京都大学　山田真澄

Earthquake Early Warning and Its Practical Applications

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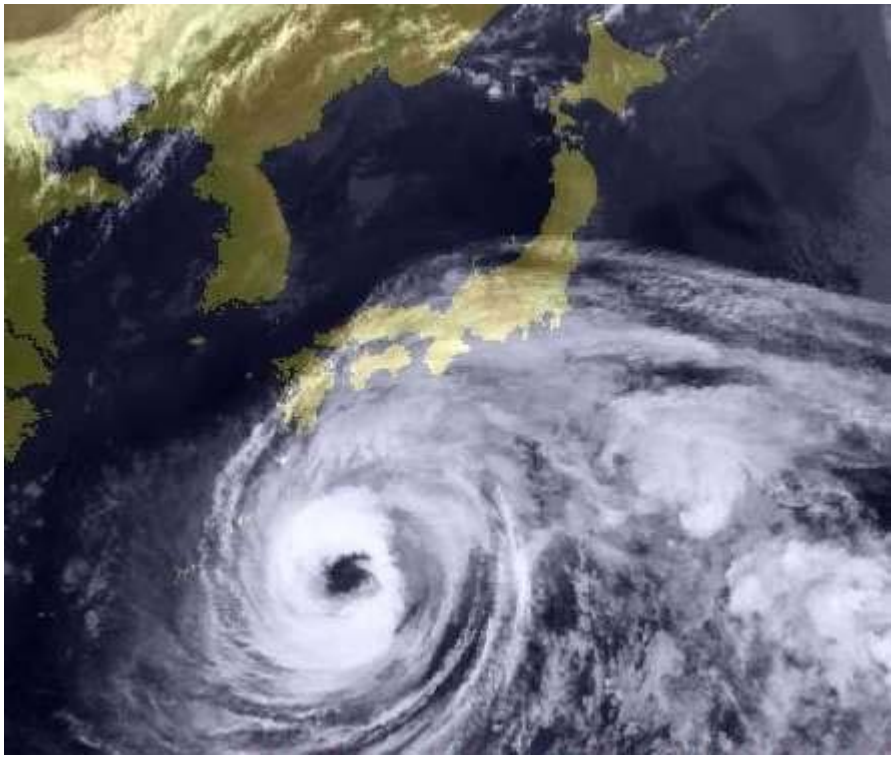
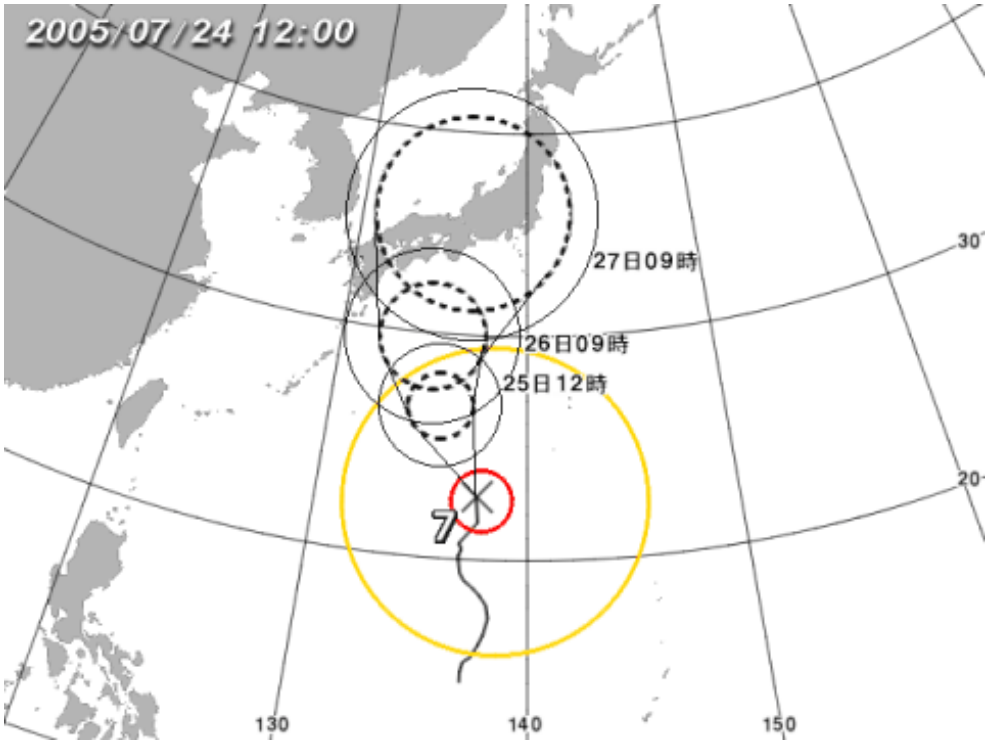
What if EQ travels as slow as typhoon,…





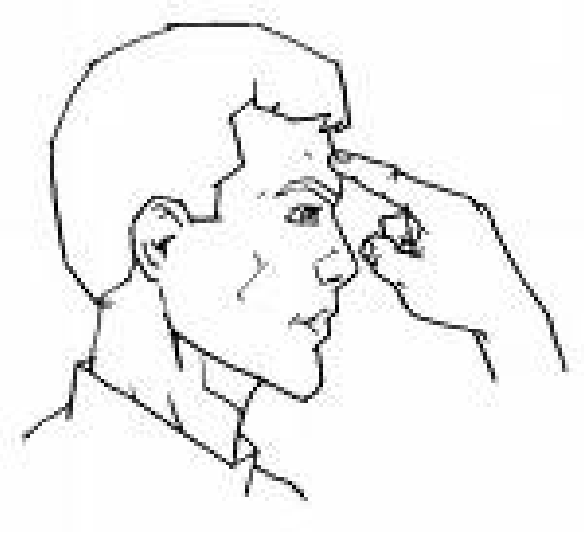
“an earthquake on the Nankai trough started yesterday. Seismologists warn that it may continue to strengthen into a great earthquake and they predict that severe shaking will hit later today.”

Heaton (2005)

Can we be faster than earthquake?

- Typhoon — 20km/h = 6m/s
- EQ P-wave — 7km/s
- EQ S-wave — 4km/s

How can we be faster than earthquake?



- Everything must be automated
  - Data analysis
  - Communication
  - Damage-mitigating Action
- Emulate human capabilities of decision making and judgment

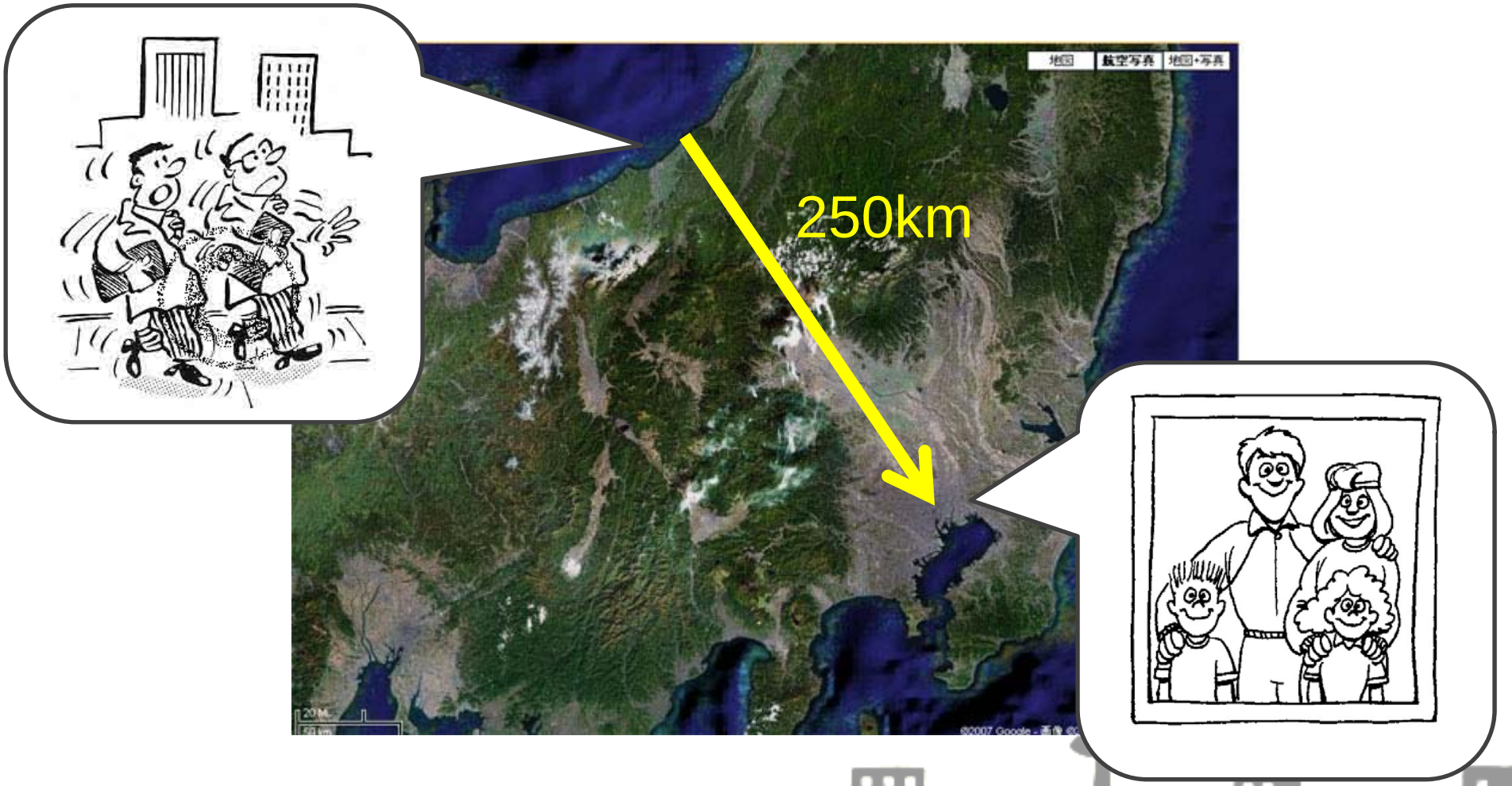
Heaton (2005)

Goal in Earthquake Early Warning (EEW)

- To provide timely information on an earthquake before the large ground motion arrival at a given site.

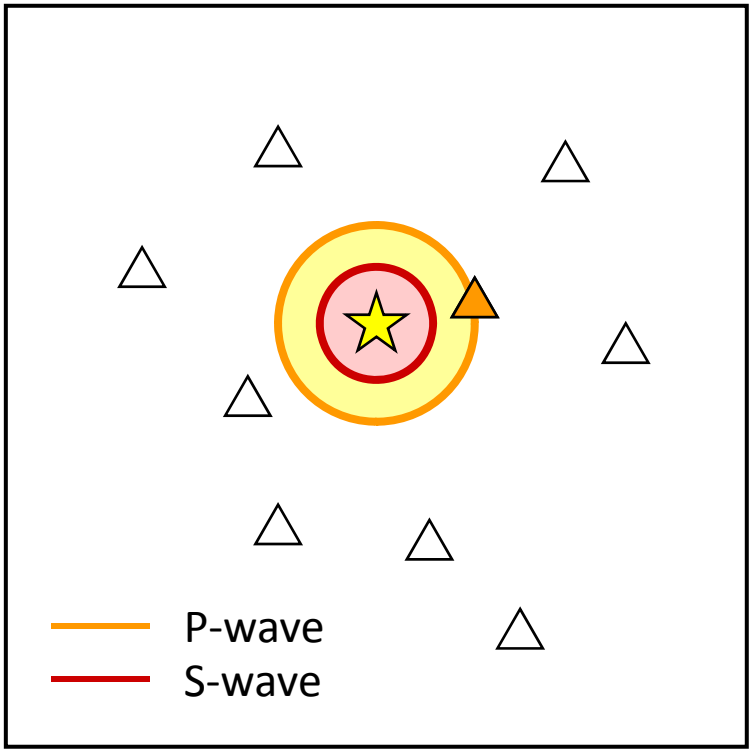
- Guide damage-mitigating actions that can be taken in the few seconds before the strong shaking.

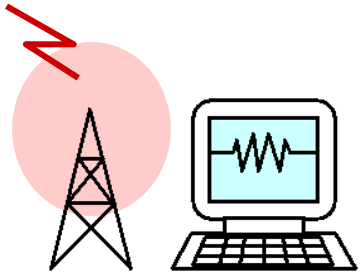
An Example of Real-time Warning

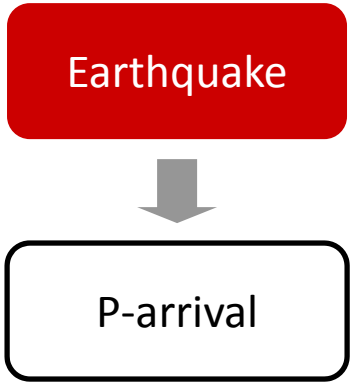


July 16, 2007, a major earthquake hit Niigata, and traveled to a family living in Tokyo

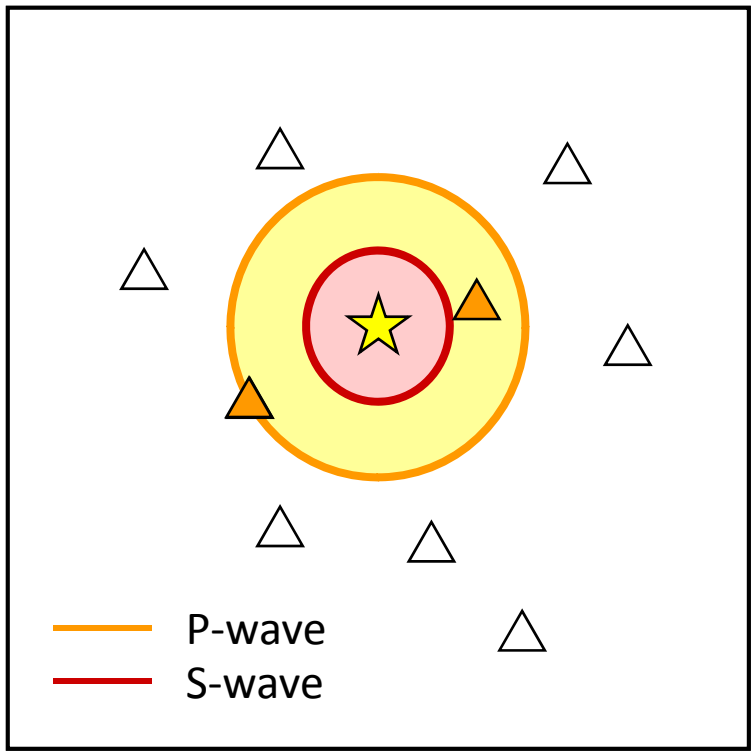
Earthquake Early Warning System

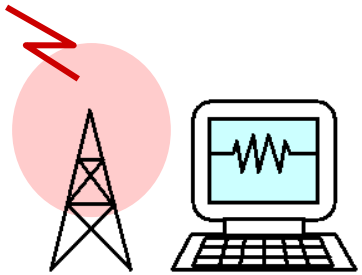


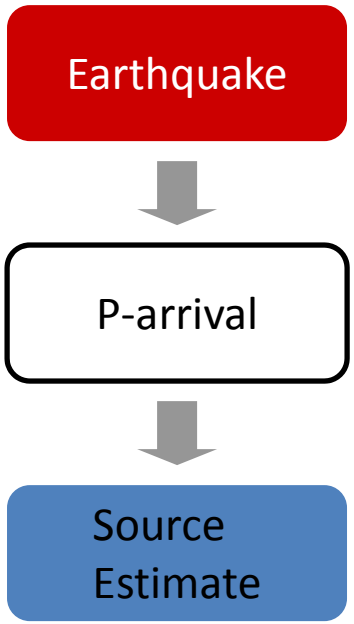




Earthquake Early Warning System







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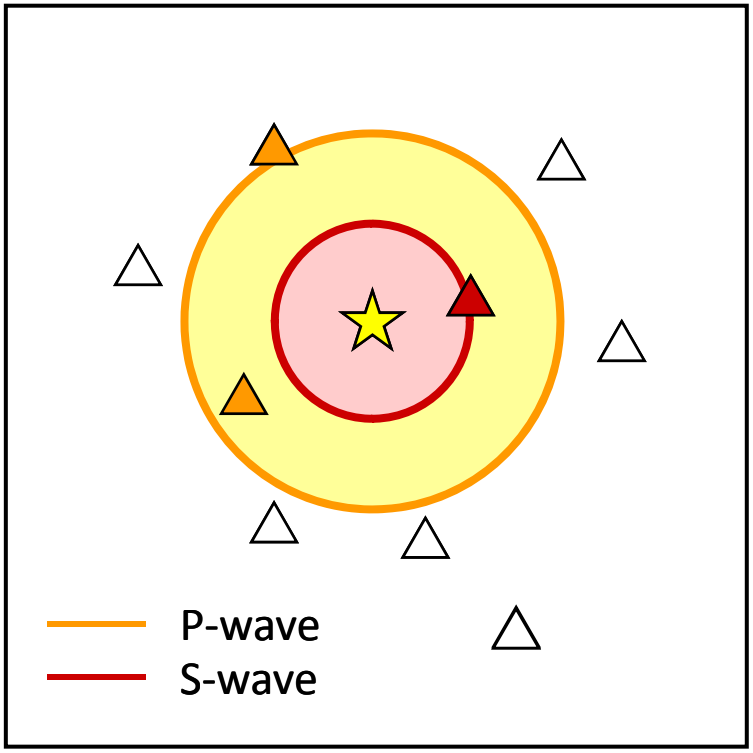
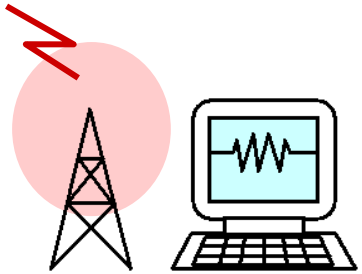
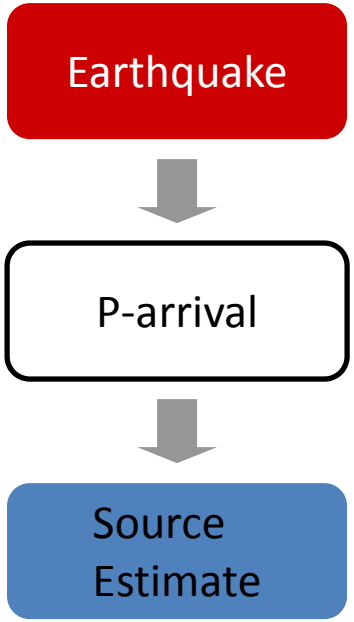
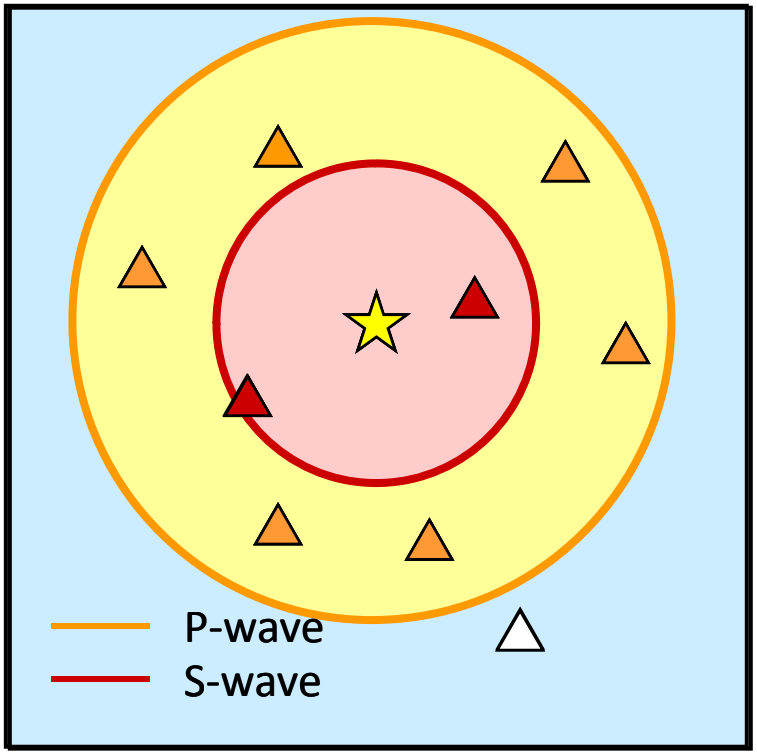
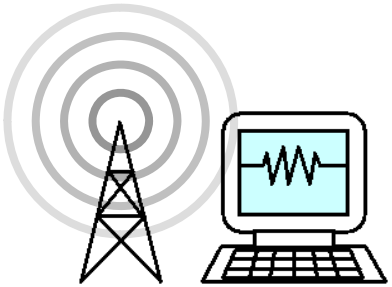






Earthquake Early Warning System





Earthquake

P-arrival

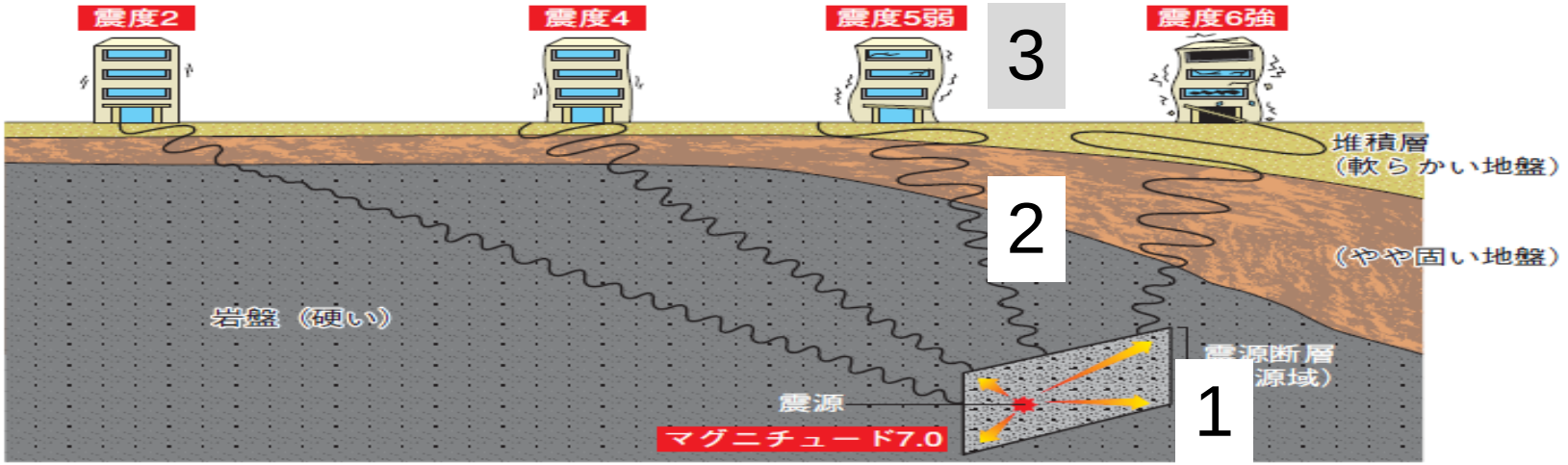
Source Estimate

Issue Warning

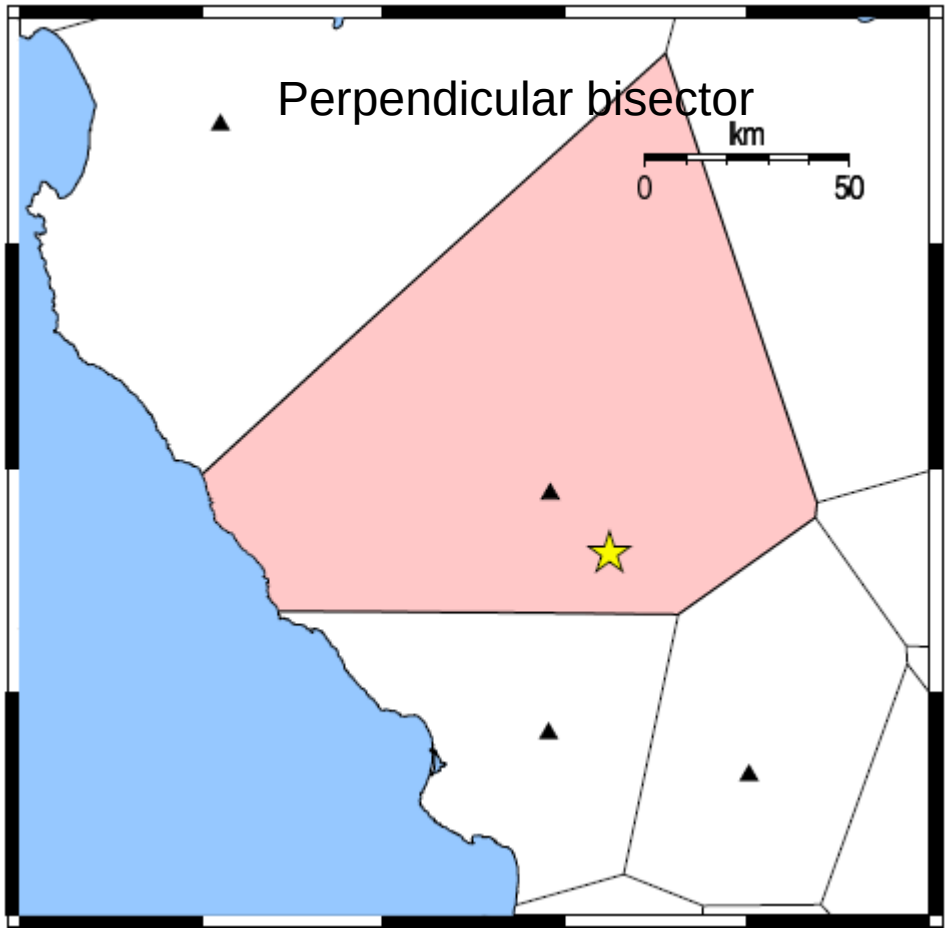
S-arrival

Predicting Ground Motion at a Site

1. Earthquake Information
    - Location
    - Magnitude
    - Fault Geometry
2. Estimate the intensity on the seismic bedrock
    - Intensity ~ fault distance
3. Estimate the intensity on the ground surface
    - soil amplification
    - PGV (peak ground velocity) or SI (seismic intensity)



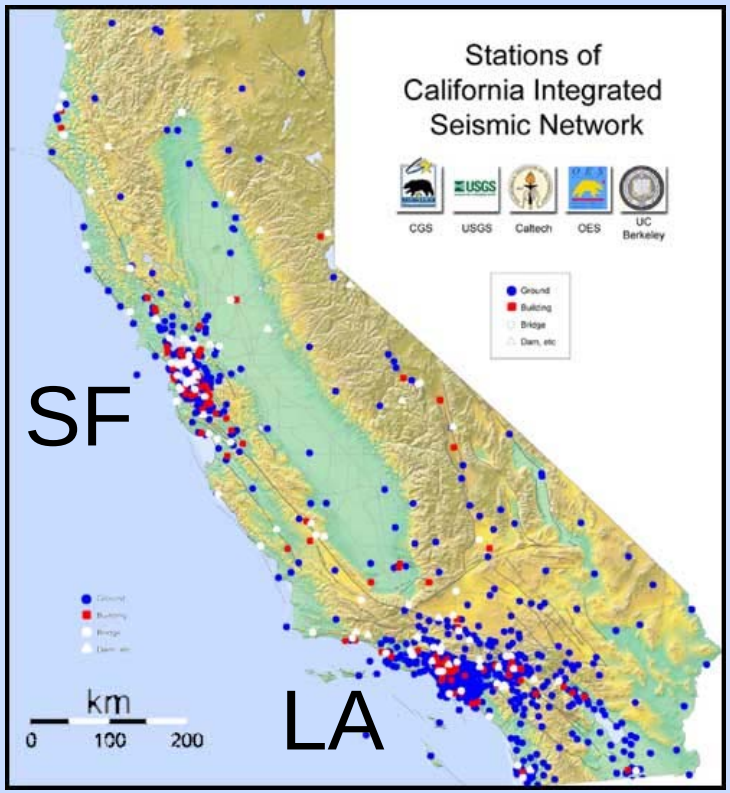
Location Estimates



Voronoi cells concept:

All points in the cell are closer to the center station than any other stations.

If one station records the ground motion first, an epicenter should be inside its polygon.



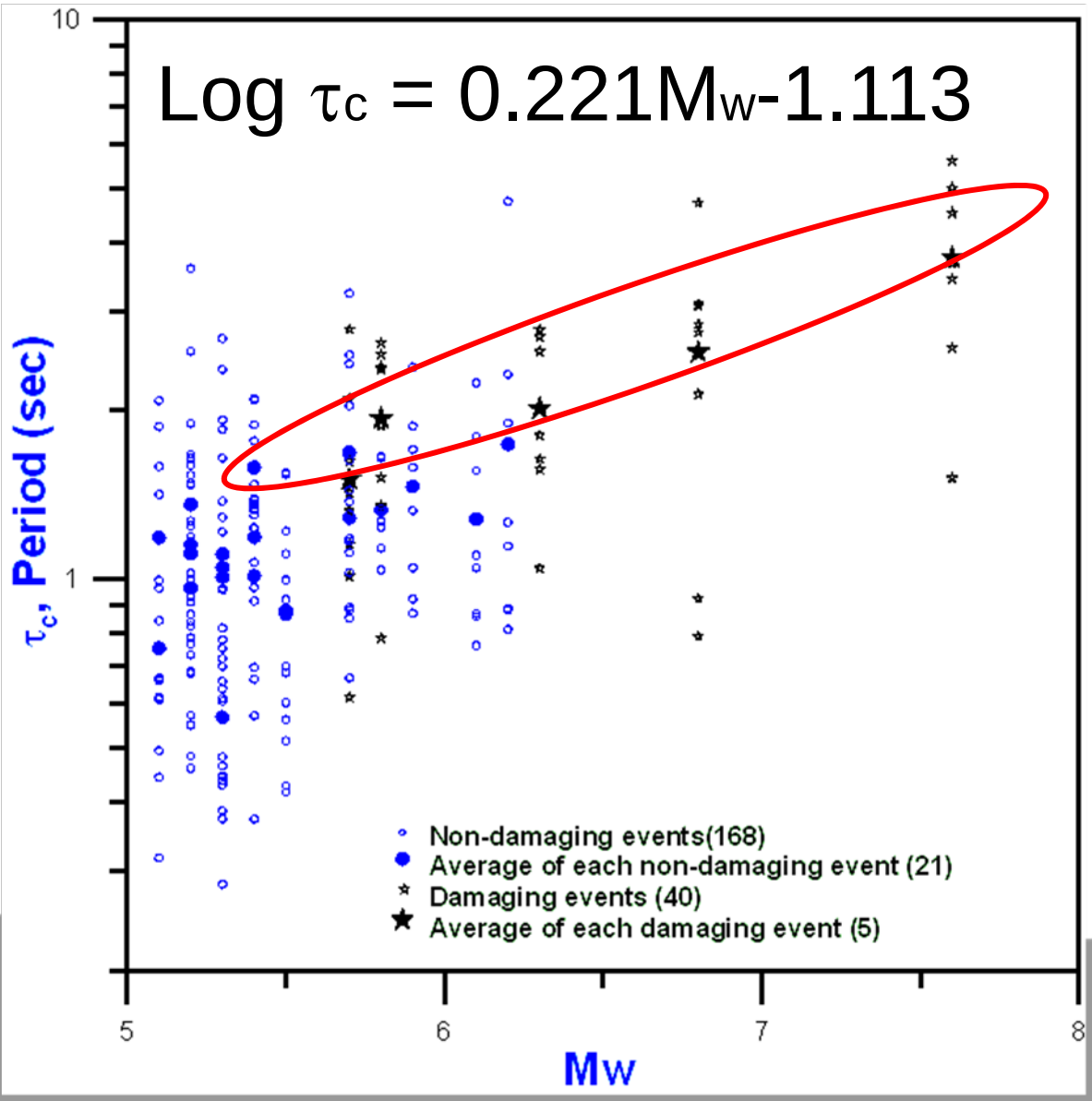
K-NET
KiK-net
Hi-net

km
0 100 200

Station distribution

Wald(2005)

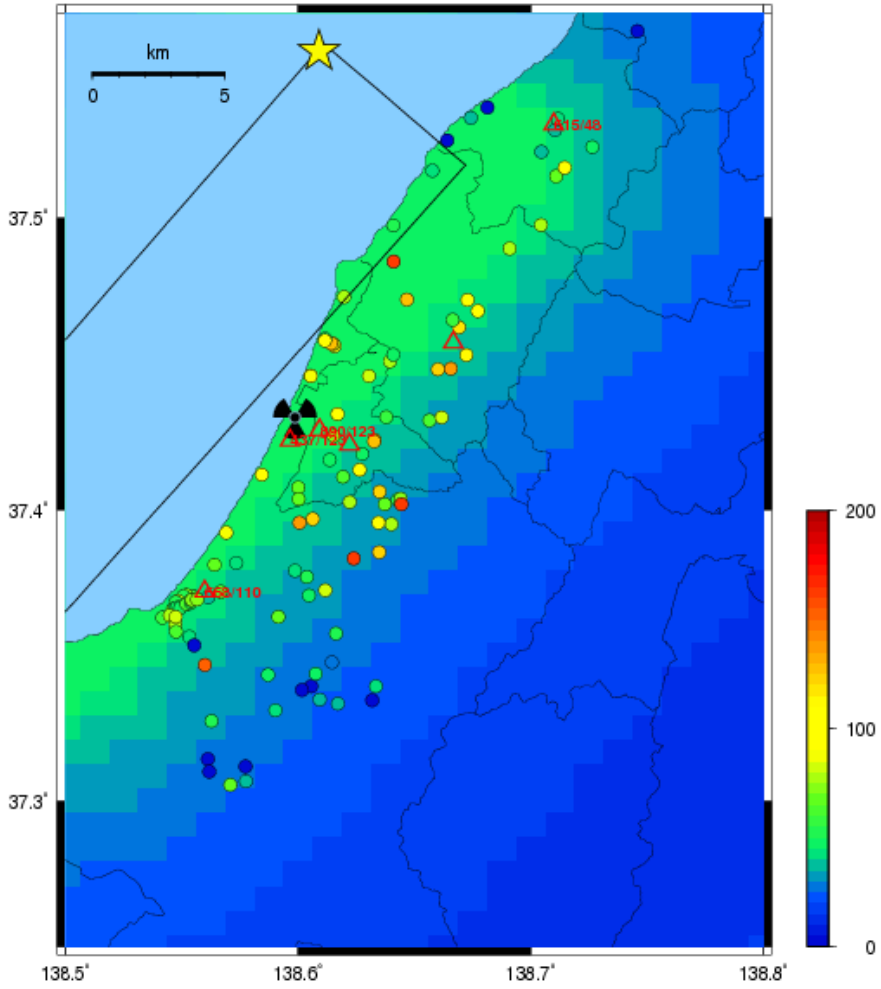
Magnitude Estimates



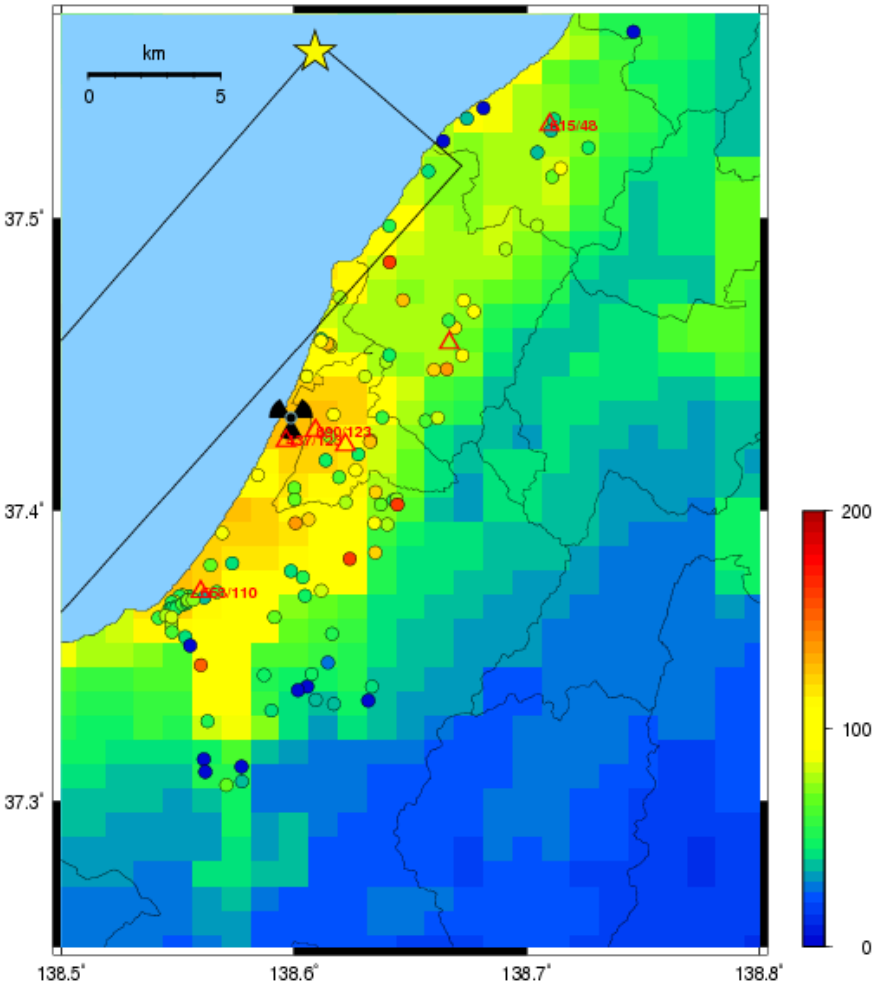
Wu and Kanamori（2005)

Ground Motion Estimates at a Site

Local site velocity ~ fault distance

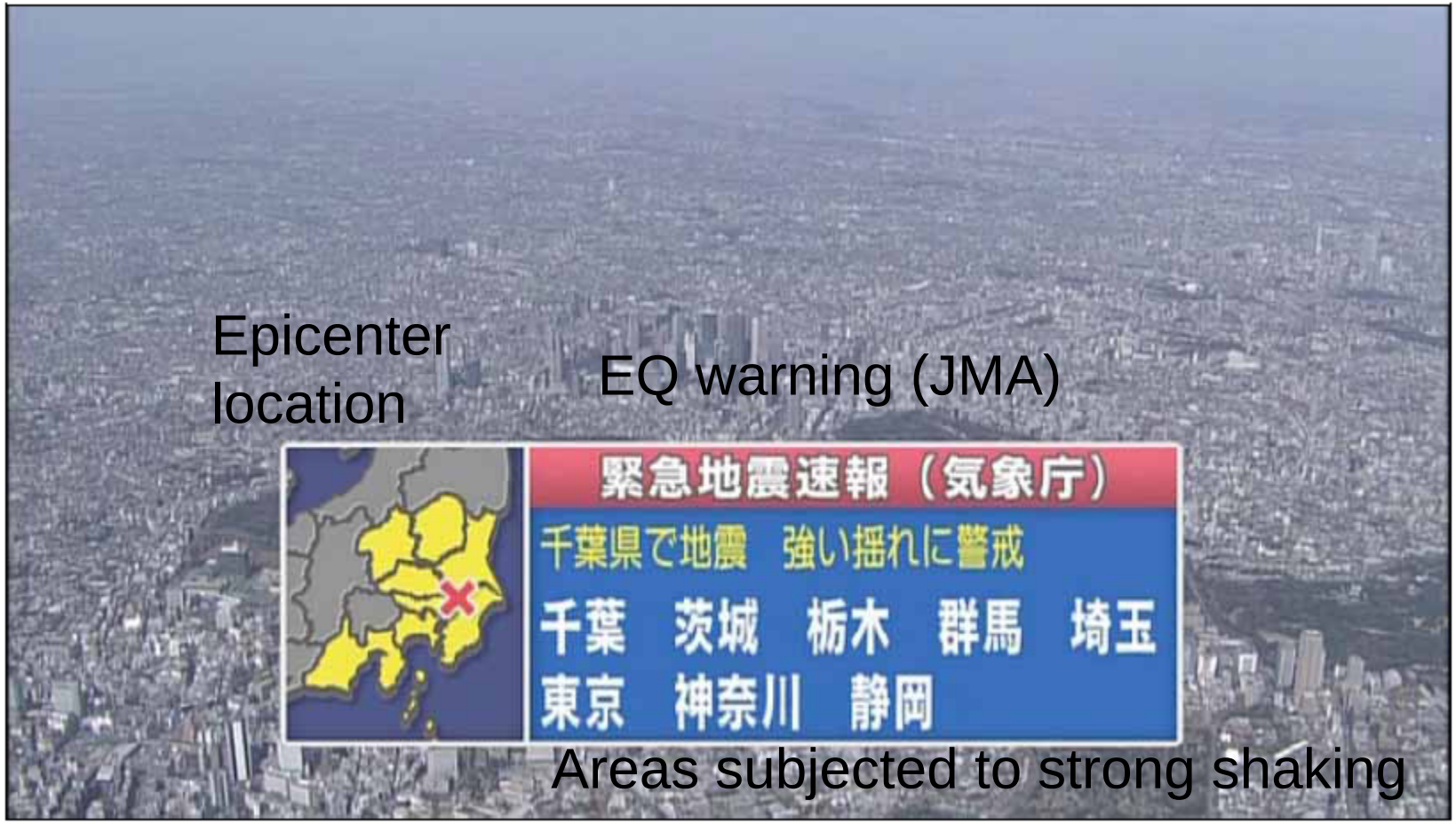


Adding soil condition



How to alert public?

NHK (national news channel) starts broadcasting EEW information this October on TV and radio.



http://www3.nhk.or.jp/pr/keiei/shiryou/soukyoku/2007/06/006.pdf

How to alert public?

JMA

Detailed Alert

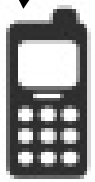
General Alert

Japan Meteorological Business Support Center

Mobile phone

Train

Provider



Community Wireless System

Media (TV and radio)

Issued after the 1st P-wave arrival
Updated every seconds as data arrives

Estimated JMA seismic intensity 5-
More than 2 stations detect P-wave

http://www.seisvol.kishou.go.jp/eq/EEW/kaisetsu/eew_receive.html

Ex1: Control Railway

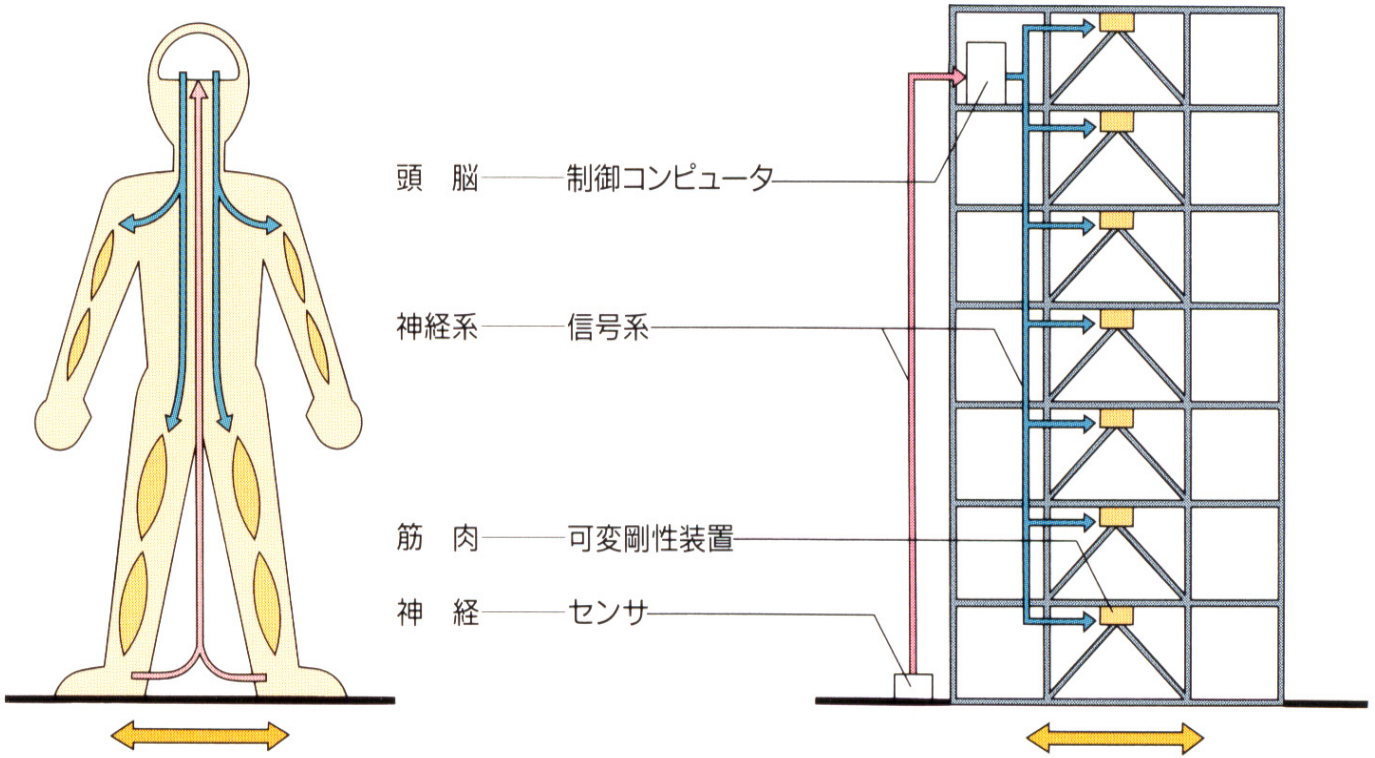
Odakyu Electric Railway

http://www.odakyu.jp/company/business/railways/safety.html

Ex2: Control Buildings

Nasu (2005)

Control Elevators
Active control system



Ex3: Stop chemical supply

Oki Electric Industry Co.

2003 S.Sanriku EQ
US$ 3 billion loss

After system installed

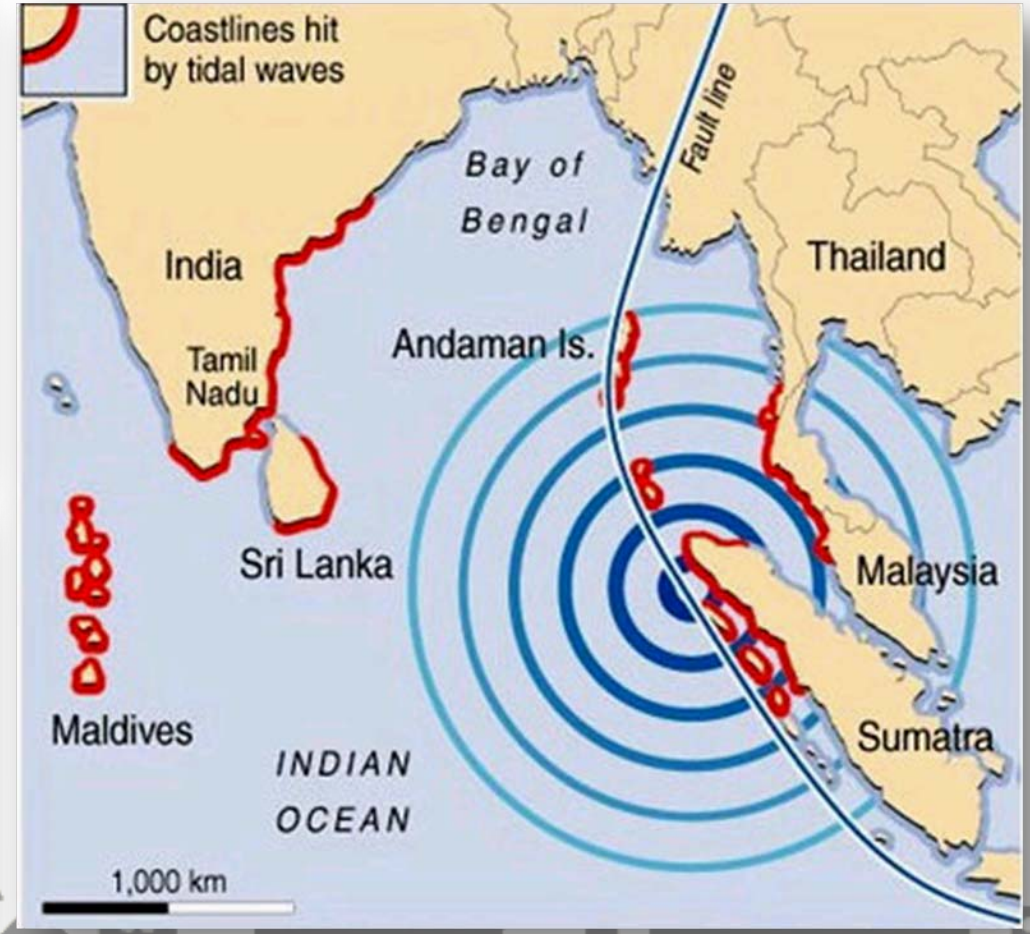
2005 S.Miyagi EQ
US$ 0.8 billion loss

Compressed gas cylinders

http://www.kahoku.co.jp/spe/spe064/060901-01.htm

Ex4: Tsunami warning

Evacuation, closure of tide wall



Nasu (2005)

Conclusion

•Algorithm of earthquake early warning

Estimate ground motion at a site from the first P-wave record. (location and magnitude estimates)

•The way to provide the early warning to public

TV and radio, second provider, cell phone, etc.

•Practical application of the early warning

Control railways, buildings, chemical supplies, and tsunami warning