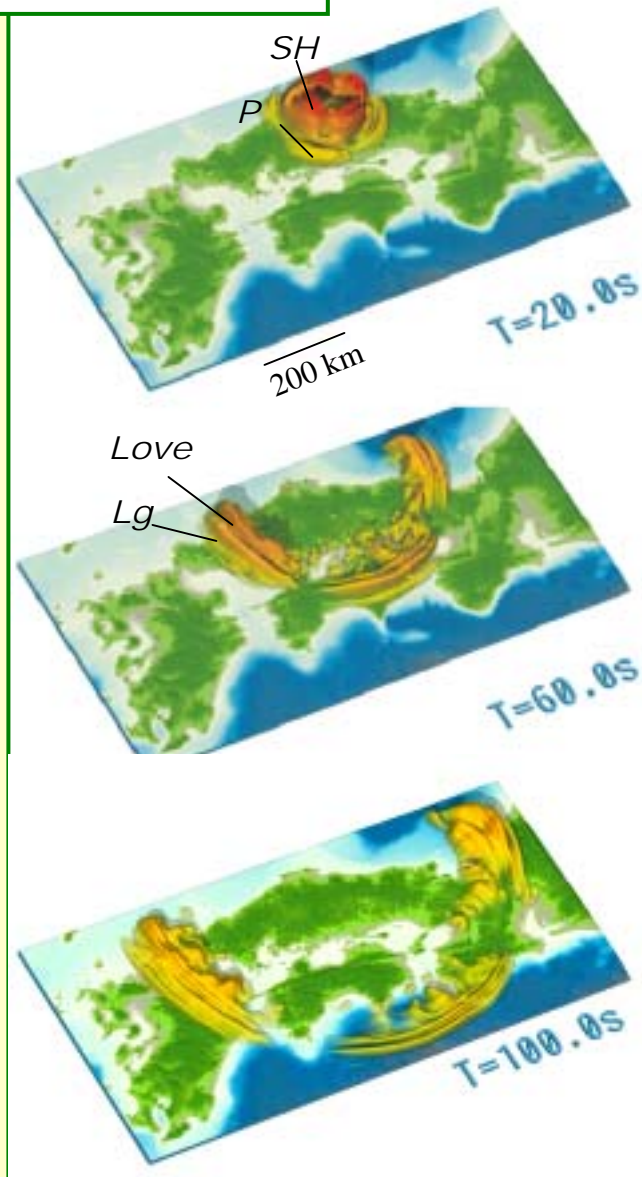
## Speed-up by Parallel Computing



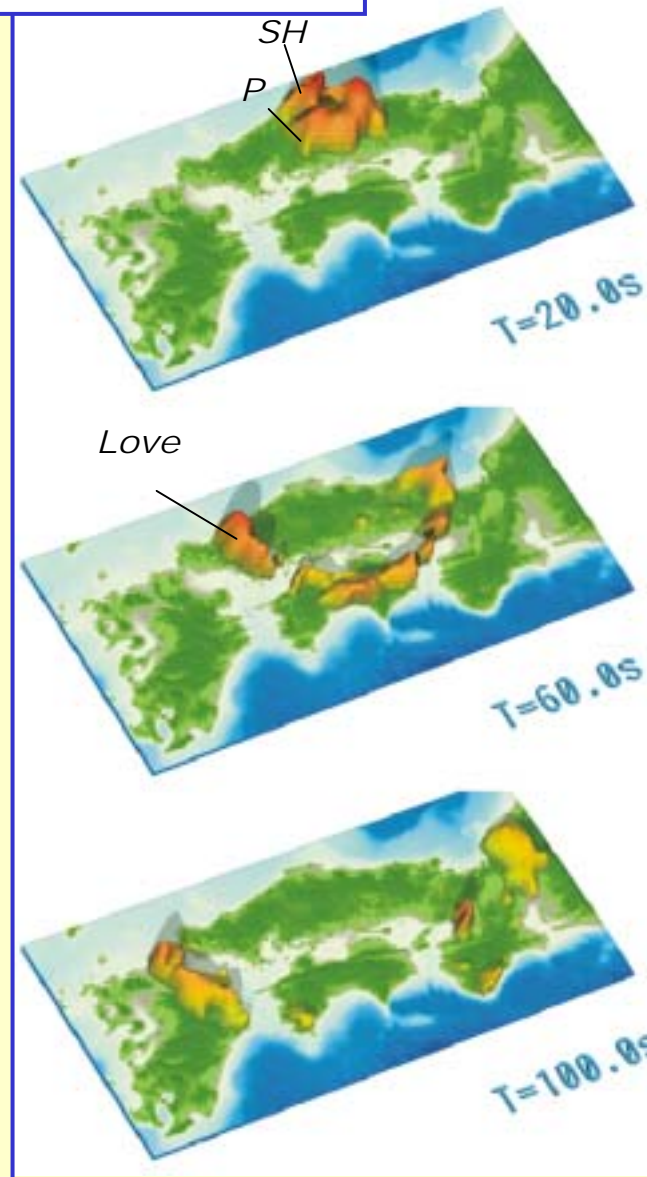


# Simulation Results (1) : Snapshots of Seismic Waves

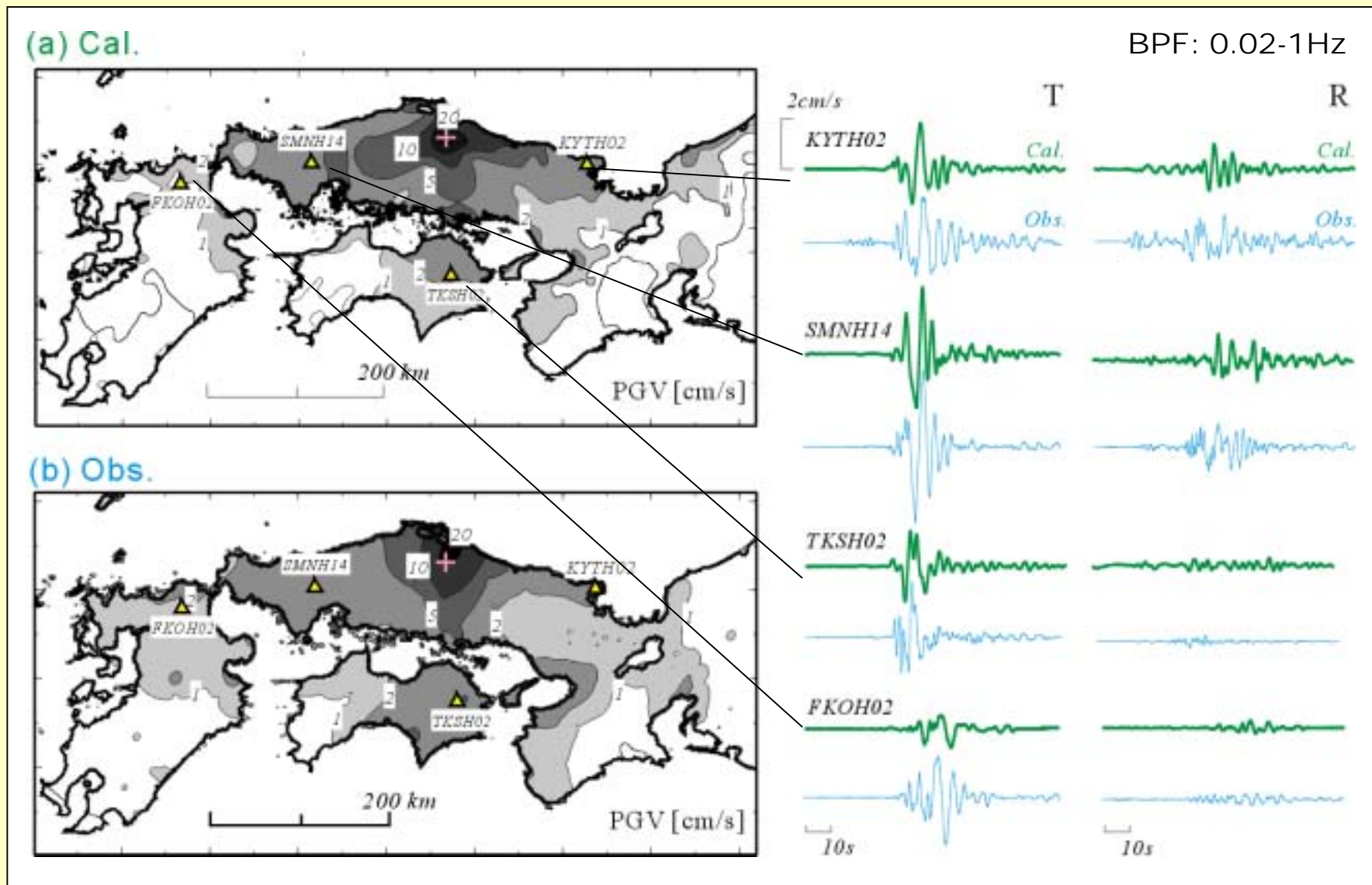
(a) Simulation



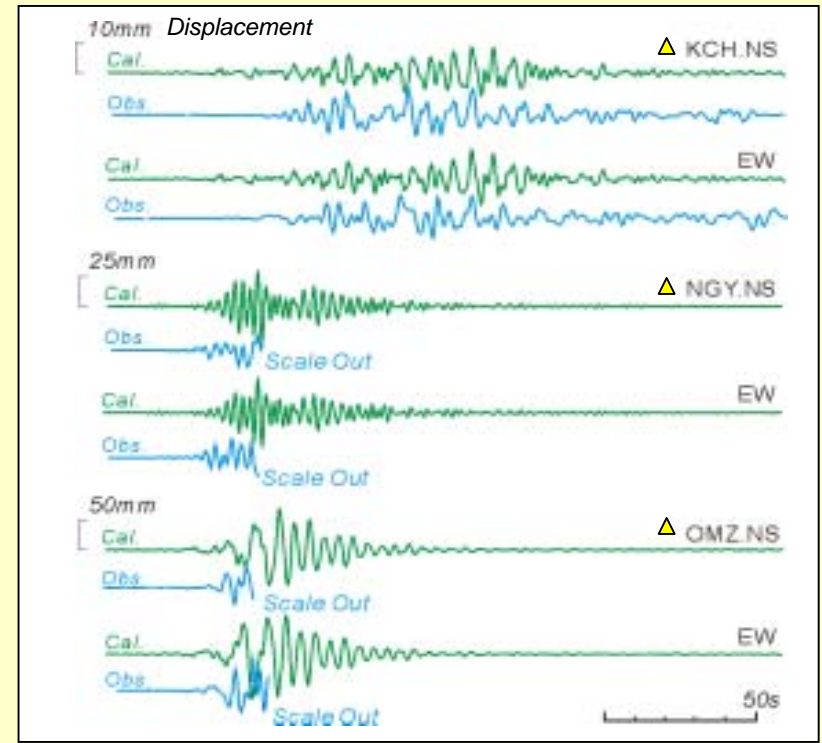
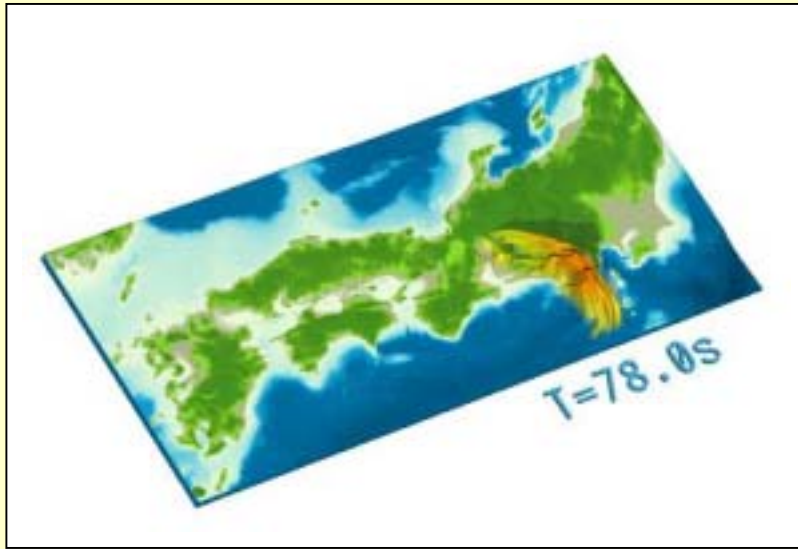
(b) Observation



# Simulation Results (2): PGV and Waveform

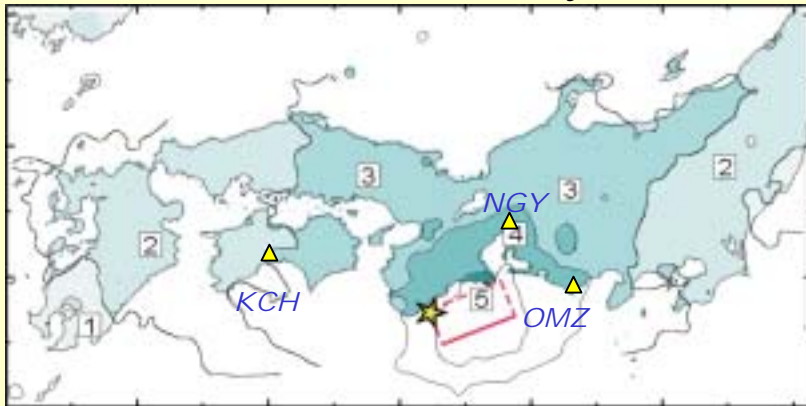


# 3D Simulation for the 1944 Nankai earthquake (Mw7.9)

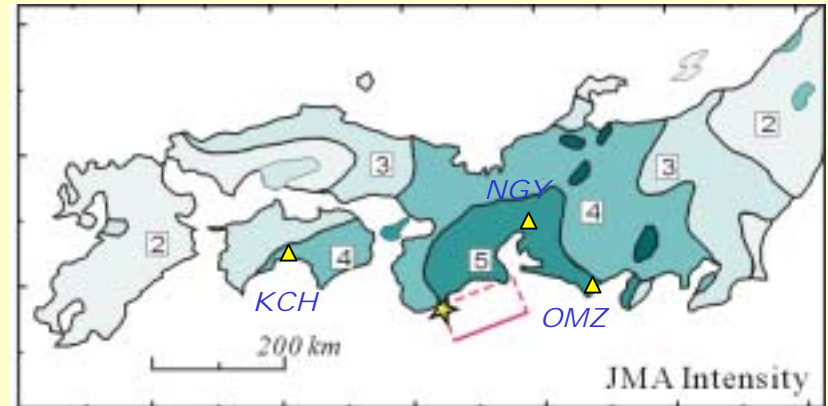


## Calculation

JMA Intensity Scale (max. 7)



## Observation

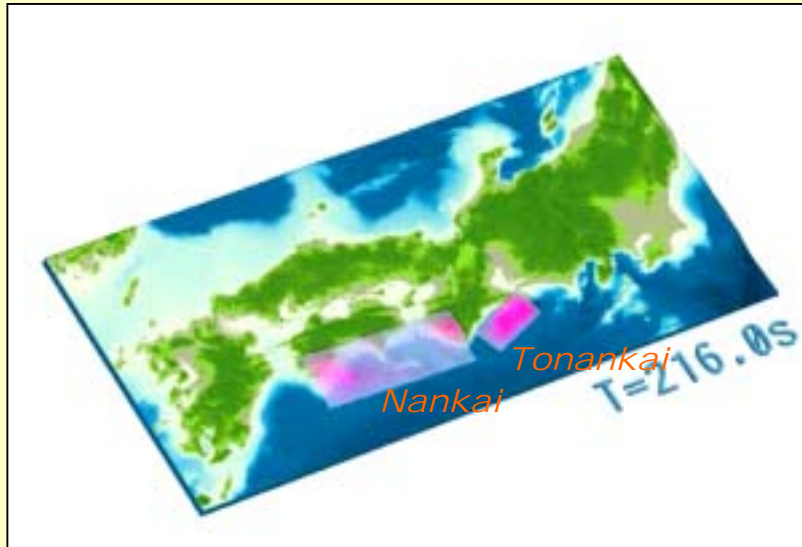


after Usami (1998)



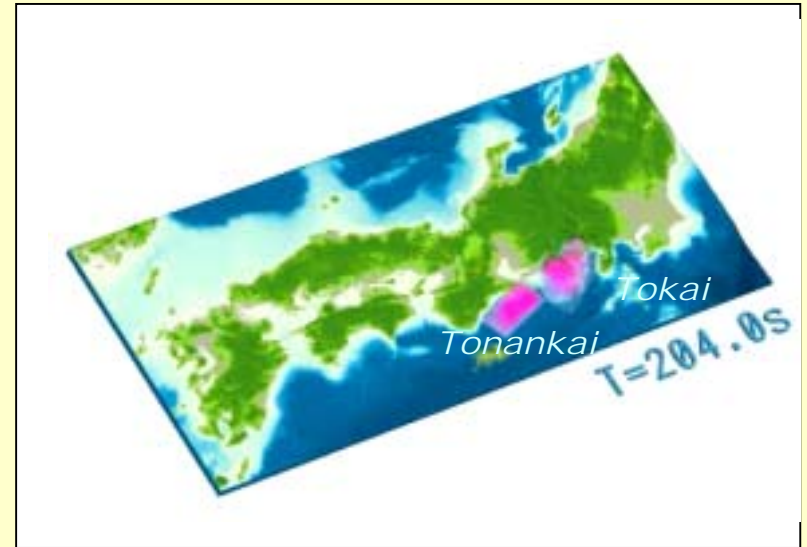
(b) Tonankai (Mw7.9)  
+ Nankai (Mw8.1)

Source model, 1946 Nankai Event  
*Yamanaka and Kikuchi (2001)*

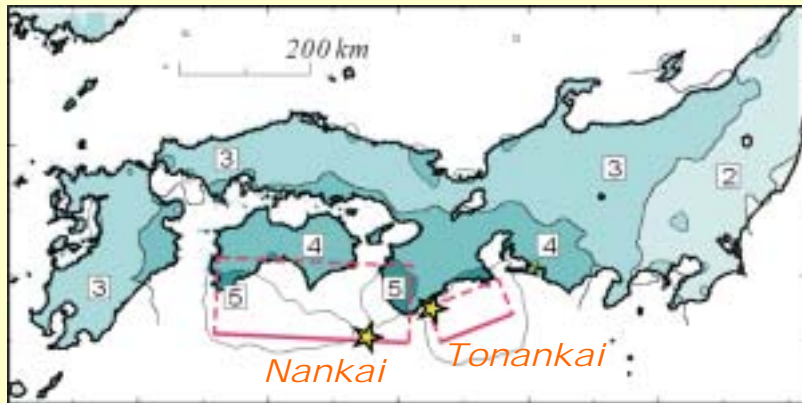


(c) Tonankai (Mw7.9)  
+ Tokai (Mw8.0)

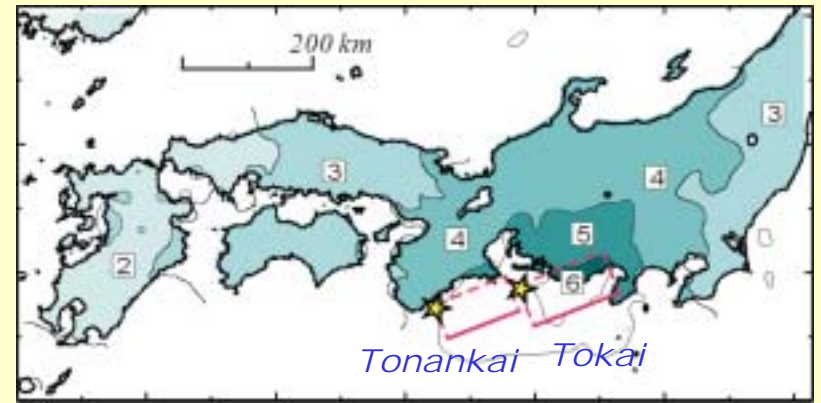
Source model, Tokai Event  
*Cabinet Office, Japan (2001)*



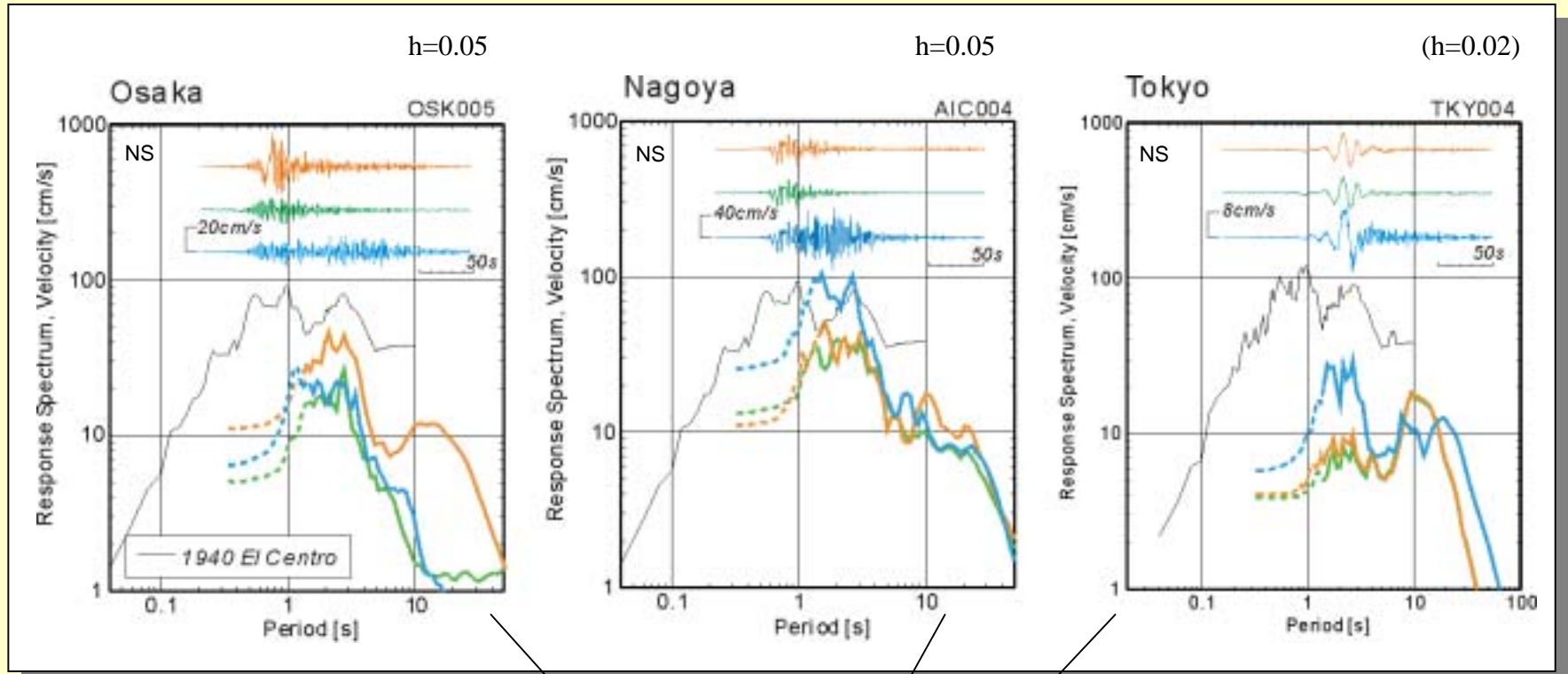
*JMA Intensity Scale*



*JMA Intensity Scale*



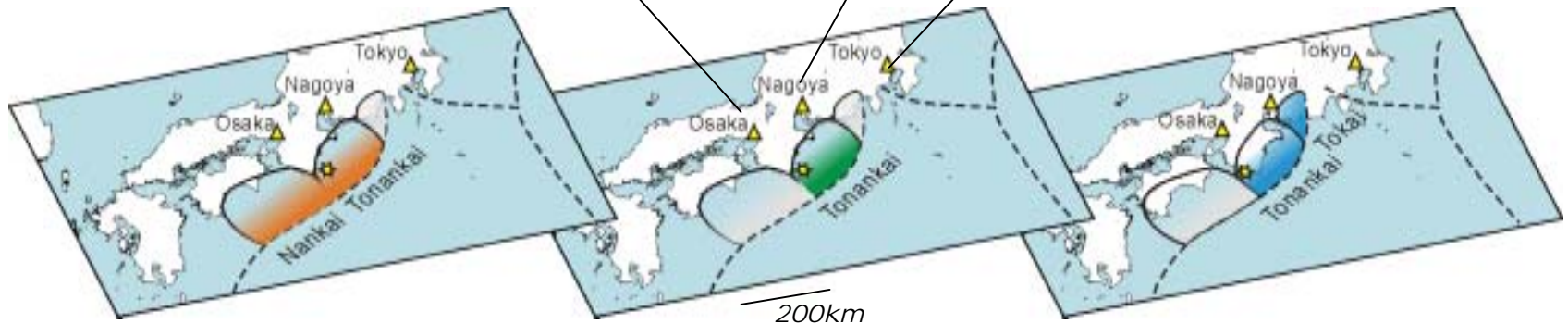
# Response Spectrum at Cities during the Nankai Earthquakes



(a) Nankai + Tonankai  
M8.1      M7.9

(b) Tonankai  
M7.9

(c) Tonankai + Tokai  
M7.9      M8.0

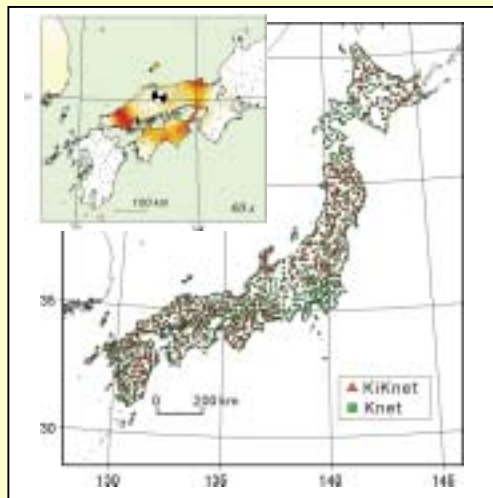




# Conclusions

1. *Observations:* Recent Developments of High-Resolution Seismic Networks Realize Direct Visualization of Wave Propagation During Large Earthquakes.
2. *Computer Simulations:* Steady Improving Computer Power and Parallel Computing Algorithms Enables Large Scale 3D Simulation of Seismic Waves.
3. *Link:* Close Link Between the Observation and the Computer Simulation Studies Promises the Evaluation of Strong Ground Motions for Future Scenario Earthquakes.

Observations



Computer Simulation



3D Structure, Source Models

