Seismic Intensity Map Triggered by Observed Strong Motion Records Considering Site Amplification and Its Service based on Geospatial International Standard

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1

Background and Objectives

- Currently, the seismic intensity information is released on the basis of the instrumental seismic intensity measured by approximately 4,200 seismographs installed throughout the nation. However, since the seismic motions vary depending on geologic and geomorphologic features, the ground motion at a location without a seismograph is not always consistent with the seismic intensity recorded by a seismograph close to the point.
- In order to take effective countermeasures against seismic disasters and implement business continuity plans (BCPs) for municipalities and private companies, the quick estimation of strong ground motions for wider area is very essential at the early stages of disaster response activities.

2

Background and Objectives

- A first step for solving the issue can be to establish wide-ranging, seamless, and consistent precision data on amplification capability of ground and estimate and release the strong ground motion map of the concerned areas immediately after the occurrence of an earthquake.
- Data and Platform

  Data: strong ground motion network (NIED), geomorphologic map and amplification capability

  Platform: GEO (Global Earth Observation) Grid (AIST)

  GEO Grid aims at providing integrated service using a wide array of geoscientific information such as geologic maps and other digital geographically referenced data based on Grid and Web service technologies in accordance with international standards.

3

Contents

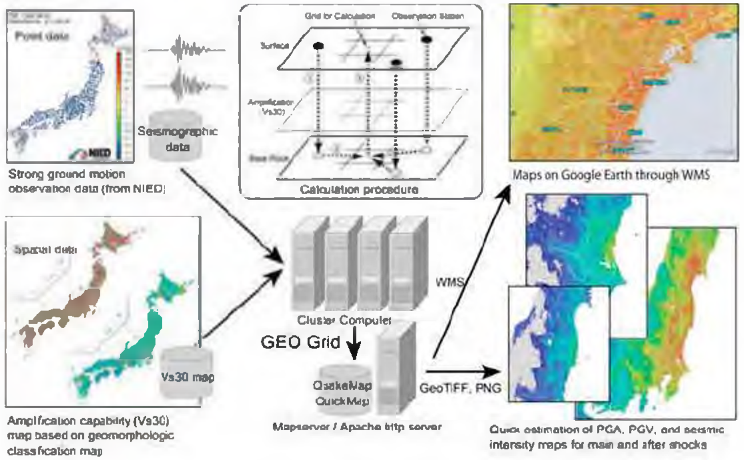
- QuiQuake (Quick estimation system for earthQuake maps triggered by observation records)

  seismic event triggered quick estimation system for the generation of earthquake maps using earthquake observation records
- Amplification capability from geomorphologic condition
- Advantages of QuiQuake

4

QuiQuake

QuiQuake is a system on GEO Grid which provides wide-ranging and detailed (250m-grid) strong ground motion maps for quick disaster response soon after the occurrence of an earthquake.

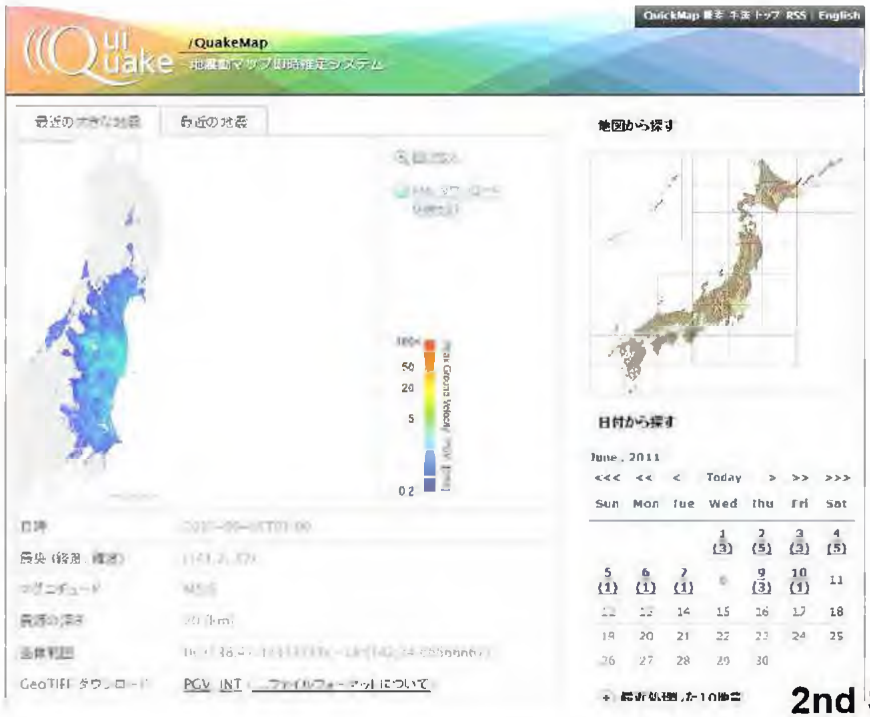


5

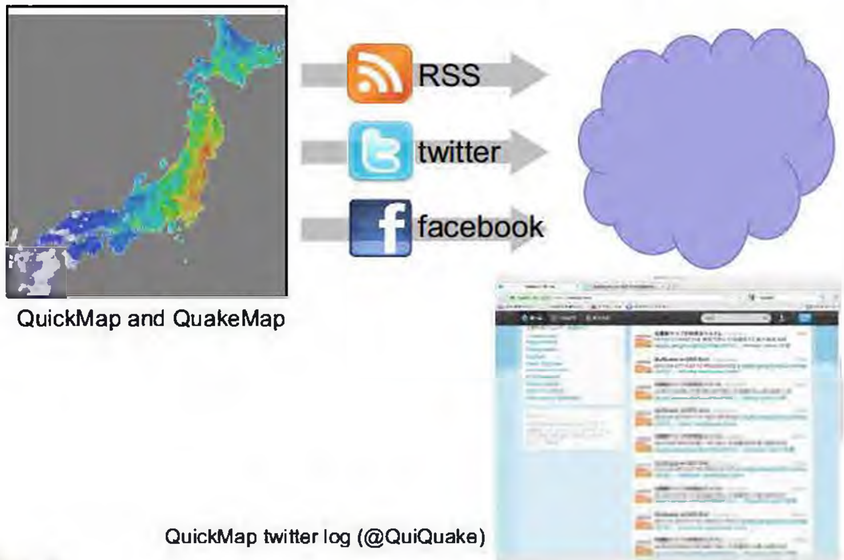
QuickMap and QuakeMap

- QuickMap http://qq.ghz.geogrid.org/QuickMap/index.en.html
  - QuickMap is calculated using the near real-time information of strong ground motion parameters of K-NET delivered by NIED right after an earthquake.
    - faster estimation
- QuakeMap http://qq.ghz.geogrid.org/index.en.html
  - QuakeMap which is calculated using the published seismic waveform records at seismic stations from the K-NET and KiK-net on the NIED portal site.
    - higher reliability

6

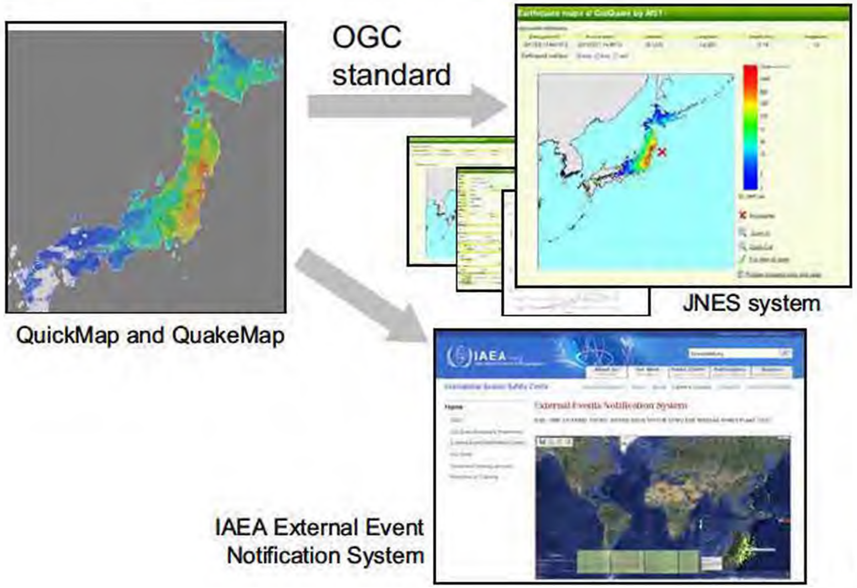


Dissemination to Social Media



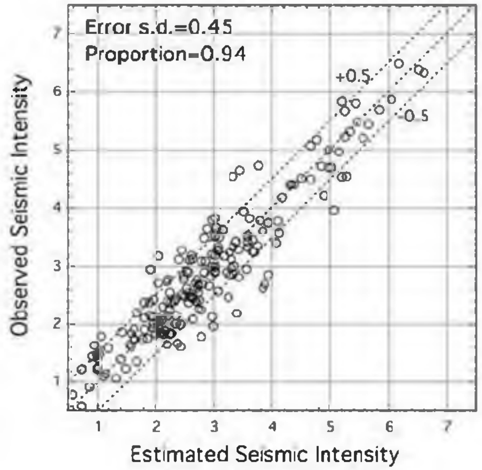
8

Dissemination to JNES and IAEA



9

Accuracy of Estimation



Comparison of the observed ground motion recorded by other organizations' seismic network stations and the estimated values at the stations estimated by Kriging using K-NET and KiK-net sites, and the amplification capability from Vs30 map for the 2004 Niigata-ken Chuetsu earthquake

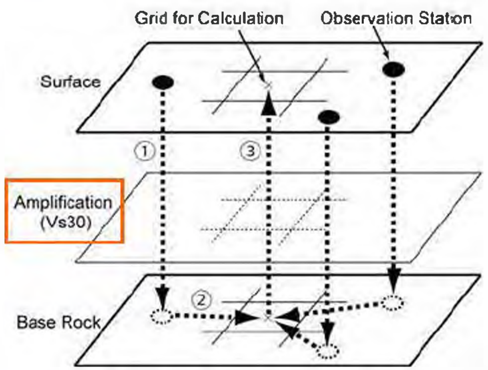
10

Interpolation Algorism

① Estimating strong ground motion intensity value on base rock from the observed record divided by the amplification factor at the seismic station

② Calculating intensity value of the target grid on base rock by interpolating of surrounding values and also attenuation characteristics into consideration

③ Calculating intensity value on surface from multiplying by amplification factor



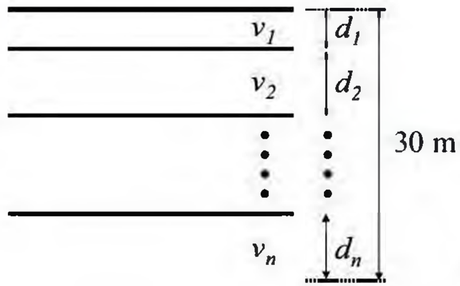
Free and Open Source Software: RASMO (Rapid Shake Map simulator with Observed records) developed by Kawasaki Lab/NIED

11

Amplification Capability Index

- For precise evaluation, soil profile data such as PS-logging is needed. However, for wider area, simple index from spatial information is useful because of the limitation of logging data.
- Average shear-wave velocity of ground in the upper 30m (Vs30) which has good correlation with PGV or seismic intensity amplification, is one of the available indices.

$$Vs30 \quad \frac{30}{\sum_{i=1}^{n} d_i / v_i} \quad [m/s]$$



12

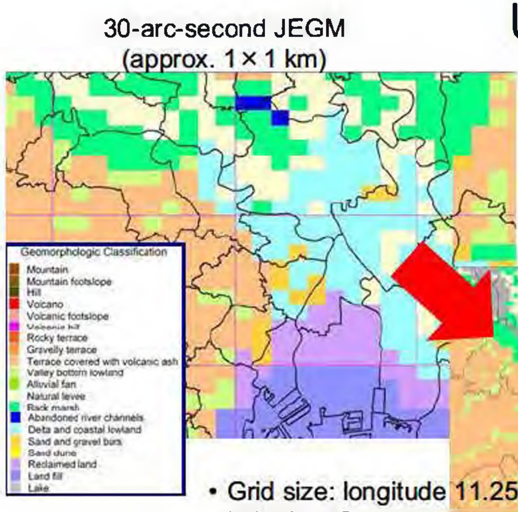
Japan Engineering Geomorphologic Classification Map (JEGM)

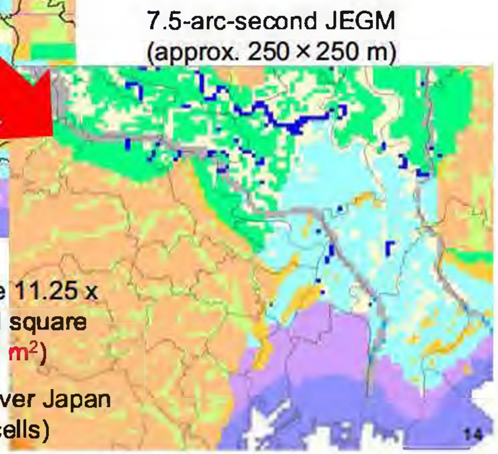
developed by Wakamatsu et al. (2004)

- Attribute: Geomorphologic classification, Surface geology, Slope gradient, and Relative relief
- Grid size: longitude 45 x latitude 30 second square (approx. 1 x 1 km^2)
- Covered area: Allover Japan (approx. 380,000 cells)

13

Upgrading JEGM





- Grid size: longitude 11.25 x latitude 7.5 second square (approx. 250 x 250 m^2)
- Covered area: Allover Japan (approx. 6 million cells)

14

Vs30 and Amplification Mapping Based on DEM and Geomorphology

In order to estimate Vs30 maps with better accuracy, geologic and/or geomorphologic information should be added to use.

Surface geology data derived from GSJ geologic map

7.5-arc-second Geomorphologic classification data

15

Description of Geomorphologic Classification

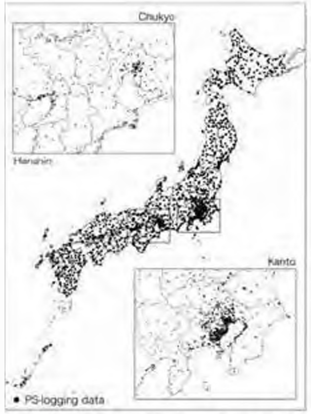
Geomorphologic classification has the information from both geology and topography.

K. Wakamatsu and M. Matsuoka: Development of the 7.5 Arc Second Engineering Geomorphologic Classification Database and its Application to Seismic Microzoning, Bulletin of Earthquake Research Institute, Vol 81, pp 317-324, 2006.

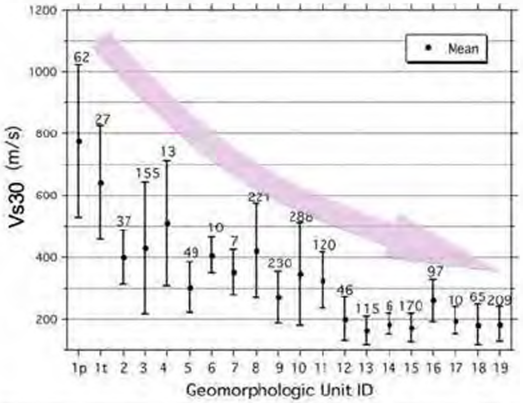
16

2nd SODB WS S3-05-4

Relationship between Vs30 and Geomorphologic Unit



about 2,000 PS-logging data



1p: Mountain(Pre-Tertiary) 1t: Mountain(Tertiary) 2: Mountain footslope 3: Hill 4: Volcano 5: Volcanic footslope 6: Volcanic hill 7: Rocky strath terrace 8: Gravelly terrace 9: Terrace covered with volcanic ash soil 10: Valley bottom lowland 11: Alluvial fan 12: Natural levee 13: Back marsh 14: Abandoned river channels 15: Delta and coastal lowland 16: Marine sand and gravel bars 17: Sand dune 18: Reclaimed land 19: Filled land

17

Estimating Vs30 from Geographic Information

According to the sedimentation process, following indices are considered to estimate Vs30 for each geomorphologic unit.

explanatory valuables:

- Elevation (*Ev*)
- Slope gradient (*Sp*)
- Distance from mountain or hill of pre-Tertiary or Tertiary (*Dm*)

Multiple regression analysis

$$\text{Vs30} \quad a + b \log Ev + c \log Sp + d \log Dm \pm \sigma$$

18

Regression Coefficient for Estimating Vs30

ID	Geomorphologic unit	Regression coefficient (Standard regression coefficient)				s.d.
		a	b	c	d	σ
1p	Mountain (pre-Tertiary)	2.900	0	0	0	0.139
1t	Mountain (Tertiary)	2.807	0	0	0	0.117
2	Mountain footslope	2.602	0	0	0	0.092
3	Hill	2.349	0	0.152 (0.219)	0	0.175
4	Volcano	2.708	0	0	0	0.162
5	Volcanic footslope	2.315	0	0.094 (0.382)	0	0.100
6	Volcanic hill	2.608	0	0	0	0.059
7	Rocky terrace	2.546	0	0	0	0.094
8	Gravelly terrace	2.493	0.072 (0.270)	0.027 (0.101)	-0.164 (-0.336)	0.122
9	Terrace covered with volcanic ash soil	2.206	0.093 (0.269)	0.065 (0.223)	0	0.115
10	Valley bottom lowland	2.266	0.144 (0.447)	0.016 (0.040)	-0.113 (-0.265)	0.158
11	Alluvial fan	2.350	0.085 (0.419)	0.015 (0.059)	0	0.116
12	Natural levee	2.204	0.100 (0.368)	0	0	0.124
13	Back marsh	2.190	0.038 (0.178)	0	-0.041 (-0.152)	0.116
14	Abandoned river channel	2.264	0	0	0	0.091
15	Delta and coastal lowland	2.317	0	0	-0.103 (-0.403)	0.107
16	Sand and gravel bars	2.415	0.000	0	0	0.114
17	Sand dune	2.289	0	0	0	0.123
18	Reclaimed land	2.373	0	0	-0.124 (-0.468)	0.123
19	Filled land	2.404	0	0	-0.139 (-0.418)	0.120

$\log AVS30 = a + b \log Ev + c \log Sp + d \log Dm \pm \sigma$

AVS30: Average S-wave velocity (m/s), *Ev*: Elevation (m), *Sp*: (Tangent of slope) * 1000,

Dm: Distance (km) from mountain or hill of pre-Tertiary or Tertiary

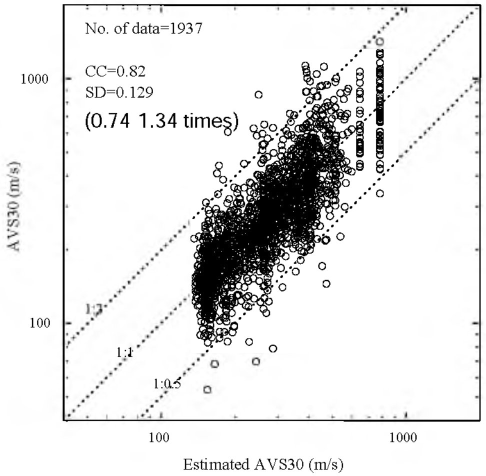
19

Discussion for Regression Coefficient

- What we can generalize from the regression coefficients is that the higher the elevation, the steeper the slope gradient and the shorter the distance from the mountain or hill, Vs30 values become larger.
- In the upstream region of a river (an area at a high altitude with steep slope gradient), the Vs30 becomes larger as the grain size of deposits is larger, and the closer the distance to the mountain or hill, the shallower the depth to a bedrock.
- The trend of the obtained regression coefficient is considered to be consistent with the sedimentary environment of the geomorphologic unit.

20

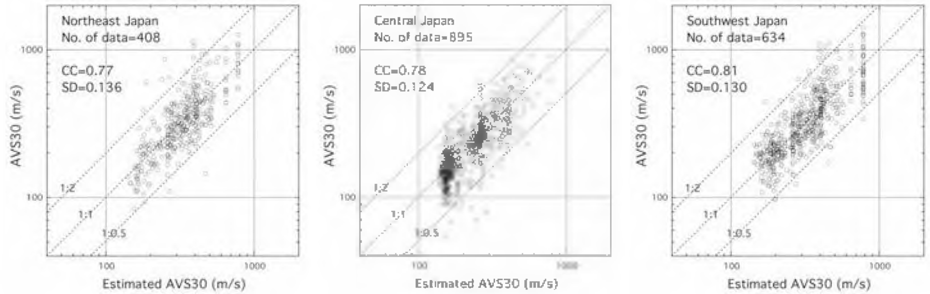
Relationship between Vs30 Estimated by Regression Analysis and Actual Vs30



- Estimation by regression equation improved the estimation accuracy by ±0.129 of logarithmic standard deviation, which shows that Vs30 can be estimated more accurately than by existing empirical formula.

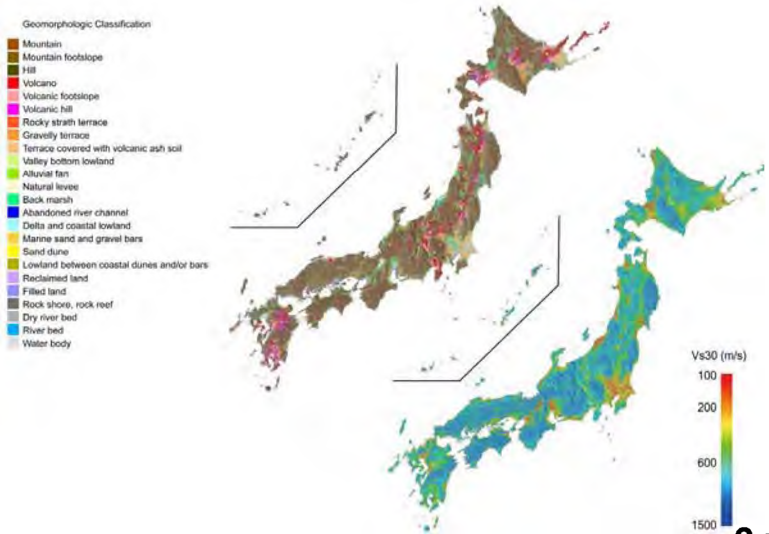
21

Relationship between Estimated Vs30 and Actual Vs30 (comparison by areas)



22

Estimated Vs30 Map Using DEM and Geomorphologic Data



23

Site Amplification Capability Map from Estimated Vs30 Map

PGA:

$$\log Amp = b \log (Vs30 / 600) \pm 0.200$$

$$b = -0.773 \; (\gamma'_{eff} < 3 \times 10^{4})$$
$$= 2.042 + 0.799 \log \gamma'_{eff} \; (\gamma'_{eff} \geq 3 \times 10^{4})$$

$$\gamma'_{eff} = 0.4 \, PGV / Vs30$$

PGV:

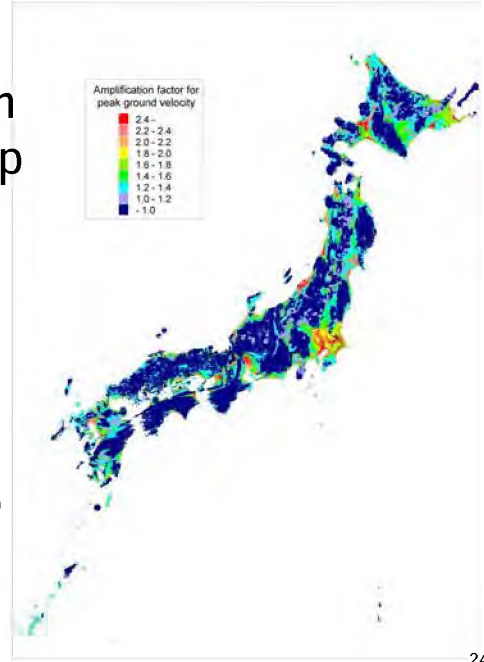
$$\log Amp = 0.852 \log (Vs30 / 600) \pm 0.166$$

(Fujimoto and Midorikawa, 2006)

I_{JMA}:

$$Amp = 3.74 \quad 1.34 \, b \log Vs30 \pm 0.18$$

(Midorikawa et al., 2008)



PGV Amplification Map

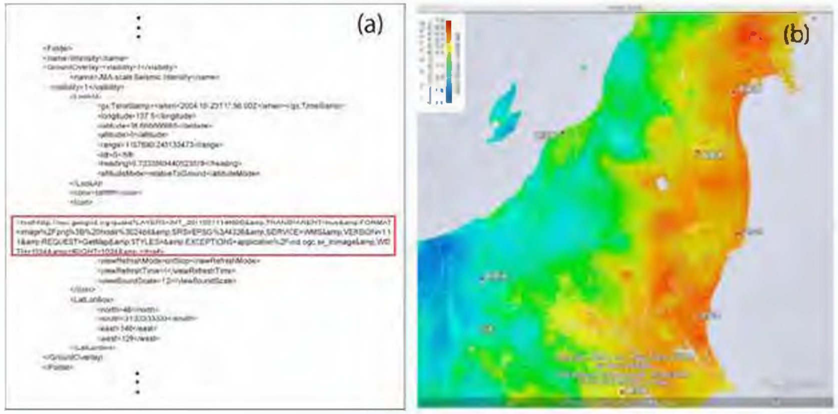
24

Advantages of QuiQuake

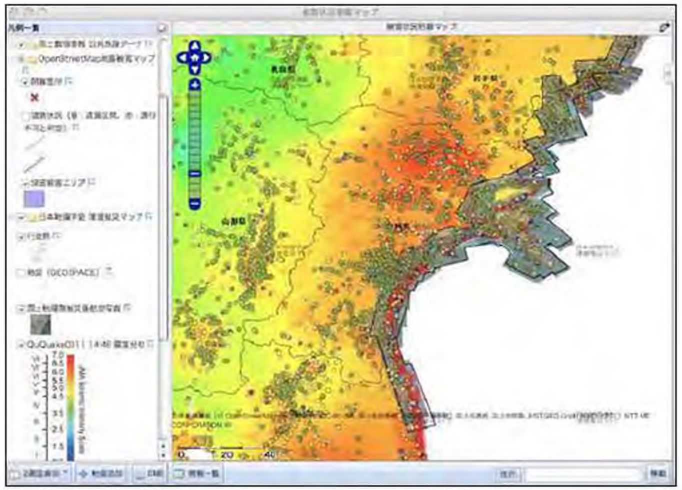
- OGC (Open Geospatial Consortium) standard
  - WMS (Web Map Service)
  - WCS (Web coverage Service)
  - KML
- Automatic and multi-task computation

KML (WMS)

The example of KML document with WMS URI of QuakeMap imagery of the I_{JMA} distribution covering the 2011 Tohoku, Japan earthquake affected area is displayed on Google Earth Red rectangle highlights the inserted WMS URI

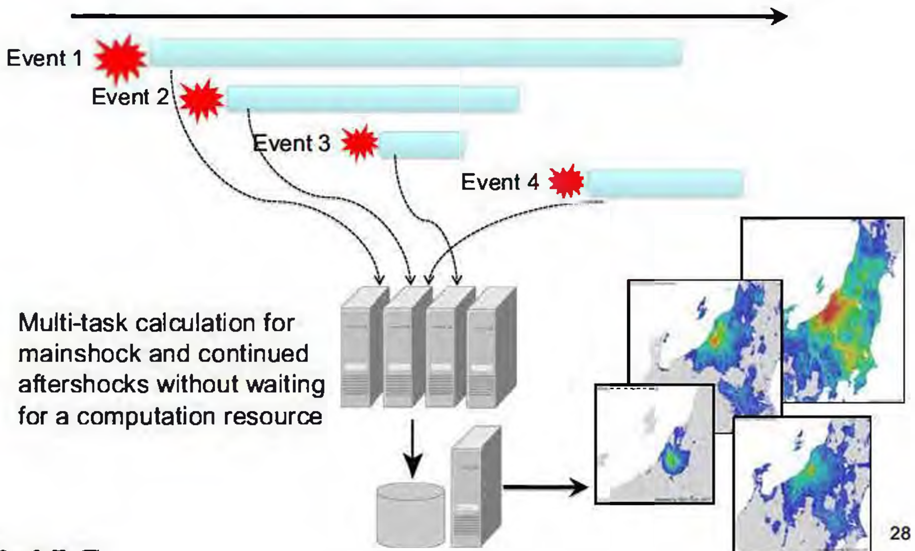


On Other Portal Sites

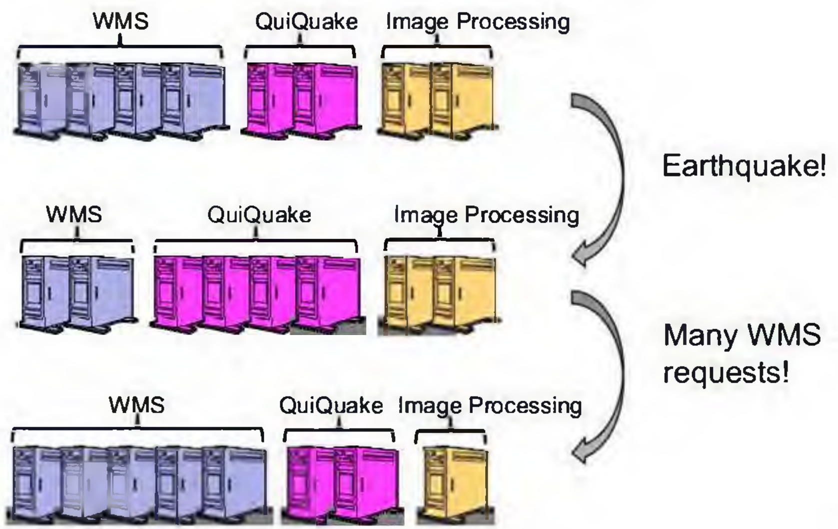


ALL311 activity operated by NIED (http://all311.ecom-plat.jp/) utilizes GEO Grid and other contents through WMS.

Automatic and Multi-task Computation



To Elastic System (Cloud)



29

Conclusions

- The QuiQuake, which provides a 250-m resolution strong ground motion maps covering wide area, for quick disaster response right after an earthquake occurrence throughout Japan, is presented.
- In this system, an amplification capability map of ground motion (Vs30 map) based on Japan Engineering Geomorphologic Classification Map (JEGM) and seismic observation records from K-NET and KiK-net released by the National Research Institute for Earth Science and Disaster Prevention (NIED) are processed on a GEO Grid cluster computer of AIST.
- The use of the GEO Grid system in producing strong ground motion maps offers the following advantages:
  - fully automatic, quick, and multi task computing for mainshock and continued aftershocks,
  - publication of the maps through Open Geospatial Consortium (OGC) compliant Web GIS server, and
  - possibility to expand more stabilized and redundant operations by Virtual Machine in external servers and Cloud system.

30