Seismic Ground Disaster Assessment System (SGDAS) of GSI Japan

Junko IWAHASHI
Geospatial Information Authority of Japan (GSI Japan)

国土地理院

Today's topic

1. What is SGDAS?
2. The technical overview of the SGDAS system and the estimation methods of the possibility of landslides and liquefactions
3. Estimation results for major earthquakes
4. Future plans

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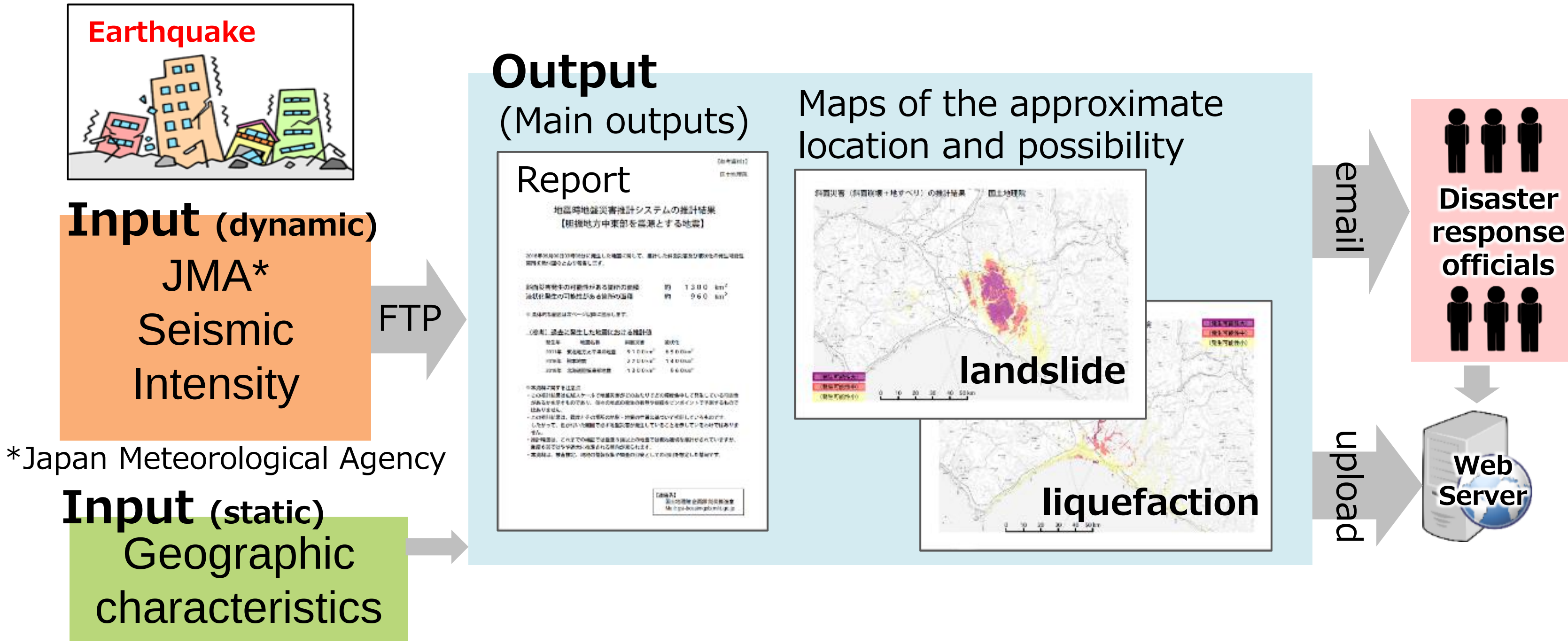
Seismic Ground Disaster Assessment System: SGDAS

Developed by GSI Japan in FY2010 to FY2012, pilot operation FY2013 -, official operation June 2019 -



The aim of SGDAS: To help determine policies for disaster responses until information is received from the field (especially at night).

- The efficacy was confirmed by evaluation throughout the pilot operation period.
- SGDAS will be improved in a five-year project that started this year.

Earthquakes and research results that were used as reference for the creation of the current SGDAS algorithm

【Small landslide】

- The 1995 Southern Hyogo Prefecture Earthquake (Mw 6.9)
  (Verified by 7 earthquakes until around 2008)

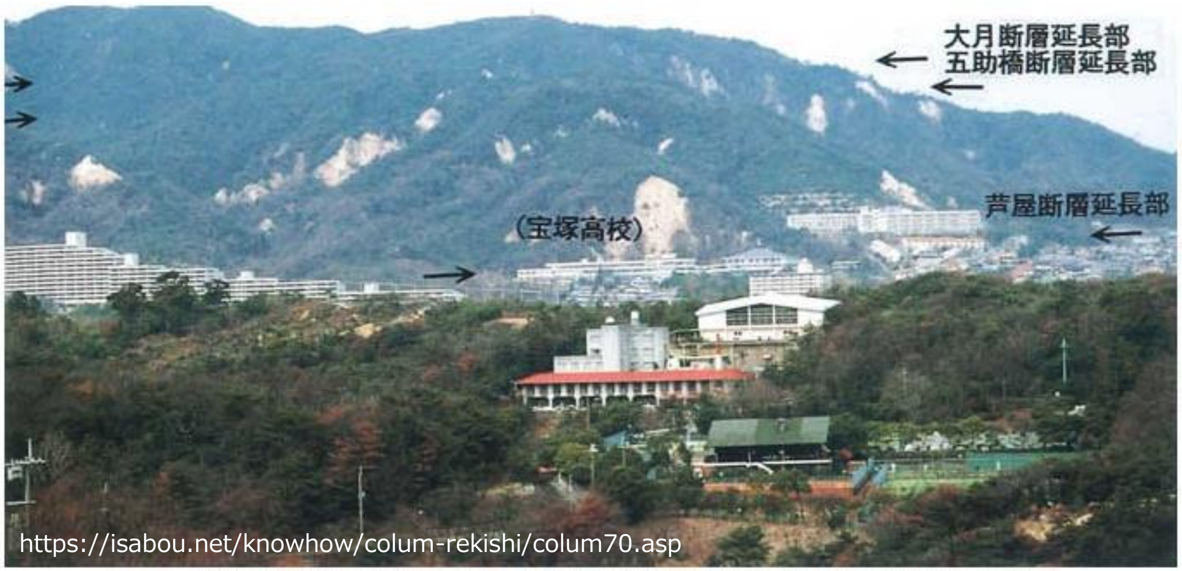


写真4　宝塚高校背後の山腹斜面に見られる小規模な崩壊地群（建設省河川局砂防部，1995）

A view of small landslides in the Rokko Mountains (photo: MLIT)

(Photos are for illustration)

Damage in Kobe City
(photos: Kobe City)

Background of the algorithm creation

Earthquakes and research results that were used as reference for the creation of the current SGDAS algorithm

【Large landslide】

- The 2004 Mid Niigata Prefecture Earthquake (Mw 6.6)
- The 2008 Iwate-Miyagi Nairiku Earthquake (Mw 6.8-6.9)
- The 2011 earthquake off the Pacific coast of Tōhoku (Mw 9.0-9.1)

(Photos are for illustration)

Large landslides caused by the Mid Niigata Prefecture Earthquake (photos: PASCO Corp.)

A large landslide caused by the Iwate-Miyagi Nairiku Earthquake (photo: PASCO Corp. and Kokusai Kogyo Co., Ltd.)

Background of the algorithm creation

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Earthquakes and research results that were used as reference for the creation of the current SGDAS algorithm

【Liquefaction】

Previous research results up to around 2011

Liquefactions caused by the Southern Hyogo Prefecture Earthquake (photos: Kobe City)

(Photos are for illustration)

Background of the algorithm creation

Earthquakes and research results that were not used as references

- Effect of seismic motion cycle
- Difference between the upper and lower panels of a reverse fault
- Subsequent earthquakes (including the 2016 Kumamoto Earthquake, 2018 Hokkaido Eastern Iburi Earthquake)
- Soil layer thickness (including tephra), mountain geomorphology
- Effect of prior rainfalls

Landslides caused by the Hokkaido Eastern Iburi Earthquake (photo & 3D model：GSI)

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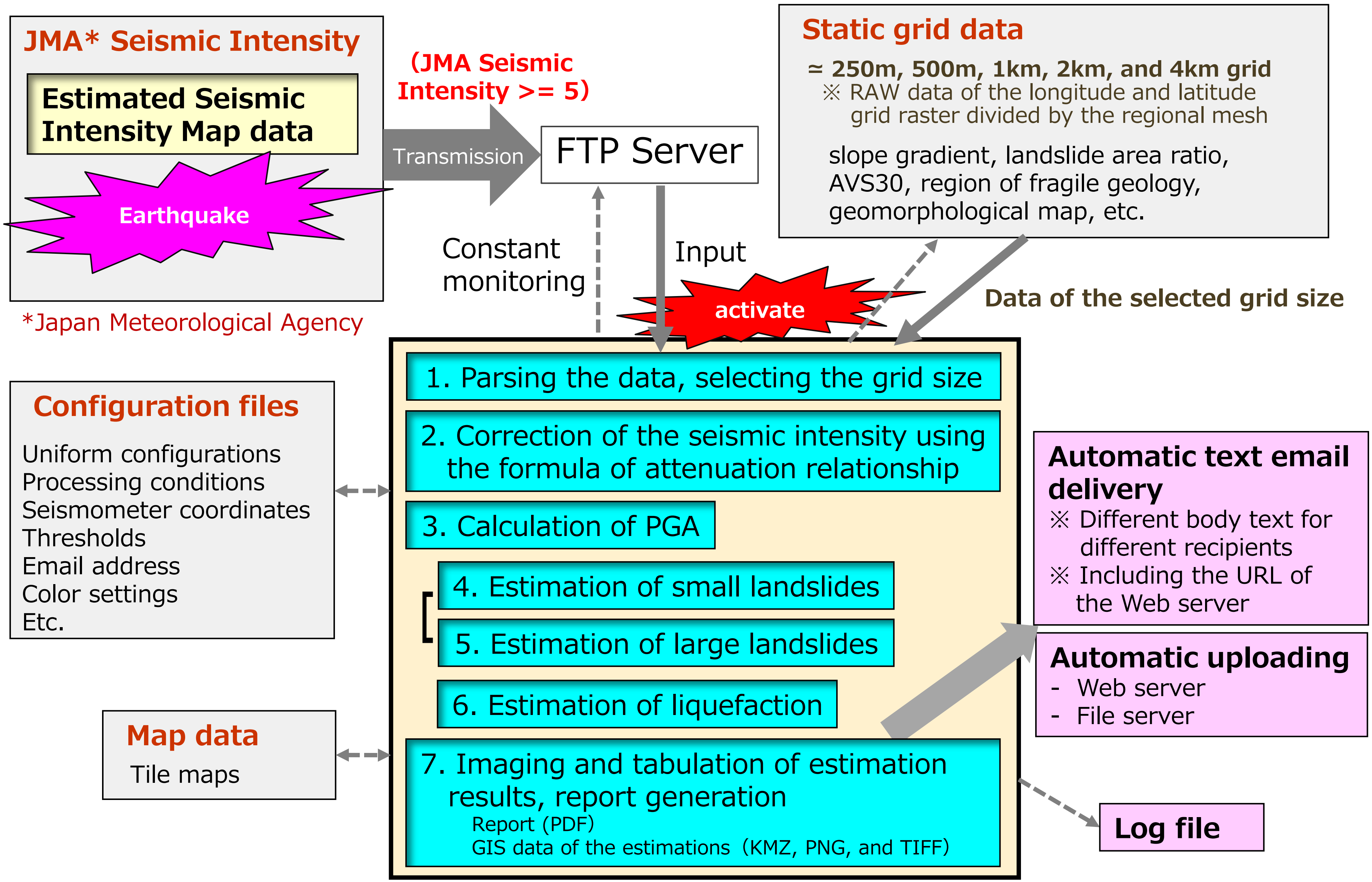
The data flow of SGDAS



1． Selecting the grid size

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Selecting the grid size according to the shaking range

Depending on the area of the shaking above the threshold （>= JMA Seismic Intensity 3.5), the grid sizes of ≃**250m**, **500m**, **1km**, **2km**, and **4km** raster data are selected from the static grid datasets.

→ This will be the resolution of the estimation and GIS data.

Speed up the calculations

e.g.

- Most of the cases: 250m grid
- The 2016 Kumamoto Earthquake (Mw 7.0): 500m grid
- The 2011 earthquake off the Pacific coast of Tōhoku (Mw 9.0-9.1): 1km grid

2．Correction of the seismic intensity

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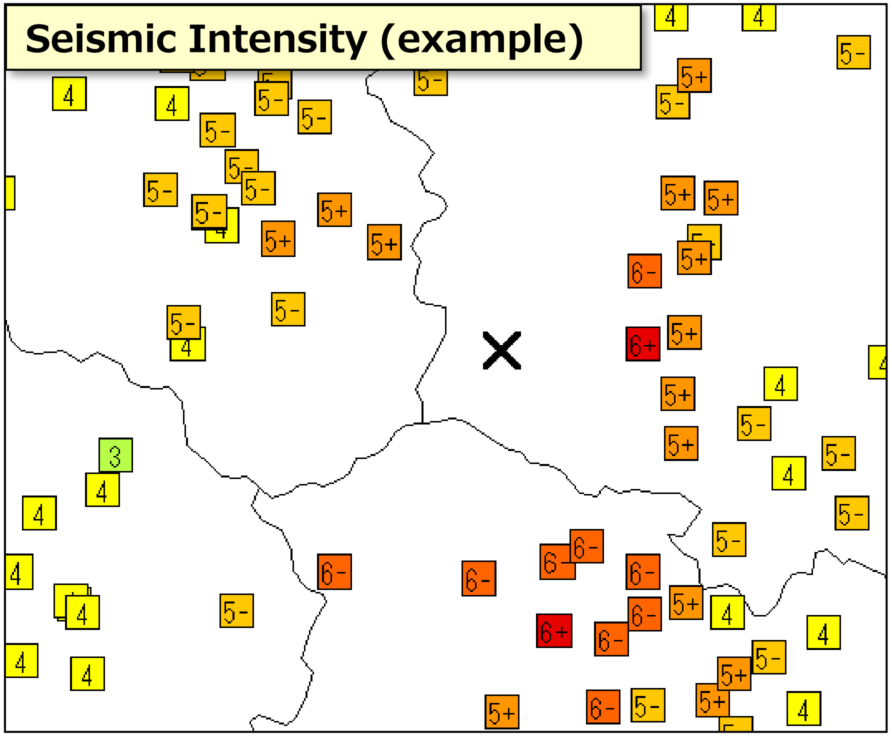
Correction of the JMA Seismic Intensity using the formula of attenuation relationship (Midorikawa et al., 2010)

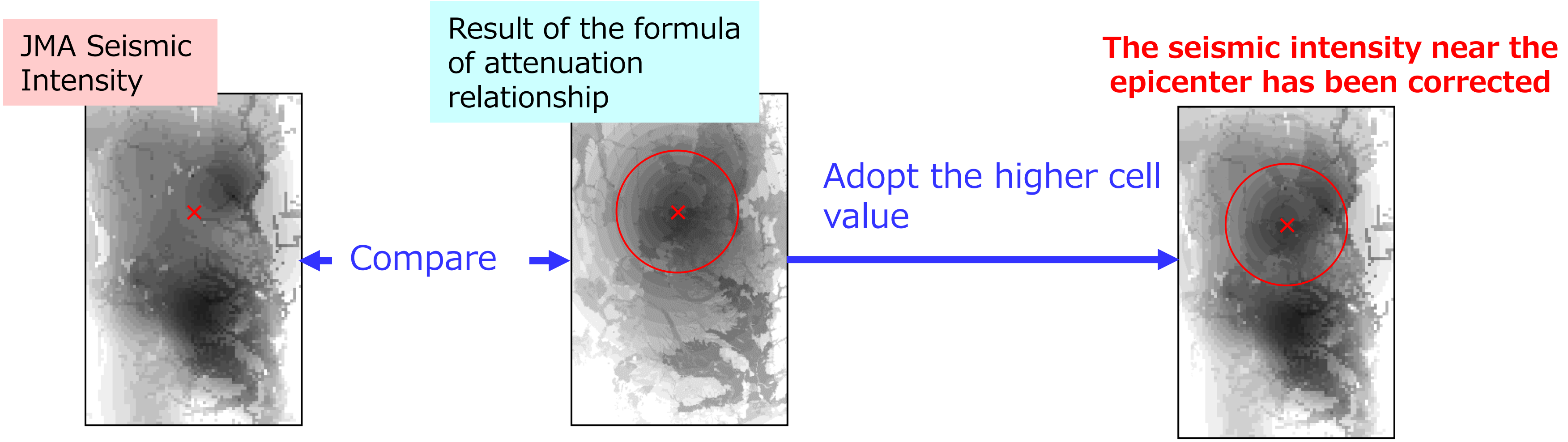
Algorithm：

Estimating errors in the JMA seismic intensity map caused by lack of seismographs

$$I = \mathrm{MAX}(I_{JMA},\ \mathrm{MIN}(I_{Att},\ I_{JMA} + \Delta I_{JMA}))$$

I_{Att}	Intensity using the formula of attenuation relationship (considering AVS30)
I_{JMA}	JMA Seismic Intensity
ΔI_{JMA}	Estimated error of JMA Seismic Intensity





3．Calculation of PGA

In order to use PGA as an input value for the estimation of slope failure, PGA* is estimated from the seismic intensity using the following method (Kamiya et al., 2012).

Conversion from JMA magnitude (Mj) to moment magnitude (Mw) (Kamiya's original formula)

$$Mw = 1.30Mj - 2.37$$

Estimation of PGA (a) using measured seismic intensity (I) and moment magnitude (Mw)
(Inversion of the equation in Fujimoto and Midorikawa (2010))

$$\mathrm{Ia} = \frac{\mathrm{I}+0.122-0.114\mathrm{Mw}}{0.841+\sqrt{0.715699+0.069I-0.007866Mw}}$$

$$\mathrm{a} = 10^{Ia}$$

*Peak Ground Acceleration

4． Estimation of small landslides

- Based on the empirical formula (Rokko Formula) in the 1995 Southern Hyogo Prefecture Earthquake (Uchida et al., 2004)
- For practical use, a revised formula (Revised Rokko Formula; Kamiya et al. 2012) is used that eliminates the disadvantages of the Rokko Formula.
- In the case of fragile geology, the estimated value is corrected to a higher value.

The Rokko Formula (Uchida et al.,2004)

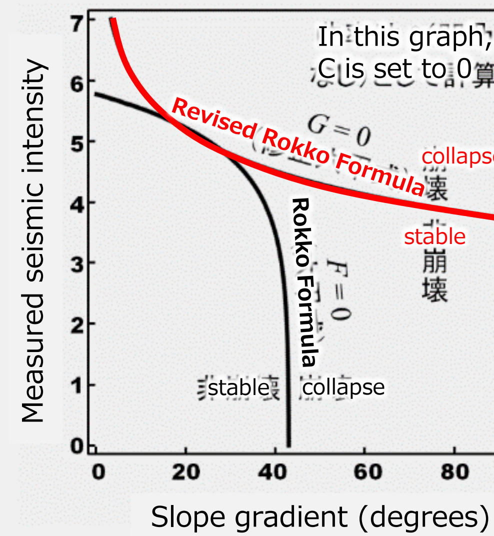
$$F = 0.075s - 8.92c + 0.006a - 0.3228$$

Revised Rokko Formula (Kamiya et al., 2012)

$$G = 3.93\log a + \underline{4.38\log(s - 119c) - 15.27}$$

Static part

s Slope gradient (degrees)
c Curvature (m^{-1})
a PGA (gal)



DEM (10m) → Slope gradient, curvature → Histograms of the static part of the revised Rokko Formula

for fast real-time processing

Seismic intensity → PGA

Histograms of the static part of the revised Rokko Formula + PGA → Calculate and integrate positive values

Calculate and integrate positive values → Correction by fragile geologies

Serpentine, high-pressure metamorphic rock, pyroclastic flow deposits, sedimentary rocks younger than Neogene, hot-spring metamorphic, etc.

Correction by fragile geologies → Proportional classification → Estimated rank of the occurrence of small landslides

5. Estimation of large landslides

- Based on the existing knowledge that landslides occur in areas with high landslide susceptibility and where the seismic intensity is above 6.
- A landslide density distribution map was prepared in advance from the 1:50,000 landslide distribution maps (NIED) with weightings for landslide certainties, and the possibility ranks are estimated using the following formula (Kamiya et al., 2014).

$$R = \frac{\log(D)}{\log(2.5)} + \frac{(I - 5.0)}{0.33} + 1$$

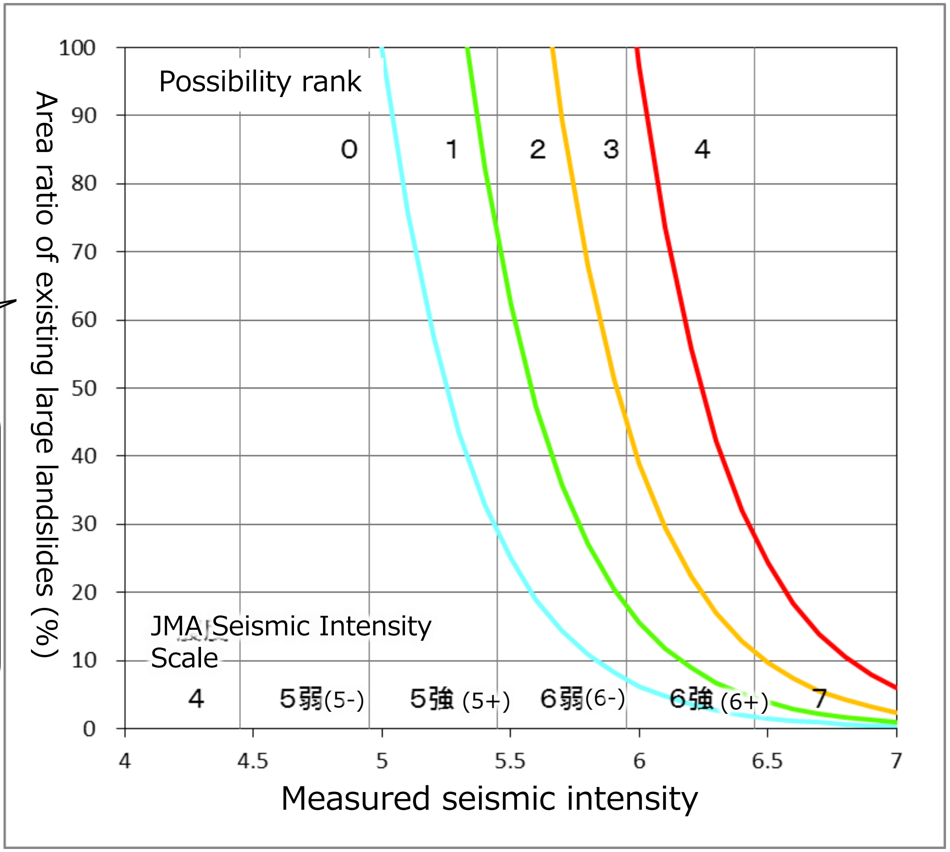
D: landslide density
I: seismic intensity

Adopt the integer part of R and classify it into 0-4

Constant term determined based on knowledge from 2010-2012.

<Overview of the algorithm>

1. **Determine the window size for landslide area ratio calculation considering the geology.** (the same geological unit: 1km, the different unit: 500m)
2. **Calculate the possibility rank by area ratio and seismic intensity**



Kamiya（2013）, Kamiya et al.（2014）

6. Estimation of liquefaction

The liquefaction possibility rank is determined in 5 steps from 0 to 4 based on the matrix table of seismic intensity and geomorphological classification.

Geomorphological classification (Wakamatsu and Matsuoka, 2009)

Seismic intensity scale	Mountains Hills Volcanic Mts. Volcanic hills Rocky shore and reef Water body	Mountain footslope Volcanic footslope Rocky terrace Loam terrace	Alluvial fan (gradient of >= 1/100) Gravelly terrace	Alluvial fan (gradient of < 1/100) Sand dune	Natural levee (relative height of >= 5m) Sand and gravel bars Back marsh Valley bottom plain (gradient of >=1/100)	Reclaimed land Delta, coastal plain Natural levee (relative height of <1/100) Valley bottom plain (gradient of <1/100)	Edge of sand dune Lowland between sand dunes and sand bars Reclaimed (filled up) land Former river channel River bed
7	0	1	2	3	4	4	4
6+	0	0	1	2	3	4	4
6 -	0	0	0	1	2	3	4
5+	0	0	0	0	1	2	3
5 -	0	0	0	0	0	1	2

Possibility rank: 0 - 4

7. Imaging of estimation results

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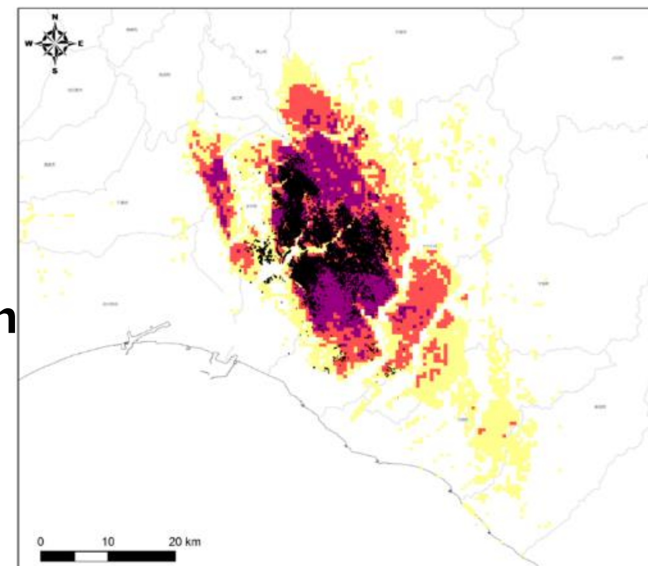
- Aggregate the possibility of small landslides and large landslides to "landslide possibility" (Adopt the one with the higher rank in each grid)
- The aggregated rank is expressed in the report in three levels: **high**, **medium**, or **low** possibility of occurrence.

Calculated possibility rank	In the report
4（危険度大）	（発生可能性大）**high**
3	（発生可能性中）**medium**
2	（発生可能性小）**low**
1（危険度小）	（発生可能性小）**low**



(Fixed form texts)
(Texts with embedded real-time information)

【参考資料1】

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地震時地盤災害推計システムの推計結果 ←Title
【胆振地方中東部を震源とする地震】←Region of the epicenter

2018年09月06日03時08分に発生した地震に関して、推計した斜面災害及び液状化の発生可能性箇所を添付図のとおり報告します。←Year, month, date, time

斜面災害発生の可能性がある箇所の面積	約	１３００	km^2
液状化発生の可能性がある箇所の面積	約	９６０	km^2

←Area of potential landslide sites
←Area of potential liquefaction sites

※ 具体的な範囲は次ページ以降に図示します。

（参考）過去に発生した地震における推計値

発生年	地震名称	斜面災害	液状化
2011年	東北地方太平洋沖地震	９１００km²	６５００km²
2016年	熊本地震	２７００km²	１４００km²
2018年	北海道胆振東部地震	１３００km²	９６０km²

←Area of potential landslide and liquefaction sites of past large earthquakes (reference information)

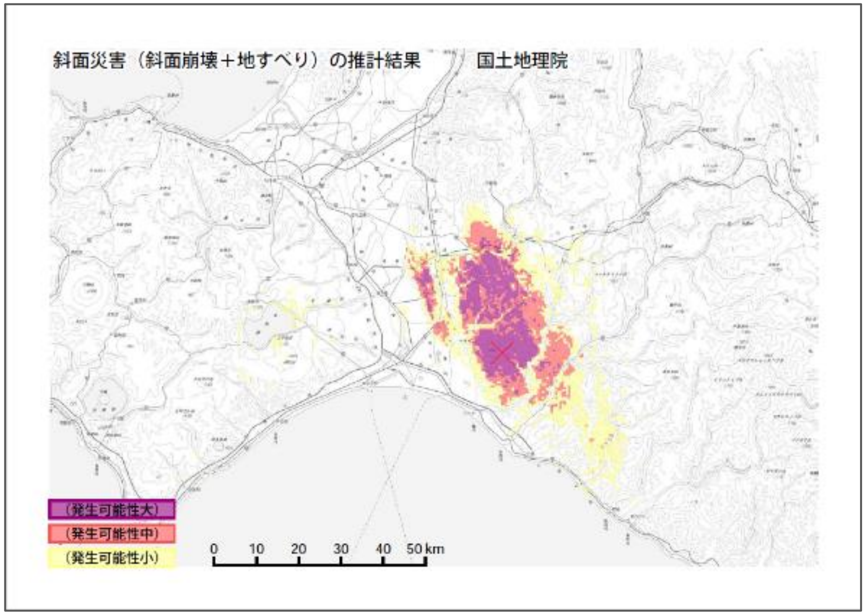
※本資料に関する注意点
- この推計結果は広域スケールで地盤災害がどのあたりでどの程度集中して発生している可能性があるかを示すものであり、個々の地点の発生の有無や規模をピンポイントで予測するものではありません。
- この推計結果は、震度とその場所の地形・地質の性質に基づいて推計しているものです。したがって、色が付いた範囲で必ず地盤災害が発生していることを示しているわけではありません。
- 推計精度は、これまでの検証では震度６強以上の地震では概ね適切な推計がされていますが、震度６弱ではやや過大に推定される傾向が見られます。
- 本資料は、被害推定、現地の情報収集や調査の目安としての利用を想定した情報です。

←Precautions for use

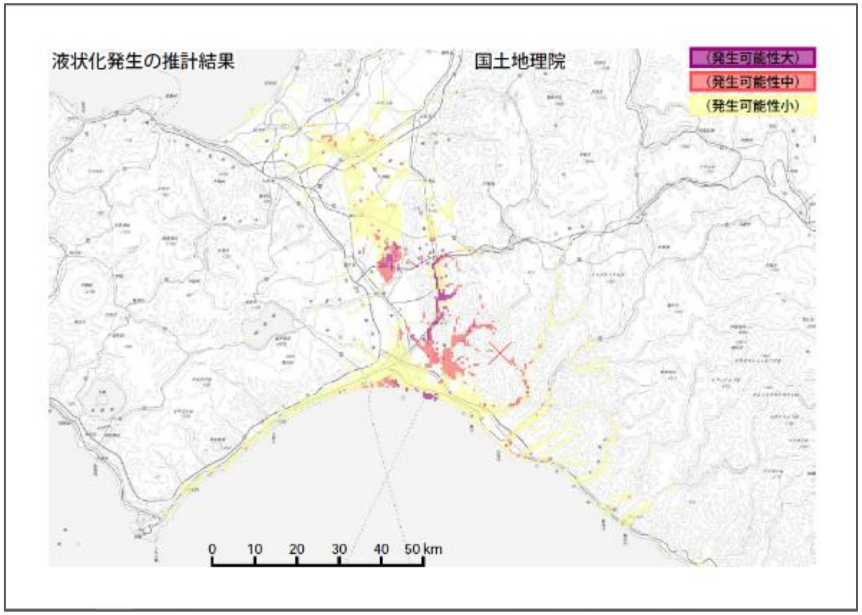
【連絡先】
[redacted]

←Contact address

Map of estimated landslide possibility



Map of estimated liquefaction possibility



- The area of the maps were automatically determined from the area with the high seismic intensity.
- The background map was automatically created from tile maps (GSI maps: https://maps.gsi.go.jp/).
- Legends and titles were automatically placed.

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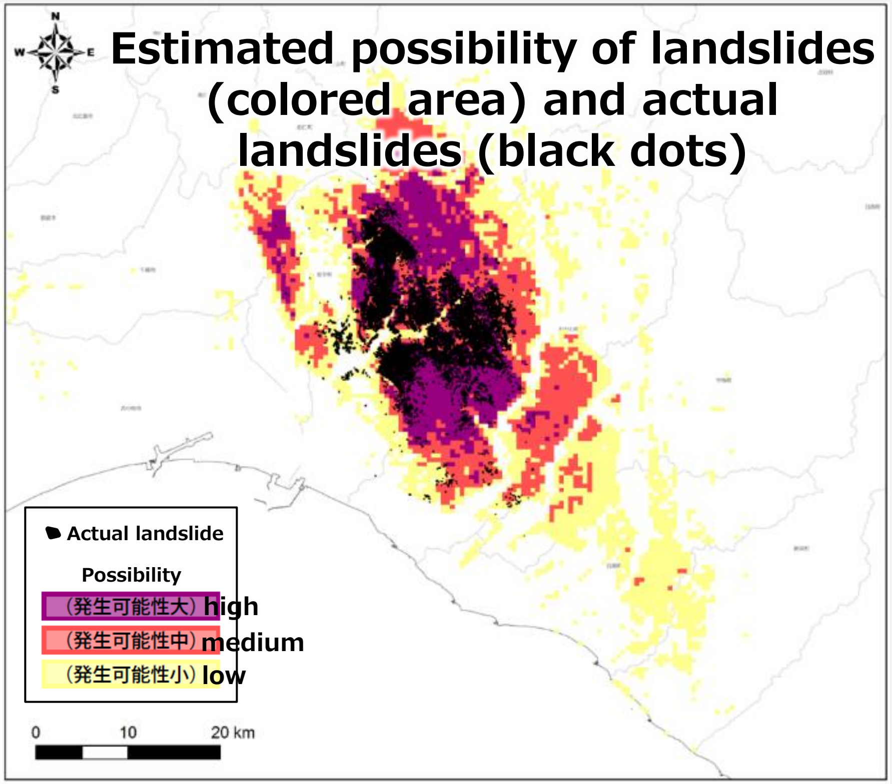
Useful cases during the pilot operations

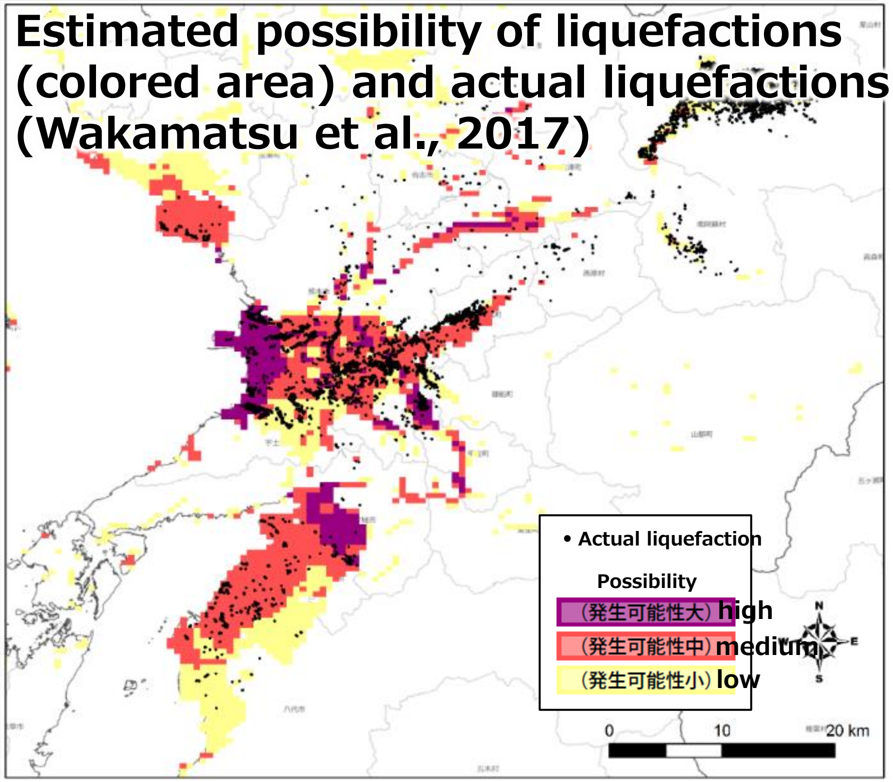
2018 Hokkaido Eastern Iburi Earthquake

(3:07 AM earthquake occurrence
➡3:13 AM report delivery)



2016 Kumamoto Earthquake

(1:25 AM earthquake occurrence
➡1:32 AM report delivery)



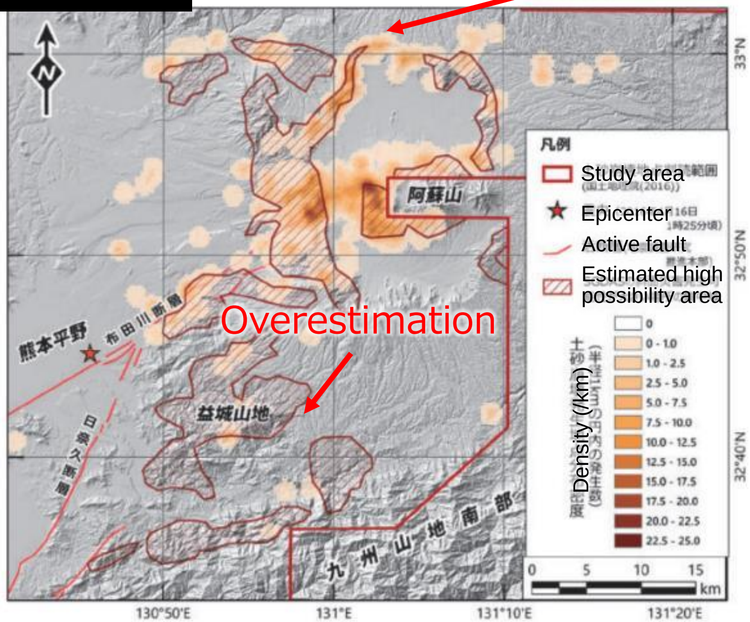
SGDAS helped policy and planning for disaster responses (aerial photography, etc.) from early in the morning on those days.

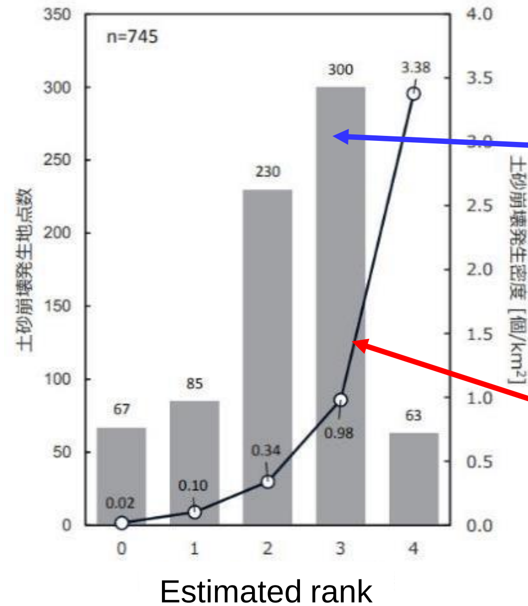
Quantitative evaluation of the results

(the 2016 Kumamoto Earthquake)

Nakano and Ohno (2018)

Landslide

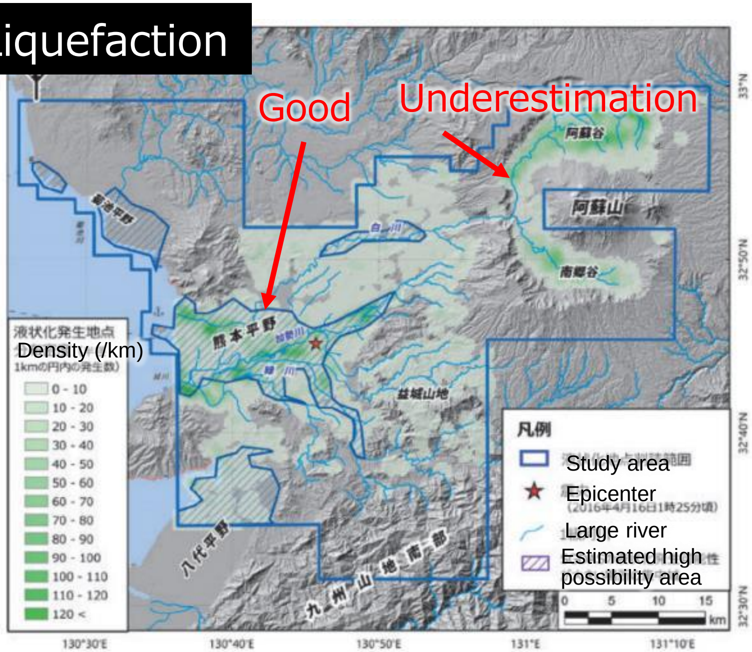


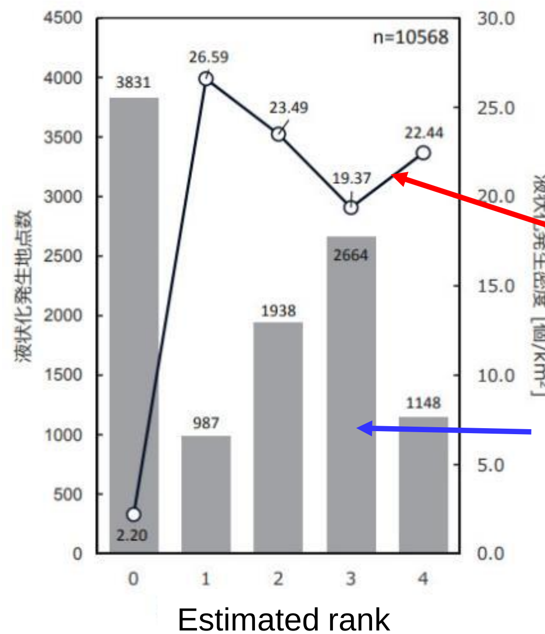


Estimated grid number of landslides

Density of actual landslides (number / km²)

Liquefaction





Density of actual liquefactions (number / km²)

Estimated grid number of liquefactions

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Research on the Improvement of Estimation Accuracy of SGDAS

FY2021 (April 2021) – FY2025 (March 2026)

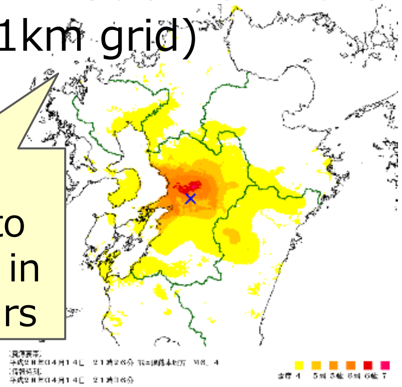
- In FY2021, the current system will be modified to solve problems such as system instability and misdirection.
- Research on the improvement of estimation methods will be conducted with reference to previous studies.
- The new system after the improvement of the estimation methods will be completed in the final year of the project after a series of experiments with prototypes.

Estimation of landslide possibility

Re-examination, investigation, and verification of the algorithm

Parameters of the current system

● **Input data**
- JMA Seismic Intensity Map (1km grid)



To be changed to 250m grid in recent years

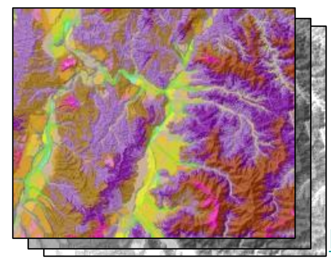
● **Pre-prepared thematic data**
- Slope gradient, curvature
- Landslide distribution map (NIED)
- Geological map (GSJ)

Ver2 was published

+

Parameters of landforms

Terrain class
Generated from DEMs



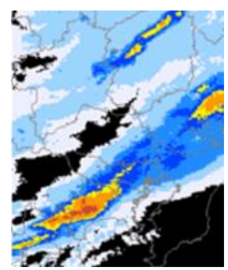
https://gisstar.gsi.go.jp/Japan_terrain

Soil layer thickness
Will generate from Yamashita's data (FFRI)

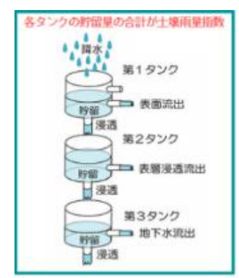
Consideration of soil layer thickness (including tephra)

Pre-earthquake rainfalls

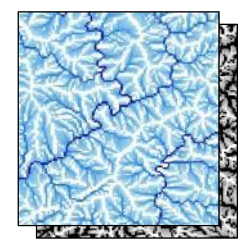
Rainfalls (JMA)



Soil Water Index (JMA)



Topographic Wetness Index



Revised algorithm

Brush up

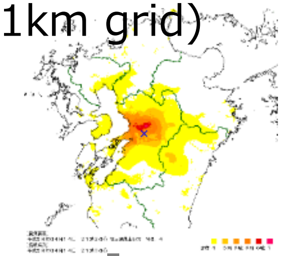
Estimation of liquefaction possibility

Re-examination, investigation, and verification of the algorithm

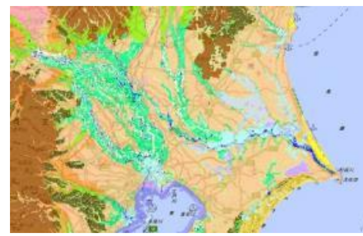
Current system

- **Input data**
  - JMA Seismic Intensity Map (1km grid)

To be changed to 250m grid in recent years



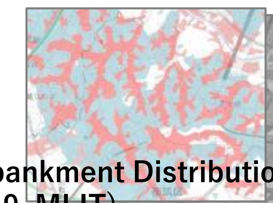
- **Pre-prepared thematic data**
  - Geomorphological map (Wakamatsu and Matsuoka, 2009)



The new table used to estimate possibility of liquefaction

Possibility ranks

- **Update latest data** (2008 →2019 edition)
- **Add data on artificially modified land**



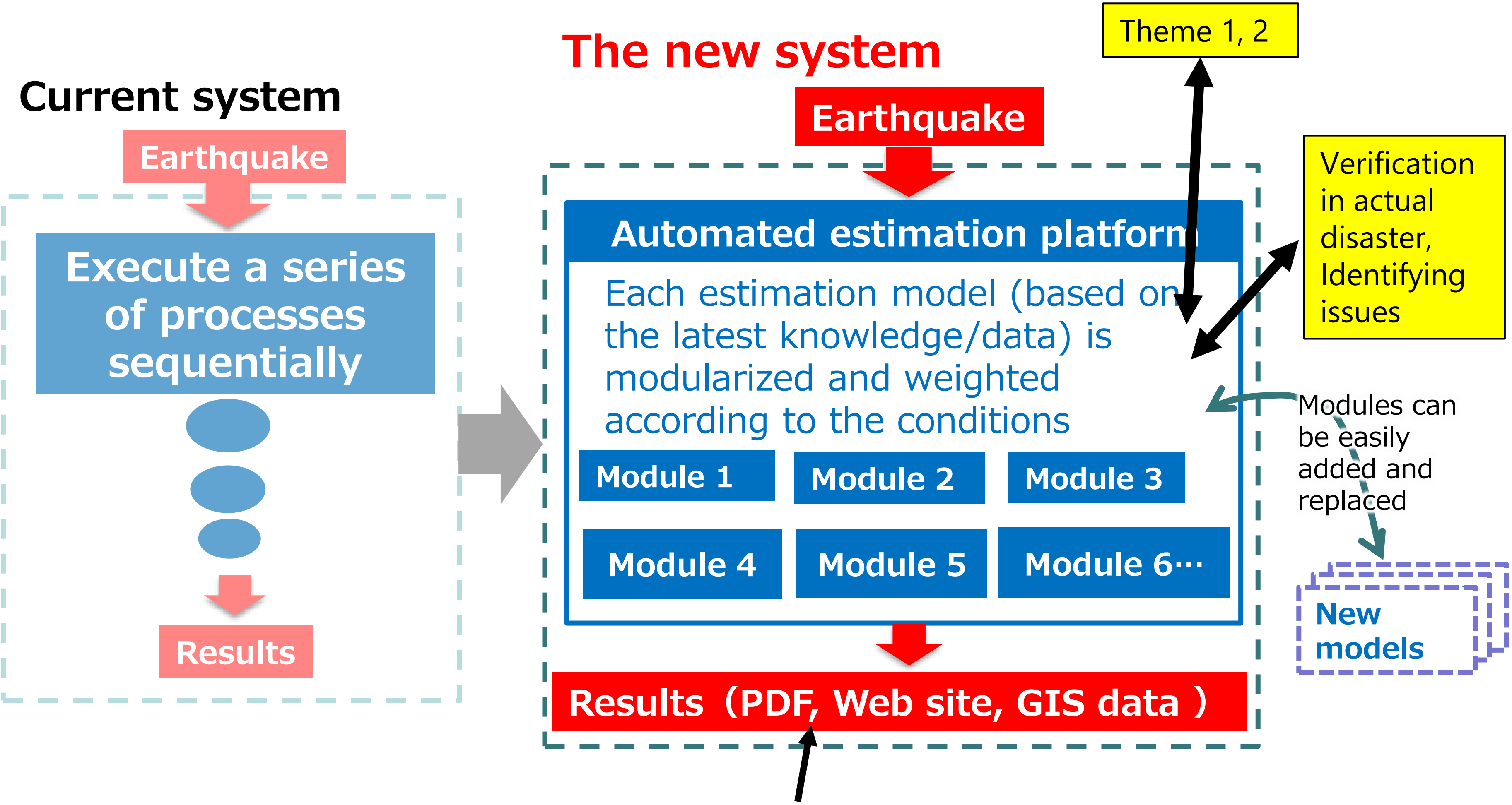
Embankment Distribution Map (2019, MLIT)

- **Analysis of new cases and reflection of results**

Revised algorithm

Brush up

Theme 3: System, report



Consider what kind of expressions are easy for users (disaster response officials) to understand

Thank you for your attention!