Amplification Capability and Geomorphologic Classification

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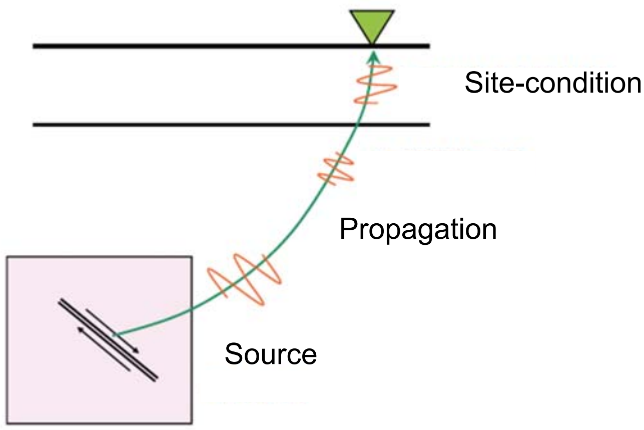
Strong Ground Motion Estimation

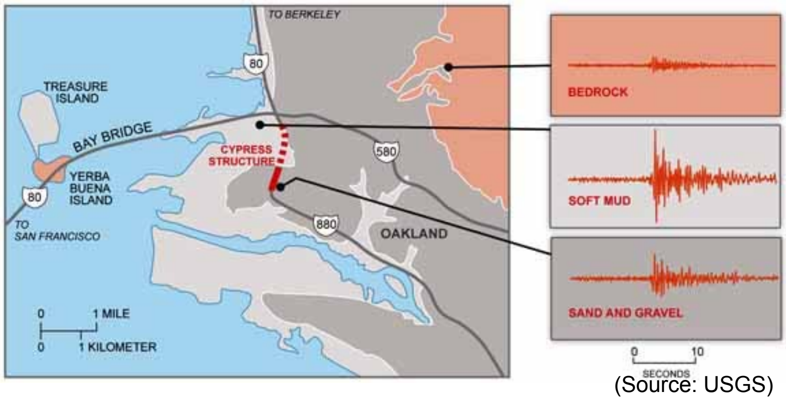
Ground motion = Source x Propagation x Site-condition

Site-condition: amplification, non-linearity, etc.



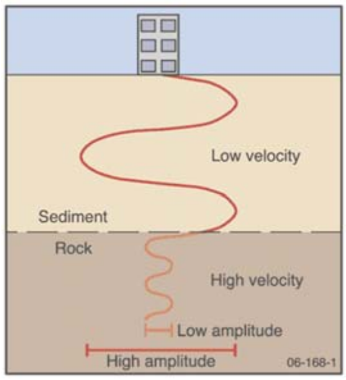
Effect of Soil Condition (Amplification)

- Surface ground motions vary depending on the soil condition.
- For precise estimation of amplification of seismic wave, shear-wave velocity of surface soil is key parameter.



(Source: USGS)

Need: amplification capability map !

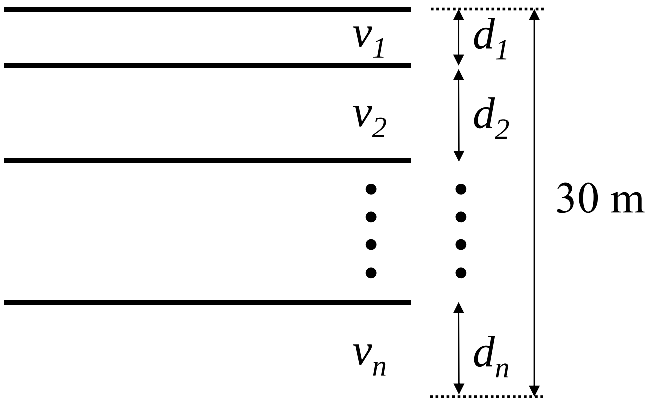


(Source: Geoscience Australia)

Amplification of Surface Soil

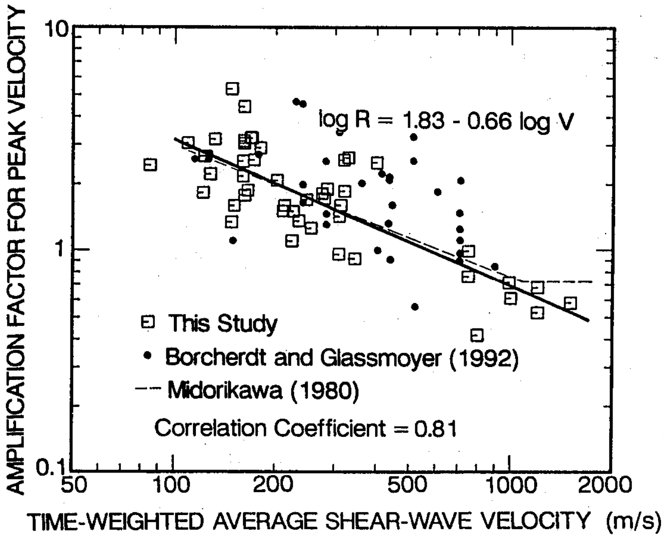
- In preparation for massive earthquakes, it is necessary to obtain appropriate site characteristics of a wide area across administrative districts.
- Approximate estimation of ground amplification is possible only with the shear-wave velocity of the surface layer (Borcherdt and Gibss 1976).
- and the amplification of strong ground motion is correlated with the average shear-wave velocity from the surface to a certain depth (Joyner and Fumal 1984, Midorikawa 1987), such as Vs30 (average shear-wave velocity of ground in the upper 30m depth).
- In the U.S., Vs30 is used for soil classification for seismic code (BSSC 2003).

Time-weighted Average Shear-wave Velocity of Ground（Vs30）



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

Relationship Between Vs30 and Amplification Factor of PGV



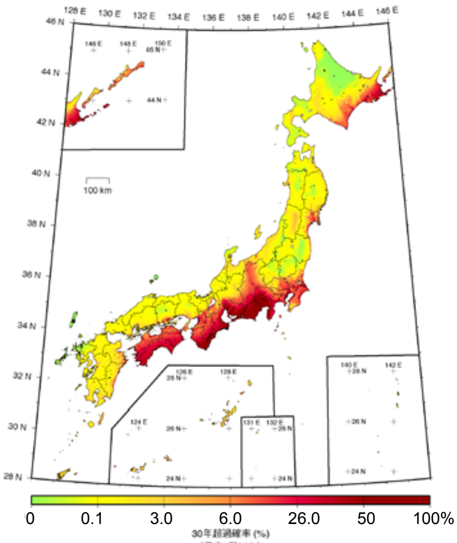
(b) Peak Ground Velocity

S. Midorikawa, M. Matsuoka, and K. Sakugawa: Site effect on string-motion records observed during the 1987 Chiba-ken-toho-oki, Japan earthquake, 9th JEES, Vol. 3, pp.85-90, 1994.

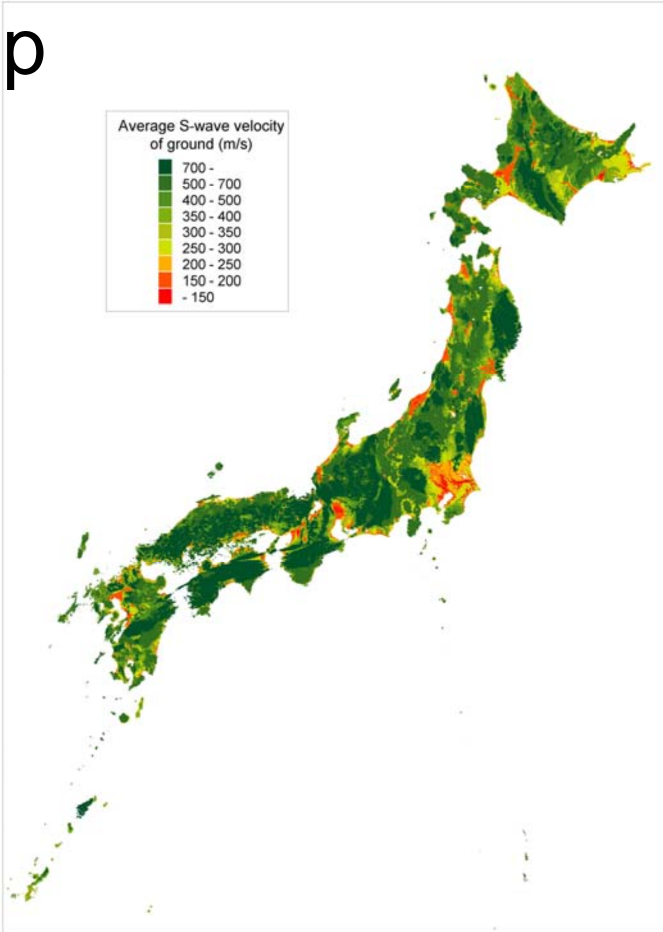
Japan Vs30 Map

Vs30 map is the basic index in terms of the site characteristics by National Seismic Hazard Mapping Project of Japan (NSHMP)

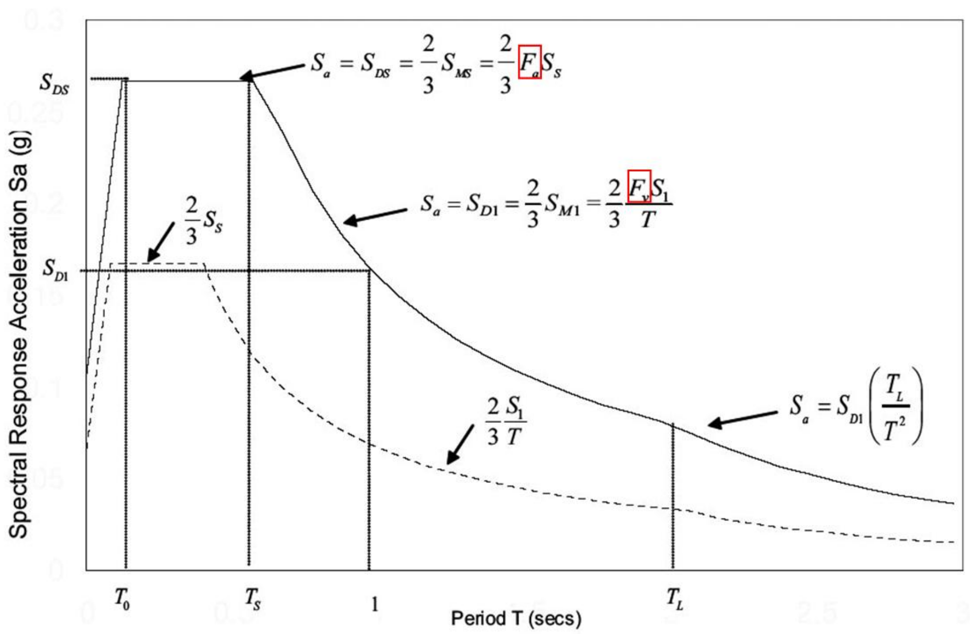
- Probabilistic seismic hazard map
- Scenario earthquake shaking map



Probabilistic seismic hazard map (MEXT)



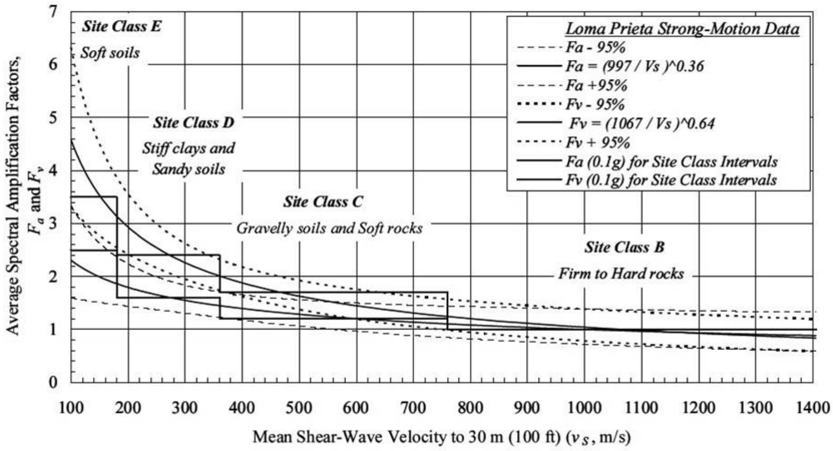
Design Response Spectral Acceleration in U.S. Seismic Code



NEHRP (National Earthquake Hazards Reduction Program) (Borcherdt, 2004)

Site Classification and Spectral Amplification Factor

A Hard rock with measured shear wave velocity, $\bar{v}_s$ > 5,000 ft/sec (1500 m/s).
B Rock with 2,500 ft/sec < $\bar{v}_s$ < 5,000 ft/sec (760 m/s < $\bar{v}_s$ < 1500 m/s),
C Very dense soil and soft rock with 1,200 ft/sec < $\bar{v}_s$ < 2,500 ft/sec (360 m/s < $\bar{v}_s$ < 760 m/s) or with either N > 50 or $\bar{s}_u$ > 2,000 psf (100 kPa),
D Stiff soil with 600 ft/sec < $\bar{v}_s$ < 1,200 ft/sec (180 m/s < $\bar{v}_s$ < 360 m/s) or with either 15 < N < 50 or 1,000 psf < $\bar{s}_u$ < 2,000 psf (50 kPa < $\bar{s}_u$ < 100 kPa)
E A soil profile with $\bar{v}_s$ < 600 ft/sec (180 m/s) or with either N < 15, $\bar{s}_u$ < 1,000 psf, or any profile with more than 10 ft (3 m) of soft clay defined as soil with PI > 20, $w \geq$ 40 percent, and $\bar{s}_u$ < 500 psf (25 kPa),



NEHRP (National Earthquake Hazards Reduction Program) (Borcherdt, 2004)

Simplified Approach to Estimate Vs30 for Wider Areas

- DEM → Vs30 (Allen and Wald 2007)
- DEM + Geomorphology → Vs30 (Matsuoka et al. 2006)

↑ (Jeong et al. 2006)

DEM

Geomorphology: combined index of geology and topography

Topographic Slope as a Proxy for Seismic Site-condition (Vs30) and Amplification by USGS

Why slope used:

Slope of topography, or gradient, should be diagnostic of Vs30, since more competent (high-velocity) materials are more likely to maintain a steep slope, whereas deep basin sediments are deposited primarily in environments with very low gradients. Furthermore, sediment fineness, itself a proxy for lower shear velocity (Park and Elrick, 1998), should relate to slope. For example, steep,coarse, mountain-front alluvial fan material typically grades to finer deposits with distance from the mountain front and is deposited at decreasing slopes by less energetic fluvial and pluvial processes.

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Topographic Slope as a Proxy for Seismic Site-condition (Vs30) and Amplification by USGS

Active tectonic regions | Stable continental regions

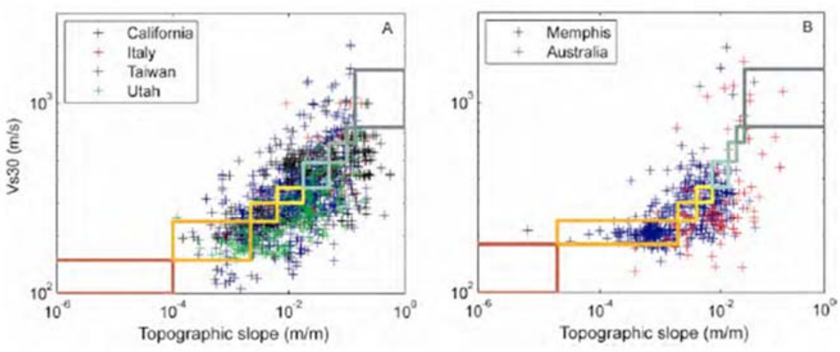


Figure 2. Correlations of measured V_S^{30} (m/s) versus topographic slope (m/m) for *A*, active tectonic, and *B*, stable continental regions. Color-coded polygons represent V_S^{30} and slope ranges consistent with ranges given in table 2 and also consistent with the V_S^{30} legends for all geologic- and topographic-based maps throughout this paper.

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Topographic Slope as a Proxy for Seismic Site-condition (vs30) and Amplification by USGS

Table 2. Summary of slope ranges for subdivided NEHRP V_S^{30} categories.

Class	V_s^{30} range (m/s)	Slope range (m/m) – (active tectonic)	Slope range (m/m) – (stable continent)
E	<180	<1.0E-4	<2.0E-5
	180–240	1.0E-4–2.2E-3	2.0E-5–2.0E-3
D	240–300	2.2E-3–6.3E-3	2.0E-3–4.0E-3
	300–360	6.3E-3–0.018	4.0E-3–7.2E-3
	360–490	0.018–0.050	7.2E-3–0.013
C	490–620	0.050–0.10	0.013–0.018
	620–760	0.10–0.138	0.018–0.025
B	>760	>0.138	>0.025

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Vs30 Maps Comparison by USGS

San Francisco Bay Area, California, USA

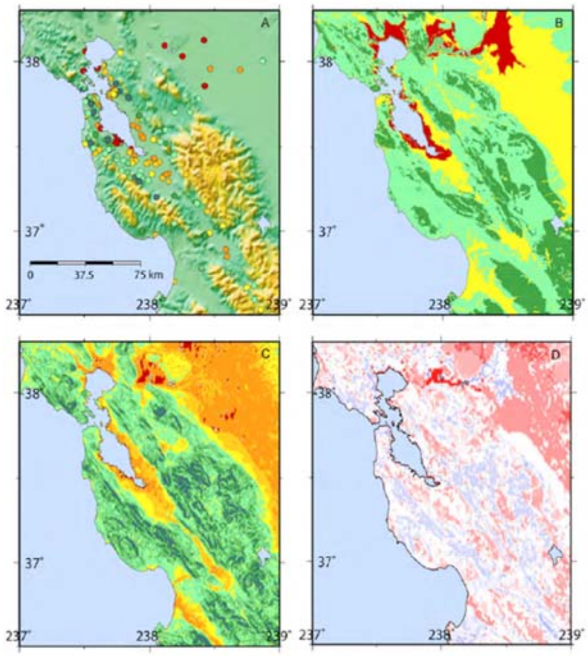
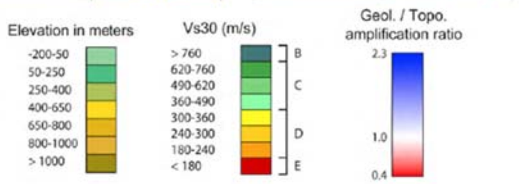


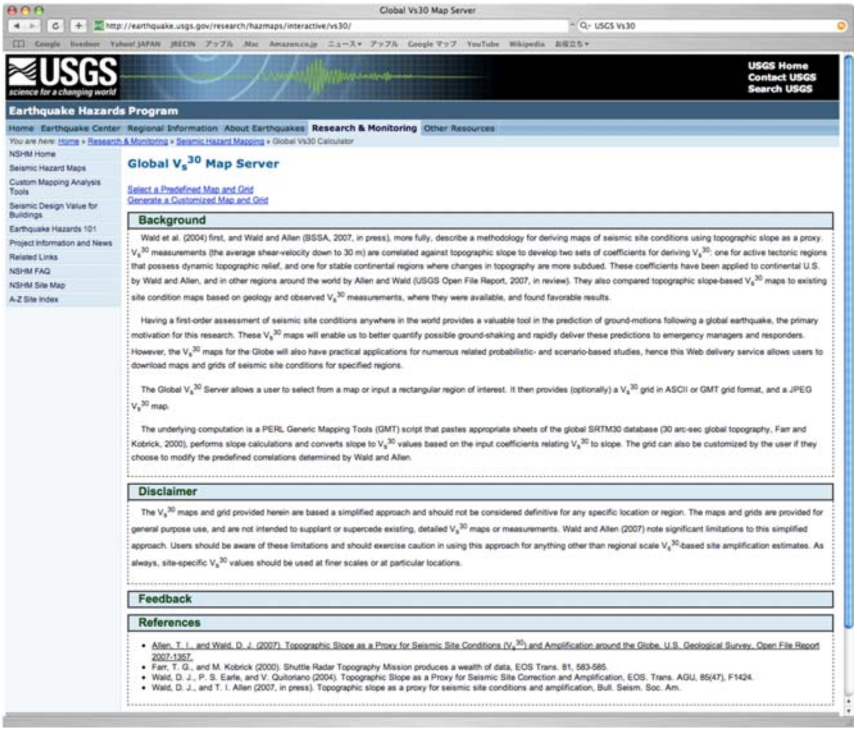
Figure 4. *A*, Topographic map of the San Francisco Bay Area. Circles indicate the location of measurements, color-coded by V_S^{30} in m/s (see left legend). *B*, Site-condition map based on geology and V_S^{30} observations (modified from Wills and others, 2000). *C*, Site-condition map derived from topographic slope. *D*, The ratio of the predicted amplification for a uniform PGA of 250 cm/s² for the geologically- and topographically-based V_S^{30} maps. Blues indicate that the Wills and others (2000) map predicts higher amplification, whereas reds indicate higher amplifications are predicted from the topographically-based map. White indicated where the two V_S^{30} maps predict the same amplification.



T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Vs30 and Amplification Mapping Around the Globe Using SRTM30 Data by USGS

STRM30: Shuttle Radar Topography Mission 30-arc-second (approx. 1km grid) DEM



Global Vs30 Map Server

http://earthquake.usgs.gov/research/hazmaps/interactive/vs30/

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NSHM Site Map
A-Z Site Index

Global V_s^{30} Map Server

Select a Predefined Map and Grid
Generate a Customized Map and Grid

Background

Wald et al. (2004) first, and Wald and Allen (BSSA, 2007, in press), more fully, describe a methodology for deriving maps of seismic site conditions using topographic slope as a proxy. V_s^{30} measurements (the average shear-velocity down to 30 m) are correlated against topographic slope to develop two sets of coefficients for deriving V_s^{30}: one for active tectonic regions that possess dynamic topographic relief, and one for stable continental regions where changes in topography are more subdued. These coefficients have been applied to continental U.S. by Wald and Allen, and in other regions around the world by Allen and Wald (USGS Open File Report, 2007, in review). They also compared topographic slope-based V_s^{30} maps to existing site condition maps based on geology and observed V_s^{30} measurements, where they were available, and found favorable results.

Having a first-order assessment of seismic site conditions anywhere in the world provides a valuable tool in the prediction of ground-motions following a global earthquake, the primary motivation for this research. These V_s^{30} maps will enable us to better quantify possible ground-shaking and rapidly deliver these predictions to emergency managers and responders. However, the V_s^{30} maps for the Globe will also have practical applications for numerous related probabilistic- and scenario-based studies, hence this Web delivery service allows users to download maps and grids of seismic site conditions for specified regions.

The Global V_s^{30} Server allows a user to select from a map or input a rectangular region of interest. It then provides (optionally) a V_s^{30} grid in ASCII or GMT grid format, and a JPEG V_s^{30} map.

The underlying computation is a PERL Generic Mapping Tools (GMT) script that pastes appropriate sheets of the global SRTM30 database (30 arc-sec global topography, Farr and Kobrick, 2000), performs slope calculations and converts slope to V_s^{30} values based on the input coefficients relating V_s^{30} to slope. The grid can also be customized by the user if they choose to modify the predefined correlations determined by Wald and Allen.

Disclaimer

The V_s^{30} maps and grid provided herein are based a simplified approach and should not be considered definitive for any specific location or region. The maps and grids are provided for general purpose use, and are not intended to supplant or supercede existing, detailed V_s^{30} maps or measurements. Wald and Allen (2007) note significant limitations to this simplified approach. Users should be aware of these limitations and should exercise caution in using this approach for anything other than regional scale V_s^{30}-based site amplification estimates. As always, site-specific V_s^{30} values should be used at finer scales or at particular locations.

Feedback

References

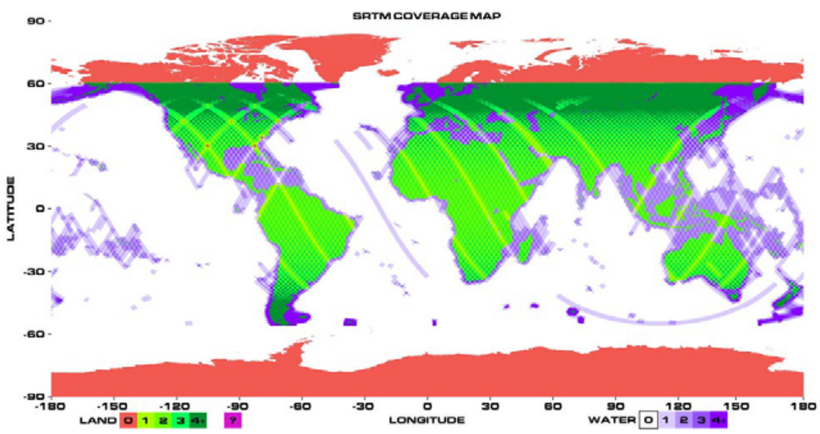
- Allen, T. I., and Wald, D. J. (2007). Topographic Slope as a Proxy for Seismic Site Conditions (V_s^{30}) and Amplification around the Globe, U.S. Geological Survey, Open File Report 2007-1357.
- Farr, T. G., and M. Kobrick (2000). Shuttle Radar Topography Mission produces a wealth of data, EOS Trans. 81, 583-585.
- Wald, D. J., P. S. Earle, and V. Quitoriano (2004). Topographic Slope as a Proxy for Seismic Site Correction and Amplification, EOS. Trans. AGU, 85(47), F1424.
- Wald, D. J., and T. I. Allen (2007, in press). Topographic slope as a proxy for seismic site conditions and amplification, Bull. Seism. Soc. Am.

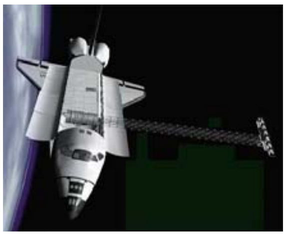
http://earthquake.usgs.gov/research/hazmaps/interactive/vs30/

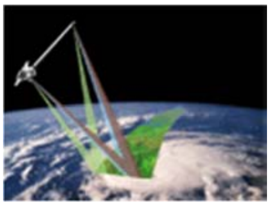
SRTM (Shuttle Radar Topography Mission)

On February 11, 2000, the Shuttle Radar Topography Mission (SRTM) payload onboard Space Shuttle Endeavour launched into space. With its radars sweeping most of the Earth's surfaces, SRTM acquired enough data during its ten days of operation to obtain the most complete near-global high-resolution database of the Earth's topography.

The Shuttle Radar Topography Mission maps 80% of the Earth's terrain at 30 meter resolution.







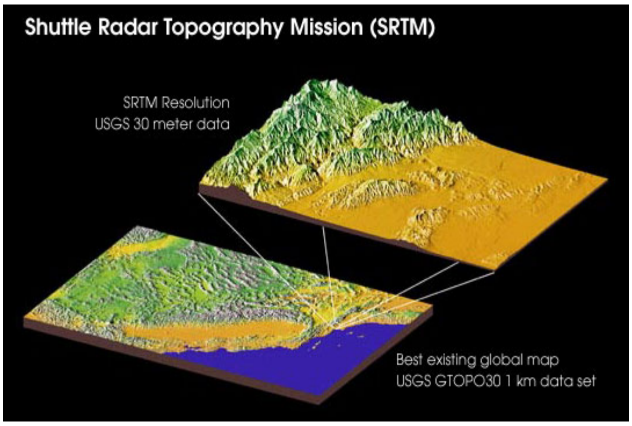
http://www2.jpl.nasa.gov/srtm/

SRTM Data

1-arc-second (about 30 meter) SRTM data postings of the continental United States can now be obtained via the USGS EDC Seamless Distribution System.

As new 3-arc-second (about 90 meter) international continental datasets are processed and received, USGS will distribute this data via the Seamless Data Distribution System.

SRTM30 is aggregated data to 30-arc-second (about 1km)

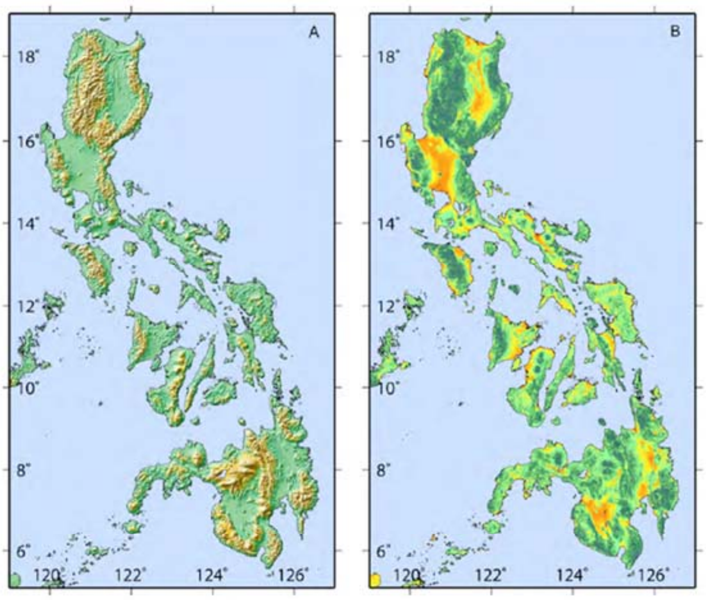


http://visibleearth.nasa.gov/cgi-bin/viewrecord?500

http://srtm.usgs.gov/

Vs30 and Amplification Mapping Using SRTM30 DEM by USGS

The Philippines



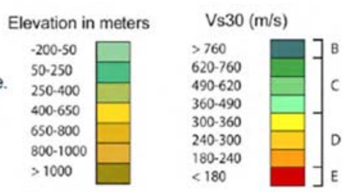


Figure 26. A, Topographic map of the Philippines. B, Site-condition map derived from topographic slope.

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Vs30 and Amplification Mapping Using SRTM30 DEM by USGS

Indonesia

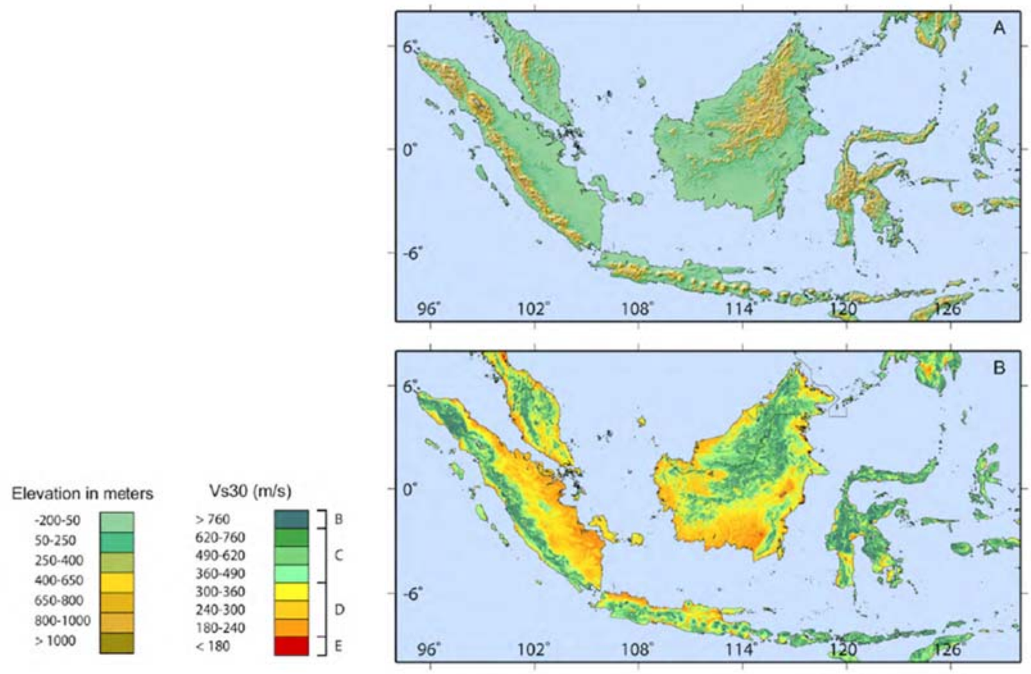


Figure 15. *A*, Topographic map of Indonesia. *B*, Site-condition map derived from topographic slope.

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Vs30 Estimation Accuracy by USGS

Based on Californian Vs30 data set, the logarithmic standard deviation (log std) of estimation is 0.15 (approx. 0.7 - 1.4 times)

The estimation accuracy depends on the areas, 0.19, 0.22, 0.21, 0.19 in log std for Italy, Japan, Turkey, Australia, respectively.

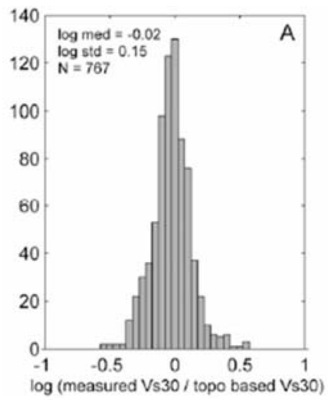


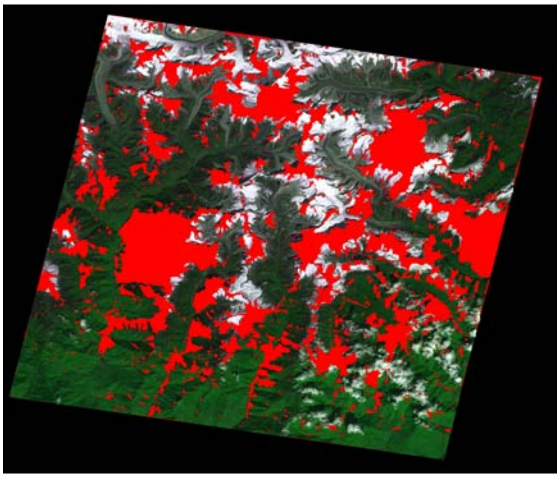
Figure 3. Histograms indicating logarithmic differences of measured Californian V_S^{30} values compared with *A*, values derived from topographic slope correlations

T. Allen and D. Wald: Open-file Report 2007-1357, USGS.

Problem of SRTM Data

- Comparison between SRTM and ASTER -

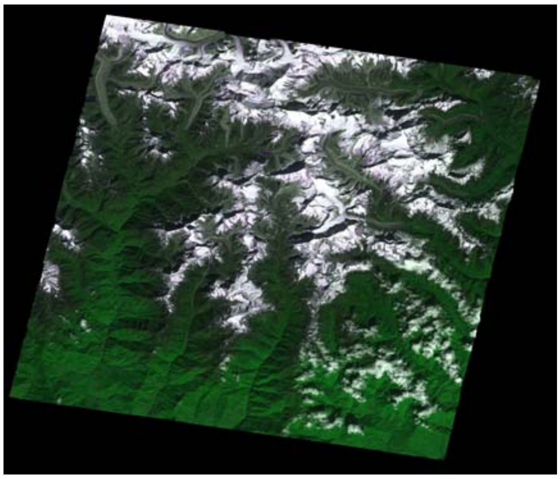
SRTM3



Spatial resolution = 90m

No data in red areas

ASTER



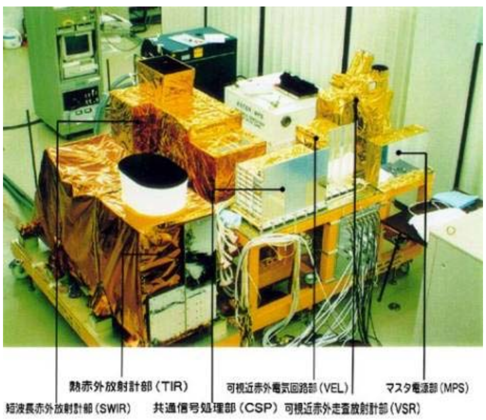
Spatial resolution = 15 m

ASTER

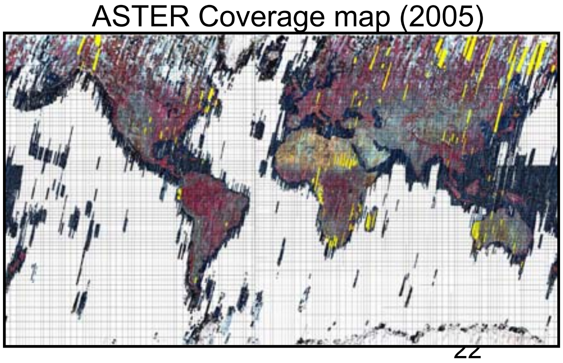
<u>A</u>dvanced <u>S</u>paceborne <u>T</u>hermal <u>E</u>mission and <u>R</u>eflection radiometer

ASTER

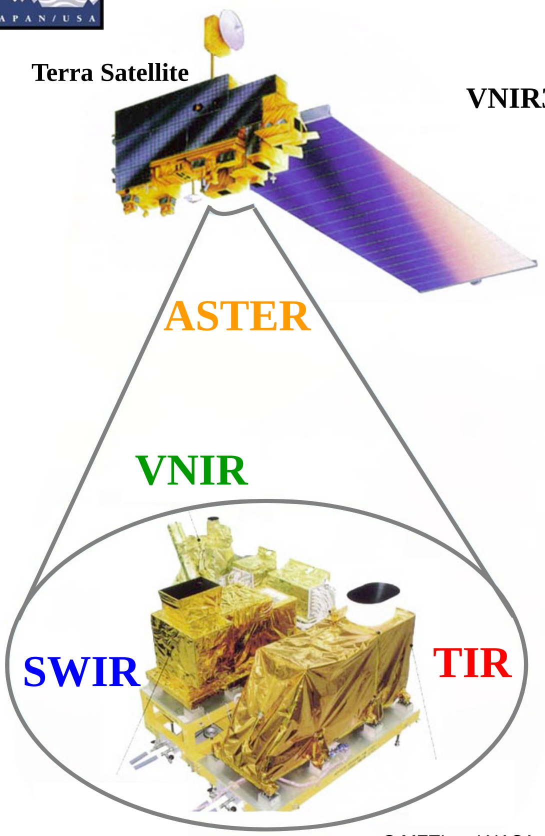
- Onboard Terra satellite (NASA) launched in December 1999
- Designed and developed for mineral resource exploration
- 14 spectral bands in visible to thermal infrared region
- Stereo camera to generate a Digital Elevation Model (DEM)
- Covers most of the lands (>1.7 million scenes)

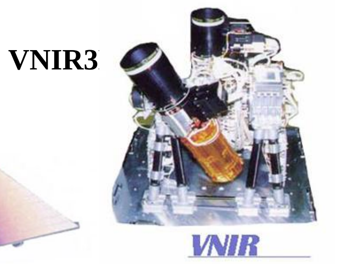


ASTER Coverage map (2005)



ASTER Sensor





VNIR

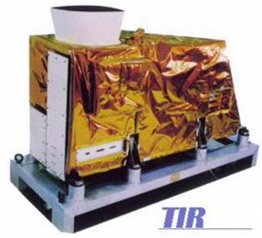
Visible Near Infrared Radiometer

Spectral Range: 3 Bands
0.52 - 0.86 μm
Spatial Resolution: 15 m
Cross Track Pointing: ±24°

SWIR

Short Wave Infrared Radiometer

Spectral Range: 6 Bands
1.60 - 2.43 μm
Spatial Resolution: 30 m
Cross Track Pointing: ±8.55°

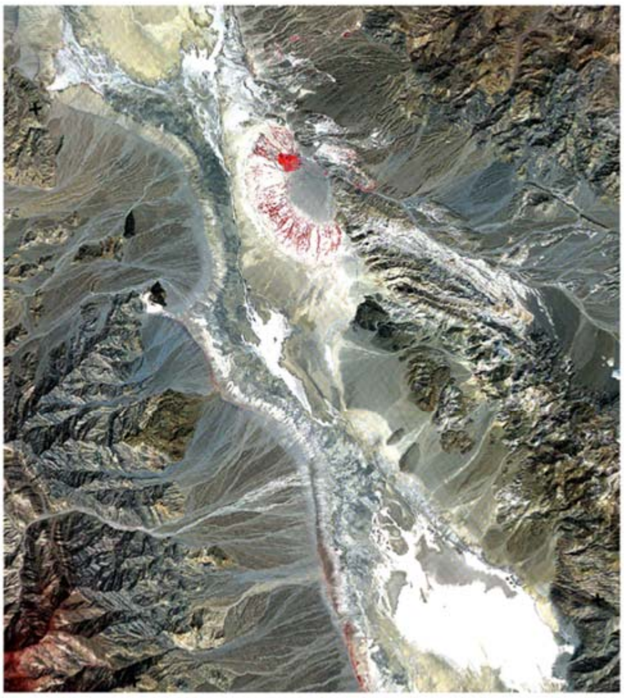


TIR

Thermal Infrared Radiometer

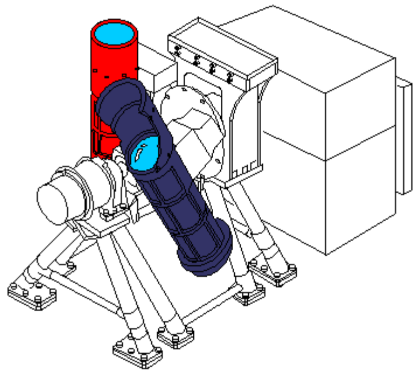
Spectral Range: 5 Bands
8.125 -11.65 μm
Spatial Resolution: 90 m
Cross Track Pointing: ±8.55°

VNIR (Visible Near Infrared)



Death Valley
Path 40, Row 100,
01 October 2000

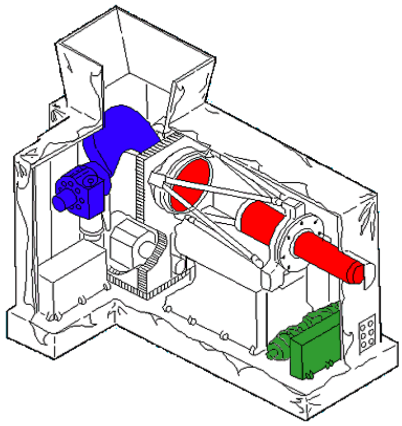
ASTER band 3
ASTER band 2
ASTER band 1



バンド	波長帯（μm）	地上分解能
1	0. 52–0. 60	15m
2	0. 63–0. 69	15m
3N	0. 76–0. 86	15m
3B	0. 76–0. 86	15m

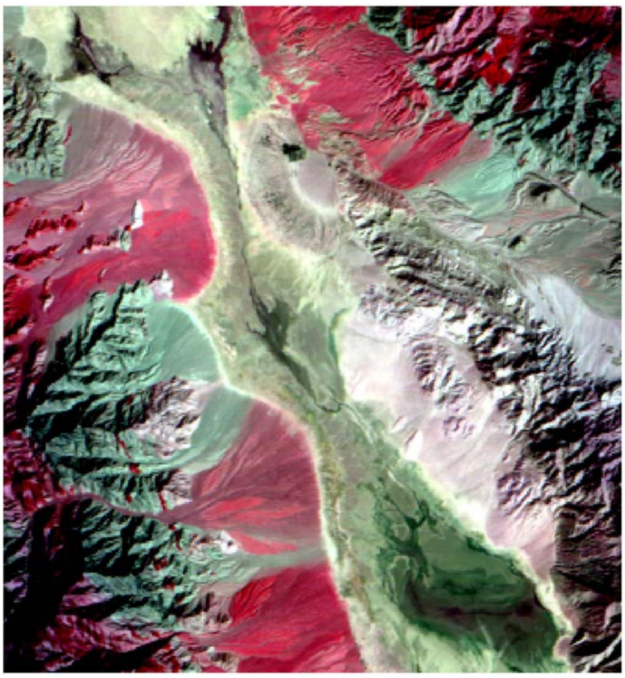
SWIR (Short Wavelength Infrared)

Death Valley
Path 40, Row 100,
01 October 2000

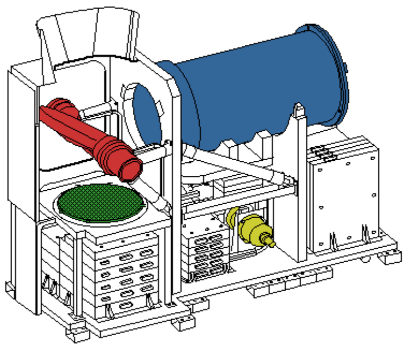


バンド	波長帯(μm)	地表分解能
4	1.600～1.70	30m
5	2.145～2.18	30m
6	2.185～2.22	30m
7	2.235～2.28	30m
8	2.295～2.36	30m
9	2.360～2.43	30m

TIR (Thermal Infrared)

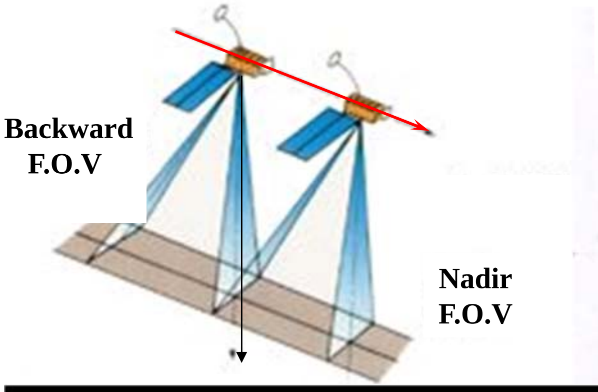


Death Valley
Path 40, Row 100,
01 October 2000

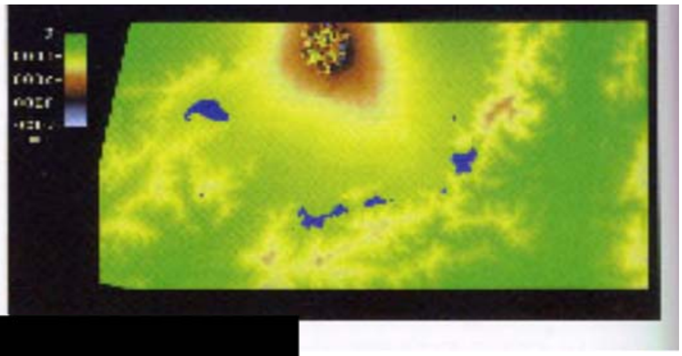


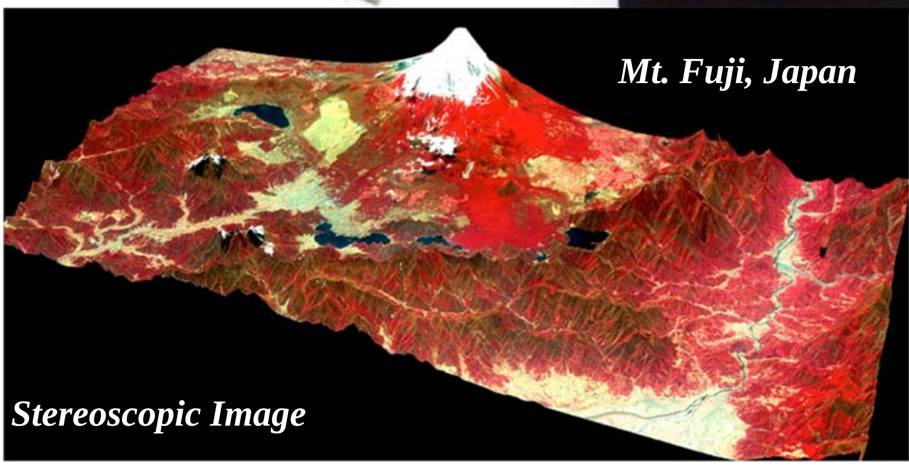
バンド	波長帯(μm)	地表分解能
10	8.125～8.475	90m
11	8.475～8.825	90m
12	8.925～9.275	90m
13	10.25～10.95	90m
14	10.95～11.65	90m

Stereoscopic Image VNIR 3B/3N



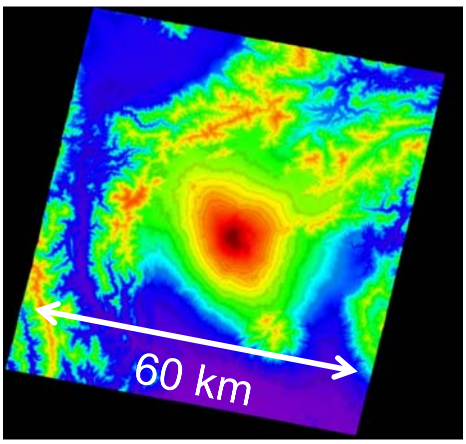
DEM **(Digital Elevation Model)**



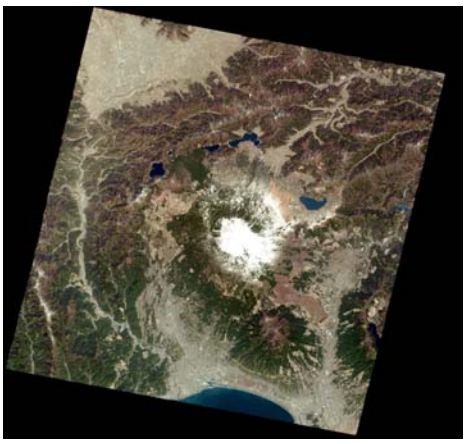


ASTER Digital Elevation Model (DEM) and Orthorectified Image

DEM/Ortho image
- Spatial resolution of 15 m (originally)
- Projected on a map coordinate

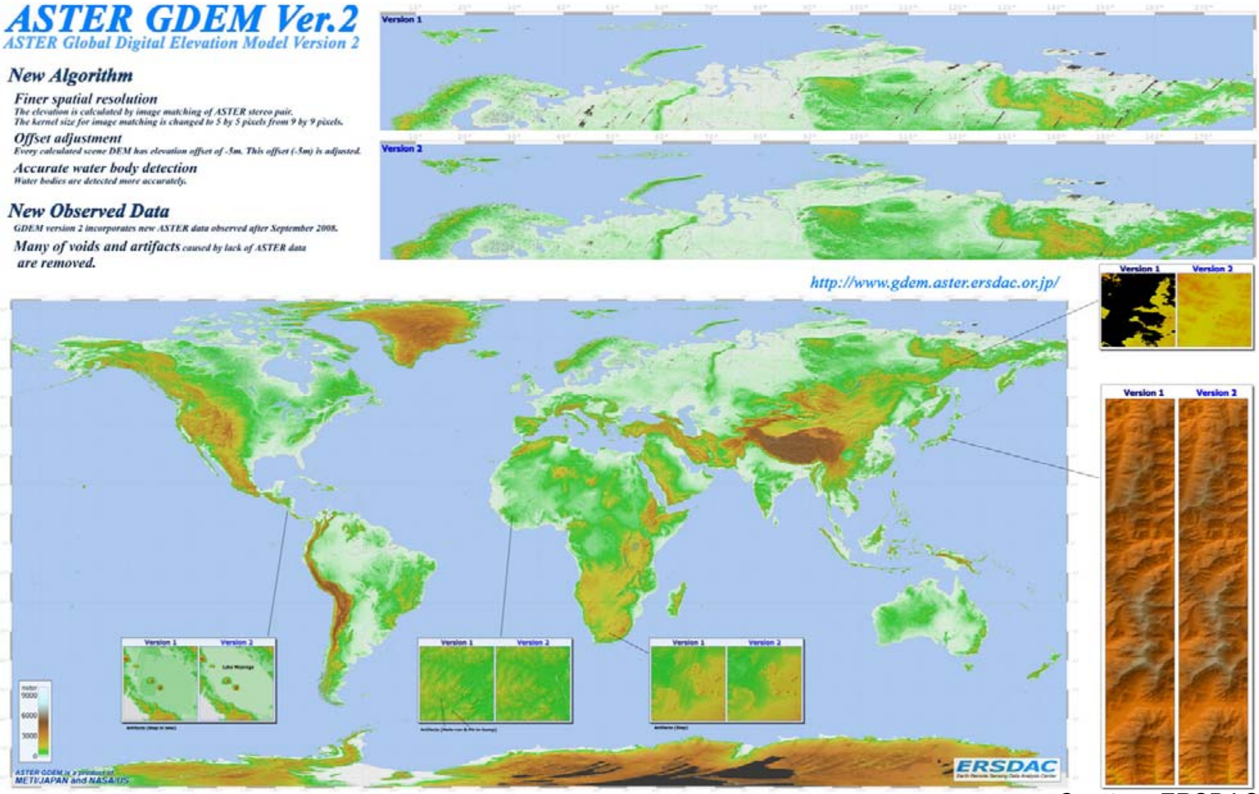


DEM



Ortho image(VNIR)

Global 30m resolution Digital Elevation Model from ASTER (by ERSDAC/USGS)
New version just released (**October 17, 2011**)

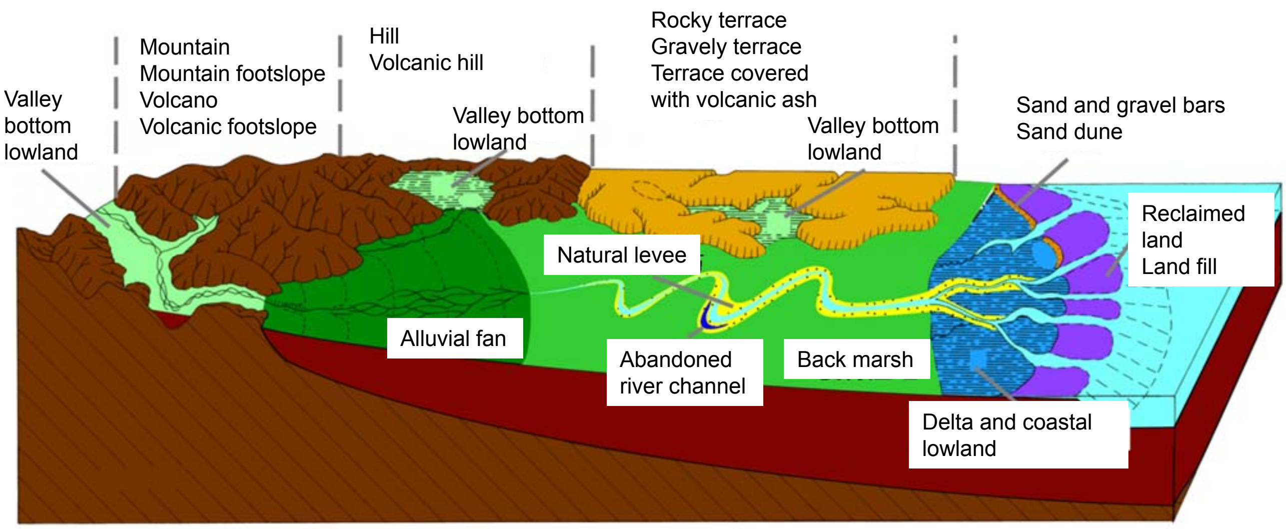


Courtesy ERSDAC

Geomorphologic Classification for Seismic Site-condition (Vs30) and Amplification Estimation

- Good correlation with building damage
- More appropriate index than slope of topography to estimate soil condition and Vs30
- In addition, the classification was previously found to correlate well with data on storm-surge-induced flood zones, tsunami-induced flood zones, and susceptibility to soil liquefaction.

Schematic Figure of Geomorphologic Units



Geomorphologic units formed by rivers and sea currents

Suzuki (1997), Kokonshoin

Geomorphologic Classification

The geomorphologic classification is eventually employed as a major attribute of the map, as this classification system is known to analyze and classify the land into units based on physical characteristics of the land, i.e., aspects of:

relief (height, slope form, slope steepness, and rate of dissection);

geomorphic processes (degradational, erosional, and mixed denudationalerosional);

Geomorphologic Classification

(*cont.*)

rock characteristics (igneous, metamorphic and sedimentary rocks, and their structures);

soil characteristics (depth, nutrient and humus content, texture, stoniness, rockiness, and drainage);

and hydrologic characteristics (surface water, ground water, and water
quality)

Coastal Geomorphologic Units

Sand bar

Suzuki (1997), Kokonshoin

Sand dune

Homepage of Tottori pref.

Difference in Sedimentation Process

Sand and gravel bars

sedimentation by coastal current

(compaction of dynamic loading by ocean wave)

↓

sand and gravel, N>15~20

Sand dune

sedimentation by wind

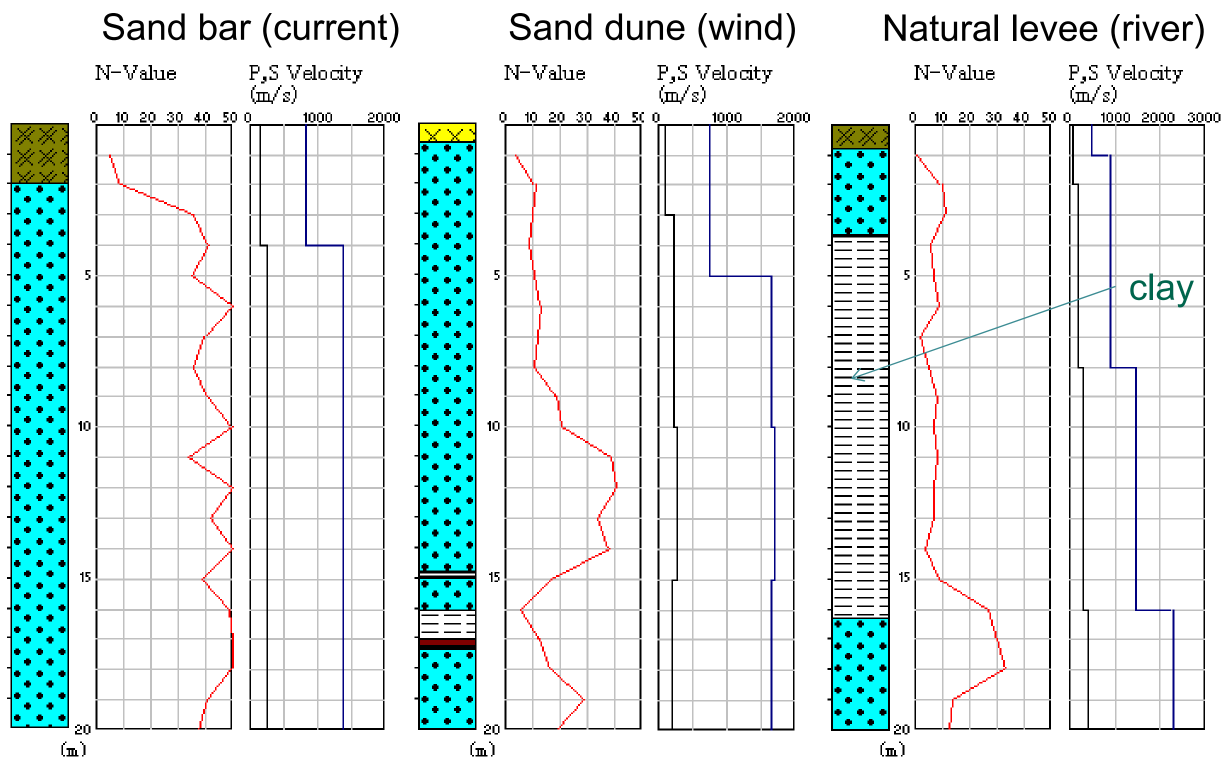
(deposits accumulate loosely)

↓

finer sand, N＜10

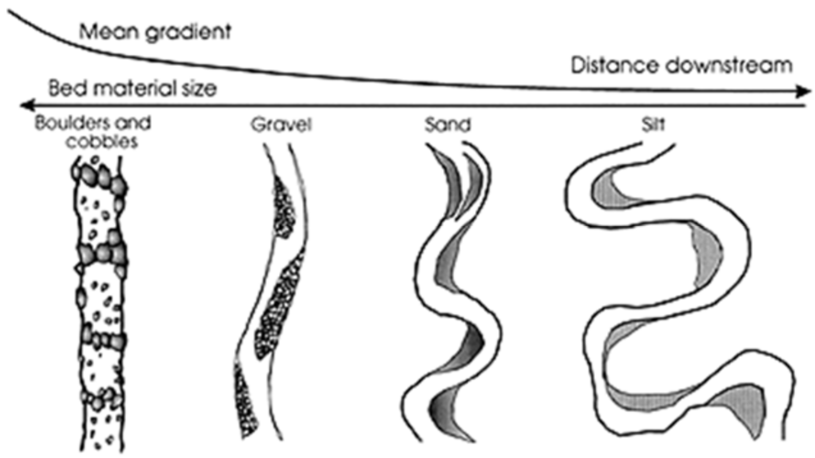
Profiles of Sandy Ground

SPT N-value and shear-wave velocity vary depending on geomorphologic unit



Sediment Transport

Beds of headwater streams usually contain large particles such as gravel and boulders that are too heavy for the stream to move. Downstream, the size of particles decreases, as large rocks are broken and worn down, and smaller particles such as finer sands and silts are sorted out, carried off and eventually deposited in the river's delta.



Church, M. 1992. Channel Morphology and Typology

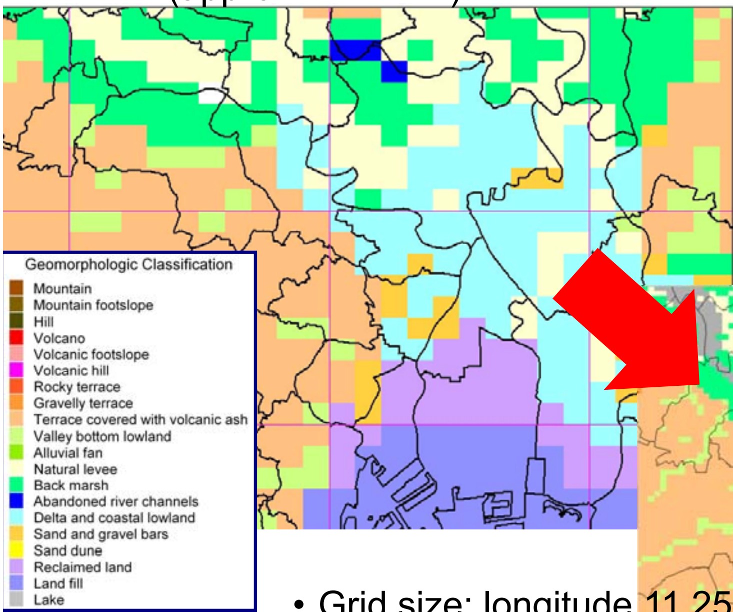
Japan Engineering Geomorphologic Classification Map (JEGM)

developed by Wakamatsu et al. (2004)

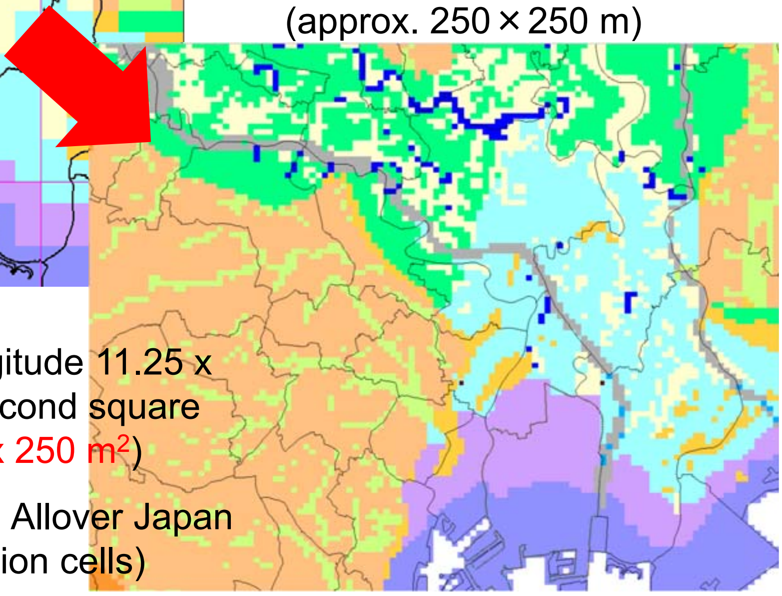
- Attribute: Geomorphologic classification, Surface geology, Slope gradient, and Relative relief
- Grid size: longitude 45 x latitude 30 second square (approx. 1 x 1 km^2)
- Covered area: Allover Japan (approx. 380,000 cells)

Upgrading JEGM

30-arc-second JEGM
(approx. 1×1 km)



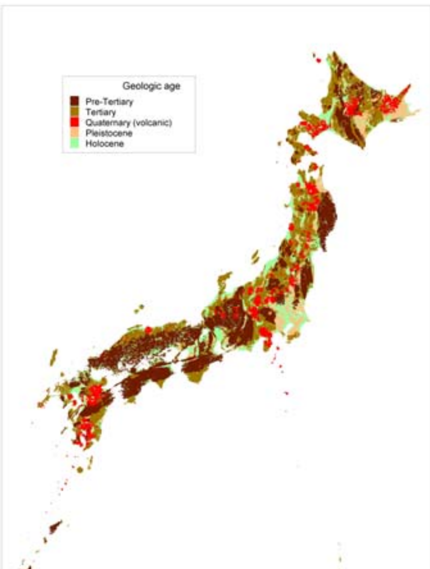
7.5-arc-second JEGM
(approx. 250×250 m)



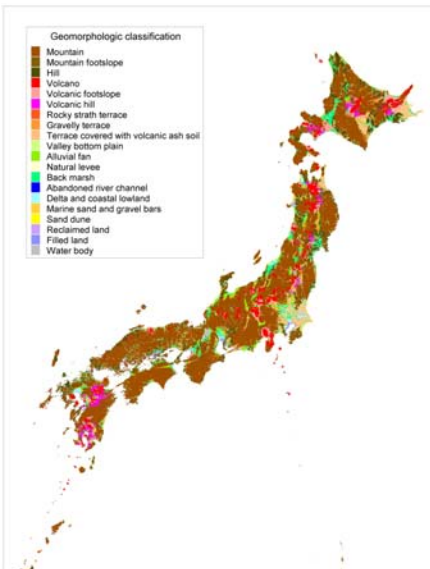
- Grid size: longitude 11.25 x latitude 7.5 second square (approx. 250 x 250 m^2)
- Covered area: Allover Japan (approx. 6 million cells)

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

Description of Geomorphologic Classification

Geomorphologic classification has the information from both geology and topography.

Geomorphologic map unit	Definition and general characteristics	Subsurface soil condition	General depth of groundwater*
Mountain	Steeply to very steeply sloping topography with highest elevation and relative relief within a grid cell of approximately more than 200 m. Moderately to severely dissected.	Pre-Quaternary hard to soft rock.	Deep
Mountain footslope	Gently sloping topography adjoining mountains and comprised of material sourced from the mountains such as colluvium, talus, landslide and debris flow deposits.	Loose debris and soils consisting of colluvium, talus, landslide, and debris flow deposits.	Deep
Hill	Steeply to moderately sloping topography with higher elevation and relative relief within a grid cell of approximately 200 m or less. Moderately dissected.	Pre- Quaternary and Quaternary hard to soft rock.	Deep
Volcano	Steeply to moderately sloping topography with higher elevation and larger relative relief, comprised of Quaternary volcanic rocks and deposits.	Quaternary hard to soft volcanic rock and/or deposits.	Deep
Volcanic footslope	Gently sloping topography located around skirt of volcano including pyroclastic-, mud- and lava-flow fields, and volcanic fan produced by dissection of volcanic body. Slightly dissected.	Quaternary loose to dense volcanic deposits consisting of ash, scoria, pumice, pyroclastic flow, lava, debris avalanche, etc.	Deep
Volcanic hill	Moderately sloping topography comprised of pyroclastic flow deposits. Moderately to severely dissected.	Loose to moderately loose pyroclastic flow deposits such as ash, scoria and pumice.	Deep
Rocky strath terrace	Fluvial or marine terrace with flat surface and step-like form, including limestone terrace of emerged coral reef. Thickness of subsurface soil deposits is less than 5 m.	Hard to soft rock.	Deep
Gravelly terrace	Fluvial or marine terrace with flat surface and step-like form. Covered with subsurface deposits (gravel or sandy soils) of more than 5 m in thickness.	Dense gravelly soil.	Deep
Terrace covered with volcanic ash soil	Fluvial or marine terrace with flat surface and step-like form. Covered with cohesive volcanic ash soil of more than 5 m in thickness.	Stiff volcanic ash (cohesive soil).	Deep
Valley bottom plain	Long and narrow lowland formed by river or stream between steep to extremely steep slopes of mountain, hill, volcano and terrace.	Moderately dense to dense gravel or boulder in mountain, but loose sandy soil to very soft cohesive soil in plain.	Shallow
Alluvial fan	Semi-cone-like form comprised of coarse materials, which is formed at boundary between mountains and lowland. Slope gradient is more than 1/1000.	Dense gravel with boulders to moderately dense sandy gravel.	Deep in the central part of fan but shallow in the distal part of fan
Natural levee	Slightly elevated area formed along the riverbank by fluvial deposition during floods.	Loose sandy soil.	Shallow
Back marsh	Swampy lowland formed behind natural levees, dunes or bars and lowlands surrounded by mountains, hills and terraces.	Very soft cohesive soil containing peat or humus.	Very shallow
Abandoned river channels	Swampy shallow depression along former river course with elongate shape.	Very loose sandy soil occasionally covered with soft cohesive soil.	Very shallow
Delta and coastal lowland	Delta: flat lowland formed at the river mouth by fluvial accumulation. Coastal lowland: flat lowland formed along shoreline by emergence of shallow submarine deposits, including discontinuous lowlands along sea- or lake- shore.	Loose fluvial sandy soil over-lying very soft cohesive soil.	Shallow
Marine sand and gravel bars	Slightly elevated topography formed along shoreline, comprised of sand and gravel, which was washed ashore by ocean wave and/or current action.	Moderately dense to dense marine sand or gravel occasionally with boulder.	Shallow
Sand dune	Wavy topography usually formed along shoreline or river, comprised of fine to moderately aeolian sand, generally overlies sandy lowland.	Very loose to loose fine to medium sand.	Deep at crest of dune but shallow near base of dune
Reclaimed land	Former bottom land adjoining sea, lake, lagoon, and river that has been reclaimed as land by drainage.	Loose sand overlying very soft cohesive soil, sometimes covered with loose sandy fill.	Very shallow
Filled land	Former water body such as sea, lake, lagoon, and river reclaimed as land by filling.	Very loose to loose sandy fill, overlying very soft cohesive soil or loose sandy soils.	Very shallow to shallow

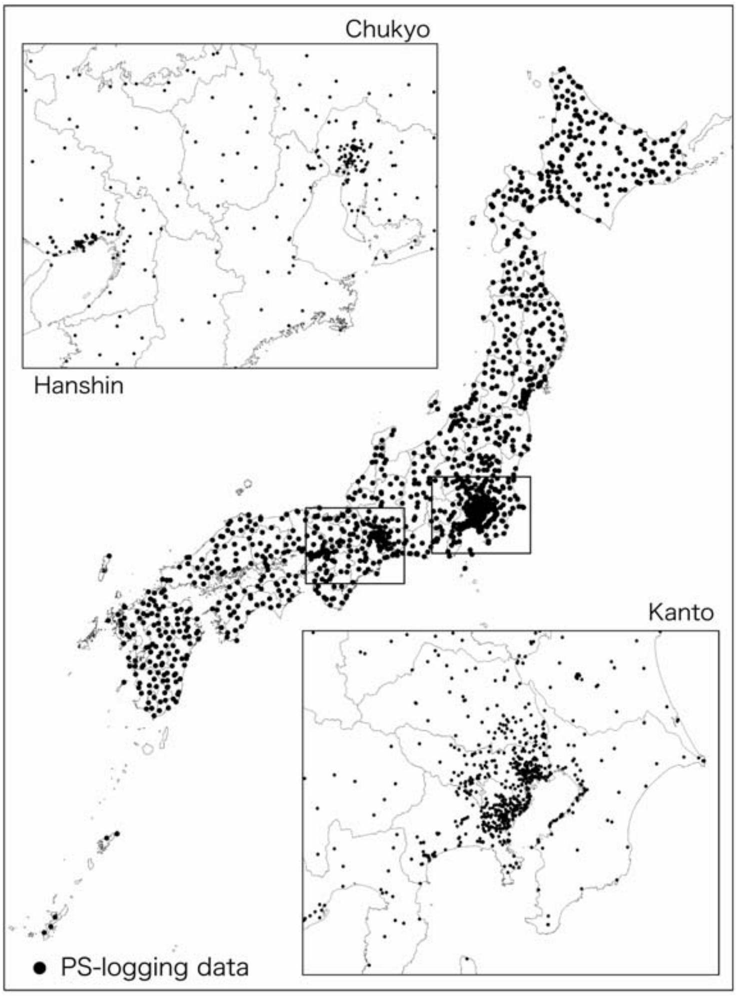
*Deep: deeper than 3 m below the ground surface, Shallow: within 3 m of the ground surface, Very shallow: within 1 m of the

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, 2006.12.

Distribution of Vs30 Sites

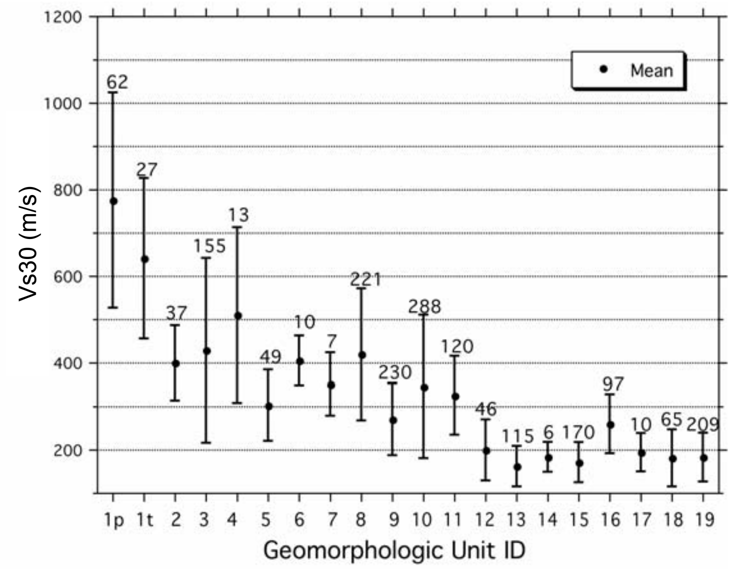
K-data 1001 → 509 sites
H-data 495 → 435 sites
Y-data 150 → 87 sites
M-data 539 → 425 sites
F-data 71 → 66 sites
T-data 650 → 415 sites

Total 1937 sites



M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

Vs30 vs. Geomorphologic Unit

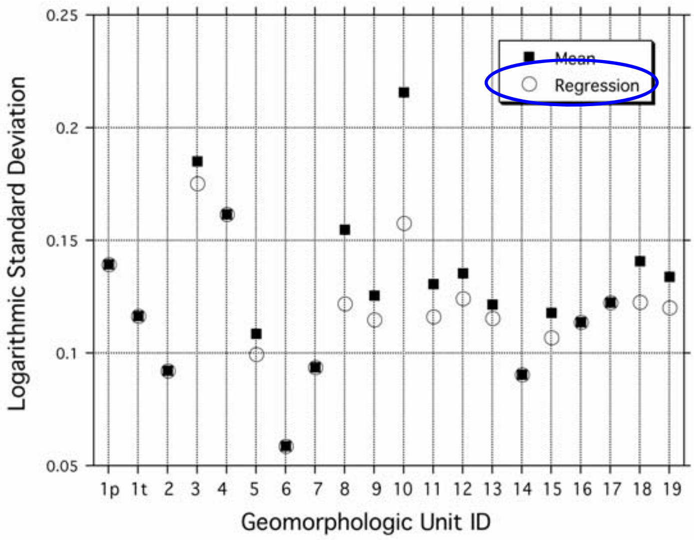


1p: Mountain(Pre-Tertiary) 1t: Mountain(Tertiary) 2: Mountain footslope
3: Hill 4: Volcano 5: Volcanic terrace 6: Volcanic hill 7: Rocky terrace
8: Gravelly terrace 9: Terrace covered with volcanic ash soil
10: Valley bottom lowland 11: Alluvial fan 12: Natural levee
13: Back marsh 14: Abandoned river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

- In general, the higher the altitude, the larger the Vs30 value becomes.
- The order of Vs30 almost corresponds to the grain size of deposits that forms each geomorphologic unit, (gravel > sand > clay).

M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

Vs30 Estimation Accuracy by Geomorphologic Unit



1p: Mountain(Pre-Tertiary) 1t: Mountain(Tertiary) 2: Mountain footslope
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13: Back marsh 14: Abandoned river channel 15: Delta and coastal lowland
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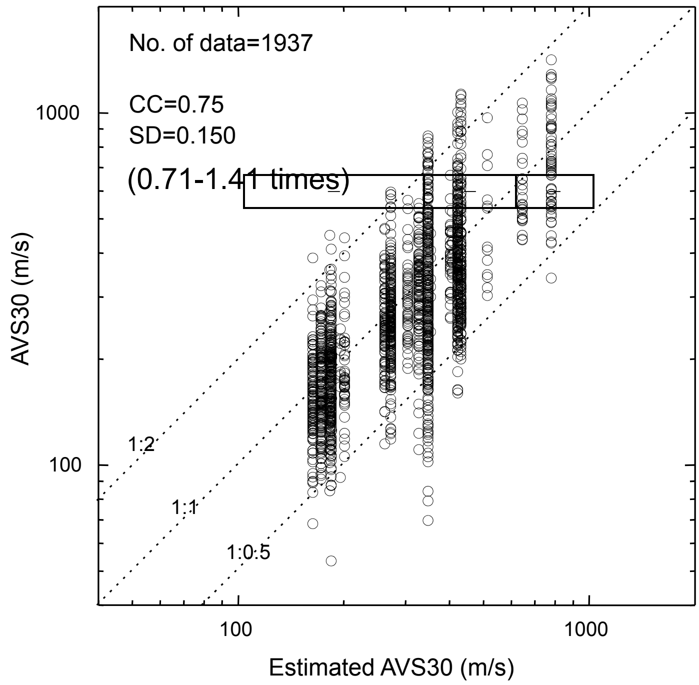
- Estimating using mean values by geomorphologic units, dispersion of valley bottom plain is especially large, with ±0.22 of logarithmic standard deviation.

- Therefore, we need to take geographic conditions other than the geomorphologic unit into consideration.

M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

Relationship between Mean Value of AVS300 by Geomorphologic Unit and Actual AVS30



M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

Estimating Vs30 from Geographic Information

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

- Elevation (Ev)
- Distance from major river (Dr)
- Distance from coastline (Dc)
- Slope gradient (Sp)
- Distance from mountain or hill of pre-Tertiary or Tertiary (Dm)

explanatory valuables

↓

Multiple regression analysis

Regression Equation and 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

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

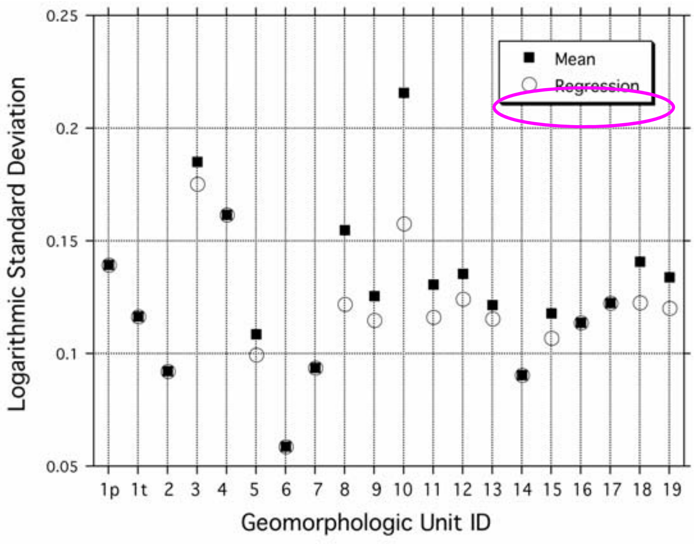
AVS30: Average S-wave velocity (m/s), *Ev*: Elevation (m), *Sp*: (Tangent of slope) * 1000, *Dm*: Distance (km) from mountain or hill of pre-Tertiary or Tertiary

M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

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.

Vs30 Estimation Accuracy by Geomorphologic Unit



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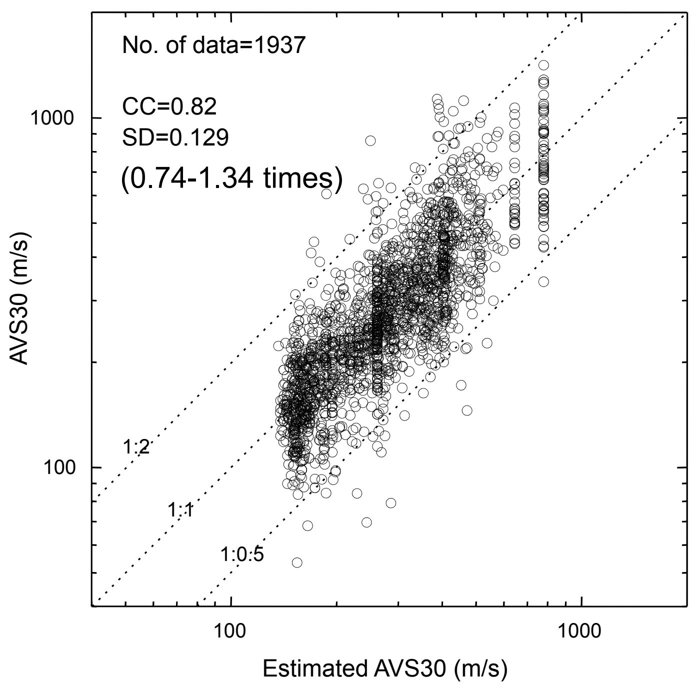
10: Valley bottom lowland 11: Alluvial fan 12: Natural levee
13: Back marsh 14: Abandoned river channel 15: Delta and coastal lowland
16: Sand and gravel bars 17: Sand dune 18: Reclaimed land 19: Filled land

- Use of a regression equation significantly improve Vs30 estimation accuracy for valley bottom plain, and other geomorphologic units also show smaller dispersion.

M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

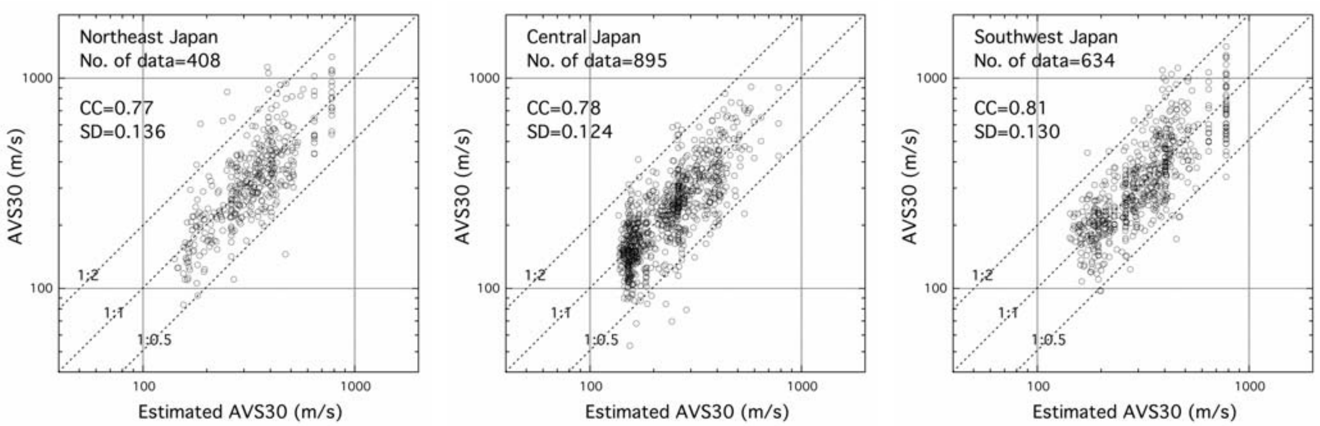
Relationship between Vs30 Estimated by Regression Analysis and Actual Vs30



- 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.

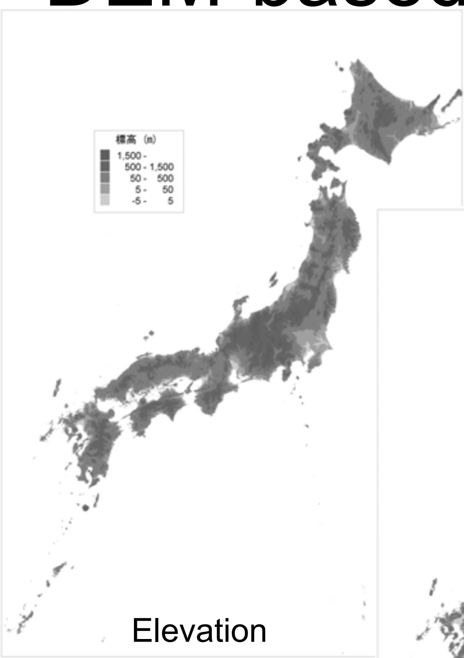
M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

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



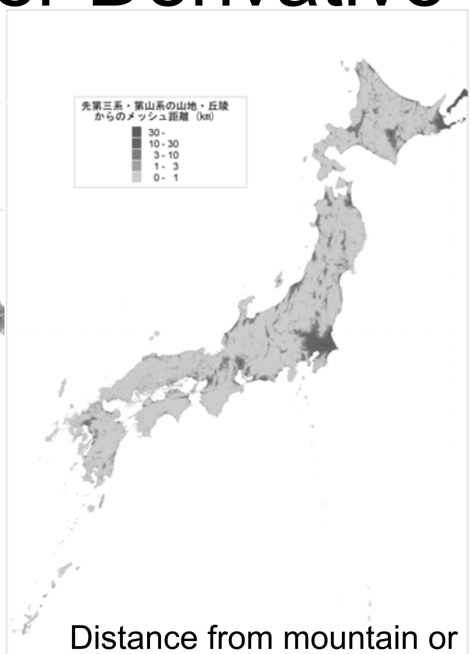
M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

DEM-based and Other Derivative Data set



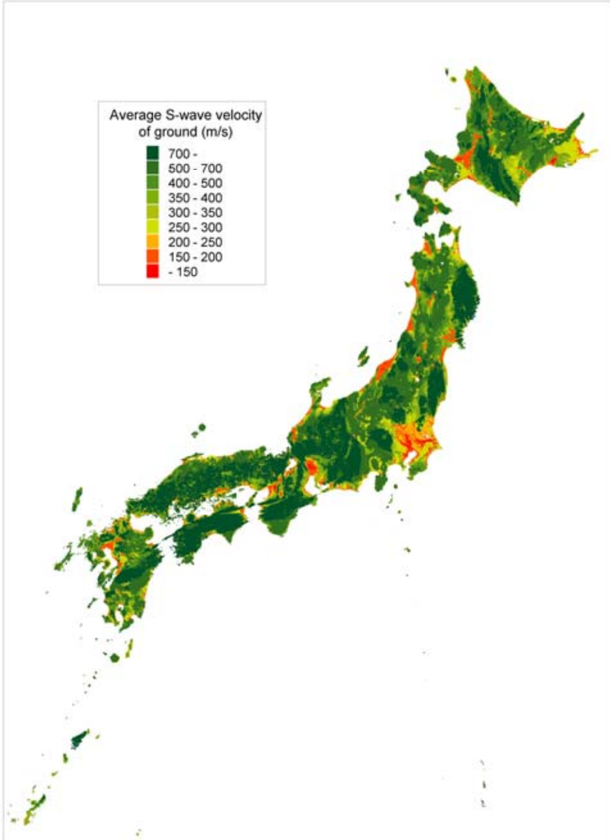
Elevation

Slope



Distance from mountain or hill of Pre-Tertiary or Tertiary

Estimated Vs30 Map Using DEM and Geomorphologic Data



M. Matsuoka et al.: Average Shear-wave Velocity Mapping Using Japan Engineering Geomorphologic Classification Map, Journal of Structural Engineering and Earthquake Engineering, Japan Society of Civil Engineers, Vol.23, No.1, pp.57s-68s, 2006.4.

Site Amplification Capability Map from Estimated Vs30 Map

(Fujimoto and Midorikawa, 2006)

PGA:

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

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

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

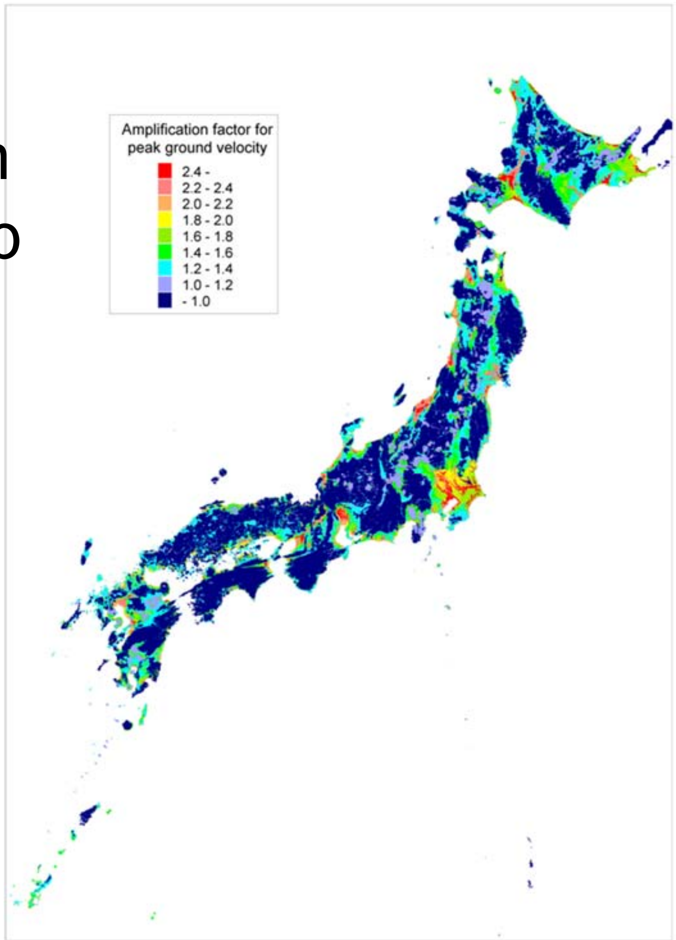
PGV:

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

(Midorikawa et al., 2008)

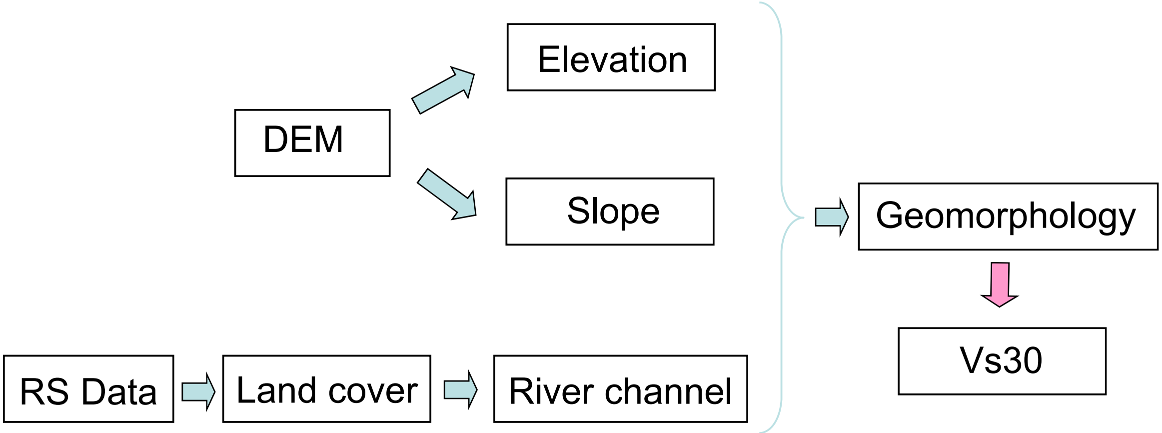
I_{JMA}:

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



PGV Amplification Map

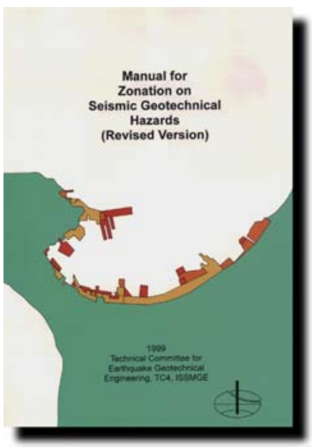
Geomorphologic Map Creation from DEM



B. Jeong et al. :A Study on Classification of Landform Using Remote Sensing and its Application to Earthquake Damage Estimation - a classification of landform using SRTM-3 for estimation of site amplification factors -, Asia Conference on Earthquake Engineering, pp.1-14, CD-ROM, 2006.

Liquefaction Susceptibility Evaluation from Geomorphologic Information and DEM

Susceptibility of detailed geomorphologic units to liquefaction subjected to ground motion of the J.M.A. intensity V or M.M.S. VIII (Wakamatsu, 1992)



by Technical Committee for Earthquake Geotechnical Engineering, TC4, International Society for Soil Mechanics and Geotechnical Engineering

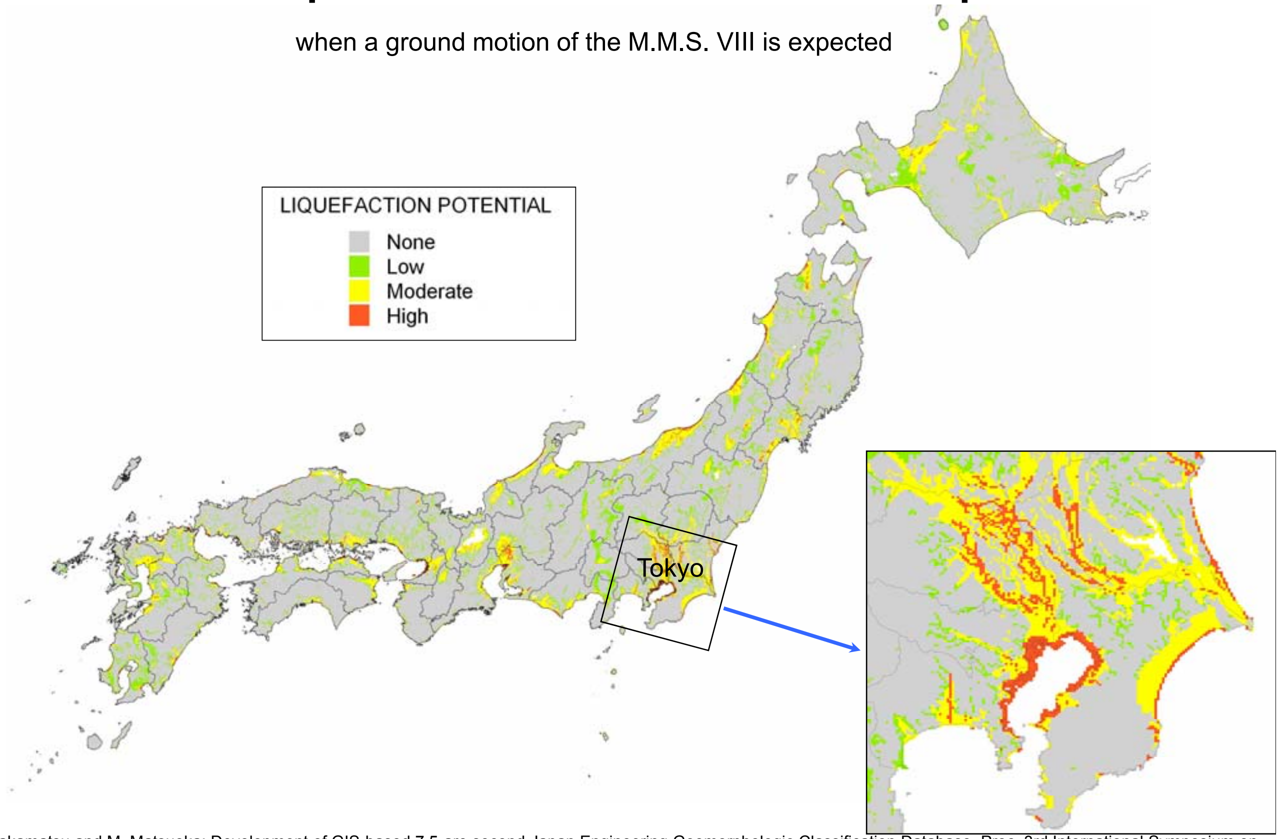
Geomorphologic conditions		Specific conditions
Classification	Specific conditions	
Valley plain	Valley plain consisting of gravel or cobble	Not likely
	Valley plain consisting of sandy soil	Possible
Alluvial fan	Vertical gradient of more than 0.5%	Not likely
	Vertical gradient of less than 0.5%	Possible
Natural levee	Top of natural levee	Possible
	Edge of natural levee	Likely
Back marsh		Possible
Abandoned river channel		Likely
Former pond		Likely
Marsh and swamp		Possible
Dry river bed	Dry river bed consisting of gravel	Not likely
	Dry river bed consisting of sandy soil	Likely
Delta		Possible
Bar	Sand bar	Possible
	Gravel bar	Not likely
Sand dune	Top of dune	Not likely
	Lower slope of dune	Likely
Beach	Beach	Not likely
	Artificial beach	Likely
Interlevee lowland		Likely
Reclaimed land by drainage		Possible
Reclaimed land		Likely
Spring		Likely
Fill	Fill on boundary zone between sand and lowland	Likely
	Fill adjoining cliff	Likely
	Fill on marsh or swamp	Likely
	Fill on reclaimed land by drainage	Likely
	Other type fill	Possible

Technical Committee for Earthquake Geotechnical Engineering, TC4, ISSMGE. Zoning for Soil Liquefaction: Manual for Zonation on Seismic Geotechnical Hazards (Revised Version), The Japanese Geotechnical Society, Tokyo (1999)

K. Wakamatsu: Liquefaction History, 416-1990, Japan, Proc., 4th Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures for Soil Liquefaction, 97-114 (1992)

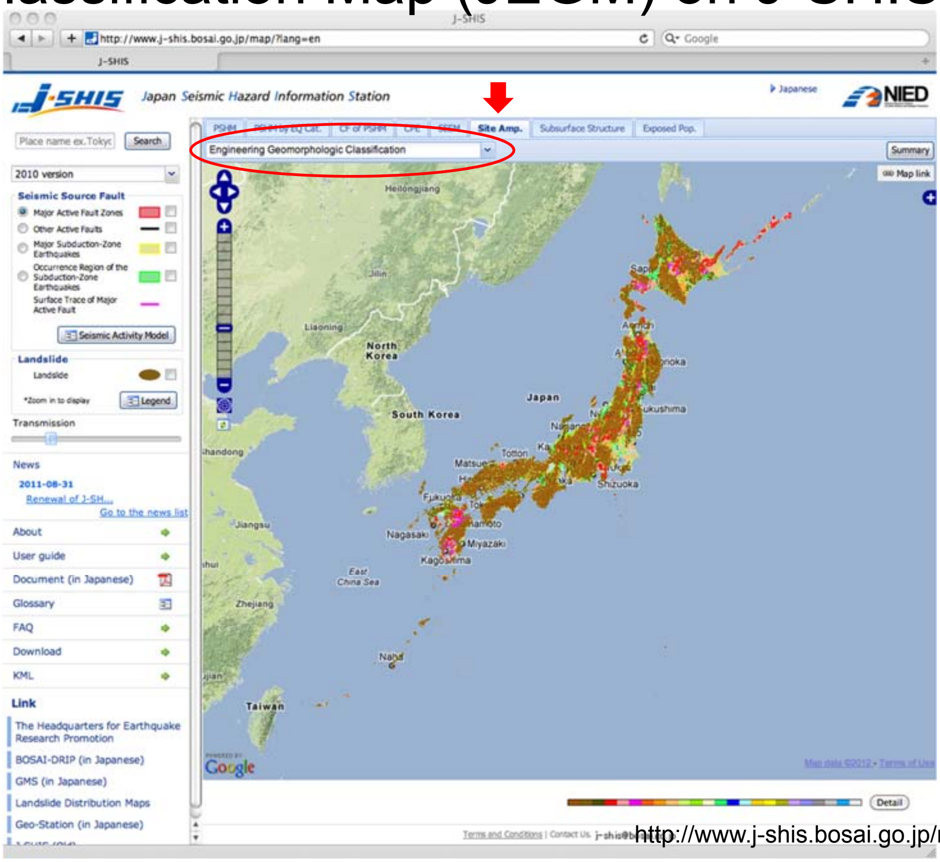
Liquefaction Potential Map

when a ground motion of the M.M.S. VIII is expected



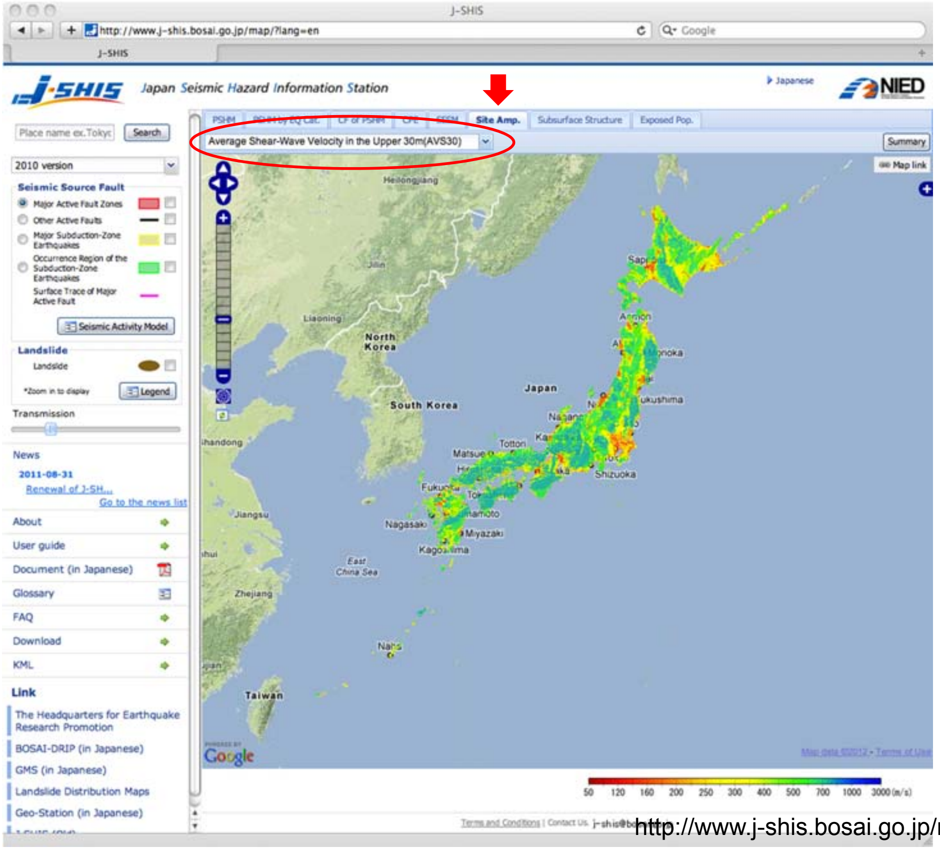
K. Wakamatsu and M. Matsuoka: Development of GIS-based 7.5-arc-second Japan Engineering Geomorphologic Classification Database, Proc. 3rd International Symposium on the Effects of Surface Geology on Seismic Motion, CD-ROM, Paper No.57, 9p., 2006.8.

Japan Engineering Geomorphologic Classification Map (JEGM) on J-SHIS



http://www.j-shis.bosai.go.jp/map/?lang=en

Vs30 Map on J-SHIS



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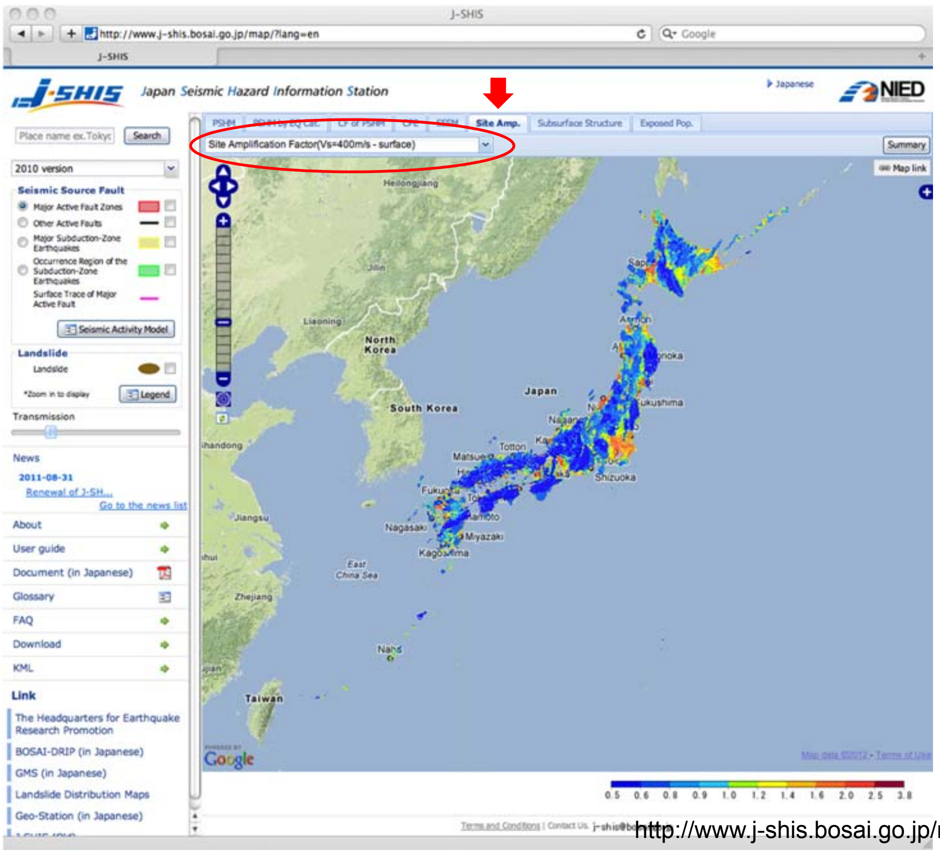
http://www.j-shis.bosai.go.jp/map/?lang=en

Amplification Capability Map on J-SHIS



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http://www.j-shis.bosai.go.jp/map/?lang=en