

The 03/11/2011 Mw9.0 Tohoku, Japan Earthquake

Educational Slides

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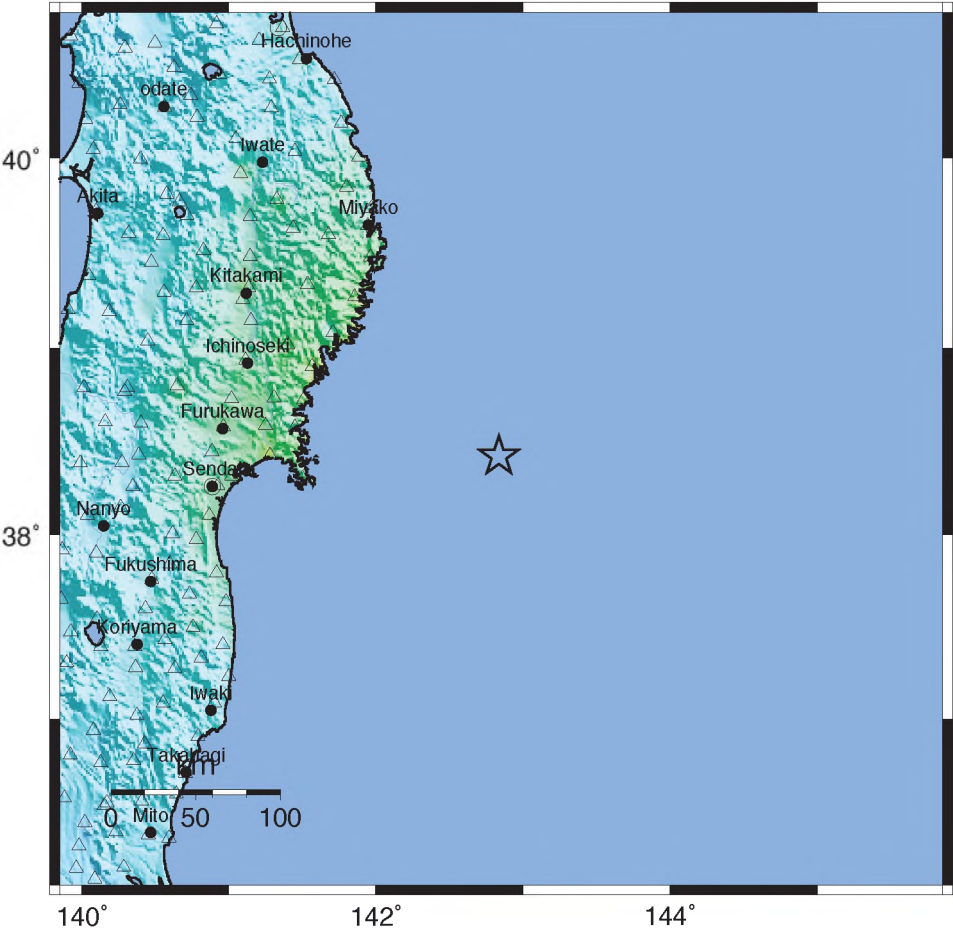
Charles Ammon, Penn State University

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Offshore Honshu, Japan Earthquake,

USGS ShakeMap : NEAR THE EAST COAST OF HONSHU, JAPAN

Wed Mar 9, 2011 02:45:20 GMT M 7.2 N38.42 E142.84 Depth: 32.0km ID:b0001r57



Map Version 4 Processed Wed Mar 9, 2011 05:27:14 PM MST -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

03/09/2011, Mw 7.2

M 7.2, NEAR THE EAST COAST OF HONSHU, JAPAN

Origin Time: Wed 2011-03-09 02:45:20 UTC (11:45:20 local)

Location: 38.42°N 142.84°E Depth: 32 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

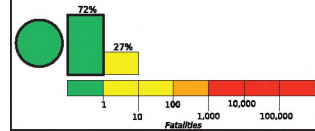
Created: 21 hours, 44 minutes after earthquake

PAGER

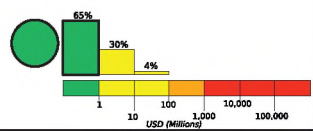
Version 4

Estimated Fatalities

Green alert for shaking-related fatalities and economic losses. There is a low likelihood of casualties and damage.



Estimated Economic Losses



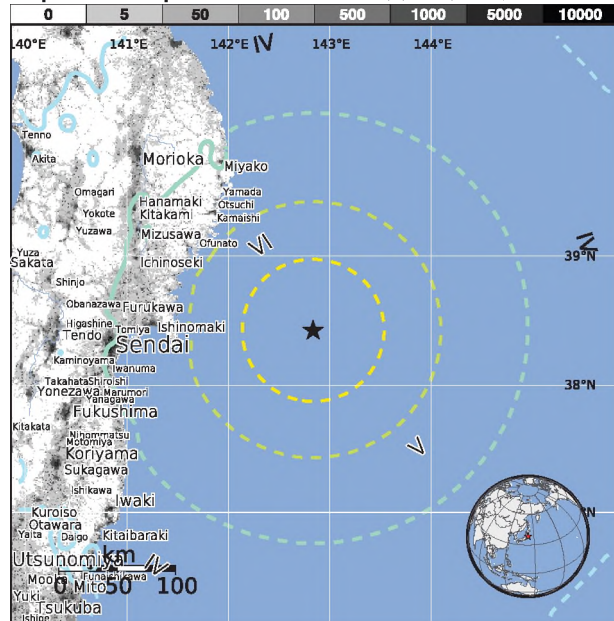
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)	I	II-III	IV	V	VI	VII	VIII	IX	X+
2,462k*	5,120k*	2,708k	17	0	0	0	0	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

*Estimated exposure only includes population within the map area

Population Exposure

population per ~1 sq. km from Landsat



Structures:

Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
2003-10-31	73	7.0	V(7,236k)	0
1980-09-23	388	5.3	V(12,718k)	1
1983-05-26	385	7.7	VII(174k)	104

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and fires that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI City	Population
V Ishinomaki	117k
V Otsuchi	16k
V Kamaishi	43k
V Hanamaki	73k
V Yamada	20k
V Yamoto	32k
V Sendai	1,038k
IV Morioka	295k
IV Fukushima	294k
III Utsunomiya	450k
III Yamagata	255k

bold cities appear on map

(k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

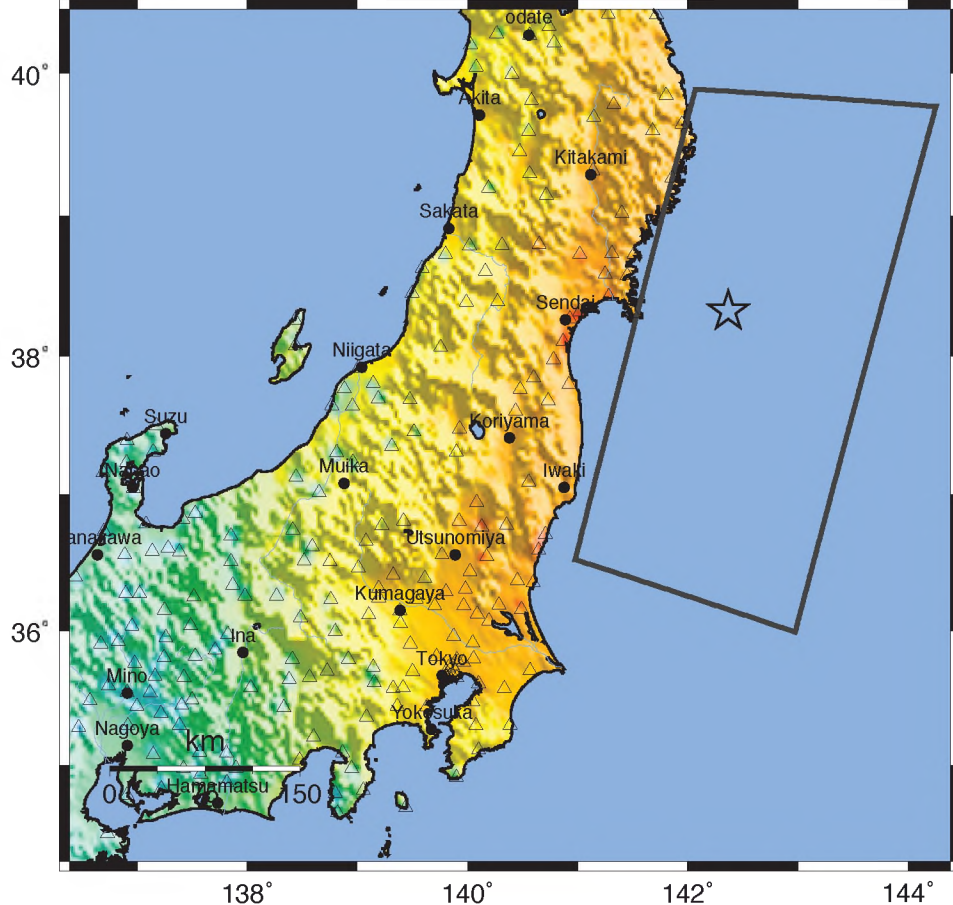
<http://earthquake.usgs.gov/pager>

Event ID: usb0001r57

Tohoku, Japan Earthquake, 03/11/2011, Mw 9.0

USGS ShakeMap : NEAR THE EAST COAST OF HONSHU, JAPAN

Fri Mar 11, 2011 05:46:23 GMT M 9.0 N38.32 E142.37 Depth: 32.0km ID:c0001xgp



Map Version 6 Processed Tue Mar 15, 2011 08:39:58 AM MDT -- NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



Earthquake Shaking **Red Alert**



M 9.0, NEAR THE EAST COAST OF HONSHU, JAPAN

Origin Time: Fri 2011-03-11 05:46:23 UTC (14:46:23 local)

Location: 38.32°N 142.37°E Depth: 32 km

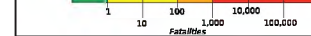
FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

Created: 4 days, 9 hours after earthquake

Estimated Fatalities

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-1% GDP of Japan. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.



Estimated Economic Losses

Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are 0-1% GDP of Japan. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

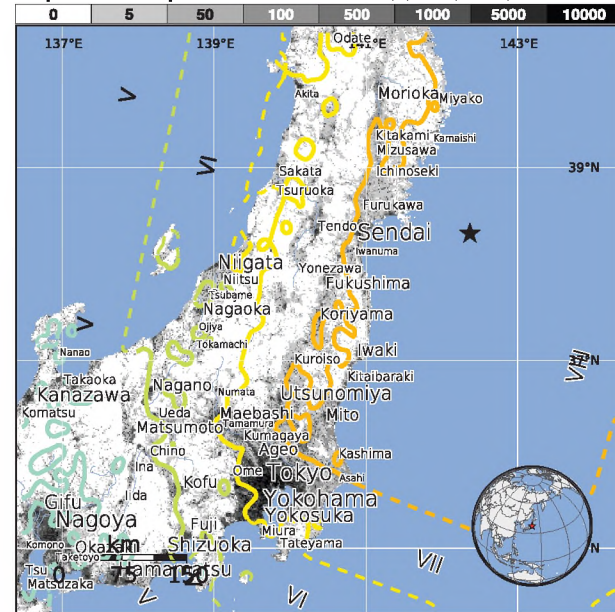


Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)	-	6k*	2,483k*	15,269k*	10,864k*	36,088k*	6,781k*	66k	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE									
Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy
Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy	V. Heavy

*Estimated exposure only includes population within the map area

Population Exposure



Structures:
Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are non-ductile reinforced concrete frame and heavy wood frame construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max. Shaking (MMI#)	Deaths
1998-06-14	363	5.7	VII(428k)	0
1994-12-28	263	7.7	VII(132k)	3
1983-05-26	369	7.7	VII(174k)	104

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and fires that might have contributed to losses.

Selected City Exposure

MMI City	Population
IX Iwanuma	42k
IX Rifu	35k
IX Shioyama	60k
IX Hitachi	186k
VIII Takahagi	34k
VIII Ishinomaki	117k
VIII Sendai	1,038k
VIII Chiba	920k
VII Yokohama	3,574k
VII Tokyo	8,337k
V Nagoya	2,191k

bold cities appear on map (k = x1000)

Event ID: usc0001xgp

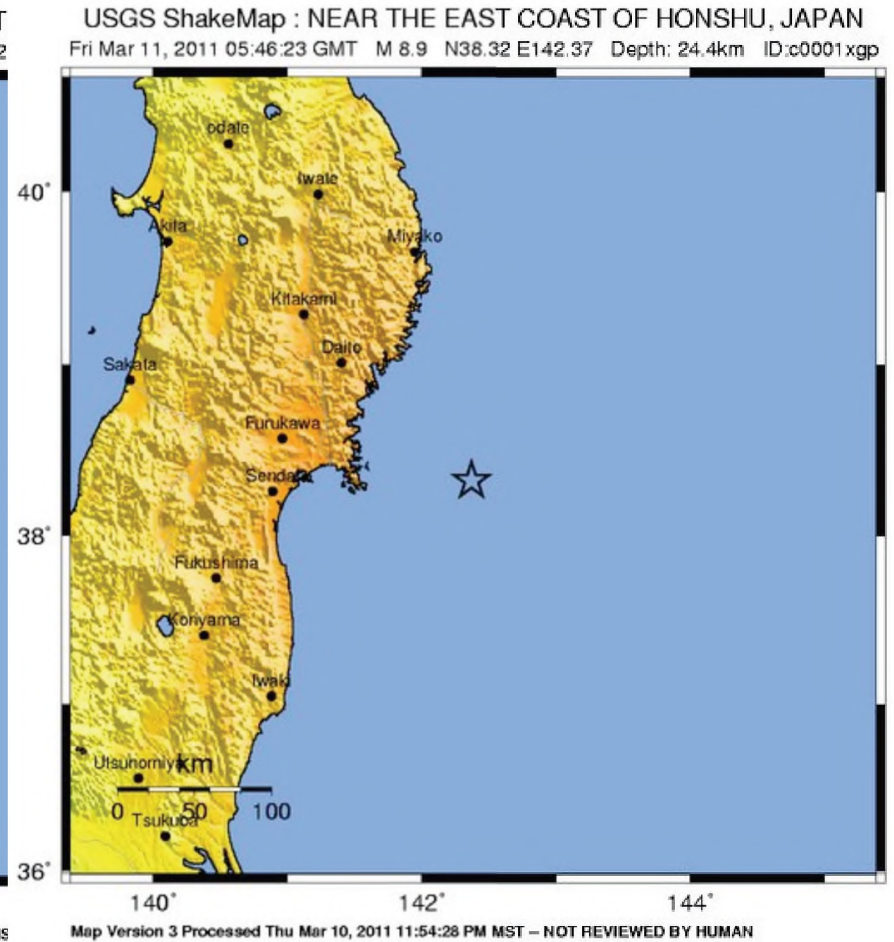
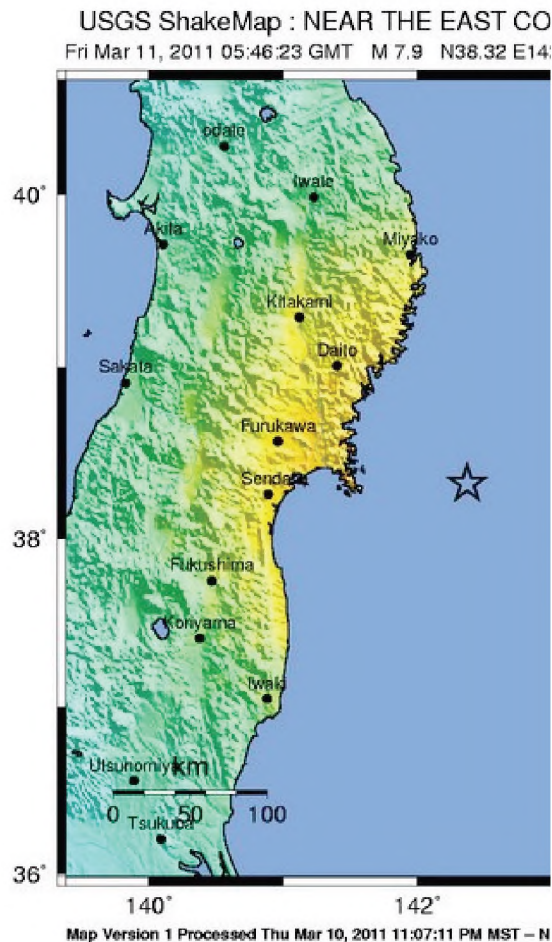
PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.
<http://earthquake.usgs.gov/pager>

Tohoku, Japan Earthquake: ShakeMap Evolution

V1: O.T. +21 min M7.9

V2: O.T. +40 min M8.8

V3: O.T. +1 hr 9 min M8.9



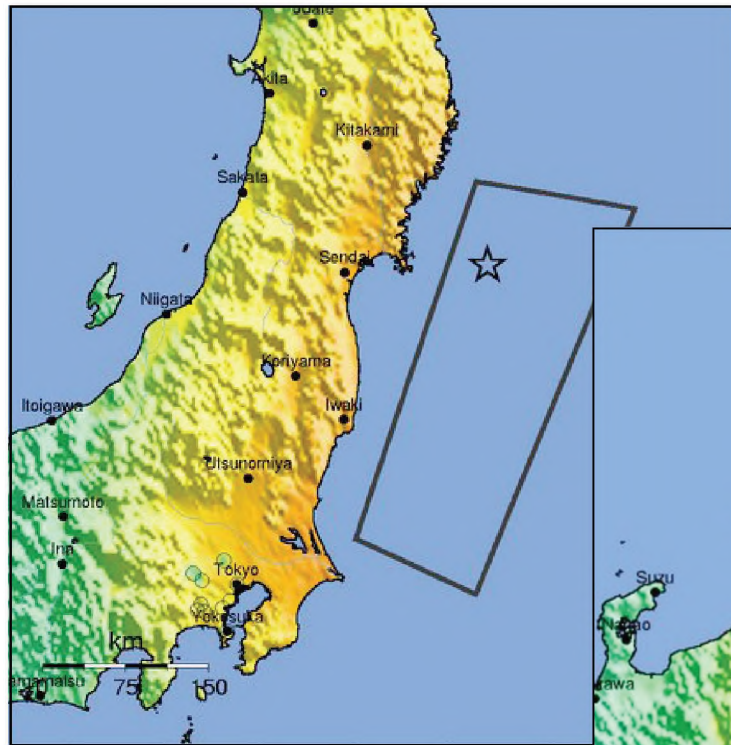
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	>18
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	>16
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong
POTENTIAL DAMAGE	none	none	none	Very light	Light
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI

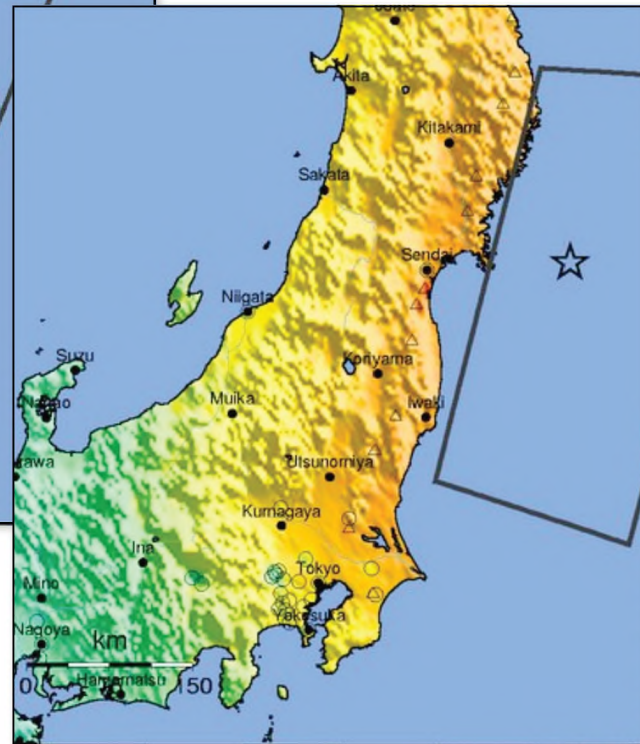
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

(Led to PAGER **RED** Alert
42.9 minutes after origin)

Tohoku, Japan Earthquake: ShakeMap Evolution



V4: O.T. +2 h 22 min
 •M8.9
 •**DYFI data**
 •Finite fault inferred from aftershocks

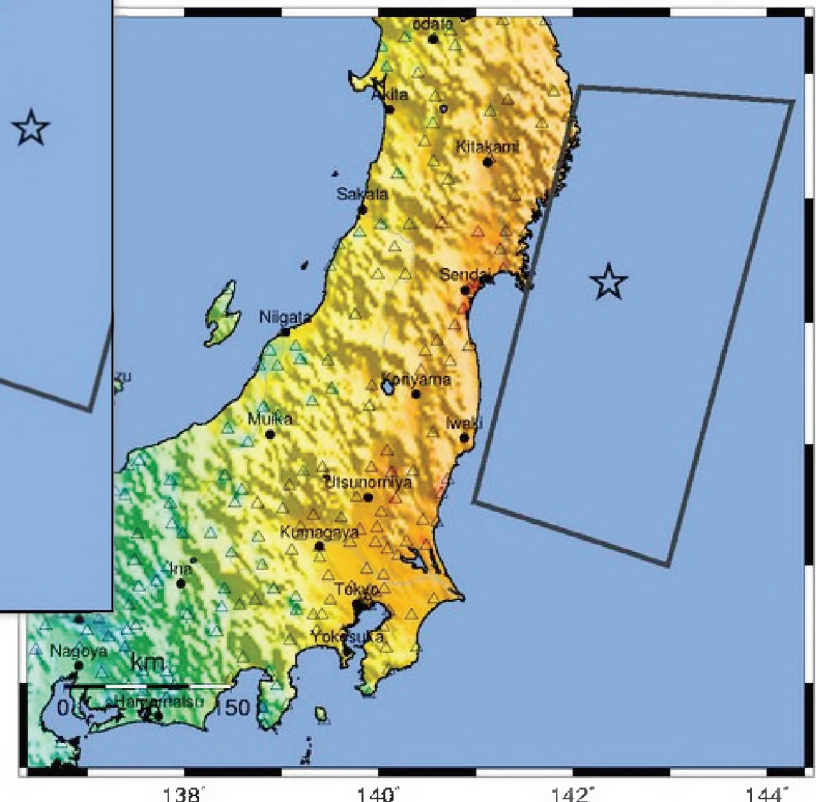


V5: O.T. +2 d 11 hr
 •M9.0
 •DYFI Data
 •**12 K-NET stations**
 •Finite fault inferred from aftershocks

V6: OT +3 d 9 hr

- M9.0
- DYFI Data
- 273 K-NET stations**
- Finite fault from K-NET (NIED) inversion

ShakeMap : NEAR THE EAST COAST OF HONSHU, JAPAN
 2011 05:46 23 GMT M 9.0 N38.32 E142.37 Depth: 32.0km ID c0001xgp



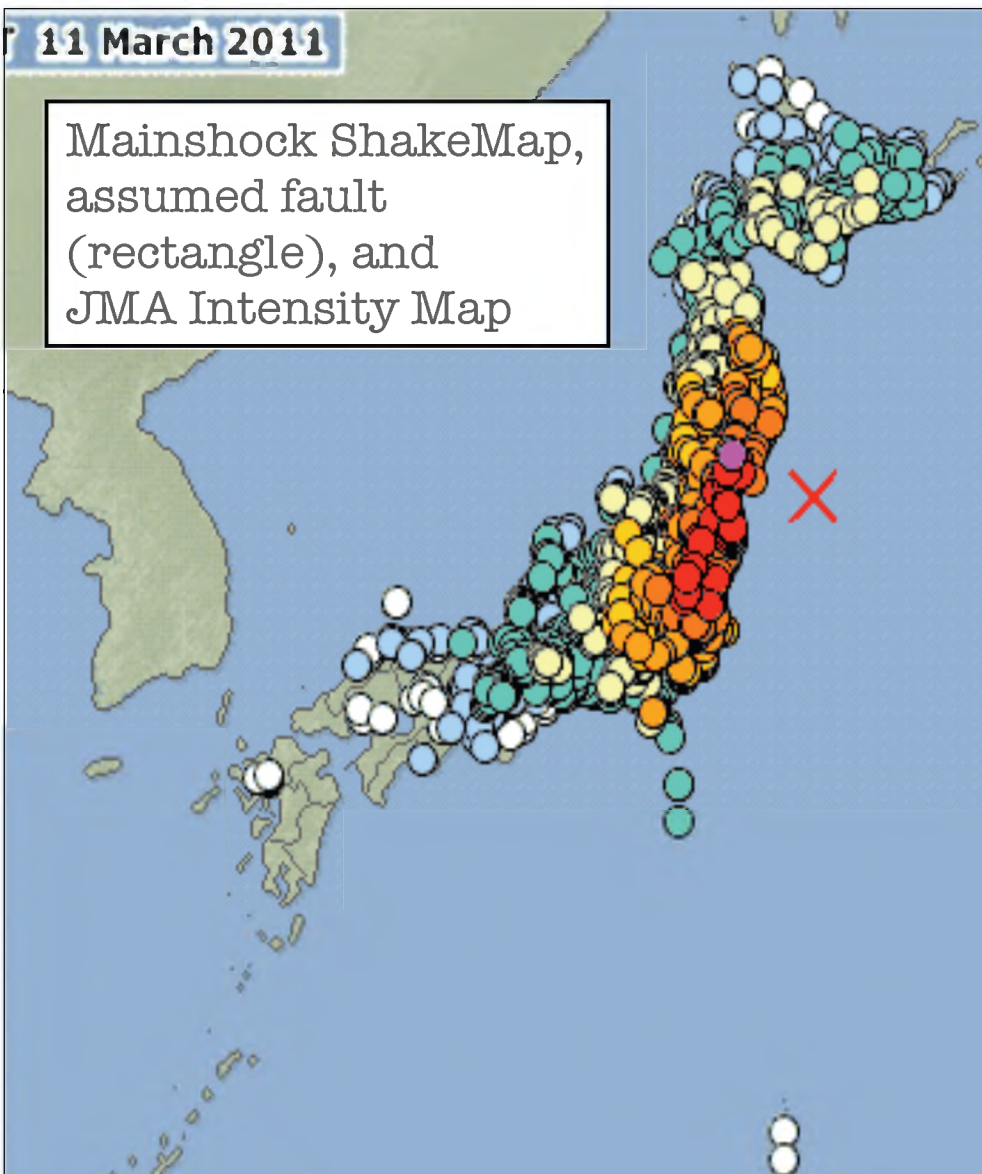
Map Version 6 Processed Tue Mar 15, 2011 08:39:58 AM MDT - NOT REVIEWED BY HUMAN

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC (%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

11 March 2011



Mainshock ShakeMap,
assumed fault
(rectangle), and
JMA Intensity Map



USGS ShakeMap : NEAR THE EAST COAST OF HONSHU, JAPAN
Fri Mar 11, 2011 05:46:23 GMT M 8.9 N38.32 E142.37 Depth: 24.4km ID:c0001xgp



Map Version 4 Processed Fri Mar 11, 2011 01:23:57 AM MST -- NOT REVIEWED BY HUMAN

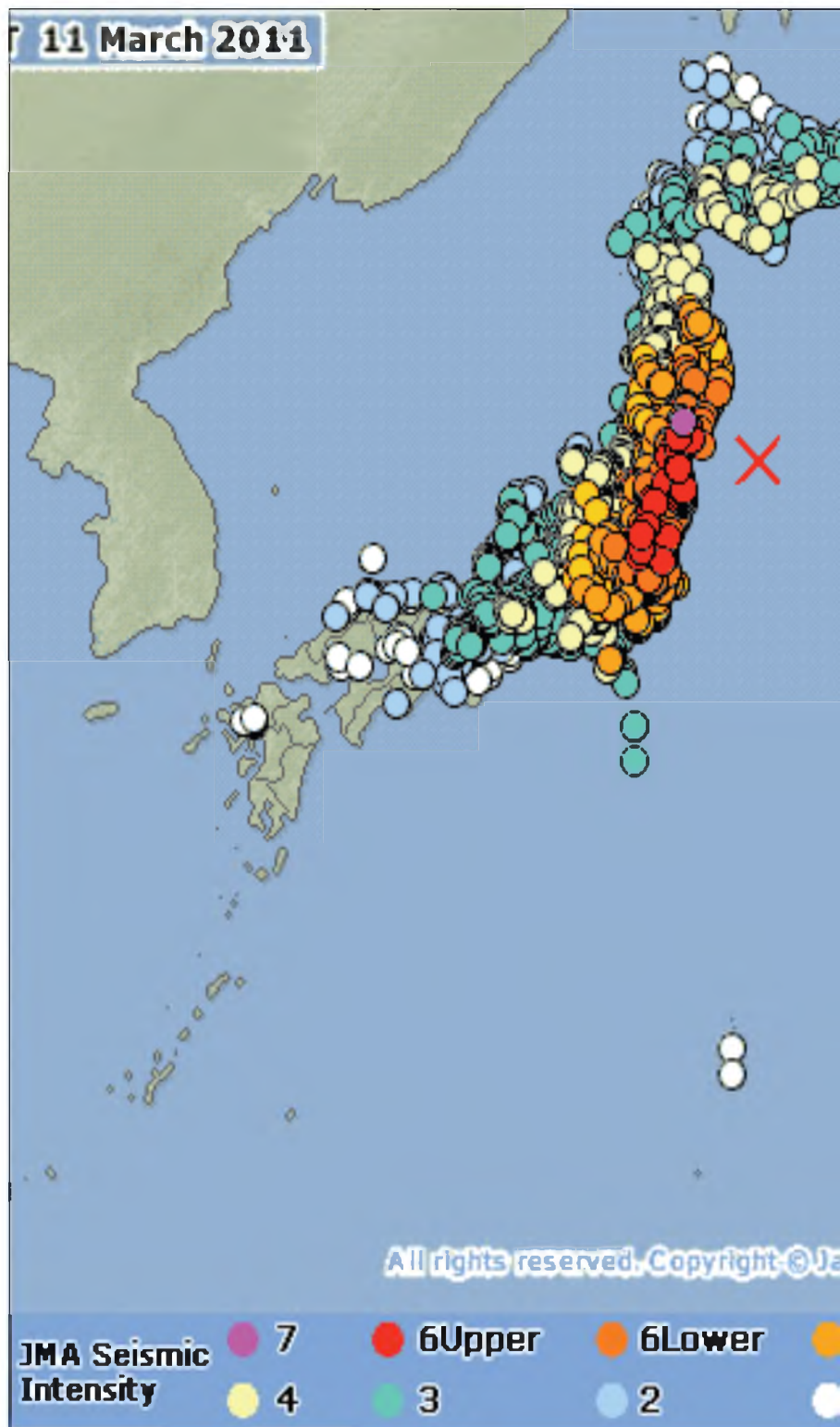
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC. (%g)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
PEAK VEL. (cm/s)	I	II-III	IV	V	VI	VII	VIII	IX	X+
INSTRUMENTAL INTENSITY									

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JMA Seismic Intensity

7	6Upper	6Lower	5Upper	5Lower
4	3	2	1	

7 11 March 2011



M 8.9, NEAR THE EAST COAST OF HONSHU, JAPAN

Origin Time: Fri 2011-03-11 05:46:23 UTC (14:46:23 local)

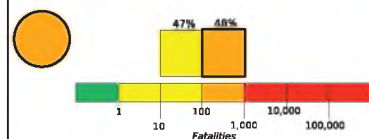
Location: 38.32°N 142.37°E Depth: 24 km

FOR TSUNAMI INFORMATION, SEE: tsunami.noaa.gov

PAGER
Version 5

Created: 2 hours, 44 minutes after earthquake

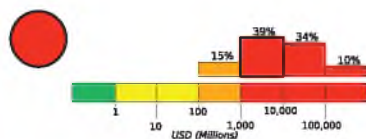
Estimated Fatalities



Red alert level for economic losses. Extensive damage is probable and the disaster is likely widespread. Estimated economic losses are less than 1% of GDP of Japan. Past events with this alert level have required a national or international level response.

Orange alert level for shaking-related fatalities. Significant casualties are likely.

Estimated Economic Losses



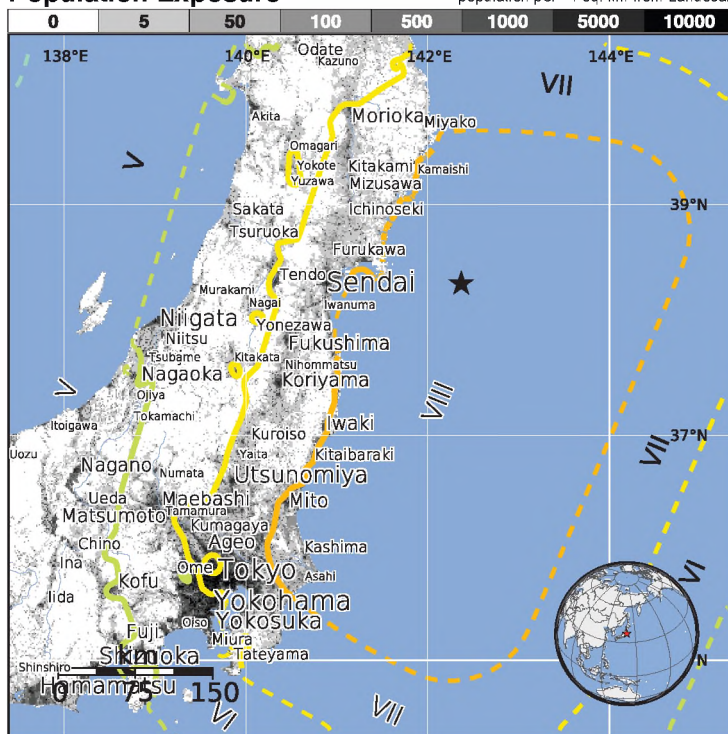
Estimated Population Exposed to Earthquake Shaking

ESTIMATED POPULATION EXPOSURE (k = x1000)	--*	--*	--*	7,071k*	19,695k*	29,969k*	2,144k	0	0
ESTIMATED MODIFIED MERCALLI INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	Resistant Structures	none	none	none	V. Light	Light	Moderate	Moderate/Heavy	Heavy
	Vulnerable Structures	none	none	none	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

*Estimated exposure only includes population within the map area.

Population Exposure

population per ~1 sq. km from Landsat



Structures:

Overall, the population in this region resides in structures that are resistant to earthquake shaking, though some vulnerable structures exist. The predominant vulnerable building types are non-ductile reinforced concrete frame and heavy wood frame construction.

Historical Earthquakes (with MMI levels):

Date (UTC)	Dist. (km)	Mag.	Max MMI(#)	Shaking Deaths
1998-06-14	363	5.7	VII(428k)	0
1994-12-28	263	7.7	VII(132k)	3
1983-05-26	369	7.7	VII(174k)	104

Recent earthquakes in this area have caused secondary hazards such as tsunamis, landslides, and fires that might have contributed to losses.

Selected City Exposure

from GeoNames.org

MMI City	Population
VIII Omigawa	26k
VIII Oarai	19k
VIII Hasaki	39k
VIII Itako	26k
VIII Ofunato	35k
VIII Takahagi	34k
VII Sendai	1,038k
VII Chiba	920k
VII Tokyo	8,337k
VI Yokohama	3,574k
V Shizuoka	702k

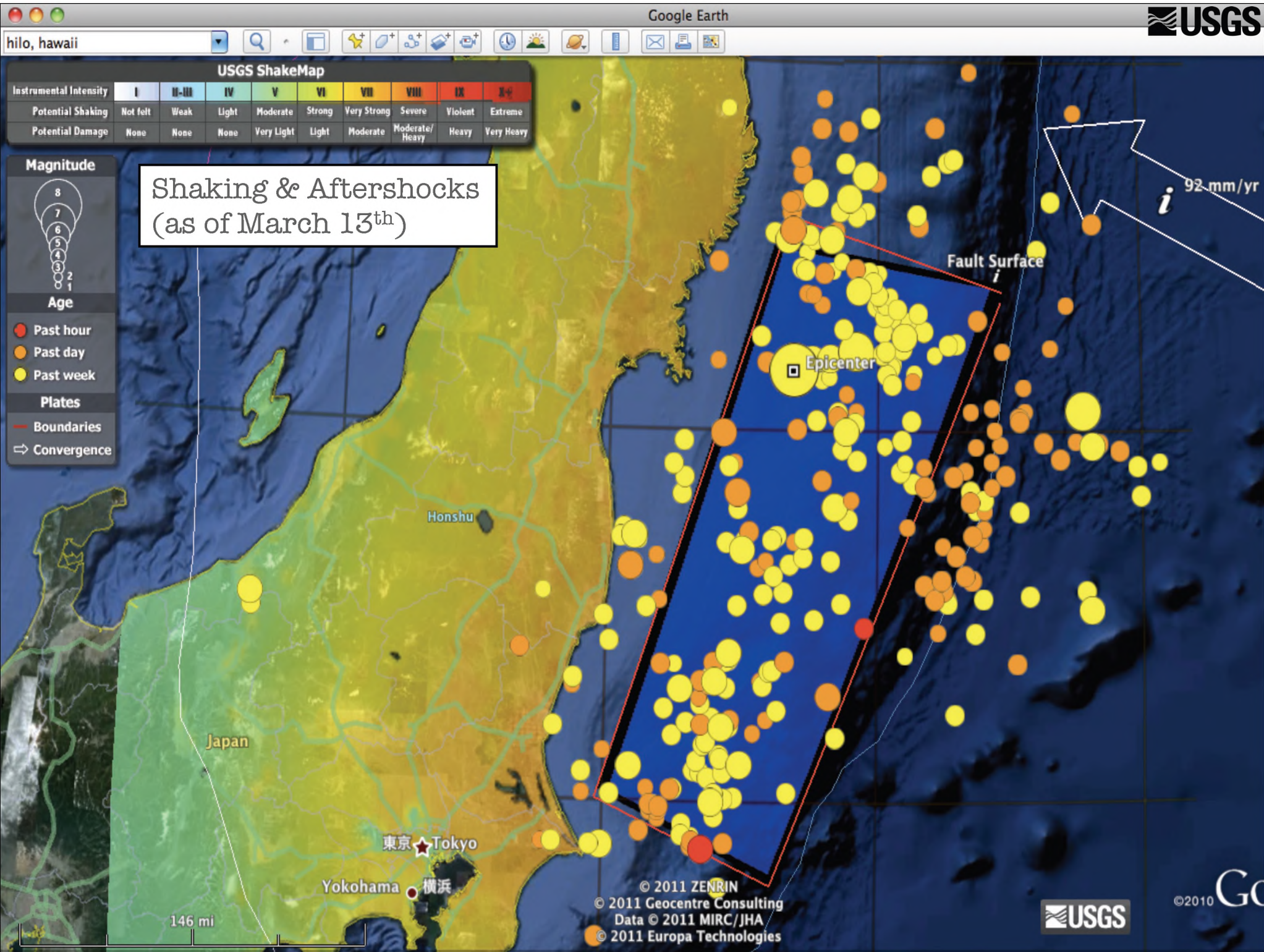
bold cities appear on map

(k = x1000)

PAGER content is automatically generated, and only considers losses due to structural damage. Limitations of input data, shaking estimates, and loss models may add uncertainty.

<http://earthquake.usgs.gov/pager>

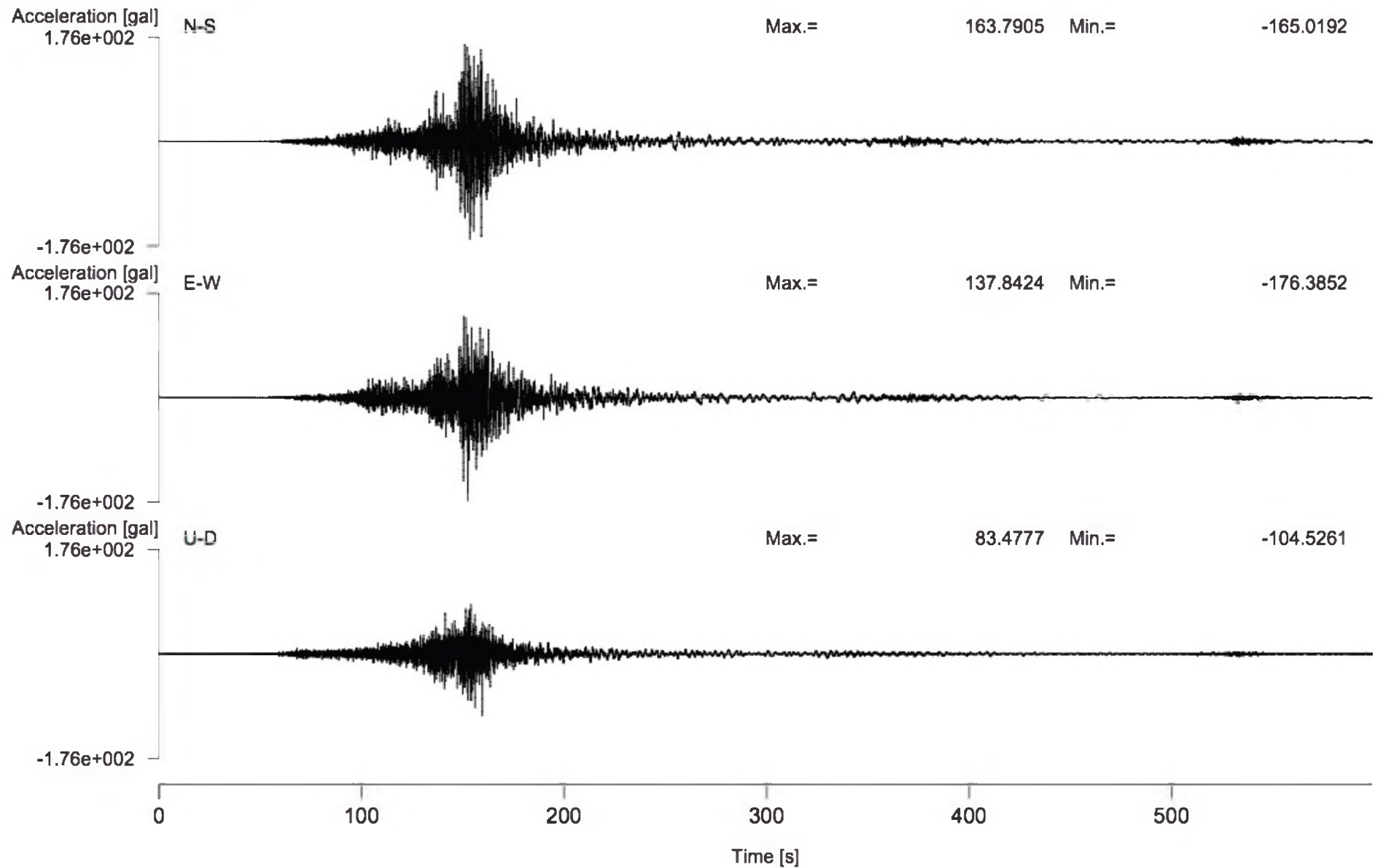
Event ID: usc0001xgp



Tohoku, Japan Earthquake: Shaking Duration in Tokyo, Ground Acceleration

ERI-1555_1_20110311144726

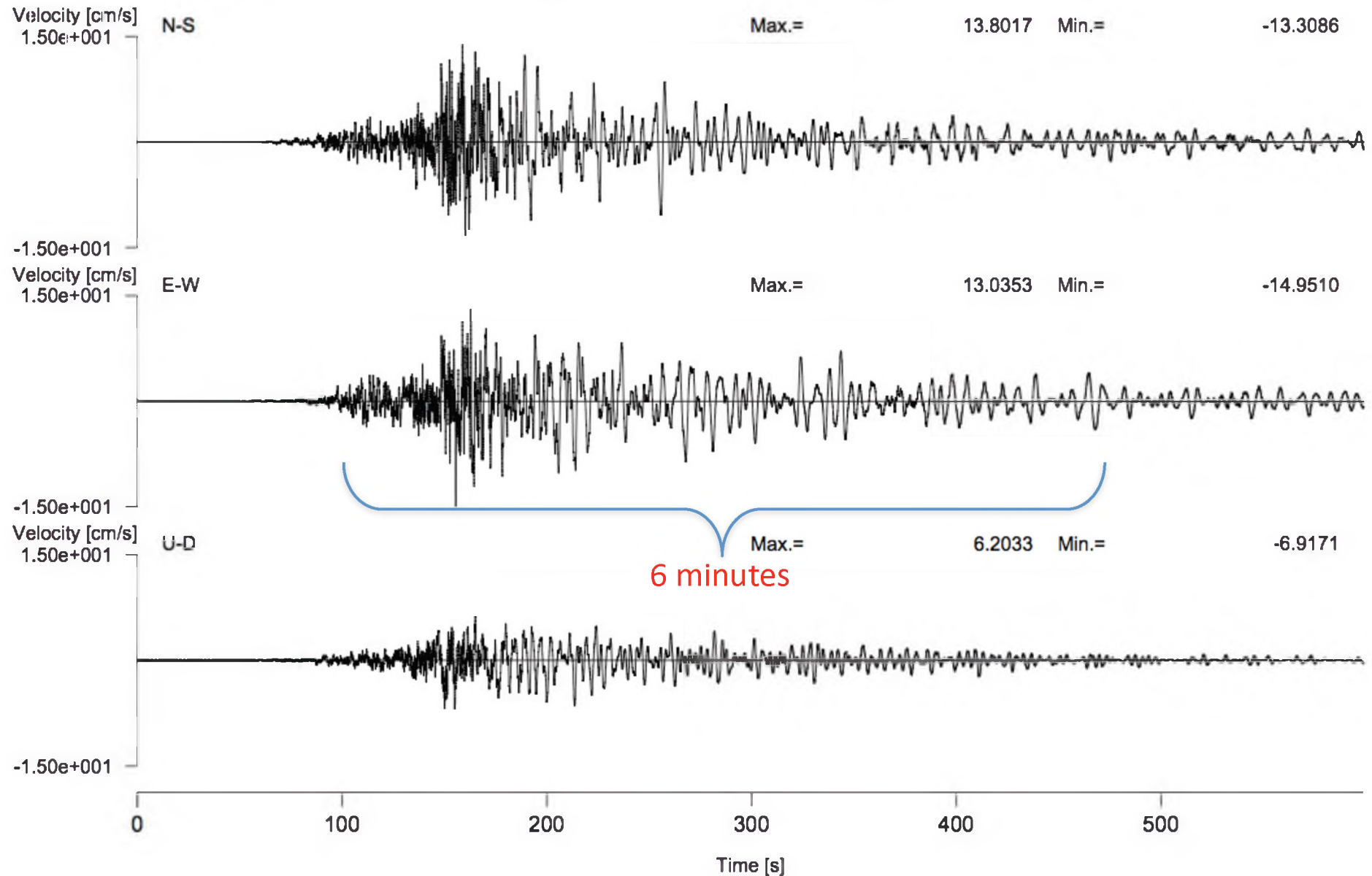
ERI-1555_1_ 2011/03/11 14:46:56 Seismic Intensity : 4.82



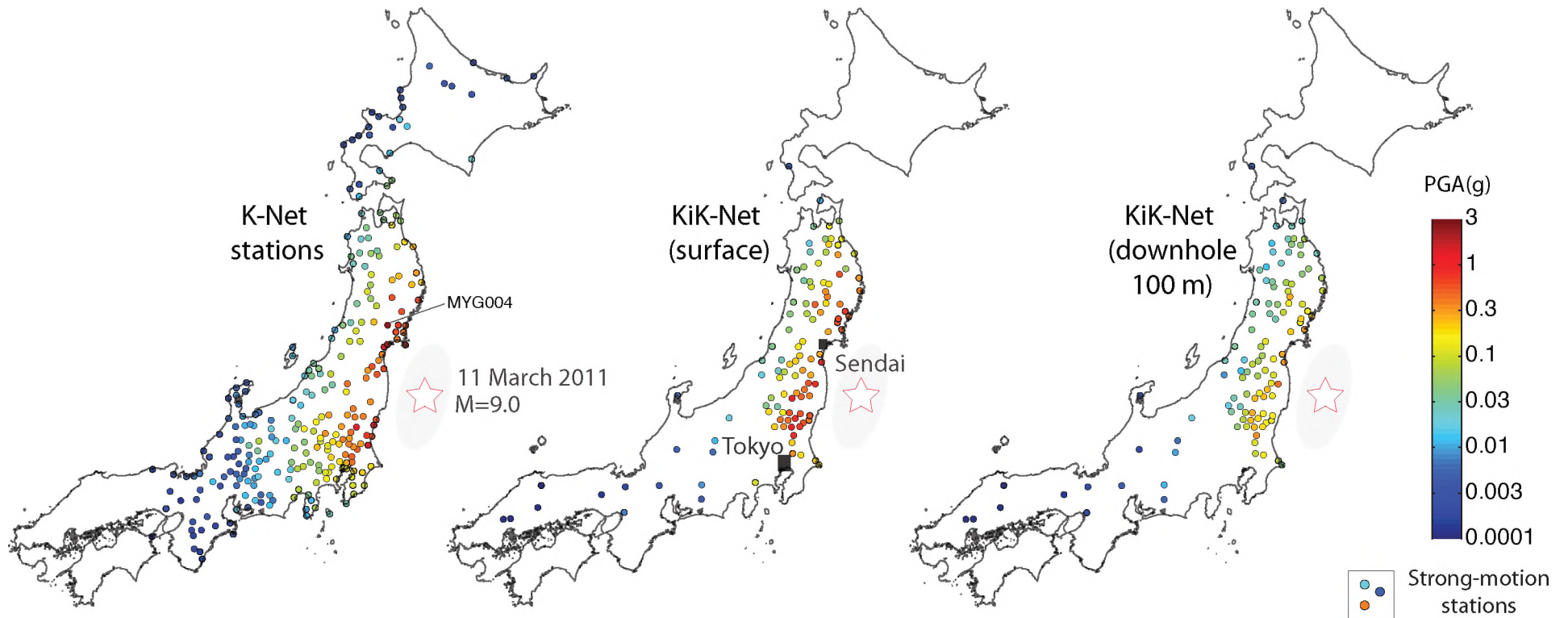
Tohoku, Japan Earthquake: Shaking Duration in Tokyo, Ground Velocity

ERI-1555_1_20110311144726

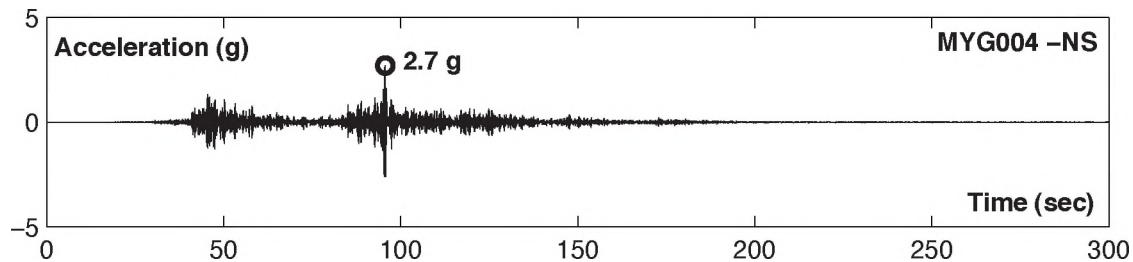
ERI-1555_1_ 2011/03/11 14:46:56 Seismic Intensity : 4.82



Peak Ground Motion Acceleration (PGA) of the 11 March 2011 Tohoku M=9.0 earthquake

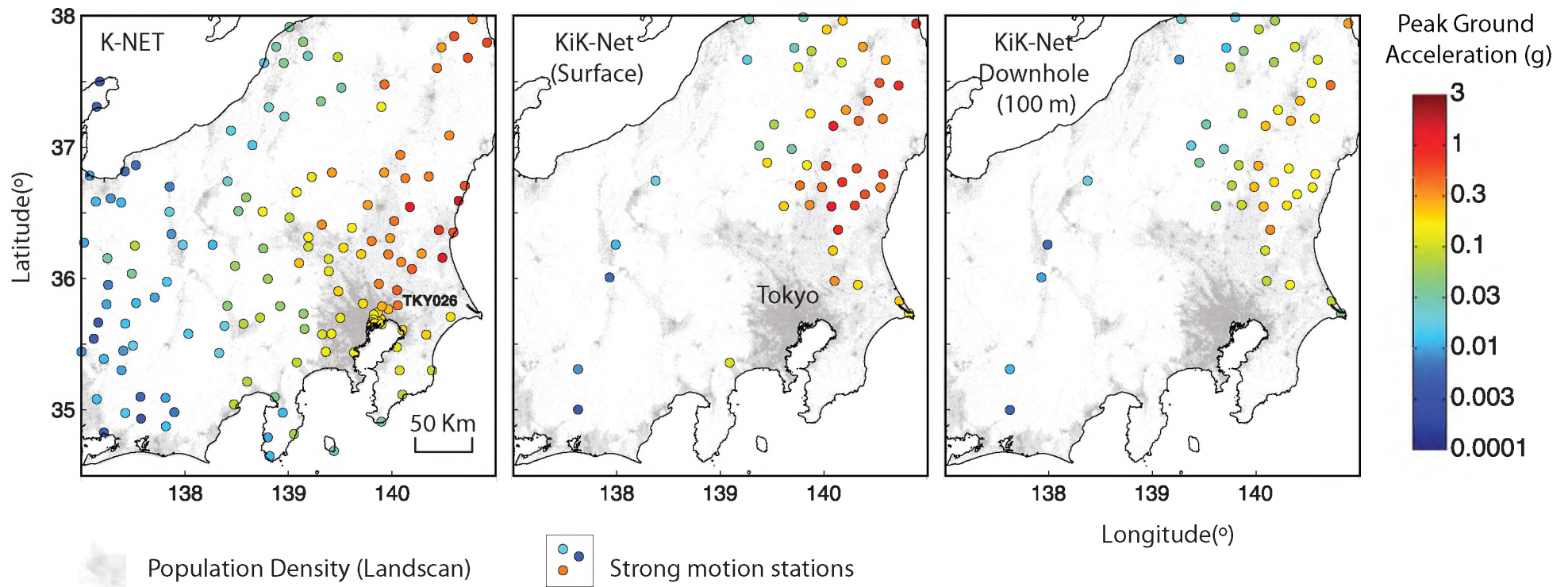


Maximum PGA of 2.7g was recorded at Miyagi Prefecture

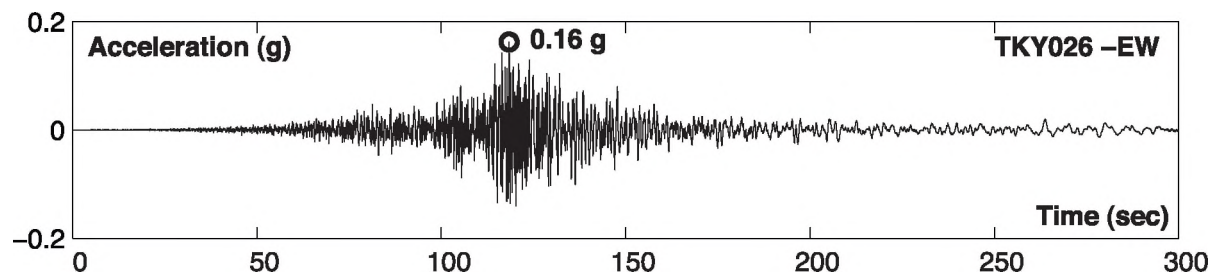


Erol Kalkan & Volkan Sevilgen (USGS)
March 17, 2011

Peak Ground Motion Acceleration (PGA) of the 11 March 2011 Tohoku M=9.0 earthquake Tokyo Metropolitan and its surroundings

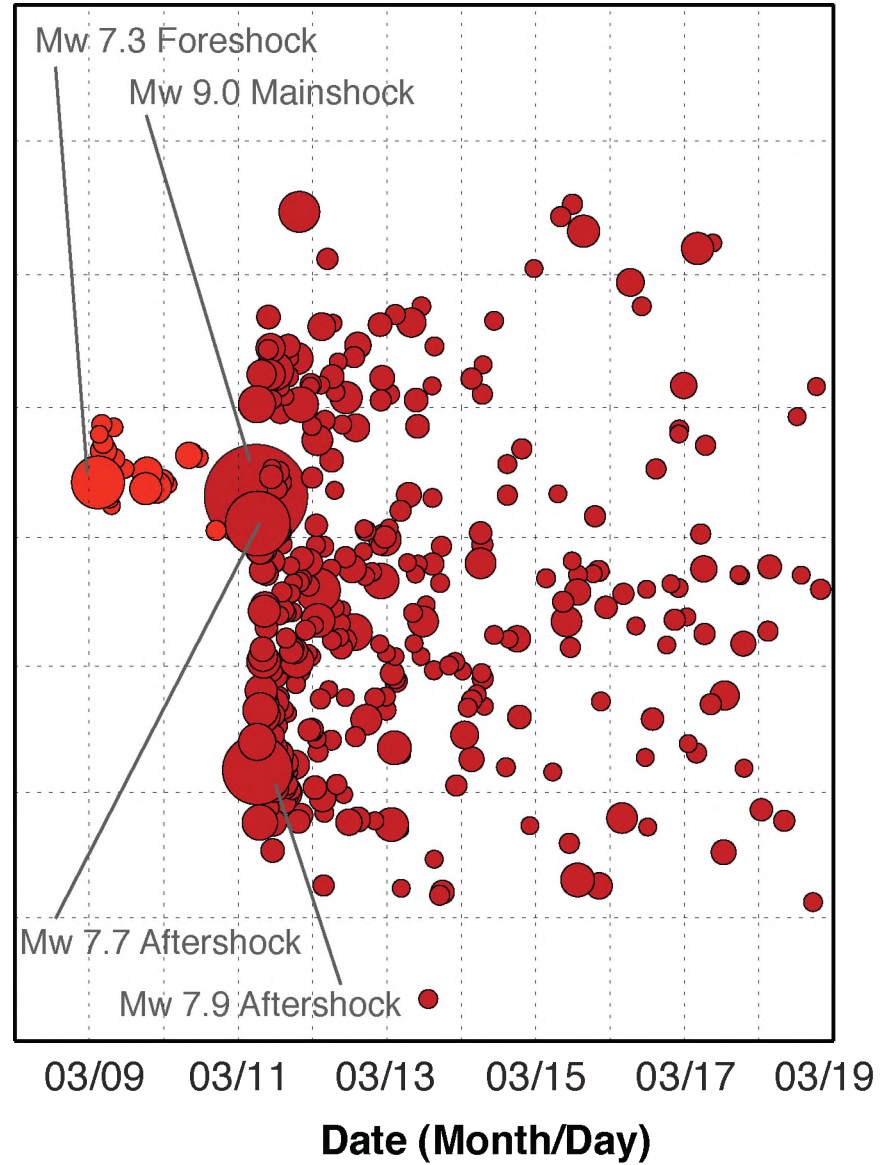
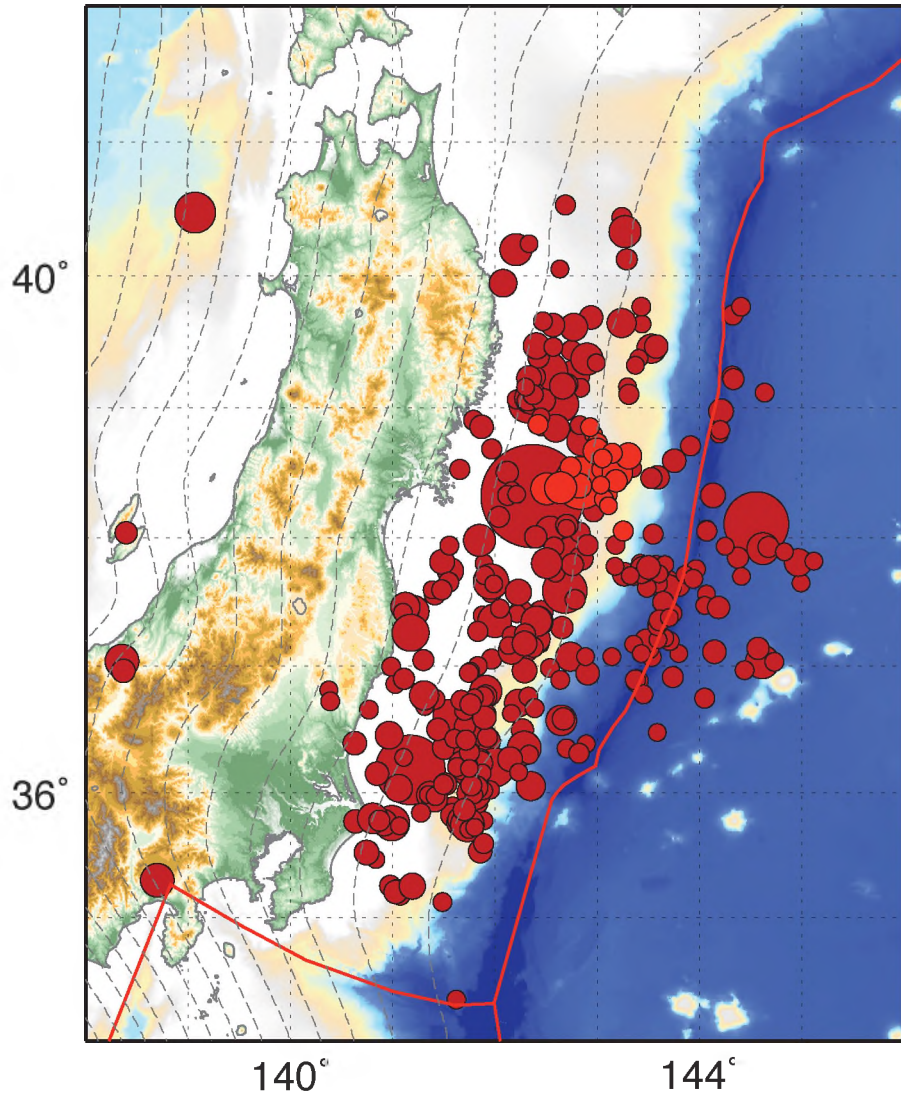


Maximum PGA of 0.16g was recorded at Tokyo Metropolitan



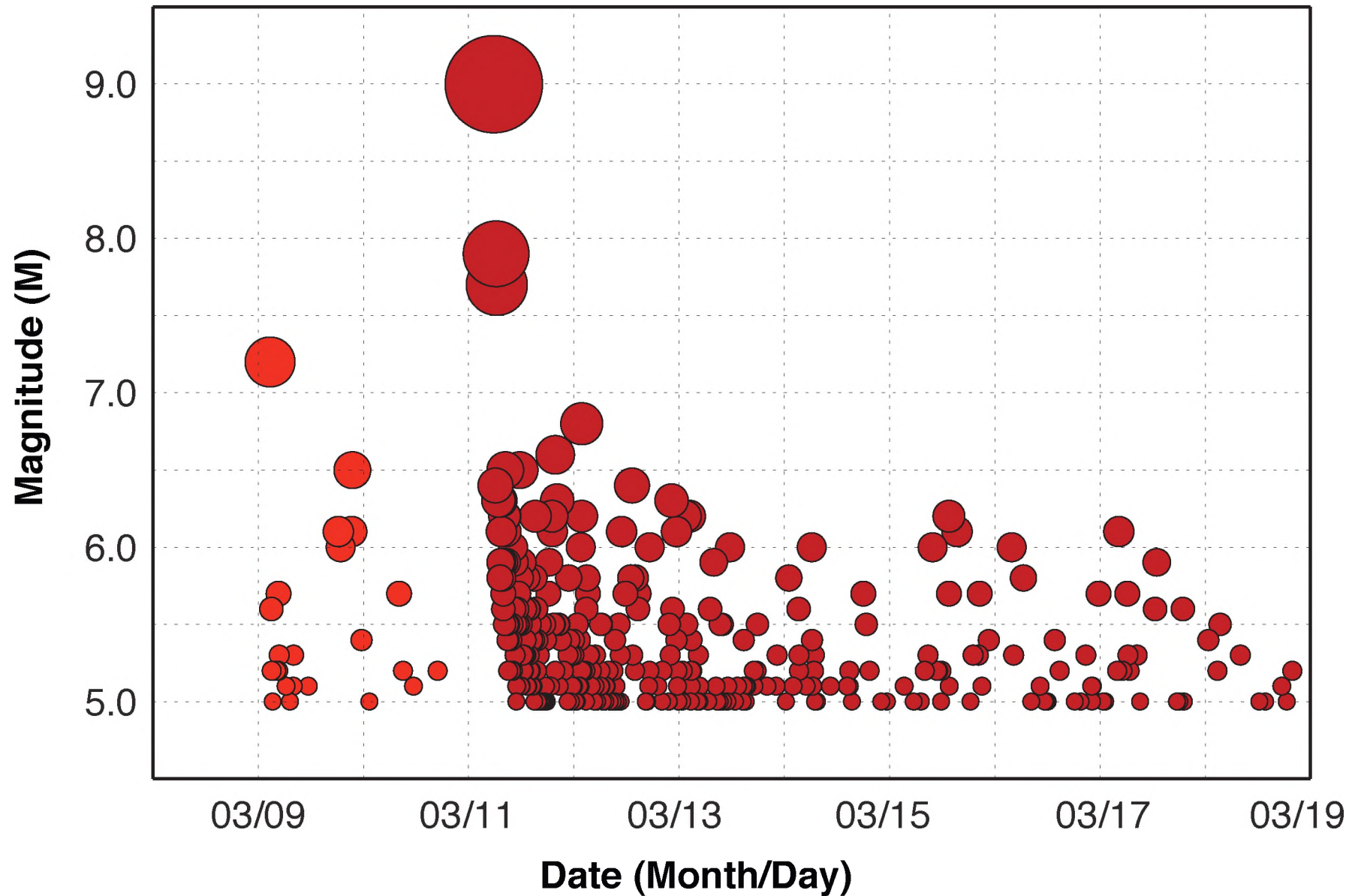
Tohoku, Japan Earthquake: Aftershock (and Foreshock) Sequence, 03/08/11 - 03/16/11

Slab Contours from Slab1.0, every 20 km



Note that the magnitudes of the 2011/03/11 06:15 (Mw 7.9) and 2011/03/11 06:25 (Mw 7.7) aftershocks were updated from earlier, lower estimates. Updates occurred on 03/16 and 03/18, respectively.

Tohoku, Japan Earthquake: Aftershock (and Foreshock) Sequence, M:Time History

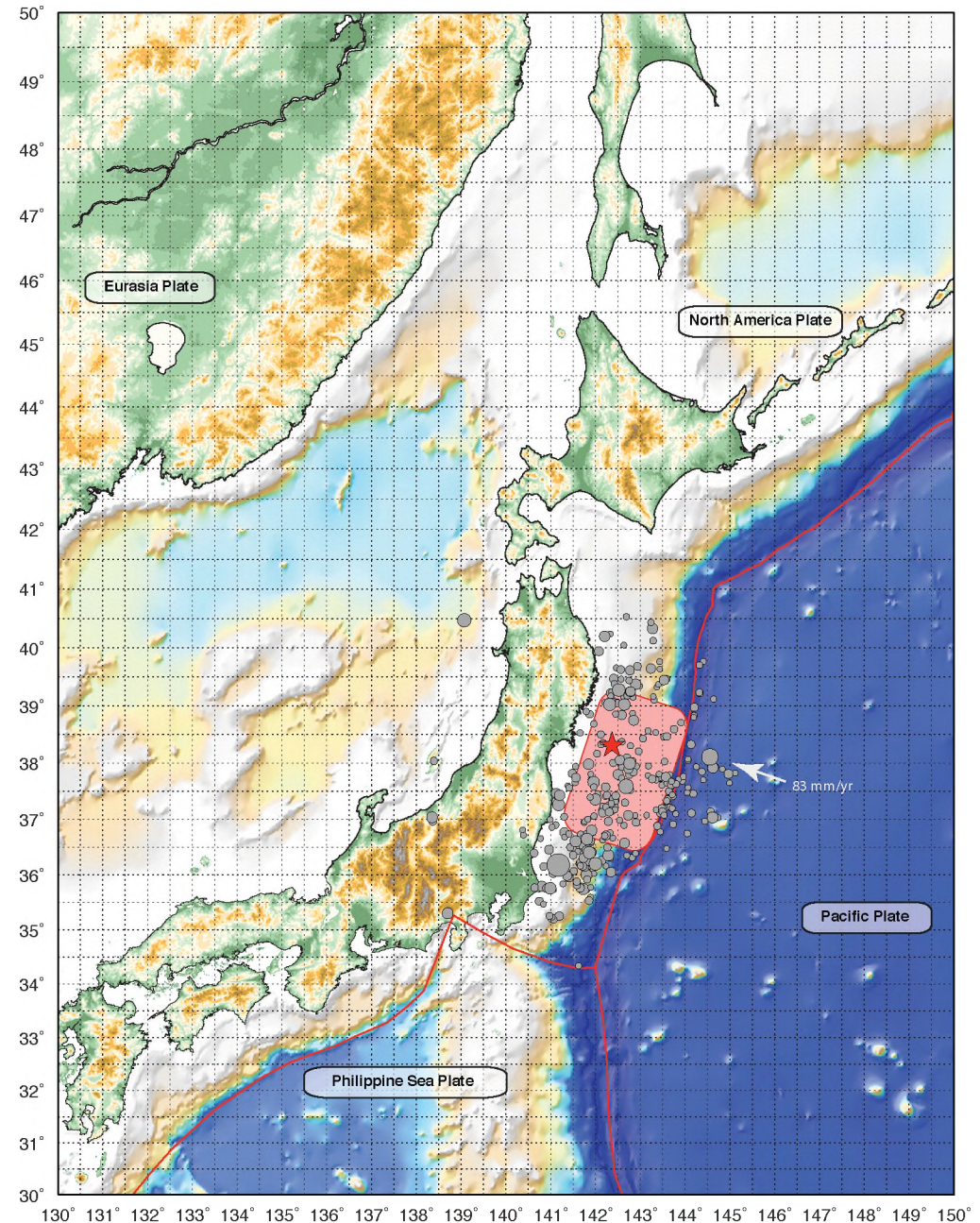


Tohoku, Japan Earthquake: Tectonic Summary

The magnitude 9.0 Tohoku earthquake on March 11, 2011, which occurred near the northeast coast of Honshu, Japan, resulted from thrust faulting on or near the subduction zone plate boundary between the Pacific and North America plates. At the latitude of this earthquake, the Pacific plate moves approximately westwards with respect to the North America plate at a rate of 83 mm/yr, and begins its westward descent beneath Japan at the Japan Trench.

The location, depth, and focal mechanism of the March 11 earthquake are consistent with the event having occurred on the subduction zone plate boundary.

Modeling of the rupture of this earthquake (**red shading**, approx.) indicate that the fault moved upwards of 30-40 m, and slipped over an area approximately 300 km long (along-strike) by 150 km wide (in the down-dip direction). The rupture zone is roughly centered on the earthquake epicenter along-strike, while peak slips were up-dip of the hypocenter, towards the Japan Trench axis. The March 11 earthquake was preceded by a series of large foreshocks over the previous two days, beginning on March 9th with a M 7.2 event approximately 40 km from the epicenter of the March 11 earthquake, and continuing with another three earthquakes greater than M 6 on the same day.



Japan Regional Seismicity, 1900-2007

USGS Poster/Open File Report 2010-1083-D



U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Seismicity of the Earth 1900-2007

Japan and Vicinity

Compiled by Susan Rhea, Arthur C. Tarr, Gavin Hayes, Antonio Villaseñor, and Harley Benz

USGS Open-File Report 2010-1083-D

OPEN-FILE REPORT 2010-1083-D
Version 1.0

TECTONIC SUMMARY
This map shows details of Japan and vicinity not visible in an earlier publication (Tarr and others, 2010). Japan and its island possessions lie on the convergent boundary between the Pacific plate, North American plate, Eurasian plate, and Philippine Sea plate. The Pacific plate is subducted into the mantle, beneath Hokkaido and northern Honshu, along the eastern margin of the Okhotsk microplate, a proposed subdivision of the North American plate (Bird, 2003). Further south, the Pacific plate is subducted beneath volcanic islands along the eastern margin of the Philippine Sea plate. This 2,000 km-long zone of subduction of the Pacific plate is responsible for the creation of the deep, efficient Ogasawara and Japan trenches as well as parallel chains of islands and volcanoes, typical of Cocos-type island arcs. Similarly, the Philippine Sea plate is being subducted under the Eurasian plate along a zone, extending from Taiwan to southeast Honshu, that comprises the Ryukyu islands and the Nansen-Shoto trench.

Subduction zones are the primary source areas for geologically complex and produce numerous earthquakes from multiple sources. Unravelling of the overriding plates generates shallow crustal earthquakes, whereas slip on the megathrusts on the plate boundaries generates great earthquakes from the base of the lithosphere to depths of 60 to 100 km. At greater depths, megathrusts are earthquakes occur within the subducting Pacific and Philippine Sea plates and can reach depths of nearly 700 km. Since 1900, two great megathrust earthquakes of Japan and the north of Hokkaido. They are the M8.0 (1918) Sagami Sea earthquake (Kawakami and Sato, 1971), the M9.2 (2011) Tohoku earthquake (Kawakami and others, 2010), and the M9.1 (1994) Great Kanto earthquake (Kobayashi and others, 1999). The M8.0 (1918) Sagami Sea earthquake (Kobayashi and others, 1999) and the M9.2 (2011) Tohoku earthquake (Kobayashi and others, 1999).

Several megathrust earthquakes along the Japan and the Nansen-Shoto trenches are considered to be the most intense ever recorded in the world. The 1906 San Francisco earthquake (M8.3) is the most intense ever recorded in the world. The 1906 San Francisco earthquake (M8.3) is the most intense ever recorded in the world. The 1906 San Francisco earthquake (M8.3) is the most intense ever recorded in the world.

DATA SOURCES
The earthquake occurrence in the main map and the depth profiles are taken from two sources: (1) the Centroidal earthquake catalog (Engdahl and Villaseñor, 2002) and annual supplements for the interval 1900-2007, where for magnitude 5.5 and greater, and (2) the catalog of earthquakes having high-quality depth determinations for the period 1960-2002 and a magnitude range of 1.0-5.5 in Engdahl, personal communication, 2007.

The inclusion points of great earthquakes (M8.3) are designated with a label showing the year of occurrence. These rupture areas are shown as pale yellow polygons. Japan earthquakes (M8.3) are labeled with the year of occurrence. Map outlines are from Hayes and Wald (2007).

The seismic hazard and relative plate motion maps display the generalized seismic hazard of the region (Hayes, et al., 1994).

Pre instrumental seismicity was obtained from the International Geophysical Year (1957-1959) catalog of earthquakes (Engdahl and Villaseñor, 2002).

Seismic hazard maps were obtained from the International Geophysical Year (1957-1959) catalog of earthquakes (Engdahl and Villaseñor, 2002).

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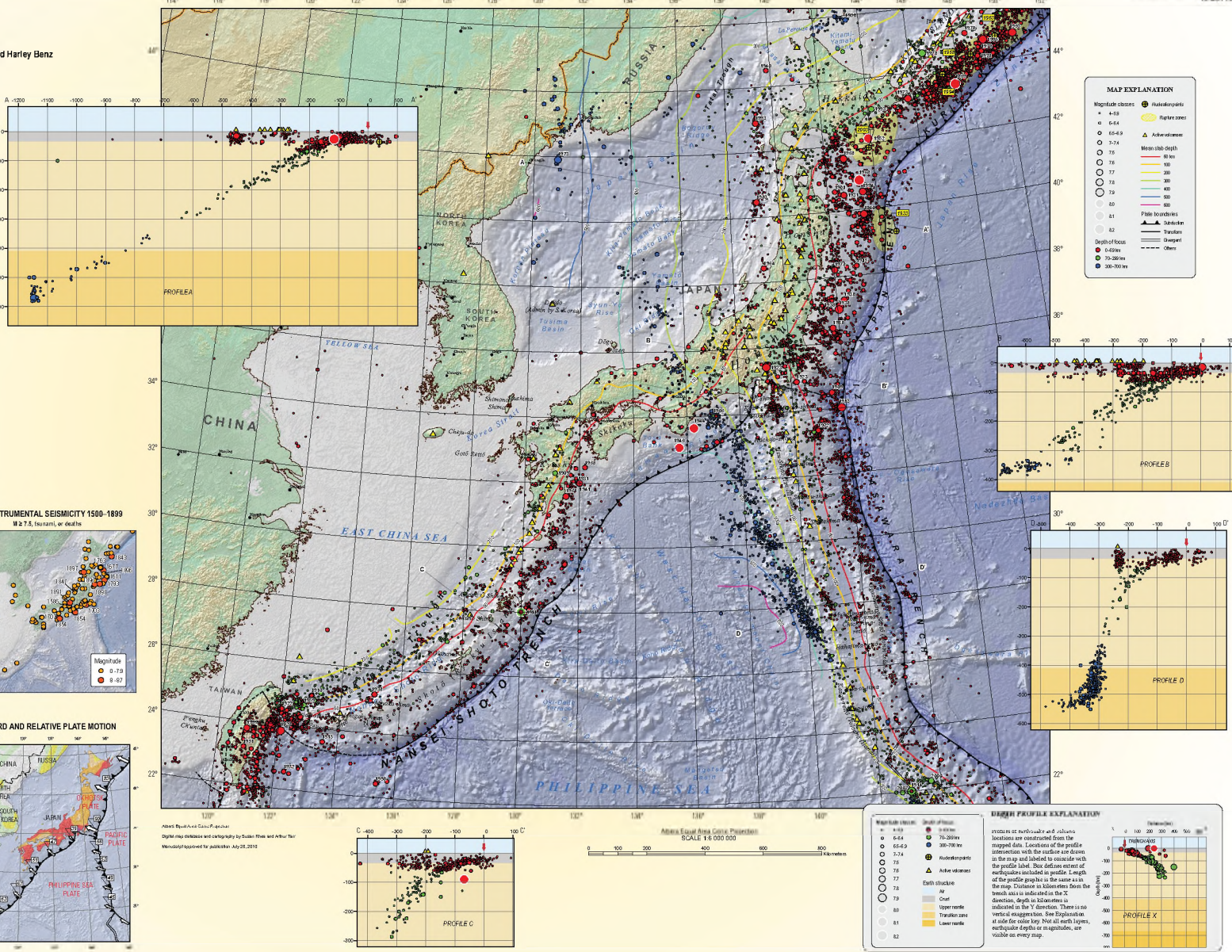
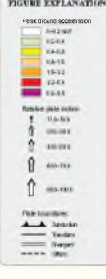
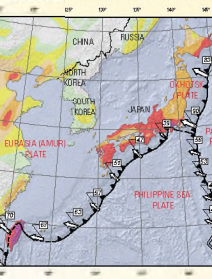


FIGURE EXPLANATION



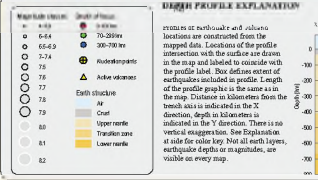
SEISMIC HAZARD AND RELATIVE PLATE MOTION



MAP EXPLANATION



DEPTH PROFILE EXPLANATION



Tohoku, Japan Earthquake: Summary Poster

USGS V1 - 4.5 hrs after OT

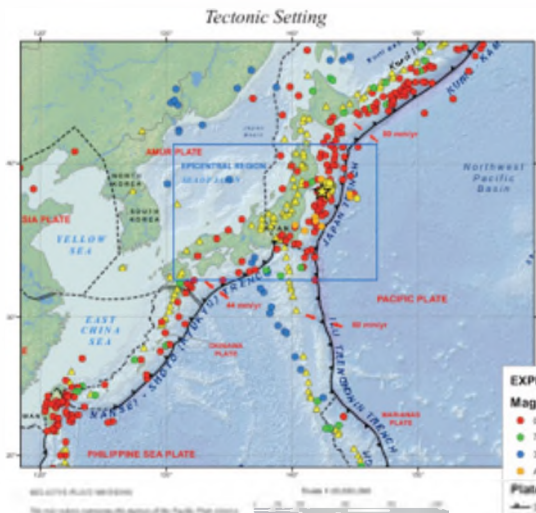


U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

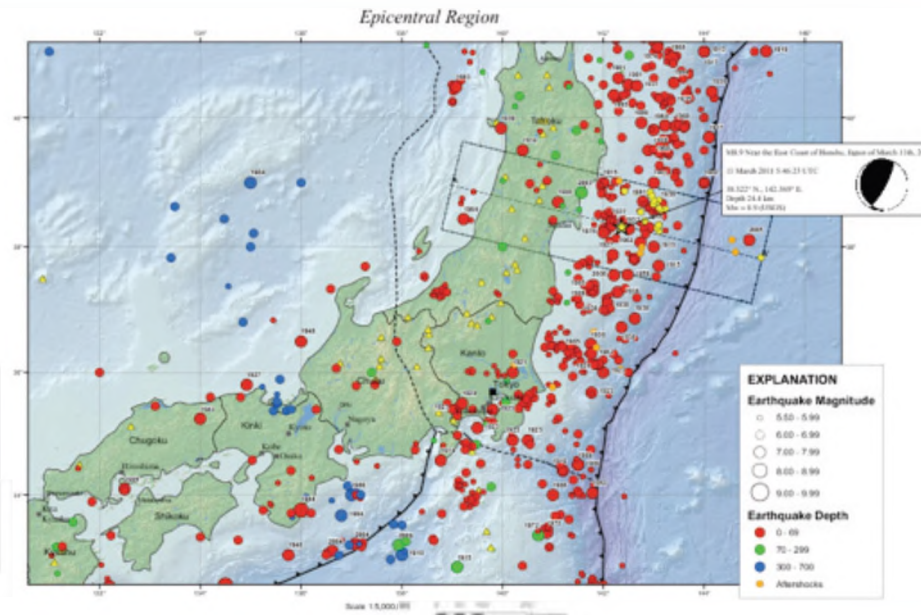
M8.9 Near the East Coast of Honshu, Japan of March 11th, 2011

SEISMOLOGICAL SUMMARY MAP V01

Prepared in
cooperation
with the Global
Seismographic
Network



EXPLANATION
Mag ≥ 7.0
● 0 - 60 km
● 70 - 299
● 300 - 600
● After shocks
--- Plate boundaries
--- Subduction
--- Transform
--- Divergent
--- Others



EXPLANATION
Earthquake Magnitude
● 5.0 - 5.99
● 6.00 - 6.99
● 7.00 - 7.99
● 8.00 - 8.99
● 9.00 - 9.99
Earthquake Depth
● 0 - 60
● 70 - 299
● 300 - 700
● After shocks



M8.9 TECTONIC SUMMARY

The March 11, 2011 earthquake (preliminary magnitude 8.9) near the east coast of Honshu, Japan, occurred as a result of thrust faulting on or near the subduction zone interface between the Pacific and North America plates. At the latitude of this earthquake, the Pacific plate moves approximately southward with respect to the North America plate at a velocity of 83 mm/yr. The Pacific plate thrusts underneath Japan at the Japan Trench, and dips to the west beneath Honshu. The location, depth, and focal mechanism of the March 11 earthquake are consistent with the event having occurred as thrust faulting associated with subduction along the plate boundary. Note that some authors divide this region into several subregions that together define the relative motions between the larger Pacific, North America and Eurasia plates; these include the Okhotsk and Amur subregions that are respectively part of North America and Eurasia.

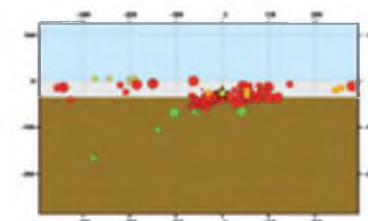
The March 11 earthquake was preceded by a series of large earthquakes over the previous two days, beginning on March 9th with an M7.2 event approximately 40 km from the March 11 earthquake and continuing with a further 1 earthquake greater than M6 from the same day.

The Japan Trench subduction zone has been the source of magnitude 7 or greater since 1975. The largest of these was an M7.6 earthquake approximately 240 km to the north of the March 11 event on December 11th, which caused 1 death and about 100 injuries. In June of 1978, an M7.1 earthquake 17 km to the southeast caused 22 deaths and over 400 injuries.

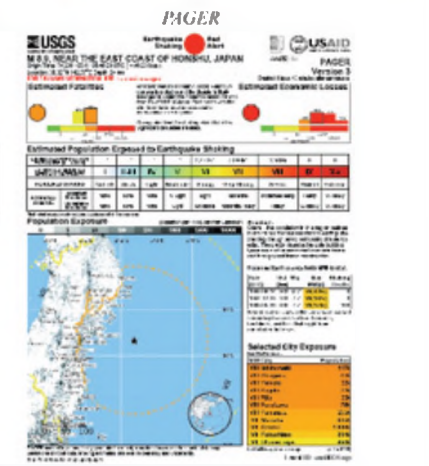
Significant Earthquakes Map ≥ 7.5

Year	Day	Time	Lat	Long	Mag	Depth
1961	08	18:53	41.400	142.150	7.5	10
1966	01	21:13	34.000	137.000	7.5	10
1969	03	14:29	34.300	141.500	7.5	10
1974	11	01:24	35.300	142.000	7.5	10
1979	09	02:59	35.400	139.500	7.5	10
1982	09	02:44	34.300	141.200	7.5	10
1987	03	07:07	35.400	141.500	7.5	10
1991	03	03:48	43.400	142.400	7.5	10
1993	02	17:50	35.200	141.200	7.5	10
1998	03	07:18	34.400	141.700	7.5	10
1998	11	08:43	37.500	142.045	7.5	10
1998	01	03:50	37.100	142.083	7.5	10
1998	11	08:48	37.267	142.283	7.5	10
1999	12	07:40	33.700	134.000	7.5	10
1999	01	17:10	34.000	141.700	7.5	10
1999	04	08:00	35.200	141.200	7.5	10
2000	03	14:00	35.300	141.500	7.5	10
2000	09	27:00	35.300	141.500	7.5	10
2001	09	24:00	34.400	141.700	7.5	10
2001	02	04:40	40.400	140.400	7.5	10
2002	03	17:00	38.100	141.200	7.5	10

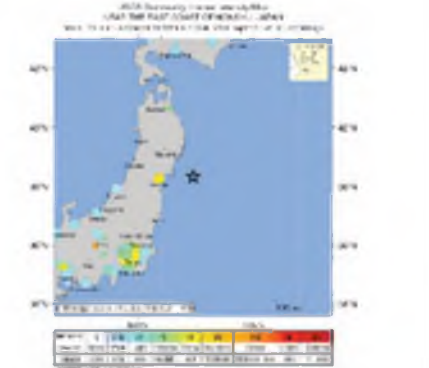
Depth Profile



These maps show the distribution of earthquakes and seismic hazard near the East Coast of Honshu, Japan. The maps are based on data from the Global Seismographic Network and the Japan Meteorological Agency.



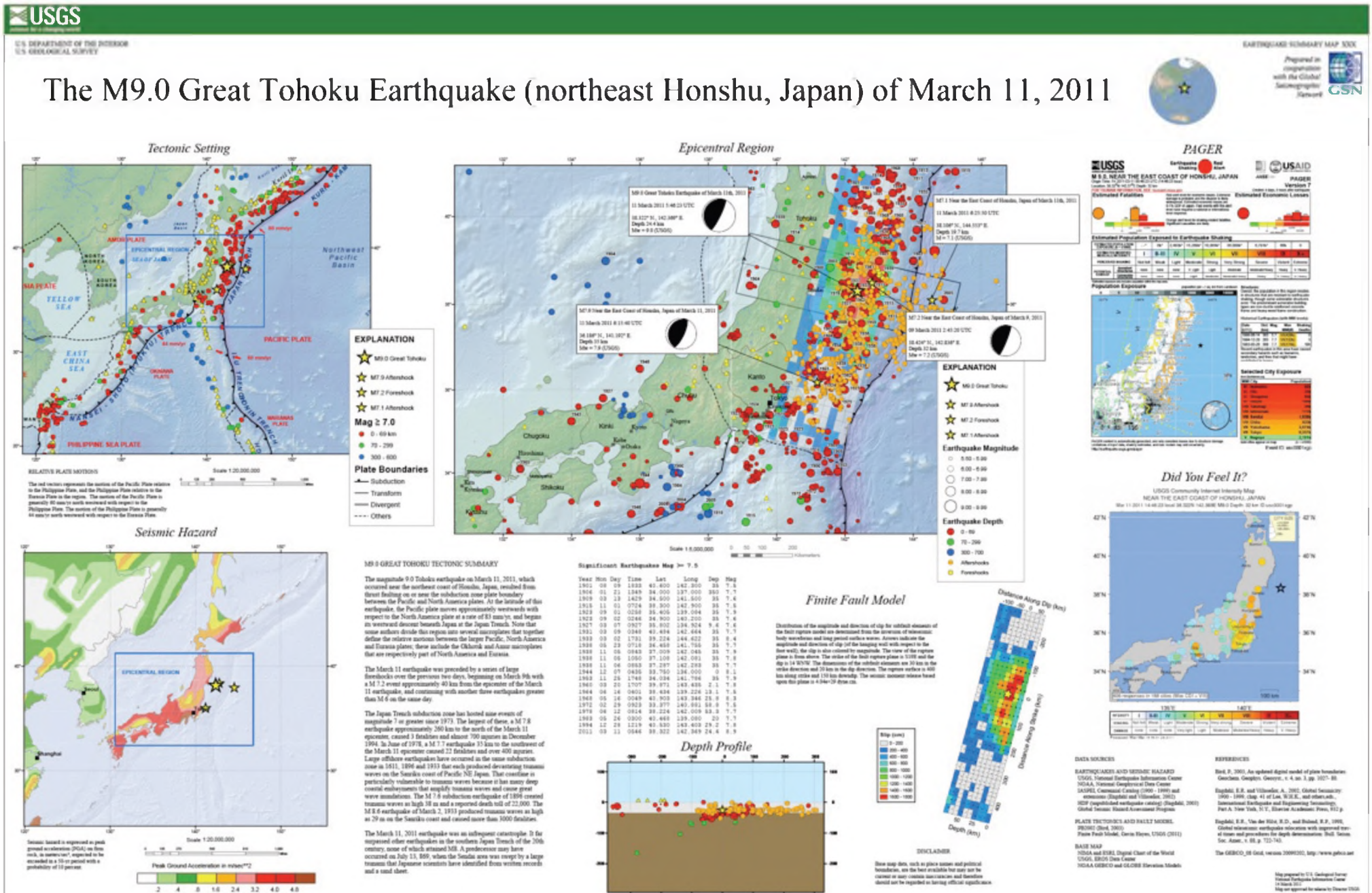
Did You Feel It?



ACKNOWLEDGMENTS
The U.S. Geological Survey is grateful to the following for their contributions to this report:
- National Earthquake Information Center (NEIC)
- National Oceanic and Atmospheric Administration (NOAA)
- National Science Foundation (NSF)
- Japan Meteorological Agency (JMA)
- International Geophysics Institute (IGI)
- International Association of Seismology and Earthquake Engineering (IASIE)
- International Association of Earthquake Engineering (IAEE)
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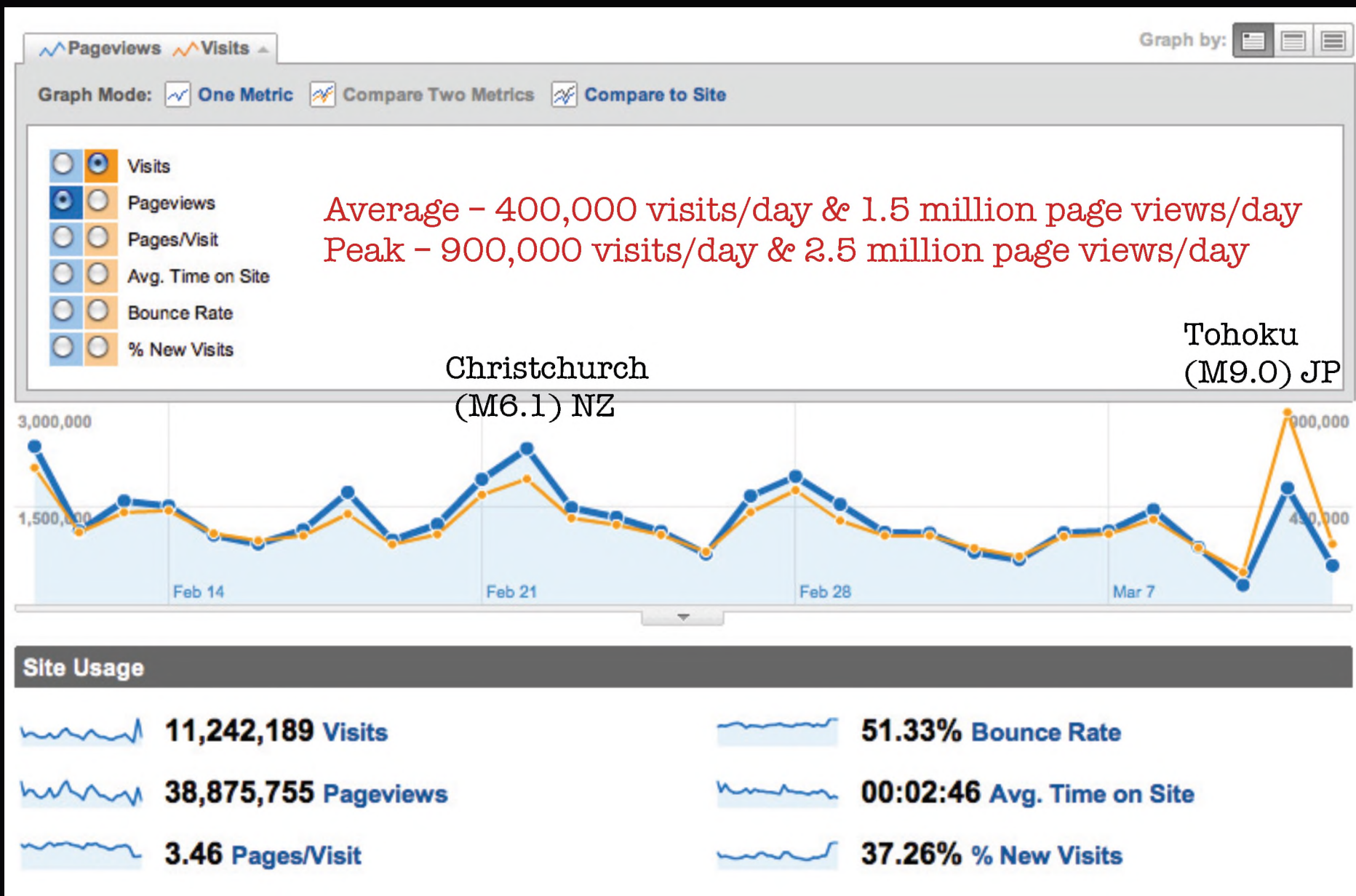
Tohoku, Japan Earthquake: Summary Poster

USGS Current Version

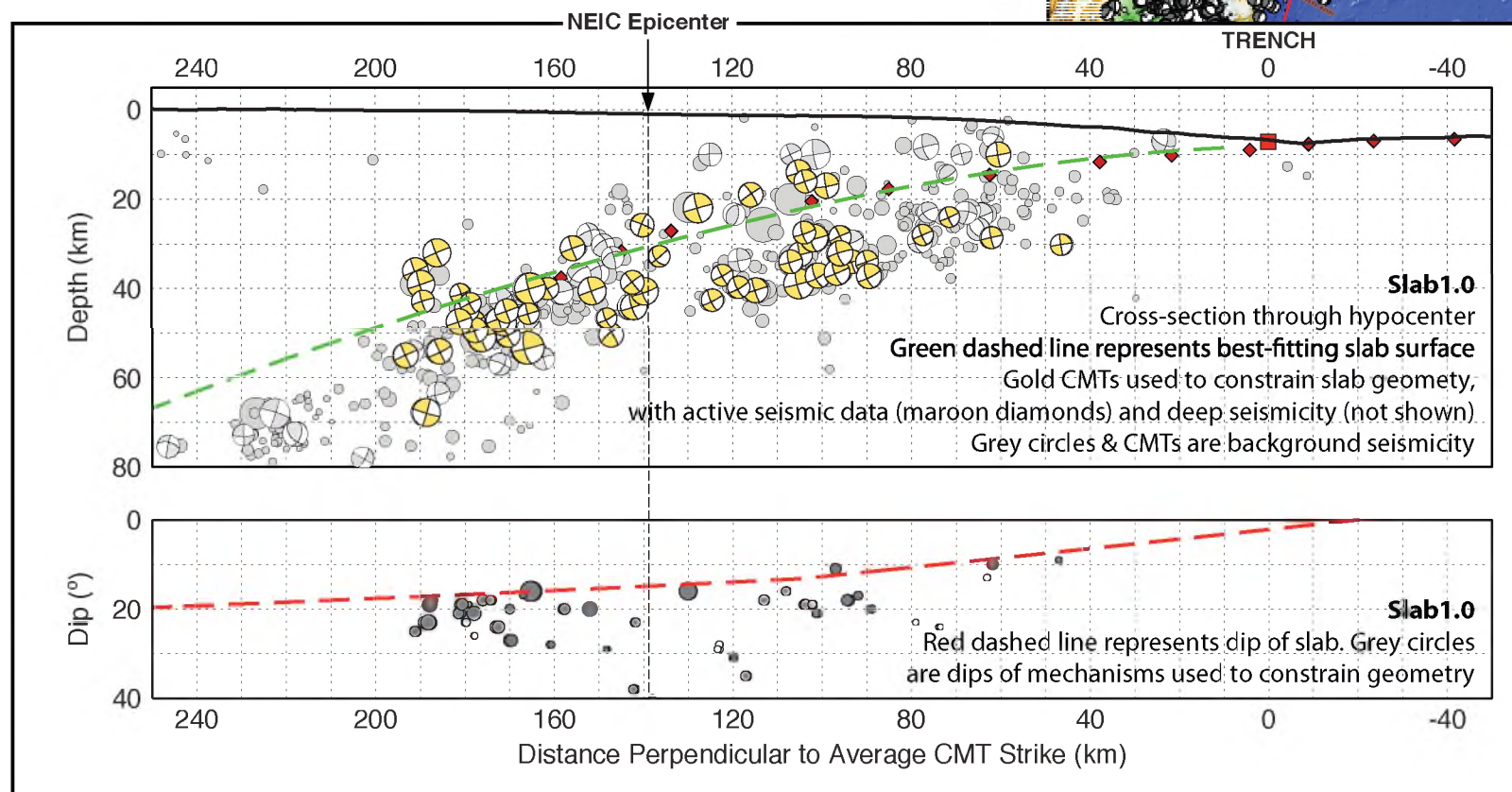
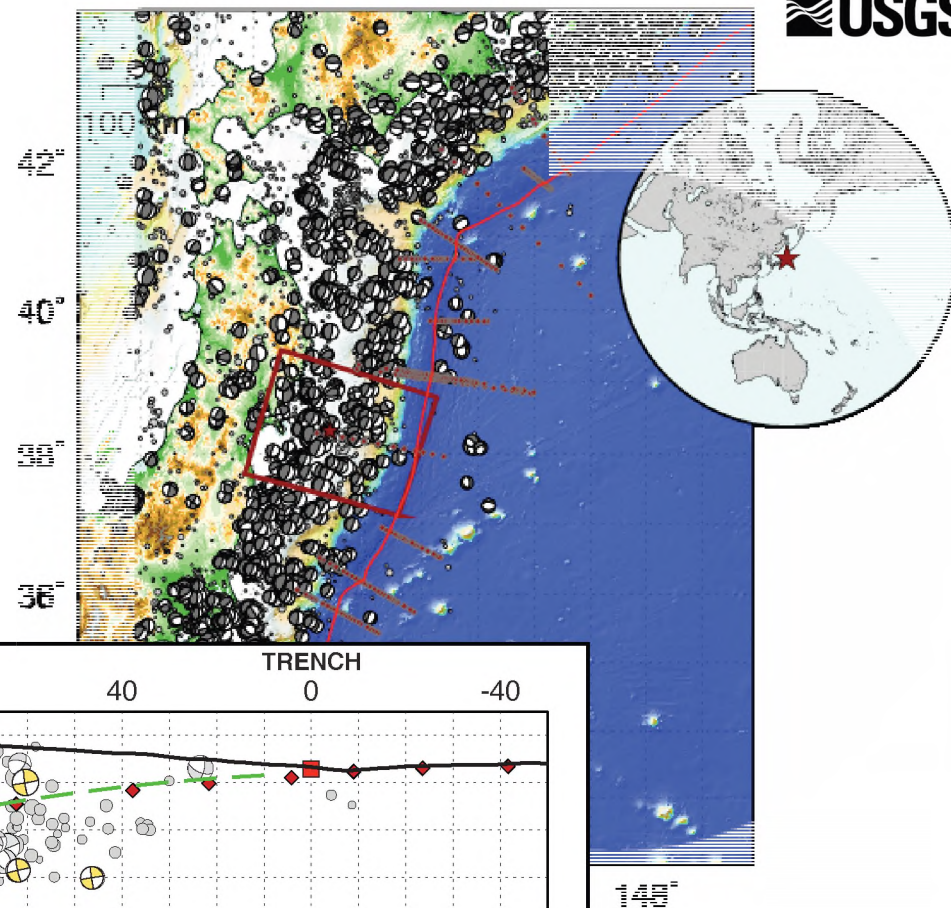




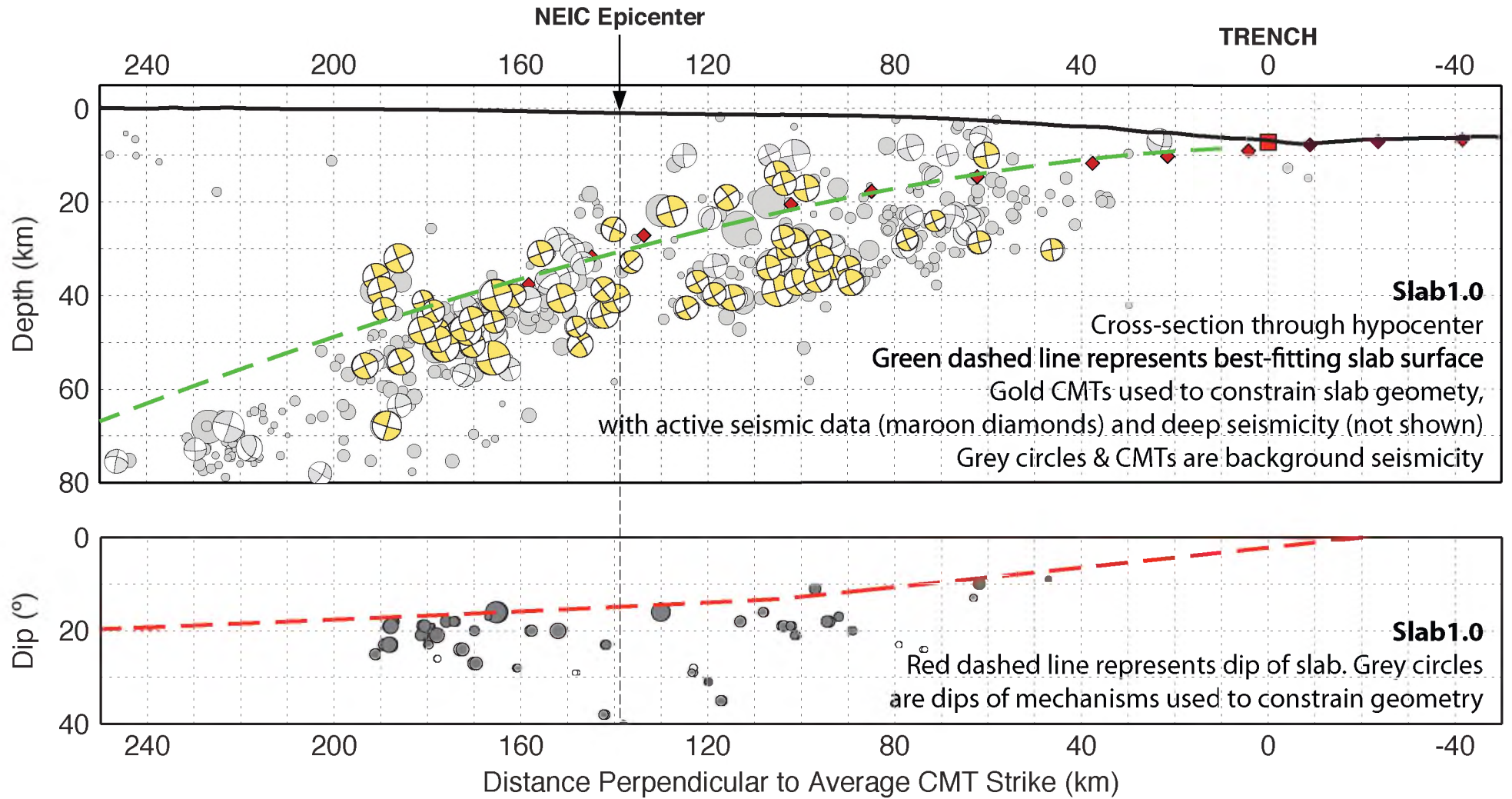
Web Traffic Statistics



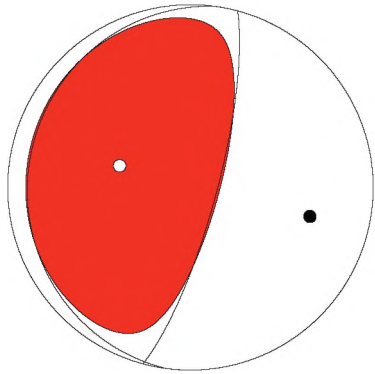
Tohoku, Japan Earthquake: Source Region Slab Geometry



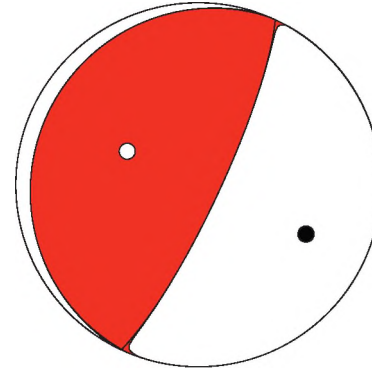
Tohoku, Japan Earthquake: Source Region Slab Geometry



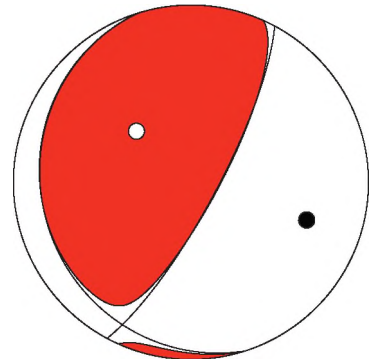
Tohoku, Japan Earthquake: Moment Tensor Solutions (Faulting Mechanisms)



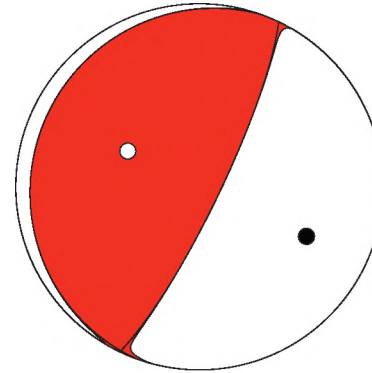
USGS Research Centroid
Moment Tensor
Mw 8.9
Distributed ~34 minutes
after OT
(Jascha Polet, Cal Poly Pomona)



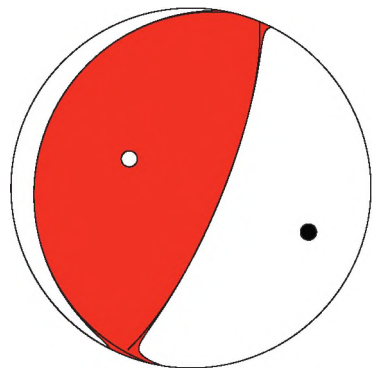
global Centroid Moment
Tensor V1
Mw 9.1
Released 7 hrs after OT



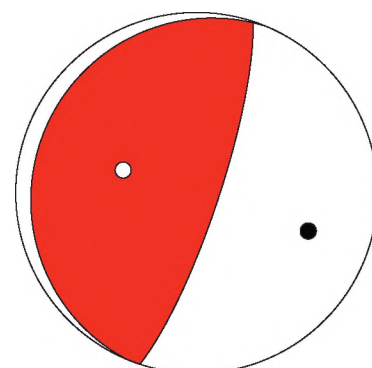
USGS W-Phase V1
Mw 8.9
Released 1 hr after OT



global Centroid Moment
Tensor V2
Mw 9.1
Released ~ 3 days after OT

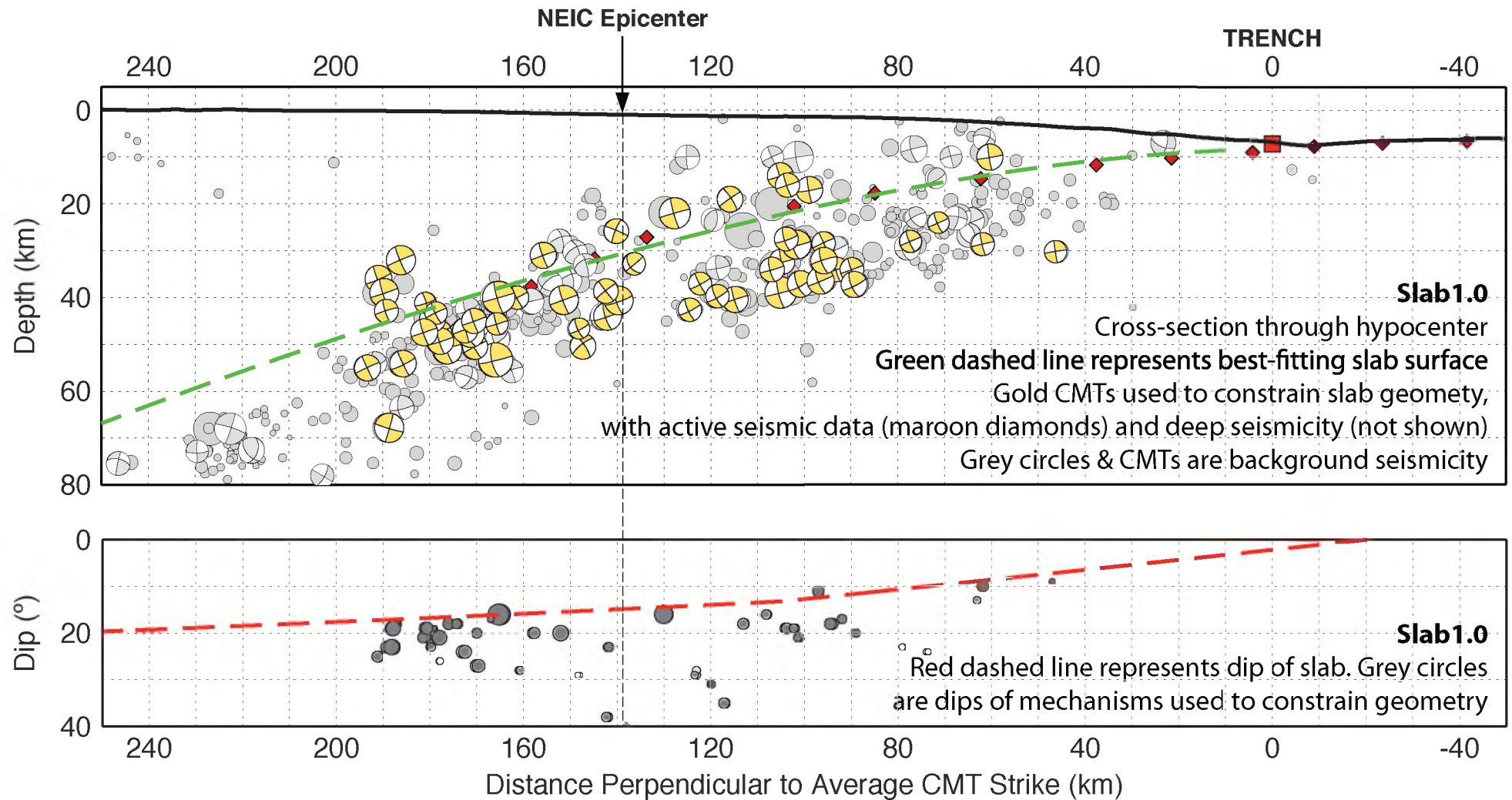


USGS W-Phase V2
Mw 9.0
Released 6 hrs after OT



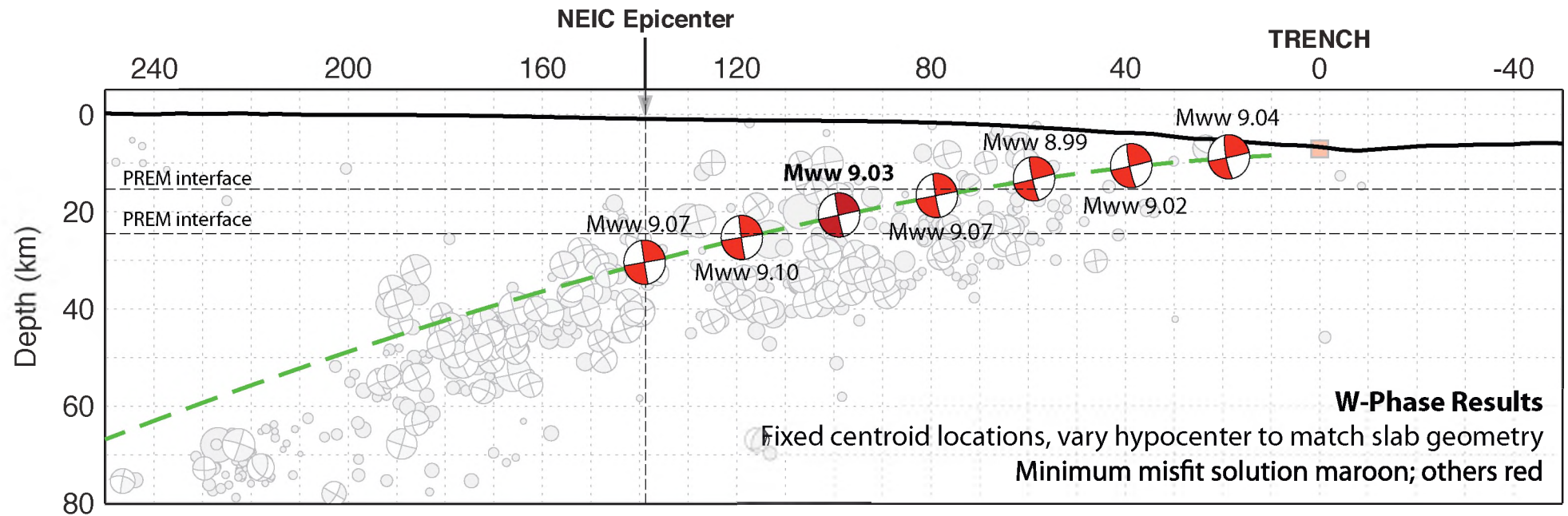
Earthquake Research
Institute, Japan, CMT V1
Mw 9.0

Tohoku, Japan Earthquake: Source Region Slab Geometry



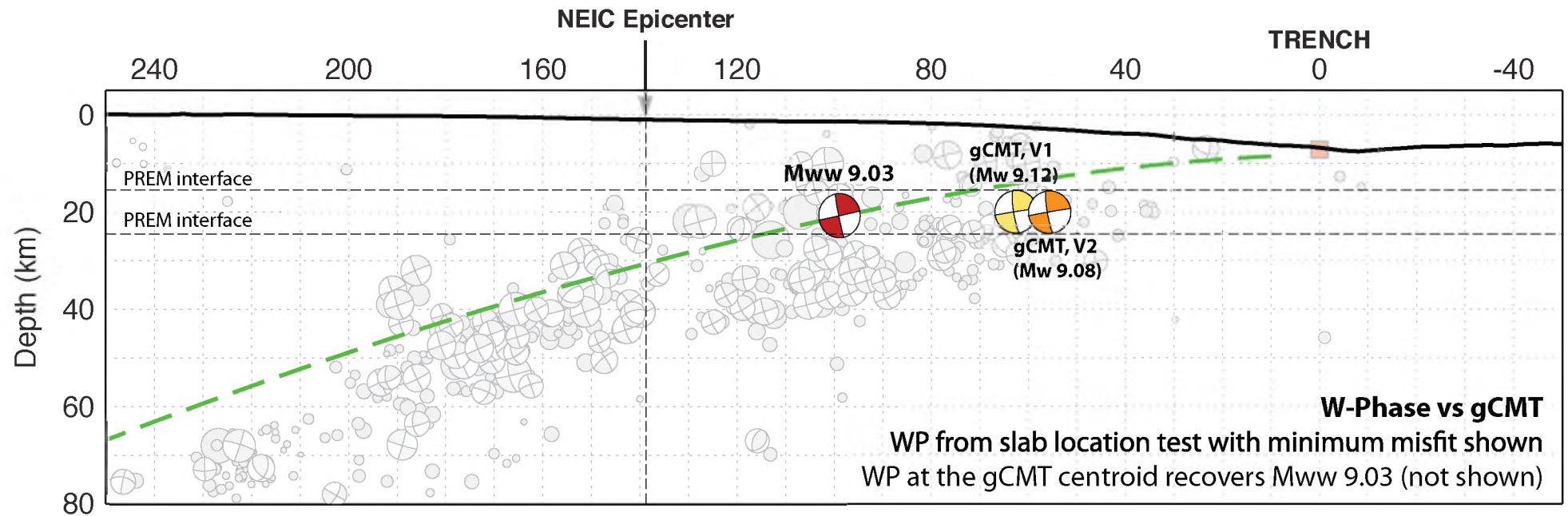
Tohoku, Japan Earthquake: Moment Tensor Analysis

Dip/Depth Sensitivity



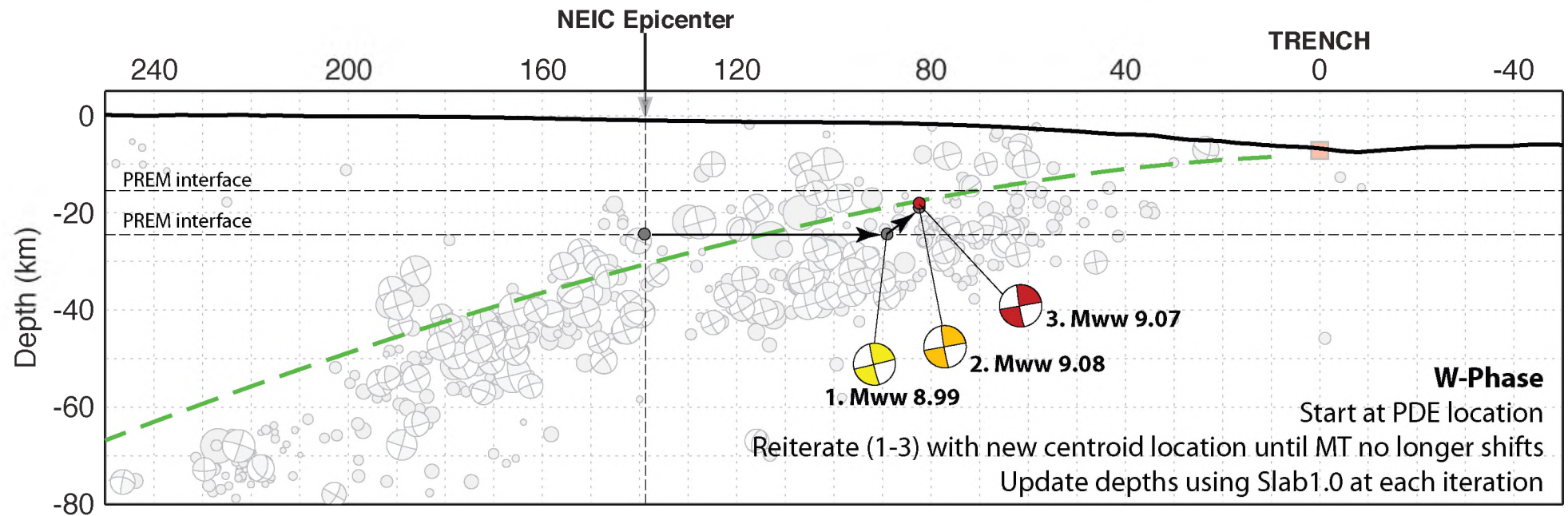
Tohoku, Japan Earthquake: Moment Tensor Analysis

Dip/Depth Sensitivity



Tohoku, Japan Earthquake: Moment Tensor Analysis

Dip/Depth Sensitivity



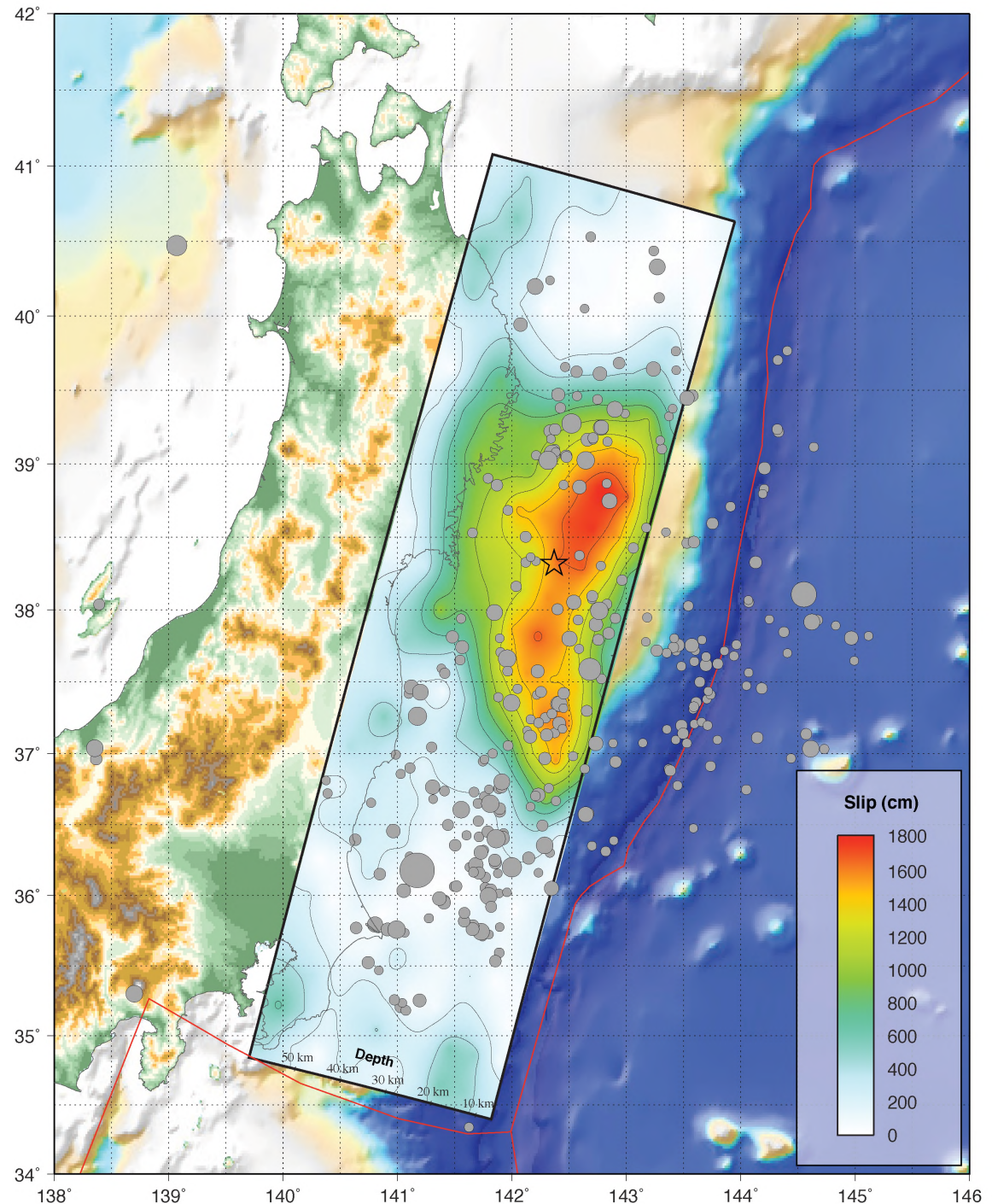
Tohoku, Japan Earthquake: Finite Fault Model

USGS V1 - 7 hrs after OT

Compact rupture, mostly bilateral about epicenter, peak slip up dip of hypocenter.

Rupture was likely restricted to the shallow trench, and GPS vectors suggest slip did not reach the plate boundary beneath the coastline.

Peak slips closer to 30+ m, inferred from updated modeling.



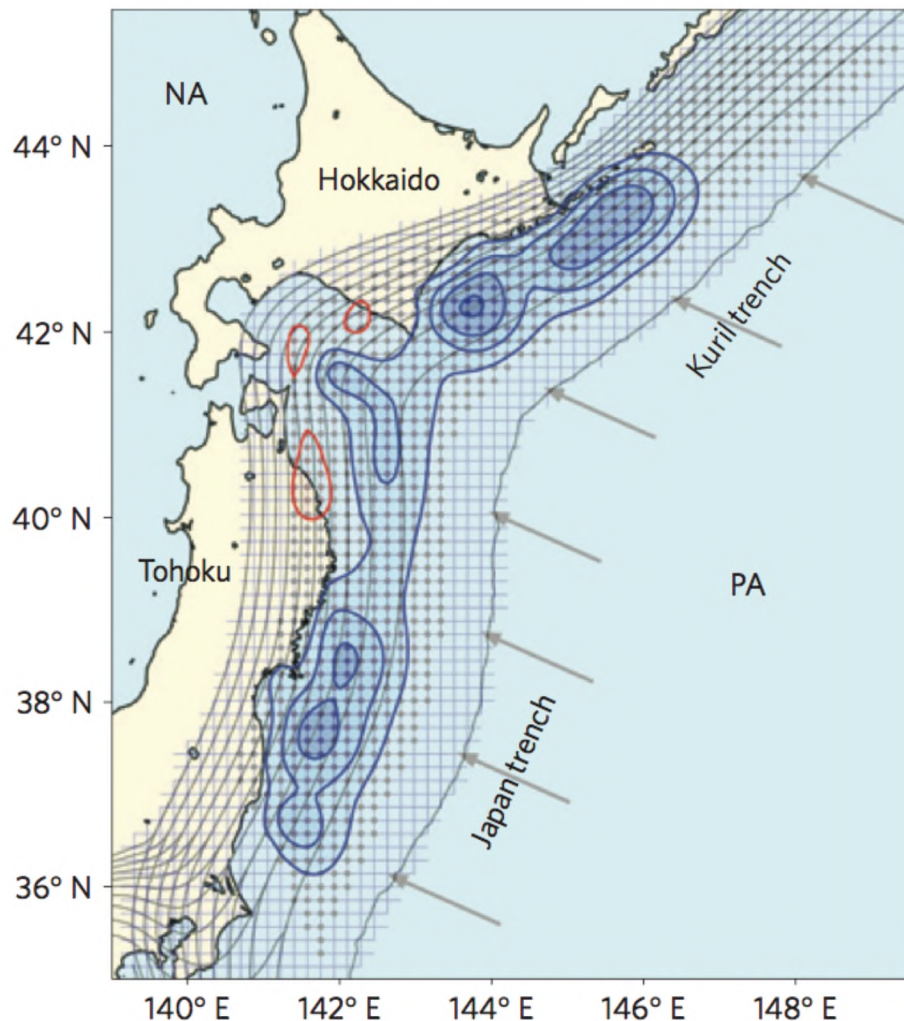
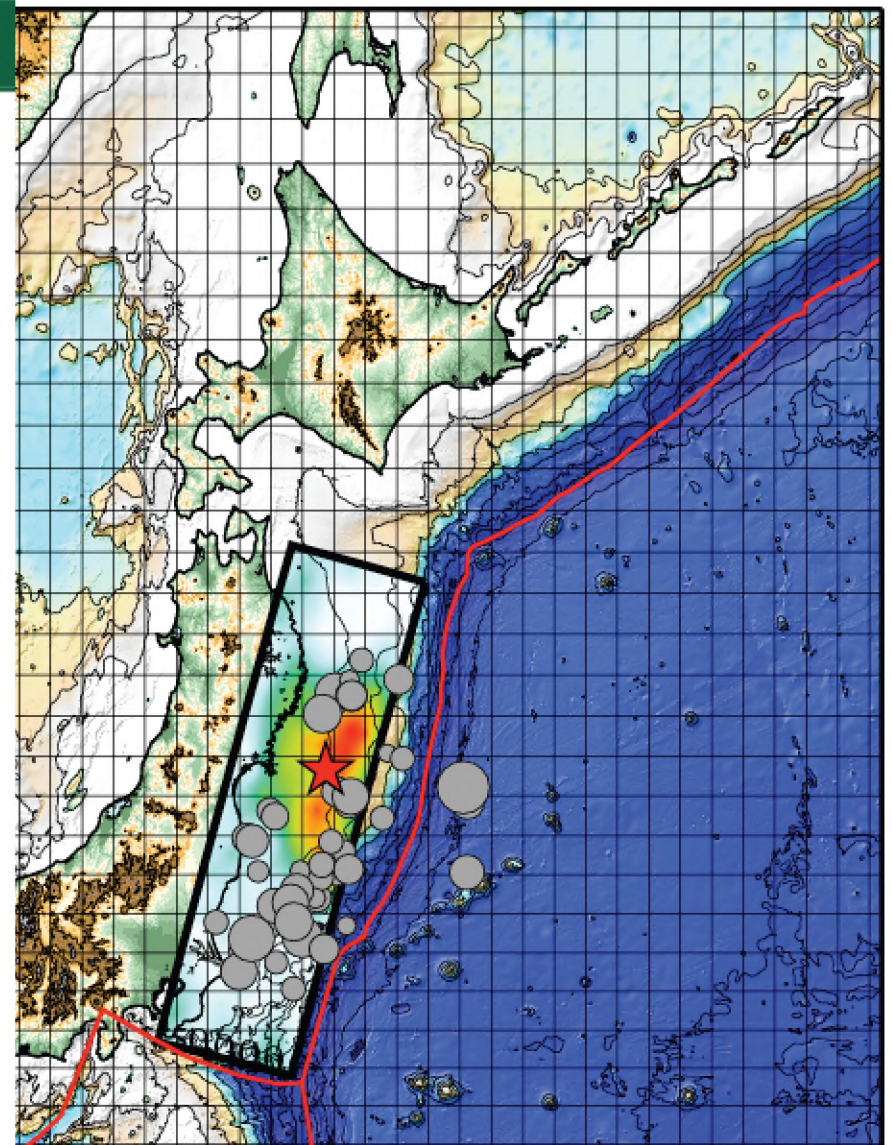
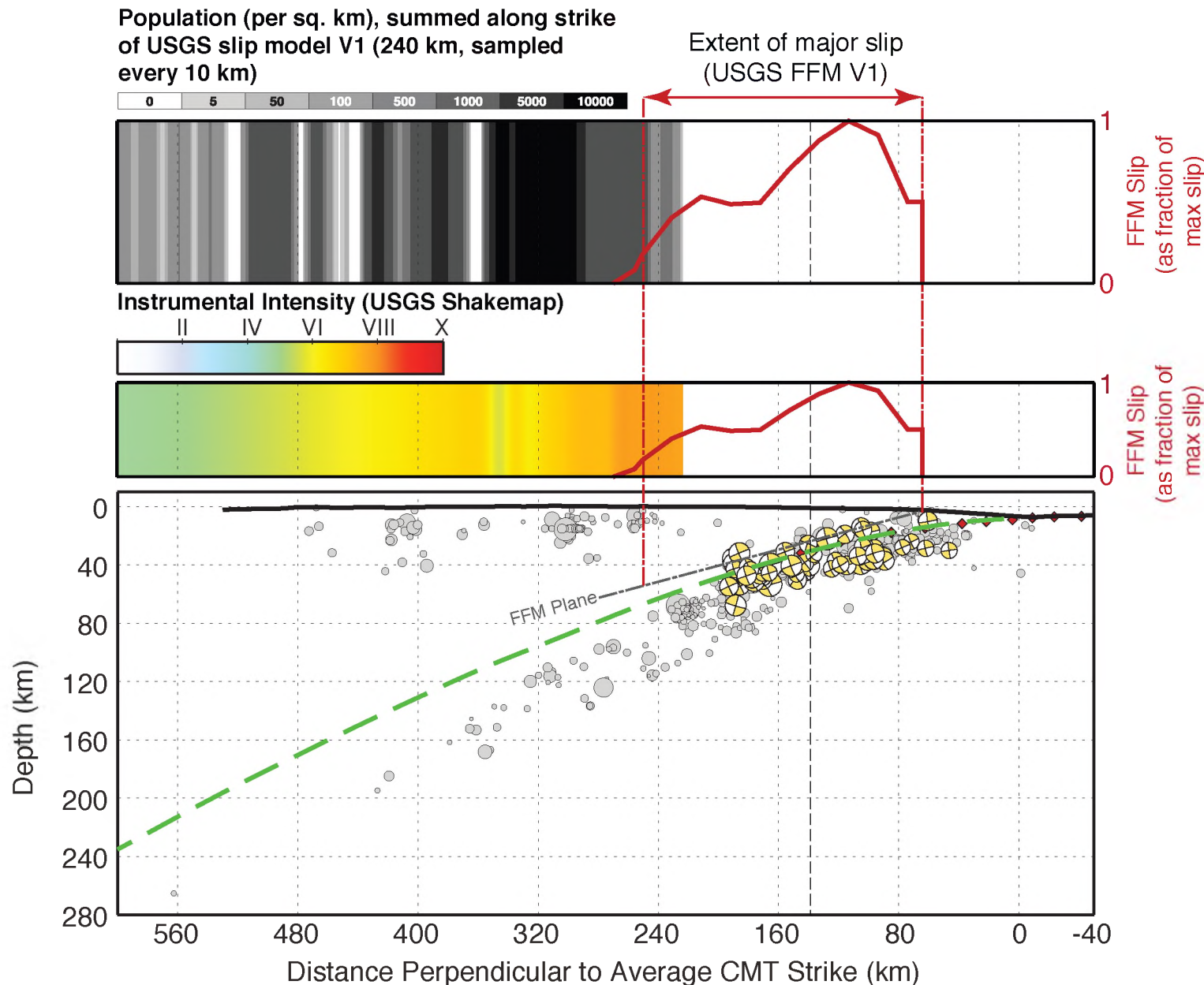


Figure 3 | Inverted slip-deficit rate distribution. The blue and red contours show, respectively, the inverted slip-deficit and slip-excess rates at intervals of 3 cm yr⁻¹. The grey dots indicate the central points of bi-cubic B-splines distributed on the North American/Pacific plate interface. The arrows indicate the relative plate motion calculated from NUVEL-1A (ref. 18).



Finite Fault Model USGS V1 - Comparison with locking estimates (Hashimoto et al., 2009, Nat. Geo.)

Tohoku, Japan Earthquake: Population Exposure & Shaking Intensities vs Slab Geometry & Slip Extent



Note that slip during the earthquake likely did not extend to the depths of the plate boundary directly under the Japan coastline as shown here, because GPS data indicate that the coastline moved down coseismically.

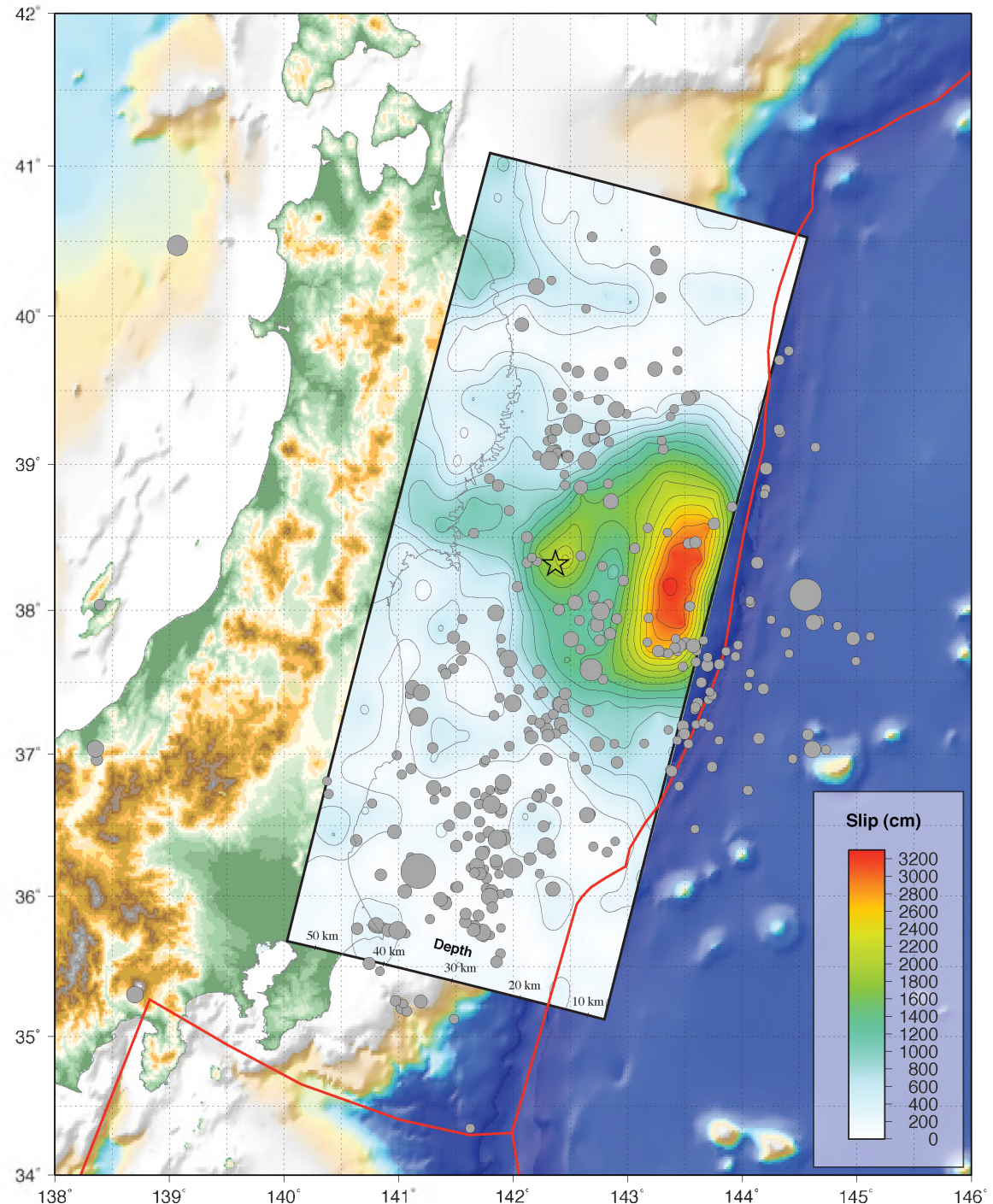
Tohoku, Japan Earthquake: Finite Fault Model

USGS V2 - 2011/03/18

Updated modeling shows peak slips of 30+ m, depending on the parameterization of rupture velocity. This updated model shows peak slip of ~32 m, using a range of rupture velocity from 1.25 - 3 km/s.

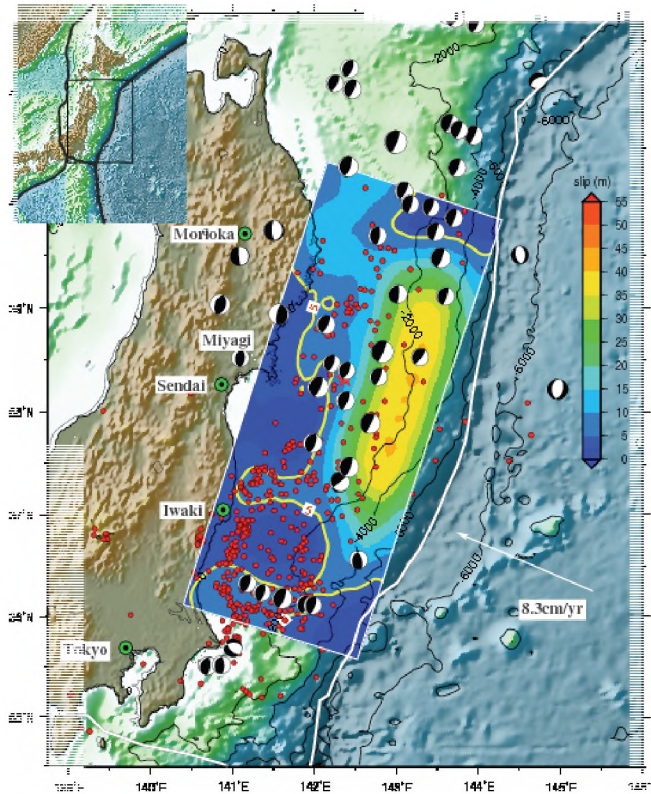
Models with constant rupture velocity show slips of 40-50 m, all at shallow depths. This may imply that the up-dip nature of rupture is well resolved, but peak slips are not.

‘Low’ slip regions near the fault edges, and fault base, are also poorly resolved.

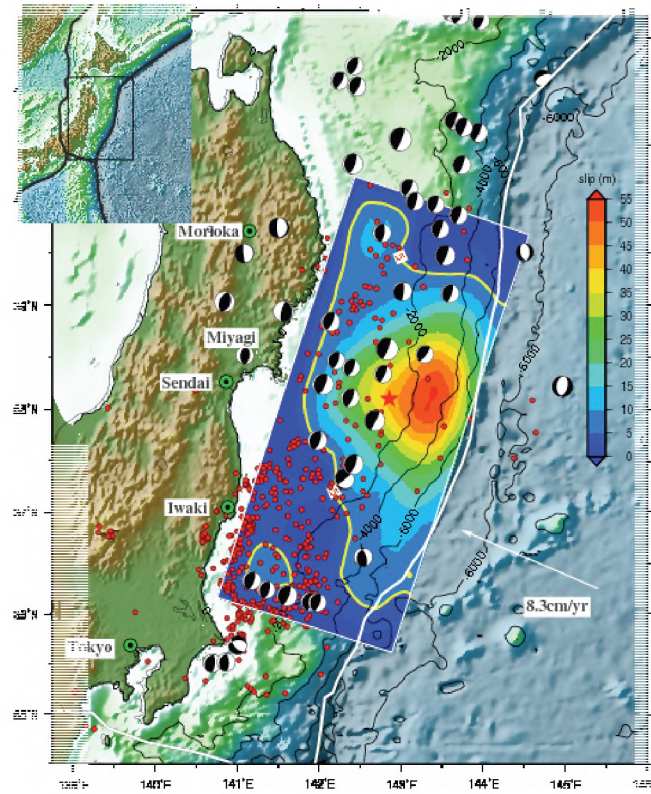


Tohoku, Japan Earthquake: Finite Fault Model

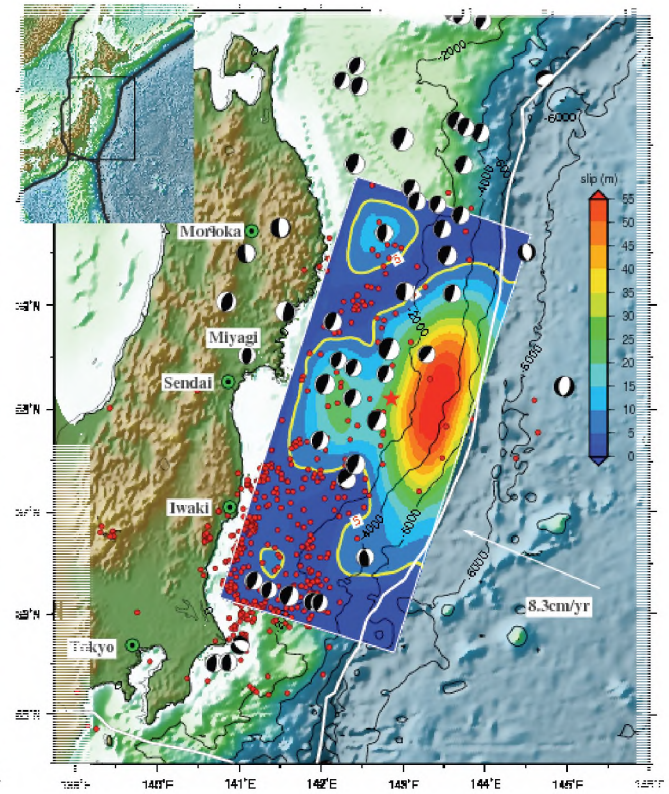
U. California, Santa Barbara



Version 1
NEIC Hypocenter



Version 2
JMA Hypocenter
(50 km ESE)



Version 3
Body & Surface Waves
realigned using the
03/09/2011 Mw 7.3
foreshock.

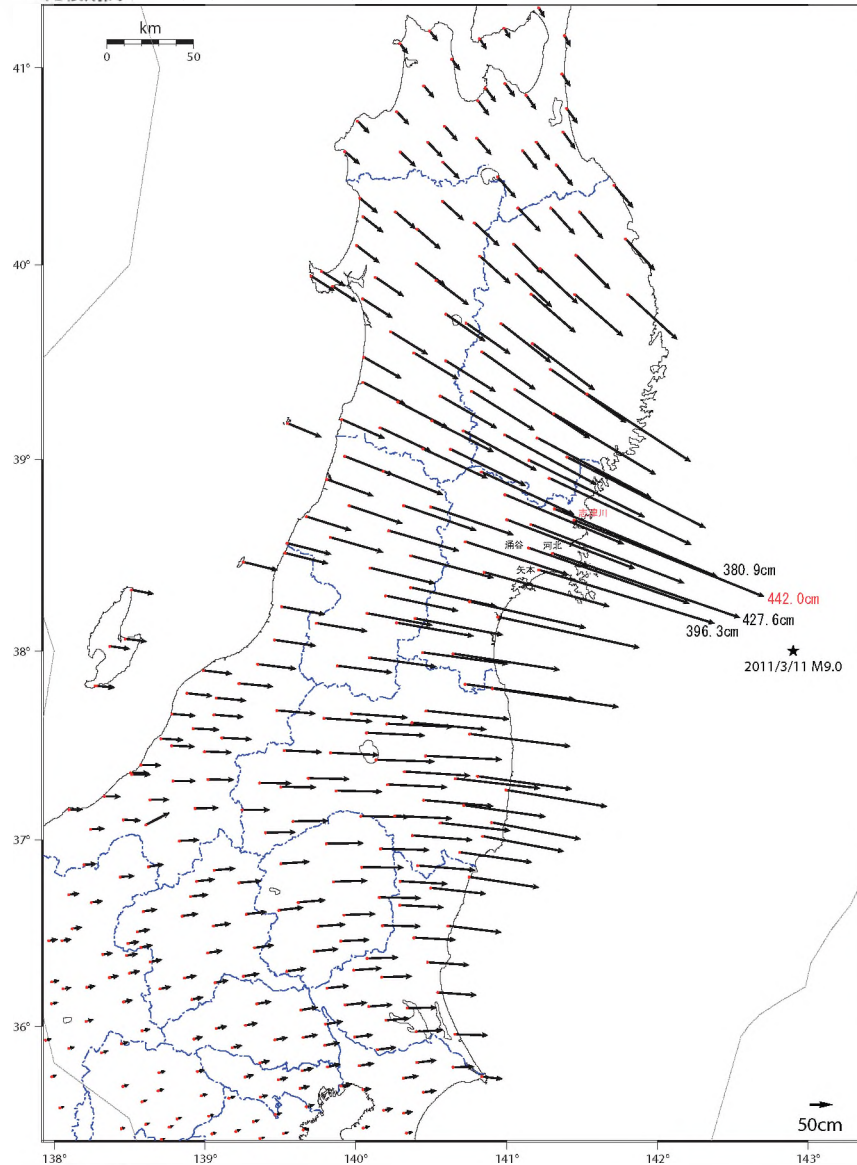
Tohoku, Japan Earthquake: GPS Displacements

Geospatial Information Authority of Japan

変動ベクトル図（水平）

暫定

基準期間：2011/03/01 21:00 - 2011/03/09 21:00
比較期間：2011/03/11 18:00 - 2011/03/13 03:00



[基準：R3速報値 比較：Q3速報値]

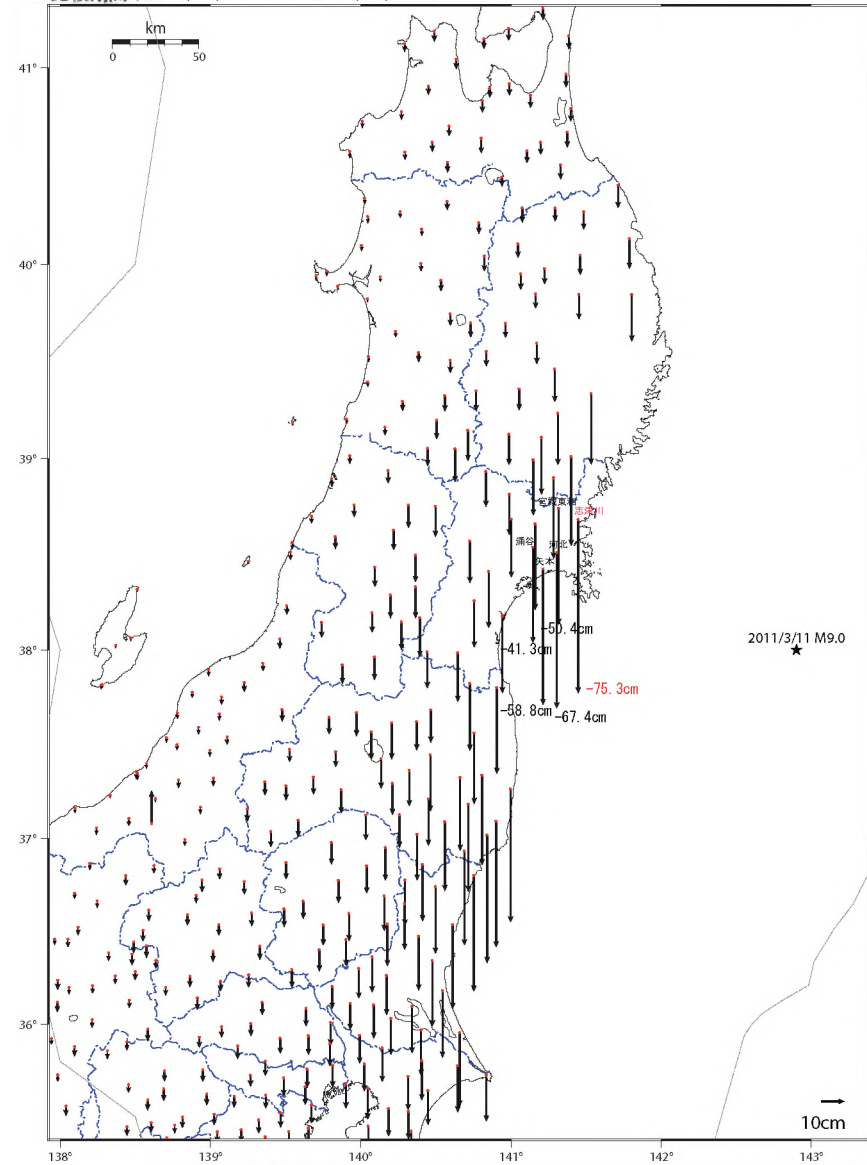
☆固定局：三隅（950388）

国土地理院

変動ベクトル図（上下）

暫定

基準期間：2011/03/01 21:00 - 2011/03/09 21:00
比較期間：2011/03/11 18:00 - 2011/03/13 03:00



[基準：R3速報値 比較：Q3速報値]

☆固定局：三隅（950388）

国土地理院

Tohoku, Japan Earthquake: Other Groups

Many groups have published (online) slip models for this earthquake; below is a list of some of these (note this is not complete):

Geospatial Information Authority, Japan (using regional GPS data):

<http://www.gsi.go.jp/cais/topic110315-index-e.html>

Charles Ammon, Penn State; Thorne Lay, UCSC; Hiroo Kanamori, Caltech:

<http://eqseis.geosc.psu.edu/~cammon/Japan2011EQ/>

Caltech Tectonics Observatory:

http://tectonics.caltech.edu/slip_history/

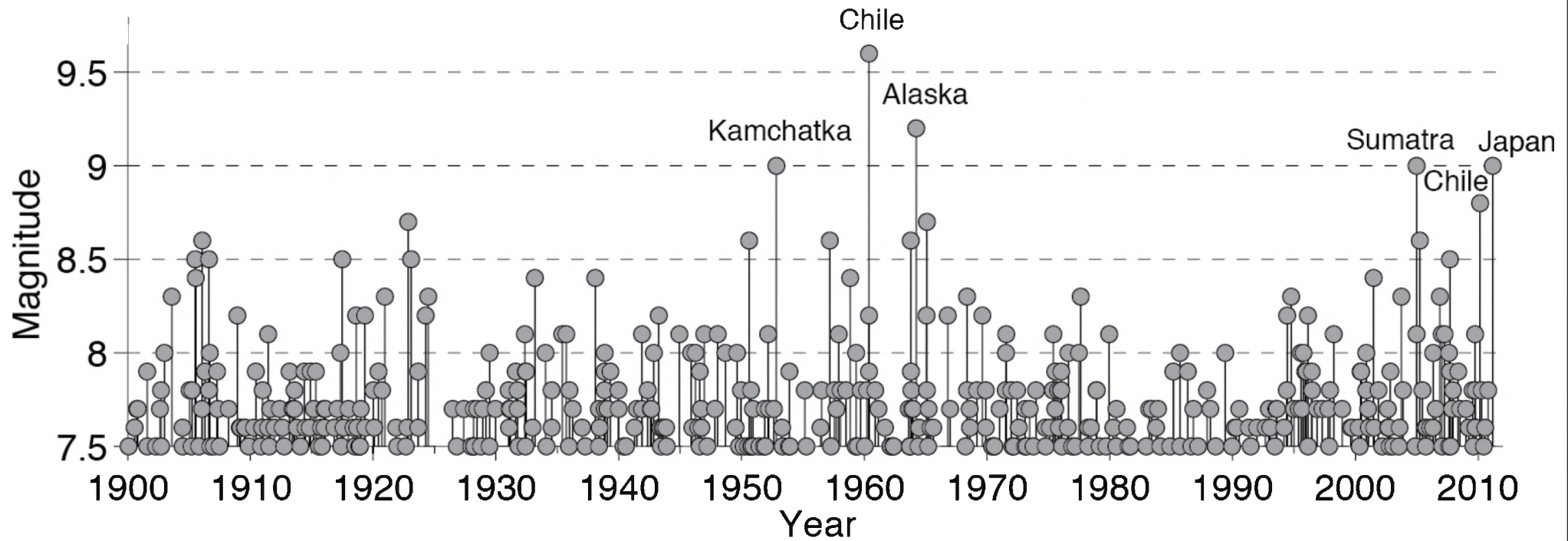
Yuji Yagi, Naoki Nishimura, University of Tsukuba:

<http://www.geol.tsukuba.ac.jp/~yagi-y/EQ/Tohoku/>

For a more comprehensive list of models, and results from other analyses, see the special IRIS website:

<http://www.iris.edu/news/events/japan2011/>

A History Of Large Earthquakes



Data: USGS PAGERCAT 1900-2008, USGS-NEIC & gCMT 2008-present

Figure courtesy of Charles Ammon, after Ammon et al., SRL, 2010