SCSTW-7, November 17-22, Taichung, Taiwan

Potential for Megathrust Earthquakes in Southern Ryukyu and Northern Manila Subduction Zones as Viewed from Background Seismicity

Yi-Ben Tsai

with special acknowledgements to the Central Weather Bureau for its travel funding.

Outline of Presentation

- Several recent studies have shown definitive potential for megathrust earthquakes in southern Ryukyu and northern Manila subduction zones, i.e. HsuYJ et al.(2012a,b,c;2014), HsuSK et al.(2013), Lin et al.(2014).

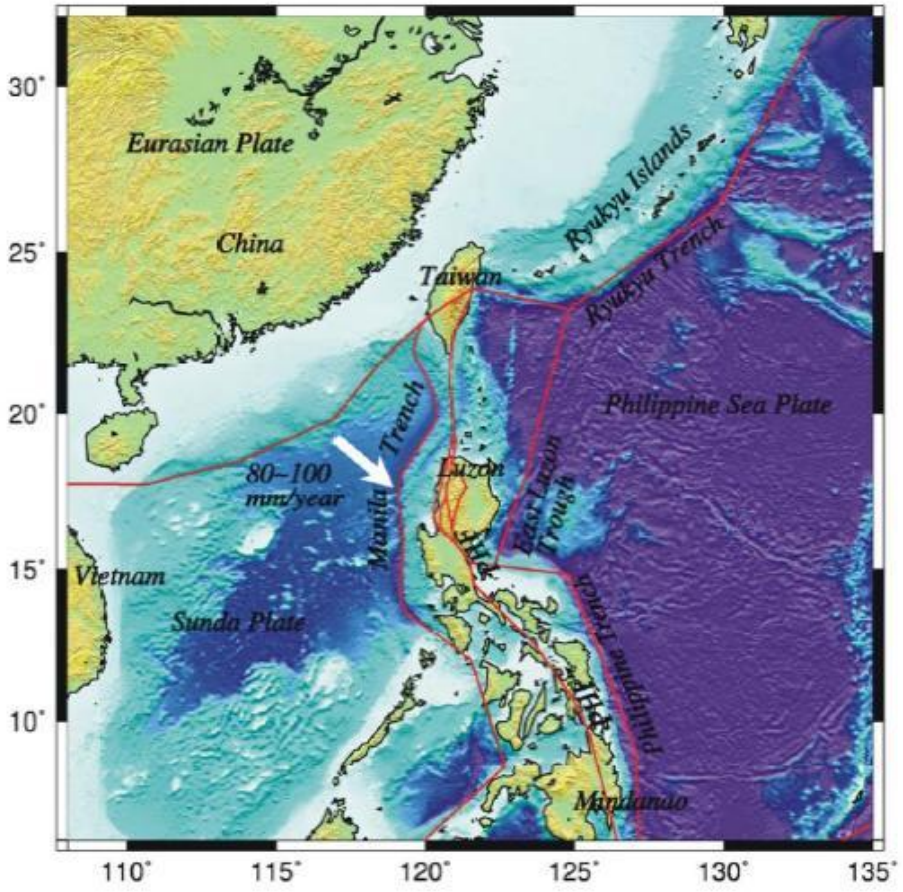
- These two regions are shown to have background seismicity rates comparable with recent five megathrust earthquakes having M8.5 to M9.1, lending additional support to previous findings.

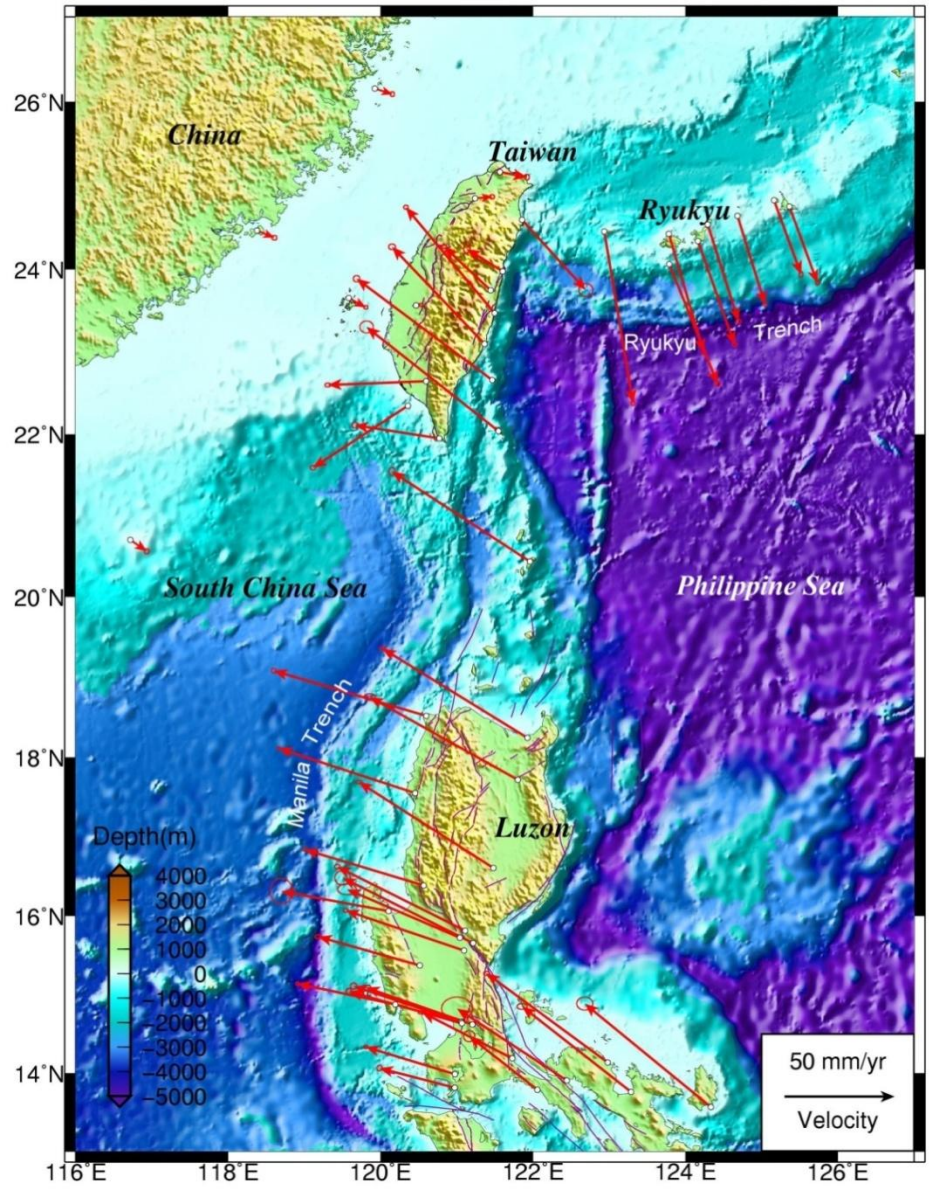
- Potential seismic, tsunami, and other hazards to Taiwan, Ryukyu Islands, Luzon Island and other surrounding regions call for serious attention.

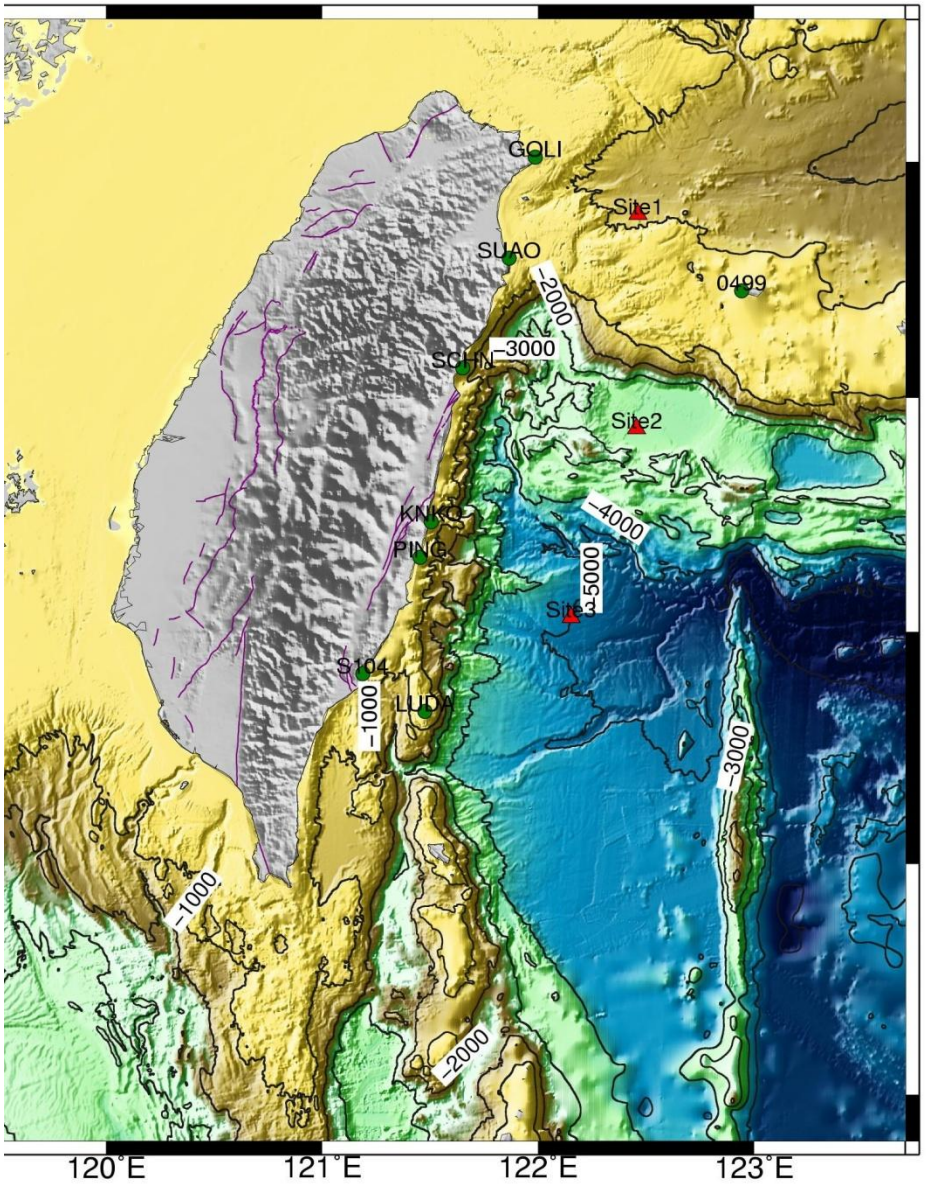
Main Data Sources

- U.S. Geological Survey: http://earthquake.usgs.gov/earthquakes/
- Earthquake Research Institute, University of Tokyo: http://www.eri.u-tokyo.ac.jp/eqvolc/ 201103_tohoku/

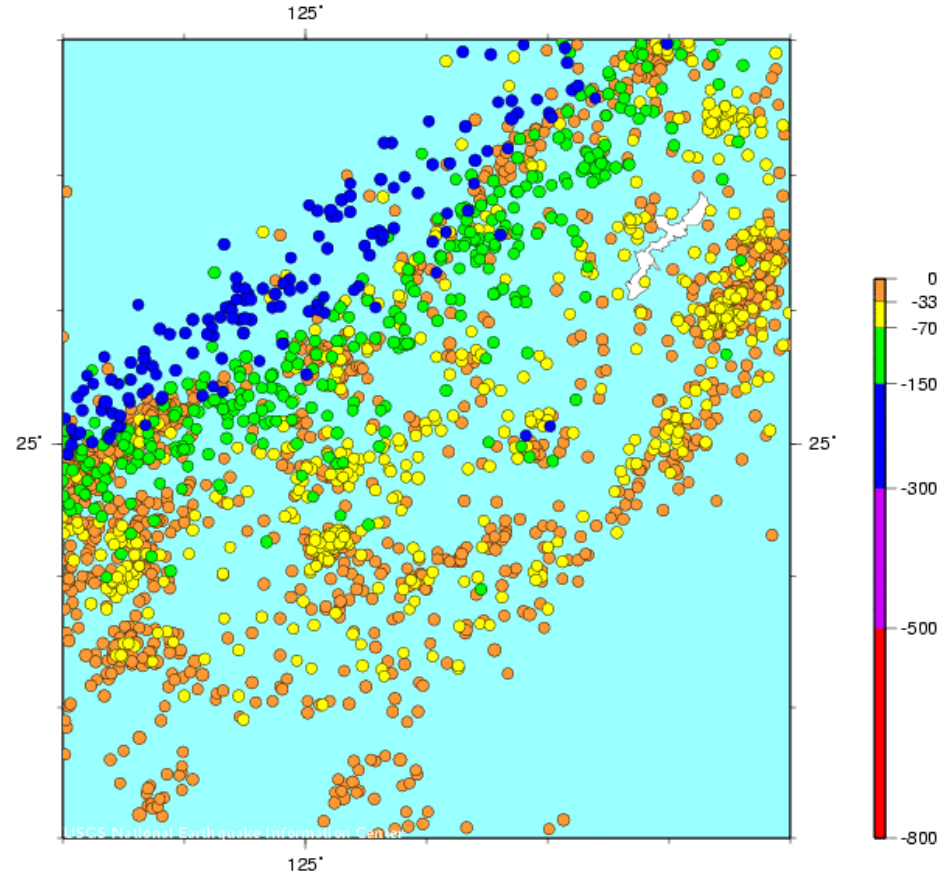
Ryukyu and Manila Subduction Zones near Taiwan
(After Hsu et al.,2014)

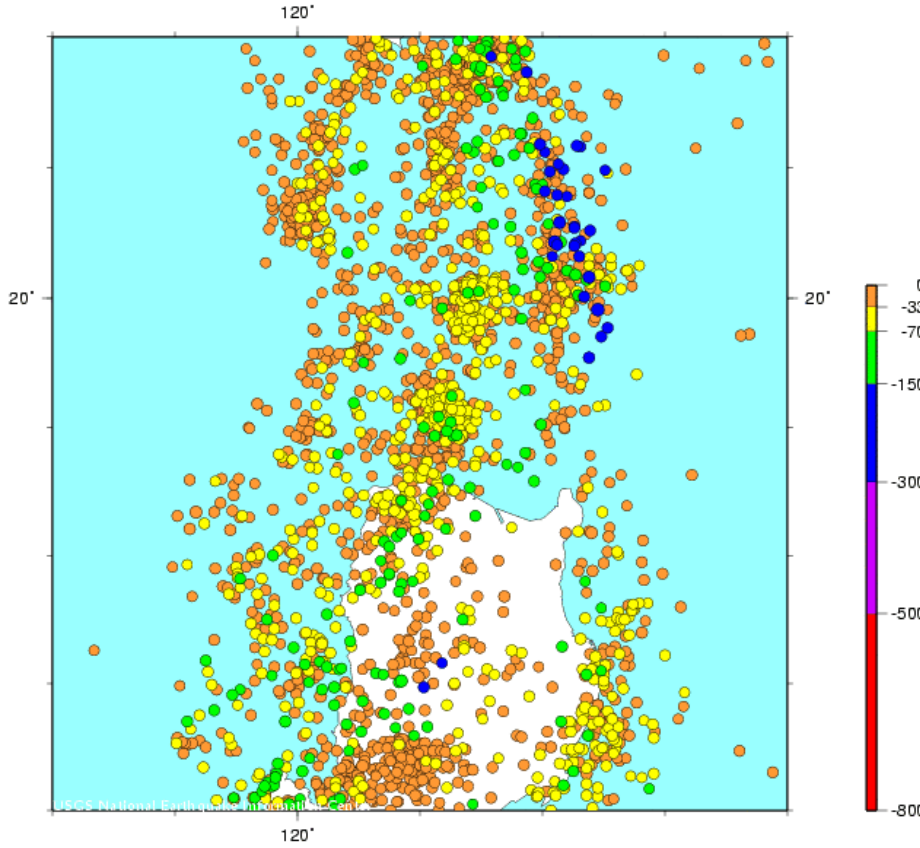



China
Taiwan
Ryukyu
Ryukyu Trench
South China Sea
Philippine Sea
Manila Trench
Luzon
Depth(m)
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
−5000
50 mm/yr
Velocity
26°N
24°N
22°N
20°N
18°N
16°N
14°N
116°E
118°E
120°E
122°E
124°E
126°E


GOLI
Site1
SUAO
0499
−2000
−3000
SCHN
Site2
KNKC
PING
−4000
−5000
Site3
S104
LUDA
−1000
−3000
−1000
−2000
120°E
121°E
122°E
123°E

Regional Seismicity in Southern Ryukyu and Northern Malina subduction zones (19730101-20110610, M≥4)





Lin et al. Earth, Planets and Space 2014, 66:49
http://www.earth-planets-space.com/content/66/1/49

Earth, Planets and Space
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Could a Sumatra-like megathrust earthquake occur in the south Ryukyu subduction zone?

Jing-Yi Lin[1*], Jean-Claude Sibuet[1], Shu-Kun Hsu[1] and Wen-Nan Wu[2]

Megathrust Earthquake Potential in Southern Ryukyu Subduction Zone (After Lin et al.,2014)

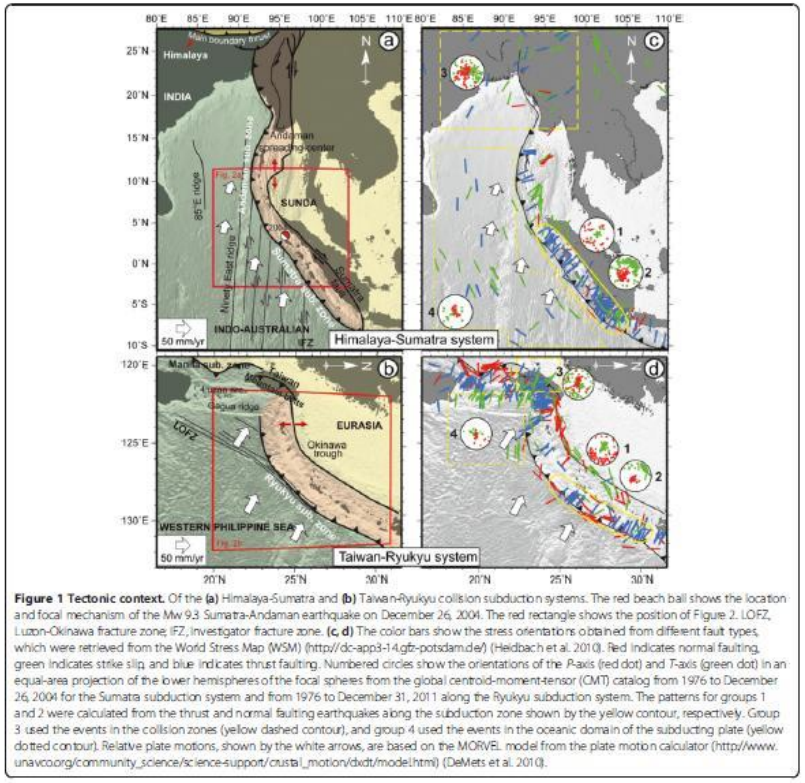

Figure 1 Tectonic context. Of the **(a)** Himalaya-Sumatra and **(b)** Taiwan-Ryukyu collision subduction systems. The red beach ball shows the location and focal mechanism of the Mw 9.3 Sumatra-Andaman earthquake on December 26, 2004. The red rectangle shows the position of Figure 2. LOFZ, Luzon-Okinawa fracture zone; IFZ, investigator fracture zone. **(c, d)** The color bars show the stress orientations obtained from different fault types, which were retrieved from the World Stress Map (WSM) (http://dc-app3-14.gfz-potsdam.de/) (Heidbach et al. 2010). Red indicates normal faulting, green indicates strike slip, and blue indicates thrust faulting. Numbered circles show the orientations of the *P*-axis (red dot) and *T*-axis (green dot) in an equal-area projection of the lower hemispheres of the focal spheres from the global centroid-moment-tensor (CMT) catalog from 1976 to December 26, 2004 for the Sumatra subduction system and from 1976 to December 31, 2011 along the Ryukyu subduction system. The patterns for groups 1 and 2 were calculated from the thrust and normal faulting earthquakes along the subduction zone shown by the yellow contour, respectively. Group 3 used the events in the collision zones (yellow dashed contour), and group 4 used the events in the oceanic domain of the subducting plate (yellow dotted contour). Relative plate motions, shown by the white arrows, are based on the MORVEL model from the plate motion calculator (http://www.unavco.org/community_science/science-support/crustal_motion/dxdt/model.html) (DeMets et al. 2010).

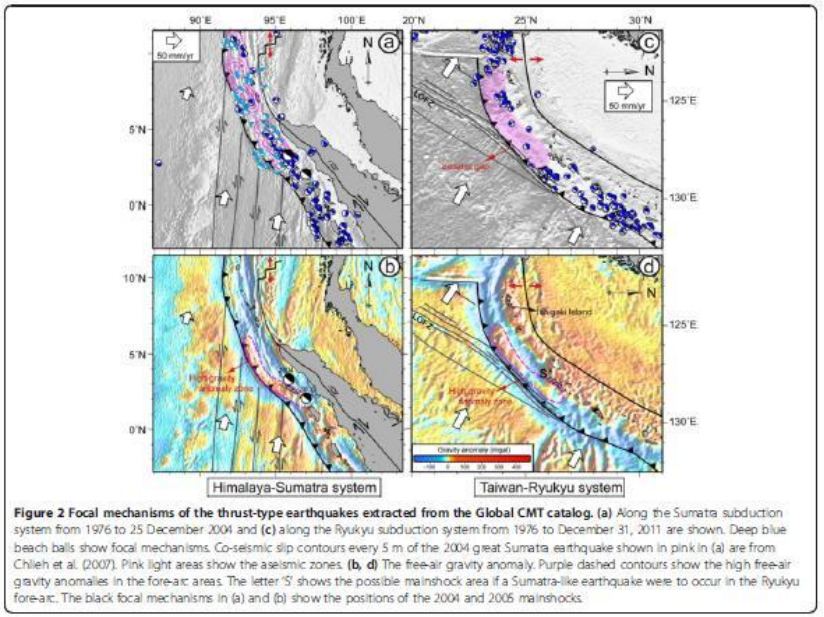

Figure 2 Focal mechanisms of the thrust-type earthquakes extracted from the Global CMT catalog. (a) Along the Sumatra subduction system from 1976 to 25 December 2004 and **(c)** along the Ryukyu subduction system from 1976 to December 31, 2011 are shown. Deep blue beach balls show focal mechanisms. Co-seismic slip contours every 5 m of the 2004 great Sumatra earthquake shown in pink in (a) are from Chlieh et al. (2007). Pink light areas show the aseismic zones. **(b, d)** The free-air gravity anomaly. Purple dashed contours show the high free-air gravity anomalies in the fore-arc areas. The letter 'S' shows the possible mainshock area if a Sumatra-like earthquake were to occur in the Ryukyu fore-arc. The black focal mechanisms in (a) and (b) show the positions of the 2004 and 2005 mainshocks.

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journal homepage: www.elsevier.com/locate/jseaes

Plate coupling along the Manila subduction zone between Taiwan and northern Luzon

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[b] Yokohama Institute for Earth Science, Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan
[c] Philippine Institute of Volcanology and Seismology, Quezon City, Philippines

Megathrust Earthquake Potential in Northern Manila Subduction Zone (Hsu et al.,2012&2014)

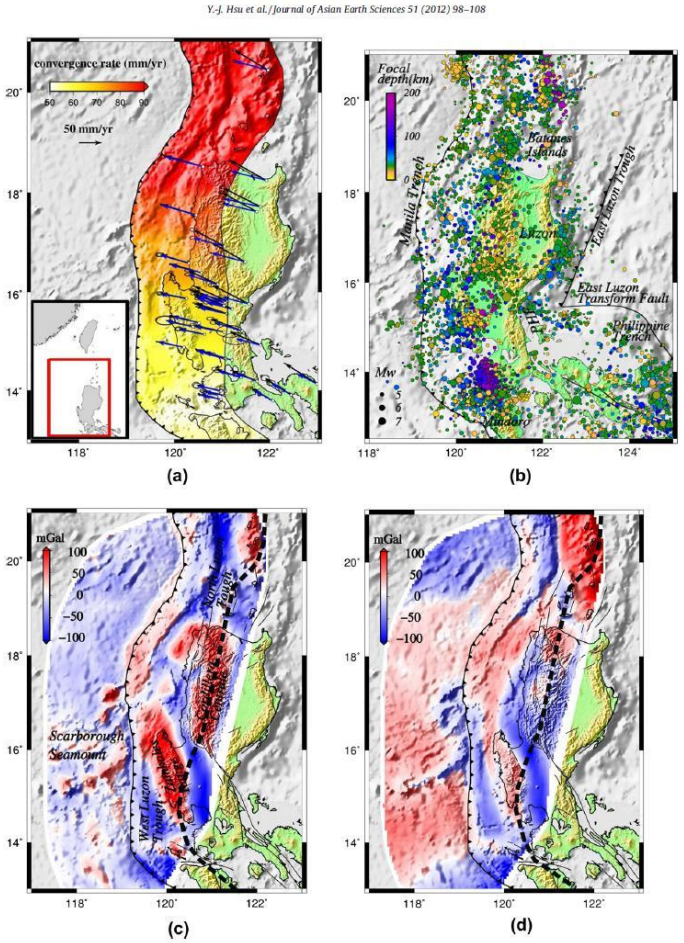
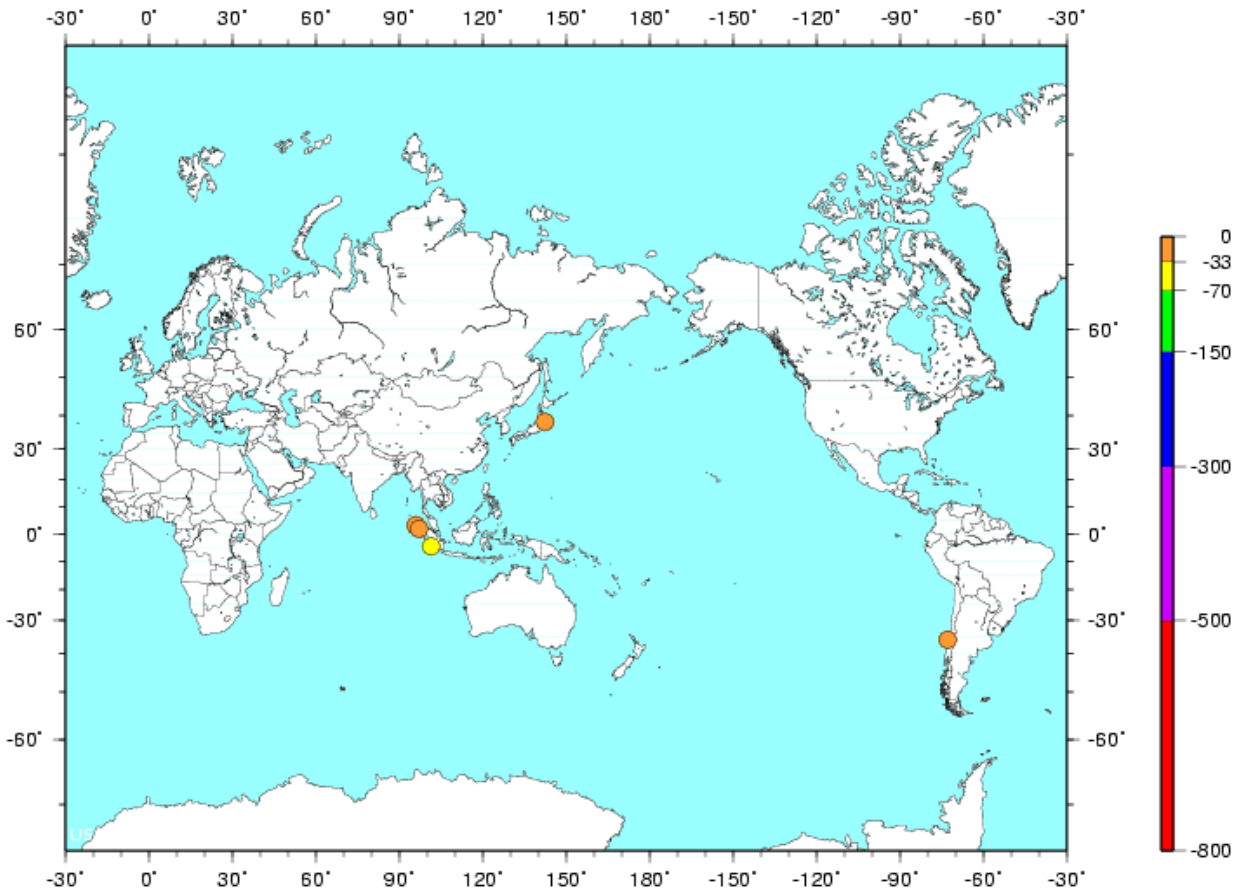


Table 2. Estimates of the sizes of largest earthquake from geodetic strain, seismic moment release rate, and long-term plate convergence at different areas.

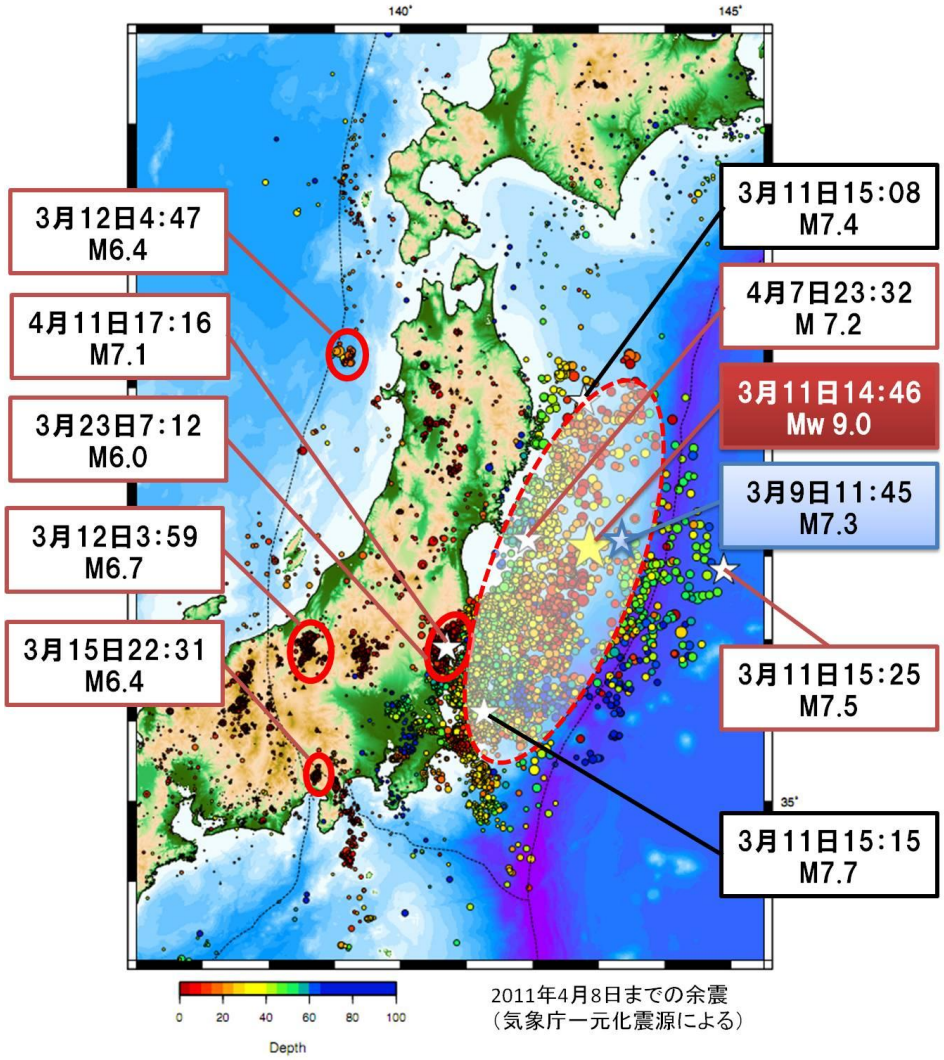
Method / Region	Geodetic (Block modeling)	Seismic (GCMT)	GCMT + plate convergence rate
Manila subduction zone (latitudes 15°~18.5°N)	M_w 8.8~9.0 (t =500~1000 yrs)	M_w 8.1~8.3 (t =500~1000 yrs)	
Major faults in Luzon	M_w 7.0~7.5 (t=100 yrs)		
The Luzon plate boundary zone	M_w 8.9~9.1 (t =500~1000 yrs)	M_w 8.6~8.8 (t =500~1000 yrs)	M_w ~9 (t =500 ~1000 yrs)

t: the recurrence interval; yrs : years

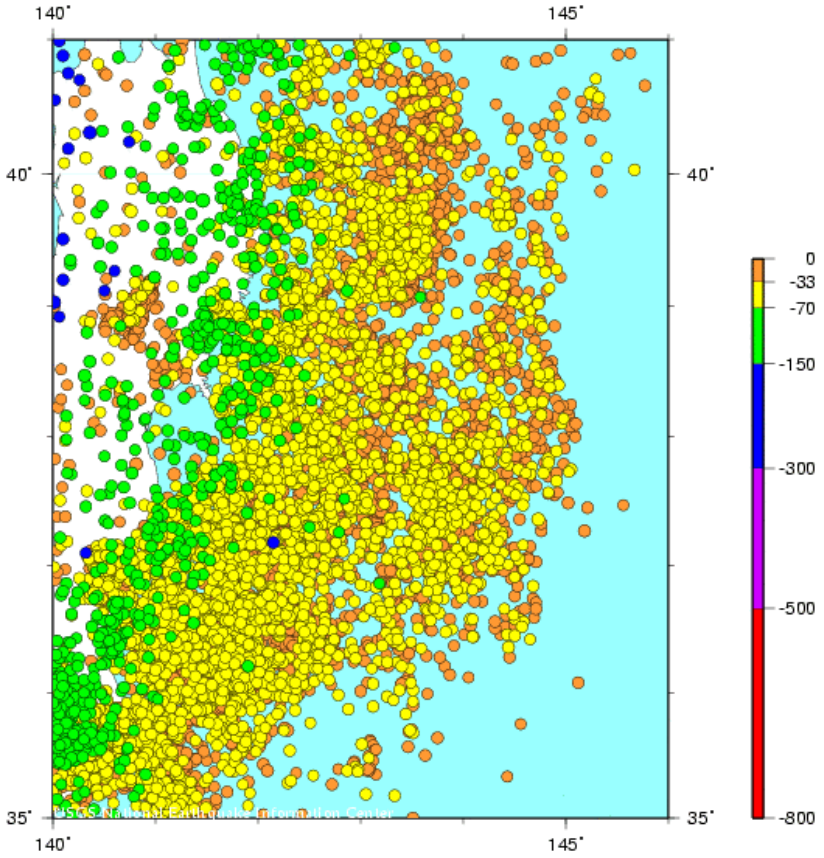
Megathrust Earthquakes (M≥8.5) since 2004



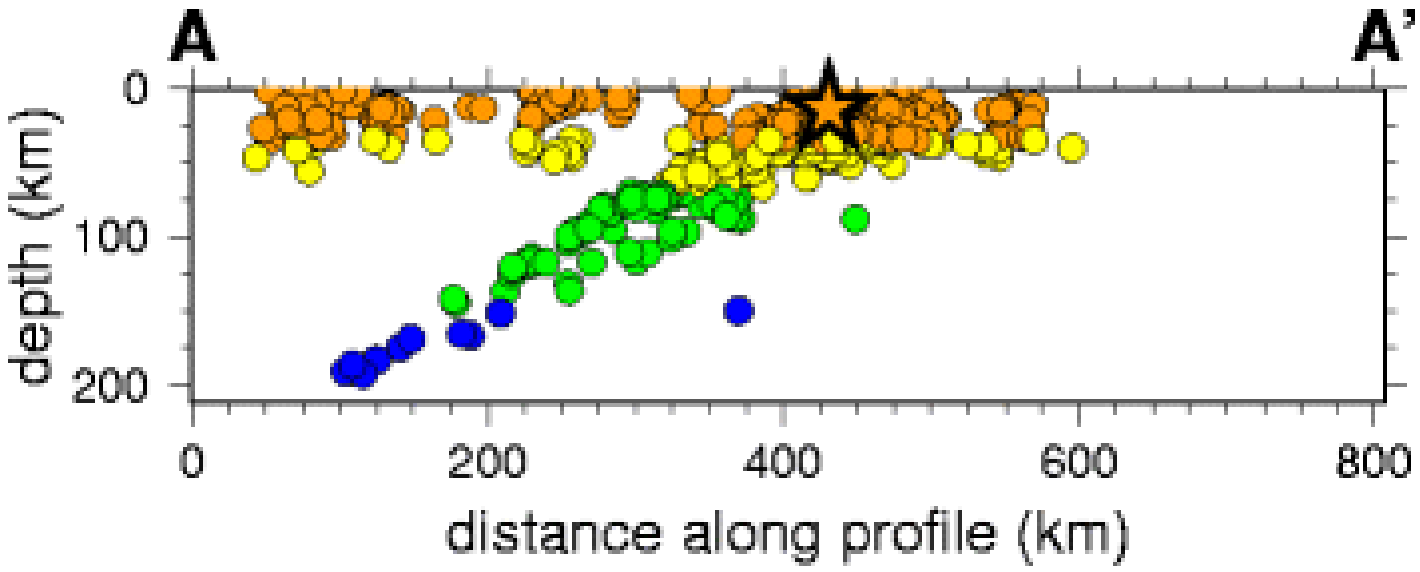
20110311 M9.0 Tohoku Earthquake and Its Major Aftershocks and Triggered Earthquakes



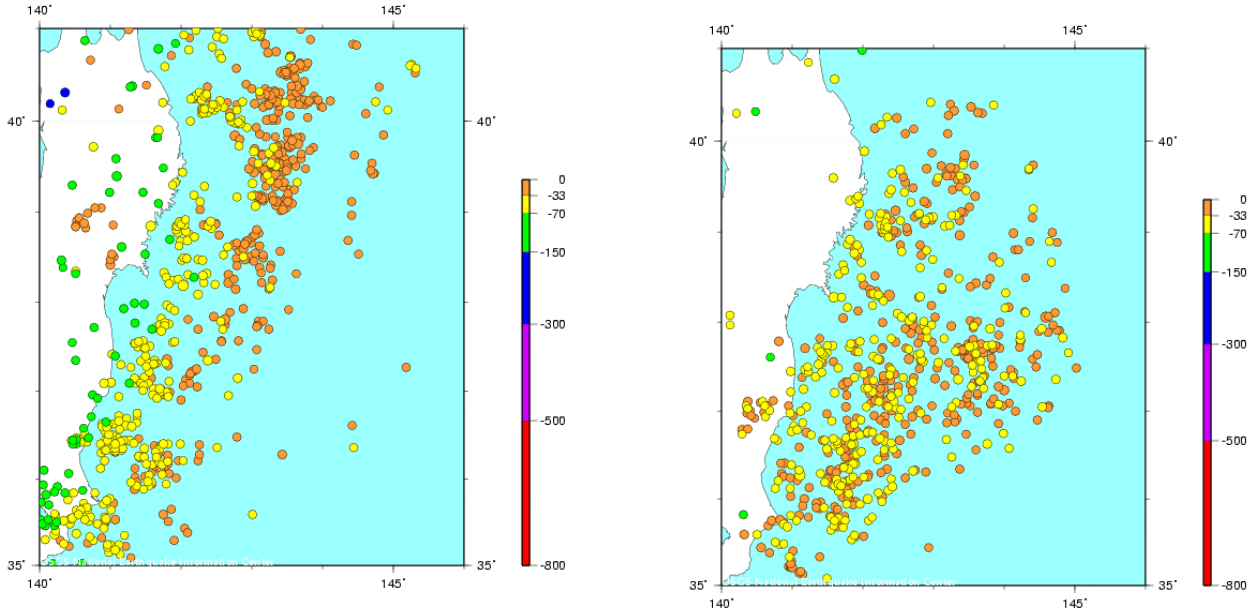
Regional Seismicity (M≥4) in Tohoku Area 19730101-20110610



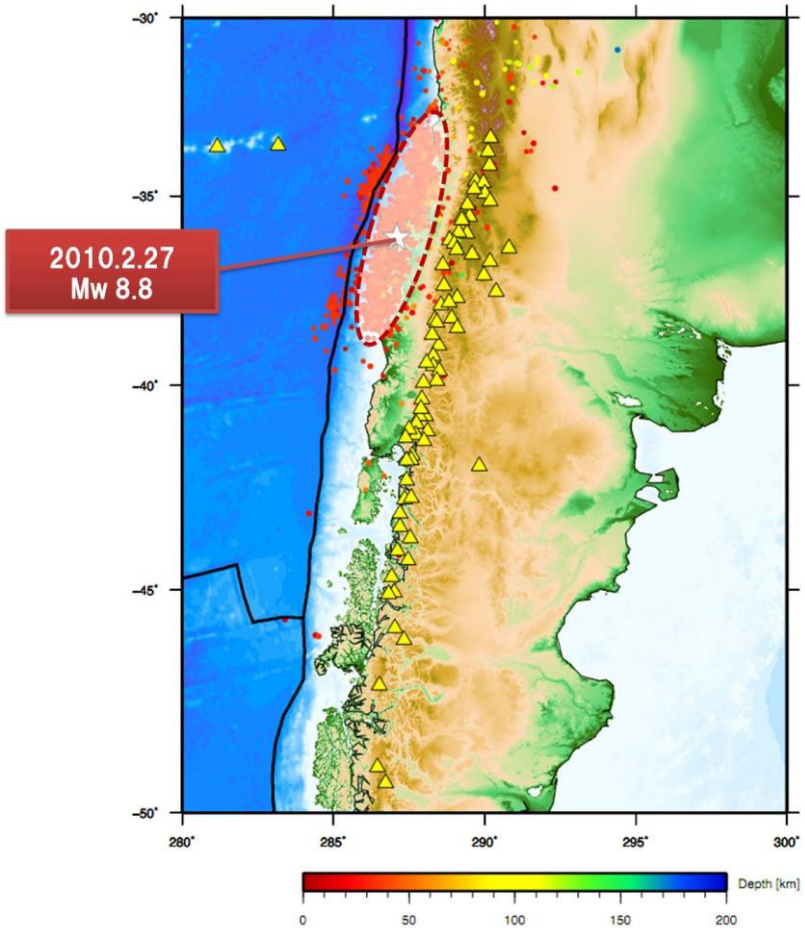
Seismicity Cross Section across Northern Japan



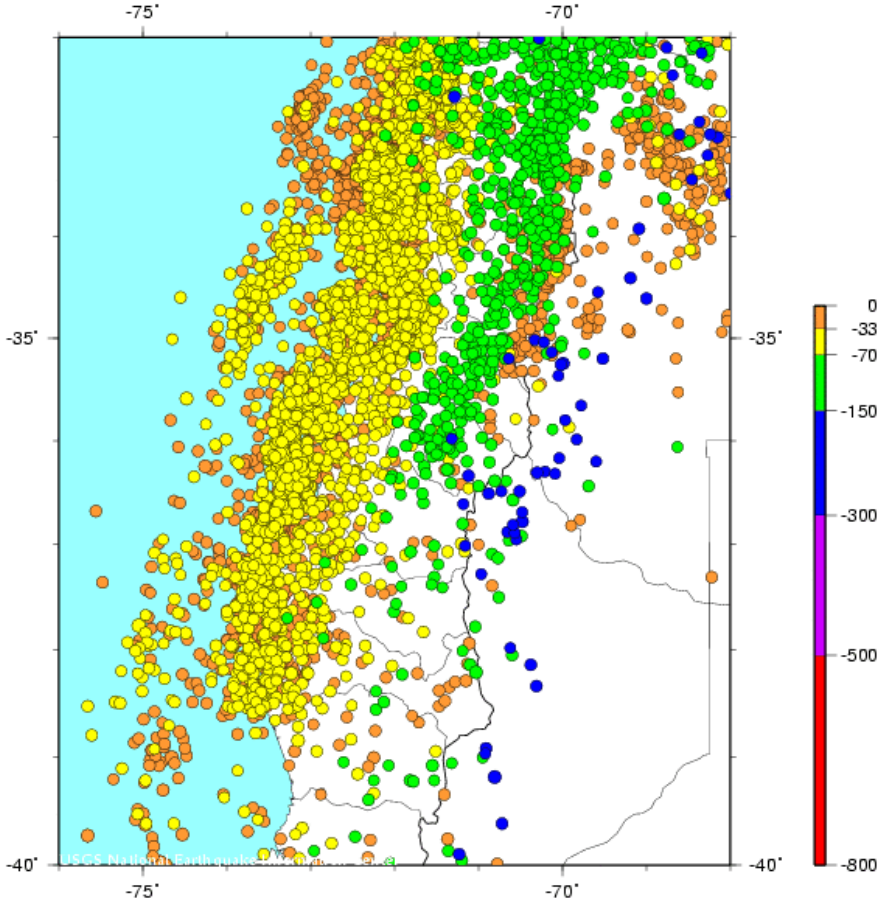
M≥5 Background Seismicity (Left,1974-2003) and Aftershocks (Right, in 3 months) of M9 Tohoku Earthquake Total Number: Left=680; Right=655



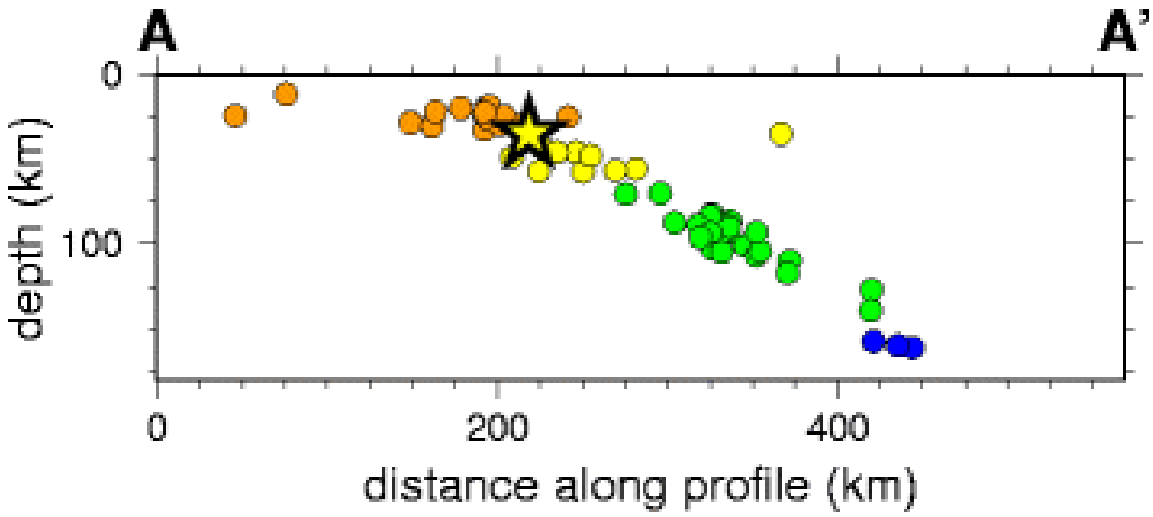
20100227 M8.8 Earthquake in Chile



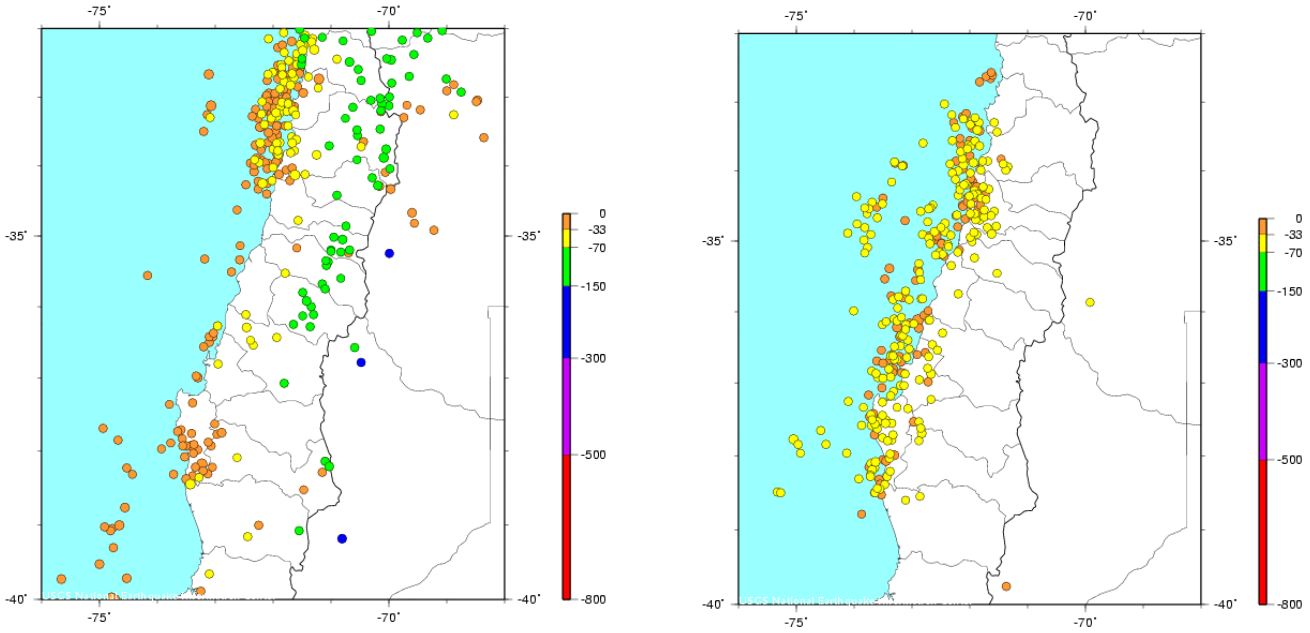
Regional Seismicity (M≥4) in Chile 19730101-20110610



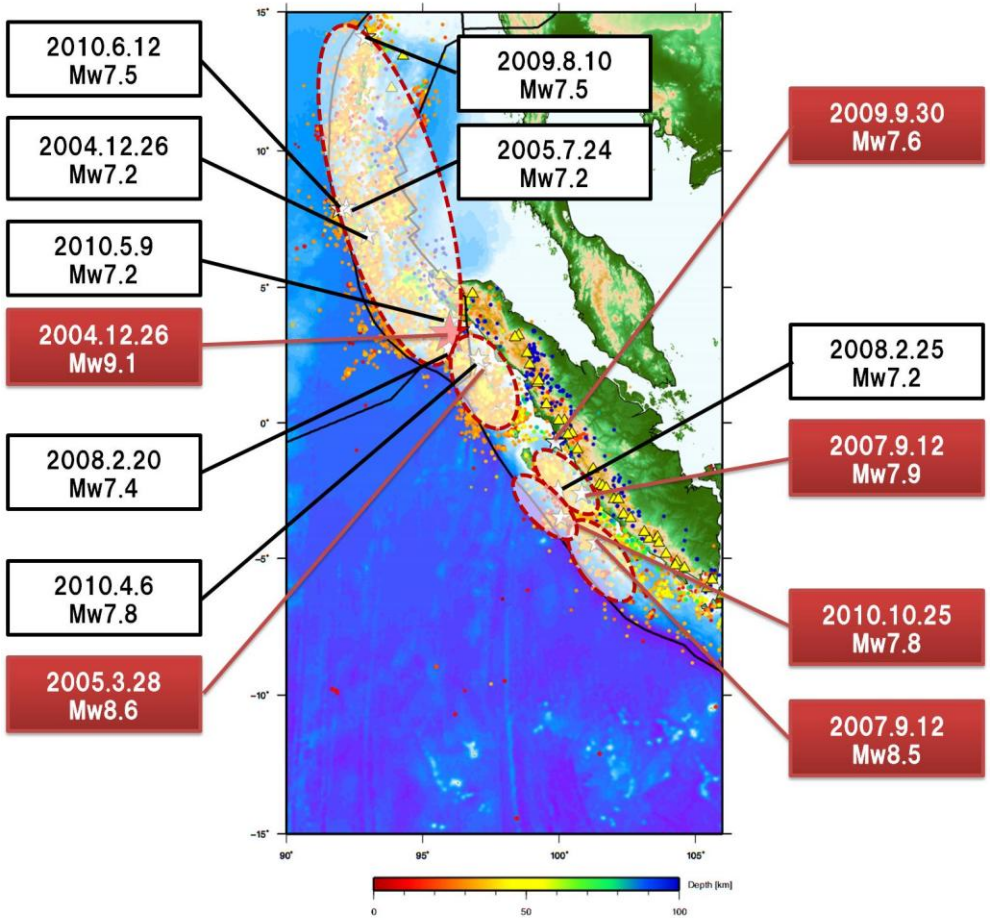
Seismicity Cross Section in Chile



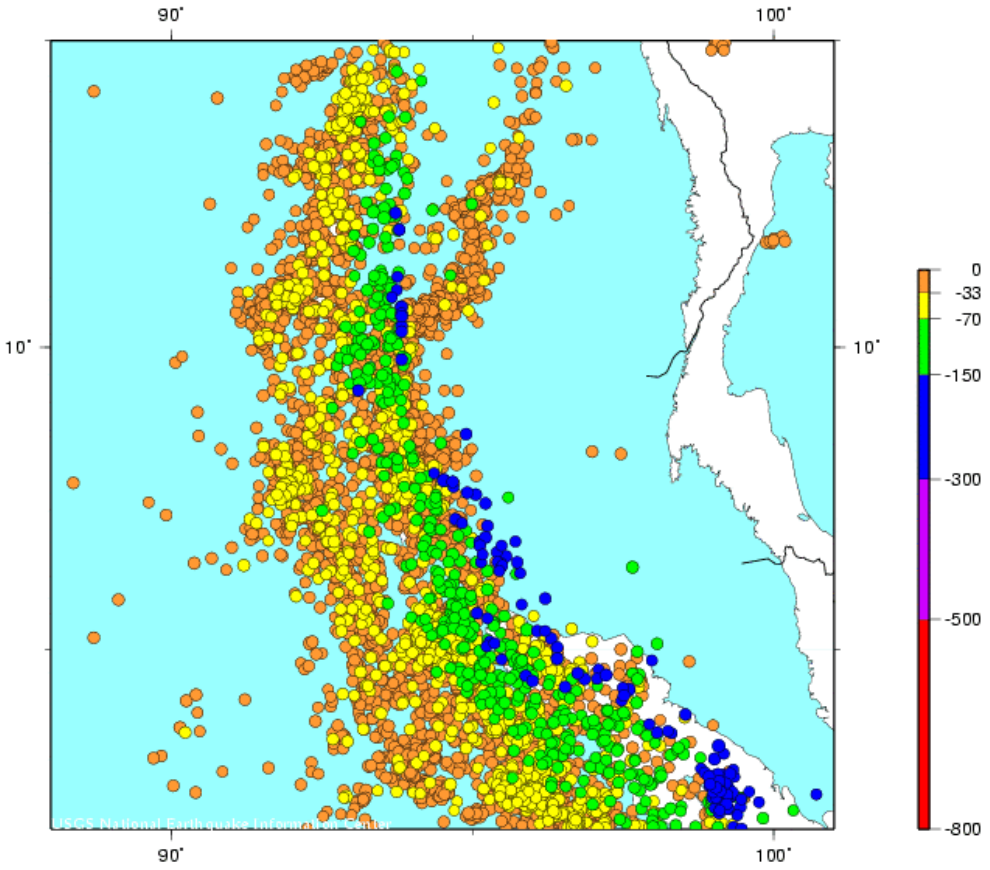
M≥5 Background Seismicity (1974-2003) and Aftershocks (in first 3 months) of the 20100227 Chile Earthquake
Total Number: Left=252; Right=313



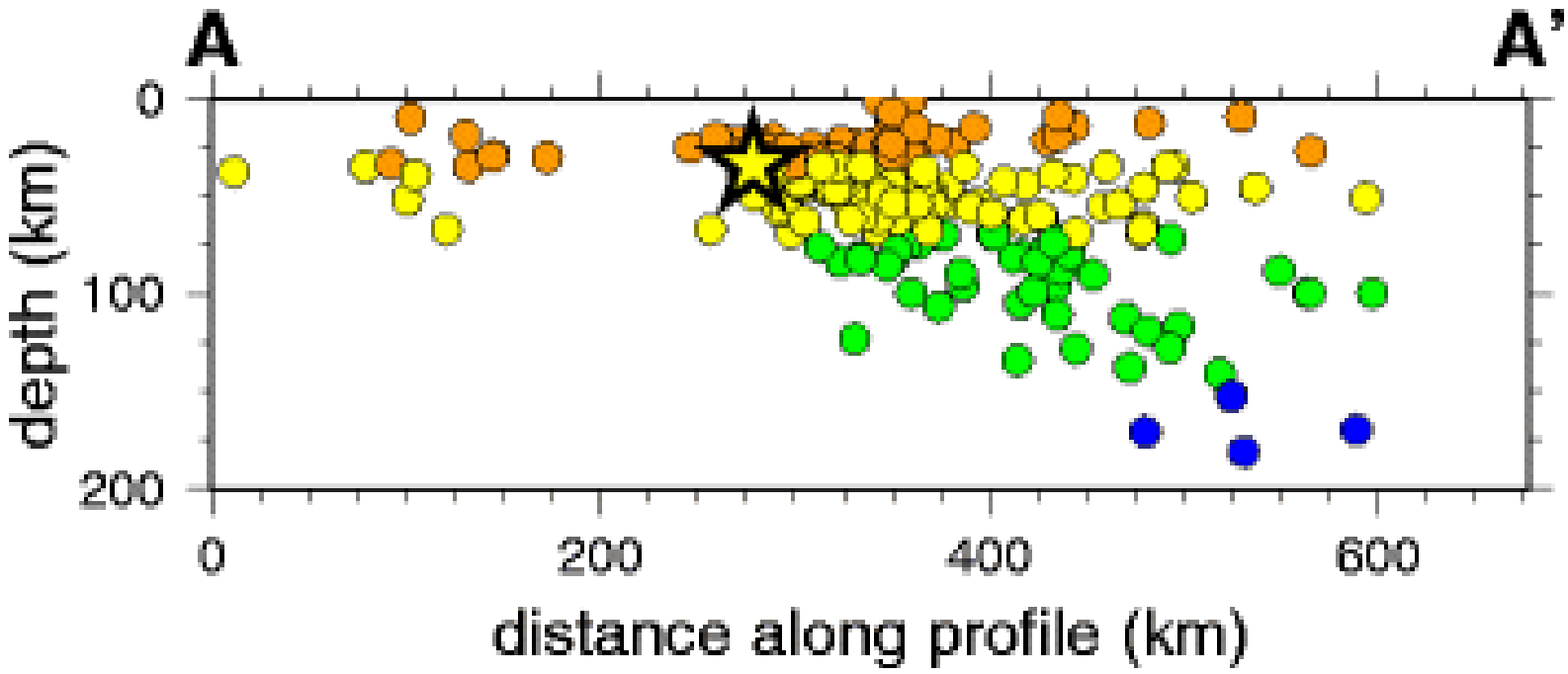
The 20041226 M9.1 Earthquake in Northern Sumatra and Its Major Aftershocks and Triggered Earthquakes



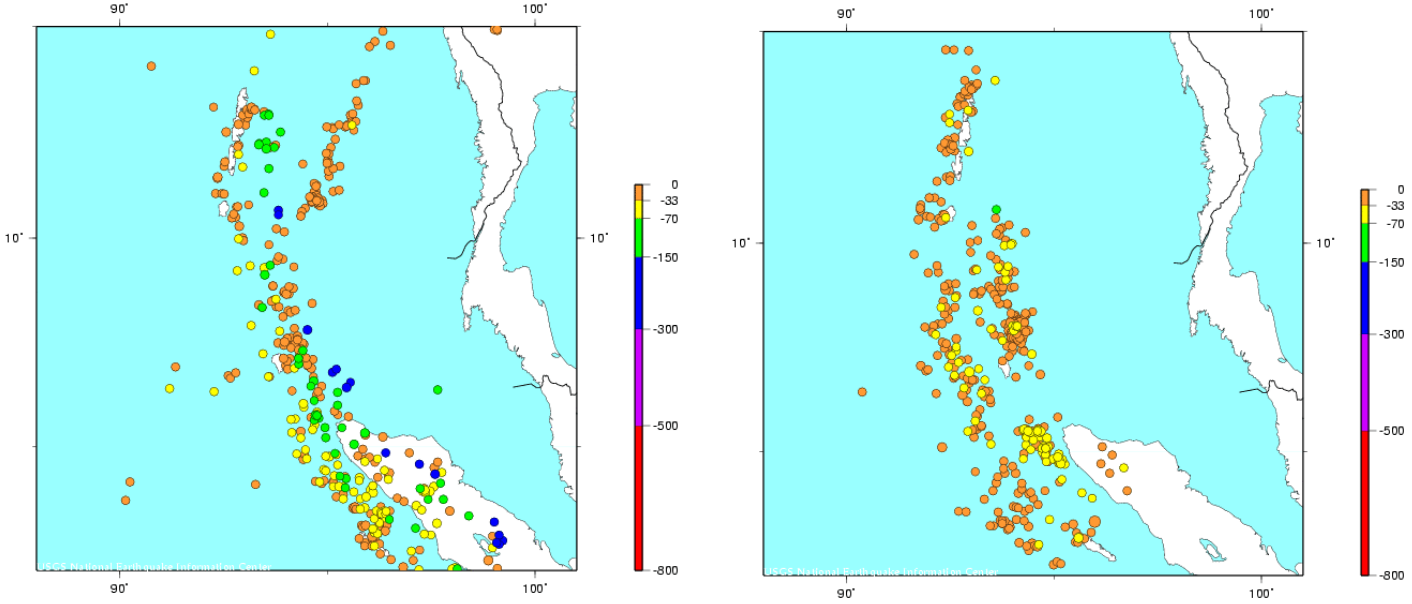
Regional Seismicity surrounding the 20041226 M9.1 Earthquake (19730101-20110610, M≥4)



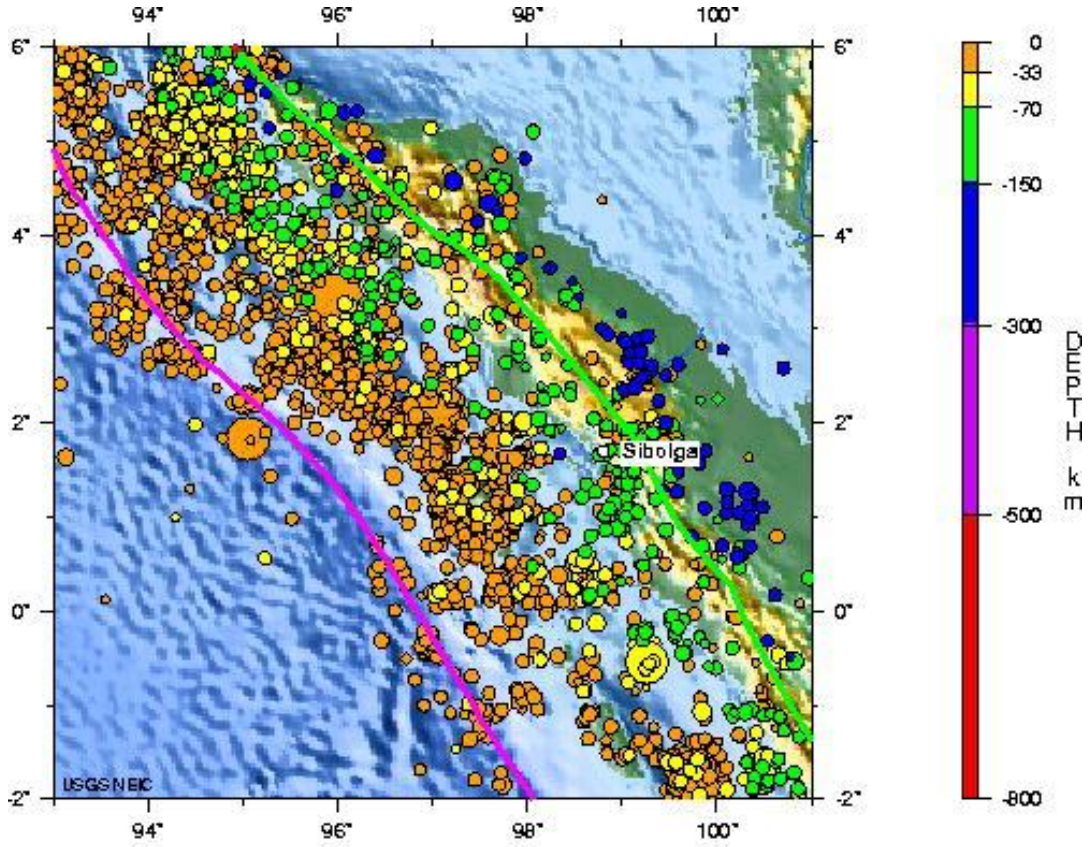
Seismicity Cross Section in Northern Sumatra



M≥5 Background Seismicity (Left,1974-2003) and Aftershocks (Right, in 3 months) of the 20041226 Sumatra-Andaman Earthquake
Total Number: Left=350; Right=492



Epicenter of 20050328 M8.6 Earthquake and the Surrounding Seismicity since 1990



NORTHERN SUMATRA, INDONESIA

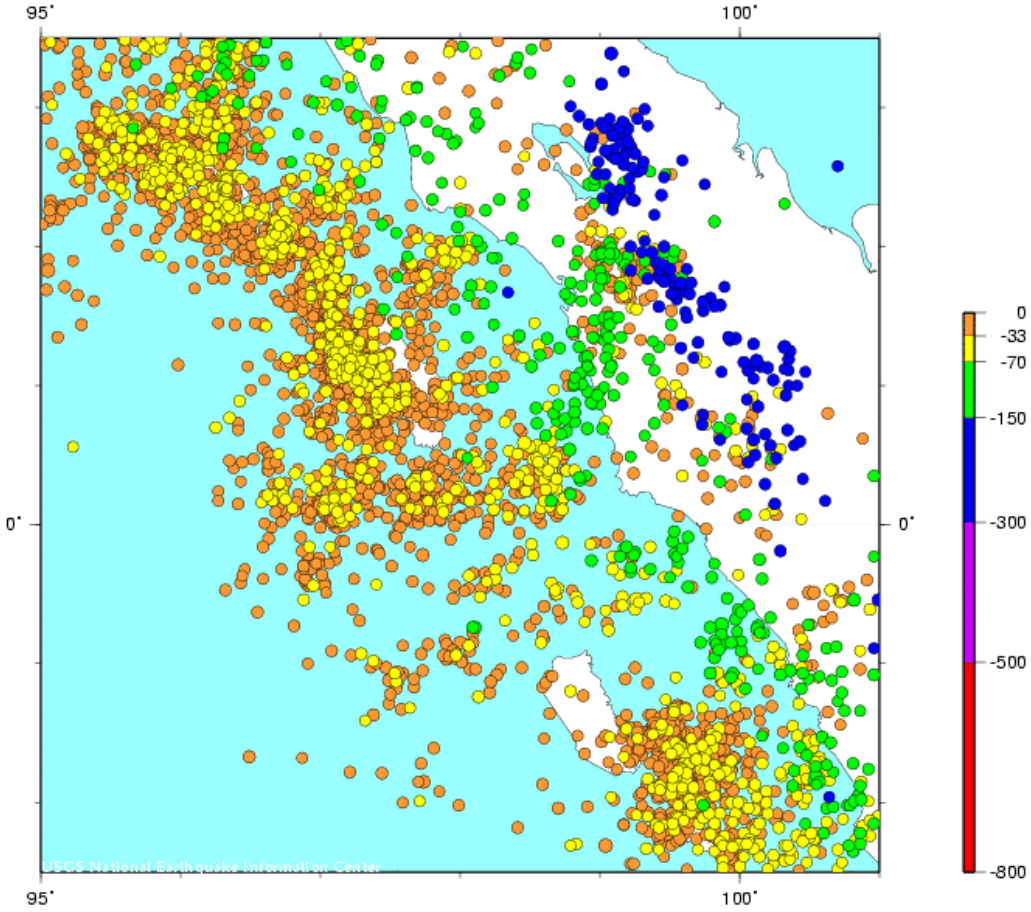
2005 03 28 16:09:36 UTC 2.08N 97.09E Depth: 30 km, Magnitude: 8.7

Seismicity 1990 to Present

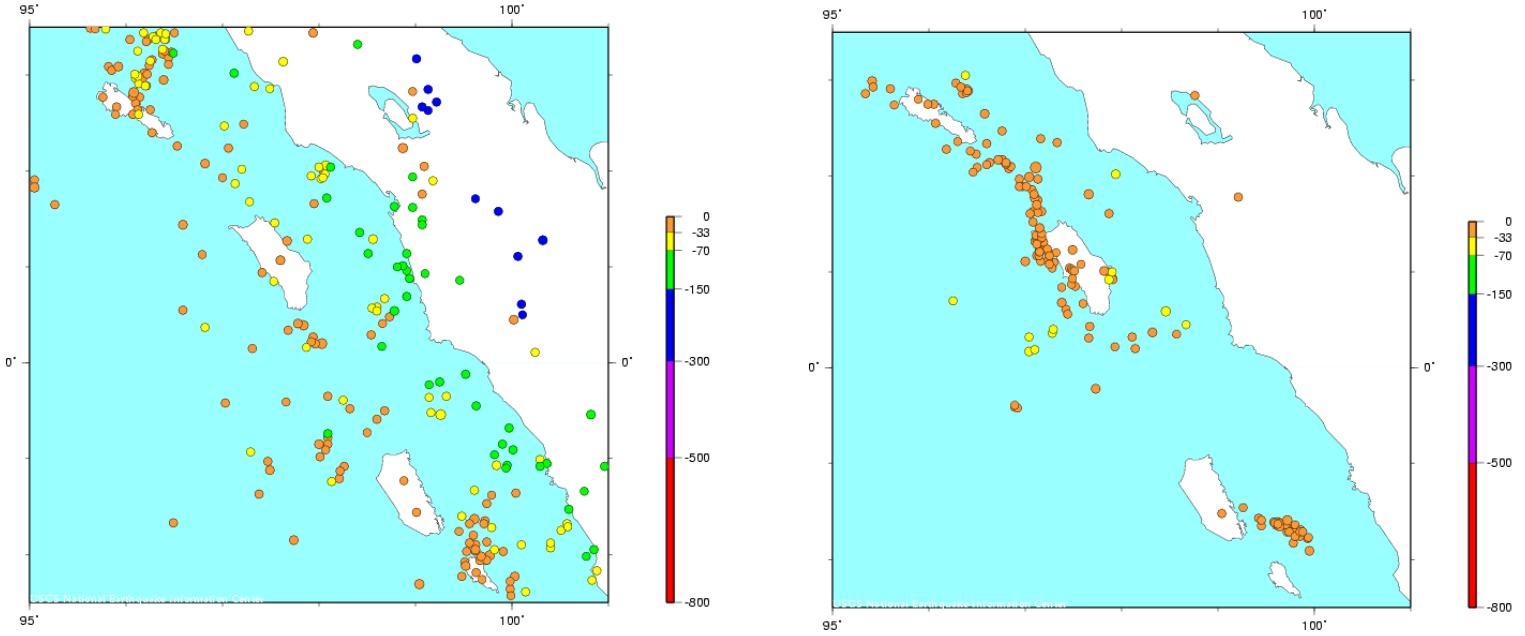
Major Tectonic Boundaries: Subduction Zones -purple, Ridges -red and Transform Faults -green

USGS National Earthquake Information Center

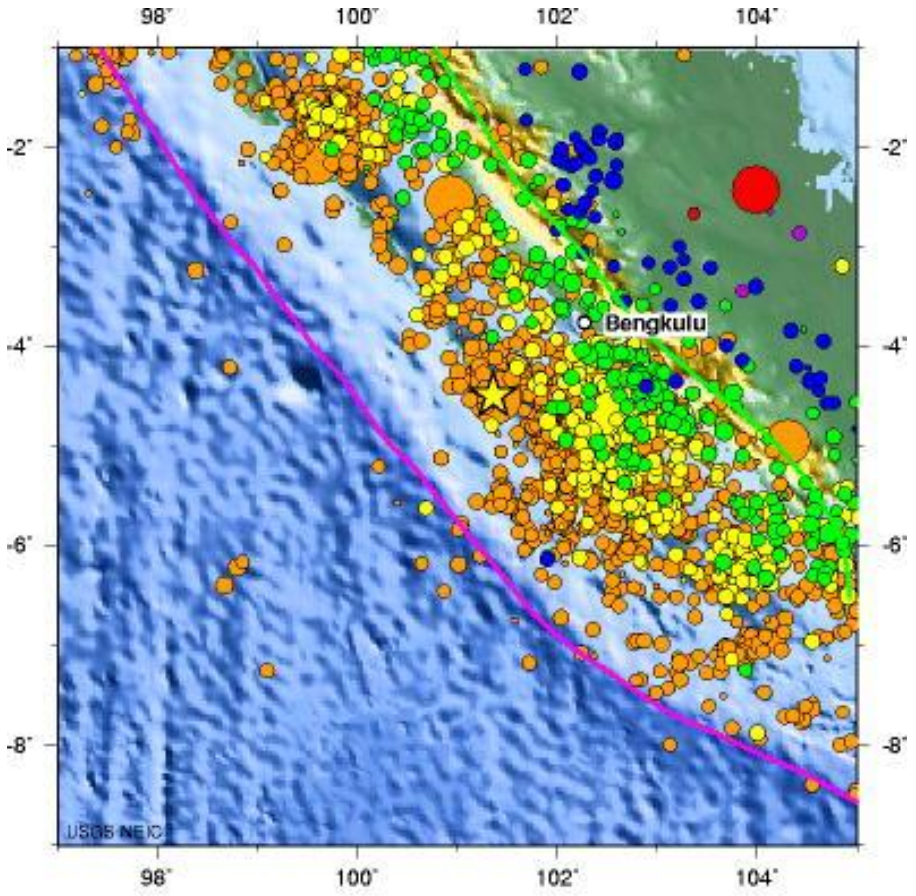
Regional Seismicity about the 20050328 Earthquake (19730101-20110610, M≥4)



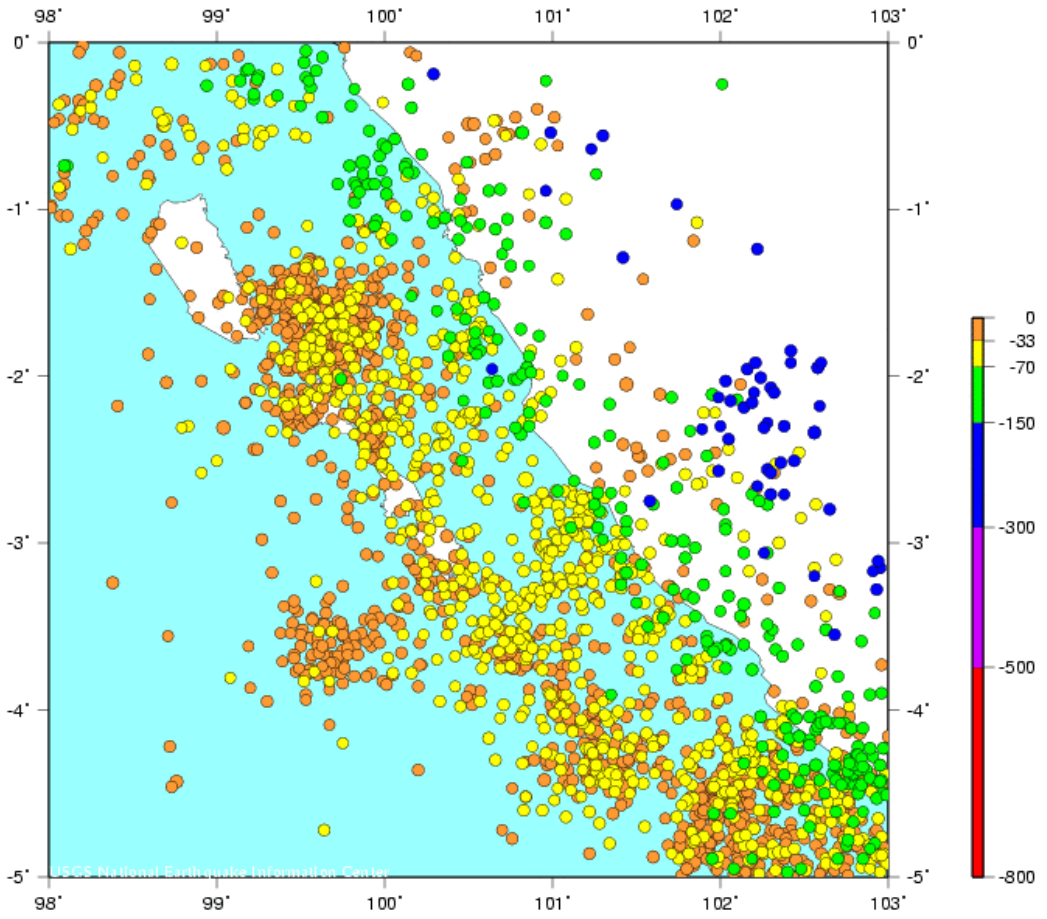
M≥5 Background Seismicity (Left,1974-2003) and Aftershocks (Right, in 3 months) of the 20050328 Earthquake
Total Number: Left=190; Right=159



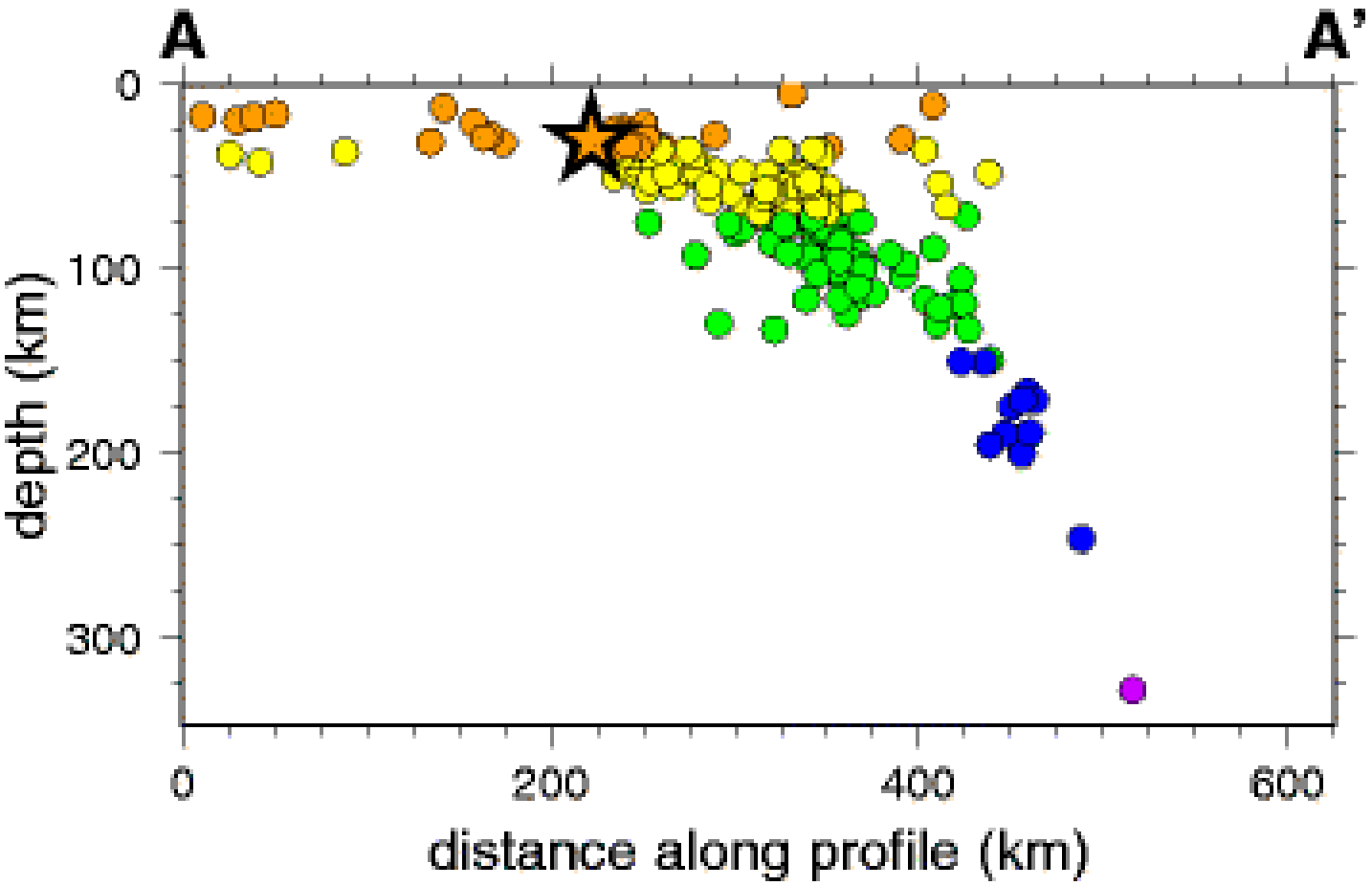
Regional Seismicity around the 20070912 M8.5 Earthquake in Southern Sumatra since 1990



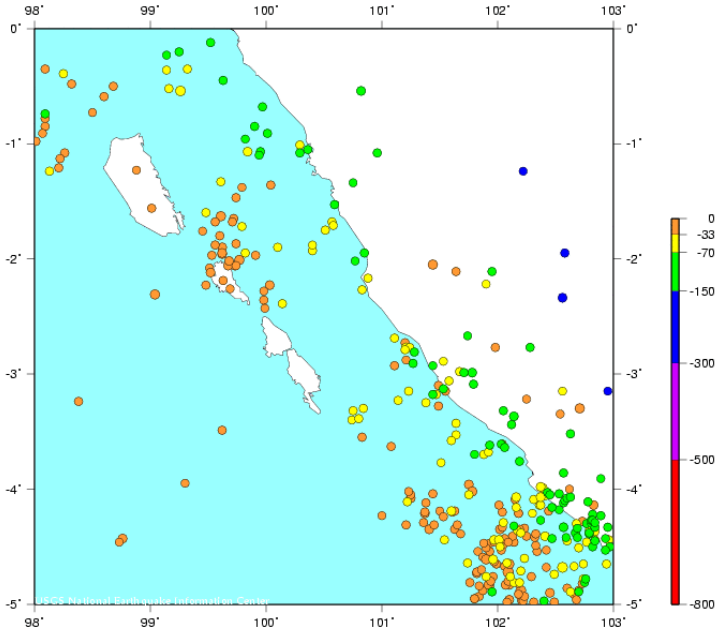
Regional Seismicity in Southern Sumatra (19730101-20110610, M≥4)

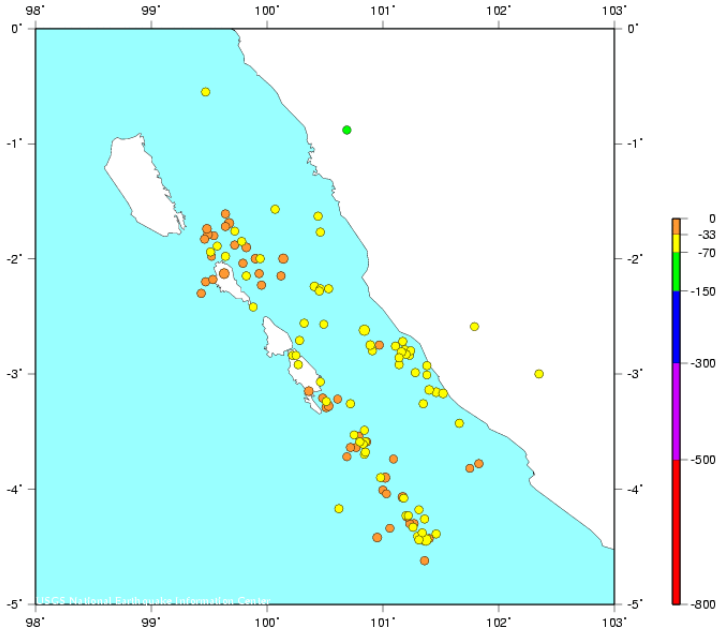


Seismicity Cross Section in Southern Sumatra



M≥5 Background Seismicity (Left,1974-2003) and Aftershocks (Right, in 3 months) of the 20070912 M8.5 Earthquake
Total Number: Left=252; Right=114

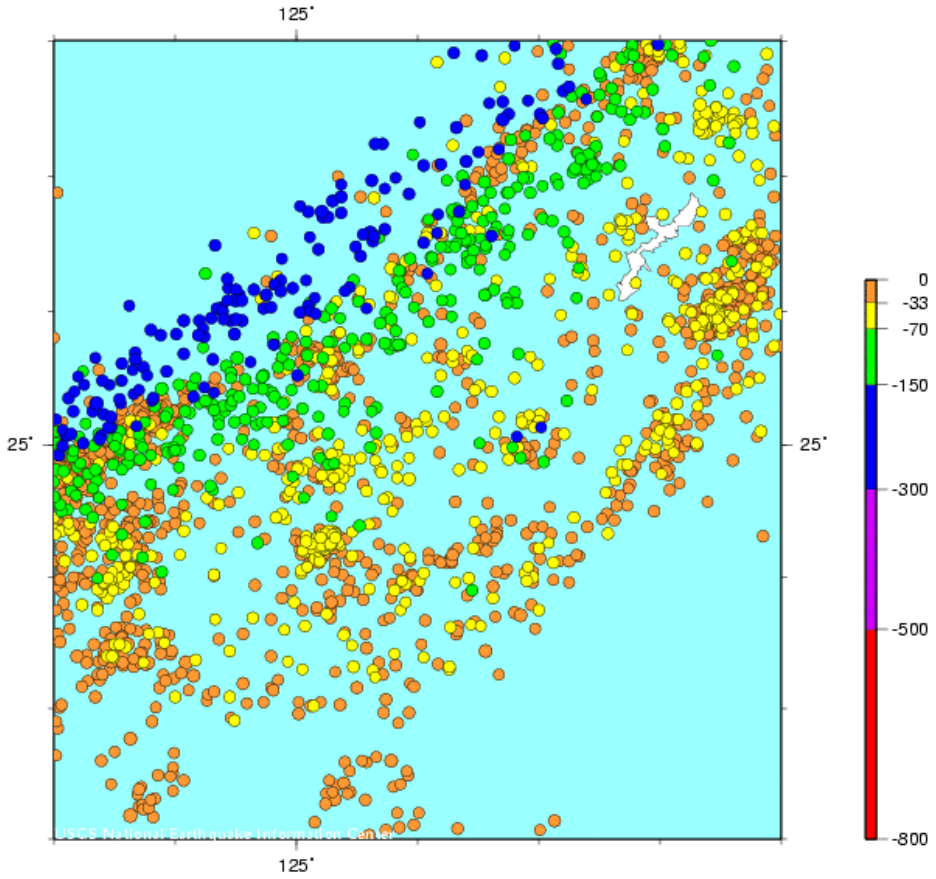




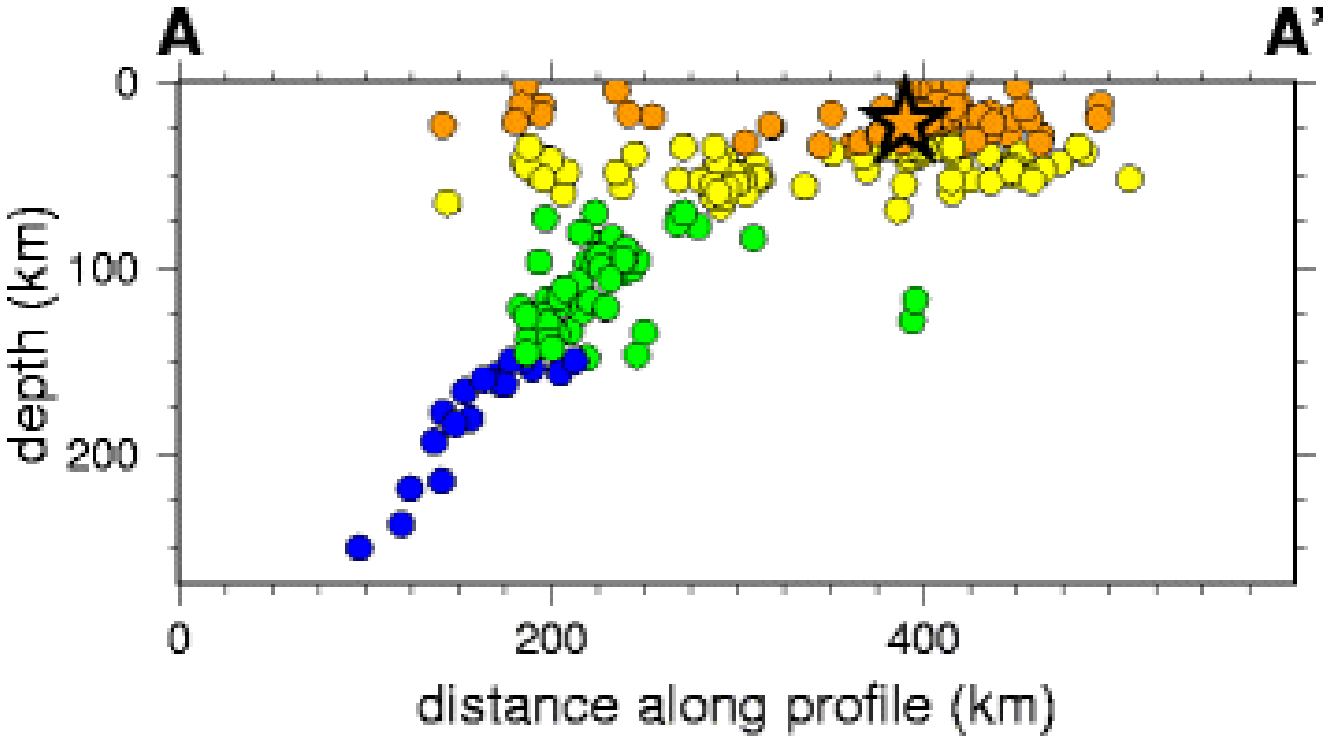
Background Seismicity and Aftershock Activity of Recent Megathrust Earthquakes (M>5, H<70 km)

Earthquake	20110311 M9.0	20100227 M8.8	20070912 M8.5	20050328 M8.6	20041226 M9.1
No. of Aftershocks (in 3 months)	655	313	114	159	492
Background seismicity (1974-2003)	680	252	252	190	350
Ratio	0.96	1.24	0.45	0.84	1.41

Regional Seismicity in Southern Ryukyu (19730101-20110610, M≥4) Total Number of M≥5.0 Events= 217

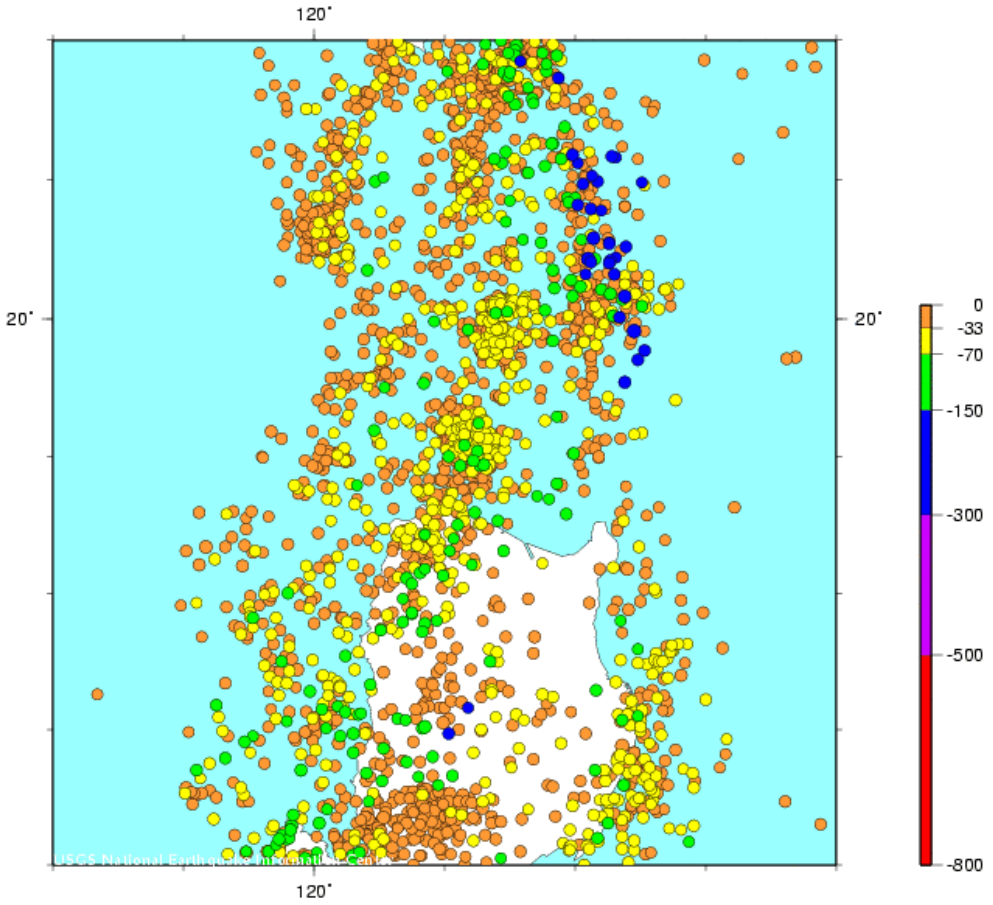


Seismicity Cross Section in Ryukyu Islands



Regional Seismicity in Northern Luzon-Taiwan Area (19730101-20110610, M≥4)

Total Number of M>5.0 Events= 328



Background Seismicity Rates (1974-2003, H<70 km) of Recent Megathrust Earthquakes and S. Ryukyu and N. Manila Subduction Zones

M>=	5.0	6.0	7.0	8.0	9.0
20110311 M9.0	680 (655)	68 (66)	6 (4)	0 (1)	0 (1)
20100227 M8.8	252 (313)	32 (24)	6 (1)	0 (1)	0 (0)
20070912 M8.5	252 (114)	22 (11)	4 (3)	0 (1)	0 (0)
20050328 M8.6	190 (159)	21 (15)	4 (1)	0 (1)	0 (0)
20041226 M9.1	350 (492)	26 (26)	2 (2)	0 (1)	0 (1)
S.Ryukyu M?	217	12	1	0	0
N. Manila M?	326	26	2	0	0

Potential Hazards of Megathrust Earthquakes

- Long-duration strong ground shakings over large areas.
- Giant trans-oceanic tsunamis.
- Major submarine landslides.
- Major foreshocks, aftershocks and distant triggered earthquakes.
- Permanent coastal subsidence or uplift.

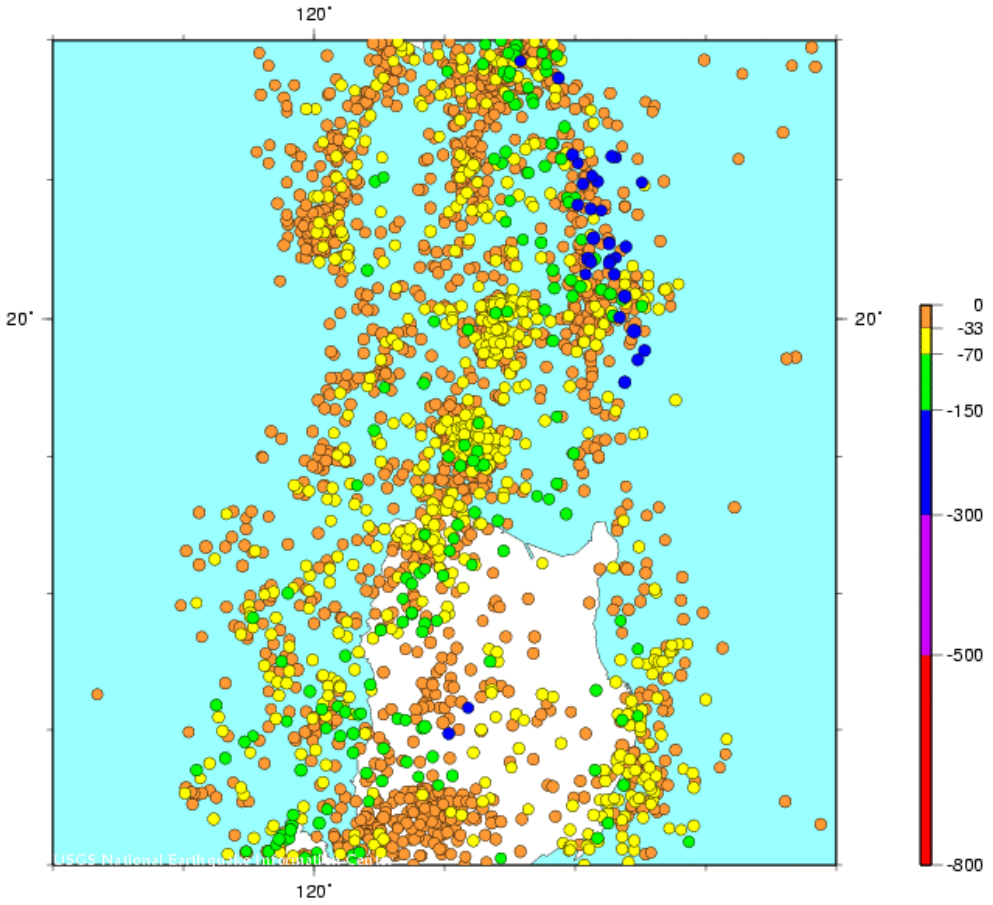
Summary

- Megathrust earthquakes (M≥8.5) occurred in relatively fast subduction zones where the subducting oceanic plate extends continuously laterally and penetrates down to depth greater than 150 km.
- Aftershock activities might spread outward into the oceanic plate beyond areas of background seismicity.
- Number of aftershocks in the first three months could exceed that of the background seismicity in thirty years over the same area.
- Both southern Ryukyu and northern Manila subduction zones near Taiwan possess common characteristics for potential megathrust earthquakes.
- Unique issues related to assessing and mitigating potential hazards of megathrust earthquakes call for serious attention.

Thank You Very Much !

Regional Seismicity in Northern Luzon-Taiwan Area (19730101-20110610, M≥4)

Total Number of M>5.0 Events= 328



Regional Seismicity in Northern Luzon-Taiwan Area (19730101-20110610, M≥4)

Total Number of M>5.0 Events= 328