Topic A: Risk Reduction and Mitigation of Sediment-related Disaster

(1) Sediment-related disaster in Japan
– The features, tendency and actual situation –
(2) Sediment Disaster Countermeasures
– Structural Measures and Monitoring for the Preservation of National Land –
(3) Non-structural Measures
– Designation of Sediment Disaster Alert Areas, Soil Precipitation Index, Warning and Evacuation systems –

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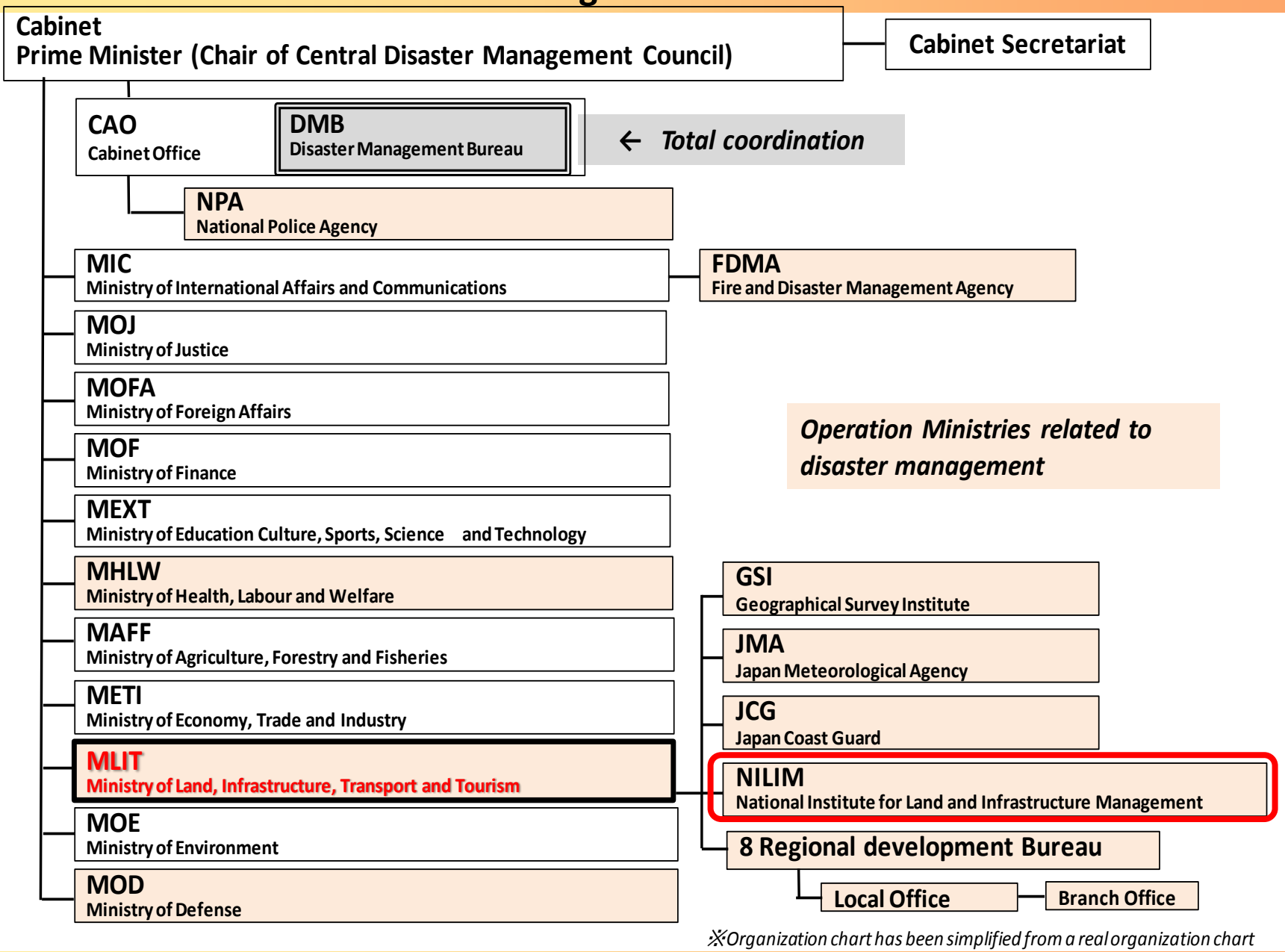
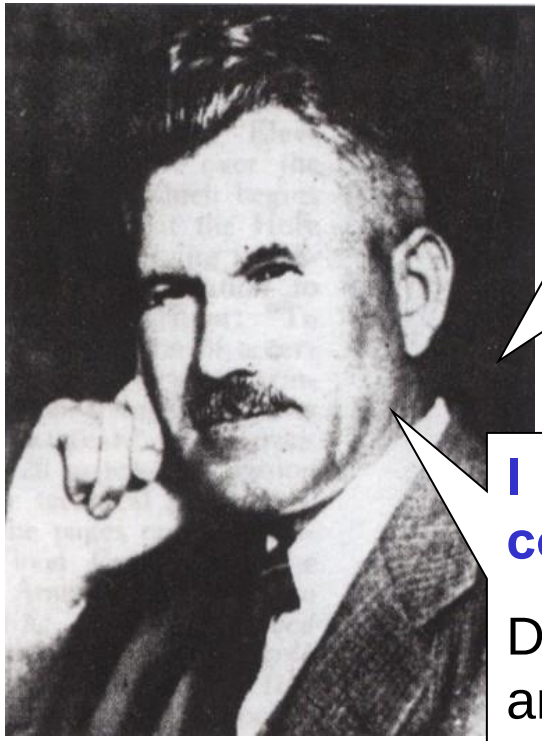
Disaster Management System in central government in case of Huge Disasters



※Organization chart has been simplified from a real organization chart

“SABO” 砂防？



I propose that we shall call erosion-control technology “SABO”.

Proposal in question and answer session at the meeting of International Association of Hydrological Sciences in Brussels, Belgium. (1951)

I expect that Japan will be the world leader in torrent control works, or “Sabo”

Description in the report to Bureau of Economic Sciences and Natural Resources Division in GHQ. (1952)

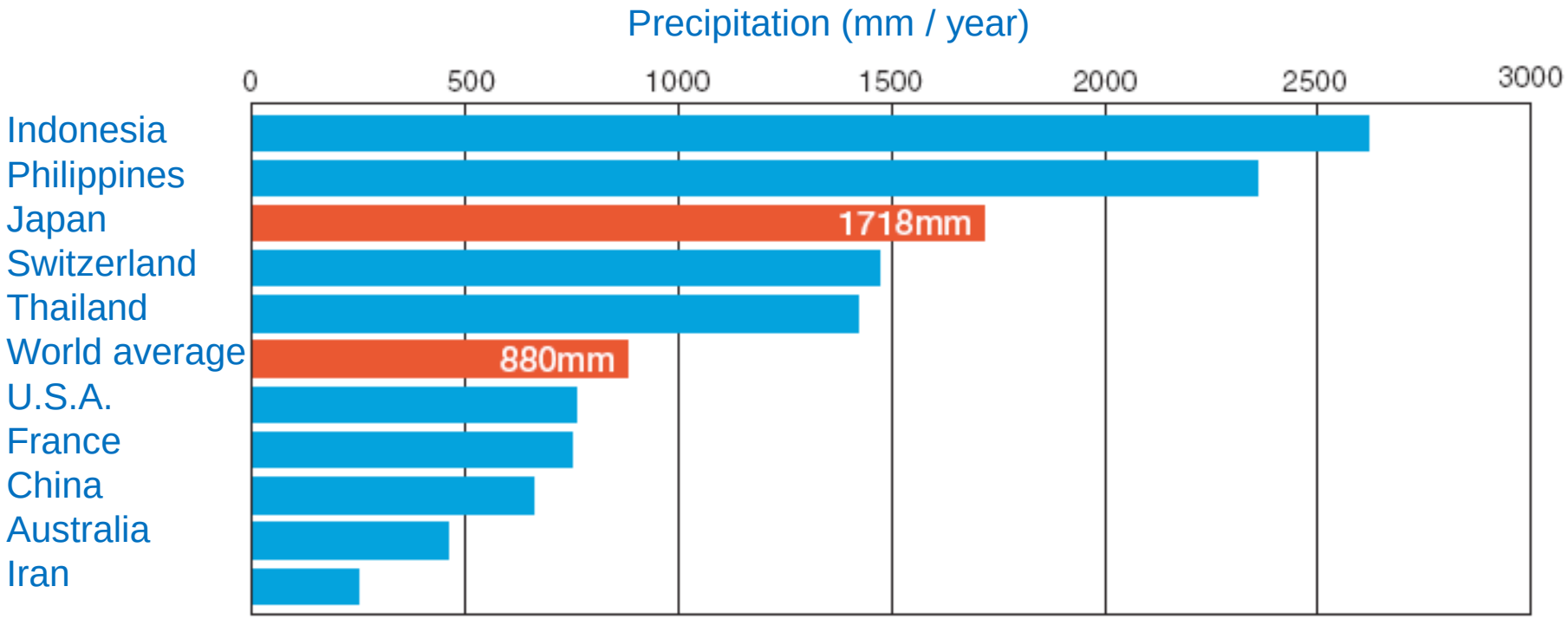
W.C.Lodermilk

U.S. Truman Presidential Technical Committee Chairman of the Supreme. He visited Japan for inspection of flood control projects in 1951.

SABO has become a global term

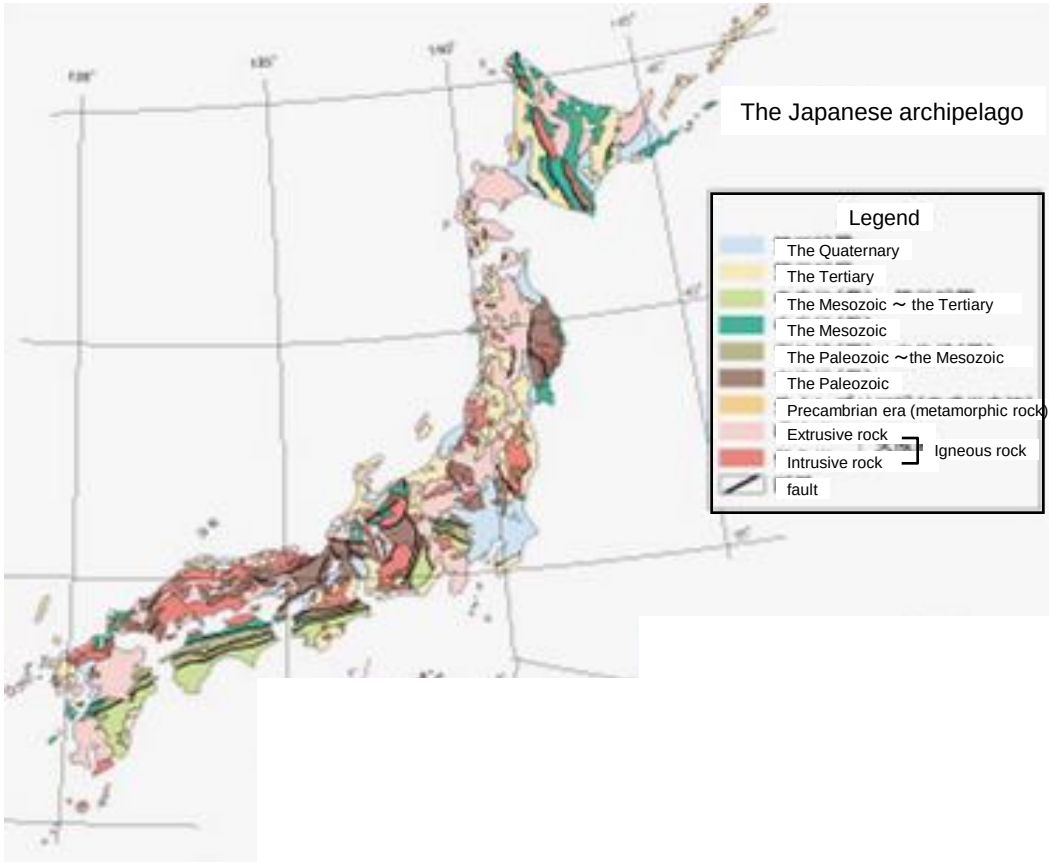
Why Do Dangerous Sediment-transport Phenomena Occur Frequently?

- Japanese precipitation is twice as much as the world average.

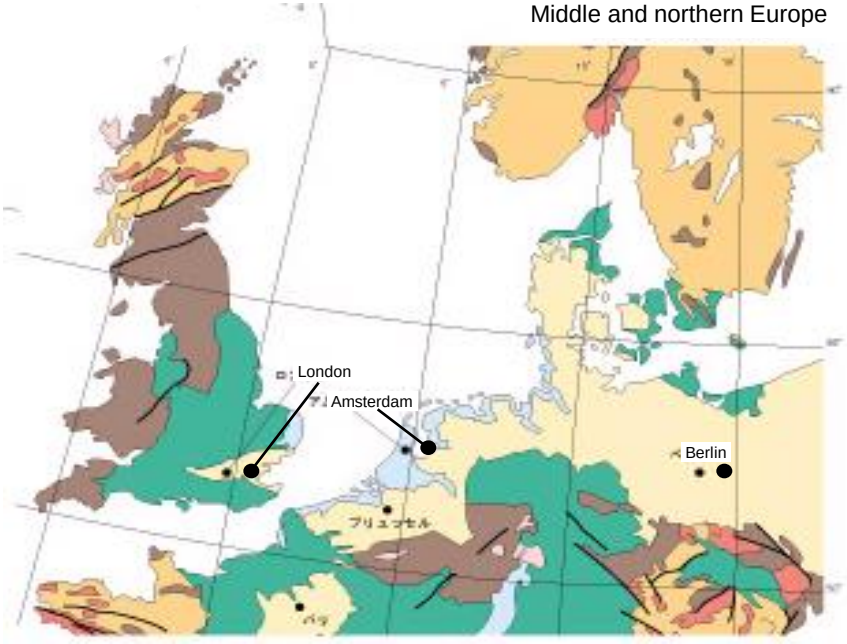


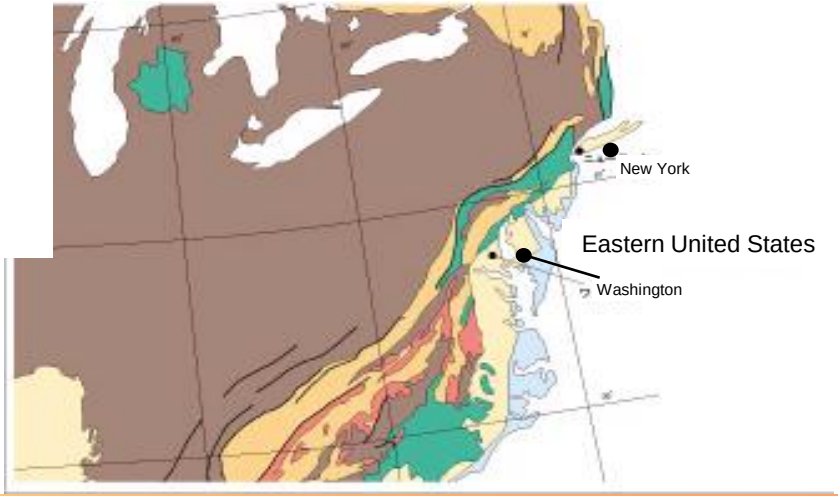
http://www.mlit.go.jp/river/pamphlet_jirei/bousai/saigai/kiroku/suigai/suigai_3-1-1.html

Complex geological formation and many faults



Middle and northern Europe





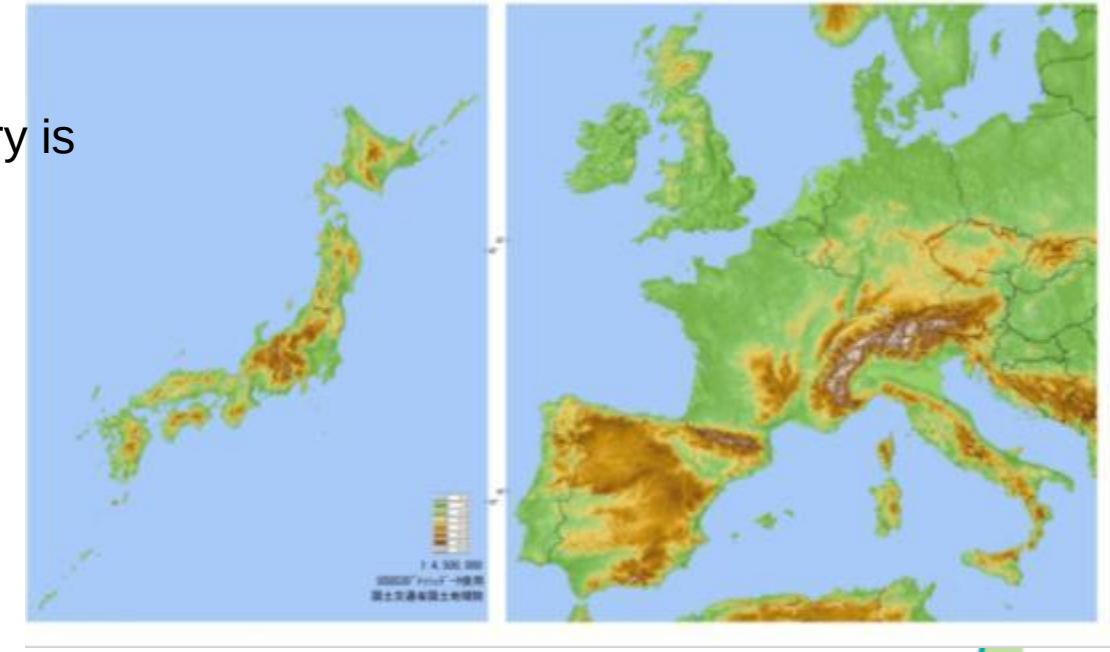
Source: "Geological Features and Geological Environment of the Japanese Archipelago: For the Management of Rich and Safe Land", Japan Geotechnical Consultants Association

The topography is very steep

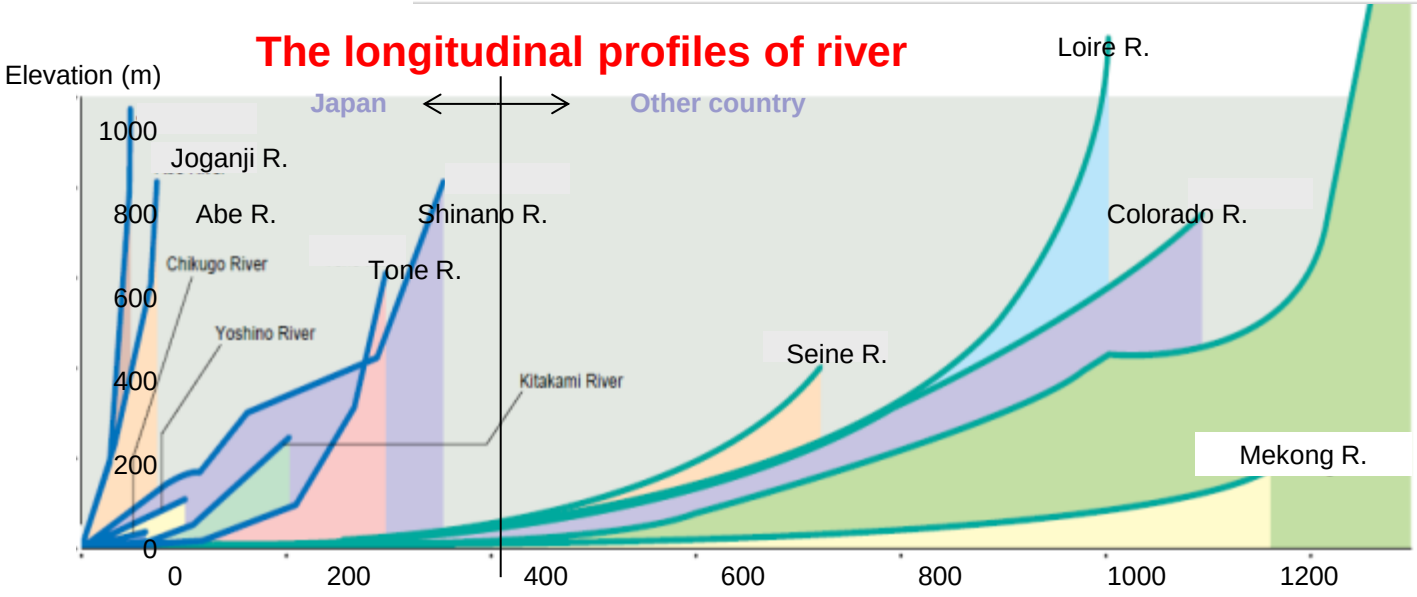
About 73% of the national territory is occupied by mountain land.

About 68% is covered by forest.

The rivers are short and rapid.



The longitudinal profiles of river



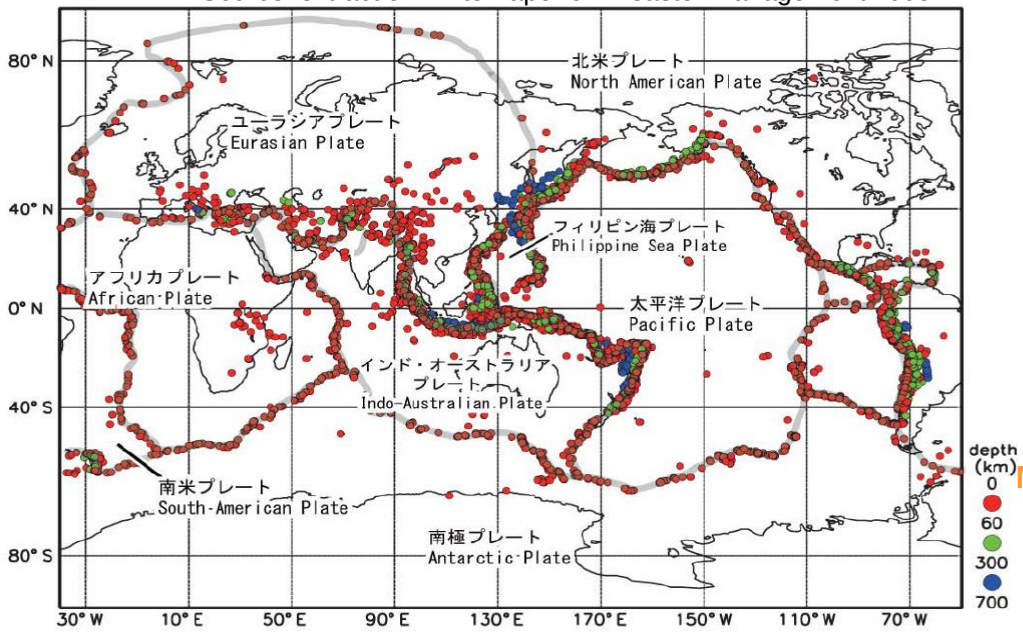
Why Does It Lead to Disaster?

- Small inhabitable land area → “Dangerous sediment-transport phenomenon” and “people’s livelihoods” tend to overlap.

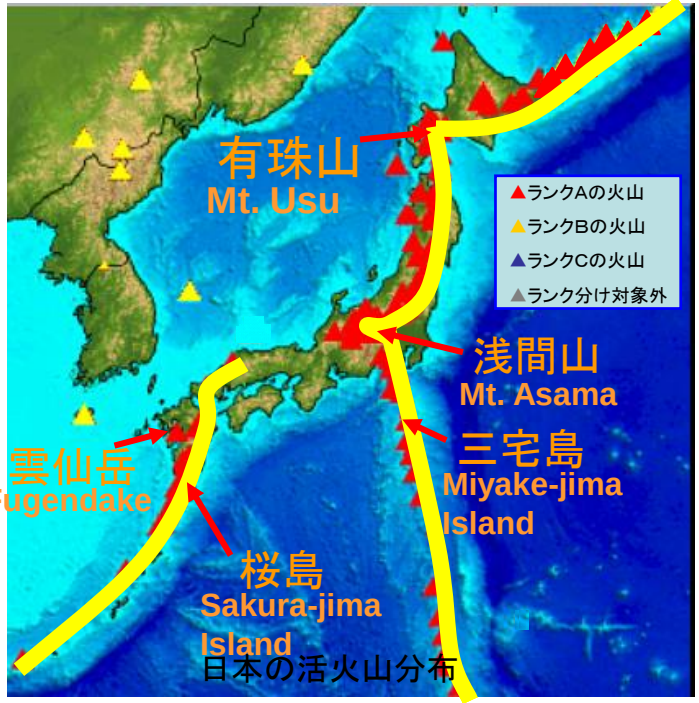
country	Area of country (10,000㎢)	Area of inhabitable land (10,000㎢)	Inhabitable land as a percentage of total land area (%)
Japan	**37.86**	**10.35**	**27.3**
UK	**24.38**	**20.63**	**84.6**
France	**54.79**	**39.72**	**72.5**
German	**35.67**	**23.79**	**66.7**

Hypocenter distribution and Plates in the world

Source: extract of White Paper on Disaster Management 2008



Active volcano distribution in Japan



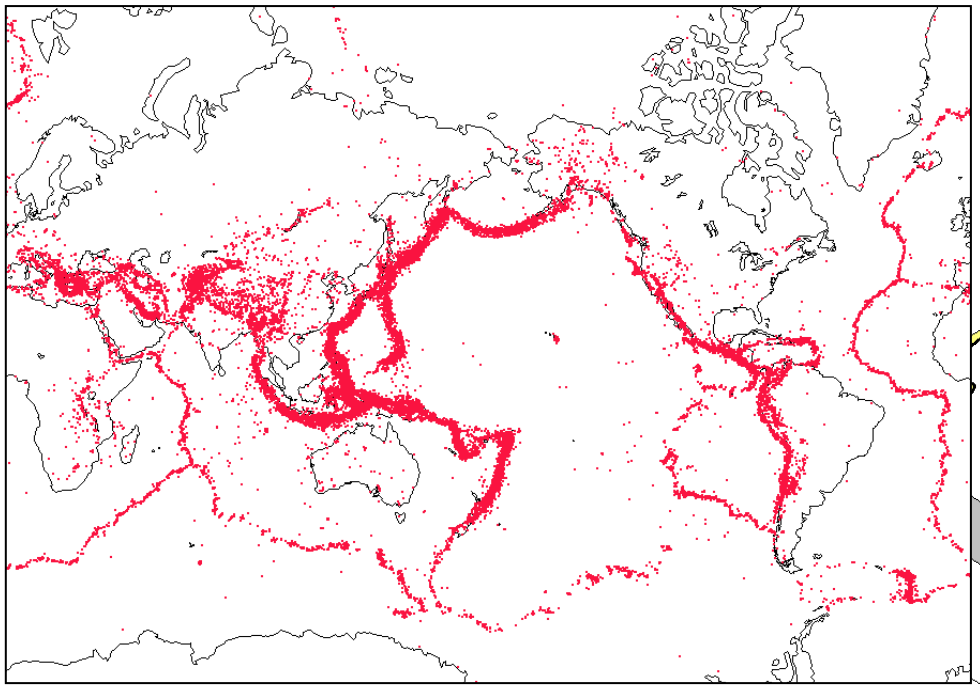
(Note)1998-2007, magnitude 5 or greater,
Source: Formulated by JMA based on the epicenter data of the United States Geological Survey

Japanese islands vulnerable to damages by earthquakes and volcanic eruptions

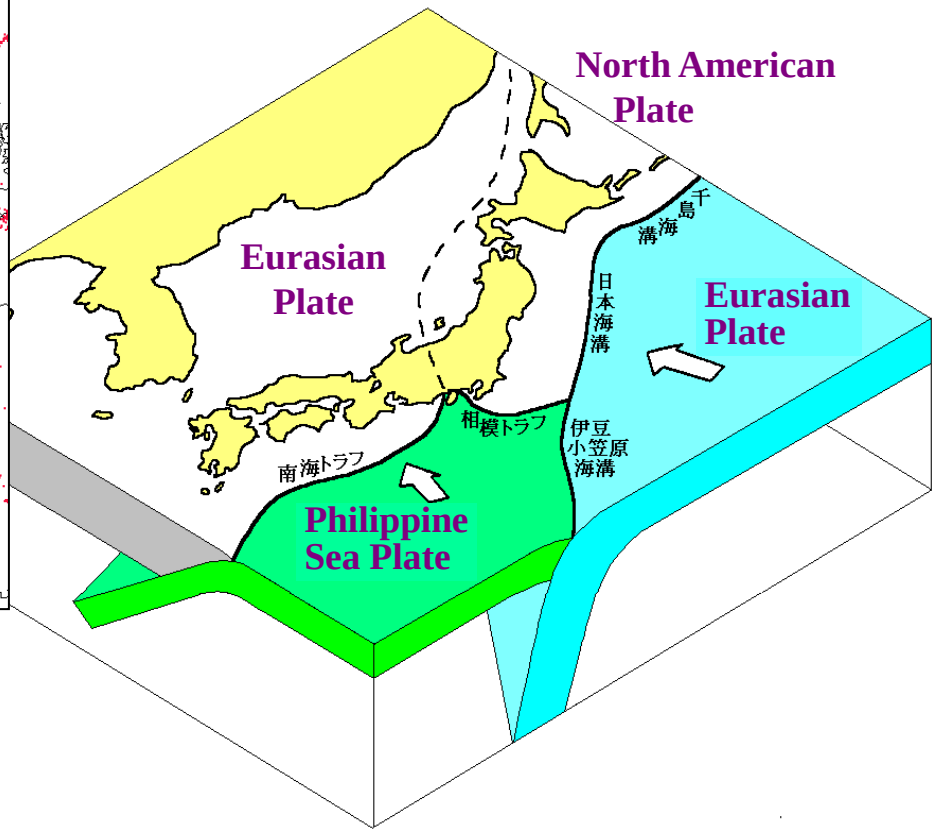
Japan is one of the most earthquake-prone nations in the world

Japan lies at the nexus of the Philippine, Eurasian, and Pacific plates.

In an area that makes up only 0.25% of the world, more than 20% of the world's earthquakes of magnitude of 6 or above occur in Japan.

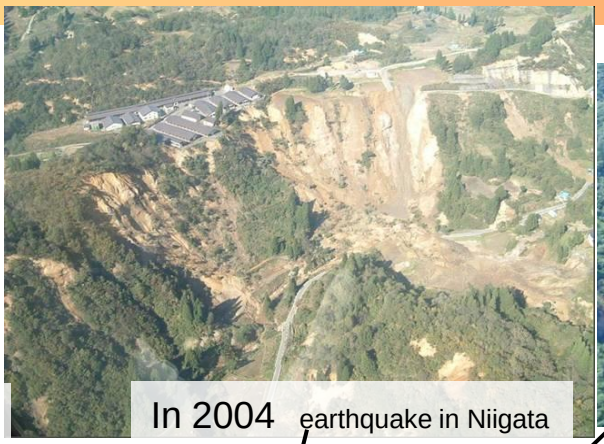


the locations of earthquakes of magnitude 4 or greater that occurred around the world from 1990 to 2000.



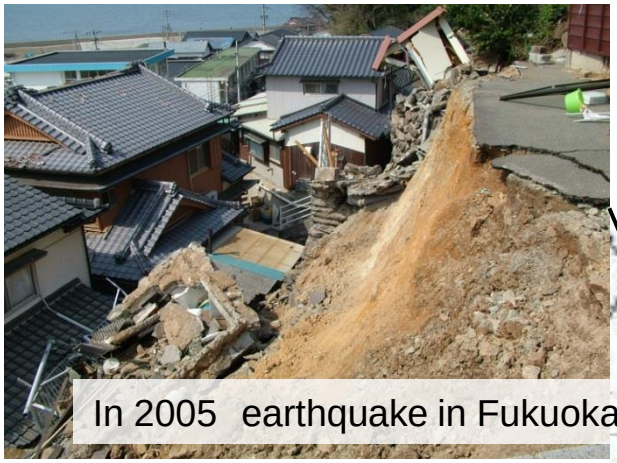
Location of the earthquakes

In 1995 earthquake in southern Hyogo



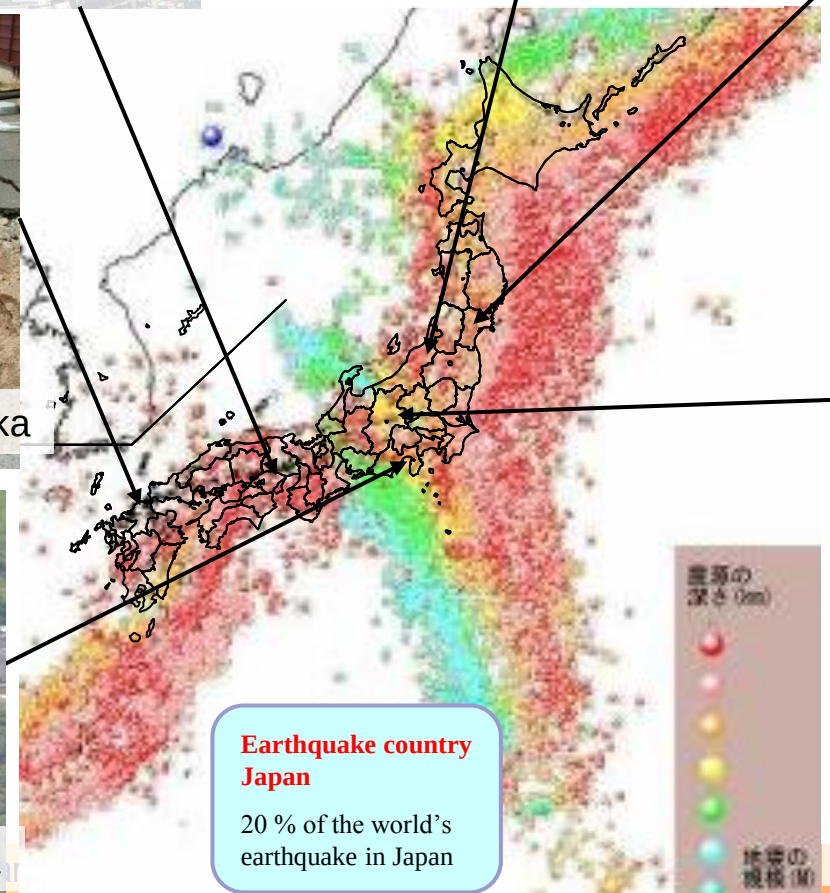
In 2004 earthquake in Niigata

In 2008 earthquake in Iwate・Miyagi



In 2005 earthquake in Fukuoka

In 2009 earthquake in Shizuoka



Earthquake country Japan

20 % of the world's earthquake in Japan

In 1984 earthquake in western Nagano

Volcanic Activity

Mount Unzen-Fugen **in 1990**

Great number of mud flood/flow occur
Dead and missing rise to 43.

Mount Usu **in March 2000**

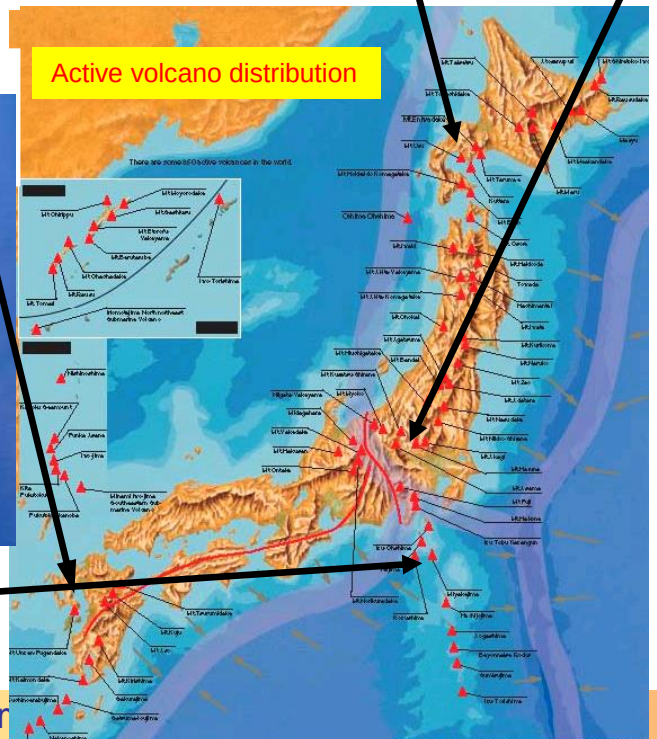
No casualties due to quick evacuation.

Mount Asama **In September 2004**

Mid-scale eruption after an absence of 21 years.

Miyake Island **In July 2000**

All of the Island's residents, 3,900 people, evacuated.

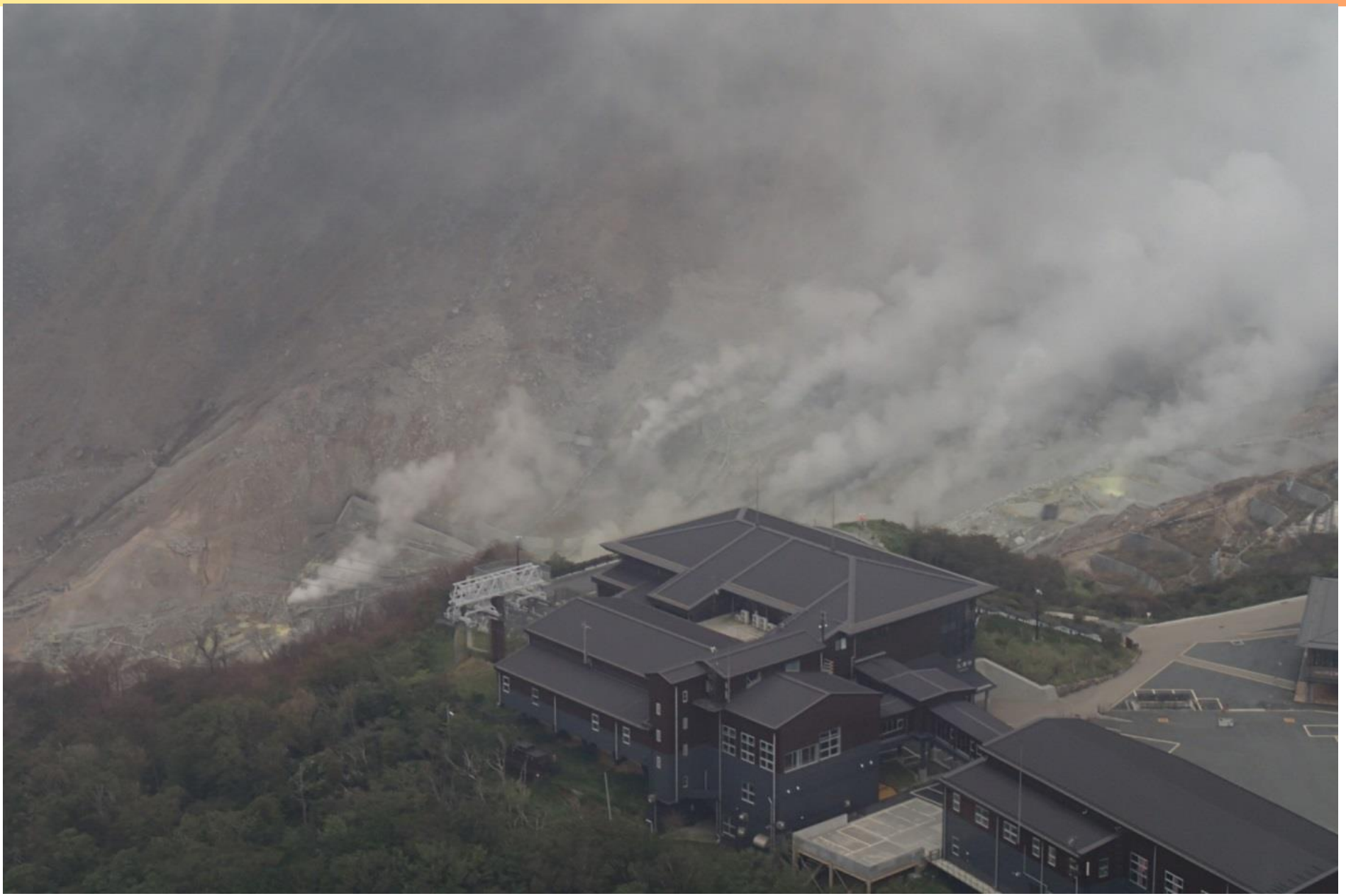


Mount Kirishima (Shinmoedake) **In January 2011**

Mid-scale eruption after an absence of 54 years.

Volcano Hakone

Volcano Hakone



Volcano Hakone

Volcano Hakone

Volcano Kuchinoerabu Island

29 MAY

Ash fall by Volcano Aso eruption on 14 SEP 2015

Ash fall by Volcano Aso eruption on 14 SEP 2015

Ash fall by Volcano Aso eruption on 14 SEP 2015

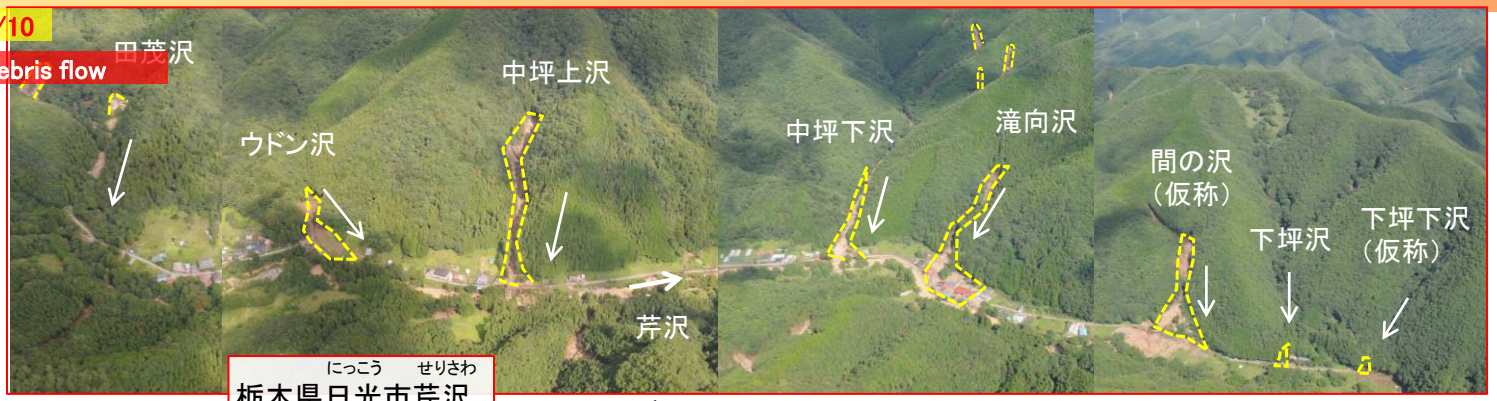
Sediment Disaster in Japan in 2015

As of 30 SEP
The number of Occurrence
737

Debris flow : 133
landslide : 40
Slope failure : 564

Damage
Dead : 2
Injured : 4

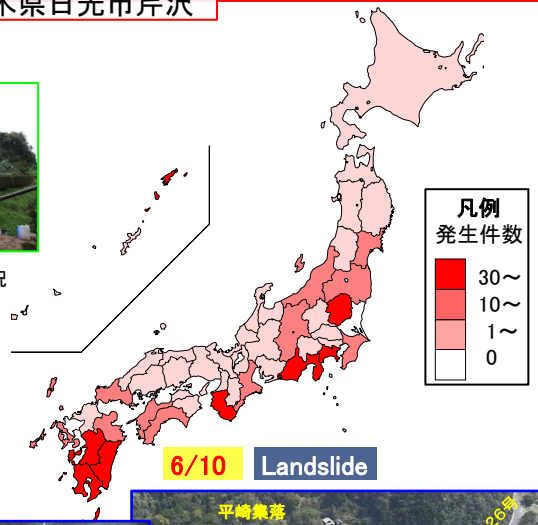
9/10
Debris flow



にっこう　せりさわ
栃木県日光市芹沢

9/10 Slope failure
かぬまし　ひよしちょう
栃木県鹿沼市日吉町

被害状況



たるみず　ふたがわふかみなと
鹿児島県垂水市二川深港

6/24ほか
土石流等

被害状況

6/14 Slope failure
みなみしんまち
鹿児島県鹿児島市南新町

被害状況

被害状況

6/10 Landslide

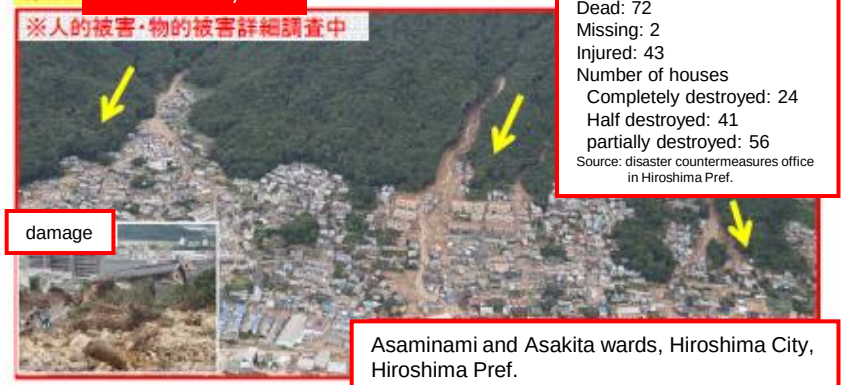
ぼうのつ
鹿児島県南さつま市坊津

4/15頃 Landslide
もがみぐん　とざわむら
山形県最上郡戸沢村

Sediment Disaster in Japan in 2014

※Quick estimation
As of Aug. 30 10:00
Number of occurrence
of sediment disasters:
889
(Debris flow, etc.: 258
Landslide : 55
Slope failure: 576)
【Damages】
Human damage
Dead: 77
Missing: 2
Injured: 51
House damage
Completely destroyed: 45
Half destroyed: 53
Partially destroyed: 129

8/20 Debris flow, etc.



damage

Dead: 72
Missing: 2
Injured: 43
Number of houses
Completely destroyed: 24
Half destroyed: 41
partially destroyed: 56
Source: disaster countermeasures office in Hiroshima Pref.

Asaminami and Asakita wards, Hiroshima City, Hiroshima Pref.

8/17 Debris flow, etc.

Dead: 1
Injured: 1
Number of houses
Completely destroyed: 1

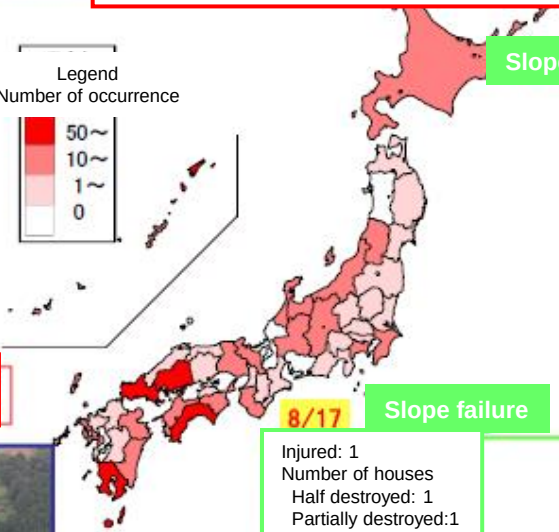
Ichijima Town, Tamba City, Hyogo Pref.

7/9 Debris flow, etc.

Dead: 1
Injured: 3
Number of houses
Completely destroyed: 10
partially destroyed: 3

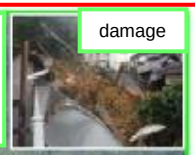
damage

NagisoTown, Kiso County, Nagano Pref.



8/6 Slope failure

Dead: 1
Number of houses
Completely destroyed: 1
Half destroyed: 1
Partially destroyed:1



damage

Shinminato Town, Iwakuni City, Yamaguchi Pref.

8/3 Landslide

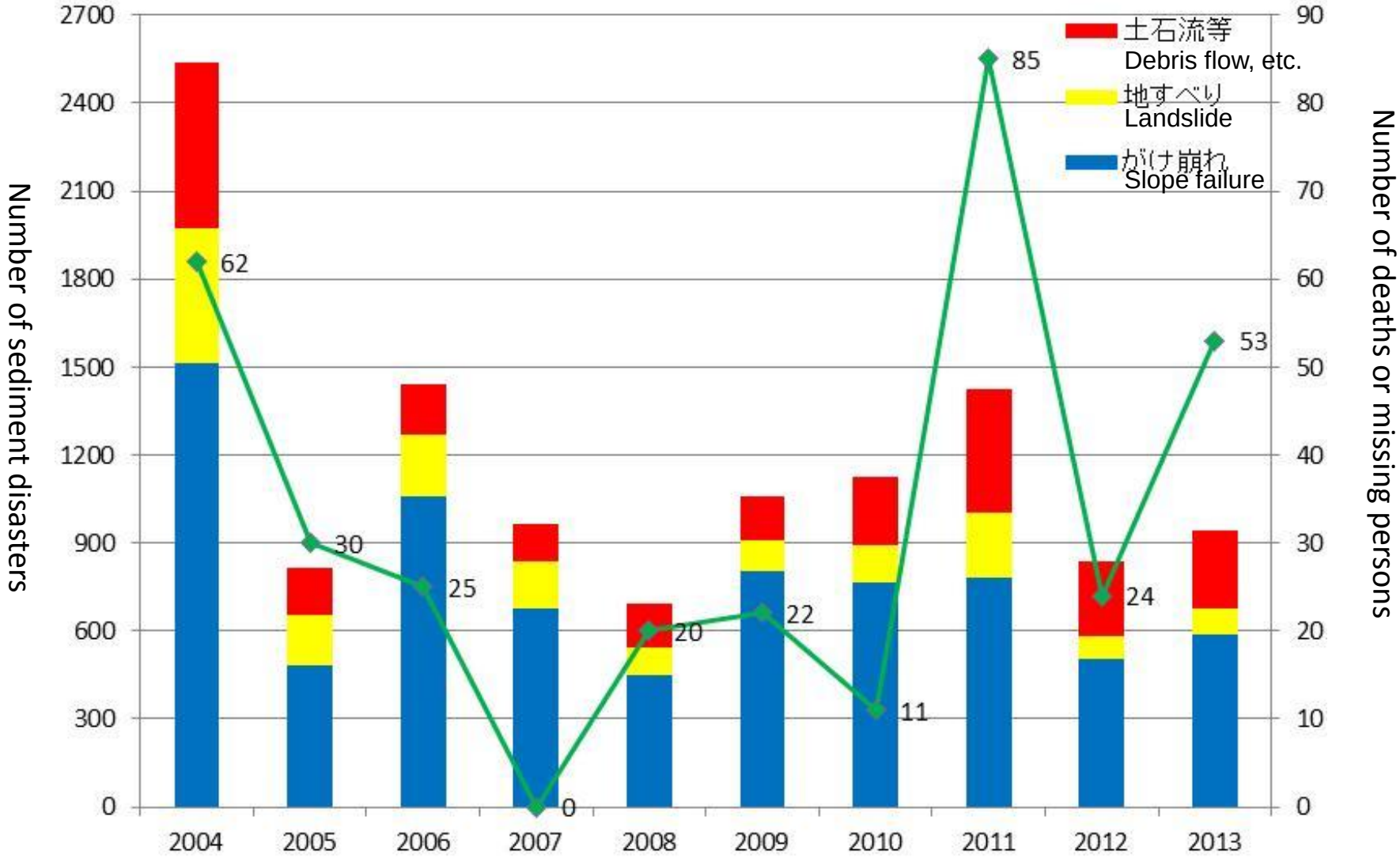
Kagamimatobuchi, Kochi City, Kochi Pref.

8/17 Slope failure

Injured: 1
Number of houses
Half destroyed: 1
Partially destroyed:1

SeikaTown, Fukuchiyama City, Kyoto Pref.

2004～2013 Number of sediment disasters, deaths or missing persons



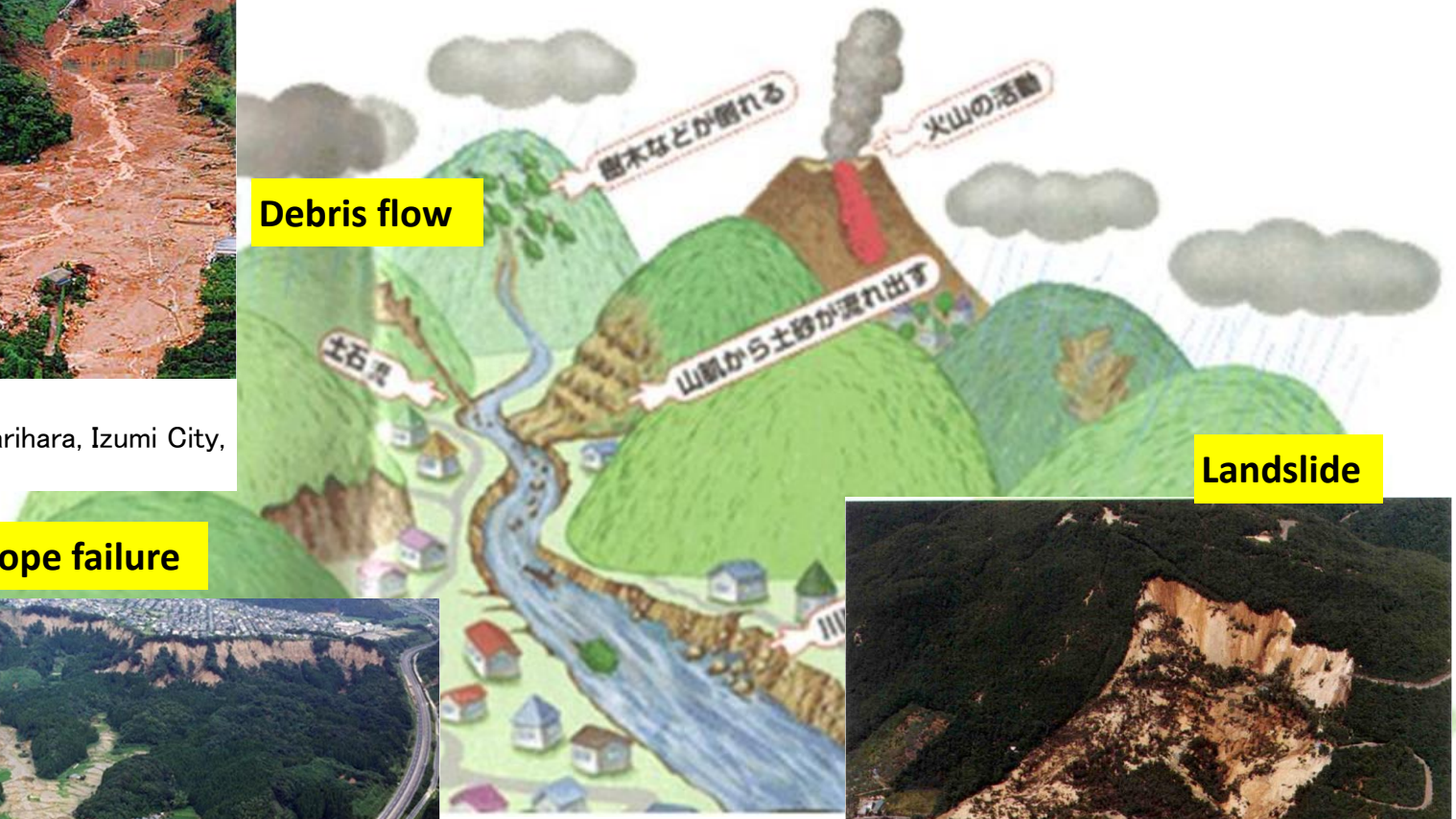
Note: (1) The graph above was created based on the press release "Number of Sediment Disasters in Japan from 2004 to 2013," Sabo Department, MLIT.

(2) The figures for 2013 are as of December 31.

Types of sediment disasters

Jul. 10, 1997
Debris flow in Harihara, Izumi City, Kagoshima Pref.

Debris flow

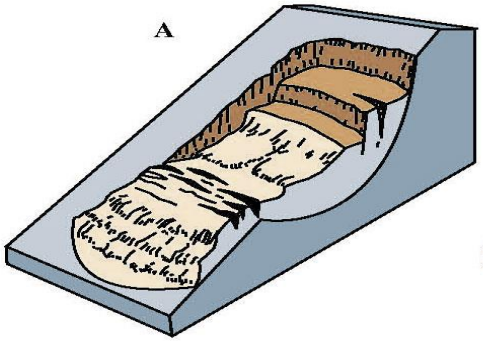


Slope failure

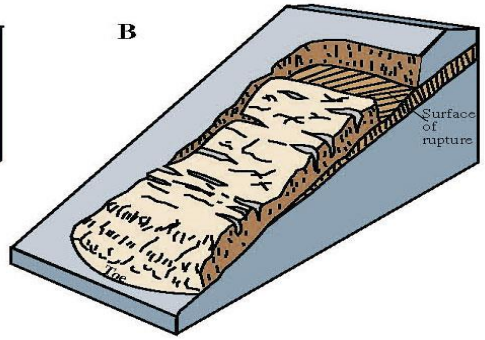
Aug. 2, 1993
Slope failure in Aira town, Kagoshima Pref.

Landslide

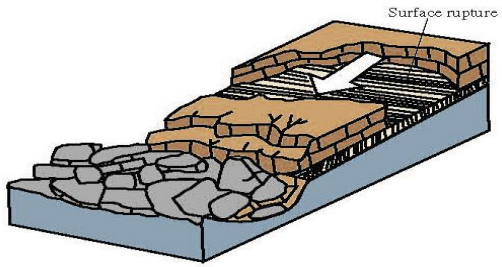
Jul. 26, 1985
Landslide around Nagano City, Nagano Pref.



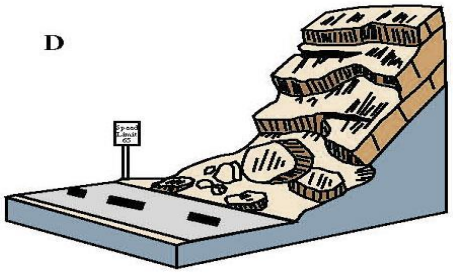
Rotational landslide



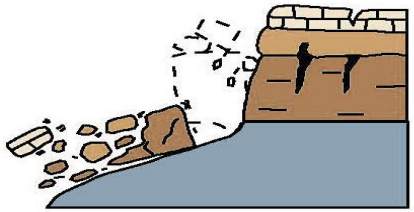
Translational landslide



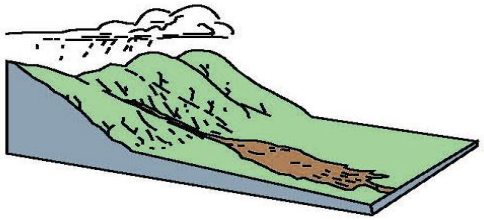
Block slide



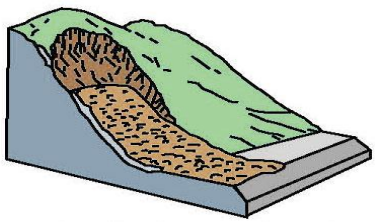
Rockfall



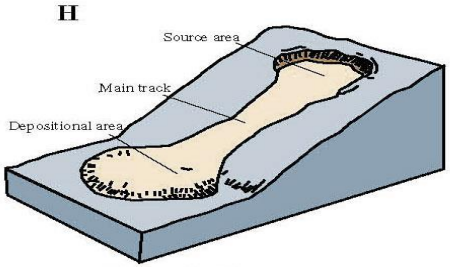
Topple



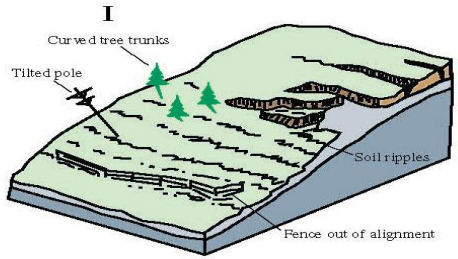
Debris flow



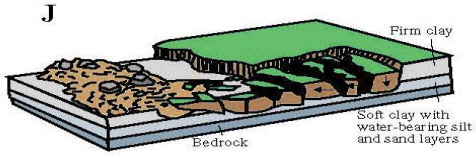
Debris avalanche



Earthflow



Creep



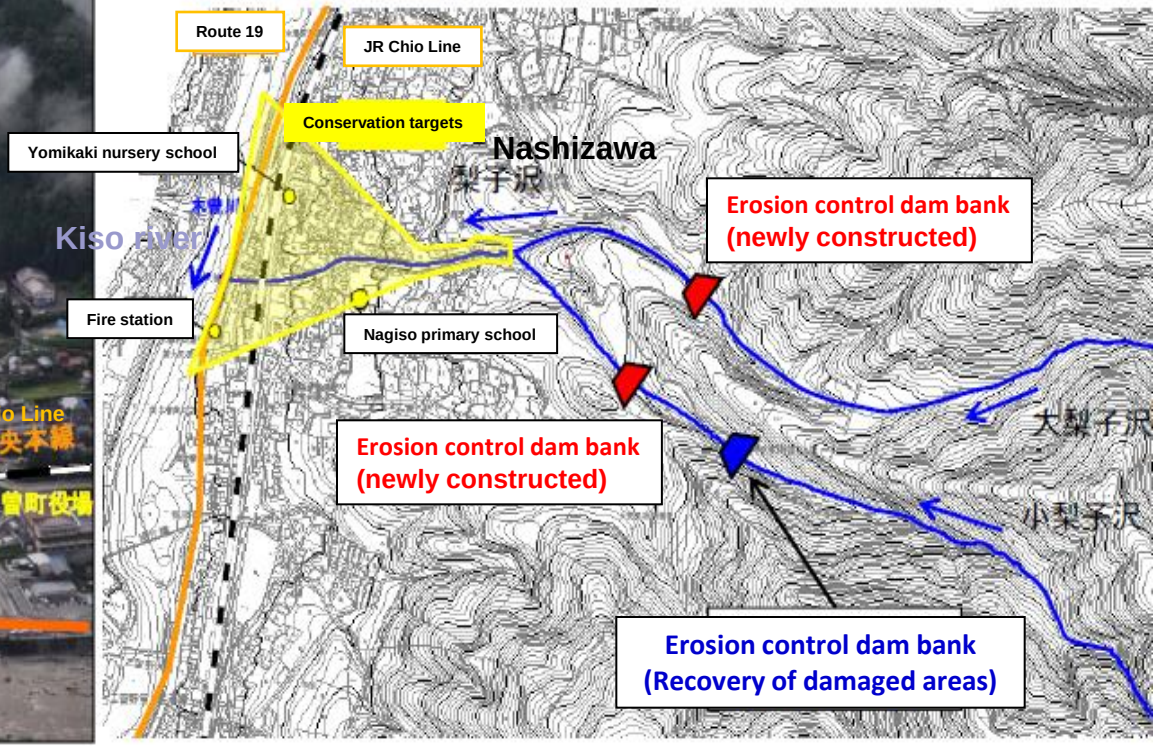
Lateral spread

Copy from USGS


2014年07月09日 17時34分03秒
梨子沢3

Debris flow in Yomikaki area (Nashizawa), Nagiso town, Nagiso county, Nagano Pref. in 2014

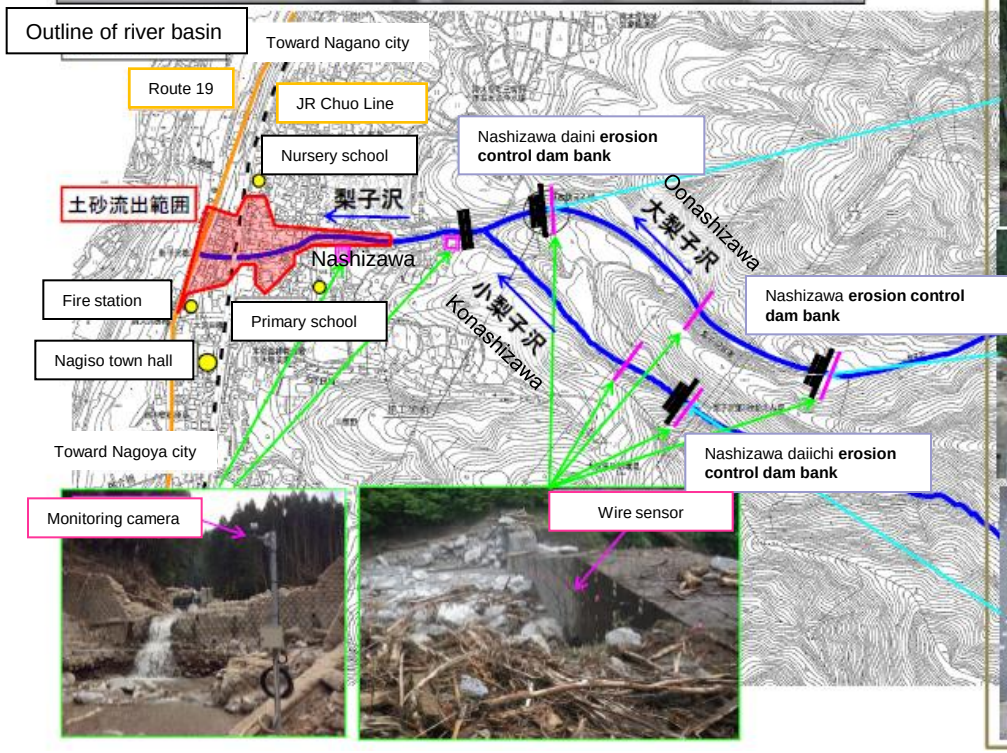
- **Occurred in Jul. 9, 2014**
- **Damages** :
  - Dead : 1
  - Slightly injured: 3
  - Completely destroyed house: 10
  - Partially destroyed house : 3
- **Conservation targets**
  - Houses : 1
  - Route 19, JR Chuo Line, etc.



Damages by debris flow

Erosion control dam bank after debris flow

【Reference】before debris flow



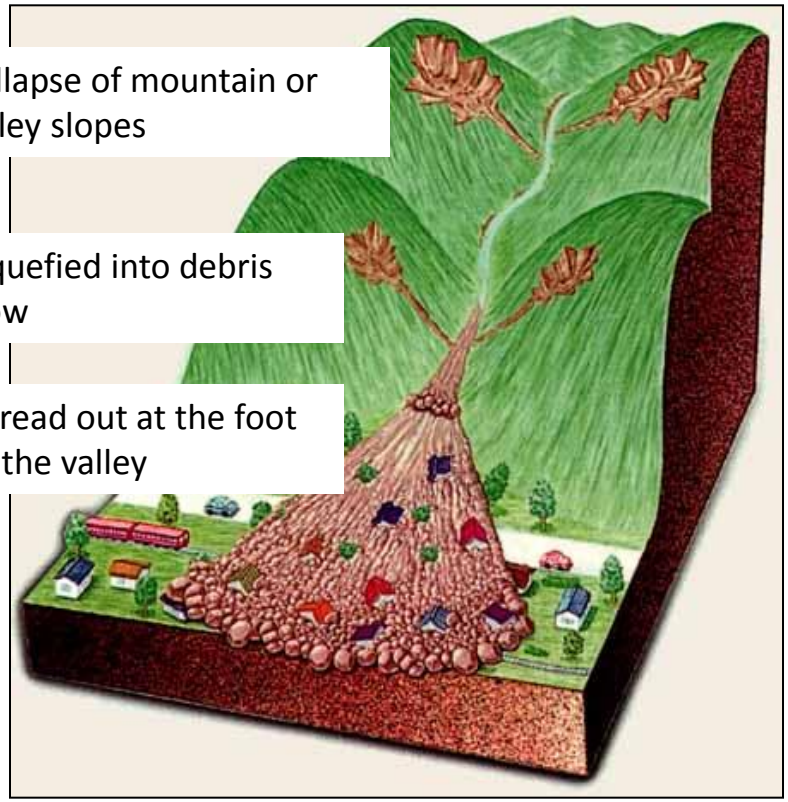
土石流
長野県・焼岳上々堀沢
１９９９．７．３

撮影　国土交通省 松本砂防事務所
提供　国土交通省 砂防部

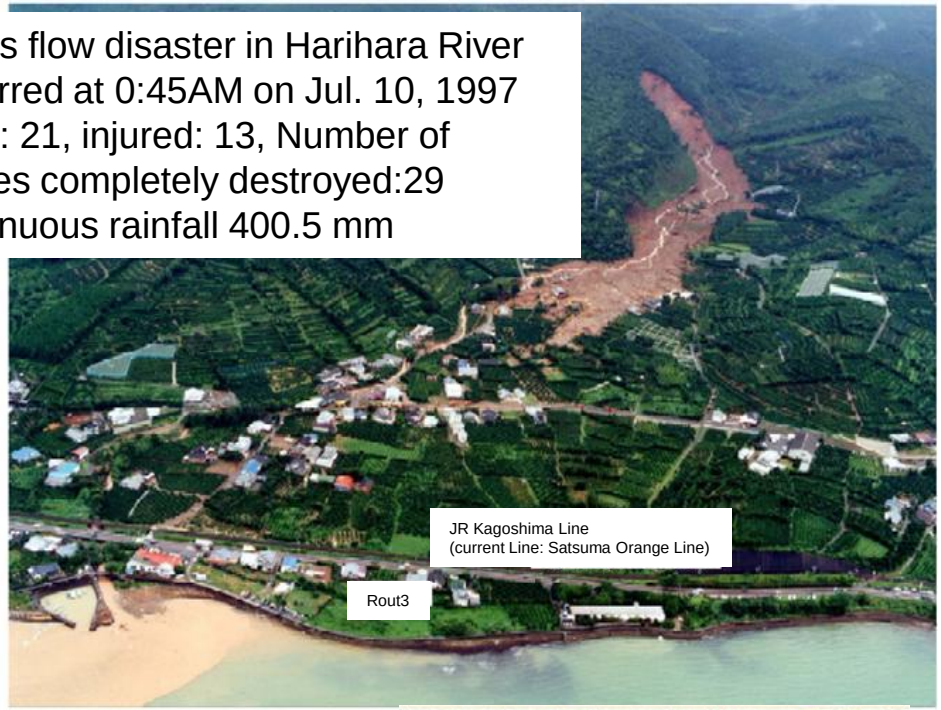
真上から見た土石流

Flash flood

Debris flow



Debris flow disaster in Harihara River
Occurred at 0:45AM on Jul. 10, 1997
Dead: 21, injured: 13, Number of houses completely destroyed:29
Continuous rainfall 400.5 mm



←Source: Website of the Sabo Department, MLIT ↑

A debris flow is a phenomenon of massive flow of liquefied debris of a mountain or valley collapsed due to heavy rain.
In some cases, a debris flow can be caused by earthquakes, snowmelt, or volcanic ash.
A debris flow can dash down the slope as fast as 60km per hour, destroying people, houses and fields in an instant.
A characteristic of a debris flow is that it travels along a river for several kilometers.

Source: Website of Sediment Disaster Pretension Publicity Center

Movie of slope failure

Slope failures

Yaotsu town, Gifu Pref. on Jul. 15, 2010

(source: Website of Chunichi newspaper ↑)

(←source: Pasco)

↑ Makinohara city, Shizuoka Pref. on Aug. 10, 2009
Tomei Expressway shoulder fall (source: Pasco)

↑ Kure City, Yamaguchi Pref. on Jul. 14, 2010

(source: Website of Mainichi newspaper)

Mimasaka City, Okayama Pref. on Aug. 9, 2009
(←source: Pasco)

(↓Website of Sanyo newspaper)

Slope failures

A slope failure is a phenomenon of a collapse of a slope caused by rainwater that seeps into the soil, an earthquake, or a change in temperature.
The scale of a slope failure is usually small compared to debris flow or a landslide, but is characterized by a sudden occurrence.
Since more people live near the foot of mountains due to residential development in hilly areas and urbanization, a slope failure occurs near the houses and the damage is increasingly evident.

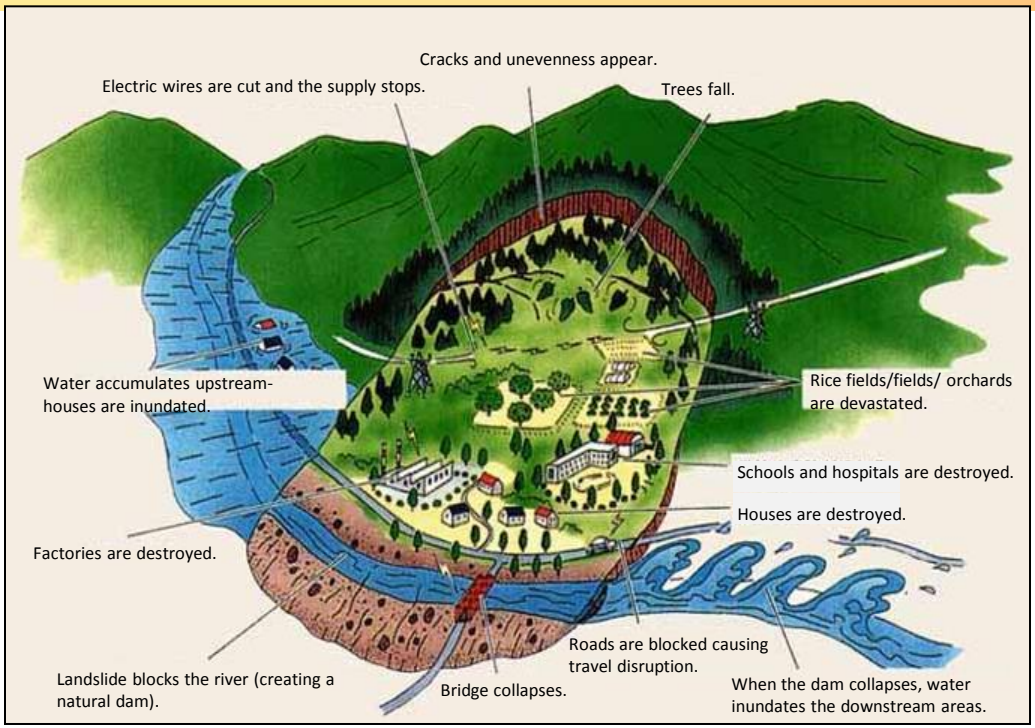
Source: Website of the Sabo Department（http://www.mlit.go.jp/river/sabo/index.html）

What is a “slope”?
Definition: Land with an inclined ground surface of 30 degrees or more from a horizontal surface excluding hard bedrock (except for extremely weathered bedrock).
Source: “Technical Standards for Slope/Retaining Wall”

August 2, 1993
A slope failure occurred along the new residential area in Aira-cho, Kagoshima Prefecture.
(The collapsed slope has been converted to an erosion control park.)

Movie of landslides

Landslides



A landslide is a phenomenon of a downward sliding of an inclined plane within a specific range.

Besides heavy rainfall, a landslide is caused by raised ground water level by snowmelt.

A landslide may also occur when an imbalance is caused by slope improvement work.

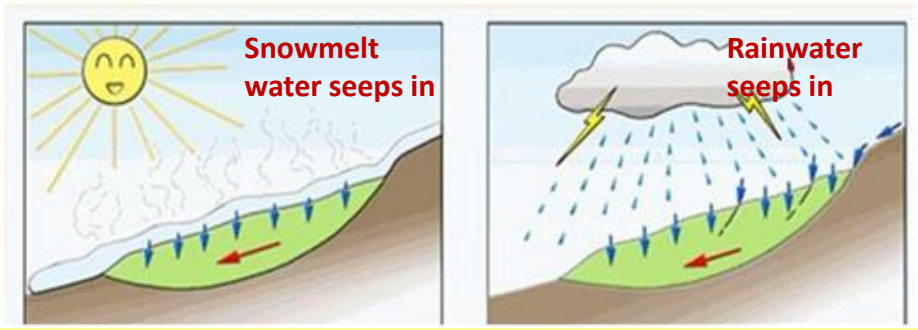
Source: Website of the Sabo Department
（http://www.mlit.go.jp/river/sabo/index.html）

Landslide
Hiesawa, Nikaho City, Akita Pref.
source: Asia Air Survey CO., LTD.

Landslides

Mechanism of Landslides

(1) Water pools between impermeable strata (bedrock, etc.) and permeable strata due to rainfall or snowmelt.



(2) The sliding force becomes greater than the friction force due to the pooled water, causing a landslide.

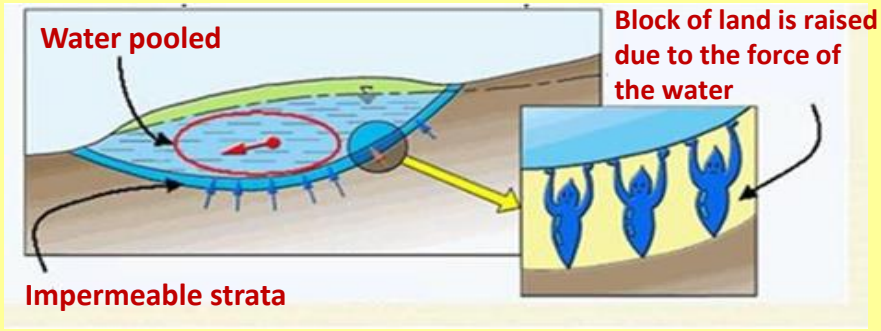


Figure: Excerpt from the "Expedition Team of Hometown Safety," Sediment Disaster Pretension Publicity Center

Category of landslides

(1) Tertiary Landslide
A large number of tertiary landslides occurs in the Tohoku region and Niigata/northern part of Nagano prefecture. When mixed with water, shale rocks and tuff become clay-like.

(2) Shear Zone Landslide
A shear zone is a belt zone created by mangled rocks affected by faulting of strata and is partially clay-like. It is commonly found in the areas along large faults, such as the Median Tectonic Line.

(3) Hot-spring Landside
It occurs where the strata becomes clay-like soil affected by hot-spring heat or gas. It is observed in volcanic and hot-spring areas.

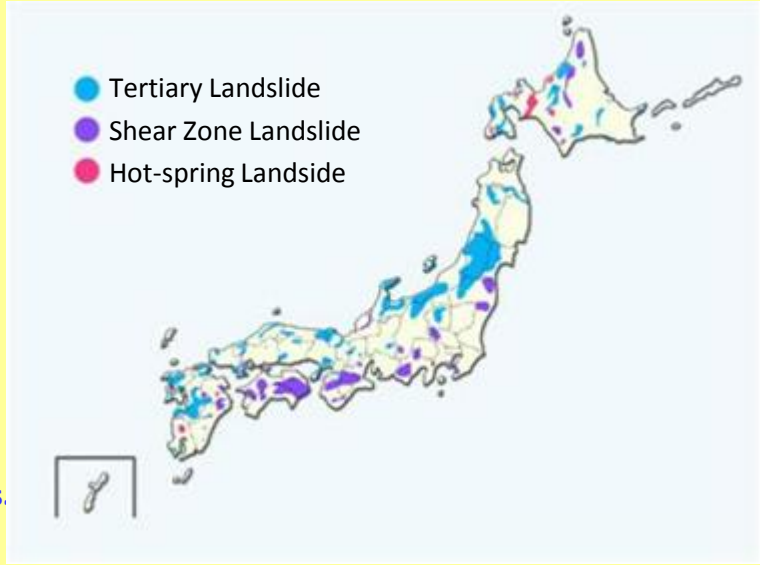


Figure: Excerpt from the "Expedition Team of Hometown Safety", Sediment Disaster Prevention Publicity Center

Landslide in Kokugawa, Niigata Pref. in 2012

Mar. 8, 2012 16:00

Photo: Public Works Department
Niigata Prefecture

Landslide in Kokugawa, Niigata Pref. in 2012

Mar. 9, 2012 7:00

Photo: Public Works Department
Niigata Prefecture

Landslide in Kokugawa, Niigata Pref. in 2012

Mar. 10, 2012 11:00

Photo: Public Works Department
Niigata Prefecture

Landslide in Kokugawa, Niigata Pref. in 2012

Mar. 13, 2012 8:00

Photo: Public Works Department
Niigata Prefecture

Deep-seated Landslides

Part of the slope of the mountains or hill indicates that a collapsing phenomenon may occur at the base as well as the topsoil layer (deeply weathered rock layers). Deep-seated landslides are characterized by a sudden and transient movement of soil and rocks at a high speed. Violent disturbance and deformation of the mountain or hill usually occurs during the event. Deep-seated landslides occur more often in areas of particular geology or geological structure, and are particular common in accretionary wedges* found in parts of Japan such as the Shimanto belt. Tree root systems cannot be expected to prevent landslides because the position of the slip surface is deep.

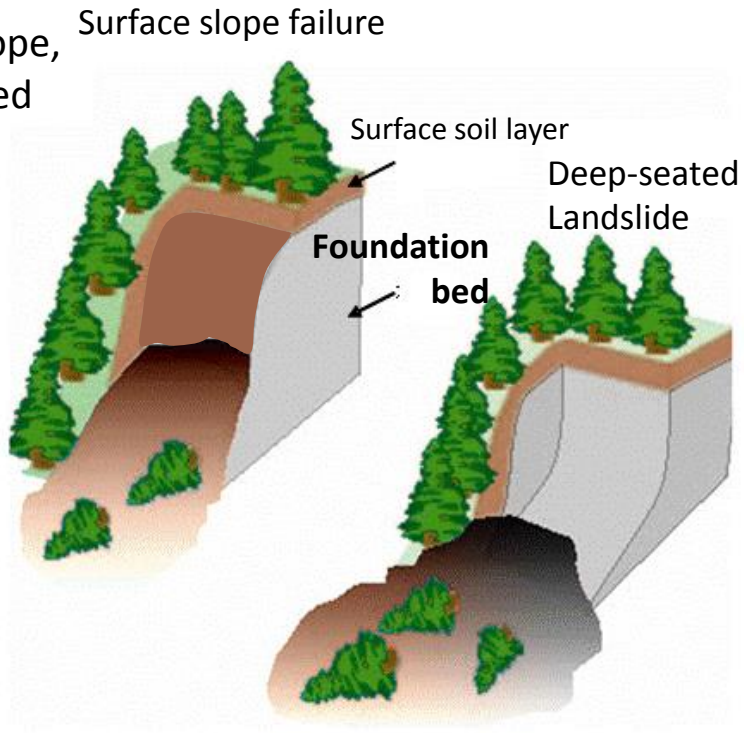
Sediment volume compared to shallow landslides is large, and the range of sediment volume is extremely large. The larger the amount of sediment, the smaller the equivalent friction coefficient becomes and the range has an increasing trend. Also, the larger the amount of sediment, the frequency of occurrence is smaller. Causes that trigger a deep-seated landslide include rainfall, earthquakes, melting snow, and volcanic eruption; however, most occurrences are due to rainfall and earthquakes.

* Accretionary wedges : Most of the material in the accretionary wedge consists of marine sediments accreted onto a subducting overriding plate.

Review Committee report and recommendations related to the basics of deep-seated landslides
March 2012, Japan Society of Erosion Control Engineering

Deep-seated Landslide

- It is a phenomenon of collapse of a part of mountain or hill slope, entailing a collapse of not only the surface soil layer (weathered layer), but also its foundation bed underneath.
- It is caused by heavy rainfall, earthquake, snowmelt, etc.



●Characteristics of deep-seated Landslide

The movement of soil and rock mass is sudden.

- Soil and rock mass move quickly.
- Soil and rock mass are smashed into pieces, losing their original form.
- The volume of sediment is larger and it travels further than in the case of surface slope failure.

Example of deep-seated landslide caused by heavy rain

There are cases where the soil moved by a deep-seated landslide slides down the slope as debris flow or forms a landslide dam.

Mimikawa, Miyazaki Pref. (2005)

Wanizukayama, Miyazaki Pref. (2005)

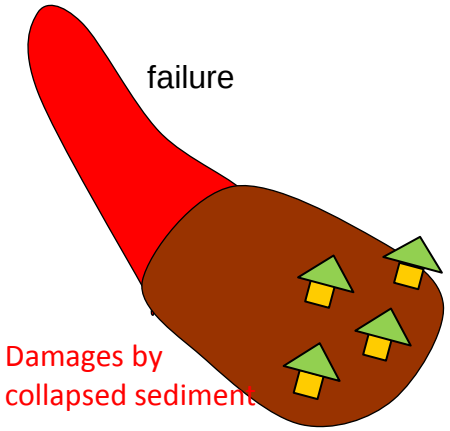
Sediment disasters caused by deep-seated Landslide

- The frequency of occurrence of deep-seated landslide is very low, at 31 cases in the 10 years from 2001 to 2010, among the sediment disasters which occur about 1000 times every year.
- Compared to the surface slope failure, it may cause huge damage when occurring because of a large volume of moving sediment.
- Types of disasters caused by the deep-seated landslide are described below.

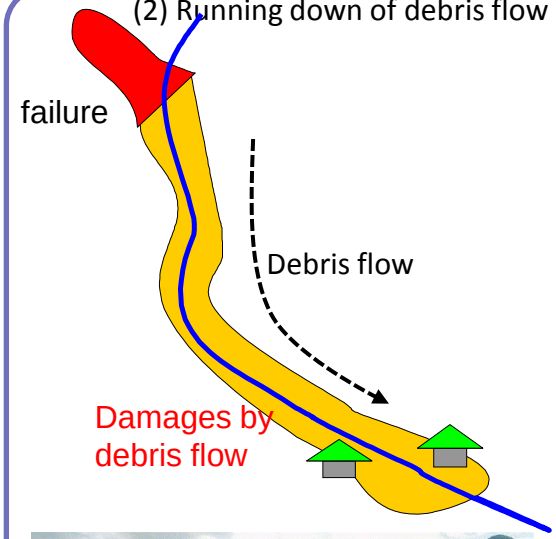
Affected area: **small** → **large**

Moving velocity: **large** → **small**

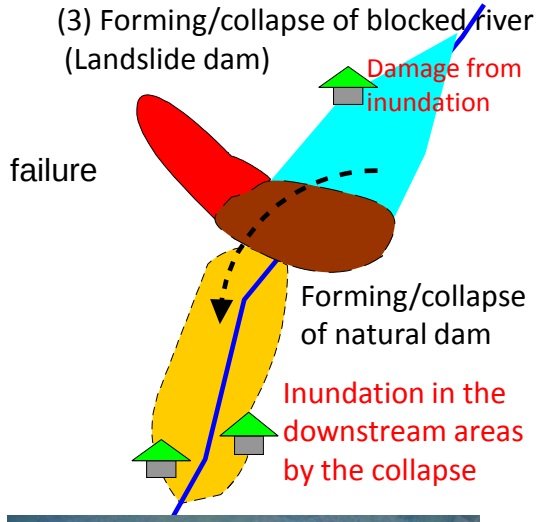
(1) Falling of collapsed sediment

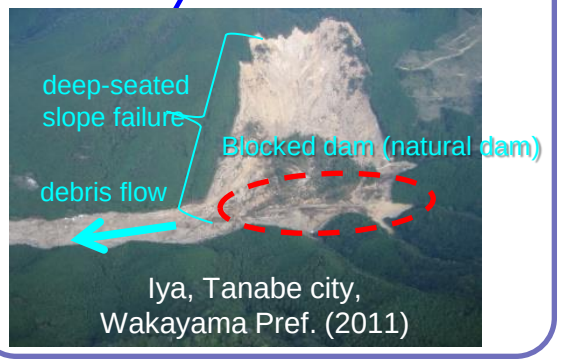


(2) Running down of debris flow



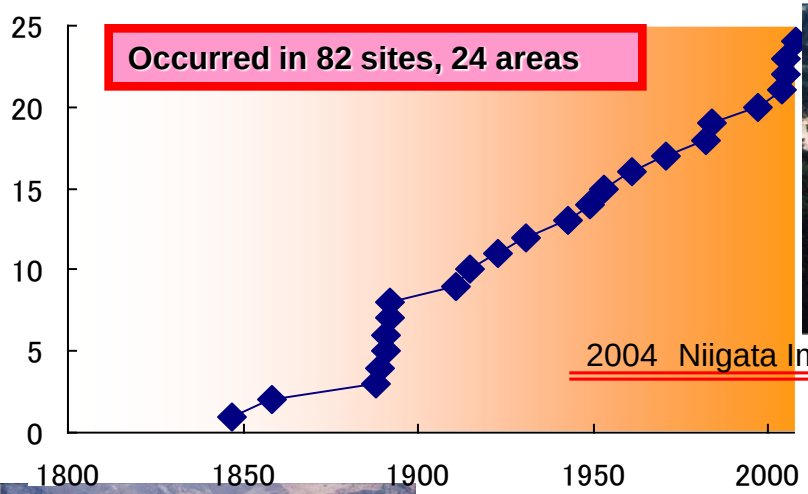
(3) Forming/collapse of blocked river (Landslide dam)





Landslide Dams

Landslide Dam occurred at 82 locations in the past 200 years, resulting from various causes, including rainfall, earthquakes, and volcanic eruptions.



2004 Niigata Imokawa river (earthquake)

2008 Iwate / Miyagi Iwai river / Hasama river (earthquake)

1888 Fukushima Mt. Bandai (earthquake and volcano)

1926 Nagano Yakedake (volcano)

1911 Nagano, Hime river (rainfall)

1891 Nagano Garagarasawa (rainfall)

1858 Tonbi-yama-kuzure (earthquake)

1889 Wakayama Totsukawa (rainfall)

1931 Osaka Kamenose (rainfall)

2002 Tottori Ichinose (rainfall)

1982 Nara Wada (rainfall)

1949 Tochigi Imaichi (earthquake)

1847 Nagano Zenkoji (earthquake)

1984 Nagano Ontake (earthquake)

1923 Kanagawa Shinsei lake (earthquake)

1891 Gifu Nobi-earthquake (earthquake)

2005 Miyazaki mimikawa (rainfall)

1953 Wakayama Aritagawa (rainfall)

1892 Tokushima Nakagawa (rainfall)

1892 Tokushima Kaifu river (rainfall)

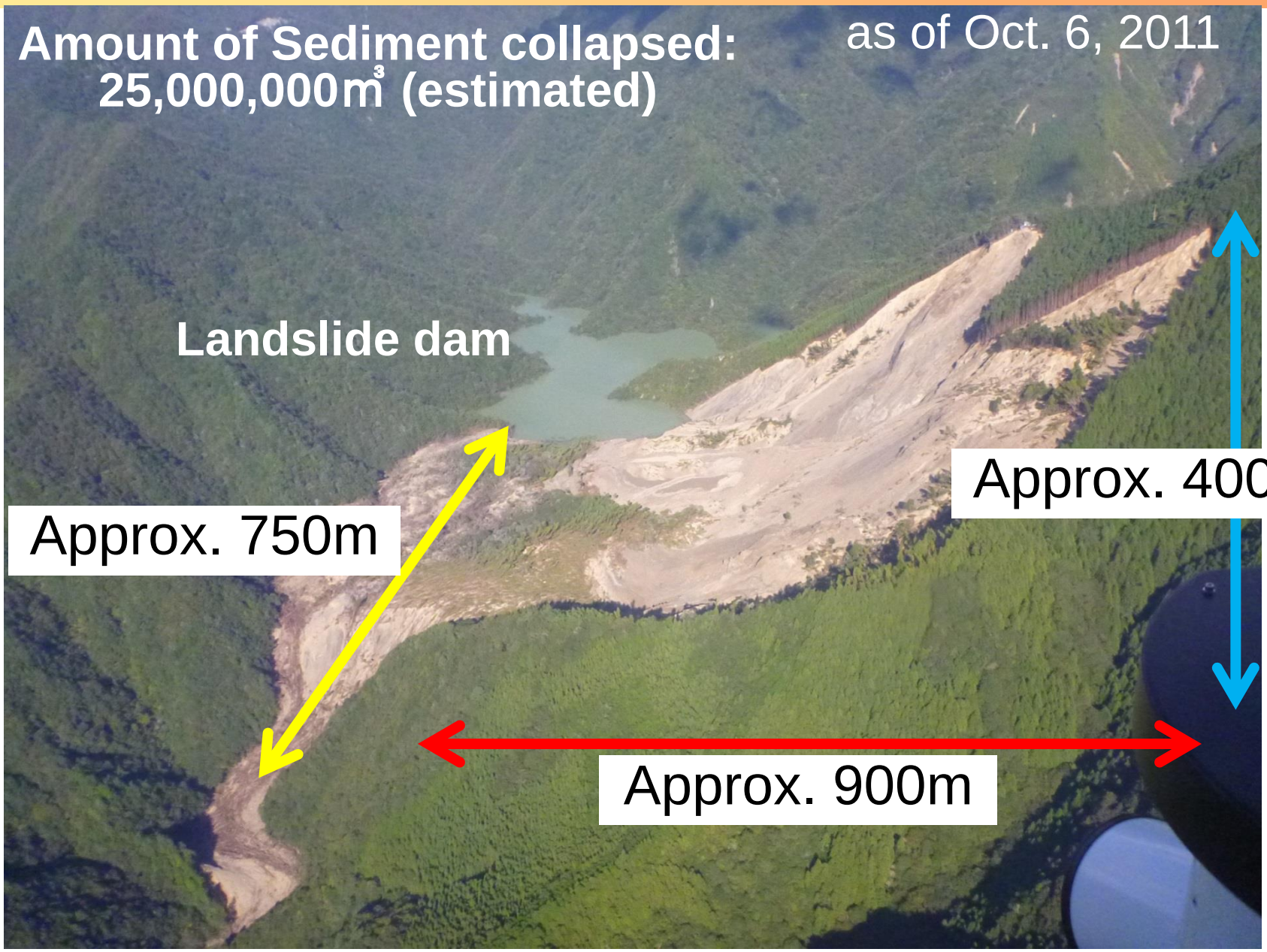
1943 Oita Banjo river (rainfall)

Legend example (cause of landslide dam)

rainfall earthquake volcano

Map was based on "natural dam and disasters"

Kuridaira, Kii peninsula in September, 2011



Collapse of Landslide dam in Indonesia in July 2013

- July 12, 2012: River blockage caused by a large-scale collapse in the Way Ela River basin, Ambon Island, Maluku Province
- Natural dam with a height of 120m and the amount of submerged water of approximately 1.6 million m^3 (estimation at the time of collapse)
- Overflow occurred at around 10:00 on July 25, 2013, and the bank broke at around 12:30. Most of the natural dam disappeared, leaving a small lake.
- Left three people dead or missing, almost all of the 470 houses of 5227 residents were swept away (60% of the village).

Jul. 12, 2012

Jul. 25, 2013

Breach of natural dam

After breach of natural dam

Source: Ministry of Public Works, Indonesia

Inundation of downstream

Cases of landslide dam breaches


北陸地方整備局

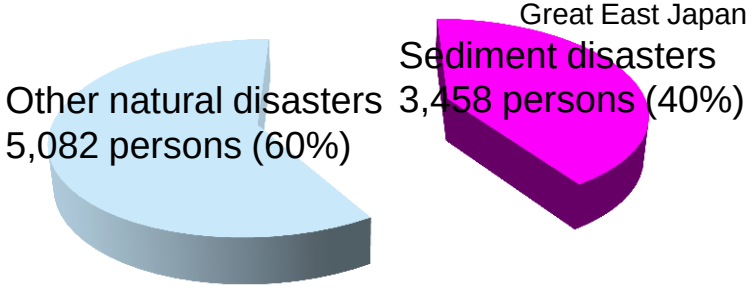
Sediment Disasters That Cause Losses in Human Lives

Sediment disasters account for a large proportion of casualties caused by natural disasters.
About 60 percent of the dead or missing in sediment disasters were people who need assistance during a disaster.

■number of deaths/missing persons by natural disasters

1967 ～2012

(except for deaths/missing by Hanshin-Awaji earthquake and Great East Japan earthquake)

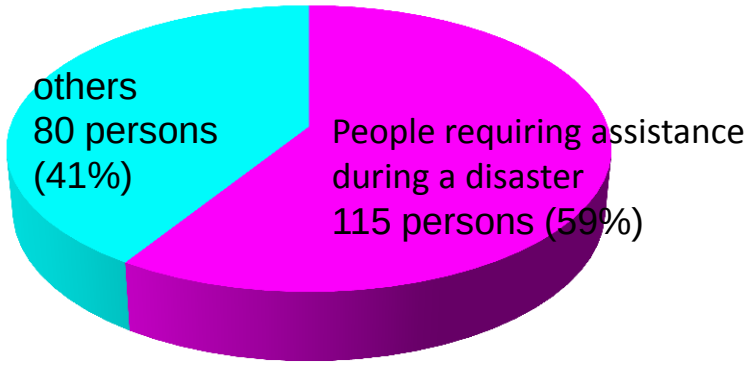


※ Source: White Paper on Disaster Management 2012 for the number of casualties (dead or missing) per year. Figures for sediment disasters are based on the study of the Sabo Department, MLIT.

Hanokidaira, Shirakawa city, Fukushima Pref.
Occurred on 11 Mar. 2011 by Great East Japan earthquake
13 persons died

■Proportion of people requiring assistance during a disaster among the casualties in sediment disasters

2009 ～2013



Hofu city, Yamaguchi Pref. Occurred in July 2009 **7 persons died**
（who need assistance during a disaster）


7 18'95

Characteristics of Sediment Disaster

○Sudden

→Earthquake: directly leading to disaster. Debris flow, etc. without rainfall or premonition

○High rate of deaths or missing persons

→Devastating phenomenon

○Various causes/factors

→ Rainfall, increase in ground water, earthquake, geographic and geological features, etc.

○Change in the geographical features

→Landslide dam, sudden rise of riverbed, volcanic activity, etc.

Intensifying damage from sediment disasters caused by localized torrential downpour/large earthquake/volcanic eruption, etc.

- Heavy rain : Debris flow disaster in Izu-Oshima island occurred by Typhoon No.26 in 2013, Northern Kyushu heavy rainfall disaster in Jul. 2012, Kii peninsula flood in Sep. 2011, etc.
- Earthquake : Great East Japan earthquake, Iwate-Miyagi interior earthquake, etc.
- Volcano : Mt. Kirishima (Shin-moe-dake) in 2011, Sakura-jima island, etc.

Eruption of Shin-moe-dake, Mt. Kirishima in Miyazaki and Kagoshima Prefectures in Jan. 2011


Landslide in Hanokidaira, Fukushima Pref. by Great East japan earthquake in Mar. 2011

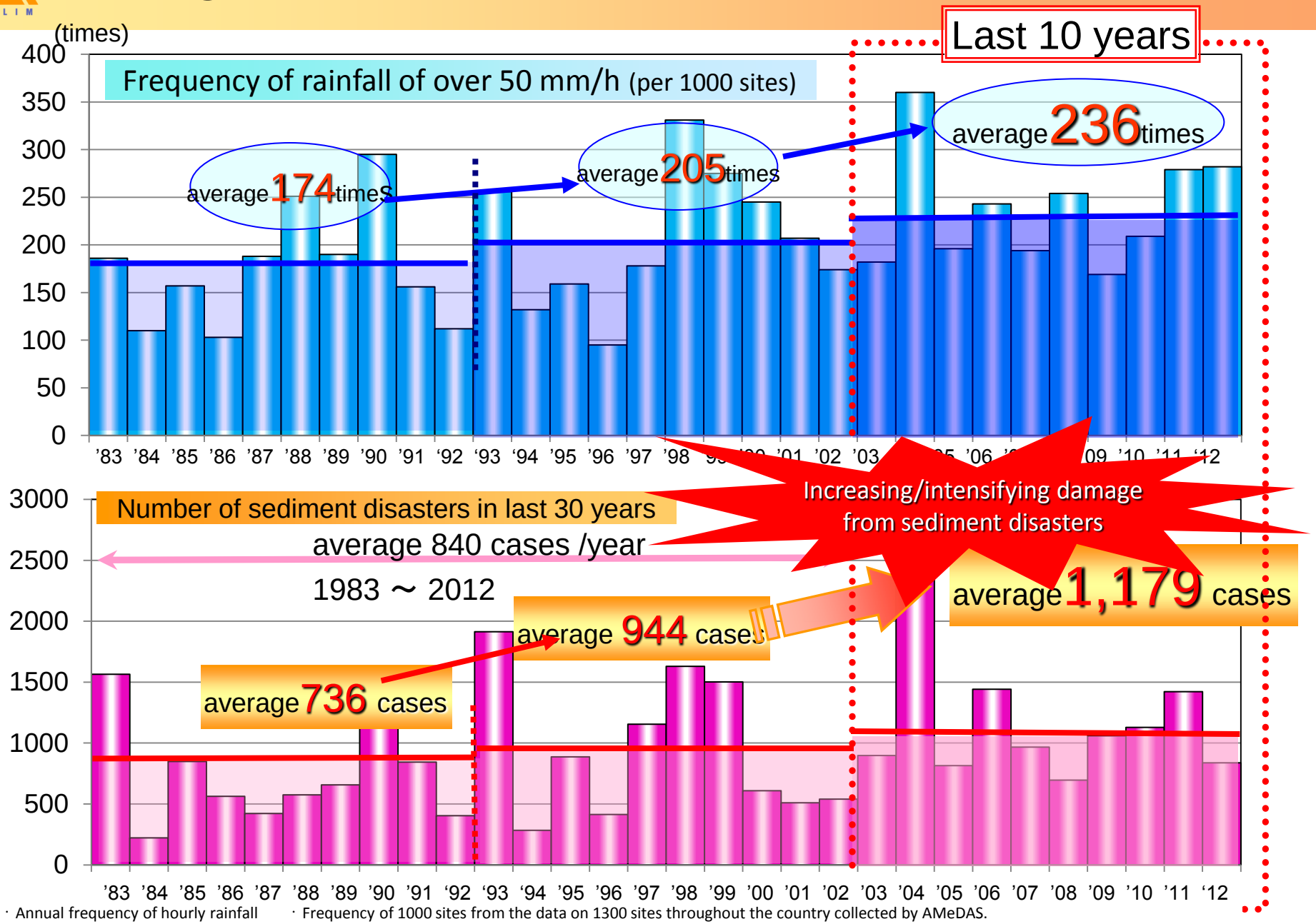

River blockage in Iya, Wakayama Pref. in Sep. 2011


Sediment disaster in Aso district, Kumamoto Pref. in Jul. 2012


Debris flow in Senboku city, Akita Pref. in Aug. 2013


Sediment disaster in Izu-Oshima island, Tokyo Pref. in Oct. 2013

Changes in Rainfall Patterns and Sediment Disasters



· Annual frequency of hourly rainfall · Frequency of 1000 sites from the data on 1300 sites throughout the country collected by AMeDAS.

The Serious Disaster by debris flow in Hiroshima 20 August 2014

The Serious Disaster by debris flow in Hiroshima 20 August 2014

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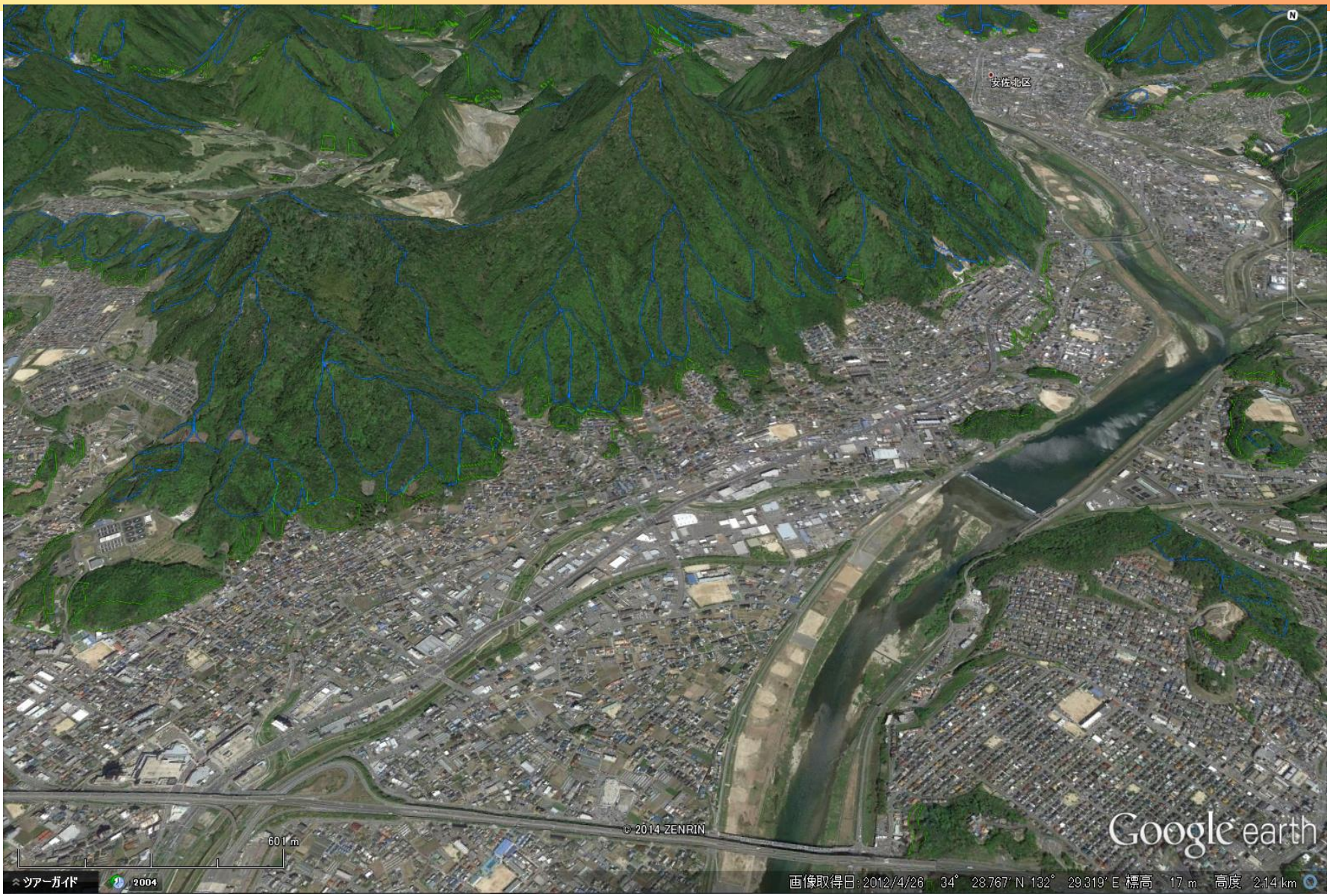
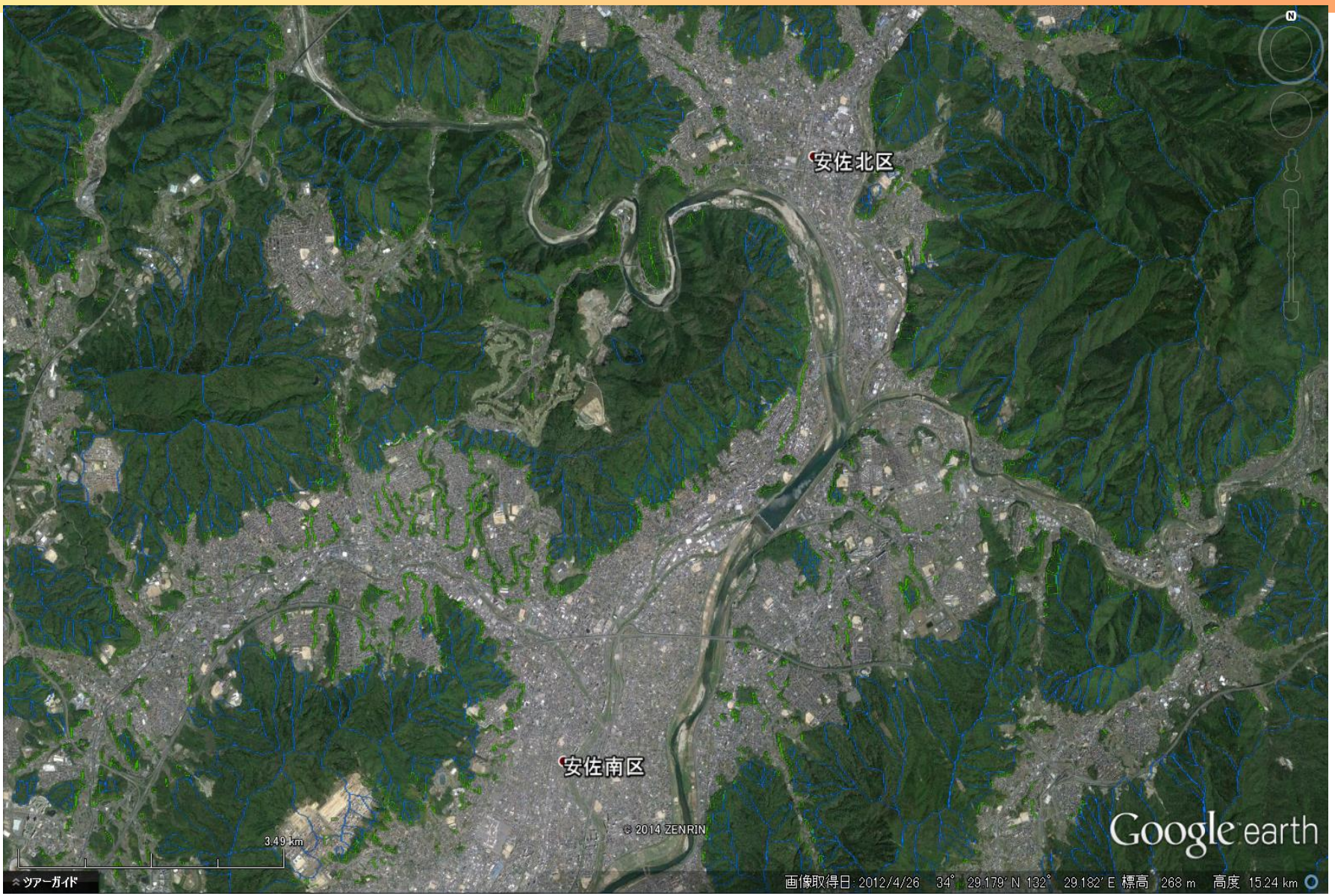


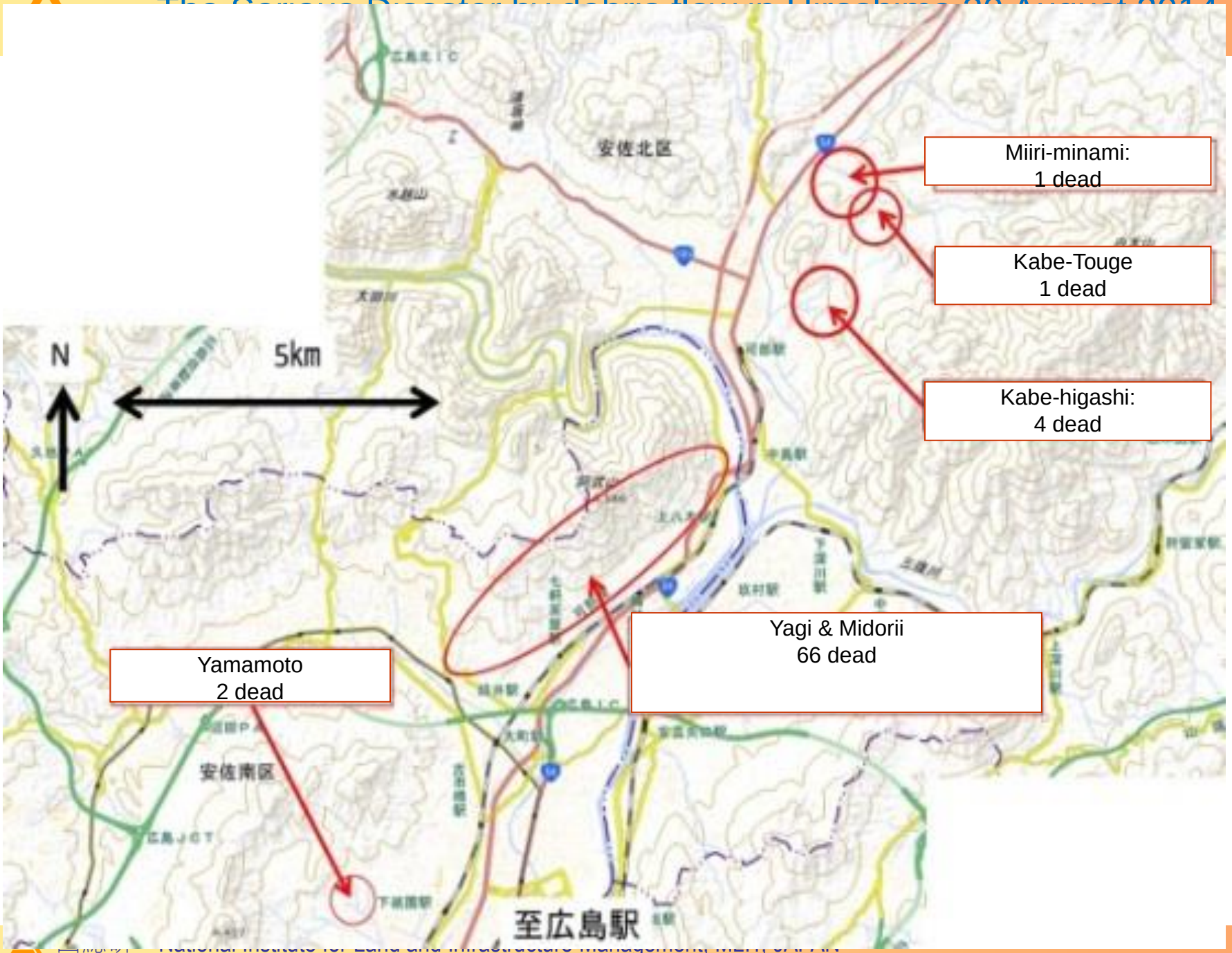
Google Earth + Debris Flow hazard area

The Serious Disaster by debris flow in Hiroshima 20 August 2014

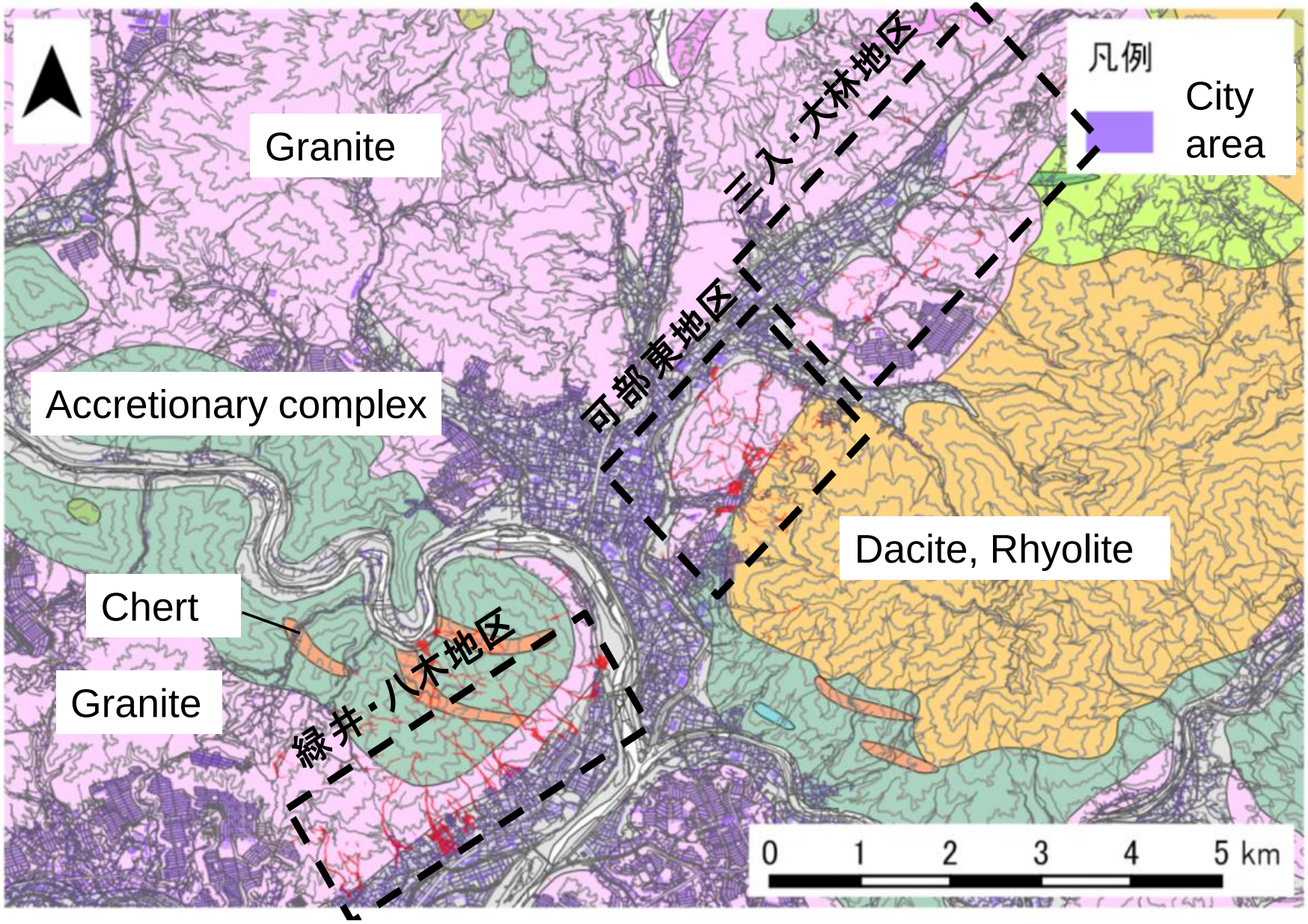


Google Earth + Debris Flow hazard area

The Serious Disaster by debris flow in Hiroshima 20 August 2014

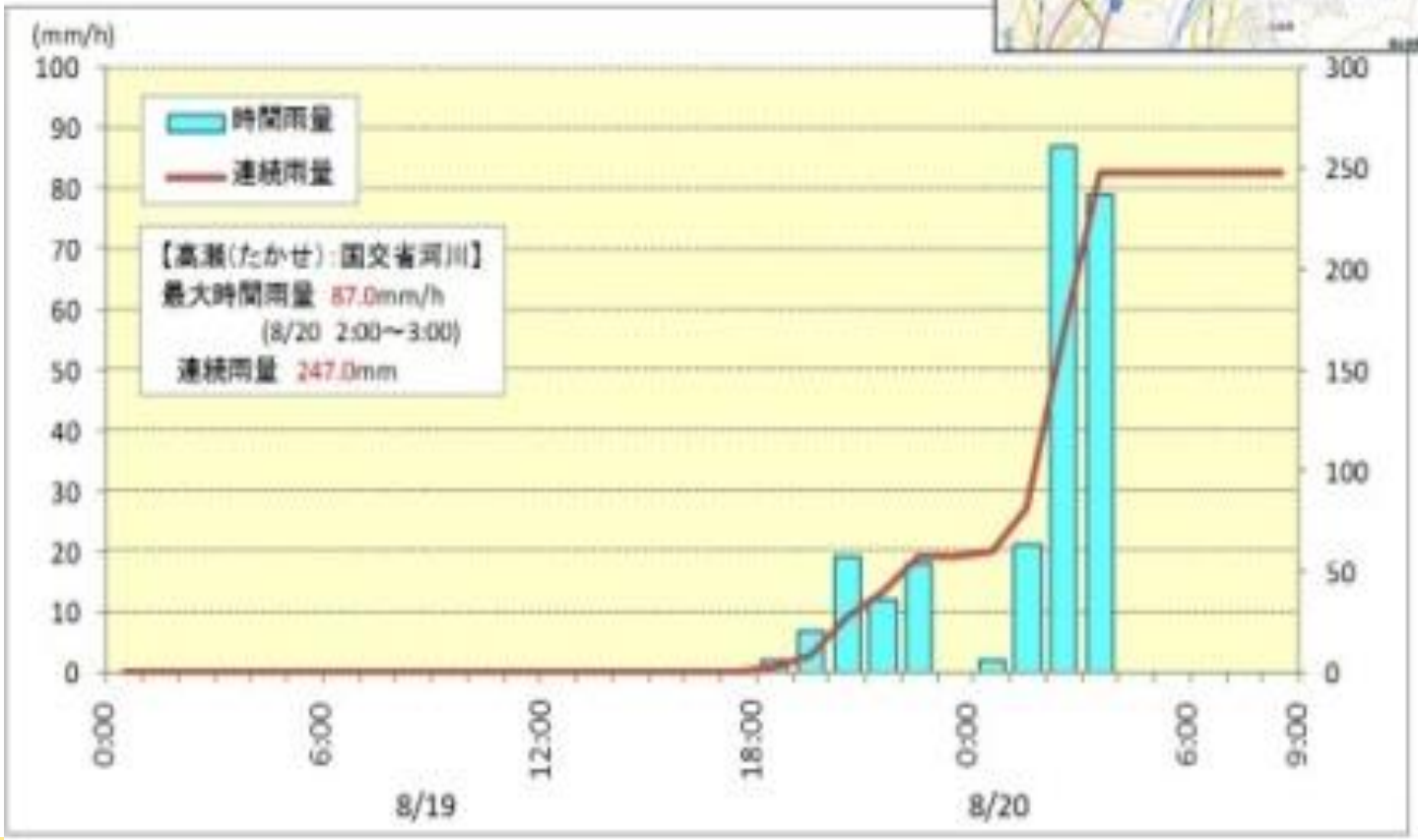


The Serious Disaster by debris flow in Hiroshima 20 August 2014

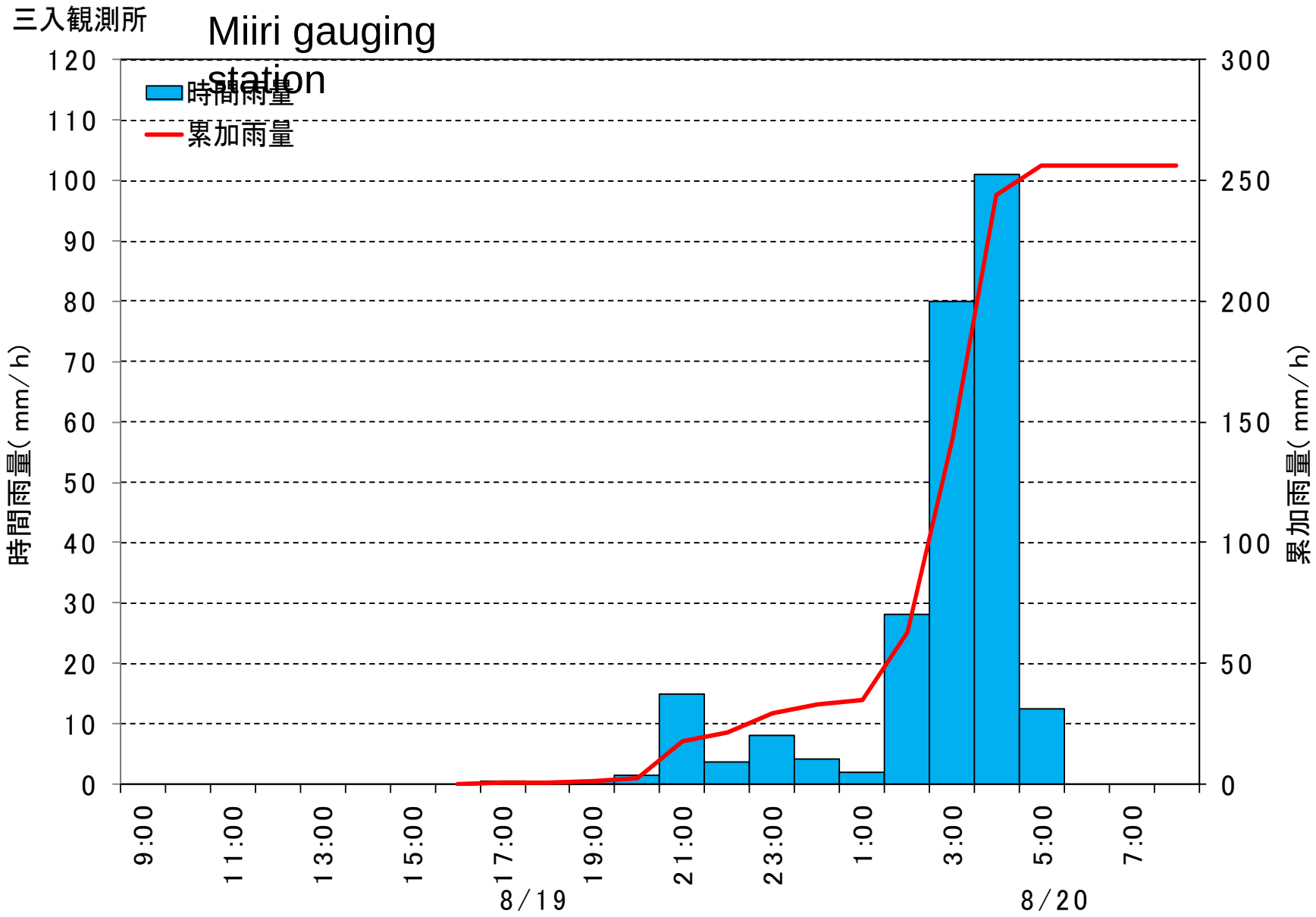


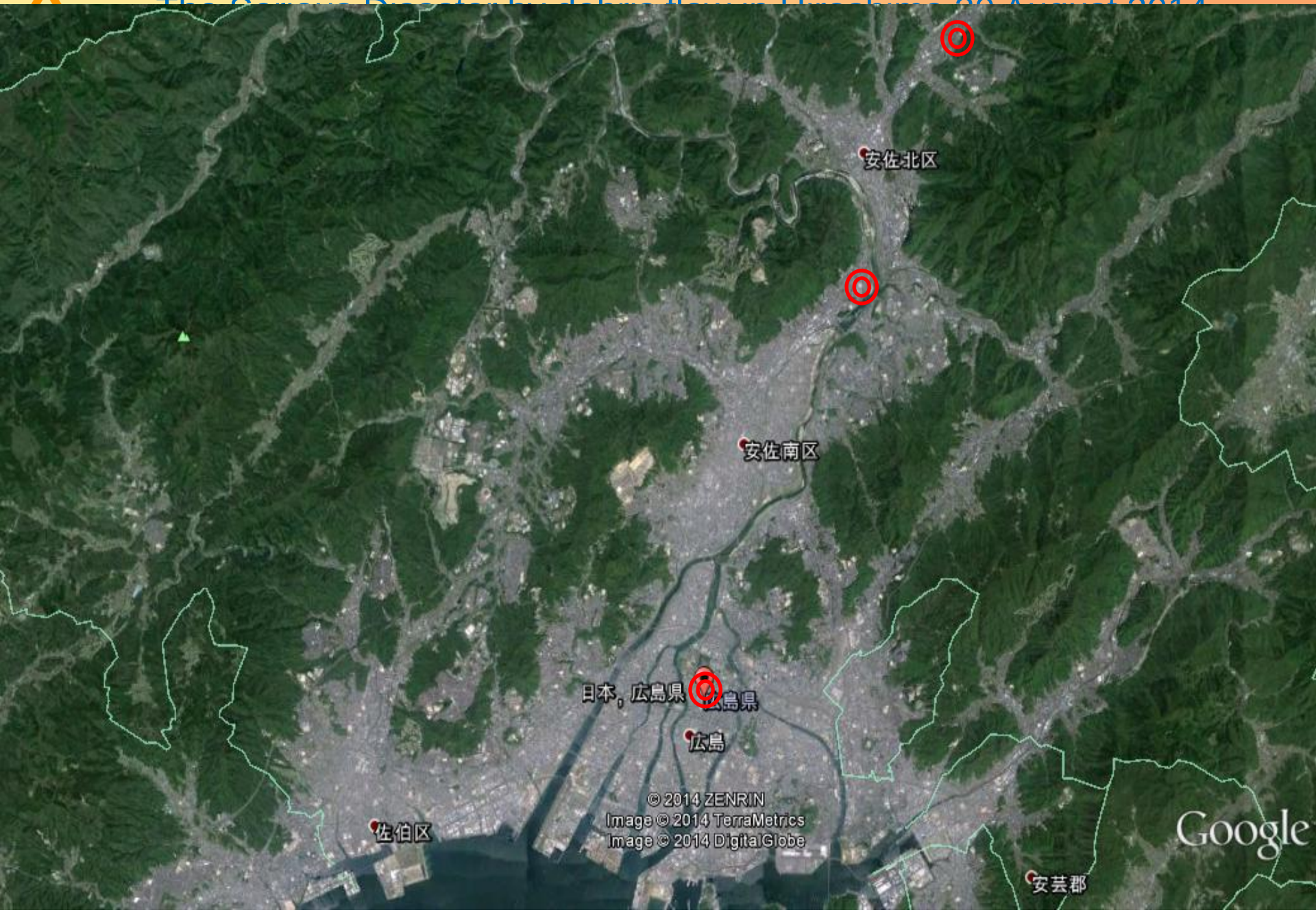
The Serious Disaster by debris flow in Hiroshima 20 August 2014

●観測所名：高瀬（たかせ）雨量観測所＜国土交通省所管＞
所在地　：広島市安佐南区八木5丁目



The Serious Disaster by debris flow in Hiroshima 20 August 2014




安佐北区
安佐南区
日本，広島県
広島県
広島
© 2014 ZENRIN
Image © 2014 TerraMetrics
Image © 2014 DigitalGlobe
佐伯区
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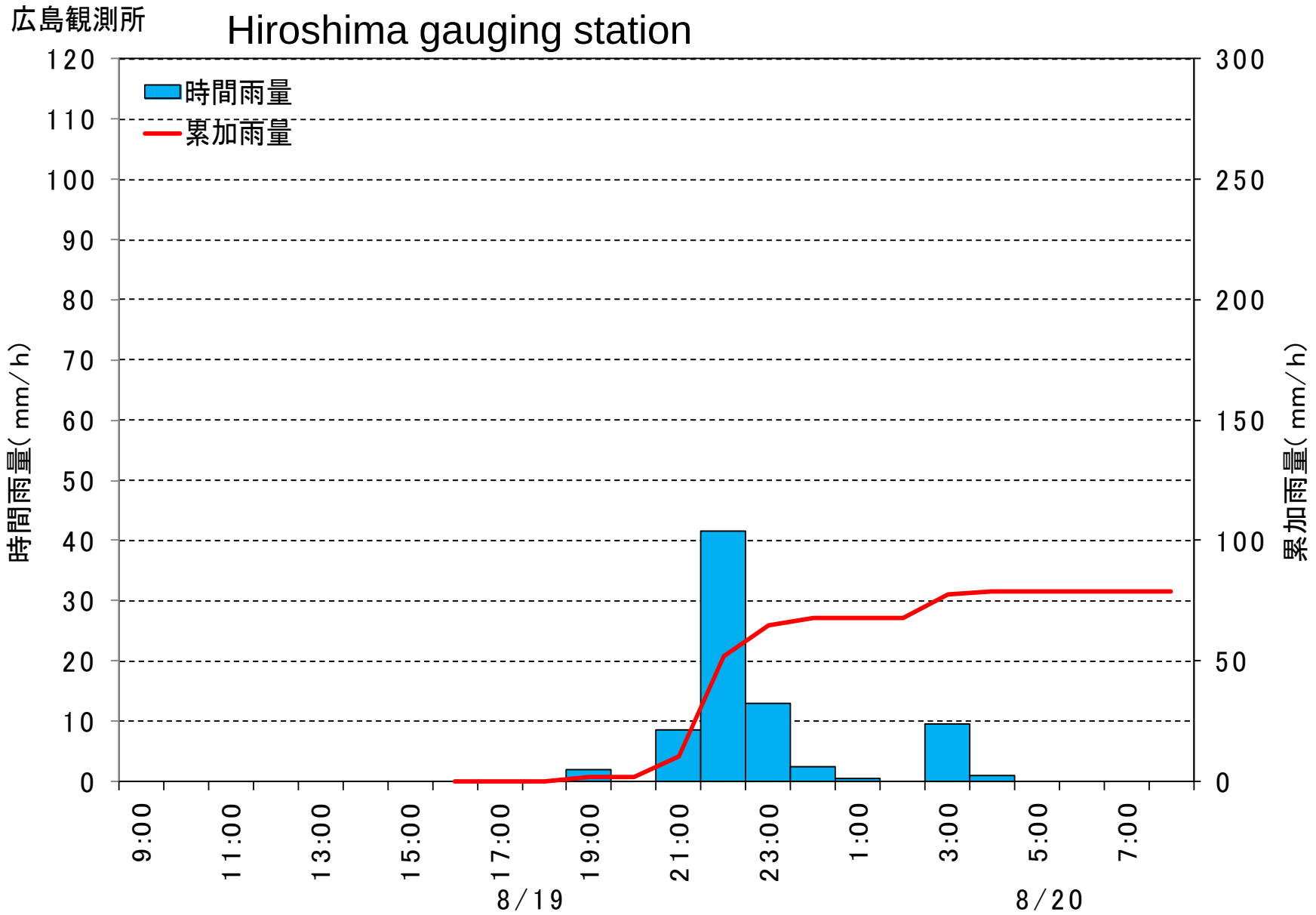
広島観測所
Hiroshima gauging station
時間雨量
累加雨量
時間雨量（mm/h）
累加雨量（mm/h）
120
110
100
90
80
70
60
50
40
30
20
10
0
300
250
200
150
100
50
0
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
1:00
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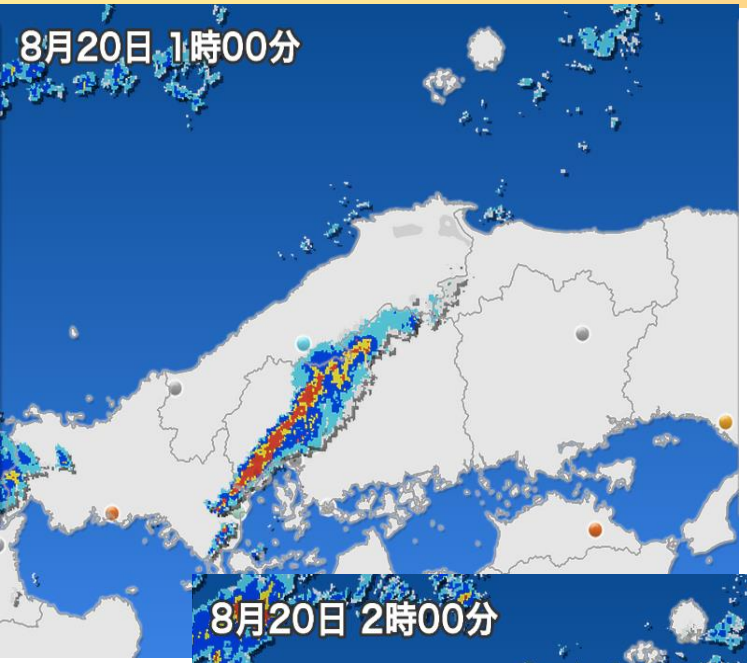
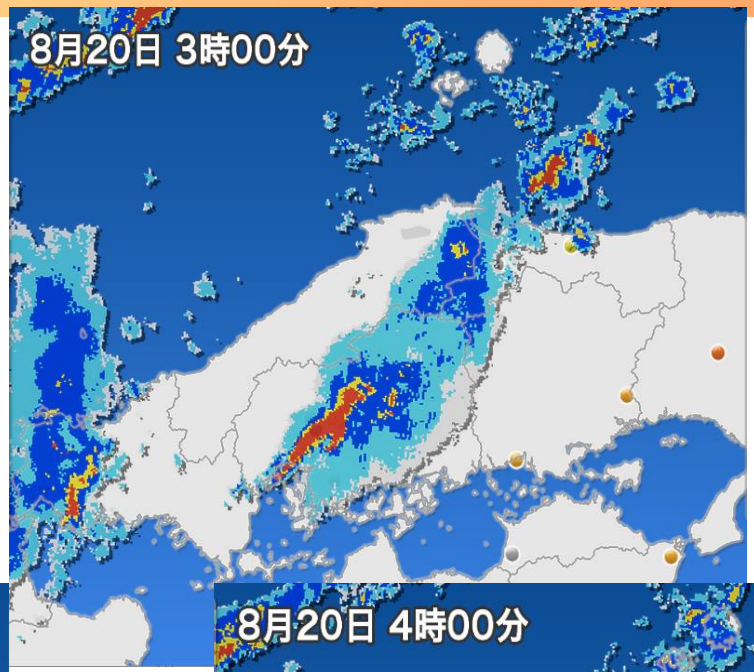
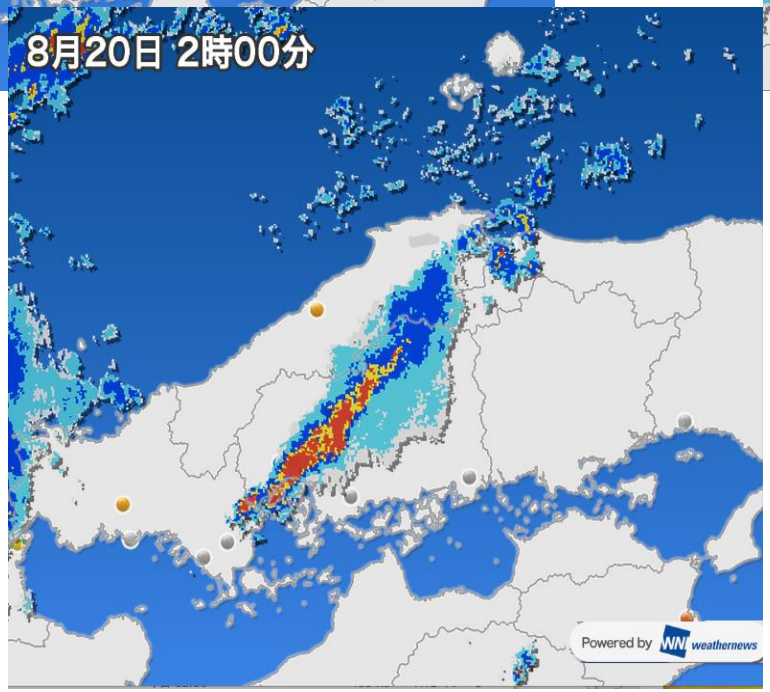
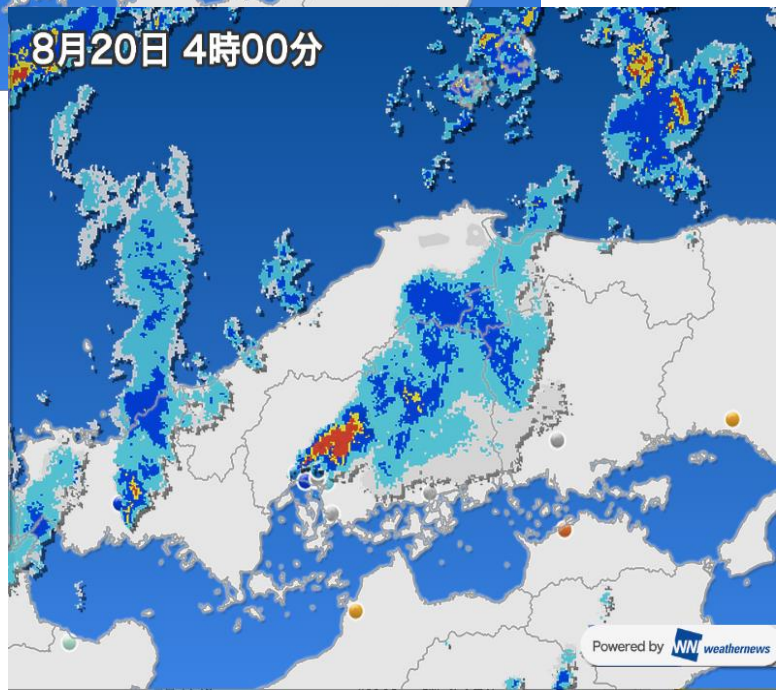
7:00
8/19
8/20

The Serious Disaster by debris flow in Hiroshima 20 August 2014

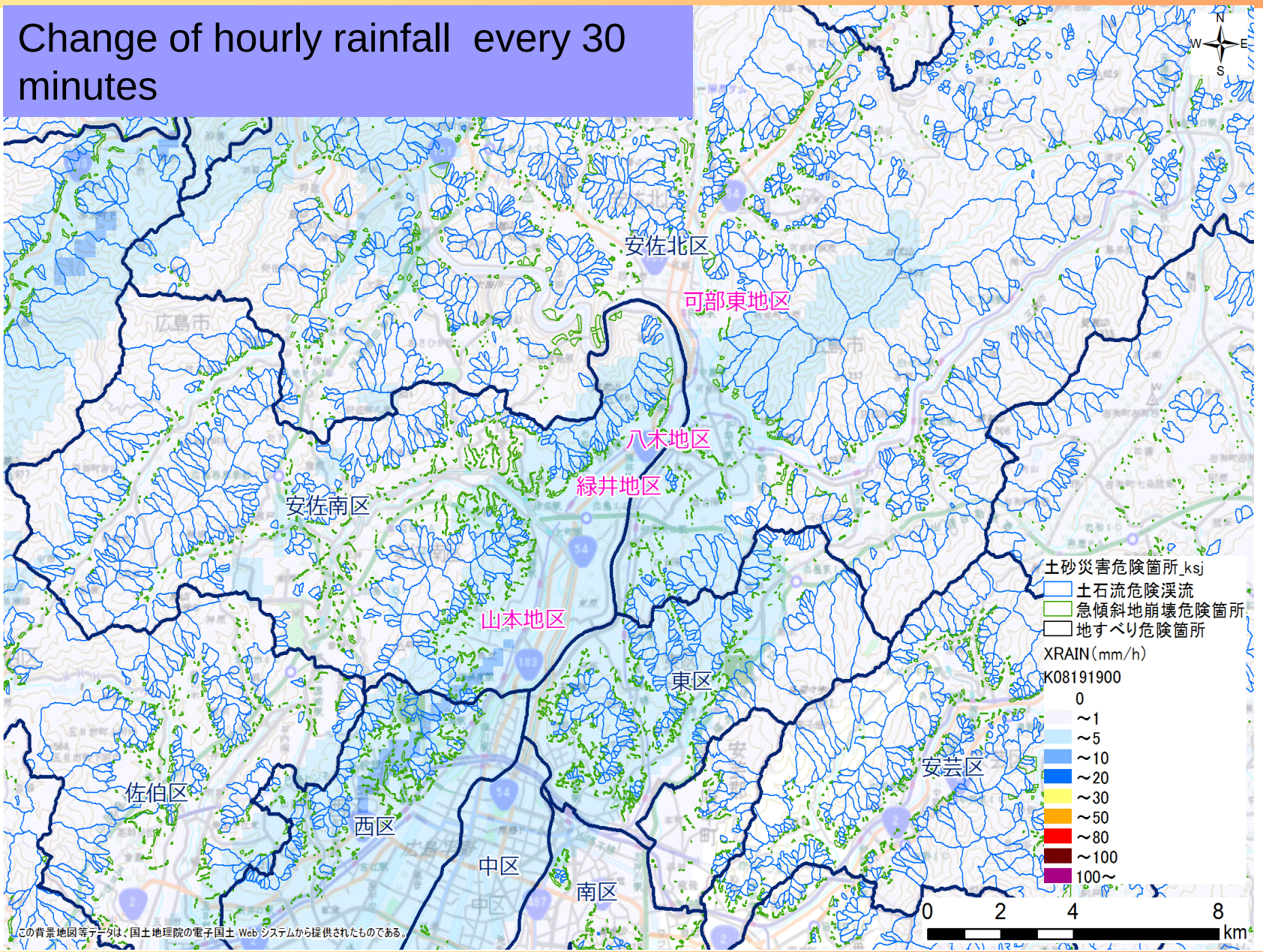




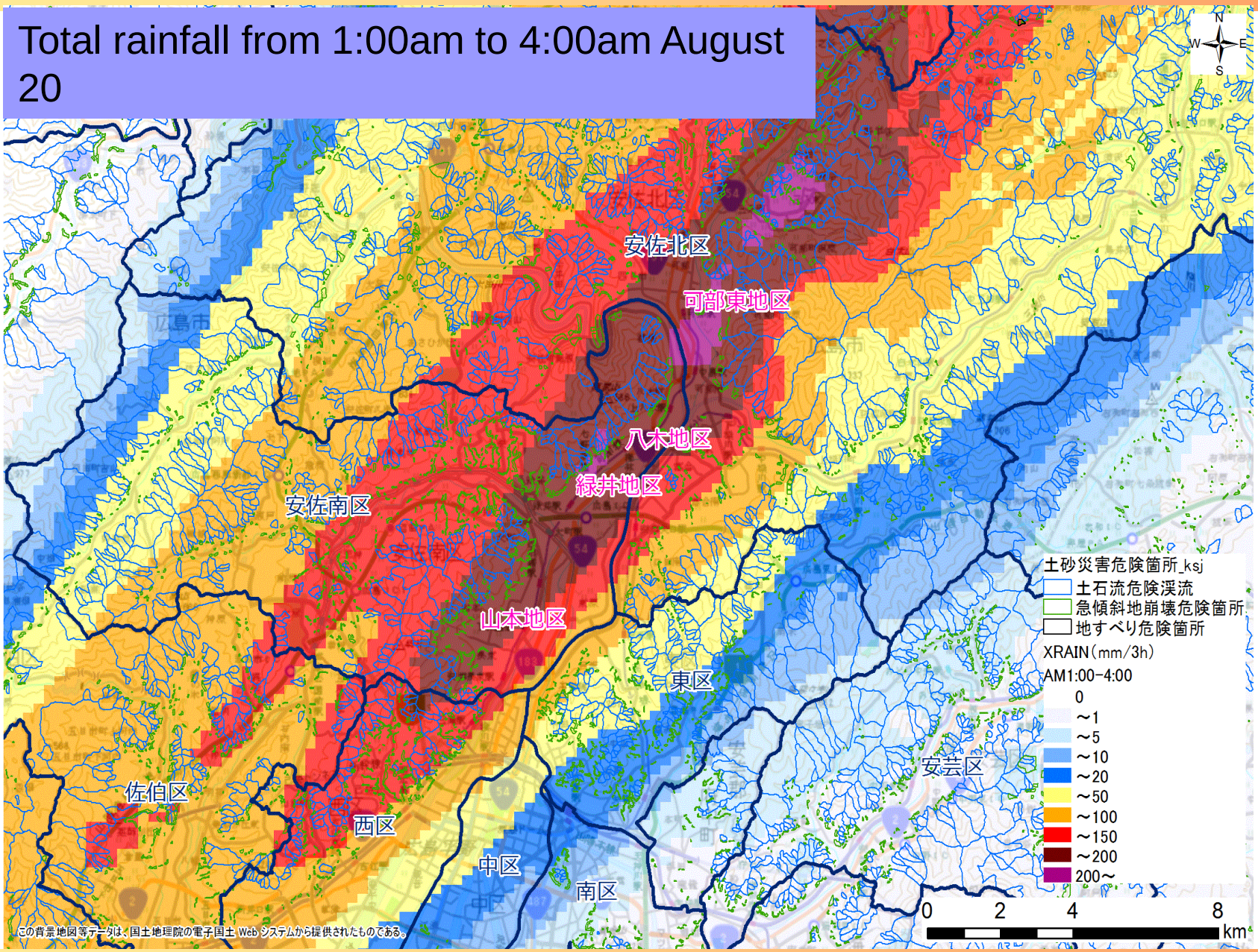




Change of hourly rainfall every 30 minutes



Total rainfall from 1:00am to 4:00am August 20



The Serious Disaster by debris flow in Hiroshima 20 August 2014

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The Serious Disaster by debris flow in Hiroshima 20 August 2014

The Serious Disaster by debris flow in Hiroshima 20 August 2014

The Serious Disaster by debris flow in Hiroshima 20 August 2014

Today's Points

- Sabo is a global technical term
- Features of Japan
- Vulnerable to damages
- 3 types of sediment movement phenomenon

Climate Change and Sediment Disasters

・Expected increase in the annual rainfall and frequency of heavy rainfalls in Japan

▼

・Increase in continuous rainfall

→Raises underground water levels and increases risk of deep-seated landslide occurrence

・Localized torrential rainfall

→Occurrence of large amount of turbid water flow and subsequent flows

・Concerning warnings and evacuations (1)

→Response to the announced sediment disaster warning in addition to record levels of torrential rain

・ Concerning warnings and evacuations (2)

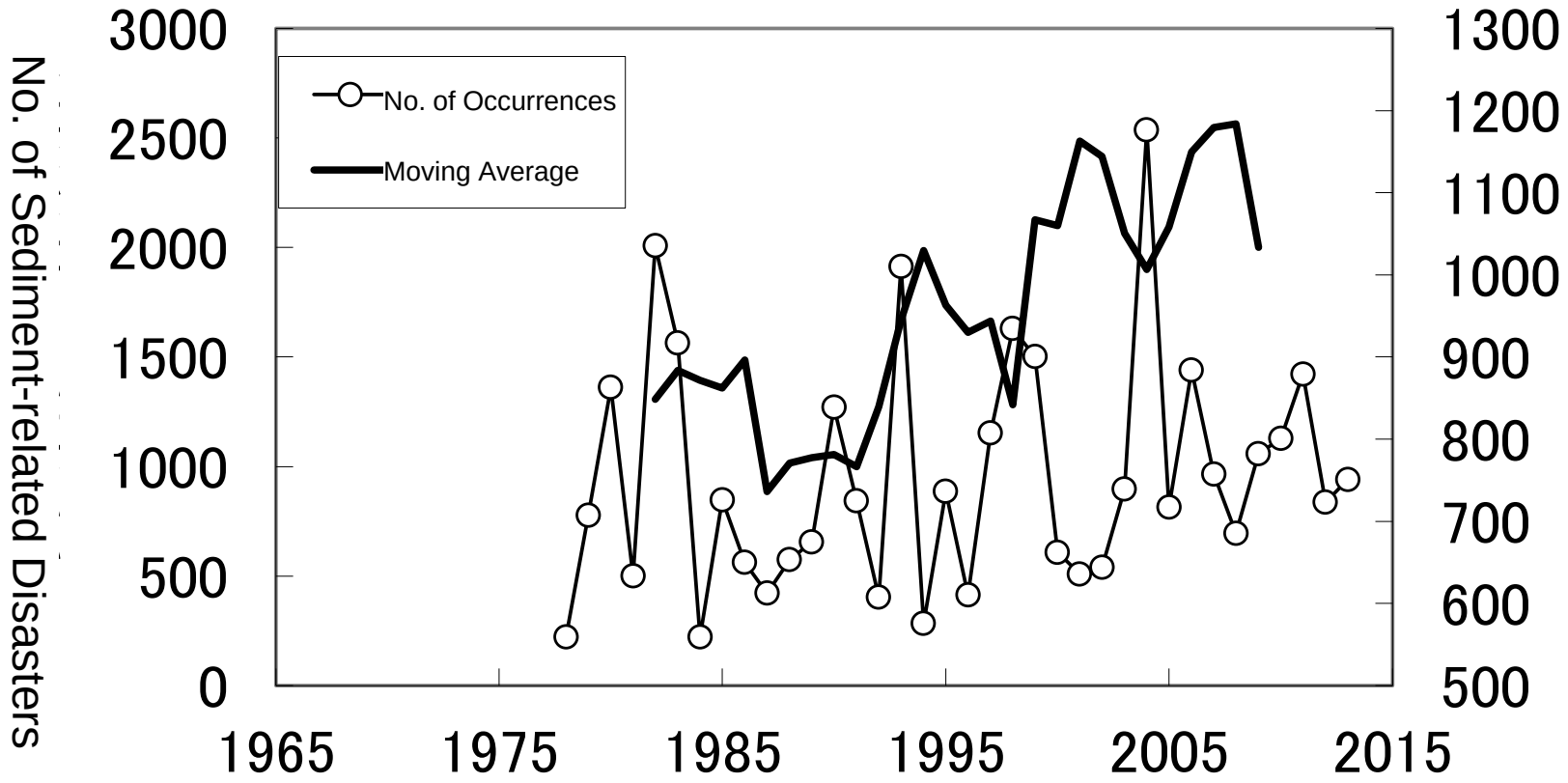
→Large rainfall differences in short distances. Local and sudden burst of torrential rain for short periods of time

・The strengthening of national land monitoring and maintenance in response to climate change is a major area of consideration

* Demonstrate robustness of facility functions against large-scale disasters
* Promote in-depth protective controls by combining soft measures
* Prolong the service life of equipment such as erosion control facilities
* Enhance national land monitoring for large-scale disasters

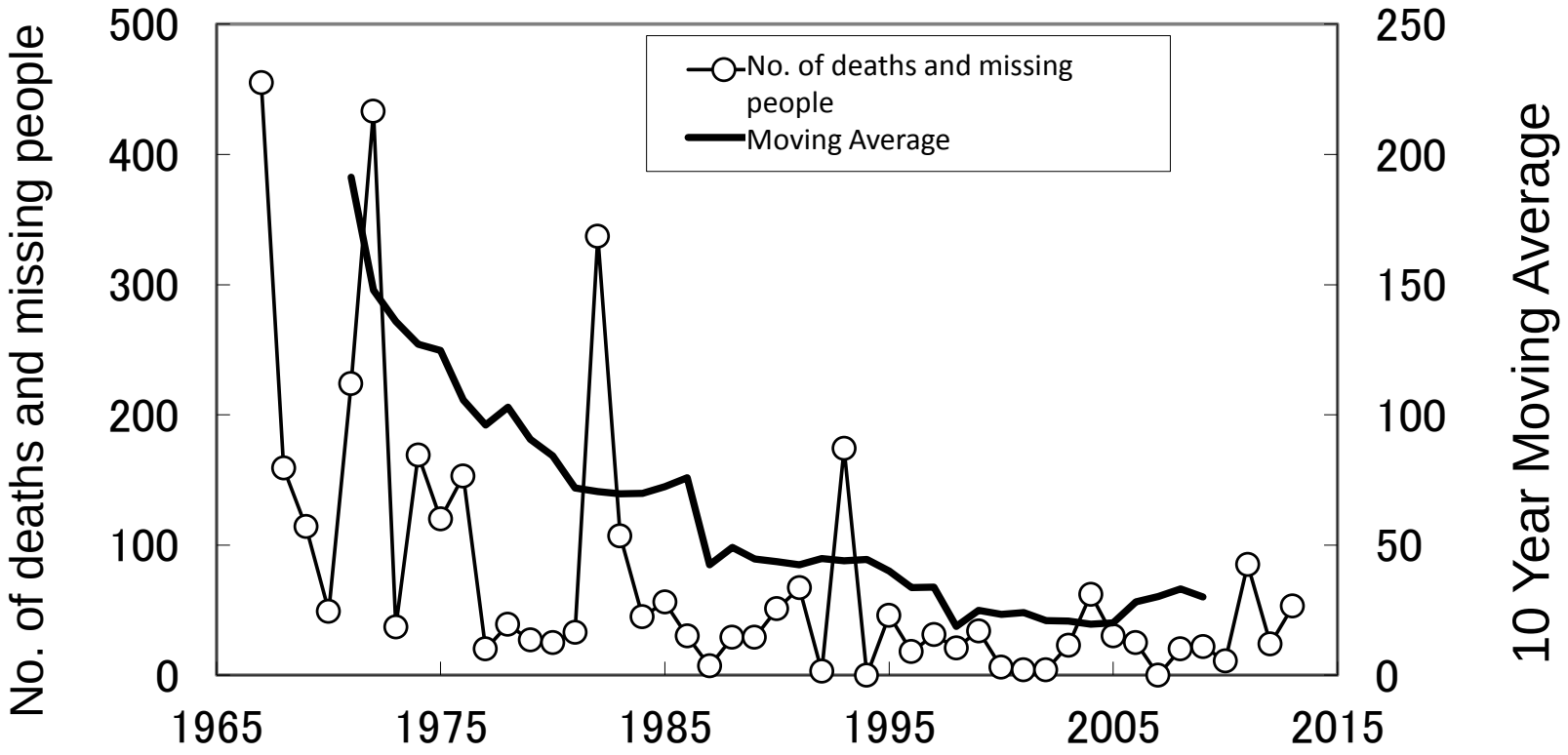
Sediment-related Disaster Incidents

- **Increasing long-term trend of sediment-related disaster cases**



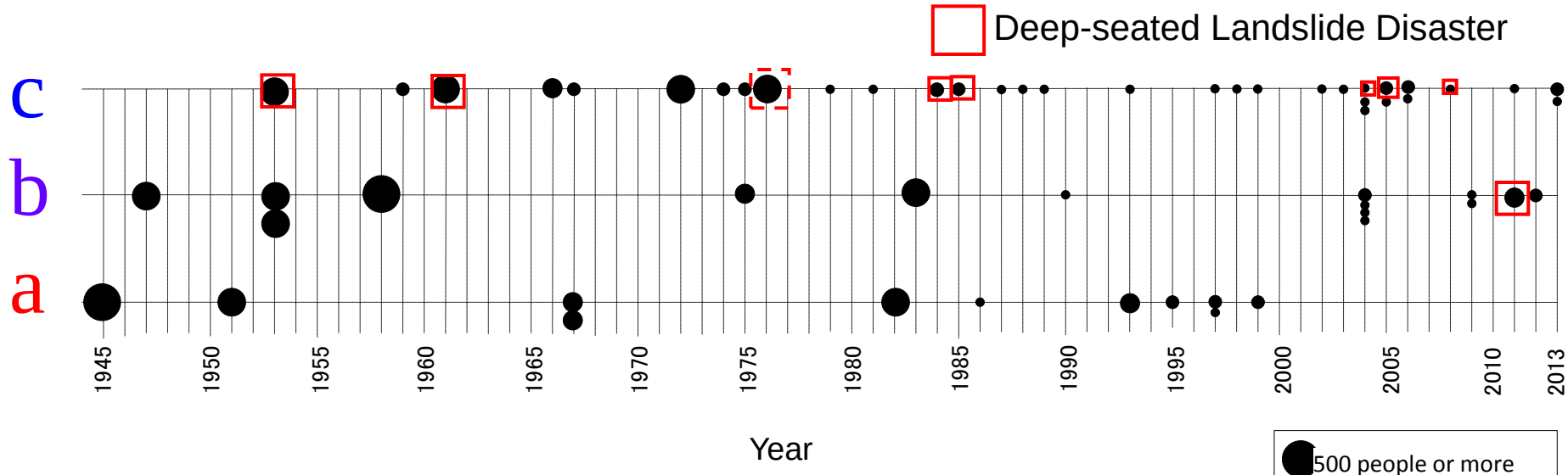
Number of Deaths and Missing People from Sediment-related Disasters

・Long-term decreasing trend for the number of deaths and missing people from sediment-related disasters
・However, the trend has been flat since the late 1990s



Number of Deaths and Missing People from Major Disasters

・An overall decreasing frequency major damage caused by large-scale sediment-related disasters (for disasters with the number of deaths and missing people exceeding 50)
・ From 2000s and later, a large-scale sediment-related disaster in an urban areas has not occurred
・ Still large-scale sediment-related disasters are frequent in hilly and mountainous areas
・Deep-seated landslide disasters are usually the cause of large-scale damage.



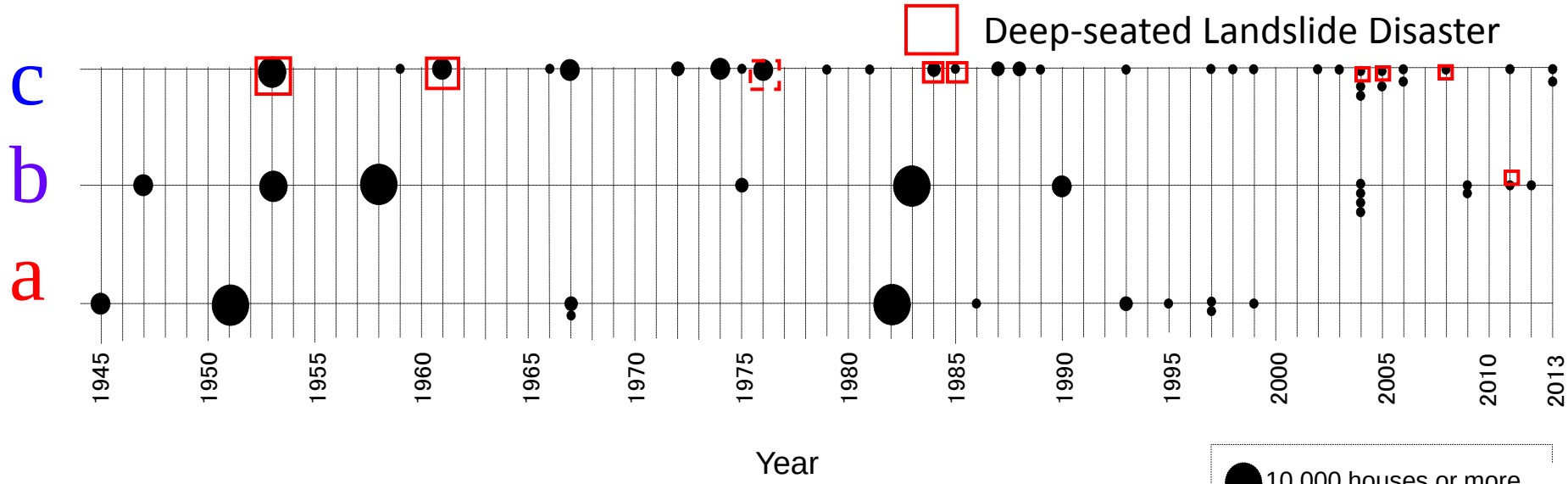
c: Intermediate agricultural areas, mountainous agricultural areas

b: Urban-plain agricultural areas and intermediate-mountainous agricultural areas

a: Urban areas, plain agricultural areas

Number of Damaged Houses from Major Disasters

・Since 1990, a large-scale sediment-related disaster has not resulted in the damage of 1000 or more houses.
・ From 2000s and later, a large-scale sediment-related disaster in an urban areas has not occurred.



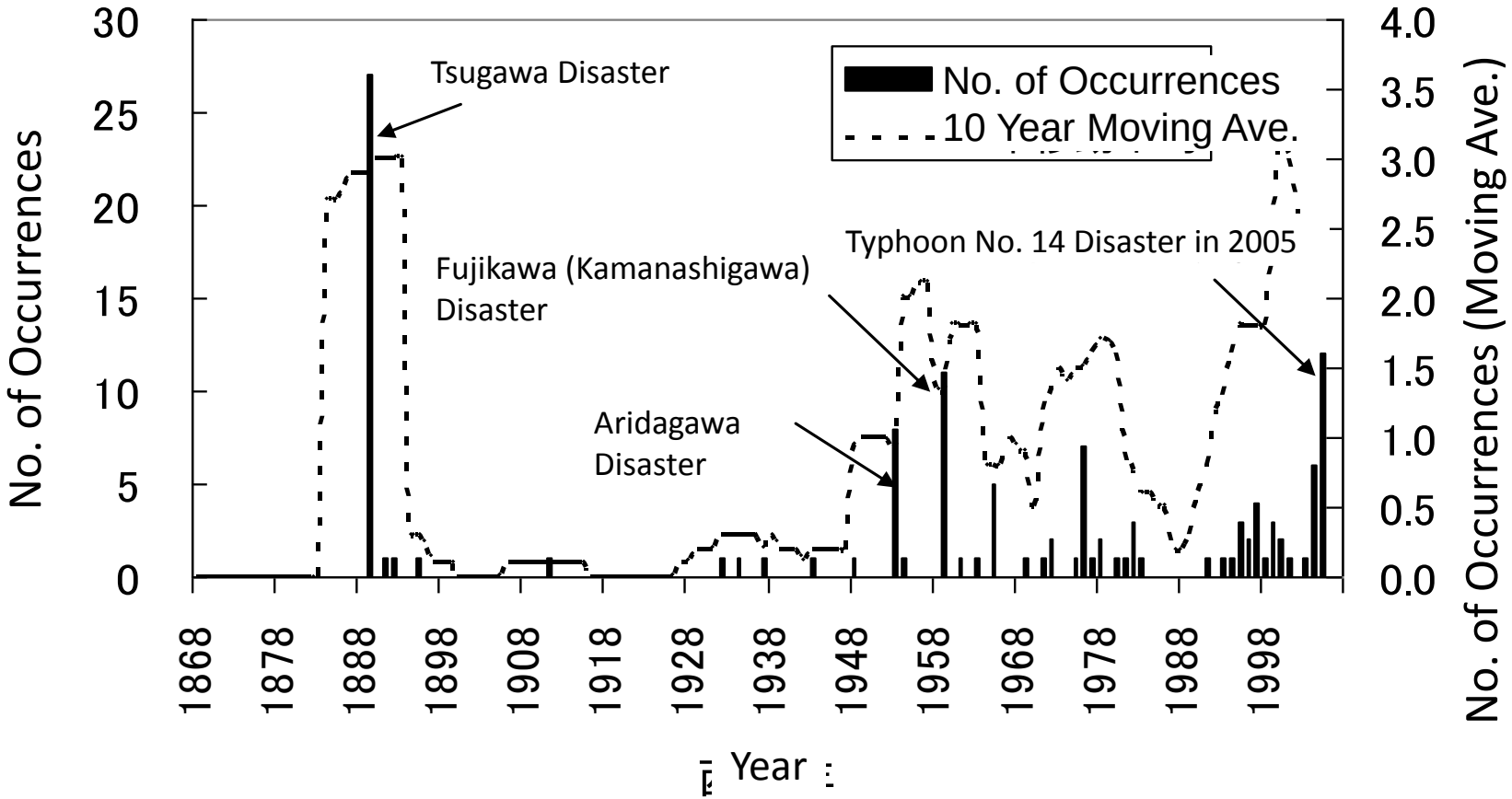
c: Intermediate agricultural areas, mountainous agricultural areas

b. Urban-plain agricultural areas and intermediate mountainous agricultural areas

a: Urban area, plain agricultural areas

Changes in Long-term Deep-seated Landslide Incidents

- **Increasing trend of deep-seated landslide incidents from 1990**
- Frequent occurrences in the 1890s and 1950s
- Prolonged periods of deep-seated landslides, less cycle period time.



Changing trend in the number of deep-seated landslides with sediment volume of 100,000 m3 or more (from Uchida et al. 2007)

Uchida Nishiguchi (2011), Journal of the Japan Society of Erosion Control Engineering

Initiation Mechanism of Debris Flow