台湾と日本の斜面崩壊発生に関する比較

防災科学技術研究所マルチハザード評価研究部門
陳　麒文

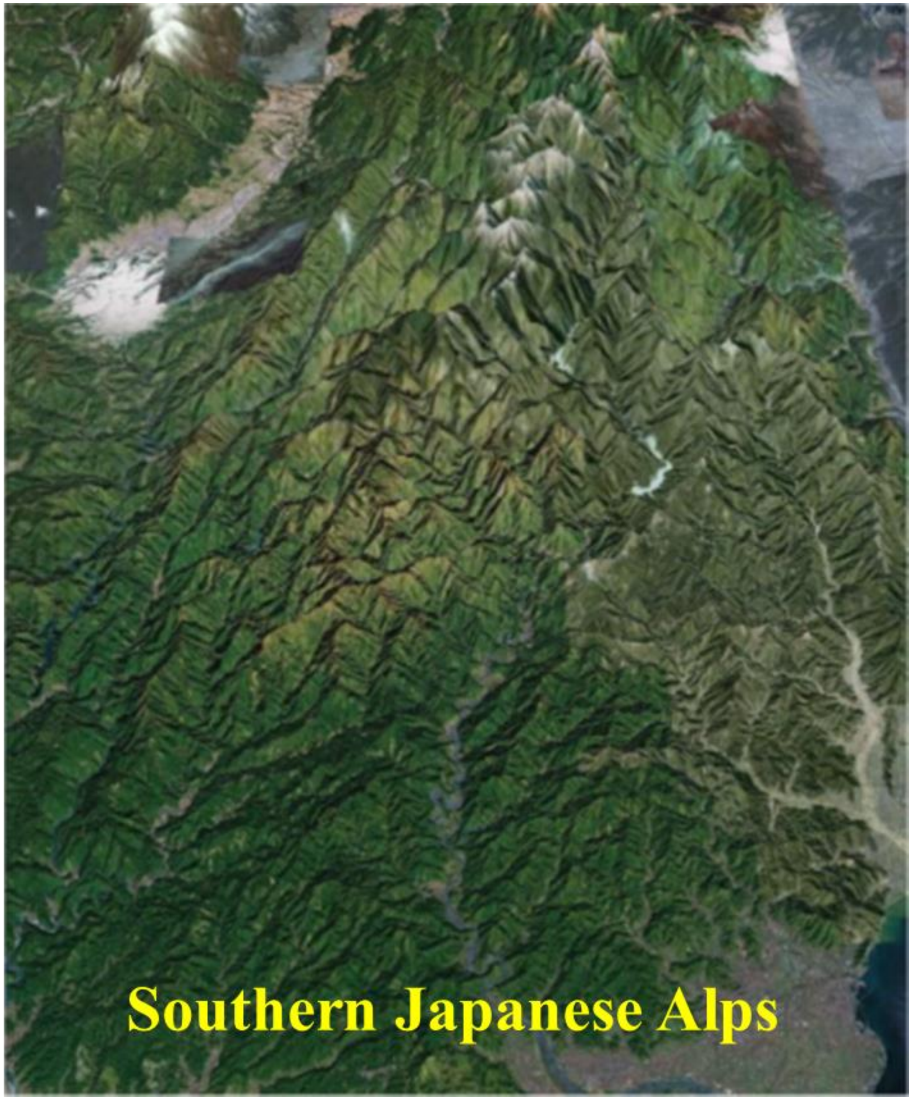
斜面崩壊とは

- 斜面を構成する土層もしくは岩盤までが，おもに重力により斜面下方に移動する現象

斜面崩壊発生の要因

- **素因**
  - 地形（例：勾配）
  - 地質
  - 植生
- **誘因**
  - 降雨
  - 地震

どちらも険しい山地地形である

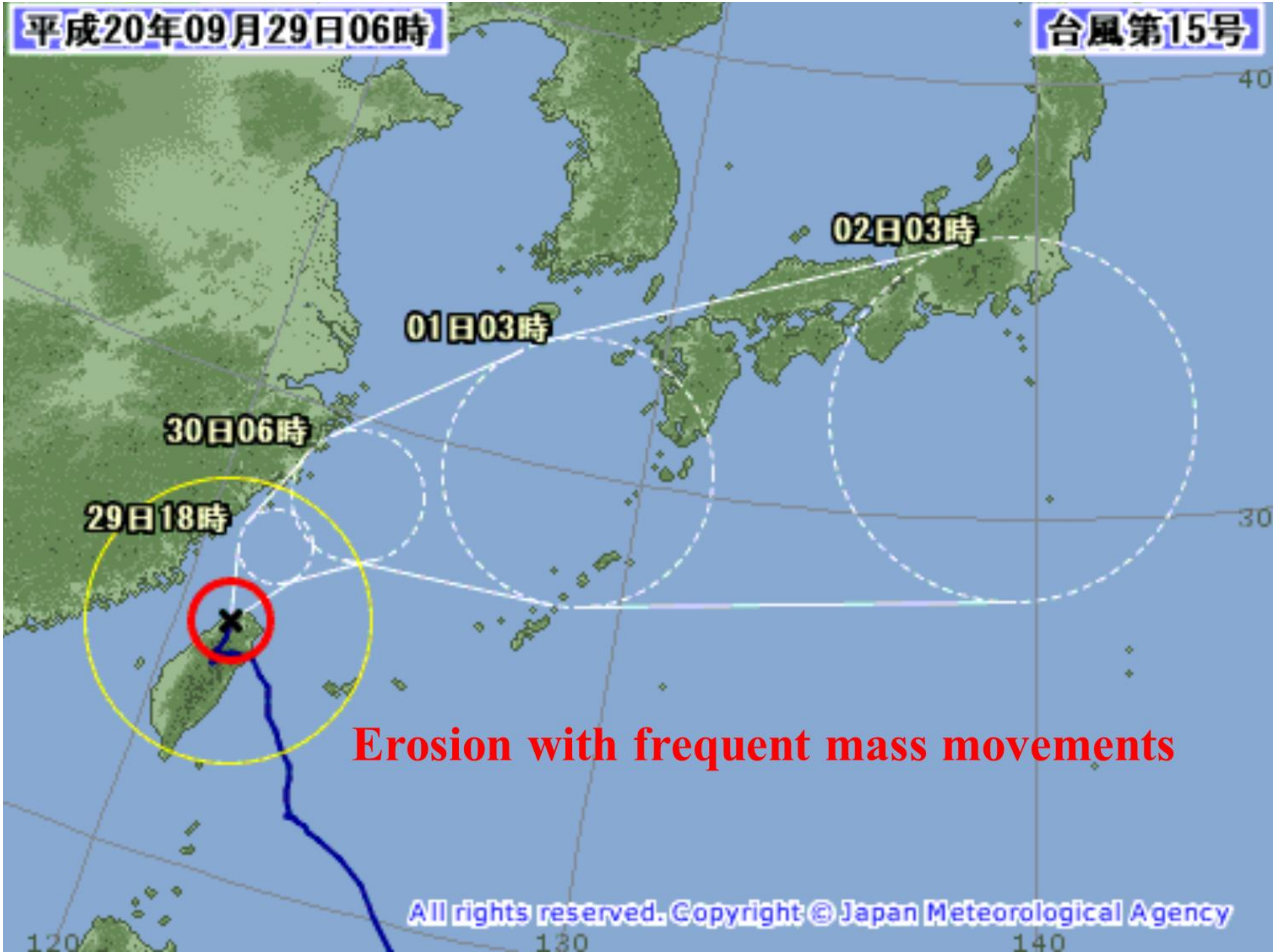


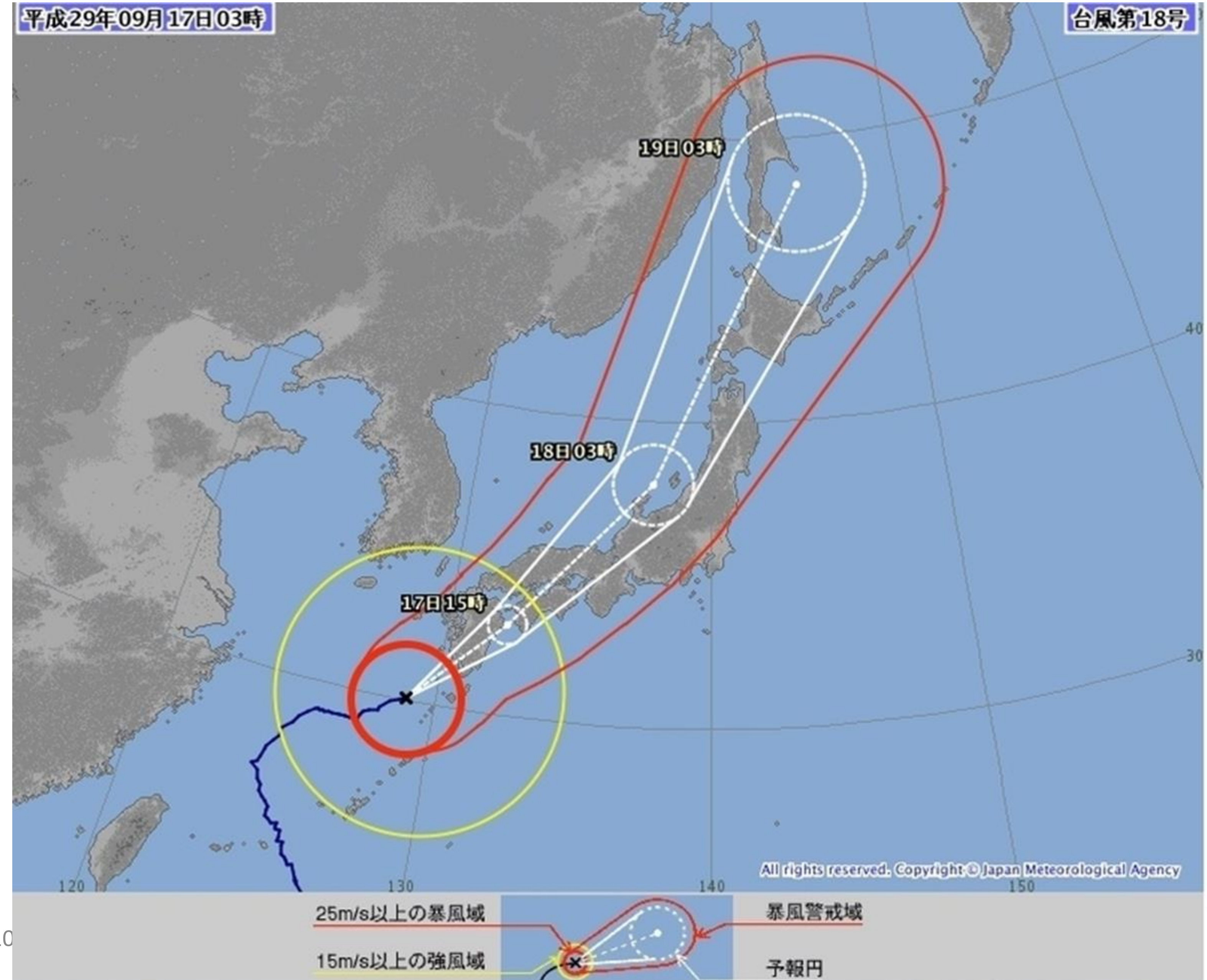
Shallow slides: Central Japanese Alps

Deep slide: Sept 2011, Kii Peninsula

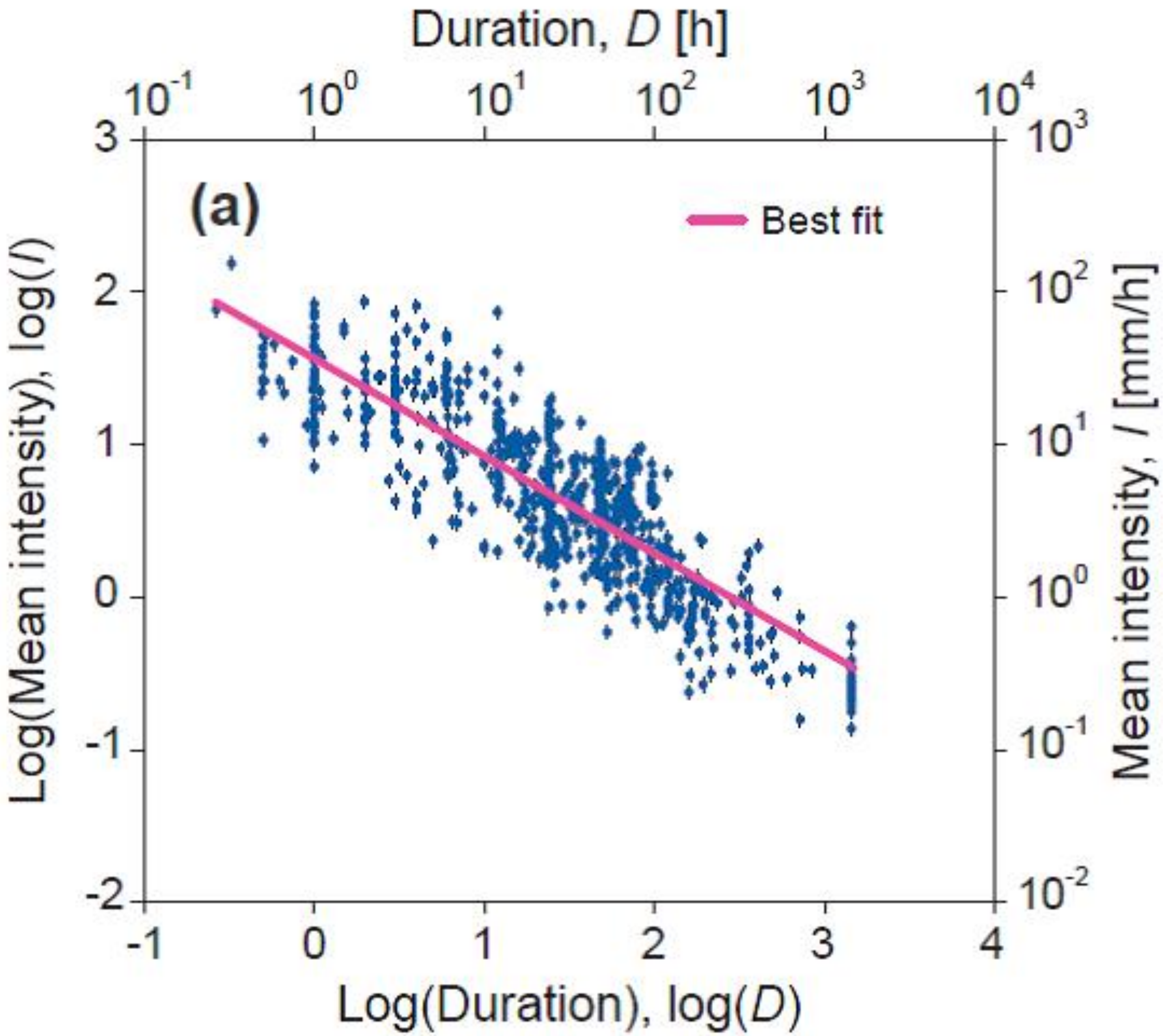
2011年８月台湾屏東県

降雨による斜面崩壊


平成20年09月29日06時
台風第15号
02日03時
01日03時
30日06時
29日18時
40
30
120
130
140
Erosion with frequent mass movements
All rights reserved. Copyright © Japan Meteorological Agency


平成29年09月17日03時
台風第18号
19日03時
18日03時
17日15時
40
30
120
130
140
150
All rights reserved. Copyright © Japan Meteorological Agency
25m/s以上の暴風域
15m/s以上の強風域
暴風警戒域
予報円

I–*D* relationship



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ELSEVIER

Relationship between the initiation of a shallow landslide and rainfall intensity–duration thresholds in Japan

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[b] Research Fellow of the Japan Society for the Promotion of Science, Japan

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Shallow landslides
I–D threshold
Rescaling
Quantile regression
East Asian summer monsoon

ABSTRACT

The empirical rainfall in
defined for Japan where
rainfall causes sedimen
induced shallow landsli
from rainfall data (Rada
regression method: $I=$
measured from the beg
absence of rainfall for 2
the mean annual precip
rainfall intensity. These
The new thresholds are
regions, the Asian mon
induced shallow landsli
and rainfall characterist

Chen *et al. Progress in Earth and Planetary Science* (2015) 2:14
DOI 10.1186/s40645-015-0049-2

Progress in Earth and Planetary Science
a SpringerOpen Journal

RESEARCH ARTICLE Open Access

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Rainfall intensity–duration conditions for mass movements in Taiwan

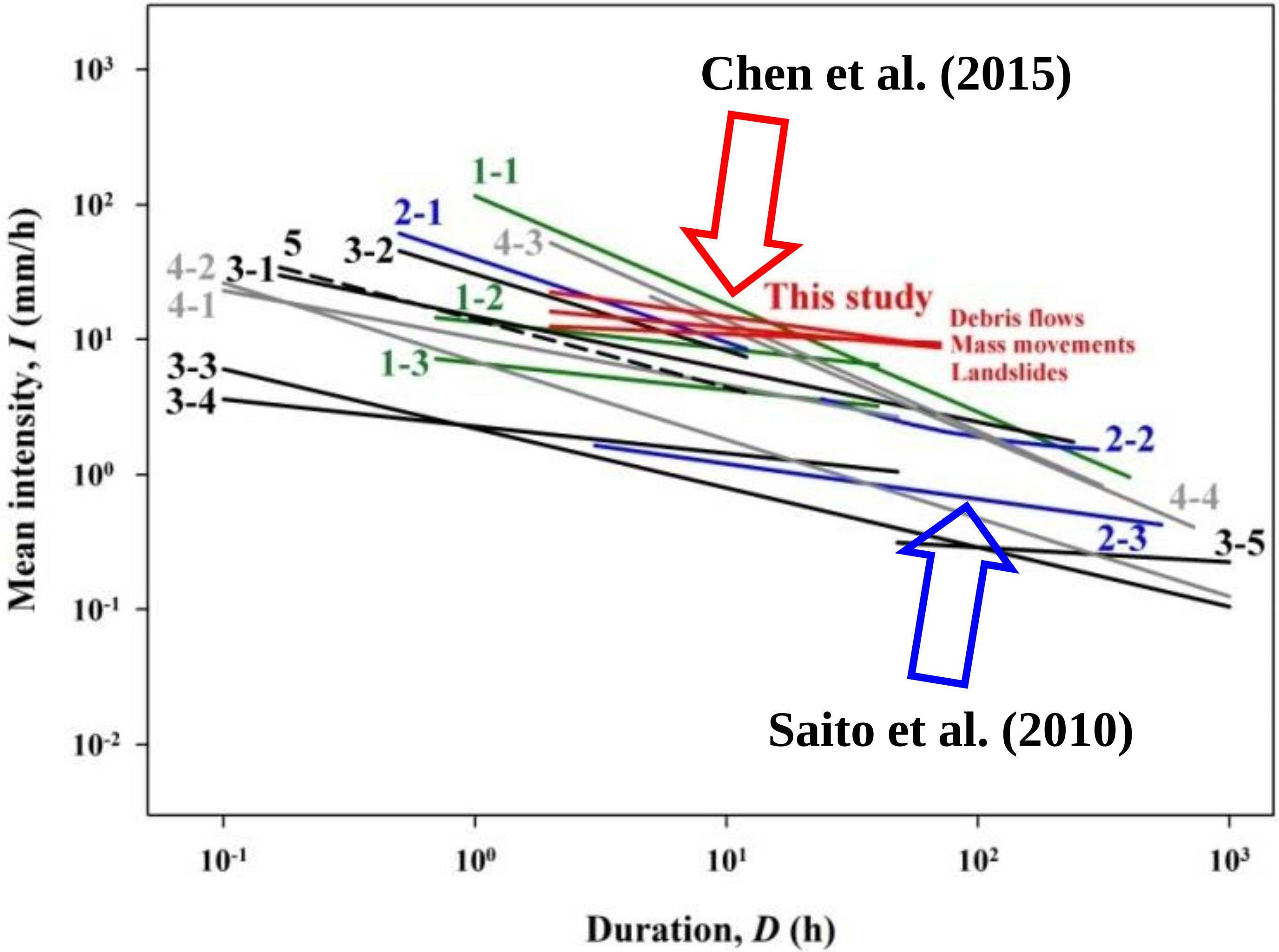
Chi-Wen Chen[1*], Hitoshi Saito[2,3] and Takashi Oguchi[1,3]

Abstract

Mass movements caused by rainfall events in Taiwan are analyzed during a 7-year period from 2006 to 2012. Data from the Taiwan Soil and Water Conservation Bureau reports were compiled for 263 mass movement events, including 156 landslides, 91 debris flows, and 16 events with both landslides and debris flows. Rainfall totals for each site location were obtained from interpolated rain gauge data. The rainfall intensity–duration (*I–D*) relationship was examined to establish a rainfall threshold for mass movements using random sampling: $I = 18.10(\pm 2.67)D^{-0.17(\pm 0.04)}$, where I is mean rainfall intensity (mm/h) and D is the time (h) between the beginning of a rainfall event and the resulting mass movement. Significant differences were found between rainfall intensities and thresholds for landslides and debris flows. For short-duration rainfall events, higher mean rainfall intensities were required to trigger debris flows. In contrast, for long-duration rainfall events, similar mean rainfall intensities triggered both landslides and debris flows. Mean rainfall intensity was rescaled by mean annual precipitation (MAP) to define a new threshold: $I_{MAP} = 0.0060(\pm 0.0009)D^{-0.17(\pm 0.04)}$, where I_{MAP} is rescaled rainfall intensity and MAP is the minimum for mountainous areas in Taiwan (3000 mm). Although the *I–D* threshold for Taiwan is high, the I_{MAP}–D threshold for Taiwan tends to be low relative to other areas around the world. Our results indicate that Taiwan is highly prone to rainfall-induced mass movements. This study also shows that most mass movements occur in high rainfall-intensity periods, but some events occur before or after the rainfall peak. Both antecedent and peak rainfall play important roles in triggering landslides, whereas debris flow occurrence is more related to peak rainfall than antecedent rainfall.

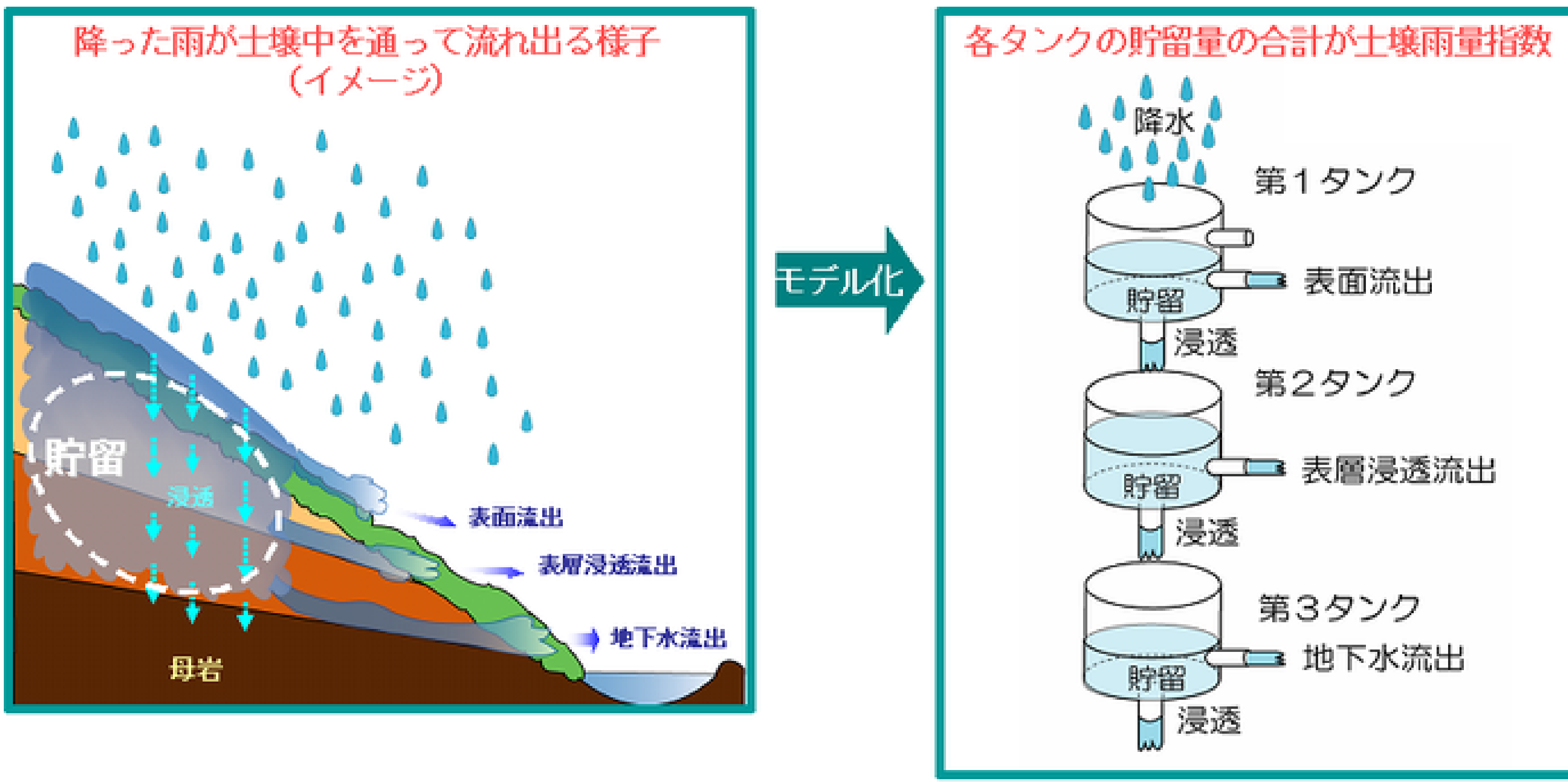
Keywords: Mass movements; Landslides; Debris flows; *I–D* thresholds; Rainfall; Typhoons

地域間の比較


Chen et al. (2015)
Saito et al. (2010)
This study
Debris flows
Mass movements
Landslides
1-1
1-2
1-3
2-1
2-2
2-3
3-1
3-2
3-3
3-4
3-5
4-1
4-2
4-3
4-4
5
Mean intensity, I (mm/h)
Duration, D (h)

土壌雨量指数

- 2008年から気象庁は、土壌雨量指数を用いて、土砂災害警戒を発信している。



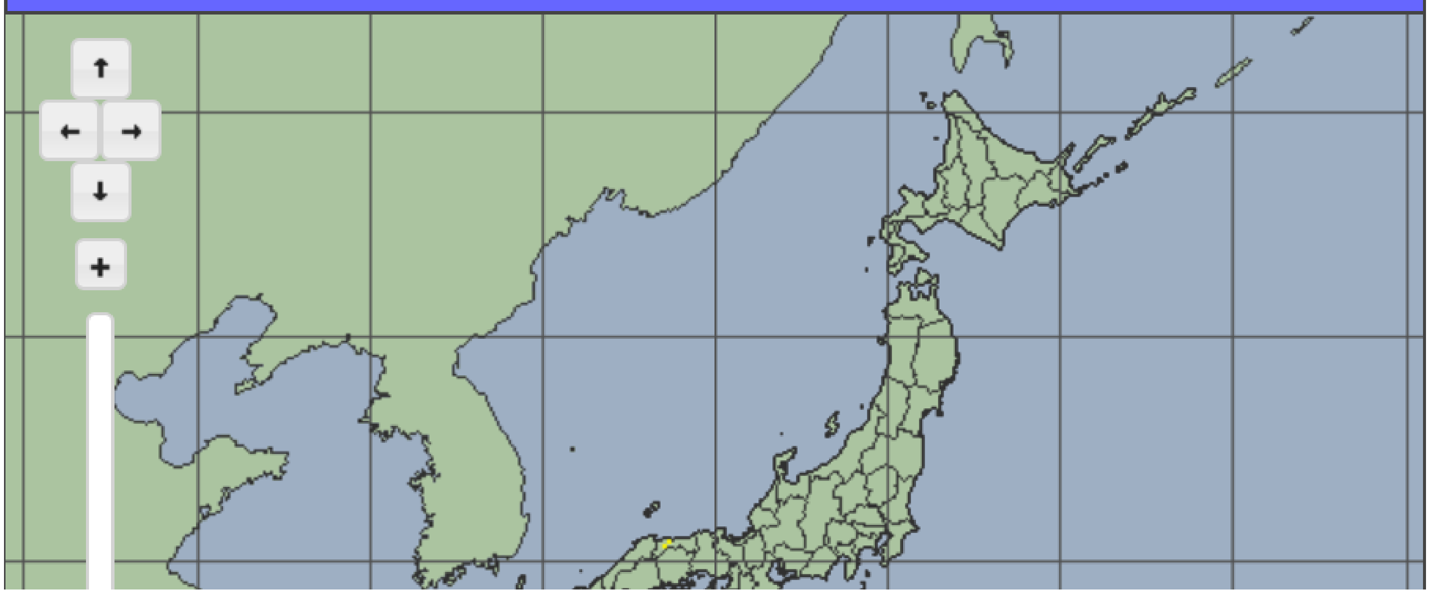
土砂災害警戒判定メッシュ情報

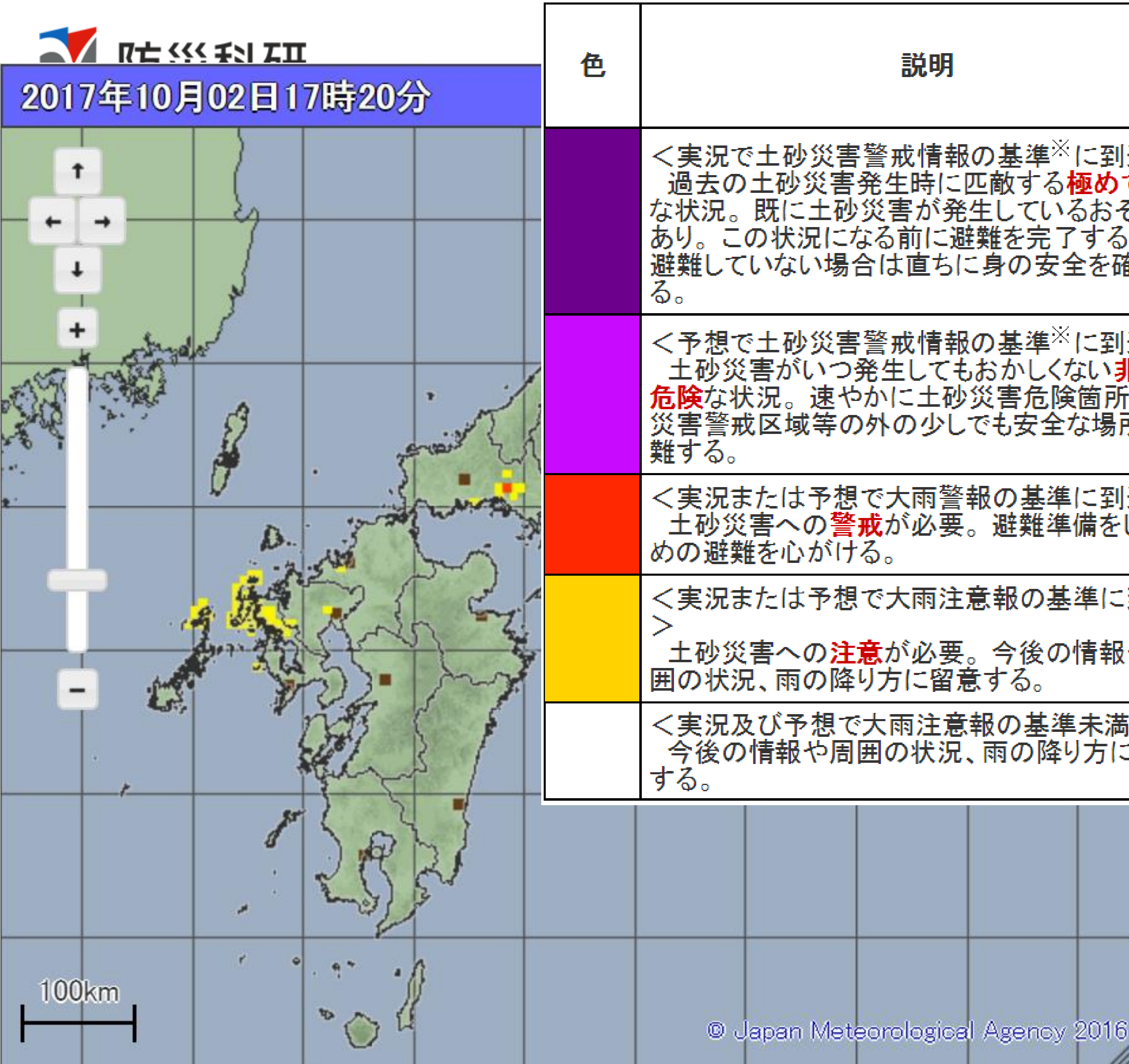
表示時間 < 10/02 17:20 ▼ > 最 新 画像保存 印刷

動画方法 6時間前から最新まで 動画表示 動画開始 動画停止

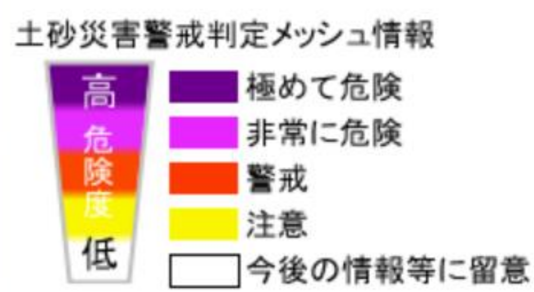
動画速度 遅く ■■■■■□□□□□ 速く 使い方

2017年10月02日17時20分

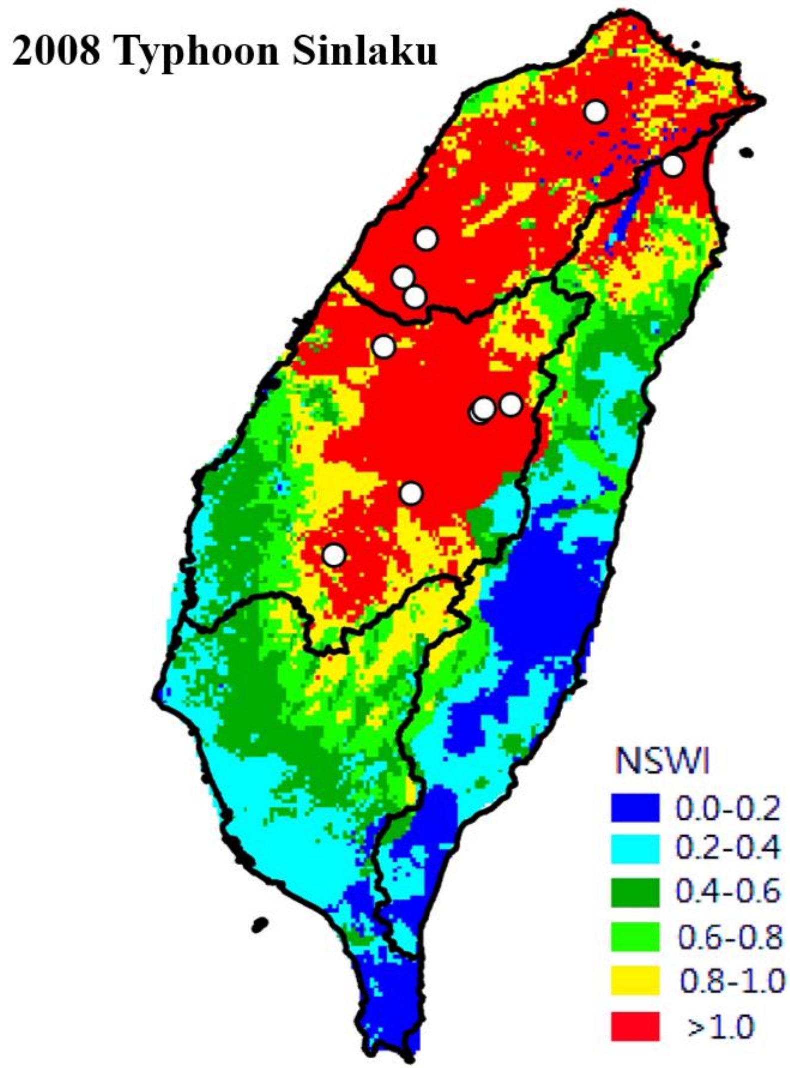




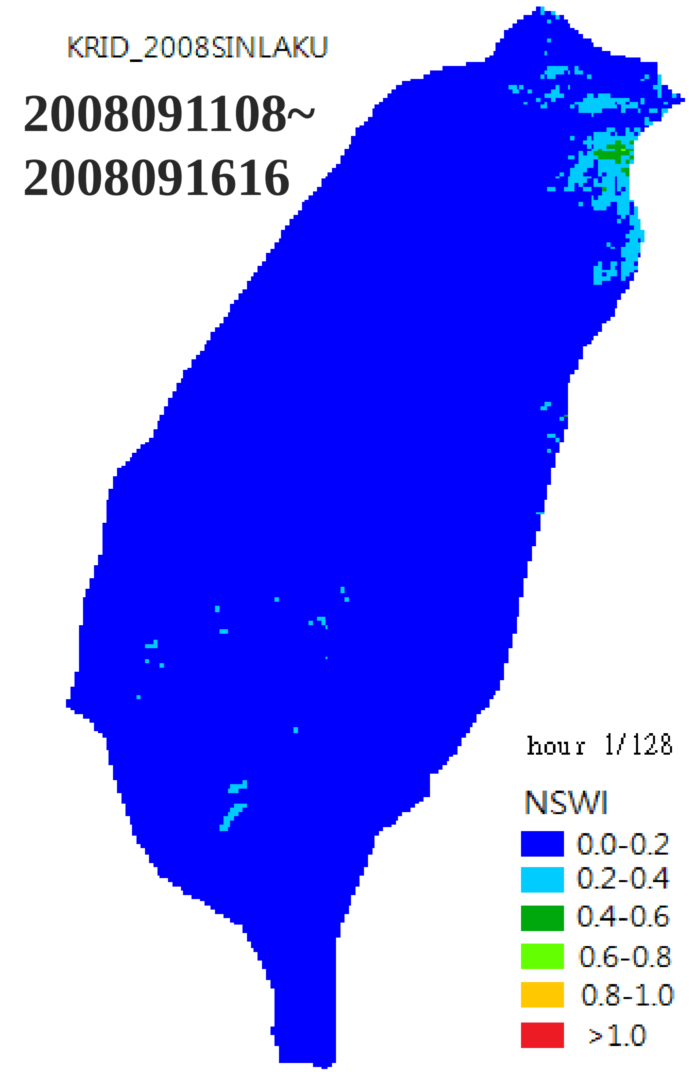
色	説明	内閣府のガイドラインで土砂災害警戒区域等を対象に発令が必要とされている避難情報
（濃い紫）	＜実況で土砂災害警戒情報の基準※に到達＞ 過去の土砂災害発生時に匹敵する**極めて危険**な状況。既に土砂災害が発生しているおそれもあり。この状況になる前に避難を完了する。まだ避難していない場合は直ちに身の安全を確保する。	避難指示（緊急）
（薄い紫）	＜予想で土砂災害警戒情報の基準※に到達＞ 土砂災害がいつ発生してもおかしくない**非常に危険**な状況。速やかに土砂災害危険箇所・土砂災害警戒区域等の外の少しでも安全な場所へ避難する。	避難勧告
（赤）	＜実況または予想で大雨警報の基準に到達＞ 土砂災害への**警戒**が必要。避難準備をし、早めの避難を心がける。	避難準備・高齢者等避難開始
（黄）	＜実況または予想で大雨注意報の基準に到達＞ 土砂災害への**注意**が必要。今後の情報や周囲の状況、雨の降り方に留意する。	－
（白）	＜実況及び予想で大雨注意報の基準未満＞ 今後の情報や周囲の状況、雨の降り方に留意する。	－



警戒システムの構築



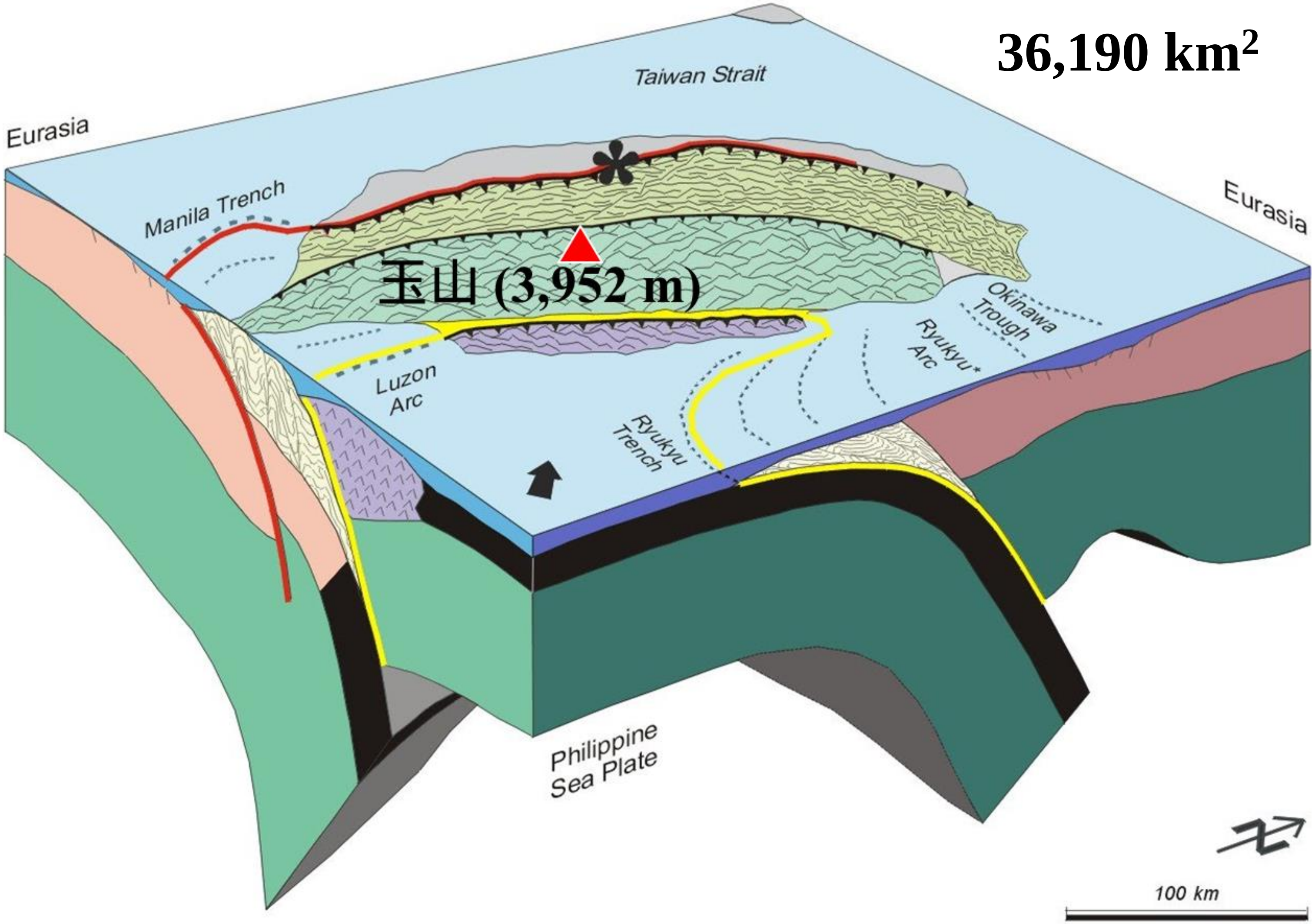
NCDR Maximum NSWI



NCDR Time series changes

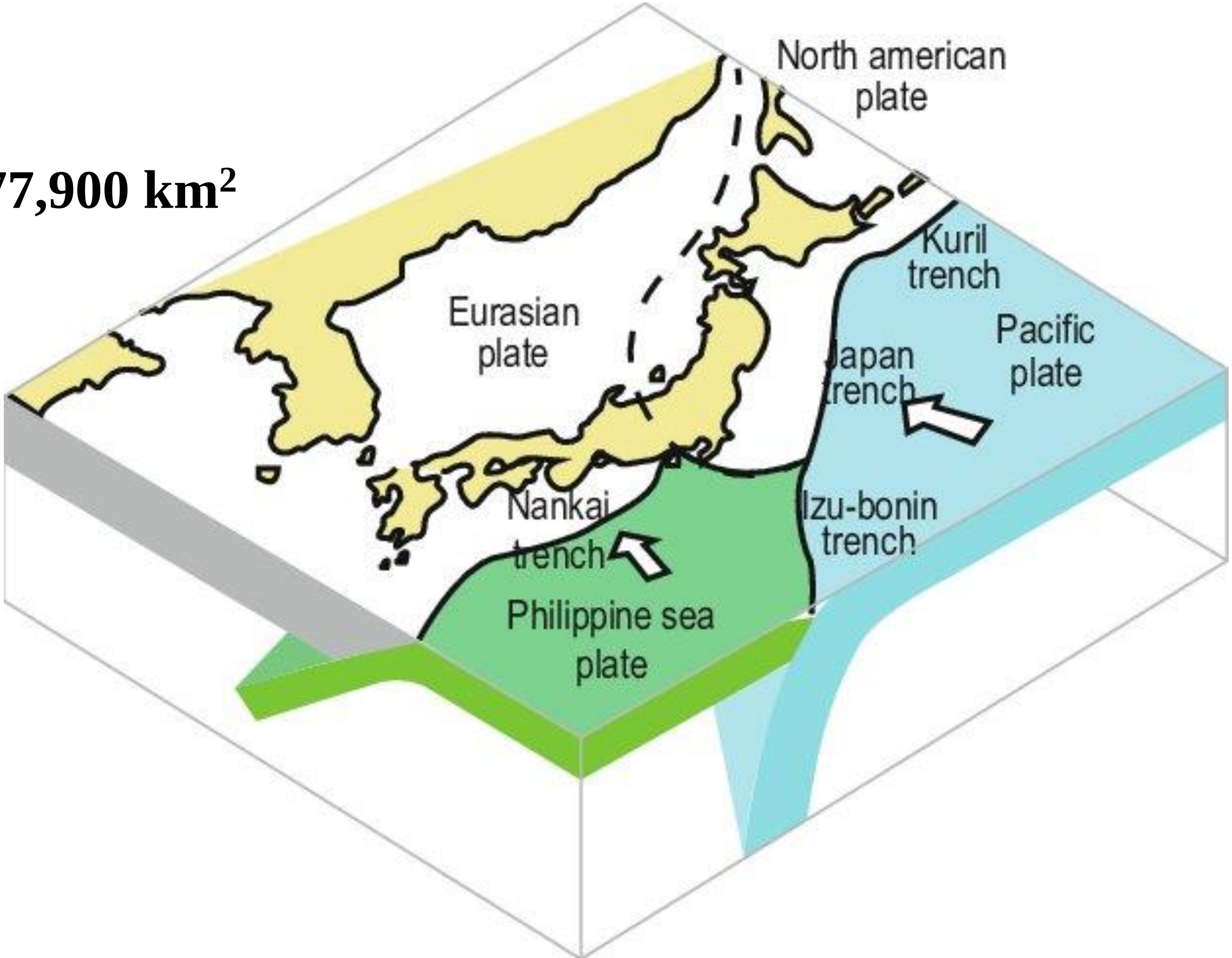
地震による斜面崩壊

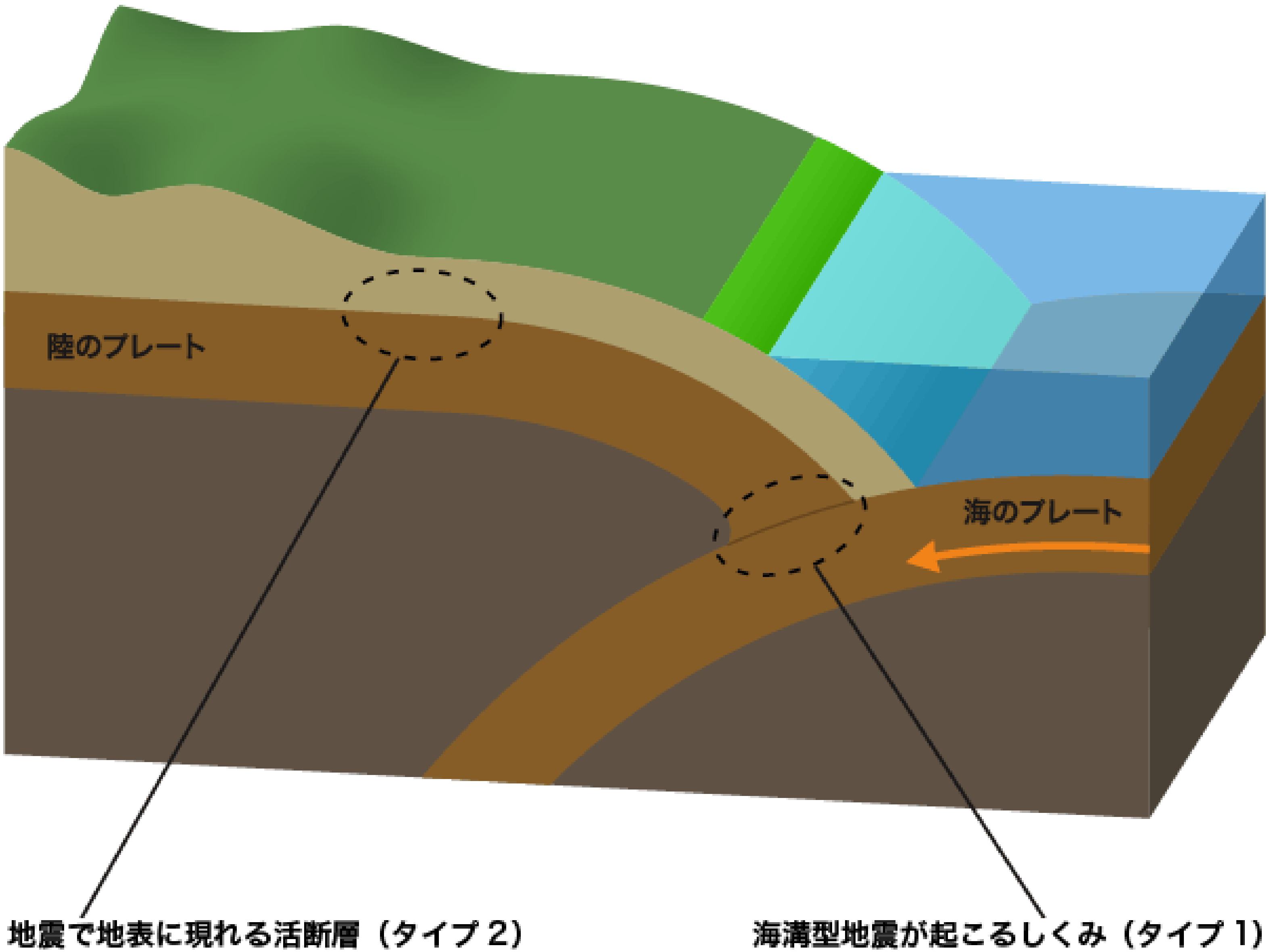
プレート境界


36,190 km²
Taiwan Strait
Eurasia
Manila Trench
Eurasia
玉山 (3,952 m)
Okinawa Trough
Ryukyu Arc
Luzon Arc
Ryukyu Trench
Philippine Sea Plate
100 km

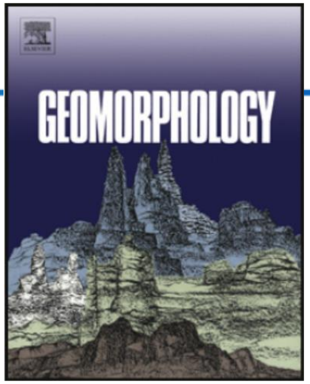
プレート境界

377,900 km^2

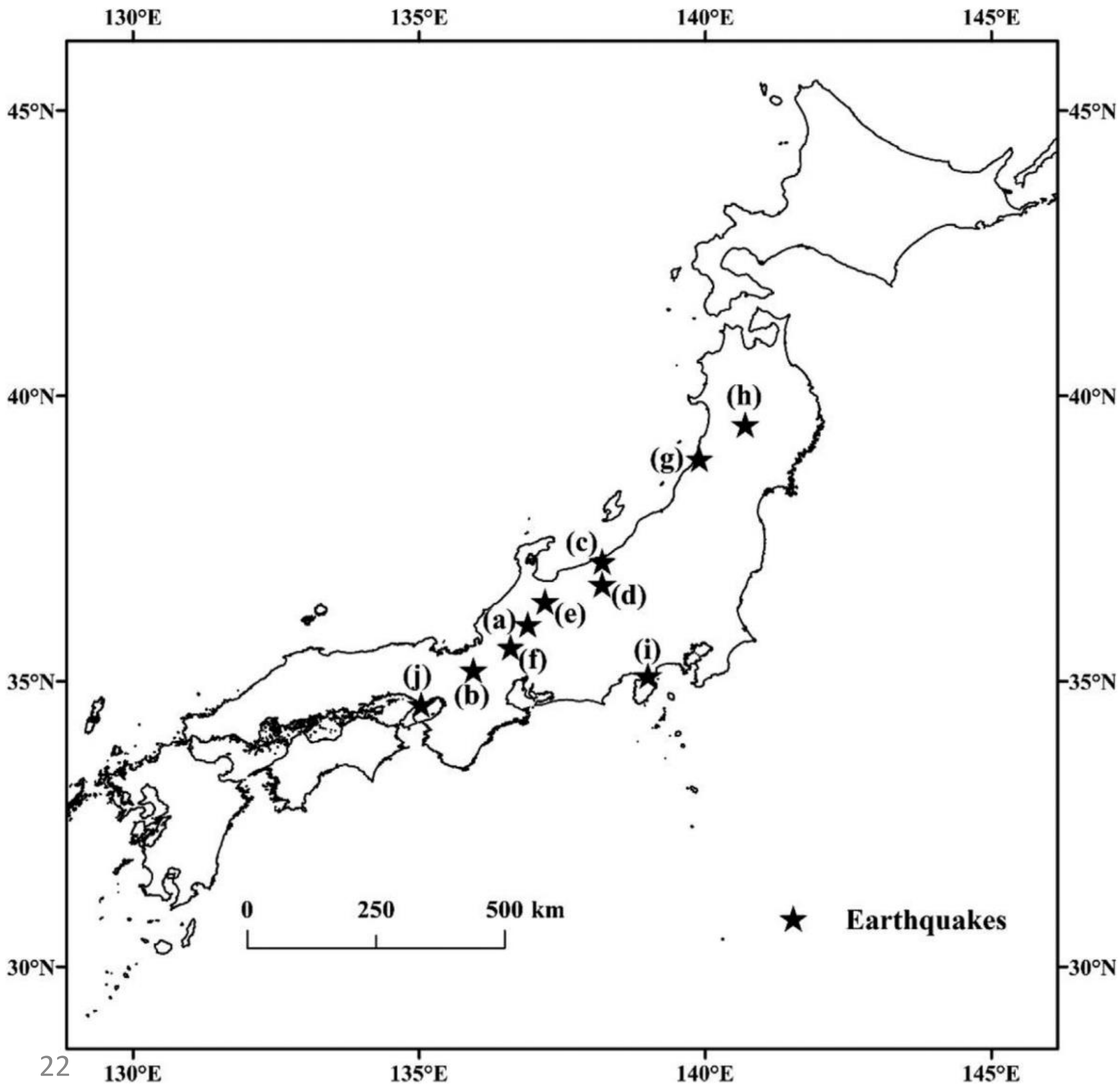




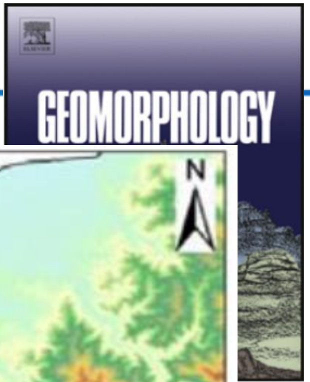
(内閣府HP)

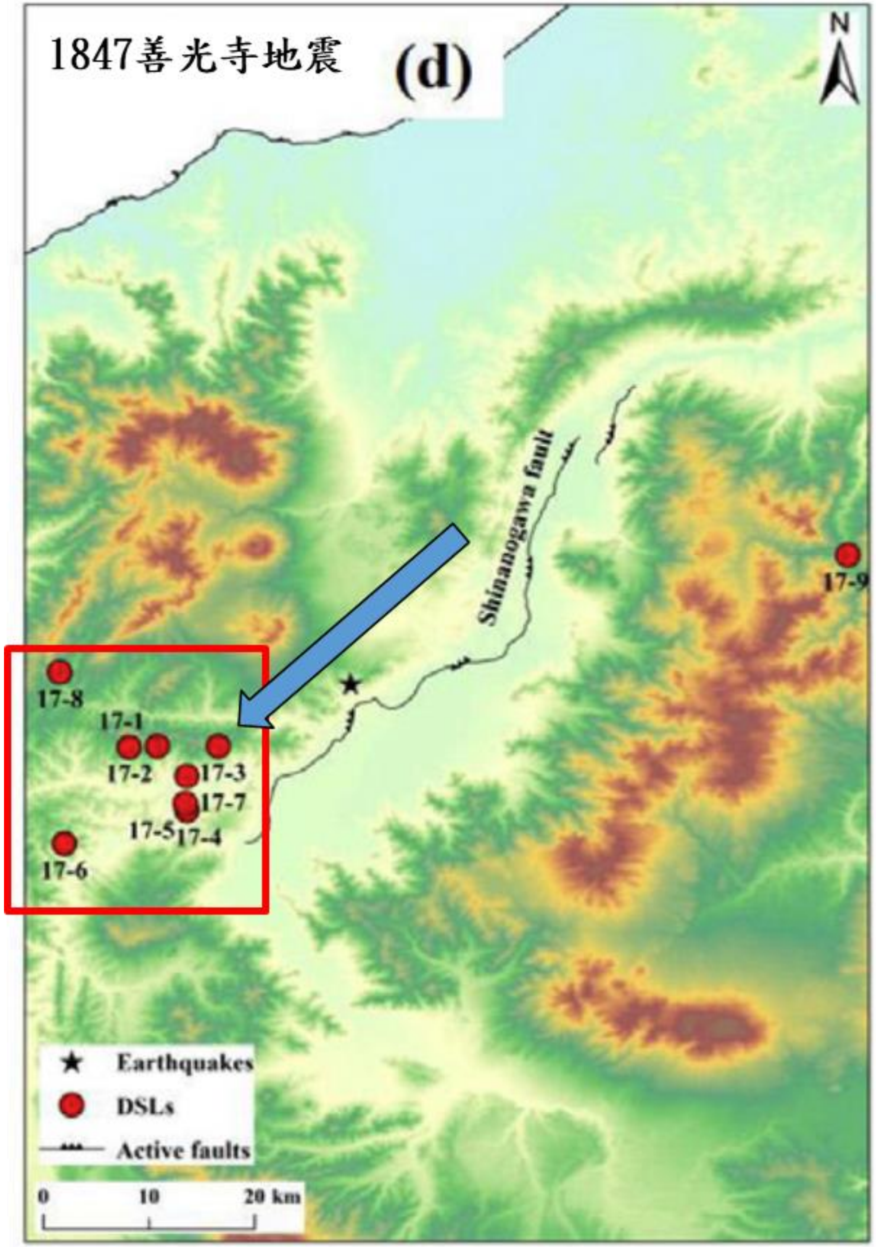


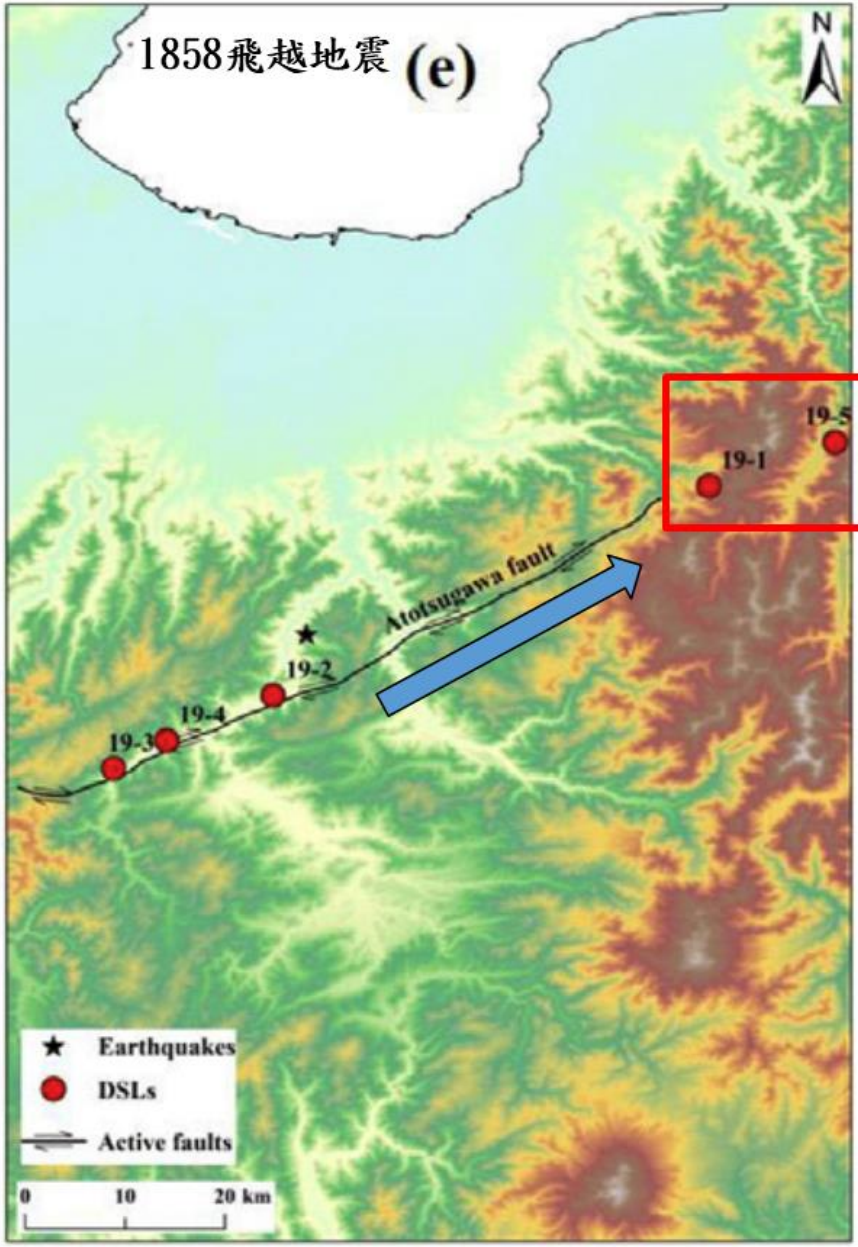
大地震と深層崩壊（1586－1995）

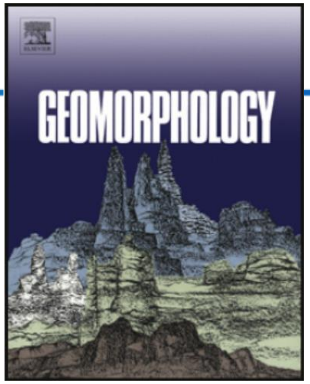


(a) 1586 天正地震
(b) 1662 近江若狭地震
(c) 1751 高田地震
(d) 1874 善光寺地震
(e) 1858 飛越地震
(f) 1891 濃尾地震
(g) 1894 庄内地震
(h) 1896 陸羽地震
(i) 1930 北伊豆地震
(j) 1995 兵庫県南部地震

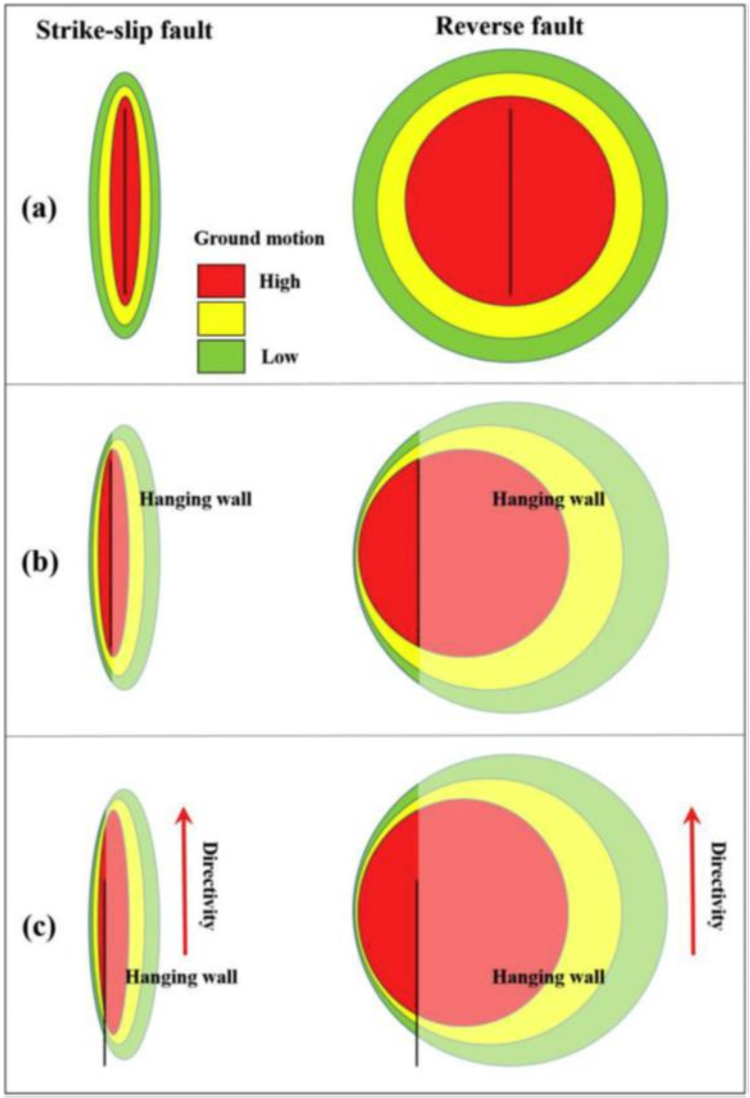

GEOMORPHOLOGY


1847善光寺地震
(d)
N
Shinanogawa fault
17-9
17-8
17-1
17-2
17-3
17-7
17-5
17-4
17-6
Earthquakes
DSLs
Active faults
0
10
20 km


1858飛越地震
(e)
N
19-5
19-1
Atotsugawa fault
19-2
19-4
19-3
Earthquakes
DSLs
Active faults
0
10
20 km

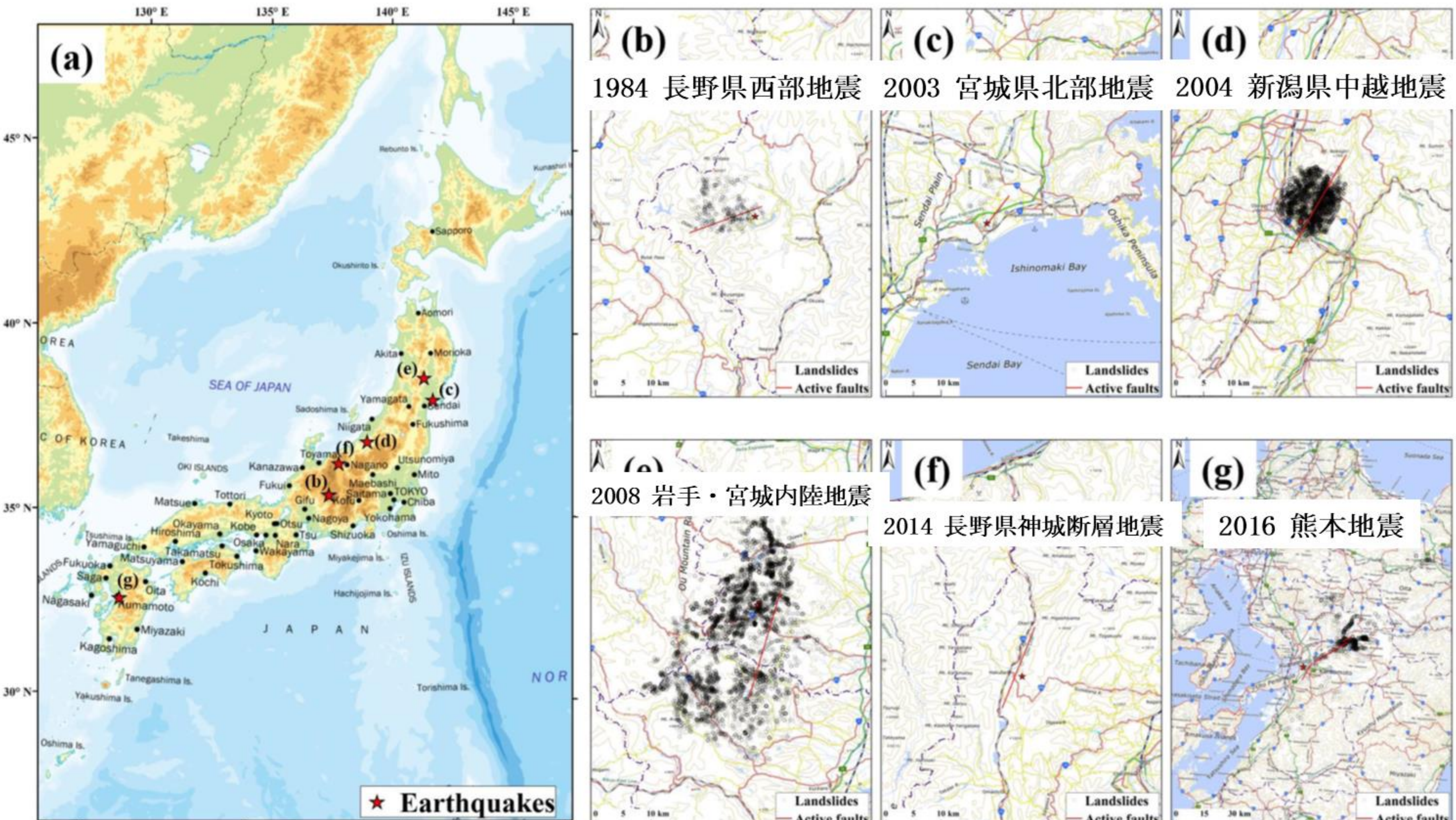


斜面崩壊分布を影響する要素

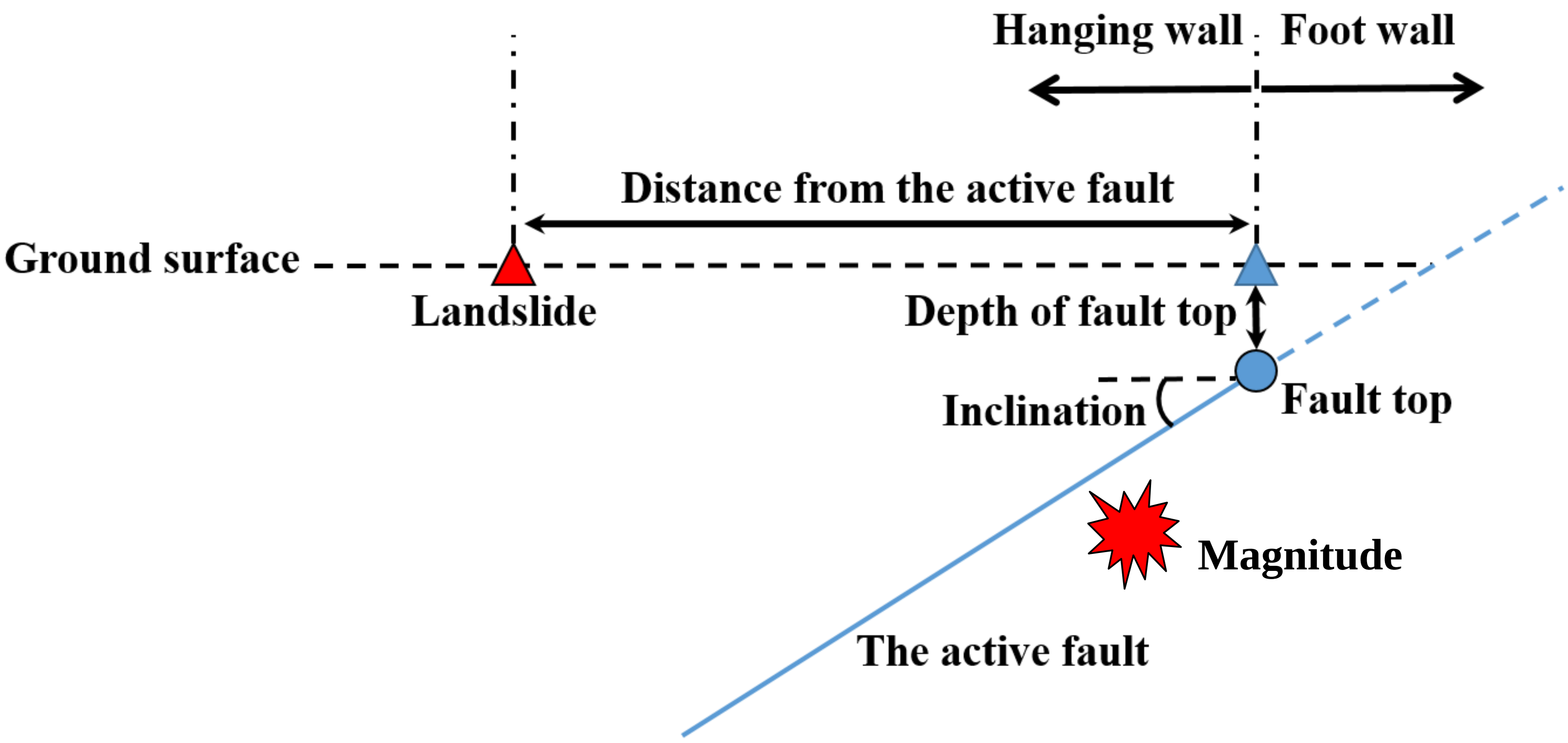


- 活断層のタイプ
- 上盤/下盤
- 地震波の指向性

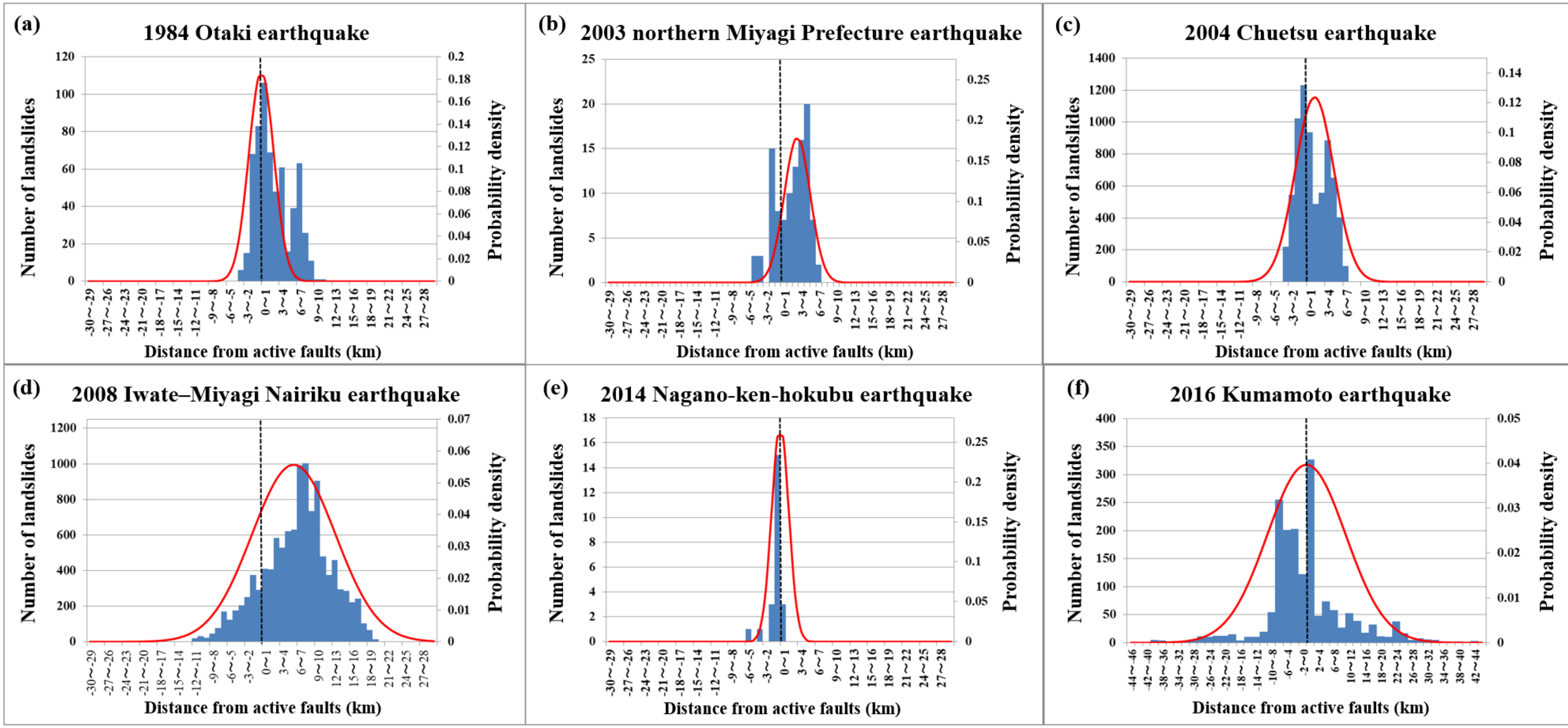
近年の事例


(a)
Earthquakes
SEA OF JAPAN
(b)
1984 長野県西部地震
(c)
2003 宮城県北部地震
(d)
2004 新潟県中越地震
(e)
2008 岩手・宮城内陸地震
(f)
2014 長野県神城断層地震
(g)
2016 熊本地震
Landslides
Active faults

地震と活断層のパラメータ



斜面崩壊分布（正規分布）



Normal distribution

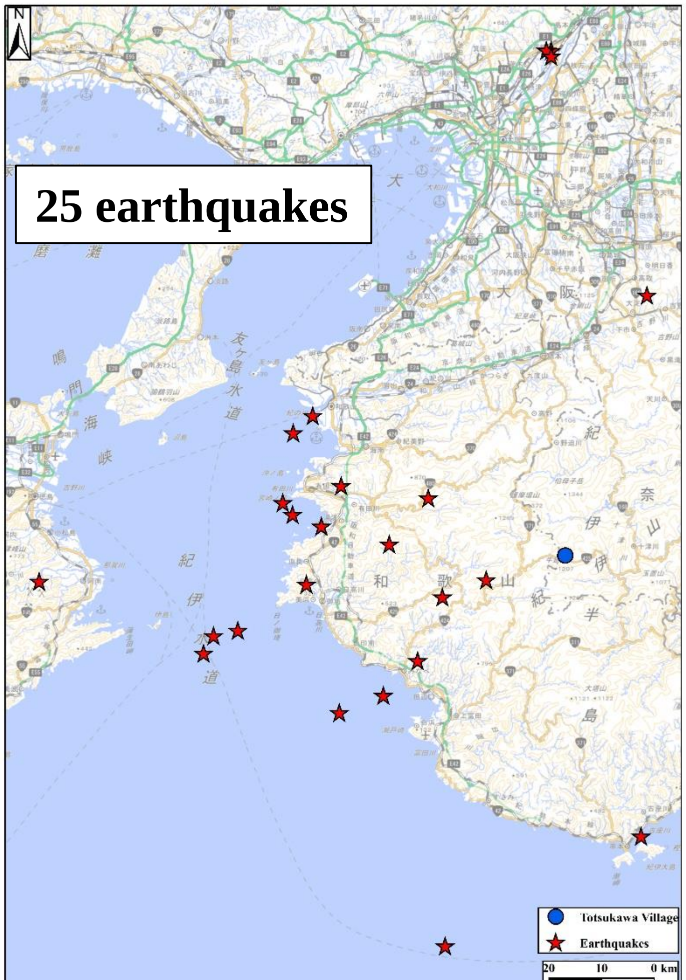
$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

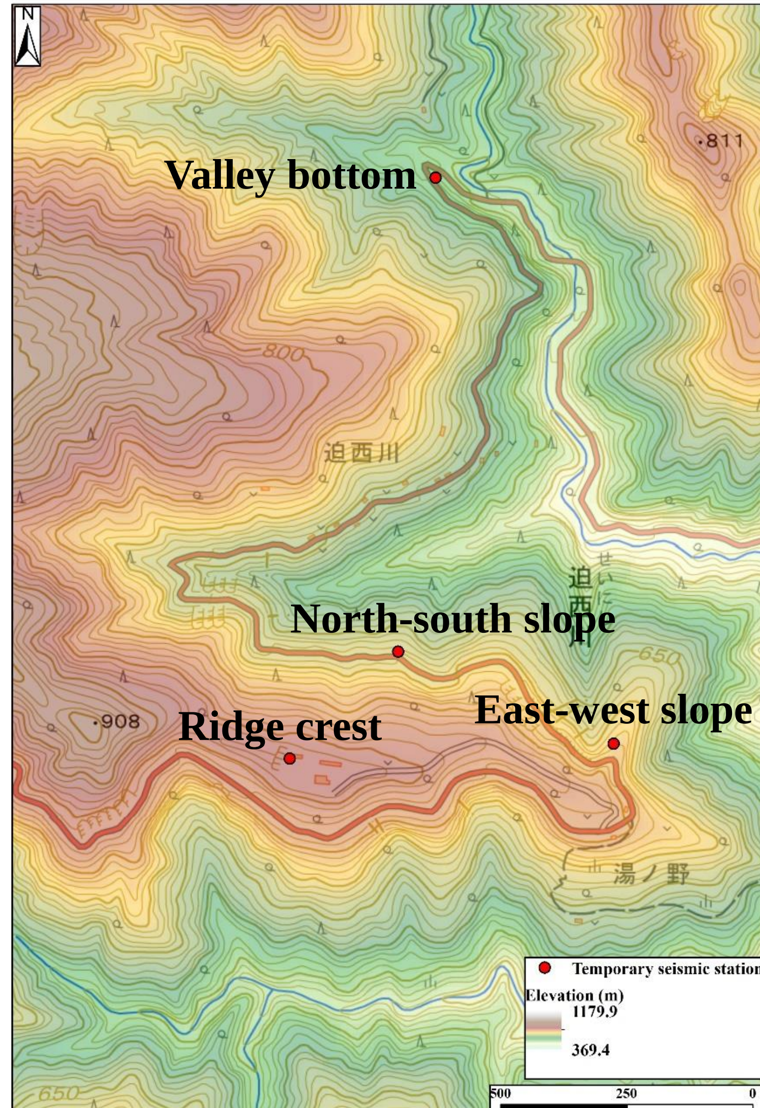
$$\begin{cases} \mu = -0.188 \times I + 11.280 \ (I \leq 60°) \\ \mu = 0 \ (I > 60°) \end{cases}$$

$$\sigma = 0.472 \times D + 1.701 \times 10^{-15} \times E + 0.202$$

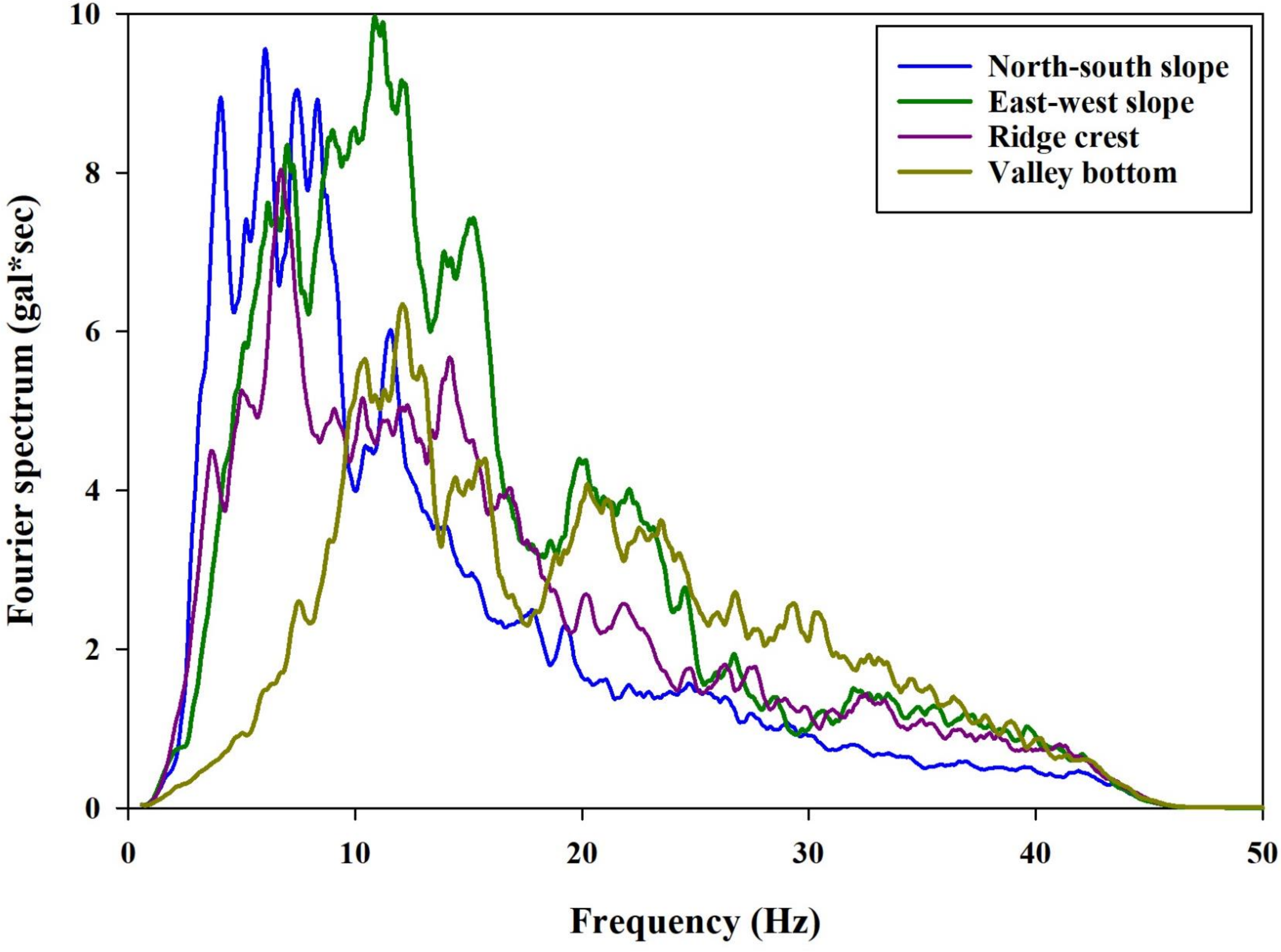
地震動臨時観測

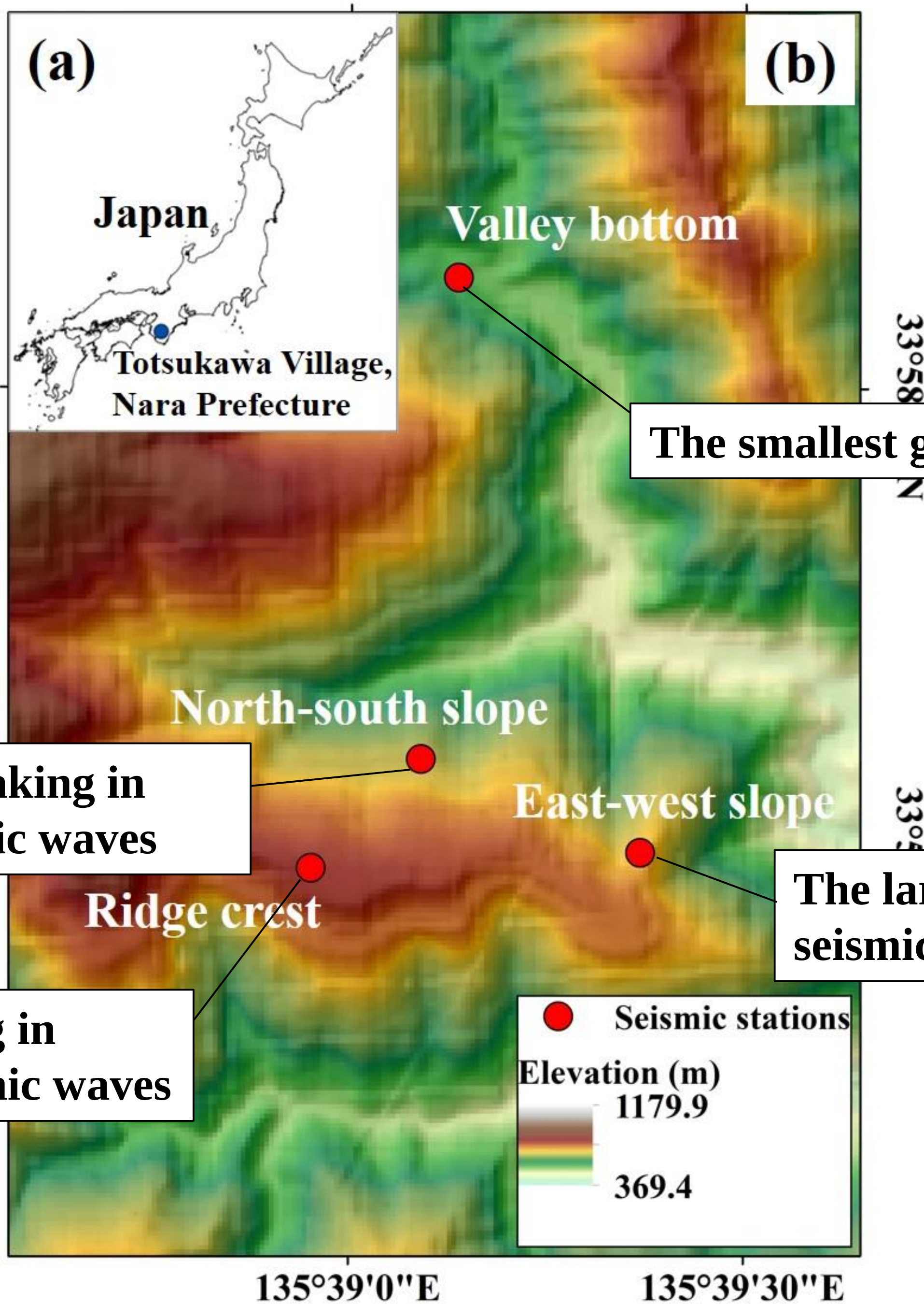
November 15, 2017 ー December 10, 2019





各地点においての振幅の中央値





The smallest ground shaking

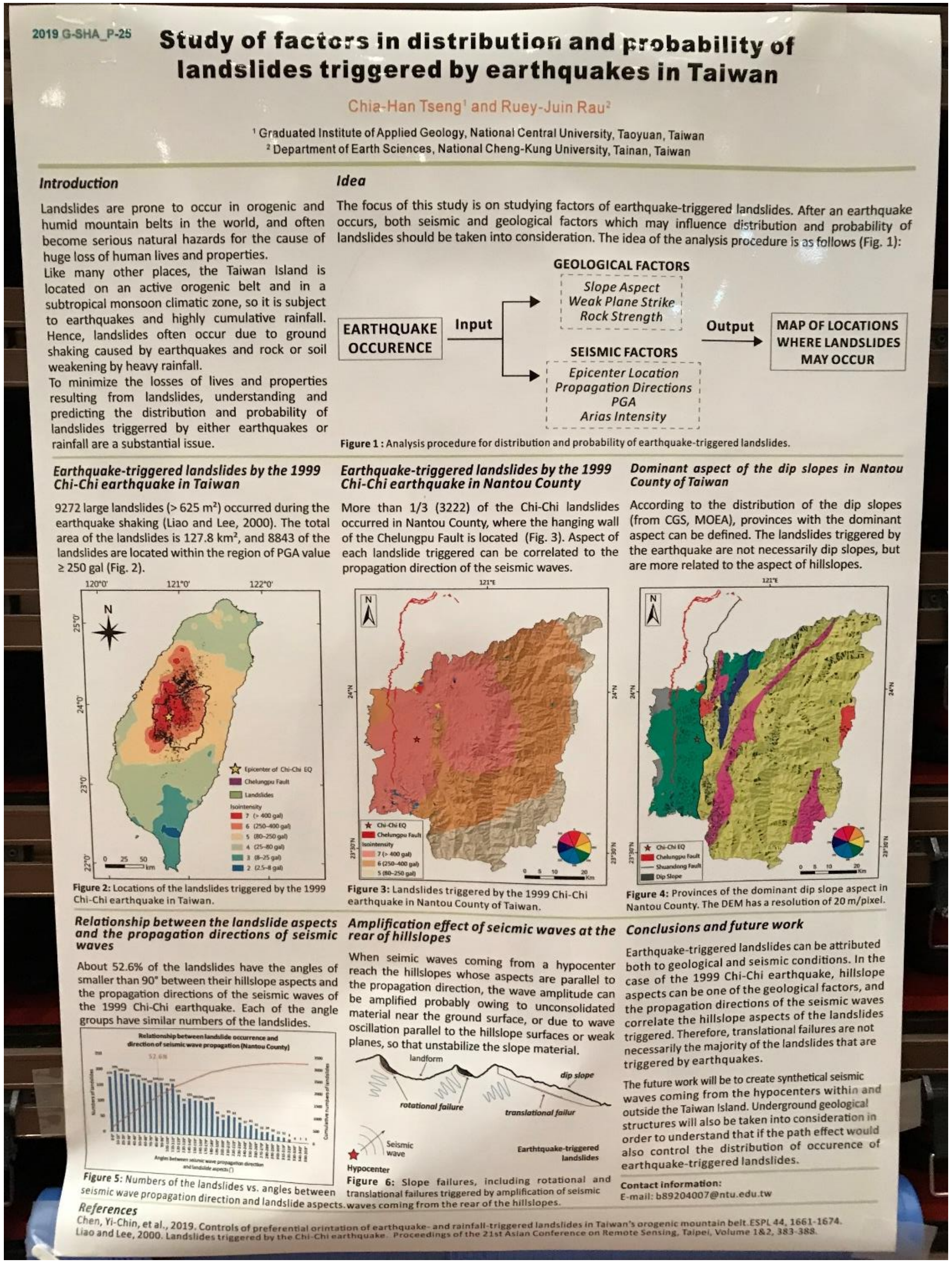
The largest ground shaking in lower-frequency seismic waves

The largest ground shaking in seismic waves with >10 Hz

Large ground shaking in lower-frequency seismic waves

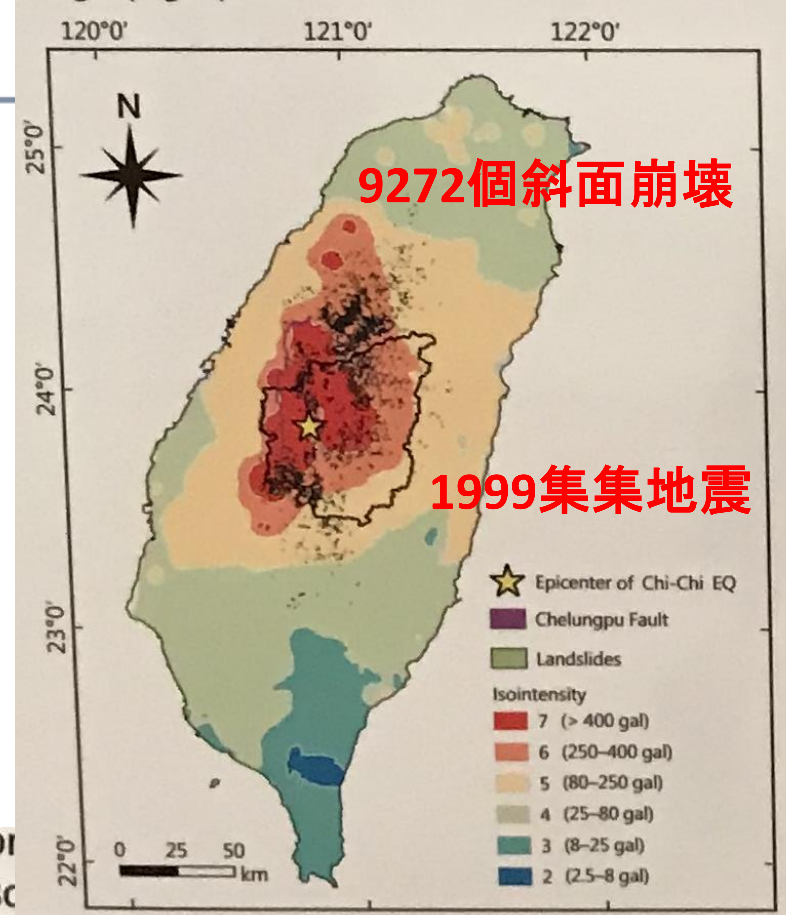
台湾の地震による斜面崩壊の分布・確率の要因に関する研究

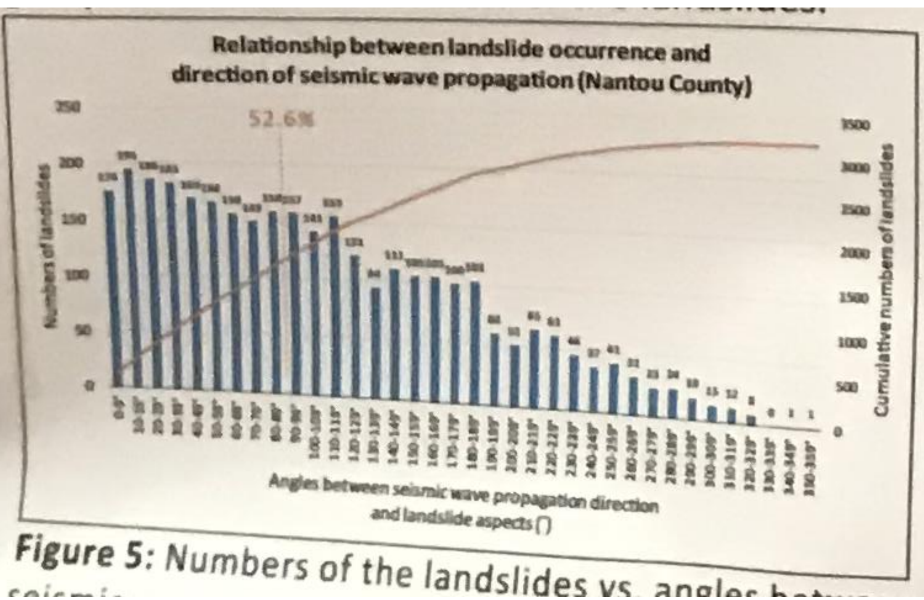
2019 Japan-New Zealand-Taiwan Seismic Hazard Workshop@洞爺湖

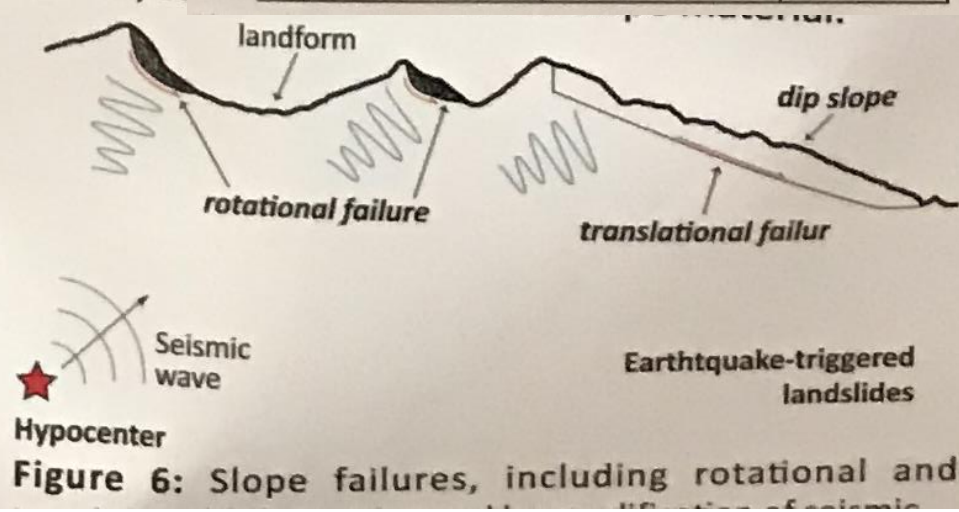


地震波方向と斜面方位の夾角

- 半数以上の崩壊は斜面方位と地震波方向の夾角<90°







まとめ

- **素因**
  - 地形 – 険しい山地地形
  - 地質 – 脆弱な地質、
    テフラは台湾にほぼ分布していない
- **誘因**
  - 降雨 – 台湾：2009年台風8号3000㎜
    – 日本：2012年台風12号2000㎜
  - 地震 – 日本がより頻繁