Review of seismic activities in the Malina-Taiwan subduction zone

Appraisal of tsunami impacts for offshore eastern Taiwan earthquakes

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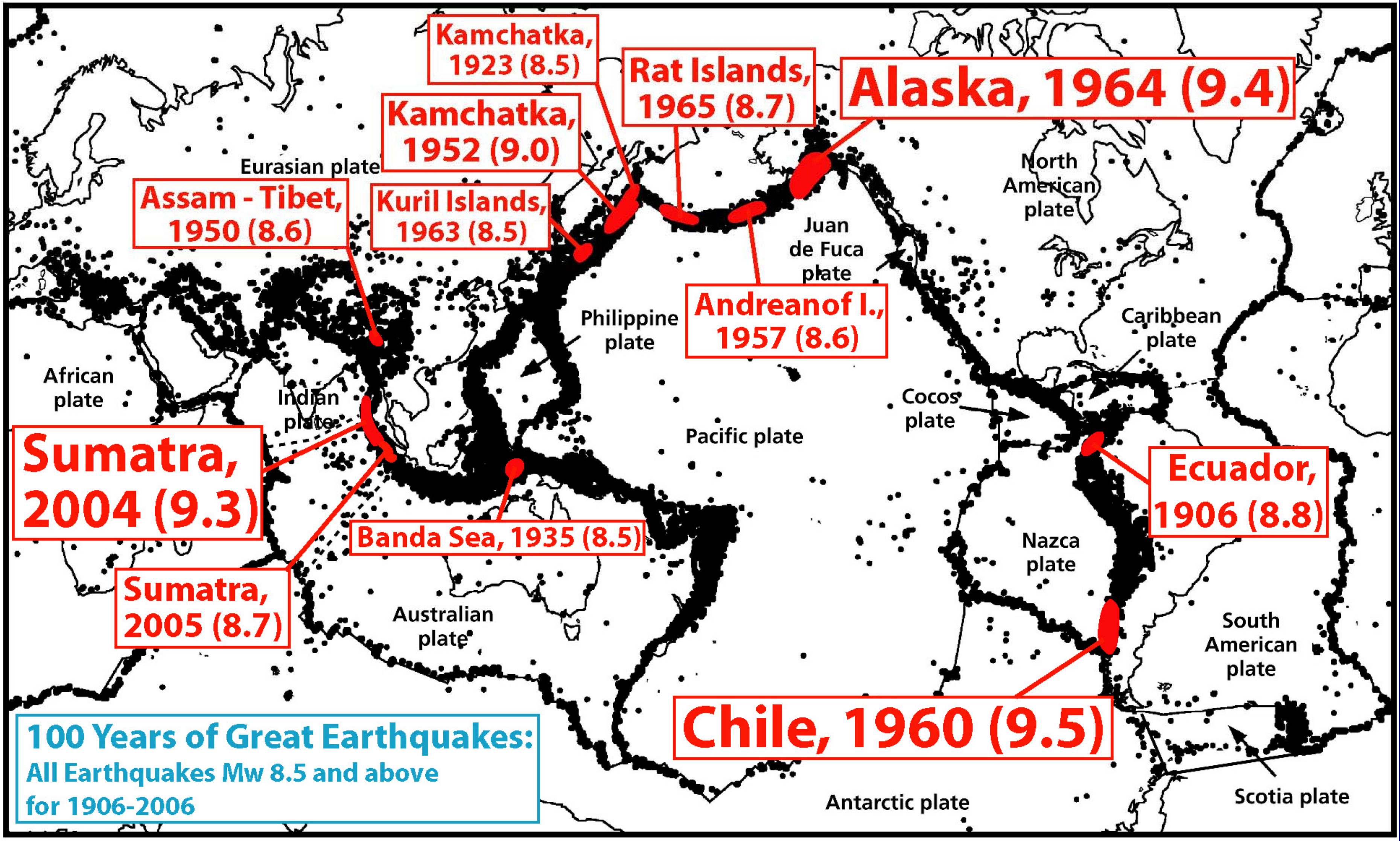
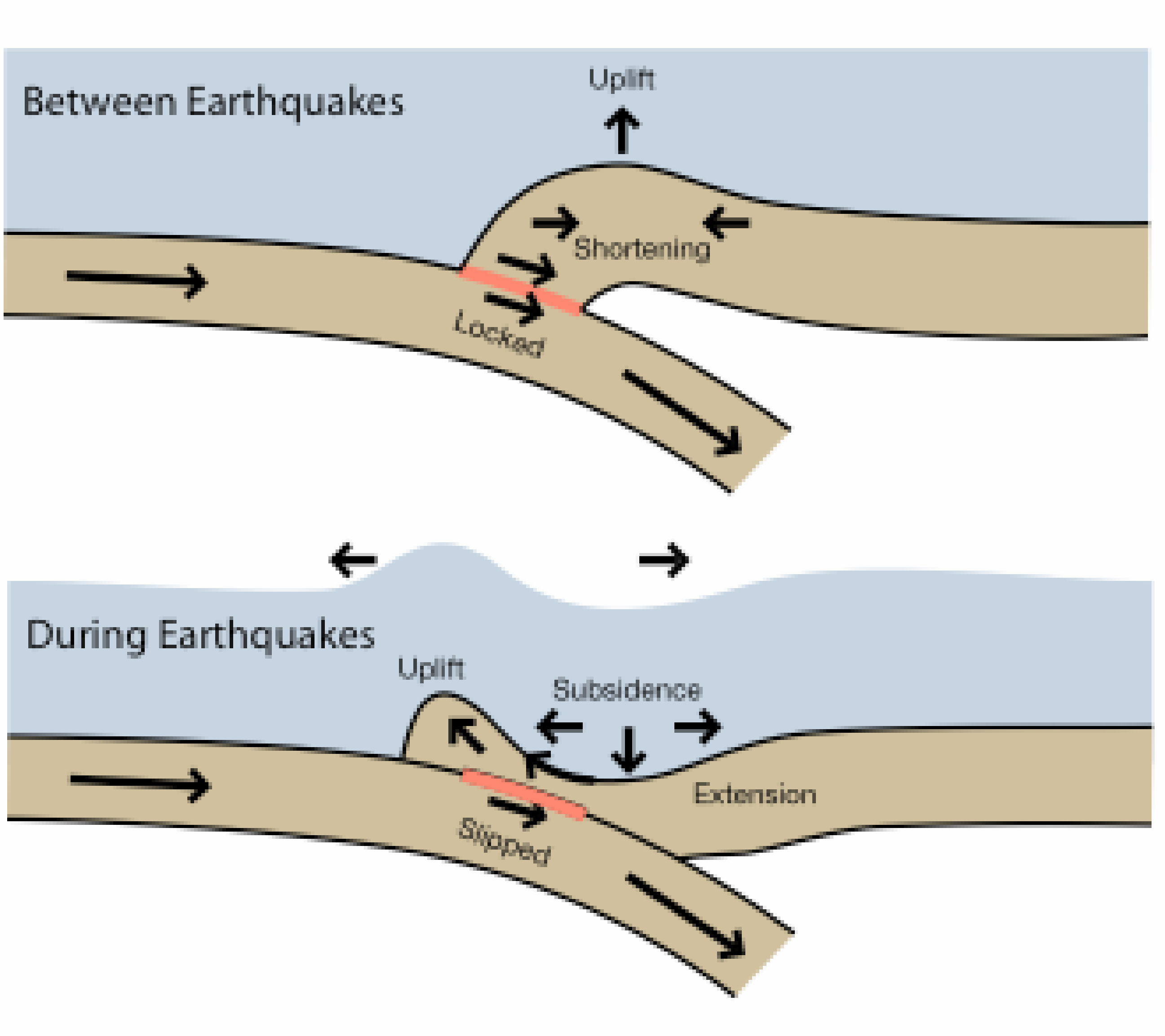

Kamchatka, 1923 (8.5)
Rat Islands, 1965 (8.7)
Alaska, 1964 (9.4)
Kamchatka, 1952 (9.0)
Eurasian plate
Assam - Tibet, 1950 (8.6)
Kuril Islands, 1963 (8.5)
North American plate
Juan de Fuca plate
Philippine plate
Andreanof I., 1957 (8.6)
Caribbean plate
African plate
Indian plate
Cocos plate
Pacific plate
Sumatra, 2004 (9.3)
Ecuador, 1906 (8.8)
Banda Sea, 1935 (8.5)
Nazca plate
Sumatra, 2005 (8.7)
Australian plate
South American plate
Chile, 1960 (9.5)
100 Years of Great Earthquakes:
All Earthquakes Mw 8.5 and above
for 1906-2006
Antarctic plate
Scotia plate

Stein, 2006



Hyndeman and Wang, 1993

PLATE MOTION

Mechanical coupling

ASEISMIC SLIDING

LOCKED AT INTERFACE

Seismic coupling

Megaquake fraction

SLOW EARTHQUAKES (ASEISMIC)

OTHER EARTHQUAKES

MEGA EARTHQUAKES

Stein, 2006

If we know the fraction of seismic coupling on a given plate boundary, we may be able to estimate the likelihood of mega earthquakes. It turns out to be difficult using seismological data.

-variability of earthquakes on a given plate boundary

-time sample is not long enough (~100 yrs)

-earlier data are less reliable

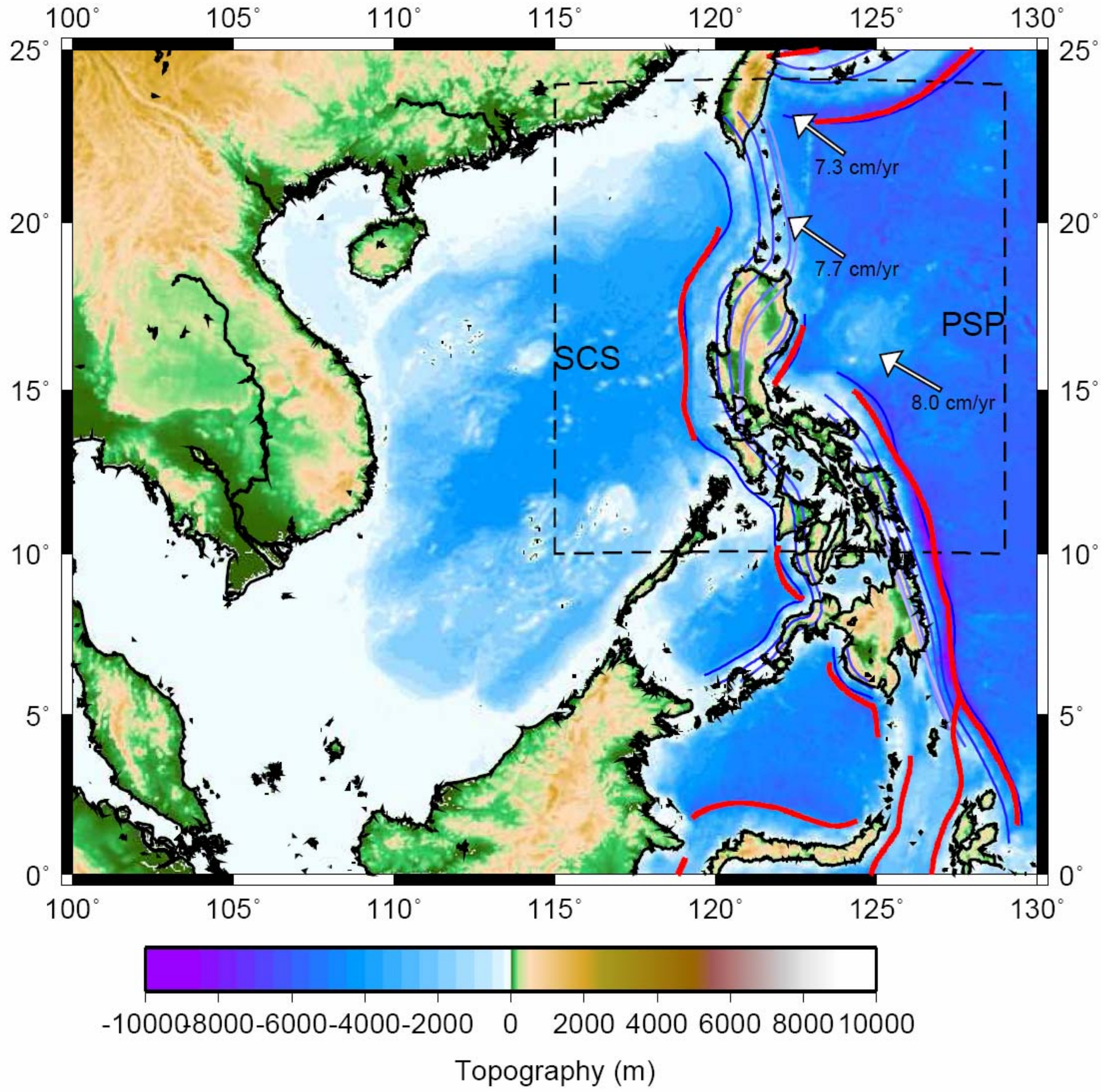
-The Harvard CMT catalogue (1977~)

However, it is still worthwhile examining what can be learned from earthquake catalogue.

Red lines:
Plate boundary

Blue lines:
Slab contour
by seismicity

Manila-Taiwan
subduction
zone

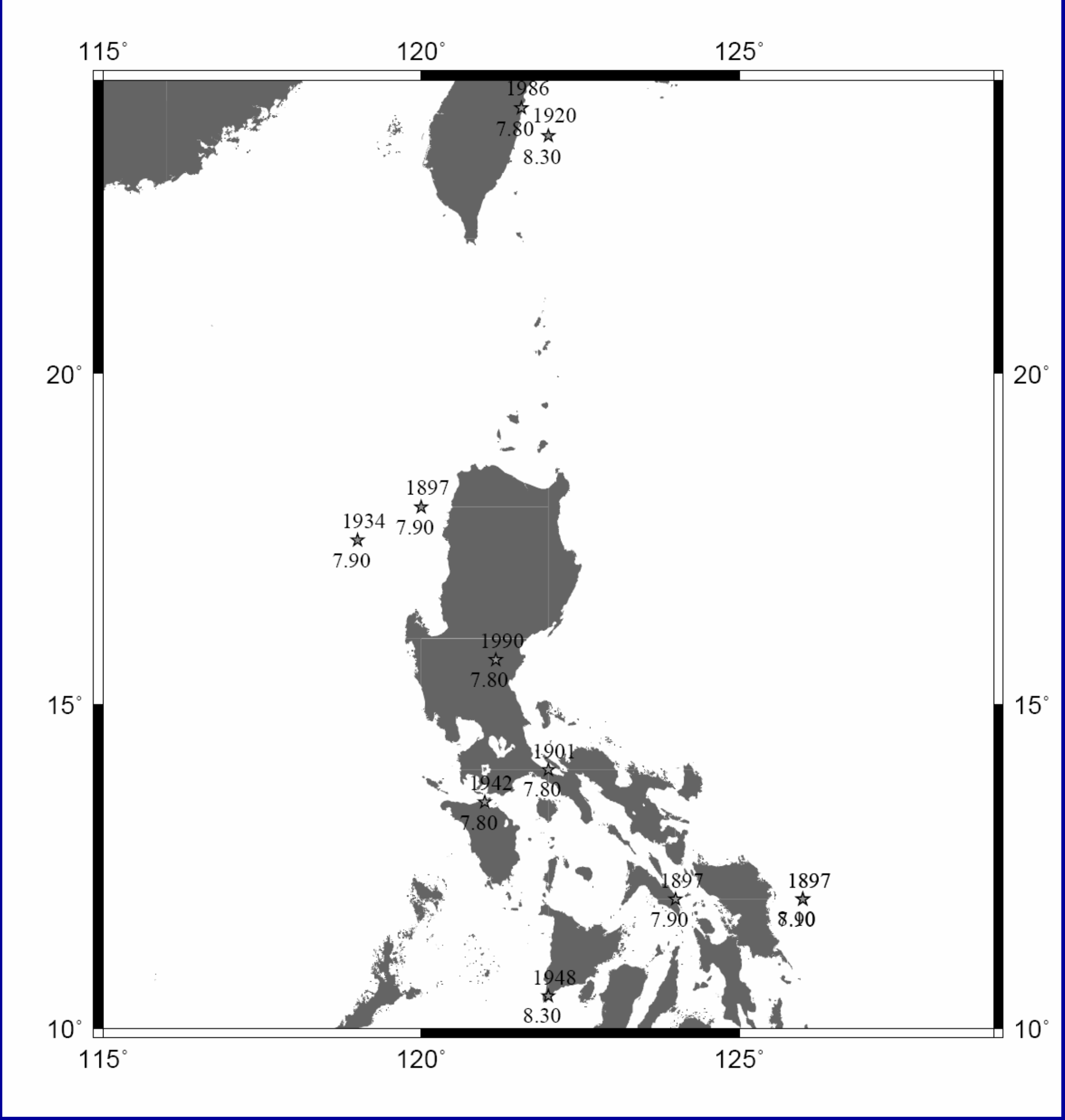


Three earthquake catalogue are used.

(1) Historical catalogue (1890~) – to examine past large earthquakes

(2) EHB catalogue (1963~) [Engdahl et al., 1998] – to conduct frequency-magnitude analysis and to estimate earthquake probability

(3) The Harvard CMT catalogue (1977~) – to calculate seismic shortening rates



According to the historical catalogue, earthquakes likely generating SCS tsunamis are the 1897, the 1920 and the 1934 events.

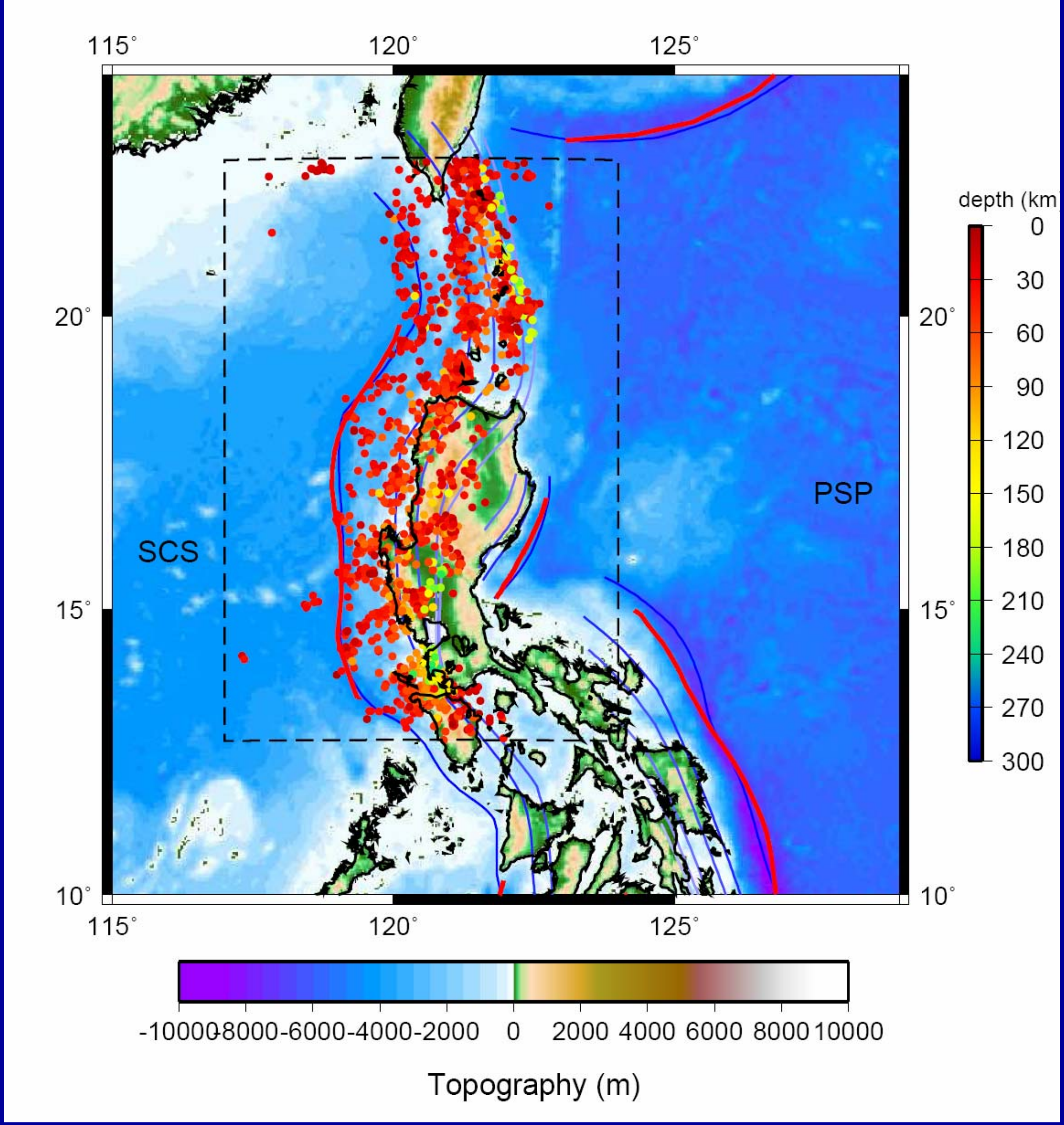
Catalogue of Tsunamis on the western shore of the Pacific Ocean

Soloviev and Go, 1974

- Not certain about the 1897 event
- No documents about the 1920 event.
- Documents about the 1934 event. (see next slot)

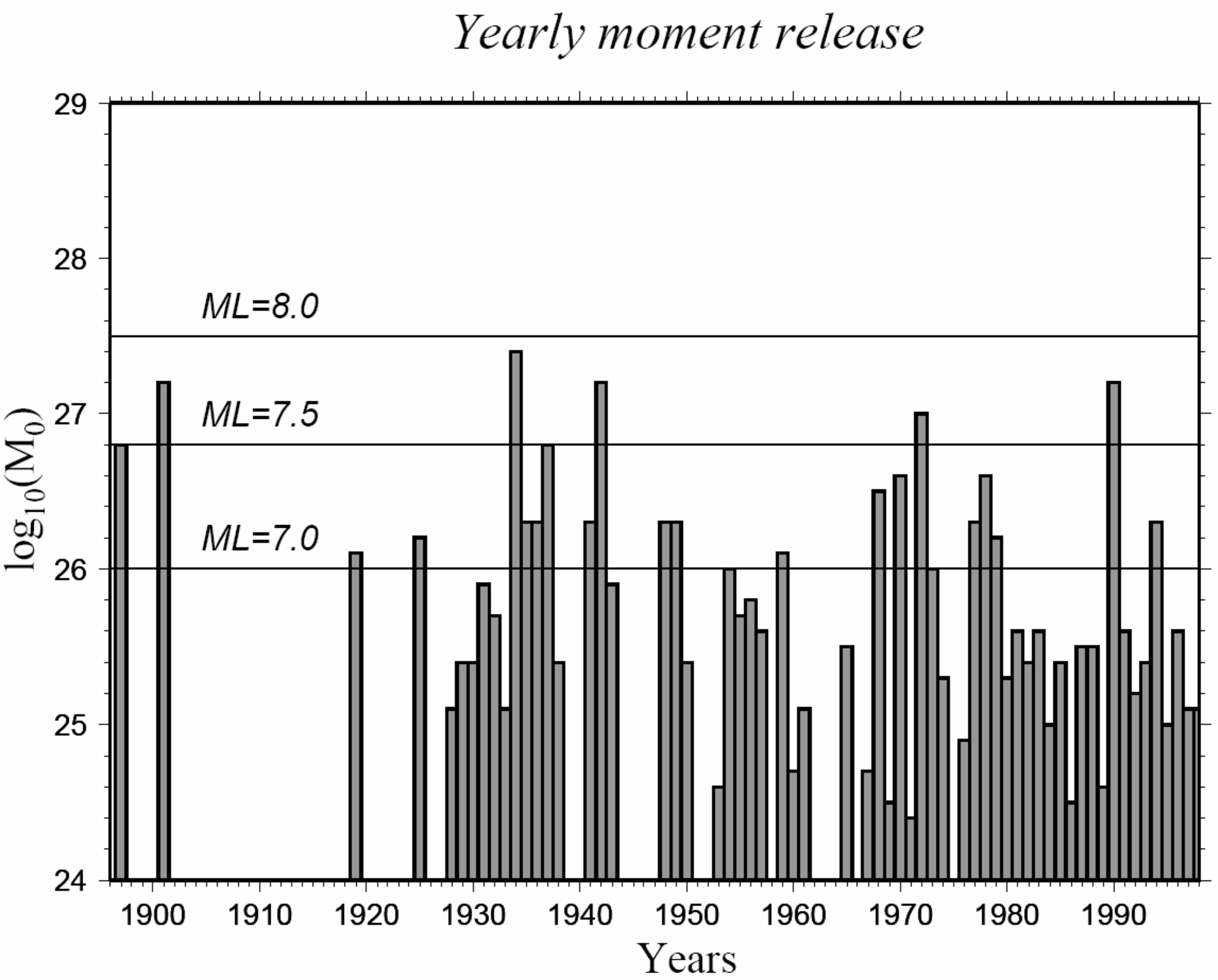
- <u>1934, Feburary 14, 12:00." </u>There was a strong earthquake in the South China Sea, off the western coast of Luzon island. It was felt all over Luzon island except for its peninsulas, on the south of Taiwan island and at Victoria (Hong Kong)."

- "The earthquake was accompanied by a small tsunami, which was observed at San Estaban. According to reports, the sea first retreated so markedly that the residents rushed the dry strip of bottom to collect fish. Some of them almost drowned when the reflux was succeeded by a tidal wave."



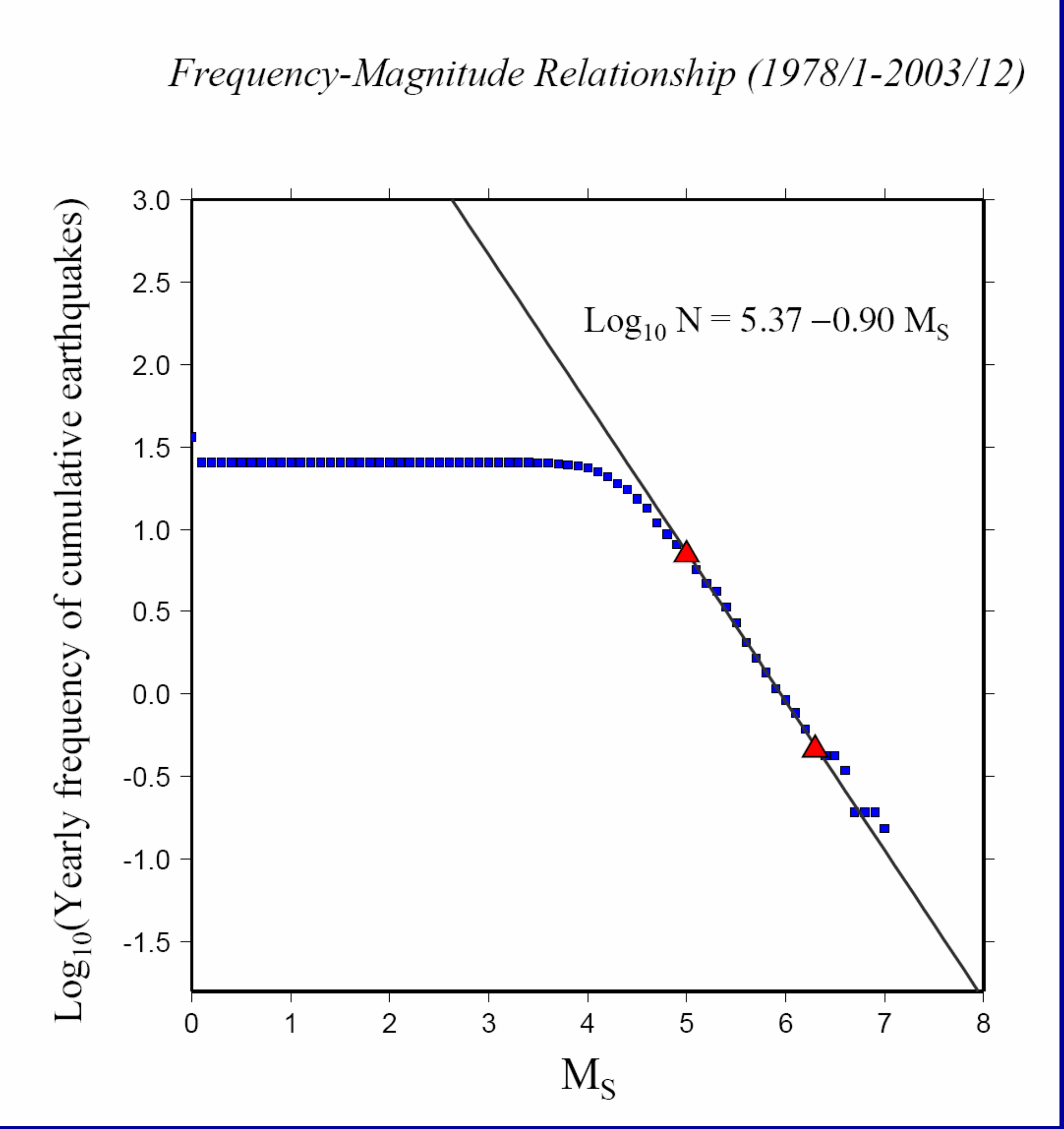
EHB catalogue

The dashed box groups the study area representing the Manila-Taiwan subduction zone.



Historical catalogue

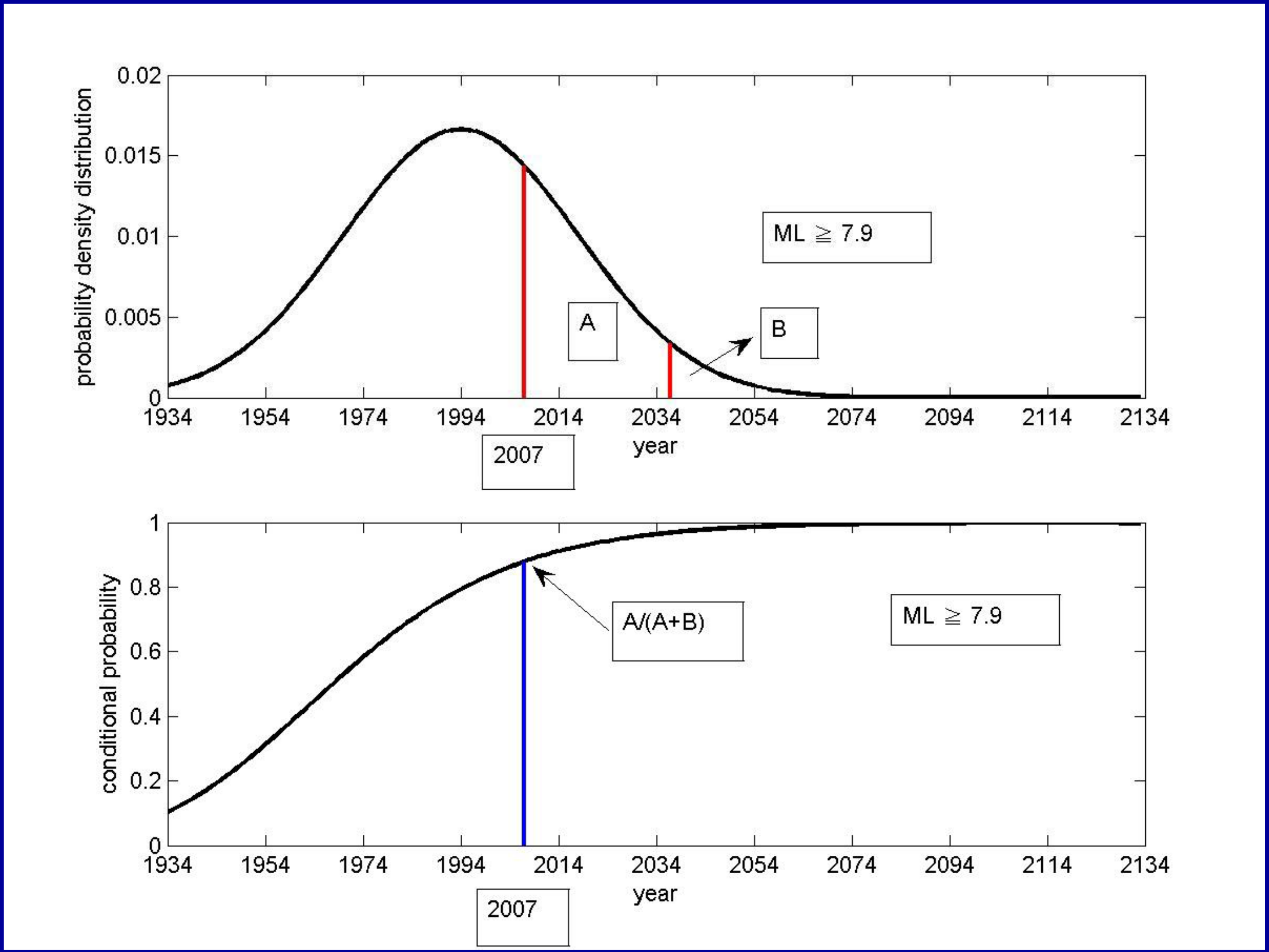
Using earthquakes with depths between 0~70 km from the EHB catalogue.



The predicted period for an $M_S \geqq 7.9$ earthquake is ~60 years.

We estimate the probability of an $M_s \geqq 7.9$ earthquake to occur within the study area in the next 30 years.

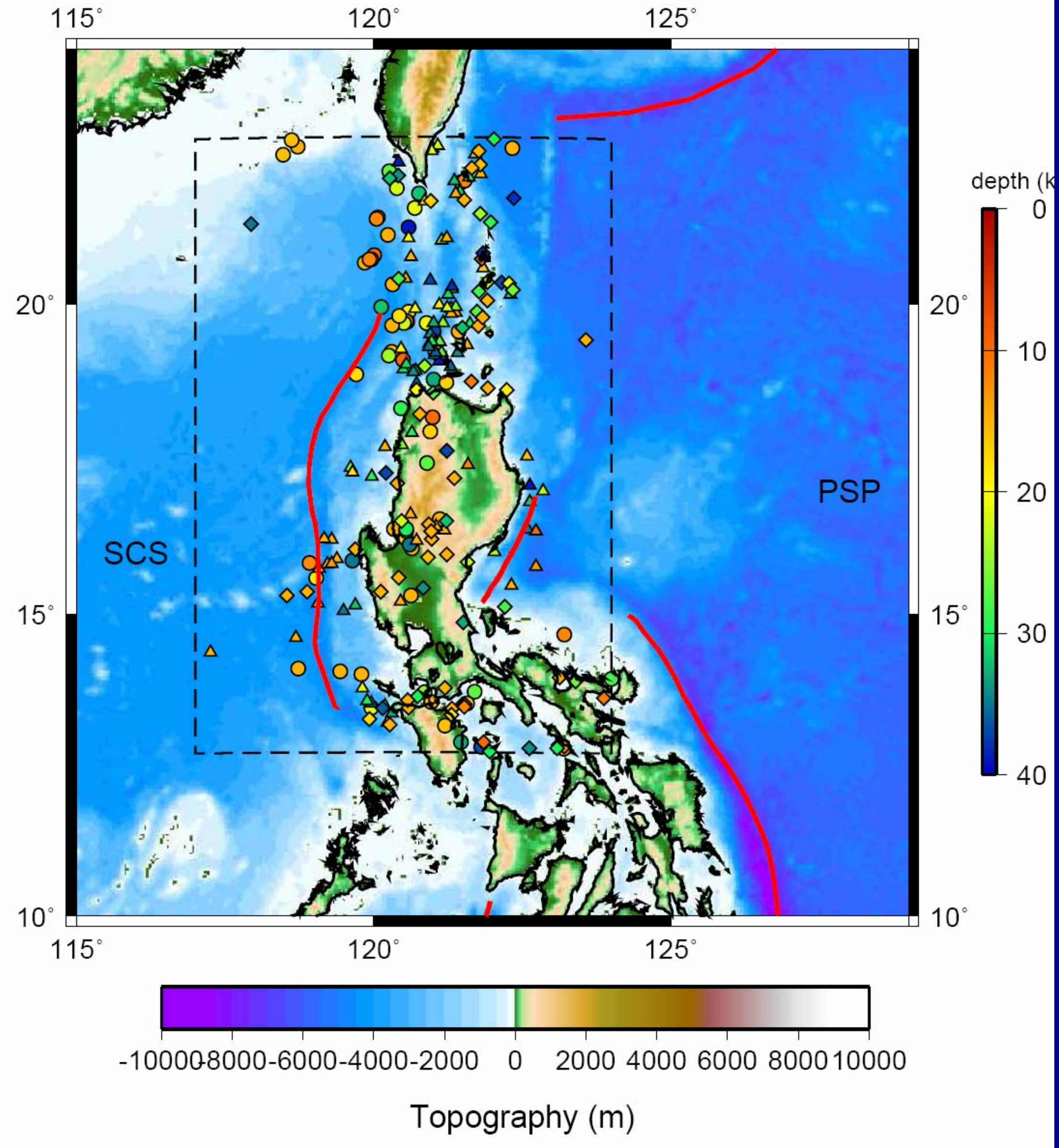
The probability density function is assumed to be Gaussian distribution with standard deviation taken as 0.4 times mean (Nishenko and Buland, 1987).
Last such earthquake occurred in 1934.



The probability is 88% for an Ms ≧7.9 earthquake to occur in the next 30 years.

Circles for normal faulting, Triangles for thrust faulting, Diamonds for strike-slip faulting

Earthquakes with depths between 0 and 40 km from the Harvard CMT catalogue.



We sum up earthquake moment tensors to obtain the strain rates of the study area (Kostrov, 1974).

$$\dot{\varepsilon}_{ij} = \frac{1}{2\mu V T_{obs}} \sum M_{ij}$$

M_{ij} : moment tensors of earthquakes

$\dot{\varepsilon}_{ij}$: average strain rates

V : sampling volume in which earthqaukes occur

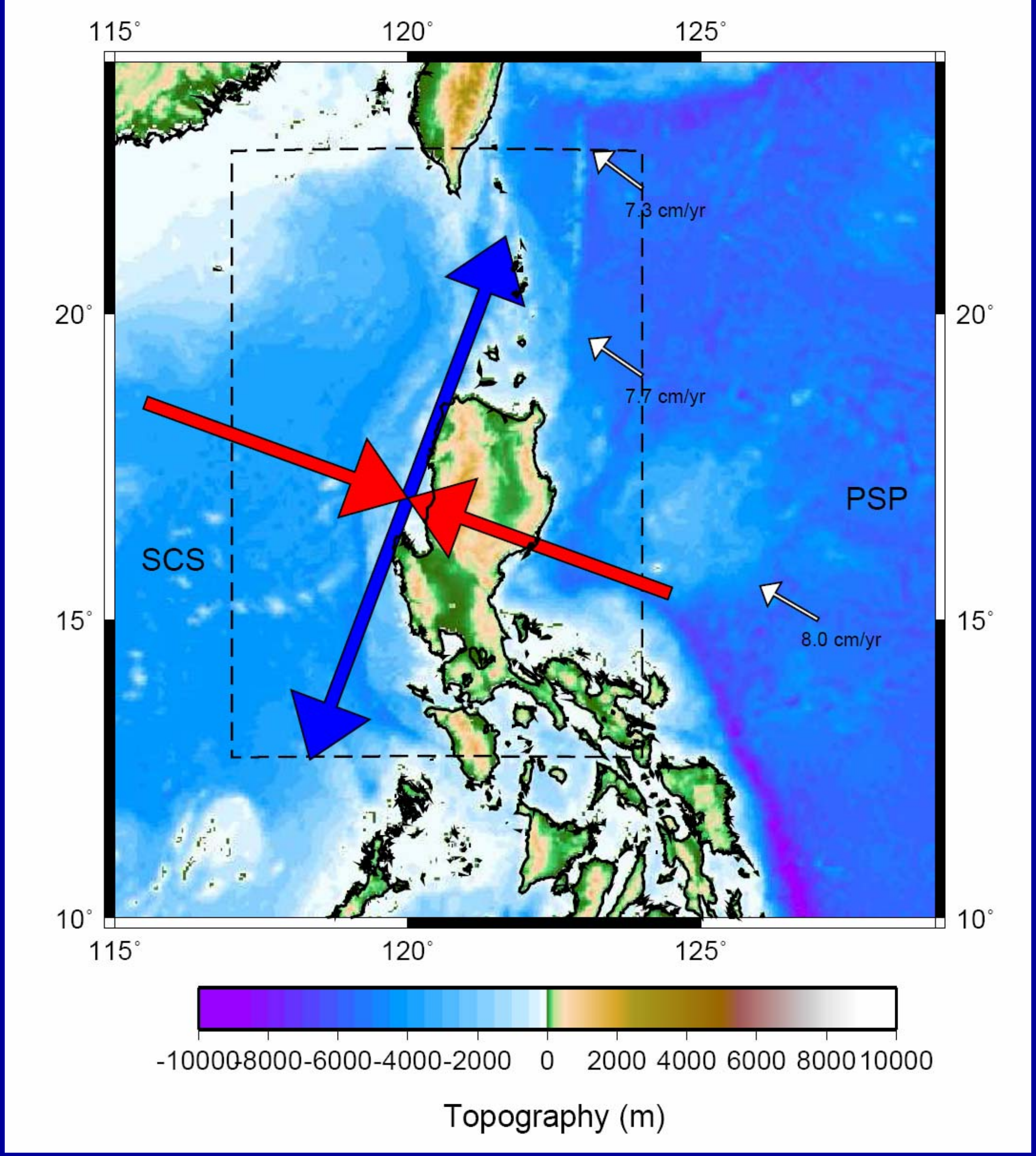
T_{obs} : time interval (1977 ~ 2007)

μ : rigidity (3.3×10^{11} dyne/cm^2)

After diagonalizing the strain rates tensor, the two principal directions correspond to directions of maximum compression and extension.

The seismic shortening rates can be derived by the contractional eigenvalue.

(Klosko et al., 2002)



The average direction of seismic compression is consistent with the direction of plate motion.

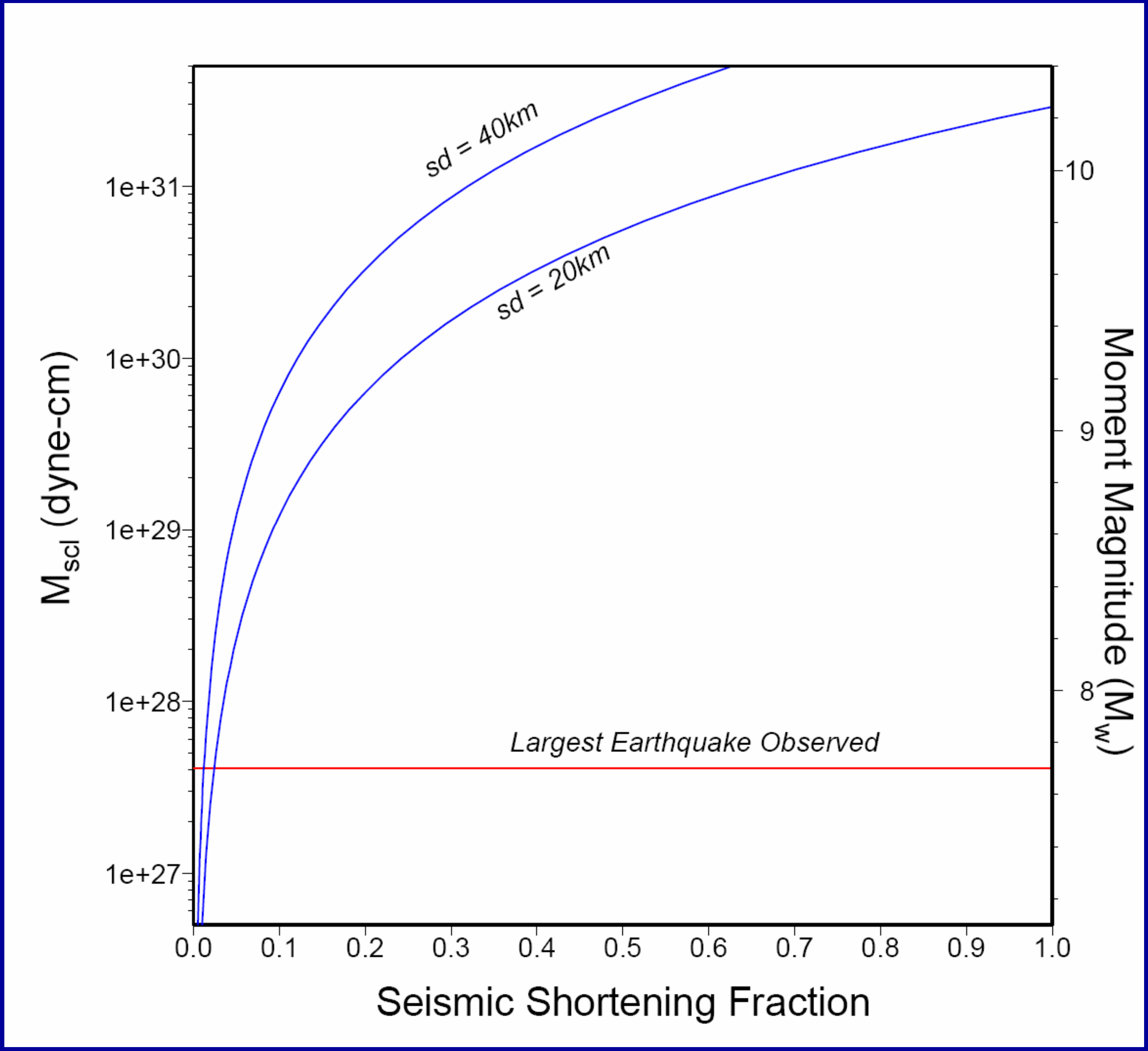
$$\text{seismic shortening fraction} = \frac{\text{seismic shortening rates}}{\text{plate motion rates}}$$

The calculated seismic shortening fraction is less than 2%.

If we await longer time and larger earthquake occurs according to $\log_{10}N = \alpha - \beta \log_{10}M_0$, the moment tensor sum will scale up and thus increase the seismic shortening fraction.

Seismic shortening fraction as a function of largest earthquake.

sd: seismogenic depth



Most of the shortening occurs aseismically.

Conclusions

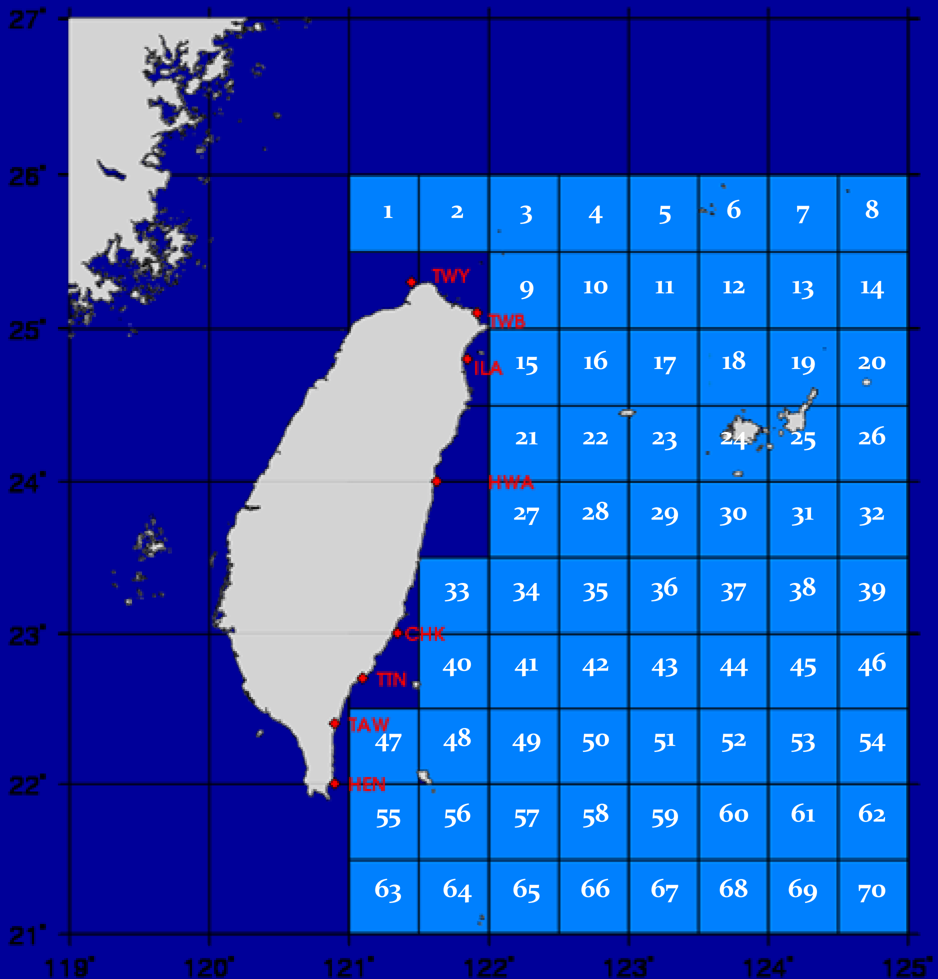
- The period for **an $M_S \geqq 7.9$ earthquake is ~60 years and there is 88% probability that such an earthquake will occur in the next 30 years.**
- **Most of the shortening is taken up aseismically.**

Appraisal of tsunami impacts for offshore eastern Taiwan earthquakes

Purposes

A. **Using tsunami simulation with different source locations to examine propagation characteristics (path effects).**

B. **Results will be combined with *in situ* seismic activities to appraise the tsunami hazard potentials offshore eastern Taiwan for future study.**



Research area :

119°E-125°E / 21°N-27°N

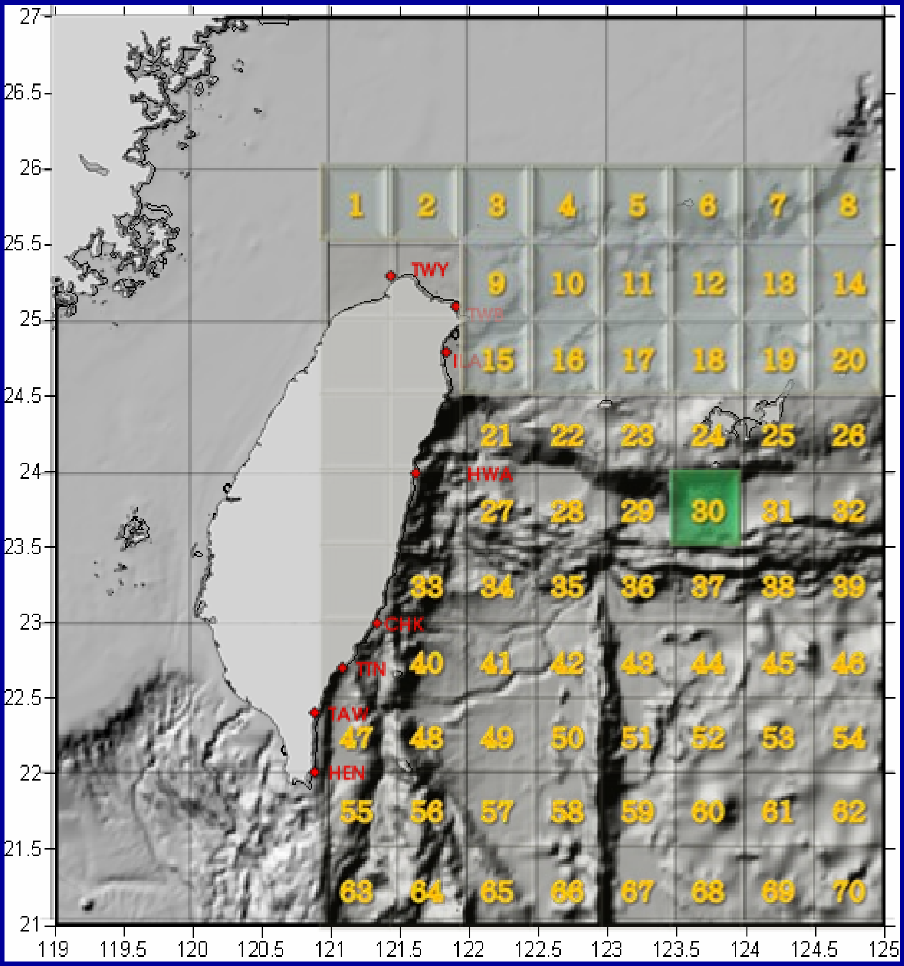
Source area :

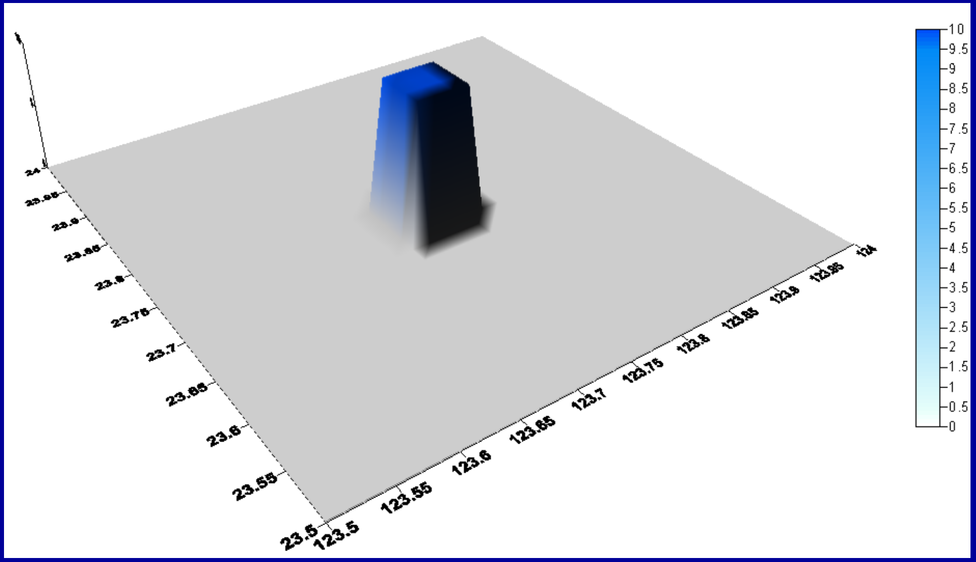
121°E-125°E / 21°N-26°N

sub-source number : 70

virtual tidal stations : 8

Scenario Source





Source area : 8x8 km

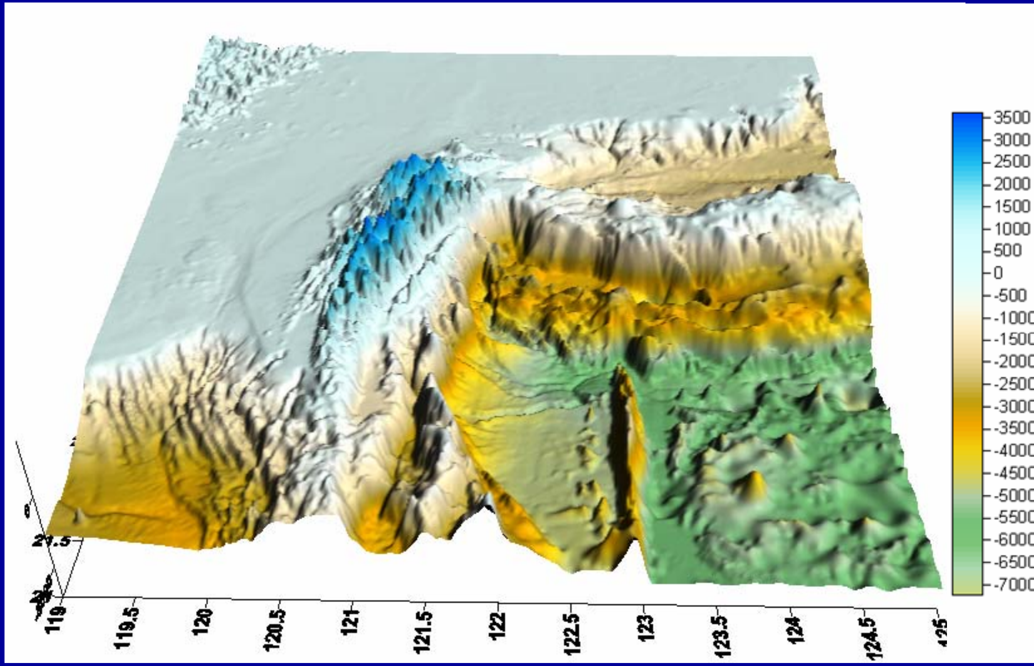
Initial amplitude : 10 m

Using finite-difference method to solve linear shallow water wave equation in spherical coordinates (Satake, 1985), the propagation of the hump is simulated.

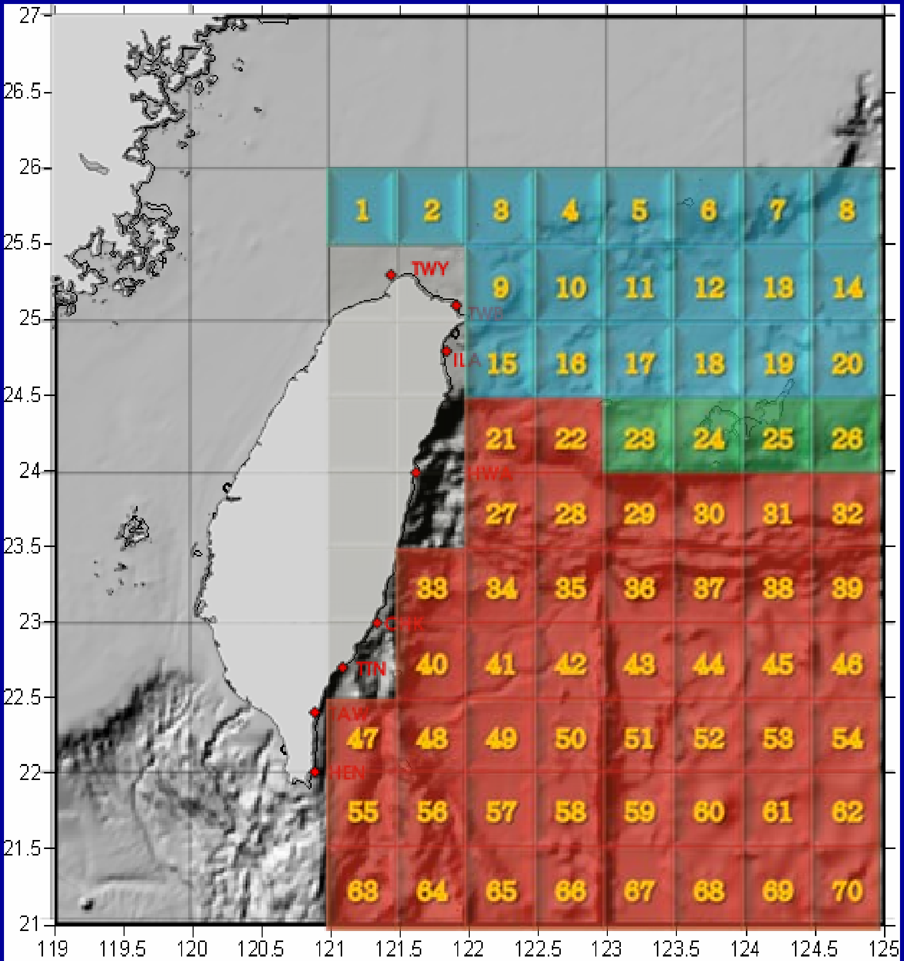
$\triangle s$ = 2 sec

- Spatial interval : 1 min.
- Radiation on map boundary

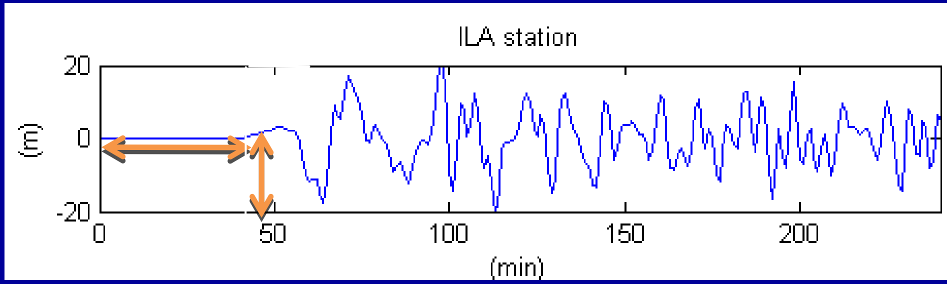
  Total reflection on ocean-land boundary
- Total time : 2hr
- Output station : 8



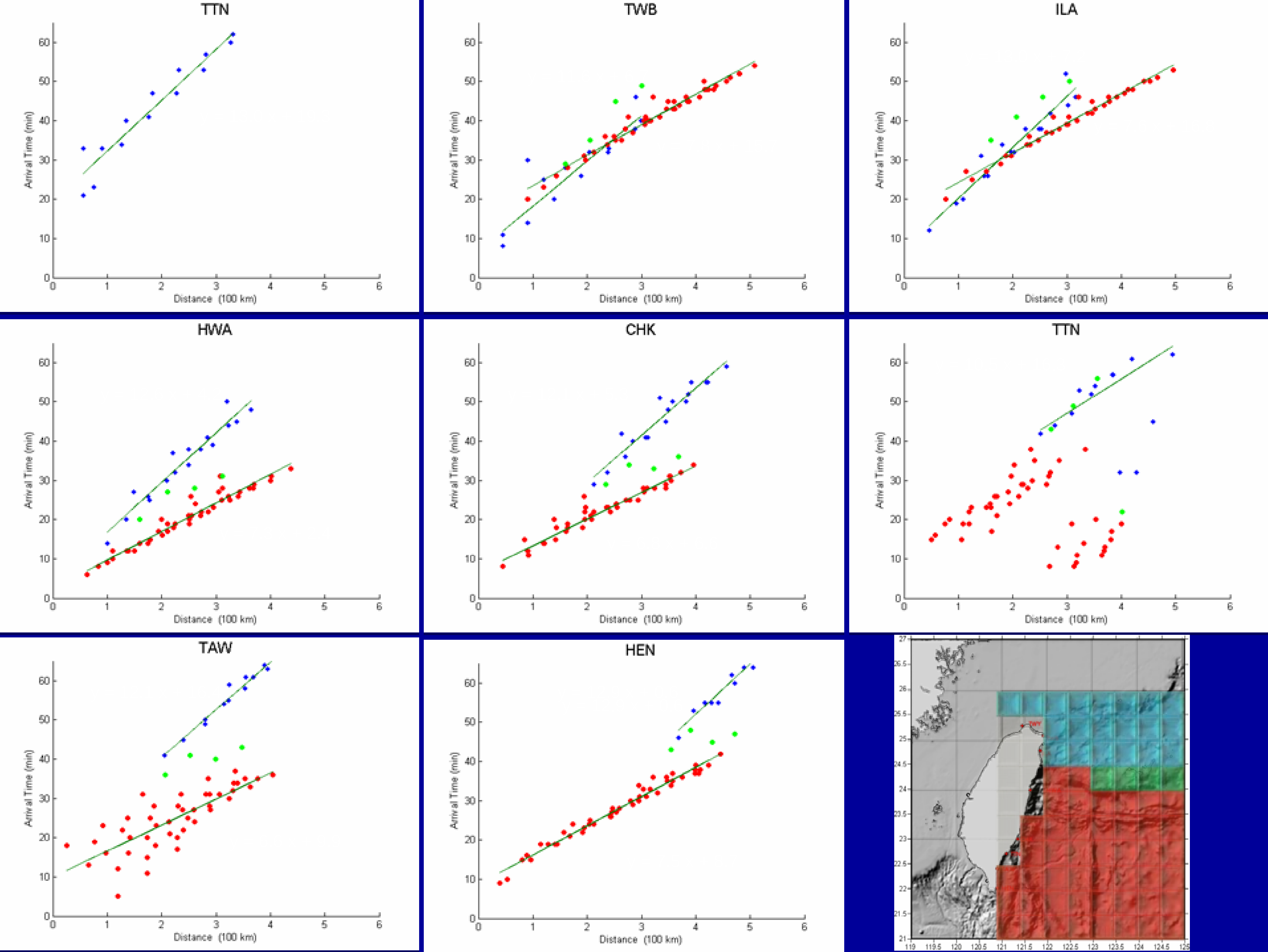
Results of arrival time – distance plot can be grouped into three distinctive patterns as shown in different colors.



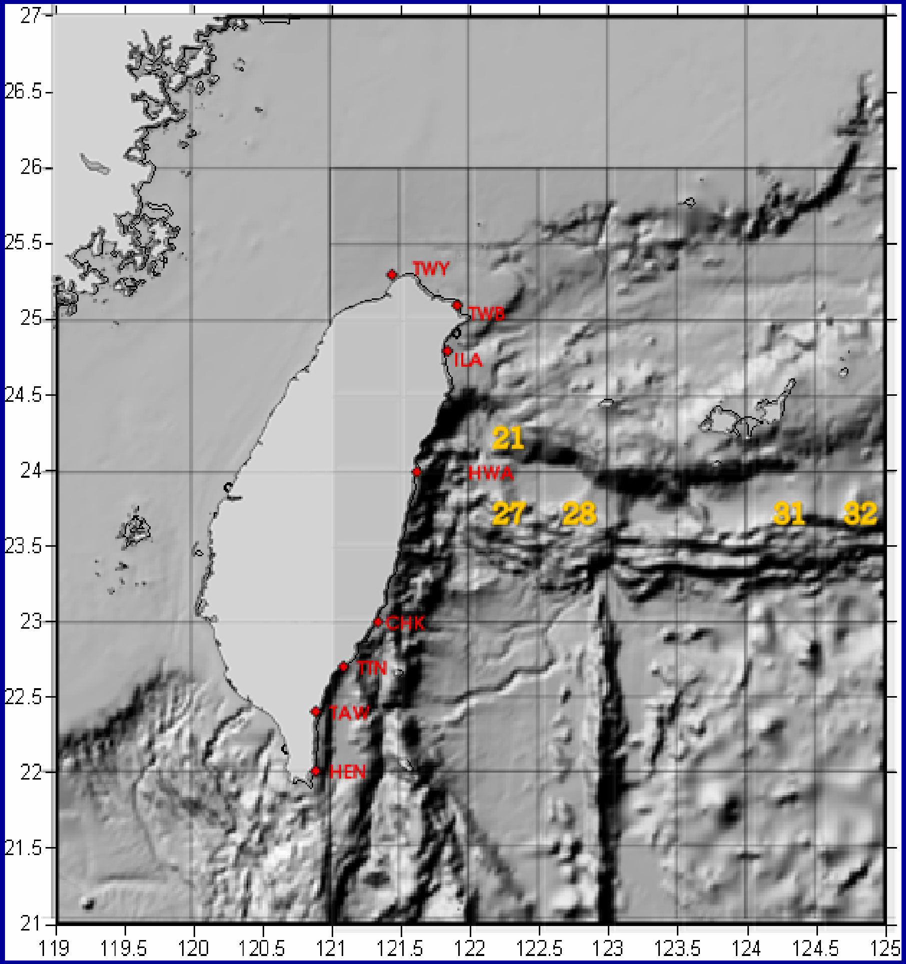
Arrival time : 41 min



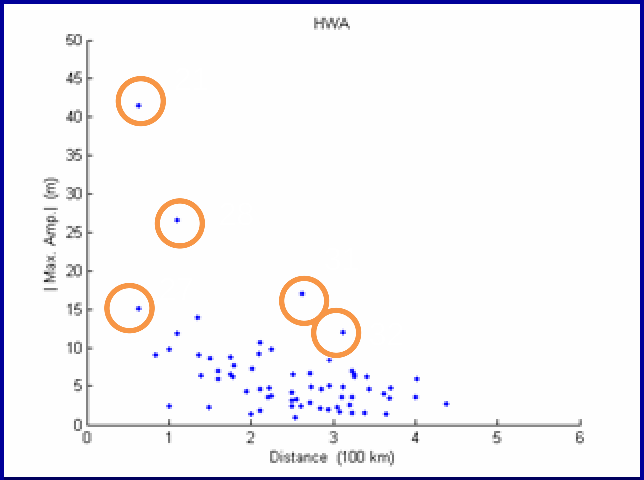
Subsidence : -11.7 m
Uplift : 3.14 m
Max. Amp. : 14.84 m


TTN
TWB
ILA
HWA
CHK
TTN
TAW
HEN
Arrival Time (min)
Distance (100 km)

HWA



- 27. 28
- 31. 32



Conclusions

- The simulation results suggest that an empirical law to predict tsunami arrival times for different station-source pair can be done.
- The shallow water channel outside Hualein can act as a waveguide to enhance tsunami wave amplitudes.