The strong-motion observation network in Japanese ports

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The strong-motion observation network in Japanese ports

- Since 1962, strong ground motions and earthquake responses of structures have been observed in the major ports in Japan.

- By the end of December 2010, 9411 accelerograms had been accumulated and analyzed at the Port and Airport Research Institute.

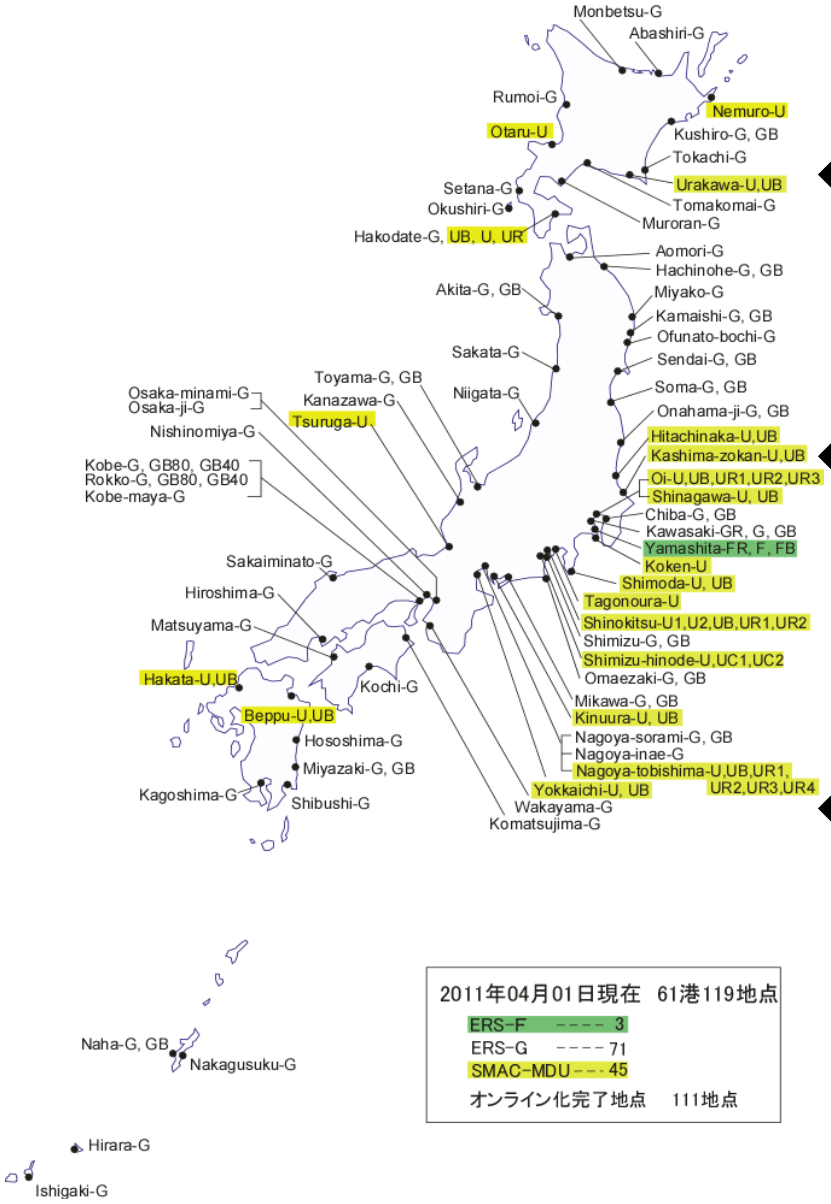
Objectives of the strong-motion observation

1. To utilize records of strong ground motions from a damaging earthquake in order to clarify causes and mechanisms of the damage
2. To investigate site-specific characteristics of ground motions
3. To utilize records of ground motions from a lot of small earthquakes in order to predict ground motions from a large earthquake in the future

Others;

4. To investigate the nonlinear response of local soil deposit
5. To investigate earthquake response characteristics of port structures.

The location of observation stations



- As of April 2011, the strong-motion observation network consists of 119 accelerometers installed at 61 ports.
- Out of 119,
  69 on ground surface
  36 in ground by using borehole
  14 on structures such as quay walls
- Most of seismometers in ground are located at the depth of less than 100m

Instrumentations

An example of stations

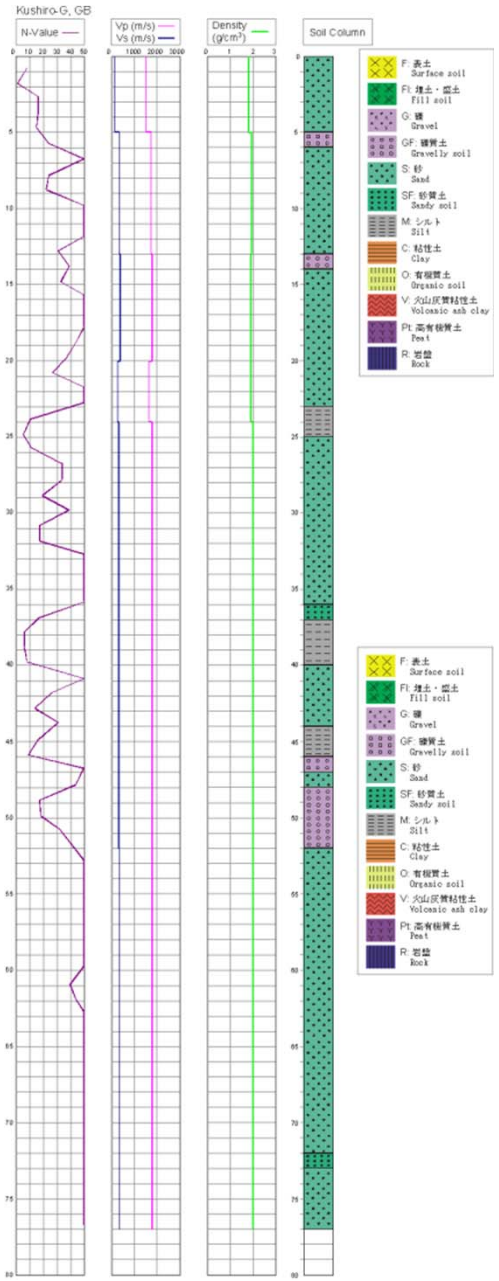
A sensor for boreholes

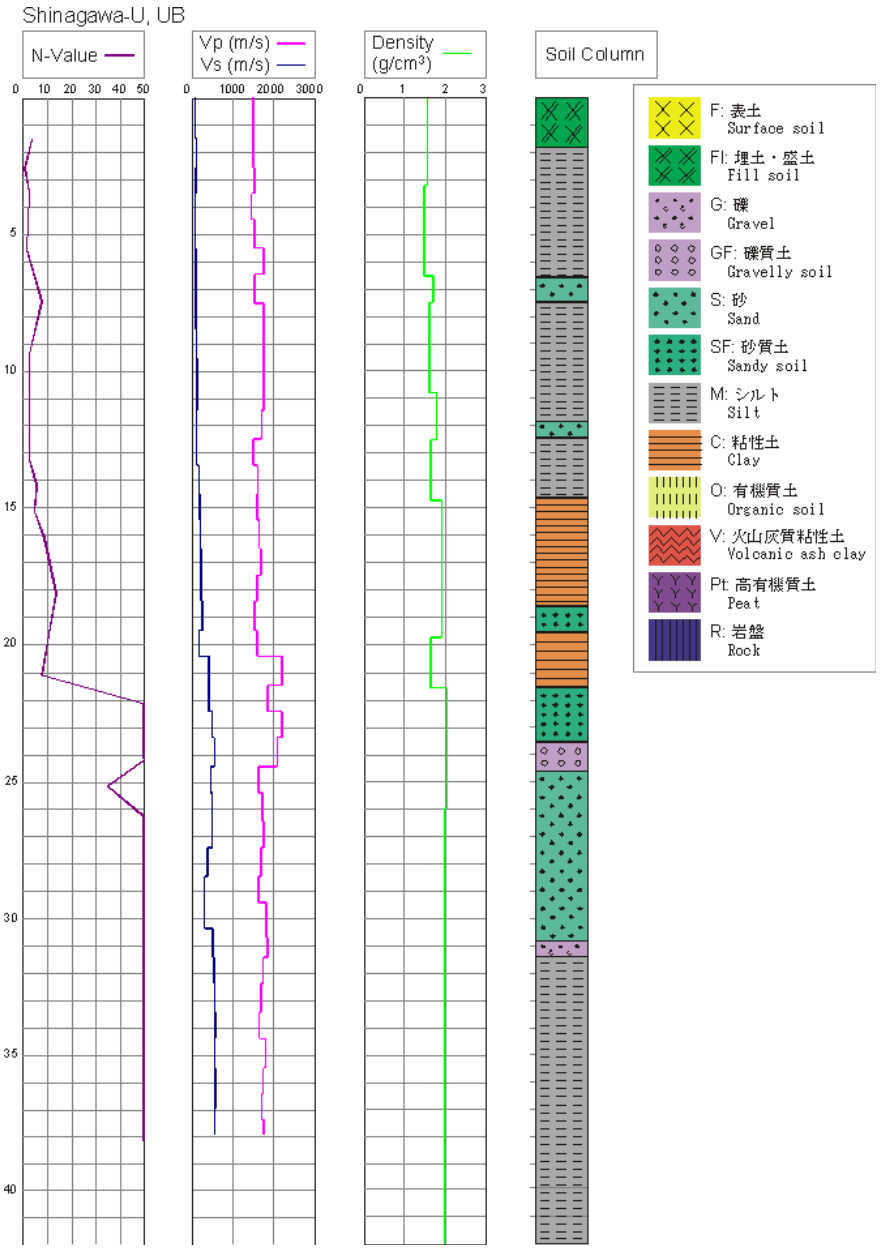
A data logger system

A seismometer with data logger
on ground surface

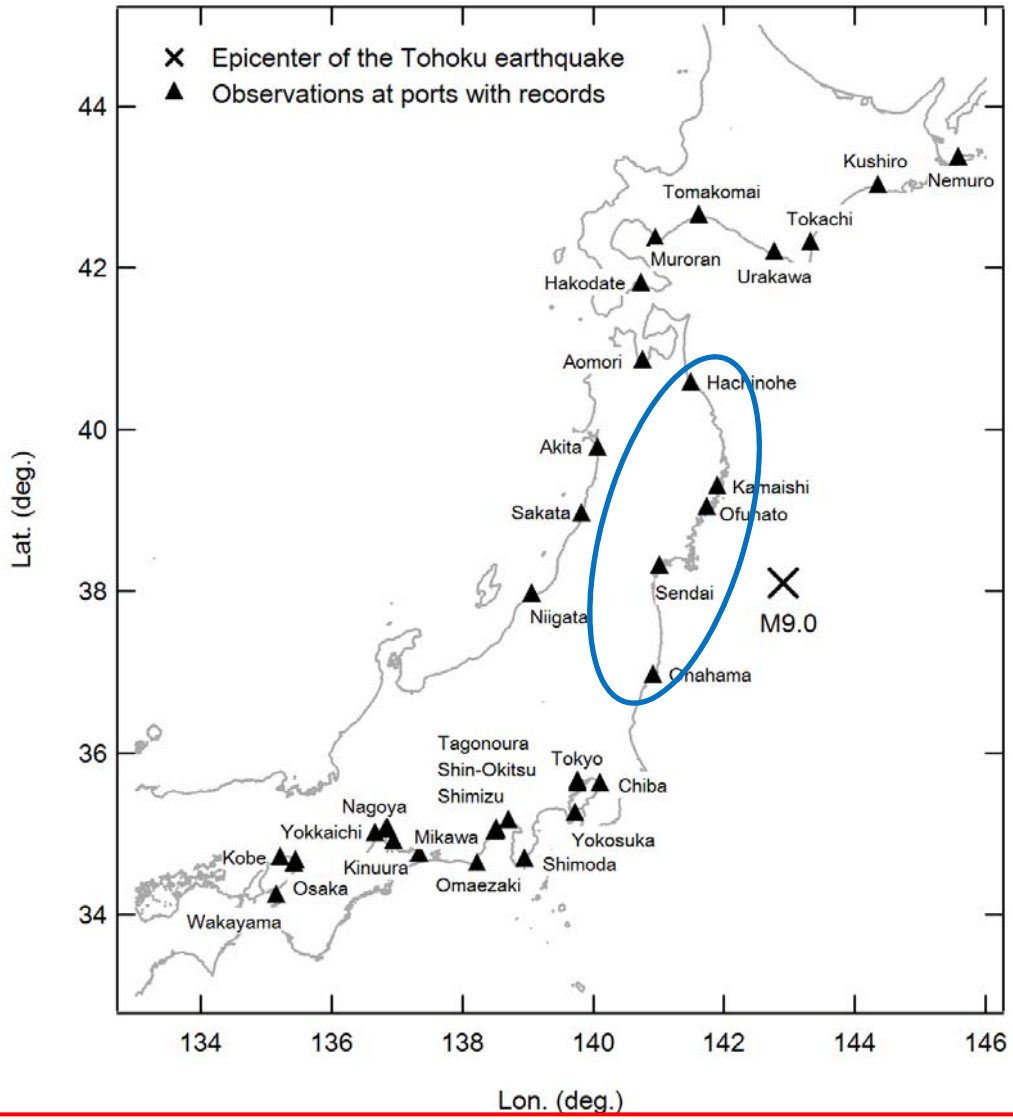
A sensor for structures

Examples of Soil profile at ports



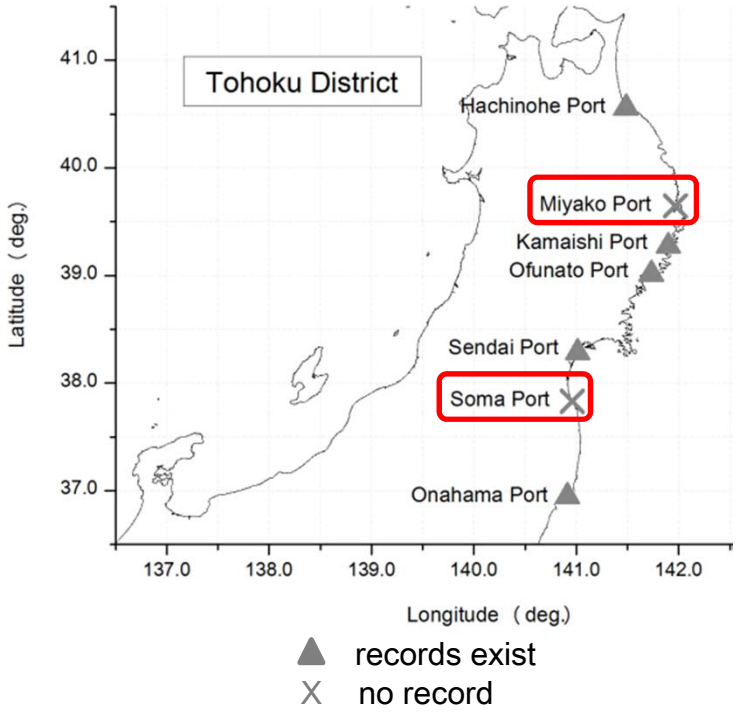


The 2011 Tohoku, Japan, Earthquake



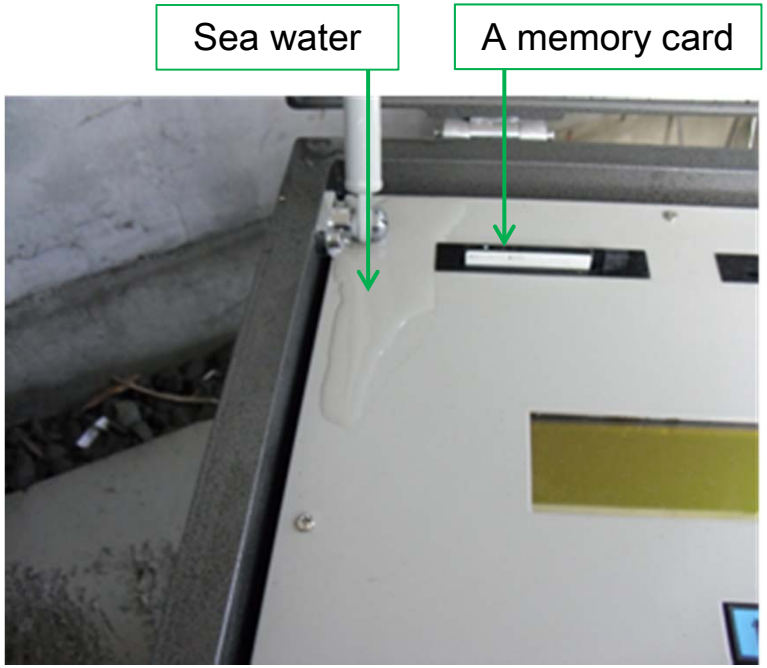
A large number of strong motion data was successfully recorded by the strong-motion observation network in Japanese ports

Two stations were ruined by Tsumami



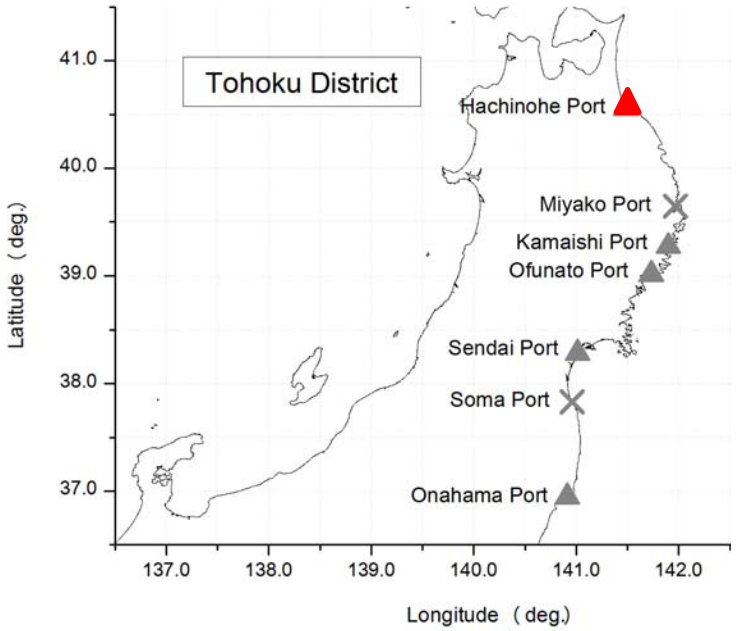
The site where there was a station (Soma port)

Submerged seismometers



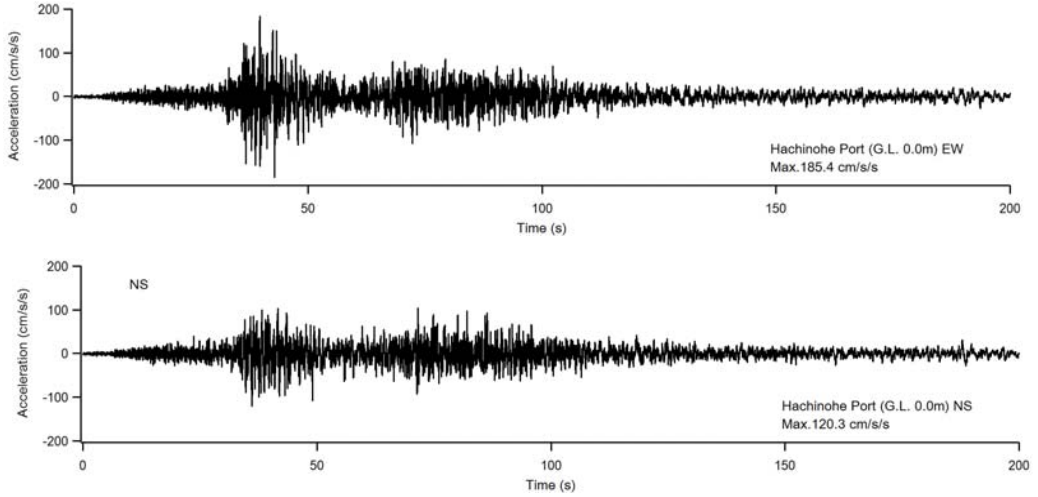
In stead of submergence, records were available at some ports.

Accelerograms on surface and in ground

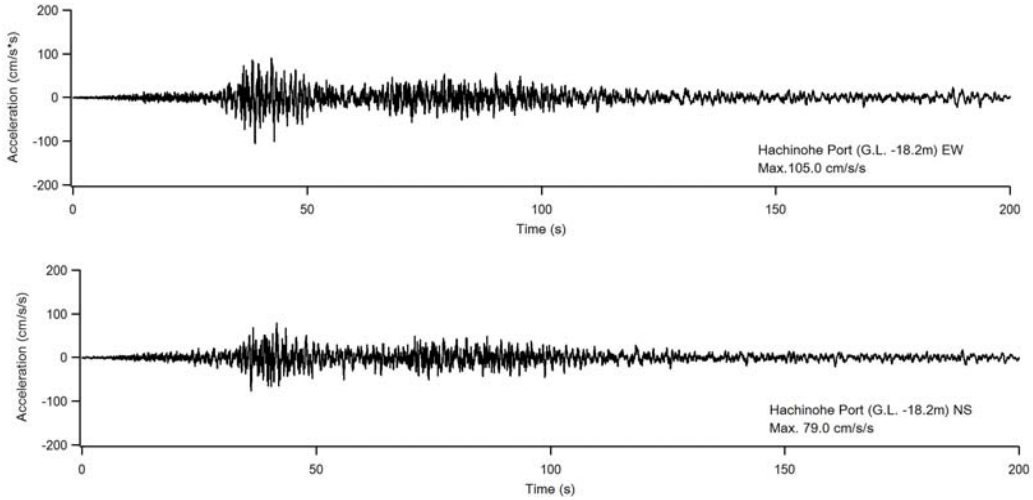


Contributions from at least two subevents

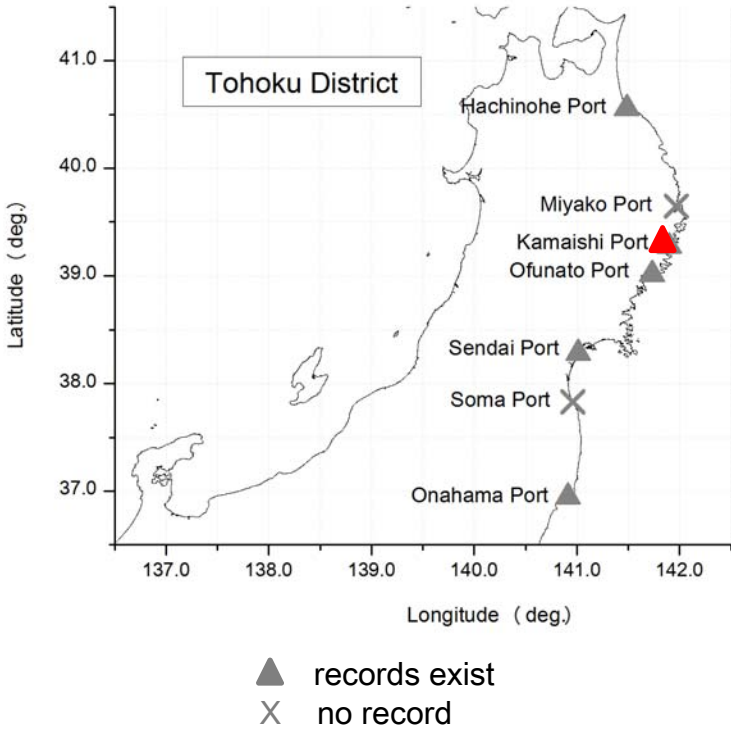
Surface



GL -18.2m

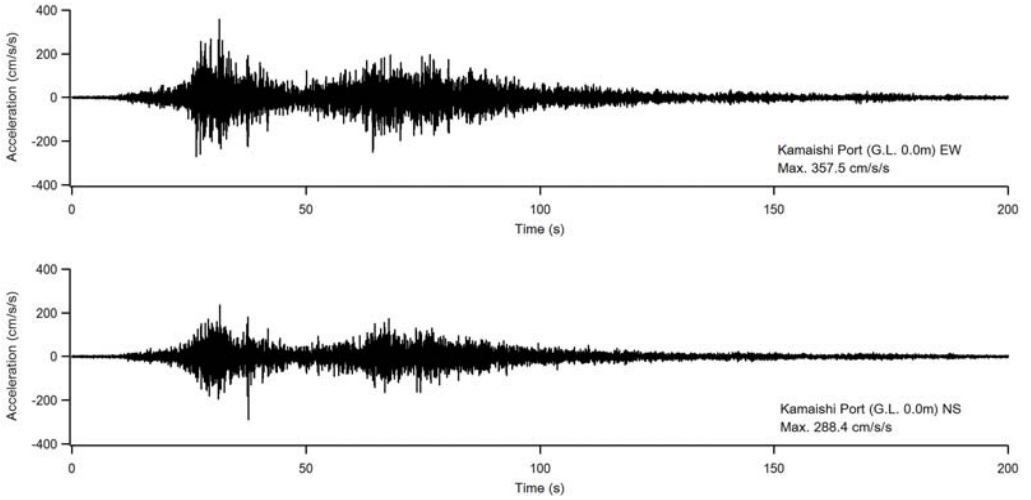


Accelerograms on surface and in ground

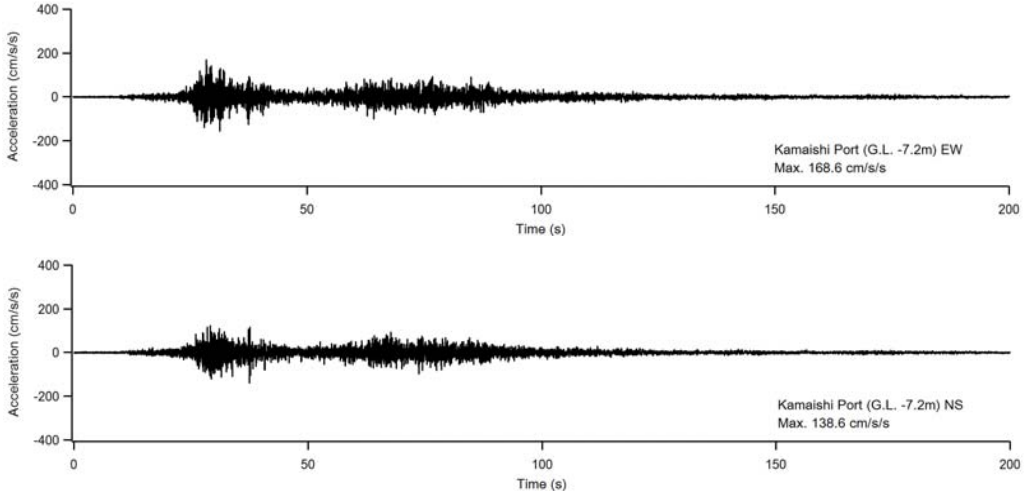


Contributions from at least two subevents

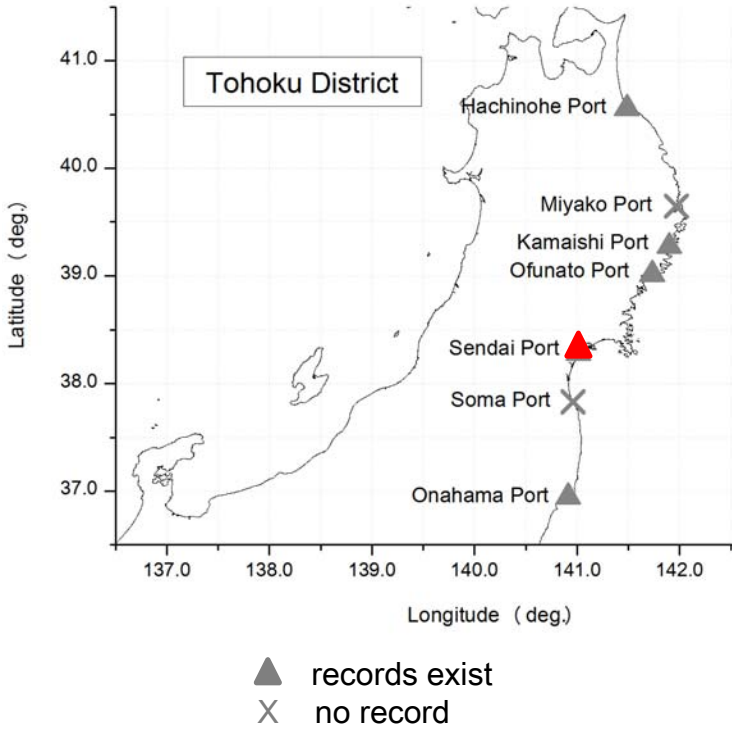
Surface



GL -7.2m

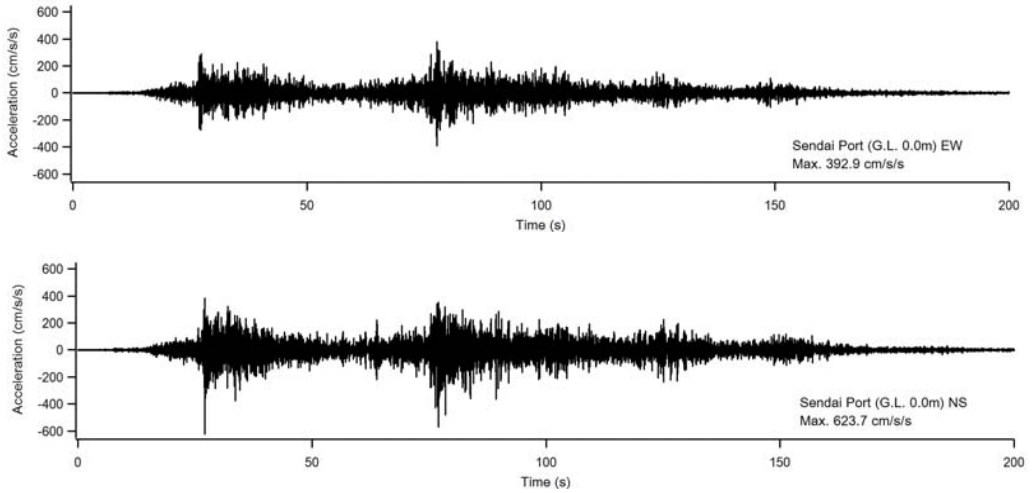


Accelerograms on surface and in ground

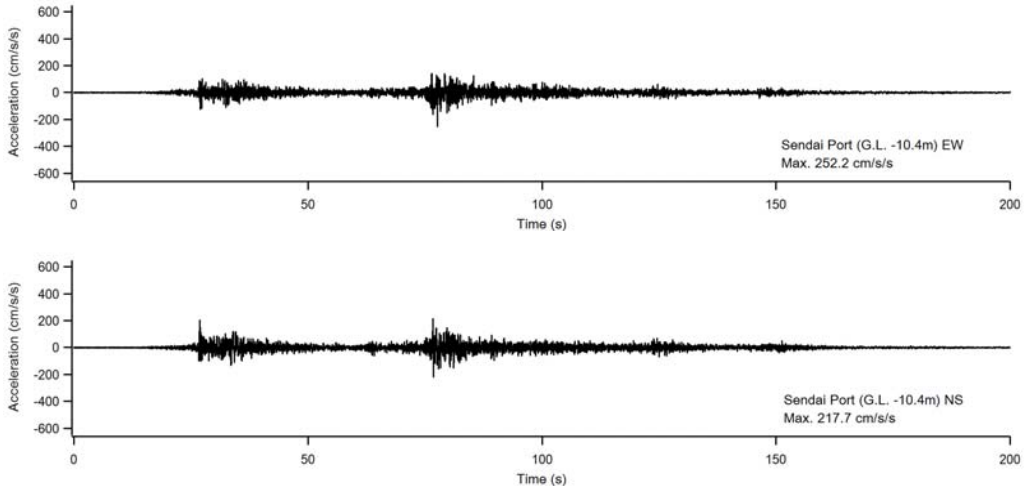


▲ records exist
X no record

Surface

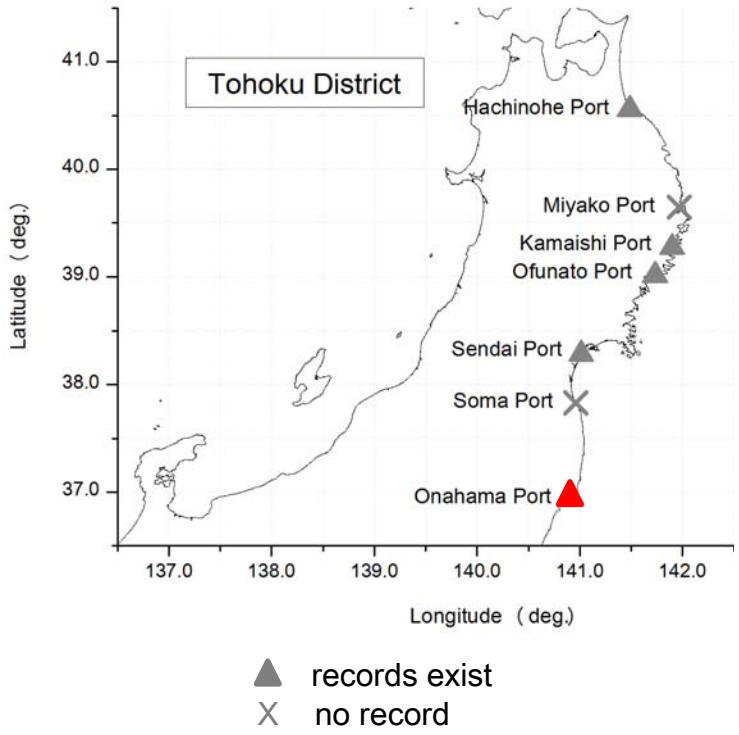


GL -10.4m

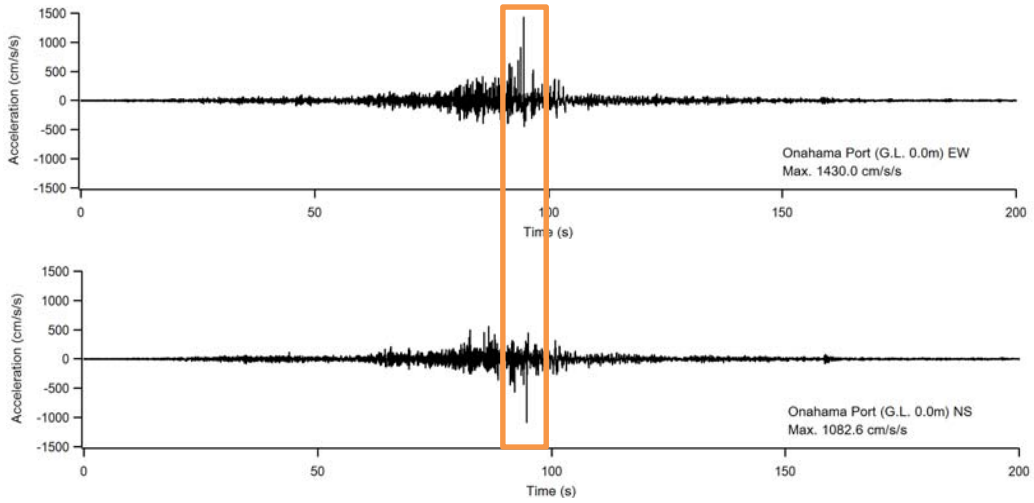


Contributions from at least two subevents

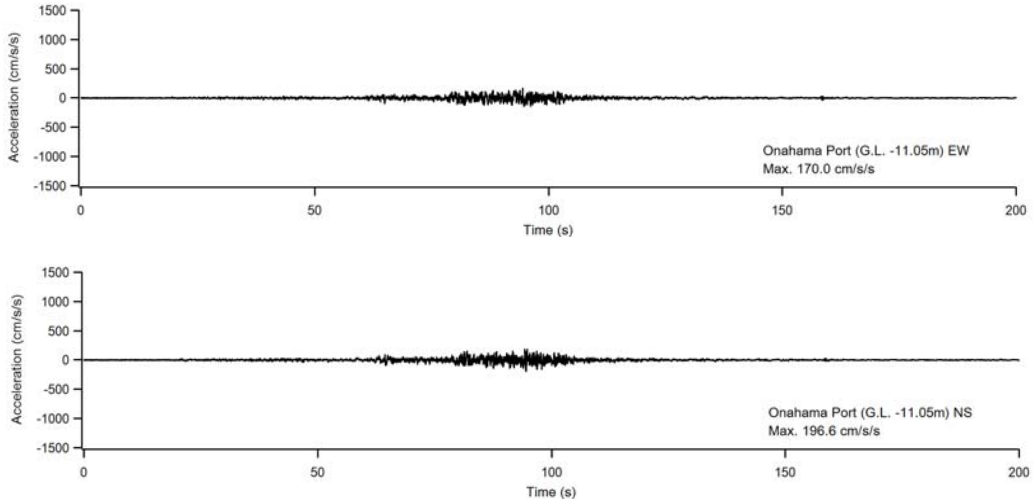
Accelerograms on surface and in ground



Surface

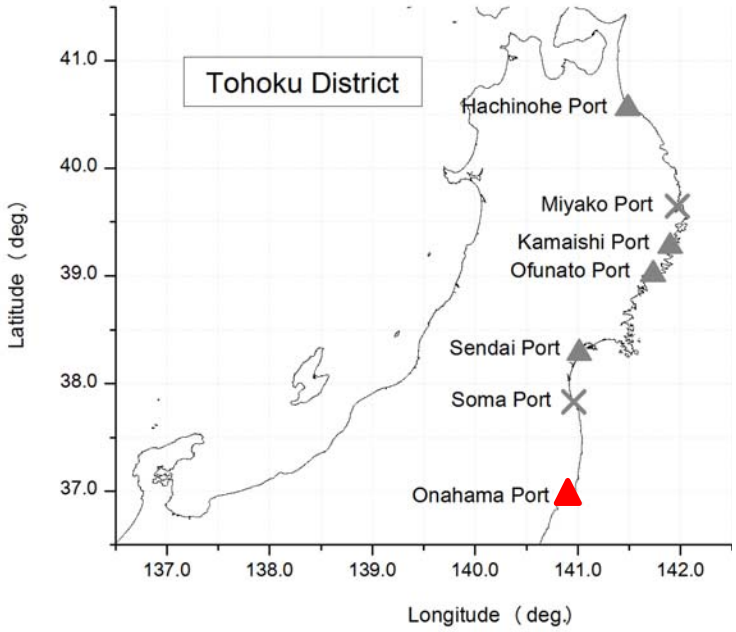


GL -11.05m



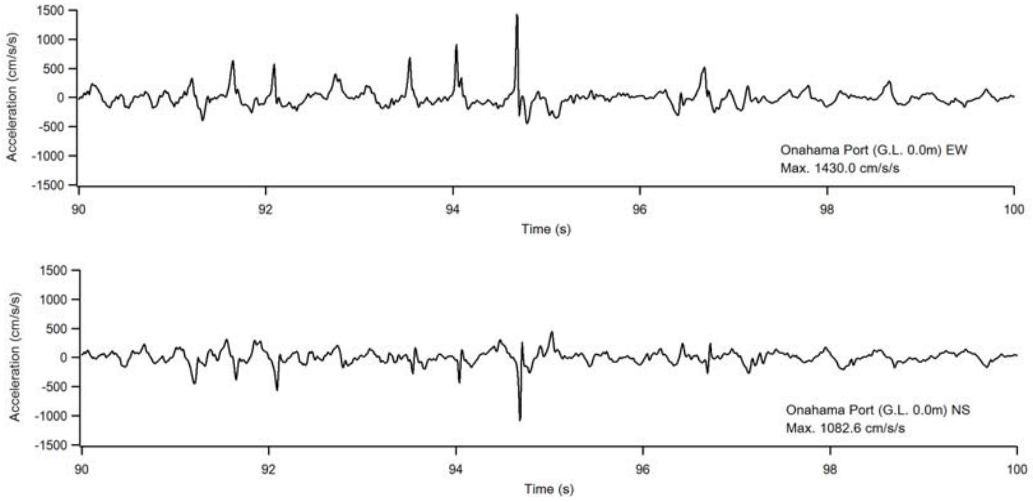
- No clear evidence for contributions of subevents.
- Spiky waveforms on the surface.

Spikes in Accelerograms on surface



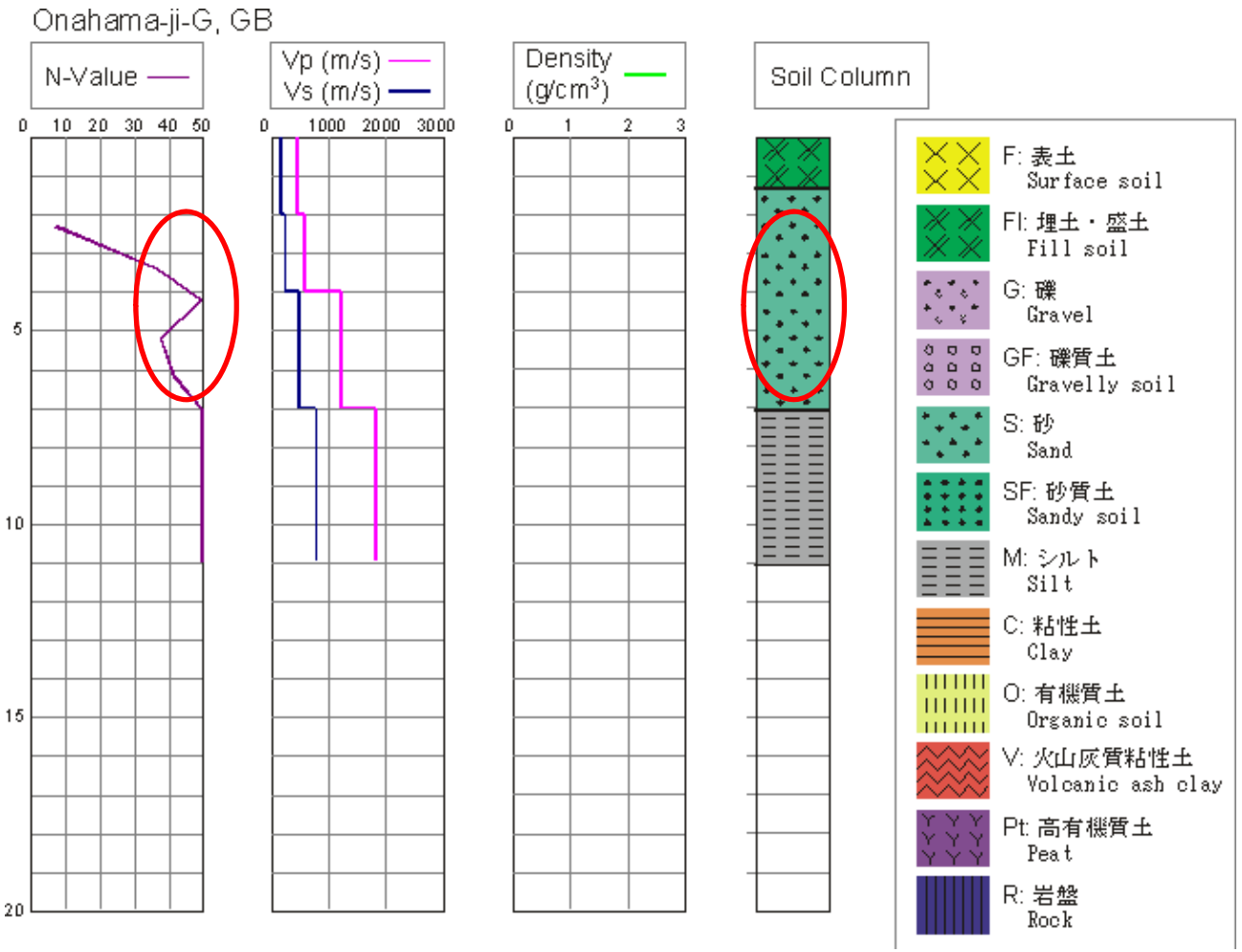
▲ records exist
X no record

Ground surface



The spikes in the acceleration waveforms can be found.
This indicates cyclic mobility due to dense sand deposit.

Soil profile at Onahama port

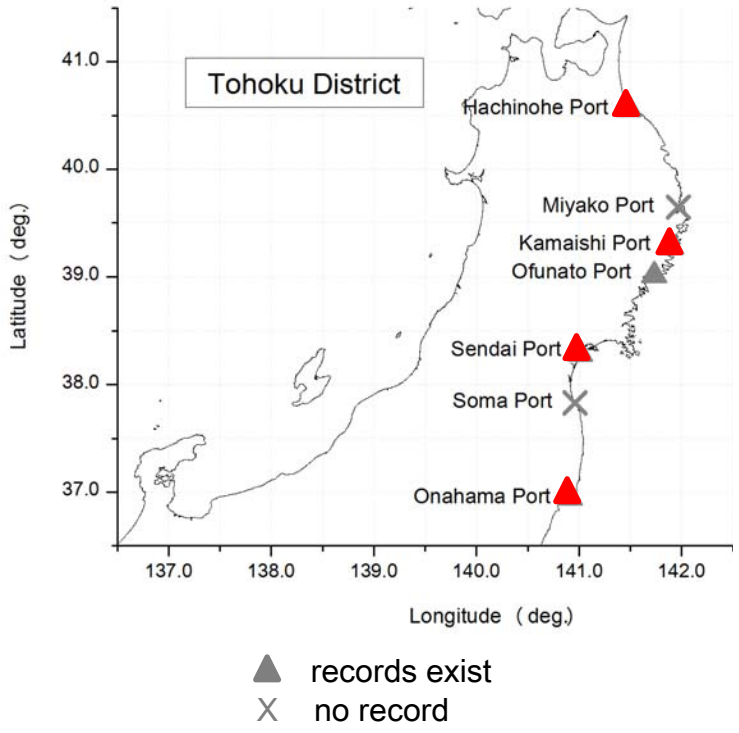


Sand deposits with large N-Value can be recognized

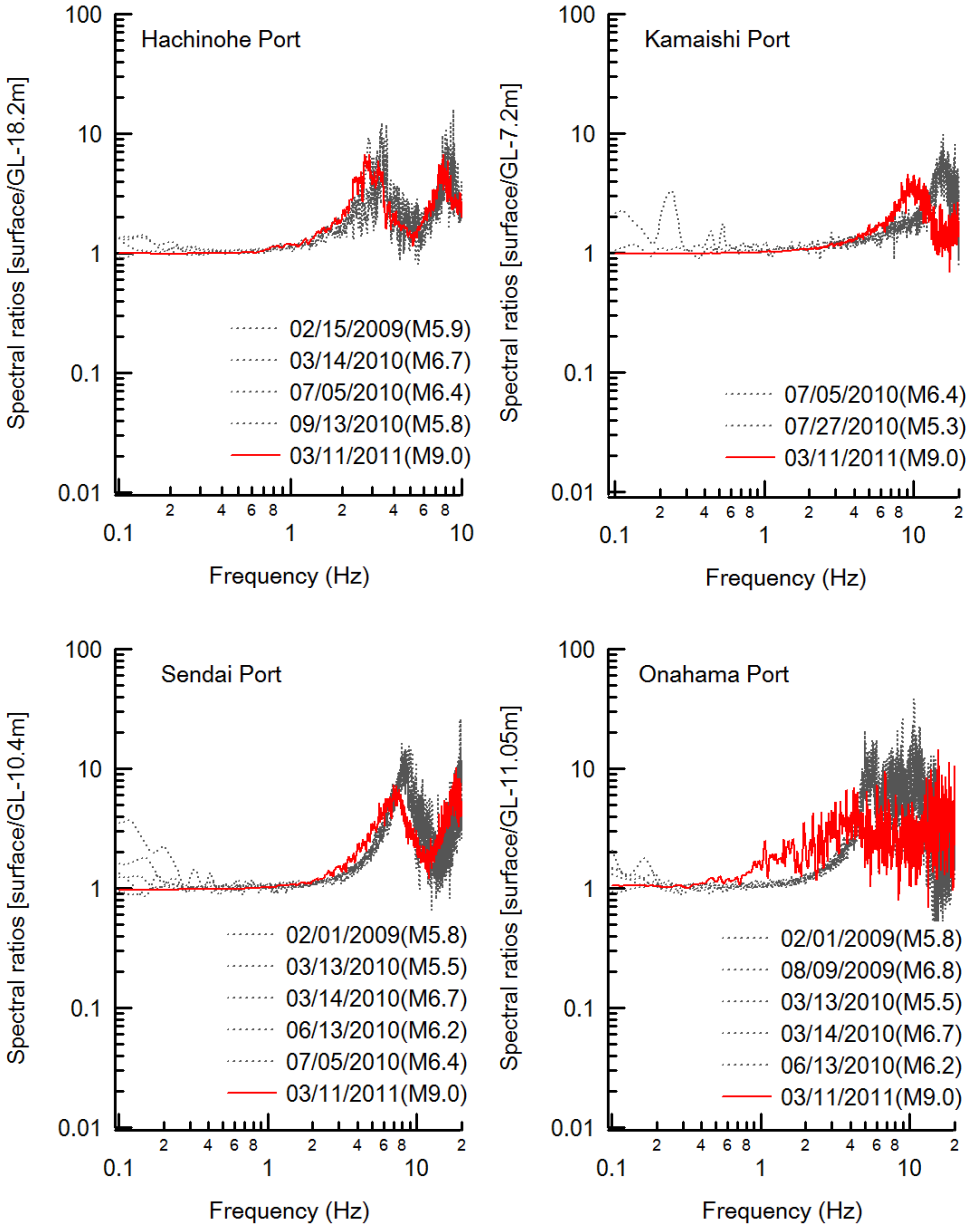
Analysis of vertical array records

- By taking surface-to-borehole spectral ratio, we can further investigate nonlinear behavior of soft soils.
- The peak frequency of the spectral ratio is obviously related to the averaged shear-wave velocity for the vertical array.
- In the next slides, the peak frequency for the Tohoku earthquake is compared with that for smaller earthquakes.

Nonlinear behavior of soft soils

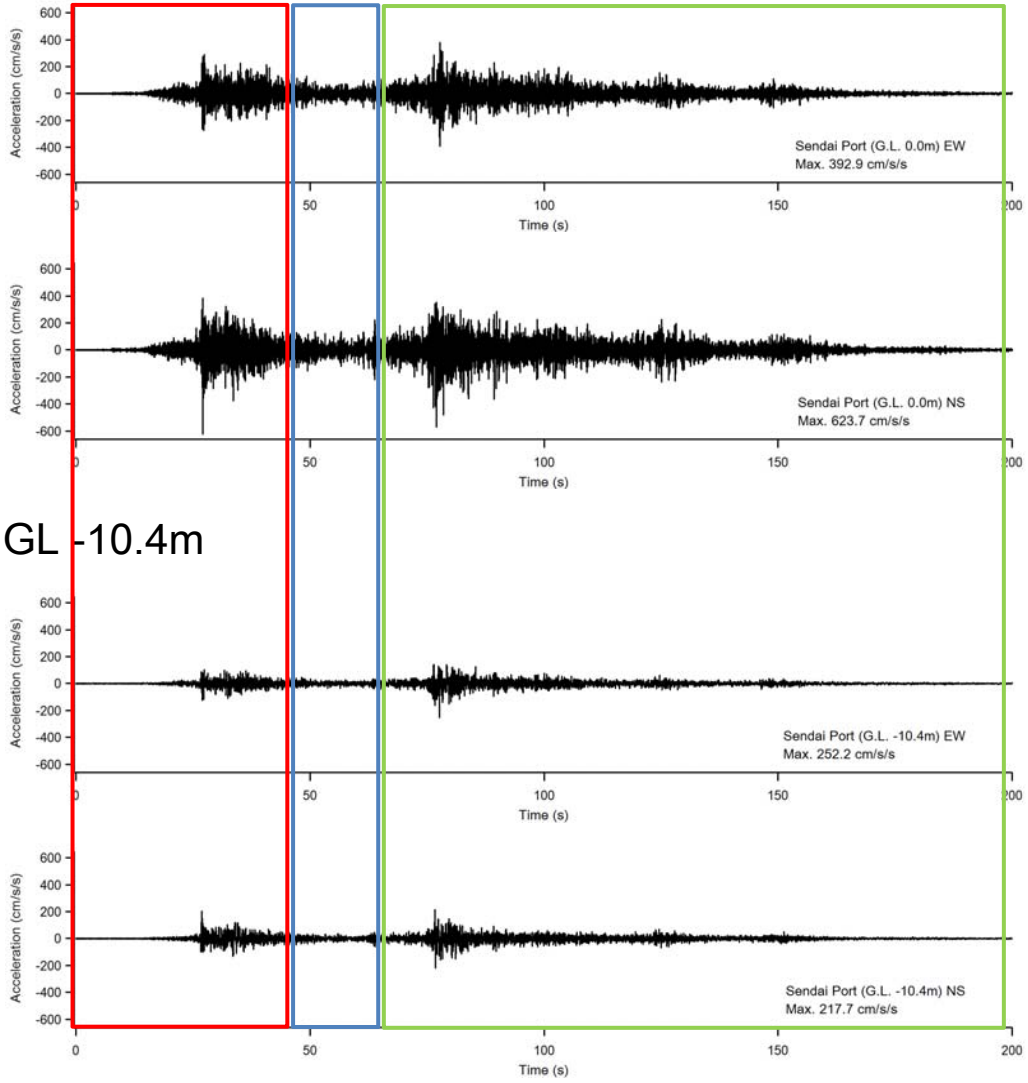


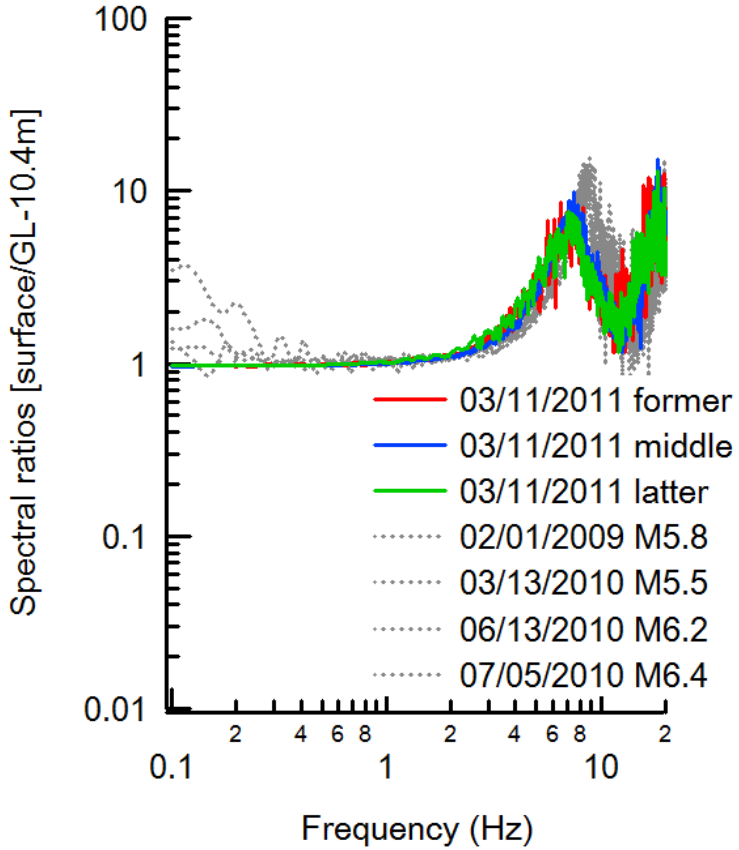
- More or less, nonlinear behavior of soft soils can be found.
- Especially, at Onahama port, strong nonlinear behavior can be found.



Nonlinear behavior of soft soils by part (Sendai port)

Surface

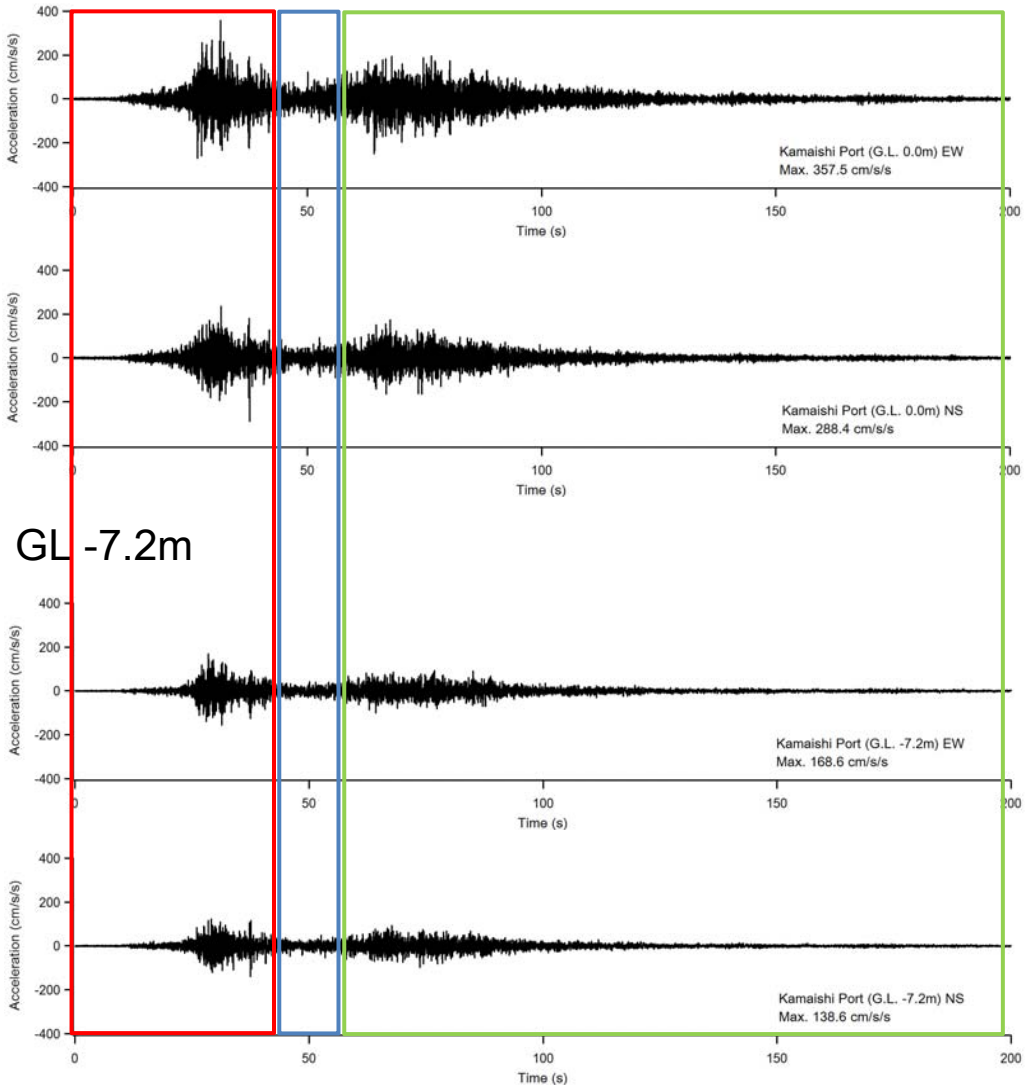


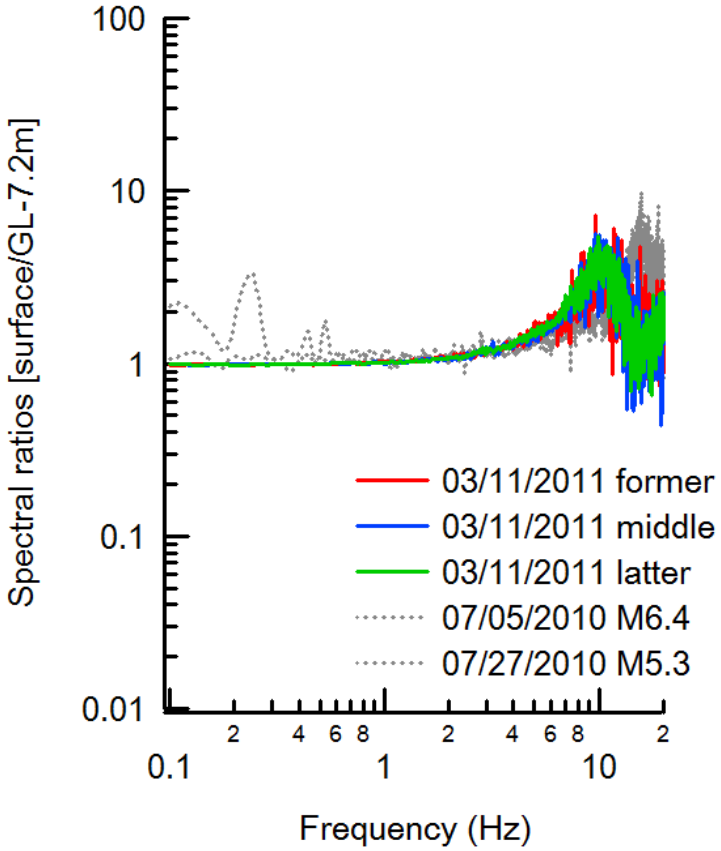


In each part, almost similar nonlinear behavior can be recognized

Nonlinear behavior of soft soils by part (Kamaishi port)

Surface





In each part, almost similar nonlinear behavior can be recognized

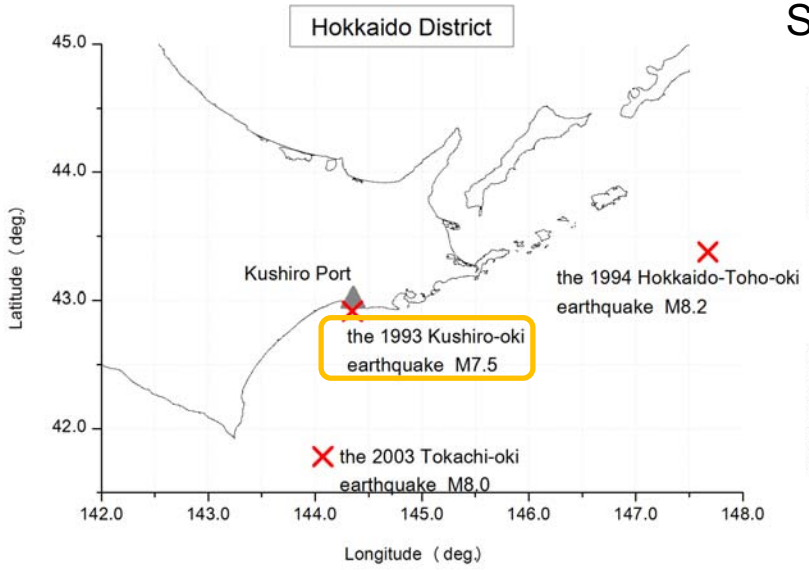
The 1993 Kushiro-oki, Japan, Earthquake

- As is well known, it was reported that the 1993 Kushiro-oki, Japan, earthquake had caused nonlinear behavior of local soft soil deposit at Kushiro port [Iai S. *et. al., 1995*]

- Since then, additional borehole records are also available at Kushiro port, and based on them, nonlinear behavior of soil deposit can be evaluated by using surface-to-borehole spectral ratios

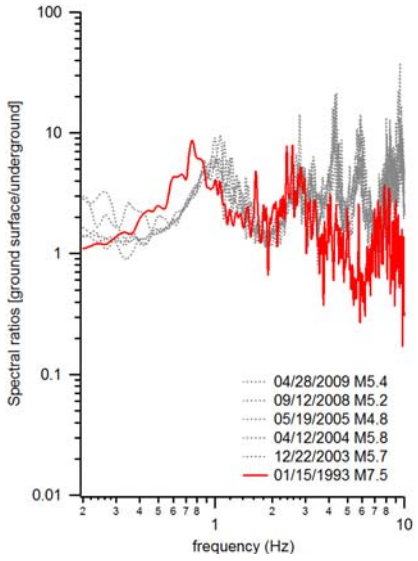
- Results for large earthquakes will be presented in the next slides.

The 1993 Kushiro-oki, Japan, Earthquake

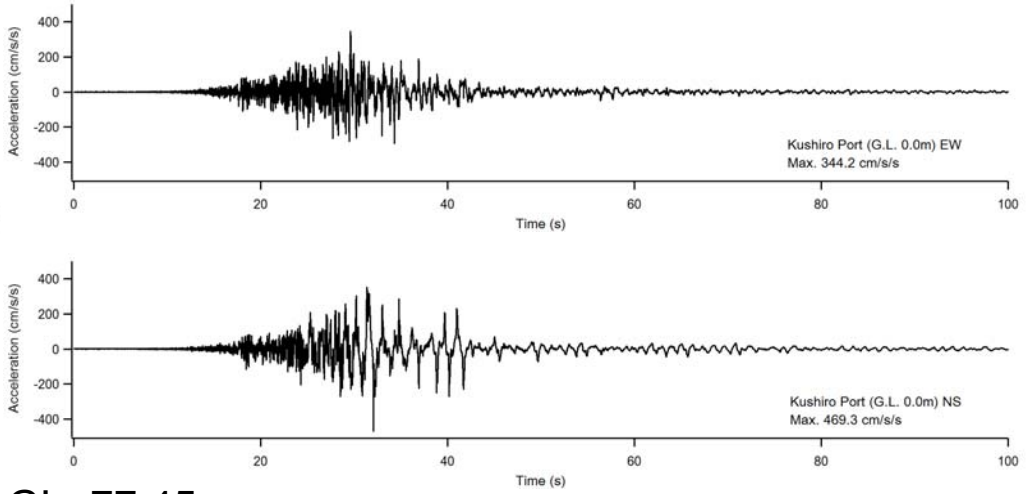


▲ Kushiro port

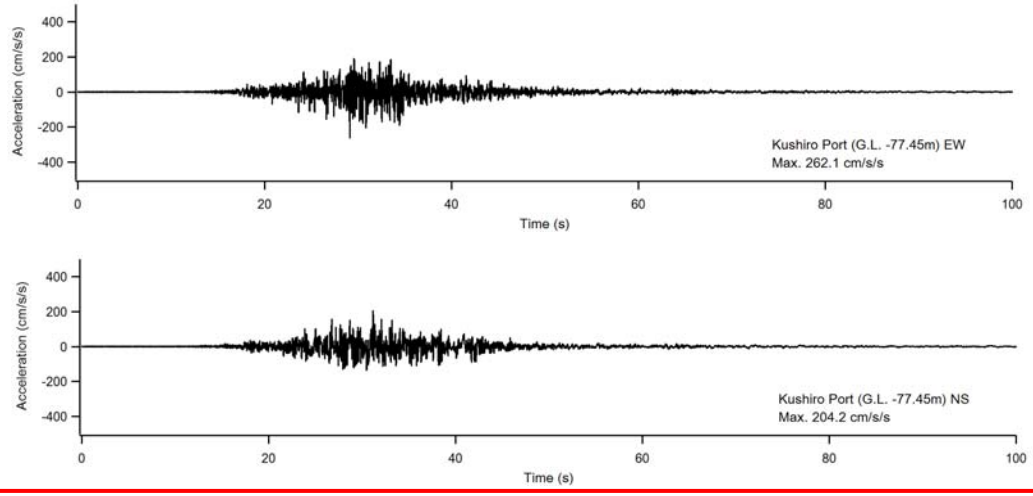
X epicenters of large earthquakes



Surface

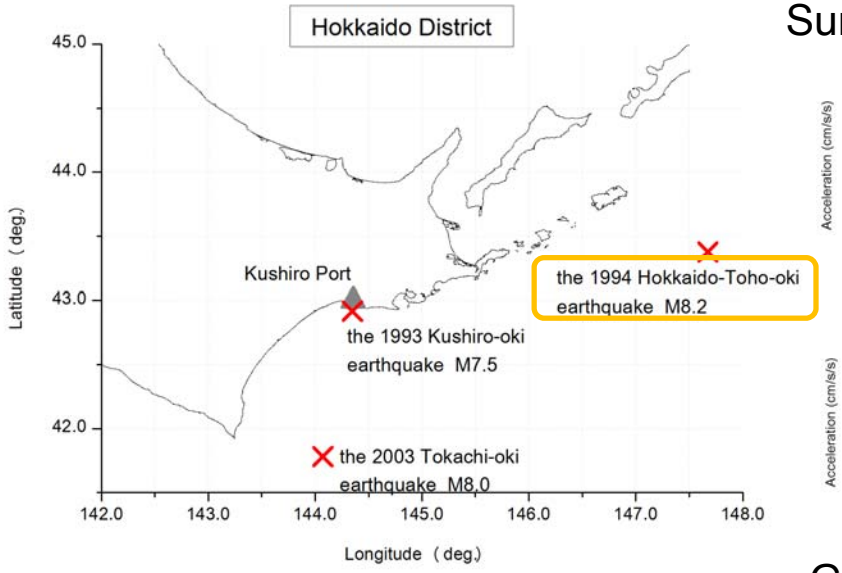


GL -77.45m



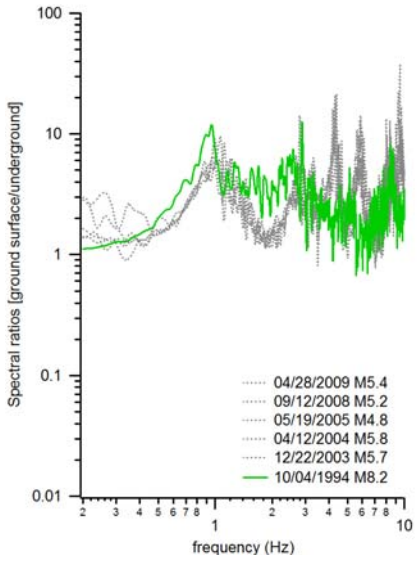
Nonlinear behavior of soft soil at Kushiro port can be recognized

The 1994 Hokkaido-Toho-oki, Japan, Earthquake

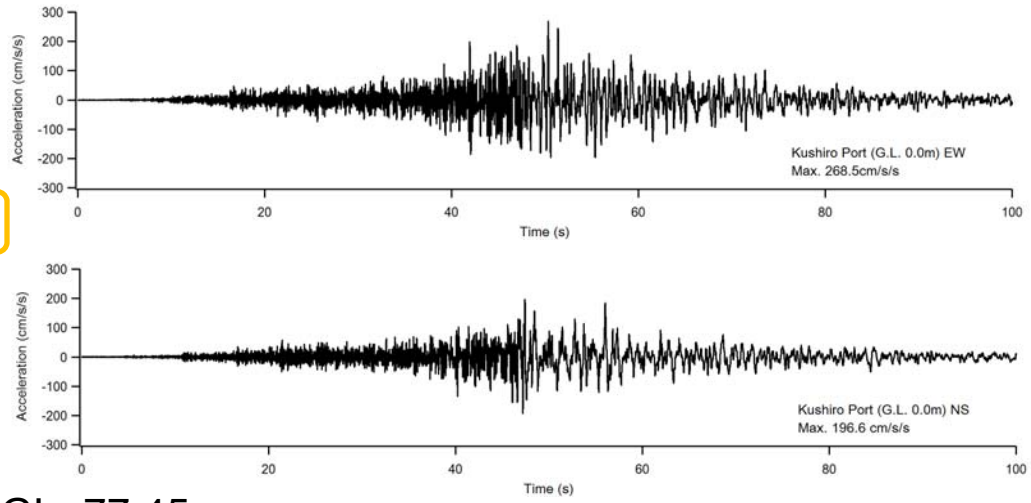


▲ Kushiro port

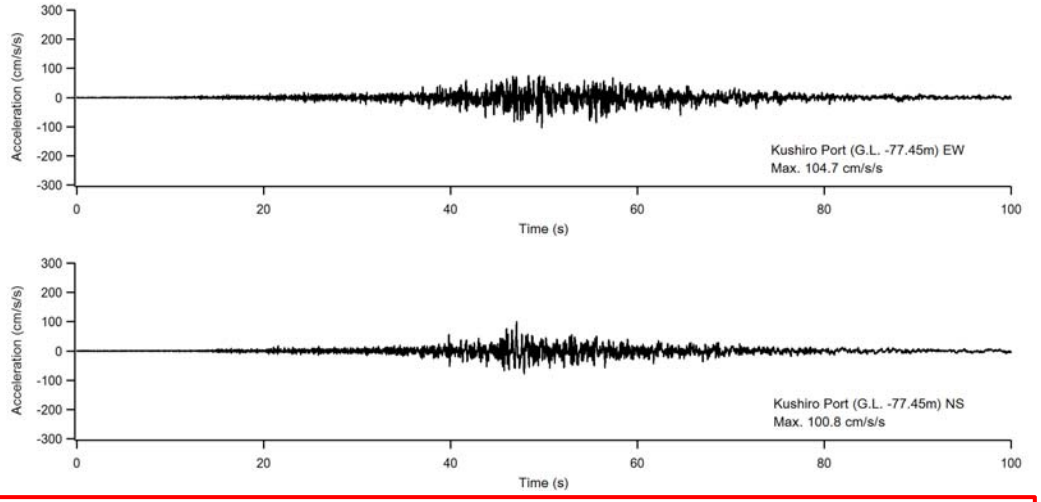
X epicenters of large earthquakes



Surface

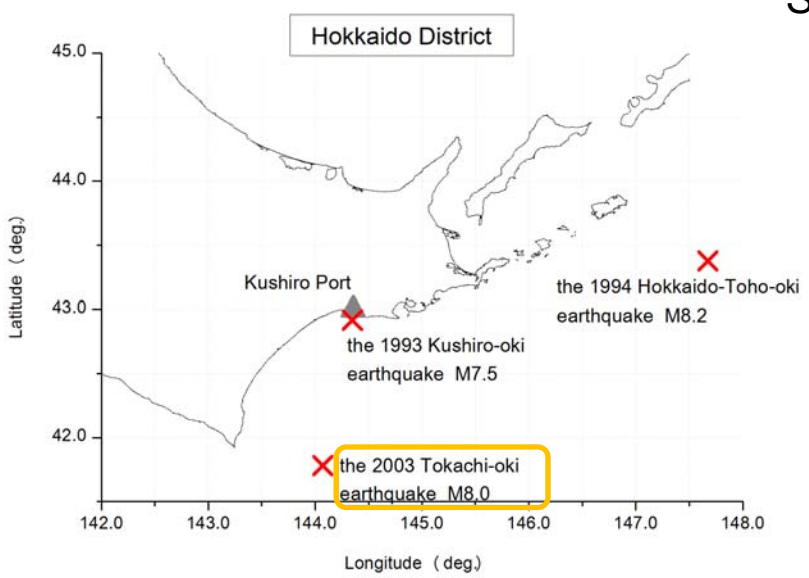


GL -77.45m



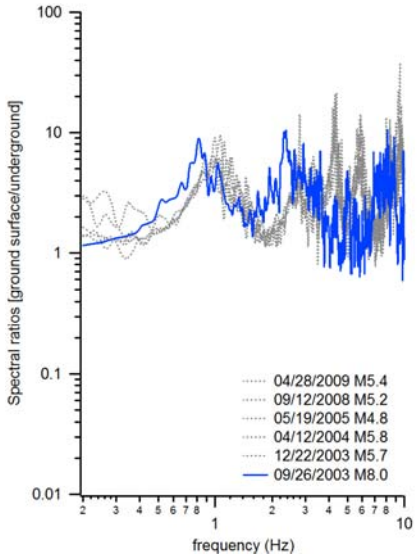
Nonlinear behavior of soft soil at Kushiro port can be recognized

The 2003 Tokachi-oki, Japan, Earthquake

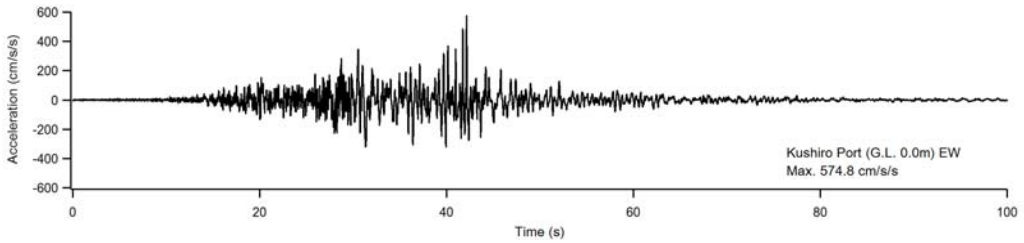


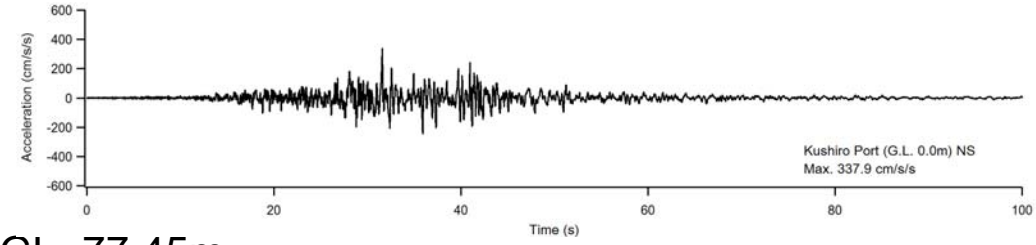
▲ Kushiro port

X epicenters of large earthquakes

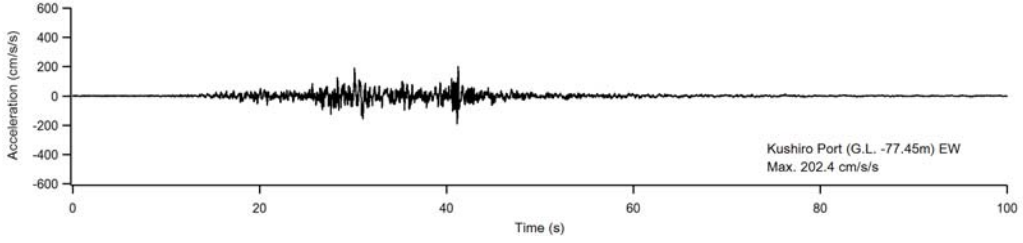


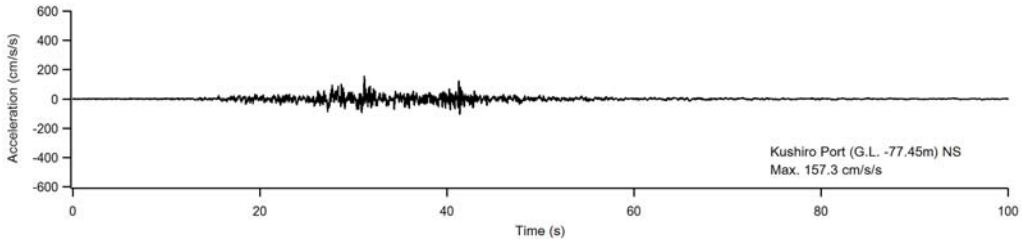
Surface





GL -77.45m





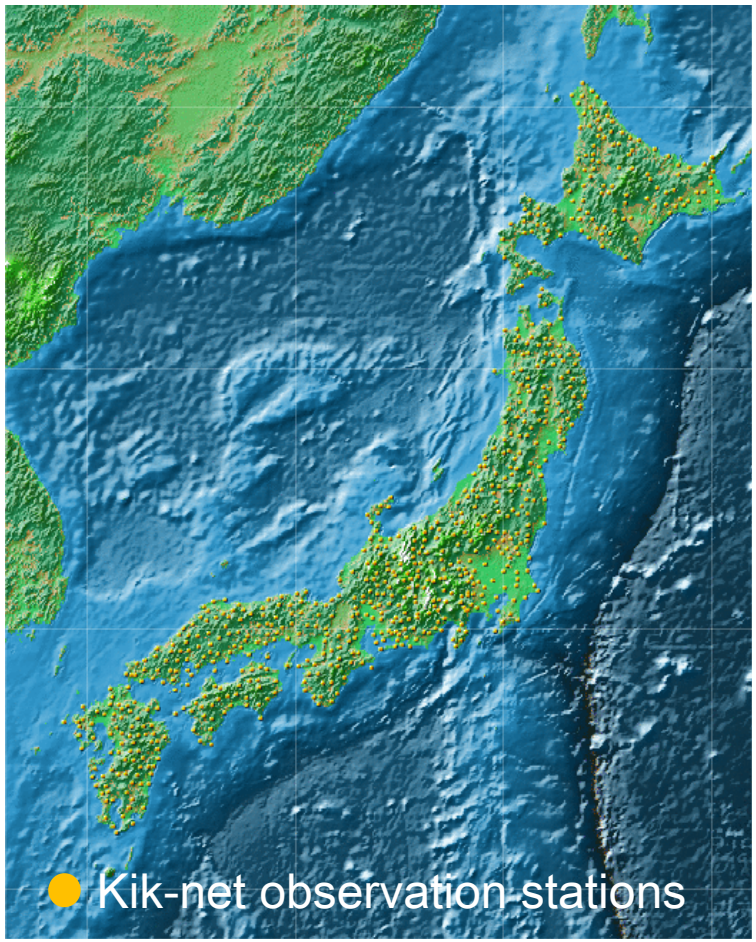
Nonlinear behavior of soft soil at Kushiro port can be recognized

Conclusions

- In the strong-motion observation network in Japanese ports, a lot of strong motions have been recorded, and many of them are vertical array records.

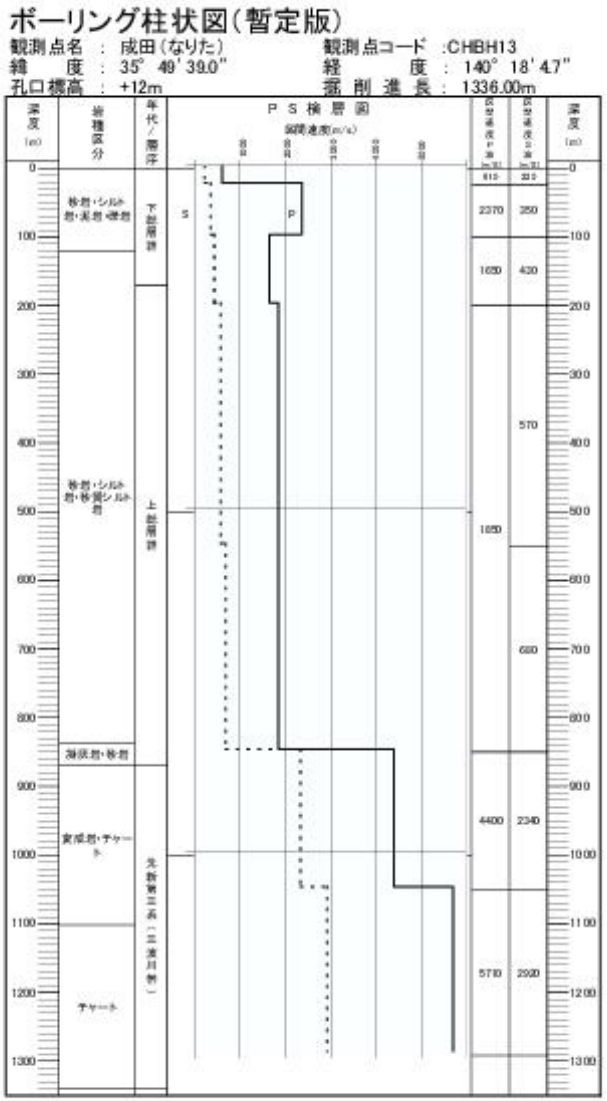
- It is important to maintain our network in the future since it is still unique in a sense that it covers coastal areas and that it is characterized by small aperture arrays, focusing on soft soils.

Kik-net operated by NIED



- Kik-net is a nationwide strong motion network with about 700 vertical arrays.
- Most of seismometers in ground are located at the depth of more than 100m, with the max. depth of about 3500m

An example of soil profile in Kik-net



◆A sensor installed in ground is located at the very deep, stiff rocks.

◆Advantage-
Ground motions at rocks can be obtained

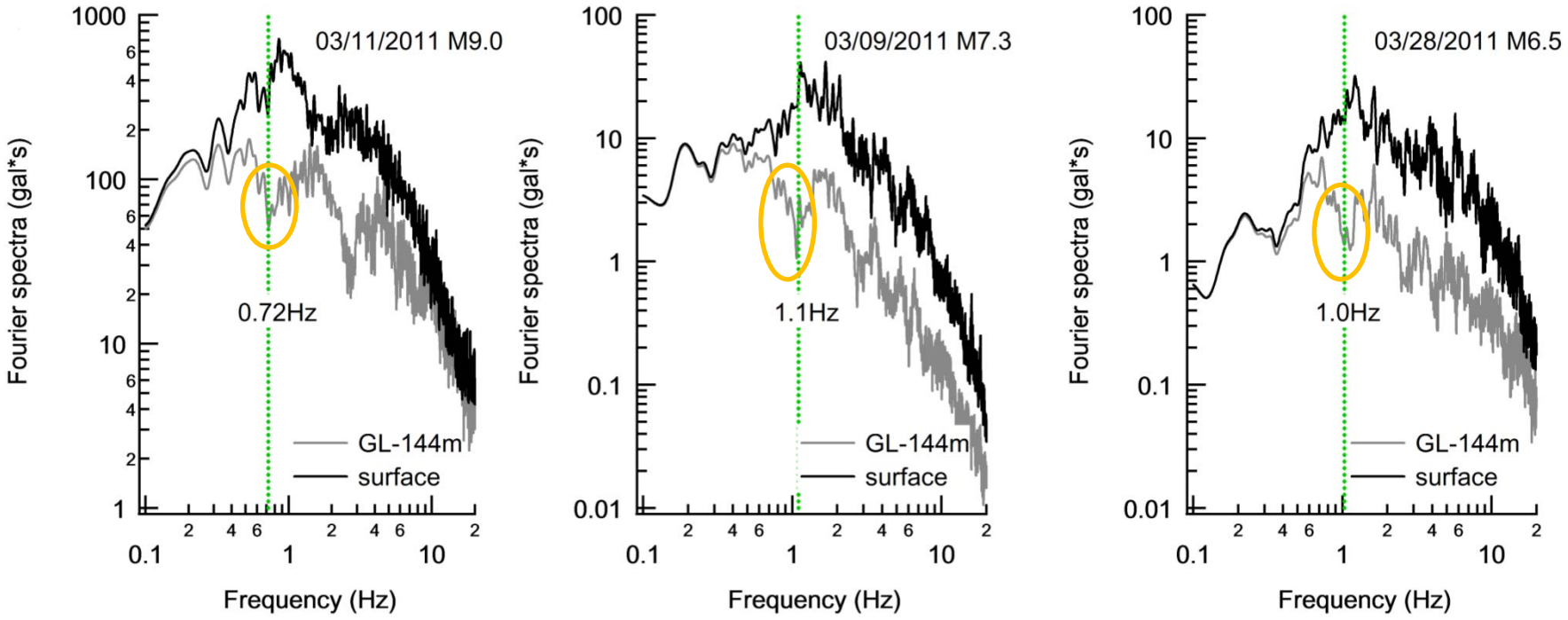
◆Disadvantage-
From the standpoint of small-aperture arrays , their resolution is a little inferior

Records on a borehole affected by nonlinearity (at FKSH14)

- Accelerometer in ground at FKSH14 is located at the sand rock, Vs=1200(m/s).
- Does nonlinear behavior of soft soils affect records on a borehole ?

- As is well known, in the Fourier spectrum in the borehole records, a sag can be found at the natural frequency of soils between two seismometers, since upward waves and downward waves interfere.

Records on a borehole affected by nonlinearity (at FKSH14)



The spectral sag for the main shock is shifted to lower frequency by comparison with that for the smaller events. This indicates that nonlinear behavior of soft soils affects even records on a borehole.

Thank you for your attention

All of the records from our network can be downloaded from our website at http://www.eq.pari.go.jp/kyosin/ but the website is written only in Japanese.

Annual reports have been published from our research institute which includes a CD with digital data. The CD is accessible through English language. If you are interested obtaining the annual reports, please let us know.